TO THE LAND COURT OF QUEENSLAND

Individual Expert Witness Report

GROUNDWATER MODELLING

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REGISTRY: Brisbane

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Applicant:	**NEW ACLAND COAL PTY LTD ACN 081 022 380**
	AND
Respondents:	**FRANK AND LYNN ASHMAN & ORS**
	AND
Statutory Party:	**CHIEF EXECUTIVE, DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION**

1. Introduction

[1] In reference to the letter of engagement dated 11 November 2015 (see **Attachment B**), from the Environmental Defenders Office (**EDO**) on behalf of Oakey Coal Action Alliance Inc. (**OCAA**), I have undertaken a review of materials pertaining to the New Acland Coal Stage 3 expansion project (**mine**) hydrogeology investigations and groundwater modelling. The following materials provided by the EDO served as the principal basis by which my opinions that follow were reached:

1. AEIS Appendix F: *Groundwater Modelling Technical Addendum, New Acland revised Stage 3 Project AEIS*, 13 August 2014 (**AEIS Report**);[1]
2. IESC (2014) *IESC 2014-045: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion, Final Advice*, 10 April 2014 (**Attachment C**);
3. AEIS Appendix N: *IESC Submission Response, New Acland Stage 3 Project*, 13 August 2014 (**IESC Response Report**);[2] and
4. IESC (2015) *IESC 2015-073: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion, Final Advice*, 10 December 2015 (**Attachment D**).

[2] My evidence is based on a review of the references listed above, focussing on groundwater modelling elements and related aspects. Given the limited time available, I have not undertaken an independent review of the groundwater modelling files, nor have I undertaken any independent modelling of the study area. As my review is not a traditional groundwater model peer review, I have not applied Review Checklists from the 2012 Australian Groundwater Modelling Guidelines[3] (**2012 Guidelines**). Rather, this report is based around the topics raised in the OCAA Notice of Issues, and the Joint Groundwater Experts Report, dated 16 February 2016 (**JER**).

[3] Prior to the meeting of experts on 4-5 February 2016, I was not informed of the details of concerns of Dr Matthew Currell. Dr Currell's expertise is more so in geology, hydrogeological conceptualisation and closely related fields, whereas my area of specialisation is computer modelling, notwithstanding that there is some overlap because we are both working in the general field of hydrogeology. Dr Currell and I focussed on different aspects of the investigation and reporting of the New Acland Coal Mine Stage 3 Project, in accordance with our primary areas of specialisation.

2. My Qualifications

[4] As outlined in my curriculum vitae (see **Attachment A**), I am a Professor in Hydrogeology at Flinders University, and a Chief Investigator within the National Centre for Groundwater Research and Training. My previous studies, work experience and

[1] Document ID: EHP.0103.
[2] Document ID: EHP.0111.
[3] Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A. 2012. Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra.

career achievements are outlined in detail in Attachment A. These include such relevant experience as:

a) Professional experience as a hydrogeologist and water resources engineer in private, public and academic sectors;

b) Co-authorship of more than 70 peer-reviewed, international journal articles, four book chapters, over 80 conference abstracts and articles, and various other technical publications and reports;

c) Contributions to a host of research projects and consultancy activities on such topics as groundwater modelling, coastal hydrogeology, water resources management, surface water-groundwater interaction and catchment hydrology; and

d) Numerous expert reviewer roles for international journals, Government agencies, Australian and international funding agencies, and other organisations.

[5] I have expertise in hydrogeology and groundwater modelling, as demonstrated through the career achievements listed above, in addition to:

a) Contributions to the current 2012 Guidelines;

b) My Chief Investigator role with the National Centre for Groundwater Research and Training;

c) My position on the Technical Advisory Panel on Coal Seam Gas Water for the Queensland Government's Office of Groundwater Impact Assessment (**OGIA**) (2010 to present); and

d) My expert witness role on the Carmichael Coal Mine objection proceedings in the Queensland Land Court (*Adani Mining Pty Ltd v Land Services of Coast and Country Inc. & Ors*).

3. Summary of My Conclusions

[6] My review of groundwater modelling investigations into potential impacts arising from the mine find that there is a high and undisclosed degree of uncertainty in the modelling results, to the degree that modelling and accompanying reports are misleading at worst, and highly uncertain at best. The opinions in the section that follows are subdivided into four main categories, reflecting the four key themes of the issues with the groundwater modelling investigation, as given below:

a) Groundwater modelling predictions are excessively uncertain;

b) The modelling investigation is unable to evaluate some of the expected impacts of mining;

c) Future impacts cannot be correctly attributed to causal factors; and

d) The reporting is highly deficient.

4. Background Facts and Assumptions

[7] The information on which my opinion is based is outlined in the JER and additional material referenced in the following section.

5. My Opinion

[8] The following builds on my opinions (as “AW”) outlined in the JER. This report needs to be considered in conjunction with the JER, which contains important elements of my opinion that may not be reproduced below for brevity.

5.1 Groundwater modelling predictions are excessively uncertain

[9] Groundwater modelling predictions are excessively uncertain for the reasons that follow.

[10] In addition to JER paragraph 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) There are not adequate data or mapping to show regional and local flow patterns. The lack of understanding of regional groundwater behaviour is evidenced by the paucity of regional groundwater flow maps that should have been created on the basis of field observations. Where the regional groundwater setting is discussed, e.g., §3.3 in the AEIS Report, the suggestion that flow is to the south is difficult to defend, especially when none of the head distributions obtained from the model(s) show flow to the south. Also, mining activities that change the flow should be mentioned and recognised, for example, the mounding to 440 m AHD in a region where flow is otherwise from 420 to 380 m AHD will create significant modification to flow paths. That is, these water levels suggest that reversal of flow directions will occur because 440 m AHD exceeds 420 m AHD (flow is from high to low water levels or “hydraulic heads”). Groundwater flow paths ought to have been drawn on contour maps to identify flow directions, in each of the aquifers under consideration, and changes in flow paths as a consequence of mining activities should be investigated and discussed.

b) Placing the current study into a regional context is essential. Existing literature demonstrate considerably greater insights into the regional setting than has been provided in the reporting by New Acland Coal (**NAC**). This is apparent from a comparison of Figure 3-1 of the IESC Response Report (Page 37; showing the study area relative to the QWC modelling region – reproduced at Figure 1) with regional data maps and interpretations, including, amongst other examples:

i) Figure 5-1 in the Queensland Water Commission's 2012 *Underground Water Impact Report for the Surat Cumulative Management Area*[4] (**Surat Basin UWIR**), which is reproduced at Figure 2;

ii) Figure 36 in Worley Parsons 2013 report *Groundwater Risks Associated With Coal Seam Gas Development in the Surat and Southern Bowen Basins*[5] (**Worley Parsons Report**), which is reproduced at Figure 3; and

iii) contours of the piezometric surface (i.e. water level distribution) in Figure 11 of John Hillier's 2010 report *Groundwater connections between the Walloon Coal Measures and the Alluvium of the Condamine River*[6] (**Hillier 2010**) which is reproduced at Figure 4.

Figure 1 shows the study area relative to the Surat Basin UWIR model domain. This region is particularly dense in water bores for irrigation and other uses (Figure 2), and that access the alluvium, basalt ("MRV" in Figure 3) and Walloon Coal Measures (**WCM**) aquifers. Furthermore, Hillier (2010) produced at least indicative regional flow contours and groundwater pathways (Figure 4) from available data, including for the NAC project area. Figures 1 to 4 highlight that significant available data allow for regional groundwater interpretations. These ought to have been undertaken to properly assign boundary conditions and to understand flow directions in the NAC project area, rather than the rudimentary correlation between water levels and land surface (see JER 3.3(a)).

[4] Available online at: https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0016/31327/underground-water-impact-report.pdf

[5] Available online at: https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0020/106148/act-5-groundwater-risks-report.pdf. See also Figures 33-35 in the Worley Parsons Report.

[6] Available online at: http://www.sodd.com.au/documents/JHillierfinal_000.doc

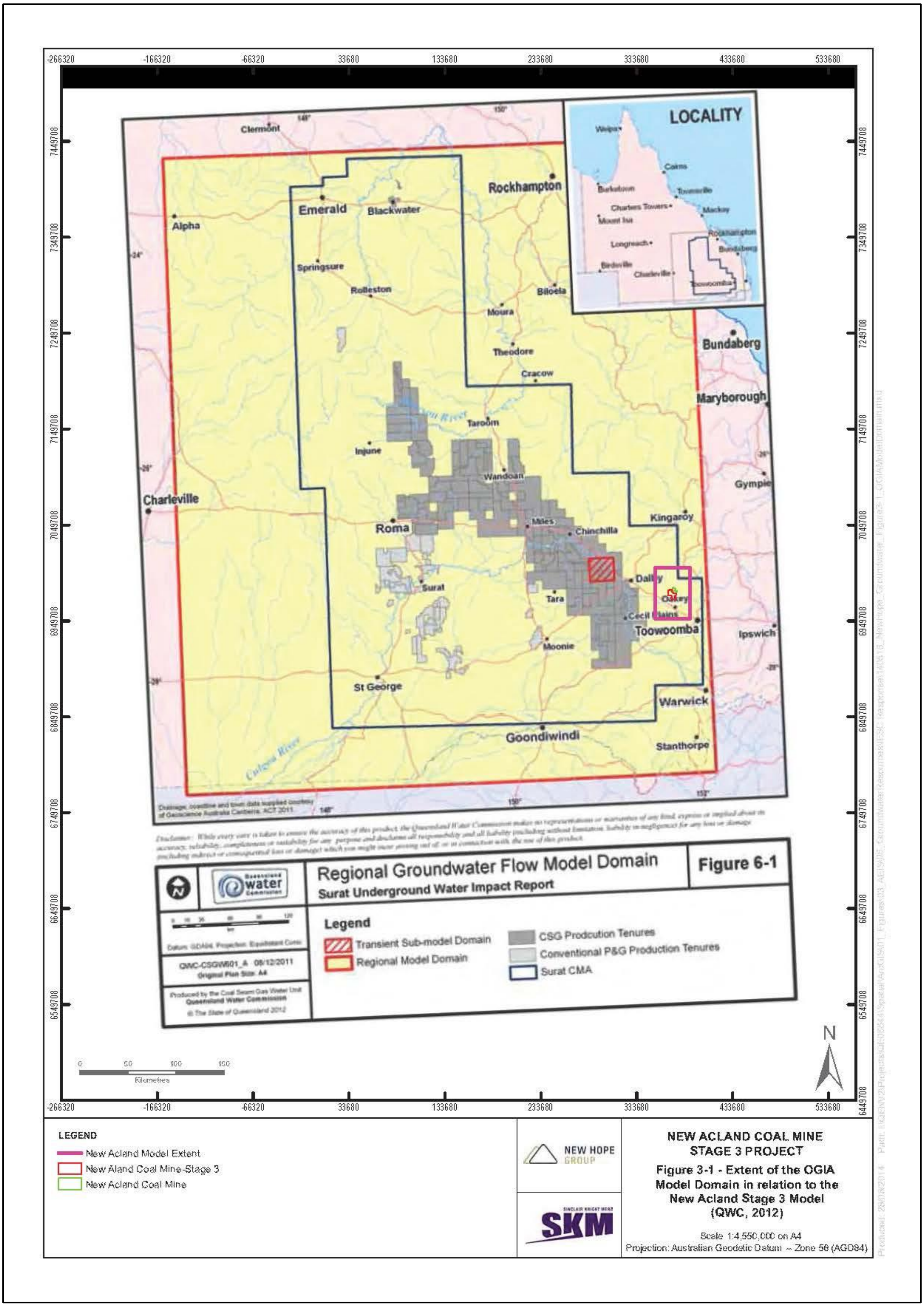

Figure 1: Figure 3-1 extracted from the IESC Response Report

Surat Underground Water Impact Report

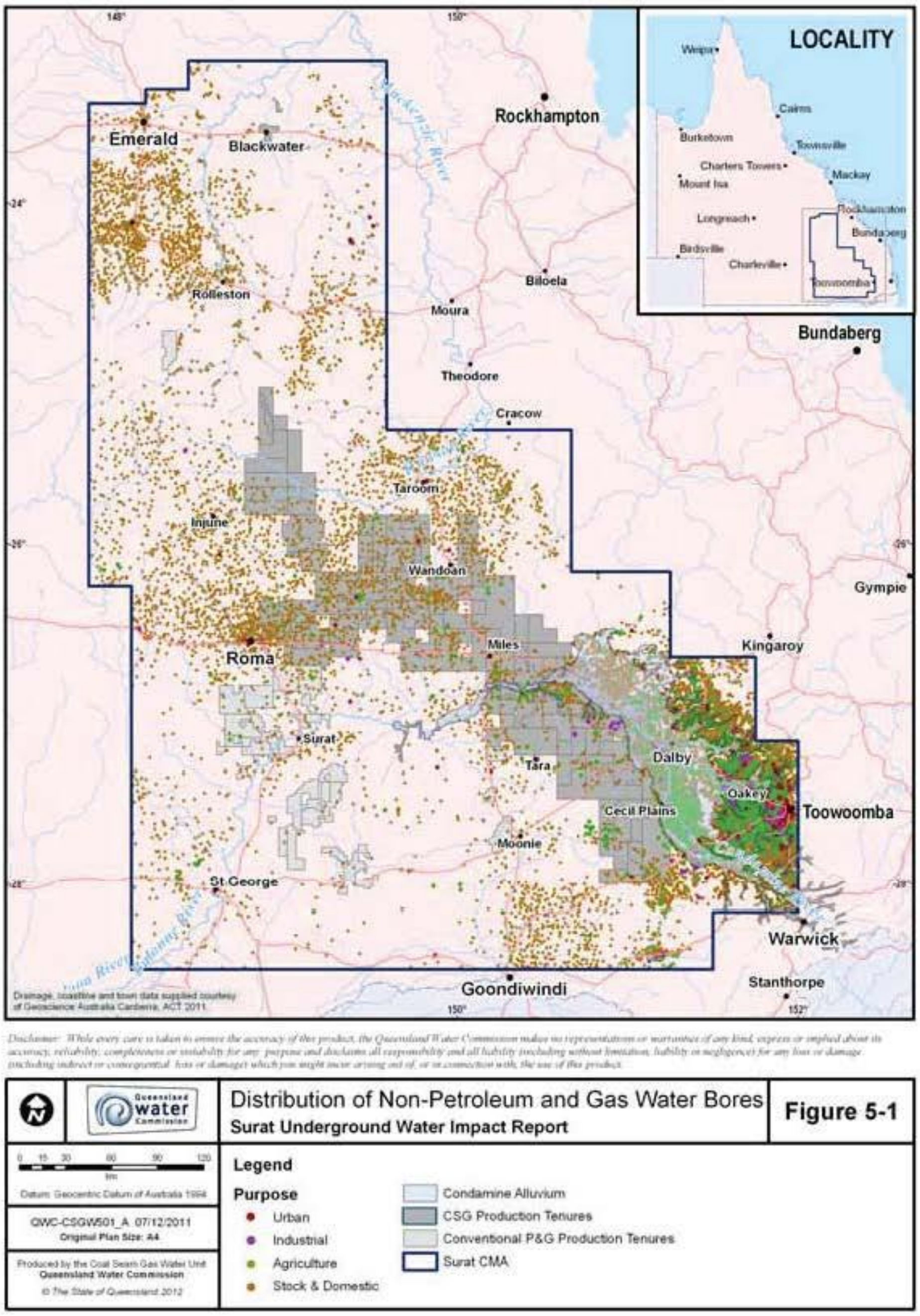

Figure 5-1 Distribution of Non-Petroleum and Gas Water Bores

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Figure 2: Figure 5-1 extracted from the Surat Basin UWIR

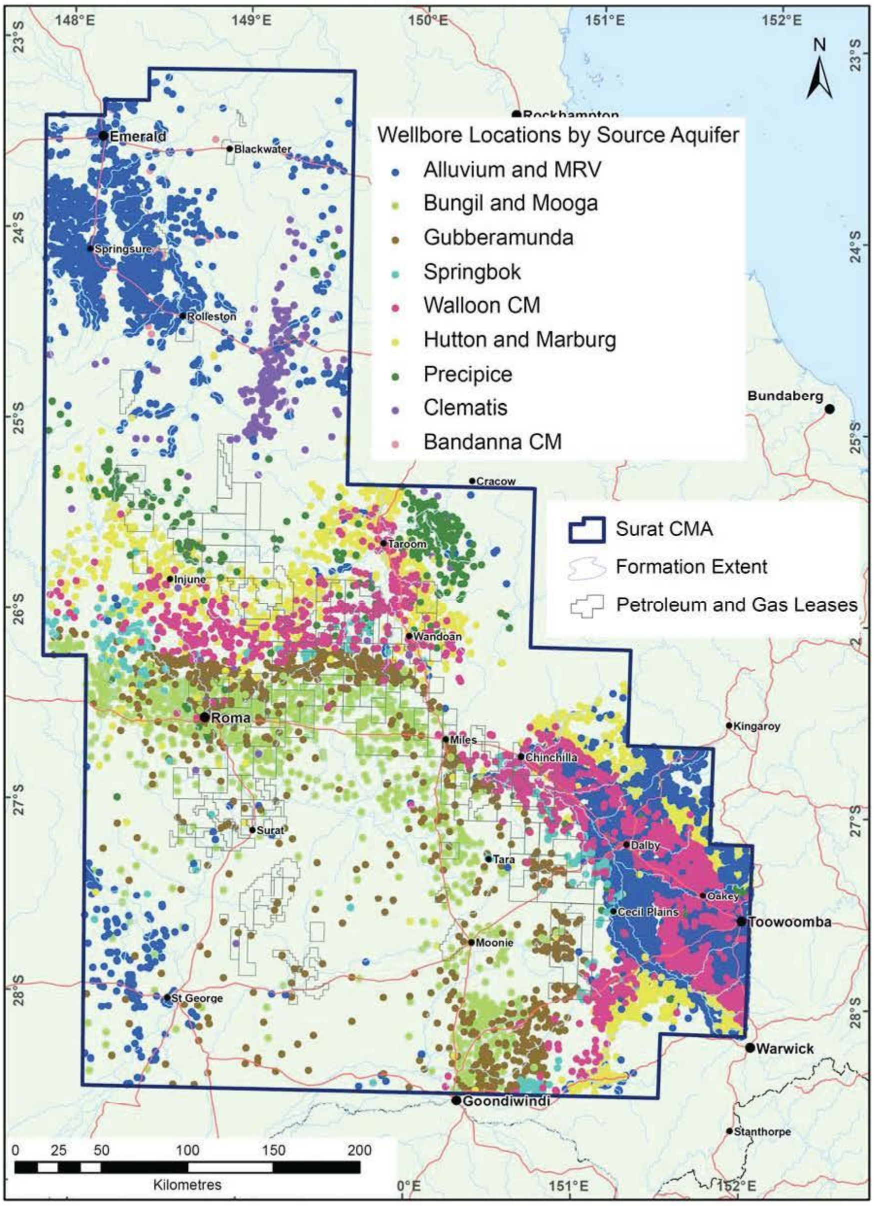

Figure 36 Identified source aquifers for water use (QWC, 2012)

Healthy HeadWaters CSG Water Feasibility Study, Activity 5 Groundwater Risks Associated With Coal Seam Gas Development in the Surat and Southern Bowen Basins
Page 83

Figure 3: Figure 6 extracted from Worley Parsons Report

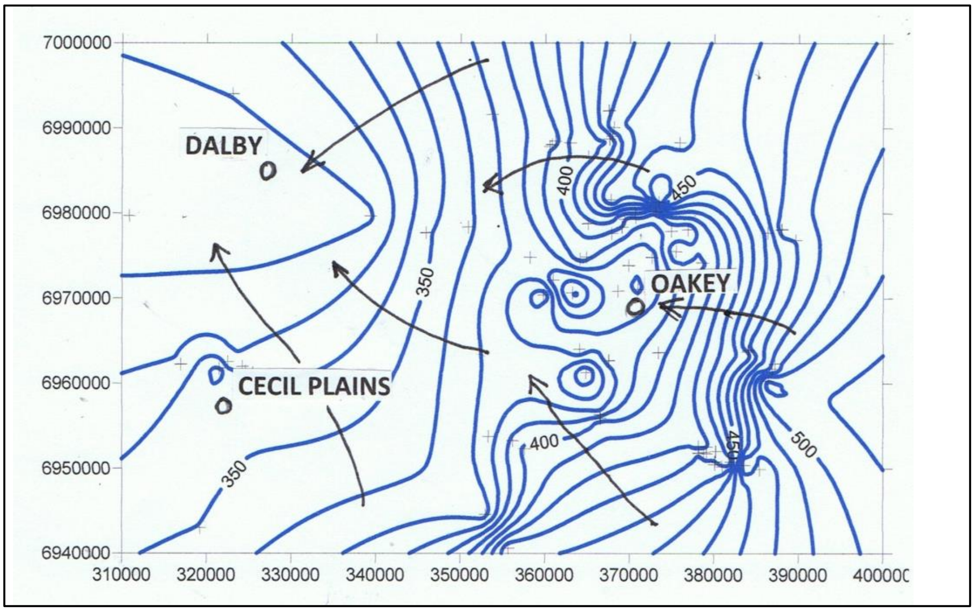

Figure 4: Figure 11 extracted from Hillier 2010

[11] In addition to JER paragraph 3.7 (*1(e)(iii)C. The proposed monitoring program is inadequate to detect potential impacts in the alluvium surrounding surface water features*):

a) The inadequacy of the proposed monitoring program is further highlighted by the lack of any measurements that inform the connectivity between the alluvium and the underlying WCM. That is, future monitoring of the alluvium appears focused on the measurement of drawdown, whereas the lack of basic and fundamental hydrogeological knowledge ought to be a motivational factor in developing the monitoring program. Further analysis (through the targeted installation of monitoring wells) of connectivity between the alluvium and the WCM should be included in the monitoring program because it is central to the objective of assessing mining impacts on other users and Groundwater Dependent Ecosystems (**GDEs**).

The above connectivity question is a key aspect of the 2012 report by QWC, who show in Figure 4-5 (reproduced below at Figure 5) that variability in the connectivity between the Condamine Alluvium (**CA**) and the WCM is very high, and that alluvium may sit directly on the coal seams (despite >40 m of intervening low-permeability sediment in other places), creating high levels of local interconnectivity.

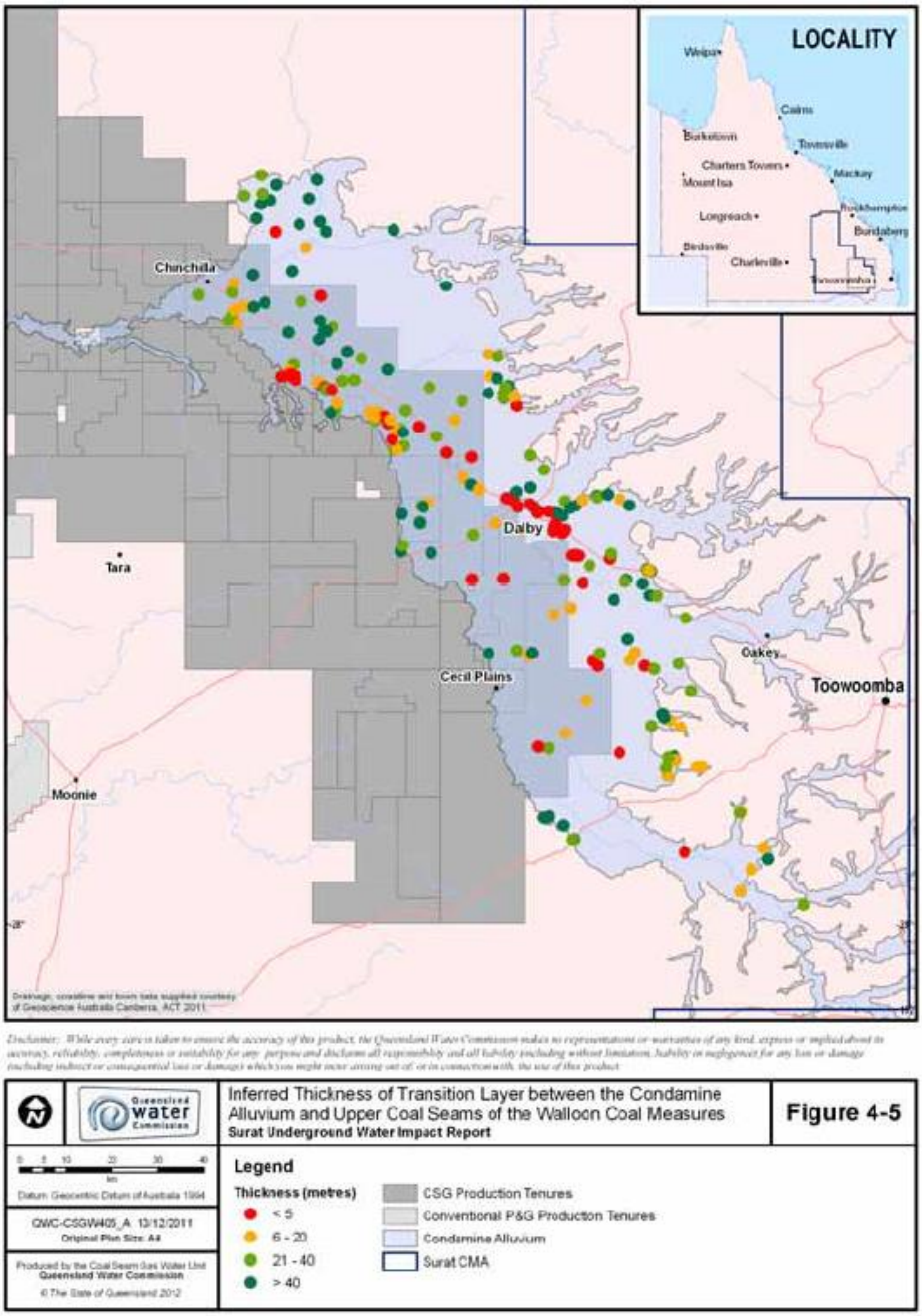

Figure 5: Figure 4-5 from QWC 2012

[12] In addition to JER paragraph 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) It is my position that without maps of regional flow directions and head contours, there is no way to know if the model's boundary heads are providing a reasonable representation of regional groundwater flow directions.

