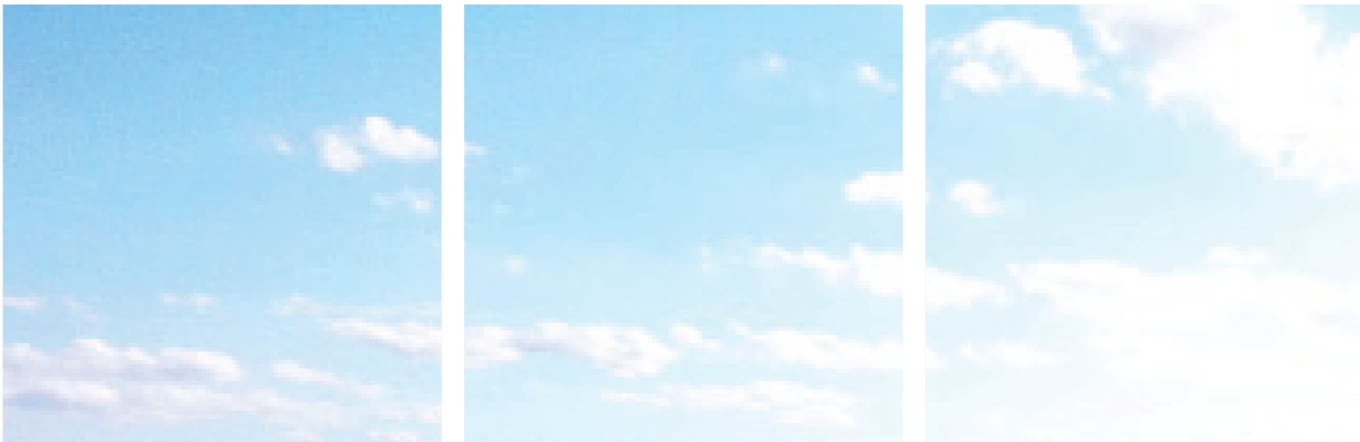

AGL Upstream Investments Pty Ltd

2012 Gloucester Groundwater and Surface Water Monitoring

Annual Status Report

September 2012

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PARSONS BRINCKERHOFF

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Glossary

Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
Anthropogenic	Occurring because of, or influenced by, human activity.
Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
Aquifer properties	The characteristics of an aquifer that determine its hydraulic behaviour and its response to abstraction.
Aquifer, confined	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Aquifer, semi-confined	An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the leaky confining layer – also known as a leaky artesian or leaky confined aquifer.
Aquifer, unconfined	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
Aquitard	A low permeability unit that can store groundwater and also transmit it slowly from one formation to another. Aquitards retard but do not prevent the movement of water to or from adjacent aquifers.
Artesian water	Groundwater that is under pressure when tapped by a bore and is able to rise above the level at which it is first encountered. It may or may not flow at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is a confined aquifer.
Australian Height Datum (AHD)	The reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of aquifers and water levels in bores.
Baseflow	The part of stream discharge that originates from groundwater seeping into the stream.

Baseline sampling	A period of regular water quality and water level measurements that are carried out over a period long enough to determine the natural variability in groundwater conditions.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Coal	A sedimentary rock derived from the compaction and consolidation of vegetation or swamp deposits to form a fossilised carbonaceous rock.
Coal seam	A layer of coal within a sedimentary rock sequence.
Coal seam gas (CSG)	Coal seam gas is a form of natural gas (predominantly methane) that is extracted from coal seams.
Concentration	The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample).
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.
Confining layer	Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients.
Datalogger	A digital recording instrument that is inserted in monitoring and pumping bores to record pressure measurements and water level variations.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Discharge area	An area in which there are upward or lateral components of flow in an aquifer.
Drawdown	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.
Electrical Conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity.

Fracture	Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions.
Fractured rock aquifer	These occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary rock aquifers.
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
Groundwater flow	The movement of water through openings in sediment and rock within the zone of saturation.
Groundwater system	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.
Hydraulic conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water).
Hydraulic gradient	The change in total hydraulic head with a change in distance in a given direction.
Hydraulic head	Is a specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between two or more points.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrology	The study of the occurrence, distribution, and chemistry of all surface waters.
Infiltration	The flow of water downward from the land surface into and through the upper soil layers.
Lithology	The study of rocks and their depositional or formational environment on a large specimen or outcrop scale.
MicroSiemens per centimetre (µS/cm)	A measure of water salinity commonly referred to as EC (see also Electrical Conductivity). Most commonly measured in the field with calibrated field meters.

Monitoring bore	A non-pumping bore, is generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter.
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permeable material	Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present.
Permian	The last period of the Palaeozoic era that finished approximately 230 million years before present.
Piezometer	See monitoring bore.
Potentiometric surface	The potential level to which water will rise above the water level in an aquifer in a bore that penetrates a confined aquifer; if the potential level is higher than the land surface, the bore will overflow and is referred to as artesian (same as piezometric surface).
Precipitation	(1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral.
Quaternary	The most recent geological period extending from approximately 2.5 million years ago to the present day.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Recharge area	A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones.
Recovery	The difference between the observed water level during the recovery period after cessation of pumping and the water level measured immediately before pumping stopped.
RL	Reduced level or height, usually in metres above or below an arbitrary or standard datum.

Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).
Salinity classification	***Fresh water quality –*** water with a salinity <800 µS/cm. ***Marginal water quality –*** water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. ***Brackish quality –*** water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. ***Slightly saline quality –*** water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. ***Moderately saline quality*** – water that is more saline than brackish water and generally waters between 10,000 and 20,000 µS/cm. ***Saline quality*** – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 µS/cm. ***Seawater quality*** – water that is generally around 55,000 µS/cm.
Saturated zone	The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric pressure. The water table is the top of the saturated zone in an unconfined aquifer.
Screen	A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material.
Sandstone	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).
Sedimentary rock aquifer	These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest volumes of groundwater.
Shale	A laminated sedimentary rock in which the constituent particles are predominantly of clay size.
Siltstone	A fine-grained rock of sedimentary origin composed mainly of silt-sized particles (0.004 to 0.06 mm).
Specific storage	Relating to the volume of water that is released from an aquifer following a unit change in the hydraulic head. Specific storage normally relates to confined aquifers.

Specific yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Specific yield generally relates to unconfined aquifers. Gravity drainage may take many months to occur.
Standing water level (SWL)	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Surface water-groundwater interaction	This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table adjacent to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater through streambeds when the elevation of the water table is lower than the water level in the stream.
Tertiary	Geologic time at the beginning of the Cainozoic era, 65 to 2.5 million years ago, after the Cretaceous and before the Quaternary.
Total Dissolved Solids (TDS)	A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). See also EC.
Tuff	Tuff is a type of volcanic rock consisting of consolidated explosive ash ejected from vents during a volcanic eruption.
Unsaturated zone	That part of an aquifer between the land surface and water table. It includes the root zone, intermediate zone and capillary fringe.
Water bearing zone	Geological strata that are saturated with groundwater but not of sufficient permeability to be called an aquifer.
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists.
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.
Well	Pertaining to a gas exploration well or gas production well.
Wellbore	A wellbore is the physical hole that makes up the well and can be cased, open or be a combination of both completions. In this report it generally refers to uncased gas exploration boreholes prior to a gas well being completed.

List of Units

m	metres
m AHD	metres Australian Height Datum
m bgl	metres below ground level
mbtoc	metres below top of casing
m/day	metres per day
m^3/day	cubic metres per day
m/year	metres per year
µS/cm	microSiemens per centimetre
mg/L	milligrams per litre

List of Abbreviations

AGL	AGL Upstream Investments Pty Ltd
BoM	Bureau of Meteorology
CSG	Coal seam gas
EC	Electrical Conductivity
GFDA	Gas Field Development Area
GGP	Gloucester Gas project
PEL	Petroleum Exploration Licence
PPL	Petroleum Production Lease

Executive summary

AGL Upstream Investments Pty Ltd (AGL) is proposing to develop the Gloucester Gas Project (GGP) which will comprise several stages of development; however, only one stage, the Stage 1 Gas Field Development Area (GFDA) is currently approved.

A comprehensive groundwater investigation (Phase 2 Groundwater Investigations) was completed in early 2012 to confirm the hydrogeological conceptual model across the Stage 1 GFDA (Parsons Brinckerhoff 2012a). The investigation established a dedicated water monitoring network to obtain baseline water level and water quality attributes for each of the hydrogeological units represented across the basin.

This annual status report provides the first annual review of the monitoring network detailing groundwater and surface water level and water quality trends for the period January 2011 to June 2012 and specifically for the period from early 2012 (following the completion of the initial Phase 2 groundwater investigation (Parsons Brinckerhoff 2012a)) to June 2012.

The following conclusions are drawn from a review of the 18 months of baseline groundwater and surface water monitoring data:

- Climatic data collected on site indicates that monthly rainfall was above long term average between June 2011 and February 2012, with approximately 380 mm (48%) more rain falling over that period than the long term average. Slightly lower than average rainfall conditions have prevailed since March 2012.

- There were three notable high rainfall events in June 2011 (201 mm), November 2011 (112 mm) and February 2012 (162 mm), each resulting in significantly higher than average rainfall in those months and local flooding of rivers and creeks.

- Groundwater level trends in monitoring bores varies depending on the lithology and depth of the screened interval:

  - **Alluvium**: Groundwater levels in monitoring bores screened within the alluvium show characteristic quick responses to rainfall events indicating rapid shallow aquifer recharge via direct rainfall infiltration and/or enhanced infiltration during high creek flow and flood events. Groundwater fluctuations over the monitoring period range from ~0.5 m to ~1.9 m.

    Rainfall recharge is impeded in areas where the alluvium is clay-rich or where thick clay layers overlie the coarser grained alluvial deposits.

  - **Shallow rock**: Monitoring bores into shallow rock at four monitoring sites show a gradual increase of between ~0.2 m and ~0.5 m over the monitoring period, with typically gradual recharge responses to the large rainfall events of June 2011 and February 2012. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall recharge over a broad area, assumed to be up-gradient of the monitoring locations.

  - **Interburden units**: Monitoring bores screened within the confining interburden units at three sites also show a gradual increase in groundwater level over the monitoring period of between ~0.2 m and ~0.5 m. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall infiltration over a broad area, assumed to be up-gradient of the monitoring locations.

Hydrographs show very slow recovery after purging and sampling events consistent with very low permeability in these units.

- **Coal seams**: Groundwater levels in monitoring bores that are screened within the coal seams show varied but typically small (<0.2 m) overall changes in groundwater level over the monitoring period. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall recharge over a broad area, assumed to be up-gradient of the monitoring locations.

  Slow water level recovery after bore purging is apparent and consistent with low permeability.

- In almost all monitoring bores (from all units), groundwater levels were higher at the end of the monitoring period (June 2012) than at the start (early 2011). This is attributed to the higher than average rainfall conditions that prevailed over most of the monitoring period.

- No groundwater level responses to private bore abstraction are known or were noted (with the exception of planned test pumping and slug testing of the monitoring bores).

- Significant vertical hydraulic gradients were noted at five of the six nested bore installations assessed:

  - Downward hydraulic gradients were noted at the S5MB, TCMB and WMB nested bore sites. Downward gradients are characteristic of recharge zones and imply potential for slow downward seepage of groundwater between units.

  - Upward hydraulic gradients were noted at the S4MB and RMB nested bore sites. Upward gradients are characteristic of discharge zones and imply potential for slow upward seepage of groundwater between units.

  - No significant vertical hydraulic gradient was noted at the BMB nested bore site.

  - In all cases it was noted that despite the potential for vertical seepage, due to the very low permeability of the interburden units, vertical seepage is likely to be limited and extremely slow. Lateral flow within each of the geological units is concluded to be the primary groundwater flow mechanism when there are no stresses on the shallow or deep groundwater systems.

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

- Water quality in streams is inversely correlated with flow: highest salinity levels are associated with prolonged dry periods and first flush events. Average electrical conductivity (EC) over the monitoring period was ~300 to ~420 µS/cm in the Avon River and ~680 µS/cm in Dog Trap Creek.

1. Introduction

AGL Upstream Investments Pty Ltd (AGL) is proposing to develop the Gloucester Gas Project (GGP) which will comprise several stages of development; however, only one stage, the Stage 1 Gas Field Development Area (GFDA) is currently approved. The current project includes the development of 110 CSG wells and associated infrastructure, the development of a central processing facility (CPF), the construction and operation of a high pressure gas transmission pipeline from Stratford to Hexham, and the Hexham Delivery System (HDS).

The GGP has been declared by the Minister for Planning as a Major Project under the *Environmental Planning and Assessment Act 1979* (EP&A Act). AGL holds a concept plan approval for the whole GGP and a planning approval for stage 1 of the GGP under Part 3A of the EP&A Act, both of which were issued in February 2011. The project was referred under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (SEWPaC). SEWPaC is currently assessing the Stage 1 project under the EPBC Act and a determination is expected shortly.

The GGP will involve the dewatering of deep groundwater and the extraction of gas from multiple coal seams within the Gloucester Coal Measures. Target coal seam depths will vary from site to site but are expected to range between 200 and 1000 metres below ground level (m bgl).

A comprehensive groundwater investigation (Phase 2 Groundwater Investigations) was completed in early 2012 to confirm the hydrogeological conceptual model across the Stage 1 GFDA (Parsons Brinckerhoff 2012a). The investigation established a dedicated water monitoring network to obtain baseline water level and water quality attributes for each of the hydrogeological units represented across the basin.

This annual status report provides the first annual review of the monitoring network detailing groundwater and surface water level and water quality trends for the period January 2011 to June 2012, and specifically for the period from early 2012 (following the completion of the initial Phase 2 groundwater investigation (Parsons Brinckerhoff 2012a)) to June 2012. Future annual status reports will be for the period 1 July to 30 June each year.

1.1 Importance of groundwater monitoring

Groundwater studies are required to confirm the baseline conditions (pre-development) and to determine the impact (if any) on shallow water resource aquifers and local ecosystems as the GGP is constructed, commissioned and then operated. The monitoring and interpretation of groundwater data allows the development and refinement of a conceptual hydrogeological model that is used to represent the groundwater regime and describe groundwater flow and linkages between shallow aquifers and deeper coal seam water bearing zones.

AGL's focus is to monitor groundwater in the main water resource aquifers being the shallow alluvium and the shallow rock aquifer, and surface water in the adjacent Avon River.
The continuous monitoring of groundwater and surface water levels is part of AGL's ongoing site investigations and required compliance monitoring program. Groundwater and surface water monitoring is currently undertaken within and just outside the Stage 1 GFDA. AGL is also currently undertaking comprehensive field investigations and baseline monitoring in parallel with supplementary exploration programs and future planning for the GGP.

1.2 Objectives

The objectives of the continuing groundwater and surface water monitoring program are to:

- Provide information on groundwater in the area by assessing regional and seasonal trends in groundwater levels, and by determining to what extent the deep water bearing zones are connected to shallow aquifers.
- Provide information on surface water systems in the area by assessing regional and seasonal trends in surface water levels and quality (specifically electrical conductivity), and connectivity between the shallow alluvial aquifers, deep water bearing zones and stream flow.
- Help the community understand what impacts, if any, there might be on local water supplies and groundwater as a result of gas exploration.

1.3 Report structure

This document provides a concise report detailing the results of continuous groundwater and surface water monitoring from early 2011 until June 2012.

The structure of the report is as follows:

- **Section 2:** provides an overview of the geological and hydrological setting of the northern Gloucester Basin.
- **Section 3:** provides an overview of the monitoring network.
- **Section 4:** discusses the groundwater level trends for the monitoring period.
- **Section 5:** discusses the surface water level and quality results for the monitoring period.
- **Section 6:** presents the conclusions and recommendations for future monitoring.

2. Background

2.1 Topography and surface drainage

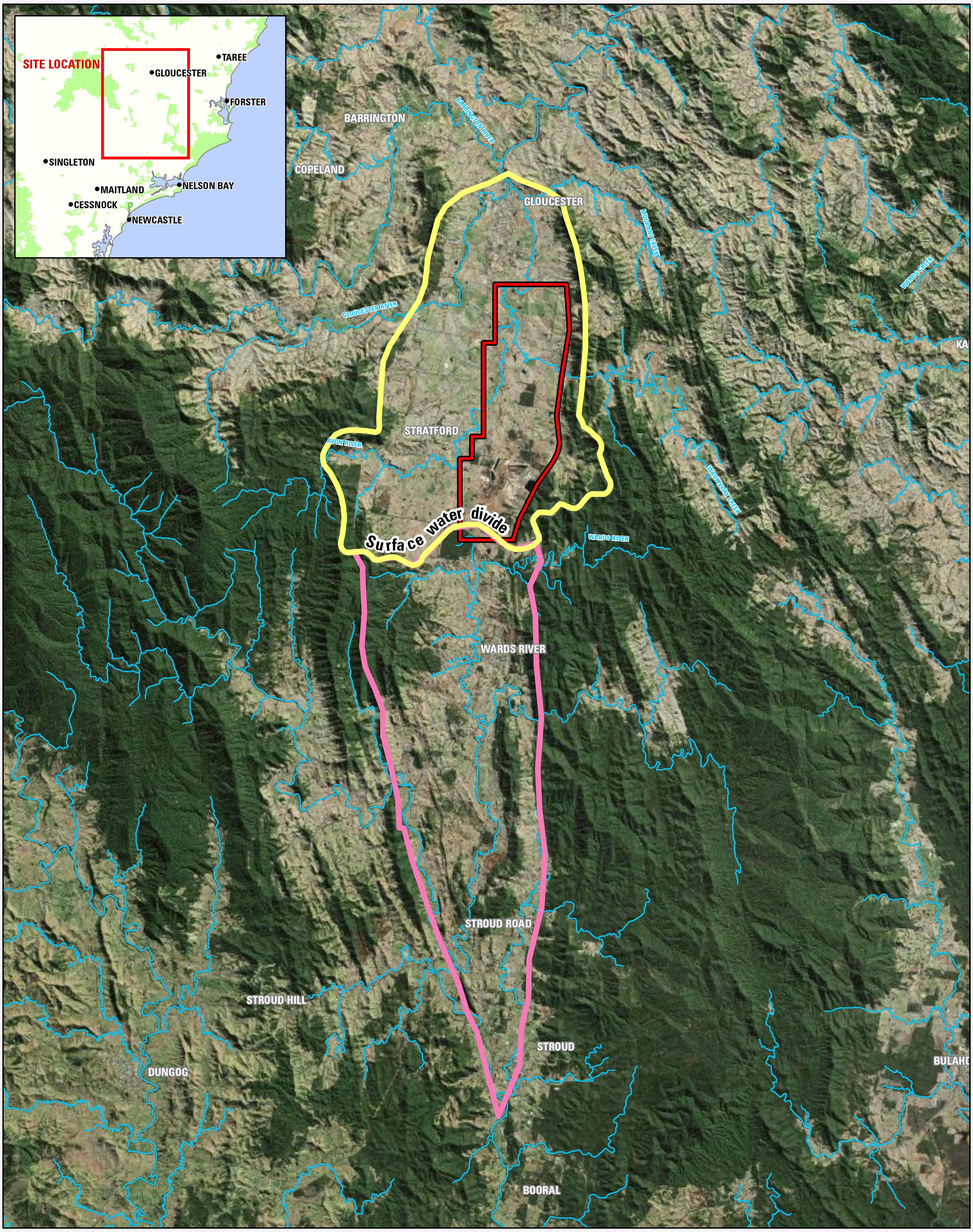
The Gloucester Basin is a narrow, north-south trending, elongated basin approximately 40 km long and 10 km wide, extending from Gloucester in the north to Stroud in the south (Figure 2.1). A major surface water divide, just north of Wards River, separates the Basin into two major catchment areas. The surface water divide between the Wards River catchment (part of the Karuah River Catchment) and the Avon River Catchment (part of the Manning River Catchment) is assumed to also represent a groundwater divide under natural equilibrium conditions.

In the southern Basin, surface water flow (and groundwater flow) is generally to the south, and is part of the Karuah River Catchment. In the northern Basin surface flow is generally to the north and is part of the Manning River Catchment (NOW 2012).

The area that forms the northern Basin is topographically enclosed to the west by the Gloucester and Barrington Tops, and to the east by the Mograni Range. The northern Basin is essentially a closed system with a narrow outflow zone.

The northern Basin is a surface water dominated system i.e. surface water accounts for the majority of water flow throughout the catchment (Parsons Brinckerhoff 2012b). Water is removed from the system as surface water flow via two major drainage systems:

- the Avon River, which is the primary watercourse (in which Waukivory Creek and Dog Trap Creek are major tributaries), and
- the Gloucester River which inflows in the mid-western margin of the northern Basin. Both drainage systems flow northward and outflow just north of the Gloucester township, at the confluence of the Avon and Gloucester Rivers.



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- Northern Gloucester Hydrogeological Basin
- Southern Gloucester Hydrogeological Basin
- Stage 1 GFDA boundary

N

0 5 10
KM

Figure 2-1
Gloucester Hydrogeological Basin
Northern and Southern Basins

2.2 Climate

2.2.1 Rainfall

The calculated mean annual rainfall for the northern Basin ranges between 983.9 mm (from the Gloucester Post Office, BoM Station 060015, monitoring commenced (intermittently) in 1888, located at the northern end of the northern Basin) and 1065.9 mm (from the Gloucester Craven Station, BoM Station 060042, monitoring commenced 1961, located at the southern end of the northern Basin).

Historically, the period between July and September records the lowest monthly rainfall, while the period between January and March typically has the highest monthly rainfall (see Figure 2.2).

All climate and rainfall data presented in this report between the period March 2011 – June 2011 has been obtained from BoM Hiawatha monitoring site (BoM station 060112, located in the centre – northern end of the Basin). An AGL weather monitoring station on the Tiedman property (installed and operational from July 2011) within the Stage 1 GFDA provides site-specific climate monitoring of wind, relative humidity, temperature, rainfall, and barometric pressure. Data from the AGL weather station is used from July 2011 onwards.

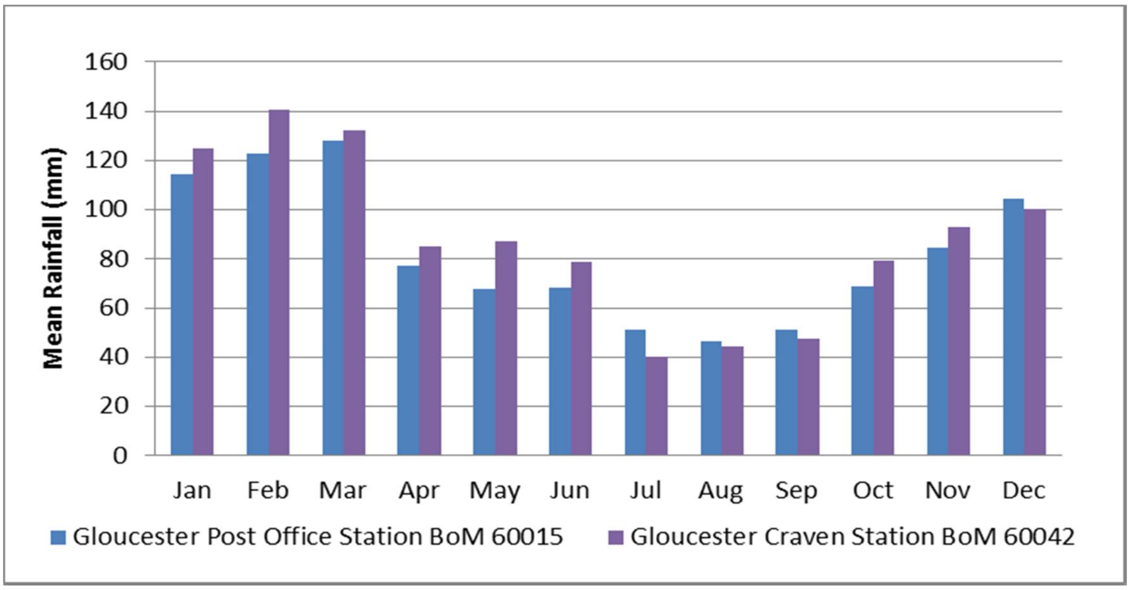

Figure 2.2 Long term mean monthly rainfall for Gloucester Post Office station and Gloucester Craven Station for all monitoring years

2.2.2 Evapotranspiration

Evapotranspiration is the collective term encompassing the transfer of water, as water vapour, to the atmosphere from both vegetated and clear land surfaces (BoM 2012). Evapotranspiration rates are affected by climate and the availability of water and vegetation.

