Water Management Plan for the Tiedman Irrigation Program - Gloucester

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Document Revision History

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Glossary

Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
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, 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.
Australian Height Datum (AHD)	The reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of aquifers and water levels in bores.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
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.
Contamination	Contamination is the presence of a non natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Deficit irrigation	Deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. Outside these periods, irrigation is limited if rainfall provides a minimum supply of water.

	Total irrigation application is therefore not proportional to the irrigation requirements throughout the crop cycle but it does maximise irrigation water productivity.
Dewatering	The process of removing formation water from a targeted coal seam. Dewatering is required to reduce pressure in the coal so gas can desorb and produce.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Drawdown	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.
Electrical Conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity.
Fractured rock aquifer	Aquifers that occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary aquifers.
Groundwater	The water contained in interconnected pores or fractures located below the water table in an unconfined aquifer or located at depth in a confined aquifer.
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.
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.
pH	potential of Hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic).
Piezometer	See monitoring bore
Produced water	Natural groundwater generated from coal seams during flow testing and production dewatering.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Sandstone	Sandstone is a sedimentary rock composed mainly of sand-sized minerals or rock grains (predominantly quartz).
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.
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.
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.
Water bearing zone	Geological strata that are saturated with groundwater but not of sufficient permeability to be called an aquifer.

Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.
Well	Pertaining to a gas exploration well or gas production well.

1. Introduction

This Water Management Plan (WMP) has been prepared in advance of the REF approval for the further irrigation of produced water from AGL's CSG exploration programs within PEL 285 at Gloucester. This WMP relates to the exploration phase produced water that is in storage on AGL's property known as Tiedmans. The proposal is not related to the Part 3A project approval for the Stage 1 GFDA of the Gloucester Gas Project (GGP) and is a "Pre-Construction" activity.

The data and results of analysis collected from this irrigation trial will however provide relevant and extensive input information for preparation of the Extracted Water Management Strategy (EWMS) required under the Part 3A project approval for the Stage 1 GFDA.

The irrigation areas are located on Tiedmans as described in the REF (PB, 2011). The property is located at Stratford about 9km south of Gloucester as shown in Figure 1. The WMP is only for the Tiedman irrigation areas as outlined in Figure 2.

The REF is to be approved by the NSW Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) – Industry and Investment (Environmental Sustainability Branch), even though the specific requirements outlined in this WMP have been requested by the NSW Office of Water (NOW).

The WMP is based on the outline provided in the REF, NOW's letter of 12 August 2011, baseline monitoring initiated by AGL (and its consultants Parsons Brinckerhoff and Fodder King), and discussions with NOW in December 2011. The GMP covers both surface water and groundwater monitoring across the property and focuses on the adjacent receptors (Avon River, Dog Trap Creek and alluvial aquifers) and the underlying shallow rock aquifers.

This WMP is written to address the baseline monitoring program and the proposed monitoring program during the irrigation trial. The irrigation period is expected to be 18-24 months but may extend to 36 months depending on the final volume of produced water from exploration program activities that is required to be reused.

The majority of the monitoring network for this program was installed as part of the extensive groundwater studies for the Stage 1 GFDA as described in PB, 2012. This report also provides useful information and characterisation of the shallow and deep groundwater systems across the Tiedman property to depths of more than 330m.

1.1. Irrigation proposal

The proposal is to irrigate a maximum of 70 megalitres (ML) of produced water over a maximum area of 40 hectares (ha) over a period of three years. This will include water from exploration programs which is already stored in the Tiedman and Stratford dams as well as any rainfall which falls in the dams and any additional produced water from 2012/2013/2014 exploration activities. This water will be blended with water from the Avon River to optimise water quality of the irrigated water.

Within the 40ha irrigation area, there will be a Stage 1A area and a Stage 1B area. The Stage 1A area is the location of an intensive irrigation trial, that involves a lateral move irrigator to:

- Irrigate a maximum area of 18.2ha comprising 16 x 0.77 ha plots (12.3ha) incorporating four different soil improvements

- Irrigate a small additional (adjacent) area for enhancements to the trial program in the second or third years
- Grow salt tolerant crops (currently forage sorghum, lucerne and cereals e.g. oats) to provide continuous cropping over summer and winter
- Irrigate with a blended water mix that has a salinity (EC) in the range of 1500 to 2000 µS/cm
- Use blended water at a ratio of about 3 parts river water: 1 part produced water

Irrigation will only occur when there is a soil moisture deficit in the underlying improved soil profile. It is expected that around 50 ML of the produced water in storage (assuming there will be a maximum 70 ML to reuse) will be used across this area. The expected river water volumes to be used for blending with the produced water will be around 150 ML, giving a total of around 200 ML that will need to be irrigated over this 2 to 3 year period.

Two catch dams will be constructed to capture runoff from the trial area during larger rainfall events. The irrigation plan is to maintain an irrigation deficit so there will always be capacity in the treated soil profile to accept rain events in a similar manner to the surrounding soils. Subject to the frequency, intensity and duration of larger rain events, surface runoff may occur from the irrigation area. In such instances, it is planned to capture the initial runoff from the area in the catch dams and return it to the produced water storage dams. After capturing the first flush, it is planned to let any further runoff to overflow the catch dams and become normal overland flow. Soil moisture monitoring will verify the irrigation deficit during the trial period.

The important (irrigation trial) design elements to protect adjacent water sources are:

- Amelioration of the clayey sub-soils by adding organic matter, lime and gypsum to counter deficiencies in the soil and water to be irrigated, and to improve the water holding capacity of the soil profile
- Installation of bund walls and diversion banks to minimise ingress of any overland flow and egress of applied water and thus minimise the volume of run-off into catch dams
- Installation of high-flow float-activated recycle pumps at each catch dam to remove/reduce the risk of overflows from the catch dams by constantly keeping them empty
- Installation of a state-of-the-art irrigation system, real time soil moisture monitoring and carry out daily water balance calculations
- Operation of the irrigation system on a deficit irrigation basis with the deficit to be determined from daily water balance and weather monitoring
- A number of automatic shut down features which include:
    - When wind velocities exceed a pre-set level
    - When rainfall exceeds a pre-set level
    - When there is a mechanical or electrical system fault
- An emergency stop button which can be activated at any time by an operator
- The system knows where it is via GPS and can be set for automatic stops at the physical extremity of the trial area
- Physical barricades anchored into the ground at both extremities of the trial area which will prevent the irrigator from leaving the trial area and activate an emergency stop should the irrigation machine come within 0.5m of the barricade

- There is also an automatic shut down provision in the event of pressure losses (e.g. pipe burst) within the supply line from the pump station. The shut off valve is located on the irrigation machine. In addition, there is a hand-operated shut off valve at the pump station

The remaining area (Stage 1B) will be less intensively irrigated using the existing travelling irrigator. This will only be used for the lower salinity produced water (generally water with a salinity (EC) under 3000 µS/cm) and will be directly irrigated during drier periods (mainly spring and summer) onto improved pasture (clovers and kikuyu grass). It is expected that around 15 ML will be irrigated across this area. This will mostly be in the first irrigation season but it could extend into the second summer irrigation season.

There will be no irrigation on the alluvial floodplain soils where water tables are highest, so this reduces potential pathways to shallow aquifers and the Avon River. The intention is that all irrigation water is transpired by the planted crops and pasture.

1.2. Objectives

The purpose of this WMP is to outline the water management strategy and the monitoring network for the quality and quantity of water used for irrigation across the site. The WMP is designed to ensure that the quality of the water used for irrigation is appropriate and that the application of produced/blended water does not result in negative impacts on the local surface water or groundwater resources.

This WMP recognises three stages of irrigation (from PB, 2011):

- Existing irrigation areas (see Figure 1) - current area is 8.6ha, and covers irrigation of the following paddocks:
    - Rough Paddock north
    - Rough paddock south
    - Dairy paddock.
- Stage 1A – is mostly the trial irrigation area serviced by the new linear move irrigator in the north west of the site (Figure 2). Even though this envelope is about 22ha, it is unlikely that any more than 18ha will be involved in the irrigation trial.
- Stage 1B - is an expansion of the existing irrigation area to include the irrigation of improved pasture to the west and south of the existing area. There is an additional 21ha in this envelope but it is uncertain whether any of this additional area will be irrigated during the period of this REF.

This WMP replaces all the initial monitoring and contingency plan details outlined in the REF (PB, 2011).

1.3. Responsibilities

AGL Upstream Investments Pty Ltd (AGL) is responsible for compliance with this WMP. Periodic monitoring of the water quality from the monitoring network will mostly be carried out by AGL's groundwater consultants Parsons Brinckerhoff. Some additional (monthly) sampling may be undertaken by AGL Operations staff based at Gloucester or technical officers employed by Fodder King who are AGL's agricultural advisors for the trial.

2. Background

This chapter provides summary information relating to the landform, geology and hydrogeology for the Stratford area. More details are provided in the REF (PB, 2011) and the Phase 2 groundwater investigation report for the wider region that is the Stage 1 GFDA (PB, 2012).

2.1. Landform

The Gloucester geological basin straddles the Manning River Catchment to the north and the Karuah River Catchment to the south.

The landforms of the locality are guided by the geology of the Stroud Gloucester Syncline and comprise ridges to the east and west, undulating low hills and flat land in the centre where the Avon River flows to the north. The lowest points in the area are on the Avon River floodplain at an elevation of approximately 100 mAHD.

2.2. Catchment and Local Hydrology

The Tiedman property is within the Manning River Catchment (approximately 8,200 km^2 in size) and the Avon River Sub Catchment. The Avon River originates to the south west of Gloucester and joins the Gloucester River to the north of the township of Gloucester. Waukivory Creek, Dog Trap Creek and Avondale Creek are also located within the Sub Catchment.

Two produced water storage dams are present on the site (Tiedman North and South dams). A third dam is proposed as part of this irrigation upgrade. These dams are of a 'turkey's nest' style construction and located on high ground (beyond the floodplain) and are designed to prevent ingress from surface run off. Stratford 1 and 3 dams are also of a turkey's nest construction and are located on the adjacent property owned by Gloucester Coal to the south of the site (Figure 1).

Groundwater recharge contributes to base-flow in local tributaries and creeks following periods of elevated rainfall. The Avon River is a gaining stream most of the time. The exception is when the river is in flood and stream levels are more elevated than the water table levels in the adjacent alluvial aquifer.

Historically correlation between water quality and stream flow typically shows a salinity peak immediately after runoff followed by a reduction in salinity after a prolonged rain event followed by a general increase in salinity as the stream flow reduces and groundwater baseflows increase. The surface water (from the available records) is generally fresh (100 < EC < 1000 µS/cm) and near neutral to slightly alkaline (PB, 2012).

2.3. Geological and Hydrogeological Setting

2.3.1. Geology

The Gloucester Basin is a synclinal structure formed by Permian consolidated sediments. The Permian Rocks display steep dips of up to 90° on the edge of the basin, dipping towards

the north south axis, and flattening towards the basin centre. They lay on a basement composed of Early and Late Carboniferous sedimentary and volcanic units that are part of the New England Fold Belt. The geology of the region 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.

The geological strata of the Gloucester Basin (from youngest to oldest) on a local scale can be summarised as:

- Unconsolidated alluvial deposits along the Avon River (Quaternary in age)
- Sedimentary rocks (including substantial coal measures at depth) of the Gloucester Coal Measures (Permian in age)
- Fractured basement rocks of the New England Fold Belt below the sedimentary rocks (Palaeozoic age)

2.3.2. Hydrogeology

Based on the latest water level, water quality and isotope data from the Phase 2 studies (PB, 2012), there is a good appreciation of groundwater recharge, discharge and flow processes through the different hydrogeological units of the Gloucester Basin. These units (based on SRK Consulting, 2010) are confirmed as:

- Alluvial aquifers;
- Shallow bedrock aquifers;
- Coal seam water bearing zones;
- Confining units.

Only the first two units are aquifers. The deeper rock types are either very poor aquifers/aquitards (coal seams, siltstones and sandstones) or confining aquitard/aquiclude layers (claystones or indurated sandstones).

The **alluvium** is only shallow (maximum 12m thickness) and in some areas contains an unconfined (sand and gravel) aquifer. Groundwater flow processes are relatively simple with rainfall being the predominant recharge source on the floodplain. Flooding occasionally adds additional recharge water to the alluvial water table. Groundwater discharge from the alluvium is to the rivers as baseflow and shallow groundwater is also expected to be transpired by riparian vegetation.

The **bedrock** (to a maximum 150m depth) contains mostly tight siltstone and indurated sandstone rock types with occasional thin semi-confined sedimentary/fractured aquifers. Rainfall is the only recharge source to the bedrock aquifers and recharge does not occur everywhere in the landscape. Recharge only appears to occur in areas of rock outcrop. In areas where there is a weathered (clayey) profile, brackish to saline water quality suggests there is negligible (vertical) rainfall recharge. Groundwater flow in bedrock aquifers is lateral, either within local fracture zones or individual strata if there are no interconnecting and open fracture zones.

The groundwater in the deeper bedrock units is moving very slowly with lateral movement within each rock unit predominating. Confining rock permeabilities are very low, coal seam permeabilities are slightly higher (but are still not high enough to be considered useful aquifers).

There are no known groundwater dependent ecosystems (apart from stream baseflow accessions) although there may be some uptake of shallow groundwater (from the alluvium) by native terrestrial vegetation. Diffuse discharge of saline groundwater from bedrock seeps is thought to occur into the alluvium as stream salinity increases during dry

periods. Groundwater discharge is diffuse and discharge does not occur at any one point in the landscape.

3. Water Management Framework

The access, taking and use of groundwater and surface water in NSW is currently managed and implemented by the NOW under two primary legal instruments — the *Water Management Act 2000* (WMA) and the *Water Act 1912* (WA).

All groundwater in the GGP area is located within two groundwater systems – the alluvial sediments associated with the unregulated streams, and the sedimentary/fractured bedrock aquifers. The alluvial sediments are managed under the Lower North Coast Unregulated and Alluvial Water Sources Water Sharing Plan (WSP) and the WMA, while the deeper sedimentary/fractured rock groundwater is currently managed under the WA.

3.1. Legislation

3.1.1. Water Act (1912)

Since 2003 the *Water Act 1912* has been progressively phased out (repealed) and replaced by the *Water Management Act 2000.*

All of AGL's bore licences for the GGP are issued under the *Water Act 1912* as this is the current water regulation for CSG exploration activity for this water source.

3.1.2. Water Management Act (2000)

There is no Water Sharing Plan for the sedimentary (porous) rocks of the Gloucester Basin at this time and therefore the *Water Management Act 2000* currently does not apply to these groundwater sources. The *Water Management Act 2000* will come into force for the Gloucester CSG project once the Water Sharing Plan for this water source commences, and the *Water Act 1912* is repealed. The timeframe for this to occur is likely to be within the next two years.

The unregulated Avon River and the associated alluvial groundwater source is managed under the Lower North Coast Unregulated and Alluvial Water Sources Water Sharing Plan (WSP). AGL has a Water Access Licence and works approval under this WSP for surface water abstraction from the Avon River.

3.2. Licences

AGL holds seven bore licences for the commercial/industrial extraction/irrigation reuse of groundwater pumped during flow testing programs. The bore licences are linked into a combined allocation of 20 ML per year (two licenses) and 15 ML per year (five licences). No new produced water has been pumped in recent years and further flow testing is not planned at any of these seven Stratford wells in the foreseeable future.

The last five bore licences issued have conditions relating to dewatering volumes and irrigation areas (Condition 9); impact assessment prior to taking water (Condition 10); and prepare, implement and report on the findings of a groundwater management plan (Condition 11). The REF and Irrigation Drainage Management Plan (PB, 2011) addresses Condition 10 while this WMP addresses the monitoring items in Condition 11. More specifically Condition 11(a) (parameter/analytes to be monitored), and Condition 11(b)

(monitoring at frequencies of no less than 6 months) are presented in this WMP while Condition 11(c) (details of baseline survey results) are presented in PB, 2011 and PB, 2012.

This produced water is currently stored in the four storage dams. If new pilots are commissioned then additional industrial/irrigation bore licences will be obtained for these gas wells. Details of the current bore licences are provided in Table 3-1.

Table 3-1 Bore Licences held by AGL for irrigation

Lot/DP	Licence No.	Issue Date	Period	Purpose	Allocation (ML/yr)	Local Bore Names
1/718347	20BL168850	16-Oct-08	5 years	Commercial	20*	Stratford 1
80/979859	20BL168851	16-Oct-08	5 years	Commercial	20*	Stratford 3
85/979859	20BL172557	8-Oct-10	5 years	Industrial and Irrigation	15^	Stratford 4
85/979859	20BL172558	8-Oct-10	5 years	Industrial and Irrigation	15^	Stratford 5
85/979859	20BL172559	8-Oct-10	5 years	Industrial and Irrigation	15^	Stratford 6
83/979859	20BL172560	8-Oct-10	5 years	Industrial and Irrigation	15^	Stratford 8
85/979859	20BL172561	8-Oct-10	5 years	Industrial and Irrigation	15^	Stratford 9

Key - * joint allocation between these two licences; ^ - joint allocation between these five licences

AGL also holds a water access licence (WAL 19521) and works approval (20CA204347) to extract 32 ML/yr from the Avon River source adjacent to the site for irrigation. This fresher surface water will be blended with the stored produced water for irrigation of salt tolerant crops.

