

Statement of Evidence

"Analysis of Carmichael coal mine assessment"

Adani Mining Pty Ltd v Land Services of Coast and Country Inc. & Ors

Report for the Queensland Land Court

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Glossary

CMB –	Chloride mass balance approach to recharge estimation
GWDB –	The Queensland Government’s Groundwater Database
GHB –	General Head Boundary package of MODFLOW
K –	Hydraulic conductivity
Kh –	Component of hydraulic conductivity in the horizontal plane
Kv –	Component of hydraulic conductivity in the vertical plane
PERFECT –	Runoff and erosion model: “Productivity Erosion Runoff Functions to Evaluate Conservation Techniques”
PEST –	Model calibration software “Parameter Estimation”
Scaled RMS (or SRMS) –	Scaled Root-Mean-Square error as a measure of the goodness of fit between two datasets
Ss –	Specific storage of a confined aquifer
Sy –	Specific yield of an unconfined aquifer
WTF –	Watertable fluctuation method of recharge estimation
%RMS –	Percentage Root-Mean-Square error as a measure of the goodness of fit between two datasets

1 Introduction

- [1] In reference to the letter of engagement dated 25 November 2014 (see attachment B), from the Environmental Defenders Office (EDO) on behalf of Land Services of Coast and Country Inc. (LSCC), I have undertaken a review of materials pertaining to the Carmichael Coal 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. *Report for Carmichael Coal Mine and Rail Project: Mine Technical Report: Hydrogeology Report 25215-D-RP-0026*, prepared by GHD for Adani Mining Pty Ltd, 403 pp, 15 November 2012 (EIS Report);
 2. *Groundwater Model Peer Review Final Comments*. GHD, 6 pp, 18 October 2013 (GHD Response to URS Review).
 3. *Carmichael Coal Mine and Rail Project SEIS: Mine Hydrogeology Report Addendum*. Adani Mining Pty Ltd, 108 pp, 24 October 2013 (SEIS Addendum).
 4. *Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report*. Adani Mining Pty Ltd, 487 pp, 13 November 2013 (SEIS Report).
 5. *Response to IESC Advice*. GHD, 147 pp, 7 February 2014 (GHD Response to IESC).
 6. *Carmichael Coal Mine and Rail project: Coordinator-General's evaluation report on the environmental impact statement*. The Department of State Development, Infrastructure and Planning, Queensland Government, 608 pp, May 2014 (CG's Report).
 7. *Carmichael Coal Project Response to hydrogeology clarifications requested by DoE*. GHD, 9 pp, 6 May 2014 (GHD Response to DoE).
 8. *Carmichael Coal Project Proposed Groundwater Boundary Revisions*. GHD, 19 pp, 10 October 2014 (First Boundary Revisions Memo).
 9. *Carmichael Coal Project Proposed Groundwater Boundary Revisions*. GHD, 28 pp, 27 October 2014 (Second Boundary Revisions Memo).
 10. *Carmichael Coal Project Response to Federal Approval Conditions-Groundwater Flow Model*. Adani Mining Pty Ltd, 681 pp, 27 November 2014 (EPBC Response Report).
- [2] The references assessed in detail were numbers 6 to 10 above, which largely supersede earlier reports.
- [3] My approach to the review, given the limited time available, was to read carefully the materials provided by the EDO, and list point-by-point any issues arising from these documents, focussing on hydrogeology and groundwater modelling elements. I have not undertaken an independent review of the groundwater modelling files, nor have I undertaken any independent modelling of the study area. Given that my review is not a traditional groundwater model peer review, I have not applied the usual Review Checklists from the 2001 MDBC Groundwater Modelling Guidelines¹ (2001

¹ Middlemis H, Merrick N, Ross J. 2001. Murray-Darling Basin Commission Groundwater flow modelling guidelines, Project No. 125, Aquaterra Consulting Pty Ltd, Perth.

Guidelines) and the 2012 Australian Groundwater Modelling Guidelines² (2012 Guidelines). Rather, my commentary is based around the topics raised in the LSCC's Preliminary Identification of Issues, and the Joint Groundwater Experts Report, dated 9 January 2015 (Joint Report).

- [4] Prior to the meeting of experts on 22 December 2014, I was not informed of the details of concerns of Dr John Webb. I received a near-final draft of his report on 5th February 2015. Dr Webb's expertise differs from mine, in that he specialises more so in geology and closely related fields, whereas my area of specialisation is computer modelling, notwithstanding that there is some overlap given that we are both working in the general field of hydrogeology. Given the distinction between our areas of expertise, it is unlikely that Dr Webb and I might disagree on key elements of our respective evaluations. On reading Dr Webb's review, I found no disagreement with the substantive content of his review. It is clear from his report that Dr Webb and I focussed on different aspects of the proposed mine impacts, so our reports are complementary with only a small amount of overlap.
- [5] It is possible that, in part, more reliable conclusions might be achieved through a review of the computer files associated with the Carmichael mine groundwater model. However, the following caveats apply:
- a) The groundwater model reporting should serve to impart confidence in the methods used to produce predictions of impacts, and it is the reporting on which decisions are made. The reports should provide a standalone account of the various aspects of model development and implementation. The current review is founded on the available reporting for these reasons.
 - b) Access to the modelling files will improve only a small sub-set of the opinions expressed in this report. For example, the application of the STR package and the method of simulating the springs are unclear in the reporting, and an evaluation of the modelling files would clarify the methods used. However, the short-comings in the report in explaining these aspects of the methods are themselves an issue, given (a) above, and hence, the same issues would need to be raised regardless of any clarification obtained through assessing the modelling files.
 - c) A thorough interrogation of the modelling files will likely require an investment in time that is beyond the current review timelines.

2 My Qualifications

- [6] As outlined in my curriculum vitae (see Attachment A), I am a Professor in Hydrogeology at Flinders University, and a Chief Investigator of the National Centre for Groundwater Research and Training. My previous studies, work experience and career achievements are outlined in detail in Attachment A. These include such relevant experience as:
- d) Professional experience as a hydrogeologist and water resources engineer in private, public and academic sectors.

² 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.

- e) Co-authorship of more than 60 peer-reviewed, international journal articles, four book chapters, over 80 conference abstracts and articles, and various other technical publications and reports.
 - f) 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.
 - g) Numerous expert reviewer roles for international journals, Government agencies, Australian and international funding agencies, and other organisations.
- [7] 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; and
 - c) my position on the Technical Advisory Panel on Coal Seam Gas Water for the Queensland Government's Office of Groundwater Impact Assessment (2010 to present).

3 Summary of my opinion

- [8] The existing modelling of the potential impacts arising from the proposed Carmichael Mine contains a significant number of short-comings, to the degree that I hold major reservations as to the accuracy and reliability of model predictions. The major issues are summarised in descending order from the most significant (in my opinion), as follows:
- a) The prediction of impacts to springs is highly uncertain, because:
 - i) the understanding of spring hydrology in the region is weak, with significant differences between the model and conceptual diagrams;
 - ii) the approach to modelling springs is unclear; and
 - iii) there is no model testing of alternative spring conceptual models to evaluate the plausible range in spring impacts arising from the Carmichael Mine operations.
 - b) The lack of a transient calibration precludes the model's capacity to predict the timing of groundwater impacts, because the model is untested in its ability to make important predictions that have a time component (e.g. the timing of groundwater level decline, the extent of drawdown at a particular time, etc.).
 - c) The situation regarding the final voids is unclear and poorly assessed, for example:
 - i) recommendations for the final void surface by the CG are contradictory; and
 - ii) the calculations of the final void's hydrology make erroneous assumptions that lead to the best-case situation of a dry void.
 - d) Analysis and understanding of the uncertainty in model predictions is weak, compounded by:
 - i) the reports significantly over-state the certainty and accuracy of the model;

- ii) only a bare-minimum investigation of the model's uncertainty has been undertaken (i.e. a rather rudimentary sensitivity analysis) that fails to follow the current 2012 Guidelines; and
 - iii) in contradiction to statements in the reports, the sensitivity analysis is insufficient to ascertain the plausible range in impacts arising from mining operations.
- e) The reports overstate the model's reliability and in particular, suggestions that the model is conservative lack a firm basis.
- f) There is a long list of fundamental misconceptions within the various reports that undermines significantly my confidence that the conceptualisation and numerical model have been properly developed. As three examples amongst dozens of others:
- i) the direction of flow is wrongly suggested to preclude impacts on the Great Artesian Basin (GAB);
 - ii) automated calibration is reportedly free from subjective intervention by the modeller; and
 - iii) the important distinction between "head differences" and "head gradients" is misunderstood.
- g) The estimates of recharge seem too low. That is:
- i) inflows from ephemeral streams are ignored; and
 - ii) rainfall recharge is at the lower end of estimates for similar regions.
- This is important because:
- iii) low recharge values will lead to low calibrated hydraulic conductivity values, which leads to prediction of lesser impacts;
 - iv) low recharge values may lead to underestimation of modelled inflows to final void; and
 - v) errors in recharge will translate to errors in the simulation of groundwater discharge to and impacts on the Carmichael River.
- h) There is insufficient monitoring data outside of the mined area to infer reliable groundwater flow directions and trends, to determine the impacts of mining once dewatering begins, and to ascertain the relationship between the water levels of springs, streams/ivers and aquifers.
- i) There is no analysis of faults or other preferential flow paths, despite the presence of springs, which are likely aligned to geological structures (e.g. faults). Pathways through aquitards caused by faults and abandoned wells may strongly influence the hydrology of the study area.
- j) The conceptualisation and modelling of groundwater interactions with surface systems interaction is weak, to the degree that impacts on the Carmichael River and other watercourses arising from mining operations are highly uncertain.
- k) The conceptual model and numerical model are inconsistent, in that the cross-sectional depiction of flow paths violates the hydrogeology.
- l) Unnecessary errors and spurious flow directions are introduced by the boundary conditions, in particular in the western part of the model, where the model violates field observations. This

arises because the assumption of solely topography-driven flow in setting boundary conditions is flawed.

