Groundwater Management Plan for the Camden Gas Project

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Document Revision History

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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.
Anthropogenic	Occurring because of, or influenced by, human activity.
Aquiclude	A very low permeability unit that forms either the upper or lower boundary of a groundwater flow system and does not transmit water or allow water to migrate from upper and lower horizons.
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 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.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Claystone	A non-fissile rock of sedimentary origin composed primarily of clay-sized particles (less than 0.004 mm).
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.
Confining bed	Low permeability strata that may be saturated but will not allow water to move through it under ordinary hydraulic gradients.
Contamination	Contamination is the presence of a non natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Control Sites	Dedicated monitoring bore sites distant from any well pad so as to avoid severe areas of depressurisation.
Dewatering	The process of removing formation water from a targeted coal seam. Dewatering is required to reduce pressure in the coal so gas can desorb and produce.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Drawdown	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.
Electrical conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity.

Flowback	The process of allowing fluids to flow from a gas well following a treatment (such as fracture stimulation), either in preparation for a subsequent phase of treatment or in preparation for cleanup and returning the well to production.
Formation water	Natural groundwater occurring within the pores of rock.
Fracture stimulation	See hydraulic fracturing.
Fractured rock aquifer	Aquifers that 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 aquifers.
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
GMP	Groundwater Management Plan
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.
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 fracturing	A fracture stimulation technique that increases a gas well's productivity by creating a pathway into the targeted coal seam by injecting sand and fluids through the perforated interval directly into the coal seam under high pressure.
Key Indicator Sites	Dedicated monitoring bore sites within 400m of a well pad location to assess any connectivity and drainage from shallow aquifers as this will be the area of greatest depressurisation.

microSiemens per centimetre (µS/cm)	A measure of water salinity commonly referred to as EC (see also Electrical Conductivity). Most commonly measured in the field with calibrated field meters.
Monitoring bore	A non-pumping bore 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.
NOW	New South Wales Office of Water
pH	Potential of Hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic).
Piezometer	See monitoring bore or vibrating wire piezometer (as appropriate).
Piezometric surface	The potential level to which water will rise above the water level in an aquifer in a bore that penetrates a confined aquifer; if the potential level is higher than the land surface, the bore will overflow and is referred to as artesian.
Produced water	Groundwater generated from coal seams during flow testing and production dewatering.
Proppant	Sand or synthetic high strength particles used during fracture stimulation to fill the fracture space and hold the fracture open during the production life of a well.
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.
Sandstone	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).
Sandstone aquifer	Permeable sandstone that allows percolation of water and other fluids, and is porous enough to store large

	quantities.
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.
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.
Shale	A laminated sediment in which the constituent particles are predominantly of clay size.
Siltstone	A fine-grained rock of sedimentary origin composed mainly of silt-sized particles (0.004 to 0.06 mm).
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.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Vibrating wire piezometer	A vibrating wire piezometer measures pore pressure and consists of a vibrating wire pressure transducer and signal cable. It can be installed in a borehole, embedded in fill or suspended in a standpipe.
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 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.
Zonal isolation	Isolating an interval or unit of rock from surrounding rock types on the basis of its lithology or other features, such as faults or fractures.

1 Introduction

This Groundwater Management Plan (GMP) has been prepared as a condition of licence attaching to all the industrial bore licences issued for the Camden Gas Project (CGP) by the NSW Office of Water (NOW). This GMP also satisfies condition U2 of Environment Protection Licence (EPL) 12003, which requires a GMP for the CGP.

The plan has been prepared by John Ross Manager Hydrogeology at AGL Energy and the interim plan has been independently peer reviewed by Liz Webb (Senior Hydrogeologist) at Parsons Brinckerhoff (PB). The peer review is available by request.

1.1 Objectives

The purpose of the GMP is to provide a framework which describes how AGL will assess any changes in the different groundwater systems located beneath the CGP area, particularly the shallow beneficial aquifers, due to dewatering of the deep coal seams. The primary risks to groundwater to be assessed are:

- The connectivity of shallow aquifers and the deep water bearing zones, and
- The contamination of shallow aquifers.

The objectives of this GMP are therefore to:

- Describe the water level and water quality monitoring network across the different groundwater systems located beneath the CGP area;
- Build a database of baseline information (both water levels and water quality for shallow beneficial use aquifers) located beneath the Camden North extension area;
- Identify water level and water quality trends that may suggest connectivity or contamination of aquifers due to dewatering activities;
- Provide a monitoring (and an action response) framework for water users and regulators on the groundwater monitoring program at Camden; and
- Outline the reporting and review requirements for the monitoring program.

1.2 Responsibilities

AGL Upstream Investments Pty Ltd (AGL) is responsible for compliance with this GMP. The gas production well monitoring (water quality sampling and tracking of produced water volumes) is undertaken by AGL Operations staff based at the Rosalind Park Gas Plant (RPGP) at Menangle Park. The nested monitoring bore monitoring programs are carried out by PB.

AGL is responsible for compiling the annual technical reports required by NOW in accordance with individual bore licences and this GMP. The GMP may also be useful in any future regulatory requirements that are initiated by the Environment Protection Authority (EPA) and the Department of Planning and Infrastructure (DoPI).

AGL is also responsible for any remedial action that may be required as a result of monitoring trends that are deemed beyond the normal seasonal range and are considered unacceptable (see approach and criteria in Section 5.5).

Response triggers will be developed in combination with the NSW Office of Water (NOW) within two years of monitoring data collection (i.e. by February 2014). A summary of the individual roles and responsibilities are provided in Table 1.

Table 1: Groundwater Management Roles and Responsibilities

Role	Responsibility	Frequency
Preparation and review of GMP	AGL Upstream Gas - Manager Hydrogeology	Annually in June each year
Peer Review of the GMP	Parsons Brinckerhoff – Senior/Principal Hydrogeologist	Every time a major change and the GMP is resubmitted to NOW/EPA
Gas Wells		
Water level monitoring within the CGP	AGL Upstream Gas (Camden) – Production Operations Manager	See Note 1
Water quality monitoring within the CGP	AGL Upstream Gas (Camden) – Environment Manager	Quarterly (see Section 5.3)
Dewatering volumes within the CGP	AGL Upstream Gas (Camden) – Production Operations Manager	Monthly (see Section 5.3)
Monitoring Bores		
Water level monitoring within the CGP	Parsons Brinckerhoff	Continuous (dataloggers) Quarterly (manual dips)
Water quality monitoring within the CGP	Parsons Brinckerhoff	Baseline (new areas) – 2 events Ongoing (operational areas) – 1 event every 2 years
Compliance Matters		
Annual (NOW) Bore Licence Compliance Report	AGL Upstream Gas - Manager Hydrogeology	Annual report by 30 September each year
Response triggers and actions	AGL Upstream Gas - Manager Hydrogeology	As required
Audits and actions regarding compliance	NOW – Regional Hydrogeologist/Licensing Manager – Parramatta Office	As required
Annual (EPA) EPL Compliance Report	AGL Upstream Gas (Camden) – Environment Manager	Annual report by 20 February each year

Notes: (1) water level monitoring is not possible within operational gas wells but levels are generally within the perforated interval of each well when operational

1.3 Reporting requirements

As part of the EPL 12003, AGL is required to prepare and submit to the EPA by 31st July 2012 a GMP for the premises and any proposed expansion areas. This report is the GMP. The reporting requirements as defined in section U2.2 of the EPL 12003 and the sections they relate to within this report are shown in Table 2.

Table 2: Reporting requirements as defined in EPL 12003

Reporting requirements as outlined in section U2.2 EPL12003	Section within this document
i) The construction, operation, monitoring and	Sections 2.3, 4, and 5.2

	abandonment of gas production wells;	
ii)	The monitoring network and frequency relating to water levels (pressures), water quality, and dewatering volumes; and	Sections 5.2, 5.3 and 5.4
iii)	Response triggers for investigation (and if required) remedial action	Sections 5.5 and 5.6

This GMP has also been prepared as a condition of licence attaching to all the industrial bore licences issued for the CGP by NOW. The reporting requirements as defined within the bore licences are addressed in Chapter 4.

2 Background

This chapter provides background information relating to geology, hydrogeology, the current wellfield layout and future development proposals for the Camden Gas Project (CGP). In this report the location where the established operational gas wells are is referred to as the existing CGP area (Figure 1), while the area located to the north, where future development of a gas field is planned, is referred to as the northern expansion area (Figure 2). More details are provided in the initial desktop study for the CGP (CM Jewell, 2001), Phase 1 groundwater investigation report for the northern expansion area (PB, 2011) and the 2010-11 bore licensing compliance report (AGL, 2011a).

2.1 Geological and Hydrogeological Setting

2.1.1 Regional and Local Geology

The whole of the CGP is located within the Southern Coalfield of the Sydney Geological Basin. The Sydney Basin is sedimentary in origin and the deposition of sediments occurred from the early Carboniferous (290 million years ago) through to the latter part of the Triassic (200 million years ago). The Sydney Basin on-laps the Lachlan Fold Belt to the west and south, with basin depth increasing to the north and east.

The geological strata of the Sydney Basin (from youngest to oldest) can be summarised as:

- Unconsolidated alluvial deposits along the major rivers and dune/beach deposits along the coast (Tertiary and Quaternary in age).
- Fractured volcanic intrusive and flows (and associate dyke swarms and occasional sills) within the Sydney Basin (Jurassic and Tertiary in age).
- Sedimentary rocks (including substantial coal measures at depth) of the Sydney Basin (Permian and Triassic age).
- Fractured basement rocks below the Sydney Basin (Palaeozoic age).

Locally the stratigraphy of the CGP area (from youngest to oldest) can be summarised as:

- Alluvial sediments (sand, gravel, silt and clay) overlie the Wianamatta Shales and Hawkesbury Sandstone along the major rivers and creeks. These sediments are rarely more than 20 m thick.
- Wianamatta Group: where alluvial deposits are not present, the Triassic Wianamatta Group comprises the surficial geology over most of the CGP area. It can be very thin to more than 100m thick in some of the more elevated areas. The Wianamatta Group primarily comprises shales, with occasional calcareous claystone, laminate and coal. Ashfield Shale is the most widespread rock type, at surface, across the area.
- Mittagong Formation: separates the Ashfield Shale from the underlying Hawkesbury Sandstone. It is a thin layer (generally less than 10 m thick) comprising dark grey to grey alternating beds of shale laminate, siltstone and quartzose sandstone.
- Hawkesbury Sandstone: alluvial in origin, with a thickness of approximately 200 m in the Camden area. Sandstone thicknesses increase to the north. The Triassic Hawkesbury Sandstone is generally medium to coarse grained quartz sandstone, with interbedded siltstone, finer grained sandstone and shale lenses. Shale lenses are common within this formation.

- Narrabeen Group: the total thickness of these Triassic rocks is approximately 450 m across the CGP area.
    - Gosford Sub-group (Triassic): Newport Formation is medium grained, light to dark grey, quartzose sandstone interbedded with siltstone. Garie Formation is a thin, cream kaolinite claystone, which grades upwards to grey.
    - Clifton Sub-group (Triassic): Bald Hill Claystone is grey to red/brown claystones and mudstones, occasional siderite nodules and generally softer than the overlying Garie Formation. Bulgo Sandstone is white to grey coarse grained sandstone, fining upwards to coarse pebbly sandstone, with interbedded siltstone. Stanwell Park Claystone comprises alternating light grey/green to brown sandstone and claystone intervals, with minor conglomerate. Scarborough Sandstone is fine to very coarse grained, white to grey sandstone, with occasional siltstone and conglomerate laminae. Wombarra Claystone consists of light grey/green to dark grey claystone, siltstone, mudstone with minor quartz lithic sandstone and conglomerate.
- Illawarra Coal Measures: the sedimentary thickness is approximately 300 m in the central area of the Southern Coalfield. The upper sections of the Permian Illawarra Coal Measures (Sydney Sub-group) contain the major coal seams: Bulli, Balgownie, Wongawilli, Tongarra and Woonona. The underlying Cumberland Sub-group generally contains thin coal seam development.
- Shoalhaven Group: The Permian Budgong Sandstone is shallow marine to littoral, typically comprising fine and course grained sandstone.
- Basement geology: The Southern Sydney Basin Permian and Triassic rocks have been deposited upon early to middle Palaeozoic basement rocks. These rocks consist of intensely folded and faulted slates, phyllites, quartzite sandstones and minor limestones of Ordovician to Silurian age.

2.1.2 Regional and Local Hydrogeology

Thin Tertiary and Quaternary alluvial deposits occur in valleys, creeks and river beds across the region. The unconfined aquifers within the alluvium are responsive to rainfall and stream flow, and are a useful aquifer across the region for stock and small scale irrigation purposes.

The Wianamatta Group shales are characterised by saline groundwater due to marine deposition, and are generally not considered beneficial aquifers. The shales are generally low permeability, occasionally have minor aquifers but mostly behave as aquitards. The underlying Mittagong Formation is low permeability and is not considered an aquifer.

The Hawkesbury Sandstone is a dual porosity regional aquifer system that occurs across the whole of the Sydney Basin. Groundwater flow is variable throughout the Hawkesbury Sandstone, and is generally dominated by secondary porosity and fracture flow when associated with structures such as faults and fracture zones. The primary porosity of the rock matrix is low, and a water bore that does not intercept major fractures or fissures is likely to yield less than 2 litres per second (L/s). Where Hawkesbury Sandstone outcrops at surface there is rainfall recharge and there is fresher water in the sandstone aquifers. There is a wide range of water quality from these aquifers across the region from fresh-brackish to moderately saline. In areas where the sandstone is not exposed, the water quality within the upper sections of the Hawkesbury Sandstone is often poorer than the lower sections due to leakage of salt from the overlying shale formations. The Hawkesbury Sandstone is the major (semi-confined) aquifer across the region.

The sandstone formations within the Narrabeen Group (predominantly the Bulgo Sandstone and the Scarborough Sandstone) are considered minor (confined) aquifers. These formations are generally considered to be much lower yielding and of poorer water quality then the overlying Hawkesbury Sandstone. They are not used for water supply purposes.

Coal seams, such as those present in the Permian Illawarra Coal Measures, generally form minor water bearing zones. Groundwater associated with coal seams is generally poor in quality, with moderate to high salinities. These zones are not used for water supply.

Locally the greatest thickness of Quaternary alluvium is along the floodplain of the Nepean River, although there are minor occurrences along tributaries, and other sediments associated with residual Tertiary terraces. The alluvial deposits are generally shallow, discontinuous (except along the Nepean River) and relatively permeable. The unconfined aquifers within the alluvium are a useful aquifer across the local area.

The aquifers within the Hawkesbury Sandstone are mostly primary permeability aquifers in the local area because of the lack of major fracturing and fault systems. Yields are highest and salinities are freshest south of the Nepean River because of the proximity to recharge areas, however north of the Nepean River, the salinities increase and become moderately saline in all aquifers within the sandstone. Beneficial uses are generally stock and limited domestic/irrigation use south of the Nepean River and generally limited stock use north of the Nepean River.

Locally the groundwater conditions in the deeper Narrabeen Group and Illawarra Coal Measures are the same as occur in the wider region.

To conclude, the only beneficial aquifers (used for water supply) across the CGP area are the shallow alluvial aquifers (where present) and the porous and fractured rock aquifers within the Hawkesbury Sandstone. There is no surface expression of any of the deeper groundwater systems and consequently there are no groundwater dependent ecosystems associated with any of the sedimentary rock groundwater systems.