The access to and use of this water is governed by the current WSP. The key features of water availability and use in the Avon are sourced from the report card for the Avon River water source (DWE, 2009) as outlined below:

- 43 surface water licences
- 1,997 ML allowed to be extracted annually
- Water cannot be traded into the Avon from downstream connected rivers (Lower Manning, Lower Barrington and Gloucester)

Under the WSP, permanent and temporary trading of water licences is allowed but can only be sourced from within the licences allocated for the Avon River source.

AGL may seek to purchase water from other licensees along the Avon River to make up possible shortfalls in fresh water for blending (a maximum of 90 ML over three years is anticipated).

Accordingly, any additional water will be sourced under permanent transfer or temporary transfer agreements with other licensees on the Avon River, with such transfers to be approved by NOW. It is noted that the WSP states, “WSPs set the rules by which irrigation licences can be traded. It is expected that over time, there will be an enhanced water market, where licences will be traded both permanently and temporarily.”

If permanent or temporary transfers are not obtained then river usage will be restricted to the volumes available under WAL 19521 and the appropriate blend ratio amount of produced water. No water purchases are required for the current water year (2011/12).

The turkey nest dams do not require licensing as they are holding dams only, they have no catchment, and the water sources feeding them are licensed.

4. Monitoring, Contingency Plan and Reporting

Government (through the NSW Office of Water (NOW)) is now requiring a higher level of water monitoring associated with all CSG exploration and production programs. Irrigation of produced water is one of these activities requiring extensive monitoring. These requirements generally relate to:

- A formal water management plan (WMP)
- Installation of dedicated monitoring bores
- Collection of periodic water level, water quality and volumetric data
- Reporting of data and trends

For this irrigation proposal, maximum irrigation rates are likely to be 4-6 ML/ha and the irrigation water quality will not exceed 3000 µS/cm, and for the main trial area the target is to use a blended water mix with a salinity between 1500 and 2000 µS/cm.

Even though the activities associated with this irrigation program are described as a trial it will gather wide-ranging data for development of a comprehensive Extracted Water Management Strategy (EWMS) as required under the Part 3A project approval for the Stage 1 GFDA. The trial aims to collect extensive data to demonstrate the viability and sustainability of irrigating produced water, growing salt tolerant crops at Gloucester and developing design information for future water treatment and irrigation designs.

For this REF the primary objective of the water monitoring network and associated monitoring program is to:

- protect the quality of the surface water flow in the adjacent Avon River
- protect the shallowest aquifers used for water supply across the area. These are the alluvial aquifers and the uppermost sedimentary/fractured rock aquifers.

The baseline monitoring program (for water quality) commenced in April 2011 (with subsequent events in October and December 2011). Water level monitoring across the site commenced in January 2011 as part of the broader Gloucester Gas Project (GGP) program. There is considered to be sufficient baseline data for the irrigation program to commence.

4.1. Proposed Monitoring Network

The proposed water monitoring network is focused on shallow groundwater and the adjacent surface water receptors. The network (together with the broader network that is installed for the GGP) is shown on Figure 3 and described below and in Table 4-1. The following locations are the primary monitoring network:

Climate

- AGL Tiedmans weather station
- Evapotranspiration (Et_o) data via iWater from Bureau of Meteorology

Produced water

- Tiedman south dam

- Tiedman north dam
- Tiedman new dam (when constructed)

Seepage Monitoring

- Seepage monitoring bores TMB04 and 05, screened in the weathered rock profile adjacent to the existing Tiedmans dams to monitor soil/perched water

Surface water

- Stream gauge ASW01 on the Avon River upstream from the site (Atkins property)
- Stream location TSW02 on Dog Trap Creek upstream of the irrigation areas (Tiedman Property)
- Stream gauge TSW01 on the Avon River down gradient of the irrigation areas Stage 1A and 1B (Tiedman Property).

Groundwater

- Monitoring bores TMB01, 02 and 03, screened in the shallow alluvial aquifer adjacent to Dog Trap Creek and the Avon River (Tiedman Property)
- Monitoring bore S4MB01 screened in the first fractured bedrock aquifer (Tiedman Property)
- Four new (paired) shallow piezometers (0.3-1.2m and 1.5m deep) in the trial irrigation area (Stage 1A) plus an additional site near Catch Dam west– yet to be constructed.

In addition, there will be additional surface water locations monitored during high rainfall events:

Irrigation plot runoff

- Western catch dam (Stage 1A)
- Eastern catch dam (Stage 1A)

Surface water

- Stream location FSW01 on Avon River downstream of Tiedman Property (on the Farley property)

Water quality is the primary monitoring requirement at all sites, although water levels will also be measured continuously at the dedicated stream gauge locations (ASW01 and TSW01) and the dedicated shallow monitoring bore locations (TMB01, 02 and 03 and S4MB01). This network was installed for the broader GGP water monitoring program and has been in place since January 2011.

Additional water level and water quality data can be obtained from the other dedicated monitoring locations across the property (if required for this irrigation monitoring program) should there be any unusual changes in the shallow water monitoring program adopted for this irrigation trial. Contingency plan details are provided in Section 4.6.

Table 4-1 Summary of Surface Water and Groundwater Monitoring Locations

Sample ID	Location	Water Levels	Routine Water Quality and Sampling Frequency by PB	Event Sampling by AGL/FK
Tiedman Nth	Tiedman North Dam	Not required	Metals, nutrients, cations/anions quarterly Hydrocarbons annually	Physical parameters – monthly
Tiedman Sth #	Tiedman South Dam	Not required	Salinity logger continuous Metals, nutrients, cations/anions quarterly Hydrocarbons annually	Physical parameters – monthly
Tiedman #3 (new)	Tiedman #3 Dam	Not required	Metals, nutrients, cations/anions quarterly Hydrocarbons annually	Physical parameters – monthly
Catch Dam east (small) (new)	North East of Irrigation trial area	Not required	Salinity logger continuous	Physical parameters, metals, nutrients, cations/anions Subject to test results from Catch Dam west overflow event
Catch Dam west (large) (new)	South West of Irrigation trial area	Not required	Salinity logger continuous	Physical parameters, metals, nutrients, cations/anions Sample and test first overflow event only Assess for future events
TMB04	Seepage MB west	Dipped quarterly	Physical parameters then purge dry and assess inflows quarterly If inflow within 12 hours then physical parameters again, metals, nutrients, cations/anions	Physical inspection of surrounding area - monthly

Sample ID	Location	Water Levels	Routine Water Quality and Sampling Frequency by PB	Event Sampling by AGL/FK
TMB05	Seepage MB east	Dipped quarterly	Physical parameters then purge dry and assess inflows quarterly If inflow within 12 hours then physical parameters again, metals, nutrients, cations/anions	Physical inspection of surrounding area - monthly
ASW01	Avon River (upgradient)	Yes continuous	Salinity logger continuous, physical parameters quarterly Metals, nutrients, cations/anions quarterly Hydrocarbons annually.	Physical parameters, metals, nutrients, cations/anions Sample and test first overflow event. Assess for future events
TSW02 (new)	Dog Trap Creek	Yes continuous	Salinity logger continuous, physical parameters quarterly Metals, nutrients, cations/anions quarterly Hydrocarbons annually.	
TSW01	Avon River (downgradient Tiedman boundary)	Yes continuous	Salinity logger continuous, physical parameters quarterly Metals, nutrients, cations/anions quarterly Hydrocarbons annually.	
FSW01 (new)	Avon River (downgradient on Farley property)	No		Physical parameters, metals, nutrients, cations/anions Sample and test first overflow event only. Assess for future events
TMB01	Avon River Alluvium (downgradient site boundary)	Yes continuous dipped quarterly	Physical parameters quarterly Metals, cations/anions quarterly Hydrocarbons and nutrients, annually	

Sample ID	Location	Water Levels	Routine Water Quality and Sampling Frequency by PB	Event Sampling by AGL/FK
TMB02	Avon River/Dog Trap Creek Alluvium (mid site)	Yes continuous dipped quarterly	Physical parameters quarterly Metals, cations/anions quarterly Hydrocarbons and nutrients, annually	
TMB03	Dog Trap Creek Alluvium (southern site)	Yes continuous dipped quarterly	Physical parameters quarterly Metals, cations/anions quarterly Hydrocarbons and nutrients, annually	
S4MB01	Northern site boundary (rock aquifer)	Yes continuous dipped quarterly	Physical parameters quarterly Metals, cations/anions quarterly Hydrocarbons and nutrients annually	
Four (paired) shallow piezometers ^ Plus one additional shallow piezometer on western boundary near Catch Dam west	Within and adjacent to the trial irrigation area	Manual each visit	(All sites) Physical parameters quarterly (each visit) Metals, cations/anions and nutrients (as required)	Monitor and assess WLs after each irrigation Sample and test if >30cm of infiltrated water. Purge after each inspection - ongoing monitoring during trial.

Notes: Physical parameters are salinity (EC), pH, redox (or Eh), dissolved oxygen (DO) and temperature

- assumed to be the blend irrigation dam (ie river water plus CSG produced water in other dams)

^ -there would be a very shallow piezometer within the irrigation trial area to assess the irrigation application rates and the efficiency of the crops to transpire all the irrigation water (variable depths 0.3 to 1.2m deep depending on plot type) then another piezometer just outside the irrigation area to ensure that no perched water table was developing in the parent sub-soils (each to a depth of 1.5m).

4.2. Monitoring Frequency

Continuous water level dataloggers are present at seven sites, and EC loggers are present (or will be installed) at six sites. Monthly water quality sampling of the groundwater sites is not justified given that this is a deficit irrigation program and the irrigation area is located off the floodplain. There will be continuous salinity loggers and tracking of field parameters monthly at selected surface water sites. Quarterly water quality sampling is proposed for most sites plus event sampling at selected sites.

4.2.1. Water Levels

Produced water – Dams

No water level monitoring in any of the dams is proposed although gauges in the dams allow the volume in storage to be estimated.

Surface water - Stream Gauges

The two stream gauges that are part of the larger GGP program are equipped with level dataloggers and salinity (EC) probes. A new gauge with a level and EC logger has been installed on Dog Trap Creek. These sites will continue indefinitely at the current data collection rate (one reading every 6 hours).

The GGP monitoring program commenced in March 2011 and currently there is 14 months of continuous data. Baseline hydrographs and salinity responses (from PB, 2012) are provided in *Appendix A*.

Groundwater - Monitoring Bores and Piezometers

The four dedicated monitoring bores are all equipped with dataloggers. These will continue indefinitely at the current data collection rate (one reading every 6 hours). The paired shallow piezometers constructed to maximum 1.5m depth will not have dataloggers installed but will be periodically inspected to take manual water levels. Manual water levels are proposed to be taken pre irrigation and then after each irrigation event.

The monitoring program for the dedicated monitoring bores commenced in January 2011 and currently there is 16 months of continuous data. Baseline hydrographs (from PB, 2012) are provided in *Appendix B*.

4.2.2. Water Quality

The proposed frequencies vary depending on whether the water sampling is baseline, during the irrigation program or event sampling, and depending on the monitoring location. Details are summarised below and in Table 4-1.

Produced water – Dams

- Four baseline events (April, October and December 2011, March 2012) then during the irrigation program
    - Physical parameters monthly
    - Metals, nutrients, cations/anions quarterly
    - Hydrocarbons annually
- A salinity (EC) probe is also located in the main blended water dam (i.e. Tiedmans South - the dam from which irrigation water will be withdrawn). It was installed in October 2011. This logger will operate for the life of the trial at the current data collection rate (one reading every 6 hours).

Surface water - Stream Gauges and Dog Trap Creek location

- Four baseline events (April, October and December 2011, March 2012) at the two Avon River sites then during the irrigation program
    - Physical parameters quarterly
    - Metals, nutrients, cations/anions quarterly
    - Hydrocarbons annually

- Salinity (EC) probes are also located at the three stream gauge sites. These loggers will continue indefinitely at the current data collection rate (one reading every 6 hours). Salinity trends are shown in the graphs in *Appendix A*.
- For the Dog Trap Creek site, monitoring commenced in December 2011 – water quality parameters are as for Avon River sites.

Seepage water – Monitoring Bores

- One baseline event (April 2011) then during the irrigation program
    - Physical parameters quarterly
    - Metals, nutrients and cations/anions quarterly (if inflow after purging)

Groundwater - Monitoring Bores

- Four baseline events (April, October and December 2011, March 2012) then during the irrigation program
    - Physical parameters quarterly
    - Metals and cations/anions quarterly
    - Hydrocarbons and nutrients annually

The event sampling locations and their sampling frequencies are:

Irrigation plot runoff

- Western catch dam (Stage 1A – overflow to Avon River)
    - Salinity (EC) probe to be installed at data collection rate (one reading every 6 hours)
    - Sample and test first overflow event for:
        - Physical parameters
        - Metals, cations/anions and nutrients
    - Assess necessity for future events
- Eastern catch dam (Stage 1A – overflow to unnamed gully)
    - Salinity (EC) probe to be installed at data collection rate (one reading every 6 hours)
    - Sample only if necessary after reviewing western catch dam results

Surface water

- Stream location FSW01 on Avon River downstream of Tiedman Property (on the Farley property)
    - Sample and test first overflow event for:
        - Physical parameters
        - Metals, cations/anions and nutrients
    - Assess necessity for future events

Groundwater - Piezometers

- Four paired locations within Stage 1A irrigation trial area, plus an additional site adjacent to Catch Dam west
    - Check, sample and test every irrigation for:

- Physical parameters, then select one site (if there is a water profile of more than 30cm) for:
    - Metals, cations/anions and nutrients

4.3. Water Quality Analytes

The specific analytical suites that are recommended for each of the monitoring locations are as follows:

Produced water – Dams

Water samples (at the three Tiedman dam sites) will be analysed for:

- Physical parameters, EC pH, redox, DO, temperature
- Major cations and anions: sodium, potassium, calcium, magnesium, bicarbonate, chloride, sulphate, total alkalinity, ionic balance
- Heavy metals: Aluminium, arsenic, beryllium, barium, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, strontium, uranium, vanadium, zinc, boron, iron, bromine
- Hydrocarbon indicators: TPH, BTEX (only for the main baseline event (October 2011), and then annually in September 2012, 2013 etc)
- Nutrients: ammonia, nitrate, nitrite, NOx, total phosphorus, reactive phosphorus, total organic carbon.

SAR and TDS values will be calculated either by the laboratory or based on the results.

Seepage water – Monitoring Bores

Water samples (at the two seepage sites) will be analysed (provided there is recharge water after purging) for:

- Physical parameters, EC pH, redox, DO, temperature
- Major cations and anions: sodium, potassium, calcium, magnesium, bicarbonate, chloride, sulphate, total alkalinity, ionic balance
- Heavy metals: Aluminium, arsenic, beryllium, barium, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, strontium, uranium, vanadium, zinc, boron, iron, bromine
- Nutrients: ammonia, nitrate, nitrite, NOx, total phosphorus, reactive phosphorus, total organic carbon.

SAR and TDS values will be calculated either by the laboratory or based on the results.

Surface water - Stream Gauges

Water samples (both Avon River sites and the Dog Trap Creek site) will be analysed for:

- Physical parameters, EC pH, redox, DO, temperature
- Major cations and anions: sodium, potassium, calcium, magnesium, bicarbonate, chloride, sulphate, total alkalinity, ionic balance
- Heavy metals: Aluminium, arsenic, beryllium, barium, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, strontium, uranium, vanadium, zinc, boron, iron, bromine

- Hydrocarbon indicators: TPH, BTEX (only for the main baseline event (October 2011), and then annually in September 2012, 2013 etc)
- Nutrients: ammonia, nitrate, nitrite, NOx, total phosphorus, reactive phosphorus, total organic carbon.

SAR and TDS values will be calculated either by the laboratory or based on the results.

Groundwater - Monitoring Bores and Piezometers

Water samples (at all four dedicated monitoring bore sites) will be analysed for:

- Physical parameters, EC pH, redox, DO, temperature
- Major cations and anions: sodium, potassium, calcium, magnesium, bicarbonate, chloride, sulphate, total alkalinity, ionic balance
- Heavy metals: Aluminium, arsenic, beryllium, barium, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, strontium, uranium, vanadium, zinc, boron, iron, bromine
- Hydrocarbon indicators: TPH, BTEX (only for the main baseline event (October 2011), and then annually in September 2012, 2013 etc)
- Nutrients: ammonia, nitrate, nitrite, NOx, total phosphorus, reactive phosphorus, total organic carbon.

For the shallow (paired) piezometer sites, if there is more than 30cm of water present in any of the sites upon checking after each irrigation, then water samples will be analysed for:

- Physical parameters, EC pH, redox, DO, temperature (all sites)
- And then for one representative site (if sufficient water is present after purging):
    - Major cations and anions: sodium, potassium, calcium, magnesium, bicarbonate, chloride, sulphate, total alkalinity, ionic balance
    - Heavy metals: Aluminium, arsenic, beryllium, barium, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, strontium, uranium, vanadium, zinc, boron, iron, bromine
    - Nutrients: ammonia, nitrate, nitrite, NOx, total phosphorus, reactive phosphorus, total organic carbon.