[13] In addition to JER paragraph 3.39 (*22 (b) there are no modelling deficiencies that detract from its fitness for purpose*):

a) In my statement of disagreement on this issue in the JER, I mention the role of the DRN package in controlling drawdown in the model.

The DRN package is part of MODFLOW, which is considered the industry-standard groundwater flow modelling software. The DRN package mathematically represents groundwater discharge to the land surface (without accounting for the movement of groundwater once it reaches the land surface) by relating the rate of groundwater discharge to the difference in elevation between the land surface and the hydraulic head (i.e. DRN discharge is this difference in elevation multiplied by a rather non-physical "conductance" parameter).

Further explanation of the potential role of the DRN package in this project is warranted. The first relevant point to make here is that the discharge to the land surface (aside from pit inflows) is a very large part of the water balance, but it is unclear whether this discharge rate and its distribution are realistic or not. This aspect is critical to the capability of the model(s) to properly simulate the aquifers' flow conditions. It is also central to the prediction of drawdown. The reasoning is this: excessively high discharge via DRN cells may act to artificially reduce drawdown by "capturing" discharge when mine-induced drawdown occurs. That is, if groundwater is discharged to the land surface at an artificially high rate, then any lowering of the groundwater levels (e.g. drawdown) will reduce this (artificial) discharge. A reduction in discharge is the same as an increase in recharge. Therefore, artificially high rates of discharge to DRN cells can have the effect of artificially enhancing the recharge wherever drawdown occurs, thereby artificially restricting the amount of drawdown that occurs.

In summary, the model(s) may significantly underestimate drawdown because any fall in water level is compensated by reductions in DRN discharge (i.e. "discharge capture" or "recharge enhancement"). In this way, the DRN cells (and potentially also EVT cells) can act somewhat like internal fixed head cells whereby drawdown is artificially muted because there are excessive levels of discharge that can readily provide "discharge capture", essentially acting to create artificial "recharge enhancement", and thereby inhibiting mining-induced falls in water levels. The likelihood that this is occurring is increased by the fact that the model produces water levels that are higher than field measurements in many places (i.e. as per the bias identified in the latest IESC Report [see Attachment D] at pages 2-3).

b) In my JER opinion (see paragraph 3.39(a)), there is a suggestion that more advanced knowledge of the groundwater system is needed. In addition to other data and conceptualisation short-comings identified in the JER, there is paucity in knowledge pertaining to historical impacts that arises because of the lack of any nested bore sites, which would usually be required to study the propagation of impacts between overlying-underlying aquifers. This would have assisted in understanding inter-aquifer connectivity, as discussed above in [11(a)]. Other factors that have led to modelling deficiencies, and yet ought to have been investigated to understand historical mining impacts, include faults, baseflow, GDEs and surface water-groundwater interaction, as discussed in numerous places in the JER.

[14] In addition to JER paragraph 3.24 (*5(h) With respect to recharge in the model: 5(h)(i) The method of recharge estimation is overly simplistic*):

a) Key literature on the estimation of recharge[7] identifies the need to use multiple approaches, because all recharge approaches are susceptible to significant uncertainties and biases. Recharge is one of the more elusive groundwater parameters to estimate, and may require the most effort to characterise to a reasonable degree of uncertainty, but it is nonetheless critical to the accuracy of any mathematical representation of the groundwater system. In the case of the current study, the simplest possible recharge estimation method is applied, without comparison to other methods, and with limited explanation as to the basis for the % applied in converting rainfall to recharge. The lack of alternative methods of recharge estimation (e.g. chloride mass balance, watertable fluctuation and unsaturated zone modelling approaches, amongst others) has an important bearing on model calibration.

Text Box 1: Calibration explained

Model calibration is the activity by which model parameters are "tuned" so that the model ideally reproduces historical field measurements. The more field measurements available, the more confidence the modeller has in the predictions made by the calibrated model(s). Also, with more field measurements, the modeller has more confidence that the parameters of the model(s) are a reasonable reflection of the real-world parameters of the aquifer and the stresses and forces that act on it.

In the current project, calibration was carried out by selecting "the best" models from a rather large set of models comprising random parameter combinations, with the aim of choosing models that best fit the field measurements. This is commonly referred to as a "stochastic approach" to calibration. A "deterministic approach" to calibration would be to seek a model (or models) that have been incrementally modified such that they ideally reproduce the field measurements and have the closest match to known aquifer parameters possible.

The stochastic approach allows for several calibrated models to be chosen, which may have several advantages, because the modeller is almost always unsure if one calibrated model is

[7] For example, Scanlon et al. (2002) 'Choosing appropriate techniques for quantifying groundwater recharge', *Hydrogeology Journal* 10: 18-39.

a particularly better representation of the aquifer system than another, especially in the absence of adequate field measurements. With the stochastic approach, the modeller can choose to show the largest drawdown, or the smallest drawdown, obtained from any of the calibrated models, or any other statistical results from the model predictions (e.g. the median drawdown and drawdown distributions representing one standard deviation from the median have been reported in this project).

In the current project, recharge was part of the model parameters that were varied to create the large set of models with random combinations of parameters, and as a consequence, recharge was part of the calibration process. However, given the general lack of field measurements, there is little hope that recharge in the calibrated models was informed by the calibration process. Or, in other words, the estimate of recharge was very unlikely to have improved by the calibration process. The lack of effort to estimate recharge prior to model calibration, resulting in virtually no knowledge of recharge to the study area, in combination with a calibration process that has not improved the recharge estimate, can only result in recharge values in the calibrated models that are likely to be in error, perhaps by an order of magnitude or more. This may result in other parameters being excessively wrong (due to model non-uniqueness; see below at [14(b)]), and this has implications for the estimation of drawdown as described below.

b) Most groundwater models suffer from parameter non-uniqueness, which is the ability of many different parameter combinations to produce the same groundwater level values. For example, in many cases, models with the same recharge-to-hydraulic conductivity ratio produce the same water levels, regardless of whether recharge is 10 and hydraulic conductivity is 20, or recharge is 100 and hydraulic conductivity is 200. This means that the model parameters can all be wrong (i.e. where "wrong" infers that the model parameters differ from real-world values obtained from pump tests and other field analyses), and yet the model produces water levels that look right. That is, despite having wrong parameters, models may nonetheless produce modelled water levels that appear to mimic the historical records of measured water levels, because the wrongness in some parameters is compensated by the wrongness in others.

This becomes a problem when the model is used in a predictive sense, e.g. to estimate future drawdown patterns, mine inflows, or other predictions that matter, because predictions from a model with wrong parameters may differ greatly to the predictions of a model that has the correct parameters. This often arises regardless of the match between the model and historical groundwater levels. If calibration and the available data do not help to constrain the parameters, then the most likely outcome is a model with an unacceptable degree of wrongness in the parameters (and most likely an unacceptable error in predictions), or at least an unknown, and perhaps considerable, degree of uncertainty in the predictions.

Given that the models used in this project very likely exhibit strong parameter non-uniqueness (mainly because water levels are few, and many field parameters are untested), it follows that calibration cannot inform recharge, and therefore, the calibration process should not be considered as an extension to the efforts to determine recharge in the study area. Thus, statements referring to "the calibrated percent of average annual recharge" in the AEIS Report §4.5, Page 19 are potentially misleading, particularly to a non-specialist reader, because calibration will not have informed recharge (as inferred by the description "calibrated" in the AEIS Report). In other words, recharge will not be any more accurate because of the calibration process, because of parameter non-uniqueness and the lack of expert knowledge of local recharge rates.

It would have been good practice and prudent for the modellers associated with the AEIS Report to have informed the readers (and decision makers) of this very important aspect of their modelling investigation. A relevant article on this topic by Hendricks Franssen et al. (2004)[8] describes this theory: "In practice the successful estimation of hydraulic conductivities and recharges depends on the amount of prior information [i.e. knowledge of the groundwater system's parameters] that is available, in order to constrain the hydraulic conductivities and recharge values sufficiently. Hydraulic conductivities and recharge values are difficult to estimate jointly because a lower hydraulic conductivity has a similar effect on the heads as a larger recharge."

c) It should also be highlighted that in the AEIS Report §3.5, Page 8, it is odd that the Helidon aquifer receives rainfall and surface water recharge, but the Marburg receives only surface water recharge, while the other aquifers receive only rainfall recharge, and yet none of these conceptual elements is captured in the overly simplistic approach to recharge estimation.

[15] In addition to JER paragraph 3.25 (*5(h)(ii) Recharge values are lower than expected*):

a) The range in recharge assigned to the models is 0.2% to 6.5% of rainfall (AEIS Report Table 5.1, p8), which, as agreed by the experts, is about half the Department of Natural Resources and Mines (**DNRM**) value. Basalt aquifers are described by QWC in the Surat Basin UWIR (2012)[9] as having low salinity groundwater (100 to 1100 mg/L), which indicates relatively high rates of recharge. That is, higher rates of recharge allow rainfall to pass into the aquifer with reduced concentration of atmospheric salts, thereby creating lower salinity groundwater. Also, these aquifers are said to "respond quickly to recharge from

[8] Joint estimation of transmissivities and recharges - Application: Stochastic characterization of well capture zones, *Journal of Hydrology* 294(1-3), 87-104 <http://www.sciencedirect.com/science/article/pii/S0022169404000927>.
[9] Queensland Water Commission (2012) *Underground Water Impact Report for the Surat Cumulative Management Area*, section 4.2.4, p25.

direct infiltration of rainfall, particularly in the elevated areas, and contribute recharge to connected aquifers".[10] The description of calibrated results (Table 5.5, Appendix B to the IESC Response Report), while not definitive about the final parameter values, indicates also that recharge to the alluvium, basalt and upper WCM is biased to lower-than-expected values. "The distribution of calibrated values is skewed or biased towards the lower range in values – as indicated by a decrease in the 50th percentile value", and therefore, my assertion that recharge is lower than expected is consistent with NAC's own reporting.

b) The relevance of the previous point is extended by considering [14(b)] above, which highlights that model non-uniqueness means that calibration is unlikely to have constrained recharge to "accurate" values, and therefore, any modification to recharge through calibration is not necessarily an accurate modification, and thus "bias" as mentioned in (a) above is essentially a deviation, potentially in error, from the expected value.

[16] In addition to JER paragraph 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) In the JER, AD suggests that pumping can be neglected, because the model is being used to assess net effects. That is, AD is suggesting that if pumping is neglected in both "no-mining" simulations and "mining" simulations (from which the difference provides estimates of drawdown), the absence of pumping is nullified, because it is missing from both models. This suggestion is analogous to having an equation, say "a = b", from which we subtract a number from both sides, say "a–c = b–c", but the equation still remains correct without knowing the value of the number we have subtracted. In this case, "c" would be the pumping we have ignored. Hence, while it might seem intuitive to be able to leave pumping out and obtain the correct drawdown, this is often not the case. More explanation is required as to why AD's position is most likely ill-founded, as follows:

i) The model is a relatively complex one, as most real-world models are, and as such, non-linear behaviour is common (e.g. changing a stress such as pumping by 20% does not cause a 20% change in drawdown, as it would for a model showing linear behaviour). Such non-linear behaviour is attributable to the drying of model cells (i.e. de-saturation of the cell removing all groundwater from the cell), stream-groundwater interaction, the groundwater discharge to the land surface, and unconfined conditions (e.g. the upper aquifer). In the absence of linearity (i.e. for models showing non-linear behaviour), the theory of superposition, which is required for the assertions of AD to hold, is violated. Given this, it is not valid to neglect important aspects of the system, but instead, both the no-

[10] Queensland Water Commission (2012) *Underground Water Impact Report for the Surat Cumulative Management Area*, section 4.2.4, p25.

mining and mining simulations ought to be as representative as possible of the actual stresses occurring within the system. Perhaps this is rather an intuitive recommendation – i.e. to develop the most accurate models possible. To simplify the point, and using the previous "a–c = b–c" analogy: if by introducing "c", we modify "a" and "b" differently (i.e. both "a" and "b" are different functions of "c"), then "a–c ≠ b–c", and we cannot neglect pumping from both models. It is my view that pumping may well modify the "mine" and "no mine" scenarios in significantly different ways due to the complex conditions of the study area.

ii) Another problem that arises from the omission of other groundwater users is related to the calibration process of selecting minimum-error models. That is, the calibration processes chooses models that deviate least from the measurements that were used as the basis for calibration, in this instance, groundwater levels primarily in the WCM and near the mine site, and a rather crude approximation of pit inflows during 2011-2012. In the absence of pumping, the models selected by the calibration processes must therefore contain erroneous parameters, which need to compensate for the lack of groundwater pumping if they are to reproduce measured water levels.

This is integral to the problem of non-uniqueness, as stated by Hendricks Franssen et al.:[11] "Hydraulic conductivities and recharge values are difficult to estimate jointly because a lower hydraulic conductivity has a similar effect on the heads as a larger recharge." The implications of parameter errors that arise from the omission of pumping are that modelling predictions (e.g. drawdown) will be wrong to an unknown degree, because the lack of pumping results in calibrated models with wrong parameters.

iii) The water levels in the CA are known to have fallen significantly in recent times (e.g. QWC (2012) state: "water levels have been lowered in the alluvium due to water extraction for irrigation"). This, in combination with maps showing considerable groundwater pumping in the general region of the mine (Refer to Figure 3 above), highlights that pumping is likely to be a major component of the water balance. Therefore, without alluvium pumping, the model and its water balance are erroneous to an unknown degree. It also follows that it is important to estimate with as much accuracy as possible the groundwater flow implications of mining on discharge to the CA, given that it is already significantly stressed by high pumping rates. See also relevant discussion on cumulative impacts in [22(b)].

[11] (2014) Joint estimation of transmissivities and recharges - Application: Stochastic characterization of well capture zones, *Journal of Hydrology* 294(1-3), 87-104 <http://www.sciencedirect.com/science/article/pii/S0022169404000927>.

iv) Finally, the simulation of impacts to groundwater users requires that they be represented in the model, because it is otherwise not possible to know whether the combined effects (i.e. the effects of pumping by others in combination with the effects of the mine) may lead to exhaustion of the aquifer in some areas. Or, in other words, while the model produces drawdown, it cannot simulate absolute water levels (see JER 2.49 (a) (ii): "AD and AW agree that… (ii) the lack of seasonality and other factors means that the model cannot provide absolute values"), which are needed to know whether an aquifer becomes exhausted in certain areas or not.

[17] In addition to JER paragraph 3.16 (*5(c) The calibration methodology demonstrates a number of misconceptions, errors and poorly explained elements including*):

a) Disagreement regarding the value of mine pit inflows in controlling the choice of parameters in the calibration process involves somewhat complex stochastic hydrogeology concepts, requiring further clarification. Note that "stochastic" refers to the statistical analysis that involves the consideration of several possible models, as opposed to a "deterministic" approach, which considers only a single model to make future predictions of the groundwater situation (see [14(a)] for an explanation of calibration concepts). Key elements of my opinions in the JER are supported by the following:

i) 300-400 m^3/d of pit inflows is 110-146 ML/year, which is a trivial fraction of the total drainage flux of some 13,000 ML/year (see AEIS Report §5.3 and §6.2).

ii) Consider that the use of pit inflows as a calibration target drastically reduces the number of "calibrated models" from 1,836 (out of 2,980) down to 18 (notwithstanding the erroneous value of 45 for the number of calibrated models reported at page 38 in Appendix B to the IESC Response Report and §5.4 of the AEIS Report). The process has therefore discarded 1,818 models that represented, equally well, the groundwater levels of the final 18 calibrated modes. The basis for discarding models was their inability to simulate some 140 ML/year of groundwater discharge into the mine pit, whereas the "calibrated" models are untested and may contain considerable errors in their estimation of some 12,860 ML/year of total groundwater discharge to land surface features other than the mine pits. Or, in other words, even a 10% error in the total groundwater flow to the land surface (12,860 ML/year) within calibrated models will corrupt the water balance well beyond any gains made by accurately estimating mine pit inflows (140 ML/year). Thus, calibration has chosen 18 models with an unknown degree of groundwater flow error, out of a possible 1,836 models that were at least equally well-matched to observed water levels.

Note that head calibration eliminated 1,144 models, but pit inflow calibration eliminated 1,818 models. If one considers that drawdown is the key prediction of interest, then the selection of models predominantly based on their ability to predict mine inflows is ill-advised. This is based directly on well-known calibration theory, i.e. that calibration targets (e.g. water levels, flow rates) ought to be as similar as possible, and be as informative as possible, to the target predictions. This is described in the 2012 Groundwater Modelling Guidelines in Guiding Principle 5.2:

> "The calibration process should be used to find model parameters that prepare a model for use during predictions of future behaviour, rather than finding model parameters that explain past behaviour."

Furthermore, the 2012 Guidelines state:

> "…the parameters that have the greatest impact during the calibration period, and to which historical measurements may be most sensitive, may have less impact on predictions. Predictions may be less sensitive to these parameters, and more sensitive to others."

This means that the model may be biased by using a calibration target (pit inflows) that is largely unrelated to the final prediction of interest (drawdown), notwithstanding the benefits of any improvements to model water balances that might arise from calibrating to mine pit inflows.

Based on these problems, I suggest that this methodology has not produced models that contain parameters that optimally or conservatively simulate the groundwater response to mining impacts, and rather, the models are each highly non-unique and the drawdown predictions thereby contain considerable uncertainty and, most likely, bias. Specifically, if the focus is to properly simulate impacts beyond the mine site, then the use of pit inflows to drastically reduce the number of "calibrated models" (i.e. pit inflows are the main control on the calibration process) should be reconsidered because it introduces considerable, and potentially unacceptable, modelling uncertainty.

iii) The previous point is important in interpreting the JER statement by AD (see JER 3.16(a)) that "the remainder of the model has been calibrated to water level elevations", because calibrating to only water levels virtually guarantees that the calibrated parameters assigned to these aquifers are non-unique (and therefore predictions from individual models are highly uncertain – see explanation in paragraph 17(a)(ii) above). In other words, calibration to only water levels does not inhibit non-uniqueness (and its accompanying predictive uncertainty), in contradiction to the implication by AD (or at least my interpretation thereof) that calibration to water levels is an adequate constraint on model parameters.

It should be considered here that calibration to water levels eliminated only 1,144 models from the original 2,980 randomly generated models, and therefore the water level calibration was not especially discerning, because it "considered" that 1,836 of 2,980 random models produced adequate water level estimates. Or, in other words, the first phase of the calibration provided 1,836 models that were all an "adequate match" (if 5% SRMS error is considered adequate) to the groundwater level measurements (i.e. they were "calibrated" to water levels). This reinforces the considerable non-uniqueness inherent in this approach (i.e. there are 1,836 models that could have been, used to make the drawdown predictions that are presented in the AEIS report, but of these, >1,818 were not considered).

b) The disagreement amongst experts regarding the use of one standard deviation to define limits to predicted impacts warrants further comment, as follows:

   i) Firstly, the choice of one standard deviation (i.e. selecting the 16th and 84th percentiles from 18 models) seems excessively restrictive, in particular given that the 5% SRMS filter and mine pit inflow filter within the calibration process had already reduced the calibration set to a small number of cases. Reducing the range of predictions (to one standard deviation from the median) will give smaller variability in the predicted drawdown extent, giving the impression of lower uncertainty, than would have been reported if all 18 models were used to predict the plausible range of drawdowns. That is, if all predictions were used, the range of drawdown would have been larger (and therefore appear more uncertain). I suggest that eliminating some of the 18 model predictions using a one-standard deviation filter was excessive and potentially served to build an impression (artificially) of low uncertainty.

   Added to this, AD reported in the JER (see JER 3.19) that 5% SRMS was a sufficient measure of calibration, so it seems odd to then filter again to reduce the breadth of calibrated results even further. That is, if 5% SRMS is a sufficient measure of calibration (to which I do not agree), then the predictions of models that meet this measure should have been considered reasonable models from which to obtain predictions, and their predictions should have been reported. Or, in other words, in accordance with NAC's own statements about the success of the calibration process to constrain parameters ("The level of constraint calibration has provided on parameter values is evident in the level of uncertainty indicated in the predictive results … uncertainty in the predictive results is considered minor"),[12] all 18 models ought to have at least been adequately head-calibrated (which they were not) and therefore not omitted from the presentation of predictive variability. This was not a conservative approach to reporting the modelling uncertainty.

[12] AEIS Appendix F: *Groundwater Modelling Technical Addendum, New Acland revised Stage 3 Project AEIS*, 13 August 2014, page 96.

ii) Secondly, as indicated in the JER (see JER 3.16 (c)), I contend that the most representative models are those that are most optimally matched to field observations, rather than the median of all predictions. The median of all predictions is not associated with the calibration fit, which has been widely used in other studies to infer the predictive ability of groundwater models. That is, the models that best match field data are the ones most likely to provide the most accurate predictions.

    There are caveats here worth mentioning, including that over-fitting (not applicable to the calibration approach used here) and significant measurement error may change the relationship between the degree of calibration misfit (often referred to as "error variance", where minimum error variance is sought in most groundwater model calibration approaches) and uncertainty. Studies by Dhar and Dhatta,[13] amongst others, support the use of error variance as a surrogate measure of uncertainty, consistent with my views for the current project.

iii) The link between calibration misfit and uncertainty (in [17(b)(ii)] above) has important implications for statements made in NAC reporting and the JER. For example, it is incorrect to state that parameter sets become more extreme and less likely beyond one standard deviation (IESC Response Report Appendix C, section 3.7.2, page 7), because this assumes that the likelihood of a particular drawdown is based on its association with the median from 18 parameters. This is incorrect (as addressed in [17(b)(ii)] above), and the correct approach should be to assume that the best calibrated model produces the most likely drawdown, and that models with worse calibration results provide less likely drawdown estimates, as a general rule.

    Moore and Doherty (2005)[14] define and extend this concept, in the following terms: "…a model's predictive uncertainty will only be reduced by calibration if the information content of the calibration data set is able to constrain those parameters that have a significant bearing on that prediction." Or, in other words, better calibration produces better predictions if the measurement data used to calibrate the model are relevant to the prediction of interest (drawdown in the case of NAC's project).

iv) Following the concepts described in [17(b)(ii) and (iii)] above, the statement by AD in the JER (see JER 3.16(c)) that "the best calibrated models may not be the most likely results as they are relying on the measures in place to define calibration" is not well-founded (noting the lack of clarity around whether "they" are the "best calibrated models" or

[13] (2009) Global Optimal Design of Ground Water Monitoring Network Using Embedded Kriging, *Ground Water* 47(6): 806-815.
[14] (2005), Role of the calibration process in reducing model predictive error, Water Resource Res., 41, W05020.

the "most likely results"). This is because the measures in place that define calibration are clearly not guiding the calibration process to produce unique or accurate models; see, for example, the significant bias found for some wells, plus the fact that calibration (to heads) eliminated less than half of the randomly generated models.

v) Put simply, I believe that 18 models (and fewer by way of adopting only the 16th and 84th percentile drawdowns) cannot represent limits to possible drawdown as a result of the proposed mining activities, because:

A. Model parameters are highly uncertain;

B. Calibration has not properly informed model parameters, which may or may not be producing accurate predictions;

C. Structural weaknesses (i.e. uncalibrated aspects such as homogeneity, geological layering, boundary conditions, etc.) in the model are considerable, important and unassessed;

D. Significant omissions (e.g. pumping by others) detract from the accuracy of model water balances, leading to parameter errors due to the need to compensate for these omissions within the calibration process; and

E. A small number of cases and the use of standard deviation filters will produce a small range in predictions and provide a false sense of the degree of model uncertainty.

[18] In addition to JER paragraph 3.18 (*5(c)(vi)A. The number of cases used to derive prediction ranges is relatively small*):

a) The points made in [16] and [17] apply to this issue, including that: (i) 18 models is most likely not a statistically representative sample of the global population of plausible models; (ii) reduction from 1,836 to 18 models has been made on the basis of a very small component of the water balance, and is therefore unlikely to have identified the most valid models; (iii) restricting drawdown estimates to within one standard deviation of the median produces an artificially smaller degree of uncertainty on the basis of the 18 "calibrated" models; and (iv) a smaller number of cases will produce a small drawdown range, and this will give an indication of lower uncertainty than is inherent in the model results.

b) Further to the issues identified in 18(a) above, it should be highlighted that many of the parameters selected through the calibration process are uninformed by pump tests and therefore highly uncertain, and yet have not been informed by the calibration process. This means that calibration has not informed many parameter values and hence the initial poorly informed estimates have been used in models. In other cases, parameters are skewed towards non-conservative values (e.g. horizontal conductivity (Kh) and vertical hydraulic conductivity

(Kv) of the upper WCM are lowered by one-to-three orders of magnitude). A larger number (much greater than 18) of stochastic realisations would be needed to sample the wide range of possible parameter values that arises from the lack of valid parameter constraints. Or, in other words, if the modellers have little knowledge of parameters, they need to use a wider range of models to produce reliable predictions of future aquifer behaviour.

[19] In addition to JER paragraph 3.19 (*5(c)(vi)B. The level of calibration is weak.*):

a) More detailed explanation of the disagreement on the use of 5% SRMS statistic for selecting calibrated model is warranted, as follows:

i) The poor calibration results, showing significant bias (acknowledged through expert agreement in the JER (see JER 2.37(a)) and misfit have arisen because the calibration criterion of 5% scaled RMS is not an adequate measure of goodness-of-fit, used on its own. A check by eye highlights the weak match to observed water levels, thereby supporting notions in the 2012 Guidelines that multiple statistical measures should be used to assess calibration misfit. Specifically, the 2012 Guidelines[15] state:

> "There is no specific measure of success. A subjective assessment is required as to the reasonableness of model results, relative to observations and expectations. The modeller should report on relevant qualitative measures and discuss the reasons for consistency and inconsistency with expectations."

It seems that the "check by eye" of the calibration results, showing serious errors in the calibration, has not been considered in statements by NAC about the low uncertainty of the model(s) and the adequacy of the calibration (e.g. "the model is able to provide a reasonable replication of water levels across the model domain", Page 41) in the AEIS Report.

ii) The statement by AD in the JER (see JER 3.19(a)) that the weak calibration "is a positive for the approach as it has allowed more simulations with more varied parameters to meet the criteria" does not seem to have a valid basis.