2.2 Phase 2 Site Groundwater Investigations

Investigations are currently under way in the northern expansion area to characterise the shallow groundwater systems and to install monitoring bores so as to monitor and protect any shallow beneficial aquifers. Nested monitoring bore locations (into the Wianamatta Shale and Hawkesbury Sandstone) are proposed at each of three locations (see Section 5.2). Permeability, water level, water chemistry and isotope information is being obtained from each site so as to establish baseline conditions in advance of any future development.

These nested monitoring bores are located in both areas close to wells (in undisturbed strata) and in background locations (in areas with minor faulting systems). The nested monitoring bores located close to well sites will enable assessment of any connectivity and drainage from shallow aquifers, as a direct result of CSG dewatering operations. The nested monitoring bores located in background locations, away from any wells will be positioned in a zone of minor faulting within the coal seams; this will allow for assessment of any potential pathways between shallow and deep aquifers/water bearing zones as a result of the fault systems.

Similar nested monitoring bores and studies may be undertaken in the existing CGP area. A final decision on whether extra sites will be required will be made in 2013/14 after the commencement of the P&A conversion program (see Section 5.2.2).

2.3 Production Wellfield

The CGP is owned and operated by AGL Upstream Investments Pty Ltd, and is located in the Macarthur region 60 km southwest of Sydney, in the Wollondilly, Camden and Campbelltown Local Government Areas. The CGP has been producing gas for the Sydney region since 2001 and currently consists of 138 gas wells, low-pressure underground gas gathering pipes and a gas plant facility. Not all production wells are currently operational. Most are licensed under the *Water Act (1912)* except for a few that are suspended and planned to be plugged and abandoned.

AGL holds five Petroleum Production Leases (PPLs 1, 2, 4, 5 and 6) and a Petroleum Exploration Licence (PEL 2) in the area under the *Petroleum (Onshore) Act 1991 (POA)* enabling exploration and the production, gathering and sale of coal seam methane gas (referred to throughout the GMP as CSG).

The well surface locations or well sites are scattered throughout the PPLs and have been determined following extensive geological exploration and analysis. Locations are mostly in areas of undisturbed (essentially flat lying) strata and away from fault systems, in order to maximise gas flow.

Once the preferred geological target areas have been identified, the well site selection process then considers the environmental and social constraints of the area. These include land use (existing and future), topography, subsurface geology, flora and fauna, archaeology and noise. This detailed design information becomes part of the environmental assessment and approvals process for new gas fields and facilities.

Wells are named and numbered according to a two letter abbreviation of the well field so that each well, even if it is co-located with a number of other wells, has its own unique name, for example EM17 or MP30.

A gas well generally has four main stages in its life cycle which are outlined below:

1. Drilling (construction and fracture stimulation (where required), includes associated civil construction);
2. Commissioning (flowback, includes initial rehabilitation of the surplus construction area);
3. Production (dewatering, operation and maintenance); and
4. Well closure, abandonment and final rehabilitation.

2.3.1 Well Construction

The production wells within the fields comprise a mixture of vertical, deviated and horizontal wells. The latest drilling programs have been entirely horizontal wells with multiple wellheads on single pads so as to minimise the land use impacts. The two well types are:

- Vertical and Deviated Drilling: Vertical and deviated wells (all of which have been fracture stimulated) are the primary gas well type in the CGP area. Wells are drilled vertically or at a deviation to a maximum of 45° (for deviated wells) to intercept the Bulli and Balgownie Coal Seams. Wells have multiple casings with a conductor casing near surface (6-30m depending on the shallow sedimentary environment) to support surface formations and avoid any cave ins near surface during drilling operations, a surface casing to around 120 – 140 m (depending on the location) to exclude shallow aquifers and a production casing to full depth. All casings are pressure cemented in place.
- Horizontal Drilling / Surface to In-Seam (SIS): Horizontal wells are used to increase the drainage area of a reservoir and provide a means of stimulating the

reservoir through the drilling process. Like vertical wells, horizontal wells also have steel conductor and surface casing which is pressure cemented in place to exclude shallow aquifers. The well is drilled vertically from the surface and gradually builds angle so as to intersect the seam near parallel with the seam dip angle. Once intersected, this portion of the well bore is cased, cemented and a smaller hole is subsequently drilled through the seam anywhere from about 1300 to 2500m. It allows a significant reduction in the number of surface locations along with the ability to access previously sterilised gas reserves.

Shallow beneficial aquifers (which in this area are mostly less than 150m from surface in the alluvium and shallow sandstone but occasionally up to 300m from surface in the Hawkesbury Sandstone) are protected by up to four barriers within the well construction: two steel and two cement barriers. The well construction design incorporates numerous contingencies to ensure zonal isolation between coal seams and other formations including the shallow aquifers. Aside from the important environmental considerations, zonal isolation is important for gas production, as water migration from any other source will hinder gas production, so all precautions are taken during well construction to ensure no communication between other formations can exist with respect to the well shaft.

Gas production is maximised once local formation water is dewatered and there is minimal ongoing water contributions from coal seam and adjacent formations.

2.3.2 Fracture Stimulation

Hydraulic fracturing consists of pumping a fluid under pressure into a steel cased and cemented wellbore to create enough pressure to fracture, including opening up existing fractures in the target rock layer. It is only used in association with improving the performance of vertical and deviated gas wells by assisting to enhance or increase the natural permeability of the rock that will not otherwise allow commercial gas flows from the coal seam without stimulation. It is not used as a gas flow improvement technique associated with SIS wells because there is already a large surface area exposed within the coal seam and the wellbore.

The fluid contains a “proppant” like sand that helps prop the fractures open to allow gas to be produced to surface. The fracture stimulation fluid recipes can change from site to site and from contractor to contractor but at Camden all 117 fracture stimulation programs have been sand and water with gels to aid viscosity and minor acids and bactericides. No fracture stimulation programs have been carried out since 2009 and none are planned for new sites at Camden that involve SIS completion techniques.

Fracturing occurs at the coal seam (and only targets the coal seam), hundreds of metres below the shallow beneficial aquifers. Aside from the important water volume and water quality considerations, zonal isolation is important for gas production, as water migration from any other source will hinder gas production. All precautions are taken during fracture stimulation programs to ensure no new communication is created between targeted coal seams and other formations (such as the much shallower beneficial aquifers).

To check the integrity of well construction and any potential impacts associated with targeted fracture stimulation, groundwater monitoring networks (mostly in shallow aquifers) can be installed in reasonable proximity to selected gas wells to assess whether there are water level drawdowns or water quality changes that would indicate connectivity (this is the strategy that is being applied in the northern expansion area of the CGP). Water quality of gas production wells is also checked to ensure that all fracture stimulation fluids are recovered as part of the ‘flowback’ program, and that on completion, the water quality is natural (coal seam) formation water.

The fluid used is recovered from the well through the ‘flowback’ and dewatering processes. Essentially, what goes down the well comes back up. This is done by using a “breaker” to

react with the gel, breaking down its viscosity back to water so that the fluid's ability to flow is increased so it can be produced back to surface.

The fluid is then captured into either lined pits or to open top tanks. It is classified as a waste under the *Protection of the Environment Operations (PoEO) Act (1997)*. The fluid can be recycled for further fracture stimulation, with appropriate treatment if required or disposed of in accordance with strict environmental regulations set out in AGL's operational licences. This is usually to offsite water recycling plants.

2.3.3 Production

During the production/operational phase of a production well, the well is initially dewatered in order to initiate and maintain gas flow from the target coal seam. To maximise gas production from production wells, the water level in the wellbore must be kept below the lowest producing coal seam. Because coal seams are usually relatively shallow, low pressure formations compared to conventional gas reservoirs, it aids gas production to pump water from coal seam gas wells continuously or intermittently to minimise and maintain the lowest bottom-hole pressure and allow gas to flow into the wellbore.

In summary the producing seams are generally flowing at very low pressure and the water levels are just above or within the perforated interval. The produced water is collected onsite in 10,000 L plastic tanks, and is collected (at regular intervals) and trucked to an offsite water recycling plant. Once gas is flowing freely, there is little work required to maintain production other than monitoring, routine maintenance and removal of produced water.

2.4 Previous Approvals

Exploration drilling and production well completions have historically been approved under the *Petroleum (Onshore) Act,* while the dewatering and produced water disposal activities are approved under the *Protection of the Environment Operations (PoEO) Act 1997* (NSW). The subsequent approvals and licences issued under these Acts for the CGP cover all drilling, maintenance activities, workovers, and fracture stimulation programs.

AGL's historical programs to protect shallow beneficial aquifers include:

- Designing and constructing gas wells with multiple casings, pressure cemented to ensure long life and to exclude shallow groundwater.
- Monitoring the integrity of gas wells constructed throughout the field to ensure that steel casings are cemented to full depth and that the pressure cementing of casing strings is to surface so as to isolate all aquifers.
- Containment of all drilling/fracturing fluids in lined pits and tanks, tankering of fluids away for disposal at licensed wastewater facilities thereby minimising the potential for impacts to surface water or groundwater.
- Monitoring and recording of produced water flows from gas wells.
- Water sampling of selected gas wells to characterise the deep groundwater quality.

This information is presented in numerous well completion reports, environmental compliance reports, annual reports and sustainability reports. Water legislation requirements are now covered under *Water Management Act* and *Water Act* licences and are specifically described in this GMP.

2.5 Future Expansion

Future expansion involves a new gas development area, incorporating additional wells and associated infrastructure, to the north-east of the existing development area, and extends from the suburb of Currans Hill to the south to Denham Court in the north bound by the Hume Highway in the east and the Camden Valley Way in the west.

This northern expansion area (currently being assessed as a transitional Part 3A project under the *EP&A Act*) involves the construction and operation of 11 additional well pad locations (with up to six well heads each), the construction and operation of gas gathering and water lines and the construction of access roads. Most of the proposed gas wells are expected to be SIS well completions.

3 Water Management Framework

In NSW, drilling activities that intersect groundwater systems and groundwater abstractions from different groundwater sources are managed by the NSW Office of Water (NOW). Activities that affect the quality of the receiving waters (in this case deep groundwater systems) are managed by the Environment Protection Authority (EPA). There are numerous groundwater policies and licensing systems that apply to different areas and different projects. Only those policies and plans that are relevant to the CGP are discussed in this GMP.

The access, taking and use of groundwater in NSW is currently managed and implemented by NOW under two primary legal instruments — the *Water Management Act 2000* and the *Water Act 1912*. Activities that could potentially impact the quality of a groundwater system are managed under the *PoEO Act 1997*.

All groundwater in the CGP area is located within two groundwater sources – the Sydney Basin Nepean Groundwater Source (south of the Nepean River) and the Sydney Basin Central Groundwater Source (north of the Nepean River). These are two of 13 groundwater sources gazetted under the Greater Metropolitan Region Groundwater Sharing Plan (GWSP).

Groundwater within these water sources was managed under the *Water Act 1912* up until 30th June 2011 but is now managed under the *Water Management Act 2000* as the GWSP for the area commenced on the 1st July 2011.

3.1 Groundwater Policies

There are several overarching policies that apply to the development and management of groundwater systems across NSW. These include:

- The **NSW State Groundwater Policy Framework** (Department of Land and Water Conservation (DLWC) 1997). The NSW State Groundwater Policy Framework introduces three policy documents:
  - NSW Groundwater Quality Protection Policy (DLWC, 1998)
  - NSW Groundwater Quantity Management Policy (draft) (DLWC, 2001)
  - NSW Groundwater Dependent Ecosystem Policy (DLWC, 2002).

  The NSW State Groundwater Policy Framework aims to slow, halt or reverse degradation in groundwater resources, ensure long-term sustainability of the biophysical characteristics of the groundwater system, maintain the full range of beneficial uses of these resources and maximise the economic benefit to the region and state.

Other policies of interest include:

- Buried Groundwater Sources Policy (NOW, 2011).
- Aquifer Interference Policy (NOW, 2012).

The **Buried Groundwater Sources Policy** has been developed to set out a framework for how access to water will be managed in groundwater sources that are fully buried or partly buried (such as deep sedimentary basins).

Water sharing plans made under the *Water Management Act 2000* set limits on the availability of water by specifying a limit on the total volume of water available for extraction from water sources within the plan area. This limit is termed the long-term

average annual extraction limit (LTAAEL). Where this water is now fully allocated under a GWSP, this policy allows additional water to be allocated from groundwater storage.

Fully buried or partly buried groundwater sources have little or no surface expression (outcrop), and therefore have very little or no water available for extraction based on rainfall recharge. Fractured rock groundwater systems generally have relatively small volumes of water in storage, whereas porous rock groundwater systems can be capable of storing large volumes of water. Consequently, this NOW policy allows the release of a very small percentage of the volume of water in storage in porous rock groundwater systems (0.002% of storage).

This policy has no application in the CGP area at this time.

The **Aquifer Interference Policy** will define aquifer interference activities and describe how these will be managed under the licensing and approvals regime in the *Water Management Act 2000*. Under this legislation, a licence is usually required to be held by anyone taking water from an aquifer or river system and a separate approval is required for aquifer interference activities. The current draft policy focuses on high risk activities such as mining, coal seam gas, sand and gravel extraction, construction dewatering, aquifer injection activities, and other activities that have the potential to contaminate groundwater or result in unacceptable loss of storage or other structural damage to an aquifer.

Coal seam gas activities have been determined as aquifer interference activities and some extra approvals for the CGP may be required when this policy is finalised and introduced.

3.2 Legislation

3.2.1 Water Act (1912)

The *Water Act 1912* came into force at the turn of the last century and since 2003 has been progressively phased out (repealed) and replaced by the *Water Management Act 2000.*

All of AGL's bore licences for the CGP have been issued under the *Water Act 1912*. In the next 12 months it is expected that all the production bore licences will transition to Water Access Licences, Works Approvals and Use Approvals under the *Water Management Act 2000*.

AGL holds 136 industrial bore licences (and an allocation of 30 ML per year) for its existing CGP and associated dewatering activities from the deep coal seams. In addition AGL holds two industrial bore licences for shallow bores (and allocations of 5 and 2.4 ML per year) for its drilling and water make up operations. This GMP only relates to the CGP wellfield, dewatering activities, monitoring activities and associated compliance activities. Application for groundwater monitoring bores remains licensable under the Water Act 1912 at this time

3.2.2 Water Management Act (2000)

The *Water Management Act 2000* is gradually being introduced across NSW. Once a water sharing plan commences, the *Water Act 1912* is repealed for that water source and existing licences are converted to new consents under the *Water Management Act 2000*. The groundwater sources in the southern Sydney Basin were included in a new GWSP in July 2011; hence groundwater licences issued under the *Water Act 1912* are in the process of being converted to water access licences.

3.2.3 Aquifer Interference Approvals

Anyone undertaking an aquifer interference activity will be required to hold an aquifer interference approval unless they are specifically exempt from this requirement. The Aquifer Interference Policy will define exemptions from approval requirements based on the level of risk. The exempt activities will be those considered to pose a low risk to water sources, their dependent ecosystems and other water users. Exemptions currently include:

- Aquifer interference activities taking less than 3ML per year for access licences.
- Existing aquifer interference activities (pre 1st July 2011).

Conditional exemptions may apply where risks can be avoided or minimised by following appropriate policies, guidelines or standards.

