Gloucester Basin Stage 1 Gas Field Development Project
Preliminary Groundwater Assessment and Initial Conceptual Hydrogeological Model

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AGL Energy Limited
Level 22, 101 Miler Street North Sydney NSW 2060

SRK Consulting (Australasia) Pty Ltd
Level 1, 10 Richardson Street West Perth WA 6005

Compiled by:

Sylvie Ogier-Halim
Senior Consultant (Hydrogeologist and Geochemist)

Email: sogier-halim@srk.com.au @srk.com.au

Peer Reviewed by:

Stefan Muller
Principal Consultant (Hydrogeologist)

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Name/Title	Company
John Ross, Manager Hydrogeology, AGL Upstream Gas	AGL Energy Ltd

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List of Abbreviations

Abbreviation	Meaning
°C	Degree Celsius
AGL	AGL Energy Limited
ALS	ALS Group
ANZECC	Australian and New Zealand Environment and Conservation Council
Bbl/day	Barrels per day
Ca	calcium
Cl	chloride
CO_3	carbonate
CPF	Central Processing Facility
CSG	coal seam gas
DMR	Department of Mineral Resources
E	east
EC	electrical conductivity
E–W	east-west
EP&A	Environmental Planning and Assessment
GCM	Gloucester Coal Measures
GFDA	Gas Field Development Area
HCO_3	bicarbonate
K	potassium
km	kilometre
km^2	square kilometre
L/s	litre per second
m	metre
m bgl	metre below ground level
m RL	metres reduced level
mm/annum	millimetres per annum
m/day	metre per day
m^3	cubic metre
m^3/day	cubic metre per day
mD	milliDarcy
mE	metres east
Mg	magnesium
mg/L	milligrams per litre
mm	millimetre
mN	metres north
mS/cm	milliSiemens per centimetre
µS/cm	microSiemens per centimetre
N	north
Na	sodium
NATA	National Association of Testing Authorities
NE	northeast

Abbreviation	Meaning
NSW	New South Wales
NW	northwest
PEL	Petroleum Exploration Licence
PJ	petrajoule
PVC	polyvinyl chloride
S	south
SE	southeast
SO_4	sulphate
SRK	SRK Consulting (Australasia) Pty Ltd
SW	southwest
SWL	static water level
Temp	temperature
TJ	tetrajoule
VWP	vibrating wire piezometer
W	west
WL	water level

1. Introduction

The overall objective of the proposed study is to conduct a review of the hydrogeological regimes operating in the Gloucester Basin and particularly within the Gloucester Stage 1 Gas Field Development Area (Stage 1 GFDA) of the Gloucester Gas project. The outcome of the study is to conceptualise the groundwater system across the Stage 1 GFDA and to assist with set-up of a ground and surface water monitoring network to evaluate the potential groundwater impacts from the development of Coal Seam Gas (CSG) in the Gloucester Basin and help develop long-term water management strategies for the project.

As part of the hydrogeological assessment, a desktop review, an initial site visit, data collection and an initial conceptual hydrogeological model have been completed and are presented herein.

2. Project Background

The Gloucester Gas Project includes works for the extraction of CSG from the Gloucester Basin within the PEL 285 area. The project involves the development of gas wells and associated infrastructure, the development of a Central Processing Facility (CPF), and the construction and operation of a high-pressure gas transmission pipeline from Stratford to a delivery station at Hexham, NSW. Hydrogeological studies are required to support the development of the project, particularly in the Stage 1 GFDA.

Project Approval is currently being sought under Part 3a of the Environmental Planning and Assessment Act (EP&A Act) for the project including:

- the extraction and treatment of CSG from up to 110 proposed wells within the Stage 1 GFDA;
- the construction and operation of the CPF with a capacity of approximately 30 PJ per year (with an 80TJ per day average);
- the construction and operation of a gas transmission pipeline from the CPF to Hexham; and
- the construction and operation of the Hexham Delivery Station.

The water management conditions under the Part 3a Planning Approvals are yet to be sighted however, they are likely to involve further groundwater studies, and the establishment of groundwater and surface water monitoring networks.

This initial desktop study and subsequent studies are expected to address the regulatory and compliance monitoring requirements associated with the project.

3. Site Description

The Gloucester Stage 1 GFDA is located near Stratford, approximately 90 km north northeast of Newcastle, in New South Wales (Figure 3-1). The project is situated within the Petroleum Exploration Licence (PEL) 285, issued under the Petroleum (Onshore) Act 1991, which completely contains the Gloucester Geological Basin. The Stage 1 GFDA of the project represents about 25% of the Gloucester Geological Basin and is situated in the northeast part of the Gloucester Basin between the townships of Craven, Stratford, Waukivory and Gloucester. The main project development area around Stratford is a much smaller area and represents about 1% of the geological basin.

The project is a coal seam gas project that involves petroleum exploration activities, including drilling and production testing.

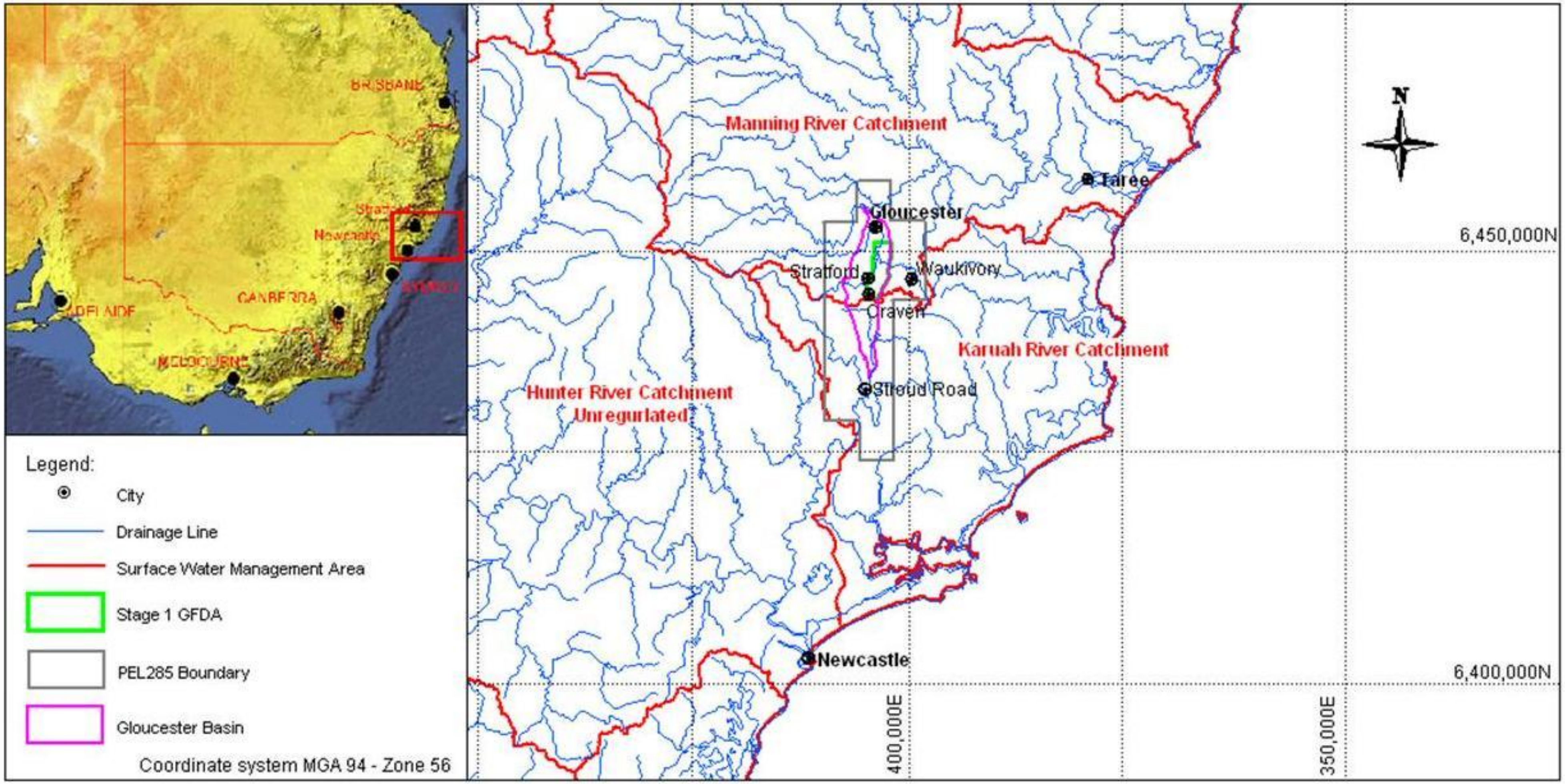

Figure 3-1: Location of Gloucester Gas Pilot Project Stage 1 GFDA

3.1 Climate

The regional climate is characterised by hot summers, averaging 26.6°C in January, with periods of humid, stormy conditions; while winters are cool to mild and dry (dropping to an average of 6.2°C in July). Exact long-term meteorological data of the project area are available at the Gloucester Post Office Station (site number 060015). The average rainfall in the period 1888 to 2008 is just below 950 mm/annum (Figure 3-2). The average annual evaporation rate is 1103 mm. Evaporation exceeds precipitation from August to January.

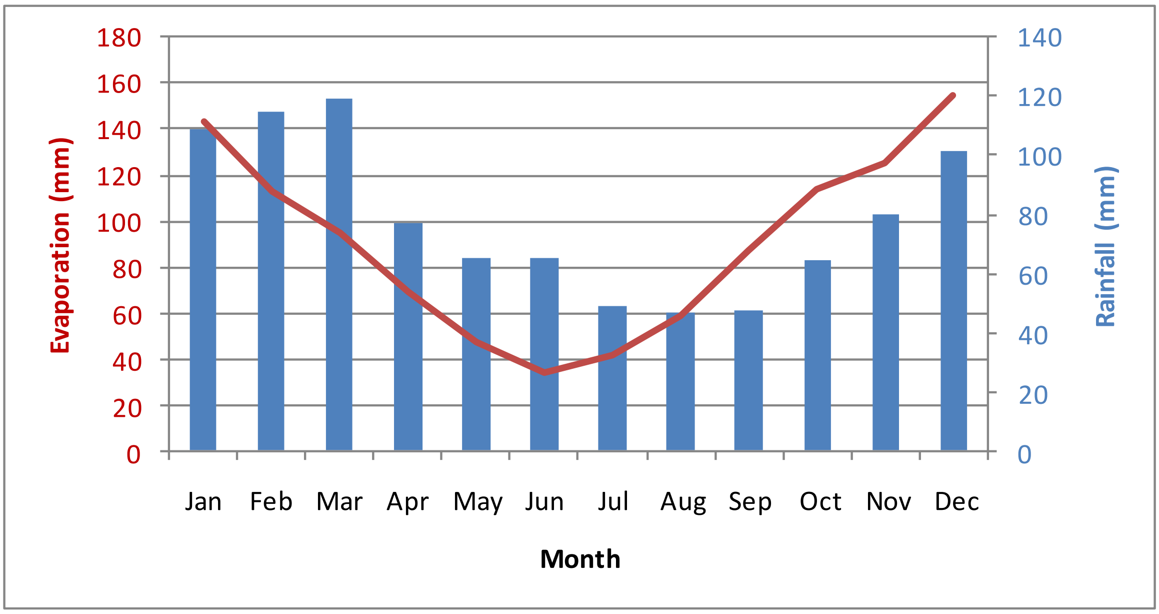

Figure 3-2: Long-term average precipitation and evaporation at Gloucester Post Office station

Average Rainfall 1888-2008, Average Evaporation 1888-2008

3.2 Topography and surface water drainage

The Gloucester Geological Basin straddles two major catchments: the Manning River Catchment to the North and the Karuah River Catchment to the South (Figure 3-3).

The Stage 1 GFDA is located within the Manning River Catchment (8,203 km^2;(Figure 3-3) and is specifically within the Avon River sub-catchment. The landforms of the locality are driven by the geology of the Stroud-Gloucester Syncline and comprise ridges to the east and the west, undulating low hills and a flat land in the centre where the Avon River flows to the north (Figure 3-3). Elevations within the Stage 1 GFDA area decrease gradually westward from 170 m RL at the base of the ridge to 110 m RL in the Avon river floodplain.

The Avon River is the primary watercourse which passes through the Gloucester Stage 1 GFDA. The Avon River originates to the south west of Gloucester and joins the Gloucester River north of Gloucester. Waukivory Creek, Dog Trap Creek and Avondale Creek are also located within the Gloucester Stage 1 GFDA, along with a number of smaller unnamed tributaries. These watercourses are unregulated and most water users rely on natural flows for their water supplies.

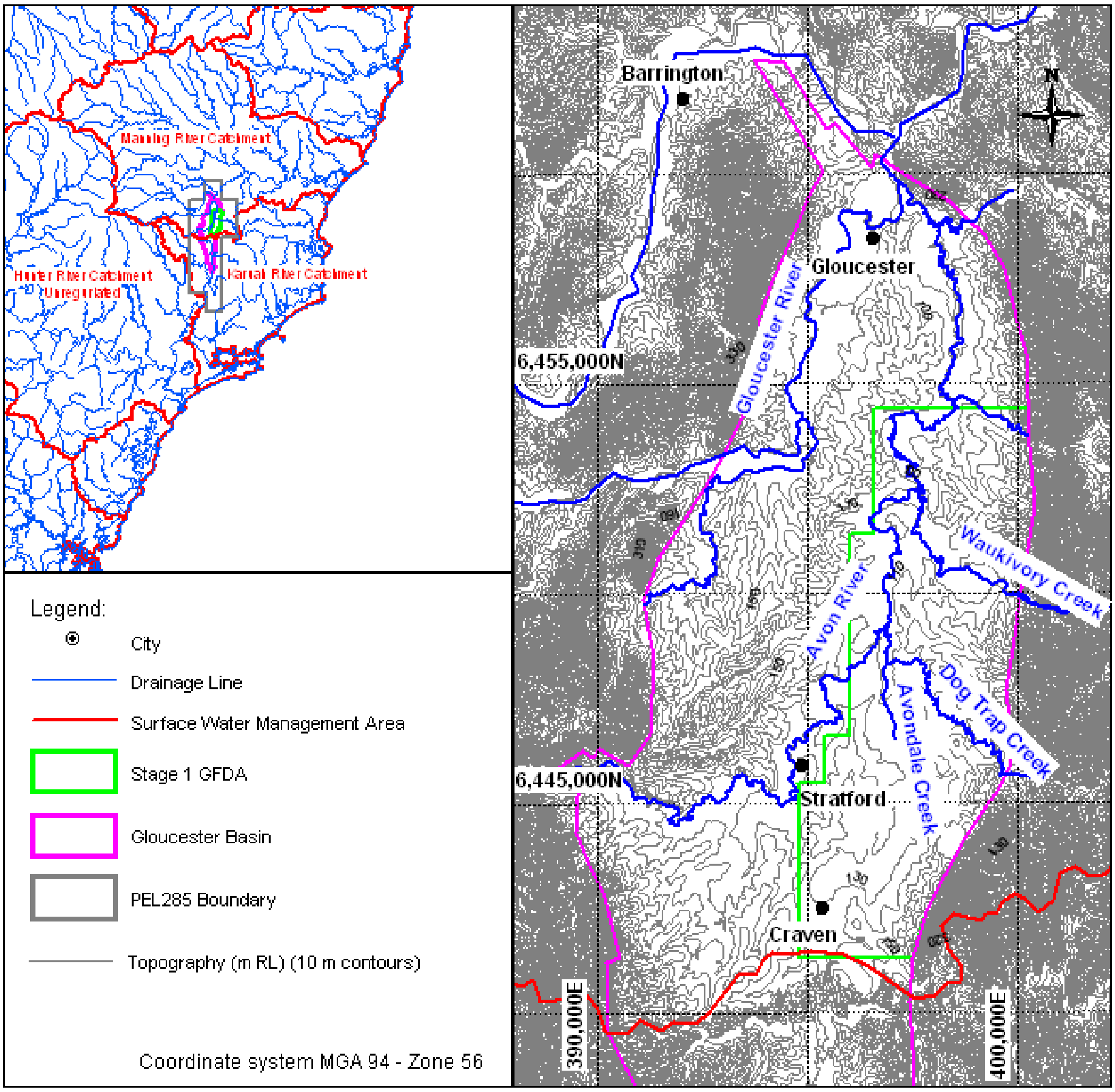

Figure 3-3: Topography and surface drainage – Gloucester Gas Project – Stage 1 GFDA

3.3 Study area geology

The Gloucester Geological Basin is a synclinal structure formed by Permian consolidated sediments (Figure 3-4). The Permian rocks display steep dips of up to 90° on the flanks of the basin, dipping towards the north-south trending basin axis and flattening towards the basin centre. They lay unconformably on a basement composed of sequences of Early and Late Carboniferous sedimentary and volcanic units that are part of the New England Fold Belt.

The geology in the study area comprises Quaternary sediments along the valley floor and Permian rocks along the flanks and over most of the catchment. Carboniferous volcanics form the major East and West ridgelines.

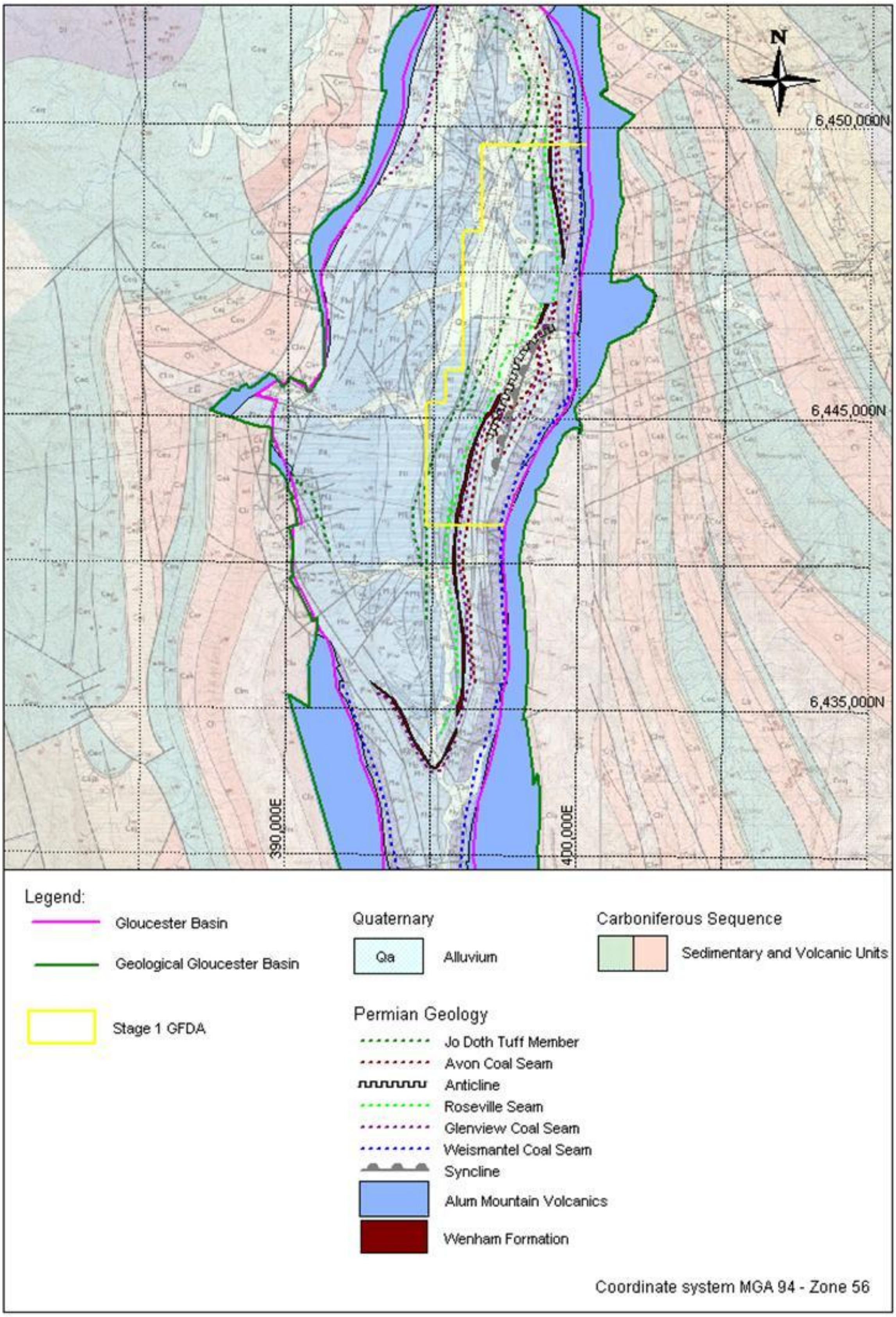

Figure 3-4: Regional geological map (NSW DMR, 1991) with exposed Permian sequences highlighted

Note: Modified after SRK, 2005

3.3.1 Surficial geology

The surficial geology in the study area comprises Quaternary sediments along the valley floor. The Quaternary sediments comprise unconsolidated alluvial and swamp sediments (sand, gravel, silt and clay). These alluvial sediments do not have a consistent thickness and generally conform to the palaeo-valleys.

In the Gloucester Stage 1 GFDA area, the Quaternary alluvium and swamp sediments occur in the floodplain of the Avon River and along the ephemeral creeks (Avondale, Dog Trap and Waukivory).

3.3.2 Gloucester Basin stratigraphy

The Gloucester Geological Basin stratigraphy indicates that the Permian basin contains around 13 coal seams thicker than 2.5 m, with an average total coal thickness of around 30 m at depths of 200 m to 700 m. The coal seams are discontinuous across the basin and at depth.

The basin sequence stratigraphy is summarised in Figure 3-5 and Table 3-1, while the detailed stratigraphy (from oldest to youngest) is provided in Figure 3-5 and is as follows:

- Alum Mountain Volcanics: Flows of albitised alkaline olivine basalt and massive to low banded rhyolite with interbedded pebble conglomerate, sandstone, mudstone, tuff, breccia and coal seams
- Dewrang Group:
  - Duralie Road Formation: Basal pebbly conglomerate dominated by porphyritic felsic volcanic clasts, thickly bedded lithic sandstone and mudstone
  - Weismantel Formation: Thick, moderately high sulphur bituminous coal and laminated mudstone
  - Mammy Johnsons Formation: Massive and thickly bedded lithic sandstone, pebble conglomerate and coarse-grained sandstone stringers, horizons of laminated dark grey mudstone, discontinuous thick coals and minor claystone after air fall tuffs
- Gloucester Coal Measures:
  - Avon Sub-group:
    - Waukivory Creek Formation: Very coarse to medium-grained trough bedded lithic sandstone, laminated fixe-grained lithic sandstone, laminated mudstone, numerous coals and minor claystone after air fall tuffs
    - Dog Trap Creek Formation: Cyclic succession of shale, siltstone and sandstone
  - Speldon Formation: Well-bedded pebbly sandstone, bioturbated mudstone, pebble conglomerate, coarse lithic sandstone
- Craven Sub-group:
  - Wenham Formation: Fine-grained sandstone; wavy and consorted bedding, plant debris laminations; palaeosols
  - Wards River Conglomerate: Boulder to pebble, clast supported, imbricated and cross-bedded polymictic conglomerate, clasts of acidic and silicic volcanic and lithic sandstone, interbedded with very coarse to medium grained lithic sandstone and medium-fine grained lithic sandstone
  - Jilleon Formation: Upward coarsening sandstone; subordinate siltstone to medium-grained sandstone; thin coal seams, sideritic bands
  - Leloma Formation: Bedded, lithic sandstone, mudstone, coal and mudstone and claystone pebble conglomerate and coarse sandstone stringers, distinctive white claystone beds after air fall tuffs, westwards coarsening
  - Crowthers Road Conglomerate: Massive polymictic boulder to pebble conglomerate, interbedded medium to coarse-grained lithic sandstone, and mudstone

Table 3-1: Summary of relevant stratigraphy (after AECOM, 2009)

Group	Sub-group	Formation	Approx. thickness (m)	Coal seams
Gloucester Coal Measures (GCM)	Craven Sub-group	Crowthers Road Conglomerate	350	
		Leloma Formation or Woods Road	585	Linden Marker M6, M7 (“JD Coals”) Bindaboo Deards
		Jilleon Formation or Bucketts Way	175	Cloverdale Roseville Marker M3, M8, M1 (“Tereel Coals”-Fairbairns Lane)
		Wards River Conglomerate	Varying thickness	
		Wenham Formation	23.9	Bowens Road (BR0-BR5) Bowens Road Lower (BR6)
	Speldon Formation		76.8	
	Avon Sub-group	Dog Trap Creek Formation	126	Glenview Marker 2
		Waukivory Creek Formation	326	Avon Triple Rombo Glen Road Valley View Parkers Road
Dewrang Group	Mammy Johnsons Formation		300	Mammy Johnsons
	Weismantel Formation		20	Weismantel
	Duralie Road Formation		250	
Unconformity				
Alum Mountain Volcanics				Clareval Basal Coal Seam

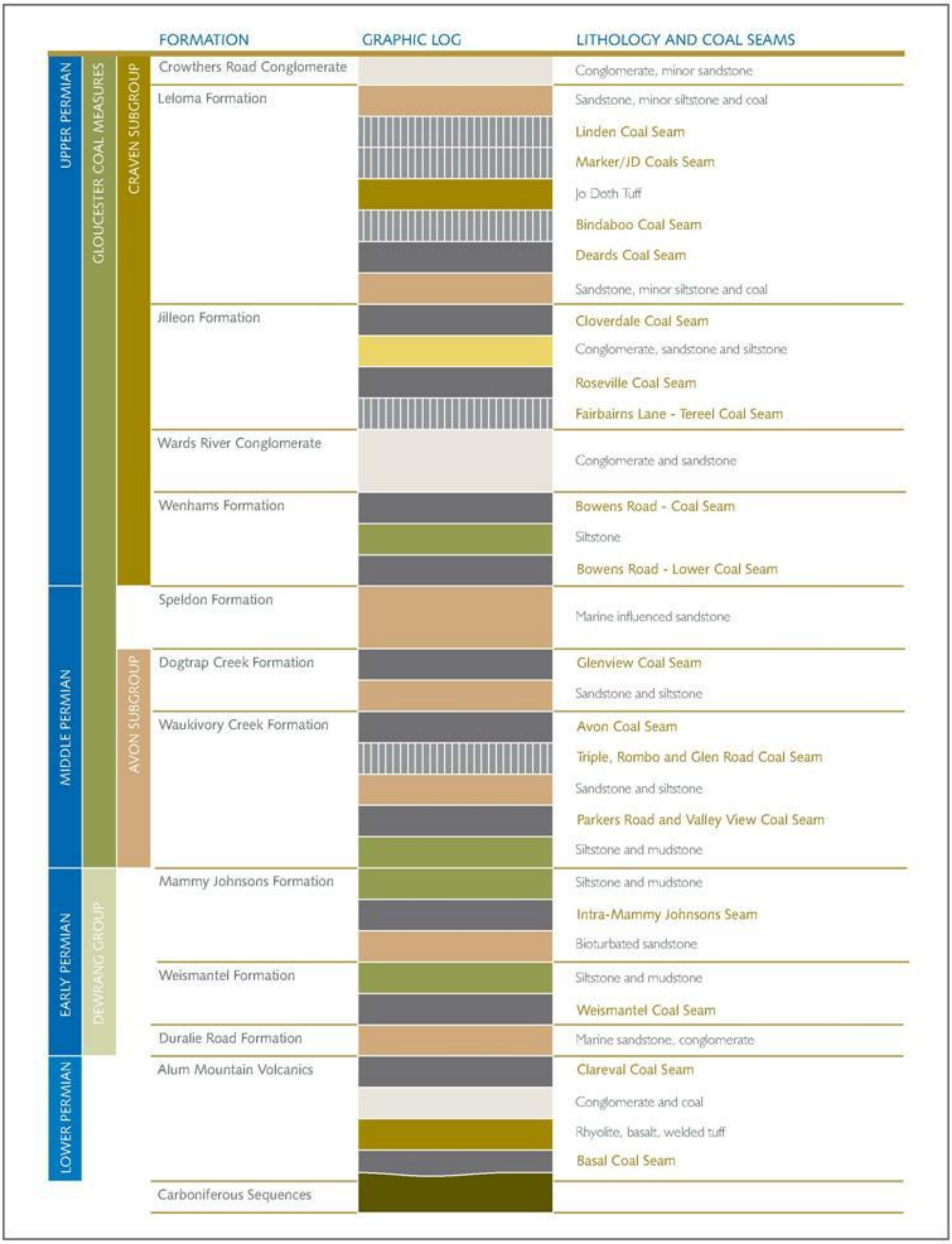

Figure 3-5: Gloucester Geological Basin stratigraphy – Stratford geology

Note: After AECOM, 2009

It is important to note that the Gloucester Basin boundary defined by AGL includes only the known extent of coal that has been well defined by drilling, seismic and field mapping. This boundary includes some of the Alum Mountain Volcanics. However, it should be noted that this unit extends further south (Figure 3-4 and Figure 4-5) and the base of this unit properly defines the extent of the Gloucester Geological Basin. The Gloucester Basin limit defined by AGL will be used in the main report except in Section 3.3 - Study area geology and Section 6 - Conceptual hydrogeological model.