Firstly, the weak calibration to heads has not limited the number of cases, because head calibration arrived at 1836 models based on the 5% SRMS filter. In other words, tightening of the 5% SRMS would have still allowed a very large number of calibrated models, and therefore, it is odd that NAC have persisted with 5% SRMS despite that it reduced the initial number of models by less than half and created poor matches to measured heads.

Secondly, it is the discharge to pit inflows that is the primary cause of the excessive restriction to the number of calibrated models, from 1,836 down

[15] See p 75.

to 18, which AD has conceded at 2.36 in the JER is a small number. There needs to be some consideration as to why pit inflows have been so difficult to reproduce (perhaps it is error in recharge or the lack of pumping by other users). That is, tightening of the head-calibration is essential to reduce head biases in calibrated models, but this would only be possible if the pit inflow calibration did not reduce the number of calibrated models as severely as it did. Hence, by investigating why the pit inflow calibration filtered as strongly as it did, a tighter head calibration may well have been possible. Or, in other words, if the difficulties (likely errors of some kind in the conceptualisation) in finding models that match pit inflows were overcome, models that better match the measured heads (and therefore are more accurate predictors of drawdown) would have been readily achievable.

Thirdly, models that are poorly calibrated to specific measurement types (e.g. heads) are more likely to produce poor predictions of those measurement types (e.g. heads and drawdown), so improving the match to field measurements (i.e. setting a stricter filter on the selection of head-calibrated models than 5% SRMS) would have improved the reliability of the models' predictions for the primary variable of concern – i.e. heads and drawdown (see [17(b)(ii)] above).

[20] In addition to JER paragraph 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) The lack of efforts to obtain information about baseflow to streams (i.e. the low-flow of streams that is commonly assumed to be groundwater discharge) is concerning and a significant oversight. Baseflow to streams is an important component of the water balance to investigate in model(s), because: (i) it is traditionally linked to ecosystem health in surface water systems, and (ii) it is one of the few opportunities to compare groundwater flow from field measurements to flow rates in the groundwater model(s), thereby providing an opportunity to improve the accuracy of the water budget.

The claim in §3.3 of the AEIS Report that groundwater has not been identified as contributing to surface water flows within nearby creeks and streams requires substantiation. Also, this seems somewhat contradictory to the large rate of groundwater discharge via the DRN package (i.e. groundwater discharge to the land surface). Flood events are a worrying omission, and there are insufficient data to prove that flooding can be neglected. Despite statements by the independent peer reviewer that groundwater hydrographs lack temporal variation (see Appendix C to the IESC Response Report, section 3.1, page 3:16 "none of the water level records show significant or sudden increases"), the representation of water level data makes it very difficult to decipher

[16] Document ID: EHP.0111.

groundwater level transience, because plotted hydrographs have been set to vertical scales (100 m) that obscure temporal variability (see [27(a)] below).

In general, NAC's reporting provides almost no sense of the relationships between aquifers and surface water features (e.g. including where and at what rate groundwater discharges to surface features in the model, relative to the field conditions), and therefore, there is little capacity to check one of the largest components of the models' water balances. The lack of analysis of the spatial distribution of groundwater discharge to/recharge from surface water bodies in the groundwater model(s) is particularly concerning.

b) In combination, these two issues (lack of seasonality, little knowledge of base flow) mean that the model(s) cannot study the impacts of mining on surface water systems, because it is unclear whether the model(s) correctly simulates the groundwater component of surface water systems during the calibration period.

To clarify by way of example, if the null simulation model(s) (i.e. modelling predictions of the future conditions without the proposed mine extension) under-predicts groundwater discharge to streams, then it will appear as though the mine induces no reduction in base flow to streams, despite that a drawdown may have been predicted immediately below a stream (causing a reduction in groundwater flow to the stream) that might otherwise receive groundwater on a periodic basis. Equally, if groundwater discharge to the land surface is grossly over-estimated, then drawdown due to mining will not propagate as far as it would normally without this over-estimation (due to "discharge capture"; see [13(a)] for a definition of this), and hence aquifers (and connected surface water features) further afield from the mine site will be modelled as unaffected when in reality, drawdown may extend considerably further.

c) The DRN package used to model streams does not allow for streams to recharge the aquifer[17], whereas they would be expected to recharge the aquifer, even where streams are ephemeral (i.e. flow is intermittent). That is, streams may serve to occasionally recharge the aquifer (i.e. during periods of stream flow following rainfall) by significant amounts, but this has not been considered in the model because of the model construction approach.

5.2 The modelling investigation is unable to evaluate some of the expected impacts of mining

[21] The modelling investigation is unable to evaluate some of the expected impacts of mining for the reasons that follow.

[22] In addition to JER paragraph 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*):

[17] See IESC, 2014: page 8, section 3.4.

a) The regional flow patterns include influxes to the CA because the mine is located at the fringes of the CA. The CA is presently being studied by OGIA[18] to explore the potential for Coal-Seam Gas (CSG) extraction to draw water from this highly valued aquifer system. The QWC investigation has focused on CA-WCM interconnectivity, because this is critical to the propagation of CSG drawdown into the CA. The investigation by NAC does not include an attempt to establish water budget impacts to the CA (i.e. losses of inflows), despite that it is critical to gain an appreciation of the losses of inflows to the CA arising from the mine, particularly given that the CA is highly stressed due to irrigation pumping, and that potential future stresses due to CSG may further impact the high-value water resources of the CA.

b) The regional context ought to additionally consider the potential and actual impacts of other groundwater users. Harty et al.[19] suggest that "Sustainable development will be impossible if cumulative effects are not considered in environmental planning…", and that "it is the accumulation of the individually minor effect of multiple human actions over time that is primarily responsible for the continued observed degradation of natural systems".

   The National Water Commission's 2009 *Report on the Inclusion and Implementation of NWI Objectives and Consideration of Cumulative Effects*[20] on cumulative effects on groundwater suggests that: "All individual disturbances in the environment created by natural and human activities have the potential to act in unison to create cumulative impacts, which in some cases may be greater than the sum of their individual impacts", and "CE's [Cumulative Effects]… are generally poorly addressed or currently absent from environmental assessment studies in Australia. It is this comprehensive assessment of CE's that is widely seen as an area in need of improvement in the environmental approvals process in Australia".

   The investigation by NAC to date makes no mention of potential cumulative impacts arising from other groundwater users in the area. It is important to evaluate cumulative impacts within the study area for a number of reasons. Firstly, without knowing cumulative impacts, it is not possible to know how

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[18] Queensland Water Commission (2012) *Underground Water Impact Report for the Surat Cumulative Management Area* <https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0016/31327/underground-water-impact-report.pdf>.

[19] Tyson Harty, Daniel Potts, Donald Potts and Jehan El-Jourbagy (2005) Chapter 27 in *Implementing Strategic Environmental Assessment*, edited by Schmidt et al, p 397.

[20] Australian Government National Water Commission (2009) *Framework for Assessing Potential Local and Cumulative Effects of Mining on Groundwater Resources, Report 1: Report on the Inclusion and Implementation of NWI Objectives and Consideration of Cumulative Effects*, available online at: http://archive.nwc.gov.au/__data/assets/pdf_file/0014/11552/Report_1.pdf. Additional information on the Framework for Assessing Potential Local and Cumulative Effects of Mining on Groundwater Resources is available online at: http://archive.nwc.gov.au/rnws/ngap/groundwater-projects/strategic-aquifer-characterisation-to-quantify-sustainable-yields/potential-local-and-cumulative-impacts-of-mining-on-groundwater-resources/final-reports-from-the-potential-local-and-cumulative-effects-of-mining-on-groundwater-resources-project.

these might be disentangled (e.g. from measured groundwater level records) where impacts are felt in the future. Deciphering which human impact is responsible for groundwater decline, which may cause losses of access to freshwater and ecosystem degradation, is central to any capacity to restore the impacted systems, notwithstanding the challenge of finding other sources of freshwater to replace lost stored groundwater in aquifers. Secondly, the sustainability of groundwater systems requires consideration of all significant stresses on the aquifers, and neglecting neighbouring human activities precludes any ability to know whether, when and where aquifer exhaustion or other adverse impacts may occur.

Cumulative impacts should be considered and discussed within NAC's evaluation, and ideally incorporated in at least a rudimentary manner in the investigation of mining impacts arising from the project. Without considering cumulative impacts, decision-makers will be ill-equipped to manage the growing number of groundwater-affecting activities in this region.

[23] In addition to JER paragraph 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) The disagreement between experts on the deficiency of the model to simulate surface water-groundwater interaction raises a critical issue with the NAC groundwater investigation. That is, the experts agree in paragraph 2.29(a) of the JER that the model is unable to simulate seasonal water level fluctuations, but that these may be important for modelling impacts to GDEs and surface water bodies, and yet the lack of seasonality and the modelling approach more generally is suggested (by AD in paragraph 3.15(a) in the JER) to be "sufficient for this level of assessment".

This raises the question as to whether the modelling scope and objectives include the analysis of impacts to GDEs and surface water bodies, using the model. Information about these sorts of objectives is normally contained in the Scope of Work section; however, in IESC Response Report,[21] a "Scope of Work" section is listed in the Table of Contents, but is not included in the report. It appears from exploration of the reporting (i.e. EIS Ch 6 - Groundwater Resources, the IESC Response Report, the AEIS Report) that, in fact, the aims and objectives of the modelling are not described to the degree that the intended use of the model in terms of predictions and impacts is clear to the reader. It would therefore appear from the respective expert opinions that AD presumes that GDEs and surface water bodies are not components of the groundwater modelling objectives, whereas AW believes that they are, and ought to be, in particular on the back of legislative requirements potentially relevant to GDEs

[21] Document ID: EHP.0111, soft pages 65 and 69.

and threatened species dependant on GDEs.[22] It can therefore be inferred that AD appears to suggest that the modelling has been intended and designed to investigate the impacts on other groundwater users only. I would agree that this appears to be the case, despite the high likelihood of other types of impacts, which are surely important to the approval of this groundwater-affecting activity.

b) To clarify the discussion of this issue in the JER, the current use of annual stress periods (i.e. the modelling time-step during which the pre-determined forces acting on the aquifer are held constant) adopted in the groundwater model(s) means that there is no seasonality in the model(s) – i.e. no wet season and no dry season. As such, water levels will not fluctuate as they would under natural conditions. This means that the intra-annual cycles of groundwater rise and fall, and subsequent changes in the fluxes between aquifers and the land surface (including surface water systems) are not considered. It follows that the models' predictions of surface water-groundwater interaction could only be correct if water levels are very stable across the study area (i.e., episodic recharge occurs rarely, if ever). The lack of monitoring has precluded an understanding of where water levels might be more dynamic (fluctuating on an intra-annual basis). Therefore, it remains unclear whether or not the models require monthly rather than annual stress periods, particularly given the 100 m vertical scale used to present the available transient groundwater level behaviour (see [27(a)]). In my experience, models are more likely to require monthly stress periods if impacts to GDEs and surface water systems need to be explored.

[24] In addition to JER paragraph 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) See [23(b)] for a discussion of the limitations of yearly stress periods for simulating stream flow and impacts on GDEs. In addition to these points, the lack of seasonality in the model precludes any ability to simulate the effects of occasional high rates of inflow to the mine pits, which are needed to understand mine pit behaviour in regards to inflows/outflows, mine pit-groundwater interactions, water levels and water quality.

[25] In addition to JER paragraph 3.27 (*5(k) The modelling of mine voids and pit lakes is deficient*):

a) In paragraph 2.51(b) of the JER, the experts agree that surface water modelling should be the primary method for determining void hydrology and yet it is clear that the groundwater model, with its coarse temporal resolution (i.e. yearly stress periods, see [24(a)]), has been used to model mine pit hydrology. The application of surface water modelling to investigate mine pit hydrology would

[22] New Hope Group, EIS Chapter 6: Groundwater Resources, New Acland Coal Mine Stage 3, January 2014, pages 6-47 to 6-48.

allow for higher frequency time-stepping to be used to properly study the mine pit water balance and the fluctuations (in both water level and water quality) of mine pit water bodies. Hence, there appears to be a disjoint between the methodology recommended in the JER (see JER 2.51(b)) and what was actually undertaken (i.e. the mine pit was modelled using the groundwater model(s)), notwithstanding that the mine pit modelling methodology is not clear in the reporting.

5.3 Future impacts cannot be correctly attributed to causal factors

[26] Future impacts cannot be correctly attributed to causal factors for the reasons that follow.

[27] In addition to JER paragraph 3.14 (*4) As a result of the above deficiencies: 4(b) The conditions proposed for the Project are inadequate to avoid or mitigate these impacts*):

a) In order for NAC to properly manage (identify, avoid and/or mitigate) groundwater impacts, they require an adequate monitoring network and sufficient investigation of the resulting data. Aside from deficiencies in the monitoring network (e.g., see [11] above), the interrogation of measured data (a necessary precursor to impact management) is poor. This is highlighted in the manner of presenting water level hydrographs in Appendix A.1 of the AEIS Report, which show extremely large vertical scales (100 m) relative to the amplitude of fluctuations. This has the effect of making it appear that variations in water levels are very small, and visually diminishes differences between modelled and observed water levels. It additionally masks the dynamic behaviour of water levels, and hence it is very difficult to draw useful hydrogeological knowledge (e.g. recharge responses, pumping effects, etc.) from the water level variations.

   Plus, errors remain undetected. For example, if one considers the hydrograph of 42231301, which is reproduced below at Figure 6,[23] there is an inexplicable and significant oscillation in water levels between two values that appears as an error. That is, water levels seem to jump between two elevations of some 3-4 m difference in a rather unnatural manner that to an experienced hydrogeologist must surely suggest an error of some kind, and that is worthy of investigation (and reporting). The fact that this error persists for many years seemingly without evaluation is worrying in terms of the checks that have been in place regarding validity of measurements and whether or not the data have been used to improve system understanding over the period of historical mining. This also raises concerns about the quality of these data more generally. This error is not mentioned in reporting on the project and may have gone undetected by the investigation team.

[23] See Appendix A1 to the AEIS Report, soft page 112.

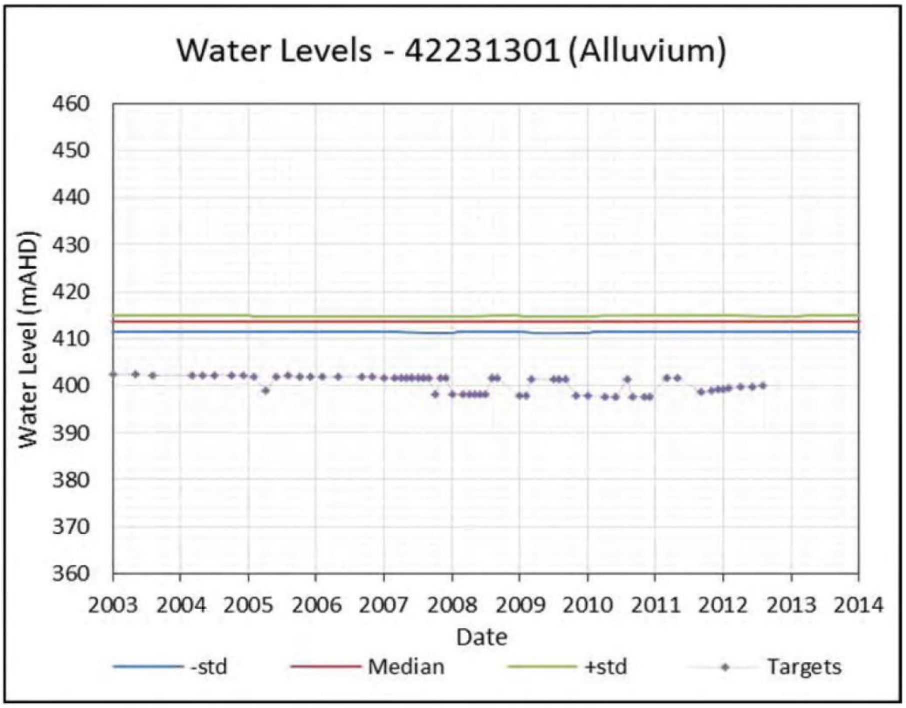

Figure 6: Hydrograph of 42231301 from Appendix A1 to the AEIS Report

[28] In addition to JER issue 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) In order to account for the impacts from previous mining activities (and climate variability), "null" simulations are needed that omit previous mining from the model design. That is, historical and future modelling is needed in which the earlier two phases of mining by NAC are omitted to try to understand the scale of impacts from previous mining (including future impacts from previous mining) so that these might be distinguished from the impacts of future mining.

[29] In addition to JER paragraph 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) See the discussions on: the lack of data for regional and local flow patterns in [10], short-comings in the monitoring network in [11], the lack of baseflow data in [20], limitations in the understanding of aquifer interconnectivity in [22], and issues around storativity in [32]. Also, the statements by AD at paragraph 2.33(c) of the JER that it is unclear whether and to what degree OGIA data and modelling, and DNRM groundwater observations were adopted in the investigation seem in contradiction to the statement at paragraph 3.22(a) of the JER that AD considers all relevant pre-mining data were used.

5.4 Reporting is highly deficient

[30] The reporting is highly deficient for the reasons that follow.

[31] In addition to JER paragraph 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) There are a number of factors that support the notion that impacts on the Tertiary Basalt aquifer from mining should not be considered as conservative (as suggested by the experts representing NAC ("AD and DI") at 3.4(a), 3.8(a), and 3.33(a), of the JER). These include:

i) The high degree of uncertainty in modelling of the study area (see also paragraphs [9] to [20]), noting that models are known to produce significantly biased water levels in the Basalt aquifer (see JER 2.37(a) and Attachment D at pages 2-3.

ii) The calibration methodology, which I believe to be deficient, has most likely resulted in models that produce smaller-than-expected impacts of mining, for example into the Basalt aquifer, than the impacts that are likely to occur in reality. That is, modelled impacts from mining are probably weaker than would have been obtained from modelling if parameters were adopted that are more realistic and reflective of available knowledge. One example amongst others (of parameters that reduce the predicted mining impacts within the model(s)) is the reduced connectivity (relative to current knowledge of aquifer parameters) between the WCM and the Basalt aquifer. That is, calibration has selected models with lower WCM horizontal hydraulic conductivity and lower Upper WCM vertical hydraulic conductivity, and these two factors will serve to reduce the model-predicted drawdown that eventuates in the Basalt aquifer.

iii) The National Water Commission's 2010 report Framework for risk-based assessment of cumulative effects to groundwater from mining[24] highlights the higher sensitivity of systems like the Basalt aquifer, which is fractured and displays local flow systems, to mining impacts, in the following terms: "Fractured rock aquifers and local groundwater flow systems have a lower buffering capacity for development than do sedimentary aquifers and regional groundwater flow systems." Or in other words, the Basalt aquifer is characteristically at higher risk of impact from human interference than other aquifer types (such as sedimentary aquifers). Given that the Basalt aquifer is treated as a sedimentary and continuous aquifer in the model, rather than fractured and compartmentalised, it follows that the Basalt aquifer may experience larger impacts than those predicted by the model, and therefore, suggestions in the JER (see paragraphs 3.33(a),

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[24] Australian Government National Water Commission (2010*) Framework for Assessing Potential Local and Cumulative Effects of Mining on Groundwater Resources, Report 3: Framework for risk-based assessment of cumulative effects to groundwater from mining*, available online at: http://archive.nwc.gov.au/__data/assets/pdf_file/0016/11554/Report_3.pdf.

3.4(a) and 3.8(a)) that impacts to the Basalt aquifer are conservative are ill-founded.

[32] In addition to JER paragraph 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) While experts agree that lower storativity will likely result in more rapid, severe and extensive drawdown in an uncomplicated situation (i.e. under idealised conditions, see JER 3.17(a)) there is not agreement that models produce conservative drawdown predictions because of the lower storativity. The following factors are relevant to this discussion:

i) The degree to which other parameters are incorrect and their importance in propagating drawdown is essentially untested, and therefore the higher drawdown expected from the erroneously low storativity may be more than compensated by errors in other parameters (see also paragraphs [9] to [20] on modelling uncertainty).

ii) The behaviour of complex aquifers is often difficult to predict based on the anticipated or intuitive expectations that are usually founded on groundwater behaviour under simple conditions. Consider, for example, that low storativity produces water levels that fluctuate at larger amplitudes, and therefore, a lower-storativity aquifer is more readily replenished by recharge following a storage decline. As such, under transient conditions, the drawdown imposed by mining may be more easily reversed during recharge events than the drawdown in an aquifer with higher storativity. This is particularly true for a system with high surface drainage, which may act to moderate water level fluctuations in a similar manner to a fixed-head condition. It follows that an erroneously low storativity may therefore produce smaller-than-expected mining impacts. Clearly, the influence of lowering storativity under these conditions (i.e., similar to those of the current study) is not straightforward to predetermine, particularly given the limitations and uncertainties of the modelling approach.

iii) Even in the case that the erroneously low storativity creates enhanced drawdown, it remains unclear as to the influence of storativity on other factors, including drawdown recovery (likely to be faster in the model than would otherwise occur with the corrected/higher storativity), seepage into mine pits, impacts on surface water systems, impacts to vegetation, etc. Therefore, the assertion that the model is conservative by AD and DI should be based on more than just the model's ability to predict drawdown.

iv) Given that models are calibrated, other parameters will be selected such that they compensate for the low value of storativity (because of the issues of non-uniqueness; see [14(b)] above), and therefore, as long as the measurement dataset is informing the calibration process, calibration should ideally nullify the error in the storativity and thereby at least minimise the accompanying conservativeness of the model predictions. Or, in other words, even if storativity is prima facie assigned a “conservative” value, the calibration process will select parameters that compensate for this conservatism and thereby reduce, eliminate or over-compensate for it. This means that calibration may in fact produce non-conservative models despite selecting a conservative storativity value. Here, “conservative” refers to an over-estimation of drawdown by the model(s). Ultimately, the result of the wrongness in parameters is very difficult to know, regardless of whether parameters are presumed to produce conservative outcomes or not, without model testing. Or, in other words, the errors in storage parameters introduced by the modellers may well have impacted predictions in unintuitive ways.

[33] In addition to JER paragraph 3.16 (*5(c) The calibration methodology demonstrates a number of misconceptions, errors and poorly explained elements including*):

a) In regards to the disagreement about the importance of wrongly reporting the number of calibrated models, the following applies. The difference between 18 and 45 calibrated models, as a subset of the global population of calibrated models, is important. Consider that if there are, say, >500 possible parameter combinations[25] that produce calibrated results. If we want to make sure that we have sampled from this population of possible parameter combinations such that we have representative statistics of the population (e.g. within 10% of the population (true) values), then we’d need 80 samples.[26] Note that it is very important to have a selection of calibrated models (i.e. the “samples”) that properly represents the range of possible models that might exist (i.e. the “population”). Otherwise, predictions from the calibrated models are likely to be biased. I suggest that the likelihood that 18 calibrated models is a representative sample of the large global population of possible calibrated models is very low (and significantly lower than the wrongly reported 45 samples), and therefore, the results obtained from these calibrated models should not be relied upon.

[34] In addition to JER paragraph 3.17 (*5(c)(i) The justification for avoiding calibration of specific storage is ill-founded*):

a) Paragraph [32] above identifies important points of relevance to this issue, including that erroneous storage parameters probably results in the erroneous

[25] This is a very conservative estimate. There are likely to be thousands, notwithstanding that parameter values are continuous and therefore the number of possible combinations is theoretically infinite.

[26] A relatively simple explanation of the relationship between sample size and representativeness of results is available online at: https://www.surveymonkey.com/blog/2011/09/15/how-many-people-do-i-need-to-take-my-survey/.

selection of other parameters, which need to compensate for the storage error, thereby detracting from the model accuracy. Additionally, the erroneously low storage parameter may impact other model predictions, aside from drawdown, in non-conservative ways. Additional explanation of my opinion stated in the JER (see JER 3.17) is warranted, as:

i) Drawdown may not necessarily be conservative if the system approaches steady-state conditions. Put mathematically, the groundwater flow equation contains a term S times dh/dt, and as dh/dt (changes in groundwater head/water level with time) approaches zero, as occurs during quasi-stable water level periods, the S term (storativity) is immaterial. Hence, it is not known up-front whether a low S is a conservative estimation or not, as suggested by AD in paragraph 3.8(a) of the JER.

ii) It is also worth noting that the justification for avoiding storativity calibration in the AEIS Report, section 5.2 is ill-founded, because plausible ranges should be assigned as bounds and storativity should therefore not end up as an implausible number. That is, if the calibration process is reasonably controlled by the modeller, there is no reason to obtain unrealistic parameter values, as suggest in the AEIS Report.

[35] In addition to JER issue 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) Disagreement within the JER regarding the consequences of homogeneous assumptions can be informed by reference to literature on the topic. In a study by Illman et al.,[27] amongst other articles on this topic, it is demonstrated that homogeneous models produce biased predictions of drawdown (at least for the somewhat synthetic problem that Illman et al.[28] considered), whereas heterogeneous models produced "excellent" predictions of drawdown. More recently, Yeh et al.[29] show that: "a mathematically well-defined inverse problem [i.e. a groundwater model calibration activity], based on an equivalent homogeneous or a layered conceptual model, may yield physically incorrect and scenario-dependent parameter values." Yeh et al.[30] find that homogeneous representations of heterogeneous conditions will require aquifer parameters that differ depending on the location of field measurements and points of extraction, and the timing of measurements. That is, if homogeneous representations of heterogeneous aquifers are adopted, it is extremely difficult to set parameters at values that adequately reproduce real-world heterogeneous behaviour, and equally difficult to make best use of the data in terms of informing model

[27] (2010) *Water Resource Research* 46, W04502.
[28] (2010) *Water Resource Research* 46, W04502.
[29] (2015) *Water Science and Engineering* 8(3): 175-194.
[30] (2015) *Water Science and Engineering* 8(3): 175-194.

parameters. This subsequently leads to non-unique model predictions that may be considerably different to the real-world drawdown that arises from imposing stresses (e.g. mining) on the aquifer. Yeh et al.[31] state this as: "A sparsely parameterized problem (such as a problem using few homogeneous zones) can be mathematically well defined. However, it may yield physically incorrect and phenomenological parameter values due to scale inconsistency…".[32] They suggest that: "A simple model always plays an important role since it provides a first-cut analysis of a complex system". In this latter statement, Yeh et al. [33] are recommending that models with strong levels of homogenization (similar to the NAC model(s)) are crude and approximate, but useful first estimates. This is in contrast to suggestions within the NAC reporting that their modelling has provided a level of uncertainty in the predictive results that can be considered minor, regardless of their rather ambiguous caveat "in hydrogeologic modelling terms".

b) In addition to the reasoning offered in the JER, it should be noted that in the AEIS Report (page 9, section 4.3) it is not sufficient to merely claim that various excluded processes will have relatively minor influences "given the existing modelling objectives and scope". There is no clear basis to discount these factors in this off-handed manner, in particular considering that the modelling reports do not have a Scope of Works section or similar explanation. Flooding, for example, may impart significant hydrological controls on the system, and heterogeneities have been recognised by all four experts as critical to the performance of basaltic aquifers.

