Appendix D

Hydrogeology Specialist Reports

Strata Control Technology

REPORT TO:

WOLLONGONG COAL

Assessment of Groundwater Data for Russell Vale Colliery and Implications for Further Mining in the Wonga East Area

WCRV4209

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Report To	Dave Clarkson Group Environment & Approvals Manager Wollongong Coal PO Box 924 Dapto NSW 2530
Subject	Assessment of Groundwater Data for Russell Vale Colliery and Implications for Further Mining in the Wonga East Area
Report No	WCRV4209
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SUMMARY

Wollongong Coal (WC) is proposing to mine additional longwall panels in an area referred to as the Wonga East mining area of Russell Vale Colliery approximately 9km north-north-west of Wollongong in New South Wales. After consideration of submissions from the community and government agencies to its earlier Underground Expansion Project Part 3A (Pt3A) application, WC (then Gujarat NRE) significantly modified the application in a proposal referred to as the Preferred Project Report (PPR). WC commissioned SCT Operations Pty Ltd (SCT) to review and interpret available groundwater data and to compile a conceptual understanding of the interaction between groundwater, subsidence, and mine water balance as input for the more extensive numerical groundwater model being prepared for the project, and to provide an assessment of the implications of this data for future mining in the Wonga East area. This report presents and analyses the available data from previous mining at the site for inflow rate, vertical and lateral extent of perceptible groundwater impacts, and hydraulic conductivity.

A conceptual/analytical model of the groundwater system in the Wonga East area has been developed based on analysis of the currently available data and its various characteristics. While this model is considered convincing and consistent with the data currently available for the Wonga East area, further calibration and ongoing improved monitoring of underground pumping systems and further monitoring of groundwater pressures using additional vibrating wire piezometers is recommended to allow continuous refinement and improvement of this conceptual model as a basis for understanding and to underpin the more extensive numerical modelling. It should be recognised that the outcomes of the conceptual model presented in this report may differ somewhat from the results of larger scale numerical modelling because of the conceptual model's greater flexibility to address the specific local site conditions in the relatively small area of Wonga East.

A review of the available monitoring data indicates approximately 1.1Ml/day is seeping into the Wonga East underground mine from the surrounding strata once the balance of water being pumped into the mine and leaving the mine in the coal product has been taken into account.

A section of the ridge south of Cataract Creek where the ground is stretched by subsidence movements and there are large tension cracks evident on the surface appears likely to be a significant source for this inflow. The hydraulic conductivity of the overburden strata appears to be significantly enhanced to a depth of at least 140m below surface and there is a downward gradient evident in the piezometer results indicating the potential for elevated downward flow in this area. Mining activity including longwall mining in the Balgownie Seam and more recently Longwalls 4 and 5 in the Wongawilli Seam is likely to have contributed to the increased vertical hydraulic conductivity along the ridge and the volume of the fracture network is estimated to be sufficient to produce the inflows observed underground.

Although surface cracking along the ridge line to the south of Cataract Creek appears likely to be a major source of seepage into the mine, the groundwater levels are still indicating that the headwaters in Cataract Creek are controlling the groundwater level and by implication receiving most of this rainfall recharge flow as a result. This balance between some inflow into the mine, generally at low levels, and lateral flow including along horizontal shear planes to/from adjacent creeks appears to occur all across the site. The inflows into the mine are indicated as being at low levels to achieve the overall water balance observed.

All the piezometers show a downward hydraulic gradient towards the mining horizons, past and present, consistent with downward flow of low magnitude. This downward hydraulic gradient existed prior to recent mining in the Wongawilli Seam and while there has been some increase in the vertical gradient evident during mining in the Wonga East area the additional increases have been relatively small.

The magnitude of downward flow appears to be largely restricted by the naturally low vertical hydraulic conductivity of the deeper overburden strata, particularly around the level the Stanwell Park Claystone, and the relatively large depth of mining. A zone of depressurisation is evident in piezometer GW-1 and the height of this zone is consistent with the method formulated by Tammetta (2012) for the mining geometry of the most recently mined panel and the combined thickness of all the seams that have been mined.

The piezometer monitoring results are consistent with the presence of horizontal shear planes that are inferred to exist from creek closure measurements and have been confirmed to exist at other sites. These shear horizons appear to have a greater hydraulic conductivity than the surrounding strata and are most likely to be present at a level just below the base of the valleys. They occur as part of natural erosion processes but are also activated by mining subsidence.

A shear plane is considered likely to be the pathway by which NRE D, some 540m from Cataract Reservoir, responds to changes in reservoir pressure. A shear plane is also the likely pathway for the upper perched water table in GW-1 to be maintained at close to the level of Cataract Creek some 175m away and for the pressure in NRE B to be drawn to zero at the level of Cataract Creek. These higher conductivity shear planes appear likely to be capable of distributing low level flows over distances of several hundred metres and into the general groundwater system while also collecting rainfall recharge and distributing it back to the creeks and reservoir.

The flow measurements underground indicates that there has been a background inflow into the Bulli and Balgownie Seam up dip of the Wongawilli Seam mining that has a magnitude of about 0.2-0.3Ml/day and this flow has responded to long term trends in rainfall deficit suggesting a degree of hydraulic connectivity with either the surface or the Illawarra Escarpment.

There may also be some minor inflow from Cataract Creek, although the characteristics of the mine inflows recorded during mining of Longwall 5 did not indicate any perceptible increase in inflow as mining approached Cataract Creek. If a significant source of inflow was from the creek, an increase in flow rate would be expected as the flow path length between the creek and the mine reduced. The resolution of the underground monitoring is of the order of 0.1Ml/day indicating any potential increase in flow from Cataract Creek into the mine during mining of Longwall 5 was less than about 0.1Ml/day.

There were no visual indications of flow loss from Cataract Creek and no losses were recorded, but it should be recognised that flow meter systems able to be installed in creek channels without major construction works only have a resolution of the order of ±0.5Ml/day and therefore may not be able to detect changes with a magnitude of 0.1Ml/day or any transient flows that may have been necessary to recharge groundwater within the overburden strata.

Where there is mining in all three seams, there is considered to be high potential for interaction with the surface and the top of the groundwater table recharged from long term rainfall trends and adjacent creeks if there is interaction between the basal shear plane activated by subsidence and the top of the zone of depressurisation above each longwall panel. The height of this zone of depressurisation can be estimated using the empirical approach formulated by Tammetta (2012) for single seam mining operations, but the approach needs to be confirmed as suitable in a multi-seam environment. The following estimates for height of depressurisation above the mining horizon are considered reasonable as a preliminary estimate:

- Bulli Seam - 60m with over 90 years to come into equilibrium

- Balgownie LWs only
  - 43m for 140m panels (T=1.4m, W=140m and D=300m)
  - 60m for 190m panels (T=1.4m, W=190m, and D=300m)

- Balgownie LWs plus Bulli Seam
  - 100m for 140m panels (T=2.6m, W=140m, D=300m)
  - 136m for 190m panels (T=2.6m, W=190m, D=300m)

- Wongawilli LWs only
  - 146m for 145m panels (T=3.2m W=150m, D=330m)

- Wongawilli plus Bulli Seam
  - 222m (T=4.4m, W=150m, D=330m)

- Wongawilli plus Balgownie Seam
  - 235m (T=4.6m, W=150m, D=330m)

- Wongawilli plus Bulli Seam plus Balgownie Seam
  - 316m (T=5.8m, W=150m, D=330m)

There is considered to be some potential for interaction between the zone of depressurisation and the basal shear planes in the shallower areas at the northern ends of Longwall 2 and 3 and at the northern end of Longwall 7.

At the northern end of Longwall 7, the area where three seams have been mined is limited in extent and the height of depressurisation may be less as a result but further monitoring is required to establish the height of depressurisation when all three seams have been mined. Further work is underway to determine the height of depressurisation above the southern end of Longwall 4 where all three seams have been mined because the multi-seam estimates of height of depressurisation are limited to the one measurement in GW-1 at this stage.

The conceptual model developed and presented in this report is not considered suitable to provide a quantitative basis to calculate inflows from further mining activity in the Wonga East mining area. However, some indications of potential for inflow can be provided based on the data available. Areas where there is considered to be increased potential for inflow into the mine can be highlighted and the flows estimated based on previous experience of mining Longwalls 4 and 5.

The total water make from the Wongawilli Seam workings is currently about 1.1Ml/day. Based on considerations of how this flow has developed over time and where it has reported to in the mine, the current water make is estimated to comprise:

- 0.3Ml/day from mining development headings in the Wongawilli Seam.
- 0.2Ml/day for up dip inflow in the Bulli and Balgownie Seams.
- 0.1Ml/day additional inflow from mining Longwall 4.
- 0.5Ml/day from mining Longwall 5.

Based on the conceptual model the following estimates of additional inflow are indicated.

The northern ends of Longwalls 1-3 are located at shallower depths in areas where there has been previous mining in the Balgownie Seam. The potential for interaction with the near surface groundwater systems directly and through the zone of horizontal stretching along the ridge at the southern ends of these panels is expected to cause inflows of the same magnitude or possibly higher than the inflows observed in Longwalls 4 and 5. None of this area is below the fourth order section of Cataract Creek or close to the FSL of Cataract Reservoir.

Longwalls 6 and 7 are expected to contribute similar inflow increases to Longwall 5 (i.e. 0.5Ml/day) with this additional flow coming mainly from the higher conductivity recharge zones along the ridgeline between Cataract Creek and Cataract River. Some additional flow may also come from

Cataract Creek and Cataract Reservoir via the horizontal shear planes that are likely to be mobilised by mining Longwalls 6 and 7.

In the vicinity of Longwalls 6 and 7, the naturally low vertical hydraulic conductivity of the overburden strata and depth of mining is expected to restrict inflows from basal shear planes at the base of Cataract Creek into the mine to low levels provided the zone of depressurisation does not reach high enough to interact with the basal shear planes. Interaction with the zone of depressurisation may be possible at the northern end of Longwall 7 in an area where all three seams have been mined in close lateral proximity but not directly above each other. Further measurements planned above the southern end of Longwall 4 are expected to provide confirmation of the significance of this potential.

Longwalls 9-11 are located away from areas of previous mining in the Balgownie Seam and the potential for interaction with the near surface groundwater system is considered low because of the lower heights of depressurisation expected. Based on experience from other longwalls at similar depths, inflow rates are expected to be less than about 0.2-0.3Ml/day per panel during active mining and to reduce over time to low levels.

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1. INTRODUCTION

Wollongong Coal (WC) is proposing to mine additional longwall panels in an area referred to as the Wonga East mining area of Russell Vale Colliery approximately 9km north-north-west of Wollongong in New South Wales. After consideration of submissions from the community and government agencies to its earlier Underground Expansion Project Part 3A (Pt3A) application, WC (then Gujarat NRE) significantly modified the application in a proposal referred to as the Preferred Project Report (PPR). WC commissioned SCT Operations Pty Ltd (SCT) to review and present the available groundwater data as input for the more extensive numerical groundwater model being prepared for the project by others, and to provide an assessment of the implications of this data for future mining in the Wonga East area. This report reviews and presents the available data from previous mining at the site for inflow rate, vertical and lateral extent of perceptible groundwater impacts, and hydraulic conductivity.

The report reviews and presents the results of:

- Mine water balance specifically for the Wongawilli Seam but also for the Bulli and Balgownie Seam operations where information is relevant to the PPR.

- Piezometric pressure monitoring within the overburden strata around the site but particularly in the Wonga East mining area.

- Hydraulic conductivity measurements representative of the overburden strata including data available from other sites.

The review aims to present the factual data, clarify assumptions, and estimate the effect of unknowns based on the data that is available to help develop a conceptual model suitable to use as a basis for the more extensive numerical groundwater model based on this data.

Section 2 presents the water balance information including detail of the pumping arrangements and interactions with water flowing and stored in the Bulli and Balgownie Seams and the adjacent collieries.

Section 3 reviews the available piezometric data and assesses the implications of this data in the context of the lateral and vertical extent of mining impacts.

Section 4 reviews the hydraulic conductivity measurements available for packer testing in GW-01.

Section 5 considers the implications of the available data for proposed mining in the Wonga East area and the opportunities that are available to better understand the various groundwater interactions.

2. MINE WATER BALANCE

The mine water balance is a measure of the water make from the surrounding strata that cannot otherwise be accounted for. The water balance for mining in the Wonga East area at Russell Vale Colliery is complex because of the long history of mining in the area and the interaction with two overlying seams and adjacent collieries. The water balance for the Wongawilli Seam mining is also somewhat compromised by the incomplete nature of the pumping records for the period to the end of Longwall 4 and the later stages of mining Longwall 5. However despite these complexities and limitations, the water balance is considered to be relatively well understood and the magnitude of maximum incremental increases in water inflow to the mine has been established with some confidence based on the data that is available.

2.1 Overview of Seam Geometry and Mining History

Figure 1 shows a plan of the mining layout at Russell Vale Colliery. Three coal seams have been mined at the colliery. The uppermost of these is the 2-2.5m thick Bulli Seam where most of the previous mining activity has been concentrated. The 1.3m thick Balgownie Seam is located some 5-10m below the Bulli Seam. The 7-9m thick Wongawilli Seam is located a further 20m below the Balgownie Seam, but only the bottom 3-3.5m of this seam is mined.

In the Wonga East mining area, the Bulli Seam was mined between the late 19th Century and about 1950 initially as a hand worked bord and pillar operation and then with some mechanized pillar extraction. Bulli Seam mining continued further west initially as a continuation of Continuous Miner pillar extraction operations and then as a longwall mining operation that continued through under various owners until 2002.