Each shallow piezometer is to be purged dry after each inspection, irrespective of the volume of water present.

SAR and TDS values will be calculated either by the laboratory or based on the results.

4.4. Water Volumes

Water volumes irrigated across the trial irrigation area in the Stage 1A area will be measured via an in-line meter located on the cart of the linear move irrigator. Meter readings will be taken at commencement and on completion of each irrigation.

In addition, water use will be estimated based on the known application rates through the overhead sprays and the hours of operation.

Estimated water application will be cross-checked with actual rainfall data on site and a network of physical rain gauges within the trial area to verify the performance of the irrigation system.

Monitoring of volumes irrigated in the Stage 1B area will be estimated based on pump rates and hours of operation.

4.5. Possible Risks and Mitigation Measures

Irrigation is carried out across the Avon River catchment and other sub-catchments of the Manning River Catchment as part of the area's typical agricultural development. Most local irrigation is for improved pasture for dairying and beef cattle. The only difference with this scheme proposed by AGL for the reuse of produced water is that:

- The water quality is brackish but suitable for salt tolerant cropping on the improved soils of the sideslope areas adjacent to the Avon River
- The irrigation is intensive as the plan is to maximise the application rate within the overall strategy of deficit irrigation
- The parent soils will be substantially improved to be able to accept intensive levels of irrigation

The assessed (water related) risks to the environment are:

- Leakage from the produced water storage dams (forming either a perched water table or infiltration to the shallow rock aquifer)
- High infiltration rates of irrigated water that migrates below the root zone and are unable to be transpired (forming either a perched water table or infiltration to the shallow rock aquifer)
- High rainfall events which cause runoff and overflow the catch dams to the Avon River

There are no (water related) risks identified to nearby water users as:

- AGL owns the (eastern) upstream and downstream properties either side of Tiedmans and there are no water supply withdrawals from the Avon River on these properties (all water comes from farm dams)
- There are no groundwater users in the immediate area (there are no works tapping the shallow alluvial or rock aquifer groundwater systems on adjacent properties)

There are no risks to surface water users further downstream as the volumes proposed to be irrigated (maximum 70 ML of produced water and 220 ML in total over 3 years) are negligible compared to the Avon River stream flow volumes (as shown by the Waukivory gauging station on the Avon River - #208028) and subsequent tributary flow increases downstream.

The extensive monitoring network is designed to identify:

- The formation of a perched water table below the root zone within and adjacent to the irrigation area
- Whether there are any seepage losses from the produced water storage dams
- Any accessions to the water table in the underlying rock aquifer
- The water quality of upstream creek and river water sources entering the site
- Any impact (outside of the normal range of responses) to the adjoining Avon River and Dog Trap Creek

The proposed mitigation measures (apart from the extensive monitoring program) are:

- Repair immediately any leaks (HDPE liner and/or dam walls) identified from either inspection of the holding dams or monitoring of shallow water levels and water quality
- Reduce irrigation application rates if a perched water table develops adjacent to the irrigation trial area
- Reduce irrigation application rates if increases in the shallow water table occur in either the shallow rock area or the nearby alluvium
- Enlarge or install extra catch dams to collect run-off from the trial area

All of the design elements described in Section 1.1 plus all of the above measures will be considered with the aim of minimising risks of impacts to the Avon River at all times. If there are identifiable impacts to the Avon River at the FSW01 (downstream) monitoring location immediately after a major rainfall event, AGL will further revise and/or improve the above measures.

4.6. Contingency Plan

Water levels in the alluvial aquifers are relatively shallow at 2.5 to 5.5 metres bgl. In the shallow rock, water levels are deeper and generally range between 5.5 and 17 metres bgl. Rising groundwater levels outside of the natural range would warrant action. For this trial, AGL recommends that an appropriate threshold (or action trigger) be a water level rise that is more than 0.5m per annum beyond the normal range (Note that based on the baseline data, 0.1m increases could not be separated from natural trends).

For the river and alluvial water quality, there is a large variation in natural salinity and other chemical analytes. It is proposed to use the background levels from the baseline sampling event and the river salinity trends over the last 12 months as the thresholds for action. Regular sampling of the dam water intended for irrigation, will ensure that it is suitable for irrigation and is consistent with the ANZECC (2000) water quality criteria for irrigation purposes.

Table 4-2 details the actions and responses to be implemented should any threshold be triggered during the intensive irrigation program on the Stage 1A trial area.

The contingency plan for the Stage 1B irrigation area is to immediately cease irrigation (and change to a new area) if there is visible overland flow or breakout areas.

Table 4-2 Contingency Plan

Indicator	Action	Response
Irrigation water EC (at Tiedman south dam) exceeds 2000 ☐S/cm for the trial area	Stop irrigating Investigate	Blend with additional fresh water to dilute Monitor EC levels in produced water and restart irrigation when EC falls below 2000 ☐S/cm If none of these options are available, store water until production phase of project for future water treatment by Reverse Osmosis or other appropriate technologies.
Visible overland flow or breakout areas while irrigating	Stop irrigating Investigate	Reduce irrigation application rate
Seepage water around the produced water dams that indicates dam leakage	Inspect dam to identify leak	Reduce dam levels to repair liner/banks as necessary

Indicator	Action	Response
Development of perched water table in natural soils adjacent to the irrigation trial area	Stop irrigating Investigate	Reduce irrigation application rate Determine need for additional sites
Rising shallow (regional) groundwater level trend outside of natural range and more than 0.5m per annum (at S4MB01 site)	Stop irrigating Investigate	Reduce irrigation application rate Stop altogether if levels reach 5 metres bgl in the bedrock aquifers (currently ~ 5.5-17 metres bgl) Check deep monitoring bores at S4MB site and more remote locations on Tiedmans for similar trends and the (unlikely) possibility of very deep drainage Store produced water pending outcome of investigations
Surface water salinity to exceed by 20% the baseline levels at downstream Avon River site (FSW01)	Stop irrigating Investigate	Reduce irrigation application rate Store produced water Blend with additional fresh water to dilute If none of these options are available, store water until production phase of project for future water treatment by Reverse Osmosis or other appropriate technologies.

4.7. Reporting

All data from the baseline investigation and the irrigation program will be collated and analysed and the results assessed and written up into several detailed technical reports:

- For the water monitoring program it is proposed to produce:
    - Brief baseline data report (February 2012)
    - Monitoring reports at the conclusion of each water year (first report by September 2012, then September 2013 etc)

5. References

DWE, 2009, *Report Card for Avon River source.* Dated August 2009

Parsons Brinckerhoff, 2011, *Irrigation Proposal, Review of Environmental Factors – Gloucester Gas Project.* Report PR_5506 Rev B dated June 2011

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

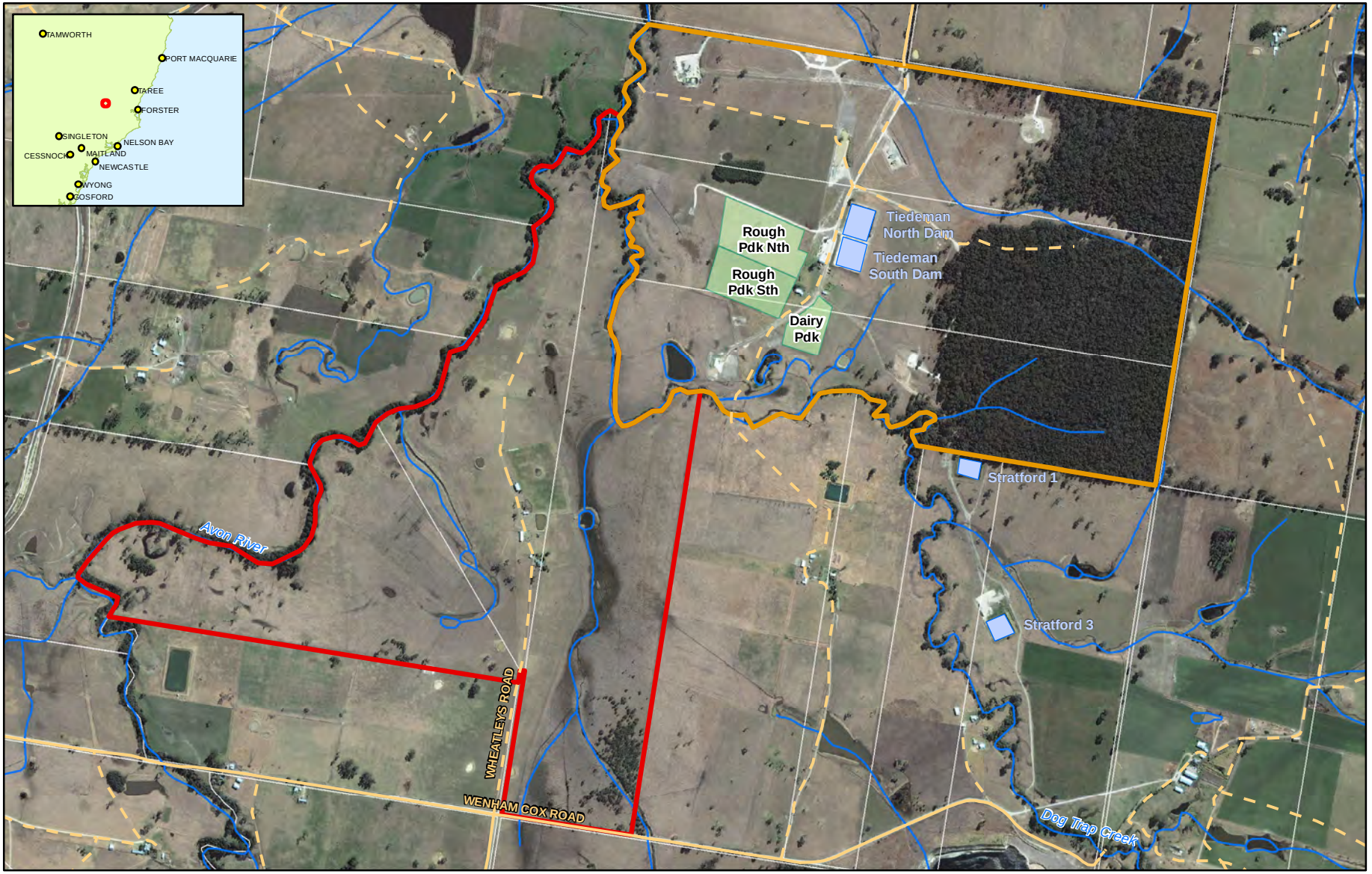
SRK Consulting, 2010, *Gloucester Basin Stage 1 Gas Field Development Project: Preliminary Groundwater Assessment and Initial Conceptual Hydrogeological Model*, Report No. AGL002_Gloucester Basin Hydrogeology Study_Rev2.

Figures

PARSONS BRINCKERHOFF

Gloucester Irrigation Location Map

Figure 1



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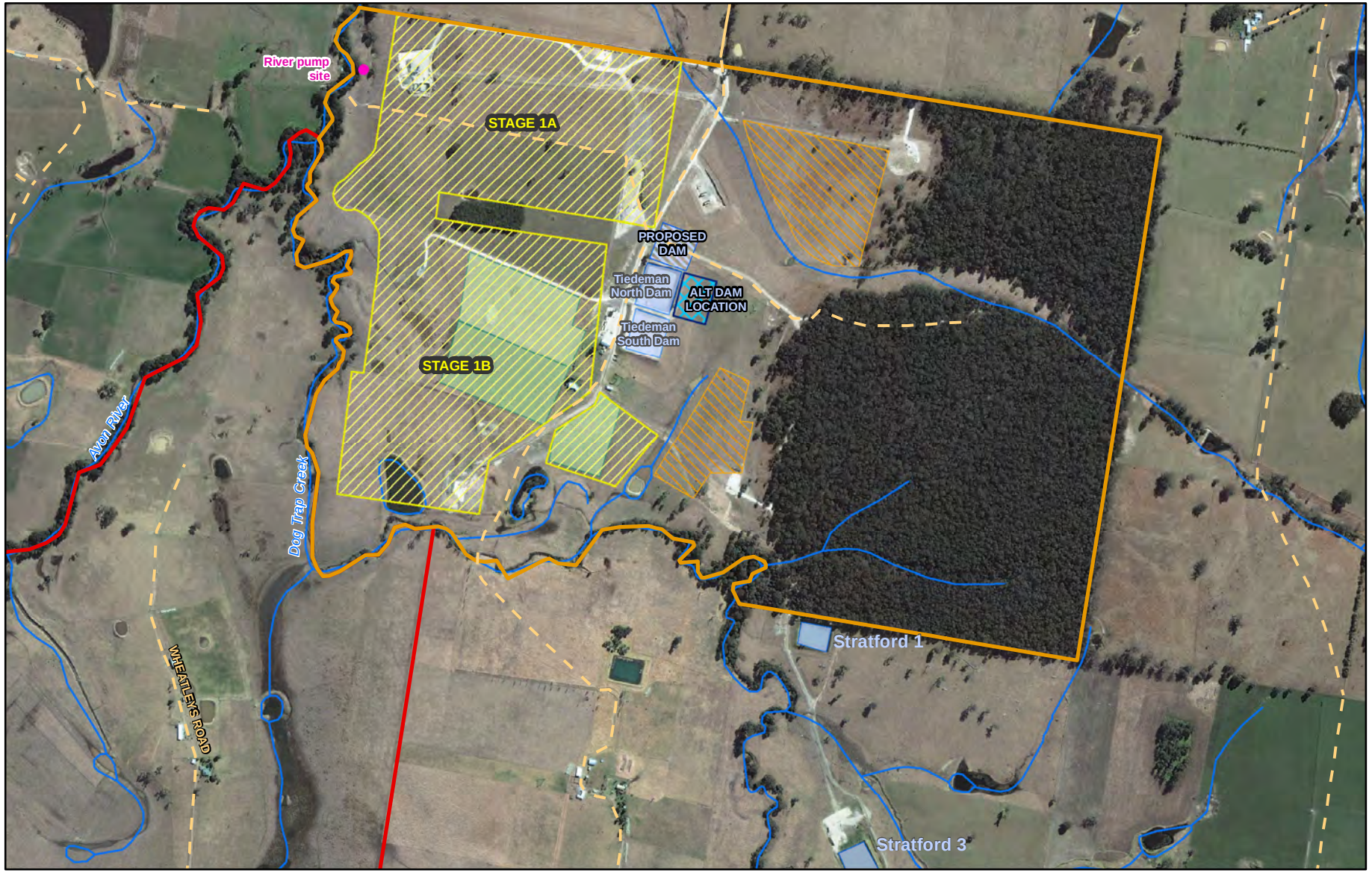
Roads
Tracks
Atkins Property
Teideman Property
Existing irrigation area
Dams

N
0
1
Kilometres

PARSONS BRINCKERHOFF

Gloucester Irrigation Project

Figure 2



\\APSYDFIL01\proj\AAGL_Energy\2162156A_AGL_GLOUCESTER_IRRIGATION_APP10_GIS\Projects\ESR\Irrigation_REFFigures\3004_2162156A_ProjectOverviewStage2_Fig3_3.mxd // vb - 15.05.2011

Roads
Tracks
Atkins Property
Teideman Property
Existing irrigation area
Existing dam
Proposed dam
Alternate dam location
Stage 1- Proposed irrigation area
Stage 2 - Proposed irrigation area*

N

0 500

Metres

***Note:** Unlikely to proceed as part of the 'preproject' irrigation scheme*

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AGL

Author:	Upstream Gas
Date:	18/01/2012
Ref:	2879R2

Figure 3

Metres
0 250 500
Scale 1:10,000

Legend

- River
- Cadastre
- Tiedemans Property
- Irrigation Trial Area

Tiedman Water Monitoring Network

- Abandoned
- Primary – Alluvial
- Primary – Perched
- Primary – River
- Primary – Seepage
- Primary – Shallow Rock
- Primary – catch dam
- Primary – holding dam
- Secondary

N

Geocentric Datum of Australia 1994

Sources: AGL Energy Limited, MapData Sciences, SKM

Appendices

Appendix A	Surface Water Hydrographs and Salinity Profiles
Appendix B	Groundwater Hydrographs