Additionally, the statement in the AEIS Report (page 26, section 5.1) that the stochastic approach accounts for inherent uncertainty is incorrect. Almost all of the uncertainties are retained for reasons given above (e.g., the small number of calibrated models, homogeneous assumptions, lack of data, etc.). In particular, the lack of assessment of vertical hydraulic gradients (see IESC Response Report Appendix A (Peer Review Checklist) to Appendix C, page A1-8, section 4.4.2) undermines confidence in predictions of flows between aquifers, and yet aspects such as these are not disclosed in discussing uncertainty. Put simply, the stochastic approach only modifies homogeneous aquifer parameters, and does not explore structural deficiencies (i.e. unmodified aspects of models), and hence there is no logical basis by which to consider that structural defects are accounted for within the stochastic framework.

[36] In addition to JER paragraph 3.38 (*22 (a) the predictive numerical model is 'fit for purpose' to undertake assessment of potential impacts resulting from the Revised Expansion Project*):

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[31] (2015) *Water Science and Engineering* 8(3): 175-194.

[32] Phenomenological: A philosophy or method of inquiry based on the premise that reality consists of objects and events as they are perceived or understood in human consciousness and not of anything independent of human consciousness. <http://www.thefreedictionary.com/phenomenological>.

[33] (2015) *Water Science and Engineering* 8(3): 175-194.

a) Aside from the extensive discussion of model and reporting short-comings given above, there is a disparity between the description of model uncertainty in IESC Response Report and the expectations of a Class 2 model in the 2012 Guidelines that detracts from the model's fitness for decision-making purposes. The IESC Response Report states that: "Given that calibration is considered within acceptable limits and the level of uncertainty in the predictive results is considered minor, in hydrogeologic modelling terms,…".[34] However, the 2012 Guidelines note that Class 2 models (which is the correct classification for the current model) will show a "relatively poor match to observations when calibration data is extended in time and/or space." That is, the 2012 Guidelines are inferring that Class 2 models are commonly inaccurate when applied in predictive mode. This is in contrast to the notions expressed in the IESC Response Report, and therefore, there is a risk that decision makers were not adequately informed of the need for contingencies in the high likelihood that the model has not accurately predicted future drawdown in the surrounding aquifers.

7. Conclusions

[37] My review of groundwater modelling investigations into potential impacts arising from the mine find that there is a high and undisclosed degree of uncertainty in the modelling results, to the degree that modelling and accompanying reports are misleading at worst, and highly uncertain at best. I conclude that there are significant issues with the modelling investigation, as summarised under four major sub-headings below:

a) <u>Groundwater modelling predictions are excessively uncertain</u>, because:

   i) Field data are inadequate and subsequently the hydrogeological conceptualisation at both local and regional scales is under-developed;

   ii) Model water balances are poorly constrained because key components rely on overly simplified methods, have not been assessed and/or are neglected, most likely causing significant errors in modelled groundwater flow rates;

   iii) The methodology and outcomes of calibration are poor, and models subsequently do not have reasonable predictive capabilities;

   iv) The influence of faults on groundwater behaviour is unknown, and the simulation of faults lacks scientific basis and yet controls mining impacts;

   v) The field-investigation and modelling-representation of surface water-groundwater interaction are inadequate and problematic; and

[34] IESC Response Report, Appendix B, Section 8, Page 96.

vi) The implications of potentially excessive surface controls on groundwater levels in the model, including artificially restricting the extent of drawdown, are unknown.

b) The modelling investigation is unable to evaluate some of the expected impacts of mining, because:

i) Important hydrological processes have been overlooked, including seasonality effects, which are needed to understand mining impacts on GDEs and stream base flow;

ii) The climate-driven transience of mine pit inflows is not considered;

iii) The water budget implications of mining on the surrounding groundwater regime has not been adequately explored; and

iv) The cumulative impacts arising from multiple groundwater users are not considered.

c) Future impacts cannot be correctly attributed to causal factors on the basis of modelling and proposed monitoring, because:

i) Data short-comings and modelling uncertainty detract from the reliability of modelling predictions; and

ii) The analysis of measurement data and the modelling investigation has not differentiated between impacts to the groundwater system from historical mining, future mining, other groundwater users and climate variability.

d) The reporting is highly deficient in the following ways:

i) Despite high levels of uncertainty and potential underestimation of impacts, reporting classifies the modelling results as conservative, reliable and accurate;

ii) Aside from issues of excessive modelling uncertainty, it is not possible to judge whether the model is "fit-for-purpose" because the reports do not disclose, in adequate detail, the intended use of the model; and

iii) Reporting errors and omissions mean that readers are uninformed and potentially misguided about key elements of the modelling approach.

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9. Expert's Statement – Additional Facts

[38] The opinions set out above are intentionally based predominantly on the reporting through which decisions on the project have been based, but with some supplementary knowledge gained from a relatively brief review of the groundwater modelling files. Obviously, further testing of the groundwater model is likely to provide a more robust understanding of the uncertainty and predictability of the modelling.

10. Declaration

[39] In accordance with rule 24F(3) of the *Land Court Rules 2000* (Qld), I confirm the following:

a) the factual matters stated in the report are, as far as I know, true;
b) I have made all enquiries considered appropriate;
c) the opinions stated in the report are genuinely held by myself;
d) the report contains reference to all matters I consider significant;
e) I understand the duty of an expert to the court and have complied with that duty;
f) I have read and understood the *Land Court Rules 2000* on expert evidence; and
g) I have not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

………………………………..

Signature

24 February 2016

Attachment A

CURRICULUM VITAE

DR ADRIAN D. WERNER
PhD, BEng (Hons), DipBus

PERSONAL DETAILS

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EDUCATION

PhD, *The interaction between a tidal estuary and a shallow unconfined aquifer: saltwater intrusion and environmental impacts in the riparian zone*, University of Queensland, Brisbane, 2004

Bachelor of Engineering (Civil), Class 1 Hons, Central Queensland University, Rockhampton, 1993

Diploma of Business (Frontline Management), Open Learning Institute and Queensland Department of Natural Resources and Water, Brisbane, 2005

EMPLOYMENT HISTORY

Professor in Hydrogeology, Level D+ (2014-present) School of the Environment, Flinders University, Adelaide

Associate Professor in Hydrogeology, Level D (2009-2014) School of the Environment, Flinders University, Adelaide

Senior Lecturer in Hydrogeology, Level C (2008-2009) School of Chemistry, Physics and Earth Sciences, Flinders University, Adelaide

Lecturer in Hydrogeology, Level B (2006-2008) School of Chemistry, Physics and Earth Sciences, Flinders University, Adelaide

Senior Hydrologist (2003-2006) Department of Natural Resources and Water, Queensland Government, Brisbane

Groundwater Consultant (Part-time) (2000-2002) PPK Infrastructure Ltd/Douglas Partners Ltd/Environmental Groundwater Consultants Ltd

Water Resources Engineer (1993-1999) Department of Natural Resources and Water, Queensland Government, Rockhampton/Brisbane

Cadet Engineer (1990-1992) Department of Natural Resources and Water, Queensland Government, Rockhampton/Emerald

AWARDS, SCHOLARSHIPS, FELLOWSHIPS

2015 Visiting Fellow, Nanjing, China, funded by the President's International Fellowship Initiative of Chinese Academy of Sciences, project number 2015VEB072, hosted by the Nanjing Institute of Geography and Limnology, Chinese Academic of Sciences, 3 February to 3 March 2015

2013 Visiting Scholar, Nanjing, China, funded by the Chinese Academy of Sciences, 12-20 October 2013

2011 Visiting Professor, Lausanne, Switzerland, funded by Ecole Polytechnique Federale De Lausanne, 1 August to 16 December 2011

2010 Visiting Scholar, Nanjing, China, funded by the Chinese Academy of Sciences, 14-23 September 2010

2009 Journal of Hydrology Editor's Award for "Excellence in editing" in 2008, selected by Editor-in-Chief Prof. Philippe Baveye

2008 Visiting Scholar, Tianjin and Nanjing, China, funded by the Chinese Academy of Sciences, 9-23 November 2008

2006 Queensland Government, Department of Natural Resources and Water Business Area Award in the category "Innovation" for *Innovations in Stream-Aquifer Interaction Modelling*

2006 Queensland Government, Department of Natural Resources and Water Excellence Award in the category "Managing our Resources"

1999-2003 Queensland Government, Department of Natural Resources and Water Ph.D. Top-up Scholarship

1999-2003 APAI PhD Scholarship, University of Queensland-Queensland Government, Department of Natural Resources and Water

1992 Royal Automobile Club of Queensland, Engineering Undergraduate Prize

1991 CSR Humes Pty Ltd, Engineering Undergraduate Prize

1990-1992 Queensland Government, Department of Natural Resources and Water Undergraduate Engineering Scholarship

AFFILIATIONS AND PROFESSIONAL MEMBERSHIP

2012-present Member of the American Geophysical Union

2009-present Chief Investigator and Program 2 Deputy/Acting Leader (2009-2012), National Centre for Groundwater Research and Training

2007-present Member of the International Association of Hydrogeologists

2007-present Member of the Hydrological Society of South Australia

2007-2009 Member of the Flinders Research Centre for Coastal and Catchment Environments (FR3cE)

2005-2009 Research Associate, eWater CRC

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RESEARCH

PUBLICATIONS

Thesis

Werner AD (2004). The interaction between a tidal estuary and a shallow unconfined aquifer: Saltwater intrusion and environmental impacts in the riparian zone. Ph.D. Thesis, University of Queensland, Brisbane.

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Ward JD, Hutson JL, Howe B, Fildes S, Werner AD, Ewenz C (2009) A modelling framework for the assessment of recharge processes and climate change. Report developed through the Eyre Peninsula Groundwater, Allocation and Planning Project, Eyre Peninsula Natural Resources Management Board, Port Lincoln, Australia, 53 pp., www.epnrm.sa.gov.au/Portals/4/Water/Recharge%20and%20Climate%20Change%20Final%20Report.pdf

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Kretschmer P, Love A, Werner AD, Pichler M (2008) Hydrological survey of the Kelly Hill Caves precinct. Report prepared for the Department of Environment and Heritage, Adelaide, 19 pp.

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Werner AD, Gallagher MR, Weeks SW (2006) Pioneer Valley groundwater amendment to the water resource plan, Report 5: Stream-aquifer interaction modelling of Sandy Creek, Queensland Department of Natural Resources and Water, Brisbane, 140 pp.

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Werner AD, Reading LP, Murphy SF (2005) Pioneer Valley groundwater amendment to the water resource plan, Report 2: Conceptualisation of Pioneer Valley seawater intrusion, Queensland Department of Natural Resources and Water, Brisbane, 66 pp.

Kuhanesan S, Durick AM, Werner AD, Weeks SW, Murphy SF (2005) Pioneer Valley groundwater amendment to the water resource plan, Report 3: Groundwater flow modelling of the Pioneer Valley, Queensland Department of Natural Resources and Water, Brisbane, 93 pp.

Werner AD (1999) Report on the preliminary groundwater modelling study of the Leichhardt Downs dewatering project, unpublished report of Queensland Department of Natural Resources and Water, Brisbane, 30 pp.

Werner AD (1999) Results from a hypothetical groundwater flow model for the Bracewell-East End area, unpublished report of Queensland Department of Natural Resources and Water, Brisbane, 39 pp.

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Other Publications

Cook SB, Sundaram B, Carey H, Werner AD (2014) Research Priorities for Australian Coastal Groundwater Management:, A strategic position paper based on outcomes of the National Coastal Groundwater Management Knowledge Transfer Workshop held in Canberra 28-29 May 2013, Geoscience Australia and the National Centre for Groundwater Research and Training, Canberra, Australia, 5 pp.

Werner AD, Jacobsen PE, Morgan LK (2013) Understanding seawater intrusion. [Poster]. Earth Sciences collection, http://hdl.handle.net/2328/26647. Flinders Academic Commons, Adelaide, South Australia.

RESEARCH PROJECTS AND GRANTS

2015 Post V, Batelaan O, Werner A, Christie M, Meredith K, Gaillard JC, *Cross-cultural management of freshwater on resource-constrained islands*, ARC Linkage Grant LP150100588, Project funding **$574,750**.

2015 Werner AD, Morgan LK, *An investigation of fresh offshore groundwater in the Perth Basin - a desktop investigation using analytical and numerical modelling*, Western Australian Department of Water, Project funding **$12,032**.

2015 Werner AD, *Provision of Uley South modelling to support the development of the Eyre Peninsula water allocation plan development*, South Australian Department of Environment, Water and Natural Resources, Project funding **$15,840**.

2015 Werner AD, Morgan LK, *Adapting SE regional groundwater model for use in water allocation planning*, South Australian Department of Environment, Water and Natural Resources, Project funding **$15,420**.

2015-2017 Werner AD, Cartwright I, Yan W, *Dynamics and management of riverine freshwater lenses*, ARC-Linkage Grant, LP140100317, Project funding **$294,000**.

2014-2015 Woods J, Werner AD, Holland K, *Modelling salt dynamics on the River Murray floodplain in South Australia – E.1.11*, Goyder Institute, Project funding **$252,900**.

2014-2015 Harrington N, Werner AD, *South east regional water balance – Phase 2 E.2.6*, Goyder Institute, Project funding **$415,624**.

2014-2015 Werner AD, *Visiting Researcher Funding* for *A/Prof. Holly Michael*, Faculty of Science and Engineering, Project funding **$2,500** (internal).

2014-2015 Werner AD, Post VEA, *Groundwater Modelling and Research – Bonriki Inundation Vulnerability Assessment Project*, The Secretariat of the Pacific Community, Project funding **$69,091**.

2014 Werner AD, *Soil modelling (using the LEACHM code) to assess recharge in the Cox Creek catchment – DEWNR*, Dept of Environment, Water and Natural Resources, South Australian Government, Project funding **$8,779**.

2014-2015 Love AJ, Bestland EA, Werner AD, Batelaan O, *Goyder Facilitating Long-Term Outback Water Solutions: Stage 2 (G-Flows Stage-2)*, Goyder Institute, Project funding **$306,891**.

2013-2015 Cook P, Batelaan O, Doherty J, Werner A, Post V, Simmons C, *Assessment of Adelaide's Groundwater Resources*, Goyder Institute, Project funding **$853,462**.

2012-2013 Cook P, Simmons C, Doherty J, Werner A, Love A, Batlle Aguilar J, Shanafield M, Ataie-Ashtiani B, Harrington N, Wallis I, Banks E, *Provision of research Services on the Impacts of Coal Seam Gas and Coal Mining on Water in a Panel Arrangement*, CSIRO and DSEWPC, Project funding **$132,280**.

2012-2013 Harrington N, Werner AD, *South east regional water balance – E.2.3*, Goyder Institute, Project funding **$117,425**.

2012-2015 Werner AD, Sebben M, *Numerical modelling of ephemeral, transient wetland systems using a fully integrated code*, PhD scholarship funding, Goyder Institute, Project funding **$30,000**.

2012-2015 Werner AD, Knowling M, *Effect of climate change and groundwater management approaches on the Uley South Basin - Eyre Peninsula SA*, PhD scholarship funding, Goyder Institute, Project funding **$30,000**.

2011-2014 Werner AD, *Development of an application test bed, In: Development of an agreed set of climate projections for South Australia*, Goyder Institute, Project funding $**183,582**.

2011-2014 Werner AD, Liggett JE, Simmons CT, *Exploration of techniques in fully coupled surface water-groundwater interaction modelling*, PhD scholarship funding, Goyder Institute, Project funding **$30,000**.

2011-2012 Werner AD, Cook P, Post V, Simmons C, Teubner MD, *Solute Transport Modelling, Chapter 8, Australian Groundwater Modelling Guidelines*, Sinclair Knight Merz with funding from the National Water Commission, Project funding **$84,150**.

2011-2012 Voelcker N, Franco C, Zhou S, Yonghua Z, Xia K, Wu M, Roddick J, Ball A, Cromar N, Powers D, Simmons C, Werner A, Gardner-Stephen P, Zhang W, Sanderson B, Young F, MacDougall C, Sykes P, Tan W, Li S, Li X, Zheng Z, Li K, Zhang Z, Wang D, Zhao H, Wu Z, Zhou G, Ward P, Pulvirenti M, *Aust China*

Council Travel Grant - Collaborative Centre for Research and Research Training in Environmental Sustainability for Healthy Populations - Australia China Council, Australia-China Council, Project funding **$22,000**.

2010-2013 Werner AD, *A national scale vulnerability assessment of seawater intrusion: Quantitative Support and Strategic Direction*, Geosciences Australia with funding from the National Water Commission, Project funding **$250,060**.

2010 Werner AD, *Seawater intrusion modelling of the Uley South Basin*, Eyre Peninsula Natural Resources Management Board, Project funding **$31,500**.

2010 Werner AD, *Model Development & scenario modelling for Uley South Basin, Southern Eyre Peninsula*, Eyre Peninsula Natural Resources Management Board, Project funding **$43,312**.

2009-2014 Simmons CT, Cook P, Werner AD, Guan H, plus 26 from other Universities., *National Centre for Groundwater Research and Training (Program 2: Hydrodynamics and Modelling of Complex Groundwater Systems)*, National Water Commission and the Australian Research Council, Project funding **$30,000,000** (Personal contribution **$2,500,000**).

2009-2012 Keppel M, Werner AD, Love A, *Evolution of Mound Springs of the South Western GAB: Evidence from Sedimentology, Hydrogeology and Hydrochemistry - PhD Scholarship*, PhD scholarship funding, GABCC (DEWHA), Project funding **$15,000**.

2009 Werner AD, *Assessing the threat of water resource contamination by seawater intrusion on the Southern Eyre Peninsula*, Honours scholarship funding, SA Water Corporation, Project funding **$7,000**.

2009-2010 Werner AD, Pichler M, *Hydrological Investigation of Flinders Lake and Surrounds (Monitoring equipment and groundwater well construction)*, Building and Property Division, Flinders University, Project funding **$35,000** (internal).

2009 Werner AD, Seidel A, *Proposal to investigate submarine groundwater discharge to Coffin Bay*, Flinders Research Centre for Coastal and Catchment Environments with funding from the Eyre Peninsula Natural Resources Management Board, Project funding **$2,000** (internal).

2008 Werner AD, Maddox L, Simmons CT, Hutson JL, Vincent D, *Developing guided discovery learning activities for an on-campus hydrological research site*, Vice Chancellor's Teaching Innovation Grant, Project funding **$10,000** (internal).

2008-2009 Werner AD, Simmons CT, *Investigation of seawater intrusion - conceptualising and modelling – Project C*, Eyre Peninsula Natural Resources Management Board, Project funding **$31,000**.

2008-2009 Werner AD, *Developing online groundwater postgraduate courses*, Faculty of Science and Engineering Developing Distance Education Fund, Project funding **$40,000**.

2008-2009 Werner AD, Ewenz C, *Regional downscaling of climate change scenarios over the Eyre Peninsula – Project B*, Eyre Peninsula Natural Resources Management Board, Project funding **$20,000**.

2008-2009 Werner AD, Hutson JL, *Investigating soil, water and vegetation processes controlling local scale rainfall driven recharge*, Eyre Peninsula Natural Resources Management Board and SA Water, Project funding **$48,000**.

2008 Kretschmer PJ, Love AL, Werner AD, Penhall M, *Hydrological Survey of the Kelly Hill Caves Precinct*, Department of Environment and Heritage, Project funding **$14,120**.

2008 Werner AD, *Evaluating the sustainability of groundwater extraction in the Southern Eyre Peninsula: An assessment of groundwater recharge*, Honours scholarship funding, SA Water Corporation, Project funding **$7,000**.

2008-2012 Werner AD, Hutson JL, Simmons CT, *Southern Eyre Peninsula Hydrogeology Research Fellowship*, Flinders Research Centre for Coastal and Catchment Environments, Project funding **$144,110** (internal).

2008-2012 Werner AD, Hutson JL, Simmons CT, *Southern Eyre Peninsula Hydrogeology Research Fellowship*, Eyre Peninsula Natural Resources Management Board and SA Water Corporation, Project funding **$180,000**.

2008-2012 Werner AD, Hutson JL, Simmons CT, *Southern Eyre Peninsula Hydrogeology Research Fellowship Operations*, Centre for Groundwater Studies, Project funding **$30,000**.

2008-2012 Love AL, et al., *Allocating water and maintaining springs in the Great Artesian Basin*, National Water Commission, Project funding **$14,000,000** (Named Investigator on Programs RAS 3, RAS 4 and D1b).

2008 Werner AD, *Visiting Scholar Grant* for *Prof. Qi Zhang*, Flinders Research Centre for Coastal and Catchment Environments, Project funding **$4,300** (internal).

2007-2009 Werner AD, *Proposal to undertake a Scoping Study of Saline Water Intrusion Up-coning in the Lower Burdekin*, Queensland Department of Natural Resources and Water, Project funding **$32,560**.

2007 Werner AD, *Groundwater Modelling of Coke Ovens Pond: OneSteel Whyalla Steel Mill*, OneSteel Manufacturing Pty Ltd, Project funding **$4,980**.

2007 Werner AD, *Improving Management of Private/NGO Owned Nature Reserves and High Biodiversity Islands: Fresh water demand study – Cousin and Cousine Islands*, Nature Seychelles, Project funding: **$7,600**.

2006-2009 Werner AD, *NRMW representation in the eWater CRC Project 1.D.103*, Queensland Department of Natural Resources and Water, Project funding **$54,429**.

2006-2009 Werner AD, *Surface water-groundwater interaction across coastal and inland landscapes*, Faculty of Science and Engineering Establishment Funding Grant, Project funding **$60,000** (internal).

2006-2008 Lockington DA, Werner AD, *Surface water groundwater interaction - the case of density-driven flow under periodic conditions*, Queensland Department of Natural Resources and Water, Lead agency the University of Queensland, Project funding **$50,000**.

2005-2008 Li L, Lockington DA, Werner AD, *Groundwater dynamics at the ocean-aquifer interface: Implications for modelling of regional flow in Pioneer Valley Aquifers*, ARC-Linkage Grant, Lead agencies the University of Queensland and Queensland Department of Natural Resource and Water, Project funding **$108,268** (industry collaboration role).