The Balgownie Seam was also started in the late 19th Century in the Wonga East area using hand worked methods for a brief period. Mining in the Balgownie Seam restarted again in the late 1960's with continuous miners and continued through from 1970 until 1982 as one of the first longwall operations in Australia. To the north, some additional mining in the Balgownie Seam included a cut and flit first workings continuous miner bord and pillar operation between 2001 and 2003 (Gibson's Colliery - Thin Seam Mining).

The Wongawilli Seam has been mined since 2008 (start of access to Wongawilli Seam) including two longwall panels to date. Longwalls 4 and 5weremined between April 2012 and September 2012 and January 2013 and January 2014 respectively.

All three seams dip to the west towards a low point in the 200 series longwall panels near No 4 Shaft. Figure 2 shows the floor contours of the Bulli Seam. The natural pathway for water flow underground is from the outcrop on the Illawarra Escarpment down to the low point in the 200 series longwall panels. However, because of the irregular nature of the lease

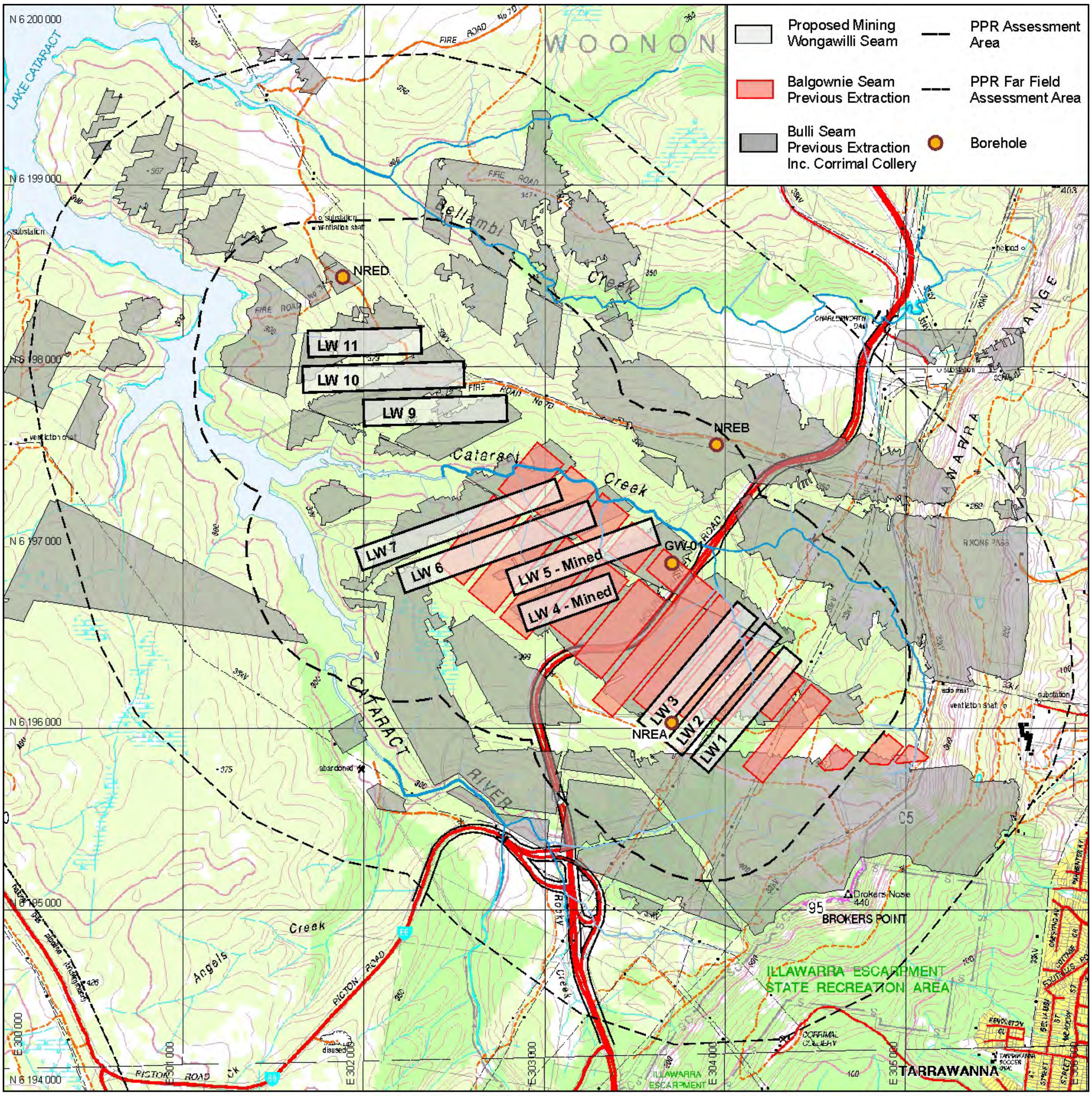


Figure 1: Plan of PPR mining area and previous mining activity.

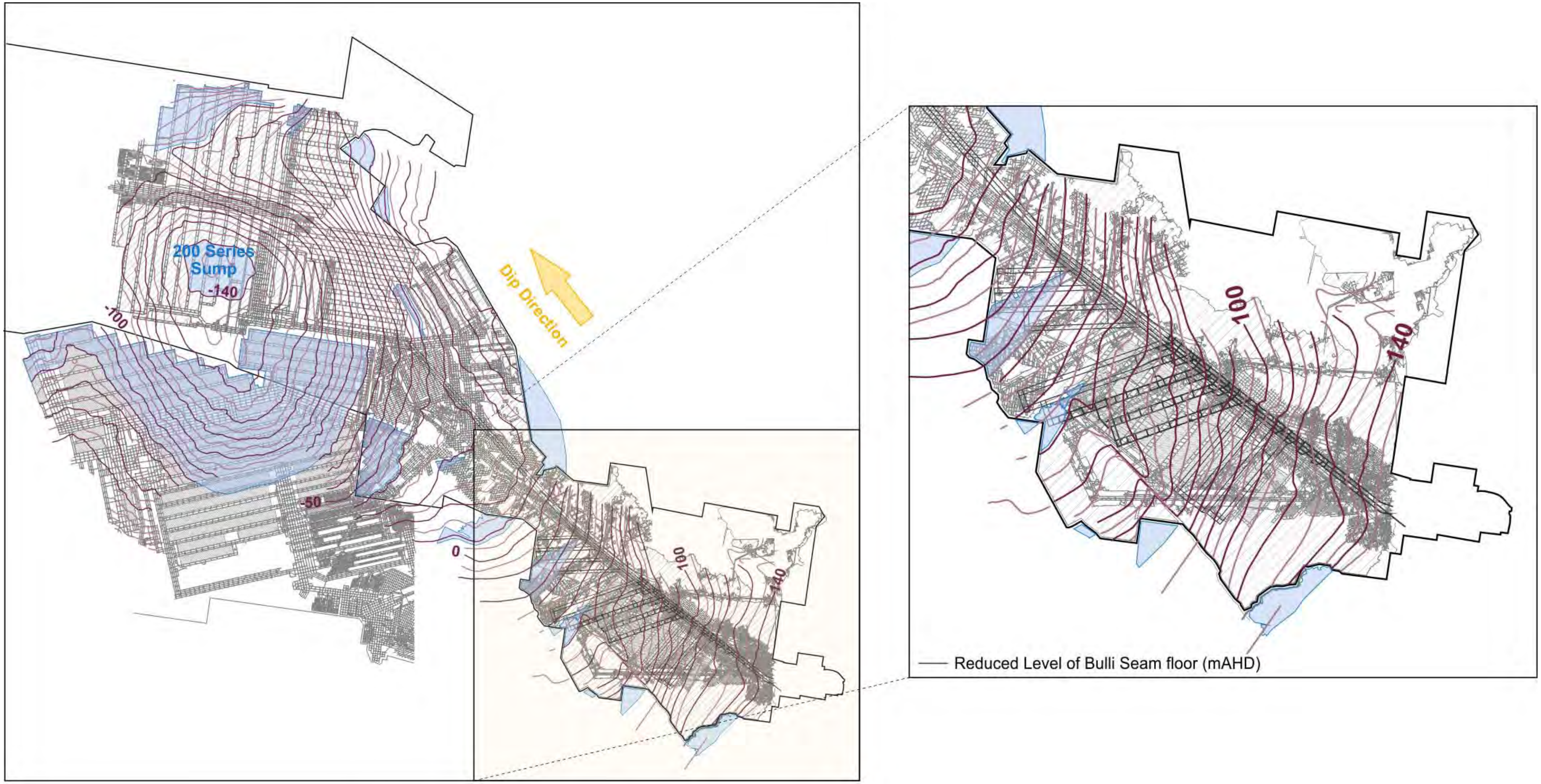


Figure 2: Plan showing floor contours of the Bulli Seam and locations of potential lodgements for water flowing down dip.

boundaries and the various panels within the mine, there are numerous underground storages created where water is impounded behind coal barriers within the mine and between mines. Water flowing from up dip flows into these underground storages until they become full and overtop allowing flow to continue down into the lowest point in the mine. Over time, all the storage areas have filled up and so any additional flow occurs through a chain-of-ponds along each of the barriers. A similar process is occurring in the adjacent Old Bulli and Corrimal Collieries.

2.2 Pumping from the Balgownie Seam at 48 Cut-Through

A borehole located at 48 Cut-through in the Bulli Seam is used to pump water from the Balgownie Seam and any water that may have drained down into the Balgownie Seam from up dip in the Bulli Seam.

During mining in the Balgownie Seam, the mine plan shows that headings that were planned to be mined below underground storages in the overlying Bulli Seam had to be stopped until the overlying storages were drained so as to eliminate any potential for an inrush of water from the Bulli Seam into the underlying Balgownie Seam workings only 5-10m below.

At the completion of mining in the Balgownie Seam and with direct hydraulic connection between the two seams through the Balgownie Seam goaf in each of the eleven longwall panels, some of the water that previously flowed down dip in the Bulli Seam was redirected into the lower seam and continued to flow down the dip in the Balgownie Seam. The lowest point in the Balgownie Seam is at the bottom of No 1 Shaft where water impounded in the Balgownie Seam, and any additional water captured in the Bulli Seam, is pumped from a borehole at 48 Cut-through to a holding tank at 47 Cut-through and then to a holding tank at 27 Cut-through. The flow in this line is metered.

When headings were developed in the Wongawilli Seam, there was a similar requirement for water stored in the overlying seams to be pumped out before mining could continue. This draining of water from the overlying seams had the effect of diverting flow from the Balgownie Seam pump out at 48 Cut-through into the Wongawilli Seam pump out. Once Longwalls 4 and 5 were mined, this diversion became permanent.

Figure 3 shows a history of the flow from the 48 Cut-through borehole into the Balgownie Seam and the rainfall deficit relative to a long term average for the same period. The pump out rate for most of 2011 increased gradually from 0.15Ml/day to a peak in late September 2011 of 0.25Ml/day. The reasons for this gradual increase in rate prior to September 2011 are not entirely certain, but it appears likely to be associated with an increase in long term rainfall recharge during this period. The possibility of rainfall recharge is considered reasonable based on experience at other sites given the 1-2m of subsidence associated with previous mining in the Bulli Seam and Balgownie Seam between the escarpment and Wonga East at overburden depths ranging between 200m and 300m.

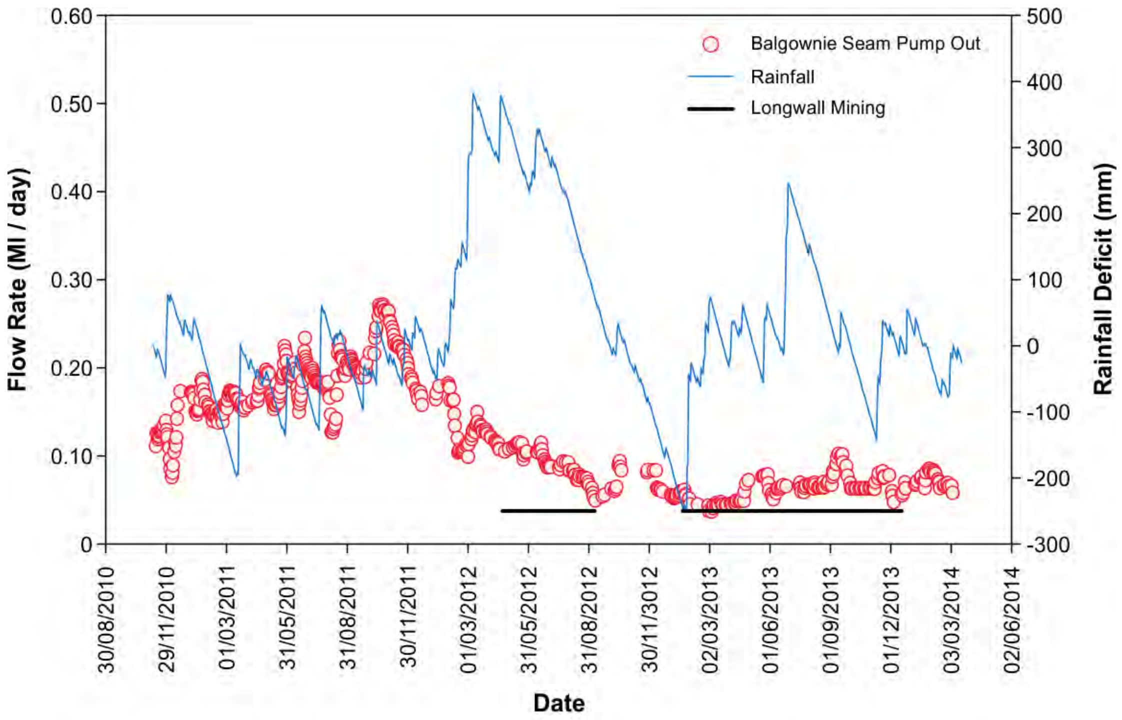


Figure 3: History of pump out from the Balgownie Seam at 48 Cut-through together with long term rainfall deficit.

