AGL Upstream Investments Pty Ltd

Water Quality Investigation Camden Gas Project

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PARSONS BRINCKERHOFF

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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.
Ammonia	A compound of nitrogen and hydrogen (NH3) that is a common by-product of animal waste and landfills but is also found naturally in reduced environments. Ammonia readily converts to nitrate in soils and streams.
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, confined	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Aquifer, semi-confined	An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the leaky confining layer – also known as a leaky artesian or leaky confined aquifer.
Aquifer, unconfined	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
Aquitard	A low permeability unit that can store groundwater and also transmit it slowly from one formation to another. Aquitards retard but do not prevent the movement of water to or from adjacent aquifers.
Bedding plane	In sedimentary or stratified rocks, the division plane which separates the individual layers, beds or strata.
Beneficial aquifer	An aquifer with a water resource of sufficient quality and quantity to provide either ecosystem protection, raw water for drinking water supply, and agricultural or industrial water.

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.
Concentration	The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample).
Confining layer	Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients.
Condensed water	Liquid water derived condensation of water vapour
Detection limit	The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration.
Deuterium (2H)	Also called heavy hydrogen, a stable isotope of hydrogen with a natural abundance of one atom in 6,500 of hydrogen. The nucleus of deuterium, called a deuteron, contains one proton and one neutron, where a normal hydrogen nucleus has just one proton.
Dissolution	Process of dissolving a substance into a liquid. If the saturation index is less than zero, the mineral is undersaturated with respect to the solution and the mineral might dissolve.

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.
Fracture	Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions.
Global Meteoric Water Line (GMWL)	A line that defines the relationship between oxygen-18 (18O) and deuterium (2H) in fresh surface waters and precipitation from a number of global reference sites.
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
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 at high pressure.
Hydraulic head	Is a specific measurement of water pressure above a datum.
Ion	An ion is an atom or molecule where the total number of electrons is not equal to the total number of protons, giving it a net positive or negative electrical charge.
Isotope	One of multiple forms of an element that has a different number of neutrons than other atoms of that element. Some elements have isotopes that are unstable or radioactive, while others have 'stable isotopes'.

Local Meteoric Water Line (LMWL)	A line that defines the local relationship between oxygen-18 (18O) and deuterium (2H) in fresh surface waters and precipitation. In this report the LMWL used is for coastal Brisbane.
Major ions	Constituents commonly present in concentrations exceeding 10 milligram per litre. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulphate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate.
Methane (CH4)	An odourless, colourless, flammable gas, which is the major constituent of natural gas. It is used as a fuel and is an important source of hydrogen and a wide variety of organic compounds.
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.
Oxygen-18 (18O)	A natural, stable isotope of oxygen and one of the environmental isotopes. It makes up about 0.2 % of all naturally-occurring oxygen on Earth.
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permian	The last period of the Palaeozoic era that finished approximately 230 million years before present.
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).
Porosity	The proportion of open space within an aquifer, comprised of intergranular space, pores, vesicles and fractures.
Porosity, primary	The porosity that represents the original pore openings when a rock or sediment formed.

Porosity, secondary	The porosity caused by fractures or weathering in a rock or sediment after it has been formed.
Precipitation	(1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral.
Produced water	Natural groundwater generated from coal seams during flow testing and production dewatering.
Quaternary	The most recent geological period extending from approximately 2.5 million years ago to the present day.
Quality assurance	Evaluation of quality-control data to allow quantitative determination of the quality of chemical data collected during a study. Techniques used to collect, process, and analyse water samples are evaluated.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Recharge area	A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones.
Redox potential (ORP or Eh)	The redox potential is a measure (in volts) of the affinity of a substance for electrons – its electronegativity – compared with hydrogen (which is set at 0). Substances more strongly electronegative than (i.e. capable of oxidising) hydrogen have positive redox potentials. Substances less electronegative than (i.e. capable of reducing) hydrogen have negative redox potentials. Also known as oxidation-reduction potential and Eh.

Redox reaction	Redox reactions, or oxidation-reduction reactions, are a family of reactions that are concerned with the transfer of electrons between species, and are mediated by bacterial catalysis. Reduction and oxidation processes exert an important control on the distribution of species like O_2, Fe^{2+}, H_2S and CH_4 etc in groundwater.
Reducing conditions	Conditions in which a species gains electrons and is present in reduced form.
RL	Reduced level or height, usually in metres above or below an arbitrary or standard datum.
Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).
Salinity classification	Fresh water quality – water with a salinity <800 µS/cm. Marginal water quality – water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. Brackish quality – water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. Slightly saline quality – water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. Moderately saline quality – water that is more saline than brackish water and generally waters between 10,000 and 20,000 µS/cm. Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 µS/cm. Seawater quality – water that is generally around 55,000 µS/cm.
Stable isotope	Stable isotopes are atoms of the same element that have different masses due to differences in the number of neutrons they contain. Stable isotopes are not subject to radioactive decay, meaning they do not breakdown over time.

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.
Total Dissolved Solids (TDS)	A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). Fresh water quality – water with a salinity <536 mg/L. Marginal water quality – water that is more saline than freshwater and generally waters between 536 and 1,072 mg/L. Brackish quality – water that is more saline than freshwater and generally waters between 1,072 and 3,216 mg/L. Slightly saline quality – water that is more saline than brackish water and generally waters with a salinity between 3,216 and 6,700 mg/L. Moderately saline quality – water that is more saline than brackish water and generally waters between 6,700 and 13,400 mg/L. Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 13,400 µS/cm. Seawater quality – water that is generally around 36,850 mg/L.
Trace element	An element found in only minor amounts (concentrations less than 10 milligram per litre) in water or sediment; includes heavy metals arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.
Tritium (3H)	A short-lived isotope of hydrogen with a half-life of 12.43 years. It is commonly used to identify the presence of modern recharge. Tritium is produced naturally in small amounts owing to the interaction of cosmic radiation with atmospheric oxygen and nitrogen in the troposphere, and is also produced by thermonuclear explosions.
Water bearing zone	Geological strata that are saturated with groundwater but not of sufficient permeability to be called an aquifer.

Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists.
Well	Pertaining to a gas exploration well or gas production well.

Abbreviations

AGL	AGL Upstream Investments Pty Ltd
ALS	Australian Laboratory Services
ANSTO	Australian Nuclear Science and Technology Organisation
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CGP	Camden Gas Project
EC	Electrical Conductivity
EPA	Environmental Protection Authority
GMWL	Global Meteoric Water Line
LOR	Limits of Reporting
NATA	National Association of Testing Authorities
ORP	Oxidation Reduction Potential
PAHs	Polycyclic Aromatic Hydrocarbons
TDS	Total Dissolved Solids
bbl/MMC	Barrel per Million Cubic Feet
L/s	Litres per second
mg/L	Milligram per litre
MMSCF/day	Million standard cubic feet per meter
mV	Millivolts
psig	Pound-force per square inch gauge
µS/cm	Micro Siemens per centimetre
^{o}C	Degrees Celsius

Executive summary

AGL Upstream Investments Pty Ltd (AGL) owns and operates the Camden Gas Project (CGP) which has been producing gas for the Sydney region since 2001 and currently comprises 144 gas wells, underground gas gathering lines and the Rosalind Park Gas Plant. AGL undertakes water quality sampling in the CGP from a selection of operational gas wells, water supply bores and groundwater monitoring bores as defined within the Groundwater Management Plan for the Camden Gas Project (GMP).

Water produced from the gas wells in the CGP area is typically slightly saline to moderately saline. During routine 2011 and 2012 monitoring events, it was found that produced water from a subset of gas wells comprising the monitoring network had a different ‘atypical’ chemical signature from the ‘typical’ chemical composition of the produced water, as determined by long term monitoring; specifically these ‘atypical’ gas wells were producing low salinity water.

The overall objective of this study was to determine the nature and origin of the low salinity produced water from the ‘atypical’ gas wells in the CGP. A working hypothesis was developed for testing, identifying three possible scenarios for the origin of the low salinity water. These included the following:

1. Hydraulic connection between targeted coal seams and shallow aquifers or surface water
2. Residual potable water trapped when wells were hydraulic fracture stimulated
3. Formation of low salinity condensed water in gas wells.

To achieve the objectives the chemical and isotopic characteristics of the various water sources was assessed including the water associated with the Permian Coal Measures, groundwater from the overlying beneficial aquifers of the Hawkesbury Sandstone, surface water from the Nepean River and potable water from the Sydney Water supply used in current and historical onsite operational activities, including previous hydraulic fracturing programs.

The chemistry and isotope results clearly rule out the first scenario of hydraulic connection between deep coal seams and shallow groundwater and/or surface water. Shallow groundwater and surface water have distinctly different geochemistry and isotopic signatures to the ‘atypical’ wells. Surface water also contains tritium, which is not detected in the ‘atypical’ gas wells, therefore indicating ‘atypical’ water is likely not derived from modern surface water.

Scenario two was also ruled out because the potable water used in hydraulic fracture stimulation contains detectable tritium, is of meteoric origin and also contains elevated fluoride. The ‘atypical’ water contains no tritium, is low in fluoride and has a more depleted isotopic composition.

The chemical and isotopic data support the third scenario. The stable isotopic data indicate that the ‘atypical’ waters have undergone condensation, a process which can occur in unconventional gas wells due to changes in pressure, temperature and water flows. At the pressures associated with unconventional gas wells, large amounts of water can move as vapour. Pressure or temperature drops in the gas wells can cause liquid to “flash” evaporate and/or water vapour to condense. The consequences of flashing high salinity coal seam water are the precipitation of solids in gas wells and/or associated piping and infrastructure, and the formation of low salinity water derived from condensation.

These processes which result in the formation of low salinity water or ‘condensed water’ have been observed in gas wells producing low volumes of gas and water. The ‘atypical’ gas wells in the Camden CGP produce very low volumes of water (0 to 22.26 L/day) and produce the lowest amount of gas in the CGP (80 to 320 Mscf/day) providing further evidence that the ‘atypical’ produced water is derived from condensation of water vapour within the well and piping.

1. Introduction

AGL Upstream Investments Pty Ltd (AGL) owns and operates the Camden Gas Project (CGP) which is located in the Macarthur region, 65 km southwest of Sydney (Figure 1.1). The CGP has been producing gas for the Sydney region since 2001 and currently comprises 144 gas wells, underground gas gathering lines and the Rosalind Park Gas Plant. Not all gas wells, however, are currently operational.

The majority of gas wells were licensed under the *Water Act (1912)* (NSW) and in 2013 all production bore licences transitioned to Water Access Licences, Works Approvals and Use Approvals under the *Water Management Act 2000* (NSW).

AGL undertakes water quality sampling in the CGP from a selection of operational gas wells, water supply bores and groundwater monitoring bores as defined within the Groundwater Management Plan for the Camden Gas Project (GMP) (AGL 2012). The GMP has been endorsed by the NSW Office of Water and the NSW Environment Protection Authority (EPA).

Long term water quality monitoring data collected by AGL in the CGP shows the water quality in the targeted Permian coal seams to be slightly to moderately saline (AGL 2013), with a sodium bicarbonate (Na-HCO3) chemical composition which is characteristic of methane producing coal seams (Van Voast 2003). Water from the Permian Coal Measures also naturally contains dissolved metals including minor concentrations of arsenic, barium, copper, iron, lead, manganese, molybdenum and strontium.

During routine 2011 and 2012 monitoring events, it was found that produced water from a subset of gas wells comprising the monitoring network had a different 'atypical' chemical signature from the 'typical' chemical composition of the produced water, as determined by long term monitoring. Specifically, the 'atypical' wells had low salinity water, low concentrations of all major cations and anions with the exception of bicarbonate, high concentrations of iron and manganese, and in some gas wells, elevated concentrations of ammonia.

In 2012, AGL engaged Parsons Brinckerhoff to undertake a hydrogeochemical and isotopic study at the CGP to determine the nature and origin of the low salinity produced water from the 'atypical' gas wells.

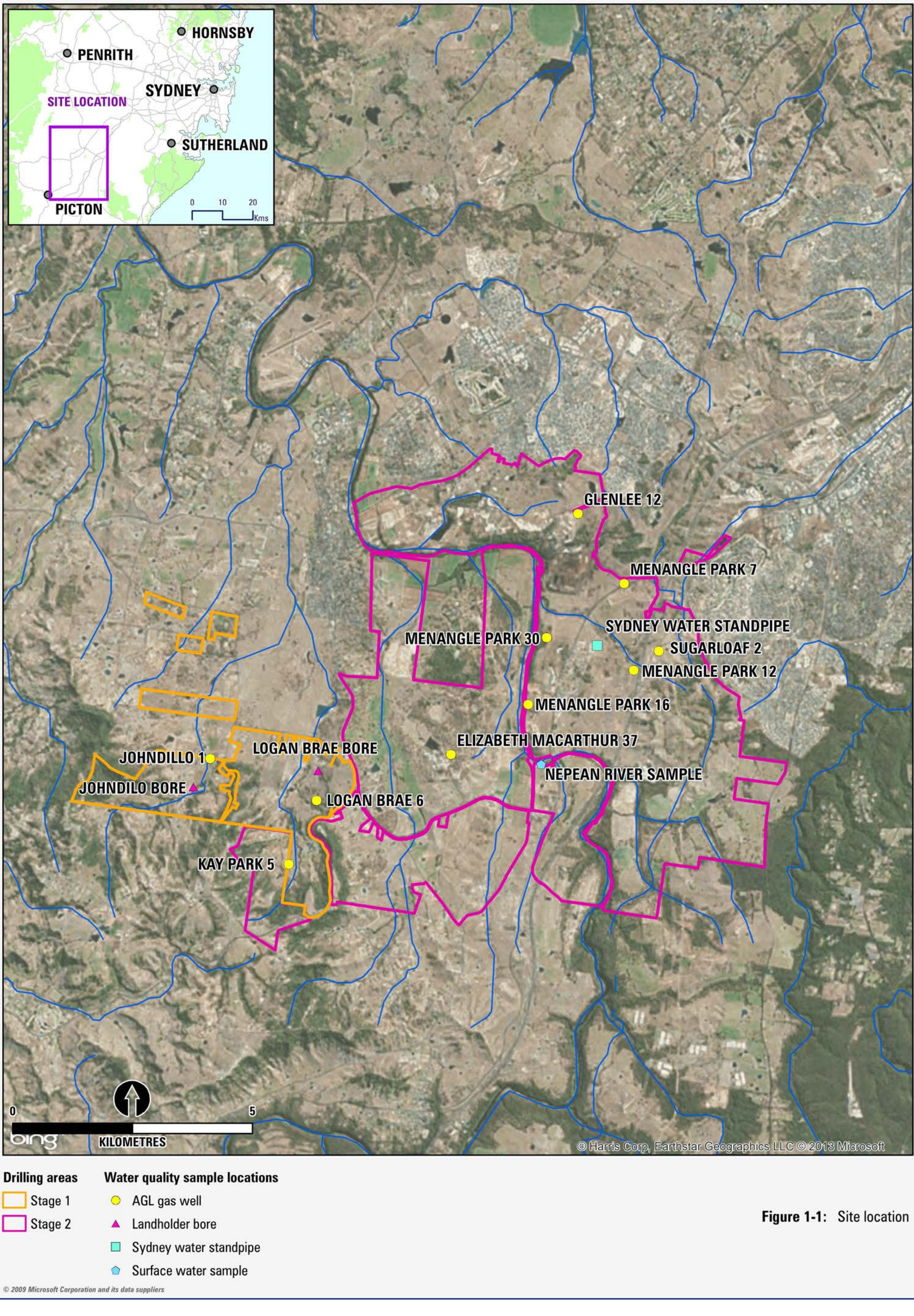


Figure 1-1: Site location

1.1 Project objectives

The overall objective of this study was to determine the nature and origin of the low salinity produced water from the 'atypical' gas wells in the CGP. A working hypothesis was developed for testing, identifying three possible scenarios for the origin of the low salinity water. These included the following:

1. Hydraulic connection between targeted coal seams and shallow aquifers or surface water
2. Residual potable water trapped when wells were hydraulic fracture stimulated
3. Formation of low salinity condensed water in gas wells.

To achieve the objectives the chemical and isotopic characteristics of the various water sources was assessed including the water associated with the Permian Coal Measures, groundwater from the overlying productive aquifers of the Hawkesbury Sandstone, surface water from the Nepean River and potable water from the Sydney Water supply used in current and historical onsite operational activities, including previous hydraulic fracturing programs.

1.2 Scope

The scope of the investigation undertaken by Parsons Brinckerhoff between October 2012 and May 2013 included the following:

- Literature review of water quality of produced water associated with shale gas or coal seam gas wells
- Collection of water samples from:
  - 10 gas wells, comprising five gas wells with 'typical' coal seam produced water quality and five gas wells with 'atypical' coal seam produced water quality
  - two water supply bores intercepting aquifers within the Hawkesbury Sandstone
  - one Sydney Water standpipe (potable water supply source)
  - the Nepean River
- Field measurement of unstable physicochemical parameters (electrical conductivity (EC), total dissolved solids (TDS), pH, dissolved oxygen, temperature, and redox potential)
- Submission of water samples to a NATA registered laboratory (ALS) for water quality analysis (major ions, metals, gases, total recoverable hydrocarbons, BTEX, PAHs and phenols), under appropriate chain-of-custody documentation and storage/transport protocols
- Submission of water samples to a qualified laboratory for stable isotope of water analysis (oxygen-18 and deuterium) (GNS Science Stable Isotope Laboratory)
- Submission of water samples to a qualified laboratory for tritium analysis (Australian Nuclear Science and Technology Organisation (ANSTO))
- Assessment of collected hydrogeochemical and isotopic data, historical water quality data, gas well construction and production volumes, hydraulic fracturing processes and other relevant literature
- Production of a report detailing results, analyses and findings.

1.3 Background information and hypothesis

A working hypothesis was developed for identifying and testing the three possible scenarios for the origin of the low salinity produced water. These were based on an extensive literature review of local and regional geology, chemistry of produced waters, local and international CSG and shale gas operations, and the chemistry of produced waters.

1.3.1 Hydraulic connection

Coal seam gas (CSG) is natural gas extracted at low pressure from coal. It is natural gas trapped in the structure of coal seams, rather than in the porous sandstone reservoirs which contain conventional natural gas. During coalification, most of the methane generated in coal seam escapes from the coal, however, some of this gas is adsorbed onto the surface of coal particles along fractures and cleats. The gas is held in place by water pressure.

Gas can de-sorb from coal if the water pressure is reduced. This is achieved by drilling wells into the target coal formations and removing water from the well. The coal seam is depressurised and gas flows from the matrix of the coal, into the cleat system and then into the well.

The water that is removed from the coal seam is known as 'produced water'. Initially, just water is released but as the coal seam becomes depressurised the proportion of gas increases and water production decreases.

The extraction of CSG and associated produced water from the Illawarra Coal Measures at the CGP will lead to the depressurisation of the coal seam water bearing zones at depth for the duration of gas extraction operations. Potential impacts to shallow groundwater resources and surface water will depend on the degree to which the Illawarra Coal Measures are in vertical connection with overlying aquifer zones within the Narrabeen Group, Hawkesbury Sandstone and thin alluvial deposits.

A detailed discussion of the geology and hydrogeology of the CGP is discussed in Section 2, and is based on data collected over 10 years from CSG exploration and operations at the CGP, and from the numerous drilling and mining programs in the Southern Coalfields. Although there are no specific monitoring or test pumping data for the CGP area to demonstrate the degree of vertical connectivity, inferences can also be drawn from studies elsewhere in the southern Sydney Basin, including impacts from longwall mining (see review by Merrick 2009) and groundwater resource investigations (e.g. PB 2008; SCA 2005).

In the Southern Coalfields, groundwater levels in shallow aquifers show a wide range of responses to the progression of longwall mining past a monitoring point from no noticeable impact to significant impact but generally transient responses (Merrick 2009). At some locations (e.g. bore DDH34 at Dendrobium Colliery, Merrick 2009) there were no discernible impacts due to depressurisation of the underlying coal seams suggesting that, in the absence of natural or mining induced fracture pathways, shallow aquifers are largely isolated by multiple aquitards in the stratigraphic succession.

Within the CGP area, although there is an absence of pump testing data, there is other physical and chemical data to assess the degree of vertical connection (or lack thereof). Interpretation of seismic data shows that many of the faults intersecting target coal seams have no surface expression. Water levels and water chemistry in Hawkesbury Sandstone monitoring bores have only shown natural variations, suggesting these beneficial aquifers are not directly connected to coal seams. Additionally, during the 2011–2012 monitoring period more than 80% of the operating wells produced negligible or no water (<50 kL per well during the financial year).

Based on the multiple lines of evidence collected during the 10 years of operation at the CGP and from these other previous studies it can be conjectured that the presence of extensive and thick claystone formations in the stratigraphy that overlies the Permian Coal Measures (refer to Section 2) in the CGP will impede vertical flow and protect shallow aquifers in the Triassic and surface water systems from drawdown impacts related to depressurisation of coal seams. However the possibility cannot be ruled out that fault zones could provide a hydraulic pathway through claystone horizons and that localised shallow groundwater impacts may be observed close to structures (refer to Merrick 2009).

The appearance of the low salinity ‘atypical’ produced water in 2011 was surprising based on the above evidence; and also considering more than 80% of the operating wells at the CGP in the 2011-2012 financial year produced negligible or no water (<50 kilolitres (kL) per well during the year). However, this connectivity scenario was not conclusively ruled out and was included in this study for further testing.

Chemical and isotopic tools were chosen to test this hypothesis. A similarity in chemistry between coal seam produced water and shallow groundwater and the presence of tritium in coal seam produced water would suggest that there may be a vertical connection and would require further testing.

1.3.2 Hydraulic fracturing

In the past, AGL has carried out hydraulic fracturing to stimulate the CSG reservoir to enhance gas production. All existing vertical and deviated gas wells within the CGP have been completed using fracture stimulation (also known as hydraulic fracturing) (AGL 2013). Typically a well is only fractured once, at the start of its production life.

Hydraulic fracturing is a process that consists of pumping a water based fluid under pressure into wellbores to open and connect fractures and cleats already present in the target coal seam or rock layer. It is only used in association with improving the performance of vertical and deviated gas wells that will not otherwise allow commercial gas flows from the coal seam without stimulation.

The fluid comprises primarily water and a proppant such as sand. The proppant is used to keep the widened fractures open to allow a pathway for gas to be produced to surface. The fracture stimulation fluid composition varies from site to site and contractor to contractor, but within the CGP fracture stimulation programs have used sand and water with gels to aid viscosity and minor acids and bactericides. Sixty-two (62%) percent of all the 117 fracture stimulation programs on wells in the CGP were performed with just water and sand; no additional chemicals were used. Since 2009 no fracture stimulations have been carried out at the CGP.

The fluid used is recovered from the well through ‘flowback’ and dewatering. This is achieved by using ‘breakers’ which react with fracturing gel, breaking down its viscosity back to water so that the fluid’s ability to flow is increased and it can be recovered back at surface. It is planned to recover 100% of the fracturing fluid however in tight coal seams, ‘flowback’ volumes are sometimes less than 100% or take very long time periods to recover this volume. To ensure full recovery, the AGL fracturing practice (where possible) involves logging, testing and disposing of around 150% of the volume of fracturing fluid as flowback water (i.e. 100% fracturing fluid and another 50% volume of formation water if the formation permeabilities are high enough).

The water used in hydraulic fracturing operations (and any subsequent maintenance operations) at the CGP was potable water sourced from the Sydney water supply. At some well sites, there is a possibility that not all water used in these programs was recovered from the coal seam and that the ‘atypical’ water now appearing in some gas wells is residual potable water from the fracture stimulation or maintenance operations. Although this scenario is unlikely, it was included for completeness.

Chemical and isotopic tools were chosen to test this hypothesis. A similarity in chemistry between coal seam produced water and Sydney water supply water and the presence of tritium in coal seam produced water would suggest that the coal seam water may be remnant hydraulic fracturing or well maintenance water and would warrant further testing.

1.3.3 Formation of low salinity condensed water

Published studies by Kharaka and Berry (1974) Kharaka *et al*. (1977) reported ‘abnormal’ water in gas and geothermal wells in the Kettleman North Dome of California and the Gulf Coast region of Texas. These waters were reported to have a lower salinity than normal, and Kharaka *et al* (1977) reported that these ‘abnormal’ waters had low salinity and silica concentration, and in some samples relatively high boron (B), ammonia (NH3) and hydrogen sulphide (H2S). Kharaka *et al*. (1977) state that chemical data from gas wells may not represent the true chemical composition of formation water because of formation of low salinity condensed water in gas wells.

Simpson *et al*. (2003) explains the process by which condensed water forms and moves in gas wells. The dew point at low pressures (such as required in CSG development) allows large volumes of water to move as vapour. This leaves mechanical separation equipment at the well heads ineffective and results in the precipitation of solids in gas wells or associated piping and infrastructure and the formation of a low salinity condensed water stream. Temperature changes in piping can also condense water vapour.

Normal gas-field field pressures limit the amount of water that can move as water vapour. At the pressures CSG fields exist under, larger amounts of water can move as vapour. Simpson *et al*. (2003) state that at 37.8°C at 30 psig bottom-hole conditions 6 bbl/MMCF of water can move as vapour. They also state that since most CSG wells produce less than this, just providing low pressures can often be an adequate artificial-lift technique.

Pressure or temperature drops up the gas wells can cause liquid to “flash” or water vapour to condense. Flashing of liquid, or flash evaporation, is the process by which partial vapour occurs when a saturated liquid stream undergoes a reduction in pressure. The consequences of flashing high salinity coal seam water is the precipitation of solids in gas wells or associated piping and infrastructure. Simpson *et al*. (2003) state that formation water which typically has a salinity in the order of approximately 10,000 mg/L will leave 1.5 kg of solids somewhere in the well/piping system when one barrel (approximately 159 L) is flashed. Waters with high total dissolved solid (TDS) content and are dominated by sodium and chloride will deposit NaCl salt. However, unless they are of marine origin, CSG produced waters are typically dominated by sodium and bicarbonate and will precipitate nahcolite (NaHCO3). Dissolved metals, such as iron, may also precipitate out as carbonates (e.g. siderite).

Formation of low salinity condensed water in the ‘atypical’ gas wells is plausible and is investigated further in this study. Chemical and isotopic tools were chosen to test this hypothesis. The absence of detectable tritium would rule out the first two scenarios. Analysis of oxygen-18 and deuterium (referred to as stable isotopes of water) could provide information on processes affecting the isotopic composition of produced water, such as evaporation or condensation.

