MOOLARBEN COAL MINES PTY LIMITED

MOOLARBEN COAL PROJECT
GROUNDWATER ASSESSMENT

RESPONSE TO CONCERNS RAISED BY INDEPENDENT HEARING AND ASSESSMENT PANEL (IHAP)

BY

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1 BACKGROUND

The Independent Hearing and Assessment Panel (the “Panel”) appointed for the Moolarben Coal Project comprised:

- Emeritus Professor Jim Galvin (Chairman) – Subsidence Expert
- Mr Colin Mackie – Groundwater Expert
- Mr Peter Karantonis – Noise Expert

During the course of the Panel’s assessment of the EA documentation, Mr Mackie has raised a number of questions or comments relating to the groundwater impact assessment, which have been detailed in a series of emails, viz:

- Email from Colin Mackie to Peter Dundon, dated 18 October 2006
- Email from Colin Mackie to Alan Wells, dated 15 November 2006
- Email from Colin Mackie to Alan Wells, dated 28 November 2006

In the following sections, responses to the various questions and concerns raised in these emails are provided.

2 EMAIL DATED 18 OCTOBER 2006

2.1 Alluvial Aquifers

Mr Mackie asked:

"The alluvial aquifer systems associated with the major surface drainages are water stores even though low storage may prevail at the present time. How accurately have these aquifers been mapped ie. has there been any definitional drilling and testing particularly in respect of the Goulburn River alluvium and major creeks?"

Response: The alluvium as shown on the plans has been derived from the published geological map, supplemented where appropriate on the basis of drilling results. No drilling carried out specifically to delineate the extent of alluvium.

Two piezometers were installed specifically in the Moolarben Creek alluvium - PZ55 (west of Open Cut 1) and PZ72C (southeast of Open Cut 3). No significant Quaternary alluvium associated with Goulburn River in the project area has been identified apart from the alluvium in the Moolarben Creek-Lagoon Creek tributary catchments. However, it is noted that Ulan Coal Mines Limited (UCML) submitted to the Panel that there is a small area of alluvium associated with Goulburn River close to their RO water treatment plant. This is adjacent to the Goulburn River diversion channel. Visual inspection of the excavated side slopes of the diversion channel indicates that the alluvium in this area would be quite shallow. Groundwater levels in the underlying Permian coal measures are well below the base of both Goulburn River and the base of alluvium in this area, indicating that the alluvium is not hydraulically connected to the coal measures in this area.

Two piezometers were installed in the Tertiary paleochannel alluvium - PZ58 (near Open Cut 3) and PZ52 (east of Open Cut 1). One test bore was drilled to test the Tertiary alluvium (TB52B). One piezometer was completed in shallow alluvium in Murragamba Creek valley (PZ50C). Additional information on the occurrence and depths of alluvium has been obtained from the drill-logs of the numerous coal exploration drill-holes in the area.

2.2 Nature of Permeability in Hard Rock Units

Mr Mackie's question was:

"Section 3.3 notes that the only significant rock mass permeability occurs in the Ulan seam and parts of the Permian coal measures. By inference, the remaining units are generally much less permeable. Is it reasonable to assume that all hardrock permeability is attributed mostly to fractures/joints?"

Response: There may be some intrinsic primary permeability in parts of the Permian coal measures, but most is fracture/joint permeability.

2.3 Cleating in the Ulan Seam

Mr Mackie asked:

"Coal seam permeability is normally related to cleating. Is cleating well developed in the Ulan seam? What are the main characteristics of the cleats - spacing, lengths, directions etc.? What are the principal stress directions in the Permian in the underground area? Are these the same as the Ulan area?"

Response: The following information has been provided by Moolarben Coal Mines' geologist Mr Mike Johnstone (pers comm).

Due to relatively shallow depth of burial and benign tectonic setting, cleat is not well developed in the Ulan seam. Measurements in the adjacent Ulan Colliery indicate the major directions are N16E (vert) and N69W (vert). The joints are open, planar, smooth and generally not penetrative tending to terminate at partings, or changes in coal type. Joint spacing is in the main between 0.5 and 1m, though in disturbed areas can be as narrow as 0.2m. The principal stress direction has not been measured at Moolarben, though in the adjoining Ulan Colliery N4E has been measured. This compares to the regional principal stress of N20-40E.

2.4 Modflow Groundwater Modelling Code

Mr Mackie asked:

"The groundwater numerical model is based on the Modflow code. Appendix F of the report states that Modflow is a suitable code for this study (ie for simulating open cut development and underground mining). Can it be assumed that processes like pit seepage faces, steep hydraulic gradients and underground panel extractions (where a failure regime is propagated upwards), are simulated with sufficient accuracy to confidently assess impacts on the groundwater systems in space and time? Would an alternative code offer an improved level of accuracy in predicting pressure distributions and fluxes?"

Response: The Modflow code was used for the modelling, as it was considered appropriate for impact assessment purposes (as described in MDBC, 2001). Modflow has sound industry standing, and we understand that Modflow is considered by DNR as its standard modelling code (DNR would require justification for the use of an alternative code for this type of impact assessment).

It is generally accepted in the modelling fraternity that there is no one particular code that can be applied to a particular problem without some constraints. (The application of the Feflow code, for example, would be constrained by its lack of a validated and benchmarked depth-dependent evapotranspiration module, which can be important to represent effects on groundwater-dependent ecosystems.)

The application of the Modflow code has acknowledged limitations, which are explained in Sections 3.1 and 5 of the modelling report (Aquaterra, 2006). With Modflow, issues such as pit seepage faces, related steep hydraulic gradients and underground panel extractions are local scale processes that can be important to water management during the mining operation, but are not necessarily relevant to the more regional scale assessment of impacts on the groundwater system. The Modflow code was used for the adjacent Wilpinjong assessment, and is still in ongoing use for investigation of underground and open cut mining by Ulan Coal. It has also been used on many other NSW coal mining projects, both open cut and underground mining, and enjoys a sound reputation for application to impact assessment purposes on mining projects generally.

The principal limitations inherent in the use of Modflow for the Moolarben project are:

- The inability to vary hydraulic properties during model simulations, and
- The possible inability to simulate dewatered goaf cells beneath saturated cells in overlying layers.

Our approach to surmounting the first limitation was to run two sets of model runs – one with no change to hydraulic parameters during the mining period, and the other with hydraulic properties in all mine area cells changed to failure zone values from the start of the mining period. The actual impact would lie between the impacts predicted by these two approaches.

Our approach to the second limitation was to employ model parameters that would minimise the total drying out of mine cells. The calibrated “base case” simulation run with Modflow was not adversely impacted by dry cell issues (Aquaterra, 2006).

Subsequent to the release of the EA report, we have re-run the model using Surfact, which does have the capability to simulate unsaturated cells, and achieved an almost identical output to the reported base case impacts, confirming that Modflow was an appropriate software in respect of the dry cell problem. **Figures 1** and **2** show the progressive inflow rates predicted to occur to the Moolarben and Ulan underground mines derived from straight Modflow model runs using both the PMPro and Vistas interface software, and from a run with Surfact.

As well as mine inflows, the three model runs generated almost identical groundwater level distributions. The head distributions for the Ulan Seam (model Layer 4) for the PMPro Modflow and Surfact runs are presented for comparison in **Figures 3** and **4**.

These model runs have been superceded by the modelling carried out for the preferred project assessment (Dundon, 2006b), and are used here merely to demonstrate the validity of using Modflow code for this impact assessment application.

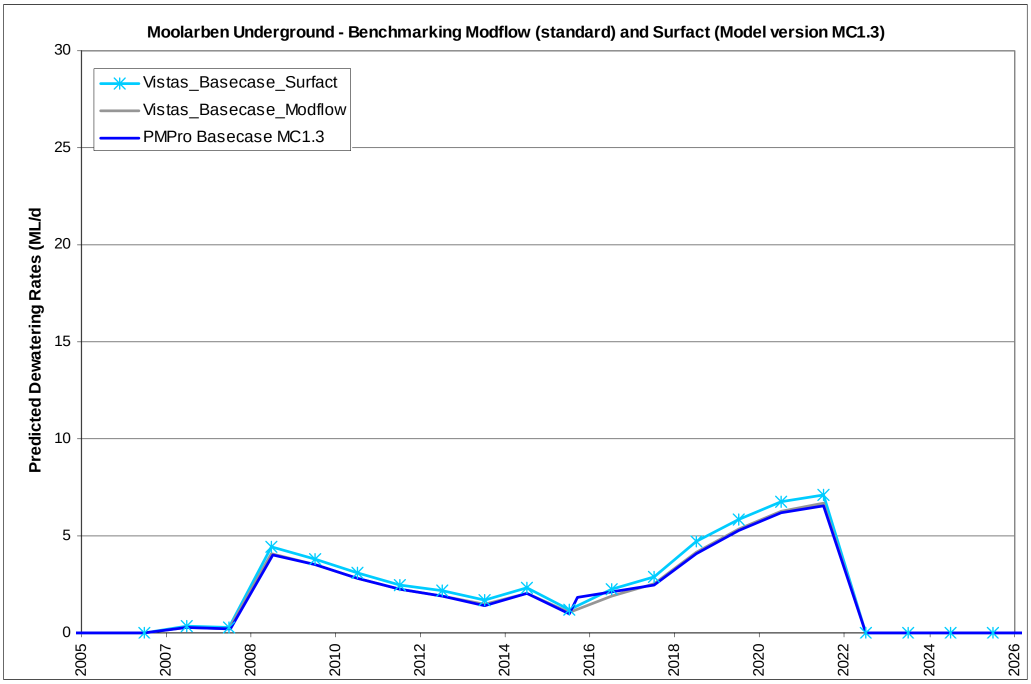


Figure 1: Predicted groundwater inflows to Moolarben underground mine

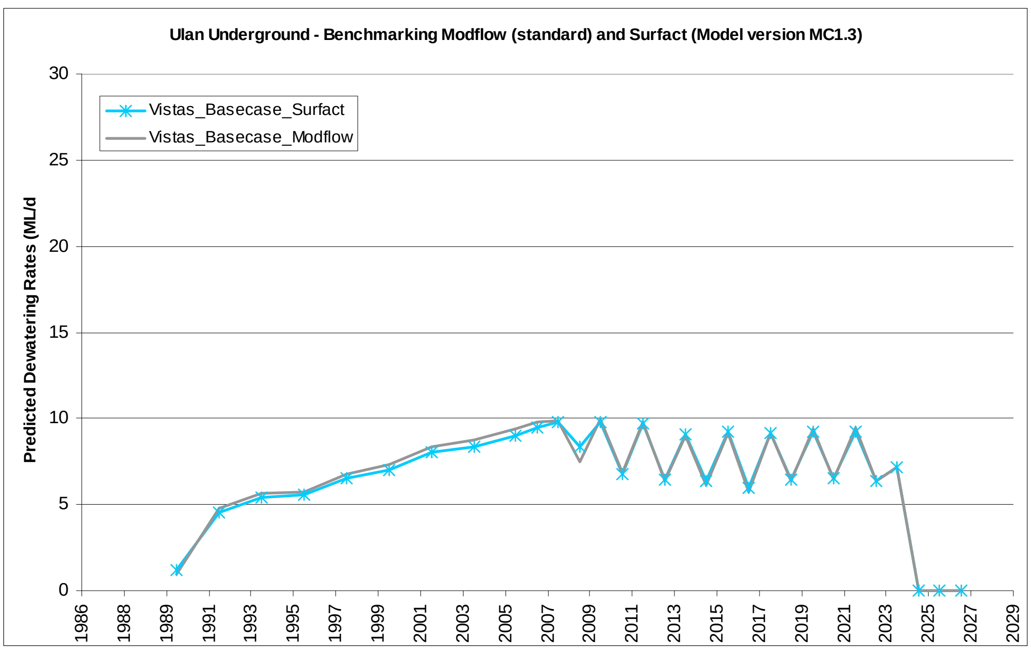


Figure 2: Predicted groundwater inflows to Ulan underground mine

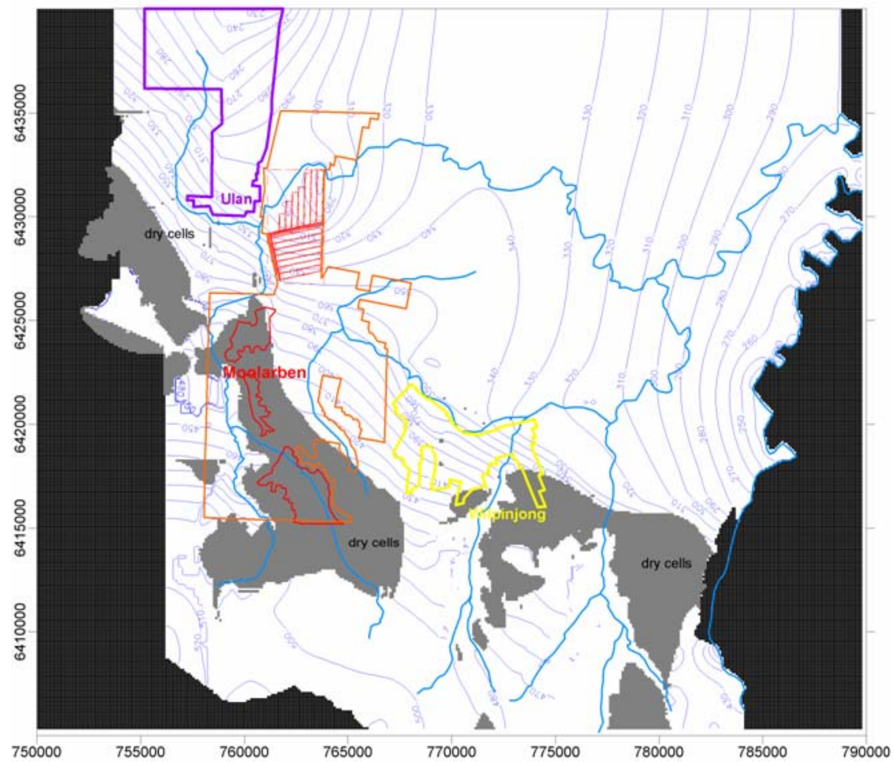


Figure 3: Predicted groundwater levels (PMPro Modflow simulation)

