Gloucester Gas Project: Independent Peer Review of Groundwater Studies

Dr Rick Evans, June 2012

Overview

> History of groundwater investigations in study area
> Scope of peer review
> Review process
> Introduction to CSG and groundwater
> General comments (from peer review)
> Specific comments (from peer review)
> Recommendations for further work
> Conclusions
>

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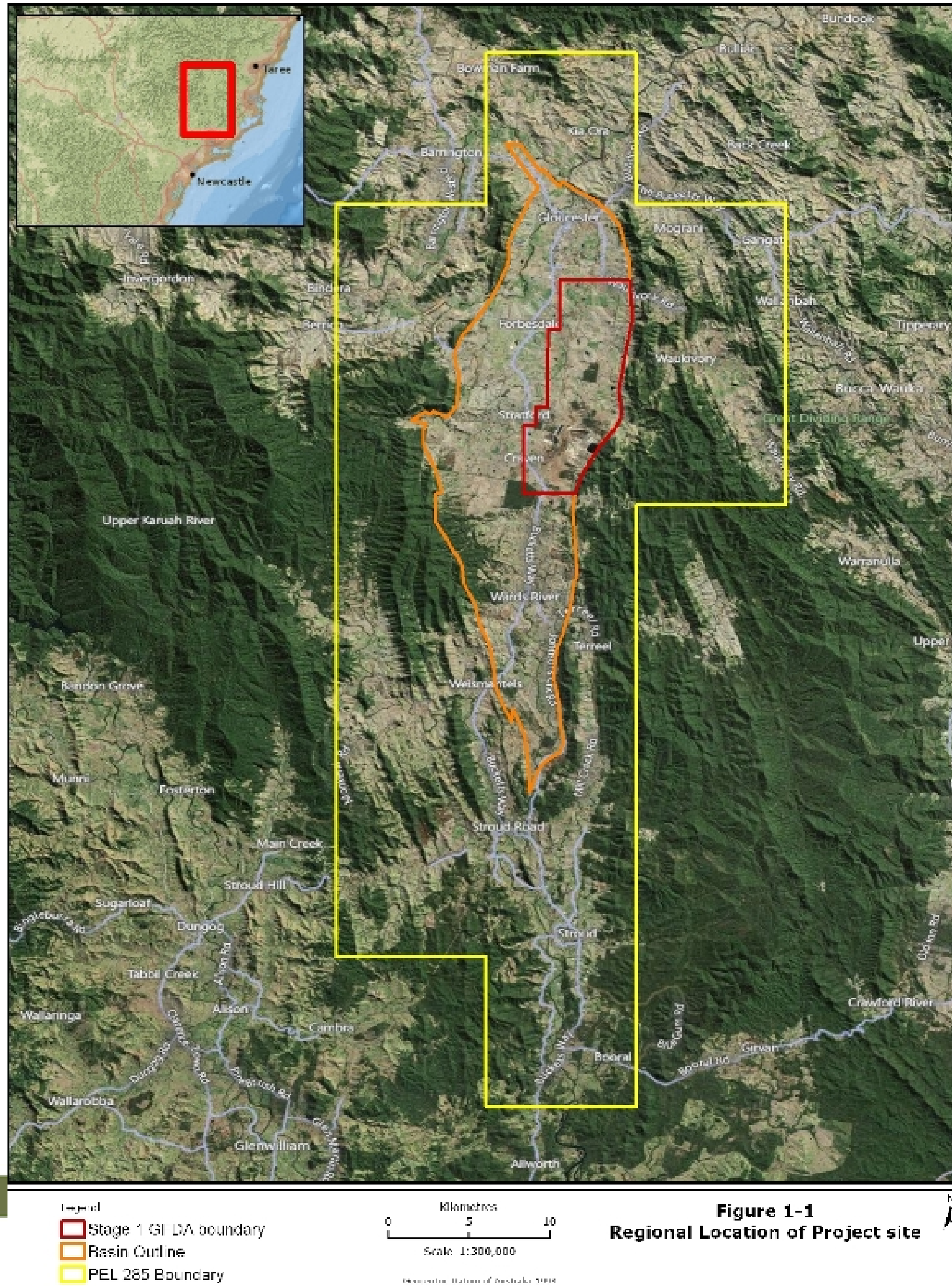

Figure 1-1
Regional Location of Project site

History of Groundwater Investigations (1)

- URS (2007). Hydrogeological Review: Proposed Coal Seam Gas Exploration Areas, Gloucester-Stroud Basin – desktop study;
- SRK Consulting (2010). Gloucester Basin Stage 1 Gas Field Development Project: Preliminary Groundwater Assessment and Initial Conceptual Hydrogeological Model Report - desktop study plus regional groundwater & surface water survey (water levels & water quality) → conceptual model;
- Parsons Brinckerhoff (2012). Phase 2 Groundwater Investigations – Stage 1 Gas Field Development Area Gloucester Gas Project (detailed gw investigation).