RESEARCH STUDENTS AND STAFF

Postdoctoral Research Staff and Research Associates

2015-present Dr Tariq Laattoe, Principal Supervisor, *Dynamics and management of riverine freshwater lenses*

2014-present Ms Leanne Morgan, Principal Supervisor, *Research fellow in the Goyder Institute Project on "South east regional water balance – Phase 2 E.2.6"*

2012-present Dr Juliette Woods, Principal Supervisor, *Research fellow (part time) in Program 2, National Centre for Groundwater Research and Training*

2013-2015 Dr Danica Jakovovic, Principal Supervisor, *Research fellow in the Goyder Institute Project on "Development of an application test bed, In: Development of an agreed set of climate projections for South Australia"*

2014 Mr Luciano Dorigo Bravo, Principal Supervisor, *Research associate (part time) An investigation of saltwater upconing using laboratory sand-tank experiments*

2014 Dr Carlos Ordens, Principal Supervisor, *Research associate (part time) in the projects: LEACHM modelling to assist in Goyder projects of Southeast South Australia and Cox Creek catchment*

2013 Ms Julie McClements, Principal Supervisor, *Research associate (part time) in Program 2, National Centre for Groundwater Research and Training*

2012-2014 Dr Daan Herckenrath, Principal Supervisor, *Research fellow in Program 2, National Centre for Groundwater Research and Training*

2012-2013 Dr Etienne Bresciani, Principal Supervisor, *Research fellow in Program 2, National Centre for Groundwater Research and Training*

2011-2013 Dr John Kozuskanich, Associate Supervisor, *Research fellow in Program 2, National Centre for Groundwater Research and Training*

2011-2014 Dr Behzad Ataie-Ashtiani, Principal Supervisor, *Research fellow in Program 2, National Centre for Groundwater Research and Training*

2011-2013 Dr Chunhui Lu, Principal Supervisor, *Research fellow in Program 2, National Centre for Groundwater Research and Training*

2011-2012 Ms Peta Jacobsen, Principal Supervisor, *Research associate (part time) in Program 2, National Centre for Groundwater Research and Training*

2010-2012 Ms Le Dung Dang, Principal Supervisor, *Research associate on the Southern Eyre Peninsula Hydrogeology Research Project*

2010-2012 Dr Lieke van Roosmalen, Principal Supervisor, *Research fellow in Program 2, National Centre for Groundwater Research and Training*

2008-2010 Dr James Ward, Principal Supervisor, *Research fellow on the Southern Eyre Peninsula Hydrogeology Research Project*

PhD

2013 present Mr Sugiarto Badaruddin, Principal Supervisor, Flinders University, *An assessment of age distributions in coastal aquifers: Willunga Basin, South Australia*

2012-present Ms Megan Sebben, Principal Supervisor, Flinders University, *A comparison of catchment simulation approaches*

2012-present Mr Matthew Knowling, Principal Supervisor, Flinders University, *Groundwater management approaches for a coastal aquifer susceptible to seawater intrusion: Uley South, South Australia*

2010-present Mr Yulong Zhu, Principal Supervisor, Flinders University, *An assessment of stream depletion and its interaction with evapotranspiration and enhanced yield effects*

2010-present Mr Tariq Laattoe, Associate Supervisor, Flinders University, *An assessment of oxidation-reduction reactions in hyporheic zones*

2010-present Mr Ty Watson, Principal Supervisor, Flinders University, *The application of groundwater tracers in model calibration and uncertainty analysis*

2010-2015 Ms Jessica Liggett, Principal Supervisor, Flinders University, *Assessing surface-subsurface interaction in ephemeral systems at the regional scale*

2010-2014 Mr James McCallum, Associate Supervisor, Flinders University, *A comparative study of groundwater tracers versus hydraulic methods in hydrogeological characterisation*

2010-2014 Mr Dylan Irvine, Associate Supervisor, Flinders University, *A comparative study of heat and solute tracer methods in groundwater*

2010-2014 Ms Leanne Morgan, Principal Supervisor, Flinders University, *Comparing simple and complex methods for the assessment of seawater intrusion vulnerability*

2009-2014 Mr Carlos Ordens, Principal Supervisor, Flinders University, *Hydrogeological and water resources management assessment of Uley South, Southern Eyre Peninsula*

2009-2014 Ms Danica Jakovovic, Principal Supervisor, Flinders University, *Experimental and Modelling Analyses of Saltwater Up-coning*

2008-2013 Mr Mark Keppel, Principal Supervisor, Flinders University, *Morphology of mound springs: Great Artesian Basin, Australia*

2008-2013 Mr Alex Evans, Associate Supervisor, Flinders University, *Downscaling of climate change scenarios onto South Australia's Eyre Peninsula*

2008-2015 Ms Brooke Swaffer, Associate Supervisor, Flinders University, *Rainfall partitioning and groundwater use in a semi-arid environment: Southern Eyre Peninsula, South Australia*

2008-2012 Mr Yeuqing Xie, Associate Supervisor, Flinders University, *Spatiotemporal complexity in unstable variable-density groundwater flow phenomena*

2007-2013 Mr Dan Partington, Associate Supervisor, Adelaide University, *Surface water-groundwater interaction in a controlled drainage network environment*

2006-2010 Mr Mothei Lenkopane, Associate Supervisor, University of Queensland, *Surface water groundwater interaction - the case of density driven flow under periodic conditions*

2005-2014 Mr Hashim Carey, Associate Supervisor, University of Queensland, *Groundwater dynamics at the ocean-aquifer interface: Implications for modelling of regional flow in Pioneer Valley Aquifers*

Masters by Research

2007-2009 Mr Eddie Banks, Associate Supervisor, Flinders University, *Surface water-groundwater interaction in a fractured rock settings*

Honours

2013 Mr Thomas Neill, Associate Supervisor, Flinders University, *Transient modelling of coastal groundwater age near Aldinga Beach, South Australia*, Class 2A Honours

2011 Ms Amy Roach, Associate Supervisor, Flinders University, *Evaluating an empirical factor for correcting transient seawater intrusion models to account for dispersion*, Class 1 Honours

2011 Ms Megan Sebben, Principal Supervisor, Flinders University, *Exploring a new test case for integrated groundwater-surface water interaction model testing*, Class 1 Honours, University Medallist

2010 Mr Chris Turnadge, Principal Supervisor, Flinders University, *A predictive uncertainty-based analysis of data worth for a simple groundwater model*, Class 1 Honours, University Medallist

2010 Mr Matthew Knowling, Principal Supervisor, Flinders University, *On the implementation of the surface conductance approach using a block-centred surface-subsurface code*, Class 1 Honours

2009-2010 Mr Tariq Laattoe, Principal Supervisor, Flinders University, *Salinization of coastal aquifers under the current sea level rise regime*, Class 1 Honours, University Medallist

2009 Ms Amy Gaukroger, Principal Supervisor, Flinders University, *Surface-subsurface flow in a V-catchment basin: A process-based analysis*, Class 1 Honours, University Medallist

2009 Mr Ty Watson, Principal Supervisor, Flinders University, *Transience of seawater intrusion in response to sea-level rise*, Class 1 Honours, University Medallist

2008-2009 Mr Darren Alcoe, Associate Supervisor, Flinders University, *Evaluating approaches to sustainable groundwater use: A case study of Uley South lens, Southern Eyre Peninsula, South Australia*, Class 1 Honours, University Medallist

2008 Ms Emma Baudinette, Associate Supervisor, Flinders University, *A proposed model for the costing of urban groundwater in South Australia*, Class 2A Honours

2008 Ms Le Dung Dang, Principal Supervisor, Flinders University, *A systematic study of pumping induced saltwater-freshwater interface movement*, Class 1 Honours, University Medallist

2008 Ms Anna Seidel, Principal Supervisor, Flinders University, *Seawater intrusion on the Southern Eyre Peninsula, South Australia: A first-order assessment*, Class 2A Honours

2007-2008 Ms Danica Jakovovic, Principal Supervisor, Flinders University, *Laboratory experiments of saltwater up-coning*, Class 1 Honours

2007-2008 Mr Jeffrey Ashenden, Associate Supervisor, Adelaide University, *The occurrence of saltwater intrusion into coastal aquifers: Geophysical methods for delineation*, Class 2B Honours

2007 Mr Peter Kretschmer, Principal Supervisor, Flinders University, *Determining the contribution of groundwater to stream flux in an upland catchment using a combined salinity mixing model and modified curve number approach*, Class 1 Honours, University Medallist

2007 Mr Ben Roudnew, Associate Supervisor, Flinders University, *Microbiology of benthic/hyporheic zones*, Class 1 Honours

<u>Masters by Coursework Projects (1-year)</u>

2015 Mr Andrew Knight, Principal Supervisor, Flinders University, *Investigation on the potential distribution of submarine freshwater within the offshore extent of the Otway basin South Australia*

2015 Mr Lexyi Damaledo, Principal Supervisor, Flinders University, *A preliminary investigation of the carbonate aquifer of Kupang basin, East Nusa Tenggara, Indonesia*

2015 Mr Luciano Dorigo, Co-supervisor, Flinders University, *Comparison of zonation and pilot points approaches in regional groundwater flow models: implications for prediction accuracy and uncertainty quantification*

2014 Mr Haile Arefayne Shishaye, Associate Supervisor, Flinders University, *Assessing coastal boundary conditions for a regional-scale groundwater model*

2014 Ms Sandra Galvis Rodriguez, Principal Supervisor, Flinders University, *An investigation of tidal impacts on a freshwater lens, Bonriki, Kiribati*

2013-2014 Ms Ekaterina Pyatin, Principal Supervisor, Flinders University, *Evaluating a dispersion-correction for transient, sharp-interface seawater intrusion*

2011-2012 Ms Kittiya Bushaway, Principal Supervisor, Flinders University, *Effect of dispersion in designing the operation of well pairs in coastal aquifers*

2011 Mr Moiteela Lekula, Associate Supervisor, Flinders University, *Analysis of unsaturated zone effects on the propagation of tides*

2011-2012 Mr Tavis Kleinig, Principal Supervisor, Flinders University, *Developing a groundwater model of Polda Basin*

2011 Ms Agatha Thuita, Principal Supervisor, Flinders University, *Assessment of chloride effects on the estimation of recharge in Uley Basin*

2010-2011 Mr Maimun, Principal Supervisor, Flinders University, *Using age information as a secondary indicator of model comparison using the Henry problem*

2010-2011 Ms Melinda Morris, Principal Supervisor, Flinders University, *The potential for seawater intrusion to impact on the available groundwater resources of the Le Fevre Peninsula, South Australia*

2010 Mr Juan Berrio, Principal Supervisor, Flinders University, *Modelling Uley South basin: Development of a 3D transient groundwater flow model*

2008 Ms Sharon de Vera, Associate Supervisor, Flinders University, *Environmental tracer methods applied to the estimation of recharge on Uley South, South Australia*

2007-2008 Mr Md Anisul Islam, Principal Supervisor, Flinders University, R*emedial measures for improving the water efficiency of the Flinders University Lake, South Australia*

2007 Mr Wasantha Palugaswewa, Principal Supervisor, Flinders University, *Exploring the water efficiency of a man-made lake; Flinders University Lake, South Australia*

2006-2007 Mr Raden Aviyanto, Principal Supervisor, Flinders University, *A modelling study of capillary barriers and the importance of moisture retention hysteresis*

Visitors

2014-2015 A/Prof. Holly Michael, University of Delaware (USA), *Investigation of seawater intrusion processes*, August 2014-June 2015

2014 Prof. Otto Strack, University of Minnesota (USA), *Application of the Analytic Element Method*, April 2014

2014 Prof. Qi Zhang, Nanjing Institute of Geography and Limnology (China), *Comparing integrated and discrete modelling approaches of the Cox Creek catchment, South Australia*, March-May 2014

2013 Prof. Jodi Mead, Boise State University (USA), *Quantifying uncertainty in models of varying degrees of complexity*, July-December 2013

2013 Mr Sadjad Mehdizadeh, Khajeh Nasir Toosi University of Technology (Iran) PhD student, *The effect of sea and groundwater level change on quality of multi-layered coastal aquifer*, February-September 2013

2013 Ms Eugenia Hirthe, Leibniz University (Germany) PhD student, *Increased Efficiency of Variable-Density Flow and Transport Simulations in Discretely-Fractured Porous Media*, August-October 2013

2012 Ms Katharina Vujevic, Leibniz University (Germany) PhD student, *The impact of fractures on density- driven flow and transport in fractured porous rock*, September-November 2012

2012 Mr Perry de Louw, Deltares (Holland) PhD student, *Natural saltwater upconing by preferential groundwater discharge through boils*, September-December 2012

2012 Ms Charlotte Schmitt, Karlsruhe Institute of Technology (Germany) Master's student, *Modeling the effects of aquifer heterogeneity on the migration of the injectant plume at a managed aquifer recharge (MAR) site*, April-October 2012

2012 Ms Karina Cucchi, Ecole Polytechnique (France) Master's student, *A simple model for water and chloride canopy interception on Uley South, Eyre Peninsula*, April-July 2012

2011 Dr Alexander Vandenbohede, University of Ghent (Belgium), *Investigation of groundwater age in coastal aquifers*, April-May 2011

2010 Ms Patrizia Burdino, Visiting independent researcher (Italy), *Application of the SWI model to assess timescales of seawater intrusion*, September 2010-April 2011

2010 Mr Oliver Mannicke, Technical University of Dresden (Germany) Master's student, *An experimental study of stable upconing*, March-October 2010

2010 Mr Dirk Eilander, Delft Technical University (Holland) Master's student, *Influence of density on saltwater breakthrough*, July-November 2010

2010 Mr Etienne Lesage, Ecole Nationale du Genie de l'Eau et de l'Environnement de Strasbourg (France) Master's student, *Assessment of density impacts on saltwater upconing*, May-August 2010

2009 Mr Soren Poulsen, Aarhu University (Denmark) PhD student, *Flow and transport in a shallow microtidal barrier aquifer during a storm surge*, January-March 2009

2008 Prof. Qi Zhang, Nanjing Institute of Geography and Limnology (China), *Exploration of surface-subsurface processes in a mountain catchment*, April 2008

EVIDENCE OF INTERNATIONAL RESEARCH STANDING

International Journal Editorship

2012-present Associate Editor/Member of the Editorial Board of the international scientific journal: *Advances in Water Resources* (Ranked 11th out of 80 Water Resources Journals by 2012 Impact Factor)

2007-present Associate Editor/Member of the Editorial Board of the international scientific journal: *Journal of Hydrology* (Ranked 5th out of 80 Water Resources Journals by 2012 Impact Factor)

Summary of Reviews of Scholarly Publications

2015 International Journals: Journal of Hydrology (1), Advances in Water Resources (1), Journal of Environmental Management (1), Geophysical Research Letters (1), Water (1)

Grants: Georgia Sea Grant (USA)

2014 International Journals: Water Science and Engineering (1), Hydrology and Earth System Sciences (3), Hydrogeology Journal (4), Water Resources Research (3), Advances in Water Resources (4), Water Resources Management (1), Groundwater (1), AMBIO (1), International Journal of Water Resources and Environmental Engineering (1), Journal of Hydrology (1), Geophysical Research Letters (1), Water (1)

Higher Degrees; PhD Thesis (Stockholm University)

Grants: Israel Science Foundation, Australian Research Council DECRA grant, National Center of Science and Technology (Kazakhstan)

2013 International Journals: Advances in Water Resources (1), Water Resources Research (5), Climate Change (1), Groundwater (1), Hydrogeology Journal (1), Environmental Earth Sciences (1), Estuarine, Coastal and Shelf Science (1), Hydrology and Earth System Sciences (1), Hydrological Processes (1), Journal of Hydrology (1), Quaternary Research (1)

Higher Degrees: PhD Thesis (Murdoch University)

Conference Reviewer: APCAMM 2013: Asia-Pacific Coastal Aquifer Management Meeting, Beijing, China (4 abstracts), IAH 2013, Perth, Australia (22 abstracts)

2012 International Journals: Ground Water (1), Soil Research (1), Advances in Water Resources (3), Water Resources Research (1), Journal of Hydrology (1), Hydrogeology Journal (1)

Conference Reviewer: SWIM22: 22nd Salt Water Intrusion Meeting, Buzios, Brazil (2 abstracts)

Grants: Ministry of Higher Education Grant, King Abdulaziz University (Saudi Arabia), Natural Sciences and Engineering Research Council (Canada), Portuguese Foundation for Science and Technology (Portugal)

2011 International Journals: Journal of Hydrology (3), Water Resources Research (3), Advances in Water Resources (1), Journal of Computational and Applied Mathematics (1), Hydrogeology Journal (2), Ground Water (1), Water Science and Engineering (1)

Conference Reviewer: 11th Australasian Environmental Isotope Conference and 4th Australasian Hydrogeology Research Conference (50 Abstracts)

Conference Reviewer: APCAMM: 2nd Asia-Pacific Coastal Aquifer Management Meeting, Jeju Island, Korea (3 Abstracts)

Higher Degrees: PhD Thesis (Universitat Politècnica de Catalunya, Barcelona)

2010 International Journals: Advanced in Water Resources (1), Hydrological Sciences Journal (1), Journal of Contaminant Hydrology (1), Hydrological Processes (1), Water Resources Research (3), Hydrogeology Journal (2), Journal of Hydrology (2)

Grants: National Science Foundation Grant (USA), Natural Sciences and Engineering Research Council (Canada)

Conference Reviewer: SWIM21: 21st Salt Water Intrusion Meeting, Azores, Portugal (11 papers), National Groundwater Conference *Groundwater 2010 – the Challenge of Sustainable Management* (15 abstracts)

2009 International Journals: Environmental Modelling and Software (1), Hydrogeology Journal (1), Ground Water (1), Journal of Hydrology (3), Journal of Contaminant Hydrology (1), Advances in Water Resources (1), Journal of Earth System Science (1), Water Resources Research (1)

Conference Reviewer: MODSIM09: 18th World IMACS Congress and MODSIM09 International congress on Modelling and Simulation, Cairns (1 paper); and APCAMM: 1st Asia-Pacific Coastal Aquifer Management Meeting, Bangkok (1 abstract)

2008 International Journals: Environmental Modelling and Software (2), Water Resource Management (1), Advances in Water Resources (1), Hydrogeology Journal (3), Water Resources Research (4)

Conference Reviewer: SWIM: 20th Salt Water Intrusion Meeting, Florida (9 papers/abstracts)

Books: Adelaide Nature of A City: Water, Wakefield Press

2007 International Journals: Journal of Hydrology (4), Water Resources Research (3), Hydrogeology Journal (3)

Higher Degrees: PhD Thesis (University of Queensland)

Grants: National Science Foundation Grant (USA)

Conference Reviewer: Water Down Under 2008 Conference, Adelaide (4 abstracts, 3 papers)

2006 International Journals: Journal of Hydrology (1), Water Resources Management (1)

Books: Selected Papers on Hydrogeology 2007, IAH Publication (2 papers).

2005 Grants: Proposal for Sabbatical Grant, King Fahd University of Petroleum and Minerals, Saudi Arabia

Conference Reviewer: NZHS-IAH-NZSSS 2005 Where Waters Meet Conference, Auckland (3 papers)

2004 Higher Degrees: Masters by Research Thesis, Queensland University of Technology

Prestigious Conference and Workshop Roles

2015-2016 Conference Organiser of the joint international conference: *24th Salt Water Intrusion Meeting* and *4th Asia-Pacific Coastal Aquifer Management Meeting* (SWIM-APCAMM), 4-8 July 2016, Cairns, Australia.

2012-2013 Chair of the Asia-Pacific Coastal Aquifer Management Meeting (APCAMM): A group of 20 leading coastal aquifer researchers from across the Asia-Pacific region who meet at two-yearly intervals.

2012 Invited Speaker on *International perspectives on surface water-groundwater modelling*, National Water Commission Workshop, Groundwater-Surface Water Interactions, 27 March 2012, Canberra.

2010 Invited Keynote Speaker on *Seawater intrusion vulnerability assessment: Improving on existing large-scale approaches*, National Groundwater Conference, Groundwater 2010 – the Challenge of Sustainable Management, 31 October-4 November 2010, Canberra.

2008 Invited Featured Speaker on *Seawater Intrusion in Australia: A National Perspective of Future Challenges*, SWIM 20th Salt Water Intrusion Meeting, 23-27 June 2008, Florida, USA.

2008 Invited Keynote Speaker on *An Australian Perspective of Seawater Intrusion*, 2nd International Salinity Forum: Salinity, Water and Society, 31 March-3 April 2008, Adelaide, Australia.

(See also *Leadership in Conference, Workshop and Short Courses*)

Expert Panels and Professional Reviews

2014-2015 Expert Witness for the Queensland Land Court, *Analysis of Carmichael Coal Mine Hydrogeology Assessment*, Environmental Defenders Office, Queensland, November 2014 to April 2015.

2012-2016 Invited Technical Advisory Panel (Post VEA, Werner AD, White I, Falkland T) for: Sinclair P (CI), Howorth R, Chandra R, *Impact on a freshwater lens in atoll environments under different climate and abstraction scenarios*, 10th European Development Fund, Pacific Community SPC and University of the South Pacific, Project funding EUR 595,450.

2012 Parliamentary Inquiry Expert witness on *Water Supplies on the Eyre Peninsula*, Natural Resources Committee Inquiry, Parliament of South Australia, 7 September 2012.

2010 Invited Facilitator, Murray Darling Basin Authority workshop on *Conceptual Modelling and Operational Plans – Stakeholders' Workshop*, 12 October 2010, Adelaide, as part of the MDBA Project *Flood Recession Salt Mobilisation from Floodplains of the River Murray*.

2008-2010 Invited Steering Committee member of the National Water Commission Project: *Potential Local and Cumulative Impacts of Mining on Groundwater Resources and the Development of Tools to Aid the Prediction and Minimisation of Cumulative Impacts*, National Water Commission, Canberra.

2005-2006 Invited Committee Member of the Innovation Gateway Committee, Natural Resource Sciences, Queensland Department of Natural Resources and Water

(See also *Expert Industry Reviews*)

Visiting Scholar Positions

2015 Invited Visiting Fellow, Nanjing, China, funded by the President's International Fellowship Initiative of Chinese Academy of Sciences, project number 2015VEB072, hosted by the Nanjing Institute of Geography and Limnology, Chinese Academic of Sciences, 3 February to 3 March 2015

2013 Invited Visiting Scholar, funded by the Nanjing Insitute of Geography and Limnology, Chinese Academy of Sciences, Nanjing (China), 12-20 October 2013.

2011 Invited Visiting Professor, funded by the Ecological Engineering Laboratory, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne (Switzerland), 1 August-16 December 2011.

2010 Invited Visiting Scholar, funded by the Nanjing Insitute of Geography and Limnology, Chinese Academy of Sciences, Nanjing (China), 14-23 September 2010.

2008 Invited Visiting Scholar, funded by the Haihe River Water Conservatory Commission, Ministry of Water Resources (Tianjin) and Nanjing Insitute of Geography and Limnology, Chinese Academy of Sciences, Nanjing (China), 9-23 November 2008.

Invited Seminars

2015 Invited Research Seminar on *Closing the Water Balance in Catchment Hydrology Modelling,* Nanjing Insitute of Geography and Limnology, Chinese Academy of Sciences, Nanjing (China), 10 February 2015.

2014 Invited Presentation on *Eyre Peninsula Hydrogeology Research*, Water Resources Advisory Committee, Eyre Peninsula Natural Resources Management Board, Port Lincoln SA, 8 October 2014.

2014 Invited Research Seminar on *Predicting climate change impacts on catchment hydrology: Are we balancing the books on the surface water-groundwater budget?* South Australian Natural Resources Management Science Conference, Adelaide SA, 15-16 April 2014.

2011-2012 Invited Research Seminars (during sabbatical) on *Controls on saltwater up-coning: Laboratory observations and numerical simulation*, University of Hong Kong (China), Leibniz University (Germany), University of Neuchâtel (Switzerland), Ecole Polytechnique Fédérale de Lausanne (Switzerland), Technical University of Athens (Greece), Universitat Politecnica de Catalunya (Spain), University of Gent (Belgium).

2011 Invited Presentation on *Eyre Peninsula Hydrogeology Research Collaboration, Progress update*, Eyre Peninsula Natural Resources Management Board, Port Lincoln SA, 9 June 2011.

2010 Invited Research Seminars on (a) *Uley South Groundwater Modelling*, (b) *Uley South Seawater Intrusion Modelling*, Eyre Peninsula Groundwater Allocation Planning Management Project *Know your Groundwater Seminar Community Forum*, Port Lincoln SA, 29 September 2010.

2010 Invited Research Seminar on *Analytical and Numerical Modelling of the Uley South basin*, Knowledge Information Sharing Workshop, Eyre Peninsula Groundwater Allocation, Planning and Management Project, Port Lincoln SA, 14 May 2010.

2009 Invited Presentation on *Groundwater – Australia's next water frontier*, Friday's at the Library: Cultural, artistic, and topical events, Flinders University, 6 November 2009.

2009 Invited Presentation on *Eyre Peninsula Hydrogeology Research Collaboration and Overview of the new National Centre for Groundwater Research and Training*, Eyre Peninsula Natural Resources Management Board, Port Lincoln SA, 8 October 2009.

2009 Invited Presentation on *Overview of the National Centre for Groundwater Research and Training*, Groundwater Users and Managers Forum (GUMS), Ayr, Queensland, 10-11 August 2009.

2008 Invited Research Seminar on *Coastal Aquifers in Australia: A National Perspective of Future Challenges*, Haihe River Water Conservatory Commission, Ministry of Water Resources, Tianjin, China.

2006 Invited Research Seminar on *DNRW Coastal Aquifer Research in Queensland*, CSIRO Land and Water, Adelaide, Australia.

2006 Invited Research Seminar on *The Status of Coastal Aquifer Research by NRW*, NRW Distinguished Seminar Series, Brisbane, Australia.

TEACHING

TEACHING ACTIVITY

The following table summarises my teaching activity (excluding student project supervision; see p21-25). Topics taught in 2015 are shaded.

Topic*	Location	Years Taught	Year Level*
9E101 Applied Mechanics (Statics)	Uni of Qld	2000-2002	1
CPES1102 Science and Society	Flinders Uni	2007	1
ENVR1101 Environmental Science 1	Flinders Uni	2006-2010	1
EASC1101 Earth and Environment I	Flinders Uni	2010	1
SERC1012 Introduction to Research	Flinders Uni	2015	1
E2233 Fluid Mechanics	Uni of Qld	2000-2002	2
SERC2011 Research Project 1	Flinders Uni	2008	2
ENVS2761 Hydrology	Flinders Uni	2015	2
CPES3017 Groundwater Hydrology (TC)	Flinders Uni	2007	2-3
CPES2019/CPES3023 Earth Sciences Field Camp	Flinders Uni	2007-2008	2-3
CPES3151 Groundwater and Soil Hydrology (TC)	Flinders Uni	2008-2010	2-3
CPES3010 Numerical Modelling	Flinders Uni	2007	3
ENVR3100 Environmental Science 3	Flinders Uni	2007-2008	3
CPES3172 Earth Fluid Dynamics and Modelling (TC)	Flinders Uni	2008-2010	3
SERC3000 Research Project 2	Flinders Uni	2008	3
EASC3741 Groundwater (TC)	Flinders Uni	2011-2015	3
EASC3742 Earth Fluid Modelling	Flinders Uni	2012-2015	3
ENGR3851 Hydraulics and Water Engineering (TC)	Flinders Uni	2016	3
C&ENVENG3003 Environmental Engineering III	Adelaide Uni	2008-2009	3-4
CIVL4140 Groundwater and Surface Water Modelling	Uni of Qld	2002, 2006	4
CPES7106 Advanced Topics in Hydrology (TC)	Flinders Uni	2007-2009	H, GE
EASC4713 Advanced Studies in Natural Systems (TC)	Flinders Uni	2011	H, GE
CPES8017 Groundwater Hydrology (TC)	Flinders Uni	2007	GE
CPES8022/CPES8023 Earth Sciences Field Camp (TC)	Flinders Uni	2007	GE
CPES8009/WARM8409 Groundwater Modelling	Flinders Uni	2007	GE
CPES8005 Environmental Research Methods	Flinders Uni	2008	GE
WARM8450 Global Water Systems I (TC)	Flinders Uni	2007-2009	GE
WARM8480 Water Resources Planning and Management	Adelaide Uni	2007-2009	GE
CPES8172/WARM8472 Earth Fluid Dynamics and Modelling (TC)	Flinders Uni	2008-2010	GE
CPES8151 Groundwater and Soil Hydrology (TC)	Flinders Uni	2008-2010	GE
EASC8742 Earth Fluid Dynamics & Modelling (TC)	Flinders Uni	2013-2014	GE
EASC8741 Groundwater (TC)	Flinders Uni	2013-2015	GE
CPES8004 CGS National Groundwater School (TC)	Flinders Uni	2008-2009	GE, D
EASC8741 Fundamentals of Groundwater (TC)	Flinders Uni	2015	GE, D
EASC8742 Earth Fluid Dynamics & Modelling External (TC)	Flinders Uni	2014-2015	GE, D
Centre for Groundwater Studies Lectures (Stream-aquifer interaction, Conceptual modelling, Groundwater modelling, Decision support tools, Island hydrology)	Various cities	2003-2006	Industry

*H – Honours, GE – Topic includes extensional component for graduate-entry students; TC – Includes topic coordination roles (including shared and alternate coordinator roles), D – Distance topic

LEADERSHIP AND INNOVATION IN TEACHING

Teaching Grants

2009-2014 Leader of initiatives to develop On-campus Hydrology Teaching Facilities, focusing on the Flinders' Lake, leading to several successful grants from Building and Property Division, Flinders University for hydrology monitoring equipment to support water savings initiatives, Werner AD, Pichler M, Guan H, Bestland E, Internal funding: **$35,000**

2009-2010 Successful in attaining the Online Postgraduate Course Development Grant (Faculty of Science and Engineering) to develop distance education materials for the Graduate Certificate in Groundwater Hydrology, Internal funding: **$40,000**

2009 Leader of the successful VC's Teaching and Learning Innovation Grant: *Developing guided discovery learning activities for an on-campus hydrological research site*, Werner AD, Maddox L, Simmons CT, Hutson JL, Vincent D, Internal funding: **$10,000**

Leadership and Innovation in Undergraduate Education

2007-2013 Leadership in the establishing and administering Undergraduate Scholarships: Aquaterra *Working in Groundwater Award*, Aquaterra *Groundwater Awards*, Queensland Department of Natural Resources and Water *Hydrology Scholarships*, SA Water *Honours Scholarships*, NCGRT *Honours Scholarships*, amongst others.