The Stage 1 GFDA is located in the north eastern flank of the main synclinal structure of the Gloucester Geological Basin and is associated with the coal bearing strata of the Dewrang Group and the Gloucester Coal Measures. Within the Stage 1 GFDA all Permian formations are dipping to the west and outcrops of coal seams can be observed in the eastern part of the project. The project area is limited on the east by the Alum Mountain Volcanics outcrops that formed the hills surrounding the Gloucester Basin.

The Gloucester Geological Basin can be divided into four stratigraphic phases, each of which has a distinctive structural and tectonic association. The four phases are summarised in Table 3-2.

Table 3-2: Stratigraphical phases in the Gloucester Basin (after SRK, 2005)

Phase	Time	Gloucester Basin stratigraphy	Environment	Tectonic event	Sydney Basin correlation
1	Early Permian	Alum Mountain Volcanics (Bimodal volcanism)	Arc-related rift	Rift?	Various basal volcanics / Greta coal measures
2	Early Permian	Dewrang Group	Marine transgression, regression and further marine transgression	Extension (normal fault development) and regional subsidence	Maitland Group
3	Middle Permian	Avon Sub-group & Speldon Formation	Marine transgression and some progradation of alluvial fans in the west	Extension (normal fault development) and regional subsidence. Uplift to west of Basin	Wittingham and Tomago coal measures
4	Middle – Late Permian	Craven Sub-group	Marine regression, progradation of alluvial fans	Uplift to west of Gloucester Basin	Wollombi and Newcastle coal measures

3.3.3 Basement geology

The Gloucester Geological Basin basement is a sequence of Early Carboniferous and Late Carboniferous sedimentary and volcanic units that are part of the New England Fold Belt.

3.4 Structural controls in the study area

The Gloucester Basin stratigraphy is affected by a number of faults and folds. The tectonic and structural development of the Basin can be divided into two stages (SRK, 2005):

1. Early – Middle Permian transcurrent (dextral) tectonic margin, resulting in reactivation of NNW-striking faults as strike-slip dextral and formation of NE and E-W-striking normal faults, particularly around the margins of the circular basement feature in the northern part of the basin. The same tectonic event may also be responsible for uplift to the west of the basin on NW-striking faults.
2. Late Permian NE shortening during the early stages of the Hunter Bowen Orogeny, resulting in reverse and thrust faulting on NNW faults and some NNE faults.

These structures are variously interpreted as fully or partially penetrating through the full geological sequence.

The key structural features identified in the Stage 1 GFDA area are presented in Figure 3-6. Normal and reverse faults are characteristic of the area as well as local folding which has accentuated dip of the strata and resulted in a reversal of dip (e.g. Bowens Road North Mine area). The folding trends N-S, while the main fracturing trends NNE and NW.

Seismic interpretation of the area around Stratford from AGL (Andrew Parker, March 2009) shows high angle faulting at the basin edge and low angle sub-parallel bedding faulting towards the basin centre (Figure 3-7).

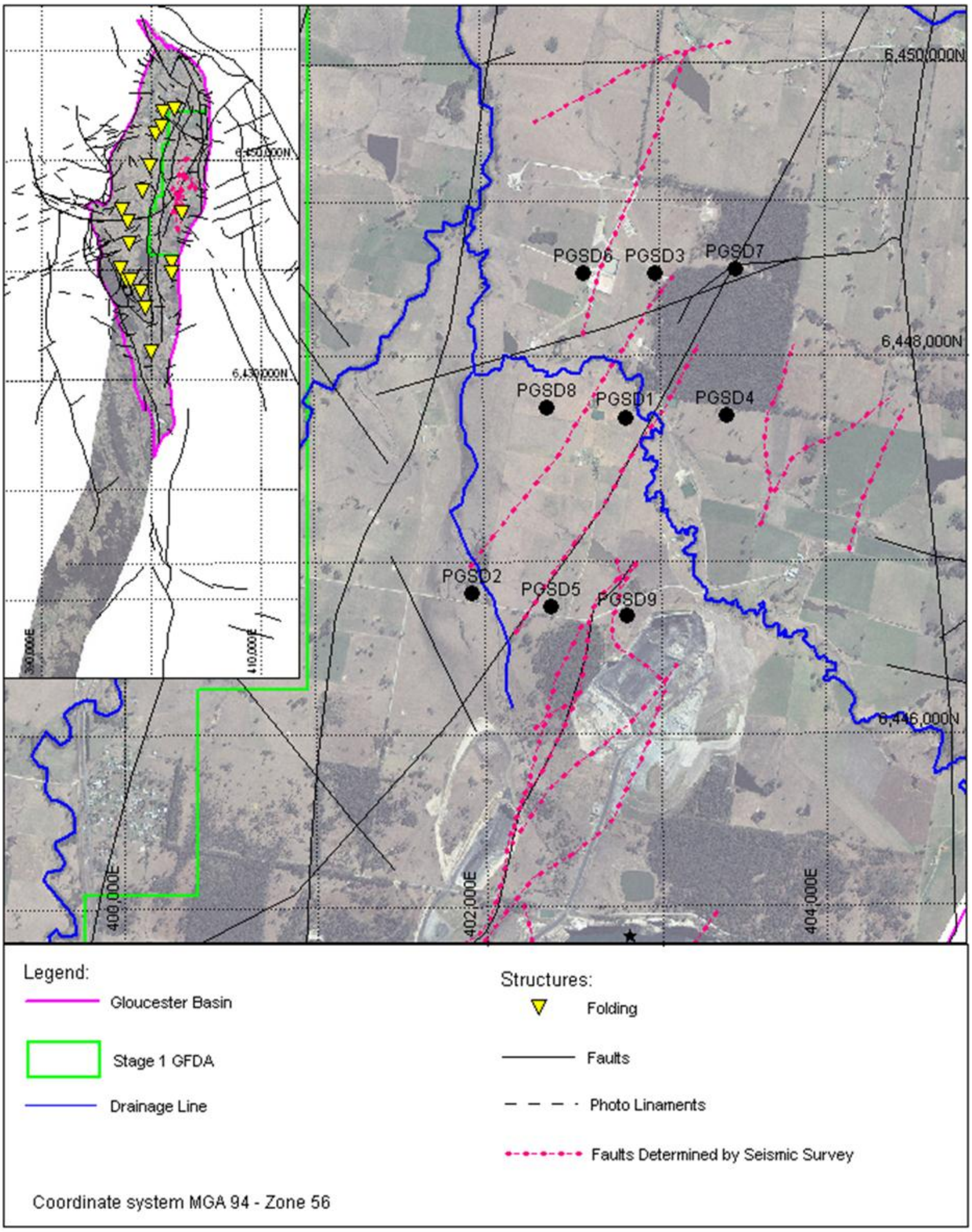

Figure 3-6: Structural controls in the study area

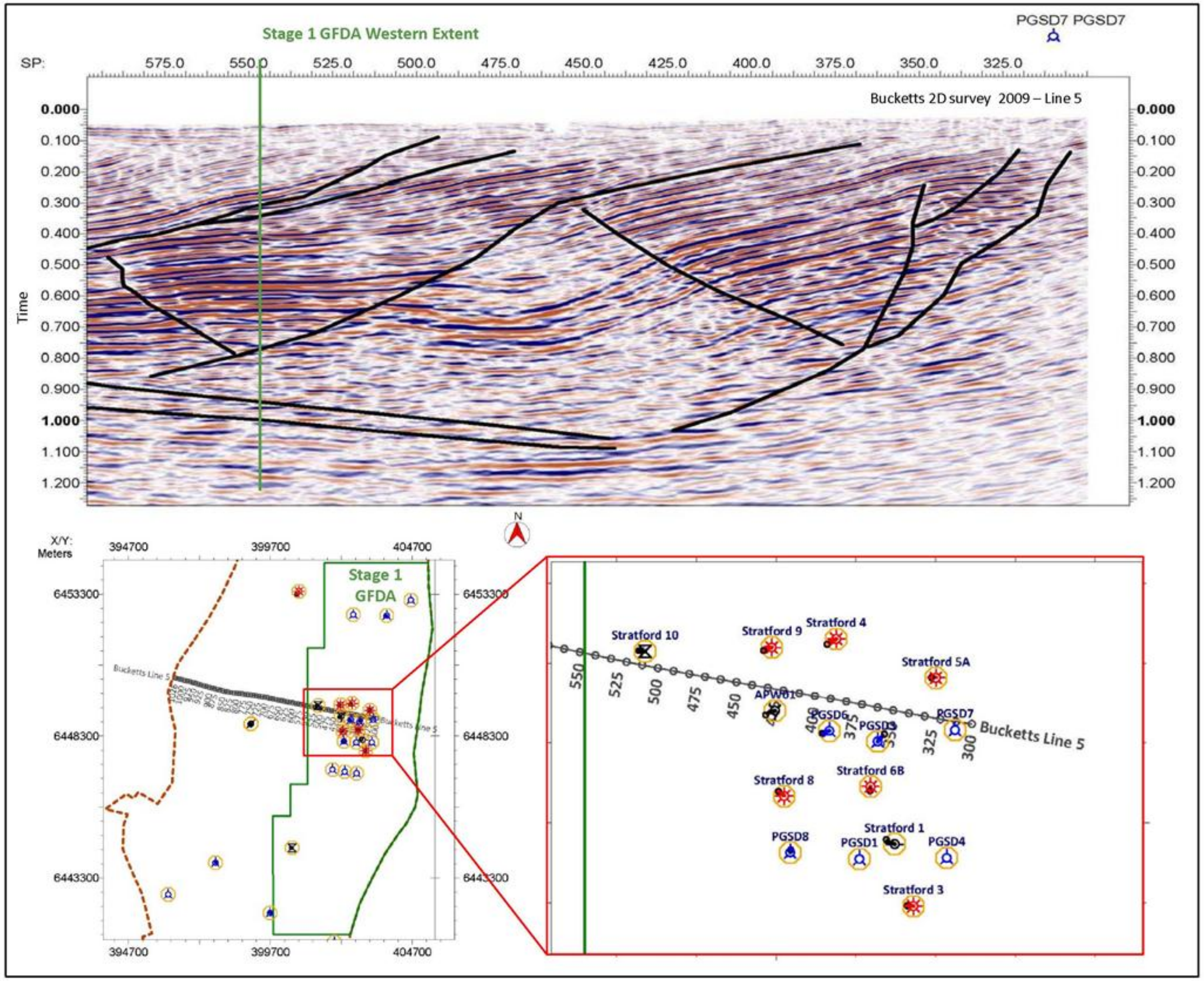

Figure 3-7: Seismic interpretation in the study area

Note: After AGL internal document, 2009

4. Desktop Review

4.1 Surface water review

A permanent gauging station, operated since 2004 by the NSW Office of Water, is located on the Avon River downstream of Waukivory Creek (Avon D/S Waukivory - GS208028; (Figure 4-1). Two other flow-gauging stations, operated by the Stratford mine site between 2001 and 2004, were located on the upstream Avon River (W2) and the Avondale Creek (Point 22).

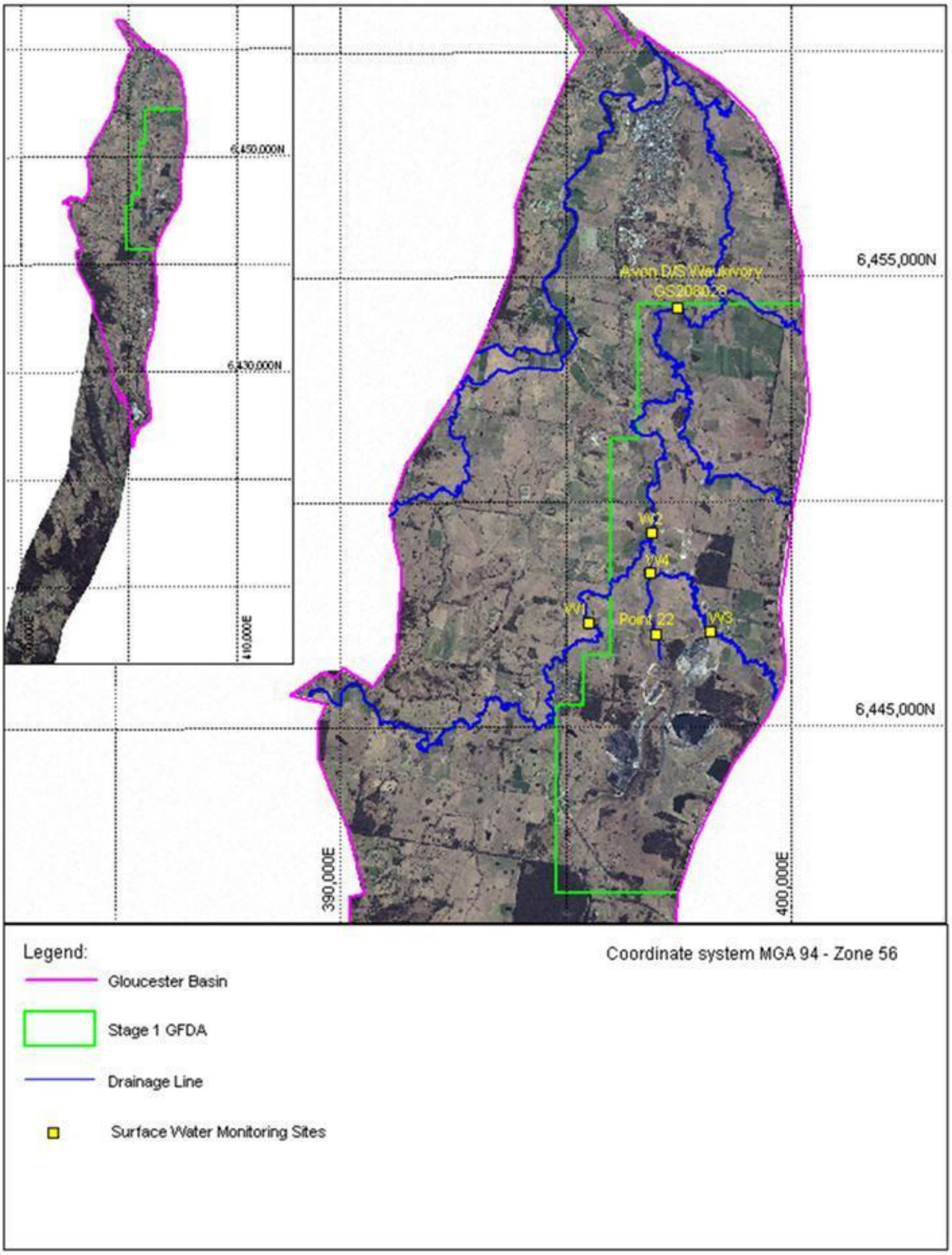

Figure 4-1: Localisation of the surface water monitoring sites

Downstream on the Avon River (Avon D/S Waukivory - GS208028), stream flows are characterised by low to moderate flow periods with periods of higher discharge following heavy rains while upstream Avon River stream flows (W2) and Avondale Creek (Point 22) are ephemeral (Figure 4-2). The zero flow recorded in the upstream Avon River for 2003 represents 75% of the year.

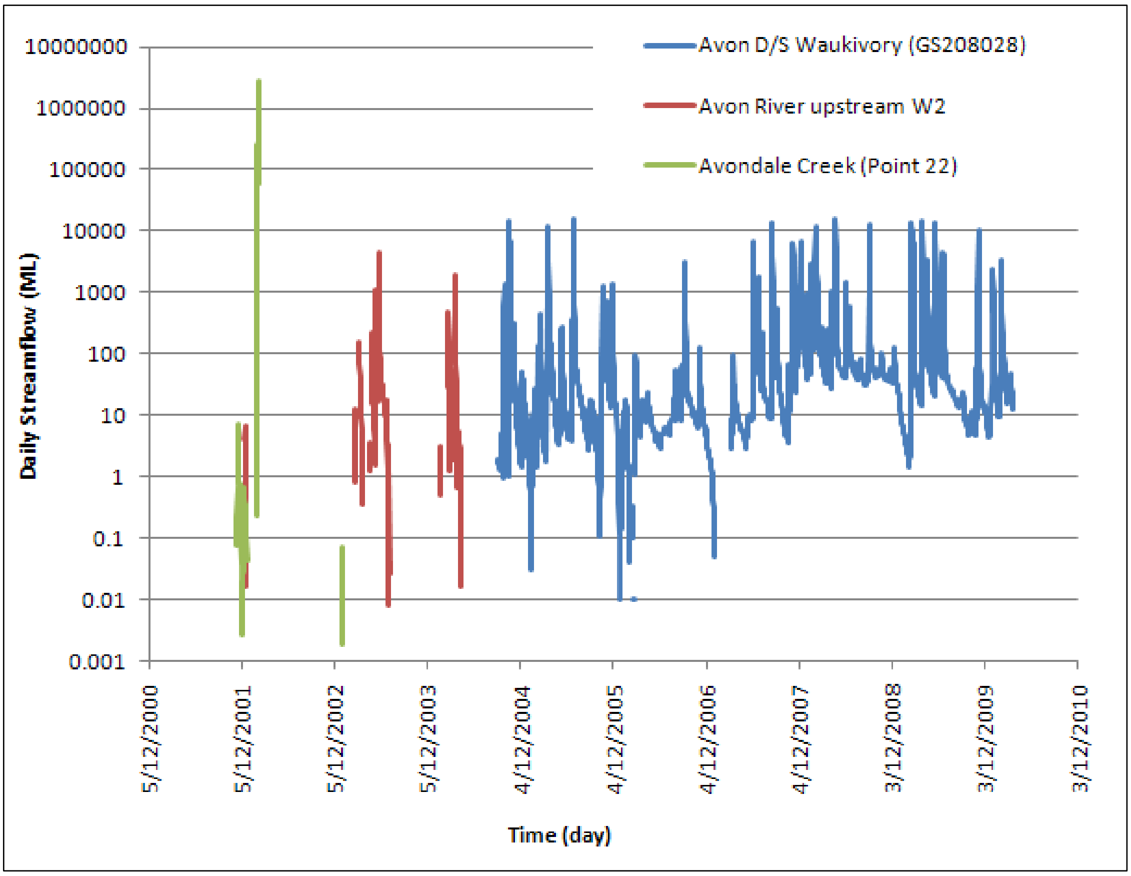

Figure 4-2: Stream flow record at GS208028, W2 and Point 22 Gauging Stations

Note: Recorded since 2004 for GS208028, between 2001 and 2004 for W2 and Point 22

The AECOM report (2009) indicated that Gloucester and the surrounding low-lying land and river flats are prone to flooding, having experienced severe floods in 1929 and 1978. The rivers and creeks within the Stage 1 GFDA are subject to flooding and water velocities in these rivers can be high after heavy rainfall. The areas most affected by flooding in the Gloucester area, as identified on the Flood Planning Land Maps for the Gloucester Draft LEP (2009), are the river flats between the town of Gloucester and the Gloucester River, which are not located within the Stage 1 GFDA. Nevertheless, rural communities and farms along the floodplains beyond the river flats may be isolated for several days after extreme rainfall events (Gloucester Shire Council, 2006).

Records of salinity (EC) and pH on Avon River, Avondale Creek and Dog Trap Creek are presented in Figure 4-3 and Figure 4-4. In the watercourse surrounding the Stage 1 GFDA, correlations between EC values and stream flow typically show a reduction in surface water salinity following periods of rainfall, followed by a general increase in salinity as the stream flow reduces and groundwater baseflows increase. Measured conductivities range from 100 to 600 µS/cm and pH is near neutral to slightly alkaline.

Elevated iron and manganese concentrations are regularly recorded in these watercourses. Only the Avon River has regular elevated phosphorus concentrations that are most probably related to a more extensive agricultural watershed. The other metals monitored in these watercourses are generally below the ANZECC irrigation trigger values and the ANZECC fresh water quality guideline (ANZECC, 2000).

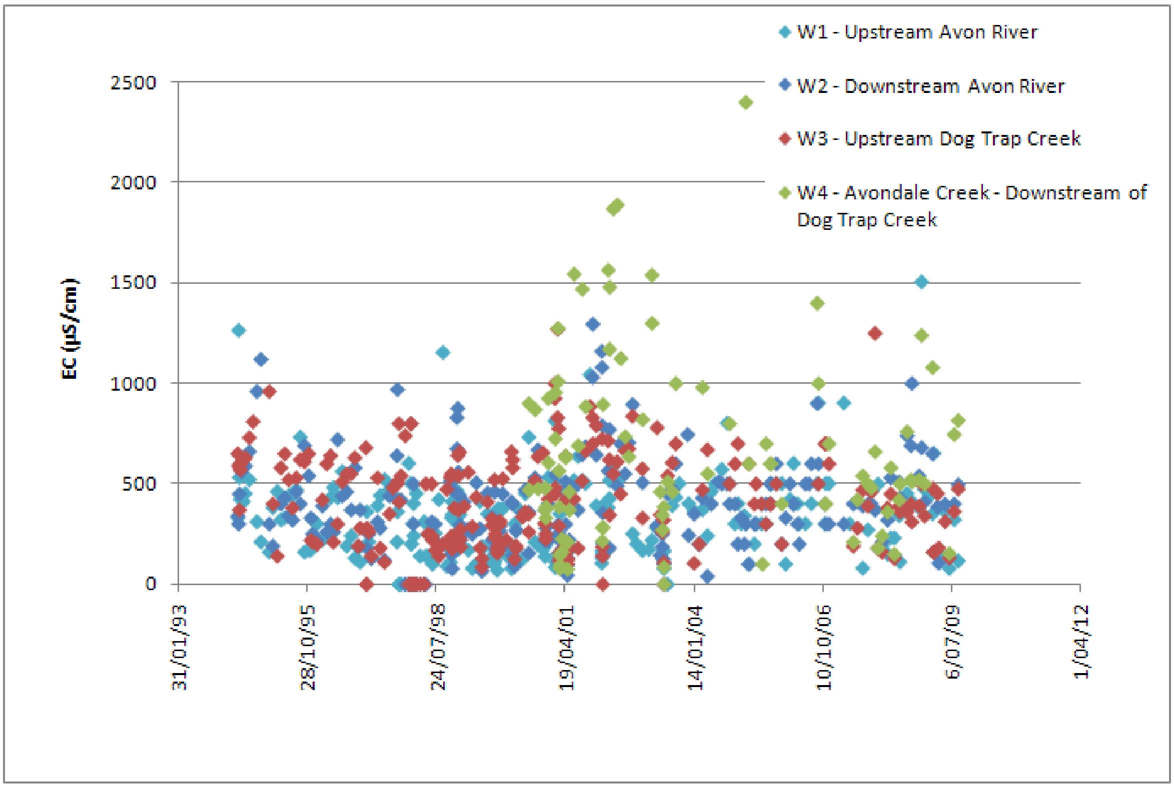

Figure 4-3: Salinity (EC) record - Avon River (W1, W2), Dog Trap Creek (W3) and Avondale Creek (W4)

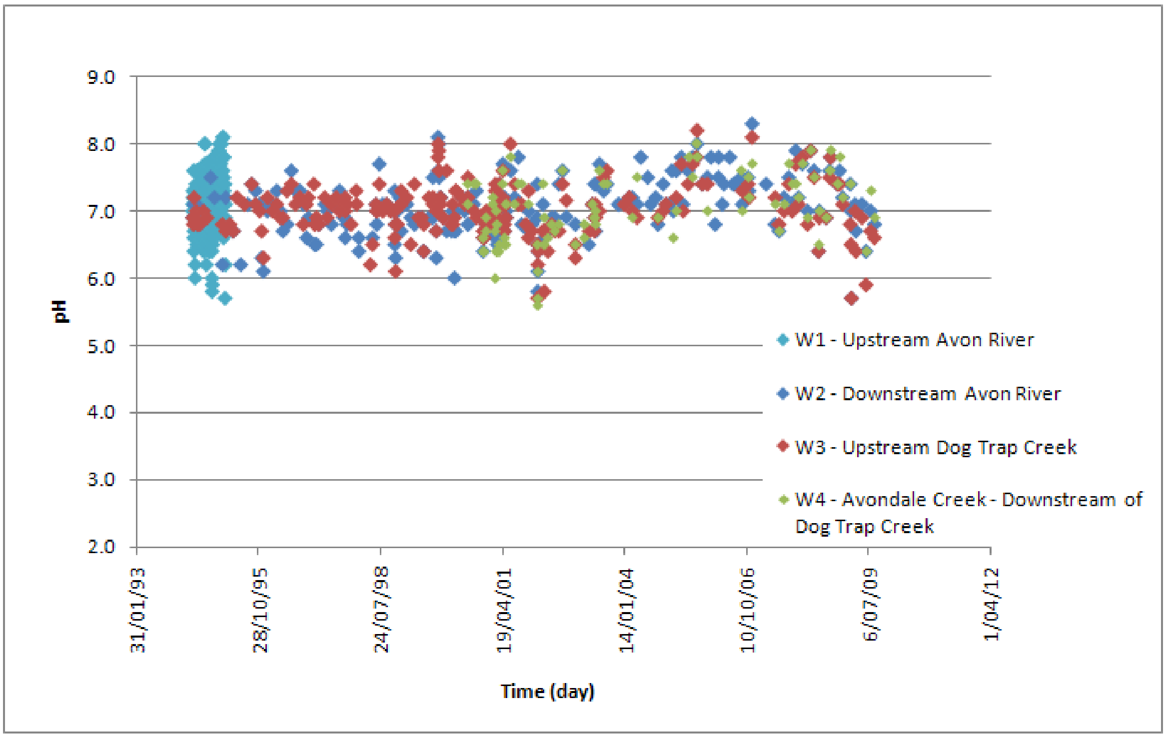

Figure 4-4: pH Record - Avon River (W1, W2), Dog Trap Creek (W3) and Avondale Creek (W4)

4.2 Groundwater review

4.2.1 Regional borehole census

SRK conducted a review of the registered bores and wells (Natural Resource Atlas, NSW Office of Water; March 2010), in the Stage 1 GFDA region.

A total of 128 bores and wells were identified during the desktop study – all located in the Gloucester Basin. Their location is shown on Figure 4-5. Information on the lithology encountered during drilling is available for only 47 bores. No surveyed collar position and elevation is documented.

