Expert Report to the Land Court by Dr Noel Patrick Merrick

1. Qualifications and Curriculum Vitae

1.1 Name

My name is Noel Patrick Merrick.

1.2 Address

My business address is:

Director, Heritage Computing Pty Ltd (trading as HydroSimulations), PO Box 241, Gerringong, NSW 2534.

1.3 Qualifications

I hold the following qualifications:

(a) PhD (UTS);

(b) Grad.Dip. (Data Proc.) (NSWIT);

(c) MSc (Syd. Uni.); and

(d) BSc (Syd. Uni.).

Annexure **A** to this report is my curriculum vitae, which sets out my professional qualifications and over 40 years of experience. My profession is hydrogeology. I am the Director of a small business enterprise (trading as HydroSimulations) which specialises in groundwater modelling and peer review services. I employ three senior groundwater modellers on salary and two junior modellers on contract. My previous employment (prior to 2009) was as the Director of the National Centre for Groundwater Management at the University of Technology, Sydney where I was an Associate Professor in Hydrogeology. My duties included Doctoral and Masters research supervision, and delivery of a course on Groundwater Modelling to graduate students. I regularly deliver short courses to industry on Groundwater Modelling for Beginners.

2. Material relied on in preparing the expert report

In producing this report, I have relied on the following material:

(a) "Brief to expert" from McCullough Robertson dated 25 June 2014:

(i) "Adani is proposing to develop a 60 million tonne per annum (product) coal mine in the north Galilee Basin approximately 160 kilometres north-west of the Town of Clermont in Central Queensland. All coal will be railed via a privately owned rail line connecting to existing rail infrastructure, and shipped through coal terminal facilities at the Port of Abbot Point. The Project will have an operating life of approximately 90 years".

(ii) The Mine component of the Project would consist of "a greenfield coal mine over Exploration Permit for Coal **(EPC)** EPC 1690 and the eastern portion of EPC 1080, which includes both open cut and underground mining, on mine infrastructure and associated mine processing facilities".

(iii) "In November 2012, Adani submitted the EIS for the Project. Public notification of the EIS was carried out from 15 December 2012 until 11 February 2013".

(iv) "Adani prepared an SEIS which underwent public notification from 25 November 2013 to 20 December 2013".

(v) "On 7 May 2014, the Coordinator-General's report evaluating the EIS was released. The Coordinator-General's report recommended approvals for the Project and contained a number of conditions and recommendations".

(vi) "At close of public notification on 17 June 2014, only two properly made submissions had been made about the EA application and one objection to the ML lodged".

(b) Land Services of Coast and Country Inc. (LSCCI) has raised objections to the applications in the following areas:

(i) "groundwater;

(ii) groundwater dependent ecosystems;

(iii) surface water;

(iv) biodiversity (primarily focused on impacts to the black throated finch);

(v) climate change; and

(vi) economic and social matters".

(c) In terms of groundwater impacts, LSCCI has specifically raised the following matters in the LSCCI Objection :

(i) "if the mine proceeds, it will cause severe adverse environmental impacts to groundwater (paragraph 11);

(ii) if the mine proceeds, it will impact groundwater dependent springs including the Doongmabulla Springs Complex and Mellaluka Springs Complex (paragraph 12);

(iii) that the full extent of such impacts cannot be stated due to inadequate information having been provided in the applications, EIS and SEIS (paragraph 13); and

(iv) it has not been demonstrated adequately that the mine will not have unacceptable adverse impacts on groundwater, particularly in terms of quality and quantity (paragraph 14(a))".

(d) The Conservation Action Trust (CAT) has raised groundwater issues that might cause impacts in India, namely:

(i) pollution from impoundments or landfills associated with coal-fired power plants; and

(ii) contamination of drinking water supplies and irrigation water.

(e) The Preliminary Identification of Issues for the LSCCI dated 2 December 2014, particularly in relation to:

(i) Conceptual hydrogeological model;

(ii) Predictive numerical model;

(iii) Doongamabulla Springs Complex;

(iv) Carmichael River; and

(v) Mellaluka Springs Complex.

(f) Joint Groundwater Experts Report (JGER) by myself and John Webb, Adrian Werner and John Bradley dated 9 January 2015.

(g) The Environmental Impact Statement (EIS), Supplementary EIS (SEIS) and Additional Information to the EIS (AEIS) prepared for Adani by GHD, in particular:

(i) GHD, 2013, Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report. Prepared for Adani Mining Pty Ltd, 13 November 2013.

(ii) GHD, 2013, Carmichael Coal Mine and Rail Project SEIS: Mine Hydrogeology Report Addendum. Prepared for Adani Mining Pty Ltd, 24 October 2013.

(iii) GHD, 2014, Carmichael Coal Project Response to IESC Advice. Letter to Hamish Manzi, Adani Mining Pty Ltd from Keith Phillipson, 7 February 2014, 19p + 8 Attachments.

(iv) GHD, 2014, Carmichael Coal Project Proposed Groundwater Boundary Revisions. Letter to Peter Baker, Office of Water Science, from James Dowdeswell, 27 October 2014

(v) GHD, 2014, Carmichael Coal Project: Response to Federal Approval Conditions - Groundwater Flow Model. Report for Mine Hydrogeology Report. Report for Adani Mining Pty Ltd, November 2014.

(h) Department of State Development, Infrastructure and Planning, 2014, Carmichael Coal Mine and Rail Project: Coordinator-General's Evaluation Report on the Environmental Impact Statement. May 2014.

(i) Middlemis, H., 2014, Carmichael Coal Project Groundwater Flow Model Independent Review (Re: Approval Conditions 22 & 23). Hydrogeologic report for Adani Pty Ltd, 28 November 2014;

In producing this report, I have relied also on the following examinations and inspection conducted by me:

(a) Merrick, N., 2014, CPD-1-2014: A Review of the Carmichael Coal Mine and Rail Project Water Hydrogeology Report. HydroSimulations report HC2014/7 for Department of State Development, Infrastructure and Planning, State of Queensland.

(b) Site inspection on 8-9 December 2014 including discussions with site geologists and mining engineers:

(c) Merrick, N., 2014, Adani - Carmichael Coal Project: Assessment of Fracturing in the Groundwater Model. HydroSimulations report HC2014/33 for Adani Mining Pty Ltd.

(d) Merrick, N., 2015, Adani - Carmichael Coal Project: Assessment of Potential Reduction in Spring Flow. HydroSimulations report HC2015/5 for Adani Mining Pty Ltd.

3. Background to the expert report

I had previous involvement with the Mine through an engagement with the Department of State Development, Infrastructure and Planning (Office of the Coordinator General), Queensland Government. In February 2014, I was asked to provide a targeted review of eight documents in order to give a considered opinion on matters raised by the Independent Expert Scientific Committee (IESC) in its Final Advice of 12 December 2013. The posed questions were:

(a) Is the Groundwater Flow direction in the Triassic and Permian aged sediments, as determined by GHD for Adani Mining at Carmichael and presented as part of the Groundwater Conceptual Model, an acceptable assessment of groundwater flow, based on groundwater data available to the proponent at the current time?

(b) Based on this assessment, are the groundwater flow contours provided as part of the model output considered likely to be representative of actual conditions based on existing knowledge?

(c) Are the model boundaries, and in particular the western model boundaries, considered to be appropriate?

I answered each question in the affirmative, which was contrary to the view held by the IESC. The eight documents are:

1. GHD, 2013, Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report. Prepared for Adani Mining Pty Ltd, 13 November 2013.

2. GHD, 2013, Carmichael Coal Mine and Rail Project SEIS: Mine Hydrogeology Report Addendum. Prepared for Adani Mining Pty Ltd, 24 October 2013.

3. URS, 2013, Adani Carmichael Coal Project Numerical Model Peer Review. Prepared for Adani Mining Pty Ltd, 14 October 2013.

4. GHD, 2013, Carmichael Coal Project Groundwater Model Peer Review Final Comments. Letter to Hamish Manzi, Adani Mining Pty Ltd from Keith Phillipson, 18 October 2013.

5. IESC, 2013, Advice to decision maker on coal mining project - Proposed Action: Carmichael Coal Mine and Rail Project, Queensland (EPBC 2010/5736) - New Development. Final Advice, 12 December 2013.

6. Bleakley, A. and McKay, A., 2014, Carmichael Mine Response to IESC Advice. 2 January 2014, 6p.

7. Bleakley, A., 2014, Groundwater Flow Direction Carmichael Project Area. 3 March 2014, 9p.

8. GHD, 2014, Carmichael Coal Project Response to IESC Advice. Letter to Hamish Manzi, Adani Mining Pty Ltd from Keith Phillipson, 7 February 2014, 19p + 8 Attachments.

Since then I have been engaged by McCullough Robertson on behalf of Adani Mining Pty Limited (Adani) to provide an expert report in the Land Court proceedings in accordance with instructions dated 4 February 2015 and attached at Annexure **B**. I have read the instructions in that letter and confirm that I understand my duties to the Land Court as an expert witness.

Through this engagement, I have had the opportunity to review more of the EIS and SEIS material than was available to me during the targeted review. My opinions on the questions posed in the targeted review are not altered. Although I had a previous recent relationship with the Mine through the Office of the Coordinator General, in respect of the targeted review, I consider this in no way has prejudiced my ability to provide an informed, independent opinion on the matters contained in my expert report.

