LAND COURT OF QUEENSLAND

REGISTRY: Brisbane
NUMBER: EPA495-15
MRA496-15
MRA497-15

Applicant: **New Acland Coal Pty Ltd ACN 081 022 380**

AND

Respondents: **Frank Ashman & Ors**

AND

Statutory Party: **Chief Executive, Department of Environment and Heritage Protection**

JOINT EXPERT REPORT - GROUNDWATER CONCEPTUALISATION, GROUNDWATER QUALITY AND GROUNDWATER MODELLING

1. Expert reasons

(a) This report is a record of the views expressed by the four experts listed below at the joint expert meeting held between the experts for OCAA and NAC. It covers the topics of groundwater conceptualisation, groundwater quality, and groundwater modelling. The report is structured with two main sections, the first listing areas of agreement and the second listing areas of dispute. The issues discussed are ordered as per the issues submitted to the Land Court by both parties under these topics in the Notice of Issues. Under each issue, it is stated whether the relevant experts agree or disagree, and if so on what aspect(s) and on what basis. In some cases all four experts offered an opinion, however on others only two of the experts discussed the issues as there was deemed to be minimal overlap between the respective areas of expertise covered by each witness. In some cases, clarifications were made to further explain the experts' meaning or interpretation of the issue.

1.2 Name and qualification

(a) This joint expert report was prepared by Duncan Irvine and Andrew Durick on behalf of the applicant, and Matthew Currell and Adrian Werner on behalf of the respondents (as Oakey Coal Action Alliance). The experts are referred to below by their initials – DI, AD, MC and AW, respectively. Nominally, MC and DI address the topics of groundwater conceptualisation and quality, while AD and AW address groundwater modelling. However, there is some overlap between the issues, and as such opinions from three or four experts were

expressed for some of the issues. The qualifications for each expert are provided below.

(b) Duncan Irvine: BSc (Rhodes University, South Africa).

(c) Andrew Durick: MAppSc (Maths), Queensland University of Technology, BEng (Environmental Engineering) (Hons), Griffith University,

(d) Matthew Currell: PhD (Geoscience, Monash University), BSc (Hons)/BA (University of Melbourne).

(e) Adrian Werner: PhD (University of Queensland), BEng (Civil) (Hons) (Central Queensland University)

1.3 **Dates of meetings of experts**

(a) The experts met on 4th and 5th February 2016 at the offices of Australasian Groundwater & Environmental Consultants Pty Ltd (AGE) located at Level 2, 15 Mallon Street, Bowen Hills Qld, Australia 4006.

2. **Key matters of agreement**

GROUNDWATER CONCEPTUALISATION AND GROUNDWATER QUALITY

1) The Applicant's assessment of the impacts of the proposed New Acland Coal Mine Stage 3 project ("Project") on groundwater rests on an unsound conceptualisation of the hydrogeology of the area.

1(a) The conceptualisation is not supported by sufficient detailed geological information. For example:

2.1 **1(a)(i) There is limited geological data provided in support of the regional geology.**

(a) MC and DI agree that the reporting of geological information in the EIS and AEIS should have been better in terms of putting the site into geological context.

(b) MC and DI agree that the information provided on faulting in the area was not at the level of detail and accuracy it should have been.

2.2 **1(a)(ii) Cross sections are conceptual only and bore logs used to construct these, if any, are not provided in assessment reports.**

(a) MC and DI agree on this issue.

2.3 **1(b) Insufficient field data has been collected to determine aquifer properties and connection between different aquifers.**

(a) MC and DI agree that there is a lack of reported field data to make judgements about vertical connectivity between aquifers – e.g. detailed geological logs that intersect multiple units and stratigraphic boundaries, and/or pumping tests conducted at nested sites where the response of one aquifer to pumping in another was monitored. MC and DI disagree however, as to whether sufficient data has been collected as a basis to determine aquifer properties.

2.4 **1(c) There is insufficient baseline data on water levels in the aquifers of the area such that regional flow patterns are not properly understood.**

(a) MC and DI agree that the water level contours shown on Figure 6-13 of the EIS[1] are faithful to the data collected in monitoring bores at the existing mine. However, MC and DI also agree that there was no attempt to put these data into regional context, for example, to show how they relate to the overall flow system in the basin. Regarding aquifers other than the Walloon Coal Measures, there was agreement that minimal water level data are shown in reports for the other aquifers to ascertain the regional flow patterns.

1(e) There remains unacceptable uncertainty about:

1(e)(i) The connection between different hydro-stratigraphic layers, for example, as a consequence of limited pumping tests:

2.5 **1(e)(i)A. Pumping tests have only monitored water levels in the Walloon Coal Measures, making no assessment of impacts on other units - the Quaternary Alluvium, Tertiary Basalts, and Marburg Sandstone (Appendix G4-1[2]).**

(a) MC and DI agree that pumping test data presented in the EIS[1] and AEIS[3] only looked at two sites in the Walloon Coal Measures, and that pumping tests were not sufficient to look at vertical interaction between different units.

---

[1] EIS Chapter 6, Groundwater Resources, New Acland Coal Mine Stage 3 - Environmental Impact Statement, New Hope Group, January 2014.

[2] EIS Appendix G.4, Groundwater, G.4.1, Stage 3 Aquifer Testing Report (July 2009).

[3] Appendix F, IESC Report – Groundwater Modelling Technical Addendum, New Acland Coal, New Acland revised Stage 3 Project AEIS, 13 August 2014.

2.6 **1(e)(i)B. Consultants SKM noted that pumping tests were conducted over short time intervals and so these tests are unlikely to capture the hydraulic behaviour of the aquifers under long-term conditions of stress.**

(a) MC and DI agree that the pumping tests were conducted over a short time interval and would not capture the behaviour of aquifers under conditions of long-term stress, for example boundary effects or leakage behaviour.

1(e)(ii) The role of faults and whether or not these act as flow barriers:

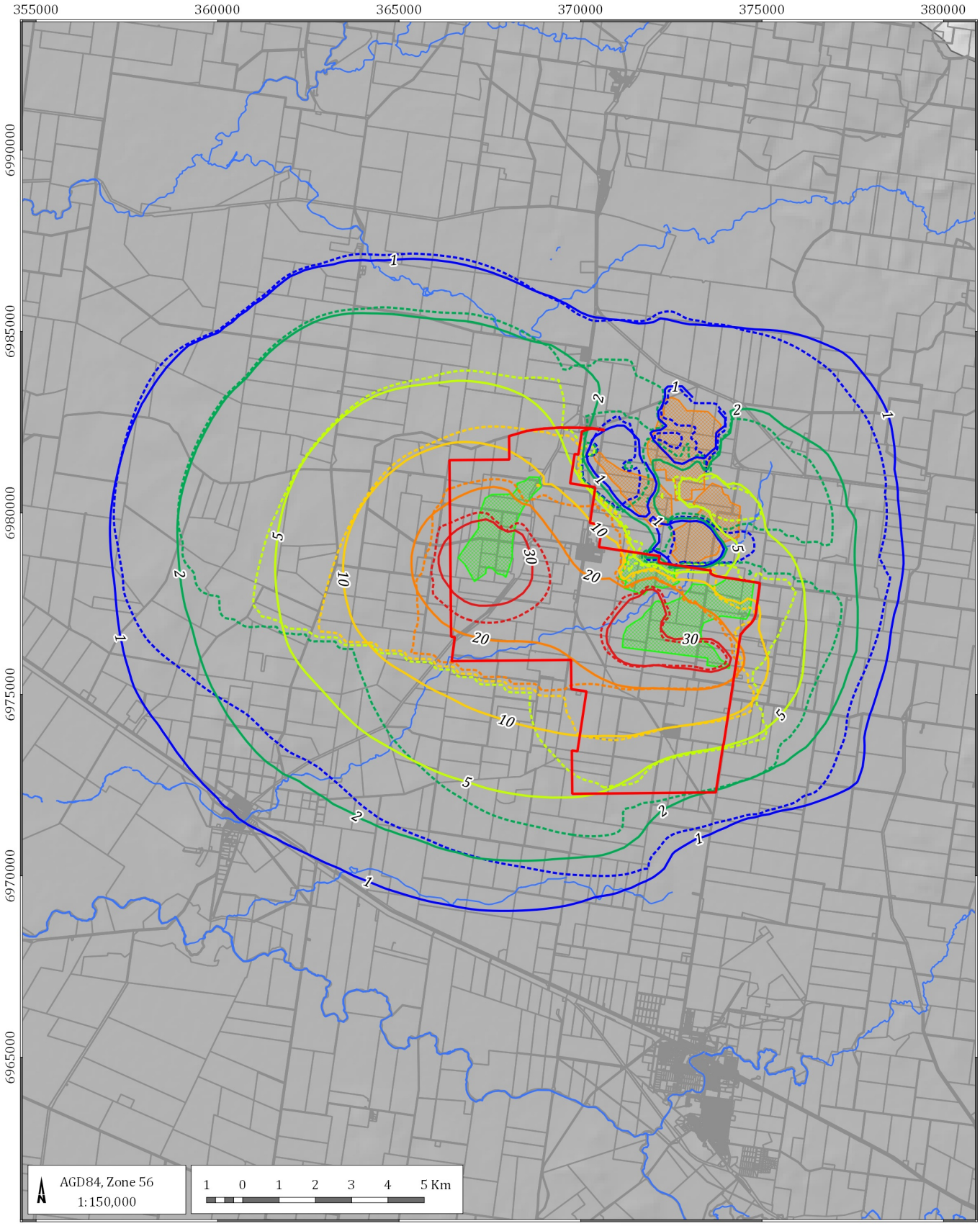
2.7 **1(e)(ii)A. A major fault immediately to the south of the Project area is conceptualised as being a barrier to groundwater flow, however, little field evidence is provided to justify this conceptualisation.**

(a) MC and DI agree on this point, and agree that there was insufficient justification of the faulting in reporting the conceptual hydrogeological model.

2.8 **1(e)(ii)B. The assumption that this fault acts as a barrier to groundwater flow has major implications for the predicted extent of the Project's impacts.**

(a) MC and DI agree on this point. AD had in fact re-run the groundwater model reported in the AEIS[3] without the horizontal flow barrier package (representing the faults), and the results showed increased drawdown extents in those places where faults were removed from the model. The difference in drawdown extents is shown in Figure 1.

