AGL Upstream Investments Pty Ltd

Hydrogeological Conceptual Model of the Gloucester Basin

28 June 2013

PARSONS BRINCKERHOFF

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Executive summary

AGL Upstream Infrastructure Investments Pty Ltd (AGL) is proposing to build the Gloucester Gas Project (GGP) which comprises several stages of development facilitating the extraction of coal seam gas (CSG) from the Gloucester Basin. Part 3A Approval (condition 3.8 and 3.9) and EPBC Approval (condition 16) require that the conceptual hydrogeological model developed during the assessment stage of the project is updated based on additional baseline data gathered. This report presents the updated hydrogeological conceptual model for the Gloucester Basin, building on previous hydrogeological conceptual models and incorporating data from current and ongoing hydrogeological investigations in the basin.

The Gloucester Basin is a broad north-south elongated valley underlain by Permian sedimentary and volcanic rocks that have been folded and faulted into a synclinal (canoe-shaped) structure. The Basin is bounded to the west by the elevated topography of the Gloucester and Barrington Tops, and to the east by the Mograni Range. These topographic divides also correspond to outcrops of the largely impermeable Alum Mountain Volcanics which forms the hydrogeological basement to the basin. By contrast, the coal measures and near surface rocks within the basin are slightly more permeable, mainly due to sparse fracturing in near-surface rocks and cleating within coal seams which form weak water bearing horizons. In hydrogeological terms, the Basin is conceptualised as an essentially closed groundwater system; all surface water and most discharging groundwater exits the basin via the Avon and Gloucester Rivers to the north and the Wards River system to the south.

The permeability and groundwater flow characteristics of rocks within the basin are controlled by multiple factors including lithology, depth and the degree of fracturing and potentially faulting. In this sense hydrogeological units and flow systems do not always correspond with defined geological boundaries. Four main hydrogeological units influence groundwater flow within the basin: 1) Alluvial deposits adjacent to major creeks and rivers; 2) Shallow rock comprising variably weathered and fractured Permian rocks extending to approximately 150 m below the surface; 3) Deep Coal Measures Interburden, indurated sandstone and siltstone of very low permeability, and, 4) Coal seams which tend to be slightly more permeable than interburden and commonly form weak water bearing zones.

A large number of faults of varying orientations are known to occur within the basin, many of which are not apparent at the surface or in drill logs. An understanding of how faults influence groundwater movement in the near surface and at depth is starting to emerge from ongoing groundwater investigations and CSG exploration.

Regional groundwater flow is controlled by gravitational flow from elevated areas where groundwater is recharged, to low-lying areas where groundwater discharges to streams and to the atmosphere via evapotranspiration. The basin can be divided into two distinct groundwater flow systems: The northern Gloucester Basin in which groundwater predominantly flows to the north, and the southern Gloucester Basin in which groundwater generally flows in a southerly direction. The boundary between the two flow systems, under natural conditions, corresponds with the catchment divide between the Avon and Wards Rivers. Rainfall is the primary source of recharge to the aquifers and water bearing zones within the Gloucester Basin. Minor recharge from streams to the alluvial aquifers may occur during periods of high rainfall/surface flow and flooding when there is the potential for the rivers to lose water, particularly in upper catchment areas.

The basin is relatively undeveloped in terms of surface and groundwater use with relatively low volumes of groundwater (less than 2 ML/d) used for agriculture, mining and stock/domestic use. There are no known groundwater dependent ecosystems apart from diffuse groundwater discharge that contributes to stream baseflow. This baseflow is a small component of total stream flow.

It is understood that Stage 1 GFDA development may result in a net consumptive dewatering volume of approximately 730 ML per annum in the initial years of the project. This dewatering volume is expected to diminish substantially with time because of the low permeability strata overlying the targeted coal seams. Most groundwater abstraction will be from the deep coal measures at depths greater than 200 m.

Glossary

Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
Anisotropy	The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.
Aquatic ecosystem	The stream channel, lake or estuary bed, water, and (or) biotic communities and the habitat features that occur therein.
Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
Aquifer properties	The characteristics of an aquifer that determine its hydraulic behaviour and its response to abstraction.
Aquifer, confined	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Aquifer, semi-confined	An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the leaky confining layer – also known as a leaky artesian or leaky confined aquifer.
Aquifer, unconfined	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
Aquitard	A low permeability unit that can store groundwater and also transmit it slowly from one formation to another. Aquitards retard but do not prevent the movement of water to or from adjacent aquifers.
Australian Height Datum (AHD)	The reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of aquifers and water levels in bores.
Baseflow	The part of stream discharge that originates from groundwater seeping into the stream.
Bedding plane	In sedimentary or stratified rocks, the division plane which separates the individual layers, beds or strata.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Boundary	A lateral discontinuity or change in the aquifer resulting in a significant change in hydraulic conductivity, storativity or recharge.
Coal	A sedimentary rock derived from the compaction and consolidation of vegetation or swamp deposits to form a fossilised carbonaceous rock.
Coal seam	A layer of coal within a sedimentary rock sequence.

Coal seam gas (CSG)	Coal seam gas is a form of natural gas (predominantly methane) that is extracted from coal seams.
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.
Confining layer	Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients.
Deeper coal measures	Generic term for all sedimentary rock units within the Gloucester Basin that are deeper than 150 m below ground level (bgl). It includes two hydrogeological units – the interburden confining units and coal seam water bearing zones.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Discharge area	An area in which there are upward or lateral components of flow in an aquifer.
Fault	A fracture in rock along which there has been an observable amount of displacement. Faults are rarely single planar units; normally they occur as parallel to sub-parallel sets of planes along which movement has taken place to a greater or lesser extent. Such sets are called fault or fracture zones.
Fluvial	Pertaining to a river or stream.
Fluvial deposit	A sedimentary deposit consisting of material transported by suspension or laid down by a river or stream.
Fracture	Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions.
Fractured rock aquifer	These occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary rock aquifers.
Gigalitre (GL)	A thousand megalitres (or a billion litres).
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
Groundwater age classification	Groundwater ages are commonly referred to as: ***Modern*** <100 years ***Sub-modern*** 100-1,000 years ***Old*** >1,000 years
Groundwater dependent ecosystems (GDEs)	Groundwater dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes are dependent (or partially dependent) on groundwater.
Groundwater flow	The movement of water through openings in sediment and rock within the zone of saturation.

Groundwater system	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.
Heterogeneous	Pertaining to a substance having different characteristics in different locations.
Hydraulic conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water).
Hydraulic gradient	The change in total hydraulic head with a change in distance in a given direction.
Hydraulic head	Is a specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between two or more points.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrogeological unit	A rock or soil unit with similar hydraulic properties. The hydrogeological unit often corresponds to the lithological or geological unit, but not always. For instance, a fault zone or weathered zone may form a hydrogeological unit that is discordant with respect to geological unit boundaries.
Hydrology	The study of the occurrence, distribution, and chemistry of all surface waters.
Monitoring bore	A non-pumping bore, is generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter.
Normal faulting	Where the fault plane is vertical or dips towards the downthrow side of a fault.
Numerical model	A model of groundwater flow in which the aquifer is described by numerical equations (with specified values for boundary conditions) that are usually solved in a computer program. In this approach, the continuous differential terms in the governing hydraulic flow equation are replaced by finite quantities. Computational power is used to solve the resulting algebraic equations by matrix arithmetic. In this way, problems with complex geometry, dynamic response effects and spatial and temporal variability may be solved accurately. This approach must be used in cases where the essential aquifer features form a complex system (i.e. high complexity models).
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permeable material	Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present.
Permian	The last period of the Palaeozoic era that finished approximately 230 million years before present.
Porosity	The proportion of open space within an aquifer, comprised of intergranular space, pores, vesicles and fractures.

Porosity, primary	The porosity that represents the original pore openings when a rock or sediment formed.
Porosity, secondary	The porosity caused by fractures or weathering in a rock or sediment after it has been formed.
Porous rock	Consolidated sedimentary rock containing voids, pores or other openings (joints, cleats, fractures) which are interconnected in the rock mass and may be capable of storing and transmitting water.
Quaternary	The most recent geological period extending from approximately 2.5 million years ago to the present day.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Recharge area	A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones.
Residence time	The time that groundwater spends in storage before moving to a different part of the hydrological cycle (i.e. it could be argued it is a rate of replenishment).
Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).
Screen	A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material.
Sandstone	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).
Sedimentary rock aquifer	These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest volumes of groundwater.
Shale	A laminated sedimentary rock in which the constituent particles are predominantly of clay size.
Shallow rock aquifer	In this report shallow rock aquifer is the hydrogeological unit that extends from the ground surface to a depth of approximately 150 m bgl that has elevated permeability and storage due to fracturing of the rock mass, compared with the deeper coal measures. It is the collective of shallow sedimentary rock and fractured rock aquifers in the shallow part of the Gloucester Basin.
Siltstone	A fine-grained rock of sedimentary origin composed mainly of silt-sized particles (0.004 to 0.06 mm).
Specific storage	Relating to the volume of water that is released from an aquifer following a unit change in the hydraulic head. Specific storage normally relates to confined aquifers.

Specific yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Specific yield generally relates to unconfined aquifers. Gravity drainage may take many months to occur.
Standing water level (SWL)	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to specific yield.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Surface water-groundwater interaction	This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table adjacent to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater through streambeds when the elevation of the water table is lower than the water level in the stream.
Unsaturated zone	That part of an aquifer between the land surface and water table. It includes the root zone, intermediate zone and capillary fringe.
Water bearing zone	Geological strata that are saturated with groundwater but not of sufficient permeability to be called an aquifer.
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists.
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.
Well	Pertaining to a gas exploration well or gas production well.
Wellbore	A wellbore is the physical hole that makes up the well and can be cased, open or be a combination of both completions. In this report it generally refers to uncased gas exploration boreholes prior to a gas well being completed.

1. Introduction

This report is the updated hydrogeological conceptual model for the groundwater systems of the Gloucester Basin. It builds on previous hydrogeological conceptual models and is an appreciation of all the hydrogeological processes happening across the whole of the geological basin.

1.1 Proposed development

AGL Upstream Infrastructure Investments Pty Ltd (AGL) is proposing to build the Gloucester Gas Project (GGP) which comprises several stages of development facilitating the extraction of coal seam gas (CSG) from the Gloucester Basin. Concept Plan and Project Approval (Part 3A Approval) for the Stage 1 Gas Field Development Area (GFDA) was granted on 22 February 2011 under Part 3A of the *Environmental Planning and Assessment Act (1979) (EP&A Act)*. In addition the project received approval under the *Environment Protection and Biodiversity Conservation Act (1999) (EPBC Act)* (EPBC Approval) on 11 February 2013.

AGL also holds Petroleum Exploration Licence (PEL) 285, under the *Petroleum (Onshore) Act 1991*, covering the whole of the Gloucester Basin, approximately 100 km north of Newcastle, NSW. AGL has also applied for a Petroleum Production Lease (PPL) for the area subject of the planning approvals. The Stage 1 GFDA in relation to the PEL boundary is shown in Figure 1.1.

The GGP will involve the dewatering of deep groundwater and the extraction of gas from multiple coal seams within the Gloucester Coal Measures. Target coal seam depths will vary from site to site but are expected to range between 200 and 1,000 metres below ground level (mbgl). The current GGP includes the construction, operation and decommissioning of not more than 110 coal seam gas wells and associated infrastructure, including gas and water gathering lines, within the Stage 1 GFDA.

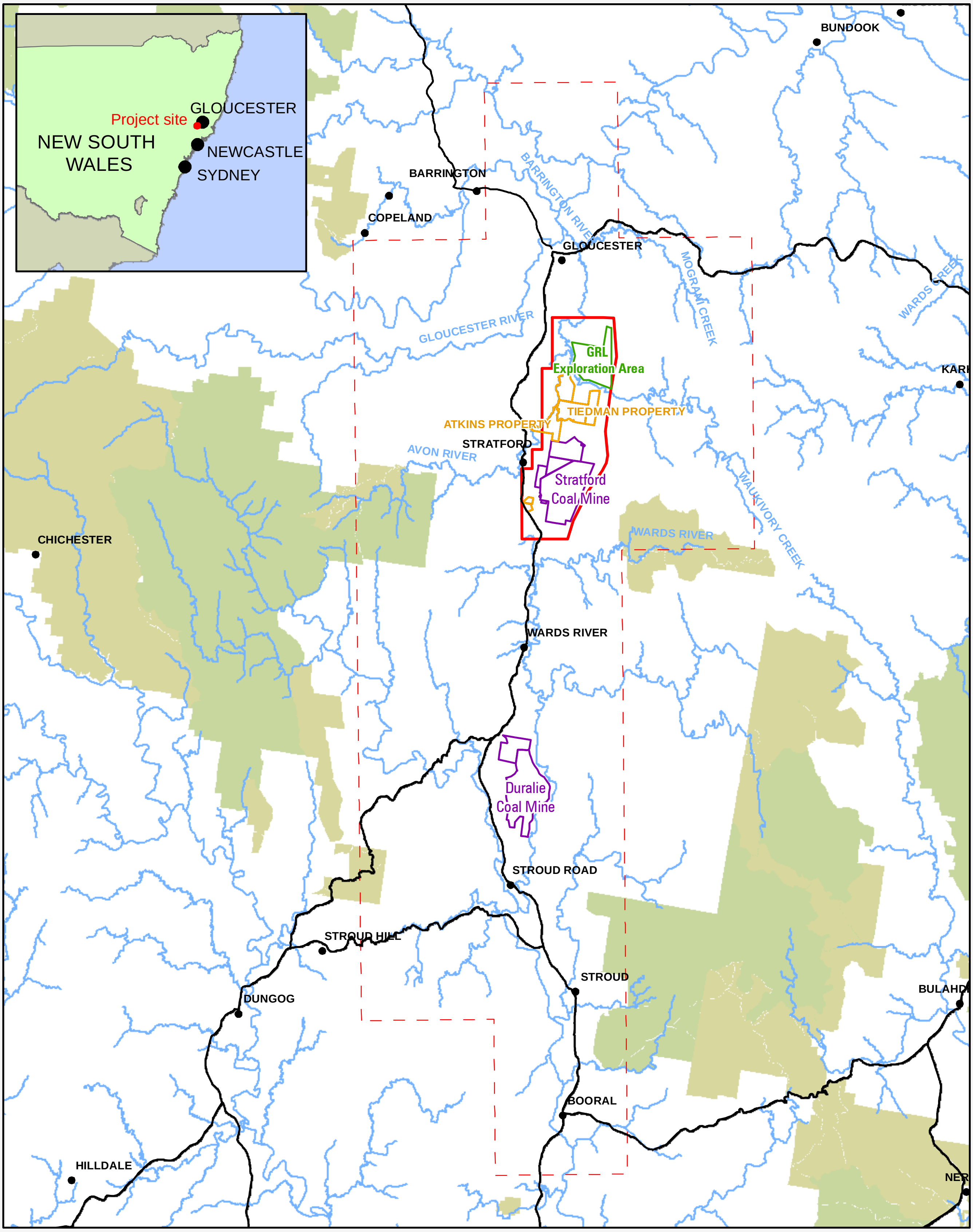
The field based groundwater studies commenced in 2010 with a comprehensive groundwater investigation, the Phase 2 Groundwater Investigations, which was completed in 2012 (Parsons Brinckerhoff, 2012a). This investigation confirmed the desktop based hydrogeological conceptual model for the Stage 1 GFDA (SRK 2010). The investigation established a dedicated water monitoring network, and enabled the collection of baseline water level, water quality and hydraulic conductivity data for each of the hydrogeological units represented across the different groundwater systems and the surface water systems.

Part 3A Approval (condition 3.8 and 3.9) and EPBC Approval (condition 16) require that the conceptual hydrogeological model developed during the assessment stage of the project is updated based on additional baseline data gathered. The collection and interpretation of groundwater and surface water level and quality data enhances and verifies the understanding of the conceptual (hydrogeological) model, and is the primary scientific data to determine whether there are any impacts resulting from CSG activities on groundwater and surface water systems.

PARSONS BRINCKERHOFF

HYDROGEOLOGICAL CONCEPTUAL MODEL OF THE GLOUCESTER BASIN

AGL UPSTREAM INVESTMENTS PTY LTD



Stage 1 GFDA boundary
PEL 285 boundary
AGL owned properties
Mining Lease Boundary
GRL exploration area boundary
Towns
Rivers and streams
Major roads
NSW State Forest
National Park, Nature Reserve or State Conservation Area

Figure 1.1
Regional Location

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1.2 Scope

The scope of works included the following:

- A literature review of previous geological and hydrogeological studies carried out in the Gloucester Basin.
- A desktop review of baseline data including:
  - geological data and geophysical data, in particular to assess local faults in the Gloucester Basin
  - groundwater level and quality data
  - surface water level and quality data
  - hydraulic property data.
- Characterisation of the groundwater systems, including identification of groundwater users and potential groundwater dependent ecosystems.
- Development and update of a conceptual hydrogeological model to be used as the basis for the development of a water balance and numerical groundwater model.
- Assessment of potential operational issues, including the potential for drawdown and subsidence, and location and development implications.

1.3 Report structure

This document provides a concise Hydrogeological Conceptual Model of the Gloucester Basin. The structure of the report is as follows:

- Chapter 2: Provides planning approval context to the proposed development.
- Chapter 3: Summary of review of previous studies of the Gloucester Basin.
- Chapter 4: Provides contextual overview of the Gloucester Basin including topography, drainage and geology.
- Chapter 5: Review of baseline hydrology and hydrogeology data for the Gloucester Basin.
- Chapter 6: Presents the (updated) hydrogeological conceptual model.
- Chapter 7: Provides a framework for numerical modelling.

1.4 Compliance with modelling guidelines

The hydrogeological conceptual model will form the basis for the development and calibration of a numerical groundwater model, and this document has therefore been prepared in accordance with the Australian Groundwater Modelling Guidelines (Waterlines Report Series No.82) (SKM, 2012a).

Section 3 of the Australian Groundwater Modelling Guidelines provides guidance on conceptualisation, and specifies that development of the conceptual model should consider:

- hydrostratigraphy
- aquifer properties
- conceptual boundaries
- stresses
- physical processes.

These criteria have been addressed throughout the report.

2. Background

This chapter provides the planning approval context for the project and in particular, the conditions that relate to this conceptual model report. For the individual conditions and sub-conditions in each approval that mention the conceptual model report, there is a reference to the appropriate report section.

2.1 Part 3A EP&A Act approval context

Stage 1 of the GGP was approved by the Planning Assessment Commission on 22 February 2011. The Part 3A Approval for the Stage 1 GFDA has several conditions relating to groundwater and surface water management. The conditions and sub-conditions are detailed in Appendix A. Table 2.1 summarises these conditions and identifies where they are addressed in this report. This report primarily covers Conditions 3.8 and 3.9.

Table 2.1 Part 3A EP&A Act approval conditions

Part 3A condition	Sub-condition	Addressed in this report	Report section
Condition 3.5 (Gas well construction, operation and decommissioning)	Not applicable	No	Not applicable
Condition 3.6 (Plug and abandon old exploration wells within 500m radius of new wells)	Not applicable	No	Not applicable
Condition 3.7 (No fracture simulation fluids with BTEX)	Not applicable	No	Not applicable
Condition 3.8 (Data and investigations for updated conceptual model)	a) Seismic surveys b) Field sampling of hydrogeological and hydrological parameters c) Long term baseline monitoring (at least 6 months)	Yes Yes Yes	Section 4.3 Section 5.2 and 5.3 Section 5.2 and 5.3
Condition 3.9 (Submit updated conceptual model)	a) Updated assessment of the potential for drawdown b) Optimal areas for gas well location within the Stage 1 GFDA c) Recommendations for phased gas well development d) Independent peer review	Yes Yes Yes No	Section 6.5.1 and 6.5.2 Section 6.5.3 Section 6.5.3 Covered elsewhere #
Condition 3.10 (Submit field development plan)	Not applicable	No	Not applicable
Condition 3.11 (Obtain water licence/s and dewatering not to exceed 2 ML/d)	Not applicable	Introduced	Section 5.3.6

Part 3A condition	Sub-condition	Addressed in this report	Report section
Condition 3.12 (Develop extracted water management strategy)	a) to i)	No	Not applicable
Condition 3.13 (Ensure all water storage ponds are lined)	Not applicable	No	Not applicable
Condition 4.1 (Develop groundwater monitoring program)	a) Identify surface and groundwater monitoring locations	Yes	Section 5.2 and 5.3
	b) Provide details of monitoring points	Yes	Section 5.2 and 5.3
	c) Identify performance criteria for gas well development	No	Not applicable
	d) Identify the frequency of reporting on monitoring results	No	Not applicable
	e) Provisions for the monitoring of coal seam dewatering rates	No	Not applicable
	f) Provisions for the monitoring of potential gas migration	Introduced	Section 5.4
	g) Provide details of fraccing fluids to be used	No	Not applicable
	h) Include provisions for ongoing monitoring	No	Not applicable
	i) Procedure for contingency or remedial action	No	Not applicable
	j) Regular review and update of the program in consultation with NOW	No	Not applicable
Condition 4.2 (Develop numerical hydrogeological model)	Not applicable	Introduced	Section 6.6

Key: # - This report is being peer reviewed separately by Dr Noel Merrick who was approved by the Director General of the Department of Planning and Infrastructure (DoPI) in March 2013.

2.2 EPBC Act approval context

Stage 1 of the GGP project was approved by the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) on 11 February 2013. The EPBC Approval for the Stage 1 GFDA has several conditions relating to the protection of water resources. The conditions and sub-conditions are detailed in Appendix B. Table 2.2 summarises these conditions and identifies where they are addressed in this report.

Table 2.2 EPBC Act approval conditions

EPBC condition	Sub-condition	Addressed in this report	Report section
Condition 15 (Comply with Part 3A EP&A Act conditions)	Not applicable	See Table 2.1	See Table 2.1
Condition 16 (Develop conceptual hydrogeological model)	Not applicable	Yes	Section 3, 4, 5 and 6
Condition 17 (Revise the water balance model)	a) Take into account the following inputs: i) Field-based investigation of the spatial distribution of strata ii) Investigation of age, depth and location of groundwater iii) Baseline investigation of gas occurrence iv) Pilot testing of Stratford and Waukivory pilot wells v) Baseline data associated with Phase 1 and 2 studies vi) Assessment of a representative site for fault testing b) Extend to 1000 metres below ground level c) Ensure all hydrological inputs and outputs are accounted for d) List of information sources	 Introduced Introduced Introduced Introduced Introduced Introduced Introduced No No	 Section 5.5 Section 5.3 and 5.5 Section 5.4 Section 5.3.3.4 and 5.5.2 Section 3, 4 and 5 Section 5.5 Section 3, 4 and 5 Not applicable Not applicable
Condition 18 (develop numerical hydrogeological model)	Not applicable	Introduced	Section 6.6
Condition 19 (Use the models to complete a risk analysis on the potential impacts on the habitats of the green and golden bell frog and giant barred frog)	(a) to (d)	No	Not applicable
Condition 20 (Provide details on any hydraulic fracturing agents likely to be used)	(a) to (e)	No	Not applicable
Condition 21 (Develop extracted water management strategy)	Not applicable	No	Not applicable
Condition 22 (Ensure that no more than 2 ML/d of groundwater is extracted)	Not applicable	Introduced	Section 5.3.6
Condition 23 (Ensure all water storage ponds are lined)	Not applicable	No	Not applicable

EPBC condition	Sub-condition	Addressed in this report	Report section
Condition 24 (Develop an acid sulphate soils management plan)	Not applicable	No	Not applicable
Condition 25 (Develop a watercourse crossing management strategy)	Not applicable	No	Not applicable

2.3 GCCC independent peer reviewer comments

Based on the recommendation of the Gloucester Community Consultative Committee (GCCC), an independent review of the hydrogeological aspects of the GGP was conducted by Dr Richard Evans in 2012 (SKM, 2012b). The review is an assessment of the suitability of the conceptual model developed in three reports (URS, 2007; SRK, 2010 and Parsons Brinckerhoff, 2012a), and assessment of the adequacy of the current monitoring infrastructure for measuring potential water impacts across the Stage 1 GFDA.

Table 2.3 summarises the recommendations for further work as a result of the independent peer review, and identifies where these recommendations have been addressed in the report.

Table 2.3 Peer review recommendations (SKM, 2012b)

Recommendation	Addressed in this report	Report section
Field work		
1. Groundwater investigations to assess the hydraulic significance of faults	Yes	Section 5.5
2. At least one of the three existing stream gauges should be rated to enable determination of flows	No	Not applicable (part of PB hydrological studies)
3. Install an additional nested monitoring site (two bores are suggested) in the vicinity of the township of Gloucester	No	Not applicable (part of 2013 and 2014 work programs)
4. Investigate the relationship between groundwater and Waukivory Creek and Dog Trap Creek	Yes	Section 5.2.3 (part of PB hydrological studies)
5. At least one VWP (nested site) should be installed in the target coal seams and interburden	No	Not applicable (part of conversion of Pontilands 03 corehole)
6. Install one shallow monitoring site with multiple monitoring level (gas monitoring bores) in the coal seam outcrop areas	No	Not applicable (completed in 2012)
7. Method of abandonment of exploration bores should be identified	No	Not applicable (part of wellfield design and development plan)
8. Investigation of the sources of baseflow to the Avon River should be conducted	No	Not applicable (part of PB hydrological studies)
9. Water level loggers should be included in TMB04 and TMB05	No	Not applicable (part of ongoing irrigation trial)
10. Install a monitoring bore down-gradient of one of the Stratford holding dams	No	Not applicable (dams being decommissioned)
11. All of the private bores surveyed and dipped in the SRK (2010) study should be re-dipped	No	Not applicable (part of property survey scope)

Recommendation	Addressed in this report	Report section
12. Surveying of springs in the project area should be undertaken	No	Not applicable (part of property survey scope)
Desk-based study/analysis		
13. A conceptual model of the hydraulic behaviour of faults should be developed	Yes	Section 5.5
14. The conceptual model should account for major structural changes related to faults	Yes	Section 4, 5 and 6
15. The proposed numerical model boundaries should be defined, and the conceptual model expanded to include this area	Yes	Section 4, 5 and 6
16. A water balance should be conducted using the boundaries in recommendation 15	No	Not applicable (part of revised PB water balance)
17. Additional bore data should be incorporated into the conceptual model to improve spatial coverage away from the centre of the Stage 1 GFDA	Yes	Section 4, 5 and 6
18. Additional analysis of the existing hydraulic conductivity data should be undertaken	Yes	Section 5.3.2
19. Further evaluation of the relevance of hydraulic conductivity data collected in or close to the Stage 1 GFDA should be undertaken	Yes	Section 5.3.2
20. Baseflow separation should be undertaken for the Avon River downstream of Waukivory Creek gauge	No	Not applicable (part of PB hydrological studies)
21. Once the new stream gauges have been rated, baseflow separation should be undertaken on the gauges	No	Not applicable (part of PB hydrological studies)
22. Conceptual model should be updated and consolidated into one report	Yes	Sections 1, 2, 3, 4, 5 and 6
23. Analysis of water levels with barometric effect removed should be undertaken	Yes	Section 5.3.3
24. Aspects of the conceptual model which are currently located in the three reports (URS, 2007; SRK, 2010 and PB, 2012a) should be consolidated	Yes	Sections 3, 4, 5 and 6

3. Data sources

This chapter provides information on previously published reports that are relevant to this conceptual model report. Previous studies carried out for the GGP and within the Gloucester Basin are outlined in Table 3.1.

Table 3.1 Previous reports

Report	Area covered	Summary
Geology of the Camberwell, Dungog and Bulahdelah 1:100,000 Geological Sheets, Roberts (1991)	Gloucester Basin	Geology of the Camberwell, Dungog and Bulahdelah 1:100,000 Geological Sheets
Gloucester Basin Geological Review, SRK (2005)	Gloucester Basin	Lucas Energy Pty Ltd, the PEL holder prior to AGL, commissioned SRK Consulting to undertake a desktop geological review of the Gloucester Basin to identify areas that have been least disturbed by faulting and contains thick sequences for coal, for the purposes of CSG exploration.
Hydrogeological Review of the Gloucester-Stroud Basin, URS (2007)	Gloucester Basin	Lucas Energy Pty Ltd, the PEL holder prior to AGL, commissioned URS Australia Pty Ltd to undertake a desktop review of the hydrogeological conditions at three CSG exploration areas within the Gloucester-Stroud Basin.
CSG pilot/flow testing programs, AGL (2012)	Stage 1 GFDA	Nine gas wells were flow tested by Lucas/AGL as part of the Stratford pilot testing program between 2006 and December 2009. Produced water volumes, water levels and water quality were assessed as part of the study.
Stroud Gloucester Trough: Review of the Geology and Coal Development, Lennox (2009)	Gloucester Basin	Summary of the work carried out in the period 1980-1985, including mapped geology at a scale of 1:10,000, photogeological studies, logged core, review of electric bore logs and measured sections at several locations within the Gloucester Basin.
Seismic Surveys, AGL (2009, 2010 and 2012)	Stage 1 GFDA (2009 & 2010) Gloucester Basin (2012)	Seismic data collected by AGL mapped a number of north-south striking thrust faults, and east-west striking sub-vertical normal faults across the Stage 1 GFDA.
Gloucester Basin Stage 1 Gas Field Development Project: Preliminary Groundwater Assessment and Initial Conceptual Hydrogeological Model, SRK (2010)	Stage 1 GFDA	Hydrogeological assessment of the Gloucester Basin, in particular the Stage 1 GFDA, including a desktop review, initial site visit, data collection and initial conceptual hydrogeological model.
A Hydrogeological Assessment of the Duralie Extension Project: Environmental Assessment, Heritage Computing (2009)	Duralie Mine Lease	Hydrogeological assessment of the Gloucester Basin, in particular the Duralie Mining Complex, including characterisation of the existing groundwater regime, collation and review of baseline geological and groundwater data; and development of conceptual and numerical groundwater models
A Hydrogeological Assessment in Support of the Stratford Coal Project: Environmental Impact Statement, Heritage Computing (2012)	Stratford Mine Lease	Hydrogeological assessment of the Gloucester Basin, in particular the Stratford Mining Complex, including characterisation of the existing groundwater regime, collation and review of baseline geological and groundwater data; and development of conceptual and numerical groundwater models

Report	Area covered	Summary
Phase 2 Groundwater Investigations – Stage 1 Gas Field Development Area, Parsons Brinckerhoff (2012a)	Stage 1 GFDA	Comprehensive groundwater investigations to confirm the conceptual model and connectivity of different groundwater systems across the Stage 1 GFDA, establishment of a dedicated monitoring network across the area; and collection of baseline water level and water quality attributes for each of these groundwater systems
Gloucester Groundwater and Surface Water Monitoring – Annual Status Report, Parsons Brinckerhoff (2012b)	Stage 1 GFDA	Annual review of the monitoring network established across the Stage 1 GFDA, detailing groundwater and surface water level and water quality trends for the period January 2011 to June 2012
Water Balance for the Gloucester Stage 1 GFDA, Parsons Brinckerhoff (2012c)	Northern Gloucester Basin	Updated conceptual model and water balance for the Gloucester Basin, with a focus on the northern Gloucester Basin within which the Stage 1 GFDA is located. Estimation of the storage and flow of water within a defined area, within a given timeframe.
Hydrogeological Investigation of a strike-slip fault in the Northern Gloucester Basin, Parsons Brinckerhoff (2013b)	Stage 1 GFDA	Following GGP referral to SEWPaC under the EPBC Act, an extension of the baseline Phase 2 Groundwater Investigations for the Stage 1 GFDA was carried out, assessing the connectivity between a strike-slip fault and shallow and deep groundwater systems.
Gloucester Resources Groundwater Investigation, Annual Monitoring Report Parsons Brinckerhoff (2012d)	Rocky Hill Coal Project Exploration Area	Hydrogeological investigation at the Gloucester Resources Ltd (GRL) proposed Rocky Hill Coal Project open cut coal mine. Annual review of the monitoring network detailing groundwater level and quality trends for the period March 2011 to March 2012

4. Physical setting

This chapter provides an overview of the physical characteristics of the Gloucester Basin including topography, drainage, climate, geology and geological structure.

4.1 Topography and drainage

The Gloucester Basin is a narrow, north-south trending, elongated basin approximately 40km long and 10km wide, extending from Gloucester in the north to Stroud in the south. A major surface water divide, just north of Wards River, separates the Basin into two major catchment areas (Figure 4.1).

The Gloucester Basin is located high in the Manning River and Karuah River coastal catchments. The area occupied by the Permian Coal Measures (about 220 km^2) is small in comparison to the size of these catchments.

In the southern catchment area, surface water flow is generally to the south, and is part of the Karuah River catchment. In the northern catchment area, surface water flow is generally to the north, and is part of the Manning River catchment. Figure 4.2 illustrates the surface water catchments, and the surface water divide between the Wards River catchment (part of the Karuah River catchment) and the Avon River catchment (part of the Manning River catchment).

The Gloucester Basin is topographically enclosed to the west by the Gloucester and Barrington Tops, and to the east by the Mograni Range.

4.2 Rainfall and evapotranspiration

There are four Bureau of Meteorology (BoM) weather stations within the Gloucester Basin (Figure 4.2), and an additional AGL weather station on the Tiedman property (Figure 1.1). Average rainfall and the period of monitoring for the BoM stations are presented in Table 4.1.

Table 4.1 BoM stations in the Gloucester Basin

BoM station number	Name	Monitoring period	Long term average annual rainfall (mm) *
BoM 60015	Gloucester Post Office	1888 to present	982.4
BoM 60112	Gloucester Hiawatha	1976 to present	1023.2
BoM 60042	Craven (Longview)	1961 to present	1061.6
BoM 61071	Stroud Post Office	1889 to present	1145.8

* Long term average annual rainfall (mm) over the monitoring period

Long term (1988–2013) cumulative deviation from the annual mean rainfall at Gloucester Post Office (BoM station 60015) is presented in Figure 4.3a. The period of highest rainfall occurred from 1888 to 1894. The period of lowest rainfall occurred from 1934 to 1948. Other significant periods of lower than average rainfall occurred from 1963 to 1975, 1978 to 1987 and 1990 to 2006, as shown by a downward sloping cumulative deviation trend. Of these periods, the following coincide with major droughts in Australia (Australian Bureau of Statistics, 2013):

- 1895–1903.
- 1911–1916.
- 1939–1945.
- 2003–2008.

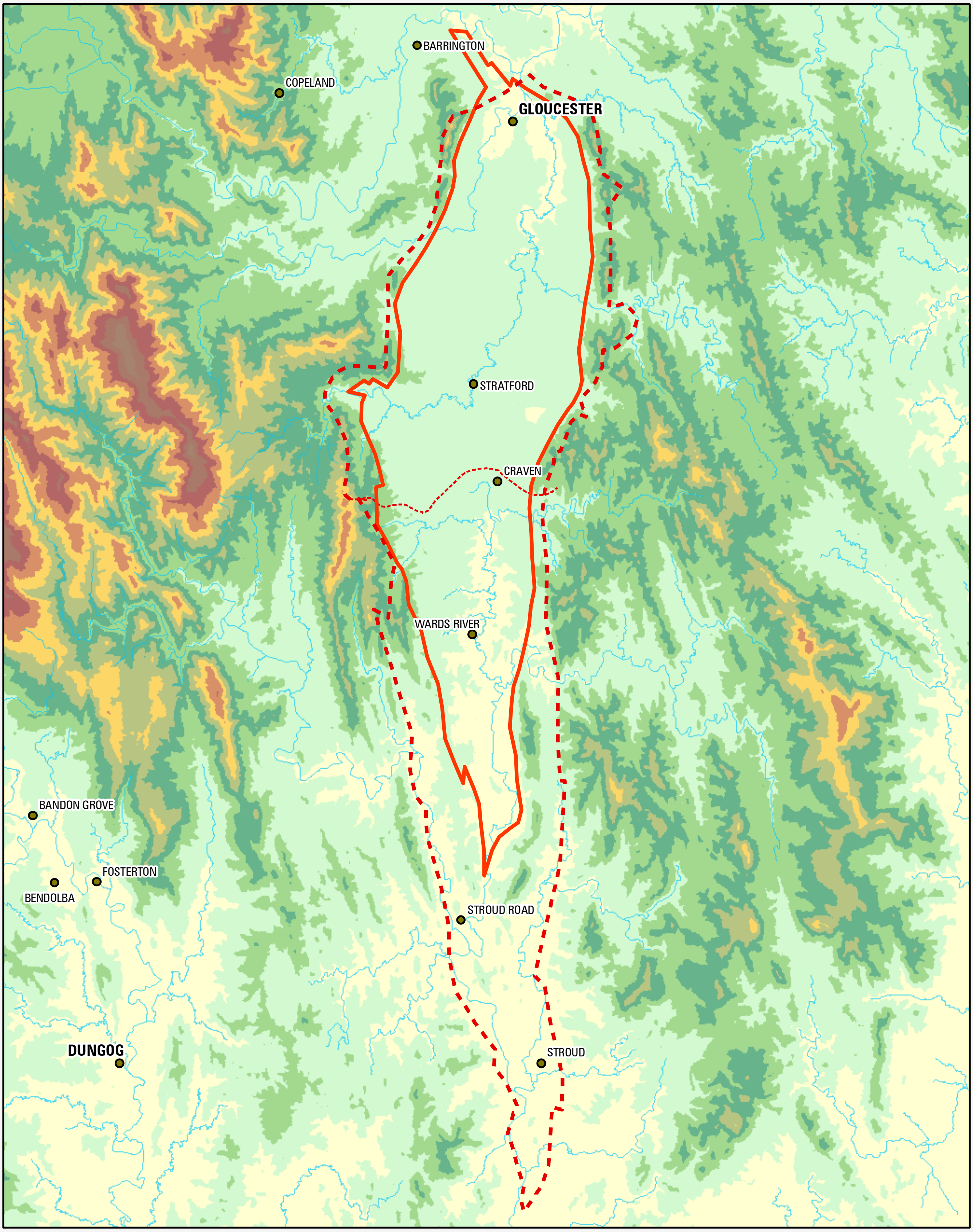
From 2006 to 2012 rainfall has been higher than the long term average, as shown by the upward sloping cumulative deviation trend.

Rainfall data for the monitoring period January 2011 to March 2013 are presented in Figure 4.3b. From February 2011 to February 2012 actual rainfall was greater than average rainfall, as confirmed by an upward sloping cumulative deviation trend. In contrast, the period between February 2012 and December 2012 shows a downward sloping cumulative deviation curve, indicating that actual rainfall was lower than the average rainfall. From December 2012 to March 2013, actual rainfall was again higher than average rainfall.

Historically, the period between July and September records the lowest monthly rainfall, while the period between January and March typically has the highest monthly rainfall.

Evapotranspiration is the collective term encompassing the transfer of water, as water vapour, to the atmosphere from both vegetated and clear land surfaces (BoM, 2013b). Evapotranspiration rates are affected by climate and the availability of water and vegetation.

The average, annual evapotranspiration for the whole Gloucester Basin is approximately 750mm; this was obtained from the average, areal, actual evapotranspiration maps created by the BoM from data collected between 1961 and 1990 (Figure 4.4) (B0M, 2013b).