New dewatering activities that are not exempt and any new fracture stimulation activities will require an aquifer interference approval.

3.2.4 Protection of the Environment Operations Act (1997)

The EPA has amended AGL's environment protection licence (EPL) 12003 for the CGP to require further detail in relation to groundwater management, produced water management, and best management practices relating to drilling, hydraulic fracturing, well workovers and periodic chemical treatments.

The primary intent of the new licence conditions is to ensure that groundwater systems (as receiving waters) are protected. An unusual aspect is that the targeted coal seams are not aquifers (these are poor water bearing zones) and the native water quality is slightly to moderately saline (salinity that is generally in the range 4500 to 9500 mg/L TDS).

The new conditions under the Pollution Studies and Reductions Programs section of the licence were included in EPL 12003 on 22 December 2011. They are generally consistent with the intent of the bore licence conditions that authorise well construction, development and dewatering under the *Water Act*.

3.3 Greater Metropolitan Groundwater Sharing Plan

The Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources (GWSP) commenced on the 1st July 2011 (NSW Govt, 2011).

The GWSP covers 13 groundwater sources. The Greater Metropolitan Region groundwater sources are located on the east coast of NSW, covering an area of approximately 32,500 km^2. The region spans from Broken Bay in the north, to Shoalhaven Heads in the south, and Lithgow and Goulburn to the west.

Most of the current CGP wellfield area is located within the Sydney Basin Nepean Groundwater Source. The northern expansion area of the CGP is located in the Sydney Basin Central Groundwater Source area. The Nepean River is the divide between the two groundwater sources, although hydrogeologically there is flow from south to north across this boundary.

The Sydney Basin Nepean Groundwater Source is bounded by the Nepean River to the north and the Woronora and Illawarra escarpments to the east and south. The area comprises mostly water supply catchments and the Metropolitan Dams network plus Warragamba Dam and its protected catchment. There are also agricultural and rural residential lands around the towns of Mittagong, Bowral, Moss Vale and Robertson. There are a substantial number of bores into the Hawkesbury Sandstone aquifer across this area. The total area of the Sydney Basin Nepean Groundwater Source is approximately 3,860 km^2.

The Sydney Basin Central Groundwater Source is bounded by the Hawkesbury River to the north and by the Nepean River to the west and south. A large proportion of Sydney's population resides within this groundwater source area and relatively few water bores are distributed across the area. The total area of the Sydney Basin Central Groundwater Source is approximately 3,760 km^2.

Both the Sydney Basin Nepean Groundwater Source and the Sydney Basin Central Groundwater Source do not specifically recognise the deeper groundwater contained in the Permian Coal Measures as a separate water source. However under the GWSP, all groundwater extracted from the sedimentary rocks, irrespective of the horizon from which groundwater is pumped, is authorised as part of the long-term average annual extraction limits (LTAAEL) for these two water sources.

AGL's 30 ML per year entitlement is a miniscule component of the LTAAEL that is available for allocation to consumptive users across the Nepean Groundwater Source (99,568 ML per year) and the Central Groundwater Source (45,915 ML per year).

4 Compliance Requirements

This chapter describes the bore licensing requirements and the specific conditions relating to each of the construction, operation, monitoring and abandonment activities.

4.1 Bore Licences

AGL holds 136 bore licences for the Camden Gas Project (CGP) gas production wells. Existing production gas wells have a combined allocation of 30 ML per year and are licensed for industrial purposes. An additional 30 ML per year will be sought for the northern expansion area once planning approval is received.

There are typically 15 conditions on existing gas wells and 17 conditions on proposed gas wells. There have been slight changes in conditions since the first bore licences for gas production wells were issued in February 2011. A copy of one of the bore licences for an existing gas well is attached at Appendix A, and for a proposed gas well is attached at Appendix B.

Operational gas production wells or those that are potentially operational are licensed under the *Water Act (1912)*. Older suspended wells never likely to produce again and plugged and abandoned wells are not licensed. The current list of operational/potentially operational gas production wells across the CGP (with their licence, field and local well number) is provided in Table 3.

Table 3: Licensed Gas Production Wells in the Camden Gas Project Wellfield

Licence No.	Field	Local Well No.	Licence No.	Field	Local Well No.
10BL603867	EMAI	EM02	10BL603953	Logan Brae	LB09
10BL603868	EMAI	EM03	10BL603954	Logan Brae	LB11
10BL603869	EMAI	EM04	10BL603955	Mahon	MH01
10BL603870	EMAI	EM05	10BL603956	Menangle Park	MP05
10BL603871	EMAI	EM06	10BL603957	Menangle Park	MP07
10BL603872	EMAI	EM07	10BL603958	Menangle Park	MP08
10BL603873	EMAI	EM08	10BL603959	Menangle Park	MP13
10BL603874	EMAI	EM09	10BL603960	Menangle Park	MP14
10BL603875	EMAI	EM10	10BL603961	Menangle Park	MP15
10BL603876	EMAI	EM11	10BL603962	Menangle Park	MP16
10BL603877	EMAI	EM12	10BL603963	Menangle Park	MP17
10BL603878	EMAI	EM13	10BL603964	Menangle Park	MP30
10BL603881	EMAI	EM14	10BL603965	Mt Taurus	MT01
10BL603882	EMAI	EM15	10BL603976	Mt Taurus	MT02
10BL603883	EMAI	EM16	10BL603978	Mt Taurus	MT03
10BL603884	EMAI	EM17	10BL603981	Mt Taurus	MT04
10BL603885	EMAI	EM18	10BL603989	Mt Taurus	MT05
10BL603886	EMAI	EM19	10BL603990	Mt Taurus	MT06

10BL603887	EMAI	EM20	10BL603991	Mt Taurus	MT07
10BL603888	EMAI	EM21	10BL603992	Mt Taurus	MT08
10BL603889	EMAI	EM22	10BL603993	Mt Taurus	MT09
10BL603890	EMAI	EM23	10BL603994	Mt Taurus	MT10
10BL603891	EMAI	EM24	10BL604007	Razorback	RB06
10BL603892	EMAI	EM25	10BL604008	Razorback	RB07
10BL603893	EMAI	EM27	10BL604009	Razorback	RB08
10BL603897	EMAI	EM28	10BL604010	Razorback	RB09
10BL603898	EMAI	EM30	10BL604011	Razorback	RB10
10BL603899	EMAI	EM31	10BL604012	Razorback	RB11
10BL603900	EMAI	EM32	10BL604013	Razorback	RB12
10BL603901	EMAI	EM33	10BL604014	Rosalind Park	RP02
10BL603902	EMAI	EM34	10BL604015	Rosalind Park	RP07
10BL603903	EMAI	EM37	10BL604016	Rosalind Park	RP08
10BL603905	EMAI	EM39	10BL604017	Rosalind Park	RP09
10BL603906	EMAI	EM40	10BL604031	Rosalind Park	RP10
10BL603911	Glenlee	GL02	10BL604032	Rosalind Park	RP12
10BL603912	Glenlee	GL04	10BL604033	Spring Farm	SF01
10BL603913	Glenlee	GL05	10BL604034	Spring Farm	SF02
10BL603914	Glenlee	GL06	10BL604035	Spring Farm	SF03
10BL603915	Glenlee	GL07	10BL604036	Spring Farm	SF17 #
10BL603917	Glenlee	GL08	10BL604037	Sugarloaf	SL02
10BL603918	Glenlee	GL09	10BL604038	Sugarloaf	SL03
10BL603919	Glenlee	GL10	10BL604039	Sugarloaf	SL09
10BL603920	Glenlee	GL11	10BL604040	Wandinong	WG01
10BL603921	Glenlee	GL12	10BL604041	Wandinong	WG02
10BL603922	Glenlee	GL13	10BL604042	Wandinong	WG03
10BL603924	Glenlee	GL14	10BL604043	Wandinong	WG04
10BL603925	Glenlee	GL15	10BL604044	Wandinong	WG05
10BL603926	Glenlee	GL16	10BL604045	Wandinong	WG06
10BL603927	Glenlee	GL17	10BL604131	EMAI	EM38
10BL603928	Johndilo	JD01	10BL604582	Menangle Park	MP10
10BL603929	Johndilo	JD04	10BL604597	Kay Park	KP06
10BL603930	Johndilo	JD05	10BL604623	Menangle Park	MP01
10BL603931	Johndilo	JD06	10BL604624	Menangle Park	MP02
10BL603932	Johndilo	JD07A	10BL604625	Menangle Park	MP03
10BL603933	Johndilo	JD11	10BL604626	Menangle Park	MP09
10BL603934	Joe Stanley	JS01	10BL604672	Menangle Park	MP11
10BL603935	Joe Stanley	JS03	10BL604673	Menangle Park	MP22
10BL603936	Joe Stanley	JS04	10BL604888	Menangle Park	MP25
10BL603937	Kay Park	KP01	10BL604877	Menangle Park	MP18

10BL603938	Kay Park	KP02	10BL604876	Menangle Park	MP33
10BL603939	Kay Park	KP03	10BL604874	Menangle Park	MP24
10BL603940	Kay Park	KP05	10BL604881	Spring Farm	SF01
10BL603941	Logan Brae	LB05	10BL604882	Spring Farm	SF02
10BL603942	Logan Brae	LB06	10BL604883	Spring Farm	SF03
10BL603952	Logan Brae	LB07	10BL604884	Spring Farm	SF05
			10BL604885	Spring Farm	SF07
Key			10BL604886	Spring Farm	SF08
10BL604888	Proposed well as at 30 June 2012		10BL604887	Spring Farm	SF09
10BL604881	Duplicate licence		10BL604878	Menangle Park	MP05A
10BL603931	Plugged and abandoned well		10BL604879	Menangle Park	MP12
#	Pad location only		10BL604880	Menangle Park	MP23

Total number of bore licences held: 136

There is only one monitoring bore licence at the date of this GMP that relates to the dedicated monitoring bores constructed in the northern part of the northern expansion area in late 2011 (10BL604845 refers). No special conditions attach to this licence regarding groundwater monitoring and reporting. Extra licences will be obtained as drill sites and access agreements are finalised.

4.2 Construction

The bore licence conditions that apply to the construction of gas production wells are described below and detailed in Appendices A and B. Where multiple conditions are listed, the first numbers are generally for existing wells and the last number is for proposed wells.

Condition 4 – discharge of water during construction, workovers, and operation

This condition states that "tailwater/drainage water" cannot be discharged to certain landscapes. This is interpreted to be those locations where water from drilling, workovers, and accidental releases during operation cannot be released.

AGL exceeds these requirements by ensuring that drill water and all workover water/fluids are fully contained in site in lined dams and tanks, and are removed and treated at licensed disposal facilities.

Condition na/6 – submittal of well/bore construction information

Drilling and construction information is required within two months of completion. Information to be supplied for proposed gas wells includes:

- Driller, drilling and equipment details
- Completion details
- Any pumping test information (not relevant to CSG well commissioning)
- Details of aquifers and water bearing zones
- Details of casing materials
- Details of final construction specifications

- Details of any chemicals used in drilling etc
- Details of any activity to improve hydraulic connection with the target coal seam
- Detailed description of strata
- Plan showing accurate location of the work

Condition na/7 – construct with annular seals to isolate aquifers

All gas production wells have been and will be completed with multiple casings (and pressure cemented in place) to ensure that aquifers remain isolated.

Under our five Petroleum Production Leases (PPLs) for the Camden Gas Project (PPL1, PPL2, PPL4, PPL5 and PPL6), the following pressure cementing conditions are stated and these will prevail:

According to the Schedule of Onshore Petroleum Exploration and Production Safety Requirements for casing, the specific requirements are:

- Wells are cased in accordance with good oilfield practice to ensure protection of aquifers.
- Design placement and cementing of casing strings is in accordance with good oilfield practice.
- Recovered casing cannot be used unless it has first been inspected and passed in accordance with good oilfield practice
- Conductor pipe must be installed in a well to protect the well and equipment against surface formation instability and to enable the circulation of drilling fluid from the well before surface casing is installed.
- Adequate surface casing is designed and set in accordance with good oilfield practice.
- Ensure that after cementing:
  - all casing strings except the conductor casing string are pressure tested to an approved pressure before drilling out of casing shoe; and
  - production casing string is pressure tested to an approved pressure before proceeding with operations to complete or test a well; and
  - the pressure test specified above is held for as long as is necessary to ascertain that there is not continuous pressure drop; and
  - the result of the test is recorded in the drillers log.
- Ensure that drilling operations or operations to complete or test the well do not commence until satisfactory results in the pressure tests described above are achieved.
- Ensure that every well can have each annulus pressure monitored and measured.

According to the Schedule of Onshore Petroleum Exploration and Production Safety Requirements for cementing, the specific requirements are:

- Casing strings are cemented in accordance with good oilfield practice
- Details of all cementing operations are recorded in the drillers log
- If there is any reason to suspect faulty cementing operations, an Inspector must be notified as soon as practicable.
- After cementing, the drilling is not commenced until a time lapse of:

- » 24hrs or
- » 8hrs under pressures for the surface casing string and 10hrs under pressure for all other casing strings. For this condition to be satisfied the cement must be restrained from movement by use of float valves.
- » If the cementing requirements are not achieved by primary cementing operations, then re-cementing or remedial cementing to achieve compliance must be undertaken.

Cementing operations in CSG wells are a critical application which must be designed properly to restrict fluid movement between the formations (zonal isolation) and to bond and support the casing. In addition to isolating hydrocarbons and water producing zones, cement also aids in protecting the casing from corrosion, and seals off any zones of lost circulation.

CSG wells in NSW require the isolation of water resource aquifers from hydrocarbon bearing zones. This is achieved by either cementing the production casing to surface or bringing the top of cement just above the surface casing shoe. Both of these practices ensures that all formations within the well have been isolated and are not in communication with each other.

Successful isolation requires an effective cement bond between the open hole and the casing. Centralizers should be run on the casing string to ensure casing is positioned in the centre of the well. This ensures there will be uniform cement volumes surrounding the casing. Centraliser positioning is incorporated in the casing program for the well. A cement bond log will give a good representation of the integrity of the cement job.

Cements used in CSG wells should be manufactured to API specifications. The most common API class cement used in CSG wells are Class G and A – tailored with additives to meet particular requirements. Cement designs are dependent on Depth, Wellbore Geometry, Temperature, Formation pressures, and Formation characteristics. Once cement, additives, and the source of the mix water have been selected for the cementing process; laboratory tests should be carried out to ensure proper properties of the slurry have been identified based on the wellbore characteristics. Cementing service companies will normally test cement slurries in their laboratories prior to pumping.

A float shoe or guide shoe must be installed on the bottom of the casing string. The float shoe has a check valve that allows the fluid to be pumped through it but will not allow fluid to come back up. A guide shoe does not have a check valve. A guide shoe is commonly used on shallower wells therefore are normally used in CSG wells in NSW.

A float collar is typically run one to two joints above the shoe. It also contains a check valve that will allow the cement to be pumped through it but will not allow the cement to flow back into the casing. The density of the cement is higher than the mud weight or displacement fluid. Without a float valve, cement would flow back into the casing.

Prior to pumping the cement slurry, a spacer fluid should be pumped ahead of the cement. When all the cement has been displaced; a displacement fluid should be pumped after the top plug.

Cement jobs normally contain a lead and tail slurry. The lead slurry is the first slurry pumped down the casing and is usually a lower density, higher yield slurry. The tail slurry is pumped next and is usually a higher density, higher compressive strength cement. It is good practice to ensure the higher compressive strength cement is placed around the producing interval.