(b) If on the other hand, for example, the fault mapped by New Hope Group (and provided by AGE in Figure 2), with 50m throw to the southwest of the Project, acts as a barrier to flow, then drawdown from the mine could extend further to the southeast of the mine lease, towards Oakey Creek. MC and DI agree that there remains uncertainty with respect to the role of faults in the propagation of drawdown from the Project.



LEGEND

- New Acland Coal Mine - Stage 3
- Cadastre
- Watercourse
- Existing mine permissions
- Stage 3 pit areas
- Walloon Coal Measures

Predicted drawdown without faults

- 1
- 2
- 5
- 10
- 20
- 30

Predicted drawdown with faults

- 1
- 2
- 5
- 10
- 20
- 30

New Acland Coal Mine Stage 3 (G1680A)

Joint Expert Report - Groundwater

Walloon Coal Measures aquifer Predicted drawdown with and without faults - end of mining (2030)

DATE 12/02/2016

FIGURE No: **1**

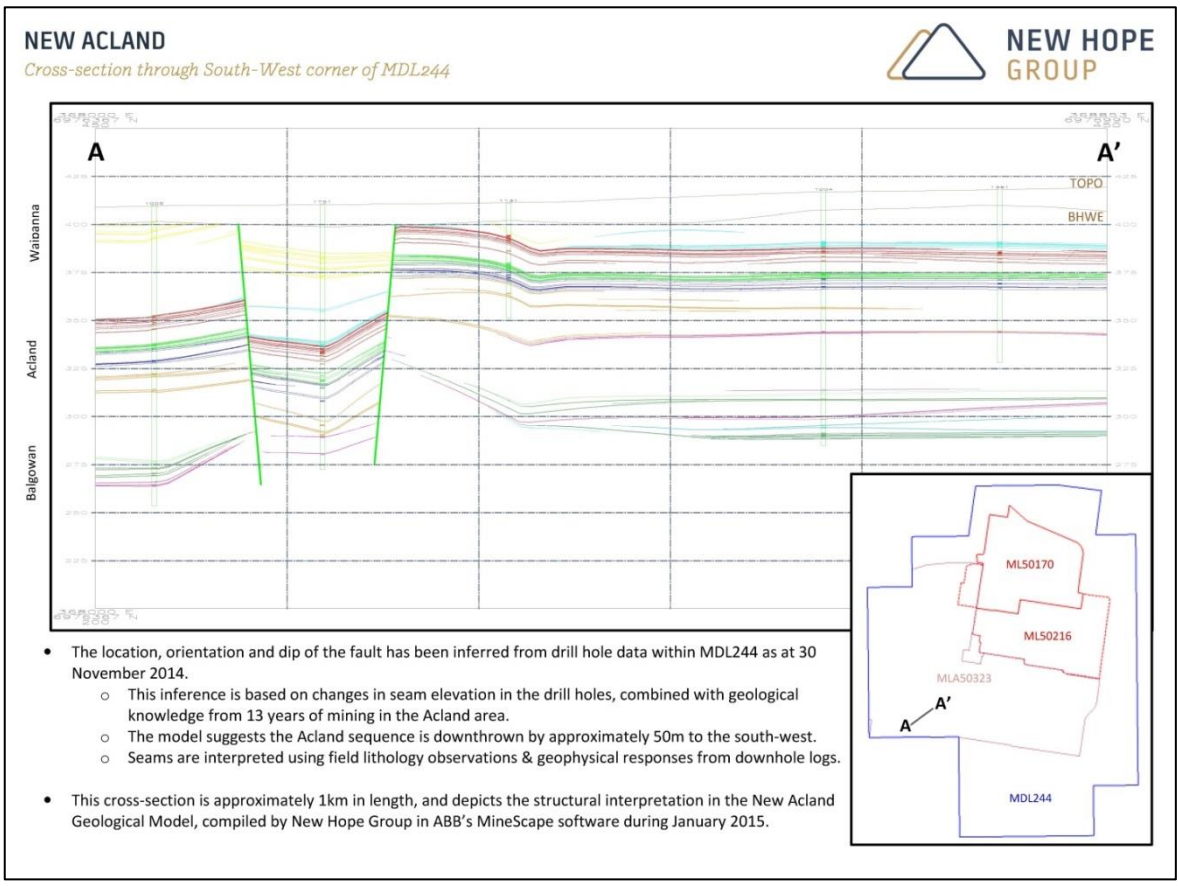


Figure 2 Geological cross section A-A' generated from NHG geology model

2.9 **1(e)(ii)C. The preliminary data (e.g. pumping test analysis) is not consistent with the presence of a nearby flow barrier.**

(a) MC and DI agree on this point – refer 1(e)(i)(B) in Item 0 above.

1(e)(iii) groundwater-surface water interaction, for example:

2.10 **1(e)(iii)A. Early assessments predicted impacts to base-flow in Oakey Creek and Myall Creek, and there is no adequate explanation of why subsequent assessments predict no effect on baseflow.**

(a) AD, MC and AW agree on this point. AD considers that the change in the model setup and modelling approach from the EIS to the AEIS has contributed to this, however he hasn't reviewed the EIS model files, and cannot pinpoint the exact change leading to the difference.

2.11 **1(e)(iii)B. Assertions that there is no groundwater-surface water interaction are not well founded.**

(a) MC clarified that this statement primarily relates to the question of baseflow. The four experts agree to defer discussion of this issue to later, when it is raised under groundwater modelling [e.g. Issue 5(b)].

2.12 **1(e)(iii)C. The proposed monitoring program is inadequate to detect potential impacts in the alluvium surrounding surface water features.**

(a) MC and DI agree that one monitoring bore in the alluvium (as proposed in the current Groundwater Monitoring and Impact Management Plan) is inadequate.

(b) *Information clarification:* In past discussion with the client, DI has recommended an additional monitoring bore should be considered into the Lagoon Creek alluvium where it exists in the south west corner of the MLA and where a 2 m drawdown response is predicted at the end of mining in 2030 (refer Figure 6-20, Appendix F, AEIS Report - Groundwater Modelling Technical Addendum[3]). There was disagreement as to whether two monitoring wells (i.e., with the inclusion of this second bore) would be adequate for detecting all potential impacts in the alluvium. (See issue 3(a)(i)A.

1(e)(iv) aquifer properties, for example:

2.13 **1(e)(iv)A. No pumping tests were conducted in the Tertiary Basalts and Alluvium, so there are no reliable site-specific estimates of storativity. This significantly increases uncertainty regarding the likely extent of drawdown.**

2.14 MC and DI agree that pumping tests from other aquifers (apart from the Walloon Coal Measures) were not shown in the EIS[1] and AEIS[3]. MC and DI agree that there are not reliable site-specific estimates of storativity and that this does create uncertainty in the likely extent of drawdown.

1(e)(v) the potential impacts on groundwater dependent ecosystems:

2.15 **1(e)(v)A. Early assessment reports by the Applicant suggested that there were no groundwater dependent ecosystems in the area of the Project.**

(a) MC and DI agree on this point.

2.16 **1(e)(v)B. The Applicant has since identified potential groundwater dependent ecosystems but only limited assessment of the potential impacts on these has been conducted.**

(a) MC clarified this point by stating that additional information and further assessment (for example, installation of monitoring bores) would be required to provide detail of the water levels and depth to groundwater occurring in those areas where possible GDEs have been identified (as presented in

AEIS Appendix N[4], p25-29). MC and DI agree that this data/information has yet to be provided.

2) The Applicant's assessment of both existing water quality and the Project's potential impacts on water quality are inadequate for the purpose of impact assessment and any proposed approval decision.

2(a) Baseline monitoring of groundwater quality in the area is not adequate for a proper characterisation of existing water quality or future impacts. For example:

2.17 **2(a)(i) Groundwater sampling within aquifers surrounding the Project has been insufficient to characterise background conditions, particularly in aquifers other than the Walloon Coal Measures.**

(a) MC and DI agree that whilst groundwater monitoring data (including water quality) does exist since 2003, this was limited to four monitoring bores in the Walloon Coal Measures and one monitoring bore in the Tertiary Basalt at the commencement of monitoring, with an additional six Walloon Coal Measures and two basalt monitoring bores being progressively added to the groundwater monitoring network since 2005. More specifically these monitoring bores are focussed around the existing Stages 1 and 2 mine areas. MC and DI agree that, hence, water quality sampling results for the Stage 3 expansion area (e.g. away from the immediate vicinity of active mining) and particularly in aquifers other than the coal measures, are currently limited for establishing a baseline water quality dataset.

2(c) The Project creates risks to water quality as a result of deficiencies in waste-rock and tailings leachate management, including:

2.18 **2(c)(ii) Geochemical analysis for the Project shows that some samples of waste rock have acid generating potential and/or elevated levels of metals and other trace elements, yet there is little information about steps that will be taken to ensure contaminants from waste rock do not spread into the surrounding groundwater or soils.**

(a) DI and MC agree that the geochemical testing showed that on the whole only a small number of samples show any acid generating potential or elevated metals content.

(b) DI and MC agree that it is somewhat unclear how monitoring of potential acidity and metal contamination from areas of mine spoil will be conducted.

---

[4] AEIS Appendix N, IESC Submission Response, New Acland Stage 3 Project, New Hope Group, August 2014.

(c) DI and MC agree that Appendix A – Revised Environmental Management Plan[5] (pages 50 to 53) identifies that any occurrences of acid rock drainage (ARD) within the Stage 3 expansion would be managed using a containment system, which include progressive backfilling into pit voids and placement below the pre-mining groundwater level, and such out-of-pit dumps encapsulated within inert or neutralising material during construction.

(d) DI and MC agree that where potential acid mine drainage could not be managed through capture within the final voids acting a groundwater sinks, down-gradient groundwater monitoring bores would be required to identify whether acid mine drainage and/or metal contamination might result in environmental harm.

2.19 **2(d) The Project creates risks to water quality as a result of long term issues with mine rehabilitation and leaching of contaminants to groundwater, and management strategies are as yet to be developed for these.**

(a) DI and MC agree that some management strategies for mine rehabilitation and leaching of contaminants to groundwater have been outlined – such as providing an impermeable cap above the tailings storage facilities, profiling of the final landforms to control rainfall run off, and creating groundwater 'sinks' within the final voids. Both agree that the final void in Willaroo Pit with a predicted void water level higher than the pre-mining groundwater surface could create a source for groundwater flow away from the mine that could be a risk and this scenario should be re-considered through redesign of the final void configuration.