History of Groundwater Investigations (2)

- Objectives of Parsons Brinckerhoff (2012):
  - Complete baselines studies to characterise gw system
  - Provide site specific information on gw occurrence & flow, incl. determining whether shallow water resource aquifers are connected to the deeper coal seam water bearing zones
  - Assist in determining the quantity and quality of deep gw likely to be produced as the CSG scheme is constructed.
  - Establish a monitoring network sufficient to cover staged development of the scheme
  - Develop a revised conceptual model of groundwater, including recharge, discharge and flow
- Activities in PB (2012): drilling, installation of monitoring bores, downhole geophysical testing, permeability testing, water level monitoring, water quality sampling (incl. isotopes), installation of stream gauge stations

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History of Groundwater Investigations (3)

Phase 1	Desktop Study (completed; SRK, 2010)
Phase 2	**Detailed groundwater investigation (PB, 2012)**
Phase 3	**Modelling** Update of the conceptual model and construction of numerical model(s) (as required) to describe initial steady state impacts then predict groundwater impacts for various development scenarios
Phase 4	**Monitoring program (under way)** Long-term monitoring and compliance reporting
Phase 5	**Project updates (under way)** Further investigations and additions to the monitoring network as required

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Scope of Peer Review (1)

- 3 main reports, a focus on PB (2012) as report with updated conceptual model (plus other background data)
- Scope summary:
  - Opinion on scope and methodology of the Reports
  - Are Reports adequate for assessing ‘connectivity’ and impacts (to surface water / groundwater)?
  - Suitability of monitoring network
  - Identify technical gaps
  - contextual comments hydraulic fracturing and under reaming
- Exclusions from scope (fracking: quality & irrigation)

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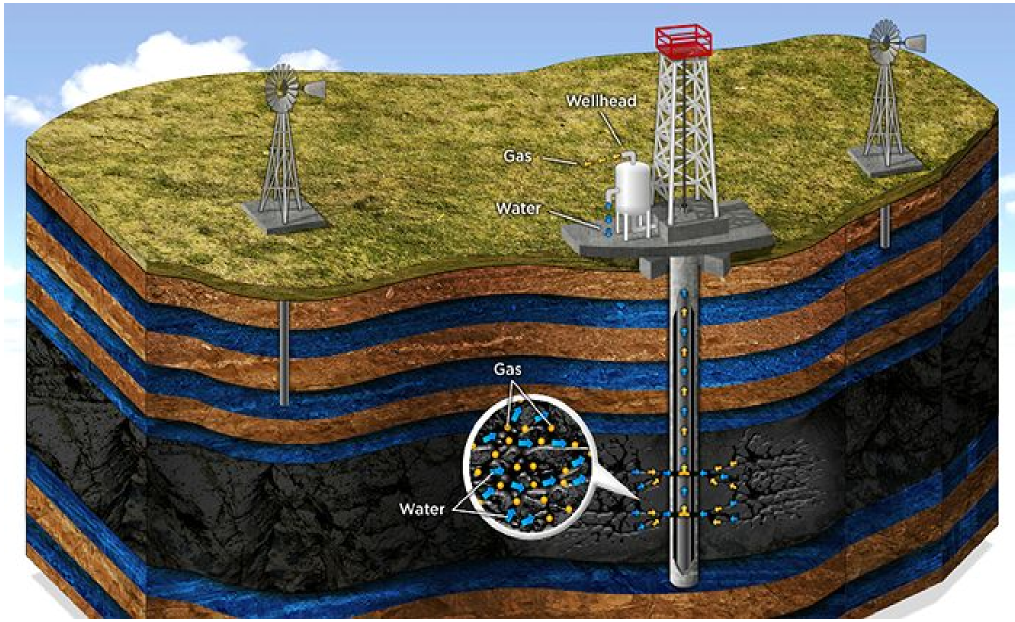
Scope of Peer Review (2)

- Important to remember that purpose of review was not to comment on the feasibility or otherwise of the proposed development from a hydrogeological perspective ... that will be based on the numerical modelling – it is around whether sufficient work has been done to build the model

Review Process

- Review timeline
  - Draft A – 19th March 2012
  - Draft B – 20th April 2012
  - Final – 3rd May 2012
- Reviewed by Gloucester Community Consultative Committee (GCCC)

What is coal seam gas?