Elevation (mAHD)

- >0
- 0 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 600
- 600 - 700
- 700 - 800
- 800 - 900
- 900 - 1,000
- 1,000 - 1,100
- 1,100 - 1,200
- 1,200 - 1,300
- 1,300 - 1,400
- Alum Mountain Volcanics boundary
- Permian Coal Measures boundary
- Surface water divide
- Rivers and streams

N
0 10
Kilometres

Figure 4.1
Gloucester Basin topography

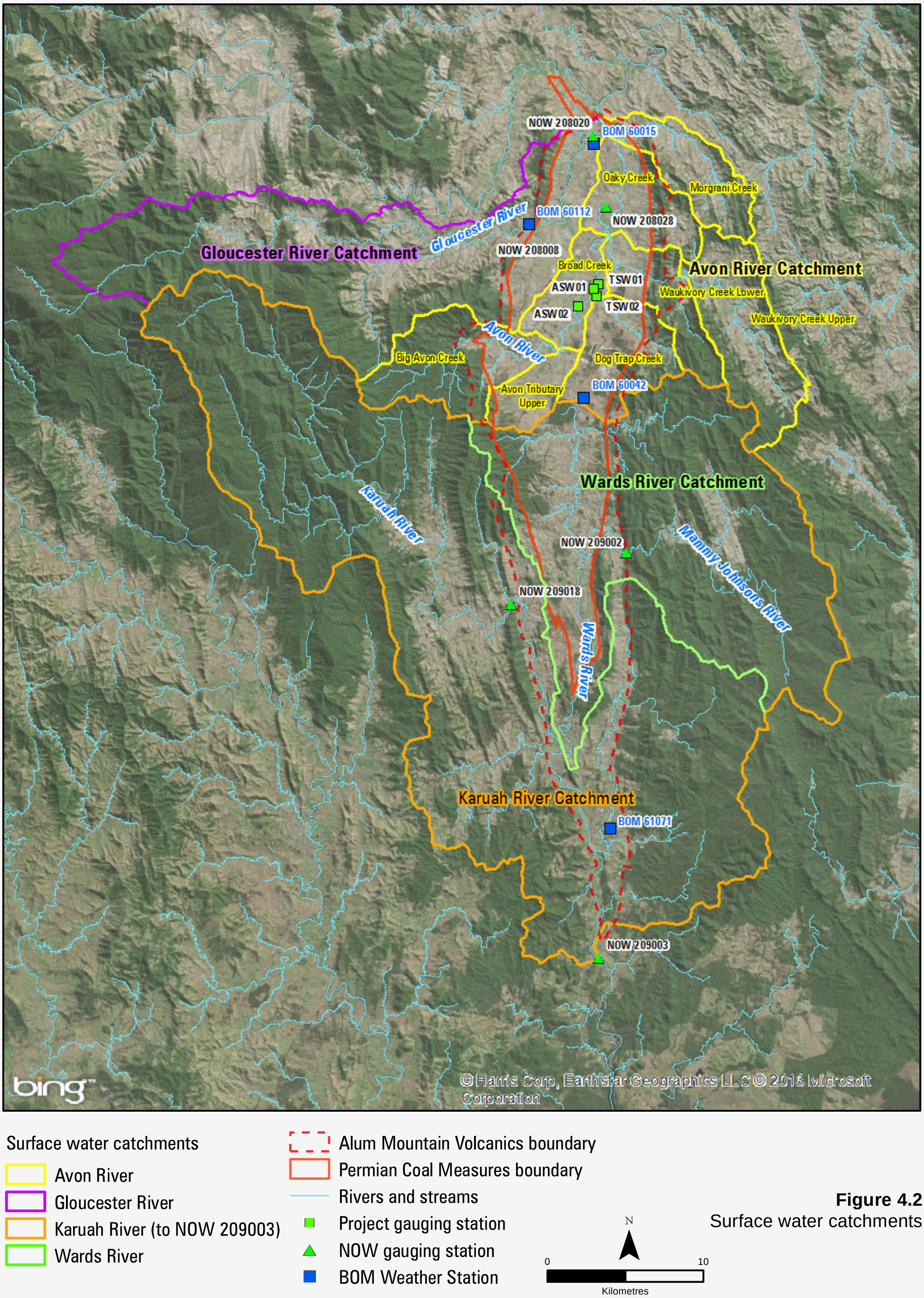


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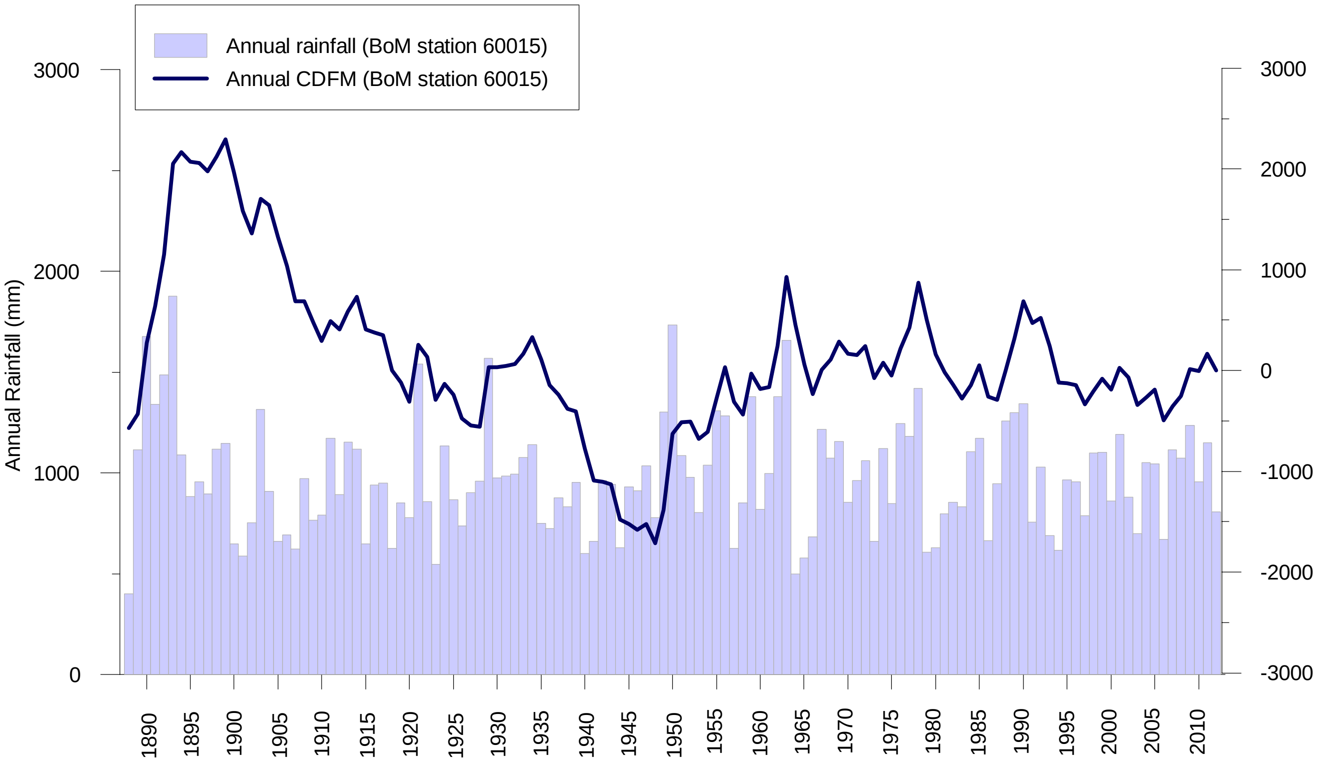
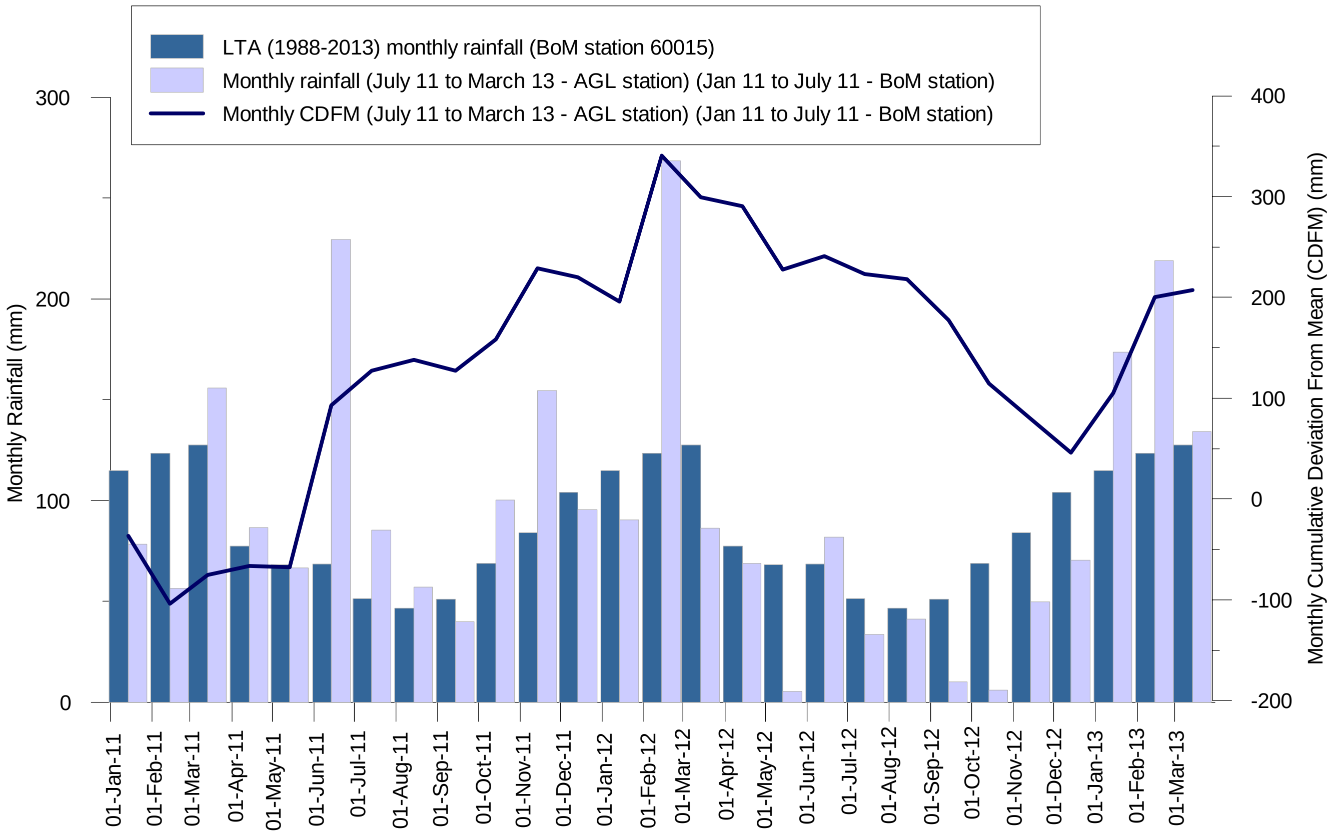
Figure 4.2
Surface water catchments



a. Long term annual rainfall, and cumulative deviation from the annual mean rainfall (CDFM) at Gloucester Post Office BoM station 060015 (BoM, 2013a)



b. Monitoring period monthly rainfall, and cumulative deviation from the monthly mean rainfall (CDFM) at the AGL Gloucester station (AGL, 2013)

Figure 4.3 Gloucester rainfall data

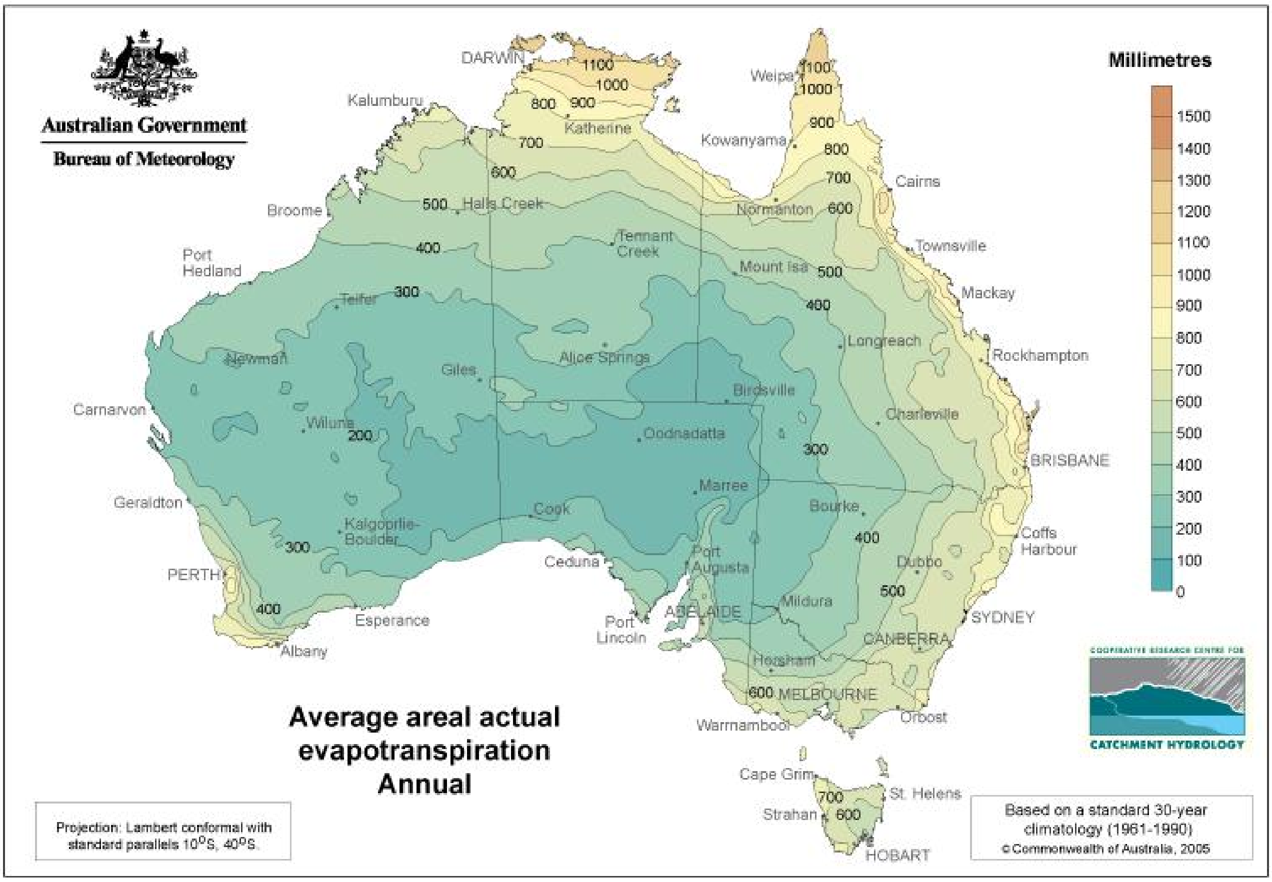


Figure 4.4 Average, areal, actual evapotranspiration (BoM, 2013b)

4.3 Geological setting

4.3.1 Overview

The Gloucester Basin represents a complex geological system formed by the interplay of extensional tectonic faulting and high rates of sedimentation. The Basin stratigraphy comprises a thick succession of Permian sedimentary rocks representing deposition in both terrestrial and marine environments during a complex period of subsidence, uplift and relative sea level change (marine transgression and regression).

The Basin is a synclinal intermontane structure formed in part of the New England Fold Belt between a major Permian plate margin and the Sydney–Gunnedah Basin (Lennox 2009). The north – south trending synclinal nature of the Gloucester Basin resulted from the collision between the East Australian and Pacific Plates.

Following a period of extension during the Early Permian the Gloucester Basin has undergone periods of normal and reverse faulting, with large scale tilting associated with late stage compressional movements towards the end of the Permian (Hughes 1995). Reverse faults dominate present day structure. A comparison with the contemporary horizontal stress field map (Hillis *et al* 1998) indicates the Basin is likely to be under compression in an east-west orientation.

The stratigraphy dips steeply (up to 90°) on the flanks of the Basin, dipping towards the north-south trending synclinal basin axis and flattening toward the centre of the Basin. Early Permian and Carboniferous hard resistive volcanics form the ridgelines of the Basin: the Mograni Range to the east; and the Gloucester and Barrington Tops to the west.

Overlying the Permian stratigraphy is a thin sequence of surficial Quaternary sediments. The Quaternary sediments are non-uniform in thickness, and comprise unconsolidated alluvial sediments (sand, gravel, silt and clay) along the drainage channels and colluvial deposits across the rest of the plain sourced from the surrounding outcropping Permian deposits.

4.3.2 Stratigraphy of the investigation area

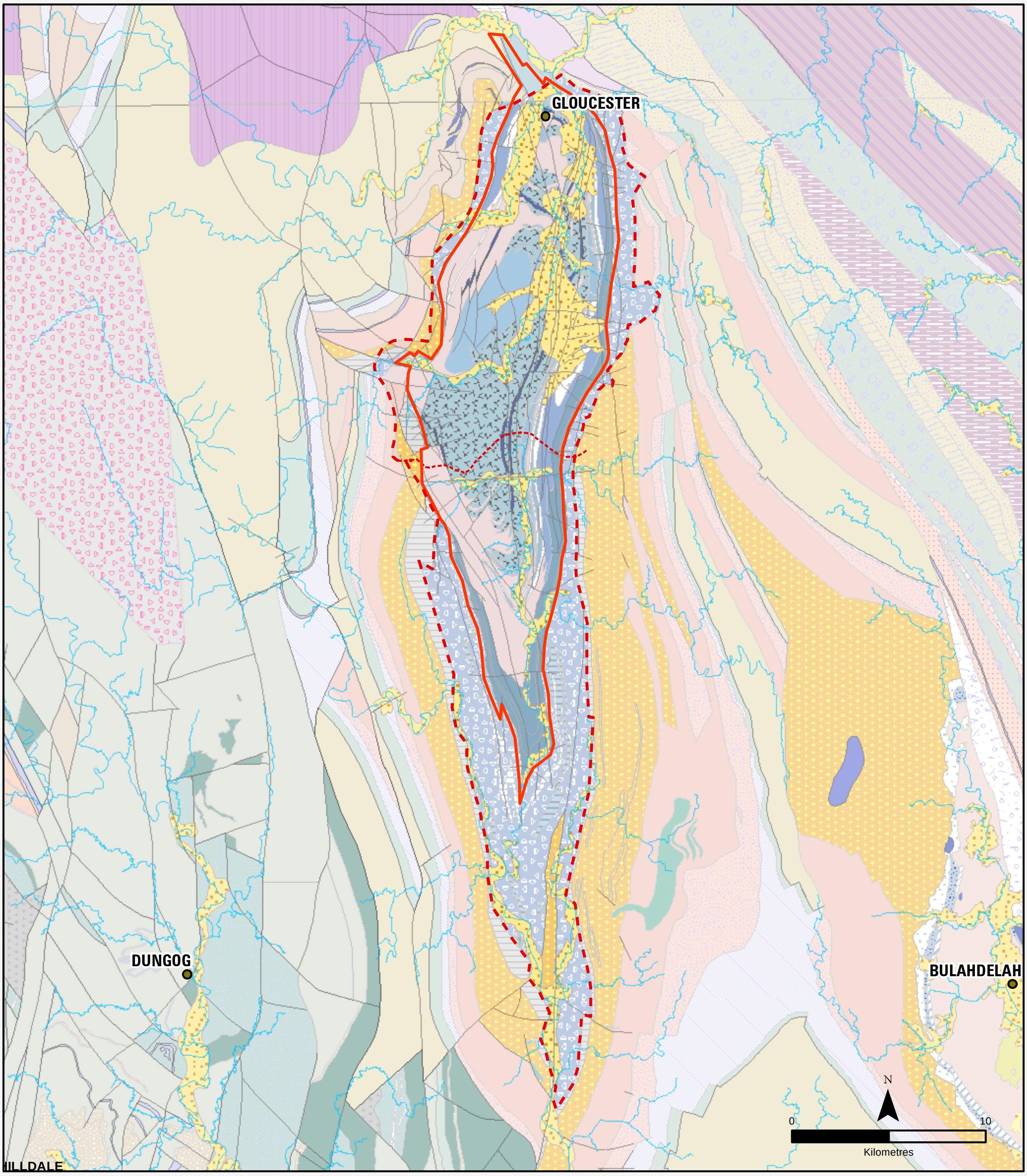
The Gloucester Basin is divided into three major Permian stratigraphic units each representing a distinct depositional setting: the Gloucester Coal Measures, the Dewrang Group, and the Alum Mountain Volcanics. The generalised stratigraphy of the basin is summarised in Table 4.2. A geological map of the basin is shown in Figure 4.5, and regional geological cross-section through the Gloucester Basin is shown in Figure 4.6.

The CSG development in the Stage 1 GFDA is targeting the intermediate and deep coal seams in the Gloucester Coal Measures generally below depths of 200m to around 1000m.

Table 4.2 Stratigraphy of the Gloucester Basin

Period	Group	Sub-group	Formation	Approx. thickness (m)	Coal seam	Depositional Environment	Tectonic Events
Upper Permian	Gloucester Coal Measures	Craven	Crowthers Road Conglomerate	350		Marine regression, pro-gradation of alluvial fans	Uplift to west of Gloucester Basin
			Leloma	585	Linden		
					JD		
					Bindaboo		
					Deards		
			Jilleon	175	Cloverdale		
					Roseville		
					Tereel/Fairbairns		
			Wards River Conglomerate	Variable			
			Wenham	23.9	Bowens Road		
					Bowens Road Lower		
		Speldon Formation				Marine transgression but also some progradation of alluvial fans in the west related to uplift	Extension (normal fault development) and regional subsidence. Uplift to west of Basin
		Avon	Dog Trap Creek	126	Glenview		
			Waukivory Creek	326	Avon		
					Triple		
					Rombo		
					Glen Road		
					Valley View		
					Parkers Road		
	Dewrang	Mammy Johnsons		300	Mammy Johnsons	Marine transgression, regression and further marine transgression	Extension (normal fault development) and regional subsidence
		Weismantel		20	Weismantel		
		Duralie Road		250			
Lower Permian	Alum Mountain Volcanics				Clareval	Arc-related rift	Rift?
					Basal		

Modified from AECOM (2009) and SRK (2005)



Alum Mountain Volcanics boundary
Permian Coal Measures boundary
Rivers and streams

Gloucester Basin Geology

- Qa — Quaternary Alluvium
- G — Unnamed microgranite

Permian Geology

- Plc — Crowthers Rd Conglomerate
- Pll — Leloma Formation
- Pllj — Jo Doth Tuff Member
- Plo — Jilleon Formation
- Plw — Wards River Conglomerate
- Pla — Wards River Conglomerate
- Plgx — Gloucester Coal Measures
- Plh — Wenham Formation
- Plp — Speldon Formation
- Plt — Dog Trap Creek Formation
- Pli — Waukivory Creek Formation
- Pldy — Mammy Johnsons Formation
- Plde — Weismantels Formation
- Pldd — Duralie Road Formation
- Pea — Alum Mountain Volcanics
- Pear — Unnamed Rhyolite Member
- Peat — Unnamed Welded Tuff Member
- Peac — Unnamed Basal Sequence

Carboniferous geology

- Clo1 — Johnsons Creek Conglomerate
- Clkm — McInnes Formation
- Clr — Booral Formation
- Fault

Figure 4.5
Regional Geology

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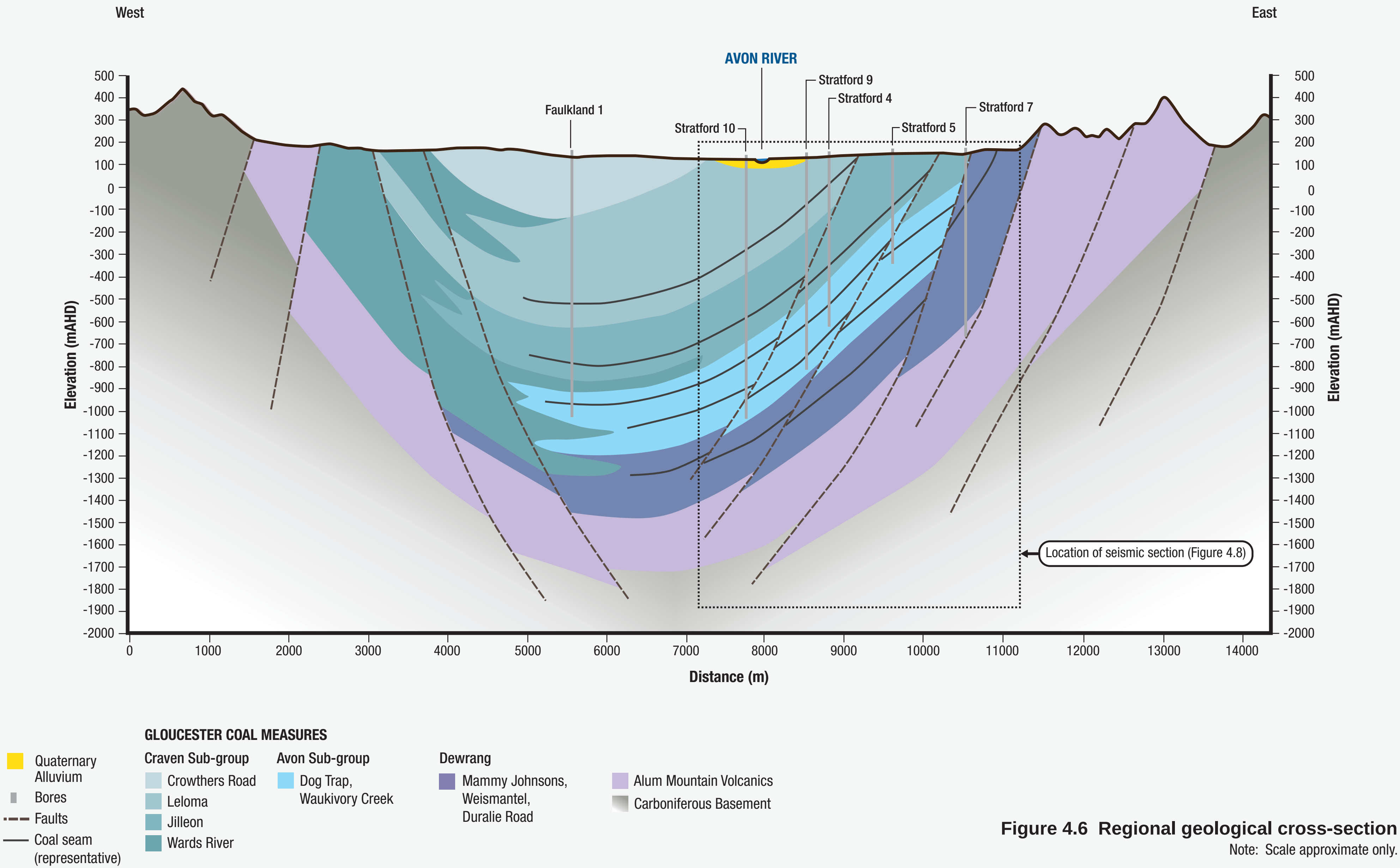


Figure 4.6 Regional geological cross-section

Note: Scale approximate only.

4.3.3 Structural development

The tectonic development and structural setting of the Gloucester-Stroud Syncline is discussed by Roberts et al. (1991) based on regional geological mapping and seismic profile interpretation. Subsequent structural interpretations have been carried out by SRK (2005) and Lennox (2009). The following summary is based on those reports.

The Gloucester-Stroud Syncline is the largest structure in the surrounding region, being more than 55 km long and 24 km wide with steeply dipping limbs containing a stratigraphic section up to 8 km thick (Roberts et al, 1991). The syncline has a sinuous axial trace that trends generally northerly (355°) but that swings eastwards (022°) between Stratford and Gloucester. The syncline is doubly plunging, closing at both ends forming a tight canoe-like structure. The axial plane is inclined slightly to the east; bedding in the limbs of the syncline tends to dip steeply toward the axis at more than 60°, with some bedding sub-vertical or slightly overturned.

The syncline is a fault bounded trough, active during the Permian. Roberts et al (1991) identify up to six deformation events that were important in the depositional and structural development of the Basin. SRK (2005) simplified the structural development into two main stages:

1. Early – Middle Permian dextral tectonic margin, resulting in reactivation of NNW-striking faults as strike-slip dextral and formation of NE and EW striking normal faults, particularly around the margins of a circular basement feature (suspected deep intrusion) in the northern part of the Basin. The majority of the Coal Measures were deposited during this complex phase.
2. Late Permian NE shortening during the early stages of the Hunter Bowen Orogeny, resulting in reverse and thrust faulting on NNW faults and some NNE faults.

Combining structural domains with the known distribution of stratigraphy, SRK (2005) divides the Basin into three structure/stratigraphic domains:

1. An eastern domain containing a number of coal seams in the Avon and Craven Sub-Groups.
2. A western domain where the surface mapping indicates sequences of Waukivory Formation and Wards River Conglomerate that mark periods of prograding fluvial systems that have significantly reduced the thickness of coal seams.
3. Major fault zones that separate the eastern and western domains.

In addition, SRK (2005) identifies a possible basement structure or intrusion overlapping with the northern part of the Basin that appears to have influenced the structural development of the Basin. The margin of that structure coincides with arcuate and east-west faulting in the mid part of the basin (e.g. west of Stratford) and may account for the contrasting deformation styles in the Carboniferous basement rocks to the north and south of this approximate line.

4.3.4 Faulting

Faulting in the Gloucester Basin is discussed by Roberts et al. (1991) who identify five distinct types or styles of faulting based on mapping and seismic interpretations:

1. Low-angle, west-dipping broadly meridional (N-S) thrust faults.
2. Sinistral shear zones striking between 300° and 350°.
3. Meridional reverse faults.
4. East-west striking normal faults.
5. Shears or normal faults striking between 040° and 060°.

These contrasting fault types reflect different episodes of deformation throughout the complex structural history of the Basin (Roberts et al. 1991), and the possible influence of basement structures (SRK, 2005). Lennox (2009) provided a spatial analysis of faults and other linear features based on air photo and seismic interpretations which follows a broadly similar classification (Figure 4.7).

Geological mapping of the Basin (Roberts et al. 1991) shows that the geological structure within the Stage 1 GFDA is dominated by moderately to steeply west-dipping strata intersected by near-vertical sinistral strike-slip faults with significant vertical components (Style 2, Figure 4.7) and westerly-dipping thrust faults (Style 1, Figure 4.7). Simular faulting and folding styles extend to the southern part of the basin. A geological cross-section through the Gloucester Basin with representative faulting is shown in shown in Figure 4.6.

Recent (deep, high resolution) seismic data acquired by AGL in the period from 2009 to 2012 identify a number of westerly dipping thrust faults striking north-south, and north-south striking high angle oblique faults. The resolution of the vertical seismic profiles is good to depths of approximately 1000 m, however the technique returns poor resolution in the top 200 m. This inhibits the ability to map these fault structures through the shallow surface rock and currently lineament traces can only be inferred. The resolution of the seismic data allows for identification of faults when displacement is greater than approximately 10 m.

The seismic section presented in Figure 4.8 shows the subsurface bedding and structure to depths of 1,900 mbgl beneath the Tiedman property in the centre of the Stage 1 GFDA. This seismic section has been interpreted to identify four major westerly dipping thrust faults and two easterly dipping north-south trending strike-slip faults with minimal vertical offset (Figure 4.8).

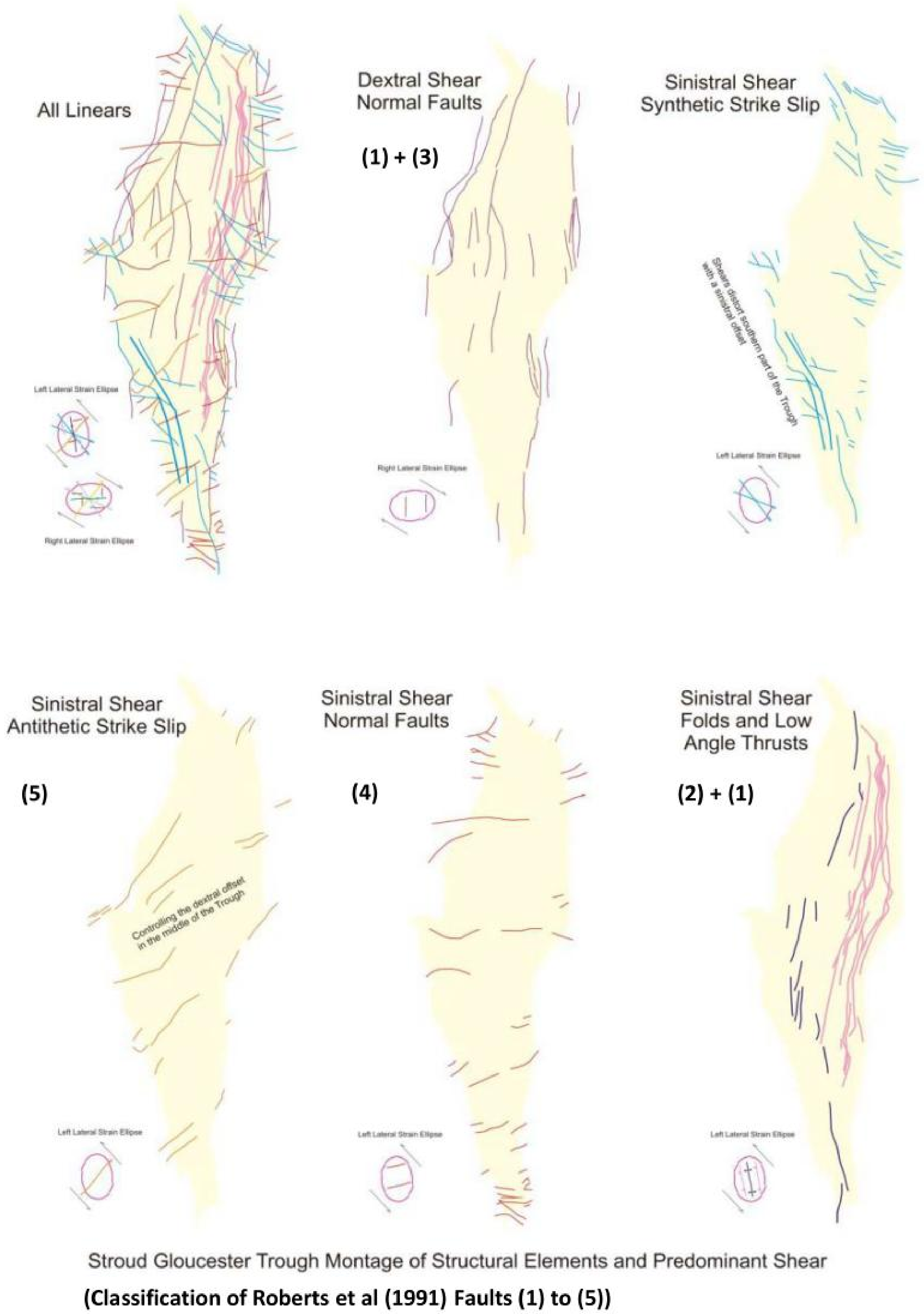


Figure 4.7 Major sets and styles of faulting in the Gloucester Basin (after Lennox, 2009)

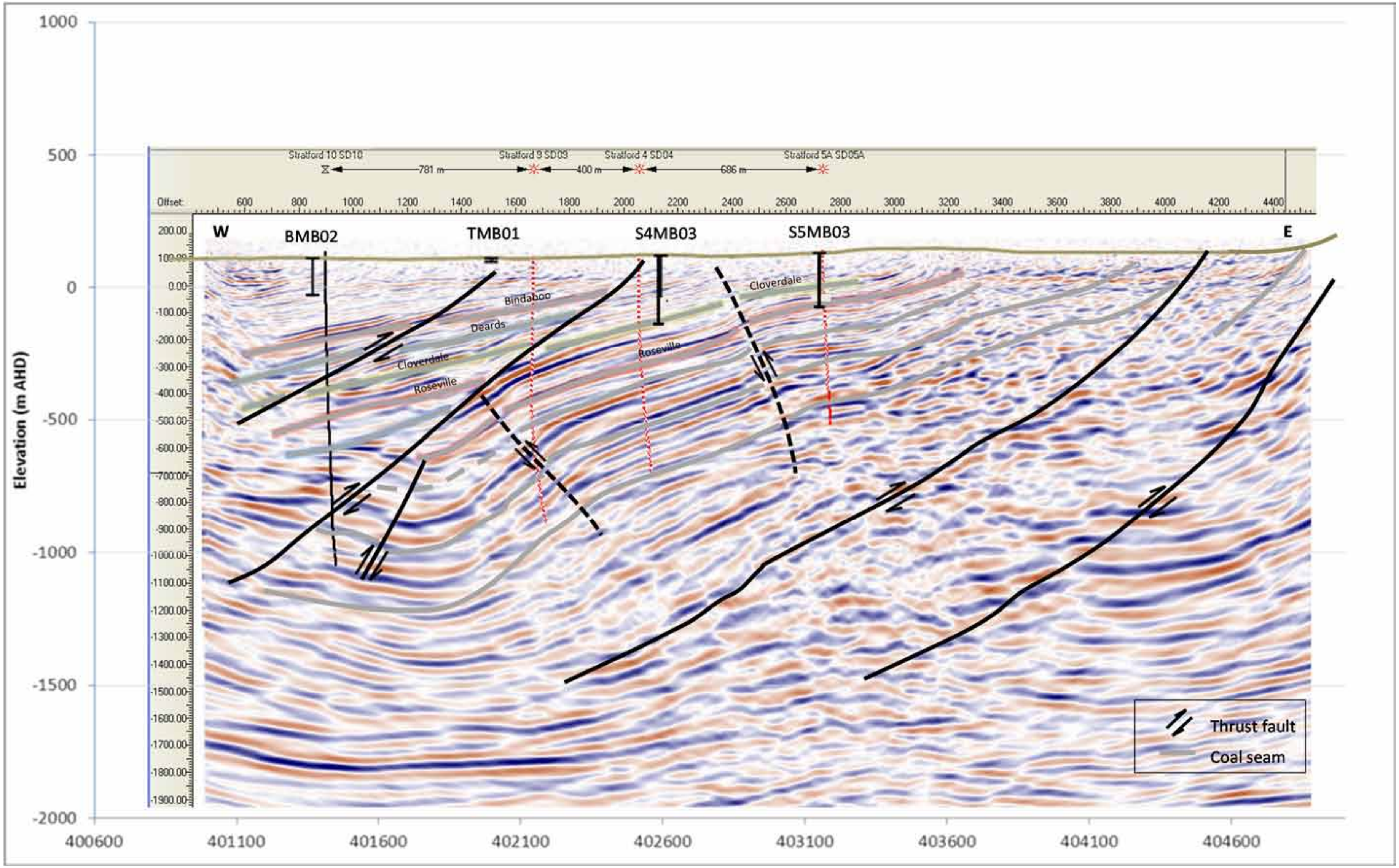


Figure 4.8 Interpreted seismic cross-section through the eastern Gloucester Basin

5. Review of Gloucester Basin hydrology and hydrogeology

This chapter provides a detailed summary of the hydrology and hydrogeology data for the Gloucester Basin, and in particular the AGL groundwater studies and most recent data from the surface and groundwater monitoring network.

5.1 Monitoring network

A groundwater and surface water monitoring network for the Stage 1 GFDA was established as part of the Phase 2 Groundwater Investigations (Parsons Brinckerhoff, 2012a).

Analysis of data from this monitoring network is presented in the Gloucester Monitoring Annual Status Report (Parsons Brinckerhoff, 2012b), and additional monitoring has been installed as part of the Hydrogeological Investigation of a strike-slip fault in the Northern Gloucester Basin (Parsons Brinckerhoff, 2013b). There are now more than 40 dedicated water monitoring locations and more than 24 months of baseline monitoring (water levels and water quality) across the project area. Several high rainfall periods and one extended dry period have occurred to provide a data set that is representative of seasonal variability.

A review of the monitoring network detailing groundwater and surface water level and water quality trends for the monitoring period January 2011 to March 2013 is presented in Sections 5.2 and 5.3.

5.1.1 Surface water

There are four AGL stream gauges constructed in the Stage 1 GFDA; three on the Avon River and one on Dog Trap Creek (Figure 5.1 and Table 5.1). There are a further two NOW gauging stations in the Gloucester Basin and three just outside of the Permian Coal Measures boundary (Figure 4.2 and Table 5.3).

Table 5.1 AGL stream gauges in the Stage 1 GFDA

Stream gauge	Easting (MGA, m)	Northing (MGA, m)	Property location	Stream location
TSW01	401994	6449417	Tiedman	Avon River
TSW02	401922	6448741	Tiedman	Dog Trap Creek
ASW01	401711	6449092	Atkins	Avon River
ASW02	400698	6447963	Atkins	Avon River

5.1.2 Groundwater

Three types of groundwater monitoring bores have been constructed in the Stage 1 GFDA (Figure 5.1 and Table 5.2):

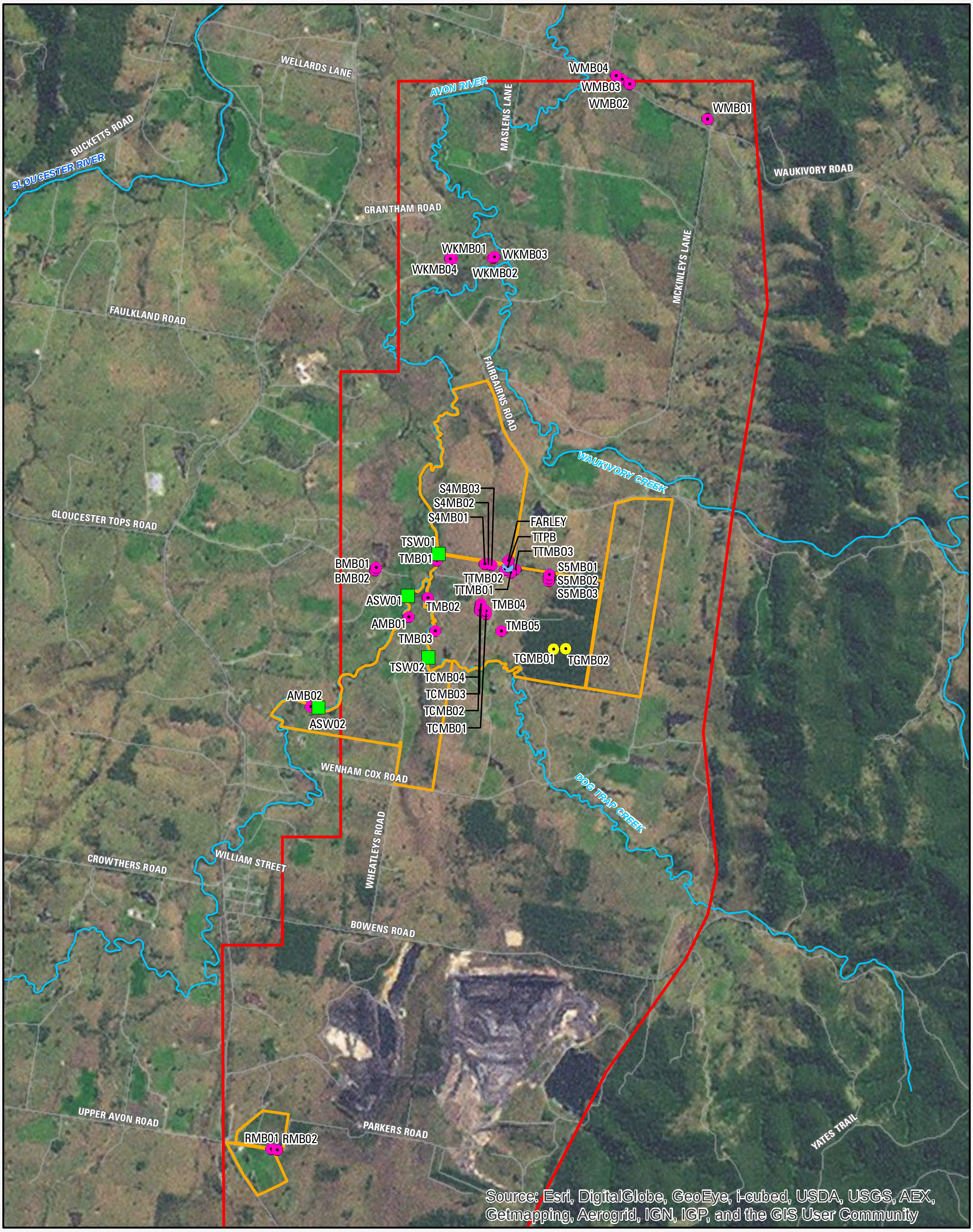
1. Bores targeting the shallow alluvial sediments of the Avon River and its floodplain.
2. Bores targeting the shallow bedrock.
3. Bores targeting the Gloucester Coal Measures, including the interburden and coal seams.