3. The monitoring program proposed to detect and assess impacts on groundwater is inadequate.

3(a) The groundwater monitoring required under the groundwater monitoring and impact management plan ("GMIMP") and conditions in the draft Environmental Authority ("EA") is deficient in a number of respects, including:

3(a)(i) Only a limited number of bores are required in various units:

2.20 **3(a)(i)A. Only one monitoring bore is proposed in the Alluvium within the stage 3 expansion.**

(a) MC and DI agree on this point – e.g. that only one monitoring bore is proposed. However, there was disagreement as to the appropriate level of additional monitoring that would be required in the Alluvium.

---

[5] Response to Information Request from the Department of Environment and Heritage Protection, New Acland Coal Mine Stage 3 Project, New Hope Group, June 2015.

2.21 **3(a)(i)B. Only one monitoring bore is proposed in the Marburg Sandstone.**

(a) MC and DI agree that in fact two bores are proposed for this aquifer in the Groundwater monitoring and impact management plan. There is disagreement as to whether two bores are adequate to detect all possible impacts in the aquifer.

2.22 **3(a)(i)C. No monitoring bores are proposed in the Helidon Sandstone.**

(a) MC and DI agree that it is highly unlikely that there will be any impact on this aquifer, so monitoring bores are unlikely to be needed.

2.23 **3(a)(i)D. Only one monitoring bore is proposed in the backfilled areas of mining to monitor future recovery and mounding of groundwater.**

(a) DI and MC agree, and agree that it would be good to have more. MC and DI would like to see more contingency for additional monitoring of the Stage 2 and Stage 3 backfilled areas (given there are multiple areas of backfill).

2.24 **3(a)(ii) For example, the revised modelling predicts drawdown impacts in the alluvium near Lagoon Creek in the southwest of the Project area, but there is no monitoring bore in the alluvium to monitor this drawdown or establish a baseline level.**

(a) MC and DI agree, see response to 3(a)(i)A. above.

2.25 **3(a)(iii) Under the EA, water level trigger thresholds have yet to be determined for the monitoring bores, and as such the appropriateness of water triggers to protect existing water users cannot be assessed.**

(a) MC and DI agree that water level triggers have yet to be determined. MC and DI agree that there is a mechanism in place within the Draft Environmental Authority EPML00335713 – New Acland Coal Mine[6] to set trigger levels in the near future. The experts agree to defer further discussion of the appropriateness of water triggers and other monitoring and management strategies for the protection of groundwater users to later items (e.g., 4b and 21).

[6] Draft environmental authority EPML00335713 – New Acland Coal Mine, 28 August 2015.

4) As a result of the above deficiencies:

2.26 **4(a) The Project risks having an unacceptable, permanent adverse impact on groundwater and on water users in the Project area.**

(a) MC and DI agree that some clarification of the wording of this issue is required to remove any ambiguity. MC and DI agree that there is a risk that the project will have an impact that is potentially unacceptable to some people (e.g. some landholders).

(b) MC also believes that there is the potential for impact to groundwater dependent ecosystems (GDEs); however, DI neither agrees nor disagrees, because he believes this requires further assessment by other disciplines.

GROUNDWATER MODELLING

5. The Applicant's predictive numerical model is deficient in a number of respects, including:

5(a) The approach to modelling faults is flawed for reasons including the following:

2.27 **5(a)(i) Faulting has not been modelled in accordance with the MODFLOW manual**.

(a) AD and AW agree that faulting has not been modelled in accordance with the MODFLOW manual, and as a result, the behaviour of faults in the model is not as the modellers intended.

(b) AD and AW agree that despite this error, this has resulted in a conservative assessment (relative to the application of faults as per the MODFLOW manual) of the potential drawdown extents in directions where there are gaps along the fault alignments.

2.28 **5(a)(ii) Faults appear to have been modelled as impermeable barriers to flow, whereas faults are usually not perfect barriers to flow.**

(a) AD, MC and AW agree that evidence for fault locations and properties is lacking.

(b) AD, MC and AW agree that faults are usually leaky rather than impermeable. AD and AW agree that with significant throw (up to 50 m as has been mapped at site), the faulting may realign permeable coal seams to lower permeable interburden and where this happens, faults will impede horizontal flow.

(c) AD and AW agree that whilst leakage can occur across a fault, faults are more likely to impede horizontal flow, compared to flow through a continuous coal seam (aquifer).

(d) AD, MC and AW agree that faults can provide enhanced vertical pathways (beyond an otherwise uncompromised aquitard) for groundwater flow, which has not been modelled in the aquifer but may nonetheless have important implications for the behaviour of the aquifer system.

2.29 **5(b) The modelling of groundwater-surface water interaction is deficient, which is compounded by the lack of surface water monitoring, or any attempt to use the available surface water data to infer base flow.**

(a) AD, MC and AW agree that if seasonality were important to the assessment of GDEs, then the model in its current setup cannot inform changes in flow rates to surface water bodies, which are expected to fluctuate with the seasons, because the seasonality of aquifer water levels in the vicinity of streams is not modelled. AD, MC and AW also agree that while the mine effects are probably not seasonal, the mine may influence seasonal fluctuations that are important for GDE behaviour.

(b) AD and AW agree that improved monitoring of surface water and inclusion of these data in future modelling iterations would improve the reliability of the model's water budget.

(c) AW, MC and AD believe that there is a possibility that capture of stream baseflow may occur due to mining. However, AD considers it unlikely because the surface drainages at and around the mine site are ephemeral.

2.30 **5(c) The calibration methodology demonstrates a number of misconceptions, errors and poorly explained elements including:**

(a) AD and AW agree that additional calibration constraints (such as baseflow estimates, should they have been available) are likely to reduce the number of simulations that would be considered calibrated.

(b) AD and AW agree that the degree of calibration has not been directly considered in assessing the most likely drawdown and ranges in expected drawdown.

(c) AD and AW agree that while the range in drawdown does indicate to some degree the level of uncertainty, there are other factors not tested that could influence the drawdown, and these should be acknowledged.

(d) AD and AW agree that there is a lack of explanation for poorly calibrated bores in the report, a lack of information on the parameters of individual

"calibrated" models, and a lack of discussion regarding uncertainty and the model's predictive capability. Nevertheless, AD and AW agree that the supplied model files from Jacobs do show each individual parameter set that met the calibration criteria, and that formed the basis of the predicted simulations. AD and AW also agree that the ranges of parameters used in the model are apparent from the report.

(e) AD and AW agree that the number of cases adopted as "calibrated models" is inconsistent in the reporting, but that the modelling files obtained from Jacobs indicates that the number of calibrated models used to derive drawdown statistics is in fact 18.

2.31 **5(c)(i) The justification for avoiding calibration of specific storage is ill-founded**

(a) AD and AW agree that including specific storage in the parameters that were modified as part of the calibration process would have been advantageous.

(b) AD and AW agree that (i) rock compressibility should be part of the specific storage equation, rather than adopting the compressibility of water in setting the specific storage parameter, and (ii) it follows that there doesn't seem to be a valid reason not to calibrate Ss, or at least conduct a sensitivity analysis.

2.32 **5(c)(ii) It is unclear which distribution was used in selecting random parameters for the Monte Carlo analysis, which may lead to profound differences**

(a) AD and AW agree that the distributions used to select random parameters from each of the parameter types in Table 5.1 of AEIS[3] are not clear in the report.

2.33 **5(c)(iii) There is no clear rationale for the omission or inclusion of bores in the calibration data set.**

(a) AD and AW agree that the reasoning behind inclusion and exclusion (if any) of monitoring data within the calibration data set is not clear from the report.

(b) AD and AW agree that the weighting of the calibration bores appears in Table 5.2 of AEIS[3], and it appears that bores owned and monitored by the mine and bores sampled by SKM staff are given the highest weights.

(c) AD and AW agree that it is unclear how OGIA data and modelling were integrated into the AEIS investigation. AD and AW agree that clarification of the application of OGIA data and modelling, and, in the event it has not been considered, consideration of OGIA data and modelling outputs, are worthwhile in future modelling iterations. AD and AW agree that any use of OGIA modelling outcomes would need to take into account the coarse resolution of the OGIA model.

2.34 **5(c)(iv) It is not clear which parameters were calibrated in steady state relative to transient calibration.**

(a) AD and AW agree that the report (Section 5.4.2 of the AEIS[3]) is not clear on which parameters were calibrated in steady-state relative to transient phase of the modelling, but that the modelling files show that the same calibration parameters exist in both due to the modelling methodology.

2.35 **5(c)(v) Assertions as to the accuracy of drawdown simulated by the model are not supported by retrospective drawdown analysis.**

(a) AD and AW agree that, in fact, some evidence of retrospective drawdown can be found in the AEIS report.

(b) AD and AW agree that more retrospective analysis of previous drawdown from mining would improve the evaluation of the model calibration process and the overall understanding of model accuracy and fitness-for-purpose.

(c) AD and AW agree that while hydrographs given in the report show some evidence of drawdown from previous mining activities, further reporting of drawdown from historical mining, in the form of mapping, would improve the report. AD and AW further agree that to achieve this, a “no-mining” historical simulation would be required, and that this would help distinguish the climate versus mining operation signal within historical groundwater level measurements and modelling predictions, and provide the model output to assess the cumulative impact from both the approved and proposed mining.

5(c)(vi) The expressed uncertainty in drawdown extent is unconvincing, because, for example:

2.36 **5(c)(vi)A. The number of cases used to derive prediction ranges is relatively small.**

(a) AD and AW agree that the number of cases used is rather small.

2.37 **5(c)(vi)B. The level of calibration is weak.**

(a) AD and AW agree that there is significant bias in some calibration hydrographs (Appendix A.1 of AEIS[3]), in agreement with the IESC’s[7] most recent advice

[7] IESC 2015-073: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion, Final New Acland Coal Mine Stage 3 Advice, 10 December 2015.

2.38 **5(c)(vi)C. Structural and conceptualisation uncertainty (e.g. measurement error, etc.) are not included in the analysis. Without considering these, an overly optimistic view of the model's accuracy and uncertainty is presented.**

(a) AD and AW agree that measurement error and some fixed model characteristics (e.g. homogeneity, treatment of faults, other groundwater users, flooding) are not considered in the uncertainty analysis, but that some of these may have a significant impact on uncertainty.

(b) AD and AW agree that if a homogeneous model is adopted that uses parameters considered to produce "worst case" conditions (for example higher hydraulic conductivity usually results in more extensive drawdown), it follows that such a homogeneous model could serve as a conservative representation of impacts (i.e., over-estimate the impacts) in what is known to be a heterogeneous aquifer. Note that here, "worst case" may differ depending on whether mine inflows/outflow, stream impacts, GDE impacts and drawdown are each considered. Also, adequate testing of the model would be required to assess whether "worst case" parameters produced the intended conservative estimates (e.g. through sensitivity analysis).