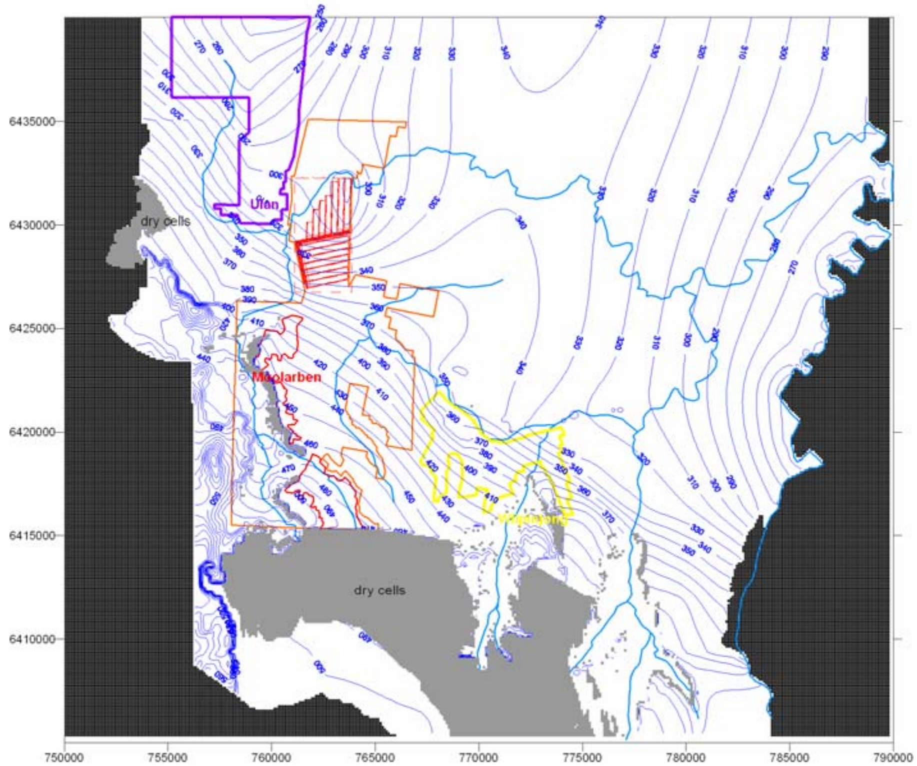


Figure 4: Predicted groundwater levels (Vistas Surfact simulation)

2.5 Groundwater Modelling Review Report

Mr Mackie asked:

"Section 5.1 indicates a review report was prepared by Dr. N. Merrick and is available in Appendix F. This reference seems to have been omitted from my copy of the report. Can a copy be forwarded to me?"

Response: Dr Merrick's review report was inadvertently omitted from the EA report, and is appended to this report (**Attachment A**).

2.6 Permeability and Storage Parameters

Mr Mackie asked:

"Table 9 lists the adopted model aquifer parameters. Vertical permeabilities (Kv) are noted to be 3 to 6 orders of magnitude lower than the horizontal permeabilities (Kh) and would clearly affect model outcomes. How were these Kv values determined? A uniform confined S value of 5e-05 is also noted. Is it correct to assume this is the dimensionless value of storativity? If so, what is the basis for adopting a constant value for all strata?"

Response: The Kv values in the model were initially set as very much lower than Kh because of numerous observations of very large vertical head differences at many sites, and the observed lack of drawdown in the Triassic Narrabeen Group strata in areas of very large drawdowns in the underlying Permian Coal Measures. At several sites where piezometers were installed to different depths, very large head differences were observed between shallow and deeper levels within the sequence confirming very low vertical conductivities, eg PZ41A and B - Figure C3; PZ50A and B - Figure C4 in Dundon (2006a).

The actual values ultimately used in the modelling were finalised during the process of model calibration to the effects of the existing dewatering operation at Ulan, where the model achieved an acceptable match to the monitoring data from nearby monitoring bores, and to the reported Ulan drainage volumes. This is discussed further in the modelling report (Aquaterra, 2006) in Sections 4.2 and 4.4.

The very low Kv value assigned to Layer 5 in the area around the Ulan and Moolarben projects arose from an attempt to improve calibration of the model against reported inflow rates at Ulan. Adoption of a less severe value made little difference to the regional water levels, but did result in unreasonably high Ulan inflow rates. In the model used for assessing the Preferred Project impacts (Dundon, 2006b), a more consistent Kv value was used throughout this model layer.

The confined S value is indeed the dimensionless value of storativity, as documented in the modelling report. The model calibration performance demonstrated that a uniform value is adequate, consistent as it is with the limited knowledge of physically-realistic values for the area, and with sensitivity scenario assessment of uncertainty in these values (Section 4.3.3 of Aquaterra (2006)).

2.7 Permeability Distributions Within Model Layers

Mr Mackie's question was:

"The model permeability distributions are exhibited by layers as model input data in Appendix F (as figures in Appendix A). With the exception of layer 1, remaining layers have a distinct north-south linear boundary which defines domains to the east and west that have differing permeabilities. A similar east-west boundary prevails roughly along an identified palaeochannel and Wilpinjong Creek. What are the underlying geological-hydrogeological controls for these domains?"

Response: The basic reason for the zonation was to differentiate between the Ulan area, where there is information available on the effects of the existing dewatering operation on the groundwater system, and other areas, where there is no such stress on the system, and where the parameters applied to the model would be subject to more uncertainty.

To a certain extent, the zones were also used to differentiate between aquifer units, with the granite outcrop occurring mainly south and west of the palaeochannel, and there being a general differentiation between the Narrabeen Group occurrence north of Wilpinjong Creek, and the Coal Measure outcrops south of the creek.

2.8 Narrabeen Group Hydraulic Property Values

Mr Mackie asked:

"The model is rainfall recharge driven. Appendix F provides a spatial distribution of recharge. Much of the region seems to be defined by 0.0001 m/day (generally Narrabeen Group) or 0.00003 m/day (generally Permian coal measures). The Narrabeen Group recharge is more than 3 times higher than the Permian coal measures and is not significantly different from rates adopted for alluvial materials. This seems to be counter intuitive since the Narrabeen Group generally prevails in elevated country suggesting weathering impacts have been less effective than the lower lying distinctly more weathered coal measures and other strata. This further suggests the Narrabeen Group is perhaps generally characterised by high rock strength and a low permeability cementation matrix. What test data supports the adopted permeability values and recharge rates for the Narrabeen Group?"

Response: The rainfall recharge assumptions are presented in detail in Section 2.2 of the modelling report (Aquaterra, 2006), including the justification of the rates applied. The rates assumed were based largely on observations and judgements by Peter Dundon on the Moolarben project site, and are consistent with site inspections by an experienced hydrogeologist and an engineer as part of the Wilpinjong project. Recharge to the Narrabeen Group occurs by infiltration directly to open fractures and joints exposed in the relatively fresh rock surfaces (compared with the Permian). The coal measures in turn are often overlain by colluvium which is less permeable than the fresher rock beneath. Higher rates of recharge could occur to fresher rock surfaces where the Permian coal seams and other more permeable zones are exposed in outcrop. However, in most areas, the more deeply weathered coal measures are covered by low permeability colluvium.

Recharge is thus able to occur more readily to the Narrabeen Group than to the Permian coal measures, due to its being generally less weathered than the coal measures. Conversely, runoff is better developed over the Permian outcrop areas than the Narrabeen Group.

Pumping tests carried out on three private bores located east and north of the Underground 4 area (UCML, 2003) were used as a basis for the hydraulic conductivity values used for the Triassic (see also **Section 3.1** below).

2.9 Use of Drain Cells to Simulate the Longwall Panels

Mr Mackie asked:

"Simulation of underground mining for all models has been undertaken by assuming drain cells are active during panel extraction, and are de-activated after extraction. Does this apply to both Ulan and Moolarben underground simulations? Is this an accurate representation of the mining process? If the cells were maintained active throughout the period of underground mining (ie. groundwater is continually pumped from up dip goaf), what are the implications for mine water make and local/regional strata depressurisation?"

Response: The approach of activating and de-activating drain cells is described in detail in Section 3.3 of Aquaterra (2006), and applies to both Ulan and Moolarben underground areas, and was implemented in this manner as a reasonable approach to represent the mining process. Although the drain cells were de-activated in the goaf areas after extraction, they were kept active in the main development headings. It is accepted that it would have been preferable to leave the drains on, however subsequent modelling showed that the adopted practice of de-activating the drains did not materially alter the predicted inflows or heads.

Figure 5 shows a comparative plot of inflows from two runs, one with goaf drain cells de-activated after extraction, and the other with all drain cells left on. The inflow rates are seen to be only marginally different. It is likely that the minimal difference between the two model runs arises because the development heading drain cells were left activated through the simulation, and were apparently sufficient to keep the mined out areas effectively dewatered.

The drain cells were kept active in the "goaf" sensitivity run as described in Section 4.3.2 of the modelling report, and in the post-mining recovery simulations (Aquaterra, 2006).

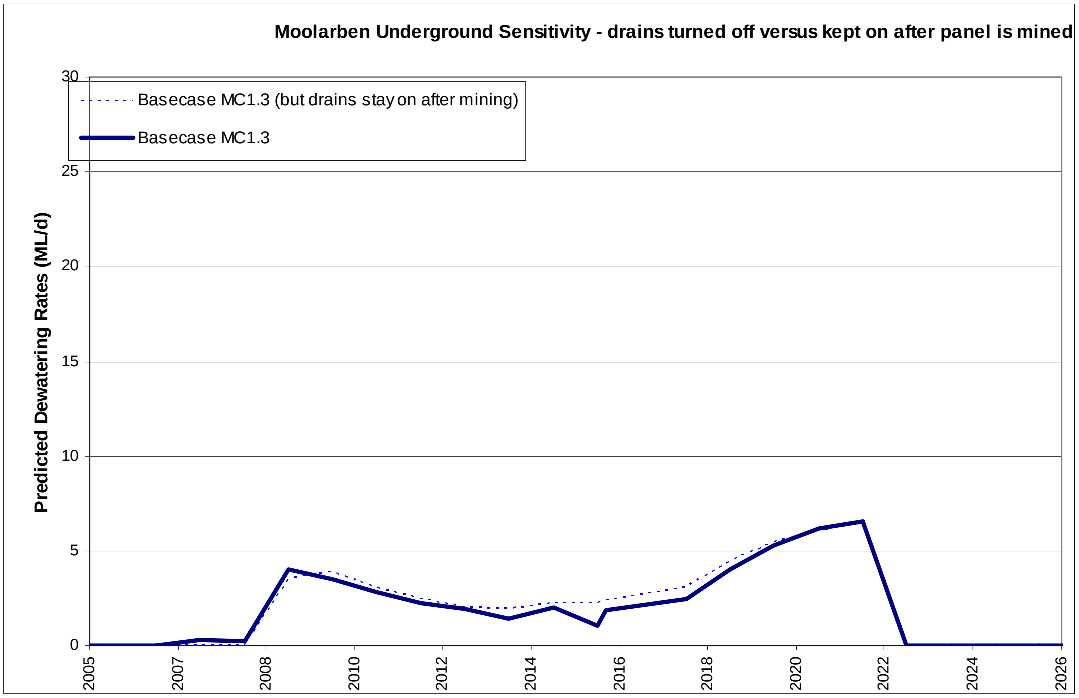


Figure 5: Predicted groundwater inflow rates at Moolarben Underground 4 (drains de-activated and drains left on)

2.10 Simulation of Failure Regime above Goaf

Mr Mackie asked:

"With the exception of the single 'goaf run', all simulations of underground mining seem to have been conducted without inclusion of a failure regime above goaf. This failure regime is normally associated with connective cracking that facilitates fairly rapid vertical drainage of overlying strata and expands strata depressurisation. The subsidence report indicates such cracking may occur to 100 m above seam. Why was this regime omitted from the bulk of the modelling effort? What are the implications for water make and strata depressurisation if a regime is included in simulations according to the mine plan?"

