University of South Australia

Forest Research Mount Gambier

Report 23/01

Groundwater recharge under softwood and hardwood forest in the Green Triangle

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Summary

The understanding of groundwater recharge characteristics for the Lower Limestone Coast (LLC) region is the subject of ongoing research by various institutions. Water licencing has been adopted to ensure that the extraction of groundwater in the region is sustainable and does not put the quality of the resource at risk for environmental or economic needs. The *Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area* (LLCWAP) (Government of South Australia, 2019) has been developed to guide the requirements of water licences in the region. The LLCWAP is underpinned by available data which determines the total amount of water available for individual sub-areas (or management areas) across the region, how much water is currently being used and identifies areas where additional water may be available or where water is over allocated and/or overused and further restrictions considered. A key component of the determination of available water in each management area is the allocated recharge estimation.

The objectives of the study were to:

- Examine manual water level observations in the weeks following a significant storm event in November 2007 to ascertain if a groundwater response / recharge occurred
- Examine winter water table responses under regional forest conditions since 2005 (that is, to consider data acquired since the last groundwater recharge evaluations were undertaken that currently inform the 2013 Water Allocation Plan (WAP)

The recharge case study was based on a significant rainfall event in November 2007 which provided a rare opportunity to monitor groundwater levels to ascertain how such rainfall, occurring in a drying part of the year, affected the water table in or near plantation forests. The methods used to investigate recharge included characterising the rainfall, ensuring that barometric pressure changes did not affect groundwater well data, examining manually collected depth to groundwater measurements and further measurements from data loggers. To examine the potential for longer term recharge, the water table fluctuation technique was applied to groundwater observation wells at locations in or adjacent to plantations forests to estimate the occurrence of recharge.

The results of the study were that

- Groundwater recharge occurred under forested areas after a significant storm event.
- Data logger water level records showed the time that groundwater recharge started and ceased at several locations in the Lower South East of South Australia.
- Manual water level records recorded since 2005 indicate groundwater recharge to be occurring under most forested areas each year, on average, despite the assumption of zero recharge for plantation land use.
- These figures varied depending on location, but were relatively small when compared to recharge under open pasture and reflect a relationship exists between depth to water table and groundwater recharge
- The value of the groundwater recharge was dependent on the well location. It is suggested that influences such as roadsides, firebreaks and reductions in plantation density all affect the extent of recharge.
- Wells located in native vegetation indicate similar recharge values to commercial forest observation wells.

Key recommendations are:

- Since there is recharge evident on an event basis, and on an annual basis, for groundwater observation wells located near plantation forests. It is recommended that the existing assumption of the LLCWAP that there is zero recharge beneath closed canopy plantation forest be re-evaluated.
- Not all existing observation wells in plantation forested areas are currently read. It is recommended that the Department for Environment and Water should consider collecting depth to groundwater data from observation wells at more locations to further explore the potential for recharge to occur annually beneath plantation forests.
- This work has demonstrated benefit from the availability of data logger records. It is recommended that additional wells adjacent or within plantations and native forests are fitted with data loggers, and that further interpretation of data logger records occur to better understand groundwater recharge in all areas including areas influenced by plantation forest.
- The estimation of groundwater extraction and by association, water licence requirements, under forested areas is related to the depth to groundwater. Given data suggesting that larger depths to groundwater result in lower recharge, and shallow groundwater results in higher recharge, it is suggested that blanket assumptions regarding land use across the region may not be suitable.

1 Introduction

The understanding of groundwater recharge characteristics for the Lower Limestone Coast (LLC) region is the subject of ongoing research by various institutions. A stronger understanding is required because land users in the region including agriculture and plantation forests are subject to water licencing arrangements. Water licencing has been adopted to ensure that the extraction of groundwater in the region is at controlled rates and groundwater levels remain sustainable to support the community, the environment and the economy. The *Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area* (LLCWAP) (Government of South Australia, 2019) has been developed to guide the requirements of water licences in the region. The LLCWAP identifies the need for sustainable management of the regional water resources and provides a framework for managing water accordingly. The framework is underpinned by available data which determines the total amount of water available for individual sub-areas (or management areas) across the region; how much water is currently being used and identifies areas where additional water may be available or where water is overused and needs further restrictions. A key component of the determination of available water in each management area is the allocated recharge estimation. This report presents the findings of two investigations into the nature of groundwater recharge in the area managed by the LLCWAP.

The first component of this investigation considers a case study of groundwater recharge occurring under plantation forest sites. In the determination of total available water for each management zone, of which annual recharge is a component, the LLCWAP assumes no groundwater recharge occurring underneath plantation forests after canopy closure. Previous investigations into the extent of recharge during fallow periods and post planting have been undertaken (Benyon et al., 2008), and shown there is no recharge occurring post canopy closure (Benyon and Doody, 2009). This report investigates a case study of recharge following a rainfall event in November 2007 where a significant volume of rain fell over the region across four days. This report includes the findings of recharge for this single case study storm of a relatively infrequent nature but may form the basis of future investigations into the occurrence of recharge.

The second component of this investigation involves applying the water table fluctuation technique, to estimate the volume of recharge occurring for groundwater monitoring wells in the LLC region that are situated in or adjacent to plantation forests.

1.1 Aims and Objectives

The objectives of the study were to:

- Examine manual water level observations in the weeks following a significant storm event in November 2007 to ascertain if a groundwater response / recharge occurred. Did a water table response occur under forested areas and was this influenced by depth to groundwater?
- Examine winter water table responses under regional forest conditions since 2005; (that is, to consider data acquired since the last groundwater recharge evaluations were undertaken that currently inform the 2013 Water Allocation Plan (WAP)

2 Methodology

2.1 A case study of recharge under plantation forest areas

The recharge case study works undertaken for this report were based on a significant rainfall event in November 2007. During November, monthly total rainfall is generally declining, transitioning into a drier 'summer' pattern in the Mount Gambier region (Mount Gambier BOM station November long term average is 46 mm and Penola 41 mm) and this intense period of wet weather over approximately four days allowed a unique opportunity to monitor groundwater levels to ascertain how such rainfall, occurring in a drying part of the year, affected the water table in or near plantation forests. Monitoring works supporting this study was initiated by the then Department for Water, Land and Biodiversity Conservation (DWLBC) (now the Department for Environment and Water, DEW) to investigate regional water table affects, particularly for under plantation forest landuse including both Pine and Blue Gum.

The methods used to investigate the occurrence of recharge following the 2007 storm event were:

- Characterising Rainfall observed in the November 2007 storm
- Examining barometric pressure data
- Examining groundwater levels following the November 2007 storm – Manual records
- Examining groundwater levels following the November 2007 storm – logger records

2.1.1 Characterising Rainfall observed in the November 2007 storm

Rainfall data records have been examined from gauges managed by the Australian Bureau of Meteorology (BOM). Gauges examined included:

- Mount Gambier Aero (BOM station 026021)
- Penola Post Office (BOM station 026025)

2.1.2 Examining barometric pressure data

An investigation into barometric pressure was undertaken to isolate and consider the influence of air pressure changes on the change in standing water level and depth to groundwater at groundwater observation wells. Barometric pressure was not collected to plot against the 2007 storm event however existing barometric data used during other aquifer testing records was compared with water level response at nearby groundwater observation wells to show whether the change in barometric pressure was relatively instantaneous or subject to a delay which may be confused with recharge, and whether changes in the groundwater level following the rainfall event may be explained by change in barometric pressure rather than recharge.

Barometric pressure data was collected from the following BOM gauges:

- Mount Gambier Aero (BOM station 026021)
- Coonawarra (BOM station 0260291)

As a first example, a groundwater investigation was conducted south of the Bool Lagoon wetland in July 2014. A deep unconfined aquifer well (ROB038) was drilled with the base formation section between 60 m and 80 m left open hole (no casing). During aquifer testing of a nearby confined aquifer well, a data logger recorded the water level response in ROB038 which was compared to the barometric pressure recorded from onsite.

As a second example, in 2006 during aquifer testing for the newly completed SA Water Kalangadoo confined aquifer town water supply well N° 3, the previous well completed in the same confined aquifer was monitored for water level. During testing a storm event occurred with observations of the change in water level.

2.1.3 Investigating groundwater response to November 2007 storm – Manual records

Following the rainfall event in 2007, groundwater monitoring was undertaken to measure depth to groundwater (and by correlation, the standing water level) was collected by a then DWLBC field officer. There were 17 observation wells (obswells) manually monitored over several weeks. The location of the wells manually monitored are shown in Figure 1.

Manual water levels after the 2007 storm event were initially compared to levels collected in the September / October routine regional groundwater monitoring data just prior to the storm. Under normal circumstances, levels in November would have been expected to have dropped in response to the drying spring period. Further manual records were collected until it was established that water levels were lowering, as per the seasonal norm for the summer months.