A sharp drop in pump out rate occurred in October 2011 when drainage of Balgownie Seam storages (lodgements) into the Wongawilli Seam started to divert flow in the Balgownie / Bulli Seams into the Wongawilli Seam system and away from the 48 Cut-through borehole. Since then 48 Cut-through has stopped providing any useful indication of inflow from the Bulli and Balgownie Seams. While it was indicating an inflow into the Balgownie / Bulli goafs, the rate was about 0.2Ml/day on average when the rainfall is trending at average rates. Pumping from the Wongawilli Seam is now providing an indication of inflow from the Balgownie and Bulli Seams but combined with inflows from other sources.

Once Longwall 4 finished, the rate of pump out at 48 Cut-through stabilised at about 0.05Ml/day. Mining of Longwall 5 has had no further effect on the rate.

These results are interpreted as indicating that 0.20Ml/day flows over the floor of the Bulli Seam and into the Balgownie Seam and now into the Wongawilli Seam. A further 0.05Ml/day still flows to the low point of the Balgownie Seam, most likely from the northern side of Balgownie Seam workings that are not intercepted by the two longwall panels mined so far in the Wongawilli Seam.

2.2 Pumping from the Bulli Seam at R Mains 29 Cut-Through (Wonga West Area)

A holding tank located at 27 Cut-through in the Bulli Seam captures water pumped from the Balgownie Seam at 48 Cut-through and water pumped from the Bulli Seam sump that has formed at the low point in the 200 series longwall panels shown in Figure 2. Water from both sources is then pumped out of the mine through the Russell Vale portal and metered at the portal.

The long term average for pump out from 27 Cut-through since mining in the Bulli Seam finished is about 0.8Ml/day. However, a pump out test conducted at the R Mains 29 Cut-Through holding tank on 19 March 2014 indicated an average pump out rate of only 0.23Ml/day. This discrepancy is significant and further work is recommended to better understand the basis for the difference.

Discussion with mine personnel indicated that water was being pumped into the holding tank from X Mains (approximately 70% of the total) and 9 Cut-through S Mains (approximately 30% of the total). The X Mains low point is adjacent to the boundary with Cordeaux Colliery but also captures all the flow from up-dip. The S Mains 9 Cut-through site pumps from the 200 series longwall panel sump and this captures water from the 200, 300 and 500 series longwall panels. Further work is recommended to differentiate the flow that may be coming from the Cordeaux Colliery from that coming from up dip in the Bulli Seam.

2.3 Pumping from the Wongawilli Seam

Pumping from the Wongawilli Seam occurs in several stages. The main sump is a tank at 18 ½ Cut-through in the main headings. Water that emerges from the bottom of Longwalls 4 and 5 (south-western ends) flows along the floor and collects in a sump in the bleeder headings where it is pumped out to the main sump at 18 ½ Cut-through. Water from the Maingate 6 development headings is pumped into a holding tank in the panel and from there to the main sump at 18 ½ Cut-through. Water from the main sump is pumped up to a holding tank at 12 Cut-through and from there out of the mine to the Wongawilli Seam portal using one of two centrifugal pumps located at 12 Cut-through. There are various operations that recycle water underground for cleaning tanks, but these do not involve the main pumps at 12 Cut-through. The flow delivered by the 12 Cut-through pumps represents the pump out from the Wongawilli Seam. This flow was determined from pump hours assuming a flow of 50l/s until recently when a flow meter was installed at the surface.

To determine the reliability of the pump out rate requires an understanding of the detail of the pumping arrangements at 12 Cut-through. There are two Hydro-Titan centrifugal pumps of similar capacity installed at 12 Cut-through. Each pump has a non-return valve and they can both work in parallel if necessary. However, so far only one pump has been required to operate at any one time and even this pump is only required to operate about 5 hours a day to clear the water from the mine, typically in short bursts of about 80 seconds at a time when about 5m^3 is pumped into a 2km long, 150mm diameter pipe range leading out of the mine. The volume of this main range is about 35m^3 so a significant part of the pump cycle involves accelerating the fluid in the pipe range.

The first pump, Pump 101 (also referred to as Pump 2) was installed on 13 June 2012 soon after Longwall 4 started. The hour meter read zero hours at this time. Although the hours of operation of this pump were recorded from time to time, the early records are considered by the mine to be unreliable. A second pump, Pump 100 (also referred to as Pump 1) was installed in March 2013 soon after Longwall 5 commenced mining. This second pump has been used as the primary duty pump since then. Reliable pump hour readings are available from 31 October 2012 when Longwall 4 was complete until October 2013 and from February 2014.

The known zero hour reading at installation and the relatively steady nature of the pump out records since the completion of Longwall 4 allows the average hours of operations of the pumps during Longwall 4 to be estimated with reasonable confidence. A conservative approach has been adopted.

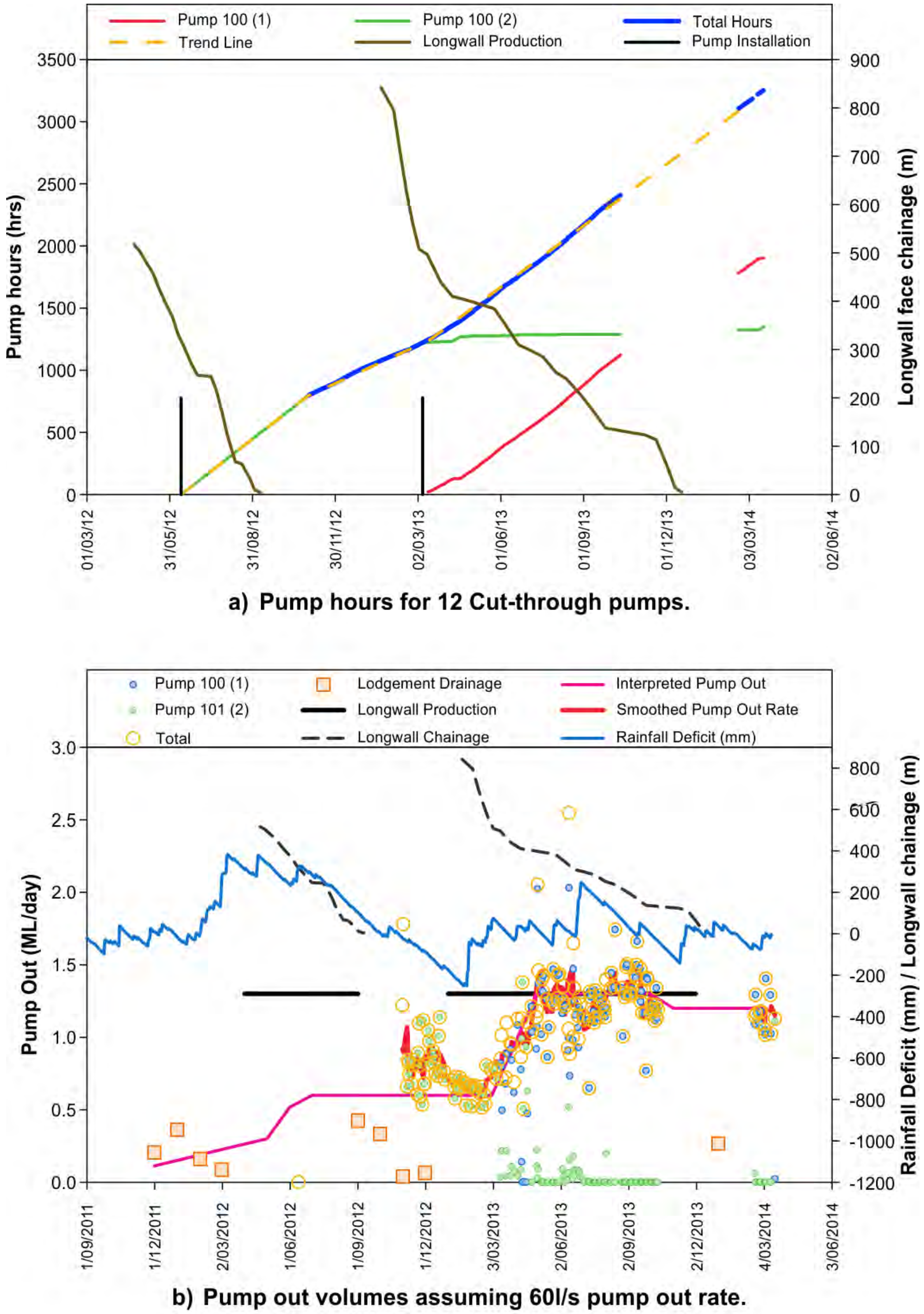
Figure 4 shows a summary of the pump out rates measured and estimated since the first pump was installed in June 2012. Both pumps appear to pump at essentially the same rate based on recent testing. Although there is an apparent change in the hours pumped when Pump 100 was installed, this seems likely to be associated with a period of reduced pumping requirements between longwall panels and the end of drier period when inflows to the mine were reduced or possibly a change in the float arrangements at the pump station.

The hours of operation of the centrifugal pumps at 12 Cut-through have been used by the mine as the primary basis for estimating pump out from the Wongawilli. Historically, an assumption has been made that the flow can be calculated from the characteristic pumping curves for each pump, nominally at a rate of 50l/s. A recent program of testing has been conducted to confirm the reliability of this rate.

A flow meter installed at the portal indicates a flow rate of 59l/s but this installation is not ideal in terms of location and the results from the flow meter were independently confirmed using a volume / time based flow test.

Pump out volume measurements conducted on 18 March 2014 indicate that the pump out rate varies from 47l/s to 64l/s depending on the volume pumped in each cycle because of the overhead associated with initially accelerating water in the pipe range. The volume pumped each cycle is a constant and the rate of 59l/s is considered reasonable for this volume. The testing conducted on 18 March confirmed the practicality of using this measurement system but further testing is recommended to confirm this rate and the characteristics of the pump out system. An average flow of 60l/s has been adopted for both pumps as a conservative estimate.

Other sources of water flow into and out of the mine are recognised. Water is pumped into the mine at an average rate of about 0.23Ml/day for dust



a) Pump hours for 12 Cut-through pumps.

b) Pump out volumes assuming 60l/s pump out rate.

Figure 4: History of Pumping at 12 Cut-through in Wongawilli Seam.

suppression, drilling operations, and other purposes. This rate increases during longwall operations. Water also leaves the mine in the coal product. In situ moisture of coal is about 2% and the run of the mine product on the belt has a moisture content of about 6.5% so between 0.1Ml/day and 0.3Ml/day leaves the mine in the coal product when the longwall is operating and less than 0.02Ml/day leaves the mine at other times. Moisture also leaves the mine in the ventilation air, but measurements provided by the mine indicate this flow is very small.

Water is also released from time to time from storages either within the Wongawilli Seam, sumps that have been allowed to fill, or from the overlying seams, as dewatering of lodgements in the Balgownie Seam prior to mining development roadways. The rates of inflow associated with dewatering these lodgements are shown in Figure 4 but they are relatively small by comparison with other inflows.

Figure 5 shows the water balance that is considered to provide a reasonable estimate of the various inflows and outflows based on the available data. The accuracy of this water balance is considered to be about ±0.2Ml/day at any given time because of the uncertainties involved with short term variations caused by different reporting timeframes but about ±0.1Ml/day over the longer term when the short term fluctuations even out.

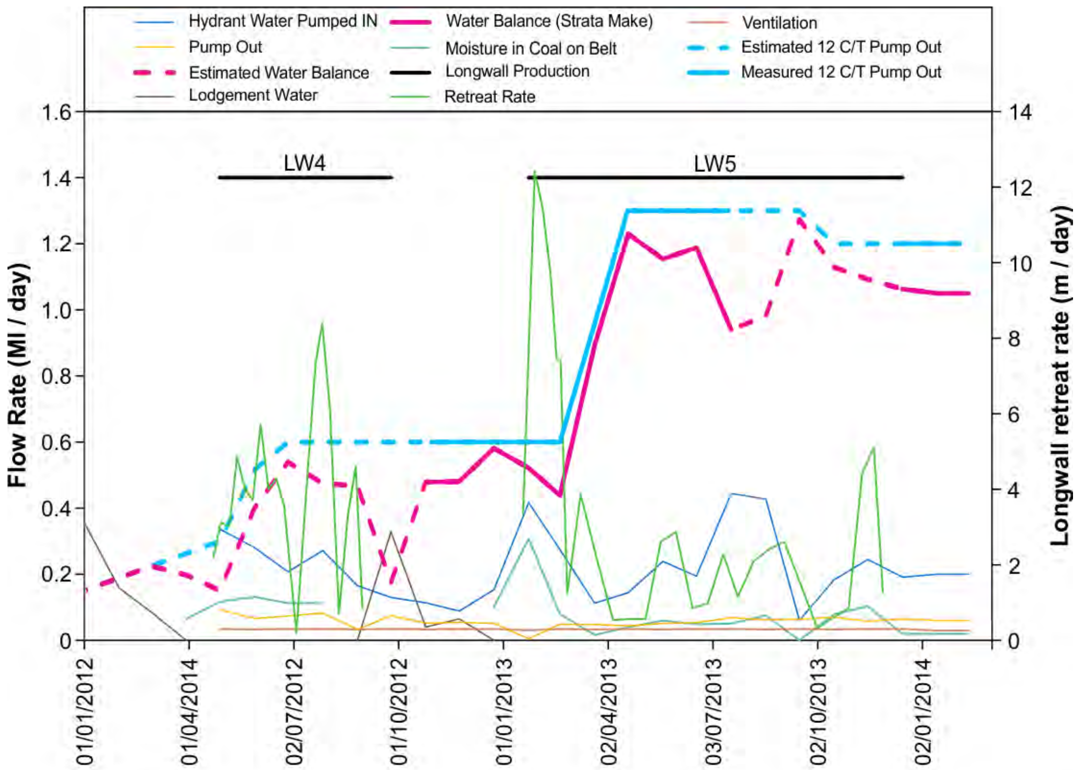


Figure 5: Mine water balance based on available and inferred pump out data.