Response: The benchmarked Modflow code does not allow for a change with time of aquifer parameters, and hence it was not possible to progressively introduce "failure zone" hydraulic parameters. Consequently, the model was calibrated against the historic inflows and drawdown impacts at Ulan mine with undisturbed hydraulic properties so that the model could then be used with confidence to assess the impacts of the Moolarben mine proposal.

The impact of enhanced permeability and storage parameters was then assessed by a separate sensitivity model run in which higher permeability and storage parameters were adopted for the goaf cells and the overlying failure zone cells over the entire mine areas throughout the simulation.

This approach constitutes a "best" and "worst" case approach, with one case being no change in aquifer parameters during mining, and the other case being an instantaneous change of aquifer parameters in all the mine and failure zone cells from the commencement of mining. The actual situation lies between these two cases, so the likely implications for water make and strata depressurisation would lie between the predictions based on the two adopted cases.

The adoption of a 50m zone of connective cracking above the goaf in the "goaf run" was based on the observed negligible impact of Ulan's underground mining on groundwater levels in the Triassic Narrabeen Group aquifer (see **Section 3.1** below), the base of which is 90-100m above the top of the Ulan Seam.

It is noted that the modelling approach described above has been superceded by the modelling carried out to assess the Preferred Project mine plan (Dundon, 2006b).

2.11 Storage Properties of the Failure Zone

Mr Mackie asked:

"The failure regime noted above has been addressed in a single 'goaf run' by apparently including the zone over the entire panel extraction area as a changed permeability and changed storage zone from the commencement of mining. That is, from commencement of panel 1, the failure zone is presumed to prevail immediately over all 14 panels at Moolarben. Is this a realistic interpretation? The failure zone is 50 m in height and the elastic or compressible storage is reported to be more than 4 orders of magnitude higher than adjacent strata. Were these changes for the 'goaf run' applied to both Ulan and Moolarben? Why were the storage parameters increased when the groundwater store in strata is unlikely to change post failure? What are the implications for water make and strata depressurisation if a 100 m thick failure zone is adopted, if storage parameters are assigned consistently with parameters beyond the subsidence zone, and if panel extractions (with overlying failure regimes) are invoked according to the mine plan?"

Response: The "goaf parameter" changes were made to only the Moolarben underground area for the reported sensitivity "goaf run" (Aquaterra, 2006). The goaf parameters were not applied to Ulan for this run because the history match calibration showed that this was not necessary (see **Section 2.10** above). The longwall panel widths used in the Ulan mine up to 2005 are 261m (Coffey, 2005) which is similar but slightly wider than the proposed panel width for the Moolarben underground mine (250m).

The adoption of a much higher storage parameter for the failure zone (rather than preserving the storage parameters applying to undisturbed strata outside the failure zone) is considered realistic, as the storage potential of the failure zone material will increase substantially due to the cracking/failure. To preserve pre-failure storage properties for this material in the model would potentially lead to an underestimation of groundwater inflows to the mine. It is also considered that the adoption of realistic (ie higher) storage parameters would have a neutral impact on regional drawdown impacts.

Nonetheless, sensitivity modeling was carried out with the storage parameters unchanged, but led to an inferior match to historical Ulan data.

The Permian coal measures overburden which has a thickness of 90-100m (ie from the top of the Ulan seam to the base of the Triassic Narrabeen Group) was divided into two model layers – Layer 3, representing the first 50m above the Ulan Seam, and Layer 2, representing the remaining Permian up to the base of the Triassic. Layer 1 represents the Triassic where present. This division of the Permian into Layers 2 and 3 was done to allow the impacts of a failure zone above the goaf extending to a height of 50m, 100m or higher.

The implications for water make and strata depressurisation of adopting a 100m failure zone rather than 50m were tested with the model used to assess impacts as reported in the EA (MCM, 2006a). In these model runs, the undisturbed storage properties were retained for all goaf and failure zone cells. A 100m failure zone led to predicted inflow rates to Moolarben Underground 4 that were less than 10% higher than for a 50m failure zone height (**Figure 6**).

[In both failure impact runs, it was assumed that horizontal permeability was 10 times higher than the undisturbed value for the first 50m and 5 times higher for the interval between 50m and 100m above the roof. This is consistent with the enhancement of horizontal permeability arising from bedding partings within the subsidence zone. However, in Run G6, it was assumed that the vertical permeability was increased by 50 times in the first 50m above the goaf and 5 times in the zone between 50 and 100m above the goaf, compared with no change in the upper zone in Run G4.]

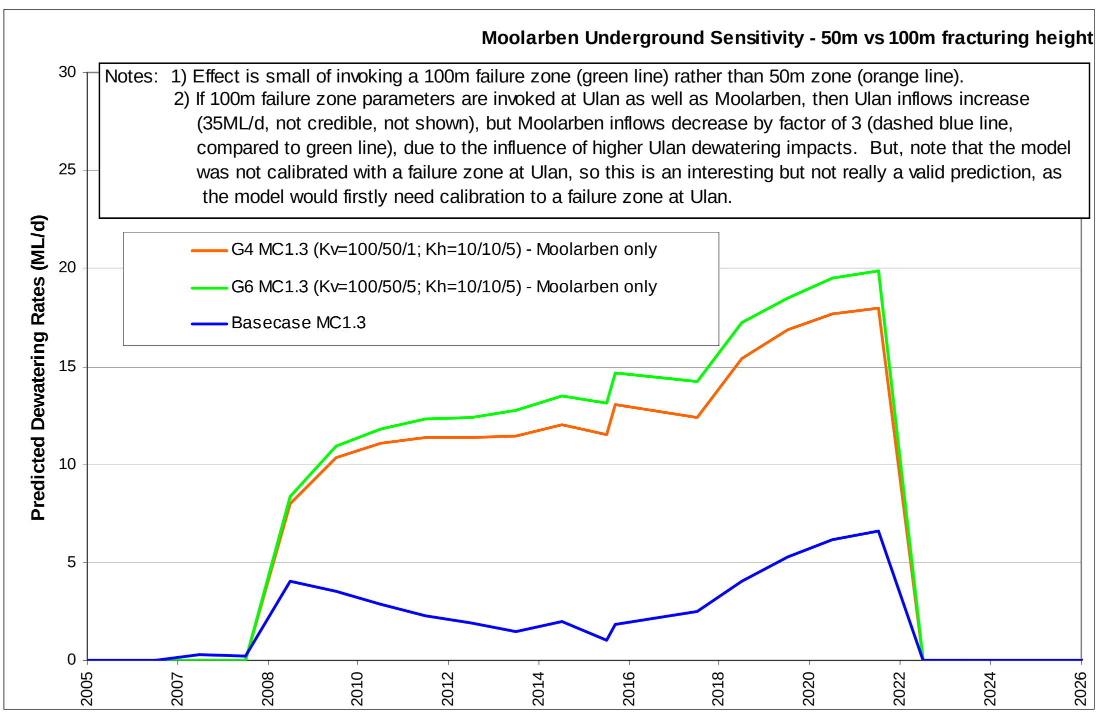


Figure 6: Predicted Inflow Rates for 100m v 50m Failure Zone Above the Goaf

It should be noted that both runs depicted in **Figure 6** predicted inflow rates at Ulan that were much greater than observed. It is considered therefore to be useful merely to compare the impacts of different failure zone heights.

The modelling discussed above has been superseded by the modelling carried out for the preferred project impact assessment. (Dundon, 2006b).

2.12 Makeup Water Supply Sources

Mr Mackie asked:

"Table 10 provides a summary of the predicted mine water makes for the 3 open cut operations and the underground. It is noted that a deficit in water demand prevails during year 1 and years 3 to 11. The deficit may be greater than indicated if actual water make to the underground is less than predicted (Section 5.4 suggests it could be as low as 50% of predicted). Make up supply is suggested from Ulan or Wilpinjong mines. Are agreements in place for water supply from the adjacent mines? Table 10 also identifies contributions from Moolarben pumping bores. Are these bore locations identified on a map? Were they included in all model simulations? What level of confidence can be assigned to the alternatives for make up water supply?"

Response: The mine water makes predicted by the modelling carried out for the EA (MCM, 2006a) are insufficient to meet the projected water demands in Year 1 and Years 3 to 11. The shortfall in those years would be made up by pumping from bores, the locations of which are shown on Figure 21 of the groundwater report (Dundon, 2006a).

The pumping rates required from these bores were determined by an iterative process, since the impacts of mine inflows and bore extractions are somewhat interdependent. The final pumping rates adopted for the bores were those required to make up any shortfall from the mine inflow volumes, and are listed in Table 10 (Dundon, 2006a).

Because they are interdependent, it is not realistic to consider the impacts of mine inflows and pumped extractions from the bores separately. The bores serve a dual purpose, ie of dewatering and water supply. In any case, it is proposed that the bores will also be used for dewatering in years when there is predicted to be a significant surplus, so that sufficient "clean" groundwater can be intercepted prior to entering the underground workings, where it could become affected by higher salinity, turbidity or pH. This would be done to minimise the need to treat the excess water to render the quality suitable for release to the stream system.

The sensitivity modelling indicated that there was a very low risk of inflows being lower than predicted (Section 4.4 of the modelling report (Aquaterra, 2006)). The reliability of the Moolarben water supply bores is considered high, based on the results of hydraulic testing and the modelling studies, and by observation of the performance of the same aquifer system at the adjacent Ulan mine.

The availability of excess water from either Ulan or Wilpinjong is not certain, but it has been recommended as the desirable source of additional water if available. The availability of water from either Wilpinjong or Ulan will be a matter to be resolved between the various coal mining companies.

2.13 Hydrochemistry

Mr Mackie's question was:

"The underground and open cut pits may ultimately re-saturate to different water table elevations post mining. Rainfall will infiltrate spoiled areas and migrate downwards resulting in a sustained saturation in pit spoils subject to various controls like the pit shell geometry, strata hydraulic properties and the geometry of any open void (pit lake). What is the geometry of the long term water table in each pit? What is the predicted hydrochemistry of the leachate that will be generated? Are there any candidate spill points for the leachate to escape?"

Response: The groundwater report describes the expected final pit voids in Section 5.15 (Dundon, 2006a). As indicated, there is expected to be a small void at the southern end of Open Cut 3 which extends to about 5m below the current water table level, and evaporation effects are expected to prevent the formation of a permanent water body. This void will not have a potential spilling point. The final void in Open Cut 2 is proposed to be above the current water table level.

Two final voids are proposed for Open Cut 1 - one on the eastern side to be preserved as an entry to a possible future underground coal mine to the east, and a second at the northern end. The eastern void would be up to about 5m below the expected ultimate groundwater level, and would have no spilling point. The northern void is proposed to have two purposes during the project - for storage of excess mine water and for the disposal of tailings form the coal preparation plant and rejects from the underground mining operation, as well as from other future mining operations that may be approved elsewhere on EL6288. Hence the final groundwater level configuration is difficult to predict. However, there are no potential spilling points, and it is also proposed to place a low permeability seal against the Ulan seam around the perimeter of this void to limit the potential for recirculation back to the underground workings downdip.

Geochemical studies have been addressed by Environmental Geochemistry International Pty Limited, and reported at Appendix 10 of MCM (2006a). It is proposed to undertake comprehensive leachate testing in conjunction with detailed mine design studies, as recommended by EGi.

3 EMAIL DATED 15 NOVEMBER 2006

Following the IHAP hearings at Mudgee between 6 and 9 November 2006, the following outstanding issues were detailed in an email dated 15 November 2006.