After the casing is run, the well should be circulated to condition the mud and hole. Conditioning the mud reduces the viscosity making it easier for the cement to displace the mud from the hole.

Other

There are no bore licence conditions that relate to fracture stimulation activities and wastewater disposal practices. These are covered in the respective PELs, PPLs or the EPL for the Camden Gas Project.

4.3 Operation

The bore licence conditions that apply to the operation of gas production wells are described below.

Condition 5 – works must not obstruct the reasonable passage of flood waters

No wells or associated infrastructure will impede the passage of these flows.

Condition 6 / 8 – all water to be distributed by dedicated pipelines

Except during the construction, fracture stimulation and flow back periods for new gas production wells, all water is distributed via dedicated pipelines to storage tanks or receiving facilities. At Camden, all produced water goes to dedicated storage tanks beside each gas well.

Condition 7 / 9 – must install an appliance to measure extracted water volumes where flows exceed 50 KL per year

As most of the gas wells at Camden are free flowing and there is little produced water, this condition refers to relatively few gas production wells. Based on averages from the last three years of data, there are currently 17 potential wells that fit the volumetric definition of requiring volumetric water monitoring. This may change year to year as dewatering volumes diminish from wells as they mature. These sites as at 31st May 2012 are listed in Table 4.

Table 4: Gas Production Wells requiring Water Volume Monitoring

Field	Gas Production Wells
Kay Park	KP05, KP06
Menangle Park	MP05A, MP07, MP08, MP22, and MP23
Elizabeth Macarthur	EM40
Glenlee	GL15
Razorback	RB10
Rosalind Park	RP12
Sugarloaf	SL02, SL03
Spring Farm	SF05, SF07, SF08, and SF09

Meters were trialled in late 2011 but were unsuccessful due to the difficult conditions present within the tested CSG wells. Failures mostly related to coal fines clogging the meters. Water flow meters have to be intrinsically safe as they are located within each well compound where there are potentially explosive gases; hence there are few suitable meters to choose from. Produced water volumes have been, and are continuing to be, measured volumetrically in the onsite storage tanks weekly and when the tanks are emptied in order to satisfy this condition.

Condition 15 / 17 – Total volume of groundwater extracted from all gas wells must not exceed 30 ML

This is the annual volumetric allocation that applies to all gas production wells in the wellfield (although a slightly larger quantity is proposed for when the northern extension area is approved). Based on produced water volumes in recent years, this is sufficient allocation to cater for existing dewatering requirements.

4.4 Monitoring

The bore licence conditions that apply to the monitoring aspects of the wellfield are described below.

Condition 10/12 – maintain records of water quality results

A water quality monitoring network of produced water from gas wells has been established for the CGP. Details are provided in Section 5.2.4.

Condition 11/13 – install monitoring bores (if and when called upon to do so)

The first dedicated monitoring bores were drilled in the Northern Expansion area in October 2011. Details are provided in Section 5.2.

No monitoring bores have been directed to be installed by NOW at this time.

Condition 12/14 – provide all raw monitoring data to NOW

Water monitoring data is restricted to produced water volumes and produced water quality as there are currently no dedicated monitoring bores within the existing CGP wellfield area.

Water level data for the gas production wells is not able to be collected because of the pumping equipment/gas well configuration. Water levels (when wells are operational) are always within the perforated intervals for each well.

Both water level and periodic water quality data is available for dedicated monitoring bores (currently only available in the northern expansion area).

It is not expected that NOW will require raw data on an ongoing regular basis, so the proposal is to retain all data and to provide it to NOW upon request.

Condition 14/16 – right to request an audit of all groundwater monitoring data collection, archiving, and QA/QC procedures

Noted. No audits were requested in 2010/11 or 2011/12.

4.5 Abandonment

Condition 3 – proper abandonment

There is only one bore licence condition under each bore licence that applies to abandonment. Full abandonment requirements are outlined in the PEL and subsequent PPL approvals under the *Petroleum (Onshore) Act (1991)*. This one condition on the bore licence (which is based on water well minimum requirements) will be exceeded as it must be consistent with the more stringent requirements under the *Petroleum (Onshore) Act (1991)*.

Under our five Petroleum Production Leases (PPLs) for the Camden Gas Project (PPL1, PPL2, PPL4, PPL5 and PPL6) there are substantial abandonment conditions (all slightly different in their wording). The abandonment conditions from PPL5 are stated below (as an example) and these will prevail over the bore licence condition:

Clause 10 Well Abandonment:

(a) At the completion of production, steel casing must be removed from the vertical interval of any potential mineable coal seam as determined by the Director Coal and Petroleum Development. Downhole geophysical surveys and/or cameras must be used to confirm the removal of all casing throughout the prescribed interval.

(b) A well must not be plugged and abandoned except in accordance with the Schedule of Onshore Exploration and Production Safety Requirements, and any other guidelines in force from time to time.

(c) All wells must fully sealed in accordance with the Departments guidelines.

(d) The Lease Holder must, within 2 weeks of the abandonment of any well, submit to the Director-General, a report providing details on the following items:

  i) Location of the abandoned well

  ii) Termination depth of drillhole and depth to worked seam

  iii) Details of drillhole diameter and casing used

  iv) Gas and water makes and composition during drilling and production test phases. The commencement and completion dates of each phase of the operation and the dates of any other significant events

  v) The estimated and actual quantities of grout used to seal the drillhole

  vi) Evidence of removal of steel casing from the interval encompassing any potential mineable coal seam.

5 Monitoring Plan, Response Triggers and Reporting

Government (through the NSW Office of Water (NOW)) is now requiring a higher level of groundwater monitoring, and in February 2011 placed a number of monitoring program conditions on AGL's water bore licences. These generally relate to:

- A formal groundwater management plan
- More precise monitoring of pumped volumes
- Installation of dedicated monitoring bores when directed
- Collection of periodic water level and water quality data
- Annual reporting of data and trends

The objective of a dedicated groundwater network and associated monitoring program is to protect the shallowest aquifers used for water supply across the area. These are the Quaternary and Tertiary alluvial aquifers and the Triassic sandstone aquifers (predominantly the Hawkesbury Sandstone). The alluvial aquifers will be monitored where there is a gas production well located in close proximity to the alluvium (less than 1km) and access to a suitable site is possible. At the present time the focus is on the Hawkesbury Sandstone aquifers and (where present) the water table aquifer in the Wianamatta Shale.

The bore licence conditions call for the Groundwater Monitoring Plan (GMP) within 12 months and the dedicated monitoring bores within 3 years of the issue of the bore licences (i.e. by February 2012 and February 2014 respectively). This document is the final GMP for 2012. An interim GMP was submitted to NOW in February 2012.

5.1 Historical Management and Monitoring

Historically, AGL has had a number of programs in place to protect shallow groundwater resources across the CGP. These have mostly been voluntary programs and have not required any specific compliance reporting except for some elements in the Annual Environmental Performance Report (AGL, 2011c). The extent of groundwater monitoring is consistent with the low risk to groundwater identified in the initial desktop report (CM Jewell, 2001). AGL's programs to monitor and protect groundwater include:

- Designing and constructing gas wells with multiple casings, pressure cemented to ensure long life and to exclude shallow groundwater.
- Monitoring the integrity of gas wells constructed throughout the field to ensure that steel casings are cemented to full depth and that the pressure cementing of casing strings is to surface so as to isolate all aquifers.
- Containment of all drilling/fracturing fluids in lined pits and tanks, tankering of fluids away for disposal at licensed wastewater facilities thereby minimising the potential for impacts to surface water or groundwater.
- Monitoring and recording of produced water flows from gas wells.
- Water sampling of selected gas wells to characterise the deep groundwater quality.

› Tracking the performance of two AGL licensed water bores (into the sandstone aquifers) used by AGL for various purposes associated with the CGP.

This information is presented in numerous well completion reports, environmental compliance reports, annual reports and sustainability reports.

Less than 12.5% of existing gas production wells produce more than 50 KL per year of produced water when operating. More than 67% of wells produce less than 10 KL per year with many mature wells producing no groundwater at all (AGL, 2011a).

There has been no monitoring or surveys of private water supply bores across the CGP area. There are a reasonable number of bores into shallow aquifers in the existing CGP area (particularly south of the Nepean River) (73 water supply bores based on NOW Pinneena database (NOW, 2010)) however there are only five registered bores in the northern expansion area (PB, 2011). In most cases these bores are not suitable for inclusion in a dedicated monitoring network because they are pumped bores where water levels are varying continuously. Also the bore completions generally involve suspended casing and/or non cemented sections of the borehole so that water quality results may not be representative of individual aquifers.

5.2 Monitoring Network

Slightly different approaches are being applied to the existing Camden Gas Project area and the proposed northern expansion area. In the northern expansion area, where there is no development to date, establishing dedicated nested monitoring wells is considered the best approach to monitor beneficial aquifers and attain baseline data. For the existing wellfield area, baseline monitoring is not possible, so it is proposed to use depleted gas wells for monitoring the different aquifer systems; this gives us the capability of monitoring the very deep groundwater in the Illawarra Coal Measures and the Narrabeen Group as well as the Hawkesbury Sandstone aquifer.

5.2.1 Northern Expansion Area

The strategy for this area at the present time is:

› Baseline monitoring at dedicated nested monitoring bores (shallow aquifers at three sites).

AGL has commenced new dedicated groundwater monitoring networks at selected sites within the Northern Extension Area and the first of these sites was installed and became operational in November 2011. Two sites are proposed as “Key Indicator” sites while one “Control” site is planned. Key Indicator sites are those within 400m of a well pad location to assess any connectivity and drainage from shallow aquifers as this will be the area of greatest depressurisation. The Control site will be distant from any well pad so as to avoid severe areas of depressurisation.

For the Key Indicator sites, one nested set of dedicated monitoring bores has been installed in the northern expansion area (at Denham Court) and another set is proposed in the southern part of the northern expansion area in 2012 (subject to site access being finalised). The control site is likely to be in the Varroville area and is subject to site access being finalised. These nested monitoring bores are planned to be located away from any production wells and positioned near a zone of minor faulting within the coal seams; this will allow for assessment of any potential pathways associated with such structures. Summary details are provided in Table 5.

This monitoring network is being installed as part of the Phase 2 groundwater investigation study, which is being undertaken by Parsons Brinckerhoff. The study involves establishing dedicated monitoring bores at the three sites within the northern expansion area of the Camden Gas Project, detailed geological analysis of the sites, field work program

(including permeability tests, datalogger installation and groundwater quality/isotope analysis), ongoing baseline monitoring, and a comprehensive technical report once all three locations are installed and fully operational.

Table 5: Summary of Nested Monitoring Bores – Northern Expansion Area

Area	Field	Nested Monitoring Bores
Key Indicator Site Stage 3 (Northern Expansion Area) *	Raby	Denham Court RMB01 – Ashfield Shale Depth – 84 m Screened Interval – 69-81m RMB02 – Hawkesbury Sandstone Depth – 150 m Screened Interval – 135-147m RMB03 – Hawkesbury Sandstone / Newport Formation Depth – 300 m Screened Interval – 288-297m
Key Indicator Site Stage 3 (Northern Expansion Area)	Currans Hill	To be determined
Control site Stage 3 (Northern Expansion Area)	Varroville	To be determined

NB. * - These are the only dedicated monitoring bores as at June 2012.

Deeper baseline monitoring of groundwater systems below the Bald Hill Claystone is not considered warranted at the present time because:

- It is most unlikely there will be any beneficial groundwater resources below 300m depth.
- There is no historical use of any groundwater from depths greater than 300m.
- The groundwater at this depth is unlikely to be linked to any ecosystems.
- Groundwater in the Narrabeen Group sandstones will most likely be moving laterally rather than being recharged by shallow groundwater resources through the Bald Hill Claystone aquitard.
- There are two more aquitards/aquicludes below the Bald Hill Claystone (Stanwell Park Claystone and the Wombarra Claystone) that will inhibit vertical leakage.
- If the Bald Hill Claystone is leaky, the basal monitoring bore in the Hawkesbury Sandstone will also react to depressurisation and provide early warning of aquifer drainage.

If there was a water level decline in the Hawkesbury Sandstone attributable to the dewatering of coal seams at depth then a monitoring bore into the deeper strata below the Bald Hill Claystone would be installed to confirm trends. Overall the risk of a water level/water quality impact to the primary aquifers in the Hawkesbury Sandstone are considered low because the likelihood of an event is considered rare and the consequence of drainage (of a relatively small volume) is also low on AGL's risk assessment scale (it's a Level 2 on a 1 to 5 scale).

5.2.2 Stage 1/2 Existing Camden CSG Area

Currently, no dedicated monitoring bores have been installed within deeper strata or the older fields of the CGP wellfield (immediately north and south of the Nepean River). The operational gas wells themselves are used for groundwater management and operational

monitoring purposes (as described above in Section 5.1). AGL plans to have dedicated monitoring bores/piezometers at selected sites, and the following strategy is planned:

- Conversion of suspended gas wells (never likely to produce again) to vibrating wire piezometers (VWPs) in the Bulli coal seam and overlying Bulgo Sandstone. The following sites are proposed:
  - WG04
  - EM16
  - JD04
- Conversion of suspended gas wells (never likely to produce again) to monitoring bores with continuous datalogger installed within the Hawkesbury Sandstone. The following sites are proposed:
  - WG01
  - JS01
- The two Hawkesbury Sandstone water bores that AGL has access to are also to be included in the water quality monitoring network (Johndilo Bore and Logan Brae Bore).
- Installation of a monitoring bore into the shallow alluvial aquifer, within close proximity to the Nepean River (site yet to be identified).

These sites will be in addition to the 9 gas wells that have been identified for water quality monitoring and all production wells that are monitored for dewatering volumes (refer to Section 5.2.4).

The location of the gas production wells that comprise the CGP, the sites for proposed conversion from production well to monitoring bore, and the proposed wellhead locations and existing monitoring bores in the northern expansion area are shown on Figures 1 and 2 respectively.

Depending on the success of this program, if deemed necessary, dedicated monitoring bores, similar to those in the northern expansion area, may also be constructed.

5.2.3 Water Levels

There are three nested monitoring bores at the Raby field in the northern expansion area. This monitoring program commenced in late 2011 (with dedicated continuous dataloggers) and is expected to continue for the project life of the northern expansion area. Another two nested monitoring sites are proposed in the northern expansion area in 2012 that will also have dataloggers installed.

There is no monitoring of water levels (at dedicated sites) across the existing CGP area at this time. It is planned to implement a monitoring network (VWPs and open hole monitoring bores with continuous dataloggers) across several aquifers in accordance with the above strategy starting in 2012/13.

Water levels are rarely monitored in gas production wells because of the nature of the internal tubing, pumping equipment, and API wellhead configuration.

Coal is a natural water bearing zone and as such in its dormant state holds water. In order to initiate and maintain gas flow from coal, this water must continuously drain from the coal seam. Initial water can be significant but the rate will decrease over a six to 12 months period to as little as zero in some cases. To maximise gas production from coal seam gas wells, the water level in the wellbore must be kept below the lowest producing coal seam. Because coal seams are usually relatively shallow compared to conventional gas reservoirs, low pressure formations, it aids gas production to pump water from coal

seam gas wells continuously or intermittently to minimise and maintain the lowest bottom-hole pressure and allow gas to flow into the wellbore. In summary the producing seams are generally flowing at very low pressure and the water levels are just above or within the perforated interval.