2. Hydrogeological setting

A detailed discussion of regional and local geological and hydrogeological settings are provided in Parsons Brinckerhoff (2011a) and AGL (2013). A brief summary of these are provided in the following sections.

2.1 Geology

The CGP is part of the Southern Coalfields of the Sydney Geological Basin. The Basin is primarily a Permo-Triassic sedimentary rock sequence (Parkin 2002) and is underlain by undifferentiated sediments of Carboniferous and Devonian age. The stratigraphy of the CGP in the Camden-Campbelltown area is summarised in Table 2.1 and shown in the schematic model in Figure 2.1.

The Illawarra Coal Measures is the economic sequence of interest for CSG development in the area, and consists of interbedded sandstone, shale and coal seams, with a thickness of approximately 300 m. The upper sections of the Permian Illawarra Coal Measures (Sydney Subgroup) contain the major coal seams: Bulli Seam, Balgownie Seam, Wongawilli Seam, and Tongarra Seam. The primary seams targeted for coal seam gas production are the Bulli and Balgownie seams.

The Illawarra Coal Measures is overlain by the Triassic sandstones, siltstones and claystones of the Narrabeen Group and the Hawkesbury Sandstone. Overlying the Hawkesbury Sandstone is the Triassic Wianamatta Group which comprises the surficial geology where thin alluvial deposits are not present (Figure 2.2).

Structurally, the CGP area and surrounds is dominated by the north-northeast plunging Camden Syncline, which is a broad and gentle warp structure (Alder *et al*. 1991; Bray *et al.* 2010). The Camden Syncline is bounded in the west and truncated in the southwest by the north-south trending Nepean Structural Zone, part of the Lapstone Structural Complex.

The CGP is relatively unaffected by major faulting apart from a set of NW-NNW trending faults associated with the Lapstone Monocline Structure (Alder *et al*. 1991; Blevin *et al*. 2007). These faults have been identified from exploration and 2D seismic studies and they have been identified as high-angle, low to moderate displacement normal faults (Blevin *et al*. 2007). Many of these features shown on Figure 2.2 intersect coal seams but very few affect the entire stratigraphic sequence displaying no expression at surface.

Table 2.1 Summary of regional Permo-Triassic geological stratigraphy

Period	Group	Sub-group	Formation	Description	Ave thickness (m)*
Quaternary			Alluvium	Quartz and lithic 'fluvial' sand, silt and clay	<20
Tertiary			Alluvium	High level alluvium.	
Triassic	Wianamatta Group		Bringelly Shale	Shale, carbonaceous claystone, laminate, lithic sandstone, rare coal.	80 (top eroded)
			Minchinbury Shale	Fine to medium-grained lithic sandstone.	
			Ashfield Shale	Black to light grey shale and laminate (Bembrick *et al*. 1987).	
			Mittagong Formation	Dark grey to grey alternating beds of shale laminate, siltstone and quartzose sandstone (Alder *et al.* 1991).	11
			Hawkesbury Sandstone	Massive or thickly bedded quartzose sandstone with siltstone, claystone and grey shale lenses up to several metres thick (Bowman, 1974; Moffitt, 2000).	173
	Narrabeen Group	Gosford Sub-group	Newport Formation	Fine-grained sandstone (less than 3 m thick) interbedded with light to dark grey, fine-grained sandstones, siltstones and minor claystones (Bowman, 1974).	35
			Garie Formation	Cream, massive, kaolinite-rich pelletal claystone, which grades upwards to grey, slightly carbonaceous claystone containing plant fossils at the base of the Newport Formation (Moffitt, 2000).	8
		Clifton Subgroup	Bald Hill Claystone	Massive chocolate coloured and cream pelletal claystones and mudstones, and occasional fine-grained channel sand units (Moffitt, 2000).	34
			Bulgo Sandstone	Thickly bedded sandstone with intercalated siltstone and claystone bands up to 3 m thick (Moffitt, 2000).	251
			Stanwell Park Claystone	Red-green-grey shale and quartz sandstone (Moffitt, 1999).	36
			Scarborough Sandstone	Quartz-lithic sandstone, pebbly in part (Moffitt, 1999).	20
			Wombarra Claystone	Grey shale and minor quartz-lithic sandstone (Moffitt, 1999).	32
Permian	Illawarra Coal Measures	Sydney Subgroup	Bulli Coal	Coal interbedded with shale, quartz-lithic sandstone, conglomerate, chert, torbante seams and occasionally carbonaceous mudstone (Moffitt 2000)	4
			Loddon Sandstone		12
			Balmain Coal Member		24
			Balgownie Coal		2
			(Remaining Sydney Subgroup)		?
		Cumberland Subgroup			–
	Shoalhaven Group			Sandstone, siltstone, shale, polymictic conglomerate, claystone; rare tuff, carbonate, evaporate.	–
Palaeozoic	Lachlan Fold Belt			Intensely folded and faulted slates, phyllites, quartzite sandstones and minor limestones of Ordovician to Silurian age (Moffitt 2000)	–

(1) *Average thickness from available information on all wells within CGP (AGL 2013)

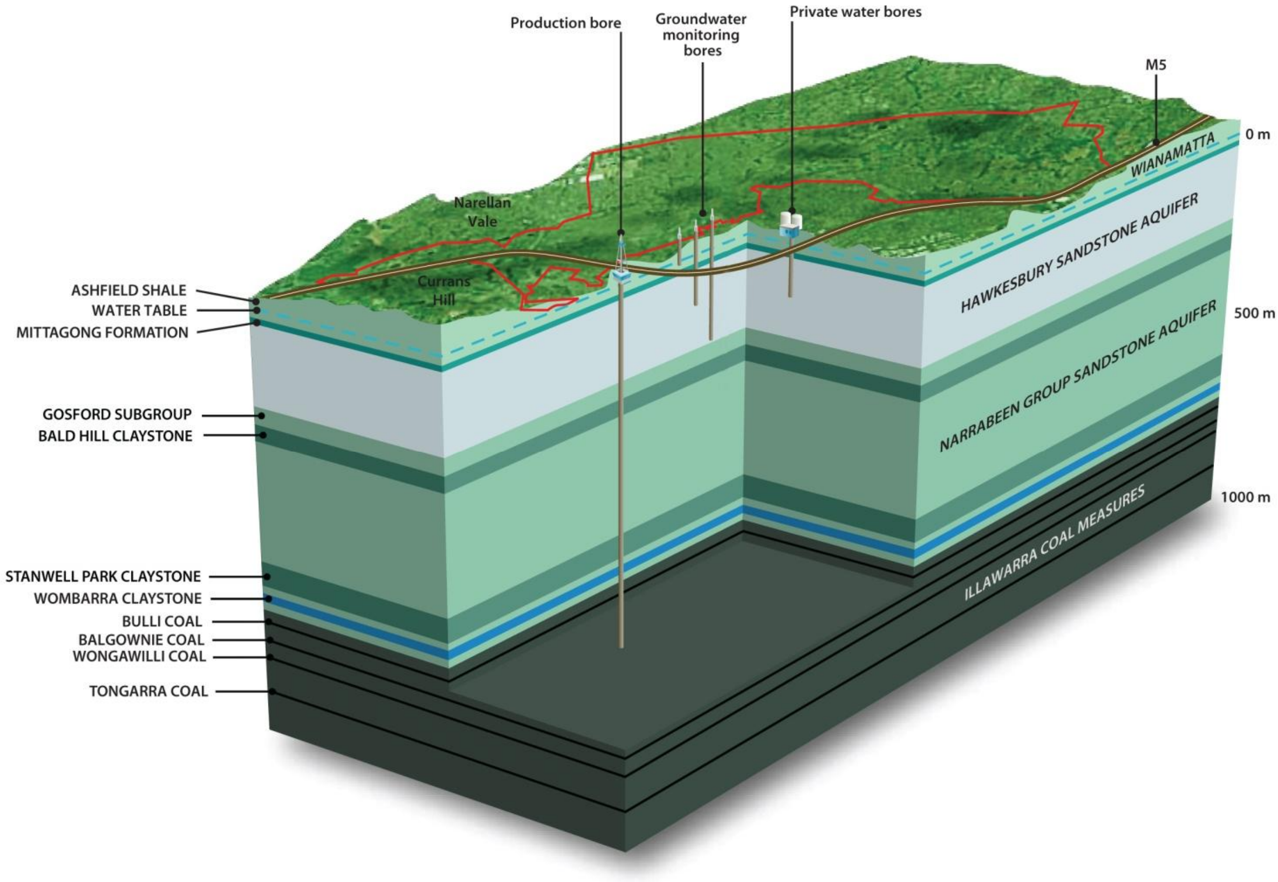
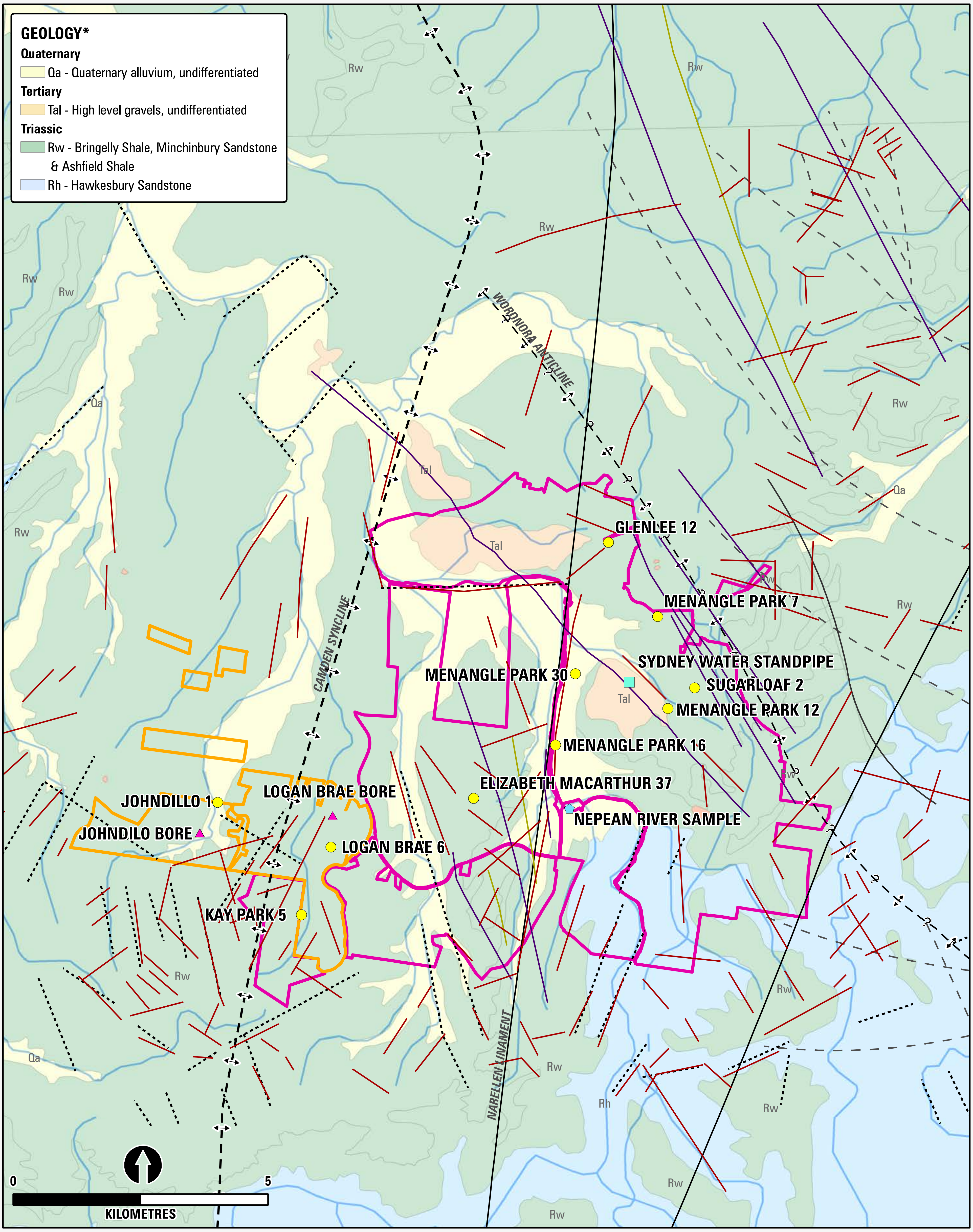


Figure 2.1 Schematic model that represents the stratigraphy of the CGP area and surrounds (Parsons Brinckerhoff 2012)

PARSONS BRINCKERHOFF

WATER QUALITY INVESTIGATION CAMDEN GAS PROJECT
AGL UPSTREAM INVESTMENTS PTY LTD



Drilling areas	Water quality sample locations	Geological structure		Faults ***
Stage 1	AGL gas well	Fold - Camden syncline *	Fault *	Certain fault
Stage 2	Landholder bore	Fold - anticline *	Fault - interpreted *	Possible fault
	Sydney water standpipe		Lineaments - Landsat interpreted (CSIRO) **	
	Surface water sample		Lineaments - air photo interpreted (CSIRO) **	

Figure 2-2: Geology and structure

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*© 2009 Microsoft Corporation and its data suppliers // *Geology 100k DPI // Mauger et al, * Southern Coalfields map, ** CSIRO 1:80,000 Landsat interpretation Fracture analysis, *** AGL Energy*

2.2 Hydrogeology

The Southern Coalfields are located within the Sydney Basin sedimentary rock groundwater system. The recognised aquifers/water bearing zones within the CGP are:

- Unconfined Quaternary and Tertiary alluvium/sediment aquifers
- Late Triassic Wianamatta Group rocks (minor aquifers or aquitards)
- Middle Triassic Hawkesbury Sandstone aquifers
- Lower Triassic Narrabeen Group sandstone aquifers
- Permian water bearing zones (Illawarra Coal Measures).

A summary of the hydrogeological properties for stratigraphic units (where known) is provided in Table 2.2.

Alluvium occurs along the floodplain of the Nepean River and its tributaries. The alluvium deposits are generally shallow, discontinuous (except along the Nepean River) and relatively permeable. The unconfined aquifers within the alluvium are responsive to rainfall and stream flow and form a minor beneficial aquifer.

The Wianamatta Group Shales (which outcrop across the majority of the CGP) are generally considered as aquitards due to low permeability and yields; however small aquifer zones are sometimes present. Water is typically brackish to saline, especially in low relief areas of western Sydney (due to the marine depositional environment of the shales) (Old 1942). Locally, the Wianamatta Group is low yielding, with average yields of 1.3 litres per second (L/s).

The Hawkesbury Sandstone and Narrabeen Group form part of an extensive confined to partially confined, regional aquifer system within the Sydney Basin sequence. The Hawkesbury Sandstone is more widely exploited for groundwater than the overlying and underlying formations, being of generally higher yield, better water quality and either outcropping or buried to shallow depths over the basin. Groundwater flow within the Hawkesbury Sandstone and Narrabeen Group aquifers at a regional scale has a major horizontal component due to the alternation of sheet and massive facies, with some vertical leakage. Both units are characterised by dual porosity, whereby the primary porosity is imparted by connected void space between sand grains and the secondary porosity is due to the interconnected rock defects such as joints, fractures, faults and bedding planes. Superior bore yield in the sandstone aquifers is often associated with major fractures or a high fracture zone density, and yields of >40 L/s have been recorded in bores intercepting these zones within deformed areas of the Sydney Basin (McLean and Ross 2009). Typically within the CGP area bore yields rarely exceed 2 L/s.

Within the CGP, the aquifers within the Hawkesbury Sandstone are mostly primary permeability aquifers due to the lack of major fracturing and fault systems. Yields are highest and salinities 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. Groundwater is used for irrigation and domestic use south of the Nepean River and immediately to the north; however, further north of the river, groundwater quality is typically only suitable for stock (AGL 2012).

Within the Narrabeen Group, both regionally and locally, aquifers are lower yielding and have poorer water quality than the overlying Hawkesbury Sandstone (Parsons Brinckerhoff 2012).

All aquifer systems within the CGP are separated by low permeability aquitards which act as confining layers and limit vertical flow between aquifers. The main aquitards within the CGP include the Bald Hill Claystone, Stanwell Park Claystone and the Wombarra Claystone.

The coal seams present in the Illawarra Coal Measures are both regionally and locally minor water bearing zones. Due to the greater depth of burial of the coal measures and fine-grained nature of the sedimentary rocks, the permeability is generally lower than the overlying sandstone aquifers. Recharge to the Permian water bearing zones is likely to occur where the formations are outcropping, which is remote (and to the south) from the CGP. Salinity of the water bearing zones is typically brackish to moderately saline.

Within the CGP, there is limited rainfall recharge to the Wianamatta Group shales with most rainfall generating runoff and overland flow. There is expected to be some leakage through the Wianamatta Group into the Hawkesbury Sandstone where there is adequate fracture spacing, however, it is anticipated that most recharge to the sandstone aquifers occurs via lateral groundwater through-flow from upgradient and updip areas to the south. Outside of the CGP, the dominant recharge mechanism is likely to be infiltration of rainfall and runoff through alluvial deposits in valleys, particularly where they are incised into weathered Hawkesbury Sandstone (PB 2010). There is insufficient data within the CGP to define local flow paths and natural discharge zones; however, regionally groundwater flow is predominantly towards the north or northeast, eventually discharging via the Georges, Parramatta or Hawkesbury River systems, and ultimately offshore to the east. Locally, there may be a small base flow or interflow discharge component to local stream headwaters during wet periods, however groundwater-surface water interactions are not well defined within the area (Parsons Brinckerhoff 2010).

Table 2.2 Hydrogeological properties for stratigraphic units where available

Age	Stratigraphic unit	Type of hydrogeological unit	Hydraulic conductivity – horizontal (m/d)	Hydraulic Conductivity – Vertical (m/d)	Transmissivity (m2/day)	Permeability (m/s)*	TDS (mg/L)
Quaternary/ Tertiary	Alluvial deposits	Unconfined aquifer	1 -10		>20		
Triassic	Wianamatta Group	Aquitard or unconfined/perched	0.01	0.05	<1 (Ashfield Shale)		>3,000
	Hawkesbury Sandstone	Unconfined/semi-confined aquifer	0.1	0.05 – 6 x 10-4	1 – 5	3 x 10-8	<500 – 10,000
	Bald Hill Claystone	Aquitard	1 x10-5	5 – 10		5 x 10-9	
	Bulgo Sandstone	Minor confined aquifer	5 x10-4 – 10-4	1 x10-4	0.1 – 0.5	6 x 10-8	1,500-5,000
	Stanwell Park Claystone	Aquitard	3x10-5	6 x10-6		3 x 10-9	
	Scarborough Sandstone	Minor confined aquifer	0.01	5 x10-3	0.1 – 0.5	2 x 10-7	
	Wombarra Claystone	Aquitard	3x10-5	6x10-6		1 x 10-9	
Permian	Illawarra Coal Measures	Confined water bearing zones	5x10-2 (Bulli)	2.5x10-2 (Bulli)	0.005 – 0.1	1 x 10-5 (Bulli)	>2,000

(1) Table summarises data from a number of investigations including SCA (2005); GHD (2007); Broadstock (2011); PB (2011); AGL (2013)

3. Hydrochemical setting

Review of available hydrochemical data from private bores registered with NSW Office of Water and from monitoring bores included in AGL's monitoring program indicate that groundwater quality in the shallow Triassic aquifer systems underlying the CGP area and surrounds is highly variable, with salinity from fresh (below 300 mg/L TDS) to slightly salty (up to 7,500 mg/L TDS).

Groundwater from the Ashfield Shale, which is part of the Triassic Wianamatta Shale Group, is typically brackish to saline. The high salinity values are due to connate seawater trapped during deposition of the sediment (Old, 1942). Values up to 31,750 mg/L TDS have been recorded in groundwaters from the shale (Woolley, 1991) within the Sydney Basin. However, the highest values are associated with groundwater in the central part of the Sydney Basin, where the base of the Wianamatta Group shale is located below sea level and natural drainage is restricted and flushing of salts very limited. Within the CGP there is very little data available for the Ashfield Shale, however the available data indicates that while the average salinity is >3,000 mg/L TDS, there are localised zones of fresher water (Parsons Brinckerhoff 2010; AGL 2013).

The groundwater salinity of the Hawkesbury Sandstone varies widely across the Sydney Basin, and even within the CGP there is a wide range in reported salinity values. The salinity of water in the Hawkesbury Sandstone within the central and south-western part of the CGP is generally fresh, with an electrical conductivity (EC) of around 600 µS/cm to 800 µS/cm. The water quality and salinity degrades to the northeast with electrical conductivity ranging from 5,500 µS/cm to 9,500 µS/cm (AGL 2013). The Basin wide salinity map produced for the Hawkesbury Sandstone aquifers (Russell 2007) indicates that the CGP is located in an area of much poorer water quality than other areas in the basin. This is due to infiltration of groundwater from the overlying Ashfield Shale which contains brackish to saline groundwater.

Table 3.1 provides a summary of groundwater quality in the Hawkesbury Sandstone aquifers and the produced water quality from the Permian Coal Measures. Included in this table is water quality from two Hawkesbury Sandstone monitoring bores located approximately 12 km north of the CGP at AGL's Raby Site at Denham Court, and from two private water supply bores included in AGL's monitoring program in the southwestern part of the CGP. The data presented in Table 3.1 was collected during historical monitoring programs, not as part of the current investigation.

In the south of the CGP, groundwater from the Hawkesbury Sandstone is fresh, and is geochemically characterised as Ca-Mg-HCO3 type water. Manganese and iron are present at low concentrations which is typical for Hawkesbury Sandstone due to the presence of siderite (FeCO3) and iron hydroxides and oxyhydroxides. The presence of metals including barium, cadmium, molybdenum, strontium and zinc is also not unexpected; these metals are commonly found in fresh groundwaters associated with Hawkesbury Sandstone aquifers (Parsons Brinckerhoff 2005). Strontium and barium are usually present in groundwater in Hawkesbury Sandstone aquifers, although not usually at high concentrations where fresh groundwaters prevail.

Monitoring bores to the north of the existing CGP indicate the slightly saline groundwater is dominated by sodium and chloride. Iron, manganese and other trace metals are generally present at higher concentrations than in groundwater in the south of CGP as is expected in higher salinity groundwater.

Table 3.1 Hydrochemical composition of Hawkesbury Sandstone

Units of measurement as mg/L unless stated	Hawkesbury Sandstone (south CGP)[a]			Hawkesbury Sandstone (north CGP)[b]		
	Sample number		8	Sample number		2
	Average of values >LOR	Minimum	Maximum	Average of values >LOR	Minimum*	Maximum*
Electrical conductivity (µS/cm@25°C)	611	578	639	7,615	–	–
Total dissolved solids	406	396	415	4,974	–	–
Hydroxide alkalinity as CaCO3	<1	<1	<1	<1	–	–
Carbonate alkalinity as CaCO3	7	<1	7	<1	–	–
Bicarbonate alkalinity as CaCO3	268	237	293	675	–	–
Total alkalinity as CaCO3	269	237	293	675	–	–
Sulfate as SO4	<1	<1	<1	63	–	–
Chloride	29	23	34	3,165	–	–
Calcium	58	38	68	253	–	–
Magnesium	17	15	19	68	–	–
Sodium	40	27	54	1,835	–	–
Potassium	6	4	8	30	–	–
Aluminium	<0.01	<0.01	<0.01	<0.01	–	–
Arsenic	0.006	<0.001	<0.008	0.008	–	–
Beryllium	<0.001	<0.001	<0.001	<0.001	–	–
Barium	1.28	0.76	1.89	3.31	–	–
Cadmium	0.0003	<0.0001	0.0003	<0.0001	–	–
Chromium	<0.001	<0.001	<0.001	0.005	–	–
Cobalt	<0.001	<0.001	<0.001	0.004	–	–
Copper	<0.001	<0.001	<0.001	<0.001	–	–
Lead	<0.001	<0.001	<0.001	0.100	–	–
Manganese	0.025	0.001	0.076	0.008	–	–
Molybdenum	<0.001	<0.001	<0.001	0.014	–	–
Nickel	<0.001	<0.001	0.001	<0.001	–	–
Selenium	<0.01	<0.01	<0.01	8.29	–	–
Strontium	0.300	0.204	0.404	0.016	–	–
Uranium	<0.001	<0.001	<0.001	<0.001	–	–
Vanadium	<0.01	<0.01	<0.01	<0.001	–	–
Zinc	0.010	<0.005	0.014	0.634	–	–
Boron	<0.05	<0.05	<0.05	0.32	–	–
Iron	3.39	<0.05	10.3	6.4	–	–
Bromine	0.15	<0.10	0.20	<0.10	–	–

a) From AGL (2013); b) From Parsons Brinckerhoff (2012) *Average calculated from two samples only.

The hydrochemical composition of produced waters from the Illawarra Coal Measures is provided in Table 3.2. The data provided in Table 3.2 were collected by AGL prior to the current study. The produced waters have been divided into two categories; 'typical' waters which are high salinity, Na-HCO3 type waters and 'atypical' waters which are low salinity waters.

Produced water from the Illawarra Coal Measures typically has a higher salinity than the Hawkesbury Sandstone aquifers, with salinity varying from moderately saline to saline. The chemical composition of produced water is typical for methane producing coal seams as described in Van Voast (2003) and Brinck (2008); it has low concentrations of sulphate due to the presence of anoxic conditions which result in sulphate reduction. The produced water also has low calcium (Ca2+) and magnesium (Mg2+), typical of coal seams where bicarbonate enrichment arising from sulphate reduction drives the inorganic precipitation of carbonates. The high levels of barium are also characteristic of produced waters; barium remains in its aqueous form in coal water bearing zones because sulphate reduction has removed sulphate ions that would cause barium to precipitate as the very insoluble species barite (BaSO4). The concentrations of dissolved metals in the 'typical' produced water in the CGP are generally near or below laboratory limits of reporting (LOR), with the exception of iron.

The 'atypical' produced water has a salinity lower than the beneficial aquifers of the Hawkesbury Sandstone in the CGP and in some gas wells is similar to that of rainfall. These waters were first observed in 2011 in the expanded monitoring program for some gas wells. There was no clear relationship between water quality and depth or no apparent spatial pattern that could explain their occurrence. The other perplexing issue was the timing; these gas wells were mostly in a mature part of the field and have been in operation for many years, some dating back to 2001, and the wells typically produced moderately saline to saline water prior to recently.

The 'atypical' gas wells still have sodium and bicarbonate as the dominant ions but these ions are present in significantly lower concentrations than in the 'typical' waters. Another major difference between the two waters is the trace metal concentrations. Barium and strontium concentrations are lower in the 'atypical' waters but concentrations of most other trace metals are higher in the 'atypical' waters, despite the lower salinity.