2.39 **5(d) The modelling and impact assessment fails to properly analyse and incorporate into the model information on the impacts of existing mining operations.**

(a) AD and AW agree that, in fact, the impacts of existing mining operations are considered in the modelling undertaken for the AEIS, but that more needs to be done to properly extract the impacts of existing mining operations from the results.

2.40 **5(d)(i) Such baseline measurements are essential to understand future impacts.**

(a) AD and AW agree that the historical mining and available data on the impacts (i.e. drawdown and mine inflows) have been included into the model.

(b) AD and AW agree that maps of observed heads, including pre-mining heads, would be useful (see Appendix A (pA1-3) of Appendix C in AEIS[4]**Error! Bookmark not defined.**)

(c) AD and AW agree that (i) clearer explanation is warranted on the modelling approach, in regards to differentiating the effects of Stage 1-2 and Stage 3 mining operations, and (ii) it would be beneficial to illustrate the drawdown (past and future) attributable to Stages 1-2, and the same for Stage 3, and then the cumulative drawdown.

2.41 **5(d)(ii) Knowledge gains from assessing historical impacts would offer critical insights into likely future impacts, for example, insights into model parameters and pit inflows ought to have been gained.**

(a) AD and AW agree that clearer reporting of previous drawdown (modelling versus observed) would be useful, and that the statement in the report at Section 5.4.2 of AEIS[3] that the model "provides a good replication of drawdown from mining activities" should be demonstrated by offering a more thorough analysis of the predicted and observed drawdown extent.]

(b) [See also earlier points (5(c)(v), 5(d) and 5(d)(i)) of relevance to this issue]

2.42 **5(d)(iii) Environmental degradation arising from previous mining must be taken into account in monitoring and differentiating impacts from the Project.**

(a) AD and AW agree that any environmental degradation (such as impacts to vegetation) arising from previous mining would need to be understood before it would be possible to attribute any new degradation of the aquifer or groundwater-dependent ecosystems to the Stage 3 project.

2.43 **5(e) The review of relevant literature and existing knowledge relating to parameters used in modelling, including in relation to faults, aquifer properties, evapotranspiration and recharge, is inadequate.**

(a) AD, MC and AW agree that it would assist in defending the assumptions and parameter ranges if the review of existing literature was improved.

2.44 **5(f) The modelling and impact assessment reporting is based on insufficient baseline data, including with respect to pre-mining water levels, and fails to take into account all available data.**

(a) AD, AW and MC agree that there is potentially useful information contained in the methods and results of the investigation by the Office of Groundwater Impact Assessment (OGIA); however, it is presently unclear in reports as to the degree to which OGIA data and modelling have been applied, beyond being used to inform the parameter bounds for the calibration.

(b) AD, AW and MC agree that the reporting is not adequately clear to determine whether or not DNRW groundwater observations were omitted, and if so, whether the reasons were valid.

2.45 **5(g) The choice of fixed-head boundary conditions in the model is not properly justified and may affect the reliability of impact predictions generated by the model.**

(a) AD and AW agree that after review by AD of the budgets of the 18 calibrated models, the maximum change between the null and predicted models for boundary inflow was negligible (<0.3%), and therefore the fixed-head boundary conditions most likely have no significant direct impact on the predictions being made.

(b) AD and AW agree that the fixed head elevations adopted in the model do conform to data bounds presented in Figures 4.7 to 4.9 of AEIS[3], except for the upper end of the basalt where the head is as high as 630 m AHD for a small portion of the eastern side of the model domain.

(c) AD and AW agree that the method of obtaining basalt boundary heads highlights that a topographical-head relationship probably doesn't exist, but that this method may be the only viable way to estimate boundary heads.

(d) AD and AW agree that the mismatch in the topography–head relationship for the basalt is probably due to compartmentalisation of the aquifer, which isolates the basalt into smaller fractured networks that recharge and discharge somewhat independently, or at least with reduced connectively with other parts of the unit, resulting in differing depths to water and variable responses to rainfall.

5(h) With respect to recharge in the model:

2.46 **5(h)(i) The method of recharge estimation is overly simplistic.**

(a) AD and AW agree that conceptual statements about recharge sources seem not consistent with the modelling approach.

(b) AD and AW agree that the report requires a clearer and more comprehensive discussion of recharge characteristics and trends over time, as used in the model.

(c) AD and AW agree that there is little difference between recharge (Figure 5-8 of AEIS[3]) to the different geological zones, when in reality they likely differ more so, and in general, the approach to assigning recharge to different geological zones is unclear.

2.47 **5(h)(ii) Recharge values are lower than expected.**

(a) AD and AW agree that the DNRM value of 12.7% is about twice the maximum used in this study. However, at the time of the Joint Expert Meetings, it was unclear as to the basis for this value.

2.48 **5(h)(iii) The complete insensitivity of the model to recharge is of concern.**

(a) AD and AW agree that: (i) more investigation is needed into the insensitivity of recharge, (ii) the insensitivity of recharge is apparent in Figure 5-8 of AEIS[3], because the calibrated models have minimum and maximum values that are the same as the input minimum and maximum (based on the 5% SRMS selection of calibrated models), and (iii) in Table 5.5 of AEIS[3], the 50th percentile values appear hardly different in Appendix B (of AEIS[3]), and that otherwise, the box and whisker plots indicate insensitivity.

(b) AD and AW agree that the insensitivity of the model to recharge change should be evaluated through sensitivity analysis (to explores changes in model output with changes in recharge), because it is an unusual model characteristic.

(c) AD and AW agree that: (i) insensitivity of the model to recharge is perhaps caused by the controlling influence of the DRN package, which discharges excess groundwater to the land surface along mapped drainage lines, (ii) therefore the calibration process has probably not informed recharge, and (iii) therefore the DRN package may be acting to control heads in the model, although this requires further investigation.

2.49 **5(i) The lack of seasonality in transient modelling is a major limitation, particularly with respect to groundwater-surface water interaction and the effect of episodic rainfall/stream recharge events.**

(a) AD and AW agree that: (i) the model is deficient for the purposes of seasonality effects and localised GDE impacts associated with streams, but otherwise, the lack of seasonality is reasonable for longer-term, regional-scale impacts, and (ii) the lack of seasonality and other factors means that the model cannot provide absolute values, but is intended to look into net effects (e.g. drawdown).

(b) AD and AW agree that without seasonality in the model, it is not possible to assess episodic recharge effects.

(c) AD and AW agree that reporting of time parameters in the model is deficient, but that the modelling files indicate that stress periods are yearly.

2.50 **5(j) The parameters adopted in the calibrated models are not all reported such that the appropriateness of parameters in the model cannot be determined.**

(a) AD and AW agree that there are summaries of parameters, but that it is not clear which parameters were combined with which parameters in calibrated models, and it is also not clear which parameter sets were best calibrated to observations. AD and AW agree, however, that the modelling files obtained from Jacobs do provide information of the parameters used in each individual model that met the calibration criteria.

(b) AD and AW agree that expert knowledge has been used to set the parameter constraints in the first instance, including field based measurements and the OGIA modelling report (Section 5.2 of AEIS[3]), and thus the calibrated parameters should fall within reasonable proximity of expected values.

2.51 **5(k) The modelling of mine voids and pit lakes is deficient.**

(a) AD and AW agree that the explanation of the methodology for representing voids is not clear in the report.

(b) AD and AW agree that surface water modelling should be the primary method for determining void hydrology, but that the groundwater model should be used in conjunction with the surface water model results to assess groundwater aspects of the mine pit hydrology.

2.52 **5(l) Many of the limitations associated with modelling assumptions are not recognised, and their importance or otherwise does not seem to have been considered, including aquifer heterogeneities, seasonality effects, the treatment of faults, and other groundwater user.**

(a) AD and AW agree that the model should include other groundwater users and an analysis of flow between aquifers. It is also agreed that the Coordinator General's conditions require periodic updating of the model into the future, and that the initial update will include abstraction from other groundwater users, based on the data collected in the baseline assessments and on metered extraction data from DNRM.

(b) As mentioned above in Issue 5(c)(vi)C, AD and AW agree that measurement error and some fixed model characteristics (e.g. homogeneity, treatment of faults, other groundwater users, flooding) are not considered in the uncertainty analysis, but that some of these may have an impact on uncertainty.

2.53 **5(n) The lack of consideration of groundwater use by users in the surrounding area brings into question the model's water balance and the predictions made by the model more generally.**

(a) AD, MC and AW agree that this is a missing component of the water balance.

(b) AD and AW agree that the Coordinator General's report[11] outlines conditions that require the model to be revisited after necessary data have been collected through the baseline assessments, and that the data collected will be used to add existing groundwater users into the model.

5(o) The impact assessment reports demonstrate a number of reporting deficiencies, including that:

2.54 **5(o)(i) The results, diagrams and key messages are not properly supported and explained in the reports.**

(a) AD and AW agree.

2.55 **5(o)(ii) The text is lacking in adequate detail to understand what was done by the modellers.**

(a) AD and AW agree.

2.56 **5(o)(iii) Various statements in the reports defy well-known groundwater and modelling theory and basic mathematics.**

(a) AD and AW agree that there appears to be a disjoint between the explanation of BoM ET rates and what has been used to parameterise the EVT package.

(b) AD and AW agree that the equation described for setting DRN conductance appears to be wrong as described in the text. Furthermore, DRN conductance values are generally considered to be non-physical parameters obtained by model calibration.

(c) AD and AW agree that in Section 5.2 of AEIS[3], the use of "random distribution" is incorrect, i.e., the normal and log-normal distributions involve random selection of values, not random distributions.

(d) AD and AW agree that in Section 5.2 of AEIS[3], there is a misunderstanding of compressibility of water and its role in specific storage, relative to the role of the rock compressibility.

(e) AD and AW agree that in Appendix B of AEIS[3], there is an error in the way these plots have been created, as described in the following: the horizontal axis has a log scale, suggesting that a log normal distribution is expected.

Subsequently, there needs to be equally spaced (in the horizontal direction) data points because each interval should be the same (logarithmically). That is, instead of a part-linear interval (10, 20, 30, 40, 50,…, 100, 200, 300…), a log interval (e.g. $10^{0.5}$ - 4E-6, 1.265E-05, 4E-5, 1.265E-4, etc.) should have been used. AD and AW agree this is primarily a presentation issue and has not influenced what was used in the model.