4 My opinion

- [9] The follow represents my opinion regarding groundwater modelling of the study area that has been described in the reference list documents. The sequence of major headings follows that of Section 3. Dot points under each heading highlight the issue in more detail relative to that provided in Section 3. Links to items in the Joint Report are identified in the following by “#” numbered references to the relevant paragraphs in the Joint Report.

4.1 The prediction of impacts to springs is highly uncertain.

Opinion:

- [10] The source of the Doongmabulla Springs is inconclusive (#7 in the Joint Report). Investigation of possible spring configurations using the model is lacking, and it is unclear whether the model offers a reasonable representation of the springs.

Details:

- [11] The statement in the CG’s Report at P110: “DEHP recommends that this information be obtained”, referring to spring flow variability information, is supported. The results are likely to assist in establishing spring sources, and transient modelling should aim to reproduce observed spring flow trends, in addition to the methods suggested in #7 in the Joint Report. Alternative representations of springs in the model (e.g. different source aquifers, different flow pathways to the surface) should be tested. In the modelling undertaken to date (e.g. in 2.3 and Tables 2 and 3 in the GHD Response to DoE), the downward gradient (upward flow) during pre-development conditions is reversed in all but Clematis-Dunda beds sequence. Hence, the flow reversal suggests that there is a risk that the Doongmabulla Springs will go dry depending on the source aquifer. An enhanced effort to examine the geology to the west of the mine area, to improve the conceptualisation of possible source aquifers for the spring, is also needed. For example, in the First Boundary Revisions Memo at P5 Section 3, and in the EPBC Response Report at P13 2.5.3, the statement that “Information held for GWDB [Queensland Government’s Groundwater Database] bores in the area was limited to basic lithological information from drillers logs and was not suitable for comparison with the modelled stratigraphy” is unconvincing. I expect that there is useful geological/stratigraphic information that has not been considered (perhaps due to time constraints) in the GWDB information – e.g. lithological data, particularly given that in the First Boundary Revisions Memo at P6 Section 4, it identifies 34 groundwater bores with water level information for the area.

4.2 The lack of a transient calibration precludes the model's capacity to predict the timing of groundwater impacts.

Opinion:

- [12] The absence of transient calibration is a model weakness. The transient behaviour of the system is not well understood (#13 in the Joint Report).

Details:

- [13] A transient analysis is necessary to simulate temporal aspects of the investigation (e.g. the speed of drawdown, seasonal effects). In order to determine whether storage parameters are reasonable, and to assess whether the model is producing reasonable transient simulation results, a transient calibration is required. There are several issues associated with the lack of transient calibration, including:
- a) The reasoning for avoiding it, given in the SEIS Report at P86, is not valid. That is, it is unsurprising that “most bores” have a short period of monitoring record. A few bores with transient records will usually provide useful insights to a transient calibration attempt. The suggestion that water level variations in time are small is also not a valid reason to avoid a transient calibration. In any case, it seems contradictory to state that there is limited time-series information, but that it is possible to discern that the system is temporally stable. The seasonality in spring flow contradicts this and indicates significant transient variations.
 - b) In the SEIS Report at P123, there is a discussion of timing of impacts, but no results or evidence are shown to support the assertions made about impact timing. In the SEIS Report at P127, the timing of predicted impacts can have a major influence on the magnitude of impacts, because magnitudes are reported for specific time periods. Plus, if the time-lag/attenuation is reduced, a bigger impact can occur before the mining ceases (compared to longer time lags or more significant attenuation).
 - c) A transient analysis is also needed to determine whether seasonally high groundwater levels may or may not cause groundwater discharge to some of the other surface systems in the region, to defend such statements as in the SEIS Report at P137 that “No significant impacts on flows in the various ephemeral creeks which drain the project (Mine) area are anticipated”.
 - d) The storage parameters given in the SEIS Report at P100 are all higher than the recommended value of Todd and Mays (2005), who suggest $S_s = 3 \times 10^{-6} \text{ m}^{-1}$ (S_s is the specific storage, which reflects the groundwater storage capability of confined aquifers, noting that higher S_s values produce slower aquifer responses to mine-induced drawdown). The model storage values lack adequate justification. In the CG's Report at P154, little is stated about aquifer storage properties, and yet these are critical for mining impact assessment. Simulation of historical aquifer trends (as a minimum) and transient groundwater model calibration should be used to assess the influence of storage properties on transient simulations.

4.3 The situation regarding the final voids is unclear and poorly assessed.

Opinion:

- [14] There is a need for clarification of conditions relating to the backfilling associated with final voids, with an expectation of adequate sealing against coal seam contacts (#20 in the Joint Report). This brings into question the manner in which the void was modelled, and in general terms, the void hydrology calculations are questionable.

Details:

- [15] There are two main issues here relating to the hydrology of the final void. Firstly, there is contradiction in the reports regarding void backfilling. For example, in the SEIS Report at P37 and the CG's Report at Pxiv, it seems impossible to fulfil the CG's recommendation to backfill the void to an elevation higher than the current groundwater levels, which are close to land surface. In the SEIS Addendum at P27, it recommends backfilling only to the top of the coal seams. The CG's recommendations regarding backfilling (i.e. "the proponent has agreed to partially backfill the final voids to the top of the coal seams" and "This backfilling will raise the final ground surface within the voids to above the current groundwater levels") are contradictory in the CG's Report at P149. In the CG's Report at P163, P165, P180, the 86 m drawdown post-closure wouldn't occur if the mine base was reinstated to current groundwater levels (as per the CG's recommendation), and hence, the CG's recommendation and the outcomes of the modelling are incompatible.
- [16] Secondly, the calculation of the final void water balance (e.g. in the SEIS Report at P108) is over-simplified. Firstly, a transient analysis is needed – steady-state conditions don't adequately evaluate the mine void hydrology. Also, the likelihood of ponded water in the void (both temporarily and permanently) is underestimated. For example, -1350 mm/year won't be realised as a net effective rainfall rate, because the void will be partly shaded and protected, reducing actual evaporation. The difference between potential and actual evaporation is not recognised elsewhere – i.e. in the SEIS Report at P83, evaporation rates are not 5.9 mm/d, and rather, this is potential evaporation. Also, it is not conservative to assume no catchment for every void in terms of the accumulation of solutes in the mine void and the capture of surface runoff. The calculations assume diffuse groundwater inflows, but these are more likely to be localised, especially if the void base is not perfectly horizontal (e.g. due to compaction, etc.). Issues of water quality are not assessed at all, despite that the water quality in the void will gradually deteriorate. The suggestion in the SEIS Report at P109 that the void base will remain "dry" is highly unlikely.

4.4 Analysis and understanding of the uncertainty in model predictions is weak.

Opinion:

- [17] An improved analysis of uncertainty is encouraged for future model development (#18 in the Joint Report). That is, the current analysis of uncertainty is inadequate to make reliable predictions with the model.

Details:

- [18] While the current uncertainty analysis might comply with the earlier 2001 Guidelines, and may be consistent with the type of analysis undertaken for other coal mining studies, the uncertainty analysis does not comply with the current 2012 Guidelines. In the interests of improved uncertainty analyses, future model improvements should bear in mind Dr Merrick's suggestion (in the CG's Report at P6 of Appendix 4, electronic P525) that a reasonable upper limit to a groundwater model is 1 million cells, and therefore it seems unwise to add additional layers to an already cumbersome model to assess regional impacts. The simulation of regional impacts may be possible with fewer layers, and this will allow a more computationally efficient uncertainty analysis.

Opinion:

- [19] Sensitivity analysis is not an adequate assessment of uncertainty in the model. For example, multiple calibration realisations are required to understand the uncertainty of predictions (#32 in the Joint Report). Also, there are misconceptions in the reports about the ability of model calibration to obtain accurate parameters.

Details:

- [20] The issues with the sensitivity analysis, the uncertainty analysis, and model calibration are inter-linked and multifaceted. For example:
- a) The sensitivity analysis (e.g. the SEIS Addendum at Piv) is not an adequate assessment of uncertainty, as highlighted in the current Australian Groundwater Modelling Guidelines. There are several reasons for this:
 - i) changing a single parameter uncalibrates the model and therefore each sensitivity simulation is not necessarily a plausible prediction. For example, if recharge is increased, K values should also increase (i.e., only R/K is determinable from calibration);
 - ii) the order-of-magnitude change described in the SEIS Addendum at P29 to develop the sensitivity analysis is not an appropriate method for assessing the plausible range of aquifer behaviour because different parameters have different plausible ranges (some parameters are unknown to greater than one order of magnitude, as mentioned in the SEIS Report at P127). In general terms, the sensitivity analyses cannot inform the extent of plausible aquifer behaviour (see the SEIS Addendum at P31 Figure 14), because sensitivity analyses only inform the degree by which a prediction will change with a parameter change – i.e. the sensitivities. The sensitivity analysis results are subsequently misinterpreted in the SEIS Report at P123, because sensitivity analyses do not identify the extent to which predictions may be different, and also, the errors in prediction from parameter errors may be cumulative.
 - b) It is not valid, in the SEIS Addendum at P36-37, to change individual parameters to reportedly implausible values to define the upper limit to the region's hydrological response to mining. The worst case should be sought using PEST (i.e. software used to calibrate the groundwater modelling, by adjusting model parameters to improve the match between field measurements and model predictions of the field measurements) whereby parameters are modified to match historical behaviour while simultaneously seeking the worst-case prediction of mine impacts.