Figure XX Stream levels and rainfall at TSW01

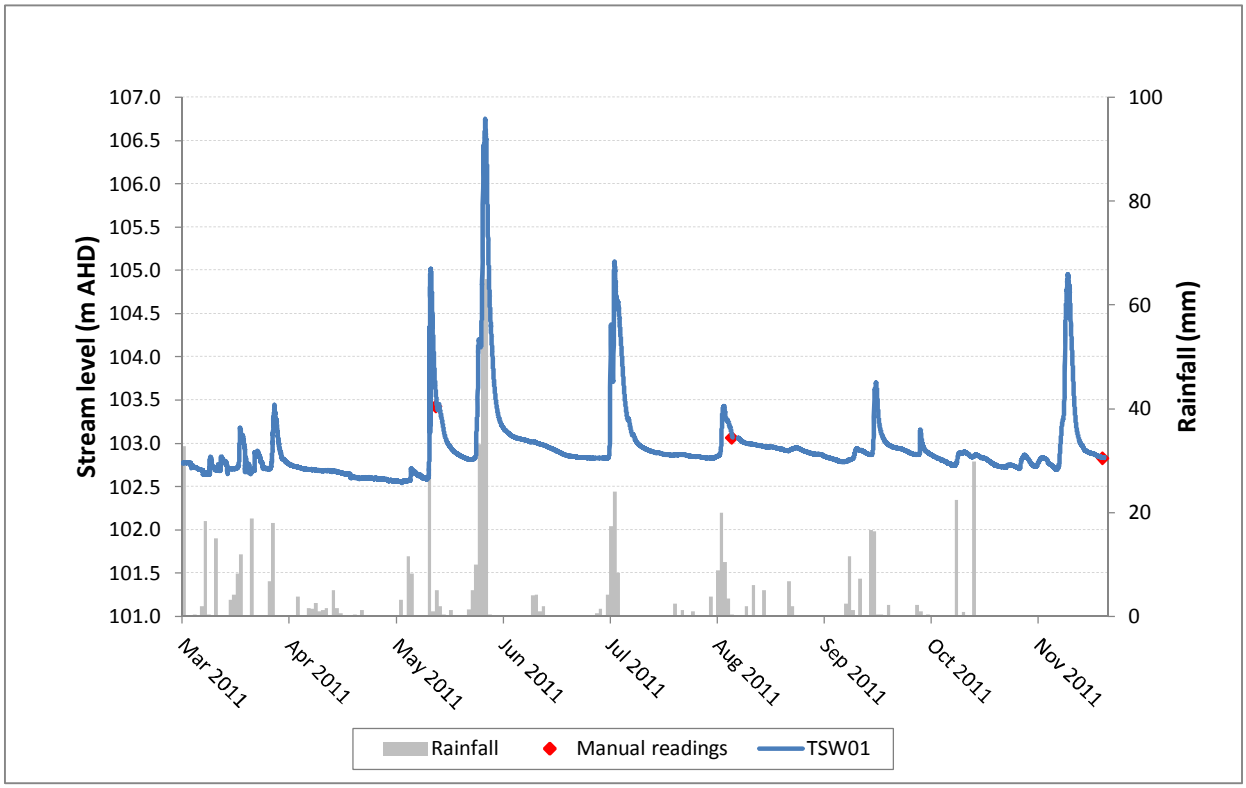


Figure XX EC levels and rainfall at TSW01

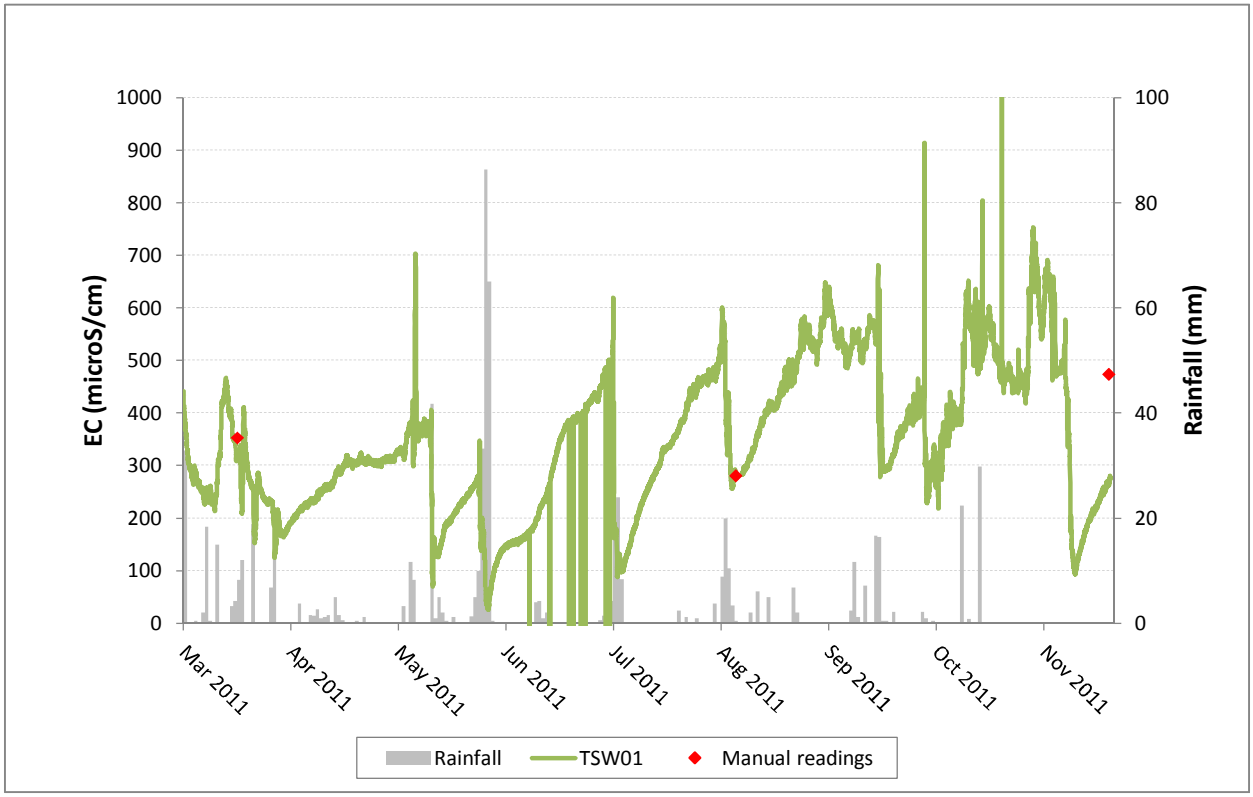


Figure XX Stream levels and rainfall at ASW01

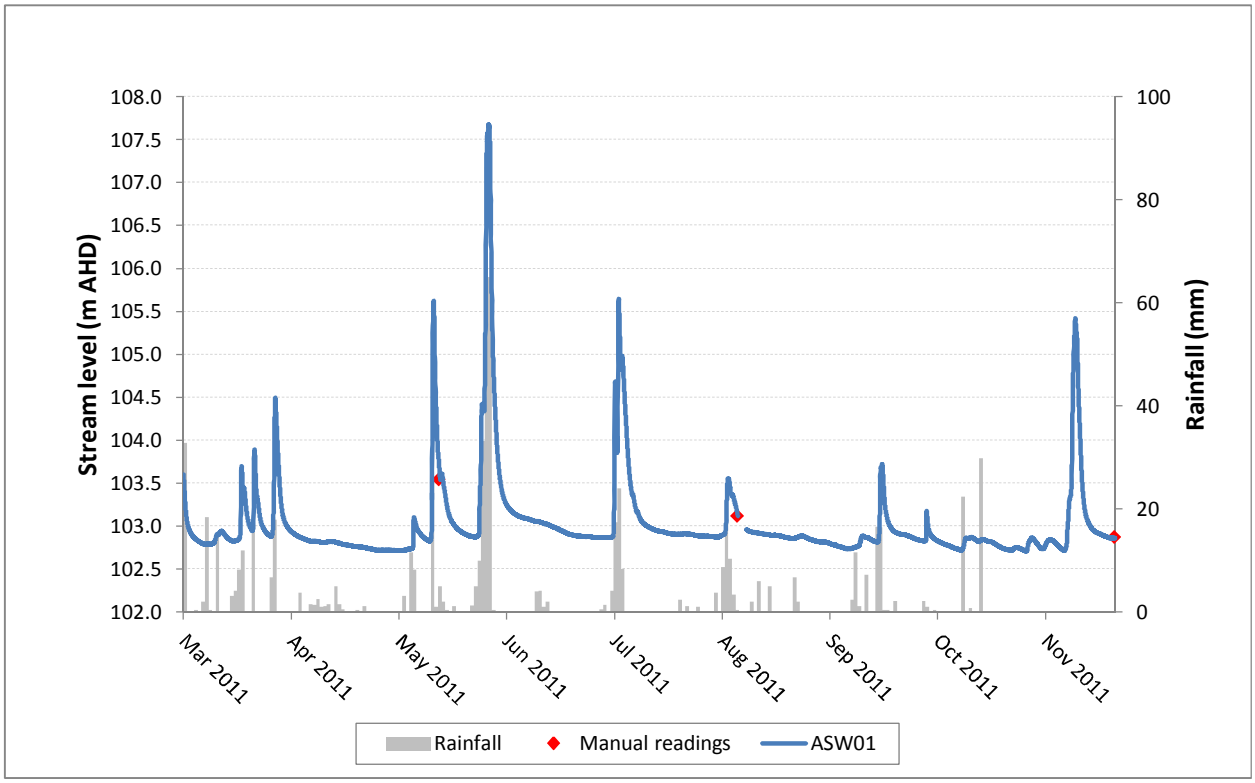


Figure XX EC levels and rainfall at ASW01

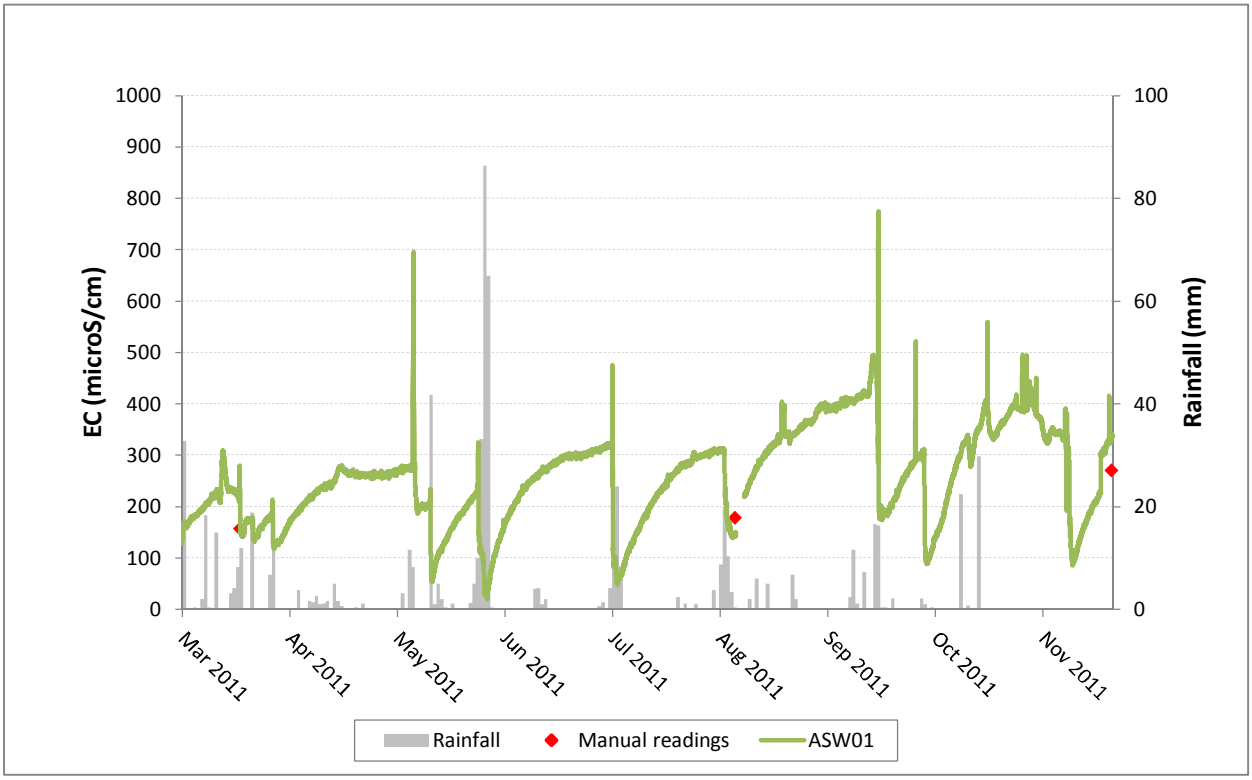


Figure Stream levels and rainfall at TSW01, ASW01, ASW02

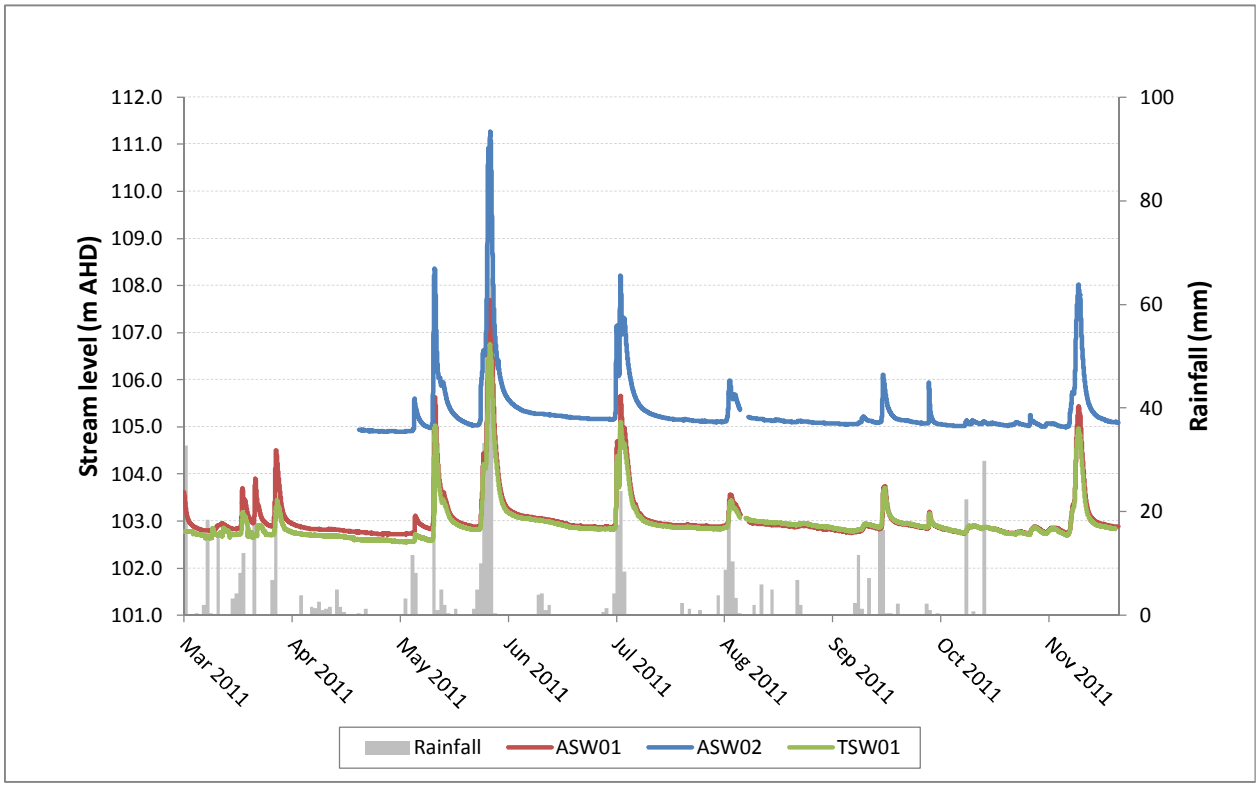


Figure XX EC levels and rainfall at TSW01, ASW01, ASW02

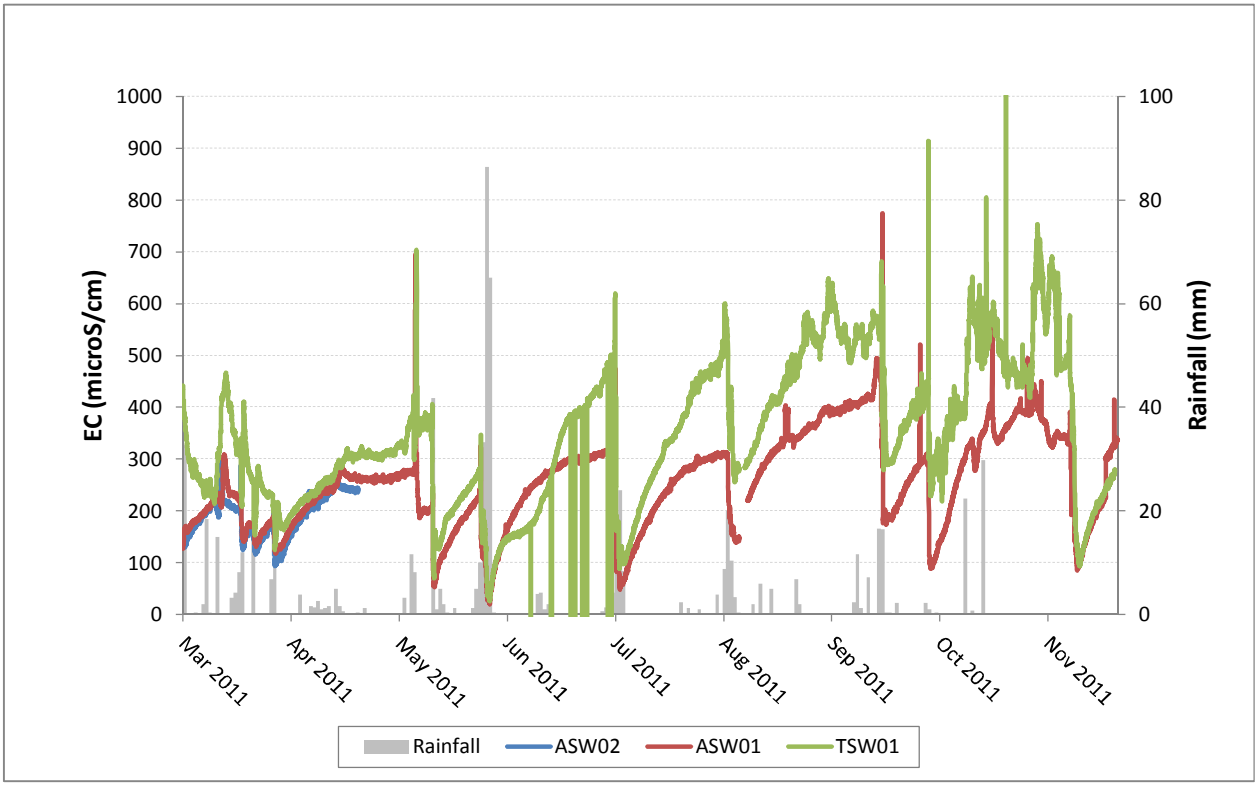