Additional groundwater monitoring bores in the Gloucester Basin associated with Stratford Mine, Duralie Mine and the Rocky Hill Coal Project are shown in Figure 5.20.

Table 5.2 AGL groundwater monitoring bores in the Stage 1 GFDA

Monitoring Bore	Property Location	Total depth (m)	Screened interval (mbgl)	Lithology	Formation	Hydrogeolog-ical Unit
S4MB01	Tiedman	66	58–64	Sandstone	Leloma Formation	Shallow roc k
S4MB02	Tiedman	97	89–95	Sandstone/ siltstone	Leloma Formation	Shallow rock
S4MB03	Tiedman	170	162–168	Coal	Jilleon Formation – Cloverdale Coal Seam	Coal
S5MB01	Tiedman	60	52–58	Sandstone/ siltstone	Jilleon Formation	Shallow rock
S5MB02	Tiedman	114	110–102	Siltstone	Jilleon Formation	Shallow rock
S5MB03	Tiedman	166	158–164	Coal/shale	Jilleon Formation – Roseville Coal Seam	Coal
TMB01	Tiedman	12	7–10	Clay	Avon River Alluvium	Alluvial
TMB02	Tiedman	15.5	9–12	Mixed gravels	Avon River Alluvium	Alluvial
TMB03	Tiedman	12.5	5–11	Mixed gravels and sand	Avon River Alluvium	Alluvial
TCMB01	Tiedman	90	87–93	Sandstone	Leloma Formation	Shallow rock
TCMB02	Tiedman	183	175–181	Sandstone	Leloma Formation	Interburden
TCMB03	Tiedman	268	260–266	Coal and sandstone	Jilleon Formation – Cloverdale Coal Seam	Coal
TCMB04 (core hole)	Tiedman	334.7	327.3–333.3	Coal	Jilleon Formation – Roseville Coal Seam	Coal
AMB01	Atkins	12.6	8–10	Mixed gravels	Avon River Alluvium	Alluvial
AMB02	Atkins	11.5	6.5–11	Mixed gravels	Avon River Alluvium	Alluvial
BMB01	Bignell	30	15–29	Sandstone/ siltstone	Leloma Formation	Shallow rock
BMB02	Bignell	138	124–136	Sandstone	Leloma Formation	Shallow rock
WMB01	Waukivory	8.5	5–8	Mixed gravel/ sand	Alluvium	Alluvial
WMB02	Waukivory	23	15–21	Sandstone	Wenhams Formation	Shallow rock
WMB03	Waukivory	36	32–34	Coal	Wenhams Formation - Bowens Road Coal Seam	Shallow rock
WMB04	Waukivory	80.5	67–79	Sandstone	Wenhams Formation	Shallow rock

Monitoring Bore	Property Location	Total depth (m)	Screened interval (mbgl)	Lithology	Formation	Hydrogeolog-ical Unit
RMB01	Rombo	51	42–48	Sandstone	Leloma Formation (upper)	Shallow rock
RMB02	Rombo	93	85–91	Sandstone	Leloma Formation (upper)	Shallow rock
WKMB01	Mitchell	54	47–53	Sandstone	Leloma Formation	Shallow rock
WKMB02	Mitchell	61	51–60	Sandstone/ siltstone	Leloma Formation	Shallow rock
WKMB03	Mitchell	210	200–209	Coal and sandstone	Leloma Formation – Deards Coal Seam	Coal
WKMB04	Mitchell	360	335–347	Coal and sandstone	Jilleon Formation – Roseville Coal Seam	Coal
Farley	Tiedman	N/A	N/A	N/A	N/A	N/A
TTPB	Tiedman	90	76–88	Sandstone/ siltstone	Leloma Formation	Shallow rock
TTMB01	Tiedman	90	76–88	Sandstone/ siltstone	Leloma Formation	Shallow rock
TTMB02	Tiedman	90	76–88	Sandstone/ siltstone	Leloma Formation	Shallow rock
TTMB03	Tiedman	198	186–199	Sandstone/ siltstone	Leloma Formation	Interburden



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- Shallow gas monitoring bore
- Groundwater monitoring bore
- Groundwater production bore
- Stream gauge
- AGL owned properties
- Stage 1 GFDA boundary
- Rivers and streams
- Roads

N

0 2
Kilometres

Figure 5.1
Groundwater and surface water monitoring network

5.2 Surface water

5.2.1 Surface water levels and flow

All AGL stream gauges on the Avon River and Dog Trap Creek show sharp increases in water level in response to rainfall events, and relatively steep recession curves (Figure 5.2). This is characteristic of rapid runoff responses from a relatively small upstream catchment and limited riverbank storage and groundwater contributions. Stream levels and flow decrease over several weeks following each rainfall event to a relatively consistent base level that represents a small baseflow component in the Avon River.

The surface water flow data from the NOW gauging stations in the Gloucester Basin is summarised in Table 5.3. The Gloucester River has the highest baseflow index (28%) and had zero days without flow over the flow record. The Avon River has a baseflow index of 6%, and is without flow 5% of time. Note that the baseflow was calculated approximately by applying a moving minimum function to the hydrograph data.

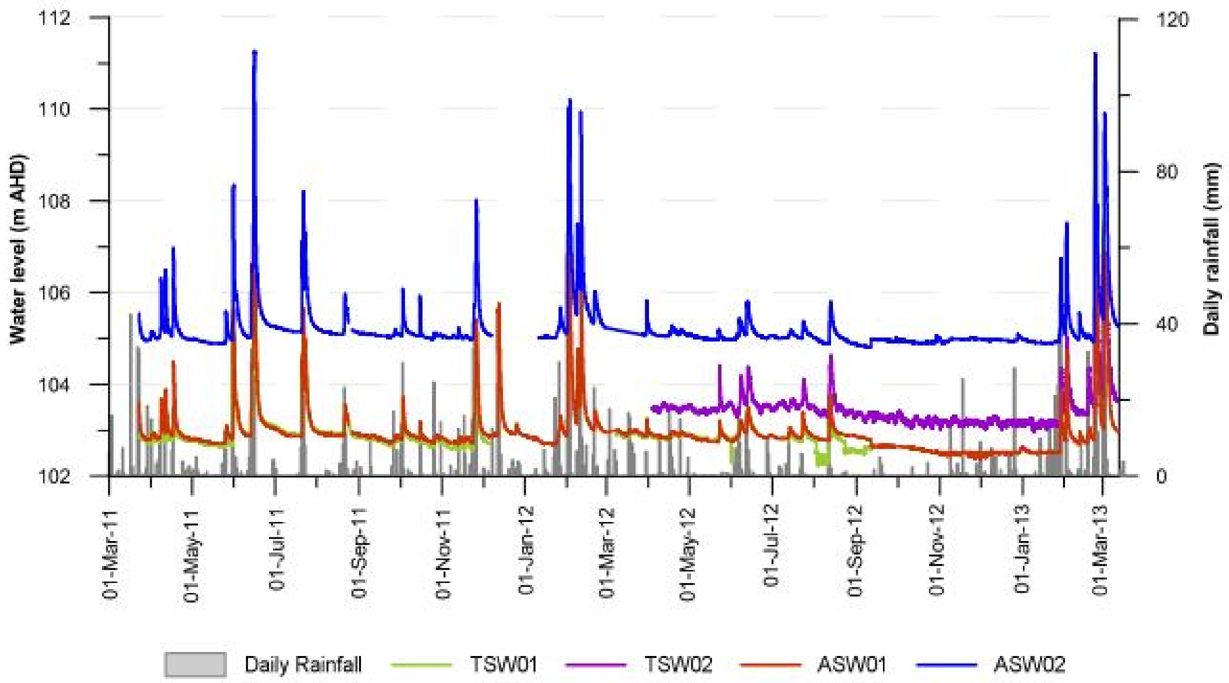

Figure 5.2 Avon River and Dog Trap Creek stream level data and rainfall

Table 5.3 NOW stream gauging stations in the Gloucester Basin

Station number	Location	Flow record	Catchment Area (km^2)	Time without flow (%)	Mean total flow (ML/day)	Mean baseflow (ML/day)	Baseflow index (%)
208028 #	Avon River D/S Waukivory Creek	01/01/2004 – present	225	5%	322.4	18.9	6%
208020 #	Gloucester River at Gloucester	01/01/2003 – present	253	0%	226.0	63.9	28%
209002 *	Mammy Johnsons River at Pikes Crossing	01/01/1967 – present	156	10%	152.7	11.0	7%
209003 *	Karuah River at Booral	01/01/1968 – present	974	2%	753.6	82.8	11%
209018 *	Karuah River at Dam Site	01/01/1979 – present	300	1%	266.8	42.4	16%

Key:
\# Within the Gloucester Basin
* On the boundary or just outside the Gloucester Basin

5.2.2 Surface water quality

Surface water salinity is inversely correlated with rainfall and flow (Figure 5.3). In general, surface water salinity measured as electrical conductivity (EC) sharply decreases after rainfall events as relatively fresh runoff is routed into streams. However an initial spike (sudden transient increase) in EC is often seen in the initial runoff phase as readily dissolvable salts are flushed from the ground surface and shallow soils. After the initial salinity spike and reduction in EC levels, the EC then gradually increases as flow decreases during periods of recession, and as groundwater discharge starts to become a more dominant component of flow. Evaporative concentration of salts may also be taking place in residual and connected pools.

Average salinities measured as EC over the monitoring period was ~300 to ~420 µS/cm in the Avon River and ~680 µS/cm in Dog Trap Creek.

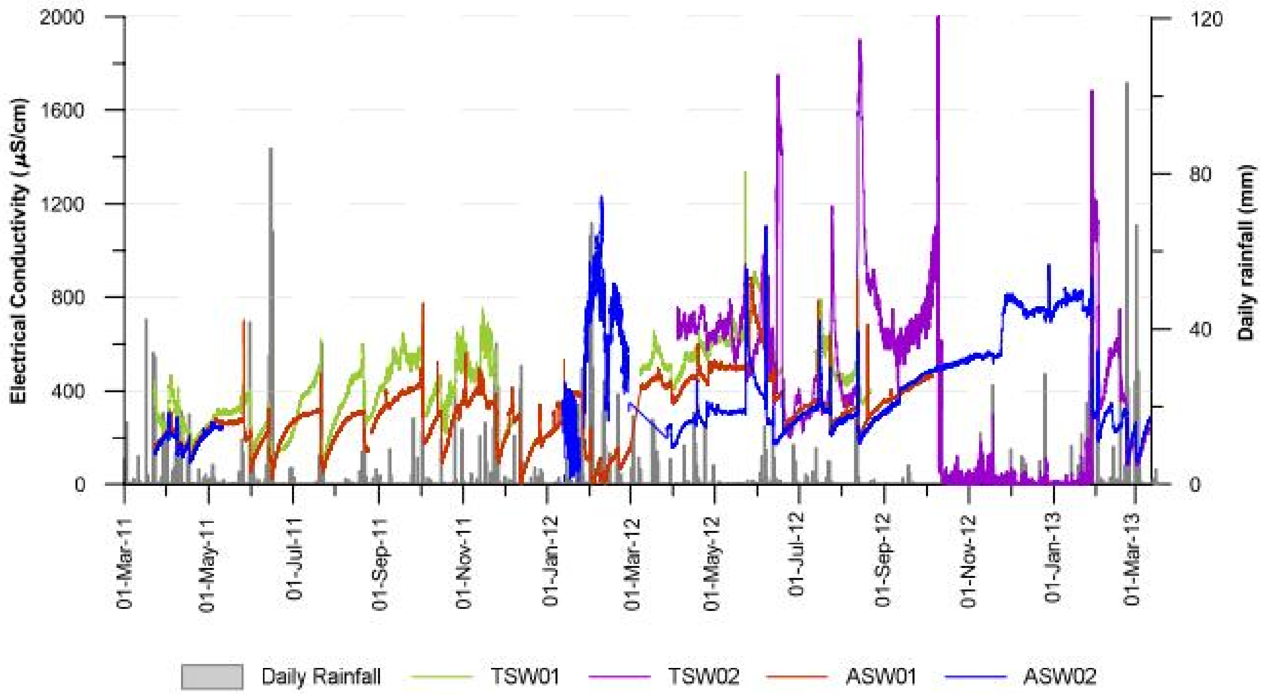

Figure 5.3 EC measurements and rainfall in the Avon River and Dog Trap Creek

5.2.3 Groundwater – surface water interaction

Stream gauge data compared with adjacent groundwater level data indicates that the Avon River and Dog Trap Creek are gaining systems in the central Stage 1 GFDA under most conditions (Figure 5.4). Groundwater levels are higher than adjacent stream levels (by between one and two metres), indicating that the streams are discharge features for shallow groundwater. It is only during relatively short periods of high stream water levels, associated with rainfall events, that groundwater is recharged from the surface water system.

Additional analysis of alluvial groundwater levels and responses to surface water flow is presented in Section 5.3.3.1.

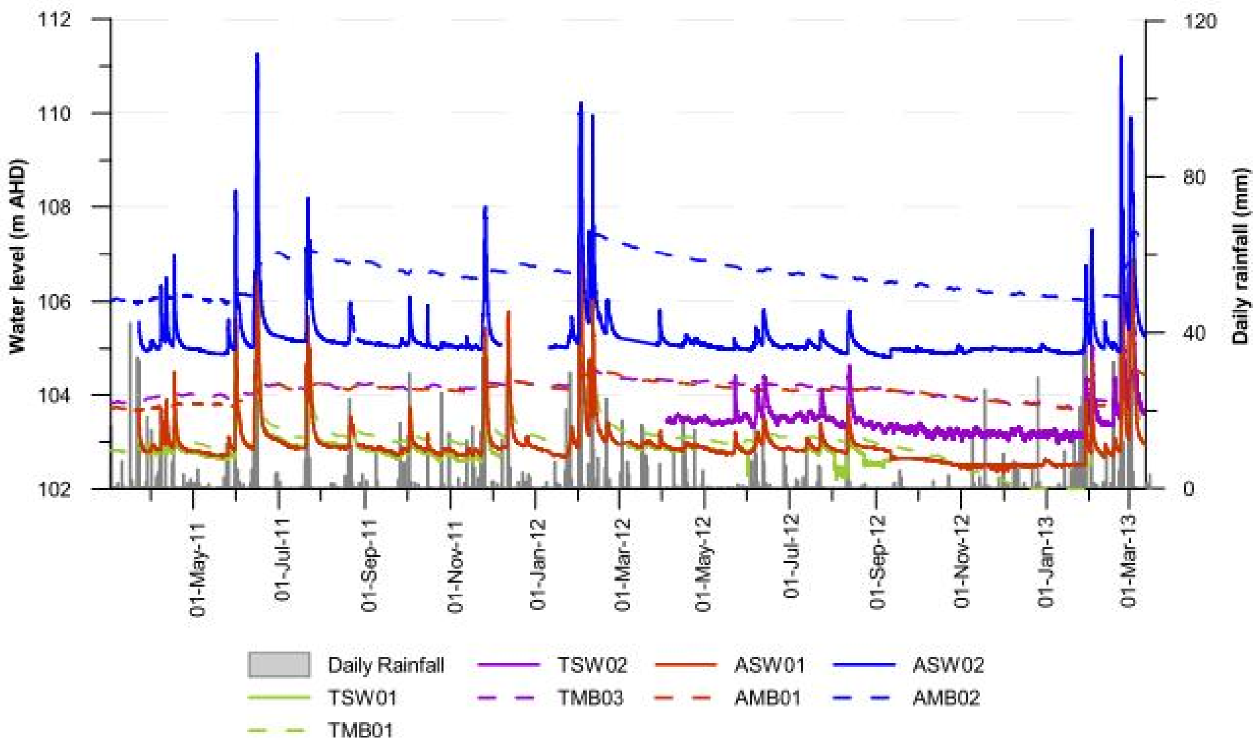

Figure 5.4 Surface water hydrographs for the River Avon and Dog Trap Creek (solid lines) and groundwater levels in adjacent alluvium (dashed lines)

5.2.4 Groundwater dependent ecosystems

5.2.4.1 Groundwater dependent ecosystem Atlas

Groundwater dependent ecosystems (GDEs) are communities of plants, animals and other organisms that depend on groundwater for survival (Department of Land and Water Conservation, 2002). A GDE may be either entirely dependent on groundwater for survival, or may use groundwater opportunistically of for a supplementary source of water (Hatton & Evans, 1998).

GDEs can potentially include wetlands, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems. The GDE Atlas (Bureau of Meteorology, 2012) categorises groundwater dependent ecosystems into three classes:

1. Ecosystems that rely on the surface expression of groundwater – this includes all the surface water ecosystems that may have a groundwater component, such as rivers, wetlands and springs. Marine and estuarine ecosystems can also be groundwater dependent.
2. Ecosystems that rely on the subsurface presence of groundwater – this includes all vegetation ecosystems.
3. Subterranean ecosystems – this includes cave and aquifer ecosystems

Ecosystems that rely on the surface expression of groundwater

Groundwater discharge can be important in maintaining baseflow in rivers and streams, and ecosystems associated with these discharge areas may have a high dependency on groundwater for their water requirements. The GDE Atlas does not identify any ecosystems that rely on the surface expression of groundwater within the Gloucester Basin (Figure 5.5). Groundwater discharge (baseflow) is a small component of total stream flow. This discharge is expected to manifest as minor seepage over broad areas so there is no strong discharge expression in the landscape.

Ecosystems that rely on the subsurface presence of groundwater

Ecosystems that rely on the subsurface presence of groundwater are most likely to occur in areas where groundwater is close to the surface. Shallow groundwater may be important for sustaining terrestrial and riparian vegetation, particularly deep rooted varieties, although it is noted that there is little undisturbed native vegetation over much of the Gloucester Basin. The GDE Atlas identifies some vegetation ecosystems that rely on the subsurface presence of groundwater within the Stage 1 GFDA and the broader Gloucester Basin (Figure 5.5). The area identified within the Stage 1 GFDA is on the Tiedman property and relates to natural vegetation cover. There is no known regional groundwater dependence for this residual vegetation cover as water levels are more than 10m below ground level in the bedrock, although there may be some occasional perched water dependency in the weathered zone from recent rainfall.

5.2.4.2 Water Sharing Plan Listings

There are two Water Sharing Plans (WSPs) and one under development that cover the Gloucester Basin:

1. Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources (2009).
2. Draft North Coast Fractured and Porous Rock Groundwater Sources (under development).
3. Water Sharing Plan for the Karuah River Water Source (2003).

The Aquifer Interference (AI) Policy lists the minimal impact considerations for less productive groundwater sources as less than or equal to 10% cumulative variation in the water table, 40m from any high priority groundwater dependent ecosystem or high priority culturally significant site (as listed in the schedule of the relevant water sharing plan). It is noted that there are no GDEs identified in the Water Sharing Plans within the Gloucester Basin (Figure 5.5).

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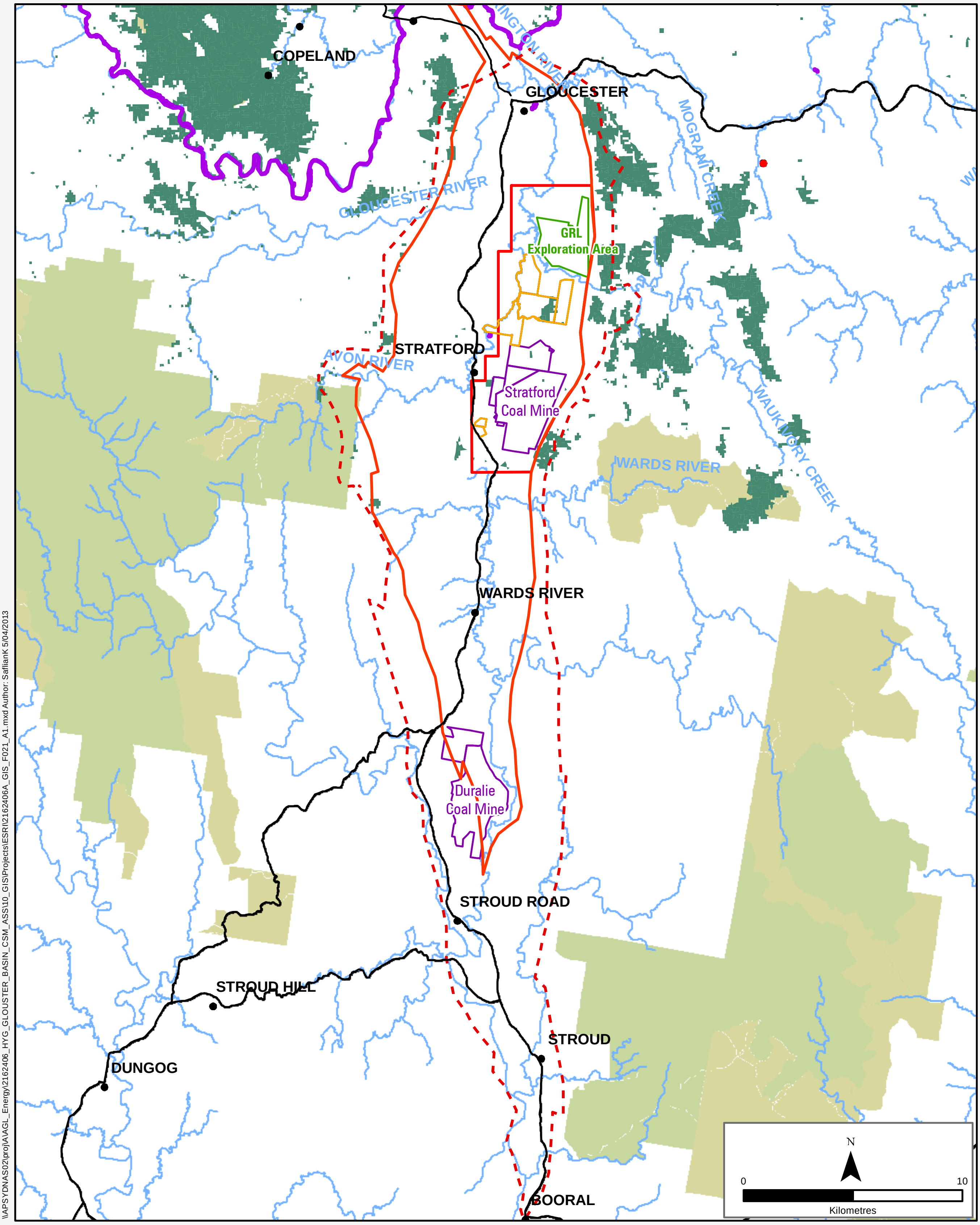
HYDROGEOLOGICAL CONCEPTUAL MODEL OF THE GLOUCESTER BASIN
AGL UPSTREAM INVESTMENTS PTY LTD



Alum Mountain Volcanics boundary
Permian Coal Measures boundary
Stage 1 GFDA boundary
AGL owned properties
Mining Lease Boundary
GRL exploration area boundary
NSW State Forest
National Park, Nature Reserve or State Conservation Area
GDEs dependent on surface groundwater (BOM)
GDEs dependent on subsurface groundwater (BOM)
GDEs in Water Sharing Plans (NOW)
Towns
Rivers and streams
Major roads

Figure 5.5
Groundwater Dependent Ecosystems

5.3 Groundwater

5.3.1 Hydrogeological units

Four broad hydrogeological units have been identified within the Gloucester Basin based on previous groundwater studies (SRK, 2010; Parsons Brinckerhoff, 2012a, Parsons Brinckerhoff, 2012b, Parsons Brinckerhoff, 2013b). The main water bearing units are: the alluvial aquifers along major creek lines, shallow rock aquifers, and; a thick succession of low permeability coal measures comprising interbedded coal seams and interburden units of very low permeability. These hydrogeological units overlie the impermeable Alum Mountain Volcanics. Table 5.4 below outlines the main hydrogeological parameters of these units.

The hydrogeological units do not correspond directly to the geological units presented in Table 4.2. Groundwater investigations have identified a relationship of decreasing hydraulic conductivity with depth across the Gloucester Basin (Section 5.3.2). This relationship is particularly evident in the deeper coal seams and interburden units below ~150m. The top ~150m of shallow rock is heterogeneous, due to high and low conductivity domains associated with fault zones and fracturing. This shallow rock unit is applied across the whole of the Gloucester Basin and includes the top ~150m of the Gloucester Coal Measures, Dewrang Group and Alum Mountain Volcanics. The alluvial aquifers along major creek lines are also heterogeneous, with highly variable hydraulic conductivity.

Table 5.4 Four key hydrogeological units

Unit	Aquifer Type	Formation name	General lithology	Hydraulic characteristics
Alluvium	Semi- confined, clay capped, porous, granular	Quaternary alluvium	Clay/mixed gravels	Heterogeneous, highly variable permeability associated with varying lithology
Shallow Rock (<150m)	Semi-confined, fractured rock	Upper Permian Coal Measures, Alum Mountain Volcanics	Interbedded sandstone/siltstone with bedding plane fractures	Heterogeneous, high and low permeability domains associated with fault zones and fracturing
Interburden	Confined, fractured rock	Upper Permian Coal Measures	Interbedded indurated sandstone/siltstone and claystone	Low permeability associated with sparse fractures, permeability decreases with depth
Coal Seams	Confined, fractured rock	Upper Permian Coal Measures	Coal/shale	Low permeability associated with cleating and fractures in coal seams, permeability decreases with depth

5.3.1.1 Alluvium

Groundwater monitoring bores drilled in the shallow Avon River alluvium as part of the Phase 2 Groundwater Investigation bores typically intercepted 3-4 m of stiff organic alluvial clay underlain by coarse sands and poorly sorted mixed gravels. The typical thickness of alluvium encountered in the vicinity of the central AGL owned properties within the Stage 1 GFDA was approximately 12 m, and elsewhere it is expected not to exceed 15 m. The alluvium is an unconfined or semi-confined aquifer. The alluvium is heterogeneous, with highly variable hydraulic conductivity associated with the varying lithology identified in the Phase 2 Groundwater Investigations.

5.3.1.2 Shallow rock

The shallow rock hydrogeological unit comprises interbedded sandstone, silt and claystone; this aquifer extends beneath the alluvium where present, and is at outcrop elsewhere in the Gloucester Basin. Although interbedded, the shallow rock typically has more dominant sandstone content in the Stage 1 study area, with hydraulic properties likely to be largely controlled by bedding plane fractures.

For the purpose of hydrogeological conceptualisation, the shallow rock unit is a zone that extends from the ground surface to a depth of approximately 150 m that has elevated permeability and storage due to fracturing of the rock mass, compared with the deeper coal measures. The 150m zone of shallow rock is heterogeneous, with high and low hydraulic conductivity domains associated with fault zones and fracturing. The known aquifer zones occur within 75m of surface.

5.3.1.3 Deeper coal measures

The deeper coal measures include both low permeability interburden units and interbedded coal seams, which typically dip towards the basin centre in relatively coherent block faulted domains. There is a relationship of decreasing hydraulic conductivity with depth in the deeper coal measures.

Interburden

The majority of the Gloucester Basin is underlain by interbedded indurated fine to medium grain sandstone and very fine grain siltstone units providing confining layers between and directly overlying the major coal seams. No significant fractures were encountered in these very low permeability rock units during the Phase 2 Groundwater Investigations. These groundwater investigations were to a maximum depth of 330 m but similar (and even lower permeability) interburden units occur to the full depth of the basin which may be up to 2,000 mbgl in the northern basin area and 1,500 mbgl in the southern basin area (Roberts et al. 1991). CSG production wells are unlikely to exceed 1,000 mbgl.

Coal seams

Four main coal seams were intercepted in the monitoring bore drilling program beneath the Stage 1 GFDA the Bindaboo, Deards, Cloverdale and Roseville coal seams (Parsons Brinckerhoff, 2012a). The seams varied in thickness from 3 to 18 m and typically comprise thin coals interbedded with dark organic siltstones and shale. Despite having low permeabilities, the coal seams investigated had a higher permeability than the surrounding interburden, and are therefore likely to form minor water bearing zones and potentially conduits for limited groundwater flow at depth (Parsons Brinckerhoff, 2012a). Deeper coal seams (Bowens Rd, Glenview, Avon etc.) are the main targets for CSG development and exploration drilling programs at multiple sites suggest even lower permeabilities to depths of 1,000 m.

5.3.1.4 Alum Mountain Volcanics

The Alum Mountain Volcanics underlie the Permian Coal Measures, and form the impermeable base of the Gloucester Basin. The Alum Mountain Volcanics outcrop on the eastern and western boundaries of the basin, forming the elevated topography of the Gloucester and Barrington Tops to the west, and the Mograni Range to the east.

It is assumed that a zone of elevated permeability and storage due to fracturing and/or weathering of the rock mass extends from the ground surface to a depth of up to approximately 150m, compared to the deeper Alum Mountain Volcanics which are essentially impermeable. Springs are known to exist along the margins of the basin and these are assumed to be associated with circulation of meteoric water through fractures in shallow parts of the Alum Mountain Volcanics.

5.3.2 Hydraulic properties

Horizontal hydraulic conductivity data from Drill Stem Tests (DST) on exploration bores in the Gloucester Basin up to a depth of 900m are presented in Figure 5.6 (AGL, 2013b). Comparative horizontal hydraulic conductivity data from the Gloucester Basin, Sydney Basin and Hunter Valley are presented in Figure 5.7 (Tammetta, 2009).

There is a linear logarithmic decrease in hydraulic conductivity with depth for coal seams in the Gloucester Basin (Figure 5.6). A maximum horizontal hydraulic conductivity of 0.5 m/d was measured at 110 mbgl, decreasing to a minimum of $7x10^{-6}$ m/d at 570 mbgl. Hydraulic conductivity at 900 mbgl was measured to be $2x10^{-5}$ m/d (AGL, 2013b).

The relationship of linear logarithmic decrease in hydraulic conductivity with depth in the Gloucester Basin is also comparative with data from the Hunter Valley and Sydney Basin (Tammetta, 2009) (Figure 5.7). There is a distinct decrease in hydraulic conductivities to depths of 800 mbgl. It is evident that interburden hydraulic conductivities from the Hunter Valley and Sydney Basin are lower than coal seam hydraulic conductivities. This suggests that the coal seams will act as relative water bearing zones within the deeper coal measures.

There is substantial variation in hydraulic conductivity data in the top 200 mbgl in the Gloucester Basin, Hunter Valley and Sydney Basin (Figure 5.7), ranging from a maximum of 10 m/d to a minimum of $1x10^{-4}$ m/d. This supports the conceptualisation of a shallow rock hydrogeological unit. This shallow rock is heterogeneous, with fracturing and fault zones resulting in varying hydraulic conductivity zones.

Hydraulic testing has been carried out on groundwater monitoring bores installed as part of the Phase 2 Groundwater Investigations (Parsons Brinckerhoff, 2012a) and the Hydrogeological Investigation of a strike-slip fault in the Gloucester Basin (Parsons Brinckerhoff, 2013b). This has included slug testing, packer testing, test pumping and laboratory testing, and the results are summarised on a hydrogeological unit basis in Figure 5.8. The shallow rock has the greatest variability in hydraulic conductivity, ranging from a minimum of $2x10^{-6}$ m/d to a maximum of 10 m/d. The coal seams on average have a higher hydraulic conductivity than the interburden.

A summary table giving the range of hydraulic conductivities for each hydrogeological unit based on hydraulic testing data from the exploration bores and monitoring bores in the Gloucester Basin is presented in Table 5.5.

Table 5.5 Hydraulic conductivity summary (interpreted to 1000 mbgl)

Hydrogeological unit	Hydraulic conductivity range (m/d)*
Alluvium	0.3 – 300†
Shallow rock (<150m)	$1x10^{-6}$ – 10
Interburden	$1x10^{-7}$ – 0.005
Coal seams	$1x10^{-6}$ – 2

* Estimates of hydraulic conductivity were based on hydraulic conductivity testing undertaken as part of the Phase 2 Groundwater Investigations (Parsons Brinckerhoff, 2012a), Hydrogeological Investigation of a strike-slip fault in the Gloucester Basin (Parsons Brinckerhoff, 2013b), Drill Stem Tests from exploration bores (AGL, 2013b), and comparative hydraulic conductivity data from the Gloucester Basin (Tammetta, 2009). † The alluvium is highly heterogeneous. All but one slug test yielded a hydraulic conductivity less than 100 m/d. The 300 m/d value is considered anomalous.

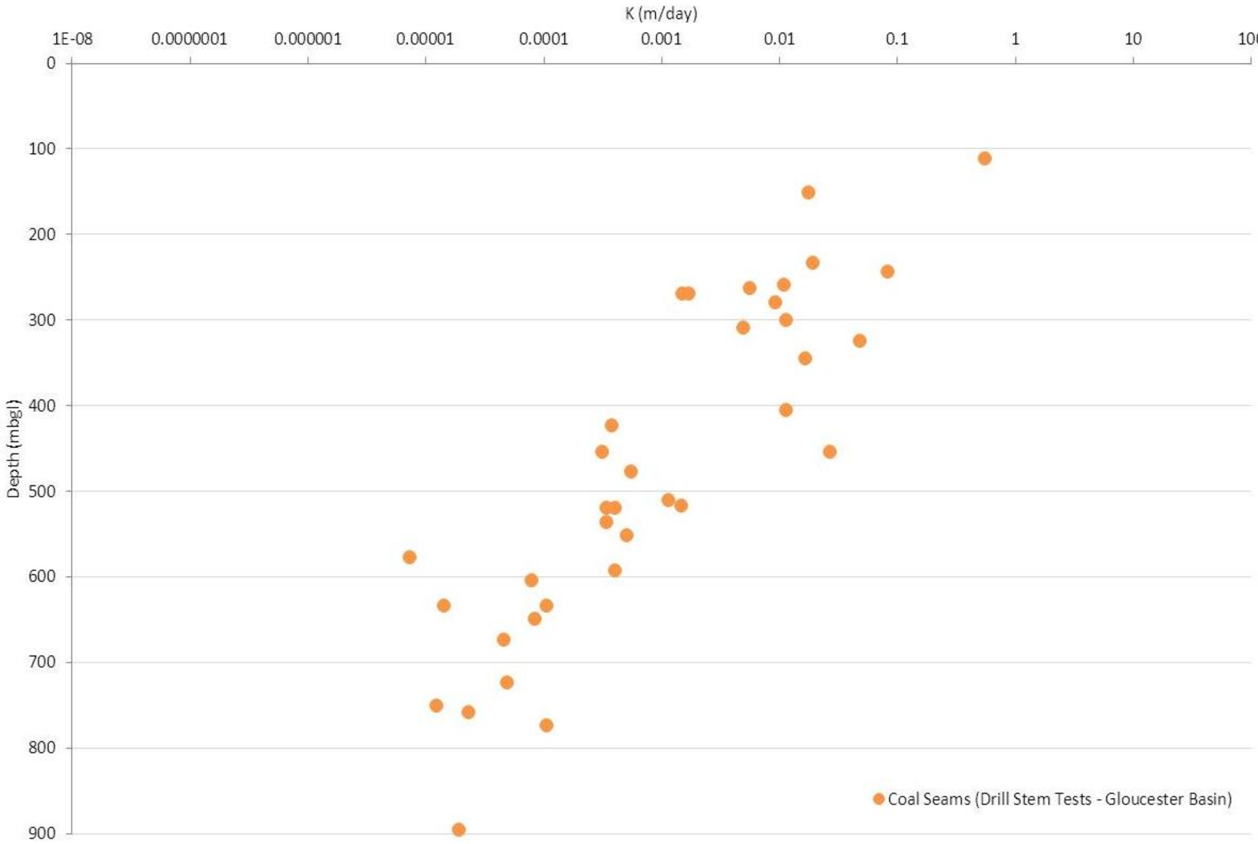


Figure 5.6 Horizontal hydraulic conductivity of coal seams in the Gloucester Basin (AGL, 2013b)

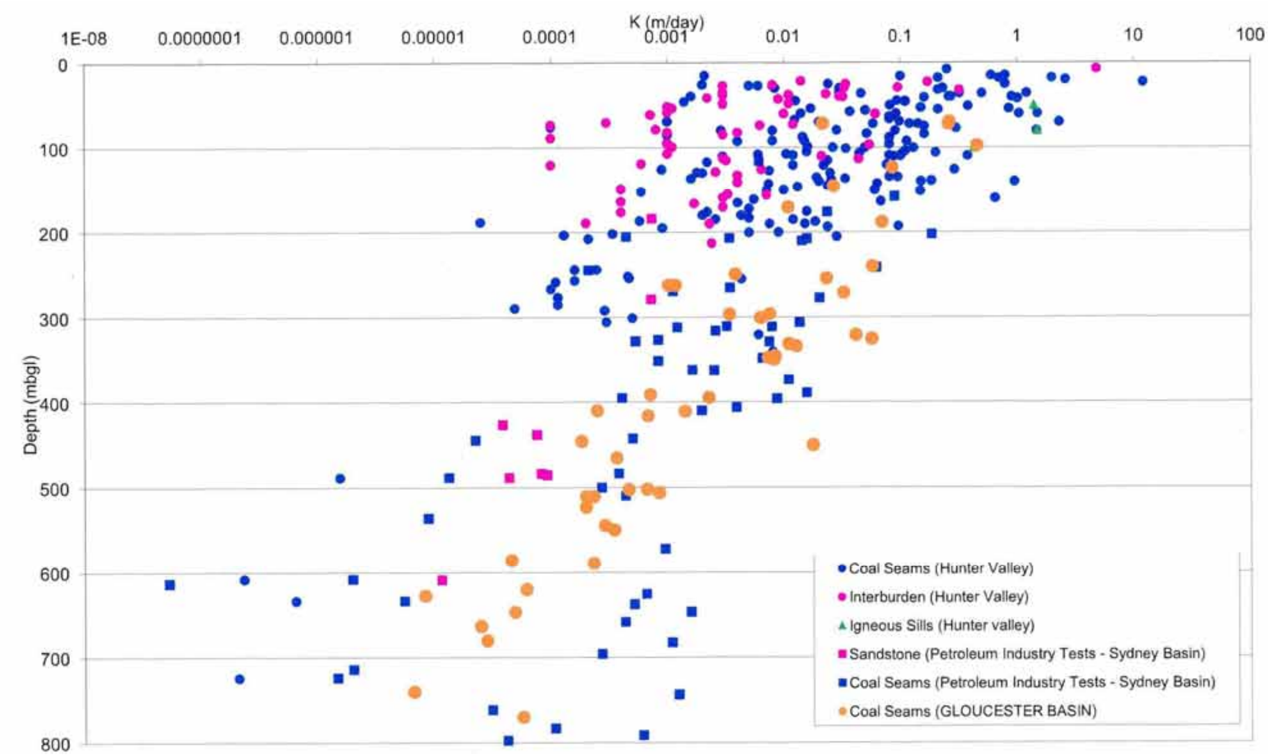


Figure 5.7 Horizontal hydraulic conductivity in the Gloucester Basin, Sydney Basin and Hunter Valley (Tammetta, 2009)

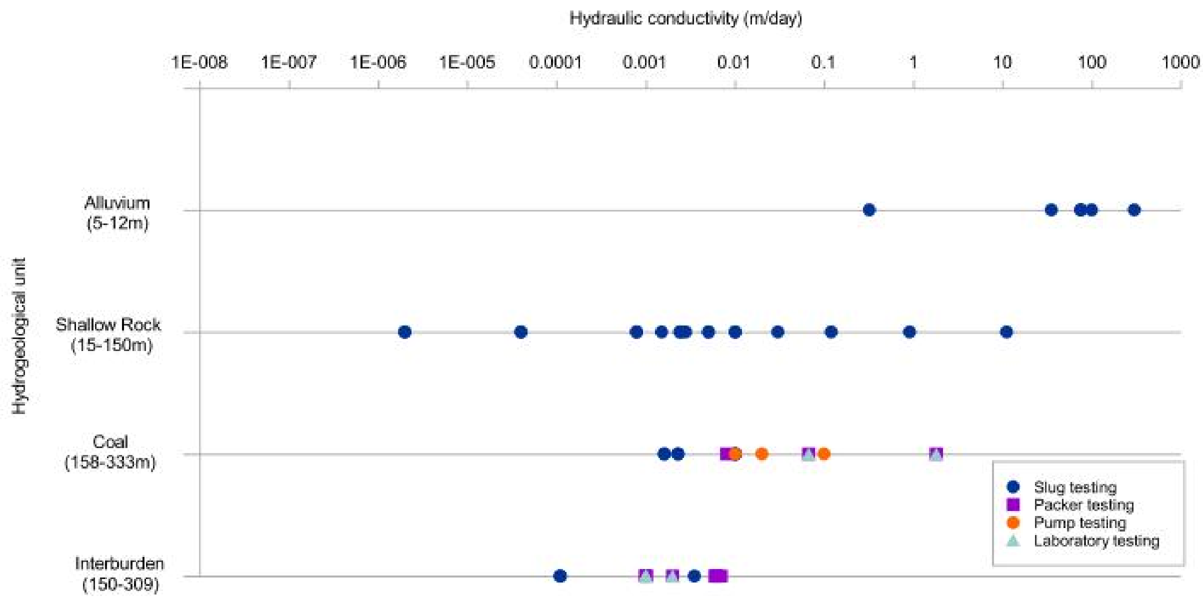


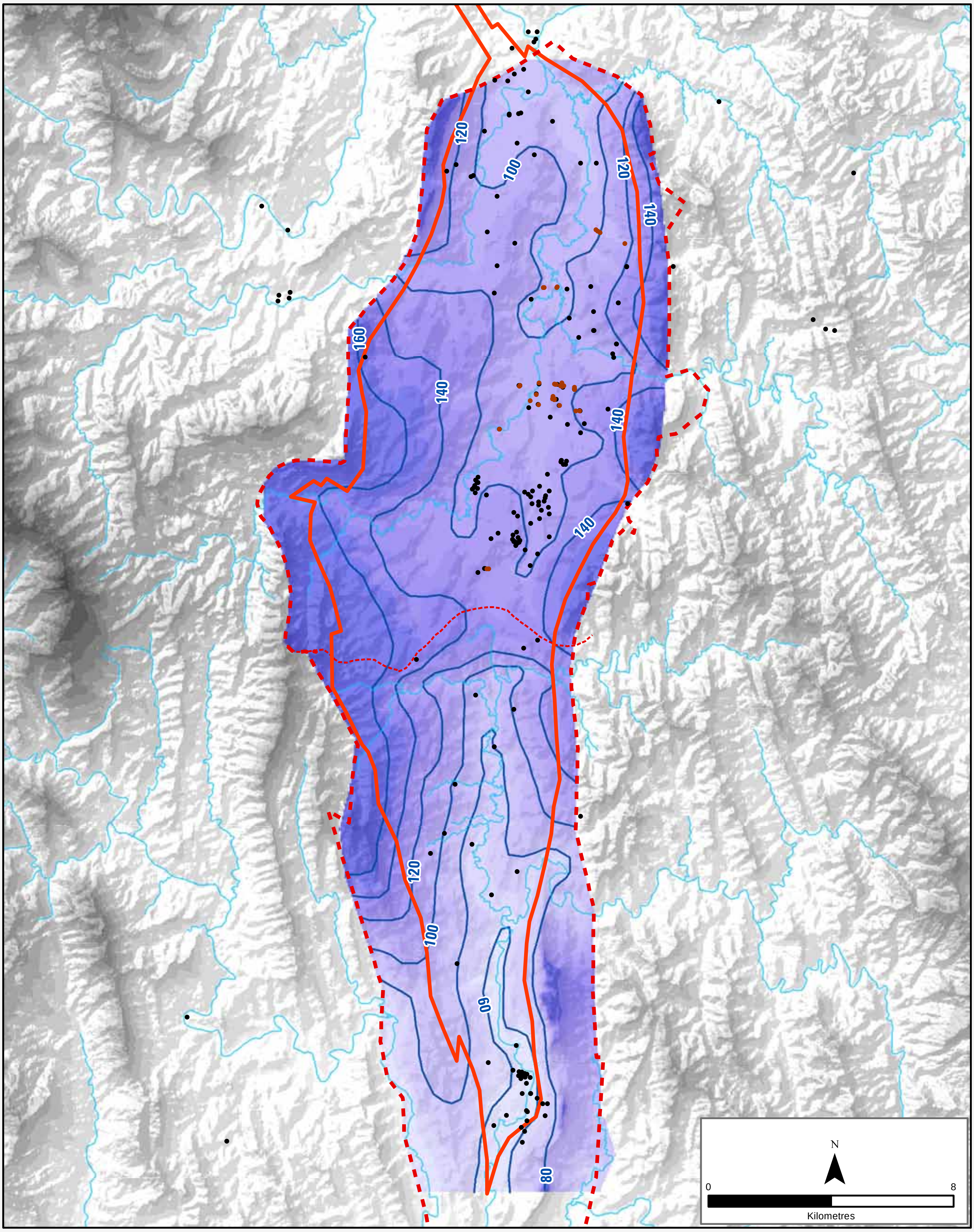
Figure 5.8 Horizontal hydraulic conductivity summary from hydraulic testing in the Stage 1 GFDA (Parsons Brinckerhoff, 2012a; Parsons Brinckerhoff, 2013b)

5.3.3 Groundwater levels

5.3.3.1 Spatial trends

There is evidence for a groundwater flow divide, just north of Wards River, following the approximate location of the surface water divide. This separates the Gloucester Basin into a northern sub-basin where regional groundwater flow is predominantly from south to north, and a southern sub-basin where regional groundwater flow is predominantly from north to south. Locally, groundwater flow can be east to west or west to east as groundwater also flows laterally from rock outcrop areas towards the centre of the basin (Figure 5.9).

