# Appendix C

## Groundwater assessment - AGE

# C

# Australasian Groundwater & Environmental Consultants Pty Ltd

*REPORT on*

## *WARKWORTH MINE MODIFICATION*

## *GROUNDWATER IMPACT ASSESSMENT*

*prepared for*
*EMGA MITCHELL McLENNAN*

*Project No. G1468/D*
*August 2013*

ABN:64 080 238 642

Australasian
Groundwater & Environmental
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Attachments

# REPORT ON

# WARKWORTH MINE MODIFICATION GROUNDWATER IMPACT ASSESSMENT

## 1 INTRODUCTION

Warkworth Mine, operated by Warkworth Mining Limited (WML), is approximately 15 km south-west of Singleton in the Hunter Valley of New South Wales (NSW). Warkworth Mine adjoins the Mount Thorley Operations (MTO), which was originally developed separately. In 2004, the participants in the Warkworth Joint Venture entered into an agreement with the participants in the Mount Thorley Joint Venture to integrate mining operations in both lease areas. The combined operation is known as Mount Thorley Warkworth (MTW).

WML is applying to the Department for Planning and Infrastructure (DP&I) to modify the current development consent (DA 300-9-2002-i). The proposal seeks to disturb up to 350 m further to the west down-dip in West Pit.

WML commissioned EMGA Mitchell McLennan Pty Ltd (EMM) to prepare an Environmental Assessment (EA) in support of the proposed minor extension to West Pit (the proposed modification). Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) completed the groundwater impact assessment described in this report at the request of EMM, on behalf of their client WML.

## 2 OVERVIEW OF PROPOSED MODIFICATION

The proposed modification continues all aspects of Warkworth Mine’s current activities, and specifically seeks approval to disturb up to 350 m further to the west as part of West Pit. The proposed modification increases the footprint of the approved pit mining area by a relatively minor 1%. The proposed modification does not seek to extend the mine life, which was approved for 18 years of mining in 2003 with the current consent expiring in 2021. It is proposed mining and associated activities will continue to target the Mount Arthur Seam in the West Pit, and continue up to a further 350 m towards the west to align the final highwall in a north south direction.

Figure 2.1 shows the extent of the approved mining and the proposed modification.


LEGEND:

Proposed modification

Aproved mining area

Proposed further mining

Coal title

Mt Thorley Warkworth (G1468D)

**Proposed Modification**

DATE: 30/8/2013

FIGURE No: **2.1**

# 3 OBJECTIVES AND SCOPE OF WORK

The objective of this groundwater study was to assess the impact of the proposed minor modification on the groundwater regime, and address the requirements of NSW Government legislation and policy. The groundwater study comprised two parts, a description of the existing hydrogeological environment, followed by an assessment of the impacts of mining on that environment.

Given the relatively small scale of the proposed modification, the groundwater study relied upon previous modelling undertaken by MER (2002) and AGE (2010). Ongoing monitoring of the groundwater regime at MTW was assessed to validate the predictions of the previous models to ensure they were suitable for assessing the impact of the proposed modification. The scope of work included updating groundwater levels and water quality for key monitoring bores to assess the impact of the currently approved open cut mining. The report also compares the impacts of the existing operation and proposed minor modification with the requirements of the Aquifer Interference Policy (AIP) introduced in 2012.

# 4 LEGISLATION, POLICY AND GUIDELINES

AGE (2010) summarised the legislation, policy and guidelines that relate to groundwater. In 2012, the NSW Government introduced the AIP. The AIP forms the basis for assessment of aquifer interference activities under the *Environmental Planning and Assessment Act 1979*. It clarifies the need to hold water licences under the *Water Management Act 2000* and *Water Act 1912* and establishes whether 'minimal impact' occurs.

Examples of aquifer interference activities (NOW, 2012) include mining, coal seam gas extraction, injection of water, and commercial, industrial, agricultural and residential activities that intercept the water table or interfere with aquifers. The AIP states that "*all water taken by aquifer interference activities, regardless of quality, needs to be accounted for within the extraction limits defined by the water sharing plans. A water licence is required under the WM Act …..where any act by a person carrying out an aquifer interference activity causes:*

- *the removal of water from a water source; or*
- *the movement of water from one part of an aquifer to another part of an aquifer; or*
- *the movement of water from one water source to another water source, such as:*
    - o *from an aquifer to an adjacent aquifer; or*
    - o *from an aquifer to a river/lake; or*
    - o *from a river/lake to an aquifer."*

In addition to the volumetric water licensing considerations, the following information needs to be considered to enable assessment and approval of the activity:

- establishment of baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area;
- a strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans;

- details of potential water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;
- details of potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;
- details of potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;
- details of potential for increased saline or contaminated water inflows to aquifers and highly connected river systems;
- details of the potential to cause or enhance hydraulic connection between aquifers; and
- details of the potential for river bank instability, or high wall instability or failure to occur.

The AIP divides groundwater sources into *"highly productive"* and *"less productive"*. Highly productive groundwater is defined by the AIP as a groundwater source that is declared in the Regulations and will be based on the following criteria:

- has total dissolved solids of less than 1,500 mg/L; and
- contains water supply works that can yield water at a rate greater than 5 L/s. Highly productive groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. "Less productive" groundwater includes aquifers that cannot be defined as "highly productive" according the yield and water quality criteria.

Section 5 discusses groundwater levels and quality data, and the productivity of the aquifer units. Section 7 compares the proposed modification's impacts against the AIP minimal impact considerations.

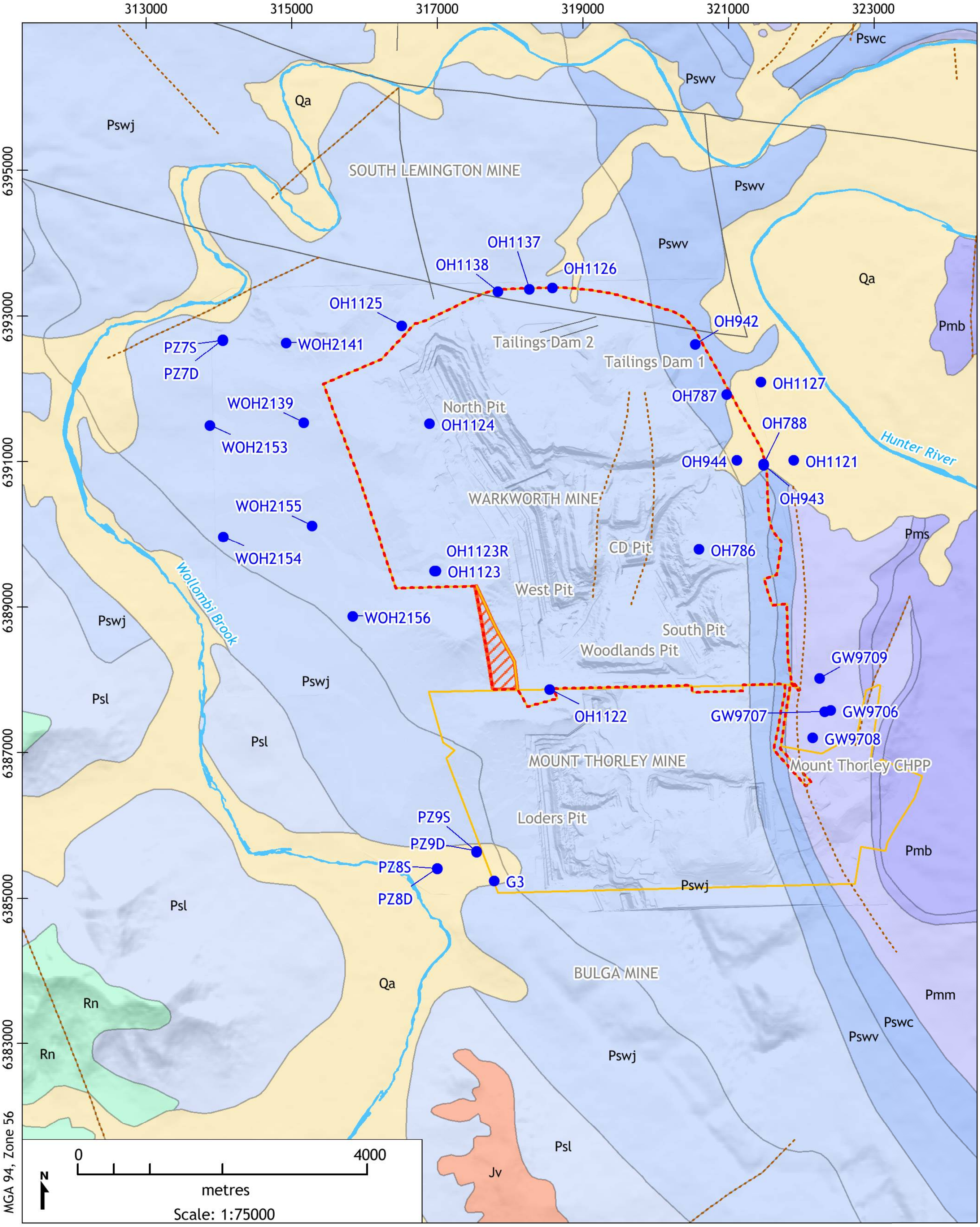
# 5 HYDROGEOLOGICAL REGIME

## 5.1 Aquifers and Aquitards

The geologic strata at MTW can be categorised into the following hydrogeological units:

- alluvium along Wollombi Brook and the Hunter River that can form a productive aquifer system, although salinity can limit use of the water;
- aoelian sands associated with the Warkworth Sands Woodland that form a shallow perched aquifer of limited extent;
- shallow weathered bedrock (regolith) near ground surface that is mainly present in the more elevated mining areas and is largely dry;
- hydrogeologically "tight" and hence very low yielding to essentially dry sandstone, siltstone and conglomerate that comprise the majority of the Permian interburden/overburden and is considered an aquitard; and
- low to moderately permeable coal seams that range in thickness from 1 m to 6 m and are the prime water bearing strata within the Permian sequence.

Figure 5.1 shows the extent of the surface geology and aquifer systems.




LEGEND:

- Monitoring bores
- Proposed modification
- Approved mining area
- Proposed further mining
- Fault
- Fold

**Hunter Coalfields 100k Geology**

- Qa - Quaternary Alluvium
- Jv - Jurassic Volcanics
- Rn - Hawkesbury Sandstone, Narrabeen G.
- Psl - Wollombi Coal Measures
- Pswj - Denman Fmt, Jerrys Plains Subgroup
- Pswv - Archerfield Ss., Vane Subgroup
- Pswc - Saltwater Creek Formation
- Pmm - Mulbring Siltstone
- Pms - Muree Sandstone
- Pmb - Braxton Formation

Warkworth Mine Modification (G1468D)

**Geology and Monitoring Bores**

AGE GROUNDWATER & ENVIRONMENTAL

DATE: 30/8/2013

FIGURE No: **5.1**

The Wollombi Brook alluvial aquifer and associated flood plain is largely restricted to the main channel of Wollombi Brook and only extends a short distance up the associated tributaries. The alluvium is typically less than 20 m thick, with many of the private bores intersecting between 10 m and 15 m of sediment. Groundwater entitlements for the Lower Wollombi Brook Water Source total 5,071 ML/year with 55% used for irrigation and 44% used for industrial purposes. This entitlement is distributed across 38 groundwater licences (DWE, 2009).

Aeolian sands overlie the Permian coal measures to the north-east of the Warkworth Mine. The sands ability to store and slowly release water supports a unique woodland known as the Warkworth Sands Woodland. The fine grained sands are approximately 3 m thick and overlie a low permeability base of residual clay associated with the underlying strata. The low permeability clays reduce vertical flow of groundwater and result in the formation of an ephemeral perched water table at the base of the sand mass.

The Permian deposits occur as a regular layered westerly dipping sedimentary sequence. Coal seams currently mined at Warkworth Mine are the Redbank Creek, Wambo, Whynot, Blakefield, Glen Munro, Woodlands Hill, Arrowfield, Bowfield, Warkworth and Mount Arthur Seams. These seams vary in thickness from 0.3 m to more than 6 m. Groundwater usage from the Permian strata is limited by the generally brackish to saline nature of the groundwater and the variable and low yields.

The prime users of groundwater from the Permian strata are the underground mines in the area. MTW do not report any significant seepage into the pits because the evaporation rate exceeds the rate of groundwater seepage from the mine face.

All the hydrostratigraphic units discussed typically yield less than 5 L/s, and therefore in terms of yield are considered less productive aquifers according to the AIP. The Hunter River to the east of MTW is the exception, which due to the presence of a basal gravel unit can support higher yielding irrigation bores in some areas and could be considered a highly productive aquifer according to the criteria in the AIP.