According to BoM data collected between 1961 and 1990, the average, actual annual evapotranspiration for the Gloucester Basin is approximately 750 mm.

2.3 Geological setting

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

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

Overlying the Permian rocks is a thin sequence of surficial Quaternary deposits. The Quaternary deposits are non-uniform in thickness, and comprise unconsolidated alluvial sediments (sand, gravel, silt and clay) along the main drainage channels and colluvial deposits across the rest of the plain sourced from the surrounding outcropping Permian rocks. The generalised stratigraphy of the basin is summarised in Table 2.1.

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

Table 2.1 Simplified Stratigraphy of the Gloucester Basin (from Parsons Brinckerhoff 2012a)

<table>
<tr><th></th><th>Group</th><th>Sub-Group</th><th>Formation</th><th>Approximate thickness (m)</th><th>Coal seam</th><th>Depositional Environment</th><th>Tectonic Events</th></tr>
<tr><td rowspan="22">Upper Permian</td><td rowspan="19">Gloucester Coal Measures</td><td rowspan="11">Craven</td><td>Crowthers Road</td><td>350</td><td></td><td rowspan="11">Marine regression, progradation of alluvial fans</td><td rowspan="11">Uplift to west of Gloucester Basin</td></tr>
<tr><td rowspan="4">Leloma</td><td rowspan="4">585</td><td>Linden</td></tr>
<tr><td>JD</td></tr>
<tr><td>Bindaboo</td></tr>
<tr><td>Deards</td></tr>
<tr><td rowspan="3">Jilleon</td><td rowspan="3">175</td><td>Cloverdale</td></tr>
<tr><td>Roseville</td></tr>
<tr><td>Tereel/Fairbair</td></tr>
<tr><td>Wards River</td><td>Variable</td><td></td></tr>
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<tr><td>Bowens Road</td></tr>
<tr><td colspan="2">Speldon Formation</td><td></td><td></td><td rowspan="8">Marine transgression but also some progradation of alluvial fans in the west related to uplift</td><td rowspan="8">Extension (normal fault development) and regional subsidence. Uplift to west of Basin</td></tr>
<tr><td rowspan="7">Avon</td><td>Dog Trap</td><td>126</td><td>Glenview</td></tr>
<tr><td rowspan="6">Waukivory Creek</td><td rowspan="6">326</td><td>Avon</td></tr>
<tr><td>Triple</td></tr>
<tr><td>Rombo</td></tr>
<tr><td>Glen Road</td></tr>
<tr><td>Valley View</td></tr>
<tr><td>Parkers Road</td></tr>
<tr><td rowspan="3">Dewrang</td><td colspan="2">Mammy Johnsons</td><td>300</td><td>Mammy Johnsons</td><td rowspan="3">Marine transgression, regression and further marine transgression</td><td rowspan="3">Extension (normal fault development) and regional subsidence</td></tr>
<tr><td colspan="2">Weismantel</td><td>20</td><td>Weismantel</td></tr>
<tr><td colspan="2">Duralie Road</td><td>250</td><td></td></tr>
<tr><td>Lower Permian</td><td colspan="3">Alum Mountain Volcanics</td><td></td><td>Clareval</td><td>Arc-related rift</td><td>Rift?</td></tr>
</table>

2.4 Hydrogeological Units

Previous studies identified four main hydrogeological units within the northern Gloucester Basin, and these were further characterised during the recent Phase 2 Groundwater Investigation undertaken by Parsons Brinckerhoff (2012a). The hydrogeological units and characteristics identified are assumed to be broadly representative of aquifer and aquitard characteristics across the northern (and possibly the southern) Basin.

Table 2.2 below outlines the main hydrogeological parameters of these units.

Table 2.2 Four key hydrogeological units

Hydrogeological unit	Aquifer type	Formation name	Hydraulic conductivity (m/day)	Specific yield
Alluvial aquifers	Semi-confined, clay capped, porous, granular	Alluvium	0.3 - 500	0.05 – 0.2
Shallow rock aquifers	Confined/unconfined	Fractured and porous rocks of the Gloucester Coal Measures	0.01 - 20	0.005 – 0.02
Interburden confining units	Confined/unconfined aquitard	Confining units of the Gloucester Coal Measures	4×10^{-5} - 0.006	0.005 – 0.01
Coal seam water bearing zones	Confined	Coal seams of the Gloucester Coal Measures	0.002 - 0.03	0.005 – 0.02

Hydraulic conductivity values are based on aquifer testing carried out for the Phase 2 Groundwater Investigation (Parsons Brinckerhoff 2012a), while estimates of specific yield (unconfined storage) are based on literature values for similar lithologies. In this report, the interburden and coal seam units may be described collectively as “Gloucester Coal Measures” as this is a useful generic term for all rock units deeper than 150 m below ground level (bgl).

3. Monitoring network

A groundwater and surface water monitoring network was established as part of the Phase 2 Groundwater Investigations (Parsons Brinckerhoff 2012a). The details of the installation of the groundwater monitoring bores and stream gauges are included in Parsons Brinckerhoff (2012a), a summary is provided below.

This status report focuses on the dedicated groundwater and surface water monitoring sites used for sub-regional monitoring, and does not include any analysis of data from the gas monitoring or dam seepage monitoring bore sites. Baseline data for these sites is provided in Parsons Brinckerhoff 2012a, and there are no new monitoring results available for 2012. There are a few additional monitoring locations associated with the irrigation trial monitoring program on Tiedmans which are reported separately (AGL 2012).

3.1 Summary of installations

3.1.1 Groundwater monitoring

Three types of groundwater monitoring bores were constructed as part of the groundwater investigations:

- Bores targeting the shallow alluvial sediments of the Avon River and its tributaries.
- Bores targeting the shallow bedrock.
- Bores targeting the Gloucester Coal Measures, including the interburden and coal seams.

The locations of all monitoring bores constructed during the Phase 2 Investigation are shown in Figure 3.1., while the construction details are summarised in Table 3.1. Since the completion of the Phase 2 Investigations, an additional bore (TCMB01) has been constructed to complete the nested bores at the TCMB site on AGL's Tiedman Property, and new monitoring bores have been completed in the close vicinity of the proposed fault investigations on Tiedmans (four locations) and at the Waukivory pilot testing program site (four locations). Data from these new investigation sites are not included in this first annual status report.

As at 30 June 2012, the sub-regional monitoring network comprised:

- Six monitoring bores in the shallow alluvium
- Twelve monitoring bores in the shallow bedrock
- Thirteen bores targeting the Gloucester Coal measures (interburden (7) and coal seams (6))
- Two seepage monitoring bore sites
- Two gas monitoring bore sites
- Four river gauging stations.

Table 3.1 Groundwater monitoring bore construction and completion details

Monitoring Bore	Location	Total depth (m)	Screened interval (m bgl)	Lithology	Formation	Aquifer
S4MB01	Tiedman	66	58 - 64	Sandstone	Leloma Formation	Confining unit
S4MB02	Tiedman	97	89 - 95	Sandstone / siltstone	Leloma Formation	Confining unit
S4MB03	Tiedman	170	162 - 168	Coal	Jilleon Formation - Cloverdale Coal Seam	Coal
S5MB01	Tiedman	60	52 - 58	Sandstone / siltstone	Jilleon Formation	Confining unit
S5MB02	Tiedman	114	110 - 102	Siltstone	Jilleon Formation	Confining unit
S5MB03	Tiedman	166	158 - 164	Coal / shale	Jilleon Formation - Roseville Coal	Coal
TMB01	Tiedman	12	7 – 10	Clay	Avon River Alluvium	Alluvial
TMB02	Tiedman	15.5	9 – 12	Mixed gravels	Avon River Alluvium	Alluvial
TMB03	Tiedman	12.5	5 – 11	Mixed gravels & sand	Avon River Alluvium	Alluvial
TCMB01	Tiedman	90	87 - 93	Sandstone	Leloma Formation	Shallow rock
TCMB02	Tiedman	183	175 - 181	Sandstone	Leloma Formation	Confining unit
TCMB03	Tiedman	268	260 - 266	Coal & sandstone	Jilleon Formation - Cloverdale Coal	Coal
TCMB04	Tiedman	334.7	327.3 – 333.3	Coal	Jilleon Formation - Roseville Coal Seam	Coal
AMB01	Atkins	12.6	8 - 10	Mixed gravels	Avon River Alluvium	Alluvial
AMB02	Atkins	11.5	6.5 – 11	Mixed gravels	Avon River Alluvium	Alluvial
BMB01	Bignell	30	15 - 29	Sandstone/ siltstone	Leloma Formation	Shallow rock
BMB02	Bignell	138	124 – 136	Sandstone	Leloma Formation	Shallow rock
WMB01	Waukivory	8.5	5 - 8	Mixed gravel /sand	Alluvium	Alluvial
WMB02	Waukivory	23	15 - 21	Sandstone	Wenhams Formation	Shallow rock
WMB03	Waukivory	36	32 - 34	Coal	Wenhams Formation - Bowens Road	Coal
WMB04	Waukivory	80.5	67 - 79	Sandstone	Wenhams Formation	Shallow rock
RMB01	Rombo	51	42 - 48	Sandstone	Leloma Formation (upper)	Shallow rock
RMB02	Rombo	93	85 - 91	Sandstone	Leloma Formation (upper)	Shallow rock

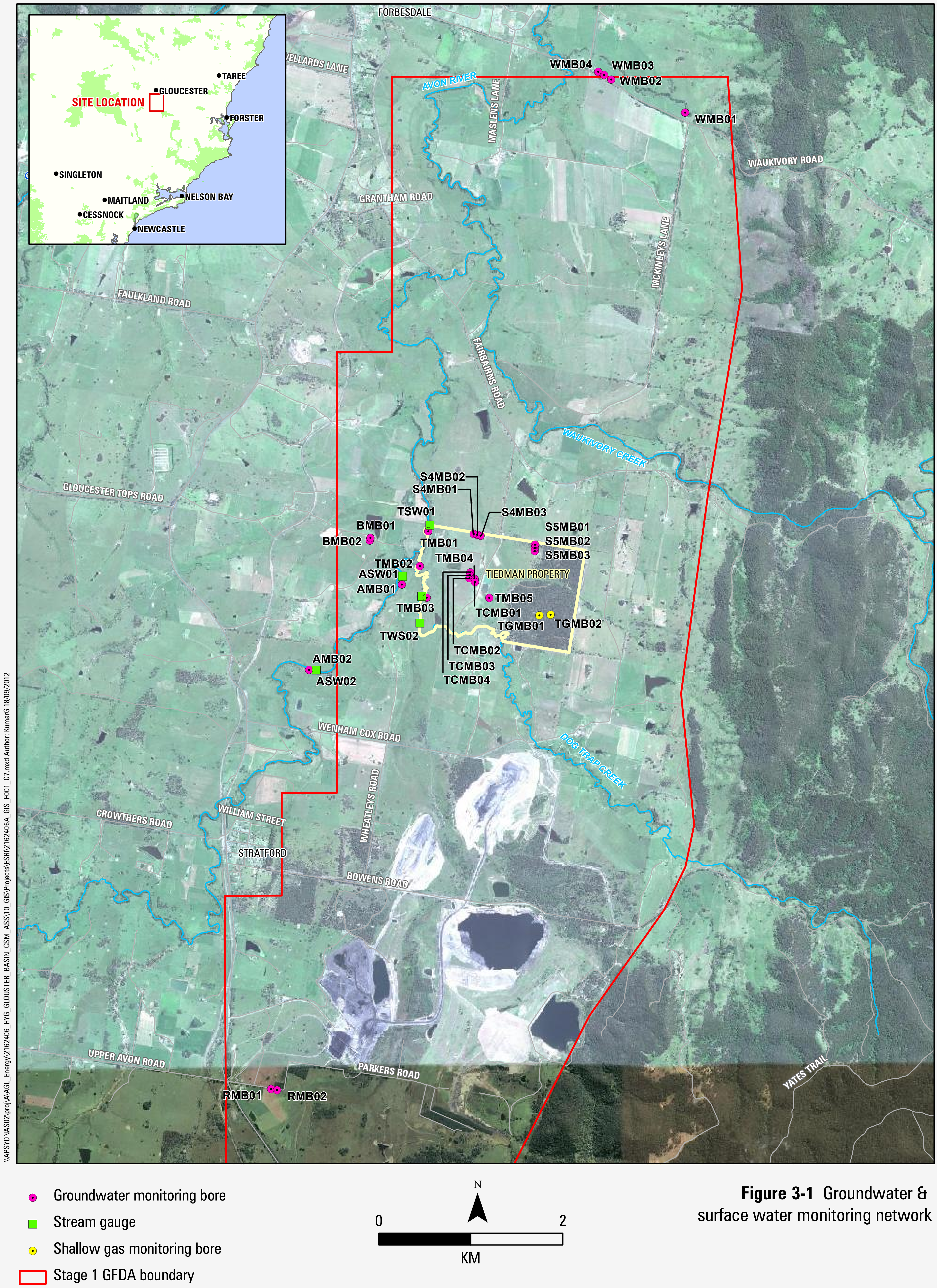


Figure 3-1 Groundwater & surface water monitoring network

3.1.2 Surface water monitoring

Three stream gauges were constructed on the Avon River as part of the Phase 2 Investigations (Parsons Brinckerhoff 2012a):

- TSW01 on the Tiedman property downstream of the confluence with Dog Trap Creek and adjacent to monitoring bore TMB01
- ASW01 on the Atkins property upstream of the confluence with Dog Trap Creek and adjacent to monitoring bore AMB01
- ASW02 further upstream on the Atkins property adjacent to monitoring bore AMB02.

An additional stream gauge (TSW02) on Dog Trap Creek has since been constructed; this gauge is also on the Tiedman property, upstream of any irrigation areas.

The locations of the surface water monitoring sites are included in Figure 3.1.

3.2 Monitoring frequency

3.2.1 Groundwater level monitoring

Groundwater levels (or standing water levels (SWLs)) are electronically and manually measured in all of the completed monitoring bores. Pressure transducer dataloggers suspended in the monitoring bore water column are programmed to record a groundwater level measurement every six hours. To calibrate the level recorded by the dataloggers, manual measurements are recorded every three months using an electronic dip meter.

A barometric datalogger installed above the water table at S5MB01 records changes in atmospheric pressure. Data from this logger are used to correct for the effects of changing barometric pressure and barometric efficiency on groundwater levels.
Continuous groundwater level data are presented as hydrographs in Appendix A.

3.2.2 Surface water monitoring

The stream gauge stations include gauge boards and dataloggers to monitor water levels and salinity every 15 minutes (at TSW01 and ASW01) or 60 minutes (TSW02 and ASW02). Water level and salinity (electrical conductivity) measurements are verified by manual gauge readings and electrical conductivity (EC) monitoring. Continuous surface water level and EC measurements are presented as hydrographs in Appendix B.

Table 3.2 details the date when monitoring commenced for each groundwater monitoring bore and stream gauge.

Table 3.2 Commencement of monitoring

Monitoring location	Commencement of monitoring
Groundwater monitoring bores	
S4MB01	April 2011
S4MB02	January 2011
S4MB03	January 2011
S5MB01	January 2011
S5MB02	January 2011
S5MB03	January 2011
TMB01	May 2011
TMB02	June 2011
TMB03	June 2011
TCMB01	November 2011
TCMB02	March 2011
TCMB03	March 2011
TCMB04	April 2011
AMB01	June 2011
AMB02	June 2011
BMB01	February 2011
BMB02	February 2011
WMB01	February 2011
WMB02	February 2011
WMB03	February 2011
WMB04	February 2011
RMB01	February 2011
RMB02	February 2011
Stream Gauges	
TSW01	March 2011
TSW02	March 2012
ASW01	March 2011
ASW02	March 2011

4. Monitoring results

4.1 Climatic conditions

In this section, climatic factors that have a bearing on groundwater and surface water trends during the monitoring period are reviewed. Figure 4.1 is a composite plot that shows daily rainfall events (as bars), the monthly cumulative deficit or surplus in rainfall from January 2011 to August 2012 (at the BoM weather station and AGL weather station), and atmospheric pressure variations over the same period.

The AGL rainfall station on the Tiedmans property at Stratford has been used to assess water level trends from the date of its installation (July 2011) because it more accurately reflects the rainfall patterns in the immediate vicinity of the monitoring network (most sites are within 5-10 km of this rainfall station).

Daily rainfall data can assist in interpreting rapid groundwater recharge responses (or flood infiltration responses) in groundwater monitoring bores and runoff responses in stream hydrographs. The cumulative deficit plot identifies periods over which rainfall has been greater than the long term average (increasing slope), or lower than the long term average (downward slope). Groundwater level trends (and aquifer storage) often reflect these relative rainfall deficit and surplus trends in cases where aquifer recharge is linked, either directly or indirectly, to rainfall.

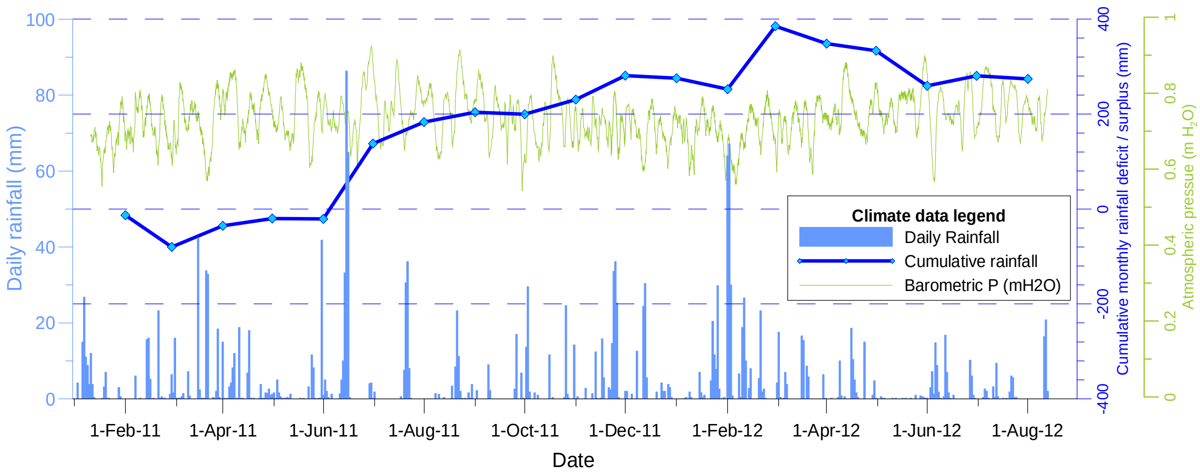


Figure 4.1 Site climatic data for the period January 2011 to August 2012: Daily rainfall (LHS), cumulative monthly deficit/surplus and atmospheric pressure (RHS).

Measured water levels in bores can be influenced by atmospheric pressure fluctuations in two main ways: Firstly, automated dataloggers measure absolute pressure including the atmospheric pressure that acts on the water column in the bore. Logger data are therefore corrected for this effect (manual water measurements do not need this correction). Secondly, in confined or semi-confined aquifers, changes in atmospheric pressure can cause water in the bore to be forced into (during a pressure increase), or drawn from (pressure decrease) elastic aquifer storage, thereby affecting the measured water level. Groundwater level data presented in this report have also been corrected to remove these responses so that any anthropogenic groundwater influences (such as pumping) can be more easily identified.

Daily rainfall data in Figure 4.1 shows that rainfall events are typically less than 40 mm per day. However there were three notable high rainfall events in June 2011 (201 mm), November 2011 (112 mm) and February 2012 (162 mm), resulting in significantly higher than average rainfall in those months and local flooding of rivers and creeks. The cumulative rainfall deficit / surplus graph indicates that monthly rainfall was, on the whole, above the long term average between June 2011 and February 2012, with approximately 380 mm (48%) more rain falling over that period than the long term average. Slightly lower than average rainfall conditions have prevailed since March 2012.

Atmospheric pressure fluctuates over daily to weekly periods as weather systems pass over the site. In general, the mean atmospheric pressure is slightly higher, and the amplitude of pressure fluctuation (between high and low pressure systems) larger in the winter than in the summer months. The amplitude of pressure fluctuation can be 20 mbar in the summer months and up to 30 mbar during the winter months. Given that 1 mbar is equivalent to 1.02 cm of water depth, atmospheric pressure fluctuations can result in observed bore level fluctuations of up to 20 to 30 cm, depending on the barometric efficiency of the bore. As noted above, this effect has been removed from the monitoring data presented here.

4.2 Groundwater levels

Groundwater levels are electronically measured every six hours using automated dataloggers installed in each monitoring bore. The electronic data are corrected for the effects of barometric pressure fluctuations. Hydrographs showing groundwater level fluctuations for all monitoring bores are shown in Appendix A, and include rainfall data and manual groundwater level measurements. Representative hydrographs from the monitoring network are reproduced in the following text to illustrate characteristic groundwater responses and processes.

4.2.1 Alluvial aquifers

Hydrographs for all monitoring bores screened within alluvial deposits adjacent to the Avon River and its tributary creeks are shown in Figure 4.2.

Groundwater levels at the monitoring bores intercepting the alluvial aquifers show characteristic quick responses to rainfall events indicating rapid aquifer recharge via direct rainfall infiltration and/or enhanced infiltration during high creek flow and flood events.

The magnitude and rate of the response varies between sites. The highest groundwater level responses (up to ~1.9 m) were observed in TMB01, TMB02, WMB01 and AMB02, while relatively minor responses (< 0.5 m) are noted on AMB01 and TMB03.

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

1. Rapid recharge response followed by a relatively steep groundwater recession curve (TMB01, TMB02, WMB01). These monitoring bores show rapid response to most rainfall events followed by a return to near-previous levels over a period of one to two months (i.e. a short term increase in storage). These responses imply relatively direct recharge from rainfall and/or flooding and relatively high permeability of the alluvium.

2. A threshold recharge response followed by a longer recession curve (TMB03, AMB01, AMB02). These monitoring bores show rapid recharge responses to the larger rainfall events, but slower responses to smaller rainfall events. In addition, the recession curves are flatter such that the groundwater level may take several months to recover to pre-existing levels and typically does not fully recover before the next major recharge event (i.e. longer term increase in storage). These responses imply rapid recharge during surface runoff and flooding events, but less significant recharge by direct rainfall infiltration alone. The shallow recession curves imply lower permeability of the alluvium at these locations.

These observations are consistent with field observations during bore installation. It was noted in the Phase 2 investigations (Parsons Brinckerhoff 2012a) that there is a clay layer (approximately 2 m in thickness) above the alluvial mixed gravels at both TMB02 and AMB02, and this is likely to be retarding rainfall recharge at these locations. The lithological log for AMB01 indicates that there is a 5 m confining clay layer above the screened section and this is likely to be retarding direct rainfall recharge, with the exception of during a major flood events.

In all monitoring bores screened within the alluvium, groundwater levels were higher at the end of the monitoring period (June 2012) than the start (early 2011). This is attributed to the higher than average rainfall conditions that prevailed over most of the monitoring period.

