Our Ref:
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Date: 26 July 2013

To: John Ross
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From: Dr Noel Merrick

Re: **Gloucester Gas Project - Water Balance Peer Review**

Introduction

This report provides a Peer Review of the extended water balance analysis for the Gloucester Basin under Condition 17 of the EPBC 2008/4432 approval for the Gloucester Coal Seam Methane Gas Project, Gloucester Region, New South Wales, issued under the authority of the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC).

Condition 17 does not insist on a peer review. Nevertheless, AGL Upstream Infrastructure Investments Pty Ltd (the grantee of the approval), has voluntarily commissioned an independent peer review.

The review has been conducted by Dr Noel Merrick of Heritage Computing Pty Ltd. Apart from over 40 years experience as a professional hydrogeologist, geophysicist and groundwater modeller, Dr Merrick has specific experience in the Gloucester Basin, having led the groundwater assessments for two recent open cut coal mine expansions (Duralie and Stratford). He also conducted the Peer Review of the conceptual (hydrogeological) model developed by Parsons Brinckerhoff (PB) under Condition 3.9 of the Part 3A approval (MP 08_0154). The Director-General of the NSW Department of Planning & Infrastructure approved the appointment of Dr Noel Merrick as an appropriately experienced and qualified hydrogeologist for the undertaking of that review.

Methodology

The peer review has been undertaken through examination of a written report, following two meetings with the developers of the water balance.

The water balance analysis has been documented in a report by PB:

- Parsons Brinckerhoff, 2013, Water Balance for the Gloucester Basin. Report No. 2162406A PR_7296 prepared for AGL Upstream Investments Pty Ltd. Revision B, Final Report. Authors S. Brown and R. Rollins. Date 12 July2013. 49p + 1 Appendix.

Conditions

SEWPaC Condition 17:

The person taking the action must revise the water balance model to:

a) take into account the following inputs:

i. field-based investigation of the spatial distribution of strata and structures within the project area and the role of faulting and its influence on migration of groundwater and/or gas into surface water systems;

ii. investigation of the age, depth and location of groundwater including proximity to known faults and fractures;

iii. a baseline investigation of gas occurrence in surface and groundwater;

iv. results from pilot testing of the Stratford and Waukivory pilot wells;

v. baseline data associated with Phase 1 and Phase 2 studies;

vi. information on the assessment of a representative site for fault testing; and

b) extend to 1000 metres below ground level;

c) ensure that all hydrological inputs and outputs are accounted for (sum to zero); and

d) include a list of information sources and statements on confidence, accuracy and precision.

A report on the revised water balance model, including the inputs described in a) above, must be approved by the minister prior to the finalisation of the numerical hydrogeological model (refer to Condition 18).

Initial Comments

The water balance report commences with an overview of data sources, existing hydrological and hydrogeological conditions, and conceptualisation. These aspects are reviewed separately by Merrick (2013[1]) and will not be revisited here. The water balance analysis follows in Chapter 4 of the PB report.

It should be recognised at the outset that a basin-wide water balance analysis is an imprecise procedure, as many of the components are not directly measurable. To allow estimation of the more intractable components, PB has constructed a simple numerical model. This is a sensible approach, as it forces consistency between the measurable and inferred component magnitudes, and ensures conservation of mass. The model has an appropriate Class 1 confidence classification, according to the definition in the Australian Groundwater Modelling Guidelines issued by the National Water Commission (NWC) in June 2012 (Barnett *et al*., 2012[2]) .

[1] Merrick, N.P., Letter Report: Gloucester Gas Project - Groundwater Peer Review. Heritage Computing Report HC2013/15 for AGL Energy Limited. 6p.

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

The opening lines of Chapter 4 of the PB report give a valid definition of a water balance in terms of net inflows and net outflows, with the difference being attributed to changes in aquifer storage. Under assumed equilibrium conditions, over the long term, the changes in storage can be equated to zero. The assumptions listed prior to Section 4.1 are considered valid and appropriate. The methodology outlined in Section 4.1 also is considered appropriate.

The conceptual water balance model is illustrated very clearly in Figure 4.1 of the PB report and the considered components of the water balance, and the main geological components of the groundwater system, are illustrated very effectively in Figure 4.2. This diagram is populated with annualised volumetric estimates in Figure 4.4. The latter figure contains the entire quantification of the water balance. The reviewer has checked that the input volumes and output volumes are in balance, under the assumption of equilibrium conditions (no significant changes in storage in the long term).

Specific Comments

Table 4.1: In the Aquifer Storage row of this table, the reference should be to unconfined storage rather than total storage, as the small volume of confined storage is to be calculated separately.

Section 4.2.1: Although unstated, the adoption of 1,053 mm as the representative annual rainfall, averaged across four stations, would have an error range of about ±8% (based on the minimum and maximum long term means at the stations). Later, in Table 4.8, the uncertainty in the total rainfall estimate is indicated correctly to be about ±10%.