## 5.2 Groundwater Levels and Hydraulic Gradients

WML routinely measure water levels in a network of monitoring bores at MTW. Figure 5.1 shows the locations of the monitoring bores. Multi-level nested monitoring bores sites are generally available at most sites, which permits the study of hydraulic gradients between the alluvium and the Permian sequence, and also within the layered Permian strata. The network of bores forms three north-south trending lines, totalling 13 nested sites that were examined to assess the impacts of the current mining on the groundwater regime.

Table 5.1 summarises the bore locations and available construction information. Groundwater levels from these selected bore sites have been compared against monthly rainfall, shown as Cumulative Rainfall Departure (CRD) in Figure 5.2 5.2 to Figure 5.5. The CRD is a measure of the recorded rainfall deviation from historical averages. A falling trend indicates a period of below average rainfall and conversely a rising trend indicates above average conditions. CRD shows a general upward trend from 2008 due to above average monthly rainfall for this period.

| Table 5.1: MONITORING BORES | | | | |
|---|---|---|---|---|
| **ID (Standpipe No)** | **Easting (m)** | **Northing (m)** | **Depth (mBGL)** | **Target Formation** |
| OH1125 (1) | 316510.8 | 6392875 | | |
| OH1125 (2) | 316510.8 | 6392875 | | |
| OH1125 (3) | 316510.8 | 6392875 | | |
| OH1124 (1) | 316893.2 | 6391526 | | |
| OH1124 (2) | 316893.2 | 6391526 | | |
| OH1123 (1) | 316980.1 | 6389503 | | |
| OH1123 (2) | 316980.1 | 6389503 | | |
| OH1123 (3) | 316980.1 | 6389503 | | |
| OH1122 (1) | 318544.6 | 6387877 | | |
| OH1122 (2) | 318544.6 | 6387877 | | |
| OH1122 (3) | 318544.6 | 6387877 | | |
| WOH2141A (PZ6) | 314922.9 | 6392636 | | |
| WOH2141B (PZ6) | 314922.9 | 6392636 | | |
| WOH2139 (PZ5) | 315165.4 | 6391540 | | |
| WOH2155 (PZ4) | 315279.0 | 6390125 | | |
| WOH2156A (PZ3) | 315837.4 | 6388878 | | |
| WOH2156B (PZ3) | 315837.4 | 6388878 | | |
| PZ7D | 314056.9 | 6392684 | 30 | Permian Seam? |
| PZ7S | 314054.9 | 6392671 | 11 | Alluvium |
| WOH2153A (PZ2) | 313874.3 | 6391503 | | |
| WOH2153B (PZ2) | 313874.3 | 6391503 | | |
| WOH2154 (PZ1) | 314064.0 | 6389972 | | |
| PZ8S | 317002.4 | 6385411 | 12 | Alluvium |
| PZ8D | 317000.8 | 6385418 | 36 | Permian Seam? |
| PZ8S | 317002.4 | 6385411 | 12 | Alluvium |
| PZ9D | 317540.7 | 6385652 | 24 | Permian Seam? |

Notes: Projection MGA94 Zone 56
Multi-level monitoring in the Permian sequence is carried out in all sites with the identifiers '(1)' denoting the shallowest interval through to '(3)' the deepest.

Figure 5.2 presents groundwater levels measured in the line of monitoring bores close to the current Warkworth pits (OH1125, OH1124 and OH1123).

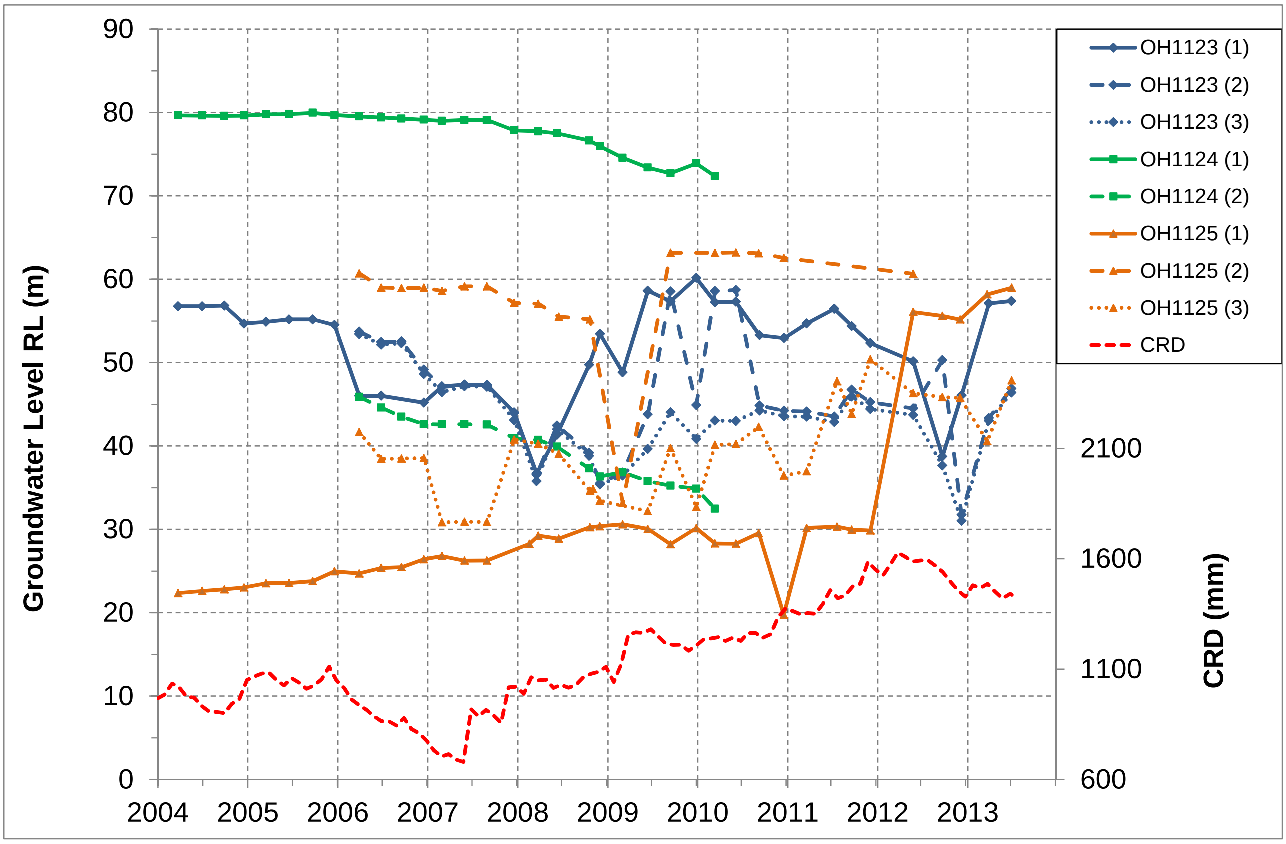



**Figure 5.2: Groundwater levels within the Permian directly west of Warkworth Mine**

Site OH1124 showed a general decline in water level until it was mined out during 2009. The general decline in water level at this site can be attributed to dewatering due to mining. Sites OH1123 and OH1125 show variable water levels over the monitoring period. This variability is likely due to a combination of depressurisation due to mining combined with episodic recharge events from above average rainfall.

Figure 5.3 shows groundwater levels further to the west along a second north to south trending line of bores (PZ6, PZ5, PZ4 and PZ3).

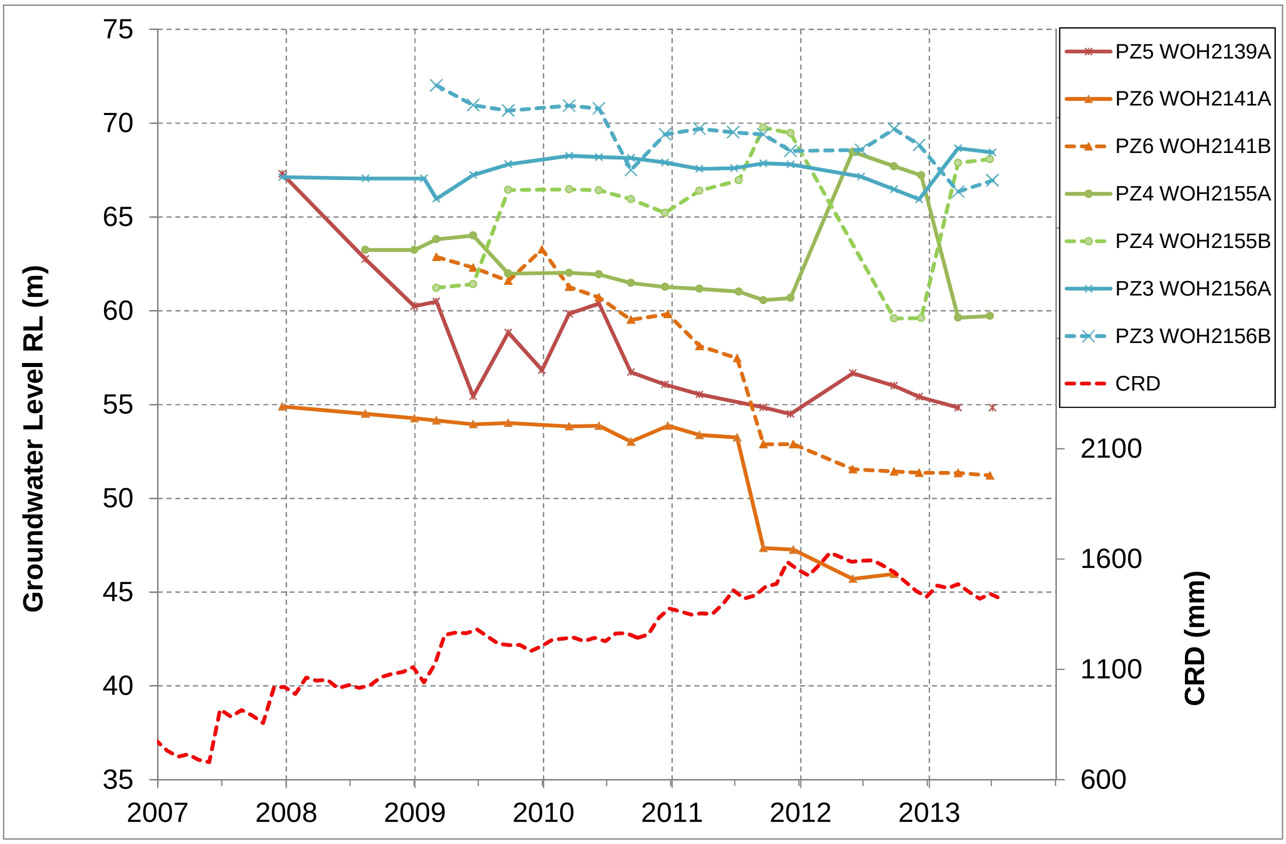



**Figure 5.3: Groundwater levels within the Permian west of Warkworth Mine Pit**

Three of these sites are twin nested monitoring bores with the A suffix denoting the shallower bore in each location. Sites PZ6 (A and B) and PZ5 to the north show downward trends indicating that depressurisation from current mining has extended to these sites, which is about 2 km from the current Warkworth Mine highwall. Depressurisation is less evident to the south at site PZ4 and particularly in the shallower piezometer at site PZ3.

Figure 5.4 presents the hydrographs for the most westerly groundwater monitoring bores between the Warkworth Mine and Wollombi Brook (PZ7, PZ2 and PZ1).