The depth of the bores and wells varies from 6 to 66 m. Among the 47 bores presenting detailed lithology, four bores are sited in the alluvial aquifer at a shallow (6 to 9 m) depth, while the others are all deeper (up to 66 m depth) and are sited in the shallow fracture aquifer (Permian rocks).

The groundwater levels available in the alluvial aquifer range between 3.50 and 5.72 m bgl. The maximum yield determined in alluvial bores and wells is 7.58 L/s. The water quality from these boreholes is only labelled “good”. No EC values are provided.

The groundwater levels available in the shallow fractured aquifer vary from 1.5 to 33.7 m bgl. The maximum yields reported vary from 0.05 to 2 L/s. The water quality from the shallow fractured aquifer is also labelled “good”. The only EC values recorded are between 820 and 1,900 μS/cm, indicating a fresh to slightly brackish groundwater.

The bores and wells desktop data are summarised in Appendix 1.

4.2.2 Shallow monitoring boreholes

Monitoring programs undertaken at the Duralie and Stratford Coal Mines in shallow boreholes prior to mining activity (February-March 2003 for Duralie mine, and 2004 for Stratford mine) provide some baseline information on the groundwater level and the groundwater quality in the shallow aquifers of the Gloucester Basin. The location of the monitoring boreholes is summarised in Figure 4-6 and their coordinates and status are included in Appendices 2 and 3.

4.2.2.1 Duralie Coal Mine

The Duralie Coal Mine is located in the southern part of the Gloucester Basin between the villages of Stroud and Wards River, 20km south of Stage1 GFDA. The pre-mining (2003) groundwater levels in the alluvial aquifer of Mammy Johnson River vary from 3.11 to 7.31 m bgl. Water from these monitoring boreholes (DB3W, BH4BW, BH5W and BH1W) is slightly acidic ($6 < pH < 6.4$) and fresh ($145 < EC < 900$ μS/cm).

As stated in the Groundwater Assessment of Duralie Extension Project report (Heritage Computing, 2009), these boreholes have shown no effect that could be attributed to mining. Instead, there is a strong correlation between groundwater levels and rainfall.

The pre- mining (2003) groundwater levels in the shallow fractured aquifer developed in the Upper Duralie Formation vary from 6.44 to 15.83 m bgl. The water from these monitoring boreholes (DB1W, DB2W, DB4W, DB5W, BH2W and DB6W) is near neutral to slightly acidic ($6 < pH < 6.7$) and fresh to brackish ($215 < EC < 3{,}860$ μS/cm).

Few other parameters are reported (Oxidation Reduction Potential, Sulphate, Calcium, Magnesium, Aluminium, Iron (filtered), Manganese and Zinc).

Generally, concentrations of iron, manganese and aluminium exceed the ANZECC irrigation trigger values (ANZECC, 2000).

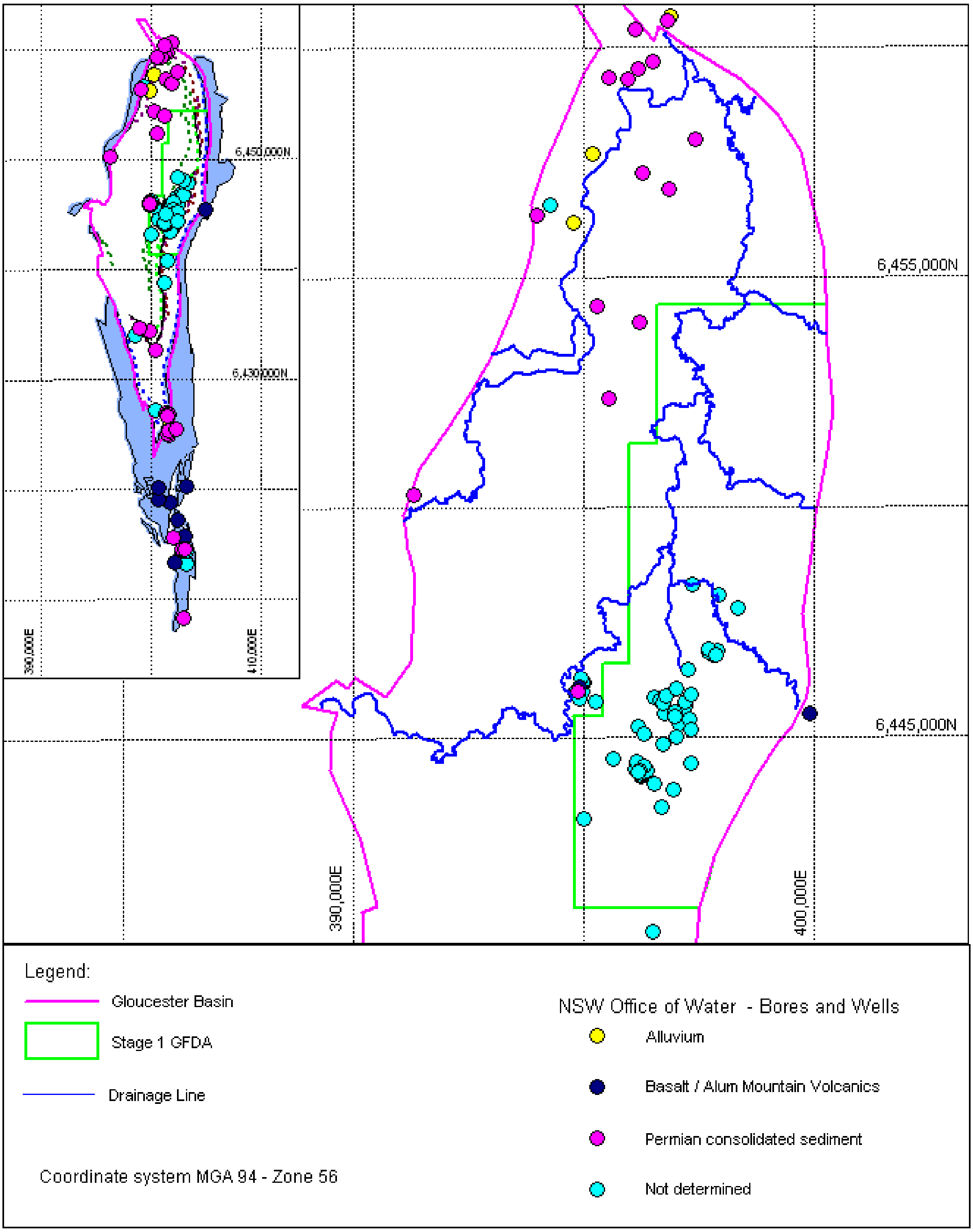

Figure 4-5: Location of bores and wells registered with the NSW Office of Water

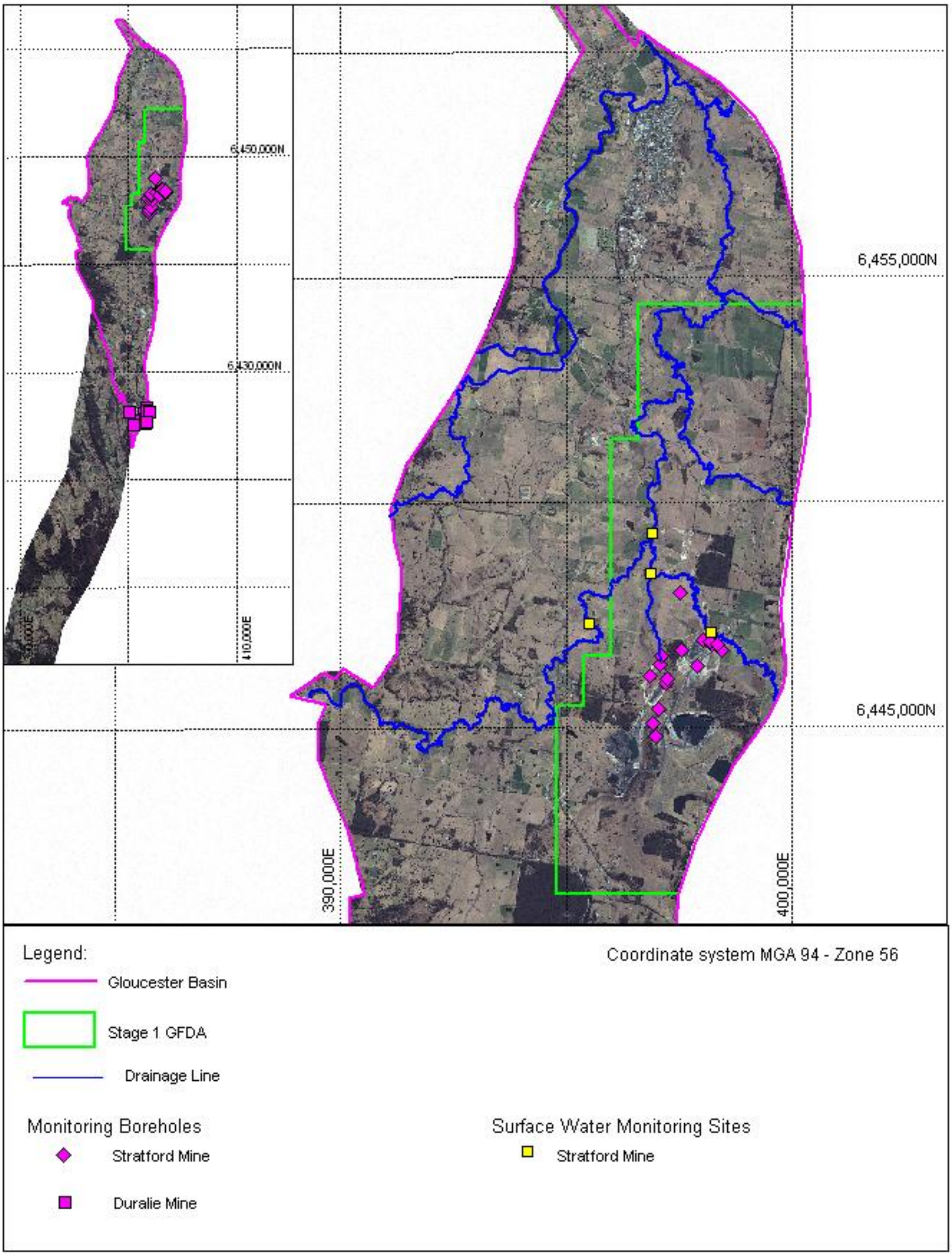

Figure 4-6: Location of monitoring boreholes and surface water monitoring sites at Duralie and Stratford coal mines

4.2.2.2 Stratford Coal Mine

The Stratford Coal Mine is located in southern part of the Stage 1 GFDA, between the villages of Stratford and Craven. Based on the lithology available on the boreholes labelled MW1 to MW12, it is assumed that all monitoring boreholes (labelled RB and MV) were completed in the shallow fractured aquifer.

The pre-mining groundwater levels available (before 2004) in the shallow fracture aquifer vary from 0.5 to 16.3 m bgl. The water from these monitoring boreholes is near neutral to slightly acidic (5.6 < pH < 7.4) and fresh to saline (981 < EC < 9,600 μS/cm).

The Piper diagram presented in Figure 4-7 compares the overall inorganic water composition from shallow monitoring boreholes prior to mining. Globally, the water is sodium chloride type in the shallow fractured aquifer surrounding the mine site. Water is a mixture of sodium chloride type and magnesium and bicarbonate type only in MW6, suggesting a mixture of brackish water of the aquifer with recent recharge from rainfall. Generally, concentrations of iron and manganese are above the ANZECC irrigation trigger values of 0.2 mg/L (ANZECC, 2000).

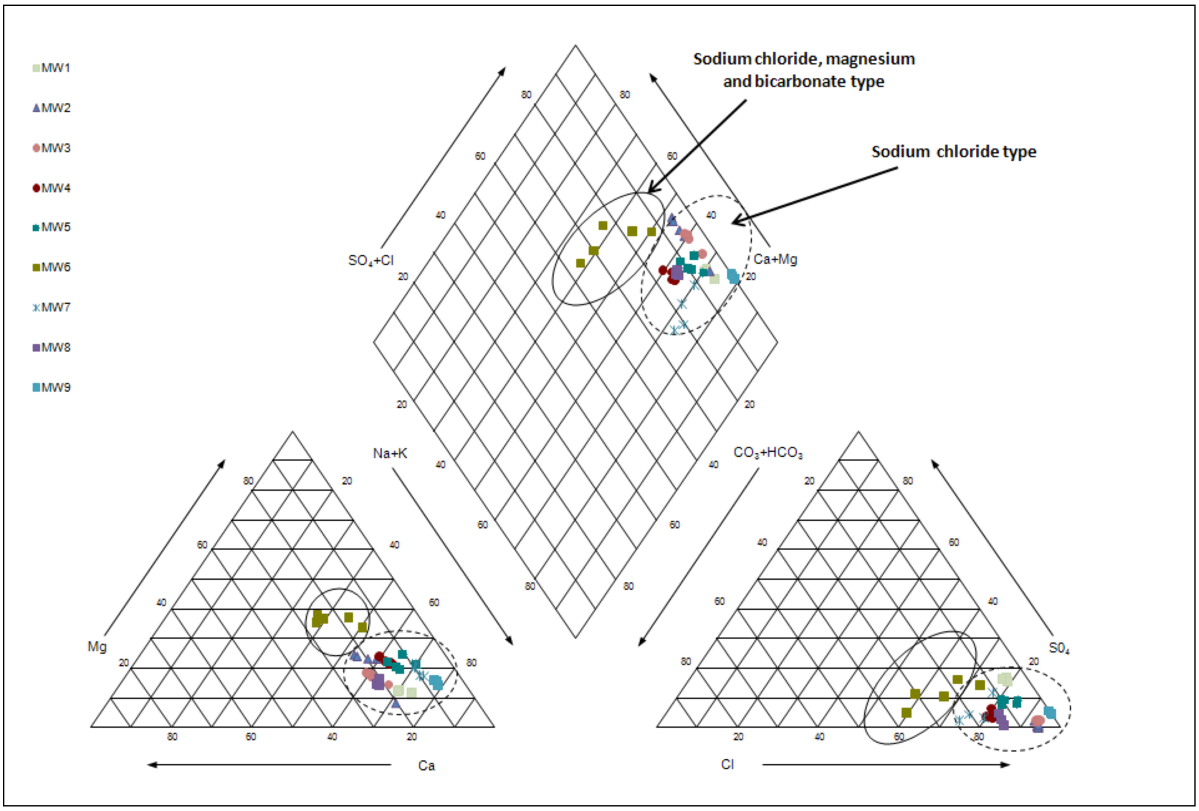

Figure 4-7: Piper diagram - water quality in monitoring boreholes of Stratford Coal Mine - pre-mining (2002-2003)

4.2.3 Regional water level

The information available from the NSW Office of Water database of registered groundwater bores and from the mine sites is insufficient (no elevation and surface survey collar) to create a regional water level contour map for the Gloucester Basin.

Inferred pre-mining groundwater level contours at the Duralie mine site indicate that the groundwater would generally move from the ridges to the natural surface drainage lines. In this area, the Mammy Johnsons River is considered as a prominent groundwater discharge feature.

4.2.4 Groundwater occurrence

Based on the regional borehole census, two aquifer systems are identified – the alluvial aquifer located along the main surface drainage, and the shallow weathered and fractured Permian aquifer. Poorer aquifers (or water bearing zones) occur also at depth in the deeper Permian Coal Measures and associated rocks.

The resistivity profiles undertaken in deep gas production wells (Craven 6; Stratford 1, 3, 4, 5A, 6B, 8, 9 and 10; Waukivory 3; see Figure 4-8) do not allow the depth of the shallow weathered and fractured aquifer to be estimated as wells are cased to ~100m. Aquifers occur in the shallow profile but there is no available information on aquifer characteristics from previous Lucas Energy or AGL Energy studies.

The coal seams within the Dewrang Group and the Gloucester Coal Measures are considered as minor aquifers as they can contain water in cleats and fractures. Based on AGL observations (AGL presentation, 2009), coal seams below ~ 150 m bgl generally produce less than 25 Bbl/day or 3.9 m^3/day. Coal seams above ~ 150m bgl are wet with gas wells producing between 180 and 600 Bbl/day (or 28.617 to 95.4 m^3/day).

4.2.5 Hydraulic conductivities

Table 4-1 summarises the hydraulic conductivities gathered during the desktop data review. No aquifer test data were provided for assessment to verify the interpreted values.

The alluvium, composed of loamy soils near surface and sands and gravels at depth is located along the river and stream lines, and is considered to be a porous granular and unconfined aquifer. The hydraulic conductivities reported for the Mammy Johnson River and regional alluvium range between 0.1 and 5 m/day.

The upper weathered and fractured rock aquifer consists of consolidated formations exposed in the syncline outcrops. This aquifer can be unconfined or locally confined (e.g. Duralie coal mine site). Water is primarily present in fractures, joints and bedding planes within the rock. Based on data derived from slug and pumping tests undertaken at the Duralie Coal mine on Mammy Johnsons, Weismantel and Duralie Road formations, the hydraulic conductivities of the shallow fractured/weathered rock aquifer range from 0.04 to 3 m/day.

The coal seams within the Dewrang Group and Gloucester Coal Measures are considered to be confined aquifers, except in the eastern outcrop/recharge areas where aquifers would be unconfined. The water movement in the coal seams occurs primarily along the cleat faces that are oriented parallel to the direction of bedding dip. The permeability tests undertaken on 28 coal intervals in exploration/production boreholes by Pacific Power in 1999 indicate that coal seam intrinsic permeability decreases sharply with increasing depth (Figure 4-9). At a depth of 100 m the intrinsic permeability averages 100 mD; at 300 m it is estimated to range from 7 to 27 mD; and at 500 m the permeability was measured at 0.56 Md.

Conversion of intrinsic permeability to hydraulic conductivity based on standard condition of fresh water at ground surface can be done by using a conversion factor of 8.64×10^{-4} m/day per mD. Based on this conversion factor, the hydraulic conductivity of the coal seams is estimated at:

- ~ 8.6×10^{-2} m/day at 100 m,
- ~ 6.1×10^{-3} to ~ 2.3×10^{-2} m/day at 300 m, and
- ~ 4.8×10^{-4} m/day at 500 m.

For comparison, useful (water resource) aquifers generally have hydraulic conductivity values greater than 10^{-2} m/day.

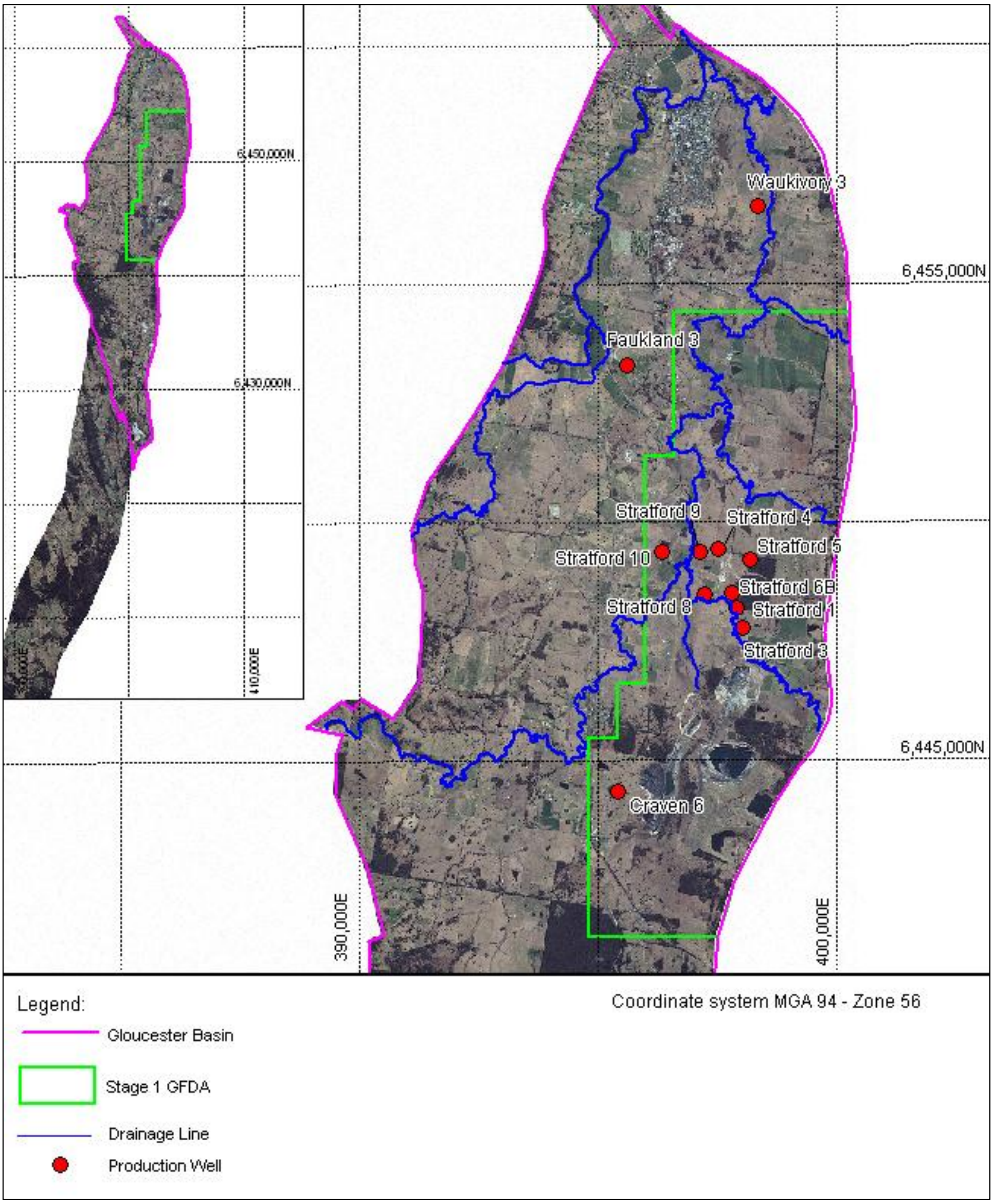

Figure 4-8: Location of the existing gas production wells

Table 4-1: Comparison of aquifer hydraulic properties for key rock units in the Gloucester Gas Pilot project area

Rock Unit / Aquifer	Aquifer type	Permeability (mD)	Hydraulic conductivity (m/day)[a]	Duralie Hydraulic conductivity (m/day)[b]	Regional Hydraulic conductivity (m/day)[c]
Alluvium	Porous granular			0.1 - 5	0.1-5
Cloverdale Coal Seam	Fractured	> 300 mD @ 70 m 10 mD @ 340 m	>2.6×10^{-1} (at 70 m) 8.6×10^{-3} (at 340 m)	N.A.	
Roseville Coal Seam	Fractured	83 mD @ 180 m 3 mD @ 390 m 13 mD @ 120 m in PGSD5	7.2×10^{-2} (at 180 m) 2.6×10^{-3}(at 390 m) 1.1×10^{-2} (at 120 m in PGSD5)	N.A.	
Bowens Road Coal Seam	Fractured	Variable 450 mD @ 125m (PGSD4) 10-14 mD @ 300 m (PGSDT5, PGSD1) 67 mD @ 325 m (PGSD3 – normal fault)	3.9 x 10-1 (at 125 m in PGSD4) 8.6 x 10-3 - 1.2 x 10-2 (at 300 m in PGSD5, PGSD1) 5.8 x 10-2 (at 325 m in PGSD3 - normal fault)	N.A.	
Glenview Coal Seam	Fractured	2.3 mD @ 390 m 0.8 mD @ 410 m	2×10^{-3} (at 390 m) 6.9×10^{-4} (at 410 m)	N.A.	
Avon Coal Seam	Fractured	15 mD @ 330 m 0.56 mD @ 500 m	1.3×10^{-2} (at 330 m) 4.8×10^{-4} (at 500 m)	N.A.	
Sandstones of Mammy Johnsons and Weismantel Formations	Shallow Fractured/ Weathered			0.04 – 3 (< 50 m depth)	10^{-3} - 0.3 (to 100m depth)
Weismantel Seam	Shallow Fractured/ Weathered			0.08 - 1.6 (< 50 m depth) 0.01 - 0.5 (to 200 m depth)	10^{-4} - 10 (to 200 m depth)
Sandstone of the upper Duralie Road Formation	Shallow Fractured/ Weathered			0.04 – 3 (< 50 m depth)	10^{-4} - 0.3 (to 200m depth)
Clareval Seam	Shallow Fractured/ Weathered			0.036 - 0.34 (< 50 m depth) 0.01 - 0.5 (to 200 m depth)	10^{-4} - 10 (to 200m depth)
Sandstone of the lower Duralie Road Formation	Shallow Fractured/ Weathered			0.04 - 3	10^{-4} - 0.3 (to 200m depth)

[a] Derived from permeability test of the Coal Seam (Pacific Power, 1999). Conversion of intrinsic permeability to hydraulic conductivity based on standard condition of fresh water at ground surface condition. The conversion factor used is: 8.64×10^{-4} m/day per millidarcy (mD).

[b] Duralie Extension Project Groundwater Assessment report November 2009 (After Golder Associates 1982 and DCPL 1996 and 2009)

[c] from Hunter Valley and Sydney Basin lithologies (coal seams, sandstones, sills, interburden) – Tammetta, pers. Comm. 2009 in Duralie Extension Project Groundwater Assessment report November 2009

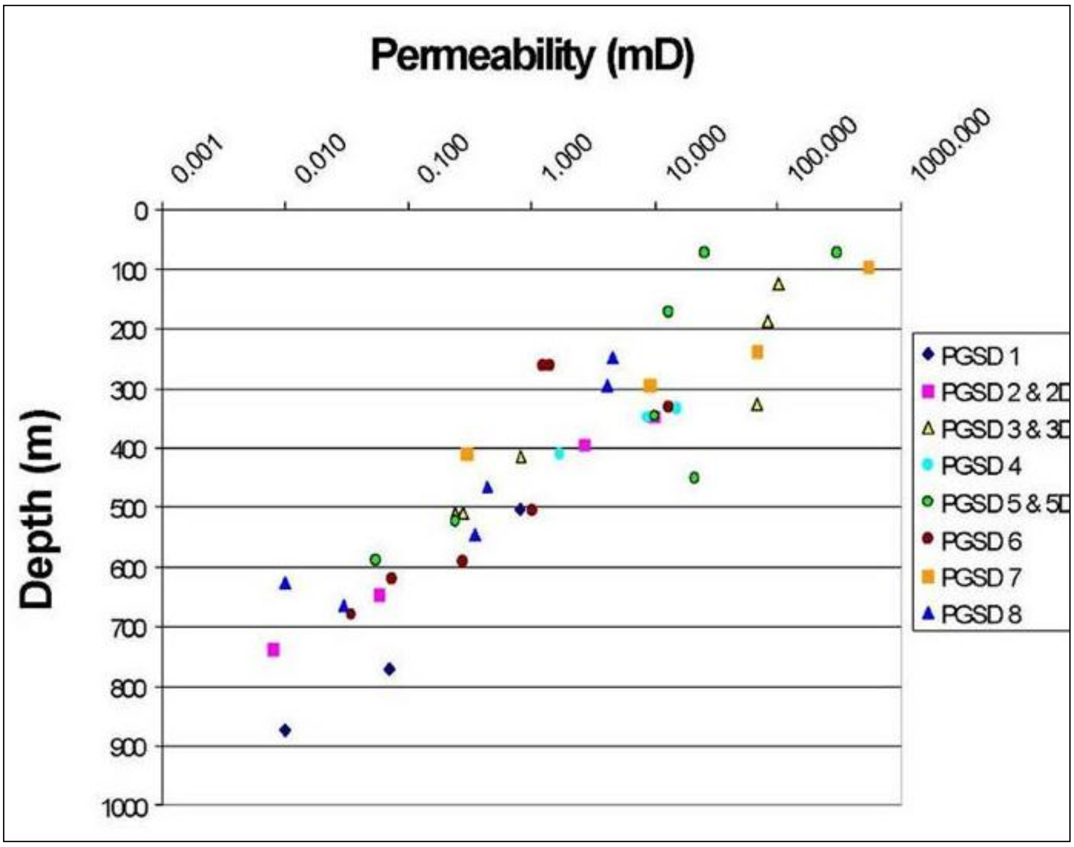

Figure 4-9: Intrinsic permeability measurement of coal seams at Stratford

Note: From AGL presentation, 2009

These results do not necessarily reflect the influence of tectonic structures in the study area. Indeed the presence of faults can enhance the hydraulic values by orders of magnitude. A normal fault intersected at 325 m bgl in the Bowens Road coal seam by cored well SGSD3 (Pacific Power, 1999) increased the hydraulic conductivity of the coal seam by one order of magnitude (~ 5.8×10^{-2} m/day).