- c) The 2001 MDBC Guidelines cited in the SEIS Report at P122 (see also the EPBC Response Report at P55) have been replaced by a 2012 version of the National Groundwater Guidelines (which are mis-referenced). The manner of applying the sensitivity analysis to explore model uncertainty has been updated in the new guidelines, which reflect alternative methods to the rudimentary sensitivity analysis of the current investigation.
- d) In the GHD Response to IESC at P5, the notion that calibration will lead to a single set of correct parameters is invalid. This is a fundamental flaw in the calibration philosophy, because the calibrated parameters are one set of a large and non-unique range of possible parameter combinations that could produce the same historical groundwater behaviour. However, each parameter set is likely to produce different future predictions. A single realisation of parameters is not a certain outcome, partly because it is only one of several possibilities. The misconception has propagated to the CG's Report at P114 – i.e., it is misleading to suggest that calibration produces a unique and correct value of K. Model non-uniqueness and the lack of flux measurements preclude this. The problem appears again in the CG's Report at P154-155, whereby the CG's review of groundwater modelling reads as though a single groundwater model is sufficient to assess impacts, when multiple calibration realisations are required to understand the uncertainty of predictions.
- e) In the Second Boundary Revisions Memo at Table 3, calibrated K values are different to those in the First Boundary Revisions Memo, but I am unable to find an explanation for the changes. Also, values like 1.00 (E-4) seem unlikely values to obtain from automated calibration unless these are from lower/upper bounds. This in itself is concerning, because it often indicates problems with the model set-up when parameters reach their limits during model calibration.
- f) From the EPBC Response Report at 2.9.1 and 2.9.3, it is clear that different fluxes are possible from different models that produce similar matches to the water level observations. Hence, the calibration does not inform the models ability to predict fluxes, which are therefore highly uncertain. It follows that it is not possible to inform recharge by calibration to heads.

Opinion:

- [21] The Type I to Type IV sensitivity analysis is no longer recommended (see the current 2012 Guidelines). The analysis as presented in the SEIS modelling report is not instructive (#19 in the Joint Report).

Details:

- [22] The use of "Type" parameters from the 2001 Guidelines is outdated (e.g. in the SEIS Report at P122), albeit it is conceded that the identification of Type IV parameters may still offer some useful insights if the results are carefully evaluated. However, there are misleading statements in the SEIS Report at P122, in that the measure of significance clearly influences the outcome of the Type-analysis of parameters. In the current study, despite the given reasoning for selecting significance levels, the definitions of significance seem biased, because:
- a) a low significance measure is used for calibration, and a high measure is used for prediction (consider that prediction errors may be cumulative);
 - b) the significance measure of spring drawdown differs for the two springs;

- c) visual inspection of the Type analysis plots (e.g. in the SEIS Report at Figure 41) gives the impression that the significance values have been chosen to avoid Type IV parameters; and
- d) the lack of data points above the prediction significance line in Figure 41 suggests that predictions are insensitive to calibrated parameters, and hence, the prediction is being controlled by uncalibrated parameters, and thus it is not informed by the calibration process and must surely be entirely uncertain. Additionally, in the SEIS Report at P122, Figure 41 does not show that the high significance parameters for calibration are high significance parameters for prediction. This figure is being misread.

4.5 The reports overstate the model's reliability.

Opinion:

- [23] All modelling contains a level of uncertainty (#9 in the Joint Report). This needs to be more strongly emphasised in the model reports, as outlined in other opinion points.

Details:

- [24] The degree of uncertainty in the modelling results is understated in many places. For example, in the First Boundary Revisions Memo, the measured heads are extremely uncertain, given that they come from different times and many were taken at the time of construction when water levels may have been significantly disturbed. This uncertainty needs to be reflected in the language used in the text, in the analysis of boundary condition effects on the model, and in any uncertainty analysis. As one example amongst many, in the SEIS Report at P89, the model is not sufficiently reliable to "confirm" aspects of baseflow accretion.

Opinion:

- [25] The occurrence of easterly groundwater flow does not necessarily preclude the occurrence of GAB impacts as stated in project groundwater reports (#12 in the Joint Report)

Details:

- [26] I disagree with statements in the SEIS Report at P107 & P134 and the CG's Report at P151-152 linking GAB impacts to flow directions, e.g. "Where this eastward groundwater flow direction is confirmed by further monitoring then no impacts on the wider GAB groundwater resources would occur as a result of dewatering". Drawdown propagates independently of the groundwater flow direction, under the principle of superposition for linear systems, and therefore the direction of flow is irrelevant to the potential for impacts from drawdown. The notions about impacts and flow directions presented by the authors are contradictory to the model's predictions. That is, the model predicts a difference in the leakage from the GAB aquifers with mine operations. The issue persists in the EPBC Response Report at 3.3.5, where incorrect ideas about flow direction and impacts are contradicted by the model. The lack of reconciliation between preconceived notions (i.e., the incorrect notion regarding impacts and flow directions) and modelling results is worrying.

Opinion:

- [27] The reporting fails to recognise that the model is highly uncertain in its prediction of flow rates (i.e. discharges to rivers, springs, the GAB, etc.), in particular relative to its ability to reproduce groundwater levels.

Details:

- [28] Altering the western boundary conditions changed significantly the Carmichael River/aquifer interactions (#16 in the Joint Report). The reporting is unclear about the distribution and significance of these changes; however this result implies that the model is highly uncertain in its prediction of flow rates relative to head predictions. Consider the following explanation:
- a) In the EPBC Response Report at 2.9.1, it is reported that the new model boundary had only a minor influence on the calibration statistics – i.e. the model is equally well calibrated.
 - b) However, the EPBC Response Report at 2.9.3 describes major changes to the flow regime – i.e. significant new inflows through the boundaries that lead to an order-of-magnitude change in groundwater flow to the Carmichael River (i.e. from -420 to -3100 m³/d net inflow) and double the discharge to other rivers.
 - c) This demonstrates a well-known groundwater philosophy that is miscommunicated within the reports: that a model calibrated to heads only is usually weak (highly uncertain) in predicting flows. This is demonstrated in the current model, which is largely insensitive to fluxes.
 - d) Model rates of flow should be compared to any available field-based estimates (e.g. base flow rates) in a re-calibration of the model before any model-based flow rates are considered reasonable, particularly given the lack of knowledge regarding hydraulic conductivity values.

Opinion:

- [29] Despite a high degree of confidence expressed in the calibration results, the latest SEIS model calibration statistics (12 %RMS on mine lease; 7 %RMS overall; here, RMS is statistical measure of the goodness of fit between field measurements and model predictions of field measurements) are at the limit of acceptability (#17 in the Joint Report).

Details:

- [30] In Table 9 of the EPBC Response Report, the SRMS values are relatively high (according to the 2001 Guidelines) and indicate that the K values in the revised model ought to have been obtained through recalibration.

Opinion:

- [31] I disagree that gradients are in “generally good agreement”, and that “The model also replicates reasonably well the magnitude of vertical gradients” as stated in the SEIS Addendum at P23 (see #30 in the Joint Report).

Details:

[32] In Table 2 of the SEIS Addendum, only one of three head differences (Δh) is adequately represented. In Table 3, only three of thirteen Δh 's are within half/double the observed gradient. Two of four Δh 's are reasonable in Table 4. Normal practice is to include head gradients in the calibration of the model, especially where flow across aquitards is critical to the predictions. This doesn't seem to have been attempted, and if it has, the calibration software PEST seems to have failed to find a good match.

Opinion:

[33] The claims for conservatism of the model appear to be overstated. As one example amongst others, the adoption of 160 m as a uniform fracturing height above longwall panels is not necessarily conservative due to the lack of field evidence for fracturing heights associated with multi-seam mining (#10 in the Joint Report).

Details:

[34] It is incorrect that the model can be assumed to be conservative, as stated in several places. The following qualifications apply:

- a) In the SEIS Addendum at P30, there is no basis for the suggestion that impacts are likely to reside amongst the lower values of the sensitivity analysis. This is not a general limitation of all numerical models of this type, in contradiction to the misleading statement in the SEIS Addendum at Page i. The statements here about attenuation are also untrue. I suspect that a higher degree of heterogeneity may cause worse impacts, e.g. due to enhanced flows through aquitards due to preferential pathways such as faults, abandoned wells, etc.
- b) In the SEIS Report at P98, the statement that more significant attenuation of impacts will occur for more variable strata requires qualification. For example, if strong layering exists, and layers are continuous over large areas, then the vertical hydraulic conductivity will be limited by the lowest permeability of the sequence. Therefore, more variable strata may indeed cause more significant attenuation, as stated, at least in terms of impacts crossing aquitards. However, other forms of variability in the strata, such as faults, discontinuities in layers, narrowing of aquitards, etc, may reduce attenuation (i.e. by allowing impacts to leak through aquitards). As a general rule of thumb, the larger the area of aquitard that is being considered, the more likely it becomes that flow through the aquitard will occur to some degree (because irregularities in the aquitard that allow for flow exchanges are more likely to be encountered). On this basis, and given the significant uncertainty in the knowledge of the properties of aquifer and aquitards more generally, I disagree with the statement in the SEIS Report at P135 that "...impacts on the Doongmabulla spring complex are therefore considered to be conservative and hence in most cases actual impacts are likely to be less than those predicted". I suggest that the uncertainty in the model's prediction of spring impacts is such that the conservative nature of some of the assumptions is not adequate to make such a statement, and that it is not possible at the present time to determine whether the model is conservative or not.

- c) In the SEIS Report at P102, in the sub-section “Groundwater level impacts at sites of specific interest”, there is not enough evidence to suggest that model estimates relating to River-groundwater flows are conservative, because there is no evidence of a persistent clay layer underlying the River, and the uncertainty precludes such a claim in any case.
- d) Long wall mining effects, described in the GHD Response to IESC at P15-16, may have a higher impact than those presented in the report. The statement that the Tertiary materials won’t develop cracks is given without a basis, and there is a significant risk of disruption to surface flow systems that is not addressed based on this poorly defended assumption. The consideration of 160 m (fracture zone above collapsed long wall mines) as “conservative” seems also without a valid basis.
- e) In the GHD Response to DoE at 2.4 and Figure 3, a 1 m drawdown at Doongmabulla Springs seems plausible.
- f) In the GHD Response to DoE at 2.5, a single bore log is not adequate to assess the hydrogeology of a set of springs that are likely controlled by structural features that were not intercepted by the bore log.