The largest groundwater flows are likely to occur in the alluvial deposits that underlie the main drainage systems. However these deposits tend to be thin (i.e. less than 15 m). In the underlying Permian deposits, age dating of the groundwater, undertaken as part of the Phase 2 Investigations indicates a very low flow environment (Parsons Brinckerhoff, 2012a).



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Water levels m(AHD)

- 41 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 120
- 120 - 130
- 130 - 140
- 140 - 150
- 150 - 160
- Alum Mountain Volcanics boundary
- Permian Coal Measures boundary
- Surface water divide
- Rivers and streams
- AGL bores
- All other bores

Figure 5.9
Interpreted regional groundwater contours

5.3.3.2 Temporal trends

Groundwater level trends in monitoring bores vary depending on the lithology and depth of the screened interval. No groundwater level responses to private bore abstraction are known during the 24-month AGL monitoring period, with the exception of planned test pumping and slug testing of the AGL monitoring bores. The available monitoring period extends from January 2011 to March 2013, and represents both above average and below average rainfall periods.

Alluvium

Groundwater levels in monitoring bores screened within the alluvial aquifers show characteristic quick responses to rainfall events (Figure 5.10). This indicates rapid shallow aquifer recharge via direct rainfall infiltrations and/or enhanced infiltration during creek high flow and flood events. Groundwater fluctuations over the monitoring period range from ~0.5m to ~2.5m.

The groundwater level hydrographs can be divided into two main response types:

1. Rapid recharge response followed by a relatively steep groundwater recession curve (TMB01, TMB02, WMB01). These monitoring bores show rapid response to most rainfall events followed by a return to near-previous levels over a period of one to two months (i.e. a short term increase in storage). These responses imply a relatively direct recharge from rainfall and/or flooding and relatively high permeability of the alluvium.
2. A threshold response followed by a longer recession curve (TMB03, AMB01, AMB02). These monitoring bores show rapid recharge responses to the larger rainfall events, but slower responses to smaller rainfall events. In addition, the recession curves are flatter such that the groundwater level may take several months to recover to pre-existing levels and typically does not fully recover before the next major recharge event (i.e. longer term increase in storage). These responses imply rapid recharge during surface runoff and flooding events, but less significant recharge by rainfall alone. The shallow recession curves imply lower permeability of the alluvium at these locations. This is supported by drilling logs at these locations which indicate clay-rich alluvium, or thick clay layers overlying coarser grained alluvial deposits.

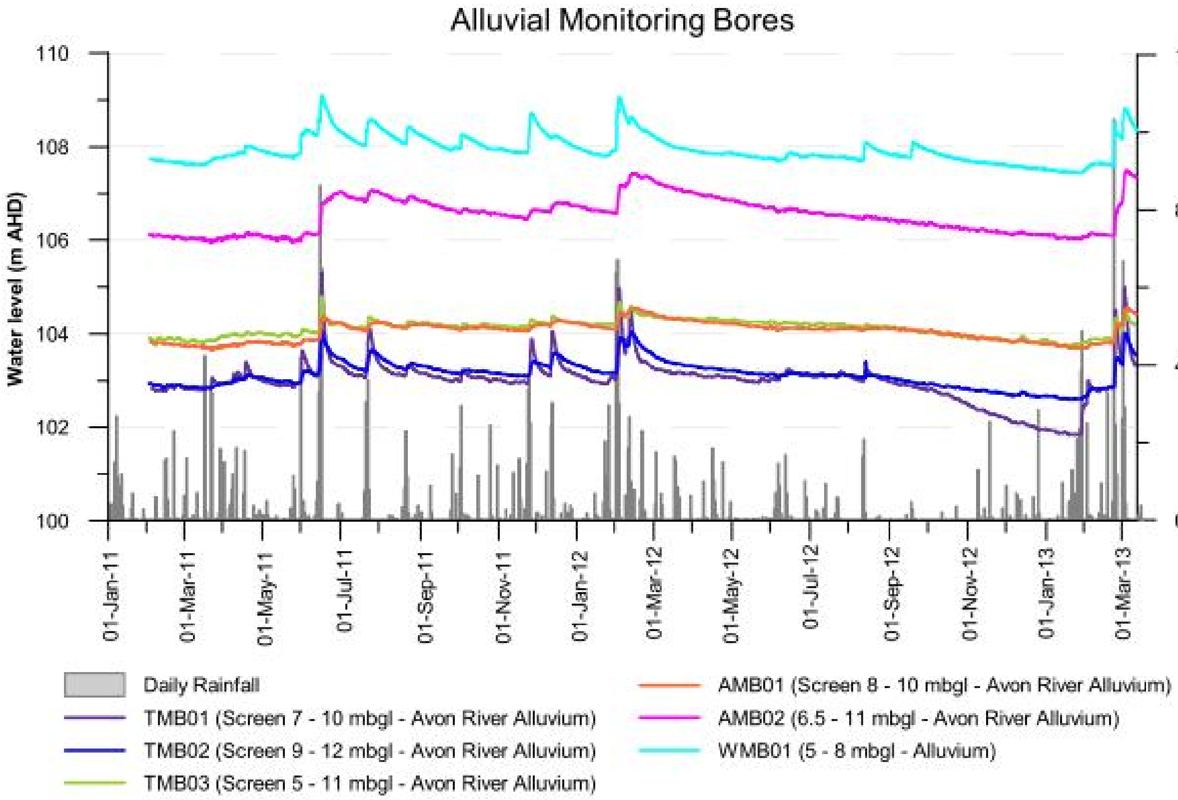

Figure 5.10 Groundwater levels and rainfall in the alluvial monitoring bores

Shallow rock

Monitoring bores into shallow rock are present at all of the nested monitoring sites:

- S4MB (Figure 5.11)
- S5MB (Figure 5.12)
- TCMB (Figure 5.13)
- TTMB (Figure 5.14)
- BMB (Figure 5.15)
- RMB (Figure 5.16)
- WMB (Figure 5.17)
- WKMB (Figure 5.18).

The following groundwater level trends were observed in the shallow rock monitoring bores:

- The shallow rock hydrographs show a gradual increase in groundwater levels between ~0.2m and ~0.5m over the period February 2011 to February 2012. This increase in groundwater levels is due to higher than average rainfall over this period, as shown in the monthly cumulative deviation from mean rainfall plot (Figure 4.3b).
- Groundwater levels continue to increase by ~0.2m from February 2012 until approximately September 2012, reflecting a continuing gradual recharge response to the period of higher than average rainfall, and the large rainfall event of February 2012.
- There is a gradual decrease in groundwater levels between ~0.2m and ~0.5m over the period September 2012 to February 2013, reflecting a delayed response to the period of lower than average rainfall from February 2012 to December 2012.

- There are no strong responses to individual rainfall events, with the exception of the WKMB site. There is a delayed response to periods of higher than average rainfall, indicating that groundwater levels are responding to slow rainfall recharge over a broad area, assumed to be up-gradient of the monitoring locations.
- Monitoring bores in the shallow rock at the WKMB site show an increase in groundwater levels of ~0.5m to ~2.5m in response to significant rainfall events in January 2013 and February 2013. The reasons for the apparent larger recharge responses at this location are uncertain at this time.

Interburden units

The following groundwater level trends were observed in the interburden monitoring bores TCMB02 and TTMB03:

- Groundwater levels do not show an overall increase or decrease over the monitoring period.
- There are no strong responses to individual rainfall events. TCMB02 shows a gradual increase of ~0.1m in response to the significant rainfall events in January 2013 and February 2013, indicating that groundwater levels are responding to slow rainfall infiltration over a broad area, assumed to be up-gradient of the monitoring bores.

Coal seams

The following groundwater level trends were observed in the coal seam monitoring bores at the S4MB, S5MB, TCMB and WKMB sites:

- A gradual increase in groundwater levels over the monitoring period January 2011 to March 2013 of between ~0.2m and ~0.7m was observed at S5MB and TCMB sites. This increase may reflect the long term period of higher than average rainfall from 2006 to 2012 (Figure 4.3a), indicating that groundwater levels are responding to slow recharge over a broad area, assumed to be up-gradient of the monitoring bores.
- Groundwater levels in the coal monitoring bores at the S4MB and WKMB sites fluctuate up to ~0.8m over the monitoring period. These fluctuations are a response to bore purging for groundwater sampling.

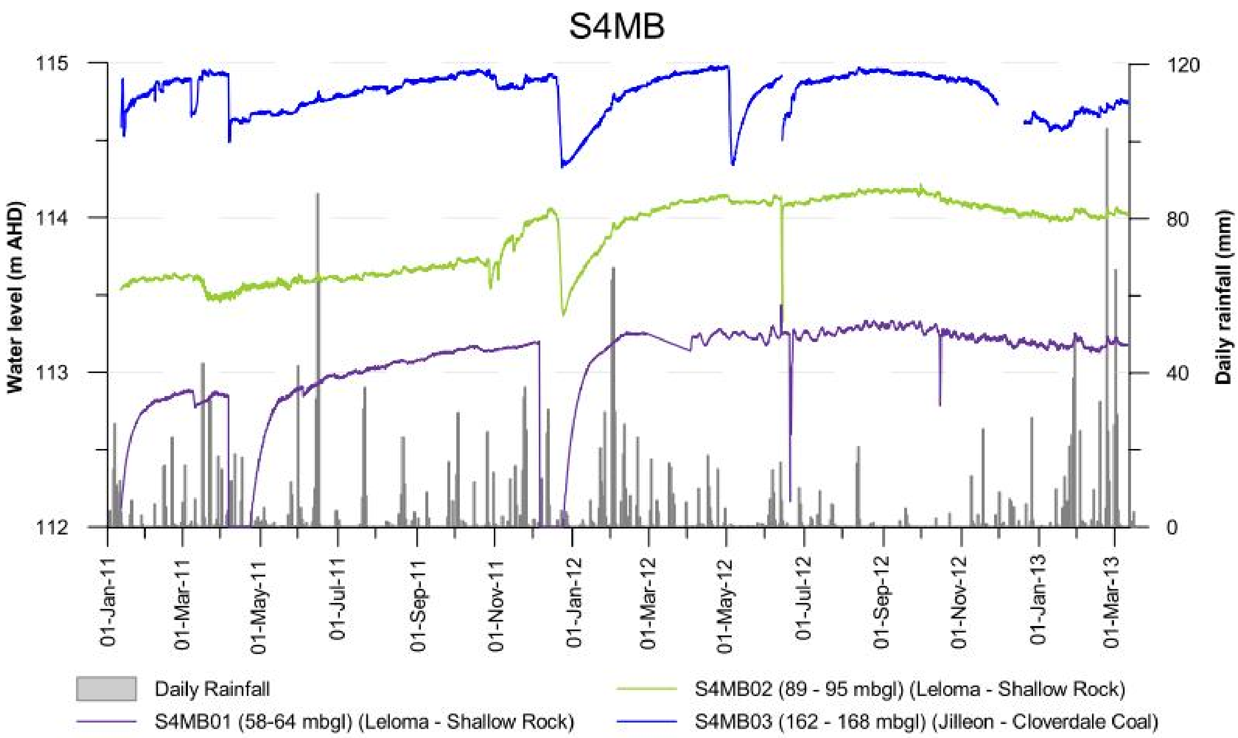

Figure 5.11 Groundwater levels and rainfall at the S4MB site

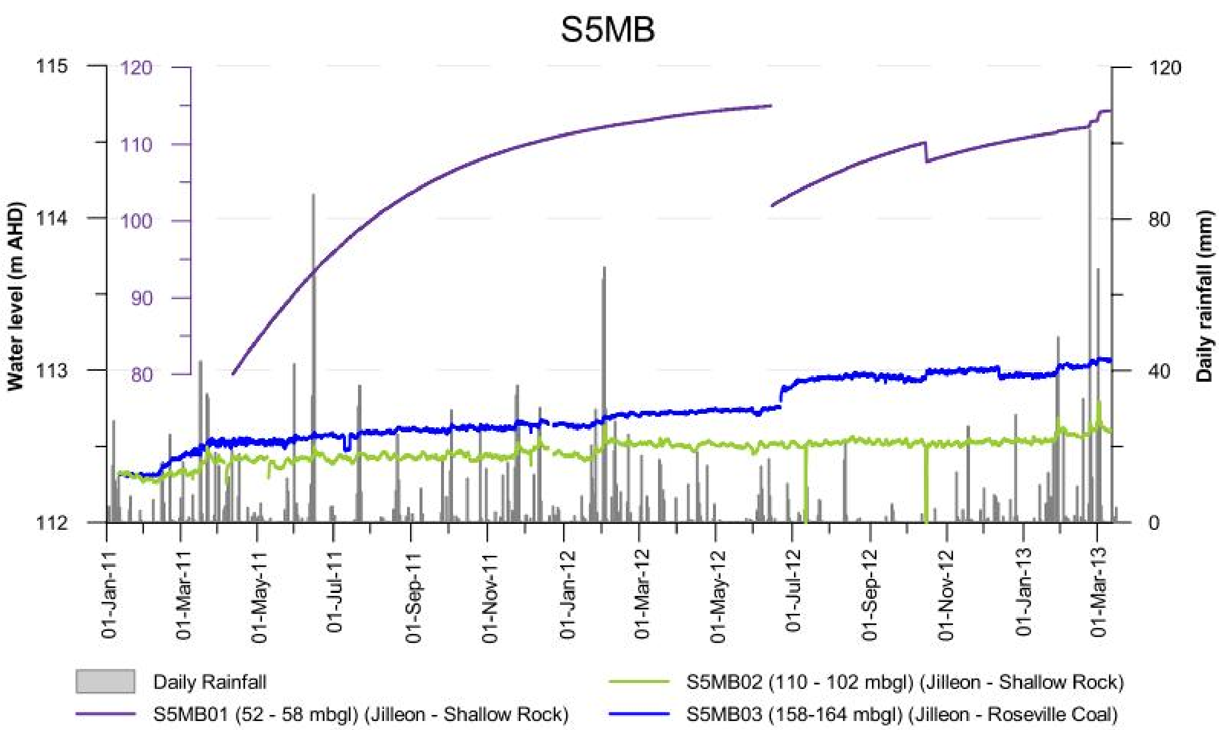

Figure 5.12 Groundwater levels and rainfall at the S5MB site

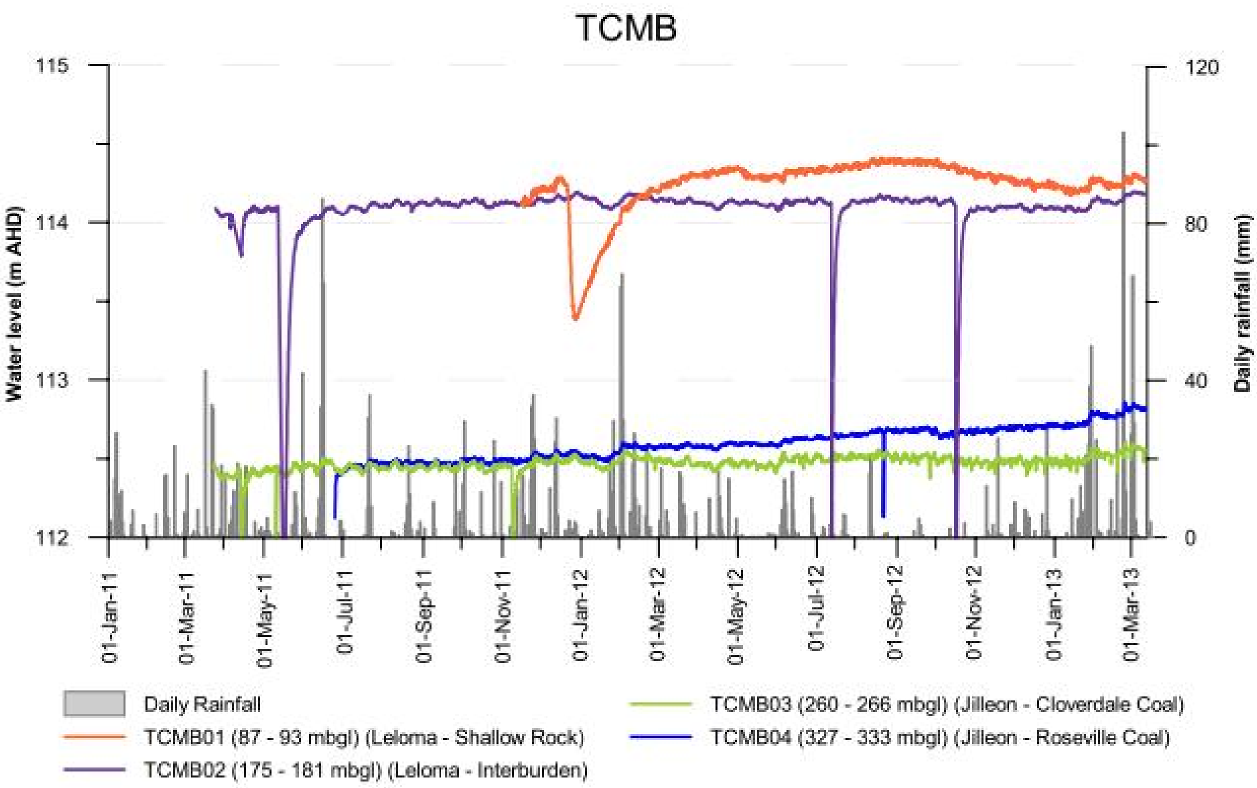

Figure 5.13 Groundwater levels and rainfall at the TCMB site

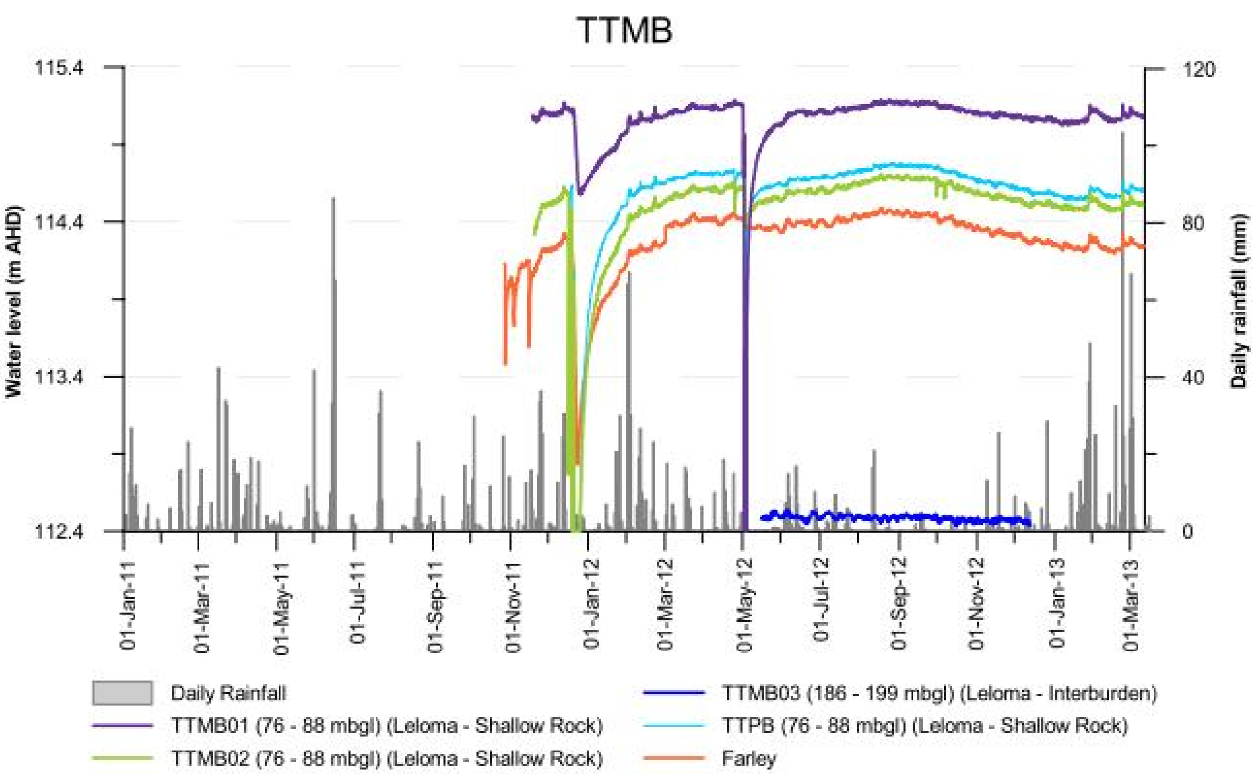

Figure 5.14 Groundwater levels and rainfall at the TTMB site

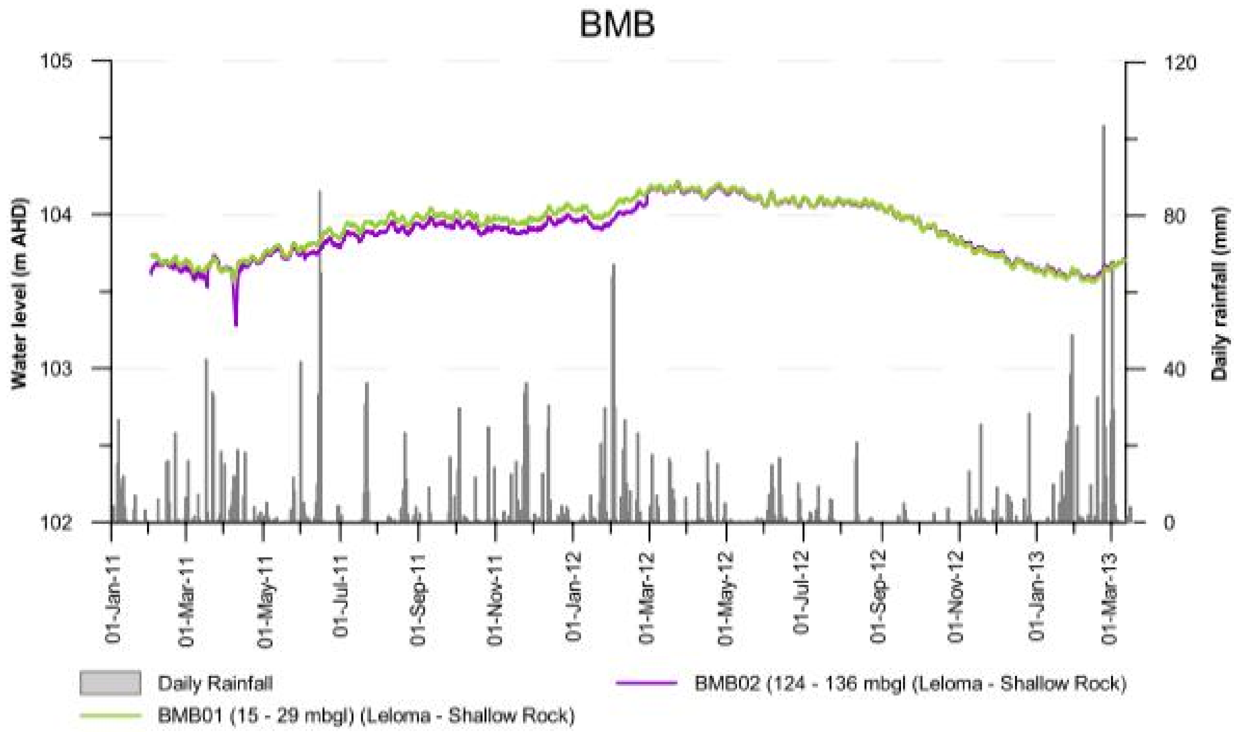

Figure 5.15 Groundwater levels and rainfall at the BMB site

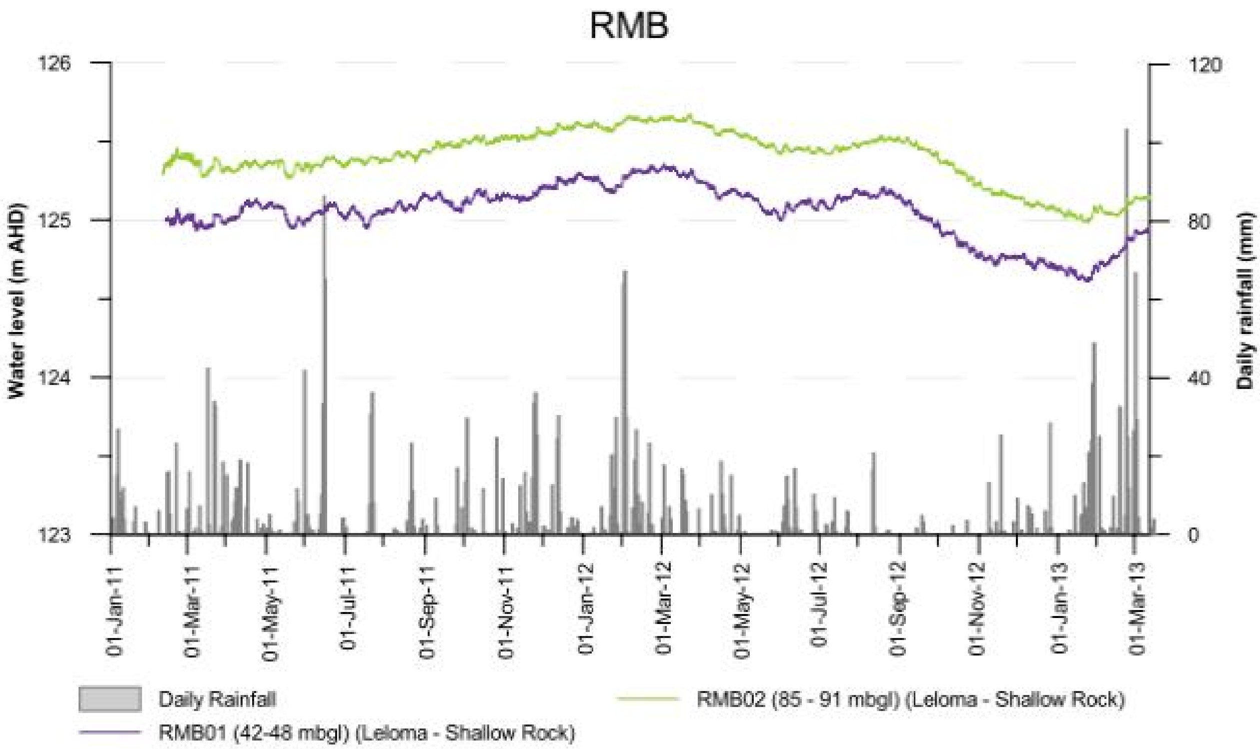

Figure 5.16 Groundwater levels and rainfall at the RMB site

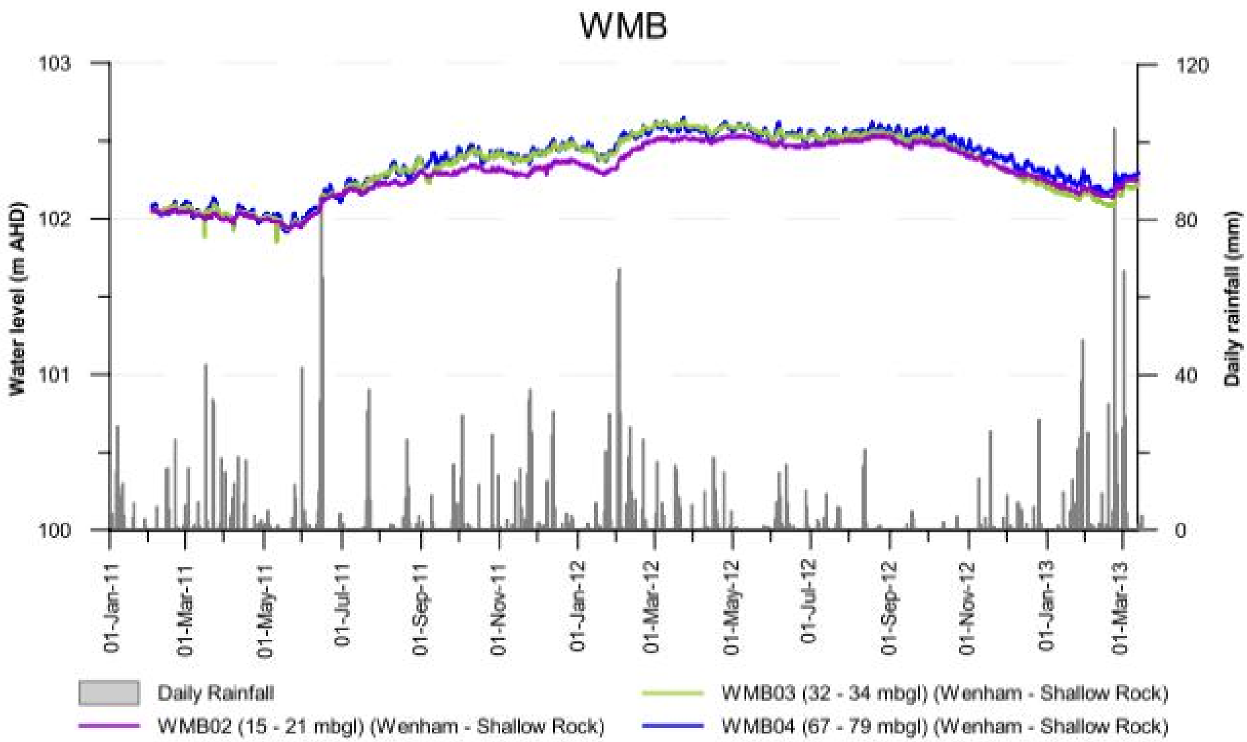

Figure 5.17 Groundwater levels and rainfall at the WMB site

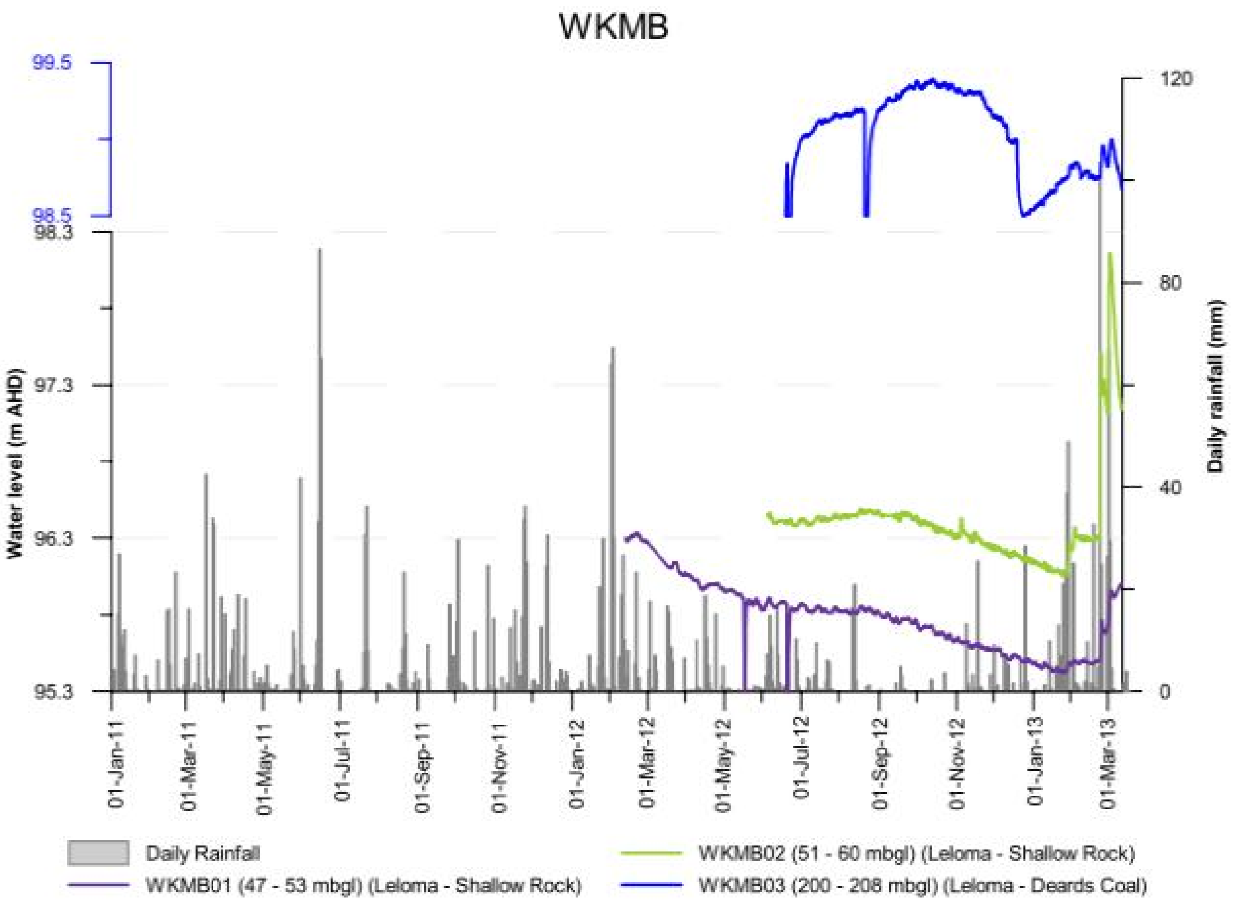

Figure 5.18 Groundwater levels and rainfall at the WKMB site

5.3.3.3 Vertical gradients

Significant vertical gradients were noted at six of the eight nested bore installations assessed:

- Downward hydraulic gradients were noted at the TCMB and TTMB nested bore sites. Downward gradients are characteristic of recharge zones and imply potential for slow downward seepage of groundwater between units.
- Upward hydraulic gradients were noted at the S4MB, S5MB, RMB and WKMB nested bore sites. Upward gradients are characteristic of discharge zones and imply potential for slow upward seepage of groundwater between units.
- No significant vertical hydraulic gradients were noted at the BMB and WMB nested bore sites.
- In all cases it is noted that despite the vertical hydraulic gradients, due to the very low permeability of the interburden units, vertical seepage is likely to be limited and slow. Lateral flow within each of the geological units is concluded to be the primary groundwater flow mechanism when there are no stresses on the shallow or deep groundwater systems.

5.3.3.4 Groundwater response to gas well flow testing

A 29 day flow test was conducted at gas production well Stratford 4 from 11 September to 9 October 2012 as part of the Hydrogeological Investigation of a strike-slip fault in the Northern Gloucester Basin (Parsons Brinckerhoff, 2013b). Stratford 4 has a total depth of 846.3 m and has 10 sections that are open (perforated) against coal seams; the shallowest being the Bowens Road seam (515 mbgl) which is stratigraphically below the intervals screened by the monitoring bores.

Groundwater hydrographs at the S4MB (Figure 5.11), S5MB (Figure 5.12), TCMB (Figure 5.13) and TTMB (Figure 5.14) nested bore sites were assessed to determine whether depressurisation of the coal seams at depth resulted in measurable drawdown of groundwater levels in the shallow groundwater system in the vicinity of Stratford 4, and two trends were identified:

1. Eight out of the 15 monitored bores (S5MB bores, TCMB02, TCMB03, TCMB04, TTMB03 and Farley) show relatively stable groundwater levels with no consistent trend during or after the flow test. These bores tend to be relatively distant from the Stratford 4 well and have screened intervals that are relatively deep compared with other monitoring bores.
2. Seven out of the fifteen monitored bores (S4MB bores, TTPB, TTMB01, TTMB02 and TCMB01) show relatively stable groundwater levels prior to the flow test, with a gradual decline in groundwater levels from early October.

It is not possible from the existing data to determine unequivocally the cause of the observed slight declining trend in groundwater levels in seven of the shallow monitoring bores that appears to start in early October. However it appears to be more consistent with the regional decline in groundwater levels due to the very low rainfall conditions in late 2012, than due to possible depressurisation effects.