Table 3.2 Historical hydrochemical data for produced water taken from CGP producing gas wells

Units of measurement as mg/L unless stated	Illawarra Coal Measures – 'typical' produced water[a]			Illawarra Coal Measures 'atypical' produced water[b]		
	Sample number		36	Sample number		5
	Average	Minimum	Maximum	Average	Minimum	Maximum
Electrical conductivity (µS/cm@25°C)	12,599	6,130	36,100	303	152	713
Total dissolved solids	7,380	3,330	14,300	295	105	810
Hydroxide alkalinity as CaCO3	<1	<1	<1	<1	<1	<1
Carbonate alkalinity as CaCO3	930	<1	3,050	<1	<1	<1
Bicarbonate alkalinity as CaCO3	7,331	3,660	16,400	88	20	148
Total alkalinity as CaCO3	7,809	3,500	16,400	88	20	148
Sulfate as SO4	21	<1	202	2	2	2
Chloride	440	93	1,240	3	1	5
Calcium	12	2	38	2	2	2
Magnesium	8	2	36	<1	<1	<1
Sodium	3,690	1,540	8,000	14	5	30
Potassium	33	11	208	<1	<1	<1
Aluminium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	<0.001	<0.001	<0.001	0.001	0.001	0.001
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	10.3	0.45	35.5	0.285	0.029	0.566
Cadmium	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
Chromium	<0.001	<0.001	<0.001	0.002	0.001	0.003
Cobalt	<0.001	<0.001	0.001	0.002	0.001	0.003
Copper	0.01	<0.001	0.03	0.003	0.001	0.007
Lead	0.01	<0.001	0.03	0.001	0.001	0.001
Manganese	0.02	<0.001	0.13	0.550	0.001	0.857
Molybdenum	0.02	<0.001	0.10	0.002	0.001	0.003
Nickel	0.01	<0.001	0.002	0.009	0.001	0.031
Selenium	<0.01	<0.01	<0.01	0.01	0.01	0.01
Strontium	3.27	0.15	10.2	0.023	0.001	0.087
Uranium	0.001	<0.001	0.002	0.001	0.001	0.001
Vanadium	<0.01	<0.01	<0.01	0.01	0.01	0.01
Zinc	0.02	<0.005	0.07	0.021	0.005	0.041
Boron	0.13	<0.05	0.26	<0.005	<0.005	<0.005
Iron	0.99	<0.05	15.4	52.6	24.6	89.8
Bromine	1.21	<0.1	5.7	<0.05	<0.05	<0.05

a) From AGL (2013); b) Unpublished data from AGL (2012)

4. Methodology

The overall objective of this study was to determine the nature and origin of the low salinity produced water from the ‘atypical’ gas wells in the CGP. To accomplish this a sampling round was undertaken in October 2012, and a comprehensive suite of chemical analytes and isotopes were analysed for ‘typical’ and ‘atypical’ gas wells, and possible water sources contributing to the origin of these ‘atypical’ gas wells, including surface water from the Nepean River, fresh groundwater from the Hawkesbury Sandstone and potable water from the Sydney Water supply used in hydraulic fracturing and maintenance operations.

4.1 Monitoring network

Samples were taken from a subset of the AGL monitoring network which includes gas wells perforated in coal seams of the upper Illawarra Coal Measures and private bores screened in the Hawkesbury Sandstone. Details of gas wells sampled for the current investigation are provided in Table 4.1 and their locations are shown on Figure 1.1. The Group A wells were identified as ‘atypical’ gas wells producing low salinity water in 2011-2012 while the Group B wells were identified as typical’ gas wells producing moderately saline to saline water.

Table 4.1 Construction details of AGL gas wells

Group	ID	Type	Target Coal Seam	TD (m) MD	Fracture stimulation date	Spud date	Pumping well? Pumping frequency	Recent ~water production (L/day)	Recent ~gas production per day (Mscfd)
A	EM37	Deviated	Bulli	860.48	17/10/07	17/08/07	No	22.26	230
A	GL12	Deviated	Bulli/ Balgownie	988.42	20/11/06	7/07/06	No	22.26	320
A	LB06	Vertical	Bulli	840	08/10/02	3/1/00		0 (very low)	130
A	JD01	Vertical	Bulli	717	07/05/99	19/02/99	No	0 (very low)	80
A	MP16	Vertical	Bulli	630.6	11/10/03	09/08/03	Was offline from Feb 2012 to Sep 2012	159	115
B	MP12	horizontal	Bulli	603.5 (TVD)	no fracture stimulation	27/10/10	Was previously a pumping well	0 (very low)	560
B	MP30	horizontal	Bulli	2,619.3 (TD) 765.65 (TVD)	no fracture stimulation	Aug-07	Downhole pump installed few years ago but now free flowing	206.7	480
B	KP05	horizontal	Bulli	~670 TVD	no fracture stimulation	Feb-08?	No	47.7	600
B	SL02	Vertical	Bulli/ Balgownie Wongawilli	769.32	6/4/06	31/10/05	No	683.7	440
B	MP07	horizontal dual lateral	Bulli/ Balgownie	695 m TVD	no fracture stimulation	14/10/08	No	159	1,070

Samples were collected from two private bores penetrating the Hawkesbury Sandstone aquifer; the Johndilo Bore drilled to a total depth of 173 m and the Logan Brae bore which is drilled to a depth of 200 m. Both bores were cased and cemented to the top of the Hawkesbury Sandstone and intercept multiple aquifers.

In addition to groundwater sampling, a surface water sample was collected from the Nepean River and a potable water sample was collected from a Sydney Water standpipe located in the CGP.

4.2 Sampling methods

4.2.1 Gas wells

Produced water samples from the gas wells were collected at the gas separator. The samples were taken from the bottom valve in the gauge area of the separator where there is a level indicator that identifies the volume of the water that has accumulated in the separator (AGL 2011). In the days prior to sampling the separator of some gas wells was purged and the separator allowed to refill thus allowing a representative sample to be collected. Some wells that were sampled were not purged prior to sampling due to low water production rates.

4.2.2 Bores

Groundwater samples from the two Hawkesbury Sandstone water bores were collected from the dedicated pump outlets. Both bores were purged (by removing a minimum of three well volumes) one week before sampling, this ensures stagnant water was removed and the groundwater sample was representative of aquifer conditions.

4.2.3 Sydney water standpipe

A sample was collected from the reticulated Sydney Water supply by fixing a standpipe onto the hydrant below the gattic cover and collecting sample in a bucket.

4.2.4 Surface water

A surface water sample was collected at one location on the Nepean River using a rinsed bucket attached to a rope. The rope was extended to a minimum distance of one metre from the bank, allowing a representative surface water sample to be collected.

4.3 Chemical analysis of water

All the water samples collected were analysed for a broad chemical suite designed specifically to assess the chemical characteristics of the water bearing zones at the monitoring sites. The following physical water quality parameters were measured in the field using a calibrated YSI water quality meter:

- Electrical conductivity (EC) – µS/cm
- Temperature - oC
- Dissolved oxygen (DO) – % saturation and mg/L
- Oxidation reduction potential (ORP) – mV
- pH – pH units
- Total dissolved solids (TDS) (calculated) – mg/L.

Samples were also analysed for stable isotopes (oxygen-18 [δ18O], deuterium [δ2H] and radioisotopes (tritium [3H]).

Table 4.2 outlines the full chemical and isotopic suites analysed and full results are provided in Appendix A.

Table 4.2 Laboratory chemical and isotope analytical suite

Category	Parameters	
General parameters	Electrical conductivity (EC)	Total dissolved solids (TDS) (calculated)
	Total suspended solids	
Major ions	*Cations* calcium magnesium sodium potassium	*Anions* chloride bicarbonate sulphate fluoride dissolved silica
Metals and minor/trace elements	aluminium arsenic barium boron beryllium bromine cadmium cobalt copper iron	manganese molybdenum mercury nickel lead selenium strontium uranium vanadium zinc
Nutrients	Total nitrogen ammonia phosphorus (reactive)	nitrate nitrite
Hydrocarbons	Phenol compounds Polycyclic aromatic hydrocarbons (PAH)	Total petroleum hydrocarbons (TPH) Benzene, toluene, ethyl benzene and xylenes (BTEX)
Dissolved gases	Methane	
Isotopes	oxygen-18 deuterium	Tritium (3H)

Water samples were collected in the sample bottles listed in Table 4.3, with appropriate preservation when required. Samples undergoing dissolved metal analysis were filtered through 0.45 µm filters in the field prior to collection.

Table 4.3 Sample containers and preservatives

Category	Sample container
Physical properties & major cations/anions & silica	1 x 1 L plastic, unpreserved
Dissolved metals	1 x 60 mL plastic, preserved with nitric acid, field filtered
Nutrients	1 x 125 mL plastic, preserved with sulphuric acid
Methane	2 x 40 mL amber glass, preserved with sulphuric acid
Phenols/PAH/TPH (C10-C36)/TRH(C10-C40)	1 x 500 mL amber glass, unpreserved
TPH (C6-C9/TRH(C6-C9)/BTEX	2 x 40 mL amber glass, preserved with hydrochloric acid
Oxygen-18 and deuterium	30 mL nalgene, unpreserved (no head space)
Tritium	1 L nalgene, unpreserved

Samples were sent to the following laboratories under appropriate chain-of-custody protocols:

- Australian Laboratory Service (ALS) Environmental Pty Ltd, Smithfield, Sydney – chemistry analysis (Appendix B).
- GNS Stable Isotope Laboratory, Lower Hutt, New Zealand – oxygen-18 and deuterium analysis (Appendix C).
- ANSTO Tritium Laboratory, Lucas Heights, NSW – tritium (Appendix D).

4.4 Quality Assurance/Quality Control

A summary of field and laboratory QA/QC protocols are provided below.

Field QA/QC

The field sampling procedures conformed to Parsons Brinckerhoff's Quality Assurance/Quality Control protocols to prevent cross-contamination and preserve sample integrity. The following QA/QC procedures were applied:

- One duplicate per ten samples was collected as a control for chemical analysis (1 in total).
- Samples were collected in appropriate bottles with appropriate preservation solutions.
- Samples were kept chilled (<4°C) at all times.
- Samples were delivered to the laboratories within the specified holding times.
- Unstable parameters were analysed in the field (field parameters).

To assess the performance of the field QA/QC program, in particular the assessment of the reproducibility of the analytical measurements or precision given the adopted field and laboratory methods, the relative percentage difference (RPD) was calculated for the primary and duplicate samples. All results, with the exception of dissolved ethane and methane, were within acceptable RPD limits (see Appendix E).

Laboratory QA/QC

The laboratories conduct their own internal QA/QC program to assess the repeatability of the analytical procedures and instrument accuracy. These programs include analysis of laboratory sample duplicates, spike samples, certified reference standards, surrogate standards/spikes and laboratory blanks.

5. Water quality results

A full set of the chemical and isotope results for the October 2012 sampling event is provided in Appendix F and a summary is provided in Table 5.1. Major ion chemistry is shown on the Piper diagram in Figure 5.1 and stable isotopic compositions are compared to the Global Meteoric Water Line (GMWL) in Figure 5.2.

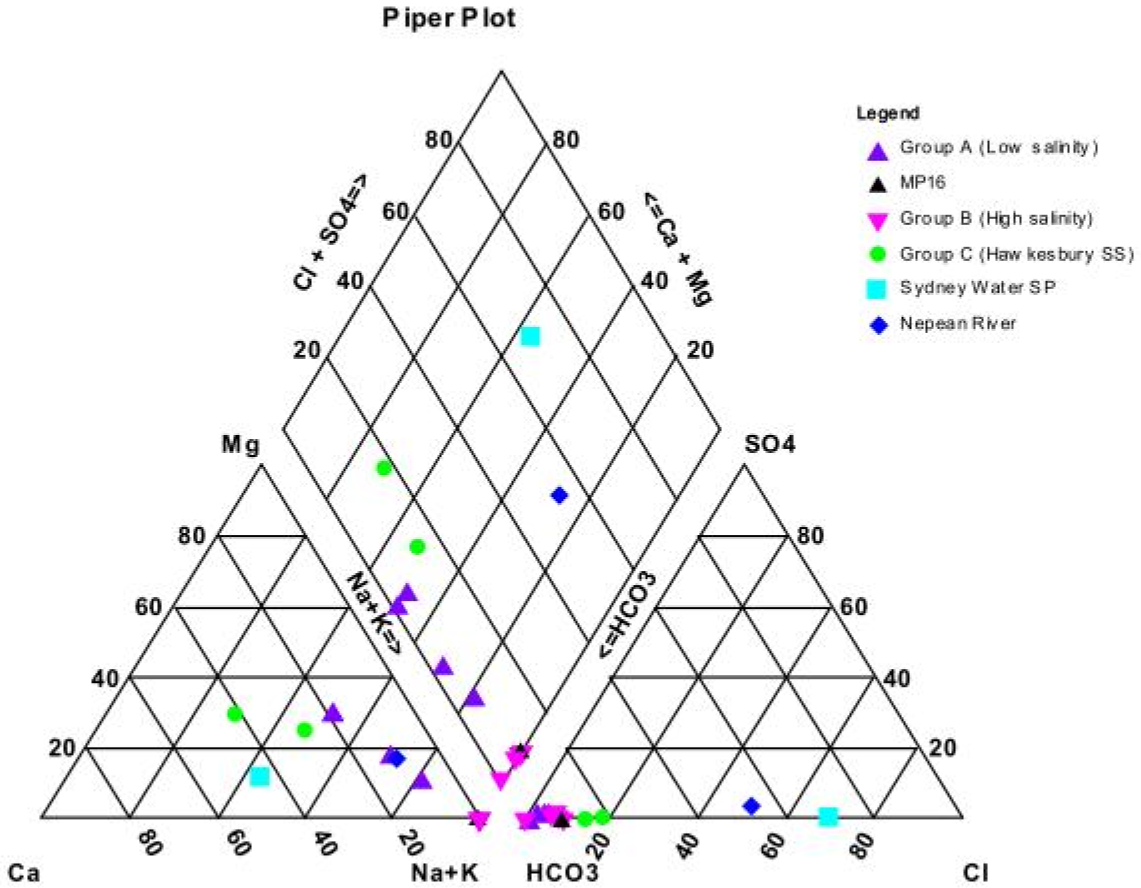

Figure 5.1 Piper diagram showing distinct water types for atypical and typical gas wells, Hawkesbury Sandstone bores, surface water and potable water (scaled to EC µS/cm)

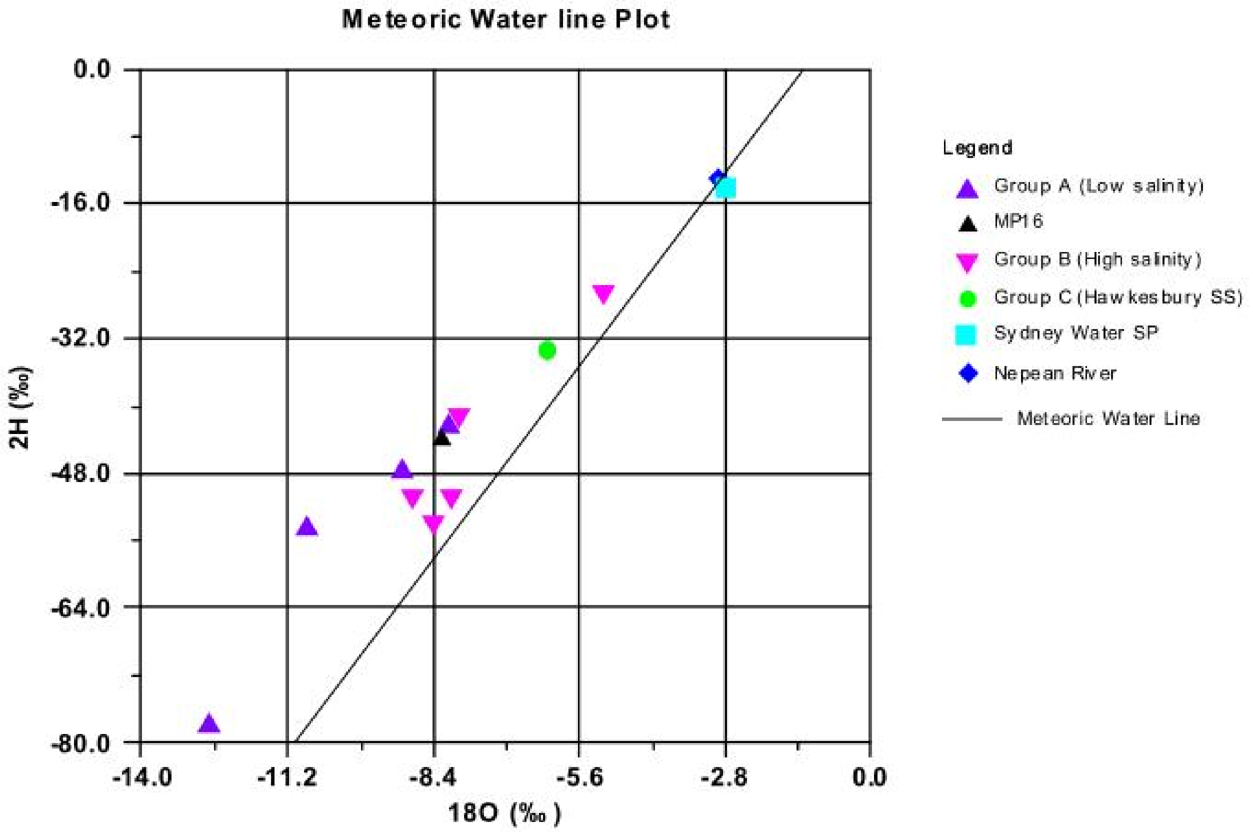

Figure 5.2 Deuterium versus oxygen for atypical and typical gas wells, Hawkesbury Sandstone bores, surface water and potable water (compared to Global Meteoric Water Line (GMWL))

Table 5.1 Hydrochemical and isotopic composition of produced water taken from CGP producing gas wells, groundwater, surface water and potable water

Units of measurement as mg/L unless stated	Illawarra Coal Measures –Group A 'atypical' produced water (n=4)			Group A outlier – MP16 (n=1)	Illawarra Coal Measures Group B 'typical' produced water (n=5)			Group C Hawkesbury Sandstone (n=2)	Group D Nepean River (n=1)	Group D Sydney Water supply (n=1)
	Average	Minimum	Maximum		Average	Minimum	Maximum	Average		
Field pH (pH units)	6.14	5.23	7.17	8.05	8.91	8.01	9.36	7.6	7.17	6.56
Electrical conductivity (µS/cm@25°C)	114	48	206	9,580	19010	5350	45700	643	262	157
Total dissolved solids (lab)	35	18	62	6480	14556	3460	37600	349	178	85
Hydroxide alkalinity as CaCO3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate alkalinity as CaCO3	<1	<1	<1	47	630	47	1770	<1	<1	<1
Bicarbonate alkalinity as CaCO3	48	20	84	5620	13046	2910	35600	248	56	17
Total alkalinity as CaCO3	57	31	84	5660	13684	2960	37400	248	56	17
Sulfate as SO4	1	1	1	<10	79	29	126	<1	<10	<1
Chloride	2	2	2	391	710	5	2440	33	43	28
Calcium	<1	<1	<1	5	6	3	9	40	5	12
Magnesium	<1	<1	<1	4	10	4	24	19.5	5	2
Sodium	5	3	6	2710	6664	1390	17700	48	38	13
Potassium	<1	<1	<1	21	52.6	12	125	6	3	<1
Silica	0.8	0.3	2.1	16.8	26.2	7.1	58.9	11.65	0.8	2.2
Fluoride	<0.1	<0.1	<0.1	1.0	1.84	0.7	4	0.15	<0.1	0.9
Aluminium	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	<0.01	0.01	0.03
Arsenic	0.001	0.001	0.001	0.001	0.028	0.002	0.068	0.002	<0.001	<0.001
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	0.123	0.029	0.276	7.6	13.2	1.7	30.3	1.056	0.107	0.038
Cadmium	<0.0001	<0.0001	<0.0001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	0.001	0.001	0.001	<0.01	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Copper	0.002	0.001	0.003	<0.01	0.003	0.003	0.003	0.002	0.001	0.002
Lead	<0.001	<0.001	<0.001	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	0.636	0.375	1.22	0.02	0.022	0.009	0.065	0.036	0.005	0.002
Molybdenum	0.001	0.001	0.001	0.136	0.082	0.003	0.283	<0.001	<0.001	<0.001
Nickel	0.003	0.001	0.004	0.021	0.003	0.001	0.005	<0.001	0.002	<0.001
Selenium	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	0.012	0.003	0.019	2.31	5.40	0.67	8.3	0.315	0.079	0.045
Uranium	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.0325	0.019	0.041	<0.05	0.007	0.005	0.009	0.011	0.006	0.012

Units of measurement as mg/L unless stated	Illawarra Coal Measures –Group A ‘atypical’ produced water (n=4)			Group A outlier – MP16 (n=1)	Illawarra Coal Measures Group B ‘typical’ produced water (n=5)			Group C Hawkesbury Sandstone (n=2)	Group D Nepean River (n=1)	Group D Sydney Water supply (n=1)
Boron	<0.05	<0.05	<0.05	<0.1	0.208	0.07	0.42	<0.05	<0.05	<0.05
Iron	87.1	33.8	169	0.83	2.04	0.12	4.12	0.22	0.1	<0.05
Bromine	<0.1	<0.1	<0.1	<0.1	2.1	0.5	6.2	<0.1	0.1	0.2
Ammonia as N	8.31	0.02	21.8	5.21	5.67	0.15	14.3	0.235	<0.01	0.13
Methane	13722	6530	27800	3560	789	352	1490	113	<10	<10
Oxygen-18 (‰)	-10.16	-12.7	-8.12	-8.22	-7.65	-8.83	-5.1	-6.21	-2.76	-2.91
Deuterium (‰)	-55.3	-77.7	-42.1	-43.7	-42.9	-53.9	-26.3	-33.5	-13.9	-12.8
Tritium (TU)	0.15	0.08	0.28	0.3	0.254	0.06	0.78	0.05	1.56	1.51

5.1 ‘Typical’ gas wells

Five gas wells which all showed high salinity ‘typical’ water quality in early 2012 were included in the October 2012 sampling event. The main findings on water quality and isotopic composition for the ‘typical’ gas wells are as follows:

- Salinity (EC and TDS) was brackish to saline
- Major ion composition was dominated by sodium and bicarbonate and carbonate alkalinity
- Fluoride concentrations were higher than all other water sources, including the Sydney Water supply which is dosed with fluoride at 1 mg/L
- Silica concentrations varied between gas wells but were higher than all other water sources
- Barium and strontium concentrations were higher than the ‘atypical’ gas wells by one to two orders of magnitude
- Zinc, iron and manganese concentrations were significantly higher than in ‘atypical’ gas wells by one to two orders of magnitude
- Molybdenum and boron concentrations are also higher than the ‘atypical’ wells
- Ammonia (as N) concentrations vary between the typical gas wells, but are not as high as the ‘atypical’ gas wells
- Dissolved methane concentrations were higher than in groundwater and surface waters
- The average stable isotopic composition was more depleted than in shallow groundwater and surface waters
- Tritium values were close to detection limit and were lower than in surface water and potable water.

5.2 ‘Atypical’ gas wells

Five gas wells which all showed low salinity ‘atypical’ water quality in early 2012 were included in the October 2012 sampling event. One of these gas wells, MP16, had returned to ‘typical’ water quality conditions in this event, and has therefore been excluded from the summary statistics and analysis of the ‘atypical’ wells. MP16 is labelled on the Piper diagram in Figure 5.1, the stable isotope graph in Figure 5.2 and ion chloride plots in Appendix F to highlight the differences between MP16 and the ‘atypical’ wells. It is necessary to analyse this well separately to understand the origin of the low salinity water and/or the processes involved in the change of gas well salinity.

The main findings on water quality and isotopic composition for the ‘atypical’ gas wells are as follows:

- Salinity (EC and TDS) was lower than all other water sources including potable water and surface water.
- Major ion composition was dissimilar to the ‘typical’ wells as seen on the Piper diagram in Figure 5.1, and is all geochemically different to the other water sources.
- Bicarbonate was the only major ion present in any appreciable concentrations, and the sum of major cations does not equal the sum of major anions. The sum of anions is therefore balanced by other cations including iron and ammonium and water is chemically classified as Fe-NH_4-HCO_3 type water.
- Fluoride concentrations were below laboratory LOR and were the lowest of all waters.
- Silica concentrations were lower than in ‘typical’ gas wells by an order of magnitude, and were similar to surface water and potable water.

- Barium concentrations were lower than in 'typical' gas wells and Hawkesbury Sandstone bores, and strontium concentrations were the lowest of all water sources sampled.
- Zinc, iron and manganese concentrations were significantly higher than in 'typical' gas wells and the other water sources.
- Ammonia (as N) concentrations vary between the atypical gas wells, and no relationship can be drawn with depth of coal seam or location.
- Dissolved methane concentrations were higher than in the 'typical' gas wells.
- The average stable isotopic composition was more depleted than 'typical' gas wells.
- Tritium values were close to detection limit and were similar to 'typical' gas wells.

5.2.1 MP16

The main findings on water quality and isotopic composition for MP16 are:

- Salinity (EC and TDS) was comparable to 'typical' gas wells.
- Major ion composition was Na-HCO_3 (Figure 5.1).
- Fluoride, silica, barium and strontium concentrations were comparable to 'typical' gas wells.
- Silica concentrations were lower than in 'typical' gas wells by an order of magnitude, and were similar to surface water and potable water.
- Ammonia (as N) concentration was high.
- Dissolved methane concentrations were higher than in the 'typical' gas wells.
- The average stable isotopic composition was more depleted than 'typical' gas wells.
- Tritium values were close to detection limit and were similar to 'typical' gas wells.

5.3 Hawkesbury Sandstone bores

Two private bores penetrating the Hawkesbury Sandstone were included in the October 2012 sampling event. The bores are cased and cemented to approximately the top of the Hawkesbury Sandstone and are then open hole for approximately 70 metres, straddling multiple aquifers. These bores are located in the south of the CGP where lower salinity values are reported. The main findings on water quality and isotopic composition for the Hawkesbury Sandstone are as follows:

- Salinity (EC and TDS) was fresh due to proximity of bores to recharge zones.
- Major ion composition was dominated by calcium, magnesium and bicarbonate.
- Fluoride concentrations are lower than the other water sources, with the exception of surface water from the Nepean River.
- Silica concentrations are higher than 'atypical' gas wells.
- Barium and strontium concentrations were higher than the 'atypical' gas wells.
- Iron and manganese concentrations were higher than in 'atypical' gas well.
- Ammonia (as N) and dissolved methane concentrations were low.
- Dissolved methane concentrations are higher in groundwater and surface waters.
- The average stable isotopic composition was more enriched than in the majority of all gas wells, and samples plotted close to the GMWL (Figure 5.2).
- Tritium values were close to detection limit.