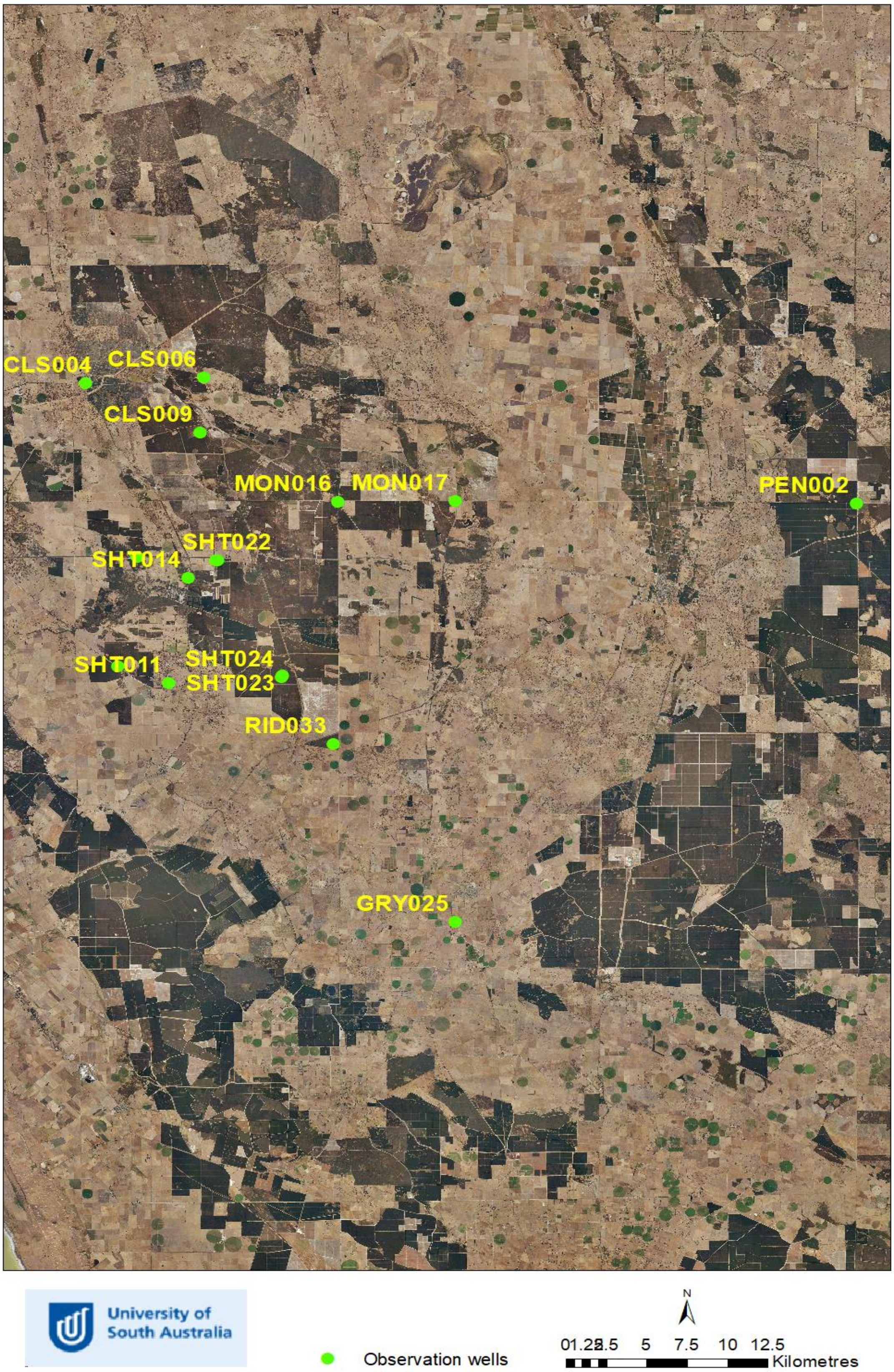

Figure 1: Location of groundwater observation wells manually monitored after the November 2007 storm event

2.1.4 Investigating groundwater response to November 2007 storm – Logger records

Observation wells which were equipped with data loggers, continuously recording water levels prior to, during and following the event also had records examined for sites both within and out of plantation forests. Groundwater data loggers collect higher intensity data and available data from November 2007 were examined to assess changes that occurred. The wells with data logger records that were examined are shown in Figure 2.

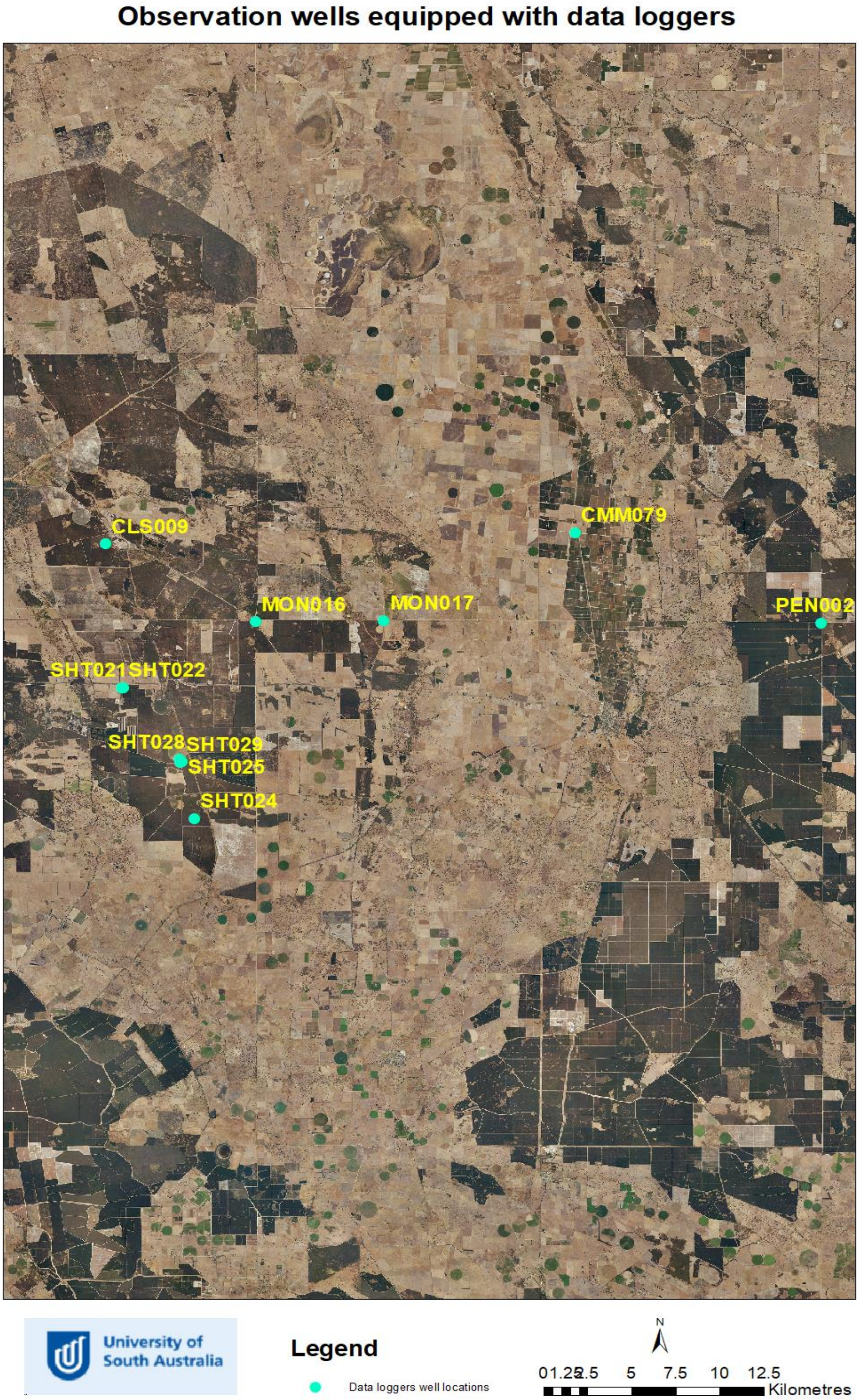

Figure 2: Location of groundwater observation wells equipped with data loggers monitored during November 2007

2.2 Examining the occurrence of recharge under plantation forest areas over the long term

The current LLCWAP (Government of South Australia, 2019) considers values of total groundwater recharge between 1995 and 2004. Total available recharge is based on data reported by Latcham et al. (2007), which reports this data based on the work of Brown et al. (2006). According to the latter, total available recharge has been determined using the water table fluctuation method or a suitable alternative across the region. The water table fluctuation method was ultimately applied to determine total recharge across most of the region.