4. Opinion on objections

4.1 Structure of Joint Groundwater Expert Report

By agreement of the groundwater experts, our Joint Groundwater Expert Report (JGER) was limited to Issues 1 to 11 in the LSCCI Preliminary Identification of Issues, which were addressed under the following headings in respect of points of agreement and points of disagreement:

(a) Regional geology;

(b) Groundwater flow directions;

(c) Conceptual model;

(d) Source aquifer for Doongmabulla Springs Complex;

(e) Source aquifer for Mellaluka Springs Complex;

(f) Numerical modelling.

I have nothing further to add to items (a) to (e), beyond what is in the JGER. I regard items (a), (d) and (e) as outside my primary field of expertise, which is numerical modelling. My comments will be confined to item (f).

4.2 Numerical modelling - Best practice

My instructions have called for explanations and definitions of a number of technical terms used during the discussion in the JGER. For conciseness and easier referencing, I have compiled a glossary in Annexure **C** for those terms highlighted in my instructions.

In Australia there are no "standards" for groundwater modelling, but there are two guides which include a number of guidelines: the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline[1], issued in 2001, and newer guidelines issued by the National Water Commission in June 2012 (Barnett et al., 2012[2]). The 2012 national guidelines build on the 2001 MDBC guide, with substantial consistency in model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details. These guides are almost silent on mine modelling and offer no specific direction on best practice methodology for such applications.

For a brief explanation of groundwater modelling, I have relied on the following extract from the Murray-Darling Basin guide issued by MDBC (2001):

"A groundwater model is a computer-based representation of the essential features of a natural hydrogeological system that uses the laws of science and mathematics. Its two key components are a conceptual model and a mathematical model. The conceptual model is an idealised representation (i.e. a picture) of our hydrogeological understanding of the key flow processes of the system. A mathematical model is a set of equations, which, subject to certain assumptions, quantifies the physical processes active in the aquifer system(s) being modelled. While the model itself obviously lacks the detailed reality of the groundwater system, the behaviour of a valid model approximates that of the aquifer(s). A groundwater model provides a scientific means to draw together the available data into a numerical characterisation of a groundwater system. The model represents the groundwater system to an adequate level of detail, and provides a predictive scientific tool to quantify the impacts on the system of specified hydrological, pumping or irrigation stresses."

Furthermore, MDBC (2001) lists typical purposes of modelling:

- *"Improving hydrogeological understanding (synthesis of data);*
- *Aquifer simulation (evaluation of aquifer behaviour);*
- *Designing practical solutions to meet specified goals (engineering design);*
- *Optimising designs for economic efficiency and account for environmental effects (optimisation);*
- *Evaluating recharge, discharge and aquifer storage processes (water resources assessment);*
- *Predicting impacts of alternative hydrological or development scenarios (to assist decision-making);*
- *Quantifying the sustainable yield (economically and environmentally sound allocation policies);*
- *Resource management (assessment of alternative policies);*
- *Sensitivity and uncertainty analysis (to guide data collection and risk-based decision-making);*
- *Visualisation (to communicate aquifer behaviour)."*

An important feature of numerical groundwater modelling is that there is no alternative procedure that can provide the level of quantitative estimation that is expected of environmental impact assessments.

4.3 Numerical modelling - Points of agreement

Points of agreement are discussed in paragraphs 9 to 20 of the JGER. My instructions have called for a clearer explanation of these agreed paragraphs:

[1] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. Contributing authors: H. Middlemis, N. Merrick, J. Ross

[2] Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). *Australian Groundwater Modelling Guidelines*. Waterlines report 82, National Water Commission, Canberra.

(a) Paragraph 9: As a model is a representation of the natural world, it cannot replicate a groundwater system perfectly. Uncertainty is unavoidable as a consequence. It is also not possible to be precise as to the level of *accuracy* of a model, as is the case with any method of prediction.

(b) Paragraph 10: To counteract uncertainty, a common practice in groundwater modelling is to err on the side of caution - in other words, to make a conservative assumption, in the sense of a predicted impact being worse than is likely. The GHD reports lay claim to conservatism with a number of assumptions, but the modelling is not uniformly conservative. The assumption of vertical hydraulic conductivity being a tenth of the horizontal value is a conservative assumption, as the model would allow easier vertical flow of water and would offer less resistance to propagation of mining effects to land surface and streams. In my experience, based on similar coal mine situations, the vertical hydraulic conductivity (in a model) is more likely to be a hundredth or a thousandth of the horizontal value. This means that the GHD model is likely to overestimate environmental impacts, based on this one assumption. Other assumptions are not conservative. For example, the height of induced deformation above an extracted coal seam, where fractures are well connected, is assumed to be uniformly 160m in height. My calculations, using an algorithm[3] not available at the time of the EIS, give a range of heights that bracket 160m[4]. The height would not be the same everywhere, and is likely to vary from about 130m to about 230m, as a worst case. This means that fracturing could reach ground surface above about 40% of the longwall panels, as a worst case, compared to about 20% for the GHD assumption. This is not of major concern, as the extra near-surface fracturing would allow more rainfall infiltration (until the cracks in the ground are sealed) than would occur naturally, thus offsetting potential lowering of the water table. As most of the fractured zone would lie within the Rewan Formation, there would be negligible enhanced vertical hydraulic conductivity in this part of the fractured zone because the fine materials in this formation would tend to close the fractures. Uniform horizontal hydraulic conductivity, while common practice, should not be claimed as a conservative assumption, as spatially varying values would mean that environmental impacts could propagate farther in same places but not as far at other places.

(c) Paragraph 11: The issue here is that the originally drawn conceptual model diagram has proved to be overly schematic. The main source of water inputs has proved to be higher ground distant from the mine rather than the Great Dividing Range adjacent to the mine. It is not an issue of concern, as the process of model calibration has redistributed the water sources so that the model is replicating sufficiently well the observed groundwater flow patterns and hydraulic gradients.

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[3] Ditton, S. and Merrick, N, 2014, A New Subsurface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields. Geological Society of Australia, 2014 Australian Earth Sciences Convention (AESC), Sustainable Australia. Abstract No 03EGE-03 of the 22nd Australian Geological Convention, Newcastle City Hall and Civic Theatre, Newcastle, New South Wales. July 7 - 10. Page 136.

[4] Merrick, N., 2014, Adani - Carmichael Coal Project: Assessment of Fracturing in the Groundwater Model. HydroSimulations report HC2014/33.

(d) Paragraph 12: The Principle of Superposition says, in simple terms, that the total effect of a number of stresses (e.g. entire mining extraction) is the sum of the individual effects of the separate stresses (e.g. each longwall panel extraction). This principle has been used by the joint experts to negate one of the GHD claims for preclusion of GAB impacts. It is not of concern, as the model outputs subsequently quantify GAB impacts.

(e) Paragraph 13: There are two types of model calibration: steady-state and transient. Steady-state calibration aims to replicate groundwater flow directions and hydraulic gradients when the only stresses on the groundwater system are assumed constant (e.g. steady rain and constant river levels, usually no pumping or mining). Transient calibration aims to replicate the fluctuations in groundwater levels when the stresses are changing (e.g. monthly rainfall or stream flow, and historical pumping or mining). Clearly, transient calibration is the more informative method, but often there is a lack of dynamic (time-varying) stresses or lack of groundwater response to these stresses. Then, steady-state calibration is sufficient. GHD chose not to do transient calibration due to inadequate duration of groundwater level readings and a generally flat response for available readings. The absence of transient calibration means there is no corroboration of the assumed storage parameters in the model (although experience elsewhere is a good guide), which are required for model prediction, and no independent assessment of rainfall recharge (the portion of rainfall that infiltrates the ground and reaches the water table). As more groundwater level readings are collected, a sensible first step (prior to transient calibration) is to use the model for transient verification - that is, to compare the observed and model-computed time-varying groundwater levels at groundwater monitoring sites. The Coordinator-General has specified future transient calibration as an approval condition.

(f) Paragraph 14: One of the IESC criticisms was the representation in the model of the western boundary. One of the Federal Approval Conditions required movement of the boundary condition to the western edge of the model domain, with the assumed boundary heads to be established with the written agreement of the Department of the Environment. The joint experts (Adrian Werner and I) regarded one of the scenarios, called Option 2, as unrealistic although we recognise it was an agreed position between GHD, the federal government, and a peer reviewer. We are of the view that the Option 2 outputs are not worth any further consideration. In my opinion, and the opinion of the peer reviewer engaged by the federal government (Hugh Middlemis), the shift of the western boundary proved to be inconsequential in terms of environmental impacts of importance. In particular, the predicted maximum drawdown in the source aquifer water level at Doongmabulla Springs reduced from 0.19m to 0.12m (Option 1). The adoption of the original internal boundary has proved to be a conservative assumption.

(g) Paragraph 15: Ephemeral streams flow, by definition, only part of the time, generally after heavy rainfall. On such occasions, there is a likelihood of some leakage from the streams to the water table. This is not included in the model, due to the difficulty of representing spasmodic events, especially in a prediction scenario. To represent such streams in a steady-state model, continual leakage must be assumed. While the natural system has a source of water input that is not in the model, the omitted volumes are likely to be very small and inconsequential. If they were significant, they would have the effect of reducing the impacts predicted by the model. I regard the method of handling of ephemeral streams in the model as a conservative assumption.