Figure A-1 Groundwater levels and rainfall TMB01

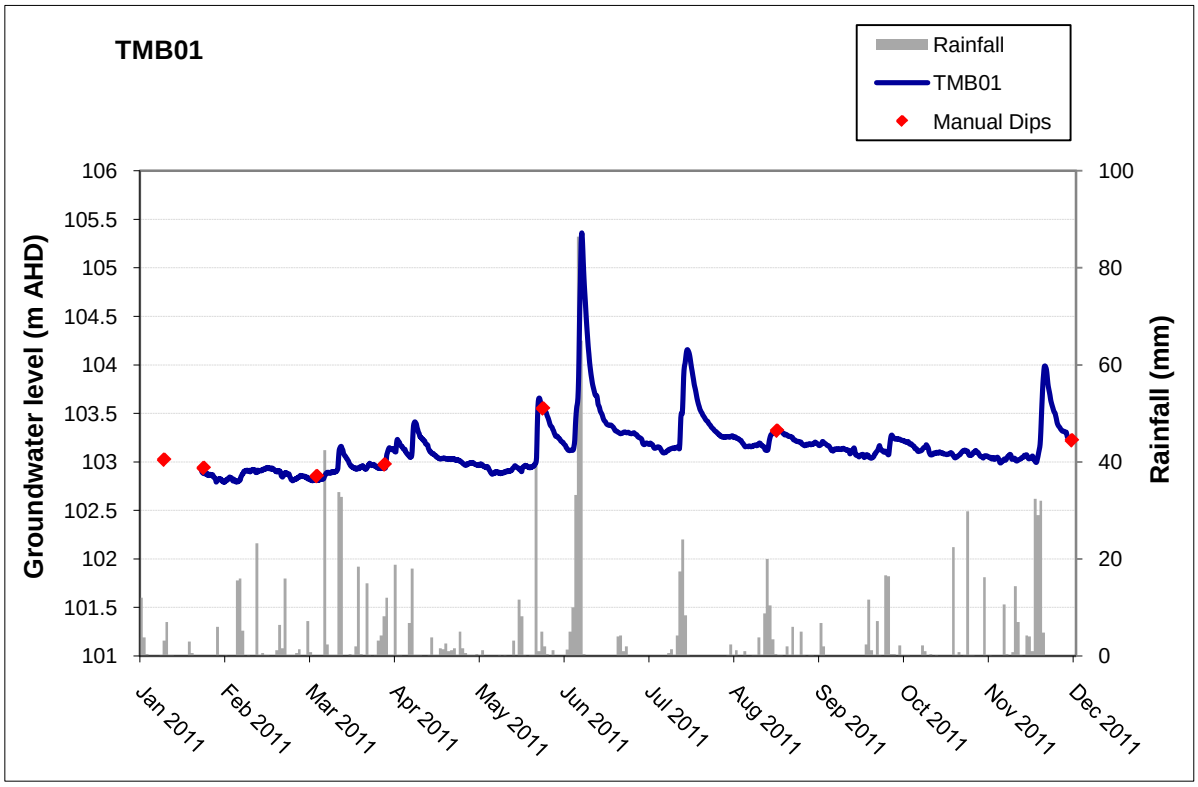


Figure A-2 Groundwater levels and rainfall at TMB02

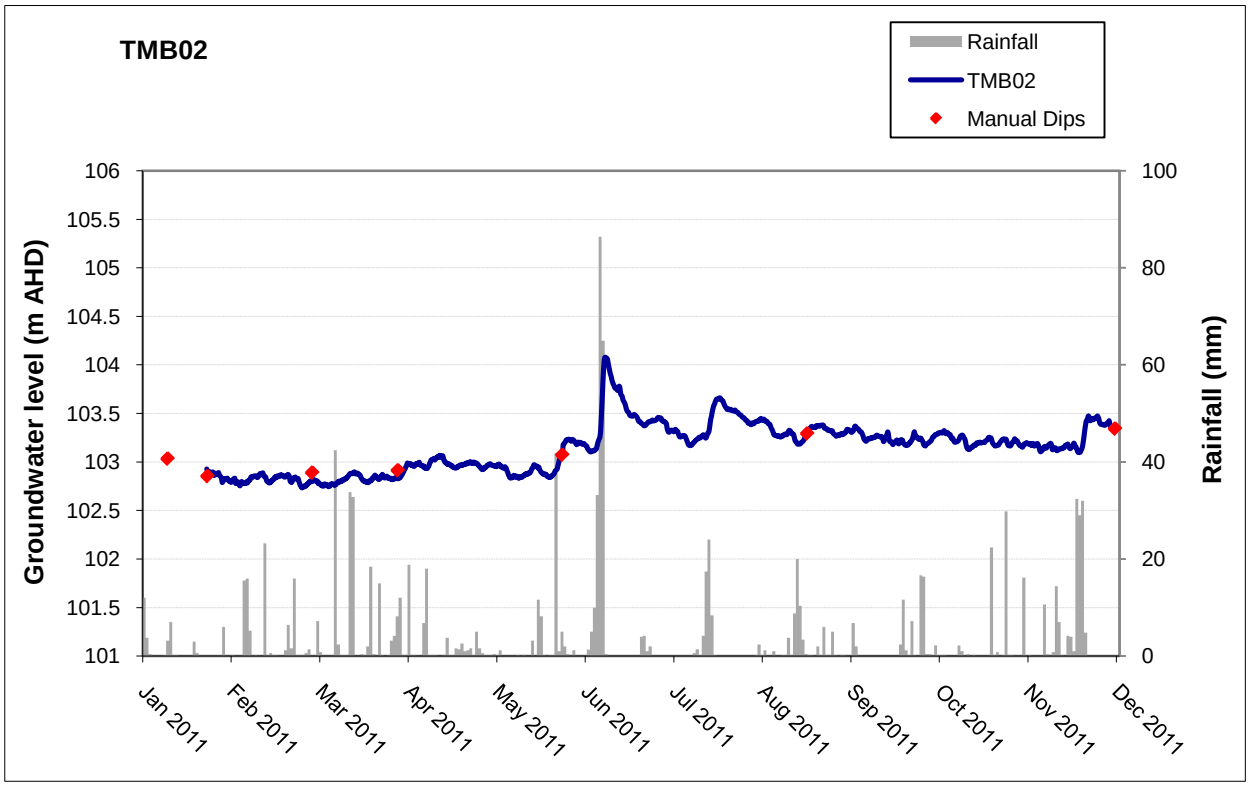


Figure A-3 Groundwater levels and rainfall at TMB03

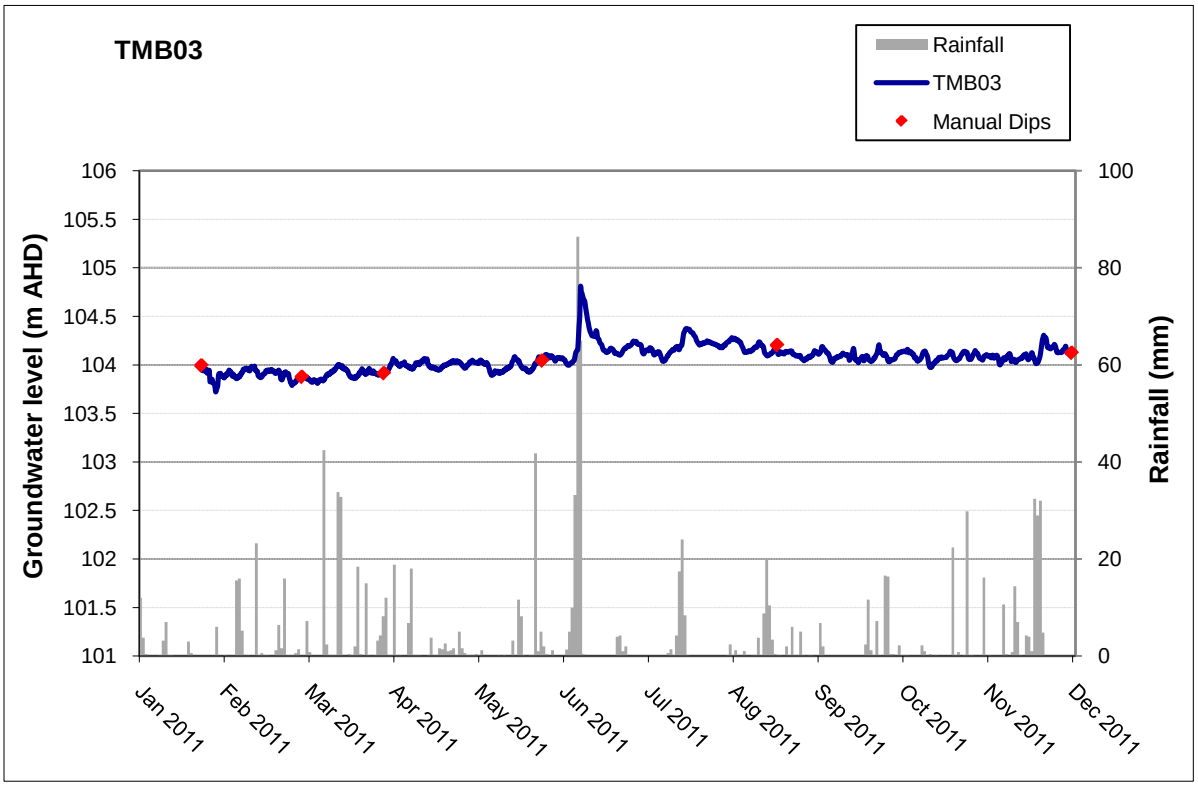


Figure A-4 Groundwater levels and rainfall at AMB01

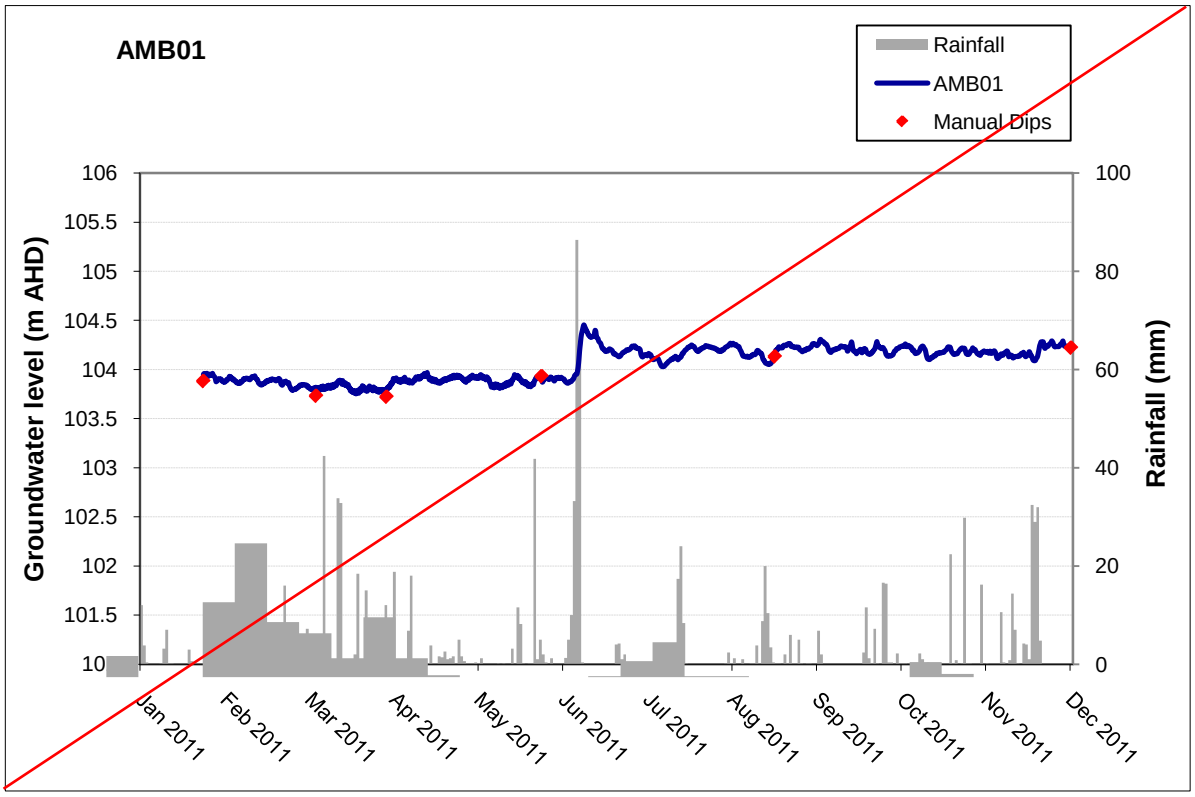


Figure A-5 Groundwater levels and rainfall at AMB02

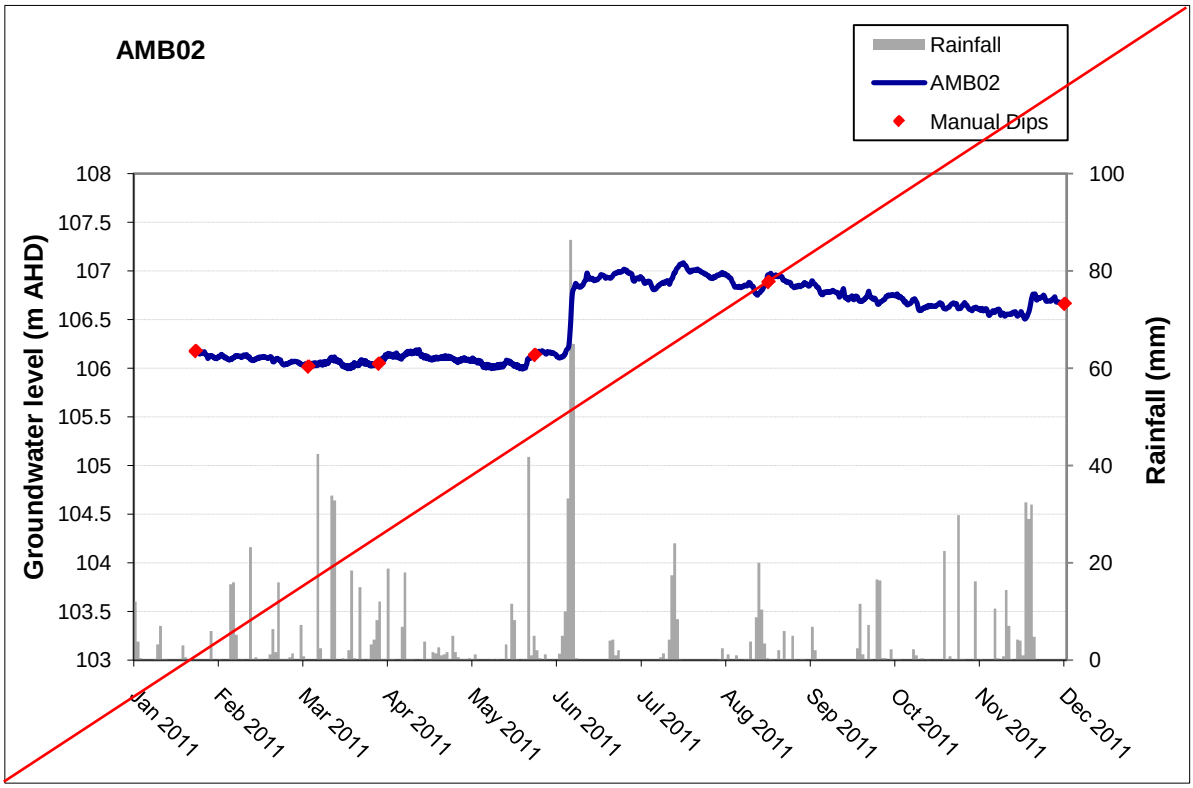


Figure A-6 Groundwater levels and rainfall at S4MB01

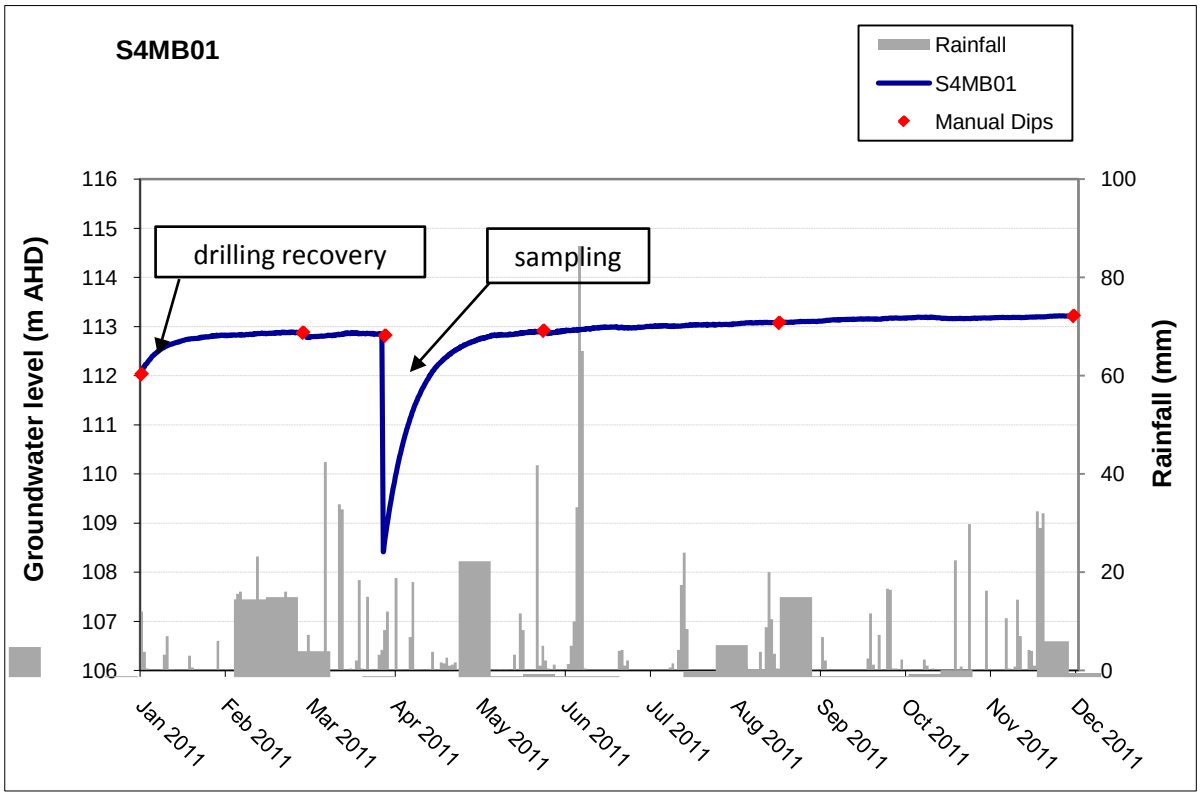