3.1 Narrabeen Group and Marrangaroo Conglomerate

The Panel described the following concern:

"The Triassic Narrabeen Group covers a large part of the proposed mining operations and surrounding areas. It is an important stratigraphic unit that governs recharge and piezometric surfaces throughout the region yet no hydraulic parameterisation of this unit has been undertaken through physical testing. Similarly, piezometric mapping of this unit is sparse. A significantly improved understanding of the water level/pressure regime and the hydraulic properties that prevail within this stratigraphic unit, is required. The deeper Marrangaroo Conglomerate (a potentially significant water yielding lithology) also seems to be poorly characterised."

Response:

a) TRIASSIC NARRABEEN GROUP

A considerable amount of information relating to the Triassic Narrabeen Group aquifer system was used to develop our understanding of the inter-relationship between the Permian and the Triassic aquifers, and between the Triassic and the Goulburn River and its tributaries. This information also enabled the assignment of appropriate hydraulic parameters for the Triassic in the groundwater model. Only a representative selection of relevant data was presented in our reports.

The available information is summarised in more detail below.

(i) Available Information from UCML AEMRs:

UCML (2003) reported the results of pumping tests on private bores drawing from the Triassic aquifer system, viz

- Imrie Bore
- Elward North Bore
- Keiren's Bore.

The test results indicate average hydraulic conductivities for these bores of 0.07m/d, 0.3m/d and 0.5m/d. On the basis of these results, we adopted a horizontal hydraulic conductivity value of 0.1m/d in our modelling.

UCML has constructed nine (9) piezometers screened in the Lower Triassic sandstones, viz

- PZ01A
- PZ04A
- PZ06C

- PZ07C
- PZ08C
- PZ09C
- PZ10A
- R753A
- R755A.

In their 2005 AEMR, UCML (2006) suggested that DDH58-25 is also screened in the Triassic. However, information presented by UCML in previous AEMRs confirms that this piezometer is in fact screened in the Permian Coal Measures (specifically the Moolarben A and B seams). The geological log of DDH58 (UCML, 2002) showed the base of the Triassic (and top of the Permian) at a depth of 77m, whereas DDH58-25 is screened between 104 and 110m depth (UCML, 2005a). The second piezometer at that site (DDH58-50) is screened at 162-165m depth in the Ulan Seam (UCML, 2005a).

Locations of the UCML piezometers and the private bores are shown on **Figure 7.** UCML's Triassic piezometers are all situated to the north of the longwall panels completed up to the end of 2004, although PZ07C, PZ09C and PZ10A are situated above the main development headings. There are no piezometers located directly above completed longwall panels.

Hydrographs regenerated from plots in UCML's 2005 AEMR are shown in the upper pane on **Figure 8**. The available water levels for the three private Triassic bores are included on **Figure 8**. The records extend back to 1996, and all bores show minimal water level change with time. The hydrograph for DDH58-25 has been added on the lower pane on **Figure 8**. It is probably the basis for Mr Tammetta's statement to the IHAP hearing that drawdowns in the order of "metres" have been observed in the Triassic piezometers. Based on my analysis, I do not agree with his assertion.

Most of UCML's groundwater monitoring sites comprise multi-level piezometers, with separate piezometers screened in the Triassic and the Ulan Seam, and at some sites in the Marrangaroo as well. Coffey Geosciences (Coffey, 2005)stated in their report accompanying UCML's SMP Application for the first of their 400m wide panels LW23-26 and W1 (UCML, 2005b) that *"… hydrographs for piezometer nests PZ01 and PZ04 located east of Panel 22 indicate that the Mesozoic Sandstone is able to maintain hydraulic head while the Ulan Coal Seam depressurises significantly".* Composite hydrographs for the UCML sites (**Figures 9** to **11**) show substantial head differences of up to at least 130m between the Triassic and the deeper units, with the Ulan Seam and Marrangaroo Conglomerate both showing substantial drawdown due to mine dewatering, whereas the Triassic shows no impact. The water levels in PZ04A fell approximately 0.9m from 2004 to the end of 2005, which may represent either a small mining-related impact or a seasonal water level decline.

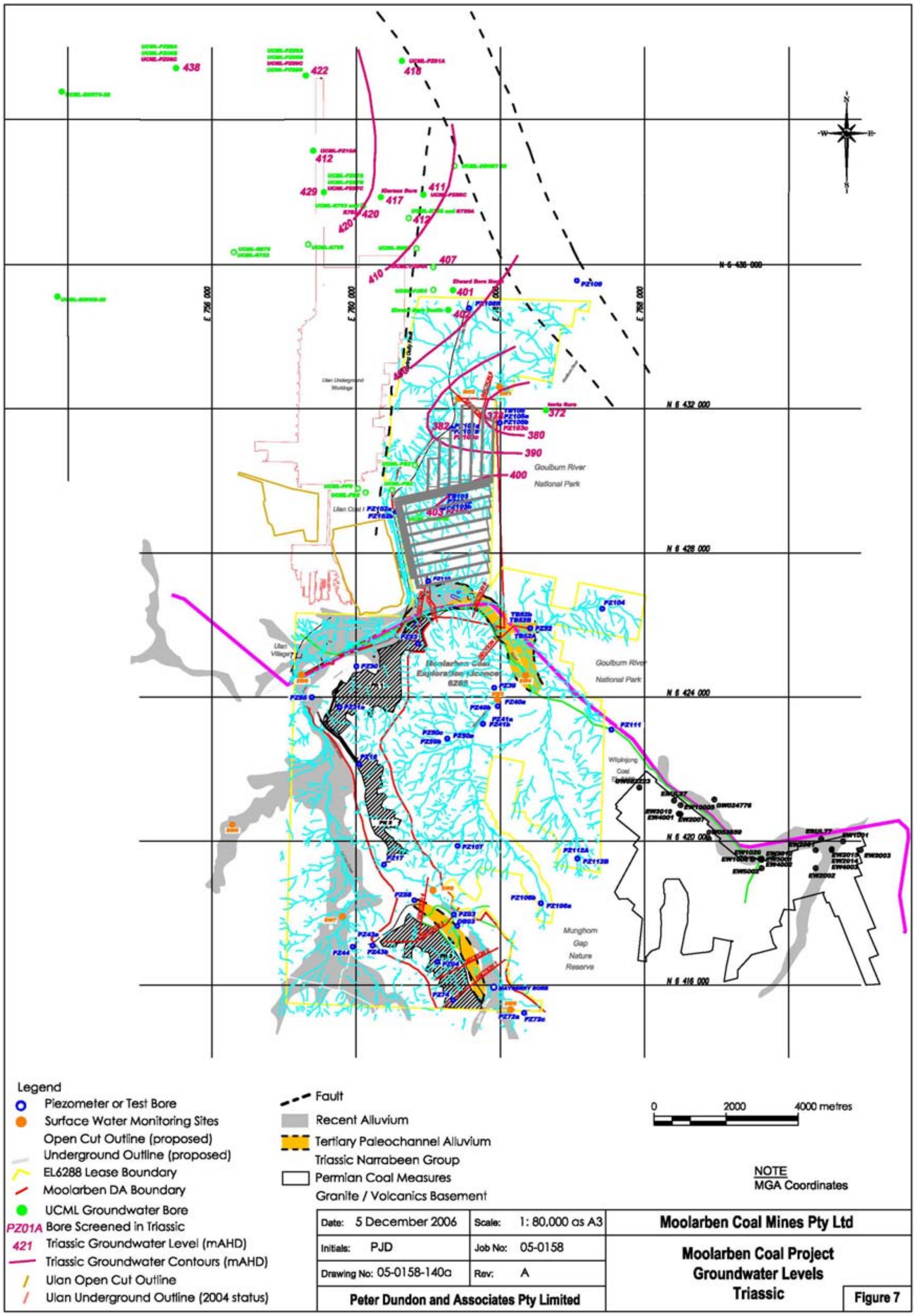


Figure 7: Triassic Groundwater Levels

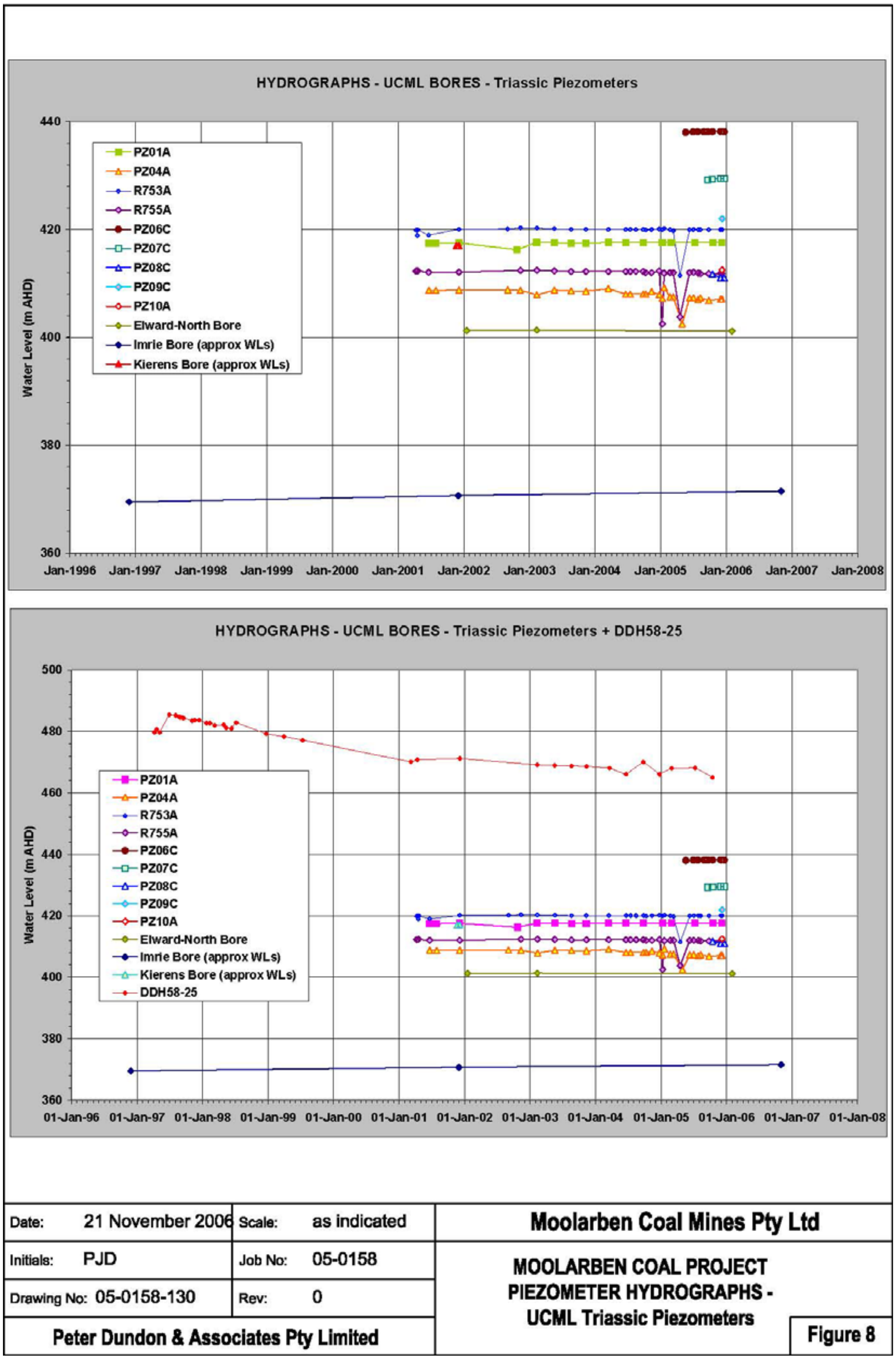
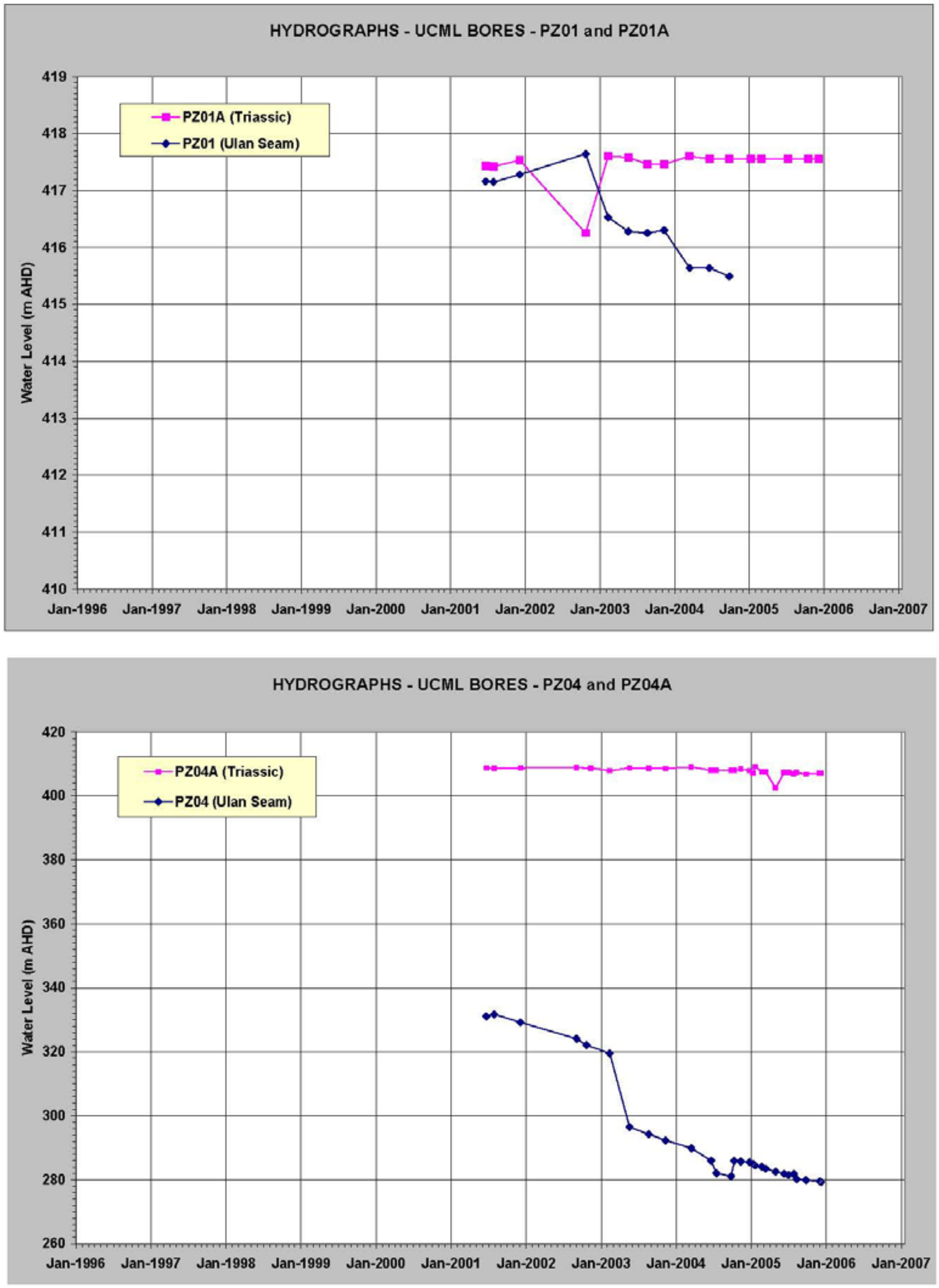