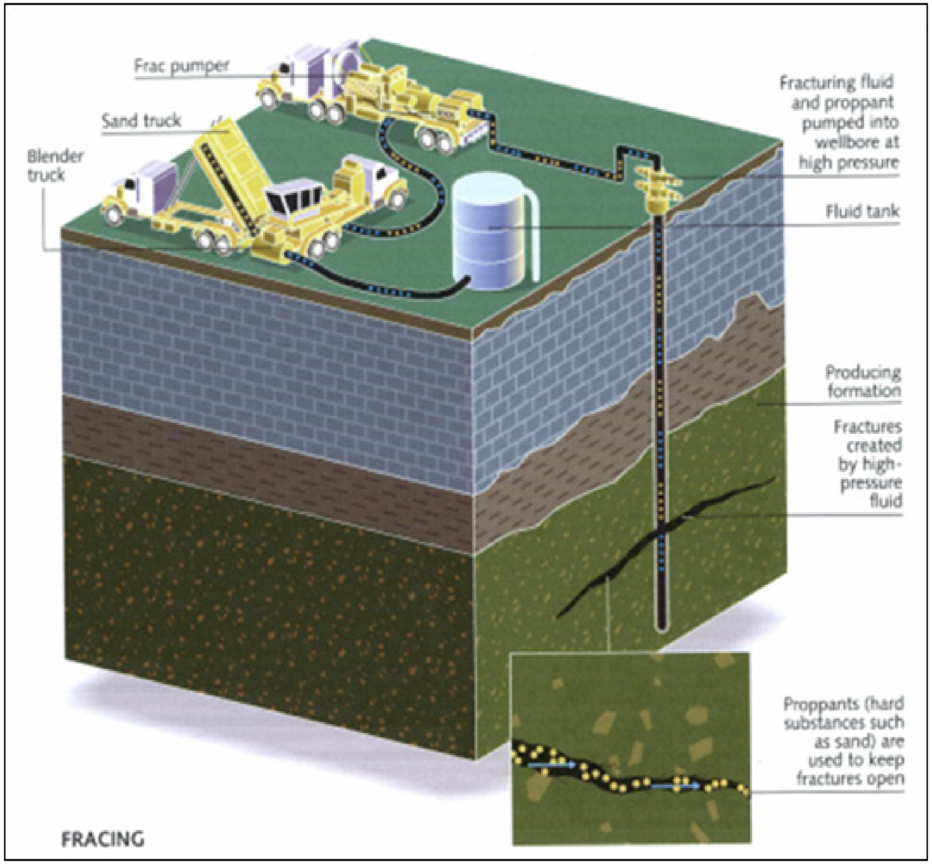


> Gas is formed from buried plant material as a result of thermogenic or bio-genic activity setting.
>
> The gas does not migrate to a conventional trap, instead it is spread throughout the reservoir formation (coal seams). Gas is adsorbed to the coal surfaces and is held in situ by water pressure.

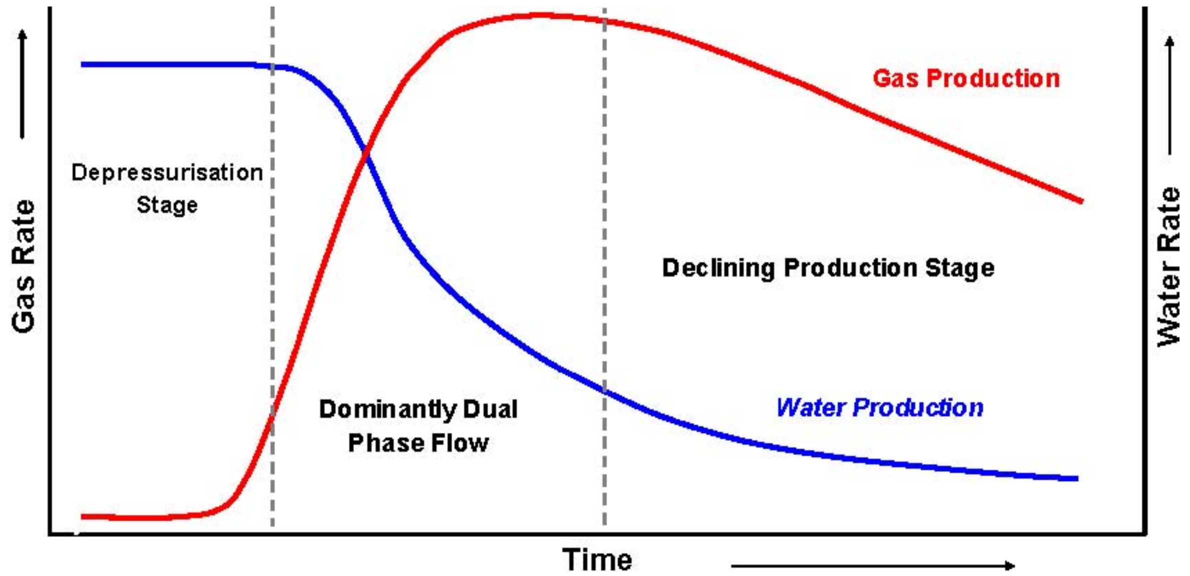
> Using wells, the coal seam is depressurised by pumping water from the well. As the water flows out of cracks in the coal, the pressure is reduced and the gas is released. A mixture of water and gas flows to the surface.