5.4 Nepean River

One surface water sample was collected from the Nepean River for the study. The main findings on water quality and isotopic composition for the Nepean River sample are as follows:

- Salinity (EC and TDS) was fresh but higher than in ‘atypical’ wells and potable water.
- Major ion composition was dominated by sodium, chloride and bicarbonate.
- Fluoride concentrations were below the laboratory LOR.
- Silica concentrations were lower than potable water.
- Dissolved metals concentrations were close or below the laboratory LOR with the exception of barium, strontium and zinc.
- Ammonia (as N) and dissolved methane were below laboratory LOR.
- The average stable isotopic composition was more enriched than groundwater and plotted on the GMWL.
- Tritium values were high and comparable to potable water.

5.5 Potable water supply

One potable water sample was collected from the Sydney Water supply system. The main findings on water quality and isotopic composition for the potable water supply sample are as follows:

- Salinity was fresh and water was chemically classified as Ca-Na-Cl-HCO_3 type water.
- Fluoride concentrations were higher than groundwater and surface water. Fluoride is added to Sydney water supply.
- Dissolved metals concentrations were close or below the laboratory LOR with the exception of barium, strontium and zinc.
- Dissolved methane were below laboratory LOR.
- The average stable isotopic composition was more enriched than groundwater and plotted on the GMWL (Figure 5.2).
- Tritium values were high and comparable to surface water.

6. Discussion

This section provides a discussion of the chemical and/or physical processes that drive the geochemical evolution of brackish to saline 'typical' produced waters and the low salinity 'atypical' produced waters in the CGP.

6.1 'Typical' gas wells

The chemistry of the produced water from the 'typical' gas wells at the CGP is characteristic of coal seams and shale formations that produce methane. These waters are typically brackish to saline, chemically classified as Na-HCO_3 type waters, and have low concentrations or are devoid of sulphate, calcium and magnesium (Van Voast 2003). They may also contain variable concentrations of barium, strontium, fluoride, some trace metals and ammonia. They may also contain high concentrations of ammonia (Brinck *et al*. 2008). In basins where the coals are in stratigraphic association with marine or marine-transitional beds, chloride and sodium are the substantial components. Many coal bed water bearing zones can contain substantial concentrations of sulphate, calcium and strontium but are not found in association with methane.

The geochemical processes that result in this distinct geochemical signature have been studied and published by a number of researchers including Van Voast (2003), Brinck *et al*. (2008) and Rice *et al*. (2008) and Healy *et al.* (2011). The principal geochemical processes include microbial sulphate reduction, bicarbonate enrichment through carbonate dissolution recharge zones, sulphate reduction and methane fermentation processes and calcium and magnesium depletion through inorganic precipitation of calcite and dolomite and possibly cation exchange. Figure 6.1 shows a summary of the geochemical processes occurring in methane producing aquifers.

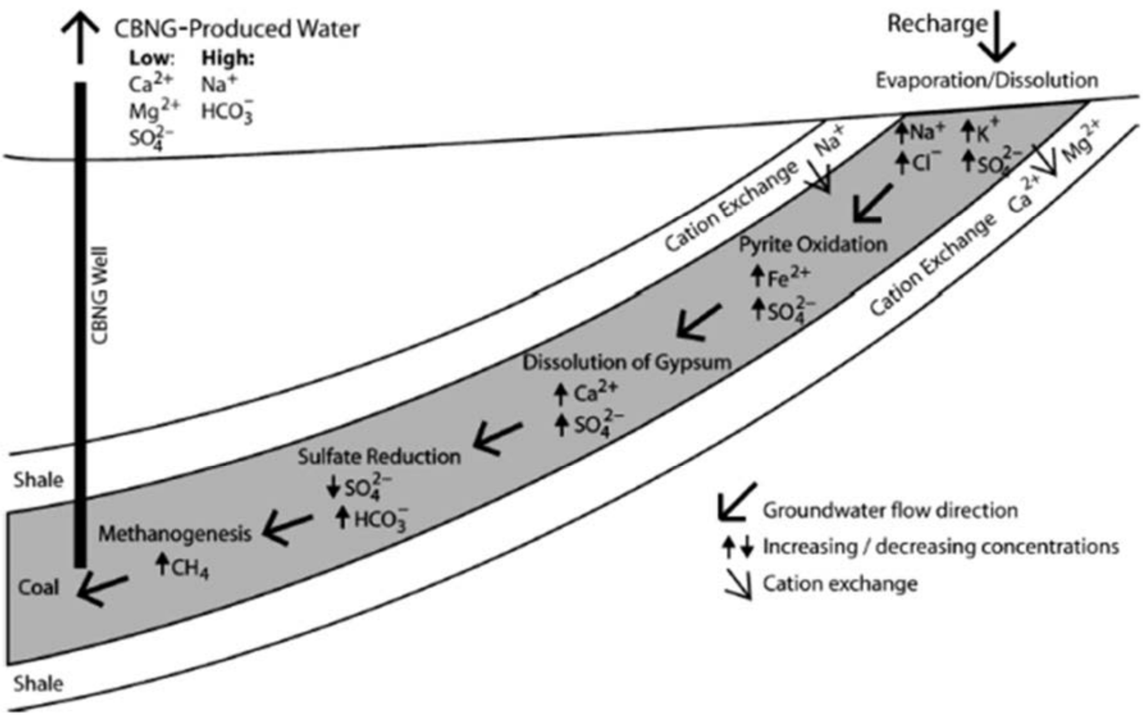

Figure 6.1 Summary of geochemical processes occurring in coal aquifers used for coal seam gas production (Brinck et al. 2008).

The 'typical' produced waters in the Camden CGP have low concentrations of sulphate. The sulphate in the coal seam water is originally produced in the recharge zone through weathering and oxidation of pyrite and marcasite and possibly dissolution of salts such as gypsum. As water enters the deeper and anoxic parts of the coal measures, the sulphate is reduced by sulphate-reducing bacteria. This reaction produces bicarbonate. Formation water in the coal seams is above pH 7 therefore the following equation describes the sulphate reduction process:

$2CH_2O + SO^{42-} \rightarrow H_2O + CO_2 + HCO_3- + HS^{2-}$ (Eqn 1)

The 'typical' produced water at the CGP is oversaturated with respect to iron sulphides, therefore it is likely that the sulphide produced in Equation 1 is being precipitated according to Equation 2:

$15CH_2O + 2Fe_2O_3 + 8SO4^{2-} + H_2CO_3 \rightarrow 8H_2O + 16HCO_{3-} + 4FeS_2$ (Eqn 2)

The 'typical' produced waters in the CGP have low concentrations of calcium and magnesium. Saturation indices indicate that these waters are oversaturated with respect to calcite and dolomite, which is the result of the presence of elevated concentrations of bicarbonate.

$Ca^2 + 2HCO_{3-} \leftrightarrow CaCO_3 + H_2O + CO_2$ (Eqn 3)

Cation exchange may also be occurring in the coal measures. As water moves from the recharge zone progressively through the coal measures, if it comes into contact with reactive clay minerals, the calcium and magnesium ions in solution adsorb to the clay and are replaced in the water solution by equivalent molar concentrations of sodium previously adsorbed on the clay. The following equation describes ion exchange:

$Na_{2-}Clay + Ca^{2+} \rightarrow 2Na^+ + Ca\text{-}Clay$

There are three principal origins of methane in groundwater:

1. Biogenic methane is the most common in shallow groundwater systems, forming from the bacterial reduction of organic matter.
2. Thermogenic methane forms by the breaking down of higher mass hydrocarbons at elevated temperatures and represents natural gas in sedimentary basins.
3. Abiogenic and mantle methane can be produced without the involvement of bacteria when strongly reducing conditions and inorganic catalysts such as Fe are found.

In the CGP area, methane is mainly thermogenic with some biogenic methane also present. Biogenic methane is produced in the coal measures by methanogenic bacteria (biogenic methane), which may occur concurrently with sulphate reduction, depending on methanogenic species present (Oremland *et al*. 1982). Biogenic methane can be formed by two processes; acetate fermentation (Eqn 4) where methanogens use acetate to produce CO^2 and methane, or CO_2 reduction (Eqn 5) where methanogens use hydrogen gas to reduce CO_2. In equation 4 inorganic carbon is represented as CO_2, although it will naturally hydrate and dissociate to form bicarbonate at ambient pH in most waters.

$CH_3COOH \rightarrow CH_4 + CO_2$ (Eqn 4)

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$; or $HCO_{3-} + 4H_2 \rightarrow CH_4 + 2H_2O + OH-$ (Eqn 5)

Thermogenic methane usually occurs at depths exceeding 1,000 m and is produced under conditions of high temperature and pressure. At temperature >70°C, generation of gas and liquids occurs by thermocatalytic conversion of coal. The main thermogenic products are H_2O, CO_2, CH_4, C_2H_6 (ethane) and higher hydrocarbon gases and liquids. At higher temperatures and higher degrees of coalification, previously formed long chain and liquid hydrocarbons will be thermally cracked to CH_4, increasing the total amounts of CH4 generated. Thermogenic gas generation ceases when temperature decreases due to basin uplift.

The 'typical' produced waters have an alkaline pH and contain trace elements including molybdenum, boron and fluoride which are more mobile in natural alkaline waters because common adsorption media, mineral oxides and hydroxides, take on a negative charge in alkaline conditions which decreases the adsorption of anionic species (Brink *et al*. 2008).

The 'typical' produced waters also have high concentrations of strontium and barium. These cations remain in solution in coal seam water bearing zones because sulphate reduction has removed sulphate ions that would cause barium to precipitate as the very insoluble species barite ($BaSO_4$) and strontium as celestite ($SrSO_4$).

The 'typical' produced waters also contain ammonia which is to be expected since coals seams contain nitrogen bearing compounds (pyridines and amines) (Berton Fisher and Santamaria 2002). Coal generally contains 0.5% to 3% (dry weight) nitrogen, most of which is organic. In coal deposits, coalification (coal formation), coal weathering, and anaerobic degradation of coal can result in the mineralisation of organic nitrogen to ammonium. Therefore, coal can contain relatively high amounts of exchangeable ammonium. The ammonium concentration in gas wells may decrease over time due to depletion of sorbed ammonium that was associated with the coal, and continued pumping causing a decrease in the pool of sorbed ammonium in the vicinity of the well bore (Smith *et al* 2009).

6.2 'Atypical' gas wells

The water chemistry of the 'atypical' gas wells is compared to the 'typical' gas wells in ion/Cl graphs in Appendix F. Apart from the anomalous gas well MP16, which historically had 'atypical' water quality but in the October 2012 sampling round had 'typical' gas well chemistry, there is a clear distinction between the two types of gas wells. The 'atypical' gas wells have the following characteristics:

- Low salinity and major ion composition with the exception of bicarbonate.
- Low silica concentrations.
- High concentrations of iron, manganese and zinc.
- Variable concentrations of ammonia.
- Low tritium concentrations.

Three scenarios were proposed for the formation of these atypical waters:

1. Hydraulic connection between targeted coal seams and shallow aquifers or surface water.
2. Residual potable water trapped when wells were hydraulic fracture stimulated.
3. Formation of low salinity condensed water in gas wells.

Based on the collected chemical and isotopic data, the first two scenarios can be discounted. There are distinct geochemical differences between the 'atypical' produced waters and shallow groundwater, surface water and potable water as described in Section 5 and shown in the Piper diagram in Figure 5.1 and ion/Cl graphs in Appendix F.

The tritium data indicates that surface water and potable water is modern. Tritium (^{3}H) is a short-lived isotope of hydrogen with a half-life of 12.43 years. It is directly incorporated into the water molecule ($^{1}H^{3}HO$ or ^{1}HTO) and so is the only radioisotope that actually dates groundwater. It is commonly used to identify the presence of modern recharge. Tritium is produced naturally in small amounts in the troposphere. However, tritium was also produced by thermonuclear explosions in the 1950s and 1960s. The concentration of tritium in Australian precipitation reached a maximum level of 160 TU in 1960, during one of the most intense periods of nuclear testing. Since this time tritium concentrations have been declining and since 1990 the levels of tritium in Australia have stabilised to 2 to 3 TU latitudinally across the continent (Tadros et al. 2004).

Using the average tritium value of 3 TU and using the radioactive decay equation ($^{3}H = {}^{3}H0lne\text{-}\lambda t$; where $^{3}H0$ is the initial value, and λ is the decay constant of tritium of 0.056 year-1), surface and potable water analysed during this study has an age estimate of 12 years. Tritium concentrations are negligible in the ‘atypical’ and ‘typical’ gas wells, confirming that no modern water (<50 years old) is present in the deep coal seams that these wells penetrate. Therefore, the produced water cannot be derived from either connection with shallow aquifers that would contain detectable tritium and surface water or from dilution by residual hydraulic fracturing fluid.

The isotopic data also confirms this conclusion; there is distinct differentiation in the stable isotopic composition (δ2H and δ18O) between the ‘atypical’ wells and the shallow groundwater, surface water and potable water. The shallow groundwater plots on the GMWL, as does the surface water and potable water indicating they are derived from rainfall. The ‘atypical” and ‘typical’ gas wells are more isotopically depleted than these waters, and lie to the left of the GMWL. Three out of four of the ‘atypical’ gas wells have the most depleted isotopic signatures; these gas wells also have the lowest salinity.

The GMWL (as seen on Figure 5.1) provides an important key to the interpretation of oxygen-18 and deuterium data. It is a line that defines the relationship between oxygen-18 (^{18}O) and deuterium (^{2}H) in fresh surface waters and precipitation from a number of global reference sites. Water with an isotopic composition that lies on the meteoric water line is assumed to have originated from the atmosphere and be unaffected by other isotopic processes. Shifts from the meteoric water line result from isotopic processes other than the typical water cycle processes. In most cases, the processes affect the relationship between $\delta^{2}H$ and $\delta^{18}O$ in a unique way that the position of the data points can help to identify the processes. This is illustrated in Figure 6.2 which illustrates the direction away from the meteoric water line in which various processes push the composition of water (Domenico and Schwartz 1998).

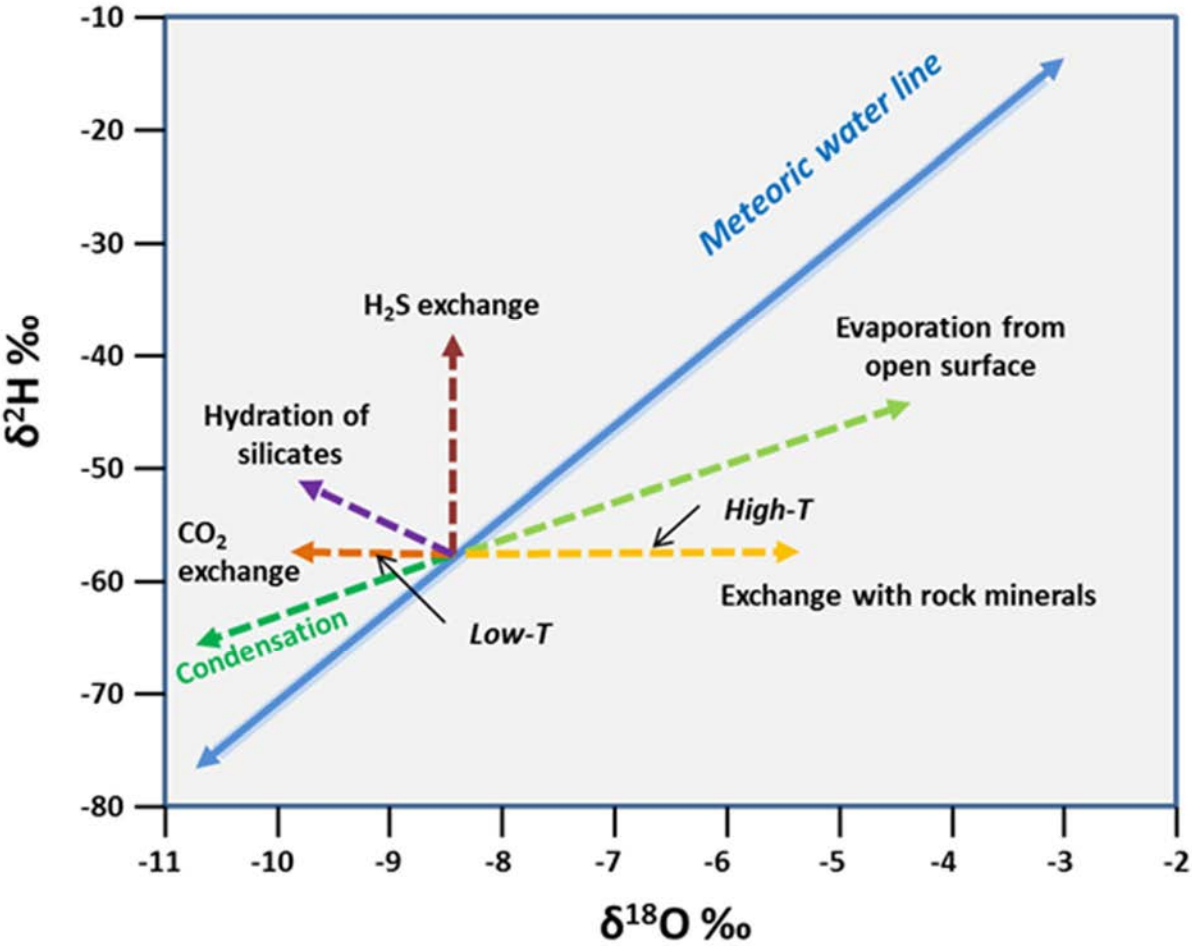

Figure 6.2 Deviations in isotopic compositions away from the meteoric water line as a consequence of various processes (Domenico and Schwartz 1998)

The 'atypical' gas wells plot on the δ^2H- $\delta^{18}O$ diagram along a trajectory consistent with condensation. Condensation forms through the cooling of a vapour mass. Cooling occurs by adiabatic expansion as warm air rises to lower pressures (as in the case of gas wells) or by radiative heat loss. When the dew point is passed (the temperature at which humidity is 100%) water vapour condenses. As water vapour cools it loses its vapour and forms condensation or liquid. Successive phase changes from liquid to vapour and from vapour to condensed water will result in progressive depletion in heavy isotopes (^{18}O and ^2H) in the vapour and condensation; a process called Rayleigh distillation. This is the reason why samples undergoing this partitioning of isotopes between the liquid and vapour phases plot on the trajectory shown on Figure 6.2.

The isotopic distinction between the 'typical' and 'atypical' gas wells and the trajectory along the condensation line on the ^2H and ^{18}O bivariate plot suggests that this process of Rayleigh distillation from vaporisation and condensation is occurring within the 'atypical' gas wells. Changes in pressure and temperature within a gas well can result in the formation of vapour and condensed water, and in effect cause the depletion of the isotopic signature through Rayleigh distillation.

The process by which condensed water forms and moves in gas wells is described in Simpson *et al*. (2003). At conventional gas-field operating pressures, the amount of water that can move as water-vapour is small. However, at the pressures CSG requires, larger amounts can move as vapour. Simpson *et al*. (2003) state that at 37.8°C at 30 psig bottom-hole conditions 6 bbl/MMcf of water can move as vapour (Figure 6.3), and since most CSG wells produce less than this (Simpson *et a*l. 2003), providing low pressures can often be an adequate artificial-lift technique. Temperature changes in piping condense the water vapour and results in precipitation of solids and leaving a low salinity condensed water.

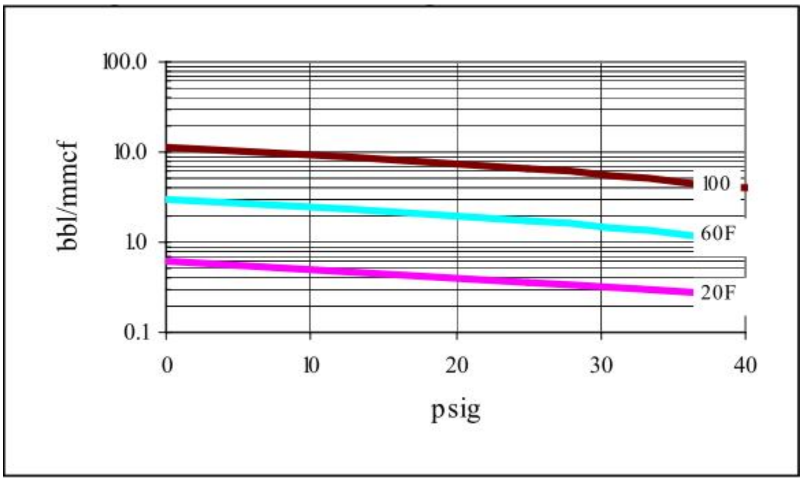

Figure 6.3 Water carrying capacity of natural gas (Simpson et al. 2003)

Pressure or temperature reductions up the gas wells can cause liquid to flash or water vapour to condense. Flashing of liquid or flash evaporation is the partial vapour that occurs when a saturated liquid stream undergoes a reduction in pressure (i.e. still two phases present). The consequences of flashing high salinity coal seam water are the precipitation of solids in gas wells or associated piping and infrastructure and formation of a low salinity condensed water (Simpson *et al*. 2003).

Simpson *et al*. (2003) state that formation water which typically has a salinity in the order of approximately 10,000 mg/L and when one barrel is flashed it will leave 1.5 kg of solids somewhere in the well/piping system. High TDS waters dominated by sodium and chloride will deposit NaCl salt. However, unless they are of marine origin, CSG produced waters are typically dominated by sodium and bicarbonate and will precipitate nahcolite ($NaHCO_3$). Dissolved metals, such as iron, may also precipitate out as carbonates (e.g. siderite, $FeCO_3$).

These processes which result in the formation of low salinity water or ‘condensed water’ at the wellhead have been observed by other authors (Kharaka and Berry 1974; Kharaka *et al*. 1977). Kharaka *et al*. (1977) found that condensed water is common in gas wells producing less than about 1 cubic metre of water per cubic metres of gas or 6 barrels per million cubic feet. From Table 4.1, it can be seen that the ‘atypical’ gas wells barely produce any water (0 to 22.26 L/day) and produce the lowest amount of gas (80 to 320 Mscf/day).

The water chemistry of the ‘atypical’ gas wells is consistent with “abnormal” water quality reported by Kharaka *et al* (1977) low salinity and silica concentration, and in some samples relatively high B and NH_3. The ‘atypical’ gas wells have high iron, manganese and zinc concentrations and this is likely to be due to condensed water picking up iron, manganese and zinc from solids that have deposited in piping or separators from previous flash evaporation. Based on the chemical, isotopic and physical flow data from the ‘atypical’ gas wells, the formation of the low salinity waters can be explained by the process described in Kharaka and Berry (1974), Kharaka *et al*. (1977) and Simpson *et al*. (2003).

The gas well MP16 was selected as part of this study as an ‘atypical’ gas well as it also historically had low salinity water. During the sampling event for this study, the salinity was brackish and the chemical and isotopic composition was that of the ‘typical’ gas wells. Historical gas and water flow rates were not available for this gas well, however, it is noted that the well was offline (not operating) for the period February – September 2012 and, following, recent water flow rates (159 L/day) were considerably higher than the ‘atypical’ gas wells, and were within the range measured in the ‘typical’ gas wells. The results from the MP16 gas well show that not only can gas wells switch from ‘typical’ to ‘atypical’, but it is also possible to switch the other way, further supporting a gas well process for the formation of low salinity waters detected in gas wells.

The results suggest the generation of very low salinity produced waters is a well life-time phenomenon whereby the gas pressures and water production decline and the well switches to dominantly vapour-phase and condensed water processes.

6.3 Summary

In summary, three hypotheses were tested for the processes resulting in the 'atypical' gas wells:

1. Hydraulic connection between target coal seams and shallow aquifers or surface water
2. Residual potable water trapped when wells were hydraulic fracture stimulated
3. Formation of low salinity condensed water in gas wells.

Table 6.1 presents the expected water quality outcomes for each hypothesis and conclusions are drawn by comparing the predicted and observed water quality. Based on the data only the last hypothesis (dilution by condensed water) is plausible.

Table 6.1 Hydrochemical composition of predicted and observed water quality

Hypothesis	Predicted water quality	Observed water quality of 'atypical' water	Conclusion plausible (yes/no)
Hydraulic connectivity with shallow aquifers, surface water or potable water:			
Surface Water	1. Fresh (~150 µS/cm) 2. Na-Cl-HCO_3 type 3. Neutral pH 4. Low barium and strontium 5. Low manganese and iron 6. Low fluoride 7. Low silica <1 mg/L 8. Low boron 9. Low ammonia (<LOR) 10. Tritium present 11. Stable isotopes plot on GMWL	1. Fresh (<250 µS/cm) 2. Na-HCO_3 type 3. Acidic pH 4. Low barium and strontium 5. High manganese and iron 6. Low fluoride 7. Low silica 0.3 to 2.1 mg/L 8. High boron 9. Low to high ammonia 10. No tritium 11. Stable isotopes plot to left of GMWL	1. Y 2. N 3. N 4. Y 5. N 6. Y 7. Y 8. N 9. N 10. N 11. N
Shallow groundwater	1. Fresh (~650 µS/cm) 2. Ca-Na-Mg-HCO_3 type 3. Neutral pH 4. Elevated barium and strontium 5. Low manganese and iron 6. Low fluoride 7. Silica>10 mg/L 8. Low boron 9. Low ammonia 10. No tritium 11. Stable isotopes plot on GMWL	1. Fresh (<250 µS/cm) 2. Na-HCO_3 type 3. Acidic pH 4. Low barium and strontium 5. High manganese and iron 6. Low fluoride 7. Low Silica 0.3 to 2.1 mg/L 8. High boron 9. Low to high ammonia 10. No tritium 11. Stable isotopes plot to left of GMWL	1. N 2. N 3. N 4. N 5. N 6. Y 7. N 8. N 9. N 10. N 11. N

Hypothesis	Predicted water quality	Observed water quality of 'atypical' water	Conclusion plausible (yes/no)
Residual Frac Fluid (Sydney Water – potable supply)	1. Fresh (~230 µS/cm) 2. Ca-Na-Cl-HCO_3 type 3. Neutral pH 4. Low barium and strontium 5. Low manganese and iron 6. High fluoride 7. Low silica <2.5 mg/L 8. Low boron 9. Low ammonia 10. Tritium present 11. Stable isotopes plot on GMWL	1. Fresh (<250 µS/cm) 2. Na-HCO_3 type 3. Acidic pH 4. Low barium and strontium 5. High manganese and iron 6. Low fluoride 7. Low silica 0.3 to 2.1 mg/L 8. High boron 9. Low to high ammonia 10. No tritium 11. Stable isotopes plot to left of GMWL	1. Y 2. N 3. N 4. Y 5. N 6. N 7. Y 8. N 9. N 10. N 11. N
Dilution by condensed water	1. Fresh (<250 µS/cm)* 2. Na-HCO_3 type 3. Acidic pH 4. Low barium and strontium 5. High manganese and iron* 6. Low fluoride 7. Low Silica* 8. High boron* 9. Low to high ammonia 10. No tritium 11. Stable isotopes plot to left of GMWL**	1. Fresh (<250 µS/cm*) 2. Na-HCO_3 type 3. Acidic pH 4. Low barium and strontium 5. High manganese and iron 6. Low fluoride 7. Low silica 0.3 to 2.1 mg/L 8. High boron 9. Low to high ammonia 10. No tritium 11. Stable isotopes plot to left of GMWL	1. Y 2. Y 3. Y 4. Y 5. Y 6. Y 7. Y 8. Y 9. Y 10. Y 11. Y

(1) *Based on abnormal water quality observed by Kharaka and Berry (1974), Kharaka et al. (1977); **based on Domenico and Schwartz 1998

7. Conclusions

AGL Upstream Investments Pty Ltd (AGL) owns and operates the Camden Gas Project (CGP). AGL undertakes water quality sampling in the CGP from a selection of operational gas wells, water supply bores and groundwater monitoring bores as defined within the Groundwater Management Plan for the Camden Gas Project (GMP).