Assigning sources to the water is recognised to be somewhat speculative. The apportionment considered to provide an overall balance is based on the following observations:

- Observations of flow from the down dip ends of Longwalls 4 and 5 observed on 18 March 2014 after a period of three months of no longwall activity estimated to be 2-3l/s and 4-5l/s respectively.

- Drawdown observed at 48 Cut-through prior to dewatering the Balgownie Seam of 0.2Ml/day.

- Changes in the water balance during mining of Longwalls 4 and 5.

- Estimated flow from Wongawilli Seam first workings.

Based on these observations and estimates, the water balance is apportioned as:

- 0.3Ml/day from Wongawilli Seam first workings.

- 0.2Ml/day from overlying Balgownie / Bulli Seam goaf (previously reporting to No 1 Shaft and now reporting to Longwall 4 goaf).

- 0.1Ml/day from Longwall 4 goaf (additional to that intercepted from Balgownie / Bulli Seam).

- 0.5Ml/day from Longwall 5 goaf (does not appear to have any intercepted Balgownie / Bulli Seam component).

There are some indications of an association between long term rainfall and the pump out records shown in Figure 4, but there is insufficient data to make a convincing association. Ongoing refinement of the underground water balance monitoring is recommended to help establish the characteristics of potential inflow sources and the potential for hydraulic connection with the groundwater recharge systems.

3. PIEZOMETER MONITORING

Vibrating wire piezometers have been installed at four locations in the Wonga East mining area. The results of these instruments are discussed in this section to provide an understanding of the groundwater system at the site. The results from these piezometer strings provide information on the height and lateral extent of perceptible changes from both short and long term rainfall trends, previous longwall mining in the Balgownie Seam, and changes in level in Cataract Reservoir. It is recognised that further piezometer monitoring is required to extend these initial findings and to confirm the hypotheses that have been drawn from these results. Additional installations are currently in progress through the approval process.

The locations of the vibrating wire piezometers in the Wonga East mining area are shown in Figure 1. The details of these piezometers are summarised in Table 1.

Table 1: Wonga East Vibrating Wire Piezometers

	Installed	Easting (m MGA)	Northing (m MGA)	Collar RL (mAHD)	Bulli Seam RL (mAHD)
NREA	18/11/09	303680	6196034	376.23	85
GW-1	23/8/12	303693	6196913	318.2	80
NREB	28/11/09	303939	6197567	372.69	90
NRED	6/11/09	301870	6198509	348.83	5

Individual piezometer results are discussed in the following sections followed by a compilation of results from all four sites.

3.1 Piezometer NRE A - East of Mount Ousley Road

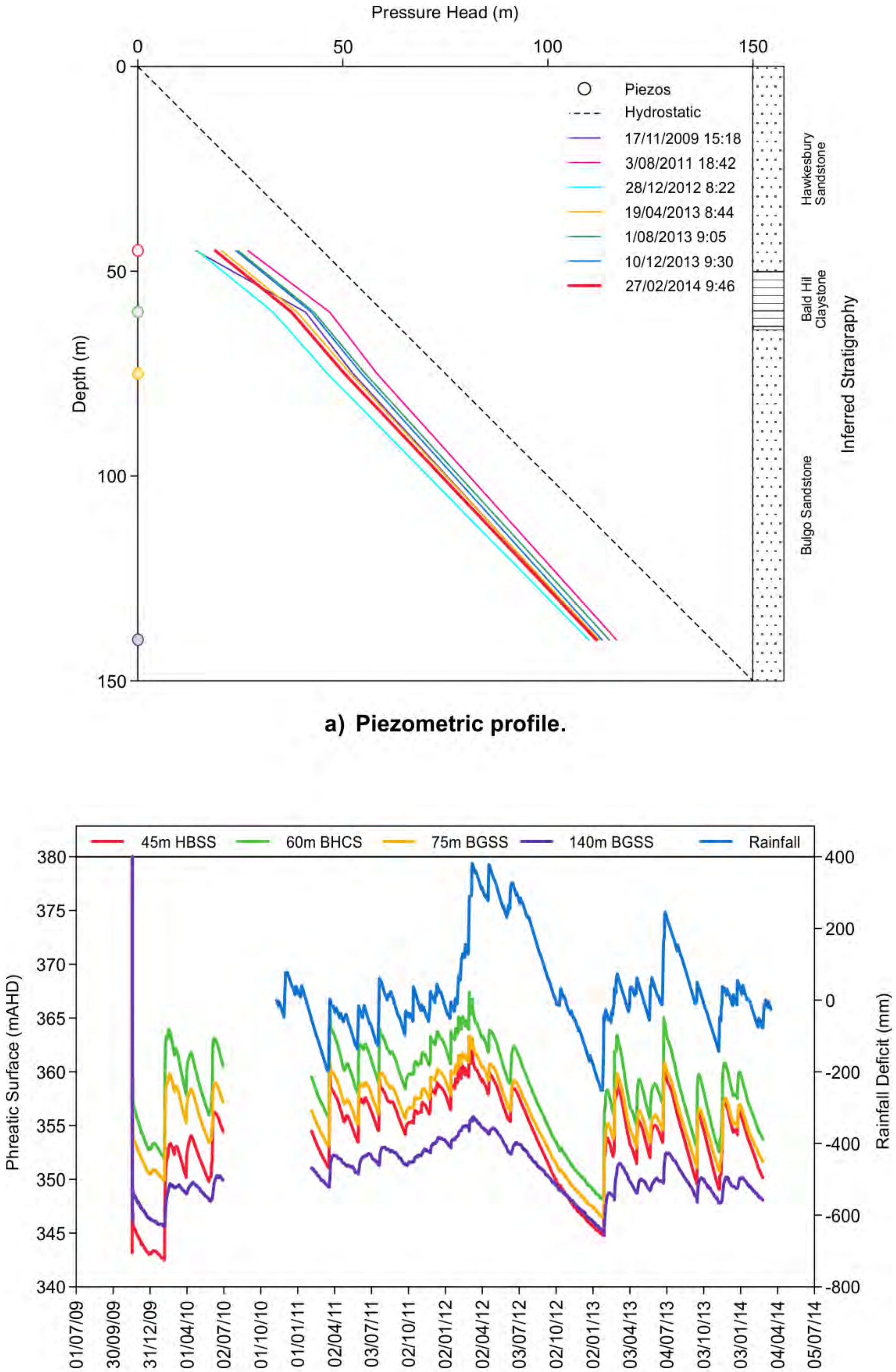
Piezometer NRE A is located on a ridge in the Hawkesbury Sandstone in an area where there are first workings in the Bulli Seam, nearby longwall mining in the Balgownie Seam and no nearby mining in the Wongawilli Seam.

Figure 6 shows the pressure profile measured on the four piezometers installed in this hole. These piezometers indicate a hydraulic gradient that is close to hydrostatic with the indicated phreatic surface varying from 15m to 30m below surface (RL360m to RL345m).

The hydrograph shows a clear and immediate response to short term rainfall trends consistent with the full column being vertically well connected through the Hawkesbury Sandstone, the Bald Hill Claystone and approximately 75m into the Bulgo Sandstone. There is some slight muting of the pressure response by a depth below surface of 140m in the Bulgo Sandstone, but the immediacy of the response in all the piezometers indicates there is nevertheless a high degree of vertical conductivity and the Bald Hill Claystone is not acting in any capacity to slow vertical flow at this location.

The individual piezometers indicate approximately the same phreatic surface level, but there is a slight trend of decreasing head with depth consistent with downward flow gradient from the surface toward the mining horizons. Given the high vertical conductivity indicated at this site by the rainfall response, the presence of a downward hydraulic gradient indicates a strong potential for this area to be a source of inflow into the mine, particularly if the height of depressurisation above the mining horizon interacts with the zone of elevated vertical connectivity from the surface.

While it is possible that the piezometer is not properly installed and the borehole is the source of the vertical conductivity, the downward trend with pressure does not support this hypothesis. A different explanation is considered much more likely. The piezometer NRE A is located on the same topographic ridge where there is clear evidence of horizontal stretching on the surface of Mount Ousley Road and open cracks in the adjacent terrain.



a) Piezometric profile.

b) Hydrograph and rainfall deficit.

Figure 6: Piezometer results for NRE A.

There were also tension cracks observed close to the site of NRE A during mining of Longwall 3 in the Balgownie Seam. The high level of vertically connected cracking and consequently a high level of vertical conductivity observed in NRE A is considered to be a result of the presence of vertical fractures and opening of existing joints caused by horizontal stretching. A second piezometer is proposed in this area in the near future and will help confirm the depth of elevated vertical conductivity.

The elevation of the phreatic surface at the NRE A site ranges from RL340m to RL360m. This elevation is at the level of the upper headwaters of Cataract Creek near the site. A phreatic surface at the levels indicated in NRE A is likely to contribute to a semi-permanent groundwater flow into the headwaters of Cataract Creek. Although there is a vertical hydraulic gradient downward toward the mine at NRE A and by implication some flow, there is also lateral flow into the headwaters of Cataract Creek at the same time and this lateral flow into the creek is still the primary control on the level of the phreatic surface.

A significant observation from NRE A is that with the high level of vertical connectivity associated with stretching movements caused by subsidence to a depth of at least 140m, the potential for downward flow into the mine is likely to be greatest directly below the stretching zone along the ridge top.

This piezometer string was installed well before the commencement of Longwall 4 and so there is a relatively long baseline of rainfall events prior to a series of high intensity rainfall events in early 2012 and the commencement of mining Longwall 4.

There is a clear reduction in piezometric pressure response post the start of mining Longwall 4 and this has continued through into Longwall 5, but close examination of the step change in the correspondence between rainfall and piezometric head change shows that the rainfall events prior to the start of Longwall 4 may have contributed to the initial lateral movement of the hillside toward the valley of Cataract Creek causing the increased correlation.

This lateral sliding mechanism occurs naturally but can also be mobilised by dilational subsidence movements generated by mining induced subsidence. This mechanism has been observed and closely monitored at Sandy Creek Waterfall (Walsh et al 2014 and Mills 2014) and observed at other sites where lateral movement on bedding plane shears in limiting equilibrium are mobilised by periods of intense rainfall. Glastonbury (2000) describes the deformation behaviour of rock slopes on pre-existing shear surfaces more generally. Young (1979) describes similar relationships between intense rainfall and slope instability on the Illawarra Escarpment. The mechanism of horizontal shear on a pre-existing natural bedding plane surface mobilised initially by mining in the Balgownie Seam and remobilised by intense rains appears likely to be operating at Wonga East as well.

The effect of the stretching movement induced by a combination of the intense rainfall, previous mining activity and recent mining activity has been to reduce the head of the background phreatic surface by about 5-10m post March 2012. Rainfall events appear capable of recharging the phreatic surface to pre-2012 levels, but the level drops back more quickly to the lower background levels. The volumes stored in open fractures in the recharge zone appear sufficient to account for the additional inflow volumes into the mine. Several large cracks observed during routine subsidence monitoring on the ridge above Longwalls 4 and 5 soon after the start of mining Longwall 5 have an estimated volume sufficient to account for the increased inflows observed underground soon after the start of Longwall 5.

3.2 Piezometer NRE B – West of Mount Ousley Road on Fire Road 7D

Figure 7 shows the results of piezometer monitoring at NRE B. Piezometer NRE B is located on a ridge to the north of Cataract Creek in an area where there has been secondary workings in the Bulli Seam but no mining in the Balgownie or Wongawilli Seams.