4.6 There is a long list of fundamental misconceptions within the various reports.

Opinion:

[35] The number of fundamental errors in the groundwater modelling reports is significant, and calls into question the overall validity of the modelling (#31 in the Joint Report).

Details:

[36] Aside from errors presented elsewhere in this document, the following bring into question the validity of modelling and associated groundwater conceptualisation/calculations (I apologise for the long list, but there is no other way to make this point):

- a) In the SEIS Addendum at P47, it is wrong to suggest that changing the GHB heads is the same as changing the GHB conductance (i.e. “increasing the conductance has the same effect as reducing the GHB elevation and vice versa”) - higher conductances are similar to fixing the heads, whereas higher boundary heads raises the boundary head elevation. In the SEIS Addendum at P47, it is suggested that the model predictions are insensitive to the boundary conductances and elevations, but the testing is inadequate to draw this conclusion. As is demonstrated in later model revisions, changes to the western boundary introduce major changes to the model’s simulation of stream-aquifer interaction, so the statements here are eventually invalidated. Also, in the SEIS Addendum and the SEIS Report (e.g. P83), the GHB conductances should have been set using the constitutive equation, and then modified through calibration, but by default they should reflect differences in aquifer K values. Also, from the SEIS Report at P82, P84, Figure 29 and the GHD Response to IESC at P10, the choice of placement of GHB cells seems to lack reasonable justification.

- b) Figures 4 to 8 in the SEIS Addendum are truncated and don't show the model results in the most western part of the model domain, so it's difficult to gain an understanding of the model performance in this area.
- c) Vertical head differences have been misrepresented as vertical gradients in project modelling reports (#30 in the Joint Report). In the SEIS Addendum at P23-25, in the text and Tables 2 to 4, hydraulic gradients greater than 10 are reported. It appears that "head differences" and "gradients" have been mixed up. According to Darcy's Law, gradients drive flow, and hence, a head difference is not meaningful without knowing the distance over which the head difference occurs. In order to properly evaluate any groundwater system, investigation and understanding of "head gradients" are essential.
- d) It is concerning to read in the SEIS Report at P55 that the hydraulic conductivity (K; a measure of the ease with which can flow through the aquifer/aquitard) values obtained for the alluvium were too low. There is no explanation to indicate that the same under-estimation of K occurred in the testing of other aquifers.
- e) A correction is needed to the understanding of the river package in the SEIS Report at P60. That is, discharge occurs when groundwater levels are higher than the river water level, not the bed.
- f) In the SEIS Report at P81, the STR (Stream) package is not the best available technology. The CHF package of MODFLOW-SURFACT is a more physically based method of simulating stream flow.
- g) In the SEIS Report at P83, the text refers to dry cells, and it is well known that dry cells are an issue for standard MODFLOW models, but it is not clear what was done in MODFLOW-SURFACT to deal with the usual issues with dry cells. There is no information on this, and rather, the text reads as though dry cells are not an issue for the code somehow.
- h) In the SEIS Report at P87 and Table 14, it is poor practice to adopt initial values for calibration at upper or lower limits, for several reasons:
 - i) this biases the direction in which calibration will modify the parameter;
 - ii) calibration parameters from a previous model (in the SEIS Report at P89) are not more reliable than field-based estimates, if the previous model was somehow inferior to the current model;
 - iii) initial values are similar to setting preferred values, because insensitive parameters remain unchanged – hence, where initial values differ to best estimates, the calibration will be biased.
- i) In the SEIS Report at P87, it is wrong to suggest that PEST is objective because it is automated. PEST is (and should be) controlled by the user.
- j) In the SEIS Report, the calibration limits don't seem to reflect plausible limits – i.e. the parameter ranges are too small. In any case, the calibration should have used regularisation (invoking expert knowledge using preferred values), which is the mainstream approach to model calibration that reduces issues of model non-uniqueness.

- k) In the SEIS Report at P96, Table 16, it appears that the model is biased in the area south of the Carmichael River in producing water levels that are too low. Model bias is concerning, because it indicates some systematic error in the model that is not caused by random uncertainty.
- l) In the SEIS Report at P97, Table 17, spring discharge is missing from the water balance of the model. Also, in the EPBC Response Report at P64, there is no mention of the manner by which the springs are simulated.
- m) I question the total pumping rate of 152 kL/d given in the SEIS Report at P97. This is the same as the pumping needed for 3000 cows (at 50 L/d) or 535 people (at 280 L/d). It seems low given the climate, study area extent, and irrigation in the area. The issues around pumping estimates are highlighted in the EPBC Response Report at 2.7.6, as:
 - i) the value of 30% as a factor of the licensed pumping for irrigation doesn't seem to have a basis;
 - ii) the source of specified volumes for stock bores is not clear; and
 - iii) there are stock bores in the inactive zone of the model that will not be simulated.

Also, in Figure 26 of the EPBC Response Report, none of the bores that were identified in the October/November gauging are included as pumping wells in the model. As such, I suspect that there are pumping wells in the region that have not been included in the model. In Table 15 of the EPBC Response Report, an explanation is needed for the lack of groundwater use from Layers 5 to 12 – it seems a little odd that no pumping comes from these formations.
- n) In the SEIS Report at P101, I am unable to reconcile the drain conductance of 1000 m²/d with $K_v = 0.4 \text{ m/d}$.
- o) The sensitivity testing of void inflows, shown in Figure 44 of the SEIS Report and at P124-P125, doesn't make sense. The little grey bar (representing the baseline condition) should be in the same y-axis position for all cases. The fact that the whole sensitivity of Riv/Str conductance falls below the baseline value is not logical. Also, 4000 m³/d is not the maximum because:
 - i) plausible ranges in parameters haven't been tested;
 - ii) errors can be cumulative;
 - iii) sensitivity testing is a linear analysis of a non-linear model; and
 - iv) uncalibrated models were used to test different parameters.
- p) In contradiction to the text in the SEIS Report at P127, the value of Rewan K (hydraulic conductivity) being lower than the minimum expected does indicate a weak sensitivity of impacts on the springs to this value. The concept expressed here, that sensitivity is associated with the value of the parameter, is invalid given that regularisation is not used.
- q) The following issues regarding springs occur in the GHD Response to IESC at P8:
 - i) predicted impacts to the spring complexes are not associated with groundwater flow directions, but with connectivity;
 - ii) the modelling results are not highly conservative and it is not "highly unlikely" that spring impacts might be worse than model results;

- iii) the conceptual model is not a worst case for flow to the springs, but rather, a high K connection (mine-to-springs) is worse;
- iv) there is a mismatch between the high confidence in the model and the weak knowledge of the spring systems.
- r) The buffer area for the Carmichael River mentioned in the GHD Response to IESC at P10 bears little relation to cumulative impacts. East-west connectivity is not necessarily maintained by a 1 km wide buffer for the River.
- s) In the CG's Report, Figure 5.18 does not indicate the impacts on the different types of springs, as suggested in the text at P111 and P113. Conceptual models of springs (i.e. Figure 5.18) should include preferential groundwater flow pathways, spring-to-wetland flow controls, and geochemical and geomechanical processes.
- t) In the CG's Report at P114, it is invalid to suggest that the height of the mound controls the degree to which the spring can withstand a head change. Rather, it is the height that the water rises above the lowest point of the mound. If the mounds cease to flow, any surrounding wetlands will be significantly impacted. Potential changes to calcite precipitation/dissolution should also be assessed. The same applies in the SEIS Report at P135 and P136 - a mound spring with a 3-4 m mound will not continue flowing if the head is dropped by 1.1 m.
- u) In the CG's Report at P119 and elsewhere, there are inadequate future commitments to accounting for cumulative impacts. From the CG's Report at P197, it seems necessary to combine the current mine's effects with those of the China Stone mine and the Waratah Coal Project. In the CG's Report at P549 of 608, there appears to be no commitments to cumulative impacts.
- v) In the Second Boundary Revisions Memo, the comparisons between modelled head contours and field observations need to show all field observations on the maps (e.g. Figure 10), rather than the inferior earlier data set.
- w) In the EPBC Response Report at P53, contradictory statements are given, whereby it is first stated that base flow to streams represent the recharge lower limit, but they also commonly over-estimate recharge.
- x) In the EPBC Response Report at P53, 0.1 to 4 mm/y is not around 1% of 550 mm/y, it is between 0.02% and 0.7%.
- y) Corrupted modelling results are apparent within the various reports. For example, in the EPBC Response Report at P56, the simulations with elevated water balance errors are meaningless. Rather than suggest that corrupted simulations should be "treated with caution", all model results should be "treated with caution", and corrupted model results should be abandoned. The sensitivity results in the SEIS Addendum at P31 and P34 seem to contain corrupted modelling results, as indicated by non-monotonic parameter-prediction relationships. This has a significant bearing on the outcomes – e.g. in Figure 30 in the EPBC Response Report, the last point on the baseflow impacts sub-graph appears erroneous (it probably has a higher y-coordinate). I suspect that non-convergence (mathematically-failed model runs) is playing a role here.

- z) In the EPBC Response Report at P83, the statement “While inferred flow in some strata, such as the GAB units, is counter to the bedding dip, which creates resistance to flow according to Darcy’s Law...” is contradictory to the laws of hydrogeology. Flow will be driven by head gradients, independently of the dip angle.
- aa) In Table 6 in the EPBC Response Report, the “permeable” AB and D coal seams have a hydraulic conductivity 800 times lower than the “moderately permeable” Dundas beds. The K doesn’t seem to match the description, bringing into question the model’s representation of aquifer properties.
- bb) In Figure 30 in the EPBC Response Report, the x-axis seems to be wrong – all of these should refer to recharge and not K values.
- cc) In Table 12 in the EPBC Response Report, there are large errors in water levels from relatively shallow wells that suggest model problems. Errors of 17, 22, 25 and 34 m highlight that the modelled heads are too high in some areas – i.e. there appears to be bias in the model.
- dd) In the EPBC Response Report at 2.9.3, the extension of the model area to include Lake Galilee should incorporate the evapotranspiration losses of the lake, and these should appear in the water balance, or at least valid reasons are needed for neglecting the lake’s influence on the groundwater systems. Other elements of the water balance are also unclear or wrong – for example, in Table 15 of the EPBC Response Report, the title infers outflow, but inflows are also included, except that recharge is neglected, and hence it’s impossible to understand the water balance of each layer. Plus, the water balance should include flows between layers to close the water balance. Also, the fluxes in Figures 34 to 45 in the EPBC Response Report are difficult to interpret, and the flow rate units are wrong.
- ee) In the EPBC Response Report at P122, I disagree with basing model evaluation only on the single statistical measure (i.e. the scaled RMS; SRMS). As recommended in both groundwater modelling guidelines (the 2001 Guidelines and the 2012 Guidelines), other statistics are required because the SRMS can be biased by the water level range.
- ff) Section 3.4.1 in the EPBC Response Report is rather confusing. I don’t understand why different zones are used for post-closure impacts relative to operational impacts. I can’t see how similarities between the two zone alignments suggest confidence in the predictions. I also can’t find where it is differentiating between the central and western zones, within the results.