In this study, the water table fluctuation method has been applied to a longer, more recent data record to estimate the total recharge occurring at groundwater observation well sites located adjacent to plantation forests. Groundwater observation well records were downloaded from 2005 to 2019 for wells located in or near plantation forests from the South Australian groundwater observation well network (Waterconnect). The average fluctuation in groundwater was determined for each year and an average annual fluctuation was determined over the period of assessment. Using specific yield values determined from the downloaded data, the total recharge at each location was estimated. The location of wells examined are shown in Figure 3. Note that commencing data analysis in 2005 reflects the period immediately after the previous groundwater recharge calculations from Brown et al. (2006).

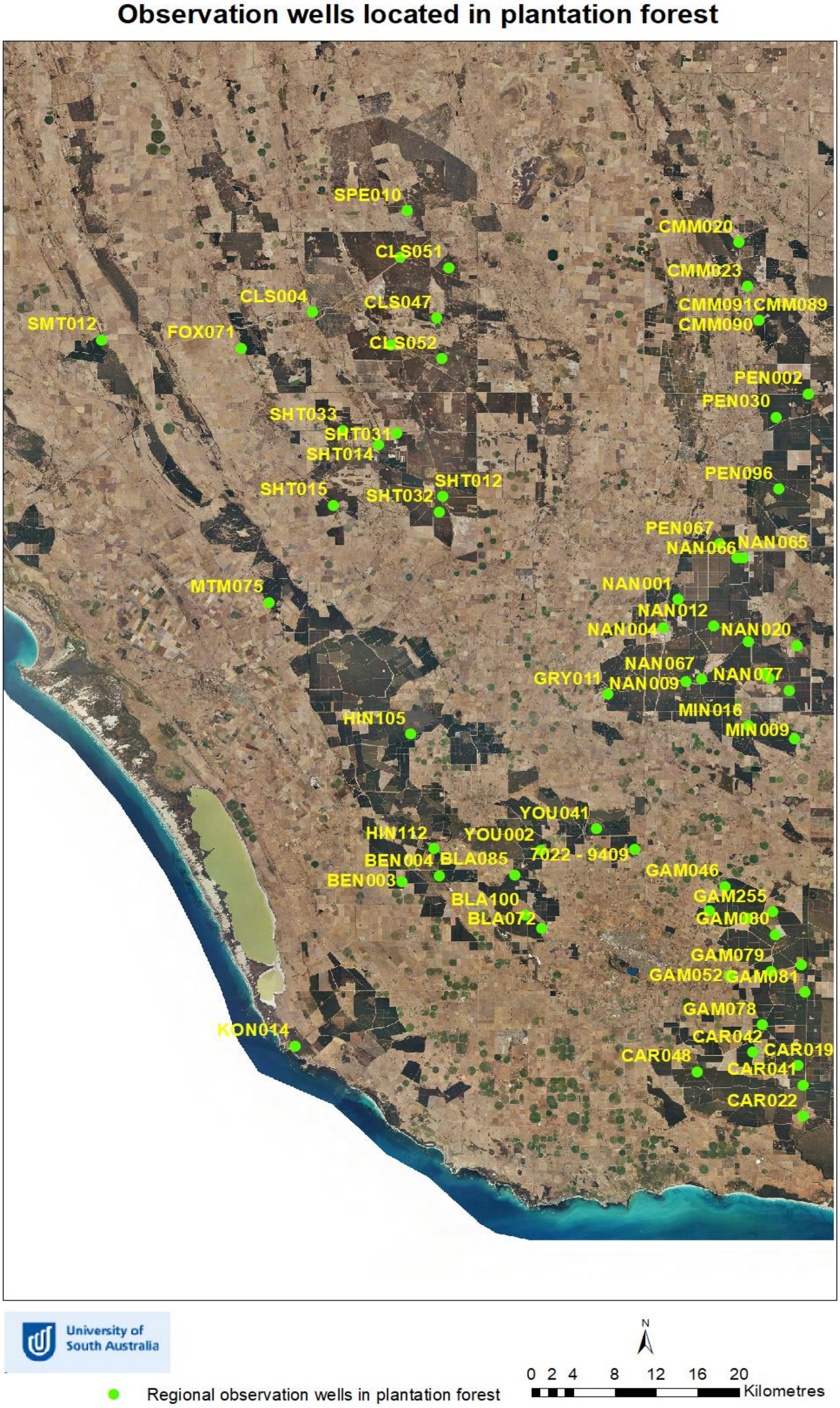

Figure 3: Location of groundwater observation wells with assessed mean annual groundwater recharge values

3 Results

3.1 Characterising rainfall - November 2007 storm

Rainfall that fell from 2 to 5 November 2007 was notable for several reasons. Penola Post Office (026025) rain gauge recorded 79.2 mm rainfall in 4 days which is almost double the average rainfall total in November for this gauge (40.8 mm). The Mount Gambier Aero (026021) rain gauge recorded 102 mm in 4 days, more than double the average rainfall total in November at this location (46.4 mm). For context, the total annual rainfall records for 2007 are plotted in Figure 4 (Mount Gambier Aero) and Figure 5 (Penola Post Office). The rainfall followed a winter of slightly above average rainfall.

In terms of storm frequency, assuming a total storm duration of 96 hours, the Annual Exceedance Probability (AEP) of the rainfall at Mt Gambier was a 5% AEP (or 20 Year Average Recurrence Interval, ARI). At Penola Post Office, the rainfall was greater than a 20% AEP (and greater than a 5 Year ARI). Daily rainfall records at these two gauges are shown in Table 1. Differences in rainfall from the storm event indicate variability across a relatively small distance (approximately 50 kilometres).

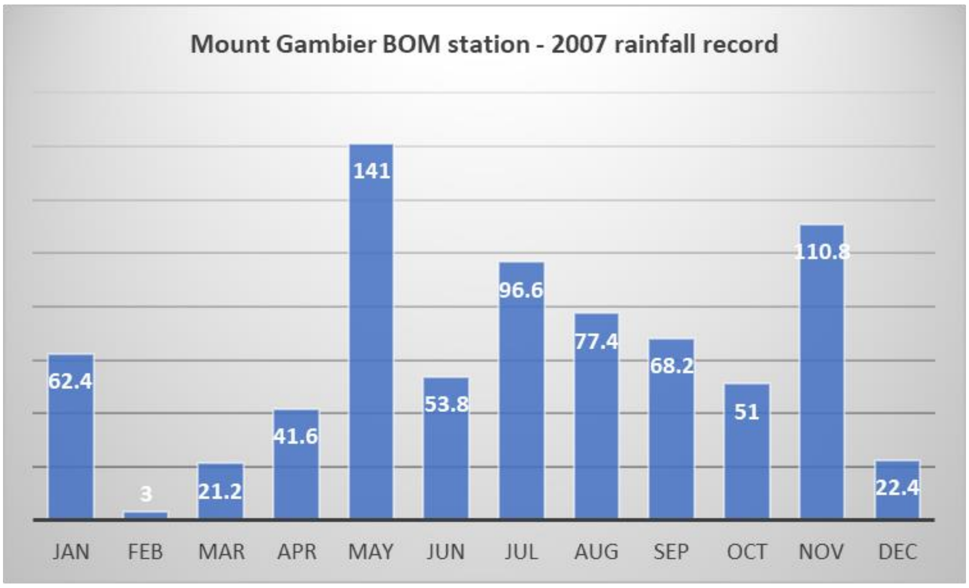

Figure 4: Monthly rainfall totals for 2007 from the BOM gauge at Mount Gambier Aero (026021).

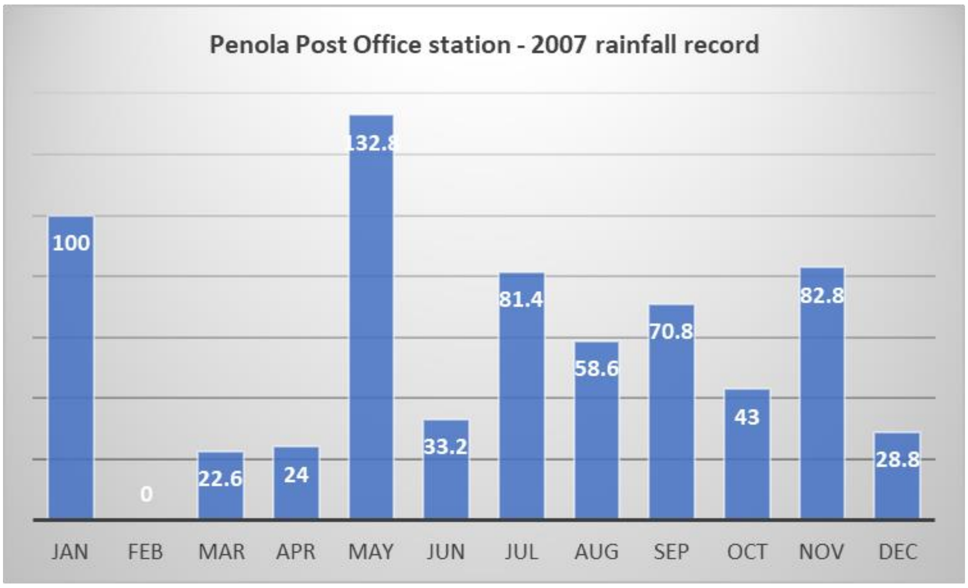

Figure 5: Monthly rainfall totals for 2007 from the BOM gauge at Penola Post Office (026025).