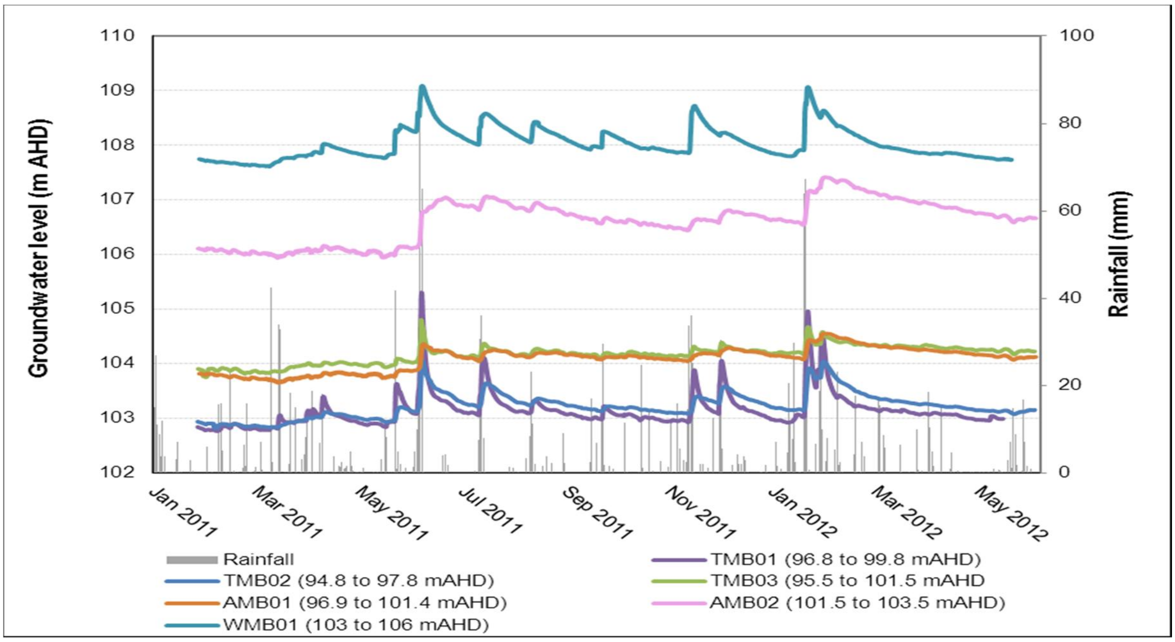


Figure 4.2 Groundwater levels and rainfall at the Tiedman/Atkins/Waukivory alluvial bores

4.2.2 Shallow rock aquifers

The Waukivory Road groundwater monitoring bores WMB02 and WMB04 intersect the shallow rock of the Wenham Formation. Groundwater levels at these locations show a decreasing trend in early 2011, but have risen gradually since the heavy rainfall events of June 2011 and February 2012 by a total of ~0.5 m. This suggests a minor response to rainfall recharge.

The shallow rock units of the Leloma Formation, intersected by BM0B1, BMB02, RMB01, and RMB02 also show a small and gradual increase in groundwater levels in response to the higher than average rainfall conditions between June 2011 and February 2012.

Monitoring bores at Rombo (RMB01 and RMB02) show a gradual increase of ~0.3 m to March 2012, after which levels begin to decline in response to slightly below average rainfall conditions. No rapid or direct rainfall recharge is observed. Groundwater levels in the two monitoring bores indicate an upward hydraulic gradient within the shallow rock at this location, characteristic of a groundwater discharge zone.

Monitoring bores intersecting shallow rock at Bignell (BMB01 and BMB02) show a gradual increase of ~0.5 m over the monitoring period, with slow recharge responses to the large rainfall events of June 2011 and February 2012. No significant vertical hydraulic gradient is apparent in the shallow rock at this location.

The shallow rock of the Leloma Formation is also intersected by TCMB01. The hydrographic records for TCMB01 start in November 2011 and are dominated by recovery after a sampling event in January 2012. The water level in the bore took approximately 6 weeks to recover after purging, indicating very low permeability of the shallow rock at this location. Following recovery in the bore, groundwater levels showed a slight increase to June 2012.

4.2.3 Interburden confining units

The interbedded indurated sandstone/siltstone ("interburden") units of the Leloma and underlying Jilleon Formation are intersected by monitoring bores S4MB01, S4MB02, S5MB01, S5MB02 and TCMB02 on the Tiedman property.

Monitoring bores screened within the confining units on the Tiedman property (S4MB01 and S4MB02) show a gradual increase in groundwater level over the monitoring period totalling ~0.5 m. Hydrographs show very slow recovery after purging and sampling events consistent with very low permeability in these units. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall recharge over a broad area, assumed to be up-gradient of this location. Groundwater levels in the two monitoring bores indicate an upward hydraulic gradient within the interburden at this location, characteristic of a groundwater discharge zone.

Monitoring bores screened within the confining units (Jilleon Formation) on the Tiedman property (S5MB01 and S5MB02) show a varied response. S5MB02 shows negligible overall increase in groundwater level over the monitoring period, although there are a number of transient rises in groundwater level that appear to correspond with major rainfall events. S5MB01 has not fully recovered since the purging and sampling event in March 2011. The hydrograph for S5MB01 therefore does not provide useful information on background groundwater trends. The slow response to purging implies extremely low permeability in the interburden at this location. TCMB02 shows negligible overall increase in groundwater level over the monitoring period

4.2.4 Coal seam water bearing zones

Groundwater levels in monitoring bores that are screened within the coal seams at various sites show varied but typically small (<0.2 m) overall changes in groundwater level over the monitoring period.

Monitoring bores S4MB03 and TCMB03 that intersect the Cloverdale Coal Seam show gradually increasing groundwater levels of up to 0.1 m over the monitoring period. Slow water level recovery after bore purging is apparent and consistent with low permeability. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall recharge over a broad area, assumed to be up-gradient of these locations.

Monitoring bores S5MB03 and TCMB04 intersect the Roseville Coal Seam. S5MB03 shows a slight and gradual increase in groundwater level over the period (~0.2 m total), consistent with a slight increase in rainfall infiltration over that period. TCMB04 also shows an overall increase in groundwater level of ~0.2 m.

Monitoring bore WMB03 that intersects the Bowens Road Coal Seam at a shallow depth shows a very similar groundwater level response to other nearby monitoring bores that are screened within the shallow rock, suggesting a hydraulic connection. The groundwater level in WMB03 shows a gradual increase of ~0.5 m over the monitoring period, with a slightly higher rate of increase in the months following the June 2011 rainfall and flooding event.

4.3 Aquifer interactions

Baseline groundwater level monitoring from the nested bore sites provides information on the unconfined groundwater levels in the shallow rock and potentiometric surfaces in confined water bearing zones, and the potential for linkages between those zones. Hydrographs are presented below for each nested site.

4.3.1 Stratford 4 Monitoring Bores (S4MB)

Groundwater level monitoring at the nested Stratford 4 site indicates distinct groundwater levels in each bore suggesting limited hydraulic connection between the units. The ground elevation at the S4MB site is 118.4 m AHD, the depth to groundwater ranges from 3.4 to 5.6 m. The potentiometric level in the confined Cloverdale Coal Seam (S4MB03) is a higher elevation (~ 114.8 m AHD) than the overlying interburden water bearing zones at S4MB02 (~ 113.6 m AHD) and the shallow water table at S4MB01 (~113 m AHD) (Figure 4.3). The upward hydraulic gradient indicates a potential for upward vertical leakage from the deep to shallow water bearing zones. However, the low permeability of the interburden units and the natural hydraulic gradient imply that any upward leakage is likely to be very slow.

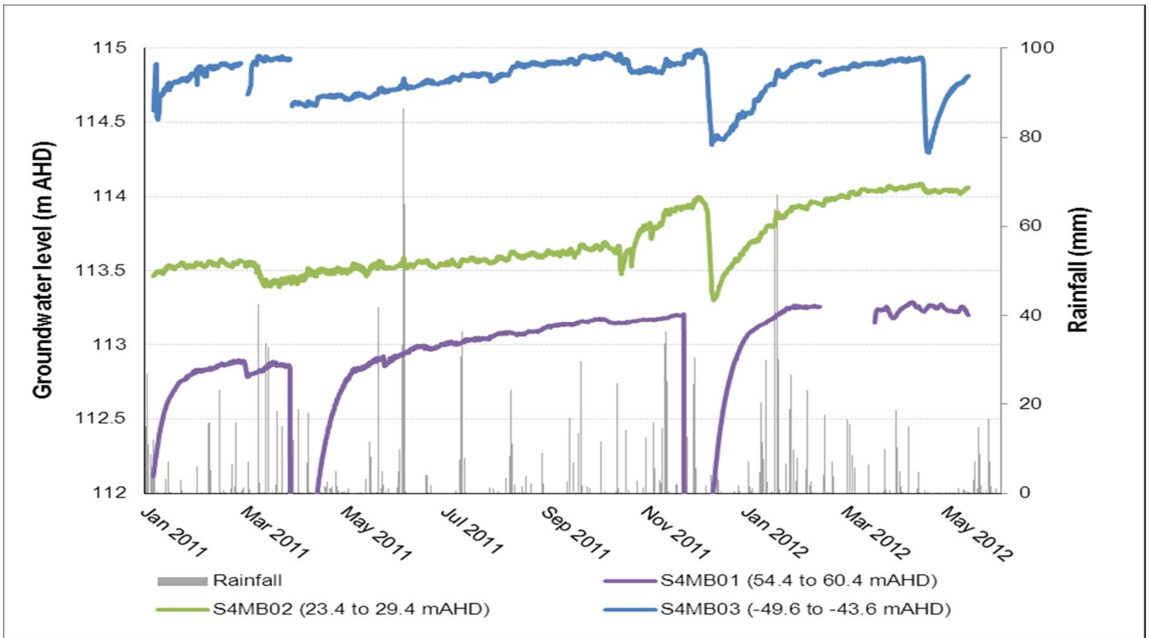


Figure 4.3 Groundwater levels and rainfall at S4MB site

4.3.2 Stratford 5 Monitoring Bores (S5MB)

Groundwater monitoring at the nested S5MB site indicates that the potentiometric surface of the siltstone/sandstone interburden (S5MB02) is similar to that of the underlying Roseville Coal Seam (S5MB03, ~ 112 m AHD) (Figure 4.4). However, it is noted that a slight upward gradient (~0.15 m) developed during 2012 due to the gradual increase in piezometric level in S5MB03 over that period. The groundwater level at S5MB01 is obscured by the very slow recovery after purging and sampling, however initial measurements indicate a significant downward gradient between the upper and lower confining units screened.

Although the vertical head gradient is indicative of potential downwards leakage, the very slow recovery of S5MB01 in response to the slug test suggests that this strata is a confining layer with very little potential for groundwater movement, either laterally or vertically. The groundwater level of the deeper interburden and Roseville Coal Seams is approximately 17.4 m below ground elevation (129.9 m AHD).

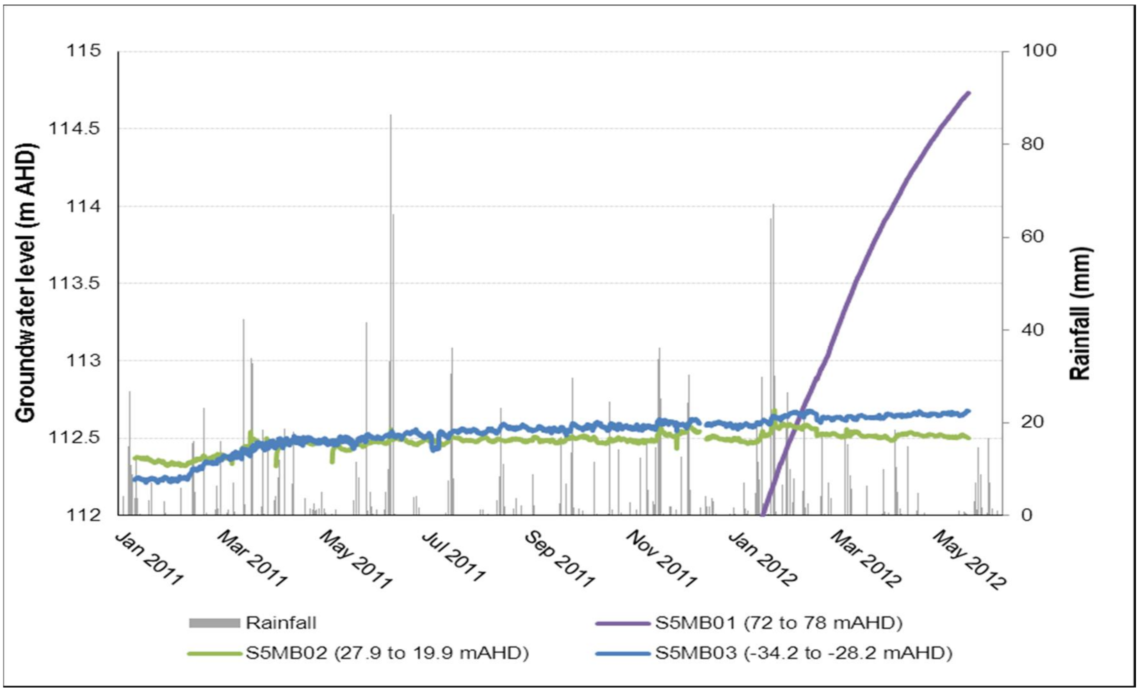


Figure 4.4 Groundwater levels and rainfall at S5MB site

4.3.3 Tiedman core hole monitoring bores (TCMB)

Groundwater level monitoring at the Tiedman core hole (TCMB) site nested bores (Figure 4.5) indicates a comparable potentiometric surface of the shallow rock aquifer (TCMB01) and the underlying interbedded siltstone/sandstone interburden unit (TCMB02) (~ 114 mAHD). However, a significant downward potentiometric head gradient (~1.5 m) exists between these units, and the underlying the Cloverdale Coal Seam (TCMB03) and Roseville Coal Seam (TCMB04), which both have a potentiometric level of ~112.5 m AHD. All bores show slow responses to slug testing and sampling indicating very low permeability limited potential for vertical leakage, despite the head difference. The depth to groundwater is approximately 9 m at TCMB01 and TCMB02, and 10.7 m at TCMB03 and TCMB04, ground elevation is 123.2 m AHD.

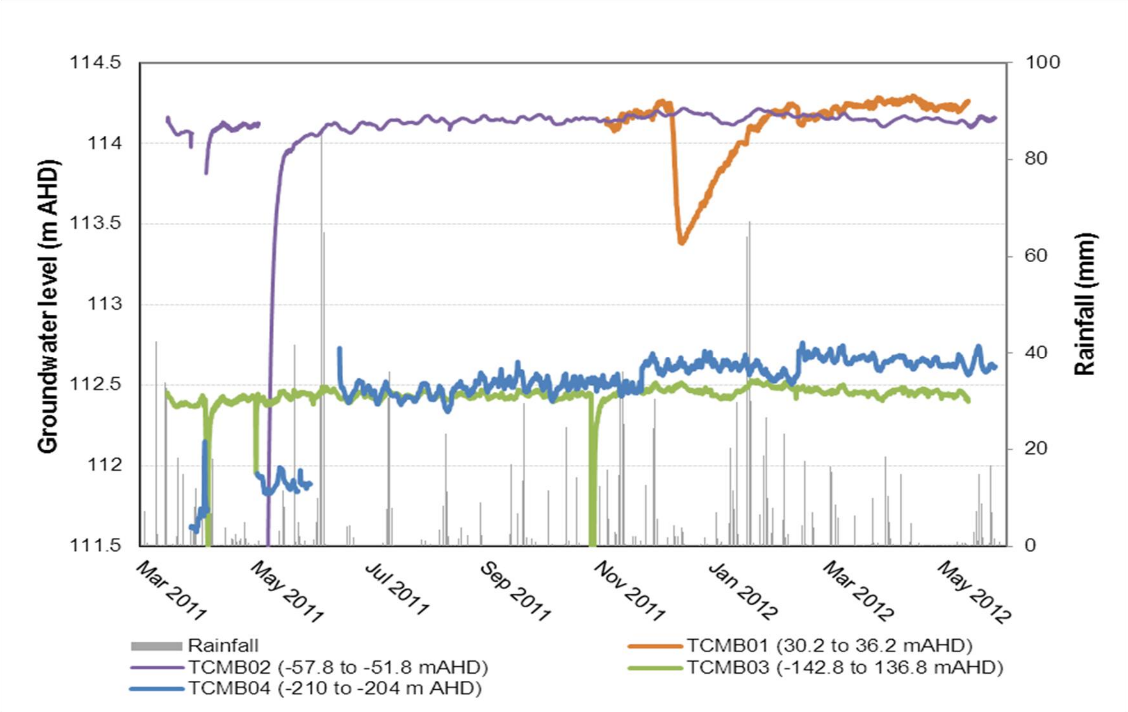


Figure 4.5 Groundwater and rainfall levels at TCMB site

4.3.4 Bignell monitoring bores

The monitoring bores at the Bignell (BMB) site indicate a uniform piezometric pressure within the shallow rock aquifer (targeted at different depths by both bores BMB01 and BMB02) to depth (Figure 4.6). The depth to groundwater ranges between 4.7 and 5.1 m, ground elevation is 108.9 m AHD. The effects of sampling and slug testing are more pronounced in the deeper bore (BMB02) indicating a relatively lower hydraulic conductivity in the deeper zone.

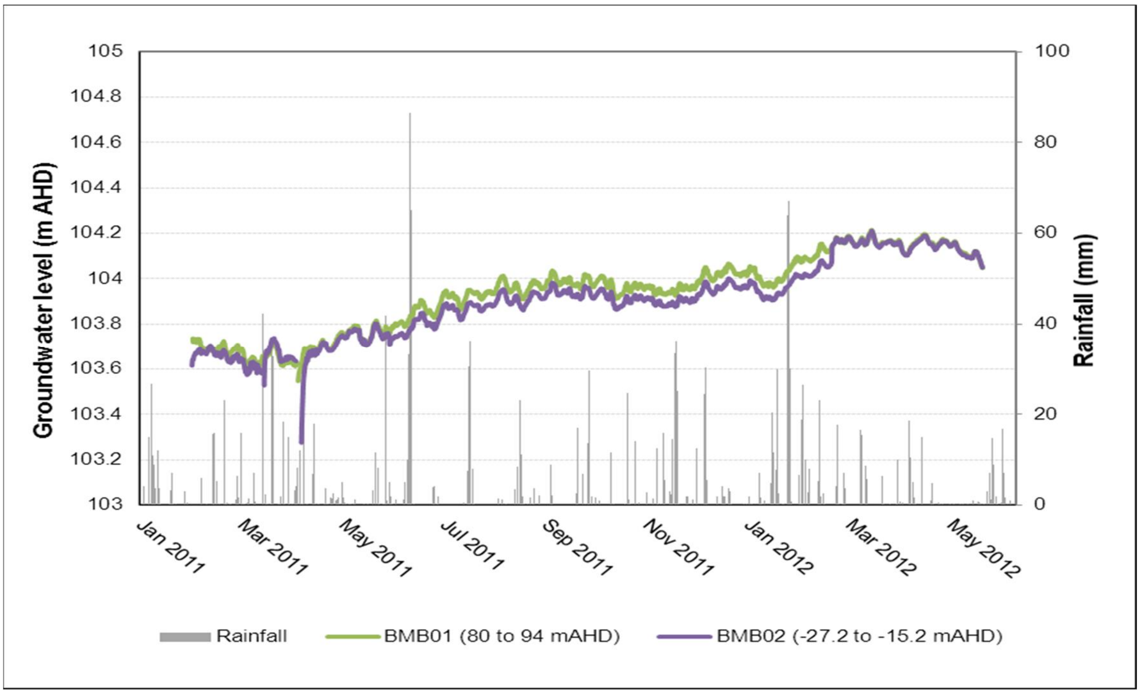


Figure 4.6 Groundwater and rainfall levels at BMB site

4.3.5 Waukivory Road monitoring bores

At the northern Waukivory Road (WMB) site the potentiometric surface of the Bowens Road Coal Seam (WMB03) and the shallow rock units (WMB02 and WMB04) is comparable therefore a minimal head gradient between these units is inferred (Figure 4.7). All three hydrographs show a steady increase in response to significant rainfall events in June 2011 and February 2012. Groundwater levels range from 8.4 to 9 m below ground level (ground elevation is 111 m AHD).

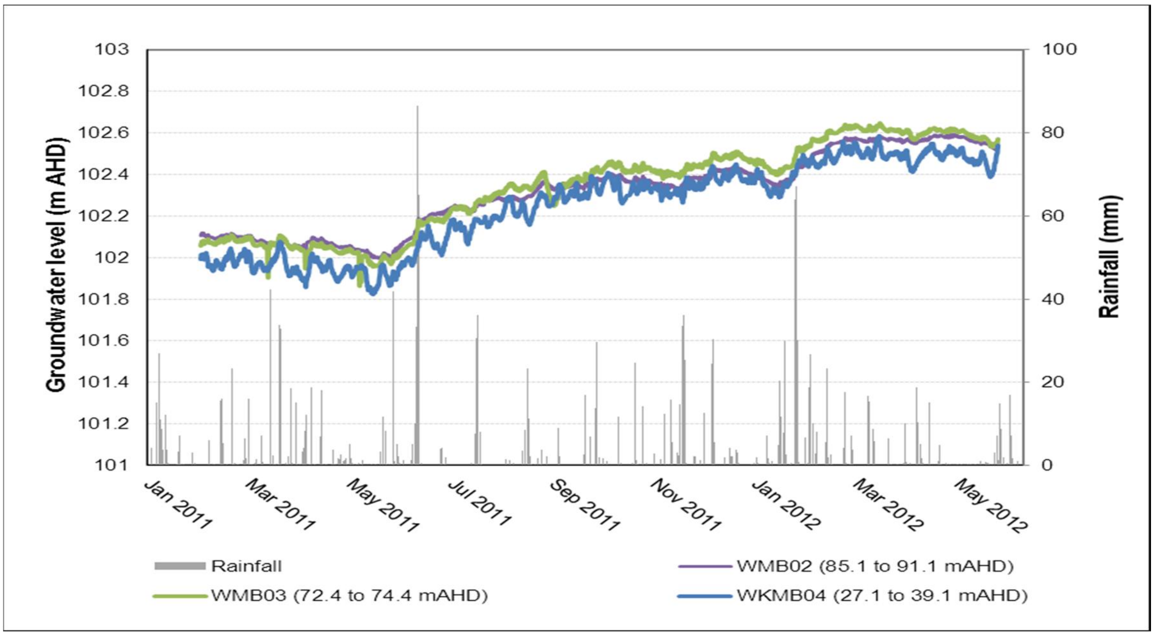


Figure 4.7 Groundwater levels and rainfall at WMB site

4.3.6 Rombo monitoring bores

Groundwater levels in monitoring bores screened within the shallow rock units at the southern Rombo (RMB) site indicate two hydraulically isolated water bearing zones (Figure 4.8). The potentiometric surface of the deeper rock aquifer (RMB02, ~ 125.5 m AHD) is higher than the groundwater level of the shallower rock aquifer (RMB01,~ 125 m AHD) indicating an upward vertical gradient and a potential for upwards leakage. This is characteristic of a zone of groundwater discharge. The ground elevation at Rombo is 128.5 m AHD, therefore the groundwater level at RMB01 is approximately 3.4 m below ground level and the groundwater level at RMB02 is 3 m below ground level.