5.3.4 Groundwater quality

The results of water quality monitoring carried out as part of the Phase 2 Groundwater Investigations (Parsons Brinckerhoff, 2012a) is shown in Table 5.6. Major ion chemistry for all groundwater samples is shown on the Piper diagram in Figure 5.19. The water quality monitoring suggests that:

- Alluvial aquifer water quality is fresh to brackish, sodium-chloride dominant, with minor dissolved metals, minor detection of naturally occurring TPH, and no detection of dissolved methane or BTEX compounds.
- Shallow rock water quality is brackish, sodium-chloride-bicarbonate dominant, with minor dissolved metals, low to moderate dissolved methane concentrations, and minor detections of naturally occurring TPH and toluene at a few sites.
- Interburden confining units water quality is brackish to slightly saline, sodium-chloride-bicarbonate dominant, with minor dissolved metals, moderate to high dissolved methane concentrations, and minor detections of naturally occurring phenol, TPH and toluene at a couple of sites.
- Deep coal seam water bearing zone water quality is brackish to slightly saline, generally sodium-chloride-bicarbonate dominant, with minor dissolved metals, generally high dissolved methane concentrations, and minor detection of naturally occurring TPH and toluene at one site.

Table 5.6 Water quality summary

Parameters	Units	Alluvial aquifer average	Shallow rock average	Interburden average	Coal seams average
Water quality parameters					
Field EC	µS/cm	3,046	6,236	4,280	4,012
Field pH	pH units	6.5	7.0	7.1	8.7
Major ions					
Calcium	mg/L	112	167	54	71
Magnesium	mg/L	80	58	26	34.5
Sodium	mg/L	531	911	720	693.4
Potassium	mg/L	3	8	24	15
Chloride	mg/L	1,012	1,386	802	867
Sulphate	mg/L	110	240	198	103
Total alkalinity as $CaCO_3$	mg/L	255	593	474	481
Metals					
Aluminium	mg/L	<0.01	0.01	0.40	1.09
Arsenic	mg/L	0.003	0.009	0.006	0.002
Barium	mg/L	0.29	0.35	0.75	0.67
Beryllium	mg/L	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0002	0.0001	0.1470	0.0002
Copper	mg/L	0.0020	0.0010	0.0002	0.0020
Lead	mg/L	<0.001	<0.001	0.001	0.001

Parameters	Units	Alluvial aquifer average	Shallow rock average	Interburden average	Coal seams average
Manganese	mg/L	1.3	0.22	0.18	0.22
Molybdenum	mg/L	<0.001	0.001	0.012	0.003
Nickel	mg/L	0.004	0.001	0.008	0.034
Selenium	mg/L	<0.001	<0.01	<0.001	<0.001
Strontium	mg/L	2.37	4.82	5.28	2.82
Uranium	mg/L	0.004	0.003	0.009	0.002
Vanadium	mg/L	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.02	0.01	0.02	0.09
Iron	mg/L	2.37	1.48	1.17	1.43
Bromine	mg/L	1.8	3.0	1.7	1.5
Nutrients					
Nitrite as N		<0.01	<0.01	0.01	<0.01
Nitrate as N		<0.01	<0.01	0.01	<0.01
Ammonia as N	mg/L	0.1	1.2	2.9	1.2
Total Phosphorus as P	mg/L	0.14	0.07	0.17	0.11
Reactive Phosphorus as P	mg/L	0.03	0.04	0.06	0.05
Total Organic Carbon	mg/L	4	14	39	17
Hydrocarbons					
Methane	µg/L	<10	140	12,786	21,931
Phenolic compounds	µg/L	<2.0	<2.0	<2.0	<2.0
Polycyclic aromatic hydrocarbons	µg/L	<1.0	<1.0	<1.0	<1.0
Monocyclic aromatic hydrocarbons					
Benzene	µg/L	<1	<1	<1	<1
Toluene	µg/L	<5	<5	<5	9
Ethyl Benzene	µg/L	<2	<2	<2	<2
m&p-Xylenes	µg/L	<2	<2	<2	<2
o-Xylenes	µg/L	<2	<2	<2	<2
Total petroleum hydrocarbons					
C_6-C_9	µg/L	<20	<20	<20	<20
C_{10}-C_{14}	µg/L	<50	<50	<50	<50
C_{15}-C_{29}	µg/L	127	172	210	<100
C_{29}-C_{36}	µg/L	196	124	67	<50

NB To calculate the average, values below detection limit are included in the calculation as half the LOR (Limit Of Reporting: the practical limit of quantitation).

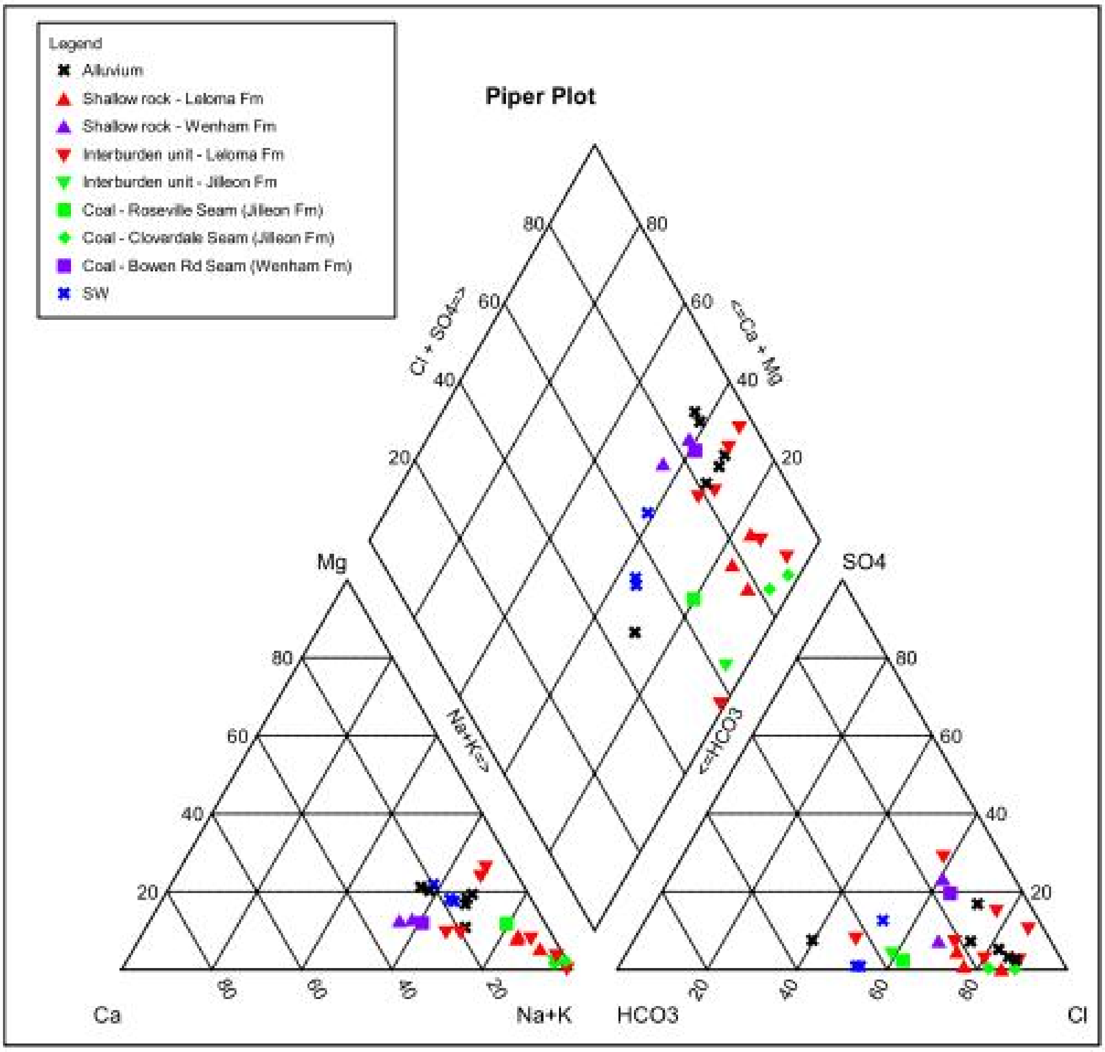

Figure 5.19 Piper diagram showing major ion composition of groundwater and surface water

Surface water quality data is not directly relevant to this conceptual model report. Data is presented in other reports (Parsons Brinckerhoff, 2012a and Parsons Brinckerhoff, 2013a) and additional water samples were collected in May–June 2013 to supplement this data set from 2011 and 2012.

5.3.5 Groundwater age and residence time

Radiocarbon analysis of groundwater samples from monitoring bores was carried out as part of the Phase 2 Groundwater Investigations (Parsons Brinckerhoff, 2012a). All these bores are located in shallow aquifers and water bearing zones in the eastern portions of the basin relatively close to recharge areas. This analysis identified that the alluvial aquifers contain modern and sub-modern water, <1,000 years BP on average. Groundwater in the shallow rock system was found to contain water that was on average 12,000 years BP. Groundwater in the interburden units was on average 10,500 years BP, and groundwater in the shallow coal seams was on average 13,600 years BP. Groundwater in the deeper interburden and coal seams (below 300m) is expected to be much older. Groundwater age was found to increase with depth at the nested monitoring bore sites.

Further investigation of groundwater age, based on radiocarbon and tritium analysis, was carried out as part of the hydrogeological investigation of a strike-slip fault in the Northern Gloucester Basin (Parsons Brinckerhoff, 2013b). Radiocarbon ages within the Tiedman fault zone were generally older (25,000 to >30,000 years BP) than in monitoring bores at equivalent depths/formations outside of the high permeability zone (5,000 to 22,000 years), suggesting there may be some contribution of deeper, older waters within the shallow fault zone.

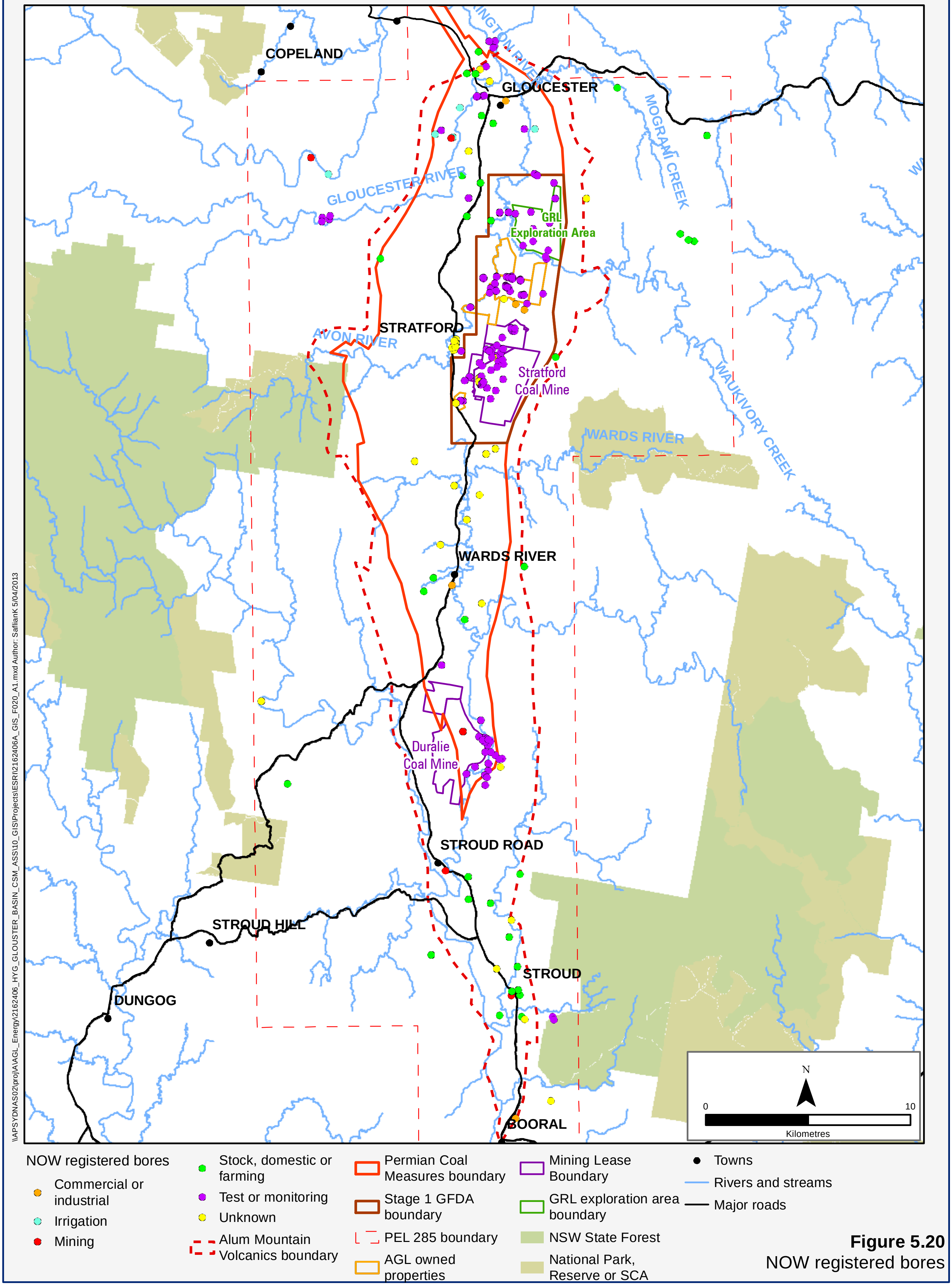

Figure 5.20
NOW registered bores

5.3.6 Groundwater use

The locations of groundwater bores registered with the NSW Office of Water (NOW) in the Gloucester Basin are shown in Figure 5.20. The registered bores are categorised by use:

- commercial or industrial
- irrigation
- mining
- stock, domestic or farming
- test or monitoring
- unknown.

5.3.6.1 Mining

Groundwater modelling carried out as part of the Hydrogeological Assessment of the Duralie Extension Project (Heritage Computing, 2009) predicts that pit inflows to the Duralie Mine open cuts are expected to vary between approximately 0.2 and 1 ML/day during mining operations.

Groundwater modelling carried out as part of the Hydrogeological Assessment in Support of the Stratford Coal Project (Heritage Computing, 2012) predicts that total pit inflows will peak at 1.35 ML/day in Year 2 of mining, for all of the open cuts at the Stratford Mining Complex. Minimum pit inflows are predicted to be 0.74 ML/day at the end of mining (Year 11). Pit inflows are predicted to be reduced by a maximum of 0.5 ML/day if CSG dewatering in the Stage 1 GFDA are coincident with mining at the Stratford Mining Complex.

Bores associated with Stratford Mine, Duralie Mine and the Rocky Hill Coal Project are shown in Figure 5.20.

5.3.6.2 Coal Seam Gas

Coal seam gas dewatering is deemed to be industrial and irrigation use as water that is pumped as part of exploration (appraisal) programs and production programs is mostly reused for drilling, fracture stimulation, industrial recycling and irrigation purposes. The long term reuse of produced waters at Gloucester will mostly be for irrigation purposes.

The GGP will involve the dewatering of deep groundwater and the extraction of gas from multiple coal seams within the Gloucester Coal Measures. Target coal seam depths will vary from site to site but are expected to range between 200 and 1,000 mbgl. The GGP includes the construction, operation and decommissioning of not more than 110 coal seam gas wells and associated infrastructure, including gas and water gathering lines, within the Stage 1 GFDA. The volumetric rate of groundwater extraction will not exceed 2 ML/d (averaged over a 12 month period), as specified in the Part 3A Approval (condition 3.11) and EPBC Approval (condition 22).

5.3.6.3 Stock and domestic use

A search of the NSW Office of Water (NOW) groundwater database indicates that there are 188 registered bores in the Gloucester Basin, within the Alum Mountain Volcanics boundary (Figure 5.20). Of the 188 registered bores, 24 are registered for stock and domestic use. A further 4 are registered for irrigation, 5 bores are registered for commercial and industrial use, 4 are registered for mining use, 121 for test and monitoring associated with mining in the area, and 30 are registered with unknown use. All those bores registered for industrial, mining, test and monitoring purposes are associated with either mining or coal seam gas developments.

The depth of the 24 private bores registered for stock and domestic use ranges between 4 and 66 mbgl, and therefore these bores are assumed to intersect the alluvium and shallow rock within the Gloucester Basin. Beneficial aquifers are not expected to exceed a depth of 75m across the basin. It is assumed that annual stock and domestic bore use is approximately 1 ML/bore, therefore the total groundwater use is not expected to exceed 24 ML per annum from the 24 privately registered bores.

5.4 Occurrence of gas in groundwater and surface water

Gas sampling was carried out as part of the Phase 2 Groundwater Investigations (Parsons Brinckerhoff, 2012a). Average methane concentrations in the alluvial aquifer, shallow rock aquifer, interburden and coal seams are presented in Table 5.6. Methane concentrations increase with depth, ranging from below detection (10 µg/L) in the alluvial monitoring bores, to an average of 12,786 µg/L in the interburden monitoring bores and an average of 21,931 µg/L in the coal seam monitoring bores.

No baseline samples for dissolved methane in surface waters have been collected at this time; however sampling programs are scheduled for May and June 2013.

Gas samples were also collected from the two shallow gas monitoring wells, TGMB01 and TGMB02 on the Tiedman property (Figure 5.1). These are dry holes above the water table. The results from 31 May 2011 are presented in Table 5.7. Concentrations of oxygen (O2), Argon (Ar) and Nitrogen (N2) are typical of air, while carbon dioxide (CO2) concentrations are slightly elevated. Methane concentrations were negligible and were too low to perform any isotopic analysis of C or H isotopes.

Table 5.7 Gas sample composition (ppm)

Analyte	TGMB01 (screened 3 to 4 mbgl)	TGMB02 (screened 12 to 15 mbgl)
O_2 + Ar	217,700	216,600
CO_2	560	1,200
N_2	781,700	782,100
CH_4	16	138

5.5 Influence of faulting on groundwater flow

5.5.1 Faulting and groundwater

5.5.1.1 Role of faults

Folding and faulting of sedimentary rocks can give rise to complex hydrogeological systems. Fault zones can act as either barriers to groundwater flow or as groundwater conduits, or have negligible influence, depending on the nature of the fault zone and the material within it (Fetter, 2001). If the fault zone consists of finely ground rock and clay (fault gouge), the material may have very low hydraulic conductivity compared with the host rock and form a barrier to flow. Such low-permeability faults may be apparent from significant differences in groundwater level across the fault, or appear as hydraulic boundaries in aquifer (pumping) tests.

Conversely, if a fault zone consists of one or more continuous open fractures, then it may act as a conduit. Under natural conditions, evidence for such conduit faults may be seen in geophysical surveys (contrasting conductivity), perturbations in groundwater levels, or the occurrence of fault related springs and discharge zones. When the groundwater system is pumped, such as in an aquifer test or extended flow test, a conduit fault may manifest as an apparent recharge boundary (source of recharge) and/or cause anomalous drawdown in monitoring bores connected to the fault. Any enhanced permeability of a fault zone is likely to apply to the migration of gasses as well as water.

On a regional (or basin) scale the influence of faulting on groundwater flow depends on numerous factors including the permeability of the fault(s) and their orientation with respect to the geological strata and dominant recharge and discharge zones (Tóth, 2009). The potential regional effects of faulting include:

- Compartmentalisation of the regional flow (differences in groundwater level and/or flow direction between fault-bounded blocks).
- Hydraulic sheltering; where quasi-stagnant zones of ‘no-flow’ are formed.
- Concentration of flow within fault zones which may enhance recharge or discharge, or form conduits, particularly where there are inclined or low-angle conduit faults within or between those zones.
- Anisotropy. Faults or joints that have a dominant orientation can impart a preferred flow direction on groundwater systems.
- May enhance vertical leakage in units assumed to be regional aquitards.

There may also be potential differences in permeability along a fault zone. Faults are more likely to be open near surface and closed at depth, however this can only be assessed during flow testing and pumping test programs and monitoring the responses in gas wells (water volumes, and water quality) and water monitoring bores (water levels and water quality).

Where there are numerous faults of contrasting orientation and permeability, there may be insignificant influence on groundwater flow patterns on a regional or basin scale, or that influence may be difficult to identify because at that scale, the fracture network may approximate a continuous porous medium.

5.5.1.2 Faulting in the Gloucester Basin

A large number of faults are known and inferred to underlie the Gloucester Basin, many of which are not apparent at the surface or in logging of drill chips. There is currently little information concerning the hydraulic properties of these faults. The following observations have been made in previous studies:

- Pacific Power (1999, in SRK, 2010): An inferred normal fault, intersected at 325 mbgl in the Bowens Road Coal Seam of cored well PGSD3 provided a hydraulic conductivity of ~5.8×10^{-2} m/d, approximately one order of magnitude higher than those estimated for the coal seams at a similar depth (~8.6×10^{-3} – 1.2×10^{-2} m/d).
- Resource Strategies (2001) suggested that faulting locally caused compartmentalisation of groundwater flow (i.e. faults are of low permeability) (from URS, 2007, p14).
- Parsons Brinckerhoff (2012a) observed that even though several monitoring bores in the Phase 2 Groundwater Investigation were located close to faults or straddle fault zones, water level data suggested that the faults do not affect the natural groundwater flow characteristics of shallow rock aquifers, interburden confining units or coal seam water bearing zones.

5.5.1.3 Faulting and regional stress

In fractured or faulted rocks, the permeability of fracture networks can be influenced by the regional stress regime (e.g. Morin and Savage, 2003), whereby fractures oriented parallel to the principal stress direction may dilate (increasing the permeability) whereas fractures oriented perpendicular to the principal stress direction are more likely to be closed (decreasing the permeability). The assumed east-west principal stress direction in the Gloucester Basin would tend to result in closed fractures within the dominant meridional (N-S) faults and shear zones in the area.

5.5.2 Fault investigations

Two investigations are being conducted by AGL into faulting in the Gloucester Basin:

1. Tiedman property fault investigation (completed) (Parsons Brinckerhoff, 2013b).
2. Waukivory fault investigation (commenced).

5.5.2.1 Tiedman property

A field based hydrogeological investigation was carried out to assess the hydraulic characteristics of a strike-slip fault within the Stage 1 GFDA on the Tiedman property (Parsons Brinckerhoff, 2013b). The investigation used field based studies and geophysical methods to identify and characterise the fault in the near surface environment. The TTMB nested bores was installed as part of this investigation, with TTPB installed as the test pumping bore (Figure 5.1).

The hydraulic characteristics of the fault zone were investigated by inducing drawdown in both the fault zone (using a pumping test) and the deeper coal seam water bearing zones (using a gas well flow test) and monitoring the effects on the shallow groundwater system.

Water level trends were used as the primary proof of any enhanced connectivity within the fault zone. Water samples were collected and analysed for groundwater quality, dissolved methane content, isotopic composition and age to place further constraints on groundwater processes.

The following conclusions are drawn from the results of these investigations:

1. The target strike-slip fault on the Tiedman property is clearly identified in the seismic sections. In the upper 200 m, the main fault zone appears to splinter into a number of related structures over a zone up to 300 m to 400 m wide. The surface projection of the fault zone corresponds to a visible surface trace and a zone of anomalous electrical conductivity in the TEM geophysical survey.
2. During the 3-day pumping test, six out of 10 monitored bores registered some drawdown response in shallow aquifer zones, ranging from 0.5m to 7.4m. The magnitude and timing of drawdown at each monitoring location reflected variation in aquifer characteristics across the site.
3. Results of the pumping test indicate that the fault zone is a broad zone of enhanced hydraulic conductivity within the shallow rock aquifer. The fault zone does not form a barrier to flow, and does not cause strong preferred longitudinal flow in the direction of the surface trace, but may form heterogeneous, weakly transmissive zones in the near surface, relative to unfractured shallow-rock domains.

4. Distinct hydrochemistry and (older) radiocarbon ages within the fault zone may indicate some vertical (upward) migration of deeper groundwater under natural conditions. However, this appears to contrast with groundwater level data from multiple nested piezometers which indicate a generally downward hydraulic gradient at this site, consistent with recharge. Therefore there is no clear indication as to whether the fault zone is a net recharge or net discharge feature based on the current data.
5. Depressurisation of deeper coal seams was carried out during the 29-day flow test on Stratford 4 (Stratford 4 is located 200m west of the edge of the fault zone on the Tiedman property). Observations of groundwater levels indicated no apparent groundwater drawdown in most monitoring bores, while a few bores show a slight declining trend that appears to start in early October after completion of the flow test. It is not possible from the existing data to determine unequivocally the cause of the observed groundwater decline. However it appears to be more consistent with the regional decline in groundwater levels due to the very low rainfall conditions in late 2012, than due to a possible depressurisation effect.
6. Dissolved methane is naturally occurring in both the shallow rock aquifer and the deeper coal seams and interburden. At depth, methane can occur in the dissolved phase at concentrations greater than saturation at atmospheric pressure (26,000 to 32,000 µg/L).
7. Most hydrochemical parameters did not change significantly in shallow groundwater during or after the flow test. However, dissolved methane declined significantly in three monitoring bores within the fault zone during the flow test. The exact mechanism for this change is not yet understood, but it is clear that no increase in dissolved methane flux resulted from the flow test.
8. Test pumping and isotopic analysis indicate that the fault zone is a broad and heterogeneous zone of increased hydraulic conductivity within the shallow rock aquifer. However monitoring of groundwater levels and dissolved methane during the Stratford 4 gas flow test provided no clear evidence of enhanced connections between the deeper coal seams and shallow groundwater system.

5.5.2.2 Waukivory

AGL plans to conduct a further hydrogeological investigation into faulting in association with the proposed Waukivory flow testing program. This is an equally (if not more important) fault investigation program than the Tiedman study as the thrust fault in this area is typical of many such features across the eastern portion of the basin (Figure 4.6).

The WKMB nested monitoring bores for this testing program have been installed (Figure 5.1). There were no noticeable increases in fracturing and water inflows when constructing those monitoring bores that were drilled through the thrust fault zone. In particular at the WKMB03 site that targeted the trust fault at depth, there were very clayey returns in the cuttings, there were no increases in water volumes, and the slug testing program suggested a hydraulic conductivity of $2x10^{-4}$ m/d.

6. Conceptual model

This chapter presents the (updated) hydrogeological conceptual model for the whole of the Gloucester Basin. It is based on earlier models described in SRK (2010) and Parsons Brinckerhoff (2012a) and is updated based on more than two years of monitoring data, and the knowledge gained from several testing programs around a slip-strike fault.

A hydrogeological conceptual model is a summary, accompanied by a graphical representation, of the key processes considered to control groundwater levels and flow within a groundwater system. The conceptual model describes how water enters, exits, is stored, and moves within a hydrogeological system and how groundwater interacts with surface water systems and potentially dependent ecosystems. Ultimately the conceptual model informs the development of a numerical predictive groundwater model which is used to assess impacts on hydrologic systems from activities such as mining and groundwater extraction.

The conceptual model for groundwater systems across the basin is based on the cumulative results from extensive groundwater investigations carried out by Parsons Brinckerhoff since 2010 and earlier studies by SRK (2010), URS (2007) and others. While our conceptual understanding is always evolving as new data comes to light, there is now a strong scientific basis for the following conceptual framework. The current conceptual understanding of the groundwater system in the central area of the basin is depicted on the hydrogeological cross section in Figure 6.1.

6.1 Gloucester Basin

The Gloucester Basin is a broad north-south elongated valley underlain by Permian sedimentary and volcanic rocks that have been folded and faulted into a synclinal (canoe-shaped) structure. The Permian geological sequence is divided into three major Permian stratigraphic units each representing a distinct depositional setting: the Gloucester Coal Measures, the Dewrang Group, and the Alum Mountain Volcanics. The geological and depositional history of the basin is such that economic coal seams are well developed on the eastern side of the basin, while coarse proximal fan deposits with relatively few coal seams prevail on the western side of the basin. The CSG development in the Stage 1 GFDA is targeting the intermediate and deep coal seams in the Gloucester Coal Measures generally below depths of 200m to around 1000m.

The Basin is bounded to the west by the elevated topography of the Gloucester and Barrington Tops, and to the east by the Mograni Range. These topographic divides also correspond to outcrops of the largely impermeable Alum Mountain Volcanics which forms the hydrogeological basement to the basin. By contrast, the coal measures and near surface rocks within the basin are slightly more permeable, mainly due to sparse fracturing in near-surface rocks and cleating within coal seams which form weak water bearing horizons. In hydrogeological terms therefore, the Basin is conceptualised as an essentially closed groundwater system, with minor surface water and groundwater inflows from adjacent tributary catchments and minor groundwater outflow at the northern and southern ends of the hydrogeological basin. All surface water and most discharging groundwater exits the basin via the Avon and Gloucester Rivers to the north and the Wards River system to the south.

In terms of groundwater flow, the basin can be divided into two distinct groundwater flow systems which are largely controlled by the topography and surface drainage features: The northern Gloucester Basin in which groundwater predominantly flows to the north, and the southern Gloucester Basin in which groundwater generally flows in a southerly direction. The boundary between the two flow systems, under natural conditions, corresponds with the catchment divide between the Avon and Wards Rivers. Unlike the surface catchment divide however, the groundwater divide may move in response to drawdown related to groundwater abstraction, CSG depressurisation or mining. The Stage 1 GFDA is confined to the northern Gloucester Basin.

The permeability and groundwater flow characteristics of rocks within the basin are controlled by several factors including lithology, depth and the degree of fracturing and faulting. In this sense hydrogeological units and flow systems do not always correspond with defined geological boundaries. Four main hydrogeological units influence groundwater flow within the basin:

1. **Alluvial deposits** adjacent to major creeks and rivers comprising unconsolidated sand, gravel and clay. These systems are heterogeneous but generally permeable with rapid recharge, through-flow and discharge associated with interactions with streams, and to a lesser extent with the underlying less permeable shallow rock. Hydraulic conductivity measurements range from 0.3 to 300 m/d, averaging around 10 m/d.

2. **Shallow rock** comprising variably weathered and fractured Permian rocks extending to approximately 150 m below the surface, across all sub-cropping Permian units. The shallow rock zone is highly heterogeneous with relatively impermeable domains separated by more permeable domains, but on the whole it is more permeable that the deeper coal measures. The areas of higher permeability are due to a higher density of fracturing associated with an irregular weathering profile and the near-surface expression of faulting. Groundwater flow within this zone is more strongly controlled by weathering and fracturing than the attitude of geological strata. Hydraulic conductivity of the shallow rock ranges from 10 m/d to $1x10^{-6}$ m/d at a depth of 150m, but is typically in the order of 10^{-3} to 10^{-4} m/d.

3. **Deep Coal Measures interburden**. Sandstone and siltstone units that form interburden to coal seams are indurated and typically of very low permeability, forming aquitards and confining layers. Permeability of interburden decreases with depth such that, at the maximum depth of CSG production is likely to be in the order of 10^{-5} to 10^{-7} m/d, or less.

4. **Coal seams**. Coal seams tend to be slightly more permeable than interburden and commonly form weak water bearing zones. Permeability and storage are provided by small fractures and cleats in the coal. As with interburden, drill-stem tests clearly show that the permeability of coal seams generally decreases with depth. At the maximum depth of CSG production, the permeability of coal seams is very low (10^{-4} to 10^{-6} m/d), but may be an order of magnitude higher than the interburden.

A large number of faults of varying orientations are known to occur within the basin, many of which are not apparent at the surface or in drill logs. An understanding of how faults influence groundwater movement in the near surface and at depth is starting to emerge from ongoing groundwater investigations and CSG exploration. Faults may form weak conduits in the near-surface environment or barriers to flow, particularly in the deeper sediments and coal measures. It will be important to test these assumptions, particularly in relation to faulting, when modelling potential impacts of CSG development on groundwater systems.

6.2 Groundwater recharge

Rainfall is the primary recharge source to the aquifers and water bearing zones within the Gloucester Basin. Minor recharge from streams may occur during periods of high rainfall/surface flow and flooding when there is the potential for the rivers to lose water, particularly in upper catchment areas. Direct recharge rates to the rock aquifers and water bearing zones are low based on water level responses, and water quality indicators such as chloride and age dating (Parsons Brinckerhoff, 2012c). Recharge to deeper rock layers through vertical leakage from overlying hydrogeological units is possible but lateral flow appears to dominate. Observations of vertical head gradients indicate that recharge is highest towards the margins of the basin due to surface runoff from the adjacent elevated areas and rockier outcrop/thinner soils in these areas.

6.3 Groundwater flow

6.3.1 Lateral flow

The groundwater flow pattern is controlled by topography, and recharge and discharge locations. The regional groundwater flow in the northern part of the basin is predominantly from south to north. The regional groundwater flow in the southern basin is predominantly from north to south. At the margins of the basin, groundwater will flow away from elevated areas of outcrop where recharge occurs and towards the centre of the basin where discharge occurs as stream baseflow and evapotranspiration.

The largest groundwater flows (in terms of through-flow per year) are likely to occur within the shallow rock unit which forms a thick and relatively permeable mantle of weathered and fractured rock over the low permeability Permian Coal Measures and basement rocks. Groundwater flow is likely to be relatively rapid within the alluvial deposits that underlie the main drainage systems. However these deposits tend to be thin (i.e. 15 m or less) and of relatively limited storage volume (compared to the deeper hydrogeological units). In the underlying Permian deposits, age dating of the groundwater, undertaken as part of the Phase 2 Investigations indicates very slow groundwater movement and very long residence times, consistent with the very low measured permeability of those rocks.

6.3.2 Vertical connectivity

Vertical gradients in groundwater head have been observed in sedimentary rock aquifers within the Stage 1 GFDA, based on information from multiple piezometer installations. Although there is no systematic spatial pattern of upward and downward gradients across the Stage 1 GFDA, it is expected that downward gradients will prevail in topographically elevated areas towards the basin margin (recharge areas) and upward gradients in topographically lower parts of the Basin, towards the drainage lines (discharge areas).

Connection between the shallow and deep systems will be limited by the permeability of the rock strata which is known to be very low. Isotopic dating indicates that groundwater in the shallow coal seams is greater than 10,000 years old, on average, while groundwater within the alluvium and shallow rock domains is mostly modern (<200 years). This does not preclude connection between the shallow and deep systems, but it implies that recharge to the deeper hydrogeological units via vertical or lateral seepage is very slow (Parsons Brinckerhoff, 2012a). This is further supported by bore hydrographs which show rapid groundwater responses to rainfall events in shallow bores and alluvium, but negligible, delayed or subdued responses in deeper bores.

6.3.3 Role of faults

Numerous faults occur throughout the basin and these have been divided into several types according to their orientation and past movement. On the eastern side of the basin (and in the vicinity of the Stage 1 GFDA) the structure is dominated by west-dipping thrust faults and near-vertical sinistral strike-slip faults.

Faulting of sedimentary rocks can give rise to complex hydrogeological systems. Fault zones can act as either barriers to groundwater flow or as groundwater conduits, or have negligible influence, depending on the nature of the fault zone and the material within it. Information from ongoing fault investigations by AGL suggests that in the near surface (shallow rock) faults may be expressed as broad zones of enhanced permeability and groundwater flow. However there is evidence that at depth, these fault zones decrease in permeability due to increasing clay content and increasing lithostatic pressure which causes fractures to close and may even form barriers to flow where water bearing zones are truncated or offset.

Monitoring of shallow groundwater systems during flow testing of gas wells intersecting deep coal seams have not yet shown any clear indication of drawdown or connection via faulting over the timescale of the tests. Simulations of such tests using numerical models suggest that drawdown impacts at the surface are likely to take many years to manifest and are likely to be minor in terms of drawdown at the water table. This is due to the very low permeability of the coal measures and the contrast in storage characteristics between the deep confined units and the shallow unconfined systems.

6.4 Groundwater discharge

Groundwater outflow predominantly occurs as discharge to gaining streams (baseflow) and, to a lesser extent, direct evapotranspiration losses from the water table where the groundwater is shallow (i.e. close to the creeks and towards the northern and southern Basin outflow points). It is expected that most baseflow to the perennial streams is derived from groundwater discharge from the alluvium via relatively short flow paths. By contrast groundwater discharge from the shallow rock and underlying coal measures via longer flow paths is expected to be a minor component of stream baseflow.

Groundwater may also exit the Basin via aquifer through-flow in the alluvium and deeper hydrogeological units beneath the Avon and Wards Rivers, although this is assumed to be a minor component of the total outflow. For the purpose of this study, the basin is assumed to be a closed groundwater system in that negligible groundwater enters from outside the basin and most groundwater exits the basin via stream baseflow or evapotranspiration from the shallow water table.

Groundwater use for mining and stock and domestic use also results in consumptive groundwater use from the Gloucester Basin. New CSG extractions will slightly increase the future consumptive uses. The cumulative impact of these consumptive uses is small based on the overall basin water balance (Parsons Brinckerhoff, 2012c). The net effect is there will be slightly less saline water discharging to the alluvium and discharging to the streams as baseflow. This will have a negligible impact on total river flows but may improve the stream water quality (especially during low flows).

6.5 Potential operational issues

Production of CSG in the Stage 1 GFDA will involve depressurisation of target coal seams by pumping groundwater from wells perforated within the target (deep) coal seams. The wells are only perforated adjacent to the target coal seams and not against the interburden or overlying shallow strata. Under normal operation conditions the pump is placed below the deepest coal seam that is perforated and the hydraulic head in the well is lowered over time. Within the well the hydraulic head is eventually reduced to the pump intake but in the adjacent natural formations (due to low permeability formations and poor well efficiency though the casing perforations) the hydrostatic heads are highly variable and are substantially higher.

It is understood that Stage 1 GFDA development may result in a consumptive dewatering volume of approximately 730 ML per annum in the initial years of the project. This dewatering volume is expected to diminish substantially with time because of the small water volumes in the adjacent coal seams and low permeability strata overlying/underlying the target coal seams. Most groundwater abstraction will be from the individual coal measures at depths greater than 200 m. During operation, the produced water pumped from the deep confined coal measures will be initially derived from storage, and over the following years and decades will be derived from recharge to and lateral flow through the sedimentary rocks with a component of vertical leakage.

Water table aquifers in the alluvium and in the uppermost fractured rock will be the least impacted and are expected to have negligible drawdown. Registered bore users with water supply bores to 75m are unlikely to notice any water level declines outside of the normal seasonal variations. Numerical modelling will assist in confirming the extent of any drawdowns within the shallow beneficial aquifers.

6.5.1 Potential for drawdown

As gas production continues, the zone of depressurisation for the confined water bearing zones will increase and expand preferentially along zones of higher permeability (the coal seams). This depressurisation is depicted in the piezometric surface for the target coal seams in the Tiedman area as shown in Figure 6.2. The zone of depressurisation will expand vertically into the adjacent interburden at a much slower rate due to its lower permeability. Over time there is potential for the zone of depressurisation to impinge on shallow groundwater systems, particularly if there are zones of enhanced connectivity such as conductive fault zones. This in turn may cause downward leakage of groundwater, localised drawdown of the water table and potentially a decrease in groundwater discharge to the alluvium. These leakage volumes and drawdowns are expected to be relatively minor given the small produced water volumes, the bulk of the water coming from storage within the coal seams and adjacent strata, and there being multiple (low permeability) aquitards between the deeper coal seams and shallow beneficial aquifers. The risk of losses to stream baseflow is considered to be very low because any slight decrease in discharge from the bedrock is likely to be offset by the high rainfall recharge rates to the alluvial aquifers.

The changes in vertical fluxes are expected to be small given the total Stage 1 GFDA wellfield extraction is capped at 2 ML per day. As all registered bore users tap shallow water table aquifers, the drawdown impacts near surface are expected to be negligible and may not be measureable.

It is expected that natural groundwater recharge and the high storage characteristics of the shallow and deep groundwater systems will mitigate any vertical leakage associated with CSG depressurisation. The drawdown impacts to the water table and surface water systems are expected to be negligible. Nevertheless, these potential impacts will be modelled in detail using numerical methods in the next phase of assessment. The modelling will allow some of the uncertainties relating to structure and hydraulic properties to be explored using sensitivity analyses and stochastic approaches. Modelling will quantify the possible range of drawdowns in both shallow and deeper groundwater systems.

6.5.2 Potential for subsidence

Subsidence can be defined as the movement of the surface strata in response to the loss of underground support. A loss of underground support can come from hydrocarbon removal from a conventional oil and gas reservoir, groundwater extraction from an unconsolidated aquifer and associated strata from the creation of voids due to mining.

Unconsolidated materials, such as gravel, sand, silt and clay are most prone to subsidence from large scale groundwater extraction. Variations within expected seasonal ranges and occasional drawdown responses would not be sufficient to cause subsidence. In cases where groundwater extraction occurs in consolidated rocks, such as sandstone or shale, subsidence is rare, as these materials do not deform easily.

Although some deformation of the target coal seams may occur, the deformation would be limited to the coal seams and would be dependent on the dewatering of seams over large areas. Currently it is expected that targeted coal seams will only be depressurised and not dewatered, thereby minimising the potential for any subsidence within the coal seams.

6.5.3 Location and development implications

Based on expected minor drawdowns in shallow aquifers, there is no one area of the Stage 1 GFDA that is considered to be more optimal than another area. However gas wells will be completed away from major fault structures where those structures intersect coal seams that are being targeted for CSG. Numerical (predictive) modelling is required to provide further insight into the drawdown effects that result from the proposed 110 wells that will comprise the Stage 1 GFDA. Numerical modelling will also assess the impacts of different phased development scenarios. It is not possible to provide any additional comments or recommendations on phased gas well development (Part 3A Approval Condition 3.9 c) as part of conceptual flow model assessment.