4.2.6 Coal seam water quality

The water produced from the coal seam intervals in the gas production wells is brackish to saline (3,060 < EC < 9,530 µS/cm).

A summary of the median salinity with the depth of the perforated interval in the coal seams is presented in Figure 4-10. The median EC value reported indicates that the water salinity globally increases with coal seam depth. The Roseville coal seam in Stratford 6B and the Bowen Rd coal seam in Stratford 3 were both high groundwater inflow zones and are the reason why the median EC in these two boreholes is lower than the other sites.

Borehole	Median EC (µS/cm)	Depth of perforated intervals in the coal seams (m)							
		Roseville	Fairbairns	Bowen Rd	Glen	Avon	Triple	Weismantel	Clareval
Stratford 6B - ST06B	3,060	149 (Roseville[a])	221	292	356	471	493		
Stratford 3 - ST03	3,140			166 (Bowen Rd[a])	262	361	404		
Stratford 5A - ST05A	4,760			312	373	470	514		
Weismantel 3 - WM03	4,550							487	634
Stratford 9 - ST09	7,040					905			
Stratford 8 - ST08	8,730				555	665	699		
Stratford 4 - ST04	9,420			515	584	705	729		
Faukland 3 - FK03	9,530		621	645					

(shaded) Coal seams with high groundwater inflow

[a] Coal seams cemented as they were high water producing zones

Figure 4-10: Median EC value of the water produced from the coal seam intervals in gas production wells

Hydrochemical data collected in 2008 and 2009 from production wells at Stratford (4, 5A, 6B and 8, Table 4-2) indicate that water produced from coal seam intervals have very low concentrations of calcium, magnesium and sulphate, and high concentrations of sodium, bicarbonate and chloride. The very low concentration of calcium, magnesium and sulphate, and the predominance of sodium, bicarbonate and chloride are typical groundwater qualities associated with CSG occurrence (deep water bearing zones) and production. The calcium and magnesium depletion is likely due to the inorganic precipitation of calcite and dolomite in presence of elevated concentrations of bicarbonate formed during the sulphate-reduction process.

The Piper diagram presented in Figure 4-11 compares the overall inorganic composition of the water produced from coal seam intervals. Water from Stratford 5A, 6B and 8 is sodium chloride and bicarbonate type, while water from Stratford 4 is sodium bicarbonate type. This difference can be interpreted as being the result of a longer residence period and being further along the groundwater path resulting in more saline groundwater in the deep basin coal seams in Stratford 4.

Elevated iron concentrations are recorded in all samples, as well as regularly elevated concentrations of phosphorus, fluoride, and mercury (above the ANZECC irrigation trigger values and the ANZECC fresh water quality guidelines; ANZECC 2000). These elevated concentrations are related to the coal quality and content. Iron, fluorine, phosphorus and mercury are typical elements occurring in coal seams. All other analytes monitored are generally below the ANZECC irrigation trigger values and the ANZECC fresh water quality guidelines (ANZECC, 2000).

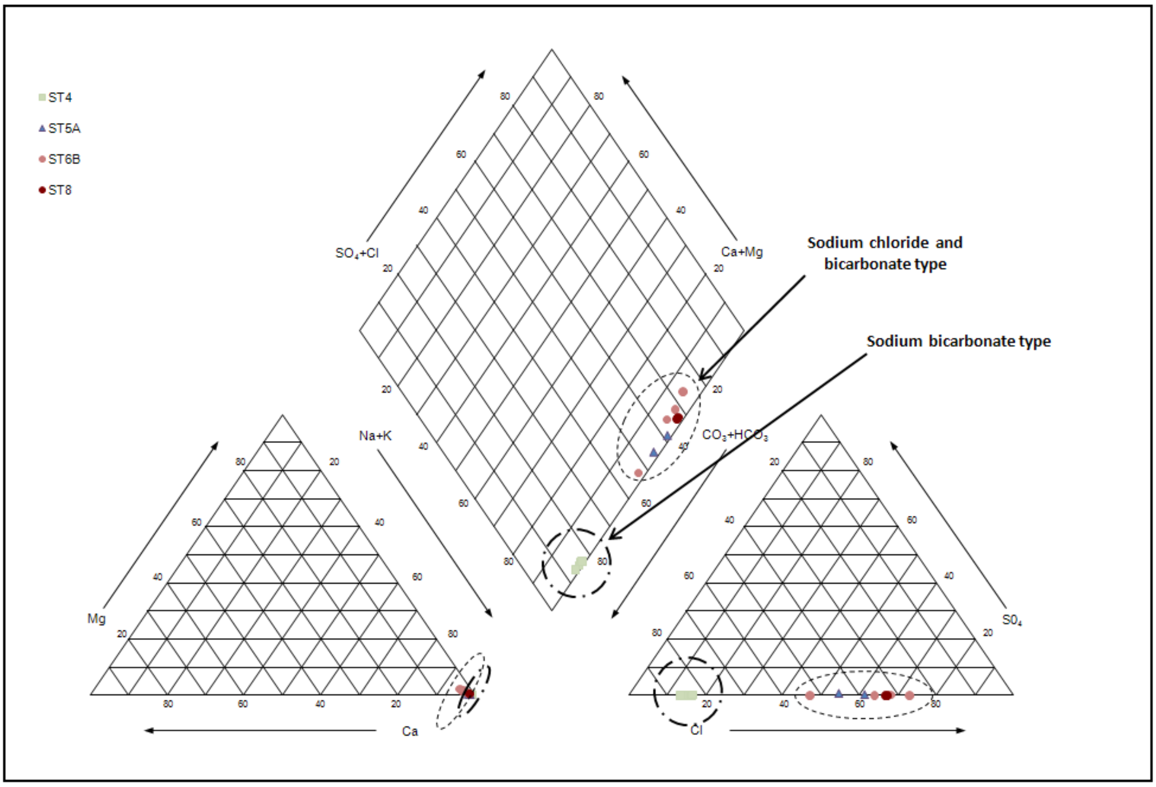

Figure 4-11: Piper diagram - water produced from the coal seam intervals in gas production wells

Table 4-2: Hydrochemistry of water produced from the coal seam intervals

Sample ID	Unit	ANZECC Fresh water	ANZECC Irrigation Triggers		Stratford 4				Stratford 5A		Stratford 6B				Stratford 8	
Sample Date					16/07/2008	20/08/2008	20/08/2008	18/09/2008	20/08/2008	22/10/2008	20/08/2008	18/09/2008	22/10/2008	30/03/2009	16/07/2008	20/08/2008
Lab Report Number					6800 3006	6800 3054	6800 3054	6800 3105	6800 3054	6800 3158	6800 3054	6800 3105	6800 3158	6800 3481	6800 3006	6800 3054
pH measured in the field	-							7.9	7.64		7.76	7.76				7.9
EC measured in the field	mS/cm					9.26	9.26	9.16	4.76		2.8	2.97				12.1
pH	-	6.5-9			7.7	8	8	8.2	7.6	7.2	8	7.5	7.7	7.5	7.2	8
Electrical Conductivity	μs/cm				11710	10300	10230	10970	5380	4500	2930	3580	2900	7900	9970	12200
Turbidity	NTU				22	16.8	9.8	9.5	197	170	16.8	65	55	20	360	63.6
Total Suspended Solids	mg/L	< 10% change seasonal mean concentration			23	36	41	19	88	68	12	24	25	88	166	35
Total Dissolved Solids	mg/L				5600	5900	6040	6840	2580	2400	1590	2780	1500	2055	4233	6580
Bicarbonate	mg/L				5270	4870	5050	5250	1290	1100	615	564	480	1120	1590	2210
Carbonate	mg/L			<	1	1	1	1	1	1	1	1	1	1	1	1
Chloride	mg/L				550	510	457	606	899	1010	595	699	757	580	1900	2570
Sulphate	mg/L			<	1	1	1	9	14	4	1	2	1	1	1	4
Sulfide	mg/L				0.1	0.1		0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1
Silica as SiO2	mg/L				21.1	20.4	19.6	22.2	12.6	11.7	15.1	15.7	14.6	15	12.7	12.5
Sodium	mg/L				2900	2300	2370	2520	1040	1000	623	664	613	830	1810	2240
Calcium	mg/L				20	18	18	17	14	9	14	13	15	10	20	19
Potassium	mg/L				15	16	16	15	62	27	7	11	5	9	320	249
Magnesium	mg/L				3	3	3	3	2	1	6	6	8	3	6	8
Total Kjeldahl Nitrogen	mg/L					3.3	3.1	0.5	2	2.3	0.7	0.8	1.4	1.3	-	6.2
Total Nitrogen	mg/L	0.1-0.75	5			3.3	3.1	0.5	2	2.4	0.7	0.8	1.4	1.3	-	6.2
Total Phosphorus	mg/L	0.01-0.1	0.05			0.06	0.04	0.01	0.4	0.26	0.04	0.01	0.01	0.11	-	0.31
Chemical Oxygen Demand	mg/L					23	279	425	396	95	51	54	33	<50	-	466
Aluminium	mg/L	<5 for pH<6.5 <100 for pH>6.5	5		0.04	0.04	0.02	0.01	0.11	0.02	0.05	0.07	0.04	0.38	0.55	0.03
Arsenic	mg/L	0.05	0.1	<	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.004	0.011	0.009
Barium	mg/L				10.3	11	11.3	10.2	3.22	2.5	1.48	1.44	1.5	1.51	6.94	13
Boron	mg/L		0.5		0.05	0.1	0.1	0.13	0.07	0.05	0.05	0.05	0.05	0.16	0.05	0.06
Bromide	mg/L				1	1	1		1.9	1	0.9		0.94		5.8	8.4
Cadmium	mg/L	0.0002-0.002	0.01	<	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium	mg/L	0.01	0.1		0.008	0.022	0.011	0.013	0.008	0.006	0.003	0.014	0.018	0.044	0.036	0.509
Copper	mg/L	0.002-0.005	0.2		0.031	0.028	0.007	0.002	0.013	0.013	0.003	0.008	0.031	0.029	0.116	0.009
Fluoride	mg/L		1		1.1	1.1	1.1	0.9	1	1.3	0.4	0.4	0.2	1.3	0.9	1.3
Iodide	mg/L			<	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Iron	mg/L	1	0.2		2.87	3.75	2.47	1.33	25.3	21.7	7.1	7.53	9.43	10.1	41	7.58
Lead	mg/L	0.001-0.005	2		0.006	0.024	0.004	0.002	0.004	0.003	0.003	0.003	0.008	0.03	0.398	0.066
Manganese	mg/L		0.2		0.049	0.05	0.04	0.026	0.316	0.255	0.089	0.099	0.161	0.119	0.416	0.044
Mercury	mg/L	0.0001	0.002	<	0.0001	0.003	0.001	0.0001	0.003	0.0001	0.002	0.0001	0.0001	0.0001	0.0001	0.004
Nickel	mg/L	0.015-0.15	0.2		0.002	0.0001	0.0001	0.001	0.0001	0.004	0.0001	0.002	0.01	0.036	0.014	0.0001
Strontium	mg/L				5.36	5.28	5.27	5.19	1.94	1.46	1.18	1.07	1.15	1.12	3.28	5.67
Zinc	mg/L	0.005-0.05	2	<	0.005	0.011	0.005	0.005	0.006	0.005	0.005	0.03	0.013	0.021	0.262	0.027
Total Petroleum Hydrocarbons	μg/L															
C6-C9 Fraction				<		20			20		20			500		20
C10-C14 Fraction				<		50			50		50			560		80
C15-C28 Fraction				<		100			100		100			100		300
C29-C36 Fraction				<		50			50		50			60		210
E.Coli	col/100mL		< 10	<				2				2		<2		

Notes: 1. Value exceeding ANZECC Irrigation Trigger Values are shown in red

5. Initial Regional Surface Water and Groundwater Survey

An initial regional surface water and groundwater survey was undertaken in May 2010 (3-6 May 2010) to provide preliminary data for the development of a monitoring programme for the project and to investigate the regional surface water and groundwater characteristics.

Water levels and quality data (pH and TDS) were collected to characterise conditions in and around the project area. Water samples from regional rivers / creeks and boreholes were also taken and analysed at the NATA-accredited ALS laboratory in Muswellbrook (NSW). Groundwater was sampled with a bailer or by using pumps installed in the boreholes / wells. Filtration and preservation of water samples were done on site.

A total of 25 boreholes / wells, 29 cemented or destroyed boreholes, 7 pilot wells, and 9 surface monitoring sites were surveyed during the site visit (Figure 5-1). The survey information for each of these categories is presented in Table 5-1 to Table 5-3.

Of the 25 boreholes / wells, only 13 boreholes / wells have information on the lithology encountered during drilling and only 6 boreholes have information on the depth of the slotted interval and aquifer zone. The regional boreholes used during the survey are generally poorly completed water supply boreholes, except for those built for monitoring purposes at the Stratford Coal Mine and the borehole GW080357.

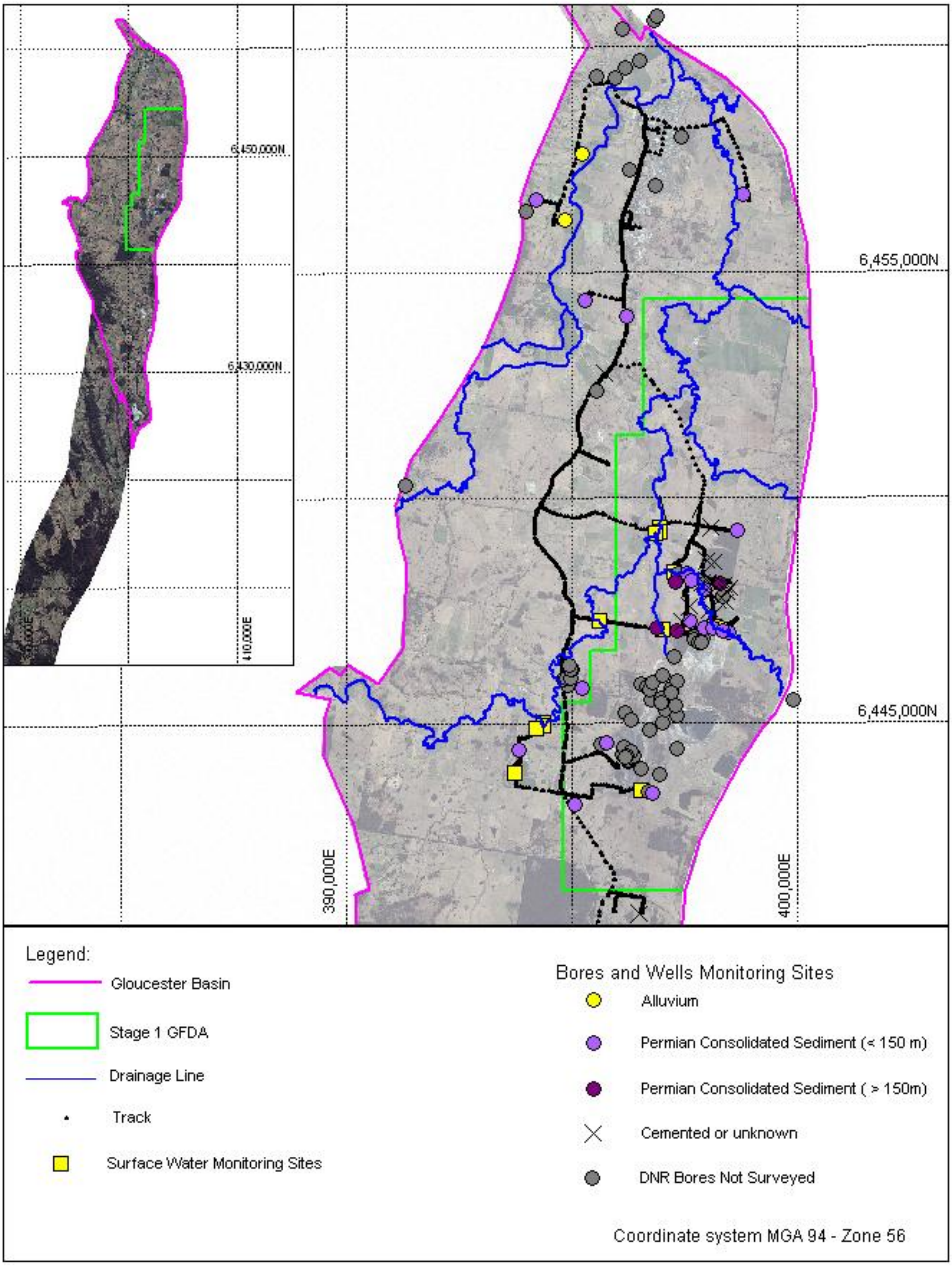

Figure 5-1: Location of surface water and groundwater monitoring sites

Table 5-1: Borehole survey – open boreholes / wells

Area	type	Name	Status	Comments	mE	mN	Elevation (m)	TOC (m)	Diameter (mm)	WL (RL)	pH	EC (µS)	Temp	EOH (m)	Owner	Lithology
Avon River downstream area	bore	GW047921	not in use	open hole - no cap	403793	6456713	100	0	125	98.55	6.5	318	20.9	60	private	N.D.
Stratford Coal Mine	bore	GW7	Gloucester Coal Mine Monitoring Bore	monitoring bore - no cap	401781	6443447	131	0.8	50	129.64	6.4	1803	20.2	N.D.	Gloucester mine	N.D.
Stratford Coal Mine	bore	GW2	Gloucester Coal Mine Monitoring Bore	monitoring bore - with cap	400772	6444581	146	1.22	50	138.7	6.4	4050	18.3	N.D.	Gloucester mine	N.D.
Stratford Coal Mine	bore	MW11	Gloucester Coal Mine Monitoring Bore	monitoring bore - with cap	403304	6447099	133	0.64	50	122.33	7.3	1255	20.2	26	Gloucester mine	0-0.2 top soil, 0.2-6 sandy clay, 6-9 gravels water free. Slotted interval between 6 and 9 m.
Stratford Coal Mine	bore	MW12	Gloucester Coal Mine Monitoring Bore	monitoring bore - with cap	403458	6447005	134	0.79	50	131.24	6.6	444	21.6	9	Gloucester mine	0-0.2 top soil, 0.2-4 sandy clay, 4-6 dry gravels, 6-17 sandstone, 17-18 water cut, 18-40 sandstone. Slotted interval between 35.5 and 40 m
Stratford Coal Mine	bore	MW6	Gloucester Coal Mine Monitoring Bore	monitoring bore - with cap	402921	6447111	135	0.45	50	dry	N.A.	N.A.	N.A.	10	Gloucester mine	0-0.1 top soil, 0.1-1 orange clay, 1-3 weathered sandstone, 3-5 mudstone, 5-5.5 siltstone, 5.5-10 mudstone miost at 7.5 m. Slotted interval between 8.5 and 10 m.
Stratford Coal Mine	bore	MW7	Gloucester Coal Mine Monitoring Bore	monitoring bore - with cap	403106	6447110	131	0.57	50	121.22	6.2	3650	20.7	10	Gloucester mine	0-0.1top soil, 0.1-0.5 clay,0.5-2.3 weathered sandstone, 3-10 mudstone. Slotted interval between 8.5 and 10 m.
Stratford Coal Mine	bore	MW8	Gloucester Coal Mine Monitoring Bore	monitoring bore - with cap	403343	6447033	136	0.62	50	dry	N.A.	N.A.	N.A.	6.9	Gloucester mine	0-0.1 top soil, 0.1-1.5 brown clay, 2.5-3 siltstone, 3-5.7 coal seam, 5.7-6.9 mudstone. Slotted interval between 5.4 and 6.9 m.
Stratford Coal Mine	bore	GW079771 (Piggery)	Gloucester Coal Mine Monitoring Bore	open hole - no cap	400065	6443201	134	0.16	152	128.76	6.9	6850	18.4	71.1	Gloucester mine	N.D.
Gloucester River area	well	Sump 1	sump	pump exist in sump, but not anymore in use. At the contact between Allum Mountain Volcanics and Consolidated Permian sediment	399208	6456613	138	N.A.		N.A.	5.8	229	21.5	7	private	Water bearing at 6m
Gloucester River area	well	GW023084 (Well1)	in use with dedicated pump for farming		399841	6456179	114	N.A.	1524	111.95	6	800	22.1	6.97	private	Water bearing at 2.7 m; Sand gravel
Gloucester River area	well	GW053390 (Well2)	in use with dedicated pump for farming		400214	6457628	104	0.14	1250	100.96	6.2	589	21.8	5.47	private	Loam soil mixed to 6 m; gravel river water bearing to end.
South of Gloucester town	bore	GW080357	in use with dedicated pump for watering	detailed bore construction available, sanitary seal present, cap, bubble in water after filtration	400291	6454386	125	0.1	115	108.61	7.2	1587	17.9	40.5	private	Brown moist clay to 1.5m; white dry clay to 4m; orange and grey layer sandstone to 7m; grey sandstone to 19m; coal seam moist to 19.4m; grey sandstone to 22m; water cut to 22.2m; grey sandstone to 29m; water cut to 29.3m; grey sandstone to 37m; water cut to 37.2m; grey sandstone to end. Slotted interval between 28 and 40 m.
South of Gloucester town	bore	GW080487	not in use	open hole - with cap, smelly, bubble in water after filtration	401225	6454017	122	0.47	140	108.52	7.5	3330	19.6	N.D.	private	Topsoil to 0.2m, brown stiff clay to 2.2m;sandy brown clay to 3m; weathered sandstone to 5m; hard grey shale to 17m, coal seam with water to 18m; hard grey shale to end.
Tiedmans area	bore	3086R	open hole	open hole - cap damaged	403655	6449267	138	0	125	127.47	7	3490	18.4	126	AGL	N.D.
Tiedmans area	bore	080_GW080491 (New one)	open hole	open hole - no cap	402534	6448304	118	0.11	125	116.33	6.9	390	19	31.3	AGL	N.D.
Tiedmans area	bore	PGSD8	open hole with valve, can access WL with deep meter but cannot take sample	with Permanent logger (working ?), a lot of gas flowing out when openning the valve	402293	6448130	118	0.215	60	104.81	N.A.	N.A.	N.A.	662	AGL	Deep hole - no data
Tiedmans area	bore	Griffin	open hole with dedicated pump for farm purpose		402632	6448175	122	0.47	140	120.77	6.8	1420	18.9	18.2	private	N.D.
Tiedmans area	well	085_well	open		402940	6447969	122	0	1500	120.99	N.A.	N.A.	N.A.	4.41	private	N.D.
Tiedmans area	bore	PGSD4	open hole with valve, can access WL with deep meter but cannot take sample	with Permanent logger (working?)	403269	6448081	136	0	60	126.27	N.A.	N.A.	N.A.	448	AGL	Deep hole - no data
Tiedmans area	bore	8013R	open hole	open hole - with cap	402623	6447273	121	0.4	140	115.11	7.1	1930	22.6	127	AGL	N.D.
Tiedmans area	bore	PGSD5	open hole with valve, can access WL with deep meter but cannot take sample	with Permanent logger (working?)	402316	6447045	129	0.52	60	116.3	N.A.	N.A.	N.A.	567	AGL	Deep hole intersecting Triple seam at 595-569m, Avom seam at 534-511m, Bowen Road at 350-340m, fault at 147m, Roseville seam at 129-228m, Cloverdalle seam at 71-67m
Tiedmans area	bore	PGSD2	open hole with valve, can access WL with deep meter but cannot take sample	with Permanent logger (working?)	401886	6447120	116	0.46	60	114.6	N.A.	N.A.	N.A.	775	AGL	Deep hole intersecting fault at 766 m, Glenview seams at 732-748m, Bowen Road seam at 646m, Roseville seams? At 420-388m, Cloverdale seams at 355-334m
West of Gloucester Coal Mine	bore	GCL	open hole - abandonned	open hole - with cap	400214	6445785	131	0.11	140	121.61	7.7	6490	18.9	19.9	Gloucester mine	N.D.
West of Gloucester Coal Mine	bore	Bore Diary Farm	open hole - abandonned	open hole - no cap	398819	6444437	139	N.A.	152	130.51	6.7	1461	18.9	60	private	Water bearing at 15 m in sandstone of Lolema formation?

N.A.= Not Applicable

N.D.= Not Determined

Table 5-2: Borehole survey – cemented/destroyed boreholes, monitoring bores (VWP) and pilot wells

Area	type	Name	Status	Comments	Owner
Tiedmans area	bore	306R	cemented		AGL
Tiedmans area	bore	3085R	cemented		AGL
Tiedmans area	bore	310R	cemented		AGL
Tiedmans area	bore	311R	cemented		AGL
Tiedmans area	bore	7015R	cemented		AGL
Tiedmans area	bore	7016R	cemented		AGL
Tiedmans area	bore	7037R	cemented		AGL
Tiedmans area	bore	7041R	cemented		AGL
Tiedmans area	bore	7042R	cemented		AGL
Tiedmans area	bore	7100R	cemented		AGL
Tiedmans area	bore	7102R	cemented		AGL
Tiedmans area	bore	7106R	cemented		AGL
Tiedmans area	bore	7107R	cemented		AGL
Tiedmans area	bore	7170R	cemented		AGL
Tiedmans area	bore	APW01	VWP - target seam: bowens Road	no accurate depth installation	AGL
Tiedmans area	bore	DDH20C	cemented		AGL
Tiedmans area	bore	PGSD3 (APW02)	VWP - target seam: bowens Road, Avon and Triple	no accurate depth installation	AGL
Tiedmans area	bore	PGSD6 (APW04)	VWP - target seam: bowens Road, Avon and Triple	no accurate depth installation	AGL
Tiedmans area	bore	PGSD7 (APW03)	VWP - target seam: Fairbairns Lane, Glenview and Avon	no accurate depth installation	AGL
Tiedmans area	bore	Stratford 1 - ST1	Pilot well		AGL
Tiedmans area	bore	Stratford 2 - ST2	Pilot well/Gas Pressure Monitoring, suspended	with Permanent Downhole Pressure Sensor	AGL
Tiedmans area	bore	Stratford 3 - ST3	Pilot well		AGL
Tiedmans area	bore	Stratford 4 - ST4	Pilot well		AGL
Tiedmans area	bore	Stratford 5 - ST5	Pilot well		AGL
Tiedmans area	bore	Stratford 6 - ST6	Pilot well		AGL
Tiedmans area	bore	Stratford 8 - ST8	Pilot well		AGL
Tiedmans area	bore	Stratford 9 - ST9	Pilot well		AGL
Tiedmans area	bore	Stratford 10 - ST10	Pilot well		AGL
Stratford Coal Mine		GW079758	destroyed - not found		Stratford mine
South of Stratford Coal Mine		GW079759	destroyed - not found	not known by the owners (Noelene and John Weismantel)	private
South of Gloucester town	bore	GW200330	backfill		private

Table 5-3: Surface water site survey

Name	mE	mN	Elevation (m)	pH	EC (µS)	Temp (°C)	Owner
Avon River_W1	400595	6447286	116	7.41	300	14.8	private
Avon River_AR1	399365	6445013	127	7.25	258	15.9	private
Avon River_AR2	399376	6444971	125	7.35	265	16.1	private
Avon River_Lemon Tree	401844	6449210	115	N.D.	N.D.	N.D.	private
Avondale Creek_W5	402018	6447067	115	N.D.	N.D.	N.D.	private
Dog Trap Creek	402256	6448351	122	N.D.	N.D.	N.D.	private
Dog Trap_Fig Tree	401941	6449247	114	N.D.	N.D.	N.D.	private
Morgan Gully1	398731	6443913	139	N.D.	N.D.	N.D.	private
Morgan Gully2	399193	6444902	129	N.D.	N.D.	N.D.	private

N.D.= Not Determined

5.1 Regional groundwater level

Regional groundwater levels measured in the shallow aquifers (alluvium and Permian rocks) in May 2010 (Figure 5-2) indicate a movement of the regional groundwater from south to north and from the ridges to the alluvial plains (e.g. Avon River) following the natural surface drainage lines. The regional water elevations range between about 130 m RL south of the Stratford Coal Mine to about 98 m RL north of the Gloucester Gas Pilot - Stage 1 and east of Gloucester town.