Hydraulic Fracture Stimulation ("Fraccing")

- Fraccing is a process that has been used in both conventional and unconventional oil and gas reservoirs, as well as by the geothermal industry.
- Strata is fractured to increase permeability by injecting fluids and proppants at high pressure, prior to de-pressurising the reservoir.
- Fraccing is not always required



CSG gas well production phases

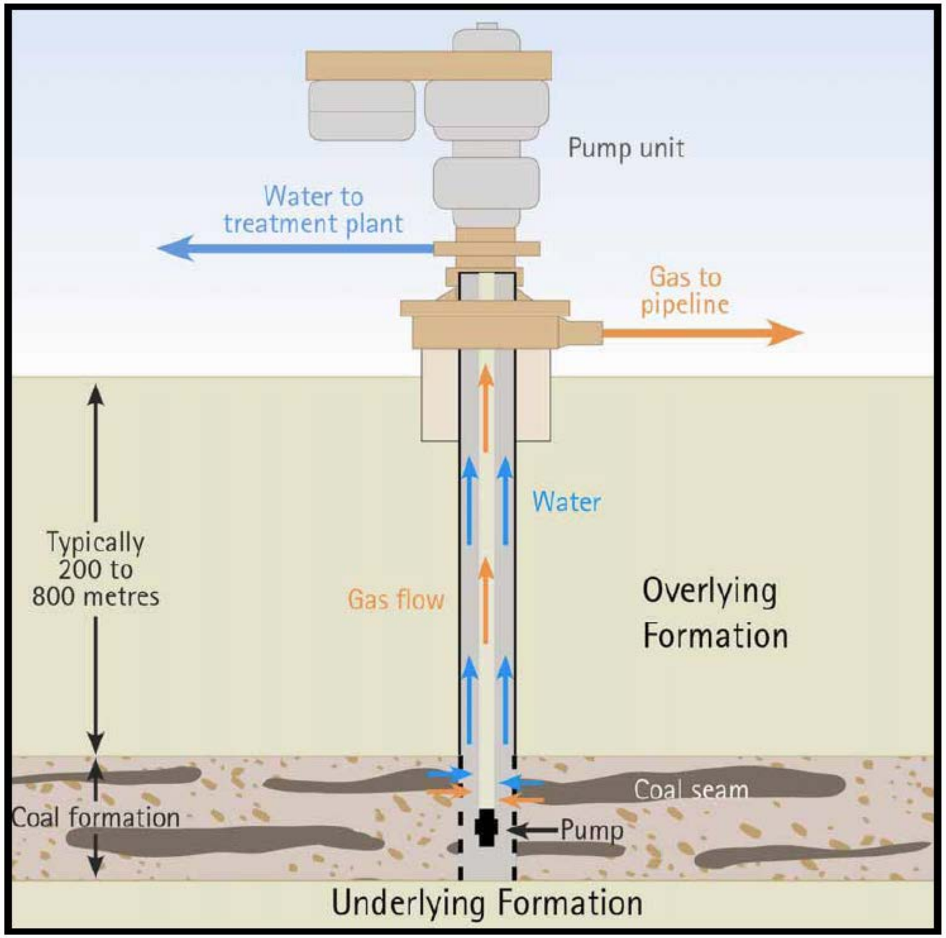


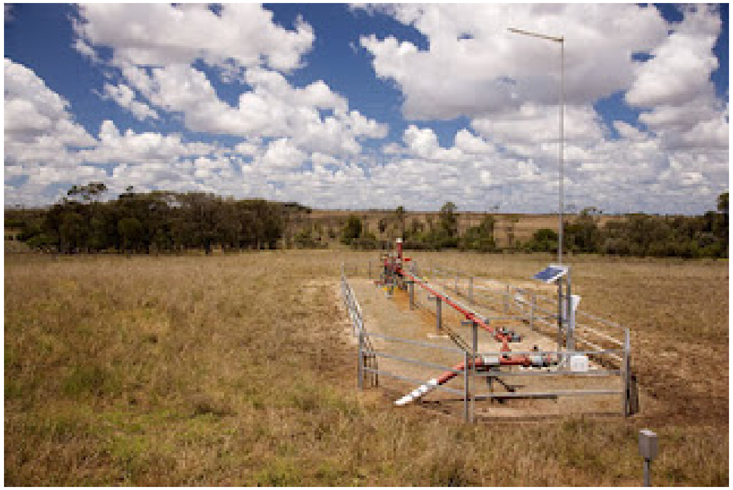
– Typical gas and water flow in CSG production

> Water and gas move together. Over time the proportion of gas increases as the formation is depressurised.

> Water production peaks early in the life of a production well.