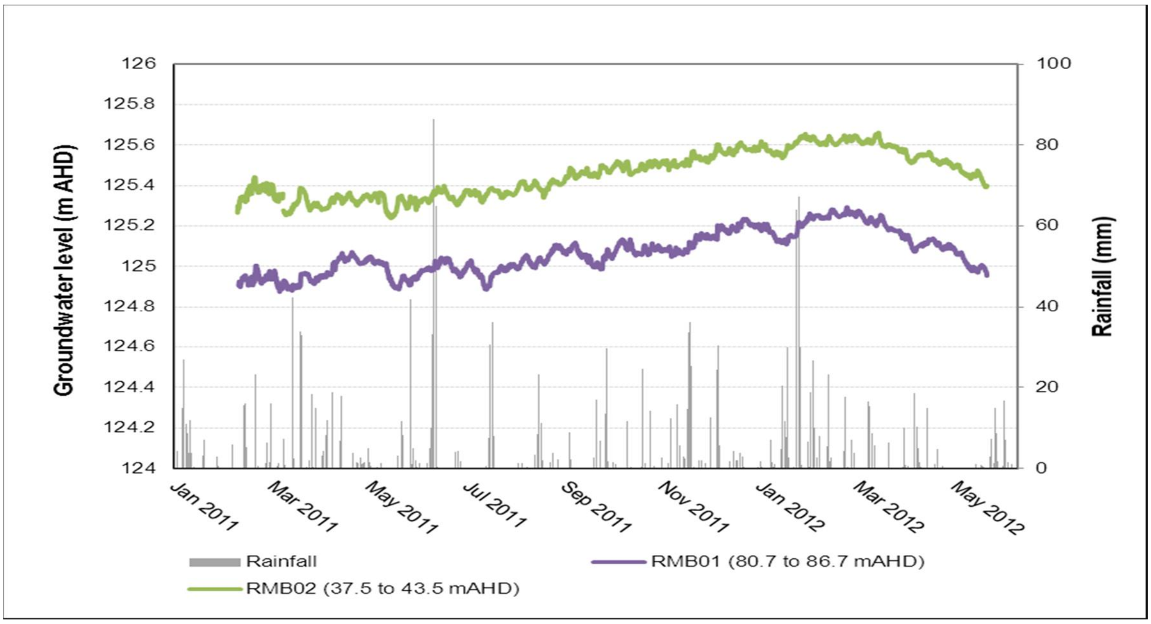


Figure 4.8 Groundwater levels and rainfall at RMB site

5. Surface water results

5.1 Surface water levels

The stream gauge stations consist of gauge boards and dataloggers recording water level and salinity (as EC). These stations monitor water levels and EC every 15 minutes (at TSW01 and, ASW01 and ASW02) or 60 minutes (TSW02).

Surface water levels from the three Avon River stream gauges and rainfall measurements (from BoM weather station and AGL weather station) are shown in Figure 5.1.

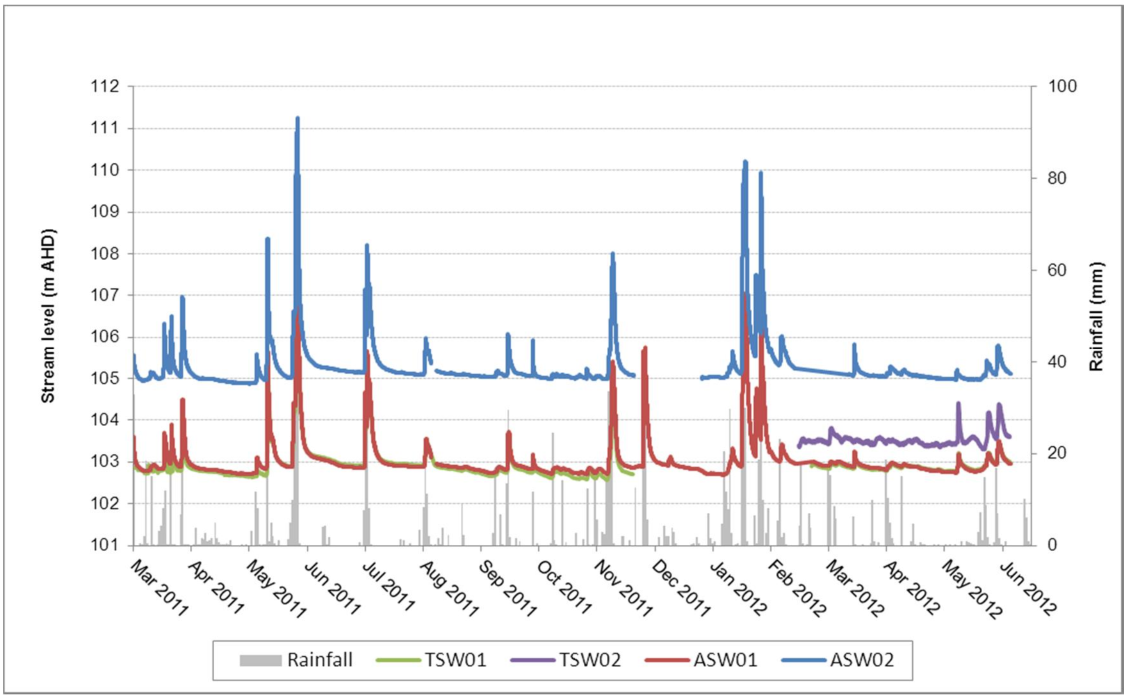


Figure 5.1 Avon River stream level data and rainfall

All three stream gauges on the Avon River show sharp increases in water level in response to rainfall events, and relatively steep recession curves. This indicates a rapid runoff response from a relatively small upstream catchment and limited riverbank storage and groundwater contributions. Stream levels and flow decrease over several weeks following each rainfall event to a relatively consistent base level that represents a small groundwater baseflow component in the Avon River.

While the monitoring period is considerably shorter, the water level at Dog Trap Creek (TSW02) shows a similar response to rainfall and flooding as seen at the Avon River.

Anecdotal information indicates that parts of the Avon River and its major tributaries may have ceased to flow in the past during prolonged drought conditions. The apparent continuous flow conditions and minor baseflow observed during the current monitoring period may therefore reflect the relatively high rainfall conditions that have prevailed over the last few years.

Stream gauge data compared with adjacent groundwater level data indicate that the Avon River is a gaining system in the central Stage 1 GFDA (Figure 5-2). That is, the stream is at a lower elevation and is a discharge feature for groundwater in the northern Gloucester Basin.

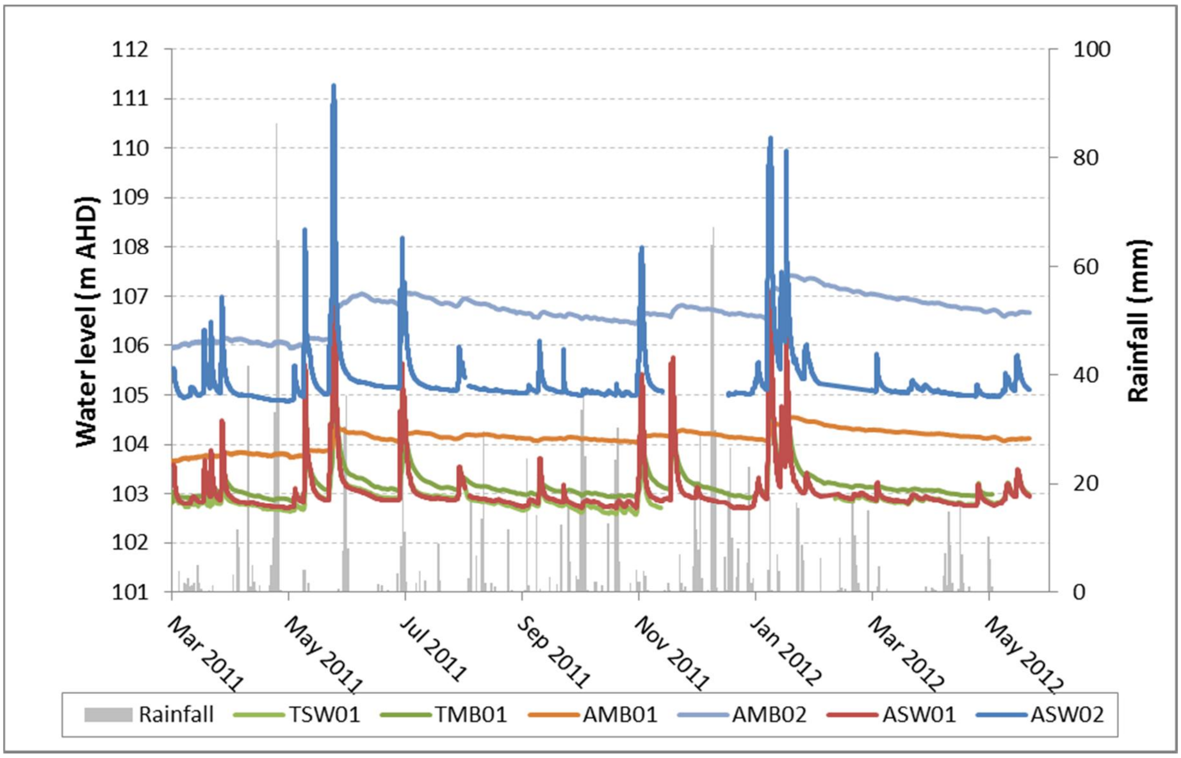
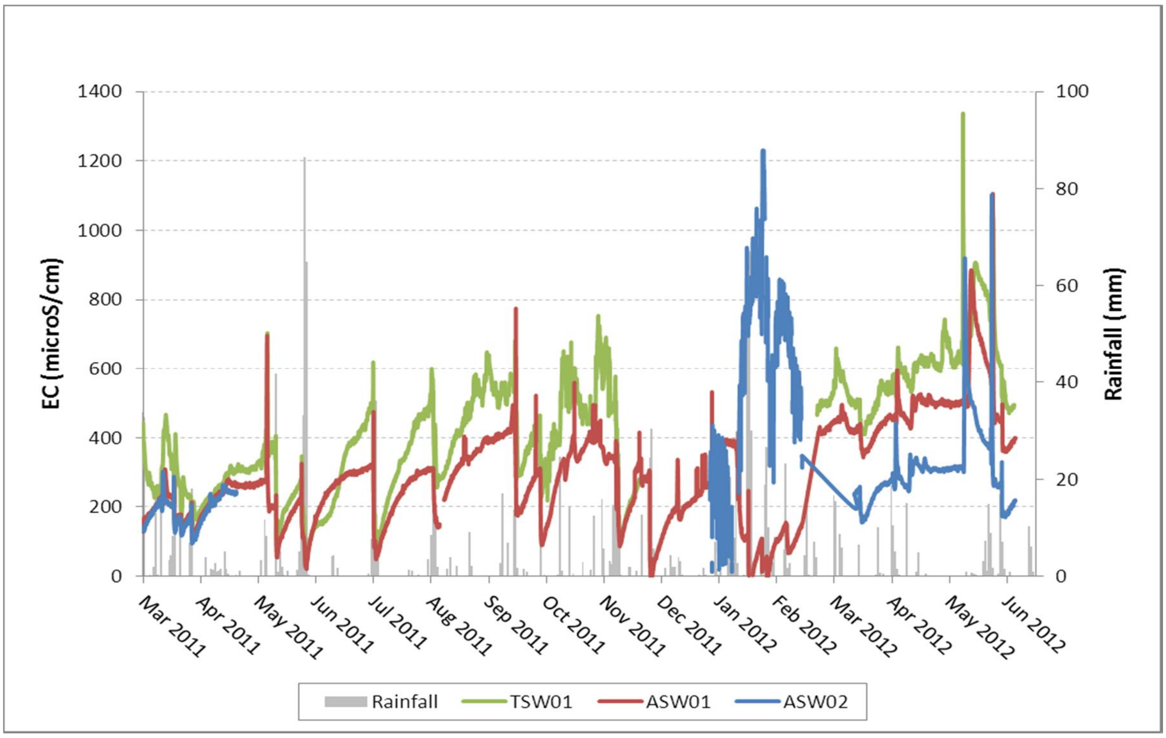


Figure 5.2 River Avon water levels and adjacent alluvial groundwater levels

5.2 Surface water quality

Salinity (EC) has been continuously measured at the four surface water locations and the EC data is compared to rainfall events from BoM Station 060112 and the AGL weather station. Figure 5.3 displays the EC and rainfall data at the Avon River and Figure 5.4 presents the EC and rainfall data at Dog Trap Creek.



Note: Data measurement from the EC probe at ASW02 was unsuccessful between April 2011 and January 2012.

Figure 5.3 Avon River EC measurements and rainfall

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

EC values are often highest at the downstream monitoring location (TSW01). During the monitoring period the following salinity ranges were observed:

- TSW01 – 25.7 to 1336.9 µS/cm (average 419.9 µS/cm)
- ASW01 – 20.2 to 1105.5 µS/cm (average 296.0 µS/cm)
- ASW02 – 11.8 to 1230.4 µS/cm (average 322.8 µS/cm).

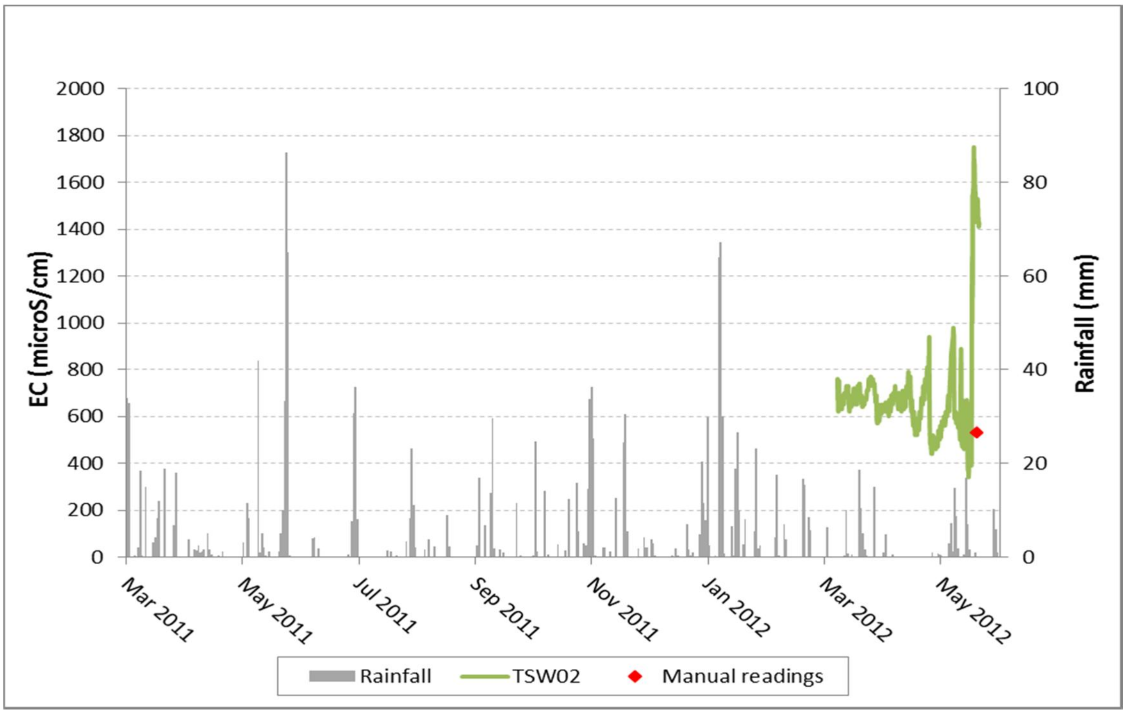


Figure 5.4 Electrical conductivity in Dog Trap Creek against rainfall

Despite the shorted monitoring period for surface water station TSW02 on Dog Trap Creek, similar inverse relationships are observed between water level (and flow) and EC (Figure 5.4).

Range:

- TSW02 – 340 to 1750 µS/cm (average ~680 µS/cm).

6. Conclusions and Recommendations

6.1 Conclusions

A comprehensive surface water and groundwater monitoring network comprising nested monitoring bores and stream gauges was established during the Phase 2 Groundwater Investigations carried out by Parsons Brinckerhoff (2012a). Subsequent and ongoing investigations have continued to expand this network. Groundwater monitoring commenced at the first installed bores in January 2011.

The following conclusions are drawn from a review of the groundwater and surface water monitoring data for the period January 2011 to June 2012, representing 18 months of baseline data:

- Climatic data collected on site indicates that monthly rainfall was above the long term average between June 2011 and February 2012, with approximately 380 mm (48%) more rain falling over that period than the long term average. Slightly lower than average rainfall conditions have prevailed since March 2012.
- There were three notable high rainfall events in June 2011 (201 mm), November 2011 (112 mm) and February 2012 (162 mm), each resulting in significantly higher than average rainfall in those months and local flooding of rivers and creeks.
- Groundwater level trends in monitoring bores varies depending on the lithology and depth of the screened interval:
  - **Alluvium**: Groundwater levels in monitoring bores screened within the alluvium show characteristic quick responses to rainfall events indicating rapid aquifer recharge via direct rainfall infiltration and/or enhanced infiltration during high stream flow and flood events. Groundwater fluctuations over the monitoring period range from ~0.5 m to ~1.9 m.

    Rainfall recharge is impeded in areas where the alluvium is clay-rich or where thick clay layers overlie the coarser grained alluvial deposits.
  - **Shallow rock**: Monitoring bores intersecting shallow rock at four monitoring sites show a gradual increase of between ~0.2 m and ~0.5 m over the monitoring period, with typically gradual recharge responses to the large rainfall events of June 2011 and February 2012. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall recharge over a broad area, assumed to be up-gradient of the monitoring locations.
  - **Interburden units**: Monitoring bores screened within the confining interburden units at three sites show a gradual increase in groundwater level over the monitoring period of between ~0.2 m and ~0.5 m. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall infiltration over a broad area, assumed to be up-gradient of the monitoring locations.

    Hydrographs show very slow recovery after purging and sampling events consistent with very low permeability in these units.

  - **Coal seams**: Groundwater levels in monitoring bores that are screened within the coal seams show varied but typically small (<0.2 m) overall changes in groundwater level over the monitoring period. There are no strong responses to individual rainfall events indicating that groundwater levels are responding to slow rainfall recharge over a broad area, assumed to be up-gradient of the monitoring locations.

    Slow water level recovery after bore purging is apparent and consistent with low permeability.

- In almost all monitoring bores (from all units), groundwater levels were higher at the end of the monitoring period (June 2012) than at the start (early 2011). This is attributed to the higher than average rainfall conditions that prevailed over most of the monitoring period.

- No groundwater level responses to private bore abstraction are known or noted (with the exception of planned test pumping and slug testing of the monitoring bores).

- Significant vertical hydraulic gradients were noted at five of the six nested bore installations assessed:

  - Downward hydraulic gradients were noted at the S5MB, TCMB and WMB nested bore sites. Downward gradients are characteristic of recharge zones and imply potential for slow downward seepage of groundwater between units.

  - Upward hydraulic gradients were noted at the S4MB and RMB nested bore sites. Upward gradients are characteristic of discharge zones and imply potential for slow upward seepage of groundwater between units.

  - No significant vertical hydraulic gradient was noted at the BMB nested bore site.

  - In all cases it was noted that despite the potential for vertical seepage, due to the very low permeability of the interburden units, vertical seepage is likely to be extremely slow. Lateral flow within each of the geological units is concluded to be the primary groundwater flow mechanism when there are no stresses on the shallow or deep groundwater systems.

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

- Water quality in streams is inversely correlated with flow: highest salinity levels are associated with prolonged dry periods and first flush events. Average electrical conductivity (EC) over the monitoring period was ~300 to ~420 µS/cm in the Avon River and ~680 µS/cm in Dog Trap Creek.

6.2 Recommendations

The following recommendations are made regarding the ongoing groundwater and surface water monitoring of the GGP Stage 1 Gas Field Development Area:

- Monitoring should continue at all sites in accordance with the existing program with the following minor modifications:
  - It is recommended that the water quality sampling procedure be revised for bores that display very long recovery responses after purging (e.g. S5MB01 and TCMB01). The long water level recovery can compromise water level trend assessments.
  - Rating of the surface water gauges should be carried out to allow reporting of stream volumetric flow rates.
- The newer monitoring bores constructed during early 2012 (and those proposed for construction during 2012/13) should be included in the annual status report for 2012/13.

7. Statement of limitations

7.1 Scope of services

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

7.2 Reliance on data

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

7.3 Environmental conclusions

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

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

Also, it should be recognised that site conditions, including the extent and concentration of contaminants, can change with time.

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

7.4 Report for benefit of client

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

7.5 Other limitations

Parsons Brinckerhoff will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

8. References

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Bureau of Meteorology (BoM), 2012. evapotranspiration: http://www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp *(accessed 10/7/2012).*

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NSW Office of Water (NOW), 2012. Department of Primary Industries, Catchment areas: www.water.nsw.gov.au/Water...catchments/...catchments/default.aspx *(accessed 25/7/2012).*

Parsons Brinckerhoff, 2012a. *Phase 2 Groundwater Investigations – Stage 1 Gas Field Development Area, Gloucester Gas Project*. Report dated January 2012 PR_5630.

Parsons Brinckerhoff, 2012b. *Water balance for the Gloucester Stage1 GFDA*. Report dated August 2012 PR_1099.