4.7 The estimates of recharge seem too low.

Opinion:

- [37] The adopted recharge rates appear to be at the low end of what might be expected. There are issues with the estimation of recharge that include rigour applied to several of the interpretation methods, the completeness of reporting, and the exclusion of other forms of recharge (e.g. episodic flooding and leakage from ephemeral streams) (#34 in the Joint Report).

Details:

[38] A number of short-comings are evident in the estimation of recharge that collectively undermine the final values adopted in the model, including:

- a) In the SEIS Report at P63-64, the recharge values considered typical do not accord with the earlier quoted values of up to 30 mm/year (river recharge) and up to 28.2 mm/year (preferred pathways).
- b) In the SEIS Report at P64, the value of S_y (specific yield or storage parameter for the upper aquifer) used in the watertable fluctuation method (WTF) of recharge estimation is not reported, and yet WTF recharge is proportional to S_y . The WTF method does not apply to confined aquifers, and hence the analysis in the SEIS Report at P65 seems invalid. Further evidence is needed for the WTF values in the EPBC Response Report at 2.10.2. In the EPBC Response Report at 2.10.2, it is invalid to assume that the WTF method over-estimates recharge – i.e., the WTF method produces a time-average flux if it is correctly applied.
- c) In the SEIS Report at P66, Carmichael River baseflow cannot be used as a surrogate for recharge to the area, because the water balance may be dominated by flow through the boundaries (according to the model at least).
- d) In the SEIS Report at P66, the potential for additional recharge from flooding by the Carmichael River should be assessed and discussed.
- e) Comments in the SEIS Report at P81 and P83 suggesting that recharge can be obtained through calibration are misleading. Non-uniqueness in the parameters of the groundwater model means that recharge is not estimable through calibration; especially given the breadth of plausible K values (see the 2012 Guidelines). Also, recharge to the extended western region is also indeterminable from calibration. It is highly doubtful, in the EPBC Response Report at P54, that PEST was used properly to infer spatial variability in recharge.
- f) The statement in the GHD Response to IESC at P4: “The fact that the numerical model has been able to replicate the observed flow directions, without recourse to unrealistic flow parameters, is considered to provide further supporting evidence that the conceptual model of topographically controlled flow is accurate” is misleading. The boundary heads dictate the flow directions, and these were set by the modeller. Hence, it is the job of the modeller to set boundary conditions to predefined notions of regional flow directions; it is not reasonable to expect the model to confirm or establish this. Thus, there is no further evidence offered by the model that topographical flow is accurate, especially given the water level mismatches evident in Figures 4 to 8 of the SEIS Addendum.
- g) The calibrated value for recharge of 0.1 mm/y seems too low, albeit, the spatial distribution of recharge is unclear from the reports. A low recharge can arise during calibration when K values in the model are too low. In comparing to recharge values from Kellet et al. (2003), it is not appropriate to consider that similar geological units have similar recharge – climate effects must also be considered (see the EPBC Response Report at 2.10.1). Also, neglecting inflows from “other water courses” (in the SEIS Report at P97 Table 17) may under-estimate wet-season recharge, given so many losing streams in the study area. Given that the short modelled length of the Carmichael River is a major source of recharge (see the EPBC Response

Report at 2.9.3), other surface systems likely also provide significant inputs, which are presently neglected.

- h) There are issues in the application of the chloride mass balance (CMB) approach. In the SEIS Report at P66 and the EPBC Response Report at P53, the CMB method shouldn't be applied without considering chloride (Cl) dryfall. Also, in the EPBC Response Report at P53, the spatial variability in Cl (and recharge) should be reported, rather than regional averages.
- i) In the EPBC Response Report at P53, it is stated that the Cl of runoff should be incorporated into any application of the CMB approach to estimate recharge, but there is no evidence that this was actually done. Furthermore, with significant stream leakage to the area, and the fact that the Carmichael River is losing but contains groundwater-like Cl levels, the CMB approach for the study must be modified accordingly.
- j) 1D unsaturated zone recharge models like PERFECT (i.e. software to model runoff and soil infiltration based on input parameters regarding the field site) are unable to inform the absolute value of recharge. PERFECT was calibrated to recharge from other methods (see the SEIS Report at P81), and therefore it shouldn't be considered as an independent and objective source of recharge estimation. Further, the details of PERFECT modelling are scant, i.e. spatial and temporal variability are not given, and runoff is not reported. In the EPBC Response Report at P54, there is insufficient explanation to understand the manner with which recharge modelling results have been incorporated into the groundwater model.

4.8 There is insufficient monitoring data outside of the mined area.

Opinion:

- [39] In general, there is insufficient monitoring to develop a baseline of current groundwater conditions (including historical transient behaviour), to reliably determine flow directions, and to allow for any future impacts of mining to be measured and assessed. For example, there remains significant uncertainty regarding flow at and beyond the western boundary of the model due to a lack of field measurements (#5 in the Joint Report).

Details:

- [40] The lack of measurements and the implications of this (e.g. the poor understanding of flow directions) are under-stated in the technical reports, such as in the EPBC Response Report and in earlier reports. For example, there are only four heads available for the Clematis Sandstone (see Figure 2 in the SEIS Addendum), and none in the northern half of this formation. The problem is compounded by short-comings in the few head measurements that are available. For example, in Figure 3 of the SEIS Addendum, there are two nearby head measurements (90258 and 17980) in the Dunda Beds that disagree, and many of the records are single measurements taken from disturbed aquifer conditions shortly after drilling.

Opinion:

- [41] Data short-comings are the primary cause of errors and inconsistencies in the interpretation of groundwater flow directions.

Details:

- [42] While the 31 March 2014 report by HydroSimulations (Appendix 4 to the CG's Report, p497) provides a reasonable best estimate of flow directions (#2 in the Joint Report), other reports describe erroneous flow directions (#11 in the Joint Report). For example, the location of the groundwater divide in the Colinlea sandstone is incorrect in the conceptual model used to develop the groundwater model (#3 in the Joint Report). The text in the EPBC Response Report at P60 ("a groundwater divide forms close to the western edge of the model") suggests that there is a groundwater divide in Figure 31, but this seems incorrect, and no such groundwater divide is evident, at least not across the entire western boundary. The pattern of flow in the north-western corner is also hard to defend – i.e. very steep and complex contours, without any nearby observations, and flow does not follow the topographic controls (e.g. Dyllingo Creek). That is, the complexity of the head contours infers a detail of knowledge that does not accord with available information.

Opinion:

- [43] The data inadequacies are worsened by neglecting a significant amount of available data in developing the numerical model.

Details:

- [44] In the EPBC Response Report at 2.5.3, I question the elimination of all water level observations that don't have depth information, because it's often possible to estimate the depth of bore intakes by reviewing any lithology/statigraphy information and presuming that the bore was constructed in the most permeable sequence. In the Second Boundary Revisions Memo, Appendix B identifies that a considerable amount of data has not been considered to this point (October 2014) in the investigation. New data amounts to some double the number of water level measurements, at least for certain formations. Figure 7 in the Second Boundary Revisions Memo should display the locations of the new data. The volume of new information warrants re-conceptualisation and a re-calibration of the model, and it is necessary to consider and report on the spatial distribution/depth/time/geology of the available head measurements, including the 54 GWDB bores mentioned in the EPBC Response Report at P14 2.5.5. Maps of these groundwater levels are required. It is concerning that such a large amount of Government data was omitted from the investigation (and approval process) to date.

4.9 There is no analysis of faults or other preferential flow paths.

Opinion:

- [45] The analysis of faults (and other preferential pathways such as abandoned wells) is inadequate to predict with reasonable certainty the competence of the aquitards as barriers to flow. Given that faulting may be feeding Doongmabulla Springs, it could be a major feature of the conceptual model in places (#26 in the Joint Report). The effect of preferential flow pathways is neglected in the analysis of aquitards, and rather, the Rewan hydraulic conductivity values are at the lower end of field-based values, and therefore, the calibrated groundwater model may under-predict leakage through the Rewan (#27 in the Joint Report).