(h) Paragraph 16: The shift in the western boundary of the model had an unexpected effect on the model-predicted groundwater discharge ("baseflow") to the Carmichael River. Although the JGER sought clarification of where the higher baseflows were occurring, the information has since been located in the November 2014 report by GHD[5]. Of relevance are Figures 65 and 67 in that report, reproduced here. In Figure 65, more baseflow is predicted with the Option 1 model than with the SEIS model. This is probably due to generally higher water table levels, intersecting river bed elevation further upstream than in the SEIS model. Output from the calibrated pre-development steady-state SEIS model suggests that long term average baseflow to the Carmichael River peaks at around 4,500 m^3/d around 7 km upstream of the site and around 3 km downstream of Doongmabulla Springs (Figure 65). Output from the predictive post-development SEIS model suggests that total baseflow to this point could be reduced to around 4,300 m^3/d at the end of the mining operational phase (year 2071) which suggests a reduction in baseflow of around 200 m^3/d. This is equivalent to a predicted 5 percent reduction in modelled groundwater discharge to the Carmichael River upstream of the Mine Area. Post-closure, a reduction of about 300 m^3/d is expected (Figure 65), which is a reduction of about 7 percent in modelled groundwater discharge to the Carmichael River upstream of the Mine Area. This is a tolerably low impact. However, the point on the river at which baseflow would cease is likely to be shifted upstream by about 10 km, and vegetation along that reach would be exposed to drier conditions. Its current position is about 25 km downstream of the eastern boundary of the mine lease. I understand this potential impact would be managed by draft Environmental Authority (EA) condition I4 which would require amendment of the Biodiversity Offset Strategy in the event that groundwater level fluctuations are in excess of thresholds stated in draft EA conditions E13 and E14 and Table E3. The conditions are appropriate, in my professional opinion.

(i) Paragraph 16 (continued): The pre-development Option 1 model predicts a maximum flow of 7,103 m^3/d (Figure 65). Output from the predictive post-closure model suggests that this baseflow could be reduced to 6,850 m^3/d in the long term, which suggests a reduction in peak baseflow of around 253 m^3/d. This is equivalent to a predicted 3.6 percent reduction in modelled groundwater discharge to the Carmichael River upstream of the mine lease. The SEIS model is more conservative.

[5] GHD, 2014, Carmichael Coal Project: Response to Federal Approval Conditions - Groundwater Flow Model. Report for Mine Hydrogeology Report. Report for Adani Mining Pty Ltd, November 2014.

Figure 65 Carmichael River accretion profile – post-closure phase (Option 1 (275m) model)

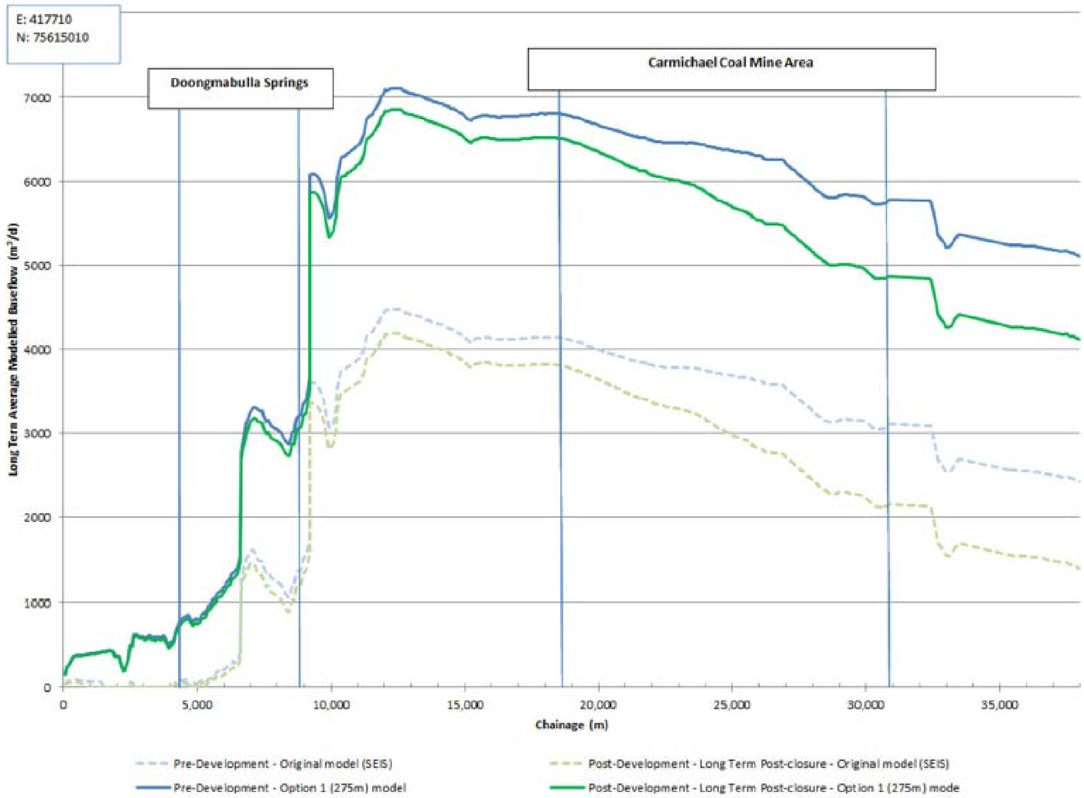
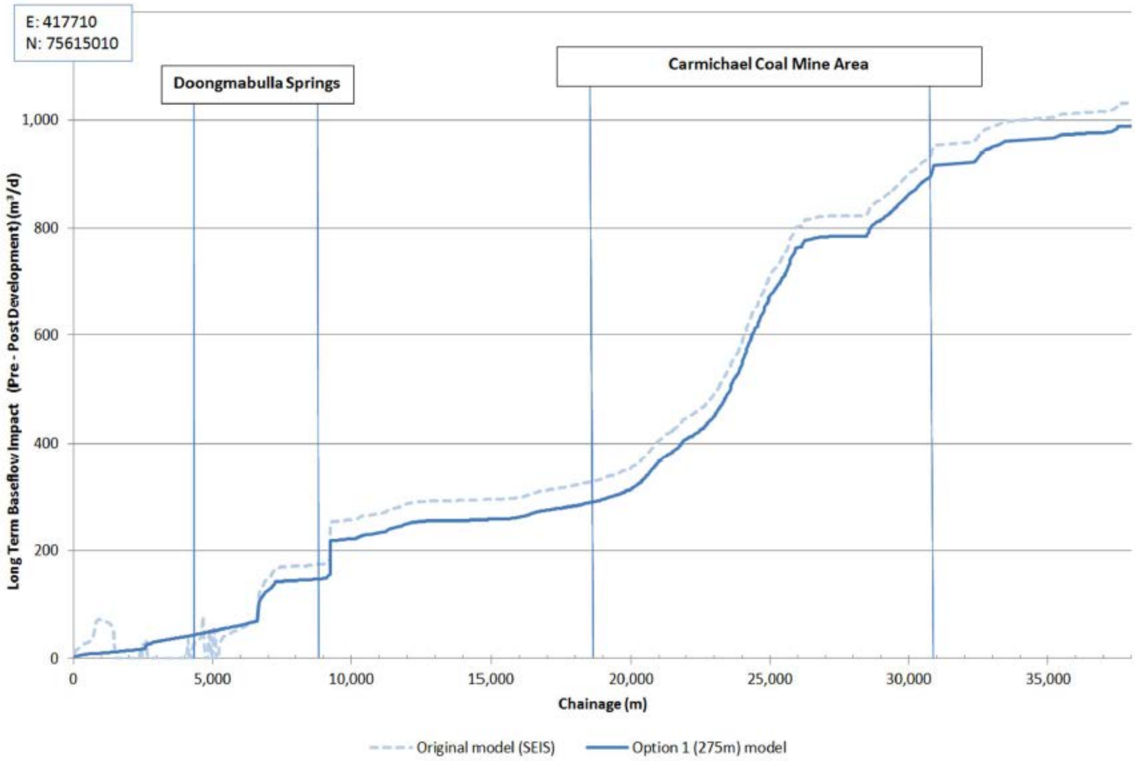


Figure 67 Carmichael River baseflow impact – post-closure phase (Option 1 (275m) model)



(j) Paragraph 16 (continued): Figure 67 shows that the impact on baseflow is very similar for the SEIS model and the Option 1 model. In the Doongmabulla Springs reach, the absolute losses are about the same. However, as the Option 1 flow is the greater, the fractional reduction in baseflow would be lower for the Option 1 model than for the SEIS model. At the downstream end of the springs, the loss is about 160 m^3/day and the pre-mine flow is about 3000 m^3/day for the Option 1 model, giving an impact of 5.3 percent. Again, the SEIS model is more conservative.

(k) Paragraph 17: "RMS" means root-mean-square, and is a way of calculating a performance statistic for a model calibration. It measures the differences between measured and simulated groundwater levels. Both a relative measure (RMS as a percentage of the range in measured water levels) and an absolute measure (RMS in metres) are recommended in guidelines. There is no firm target for a good calibration, but 5 %RMS is commonly used for water resource models and 10 %RMS for mining models. As model performance is site-specific, the suggested targets are not always achievable.