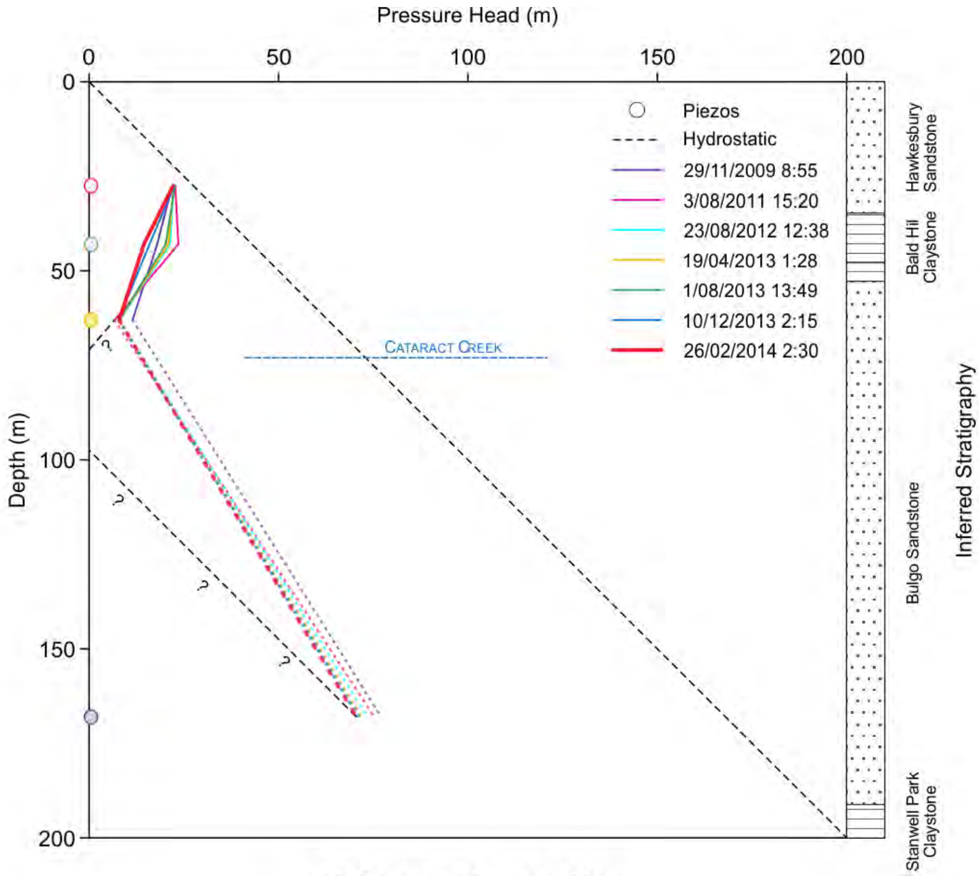
The piezometric profile shows a perched water table under the ridge that is drawn down to zero at an elevation above Cataract Creek. It is difficult to draw many conclusions from the single pressure reading at 168m depth below surface in the Bulgo Sandstone, but this single value is consistent with a groundwater level at about 100m below the surface or 30m below the base of Cataract Creek. The upper two piezometers in the Hawkesbury Sandstone respond slightly to long term rainfall trends, but the correlation is much less clearly evident in NRE B compared to NRE A.

Although there has been some mining below this site in the Bulli Seam, the extraction of coal has been much less systematic compared to the southern side of Cataract Creek where eleven longwall panels were mined in the Balgownie seam. The pore pressures in the Hawkesbury Sandstone are perched well above the level of Cataract Creek and the Cataract Reservoir. The pore pressure in the Bulgo Sandstone is below the RL289.87m Full Supply Level (FSL) of Cataract Reservoir.

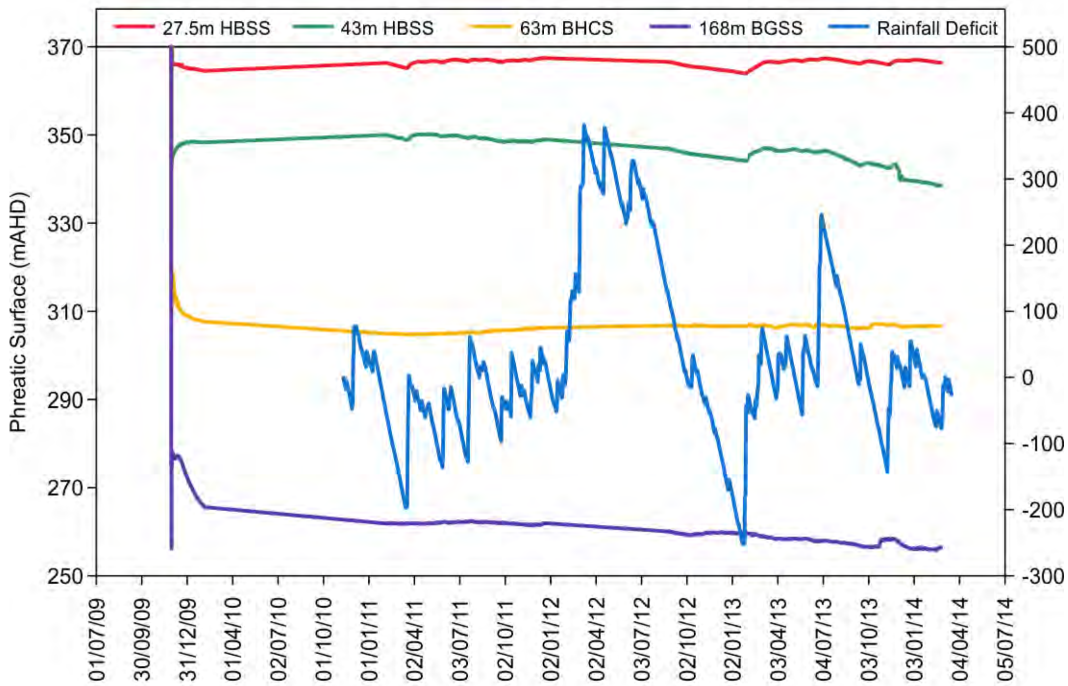
The piezometer data from NRE B indicates that there is a downward hydraulic gradient, but the hydraulic properties of the intact strata are sufficiently low in the undisturbed strata that there is almost no flow. The response to long term rainfall trends even at relatively shallow depths within the Hawkesbury Sandstone is muted and only varies around a long term average by a few metres. There is a slow downward trend evident in the lower Hawkesbury Sandstone at 43m and the Bulgo Sandstone at 168m from about July 2011, but there is not clear reason for this trend and it is not replicated in the piezometer located vertically between the two that are trending downward.

3.3 Piezometer NRE D – Western Edge of Wonga East Mining Area

Figure 8 shows the results of piezometer monitoring in piezometer NRE D. Piezometer NRE D is located further west along the ridge to the north of Cataract Creek from NRE B. The strata dips to the west so the equivalent geological units are about 75m lower at NRE D compared to NRE B. There have been some limited secondary workings in the Bulli Seam but no mining in the Balgownie or Wongawilli Seams.

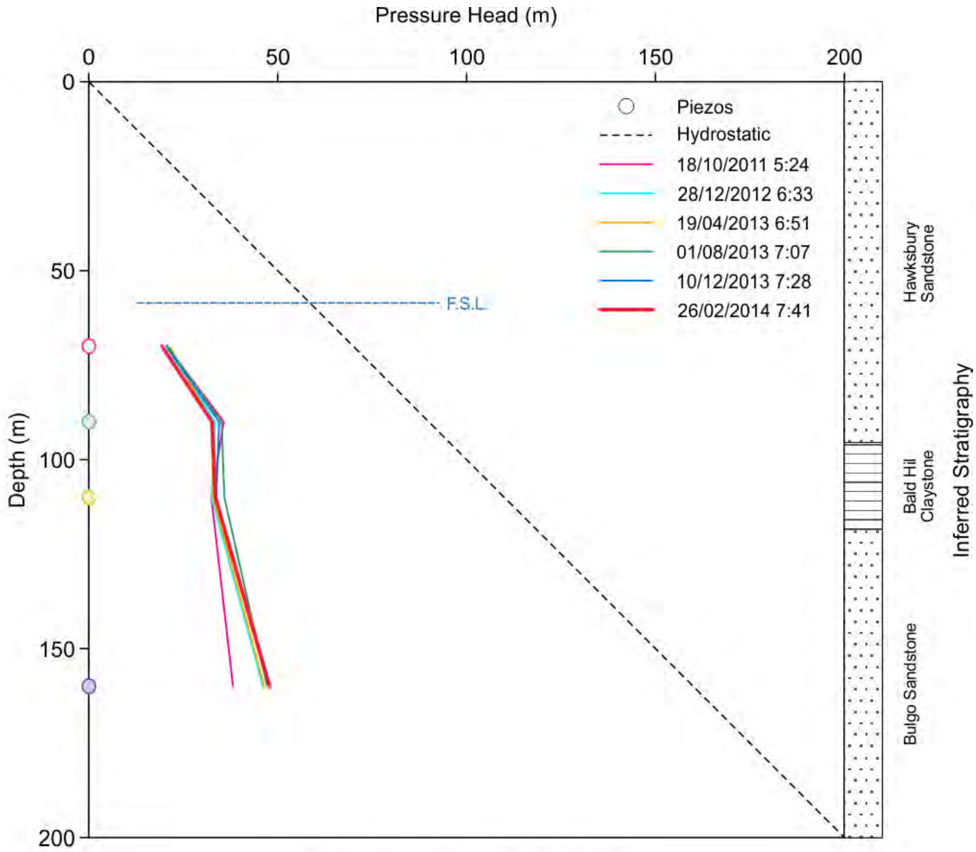


a) Piezometric profile.

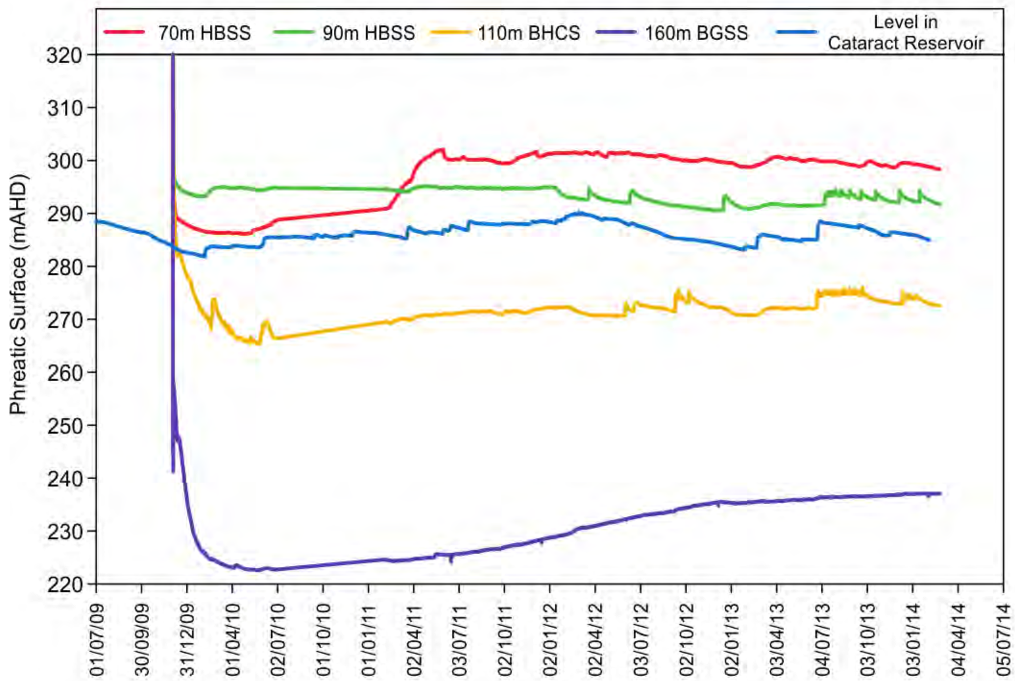


b) Hydrograph and rainfall deficit.

Figure 7: Piezometer results for NRE B.



a) Piezometric profile.



b) Hydrograph and level in Cordeaux Reservoir.

Figure 8: Piezometer results for NRE D.

The piezometric profile shows the phreatic surface in the Hawkesbury Sandstone under the ridge is only slightly above the Full Supply Level (FSL) of Cataract Reservoir (RL289.87m). The pore pressure in the Bald Hill Claystone is drawn down 20m below FSL and the pore pressure in the Bulgo Sandstone is drawn down about 60m below FSL. This profile indicates a downward hydraulic gradient but the mine pump out records indicate there is very limited vertical flow down into the Bulli Seam workings so the in situ vertical hydraulic conductivity appears to be limiting the downward flows to the low levels observed underground.

The piezometer responses show a slight correlation with long term rainfall trends particularly the responses of the two lower piezometers. However in addition to the gradual rainfall deficit trends, there is a very strong correlation with the level of Cataract Reservoir, particularly for the piezometer located in the Bald Hill Claystone.

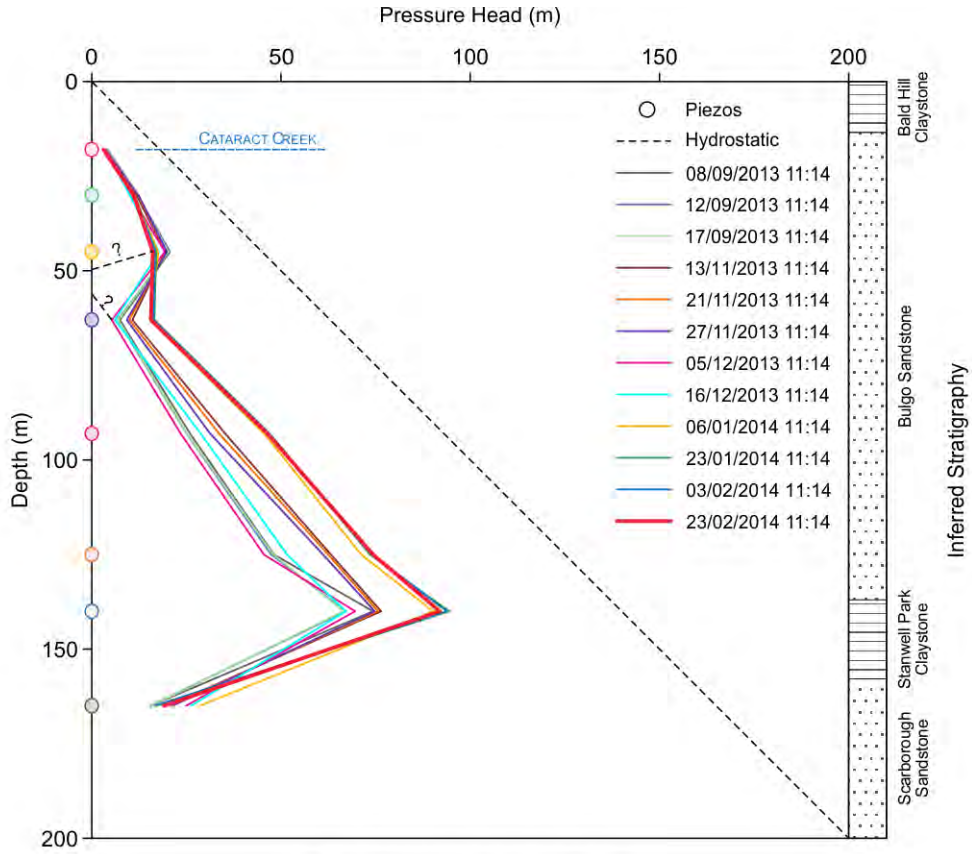
The correlation indicates that there is some lateral connectivity between the reservoir and the NRE D piezometer. NRE D is located approximately 540m from the nearest edge of Cataract Reservoir. This lateral connection is considered most likely to be along a bedding plane shear at a level just below the base of Cataract Reservoir (estimated in this area to be at about RL282m) and an equivalent depth below surface of about 70m in NRE D.