Details:

- [46] The assessment of faults and discussion of the impacts of faults is unconvincing. For example, in the GHD Response to IESC at P12-14, a fault does not need to have a throw that is sufficiently large to bring aquifers in contact before it can influence groundwater flow. I disagree with the statements in the GHD Response to IESC at P6 – i.e., sensitivity testing assumes that the Rewan Group acts uniformly as an aquitard. The role of faults should be considered at two different scales: (i) the influence on spring flow, and (ii) the influence on regional-scale linkages between aquifers. The Rewan hydraulic conductivity values are at the lower end of field-based values, and therefore, the calibrated groundwater model may under-predict leakage through the Rewan, especially if the Rewan has faults through it. For example, in the SEIS Addendum at P7, the lower limit to K values in the Rewan is lower than any of the site-specific tests. In the SEIS Addendum at P38 Figure 16, it seems that the K value adopted for the Rewan is lower than six of seven previous studies. In the CG's Report at P114, the K values of the Rewan ($K_h = 7.4E-5$, $K_v = 7.4E-6$ m/d) are lower than field-testing values ($K_h = 9.5E-5$) and the Surat median value ($3.6E-4$ m/d). Without further evidence of the extensiveness of lithological sequences within the Rewan, it's not clear that Rewan vertical K values in the model should be lower than field tests. It is likely that field testing, focusing on in-situ vertical hydraulic conductivity properties of the Rewan, are needed to obtain reliable information about the Rewan. In the absence of these, there is high uncertainty in the potential rates of leakage through the Rewan (e.g. QGC (2012) International Aquitard Vertical Hydraulic Conductivity Review by SKM finds 10-14 orders of magnitude in plausible ranges of K_v). QGC (2012) also find that fractures and abandoned wells may provide significant connectivity through aquitards (e.g. a 0.1 mm, non-intersecting fracture every 10 km in an otherwise impermeable aquitard increases K_v to 5×10^{-6} m/d. Applying K values from a small number of laboratory and field tests, under pre-mining conditions, has the potential to underestimate significantly the system's regional-scale transmissiveness/leakances, rates of groundwater movement, and extent of mining impacts.

4.10 The conceptualisation and modelling of groundwater interactions with surface systems interaction is weak

Opinion:

- [47] The approach to modelling surface water features, such as ephemeral streams, is likely to have introduced significant errors and uncertainty in the model results. In particular, it is thought that the simulation of ephemeral streams may have produced an error in the modelled recharge to the groundwater system (#15 in the Joint Report).

Details:

- [48] Several issues led to the conclusion that there are errors in the simulation of surface systems (i.e. ephemeral streams and the Carmichael River), including:
- a) Ephemeral streams have been modelled as drain cells and therefore can only take water from the model rather than allowing recharge into the model. While it is recognised that modelling of ephemeral streams is difficult, they may in reality present an additional source of recharge to the groundwater system.

- b) It is unclear how the Carmichael River was simulated aside from the STR package (i.e. the MODFLOW package that simulates stream flow whereby surface water moving between model cells is accounted for) cells, i.e. in the SEIS Addendum at P26. There is surprisingly limited drawdown near the Carmichael River that might be caused by high conductances assigned to the Carmichael River. A clearer description of the modelling methodology for representing the Carmichael River is required to understand the approach to its simulation.
- c) River and streams were not correctly modelled in the SEIS Report at P82, in that the “largest horizontal cell direction” is not a valid means for setting the RIV (i.e. the River package of MODFLOW) and STR conductances (i.e. the conductance is the resistance to flow of the bed of the river/stream). Also, it is incorrect that aquifer K will control the flow if high conductances are used. The conductance ought to be treated as a flow rate controller, whereby a high conductance equals a high flow rate for a given head difference. Further, in the SEIS Report at P124, 0.4 m/d is not a “relatively high K value” for a sandy river bed in determining the Carmichael River conductance. Also, in the EPBC Response Report at 2.7.5, the riverbed should be lower than the land surface elevation at the centre of a model cell, because water courses are always embedded in the landscape. Further, the application of RIV cells with water level = bed elevation precludes recharge from losing rivers, in contradiction to the known hydrology of the region’s surface water systems. In the SEIS Report at P82, it is unclear what is meant by the undefined parameters Stop and Sbot, which “were set at 0.1 m and 0.2 m from the stream stage, respectively”. The reader requires more explanation to understand what was done, and hence there can be little confidence that streams and rivers are correctly represented.
- d) In the SEIS Report at P82, it is odd that the STR package was used for only a limited stretch of the Carmichael River. It is unclear how the remainder of the Carmichael River was simulated, but it may have a significant bearing on the model’s performance.
- e) In the SEIS Report P83, it is misleading to suggest that the EVT package (the MODFLOW package that simulates groundwater evaporation as a function of the watertable depth below the land surface) simulates evaporation losses from the Carmichael River. Also in the SEIS Report at P83, some basis is needed for the 1 m extinction depth of the EVT package, which seems small for areas with significant tree coverage. Further, it is not the case that there is conflict between EVT and stream and river packages.
- f) In the SEIS Report at P113, there is inadequate investigation to estimate a 10 km migration upstream. More is needed to produce an estimation of distances of reduced river flows than this simplistic, unphysical extrapolation.

4.11 The conceptual model and numerical model are inconsistent

Opinion:

- [49] The conceptual cross sections used in the major modelling reports, e.g. the SEIS Report, the EPBC Response Report, are simplistic and do not accurately represent the probable flow conditions (#6 in the Joint Report). More detail is required to indicate flow directions, and flow lines crossing the Rewan violate the basic premise of this formation being an aquitard (#25 in the Joint Report).

Details:

[50] The conceptual diagram used across several of the reports (e.g. Figure 3 in the EPBC Response Report) indicates only topographical controls on flow when the geology is also a critical factor. While topographical controls are important, the heads will be independent of the topography in places, and important flow features will almost certainly be overlooked with the application of a topography-groundwater level relationship to define the boundary heads. Hence, the assumption used to define boundary conditions is incorrect, and has led to model water levels that do not comply with field observations (see section 4.5). The mismatch between the conceptualisation and the numerical model is highlighted by the following shortcomings:

- a) the flow in Figure 3 of the EPBC Response Report is drawn as simple 1D flow lines, but there are multiple aquifers, and flow between them needs to be incorporated into the conceptualisation;
- b) flow lines are drawn crossing the Rewan Formation to create flow in an easterly direction (e.g. in the SEIS Addendum at P19) – this violates the basic premise of this formation being an aquitard;
- c) there is nothing in the conceptual model about spring flows – i.e. in terms of preferential flow paths to the surface from underlying sequences;
- d) the interactions between Lake Galilee and the underlying aquifer are not indicated; and
- e) the flows in the schematic are not consistent with the numerical model flow directions.

4.12 Unnecessary errors and spurious flow directions are introduced by the boundary conditions.

Opinion:

[51] The numerical model does not comply with head measurements in the north and northwest of the model domain (#4 in the Joint Report).

Details:

[52] Water level mismatches evident in Figures 4 to 8 of the SEIS Addendum, amongst other model-measurement mismatches (see section 4.5). With so few measurements available to define boundary (GHB) heads, it is surprising that some wells are poorly calibrated to (e.g. 69443 in Figure 2 of the SEIS Addendum), because of the latitude available to define boundary heads. That is, it is odd to misrepresent heads near the boundary given that the heads near the boundary are defined by the modeller through the GHB cells.

Opinion:

[53] The numerical model does not comply with flow directions indicated by head measurements.

Details:

- [54] There is significant uncertainty and a lack of clarity relating to the boundary flows in Table 10 of the EPBC Response Report and as inferred from groundwater contours in Figure 31. The three wells in the south-western corner indicate a strong westerly component of flow whereas the modelled flow direction is easterly in this direction. The field observations in the Permian overburden (in Figure 4 of the SEIS Addendum), the AB seam (in Figure 5 of the SEIS Addendum), the Permian interburden (in Figure 6 of the SEIS Addendum), and the D seam (in Figure 7 of the SEIS Addendum) indicate components of westerly flow in various locations adjacent to the mine area that are not reproduced by the model.

Opinion:

- [55] The method of assigning boundary head values to the model, i.e. assuming that water levels reflect changes in topography, has led to significant misrepresentations of groundwater conditions at the boundaries.

Details:

- [56] In the EPBC Response Report at P79, the statement that Figure 46 “indicates a strong correlation between ground elevation and groundwater level” is disputable. Figure 48 shows a rather weak correlation, and Appendix B to the Second Boundary Revisions Memo indicates that the notion of linking groundwater levels to land surface elevations is not a valid approach. I question the exclusion of 16898 and 103561 in the EPBC Response Report on the grounds that they don’t agree with the topography-water level correlation. The use of topographic controls to define boundary heads should be reconsidered, and rather than a simple topography-groundwater level function, boundary heads should be determined based on a wider array of information – e.g. water levels in all aquifers, topography, expert interpretation of recharge and discharge features, etc. While it is generally true that a stronger topographic control on water levels is expected in shallower aquifers, the results are not sufficiently compelling (for all but the uppermost formations) to use such a relationship to define extensive lengths of boundary at the detriment of honouring field measurements. The persistent issues with flows in the western part of the model should invoke a re-think of the methodology here.

Opinion:

- [57] The assignment of boundary conditions ought to have considered water levels outside of the model domain.

Details:

- [58] Setting GHB heads ought to have considered water levels outside of the modelled domain, rather than simply using water level measurements that are clustered in and around the mine area (e.g. in Figures 4 to 8 of the SEIS Addendum). Given this, and statements in the SEIS Report at P18, P76, P86, and the GHD Response to IESC at P2-3, an improved understanding of the groundwater conditions to the west of the mine area is required to model this area with reasonable confidence. The search for heads ought to be extended further to the west and north, given the sparseness of available heads near the boundary in the north-western area.

Opinion:

[59] The Option 2 scenario (250 m AHD boundary) in the latest GHD model (EPBC Response Report) is unrealistic. Lowering all of the boundary heads by 25 m is an indefensible approach which has created a greater degree of inconsistency with the field data than is already apparent in Option 1 (275 m AHD boundary) (#14 in the Joint Report).

Details:

[60] While it is understood that Option 2 is an approval condition imposed by the Australian Government Department of the Environment, this doesn't preclude appropriate caveats in the reports in regards to the unrealistic nature of this simulation.

Opinion:

[61] Changes to the western boundary introduced major changes to the model's predictions (#33 in the Joint Report).

Details:

[62] Changes to the western model boundary provide for an estimate of impacts in the vicinity of the previous model boundary that would otherwise have been considered invalid. While most of the drawdowns are similar, and up to moderate changes in fluxes have been observed, the boundaries of the previous model were too close to predicted drawdown contours to allow for a confident prediction of drawdown extent.

5 Response to new spring flow assessment

[63] Having read the document by Noel Merrick dated 3 February 2015, *re: Adani - Carmichael Coal Project: Assessment of Potential Reduction in Spring Flow*, I have concerns about the calculations undertaken here, as follows.