During 2011 and 2012 monitoring events, it was found that produced water from a subset of gas wells comprising the monitoring network had a different ‘atypical’ chemical signature from the ‘typical’ chemical composition of the produced water, as determined by long term monitoring. Specifically, the ‘atypical’ wells had low salinity water, low concentrations of all major cations and anions with the exception of bicarbonate, high concentrations of iron and manganese, and in some gas wells, elevated concentrations of ammonia.

In 2012, AGL engaged Parsons Brinckerhoff to undertake a hydrogeochemical and isotopic study at the CGP to determine the nature and origin of the low salinity produced water from the ‘atypical’ gas wells. Three hypotheses were proposed for their origin and a field based hydrochemical and isotopic investigation was undertaken to test these hypotheses:

1. Hydraulic connection between targeted coal seams and shallow aquifers or surface water
2. Residual potable water trapped when wells were hydraulic fracture stimulated
3. Formation of low salinity condensed water in gas wells.

The following conclusions are drawn from the results of the investigation:

- The chemistry of the produced water from the ‘typical’ gas wells at the CGP is characteristic of coal seams formations that produce methane. These waters are typically brackish to saline, chemically classified as sodium bicarbonate (Na-HCO_3) type waters, and have low concentrations or are devoid of sulphate, calcium and magnesium. They may also contain slightly elevated concentrations of barium, strontium, fluoride and some trace metals. Major ion composition was dominated by sodium and bicarbonate.
- The geochemical processes that result in this (‘typical’) distinct geochemical signature have been studied and published by a number of researchers and include microbial sulphate reduction, bicarbonate enrichment through carbonate dissolution recharge zones, sulphate reduction and methane fermentation processes and calcium and magnesium depletion through inorganic precipitation of calcite and dolomite and possibly cation exchange.
- The ‘atypical’ gas wells have similar chemistry to those observed in unconventional gas and geothermal wells. These gas wells have low salinity and silica concentrations, and in some samples relatively high boron and ammonia. The Camden ‘atypical’ waters also have high concentrations of iron, manganese and zinc.
- The chemistry and isotope data clearly rule out hydraulic connection between deep coal seams and shallow groundwater and/or surface water. Shallow groundwater and surface water plot on the GMWL, indicating they are of meteoric (rainfall) origin and have not been altered by any processes resulting in isotope fractionation.
- Surface water also contains tritium, which is not detected in the ‘atypical’ gas wells, therefore indicating ‘atypical’ water is likely not derived from modern surface water.
- The potable water used in hydraulic fracture stimulation and maintenance operations contains detectable tritium, is of meteoric origin and also contains elevated fluoride; therefore can also be discounted as the source since the atypical water contains no tritium, is low in fluoride and has a more depleted isotopic composition.

- Shifts from the meteoric water line result from isotopic processes which fractionate the heavy and light isotopes ($^{18}O/^{16}O$ and ($^{2}H/H$). In most cases, the processes affect the relationship between $\delta^{2}H$ and $\delta^{18}O$ in a unique way such that the position of the data points can help to identify processes. The systematic way in which the 'atypical' gas wells have shifted to the left of the GMWL suggests that these sampled waters have been affected by condensation.
- At the pressures unconventional gas wells require, large amounts of water can move as vapour. Pressure or temperature drops up the gas wells can cause liquid to flash or water vapour to condense. The consequences of flashing high salinity coal seam water are the precipitation of solids in gas wells or associated piping and infrastructure and the formation of a low salinity condensed water.
- These processes which result in the formation of low salinity water or 'condensed water' have been observed in gas wells producing low volumes of gas and water. The 'atypical' gas wells in the Camden CGP barely produce any water (0 to 22.26 L/day) and produce the lowest amount of gas (80 to 320 Mscf/day) providing further evidence that the 'atypical' produced water is derived from condensed waters within the well and piping, and not shallow groundwater or surface water.
- The results for the MP16 gas well which converted from 'atypical' to 'typical' water chemistry during this study show that not only can gas wells switch from typical to atypical, but it is possible to switch the other way, further supporting a gas well process for the formation of low salinity waters detected in gas wells. The results suggest it is a well life-time phenomenon whereby the gas pressures and water production decline and the well switches to dominantly vapour-phase and condensed water processes.

8. Statement of limitations

8.1 Scope of services

This report has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client and Parsons Brinckerhoff (scope of services). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

8.2 Reliance on data

In preparing the report, Parsons Brinckerhoff has relied upon data, surveys, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, Parsons Brinckerhoff has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Parsons Brinckerhoff will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Parsons Brinckerhoff.

8.3 Environmental conclusions

In accordance with the scope of services, Parsons Brinckerhoff has relied upon the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants or emissions.

Within the limitations imposed by the scope of services, the monitoring, testing, sampling and preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, expressed or implied, is made.

8.4 Report for benefit of client

The report has been prepared for the benefit of the client (and no other party). Parsons Brinckerhoff assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of Parsons Brinckerhoff or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Parties other than the client should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

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The scope of services did not include any assessment of the title to or ownership of the properties, buildings and structures referred to in the report nor the application or interpretation of laws in the jurisdiction in which those properties, buildings and structures are located.

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Appendix A

Chemistry and isotope data

Summary Table A-1: Water quality of 'atypical' gas wells

Analyte	Units	LOR	ANZECC 2000 Guidelines	EM37	GL12	LB6	JD01	MP16
Sample date				11/10/2012	11/10/2012	11/10/2012	11/10/2012	11/10/2012
Project area				Camden	Camden	Camden	Camden	Camden
Sceen Depth				801.1-804.1	887.5-890.5 / 910.75-911.75	689-692.2	Assume 693.34-696.8	572-574.8
Aquifer				**Bulli**	**Bulli / Balgownie**	**Bulli**	**Bulli**	**Bulli**
Water level								
Field parameters								
Temperature	oC	0.1	-	23.53	20.86	23.1	20.63	23.74
Conductivity	µS/cm	1	125 - 2200*	260	587	218	190	8131
Dissolved Oxygen	% sat	0.1	85-110 %* saturation	24.5	7.3	47.6	39.3	61.8
Dissolved Oxygen	mg/L	0.01	-	2.08	0.65	4.07	3.52	5.09
pH	pH units	0.01	6.5-8*	5.23	7.17	5.64	6.51	8.05
TDS	mg/L	1	-	0.169	0.381	0.141	0.123	5.285
Redox	mV	0.1	-	-85.1	-140.4	-77.5	-108.7	-88.1
Laboratory Water Quality Parameters								
pH	pH units	0.01	6.5-8*	6.56	6.08	5.86	6.24	8.26
Conductivity	µS/cm	1	125 - 2200*	206	139	48	63	9580
TDS	mg/L	1	-	18	62	28	31	6480
Suspended solids	mg/L	5	-	38	262	128	84	36
Laboratory Analytes								
Hydroxide Alkalinity as CaCO3	mg/L	1	-	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	-	<1	<1	<1	<1	47
Bicarbonate Alkalinity as CaCO3	mg/L	1	-	84	57	20	31	5620
Total Alkalinity as CaCO3	mg/L	1	-	84	57	<20	31	5660
Sulfate as SO4 2-	mg/L	1	-	<1	1	<1	<1	<10
Chloride	mg/L	1	-	<1	2	<1	<1	391
Calcium	mg/L	1	-	<1	<1	<1	<1	5
Magnesium	mg/L	1	-	<1	<1	<1	<1	4
Sodium	mg/L	1	-	<1	6	<1	3	2710
Potassium	mg/L	1	-	<1	<1	<1	<1	21
Silica	mg/L	0.1	-	0.3	2.1	0.5	0.3	16.8
Fluoride	mg/L	0.1		<0.1	<0.1	<0.1	<0.1	1
Ions								
Total Anions	meq/L	0.01	-	1.68	1.22	0.4	0.62	124
Total Cations	meq/L	0.01	-	1.52	1.07	0.21	0.23	119
Ionic Balance	%	0.01	-					2.17
Dissolved Metals								
Aluminium	mg/L	0.01	0.055	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	mg/L	0.001	0.013 (As V)	<0.001	0.001	0.001	<0.001	0.001
Beryllium	mg/L	0.001	ID	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.001	-	0.072	0.276	0.029	0.115	7.6
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.001
Cobalt	mg/L	0.001	ID	0.001	<0.001	<0.001	<0.001	<0.01
Copper	mg/L	0.001	0.0014	<0.001	0.001	0.001	0.003	<0.01
Lead	mg/L	0.001	0.0034	<0.001	<0.001	<0.001	<0.001	<0.01
Manganese	mg/L	0.001	1.9	0.375	1.22	0.543	0.405	0.02
Molybdenum	mg/L	0.001	ID	<0.001	<0.001	0.001	<0.001	0.136
Nickel	mg/L	0.001	0.011	0.001	0.004	0.003	0.002	0.021
Selenium	mg/L	0.01	0.011 (total)	<0.01	<0.01	<0.01	<0.01	<0.1
Strontium	mg/L	0.001	-	0.014	0.019	0.003	0.013	2.31
Uranium	mg/L	0.001	ID	<0.001	<0.001	<0.001	<0.001	<0.01
Vanadium	mg/L	0.01	ID	<0.01	<0.01	<0.01	<0.01	<0.1
Zinc	mg/L	0.005	0.008	0.041	0.019	0.033	0.037	<0.05
Boron	mg/L	0.05	0.37	<0.05	<0.05	<0.05	<0.05	<0.1
Iron	mg/L	0.05	ID	33.8	169	89.8	55.7	0.83
Bromine	mg/L	0.1	ID	<0.1	<0.1	<0.1	<0.1	<0.1
Iodine	mg/L	0.1		na	na	<1		na
Mercury	mg/L	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nutrients								
Ammonia as N	mg/L	0.01	0.02*	21.8	11.4	0.02	0.03	5.21
Nitrite as N	mg/L	0.01	-	<0.01	0.02	0.02	0.02	<0.01
Nitrate as N	mg/L	0.01	0.7	0.01	<0.01	0.02	0.01	<0.01
Nitrite + Nitrate as N	mg/L	0.01	0.04*	0.01	0.02	0.02	0.03	<0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1		24.9	13.3	0.1	<0.1	7.6
Total nitrogen as N	mg/L	0.1		24.9	13.3	0.1	<0.1	7.6
Total Phosphorous	mg/L	0.01	0.05*	na	na	na	na	na
Reactive Phosphorous	mg/L	0.01	0.02*	<0.01	<0.01	<0.01	<0.01	0.06
Total Organic Carbon	mg/L	1	-	na	na	na	na	na
Dissolved Gases								
Methane	µg/L	10	-	27800	8860	6530	11700	3560
Ethene	µg/L	10	-	<10	<10	<10	<10	<10
Ethane	µg/L	10	-	60	13	16	38	27
Propene	µg/L	10	-	<10	<10	<10	<10	<10
Propane	µg/L	10	-	<10	<10	<10	<10	<10
Butane	µg/L	10	-	<10	<10	<10	<10	<10
Butene	µg/L	10	-	<10	<10	<10	<10	<10
Phenolic compounds								
Phenol	µg/L	1	320	<1	<1	<1	<1	<1
2-Chlorophenol	µg/L	1	490	<1	<1	<1	<1	<1
2-Methylphenol	µg/L	1	-	<1	<1	<1	<1	<1
3-&4-Methylphenol	µg/L	2	-	<1	<1	<1	<1	<1
2-Nitrophenol	µg/L	1	ID	<1	<1	<1	<1	<1
2.4-Dimethylphenol	µg/L	1	ID	<1	<1	<1	<1	<1
2.4-Dichlorophenol	µg/L	1	160	<1	<1	<1	<1	<1
2.6-Dichlorophenol	µg/L	1	ID	<1	<1	<1	<1	<1
4-Chloro-3-Methylphenol	µg/L	1	-	<1	<1	<1	<1	<1
2.4.6-Trichlorophenol	µg/L	1	20	<1	<1	<1	<1	<1
2.4.5-Trichlorophenol	µg/L	1	ID	<1	<1	<1	<1	<1
Pentachlorophenol	µg/L	2	ID	<2	<2	<2	<2	<2
Polycyclic aromatic hydrocarbons								
Naphthalene	µg/L	1	0.016	<1	<1	<1	<1	<1
Acenaphthylene	µg/L	1	-	<1	<1	<1	<1	<1
Acenaphthene	µg/L	1	-	<1	<1	<1	<1	<1
Fluorene	µg/L	1	-	<1	<1	<1	<1	<1
Phenanthrene	µg/L	1	ID	<1	<1	<1	<1	1.5
Anthracene	µg/L	1	ID	<1	<1	<1	<1	<1
Fluoranthene	µg/L	1	ID	<1	<1	<1	<1	<1
Pyrene	µg/L	1	-	<1	<1	<1	<1	<1
Benz(a)anthracene	µg/L	1	-	<1	<1	<1	<1	<1
Chrysene	µg/L	1	-	<1	<1	<1	<1	<1
Benzo(b)fluoranthene	µg/L	1	-	<1	<1	<1	<1	<1
Benzo(k)fluoranthene	µg/L	1	-	<1	<1	<1	<1	<1
Benzo(a)pyrene	µg/L	0.5	ID	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	µg/L	1	-	<1	<1	<1	<1	<1
Dibenz(a.h)anthracene	µg/L	1	-	<1	<1	<1	<1	<1
Benzo(g.h.i)perylene	µg/L	1	-	<1	<1	<1	<1	<1
Sum of polycyclic aromatic hydrocarbons				<0.5	<0.5	<0.5	<0.5	1.5
Total petroleum hydrocarbons								
C6-C9 Fraction	µg/L	20	ID	<20	<20	<20	<20	<20
C10-C14 Fraction	µg/L	50	ID	<50	<50	<50	<50	<50
C15-C28 Fraction	µg/L	100	ID	4590	<100	<100	210	2730
C29-C36 Fraction	µg/L	50	ID	<50	<50	<50	160	2940
C10-C36 Fraction (sum)	µg/L	50	-	4590	<50	<50	370	5670
Total recoverable hydrocarbons								
C6-C10 Fraction	µg/L	20	-	<20	<20	<20	<20	<20
C6-C10 Fraction minus BTEX (F1)	µg/L	20	-	<20	<20	<20	<20	<20
>C10-C16 Fraction	µg/L	100	-	200	<100	<100	<100	<100
>C16-C34 Fraction	µg/L	100	-	4040	<100	<100	350	4490
>C34-C40 Fraction	µg/L	100	-	<100	<100	<100	<100	1960
>C10-C40 Fraction (sum)	µg/L	100	-	4240	<100	<100	350	6450
Aromatic Hydrocarbons								
Benzene	µg/L	1	950	<1	<1	<1	<1	<1
Toluene	µg/L	2	ID	<2	<2	<2	<2	<2
Ethyl Benzene	µg/L	2	ID	<2	<2	<2	<2	<2
m&p-Xylenes	µg/L	2	ID	<2	<2	<2	<2	<2
o-Xylenes	µg/L	2	350	<2	<2	<2	<2	<2
Total xlyenes	µg/L	2		<2	<2	<2	<2	<2
Sum of BTEX	µg/L	1		<1	<1	<1	<1	<1
Naphthalene	µg/L	5		<5	<5	<5	<5	<5
Isotopes								
Oxygen-18	‰	0.01	-	-8.12	-8.99	-10.84	-12.7	-8.22
Deuterium	‰	0.1	-	-42.1	-47.3	-54.1	-77.7	-43.7
Tritium	TU	0.01	-	0.28±0.03	0.13±0.03^	0.08±0.03^	0.11±0.03^	0.30±0.03

exceeds guideline limits   ID - Insufficient data

Guideline values

ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems.

* ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems, South-East Australia, low lying river ecosystems

Calculated using Aquachem

^ This result is below the Minimum Detectable Activity (MDA) and Limit of Quantification (Quant Limit) and therefore has an unacceptable level of uncertainty. Hence the data should only be used as an indicator of true concentration.

** Total Recoverable Hydrocarbons as defined in Schedule B1: Guideline on the investigation Levels for Soil and Groundwater of the Draft Variation to the National

NR - results not reported at time of reporting

na - not analysed

PARSONS BRINCKERHOFF

Summary Table A-2: Water Quality of 'typical' gas wells

Analyte	Units	LOR	ANZECC 2000 Guidelines	MP12	MP30	KP05	SL02	MP07
Sample date				11/10/2012	11/10/2012	11/10/2012	11/10/2012	11/10/2012
Project area				Camden	Camden	Camden	Camden	Camden
Sceen Depth							648.0-651.0/666.0-668.0/ 706.5-709.5/ 720.7-723.7	
Aquifer				**Bulli**	**Bulli**	**Bulli**	**Bulli / Balgownie / Wongawilli**	**Bulli / Balgownie**
Water level								
Field parameters								
Temperature	oC	0.1	-	15.79	15.9	17.64	21.05	18.33
Conductivity	µS/cm	1	125 - 2200*	37912	13186	4373	10329	1325
Dissolved Oxygen	% sat	0.1	85-110 %* saturation	69.8	90.8	68.7	55.9	66.7
Dissolved Oxygen	mg/L	0.01	-	5.99	9.69	6.46	4.81	5.99
pH	pH units	0.01	6.5-8*	9.36	8.81	8.81	9.22	9.16
TDS	mg/L	1	-	24.65	96.2	2.843	6.714	0.349
Redox	mV	0.1	-	-78.1	-80.1	-80.2	-127.7	-141.6
Laboratory Water Quality Parameters								
pH	pH units	0.01	6.5-8*	na	na	na	na	na
Conductivity	µS/cm	1	125 - 2200*	45700	15900	5350	12100	16000
TDS	mg/L	1	-	37600	11800	3460	8320	11600
Suspended solids	mg/L	5	-	1430	1440	482	10	17890
Laboratory Analytes								
Hydroxide Alkalinity as CaCO3	mg/L	1	-	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	-	1770	658	47	347	329
Bicarbonate Alkalinity as CaCO3	mg/L	1	-	35600	9460	2910	7410	9850
Total Alkalinity as CaCO3	mg/L	1	-	37400	10100	2960	7760	10200
Sulfate as SO4 2-	mg/L	1	-	<100	126	58	29	104
Chloride	mg/L	1	-	2440	404	143	5	556
Calcium	mg/L	1	-	3	4	<1	9	7
Magnesium	mg/L	1	-	24	6	<1	7	4
Sodium	mg/L	1	-	17700	5390	1390	3520	5320
Potassium	mg/L	1	-	125	83	25	12	18
Silica	mg/L	0.1	-	58.9	19.1	7.1	25.7	20.2
Fluoride	mg/L	0.1		4	1.9	0.7	1.1	1.5
Ions								
Total Anions	meq/L	0.01	-	816	216	64.4	170	222
Total Cations	meq/L	0.01	-	775	237	61.1	154	232
Ionic Balance	%	0.01	-	2.63	4.67	2.68	4.8	2.33
Dissolved Metals								
Aluminium	mg/L	0.01	0.055	<0.1	0.02	0.02	<0.01	<0.1
Arsenic	mg/L	0.001	0.013 (As V)	0.068	0.015	0.002	<0.001	<0.01
Beryllium	mg/L	0.001	ID	<0.01	<0.001	<0.001	<0.001	<0.01
Barium	mg/L	0.001	-	12.6	14.9	1.7	6.52	30.3
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	ID	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	0.0014	<0.001	<0.001	0.003	<0.001	<0.001
Lead	mg/L	0.001	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	1.9	0.013	0.009	0.016	0.009	0.065
Molybdenum	mg/L	0.001	ID	0.283	0.036	0.006	0.003	<0.01
Nickel	mg/L	0.001	0.011	<0.01	0.005	0.001	<0.001	<0.01
Selenium	mg/L	0.01	0.011 (total)	<0.1	<0.01	<0.01	<0.01	<0.1
Strontium	mg/L	0.001	-	8.3	5.53	0.67	4.77	7.72
Uranium	mg/L	0.001	ID	<0.01	<0.001	<0.001	<0.001	<0.01
Vanadium	mg/L	0.01	ID	<0.1	<0.01	<0.01	<0.01	<0.1
Zinc	mg/L	0.005	0.008	<0.05	0.005	0.009	<0.005	<0.05
Boron	mg/L	0.05	0.37	0.42	0.09	0.07	0.27	0.19
Iron	mg/L	0.05	ID	2.34	1.58	0.12	<0.05	4.12
Bromine	mg/L	0.1	ID	6.2	1	0.5	0.8	<1
Iodine	mg/L	0.1		NA	na	na	na	na
Mercury	mg/L	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nutrients								
Ammonia as N	mg/L	0.01	0.02*	0.15	8.12	14.3	4.66	1.1
Nitrite as N	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.7	1.04	0.02	0.22	<0.01	<0.01
Nitrite + Nitrate as N	mg/L	0.01	0.04*	1.04	0.02	0.22	<0.01	<0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1		21.8	45.5	21.4	5.3	23.6
Total nitrogen as N	mg/L	0.1		22.8	45.5	21.6	5.3	23.6
Total Phosphorous	mg/L	0.01	0.05*					
Reactive Phosphorous	mg/L	0.01	0.02*	0.32	1.17	0.03	0.08	0.85
Total Organic Carbon	mg/L	1	-					
Dissolved Gases								
Methane	µg/L	10	-	1490	352	985	625	492
Ethene	µg/L	10	-	<10	<10	<10	<10	<10
Ethane	µg/L	10	-	32	16	<10	<10	11
Propene	µg/L	10	-	<10	<10	<10	<10	<10
Propane	µg/L	10	-	<10	<10	<10	<10	<10
Butane	µg/L	10	-	<10	<10	<10	<10	<10
Butene	µg/L	10	-	<10	<10	<10	<10	<10
Phenolic compounds								
Phenol	µg/L	1	320	<1	<1	<1	<1	<1
2-Chlorophenol	µg/L	1	490	<1	<1	<1	<1	<1
2-Methylphenol	µg/L	1	-	<1	<1	<1	<1	<1
3-&4-Methylphenol	µg/L	2	-	<1	<1	<1	<1	<1
2-Nitrophenol	µg/L	1	ID	<1	<1	<1	<1	<1
2.4-Dimethylphenol	µg/L	1	ID	<1	<1	<1	<1	<1
2.4-Dichlorophenol	µg/L	1	160	<1	<1	<1	<1	<1
2.6-Dichlorophenol	µg/L	1	ID	<1	<1	<1	<1	<1
4-Chloro-3-Methylphenol	µg/L	1	-	<1	<1	<1	<1	<1
2.4.6-Trichlorophenol	µg/L	1	20	<1	<1	<1	<1	<1
2.4.5-Trichlorophenol	µg/L	1	ID	<1	<1	<1	<1	<1
Pentachlorophenol	µg/L	2	ID	<2	<2	<2	<2	<2
Polycyclic aromatic hydrocarbons								
Naphthalene	µg/L	1	0.016	2.6	2.7	<1	<1	<1
Acenaphthylene	µg/L	1	-	<1	<1	<1	<1	<1
Acenaphthene	µg/L	1	-	<1	<1	<1	<1	<1
Fluorene	µg/L	1	-	1.7	3.5	<1	<1	<1
Phenanthrene	µg/L	1	ID	3.8	8	1.1	<1	<1
Anthracene	µg/L	1	ID	<1	<1	<1	<1	<1
Fluoranthene	µg/L	1	ID	<1	<1	<1	<1	<1
Pyrene	µg/L	1	-	<1	1	<1	<1	<1
Benz(a)anthracene	µg/L	1	-	<1	1.4	<1	<1	<1
Chrysene	µg/L	1	-	<1	1.5	<1	<1	<1
Benzo(b)fluoranthene	µg/L	1	-	<1	1.2	<1	<1	<1
Benzo(k)fluoranthene	µg/L	1	-	<1	<1	<1	<1	<1
Benzo(a)pyrene	µg/L	0.5	ID	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	µg/L	1	-	<1	<1	<1	<1	<1
Dibenz(a.h)anthracene	µg/L	1	-	<1	<1	<1	<1	<1
Benzo(g.h.i)perylene	µg/L	1	-	<1	<1	<1	<1	<1
Sum of polycyclic aromatic hydrocarbons				8.1	19.3	1.1	<0.5	<0.5
Total petroleum hydrocarbons								
C6-C9 Fraction	µg/L	20	ID	<20	<20	<20	<20	<20
C10-C14 Fraction	µg/L	50	ID	<50	250	<50	<50	<50
C15-C28 Fraction	µg/L	100	ID	220	660	110	<100	200
C29-C36 Fraction	µg/L	50	ID	130	250	<50	<50	120
C10-C36 Fraction (sum)	µg/L	50	-	350	1160	110	<50	320
Total recoverable hydrocarbons								
C6-C10 Fraction	µg/L	20	-	<20	<20	<20	<20	<20
C6-C10 Fraction minus BTEX (F1)	µg/L	20	-	<20	<20	<20	<20	<20
>C10-C16 Fraction	µg/L	100	-	<100	410	<100	<100	<100
>C16-C34 Fraction	µg/L	100	-	300	660	130	<100	250
>C34-C40 Fraction	µg/L	100	-	<100	160	<100	<100	<100
>C10-C40 Fraction (sum)	µg/L	100	-	300	1230	130	<100	250
Aromatic Hydrocarbons								
Benzene	µg/L	1	950	<1	<1	<1	<1	<1
Toluene	µg/L	2	ID	<2	<2	<2	<2	<2
Ethyl Benzene	µg/L	2	ID	<2	<2	<2	<2	<2
m&p-Xylenes	µg/L	2	ID	<2	<2	<2	<2	<2
o-Xylenes	µg/L	2	350	<2	<2	<2	<2	<2
Total xlyenes	µg/L	2		<2	<2	<2	<2	<2
Sum of BTEX	µg/L	1		<1	<1	<1	<1	<1
Naphthalene	µg/L	5		<5	<5	<5	<5	<5
Isotopes								
Oxygen-18	‰	0.01	-	-5.1	-7.89	-8.02	-8.83	-8.42
Deuterium	‰	0.1	-	-26.3	-41	-42.7	-50.7	-53.9
Tritium	TU	0.01	-	0.14±0.05^	0.78±0.05	0.11±0.03	0.18±0.03	0.06±0.03^

exceeds guideline limits   ID - Insufficient data

Guideline values

ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems.

* ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems, South-East Australia, low lying river ecosystems

Calculated using Aquachem

^ This result is below the Minimum Detectable Activity (MDA) and Limit of Quantification (Quant Limit) and therefore has an unacceptable level of uncertainty. Hence the data should only be used as an indicator of true concentration.

** Total Recoverable Hydrocarbons as defined in Schedule B1: Guideline on the investigation Levels for Soil and Groundwater of the Draft Variation to the National

NR - results not reported at time of reporting

na - not analysed

PARSONS BRINCKERHOFF

Summary Table A-3: Water quality for Hawkesbury Sandstone bores

Analyte	Units	LOR	ANZECC 2000 Guidelines	Johndilo Bore	Logan Brae Bore
Sample date				11/10/2102	11/10/2102
Project area				Camden	Camden
Sceen Depth					
Aquifer				**Hawkesbury Sandstone**	**Hawkesbury Sandstone**
Water level					
Field parameters					
Temperature	oC	0.1	-	16.97	20.56
Conductivity	µS/cm	1	125 - 2200*	537	561
Dissolved Oxygen	% sat	0.1	85-110 %* saturation	23	41.4
Dissolved Oxygen	mg/L	0.01	-	2.23	3.72
pH	pH units	0.01	6.5-8*	7.62	7.58
TDS	mg/L	1	-	0.349	0.365
Redox	mV	0.1	-	-91.8	-86.3
Laboratory Water Quality Parameters					
pH	pH units	0.01	6.5-8*	7.67	7.79
Conductivity	µS/cm	1	125 - 2200*	630	656
TDS	mg/L	1	-	360	338
Suspended solids	mg/L	5	-	<5	<5
Laboratory Analytes					
Hydroxide Alkalinity as CaCO3	mg/L	1	-	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	-	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	-	236	260
Total Alkalinity as CaCO3	mg/L	1	-	236	260
Sulfate as SO4 2-	mg/L	1	-	<1	<1
Chloride	mg/L	1	-	36	30
Calcium	mg/L	1	-	46	34
Magnesium	mg/L	1	-	20	19
Sodium	mg/L	1	-	34	62
Potassium	mg/L	1	-	4	8
Silica	mg/L	0.1	-	11.1	12.2
Fluoride	mg/L	0.1		0.1	0.2
Ions					
Total Anions	meq/L	0.01	-	5.73	6.04
Total Cations	meq/L	0.01	-	5.52	6.16
Ionic Balance	%	0.01	-	1.85	0.97
Dissolved Metals					
Aluminium	mg/L	0.01	0.055	<0.01	<0.01
Arsenic	mg/L	0.001	0.013 (As V)	0.002	<0.001
Beryllium	mg/L	0.001	ID	<0.001	<0.001
Barium	mg/L	0.001	-	0.512	1.6
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001
Cobalt	mg/L	0.001	ID	<0.001	0.001
Copper	mg/L	0.001	0.0014	<0.001	0.002
Lead	mg/L	0.001	0.0034	<0.001	<0.001
Manganese	mg/L	0.001	1.9	0.013	0.059
Molybdenum	mg/L	0.001	ID	<0.001	<0.001
Nickel	mg/L	0.001	0.011	<0.001	<0.001
Selenium	mg/L	0.01	0.011 (total)	<0.01	<0.01
Strontium	mg/L	0.001	-	0.226	0.404
Uranium	mg/L	0.001	ID	<0.001	<0.001
Vanadium	mg/L	0.01	ID	<0.01	<0.01
Zinc	mg/L	0.005	0.008	<0.005	0.011
Boron	mg/L	0.05	0.37	<0.05	<0.05
Iron	mg/L	0.05	ID	0.11	0.33
Bromine	mg/L	0.1	ID	<0.1	<0.1
Iodine	mg/L	0.1		na	na
Mercury	mg/L	0.0001		<0.0001	<0.0001
Nutrients					
Ammonia as N	mg/L	0.01	0.02*	0.1	0.37
Nitrite as N	mg/L	0.01	-	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.7	0.02	0.01
Nitrite + Nitrate as N	mg/L	0.01	0.04*	0.02	0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1		0.2	0.5
Total nitrogen as N	mg/L	0.1		0.2	0.5
Total Phosphorous	mg/L	0.01	0.05*	na	na
Reactive Phosphorous	mg/L	0.01	0.02*	0.01	<0.01
Total Organic Carbon	mg/L	1	-		
Dissolved Gases					
Methane	µg/L	10	-	65	2180
Ethene	µg/L	10	-	<10	<10
Ethane	µg/L	10	-	<10	<10
Propene	µg/L	10	-	<10	<10
Propane	µg/L	10	-	<10	<10
Butane	µg/L	10	-	<10	<10
Butene	µg/L	10	-	<10	<10
Phenolic compounds					
Phenol	µg/L	1	320	<1	<1
2-Chlorophenol	µg/L	1	490	<1	<1
2-Methylphenol	µg/L	1	-	<1	<1
3-&4-Methylphenol	µg/L	2	-	<1	<1
2-Nitrophenol	µg/L	1	ID	<1	<1
2.4-Dimethylphenol	µg/L	1	ID	<1	<1
2.4-Dichlorophenol	µg/L	1	160	<1	<1
2.6-Dichlorophenol	µg/L	1	ID	<1	<1
4-Chloro-3-Methylphenol	µg/L	1	-	<1	<1
2.4.6-Trichlorophenol	µg/L	1	20	<1	<1
2.4.5-Trichlorophenol	µg/L	1	ID	<1	<1
Pentachlorophenol	µg/L	2	ID	<2	<2
Polycyclic aromatic hydrocarbons					
Naphthalene	µg/L	1	0.016	<1	<1
Acenaphthylene	µg/L	1	-	<1	<1
Acenaphthene	µg/L	1	-	<1	<1
Fluorene	µg/L	1	-	<1	<1
Phenanthrene	µg/L	1	ID	<1	<1
Anthracene	µg/L	1	ID	<1	<1
Fluoranthene	µg/L	1	ID	<1	<1
Pyrene	µg/L	1	-	<1	<1
Benz(a)anthracene	µg/L	1	-	<1	<1
Chrysene	µg/L	1	-	<1	<1
Benzo(b)fluoranthene	µg/L	1	-	<1	<1
Benzo(k)fluoranthene	µg/L	1	-	<1	<1
Benzo(a)pyrene	µg/L	0.5	ID	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	µg/L	1	-	<1	<1
Dibenz(a.h)anthracene	µg/L	1	-	<1	<1
Benzo(g.h.i)perylene	µg/L	1	-	<1	<1
Sum of polycyclic aromatic hydrocarbons				<0.5	<0.5
Total petroleum hydrocarbons					
C6-C9 Fraction	µg/L	20	ID	<20	<20
C10-C14 Fraction	µg/L	50	ID	<50	<50
C15-C28 Fraction	µg/L	100	ID	<100	<100
C29-C36 Fraction	µg/L	50	ID	<50	<50
C10-C36 Fraction (sum)	µg/L	50	-	<50	<50
Total recoverable hydrocarbons					
C6-C10 Fraction	µg/L	20	-	<20	<20
C6-C10 Fraction minus BTEX (F1)	µg/L	20	-	<20	<20
>C10-C16 Fraction	µg/L	100	-	<100	<100
>C16-C34 Fraction	µg/L	100	-	<100	<100
>C34-C40 Fraction	µg/L	100	-	<100	<100
>C10-C40 Fraction (sum)	µg/L	100	-	<100	<100
Aromatic Hydrocarbons					
Benzene	µg/L	1	950	<1	<1
Toluene	µg/L	2	ID	<2	<2
Ethyl Benzene	µg/L	2	ID	<2	<2
m&p-Xylenes	µg/L	2	ID	<2	<2
o-Xylenes	µg/L	2	350	<2	<2
Total xlyenes	µg/L	2		<2	<2
Sum of BTEX	µg/L	1		<1	<1
Naphthalene	µg/L	5		<5	<5
Isotopes					
Oxygen-18	‰	0.01	-	-6.19	-6.22
Deuterium	‰	0.1	-	-33.6	-33.4
Tritium	TU	0.01	-	0.03±0.02^	0.07±0.02^

exceeds guideline limits

ID - Insufficient data

Guideline values

ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems.

* ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems, South-East Australia, low lying river ecosystems

Calculated using Aquachem

^ This result is below the Minimum Detectable Activity (MDA) and Limit of Quantification (Quant Limit) and therefore has an unacceptable level of uncertainty. Hence the data should only be used as an indicator of true concentration.

** Total Recoverable Hydrocarbons as defined in Schedule B1: Guideline on the investigation Levels for Soil and Groundwater of the Draft Variation to the National

NR - results not reported at time of reporting

na - not analysed

PARSONS BRINCKERHOFF

Summary Table A-4: Water Quality fr Nepean River and Sydney Water Supply

Analyte	Units	LOR	ANZECC 2000 Guidelines	Nepean River	Sydney Water SP
Sample date				11/10/2012	11/10/2012
Project area				Camden	Camden
Sceen Depth					
Aquifer					
Water level					
Field parameters					
Temperature	oC	0.1	-	15.06	16.29
Conductivity	µS/cm	1	125 - 2200*	149	232
Dissolved Oxygen	% sat	0.1	85-110 %* saturation	82.9	79.2
Dissolved Oxygen	mg/L	0.01	-	8.34	7.76
pH	pH units	0.01	6.5-8*	7.17	9.45
TDS	mg/L	1	-	0.091	
Redox	mV	0.1	-	-21.9	-61.1
Laboratory Water Quality Parameters					
pH	pH units	0.01	6.5-8*	na	na
Conductivity	µS/cm	1	125 - 2200*	262	157
TDS	mg/L	1	-	178	85
Suspended solids	mg/L	5	-	<5	<5
Laboratory Analytes					
Hydroxide Alkalinity as CaCO3	mg/L	1	-	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	-	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1	-	56	17
Total Alkalinity as CaCO3	mg/L	1	-	56	17
Sulfate as SO4 2-	mg/L	1	-	<10	<1
Chloride	mg/L	1	-	43	28
Calcium	mg/L	1	-	5	12
Magnesium	mg/L	1	-	5	2
Sodium	mg/L	1	-	38	13
Potassium	mg/L	1	-	3	<1
Silica	mg/L	0.1	-	0.8	2.2
Fluoride	mg/L	0.1		<0.1	0.9
Ions					
Total Anions	meq/L	0.01	-	2.33	1.13
Total Cations	meq/L	0.01	-	2.39	1.33
Ionic Balance	%	0.01	-		
Dissolved Metals					
Aluminium	mg/L	0.01	0.055	0.01	0.03
Arsenic	mg/L	0.001	0.013 (As V)	<0.001	<0.001
Beryllium	mg/L	0.001	ID	<0.001	<0.001
Barium	mg/L	0.001	-	0.107	0.038
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001
Cobalt	mg/L	0.001	ID	<0.001	<0.001
Copper	mg/L	0.001	0.0014	0.001	0.002
Lead	mg/L	0.001	0.0034	<0.001	<0.001
Manganese	mg/L	0.001	1.9	0.005	0.002
Molybdenum	mg/L	0.001	ID	<0.001	<0.001
Nickel	mg/L	0.001	0.011	0.002	<0.001
Selenium	mg/L	0.01	0.011 (total)	<0.01	<0.01
Strontium	mg/L	0.001	-	0.079	0.045
Uranium	mg/L	0.001	ID	<0.001	<0.001
Vanadium	mg/L	0.01	ID	<0.01	<0.01
Zinc	mg/L	0.005	0.008	0.006	0.012
Boron	mg/L	0.05	0.37	<0.05	<0.05
Iron	mg/L	0.05	ID	0.1	<0.05
Bromine	mg/L	0.1	ID	0.1	0.2
Iodine	mg/L	0.1		na	na
Mercury	mg/L	0.0001		<0.0001	<0.0001
Nutrients					
Ammonia as N	mg/L	0.01	0.02*	<0.01	0.13
Nitrite as N	mg/L	0.01	-	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.7	0.02	0.12
Nitrite + Nitrate as N	mg/L	0.01	0.04*	0.02	0.12
Total Kjeldahl Nitrogen as N	mg/L	0.1		0.3	0.4
Total nitrogen as N	mg/L	0.1		0.3	0.5
Total Phosphorous	mg/L	0.01	0.05*	na	na
Reactive Phosphorous	mg/L	0.01	0.02*	<0.01	<0.01
Total Organic Carbon	mg/L	1	-		
Dissolved Gases					
Methane	µg/L	10	-	<10	<10
Ethene	µg/L	10	-	<10	<10
Ethane	µg/L	10	-	<10	<10
Propene	µg/L	10	-	<10	<10
Propane	µg/L	10	-	<10	<10
Butane	µg/L	10	-	<10	<10
Butene	µg/L	10	-	<10	<10
Phenolic compounds					
Phenol	µg/L	1	320	<1	<1
2-Chlorophenol	µg/L	1	490	<1	<1
2-Methylphenol	µg/L	1	-	<1	<1
3-&4-Methylphenol	µg/L	2	-	<1	<1
2-Nitrophenol	µg/L	1	ID	<1	<1
2.4-Dimethylphenol	µg/L	1	ID	<1	<1
2.4-Dichlorophenol	µg/L	1	160	<1	<1
2.6-Dichlorophenol	µg/L	1	ID	<1	<1
4-Chloro-3-Methylphenol	µg/L	1	-	<1	<1
2.4.6-Trichlorophenol	µg/L	1	20	<1	<1
2.4.5-Trichlorophenol	µg/L	1	ID	<1	<1
Pentachlorophenol	µg/L	2	ID	<2	<2
Polycyclic aromatic hydrocarbons					
Naphthalene	µg/L	1	0.016	<1	<1
Acenaphthylene	µg/L	1	-	<1	<1
Acenaphthene	µg/L	1	-	<1	<1
Fluorene	µg/L	1	-	<1	<1
Phenanthrene	µg/L	1	ID	<1	<1
Anthracene	µg/L	1	ID	<1	<1
Fluoranthene	µg/L	1	ID	<1	<1
Pyrene	µg/L	1	-	<1	<1
Benz(a)anthracene	µg/L	1	-	<1	<1
Chrysene	µg/L	1	-	<1	<1
Benzo(b)fluoranthene	µg/L	1	-	<1	<1
Benzo(k)fluoranthene	µg/L	1	-	<1	<1
Benzo(a)pyrene	µg/L	0.5	ID	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	µg/L	1	-	<1	<1
Dibenz(a.h)anthracene	µg/L	1	-	<1	<1
Benzo(g.h.i)perylene	µg/L	1	-	<1	<1
Sum of polycyclic aromatic hydrocarbons				<0.5	<0.5
Total petroleum hydrocarbons					
C6-C9 Fraction	µg/L	20	ID	<20	<20
C10-C14 Fraction	µg/L	50	ID	<50	<50
C15-C28 Fraction	µg/L	100	ID	<100	<100
C29-C36 Fraction	µg/L	50	ID	<50	<50
C10-C36 Fraction (sum)	µg/L	50	-	<50	<50
Total recoverable hydrocarbons					
C6-C10 Fraction	µg/L	20	-	<20	<20
C6-C10 Fraction minus BTEX (F1)	µg/L	20	-	<20	<20
>C10-C16 Fraction	µg/L	100	-	<100	<100
>C16-C34 Fraction	µg/L	100	-	<100	<100
>C34-C40 Fraction	µg/L	100	-	<100	<100
>C10-C40 Fraction (sum)	µg/L	100	-	<100	<100
Aromatic Hydrocarbons					
Benzene	µg/L	1	950	<1	<1
Toluene	µg/L	2	ID	<2	<2
Ethyl Benzene	µg/L	2	ID	<2	<2
m&p-Xylenes	µg/L	2	ID	<2	<2
o-Xylenes	µg/L	2	350	<2	<2
Total xlyenes	µg/L	2		<2	<2
Sum of BTEX	µg/L	1		<1	<1
Naphthalene	µg/L	5		<5	<5
Isotopes					
Oxygen-18	‰	0.01	-	-2.76	-2.91
Deuterium	‰	0.1	-	-13.9	-12.8
Tritium	TU	0.01	-	1.56±0.08	1.51±0.08

exceeds guideline limits   ID - Insufficient data

Guideline values

ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems.

* ANZECC 2000 - Water Quality Guidelines: 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems, South-East Australia, low lying river ecosystems

Calculated using Aquachem

^ This result is below the Minimum Detectable Activity (MDA) and Limit of Quantification (Quant Limit) and therefore has an unacceptable level of uncertainty. Hence the data should only be used as an indicator of true concentration.

** Total Recoverable Hydrocarbons as defined in Schedule B1: Guideline on the investigation Levels for Soil and Groundwater of the Draft Variation to the National

NR - results not reported at time of reporting

na - not analysed

PARSONS BRINCKERHOFF

Appendix B

ALS laboratory results

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES1224372**	Page	: 1 of 7
Client	: **PARSONS BRINCKERHOFF AUST P/L**	Laboratory	: Environmental Division Sydney
Contact	: MR JAMES DUGGLEBY	Contact	: Loren Schiavon
Address	: GPO BOX 5394 SYDNEY NSW, AUSTRALIA 2001	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: jduggleby@pb.com.au	E-mail	: loren.schiavon@alsglobal.com
Telephone	: +61 02 9272 5100	Telephone	: +61 2 8784 8503
Facsimile	: +61 02 9272 5101	Facsimile	: +61 2 8784 8500
Project	: 2114759C	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 12-OCT-2012
Sampler	: NPH	Issue Date	: 19-OCT-2012
Site	: ----		
		No. of samples received	: 2
Quote number	: SY/394/09	No. of samples analysed	: 2

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Ashesh Patel	Inorganic Chemist	Sydney Inorganics
Pabi Subba	Senior Organic Chemist	Sydney Organics
Raymond Commodor	Instrument Chemist	Sydney Inorganics
Sanjeshni Jyoti Mala	Senior Chemist Volatile	Sydney Organics
Sarah Millington	Senior Inorganic Chemist	Sydney Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **ED041G: LOR raised for SO4 analysis on sample ID: N.RIVER due to sample matrix.**
- **EG020: 'Bromine' quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.**

Analytical Results

Sub-Matrix: **WATER**

			Client sample ID	N.RIVER	SYD WATER	----	----	----
			Client sampling date / time	11-OCT-2012 09:30	11-OCT-2012 08:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224372-001**	**ES1224372-002**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**262**	**157**	----	----	----
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	10	mg/L	**178**	**85**	----	----	----
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	<5	<5	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**56**	**17**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**56**	**17**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<10	<1	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**43**	**28**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**5**	**12**	----	----	----
Magnesium	7439-95-4	1	mg/L	**5**	**2**	----	----	----
Sodium	7440-23-5	1	mg/L	**38**	**13**	----	----	----
Potassium	7440-09-7	1	mg/L	**3**	<1	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.01**	**0.03**	----	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.107**	**0.038**	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.001**	**0.002**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.005**	**0.002**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	----	----	----
Nickel	7440-02-0	0.001	mg/L	**0.002**	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	----	----	----
Strontium	7440-24-6	0.001	mg/L	**0.079**	**0.045**	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.006**	**0.012**	----	----	----

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	N.RIVER	SYD WATER	----	----	----
			Client sampling date / time	11-OCT-2012 09:30	11-OCT-2012 08:00	----	----	----
				ES1224372-001	**ES1224372-002**	**----**	**----**	**----**
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.10**	<0.05	----	----	----
Bromine	7726-95-6	0.1	mg/L	**0.1**	**0.2**	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EG052F: Dissolved Silica by ICPAES								
Silica	7631-86-9	0.1	mg/L	**0.8**	**2.2**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	**0.9**	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	<0.01	**0.13**	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.02**	**0.12**	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.02**	**0.12**	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.3**	**0.4**	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	**0.3**	**0.5**	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	----	0.01	mg/L	<0.01	<0.01	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**2.33**	**1.13**	----	----	----
Total Cations	----	0.01	meq/L	**2.39**	**1.33**	----	----	----
EP033: C1 - C4 Hydrocarbon Gases								
Methane	74-82-8	10	µg/L	<10	<10	----	----	----
Ethene	74-85-1	10	µg/L	<10	<10	----	----	----
Ethane	74-84-0	10	µg/L	<10	<10	----	----	----
Propene	115-07-1	10	µg/L	<10	<10	----	----	----
Propane	74-98-6	10	µg/L	<10	<10	----	----	----
Butene	25167-67-3	10	µg/L	<10	<10	----	----	----
Butane	106-97-8	10	µg/L	<10	<10	----	----	----
EP075(SIM)A: Phenolic Compounds								

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	N.RIVER	SYD WATER	----	----	----
			Client sampling date / time	11-OCT-2012 09:30	11-OCT-2012 08:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224372-001**	**ES1224372-002**	**----**	**----**	**----**
EP075(SIM)A: Phenolic Compounds - Continued								
Phenol	108-95-2	1.0	µg/L	<1.0	<1.0	----	----	----
2-Chlorophenol	95-57-8	1.0	µg/L	<1.0	<1.0	----	----	----
2-Methylphenol	95-48-7	1.0	µg/L	<1.0	<1.0	----	----	----
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	<2.0	<2.0	----	----	----
2-Nitrophenol	88-75-5	1.0	µg/L	<1.0	<1.0	----	----	----
2.4-Dimethylphenol	105-67-9	1.0	µg/L	<1.0	<1.0	----	----	----
2.4-Dichlorophenol	120-83-2	1.0	µg/L	<1.0	<1.0	----	----	----
2.6-Dichlorophenol	87-65-0	1.0	µg/L	<1.0	<1.0	----	----	----
4-Chloro-3-Methylphenol	59-50-7	1.0	µg/L	<1.0	<1.0	----	----	----
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	<1.0	<1.0	----	----	----
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	<1.0	<1.0	----	----	----
Pentachlorophenol	87-86-5	2.0	µg/L	<2.0	<2.0	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	----	----	----
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	----	----	----
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	----	----	----
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(b)fluoranthene	205-99-2	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	----	----	----
^ **Benzo(a)pyrene TEQ (WHO)**	----	0.5	µg/L	<0.5	<0.5	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----

Work Order : ES1224372
Client : PARSONS BRINCKERHOFF AUST P/L
Project : 2114759C

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**N.RIVER**	**SYD WATER**	----	----	----
			Client sampling date / time	11-OCT-2012 09:30	11-OCT-2012 08:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224372-001**	**ES1224372-002**	**----**	**----**	**----**
EP080/071: Total Petroleum Hydrocarbons - Continued								
^ **C10 - C36 Fraction (sum)**	----	50	µg/L	<50	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2010 Draft								
C6 - C10 Fraction	----	20	µg/L	<20	<20	----	----	----
^ **C6 - C10 Fraction minus BTEX (F1)**	----	20	µg/L	<20	<20	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	----	----	----
^ **>C10 - C40 Fraction (sum)**	----	100	µg/L	<100	<100	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	----	----	----
Toluene	108-88-3	2	µg/L	<2	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	----	----	----
^ **Total Xylenes**	1330-20-7	2	µg/L	<2	<2	----	----	----
^ **Sum of BTEX**	----	1	µg/L	<1	<1	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	<5	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	0.1	%	**15.2**	**18.0**	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	**59.2**	**49.9**	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	**50.7**	**43.4**	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	**56.6**	**48.8**	----	----	----
Anthracene-d10	1719-06-8	0.1	%	**63.8**	**43.9**	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	**87.6**	**70.9**	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**94.4**	**99.2**	----	----	----
Toluene-D8	2037-26-5	0.1	%	**113**	**109**	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**104**	**104**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	*CAS Number*	*Recovery Limits (%)* Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10.0	64.1
2-Chlorophenol-D4	93951-73-6	11.3	122.9
2.4.6-Tribromophenol	118-79-6	11.7	144.0
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	19.9	122.8
Anthracene-d10	1719-06-8	23.3	125.8
4-Terphenyl-d14	1718-51-0	20.3	134.5
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

ALS Group

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES1224373**	Page	: 1 of 7
Client	: **PARSONS BRINCKERHOFF AUST P/L**	Laboratory	: Environmental Division Sydney
Contact	: MR JAMES DUGGLEBY	Contact	: Loren Schiavon
Address	: GPO BOX 5394 SYDNEY NSW, AUSTRALIA 2001	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: jduggleby@pb.com.au	E-mail	: loren.schiavon@alsglobal.com
Telephone	: +61 02 9272 5100	Telephone	: +61 2 8784 8503
Facsimile	: +61 02 9272 5101	Facsimile	: +61 2 8784 8500
Project	: 2114759B	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 12-OCT-2012
Sampler	: NPH	Issue Date	: 19-OCT-2012
Site	: ----		
		No. of samples received	: 2
Quote number	: SY/394/09	No. of samples analysed	: 2

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

NATA WORLD RECOGNISED ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Ashesh Patel	Inorganic Chemist	Sydney Inorganics
Pabi Subba	Senior Organic Chemist	Sydney Organics
Raymond Commodor	Instrument Chemist	Sydney Inorganics
Sarah Millington	Senior Inorganic Chemist	Sydney Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG020: 'Bromine' quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.**