5.2.4 Water Quality

Baseline water quality monitoring data has been recorded at the nested monitoring bores at the Raby field in the northern expansion area.

Some 15 gas wells across the existing CGP area were water sampled in 2010/11 and continued in 2011/12 to determine the most appropriate network to assess deep groundwater quality. A network of 9 (gas well) sites has now been selected for ongoing monitoring and these are listed below in Table 6. The sites were chosen predominantly on the basis of their geographic spread and the fact that they produce deep formation water when depressurised. The current sites are shown on Figure 1.

As is the nature of coal seam gas wells, water production significantly decreases over the life of the well. Therefore, a nominated production well may not produce sufficient water in the future to carry out routine monitoring. If a well does not produce sufficient water to sample three times out of the four scheduled monitoring rounds in any given water year the well will be removed from the network and, if possible, replaced with a more suitable well from that area.

The water samples from individual wells together with combined total water ('batch') samples are also used to assess the suitability of these waters for reuse or disposal. Batch water samples taken through the year are not part of this GMP. Currently all produced water is trucked offsite to a licensed wastewater recycling facility.

Table 6: Water Quality Monitoring Network – Camden Gas Project

Location	Well type	Field	Comments
EM40	Free flowing, vertical well, water/ sand frac	EMAI	Moderate volume well (10 - 50 KL pa)
RB10	Pumping, vertical well, nitrogen/ sand frac	Razorback	High volume well (> 50 KL pa)
RP12	Pumping, vertical well, water/ sand frac	Rosalind Park	Moderate volume well (10 - 50 KL pa)
SL03	Pumping, vertical well, water/ sand frac	Sugarloaf	High volume well (> 50 KL pa)
SF08 *	SIS well, free flowing	Spring Farm	High volume well (> 50 KL pa) - Has high coal fines
MP12 *	SIS well, pumping	Menangle Park	Moderate volume well (10-50 KL pa)
MP17	Pumping, vertical well, water/ sand frac	Menangle Park	Moderate volume well (10- 50 KL pa)
MP30	Free flowing, SIS well, water/sand frac	Menangle Park	Moderate volume well (10- 50 KL pa)
MT05	Pumping, vertical well, water/ sand frac	Mt Taurus	Moderate volume well (10-50 KL pa)

Legend * alternative for SF08 is SF01 and for MP12 is MP22

When water samples are taken in the field the following field parameters are measured and recorded – electrical conductivity (EC), TDS, pH, temperature, Eh, and dissolved oxygen.

The analytical suites listed in Table 7 have been adopted for AGL's CSG water sampling programs from August 2010. All analyses have been undertaken by NATA accredited laboratories. This suite is under review and may be slightly expanded based on EPA's requirements under the recent changes to EPL 12003. The DRAFT expanded suite is listed in Appendix C.

The **Comprehensive suite** is used for at least one sampling (gas well) event per annum. It has also been used for the baseline event from new nested monitoring bores. The **Intermediate suite** is unlikely to be used for the CGP monitoring program at this time. The **Basic suite** is for all other sampling events and is mainly used for tracking major salinity / chemistry changes in the CSG produced water (wells and ponds).

The basic suite contains the field parameters, major ions and dissolved metals, the intermediate suite is the same plus total suspended solids and nutrients, while the comprehensive suite is everything in this list.

Major changes in produced water quality from a saline water quality signature would trigger investigations and repeat sampling to identify the source. Any significant changes in the basic suite would trigger either repeat sampling or an intermediate or comprehensive sampling event.

Table 7: Laboratory analytical suites

Category	Suites			Parameters	
Check on Field Parameters	Basic	Intermediate	Comprehensive	Electrical conductivity and TDS	
Major ions				*Cations*	*Anions*
				calcium	chloride
				magnesium	carbonate
				sodium	bicarbonate
				potassium	sulphate
Dissolved metals and minor / trace elements				aluminium	lead
				arsenic	manganese
				barium	mercury
				beryllium	molybdenum
				boron	nickel
				bromine	selenium
				cadmium	strontium
				chromium	uranium
				cobalt	vanadium
				copper	zinc
				iron	
Other analytes				Fluoride	Silica
Total Suspended Solids				TSS	
Nutrients				Nitrate	Reactive phosphorous
				Nitrite	
				Ammonia	
Dissolved gases				Methane	
Hydrocarbons				Phenol compounds	Total petroleum hydrocarbons (TPH)/ benzene, toluene, ethyl benzene and xylenes (BTEX)
				Polycyclic aromatic hydrocarbons (PAH)	

5.3 Monitoring Frequency

Historically the primary proof that shallow aquifers were protected was the integrity of gas production well construction and the diminishing produced water volumes (that have always been monitored at least monthly).

Water levels are now an additional primary proof of any shallow groundwater impacts associated with CSG dewatering in new areas, so dataloggers are being installed at key sites in the northern expansion area to continuously collect water level/pressure data. Dataloggers will also be installed in new nested monitoring bores and converted gas wells (where converted to monitoring bores) as they are completed.

Produced volumes continue to be monitored at all gas production well sites, and water quality is increasingly being used to assess natural trends and any changes in the integrity of gas wells.

5.3.1 Water Levels

Water levels are rarely monitored in gas production wells because of the nature of the internal tubing, pumping equipment, and API wellhead configuration. Occasional water levels are obtained during production and workovers (using sonologs) but ongoing water level data is not available routinely from gas production wells (see also Section 5.2.3 for explanation).

Continuous water level monitoring is in place at all nested monitoring bores in the northern expansion area. This monitoring program commenced in November 2011 and is expected to continue for the life of the expanded CGP in this area. Water level checks are maintained quarterly when each of the dataloggers is downloaded.

5.3.2 Water Quality

The water quality monitoring frequency for the nested monitoring bores in the northern expansion area is a baseline sample in late 2011, then another sampling event immediately prior to the construction/commissioning of any gas production wells (or two years, whichever is the lesser). For these baseline events, comprehensive suites are proposed (plus an isotope sampling program during the initial baseline event).

Once the northern expansion area wellfield becomes operational, the nested monitoring bores would be monitored for (basic) water quality once every two years unless other results indicate significant changes, whereby the frequency would be increased. In addition, a selection of production wells would be monitored for water quality in this northern expansion area similar to the current program for the CGP. No sites have been nominated at this time.

For the CGP gas wells, a comprehensive suite water sample is collected during the September quarter each year. The preferred months for water sampling are August (comprehensive), November (basic), February (basic), and May (basic). The current water sampling suites and frequencies are provided in Table 8. If a comprehensive sample is missed in Q1 (August) because the well was not producing water then a comprehensive sample will be obtained for the next quarter when there is sufficient produced water to sample. If sampling is missed for three or more out of the four annual sampling rounds due to lack of produced water, the well will be removed from the monitoring network, and replaced with a more suitable well if possible from that area.

In addition, if a well within the network has undergone maintenance and exotic water (town water or produced water from a different well) has been used during the maintenance, the well will temporarily be removed from the monitoring network until it can be sure that formation water is being produced and reliable water samples can be obtained again.

Table 8: Groundwater Monitoring Suites and Frequencies

	2010/11	2011/12				2012/13			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Basic			X	X	X		X	X	X
Intermediate									
Comprehensive	X	X				X			

It is proposed that quarterly sampling will reduce to 6-monthly sampling at the conclusion of 2012/13 if there is no variation in the water qualities across each of the wells that comprise the gas well produced water monitoring network. If the wells that comprise the water quality network are changed then there will be at least two years of quarterly water quality data before a well is reduced to a 6-monthly sampling program.

5.4 Produced Water Volumes

At the present time, produced water volumes are derived from the water volumes that are trucked away from each site. Data is compiled monthly.

Considering the difficult requirements for the installation of a flow meter in the produced water line of a CSG well (the meter must be intrinsically safe, be able to deal with solid material, and be able to deal with two phase flow), there is currently no alternate method in measuring the produced water volumes. For the foreseeable future, produced water volumes for all gas wells will continue to be monitored and recorded based on volumes in the storage tanks and trucked off site for disposal.

5.5 Response Triggers

Several triggers are proposed including a change in the beneficial use of an aquifer (note that “aquifer” in this GMP refers only to the alluvial and Hawkesbury Sandstone aquifers as deeper zones are deemed to be water bearing zones and are non-aquifers). The other response triggers relate to water level and water quality trends where those trends are clearly related to CSG dewatering activities. The primary proofs of aquifer connectivity and potential aquifer contamination (or the lack thereof) are water level drawdowns and water quality changes.

5.5.1 Beneficial Use

A generalised beneficial use matrix has been designed (in accordance with both yield and water quality characteristics) (Table 9). Each aquifer/water bearing zone can be assigned one or more beneficial use categories (based on cells within the matrix). Beneficial use category varies spatially for each aquifer. The scale or volume of water required for individual uses may influence the beneficial use; for example, a small scale farming operation may be able to make use of a water supply bore that has a yield of <1.5 L/s, whereas for a large scale farming operation this may not be sufficient. The aquifers in the CGP area rarely yield water at a rate >5 L/s. Recycling, as a beneficial use category, has been added and mainly applies to incidental water, which is a by-product of coal mining and CSG operations.

The following beneficial use categories can be assigned to each aquifer/water bearing zone (in accordance with Table 9):

- Alluvial aquifers – A1, A2, A3, B2, B3, and C2
- Hawkesbury Sandstone aquifer – A2, A3, B2, B3, and C2
- Narrabeen Group aquifers – C3 (?)

› Illawarra coal water bearing zones – C3, D3

Note that some of the (high yield) beneficial use categories do not occur in the CGP area.

Should water quality monitoring results indicate alteration of the beneficial use category over time, during the project or within 3 years post development, where it is suspected that the change is the result of AGL's dewatering activities, AGL will investigate the likely cause. Where a change in an aquifer's beneficial use category is the result of AGL's activities, mitigation measures will be undertaken in accordance with the measures outlined in Section 5.6.

Table 9: Generalised beneficial use matrix, based on salinity and yield (adapted from EPA Vic, 1997).

		Yield (L/s)			
		>5	1.5-5	<1.5	
Salinity (µS/cm)	0-800	D+I+S+In	D+I+S	D+S	A
	801-1600	D+I+S+In	D+I+S	D+S	B
	1601-6000	I+S+In	I+S	S+R	C
	6001-25000	S+In	S	R	D
	>25000	In			E
		1	2	3	

Key: D – domestic; I – irrigation; S – stock; In – industry, R - recycling

5.5.2 Drawdowns

There are very large drawdowns in the coal seam water bearing zones during wellfield operation that are normal for the operation of a CSG wellfield. The key connectivity issue is if there are water level declines in shallow aquifers as a consequence of this depressurisation. Whilst AGL continues to build an understanding of the historical/seasonal variability in the water level drawdowns across the different field areas, if such an event was to occur, AGL would work closely with NOW to gather all possible water level data from the broader area to best understand the geographical extent, possible causes and to decide practical solutions.

Response triggers for shallow aquifers will be reviewed after monitoring data has been collected and natural characteristics and trends identified. They will be further developed with NOW during 2012/13 as historical/seasonal variability in the existing and northern extension wellfield areas becomes more precisely known and become part of the revised GMP in mid 2013.

The current adopted indicator is if there was a water level decline of more than 5m (outside of the normal range) in any Hawkesbury Sandstone monitoring bore. This approach is appropriate in the northern expansion area but not the southern areas due to lack of baseline data. Indicators for the existing wellfield area are yet to be determined. Declines outside of the agreed range would be sufficient to justify an investigation and management response involving:

› A check of nearby water bore use

› A check of nearby and recent (water bore and gas) drilling activities

- A check of the climatic conditions and expected trends
- A check of the integrity of the monitoring bore and datalogger

If it was suspected that the water level decline was due to CSG dewatering activities at depth, then the decline would be reported to NOW and a more detailed action plan would be implemented involving:

- A check of produced water volumes from nearby gas wells
- A check of the integrity of local water bores (if any) and gas wells
- Other recommendations as discussed and agreed with NOW

If the decline was reported at a private water bore location, then the apparent water level decline would involve:

- Referral to NOW in the first instance to assess the validity of the claim and to recommend a course of action.

5.5.3 Water Quality

Water quality variations could also be an indication of connectivity (for instance if produced water was becoming fresher rather than maintaining its slightly to moderately saline characteristics). Changed water quality could also be an indication of contamination from different anthropogenic activities. Whilst AGL continues to build an understanding of the historical/seasonal variability in the water quality across the different field areas, if such an event was to occur, AGL would work closely with NOW to gather all possible water quality data from the broader area to best understand the geographical extent, and possible causes.

Response triggers for shallow aquifers will be defined after more monitoring data has been collected and natural characteristics and trends identified. They will be further developed with NOW during 2012/13 as historical / seasonal variability in the existing and northern extension wellfield areas becomes more precisely known and become part of the revised GMP in mid 2013.

If water quality, with respect to salinity, at all monitoring sites (including the monitored gas wells) over time changes to a different beneficial use category (Table 9) or if water quality, with respect to other analytes, deviates significantly from the typical observed trend, and if the change is attributable to CSG activities, then this would be sufficient variability to justify an investigation and management response involving:

- A check of nearby water bore use or land use changes.
- A check of nearby and recent (water bore and gas) drilling, fracture stimulation and workover activities.
- A check of the integrity of the monitoring bore or gas production well.

If it was suspected that the change in water quality was due to CSG dewatering activities at depth, then the change in salinity would be reported to NOW/EPA and a more detailed action plan would be implemented involving:

- A check of the integrity of local water bores (if any) and gas wells.
- Other recommendations as discussed and agreed with NOW/EPA.

If the change in water quality was reported at a private water bore location, then the management response would involve:

- Referral to NOW/EPA in the first instance to assess the validity of the claim and to recommend a course of action.

5.6 Management Responses

Changes in groundwater levels and water quality changes observed in the dedicated Camden CGP monitoring network may not be the result of the CSG activities. It is important that any identified trends, or impacts notified to either AGL or to NOW/EPA, be thoroughly investigated in the first instance and a conclusion drawn that the impact is (or possibly is) or is not the result of the CSG activities.

This section details the management responses if a trend or an impact is (or is possibly) associated with the Camden CGP activities. The assessment of whether an impact is or is not CSG related, and a more detailed protocol that describes AGL's water management responses if there is a water level or water quality impact is provided in Appendix D.

5.6.1 Water Levels

If water levels change at dedicated monitoring sites (except for Illawarra Coal Measures monitoring sites) by more than the response trigger (i.e. greater than 5m outside of the normal range) or if the yield of a water supply bore changes to another beneficial use category (Table 9) over time, and if the change is attributable to CSG activities, then consider:

- Suspension of dewatering from proximate gas well(s) to assess whether any recovery can be achieved and/or;
- Suspension of dewatering if private water supply bores occur within 2kms and water level changes (outside of the normal range) are proven and/or;
- Other management responses as may be agreed/directed by NOW.

5.6.2 Water Quality

If water quality, with respect to salinity, at dedicated monitoring sites over time changes to a different beneficial use category (Table 9) or if water quality, with respect to other analytes, deviates significantly from the typical observed trend, and if the change is attributable to CSG activities, then consider:

- Suspension of dewatering from proximate gas well(s) to assess whether any remediation in water quality can be achieved and/or;
- Suspension of dewatering if private water supply bores occur within 2kms and water quality changes (outside of the normal range) are proven and/or;
- Other management responses as may be agreed/directed by NOW (or EPA).