Appendix A

Groundwater hydrographs

Figure A-1 Groundwater levels and rainfall TMB01

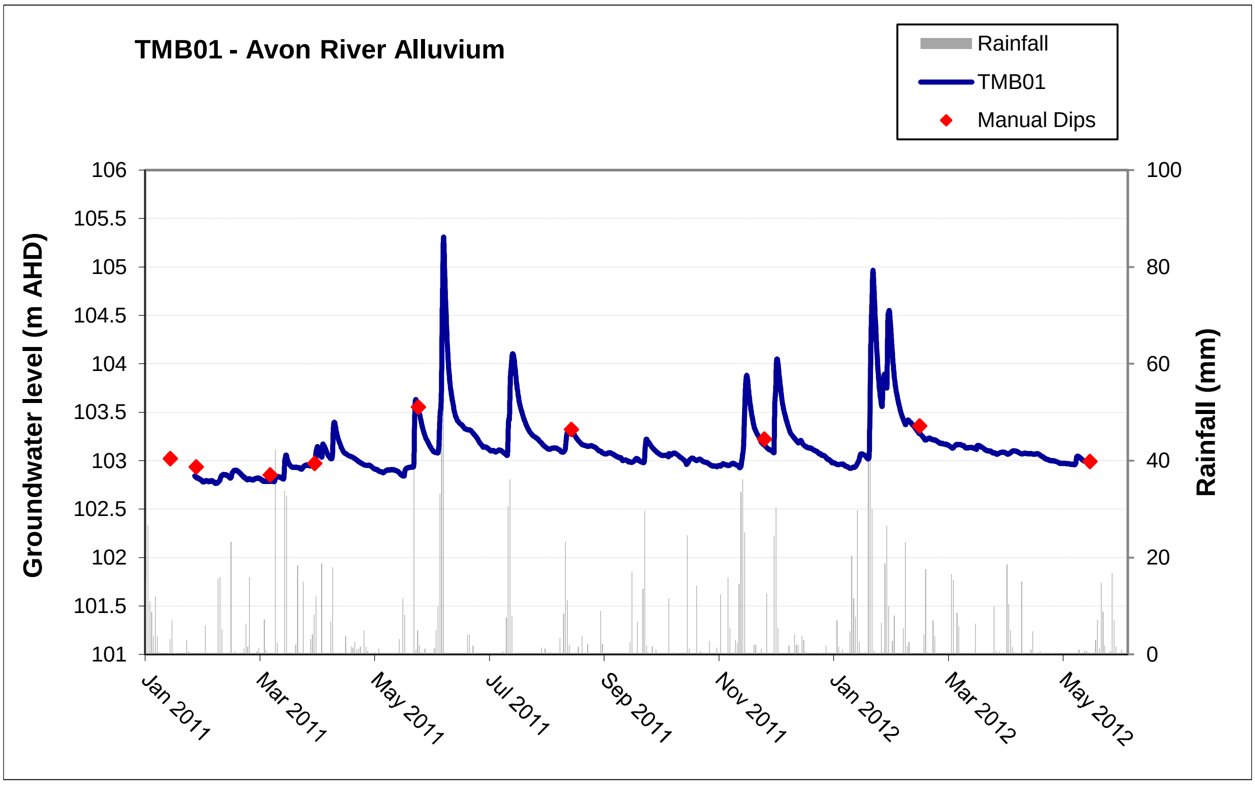
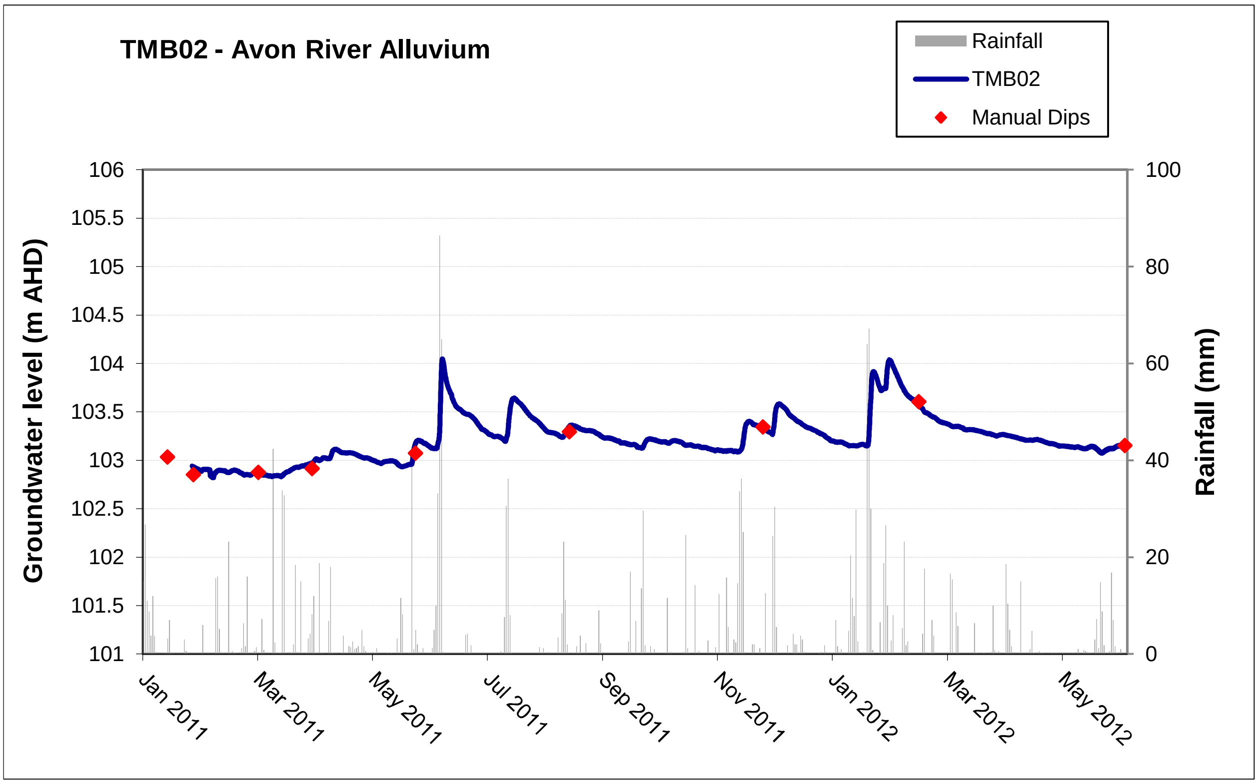


Figure A-2 Groundwater levels and rainfall at TMB02



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Project: Gloucester groundwater investigation and monitoring
Location: Gloucester, NSW

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Figure A-3 Groundwater levels and rainfall at TMB03

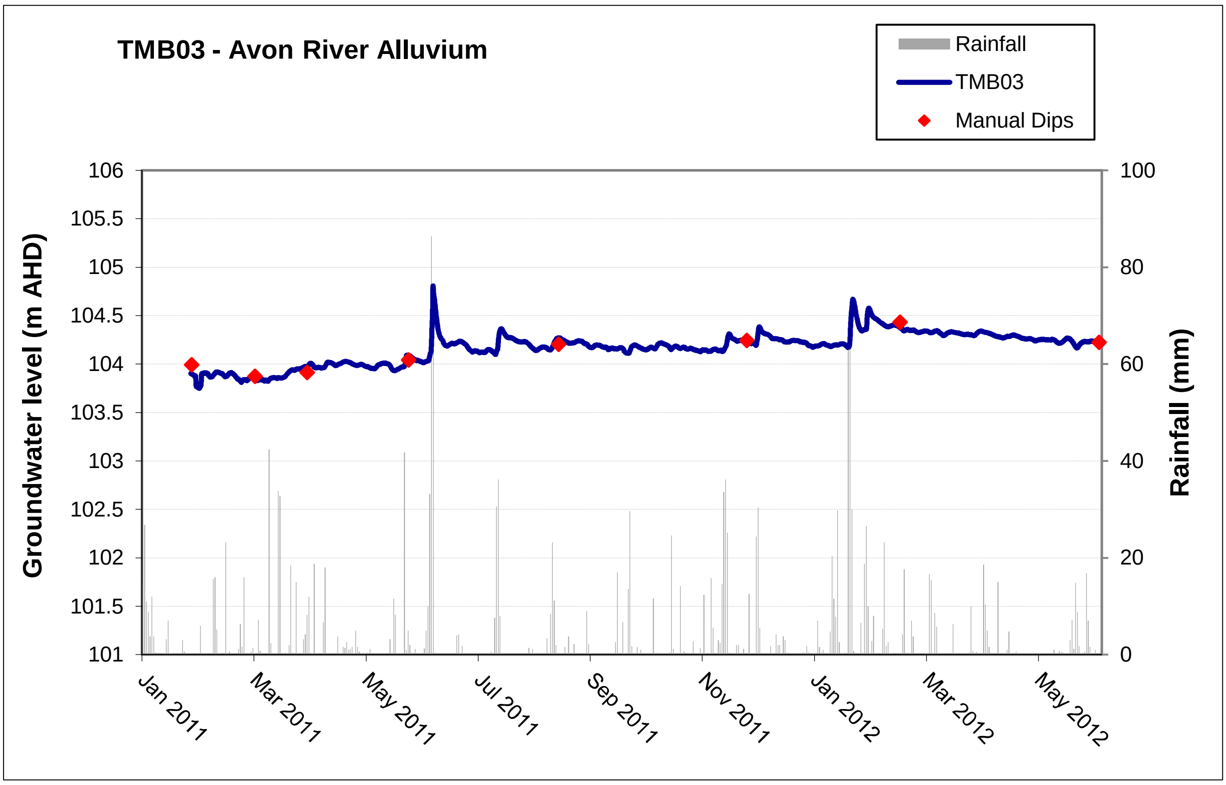

Figure A-4 Groundwater levels and rainfall at AMB01

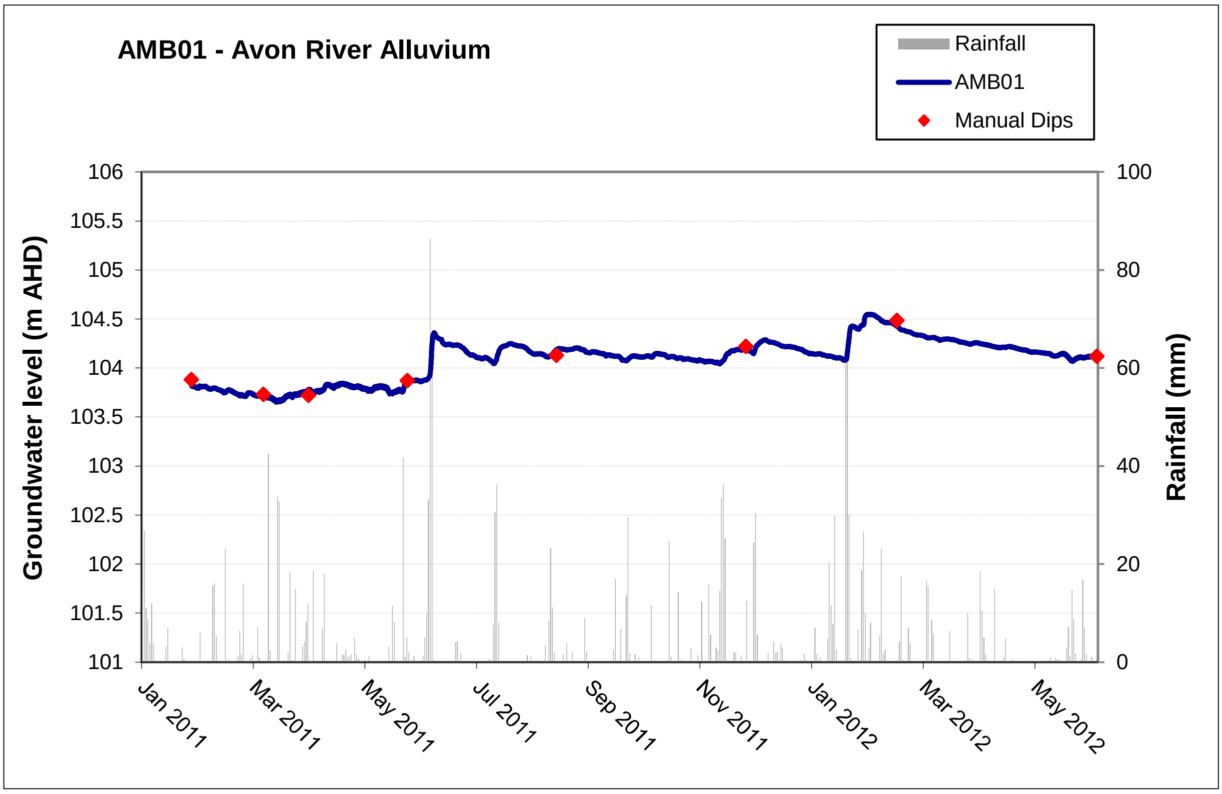

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Figure A-5 Groundwater levels and rainfall at AMB02

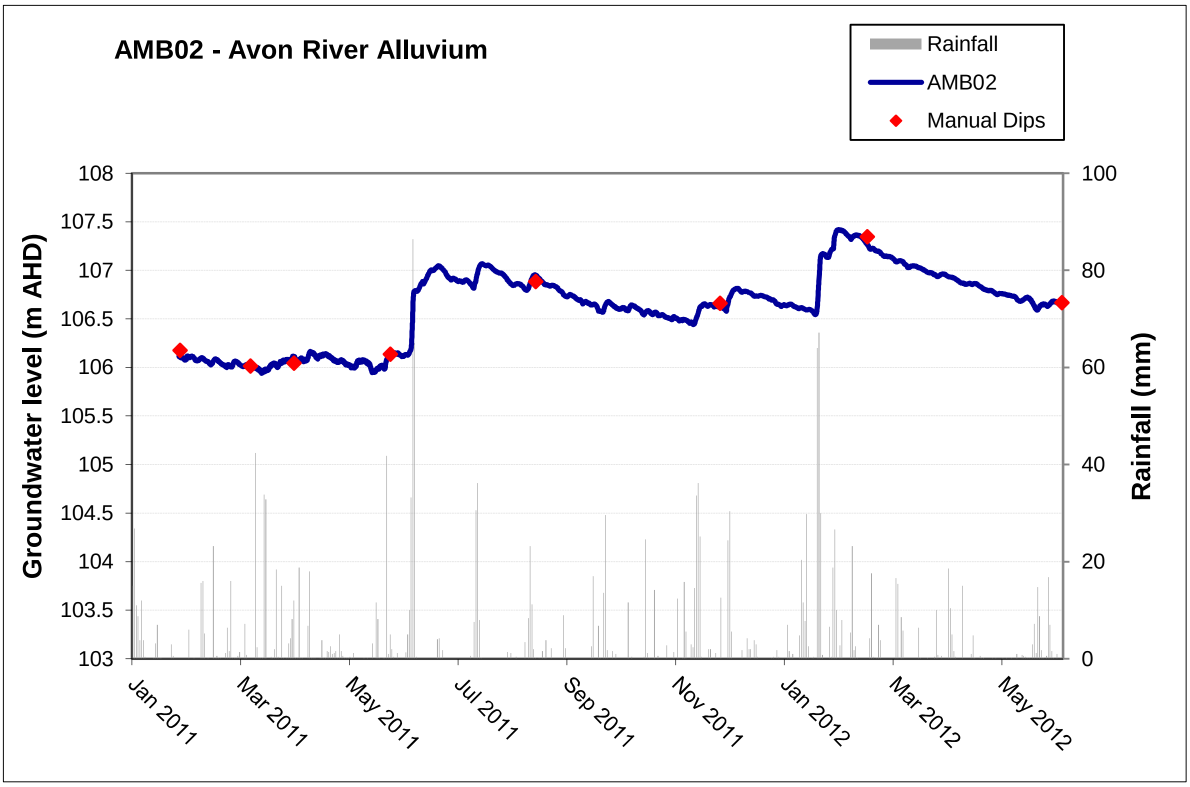

Figure A-6 Groundwater levels and rainfall at S4MB01

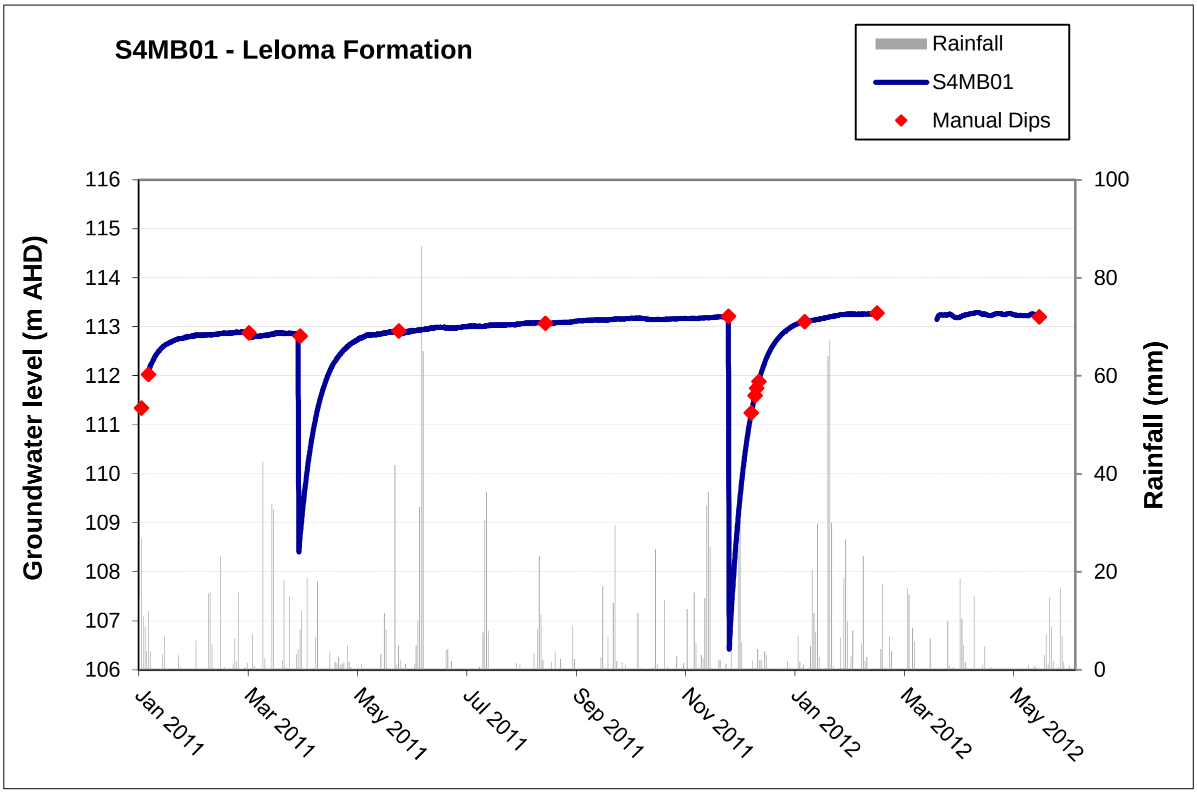

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Figure A-7 Groundwater levels and rainfall at S4MB02

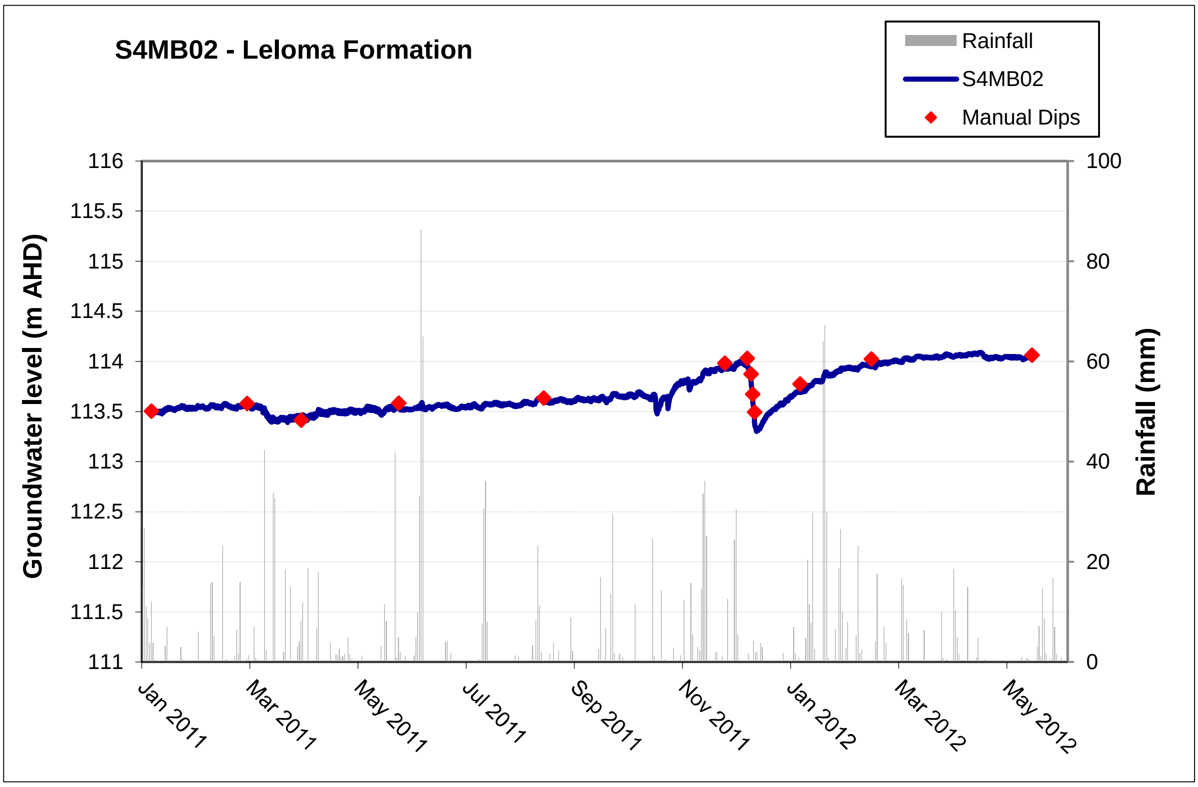
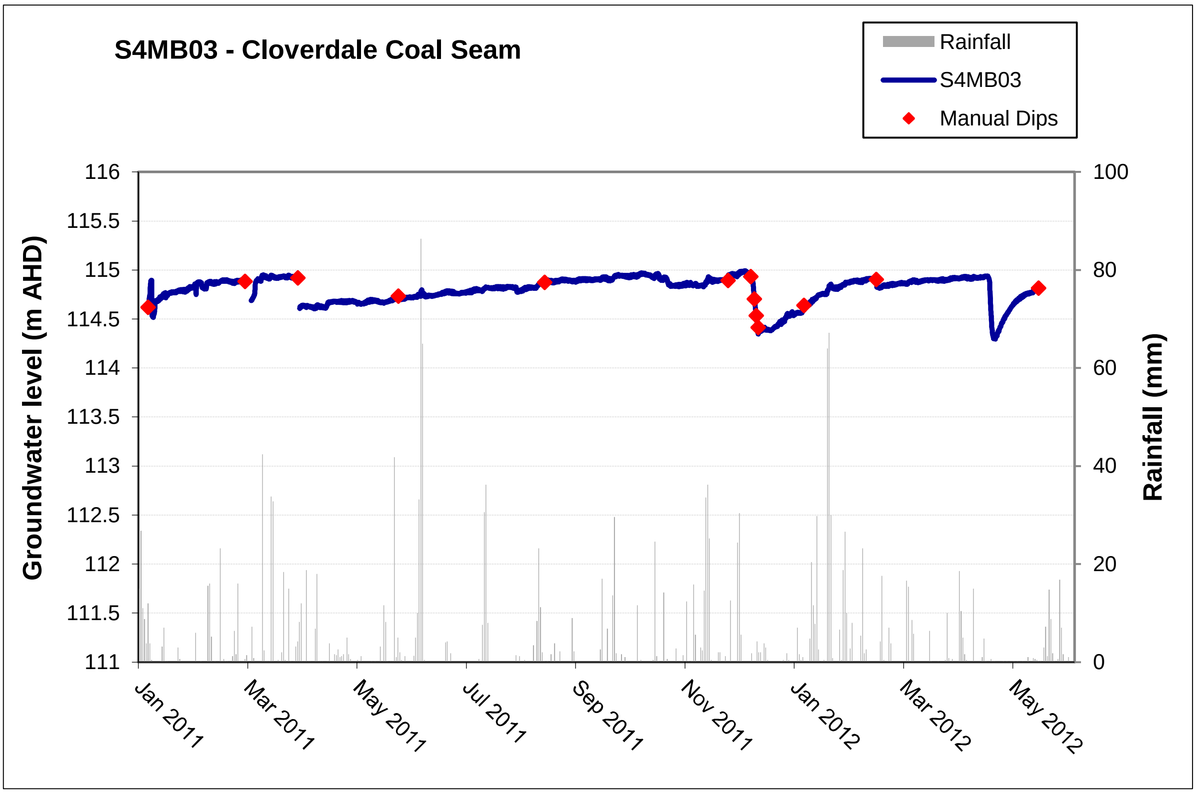


Figure A-8 Groundwater levels and rainfall at S4MB03



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Location: Gloucester, NSW

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Figure A-9 Groundwater levels and rainfall at S5MB01