The piezometric pressure in the Bald Hill Claystone and Bulgo Sandstone below hydrostatic and below the level of Cataract Reservoir indicates there is a downward hydraulic gradient towards the mine in these units. The correlation with the changes in water level in Cataract Reservoir indicates there is a connection between NRE D and the reservoir even at a distance of 540m. There is a hydraulic gradient away from the mine towards the reservoir in the Hawkesbury Sandstone and a hydraulic gradient from the reservoir back toward the mine at the Bald Hill Claystone and Bulgo Sandstone horizons. The very low levels of inflow observed into the Bulli Seam indicate the hydraulic conductivity of the strata must be sufficiently low to limit any significant inflows into the mine to low levels despite this apparent connection.

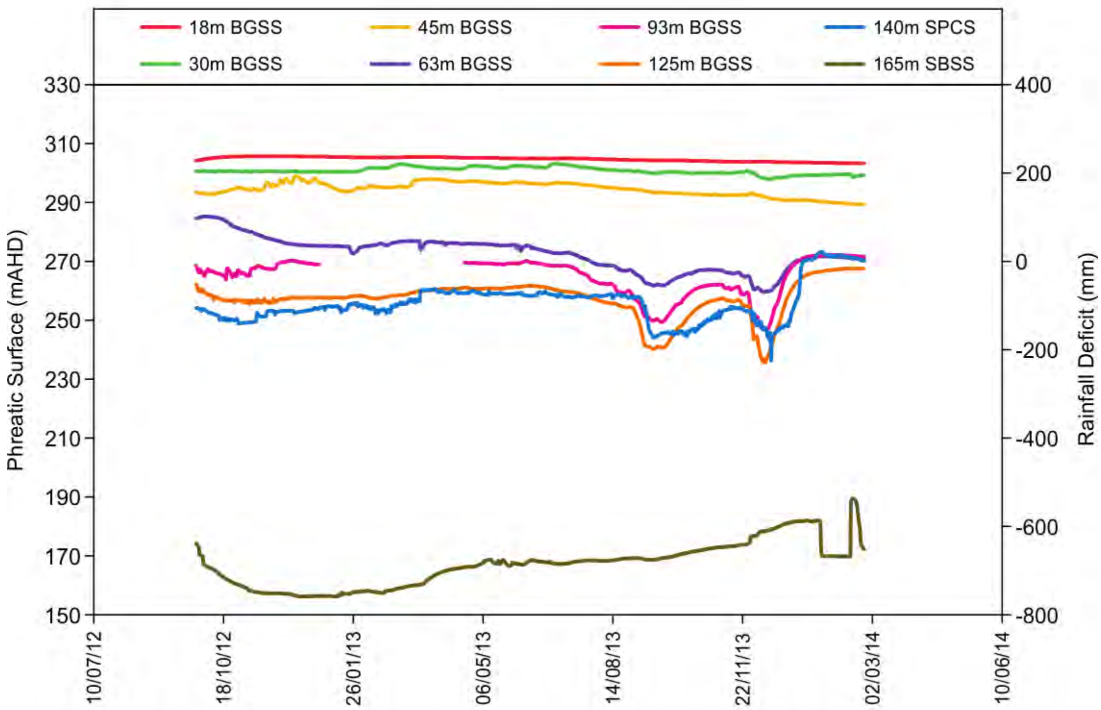
3.4 Piezometer GW-1 – Old Mount Ousley Road South of Cataract Creek

Figure 9 shows the results from Piezometer GW-1. Piezometer GW-1 was installed on the original alignment of Mount Ousley in September 2012 after completion of Longwall 4. The borehole is located above the goaf of Longwall 7B in the Balgownie Seam in an area where the Hawkesbury Sandstone has been completely eroded away. The site is approximately 175m from Cataract Creek, 345m from the northern end of Longwall 4 and 125m from the finishing corner of Longwall 5.

The piezometric pressure profile in GW-1 indicates there are two groundwater systems operating in this area. There is a near surface perched water table and a second deeper groundwater system. Both are located within the Bulgo Sandstone. There is likely to be a degree of vertical connection between the two, but they are regarded in this report as being essentially separate systems.



a) Piezometric profile.



b) Hydrograph and rainfall deficit.

Figure 9: Piezometer results for GW-1.

3.4.1 Perched Water Table

Figure 10 shows close ups of the hydrographs for the piezometers in the two groundwater systems at GW-1; the perched water table and the deeper piezometers both in the Bulgo Sandstone.

Figure 10a shows that the phreatic surface of the perched water table indicated by all three piezometers in the perched water table is close to the level of Cataract Creek (approximately RL300m). During the period of monitoring to date only the lower two piezometers have correlated responses to rainfall and the effect has not been strong.

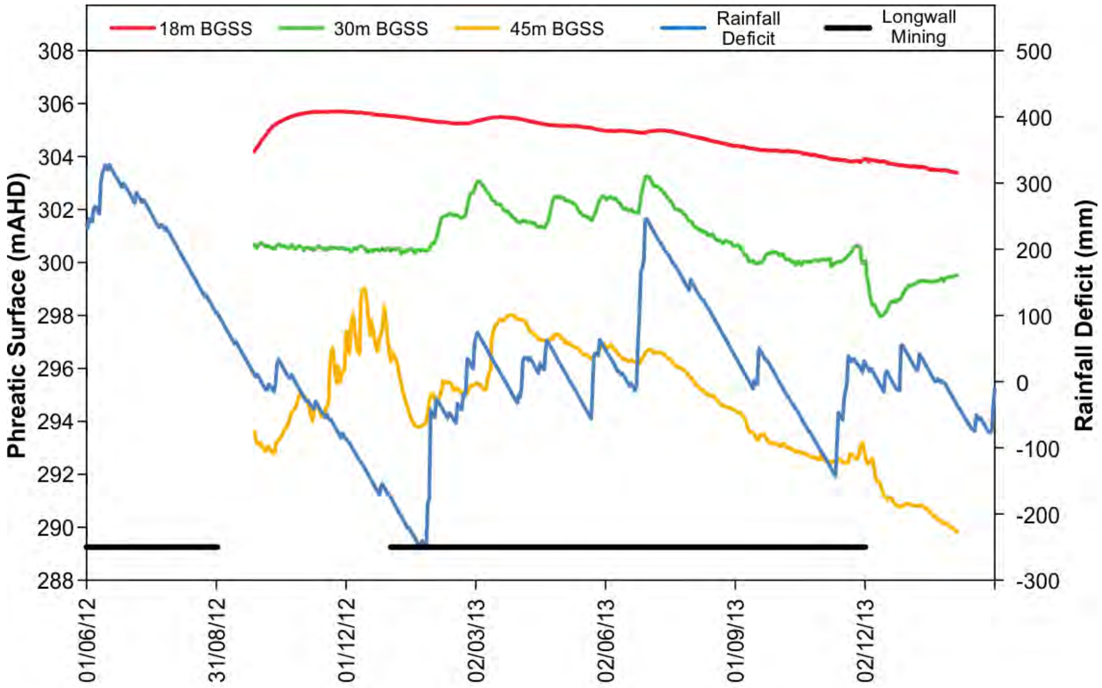
There is a slight reduction in the level of the phreatic surface in all three piezometers located in this perch. The reduction commenced soon after Longwall 5 started and continued throughout the period of mining Longwall 5. The long term downward trend from the start of Longwall 5 is considered to be a result of mining and the reactivation of a basal shear plane that may have originally been natural but was likely also reactivated or formed during previous mining in the Balgownie Seam and Longwall 4.

The approach of Longwall 5 appears to have caused a reduction in the level of the phreatic surface that is still nominally above the level of Cataract Creek at 18m below the surface (RL300m) but is lower than the creek at 30m and 45m below the surface. The effect of mining Longwall 5 appears to have been to slightly elevate the horizon separating a flow gradient toward Cataract Creek from the flow gradient toward the mine, in effect increasing slightly the potential for flow from Cataract Creek toward the mine via the deeper strata. The surface strata is still indicated as having a flow gradient toward the creek at the top of the perch but this gradient has been reduced slightly by mining Longwall 5.

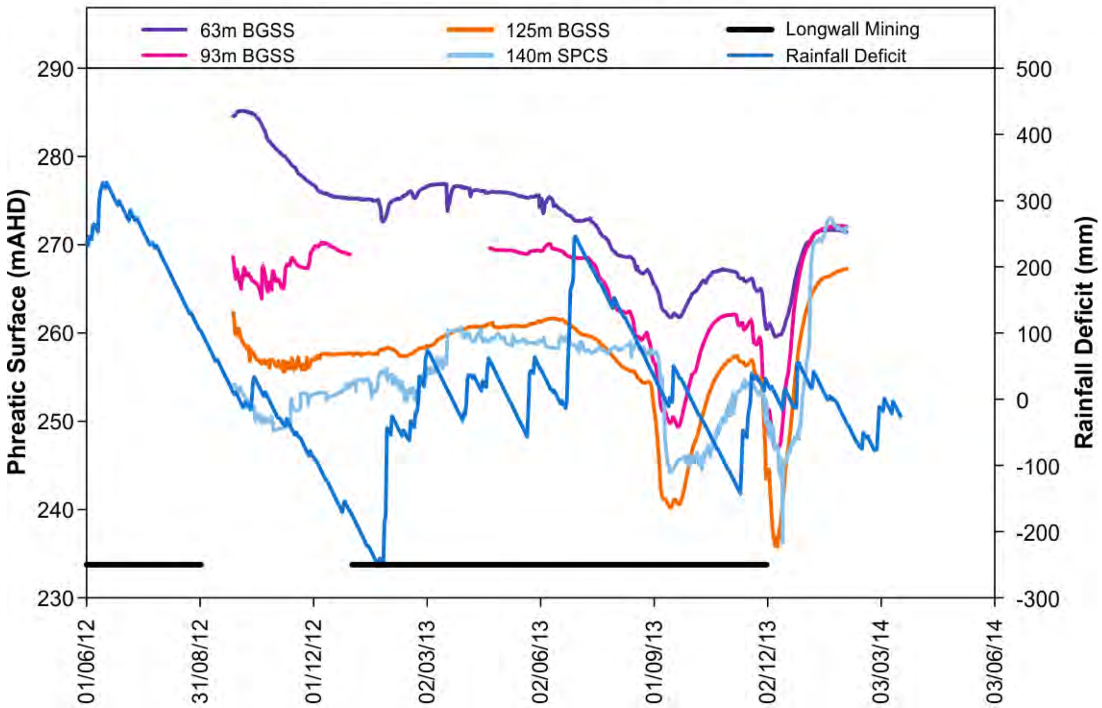
The uppermost piezometer at 18m below the surface does not change significantly over time or show much response to rainfall but this may be because it is operating at very low pressures and is close to dry.

The 30m piezometer is steady prior to the start of Longwall 5, possibly because of an extended dry period prior to installation, but coincident with the start of Longwall 5 and an intense rainfall event there is a clear response to rainfall that continues from then on. The level of the phreatic surface indicated by the 30m piezometer was initially several metres higher than the RL300m level of nearest point on Cataract Creek, but with the mining of Longwall 5, the phreatic surface indicated is 299.5m or about half a metre below the level of the nearest point on Cataract Creek. In other words, at the 30m depth horizon in GW-1 (about 12m below the level of Cataract Creek) the hydraulic gradient is slightly away from Cataract Creek toward the mine.

The deepest of the three piezometers in the near-surface perch at 45m shows a more muted response to rainfall but shows the strongest decline in head of the three with a fall from RL298m to RL290m during the period of mining Longwall 5.



a) Hydrograph in the perched water table.



b) Hydrograph in the deeper water table.

Figure 10: Close up of the hydrographs for GW-1.

The relative water levels indicated by each of the piezometers shows that there is a slight downward gradient within the perch suggesting downward flow from the perch into the lower groundwater system and the change in gradient indicates the downward gradient has increased during the period of mining Longwall 5.

The perched water level is interpreted as being hydraulically connected to Cataract Creek most likely via a horizontal shear horizon just below the level of Cataract Creek. The hydraulic conductivity of this connection is such that rainfall recharge from the surface is able to flow back into Cataract Creek but mining increased the gradient toward the mine, particularly in the deeper strata.