AGL has adopted the following principles in relation to locating gas production wells:

1. Locate production wells away from known major faults and structures. Faults are also avoided by AGL on grounds of gas prospectivity since they are likely to offset and truncate productive coal seams.
2. Monitor shallow groundwater systems and piezometric pressures in intermediate interburden and coal seam units to identify, and if necessary, manage depressurisation and drawdown effects.
3. Maintain a focus on the existing monitoring networks in the vicinity of known faults at the Tiedman and Waukivory locations.
4. Track produced water volumes and chemistry to monitor any trends that would suggest enhanced recharge or vertical leakage.

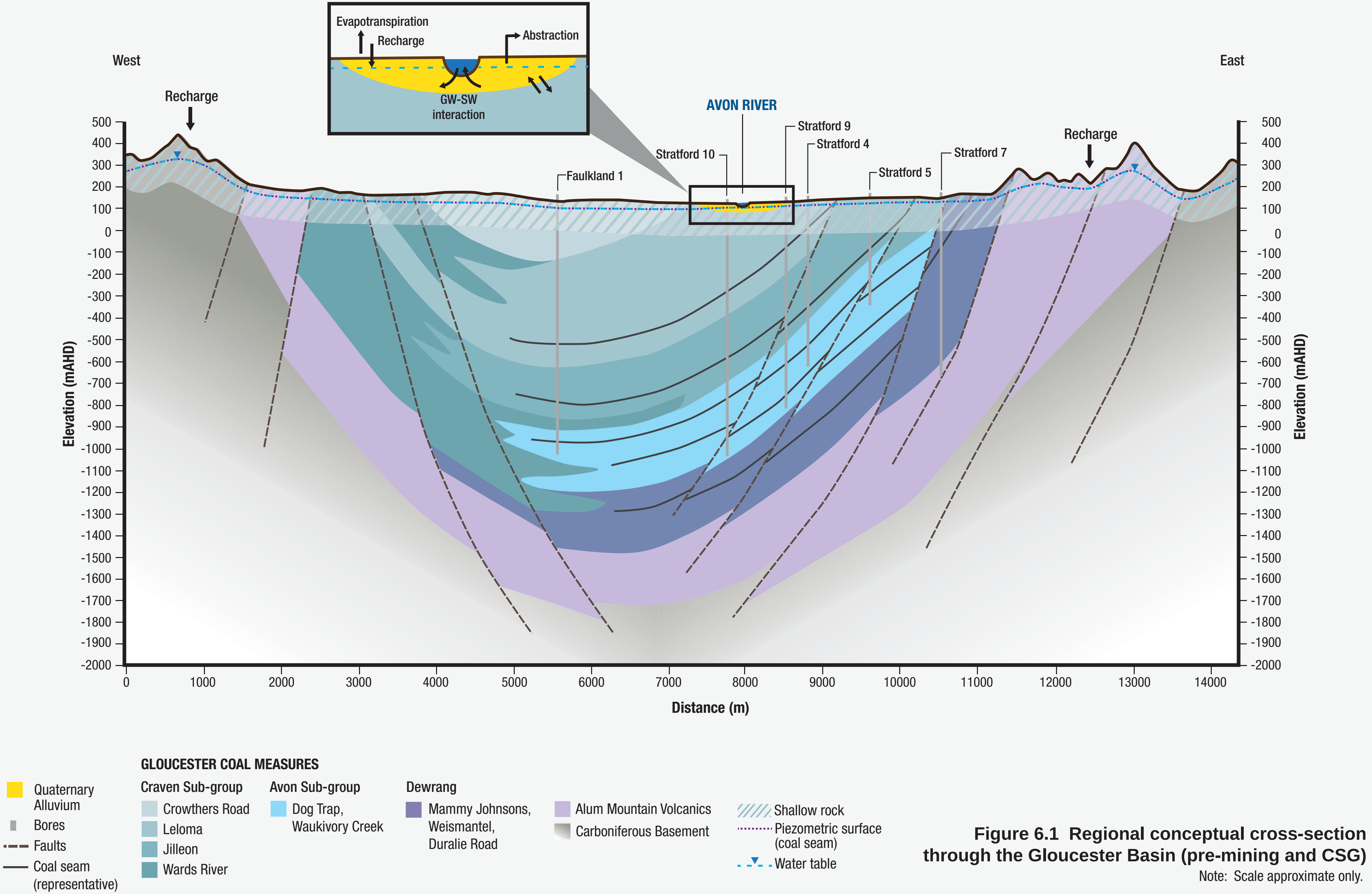

Figure 6.1 Regional conceptual cross-section through the Gloucester Basin (pre-mining and CSG)

Note: Scale approximate only.

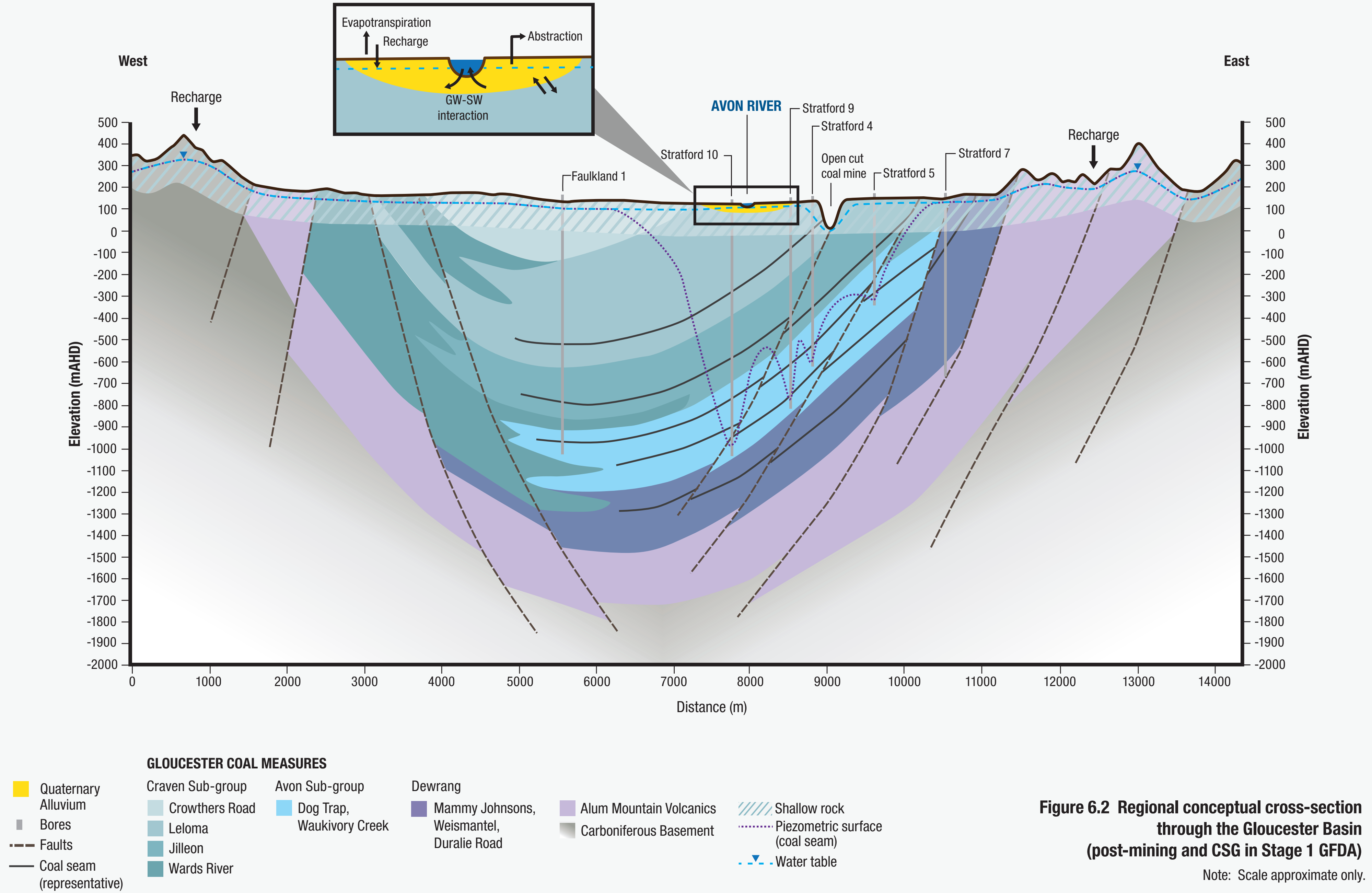

Figure 6.2 Regional conceptual cross-section through the Gloucester Basin (post-mining and CSG in Stage 1 GFDA)

Note: Scale approximate only.

7. Framework for numerical modelling

The hydrogeological conceptual model provides the framework for the development of a numerical groundwater model that will be used to assess the impacts of the proposed development on groundwater and connected surface water resources. This chapter provides a detailed framework for the numerical modelling which is the next phase of work to be completed in the groundwater investigation program.

The Australian Groundwater Modelling Guidelines (SKM, 2012a) provides guiding principles and minimum standards for numerical groundwater models. A framework for numerical modelling for the Gloucester Gas Project based on those guidelines is provided below. The framework considers the following aspects:

- Model planning:
  - intended use
  - modelling objectives
  - confidence level.
- Conceptual framework:
  - model domain
  - hydrostratigraphy
  - aquifer properties
  - conceptual boundaries
  - stresses
  - physical processes.
- Model design:
  - modelling code
  - user interface.

7.1 Model planning

Intended use

Condition 18 of the Federal approval under the EPBC Act requires that a numerical model must be developed, based on the revised water balance model (Parsons Brinckerhoff, in preparation). The model is to be used to '*explore the pressure at which gas and water may be released and transmitted along faults*' (Condition 18), and to assist in a risk analysis in relation to impacts to potential habitats for the green and golden bell frog and giant barred frog (Condition 19). The following potential impacts are specified: the surface expression of methane gas; water pollution including salinity; water drawdown; and any impacts on surface water.

Condition 4.2 of Part 3A approval under the EP&A Act requires that a model be developed of the Stage 1 GFDA based on the conceptual model already developed. The model '*is to be used as a predictive, adaptive management and verification tool*' to guide ongoing operations. This includes identifying any impact from the initial development and subsequent development stages.

In addition, numerical modelling should satisfy requirements of the NSW Aquifer Interference Policy. Under the policy, numerical modelling should be of sufficient scope and complexity to identify and assess potential impacts to groundwater, connected surface water systems, groundwater dependent ecosystems, and sites of cultural significance and water users. Criteria of minimal harm to receptors are assessed against three attributes: water table; water pressure; and water quality. The model should allow water use and induced losses from connected groundwater and surface water sources to be quantified for the purpose of wellfield licensing and ongoing water management.

Modelling objectives

Bearing in mind the above regulatory and operational requirements, the model should enable AGL to:

1. Simulate the main features of the basin water balance, groundwater systems and contributions to surface water systems.
2. Assess impacts to groundwater and connected surface water resources as a result of the coal seam depressurisation related to the proposed development. The model should allow assessment of:
    a) depressurisation of coal measures at depth
    b) changes to the water table
    c) changes to groundwater contributions to surface water flows
    d) changes to the basin-scale water balance and water fluxes to and from each water source (for licencing purposes).
3. Identify potential impacts to water users, dependent ecosystems and/or sites of cultural significance.
4. Assess the role of faults in transmitting changes in hydraulic pressure to the near surface groundwater systems, and their potential role in the migration of methane gas.
5. Provide an adaptive management tool in relation to groundwater impacts, for ongoing operations.
6. Assess cumulative impact of open cut coal mining in terms of the minimum harm considerations of the Aquifer Interference Policy.

Confidence level

The Australian Groundwater modelling guidelines recommends that the overall reliability, complexity and confidence level of the model(s) should be assessed and agreed prior to construction of the model, and if possible re-assessed at a later stage in the modelling project. The confidence level classification comprises three classes; Class 1, Class 2 and Class 3, in order of increasing confidence level. The level of confidence typically depends on the available data, calibration procedures, consistency between the calibration conditions and predictive analysis scenario, and the level or severity of stresses being simulated. A table of quantifiable indicators with which to assess a models confidence level based on those attributes is included in the Modelling Guidelines.

The confidence level classification is often constrained by the available data, budget and/or time. Typically in impact assessments for mining or CSG projects, the paucity of time series and spatial data for calibration compared with the proposed development timeframe is such that a Class 2 confidence level is the highest feasible. Class 1 models, in which data are not sufficient for calibration, are nonetheless often useful to provide initial assessments or to demonstrate processes and relationships based on the conceptual model and reasonable parameter estimates.

Comparison of available data and the modelling objectives indicates that a basin-scale model of the Gloucester Basin designed to assess regional impacts from CSG would fall into the Class 2 category. It should be noted that models that are designed to assess regional scale phenomena may not be appropriate for predicting more local scale effects. For this reason it may be necessary to employ additional, local scale models, to address some of the modelling objectives such as assessing the role of faulting within the Stage 1 GFDA.

7.2 Conceptual framework

Conceptualisation is a process that provides the basis for model design and communicates how the system works to a wide range of audiences (SKM, 2012a). A hydrogeological conceptual model is a descriptive representation of a groundwater system that incorporates an interpretation of the geological and hydrogeological conditions, and description of existing and possible future stresses.

An updated conceptual model for the Gloucester groundwater basin has been developed from several groundwater investigations, including high quality baseline hydrological and hydrogeological data, and is presented in Sections 3 to 6 of this report. The following subsections highlight key aspects of the conceptual framework and implications for numerical model development.

Model domain

The hydrogeological model domain should be large enough to cover the location of the key stresses on the groundwater system (both current and future) and the area influenced or impacted by those stresses. It should also be large enough to adequately capture the processes controlling groundwater behaviour in the study area (SKM, 2012a).

The Gloucester Basin has been conceptualised as an essentially closed groundwater system, bounded to the east and west by topographic divides and with outflows via surface water flows to the north (Avon River) and south (Wards River). In reality no system is entirely closed and in the case of the Gloucester Basin there are some surface water inputs and outputs to the basin from catchments that extend beyond the geological basin, and possibly some lateral groundwater flow (e.g. springs) from shallow rock domains that extend outside of the geological basin.

For the purposes of numerical modelling the outer outcrop limit of the impermeable Alum Mountain Volcanics is considered to be an appropriate model boundary, beyond which groundwater impacts are unlikely to propagate.

Hydrostratigraphy

Four broad hydrogeological units have been identified within the Gloucester Basin: the alluvial aquifers along major creek lines, shallow rock aquifers, and; a thick succession of low permeability coal measures comprising interbedded coal seams and interburden units of very low permeability. These hydrogeological units overlie the impermeable Alum Mountain Volcanics.

These hydrogeological units should be represented as separate layers within the numerical model. Multiple layers within the interburden and coal seam units will be required to represent the alternating sequence of low permeability coal seam water bearing zones, and very low permeability interburden units. The geometry of model layers representing geological units and coal seams should be based on all available geological information, including exploration drill hole data, available company geological models and seismic surveys. In particular, the model will need to have specific layers for those coal seams that are to be stressed by open cut coal mines to enable focussed cumulative impact assessment of other existing/approved projects. Coal plies associated with a particular seam can be lumped into a single model layer which honours the floor elevation rather than the roof.

Model layering should be assigned to allow realistic estimates of time delays associated with pressure changes across aquitards.

Throughout the Gloucester Basin there are numerous faults of various types and orientation which may have some local influence on groundwater flow. In addition there are likely to be structures outside of the immediate area of investigations that are either unknown or for which there is limited detailed information. It would therefore be impractical and erroneous to include only the known faults as individual elements in a regional scale model.

As foreshadowed above, a pragmatic approach would be to adopt one or more separate local-scale models to assess the role of known and mapped faults in depressurisation and groundwater flow. These separate models could be of more limited extent or be 2D cross sections. The results of the limited scale modelling would provide an indication as to whether individual faults should be included in the regional scale models or represented as part of the up-scaled parameterisation.

Aquifer properties

A summary of hydraulic property estimates for each hydrogeological unit is presented in this report. This information and other available estimates should be considered when assigning initial parameter estimates in the model. Hydraulic conductivity values presented in this report are considered representative based on literature review and field investigations across the Gloucester Basin. Two important attributes that should be taken into account in numerical modelling are:

- Field testing shows that each of the hydrogeological units has distinct hydraulic characteristics, but each is quite heterogeneous with a wide range in measured values. Therefore uncertainty in parameters should be taken into account and quantified with regard to any model predictions.
- There is a clear relationship of decreasing hydraulic conductivity with depth, typical of fractured rock terrains. This depth dependence should be represented in the numerical model.

Conceptual boundaries

The main conceptual boundaries relevant to numerical modelling are as follows:

1. The Gloucester Basin Groundwater system: The outer boundary of the groundwater systems relevant to the model is the base of the synclinal trough of the Permian Coal Measures. These coal measures are essentially enclosed and bounded by the impermeable Alum Mountain Volcanics within which groundwater flow is likely to be negligible (except within the shallow fractured rock).
2. Recharge boundaries: Recharge occurs via distributed rainfall recharge through the unsaturated zone, river recharge in losing sections of streams and during flood events, and groundwater movement from adjacent aquifers.
3. Rivers and streams are the main natural discharge features within the basin. However they can also act as recharge features depending on the river stage relative to the adjacent groundwater levels. These factors can vary both spatially and temporally across the basin.
4. Evapotranspiration from the shallow water table (<5 m bgl) is also likely to be a significant mechanism of groundwater discharge from the basin.

The numerical model boundary conditions should be consistent with the conceptual model boundaries and their controls on groundwater flow in the basin. It is noted that most numerical modelling codes have capabilities to effectively simulate these boundaries.

Stresses

The non-natural stresses on the groundwater system in the Gloucester Basin include the following:

1. Abstraction for stock and domestic use.
2. Mine pit inflows.
3. Dewatering as a result of CSG activities.

These stresses should be represented by appropriate boundary conditions in the numerical model. Possible candidate boundary conditions in MODFLOW include DRN, WEL and modified EVT. Mine pit inflows due to open cut mining and dewatering as a result of CSG activities will vary over time depending on the stage in development. Time varying boundary conditions should therefore be used in the numerical flow model.

Physical processes

Groundwater flow processes identified in the conceptual model should be accurately represented in the numerical model. These include the following:

- Recharge, evapotranspiration and groundwater discharge to (or recharge from) streams are fundamental processes in the basin water cycle and should be realistically represented in the numerical model. Boundary conditions have been developed in the MODFLOW family of codes to represent recharge (e.g. RCH), evapotranspiration (EVT) and stream interaction (DRN, STR, SFR and RIV packages).
- The equilibrium condition of the aquifer prior to development. On a regional scale and over long timescales, the groundwater system approaches a quasi-steady state. On smaller timescales (months) however, groundwater systems are constantly adjusting to seasonal variations and rainfall patterns – a condition referred to as a ‘dynamic equilibrium’. In order to ensure that the model can adequately simulate these natural variations, key model parameters should be calibrated in transient mode using baseline observations. The selection of a relative stable period that approximates equilibrium should be guided by a residual rainfall mass curve.
- Vertical hydraulic gradients. There is some evidence for vertical gradient components at some multi-piezometer sites. These data should be included in the calibration to simulate vertical gradients where they are significant.
- Groundwater density effects. Due to the generally low to moderate salinity of groundwater in the basin, density effects can be assumed to be insignificant in terms of regional groundwater flow and drawdown impact assessment.
- Dual phase effects are likely to be important, particularly in the vicinity of the production wells where methane is transported as a separate gas phase within groundwater, or may be the dominant phase over water.

7.3 Model design

The design stage of modelling involved describing how the modeller(s) intend to represent the conceptual model in a quantitative (mathematics-based) framework. SKM (2012a) outlines a number of well-established principles relating to model design and construction including model extent, structure, spatial and temporal discretisation and boundary conditions. The numerical model should be developed on the basis of those principles. Many of those design decisions will be made prior to the model construction phase, in light of the available data.

Model code

Of particular importance prior to embarking on model design is the choice of modelling code. Model code relates to the mathematical approach adopted in the software code for modelling. For example, common approaches are finite elements (FE), finite difference (FD), or finite volume (FV). A recently developed variant of MODFLOW (USG) allows the use of unstructured grids and uses a Control Volume Finite Difference approach (CVFD). Some codes are designed to simulate porous flow of a single phase (water), while others extend to multiple phases (water/gas/oil).

SKM (2012a) suggest that multi-phase effects may be important for modelling of CSG depressurisation, particularly in the vicinity of the gas field, and recommend the use of specialised petroleum reservoir software such as ECLIPSE. There is currently no consensus regarding the most appropriate code to use for predicting regional (far-field) groundwater drawdown impacts, although it is expected that single-phase models will tend to over-estimate depressurisation where two phase flow occurs (i.e. will be conservative with respect to impacts on water). A guideline report that specifically addresses modelling of impacts related to CSG is currently in preparation by the Commonwealth's Independent Expert Scientific Committee (IESC), but was not published at the time of writing this report.

For the purpose of modelling regional impacts on groundwater due to depressurisation of coal seams, it is considered that a single-phase saturated groundwater flow code will be suitable. All four numerical methods (FE, FD, FV and CVFD) would be capable of modelling the basin-scale groundwater flow and impacts. It is noted that the FD method and specifically MODFLOW Surfact is most commonly used by industry and the NSW Office of Water in groundwater impact and management assessments, although the CVFD approach is likely to gain wider acceptance.

User interface

There are many interfaces commercially available for groundwater modelling. These facilitate the preparation of data files for the modelling code. A GUI should be chosen that is relatively widely used and allows access to the relevant features of the modelling code.

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Appendix A

Part 3A Project Approval

Project Approval

Section 75J of the *Environmental Planning and Assessment Act 1979*

The Planning Assessment Commission of New South Wales (the Commission) having considered all relevant matters prescribed under Section 75I(2) of the *Environmental Planning and Assessment Act 1979* (the Act), grant project approval pursuant to Section 75J of the Act to the Proposal referred to in Schedule 1, subject to the conditions in Schedule 2.

These conditions are required to:

- prevent, minimise, and/or offset adverse environmental impacts;
- set standards and performance measures for acceptable environmental performance;
- require regular monitoring and reporting; and
- provide for the ongoing environmental management of the project.

Member of the Commission **Member of the Commission**

Sydney 22 February 2011 File No: 10/02017

SCHEDULE 1

Application No:	08_0154
Proponent:	AGL Upstream Infrastructure Investments Pty Ltd and its successors and assigns.
Approval Authority:	Planning Assessment Commission.
Land:	Land required for the development of the proposal, otherwise referred to as the Site.
Proposal:	Stage 1 project comprising the pre-construction, construction, commissioning, operation, decommissioning and rehabilitation of the: • *Stage 1 Gas Field Development Area* - 110 gas wells and associated infrastructure including gas and water gathering lines, within an approximately 50 km^2 section of the overall 210 km^2 gas field development area, between the townships of Gloucester and just south of Stratford in the Gloucester local Government area; • *Central Processing Facility* - a facility for the compression and processing of the extracted gas, and associated

infrastructure (including extracted and treated water storage ponds, salt evaporation ponds, water treatment plant, options for treated water disposal (excluding groundwater re-injection) and an up to 15 megawatt gas-fired electricity generating facility) at one of two locations in the Gloucester Shire local Government area: site 1 (within the property owned by the Proponent known as the "Tiedeman" property) or site 7 (land currently owned by Gloucester Coal, adjacent to a rail loop which currently services the Stratford Colliery);

- *Gas Transmission Pipeline* - an approximately 95-100 kilometre length pipeline between the central processing facility and existing gas supply network at Hexham (located within an overall assessment corridor of 100 metres width), traversing the Gloucester Shire, Great Lakes Shire, Dungog Shire, Port Stephens, Maitland City and Newcastle City local Government areas;
- *Hexham Delivery Station* - a gas delivery station at Hexham to deliver the transported gas to the existing Newcastle-Sydney gas supply pipeline, in the Newcastle City local Government area; and
- associated ancillary infrastructure such as access roads, temporary construction facilities and construction personnel camps.

Major Project: The proposal was declared a Major Project under section 75B(1)(a) of the *Environmental Planning and Assessment Act 1979*, because it is development of a kind described in clauses 6 and 26A of Schedule 1 of *State Environmental Planning Policy (Major Development) 2005.*

KEY TO CONDITIONS

SCHEDULE 2

Act, the	*Environmental Planning and Assessment Act, 1979*
Conditions of Approval	The Minister's conditions of approval for the project.
Construction	All pre-operation activities associated with the project other than pre-construction and commissioning.
Councils	Gloucester Shire, Great Lakes Shire, Dungog Shire, Port Stephens, Maitland City and Newcastle City
DECCW	NSW Department Environment, Climate Change and Water
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities
Department, the	Department of Planning
Director-General, the	Director-General of the Department of Planning (or delegate).
Director-General's approval/ agreement or satisfaction	A written approval from the Director-General (or delegate).
DII	Industry and Investment NSW
Dust	Any solid material that may become suspended in air or deposited.
Environmental Assessment	*Gloucester Gas Project Environmental Assessment,* dated November 2009 and prepared by AECOM
HCRCMA	Hunter-Central Rivers Catchment Management Authority
NOW	NSW Office of Water
Operation	Operation comprises the following, however does not include commissioning activities: • for the Stage 1 Gas Field Development Area – when wells commence gas extraction; • for the Central Processing Facility - when gas commences to be processed at the facility; and • for the Pipeline and Hexham Delivery Station – when gas commences to be transported via the pipeline.
Publicly Available	Available for inspection by a member of the general public (for example available on an internet site or at a display centre).
Pre-construction	Activities including survey, acquisitions, fencing, investigative drilling or excavation, building/road dilapidation surveys or other activities determined by the Environmental Representative to have minimal environmental impact such as minor access roads, minor adjustments to services / utilities, or minor clearing (except where threatened species, populations or ecological communities would be affected).
Reasonable and Feasible	Consideration of best practice taking into account the benefit of proposed measures and their technological and associated operational application in the NSW and Australian context. **Feasible** relates to engineering considerations and what is practical to build. **Reasonable** relates to the application of judgement in arriving at a decision, taking into account: mitigation benefits, cost of mitigation versus benefits provided, community views and nature and extent of potential improvements.
RTA	NSW Roads and Traffic Authority
Site	Land required for the development of the project.
Statement of Commitments	Statement of Commitments contained in the Environmental Assessment
Submissions Report	*Gloucester Gas Project Submissions Report*, dated May 2010, and prepared by AECOM

1. ADMINISTRATIVE CONDITIONS

Terms of Approval

1.1 The Proponent shall carry out the project generally in accordance with the:
   a) Major Project Application 08_0154;
   b) *Gloucester Gas Project Environmental Assessment,* dated November 2009 and prepared by AECOM;
   c) *Gloucester Gas Project Submissions Report*, dated May 2010, and prepared by AECOM;
   d) *Gloucester Basin Stage 1 Gas Field Development Project Preliminary Groundwater Assessment and Initial Conceptual Hydrogeological Model,* dated July 2010, and prepared by SRK Consulting;
   e) additional information on offset site(s) and pre-construction surveys submitted to the Department by email on 10 August 2010 and 31 August 2010, respectively;
   f) draft management plans on acid sulphate soil and the threatened species *Grevillea Parviflora sub. Species parviflora*, submitted to the Department by email on 12 October 2010;
   g) the concept plan approval granted with respect to the Gloucester Gas Project (08_0154); and
   h) the conditions of this approval.

1.2 In the event of an inconsistency between:
   a) the conditions of this approval and any document listed from condition 1.1a) to 1.1f) inclusive, the conditions of this approval shall prevail to the extent of the inconsistency; and
   b) any document listed from condition 1.1a) to 1.1f) inclusive, the most recent document shall prevail to the extent of the inconsistency.

1.3 The Proponent shall comply with any reasonable requirement(s) of the Director-General arising from the Department's assessment of:
   a) any reports, plans or correspondence that are submitted in accordance with this approval; and
   b) the implementation of any actions or measures contained in these reports, plans or correspondence.

Limits of Approval

1.4 This project approval shall lapse five years after the date on which it is granted, unless the Proponent has demonstrated to the satisfaction of the Director-General prior to this time that orders have been placed for key plant/ elements essential and fundamental for the development of at least two project components (gas extraction, central processing facility, pipeline and/or Hexham Delivery Station).

1.5 To avoid any doubt, this approval only allows for the development of a single central processing facility at either site 1 or site 7.

1.6 To avoid any doubt, this approval does not authorise the following activities or works unless the subject of additional assessment and approval as part of a modification application under section 75W of the Act:
   a) construction or operation of a transmission line connection between the central processing facility (15 megawatt gas-fired electricity generating facility) and existing electricity grid; and
   b) direct re-injection of groundwater produced during gas well development, back into groundwater aquifers as a water disposal option.

Statutory Requirements

1.7 The Proponent shall ensure that all necessary licences, permits and approvals required for the development of the project are obtained and maintained as required throughout the life of the project. No condition of this approval removes the obligation for the Proponent to obtain, renew or comply with such necessary licences, permits or approvals.

1.8 The Proponent may elect to construct the project in discrete work packages or stages. Where that occurs, these conditions of approval need only be complied with to the extent that they are relevant to that discrete work package or stage.

2. PROJECT DESIGN REQUIREMENTS

2.1 The Proponent shall in consultation with DII and NOW ensure that gas wells within the Stage 1 Gas Field Development Area are located consistent with the locational principles identified in Statement of Commitment 3 (concept area) of the Environmental Assessment, with consideration to flood prone land and with consideration to minimising the risk of groundwater impacts consistent with the requirements of condition 3.10. Prior to the commencement of construction of the Stage 1 Gas Field Development Area, the Proponent shall submit to DII location sheets identifying the final location of wells including associated infrastructure such as gas/water gathering lines and access roads. Where gas development is phased, the Proponent shall submit the above information (with appropriate updates) to DII prior to the commencement of each phase.

Nothing in this condition precludes the Proponent from submitting the above required information as part of the Field Development Plan referred to in condition 3.10.

2.2 The Proponent shall finalise the route alignment of the gas transmission pipeline within the 100 metre assessment corridor identified in the Environmental Assessment, in consultation with affected landowners, with the aim of maximising the length of route within existing disturbed areas (including existing infrastructure easements) and minimising conflict with private properties and landuse. Where the route is proposed to traverse existing infrastructure easements, the Proponent shall ensure that the pipeline route is located in consultation with the owners of existing infrastructure within the easement with the aim of minimising conflict with the ongoing operation and future upgrade/ maintenance requirements of that infrastructure. Prior to the commencement of construction of the gas transmission pipeline, the Proponent shall submit to the Department route alignment sheets identifying the final location of the pipeline.

2.3 The Proponent shall ensure that the final design of the gas transmission pipeline makes provisions for all reasonable requirements of the Mine Subsidence Board, where the gas pipeline route traverses a Mine Subsidence District.

2.4 The Proponent shall ensure that engineering measures are incorporated into the design of the central processing facility so that the associated flare plant is shielded (visually and in relation to noise emissions) from nearest sensitive receptors, as far as reasonable and feasible. The Proponent shall also ensure that gas wells are designed so as to ensure that associated flaring is visually shielded from nearest sensitive receptors as far as reasonable and feasible. The Proponent shall submit details of engineering measures incorporated into the design of the flare plant and gas wells for the approval of the Director-General, prior to the commencement of construction.

3. SPECIFIC ENVIRONMENTAL CONDITIONS

Surface Water Quality

3.1 Except as may be expressly provided by an Environment Protection Licence for the project, the Proponent shall comply with section 120 of the *Protection of the Environment Operations Act 1997* which prohibits the pollution of waters.

3.2 Soil and water management measures consistent with Landcom's *Managing Urban Stormwater: Soils and Conservation* shall be employed during the construction of the project for erosion and sediment control.

Watercourse Crossings

3.3 All pipeline crossings of the Karuah River, Williams River, Hunter River, Deadmans Creek and any wetlands listed under *State Environmental Planning Policy No 14 – Coastal Wetlands* shall be undertaken using horizontal directional drilling techniques.

3.4 Unless otherwise agreed to by the Director-General, the Proponent shall ensure that any disturbance to watercourses and/or associated riparian vegetation is rehabilitated to a standard equal to or better than the existing condition in consultation with the NOW, HCRCMA and DII (Fisheries). Measures to facilitate the long-term rehabilitation of the site (including land stabilisation and re-vegetation) shall be implemented within six months of the cessation of construction activities at the relevant area.

Unless otherwise agreed to by the Director-General, the Proponent shall monitor and maintain the condition of the rehabilitated area until such time that the area (including re-vegetated areas) has been verified by an independent and suitably qualified expert (whose appointment has been agreed to by the Director-General) as being well established, in good health and self sustaining and rehabilitated to the standard required by this condition.

Groundwater Management

3.5 The Proponent shall implement all reasonable and feasible measures to ensure that gas wells are constructed, operated and decommissioned to avoid and minimise gas migration risks and adverse impacts to beneficial aquifers including associated groundwater users, surface waters and groundwater dependent ecosystems.

3.6 Unless otherwise agreed to by the Director-General, prior to the commencement of construction of the Stage 1 Gas Field Development Area, the Proponent shall identify and plug with cement any abandoned or old exploration wells located within a 500 metre radius of finalised gas well locations to minimise the risk of gas migration via these wells.

3.7 The Proponent shall ensure that no fraccing fluids containing Benzene, Toluene, Ethylbenzene and Xylene (BTEX) chemicals are used in gas field development.

Baseline Monitoring and Updated Hydrogeological Model

3.8 Prior to the commencement of construction the project, the Proponent shall in consultation with NOW update the conceptual hydrogeological model developed during the assessment stage of the project (referred to in the document listed in condition 1.1d) based on baseline data gathered from (but not necessarily limited to), the pre-construction investigations identified below:

a) seismic surveys of the site to identify geological features of risk;
b) preliminary field sampling of hydraulic conductivity, groundwater levels, groundwater quality and surface water quality based on a packer, pump and slug testing program and surface water sampling; and
c) long-term baseline monitoring (i.e. at least six months) at groundwater and surface water locations determined in consultation with NOW, to ensure representative baseline data on pre-construction conditions (including seasonal variability) in relation to the shallow rock and alluvial beneficial aquifers, deeper coal seam water bearing zones, groundwater users and surface waters.

3.9 The updated conceptual hydrogeological model referred to in condition 3.8 shall be submitted for the Director-General's approval, prior to the commencement of construction and shall include:

a) updated assessment of the potential for drawdown and displacement of shallow rock and alluvial beneficial aquifers, considering impacts to nearby registered bore users, based on detailed baseline data gathered from condition 3.8 a) to c);
b) optimal areas for gas well location within the Stage 1 Gas Field Development Area based on minimising the risk of gas migration and of interaction with beneficial aquifers and the outcomes of the updated assessment;

c) recommendations for phased gas well development including indentifying the maximum number of gas wells that would be developed during the first phase of development and associated operational groundwater monitoring strategy consistent with the requirements of condition 4.1; and

d) include an independent peer review by an appropriately experienced and qualified hydrogeologist (who is approved by the Director-General for the purposes of this condition) on the robustness and technical veracity of the model.

In submitting the updated conceptual hydrogeological model for the Director-General's approval, the Proponent shall provide written evidence of consultation with NOW on the robustness and technical veracity of the model (including well location areas and phasing program) identifying the issues raised by NOW and how these have been addressed by the Proponent.

Field Development Plan Implementation during Operation

3.10 Unless otherwise agreed to by the Director-General, the Proponent shall ensure that gas wells within the Stage 1 Gas Field Development Area are developed in a phased manner to avoid and minimise adverse impacts to beneficial aquifers consistent with the requirements of condition 3.5. Prior to the commencement of construction of the Stage 1 Gas Field Development Area, the Proponent shall in consultation with NOW develop and submit to the Director-General a **Field Development Plan**, which includes a phasing program for the development of gas wells and details of the final location of gas wells and associated infrastructure such as gas/water gathering lines and access roads for at least the first phase of gas well development identified in the Field Development Plan. As gas field development progresses, the Proponent shall in consultation with NOW update the Field Development Plan with phasing and location details of gas wells and associated infrastructure for subsequent phases, and submit the plan to the Director-General prior to the commencement of each phase.

The first phase of gas well development within the Field Development Plan shall be as per the requirements of condition 3.9c). All subsequent phases of gas field development shall be consistent with the outcomes of the groundwater monitoring program and associated numerical hydro-geological model implemented in accordance with conditions 4.1 and 4.2, demonstrating satisfactory management of groundwater risks consistent with the requirements of condition 3.5, to the satisfaction of the Director-General in consultation with NOW. Subsequent phases shall be undertaken in accordance with any requirements of the Director-General (in consultation with NOW) following its review of groundwater monitoring results in accordance with conditions 4.1 and 4.2.

Rate of Groundwater Extraction

3.11 Prior to the commencement of any groundwater extraction associated with the project, the Proponent shall ensure that all relevant Water Licence(s) have been obtained from NOW for groundwater extraction at the volumetric rate of two mega litres per day (averaged over a 12 month period). Except as may be expressly provided by a Water Licence for the project, the Proponent shall ensure that the volumetric rate of groundwater extraction for the project is no greater than two mega litres per day (averaged over a 12 month period).

Extracted Water Management

3.12 Unless otherwise agreed to by the Director-General, prior to the commencement of construction of the project, the Proponent shall develop an **Extracted Water Management Strategy** in consultation with DII, NOW, HCRCMA, DECCW and relevant Councils and to the satisfaction of the Director-General, which:

a) identifies the final suite of water disposal and re-use option(s) that would be implemented to manage groundwater extracted from the gas production wells;

b) identifies the water quality required to achieve the disposal/ re-use option(s) identified in a) above including the procedure for monitoring of treated water to ensure that required water quality criteria are achieved;

c) if discharge to surface waters is proposed – identifies details of all practical measures investigated to prevent, control, abate or mitigate that discharge; details of the receiving environment including water quality and flow conditions; proposed discharge rate and frequency; and details of all practical measures investigated to protect the environment from harm as a result of that discharge including demonstration that any discharge would satisfy the requirements of condition 3.1;

d) if re-use for irrigation is proposed – demonstrates that there is demand for the volumes of water to be generated, details of all practical measures investigated to protect the environment from harm including details of optimal application rates to prevent over-irrigation and associated salinity issues or groundwater contamination, and demonstration that any discharge would satisfy the requirements of condition 3.1;

e) if extracted water is proposed to be made available to the market – demonstrates that suitable buyers of the water have been secured and where the water is proposed to supplement drinking water supplies, demonstration that the water quality is suitable for drinking water supplies;

f) identifies the final option for the management of the salt volumes produced from the extracted water treatment process;

g) includes a contingency strategy for the management of extracted water should the volumetric rate of groundwater extraction be greater than two mega litres per day (consistent with the requirements of condition 3.11), including analysis of associated risks to groundwater users and/ or surface waters and groundwater dependent ecosystems-

h) provides an assessment of the need for control measures to be implemented at the extracted water and brine evaporation ponds to minimise wildlife (including bird) access to these ponds, with consideration to the water quality and associated risks to wildlife likely to be posed by these storage ponds; and

i) provide for the development of site specific water quality criteria in accordance with the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC 2000 Guidelines), as necessary, in consultation with DECCW, for the purposes of conditions b), c), d) and e) above.

3.13 The Proponent shall ensure that any water storage ponds developed at the central processing facility or on the Tiedeman property as part of the project (including extracted water, treated water and brine evaporation ponds) are appropriately lined to ensure no leaching of stored waters and designed consistent with a 1 in 100 year flood design standard.

Noise Impacts

Construction Hours

3.14 With the exception of construction of the pipeline, the Proponent shall only undertake construction activities associated with the project that would generate an audible noise at any sensitive receptor during the following hours:

a) 7:00 am to 6:00 pm, Mondays to Fridays, inclusive;

b) 8:00 am to 1:00 pm on Saturdays; and

c) at no time on Sundays or public holidays.

This condition does not apply in the event of a direction from police or other relevant authority for safety reasons or emergency work to avoid the loss of lives, property and/or to prevent environmental harm.

Construction works associated with the gas pipeline that would generate audible noise at any sensitive receptor shall only be undertaken during the following hours: 7.00 am to 6.00 pm Monday to Saturday and 8.00 am to 6.00 pm Sundays or public holidays for a maximum period of 28 days at a time, separated by a minimum respite period of nine days.

3.15 Blasting associated with the construction of the project shall only be undertaken during the following hours:

a) 9:00 am to 5:00 pm, Mondays to Fridays, inclusive;

b) 9:00 am to 1:00 pm on Saturdays; and
c) at no time on Sundays or public holidays.

3.16 The hours of construction activities specified under conditions 3.14 and 3.15 of this approval may be varied with the prior written approval of the Director-General. Any request to alter the hours of construction specified under condition 3.14 and 3.15 shall be:

a) considered on a case-by-case basis;
b) accompanied by details of the nature and need for activities to be conducted during the varied construction hours including alternatives considered;
c) accompanied by details of the likely noise levels at nearest sensitive receptors with and without mitigation;
d) accompanied by details of all reasonable and feasible measures identified to minimise noise impact at nearest sensitive receptors;
e) accompanied by details of consultation and notification undertaken with surrounding receptors (including, in respect to proposed gas drilling works on a 24 hour basis – written agreement from affected landowners, where relevant construction noise goals are not expected to be achieved); and
f) accompanied by written evidence demonstrating consultation with the DECCW in relation to the proposed variation in construction times (including consideration of any comments made by the DECCW).

Construction Noise

3.17 The Proponent shall implement all reasonable and feasible measures to minimise noise generation from the construction of the project consistent with the requirements of the *Interim Construction Noise Guideline* (DECC, July 2009) including noise generated by heavy vehicle haulage and other construction traffic associated with the project.