[64] It is correct that the head difference that drives water to the surface causing spring flow is the difference between the artesian source aquifer and the watertable head at the surface.

[65] However, Dr Merrick's calculations are problematic, for the following reasons:

- a) The "watertable head at the surface" needs to be the head directly at the spring vent, and not a watertable estimate at some distance away from the spring.
- b) The source aquifer head must be obtained from head measurements from a well that accesses the source aquifer.
- c) I expect that, given [a], the head at the spring (which is the watertable head that is needed in any spring flow calculation) is actually higher than the watertable head that is reported by Dr Merrick (i.e. noting that the spring outflows are above the land surface and the watertable nearby is below the land surface).
- d) I expect that the source aquifer head is actually unknown, given that Dr Merrick is using the spring water level as the source head. Note that if there are springs that do not flow, then

their water levels (e.g. in a turkey's nest) will likely be a good estimate of the source aquifer head.

[66] Given [64](a) to (d), Dr Merrick's calculation need to be reconsidered as:

- a) The source aquifer head is probably about the turkey's nest water level at Doongmabulla Springs.
- b) The "watertable head at the surface" (i.e. the spring water level) is the respective elevation at which each spring is flowing.
- c) Hence, each spring will have a different driving head difference (source aquifer head minus watertable head at the surface/spring water level) – depending on the elevation at which it is presently flowing. This assumes that the source aquifer's head is constant across the spring group.

[67] In conclusion:

- a) The use of the nearby watertable head (i.e. 2-3 m below ground surface) in the estimation of the head difference is incorrect. The head difference (source aquifer head minus spring water level head) is probably much smaller than that suggested by Dr Merrick, because the heads at the springs are higher than 2-3 m below ground surface. Hence, the springs are much more susceptible to drawdown impacts (i.e. ΔH_B in Dr Merrick's equation is much smaller and therefore the relative reduction in flow is much larger).
- b) The assumption by Dr Merrick that the spring will continue to flow if the head at the spring was 2-3 m below land surface is incorrect. The spring ceases to flow when the head at the surface is below the surface.
- c) I expect that any springs with points of discharge that are low (near the land surface), and/or that are presently slow flowing (i.e. suggesting that they perhaps have a small driving head difference), will cease to flow with small changes in the source aquifer head.
- d) Any estimate of the spring behaviour requires knowledge of the source aquifer heads.
- e) In many cases, a spring will cease to flow when evaporation is able to account for the upward groundwater leakage. Given the climate of the area, I expect that the evaporation losses are rather large, and this needs to be taken into account in any calculation of spring flow susceptibility to drawdown. That is, in order for the spring to flow, the upward flux must account for evaporation and hence be higher than one might otherwise expect.
- f) Ultimately, given that there are springs with discharge points that are almost at the land surface, the change in flow will be up to 100% of spring flow, and not the small values of a few % suggested by Dr Merrick.

6 Confirmation

[68] I confirm that:

- a. the factual matters included in this statement are, as far as I know, true; and
- b. I have made all enquiries I consider appropriate; and

- c. the opinions included in this statement are genuinely held by me; and
- d. this statement contains reference to all matters I consider significant; and
- e. I understand my 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 my fees or expenses, and I have complied with the duty; and
- f. I have read and understood the rules contained in Part 5 of the Land Court Rules 2000, as far as they apply to the me; 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.

7 Signature



Adrian Werner, 6th February 2015

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EDUCATION

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EMPLOYMENT HISTORY

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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

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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
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- 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*
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- 1992** Royal Automobile Club of Queensland, Engineering Undergraduate Prize
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- 2012-present** Member of the American Geophysical Union
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PUBLICATIONS

Thesis

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- Morgan LK, Werner AD, Carey H (2013) A national-scale vulnerability assessment of seawater intrusion: Seawater intrusion vulnerability indexing – quantitative, Geoscience Australia Record 2013/20, Canberra, Australia, 93 pp., ISBN: 978-1-922201-50-8, www.ga.gov.au/corporatedata/74959/Rec2013_020.pdf.
- Morgan LK, Werner AD, Ivkovic KM, Carey H, Sundaram B (2013) A national-scale vulnerability assessment of seawater intrusion: First-order assessment of seawater intrusion for Australian case study sites, Geoscience Australia Record 2013/19, Canberra, Australia, 159 pp., ISBN: 978-1-922201-49-2, www.ga.gov.au/corporatedata/74959/Rec2013_019.pdf.
- Cook S, Dixon-Jain P, Hocking M, Sundaram B, Morgan LK, Ivkovic KM, Werner AD, Norman R, Caruana L, Garlapati N (2013) A national-scale vulnerability assessment of seawater intrusion: Vulnerability factor analysis, Geoscience Australia Record 2013/08, Canberra, Australia, 329 pp., ISBN: 978-1-922201-28-7, www.ga.gov.au/corporatedata/74661/Rec2013_008.pdf.
- Ivkovic KM, Dixon-Jain P, Marshall SK, Sundaram B, Clarke JDA, Wallace L, Werner AD (2013) A national-scale vulnerability assessment of seawater intrusion: Literature review, data review, and method development. Geoscience Australia Record 2013/03, Canberra, Australia, 188 pp., ISBN: 978-1-922201-19-5, https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=74650.
- Ivkovic KM, Marshall SK, Carey H, Morgan LK, Sundaram B, Dixon-Jain P, Caruana L, Garlapati N, Werner AD (2012) A national-scale vulnerability assessment of seawater intrusion: Coastal aquifer typology, Geoscience Australia Record 2013/04, Canberra, Australia, 215 pp., ISBN: 978-1-922201-22-5, www.ga.gov.au/corporatedata/74648/Rec2013_004.pdf.
- Morgan L, Werner A, Morris M, Teubner M (2012) Modelling seawater intrusion in the Willunga Basin, South Australia, In: Harrington N, Cook P (eds) Willunga research update: October 2012, pp. 44-54, National Centre for Groundwater Research and Training, Adelaide, Australia, 78 pp. <http://www.groundwater.com.au/publications>
- Ivkovic KM, Marshall SK, Morgan LK, Werner AD, Carey H, Cook S, Sundaram B, Norman R, Wallace L, Caruana L, Dixon-Jain P, Simon D (2012) National-scale

- vulnerability assessment of seawater intrusion: Summary report, Waterlines report no. 85, National Water Commission, Canberra, 182 pp., ISBN: 978-1-922136-00-8, http://www.nwc.gov.au/data/assets/pdf_file/0014/23162/85-Seawater-intrusion.pdf.
- Post VEA, Werner AD (2012; Awarded a 2013 Water Industry Alliance Smart Water Award) Solute transport modelling, Chapter 10, pp. 125-153, In: Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapp A, Boronkay A, Australian groundwater modelling guidelines, Waterlines report no. 82, National Water Commission, Canberra, Australia, 203 pp., ISBN: 978-1-921853-91-3, <http://archive.nwc.gov.au/library/waterlines/82>.
- Keppel M, Halihan T, Love A, Post V, Werner A, Clark J (2012) Formation and evolution of mound springs, Chapter 3, pp34-59, In: Love AJ, Shand P, Crossey L, Harrington G, Rousseau-Gueutin P (eds) Groundwater discharge of the western margin of the Great Artesian Basin, Australia, project report prepared for the National Water Commission, Canberra ISBN: 978-1-922136-08-4. http://nwc.gov.au/data/assets/pdf_file/0020/29315/AWMSGAB_Volume_III_Part1.pdf.
- Werner AD (2010) A groundwater flow model of Uley South basin, South Australia, Report prepared for the Eyre Peninsula Natural Resources Management Board, Port Lincoln, Australia, 109 pp.
- Werner AD (2010) A seawater intrusion model of Uley South basin, South Australia, Report prepared for the Eyre Peninsula Natural Resources Management Board, Port Lincoln, Australia, 69 pp.
- Werner AD, Barratt R, Turnadge C (2010) Hydrological assessment of the Flinders University lake catchment: Minimising tap water use. Report prepared for Flinders University, Adelaide, Australia, 58 pp.
- 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
- Ward JD, Werner AD, Howe B (2009) Saltwater intrusion in Southern Eyre Peninsula, Report developed through the Eyre Peninsula Groundwater, Allocation and Planning Project, Eyre Peninsula Natural Resources Management Board, Port Lincoln, Australia, 62 pp., www.epnrm.sa.gov.au/Portals/4/Water/Saltwater%20Intrusion%20Final%20Report.pdf
- Dittmann S, Duong S, Fairweather P, Fallowfield H, Kämpf J, Lester R, Leterme S, Seidel A, Seuront L, Werner A (2009) Investigating the coastal waters of Coffin Bay: Research plans and recommendations, Unpublished report prepared by the Flinders Research Centre for Coastal and Catchment Environments for the Eyre Peninsula Natural Resources Management Board, Flinders University, Adelaide, Australia, 117 pp.
- Reid MA, Cheng X, Banks EW, Jankowski J, Jolly I, Kumar P, Lovell DM, Mitchell M, Mudd GM, Richardson S, Silburn M, Werner AD (2009) Catalogue of conceptual

- models for groundwater-stream interaction. eWater Technical Report, eWater Cooperative Research Centre, Canberra, 134 pp, ISBN: 978-1-921543-22-7. www.ewater.com.au/uploads/files/Reid_et_al-2009-Model_Catalogue.pdf
- Rassam DW, Werner AD (2008) Review of groundwater-surfacewater interaction modelling approaches and their suitability for Australian conditions, eWater Technical Report, eWater Cooperative Research Centre, Canberra, Australia, 58 pp., ISBN: 978-1-921543-02-9. www.ewater.com.au/uploads/files/Rassam_Werner-2008-Groundwater_Review.pdf
- Ward JD, Evans AD, Hutson JL, Werner AD (2008) Recharge, climate change and seawater intrusion: Southern Eyre Peninsula, South Australia, Report prepared by Flinders University through the Southern Eyre Peninsula Hydrogeology Research Collaboration, Adelaide, Australia, 65 pp.
- 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.
- Werner AD, van Den Akker B, Jakovovich D, Jacob A, Bestland EA (2007) A desktop study of the groundwater resources of Cousine and Cousin Islands, Seychelles, Nature Seychelles – MSP GEF Funded: Improving Management of Private/NGO-Owned Nature Reserves and High Biodiversity Islands, 98 pp.
- 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.
- Werner AD (2005) Pioneer Valley groundwater amendment to the water resource plan, Report 4: Seawater intrusion modelling of the Pioneer Valley, Queensland Department of Natural Resources and Water, Brisbane, 65 pp.
- 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.
- Werner AD (1998) Report on a groundwater flow model for Bribie Island, unpublished report of Queensland Department of Natural Resources and Water, Brisbane, 88 pp.