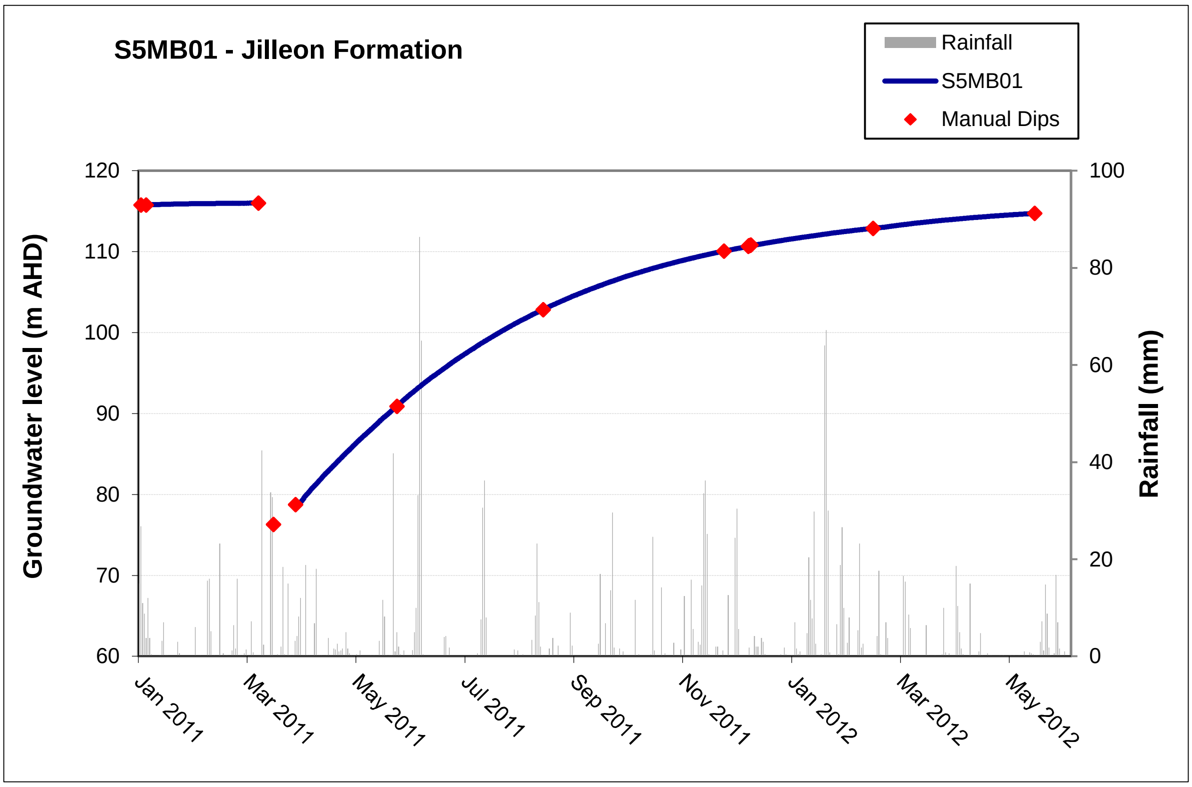

Figure A-10 Groundwater levels and rainfall at S5MB02

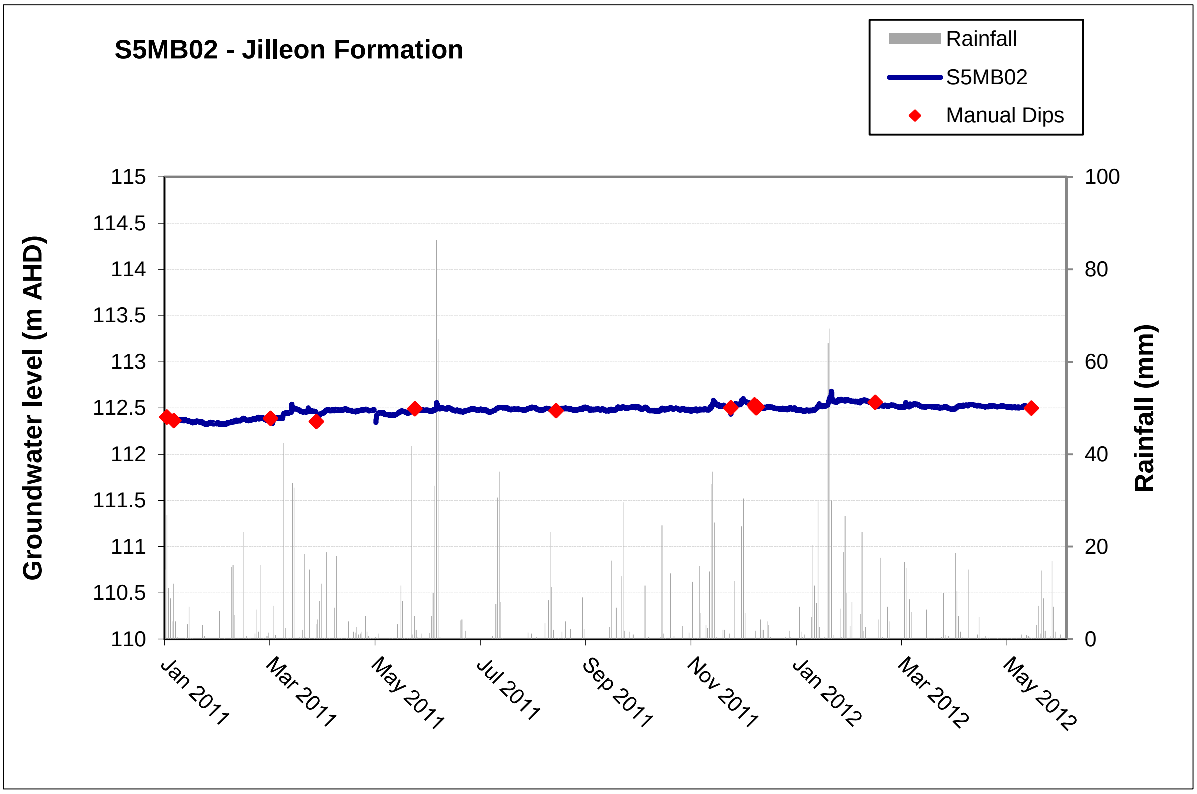

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Figure A-11 Groundwater levels and rainfall at S5MB03