PART 1: Additional issues that the Applicant's notified experts propose to seek agreement on at the joint expert meeting, where there is an expert proposed by the objectors relating to that issue

GROUNDWATER CONCEPTUALISATION

OCAA LIST OF ISSUES

2.57 **20. In relation to paragraphs 2(c)(ii) and 2(d) of the OCAA List of Issues, there is minimal waste rock-acid generating potential and there are mitigation measures proposed to minimise impact on the groundwater receiving environment.**

(a) DI and MC agree that only a small proportion of sampled rocks have any acid generating potential, however that some uncertainty remains as to how potential leaching from waste rock areas will be monitored and managed.

PART 2: Additional issues that the notified experts of the applicant will address, where there is no expert proposed by the objectors relating to that issue

GROUNDWATER

2.58 **35. The predicted water usage is within the New Acland Mine's allocation under existing authorisations to take water.**

(a) DI and MC agree that the water usage under the Stage 3 Expansion from the Tertiary basalts, Marburg Sandstone, Walloon Coal Measures and Helidon Sandstone are unlikely to exceed allocations and that there is significant un-used allocation in these aquifers.

(b) Regarding the Quaternary Alluvium, MC and DI agree that NAC does not have an allocation to take or interfere with water in the Quaternary Alluvium.

3. **Key issues in dispute**

GROUNDWATER CONCEPTUALISATION AND GROUNDWATER QUALITY

1) The Applicant's assessment of the impacts of the proposed New Acland Coal Mine Stage 3 project ("Project") on groundwater rests on an unsound conceptualisation of the hydrogeology of the area.

1(a) The conceptualisation is not supported by sufficient detailed geological information. For example:

3.1 **1(a)(i) There is limited geological data provided in support of the regional geology.**

(a) There was disagreement as to whether the information and data provided on the regional geology was adequate for the purpose, e.g., to assess groundwater impacts of the mine expansion. DI believes sufficient information was provided to understand the main geological features and relationships, although bore logs should have been provided [see point 1(a)(ii), Item 2.2 of Key matters of agreement]. MC believes that the lack of regional geological information, particularly with regard to putting the site into geological context, such as the site's proximity to basin boundaries, the structural setting, deformation history, and major stratigraphic relationships could all be important in how the hydrogeology is conceptualised and therefore this is an important omission.

3.2 **1(b) Insufficient field data has been collected to determine aquifer properties and connection between different aquifers.**

(a) There was disagreement as to whether there are adequate data to make a reasonable conceptualisation of aquifer properties and cross-aquifer connection. DI believes that the data provided on aquifer properties are adequate (as a bare minimum), but MC believes further field data would be required to properly assess the properties of multiple aquifers, and their level of hydraulic connection.

(b) In relation to the 6 hour pumping tests conducted in the Walloon Coal Measures, DI believes data collected were sufficient to provide a basis for establishing aquifer parameters (that is, the minimum amount of data has been presented to get an idea of the relevant aquifer properties). DI believes the drawdown responses observed in the nearby monitoring bores indicate that the outcome of the tests were sufficient for determining aquifer properties for the Walloon Coal Measures. However, MC believes that the data are not adequate to obtain accurate estimates of transmissivity,

storativity and (if applicable) the degree of leakage, as pumping duration was too short.

3.3 **1(c) There is insufficient baseline data on water levels in the aquifers of the area such that regional flow patterns are not properly understood.**

(a) AD and DI believe that the AEIS does demonstrate an understanding of groundwater flow both locally and regionally. This is evidenced in Figures 4.8 and 4.9 of the AEIS[3], which both show a good correlation between water level elevation and topography. In addition, the groundwater contours presented from the model output also reflect the regional flow pattern shown in Figure 4.2 of the OGIA Surat UWIR[8] which shows an overall groundwater flow to the southwest.

(b) MC and AW disagree that there are adequate data to show that flow patterns both regionally and locally are clearly understood in the major aquifers, as a water level contour map is only presented for the Walloon Coal Measures (EIS Figure 6-13) and the dominant flow direction does not match the flow direction in the model's simulated early stages of mining (e.g., Figure 6-12 of the AEIS[3]). Additionally, there is not a clear and simple relationship between topography and groundwater elevations in the Tertiary Basalts (shown by the lack of linear correlation in Figure 4-7 of the AEIS[3]), indicating that topography is not always a good predictor of flow patterns in this aquifer. For the Marburg Sandstone and Walloon Coal Measures, the slopes of both trend-lines in figures 4.8 and 4.9 deviate from one, and there are a number of points where water levels show a mismatch with topography by 10s of metres. This indicates that while the flow directions do broadly follow the topography as would typically be expected, the use of topography as a proxy for flow direction would result in biases in the estimation of water levels in some cases.

3.4 **1(d) Impacts on the Tertiary Basalt aquifer from mining are likely to be underestimated due to assumptions about the connectivity and interaction of the Project with the overlying basalts.**

(a) Whilst all experts believe that there remains uncertainty as to the likely impacts on the basalt, in particular, the extent and magnitude of drawdown likely to be experienced, there was some disagreement on this issue. AD and DI believe that the estimates of drawdown extent in the basalt (derived from groundwater modelling) are conservative – i.e., probably overestimates, due to compartmentalisation of the aquifer. MC and AW believe that while it is

[8] OGIA, Underground Water Impact Report for the Surat Cumulative Management Area, report prepared by the Queensland Water Commission, 18 July 2012.

possible that the drawdown extent is conservative, there is still significant uncertainty regarding this, and that drawdown extent could also be underestimated. MC believes this is primarily due to a lack of field data to inform an understanding of the aquifer's properties and vertical connectivity with the Walloon Coal Measures. AW and MC also pointed out that compartmentalisation would likely mean that the drawdown *magnitude* in more localised areas has been underestimated (i.e. not conservative). AW and MC believe that, more generally, heterogeneity may create higher localised drawdown than has been predicted to occur, because the conceptual and numerical models of the investigation adopt homogeneous hydrostratigraphic units, and don't necessarily adopt worst-case aquifer parameters.

(b) For example, MC believes it is likely that the drawdown magnitude in some areas (e.g. immediately northwest of the existing mine pits) has been under-estimated, because the model predictions suggest that water levels in the WCM directly below areas of basalt will be 10 m below those in the basalt, and without a significant barrier to vertical flow (for which insufficient field evidence has been provided), it will be difficult to maintain a vertical head difference of this magnitude. DI believes however that there is likely to be a level of vertical separation between the two aquifers which could prevent significant leakage.

1(e) There remains unacceptable uncertainty about:

(i) The connection between different hydro-stratigraphic layers, for example, as a consequence of limited pumping tests:

3.5 **1(e)(i)A. Pumping tests have only monitored water levels in the Walloon Coal Measures, making no assessment of impacts on other units - the Quaternary Alluvium, Tertiary Basalts, and Marburg Sandstone (Appendix G4-1).**

(a) There was disagreement regarding the adequacy of pumping test data for assessing impacts of mining on the other units (apart from the Walloon Coal Measures). DI stated additional pumping tests were previously carried out in the Tertiary basalt and Hutton (Marburg) Sandstone as part of previous studies for the mine (e.g. for NAC Stage 2[9]) and that these data have been used to inform aquifer properties in other layers (EIS[1] [pages 6-15] and Appendix N, IESC Submission Response[4] [pages 6, 7 & 8]. MC reviewed the Stage 2[9] documentation (provided by DI during the expert meeting) and relevant sections of Appendix N. MC believes that the details provided about

[9] New Acland Coal Mine Stage 2 Expansion Project Environmental Impact Statement, report prepared by Sinclair Knight Merz (Jacobs) for New Hope Coal Australia, January 2006.

pumping tests conducted in other aquifers are insufficient to assess whether these provide confident estimates of aquifer properties for use in the Stage 3 impact assessment. MC also believes that with regard to the test in the Walloon Coal Measures, because no monitoring of the response of aquifers other than that being pumped was conducted and the tests were too short to assess leakage behaviour, the pumping test results are of limited use in determining vertical connectivity between aquifers.

3.6 **1(e)(i)B. Consultants SKM noted that pumping tests were conducted over short time intervals and so these tests are unlikely to capture the hydraulic behaviour of the aquifers under long-term conditions of stress.**

(a) Regarding the adequacy of the tests for determining the basic aquifer parameters in the Walloon Coal Measures, there was some level of disagreement; DI believes the tests were adequate to provide a basis for determining aquifer parameters and that pumping for longer in the bores would unlikely have resulted in a drawdown response in the nearest basalt aquifer given the distance from these bores. MC however believes 6 hour tests are too short to get reliable aquifer properties for the Walloon Coal Measures aquifer(s), particularly the storage coefficient, and that additional or alternative test locations could have been used to monitor the response in the basalts to pumping in the coal measures.

3.7 **1(e)(iii)C. The proposed monitoring program is inadequate to detect potential impacts in the alluvium surrounding surface water features.**

(a) There is disagreement as to whether the one additional bore proposed by DI in the alluvium of Lagoon Creek would mean that there is adequate monitoring for detecting potential drawdown impacts in the alluvium. DI believes that this additional bore, plus the existing proposed bore (bore 5A shown in Appendix C - GMIMP[5], Figure 3-1 proposed monitoring locations) are adequate to assess drawdown impacts (based on review of borelogs indicating the alluvium in areas that may experience drawdown is likely to not be a productive aquifer). However, MC and AW believe that greater certainty in drawdown predictions in the alluvium and underlying Walloon Coal Measures (from which any drawdown in the alluvium will propagate) is required to assess the minimum number of bores required in the alluvium, but that two bores in total is unlikely to be adequate. This is particularly in the context of uncertainty in the effect of faulting on drawdown extent in the coal measures, and the vertical connection between the coal measures and other aquifers, including the alluvium (1(e)(i)A and 1(e)(ii)).