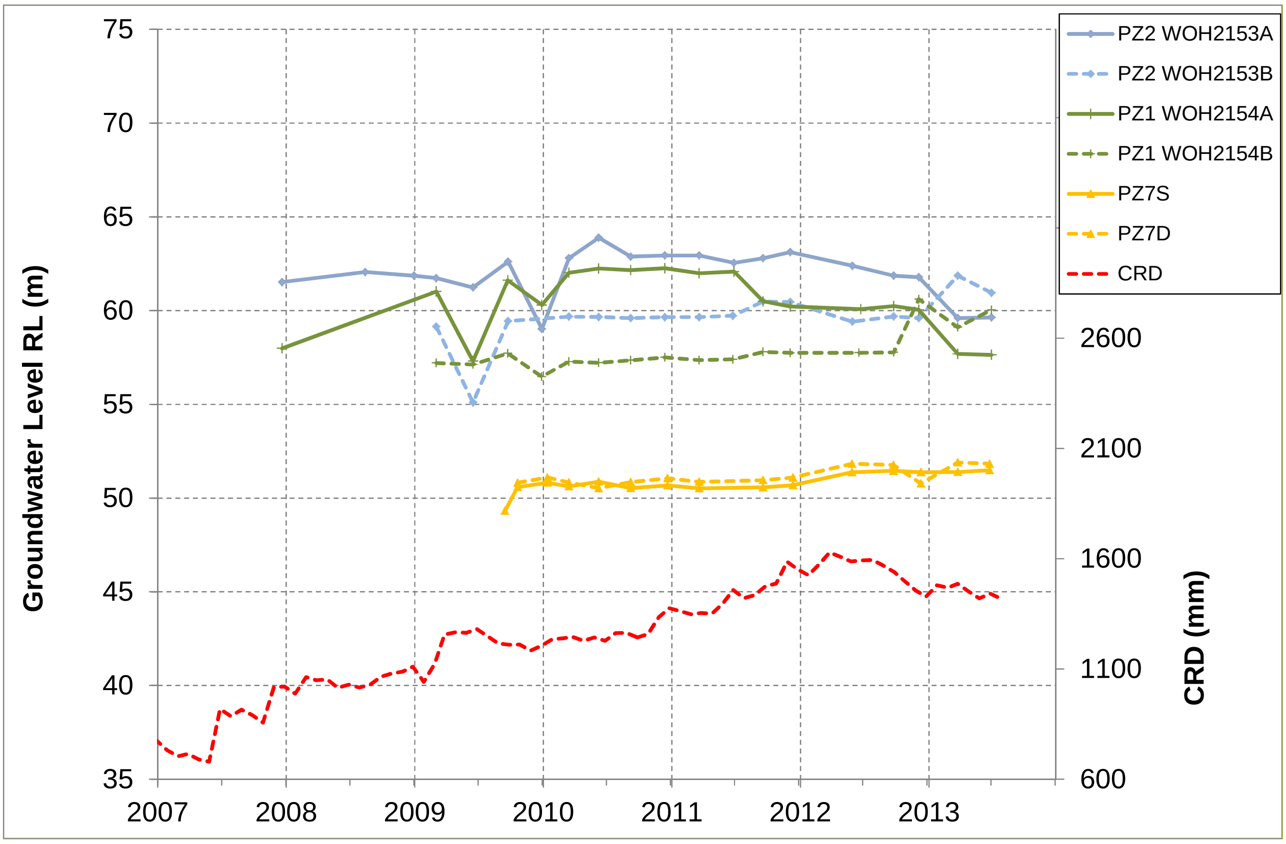



**Figure 5.4: Groundwater levels within the Wollombi Brook alluvium Permian west of Warkworth Mine Pit**

The twin nested completion PZ7 is constructed within alluvium (PZ7S) and the underlying Permian (PZ7D), while the other two sites have both monitoring intervals within the Permian. The three monitoring locations show stable trends and no impact from mining. Hydraulic gradients in this line of bores is likely indicative of a pre-mining condition with a slight downward gradient within the Permian, and slight gradient from the Permian (PZ2 and PZ1) to the north to the Wollombi Brook Alluvium (PZ7). The vertical hydraulic gradient at the Wollombi Brook site PZ7 is relatively flat, indicating limited natural discharge from Permian to the alluvium and vice versa.

To the south of the Warkworth Mine (and the minor extension area) there is a series of three bores close to the MTO Loders Pit where the Wollombi Brook and associated alluvium is at one of its closest points (800 m) to mining. Figure 5.5 shows the groundwater levels measured at these sites.

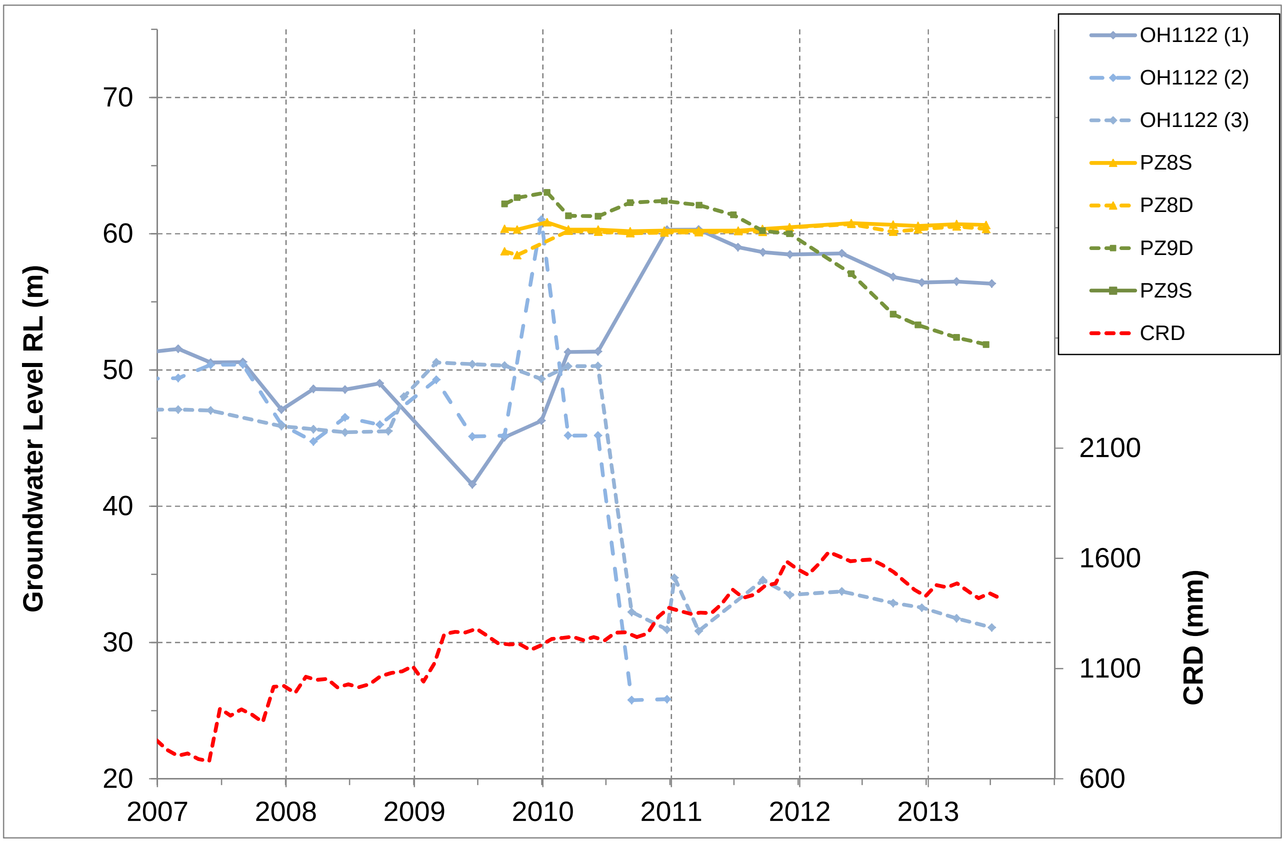



**Figure 5.5: Groundwater levels within the Wollombi Brook alluvium Permian south west of Warkworth Mine Pit**

The nested site OH1122 is between the Warkworth Mine's West Pit to the north and MTO's Loders Pit directly to the south. Depressurisation in the deeper two monitoring zones (OH1122 [2] and [3]) is evident, while perching within the shallow zone {OH1122 (1)} is also evident. This perching demonstrates the low vertical permeability between coal seams in the Permian sequence. Sites PZ8 and PZ9 are twin nested monitoring bores within the Wollombi Brook alluvium and the underlying Permian. There is little difference between the groundwater levels in the two standpipes at site PZ8. There is evidence of drawdown in the Permian underlying the alluvium in site PZ9D, which is also the closest nested monitoring site within alluvium to the currently mine areas. As can be seen in Figure 5.5, drawdown is evident at this site, but is not as obvious in the alluvium monitoring site PZ9S.

## 5.3 Groundwater Users

AGE (2010) assessed groundwater usage from the aquifer systems by reviewing data held on the NSW Government groundwater database and by conducting a bore census on private landholdings to the east of the mine. The bore census included ten bores to the north of the village of Bulga.

The census found that nine of the ten sites were relatively shallow at about 14 m or less in depth, indicating that these facilities are likely to be constructed in the alluvial sediments. AGE (2010) concluded these bores will not be affected by the proposed modification as there was no significant drawdown predicted in the alluvial aquifer. One bore was identified which is expected to be constructed in the underlying bedrock with a depth greater than 60 m where depressurisation was predicted to be in the range of 2 m to 5 m. It was concluded the yield of this bore was unlikely to be affected given the depth of the bore and the available drawdown.

### 5.4 Groundwater Dependent Ecosystems

Cumberland Ecology (2010) identified two potentially groundwater dependent vegetation communities along the Wollombi Brook. These were the Hunter Valley River Oak Forest and the River Red Gum Floodplain Woodland which are in a thin riparian zone along Wollombi Brook about 4 km from the proposed modification.

# 6 IMPACT OF PROPOSED MODIFICATION

### 6.1 Previous Numerical Models

Coal & Allied commissioned Mackie Environmental Research (MER, 2002) to assess the impact of the Warkworth Extension on surface and groundwater as part of the Environmental Impact Statement prepared in 2002. The groundwater study included a numerical groundwater flow model, which assessed the impacts on the groundwater regime. The Department of Planning approved the extension to the Warkworth Mine the following year in 2003 (DA 300-9-2002-i).

As part of that study, MER (2002) recommended additional monitoring bores be installed to monitor depressurisation and water quality in areas west of the extension. Coal & Allied commenced installing the recommended monitoring bores (PZ1 to PZ6) in 2004 after approval. Subsequent water level monitoring in these bores has shown that the predictions of MER (2002) were conservative as the magnitude or extent of depressurisation has not been as extensive as predicted by the model. The inflows to the open cut pit have also not reached the rates predicted by MER (2002).

In 2010, Coal & Allied proposed to further extend Warkworth Mine (the Warkworth Extension Project) about 1 km down-dip and to the west of the area approved in 2003 and commissioned AGE (2010) to assess the potential groundwater impacts. The study included a numerical model that built upon the work of MER (2002). Both the Commonwealth and NSW Governments approved this project, but a subsequent appeal in the NSW Land and Environment Court overturned this approval based on issues unrelated to groundwater. Despite this, the AGE (2010) model is a useful tool to assess the impact of the existing approved mining and the minor extension as it replicated the approved mining. The sections below outline the results of the modelling and the potential impacts of the proposed minor modification.

### 6.2 Depressurisation and Drawdown in Aquifer Systems

MER (2002) simulated the impact of mining from 1981 until 2020, a period of 18 years representing the extension of the mine. Table 6.1 presents measured drawdown in the monitoring bores to the west of the mine in 2012 compared to the drawdown predicted by the MER (2002) numerical model.

| Table 6.1: MEASURED AND PREDICTED DRAWDOWN | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bore ID | Nested Bore No. | Date First Water Level Record | Water Level (mAHD) | | Drawdown 2012 (m) | | Comment |
| | | | First Record (mAHD) | 2012 | Measured | Predicted | |
| OH1122 | A | 22/03/2004 | 50.5 | 56.4 | -5.9 | 28 | less than predicted |
| | B | 30/03/2006 | 44.4 | 25.8 | 18.6 | 28 | less than predicted |
| | C | 1/03/2006 | 47.9 | 32.6 | 15.3 | 28 | less than predicted |
| OH1123 | 1 | 23/03/2004 | 56.8 | 37.7 | 19.1 | 25 | less than predicted |
| | 2 | 30/03/2006 | 53.7 | 31.8 | 21.9 | 25 | less than predicted |
| | 3 | 30/03/2006 | 53.4 | 31.02 | 22.38 | 25 | less than predicted |
| OH1124 | 1 | 23/03/2004 | 79.7 | 72.7 | 7 | 32 | less than predicted |
| | 2 | 30/03/2006 | 45.9 | 32.5 | 13.4 | 32 | less than predicted |
| OH1125 | 1 | 23/03/2004 | 22.3 | 55.2 | -32.9 | 22 | less than predicted |
| | 2 | 30/03/2006 | 60.7 | 60.7 | 0 | 22 | less than predicted |
| | 3 | 30/03/2006 | 41.7 | 45.8 | -4.1 | 22 | less than predicted |
| WOH2139 | A | 21/12/2007 | 67.3 | 54.8 | 12.5 | 14 | less than predicted |
| WOH2141 | A | 21/12/2007 | 54.9 | 46 | 8.9 | 10 | less than predicted |
| | B | 4/03/2009 | 62.9 | 51.2 | 11.7 | 10 | greater than predicted |
| WOH2153 | A | 21/12/2007 | 61.5 | 61.8 | -0.3 | 5 | less than predicted |
| | B | 4/03/2009 | 59.1 | 59.7 | -0.6 | 5 | less than predicted |
| WOH2154 | A | 21/12/2007 | 58 | 60.24 | -2.24 | 3 | less than predicted |
| | B | 4/03/2009 | 57.2 | 57.8 | -0.6 | 3 | less than predicted |
| WOH2155 | A | 14/08/2008 | 62.3 | 59.7 | 2.6 | 10 | less than predicted |
| | B | 4/03/2009 | 61.2 | 59.6 | 1.6 | 10 | less than predicted |
| WOH2156 | A | 21/12/2007 | 67.1 | 65.9 | 1.2 | 12 | less than predicted |
| | B | 4/03/2009 | 72 | 68.8 | 3.2 | 12 | less than predicted |
| PZ7 | S | 22/10/2009 | 50.6 | 50.8 | -0.2 | 5 | less than predicted |
| | D | 22/10/2009 | 50.8 | 50.8 | 0 | 5 | less than predicted |
| PZ8 | S | 16/09/2009 | 60.4 | 60.4 | 0 | 4 | less than predicted |
| | D | 16/09/2009 | 58.7 | 60.4 | -1.7 | 4 | less than predicted |
| PZ9 | S | 16/09/2009 | 61.4 | 60.8 | 0.6 | 4 | less than predicted |
| | D | 16/09/2009 | 62.2 | 51.9 | 10.3 | 4 | greater than predicted |

Table 6.1 indicates that the MER (2002) model was relatively conservative and the magnitude and extent of depressurisation in the Permian coal measures was less than predicted at most monitoring sites. This conservatism is preferable for environmental assessments and is likely due

to a combination of conservative assumptions in the model and above average rainfall since 2008 that resulted in high recharge rates over the last four years.