Figure A-7 Groundwater levels and rainfall at S4MB02

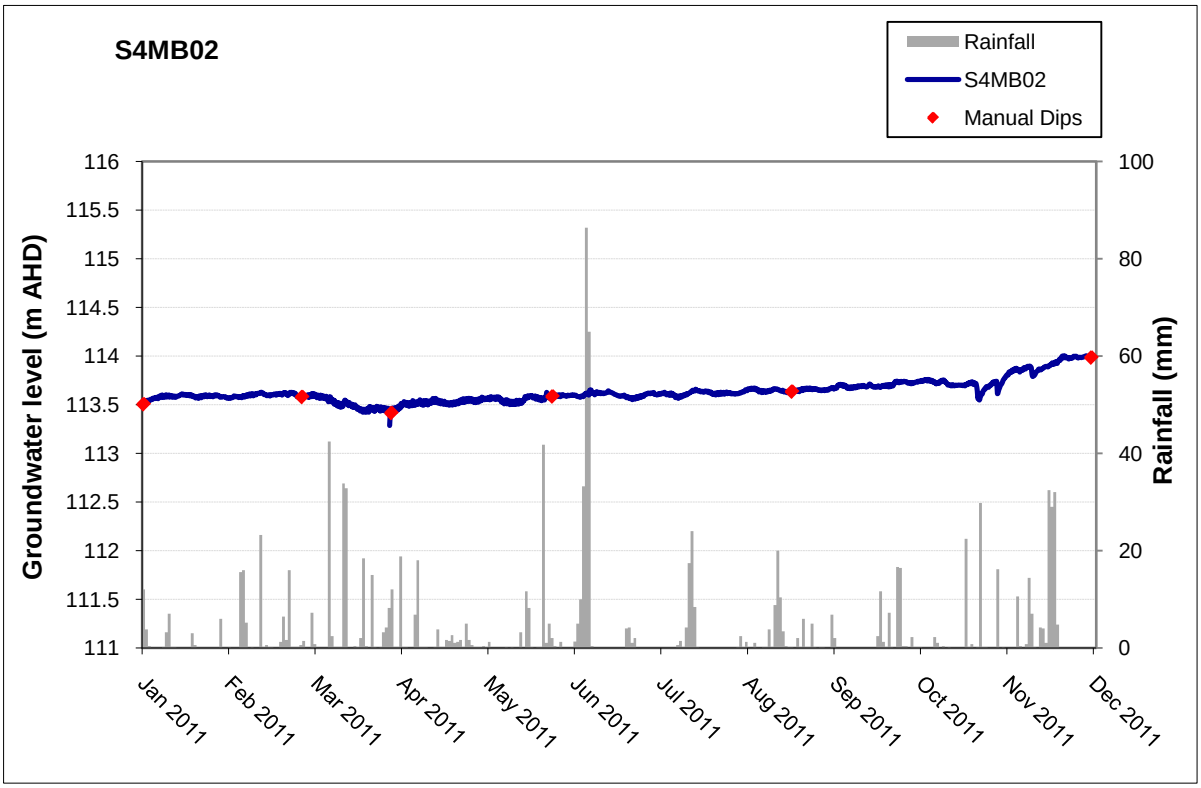


Figure A-8 Groundwater levels and rainfall at S4MB03

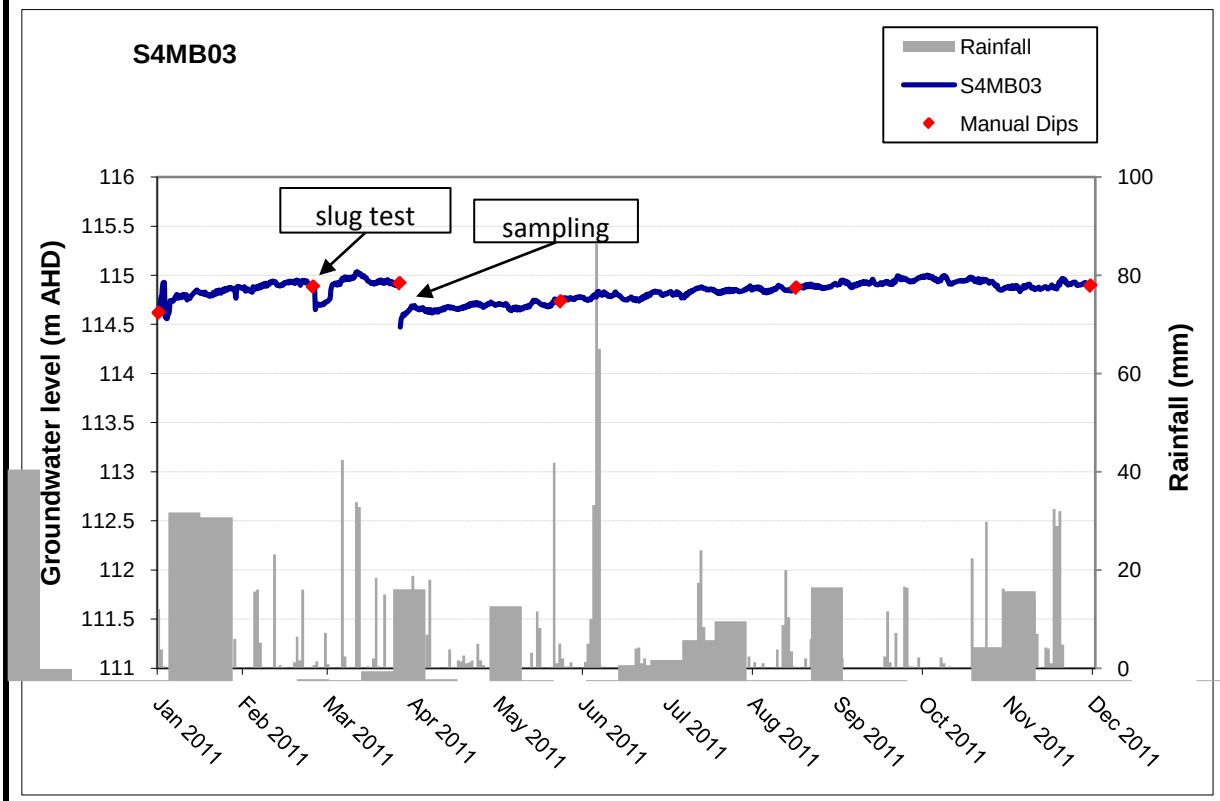


Figure A-9 Groundwater levels and rainfall at S5MB01

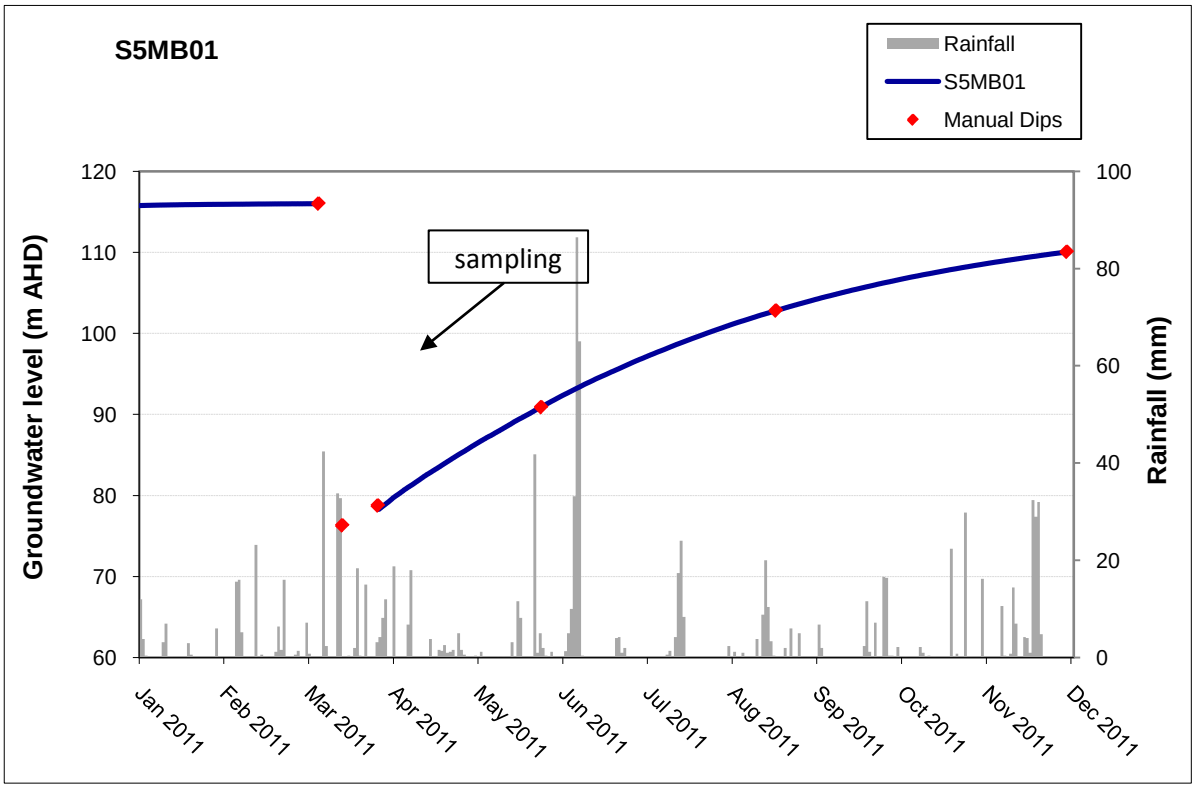


Figure A-10 Groundwater levels and rainfall at S5MB02

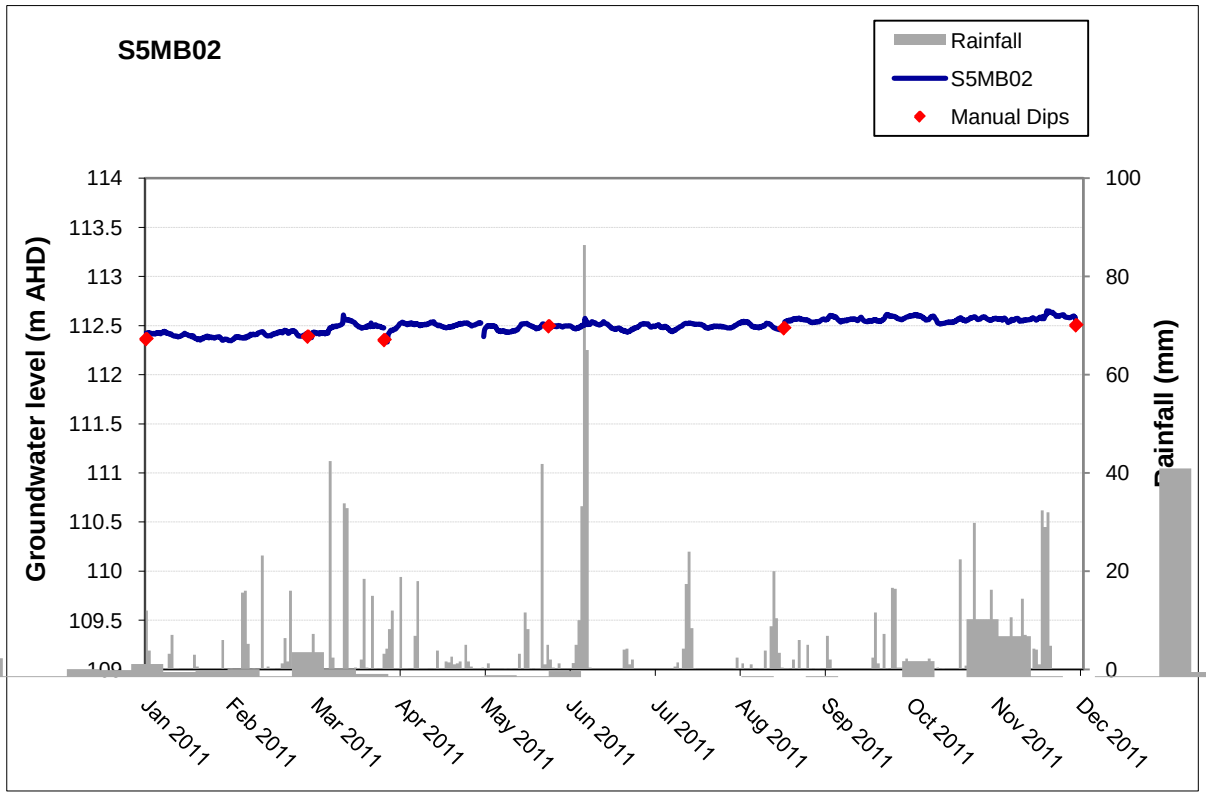


Figure A-11 Groundwater levels and rainfall at S5MB03

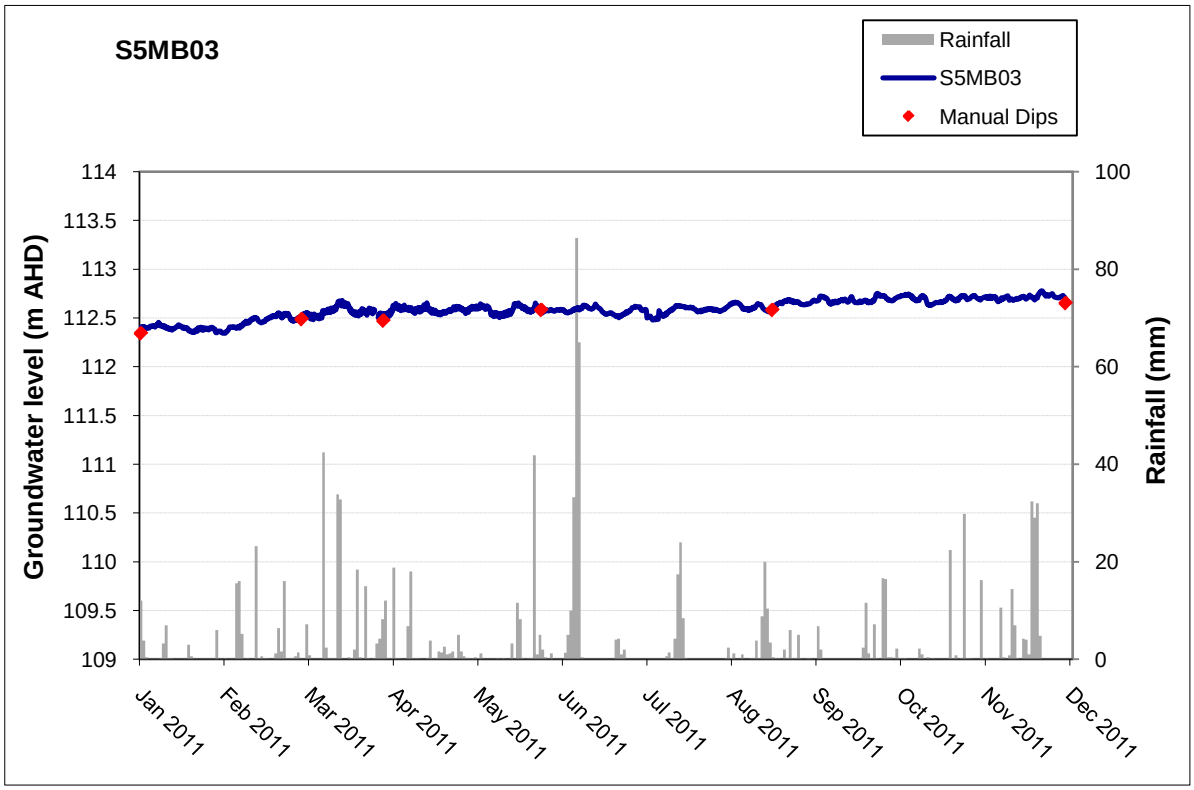


Figure A-12 Groundwater levels and rainfall at WMB01

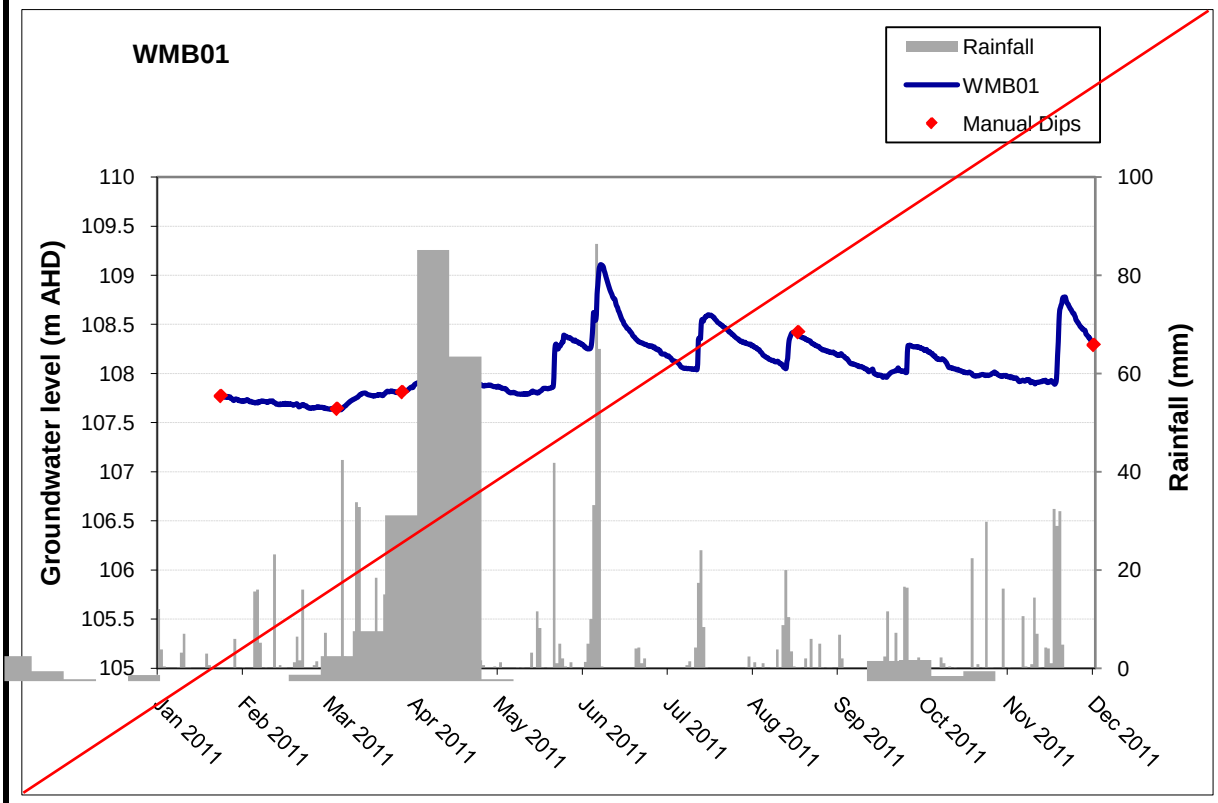