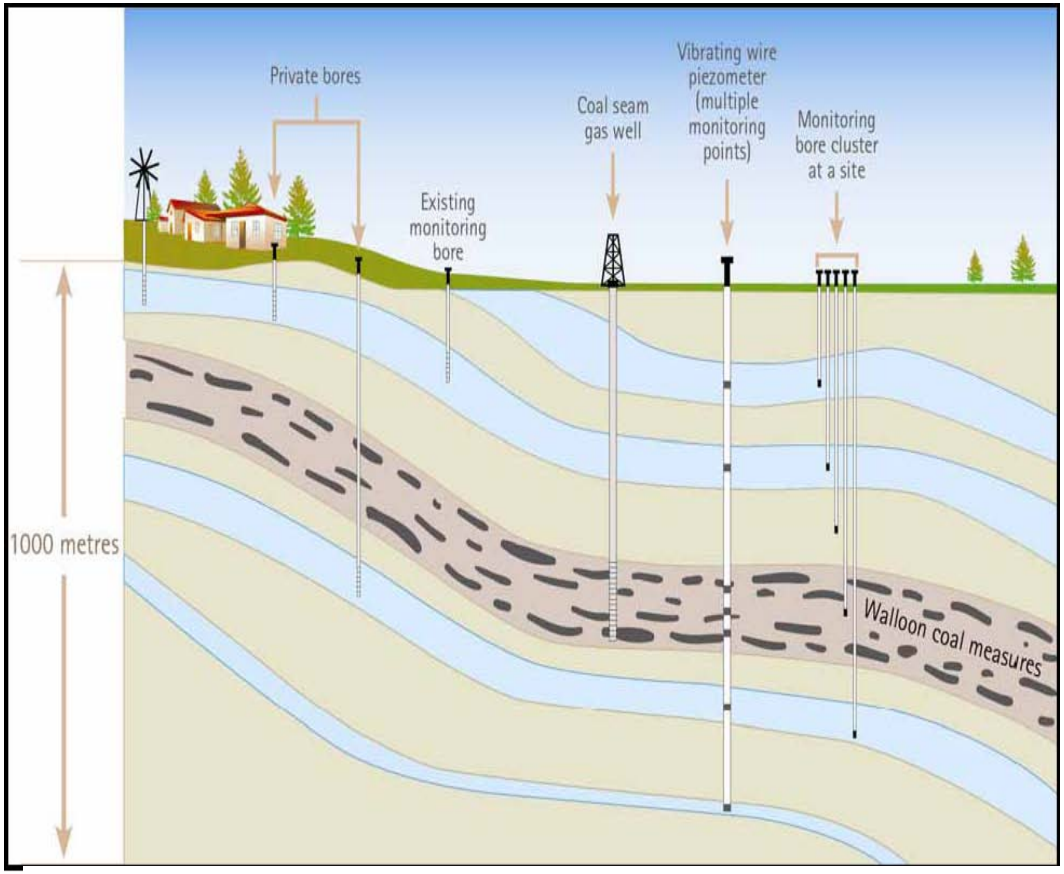
Gas and water yield





Monitoring networks

- Monitoring bore networks are important to assess:
  - lateral and vertical variability in the different groundwater systems
  - obtain baseline water level and water quality data
- Identify potential water level & quality changes
- Information to build and calibrate the numerical groundwater model



Groundwater monitoring bores

Overview Comments (1)

- In general, conceptualisation presented in PB (2012) is appropriate, including:
  - Four conceptual units
  - Decreasing k with depth, relative k
  - Discharge conceptualisation
  - Dominance of lateral processes (in natural state)
- Agree with conclusion that further work required to understand hydraulic significance of faults

Overview Comments (2)

- However, in some instances:
  - the wrong conclusion has been drawn from the data (e.g. interpretation of gw hydrographs)
  - some work omitted which would improve conceptual understanding (e.g. water balance, baseflow analysis)
- While the above form the focus of much of the report they do not represent criticisms which cannot be addressed via additional work and/or modifying the conceptual model

Conceptual Model – Coverage of model and model boundaries

- Conceptual model spatially limited compared to Stage 1 GFDA, and vertically limited (e.g. does not cover extent that numerical model would be required to cover)
- Conceptual model should define hydrogeological domain and model boundaries of the numerical model
- Currently not clear what proposed numerical model boundaries are