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

2015-2017 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

- 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”*
- 2013-present** 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”*
- 2012-present** Dr Juliette Woods, Principal Supervisor, *Research fellow (part time) in Program 2, National Centre for Groundwater Research and Training*
- 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

Masters by Coursework Projects (1-year)

- 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 Poldia 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, *Remedial 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, Aarhus 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)
- 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, IAHI 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

- 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

- 2012-2015** 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** 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 Academy of Sciences, 3 February to 3 March 2015
- 2013** Invited Visiting Scholar, funded by the Nanjing Institute 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 Institute 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 Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing (China), 9-23 November 2008.

Invited Seminars

- 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 Politècnica 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 (2000-2014; excluding student supervision):

Topic	Location	Years Taught	Year Level	Class size	L*	PW*	T*	FP*
Centre for Groundwater Studies Lectures (Stream-aquifer interaction, Conceptual modelling, Groundwater modelling, Decision support tools, Island hydrology)	Various cities	2003-2006	Industry	40-90	5	-	-	
E2233 Fluid Mechanics	Uni of Qld	2000-2002	2	~40		3	2	
9E101 Applied Mechanics (Statics)	Uni of Qld	2000-2002	1	~40		3	8	
CIVL4140 Groundwater and Surface Water Modelling	Uni of Qld	2002, 2006	4	30-40	13	3	3	
ENVR1101 Environmental Science 1	Flinders Uni	2006-2010	1	21-33	1			
CPES1102 Science and Society	Flinders Uni	2007	1	52	2	1		
CPES3017 Groundwater Hydrology (TC)	Flinders Uni	2007	2-3, GE	34	26	6	12	8
ENVR3100 Environmental Science 3	Flinders Uni	2007-2008	3, GE	18-20	2	6		8
CPES2019/CPES3023 Earth Sciences Field Camp (TC)	Flinders Uni	2007-2008	2-3, GE	53-61	3	5d	6	24
WARM8450 Global Water Systems I (TC)	Flinders Uni	2007-2009	GE	17-48	7		4	
WARM8480 Water Resources Planning and Management	Adelaide Uni	2007-2009	GE	~30	2			
CPES7106 Advanced Topics in Hydrology (TC)	Flinders Uni	2007-2009	H, GE	8-13	6	18		
CPES3172 Earth Fluid Dynamics and Modelling (TC)	Flinders Uni	2007-2010	3, GE	15-27	18	9	2	
SERC2011 Research Project 1	Flinders Uni	2008	2	10		12		
SERC3000 Research Project 2	Flinders Uni	2008	3	5		12		
C&ENVENG3003 Environmental Engineering III	Adelaide Uni	2008-2009	3-4	~60	5		3	
CPES8004 CGS National Groundwater School (TC)	Flinders Uni	2008-2009	GE, D	3-16				
CPES3151 Groundwater and Soil Hydrology (TC)	Flinders Uni	2008-2010	2-3, GE	21-34	24	10	12	8
EASC1101 Earth and Environment I	Flinders Uni	2010	1	207	1			
EASC4713 Advanced Studies in Natural Systems (TC)	Flinders Uni	2011	H, GE	12		28		
EASC3741 Groundwater (TC)	Flinders Uni	2011-2014	3, GE	25-41	24	8	10	8
EASC3742 Earth Fluid Modelling (TC)	Flinders Uni	2012-2014	3, GE	19-27	16	8		

*Number of contact hours is the maximum for the given years, L – approximate lecture contact hours; PW – approximate contact hours for practicals, laboratories or workshops; T – approximate tutorial contact hours, FP – approximate field practical contact hours, 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

- 2010-2014** 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), Webinar for NCGRT on *Balancing the Books Across Discrete Surface-Subsurface models* (27 April 2014)

Teaching Administration

- 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
- 2010-present** Member of the Flinders Research Centre for Water and Sustainable Environments
- 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
- 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)
 - 2007-present** Associate Editor of the international scientific journal: *Journal of Hydrology* (Ranked 5th from 80 “Water Resources” journals, by 2012 Impact Factor)
 - 2009** Awarded “Excellence in Editing” for Associate Editorial work for the Journal of Hydrology
- (See also *Invited Roles for International Journals*)

LEADERSHIP IN PROFESSIONAL/COMMUNITY SERVICE ACTIVITIES

Expert Industry Reviews

- 2012-2015** 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** 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.

Other Reviews

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

Leadership in Conferences, Workshops and Short Courses

- 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, *LAH 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, *APCMM: 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-LAH-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 - Letter of instructions



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

25 November 2014

Professor Adrian Werner
School of the Environment
Flinders University
Bedford Park, South Australia 5042

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

Dear Professor Werner

Land Services of LSCC Inc. – Analysis of Carmichael coal mine assessment

We confirm that we act for Land Services of Coast and Country Inc. (**LSCC**) in respect of its concerns with the Carmichael Coal Mine (**Project**). LSCC has made an objection to the grant of a mining lease (**ML**) and 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 LSCC, we wish to engage you to act as an independent expert witness in the Proceedings in relation to your area of expertise; groundwater modelling.

2. Instructions

- 2.1 You are instructed to review this letter and accompanying documents and advise generally as to whether you consider there are any significant issues or deficiencies in the assessment of your area of expertise for the Project.
- 2.2 Participate in the court process in the manner set out in the orders of the Court made on 20 October 2014.

3. Background information

- 3.1 The Project is a proposed open-cut and underground coal mine 160 km north-west of the town of Clermont, in Central Queensland. The mining lease application is for 30

years with an annual coal production rate of around 60 million tonnes per annum, but it is noteworthy that the Applicant's intention is to run the mine for 60 years.

- 3.2 The Project is situated in the Galilee Basin in the catchment of the Burdekin River, which flows into wetlands and the Great Barrier Reef, and the area of the Project and its surroundings is predominantly used for agriculture, particularly grazing.
- 3.3 The thermal coal deposits for the Project are located within Mining Lease Applications 70441, 70505 and 70506 (**MLAs**). Approximately 28,000 hectares of the mining lease area is proposed to be disturbed by the open-cut and underground mining operations and related activities.
- 3.4 Adani Mining Pty Ltd (**Applicant**) lodged MLA 70441 for a mining lease (**ML**) under the *Mineral Resources Act 1989* (Qld) (**MR Act**) on or about 8 November 2010 and subsequently applied for MLAs 70505 and 70506 on 9 July 2013.
- 3.5 The Coordinator-General declared the Project a significant project¹ for which an environmental impact state (**EIS**) was required under the *State Development and Public Works Organisation Act 1971* (Qld) (**SDPWO Act**) by [gazettal notice](#) on 26 November 2010.
- 3.6 The Applicant's EIS was published and public submissions invited from 15 December 2012 to 11 February 2013. A Supplementary EIS (**SEIS**) was published and public submissions invited from 25 November 2013 to 20 December 2013.
- 3.7 The Coordinator-General's report on the Project under the SDPWO Act was delivered on 7 May 2014. The Coordinator-General recommended that the mine be approved subject to conditions.
- 3.8 The Applicant made an application for an environmental authority (**EA**) under the *Environmental Protection Act 1994* (Qld) (**EP Act**) on 11 April 2014.
- 3.9 Objections to the MLAs and EAs were referred to the Queensland Land Court on about 29 September 2014.

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 (a copy of the index to the current Dropbox brief is **Annexure A**). We can provide these document in other electronic format or in hard copy if necessary.
- 4.2 We draw your attention in particular to the general application and approval documents in Index B.

5. **Timing**

- 5.1 Our client lodged an objection to the ML on 17 June 2014, and an objection to the EA on 10 September 2014.

¹ Note that the SDPWO Act was amended in December 2012 (with the amendments taking effect on 21 December 2012). The amendments replaced the term 'significant project' with the term 'coordinated project' and these terms may be used interchangeably.

- 5.2 You be required to participate in the proceedings in accordance with the Orders made on 20 October 2014 (document 22 of Index A of your Brief).
- 5.3 You may be required to meet with any corresponding expert from the other parties and prepare a joint report on setting out points of agreement and disagreement.
- 5.4 You may be required to give oral evidence, or be cross-examined on your evidence, at a hearing.

6. Your duty to the Land Court

- 6.1 We enclose as **Annexure B** 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 LSCC as your client.
- 6.3 We also emphasise that we and our client don't 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 Suggestions for the format of your report are set out in **Annexure C**, "Format of your statement of evidence".
- 7.2 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.
- 7.3 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—
 - 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;
- (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 the Carmichael 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

A handwritten signature in black ink, appearing to be 'Sean Ryan', with a stylized, cursive script.

Sean Ryan

Senior Solicitor

To provide feedback on EDO services, write to us at the above address.

ANNEXURE A – Index to Brief

ANNEXURE B

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 C

Court Rules

- 1 A copy of the relevant sections of the *Land Court Rules 2000* is provided at Annexure B.
- 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 us;
- specifically identify and refer to any literature or other source materials (eg text books, industry guidelines and handbooks) used in support of your opinion. 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 to the court and has complied with the duty;
- f) the expert has read and understood the Land Court Rules 2000, as far as they apply to the expert;
- 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

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.