(l) Paragraph 18: The MDBC and NWC guidelines, issued a decade apart, differ in the amount of uncertainty analysis that is recommended. The NWC guide notes: *"In uncertainty analysis, sensitivities of predictions to model parameters are combined with a (statistical) description of parameter uncertainty, leading eventually to quantitative estimates of prediction uncertainty."* With the evolution of groundwater modelling capability, it is reasonable to put more effort into this activity although it is computationally demanding. The NWC guide is not prescriptive as to which method should be used. GHD has used a relatively simple approach based on scenario analysis by perturbing a number of important model properties.

(m) Paragraph 19: The joint experts are of the view that the Type I to Type IV sensitivity analysis advocated in the MDBC guide is better left unused, as the results of the analysis are easily misunderstood. The rationale for the method is to detect model properties that might be very important for prediction but not so significant during calibration. The method can be wrongly used to assess the likelihood of an impact threshold being breached.

(n) Paragraph 20: The JGER sought clarification on conditions relating to the backfilling of final voids, as there seemed to be an inconsistency as to the required height of backfilling. I have had the opportunity to examine the Coordinator-General's report (Department of State Development, Infrastructure and Planning, 2014) more closely, in particular Figure H1 and draft EA Conditions H6 and H7, and I am satisfied there is no inconsistency and that the conditions are appropriate in my professional opinion. The confusion arose from reading preliminary commitments in an early report (GHD, November 2013). The final voids are to be filled to the top of the coal seams (Pit B, D and G to the top of Seam D1; Pit C, E and F to the top of Seam AB1). This would obviate the concern expressed in the JGER as to adequate sealing of coal seam contacts, as the coal seams would no longer be in contact with saline water in the voids.

As I was the architect of the peer review protocols in the MDBC guide, including the development of the peer review checklists (subsequently modified in the NWC guide), I have been called upon to conduct hundreds of peer reviews of groundwater models over the past 15 years, at the rate of about 20 per year. Reviews have been conducted in all states of Australia (except Tasmania and the Northern Territory), as well as New Zealand, for a wide range of applications and for both government and industry clients. I claim to have as good an appreciation of the practice of groundwater modelling in Australia as anyone, and can therefore place the GHD model confidently towards the upper end of the spectrum of model merit, certainly better than the "average" model. I am in full agreement with the Department of the Environment peer reviewer (Hugh Middlemis, another experienced peer reviewer) in declaring the model to be fit-for-purpose:

"The review process did not identify any material weaknesses in the model design, boundary conditions, parameter values or calibration performance. The exploration of model uncertainty in conceptual and parameter value terms is commendable and the results indicate low sensitivity/uncertainty. It is my professional opinion that the model revisions have been undertaken competently, consistent with condition 23, and the revised model design and performance is consistent with guidelines and suitable as is for impact assessment purposes, with future model refinements dependent on monitoring to obtain data for validation."

With respect to Doongmabulla Springs in particular, I see no reason to question the likely drawdown estimate made with the SEIS model, namely 0.19m at Joshua Spring and from less than 0.05m to 0.12m at the various Moses springs. A sensitivity analysis in which either the Clematis Sandstone or Rewan Formation hydraulic conductivity was increased by one order of magnitude gave rise to a maximum drawdown of about 0.3m, which I regard as unlikely due to the adopted hydraulic conductivity values, noting that I have previously said that the vertical hydraulic conductivities are likely to be lower in reality than adopted in the base model. The Western Boundary sensitivity scenario led to a 37 percent reduction in the estimate (from 0.19m to 0.12m) at Joshua Spring.

Using a range of possible drawdown magnitudes, I have calculated that the loss in spring flow is likely to be in the 3 percent to 5 percent range at the Doongmabulla Springs[6].

4.4 Numerical modelling - Points of disagreement

Points of disagreement are discussed in paragraphs 30 to 34 of the JGER. My instructions have called for a clearer explanation of these paragraphs and for definition of unfamiliar terms (given in Annexure **C**):

(a) Paragraph 30 relates to vertical head differences. To place the issue in context, some explanation of model structure and geometry is proffered. A numerical model is subdivided horizontally into a large number of rectangular cells, of dimension 50m to 1km in the GHD model, and into a small number of model layers to represent aggregations of geological strata. In the GHD model there are 12 model layers. The model consists, therefore, of a large number of cubes of different sizes, each of which has adopted or calibrated model properties to represent the

[6] Merrick, N., 2015, Adani - Carmichael Coal Project: Assessment of Potential Reduction in Spring Flow. HydroSimulations report HC2015/5.

transmission, storage and leakage physical properties of the real earth. As the GHD model has 4 million of these cubes, complete characterisation is impossible. That is the case for every groundwater model. The science of groundwater modelling has techniques that aim to minimise the uncertainty in characterisation, but there will always be uncertainty. In each model cell there is a computed groundwater level, or "head", which is equivalent to the pressure head averaged over the thickness of a model layer plus the elevation of the mid-point of the layer. Field measurements, however, reveal a groundwater head at a point, or more correctly over the length of the screen (typically 3-6m) in a bore that allows communication between the rocks and the open space inside a bore. Nested field measurements give "point" head values at different depths at the same location, and by subtraction "vertical head differences", in metre units. A vertical head gradient can be computed by dividing the head difference by the vertical distance between the two measurement depths, in dimensionless (metre/metre) units. The GHD reports have been incorrect in referring to vertical gradients in metre units, when the term vertical head difference should have been used. The GHD modellers have used the measured vertical head difference as a calibration target, a feature of the real groundwater system that the model is aiming to replicate. The problem is that the vertical separation distances are different for field measurements and for model references, as the former is a real distance while the latter is the distance between the mid-points of two layers. A better practice is to compare vertical gradients, which essentially corrects for this inconsistency. Apart from the absolute value of the head difference or the gradient, the "polarity" is important, in other words whether the value is positive or negative. This reveals the potential for groundwater to move up or down at a given location. Adrian Werner disagrees that gradients are in “generally good agreement”, and that “The model also replicates reasonably well the magnitude of vertical gradients” as stated in modelling reports. I have examined Tables 2-4 in GHD (24 October 2013), and note the following performance results: the model gives the correct polarity in 80% of cases, and the error in absolute vertical head difference values is no more than 2m for 70% of cases. This is generally good agreement, in my opinion.

(b) Paragraph 31 relates to inconsistencies in reporting and minor errors in model application. Adrian Werner takes the view that lots of small errors call into question the overall validity of the modelling. I consider this an unwarranted extrapolation. Given the complexity of a numerical model, where the aim of characterisation is to populate 4 million cells (in this case) with multiple attributes, there will always be minor errors. Inconsistencies in reporting are inevitable when there are multiple authors across multiple reports over several years. The large number of lengthy GHD reports has exacerbated the issue of consistency between documents. A big-picture point of view is required for assessing whether a model is fit-for-purpose, whether it achieves its objectives, whether the predicted outcomes have a low risk of being wrong, and whether there is any alternative method of meeting those objectives. My view is that the model is fit-for-purpose, and this view is held also by the peer reviewer engaged by the Department of the Environment (Hugh Middlemis).

(c) Paragraph 32 relates to uncertainty analysis. Given that the calibrated/adopted properties in model cells are non-unique and incapable of perfect resolution, there is no doubt that all model predictions carry a level of uncertainty. The aim of uncertainty analysis is to arrive at a position that allows a decision-maker to regard predicted outcomes as having a low risk or a high risk of being wrong, and whether the magnitude of those impacts is consequential or not. There are many recognised approaches to uncertainty analysis, but no particular method is prescribed in the NWC guide. There is, however, an expectation of more attention being given to uncertainty analysis as groundwater modelling becomes more sophisticated and advances in computer technology provide a capability for probabilistic assessment. GHD has followed a simple approach, by running prediction scenarios for a number of key properties perturbed from their expected values. It is true that this method will not give the probability of a predicted outcome, but it will give an idea of the possible range of outputs, and that is normally sufficient for a decision-maker as well as being consistent with industry practice. I agree with GHD (November 2014) that the "level of uncertainty is commensurate with the confidence required in a groundwater model at the current stage of project maturity". As the model has not yet reached the stage of maturity of transient calibration, and the project is a greenfield site, the multiple calibration realisations and probabilistic analysis advocated by Adrian Werner is unnecessary in my opinion. I acknowledge this as an aspirational target but it is beyond current best practice in the groundwater modelling of mines. There are rare instances of this being done (e.g. when an approval condition is expressed in probability terms), but in practice scenario analysis for extreme conditions is the more common approach. Model runtime is one of the reasons the probabilistic approach is not followed in practice. It is not unusual for a single model run to take in the order of a day, and the probabilistic approach requires several hundred model runs. I disagree with Adrian Werner's view that sensitivity analysis is not an adequate assessment of uncertainty. It is adequate, but it is not the best method for uncertainty analysis. Hugh Middlemis, the peer reviewer engaged by the Department of the Environment, regards sensitivity analysis as an adequate method for providing information on uncertainty in model predictions: "*Model uncertainties have been adequately addressed (as discussed at various points herein), notably including the 2014 revisions to address condition 23, which invoked a best practice alternative conceptualisation approach that confirmed the previous impact predictions, and the south to north topographically driven flow whether or not there is a significant western component of flow to the GAB*." However, I agree with Adrian Werner that GHD has been remiss in not filtering out prediction results associated with model perturbations that would materially de-calibrate the model. As these outlier simulations would normally give more extreme values for model outputs, their inclusion would make the range of reported modelled impacts conservative in the sense of overestimating the effects of extreme cases.