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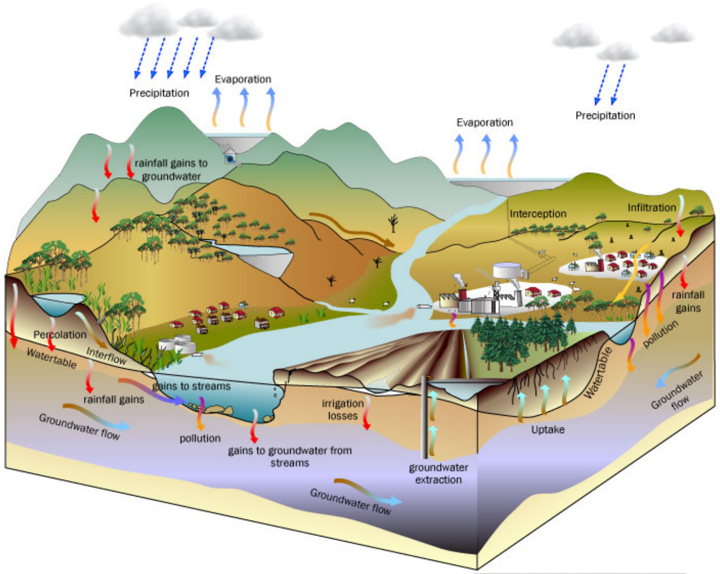
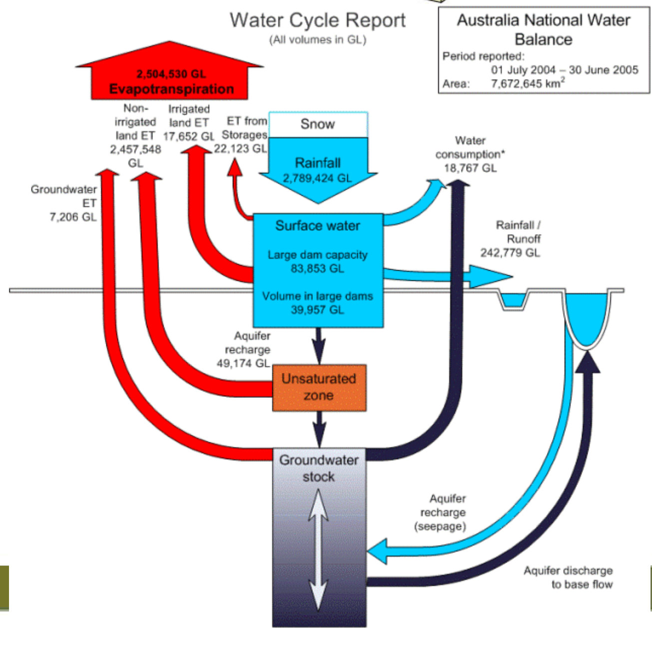
Conceptual Model – Water Balance

- Conceptual model will be strengthened by a water balance (WB).
- Should include pre-, maximum & post-development
- Advantage of conducting a water balance:
  - Helps define model boundaries
  - Begins to put into perspective possible scale of potential impacts
  - Highlights assumed rate and timing of recharge after end of CSG dev't.





NB: Please note volumes for some items was not available.
Unless marked data sourced from Bureau of Rural Sciences, 2006, *Water 2010*
* Australian Bureau of Statistics, 2006, *Australian Water Account*

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Conceptual Model – Natural versus developed state

> ‘Connectivity’ between deep and shallow groundwater systems (including surface water features) in the natural state is not necessarily an indicator of interaction in the developed state

> Changes in pressure under development will result in significant changes in hydraulic gradients between aquifer systems compared to natural state

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Conceptual Model (general)

> Potentiometric surface data – only mapped for the alluvial aquifer. Conceptual model should include an estimate of starting heads in other layers, including the coal seams.

> Recharge processes:
  - Significance of vertical leakage to recharge of deeper units (not covered)
  - Limited discussion on potential role of faults as enhanced recharge areas
  - Significance of recharge from creeks over outcropping units (coals etc), (not covered)

> Continuity of coal seams – lateral continuity?

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Connectivity and potential shallow aquifer / surface impacts (1)

> “there is no evidence of natural connectivity between shallow and deep gw systems” (PB, 2012)
  - ‘low permeability’ material does not create a hydraulically separating layer (missing element in the discussion is around quantities and timeframes)

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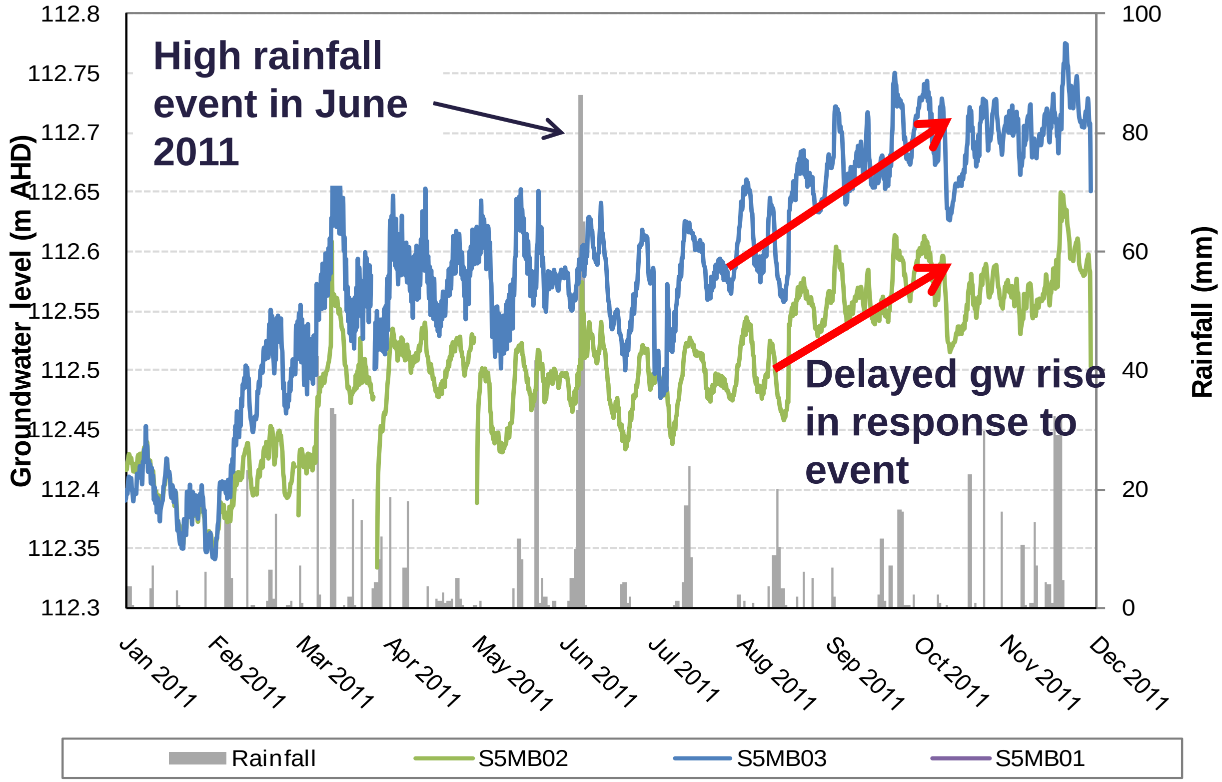
Connectivity and potential shallow aquifer / surface impacts (2)