Figure 8: Piezometer Hydrographs – UCML Triassic Piezometers



Date: 21 November 2006	Scale: as indicated	**Moolarben Coal Mines Pty Ltd**		
Initials: PJD	Job No: 05-0158	**MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - UCML Triassic Piezometers PZ01, PZ01A; PZ4, PZ4A**		
Drawing No: 05-0158-131	Rev: 0			
Peter Dundon & Associates Pty Limited			**Figure 9**	

Figure 9: Piezometer Hydrographs – UCML Multi-Level Piezometers PZ01, PZ01A; PZ04, PZ04A

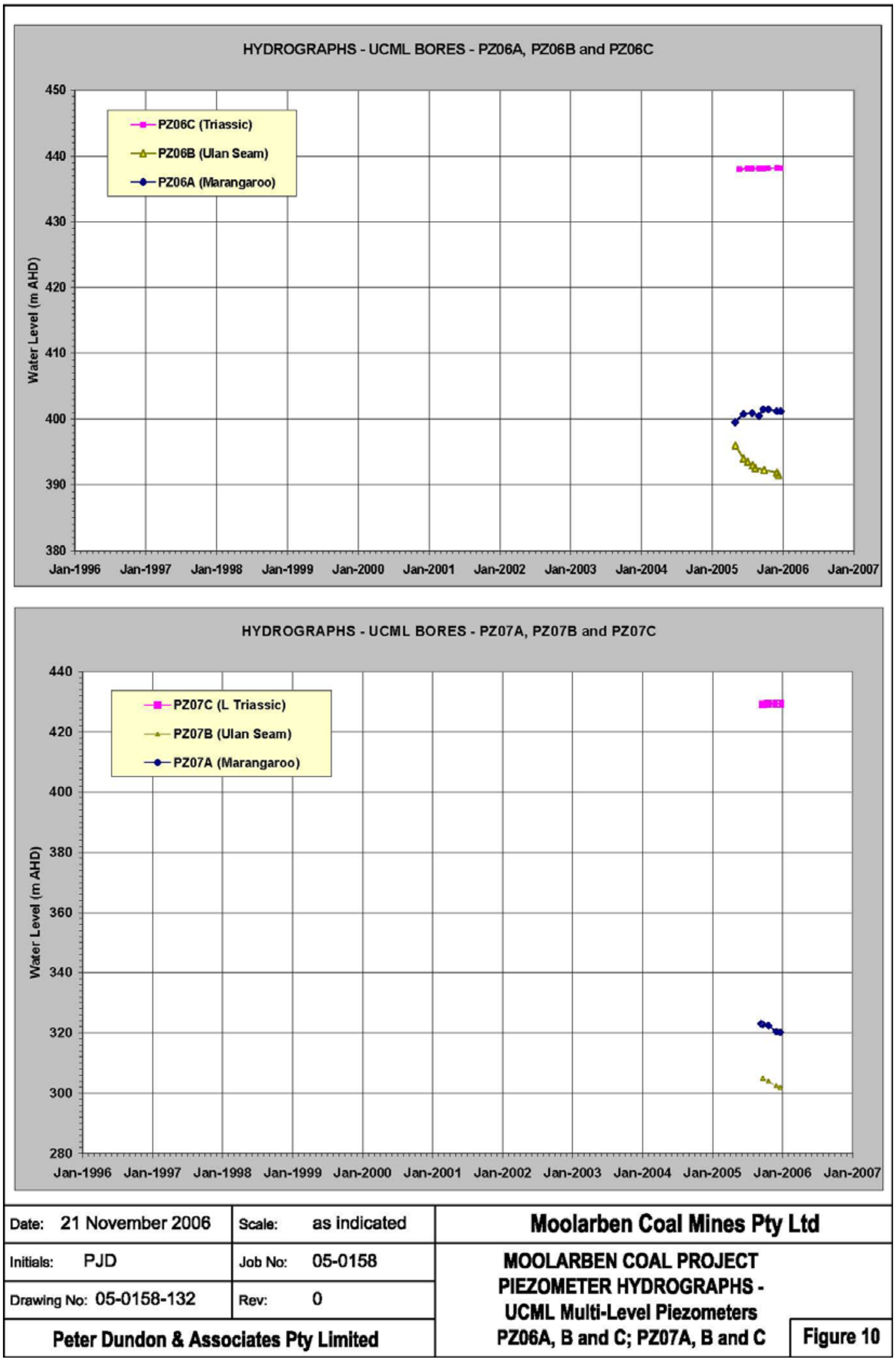


Figure 10: Piezometer Hydrographs – UCML Multi-Level Piezometers PZ06A, B and C; PZ07A, B and C

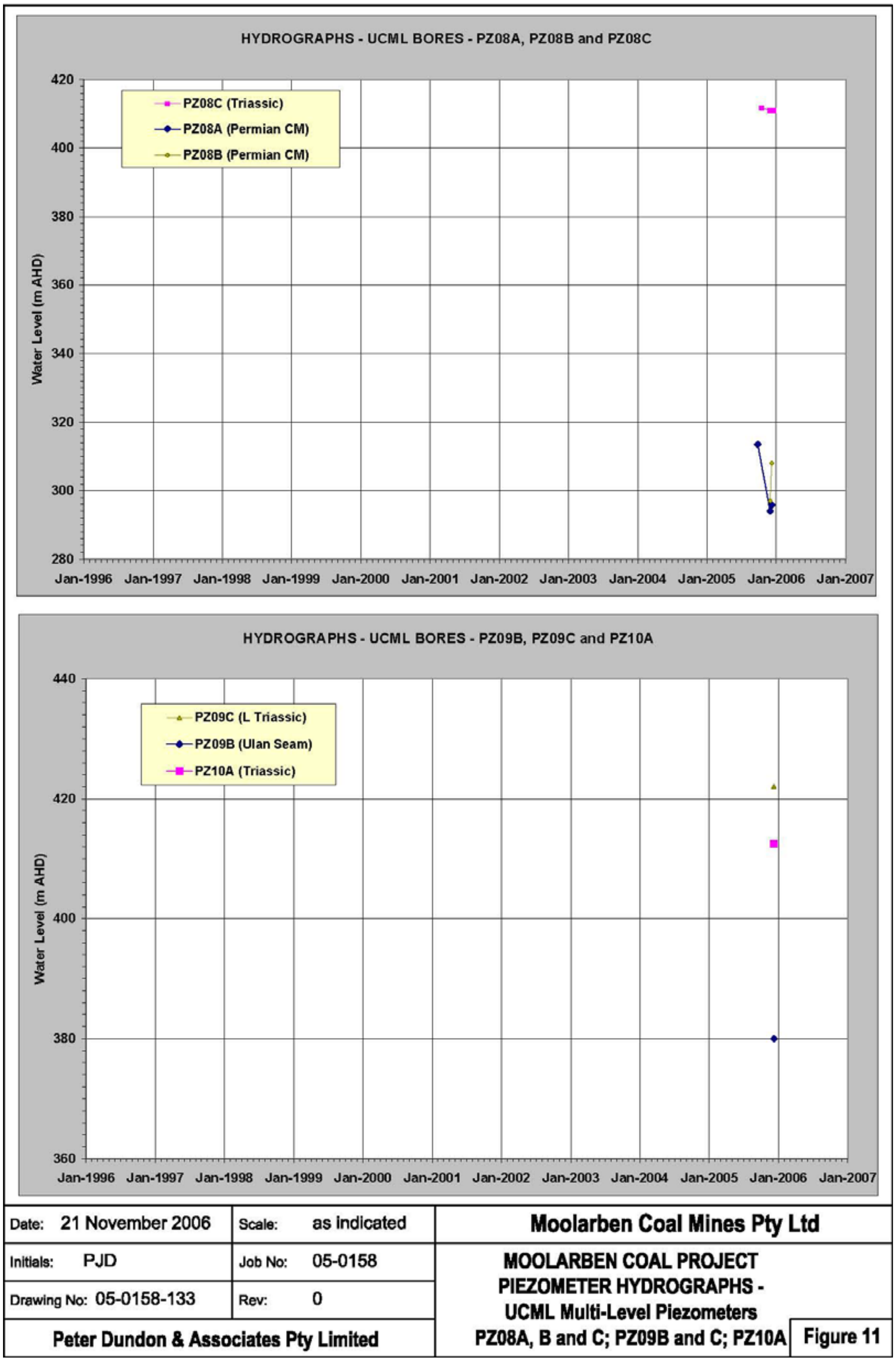


Figure 11: Piezometer Hydrographs – UCML Multi-Level Piezometers PZ08A, B and C; PZ09B and C; PZ10A

(ii) Information Obtained from Moolarben Groundwater Investigations:

During our piezometer installation program carried out in 2005-2006, we did not install any piezometers in the Triassic, due to a lack of groundwater intersections above the top of the Permian during drilling. (All piezometer drilling was carried out by air rotary, so groundwater intersections were easy to recognise if there were any.)

Relevant information from the eleven piezometers and two test bores drilled within or north of the Underground 4 area is summarised as follows:

- PZ101A -
  - First water intersection occurred at 30m (top of Permian) - minor flow.
  - Piezometer screened in Ulan seam, and Triassic sealed off by annular grout.
  - Maximum airlift yield during drilling was 3L/s from the Permian above the Ulan Seam.
  - SWL at this site is below top of Permian.

- PZ101B -
  - First water intersection was at 40m (10m below the top of the Permian).
  - Piezometer screened at 54-60m in Permian Coal Measures overburden.
  - Airlift yield at completion was 0.4L/s.

- PZ102A -
  - No Triassic present (eroded).
  - First water intersection was at Ulan Seam, minor flow.
  - More water was intersected at 113m (Marrangaroo Conglomerate), minor flow.

- PZ102B -
  - No Triassic present.
  - Maximum airlift yield 0.6L/s.

- PZ103A -
  - No significant water intersection (drilled after PZ103B).

- PZ103B -
  - Top of Permian at 25m.
  - First water intersection at 55m (0.2L/s).
  - No increase in flow to TD.