(d) Paragraph 33 relates to the findings of experimental scenarios for three different western boundary head scenarios (known as the SEIS model and Options 1 and 2 scenarios). Adrian Werner and I agree that Option 2 should be dismissed from further consideration. I maintain that the three model variants show insignificant differences in predicted environmental impacts of importance and that the adoption of different boundary conditions proved to be inconsequential. Hugh Middlemis, the peer reviewer engaged by the Department of the Environment, shares this view. Adrian Werner notes that changes to the western boundary introduce major changes to the model's predictions. While that is true in places, as already examined in the different Carmichael River baseflow magnitudes in Figure 65 (above), the changes to potential *impacts* of concern are minor, as illustrated in Figure 67 (above).

(e) Paragraph 34 relates to rainfall recharge estimation. Rainfall recharge is the amount of rainfall that infiltrates the ground and passes through the soil zone to reach the water table. Normally, this is a low fraction of actual rainfall (in the order of a few percent at most). It should be noted that recharge is not directly measurable, and has to be inferred. GHD has applied a number of different inference techniques and has done a comprehensive assessment of relevant literature, and generally has put more effort into this aspect than is normal practice. Adrian Werner is critical of the rigour applied to several of the interpretation methods, and the completeness of reporting. What matters is whether the modellers have arrived at reasonable ballpark recharge rates that can be further refined during model calibration. Unfortunately, rainfall recharge is correlated with the adopted hydraulic conductivity for model layer 1 (at the top). This means that the two parameters cannot be separately resolved. When model calibration is limited to steady-state, the rainfall recharge is unlikely to be well resolved. Transient calibration offers more control, as the amount of recharge must be consistent with the amplitude of measured groundwater level responses. However, the model has not yet reached this level of maturity. There remains uncertainty in the level of recharge adopted in the model. The adopted rates are 0.1 to 1.1 mm/year. These values are at the low end of values reported in the literature review. Personally, I would have expected the rates to be higher, based on modelling done by me elsewhere in the Galilee Basin, where I used values ranging from 0.1 to 30 mm/year. If the rates were higher, then the computed drawdowns would be less (if calibration is not significantly affected). Adrian Werner is critical also of the exclusion of episodic flooding and leakage from ephemeral streams. While these sources of water in the natural system are not in the model, the omitted volumes are likely to be very small and inconsequential. Again, they would reduce the estimated drawdowns.

I do not regard the differences between myself and Adrian Werner as overly significant. There are differences in our expectations as to the rigour of the detail in the model, but my view is that the big-picture conclusions as to the locations and the magnitudes of potential impacts are sufficiently robust for the purpose of an environmental impact assessment.

5. Summary of conclusions

My conclusions are summarised in relation to the four stated objections of LSCCI. No comment is offered on the CAT submission, as it is beyond my field of expertise to assess potential pollution or contamination impacts that might arise from coal-fired power plants in India.

5.1 LSCII Objection 1

The objection is: "if the mine proceeds, it will cause severe adverse environmental impacts to groundwater". My conclusions are:

(a) I do not agree with the claim that the adverse environmental impacts will be severe.

(b) The main impacts on groundwater are the drawdown of the water table and the depressurisation of the groundwater heads in deeper geological strata.

(c) The drawdowns of the water table have been shown to be tolerable, with reasonable confidence, where there are assets to be protected, except at one private irrigation bore where a drawdown of about 3m is expected.

(d) Deeper depressurisation would be substantial, as heads must be reduced to coal seam elevations, but the depressurisation would be inconsequential to the water resource in general where the depressurisation is predicted to occur, except at bores that might be extracting water from the Dunda Beds or Permian strata.

(e) The impact on the aquifers of the Great Artesian Basin (GAB) is expected to be very small, the expected capture of lateral flow being less than 0.2 ML/day.

5.2 LSCII Objection 2

The objection is: "if the mine proceeds, it will impact groundwater dependent springs including the Doongmabulla Springs Complex and Mellaluka Springs Complex". My conclusions are:

(a) I agree with the claim that there will be an impact on the Doongmabulla Springs.

(b) The magnitude of the drawdown impact at Doongmabulla Springs is likely to be about 0.2m or less, which is tolerably small.

(c) The magnitude of the spring flow reduction is likely to be about 5 percent or less, which is tolerably small also.

(d) The magnitude of baseflow reduction in the Carmichael River in the vicinity of Doongmabulla Springs is likely to be about 5-7 percent, which is tolerably small also.

(e) I agree with the claim that there will be an impact on the Mellaluka Springs.

(f) The expected drawdown at Mellaluka Springs suggests that the impact is likely to be severe.

5.3 LSCII Objection 3

The objection is: "that the full extent of such impacts cannot be stated due to inadequate information having been provided in the applications, EIS and SEIS". My conclusions are:

(a) I agree that the full extent of impacts cannot be predicted with precision, as that expectation is beyond the capacity of practical science. There will always be a level of uncertainty in predictions of environmental impact, especially for a greenfield site.

(b) I do not agree that the reason for this situation is the inadequacy of information provided in the applications.

(c) The amount of information provided in the EIS/SEIS reports is normal for an environmental assessment.

5.4 LSCII Objection 4

The objection is: "it has not been demonstrated adequately that the mine will not have unacceptable adverse impacts on groundwater, particularly in terms of quality and quantity". My conclusions are:

(a) It is my professional opinion that there is adequate demonstration of the locations and magnitudes of potential environmental impacts.

(b) Much of the demonstration relies on a groundwater model, which I judge to be fit-for-purpose.

(c) There is no denial that some of the impacts would be adverse, but they appear to be low magnitude impacts that will require ongoing scrutiny and management, as appropriately conditioned in the draft EA.

6. Expert's confirmation

I confirm the following:

(a) I have read and understood relevant extracts of the Land Court Rules 2010 (Qld) and the Uniform Civil Procedure Rules 1999 (Qld). I acknowledge that I have an overriding duty to assist the Court and state that I have discharged that duty.

(b) I have provided within my report:

- (i) details of my relevant qualifications;
- (ii) details of material that I relied on in arriving at my opinions; and
- (iii) other items as required by the Land Court Rules.

(c) I confirm that:

- (i) the factual matters included in the statement are, to the best of my knowledge, true;
- (ii) I have made all enquiries I consider appropriate for the purpose of preparing this statement;
- (iii) the opinions included in this statement are genuinely held by me;
- (iv) this statement contains reference to all matters I consider significant for its purpose;
- (v) I have not received or accepted any instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

(d) If I become aware of any error or any data which impact significantly upon the accuracy of my report, or the evidence that I give, prior to the legal dispute being finally resolved, I shall use my best endeavours to notify those who commissioned my report or called me to give evidence.

(e) I shall use my best endeavours in giving evidence to ensure that my opinions and the data upon which they are based are not misunderstood or misinterpreted by the Land Court.

(f) I have not entered into any arrangement which makes the fees to which I am entitled dependent upon the views I express or the outcome of the case in which my report is used or in which I give evidence.

Noel Merrick

9 February 2015

ANNEXURE A: CURRICULUM VITAE

NOEL MERRICK

Senior Principal Groundwater Modeller
Director, Heritage Computing Pty Ltd trading as HydroSimulations
Director, HydroAlgorithmics Pty Ltd
More than 40 Years experience (from 1972)

Residence	**Languages**
Gerringong NSW Australia	English

Education

PhD (Groundwater Management) (2000), University of Technology, Sydney;
Graduate Diploma in Data Processing (1980), The New South Wales Institute of Technology;
MSc Research (geophysics) (1977), The University of Sydney;
BSc (1971), The University of Sydney.

Professional affiliations

Associate Editor, *Hydrogeology Journal*, 2002-2007 (international).

Vice President – Australasia and the Pacific, International Association of Hydrogeologists, 2000-2004.

Committee Member, International Association of Hydrogeologists, NSW Branch (2000-2003).

Member, International Association of Hydrogeologists.

Member, New Zealand Hydrological Society.

Member, National Ground Water Association (USA).

Key qualifications

Noel is a senior groundwater modeller, hydrogeologist and geophysicist with over 40 years of experience in groundwater science. He retired in May 2009 from the University of Technology, Sydney, where he was Associate Professor and Director of the National Centre for Groundwater Management. He ran courses in Groundwater Modelling, Groundwater Geophysics and Groundwater Policy and Management. As a researcher, he pioneered methods for resource sustainability quantification and management, particularly using optimisation techniques, and has been engaged in research projects with the Aquaculture, Rice, Cotton and Contaminant CRCs. He was a member of the NSW working group that drafted the State Groundwater Policy documents and advised the Office of Water on prescriptive elements of the Aquifer Interference Policy (2012). Having authored the peer review section of MDBC groundwater flow model guidelines, he has been heavily involved in peer reviewing modelling studies for mines in NSW, Victoria and Queensland, and he actively builds groundwater models for open cut and longwall coal mines.