Section 4.2.2: The estimates of aquifer recharge by three independent methods are in reasonable agreement. The subsequent application of the simple numerical model provides a fourth method. The highest values (4-13% of rainfall) are obtained by the water table fluctuation method in alluvium by assuming a specific yield of 0.1. It is noted that a different estimate for specific yield (0.2) is used subsequently in Table 4.6 for aquifer storage calculations. If 0.2 were used consistently for specific yield, the alluvial recharge rate would reduce to 2-7% which is in better agreement with the baseflow analysis method. The numerical model method settled on 3.5% overall, but it is not clear what separate rates were applied to the alluvium and to the shallow rock unit.

Section 4.2.2: No separate estimate has been made for aquifer recharge by flooding. This is likely to be insignificant for the shallow rock unit but could be important for the alluvium. As this would be difficult to estimate *a priori*, its determination should be deferred until a detailed numerical model is built. In the meantime, the contribution from flooding would be absorbed in the long term rainfall recharge estimate.

Section 4.3.1: For consistency, the baseflow should be expressed as 8-9 GL/y rather than 9 GL/y, as this results from a range of 2.4-2.9% of rainfall for two catchments within the basin.

There is an inconsistency in the stated estimate for total stream flow. In Section 4.3.2 it is said to be 150-160 GL/y. In Section 4.3.4, ~160 GL/y has been used to estimate unsaturated zone evapotranspiration (ET). In Section 4.6 (Table 4.8), 150 GL/y is nominated as "Total surface flow (incl. baseflow)"; this figure would be correct only if the definition is changed to "Total surface flow (excl. baseflow)", as the net inflows and net outflows in Table 4.8 are out of balance by 10 GL/y. In Figure 4.4, the value is 160 GL/y.

Section 4.3.4: If ~160 GL/y is adopted for total stream flow, the estimate for unsaturated zone ET should be ~164 GL/y rather than the stated ~160 GL/y. If the 150-160 GL/y range is used, the estimate for unsaturated zone ET would average ~169 GL/y. The definitive Figure 4.4 has settled on 159 GL/y, as has Table 4.8. It is assumed by the reviewer that the final estimate has been guided by the simple numerical model, as Figure 4.4 is in balance.

Section 4.4: In Table 4.6, it is likely that the Volume for coal measures should be 1.5 x 10^{11} m^3 rather than 1.1 x 10^{11} m^3 to give consistency with all subsequent statements of the storage estimates. The reviewer considers that the storage estimates should be limited in precision to two significant figures rather than the nearest GL, as the estimates necessarily have substantial uncertainty.

Section 4.5: The simple numerical model has provided plausible estimates of inter-aquifer flows, although the values can be expected to be refined during detailed numerical modelling. There is no reliable alternative method for making these estimates.

Section 4.6: Table 4.8 includes an indicative estimate of the uncertainty in each component of the water balance. The magnitudes of uncertainty are considered reasonable.

Section 4.6: There is no reference to the bar chart in Figure 4.5.

Section 4.6: Valid conclusions are drawn from an interpretation of the water balance summary in Figure 4.4. One of the conclusions is that most groundwater flow occurs in the uppermost part of the groundwater system, with short residence times in the alluvium. This conclusion can be emphasised by calculation of the storage/recharge ratio, which the reviewer has calculated to be about 6 years. This is very short for a groundwater system, and indicates that the status of the aquifer units is dynamic and dependent on frequent recharge episodes for sustainability as a resource. The groundwater system would not be expected to be a reliable source of water under prolonged drought conditions.

The proneness of the groundwater system to dry conditions is explored in Section 4.7. A sensitivity to climate is confirmed.

Section 4.8 places CSG produced water volumes in perspective by showing that the volumes are a small component of annual recharge (6% in Section 4.8; 5% in Chapter 5) and a small component of aquifer storage (about 5% over 20 years of production).

The Conclusions in Chapter 5 are valid and well substantiated by the preceding water balance analysis.

Finally, several citations are not included in the Reference list: e.g. Hutton (1976); Evans (2007); Healy (2010).

Final Comments

The water balance analysis completed by PB (2013) has been conducted comprehensively and is considered by the reviewer to be as accurate as is reasonably possible prior to construction of a detailed numerical model. The latter method is the best way to establish a reliable water balance. *A priori* water balance analysis is necessarily imprecise as many of the components are not directly measurable.

To allow estimation of the more intractable components, PB has constructed a simple numerical model. This is a sensible approach, as it forces consistency between the measurable and inferred component magnitudes, and ensures conservation of mass.

The water balance analysis has been useful in demonstrating that the dynamics of the groundwater system are localised to the uppermost part of the groundwater system, with short residence times in the alluvium. The short storage/recharge ratio, about 6 years, indicates that the groundwater system is dependent on frequent recharge episodes for sustainability as a resource. The groundwater system would not be expected to be a reliable source of water under prolonged drought conditions.

Yours sincerely

Dr Noel Merrick