- TB103 -
  - Moisture at 15m in Triassic. No measurable flow.
  - First measurable flow occurred at 67m in Permian (0.2L/s).
  - Increased to 5L/s by 96m (coal measures above Ulan Seam).
  - SWL in completed bore is 55m below surface (ie 30m below base of Triassic).

- PZ105A -
  - Base of Triassic 29m.
  - First water intersection 38m in Permian coal measures (1.4L/s).

- PZ105B -
  - Base of Triassic 27m.
  - No water intersected until 55m (0.2L/s).

- TB105 -
  - Base of Triassic 27m.
  - First water intersected 30m (2.8L/s).
  - Main water intersection 81m (8.5L/s).

- PZ108 -
  - No significant water intersection entire hole.
  - Base of Triassic 118m depth (301mAHD).
  - Open hole SWL was 402mAHD (hole open to both Triassic and Permian).
  - After Triassic sealed off, WL fell to 333mAHD.

- PZ109 -
  - No recorded water intersection.

- PZ110 -
  - No Triassic present.
  - First water intersection at 55m depth in Permian coal measures.

New piezometers have been installed (December 2006) at three sites above the northern half of Underground 4, viz PZ101C, PZ103C and PZ105C. At all other piezometer sites within the Underground 4 area, the Triassic was absent. Locations are shown on **Figure 7.**

The drilled depths and screen intervals of the new piezometers are detailed in bold in **Table 1**, together with the existing piezometers at the same sites. Construction details are shown on **Figures 12** to **14**.

Table 1: Details of Triassic Piezometers above Underground 4

Piezometer	Depth	Screen Interval	Groundwater Level		Aquifer	Status
			m below GL	m AHD		
PZ101A	131m	120-129m	-	-	Ulan seam	Failed piezometer
PZ101B	60m	54-60m	39.0	364.3	PCM o/b	Piezometer
PZ101C	**30m**	**24-30m**	**21.5**	**381.5**	**Triassic**	**Piezometer**
TB103	100m	76-79m 82-85m 94-97m	55.9	369.3	PCM o/b	Test/Production Bore
PZ103A	128m	118-127m	68.8	356.4	Ulan seam	Piezometer
PZ103B	87m	81-87m	55.9	369.2	PCM o/b	Piezometer
PZ103C	**30m**	**24-30m**	**22.7**	**402.3**	**Triassic**	**Piezometer**
TB105	133m	78-84m 126-132m	29.3	359.5	PCM o/b Ulan seam	Test/Production Bore
PZ105A	115m	87-96m	29.4	359.2	PCM o/b	Piezometer
PZ105B	64m	58-64m	11.9	377.1	PCM o/b	Piezometer
PZ105C	**28m**	**22-28m**	**11.0**	**378.0**	**Triassic**	**Piezometer**

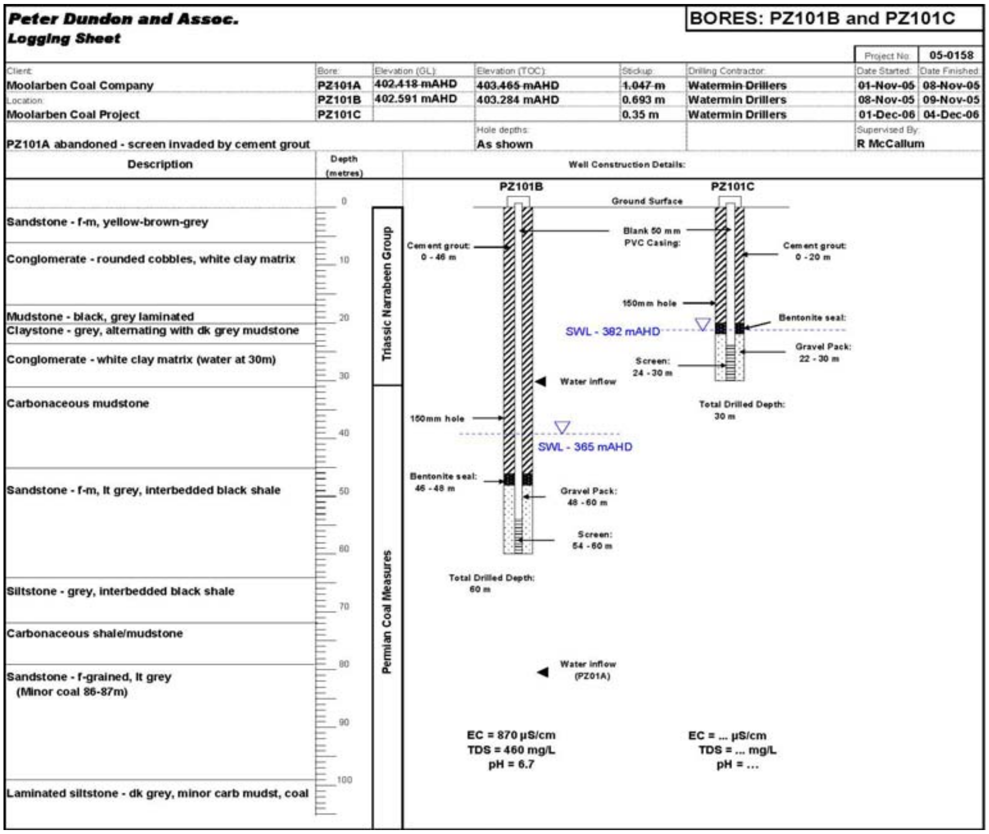


Figure 12: Bore Log – PZ101A, PZ101B and PZ101C

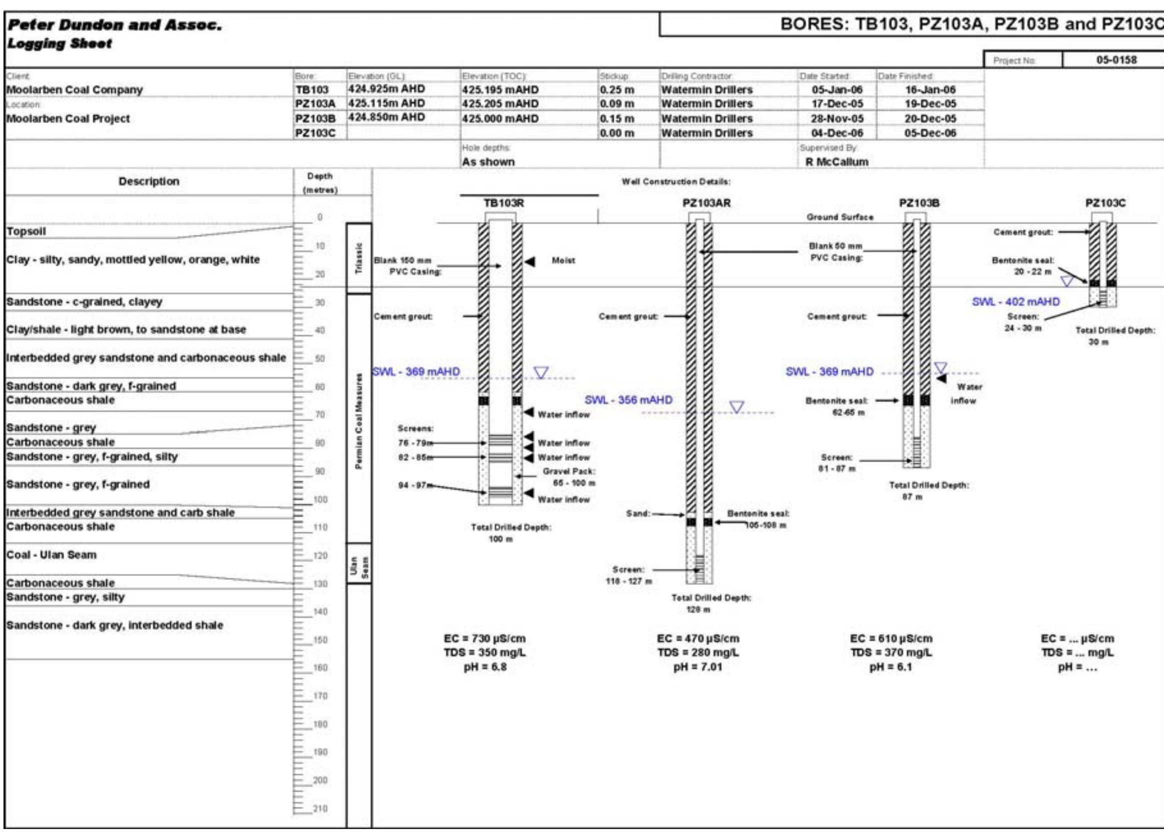


Figure 13: Bore Logs – TB103, PZ103A, PZ103B and PZ103C

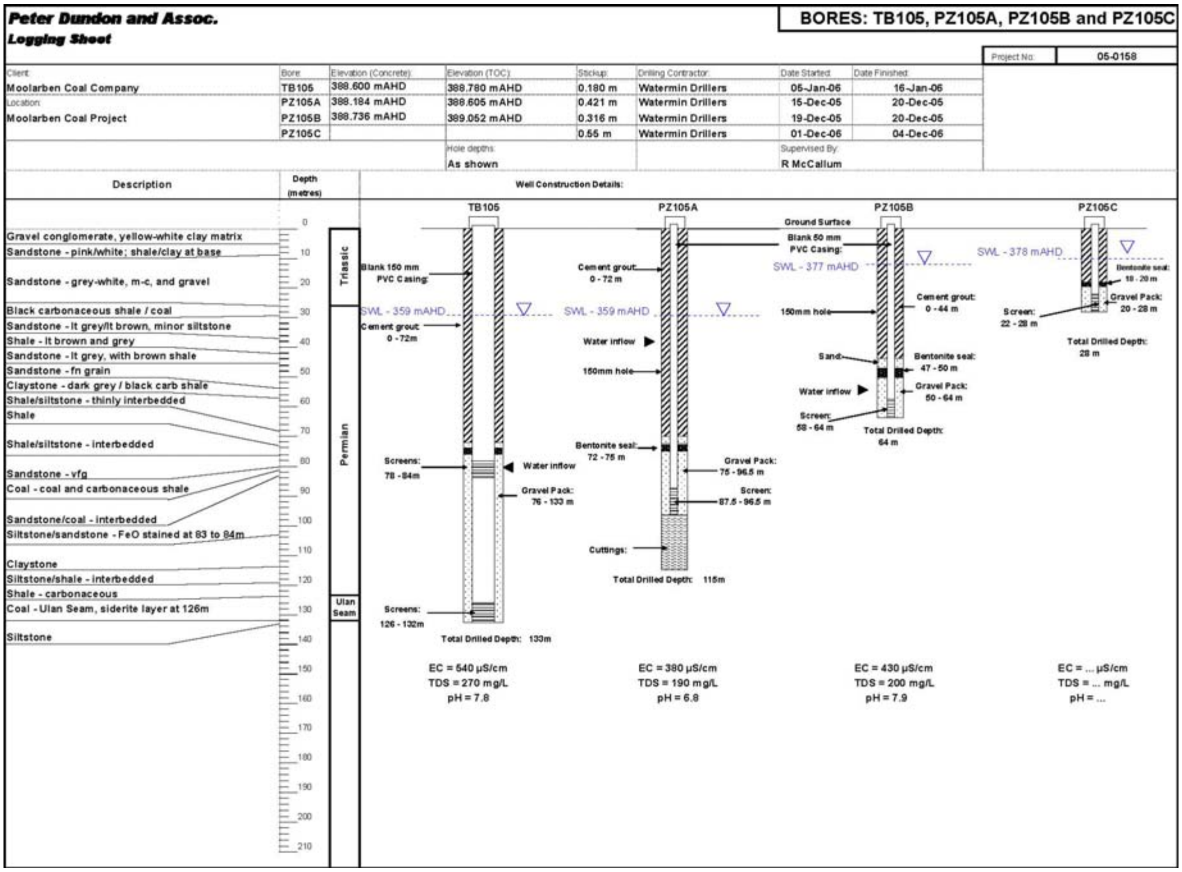


Figure 14: Bore Logs – TB105, PZ105A, PZ105B and PZ105C

None of the three new piezometers yielded water during air drilling, although moist samples were reported. After completion, water levels were measured as above.

A pumping test has been attempted on PZ105C, and falling head permeability tests have been conducted on the other two new piezometers. The test on PZ101C was affected by a cavity above the water table, and could not be analysed. The results are detailed in **Table 2**. The results of tests on PZ103C and PZ105C are shown on **Figures 15** and **16**.