Noel has participated on a number of expert panels as the water expert for the NSW government, in particular the Strategic Inquiry into Potential Coal Mining Impacts in the Wyong LGA, and the Somersby Fields Project Independent Hearing and Assessment Panel. He regularly reviews groundwater resource models for Commonwealth, WA, Qld, Vic and SA government departments. He is a member of the *Murray-Darling Basin Independent Audit Group – Salinity*, and is currently on Technical Advisory Panels for the NSW, Qld and Vic governments.

His key skills include:

- Numerical modelling, solute transport and mathematical optimisation.
- Assessment and modelling of groundwater/surface water interactions.
- Groundwater impact assessment for infrastructure and mining projects.
- Groundwater management.
- Peer reviews of environmental assessments and government programs.
- Electrical and electromagnetic geophysics.
- Computer programming.

Professional experience

Mining Projects

- Development of open cut coal models: Duralie (Gloucester); Stratford (Gloucester); Tarrawonga (Boggabri); Vickery (Boggabri); Wilpinjong (Mudgee); Baralaba (Bowen Basin).
- Development of longwall coal models: Ulan (Mudgee), Metropolitan (Helensburgh), Bulli Seam Operations (Appin), Dendrobium (Cordeaux), Tahmoor (NSW), South Galilee (Qld), Galilee (Qld), Wambo (Hunter), Doyles Creek (Hunter), Spur Hill (Hunter), Caroona (Hunter).
- Development of quarry models: Calga NSW.
- Development of density-coupled solute model for lithium mine (Argentina).
- Peer reviews of numerous mining models: Clermont Qld, Wilpinjong NSW, Latrobe Vic, Phulbari Bangladesh, Boggabri NSW, Ulan NSW, Bickham NSW, Moolarben NSW, Ashton NSW, Narrabri NSW, Cobbora NSW, Cadia NSW, Maules Creek NSW, Caroona NSW, Watermark NSW, Werris Creek NSW, Dendrobium NSW, Woodlawn NSW, North Parkes NSW, Springvale/Angas Place NSW, Bylong NSW, Drayton South NSW, Somersby NSW, Caroona NSW, Mt Penny NSW, West Wallsend NSW, Neubeck NSW, Liddell NSW, Mt Owen NSW, Mandalong NSW, Kestrel Qld, Silangan Philippines, Russell Vale NSW, Airly NSW, etc.
- Preparation of groundwater management plans: Metropolitan NSW, Stratford NSW, Wilpinjong NSW, Wambo NSW, Springvale/Angas Place NSW, Dendrobium NSW.

Coal Seam Gas Projects

- Member of Queensland Water Commission Technical Advisory Panel for development of Surat-Bowen cumulative impacts groundwater model;
- Member of Office of Groundwater Impact Assessment Technical Advisory Panel for Surat-Bowen research theme guidance and review;
- Member of Advisory Group for Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) for Comparison of Modelling Approaches (CSG) project;
- Peer review of Eastern Star Gas initial modelling, Narrabri-Gunnedah;
- Peer review of QGC model development, Surat Basin;
- Peer review of AGL modelling, Gloucester Basin;
- Member of New South Wales Steering Committee for Department of Primary Industries (NICTA Data-Centric Groundwater Modelling for Coal Seam Gas and Large Scale Coal Mining).

Water Resource Investigations

- Development of regional water resource flow models: Lower Namoi Valley, Mooki Valley, Botany Sands, Buronga (all NSW).
- Development of solute transport models: Buronga, Helensburgh.

- Peer reviews of numerous models and groundwater investigations: water supply (Parkes-Forbes NSW; North Stradbroke Island Qld; Perth WA; Upper Namoi NSW; Corangamite Vic.; Pilbara WA; Bribie Island Qld; Pioneer Qld; Murrumbidgee NSW; Adelaide Plains SA; Loddon Vic.; Campaspe Vic.; Anglesea Vic.; Northern Victoria; Murray-Darling Basin; Baruun Naran, Mongolia), sewage (Gerringong; Cronulla), waste (Castlereagh), contamination (Botany; Mascot; Homebush), irrigation (Swagman-Farm software; Coleambally; Werribee Vic), infrastructure (Badgery's Creek airport, Epping-Chatswood Rail Link), seawater intrusion (Pioneer Qld; Uley SA), swamps (Newnes NSW).

Stream-Aquifer Interaction

- National Water Commission (2008-2010) – development and project management of local area stream-aquifer models at six sites in NSW with daily time scale and 50-100m spatial scale; supervision of research models exploring temporal scale and spatial scale effects at two sites; development of a rapid assessment simulation tool (Gwydir Valley) for borefield design constrained by stream losses.
- Technical Expert Panel (2014; DEPI, Vic Government): Assessing groundwater contribution to wetlands and the environmental risk assessment of licensed water extraction.

Environmental Impact Assessment

- Preparation of groundwater components for Environmental Assessments: Metropolitan Mine NSW; Bulli Seam Operations NSW; Duralie NSW; Tarrawonga NSW; Stratford NSW; Vickery NSW; Wambo NSW; Galilee Qld; Wilpinjong NSW; Tahmoor NSW; Baralaba Qld.
- Preparation of NSW Gateway Application groundwater assessments: Spur Hill; Caroona.
- Development of triggers for groundwater management plans: Metropolitan Mine NSW; Duralie NSW; Stratford NSW; Springvale NSW; Angas Place NSW.
- Member of Victoria Technical Audit Panel for Department of Environment and Primary Industries (DEPI).

Salinity Programs

- MDBA salinity auditor for a six-year term.
- Peer review of Eastern Mallee model for MDBA accreditation.

Contaminated Site Assessment

- Development of groundwater contamination models: Castlereagh Landfill (Waste Service NSW), Botany Sands (Orica); Boolaroo (Pasminco); Boolaroo (Incitec); Sydney Domestic Airport; Mt Piper (Delta Electricity); Blenheim (NZ); Pinkenba (Qld).

Optimisation Projects

- Development of proprietary software: WELLNET; OPTIMAQ; HotSpots.
- Optimal rationalisation of groundwater monitoring networks: Eastern Murray Basin, Botany Basin, Great Artesian Basin, Latrobe Valley, Gwydir Valley, Coleambally Irrigation Area, Perth aquifer.
- Pump-and-treat borefield optimisation (Botany NSW).
- Salt interception scheme optimisation (Buronga, NSW).
- Water supply borefield optimisation: Gnangara WA; Wagga Wagga NSW.
- Water allocation optimisation: Lower Namoi NSW; Upper Namoi NSW; Mangrove Mountain NSW.

Expert Witness

- Land Court of Qld, Brisbane, 2014: Adani Mining Pty Ltd, hearing of objections to Carmichael Coal Mine and Rail Project. Effect of coal mine on water resource and ecosystems.

- Land & Environment Court of NSW, Sydney, 2014: Rocla Materials Pty Ltd & Anor ats The Trustee for the Gerald and Catherine Barnard Family Trust tla Australian Walkabout Wildlife Park Pty Ltd. Effect of sand quarry on water resource and ecosystems.
- Land Court of Qld, Brisbane, 2014: Endocoal Limited v Glencore Coal Queensland Pty Ltd and Chief Executive, Department of Environment and Heritage Protection. Effect of open cut coal mining on water supply dam.
- Land & Environment Court of NSW, Sydney, 17 November 2009: Rivers SOS Inc. vs. NSW Minister for Planning and Helensburgh Coal Pty Ltd. Water impacts of longwall coal mining.
- Land & Environment Court of NSW, Sydney, 2 April 2004: Allan Carriage vs. Stockland Development Pty Limited. Ecological impacts of residential development.
- High Court of New Zealand, Wellington, 15 July 2002: G. J. Appleton, K. M. Daly & M. V. Appleton vs. The Attorney-General. Contaminated farm compensation claim.
- Land Court of Qld, Townsville, 21 March - 1 April 1998: CA, VM & LH Cox vs. Department of Natural Resources. Land resumption compensation claim.

Professional training

- Supervision of 20 PhD research projects;
- Supervision of 72 Masters research projects;
- Academic lecturer from 1987 to 2009;
- Presenter at National Groundwater Schools from 1975;
- Presenter at specialist introductory and advanced modelling short courses from 1997;
- Chairman and presenter at "Water in Coal Mining" schools 2011 (Brisbane), 2012 (Newcastle);
- Chairman and presenter at "Water in Mining" school 2013 (Canberra, SEWPaC).

Professional outputs

- Keynote Speaker at six conferences (four international);
- About 100 media interviews including ABC Catalyst;
- Over 400 report and journal publications.

Professional history

May2013-now	Director, HydroAlgorithmics Pty Ltd, Gerringong N.S.W.
May2013-now	Director, Heritage Computing Pty Ltd trading as HydroSimulations, Gerringong N.S.W.
2010-April2013	Director, Heritage Computing Pty Ltd, Blue Mountains N.S.W.
2005-2009	Associate Professor, University of Technology, Sydney
2004-2008	Acting Director, National Centre for Groundwater Management, UTS
2001-2008	Research Scientist, UTS Institute for Water and Environmental Research Management
1992-2005	Senior Lecturer in Groundwater Modelling and Geophysics, UTS
1991-1992	Senior Lecturer in Geophysics, University of N.S.W.
1987-1990	Lecturer, University of N.S.W.
1987	Senior Hydrogeologist (Modelling), Department of Water Resources, N.S.W.
1982-1986	Hydrogeologist, Water Resources Commission, N.S.W.
1972-1981	Geophysicist, Water Resources Commission, N.S.W.