Table 1: Daily rainfall recorded at the Mount Gambier Aero and Penola Post Office BOM rain gauges from 2 to 5 November 2007

Date	**Rainfall - Mount Gambier Aero 026021 (mm)**	**Rainfall - Penola Post Office 026025 (mm)**
2/11/2007	19.2	12
3/11/2007	12.2	0
4/11/2007	71	0
5/11/2007	0.4	67.2
Sum	**102.8**	**79.2**

3.2 Examining Barometric Pressure Data

A groundwater investigation was conducted south of the Bool Lagoon wetland. A deep unconfined aquifer observation well (ROB038) was drilled with the base formation section between 60 m and 80 m left open hole (no casing). During aquifer testing of a nearby confined aquifer well, a data logger recorded the water level response in ROB038 which was compared to the barometric pressure recorded from onsite with the result shown in Figure 6. These indicate that the water levels in the unconfined aquifer move in response to barometric pressure changes.

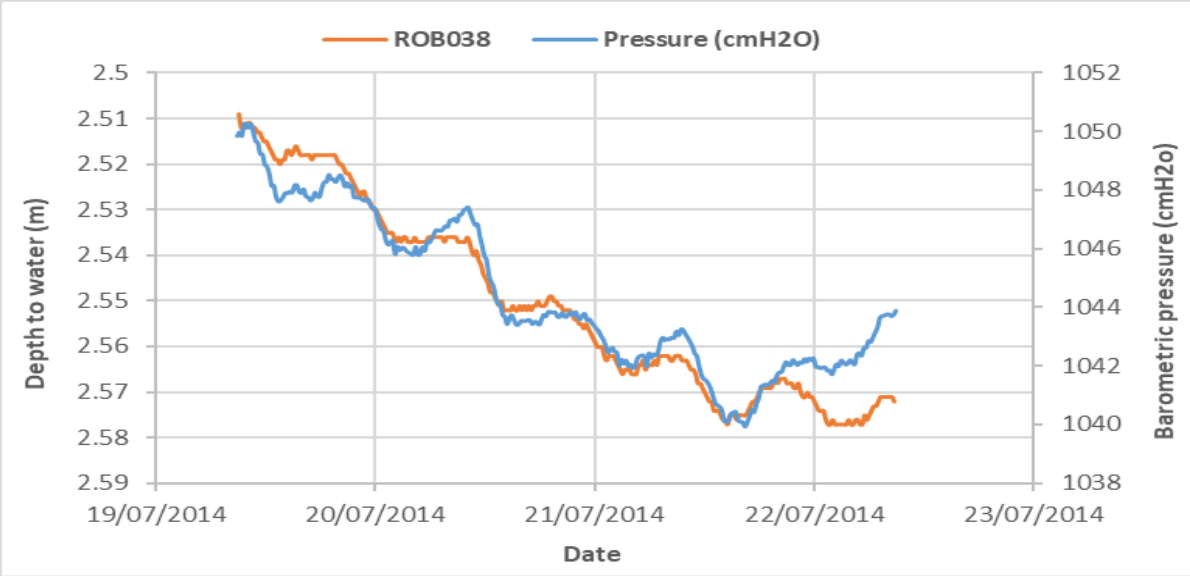

Figure 6: Observation well ROB038 compared to barometric pressure July 2014

This reflects observations of the author in 2006 during aquifer testing for the newly completed SA Water Kalangadoo confined aquifer town water supply well N° 3. The well it replaced, town water supply well N°1 which was also completed in the confined aquifer, and the water levels in this well were monitored while testing the new well. During testing a storm event built up as a cold front passed through the area leading to rainfall. During the storm build-up the confined aquifer water level rose 4 cm and immediately after the front passed, began dropping again to its starting point. This was attributed to the drop in air pressure.

In conclusion water level response to changes in barometric pressure occur in parallel, indicating small but immediate aquifer responses to changes in pressure. If groundwater recharge occurs even during a short but strong storm event, the water level response tends to be much longer in duration. This is demonstrated in Sections 3.3 and 3.4.

3.3 Investigating groundwater response to November 2007 storm – Manual records

Table 2 records the observation wells manually recorded, the record dates, the land use in November 2007 and water level change since previous records were taken. The results indicate that for observation wells located adjacent to plantation forests within the Short, Coles and Zone 3A management areas (either pine or blue gum plantations), water level rises were observed following the storm event.

Note that some of the observation wells in the Short management area did not correspond with the increasing water level trend. Manual water levels after the November 2007 storm indicated no positive water level response, rather a small decline was recorded (SHT002, SHT 021, SHT022, SHT015, SHT014 and SHT011). However, it should be noted that some of those wells had data loggers installed which indicated groundwater recharge occurring with a delayed effect (see Section 3.4).

Table 2: Observation well recordings for wells located near forests in November 2007 compared to water table response to the September / October regional monitoring (prior to storm).

Management area	Observation well	Monitoring date	Land use	Water level (m)	Rise (mm)	Fall (mm)
Coles	CLS004	19/09/2007	Blue Gum	4.81		
		8/11/2007		4.82		10
Coles	CLS006	19/09/2007	Blue Gum	3.92		
		8/11/2007		3.84	80	
Coles	CLS009	19/09/2007	Blue Gum	4.4		
		8/11/2007		4.38	20	
		16/11/2007		4.34	40	
		26/11/2007		4.36		20
Monbulla	MON016	18/09/2007	Blue Gum	4.79		
		8/11/2007		4.84		50
		16/11/2007		4.80	40	
		26/11/2007		4.80	0	
Monbulla	MON017	18/09/2007	Blue Gum	5.18		
		8/11/2007		5.12	60	
		16/11/2007		5.12	0	
		26/11/2007		5.16		40
Zone 3A	PEN002	4/10/2007	Pine	6.51		
		8/11/2007		6.48	30	
		16/11/2007		6.40	80	
Zone 3A	Penola well	8/11/2007	Pine	6.01	10	
		8/11/2007		5.96	50	
Short	SHT002	14/09/2007	Blue Gum	3.64		
		8/11/2007		3.7		60
Short	SHT021	14/09/2007	Blue Gum	4.11		
		8/11/2007		4.21		100
Short	SHT022	14/09/2007	Blue Gum	3.98		
		8/11/2007		4.08		100
Short	SHT014	14/09/2007	Blue Gum	3.80		
		8/11/2007		3.88		80
Short	SHT015	14/09/2007	Blue Gum	3.82		
		8/11/2007		3.85		30
Short	SHT011	14/09/2007	Blue Gum	4.83		
		8/11/2007		4.87		40
Short	SHT023	14/09/2007	Blue Gum	5.52		
		8/11/2007		4.37	115	
Short	SHT024	14/09/2007	Blue Gum	5.2		
		8/11/2007		5.18	20	
Riddoch	RID022	19/09/2007	Blue Gum	3.34		
		8/11/2007		3.2	140	
		16/11/2007		3.09	110	
		26/11/2007		3.09	0	
Grey	GRY025	20/09/2007	Pasture	8.38		
		8/11/2007		8.36	20	
		16/11/2007		8.35	10	
		26/11/2007		8.35	0	

The manual water levels for the Coles management area indicate water level rises of 60 to 80 mm in November 2007, when they would normally be declining. Observation well CLS009 had a data logger installed but unfortunately it was not working and was restarted on 8 November (after the event), and the data available indicates that the water level peaked at approximately 26 November.

Data indicates that groundwater recharge occurred in this hardwood forest plantation and if not by direct recharge via sand infill holes or other direct recharge route, then through piston flow where soil moisture exceeds field capacity. Figures indicating the occurrence of the late season recharge are shown in Figure 7 (Coles, CLS009), Figure 8 (Monbulla, MON016), Figure 9 (Monbulla, MON017) and Figure 10 (Zone 3A, PEN002).