3.4.2 Deeper Water Table

Figure 10b shows that the deeper groundwater table has clearly responded to the later stages of mining Longwall 5. As the longwall approached within about 400m of the piezometer, there was a drop in pressure that was greater with depth below surface. Mining then ceased for a period, recommenced and then the longwall finished. The pore pressure recovered each time to pre-mining levels and following the completion of Longwall 5 the pore pressures have recovered to levels higher than at any time in the past.

This response is thought to be a result of mining activity slightly increasing the volume of pore space within the strata causing the pore pressure to be temporarily reduced. Inflow from above and possibly laterally has allowed the pore pressures to recover to above pre-Longwall 5 levels, possibly as a result of enhanced vertical connectivity caused by mining induced ground movements. The volumes involved in this process are likely to be transitory but may have caused a temporary period of increased recharge from Cataract Creek.

There is still a downward hydraulic gradient toward the mine evident throughout the Bulgo Sandstone but the flows appear to be of a low magnitude based on the mine inflow records. The low flow would be consistent with the low hydraulic conductivity of only slightly disturbed strata.

3.4.3 Height of Depressurisation

The piezometric profile in GW-1 shows the height above the mining horizon where there is depressurisation below hydrostatic and by implication the vertical height above an existing mined void where there is sufficient downward flow into the mine that the pressure profile can no longer be maintained. Extrapolation indicates that the point of zero pressure has occurred at a depth of approximately 170m below surface in the Scarborough Sandstone.

For the longwall panel geometry in the Balgownie Seam (in this case the 150m length of Longwall 7B) and a depth to the mining horizon of 240m, the height of depressurisation calculated using the approach formulated by

Tammetta (2012) is approximately 200m for a nominal 1.3m mining height in the Balgownie Seam. The effective mining height from two seams would need to be about 2.0m for the observed height of depressurisation to be 170m below surface.

The Bulli Seam is nominally 2.2m thick but mining in this area did not involve full extraction. It is credible that the effective height of mining in both seams could be 2.0m and that the Tammetta approach provides a basis to estimate the height of depressurisation above the most recent panel mined if the combined mining height is assumed. Further measurements in a multi-seam mining environment are planned to confirm this single data point.

3.5 Compilation of Piezometer Measurements

Figure 11 shows the four vibrating wire piezometer installations NRE A, GW-1, NRE B, and NRE D plotted at a common scale and reduced level. The stratigraphy indicated is only approximate and a composite based on the known depth to the Bulli Seam at each location and a geological section interpreted from geophysical logs in GW-1, but it serves to show the approximate position of the various measurements relative to stratigraphy.

Figure 11 shows that only GW-1 goes deep enough to measure the piezometric pressure in the Scarborough Sandstone and the inferred top of the zone of depressurisation above the Balgownie Seam longwall panels. GW-1 and NRE B indicate that there is effectively zero pressure at the level of Cataract Creek. NRE D shows that the groundwater table at a location 540m from the reservoir is influenced by the level of Cataract Reservoir.

Figure 12 shows the four vibrating wire piezometer installations plotted at scale on both the horizontal and vertical axes along a section that joins them all. No attempt is made to estimate the variation between boreholes; the connections are shown as straight lines except for Cataract Creek which provides another control point. The surface and the stratigraphy are based on the measured collar heights and the stratigraphy at each location. The reduced levels of the phreatic surfaces indicated by piezometers in the Bulgo Sandstone and in the Bald Hill are also plotted.

This data indicates that apart from in the vicinity of Cataract Creek near the Mount Ousley Road Crossing, the phreatic surface in the Bald Hill Claystone is above the level of the Bald Hill Claystone itself. The phreatic surface in the Bulgo Sandstone is only above the level of the Bald Hill Claystone at NRE A.

In the vicinity of GW-1, NRE B, and to a lesser extent at NRE D, the groundwater level in the Bulgo Sandstone is drawn down below the level of both Cataract Creek and the FSL of Cataract Reservoir. The phreatic surface of the Bulgo Sandstone is also indicated as being drawn down below the phreatic surface indicated in the Bald Hill Claystone by between 50m and 55m at all three locations. This indicates that there is a consistent downward hydraulic gradient evident at GW-1, NRE B, and NRE D. There is also some lesser downward hydraulic gradient evident at NRE A but given the elevated vertical hydraulic gradient at NRE A, the inflow potential at NRE A is considered much more significant.

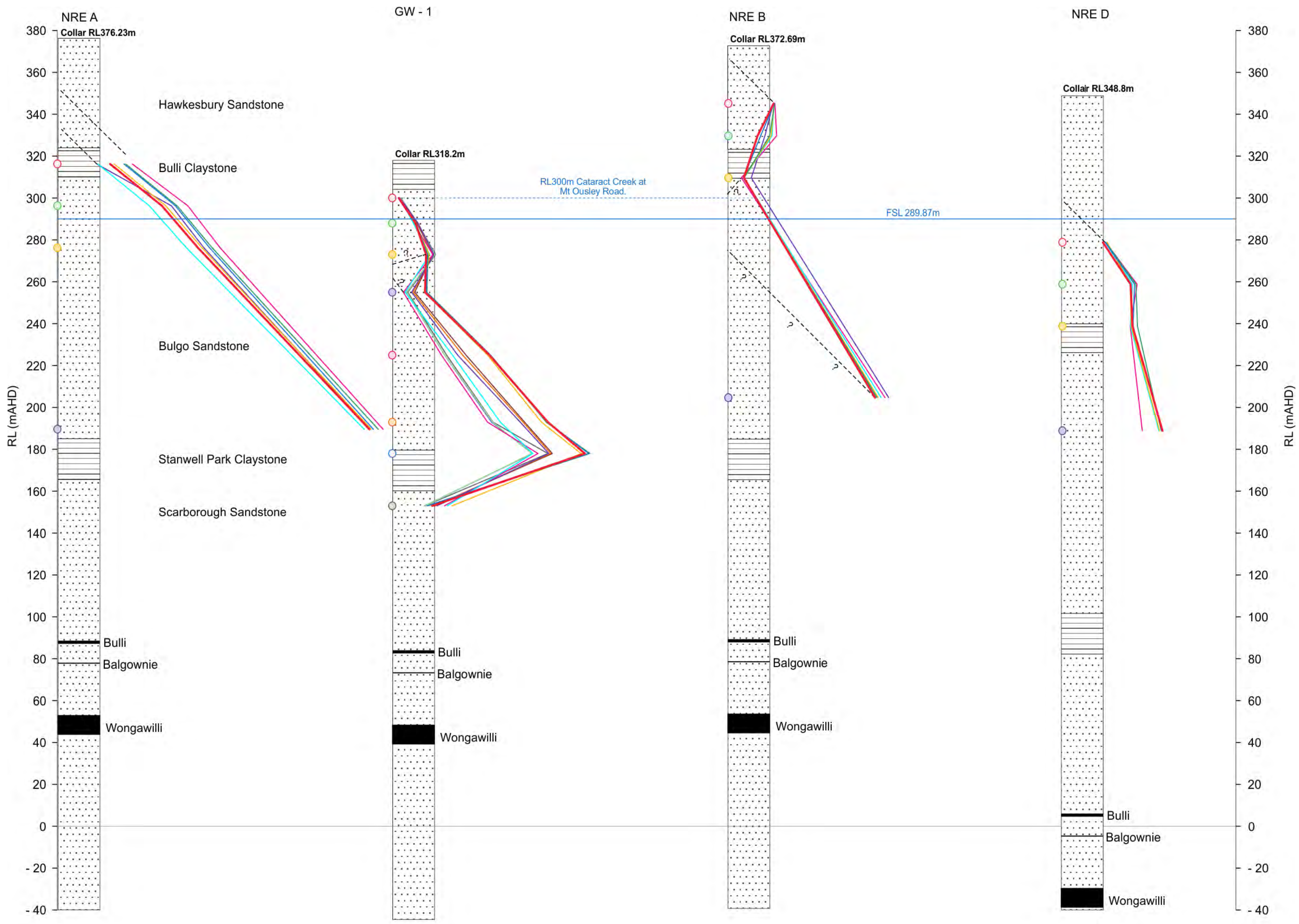


Figure 11: Piezometer monitoring across the Wonga East area plotted at the same vertical scale and elevation.

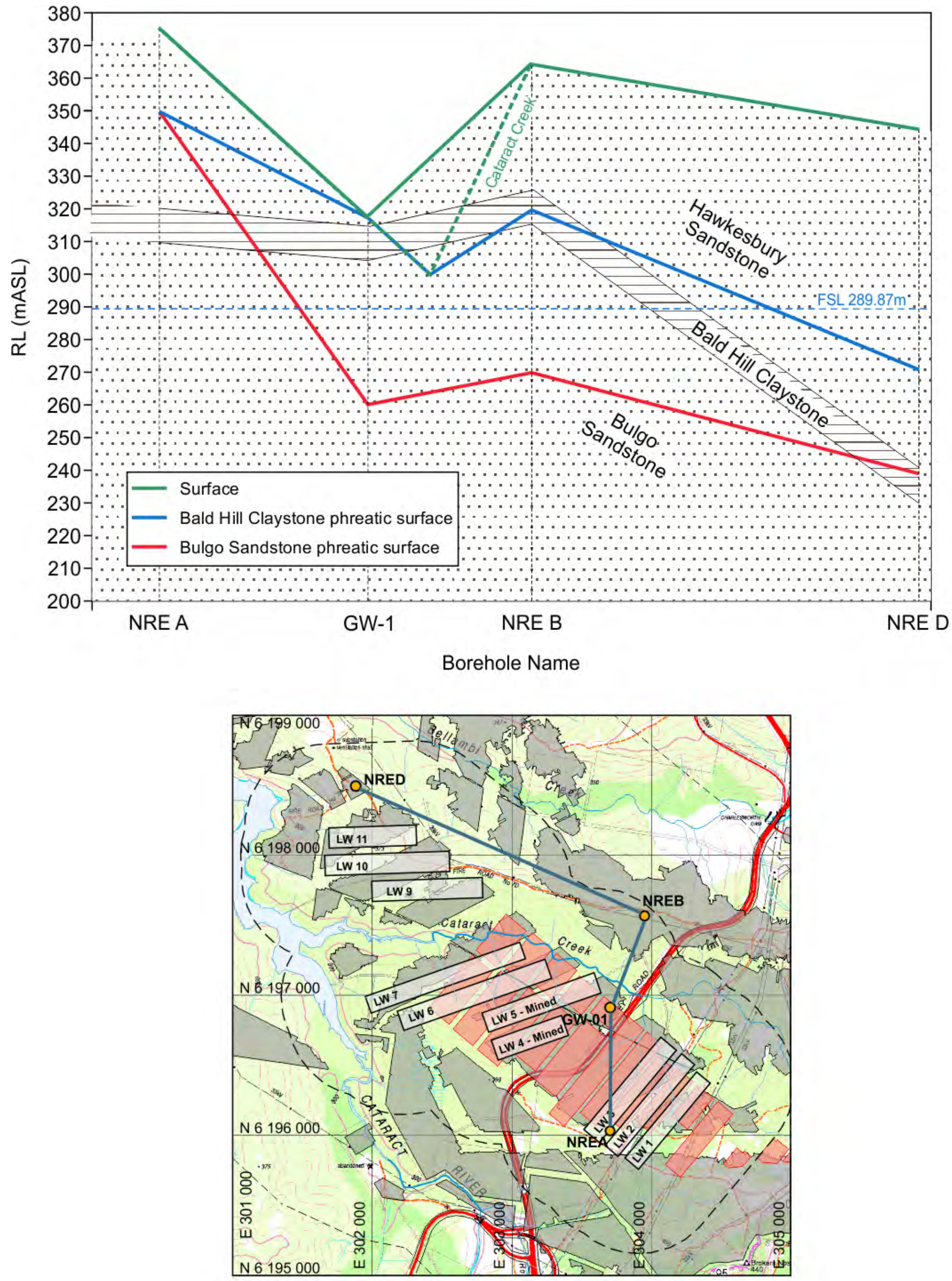


Figure 12: Piezometer monitoring across the Wonga East area plotted in section at a common horizontal and vertical scale.

By comparison with the other sites, NRE A is clearly in a location where there is elevated vertical hydraulic conductivity and a likely source of recharge from surface rainfall and over land flow into a large open fracture network. The other piezometers are located in areas where the vertical hydraulic conductivity is indicated as being low and the downward hydraulic gradients is interrupted by lateral flow into and out of Cataract Creek and Cataract Reservoir at different horizons.

4. HYDRAULIC CONDUCTIVITY MEASUREMENTS

Hydraulic conductivity measurements from the Wonga East area that have been reviewed for this assessment are limited to packer testing in GW-1. The results from GW-1 are considered to be within the range that would be expected for Bulgo Sandstone.

The results of the packer testing are summarised in Figure 13. These results indicate that the hydraulic conductivity of the overburden strata reduces with depth below surface. At 20m below surface, the hydraulic conductivity is about 1×10^{-6}m/s. At 150m below surface the hydraulic conductivity has reduced to about 2×10^{-9}m/s. There are several zones of higher hydraulic conductivity apparent and some of these are considered likely to be mining induced.

The packer testing measurements do not provide any differentiation between hydraulic conductivity in a vertical direction and hydraulic conductivity in a horizontal direction. Horizontal hydraulic conductivity is usually assumed to be about an order of magnitude greater than vertical hydraulic conductivity in horizontal bedded strata but this ratio needs to be confirmed at this site.