Appendix A presents the measured and predicted water levels from the AGE (2010) model for the Warkworth Extension Project. This model also appears conservative with the magnitude and extent of depressurisation less than predicted at most monitoring sites, although less so than the MER (2002) model. Importantly, the AGE (2010) model and the monitoring data both indicate no impact on water levels in the Wollombi Brook alluvial aquifer, which has been validated by monitoring.

The proposed modification only increases the approved footprint of mining by about 1%, and the length of the highwall remains unchanged. The timing of the mining also remains unchanged. The proposed modification is therefore not expected to result in any significant or detectable increase in the depressurisation beyond that predicted by previous models, of either MER (2002) or AGE (2010).

## 6.3 Impact on Groundwater Users

AGE (2010) concluded no private bores in the alluvial aquifers will be affected by the Warkworth Extension Project as the numerical model did not predict any significant drawdown in the alluvium. One bore was identified which was expected to be constructed in the underlying Permian bedrock with a depth of greater than 60 m where depressurisation was predicted to be in the range of 2 m to 5 m at the end of mining in 2031. It was concluded the yield of this bore was unlikely to be affected given the depth of the bore and the available drawdown.

It is improbable that the existing approved mine and the minor extension will impact water levels in private bores because:

- two previous modelling efforts by MER (2002) and AGE (2010) are demonstrated to be conservative and have indicated mining will not induce any significant drawdown in the surrounding alluvium where most private bores are located;
- monitoring of the alluvium has confirmed this conclusion to date, with no detectable impact on the alluvial groundwater levels, even in the case where the underlying Permian has been depressurised;
- the AGE (2010) model assumed mining till 2031. Because the proposed modification will be completed by 2021, the drawdown will be less extensive than shown in AGE (2010); and
- the proposed modification only increases the mine footprint by about 1% and therefore the predictions of MER (2002) and AGE (2010) remain valid and conservative indicators of potential impacts.

## 6.4 Groundwater Seepage to Mine

MER (2002) predicted the seepage rate to the open cut pit would increase gradually over the mine life to about 5 ML/day at the end of mining in 2021. This was a relatively conservative prediction, as WML has not observed any significant seepage of groundwater from the active highwall during mining. WML report that no pumping of groundwater seepage from the pits is required, indicating groundwater is removed by evaporation or as moisture within the coal.

AGE (2010) predicted a lower seepage rate to the open cut for the Warkworth Extension that peaked at about 1.25 ML/day (457 ML/year) in Year 18 (2021). This lower rate of seepage is considered more representative given the fact that no significant seepage of groundwater has been observed from the highwall during mining. The seepage rate to the existing mine is not likely to change due to the proposed modification. This is due to its relatively small size and the fact that the length of mined face will not increase, and the mining schedule will remain unchanged.

WML hold Water Licence 20BL170012 under the *Water Act 1912* for dewatering 750 ML/year of Permian groundwater from the Warkworth Mine. This volume is more than sufficient to license the take of water due to the current mining and the proposed modification.

## 6.5 Water Take from Alluvial Aquifer

Both MER (2002) and AGE (2010) predicted the take of groundwater from the surrounding alluvial aquifers due to mining. The graphs presented by MER (2002) show mining gradually depressurising the Permian sequence, which reduces the flux of groundwater from the Permian to the alluvium, and eventually (after decades of mining) reverses the direction of flow from the alluvium into the underlying Permian in some areas. MER (2002) predicted that the loss of upward flow to the alluvium peaks at 0.25 ML/day (73 ML/year) for the Hunter River alluvium, and 0.28 ML/day (102.3 ML/year) to Wollombi Brook alluvium in 2021.

As discussed above, the monitoring of water levels has shown that the magnitude and extent of depressurisation predicted by MER (2002) was conservative and the actual take of water from the alluvium is likely to be much lower than is predicted. Unfortunately this water take cannot be directly measured, only estimated using modelling.

AGE (2010) predicted that the flow of Permian groundwater to the Wollombi Brook alluvium would reduce by 0.1 ML/day (36.3 ML/year) by 2031 due to the Warkworth extension. The predicted take at the end of the currently approved operation was very low and essentially undetectable at about 0.02 ML/day (7.3 ML/year). AGE (2010) assessed the take of water from the Warkworth extension only, and filtered out the take resulting from the approved mining at Warkworth and surrounding mines. When the take of water from the approved mining is considered, it could reach 0.1 ML/day (36.3 ML/year) at 2020.

The AIP requires groundwater loss or leakage from the alluvium is accounted for with water licences. The modelling indicates the proposed modification, inclusive of the existing operations, will induce up to (36 ML/year) water loss from the Wollombi Brook alluvium.

WLM has an existing Part 5 licence (Water Licence 20BL170012) that licences seepage into the pit from the Permian. WML intend to request the New South Wales Office of Water (NOW) disaggregate Water Licence 20BL170012 and apportion sufficient volume to licence the predicted loss of this water from the Wollombi Brook alluvium due to the current mining and the proposed minor modification.

## 6.6 Base Flows in Creeks

AGE (2010) assessed the impact of the Warkworth Extension Project on groundwater base flow in Wollombi Brook. It was concluded that the Warkworth Extension Project would have resulted in a slight decrease in base flow in Wollombi Brook of about 0.1 ML/day (36.25 ML/year) at the end of mining in 2031. At year 2020, the data presented by AGE (2010) indicates the decrease in flow will be undetectable. The flow monitoring gauge at Bulga in the Wollombi Brook indicates flow exceeds 30 ML/day for 50% of measurements, but is essentially dry for 10% of the time. Given the existing flow regime and the very small volumes of water predicted to be lost from the Wollombi Brook, it is considered the proposed modification, inclusive of existing operations, will have no detectable impact on flows.

WML hold Water Licence WAL 18558 under the *Water Management Act 2000* to extract 50 ML/year of Wollombi Brook. The modelling completed to date indicates this is more than sufficient to licence the very small volumes of water predicted to be lost from the Wollombi Brook.

MER (2002) concluded there would be no impact on flow in the Hunter River because the sedimentary sequence beneath the coal seams "*provides a thick and relatively impermeable succession of siltstone and claystones that probably serves to isolate groundwater movement in the Jerry's Plains Group from the shallow alluvial aquifer systems associated with the Hunter River".* AGE (2010) confirmed this with modelling to show no impacts on flows in the Hunter River.

## 6.7 Impact on Hydraulic Connections

The proposed modification, inclusive of existing operations, will not impact on the hydraulic properties or hydraulic connections between aquifers.

## 6.8 Water Quality

The model predictions do not indicate any significant drawdown is likely to occur in the alluvial aquifer and therefore a significant change in alluvial groundwater quality, or base flow quality in Wollombi Brook is not expected to occur.

To protect surface water the AIP requires *"no increase of more than 1% per activity in the long term average salinity in a highly connected surface water source at the nearest point to the activity".* Dewatering due to pit development is expected to reduce the flux of saline groundwater to local streams. This effectively reduces the discharge of more saline groundwaters into the streams and therefore it is improbable that the proposed modification, inclusive of existing operations, would increase stream salinity.

At closure of the mine, the evaporative pumping effect of the final void will act as a local sink for groundwater and will result in a gradual increase in the salinity of the void water over time. The quality of the water will be controlled by the groundwater seepage quality, leaching of salts from the spoil piles and evaporative concentration of rainfall inputs. The salinity of the water would be expected to be brackish, becoming saline over time, which is typical for coal mine voids. The void will act as a sink for the local groundwater and therefore attract water from the surrounding coal measures, with the hydraulic gradients preventing any migration of pit water back into the coal measures, or migration from the pit to Wollombi Brook or the Hunter River.

## 6.9 Groundwater Dependent Ecosystems

An ephemeral perched aquifer is present in the aeolian Warkworth Sands that overlies the coal measures to the north-east of Warkworth Mine. Due to their ability to store water, the sands support a unique woodland known as the Warkworth Sands Woodland. The fine grained sands are up to approximately 3 m thick and overlie a low permeability base of residual clay associated with the underlying strata. The low permeability clays reduce vertical flow of groundwater and result in the formation of an ephemeral perched water table at the base of the sand mass.

The water table formed at the base of the Warkworth Sands is perched and not in direct hydraulic connection with the underlying Permian fractured rock. Therefore, the existing mine and the proposed minor extension will not impact on the Warkworth Sands ephemeral aquifer or the associated vegetation community.

Cumberland Ecology (2010) identified groundwater dependent vegetation communities along Wollombi Brook about 2.5 km from the proposed modification. These vegetation communities are likely to be extracting groundwater from the shallow alluvial aquifer, which will not be impacted by mine dewatering in this location.

### 6.10 Groundwater Recovery

Once mining operations cease, dewatering of the open pit will not be required and a slow recovery in groundwater levels in the area will occur over time. Groundwater and rainfall inflows will slowly fill the void forming a lake and eventually reach an average stable water level, which will be influenced by the balance of inflows from groundwater, surface runoff from the pit walls and spoil, and losses from evaporation.

At the cessation of mining, a relatively high groundwater gradient between the open void and the coal seam aquifers, established during mining will remain initially; however, as a lake begins to form in the void, the gradient is reduced and the rate of groundwater inflow will slow. Eventually a state of equilibrium will occur where inputs are balanced by outputs.

The rate of recovery of groundwater levels in the aquifers depends on rainfall, with years of below average rainfall extending the recovery period and wet years reducing the time for stabilisation.

The configuration of the final void will be unaffected by the proposed modification with the deepest area of mining in the north pit remaining open. Both MER (2002) and AGE (2010) predicted groundwater levels will stabilise at about RL -30m AHD.

The pre-mining groundwater levels in the area of the open void are about 60m AHD, and therefore the void lake level will reach a new equilibrium level be approximately 90 m below the water level in the surrounding aquifers and act as an evaporative sink. Full recovery back to the pre-mining groundwater levels will not occur as the rate of evaporation exceeds the inputs of direct rainfall, runoff and groundwater seepage.

The evaporative pumping effect of the final void lake will result in a permanent zone of depressurisation developing in the surrounding Permian units. However as the hydraulic gradients at the pit will be less than that induced by mining, the long-term drawdown and take of water from the Permian and alluvial aquifer systems is expected to be within the limit predicted for the mining phase. Therefore, the water licenses WML hold to license water take from the Permian and alluvial groundwater systems are sufficient to license post mining take of water for the proposed modification, inclusive of existing operations. The post mining zone of depressurisation that will remain in the Permian will not impact on water users in the surrounding alluvial aquifers as the recharge rate from the diffuse recharge and river leakage is sufficient to replace the relatively small water loss from the depressurisation of the underlying Permian.