> The following evidence provided for hydraulic separation of shallow and deep groundwater systems:
>
> - Different chemistries – imply limited impact of vertical processes, not isolation of units
> - Static nature of hydrographs
> - Absence of response to rainfall recharge

The latter two are not supported by the data, as shown in subsequent slides

Assessment of Monitoring Bore Hydrographs: S5MB



Apparent response to rainfall recharge (not static)

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Characterisation of vertical hydraulic conductivity (1)

> Reports currently don't address distinction between vertical (Kv) and horizontal (Kh) hydraulic conductivity

> Most results are Kh, what Kv values will be used in model? (model results likely to be sensitive to Kv)

> Range in results for 4 units is large – what will be used in the model?

> How will differences in results between slug tests and packer testing / lab testing be handled?

Characterisation of GDEs

> **Baseflow GDEs**

- Baseflow assessment is recommended to determine baseflow contribution (will require gauging of at least one of the new stream gauges)
- Can’t assume it is small based on visual inspection or not important based on salinity
- Difference in salinity between alluvial groundwater and baseflow should be investigated. Relates to important question of proportion of b’flow that is gw
- Given conceptual understanding of discharge (to north of study area), a baseflow assessment at stream gauge GS208028 is recommended and also the next gauge downstream

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Characterisation of GDEs

> **Springs**
  - Some reference to monitoring of ‘at least one spring’ in the Alum Mountain Volcanic formation
  - No other discussion on number, use, importance etc of these springs

> **Terrestrial vegetation**
  - There is potential for ET wherever gw is shallow.
  - Unlikely to be a relationship of high dependence (given generally brackish nature of gw and consistent nature of rainfall)

Characterisation of fault zones (1)

> 1. Fault zones potentially important influences on groundwater hydraulics; at present not enough known to characterise faults

- o URS (2007) and SRK (2010) tend to favour theory of enhanced hydraulic conductivity
- o Some inconsistent conclusions from gw age, isotopes, chemistry regarding data either side of a fault

Characterisation of fault zones (2)

> 2. Two investigation programs are underway to improve understanding of the faults

   i. program outlined in Section 7.3 of PB (2012), involving investigation of fault between S4MB and S5MB.

   ii. The Waukivory Flow Testing Program, as described in AGL report (8 March 2012) and supplementary information by AGL (13 March 2012).

Importantly, both of these programs involve examination of fault behaviour under stress. Broadly agree with the proposed programs – some changes or additions to the method have been recommended

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Characterisation of fault zones (3)

It is important that the results of the characterisation of the faults derived from the above two programs is brought into the conceptual model, so that the effect of faults can be accounted for (if required) in the development of the numerical model

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Conclusion (1)

- In general conceptualisation broadly considered appropriate, however this review recommends further work
- Issues with conceptualisation fall into categories of connectivity between deep/shallow systems, recharge & discharge processes, characterisation of vertical K and specific improvements to the conceptual model.
- The most important improvements to conceptual model relate to its spatial coverage, definition of model boundaries and need for a water balance.

Conclusion (2)

- Apparent that not all available information has been used to develop the conceptual model, incorporation of additional data will enhance conceptualisation.
- Review has highlighted the importance of not drawing conclusions regarding the developed hydrogeological system based on observations from natural condition.
- Currently insufficient information to characterise hydraulic behaviour of faults. Given potential importance to gw flow, the two proposed programs are important activities to fill this knowledge gap.