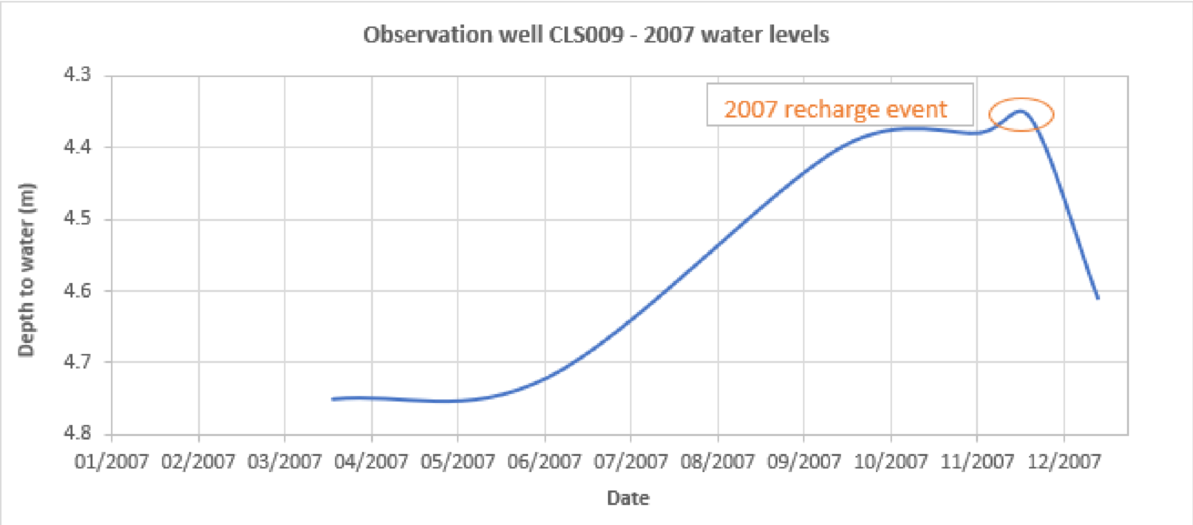

Figure 7: Manual water level record for observation well CLS009 in 2007 highlighting recharge event

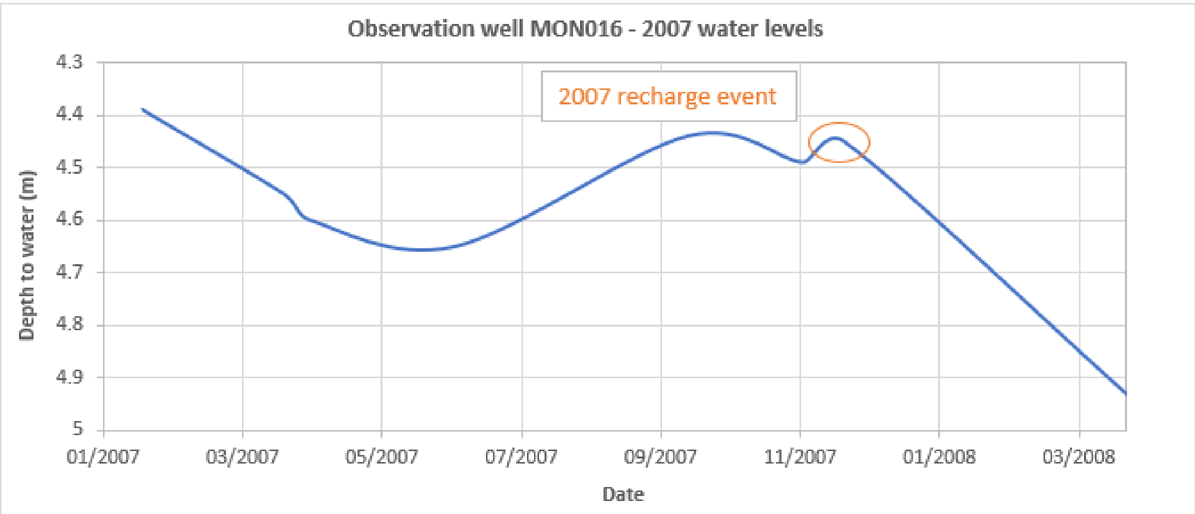

Figure 8: Manual water level record for observation well MON016 in 2007 highlighting recharge event

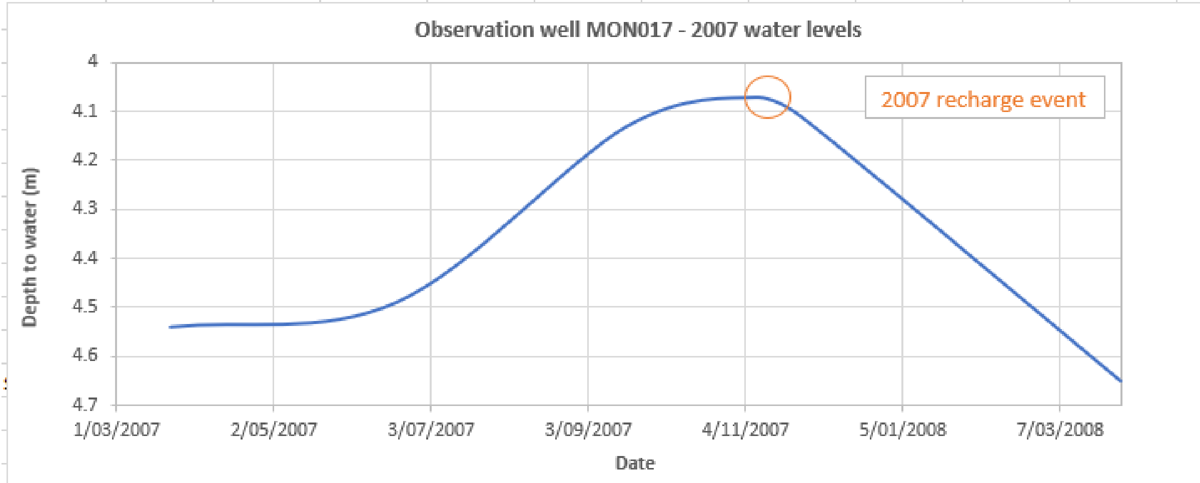

Figure 9: Manual water level record for observation well MON017 in 2007 highlighting recharge event

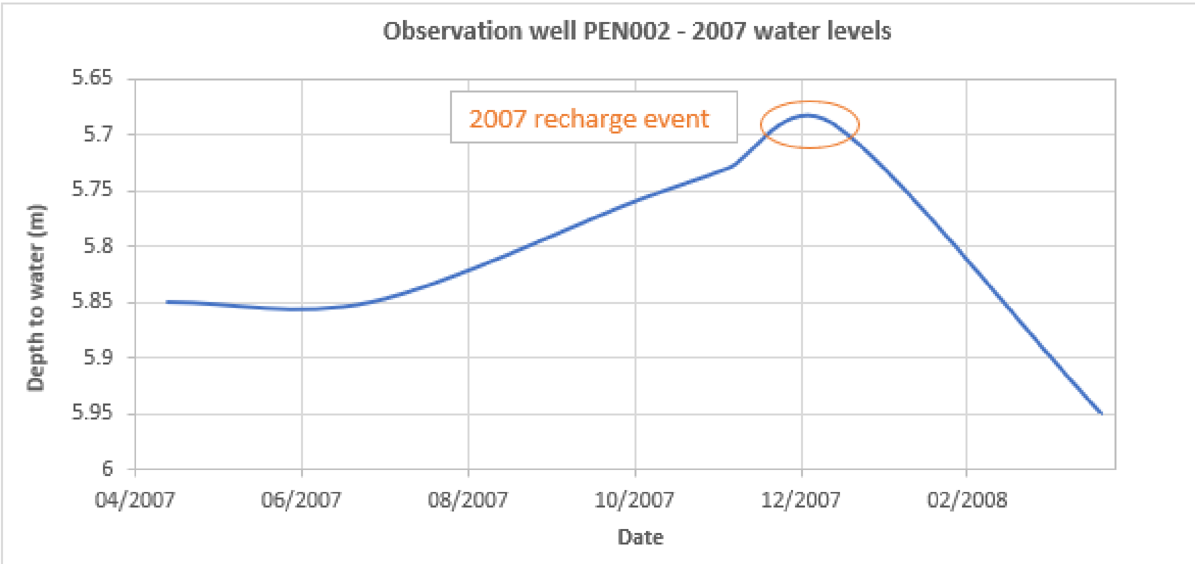

Figure 10: Manual water level record for observation well PEN002 in 2007 highlighting recharge event

3.4 Investigating groundwater response to November 2007 storm – Logger records

The data logger records available are presented in Appendix A. Overall, the data shows that the anticipated drop in water level in September to October 2007, following a peak in the wet winter season, was evident by November. Logger data also clearly shows that this decline in water level reversed in the days following the November 2007 storm. Logger data shows the decline continued until mid to late November 2007, before declining once again in the absence of rainfall. As such, the increase in water levels following the storm in November 2007 may be characterised as recharge.