Table 2: Hydraulic Testing Program – Triassic Piezometers

Bore	Test Date	Type of Test	Pumping Rate (kL/d)	Duration (min)	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)
PZ101C	5 Dec 2006	Slug test	-	-	-	ND
PZ103C	5 Dec 2006	Slug test	-	-	-	0.01
PZ105C	5 Dec 2006	CR Recovery	5.8	3	0.16	0.03
PZ105C	5 Dec 2006	Slug test	-	-	-	0.02

The above results are consistent with the results of testing of private Triassic water supply bores by UCML (2003) and with the horizontal permeability values adopted in our modelling.

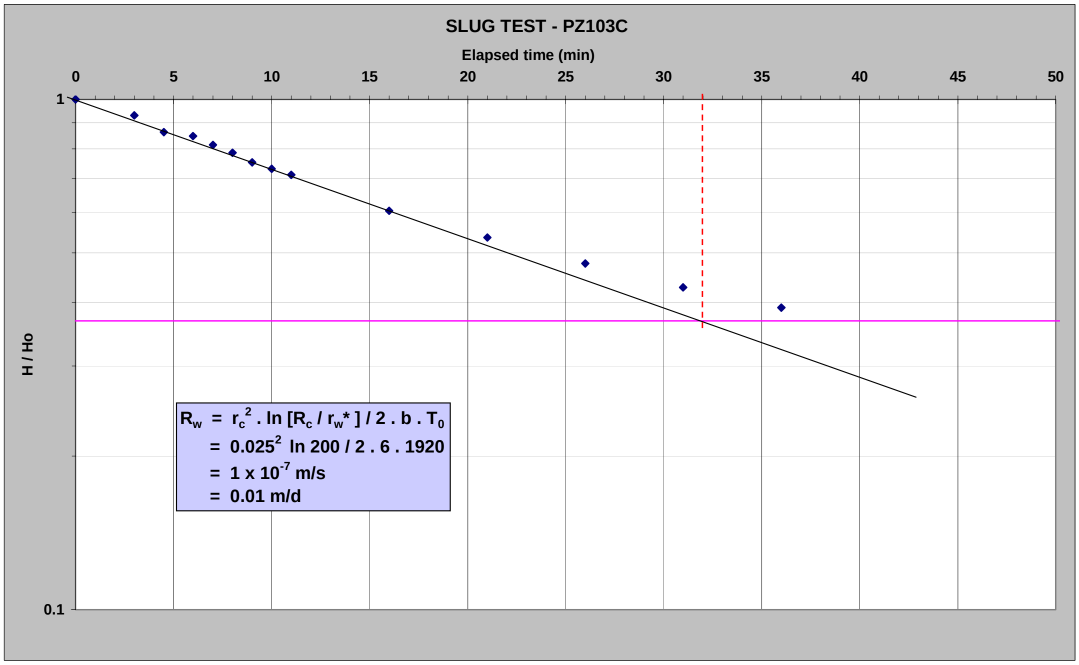


Figure 15: Slug Permeability Test on Triassic Piezometer PZ103C

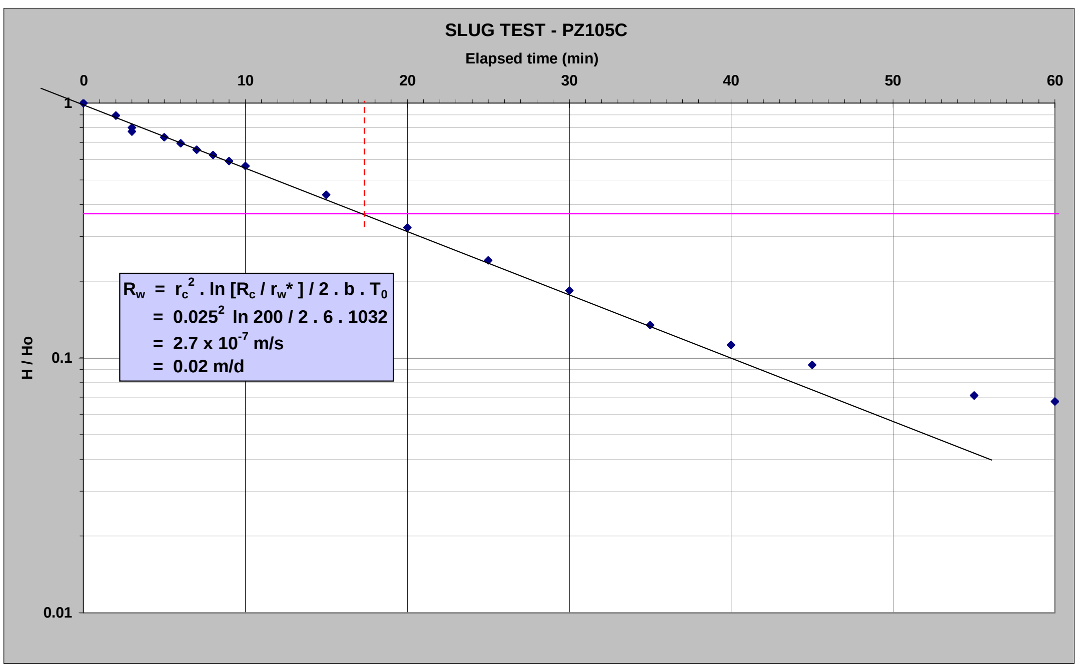


Figure 16: Slug Permeability Test on Triassic Piezometer PZ105C

(iii) Summary

The most recent measured water levels in each Triassic bore are shown on **Figure 7**, and the water levels have been contoured. The contours show a general decline in groundwater levels to the south-east from the UCML area (ie towards Goulburn River), which seems to be related to topography, and is unrelated to either the underlying Permian or to the longwall mining. The water levels from the new MCM piezometers show that the groundwater in the Triassic flows generally towards Goulburn River, both from the north and the south.

All the available information confirms that no matter what height of fracturing might have occurred above the goaf areas, the longwall mining at Ulan Coal has had no impact on the Triassic aquifer system. The substantial head differences between the Triassic and Permian also confirm that the connectivity between the Triassic and the Permian is very poor (ie vertical permeability extremely low).

Coffey Geosciences (Coffey, 2005) stated in their report accompanying UCML's 2005 SMP Application (UCML, 2005b) that *"… proposed mining within the application area is not expected to have a significantly greater impact on three* (private) *bores located some 2km to the south east of the application area (Bore E, GW047495, GW047195) than previous mining has already had. …. Bore GW047495* (Elward North bore) *is expected to have already been impacted from mining as it is located east of Panel 20. The owner was consulted in relation to the operation of the bore and informed UCML that it was still in use and that if it has been impacted then the result has not been noted."* We measured the water level in bore GW047495 (Elward North Bore) in February 2006, and found the water level unchanged from historical measurements dating back to January 2002 (**Figure 8**).

In relation to height of fracturing above the extracted longwall panels, Coffey (2005) state that *"… the base of the sandstone is located around 80m above the roof of the working section and is therefore not expected to intersect the caved zone."*

In their assessment of likely impacts of UCML's plan to commence mining from 400m wide panels compared with the previous 261m, SCT (2005) stated that *"… ground-water aquifers are likely to be affected by mining in a similar way to which they have been affected over previous longwall panels at the mine …"* and *"…proposed mining within the application area is not expected to have a significantly greater impact on three bores located some 2km to the south east of the application area (Bore E, GW047495, GW047195) than previous mining has already had."*

As proposed in the EA report, additional Triassic piezometers are to be installed above Underground 4 and to the north, prior to the commencement of longwall extraction. The EA also outlines a subsidence impact monitoring program to be implemented initially above the first few panels, where the Triassic is either absent or is dry (above the regional Triassic water table level), so that the actual fracturing response to longwall extraction can be studied prior to mining extending beneath saturated Triassic. The results of this program will be used to confirm or modify the mining approach in the more sensitive northern panels.

b) MARRANGAROO CONGLOMERATE

Within the Underground 4 area, two piezometers were completed with screens in the Marrangaroo Conglomerate:

- PZ102A -
  - Average hydraulic conductivity 0.2 m/d, determined from falling head test.

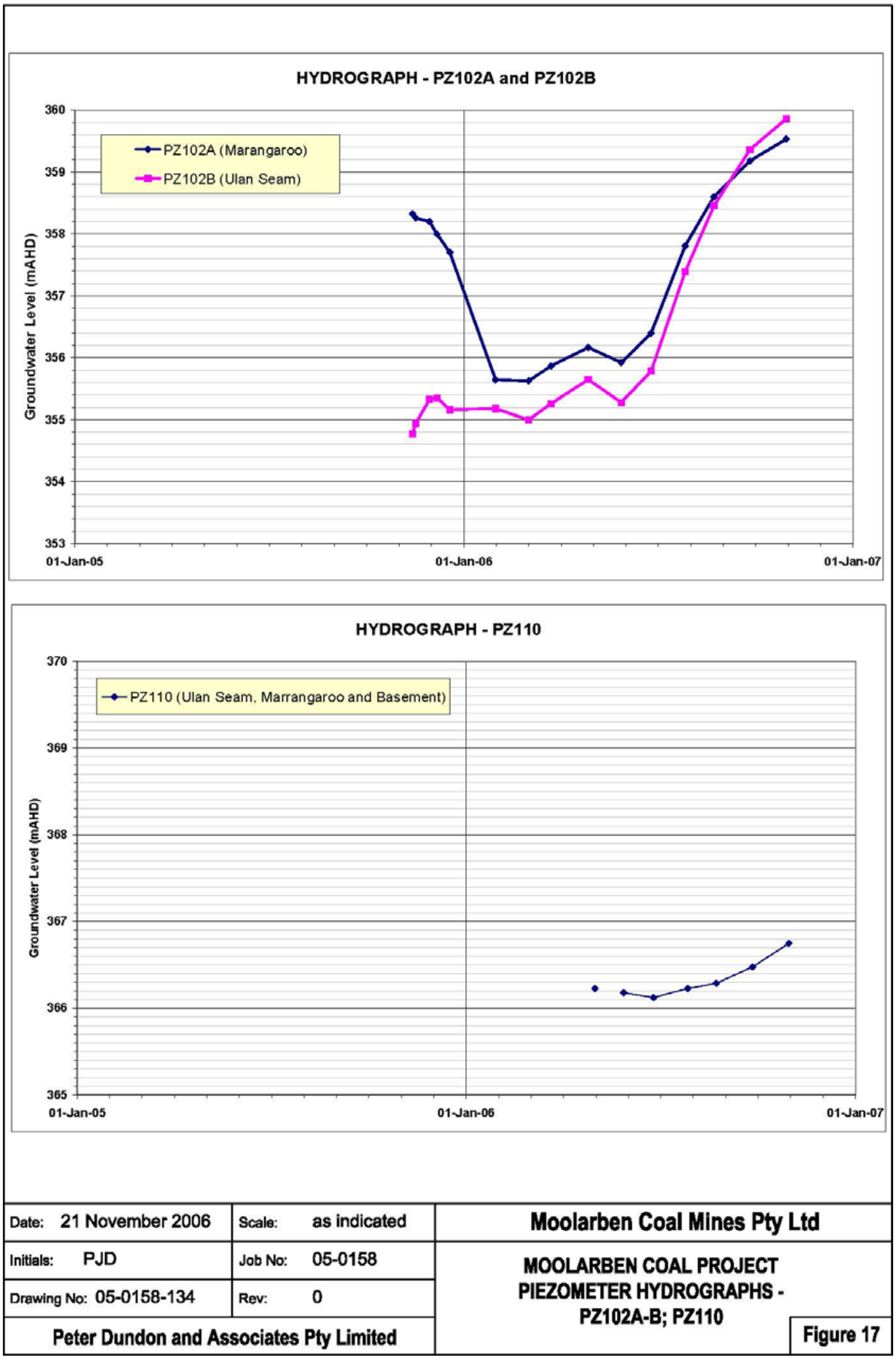


Figure 17: Piezometer Hydrographs – PZ102A and B; PZ110

  - Groundwater level broadly similar to the Ulan Seam (**Figure 17**). Both PZ102A and PZ102B appear to be responding to changes in pumping rates at Ulan.

- PZ110 -
  - Drilled through full sedimentary sequence to top of underlying volcanics.
  - Screened in Ulan Seam, floor coal measures, Marrangaroo Conglomerate and basement.
  - Average hydraulic conductivity (all above units combined) 6.8m/d (believed to be dominated by Ulan Seam - first water intersection).

Five further piezometers were completed in other parts of EL6288 with screens in the Marrangaroo Conglomerate or equivalent lithologies below the Ulan Seam:

- PZ17 - dry.

- PZ30 -
  - Partly unsaturated - water level 15m below top of Marrangaroo.
  - Very low hydraulic conductivity - pumped dry in less than 1 minute.

- PZ31A - dry.