## 7 AQUIFER INTERFERENCE POLICY

The tables below compare the proposed modification against the NSW AIP (NOW, 2012).

| Table 7.1: ACCOUNTING FOR OR PREVENTING THE TAKE OF WATER | | |
|---|---|---|
| AIP requirement | | Proponent response |
| 1 | Described the water source (s) the activity will take water from? | Based on the AIP the groundwater system impacted by the proposed modification can be separated into two systems, as follows:<br>• porous and/or fractured consolidated sedimentary rock of the Permian coal measures; and<br>• groundwater within alluvium associated with the Wollombi Brook and Hunter River alluvium.<br>Water quality and yields for the coal measures and Wollombi Brook is considered a less productive aquifer according to the AIP, while the Hunter River alluvium is considered a highly productive aquifer. |
| 2 | Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity? | Predicted take from for existing mine and proposed minor modification:<br>• Permian coal measures: 457 ML/year<br>• Wollombi Brook alluvium: <36.3 ML/year<br>• Hunter River alluvium: 0 ML/year<br>• Hunter River (surface water): 0 ML/year |
| 3 | Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity? | Predicted take from:<br>• Permian coal measures: <457 ML/year<br>• Wollombi Brook alluvium: <36.3 ML/year<br>• Hunter River alluvium: 0 ML/year<br>• Hunter River (surface water): 0 ML/year |
| 4 | Made these predictions in accordance with Section 3.2.3 of the AIP? (page 27) | Based on 3D numerical modelling conducted by AGE (2010) and MER (2002). |
| 5 | Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources? | Predicted take from:<br>• Permian coal measures: <457 ML/year<br>• Wollombi Brook alluvium: <36.3 ML/year<br>• Hunter River alluvium: 0 ML/year<br>• Hunter River (surface water): 0 ML/year |
| 6 | Described how any licence exemptions might apply? | Not necessary. |
| 7 | Described the characteristics of the water requirements? | There are no water requirements; however, additional interception of groundwater due to the proposed modification is predicted |
| 8 | Determined if there are sufficient water entitlements and water allocations that are able to be | Coal & Allied hold Water License 20BL170012 under *Water Act 1912* for dewatering 750 ML/year of Permian groundwater from the Warkworth mine per year. This volume is more than sufficient to license the take of water due to the proposed |

| Table 7.1: ACCOUNTING FOR OR PREVENTING THE TAKE OF WATER | | |
|---|---|---|
| **AIP requirement** | | **Proponent response** |
| | obtained for the activity? | modification.<br><br>WML intend to request NOW disaggregate Water Licence 20BL170012 and apportion sufficient volume to licence the predicted loss of this water from the Wollombi Brook alluvium.<br><br>WML hold Water Licence WAL 18558 under the Water Management Act 2000 to extract 50 ML/year of Wollombi Brook. The modelling completed to date indicates this is more than sufficient to licence the very small volumes of water predicted to be lost from the Wollombi Brook. |
| 9 | Considered the rules of the relevant water sharing plan and if it can meet these rules? | Compliant – see Section 6 of report. |
| 10 | Determined how it will obtain the required water? | Via seepage to the highwall face, but most will likely evaporate or be removed as moisture in coal and will not enter the site water circuit. |
| 11 | Considered the effect that activation of existing entitlement may have on future available water determinations? | Current surface water entitlement is 2,703 ML/yr, and groundwater entitlement is 10 ML/yr - impacts are considered negligible against existing entitlements. |
| 12 | Considered actions required both during and post-closure to minimize the risk of inflows to a mine void as a result of flooding? | Flood assessment was undertaken as part of the Warkworth Extension Project. The results indicated that the Project's footprint was above the 1 in 100 year ARI flood event. |
| 13 | Developed a strategy to account for any water taken beyond the life of the operation of the project? | Surrender of existing water entitlements that are used to license take of water. |
| | *Will uncertainty in the predicted inflows have a significant impact on the environment or other authorized water users?*<br><br>*Items 14-16 must be addressed if so.* | Risks to groundwater systems are low as the proposed modification is relatively distant from the alluvial aquifer systems. Available monitoring data indicates the two groundwater models MER (2002) and AGE (2010) have been relatively conservative, and despite this conservatism the predicted impacts are still negligible and manageable, so the uncertainty in the predictions is not considered to have the potential to impact on the environment or water users. |
| 14 | Considered any potential for causing or enhancing hydraulic connections, and quantified the risk? | See Section 6 of report. |
| 15 | Quantified any other uncertainties in the groundwater or surface water impact modeling conducted for the activity? | Risks to groundwater systems are low as the proposed modification is relatively distant from the alluvial aquifer systems. Available monitoring data indicates the two groundwater models MER (2002) and AGE (2010) have been relatively conservative, and despite this conservatism the predicted impacts are still negligible and manageable, so the uncertainty in the predictions is not considered to have the potential to impact on the environment or water users. |
| 16 | Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for? | Yes.<br>See Section 8 of report. |

| Table 7.2: DETERMINING WATER PREDICTIONS | | |
|---|---|---|
| AIP requirement | | Proponent response |
| 1 | Addressed the minimum requirements found on page 27 of the AIP for the estimation of water quantities both during and following cessation of the proposed activity? | Based on two conservative numerical groundwater MER (2002) and AGE (2010). |

| Table 7.3: OTHER REQUIREMENTS | | |
|---|---|---|
| AIP requirement | | Proponent response |
| 1 | Establishment of baseline groundwater conditions? | Compliant - Refer Section 5 of report. |
| 2 | A strategy for complying with any water access rules? | Water licenses held by proponent |
| 3 | Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users? | None predicted – see Section 6 of report. |
| 4 | Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources? | None predicted – see Section 6 of report. |
| 5 | Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems? | None predicted – see Section 6 of report. |
| 6 | Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems? | None predicted – see Section 6 of report. |
| 7 | Potential to cause or enhance hydraulic connection between aquifers? | None predicted – see Section 6 of report. |
| 8 | Potential for river bank instability, or high wall instability or failure to occur? | Not assessed, but improbable. |
| 9 | Details of the method for disposing of extracted activities (for CSG activities)? | N/A |

# 8 GROUNDWATER MONITORING SYSTEM

Groundwater monitoring undertaken by WML is detailed in MTW's Water Management Plan. The groundwater monitoring program specifies routine measurements of pH, EC and standing water level. On a periodic basis (nominally once per annum), a comprehensive suite of analytes are measured, including major anions, cations and metals. The currently approved monitoring program is considered sufficient to monitor the impact of the existing mining and the proposed minor modification on the groundwater regime.

The AIP requires consideration of *"strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for".* It is recommended that the existing groundwater models be updated every four years to reassess the take of water from the Permian and alluvial aquifer systems.

# 9 REFERENCES

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Department of Mineral Resources, (1993),*"Hunter Coal Field Regional Geology",* Geological Series Sheet 9033 and part of 9133, 9032 and 9132, second edition 1993.

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Glen, R.A and Beckett, J., (1993), *"Hunter Coal Field Regional Geology",* (Second Edition).

Mackie Environmental Research, (2002), *"Extension of Warkworth Coal Mine Assessment of Environmental Impacts Surface and Groundwater Management Studies"*, August 2002.

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**AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD**

Reviewed by:

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Principal Hydrogeologist

**DANIEL BARCLAY**
Principal Hydrogeologist

# LIMITATIONS OF REPORT

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this report for the use of EMGA Mitchell McLennan in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 12 August 2013.

The methodology adopted and sources of information used by AGE are outlined in this report. AGE has made no independent verification of this information beyond the agreed scope of works and AGE assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to AGE was false.

This study was undertaken between 22 August and 3 September 2013 and is based on the conditions encountered and the information available at the time of preparation of the report. AGE disclaims responsibility for any changes that may occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. It may not contain sufficient information for the purposes of other parties or other users. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

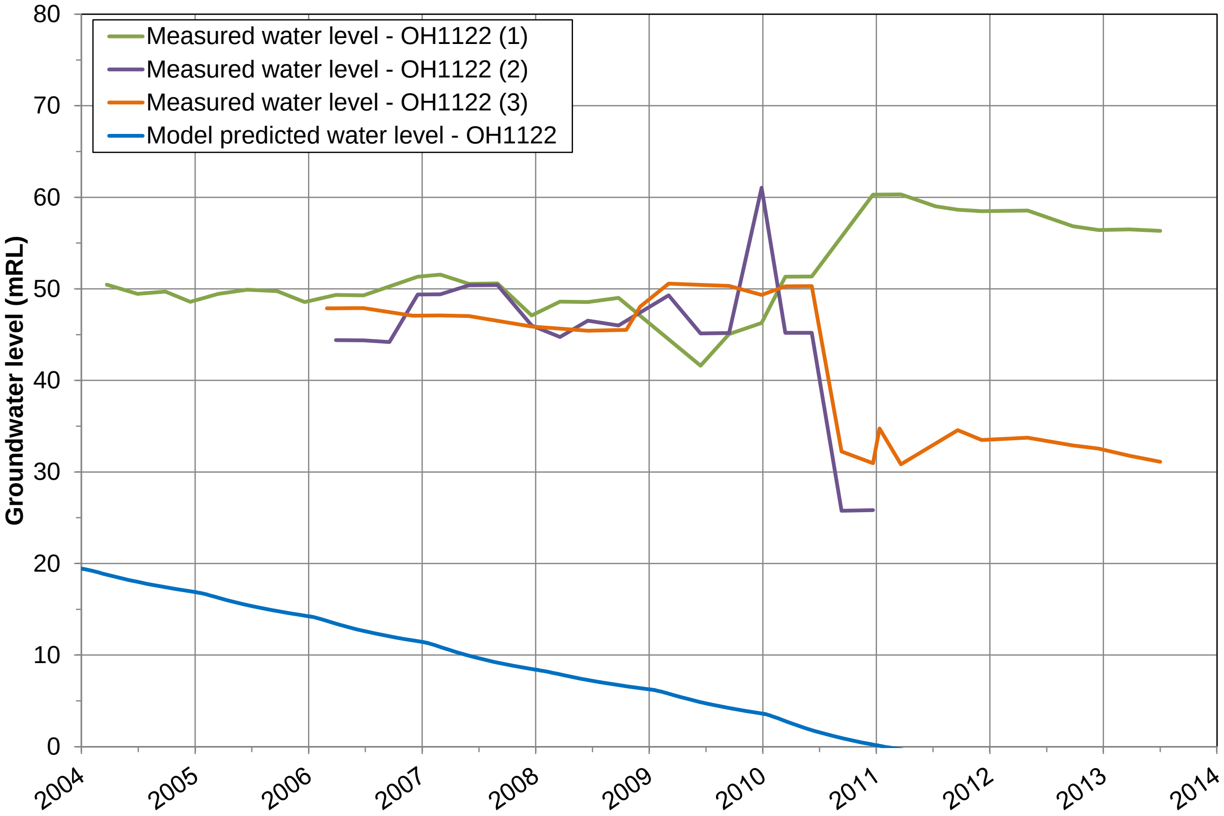
This report contains information obtained by inspection, sampling, testing and other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. Where borehole logs are provided they indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of the site, as constrained by the project budget limitations. The behaviour of groundwater is complex. Our conclusions are based upon the analytical data presented in this report and our experience.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, AGE must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge, information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