It is suggested that the unsaturated profile between the ground level and water table still contained elevated moisture levels and the heavy rain recharged any decline in moisture. The result was increased groundwater recharge, either through direct access to the water table (via sand conduit holes), or more likely, through pressure or piston flow (that is, as more water was added to the top of the soil profile, the field capacity of the soil profile was exceeded and water proceeded to the water table as recharge).

For example, data logger water level records for observation well SHT022 are shown in Figure 11. This well is situated adjacent to blue gum plantation forest. The data indicates groundwater recharge occurring from July 2007 until the middle of September 2007, peaking at about 3.97 m below ground (a rise of 290 mm). Water levels then declined to show a depth to water of approximately 4.07 m to the end of October. The water level rose in response to the November storm event to a depth below ground of about 4 m in the middle of the month (a 70 mm rise). After this, water levels again declined in response to drier summer conditions.

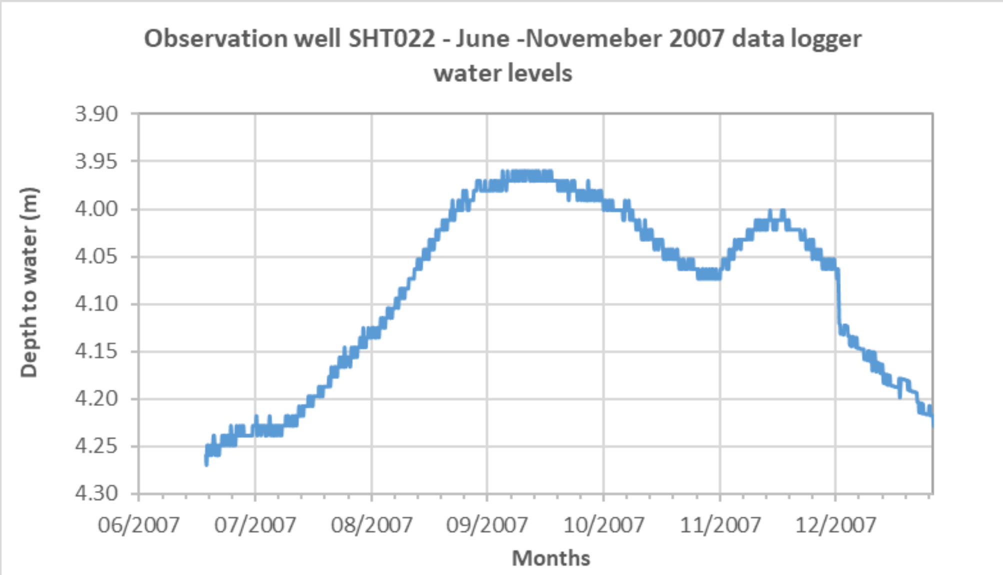

Figure 11: Observation well SHT022 data logger water level record – June / December 2007

Water level logger records for observation well SHT021 are shown in Figure 12. These also indicate a water level recovery during November 2007. The water level begins to rise from 3 to 16 November. From the peak on 16 November, the level is maintained until it begins declining again from 27 November. The overall rise in water level following the November 2007 storm was 90 mm. If a typical specific yield is assigned for sandstone of approximately 15% (Domenico and Schwartz, 1997; Mustafa et al., 2006) this indicates that approximately 14 mm of groundwater recharge occurred at this site.

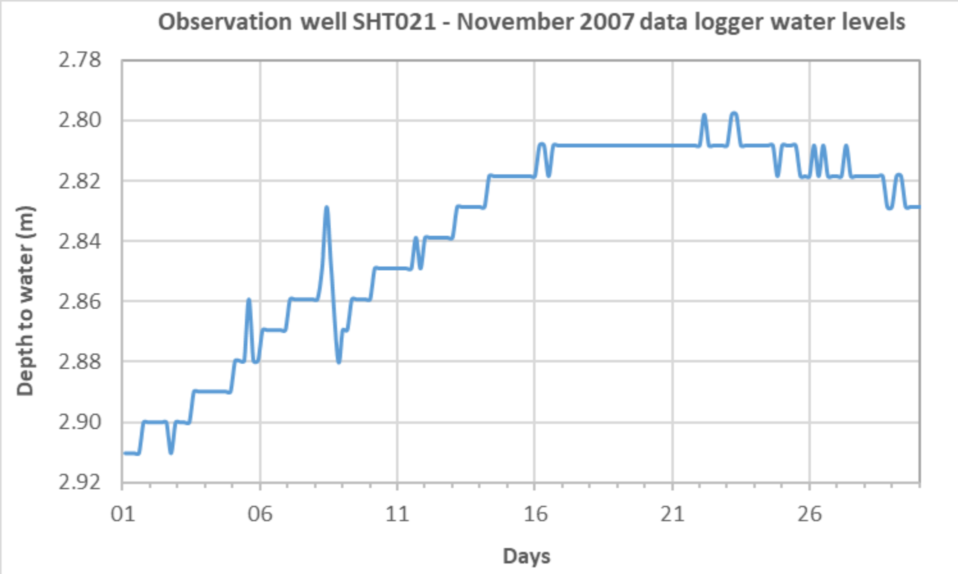

Figure 12: Observation well SHT021 data logger water level record – November 2007

Table 3 summarises water level rises that occurred after the November 2007 storm based on logger data records. A value for the potential groundwater recharge has been shown based on applying the water table fluctuation method, based on an assumed specific yield of 15%, common for sandstone (Domenico and Schwartz, 1997; Mustafa et al., 2006). The results indicate groundwater recharge occurred in both hardwood and softwood plantation forest land uses.

Table 3: Summary of data logger records for groundwater observation wells in November 2007

Observation Well	Water table rise after the November 2007 storm (mm)	Potential groundwater recharge (mm)*	Land use
SHT021	53	8	Blue gum
SHT022	70	11	Blue gum
SHT025	140	21	Blue gum
SHT028	171	26	Blue gum
SHT029	240	36	Blue gum
CLS009	60	9	Blue gum
PEN002	70	11	Pine
MON016	40	6	Blue gum
MON017	60	9	Blue gum
SHT024	140	21	Blue gum
Average		**15.8 mm**	
CAR039	160	24	Irrigation area
MAC046	190	29	Irrigation area
KON001	100	15	Irrigation area
Average		**22.7 mm**	
CMM079	140	21	Vineyard
GAM029	0	0	Dryland pasture
GAM251	100	15	Dryland pasture
GAM079	15	2	Pine deep water table
** Assuming specific yield of the sandstone aquifer in this region is 15%*			

3.5 Long term groundwater recharge under regional forests

Estimated recharge based on the water table fluctuation method are shown in Table 4. The long-term observation well data collected between 2005 to 2019 at sites in or near plantation forests indicate that, on average, some groundwater recharge has been occurring at these sites annually. Recharge in some wells indicated values that may be associated with either well problems or landuse, most likely direct water ingress down the side of the casing resulting in mounding and greater water level responses.

It is suggested that the occurrence of groundwater recharge in forest land use can be through:

- Roads, major and minor fire breaks
- Rainfall reaching the ground, passing the tree canopy – some forests prior to thinning have very dense canopies, however after thinning have significant open area
- Water that reaches the ground and not used by roots in the high rainfall period of winter can travel deeper and reach the water table
- A current National Institute for Forest Product Innovation (NIFPI) investigation indicates a significant percentage of rainfall reaching ground level in throughfall collectors at eight monitoring sites (Lawson et al., In Prep).

Other findings from the data in Table 4 include:

- Wells located in native vegetation (NAN001, NAN067) indicate similar recharge values to commercial forest observation wells. This may indicate that native forest has similar impacts to commercial plantations, or may be related to a 'whole of forestry' affect – that is, the regional land use (commercial and native forests combined) is influencing the water table more than discrete local landuse near the well.
- Observation wells located on forest edges (i.e. GAM046) seem to indicate a boundary effect, with recharge values reflecting open pasture recharge more than forest recharge.
- Recharge in observation forest affected wells where there is a greater depth to groundwater, such as in Donovans and Glenburnie, is typically lower than those forest affected wells located in shallow water tables, such as those in Coles and Zone 3A.