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**JD BORE**	**LB BORE**	----	----	----
			Client sampling date / time	11-OCT-2012 11:00	11-OCT-2012 10:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224373-001**	**ES1224373-002**	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.67**	**7.79**	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**630**	**656**	----	----	----
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	10	mg/L	**360**	**338**	----	----	----
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	<5	<5	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**236**	**260**	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**236**	**260**	----	----	----
ED040F: Dissolved Major Anions								
Silicon as SiO2	14464-46-1	0.1	mg/L	**11.1**	**12.2**	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	<1	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**36**	**30**	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**46**	**34**	----	----	----
Magnesium	7439-95-4	1	mg/L	**20**	**19**	----	----	----
Sodium	7440-23-5	1	mg/L	**34**	**62**	----	----	----
Potassium	7440-09-7	1	mg/L	**4**	**8**	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.002**	<0.001	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.512**	**1.60**	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.001	**0.001**	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.001	**0.002**	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.013**	**0.059**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	----	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	JD BORE	LB BORE	----	----	----
			Client sampling date / time	11-OCT-2012 11:00	11-OCT-2012 10:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224373-001**	**ES1224373-002**	**----**	**----**	**----**
EG020F: Dissolved Metals by ICP-MS - Continued								
Strontium	7440-24-6	0.001	mg/L	**0.226**	**0.404**	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.005	**0.011**	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.11**	**0.33**	----	----	----
Bromine	7726-95-6	0.1	mg/L	<0.1	<0.1	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	----	----	----
EG052F: Dissolved Silica by ICPAES								
Silica	7631-86-9	0.1	mg/L	**11.1**	**12.2**	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.1**	**0.2**	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.10**	**0.37**	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.02**	**0.01**	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.02**	**0.01**	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.2**	**0.5**	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.2**	**0.5**	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	----	0.01	mg/L	**0.01**	<0.01	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**5.73**	**6.04**	----	----	----
Total Cations	----	0.01	meq/L	**5.52**	**6.16**	----	----	----
Ionic Balance	----	0.01	%	**1.85**	**0.97**	----	----	----
EP033: C1 - C4 Hydrocarbon Gases								
Methane	74-82-8	10	µg/L	**65**	**2180**	----	----	----
Ethene	74-85-1	10	µg/L	<10	<10	----	----	----
Ethane	74-84-0	10	µg/L	<10	<10	----	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	JD BORE	LB BORE	----	----	----
			Client sampling date / time	11-OCT-2012 11:00	11-OCT-2012 10:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224373-001**	**ES1224373-002**	**----**	**----**	**----**
EP033: C1 - C4 Hydrocarbon Gases - Continued								
Propene	115-07-1	10	µg/L	<10	<10	----	----	----
Propane	74-98-6	10	µg/L	<10	<10	----	----	----
Butene	25167-67-3	10	µg/L	<10	<10	----	----	----
Butane	106-97-8	10	µg/L	<10	<10	----	----	----
EP075(SIM)A: Phenolic Compounds								
Phenol	108-95-2	1.0	µg/L	<1.0	<1.0	----	----	----
2-Chlorophenol	95-57-8	1.0	µg/L	<1.0	<1.0	----	----	----
2-Methylphenol	95-48-7	1.0	µg/L	<1.0	<1.0	----	----	----
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	<2.0	<2.0	----	----	----
2-Nitrophenol	88-75-5	1.0	µg/L	<1.0	<1.0	----	----	----
2.4-Dimethylphenol	105-67-9	1.0	µg/L	<1.0	<1.0	----	----	----
2.4-Dichlorophenol	120-83-2	1.0	µg/L	<1.0	<1.0	----	----	----
2.6-Dichlorophenol	87-65-0	1.0	µg/L	<1.0	<1.0	----	----	----
4-Chloro-3-Methylphenol	59-50-7	1.0	µg/L	<1.0	<1.0	----	----	----
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	<1.0	<1.0	----	----	----
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	<1.0	<1.0	----	----	----
Pentachlorophenol	87-86-5	2.0	µg/L	<2.0	<2.0	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	----	----	----
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	----	----	----
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	----	----	----
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(b)fluoranthene	205-99-2	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	<0.5	----	----	----
^ **Benzo(a)pyrene TEQ (WHO)**	----	0.5	µg/L	<0.5	<0.5	----	----	----

Analytical Results

Sub-Matrix: WATER	Client sample ID			JD BORE	LB BORE	----	----	----
	Client sampling date / time			11-OCT-2012 11:00	11-OCT-2012 10:00	----	----	----
Compound	CAS Number	LOR	Unit	ES1224373-001	ES1224373-002	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	----	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	----	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	----	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2010 Draft								
C6 - C10 Fraction	----	20	µg/L	<20	<20	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	----	20	µg/L	<20	<20	----	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	<100	----	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	----	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	----	----	----
Toluene	108-88-3	2	µg/L	<2	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	----	----	----
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	<1	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	<5	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	0.1	%	**20.3**	**21.1**	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	**58.1**	**58.8**	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	**44.1**	**47.5**	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	**54.0**	**52.1**	----	----	----
Anthracene-d10	1719-06-8	0.1	%	**71.6**	**59.1**	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	**89.3**	**70.7**	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**98.8**	**96.5**	----	----	----
Toluene-D8	2037-26-5	0.1	%	**109**	**124**	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**107**	**119**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	*CAS Number*	*Recovery Limits (%)* Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10.0	64.1
2-Chlorophenol-D4	93951-73-6	11.3	122.9
2.4.6-Tribromophenol	118-79-6	11.7	144.0
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	19.9	122.8
Anthracene-d10	1719-06-8	23.3	125.8
4-Terphenyl-d14	1718-51-0	20.3	134.5
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

Environmental Division

CERTIFICATE OF ADVANCE

Work Order	: **ES1224374**	Page	: 1 of 8
Client	: **PARSONS BRINCKERHOFF AUST P/L**	Laboratory	: Environmental Division Sydney
Contact	: MR JAMES DUGGLEBY	Contact	: Loren Schiavon
Address	: GPO BOX 5394 SYDNEY NSW, AUSTRALIA 2001	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: jduggleby@pb.com.au	E-mail	: loren.schiavon@alsglobal.com
Telephone	: +61 02 9272 5100	Telephone	: +61 2 8784 8503
Facsimile	: +61 02 9272 5101	Facsimile	: +61 2 8784 8500
Project	: 2114759B	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 12-OCT-2012
Sampler	: ----	Issue Date	: 19-OCT-2012
Site	: ----		
		No. of samples received	: 7
Quote number	: SY/394/09	No. of samples analysed	: 7

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics
Ashesh Patel	Inorganic Chemist	Sydney Inorganics
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics
Pabi Subba	Senior Organic Chemist	Sydney Organics
Raymond Commodor	Instrument Chemist	Sydney Inorganics
Sarah Millington	Senior Inorganic Chemist	Sydney Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EA015: TDS by method EA-015 may bias high for various samples due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.**
- **ED041G: LOR raised for SO4 analysis on sampl eID:12 due to sample matrix.**
- **EG020: 'Bromine' quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.**
- **EG020: Some samples were rerun (X10) due to matrix interference and LOR's have been raised accordingly.**
- **EP080:Sample TRIP SPIKE contains volatile compounds spiked into the sample containers prior to dispatch from the laboratory. BTEX compounds spiked at 20 ug/L.**

Analytical Results

Sub-Matrix: WATER			Client sample ID	SL02	MP30	KP01	12	MP07
			Client sampling date / time	11-OCT-2012 03:00	11-OCT-2012 08:45	11-OCT-2012 10:30	11-OCT-2012 08:15	11-OCT-2012 12:00
Compound	CAS Number	LOR	Unit	ES1224374-001	ES1224374-002	ES1224374-003	ES1224374-004	ES1224374-005
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	12100	15900	5350	45700	16000
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	10	mg/L	8320	11800	3460	37600	11600
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	10	1440	482	1430	1790
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	347	658	47	1770	329
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	7410	9460	2910	35600	9850
Total Alkalinity as CaCO3	----	1	mg/L	7760	10100	2960	37400	10200
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	29	126	58	<100	104
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	501	404	143	2440	556
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	9	4	<1	3	7
Magnesium	7439-95-4	1	mg/L	7	6	<1	24	4
Sodium	7440-23-5	1	mg/L	3520	5390	1390	17700	5320
Potassium	7440-09-7	1	mg/L	12	83	25	125	18
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	0.02	0.02	<0.10	<0.10
Arsenic	7440-38-2	0.001	mg/L	<0.001	0.015	0.002	0.068	<0.010
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.010	<0.010
Barium	7440-39-3	0.001	mg/L	6.52	14.9	1.70	12.6	30.3
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0010	<0.0010
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.010	<0.010
Copper	7440-50-8	0.001	mg/L	<0.001	<0.001	0.003	<0.010	<0.010
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.010	<0.010
Manganese	7439-96-5	0.001	mg/L	0.009	0.009	0.016	0.013	0.065
Molybdenum	7439-98-7	0.001	mg/L	0.003	0.036	0.006	0.283	<0.010
Nickel	7440-02-0	0.001	mg/L	<0.001	0.005	0.001	<0.010	<0.010
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.10	<0.10
Strontium	7440-24-6	0.001	mg/L	4.77	5.53	0.670	8.30	7.72
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.010	<0.010
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.10	<0.10
Zinc	7440-66-6	0.005	mg/L	<0.005	0.005	0.009	<0.050	<0.050

Analytical Results

Sub-Matrix: WATER			Client sample ID	SL02	MP30	KP01	12	MP07
			Client sampling date / time	11-OCT-2012 03:00	11-OCT-2012 08:45	11-OCT-2012 10:30	11-OCT-2012 08:15	11-OCT-2012 12:00
Compound	CAS Number	LOR	Unit	ES1224374-001	ES1224374-002	ES1224374-003	ES1224374-004	ES1224374-005
EG020F: Dissolved Metals by ICP-MS - Continued								
Boron	7440-42-8	0.05	mg/L	**0.27**	**0.09**	**0.07**	**0.42**	**0.19**
Iron	7439-89-6	0.05	mg/L	<0.05	**1.58**	**0.12**	**2.34**	**4.12**
Bromine	7726-95-6	0.1	mg/L	**0.8**	**1.0**	**0.5**	**6.2**	<1.0
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG052F: Dissolved Silica by ICPAES								
Silica	7631-86-9	0.1	mg/L	**25.7**	**19.1**	**7.1**	**58.9**	**20.2**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**1.1**	**1.9**	**0.7**	**4.0**	**1.5**
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**4.66**	**8.12**	**14.3**	**0.15**	**1.10**
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	**0.02**	**0.22**	**1.04**	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	**0.02**	**0.22**	**1.04**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**5.3**	**45.5**	**21.4**	**21.8**	**23.6**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**5.3**	**45.5**	**21.6**	**22.8**	**23.6**
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	----	0.01	mg/L	**0.08**	**1.17**	**0.03**	**0.32**	**0.85**
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**170**	**216**	**64.4**	**816**	**222**
Total Cations	----	0.01	meq/L	**154**	**237**	**61.1**	**775**	**232**
Ionic Balance	----	0.01	%	**4.80**	**4.67**	**2.68**	**2.63**	**2.33**
EP033: C1 - C4 Hydrocarbon Gases								
Methane	74-82-8	10	µg/L	**625**	**352**	**985**	**1490**	**492**
Ethene	74-85-1	10	µg/L	<10	<10	<10	<10	<10
Ethane	74-84-0	10	µg/L	<10	**16**	<10	**32**	**11**
Propene	115-07-1	10	µg/L	<10	<10	<10	<10	<10
Propane	74-98-6	10	µg/L	<10	<10	<10	<10	<10
Butene	25167-67-3	10	µg/L	<10	<10	<10	<10	<10
Butane	106-97-8	10	µg/L	<10	<10	<10	<10	<10

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**SL02**	**MP30**	**KP01**	**12**	**MP07**
			Client sampling date / time	11-OCT-2012 03:00	11-OCT-2012 08:45	11-OCT-2012 10:30	11-OCT-2012 08:15	11-OCT-2012 12:00
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224374-001**	**ES1224374-002**	**ES1224374-003**	**ES1224374-004**	**ES1224374-005**
EP075(SIM)A: Phenolic Compounds								
Phenol	108-95-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2-Chlorophenol	95-57-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2-Methylphenol	95-48-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0
2-Nitrophenol	88-75-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dimethylphenol	105-67-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dichlorophenol	120-83-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.6-Dichlorophenol	87-65-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
4-Chloro-3-Methylphenol	59-50-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pentachlorophenol	87-86-5	2.0	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	**2.7**	<1.0	**2.6**	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	**3.5**	<1.0	**1.7**	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	**8.0**	**1.1**	**3.8**	<1.0
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	**1.0**	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	**1.4**	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	**1.5**	<1.0	<1.0	<1.0
Benzo(b)fluoranthene	205-99-2	1.0	µg/L	<1.0	**1.2**	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	<0.5	**19.3**	**1.1**	**8.1**	<0.5
^ **Benzo(a)pyrene TEQ (WHO)**	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	**250**	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	<100	**660**	**110**	**220**	**200**
C29 - C36 Fraction	----	50	µg/L	<50	**250**	<50	**130**	**120**

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	SL02	MP30	KP01	12	MP07
			Client sampling date / time	11-OCT-2012 03:00	11-OCT-2012 08:45	11-OCT-2012 10:30	11-OCT-2012 08:15	11-OCT-2012 12:00
				ES1224374-001	ES1224374-002	ES1224374-003	ES1224374-004	ES1224374-005
EP080/071: Total Petroleum Hydrocarbons - Continued								
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	**1160**	**110**	**350**	**320**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2010 Draft								
C6 - C10 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	----	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	**410**	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	**660**	**130**	**300**	**250**
>C34 - C40 Fraction	----	100	µg/L	<100	**160**	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	**1230**	**130**	**300**	**250**
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	0.1	%	**23.1**	**26.1**	**24.1**	**14.4**	**24.2**
2-Chlorophenol-D4	93951-73-6	0.1	%	**55.1**	**59.4**	**56.9**	**62.7**	**55.6**
2.4.6-Tribromophenol	118-79-6	0.1	%	**50.0**	**51.1**	**46.2**	**55.7**	**46.0**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	**50.8**	**56.6**	**63.4**	**63.8**	**65.4**
Anthracene-d10	1719-06-8	0.1	%	**64.0**	**68.8**	**60.8**	**78.3**	**60.9**
4-Terphenyl-d14	1718-51-0	0.1	%	**79.4**	**66.2**	**62.3**	**86.3**	**65.6**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**83.8**	**93.4**	**115**	**74.8**	**80.5**
Toluene-D8	2037-26-5	0.1	%	**111**	**108**	**118**	**115**	**125**
4-Bromofluorobenzene	460-00-4	0.1	%	**106**	**98.6**	**111**	**96.9**	**113**

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	TS	TB	----	----	----
			Client sampling date / time	11-OCT-2012 15:00	11-OCT-2012 15:00	----	----	----
Compound	CAS Number	LOR	Unit	**ES1224374-006**	**ES1224374-007**	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	----	<20	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2010 Draft								
C6 - C10 Fraction	----	20	µg/L	----	<20	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	----	20	µg/L	----	<20	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	**15**	<1	----	----	----
Toluene	108-88-3	2	µg/L	**14**	<2	----	----	----
Ethylbenzene	100-41-4	2	µg/L	**14**	<2	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	**14**	<2	----	----	----
ortho-Xylene	95-47-6	2	µg/L	**15**	<2	----	----	----
^ Total Xylenes	1330-20-7	2	µg/L	**29**	<2	----	----	----
^ Sum of BTEX	----	1	µg/L	**72**	<1	----	----	----
Naphthalene	91-20-3	5	µg/L	**17**	<5	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**91.3**	**120**	----	----	----
Toluene-D8	2037-26-5	0.1	%	**108**	**116**	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**111**	**112**	----	----	----

Surrogate Control Limits

Sub-Matrix: **WATER**

Compound	CAS Number	Recovery Limits (%) Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10.0	64.1
2-Chlorophenol-D4	93951-73-6	11.3	122.9
2.4.6-Tribromophenol	118-79-6	11.7	144.0
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	19.9	122.8
Anthracene-d10	1719-06-8	23.3	125.8
4-Terphenyl-d14	1718-51-0	20.3	134.5
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

ALS Group

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **ES1224375**	Page	: 1 of 11
Client	: **PARSONS BRINCKERHOFF AUST P/L**	Laboratory	: Environmental Division Sydney
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Project	: 2114759B	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: ----		
C-O-C number	: ----	Date Samples Received	: 12-OCT-2012
Sampler	: NPH	Issue Date	: 20-OCT-2012
Site	: ----		
		No. of samples received	: 6
Quote number	: SY/394/09	No. of samples analysed	: 6

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

NATA WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
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General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EA015 TDS result has been confirmed by re-analysis for sample ID EM37.**
- **ED041G: LOR raised for SO4 analysis on sample ID:MP16 due to sample matrix.**
- **EG020: 'Bromine' quantification may be unreliable due to its low solubility in acid, leading to variable volatility during measurement by ICPMS.**
- **EG020: Some samples were rerun (X10) due to matrix interference and LOR's have been raised accordingly.**
- **EN055 - PG: Ionic Balance out of acceptable limits for sample ID 'JD1' due to analytes not quantified in this report.**

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	JD1	EM37	GL12	LB6	MP16
			Client sampling date / time	11-OCT-2012 03:45	11-OCT-2012 02:00	11-OCT-2012 12:10	11-OCT-2012 01:30	11-OCT-2012 02:30
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224375-001**	**ES1224375-002**	**ES1224375-003**	**ES1224375-004**	**ES1224375-005**
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**6.24**	**6.56**	**6.08**	**5.86**	**8.26**
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**63**	**206**	**139**	**48**	**9580**
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	10	mg/L	**31**	----	----	**28**	**6480**
Total Dissolved Solids @180°C	GIS-210-010	10	mg/L	----	**18**	**62**	----	----
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	**84**	**38**	**262**	**128**	**36**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	**47**
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**31**	**84**	**57**	**20**	**5620**
Total Alkalinity as CaCO3	----	1	mg/L	**31**	**84**	**57**	**20**	**5660**
ED040F: Dissolved Major Anions								
Silicon as SiO2	14464-46-1	0.1	mg/L	**0.3**	**0.2**	**2.1**	**0.5**	**16.8**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	<1	<1	**1**	<1	<10
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	<1	<1	**2**	<1	**391**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	<1	<1	<1	<1	**5**
Magnesium	7439-95-4	1	mg/L	<1	<1	<1	<1	**4**
Sodium	7440-23-5	1	mg/L	**3**	<1	**6**	<1	**2710**
Potassium	7440-09-7	1	mg/L	<1	<1	<1	<1	**21**
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.10
Arsenic	7440-38-2	0.001	mg/L	<0.001	<0.001	**0.001**	<0.001	<0.010
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Barium	7440-39-3	0.001	mg/L	**0.115**	**0.072**	**0.276**	**0.029**	**7.60**
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0010
Cobalt	7440-48-4	0.001	mg/L	<0.001	**0.001**	<0.001	<0.001	<0.010
Copper	7440-50-8	0.001	mg/L	**0.003**	<0.001	**0.001**	**0.001**	<0.010
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Manganese	7439-96-5	0.001	mg/L	**0.405**	**0.375**	**1.22**	**0.543**	**0.020**
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	**0.001**	**0.136**
Nickel	7440-02-0	0.001	mg/L	**0.002**	**0.001**	**0.004**	**0.003**	**0.021**

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	JD1	EM37	GL12	LB6	MP16
			Client sampling date / time	11-OCT-2012 03:45	11-OCT-2012 02:00	11-OCT-2012 12:10	11-OCT-2012 01:30	11-OCT-2012 02:30
Compound	CAS Number	LOR	Unit	ES1224375-001	ES1224375-002	ES1224375-003	ES1224375-004	ES1224375-005
EG020F: Dissolved Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.10
Strontium	7440-24-6	0.001	mg/L	**0.013**	**0.014**	**0.019**	**0.003**	**2.31**
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.10
Zinc	7440-66-6	0.005	mg/L	**0.037**	**0.041**	**0.019**	**0.033**	<0.050
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.10
Iron	7439-89-6	0.05	mg/L	**55.7**	**33.8**	**169**	**89.8**	**0.83**
Bromine	7726-95-6	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	<1.0
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG052F: Dissolved Silica by ICPAES								
Silica	7631-86-9	0.1	mg/L	**0.3**	**0.2**	**2.1**	**0.5**	**16.8**
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	**1.0**
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.03**	**21.8**	**11.4**	**0.02**	**5.21**
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	**0.02**	<0.01	**0.02**	**0.02**	<0.01
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.01**	**0.01**	<0.01	<0.01	<0.01
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.03**	**0.01**	**0.02**	**0.02**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<0.1	**24.9**	**13.3**	**0.1**	**7.6**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	<0.1	**24.9**	**13.3**	**0.1**	**7.6**
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	----	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	**0.06**
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**0.62**	**1.68**	**1.22**	**0.40**	**124**
Total Cations	----	0.01	meq/L	----	----	----	----	**119**
Total Cations	----	0.01	meq/L	**0.23**	**1.52**	**1.07**	**0.21**	----
Ionic Balance	----	0.01	%	----	----	----	----	**2.17**
EP033: C1 - C4 Hydrocarbon Gases								
Methane	74-82-8	10	µg/L	**11700**	**27800**	**8860**	**6530**	**3560**

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	JD1	EM37	GL12	LB6	MP16
			Client sample ID	**JD1**	**EM37**	**GL12**	**LB6**	**MP16**
			Client sampling date / time	11-OCT-2012 03:45	11-OCT-2012 02:00	11-OCT-2012 12:10	11-OCT-2012 01:30	11-OCT-2012 02:30
				ES1224375-001	**ES1224375-002**	**ES1224375-003**	**ES1224375-004**	**ES1224375-005**
EP033: C1 - C4 Hydrocarbon Gases - Continued								
Ethene	74-85-1	10	µg/L	<10	<10	<10	<10	<10
Ethane	74-84-0	10	µg/L	**38**	**60**	**13**	**16**	**27**
Propene	115-07-1	10	µg/L	<10	<10	<10	<10	<10
Propane	74-98-6	10	µg/L	<10	<10	<10	<10	<10
Butene	25167-67-3	10	µg/L	<10	<10	<10	<10	<10
Butane	106-97-8	10	µg/L	<10	<10	<10	<10	<10
EP075(SIM)A: Phenolic Compounds								
Phenol	108-95-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2-Chlorophenol	95-57-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2-Methylphenol	95-48-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0
2-Nitrophenol	88-75-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dimethylphenol	105-67-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4-Dichlorophenol	120-83-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.6-Dichlorophenol	87-65-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
4-Chloro-3-Methylphenol	59-50-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pentachlorophenol	87-86-5	2.0	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Acenaphthene	83-32-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluorene	86-73-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Phenanthrene	85-01-8	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	**1.5**
Anthracene	120-12-7	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Fluoranthene	206-44-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Pyrene	129-00-0	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chrysene	218-01-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(b)fluoranthene	205-99-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0

Analytical Results

Sub-Matrix: WATER			Client sample ID	JD1	EM37	GL12	LB6	MP16
			Client sampling date / time	11-OCT-2012 03:45	11-OCT-2012 02:00	11-OCT-2012 12:10	11-OCT-2012 01:30	11-OCT-2012 02:30
Compound	CAS Number	LOR	Unit	ES1224375-001	ES1224375-002	ES1224375-003	ES1224375-004	ES1224375-005
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons - Continued								
^ Sum of polycyclic aromatic hydrocarbons	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	**1.5**
^ Benzo(a)pyrene TEQ (WHO)	----	0.5	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	<50	<50
C15 - C28 Fraction	----	100	µg/L	**210**	**4590**	<100	<100	**2730**
C29 - C36 Fraction	----	50	µg/L	**160**	<50	<50	<50	**2940**
^ C10 - C36 Fraction (sum)	----	50	µg/L	**370**	**4590**	<50	<50	**5670**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2010 Draft								
C6 - C10 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	----	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	**200**	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	**350**	**4040**	<100	<100	**4490**
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	<100	**1960**
^ >C10 - C40 Fraction (sum)	----	100	µg/L	**350**	**4240**	<100	<100	**6450**
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	0.1	%	**27.5**	**19.0**	**26.1**	**28.7**	**20.2**
2-Chlorophenol-D4	93951-73-6	0.1	%	**66.9**	**58.3**	**65.0**	**63.5**	**55.3**
2.4.6-Tribromophenol	118-79-6	0.1	%	**60.6**	**49.0**	**51.8**	**59.1**	**40.7**
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	**58.6**	**54.4**	**54.3**	**56.1**	**55.1**
Anthracene-d10	1719-06-8	0.1	%	**69.3**	**53.4**	**61.3**	**60.1**	**70.2**
4-Terphenyl-d14	1718-51-0	0.1	%	**73.8**	**69.2**	**83.5**	**74.7**	**69.4**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**121**	**109**	**121**	**131**	**125**
Toluene-D8	2037-26-5	0.1	%	**120**	**106**	**119**	**129**	**126**
4-Bromofluorobenzene	460-00-4	0.1	%	**94.7**	**88.6**	**102**	**99.1**	**99.1**

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**QA1**	----	----	----	----
			Client sampling date / time	11-OCT-2012 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224375-006**	----	----	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**8.36**	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**15600**	----	----	----	----
EA015: Total Dissolved Solids								
Total Dissolved Solids @180°C	GIS-210-010	10	mg/L	**11800**	----	----	----	----
EA025: Suspended Solids								
Suspended Solids (SS)	----	5	mg/L	**2050**	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	**352**	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**10000**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**10400**	----	----	----	----
ED040F: Dissolved Major Anions								
Silicon as SiO2	14464-46-1	0.1	mg/L	**13.9**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**127**	----	----	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**404**	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**4**	----	----	----	----
Magnesium	7439-95-4	1	mg/L	**6**	----	----	----	----
Sodium	7440-23-5	1	mg/L	**5220**	----	----	----	----
Potassium	7440-09-7	1	mg/L	**82**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.10	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.011**	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.010	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**15.7**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0010	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	<0.010	----	----	----	----
Copper	7440-50-8	0.001	mg/L	<0.010	----	----	----	----
Lead	7439-92-1	0.001	mg/L	<0.010	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	<0.010	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.031**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.010	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.10	----	----	----	----