## Appendix A

## HYDROGRAPHS – MEASURED AND PREDICTED WATER LEVELS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Measured water level - OH1122 (2)
Measured water level - OH1122 (3)
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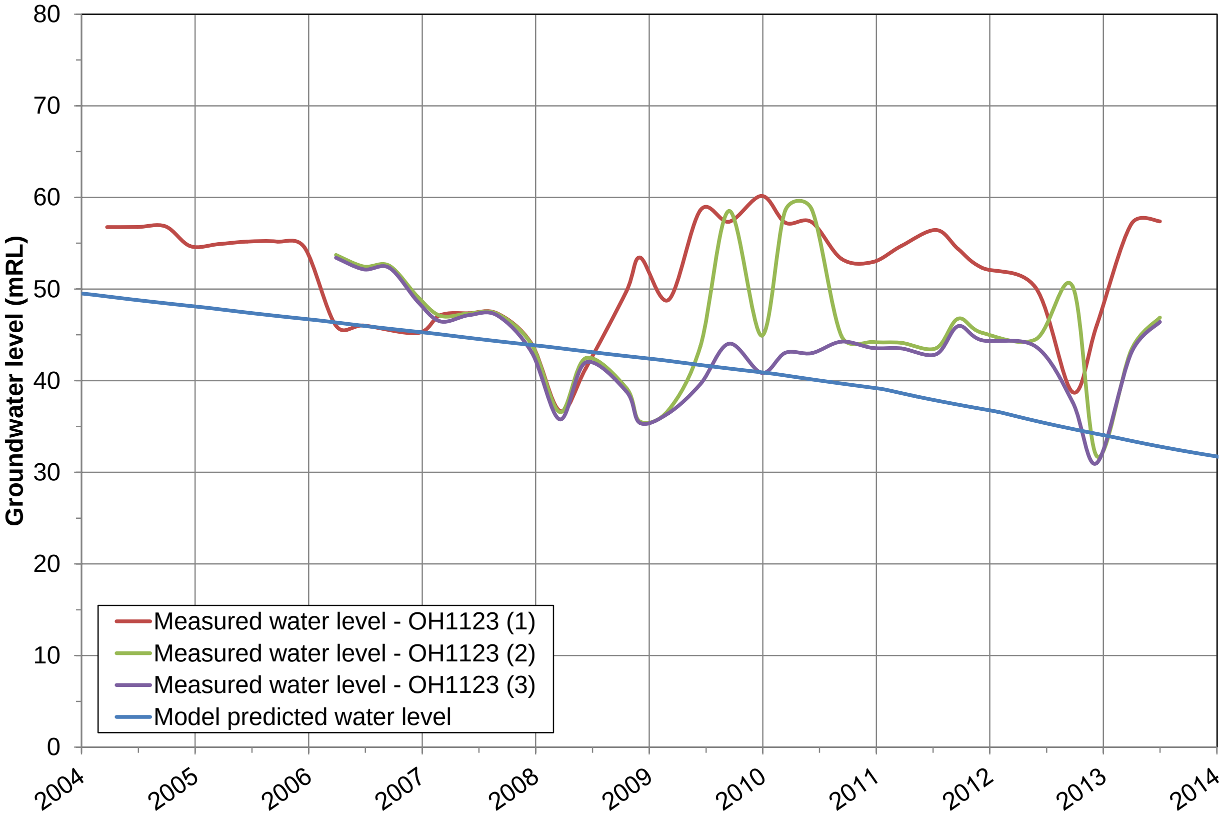
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Measured water level - OH1123 (3)
Model predicted water level
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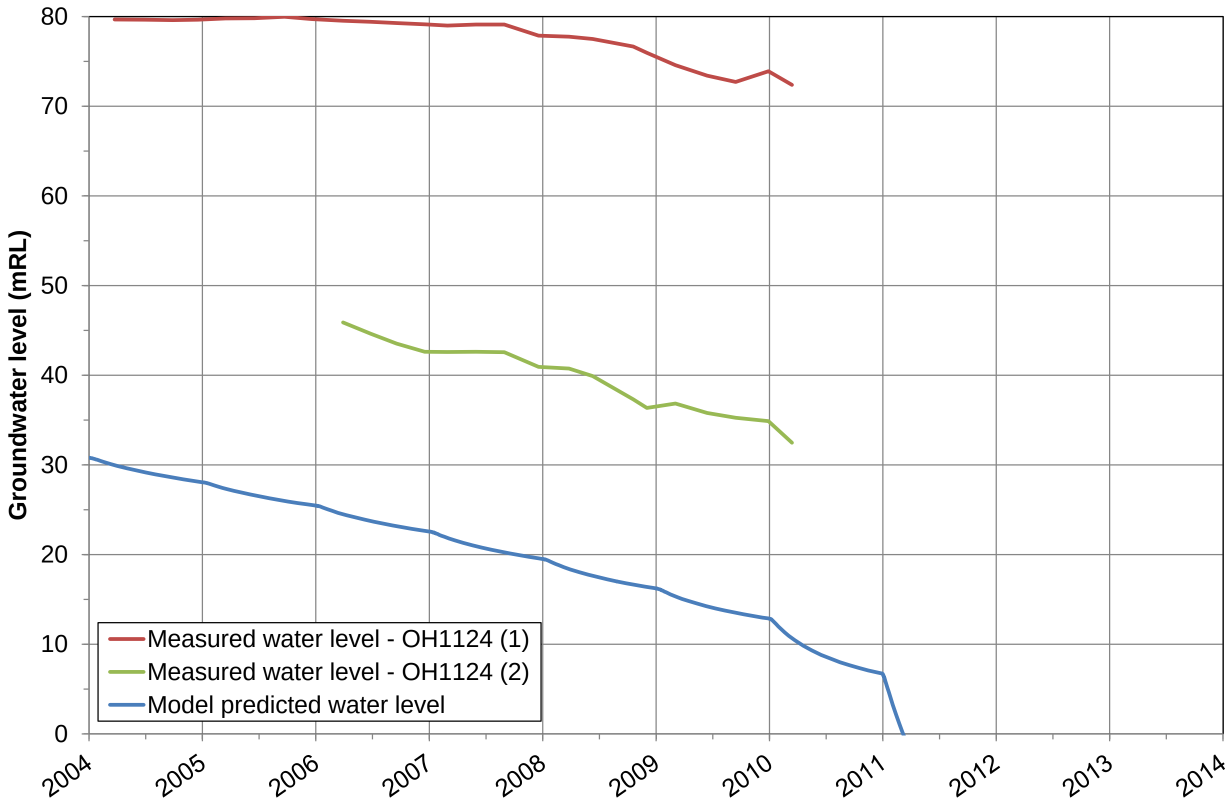
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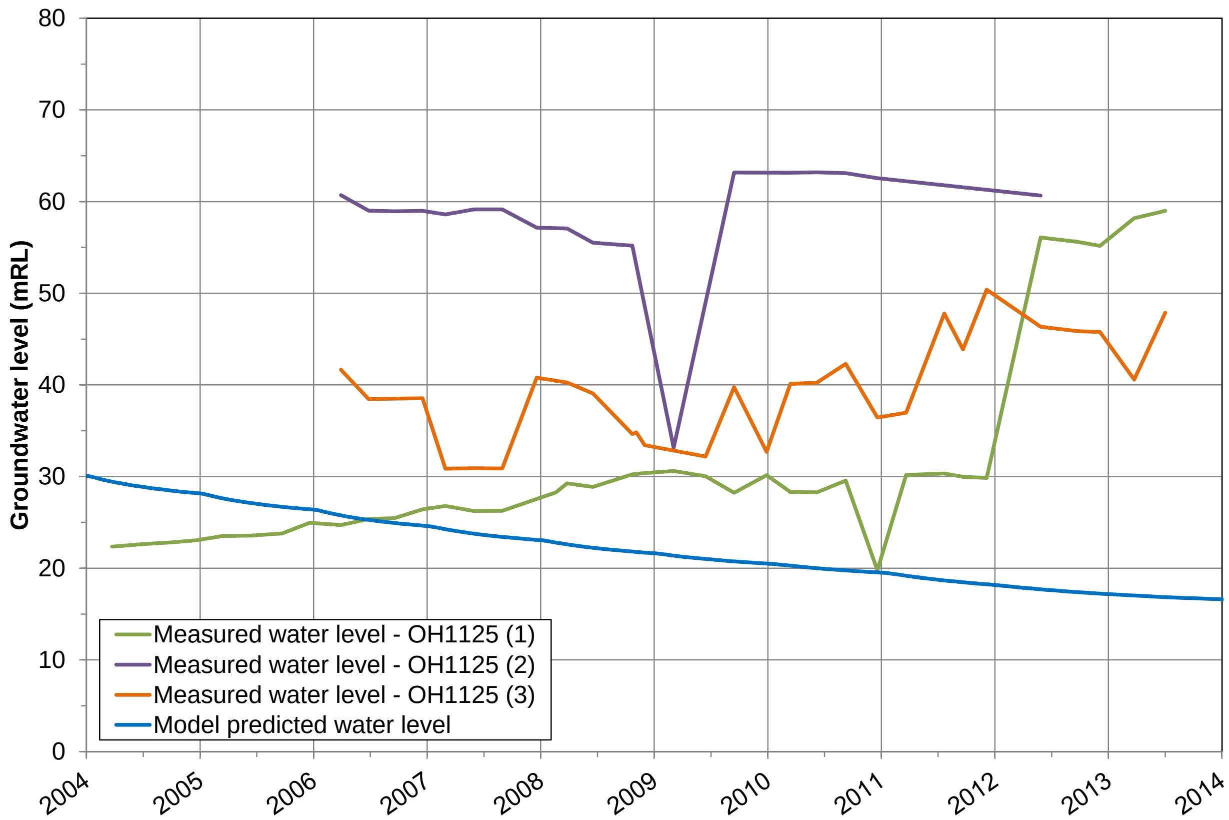
2014
Measured water level - OH1124 (1)
Measured water level - OH1124 (2)
Model predicted water level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2014
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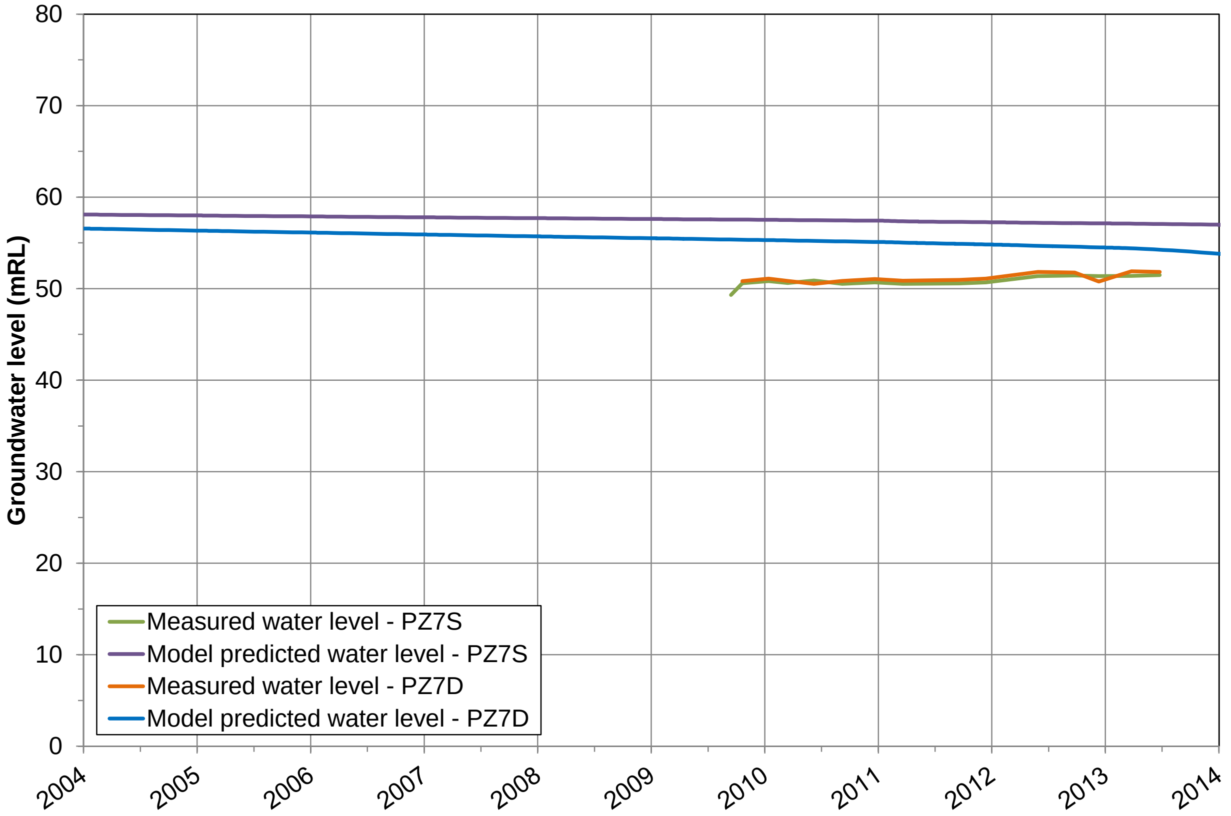
Measured water level - OH1125 (3)