5.7 Annual Reporting

A technical compliance report must be submitted to NOW annually for each water year commencing 1st July. The compliance report will include details on:

- Activities during the period (new wells, refurbishment of existing wells, maintenance of wells, and decommissioning of abandoned wells);
- Volumes of produced water during the period;
- Impacts of the wellfield operation on monitored groundwater systems;
- Predictions of produced water volumes, and any potential adverse impacts for the next operating period; and
- Any changes to the monitoring network for the upcoming water year

AGL's commitment is to lodge these reports by the 30th September each year for the preceding water year (July to June).

5.8 Review of the Plan

It is planned to review and update the GMP annually in June each year immediately prior to the commencement of the new water year.

The plan is not static, but will evolve over time, and is interpreted as a "living" document. The plan will only be formally resubmitted to NOW and EPA if there are major changes to the monitoring network, water quality monitoring suite, or the proposed monitoring frequency; however, the agencies will be involved in the review process where appropriate.

6 Supporting Documents

Some additional documents have been prepared by AGL that complement the detail in this GMP. The Camden Gas Project (CGP) Environmental Management Plan (AGL, 2012) is a condition of approval, while the water sampling protocol (AGL, 2011b) has been written to assist field staff to collect accurate water level data and representative water quality samples.

6.1 Environmental Management Plan

This Environmental Management Plan (EMP) for the CGP describes AGL's system to manage potential environmental issues associated with the project.

The CGP activities can be summarised as the construction, operation, maintenance and rehabilitation of well sites and the gas gathering systems, and the operation and maintenance and of the Rosalind Park Gas Plant (RPGP) and the sales gas pipeline.

The objective of the EMP is to describe the overall environmental management framework for the CGP, setting out what AGL are required to do, how AGL will do it and the monitoring AGL use to ensure compliance and improve operations.

It identifies the petroleum titles, development consents, Environment Protection Licence(s), water licences and relevant legislation. The EMP describes activities, contains specific environmental management plans (Sub Plans) for key aspects of our operations, and sets out the processes for implementation, monitoring and review. Detailed site specific information is provided in site specific plans which are referenced in the Sub Plans as applicable. This GMP is a Sub Plan of the EMP.

6.2 Water Sampling Protocol

A water sampling protocol has been written for AGL field staff and contractors tasked with collecting groundwater water samples from gas wells, monitoring bores, private water bores and pits/detention ponds associated with the CGP. It primarily applies to fracture stimulation water, flowback water, workovers, and produced water generated from new and existing gas wells. It also applies to sampling:

- Ponds where water is retained prior to reuse or disposal, and
- Dedicated monitoring bores, and potentially private water bores (if ever sampled).

It complements this GMP.

This protocol describes the required analytical suites, sampling, preserving and despatching of water samples to NATA certified laboratories for chemical analysis. The protocol also covers the collection of field parameters which are obtained in the field using calibrated water quality meters.

7 References

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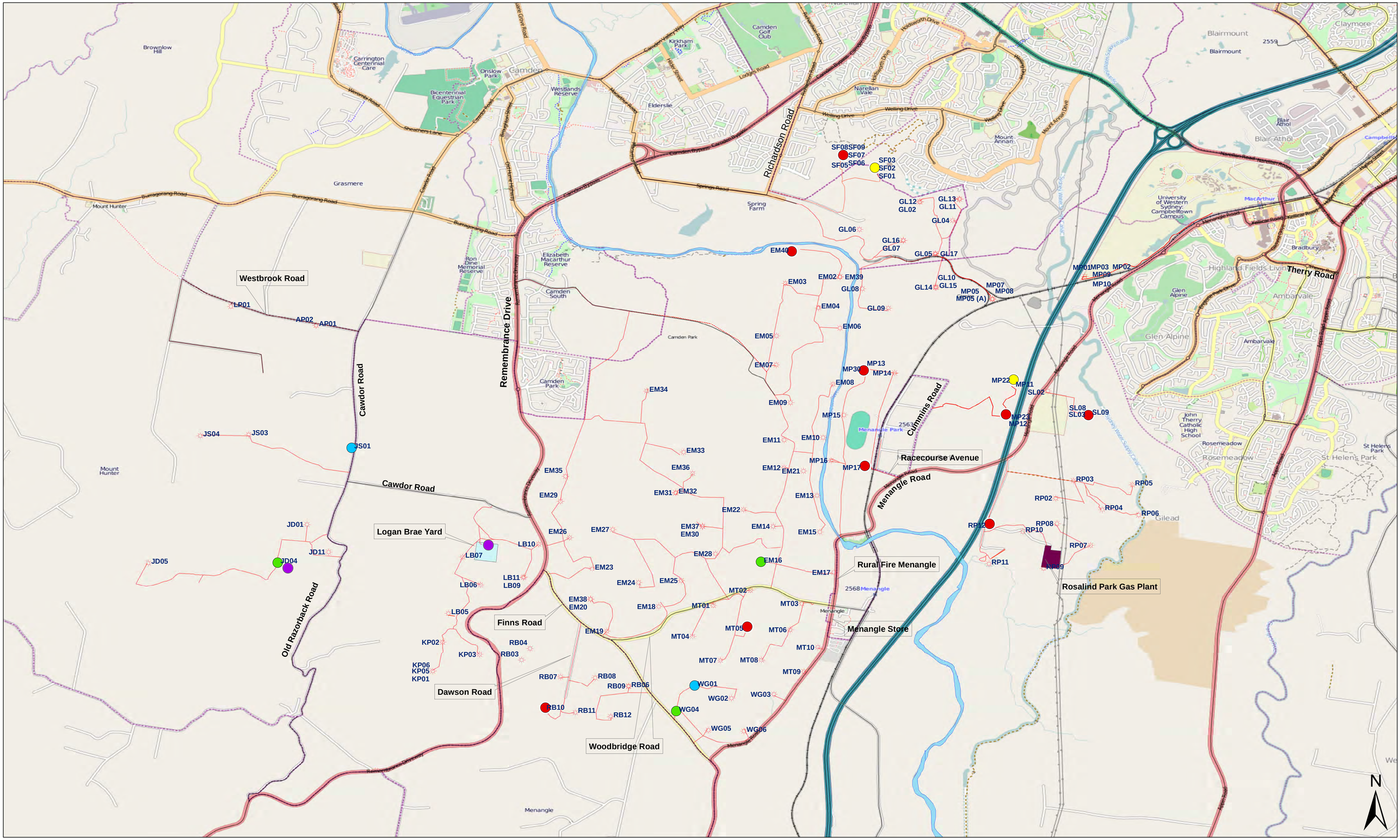
8 Figures



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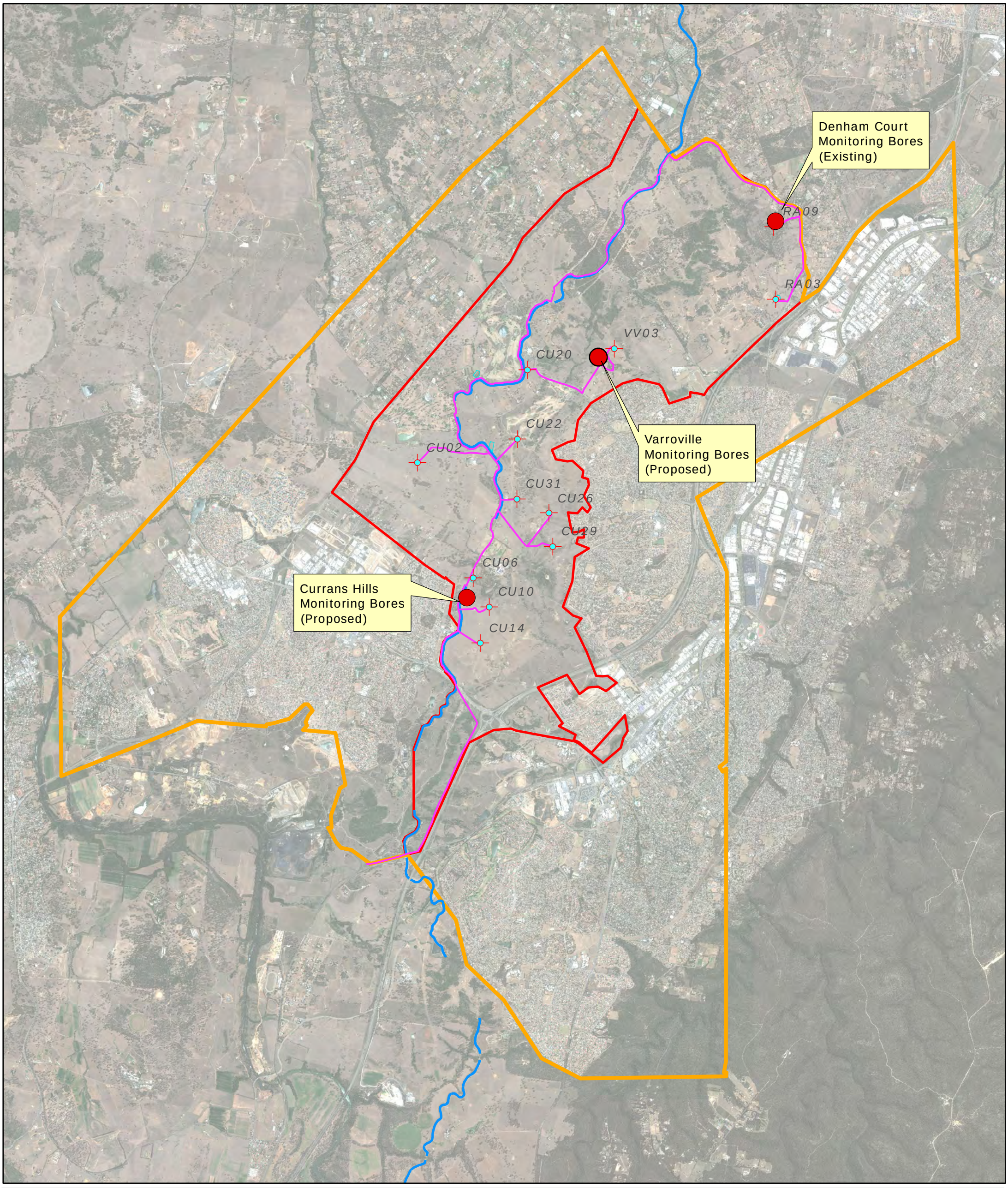
Camden North Gas Project Groundwater Monitoring Bores



AGL

Author: Upstream Gas

Date: 18/6/2012

Ref: 2278R4

Kilometres

0 2

Scale 1:60,194

Legend

- Nested Groundwater Monitoring Bores
- WELLS
- Gas Gathering
- Canal
- Subsurface Project Area Region
- Preliminary Project Area

N W E S

Figure 2

Appendix A

An Example of Bore Licence Conditions for an Existing Gas Production Well (10BL603867 – Elizabeth Macarthur 02)

NSW Office of Water

Sydney South Coast Region
P O Box 3720
10 Valentine Ave
Parramatta NSW 2124
Phone: (02) 98957814

BORE LICENSE CERTIFICATE
UNDER SECTION 115 OF THE WATER ACT, 1912

10BL603867

NSW Office of Water

Sydney Gas (Camden) Operations Pty Ltd
Att:- David Kelly
Locked Bag 1837
St Leonards NSW 2065

LICENSE NUMBER
10BL603867
DATE LICENSE VALID FROM
11-Feb-2011
DATE LICENSE VALID TO
10-Feb-2016
FEE
$151.00 PAID

ABN 47661556763 GST NIL

LOCATION OF WORKS

Portion(s) or Lot/Section/DP	PARISH	COUNTY
2//1050479	Camden	Camden

TYPE OF WORKS	PURPOSE(S) FOR WHICH WATER MAY BE USED
Bore	Industrial

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 10BL603867 ISSUED UNDER PART V OF THE WATER ACT, 1912 ON 11-Feb-2011

(1) WATER MUST NOT BE PUMPED, OTHERWISE EXTRACTED, OR INJECTED FROM THE WORKS AUTHORISED BY THIS LICENSE FOR ANY PURPOSE OTHER THAN COAL SEAM GAS PRODUCTION.

(2) SUBJECT TO APPROPRIATE OCCUPATIONAL HEALTH AND SAFETY PROVISIONS THE LICENSEE SHALL ALLOW THE NSW OFFICE OF WATER, OR ANY PERSON AUTHORISED BY IT, FULL AND FREE ACCESS TO THE WORKS, EITHER DURING OR AFTER CONSTRUCTION, FOR THE PURPOSE OF UNDERTAKING INSPECTION OR TEST OF WORKS AND ITS FITTINGS, AND SHALL CARRY OUT ANY WORK OR ALTERATIONS DEEMED NECESSARY BY THE NSW OFFICE OF WATER TO ENSURE THE PROTECTION AND MAINTENANCE OF THE WORKS, OR THE CONTROL OF THE WATER EXTRACTED AND FOR THE PROTECTION OF THE QUALITY AND THE PREVENTION FROM POLLUTION/CONTAMINATION OF SURFACE AND SUBSURFACE WATER.

(3) IF A WORK IS ABANDONED AT ANY TIME, THE LICENSEE SHALL NOTIFY NSW OFFICE OF WATER THAT THE WORK HAS BEEN ABANDONED AND SEAL OFF THE AQUIFER BY:-

(A) BACKFILLING THE WORK WITH CLAY OR CEMENT TO GROUND LEVEL AFTER WITHDRAWING THE CASING (LINING): OR
(B) SUCH METHODS AS AGREED TO OR DIRECTED BY NSW OFFICE OF WATER.

(4) THE LICENSEE SHALL NOT ALLOW ANY TAILWATER/DRAINAGE TO DISCHARGE FROM THE LICENSEE'S PROPERTY INTO OR ONTO:-

- ANY ADJOINING PUBLIC OR CROWN ROAD;
- ANY OTHER PERSONS LAND;
- ANY CROWN LAND;
- ANY RIVER, CREEK OR WATERCOURSE;
- ANY GROUNDWATER AQUIFER;
- ANY NATIVE VEGETATION AS DESCRIBED UNDER THE NATIVE VEGETATION CONSERVATION ACT 1997;
- ANY WETLANDS OF ENVIRONMENTAL SIGNIFICANCE.

(5) WORKS USED FOR THE PURPOSE OF CONVEYING, DISTRIBUTING OR STORING WATER TAKEN BY MEANS OF THE LICENSED WORK SHALL NOT BE CONSTRUCTED OR INSTALLED SO AS TO OBSTRUCT THE REASONABLE PASSAGE OF FLOOD WATERS FLOWING INTO OR FROM A RIVER.

(6) ALL GROUNDWATER EXTRACTED MUST BE DISTRIBUTED VIA DEDICATED TRANSFER PIPELINES THAT ARE TO BE MONITORED TO ENSURE PIPELINE FAILURE DOES NOT OCCUR.