The survey of four deep holes (PGSD2, PGSD4, PGSD5 and PGSD8) intersecting deep aquifers in the Permian rocks (< 150 m) indicates variable static water levels from 104.8 to 126.3 m RL. However, the measurement undertaken at PGSD8 (i.e. 104.8 m RL) needs to be used carefully and should be confirmed by further measurements, as a gas gap was present in this well which may have affected the water level. Unfortunately, the tight schedule during the site visit did not allow enough time to wait until the borehole stabilised. For future water level monitoring, the valve at PGSD8 should be open at least 24 hours before any measurement allowing gas to escape. Detailed stratigraphic logs with fault depth and borehole construction details, as well as past and present water level logger data recorded in these boreholes, are required to allow further discussion on the observed static water level.

5.2 Regional surface water and groundwater quality

5.2.1 Regional water salinity

The salinity readings (258 < EC <300 µS/cm) obtained from the Avon River are in accordance with the long-term monitoring data provided and indicate that the water is fresh (Figure 5-3).

In Figure 5-3, the groundwater salinity recorded during the survey indicates that the groundwater from alluvium is fresh with values ranging between 589<EC<800 µS/cm. The groundwater salinity from shallow Permian rocks is variable, from fresh to brackish (318<EC< 6,850 µS/cm). Neither saline (7,000 < EC < 20,000 µS/cm) nor hypersaline (EC > 20,000 µS/cm) water was encountered during the regional survey.

5.2.2 Regional water pH

The pH recorded on the Avon River indicate that the surface water is near neutral (7.3 < pH< 7.4).

Mapping of the regional groundwater pH (Figure 5-4) indicates that the groundwater coming from the alluvium is slightly acidic (6 < pH < 6.2) compared to the pH recorded in the shallow Permian fractured aquifer. The groundwater pH in the shallow fractured aquifer is near neutral at 6.4 < pH < 7.7.

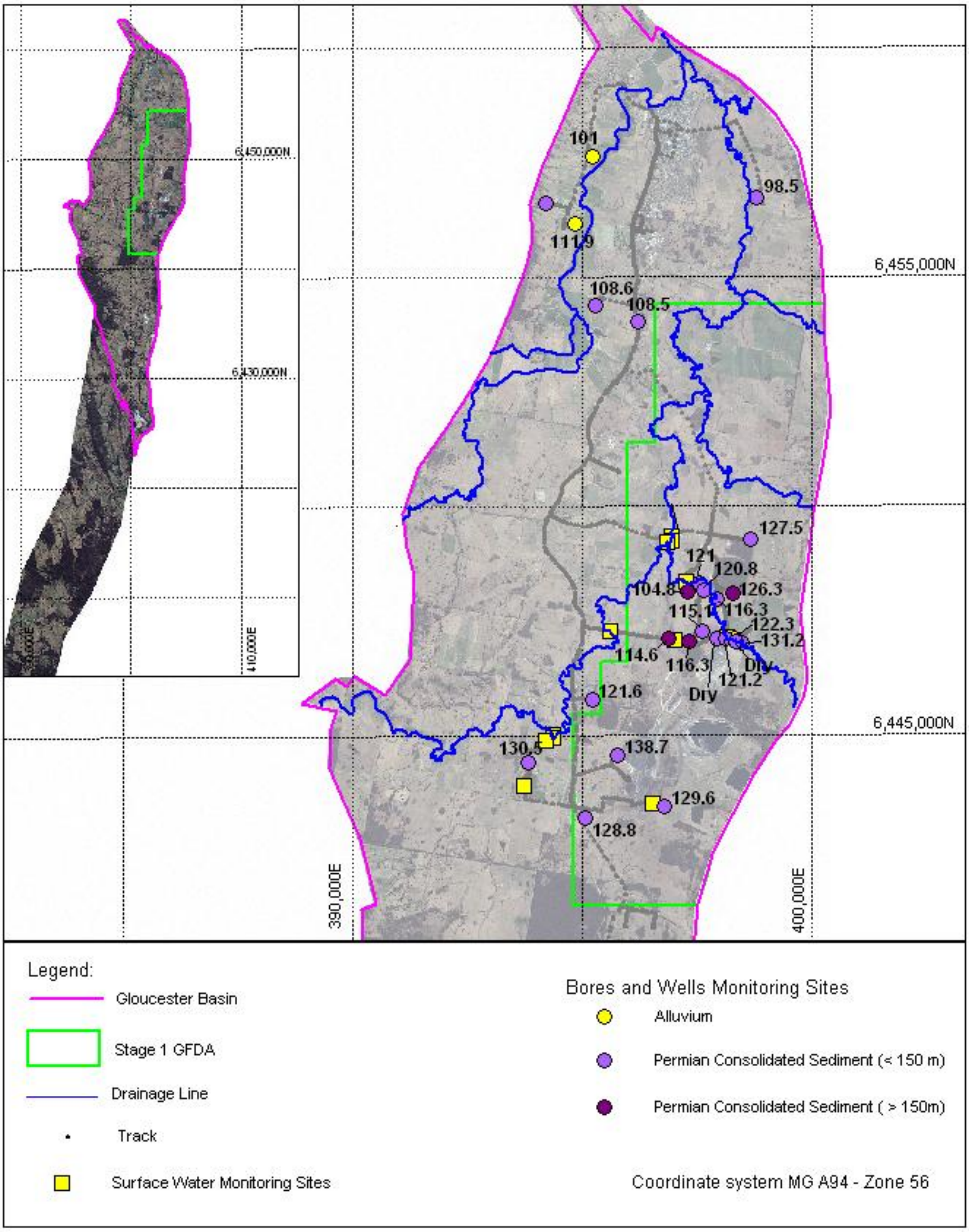

Figure 5-2: Regional groundwater level (m RL) May 2010

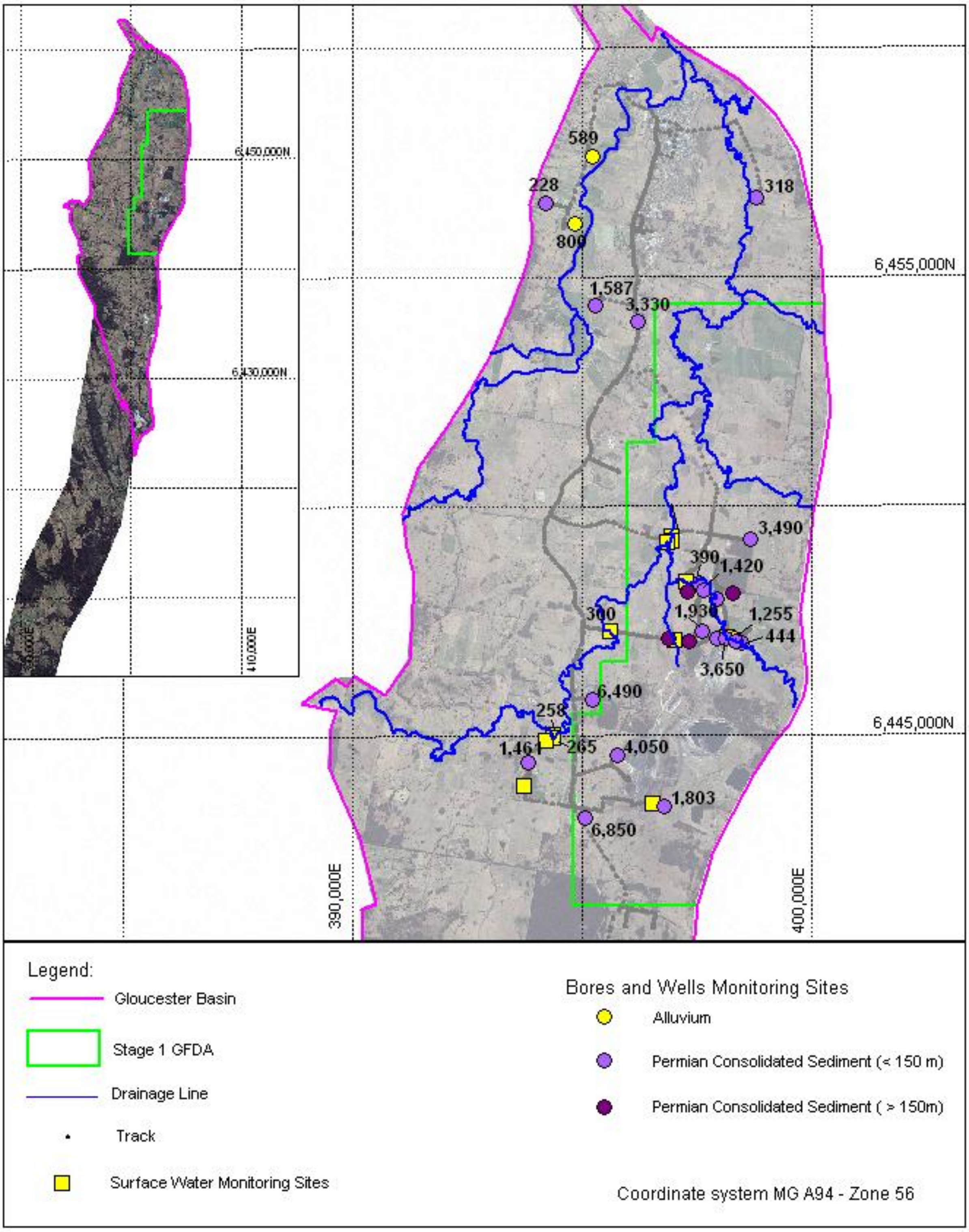

Figure 5-3: Regional surface and groundwater field electric conductivity measurement (μS/cm) May 2010

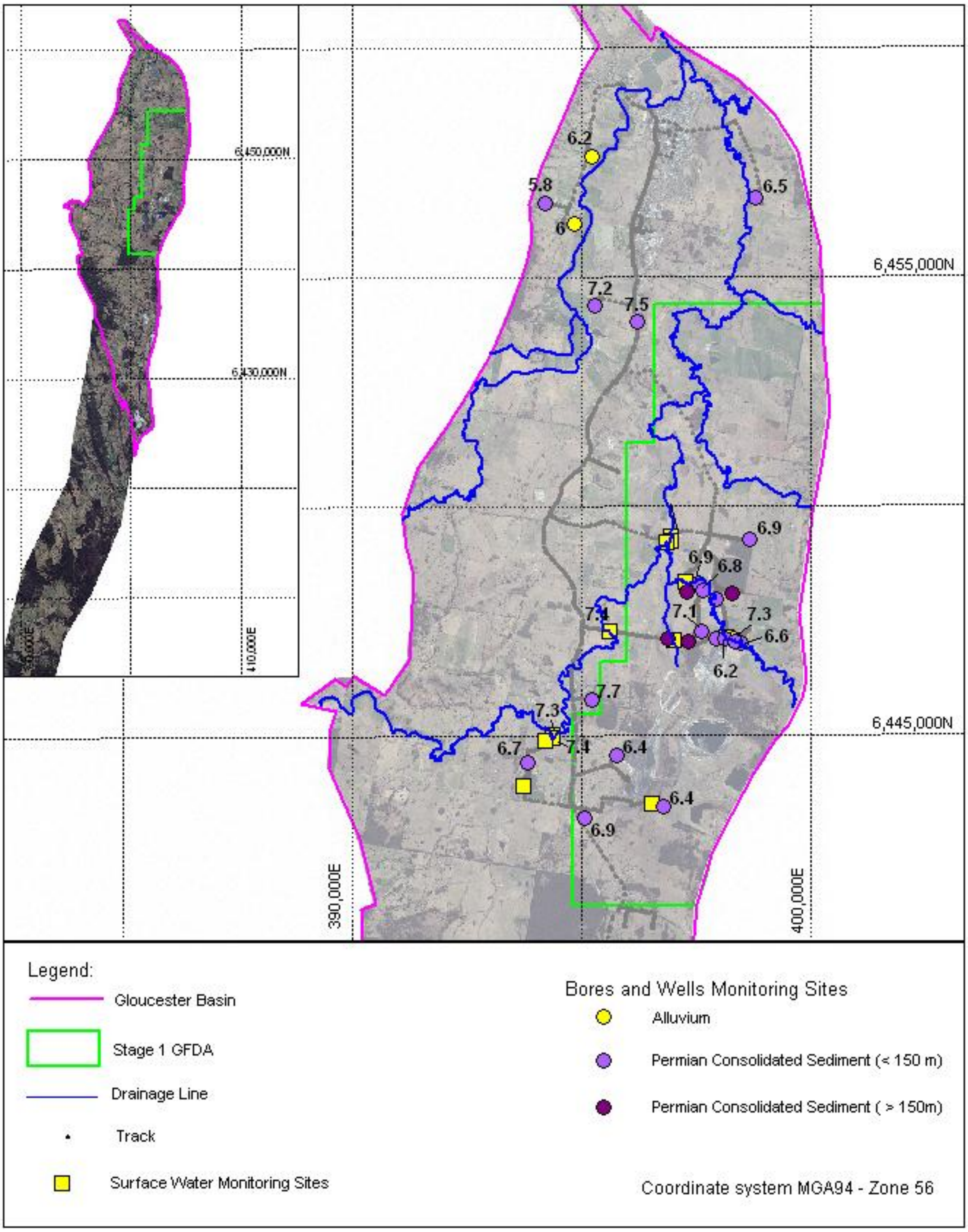

Figure 5-4: Regional surface and groundwater field pH measurement, May 2010

5.2.3 Regional hydrochemistry

During the site visit, three surface water and 14 groundwater monitoring sites were sampled for detailed water quality analysis. One surface water sample was duplicated for QA/QC purpose.

All the samples were collected in laboratory-prepared bottles. Water samples for trace metals analyses were field-filtered through a 0.45 μm filter, poured into acid-washed bottles and acidified. Samples were chilled and stored with ice packs in an Esky and submitted to the ALS Laboratory in Muswellbrook for chemical analysis.

Results of the analytical testing and comparison results with the ANZECC fresh water quality guideline and irrigation trigger values (ANZECC, 2000) are presented in Table 5-4. The ANZECC fresh water quality guideline is used as standard reference to compare the analysis, and is used to characterise the hydrogeological environment in the Gloucester Basin.

A Piper diagram compares the overall inorganic composition of the water collected during the survey (Figure 5-5).

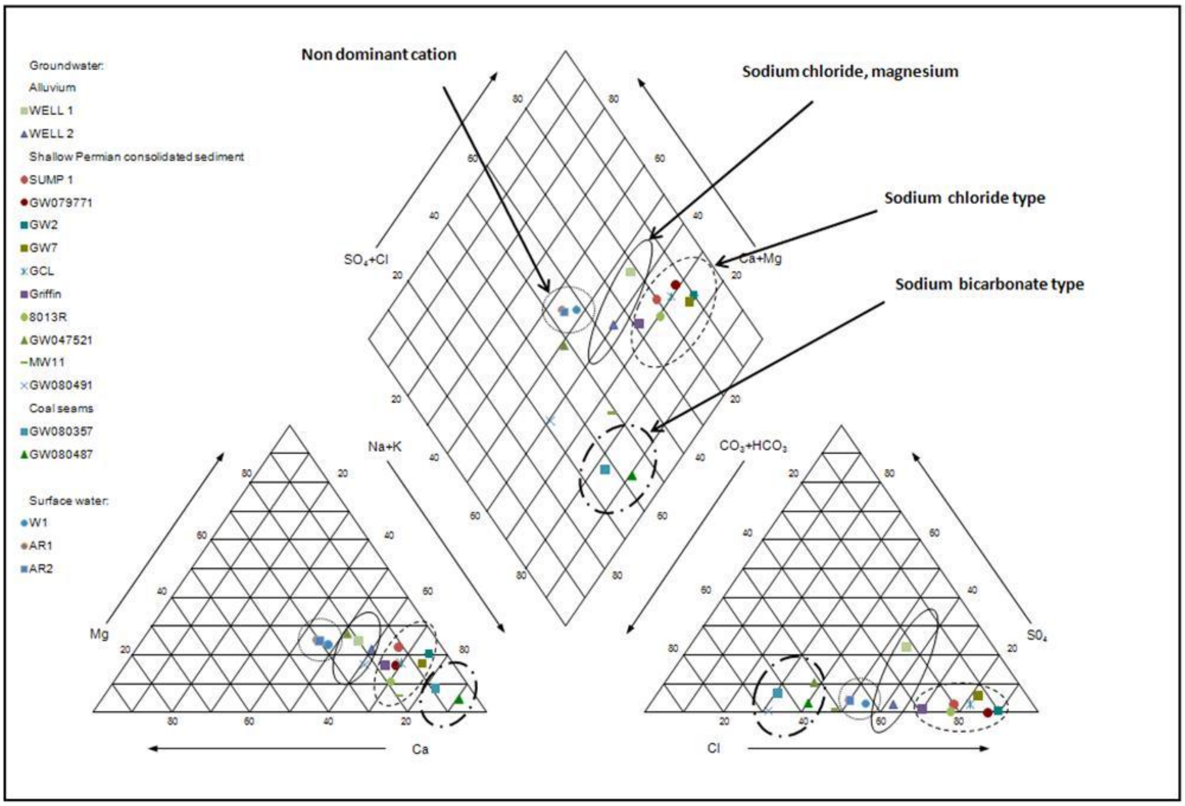

Figure 5-5: Piper diagram – regional surface and groundwater hydrochemistry

Figure 5-5 indicates that surface water is characterised by a non-dominant cation-anion signature, while regional groundwater can be classified into three broad chemical types. Groundwater from the alluvial aquifer of the Gloucester River (Well 1 and Well 2) is a mixture of sodium chloride, and magnesium, calcium and bicarbonate type. This type of water generally represents a mixture of water from the aquifer with recent recharge from rainfall infiltration. Groundwater from the shallow Permian fractured aquifer (e.g. GW079771, GW2, GW7, GCL, Griffin and 8013R) is more brackish and generally sodium chloride type. As no analysis of local rainfall is available, it is therefore not possible to attribute the sodium chloride type water to geological factors or to the chemical composition of the rainfall. Groundwater originating from GW080357 and GW080487 (boreholes which are both sited in shallow coal seams) has a different signature. Groundwater from these boreholes is sodium bicarbonate type as per the water extracted from deep coal seams (e.g. water from Stratford 4, see Section 3.2.6 Coal Seam Water Quality). These preliminary results suggest that the water from shallow or deep coal seam aquifers/water bearing zones has a similar signature and if there was groundwater migrating from the alluvial and shallow fractured rock aquifers then this trend would be easily identified.

Groundwater samples were also analysed for a broad suite of major and trace elements. Generally, the water samples have only iron, manganese and phosphorus concentrations in excess of the ANZECC irrigation trigger values (ANZECC, 2000). Iron is one of the most abundant constituents of rocks and soils. The elevated concentrations are generated by the leaching of iron from the rock mass over extended periods. High iron concentration can also occur in relation to acid sulphate soils. However, this area has no acid sulphate soils and no high sulphate concentration was reported.

The chemical behaviour and occurrence of manganese in water resembles iron, but is typically much less abundant in rocks than iron. As a result, the manganese concentration in water is generally much less than that of iron. The manganese found in water is probably most often the result of solution of manganese from soils and sediments aided by bacteria or complexing with organic materials. The sources of phosphorus can be widespread, and can be related to extensive agricultural practice in the watershed or phosphorous can be released by the coal seams present in the Permian rocks.

Trace metals were generally low although elevated barium and strontium occurs in some of the brackish and more saline waters (e.g. GW079771, Griffin, MW11 and 8013R).

Table 5-4: Hydrochemistry of groundwater and surface water, May 2010

Sample ID	Unit	ANZECC Fresh water	ANZECC Irrigation Triggers	Groundwater samples														Surface water samples - Avon River			
				GW023084 (WELL 1)	GW053390 (WELL 2)	SUMP 1	GW079771 (Piggery)	GW2	GW7	GCL	Griffin	GW080357	GW080487	GW047521	MW11	GW080491	8013R	W1	W1 duplicated - AVON RIVER	Upstream Morgan Gully creek AR1	Downstream Morgan Gully creek AR2
Sample Date				3/05/2010	3/05/2010	3/05/2010	4/05/2010	4/05/2010	4/05/2010	4/05/2010	4/05/2010	5/05/2010	5/05/2010	5/05/2010	5/05/2010	6/05/2010	6/05/2010	4/05/2010	4/05/2010	4/05/2010	4/05/2010
Lab Report Number																					
pH measured in the field	-			6.03	6.21	5.84	6.93	6.36	6.42	7.68	6.78	7.24	7.5	6.53	7.27	6.92	7.07	7.41	7.41	7.25	7.35
EC measured in the field	µs/cm			800	589	228.5	6850	4050	1803	6490	1420	1587	3330	318	1255	390	1930	300	300	258	265
Temperature measured in the field	°C			22.1	21.8	21.5	18.4	18.3	20.2	18.9	18.9	17.9	19.6	20.9	20.2	19	22.6	14.8	14.8	15.9	16.1
pH	-	6.5-9	4.5-9	6.2	6.2	6	6.7	6.5	6.4	7.3	6.8	7.1	7.3	6.1	7	6.9	6.8	7.7	7.3	7.1	7.1
Electrical Conductivity	µs/cm			570	590	220	7700	4500	1900	7000	1500	1600	3400	250	1300	340	1940	350	310	270	270
Total Suspended Solids	mg/L	< 10% change seasonal mean concentration		4	3	33	12	18	147	37	1	1	2	216	2	58	1	1	1	2	2
Total Dissolved Solids	mg/L			226	258	74	4375	2115	958	3845	812	904	2022	22	796	22	964	136	120	126	100
Bicarbonate	mg/L			66	108	22	600	247	126	670	238	578	1090	64	373	106	244	70	69	63	63
Carbonate	mg/L			<1	<1	<1	<1	<1	<1	<1	<1	19	57	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity	mg/L			66	108	22	600	247	126	670	238	597	1150	64	373	106	244	70	69	63	63
Chloride	mg/L			96	109	49	2390	1290	489	2000	335	174	492	27.2	204	28.2	499	52.7	53.1	39.6	40.1
Sulphate	mg/L			53.3	7.07	2.44	2.57	14	47.6	98.5	8.44	52	52.2	10.4	5.52	0.8	3.32	4.16	4.04	4.76	4.64
Sillicon	mg/L			11.2	8.59	13.4	7.96	17.8	13.6	10.5	18.3	10.5	9.51	4.2	8.87	7.1	15.7	8.11	7.81	7.98	7.94
Sodium	mg/L			59	68	26	1160	697	306	1180	220	366	859	22	243	24	320	29	29	22	23
Calcium	mg/L			20	19	4	222	37	28	194	51	34	38	9	55	9	76	16	16	14	14
Potassium	mg/L			6	6	3	14	24	5	8	2	4	6	4	3	6	4	3	3	2	2
Magnesium	mg/L			15	14	5	148	102	37	156	29	20	23	7	10	4	26	8	8	7	7
Nitrate	mg/L	0.1-0.75		<0.01	<0.01	0.07	2.39	0.23	0.51	0.02	0.01	0.01	0.03	0.12	<0.01	0.02	1.6	0.06	0.05	0.02	0.04
Total Phosphorus	mg/L	0.01-0.1	0.05	<0.01	0.04	0.17	0.6	0.08	0.44	0.03	0.12	0.09	0.17	0.37	0.12	1.54	0.18	0.04	0.05	0.21	0.12
Aluminium	mg/L	<5 for pH<6.5 <100 for pH>6.5	5	<0.01	<0.01	0.08	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.11	0.01	0.06	<0.01	<0.01	0.01	0.02	0.01
Arsenic	mg/L	0.05	0.1	0.001	<0.001	<0.007	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	mg/L	0.004	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L			0.116	0.126	0.037	6	2.05	0.075	0.133	1.4	0.171	0.672	0.051	2.3	0.275	2.58	0.039	0.039	0.023	0.023
Boron	mg/L		0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cobalt	mg/L			0.003	0.002	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0002-0.002	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.01	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.002-0.005	0.2	0.001	<0.001	0.002	0.004	0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.002	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001
Fluoride	mg/L		1	0.04	0.03	<0.02	<0.02	0.46	0.1	<0.02	0.04	0.38	0.07	0.03	0.09	0.13	0.14	0.09	0.09	0.09	0.09
Iron	mg/L	1	0.2	0.06	0.09	<0.05	0.58	7.55	5.66	<0.05	2.62	2.58	<0.05	0.32	0.5	2.9	<0.05	1	1.09	0.93	0.87
Lithium	mg/L		2.5	0.002	<0.001	<0.001	0.403	0.228	0.034	0.411	0.168	0.074	0.315	<0.001	0.044	0.014	0.163	0.002	0.002	0.001	0.002
Lead	mg/L	0.001-0.005	0.2	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L		0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L		0.2	0.551	0.69	0.004	0.158	1.33	0.726	0.244	0.191	0.25	0.034	0.107	0.026	0.053	0.037	0.088	0.086	0.044	0.052
Mercury	mg/L	0.0001	0.002	<0.0001	<0.0001	<0.0001	0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	0.015-0.15	0.2	<0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	mg/L	0.0001		<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	0.005	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tin	mg/L	0.000008		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	mg/L			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	mg/L			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	mg/L	0.03		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	mg/L		0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L		0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L			0.355	0.343	0.058	7.94	0.488	0.578	8.47	1.04	1.07	3.81	0.088	2.74	0.436	3.2	0.196	0.189	0.161	0.158
Zinc	mg/L	0.005-0.05	2	0.011	<0.005	0.006	0.01	0.016	<0.005	<0.005	0.008	0.012	<0.005	<0.005	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	<0.005
Total Anions	meq/L			5.14	6.37	1.86	79.5	41.6	17.3	71.8	14.4	17.9	37.9	2.26	13.3	2.68	19	2.97	2.96	2.48	2.49
Total Cations	meq/L			4.95	5.25	1.79	73.9	41.2	17.9	73.8	14.6	19.4	41.3	2.06	14.2	2.67	20	2.79	2.79	2.31	2.36
Iconic Balance	meq/L			1.81	1.18	0	3.67	0.45	1.62	1.42	0.69	3.83	4.22	0	3.12	0.17	2.48	0	0	0	0

Notes: 1. Value exceeding ANZECC Trigger Values are shown in red

6. Conceptual Hydrogeological Model

The conceptual hydrogeological model for the Gloucester Basin was developed based on the previously described regional and site-specific geological information and hydrogeological data.

The model area is illustrated in Figure 6-1 and Figure 6-2. The cross sectional model is based on the real 2D cross section through the Stratford wells on the Tiedman property. This model should be used as a base for planning additional work in later stages of investigations and site monitoring networks.