Recommendations for Further Work (field work)

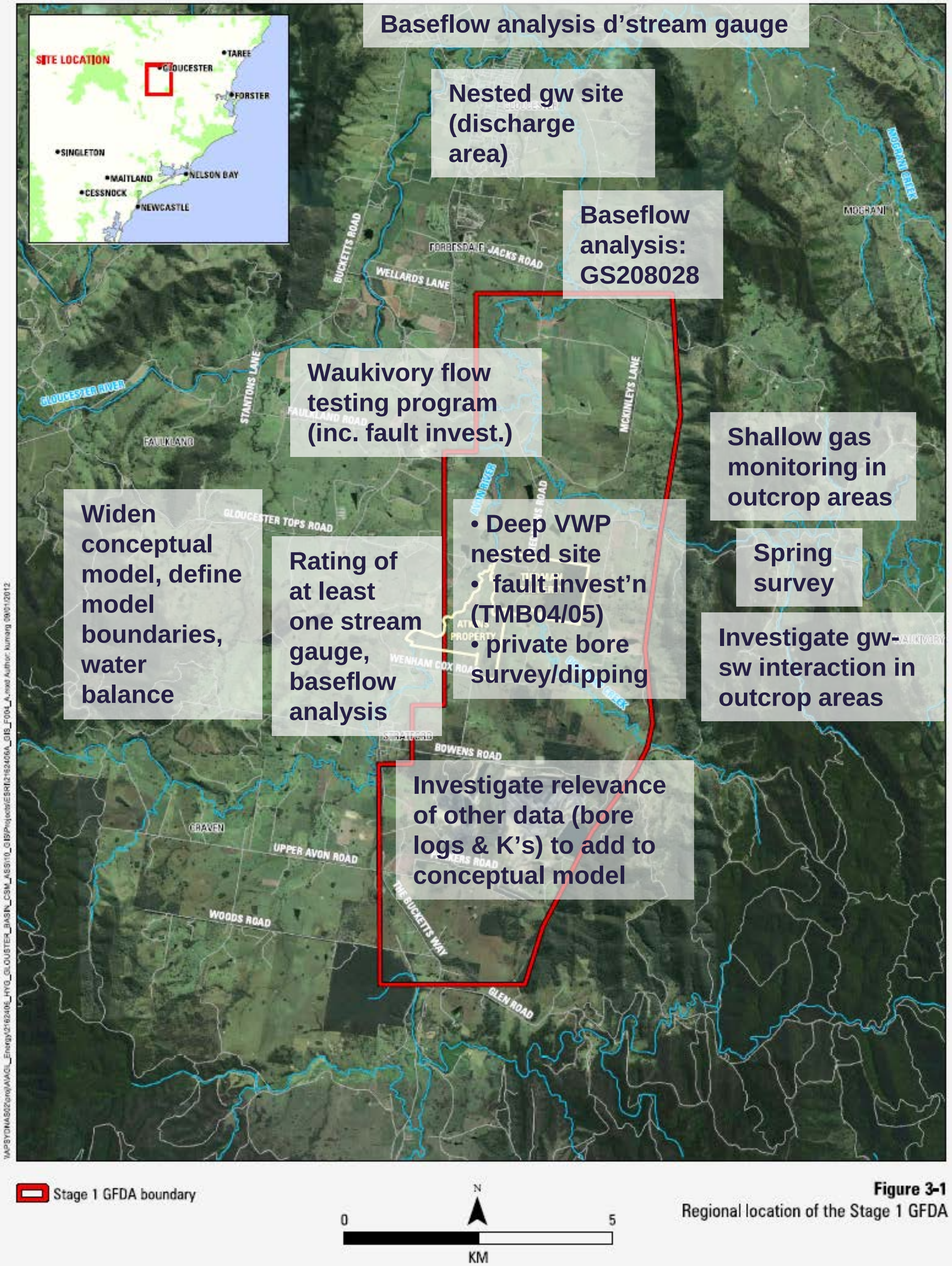

Figure 3-1
Regional location of the Stage 1 GFDA

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Recommendations for Further Work – Desk Based (High Priority - 1)

- Develop conceptual model of fault behaviour (post-field investigations)
- Conceptual model to account for major structural changes related to faults
- Define model boundaries. Expand boundaries of conceptual model.
- Conduct water balance
- Use currently available bore data to improve spatial coverage of conceptual model

Recommendations for Further Work – Desk Based (High Priority - 2)

> Additional analysis of existing K data (Kv, differences in K for different methods, define representative values for 4 units, consider relevance of other K data)

> Baseflow separation be undertaken for the Avon River downstream of Waukivory Creek gauge, and downstream gauge if one within 10-15km

> Baseflow separation be undertaken for the gauge(s) which is rated

> Update conceptual model once all of above complete

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Concluding Comments

> None of the criticisms presented in this review considered to be issues that cannot be readily addressed or the conceptual model revised to take account of the comments.

> The review has not identified any issues which necessarily indicate the project represents a high or unacceptable risk from a hydrogeological impact perspective at the conceptual model stage, BUT it is the role of the numerical modelling to assess impacts.