2007-2008 Co-leader of *Project Management in Hydrologic Investigation* (with Katie Cavanagh, Lecturer in Project Management), an initiative to combine CPES3100 *Environmental Science 3* and PROF2107 *Project Management Essentials* through collaborative planning and execution of hydrology field-projects

2007-2009 Developed the *Flinders University Hydrological Teaching Catchment*, for on-campus instruction in hydrological field methods (used in CPES3100, CPES3151 and others)

Leadership and Innovation in Postgraduate Education

2010-2015 Team member contributions to continued development of distance education in postgraduate groundwater courses, leading to the development of an external version of the Graduate Diploma in Groundwater Hydrology

2010 Invited reviewer of the National Water Commission's Terms of Reference for *Scoping Study for Development of Postgraduate Courses in Hydrogeology by Flexible Learning*

2008-2014 Leadership in attaining Postgraduate Scholarships: GABCC Ph.D. scholarship, Goyder Ph.D. scholarships, NCGRT Ph.D. scholarships.

2007 Developed and delivered postgraduate teaching materials for the School's first application of the real-time, web-based Access Grid

Education Outreach

2014 Co-authored the Fact Sheet *Seawater intrusion* for the National Centre for Groundwater Research and Training

2013 Led the development of an educational guide to seawater intrusion, as: Werner AD, Jacobsen PE, Morgan LK (2013) *Understanding seawater intrusion*, http://hdl.handle.net/2328/26647, Flinders Academic Commons, Adelaide, Australia

2008 Presented labs and seminars on *Laboratory experiments in Groundwater Hydrology - Teaching and Research in Groundwater Flow and Solute Transport*, Australian Government Science Summer School for Teachers, Flinders University, 8-9 January 2008

2008 Presented *Groundwater Training and Research in a National Setting of Water Supply Crises* at the Secondary Teacher Professional Development Evening

2007 Team member of the Faculty High-School Outreach initiative: *New Science Showcase: Building New Curriculum in Schools* (May-Nov), involving presentations to school teachers on groundwater lab and field methods

2003-present Leadership in industry training: Various invited lectures for the Centre for Groundwater Studies (2003-2006), Delivery of *ABC's of Groundwater* (Port Lincoln, 21-23 May 2008), Short-course organising committee and presenter of *1st Surface Water-Groundwater Interactions Workshop* (24-26 September 2008), Short-course Organiser, *PEST, Parameter Estimation and Uncertainty Analysis* (29 March-1 April 2010), Organising committee for *2nd Surface Water-Groundwater Interactions Workshop* (3-4 Nov 2011)

Teaching Administration

2015 Organising Committee Chair, School of the Environment Research Higher Degree Conference, 30th September-1st October 2015

2015-present Chair of the School's Higher Degree Committee, and member of the Faculty's Higher Degree Committee

2014 Member of the School's Teaching and Learning Committee

2008-2011 Chair of the School's Higher Degree Committee, and member of the Faculty's Higher Degree Committee

2008-2010 University representative on the Board of Studies of ICEWaRM (International Centre of Excellence in Water Resources Management)

2008 Representative on the BA Examinations Board for the Bachelor of Arts, Earth Sciences stream (substitute for John Hutson)

2008 Committee member for developing the Sustainable Energy degree, School of Chemistry, Physics and Earth Sciences

2007-2009 Member of the School's Honours Committee

2007-2008 Member of Flinders-Australian Science and Mathematics School Core Team Committee

2007-2008 SA Water Honours Scholarships selection committee member

(See also *Administration and Service to the University, Committee Representation*)

Coordination Roles

2014-present Course Director of the *Bachelor of Science* (*Environmental Hydrology and Water Resources*) undergraduate degree

2008-2012 Course Director of the *Groundwater Hydrology postgraduate degrees* (Graduate Certificate, Graduate Diploma, Masters)

2008-2010 Course Director of the *Water Resources Management postgraduate degrees* (Graduate Certificate, Graduate Diploma, Masters)

2007-present Topic Coordinator roles: Nine different postgraduate and seven different undergraduate topics (see the table above)

Other

2008 Completion of *Flinders Foundation of University Teaching* (FFOUT), a Flinders University Training Program aimed at developing tertiary teaching skills

PROFESSIONAL ACTIVITY AND COMMUNITY SERVICE

AFFILIATIONS AND PROFESSIONAL MEMBERSHIP

2012-present Member of the American Geophysical Union

2009-present Chief Investigator with the National Centre for Groundwater Research and Training

2007-present Member of the International Association of Hydrogeologists

2007-present Member of the Hydrological Society of South Australia

2010-2014 Member of the Flinders Research Centre for Water and Sustainable Environments

2007-2009 Member of the Flinders Research Centre for Coastal and Catchment Environments (FR3cE)

2006-2009 Research Associate, eWater CRC (as a representative of the Queensland Department of Natural Resources and Water)

2004-2008 Research Associate, Centre for Water Studies, University of Queensland

SERVICE TO INTERNATIONAL PROFESSIONAL ORGANISATIONS

2012-present Associate Editor of the international scientific journal: *Advances in Water Resources* (Ranked 11th from 80 "Water Resources" journals, by 2012 Impact Factor)

2009 Awarded "Excellence in Editing" for Associate Editorial work for the Journal of Hydrology

2007-present Associate Editor of the international scientific journal: *Journal of Hydrology* (Ranked 5th from 80 "Water Resources" journals, by 2012 Impact Factor)

(See also *Invited Roles for International Journals*)

LEADERSHIP IN PROFESSIONAL/COMMUNITY SERVICE ACTIVITIES

Expert Industry Reviews

2015 Werner AD, *Provision of advice on flood hydrology for the Grantham Flood investigation*, Saul Holt QC.

2015 Werner AD, *Review of "The Abbot Point Growth Gateway Project - Groundwater Studies"*, Queensland Environmental Defender's Office.

2015 Werner AD, Knowling MJ, *Model calibration and uncertainty analysis training and review for DEWNR*, South Australian Department of Environment, Water and Natural Resources.

2015 Werner AD, *Provide expert advice to Rio Tinto and the Widi Cultural Heritage, Environment and Land Advisory Committee on the links between coal mining and the persistence of Brumby Waterhole*, Rio Tinto Coal Australia Pty Ltd.

2015 Werner AD, Review of *2014 Stage 1 Review of SIMRAT V2.0.1* by Woods JA, Peat V and Middlemis H, South Australian Department of Environment, Water and Natural Resources, Adelaide.

2014-2015 Expert Witness for the Queensland Land Court, *Analysis of Carmichael Coal Mine Hydrogeology Assessment*, Environmental Defenders Office, Queensland, November 2014 to April 2015.

2012-2016 Invited Technical Advisory Panel (Post VEA, Werner AD, White I, Falkland T) for: Sinclair P (CI), Howorth R, Chandra R, *Impact on a freshwater lens in atoll environments under different climate and abstraction scenarios*, 10th European Development Fund, Pacific Community SPC and University of the South Pacific.

2012 Werner AD (CI), Review of *Relationship between Aquifer Pressure Changes and Spring Discharge Rates*, Chapter 7, GAB Mound Springs Project Reports by Green G, Berens V, South Australian Department for Environment, Water and Natural Resources.

2012 Parliamentary Inquiry Expert witness on *Water Supplies on the Eyre Peninsula*, Natural Resources Committee Inquiry, Parliament of South Australia, 7 September 2012.

2011 Werner AD, Review of *Namoi Catchment Water Study*, Schlumberger Water Service.

2011 Werner AD, Review of *CSG modelling by the University of Southern Queensland*, University of Southern Queensland.

2010-present Werner AD, *Technical Advisory Panel (TAP) – Coal Seam Gas Water: Provision of Technical Advice for project to develop a Regional Groundwater Flow Model for the Surat Basin to assess impacts of Coal Seam Gas Water Extraction*, Queensland Water Commission/Office of Government Impact Assessment.

2010 Werner AD, Expert advice and workshop Facilitation for *MDBA project on flood recession salt mobilisation from floodplains of River Murray*, Murray Darling Basin Authority.

2010 Werner AD, Review of *Mulgrave River Aquifer Scheme – Stage 1: Groundwater and Streamflow Monitoring*, GHD Consultants.

2009 Werner AD, Review of *Risks and Benefits to Environmental Values of the West Avenue Watercourse & Bald Hill Flat Associated with Hydrological Manipulation and Drainage*, GHD Consultants for the Department of Water, Land and Biodiversity Conservation.

2008-2010 Invited Steering Committee member of the National Water Commission Project: *Potential Local and Cumulative Impacts of Mining on Groundwater Resources and the Development of Tools to Aid the Prediction and Minimisation of Cumulative Impacts*, National Water Commission, Canberra.

2008 Werner AD, *Deutgam WSPA – Technical Summary* by Southern Rural Water, Victorian State Government, April 2008.

2007 Fallowfield HJ, Bentham RH, Werner AD, *Review of Previous Investigations on the Sturt Reserve Landfill*, Rural City of Murray Bridge.

2007 Werner AD, *Third Party Review: Land Degradation on Lot 11 on RP743775, Crocodile Creek Road, Cape Cleveland, Queensland*, Queensland Environmental Protection Agency.

2007 Werner AD, *Third Party Review: Trent Road salinity issue, Lower Burdekin, North Queensland*, Queensland Environmental Protection Agency.

2007 Werner AD, *Seawater Intrusion in the Deutgam Water Supply Protection Area* by Southern Rural Water, Victorian State Government, April 2007.

2005-2006 Invited Committee Member of the Innovation Gateway Committee, Natural Resource Sciences, Queensland Department of Natural Resources and Water.

<u>Other Reviews</u>

See *Invited Reviews of Grants, Postgraduate Student Theses, and Books*

<u>Leadership in Conferences, Workshops and Short Courses</u>

2015-2016 Conference Organiser of the joint international conference: *24th Salt Water Intrusion Meeting* and *4th Asia-Pacific Coastal Aquifer Management Meeting* (SWIM-APCAMM), 4-8 July 2016, Cairns (Australia).

2014 International Conference Scientific Committee and Reviewer, *SWIM: 23rd Salt Water Intrusion Meeting*, 16-20 June 2014, Husum (Germany).

2013 International Conference Steering Committee, Session Chair, Scientific Committee and Reviewer, *3rd APCAMM*, 21-24 October 2013, Beijing (China).

2013 International Conference Scientific Committee and Reviewer, *IAH 2013*, 15-20 September 2013, Perth (Australia).

2012-2013 Chair of *Asia-Pacific Coastal Aquifer Management Meeting (APCAMM)* group; twenty Asia-Pacific researchers focusing on coastal aquifer problems.

2012 International Conference Organising Committee, Scientific Committee and Session Chair, *Measurement, Modeling and Management of Coastal Aquifers* (*2012 AGU Fall Meeting*), 3-7 December 2012, San Francisco (USA).

2012 International Conference Scientific Committee and Reviewer, *SWIM: 22nd Salt Water Intrusion Meeting*, 17-21 June 2012, Buzios (Brazil).

2012 National Workshop Invited Speaker (*International perspectives on surface water-groundwater modelling*), National Water Commission Workshop *2012 Groundwater-Surface Water Interactions Workshop*, 27 March 2012, Canberra (Australia).

2011 International Conference Scientific Committee and Reviewer, *2nd APCAMM*, 18-21 October 2011, Jeju Island (Korea).

2011 International Conference Organising Committee and Reviewer, *11th Australasian Environmental Isotope Conference and 4th Australasian Hydrogeology Research Conference*, 12-14 July 2011, Cairns (Australia).

2010 National Conference Keynote Speaker (*Seawater intrusion vulnerability assessment: Improving on existing large-scale approaches*), Session Chair, Technical Organising Committee and Reviewer, *Groundwater 2010 – the Challenge of Sustainable Management*, 31 October-4 November 2010, Canberra (Australia).

2010 International Conference Scientific Committee, Session Chair and Reviewer, *SWIM 21 - 21st Salt Water Intrusion Meeting*, 21-25 June 2010, Azores (Portugal).

2010 Short-course organiser, *PEST, Parameter Estimation and Uncertainty Analysis*, 29 March-1 April 2010, Adelaide (Australia).

2009 International Conference Scientific Committee, Session Chairperson and Reviewer, *APCAMM: 1st Asia-Pacific Coastal Aquifer Management Meeting*, 9-11 December 2009, Bangkok (Thailand).

2009 International Conference Reviewer, *MODSIM09: 18th World IMACS Congress and MODSIM09 International congress on Modelling and Simulation*, 13-17 July 2009, Cairns (Australia).

2008 International Conference Featured Speaker (*Seawater Intrusion in Australia: A National Perspective of Future Challenges*), Scientific Committee, Session Chairperson and Reviewer, *SWIM: 20th Salt Water Intrusion Meeting*, 23-27 June 2008, Florida (USA).

2008 Short-course Presenter, *ABC's of Groundwater*, 21-23 May 2008, Port Lincoln (Australia).

2008 International Conference Session Chairperson and Reviewer, *Water Down Under 2008 Conference*, 15-17 April 2008, Adelaide (Australia).

2008 International Conference Keynote Speaker (*An Australian Perspective of Seawater Intrusion*), *2nd International Salinity Forum: Salinity, Water and Society*, 31 March-3 April 2008, Adelaide (Australia).

2008 Short-course Organising Committee and Presenter, *Groundwater-surface water interaction* at *1st Surface Water-Groundwater Interactions Workshop*, 24-26 September 2008, Brisbane (Australia).

2006 International Conference Session Chairperson, *Joint Congress of 9th Australasian Environmental Isotope Conference and 2nd Hydrogeology Research Conference*, 13-15 December 2006, Adelaide (Australia).

2005 International Conference Session Chairperson and Reviewer, *NZHS-IAH-NZSSS Auckland 2005 Conference*: *Where Waters Meet*, 28 November-2 December 2005, Auckland (New Zealand).

MEDIA-RELATED ACTIVITIES

2013 ABC Radio South West interview with Ronald Tait on "Threat of seawater intrusion to Australian coastal aquifers" (17 January 2013)

2013 ABC Local Radio South Australia and Broken Hill interview with Annabelle Homer on "Reliability of Eyre Peninsula's groundwater supplies and the risk of seawater intrusion" (16 January 2013)

2013 ABC Radio Rural Hour interview with Nikolai Beilharz on "Do you want salt with that? Coastal aquifer sustainability" (14 January 2013)

2012 ABC Radio National interview with Tom Nightingale on "Coastal water supply at risk of being unusable" (8 August 2012)

2012 ABC Radio South East SA interview with Alan Richardson on saltwater intrusion and the risk to southeast aquifers (22 May 2012)

2011 Port Lincoln Times (newspaper) article titled "International students monitoring our water" (5 July 2011)

2010 Coast FM Radio interview with Allan Baird on the Bradfield Scheme, which proposes to direct northern Australian rivers inland to fill Lake Eyre and thereby enhance evaporation in the Murray-Darling system (16 December 2010)

2009 ABC National Radio interview with Grant Cameron on the use of excess dam water for public use during periods of spillway discharge (October 2009)

2009 ABC National Radio interview on the Eyre Peninsula groundwater situation relating specifically to seawater intrusion (February 2009)

2009 Independent Weekly story on the Eyre Peninsula groundwater research "Groundwater under threat" (January 2009)

2008 Eastern Courier (local newspaper) story on urban groundwater use "Adelaide residents decisive: every drop counts" (October 2008)

2008 ABC Rural Report (radio) story on Eyre Peninsula groundwater research "Groundwater study announced" (May 2008)

2007 Channel 7 news story on urban groundwater use (November 2007)

2007 Aqua Australis (newsletter of the Hydrological Society of South Australia) story on *Murray's Point Wetland – Flinders University Earth Science Field Camp 2007*, Powell L, Milgate S, Watt E, Kretschmer P, Werner AD (July 2007)

Attachment B

EDO Qld.
Environmental Defenders Office
Using the law to protect
our environment.
30 Hardgrave Rd WEST END, QLD 4101
tel +61 7 3211 4466 *fax* +61 7 3211 4655
edoqld@edo.org.au www.edo.org.au/edoqld

11 November 2015

Professor Adrian Werner
School of the Environment
Flinders University

Sent by email: adrian.werner@flinders.edu.au

Dear Professor Werner

Oakey Coal Action Alliance Inc. – Analysis of New Acland Coal Stage 3 Project mine assessment

We confirm that we act for Oakey Coal Action Alliance Inc. (OCAA) in respect of its concerns with the New Acland Coal Stage 3 Project (**Project**). OCAA has made an objection to the grant of two mining leases (**ML**) and an environmental authority (**EA**) for the Project which are currently the subject of proceedings in the Queensland Land Court (**Proceedings**).

1. **Engagement**

1.1 On behalf of OCAA, we wish to engage you to act as an independent expert witness in the Proceedings in relation to your area of expertise: groundwater modelling impact assessment.

2. **Instructions**

2.1 You are instructed to:

(1) review this letter and accompanying documents and advise generally as to whether you consider there are any significant issues or deficiencies in the groundwater modelling assessment, or relevant conditions imposed, for the Project; and

(2) participate in the court process in the manner set out in the orders of the Court made on 9 November 2015.

3. Background information

3.1 The New Acland Coal Mine Stage 3 Project includes the expansion of an existing open-cut coal mine, located 14 km north-west of Oakey, west of Brisbane, and the construction of associated infrastructure. New Acland Coal Pty Ltd (**NAC**) is the proponent.

3.2 The mine currently produces 5.2 million tonnes per annum (**Mtpa**) of thermal product coal, which is forecast to be depleted by 2017.

3.3 The proposed expansion involves extending the mine's operating life to approximately 2029 and increasing production up to 7.5 Mpta by including open-cut mining of additional areas.

3.4 Approximately 1,466 hectares will be disturbed by the proposed expansion's open-cut mining activities. 1,361 hectares of this area is designated as strategic cropping land.

3.5 In May 2007, the Queensland Coordinator-General declared the proposed expansion a 'coordinated project' under the *State Development and Public Works Organisation Act 1971*, for which an environmental impact statement (**EIS**) was required. In the same month, the Commonwealth Minister for the Environment declared the project a 'controlled action' under the *Environment Protection and Biodiversity Conservation Act 1999* (**EPBC Act**).

3.6 In October 2007, the Coordinator-General released terms of reference for the EIS. From 14 November 2009 to 3 February 2010, NAC published an EIS was published and invited public submissions.

3.7 In March 2012, the then incoming Queensland Government declared that it would not support the expansion as proposed. In November 2012, NAC submitted a revised proposal.

3.8 In March 2013, the Coordinator-General released new terms of reference for the EIS. From 18 January 2014 to 3 March 2014, NAC published a new draft EIS and invited public submissions.

3.9 In April 2014, and at the request of the Queensland and Commonwealth governments, the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) provided advice on the project. The IESC advice raised a number of concerns with the assessment.

3.10 During September 2014, NAC published additional information to the EIS (**AEIS**), including a response to the IESC advice, and published the final EIS, and again invited public submissions.

3.11 In December 2014, NAC provided final information on the AEIS. On 19 December 2014, the Coordinator-General released his report on the final EIS, which included conclusions that groundwater drawdown would be up to 47m at the project site, that a drawdown contour of 1 metre may extend across an area of around 21 km in diameter, and that 357 registered bores may be affected. The Coordinator-General recommended that the proposed expansion be approved subject to conditions, including conditions requiring:

(1) a groundwater management and monitoring program;

(2) a review of the program;

(3) a review of the groundwater model within two years of commencement of mining activities;

(4) make-good agreements with potentially affected groundwater users; and

(5) groundwater offsets.

3.12 In February 2015, the Commonwealth Government extended the decision-making period for whether or not to approve the proposal under the EPBC Act to 30 April 2015. It is awaiting advice from the Queensland Government about a review being undertaken of the state approvals process.

3.13 In April 2015, NAC applied to Department of Environment and Heritage Protection (**DEHP**) under the Queensland *Environmental Protection Act 1994* to amend its environmental authority (**EA**) for the mine to include the proposed expansion.

3.14 In May 2015, NAC issued public notice of the EA application, and of applications for additional mining leases required, and invited public submissions.

3.15 In mid-June 2015, NAC replied to an information request from DEHP about the EA application. NAC's reply included an updated 'Groundwater Monitoring and Impact Management Plan'.

3.16 On 28 August 2015, DEHP approved the EA amendment application subject to conditions, and issued NAC with a draft EA.

3.17 Objections to the MLAs and EAs were referred to the Queensland Land Court on about 14 October 2015.

3.18 The Land Court made a directions order for the matter on 9 November 2015.

4. Brief of Material

4.1 Once you have confirmed your availability to act in this matter, we will send you an invite to the electronic brief in this matter through Dropbox. We can provide these documents in other electronic format or in hard copy if necessary.

4.2 A copy of the Index to that brief is **Annexure C** to this letter.

4.3 We draw your attention in particular to the general application and approval documents in Index B and the groundwater key documents in Index C of the Brief.

4.4 All EIS material is also available here (Qld Govt website) and here (NAC website).

5. **Timing**

5.1 The court proceedings are already afoot.

5.2 You will be required to participate in the proceedings in accordance with the Orders made on 9 November 2015 (document 3 of Index A of your Brief) unless these orders are further altered by the Court. These include:

(1) by 29 January 2016, meeting with the corresponding expert from the other parties and have prepared a joint report on setting out points of agreement and disagreement (order 19);

(2) by 12 February 2016, preparing any individual report (order 24);

(3) attending any required further expert meeting by 19 February 2016, and any associated joint report by 26 February 2016 (order 25);

(4) giving any oral evidence, or being cross-examined on your evidence, at the hearing, currently scheduled to start 1 March 2016 (order 29).

6. **Your duty to the Land Court**

6.1 We enclose as **Annexure A** rules 22 to 24I of the *Land Court Rules 2000* which govern experts in the Land Court.

6.2 In particular we note that rule 24C of the *Land Court Rules 2000* provides that you have a duty to assist the Land Court which overrides any obligations you may have to our client.

6.3 We also emphasise that we and our client do not seek to influence your views in any way and we ask for your independent opinion to assist the Land Court. Consequently, please note that any statements of fact or opinion in this letter of instructions, the above documents, or anything given or said to you by us relevant to the issues in your report do not constrain you in any way and are not intended to influence your views. We ask you to form your own opinion about the relevant facts and circumstances for the purposes of your report.

6.4 Any joint report or separate expert report you prepare should confirm that each expert understands the expert's duty to the court and has complied with that duty.

7. **Format of your statement of evidence (other than joint report)**

7.1 If you have taken part in a meeting of experts, the joint report is taken to be your statement of evidence and you are to produce a further statement of evidence in relation to any issue of disagreement.

7.2 Suggestions for the format of your report are set out in **Annexure B**, "Format of your report".

7.3 Your report must:

(1) be addressed to the Court;

(2) include your qualifications;

(3) include all material facts, whether written or oral, on which your report is based;

(4) include references to any literature or other material you relied on to prepare the report;

(5) include for any inspection, examination or experiment you conducted, initiated, or relied on to prepare your report—

a) a description of what was done; and

b) whether the inspection, examination or experiment was done by the expert or under the expert's supervision; and

c) the name and qualifications of any other person involved; and

d) the result;

(6) if there is a range of opinion on matters dealt with in your report, include a summary of the range of opinion, and the reasons why you adopted a particular opinion;

(7) include a summary of the conclusions you reached; and

(8) include a statement about whether access to any readily ascertainable additional facts would assist you in reaching a more reliable conclusion;

(9) include a confirmation at the end of the statement of evidence:

a) the factual matters included in the statement are, as far as the expert knows, true; and

b) the expert has made all enquiries considered appropriate; and

c) the opinions included in the statement are genuinely held by the expert; and

d) the statement contains reference to all matters the expert considers significant; and

e) the expert understands the expert's duty to the court and has complied with the duty; and

f) the expert has read and understood the rules contained in this part, as far as they apply to the expert; and

g) the expert has not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

(10) include your signature.

7.4 You should attach to the report:

(1) a copy of your Curriculum Vitae; and

(2) a copy of this letter.

7.5 Please number all pages and paragraphs of your report. You may wish to include an index.

7.6 If your report includes any photographs, measurements, graphs or illustrations these should be firmly attached to the report, and clearly identified and numbered.

8. Change of opinion

8.1 If for some reason, you change your opinion after delivering your report, please advise us as soon as possible. If that change is material, a supplementary report will need to be prepared, which explains the reasons for the change in your opinion.

9. Confidentiality and privilege

9.1 In accepting this engagement, you agree that:

(1) this letter and all future communications (whether electronically maintained or not) between us are confidential. These communications may be subject to client legal privilege;

(2) you must take **all** steps necessary to preserve the confidentiality of our communications and of any material or documents created or obtained by you in the course of preparing your report;

(3) you must not disclose the information contained in our communications or obtained or prepared by you in the course of preparing your report without obtaining consent from us;

(4) you must not provide any other person with documents which come into your possession during the course of preparing this report, whether created by you or provided to you by us or our clients, without obtaining consent from us.

9.2 The duty of confidentiality continues beyond the conclusion of your instructions.

9.3 If you are ever obliged by law to produce documents containing any of this confidential information (whether by subpoena, notice of non-party discovery or otherwise) please contact us immediately so that we may take steps to claim client legal privilege.