6.1 Surface water

For the Stage 1 GFDA within the Manning River Catchment, the general surface drainage direction flows towards the north. Local ephemeral creeks (Waukivory, Dog Trap, Avon Dale and Morgan Gully) flow north easterly and north westerly as they descend from the ridge area to the Avon River plain.

Correlation between water quality and stream flow typically shows a reduction in surface water salinity after periods of rain followed by a general increase in salinity as the stream flow reduces and groundwater baseflows increase. The surface water is generally fresh (100 < EC < 600 μS/cm) and near neutral to slightly alkaline. Groundwater baseflows (and even discharge from deeper aquifers/water bearing zones) are suspected in the northern catchment area around Gloucester. Groundwater discharge to streams is likely to be diffuse over a large area unless there are substantial fault systems that are contributing. A run-of-river survey of water quality during low flow periods would be required to confirm discharge areas and any point source locations.

6.2 Hydrogeological units

The local and regional geology was used to define a total of four hydrogeological units in the Stage 1 GFDA area. Table 6-1 summarises the hydraulic properties known or calculated for these hydrogeological units. The two upper units are the water resources aquifers for the catchment. Figure 6-3 illustrates the complex stratigraphy of the interbedded water bearing zones.

Table 6-1: Hydrogeological units of the Gloucester Basin

Hydrogeological units	Aquifer type	Formation name	Hydraulic conductivity (m/day)
Alluvial aquifers	Unconfined porous granular	Quaternary Alluvium	0.1 – 5 [a]
Upper weathered and fractured Permian aquifers (<150 m depth)	Confined/ Unconfined	Weathered and fractured Permian formation	0.04 – 3 [b]
Coal Seam water bearing zones	Poored aquifers Unconfined & Confined	Coal seams of the Dewrang Group and Gloucester Coal Measures	~ 8.6×10^{-2} m/day at 100 m ~6.1×10^{-3} to $2.3\ 10^{-2}$ m/day at 300 m ~4.8×10^{-4} m/day at 500 m
Confining units	Confined/ Unconfined Aquitard	Confining units of the Gloucester Coal Measures, Dewrang Group and Alum Mountain Volcanics	?

[a] Regional data from Duralie Extension Project Groundwater Assessment report November 2009

[b] Derived from slug and pumping tests undertaken in the Mammy Johnsons, Weismantel and Duralie Road Formations.

[c] Derived from intrinsic permeability testing of Coal Seams by Pacific Power in 1999. Conversion of permeability to hydraulic conductivity based on standard condition of fresh water at ground surface condition. The conversion factor used is: 8.64×10^{-4} m/day per millidarcy (mD).

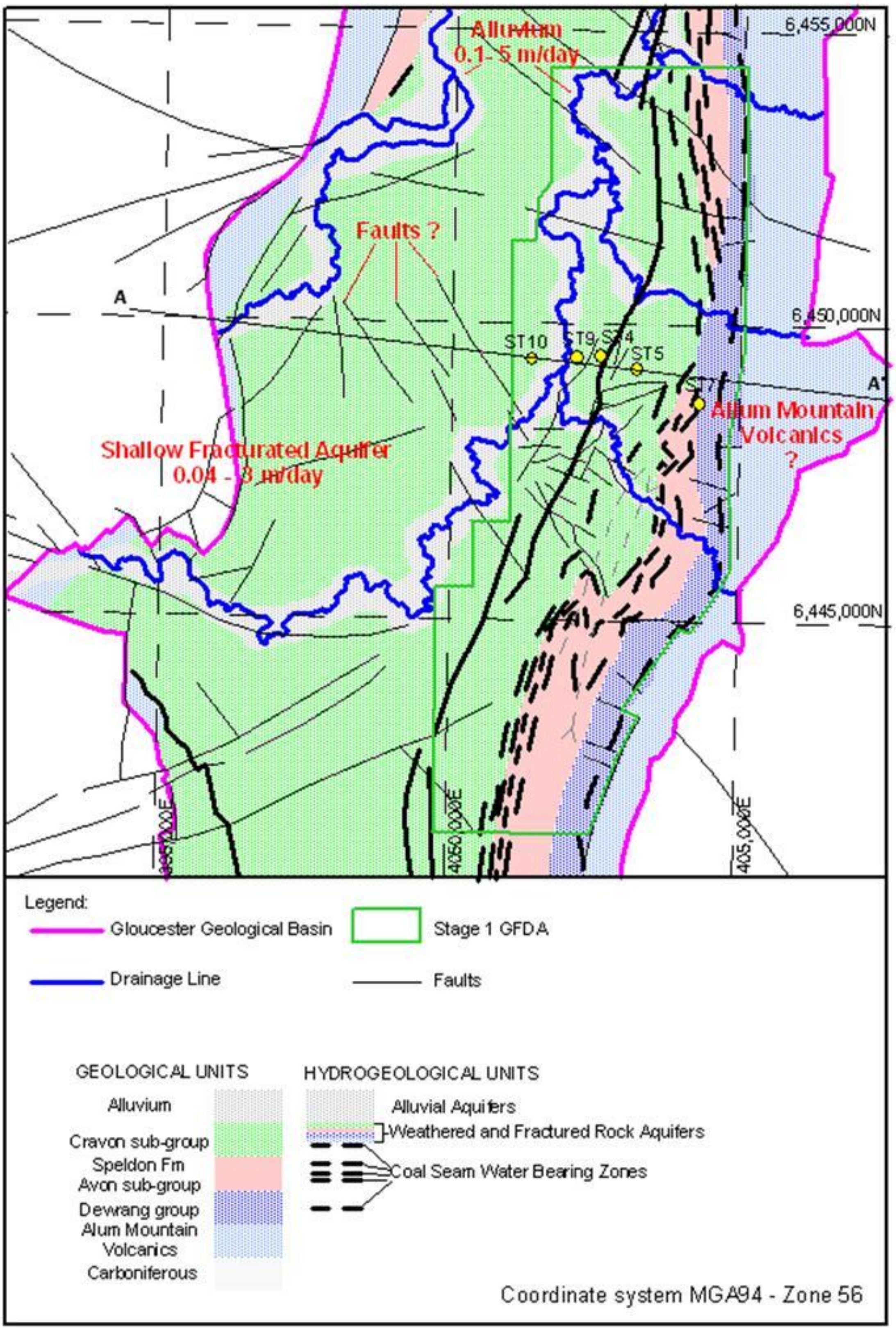

Figure 6-1: Initial conceptual hydrogeological model (plan view)

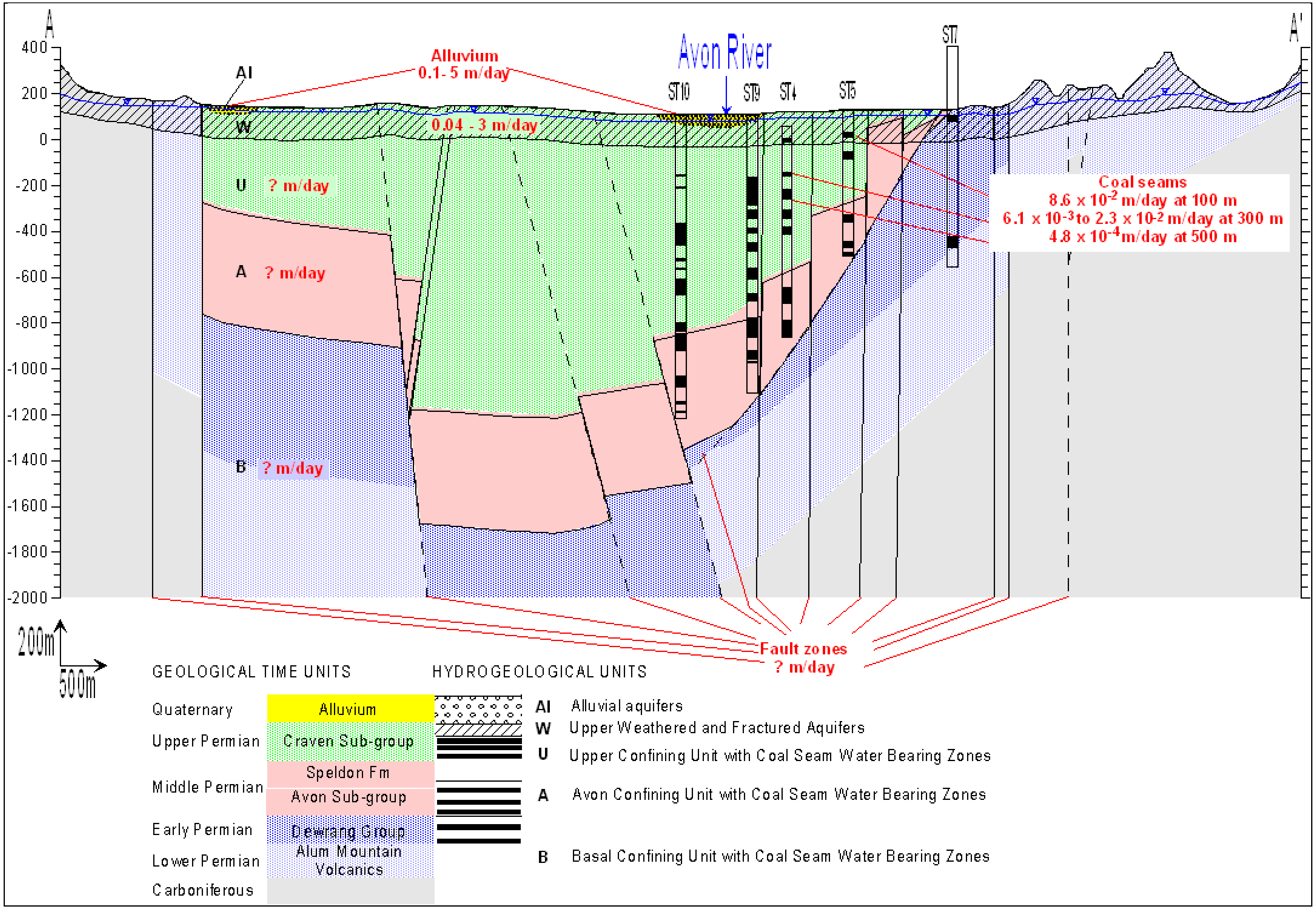

Figure 6-2: Initial conceptual hydrogeological model (cross-section AA')

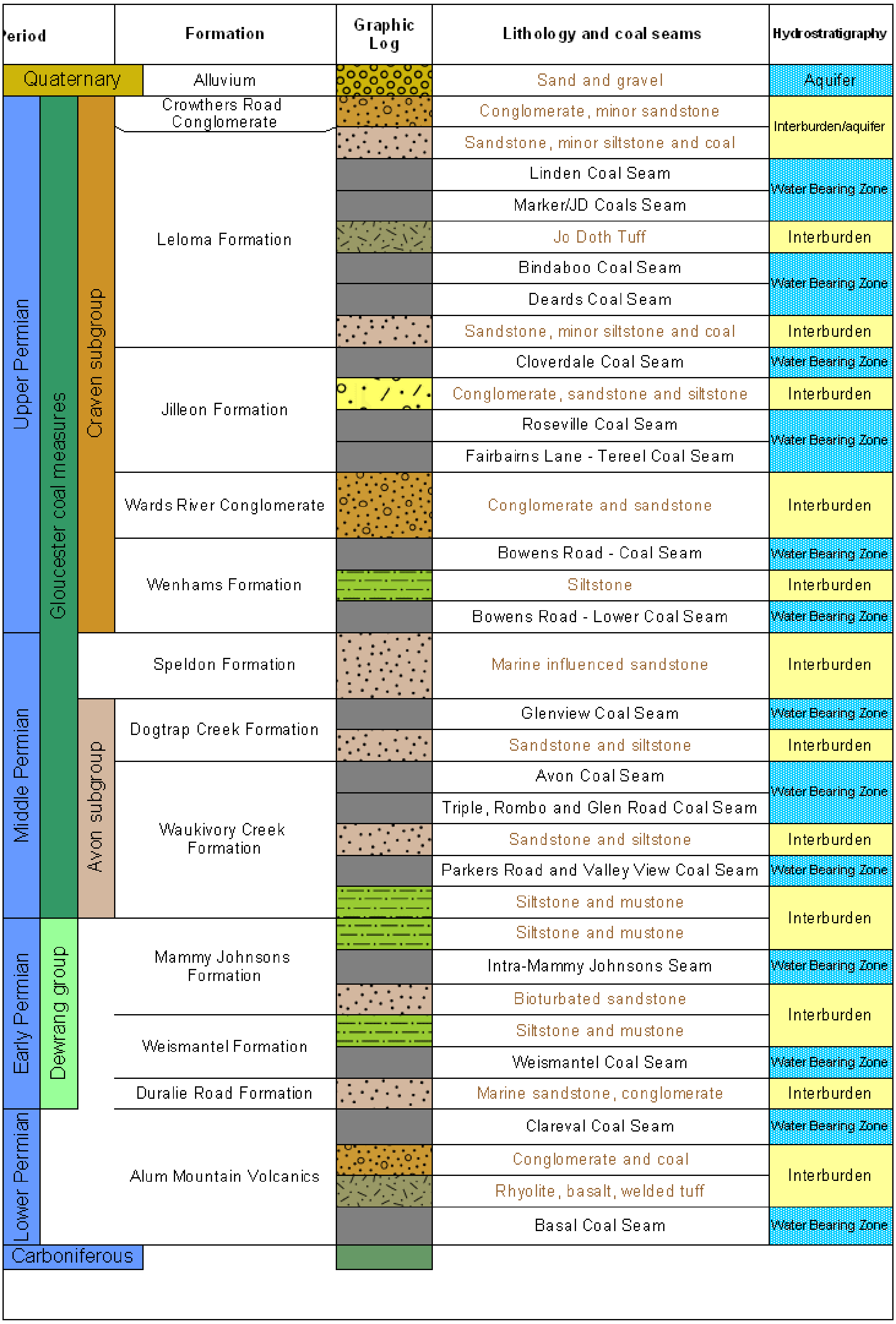

Figure 6-3: Lithology and inferred hydrostratigraphy of the Gloucester Basin

6.2.1 Alluvial aquifers

The alluvial aquifer properties vary regionally and locally depending on the extent and thickness of the alluvial deposits and the nature of the sediments. These aquifers generally occur along the floors of the valleys and occupy the floodplain areas. They are derived from streams draining the ranges and depositing sediments along their path. The alluvium is considered to form porous granular and unconfined aquifers. The hydraulic conductivities reported regionally for the alluviums range between 0.1 and 5 m/day. The water quality reported from the Mammy Johnson River alluvial aquifer indicates that water is slightly acidic (6 < pH < 6.4) and fresh (145 < EC < 900 μS/cm). In the alluvial aquifer of the Gloucester River, water is also slightly acidic (6 < pH < 6.2) and fresh (589 < EC < 800 μS/cm) and the overall inorganic water composition is a mixture of sodium chloride, and magnesium, calcium and bicarbonate type.

6.2.2 Weathered and fractured upper Permian aquifers

The shallow weathered and fractured rock aquifer comprises Permian consolidated formations exposed in the syncline outcrops. Water in the upper Permian rock aquifer is primarily present in fractures, joints and bedding planes within the rocks to depths of 100-150m. These openings are due to the effects of weathering and stress relief when the Permian rocks were exposed at ground surface. This aquifer can either be unconfined or confined locally. At the Duralie Coal Mine site, the clay / claystone layers, varying from 2.5 to 6 m in thickness, effectively act as aquitards, separating the sub-cropping / outcropping Permian formation and the overlying alluvium of the Mammy Johnsons River. Based on data derived from slug and pumping tests undertaken at the Duralie Coal Mine, the hydraulic conductivities of the upper weathered and fractured Permian aquifer located in the Weismantel and Duralie Road Formations range from 0.04 to 3 m/day. The basal depth of the upper weathered and fractured aquifer is estimated at about 150 m bgl.

The water is near neutral to slightly acidic (5.6 < pH < 7.7) and fresh to saline (215 < EC < 9,600 μS/cm). The water is generally a sodium chloride type.

6.2.3 Coal seam water bearing zones

The coal seam water bearing zones are located in the discrete horizons of the coal seams of the Dewrang Group and Gloucester Coal Measures, and can be considered as poored aquifers that are confined. In this report they are mostly referred to as water bearing zones rather than aquifers.

The water movement in the coal seams occurs primarily along the cleat faces that are oriented parallel to the bedding dip direction. Therefore, the hydraulic properties of the coal seams depend on the degree of cleat development and fracturing. The permeability tests undertaken on 28 coal intervals in four exploration boreholes (PGSD 1, 2, 3 and 5) by Pacific Power in 1999 indicate that coal seam permeability decreases sharply with increasing depth. At a depth of 100 m, the permeability averages 100 mD; at 300 m it is 7-27 mD; and at 500 m the permeability is 0.56 mD. The hydraulic conductivity values estimated from these intrinsic permeability data are the following:

- ~ 8.6×10^{-2} m/day at 100 m depth
- ~6.1×10^{-3} to 2.3×10^{-2} m/day at 300 m depth
- ~4.8×10^{-4} m/day at 500 m depth

Water produced from coal seam intervals is reported to be brackish to saline (3,000 < EC < 9,500 μS/cm) with EC measurements increasing with depth. Water is characterised by very low concentration of calcium, magnesium and sulphate, and high concentration of sodium, bicarbonate and chloride. This groundwater quality is typically associated with coal seam methane occurrence and production.

6.2.4 Interburden confining units

Various sandstone and siltstone units horizontally separate the coal seams of the Dewrang Group and Gloucester Coal Measures. The sandstone units are hard and tight with a clay matrix and are not aquifers or water bearing zones. No information is available to describe the hydraulic characteristics of these formations that function as confining units to the coal seam water bearing zones. These units are expected to have lower hydraulic conductivities than the coal seams, and therefore may act as aquitards rather than aquifers/water bearing zones.

6.3 Major features

6.3.1 Faults and fractures

A number of faults have been reported in the area. Some have been geologically mapped on surface and intersected by drilling whilst others have been identified as lineaments on aerial photos. Nevertheless, the exact location, dip and strike of these faults are not yet known but 3D seismic surveys acquired by AGL in 2010 will assist in a better understanding of the structural complexity.

An inferred normal fault intersected at 325 m depth in the Bowens Road coal seam of cored well PGSD3 provides an intrinsic permeability of 67 mD (Pacific Power, 1999). This latter converted in hydraulic conductivity provides an estimated hydraulic conductivity of~5.8 x 10^{-2} m/day, nearly one order of magnitude higher than those estimated for the coal seams at similar depth (~8.6 x 10^{-3} - 1.2 x 10^{-2} m/day).

Fractures present in coal seams or Permian formations can enhance the hydraulic conductivity of the formations by orders of magnitude. If open, and extending for long distances, fractures are also potential pathways for water to migrate to deep coal measures. If closed, fractures may in fact impede groundwater flow.

6.3.2 Igneous rocks

Dolerites are described in the Gloucester Basin and in the Gloucester Gas Pilot project area. Igneous rocks in the form of two thin dykes of presumed tertiary age have been reported in the south of the basin. In the Stratford area, an irregular dolerite intrusion, 5 m thick, and two thin dolerite sills were intersected at the level of the Avon seams in one exploration borehole (PGSD 1). LMGW01 also intersected approximately 5 m of dolerite intrusive at the Avon seams level.

No information on the hydraulic characteristics of these intrusive rocks is available. Generally, dolerites are characterised by low primary hydraulic conductivity values. However, the contact between intrusive rocks and the Permian formations needs to be considered as a local area of high hydraulic conductivity..

6.4 Groundwater level

The regional groundwater levels measured in the regional shallow aquifers (alluvium and Permian rocks) in May 2010 indicate a movement of the regional groundwater from the south towards the north, and from the ridges to the alluvial plains following the natural surface drainage lines. The regional water elevations range between about 130 m RL south of the Stratford Coal Mine to about 98 m RL north of the Stage 1 GFDA.

Therefore, the groundwater flow pattern appears to be controlled by the topography and the recharge / discharge points. The water table depth mimics the topography and is shallower beneath topographic lows, including rivers and streams where seepage is observed, and deeper beneath higher areas including the ridges.

Groundwater levels should fluctuate in response to local rainfall in the alluvial aquifer, whereas such a response should be lower in the upper weathered and fractured Permian aquifers as they present lower hydraulic conductivities.

6.5 Recharge and discharge

Ridges and outcrops are generally considered as being zones of preferred rainfall recharge. Outcropping aquifers, including the alluvial sediments along the valley floor,are recharged via direct infiltration of rainfall. Shallow Permian fractured aquifers and deeper water bearing zones (e.g. coal seams) are recharged around the margin of the basins where individual formations outcrop. Some recharge will also occur through vertical leakage or fault areas where high hydraulic conductivity zones occur.

Towards the centre of the Gloucester Basin, deeper coal seams are confined and artesian conditions are suspected in the Permian water bearing zones. Upward leakage may occur through fault zones. Further geological and hydrogeological studies will assist in determining groundwater flow directions.

Rainfall recharge rates to the alluvial aquifers are considered to be high, as evidenced by the overall inorganic water composition characterised by a mixture of sodium chloride, and magnesium, calcium and bicarbonate type.

Groundwater salinity / quality in the shallow Permian fractured aquifer depends essentially on the proximity to recharge (e.g. faults or sub-crops) and the time that groundwater has been stored in these rocks.

Recharge in the coal seam aquifers (deep aquifers) is considered to be relatively low, as evidenced by the groundwater quality of the coal seams. Indeed, water produced from coal seam intervals is depleted in calcium, magnesium and sulphate, due to sulphate-reduction processes and precipitation of calcite and dolomite at depth.

Discharge from all the hydrogeological units occurs by seepage to springs, rivers and streams. As the Gloucester Basin is a closed basin, most groundwater is expected to discharge in the lower catchment areas of the Avon River and Gloucester River in the vicinity of Gloucester.

7. Gap Analysis and Recommendations

The main objective of the report was to summarise the available hydrological and hydrogeological information, identify gaps in the information and provide inputs and guidance for subsequent phases. The focus is the Gloucester-Stratford-Craven areas so that effective surface water/groundwater monitoring networks can be installed. The main areas in which further investigations are needed, are described below and the specific tasks that should be performed are detailed.

1 Long-term site-specific climatic data is incomplete. More complete information, combined with monitoring data will improve the understanding of the hydrogeology of the area. The meteorological station located at Stratford mine site or the Gloucester Post Office station (site number 060015) can be used for this purpose.

Onsite record of the daily rainfall, temperature and evaporation should be stored in a database format.

2 Detailed geological and structural model of the basement rocks surrounding the area is not available. Spatial distribution of faults and fractures, intrusive dyke locations, as well as formation thicknesses will improve the understanding of the hydrogeology of the area and will help determining the location of any future boreholes for aquifer testing purposes.

A geological 2D or 3D geological model should be developed as more information becomes available.

3 Reliable long-term surface water monitoring data in the vicinity of the Stage 1 GFDA area are not available. The northern part of the project area is not monitored. Based on the government website, the level record at the Avon D/S Waukivory (GS208028) gauging station ended 1 April 2010 and the daily discharge record will end 1 January 2011. Both water level and water quality data sets should be collected – flow data is of lesser importance. Water level should be collected at upstream and downstream gauging stations/gauge boards while water quality should be collected at the same locations and perhaps some sensitive areas in between the gauging sites. A comprehensive monitoring programme, including water quality analyses (physicochemical properties, EC, pH, major cations and anions, trace metals, nutrients, and total dissolved organic carbon) will provide a better understanding of natural variations and, most importantly, will assist in the timely determining of any potential impacts of CSG activities.

Several gauging boards on the Avon River, and several monitoring points on the main creeks surrounding the project area, should be installed. Exact location of the monitoring point will be defined in the phase 2 of the programme. Permanent gauging boards upstream and downstream of the main irrigation areas on the Aitken and Tiedman properties are also recommended.

4 Reliable long-term monitoring data in the shallow aquifers (alluvial and fractured aquifers) in and surrounding the Stage 1 GFDA area are not available. The regional boreholes identified during the survey are mainly poorly completed water supply bores. Dedicated monitoring boreholes would remove any uncertainties regarding the local hydraulic head and groundwater quality. A comprehensive monitoring programme will provide a better understanding of natural variations and, most importantly, will assist in the timely determination of potential impacts of CSG activities (if any) on shallow groundwater aquifers, primarily used by the local landowners.

Monitoring boreholes should be installed in the alluvial and shallow fractured aquifers within the Stage 1 GFDA area. The number of monitoring boreholes required will depend on the geological and hydrogeological site conditions in the area of gas production boreholes. It is estimated that some four to six shallow monitoring bores (< 100 m depth) will be required at several key sites within the Stage 1 GFDA. An initial network should be established on the Tiedman property in the vicinity of the Stratford wells. Regional shallow boreholes within a 600 to 800 m radius from CSG wells could also be used to augment any dedicated monitoring network.

5 Reliable long-term monitoring data of the deep water bearing zones (coal seams) in the Gloucester Gas Pilot area are not available. VWPs should be installed in the targeted coal seams as well as above and below the coal seams in order to determine the impact of CSG extraction on the deep aquifers.

A number of VWPs should be installed in the deep fractured water bearing zones if suitable core sites become available. Ideally monitoring sites should be based on the geological model and hydrogeological site conditions.

6 The thickness of the unconsolidated sediments (alluvium), the hydraulic characteristics of these sediments and the underlying Permian rocks in the Stage 1 GFDA area are reasonably well known. However, the hydraulic characteristics of the contact between the alluvium and the upper fractured rocks, as well as between any intrusive rocks and the deeper Permian rocks are also unknown. The connectivity of the alluvial and fractured Permian aquifers/water bearing zones is an important consideration and at present unknown.

A number of deep holes (150-200 m depth) should be aquifer tested as soon as suitable sites become available. For small diameter holes, it is recommended to core these boreholes and perform continuous packer testing to obtain hydraulic values for the unconsolidated sediments, underlying Permian rocks and intrusive rocks.

7 The impacts of long term irrigation of untreated/treated CSG water is unknown. Shallow water tables can increase in level and volume, and discharge seepage water generated by the over irrigation of treated CSG water to surface water receptors.

It is recommended that additional shallow monitoring bores be constructed in the alluvial areas (near creeks and rivers) where irrigation is proposed. It is important to monitor both shallow groundwater, and upstream and downstream water quality.

8 Water level monitoring programs are required to established baseline variables and impacts (if any) associated with CSG production and irrigation development.

Baseline WL monitoring programs are important to understand the natural variability of the different aquifers systems to rainfall recharge, drought and pumping. A number of baseline monitoring locations should be established to obtain the required data in the main gas production areas.

9 The hydraulic characteristics of the faults and fractures in the Stage 1 GFDA area were not tested. The current understanding of the system considers that the fracture network may contain large volumes of water and may act as preferred pathway for groundwater recharge and the connectivity of aquifers. Therefore, the structural hydraulic characteristics should be investigated.

Two boreholes should be drilled into identified faults. The boreholes should be constructed to a minimum internal diameter of 203 mm. A pumping test should be conducted for at least 72 hours (with a 48-hour recovery) to estimate hydraulic parameters of these structures. Geochemical parameters should also be recorded during the test, and water should be sampled regularly for laboratory analyses (composition and isotope characteristics).

10 Hydrochemical characteristics of the aquifers are also not well understood. A comprehensive baseline assessment of the composition (physicochemical properties, EC, pH, major cations and anions, minors, trace metals, nutrients, and total dissolved organic carbon) and isotopic characteristics of each aquifer in the Stage 1 GFDA area will establish the origin, age and quality of each aquifer and identify any interconnectivity or recharge flow path. This will allow provide data on the hydrodynamic functioning of the multilayered aquifer system and provide a baseline with which subsequent analyses can be compared, to reveal changes in groundwater hydraulics during CSG extraction.