3.8 **1(e)(iv)A. No pumping tests were conducted in the Tertiary Basalts and Alluvium, so there are no reliable site-specific estimates of storativity. This significantly increases uncertainty regarding the likely extent of drawdown.**

(a) DI stated that additional pumping tests were previously carried out in the Tertiary basalt. Appendix F, Groundwater Modelling Technical Addendum[3], references pumping tests undertaken as part of the Stage 2 EIS for the Tertiary basalt aquifer (page 6). However, MC reviewed this information, including the Stage 2 EIS[9], and believes that insufficient detail is given regarding the pumping test(s) conducted in the Basalt – for example, it was not explained as to where testing was conducted, the duration of testing, where monitoring bores were placed, and how these responded to pumping – to determine whether they provide reasonable estimates of the storativity. The experts disagreed as to whether this is a significant issue in terms of groundwater impact prediction. DI and AD propose that the storativity value adopted and used in the modelling for the Tertiary basalt aquifer would represent the lower end for this parameter, resulting in a larger (i.e., conservative) predicted drawdown. MC and AW disagree that low storativity necessarily results in drawdown that is conservative, and believe that the high degree of uncertainty in the storage coefficient and other aquifer parameters (e.g., transmissivity and vertical hydraulic conductivity) in multiple aquifers means that it is not possible to assess whether predictions of drawdown extent are indeed conservative.

2) The Applicant's assessment of both existing water quality and the Project's potential impacts on water quality are inadequate for the purpose of impact assessment and any proposed approval decision.

3.9 **2(b)(i) Groundwater monitoring results showed highly elevated values of aluminium and iron in some groundwater samples around the existing mine (up to 750 mg/Land 800 mg/L respectively), which have not been adequately explained or investigated.**

Information clarification: MC and DI re-examined the data and agree that these very high values were reported for a single sampling event (dated 13 April 2004). As these very high levels have not been replicated with continued sampling, they are considered outliers that are probably the result of poor/incorrect sample collection procedure during the sampling event in question. MC and DI agree that a review of subsequent water quality data indicates that these results are unlikely to indicate a major departure from background levels.

3.10 **2(d) The Project creates risks to water quality as a result of long term issues with mine rehabilitation and leaching of contaminants to groundwater, and management strategies are as yet to be developed for these.**

(a) There is disagreement that management strategies for mine rehabilitation and leaching of contaminants are yet to be developed. DI identified strategies documented in Appendix D of the AEIS[10], provide a 'Commitments Register' that outline actions for management strategies in accordance with the In-Pit Tailings Storage Facility Management and Final Land Use and Rehabilitation Plans. MC agrees that strategies are outlined, but believes that in some instances there is insufficient detail to judge whether or not these strategies will be adequate – such as outlining whether and/or how leaching of contaminants to groundwater from waste rock storage will be monitored.

3.11 **3(a)(i)A. Only one monitoring bore is proposed in the Alluvium within the stage 3 expansion**

(a) There is disagreement regarding the adequacy of proposed alluvium monitoring. DI believes that with the addition of one other bore in the alluvium of Lagoon Creek, there would be adequate monitoring for detecting potential drawdown impacts in the alluvium. This is based on these two bores being located within the two main areas of predicted drawdown in the alluvium, where this alluvium is likely to be an unproductive aquifer (in his opinion). MC and AW believe that two monitoring bores is unlikely to be adequate to detect significant drawdown impacts that may occur in the alluvium, as there are still significant uncertainties, including the extent of drawdown in the Walloon Coal Measures, the role of faulting, the aquifer properties of the alluvium, and the connectivity between the coal measures and alluvium.

3.12 **3(a)(i)B. Only one monitoring bore is proposed in the Marburg Sandstone.**

(a) DI believes that the two bores proposed in the Groundwater Monitoring and Impact Management Plan in the Marburg Sandstone will be adequate to monitor drawdown, which he expects to be less than what is predicted by the model (i.e., the model prediction is conservative). MC believes that given uncertainty regarding the effects of faulting, the extent of drawdown and the connection between aquifers, two bores is a small number and more are required.

---

[10] Appendix D Commitments Register, New Acland Coal Mine Stage 3 Project AEIS, New Hope Group, August 2014.

4) As a result of the above deficiencies:

3.13 **4(a) The Project risks having an unacceptable, permanent adverse impact on groundwater and on water users in the Project area.**

(a) MC believes that in addition to impacts that may be deemed unacceptable by some landholders in the region (which DI and MC agree may occur), there is the potential for impact to groundwater dependent ecosystems (GDEs). However, DI neither agrees nor disagrees regarding GDEs, as this requires further assessment by other disciplines.

3.14 **4(b) The conditions proposed for the Project are inadequate to avoid or mitigate these impacts.**

(a) There is disagreement on this issue. DI believes that the impacts and risks are defined, were estimated conservatively, and are manageable under the conditions proposed. MC believes however that additional monitoring requirements (e.g. additional compliance bores) are needed and that additional field data are required to obtain a necessarily more detailed understanding of aquifer properties and aquifer interconnectivity before impacts and risks are adequately defined and are manageable. This is in line with the most recent advice from the IESC (2015[7]) which raises outstanding issues that are not covered under the CG's conditions (e.g. response to Question 2, points 12b, 12d and 13). MC and AW also believe that the existing groundwater monitoring infrastructure has been under-utilised in terms of obtaining field data for further development of the groundwater model, and that the groundwater model has not been applied to interpret, redesign, and/or optimise the groundwater monitoring infrastructure and sampling frequency. MC and AW believe that this type of analysis is required to gain an understanding of how the groundwater system responds to change. AW and MC believe that even with monitoring of water levels under the proposed conditions, without a strong understanding of the hydrogeological system's responses, impacts to both groundwater users and (potentially) GDEs may be difficult to detect and separate from other influences such as climate.

GROUNDWATER MODELLING

5. The Applicant's predictive numerical model is deficient in a number of respects, including:

3.15 **5(b) The modelling of groundwater-surface water interaction is deficient, which is compounded by the lack of surface water monitoring, or any attempt to use the available surface water data to infer base flow.**

(a) AW and AD disagree as to whether model is deficient for the purposes of modelling groundwater-surface water interaction. AW suggests that the model is deficient for the purposes of studying seasonality effects in surface water systems and localised GDE impacts associated with streams, due to the annual stress periods. AD contends that the lack of seasonality is not a deficiency in the model due to the regional context, and that the modelling approach using the 'null' and 'predictive' models to determine the impacts is sufficient for this level of assessment.

3.16 **5(c) The calibration methodology demonstrates a number of misconceptions, errors and poorly explained elements including:**

(a) AW and AD disagree on the value of pit inflows in identifying "calibrated models". AW has the view that the calibration to pit inflows, which are a small percentage of the total flows to surface water features (Section 6.2 of AEIS[3]), does not eliminate the common issue of model non-uniqueness (i.e. different sets of model parameters producing the same predictions), notwithstanding that the stochastic approach was intended to at least partly account for model non-uniqueness. That is, AW believes that correct pit inflows in the model are unlikely to adequately inform the parameters that are eventually selected through the calibration approach. That is, the parameters of the calibrated models cannot be deemed as "correct" (for subsequently making drawdown estimates) on the basis of matching pit inflows, notwithstanding that it remains advantageous to use pit inflows in the calibration approach. Rather, an evaluation of other drainage fluxes should have been considered because these much larger rates of flow will influence more so the choice of parameters in the selection of calibrated models. AD considers the pit inflow estimates are a valid measure to discount parameter realisations that do not match observations, recognising that the inflow prediction is largely influenced by parameters of the Walloon Coal Measures, but the remainder of the model has been calibrated to water level elevations.

(b) AD and AW disagree as to whether one standard deviation from the median amounts to upper and lower limits (Section 6.3 of AEIS[3]). AW suggests that one standard deviation should not be referred to as a limit, and recommends that there is plausible behaviour outside of that. AW would prefer that the text

include terminology that better identifies that there is significant uncertainty as to whether model predictions beyond one standard deviation are reliable or not. In particular, without assessing which predictions have minimum error variance (i.e. are best calibrated), it is presently unclear which of the 18 “calibrated models” produce the most likely predictions of drawdown, and therefore, there is not a basis (within the report) to refer to some predictions as being more or less likely than others, regardless of which ones produce more or less drawdown. AD notes that (Section 6.3 of AEIS[3]) does qualify the use of the terms upper and lower limits with the measure of 1 standard deviation for this study. Jacobs have stated in communication with AD that the overriding objective in this decision was to select a range that could provide a reasonable assessment of the most probable range of impacts. Adopting one standard deviation is to neither understate nor overstate the predicted extents as there is too much uncertainty associated with the fringe results to be considered defensible.

(c) AD and AW disagree on the implications of not considering the degree of calibration for the most likely drawdown. AW considers that the best calibrated models should produce the most likely drawdown and that further analysis should be done to determine the relationship between drawdown and degree of calibration. AW suggests that from this, it follows that the expected ranges of drawdown may change if the degree of calibration is considered in the drawdown analysis. AD suggests that the best calibrated models may not be the most likely results as they are relying on the measures in place to define calibration.

(d) AD and AW disagree as to whether the error in reporting, whereby the number of reported calibrated cases is given as 18 in one place and 45 in another, is important.

3.17 **5(c)(i) The justification for avoiding calibration of specific storage is ill-founded**

(a) AD and AW disagree on the implications of the chosen value of Ss. AD is of the view that the smaller specific storage value adopted in the modelling would amplify the extent of predicted drawdown. AW agrees that drawdown will extend more rapidly with a lower Ss value, but suggests that where the conditions approach steady-state conditions (i.e., equilibrium conditions), the Ss value may be immaterial. AW also suggests that the role of Ss on the transience and long-term rates in pit inflows is difficult to a-priori ascertain without model testing.

5(c)(vi) The expressed uncertainty in drawdown extent is unconvincing, because, for example:

3.18 **5(c)(vi)A. The number of cases used to derive prediction ranges is relatively small.**

(a) While AD agrees that the number of runs is small, they are what are available; however this could be increased by undertaking more simulations of random combinations of parameters to find additional runs that meet calibration criteria. AD is of the opinion that this would not significantly change the median result. AW agrees that a larger number of calibrated models could have been achieved through additional simulations, but suggests (in disagreement with AD) that the median result could change significantly with the addition of more calibrated models. Further, AW suggests that it is unclear as to the accuracy and sensitivity (to parameter changes) of the median result, and hence, it is not presently possible to know that the median estimate of drawdown is the most likely one and that it will remain unchanged if more runs were performed.

3.19 **5(c)(vi)B. The level of calibration is weak.**

(a) AD and AW disagree on the consequences of the weak calibration. AW suggests that while the 5% SRMS value is a reasonable cut-off for selecting "calibrated models", the 5% SRMS statistic does not guarantee that models are well-calibrated because other calibration measures ought to be considered in deciding whether models provide a reasonable match to field data. AD considers the SRMS measure used as it is in this stochastic approach entirely appropriate. AD suggests that while the calibration may be considered weak, this is a positive for the approach as it has allowed more simulations with more varied parameters to meet the criteria and be considered for the predictive phase.