Figure A-19 Groundwater levels and rainfall at BMB02

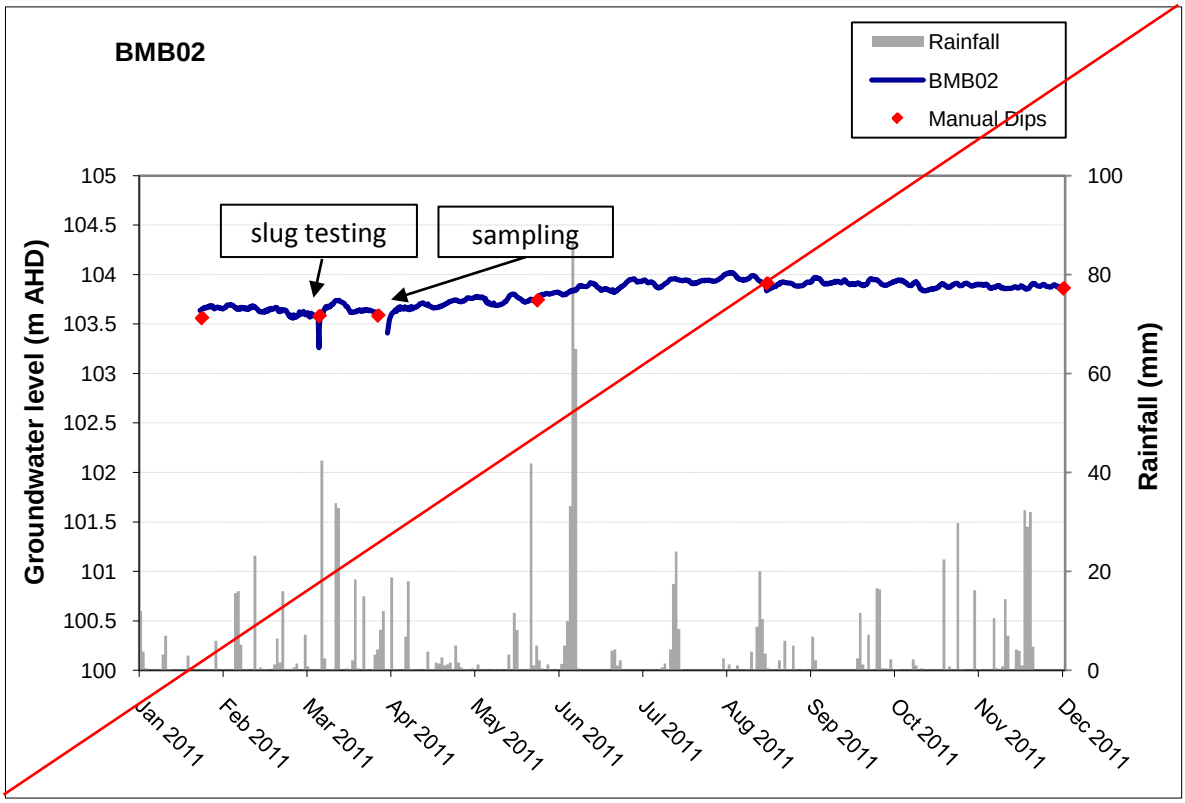


Figure A-20 Groundwater levels and rainfall at TCMB01

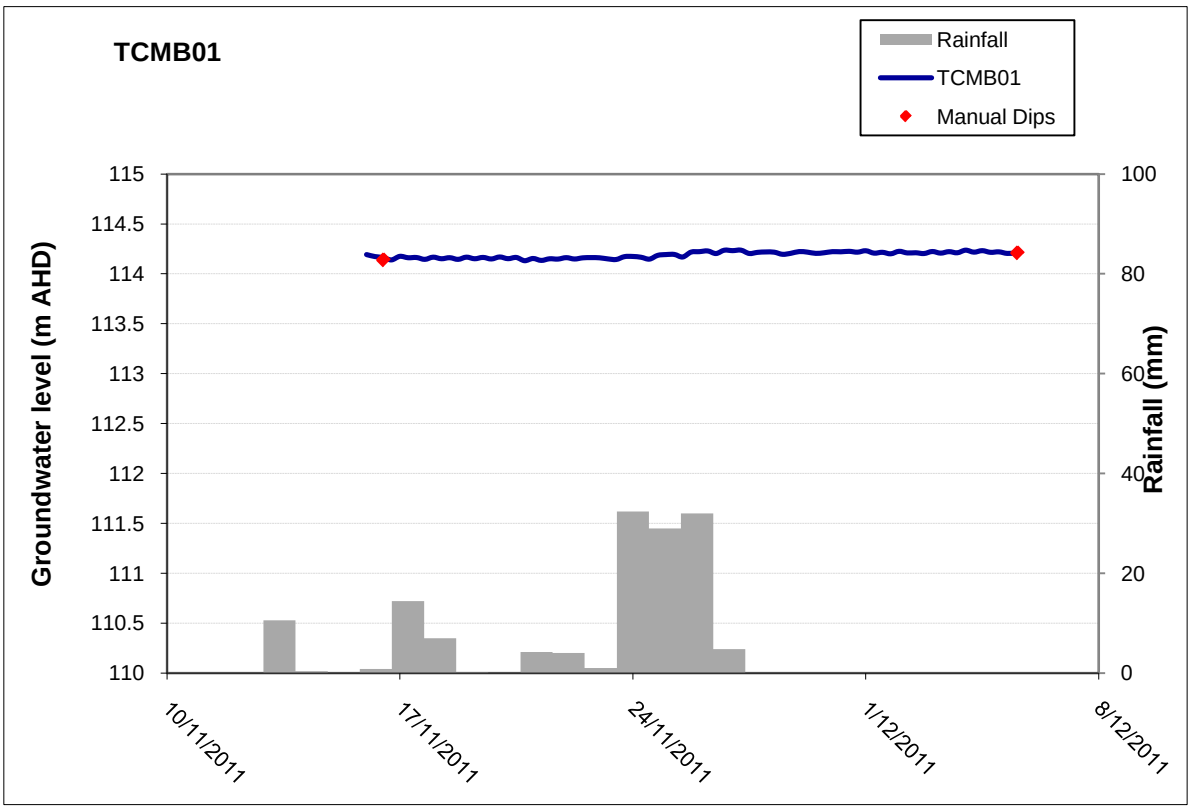


Figure A-21 Groundwater levels and rainfall at TCMB02

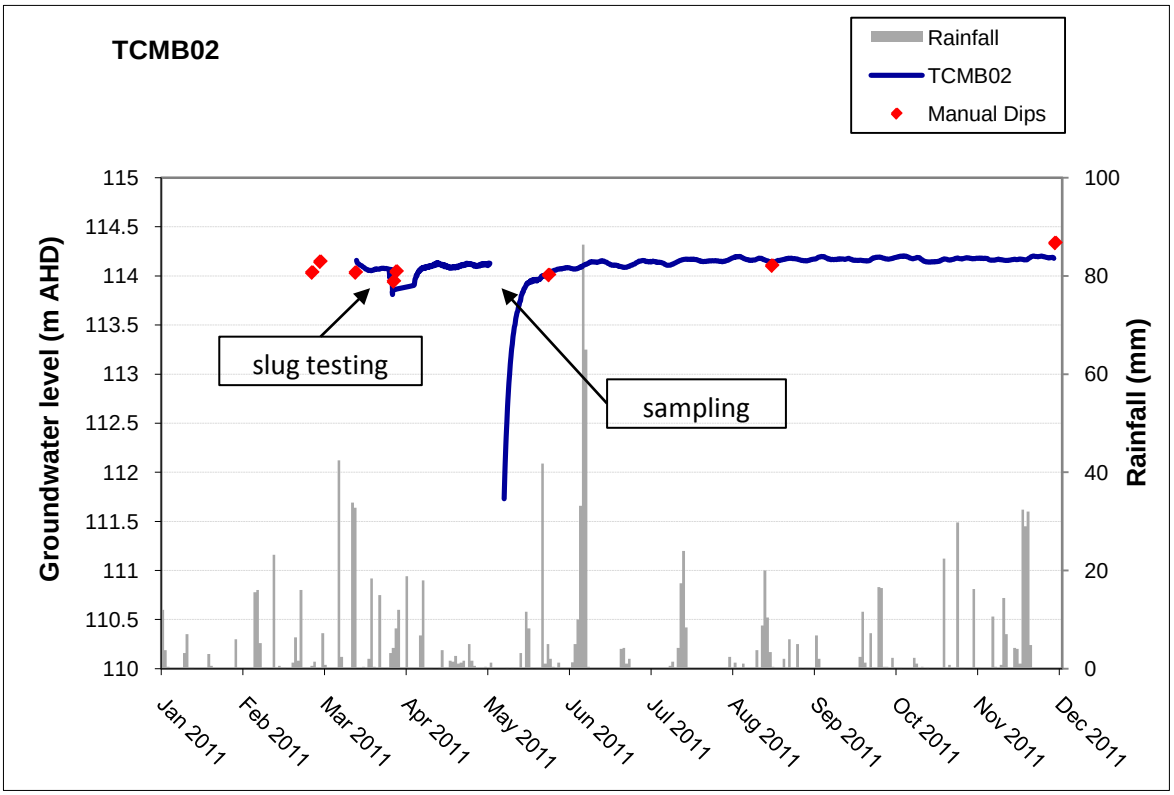


Figure A-22 Groundwater levels and rainfall at TCMB03

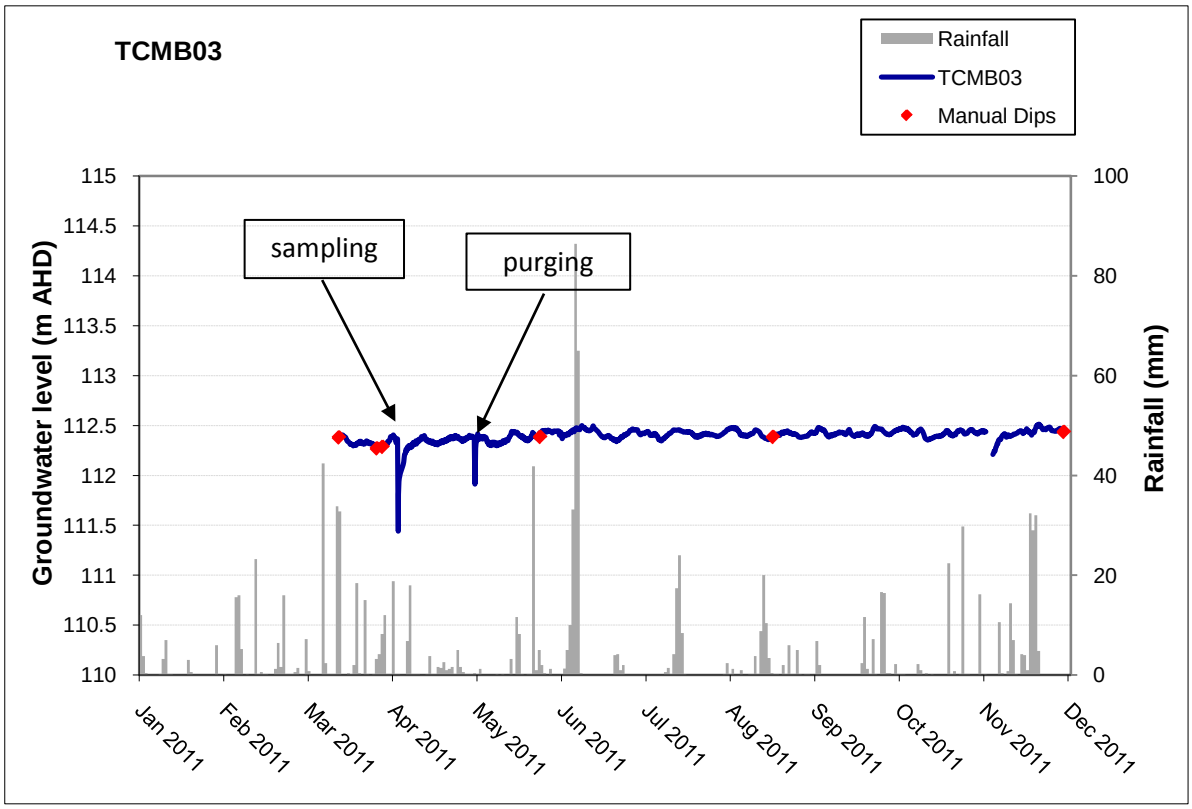


Figure A-23 Groundwater levels and rainfall at TCMB04

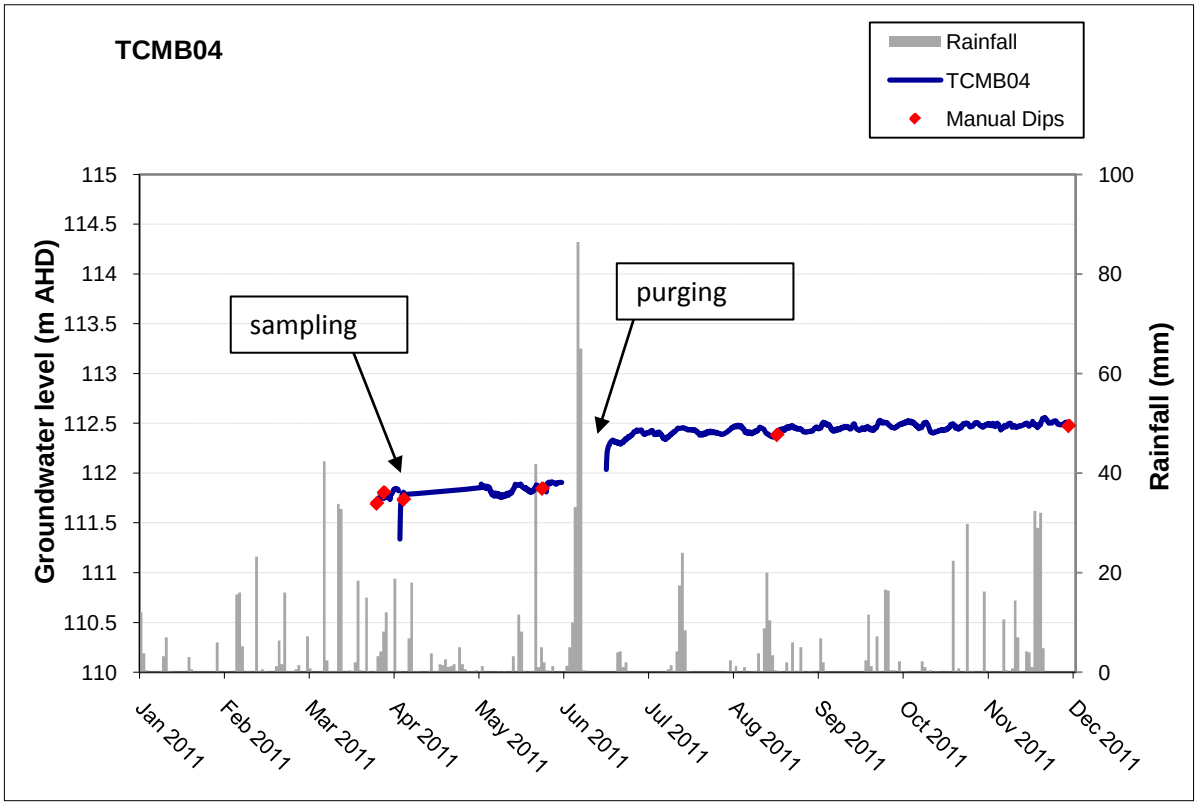


Figure XX Groundwater levels and rainfall at the Tiedeman/Atkins alluvial bores