9.4 You should ensure that you retain copies of all drafts of your report together with all documents that you rely on in preparing your report. We will inform you when you are no longer required to retain them.

9.5 If requested, you must return to us all documents and other material (including copies) containing confidential information. Where any confidential information is in electronic form, we may require you to delete this information instead.

9.6 Any internal working documents and draft reports prepared by you may not be privileged from disclosure and may be required to be produced to the opposing parties in the litigation, and to the Court.

9.7 You may be cross-examined about any changes between your working documents and your report. The Court will be interested to understand the reason or reasons for any changes, and you should be prepared to, and able to, explain them.

10. Document management

10.1 Please ensure that all documents created pursuant to this retainer are marked "Privileged and Confidential: prepared for the purpose of the Queensland Land Court objection hearing to Stage 3 New Acland Coal Mine".

11. Court appearance

11.1 At the hearing of any objection, you may be required to attend Court and give evidence. You must be personally involved and knowledgeable in all aspects of the preparation of the report.

11.2 If you are required to attend Court to give evidence, we will contact you to discuss your availability and make the necessary arrangements.

If you have any questions regarding your engagement or require further information, please do not hesitate to call us on 3211 4466.

Yours faithfully

Environmental Defenders Office (Qld) Inc

Andrew Kwan

Senior Solicitor

ANNEXURE A - ***Land Court Rules 2000*** **(Qld)**

Part 5 Evidence

Division 1 Preliminary

22 Definitions for pt 5

In this part—

expert means a person who would, if called as a witness in a proceeding, be qualified to give opinion evidence as an expert witness in relation to an issue in dispute in the proceeding.

joint report, for a proceeding, means a report—

(a) stating the joint opinion of experts in relation to an issue in dispute in the proceeding; and

(b) identifying the matters about which the experts agree or disagree and the reasons for any disagreement.

meeting of experts—

1 A meeting of experts is a meeting at which experts in each area of expertise relevant to a proceeding meet, in the absence of the parties—

(a) to discuss and attempt to reach agreement about the experts' evidence in relation to an issue in dispute in the proceeding as it relates to the experts' area of expertise; and

(b) to prepare a joint report.

2 The term includes

(a) a resumed meeting of experts or further meeting of experts; and

(b) a meeting attended by the experts in either, or a combination, of the following ways—

(i) personally;

(ii) a way that allows contemporaneous communication between the experts, including by telephone, video link or email.

party, for a proceeding, means a party to the proceeding or the party's lawyer or agent.

statement of evidence, of an expert, see rule 24E.

Division 2 Meetings of experts

23 Application of div 2

Unless the court otherwise orders, this division applies in relation to a meeting of experts ordered or directed by the court at any time in a proceeding.

24 Party must ensure expert ready to take part in meeting of experts

Before a meeting of experts, a party to a proceeding must do all things reasonably necessary or expedient to ensure an expert chosen by the party is ready to take part fully, properly and promptly in the meeting, including by giving the expert—

(a) reasonable prior notice that the court has ordered or directed a meeting of experts; and

(b) notice of the contents of any order or direction about the meeting, including the time by which the meeting must be held; and

(c) reasonable notice of the issue in dispute in the proceeding to the extent it is relevant to the expert's expertise; and

(d) enough information and opportunity for the expert to adequately investigate the facts in relation to the issue in dispute in the proceeding; and

(e) written notice that the expert has a duty to assist the court and the duty overrides any obligation the expert may have to the party or any person who is liable for the expert's fee or expenses.

24A Experts attending meeting must prepare joint report

(1) The experts attending a meeting of experts must, without further reference to or instruction from the parties, prepare a joint report in relation to the meeting.

(2) However, the experts attending the meeting may, at any time before the joint report is completed, ask all parties to respond to an inquiry the experts make jointly of all parties.

(3) Despite subrule (1), any of the experts may participate in a mediation involving the parties.

(4) The joint report must—

  (a) confirm that each expert understands the expert's duty to the court and has complied with the duty; and

  (b) be given to the parties.

(5) The applicant or appellant must deliver to the registry, personally or by facsimile or email, a copy of the joint report received under subrule (4) at least 21 days before the date set for the hearing.

24B Admissions made at meeting of experts

(1) Subrule (2) does not apply to a joint report prepared in relation to a meeting of experts.

(2) Evidence of anything done or said, or an admission made, at a meeting of experts is admissible at the hearing of the proceeding or at the hearing of another proceeding in the court or in another civil proceeding only if all parties to the proceeding agree.

(3) In this rule—

civil proceeding does not include a civil proceeding founded on fraud alleged to be connected with, or to have happened during, the meeting.

Division 3 Evidence given by experts

24C Duty of Expert

(1) A witness giving evidence in a proceeding as an expert has a duty to assist the court.

(2) The duty overrides any obligation the witness may have to any party to the proceeding or to any person who is liable for the expert's fee or expenses.

24D Giving or accepting instructions to adopt or reject a particular opinion prohibited

A person must not give, and an expert must not accept, instructions to adopt or reject a particular opinion in relation to an issue in dispute in a proceeding.

24E Expert must prepare statement of evidence

(1) An expert must prepare a written statement of the expert's evidence (a statement of evidence) for the hearing of a proceeding.

(2) If the expert has taken part in a meeting of experts—

- (a) a joint report prepared in relation to the meeting is taken to be the expert's statement of evidence in the proceeding; and
- (b) a further statement of evidence in relation to any issue of disagreement recorded in the joint report is to be prepared by the expert.

(3) However, the further statement of evidence must not, without the court's leave—

- (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.

24F Requirements for statement of evidence other than joint report

(1) An expert's statement of evidence, other than a joint report, must be addressed to the court and signed by the expert.

(2) The statement of evidence must include the following information, to the extent the information is not already contained in a joint report prepared for the proceeding—

- (a) the expert's qualifications;
- (b) all material facts, whether written or oral, on which the statement is based;
- (c) references to any literature or other material relied on by the expert to prepare the statement;
- (d) for any inspection, examination or experiment conducted, initiated or relied on by the expert to prepare the statement—

(i) a description of what was done; and

(ii) whether the inspection, examination or experiment was done by the expert or under the expert's supervision; and

(iii) the name and qualifications of any other person involved; and

(iv) the result;

(e) if there is a range of opinion on matters dealt with in the statement, a summary of the range of opinion and the reasons why the expert adopted a particular opinion;

(f) a summary of the conclusions reached by the expert;

(g) a statement about whether access to any readily ascertainable additional facts would assist the expert in reaching a more reliable conclusion.

(3) The expert must confirm, at the end of the statement of evidence—

(a) the factual matters included in the statement are, as far as the expert knows, true; and

(b) the expert has made all enquiries considered appropriate; and

(c) the opinions included in the statement are genuinely held by the expert; and

(d) the statement contains reference to all matters the expert considers significant; and

(e) the expert understands the expert's duty to the court and has complied with the duty; and

(f) the expert has read and understood the rules contained in this part, as far as they apply to the expert; and

(g) the expert has not received or accepted instructions to adopt or reject a particular opinion in relation to an issue in dispute in the proceeding.

24G Serving statement of evidence other than joint report

(1) This rule applies to a statement of evidence other than a joint report.

(2) A party to a proceeding intending to call evidence by an expert in the proceeding must deliver to the registry, personally or by facsimile or email, and serve on each other party to the proceeding, a copy of the expert's statement of evidence.

(3) A party must comply with subrule (2) at least 21 days before the date set for the hearing or, if the court directs a different time, within the time directed by the court.

24H Matters contained in statement of evidence not to be repeated

During examination in chief, an expert must not, without the court's leave, repeat or expand on matters contained in the expert's statement of evidence or introduce new material.

24I Evidence from only 1 expert may be called

Other than with the court's leave, a party to a proceeding, at any hearing of the proceeding, may call evidence from only 1 expert for each area of expertise dealt with in the hearing.

ANNEXURE B – Format of report

Court Rules

1 A copy of the relevant sections of the *Land Court Rules 2000* is provided at Annexure A.

2 While the format of your report is discretionary, you should ensure that your report complies with the above requirements, and that compliance with these requirements is readily apparent.

Format

3 We make the following suggestions regarding the layout of your report.

4 Ensure that your report contains your full name and address.

5 Please number all pages and paragraphs of your report. You may wish to include an index. If your report includes any photographs, measurements, graphs or illustrations these should be firmly attached to the report, and clearly identified and numbered.

6 Your report may include the following sections and headings:

6.1 "Introduction"

This section should:

- refer to, and annex, the letter of instructions received from me;
- refer to, and disclose, the substance of any conversations that you have had **and** to which you have had regard in preparing the report;
- specifically identify and refer to any literature or other source materials (eg text books, industry guidelines and handbooks) used in support of your opinion. This will include the documents supplied by me, as well as any other documents to which you have referred. If lengthy, it may be practical to list this material in an annexure to the report. If for some reason, you do not refer to certain material when preparing your report, please specifically identify this material and outline the reasons it was not referred to; and
- refer to any methodology you have adopted in preparing the report, including a detailed description of any test or examinations, who carried them out, their qualifications and the results.

6.2 "My qualifications"

In this section of your report, you need to qualify yourself as an expert in the areas in which you have been asked to provide an opinion. You should describe how your specialist knowledge (whether obtained through training, study or experience), your experience and qualifications qualify you as an expert in these areas.

Your curriculum vitae should also be annexed to your report and referred to under this heading.

6.3 "Summary of my opinion"

You are required to include a summary of your opinion.

6.4 "Background facts and assumptions"

The Court Rules require you to list all "facts, matters and assumptions on which each opinion expressed in the report is based".

The facts and assumptions you rely on need to be linked to their sources and clearly stated and verifiable. These may be sufficiently set out in our letter of instructions.

If you are called as a witness, you may be required to give evidence in relation to your assumptions.

6.5 "My opinion"

This part of your report should contain your detailed reasons for your opinions on the questions put to you. This will be the most substantial part of your report.

When drafting your report, you should make it clear that the opinion is wholly or substantially based on your expert knowledge. Your opinions must be confined to areas within your expert knowledge.

You must set out the process of reasoning that you followed in coming to your opinion and identify the facts and assumptions upon which you rely for the opinion. Where there are alternative views available, you should explain why you have chosen a particular alternative.

6.6 "Qualification of the opinion"

If appropriate, you should set out any qualification of your opinion, without which the report would be incomplete or inaccurate. If applicable, you should state that a particular question or issue falls outside your relevant field of expertise.

You should also state if your opinion is not concluded because of insufficient research or data or for any other reason.

6.7 "Confirmation"

You must confirm, at the end of the report—

(a) the factual matters stated in the report are, as far as the expert knows, true; and

(b) the expert has made all enquiries considered appropriate; and

(c) the opinions stated in the report are genuinely held by the expert; and

(d) the report contains reference to all matters the expert considers significant; and

(e) the expert understands the expert's duty as an expert witness is to assist the court, and that this duty overrides any obligation to any party to the proceeding or to any person who is liable for the experts fees or expenses, and the expert has complied with the duty; and

(f) the expert has read and understood the rules contained in Part 5 of the Land court Rules 2000; and

(g) the expert has not received or accepted instructions to adopt or reject a particular option in relation to an issue in dispute in the proceeding.

Please ensure that you make all necessary inquiries in a timely fashion to enable you to confirm these matters.

6.8 "Signature"

The final page of your report must be signed by you.

ANNEXURE C – Index to Brief

IN THE LAND COURT
OF QUEENSLAND

Land Court Reference: EPA495-15
MRA496-15
MRA497-15

In the matter of: **Oakey Coal Action Alliance**

Objector

v.

New Acland Coal Pty Ltd

Applicant

Department of Environment and Heritage Protection

Statutory Party

INDEX TO BRIEF

INDEX A – COURT DOCUMENTS

No.	Document Title	Date	Date Filed	Doc ID	Exhibit No.
1.	OCAA Objection to EA	02/10/15			
2.	OCAA Objection to ML	30/02/15			
3.	Directions Order	09/11/15			

INDEX B – GENERAL APPLICATION AND APPROVAL DOCUMENTS

No.	Document title	Date
1.	EIS Appendix D - Terms of Reference for EIS	--/03/2013
2.	EIS Chapter 00 Executive Summary	--/01/2014
3.	EIS Chapter 3 Project Description	--/01/2014
4.	EIS Chapter 22 Conclusions and Recommendations	--/01/2014
5.	EIS Appendix J-19 EM Plan	--/01/2014
6.	AEIS Appendix C Revised Project EM Plan	--/08/2014
7.	Coordinator General's Report on the EIS	--/12/2014
8.	Notice of Decision on EA	28/08//2015
9.	Draft EA	28/08//2015

INDEX C –GROUNDWATER KEY DOCUMENTS

No.	Document title	Date
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1.	Chapter 5 Surface Water Resources	--/01/2014

2.	Chapter 6 Groundwater Resources	--/01/2014
3.	Appendix G4-1 Aquifer Testing Report	--/01/2014
4.	Appendix G4-2 Landholder Bore Survey Results	--/01/2014
5.	Appendix G4-3 WSA Water Quality Lab Reports	--/01/2014
6.	Appendix G4-4 Stage 3 Groundwater Quality Lab Reports	--/01/2014
7.	Appendix H2 IESC Submissions	--/01/2014
8.	Appendix J-4 Water Resource Management Plan	--/01/2014
9.	Appendix J-5 Groundwater Monitoring and Impact Management Plan	--/01/2014
Final Addendum to the Supplementary EIS (**AEIS**) Documents		
10.	AEIS Appendix F Updated Groundwater Model Tech Report V3	--/08/2014
11.	AEIS Appendix G Additional Landholder Bore Survey	--/08/2014
12.	AEIS Appendix H Groundwater Monitoring and Impact Management Plan	--/08/2014
13.	AEIS Appendix N IESC Submission Response	--/08/2014

Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development

Advice to decision maker on coal mining project

IESC 2014-045: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion

Requesting agency	The Australian Government Department of the Environment and the Queensland Office of the Coordinator-General
Date of request	25 February 2014
Date request accepted	5 March 2014
Advice stage	Assessment

Advice

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) was requested by the Australian Government Department of the Environment and the Queensland Office of the Coordinator-General to provide advice on the New Acland Coal Mine Stage 3 Project in Queensland at the draft Environmental Impact Statement (EIS) stage.

This advice draws upon aspects of information in the draft EIS, together with the expert deliberations of the IESC. The project documentation and information accessed by the IESC are listed in the source documentation at the end of this advice.

The proposed project is to expand and extend by up to 12 years, the New Acland Coal Mine, located approximately 35 km northwest of Toowoomba in the Lagoon Creek Catchment in the Clarence-Moreton Basin of Queensland. The proposed project involves creation of three open cut pits to increase production of coal from the Walloon Coal Measures from 4.8 Mtpa to 7.5 Mtpa of thermal product coal. Ancillary infrastructure developments would include upgrading the existing coal handling and preparation plant (CHPP) and associated stockpile areas as well as construction of an 8 km rail spur and balloon loop, and a train load-out facility.

The proposed project is located in the Lagoon Creek catchment. Lagoon Creek is an ephemeral creek flowing only after periods of significant rainfall. Lagoon Creek flows into Oakey Creek, which is part of the larger Condamine River Catchment of the Murray Darling Basin. Vegetation within the proposed project's development area provides habitat for *Pteropus poliocephalus* (Grey-headed Flying-fox) and *Phascolarctos cinereus* (Koala), which are listed as 'vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999*. Three 'endangered' and five 'of concern' regional ecosystems listed under the Queensland *Vegetation Management Act 1999* are also located within the proposed project's development area.

The IESC, in line with its Information Guidelines[1], has considered whether the proposed project assessment has used the following:

Relevant data and information: key conclusions

The following data and information are needed for potential impacts arising from proposed project to be fully assessed:

- A comparison between observed and modelled potentiometric heads, presented in a series of maps, to enable better assessment of the reliability of the groundwater flow model;
- Measured flow data to improve confidence in the characterisation of Lagoon Creek's flow regime;
- Additional monitoring data, across a greater spatial and temporal extent, to more robustly characterise existing surface water quality in Lagoon Creek;
- Use of consistent salinity thresholds for discharges of mine-affected water to Lagoon Creek and inclusion of other key water quality indicators in the site water management system's release rules;
- Assessment of ecosystems associated with Oakey Creek and Myall Creek; and
- Identification and assessment of terrestrial groundwater dependent ecosystems within the predicted cone of depression.

Application of appropriate methodologies: key conclusions

Confidence in the predictive capacity of the numerical groundwater model is low due to the adopted boundary conditions, anisotropic hydraulic conductivity and recharge values, and the lack of sensitivity testing of the model to these parameters. The exclusion of other groundwater users within the model domain further limits confidence in the model's predictions. A revised groundwater study is needed to improve confidence in the conclusions of the assessment documentation and enable development of appropriate measures to monitor and manage uncertainties and risks to water-related assets.

Reasonable values and parameters in calculation: key conclusions

Justification and/or further information are needed to support the proponent's approach or conclusions in relation to:

- Numerical groundwater model boundary conditions;
- The substantial differences between vertical and horizontal permeability values used in the numerical groundwater model;
- The application of a uniform percentage for recharge from rainfall for each time step in the numerical groundwater model; and
- Uncertainties in the mine water balance resulting from:
  - The thresholds used for discharges of mine-affected water, which do not adequately consider ambient water quality or flow; and
  - The assumed flow regime in Lagoon Creek, which is likely to over-estimate opportunities for discharges of mine-affected water.

The IESC recommends that the proponent develop any further project assessment documentation in line with its Information Guidelines[1].

The IESC's advice, in response to the requesting agencies' specific questions, is provided below.

Question 1: What does the Committee consider are the key uncertainties and risks of the project in relation to water resources and water-related assets? What does the Committee consider are the features of a monitoring and management framework that would address these uncertainties and risks? In responding to this question, please consider the matters raised by the State and Commonwealth (Attachments B and C) as well as additional information contained in the RFA.

1. There are uncertainties and risks in the hydrogeological conceptualisation and numerical groundwater model relating to design and implementation, which impact on the reliability of model predictions. An updated hydrogeological study that considers the following matters would enable risks to water resources to be more accurately evaluated. Suggested enhancements to the proponent's Groundwater Monitoring and Impact Management Plan (GMIMP) are provided in the response to Question 3. However, until the IESC's concerns about the groundwater model are addressed it is difficult to determine the appropriateness of the management and mitigation measures.

<u>Conceptualisation</u>

a. The absence of confining units of low hydraulic conductivity (with the exception of the Evergreen Formation) in the conceptual and numerical models will result in an unrealistic parameterisation of the hydrogeological regime. In particular, the low vertical hydraulic conductivities assigned to aquifers within the model will result in the underestimation of vertical drawdown propagation.

<u>Model Documentation</u>

b. Several predicted drawdown maps are provided; however, the pre-development head patterns have not been presented. A qualitative comparison between observed and modelled potentiometric heads, in a series of maps, would enable better assessment of model reliability. Modelled heads in each layer need to be presented, across the entire model domain, and at intervals representing pre-mining, the proposed project's operational phase, immediately post-mining, and longer term, in order to evaluate the modelled spatial and temporal pattern of groundwater flow.

c. Extension of the water balance to include predicted post-mining groundwater levels data would enable evaluation of long term risks. An indication of fluxes by aquifer is also needed.

<u>Boundaries</u>

d. Constant head cells have been assigned along the northern, western, southern and part of the eastern margins of the model domain, which may result in unrealistic water budgets and laterally constrained drawdown within the model. Small variations in flow through these constant head boundaries may introduce large uncertainties in groundwater impact predictions.

e. The setting of boundary conditions has relied on one potentiometric head map for the Walloon Coal Measures that is restricted to the vicinity of the proposed project. Confidence in the adopted boundary conditions could be improved by incorporating potentiometric head maps from other hydrostratigraphic units as this would help to identify groundwater flow features and provide justification for the selected model boundaries. The use of the Queensland Government's Office of Groundwater Impact Assessment (OGIA)[2] groundwater flow model would assist in determining the wider groundwater flow conditions.

f. Confidence in the groundwater model's predictive capability would be improved by providing and justifying the numerical values assigned to the constant head cells along the northern, western, southern and eastern boundaries. These values, in particular the relationship between the constant head values adopted at the same location but for different layers, may have a strong influence on the flow fields and heads, and hence the model's performance, including its predictive capability.

g. Choices for groundwater model boundaries should be described with respect to the spatial distribution of water entitlements and developments. The model excludes wells associated with other developments within the model domain; for example, the 9,000 ML/year groundwater entitlements that exist within 8 km of the proposed project. These developments are likely to invalidate the assumed boundary conditions, resulting in model constraints that produce inaccurate water budgets and model predictions.

h. Modelling of recharge as a fixed percentage of rainfall is considered simplistic in a climate where evaporation exceeds rainfall for most of the year. As recharge is the largest inflow to the model, even small variations in recharge introduce large uncertainties in groundwater impact predictions. It is recommended that the magnitude of recharge be estimated using methods other than model calibration (refer to Scanlon et al., 2002) and that a sensitivity analysis be undertaken to explore the robustness of the model predictions to variations in recharge rates.

i. The evaporation rate and extinction depth adopted in the model are not described. Evaporation appears to be the second most important contributor to flows leaving the model domain and small variations in evaporation may introduce large uncertainties in groundwater impact prediction.

j. Walls or flow barriers have been used to simulate faults in the model. While some faults may form barriers to flow, others may provide conduits for groundwater flow. Therefore, a justification for the use of flow barriers in the groundwater model is warranted.

k. Myall Creek is included in the groundwater model as a drain boundary condition despite evidence that groundwater elevations lay significantly below stream bed elevations. While it is noted that Myall Creek is situated to the north of the proposed project, justification is needed for the assumed boundary condition as it does not allow for seasonal flows to recharge groundwater.

Model Layers

l. An understanding of the conceptual hydrology across the entire model domain would improve understanding of lateral drawdown propagation from the Walloon Coal Measures to the Quaternary Alluvium. This may be achieved by inclusion of north-east to south-west cross-sections across the entire model domain and identification of the extent of each hydrogeological unit.

m. Information in relation to the geometry of the hydrostratigraphic units across the model, including the top, base and thickness of model layers, would aid understanding of how the numerical model parameterisation relates to the conceptual model. Individual model layers may include more than one unit which can result in an oversimplification of the hydrostratigraphy; in particular, inaccurate representation of hydraulic conductivity values. A description of how the south-west dipping conceptual hydrogeology was incorporated in the groundwater model is also needed.

n. The Lower Walloon Coal Measures are conceptualised as separated from the Walloon Coal Measures by clays with low primary porosity, rather than low vertical hydraulic conductivity.

Evidence, in the form of a potentiometric head map for the Lower Walloon Coal Measures, a comparison between heads from adjacent bores, or a head to elevation analysis within the Walloon Coal measures is needed to support this conceptualisation.

Model parameterisation and calibration

o. Calibrated model parameters indicate substantially higher horizontal and vertical hydraulic conductivity ratios than generally expected for alluvium, sandstone, and shale. Further, specific yield values are substantially lower than generally applied in groundwater models (for example, in Freeze and Cherry (1979)), which may underestimate unconfined aquifer storage. The rationale for the adopted values should be explained.

p. The information provided in the assessment documentation does not appear to support a scaled Root Mean Square (RMS) value of 8 per cent. Further explanation of the scaled RMS errors, including an analysis of those across the entire model domain, at appropriate time intervals and for each model layer, would improve confidence in model calibration.

Model predictions

q. Given the uncertainties in determining recharge and the limited documentation of the constant head boundaries across which flow occurs, there is the potential for large variations in the predicted drawdown and pit inflows, and an uncertainty/sensitivity analysis should be undertaken.

r. Predicted drawdown in 2030 indicates a steep cone of depression in the Walloon Coal Measures and basalts. Given the comparatively high hydraulic conductivity assigned to the adjoining Oakey Alluvium at this location, and the potential presence of groundwater dependent ecosystems in the Oakey Creek catchment, the cause of the restricted lateral drawdown in all hydrostratigraphic units should be clarified.

s. The presentation of drawdown contours for the Marburg Sandstone indicates that drawdown in this aquifer in the vicinity of the proposed project is greater than drawdown in the coal measures and basalts. This presentation is inconsistent with assessment documentation conclusions, which state that drawdown in the Marburg Sandstone is less that in the coal measures and basalts. This discrepancy should be reconciled.

t. The presentation of drawdown maps should be reviewed and amended to ensure that groundwater drawdown predictions in the alluvium are accurate. The assessment documentation lacks clarity around why contour lines cross the Lagoon Creek Alluvium but do not cross the alluvium associated with Oakey Creek.

u. The model predictions in terms of drawdown or stream depletion are shown in a deterministic manner; however, the model has considerable uncertainties in the calculation of the much larger components of recharge, flow across constant head boundary cells, and evapotranspiration. Inclusion of stochastic results or error/confidence intervals would better reflect the model uncertainties in the presentation of drawdown and stream depletions.

v. Use of pan evaporation to assess the final void water balance may lead to overestimation of evaporation rates as void walls can protect water in the void from wind and sunlight. It is suggested that this effect is explored in the revised hydrogeological study and alternate evaporation rate factors are adopted if applicable; for example, Castendyk and Eary (2009) use a factor of 0.7 to account for the reduced evaporation from pit lakes. If the rate of evaporation is reduced in the model, the predicted post-mining drawdown will be smaller and the predictions for the post mining water levels in the Manning Vale West, Willeroo and Manning Vale East voids would need to be revised. Inclusion of either stochastic results or error/confidence intervals would better reflect the model uncertainties in the presentation of post-mining drawdown and groundwater levels in the final voids.

w. The proponent states that the final voids will act as groundwater sinks and therefore will not permit pooled water to flow outwards into the regional groundwater system. This concept may apply to times when evaporation is larger than rainfall. If, however, episodic large rainfall events bring the pool level above that of the surrounding groundwater, there may be flow to the groundwater system; the probability of which would increase with a decreased model evaporation rate factor. Evaluation of the potential for groundwater recharge from the final voids would enable assessment of the proposed project's long term risks to groundwater quality.

x. A sensitivity and uncertainty analysis of the major components of the proponent's groundwater balance would enable evaluation of confidence limits for model outputs.

2. Additional characterisation of surface water resources associated with Lagoon and Oakey Creeks, as described below, would enable potential impacts on water quality and aquatic ecosystems to be more robustly evaluated.