3.20 **5(c)(vi)C. Structural and conceptualisation uncertainty (e.g. measurement error, etc.) are not included in the analysis. Without considering these, an overly optimistic view of the model's accuracy and uncertainty is presented.**

(a) AD and AW disagree about the consequences of homogeneity on the extent of predictions. AD considers that the homogeneity adopted in the approach (i.e. the entire geology unit is set to a single value) is likely to result in overestimates of drawdown. This is particularly the case when the desired outcome of the model is to determine drawdown extent across a large area of aquifer. In contrast, the use of heterogeneous realisations over the same large area is likely to arrive at a similar overall transmissivity as the homogeneous approach, but with 'pockets' of high and low hydraulic conductivity (the distribution of which is dependent on the assigned spatial

variability and search function used). The results of these pockets of high and low hydraulic conductivity in the heterogeneous approach are likely to be greater drawdown close to the mine, but diminished (or at worst equal) drawdown further away in comparison to the homogeneous approach. Further to this, AD is of the opinion that the current observation dataset is not of a distribution that would support heterogeneous calibration; hence the homogeneous approach is the most appropriate approach at this time. AW is of the opinion that stochastic heterogeneous simulations, with parameters that average to homogeneous simulations, are likely to produce a range of drawdown predictions that extend beyond a homogeneous model, because high hydraulic conductivity regions within a heterogeneous representation are likely to propagate drawdown more extensively, and not only in the area close to the mine, as AD recommends above. AW agrees with AD that the current dataset (and industry practice) does not support heterogeneous calibration at this stage of development. However, AW qualifies this agreement by suggesting that the history of significant groundwater-affecting activities in this area should have led to adequate data and prior modelling to allow for more detailed groundwater investigation, including potentially the consideration of aquifer heterogeneity, than has been achieved for the current project. Nonetheless, AW agrees with AD that homogeneous calibration could be considered appropriate; however, AW suggests that the uncertainty of undertaking homogeneous calibration is under-stated in the report. AW also believes that in order to obtain predictions (using a homogeneous model) that are similar to the sorts of drawdown predictions (away from the mine) one might obtain from a heterogeneous stochastic analysis, hydraulic conductivities higher than expected average values are probably needed.

(b) AD and AW disagree that there is an overly optimistic view of the model's accuracy and uncertainty expressed in the report. AW believes that "the level of uncertainty in the predictive results is considered minor, in hydrogeologic modelling terms" (Section 8 of AEIS[3]) is a critical under-statement of the level of uncertainty, and it expresses over-confidence in the accuracy of the modelling predictions. AW believes that statements such as these have the potential to lead to less monitoring and over-reliance on modelling outcomes, because they give an impression that the model is able to accurately predict future aquifer conditions, when in reality, the modelling uncertainty is considerable and should be accounted for through extensive field monitoring, other methods of investigation, and rigorous model testing. AD recognises the concerns of AW, but also believes that the stochastic approach combined with the inherent conservativeness of the model setup has resulted in predictions that encompass the likely drawdown impacts from the mine.

3.21 **5(d) The modelling and impact assessment fails to properly analyse and incorporate into the model information on the impacts of existing mining operations.**

(a) While AD and AW agree that, in fact, the impacts of existing mining operations are modelled and briefly mentioned in the AEIS[3], AD and AW are in agreement that the impact assessment has not properly analysed the impacts of existing mining operations.

3.22 **5(f) The modelling and impact assessment reporting is based on insufficient baseline data, including with respect to pre-mining water levels, and fails to take into account all available data.**

(a) AD disagrees with the statement, and he considers all relevant and available pre-mining data were used in the assessment of pre-mining water levels through the steady-state model. These data are presented in Table 5.2 of AEIS[3]. AW and MC retain their view that there are insufficient baseline data (e.g., in order to determine future impacts attributable to the different stages of mining), and that neglecting to obtain and account for pumping data and parameter data from other relevant studies, combined with the uncertainty in the report regarding the use of Government data, reflects a failure to take into account all available data.

3.23 **5(g) The choice of fixed-head boundary conditions in the model is not properly justified and may affect the reliability of impact predictions generated by the model.**

(a) AD and AW disagree that the choice of fixed head is not properly justified in the report. AW would prefer that reporting identifies investigation (such as that undertaken during the expert review period by AD) into boundary effects to evaluate the extent of any boundary impacts. AD considers that the report justifies the adopted approach, including the location, reasons for using fixed heads and sufficient justification for the adopted head values.

5(h) With respect to recharge in the model:

3.24 **5(h)(i) The method of recharge estimation is overly simplistic.**

(a) AD and AW disagree that recharge estimation is overly simplistic for the approach being undertaken.

3.25 **5(h)(ii) Recharge values are lower than expected.**

(a) AD and AW disagree that the recharge rates that are used in the model are lower than expected. AD considers that the recharge ranges adopted in the model are reasonable and align to expert opinion of similar geologies. AW

considers that the adopted recharge ranges assigned to some geological areas are lower than he would expect, and on the basis of the DNRM value.

3.26 **5(i) The lack of seasonality in transient modelling is a major limitation, particularly with respect to groundwater-surface water interaction and the effect of episodic rainfall/stream recharge events.**

(a) AD and AW disagree that yearly time steps are adequate. AD believes that this is not a major limitation given the use of the model. AW feels that stream base flow and flooding episodicity should be considered to understand GDE impacts in streams.

3.27 **5(k) The modelling of mine voids and pit lakes is deficient.**

(a) AD and AW disagree as to whether the current modelling of void lakes is deficient. AD considers the modelling undertaken for the AEIS (although preliminary) is not deficient and has been undertaken in line with the current industry standard approach of simulating the void within a groundwater model using the 'high-k' lake. AW is of the view that the mine pits ought to have been modelled taking into account the expected variability (seasonality and climatic/intra-annual variability) in rainfall and runoff to the mine pit, notwithstanding the lack of clarity around the methodology in the report. That is, it remains unclear as to how the mine pit will perform in the future, because model simulations of future events appear to have adopted a constant rate of rainfall recharge, and average annual runoff from the surrounding pit catchments. It follows that a time-varying (i.e. realistic) climate signal is likely to produce mine pit hydrological responses that are considerably different to the artificially stable (i.e. time-invariant) climatic conditions adopted in the simulations of the mine pit behaviour (Section 4.7.4 of AEIS[3]).

3.28 **5(m) The impact assessment reports express in places an overoptimistic view of the modelling, and give the impression that key uncertainties have not been considered.**

(a) See section 5(c)(vi)C.

3.29 **5(n) The lack of consideration of groundwater use by users in the surrounding area brings into question the model's water balance and the predictions made by the model more generally.**

(a) AD and AW disagree on the implications of the lack of groundwater users in the model. AD believes that the model predictions (of net effects, such as drawdown) will not have been adversely impacted by this assumption, whereas AW believes that it is unclear, but quite possible, that the lack of

other groundwater users in the model significantly influences the model predictions of drawdown (i.e. due to the possibility that model behaves in a non-linear way – e.g. due to the possible control of the high rates of DRN discharge).

3.30 **6. As a consequence of the modelling deficiencies, the Applicant's assessment of groundwater impacts cannot be relied on and should not be used as the basis for assessment or approval of the Project.**

(a) AD and AW disagree on the reliability of the model for assessment or approval of the Project. AD believes that the model is fit-for-purpose. AW believes that further analysis and modification of the model is warranted before it can be used, in a reliable manner, to explore potential impacts on surface water systems, other groundwater users, groundwater-dependent ecosystems, and the relationship between the groundwater system and the mine voids. AW finds that, in particular, more investigation is warranted if the low levels of model uncertainty that are claimed in the AEIS report[3] are to be achieved.

PART 1: Additional issues that the Applicant's notified experts propose to seek agreement on at the joint expert meeting, where there is an expert proposed by the objectors relating to that issue

GROUNDWATER CONCEPTUALISATION

OCAA LIST OF ISSUES

18. In relation to paragraph 1 of the OCAA List of Issues:

3.31 **18 (a) the groundwater impacts for the Revised Expansion Project were assessed at a regional scale, and were based on an appropriate conceptualisation of the hydrogeology of the area;**

(a) DI clarified that 'regional scale' in this context means within the catchment relevant to the project area. There was some level of disagreement on whether the conceptualisation of the hydrogeology is appropriate. DI believes that this is largely the case, although with the exception of the role of faulting. MC believes there are still deficiencies in the conceptualisation (as well as uncertainty related to faulting), such as: the nature of stratigraphic contacts between units, the degree of vertical connectivity between aquifers, the horizontal connectivity of aquifers, the aquifer properties (horizontal and vertical hydraulic conductivity, storativity, stream-groundwater connectivity) and the groundwater flow directions.

3.32 **18 (b) there is sufficient data for the various aquifers to provide a suitable basis for assessing aquifer properties;**

(a) There is disagreement on this issue. DI believes the estimates of aquifer parameters are adequate to provide a basis for establishing aquifer parameters (that is, the minimum amount of data has been presented to get an idea of the relevant aquifer properties) to inform the conceptual hydrogeology. MC believes that estimates of aquifer properties are not based on strong enough field data. MC believes additional pumping tests monitoring longer periods and the response of other aquifers are needed.

3.33 **18 (c) predicted impacts on the basalt aquifer are conservative as they do not take into consideration likely compartmentalisation through discrete fracturing that forms the aquifer.**

(a) As discussed under point 1(d) above, there is some disagreement regarding drawdown impacts in the basalt. The experts all agree that there is uncertainty about the extent and magnitude of impact likely to be experienced in the basalts, due to the heterogeneous distribution and discontinuities in the basalt. However, DI and AD maintain that the predicted extent of drawdown is a conservative estimate, while MC and AW are still uncertain about a) the extent of predicted drawdown in the basalt, which in some cases may be under-estimated because of the possibility of drawdown propagating through preferential flow pathways in the basalt, and variability in the connectivity to the underlying aquifer , and b) the magnitude of drawdown in the basalt in some areas, which may be locally under-estimated due to lateral discontinuities and compartmentalisation.