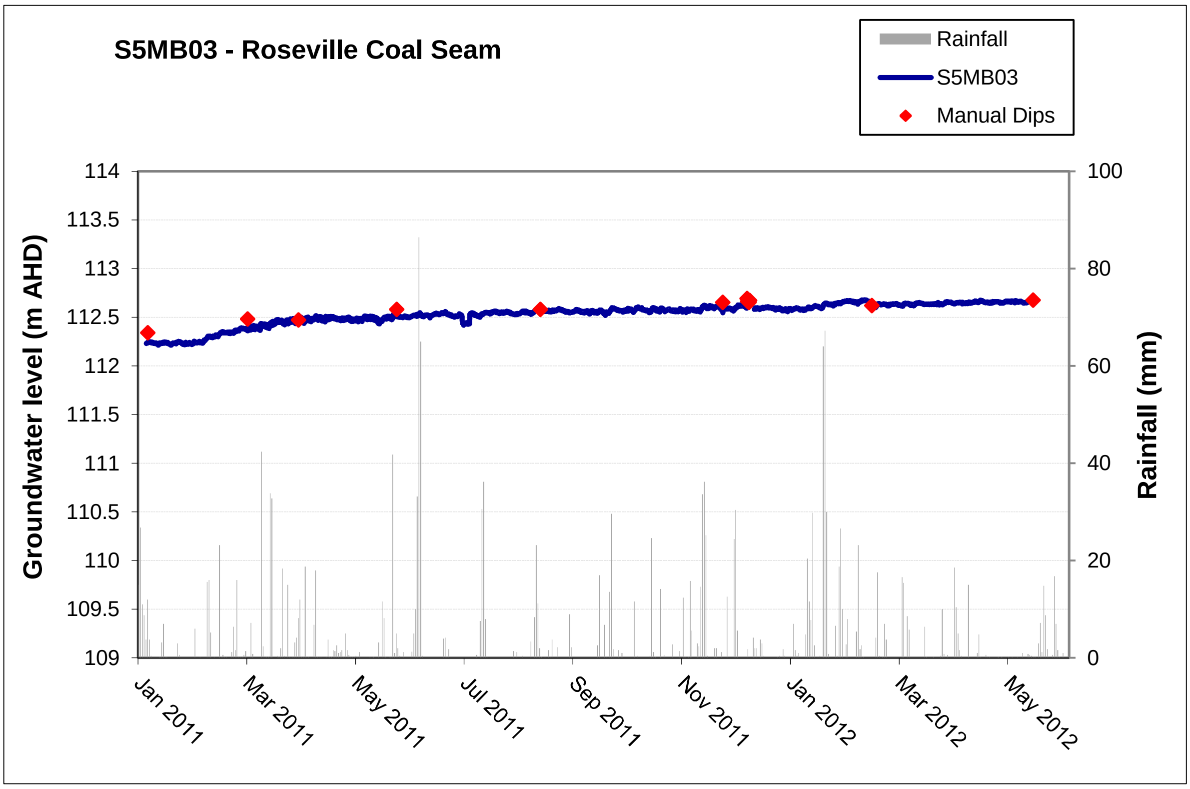

Figure A-12 Groundwater levels and rainfall at WMB01

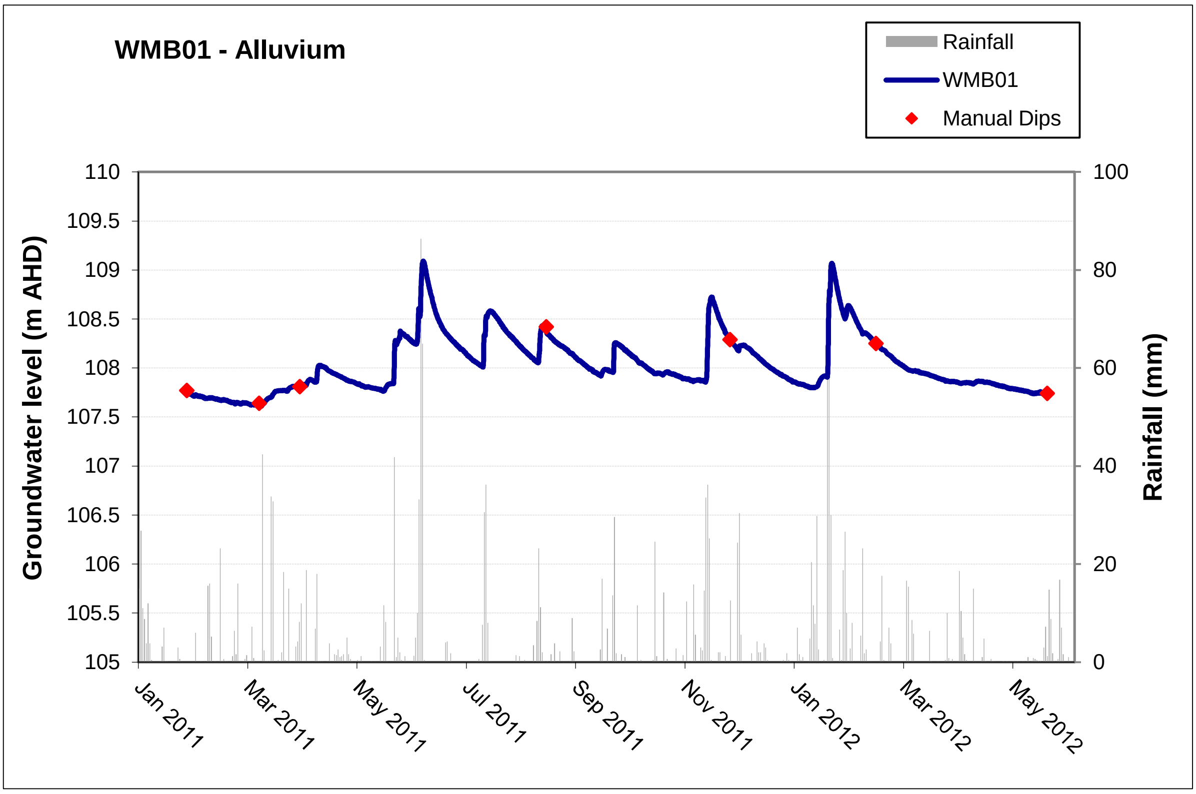

Figure A-13 Groundwater levels and rainfall at WMB02

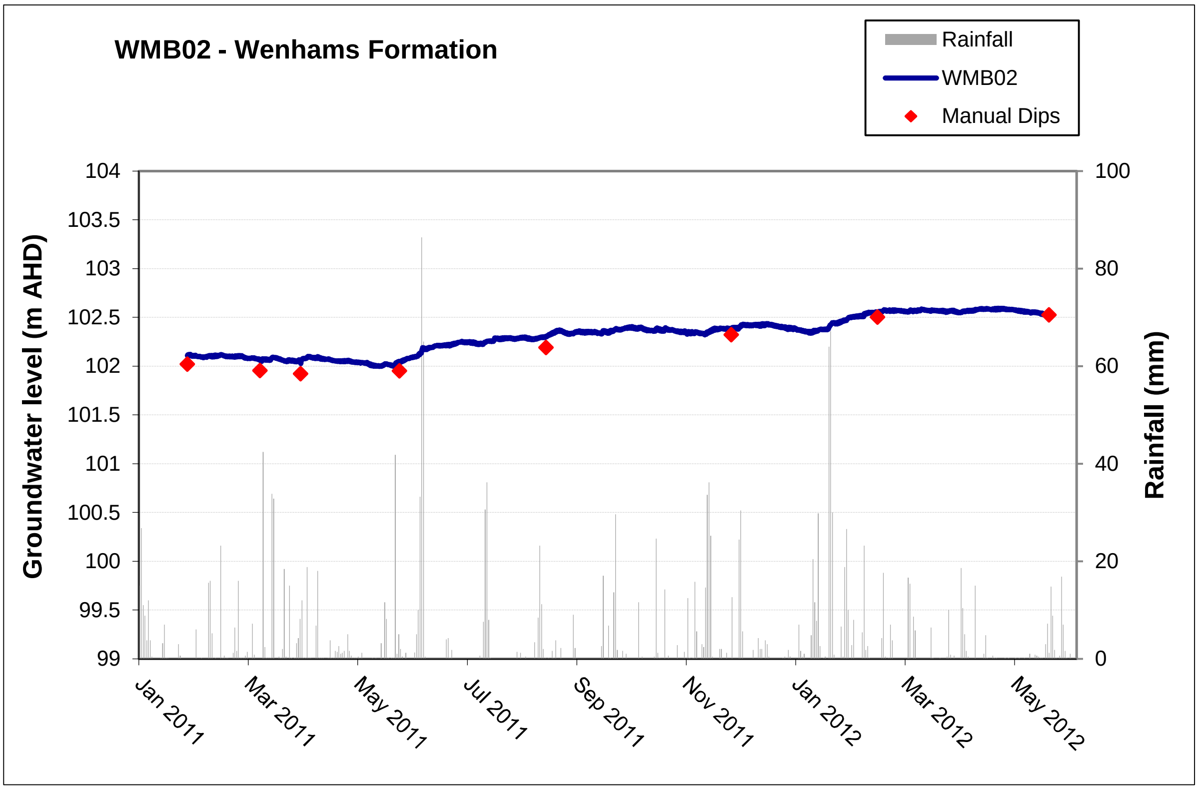

Figure A-14 Groundwater levels and rainfall at WMB03

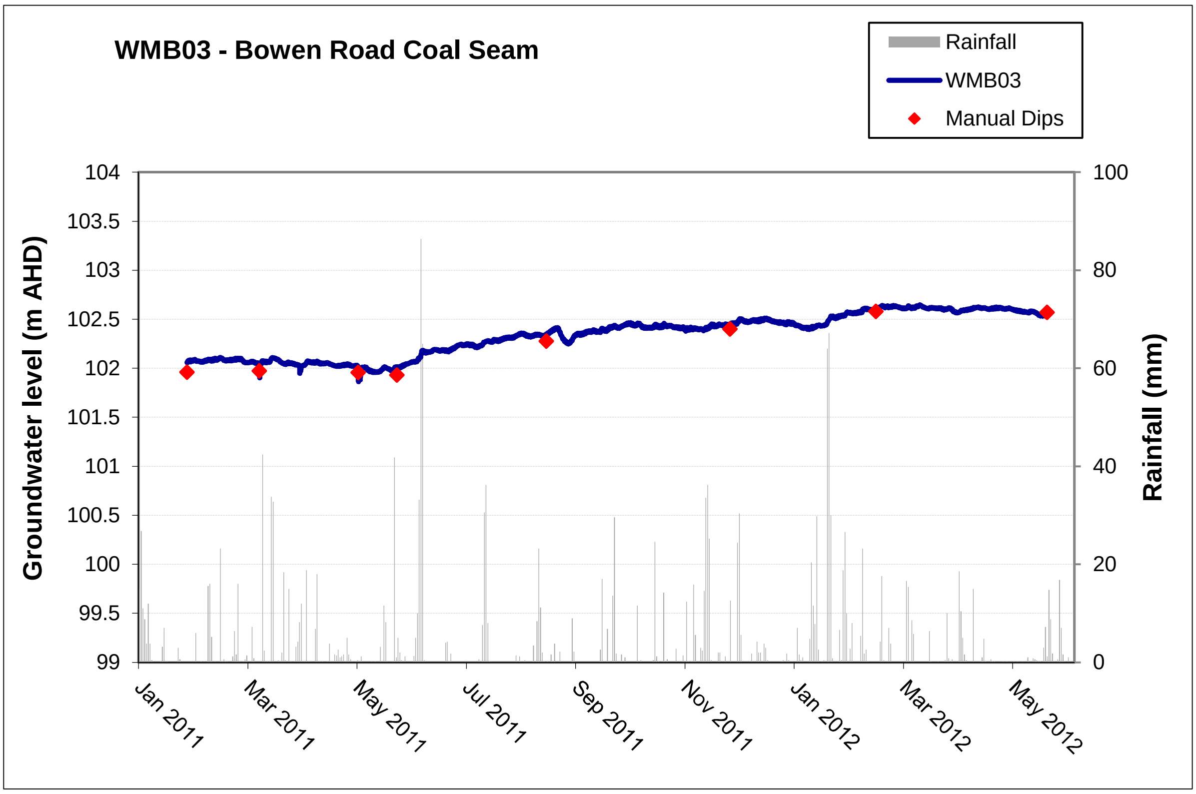

Figure A-15 Groundwater levels and rainfall at WMB04

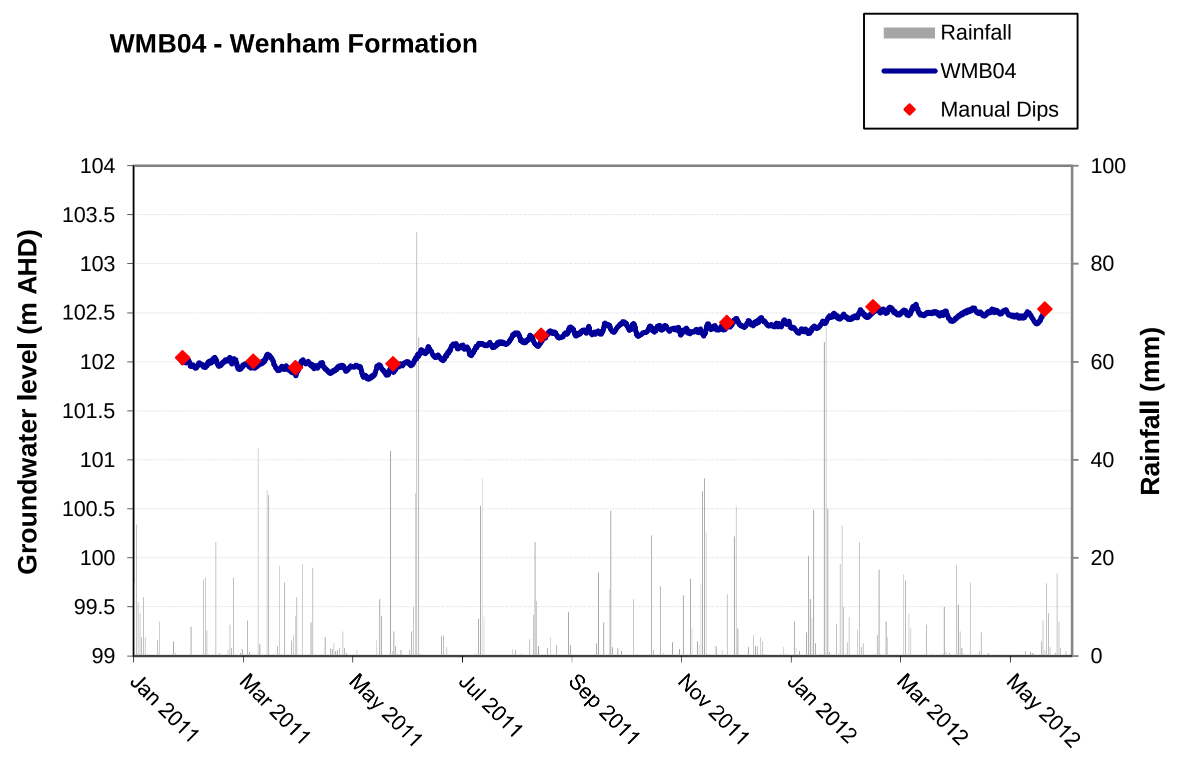

Figure A-16 Groundwater levels and rainfall at RMB01

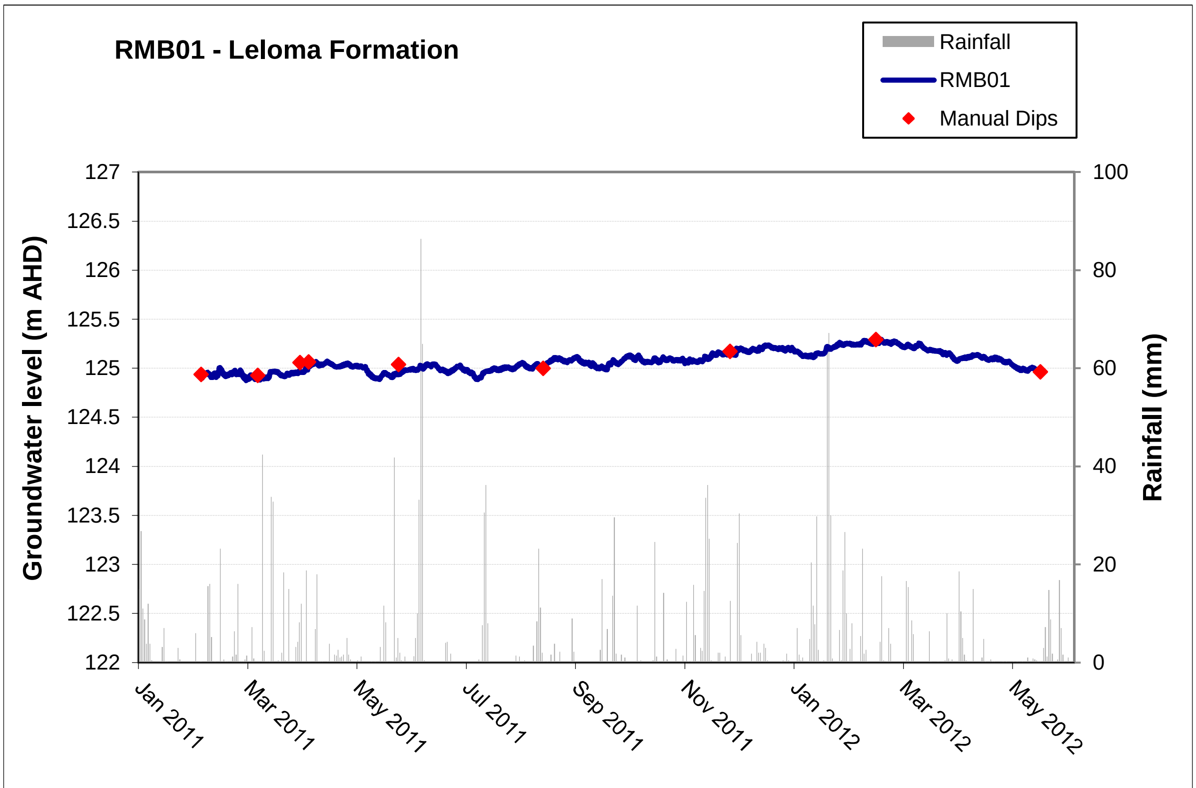

Figure A-17 Groundwater levels and rainfall at RMB02

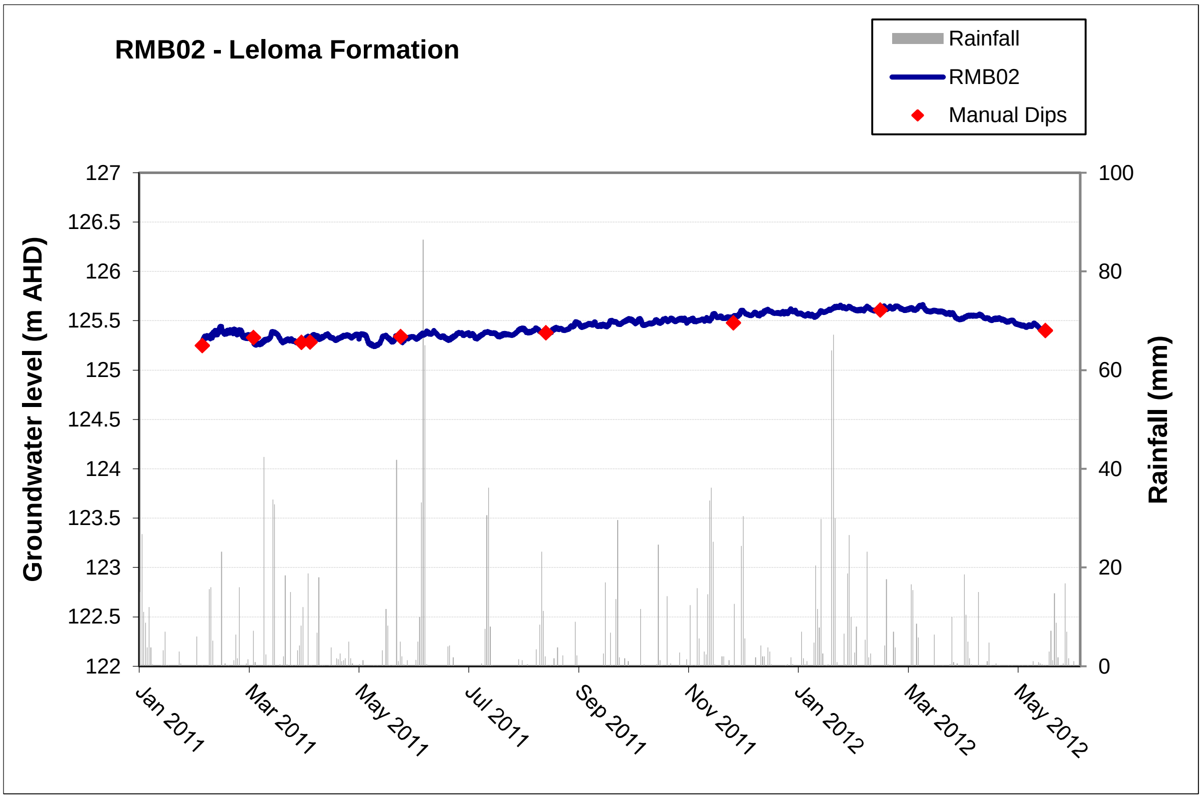

Figure A-18 Groundwater levels and rainfall at BMB01

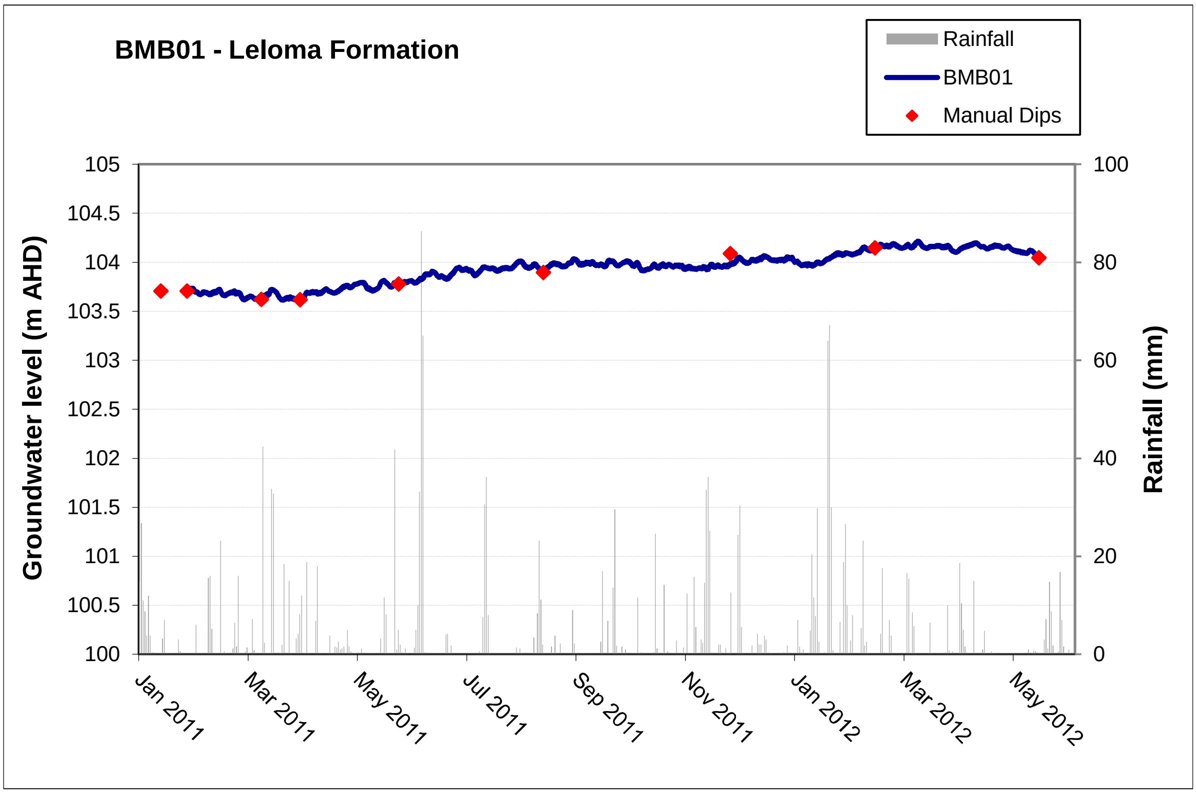

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Figure A-19 Groundwater levels and rainfall at BMB02

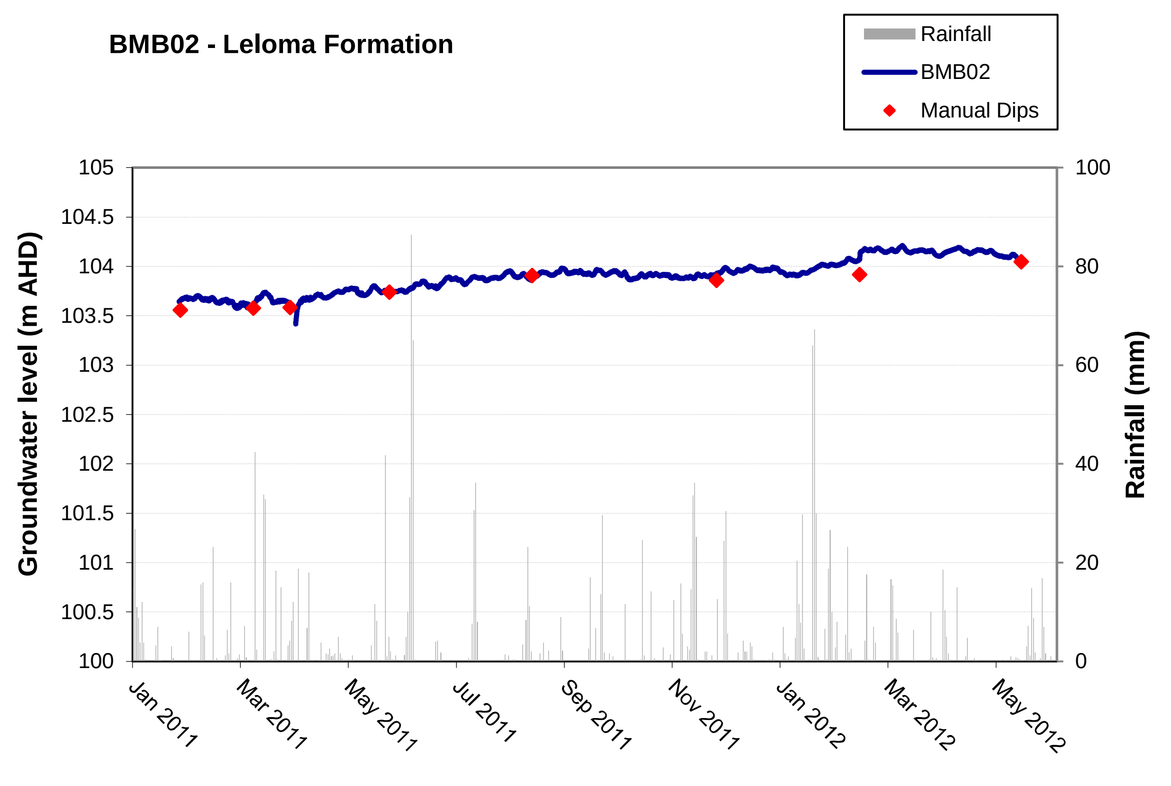
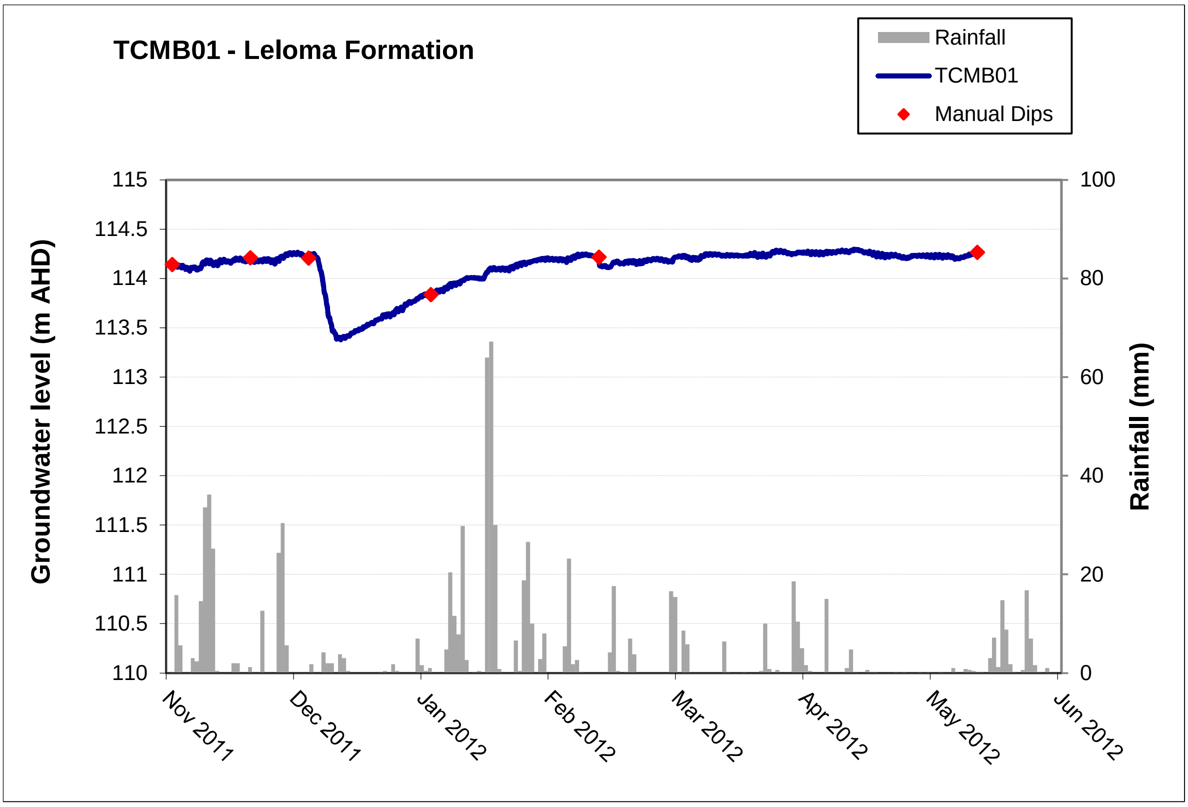


Figure A-20 Groundwater levels and rainfall at TCMB01



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Project: Gloucester groundwater investigation and monitoring
Location: Gloucester, NSW

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Figure A-21 Groundwater levels and rainfall at TCMB02

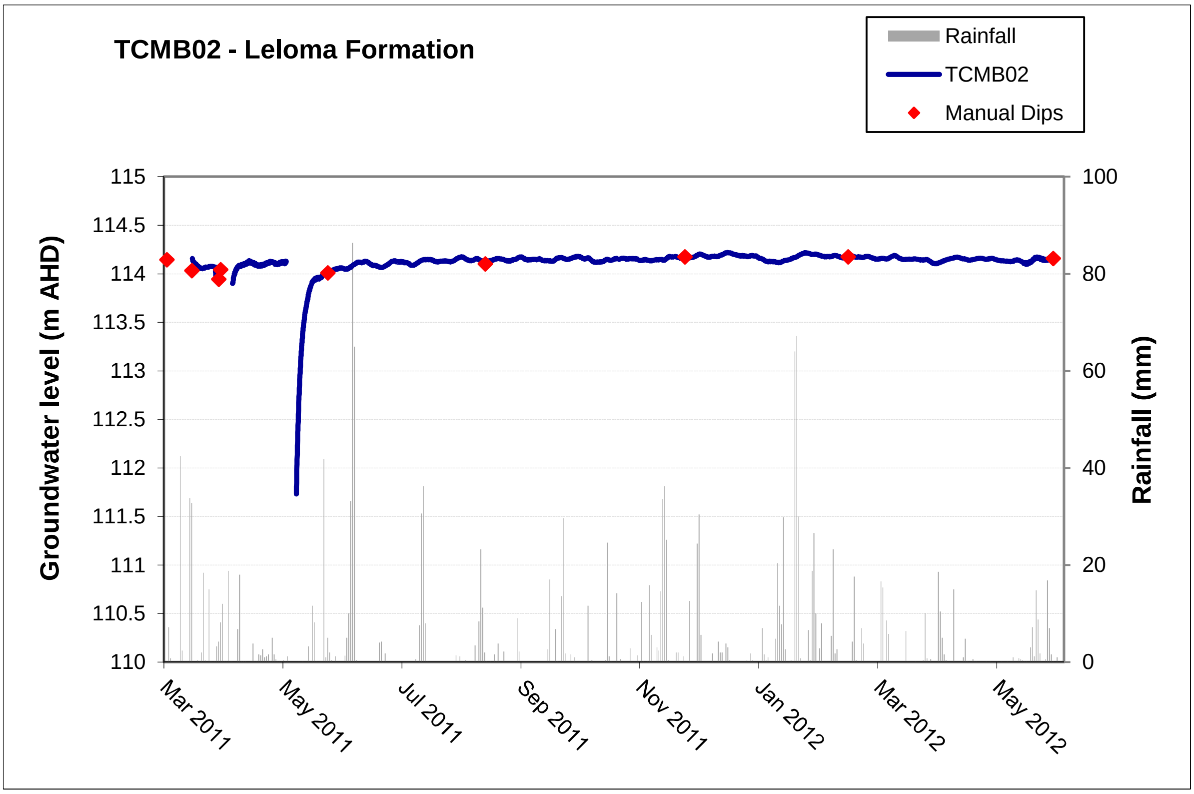

Figure A-22 Groundwater levels and rainfall at TCMB03

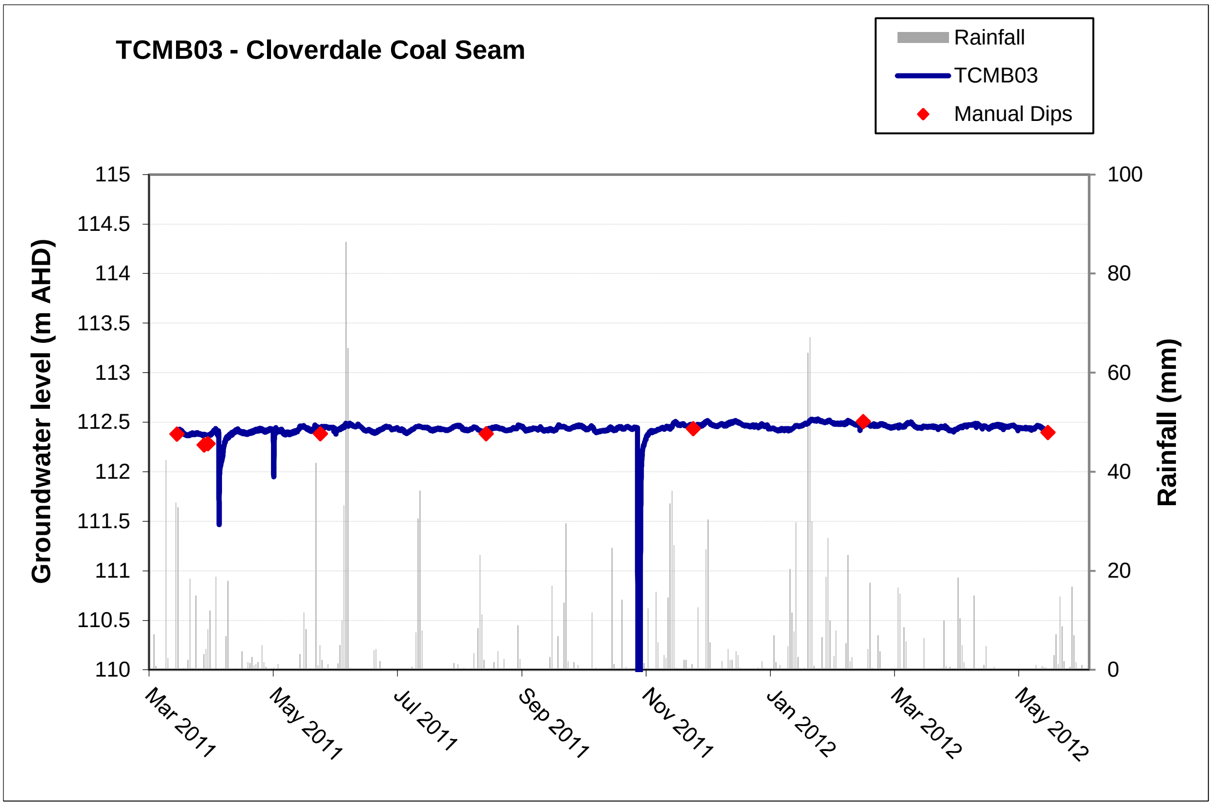

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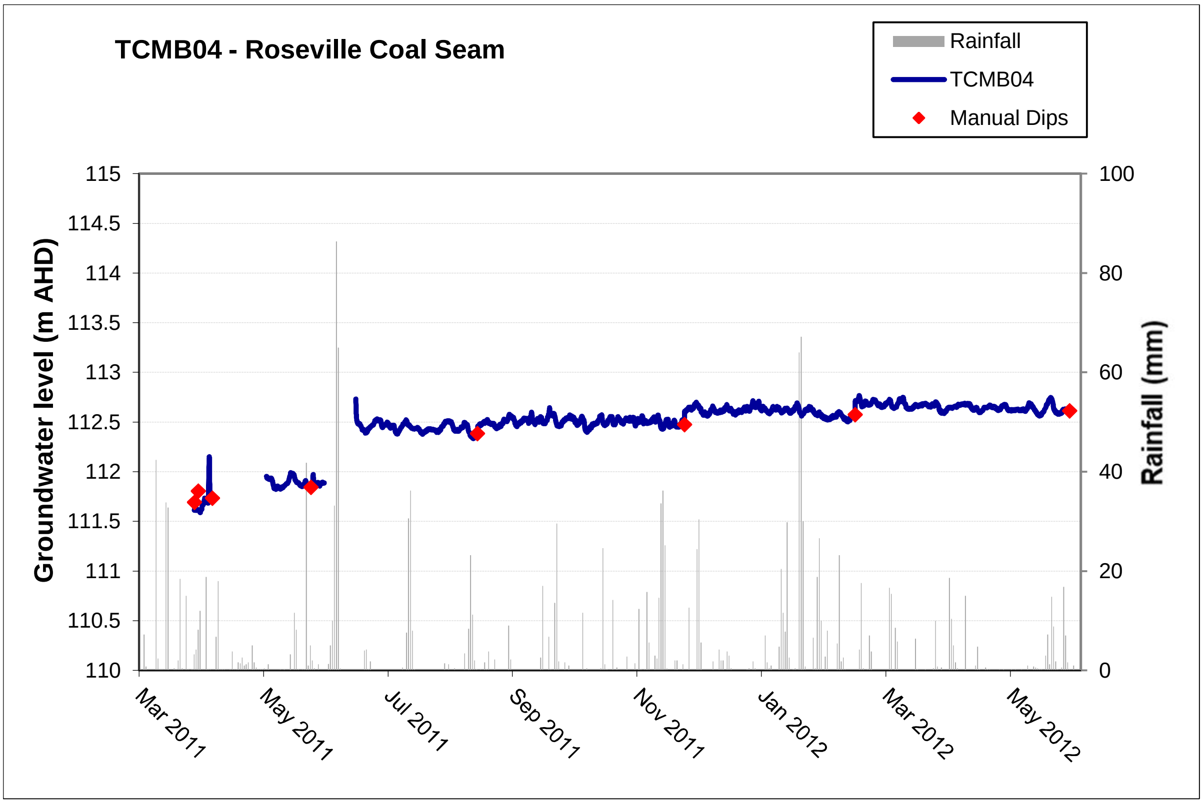
Figure A-23 Groundwater levels and rainfall at TCMB04