ANNEXURE B: INSTRUCTIONS

Partner Peter Stokes
Writer Siobhan Moloney
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Our reference SEM:PWS:159359-00022

Lawyers McCullough Robertson

4 February 2015

Dr N Merrick
Senior Principal Hydrogeologist
HydroSimulations

Email noel.merrick@heritagecomputing.com

Dear Dr Merrick

Adani Mining Pty Ltd v Land Services of Coast & Country Inc. & Anor
Land Court objections hearing
Land Court of Queensland Proceedings no. MRA428-14, EPA429-14, MRA430-14, EPA431-14, MRA432-14 and EPA433-01

We refer to:

1 Mining Lease Applications (**MLAs**) 70441, 70505 and 70506 made by Adani Mining Pty Ltd (**Adani**);

2 the associated environmental authority application, as re-made on 14 April 2014;

3 the Environmental Impact Statement (**EIS**), Supplementary EIS (**SEIS**) and Additional Information to the EIS (**AEIS**) prepared for Adani and made publicly available under the *State Development and Public Works Organisation Act 1971* (Qld);

4 the draft Environmental Authority (**EA**) issued by the Statutory Party on 28 August 2011;

5 the Objection of Land Services of Coast and Country Inc (**LSCCI**) to the MLAs dated 16 June 2014;

6 the Objection of LSCCI to the EA made 10 September 2014;

7 the submission (dated 17 June 2014) and objection (dated 25 September 2014) about the EA made by Debi Goenka of the Conservation Action Trust (**CAT**);

8 the Preliminary List of Issues for the LSCCI dated 2 December 2014;

9 your joint report, with John Webb, Adrian Werner and John Bradley dated 9 January 2015 (**Joint Report**); and

10 our letter of instruction to you dated 25 June 2014.

Instructions

11 We require you to provide a further statement of evidence under the *Land Court Rules 2000* (Qld) (**Rules**).

12 In accordance with orders made by the Court, your further statement of evidence is required by **Friday, 6 February 2015**.

Format of report

13 When preparing the further statement of evidence, and responding to the questions dealt with in Section E below, please deal with the following:

SECTION A - Qualifications and Curriculum Vitae

14 Please attach your curriculum vitae to the report.

SECTION B - Material relied on in preparing the statement

15 Lists are sufficient for the statement, however, it would be useful to ensure that you (and we) have a copy of all the listed material when finalising your report. In particular, you should list:

(a) all material facts, written or oral, on which the statement of evidence is based; and

(b) reference to any literature or other material relied on by you to prepare the statement.

16 It may also be necessary to review the Joint Report to ensure your lists include sources that may not be specifically identified in that report.

17 You do not need to list material you have **not** relied on.

18 Any inspection, examination or experiment conducted, initiated or relied on by you to prepare the statement must also be described.

SECTION C – Background to Report

19 Please set out the extent of your previous involvement in the Mine. Specifically, we would like you to:

(a) indicate whether you were involved in the preparation of any material in support of the proposed Mine and, if so, provide details of that work;

(b) confirm that you have since been engaged by McCullough Robertson, on behalf of Adani, to provide an expert report in the Land Court proceedings;

(c) confirm that you have read this letter of instruction (and attach a copy of this letter of instruction to your report), and confirm that you understand your duties to the Land Court as an expert witness;

(d) confirm that, notwithstanding your previous relationship with the Mine (if any), you consider you are able to provide an informed, independent opinion about the matters contained within your Report.

SECTION D – Opinion on objections

Instructions for your report

20 Please review the objections and respond to any issues within your field of expertise which concern the MLAs and EAs.

21 You should not respond to matters raised by Messrs Werner, Webb, and Bradley that are outside your field of expertise (except to state that you will not be responding, unless you have already indicated this in the Joint Report).

22 In your further statement of evidence, the Rules also require that where:

(a) there is a range of opinion on matters dealt with, a summary of the range of opinion and the reasons why you have adopted a particular opinion be provided; and

(b) access to any **readily ascertainable** additional facts would assist you in reaching a more reliable conclusion, a statement to that effect be included.

23 We request that you specifically identify, in your further report, those areas of disagreement in the Joint Report where your counterparts have made assertions for which you have not been provided a factual basis or material to rely upon.

24 For each such assertion, please make your own enquiries or seek further instructions from us to ascertain whether a factual basis or material is available. If no factual basis or material exists for a particular assertion, please further identify this in your individual report.

25 In dealing with the points of disagreement in your joint report, and responding to the relevant Facts and Circumstances and grounds of the objections, please also specifically identify any relevant conditions of the draft EA and express your opinion as to the appropriateness of the draft condition or its relevance to the grounds of the objections.

Restrictions on your report

26 Your further statement of evidence should also refer to, and expand upon, matters of disagreement in the Joint Report which require further explanation.

27 Please note that, pursuant to the Rules, your further statement may not:

(a) contradict, depart from or qualify an opinion in relation to an issue the subject of agreement in the Joint Report; or

(b) raise a new matter not already mentioned in the Joint Report.

Key questions

28 In preparing your statement of evidence, please have reference to the following matters in the LSCCI Objection (as set out on page 3 of the joint report) and express an opinion on each to the extent it within your expertise:

(a) *if the mine proceeds, it will cause severe adverse environmental impacts to groundwater (paragraph 11);*

(b) *if the mine proceeds, it will impact groundwater dependent springs including the Doongmabulla Springs Complex and Mellaluka Springs Complex (paragraph 12);*

(c) *that the full extent of such impacts cannot be stated due to inadequate information having been provided in the applications, EIS and SEIS (paragraph 13); and*

(d) *it has not been demonstrated adequately that the mine will not have unacceptable adverse impacts on groundwater, particularly in terms of quality and quantity (paragraph 14(a)).*

Specific questions

29 We also ask that you address the following specific questions (either separately, or as part of the responses to the issues in the objections). All paragraph references are references to the Joint Report.

Numerical modelling (agreed)

30 Paragraphs 9 to 20 set out a detailed discussion of the agreed items relating to numerical modelling. Please explain, in plain English, what these paragraphs mean. To do so, you may need to give a brief overview of how the modelling works.

31 In your explanation, please define (if you have not already) the following terms:

(a) 'vertical hydraulic conductivities' (paragraph 10);

(b) 'conductivity values'. For example, what is a high conductivity value, compared with a low conductivity value;

(c) 'lateral heterogeneity' (paragraph 10);

(d) 'permeability' as it is used in this field of expertise. For example, what does it mean when a substance has 'low permeability' compared with 'high permeability'? (paragraph 10);

(e) 'fracturing heights' (paragraph 10);

(f) 'groundwater mound' (paragraph 11);

(g) 'principle of superposition for linear systems' (paragraph 12);

(h) 'transient calibration' (paragraph 13);

(i) 'transient verification' (paragraph 13);

(j) 'dynamic response' of the model (paragraph 13);

(k) 'historical stresses' (paragraph 13);

(l) 'mAHD boundary' (paragraph 14);

(m) 'drain cells' (paragraph 15);

(n) 'recharge into the model' (paragraph 15);

(o) 'baseflow' (paragraph 15); and

(p) 'ephemeral streams' (paragraph 15).

32 Please comment, to the extent it is within your field of expertise, on the accuracy of the numerical modelling you have reviewed particularly with respect to the Doongmabulla Springs and whether it is

likely to be the same as the drawdown predicted under the numerical modelling, having regard to the permeability assumptions included within the modelling, for example:

(a) as predicted;

(b) higher; or

(c) lower or nil.

33 Please explain:

(a) the significance of the numerical modelling; and

(b) your conclusions about the numerical modelling.

34 Paragraph 14 of the joint report states:

'We agree that the Option 2 scenario (250 mAHD boundary) in the latest GHD model (November 2014) is unrealistic. Lowering all of the boundary heads by 25 m is an indefensible approach which has created a greater degree of inconsistency with the field data than is already apparent in Option 1 (275 mAHD boundary). It is understood that Option 2 is an approval condition imposed by the Australian Government Department of the Environment.'

35 We are instructed, however, that option 2 was not imposed by the Department of the Environment. In fact, GHD, Adani and the peer reviewer decided to use Option 2 (due to a greater westerly flow) to address the uncertainty; the differences in impact were negligible.

Numerical modelling (not agreed)

36 Paragraphs 9 to 20 of the Joint Report set out a detailed discussion of the numerical modelling items that are not agreed between the experts. Please explain, in plain English, what these paragraphs mean.

37 In your explanation, please define the following terms:

(a) 'vertical head gradients' (paragraph 30)

(b) 'vertical head differences' (m units over unspecified depth intervals) (paragraph 30)

(c) 'vertical gradients' (m/m units) (paragraph 30)

(d) 'point measurements in the field' versus 'depth-averaged heads across a model layer' (paragraph 30)

(e) 'vertically adjacent model layers' (paragraph 30)

(f) 'uncertainty analysis' (paragraph 32)

(g) 'sensitivity analysis' (paragraph 32)

(h) 'RMS measures' (paragraph 32)

(i) 'diffuse recharge' (paragraph 32)

38 Please explain:

(a) the significance of the numerical modelling;

(b) the significance of the disagreements about the numerical modelling; and

(c) your conclusions about the numerical modelling.