3.34 **19. In relation to paragraphs 1(c), 2(a), 2(b)(i) and 3 of the OCAA List of Issues, there is sufficient long term water level and groundwater quality data to provide a baseline for the Revised Expansion Project and the Draft EA conditions and CG's imposed conditions are adequate to detect and assess any other impacts on groundwater.**

(a) There is some disagreement on this issue. DI believes the data collected to date are a reasonable starting point as a baseline, and that the conditions imposed allow for adequate baseline data collection and impact assessment to be conducted. MC believes however, that the baseline data are inadequate for Stage 3, particularly as no data from the new Stage 3 monitoring wells at the edge of the mining lease are as yet available, and also given that the potential impacts may extend further than what the monitoring network will be able to detect.

(b) As noted under points 3(a)(i)A, 3(a)(i)B and 4b, MC and AW believe that should the project proceed under the existing conditions, the assessment of

future impacts using the proposed monitoring network will be difficult and potentially deficient due to uncertainty in the extent and magnitude of likely impacts, and given the lack of ability to properly decipher the causes of groundwater level changes. Therefore, a greater level of certainty regarding the likely impacts informed by additional field data and modelling, along with an expanded monitoring bore network is required to detect and assess impacts on groundwater. This is consistent with the most recent advice from the IESC[7] (e.g. response to Question 1, points 2, 3 & 4 and Question 2, points 12b, 12d and 13).

21. In relation to paragraph 4 of the OCAA List of Issues:

3.35 **21 (a) the impact and risks to groundwater from the Revised Expansion Project were defined, and were assessed to be manageable;**

(a) There was some disagreement on this point (as noted in points 4b and 19 above). DI believes impact assessment is conservative. MC believes the impact assessment still has considerable uncertainty and may not be conservative in some regards. DI believes the impacts are manageable (e.g. through make good arrangements); MC believes that it is likely to be difficult to establish that impacts have occurred in some cases under the current monitoring, and therefore some impacts might not be properly managed under these arrangements.

3.36 **21 (b) the CG's conditions and Draft EA conditions provide for ongoing review and assessment and are adequate; and**

(a) There is some disagreement on this issue. DI believes that the conditions for ongoing review and assessment are adequate; MC believes that they likely don't allow for some potentially significant impacts to be detected and adequately quantified (see points 19, 21a and 4b above).

3.37 **21 (c) the potential impacts on groundwater and on water users will be addressed and managed through compliance with conditions 10, 11 and 12 of the CG's imposed conditions and Schedule D of the Draft EA and implementation of a Bore Baseline Assessment Program and Make Good Agreements.**

(a) There is disagreement on this issue. DI believes that the conditions in the CG's report[11] and EA[6] will adequately address and manage the potential impacts on water users (e.g. responses to 4b, 19, 21a and 21b above). MC believes that in light of considerable uncertainty in the groundwater impact predictions, these conditions may not be adequate to address significant

[11] New Acland Coal Mine Stage 3 project, Coordinator-General's evaluation report on the environmental impact statement, December 2014.

impacts. MC believes that revision of these conditions may be required, following a more detailed and rigorous assessment of potential groundwater impacts (based on additional field data and modelling). Such revisions include the requirement of additional monitoring and compliance bores (e.g. in areas where impact is predicted but no monitoring bores exist in the groundwater monitoring and impact management plan, and additional areas which are currently not predicted to be impacted by drawdown but which may be impacted, due to uncertainty in the conceptualisation), a re-design of the bore baseline assessment program, and the development of monitoring criteria and management strategies for the protection of groundwater dependent ecosystems (which are yet to be adequately assessed). This is in line with the most recent advice from the IESC (2015[7]) which raises outstanding issues that are not covered under the CG's conditions[11] (e.g. response to Question 2, points 12b, 12d and 13).

GROUNDWATER MODELLING

22. In relation to paragraphs 5 and 6 of the OCAA List of Issues:

3.38 **22 (a) the predictive numerical model is 'fit for purpose' to undertake assessment of potential impacts resulting from the Revised Expansion Project; and**

(a) AD and AW disagree that the model is fit for purpose. AD is of the opinion that the model, in the way it has been developed and the way it has been used, is 'fit for purpose'. The model meets the criteria of a Class 2 model as described by the Australian modelling guidelines[12], making it suitable for estimating mine dewatering requirements and associated impacts in relation to the proposed Stage 3 mine expansion. AW considers that further analysis and modification of the model is warranted before it can be used to explore potential impacts on surface water systems, other groundwater users, groundwater-dependent ecosystems, and the relationship between the groundwater system and the mine voids, in particular to achieve the level of uncertainty that is reported. AW also considers that the report is integral to the use of the model and is a critical companion document, and hence the under-appreciation of model uncertainty in the AEIS report[3], which provides an overly optimistic view of the model, may have misled decision makers and thereby detracted from the model's fitness-for-purpose. AW also considers that the previous mining activities potentially impact surrounding aquifers and users, and therefore, there should be a more extensive data set, a greater appreciation of neighbouring groundwater users, a stronger understanding of the regional hydrogeology, and prior modelling of the system, compared to

[12] Barnett et al, 2012, Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra.

what might otherwise be expected for a new mine site. Therefore, the Stage 3 model ought to be a more reliable Class of model (e.g. according to what is expected in the Groundwater Modelling Guidelines[12]) than what might be considered appropriate for a mine-dewatering investigation of a new mine site. That is, AW believes that where the Groundwater Modelling Guidelines[12] refer to appropriate confidence levels for mine-dewatering models (e.g. Example 2.3, Page 22), these were intended for new mining activities and not mine expansion projects, in which a higher level of understanding of historical mining impacts on the aquifer and surrounding users would be expected and therefore certain aspects of the model should be at a standard that match those of a higher Class (e.g. a Class 3 model is needed "To provide quantitative estimates of drawdown, loss of baseflow and reduction in water availability to groundwater dependent ecosystems for various levels of groundwater extraction and future climate assumptions" in the Guidelines[12] (Page 22).

3.39 **22 (b) there are no modelling deficiencies that detract from its fitness for purpose.**

(a) AD and AW disagree as to whether or not there are no modelling deficiencies that detract from its fitness-for-purpose. AD considers that the modelling deficiencies identified, such as the lower than usual specific storage value or the incomplete fault application has resulted in a larger predicted impact extent. AD is also of the opinion that the conservatism inherent in the model (such as vertical connection between the aquifers and homogeneity within the basalt) has resulted in predicted impact extents that more than likely encompass the eventual actual impacts. AW considers that there are deficiencies in the modelling that reduce the model's ability to reliably predict impacts from the proposed mining, and that short-comings in the model, and particularly in the modelling report, have had a largely unknown impact on modelling predictions. AW suggests that the advice and conclusions of decision-makers, charged with setting conditions on future mining activities, have not been founded on a proper explanation of the model's accuracy in making predictions of mining impacts. AW believes that there are important elements of the model that remain untested, such as the role of the DRN package in controlling drawdown, and model sensitivities more generally. AW does not consider the model to be a reliable predictor of future aquifer behaviour in the absence of a proper exploration of the model's predictive capability. AW also believes that prior mining activities should have led to hydrogeological understanding and a numerical model that are well advanced beyond what might be expected for an entirely new mine area, whereas the current knowledge and historical investigations are deficient to the degree that it raises concerns about the capacity of NAC to properly monitor and investigate impacts in the future.

PART 2: Additional issues that the notified experts of the applicant will address, where there is no expert proposed by the objectors relating to that issue

GROUNDWATER

3.40 **34. The Applicant's current mining impacts to groundwater have been restricted to immediately adjacent to the active mining area, with minimal impact observed on the surrounding groundwater environment.**

(a) There was some disagreement on this issue. MC believes that the extent of the monitoring well network has not been adequate to say how far drawdown has extended away from existing areas where mining has caused drawdown (e.g. to the east of the mine). DI believes the monitoring network shows that impacts are likely to be largely restricted to the immediate surrounds.

For water quality, MC and DI examined groundwater EC and sulfate data (Appendix G.4.3, WSAA Water Quality Monitoring Report[13]) and noted elevated readings in bore 2289 (and to a lesser extent CSMH1) during 2011 which have not been explained. MC believes this could be related to mining and indicate an impact some distance (e.g. >500m) away from existing mining.

3.41 **35. The predicted water usage is within the New Acland Mine's allocation under existing authorisations to take water.**

(a) While DI agrees that NAC does not hold an authorisation to take water from the Quaternary Alluvium within the Oakey Creek groundwater management area (as a result of mining), DI believes that based on a review of available drill logs from registered bores within the areas of predicted drawdown in the alluvium, areas that may be impacted are not productive groundwater supply aquifers, and therefore negligible take or interference would occur. MC believes that this is unproven and that the predictions that some drawdown will occur in the alluvium under the current model indicate that not all predicted water usage is within NAC's existing authorisations. MC also believes that the extent of drawdown in the alluvium is as yet uncertain and therefore drawdown could potentially occur in additional areas of alluvium (e.g. further south of the current predicted extent), which would result in further take of water from this aquifer that is not authorised.

[13] Appendix G.4.3, WSAA Water Quality Monitoring Report, Establishment of Groundwater Quality Background Limits (2012), New Acland Coal Pty Ltd, December 2012.

4. Definitions

In this report, unless otherwise defined, specific terms in relation to groundwater and modelling used in this report have the following meanings:

Alluvium means sediments deposited by flowing rivers. Depending upon the location in the floodplain of the river, different-sized sediments are deposited.

Aquifer means rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Barrier boundary means an aquifer-system boundary represented by a rock mass that is not a source of water.

Baseflow means that part of stream flow that originates from groundwater seeping into the stream.

Drawdown means a lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells or from other human-induced losses from the aquifer (e.g., seepage into excavations).

Evaporation means the process by which water passes from the liquid to the vapour state.

Evapotranspiration means the sum of evaporation plus transpiration.

Groundwater means the water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer.

Groundwater flow means the movement of water through openings in sediment and rock; occurs in the zone of saturation.

Heterogeneous means pertaining to a substance having different characteristics in different locations. A synonym is non-uniform.

Homogeneous means pertaining to a substance having identical characteristics everywhere. A synonym is uniform.

Hydraulic conductivity means a coefficient of proportionality describing the rate at which water can move through a permeable medium. The density and kinematic viscosity of the water must be considered in determining hydraulic conductivity.

Storativity means the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of

specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to the specific yield. Also called storage coefficient.

Transmissivity means the rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.

5. **Expert's statement**

I confirm that I understand I have a duty to assist the court and that duty overrides any obligation I may have to any party to these proceedings or any person who is liable for my fees or expenses and I have complied with that duty.

……
Duncan Irvine – 16 February 2016

……
Andrew Durick – 16 February 2016

……
Matthew Currell – 16 February 2016

……
Adrian Werner – 16 February 2016