Assuming the hydraulic conductivities measured in GW-1 are representative of the strata generally, inflow rates from the surface are expected to be of a low magnitude. However, the data that is most relevant to mine inflows is directly over the longwall panels and in the vicinity of the ridge where NRE A is located and stretching subsidence movements have occurred. There are currently no hydraulic conductivity measurements in either area but WC is expanding the groundwater monitoring program in the near future to include piezometer and packer testing in both areas.

5. CONCEPTUAL MODEL AND IMPLICATIONS FOR FURTHER MINING

A conceptual/analytical model of the groundwater system in the Wonga East area has been developed based on analysis of the currently available data and its various characteristics. While this model is considered convincing and consistent with the data currently available for the Wonga East area, further calibration and ongoing improved monitoring of underground pumping systems and further monitoring of groundwater pressures using piezometers will allow continuous refinement and improvement as a basis for understanding as well as to underpin the more extensive numerical modelling. It should be recognised that the outcomes of the conceptual model presented in this report may differ somewhat from the results of larger scale numerical modelling because of the conceptual model's greater flexibility to address the specific local site conditions in the relatively small area of Wonga East.

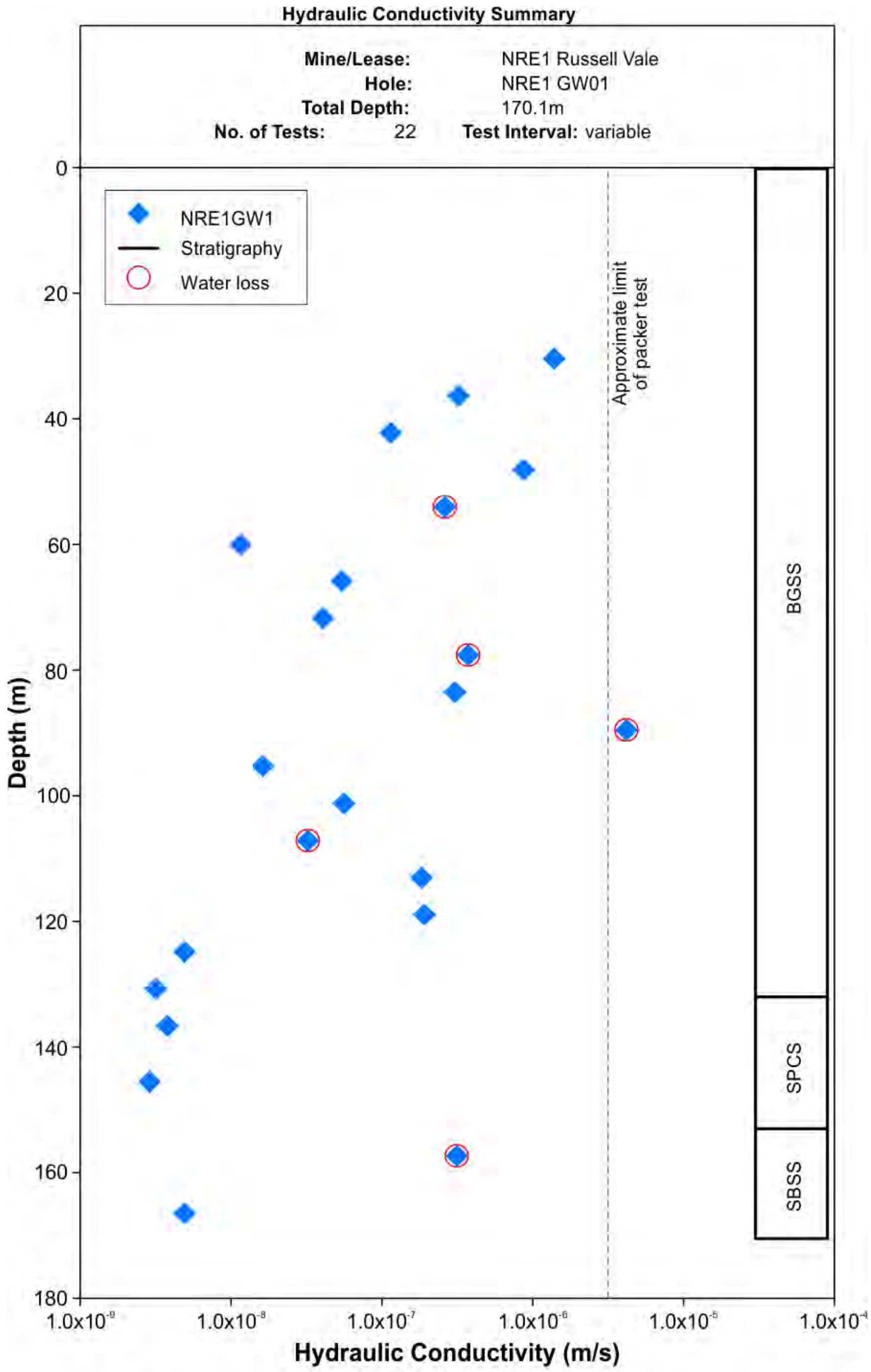


Figure 13: Summary of packer testing in GW - 1.

This model indicates that approximately 1.1Ml/day is seeping into the Wonga East underground mine from the surrounding strata once the balance of water that is pumped into the mine and leaving the mine in the coal product and ventilation has been taken into account.

5.1 Sources of Mine Inflow

A section of the ridge south of Cataract Creek where the ground is stretched by subsidence movements and there are large tension cracks evident on the surface appears likely to be a significant source of inflow into the mine. In this area, the hydraulic conductivity of the overburden strata appears to be significantly enhanced to a depth of at least 140m below surface and yet there is still a downward gradient evident in the piezometer results. Mining activity including longwall mining in the Balgownie Seam and more recently Longwalls 4 and 5 in the Wongawilli Seam is likely to have contributed to the increased vertical hydraulic conductivity observed and is estimated to be sufficient to produce the inflows observed underground.

Although surface cracking along the ridge line to the south of Cataract Creek appears likely to be a major source of seepage into the mine, the groundwater levels are still indicating the headwaters in Cataract Creek are controlling the groundwater level and by implication receiving most of this rainfall recharge flow as a result. This balance between some inflow into the mine, generally at low levels, and lateral flow including along horizontal shear planes from/to adjacent creeks appears to occur all across the site. The inflows into the mine are indicated as being at low levels based on the overall water balance observed.

Further work is underway to test the calibration of the underground pump out system and measure the hydraulic conductivity and deeper piezometric pressure profile at two locations along the ridge line to the south of Cataract Creek.

All the piezometers show a downward hydraulic gradient towards the mining horizons past and present consistent with downward flow of low magnitude. This downward hydraulic gradient existed prior to recent mining in the Wongawilli Seam and while there has been some increase in the vertical gradient evident during mining in the Wonga East area the additional increases have been relatively small.

The magnitude of downward flow appears to be largely restricted by the naturally low vertical hydraulic conductivity of the deeper overburden strata, particularly around the level the Stanwell Park Claystone, and the relatively large depth of mining. A zone of depressurisation is evident in piezometer GW-1 and the height of this zone is consistent with the method formulated by Tammetta (2012) for the mining geometry of the most recently mined panel and the combined thickness of all the seams that have been mined.

The flow measurements underground indicates that there has been a background inflow into the Bulli and Balgownie Seam up dip of the Wongawilli Seam mining that has a magnitude of about 0.2-0.3Ml/day and this flow has responded to long term trends in rainfall deficit suggesting a degree of hydraulic connectivity with either the surface or the Illawarra Escarpment.

There may also be some minor inflow from Cataract Creek, although the characteristics of the mine inflows recorded during mining of Longwall 5 did not indicate any perceptible increase in inflow as mining approached Cataract Creek. If a significant source of inflow was from the creek, an increase in flow rate would be expected as the flow path length between the creek and the mine reduced. The resolution of the underground monitoring is of the order of 0.1Ml/day indicating any potential increase in flow from Cataract Creek into the mine during mining of Longwall 5 was less than about 0.1Ml/day.

There were no visual indications of flow loss from Cataract Creek and no losses were recorded, but it should be recognised that flow meter systems able to be installed in creek channels without major construction works only have a resolution of the order of ±0.5Ml/day and therefore may not be able to detect changes with a magnitude of 0.1Ml/day or any flows that may have recharged groundwater levels in the deeper strata.

5.2 Horizontal Shear Planes

The piezometer monitoring results from the Wonga East area are consistent with the presence of horizontal shear planes with higher hydraulic conductivity than the surrounding strata. These shear planes are inferred to be associated with creek closure both natural and mining induced and have been confirmed to exist at other sites. These shear horizons are most likely to be present at a level just below the base of the valleys. They occur as part of natural erosion processes but are also activated by mining subsidence. These shear planes appear likely to be capable of distributing low level flows over distances of several hundred metres and into the general groundwater system while also collecting rainfall recharge and distributing it back to the creeks and reservoir.

A shear plane is considered likely to be the pathway by which NRE D, some 540m from Cataract Reservoir, responds to changes in reservoir pressure. A shear plane is also the likely pathway for the upper perched water table in GW-1 to be maintained at close to the level of Cataract Creek some 175m away and for the pressure in NRE B to be drawn to zero at the level of Cataract Creek.

5.3 Height of Depressurisation

Where there is mining in all three seams, there is considered to be high potential for interaction with the surface and the top of the groundwater table recharged from long term rainfall trends and adjacent creeks if there is interaction between the basal shear plane reactivated by subsidence and the top of the zone of depressurisation above each longwall panel. The height of this zone of depressurisation can be estimated using the empirical approach formulated by Tammetta (2012) for single seam mining operations, but the approach needs to be confirmed as suitable in a multi-seam environment. The following estimates for height of depressurisation above the mining horizon are considered reasonable as a preliminary estimate:

- Bulli Seam - 60m with over 90 years to come into equilibrium

- Balgownie LWs only
  - 43m for 140m panels (T=1.4m, W=140m and D=300m)
  - 60m for 190m panels (T=1.4m, W=190m, and D=300m)

- Balgownie LWs plus Bulli Seam
  - 100m for 140m panels (T=2.6m, W=140m, D=300m)
  - 136m for 190m panels (T=2.6m, W=190m, D=300m)

- Wongawilli LWs only
  - 146m for 145m panels (T=3.2m W=150m, D=330m)

- Wongawilli plus Bulli Seam
  - 222m (T=4.4m, W=150m, D=330m)

- Wongawilli plus Balgownie Seam
  - 235m (T=4.6m, W=150m, D=330m)

- Wongawilli plus Bulli Seam plus Balgownie Seam
  - 316m (T=5.8m, W=150m, D=330m)

There is considered to be some potential for interaction between the zone of depressurisation and the basal shear planes in the shallower areas at the northern ends of Longwall 2 and 3 and at the northern end of Longwall 7.

At the northern end of Longwall 7, the area where three seams have been mined is limited in extent and the height of depressurisation may be less as a result but further monitoring is required to establish the height of depressurisation when all three seams have been mined. Further work is underway to determine the height of depressurisation above the southern end of Longwall 4 where all three seams have been mined because the multi-seam estimates of height of depressurisation are limited to the one measurement in GW-1 at this stage.

5.4 Estimated Inflows from Proposed Panels

The conceptual model developed and presented in this report is not considered sufficiently robustness to provide a strong quantitative basis to calculate inflows from further mining activity in the Wonga East mining area. However, some indications of potential for inflow can be provided based on the data available. Areas where there is considered to be increased potential for inflow into the mine can be highlighted and the flows estimated based on previous experience of mining Longwalls 4 and 5.

The total water make from the Wongawilli Seam workings is currently about 1.1Ml/day. Based on considerations of how this flow has developed over time and where it has reported to in the mine, the current water make is estimated to comprise:

- 0.3Ml/day from mining development headings in the Wongawilli Seam.
- 0.2Ml/day for up dip inflow in the Bulli and Balgownie Seams.
- 0.1Ml/day additional inflow from mining Longwall 4.
- 0.5Ml/day from mining Longwall 5.

Based on the conceptual model the following estimates of additional inflow are indicated.

The northern ends of Longwalls 1-3 are located at shallower depths in areas where there has been previous mining in the Balgownie Seam. The potential for interaction with the near surface groundwater systems directly and through the zone of horizontal stretching along the ridge at the southern ends of these panels is expected to cause inflows of the same magnitude or possibly higher than the inflows observed in Longwalls 4 and 5. None of this area is below the fourth order section of Cataract Creek or close to the FSL of Cataract Reservoir so any recharge is likely to be more closely related to rainfall.

Longwalls 6 and 7 are expected to contribute similar inflow increases to Longwall 5 (i.e. 0.5Ml/day) with this additional flow coming mainly from the higher conductivity recharge zones along the ridgeline between Cataract Creek and Cataract River. Some additional flow may also come from Cataract Creek and Cataract Reservoir via the horizontal shear planes that are likely to be mobilised by mining Longwalls 6 and 7.

The relatively low vertical hydraulic conductivity of the overburden strata and depth of mining is expected to restrict inflows from these basal shear planes into the mine to low levels in the vicinity of Longwalls 6 and 7 provided the zone of depressurisation does not reach high enough to interact with the basal shear planes. Interaction with the zone of depressurisation may be possible at the northern end of Longwall 7 in an area where all three seams have been mined in close lateral proximity but not directly above each other. Further measurements planned above the southern end of Longwall 4 are expected to provide confirmation of the significance of this potential.

Longwalls 9-11 are located away from areas of previous mining in the Balgownie Seam and the potential for interaction with the near surface groundwater system is considered likely to be much lower because of the lower heights of depressurisation expected. Based on experience from other longwalls at similar depths, inflow rates are expected to be less than about 0.2-0.3Ml/day per panel during active mining and to reduce over time to low levels.

6. REFERENCES

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