The long-term monitoring boreholes installed in the shallow (alluvial and fractured) aquifers as well as pilot / production wells should be sampled according to an accepted sampling protocol.

11 The occurrence and extent of free gas seeping out of the coal seams in the outcrop areas is not well understood. At least one monitoring site in the outcrop areas on the Tiedman property should be considered to investigate the possibility of updip gas migration when the CSG coal seams are depressurised. The comparison of the composition and isotopic characteristics of any updip gas migrating with those of the coal seam gas will establish their origin..

A suitable (updip) site (to maximum 20 m depth) with multiple monitoring levels should be identified and instrumented.

12 The regional surface and groundwater survey was incomplete and groundwater sampling was undertaken with a bailer or by using the pump installed in the boreholes / wells. Additional boreholes and surface points need to be surveyed in the Gloucester Basin (at least one spring and one boreholes located in the Alum Mountain Volcanic formation and one or two boreholes located in the Alluvium of the Avon River. It is also recommended to site at least two groundwater monitoring sites in the Stage 1 GFDA targeting the alluvial aquifers of the Avon River, Dog Trap creek and Waukivory creek. A portable submersible pump (e.g. Grundfos, MP1) is recommended for the groundwater sampling to minimise the collection of stagnant water in the borehole and get representative samples from the aquifer.

Additional regional surface and groundwater monitoring points should be surveyed and a dedicated submersible pump should be used for future groundwater sampling.

13 The current conceptual model has been constructed using the limited available information.

The conceptual model should be revised and updated once additional information is available from geological and hydrogeological investigations.

8. References

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Appendices

Appendix 1: Bore and Well Desktop Data Summary

Type	Name	mE	mN	Elevation	Owner	Property	Purpose	Casing type	OD (mm)	Depth (m bgl)	WL (m bgl)	Max yield (L/s)	Salinity/ EC (µS/cm)	Lithology
bore	GW200398	396312	6450304	-	-	N/A	Domestic stock	Steel 1mm	140	50	21	1	-	Topsoil to 0.1; tan clay to 0.5m; weathered conglomerate to 8m; hard conglomerate to 15m; hard sandstone to 37m; water cut to 38m; hard sandstone to end.
well	GW011316	398447	6434075	-	private	Coal & Allied	Stock		1219	18.3	17.1	-	good stock	water bearing nominal rock to 18.29m; nominal clay to end
bore	GW200432	398903	6434728	-	-	Glengourdie	Domestic stock	hole	170	60	-	-	-	Topsoil to 0.1m; tan clay to 3m; weathered sandstone to 5m; hard grey sandstone to end.
bore	GW200243	398985	6456378	-	-	-	Test bore	hole	165	40.5	-	-	-	Clay to 3m; hard conglomerate layer to 5m; sticky brown clay to 6m; very weathered rock-conglomarate to 12m; soft grey sandstone to 12.5m; coal seam to 13m; grey shale to 18m; grey sandstone to 23m; grey shale to 26m; coal seam to 27.5; grey shale to 38m; white sandstone to end.
bore	GW80321	399282	6456589	-	-	-	-	-	-	-	-	-	-	-
well	GW023084	399773	6456199	-	private	-	Domestic stock	concrete	1524	6.1	3.7	7.58	good	Water bearing to 2.7m; Sand gravel
bore	GW047870	399805	6434366	-	private	-	Industrial	PVC open thru rock	125	30	12	0.76	-	Soil to 2m; Clay to 4m; Shale Water Supply to end. Water bearing 23-24m
well	GW079760	399821	6445976	-	private	-	-	-	-	-	16.79	-	-	-
bore	GW078436	399862	6446023	-	-	-	Domestic	PVC Class 9 2.5mm	137	27.4	-	0.5	-	Topsoil to 0.5m; yellow clay to 2m; grey clay to 3m; red and white clay to 6m; grey sandstone with clay seams to 12m; coal seam to 12.5m; grey sandstone to 23.5m; coal seam to 24m; grey sandstone to end.
bore	GW071556	399895	6446100	-	-	Stratford public school	Domestic	PVC 2mm	125	34.7	11	0.07	good	Clay to 4.5m; sandstone to 15.5m; volcanic rock to 28m; basalt to end.
well	GW079766	399901	6445853	-	private	-	-	-	-	-	4.4	-	-	-
well	GW079770	399923	6446285	-	private	-	-	-	-	-	3.25	-	-	-
well	GW079769	399970	6446210	-	private	-	-	-	-	-	10.04	-	-	-
well	GW079763	399976	6446193	-	private	-	-	-	-	-	10.31	-	-	-
well	GW079762	399978	6446008	-	private	-	-	-	-	-	18.09	-	-	-
well	GW079768	399981	6446210	-	private	-	-	-	-	-	9.92	-	-	-
well	GW079761	399996	6443251	-	private	-	-	-	-	-	13.39	-	-	-
well	GW079764	400003	6446193	-	private	-	-	-	-	-	10.46	-	-	-
well	GW053390	400204	6457682	-	private	-	Domestic irrigation stock	concrete	1250	6	-	-	-	Loam soil mixed to 6m; gravel river water bearing to end.
bore	GW079771	400268	6445796	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW080357	400296	6454380	-	-	-	Domestic	PVC 2mm	115	40.5	14	0.05	820	brown moist clay to1.5; white dry clay to 4m; orange and grey layer sandstone to 7m; grey sandstone to 19m; coal seam moist to 19.4m; grey sandstone to 22m; water cut to 22.2m; grey sandstone to 29m; water cut to 29.3m; grey sandstone to 37m; water cut to 37.2m; grey sandstone to end.
bore	GW080339	400339	6427228	-	private	Mine site	Mining	-	-	12.8	-	-	-	-
bore	GW080288	400436	6432706	-	-	-	Irrigation Stock	PVC Class 9 2 mm	105	58.2	4.2	0.3	-	Top Soil to 0.3m; Brown Clay to 1m; Hard conglomerate rock pre case. Hole to 5 m - cave in; hard basalt to 9m; water cut at 9.2m; hard basalt to 33m; water cut at 33.3m; hard granite to end
bore	GW200330	400528	6452381	-	-	-	test bore	hole	175	50	-	-	-	Topsoil to 0.1m; tan clay to 1m; weathered shale to 8m; grey shale to end.
bore	GW200451	400540	6459345	-	-	-	Domestic	PVC Clas 9 2mm	140	59	10.5	0.5	-	Topsoil to 0.1m; tan clay to 2.8m; weathered sandstone to 5m; grey shale to 17m; water cut to 17.5m; coal seam to 19m; grey shale to 35m; water cut to 36m; grey shale to end.
bore	GW079742	400597	6420147	-	-	Cedar Grove	Domestic stock	PVC	132	30	4	-	good	Topsoil to 1m; shale to 5m; basalt to end.
bore	GW078759	400610	6419041	-	-	Telegherry	Domestic stock	PVC	125	22	1.5	-	good	Topsoil to 0.5m; clay to 12m; basalt to end.
bore	GW07946	400652	6444553	-	mine	Mine site	Monitoring bore	-	-	17.03	-	-	-	-
bore	GW080577	400967	6459322	-	-	not known	Domestic	PVC Class 9 2mm	144	66	19	0.15		Topsoil to 0.1m; tan clay to 0.6m; conglomerate to 12m; waer cut to 21-21.4m; grey sandstone to 40m; water cut to 40.3m; grey sandstone to end.
bore	GW200271	401117	6460403	-	-	Wattle Close	Domestic	hole	195	42	-	-	-	Topsoil to 0.7m; grey clay to 5m; grey sandstone to 15m; hard grey shale to end.
bore	GW078171	401122	6444326	-	mine	-	-	-	-	-	-	-	-	-
bore	GW078172	401146	6444480		mine	-	-	-	-	-	-	-	-	-
bore	GW07945	401169	6445223	-	mine	Mine site	Monitoring bore	-	-	16.42	-	-	-	-
bore	GW079618	401175	6444265	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079759	401176	6438783	-	private	-	-	-	-	-	-	-	-	-
bore	GW063052	401183	6459539	-	Local gvt	-	Town Water Supply	PVC 4mm slot	140	49.7	-	-	-	Topsoil to 0.2m; clay to 3.5; clay shale to 24.5m; gravel fine water supply to 26.4m; shale to 32.2m; gravel fine water supply to 24.6m; sandstone to end.

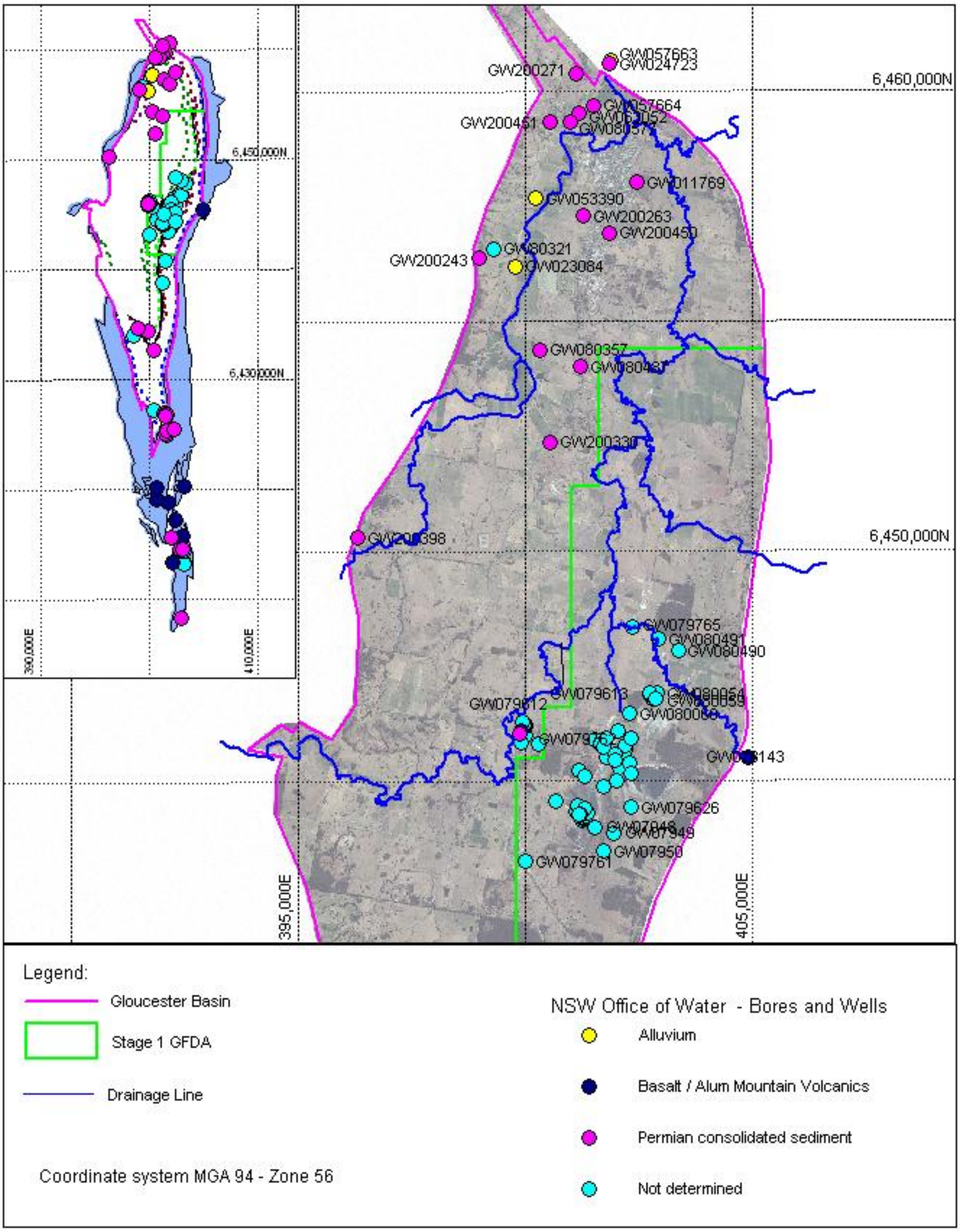
- : No Data

Type	Name	mE	mN	Elevation	Owner	Property	Purpose	Casing type	OD (mm)	Depth (m bgl)	WL (m bgl)	Max yield (L/s)	Salinity/ EC (µS/cm)	Lithology
bore	GW080487	401204	6454014	-	-	-	Domestic	PVC 2mm	140	60	17	0.1	-	Topsoil to 0.2m, brown stiff clay to 2.2m;sandy brown clay to 3m; weathered sandstone to 5m; hard grey shale to 17m, coal seam with water to 18m; hard grey shale to end.
bore	GW079617	401207	6444274	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079610	401228	6444142	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079611	401254	6444173	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079628	401258	644457	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW200263	401272	6457289	-	-	-	Domestic stock	hole	165	45	-	-	-	Topsoil to 0.2m; brown clay to 2.5m; cream sandstone to 7m; coal seam to 8m; grey sandstone to 14m; coal seam to 16m; hard grey shale to 24m; coal seam to 25.5m; hard grey shale to end.
bore	GW079612	401280	6444204	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079629	401291	6445088	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079616	401304	6444389	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079613	401306	6444235	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079614	401332	6444235	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW080776	401342	6426938	-	-	Mine site	Monitoring bore	PVC Class 9 1mm	50	40	9	-	-	Topsoil to 0.1m; sandy tan clay to 0.5m; weathered tan sandstone to 3m; creamy grey sandstone to 6m; soft grey sandstone to 13m; hard grey sandstone to 27m; water cut to 27.5m; hard grey sandstone to 38m; coal seam to 38.5m; hard grey sandstone to end.
bore	GW079615	401366	6444296	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW080781	401396	6426717	-	-	Mine site	Monitoring bore	PVC Class 9 1mm	50	58	25	0.35	-	Topsoil to 0.05m; brown clay to 1m; mudstone to 7m; orange sandstone to 8m; shale to 14m; hard grey shale to 17m; coal seam to 17.5m; shale to 19m; grey sandstone to 36m; coal seam to 26.8m; soft grey shale to 50m; hard grey sandstone to 53m; water cut to 53.5m; hard grey sandstone to end.
bore	GW080778	401407	6426825	-	-	Mine site	Monitoring bore	PVC Class 9 1mm	50	36.5	18	0.75	-	Topsoil to 0.1m; weathered grey sandstone to 9m; creamy grey sandstone to 13m; dark grey sandstone to 14m; coal seam to 14.5m; grey sandstone to 18m; light grey sandstone to 23.6m; water cut to 24.6; hard grey sandstone to end.
bore	GW080638	401416	6425106	-	-	Mine site	Monitoring bore	PVC Class 18 1-2mm	50	28.2	-	-	-	Topsoil to 1m; silstone with iron stone layers to end.
bore	GW078141	401423	6426930	-						36.5	14.09	0.8		Grey, brown soil/sand loam to 2m; Cream/orange, fine grained, weathered litchi sandstone to 9m; dark to mid grey, fine grained litchi sandstone to end
bore	GW080636	401453	6426839	-	-	Mine site	Monitoring bore	PVC Class 18 1-2mm	50	35.7	33.7	0.25	-	Topsoil to 0.5m; extrem weathered rock to 5m; weathered rock to 15m; rock to 35.7.
bore	GW079758	401497	6440788	-	private	-	-	-	-	-	-	-	-	-
bore	GW057664	401497	6459696	-	Local gvt	-	Town Water Supply	PVC 4mm slot	140	54	-	-	-	topsoil clay to 5m; gravel fine to 7.5; shale water bearing (fractures at 10.2-10.4m and 22.6-23m) to 23; coal to 24.1m; shale to 32.4m; coal to 32.7m; shale water bearing (at 37.1-39.8m and 46.7-47.5m) sandstone to end.
bore	GW080063	401517	6445880	-	mine	Mine site	Monitoring bore	-	-	-	4.16	-	-	-
bore	GW080637	401520	6424997	-	-	Mine site	Monitoring bore	PVC Class 18 1-2mm	50	16.4	14	-	-	Topsoil to 1m; siltstone to end. Water bearing from 14-16.4m.
bore	GW080777	401522	6426872	-	-	Mine site	Monitoring bore	PVC Class 9 1mm	50	40	22	1	-	Topsoil to 0.1m; sandy tan clay to 0.5m; weathered tan sandstone to 3m; creamy grey sandstone to 6m; soft grey sandstone to 23m; hard grey sandstone to 33.8m; water cut to 34.2m; hard grey sandstone to end.
bore	GW07948	401532	6444000	-	mine	Mine site	Monitoring bore	-	-	5.97	-	-	-	-
bore	GW200048	401589	6425668	-	Mines	Duralie coal mine	Monitoring bore	PVC Class 9 2mm	50	6	5.72	-	-	sandy loam to 2m; sandy silt to 4m; loam moist to 5m; sandy silt to 6.5m.
bore	GW200049	401595	6425329	-	Mines	Duralie coal mine	Monitoring bore	PVC Class 9 2mm	50	7	4.9	-	-	loam to 0.1m; volcanics to 2m; hard rock to 5m; highly weathered rock to end.
bore	GW080780	401599	6426842	-	-	Mine site	Monitoring bore	PVC Class 9 1mm	50	40	22	0.3	-	Topsoil to 0.1m; brown sandy clay to 0.3m; weathered sandstone to 15m; hard grey sandstone to 30m; water cut to 30.3; hard grey sandstone to end.
bore	GW080064	401643	6445805	-	mine	Mine site	Monitoring bore	-	-	-	3.79	-	-	-
bore	GW078219	401700	6418851	-	-	-	Commercial irrigation	PVC	125	31.5	3	0.53	-	Topsoil to 1m; clay to 12m; blue shale to 20m; basalt to end
bore	GW07950	401701	6443473	-	mine	Mine site	Monitoring bore	-	-	8.28	-	-	-	-
bore	GW080065	401724	6445741	-	mine	Mine site	Monitoring bore	-	-	-	10.46	-	-	-
bore	GW07947	401726	6444863	-	mine	Mine site	Monitoring bore	-	-	6.38	-	-	-	-
bore	GW079625	401765	6445512	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW080066	401776	6445912	-	mine	Mine site	Monitoring bore	-	-	-	3.93	-	-	-
bore	GW024723	401829	6460592	-	Local gvt	-	-	-	-	-	-	-	-	Silt to 3.5m; Sand cobbles to 5m; bedrock EOH
bore	GW200450	401836	6456917	-	-	-	Domestic	hole	170	60	-	-	-	Topsoil to 0.2m; tan clay to 3m; weathered shale to 7m; hard conglomerate to 18m; grey shale to 30m; hard conglomerate to end.
bore	GW057663	401881	6460685	-	Local gvt	-	test bore	-	-	9	-	-	-	Topsoil to 0.6; gravel river very large to 9m.

- : No Data

Type	Name	mE	mN	Elevation	Owner	Property	Purpose	Casing type	OD (mm)	Depth (m bgl)	WL (m bgl)	Max yield (L/s)	Salinity/ EC (µS/cm)	Lithology
bore	GW07949	401944	6443867	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW080061	401979	6445562	-	mine	Mine site	Monitoring bore	-	-	-	11.38	-	-	-
bore	GW080126	401980	6445458	-	mine	Mine site	Monitoring bore	-	-	12.8	-	-	-	-
bore	GW011988	402003	6415663	-	private	-	Fire fighting	steel	152	17.7	-	-	-	Clay to 6.1m; Sandstone to end
bore	GW079606	402008	6445014	-	mine	Mine site	Monitoring bore	-	-	6.03	-	-	-	-
bore	GW080067	402016	6446069	-	mine	Mine site	Monitoring bore	-	-	-	1.51	-	-	-
bore	GW079607	402075	6445297	-	mine	Mine site	Monitoring bore	-	-	-	3.13	-	-	-
bore	GW078586	402152	6413376	-	private	-	Domestic stock	hole	125	33.5	9	-	good	Topsoil to 6m; shale to 12m; basalt to end.
bore	GW079608	402166	6445581	-	mine	Mine site	Monitoring bore	-	-	-	3.98	-	-	-
bore	GW080062	402189	6445683	-	mine	Mine site	Monitoring bore	-	-	-	5.57	-	-	-
bore	GW200244	402195	6425490	-	Mines	Mine site	Mining	PVC Class 9 2mm	50	40	9	0.25	-	Topsoil to 0.1m; tan clay to 0.5m; weathered sandstone to 3m; creamy grey sandstone to 6m; soft grey sandstone to 13m; hard grey sandstone to 27m; water cut to 27.5m; hard grey sandstone to 38m; coal seam to 38.5m; hard grey sandstone to end.
bore	GW079609	402203	6445758	-	mine	Mine site	Monitoring bore	-	-	-	1.92	-	-	-
bore	GW080060	402274	6446469	-	mine	Mine site	Monitoring bore	-	-	-	1.19	-	-	-
bore	GW079624	402294	6445382	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079626	402321	6444431	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079627	402323	6445917	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW079623	402330	6445171	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
well	GW079765	402361	6448334	-	private	-	-	-	-	-	-	-	-	-
well	GW011769	402431	6458011	-	private	-	Domestic	concrete	1524	7.3	-	-	-	shale soft
bore	GW078585	402432	6417275	-	private	Not known	test bore	PVC	125	19	3	9.3	good	Topsoil to 0.5m; red shale to 12m; basalt to end.
bore	GW080057	402714	6446868	-	mine	Mine site	Monitoring bore	-	-	-	0.08	-	-	-
bore	GW080055	402719	6446918	-	mine	Mine site	Monitoring bore	-	-	-	0.85	-	-	-
bore	GW022488	402721	6414346	-	private	-	Irrigation Stock	steel	152	25.2	-	-	-	
bore	GW080484	402734	6414554	-	-	Keepers Cottage	Domestic	PVC Class 9 2 mm	140	39	8.5	2	-	Top soil to 0.4m; tan clay to 4.5m; weathered silstone to 5.5m; hard blue sildtone to 32m; water cut to 33m; hard blue silstone to end.
bore	GW080058	402788	6446780	-	mine	Mine site	Monitoring bore	-	-	-	2.67	-	-	-
bore	GW080059	402866	6446786	-	mine	Mine site	Monitoring bore	-	-	-	0.83	-	-	-
bore	GW080054	402888	6446898	-	mine	Mine site	Monitoring bore	-	-	-	-	-	-	-
bore	GW080491	402924	6448098	-	private	Stratford Colliery	Commercial	-	-	-	-	-	-	-
bore	GW047793	402936	6408343	-	private	Not known	Domestic irrigation stock	PVC open thru rock	155	59	-	0.13	-	Soil to 1m; clay to 16m; Shale to end. Water bearing fracture 21-22m and 47-48m
bore	GW051643	403021	6415765	-	private	-	Farming stock	PVC open thru rock	155	23	7.6	1.89	good	Soil to 1m; clay to 6m; clay decomposed to 12m; shale water supply to 16m; basalt to end. Fracture water bearing at 12-13m.
bore	GW080578	403069	6414614	-	-	-	Domestic stock	PVC 2 mm	140	26	7	1	-	Topsoil to 0.2m; brown clay to 1m; weathered siltstone to 3m; hard blue siltstone to 26m.
bore	GW080509	403129	6413159	-	Local gvt	-	test bore	-	-	-	-	-	-	-
bore	GW080571	403129	6414366	-	private	-	Domestic	-	-	-	-	-	-	-
bore	GW050402	403134	6420263	-	private	-	Stock	PVC open thru rock	150	26	-	0.75	good	Soil to 1m; Loam clay to 8m; Basalt water supply to end. Fracture water bearing 18-19m.
bore	GW054253	403228	6413304	-	private	-	Domestic farming stock	PVC 6mm	160	22	9	1.77	good	-
bore	GW080490	403349	6447816	-	private	Stratford Colliery	Commercial	-	-	-	-	-	-	-
bore	GW200431	403353	6435280	-	-	Myidaho	Domestic stock	Stell 2mm	116	60	8	-	1300	Topsoil to 0.2m; light grey clay to 1.5m; tan clay to 4m; grey shale to 20m; grey sandstone to 30m; water cut to 30.5m; grey sandstone to end.
bore	GW078143	404884	6445501	-	-	-	Stock	PVC 2.5mm	137	18	1.5	1.9	1900	Topsoil to 1m; clay to 4m; decomposed basalt to end. Water bearing at 10.8-11m.