Construction Blasting

3.18 The Proponent shall ensure that air blast overpressure generated by blasting associated with the project does not exceed the criteria specified in Table 1 when measured at the most-affected residential or sensitive receiver.

Table 1 – Airblast Overpressure Criteria

Air blast Overpressure (dB(Lin Peak))	Allowable Exceedance
115	5% of total number of blasts over a 12 month period
120	Never

3.19 The Proponent shall ensure that the ground vibration generated by blasting associated with the project does not exceed the criteria specified in Table 2 when measured at the most-affected residential or sensitive receiver.

Table 2 – Peak Particle Velocity Criteria

Peak Particle Velocity Criteria (mms^{-1})	Allowable Exceedance
5	5% of total number of blasts over a 12 month period
10	Never

3.20 Prior to each blasting event, the Proponent shall notify the relevant local council and potentially-affected landowners, including details of time and location of the blasting event and providing a contact point for inquiries and complaints.

Vibration Impacts

3.21 The Proponent shall ensure that the vibration resulting from construction and operation of the project does not exceed the preferred values vibration (for low probability of adverse comment) presented in *Assessing Vibration: A Technical Guideline* (DECC, February 2006), at any surrounding sensitive receptor.

Operational Noise

3.22 The Proponent shall design, construct, operate and maintain the project to ensure that the noise contributions from the project do not lead to an exceedence of the noise limits specified in Table 3 (at the locations and during the periods indicated) for the operation of the project unless subject to a negotiated noise agreement established consistent with Section 8.3 of the *New South Wales Industrial Noise Policy* (EPA, 2000). The noise limits apply under wind speeds up to 3 ms^{-1} (measured at 10 metres above ground level), or under temperature inversion conditions of up to 3 ºC/ 100 metres and wind speeds of up to 2m/s at 10 metres above the ground.

This condition only applies to the project operating under normal operating conditions and does not apply to:

a) start-up, shut-down or emergency situations (emergency situations being defined as situations where there is the potential for the loss of lives, property and/ or environmental harm); or

b) the re-drilling and/ or re-fraccing activities of previously operational wells or gas well maintenance activities, which are specifically agreed to by the Director-General in writing, on a case by case basis, and which are undertaken in accordance with an approved noise management protocol prepared in accordance with the requirements of condition 7.4e)(iii).

Table 3 - Operational Noise Limits

Project Component	Location	Project Specific Noise Limit (all time periods)	
		dB(A) $L_{Aeq(15\ minute)}$	dB(A) $L_{A1\ (1\ minute)}$
Gas Wells	Nearest Sensitive Receptor	35	45
Central Processing Facility (Site 1)	P7	36	46
	P8	36	46
	P9	35	45
	P10	36	46
	P11	36	46
	P12	36	46
	P13	36	46
Central Processing Facility (Site 7)	P1	36	46
	P2	42	52
	P3	37	47
	P4	35	45
	P5	35	45
	P6	35	45
Hexham Delivery Station	P15	45	55
	P16	43	53
	P17	43	53

3.23 For the purpose of assessment of noise contributions specified under condition 3.22 of this approval, noise from the project shall be:

a) measured at the most affected point within the residential boundary or at the most affected point within 30 metres of the dwelling where the dwelling is more than 30 metres from the boundary to determine compliance with the $L_{Aeq(15\ minute)}$ noise limits;

b) measured at 1 metre from the dwelling façade to determine compliance with the $L_{A1\ (1\ minute)}$ noise limits; and

c) subject to the modification factors provided in Section 4 of the *New South Wales Industrial Noise Policy* (EPA, 2000).

Notwithstanding the above, should direct measurement of noise from the project be impractical, the Proponent may employ an alternative noise assessment method deemed acceptable by the DECCW (refer to Section 11 of the *New South Wales Industrial Noise Policy* (EPA, 2000)). Details of such an alternative noise assessment method accepted by the DECCW shall be submitted to the Director-General prior to the implementation of the assessment method.

Detailed Design Noise Report

3.24 Unless otherwise agreed to by the Director-General, at least 3 months prior to the commencement of construction of the central processing facility and Hexham Delivery Station, the Proponent shall in consultation with DECCW prepare and submit a **Detailed Design Noise Report** for the Director-General's approval to confirm the predicted noise levels associated with the central processing facility and Hexham Delivery Station considering all reasonable and feasible at-source control measures (based on detailed design) at the sensitive receptors identified in Table 3.

Acquisition Rights

3.25 Unless otherwise agreed to by the Director-General, where the **Detailed Design Noise Report** required to be prepared under condition 3.24 predicts exceedences of greater than 5 dB(A) of project specific noise limits at any sensitive receptor identified in Table 3 for either the operation of the central processing facility or the operation of the Hexham Delivery Station, the relevant receptors shall be subject to acquisition rights in accordance with condition 3.26 unless a negotiated agreement is in place with respect to that receptor in accordance with condition 3.22. The Proponent shall ensure that any receptor subject to acquisition rights is notified of his/her rights as outlined in condition 3.26 within one month of the Department's approval of the Detailed Design Noise Report.

3.26 Within three months of receiving a written request from a landowner with acquisition rights under condition 3.25 of this approval, the Proponent shall make a binding written offer to the landowner based on:

a) the market value of the landowner's interest in the property at the date of this written request, as if the property was unaffected by the project:
b) the reasonable costs associated with;
    i) property relocation;
    ii) obtaining legal advice and expert advice for determining the acquisition price of the land, and the terms upon which it is acquired; and
c) reasonable compensation for any disturbance caused by the land acquisition process.

However, if at the end of this period, the Proponent and landowner cannot agree on the acquisition price of the land, and/or the terms upon which the land is to be acquired, then either party may refer the matter to the Director-General for resolution.

Upon receiving such a request, the Director-General shall request the President of the NSW Division of the Australian Property Institute to appoint a qualified independent valuer or Fellow of the Institute, to:

a) consider submissions from both parties;
b) determine a fair and reasonable acquisition price for the land, and/or terms upon which the land is to be acquired having regard to the matters in a), b) and c) above; and
c) prepare a detailed report setting out the reasons for any determination and provide a copy of the report to both parties.

Within 14 days of receiving the independent valuer's determination, the Proponent shall make a written offer to purchase the land at a price not less than the independent valuer's determination.

If the landowner refuses to accept the Proponent's binding written offer within six months of the date of the Proponent's offer, the Proponent's obligations to acquire the land shall cease, unless the Director-General determines otherwise.

The Proponent shall bear the reasonable costs of any valuation or survey assessment requested by the independent valuer or the Director-General and the reasonable costs of determination referred to above.

Any receptor, for which acquisition rights have ceased in accordance with the requirement of this condition, would nevertheless be eligible to receive at-receptor acoustic treatments in accordance with condition 3.27.

At-Receptor Acoustic Treatment

3.27 Unless otherwise agreed to by the Director-General, where the **Detailed Design Noise Report** required to be prepared under condition 3.24, predicts exceedences of project specific noise criteria of no greater than 5 dB(A) at any sensitive receptor identified in Table 3 for either the operational of the central processing facility or the operational of the Hexham Delivery Station, the relevant receptors shall be eligible to receive at-receptor acoustic treatments, at the Proponent's expense, to minimise noise impacts at the receptors as far as reasonable and feasible, unless operational noise monitoring undertaken in accordance with condition 4.3 confirms that project specific noise limits would be achieved at these receptors. All receptors eligible for at-receptor mitigation measures in accordance with the requirements of this condition shall be informed of their rights following the confirmation of noise levels at these receptors as part of the Noise Verification Report required to be prepared under condition 4.3, within one month of the Director-General's approval of that Noise Verification Report.

Air Quality Impacts

Dust Generation

3.28 The Proponent shall employ all reasonable and feasible measures (including temporary cessation of relevant works, as appropriate) to ensure that the project is constructed in a manner that minimises dust emissions from the site, including wind-blown and traffic-generated dust. All activities on the site shall be undertaken with the objective of preventing visible emissions of dust from the site, as far as practicable.

Odour

3.29 The Proponent shall not permit any offensive odour, as defined under section 129 of the *Protection of the Environment Operations Act 1997*, to be emitted from the site which impacts on any sensitive surrounding receptor.

Monitoring and Discharge Points

3.30 For the purposes of this approval, air monitoring/ air discharge points shall be identified as provided in Table 4 below.

Table 4 - Identification of Air Monitoring and Discharge Points

Monitoring / Discharge Point Identifier	Monitoring/ Discharge Point Location
1	Water Bath Heater, Hexham Delivery Station
2	Internal Combustion Engine, Power Generation Facility, Central Processing Facility
3	Reciprocating Multistage Compressor, Gas Compression Plant, Central Processing Facility
4	Alternator, Central Processing Facility
5	Triethylene Glycol Regeneration Skid, Central Processing Facility
6	Triethylene Glycol Boiler, Central Processing Facility

Discharge Limits

3.31 The Proponent shall design, construct, operate and maintain the project to ensure that for each discharge point, identified in condition 3.30, the concentration of each pollutant listed in Table 5 is not exceeded during the operation of the project. This condition only applies to the project operating under normal operating conditions and does not apply during start-up, shut-down or emergency situations.

Table 5 - Maximum Allowable Discharge Concentration Limits (Air)

Discharge Point	Pollutant	Units of Measure	100 Percentile limit (mgm^{-3})	Averaging Period	Reference conditions
1	Oxides of Nitrogen	mg/m^3	350	1 hour	dry, 273 K, 101.3 kPa, and 3% O_2
	Volatile Organic compounds or carbon monoxide	mg/m^3	40 (VOCs or 125 (CO)	Rolling 1-hour	dry, 273 K, 101.3 kPa, and 3% O_2
2	Oxides of Nitrogen	mg/m^3	450	1 hour	dry, 273 K, 101.3 kPa, and 3% O_2
	Formaldehyde	mg/m^3	6	1 hour	dry, 273 K, 101.3 kPa, and 3% O_2
	Volatile Organic compounds or carbon monoxide	mg/m^3	40 (VOCs or 125 (CO)	Rolling 1-hour	dry, 273 K, 101.3 kPa, and 3% O_2
3	Oxides of Nitrogen	mg/m^3	250	1 hour	dry, 273 K, 101.3 kPa, and 13% O_2
	Formaldehyde	mg/m^3	10	1 hour	dry, 273 K, 101.3 kPa, and 13% O_2
	Volatile Organic compounds or carbon monoxide	mg/m^3	40 (VOCs or 125 (CO)	Rolling 1-hour	dry, 273 K, 101.3 kPa, and 13% O_2
4	Oxides of Nitrogen	mg/m^3	60	1 hour	dry, 273 K, 101.3 kPa, and 13% O_2
	Formaldehyde	mg/m^3	10	1 hour	dry, 273 K, 101.3 kPa, and 13% O_2
	Volatile Organic compounds or carbon monoxide	mg/m^3	40 (VOCs or 125 (CO)	Rolling 1-hour	dry, 273 K, 101.3 kPa, and 13% O_2
5	Oxides of Nitrogen	mg/m^3	35	1 hour	dry, 273 K, 101.3 kPa, and 3% O_2
	Formaldehyde	mg/m^3	5	Rolling 1-hour	dry, 273 K, 101.3 kPa, and 3% O_2
6	Oxides of Nitrogen	mg/m^3	60	1 hour	dry, 273 K, 101.3 kPa, and 3% O_2
	Formaldehyde	mg/m^3	5	Rolling 1-hour	dry, 273 K, 101.3 kPa, and 3% O_2

Gas Flare Management

3.32 In relation to gas wells under flare during the commissioning of the Stage 1 Gas Field Development Area, the Proponent shall ensure that a separation distance of at least 500 metres is maintained for flaring wells positioned in a straight line (maximum of five wells simultaneously flaring) and 800 metres for flaring wells positioned in a triangular grid (maximum of four wells simultaneously flaring). If additional wells are to be flared simultaneously a four kilometre separation distance shall be maintained between flaring well clusters.

3.33 The Proponent shall ensure that records of gas venting from the central processing facility, either through flare or directly to the atmosphere shall be recorded and reported to the Director-General and DECCW on an annual basis.

Biodiversity Offset

3.34 Unless otherwise agreed to by the Director-General, prior to the commencement of construction of the project, the Proponent shall in consultation with DECCW and DSEWPaC finalise and secure in perpetuity (through appropriate legal mechanisms), a compensatory habitat package, which offsets the biodiversity impacts of the project as specified below to the satisfaction of the Director-General. Unless otherwise agreed to by the Director-General, the package shall be finalised following:

a) targeted surveys of the gas transmission pipeline corridor to confirm the project's impacts on the following listed flora species, based on survey methodology determined in consultation with DECCW: *Asperula conferta* (Trailing Woodruff), *Galium australe* (Tangled Bedstraw), *Callistemon linearifolius* (Nettled Bottle Brush), *Cryptostylis hunteriana* (Leafless Tongue Orchid), *Cynanchum elegans* (White-flaxed Wax Plant), *Grevillea Parviflora sub. Species parviflora* (Small-flower Grevillea), *Persicaria elatior* (Tall Knotweed), *Pomaderris queenslandica* (Scant Pomaderris), *Rhizanthella slateri* (Eastern Australian Underground Orchid) and *Tetratheca juncea* (Black-eyed Susan);
b) survey of the offset site identified in the documents listed under condition 1.1e) in consultation with DECCW and consistent with DECCW's Biobanking Methodology to confirm the ecological values of the site(s);
c) based on b) above, demonstration that the offset site referred to in b) above, provides suitable offset (consistent with the principles of "maintain or improve") for the biodiversity impacts of the project on:
    i) *Grevillea Parviflora sub. Species parviflora*, any additional listed flora species identified to be impacted by the gas transmission pipeline corridor based on a) above, and the habitat of any listed flora species identified to have a medium to high potential of occurring within the remaining disturbance footprint of the project;
    ii) habitat of the Grey-crowned Babbler species and any other fauna species identified to have a medium to high potential of occurring within the disturbance footprint of the project;
    iii) the Hunter Lowland Redgum Forest in the Sydney Basin and New South Wales North Coast Bioregions endangered ecological community; and
    iv) important native vegetation and habitat values within the disturbance footprint of the project;
d) where the offset site referred to in b) above does not provide all required offset values as identified in c) above, the identification of additional offset measures and / or sites in consultation with DECCW and DSEWPaC, to address residual offset requirements including survey of additional offset sites in accordance with b) above, where required; and
e) finalisation of the management measures required to maintain the biodiversity values of each offset option identified, in perpetuity in consultation with DECCW and DSEWPaC.

In submitting the compensatory habitat package for the Director-General's approval, the Proponent shall clearly detail the consultation undertaken with DECCW and DSEWPaC, including opportunity provided to review draft versions of the package (should this be required by the agencies) and identification of the issues raised by the agencies and how these have been addressed in the package.

Heritage Impacts

3.35 If during the course of construction the Proponent becomes aware of any previously unidentified Aboriginal object(s), all work likely to affect the object(s) shall cease immediately and the objects managed in accordance with the requirements of condition 7.2g)iv), in consultation with registered Aboriginal stakeholders.

3.36 The Proponent shall ensure that the Stage 1 Gas Field Development Area is developed such as to avoid impacts to AHIMS 38-1-0008 and AHIMS 38-1-0031.

3.37 The Proponent shall ensure that pipeline construction in the vicinity of AHIMS 28-1-0006 and AHIMS 38-4-0010 is restricted to the existing disturbed road alignment to ensure no disturbance or interference with these sites. The Proponent shall ensure that a qualified archaeologist and relevant Aboriginal stakeholders are on site at all times during construction works in the vicinity of these sites to monitor the construction works and ensure that appropriate buffer distances are maintained to these sites to avoid disturbance.

3.38 Should the Central Processing Facility or any temporary construction facilities be located within Site 1, the Proponent shall prior to the commencement of construction provide opportunity for representatives from the Forster Local Aboriginal Land Council to survey the site, re-locate and salvage the three isolated finds that have been previously identified on site (but which were unable to be relocated during studies undertaken as part of the Environmental Assessment).

3.39 If during the course of construction the Proponent becomes aware of any unexpected historical relic(s), all work likely to affect the relic(s) shall cease immediately in the vicinity of the relics and the Heritage Office notified in accordance with the *Heritage Act 1977*. Works shall not recommence until the Proponent receives written authorisation from the Heritage Office.

Visual Amenity Impacts

3.40 The Proponent shall minimise the use of reflective building elements and maximise the use of building materials and treatments which visually complement the surrounding landuse.

3.41 The Proponent shall ensure that all external lighting associated with the project is mounted, screened, and directed in such a manner so as not to create a nuisance to the surrounding environment, properties and roadway. The lighting shall be the minimum level of illumination necessary and shall comply with *AS 4282(INT) 1997 – Control of Obtrusive Effects of Outdoor Lighting.*

3.42 Unless otherwise agreed to by the Director-General, within six months of the completion of the construction of the central processing facility, the Proponent shall implement all reasonable and feasible landscaping measures within the central processing facility site to screen views of this facility from nearest sensitive receptors. The Proponent shall monitor and maintain the health of these landscape plantings for the life of the central processing facility, including replacing of any plantings which fail.

Traffic, Transport and Access Impacts

3.43 The Proponent shall ensure that any disturbance to public roads associated with the pipeline crossing or any road upgrades to accommodate the construction or operational traffic associated with the project is designed and constructed in consultation with and to meet the reasonable requirements of the relevant road authority (relevant Council or the RTA), to the satisfaction of the Director-General.

3.44 Prior to the commencement of construction of the project, the Proponent shall commission a suitably qualified expert to assess the condition of all public roads proposed to be traversed by construction traffic associated with the project (including over-mass or over-dimensional vehicles) in consultation with relevant Councils and the RTA, and identify any upgrade requirements to accommodate project traffic for the duration of construction (including culvert, bridge and drainage design; intersection treatments; vehicle turning requirements; and site access) considering final traffic volumes. The road dilapidation report shall be submitted to the Director-General prior to the commencement of construction clearly identifying recommendations made by the Council and the RTA and how these have been addressed. The Proponent shall ensure that all upgrade measures identified in the report are implemented to meet the reasonable requirements of the relevant Council and the RTA, prior to the commencement of construction, to the satisfaction of the Director-General.

3.45 Prior to the commencement of operation of the project, the Proponent shall commission a suitably qualified expert to assess the condition of all public roads traversed by construction traffic associated with the project (including over-mass or over-dimensional vehicles) in consultation with Council and the RTA. Should the pre-operational dilapidation survey report identify any damage to roads attributable to construction traffic associated with the project, the Proponent shall repair the roads consistent with the recommendations of the pre-operational dilapidation survey report, within such time as agreed to with the relevant Council and the RTA and to meet the reasonable requirements of the relevant Council and the RTA. The pre-operation road dilapidation report shall be submitted to the Director-General prior to the commencement of operation, clearly identifying recommendations made by relevant Councils and the RTA and how these have been addressed, to the satisfaction of the Director-General.

Hazards and Risk

Technical Controls

3.46 The design, operation and technical controls for the well heads shall be consistent with the requirements of the Department's Guideline – *'Development in the Vicinity of Operating Coal Seam Methane Wells'.*

Pre-Construction

3.47 The Proponent shall prepare and submit the following studies to the Director-General no later than one month prior to the commencement of construction of the project, or within such further period as the Director-General may agree. Construction, other than of works that are outside the scope of the hazard studies, shall not commence until study recommendations have been considered and, where appropriate, acted upon. The Proponent shall submit:

a) a **Fire Safety Study** covering the relevant aspects of the Department's *'Hazardous Industry Planning Advisory Paper No. 2, 'Fire Safety Study Guidelines'*. The study shall meet the requirements of the NSW Fire Brigades. For the Central Processing Facility, the study shall also consider the New South Wales Government's *'Best Practice Guidelines for Contaminated Water Retention and Treatment Systems'*;

b) a **Hazard and Operability Study** for the Central Processing Facilities, including any abnormal operating modes such as flare and blowdown operations, chaired by a qualified person, independent of the project. The study shall be consistent with the Department of Planning's '*Hazardous Industry Planning Advisory Paper No. 8, 'HAZOP Guidelines*';

c) a **Final Hazard Analysis** consistent with the Department's Hazardous Industry Planning Advisory Paper No. 6, *'Guidelines for Hazard Analysis'*. The final design shall apply appropriate risk mitigation measures for the Export Sales Pipeline (ESP) in locations where the pipeline risk transects exceed the Department's risk criteria. Further, the final design shall consider all recommendations in Table A1.1 to A1.5 of the Preliminary Hazard Analysis presented in the Environmental Assessment; and

d) a **Construction Safety Study**, consistent with the Department's Hazardous Industry Planning Advisory Paper No. 7, *'Construction Safety Study Guidelines'*. The study should consider the bush fire risk during construction of the project.

Pre-commissioning

3.48 Prior to the commencement of commissioning, the Proponent shall develop and implement the plans and systems set out below. The Proponent shall submit to the Director-General documentation describing the plans and systems no later than two months prior to the commencement of commissioning of the project, or within such further period as the Director-General may agree:

a) a comprehensive **Emergency Response Plan** detailing emergency procedures for the Central Processing Facility. The plan shall include detailed procedures for the safety of all people outside of the project who may be at risk from the project. The plan shall be consistent with the Department's Hazardous Industry Planning Advisory Paper No. 1, *'Industry Emergency Planning Guidelines'*; and

b) a document setting out a comprehensive **Safety Management System** for the Central Processing Facility, covering all on-site operations. The document shall clearly specify all safety related procedures, responsibilities and policies, along with details of mechanisms for ensuring adherence to the procedures. The Safety Management System shall be consistent with the Department's Hazardous Industry Planning Advisory Paper No. 9, *'Safety Management'*.

Pre-Operation

3.49 At least one month prior to the commencement of operation of the project, the Proponent shall submit to the Director-General, a report detailing compliance with conditions 3.47 and 3.48, including:

a) dates of study/plan/system completion;
b) actions taken or proposed, to implement recommendations made in the studies/plans/systems; and
c) responses to each requirement imposed by the Director-General following its review of the studies/ reports.

Post Operation

3.50 Three months after the commencement of operation of the project, the Proponent shall submit to the Director General, a report verifying that:

a) the Emergency Response Plan required under condition 3.48a) is effectively in place and that at least one emergency exercise has been conducted; and
b) the Safety Management System required under condition 3.48b) has been fully implemented and that records required by the system are being kept.

Waste Generation and Management

3.51 The Proponent shall not cause, permit or allow any waste generated outside the site to be received at the site for storage, treatment, processing, reprocessing, or disposal on the site, except as expressly permitted by a licence under the *Protection of the Environment Operations Act 1997*, if such a licence is required in relation to that waste.

3.52 Except in the case of water or salt waste managed in accordance with condition 3.12, the Proponent shall maximise the reuse and/or recycling of waste materials generated on site as far as practicable, to minimise the need for treatment or disposal of those materials off site.

3.53 The Proponent shall ensure that all liquid and/or non-liquid waste generated on the site is assessed and classified in accordance with *Waste Classification Guidelines* (DECC, 2008), or any future guideline that may supersede that document and where removed from the site is only directed to a waste management facility lawfully permitted to accept the materials.

Temporary Construction Facilities

3.54 Prior to the commencement of construction of the Project, the Proponent shall prepare a **Temporary Construction Facilities Management Strategy** in consultation with DECCW and relevant Councils to the satisfaction for the Director-General detailing:

a) the final location of all temporary construction facilities including construction camps, demonstrating that the facilities have been located consistent with the location principles identified in Statement of Commitment 4 (project area) of the Environmental Assessment; within the assessed footprint of the project; and to ensure that the facilities would not result in any increased impacts (including biodiversity, heritage items and noise) as assessed in the Environmental Assessment and Submissions Report;
b) the scale and dimension of facilities including duration of establishment;
c) utility and service requirements (such as sewage, water supply and electricity) required to operate the facilities for the duration of construction including demonstration that all relevant approvals for these services and connections have been obtained;
d) management measures that would be implemented on site including behavioural protocols to ensure that the facilities do not pose a disturbance to surrounding receptors including noise, air quality, visual (and lighting), and traffic impacts;
e) protocols that would be put in place to control or avoid any unintended social impacts (such as anti-social behaviour), particularly from the construction camps; and
f) detailed decommissioning and rehabilitation requirements at the cessation of the construction period.

Rehabilitation

3.55 The Proponent shall ensure that all surface areas of the project footprint which are disturbed during the construction but which are not required for the ongoing operation of the project (including temporary construction facility sites, construction access roads, relevant areas of the pipeline construction corridor and buried gas and water gathering lines) are rehabilitated consistent with existing landuse in consultation with affected landowners, to a standard better than or equal to existing. In relation to areas which were vegetated prior to disturbance, this shall comprise a program of revegetation to a standard equal to or better than the existing condition (where this does not conflict with the ongoing operation of the gas transmission pipeline).

Measures to facilitate the long-term rehabilitation of applicable surface areas (including land stabilisation and re-vegetation measures) shall be implemented within six months of the cessation of construction activities, at the relevant area unless an alternative timeframe is agreed to with the landowners. Unless otherwise agreed to by the Director-General, the Proponent shall monitor and maintain the condition of the rehabilitated areas until such time that the areas (including re-vegetated areas) have been verified by an independent and suitably qualified expert (whose appointment has been agreed to by the Director-General) as being well established, in good health and self sustaining and rehabilitated to the standard required by this condition.

3.56 The Proponent shall ensure that all gas wells are decommissioned and rehabilitated at the cessation of operation in accordance with the requirements of and to the satisfaction of DII. Unless otherwise agreed to by DII, the Proponent shall ensure that the decommissioning and rehabilitation of gas wells are independently verified within three-months of the decommissioning of the well, to the satisfaction of DII.

4. ENVIRONMENTAL MONITORING AND AUDITING

Ground Water Monitoring

4.1 Prior to the commencement of construction of the Project, the Proponent shall develop a **Groundwater Monitoring Program** in consultation with NOW and to the satisfaction of the Director-General, covering the operation of the Stage 1 Gas Field Development Area. The program shall detail the monitoring strategy that would be implemented to measure dewatering and water quality impacts of gas well development on beneficial aquifers (including associated groundwater users, surface waters and groundwater dependent ecosystems) during the implementation of the Field Development Plan for the Stage 1 Gas Field Development Area and measure any residual impacts following the decommissioning of wells. The program shall:

a) identify surface and groundwater monitoring locations demonstrating their appropriateness for obtaining representative water quality and water level data on operational impacts in relation to beneficial aquifers, groundwater users and surface waters. In the first instance the monitoring locations shall focus on the first phase of gas well development in the Field Development Plan, as identified under condition 3.10 and shall be updated as well development progresses;
b) provide details of the monitoring points (including location, depth of monitoring, duration and frequency of monitoring and parameters to be monitored);
c) identify performance criteria for gas well development, including monitoring criteria to detect early indicators of drawdown impacts to beneficial aquifers or of cumulative drawdown effects and hold points (based on risk assessment) for further development where adverse impacts are identified;
d) identify the frequency of reporting on monitoring results including at a minimum prior to the commencement of each phase of the Field Development Plan (subsequent to the first phase) in accordance with the requirements of condition 3.10;
e) include provisions for the monitoring of coal seam dewatering rates and hold points (based on risk assessment) in the case that water volumes are greater than the predicted two mega litres per day (unless managed in accordance with condition 3.12g);
f) include provisions for monitoring the potential for gas migration to the surface;
g) provide detailed specifications (including information on toxicity and/ or carcinogenicity) of fraccing fluids to be used in gas well development, with annual updates;
h) include provisions for ongoing monitoring, post decommissioning of wells to determine any residual impacts;

i) identify a procedure for contingency or remedial action where adverse impacts are identified including compensation to groundwater users and/or rehabilitation measures where affects to groundwater dependent ecosystems/ communities are attributed to the project; and
j) identify mechanisms for the regular review and update of the program in consultation with NOW as required.

In submitting the program for the Director-General's approval, the Proponent shall provide written evidence of consultation with NOW on the robustness and acceptability of the monitoring program, including issues raised by NOW and how these have been addressed.

The monitoring program shall be updated in consultation with NOW to the satisfaction of the Director-General, prior to the commencement of each phase of the Field Development Plan, taking into account the recommendations of the Numerical Hydrogeological Model developed in accordance with condition 4.2.

4.2 The Proponent shall in consultation with NOW develop a **Numerical Hydrogeological Model** of the Stage 1 Gas Field Development Area building on the detailed conceptual hydrogeological model developed in accordance with conditions 3.8 and 3.9 and based on the monitoring results from the operation of the project, obtained in accordance with condition 4.1. The Model shall be used as a predictive, adaptive management and verification tool to guide the ongoing operation and implementation of gas wells as part of the Field Development Plan including feeding into recommendations on the phasing of gas wells in accordance with condition 3.10 (this includes identifying any impacts of the project from the previous phase of gas well development and the mitigation and contingency measure employed to control any impacts including their effectiveness and the recommended number and location of gas well to be developed in the next phase). The Model shall also feed into recommendations on updates to the Groundwater Monitoring program in accordance condition 4.1.

Noise Monitoring

4.3 Within 90 days of the commencement of operation of the project or as otherwise agreed by the Director-General, and during a period in which the project is operating under normal operating conditions, the Proponent shall undertake a program to confirm the noise emission performance of the project. The program shall meet the requirements of the DECCW, and shall include, but not necessarily be limited to:
a) noise monitoring, consistent with the guidelines provided in the *New South Wales Industrial Noise Policy* (EPA, 2000), to assess compliance with condition 3.22 of this approval;
b) methodologies, locations and frequencies for noise monitoring;
c) identification of monitoring sites at which pre- and post-project noise levels can be ascertained; and
d) details of any entries in the Complaints Register (condition 6.3 of this approval) relating to noise impacts.

Unless otherwise agreed to by the Director-General, a report providing the results of the program shall be submitted to the Director-General and the DECCW within 28 days of completion of the testing required under a).

4.4 In the event that the program undertaken to satisfy condition 4.3 of the approval indicates that the operation of the project, under normal operating conditions, will lead to greater noise impacts than permitted under condition 3.22 of this approval, then the Proponent shall provide details of remedial measures to be implemented to reduce noise impacts to levels required by that condition, including (but not necessarily limited to) at-receptor acoustic screening as required under condition 3.27. At-receptor acoustic screening shall only be considered where other at-source methods of acoustic amelioration are found to not be reasonable or feasible. A report providing details of the remedial measures and a timetable for implementation shall be submitted to the Director-General for approval within such period as the Director-General may require, and be accompanied by evidence that the DECCW is satisfied that the remedial measures are acceptable.

Following review of the report, the Director-General may require additional noise monitoring to confirm the performance of the implemented remediation measures. Where such additional noise monitoring indicates exceedences of project specific noise criteria specified in condition 3.22 of this approval at any sensitive receptor identified in Table 3 after the implementation of all reasonable and feasible remedial measures, these receptors (unless otherwise agreed to by the Director-General) shall be subject to noise agreements within such time period as agreed to by the Director-General or in the case that exceedences greater than 5dB(A) are indicated, subject to acquisition criteria in accordance with condition 3.26 (except in the case where a noise agreement is in place).

Air Quality Monitoring

4.5 The Proponent shall determine the pollutant concentrations and emission parameters specified in Table 6 below, at each of the discharge points (established in strict accordance with the requirements of test method TM-1 as specified in *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (EPA, 2001)). Monitoring shall be undertaken during operation of the project, at the frequency indicated in the Table, unless otherwise agreed by the DECCW.

Table 6 – Periodic Pollutant and Parameter Monitoring (Air)

Discharge Point	Pollutant/ Parameter	Units of Measure	Method	Frequency
1	Oxides of Nitrogen	mgm^{-3}	TM-11	Post commissioning and annually thereafter
	Carbon Monoxide or Volatile Organic Compounds	mgm^{-3}	TM 34 or TM 32	
	Velocity	m/s	TM-2	
	Volumetric flow rate	m^3/s	TM-2	
	Temperature	^oC	TM-2	
	Moisture	%	TM-22	
	Dry gas density	kgm^3	TM-23	
	Molecular weight of stack gases	g/gmol	TM-23	
	Oxygen	%	TM-25	
	Carbon dioxide	%	TM-24	
	Selection of Sampling Positions	-	TM-1	-
2	Oxides of Nitrogen	mgm^{-3}	TM-11	Post commissioning and annually thereafter
	Formaldehyde	mgm^{-3}	US EPA Method 323, upon confirmation by DECCW in accordance with condition 0.	
	Carbon Monoxide or Volatile Organic Compounds	mgm^{-3}	TM 34 or TM 32	
	Velocity	m/s	TM-2	
	Volumetric flow rate	m^3/s	TM-2	
	Temperature	^oC	TM-2	
	Moisture	%	TM-22	
	Molecular weight of stack gases	g/gmol	TM-23	
	Oxygen	%	TM-25	
	Carbon dioxide	%	TM-24	
	Oxides of Nitrogen	mgm^{-3}	CEM-2	Continuous
	Temperature	^oC	TM-2	
	Moisture	%	TM-22	
	Volumetric flow rate	m^3/s	CEM-6	
	Oxygen	%	CEM-3	

	Selection of Sampling Positions	-	TM-1	-
3, 4, 5 and 6	Oxides of Nitrogen	mgm^{-3}	TM-11	Post commissioning and annually thereafter
	Formaldehyde	mgm^{-3}	US EPA Method 323, upon confirmation by DECCW in accordance with condition 0.	
	Carbon Monoxide or Volatile Organic Compounds	mgm^{-3}	TM 34 or TM 32	
	Velocity	m/s	TM-2	
	Volumetric flow rate	m^3/s	TM-2	
	Temperature	^oC	TM-2	
	Selection of Sampling Positions	-	TM-1	-

4.6 Unless otherwise agreed to by the Director-General, prior to the commencement of construction, the Proponent shall confirm the methodology for the monitoring of formaldehyde from discharge points 2, 3, 4 and 5 in Table 6 to the satisfaction of DECCW. The monitoring methodology agreed to by DECCW shall apply to discharge points 2, 3, 4 and 5 for the purposes of condition 4.5.

Air Quality Performance Verification

4.7 Unless otherwise agreed to by DECCW, the Proponent shall in consultation with DECCW, prior to the commencement of construction, establish a meteorological station(s) at a representative location(s) to collect meteorological information representative of the Gloucester Valley, to enable air quality performance verification for the central processing facility in accordance with condition 4.8. At least one year's data must be collected for the purpose of undertaking the air quality performance verification required under condition 4.8 for the central processing facility.

4.8 Within 90 days of the commencement of operation of the project or as otherwise agreed by the Director-General, and during a period in which the project is operating under normal operating conditions, the Proponent shall undertake a program to confirm the air emission performance of the project. The program shall include, but not necessarily be limited to:

a) point source emission sampling and analysis subject to the requirements listed under condition 4.5 to determine compliance with the discharge concentration limits identified in condition 3.31;
b) a comprehensive air quality impact assessment in accordance with the methods outlined in *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DECC, 2005), using actual air emission data collected under condition 4.5 to determine performance against the ground-level concentrations for air pollutants predicted for the project; and
c) details of any entries in the Complaints Register (condition 6.3 of this approval) relating to air quality impacts.

A report providing the results of the program shall be submitted to the Director-General and DECCW within 28 days of completion of the testing required under a).

4.9 In the event that the program undertaken to satisfy condition 4.8 of this approval indicates that the operation of the project, under normal operating conditions, will lead to:

a) greater point source emissions than the discharge concentration limits identified in condition 3.31; or
b) greater ground-level concentrations of air pollutants than that predicted for the project in the documents listed under condition 1.1 of this approval;

then the Proponent shall provide details of remedial measures to be implemented to reduce point source emissions to no greater than the discharge concentration limits identified in condition 3.31 and to reduce ground-level concentrations of air pollutants to no greater than that predicted for the project in the documents listed under condition 1.1 of this approval and under no circumstance greater than the limits detailed in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DECC, 2005). Details of the remedial measures and a timetable for implementation shall be submitted to the Director-General for approval within such period as the Director-General may require, and be accompanied by evidence that the DECCW is satisfied that the remedial measures are acceptable.

Hazard Audit

4.10 Twelve months after the commencement of operations of the project and every three years thereafter, or at such intervals as the Director-General may agree, the Proponent shall carry out a comprehensive Hazard Audit of the project and submit the audit report to the Director-General within one month of the audit report being completed. The audits shall be carried out by a qualified person or team, independent of the project and shall be consistent with the Department's Hazardous Industry Planning Advisory Paper No. 5, *'Hazard Audit Guidelines'*.

5. COMPLIANCE MONITORING AND TRACKING

5.1 The Proponent shall develop and implement a **Compliance Tracking Program** to track compliance with the requirements of this approval. The Program shall be submitted to the Director-General prior to the commencement of construction. The Program shall relate to both construction and operational stages of the project and shall include, but not necessarily be limited to:

a) provisions for periodic review of the compliance status of the project against the requirements of this approval, Statement of Commitments and relevant environmental approvals, licences or permits required and obtained in relation to the project;
b) provisions for periodic reporting of compliance status against the requirements of this approval and Statement of Commitments to the Director-General including at least one month prior to the commencement of construction and operation of the project;
c) a program for independent environmental auditing in accordance with *AS/NZ ISO 19011:2003 - Guidelines for Quality and/or Environmental Management Systems Auditing*; and
d) mechanisms for rectifying any non-compliance identified during environmental auditing or review of compliance.

6. COMMUNITY INFORMATION, CONSULTATION AND INVOLVEMENT

6.1 Subject to confidentiality, the Proponent shall make all relevant documents required under this approval available for public inspection on request.

Complaints Procedure

6.2 Prior to the commencement of construction of the project, the Proponent shall ensure that the following are available for community complaints for the life of the project (including construction and operation):

a) a telephone number on which complaints about construction and operational activities at the site may be registered;
b) a postal address to which written complaints may be sent; and
c) an email address to which electronic complaints may be transmitted.

The telephone number, postal address and email address shall be published in a newspaper circulating in the local area prior to the commencement of construction of the project. The above details shall also be provided on the website required by condition 6.4 of this approval.

6.3 The Proponent shall record details of all complaints received through the means listed under condition 6.2 of this approval in an up-to-date Complaints Register. The Register shall record, but not necessarily be limited to:

a) the date and time, where relevant, of the complaint;
b) the means by which the complaint was made (telephone, mail or email);

c) any personal details of the complainant that were provided, or if no details were provided, a note to that effect;
d) the nature of the complaint;
e) any action(s) taken by the Proponent in relation to the complaint, including any follow-up contact with the complainant and the timing for implementing action; and
f) if no action was taken by the Proponent in relation to the complaint, the reason(s) why no action was taken.

The Complaints Register shall be made available for inspection by the Director-General upon request.

The Complaints Register for the project may be incorporated into an existing complaints handling system managed by the Proponent if it is demonstrated to meet the requirements of condition 5.3.

Provision of Electronic Information

6.4 Prior to the commencement of construction of the project, the Proponent shall establish a dedicated website or maintain dedicated pages within its existing website for the provision of electronic information associated with the project subject to confidentiality. The Proponent shall publish and maintain up-to-date information on this website or dedicated pages including, but not necessarily limited to:
a) information on the statutory context and current implementation status of the project;
b) the documents referred to under condition 1.1 of this approval;
c) a copy of this approval and any future modification to this approval;
d) a copy of each relevant environmental approval, licence or permit required and obtained in relation to the project;
e) all plans, monitoring programs and strategies required under this project approval; and
f) details of the outcomes of compliance reviews and audits of the project.

Community and Stakeholder Engagement Plan

6.5 The Proponent shall prepare a **Community and Stakeholder Engagement Plan** which outlines measures for disseminating information on the development status of the project and methods for actively engaging with surrounding landowners, members of the community and affected stakeholders regarding issues that would be of interest/ concern to them during the detailed design, construction and operation of the project. This may include distribution of community newsletters, stakeholder meetings, community consultative committees and opportunities for site visits. The Plan shall include but not be limited to:
a) procedures to finalise the detailed design of the project including gas well locations and gas transmission pipeline route in consultation with landowners;
b) measure and procedures to work consultatively with landowners during construction and operational activities so as to minimise intrusion and disruption to existing landuse including agricultural activities;
c) measure and procedures to consult with affected stakeholders (including the owners of existing infrastructure within the proposed pipeline easement, mineral titleholders and quarry and mining operators) to minimise design, construction or operational impacts on existing infrastructure and future development potential and to manage cumulative impacts from neighbouring development;
d) procedures to inform the local community of planned construction activities including construction traffic routes, potential traffic disruptions, high noise generating activities and works outside of normal construction hours; and
e) dispute resolution processes in case of disagreement between parties including provision for an independent arbitrator.

The Community and Stakeholder Engagement Plan shall be submitted for the approval of the Director-General prior to the commencement of the detailed design stage of the project covering at least the community engagement and consultation measures to be implemented during the detailed design phase. An updated plan shall be subsequently submitted for the approval of the Director-General, prior to the commencement of the construction stage and prior to the commencement of the operational stage of the project covering the community engagement and consultation measures to be undertaken in these respective stages of the project.