(7) THE LICENSEE MUST INSTALL TO THE SATISFACTION OF THE NSW OFFICE OF WATER IN RESPECT OF TYPE AND CONSTRUCTION AN APPLIANCE(S) TO MEASURE THE QUANTITY OF WATER EXTRACTED FROM THE WORKS WHERE EXTRACTION EXCEEDS 50 KILOLITRES IN ANY 12 MONTH PERIOD.
(A) THE APPLIANCE(S) TO CONSIST OF EITHER A METER OR SUCH OTHER MEANS OF MEASUREMENT AS MAY BE APPROVED BY THE NSW OFFICE OF WATER.
(B) THE APPLIANCE(S) SHALL BE MAINTAINED IN GOOD WORKING ORDER AND CONDITION AND PERIODICALLY TESTED FOR APPROPRIATE FUNCTIONAL PERFORMANCE.
(C) THE LICENSEE WHEN REQUESTED MUST SUPPLY A TEST CERTIFICATE AS TO THE ACCURACY OF THE APPLIANCE(S) FURNISHED EITHER BY THE MANUFACTURER OR BY SOME PERSON DULY QUALIFIED

(8) THE LICENSEE MUST MAINTAIN RECORDS OF THE ACTUAL VOLUME OF GROUNDWATER PUMPED (IN KILOLITRES OR MEGALITRES) AS MEASURED BY THE INSTALLED APPLIANCE(S) AS WELL AS VOLUMES OF WATER TRANSPORTED FROM INDIVIDUAL WELL SITES FOR DISPOSAL OR USE AND

PROVIDE THIS INFORMATION TO THE NSW OFFICE OF WATER ON AN AGREED BASIS, AT THE COMPLETION OF THE PROJECT, OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

(9) THE LICENSE HOLDER SHALL ENGAGE A QUALIFIED GROUNDWATER CONSULTANT TO PRODUCE OR INDEPENDENT PEER REVIEW, A GROUNDWATER MANAGEMENT PLAN FOR THE CAMDEN GAS PROJECT. THE GROUNDWATER MANAGEMENT PLAN SHALL BE PREPARED IN CONSULTATION WITH AND TO THE SATISFACTION OF NSW OFFICE OF WATER. THE GROUNDWATER MANAGEMENT PLAN SHALL BE PREPARED AND IMPLEMENTED WITHIN 12 MONTHS OF THE ISSUE OF THIS LICENSE

(10) THE LICENSEE MUST MAINTAIN RECORDS OF THE RESULTS OF WATER QUALITY TESTING OF SAMPLES FROM ANY EXTRACTION OR MONITORING LOCATIONS AND PROVIDE THIS INFORMATION TO THE NSW OFFICE OF WATER ON AN AGREED BASIS, AT THE COMPLETION OF THE PROJECT, OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

(11) THE LICENSE HOLDER MUST INSTALL, IF AND WHEN CALLED UPON TO DO SO, MONITORING BORES TO THE SATISFACTION OF THE NSW OFFICE OF WATER IN RESPECT TO LOCATION AND DEPTH.
(A) THE INSTALLATION OF MONITORING BORES IS TO BE CARRIED OUT WITHIN THREE YEARS OF THE COMMENCEMENT OF THIS LICENSE.
(B) THE LICENSE HOLDER MUST MAINTAIN RECORDS OF THE GROUNDWATER LEVELS AS MEASURED IN THE MONITORING BORES.
(C) MEASUREMENTS OF GROUNDWATER LEVELS ARE TO BE TAKEN AND RECORDED AS A MINIMUM THROUGHOUT THE DURATION OF THE PROJECT AND QUARTERLY FOR A FIVE YEAR PERIOD THEREAFTER AS REQUIRED BY THE NSW OFFICE OF WATER.
(D) GROUNDWATER LEVEL RECORDS ARE TO BE MAINTAINED FOR ALL AQUIFER(S) AND ANY ADDITIONAL WATER BEARING ZONE(S) OR STRATIGRAPHIC HORIZON(S) IF REQUIRED BY THE NSW OFFICE OF WATER OVERLYING THE COAL SEAM(S) FROM WHICH GAS IS TO BE EXTRACTED.
(E) RECORDS OF GROUNDWATER LEVELS FROM THE MONITORING BORES ARE TO BE PROVIDED TO THE NSW OFFICE OF WATER ON AN ANNUAL BASIS AFTER THE MONITORING PERIOD HAS EXPIRED, OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

(12) THE LICENSEE MUST PROVIDE ALL RAW MONITORING DATA TO THE NSW OFFICE OF WATER IN AN ELECTRONIC FORMAT THAT IS COMPATIBLE WITH MICROSOFT OFFICE AND ADOBE ACROBAT SOFTWARE

(13) THE LICENSEE SHALL PROVIDE TO THE NSW OFFICE OF WATER FOR EVERY OPERATING PERIOD (HEREIN ADOPTED AS 12 MONTHS) AN INTERPRETED TECHNICAL GROUNDWATER REPORT IN HARD COPY FORMAT THAT DOCUMENTS THE FOLLOWING.
(A) ACTIVITIES ASSOCIATED WITH THE PROJECT FOR THE PRECEDING OPERATING PERIOD, INCLUDING THE INSTALLATION OF NEW WELLS, THE REFURBISHMENT OF EXISTING WELLS, THE MAINTENANCE OF DISUSED WELLS AND THE DECOMMISSIONING OF ABANDONED WELLS.
(B) VOLUMES OF GROUNDWATER EXTRACTED DURING THE PRECEDING OPERATING PERIOD FROM INDIVIDUAL WELLS AND IN TOTAL FROM THE PROJECT WELLFIELD, TOGETHER WITH VOLUMES OF WATER TRANSPORTED FOR DISPOSAL OR USE FROM INDIVIDUAL WELLS.
(C) RECONCILIATIONS OF THE EXTRACTED FLOW MEASUREMENTS WITH VOLUMES OF WATER TRANSPORTED FOR DISPOSAL OR USE FOR INDIVIDUAL WELLS FOR THE PRECEDING OPERATING PERIOD AND IDENTIFICATION OF CAUSES OF ANY INCONSISTENCIES AND RECTIFICATION MEASURES THAT WILL BE UNDERTAKEN.
(D) THE IMPACTS OF THE WELLFIELD OPERATION AND INDIVIDUAL WELLS ON THE MONITORED GROUNDWATER SYSTEMS FOR THE PRECEDING OPERATING PERIOD.
(E) PREDICTIONS OF GROUNDWATER EXTRACTION, POTENTIAL ADVERSE EFFECTS OF PUMPING AND PROPOSED MITIGATION MEASURES FOR THE NEXT OPERATING PERIOD

(14) THE NSW OFFICE OF WATER SHALL HAVE THE RIGHT DURING THE CURRENCY OF THIS LICENSE TO REQUEST AN AUDIT OF ALL GROUNDWATER MONITORING DATA COLLECTION, ARCHIVING AND QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROCEDURES. SUBJECT TO CONSTRAINTS IMPOSED BY THE REGULATION OF THE OPERATION, THE LICENSEE SHALL TAKE ANY ACTIONS DEEMED NECESSARY BY THE NSW OFFICE OF WATER AS A CONSEQUENCE OF THE AUDIT FINDINGS.

(15) THE VOLUME OF GROUNDWATER EXTRACTED FROM THE WORKS AUTHORISED BY THIS LICENSE AND BY LICENSE(S) LISTED IN THE ATTACHED SCHEDULE SHALL NOT EXCEED 30 MEGALITRES IN ANY 12 MONTH PERIOD COMMENCING 1ST JULY.

SCHEDULE 1

LIST OF LICENCES ISSUED – CONJUNCTIVE ENTITLEMENT OF 30ML

	Licence Numbers
1.	10BL603867 to 10BL603878
2.	10BL603881 to 10BL603893
3.	10BL603897 to 10BL603903
4.	10BL603905 & 10BL603906
5.	10BL603911 to 10BL603915
6.	10BL603917 to 10BL603922
7.	10BL603924 to 10BL603942
8.	10BL603952 to 10BL603965
9.	10BL603976
10.	10BL603978
11.	10BL603981
12.	10BL603989 to 10BL603994
13.	10BL604007 to 10BL604017
14.	10BL604031 to 10BL604045
15.	10BL604131

Appendix B

An Example of Bore Licence Conditions for a Proposed Gas Production Well (10BL604597 – Kay Park 06)

NSW Office of Water

Sydney South Coast Region
P O Box 3720
10 Valentine Ave
Parramatta NSW 2124
Phone: (02) 98957814

BORE LICENSE CERTIFICATE
UNDER SECTION 115 OF THE WATER ACT, 1912

10BL604597

Office of Water

A G L Upstream Investments Pty Ltd
Locked Bag 1837
St Leonards NSW 2065

LICENSE NUMBER
10BL604597
DATE LICENSE VALID FROM
04-Apr-2011
DATE LICENSE VALID TO
03-Apr-2016
FEE
$151.00 PAID

ABN 47661556763 GST NIL

LOCATION OF WORKS

Portion(s) or Lot/Section/DP	PARISH	COUNTY
2//594242	Camden	Camden

TYPE OF WORKS	PURPOSE(S) FOR WHICH WATER MAY BE USED
Bore	Industrial

CONDITIONS APPLYING TO THIS LICENSE ARE

As shown on the attached Condition Statement

ORIGINAL

NSW Office of Water

CONDITIONS STATEMENT REFERRED TO ON 10BL604597 ISSUED UNDER PART V OF THE WATER ACT, 1912 ON 04-Apr-2011

(1) WATER MUST NOT BE PUMPED, OTHERWISE EXTRACTED, OR INJECTED FROM THE WORKS AUTHORISED BY THIS LICENSE FOR ANY PURPOSE OTHER THAN COAL SEAM GAS PRODUCTION.

(2) SUBJECT TO APPROPRIATE OCCUPATIONAL HEALTH AND SAFETY PROVISIONS THE LICENSEE SHALL ALLOW THE NSW OFFICE OF WATER, OR ANY PERSON AUTHORISED BY IT, FULL AND FREE ACCESS TO THE WORKS, EITHER DURING OR AFTER CONSTRUCTION, FOR THE PURPOSE OF UNDERTAKING INSPECTION OR TEST OF WORKS AND ITS FITTINGS, AND SHALL CARRY OUT ANY WORK OR ALTERATIONS DEEMED NECESSARY BY THE NSW OFFICE OF WATER TO ENSURE THE PROTECTION AND MAINTENANCE OF THE WORKS, OR THE CONTROL OF THE WATER EXTRACTED AND FOR THE PROTECTION OF THE QUALITY AND THE PREVENTION FROM POLLUTION/CONTAMINATION OF SURFACE AND SUBSURFACE WATER.

(3) IF A WORK IS ABANDONED AT ANY TIME, THE LICENSEE MUST NOTIFY THE NSW OFFICE OF WATER THAT THE WORK HAS BEEN ABANDONED AND SEAL OFF THE AQUIFER BY:-
(A) BACKFILLING THE WORK WITH CLAY OR CEMENT TO GROUND LEVEL AFTER WITHDRAWING THE CASING (LINING); OR
(B) SUCH METHODS AS AGREED TO OR DIRECTED BY THE NSW OFFICE OF WATER.

(4) THE LICENSEE MUST NOT ALLOW ANY TAILWATER/DRAINAGE TO DISCHARGE FROM THE LICENSEE'S PROPERTY INTO OR ONTO:-

- ANY ADJOINING PUBLIC OR CROWN ROAD;
- ANY OTHER PERSONS LAND;
- ANY CROWN LAND;
- ANY RIVER, CREEK OR WATERCOURSE;
- ANY GROUNDWATER AQUIFER;
- ANY NATIVE VEGETATION AS DESCRIBED UNDER THE NATIVE VEGETATION CONSERVATION ACT 1997;
- ANY WETLANDS OF ENVIRONMENTAL SIGNIFICANCE.

(5) WORKS USED FOR THE PURPOSE OF CONVEYING, DISTRIBUTING OR STORING WATER TAKEN BY MEANS OF THE LICENSED WORK MUST NOT BE CONSTRUCTED OR INSTALLED SO AS TO OBSTRUCT THE REASONABLE PASSAGE OF FLOOD WATERS FLOWING INTO OR FROM A RIVER.

(6) THE LICENSEE SHALL WITHIN TWO MONTHS OF COMPLETION OR AFTER THE ISSUE OF THE LICENSE IF THE WORK IS EXISTING, FURNISH TO THE NSW OFFICE OF WATER THE FOLLOWING INFORMATION.

(A) DETAILS OF THE DRILLER, DRILLING RIG, EQUIPMENT AND TECHNIQUES USED IN ESTABLISHING THE WORK, AS WELL AS COMMENCEMENT AND COMPLETION DATES.

(B) SPECIFICATIONS OF THE HOLE INCLUDING THE DIAMETER, FINAL DEPTH AND FINAL LENGTH (IN LINEAR METRES TO THE NEAREST 0.1 M) AS WELL AS THE DIRECTION OF THE HOLE IF DRILLING DIVERTS FROM THE HORIZONTAL.

(C) DETAILS OF ANY PUMPING TESTS CARRIED OUT, INCLUDING THE COMMENCEMENT DATE, DURATION, INITIAL STANDING WATER LEVEL, DRAWDOWN LEVEL, PUMPING FLOW RATE AND PUMP INTAKE DEPTH, AS WELL AS RAW MEASUREMENT DATA FOR THE WORK OR ANY OBSERVATION HOLES.

(D) DETAILS OF AQUIFERS OR WATER BEARING ZONES INTERSECTED BY THE DRILLING, INCLUDING

DEPTH INTERVALS (FROM GROUND SURFACE LEVEL TO THE NEAREST 0.1 M), YIELDS, SALINITY, TEST METHODS, AND STANDING WATER LEVELS.

(E) DETAILS OF THE CASING MATERIALS USED IN THE CONSTRUCTION OF THE WORK, INCLUDING DEPTH OR LENGTH INTERVALS, OR BOTH (FROM GROUND SURFACE LEVEL TO THE NEAREST 0.1 M), MATERIALS TYPES, DIAMETERS, AND THE METHODS OF CONNECTION AND FIXING.

(F) DETAILS OF THE FINAL CONSTRUCTION OF THE WORK INCLUDING THE DEPTH OR LENGTH INTERVALS, OR BOTH (TO THE NEAREST 0.1 M) OF THE HOLE OVER WHICH OPENINGS ARE INSTALLED, THE DEPTH OR LENGTH INTERVALS, OR BOTH (TO THE NEAREST 0.1 M) IN WHICH ANNULAR SEALS ARE PLACED, THE DEPTH OR LENGTH INTERVALS, OR BOTH (TO THE NEAREST 0.1 M) IN WHICH FILTER MATERIALS ARE PLACED, AND THE TYPES OF MATERIALS USED.
(G) DETAILS OF ANY CHEMICALS USED IN THE INSTALLATION, CONSTRUCTION OR COMMISSIONING OF THE WORK.

(H) DETAILS OF ANY DEVELOPMENT ACTIVITY UNDERTAKEN TO FACILITATE OR IMPROVE THE HYDRAULIC CONNECTION OF THE WORK WITH THE TARGET AQUIFER.

(I) DETAIL DESCRIPTIONS OF THE STRATA TYPES INTERSECTED BY THE WORK, AND THE CORRESPONDING DEPTH OR LENGTH INTERVALS, OR BOTH (FROM GROUND SURFACE LEVEL TO THE NEAREST 0.1 M) FOR EACH OF THE IDENTIFIED GEOLOGICAL UNITS.

(J) A PLAN SHOWING ACCURATELY THE LOCATION OF THE WORK, IN RELATION TO PORTION AND PROPERTY BOUNDARIES, AS WELL AS CADASTRAL PARCEL DETAILS (LOT, DEPOSITED PLAN NO., PARISH AND COUNTY).