- : No Data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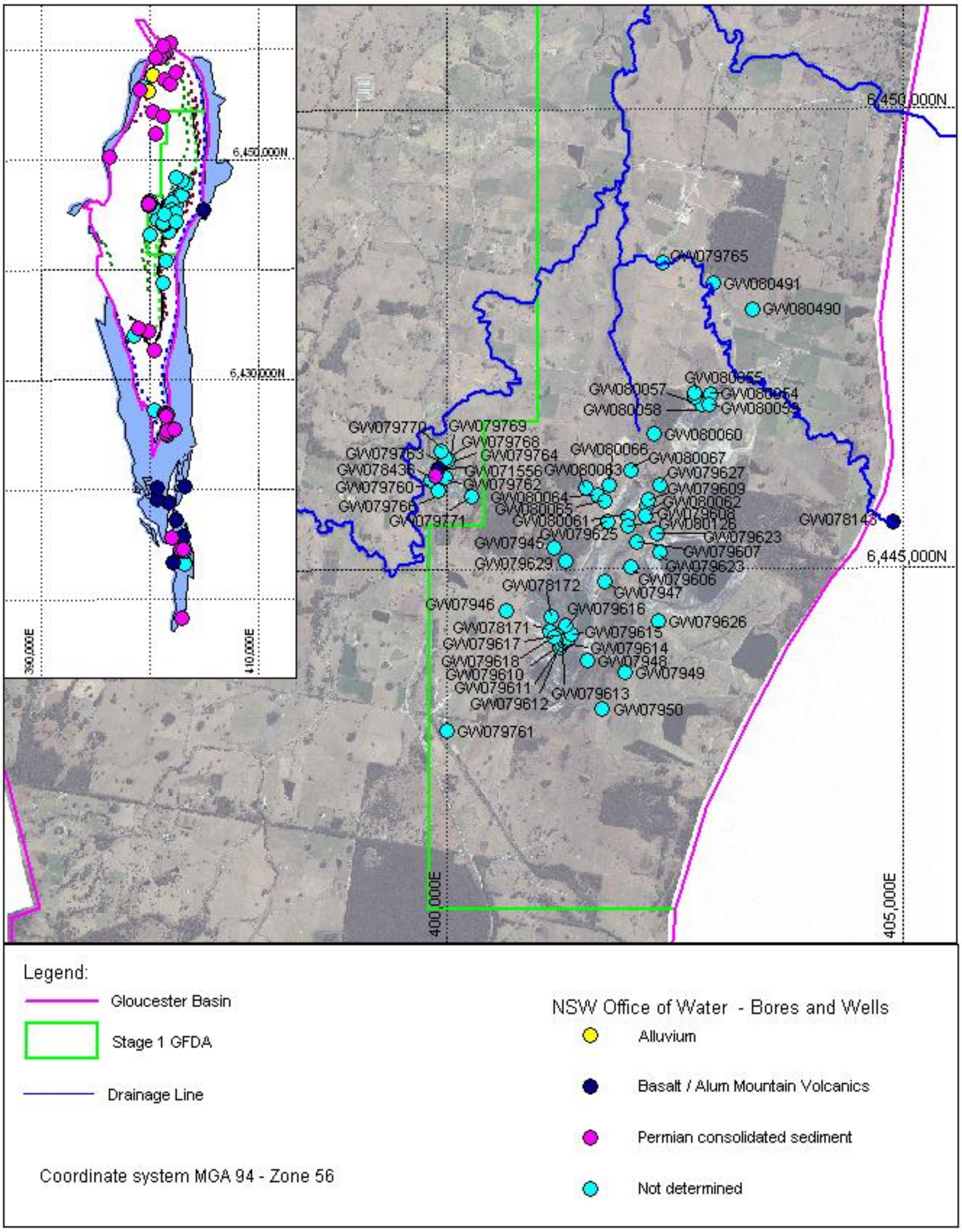
Gloucester Basin
Stage 1 GFDA
Drainage Line
Coordinate system MGA 94 - Zone 56
NSW Office of Water - Bores and Wells
Alluvium
Basalt / Alum Mountain Volcanics
Permian consolidated sediment
Not determined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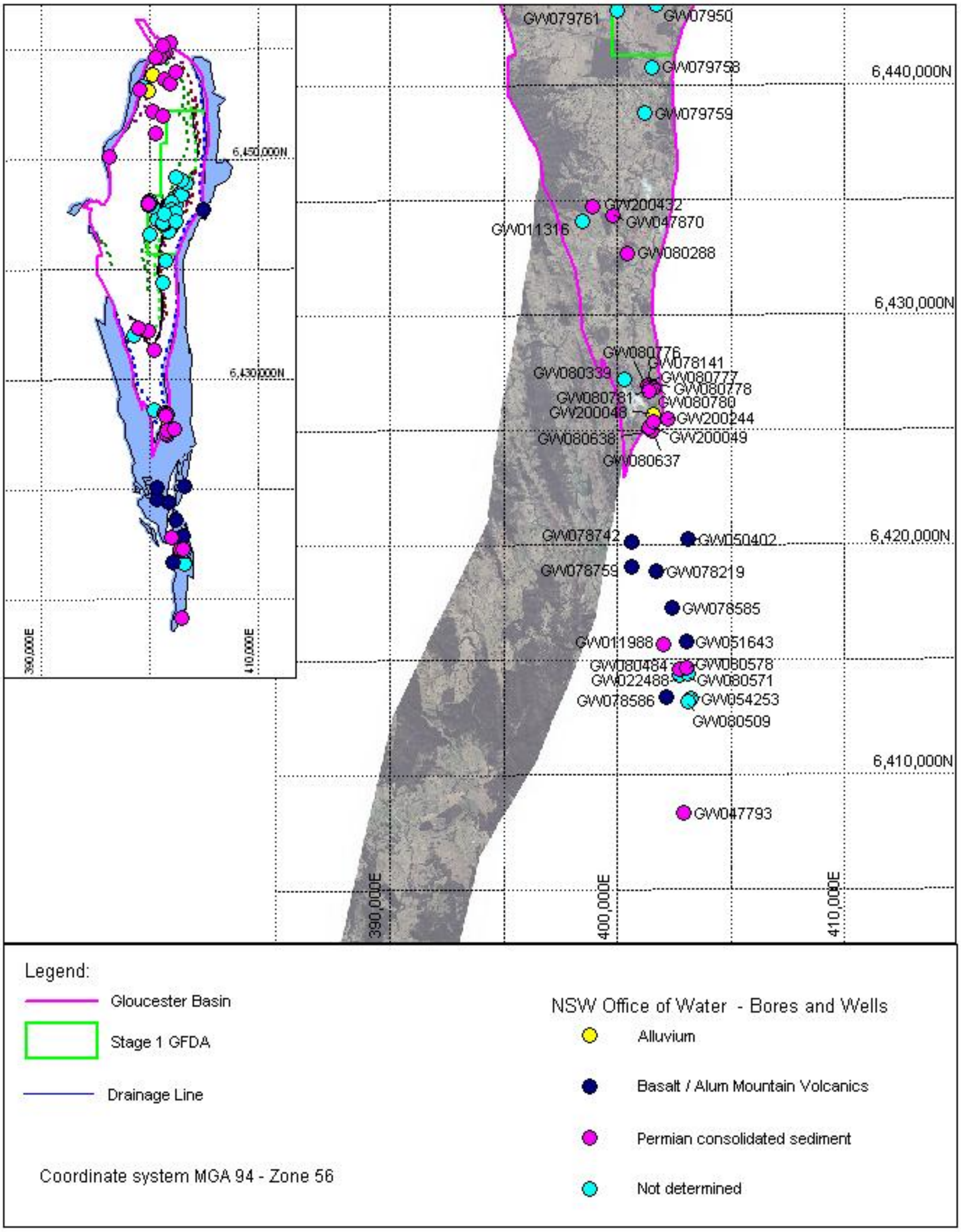
Stage 1 GFDA
Drainage Line
Coordinate system MGA 94 - Zone 56
NSW Office of Water - Bores and Wells
Alluvium
Basalt / Alum Mountain Volcanics
Permian consolidated sediment
Not determined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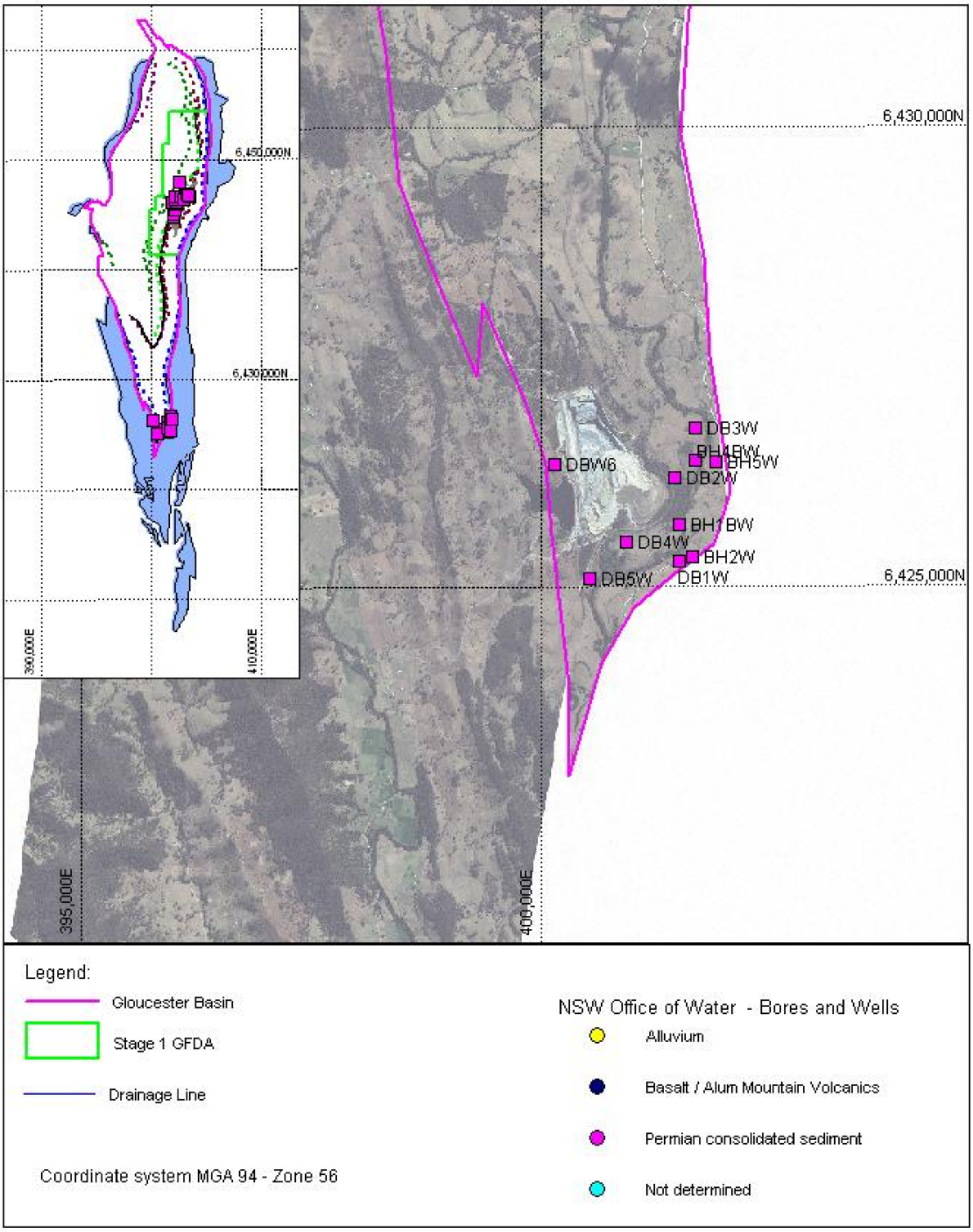
Legend:
Gloucester Basin
Stage 1 GFDA
Drainage Line
Coordinate system MGA 94 - Zone 56
NSW Office of Water - Bores and Wells
Alluvium
Basalt / Alum Mountain Volcanics
Permian consolidated sediment
Not determined

Appendix 2: Duralie Coal Mine Monitoring Borehole Coordinates

Borehole	mE	mN	Formations targeting
DB1W	401490	6425280	Upper Duralie Road Formation
DB2W	401450	6426190	Upper Duralie Road Formation
DB3W	401670	6426730	Alluvium
DB4W	400920	6425480	Upper Duralie Road Formation
DB5W	400530	6425090	Upper Duralie Road Formation
DBW6	400140	6426330	Alluvium
BH1BW	401500	6425670	Sandstone of the Duralie Road Formation
BH4BW	401660	6426370	Alluvium
BH5W	401890	6426350	Alluvium
BH2W	401640	6425320	Sandstone of the Duralie Road Formation
BH6W	-	-	Sandstone of the Duralie Road Formation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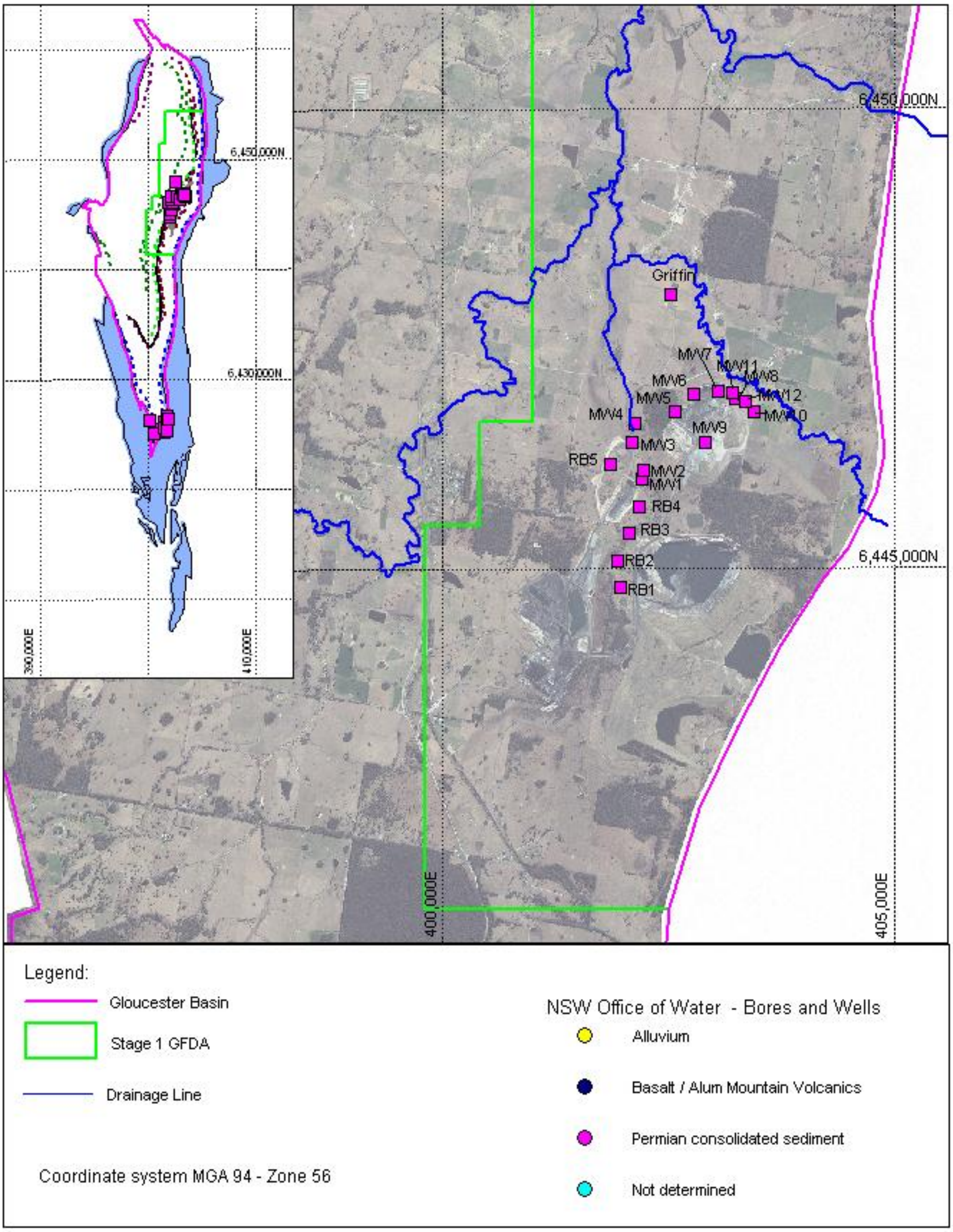
BH4BW
BH5W
DBW6
DB2W
BH1BW
DB4W
BH2W
DB5W
DB1W
395,000E
400,000E
Legend:
Gloucester Basin
Stage 1 GFDA
Drainage Line
Coordinate system MGA 94 - Zone 56
NSW Office of Water - Bores and Wells
Alluvium
Basalt / Alum Mountain Volcanics
Permian consolidated sediment
Not determined

Appendix 3: Stratford Coal Mine Monitoring Borehole Coordinates

Borehole	Depth borehole depth (m)	mE	mN	RL	Status	Details
RB1	12.9	402527	6447985	110	monitoring	no data
RB2	6	401969	6444798	119	monitoring	no data
RB3	12	401935	6445091	115	monitoring	no data
RB4	3	402062	6445391	117	destroyed	no data
RB5		401847	6446127	110	monitoring	no data
MW1	4.7	402207	6445970	112	monitoring	0-0.1 top soil, 0.1-0.6 moist clay, 0.6-1 snady miost clay, 1-2 miost clay, 2-3 miost silty clay, 3-4.7 weathered sandstone
MW2	7	402224	6446068	113	monitoring	0-0.1 top soil, 0.1-0.5 dry clay, 0.5-3 sandy miost clay, 3-5 weathered sandstone, 5-6 weathered mudstone, 6-7 mudstone
MW3	5	402092	6446380	118	monitoring	0-1.8 miost clay, 1.8-2 clay, 2-3 sandy miost clay, 3-4 wet sandy clay, 4-5 gravels with water
MW4	15.5	402121	6446587	124	monitoring	0-0.5 top soil, 0.5-1 dry clay, 1-2.2 weathered siltstone, 2.2-4.5 mudstone, 4.5-5 sandstone, 5-9.3 mudstone, 9.3-10 ryolith, 10-15.5 mudstone moisture 13.5
MW5	16.5	402569	6446707	124	monitoring	0-0.1 top soil, 0.1-2-clay, 2-3 miost clay, 3-3.8 iron stone band, 3.8-5.3 mudstone, 5.3-8.8 sandstone, 8.8-13.4 mudstone, 13.4-13.6 coal seam, 13.6-16.5 mudstone
MW6	10			121	monitoring	0-0.1 top soil, 0.1-1 orange clay, 1-3 weathered sandstone, 3-5 mudstone, 5-5.5 siltstone, 5.5-10 mudstone miost at 7.5 m
MW7	10	403041	6446928	118	monitoring	0-0.1top soil, 0.1-0.5 clay,0.5-2.3 weathered sandstone, 3-10 mudstone
MW8	6.9	403239	6446839	120	monitoring	0-0.1 top soil, 0.1-1.5 brown clay, 2.5-3 siltstone, 3-5.7 coal seam, 5.7-6.9 mudstone
MW9	8	402907	6446369	120	monitoring	0-0.5 top soil, 0.05-1 silt, 1-2.5 clay, 2.5-4.5 weathered sandstone, 5-5.5 mudstone, 5.5-7 sandstone, 7-7.5 mudstone, 7.5-8 coal seam
MW10	20	403440	6446694	125	destroyed	0-0.2 top soil, 0.2-2.5 clay, 2.5-6 weathered sanstone, 6-16.6 sandstone caol, 16.6-20 sandstone
MW11	9	403200	6446910	118	monitoring	0-0.2 top soil, 0.2-6 sandy clay, 6-9 gravels water free
MW12	40	403355	6446816	121	monitoring	0-0.2 top soil, 0.2-4 sandy clay, 4-6 dry gravels, 6-17 sandstone, 17-18 water cut, 18-40 sandstone
Griffin	-	402527	6447985	110	monitoring	no data

RB : Groundwater Bores Monitored as Part of Roseville Pit Development Consent
MW : Bowens Road North Groundwater Monitoring Bores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MW11
MW8
MW6
MW5
MW12
MW4
MW10
MW9
MW3
RB5
MW2
MW1
RB4
RB3
RB2
RB1
Legend:
Gloucester Basin
Stage 1 GFDA
Drainage Line
Coordinate system MGA 94 - Zone 56
NSW Office of Water - Bores and Wells
Alluvium
Basalt / Alum Mountain Volcanics
Permian consolidated sediment
Not determined

Appendix 4: Lab Reports - ACIRL Pty Ltd Hydrochemistry Analysis

ACIRL Pty Ltd

(ABN 66 876)
Unit 2, Lot 6 Industrial Close 003 451
, Muswellbrook 2333
Phone: (02) 6542 2400
Fax: (02) 6543 3234

Origin:	AGL Gloucester LE Pty Ltd	**Report No:**	6800 4114 – 00 Page 1 of 3
Description:	Water Samples Received 6th May 2010	**Date:**	9th July 2010
Report To:	Kate Harper	**Copy to:**	File

	Units of Measure	WELL 1 03/05/10	WELL 2 03/05/10	SUMP 1 03/05/10	PIGGERY 04/05/10	W1 04/05/10
pH	-	6.2	6.2	6.0	6.7	7.7
Electrical Conductivity	µs/cm	570	590	220	7700	350
Total Suspended Solids	mg/L	4	3	33	12	1
Total Dissolved Solids	mg/L	226	258	74	4375	136
Bicarbonate	mg/L	66	108	22	600	70
Carbonate	mg/L	<1	<1	<1	<1	<1
Total Alkalinity	mg/L	66	108	22	600	70
Chloride	mg/L	96	109	49	2390	52.7
Sulphate	mg/L	53.3	7.07	2.44	2.57	4.16
Sillicon	mg/L	11.2	8.59	13.4	7.96	8.11
Sodium	mg/L	59	68	26	1160	29
Calcium	mg/L	20	19	4	222	16
Potassium	mg/L	6	6	3	14	3
Magnesium	mg/L	15	14	5	148	8
Nitrate	mg/L	<0.01	<0.01	0.07	2.39	0.06
Total Phosphorus	mg/L	<0.01	0.04	0.17	0.6	0.04
Aluminium	mg/L	<0.01	<0.01	0.08	<0.01	<0.01
Arsenic	mg/L	0.001	<0.001	<0.007	<0.001	<0.001
Beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.116	0.126	0.037	6	0.039
Boron	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Cobalt	mg/L	0.003	0.002	<0.001	<0.001	<0.001
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	<0.001	0.002	0.004	<0.001
Fluoride	mg/L	0.04	0.03	<0.02	<0.02	0.09
Iron	mg/L	0.06	0.09	<0.05	0.58	1
Lithium	mg/L	0.002	<0.001	<0.001	0.403	0.002
Lead	mg/L	<0.001	<0.001	<0.001	0.008	<0.001
Molybdenum	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.551	0.69	0.004	0.158	0.088
Mercury	mg/L	<0.0001	<0.0001	<0.0001	0.0002	<0.0001
Nickel	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	mg/L	<0.001	<0.001	<0.001	0.001	<0.001
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Tin	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	0.355	0.343	0.058	7.94	0.196
Zinc	mg/L	0.011	<0.005	0.006	0.01	<0.005

ACIRL Pty Ltd

(ABN 66 003 451 876)
Unit 2, Lot 6 Industrial Close, Muswellbrook 2333
Phone: (02) 6542 2400
Fax: (02) 6543 3234

Origin: AGL Gloucester LE Pty Ltd
Description: Water Samples
Received 6th May 2010
Report To: Kate Harper

Date: 9th July 2010
Copy to: File

	Units of Measure	GRIFFIN 04/05/10	AR1 04/05/10	AR2 04/05/10	GW080357 05/05/10	GW080487 05/05/10
pH	-	6.8	7.1	7.1	7.1	7.3
Electrical Conductivity	µs/cm	1500	270	270	1600	3400
Total Suspended Solids	mg/L	1	2	2	1	2
Total Dissolved Solids	mg/L	812	126	100	904	2022
Bicarbonate	mg/L	238	63	63	578	1090
Carbonate	mg/L	<1	<1	<1	19	57
Total Alkalinity	mg/L	238	63	63	597	1150
Chloride	mg/L	335	39.6	40.1	174	492
Sulphate	mg/L	8.44	4.76	4.64	52	52.2
Sillicon	mg/L	18.3	7.98	7.94	10.5	9.51
Sodium	mg/L	220	22	23	366	859
Calcium	mg/L	51	14	14	34	38
Potassium	mg/L	2	2	2	4	6
Magnesium	mg/L	29	7	7	20	23
Nitrate	mg/L	0.01	0.02	0.04	0.01	0.03
Total Phosphorus	mg/L	0.12	0.21	0.12	0.09	0.17
Aluminium	mg/L	<0.01	0.02	0.01	<0.01	<0.01
Arsenic	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	1.4	0.023	0.023	0.171	0.672
Boron	mg/L	<0.05	<0.05	<0.05	<0.05	0.06
Cobalt	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	<0.001	<0.001	<0.001	0.001	<0.001
Fluoride	mg/L	0.04	0.09	0.09	0.38	0.07
Iron	mg/L	2.62	0.93	0.87	2.58	<0.05
Lithium	mg/L	0.168	0.001	0.002	0.074	0.315
Lead	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.191	0.044	0.052	0.25	0.034
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Tin	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	1.04	0.161	0.158	1.07	3.81
Zinc	mg/L	0.008	<0.005	<0.005	0.012	<0.005

ACIRL Pty Ltd

(ABN 66 003 451 876)
Unit 2, Lot 6 Industrial Close, Muswellbrook 2333
Phone: (02) 6542 2400
Fax: (02) 6543 3234

ACIRL

Origin:	AGL Gloucester LE Pty Ltd	**Report No:**	6800 4114 – 00 Page 3 of 3
Description:	Water Samples Received 6th May 2010	**Date:**	9th July 2010
Report To:	Kate Harper	**Copy to:**	File

	Units of Measure	GW047521 05/05/10	GW080491 06/05/10
pH	-	6.1	6.9
Electrical Conductivity	µs/cm	250	340
Total Suspended Solids	mg/L	216	58
Total Dissolved Solids	mg/L	22	22
Bicarbonate	mg/L	64	106
Carbonate	mg/L	<1	<1
Total Alkalinity	mg/L	64	106
Chloride	mg/L	27.2	28.2
Sulphate	mg/L	10.4	0.8
Sillicon	mg/L	4.2	7.1
Sodium	mg/L	22	24
Calcium	mg/L	9	9
Potassium	mg/L	4	6
Magnesium	mg/L	7	4
Nitrate	mg/L	0.12	0.02
Total Phosphorus	mg/L	0.37	1.54
Aluminium	mg/L	0.11	0.06
Arsenic	mg/L	<0.001	0.001
Beryllium	mg/L	<0.001	<0.001
Barium	mg/L	0.051	0.275
Boron	mg/L	<0.05	<0.05
Cobalt	mg/L	<0.001	<0.001
Cadmium	mg/L	<0.0001	<0.0001
Chromium	mg/L	<0.001	<0.001
Copper	mg/L	0.002	0.001
Fluoride	mg/L	0.03	0.13
Iron	mg/L	0.32	2.9
Lithium	mg/L	<0.001	0.014
Lead	mg/L	<0.001	<0.001
Molybdenum	mg/L	<0.001	<0.001
Manganese	mg/L	0.107	0.053
Mercury	mg/L	<0.0001	<0.0001
Nickel	mg/L	<0.001	<0.001
Silver	mg/L	<0.001	<0.001
Selenium	mg/L	<0.01	<0.01
Tin	mg/L	<0.001	<0.001
Titanium	mg/L	<0.01	<0.01
Thallium	mg/L	<0.001	<0.001
Antimony	mg/L	<0.001	<0.001
Uranium	mg/L	<0.001	<0.001
Vanadium	mg/L	<0.01	<0.01
Strontium	mg/L	0.088	0.436
Zinc	mg/L	<0.005	<0.005

Note: *1. Sampled by client, Analysis as received*
2. Elemental analysis analysed as total unless indicated otherwise

Reported By: T. Tomkins

Tammy Tomkins
Environmental Supervisor

- Analysed Analysed in accordance with APHA Standard Methods.

ALS Environmental Report – ES1009017

ACIRL Pty Ltd

(ABN 66 003 451 876)
Unit 2, Lot 6 Industrial Close, Muswellbrook 2333
Phone: (02) 6542 2400
Fax: (02) 6543 3234

Origin:	AGL Gloucester LE Pty Ltd	**Report No:**	6800 4114 – 00a Page 1 of 1
Description:	Water Samples Received 6th May 2010	**Date:**	9th July 2010
Report To:	Kate Harper	**Copy to:**	File

	Units of Measure	GW2 04/05/10	GW7 04/05/10	GCL 04/05/10	AVON RIVER 04/05/10	MW11 05/05/10	8013R 06/05/10
pH	-	6.5	6.4	7.3	7.3	7.0	6.8
Electrical Conductivity	µs/cm	4500	1900	7000	310	1300	1940
Total Suspended Solids	mg/L	18	147	37	1	2	1
Total Dissolved Solids	mg/L	2115	958	3845	120	796	964
Bicarbonate	mg/L	247	126	670	69	373	244
Carbonate	mg/L	<1	<1	<1	<1	<1	<1
Total Alkalinity	mg/L	247	126	670	69	373	244
Chloride	mg/L	1290	489	2000	53.1	204	499
Sulphate	mg/L	14	47.6	98.5	4.04	5.52	3.32
Sillicon	mg/L	17.8	13.6	10.5	7.81	8.87	15.7
Sodium	mg/L	697	306	1180	29	243	320
Calcium	mg/L	37	28	194	16	55	76
Potassium	mg/L	24	5	8	3	3	4
Magnesium	mg/L	102	37	156	8	10	26
Nitrate	mg/L	0.23	0.51	0.02	0.05	<0.01	1.6
Total Phosphorus	mg/L	0.08	0.44	0.03	0.05	0.12	0.18
Aluminium	mg/L	<0.01	0.02	<0.01	0.01	0.01	<0.01
Arsenic	mg/L	<0.001	0.003	<0.001	<0.001	0.001	<0.001
Beryllium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	2.05	0.075	0.133	0.039	2.3	2.58
Boron	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cobalt	mg/L	0.002	0.002	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.001
Fluoride	mg/L	0.46	0.1	<0.02	0.09	0.09	0.14
Iron	mg/L	7.55	5.66	<0.05	1.09	0.5	<0.05
Lithium	mg/L	0.228	0.034	0.411	0.002	0.044	0.163
Lead	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	1.33	0.726	0.244	0.086	0.026	0.037
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel	mg/L	0.002	0.001	<0.001	<0.001	<0.001	<0.001
Silver	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tin	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Antimony	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	0.488	0.578	8.47	0.189	2.74	3.2
Zinc	mg/L	0.016	<0.005	<0.005	<0.005	<0.005	0.008

Note: *1. Sampled by client, Analysis as received*
2. Elemental analysis analysed as total unless indicated otherwise

Reported By: ______________________
Tammy Tomkins
Environmental Supervisor

- Analysed Analysed in accordance with APHA Standard Methods.

ALS ALS Environmental Report – ES1009017