Model predicted water level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Groundwater level (mRL)
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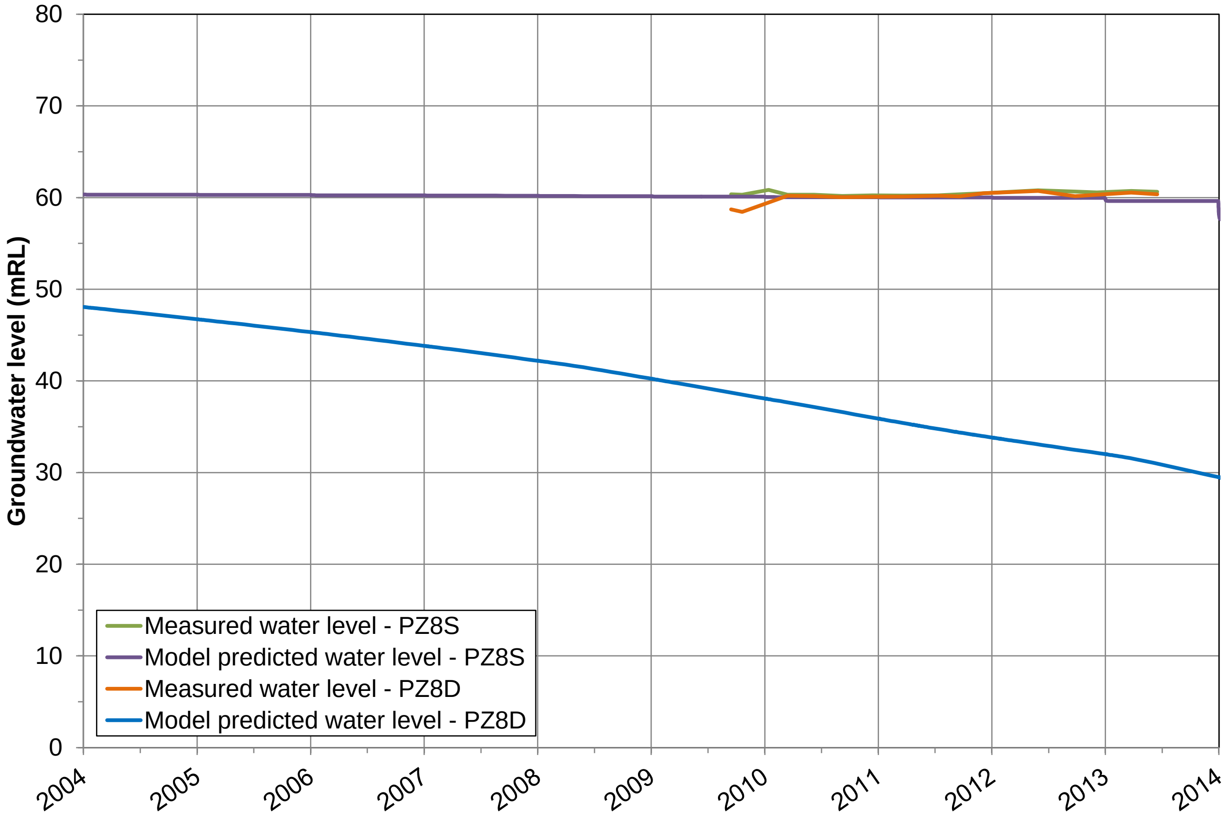
2014
Measured water level - PZ7S
Model predicted water level - PZ7S
Measured water level - PZ7D
Model predicted water level - PZ7D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2014
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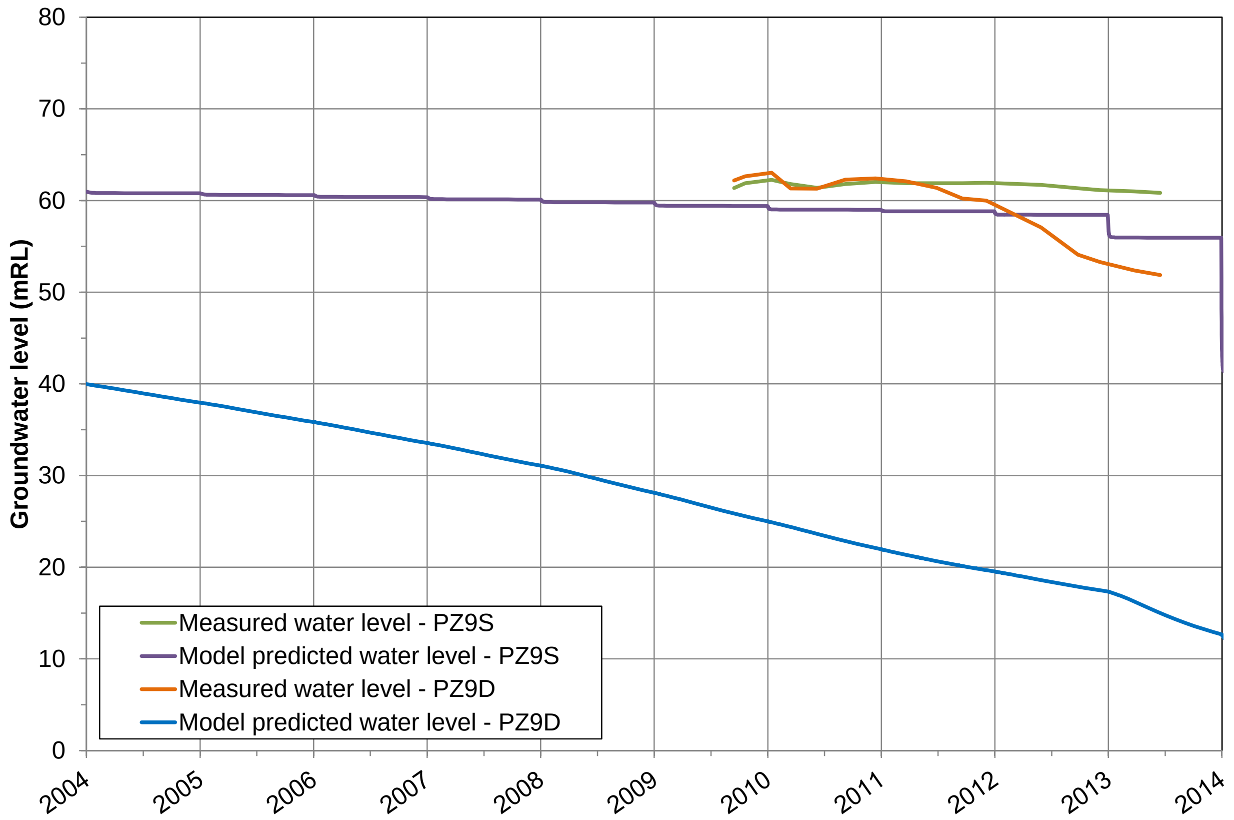
Model predicted water level - PZ8S
Measured water level - PZ8D
Model predicted water level - PZ8D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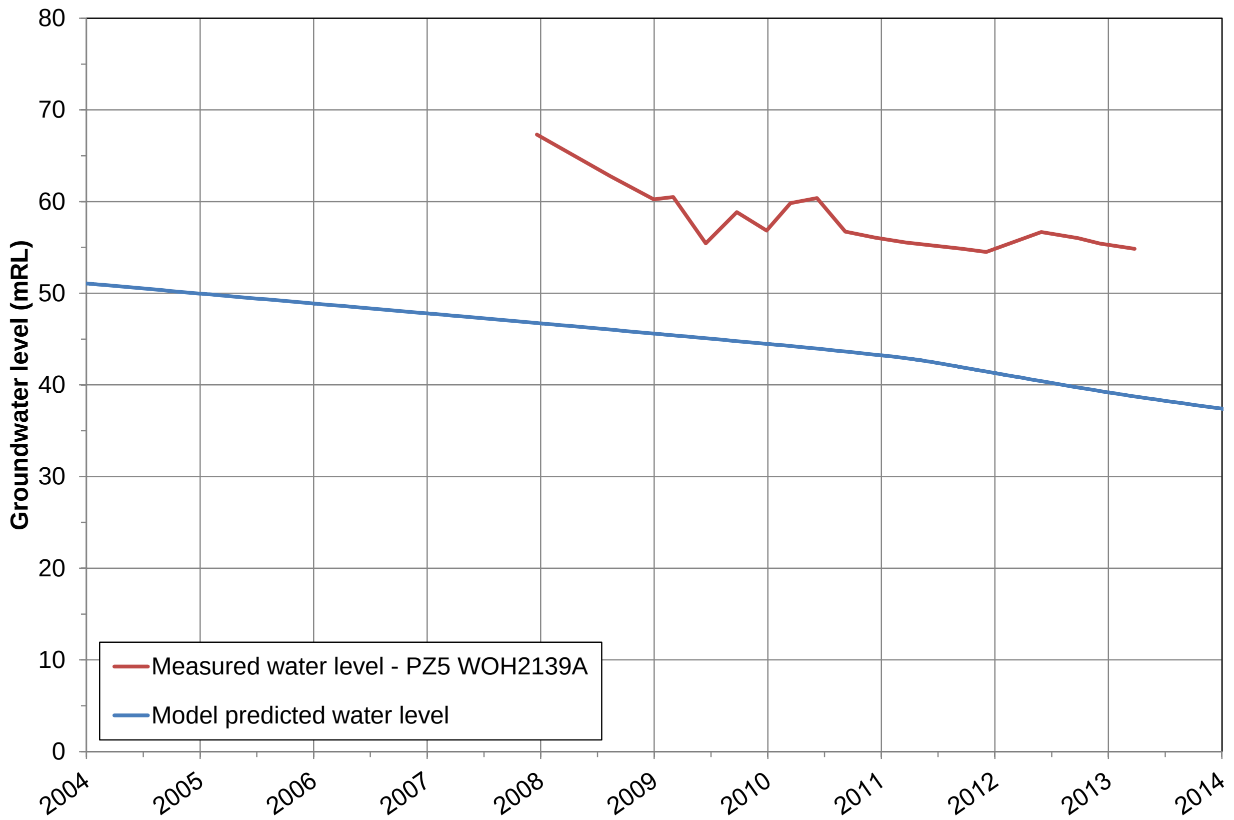
Measured water level - PZ9D
Model predicted water level - PZ9D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2014
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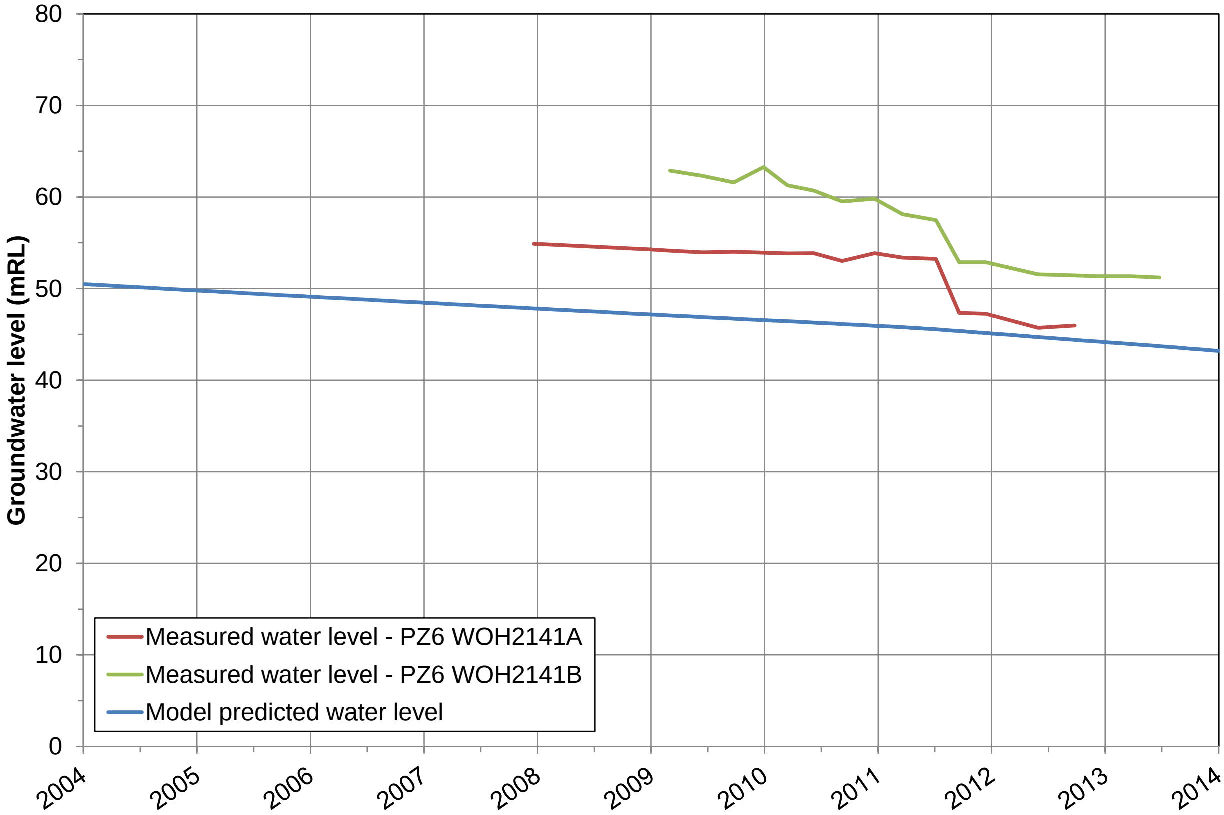