Analytical Results

Sub-Matrix: WATER			Client sample ID	QA1	----	----	----	----
			Client sampling date / time	11-OCT-2012 15:00	----	----	----	----
Compound	CAS Number	LOR	Unit	ES1224375-006	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Strontium	7440-24-6	0.001	mg/L	**5.14**	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	<0.010	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.10	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	<0.050	----	----	----	----
Boron	7440-42-8	0.05	mg/L	<0.10	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**1.58**	----	----	----	----
Bromine	7726-95-6	0.1	mg/L	<1.0	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EG052F: Dissolved Silica by ICPAES								
Silica	7631-86-9	0.1	mg/L	**13.9**	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**2.0**	----	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**7.63**	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	----	0.01	mg/L	<0.01	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.02**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.02**	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**40.0**	----	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**40.0**	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	----	0.01	mg/L	**1.15**	----	----	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**222**	----	----	----	----
Total Cations	----	0.01	meq/L	**230**	----	----	----	----
Ionic Balance	----	0.01	%	**1.71**	----	----	----	----
EP033: C1 - C4 Hydrocarbon Gases								
Methane	74-82-8	10	µg/L	**1820**	----	----	----	----
Ethene	74-85-1	10	µg/L	<10	----	----	----	----
Ethane	74-84-0	10	µg/L	**73**	----	----	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	QA1	----	----	----	----
			Client sampling date / time	11-OCT-2012 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224375-006**	----	----	----	----
EP033: C1 - C4 Hydrocarbon Gases - Continued								
Propene	115-07-1	10	µg/L	<10	----	----	----	----
Propane	74-98-6	10	µg/L	<10	----	----	----	----
Butene	25167-67-3	10	µg/L	<10	----	----	----	----
Butane	106-97-8	10	µg/L	<10	----	----	----	----
EP075(SIM)A: Phenolic Compounds								
Phenol	108-95-2	1.0	µg/L	<1.0	----	----	----	----
2-Chlorophenol	95-57-8	1.0	µg/L	<1.0	----	----	----	----
2-Methylphenol	95-48-7	1.0	µg/L	<1.0	----	----	----	----
3- & 4-Methylphenol	1319-77-3	2.0	µg/L	<2.0	----	----	----	----
2-Nitrophenol	88-75-5	1.0	µg/L	<1.0	----	----	----	----
2.4-Dimethylphenol	105-67-9	1.0	µg/L	<1.0	----	----	----	----
2.4-Dichlorophenol	120-83-2	1.0	µg/L	<1.0	----	----	----	----
2.6-Dichlorophenol	87-65-0	1.0	µg/L	<1.0	----	----	----	----
4-Chloro-3-Methylphenol	59-50-7	1.0	µg/L	<1.0	----	----	----	----
2.4.6-Trichlorophenol	88-06-2	1.0	µg/L	<1.0	----	----	----	----
2.4.5-Trichlorophenol	95-95-4	1.0	µg/L	<1.0	----	----	----	----
Pentachlorophenol	87-86-5	2.0	µg/L	<2.0	----	----	----	----
EP075(SIM)B: Polynuclear Aromatic Hydrocarbons								
Naphthalene	91-20-3	1.0	µg/L	**2.6**	----	----	----	----
Acenaphthylene	208-96-8	1.0	µg/L	<1.0	----	----	----	----
Acenaphthene	83-32-9	1.0	µg/L	<1.0	----	----	----	----
Fluorene	86-73-7	1.0	µg/L	**3.1**	----	----	----	----
Phenanthrene	85-01-8	1.0	µg/L	**7.4**	----	----	----	----
Anthracene	120-12-7	1.0	µg/L	<1.0	----	----	----	----
Fluoranthene	206-44-0	1.0	µg/L	<1.0	----	----	----	----
Pyrene	129-00-0	1.0	µg/L	<1.0	----	----	----	----
Benz(a)anthracene	56-55-3	1.0	µg/L	<1.0	----	----	----	----
Chrysene	218-01-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(b)fluoranthene	205-99-2	1.0	µg/L	**1.1**	----	----	----	----
Benzo(k)fluoranthene	207-08-9	1.0	µg/L	<1.0	----	----	----	----
Benzo(a)pyrene	50-32-8	0.5	µg/L	<0.5	----	----	----	----
Indeno(1.2.3.cd)pyrene	193-39-5	1.0	µg/L	<1.0	----	----	----	----
Dibenz(a.h)anthracene	53-70-3	1.0	µg/L	<1.0	----	----	----	----
Benzo(g.h.i)perylene	191-24-2	1.0	µg/L	<1.0	----	----	----	----
^ **Sum of polycyclic aromatic hydrocarbons**	----	0.5	µg/L	**14.2**	----	----	----	----
^ **Benzo(a)pyrene TEQ (WHO)**	----	0.5	µg/L	<0.5	----	----	----	----

Analytical Results

Sub-Matrix: **WATER**			Client sample ID	**QA1**	----	----	----	----
			Client sampling date / time	11-OCT-2012 15:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES1224375-006**	----	----	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	----	----	----	----
C10 - C14 Fraction	----	50	µg/L	**260**	----	----	----	----
C15 - C28 Fraction	----	100	µg/L	**650**	----	----	----	----
C29 - C36 Fraction	----	50	µg/L	**260**	----	----	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	**1170**	----	----	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2010 Draft								
C6 - C10 Fraction	----	20	µg/L	<20	----	----	----	----
^ C6 - C10 Fraction minus BTEX (F1)	----	20	µg/L	<20	----	----	----	----
>C10 - C16 Fraction	----	100	µg/L	**480**	----	----	----	----
>C16 - C34 Fraction	----	100	µg/L	**680**	----	----	----	----
>C34 - C40 Fraction	----	100	µg/L	**150**	----	----	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	**1310**	----	----	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	----	----	----	----
Toluene	108-88-3	2	µg/L	<2	----	----	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	----	----	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	----	----	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	----	----	----	----
^ Total Xylenes	1330-20-7	2	µg/L	<2	----	----	----	----
^ Sum of BTEX	----	1	µg/L	<1	----	----	----	----
Naphthalene	91-20-3	5	µg/L	<5	----	----	----	----
EP075(SIM)S: Phenolic Compound Surrogates								
Phenol-d6	13127-88-3	0.1	%	**23.7**	----	----	----	----
2-Chlorophenol-D4	93951-73-6	0.1	%	**60.3**	----	----	----	----
2.4.6-Tribromophenol	118-79-6	0.1	%	**50.1**	----	----	----	----
EP075(SIM)T: PAH Surrogates								
2-Fluorobiphenyl	321-60-8	0.1	%	**57.8**	----	----	----	----
Anthracene-d10	1719-06-8	0.1	%	**67.9**	----	----	----	----
4-Terphenyl-d14	1718-51-0	0.1	%	**70.4**	----	----	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	0.1	%	**132**	----	----	----	----
Toluene-D8	2037-26-5	0.1	%	**124**	----	----	----	----
4-Bromofluorobenzene	460-00-4	0.1	%	**101**	----	----	----	----

Surrogate Control Limits

Sub-Matrix: WATER		Recovery Limits (%)	
Compound	CAS Number	Low	High
EP075(SIM)S: Phenolic Compound Surrogates			
Phenol-d6	13127-88-3	10.0	64.1
2-Chlorophenol-D4	93951-73-6	11.3	122.9
2.4.6-Tribromophenol	118-79-6	11.7	144.0
EP075(SIM)T: PAH Surrogates			
2-Fluorobiphenyl	321-60-8	19.9	122.8
Anthracene-d10	1719-06-8	23.3	125.8
4-Terphenyl-d14	1718-51-0	20.3	134.5
EP080S: TPH(V)/BTEX Surrogates			
1.2-Dichloroethane-D4	17060-07-0	71	137
Toluene-D8	2037-26-5	79	131
4-Bromofluorobenzene	460-00-4	70	128

Appendix C

GNS Science stable isotope laboratory results

STABLE ISOTOPE RESULTS

Parsons Brinckerhoff
Level 27, 680 George St
World Square, Sydney
NSW 2001
Australia

National Isotope Centre
30 Gracefield Road
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PO Box 31 312
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New Zealand
T +64-4-570 1444
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www.gns.cri.nz

Project Title 2114759C
SIL Order No.: W-1204543
Client Ref.:
Date Received: 25/10/2012
Date Measured:
Approved By:
Date Reported: 19/11/2012

Invoice Attn:
Parsons Brinckerhoff
Nina Pearse-Hawkins
Level 27, 680 George St
World Square, Sydney
NSW 2001
Australia

Sample Type: **water (H & O)**

SIL ID	External ID	δD Value	δ18O Value	Analysis Type	Country Code	Collection Date/Time (Start)	Other Info
W-1204543	N.River	-13.9	-2.76	D, O18	AS	11/10/2012	groundwater
W-1204544	LB6	-54.1	-10.84	D, O18	AS	11/10/2012	groundwater
W-1204545	MP12	-26.3	-5.10	D, O18	AS	11/10/2012	groundwater
W-1204546	MP30	-41.0	-7.89	D, O18	AS	11/10/2012	groundwater
W-1204547	MP07	-53.9	-8.42	D, O18	AS	11/10/2012	groundwater
W-1204548	Syd.Water	-12.8	-2.91	D, O18	AS	11/10/2012	groundwater
W-1204549	EM37	-42.1	-8.12	D, O18	AS	11/10/2012	groundwater
W-1204550	SL02	-50.7	-8.83	D, O18	AS	11/10/2012	groundwater
W-1204551	JD1	-77.7	-12.70	D, O18	AS	11/10/2012	groundwater
W-1204552	JD Bore	-33.6	-6.19	D, O18	AS	11/10/2012	groundwater
W-1204553	LB Bore	-33.4	-6.22	D, O18	AS	11/10/2012	groundwater
W-1204554	GL12	-47.3	-8.99	D, O18	AS	11/10/2012	groundwater
W-1204555	MP16	-43.7	-8.22	D, O18	AS	11/10/2012	groundwater
W-1204556	KP05	-42.7	-8.02	D, O18	AS	11/10/2012	groundwater

Water samples are analysed on an Isoprime mass spectrometer; for $\delta^{18}O$ by water equilibration at 25°C using an Aquaprep device, for $\delta^{2}H$ by reduction at 1100 °C using a Eurovector Chrome HD elemental analyser.

All results are reported with respect to VSMOW2, normalized to our internal standards: SM1 with reported values of -29.12‰ for $\delta^{18}O$, -227.4‰ for $\delta^{2}H$, and INS11 with reported values of -0.36‰ for $\delta^{18}O$, -3.8‰ for $\delta^{2}H$. The analytical precision for this instrument is 0.2‰ for $\delta^{18}O$ and 2.0‰ for $\delta^{2}H$.

Appendix D

ANSTO tritium results

ANSTO TRITIUM RESULTS

ANSTO ID	**Sample Description**	Date Sampled	Activity (Bq/kg)	Combined standard uncertainty (Bq/kg)	MDA (Bq/kg)
2012/0283/1	WKMB02	21/08/2012	0.028	0.003	0.017
2012/0283/2	WKMB03	21/08/2012	0.040	0.004	0.016
2012/0283/3	TCMB04	21/08/2012	0.063	0.004	0.017
2012/0283/4	Strat4	17/09/2012	0.044	0.004	0.016
2012/0283/5	S4	26/09/2012	0.036	0.004	0.017
Blank_12.10.2012		12/10/2012	0.004	0.003	0.017
2012/0283/6	N.River	11/10/2012	0.186	0.009	0.018
2012/0283/7	LB6	11/10/2012	0.009	0.003	0.018
2012/0283/11	Syd. Water	11/10/2012	0.180	0.009	0.018
2012/0283/12	EM37	11/10/2012	0.033	0.004	0.018
2012/0283/14	JD1	11/10/2012	0.013	0.003	0.018
2012/0283/15	JD Bore	11/10/2012	0.003	0.003	0.018
2012/0283/17	GL 12	11/10/2012	0.016	0.0033	0.018

Note: some values are below the Minimum Detectable Activity (MDA); this data should be used as a guide only

Appendix E

QA/QC table

Summary Table E: October 2012 Water Quality QA/QC

Analyte	Units	LOR	MP30	QA1	RPD
Sample date			11/10/2012	11/10/2012	
Laboratory Water Quality Parameters					
pH	pH units	0.01	na	8.36	
Conductivity	µS/cm	1	15900	15600	1.9
TDS	mg/L	1	11800	11800	0.0
Suspended solids	mg/L	5	1440	2050	-35.0
Laboratory Analytes					
Hydroxide Alkalinity as CaCO3	mg/L	1	<1	<1	
Carbonate Alkalinity as CaCO3	mg/L	1	658	352	60.6
Bicarbonate Alkalinity as CaCO3	mg/L	1	9460	10000	-5.5
Total Alkalinity as CaCO3	mg/L	1	10100	10400	-2.9
Sulfate as SO4 2-	mg/L	1	126	127	-0.8
Chloride	mg/L	1	404	404	0.0
Calcium	mg/L	1	4	4	0.0
Magnesium	mg/L	1	6	6	0.0
Sodium	mg/L	1	5390	5220	3.2
Potassium	mg/L	1	83	82	1.2
Silica	mg/L	0.1	19.1	13.9	31.5
Fluoride	mg/L	0.1	1.9	2	-5.1
Dissolved Metals					
Aluminium	mg/L	0.01	0.02	<0.1	nc
Arsenic	mg/L	0.001	0.015	0.011	30.8
Beryllium	mg/L	0.001	<0.001	<0.01	nc
Barium	mg/L	0.001	14.9	15.7	-5.2
Cadmium	mg/L	0.0001	<0.0001	<0.001	nc
Cobalt	mg/L	0.001	<0.001	<0.01	nc
Copper	mg/L	0.001	<0.001	<0.01	nc
Lead	mg/L	0.001	<0.001	<0.01	nc
Manganese	mg/L	0.001	0.009	<0.010	nc
Molybdenum	mg/L	0.001	0.036	0.031	14.9
Nickel	mg/L	0.001	0.005	<0.01	nc
Selenium	mg/L	0.01	<0.01	<0.1	nc
Strontium	mg/L	0.001	5.53	5.41	2.2
Uranium	mg/L	0.001	<0.001	<0.01	nc
Vanadium	mg/L	0.01	<0.01	<0.1	nc
Zinc	mg/L	0.005	0.005	<0.05	nc
Boron	mg/L	0.05	0.09	<0.1	nc
Iron	mg/L	0.05	1.58	1.58	0.0
Bromine	mg/L	0.1	1	<1	nc
Iodine	mg/L	0.1	na	na	
Mercury	mg/L	0.0001	<0.0001	<0.0001	nc
Nutrients					
Ammonia as N	mg/L	0.01	8.12	7.63	6.2
Nitrite as N	mg/L	0.01	<0.01	<0.01	nc
Nitrate as N	mg/L	0.01	0.02	0.02	0.0
Nitrite + Nitrate as N	mg/L	0.01	0.02	0.02	0.0
Total Kjeldahl Nitrogen as N	mg/L	0.1	45.5	40	12.9
Total nitrogen as N	mg/L	0.1	45.5	40	12.9
Total Phosphorous	mg/L	0.01	na	na	nc
Reactive Phosphorous	mg/L	0.01	1.17	1.15	1.7
Total Organic Carbon	mg/L	1	na	na	nc
Dissolved Gases					
Methane	µg/L	10	352	1820	-135.2
Ethene	µg/L	10	<10	<10	nc
Ethane	µg/L	10	16	73	-128.1
Propene	µg/L	10	<10	<10	nc
Propane	µg/L	10	<10	<10	nc
Butane	µg/L	10	<10	<10	nc
Butene	µg/L	10	<10	<10	nc
Phenolic compounds					
Phenol	µg/L	1	<1	<1	nc
2-Chlorophenol	µg/L	1	<1	<1	nc
2-Methylphenol	µg/L	1	<1	<1	nc
3-&4-Methylphenol	µg/L	2	<1	<1	nc
2-Nitrophenol	µg/L	1	<1	<1	nc
2.4-Dimethylphenol	µg/L	1	<1	<1	nc
2.4-Dichlorophenol	µg/L	1	<1	<1	nc
2.6-Dichlorophenol	µg/L	1	<1	<1	nc
4-Chloro-3-Methylphenol	µg/L	1	<1	<1	nc
2.4.6-Trichlorophenol	µg/L	1	<1	<1	nc
2.4.5-Trichlorophenol	µg/L	1	<1	<1	nc
Pentachlorophenol	µg/L	2	<2	<2	nc
Polycyclic aromatic hydrocarbons					
Naphthalene	µg/L	1	2.7	2.6	3.8
Acenaphthylene	µg/L	1	<1	<1	nc
Acenaphthene	µg/L	1	<1	<1	nc
Fluorene	µg/L	1	3.5	3.1	12.1
Phenanthrene	µg/L	1	8	7.4	7.8
Anthracene	µg/L	1	<1	<1	nc
Fluoranthene	µg/L	1	<1	<1	nc
Pyrene	µg/L	1	1	<1	nc
Benz(a)anthracene	µg/L	1	1.4	<1	nc
Chrysene	µg/L	1	1.5	<1	nc
Benzo(b)fluoranthene	µg/L	1	1.2	1.1	nc
Benzo(k)fluoranthene	µg/L	1	<1	<1	nc
Benzo(a)pyrene	µg/L	0.5	<0.5	<0.5	nc
Indeno(1.2.3.cd)pyrene	µg/L	1	<1	<1	nc
Dibenz(a.h)anthracene	µg/L	1	<1	<1	nc
Benzo(g.h.i)perylene	µg/L	1	<1	<1	nc
Sum of polycyclic aromatic hydrocarbons			19.3	14.2	30.4
Total petroleum hydrocarbons					
C6-C9 Fraction	µg/L	20	<20	<20	nc
C10-C14 Fraction	µg/L	50	250	260	-3.9
C15-C28 Fraction	µg/L	100	660	650	1.5
C29-C36 Fraction	µg/L	50	250	260	-3.9
C10-C36 Fraction (sum)	µg/L	50	1160	1170	-0.9
Total recoverable hydrocarbons					
C6-C10 Fraction	µg/L	20	<20	<20	nc
C6-C10 Fraction minus BTEX (F1)	µg/L	20	<20	<20	nc
>C10-C16 Fraction	µg/L	100	410	480	-15.7
>C16-C34 Fraction	µg/L	100	660	680	-3.0
>C34-C40 Fraction	µg/L	100	160	150	6.5
>C10-C40 Fraction (sum)	µg/L	100	1230	1310	-6.3
Aromatic Hydrocarbons					
Benzene	µg/L	1	<1	<1	nc
Toluene	µg/L	2	<2	<2	nc
Ethyl Benzene	µg/L	2	<2	<2	nc
m&p-Xylenes	µg/L	2	<2	<2	nc
o-Xylenes	µg/L	2	<2	<2	nc
Total xlyenes	µg/L	2	<2	<2	nc
Sum of BTEX	µg/L	1	<1	<1	nc
Naphthalene	µg/L	5	<5	<5	nc
Isotopes					
Oxygen-18	‰	0.01	na	na	na
Deuterium	‰	0.1	na	na	na
Tritium	TU	0.01	na	na	na

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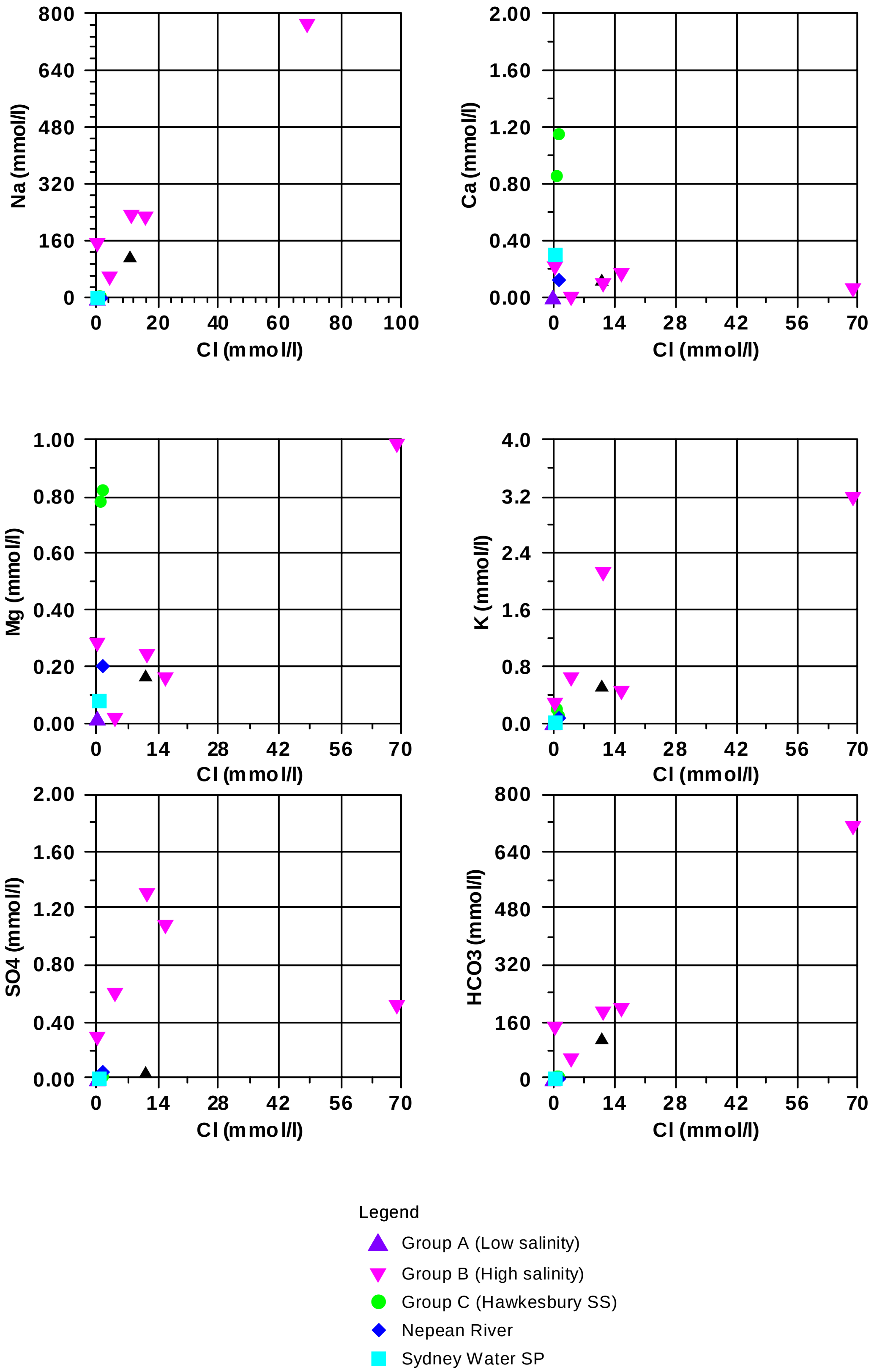
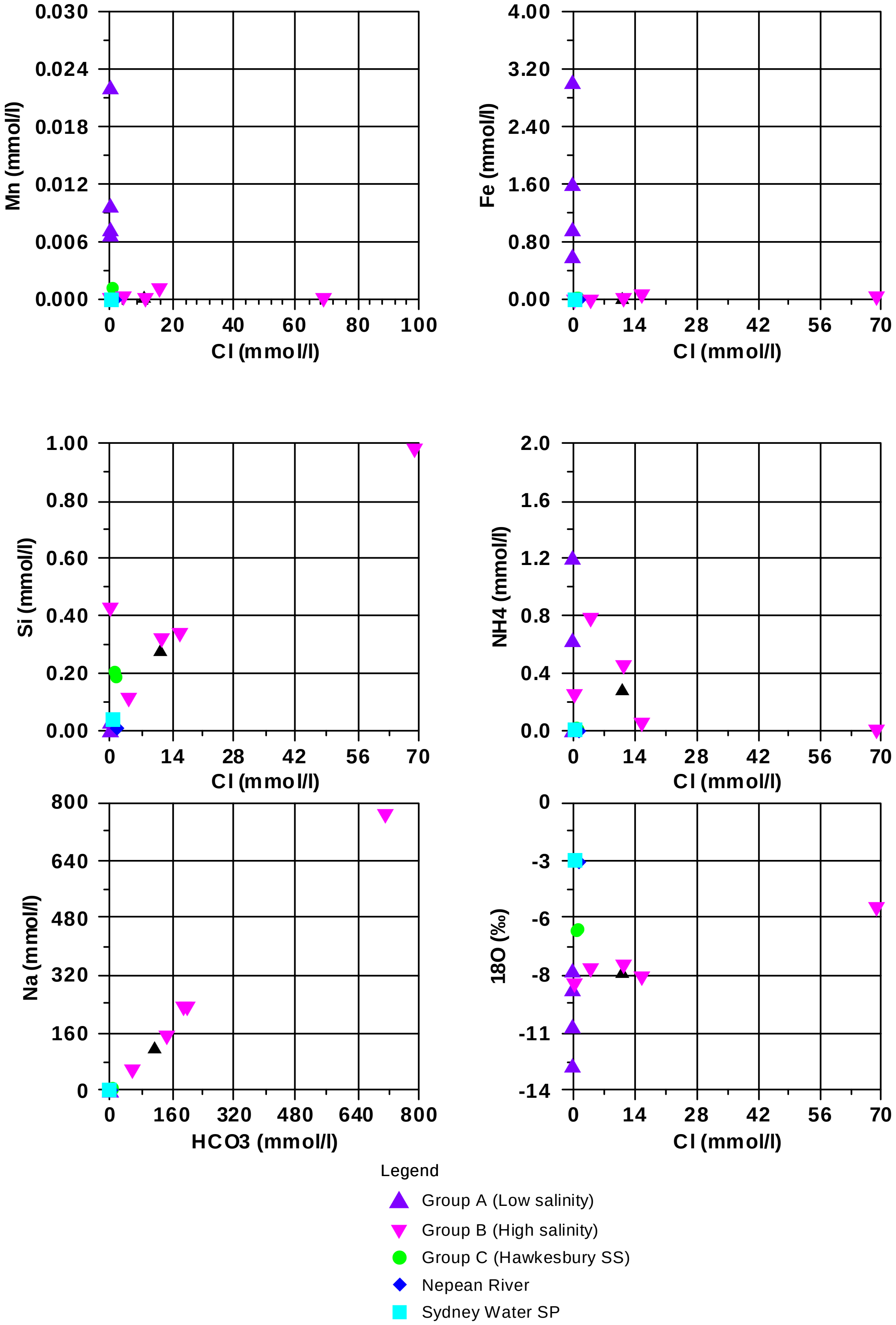
Appendix F

Chemistry figures – ion/Cl graphs



Appendix F - ion/Cl plots



Appendix F - ion/Cl and 18O/Cl plots