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Location: Gloucester, NSW

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Appendix B

Surface water hydrographs

Figure B1.1. Stream levels and rainfall at TSW01

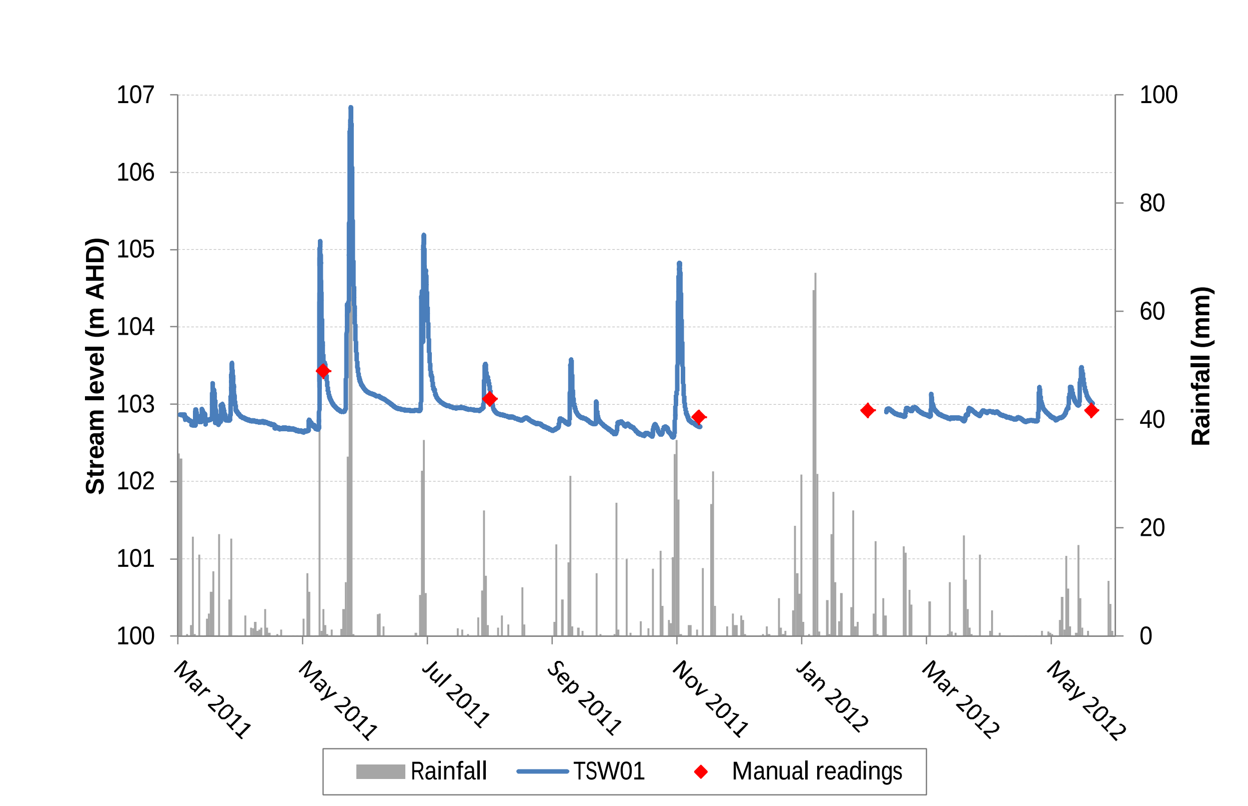

Figure B1.2. EC levels and rainfall at TSW01

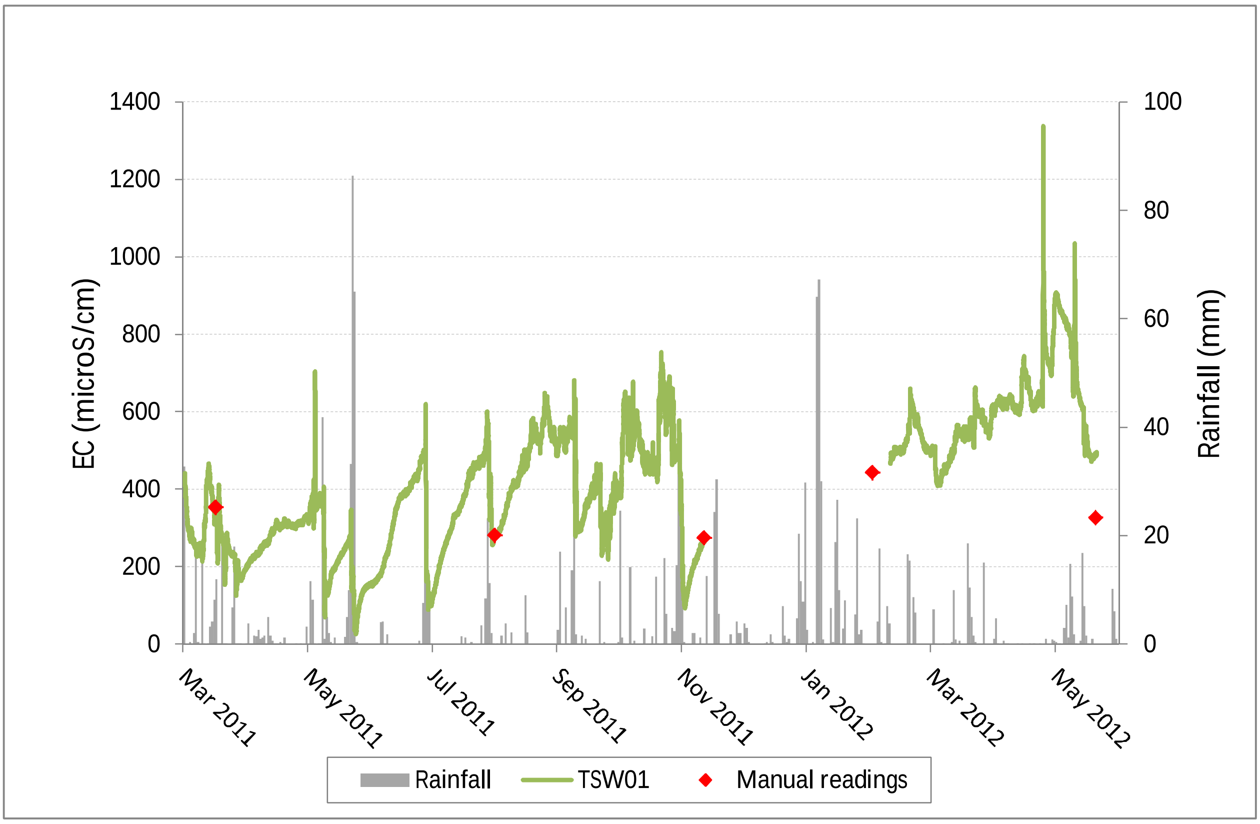

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Figure B1.3. Stream levels and rainfall at TSW02

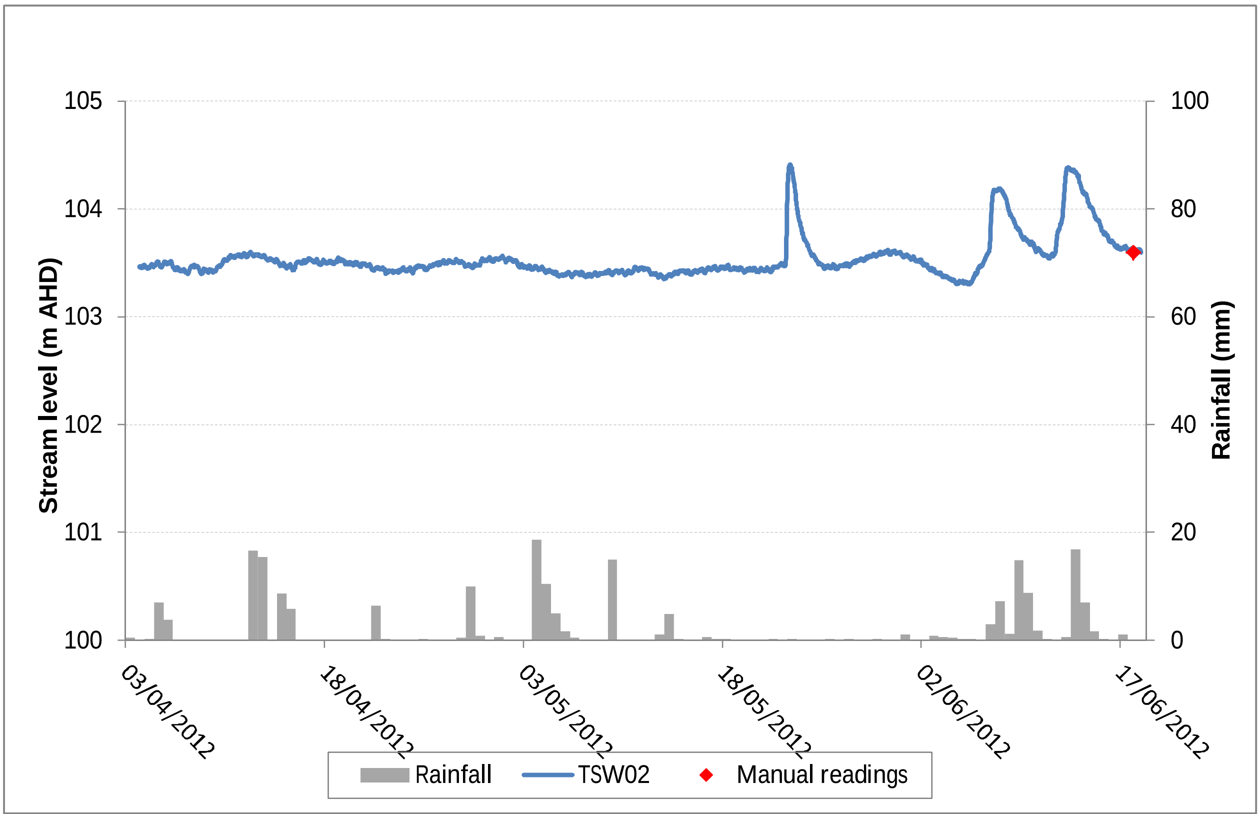

Figure B1.4. EC levels and rainfall at TSW02

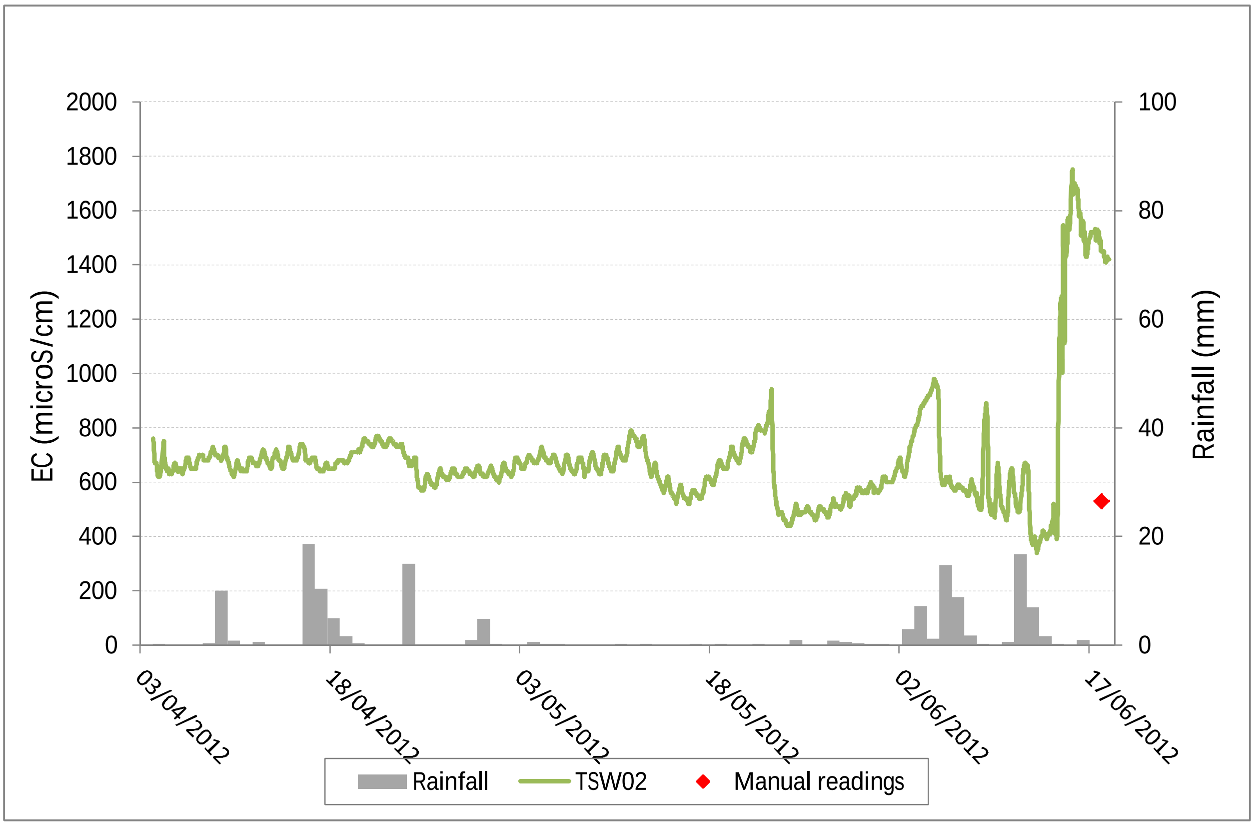

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Figure B1.5. Stream levels and rainfall at ASW01

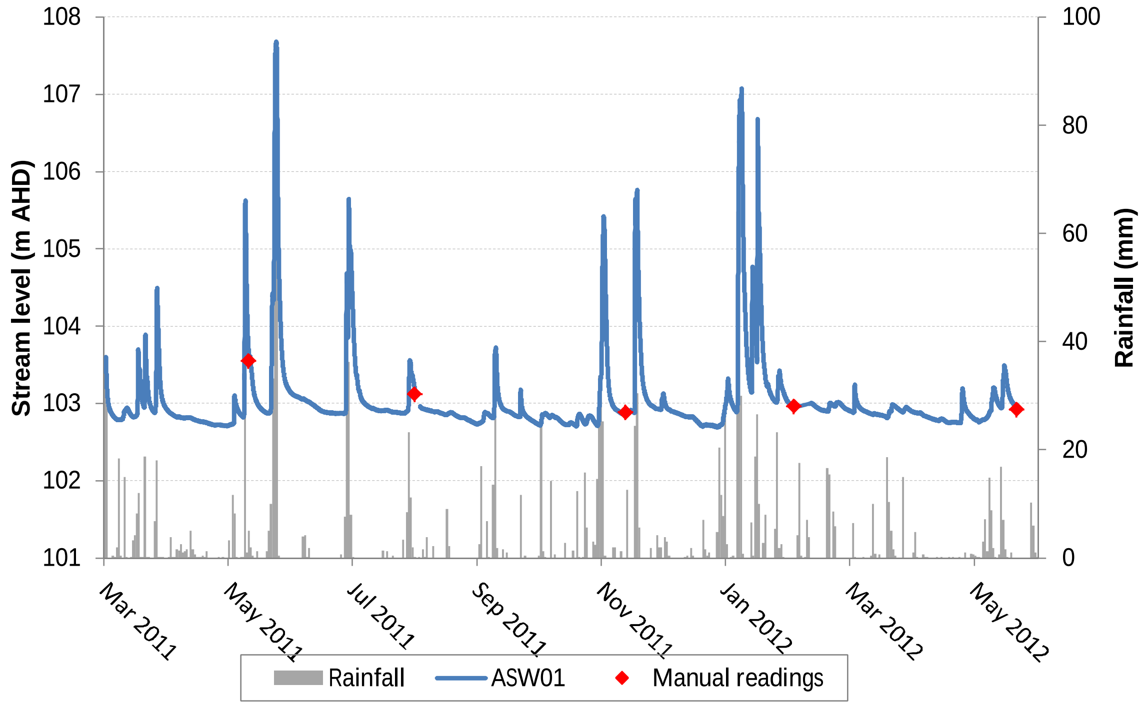

Figure B1.6. EC levels and rainfall at ASW01

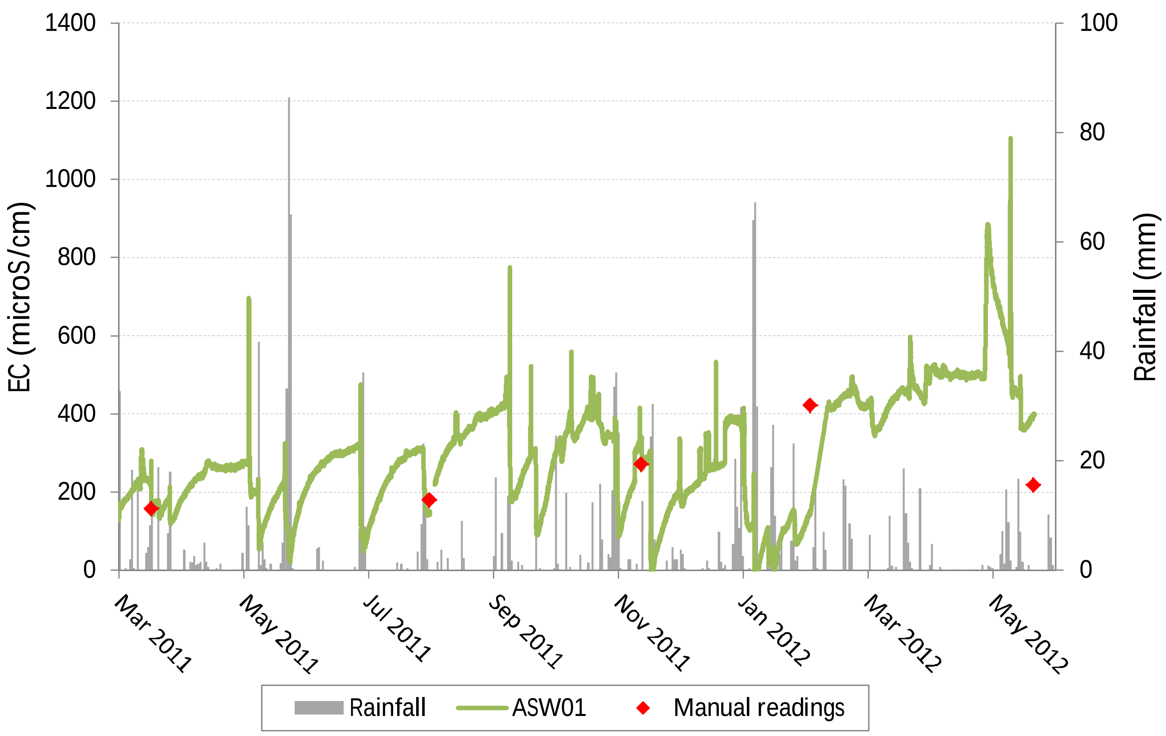

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Figure B1.7. Stream levels and rainfall at ASW02

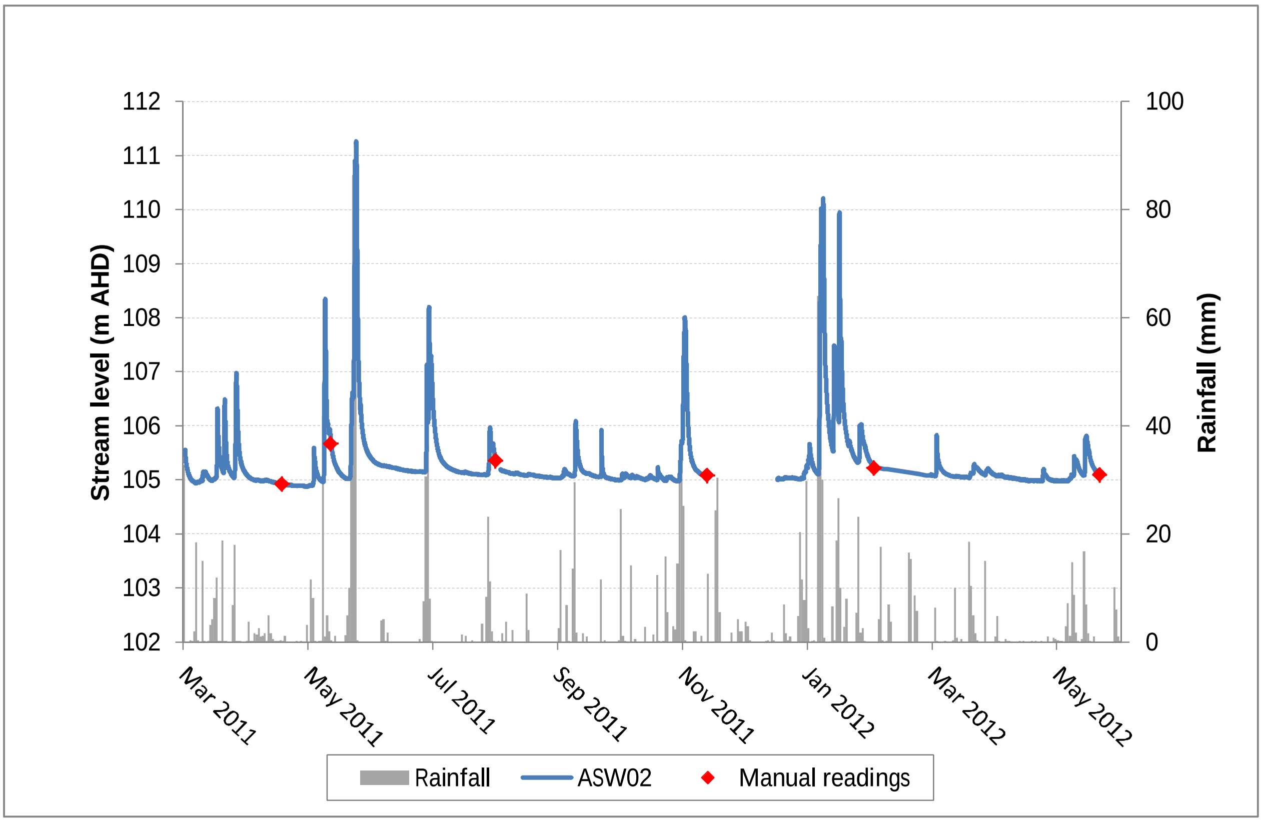
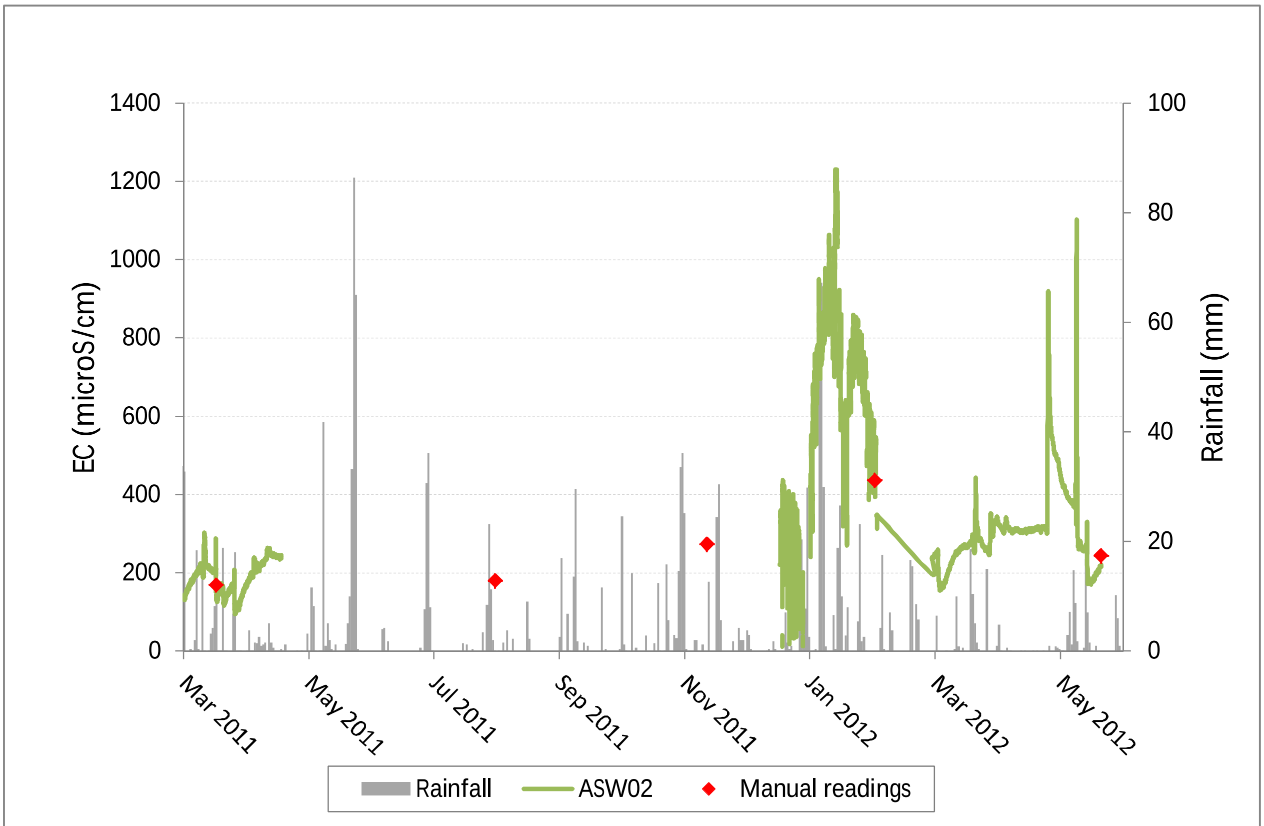


Figure B1.8. EC levels and rainfall at ASW02



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