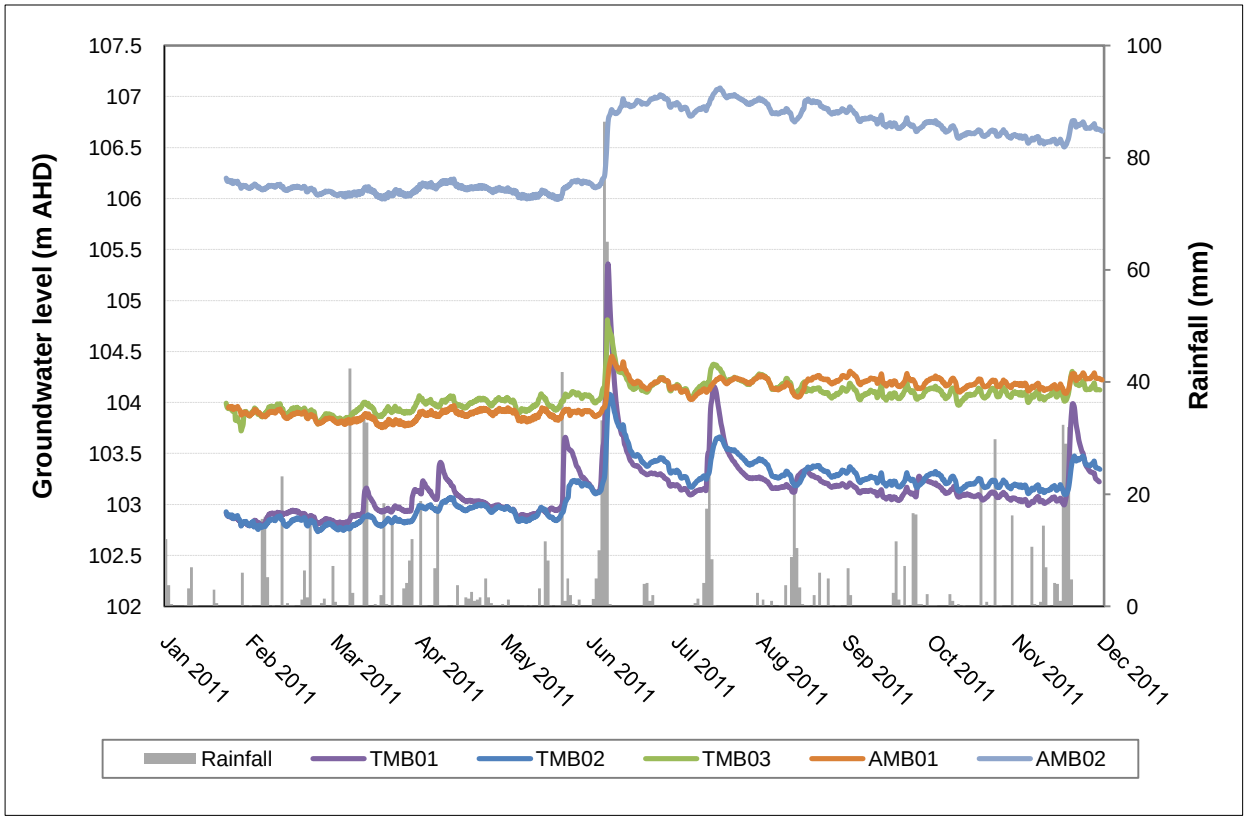
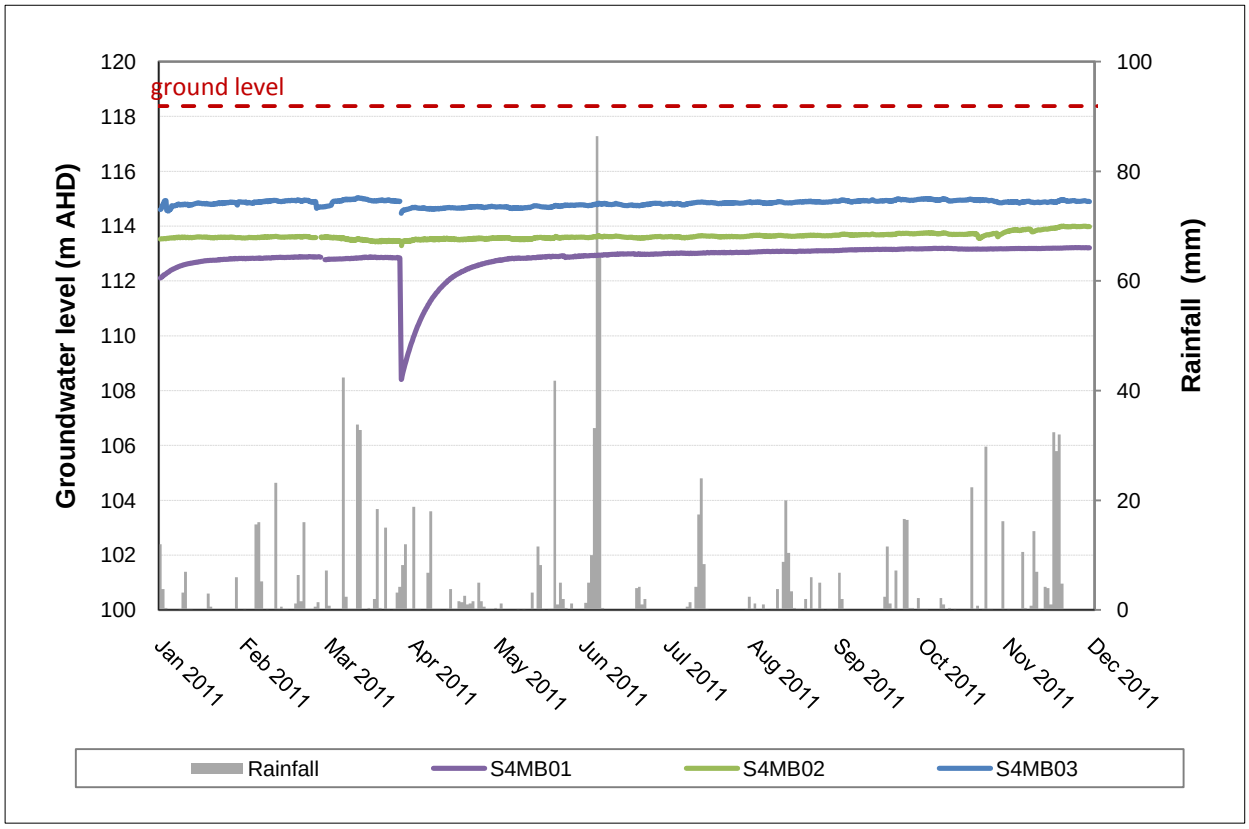


Figure XX Groundwater levels and rainfall at Stratford 4 nested sites



Client: AGL Energy Ltd
Project: Gloucester groundwater investigation and monitoring
Location: Gloucester, NSW

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Figure XX Groundwater levels and rainfall at S5MB nested sites

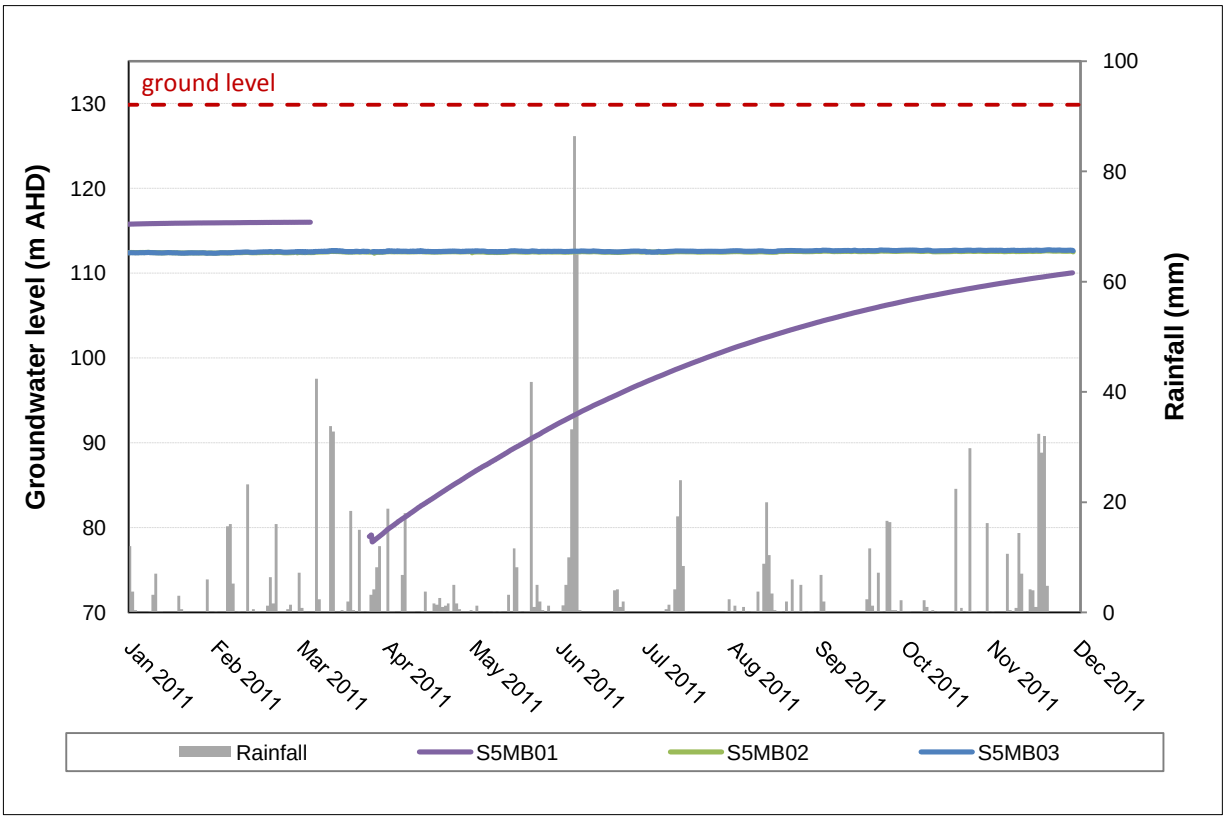

Figure XX Groundwater levels and rainfall at WMB nested sites

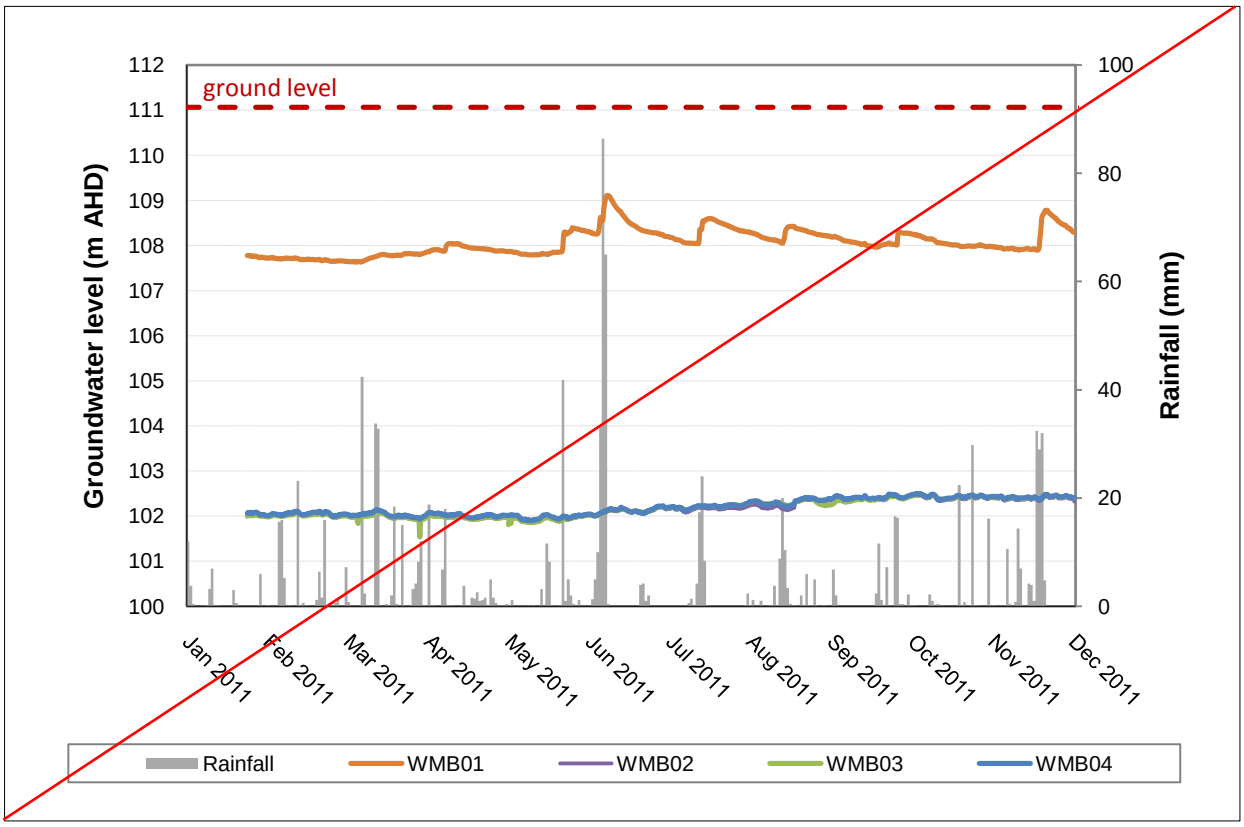

Figure XX Groundwater levels and rainfall at TCMB nested sites