7. ENVIRONMENTAL MONITORING AND MANAGEMENT

Environmental Representative

7.1 Prior to the commencement of any construction activities, or as otherwise agreed by the Director-General, the Proponent shall nominate for the approval of the Director-General a suitably qualified and experienced Environmental Representative(s) independent of the design, construction and operation personnel. The Proponent shall engage the Environmental Representative(s) during any construction activities. The Environmental Representative(s) shall:

a) oversee the implementation of all environmental management plans and monitoring programs required under this approval, and advise the Proponent upon the achievement of these plans/programs;

b) consider and advise the Proponent on its compliance obligations against all matters specified in the conditions of this approval and the Statement of Commitments as referred to under condition 1.1c) of this approval, and any other relevant environmental approval, licence or permit required and obtained in relation to the project; and

c) have the authority and independence to recommend to the Proponent reasonable steps to be taken to avoid or minimise unintended or adverse environmental impacts, and, failing the effectiveness of such steps, to recommend to the Proponent that relevant activities are to be ceased as soon as reasonably practicable if there is a significant risk that an adverse impact on the environment will be likely to occur.

Construction Environmental Management Plan

7.2 The Proponent shall prepare and implement a **Construction Environmental Management Plan** (CEMP) prior to the commencement of construction of the project to outline environmental management practices and procedures to be followed during construction of the project. The CEMP shall be consistent with *Guideline for the Preparation of Environmental Management Plans* (DIPNR, 2004) and shall include, but not necessarily be limited to:

a) a description of all activities to be undertaken on the site during construction including an indication of stages of construction, where relevant;

b) identification of the potential for cumulative impacts with other construction activities or existing development (including mining) in the vicinity and how such impacts would be managed;

c) identification of the location of temporary construction sites, details of construction material sourcing (including gravel and water requirements);

d) a description of the statutory obligations that the Proponent is required to fulfil prior to and during construction including all relevant approvals, licences and permits required and applicable key legislation and policies;

e) evidence of consultation with relevant public authorities including all applicable Councils, identifying how issues raised by these public authorities have been addressed in the plan;

f) a description of the roles and responsibilities for all relevant employees and contractors involved in the construction of the project including relevant training and induction provisions for ensuring that all employees, contractors and sub-contractors are aware of their environmental and compliance obligations under these conditions of approval;

g) an environmental risk analysis to identify the key environmental performance issues associated with the construction phase and details of how environmental performance would be monitored and managed to meet acceptable outcomes including what actions will be taken to address identified potential adverse environmental impacts. In particular, the following environmental performance issues shall be addressed in the Plan:

i) measures to monitor and manage **dust emissions** including dust generated by traffic on unsealed public roads and unsealed internal access tracks;

ii) measures to monitor and manage **noise, vibration and blasting** impacts with consideration to cumulative impacts from surrounding development including: identification of nearest sensitive receptors and relevant construction noise and vibration goals applicable, identification of all reasonable and feasible measures proposed to be implemented to minimise construction noise and vibration impacts (including construction traffic noise impacts), measures for notifying surrounding receptors of noisy activities or works outside of standard hours, measures for monitoring compliance and responding to complaints and contingency strategy in the case that project related vibration or blasting results in damage to buildings or structures;

iii) measures to monitor and manage **traffic impacts** in consultation with relevant road authorities (Council and RTA, as relevant) including: identification of construction traffic routes and traffic volumes along each route with considering to minimising traffic on local/ residential streets, potential traffic disruptions considering road safety and level of service, specific measures for minimising traffic impacts and mechanisms to monitor road condition during construction and remediate any damage attributable to the project (should such remediation be required prior to the requirements of condition 3.45 taking effect);

iv) measures to monitor and manage **Aboriginal heritage impacts** in consultation with registered stakeholders and DECCW including:

  i. details of management measures to be carried out in relation to already recorded sites and potential Aboriginal deposits (including further archaeological investigations and/ or salvage measures);

  ii. procedures for dealing with previously unidentified Aboriginal objects excluding human remains (including halting of works in the vicinity, assessment of the significance of the item(s) and determination of appropriate mitigation measures including when works can re-commence by a qualified archaeologist in consultation with registered Aboriginal stakeholders, assessment of the consistency of any new Aboriginal heritage impacts against the approved impacts of the project, and registering of the new site in the DECCW AHIMS register);

  iii. procedures for dealing with human remains (including halting of works in the vicinity and notification of the NSW Police, DECCW and registered Aboriginal stakeholders and not-recommending any works in the area unless authorised by DECCW and/ or the NSW Police); and

  iv. Aboriginal cultural heritage induction processes for construction personnel and procedures for ongoing Aboriginal consultation and involvement; and

ii) emergency management measures including measures to control bushfires; and

h) procedures for the periodic review and update of the Construction Environmental Management Plan as necessary.

The Plan shall be submitted for the approval of the Director-General no later than one month prior to the commencement of Construction of the project or within such period as otherwise agreed by the Director-General. Construction shall not commence until written approval has been received from the Director-General.

7.3 As part of the Construction Environmental Management Plan for the project, required under condition 7.2 of this approval, the Proponent shall prepare and implement the following:

a) a **Flora and Fauna Management Plan** to manage the construction impacts of the project on flora and fauna. The Flora and Fauna Management Plan shall be prepared in consultation with the DECCW and the HCRCMA and shall include, but not necessarily be limited to:

(i) detailed constraint mapping of the final project area clearly identifying sensitive vegetation/habitat areas to be avoided and/or areas where site-specific management measures are required;
(ii) measures for minimising and managing impacts to native vegetation and important habitat features including but not necessarily limited to: pre-clearance surveys by a qualified ecologist to identify sensitive vegetation areas or habitat features (such as hollow bearing trees and surface rock) and weed and pest management (including phytophthora management);
(iii) measures to minimise disturbance of riparian and instream habitat including pre-construction surveys of each water crossing to identify habitat sensitivity (in particular habitat suitability for sensitive frog species) and measures to be undertaken to avoid and minimise impacts to riparian and instream habitat, including for sensitive frog species;
(iv) small-flower Grevillea Management strategy in consultation with the DECCW and DSEWPaC to manage impacts to the population identified within the pipeline corridor including pre-construction baseline surveys to identify the distribution and extent of the species and construction methodology to minimise construction widths and disturbance as far as practicable;
(v) construction practices to avoid direct interaction/ injury to fauna including but not necessarily limited to:
    i. timing of construction so as to take into account sensitive life cycle stages for sensitive species;
    ii. pre-construction surveys for the presence of sensitive fauna by a qualified ecologist and protocols for the safe capture and release of fauna to adjacent habitat where fauna are identified to be in danger of injury or harm from construction; and
    iii. measures to minimise the potential for fauna to get trapped in trenches during construction and measures for monitoring and rescuing any species should they become trapped including ensuring that monitoring and rescue measures are undertaken by a qualified ecologist; and
(vi) measures for progressive rehabilitation during construction including identification of performance indicators and completion criteria for revegetation works and measures for the monitoring and maintenance of revegetation works consistent with the requirements of condition 3.55;

b) a **Watercourse Crossing Management Strategy** prepared in consultation with NOW and DII (Fisheries) to manage the construction impacts of pipeline waterway crossings including:
(i) baseline surveys of each water crossing to identify habitat sensitivity and water course integrity;
(ii) design details of each water course crossing;
(iii) site specific mitigation measures to be implemented to minimise disturbance during construction; and
(iv) rehabilitation requirements to stabilise bank structure and rehabilitate affected riparian vegetation including performance and completion criteria (based on base line surveys) and monitoring requirements; and

c) a **Soil and Water Management Plan** prepared in consultation with NOW and DII (Fisheries) to manage the water quality impacts during construction. The plan shall detail:
(i) pre-construction investigations including: soil testing to determine the likely potential for uncovering acid sulphate soils, investigation of the risk of groundwater interception (particularly, shallow perched groundwater tables) during pipeline trenching or horizontal directional drilling, and identification of any sites of potentially contaminated soils which require remediation prior to the commencement of construction (such as previous industrial land use or intensive agricultural activity);
(ii) base-line water quality monitoring (both up stream and down stream of the construction sites) and where required pre-construction monitoring of groundwater quality (particularly where there is a high risk of groundwater interception coupled with potential acid sulphate soils);

(iii) a management strategy to control acid sulphate soil impacts at any identified acid sulphate soil areas and should they be uncovered during construction (including measures for testing, treatment, and disposal; protection and treatment of groundwater; and contingency measures in the case of an incident);

(iv) site specific erosion and sediment control plans (detailing measures to control and protect waterways from runoff, control measures in the case of groundwater interception, measures to minimise the extent and duration of soil disturbance, measures for ground stabilisation including progressive rehabilitation, and contingency measures in the case of an incident);

(v) strategy for contaminated soil management should any such areas be uncovered during construction (including measures for pre-construction testing, treatment, and disposal; measures for surface groundwater protection; and contingency measures in the case of an incident); and

(vi) a water quality monitoring strategy to monitor down stream impacts to water quality during the construction phase, including a program for monitoring groundwater quality (where required) and trigger and hold points for compliance actions should adverse water quality be detected.

Operation Environmental Management Plan

7.4 The Proponent shall prepare and implement an **Operation Environmental Management Plan** to detail an environmental management framework, practices and procedures to be followed during operation of the project. The Plan shall be consistent with *Guideline for the Preparation of Environmental Management Plans* (DIPNR 2004) and shall include, but not necessarily be limited to:

a) a description of key operational and maintenance activities associated with the project;

b) identification of all statutory and other obligations that the Proponent is required to fulfil in relation to operation of the project, including any approvals, licences, approvals and consultations;

c) a description of the roles and responsibilities for all relevant employees and contractors involved in the operation of the project including relevant training and induction provisions for ensuring that all employees, contractors and sub-contractors are aware of their environmental and compliance obligations under these conditions of approval;

d) overall environmental policies and principles to be applied to the operation of the project;

e) an environmental risk analysis to identify the key environmental performance issues associated with the operation phase and details of how environmental performance would be monitored and managed to meet acceptable outcomes including what actions will be taken to address identified potential adverse environmental impacts. In particular, the following environmental performance issues shall be addressed in the Plan:

(i) measures to monitor and manage groundwater impacts including residual impacts following decommissioning of gas wells in accordance with conditions 4.1and 4.2;

(ii) measures to monitor and manage flood risks including risks of equipment damage or disconnection during flood events and measures for clean up and restoration;

(iii) measures to monitor and manage noise emissions including measures for regular performance monitoring of noise generated by the project (in addition to measures identified in conditions 4.3) and 4.4), measures to proactively respond to and deal with noise complaints and procedure for the development of a case-specific noise management protocol in consultation with DECCW to manage short-term noise amenity impacts at surrounding receptors in the case of works identified in condition 3.22b);

(iv) measures to monitor and manage air quality impacts in accordance with the requirements of this approval;

(v) measures to monitor and manage landscape plantings and revegetation measures;

(vi) measures to monitor and manage operational traffic impacts particularly during maintenance events where operational traffic volumes associated with the project may increase and procedures for restoring any damage attributable to the project during the operation phase;
(vii) hazard and safety and emergency management measures including measures to control bushfires; and
(viii) rehabilitation and completion criteria for the decommissioning and rehabilitation of the project; and

f) procedures for the periodic review and update of the Operation Environmental Management Plan as necessary.

The Operation Environmental Management Plan shall be submitted for the approval of the Director-General no later than one month prior to the commencement of Operation of the project or within such period as otherwise agreed by the Director-General. Operation shall not commence until written approval has been received from the Director-General.

Appendix B

EPBC Project Approval

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

Approval

Gloucester Coal Seam Methane Gas Project, Gloucester region, New South Wales (EPBC 2008/4432)

This decision is made under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999.*

proposed action

person to whom the approval is granted	AGL Upstream Infrastructure Investments Pty Ltd
proponent's ACN	092 684 010
proposed action	To construct, operate and decommission: • not more than 110 coal seam gas wells and associated infrastructure including gas and water gathering lines; • a central processing facility (at one of two proposed alternative sites); • a gas receiving station at Hexham; and • a pipeline from the central processing facility to the Hexham receiving station; as described in the referral received on 29 August 2008 and subsequently varied on 1 May 2012 (referral EPBC 2008/4432).

approval decision

controlling provision	**decision**
wetlands of international importance (sections 16 & 17B)	approve
listed threatened species and communities (sections 18 & 18A)	approve

conditions of approval

This approval is subject to the conditions specified below.

expiry date of approval

This approval has effect until 30 November 2062.

decision-maker

name and position The Hon Tony Burke MP

Minister for Sustainability, Environment, Water, Population and Communities

signature

date of decision 11 February 2013

Conditions attached to the approval

Scope of proposal

1. The person taking the action must ensure that the action is undertaken in accordance with the ***finalised assessment documentation*** and entirely within the Stage 1 Gas Field Development Area and Pipeline Corridor as identified in Attachments 1 and 2 to the conditions of this approval.

2. The following ***disturbance limits*** apply to the action:
   - 1000 individuals (loss or damage) in the case of small-flower grevillea (*Grevillea parviflora* subsp. *parviflora*).

Pre-clearance surveys

3. At least three months prior to ***clearance of native vegetation*** within a defined area, a suitably qualified person with prior written approval of ***the department*** must undertake pre-clearance surveys for ***listed threatened species*** (including their habitat) ***and communities*** within that defined area. Surveys must be undertaken in accordance with current relevant survey guidelines published by ***the department***, or best practice if no guidelines are available.

   Alternatively, recent surveys undertaken prior to this approval may satisfy this condition if ***the department*** agrees in writing that they are adequate.

4. Reports must be prepared in relation to any surveys (including but not limited to pre-clearance surveys) by a suitably qualified person with prior written approval of ***the department***, and must include information on:

   a) survey methodology (including reasons for any deviation from relevant survey guidelines if any have been published by ***the department***) and habitat definitions / threshholds used;

   b) results;

   c) analysis of significant findings (including quality, size and location of any habitat identified); and

   d) personnel involved and their qualifications.

   Survey reports must be published by the person taking the action on their website for the duration of this approval within three (3) months of completion of the corresponding survey, and be provided to ***the department*** on request.

Alternatively, recent reports prepared prior to this approval may satisfy this condition if ***the department*** agrees in writing that they are adequate.

Species management plans

5. If a ***listed threatened species*** (or species habitat) ***or community*** (other than small-flower grevillea, green and golden bell frog or giant barred frog) is encountered during a pre-clearance survey (or at any other time), prior to any further ***clearance of native vegetation*** which has been identified as supporting a ***listed threatened species*** (or species habitat) ***or community***, the person taking the action must provide ***the minister*** with the survey report prepared under Condition 4. ***The minister*** may direct the person taking the action to prepare a management plan for the ***listed threatened species*** (or species habitat) ***or community***. The plan must be prepared by a suitably qualified person with prior written approval of ***the department*** and must include:

   a) discussion of distribution and current legal status;

   b) discussion of key ecological features of the species or community;

   c) discussion of the biology and reproductive needs of the species (if a species);

   d) discussion and working definition(s) of "habitat" (if a species), considering:

      i. habitat function (for example distinguishing where relevant between breeding habitat and foraging habitat); and

      ii. habitat quality (with reference to both key features and landscape context);

   e) results of targeted surveys, including quantification of occurrence or habitat extent and a map of the location of the species or community occurrence on the site of the action (or its area of influence);

   f) description of measures that will be employed to avoid or mitigate impacts on the species or community;

   g) quantification of any unavoidable impact (expressed as an area in hectares in the case of a community or fauna habitat or number of individuals); and

   h) a detailed description of measures to ***offset*** that impact (including in relation to direct ***offsets***, size, location, ecological attributes and mechanisms for legal ensuring enduring protection).

   Clearance of native vegetation which has been identified as supporting a ***listed threatened species*** (or species habitat) ***or community*** may only recommence on the written authorisation of ***the minister*** or the approval by ***the minister*** of a species management plan.

   Each approved species management plan must be published by the person taking the action on their website, for the duration of this approval, within twenty (20) business days of its approval by ***the minister***, and must be implemented.

Green and golden bell frog management

6. A suitably qualified person with prior written approval of ***the department*** must undertake targeted surveys for the green and golden bell frog (*Litoria aurea*) in all potential habitat within twenty (20) metres of the entire pipeline route and within twenty (20) metres of any proposed infrastructure. Surveys must be undertaken in accordance with current relevant survey guidelines published by ***the department***, or best practice if no guidelines are available.

Alternatively, recent surveys undertaken prior to this approval may satisfy this condition if ***the department*** agrees in writing that they are adequate.

7. A green and golden bell frog management plan must be prepared for each ***component of the action*** by a suitably qualified person with prior written approval of ***the department***. The plan must include:
   a) discussion of distribution and current legal status;
   b) discussion of key ecological,biological and reproductive needs;
   c) discussion and working definition(s) of habitat for the species, considering:
      i. habitat function (for example distinguishing where relevant between breeding habitat and foraging habitat); and
      ii. habitat quality (with reference to both key features and landscape context);
   d) results of targeted surveys, including quantification of occurrence and habitat extent and a map of the location of occurrence on the site of the action (and its area of influence);
   e) description of measures that will be employed to avoid or mitigate impacts;
   f) quantification of any unavoidable impact (expressed in terms of habitat and individuals) with a detailed description of measures to ***offset*** that impact (including in relation to direct ***offsets***, size, location, ecological attributes and mechanisms for legal ensuring enduring protection);
   g) measures for the monitoring (using at least eight (8) reference sites), and remediation as required, of impacts of the operation of the gas field on sites of potential habitat, including:
      i. surface expression of methane gas;
      ii. water pollution including salinity;
      iii. water drawdown; and
      iv. any impacts on surface water; and
   h) a list of personnel involved in survey and management activities and their qualifications.

   The plan must be approved by ***the minister*** prior to ***commencement*** of the relevant ***component of the action***, and the approved plan must be implemented.

   Note: Plans prepared under Conditions 7 and 10 may be combined.

8. Within three (3) months of completion of the risk analysis described in Condition 19, the person taking the action must update the management plan described in Condition 7 to incorporate:
   a) results of the risk analysis;
   b) additional surveys (undertaken by a suitably qualified person with prior approval of the department, in accordance with current relevant survey guidelines published by ***the department***, or best practice if no guidelines are available) wherever either of the hydrogeological models described in Conditions 16 and 18 predict impacts on surface water;
   c) if necessary, a description of revised measures that will be employed to avoid or mitigate impacts on the species or community; and
   d) if necessary, revised quantification of any unavoidable impact (expressed as an area in hectares or number of individuals) with a description of measures to ***offset*** that impact.

The updated plan must be approved by ***the minister*** prior to the commissioning of the approved central processing facility, and once approved must be implemented.

Giant barred frog management

9. A suitably qualified person with prior written approval of ***the department*** must undertake targeted surveys for giant barred frog (*Mixophyes iterates*) in all potential habitat within twenty (20) metres of the entire pipeline route and within twenty (20) metres of any proposed infrastructure. Surveys must be undertaken in accordance with current relevant survey guidelines published by ***the department***, or best practice if no guidelines are available.

   Alternatively, recent surveys undertaken prior to this approval may satisfy this condition if ***the department*** agrees in writing that they are adequate.

10. A giant barred frog management plan must be prepared for each ***component of the action*** by a suitably qualified person with prior written approval of ***the department***. The plan must include:

   a) discussion of distribution and current legal status;

   b) discussion of key ecological biological and reproductive needs;

   c) discussion and working definition(s) of habitat for the species, considering:

      i. habitat function (for example distinguishing where relevant between breeding habitat and foraging habitat); and

      ii. habitat quality (with reference to both key features and landscape context);

   d) results of targeted surveys, including quantification of occurrence and habitat extent and a map of the location of occurrence on the site of the action (and its area of influence);

   e) description of measures that will be employed to avoid or mitigate impacts;

   f) quantification of any unavoidable impact (expressed in terms of habitat and individuals) with a detailed description of measures to ***offset*** that impact (including in relation to direct ***offsets***, size, location, ecological attributes and mechanisms for legal ensuring enduring protection);

   g) measures for the monitoring (using at least eight (8) reference sites), and remediation as required, of impacts of the operation of the gas field on sites of potential habitat, including:

      i. surface expression of methane gas;

      ii. water pollution including salinity;

      iii. water drawdown; and

      iv. any impacts on surface water; and

   h) a list of personnel involved in survey and management activities and their qualifications.

   The plan must be approved by ***the minister*** prior to ***commencement*** of the relevant ***component of the action***, and the approved plan must be implemented.

   Note: Plans prepared under Conditions 7 and 10 may be combined.

11. Within three (3) months of completion of the risk analysis described in Condition 19, the person taking the action must update the management plan described in Condition 10 to incorporate:

a) results of the risk analysis;

b) additional surveys (undertaken by a suitably qualified person with prior approval of the department, in accordance with current relevant survey guidelines published by ***the department***, or best practice if no guidelines are available) wherever either of the hydrogeological models described in Conditions 16 and 18 predict impacts on surface water;

c) if necessary, a description of revised measures that will be employed to avoid or mitigate impacts on the species or community; and

d) if necessary, revised quantification of any unavoidable impact (expressed as an area in hectares or number of individuals) with a description of measures to ***offset*** that impact.

The updated plan must be approved by ***the minister*** prior to the commissioning of the approved central processing facility, and once approved must be implemented.

Small-flower grevillea management

12. The person taking the action must prepare a plan for the management of small-flower grevillea on each ***component of the action***. The plan must include:

a) discussion of preferred habitat of the species, known distribution and current legal status;

b) discussion of key ecological features of the species;

c) discussion of the biology and reproductive needs of the species;

d) a map and ***shapefiles*** of the location of the species at the site of the action;

e) a description of measures that will be employed to avoid or mitigate impacts on the species at the site of the action, specifically addressing the following;

   i. access, signage and fencing;

   ii. fire management;

   iii. browsing management;

   iv. weed and pathogen management;

   v. post construction rehabilitation;

   vi. measures for monitoring and reporting on the health of the population including in particular, survival and recruitment;

   vii. performance measures and response actions (if performance measures are not met); and

f) a list of personnel involved in survey and management activities and their qualifications: and

g) an assessment of offset requirements consistent with the *Environment Protection and Biodiversity Conservation Act 1999 Biodiversity Offsets Policy* (October 2012).

The plan must be approved by ***the minister*** prior to the removal of any small-flower grevillea plants, and the approved plan must be implemented.

Note: Plans prepared under Conditions 12 and 14 may be combined.

13. The person taking the action must secure enduring protection of, and actively manage, habitat suitable for the conservation of small-flower grevillea (the offset site) in accordance with the plans referred to in Conditions 12 and 14.

14. The person taking the action must prepare a plan for the management of small-flower grevillea at the offset site. The plan must include:
   a) discussion of preferred habitat of the species, known distribution and current legal status;
   b) discussion of key ecological features of the species;
   c) discussion of the biology and reproductive needs of the species;
   d) documentary evidence of enduring protection of the offset site;
   e) a map and ***shapefiles*** of the offset site;
   f) a description of measures that will be employed to establish and / or maintain a population, with reference to;
      i. access, signage and fencing;
      ii. fire management;
      iii. browsing management;
      iv. weed and pathogen management;
      v. post construction rehabilitation;
      vi. propagation methods (if relevant)
      vii. measures for monitoring and reporting on the health of the population including in particular, survival and recruitment; and
      viii. performance measures and response actions (if performance measures are not met); and
   g) a list of personnel involved in survey and management activities and their qualifications.

   The plan must be approved by ***the minister*** prior to the removal of any small-flower grevillea plants, and the approved plan must be implemented.

   Note: Plans prepared under Conditions 12 and 14 may be combined.

Conditions for the protection of water resources

15. The person taking the action must comply with Conditions 3.5 to 3.13 and 4.1 to 4.2 of the ***state approval conditions***.

   Note: It is noted that some of the requirements of ***state approval conditions*** are similar to requirements under the conditions of this approval. While no unnecessary duplication is intended, where requirements are similar, the conditions of this approval must be met in full.

16. The person taking the action must consult the department on the development of the conceptual hydrogeological model required under Conditions 3.8 and 3.9 of the ***state approval conditions***, and must provide a copy of the model to the department within twenty (20) business days of its finalisation.

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).

18. The person taking the action must provide ***the minister*** with a numerical hydrogeological model that explores the pressure at which gas and water may be released and transmitted along faults. The model must be based on the water balance model described in Condition 17 and informed by monitoring data, for example as collected in accordance with Condition 4.1 of the ***state approval conditions***.

The model must be approved by ***the minister*** prior to the commissioning of the approved central processing facility.

Note: It is expected that ***the minister*** will require the model to be peer-reviewed prior to approval.

19. Within three (3) months of the approval of the numerical hydrogeological model described in Condition 18, or the conceptual hydrogeological model required under Conditions 3.8 and 3.9 of the ***state approval conditions*** (whichever is the later), the person taking the action must use the models to complete a risk analysis in relation to the following potential impacts on the green and golden bell frog and giant barred frog, and their potential habitats:

a) surface expression of methane gas;

b) water pollution including salinity;

c) water drawdown; and

d) any impacts on surface water.

20. Prior to undertaking any hydraulic fracturing, the person taking the action must provide ***the minister*** with the following details on any hydraulic fracturing agents or other reinjected fluids likely to be used under this approval:

  a) estimated number and location (mapped, and expressed in latitude, longitude and depth) of wells where the agent or fluid may be used;
  b) Chemical Abstracts Service Number;
  c) typical load;
  d) typical concentration; and
  e) toxicity as total effluent toxicity and ecotoxicity, based on methods outlined in the ***National Water Quality Management Strategy***.

  This information must be updated prior to the first use of any new any hydraulic fracturing agents or other reinjected fluids.

  No agents or fluids may be used without the prior written approval of ***the minister***.

21. The person taking the action must provide ***the department*** with a copy of the extracted water management strategy (also known as produced water management strategy) required under ***state approval conditions***. If the strategy is not to the satisfaction of ***the minister*** (and in particular if it does not consider the feasibility and likely effectiveness of reinjection of extracted water), he may require a supplement to be developed, which must be approved by ***the minister*** prior to ***commencement*** of the action, and must be implemented.

22. The person taking the action must ensure that no more than 2 megalitres per day (averaged over a twelve month period) of groundwater is extracted. In addition, the person taking the action may only extract sufficient groundwater as is required to undertake the action in accordance with the conditions of this approval.

23. The person taking the action must ensure that any water storage ponds associated with the action are appropriately lined to ensure no leaching of stored waters and designed consistent with a 1 in 100 year flood design standard.

24. The person taking the action must prepare an acid sulphate soils management plan (or plans, based on ***components of the action***) to predict, detect, map and manage acid sulphate soils along the entire pipeline route, on and adjacent to the sites of any proposed infrastructure. The plan must be approved by ***the minister*** prior to ***commencement*** of the relevant ***component of the action***, and must be implemented. The person taking the action must ensure that the plan is updated (at least quarterly) as field work progresses and site specific information becomes available. The plan must also ensure an appropriate regime for reporting water quality monitoring results to the New South Wales Government.

25. The person taking the action must provide ***the department*** with a copy of the watercourse crossing management strategy required by ***state approval conditions***. If the strategy is not to the satisfaction of ***the minister***, he may require a supplement to be developed, which must be approved by ***the minister*** prior to ***commencement*** of the action, and must be implemented. In particular, it is expected that the strategy should include:

a) baseline surveys of each crossing to identify any habitat for ***listed threatened species and communities***; and

b) design details of each watercourse crossing to avoid and mitigate impacts on ***wetlands of international importance*** and ***listed threatened species and communities***.

Standard and administrative conditions

26. Within twenty (20) business days after the ***commencement*** of the action, the person taking the action must advise ***the department*** in writing of the actual date of ***commencement***.

27. If, at any time after five (5) years from the date of this approval, the person taking the action has not ***substantially commenced*** the action, then the person taking the action must not ***substantially commence*** the action without the written agreement of ***the minister***.

28. Unless otherwise agreed to in writing by ***the minister***, the person taking the action must publish all ***management documents*** referred to in the conditions of this approval on their website, within twenty (20) business days of being approved. A ***management document*** must be published in a specified location or format and / or with specified accompanying text, if requested by ***the minister***.

29. If the person taking the action wishes to carry out any activity otherwise than in accordance with a relevant ***management document***, the person taking the action must submit to ***the department*** for ***the minister***'s written approval a revised version of that ***management document***. The varied activity shall not commence until ***the minister*** has approved the varied ***management document*** in writing. ***The minister*** will not approve a varied ***management document*** unless the revised ***management document*** would result in an equivalent or improved environmental outcome over time. If ***the minister*** approves the revised ***management document***, that ***management document*** must be implemented in place of the ***management document*** originally approved.

30. If ***the minister*** believes that it is necessary or convenient for the better protection of wetlands of international importance, or listed threatened species and communities, to do so, ***the minister*** may request that the person taking the action make specified revisions to a ***management document*** specified in the conditions of this approval and submit the revised ***management document*** for ***the minister***'s written approval. The person taking the action must comply with any such request. The revised approved ***management document*** must be implemented. Unless ***the minister*** has approved the revised ***management document***, then the person taking the action must continue to implement the ***management document*** originally approved, as specified in the conditions of this approval.

31. The person taking the action must maintain accurate records substantiating all activities associated with or relevant to the conditions of this approval, including measures taken to implement ***management documents*** required by this approval, and make them available upon request to ***the department***. Such records may be subject to audit by ***the department*** or an independent auditor in accordance with section 458 of the EPBC Act, or used to verify compliance with the conditions of this approval. Summaries of audits will be posted on ***the department's*** website. The results of audits may also be publicised through the general media.

32. ***The person taking the action*** must:

    a) report any non-compliance with these conditions or a ***management document*** to ***the department*** within five (5) business days of the date of the incident;

    b) discuss with ***the department*** how the matter may be brought into compliance within a reasonable timeframe; and

    c) comply with any consequent written direction from ***the minister*** regarding the matter.

33. By 30 November of each year after the ***commencement*** of the action, the person taking the action must publish an annual report on their website addressing compliance (including any non-compliance) with the conditions of this approval, including any ***management documents***, since the previous compliance report. The report must specifically include the following:

    a) a reconciliation statement comparing impacts on small-flower grevillea against the ***disturbance limit*** for the species;

    b) a summary of well activity for the past year, including:

        i. number and spatial distribution of extant wells (mapped and also expressed in latitude, longitude and depth);

        ii. identification of which wells are new, continuing, inactive and exhausted since the previous compliance report;

        iii. information on how many times each well has been hydraulically fractured;

        iv. information on all hydraulic fracturing agents and other reinjected fluids as per Condition 20;

        v. information on volumes of gas and water produced by each well; and

        vi. identification of which wells have been implicated in incidents of non-compliance.

    c) a forecast of well activity (including hydraulic fracturing) for the coming year.

34. Upon the direction of ***the minister***, the person taking the action must ensure that an independent audit of compliance with the conditions of this approval is conducted (at the expense of the person taking the action) and a report submitted to ***the department***. The independent auditor and audit criteria must be approved by ***the minister*** prior to the commencement of the audit. The audit report must address the criteria to the satisfaction of ***the minister***.

35. The person taking the action must provide all data and related information from ecological surveys relevant to this approval or otherwise to ***matters of national environmental significance***, if requested by ***the department***.

36. The person taking the action must provide ***the department*** with a copy of any management document required under a state government approval, if requested by ***the minister***.

Definitions applying to the conditions

Clearance of native vegetation means the complete or partial removal, by any means, of plants native to the site of the action. Note that native vegetation can include grasslands.

Commencement of the action (except in the sense of ***substantial commencement***), includes the construction of any infrastructure associated with the proposed action, excluding geotechnical and survey works, signage, fencing, unsealed roads not requiring ***clearance of native vegetation***.

Completion of the action includes all rehabilitation and remediation works planned or required under these or any other conditions on approval, noting that this approval expires on 30 November 2062.

The ***components of the action*** are:

- areas of the Stage 1 Gas Field as defined by the proponent
- the central processing facility (at either of the proposed locations)
- areas of the pipeline route as defined by the proponent

A ***disturbance limit*** is the maximum impact (expressed as an area or a number of individuals) on wetlands of international importance or listed threatened species and communities that may occur as a direct consequence of the action before specified consequences are triggered. Disturbance limits do not apply to indirect impacts such as impacts of the action on water resources that may affect protected matters.

Management documents are any plans, strategies, reports or other documents required by the conditions of this approval that direct or report on management arrangements for the proposal. To avoid any doubt, multiple management documents (including those required under a state approval) may be combined, provided that the person taking the action, when submitting the documents, explains how they have been arranged.

Matters of national environmental significance are as defined in the EPBC Act, and include ***wetlands of international importance***, and ***listed threatened species and / or communities***.

National Water Quality Management Strategy is the policies, processes and guidelines in effect at the time of approval that together comprises the National Water Quality Management Strategy.

Offset means "compensate for", and is interpreted in light of the *Environment Assessment and Biodiversity Conservation Act 1999 Environmental Offsets Policy*, October 2012 (or as updated).

Phase 1 refers to a completed desktop study, *Preliminary Groundwater Assessment and Initial Conceptual Hydrogeological Model*. SRK Consulting, 2010.

Phase 2 refers to a detailed groundwater investigation initiated in November 2010, as described in information provided by the person taking the action 1 August 2011.

A ***shapefile*** is an ESRI Shapefile, containing .shp, .shx and .dbf files and other files capturing attributes including at least the EPBC reference number of the proposaland matters of national environmental significance present at the relevant site Attributes should also be captured in .xls format.

State approval conditions are those conditions imposed by the NSW Planning Assessment Commission on the Gloucester Coal Seam Gas Project under section 75J of the *Environmental Planning and Assessment Act 1979* and reflected in the corresponding project approval notice signed 22 February 2011.

Substantial commencement means the drilling of any wells subject to this approval, to a depth of at least 100 metres.

The department is the Australian Government department administering the ***EPBC Act***.

The ***EPBC Act*** is the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

The minister is the Australian Government minister administering the ***EPBC Act*** and includes delegates of ***the minister*** as established by a relevant legal instrument.

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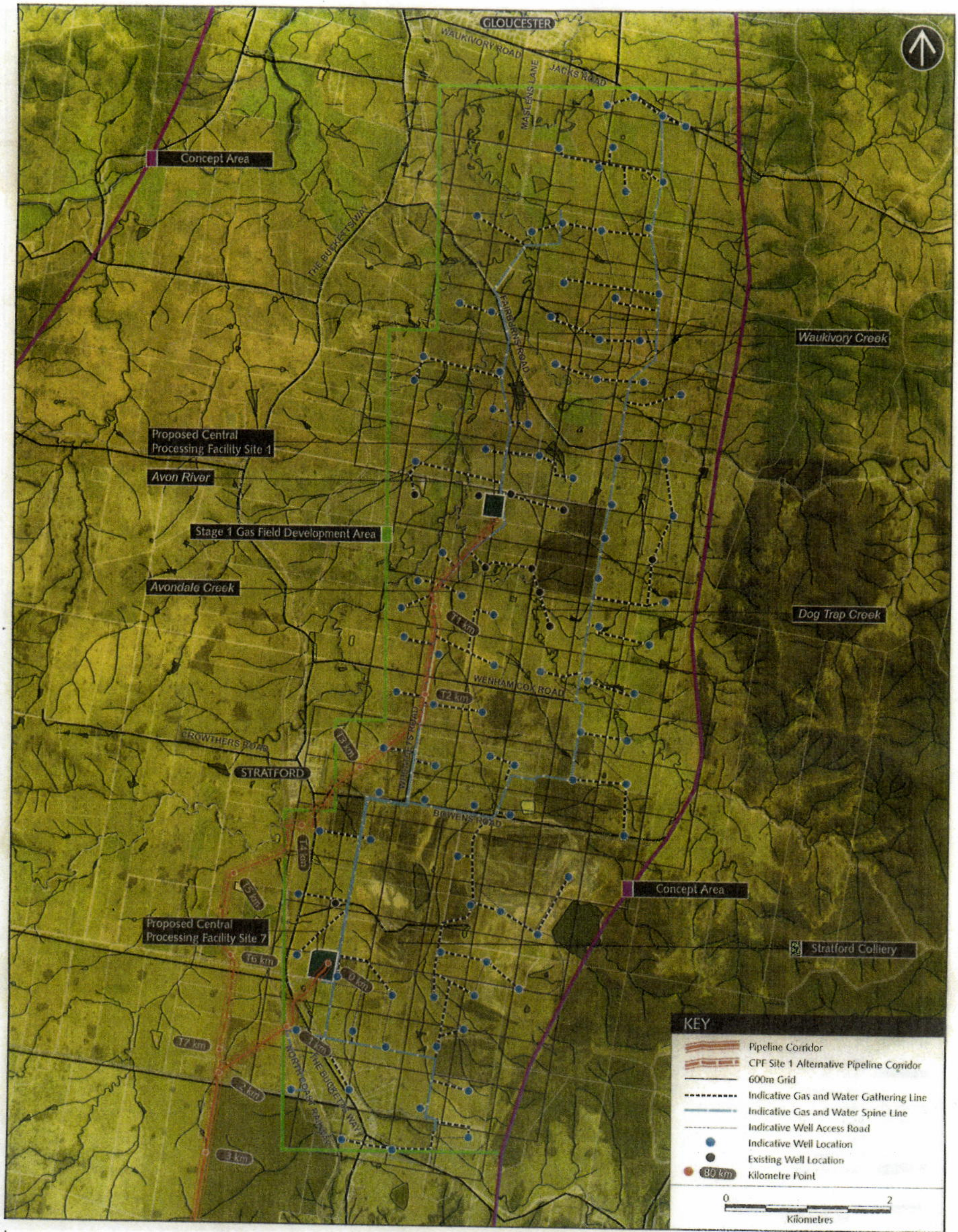

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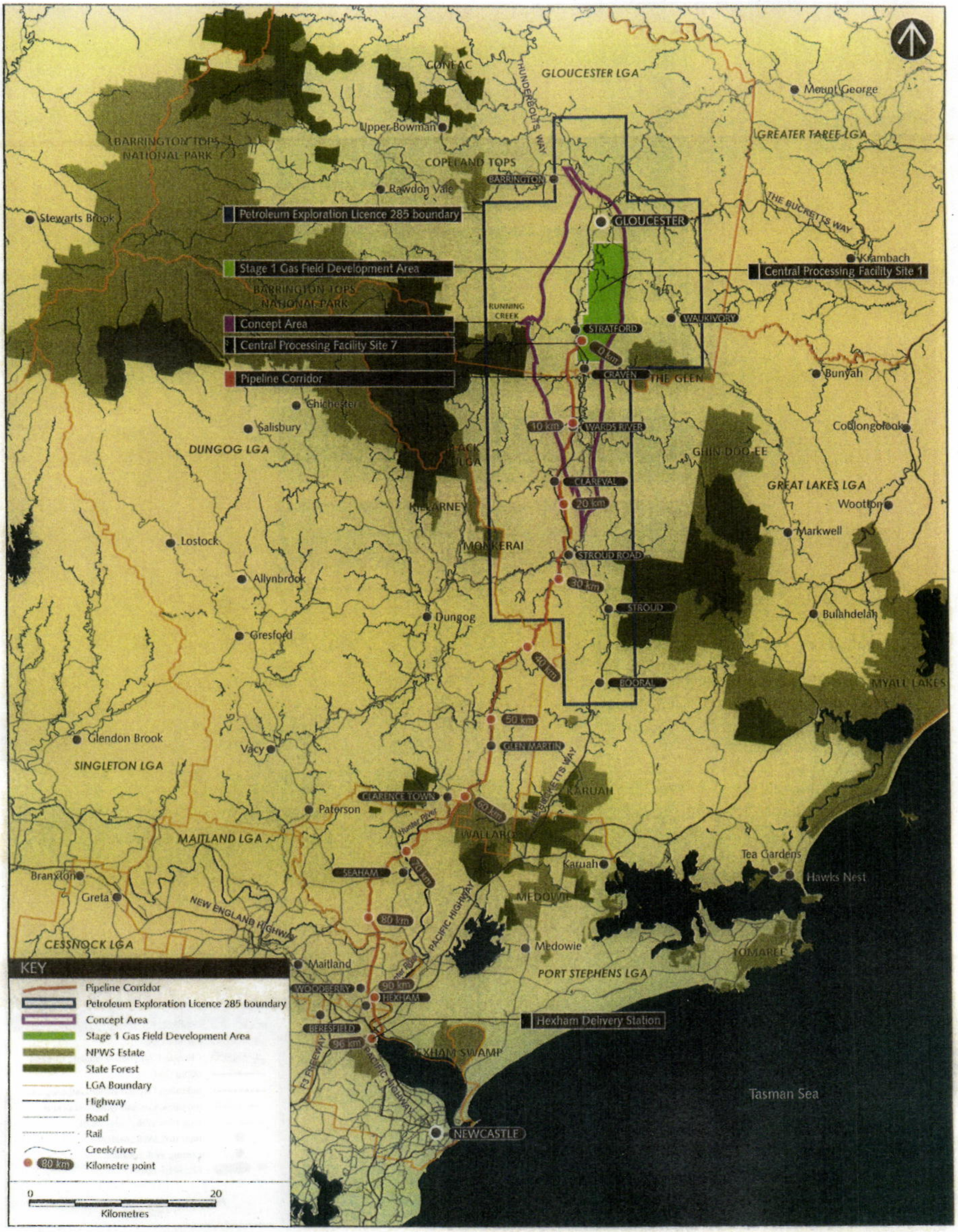
GLOUCESTER GAS PROJECT - STAGE 1 GFDA

<u>Attachment 1</u> – Stage 1 Gas Field Development Area



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GLOUCESTER GAS PROJECT LOCATION AND PEL 285 BOUNDARY

Attachment 2 – Pipeline Corridor