Existing Conditions

a. Spatial and temporal limitations of the baseline monitoring program are not acknowledged in the assessment documentation. For example, characterisation of existing metals concentrations is based on one sampling event; however, the uncertainty associated with this limitation is not discussed. Consequently, existing conditions are difficult to ascertain and describe, which leads to reduced confidence levels when determining current state and condition; and attributing future impacts associated with the proposed works/activities. The following additional information would enable a more confident characterisation of the existing condition:

   i. existing and background water resource conditions, including explicit identification of processes such as different flow, mixing, chemical and redox regimes;

   ii. key water quality indicators and the appropriate sensitivity of measurement;

   iii. temporal and spatial sampling frequency; and

   iv. appropriate sample collection, sampling preservation and analytical methods.

b. Methods used to characterise macroinvertebrate diversity in Lagoon Creek are not appropriate for dams or dry season pools. It is suggested that future sampling rounds are undertaken in accordance with the Queensland Monitoring and Sampling Manual 2009 (DEHP, 2013)[3].

c. Groundwater dependent ecosystems, particularly those dependent on the alluvium and tertiary basalt aquifer, are not clearly identified in the assessment documentation. A map identifying seasonal groundwater depths and the vegetation present within the predicted area of groundwater drawdown would aid understanding of the extent and type of groundwater dependent ecosystems across the proposed project's area of influence. The identification of groundwater dependent ecosystems should be undertaken with reference to the Queensland Government's groundwater dependent ecosystem mapping in WetlandInfo.[4] Quantification of groundwater dependent ecosystem water requirements as well as the reliance of terrestrial ecosystems on shallow groundwater systems would inform the evaluation of the risks to these ecosystems posed by proposed project development.

d. Assessment of the dependency of threatened species, such as *Pteropus poliocephalus* (Grey-headed Flying-fox) and *Phascolarctos cinereus* (Koala) on groundwater dependent vegetation would provide a more comprehensive understanding of the significance of groundwater dependent ecosystems in the proposed project's development area.

e. The assessment documentation would benefit from a review of published literature in relation to existing aquatic and terrestrial ecosystems in the region; for example, see Cosser, P. (1988)[5].

Water Quality Objectives

a. The proponent identifies three possible descriptors of aquatic ecosystem environmental values for Lagoon Creek; however, the 'slightly to moderately disturbed' value has been adopted without explanation. Further justification for adoption of this environmental value, with due consideration of the spatial distribution of the environmental values along potentially affected watercourses, would ensure that this watercourse has been appropriately classified.

b. Explanation of the rationale for using water quality objectives developed for south-eastern Australia and the Fitzroy Basin would enable evaluation of their applicability to the Lagoon Creek and Oakey Creek catchments.

c. Evidence is needed to support the proponent's adoption of a water quality objective for electrical conductivity which is double the typical measured values in the upper reaches of Lagoon Creek. This should be informed by continuous, flow weighted electrical conductivity measurements.

Integrity and Limitations of the Data

d. Limitations of the monitoring data should be described in the assessment documentation; particularly in relation to: the ability of the existing data to describe the water resources both spatially and temporally; data quality; discussion on the analytes collected (for example, the suitability of some analytes as indicators or surrogates for other analytes).

3. Aquatic and terrestrial ecosystem assessments are limited to Lagoon Creek and do not acknowledge the potential for the following groundwater drawdown-induced impacts.

   a. The groundwater model predicts a reduction in baseflow for Oakey Creek and Myall Creek, indicating that there is a connection between the proposed project's operations and baseflow discharges to these watercourses. Characterisation of the existing aquatic and terrestrial ecosystems associated with Oakey Creek and Myall Creek is needed, clearly integrating the hydrological and water quality characterisations with the hydrogeological and ecological characteristics of the catchment.

   b. The assessment of potential groundwater drawdown impacts on terrestrial vegetation is based on the depth to groundwater in the Walloon Coal Measures. It is suggested that consideration of groundwater drawdown in the alluvium and tertiary basalt aquifers would more appropriately inform risks to groundwater dependent ecosystems.

   c. If the studies suggested in Paragraphs 2(c), 3(a) and 3(b) above indicate that groundwater dependent ecosystems are present and would be affected by groundwater drawdown, the consequential impacts on threatened species should be evaluated.

4. The proposed project's site water balance and proposed discharge scenarios are likely to underestimate potential impacts on water resources. The site water balance should be updated to address the following matters:

a. The simulated daily flow regime in Lagoon Creek is a poor fit in comparison to the calibration data set. The flow duration curve for Lagoon Creek is not consistent with measured data at the Oakey Creek stream gauge, which indicates that the proponent has assumed higher and more frequent flows in Lagoon Creek than are likely to be the case. This creates uncertainty with respect to the modelled mine water balance and a mine water management system that relies on releases to Lagoon Creek. Real time flow and water quality measurements on Lagoon Creek would more effectively direct the release of water from environmental dams to Lagoon Creek and inform the significance of any potential impacts;

b. Salinity trigger values for discharge water quality exceed the measured salinity within Lagoon Creek and may be expected to result in water quality exceeding the water quality objectives. This assessment is supported by model predictions which indicate that water quality downstream of the mixing zone in Lagoon Creek will exceed the 500 µS/cm water quality salinity objective proposed by the proponent. Adoption of release rules that enable water quality objectives to be achieved would minimise risks to water quality and water-related assets;

c. Inclusion in the water release rules of additional water quality indicators which can be measured reliably in the field, such as dissolved oxygen, turbidity, temperature and pH, would reduce the risk of adverse impacts to water quality and aquatic ecosystems. In addition, routine sampling of a more detailed list of analytes (e.g. metals) should be implemented to verify the effectiveness of mitigation and management measures;

d. Release rules that are specified in terms that relate to the measured ambient water quality in Lagoon Creek, in addition to flow rates during a release, could provide a more appropriate approach to avoiding environmental impacts, including changes to the flow regime; and

e. The provision of verified, measured electrical conductivity values for treated wastewater proposed to be imported for operational use by the proposed project would justify the proponent’s adopted value of 250 µS/cm. This water will be managed as part of the mine water management system and potentially released to Lagoon Creek. Therefore, it is important that water quality parameters are accurately reflected within the site water balance.

5. An investigation of the cause of the elevated copper concentration in Lagoon Creek is needed to understand whether these concentrations result from natural processes. The analysis of measured data from the mine water management system would inform this assessment. If a link with existing mining operations is suspected and expected to be continued under the proposed project, water quality management and monitoring strategies would be needed to minimise water quality risks.

6. An evaluation of the potential impacts of mine-affected water discharges on surface water users downstream of the proposed project would provide a more comprehensive analysis of risks to water-related assets.

Question 2: Have cumulative impacts with other developments in the region that may impact water resources been sufficiently addressed?

7. The proponent has qualitatively considered cumulative groundwater impacts, which the IESC considers reasonably deals with 4 surrounding mines but not coal seam gas (CSG) activities, or entitlements. Confidence in the proponent’s assessment of potential cumulative impacts on water resources and water-related assets would be improved by:

   a. Describing the choice for groundwater model boundaries used in this model with respect to OGIA’s groundwater flow model. In particular, CSG activities may affect the heads in the proponent's groundwater model, in particular along boundaries, which could render the proponent's boundary assumptions invalid; and

b. Incorporating entitlements from other groundwater users in the model domain into an updated groundwater model. These entitlements represent over 9,000 ML/year of groundwater abstraction, which is large compared to modelled pit inflows. Therefore, their exclusion may result in inaccurate model predictions.

Question 3: Are additional measures and commitments required to mitigate and manage impacts to water resources and water-related assets?

8. A number of additional measures and commitments are suggested to mitigate and manage impacts:

   a. Following revision of the numerical groundwater model, it is suggested that the proponent's GMIMP consider and incorporate:

      i. Selection of key groundwater monitoring bores on the basis of criteria such as target aquifers, and potentially affected groundwater users and groundwater dependent ecosystems;

      ii. Selection of key groundwater monitoring bores and commencement of monitoring within a timeframe than enables seasonal and inter-annual measurement of groundwater flux;

      iii. Identification of modelled drawdowns and triggers based on the updated hydrogeological study suggested in this advice;

      iv. Groundwater data from the existing New Acland Mine's monitoring program and/or other regional monitoring programs;

      v. A bore at coordinates 370000:6976000 to monitor the predicted 20m drawdown in the Walloon Coal Measures between monitoring bores 114P and the unnamed monitoring bore to the west near Lagoon Creek; and

      vi. An additional monitoring bore in the Marburg Sandstone (near bores 5a and 5b), given the uncertainties in relation to predicted drawdown within this aquifer described in Paragraph 1(s);

   c. Real time flow and water quality monitoring stations on Lagoon Creek would enhance management of controlled releases from the proposed project's environmental dams. It is suggested that measured water quality parameters include turbidity, dissolved oxygen, pH and electrical conductivity, and that these are measured in the environmental dams, as well as near the release point and at the junction with Oakey Creek;

   d. Risks to water quality would be minimised by updating the water balance to incorporate a more robustly calibrated representation of the flow and quality regime within Lagoon Creek. Based on the results of the updated study, the size of the environment dams and frequency and duration of releases may need to be reassessed;

   e. Regular monitoring of wastewater treatment plant effluent quality would enable early detection of any changes to effluent quality over time;

   f. Incorporation of suitable strategies to manage leachate from waste rock with elevated manganese concentrations into the proponent's environmental management plan would minimise risks to water quality;

g. Independent certification of infrastructure design by a practising erosion control or waterway specialist would provide a greater level of confidence that works within the floodplain would create minimal long term impacts;

h. Implementation of an environmental inspection program to identify emerging erosion and sediment mobilisation issues would enable early detection and management of potential impacts; and

i. Commitments for surface and groundwater monitoring should be presented as part of a water monitoring plan and should be consistent with the National Water Quality Management Strategy.

9. The Northland Inland Catchment has been identified as a Bioregional Assessment priority region. Data and relevant information from the proposed project should be made accessible for this Bioregional Assessment to assist the knowledge base for regional scale assessments.

Date of advice	10 April 2014
Source documentation available to the Committee in the formulation of this advice	New Hope Group (2014) Environmental Impact Statement for the New Acland Coal Mine Stage 3 Project
References cited within the Committee's advice	[1] Information Guidelines for Proposed projects Relating to the Development of Coal Seam Gas and Large Coal Mines where there is a Significant Impact on Water Resources available at: http://iesc.environment.gov.au/pubs/iesc-information-guidelines.pdf [2] Queensland Water Commission (QWC), 2012. *Underground Water Impact Report for the Surat Cumulative Management Report* [3] Department of Environment and Heritage Protection (2013) *Monitoring and Sampling Manual 2009*, State of Queensland, Brisbane [4] Queensland Government (2014) Wetland Info. URL: http://wetlandinfo.ehp.qld.gov.au/ [5] Cosser, P. R. (1988) Macroinvertebrate Community Structure and Chemistry of an Organically Polluted Creek in South-east Queensland, *Australian Journal of Marine and Freshwater Research*, 39, 671-83

Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development

Advice to decision maker on coal mining project

IESC 2015-073: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion

Requesting agency	The Australian Government Department of the Environment
Date of request	27 October 2015
Date request accepted	27 October 2015
Advice stage	Assessment

Context

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) was requested by the Australian Government Department of the Environment to provide advice on the New Acland Coal Mine Stage 3 project (the proposed project) in Queensland.

The IESC has previously provided advice to the Commonwealth Department of the Environment and the Queensland Office of the Coordinator-General on the draft Environmental Impact Statement (EIS) for the proposed New Acland Coal Mine Stage 3 project, EPBC 2007/3423 (IESC 2014-045 dated 10 April 2014).

This advice draws upon aspects of information in the proponent's Additional information to the Environmental Impact Statement (AEIS), together with the expert deliberations of the IESC. The project documentation and information accessed by the IESC are listed in the source documentation at the end of this advice.

The proposed project is to expand and extend by up to 12 years, the New Acland Coal Mine, located approximately 35 km northwest of Toowoomba in the Lagoon Creek Catchment and the Clarence-Moreton Basin of Queensland. The proposed project involves creation of three open cut pits to increase production of coal from the Walloon Coal Measures from 4.8 Mtpa to 7.5 Mtpa of thermal product coal. Ancillary infrastructure developments would include upgrading the existing coal handling and preparation plant (CHPP) and associated stockpile areas as well as construction of an 8-km rail-spur and balloon loop, and a train load-out facility.

The proposed project is located in the catchment of Lagoon Creek. Lagoon Creek is an ephemeral creek that flows into Oakey Creek, which is part of the larger Condamine River Catchment of the Murray-Darling Basin.

Key potential impacts

The IESC's advice of April 2014 identified significant uncertainty in the proponent's groundwater model predictions. While the proponent's groundwater model has been improved, uncertainties remain in the hydrogeological conceptualisation and subsequent revised groundwater impact predictions including the magnitude of drawdown and the lateral extent of potential impacts. Based on the revised assessment documentation, key potential impacts resulting from the proposed project are to groundwater resources, groundwater and surface water users and groundwater dependent ecosystems (GDEs), including the EPBC Act-listed endangered ecological community Brigalow (*Acacia harpophylla* dominant and co-dominant).

Assessment against information guidelines

The IESC, in line with its Information Guidelines (IESC, 2015), and consistent with matters raised in its April 2014 advice on the proposed project, has considered whether the proposed project assessment has used the following:

Relevant data and information: key conclusions

Evidence of faulting to the south and east of the proposed open cut pits has not been provided. Hydrogeological monitoring data to validate the stated groundwater flow "barrier" effect of faults (including justification of existence and extent of faulting) has not been provided. The proponent has not included groundwater abstraction data from surrounding groundwater users in the groundwater model. Surface water quality objectives remain undetermined.

Application of appropriate methods and interpretation of model outputs: key conclusions

Calibration hydrographs indicate the groundwater model has bias which results in frequent over-prediction of groundwater head in the alluvium and Walloon Coal Measures, when compared to observed data in monitoring bores. Updated modelling also predicts water levels within final voids will exceed the existing groundwater level, contributing to continued low confidence in the model conceptualisation and predictions.

Identification of GDEs, including EPBC Act-listed endangered ecological communities, has not occurred within the predicted lateral extent of groundwater drawdown, including outside of the proposed project area. Mapping of depth to groundwater and consideration of seasonal groundwater requirements of GDEs have not been provided.

Advice

The IESC's advice in response to the requesting agency's specific questions is provided below.

Question 1: The proponent has revised the groundwater modelling in response to the IESC advice of 10 April 2014, including a sensitivity and uncertainty analysis of the parameters and assumptions used within the original model. The revised modelling has been peer-reviewed and assessed by Queensland Government groundwater experts.

Does the IESC consider that the matters raised in its advice of 10 April 2014 are adequately addressed in the updated information provided in the proponent's EIS?

Response

1. No. A number of key matters raised in the IESC's advice of April 2014 remain unresolved, including evidence for the existence and justification of hydraulic properties of faults; representation of model domain boundaries, final voids and groundwater users in the groundwater model; identification of surface water quality objectives; and appropriate identification of GDEs. The unresolved matters, particularly regarding the chosen hydrogeological

conceptualisation (specifically the representation of faults) and model calibration approach, which may be contributing to bias and over-prediction of groundwater heads, result in continued uncertainty in the proponent's groundwater model and hence impact assessment.

Explanation

Groundwater modelling

2. Evidence, characterisation and validation of the role of faulting with regards to lateral extent and magnitude of impacts to groundwater resources is needed, with particular emphasis on faults to the south and east of the proposed open cut pits. Assessment data and monitoring bores are required to validate the assumptions made regarding faults. Monitoring bores need to be strategically positioned so that the influence of faults on groundwater head and flow can be determined.

3. The presented calibration hydrographs indicate that the updated groundwater modelling consistently over-predicts groundwater heads, by tens of metres in some cases, particularly in the alluvium and Walloon Coal Measures (e.g. monitoring bores 116P, 40Pc, CSMH1 east of proposed project area). This results in a lack of confidence in the hydrogeological conceptualisation, model calibration and predictions across the model domain. Future modelling and monitoring should consider specific environmental objectives (for example, estimating volumetric take from Oakey Creek Alluvium) using relevant calibration targets to improve groundwater impact predictions.

4. In the updated modelling, the proponent has used a relationship between topography and head level to determine constant head boundary conditions, except for alluvium for which a set value of 13.5 metres below ground level was used. These estimates need to be validated with measured groundwater level data in the vicinity of the model boundary, especially the closer eastern and western boundaries which are likely to have greater influence over model predictions.

5. The IESC considers there is a high degree of uncertainty regarding the scale of potential impacts associated with the proposed voids. This uncertainty is due to the predicted temporally variable source/sink status of the final voids, the associated potential seepage to the groundwater system, and the revised prediction that water levels will now recover to greater than pre-mining levels in Willeroo Pit (and Manning Vale East Pit in the 84^{th} percentile prediction).

6. The proponent has not included surrounding groundwater user abstraction data in the groundwater model. All groundwater fluxes should be represented in the model, and differentiation of mine- and landholder-induced impacts on groundwater levels is needed for assessment of impacts on specific areas or bores.

Surface water quality

7. Some physicochemical and nutrient monitoring data has been collected over a representative period. However, surface water quality monitoring for dissolved oxygen and contaminant metals from more than one sampling episode has not been undertaken. Representative surface water quality data (including dissolved oxygen and contaminant metals) is needed to determine the existing surface water quality within the project area because water quality of ephemeral rivers such as Lagoon Creek is typically highly variable with time. This data will then need to be used to determine downstream surface water quality objectives (see paragraph 16).

8. As noted in the IESC's April 2014 advice, the proponent agreed with the need for a study into the cause of elevated levels of copper in Lagoon Creek to determine if these concentrations are naturally occurring, mining-related or caused by an anomalous reading. The study has not been undertaken. Once complete, the study should be used to provide a better understanding of the

existing water quality during periods of flow in Lagoon Creek, especially "first pulse" flows, and inform the assessment of impacts to ecosystems and water users downstream of the proposed project.

Groundwater dependent ecosystems

9. Consistent with the IESC's April 2014 advice, GDEs need to be clearly identified within the zone of predicted groundwater impact. While the proponent utilised the Wetland*info* tool, a systematic approach to identifying vegetation GDEs is still needed and should include:

    a. using the hydrogeological conceptualisation to identify areas of shallow groundwater,

    b. maps that show depth to groundwater (ideally seasonal) contours in the basalt and alluvial aquifers, overlaid with vegetation and wetland mapping to aid identification of potential GDEs,

    c. application of this approach to the full extent of predicted drawdown impacts associated with the proposed project including outside of the project area, and

    d. application of techniques from, for example, the Australian GDE Toolbox (Richardson et al., 2011) and Eamus et al. (2015), to confirm groundwater use by vegetation and groundwater discharge to surface water bodies.

10. Identification of remnant patches of the EPBC Act-listed endangered ecological community Brigalow (*Acacia harpophylla* dominant and co-dominant), a known vegetation GDE, is needed. Identification of, and assessment of potential impacts to, this endangered ecological community needs to occur within the predicted zone of groundwater drawdown, including outside the project area.

Question 2: The Queensland Coordinator-General has imposed, stated and recommended conditions to mitigate and manage impacts to surface and groundwater, at Appendices 1, 2 and 4 respectively of the *New Acland Coal Mine Stage 3 project: Coordinator-General's evaluation report on the environmental impact statement (December 2014)* and these are reflected in the draft *Environmental Authority – New Acland Coal Mine (August 2015)*.

Does the IESC consider that the outstanding matters raised in its advice of 10 April 2014 in managing impacts to surface and groundwater are adequately addressed through the Queensland Coordinator-General's conditions of approval (December 2014)? If not, what outstanding matters are still required to be addressed?

Response

11. The Queensland conditions proposed under the draft Environmental Authority and imposed, stated and recommended by the Coordinator-General address a number of issues raised in the IESC's advice of 10 April 2014 that were not resolved by the proponent's AEIS. Residual matters raised in response to Question 1 (and the IESC's April 2014 advice) are outlined below.

Groundwater

12. The IESC has remaining concerns regarding the high degree of uncertainty over the role of faulting and its influence on propagation of drawdown impacts to areas surrounding the proposed project site. Specifically:

    a. The groundwater impact assessment is lacking a geological map to show locations of faults. Without a detailed hydrogeological investigation it is difficult to determine the hydraulic nature of a fault, particularly whether it is a barrier or conduit to groundwater flow (as also noted by the peer review of the proponent's revised groundwater modelling (AGE 2014)). Geological maps and hydrogeological field investigations (such as groundwater head measurements on either side of modelled faults) should be provided to validate the proponent's conceptualisation of the nature of faults, including verification of their existence, vertical and lateral extent, hydraulic properties and how they are parameterised in the groundwater model.

b. Further monitoring bores (in addition to those stated in the Coordinator General's report and the draft Environmental Authority) are needed to validate the predicted lateral extent of drawdown propagation, which is controlled in the Walloon Coal Measures by the faulting.

c. Future reviews of modelling should require validation of the existence and nature of faulting in terms of their effect on groundwater and a sensitivity analysis of their impact on predictions.

d. Monitoring requirements should be targeted towards reducing the uncertainty of the predicted lateral drawdown extent. This will be particularly important when determining the proponent's offsets requirements for the Commonwealth Government's Murray-Darling Basin Plan aquifers (the Oakey Creek Alluvial aquifer and the Main Range Volcanics aquifer) and make-good requirements. Additional investigations and modelling are required to reduce uncertainties in predictions of scale of impact to these aquifer systems.

13. In addition to the Coordinator-General's Schedule 3, Condition 2 regarding requirements for Oakey Creek Alluvial aquifer, inclusion of other water users' take within the groundwater model is needed. Accurate representation of landholder water use within the model, appropriate model outputs and presentation would be required to facilitate differentiation of mine-induced impacts from landholder impacts for specific wells or areas of importance to local landholders.

14. Further to the investigation into residual voids (draft Environmental Authority - Condition E20), inclusion of updated groundwater modelling and subsequent analysis of potential impacts associated with the final voids is needed. Such modelling and analysis would result in improved predictions of final water levels, changes in water quality with time, ongoing estimates of take via evaporation (and estimates of associated volumetric take from regulated alluvial and volcanic aquifers), and the scale and impact of seepage to surrounding aquifers. This would inform subsequent adaptive management measures that may need to be implemented during the proposed project.

Surface water

15. A large proportion of the water quality objectives for contaminants in surface waters and mine release waters has not yet been determined in conditions. Given the previously identified exceedances of pH, electrical conductivity as well as sulphate levels that are higher downstream of the existing mining operations in Lagoon Creek when compared to upstream, water quality objectives are needed to determine existing conditions and to allow identification of surface water quality impacts during the proposed project.

16. Water quality objectives should be informed by monitoring data gathered from the existing mine. While preference would be to use local data or monitoring information, the use of ANZECC/ARMCANZ (2000) guideline values would be appropriate while baseline data is being gathered. The Queensland Monitoring and Sampling Manual 2009 (DEHP, 2013) presents details on the design and implementation of baseline sampling techniques, especially in ephemeral rivers such as Lagoon Creek.

17. A range of surface water quality variables, including dissolved oxygen and contaminant metals, should be included in conditions that detail the monitoring requirements for surface and discharged waters. The IESC's April 2014 advice identified contaminants that were naturally elevated (i.e. copper, manganese and aluminium) and would be mobilised into surface water during flow events.

18. Further to the currently proposed state conditions, and as identified in the IESC's April 2014 advice, existing surface water quality and flow monitors along Lagoon Creek should be upgraded to facilitate continuous monitoring during discharges and natural flow events.

19. Schedule C of the draft Environment Authority sets out the monitoring requirements for environmental dams. Further to these conditions, consideration should be given to setting regular water quality monitoring requirements including frequency of monitoring and specific parameters to be monitored (e.g. physicochemical, nutrients and contaminants) within hazardous waste and environmental dams. This information should be used to inform options for improving water quality prior to release.

Groundwater dependent ecosystems

20. Vegetation mapping and identification has largely only occurred within the project area. Identification of impacts to vegetation GDEs (including EPBC Act-listed endangered ecological communities containing Brigalow) caused by groundwater drawdown within the full extent of the proposed project's resultant impact (including outside of the mining lease area) is needed to support the existing proposed offset and monitoring conditions.

Date of advice	10 December 2015
Source documentation available to the IESC in the formulation of this advice	Australian Groundwater and Environmental Consultants (AGE), 2014. *Groundwater Model Peer Review New Acland Mine – Stage 3.* Report prepared for New Acland Coal Pty Ltd. June 2014. (Appendix C of Appendix N, AEIS) New Acland Coal, 2014a. New Acland Coal Stage 3 Project Environmental Assessment documents, EIS. January 2014. New Acland Coal, 2014b. New Acland Coal Stage 3 Project Environmental Assessment documents, Additional information to the EIS. August 2014. Department of Environment and Heritage Protection, 2015. *Draft Environmental Authority – New Acland Coal Mine*. State of Queensland. 14 July 2015. Department of State Development, Infrastructure and Planning, 2014. *New Acland Coal Mine Stage 3 project. Coordinator-General's evaluation report on the environmental impact statement.* State of Queensland. December 2014.
References cited within the IESC's advice	ANZECC/ARMCANZ, 2000. Australian Guidelines for Water Quality Monitoring and Reporting. *National Water Quality Management Strategy (NWQMS).* Canberra: Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. DEHP, 2013. *Monitoring and Sampling Manual 2009 (Version 2)* [Online]. Brisbane: State of Queensland. Available: https://www.ehp.qld.gov.au/water/pdf/monitoring-man-2009-v2.pdf. Eamus, D., Zolfaghar, S., Villalobos-Vega, R., Cleverly, J. & Huete, A., 2015. Groundwater-dependent ecosystems: recent insights from satellite and field-based studies. *Hydrology and Earth System Sciences,* 19**,** 4229-4256. IESC, 2015. *Information Guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* [Online]. Available: http://www.iesc.environment.gov.au/system/files/resources/012fa918-ee79-4131-9c8d-02c9b2de65cf/files/iesc-information-guidelines-oct-2015.pdf. Richardson, S., Irvine, E. C., Froend, R. H., Boon, P., Barber, S. & Bonneville, B., 2011. Australian groundwater dependent ecosystem toolbox Part 1: assessment framework. Canberra: Waterlines report, National Water Commission.