(7) THE WORKS AUTHORISED BY THIS LICENCE SHALL BE CONSTRUCTED WITH ANNULAR SEALS TO ISOLATE AQUIFERS OVERLYING THE PRODUCING AQUIFER AND PREVENT THE LOSS OR MIXING OF WATER FROM DIFFERENT GROUNDWATER SOURCES.

(8) ALL GROUNDWATER EXTRACTED MUST BE DISTRIBUTED VIA DEDICATED TRANSFER PIPELINES THAT ARE TO BE MONITORED TO ENSURE PIPELINE FAILURE DOES NOT OCCUR.

(9) THE LICENSEE MUST INSTALL TO THE SATISFACTION OF THE NSW OFFICE OF WATER IN RESPECT OF TYPE AND CONSTRUCTION AN APPLIANCE(S) TO MEASURE THE QUANTITY OF WATER EXTRACTED FROM THE WORKS WHERE EXTRACTION EXCEEDS 50 KILOLITRES IN ANY 12 MONTH PERIOD.

(A) THE APPLIANCE(S) TO CONSIST OF EITHER A METER OR SUCH OTHER MEANS OF MEASUREMENT AS MAY BE APPROVED BY THE NSW OFFICE OF WATER.

(B) THE APPLIANCE(S) SHALL BE MAINTAINED IN GOOD WORKING ORDER AND CONDITION AND PERIODICALLY TESTED FOR APPROPRIATE FUNCTIONAL PERFORMANCE.

(C) THE LICENSEE WHEN REQUESTED MUST SUPPLY A TEST CERTIFICATE AS TO THE ACCURACY OF THE APPLIANCE(S) FURNISHED EITHER BY THE MANUFACTURER OR BY SOME PERSON DULY QUALIFIED.

(10) THE LICENSEE MUST MAINTAIN RECORDS OF THE ACTUAL VOLUME OF GROUNDWATER PUMPED (IN KILOLITRES OR MEGALITRES) AS MEASURED BY THE INSTALLED APPLIANCE(S) AS WELL AS VOLUMES OF WATER TRANSPORTED FROM INDIVIDUAL WELL SITES FOR DISPOSAL OR USE AND PROVIDE THIS INFORMATION TO THE NSW OFFICE OF WATER ON AN AGREED BASIS, AT THE COMPLETION OF THE PROJECT, OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

(11) THE LICENSE HOLDER SHALL ENGAGE A QUALIFIED GROUNDWATER CONSULTANT TO PRODUCE OR INDEPENDENT PEER REVIEW, A GROUNDWATER MANAGEMENT PLAN FOR THE CAMDEN GAS PROJECT. THE GROUNDWATER MANAGEMENT PLAN SHALL BE PREPARED IN CONSULTATION WITH AND TO THE SATISFACTION OF NSW OFFICE OF WATER. THE GROUNDWATER MANAGEMENT PLAN SHALL BE PREPARED AND IMPLEMENTED WITHIN 12 MONTHS OF THE ISSUE OF THIS LICENSE.

(12) THE LICENSEE MUST MAINTAIN RECORDS OF THE RESULTS OF WATER QUALITY TESTING OF SAMPLES FROM ANY EXTRACTION OR MONITORING LOCATIONS AND PROVIDE THIS INFORMATION TO THE NSW OFFICE OF WATER ON AN AGREED BASIS, AT THE COMPLETION OF THE PROJECT, OR UPON

REQUEST FROM THE NSW OFFICE OF WATER.

(13) THE LICENSE HOLDER MUST INSTALL, IF AND WHEN CALLED UPON TO DO SO, MONITORING BORES TO THE SATISFACTION OF THE NSW OFFICE OF WATER IN RESPECT TO LOCATION AND DEPTH.

(A) THE INSTALLATION OF MONITORING BORES IS TO BE CARRIED OUT WITHIN THREE YEARS OF THE COMMENCEMENT OF THIS LICENSE.

(B) THE LICENSE HOLDER MUST MAINTAIN RECORDS OF THE GROUNDWATER LEVELS AS MEASURED IN THE MONITORING BORES.

(C) MEASUREMENTS OF GROUNDWATER LEVELS ARE TO BE TAKEN AND RECORDED AS A MINIMUM THROUGHOUT THE DURATION OF THE PROJECT AND QUARTERLY FOR A FIVE YEAR PERIOD THEREAFTER AS REQUIRED BY THE NSW OFFICE OF WATER.

(D) GROUNDWATER LEVEL RECORDS ARE TO BE MAINTAINED FOR ALL AQUIFER(S) AND ANY ADDITIONAL WATER BEARING ZONE(S) OR STRATIGRAPHIC HORIZON(S) IF REQUIRED BY THE NSW OFFICE OF WATER OVERLYING THE COAL SEAM(S) FROM WHICH GAS IS TO BE EXTRACTED.

(E) RECORDS OF GROUNDWATER LEVELS FROM THE MONITORING BORES ARE TO BE PROVIDED TO THE NSW OFFICE OF WATER ON AN ANNUAL BASIS AFTER THE MONITORING PERIOD HAS EXPIRED, OR UPON REQUEST FROM THE NSW OFFICE OF WATER.

(14) THE LICENSEE MUST PROVIDE ALL RAW MONITORING DATA TO THE NSW OFFICE OF WATER IN AN ELECTRONIC FORMAT THAT IS COMPATIBLE WITH MICROSOFT OFFICE AND ADOBE ACROBAT SOFTWARE.

(15) THE LICENSEE SHALL PROVIDE TO THE NSW OFFICE OF WATER FOR EVERY OPERATING PERIOD (HEREIN ADOPTED AS 12 MONTHS) AN INTERPRETED TECHNICAL GROUNDWATER REPORT IN HARD COPY FORMAT THAT DOCUMENTS THE FOLLOWING.

(A) ACTIVITIES ASSOCIATED WITH THE PROJECT FOR THE PRECEDING OPERATING PERIOD, INCLUDING THE INSTALLATION OF NEW WELLS, THE REFURBISHMENT OF EXISTING WELLS, THE MAINTENANCE OF DISUSED WELLS AND THE DECOMMISSIONING OF ABANDONED WELLS.

(B) VOLUMES OF GROUNDWATER EXTRACTED DURING THE PRECEDING OPERATING PERIOD FROM INDIVIDUAL WELLS AND IN TOTAL FROM THE PROJECT WELLFIELD, TOGETHER WITH VOLUMES OF WATER TRANSPORTED FOR DISPOSAL OR USE FROM INDIVIDUAL WELLS.

(C) RECONCILIATIONS OF THE EXTRACTED FLOW MEASUREMENTS WITH VOLUMES OF WATER TRANSPORTED FOR DISPOSAL OR USE FOR INDIVIDUAL WELLS FOR THE PRECEDING OPERATING PERIOD AND IDENTIFICATION OF CAUSES OF ANY INCONSISTENCIES AND RECTIFICATION MEASURES THAT WILL BE UNDERTAKEN.

(D) THE IMPACTS OF THE WELLFIELD OPERATION AND INDIVIDUAL WELLS ON THE MONITORED GROUNDWATER SYSTEMS FOR THE PRECEDING OPERATING PERIOD.

(E) PREDICTIONS OF GROUNDWATER EXTRACTION, POTENTIAL ADVERSE EFFECTS OF PUMPING AND PROPOSED MITIGATION MEASURES FOR THE NEXT OPERATING PERIOD.

(16) THE NSW OFFICE OF WATER SHALL HAVE THE RIGHT DURING THE CURRENCY OF THIS LICENSE TO REQUEST AN AUDIT OF ALL GROUNDWATER MONITORING DATA COLLECTION, ARCHIVING AND QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PROCEDURES. SUBJECT TO CONSTRAINTS IMPOSED BY THE REGULATION OF THE OPERATION, THE LICENSEE SHALL TAKE ANY ACTIONS DEEMED NECESSARY BY THE NSW OFFICE OF WATER AS A CONSEQUENCE OF THE AUDIT FINDINGS.

(17) THE VOLUME OF GROUNDWATER EXTRACTED FROM THE WORKS AUTHORISED BY THIS LICENSE AND BY THE LICENSE(S) LISTED IN THE ATTACHED SCHEDULE SHALL NOT EXCEED 30 MEGALITRES IN ANY 12 MONTH PERIOD COMMENCING 1ST JULY.

SCHEDULE 1

LIST OF LICENCES ISSUED – CONJUNCTIVE ENTITLEMENT OF 30ML

	Licence Numbers
1.	10BL603867 to 10BL603878
2.	10BL603881 to 10BL603893
3.	10BL603897 to 10BL603903
4.	10BL603905 & 10BL603906
5.	10BL603911 to 10BL603915
6.	10BL603917 to 10BL603922
7.	10BL603924 to 10BL603942
8.	10BL603952 to 10BL603965
9.	10BL603976
10.	10BL603978
11.	10BL603981
12.	10BL603989 to 10BL603994
13.	10BL604007 to 10BL604017
14.	10BL604031 to 10BL604045
15.	10BL604131
16.	10BL604582
17.	10BL604597

Appendix C

Expanded Analytical Suite currently under consideration for EPA

Parameter		Site Descriptor		Gas Wells/Monitoring Bores	From Ponds or Batch Tanks
Physical	Temperature	oC		✓	✓
	pH	-		✓	✓
	EC	µS/cm		✓	✓
	TDS*	mg/L		✓	✓
	SAR	-		✓	✓
	Alkalinity	mg/L		✓	✓
Ionic	Sodium	mg/L		✓	✓
	Potassium	mg/L		✓	✓
	Calcium	mg/L		✓	✓
	Magnesium	mg/L		✓	✓
	Barium	mg/L		✓	✓
	Chloride	mg/L		✓	✓
	Fluoride	mg/L		✓	✓
Nutrients	Total Nitrogen	µg/L		✓	✓
	Total Phosphorus	µg/L		✓	✓
	Filterable Reactive Phosphate	µg/L		✓	✓
	Sulfate	mg/L		✓	✓
Metals and Metalloids	Aluminium (pH > 6.5)	µg/L		✓	✓
	Arsenic	µg/L		✓	✓
	Beryllium	µg/L		✓	✓
	Boron	µg/L		✓	✓
	Cadmium #	µg/L		✓	✓
	Chromium	µg/L		✓	✓
	Cobalt	µg/L		✓	✓
	Copper #	µg/L		✓	✓
	Iron	µg/L		✓	✓
	Lead #	µg/L		✓	✓
	Manganese	µg/L		✓	✓
	Mercury	µg/L		✓	✓
	Molybdenum	µg/L		✓	✓
	Nickel #	µg/L		✓	✓
	Selenium	µg/L		✓	✓
	Strontium	µg/L		✓	✓
	Uranium	µg/L		✓	✓
	Vanadium	µg/L		✓	✓
	Zinc #	µg/L		✓	✓
Non-Metallic Inorganics	Ammonia	µg/L		✓	✓
	Nitrate	µg/L		✓	✓
	Nitrite	µg/L		✓	✓
	Methane	µg/L		✓	✗
Organic Toxicants	Phenol	µg/L		✓	✓
	PAH - Naphthalene	µg/L		✓	✓
	PAH - Anthracene	µg/L		✓	✓
	PAH - Phenanthrene	µg/L		✓	✓
	PAH - Fluoranthene	µg/L		✓	✓
	PAH - Benzo(a)pyrene	µg/L		✓	✓
	Benzene	µg/L		✓	✓
	Toluene	µg/L		✓	✓
	Ethylbenzene	µg/L		✓	✓
	Xylene	µg/L		✓	✓
	o-xylene	µg/L		✓	✓
	m-xylene	µg/L		✓	✓
	p-xylene	µg/L		✓	✓

Appendix D

Management response protocol

The following management response protocol will be adopted for any confirmed or possible changes in water resource trend or impact arising from the operation of the CGP.

i) Situations that trigger management response – shallow aquifers

In this context, shallow aquifer/s refers to alluvial aquifers, Hawkesbury Sandstone aquifers, and any Narrabeen Group sandstone aquifers.

A situation that triggers a management response would be if water levels change at dedicated shallow aquifer monitoring sites by more than the response trigger (i.e. greater than 5m outside of the normal range) or if the yield of a water supply bore changes to another beneficial use category (Table 9) over time, and if the change is attributable to CSG activities.

A situation that triggers a management response would be if water quality, with respect to salinity, at dedicated shallow aquifer monitoring sites over time changes to a different beneficial use category (Table 9) or if water quality, with respect to other analytes, deviates significantly from the typical observed trend, and if the change is attributable to CSG activities.

To assess whether a water level or water quality impact is attributable to a CSG activity, the following process will be implemented by AGL and each case reviewed/endorsed by NOW and EPA:

- Review the data set or incident/complaint (if from a private landowner) to identify possible causes
- Implement additional sampling and monitoring as appropriate
- Inspect the bore site and interview the landowner (if it is a private water supply impact)
- Assess the trend or impact in terms of local CGP operations issues (such as dewatering volumes, performance of individual wells, workovers, timing of events etc)
- Conclude whether the trend or impact is or is not attributable to a CSG activity
- Advise NOW/EPA and recommend a course of action if the trend is or is possibly attributable to a CSG activity

The two responses below are based on a trend or impact that is proven or is likely to be attributable to CSG operations.

a) Management response for a situation observed at shallow aquifer monitoring site

If a situation that triggers a management response is identified at one of the shallow aquifer monitoring sites, the following procedure would be employed, until the situation is rectified.

1) Develop a remedial action plan (RAP) for NOW/EPA to endorse. Actions could include:
   - Perform maintenance on relevant gas well(s) if appropriate, in order to attempt to rectify situation;
   - Suspend dewatering from proximate gas well(s) to assess whether any remediation/recovery in water quality/levels can be achieved;

b) Management response for a situation observed at private water supply bore

If a situation that triggers a management response is identified at a shallow aquifer (private water supply) site, the following procedure would be employed, until the situation is rectified.

1) Develop a remedial action plan (RAP) for NOW/EPA to endorse. Actions could include:
   - Perform maintenance on relevant gas well(s) if appropriate, in order to attempt to rectify situation;
   - Suspend dewatering from gas well(s) within 2kms to assess whether any remediation/recovery in water quality/levels can be achieved;
2) Determine appropriate alternative water supply arrangement with bore owner if situation cannot be rectified.

ii) Situations that trigger management response – coal seam monitoring site

In those instances where a change is identified at an Illawarra Coal Measure monitoring site (which is not recognised as a beneficial aquifer) then there is a lesser requirement for a water management response.

A situation that triggers a management response would be if water quality, with respect to salinity, at dedicated shallow aquifer monitoring sites over time changes to a different beneficial use category (Table 9) or if water quality, with respect to other analytes, deviates significantly from the typical observed trend, and if the change is attributable to CSG activities. Note there are no water level triggers only water quality triggers that are salinity related (see Table 9). Nonetheless the following response will be adopted by AGL.

a) Management response for a situation observed at coal seam monitoring site

If a situation is identified at a deep coal seam monitoring site, the following procedure would be employed.

1) Desktop analysis of situation in order to attempt to identify possible causes and history;
2) Inspect the monitoring or production site and implement additional sampling and monitoring as appropriate;
3) Assess the water quality trend in terms of local CGP operations issues (such as dewatering volumes, performance of individual wells, workovers, timing of events etc);
4) Conclude whether the trend is or is not attributable to a CSG activity
5) Advise NOW/EPA where necessary