Model predicted water level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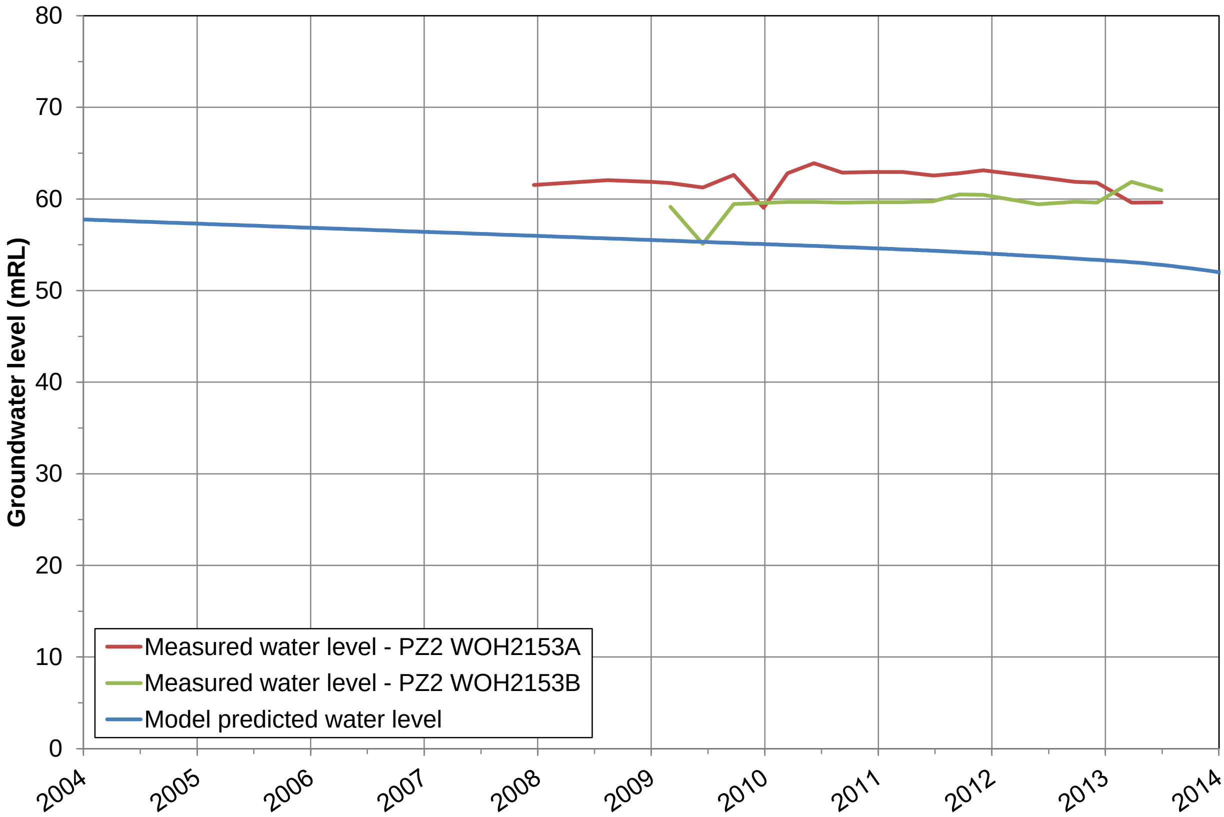
Model predicted water level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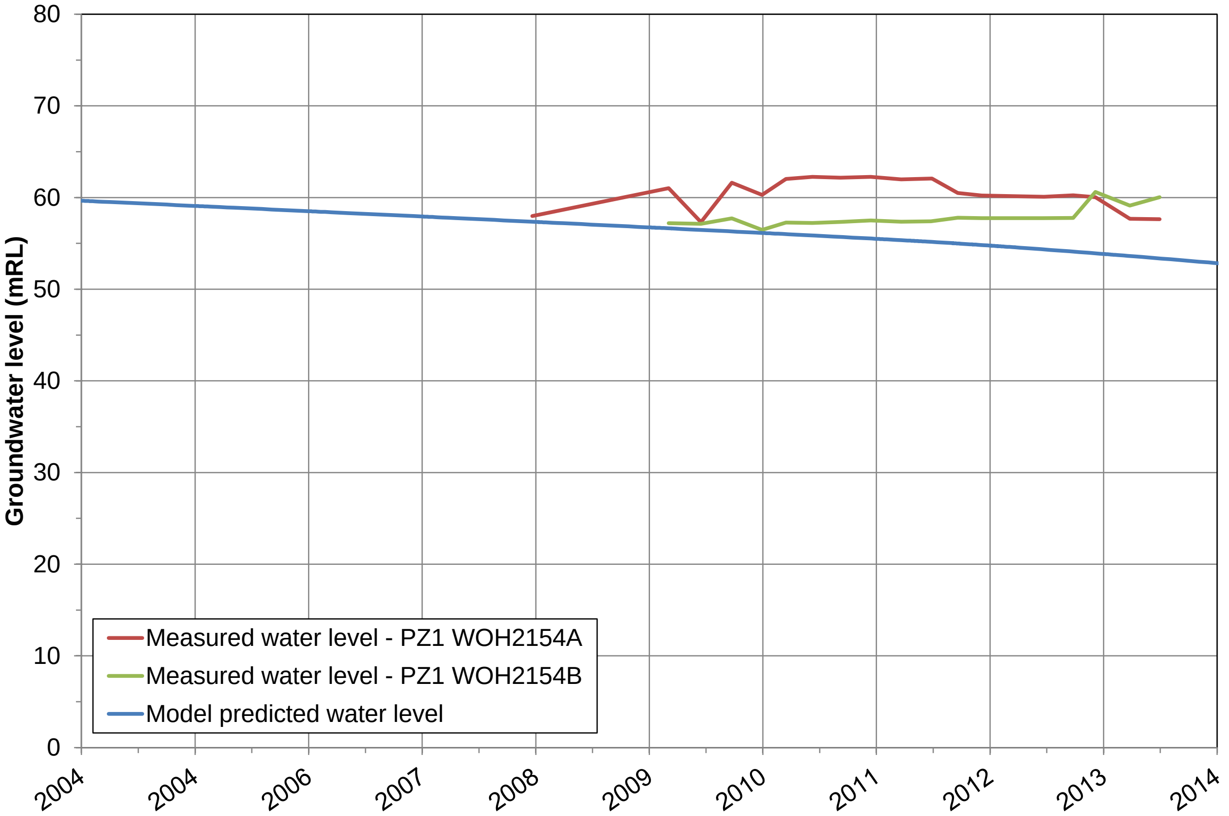
Model predicted water level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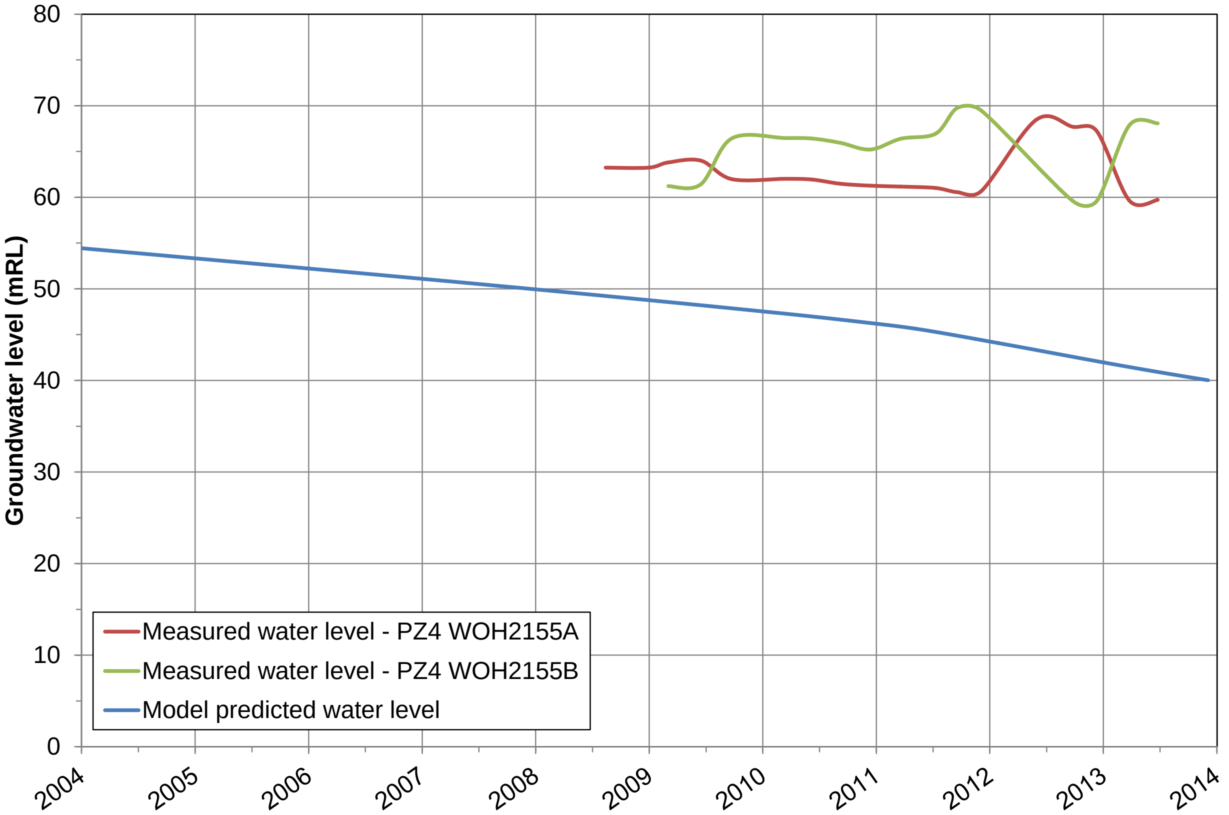
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Groundwater level (mRL)
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Measured water level - PZ4 WOH2155B
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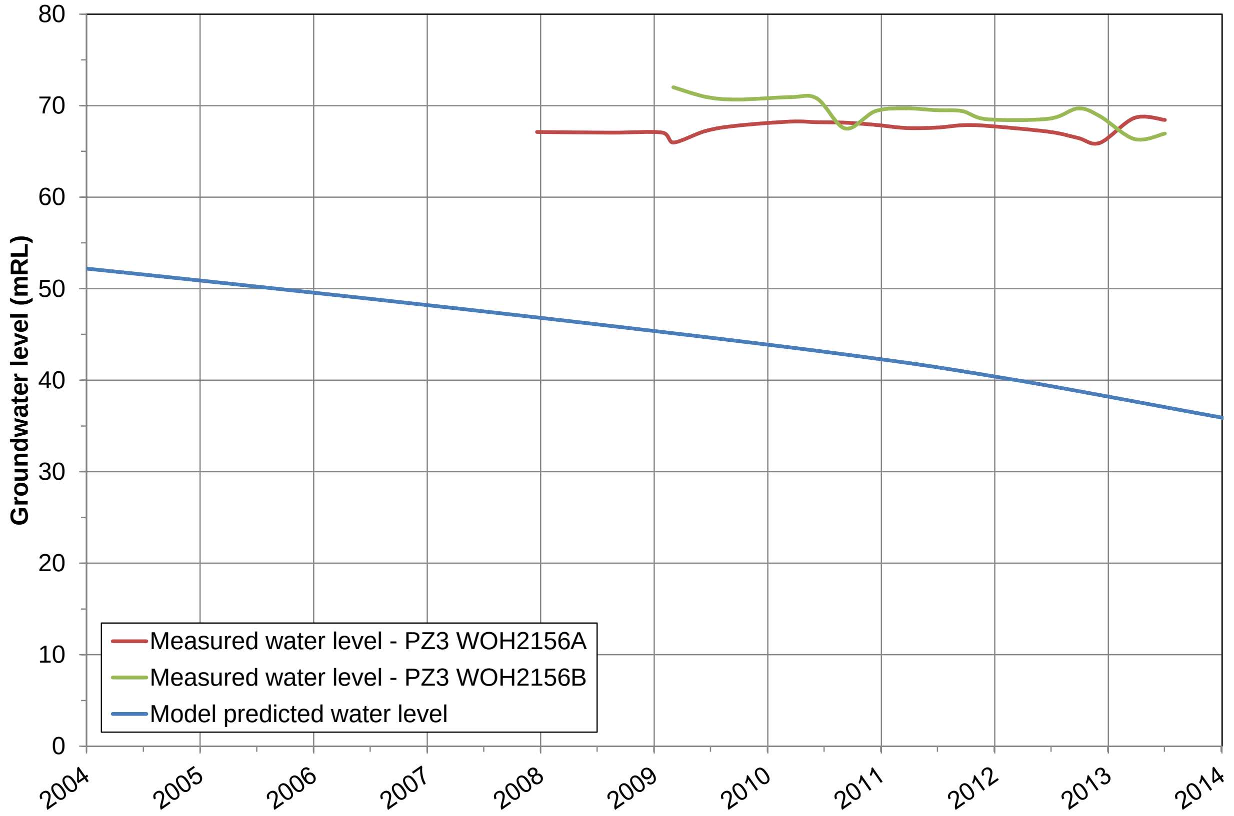
Groundwater level (mRL)
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2011
2012
2013
2014
Measured water level - PZ3 WOH2156A
Measured water level - PZ3 WOH2156B
Model predicted water level