Table 4: Observation wells located in forested areas with depth to groundwater, assessed specific yield (Sy) and assessed groundwater recharge

Management Zone	Observation well	Easting	Northing	SWL (m) – Sept2020	Assessed Sy	2005 – 2019 Assessed recharge (mm/year)
DONOVANS	CAR022	497089	5796470	18.23	0.10	15
	CAR040	489131	5795118	22.32	0.10	28
	CAR077	491989	5799206	26.76	0.10	11
						Ave 18 mm
GLENBURNIE	CAR019	496579	5801615	20.6	0.10	4
	CAR041	497105	5799609	24.72	0.10	1
	CAR042	492205	5802918	25.41	0.10	8
	CAR048	486931	5800969	19.19	0.10	6
	GAM052	489966	5810657	28.10	0.10	3
	GAM078	493181	5805673	26.57	0.10	4
						Ave 4 mm
MYORA	GAM037	488101	5817138	13.80	0.10	11
	GAM046	489591	5819618	5.32	0.15	50
	GAM070	496938	5811744	12.06	0.10	43
	GAM072	491760	5816374	6.61	0.10	11
	GAM079	493959	5811070	28.17	0.10	3
	GAM080	494405	5814751	10.54	0.10	9
	GAM081	497289	5808944	17.95	0.10	11
	GAM255	494206	5817054	6.21	0.10	14
						Ave 19 mm
COMPTON	BLA085	469305	5820786	16.53	0.10	6
						Ave 6 mm
BLANCHE CENTRAL	BLA072	471969	5815375	26.25	0.10	11
	BLA071	471683	5816484	42.03	0.1	34
	BLA100	470356	5816732	19.26	0.05	2
						Ave 16 mm
BENARA	BEN003	458451	5820060	6.85	0.15	63
	BEN004	462030	5820625	5.87	0.15	60
						Ave 62 mm
KONGORONG	KON014	448231	5803537	2.60	0.10	23
	KON016	450740	5807969	N/A	0.15	57
						Ave 40 mm
HINDMARSH	HIN041	455237	5829258	24.72	0.10	41
	HIN105	459345	5834919	25.52	0.10	13
	HIN112	461530	5823412	19.12	0.10	5
						Ave 20 mm
YOUNG	YOU002	471834	5823239	13.11	0.10	15
	YOU010	470373	5821399	N/A	0.10	84
	YOU026	469225	5826973	3.58	0.10	110
	YOU041	477181	5825394	6.55	0.10	31
						Ave 60 mm
GREY	GRY011	478322	5838931	9.10	0.15	27
						Ave 27 mm
ZONE 2A	MIN009	496294	5834433	4.99	0.15	40
	MIN016	491787	5835776	6.03	0.15	19
	NAN004	483634	5845629	10.01	0.15	19
	NAN009	485791	5840201	6.97	0.15	30
	NAN012	488517	5845821	13.64	0.15	38
	NAN019	491839	5844196	17.66	0.15	5
	NAN020	496522	5843845	9.87	0.15	2
	NAN021	493310	5841033	5.91	0.15	34
	NAN068	493835	5840573	5.84	0.15	33

Management Zone	Observation well	Easting	Northing	SWL (m) – Sept2020	Assessed Sy	2005 – 2019 Assessed recharge (mm/year)
	NAN077	495749	5839321	5.47	0.15	50
	7022-9409	480842	5823331	5.2	0.1	64
						Ave 30 mm
ZONE 3A	PEN002	497573	5869153	6.19	0.15	47
	PEN030	494514	5866830	8.64	0.15	31
	PEN096	494795	5859614	6.77	0.15	44
	NAN063	490777	5852661	9.38	0.15	15
	NAN064	490777	5852659	9.44	0.15	13
	NAN065	491294	5852662	9.82	0.15	14
	NAN066	491294	5852660	9.03	0.15	15
	CMM092	494850	5875265	6.20	0.10	62
	CMM093	496610	5876615	N/A	0.10	17
	CMM094	493670	5873565	N/A	0.10	32
						Ave 29 mm
COMAUM	CMM020	490893	5884413	16.33	0.2	35
	CMM023	491720	5879986	6.77	0.1	10
	CMM089	492798	5876554	6.27	0.15	74
	CMM090	492796	5876554	6.34	0.15	71
	CMM091	492794	5876554	6.41	.015	64
						Ave 51 mm
COLES	CLS004	449905	5877390	4.84	0.15	89
	CLS047	461858	5876797	3.87	0.15	91
	CLS049	458295	5882980	3.22	0.15	210
	CLS050	457361	5874076	3.82	0.15	109
	CLS051	462966	5881878	2.59	0.15	161
	CLS052	462359	5872725	4.01	0.15	136
						Ave 98 mm
SPENCE	SPE010	458977	5887605	6.97	0.15	43
						Ave 43 mm
FOX	FOX071	443031	5873747	0.92	0.15	152
SMITH	SMT012	429587	5874578	4.28	0.15	110
MOUNT MUIRHEAD	MTM075	445693	5848193	18.00	0.10	68
						Ave 68 mm
SHORT	SHT012	462407	5858855	Drain effect	0.15	151
	SHT014	456247	5864063	4.66	0.15	58
	SHT015	451881	5857961	2.63	0.15	107
	SHT031	458017	5865207	5.46	0.15	48
	SHT032	462065	5857310	4.39	0.15	166
	SHT033	452773	5865467	3.87	0.15	78
						Ave 101 mm
MONBULLA	MON016	465516	5869232	3.53	0.20	83
	MON017	472769	5869322	4.20	0.20	113
						Ave 98 mm
MOUNT BENSON	MTB014	393449	5903846	N/A	0.10	9
						Ave 9 mm
JOANNA	JOA027	486429	5886751	3.08	0.15	82
						Ave 82
NATIVE VEGETATION	NAN001	485049	5848495	13.45	0.10	12
	NAN067	487280	5840455	5.93	0.10	13
	PEN067	489106	5854067	7.37	0.15	43
						Ave 23 mm

4 Conclusions

It is concluded from this work that:

- Groundwater recharge occurred under forested areas after a significant 2007 storm event.
- Data logger water level records indicated the time groundwater recharge started and the extinction point at a number of locations in the Lower South East of South Australia.
- Manual water level records recorded since 2005 indicate groundwater recharge to be occurring under most forested areas year on year.
- These figures can vary but are relatively small when compared to recharge under open pasture and reflect a relationship between depth to water table and groundwater recharge.
- The value of the groundwater recharge is dependent on the well location as influences such as roadsides, firebreaks and reductions in plantation density all affect the extent of recharge
- Groundwater recharge can vary by up to 20% if the well is equipped with a data logger. For example, groundwater observation well JOA027 has been assessed in this report using both manual and logger data records. Manual water levels indicate a recharge value of 82 mm, but water levels from the data logger indicate a recharge of 95 mm. The data logger also suggests the specific yield (Sy) was higher although for the purposes of this report, the specific yield determined using manual records was used.
- Wells located in native vegetation indicate similar recharge values to commercial forest observation wells.

5 Recommendations

- This report has demonstrated that there is ongoing recharge evident on an event basis, and on an annual basis, for groundwater observation wells located near plantation forests. It is recommended that the existing assumption of the LLCWAP that there is zero recharge beneath closed canopy plantation forest be re-evaluated.
- Not all existing observation wells in forested areas are currently read. The Department for Environment and Water or forest industry representatives should consider reading wells more frequently to further explore the potential for recharge to occur annually beneath plantation forests.
- This work has demonstrated benefit from the availability of data logger records. It is recommended that additional wells affected by forestry are fitted with data loggers, and that further interpretation of data logger records occur to better understand groundwater recharge in all areas including areas influenced by plantation forest.
- The estimation of groundwater extraction and by association, water licence requirements, under forested areas is related to the depth to groundwater. Given data suggesting that larger depths to groundwater result in lower recharge, and shallow groundwater results in higher recharge, blanket assumptions regarding land use across the region may not be appropriate.