39 Your opinions are noted throughout this section (paragraphs 30 to 34) of the Joint Report. Please explain:

(a) the reasons for your opinions;

(b) why you consider your opinion to be correct, and Mr Werner's opinion to be incorrect; and

(c) any conclusions you have reached (including by reference to the objections summarised in paragraphs (c) and (d) on page 3 of your Joint Report).

40 Further, paragraph 32 of the Joint Report states that you consider the sensitivity analysis completed to date is sufficient. Please explain:

(a) the reasons for your view;

(b) whether your view complies with standard methodology and practices in this area of expertise;

(c) why you disagree with John Webb's view that multiple calibration realisations are required; and

(d) whether performing multiple calibration realisations is going beyond what is typically required for this type of exercise? I.e. would it be undertaking a task over and above what is normally done?

41 Further, paragraph 34 of your joint report states that you consider that 'ballpark' recharge rates have been reached through assessment through a number of means. It is further stated '*.. the adopted rates do appear to be at the low end of what might be expected.*' In respect to the second statement, please:

(a) advise whether this is your opinion or the opinion of all of the experts; and

(b) the significance of this statement, specifically by reference to the objections summarised in paragraphs (c) and (d) on page 3 of your Joint Report.

42 We think it is essential you explain your expertise as distinct from John Bradley and identify the matters upon which you express an opinion and those that you do not – leaving it to the expert opinion of Mr Bradley. It is necessary then that the court can identify with whom of the objectors experts your opinion differs.

SECTION E – Summary of conclusions

43 The Rules require your further statement to provide a summary of the conclusions you have reached. In our view, this is often best presented in a separate, concluding section (or at the start of the statement).

44 If there are no issues raised in the CAT submission relevant to your field of expertise, please indicate that in your summary of conclusions.

SECTION F – Expert's confirmation

45 It is important that the report you prepare be an independent report prepared bearing in mind an expert witness' overriding duty to the court. The overriding duty encompasses the following points:

(a) You have an overriding duty to assist the Court on matters relevant to your area of expertise;

(b) You are not an advocate for a party, even when giving testimony that is necessarily evaluative rather than inferential; and

(c) Your paramount duty is to the Court and not to the person retaining you.

46 An example of the type of thing that might be said in this section is as follows:

(a) *I have read and understood relevant extracts of the Land Court Rules 2010 (Qld) and the Uniform Civil Procedure Rules 1999 (Qld). I acknowledge that I have an overriding duty to assist the Court and state that I have discharged that duty.*

(b) *I have provided within my report:*

(i) *details of my relevant qualifications;*

(ii) *details of material that I relied on in arriving at my opinions; and*

(iii) *other things as required by the Land Court Rules.*

(c) *I confirm that:*

(i) *the factual matters included in the statement are, to the best of my knowledge, true;*

(ii) *I have made all enquiries I consider appropriate for the purpose of preparing this statement;*

(iii) *the opinions included in this statement are genuinely held by me;*

(iv) *this statement contains reference to all matters I consider significant for its purpose;*

(v) *I have not received or accepted any instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.*

(d) *If I become aware of any error or any data which impact significantly upon the accuracy of my report, or the evidence that I give, prior to the legal dispute being finally resolved, I shall use my best endeavours to notify those who commissioned my report or called me to give evidence.*

(e) *I shall use my best endeavours in giving evidence to ensure that my opinions and the data upon which they are based are not misunderstood or misinterpreted by the Land Court.*

(f) *I have not entered into any arrangement which makes the fees to which I am entitled dependent upon the views I express or the outcome of the case in which my report is used or in which I give evidence.*

Confidentiality

47 Any report generated by you should remain in draft until such time as we are in a position to discuss the contents of the report with you. We ask that the report be kept strictly confidential as it is to be used

for the purpose of obtaining legal advice or for use in legal proceedings. You are not authorised to provide these instructions or your report to any other person or party.

If you would like any further material, or have any questions, please contact us.

Yours sincerely

Peter Stokes
Partner

ANNEXURE C: GLOSSARY

TERM	EXPLANATION
Baseflow	The part of stream discharge that originates from groundwater seeping into the stream, and supports stream flows during long periods of no rainfall.
Calibration	The process by which the independent variables (parameters) of a numerical model are adjusted, within realistic limits, to produce the best match between simulated and observed data (usually water-level values). This process involves refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve the desired degree of correspondence between the model simulations and observations of the groundwater flow system.
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and our hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.
Conductivity values	Depending on context, referring to hydraulic conductivity or electrical conductivity.
Depth-averaged head	The average head across a vertical interval of space, usually applied to a model layer thickness. An outcome of the Dupuit Assumption to simplify modelling to two dimensions across a model layer.
Diffuse recharge	Generally applied to rainfall across a widespread non-specific area as opposed to a localised water source. Recharge is the portion of rainfall that infiltrates through the soil and reaches the water table.
Drain cells	A model feature that establishes a groundwater sink by specifying a reference head similar to the invert level of a real drain. A common method of simulating mining excavation.
Dynamic response	The time-varying reaction of an aquifer attribute, usually water level or chemical concentration, to a recharging or discharging stress.
Ephemeral stream	A stream or part of a stream that flows only in direct response to rainfall or occasional baseflow. Its channel is above the normal water table.
Fracturing height	The height of substantial deformation in the rock overlying an extracted longwall panel, within which free drainage occurs through a connected induced fracture network.
Groundwater	The water contained in interconnected pores located below the water table in the saturated zone. Excluding soil water in the unsaturated zone.

Groundwater model	An application of a mathematical model to represent a site-specific groundwater flow system. A groundwater model provides a scientific means to synthesise the available data into a numerical characterisation of a groundwater system. The model represents the groundwater system to an adequate level of detail, and provides a predictive tool to quantify the effects on the system of specified hydrological stresses.
Groundwater mound	The high point on a water table usually established by preferential recharge related to topography. Similar to a groundwater divide.
Historical stresses	Recharging and discharging processes that have occurred in the past; e.g. past rainfall, streamflow or pumping.
Hydraulic conductivity	The capacity of a rock to transmit water, determined mutually by properties of the rock and of the water. The proportionality coefficient linking water flow and hydraulic gradient.
Lateral heterogeneity	The nature of a medium which consists of different (non-uniform) characteristics in different locations in a pseudo-horizontal direction. Equivalent to "spatial variability"
mAHD	The official elevation unit in Australia: metres Australian Height Datum. Loosely height above mean sea level.
Numerical model	A model of groundwater flow in which the aquifer is described by numerical equations, with specified values for boundary conditions, that are usually solved on a digital computer. In this approach, the continuous differential terms in the governing hydraulic flow equation are replaced by finite quantities. The computational power of the computer is used to solve the resulting algebraic equations by matrix arithmetic. In this way, problems with complex geometry, dynamic response effects and spatial and temporal variability may be solved accurately. This approach must be used in cases where the essential aquifer features form a complex system, and where surface-groundwater interaction is an important component (i.e. high complexity models).
Permeability	Loosely equivalent to "hydraulic conductivity" in groundwater reports. Strictly there is a difference, as permeability is a fundamental transmissive property determined only by properties of the rock.
Point measurements	Measurements taken at a specific location of limited dimension, either at a point or across a short interval.
Pressure head	Groundwater pressure at a point, measured in metres above the measuring point.
Principle of Superposition	For all linear systems, the net response at a given place and time caused by two or more stimuli is the sum of the responses which would have been caused by each stimulus individually.
Recharge (into the model)	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the watertable and by river water entering the watertable

	or exposed aquifers. The addition of water to an aquifer.
RMS measure	Root Mean Square, a measure of the degree of match between two datasets (usually measured and simulated)
Sensitivity analysis	The measurement of the uncertainty in a calibrated model as a function of uncertainty in estimates of aquifer parameters and boundary conditions.
Transient calibration	The calibration process applied to time-varying measurements and time-varying simulated equivalents. Modification of model properties to minimise the error between two time-varying datasets.
Transient verification	A comparison of two time-varying datasets (measured and simulated) as a check on whether they are similar or not. No remedial action is taken.
Uncertainty analysis	The quantification of uncertainty in model results due to incomplete knowledge of model properties, boundary conditions or stresses.
Vertical gradient	Usually applied to vertical head gradient.
Vertical head difference	The difference between the groundwater heads at two points separated by a vertical distance, with little if any lateral separation.
Vertical head gradient	The difference between the groundwater heads at two points separated by a vertical distance, divided by the vertical separation
Vertical hydraulic conductivity	Hydraulic conductivity applying in the vertical direction, or more generally the direction transverse to a bedding plane.
Vertically adjacent model layers	Model layers that share a common pseudo-horizontal boundary.

<u>Sources</u>

Middlemis, H., Merrick, N.P., and Ross, J.B., 2000, Groundwater Modelling Guidelines. Aquaterra Report for Murray Darling Basin Commission, October 2000, 125p.

Sustainable Resources Industry Training (SRIT), 2011, Water Glossary of Terms. *[With contributions from Noel Merrick]*