6 References

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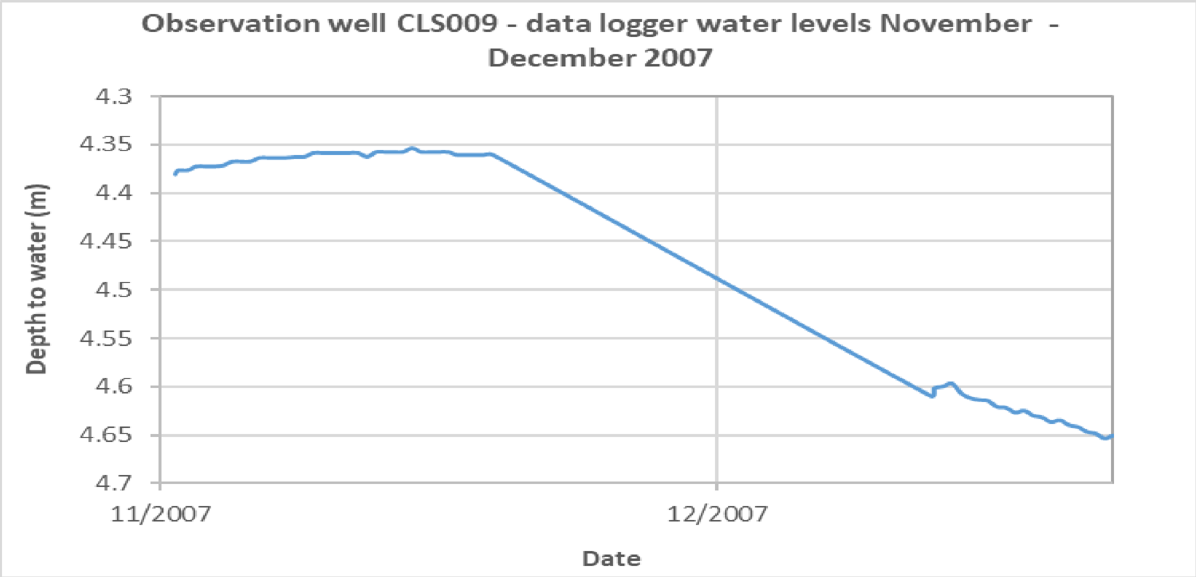
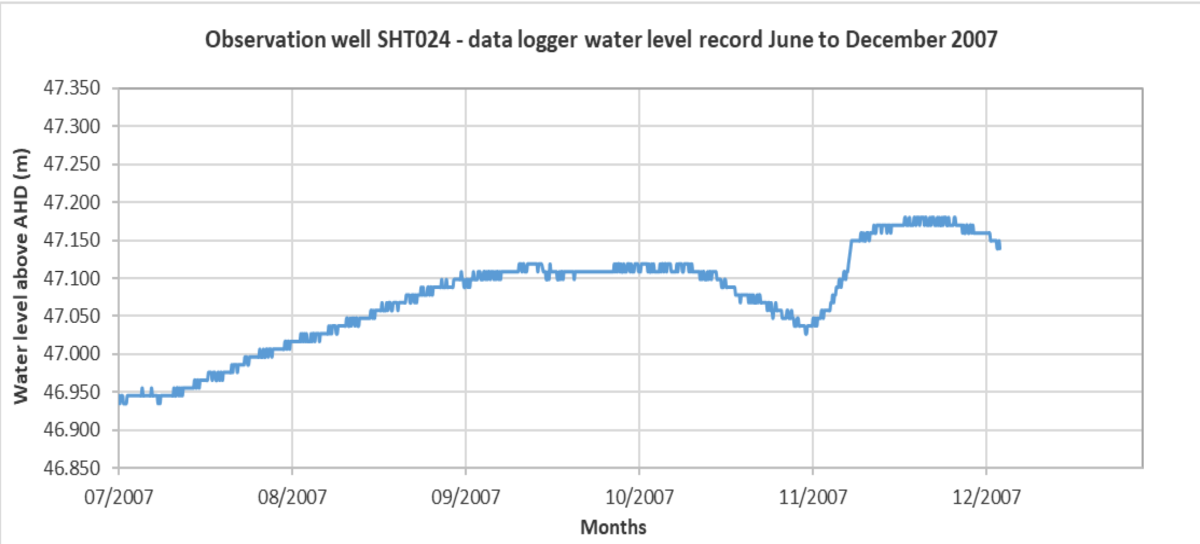
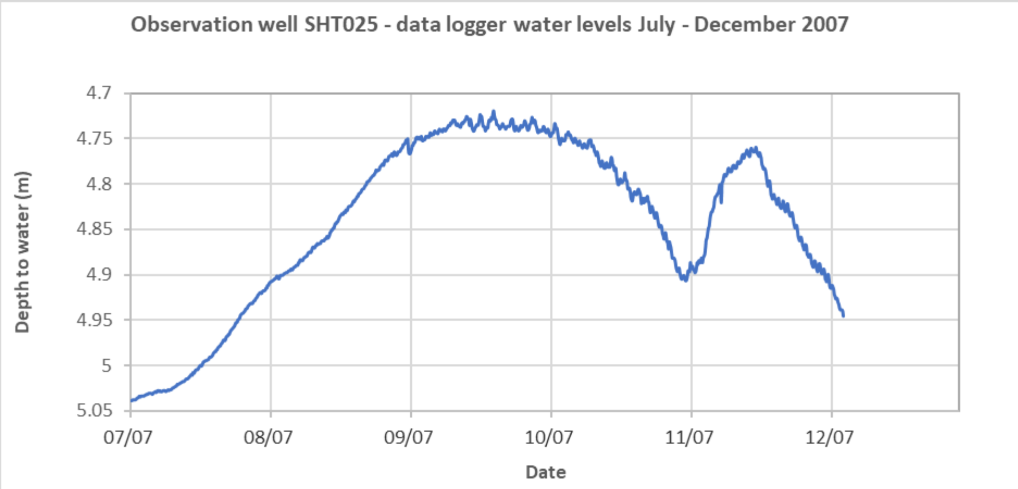
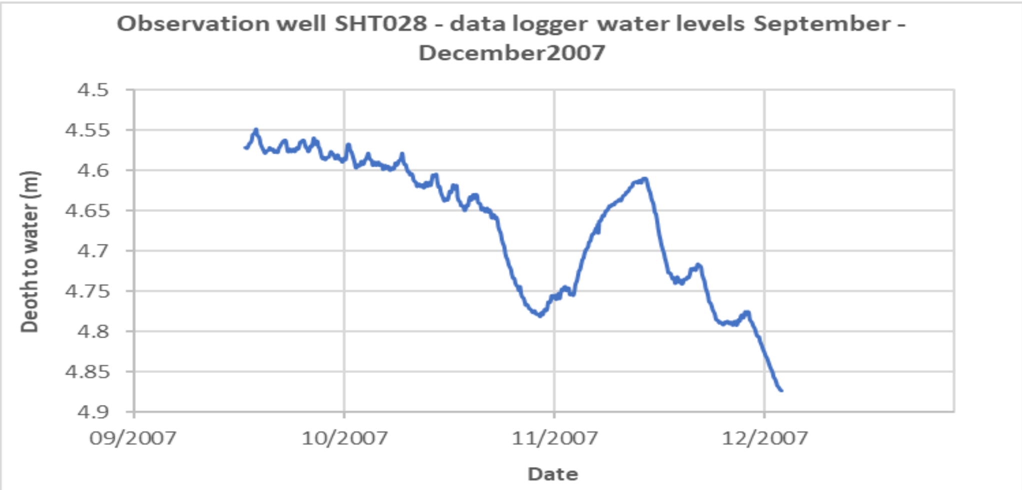
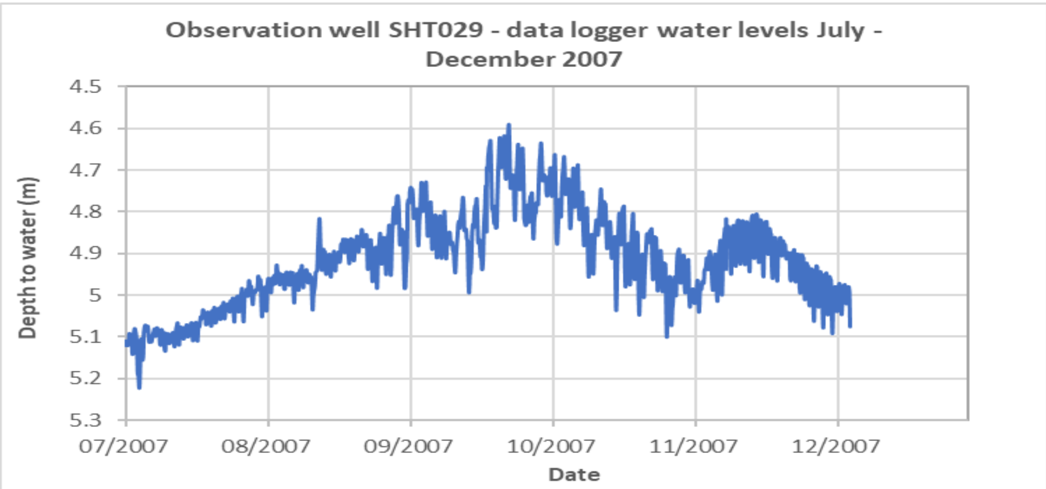
Appendix 1 – Additional data logger plots






Observation well SHT025 - data logger water levels July - December 2007
Depth to water (m)
4.7
4.75
4.8
4.85
4.9
4.95
5
5.05
07/07
08/07
09/07
10/07
11/07
12/07
Date


Observation well SHT028 - data logger water levels September - December2007
Deoth to water (m)
4.5
4.55
4.6
4.65
4.7
4.75
4.8
4.85
4.9
09/2007
10/2007
11/2007
12/2007
Date


Observation well SHT029 - data logger water levels July - December 2007
Depth to water (m)
4.5
4.6
4.7
4.8
4.9
5
5.1
5.2
5.3
07/2007
08/2007
09/2007
10/2007
11/2007
12/2007
Date