- PZ41A -
  - Screened 77-80m depth. Adjacent PZ41B screened at 66-69m in Ulan Seam.
  - SWL in Marrangaroo is 40m lower than Ulan Seam at same site (PZ41B) despite there being less than 5m vertical separation (**Figure 18**).
  - Hydraulic conductivity 0.06m/d, determined from falling head test.

- PZ106A -
  - Screened 125-131m depth. Adjacent PZ106B screened at 29-35m in Permian coal measures.
  - SWL in Marrangaroo is 80m lower than in the coal measures above the Ulan Seam (**Figure 18**).
  - Average hydraulic conductivity 0.005 m/d, determined from falling head test.

The hydraulic testing results indicate that the Marrangaroo Conglomerate has low to very low horizontal hydraulic conductivity. The very large head differences between the Marrangaroo and the overlying Permian in the southern part of EL6288 indicate a very low vertical hydraulic conductivity as well. However, in the Underground 4 area, the Marrangaroo Conglomerate and Ulan Seam appear to be in reasonable hydraulic connection. The UCML multi-level piezometers (**Figure 10**) suggest a reasonable degree of hydraulic connection between the Marrangaroo and the Permian in the UCML underground area as well.

UCML have 4 Marrangaroo Conglomerate piezometers:

- DDH116
- PZ06A

- PZ07A
- PZ09A.

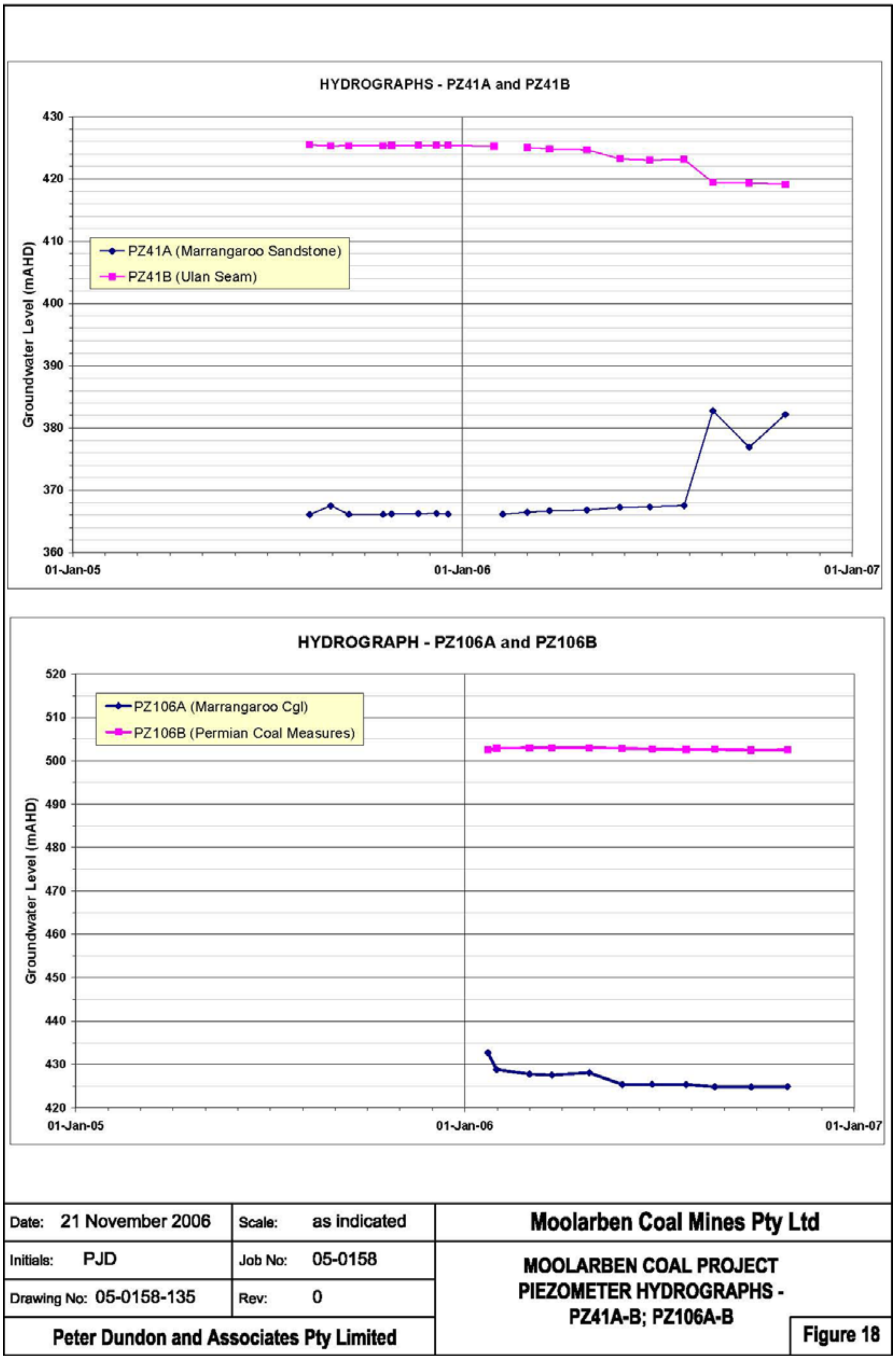
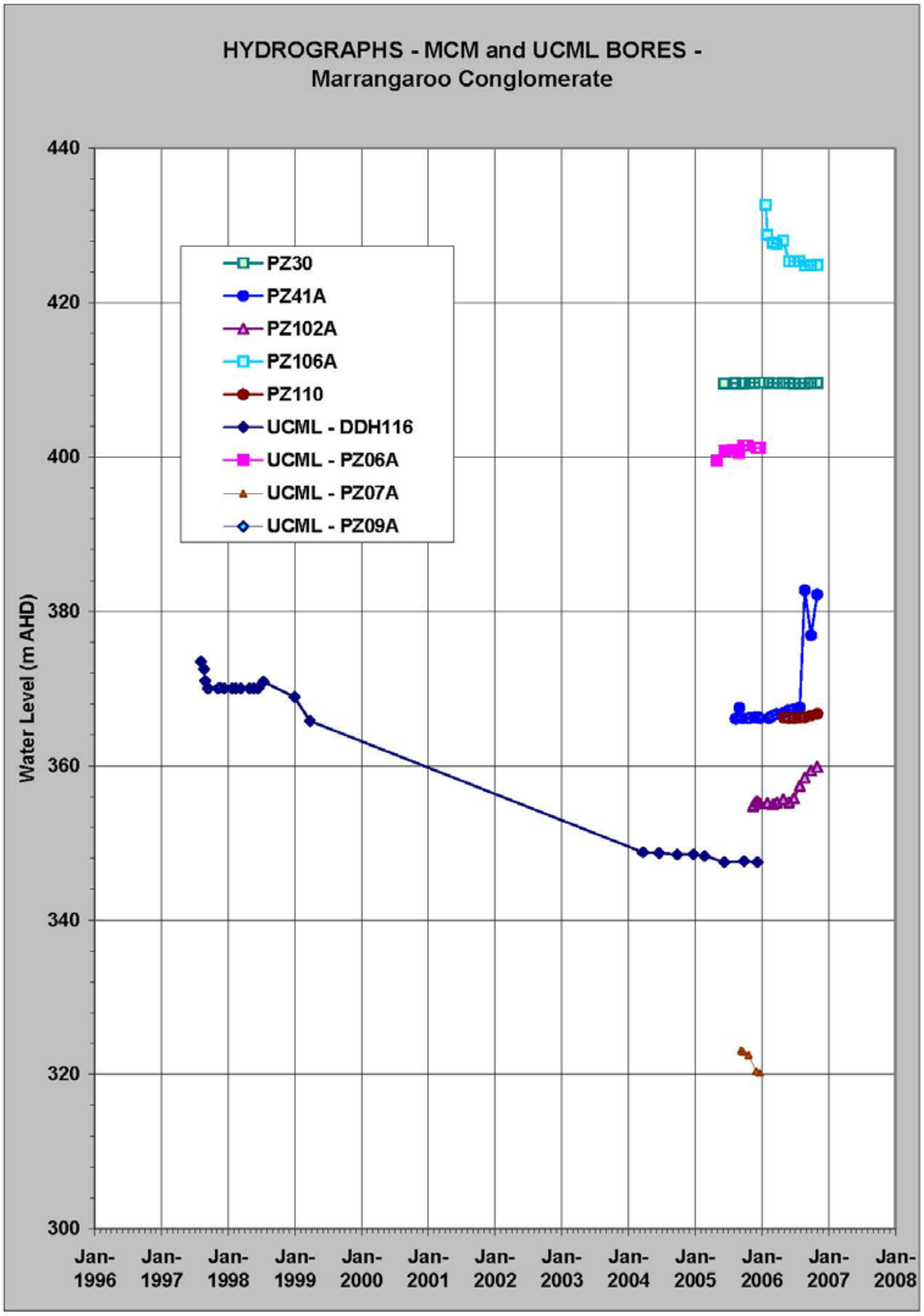


Figure 18: Piezometer Hydrographs – PZ41A and B; PZ106A and B

A composite plot of hydrographs for the UCML and MCM Marrangaroo Conglomerate piezometers is shown on **Figure 19**.



Date: 21 November 2006	Scale: as indicated	Moolarben Coal Mines Pty Ltd	
Initials: PJD	Job No: 05-0158	MOOLARBEN COAL PROJECT PIEZOMETER HYDROGRAPHS - Marrangaroo Conglomerate	
Drawing No: 05-0158-136	Rev: 0		
Peter Dundon and Associates Pty Limited			Figure 19

Figure 19: Piezometer Hydrographs – Marrangaroo Conglomerate

3.2 Distribution of Hydraulic Conductivities Within Model Layers

The Panel expressed the following concern:

"It is acknowledged that the simulation of groundwater impacts arising from mining operations is difficult and challenging at times, and that the calibration of a groundwater model can sometimes lead to unsupported aquifer property distributions and boundary conditions. The calibrated model presented in the EAR exhibits a number of domains for hydraulic conductivity distributed within 5 model layers. With the exception of layer 1, remaining layers have a distinct north-south linear boundary which defines domains to the east and west that have differing hydraulic conductivities by up to an order of magnitude. A similar east-west boundary prevails roughly along an identified palaeochannel and Wilpinjong Creek. These differing conductivities (especially vertical conductivities) appear in large part, to be an artefact of the model calibration process and are likely to have an impact on the evolution of regional depressurisation of strata. The panel has concerns that there appear to be no underlying geological-hydrogeological controls for these domains and seeks justification."

Response: Refer to **Section 2.8** above.

3.3 Simulation of Failure Regime above Goaf Areas

The Panel expressed this concern as follows:

"Underground mining simulations represented in the EAR predominantly support a scenario where only the coal seam has been extracted in longwall panel areas without regard to the failure regime above goaf (8 out of 9 simulations). The panel is of the understanding that this regime is currently estimated to prevail from the seam working section up to 122m above the seam depending upon the various submissions provided during the hearing. Omission of this regime may have a significant effect on model outcomes in terms of both mine water make and regional drawdown impacts (in all stratigraphic units). The panel requires clarification on the geometry and the hydraulic characteristics of this regime, and the inclusion of this regime in appropriate model simulations."

Response: Refer to **Section 2.10** above.

The results from UCML's monitoring of Triassic groundwater levels indicates that whatever height of fracturing might have occurred above the goaf areas, the longwall mining at Ulan Coal has had no significant impact on the Triassic aquifer system.

3.4 Model Storage Properties of Failure Regime

The Panel expressed the following concern:

"A single 'goaf run' model presented in the EAR addressed a 50m failure regime but storage properties within the seam and the failure regime were changed. The inelastic storage appears to have been doubled while elastic storage appears to have been elevated by 3 orders of magnitude (1000 times) thereby introducing a significant volume of groundwater into the model. These significant changes seem inconsistent with the geological setting and longwall mining practice. Justifications for these changes in storage are required."

Response: Refer to **Section 2.6** above.

In the modelling to assess impacts of the preferred project (Dundon, 2006b), the storage properties of the goaf and failure zone model cells were retained at the undisturbed values for simulation of the mining phase, but were amended for the post-mining recovery simulations.

3.5 Drain Conductance of Longwall Drain Cells

The Panel expressed the following concern:

"In all model simulations, the drain conductance for the underground seam extraction is significantly lower (250 times lower for the base case), than the drain conductance applied to the open cut seam extraction. This parameter is understood to govern the rate of water removal from the simulated mining operations. The panel requires justification for the very low conductance employed in underground operations and questions why a high value that might permit more rapid drainage and removal of groundwater reporting to mined panels, was not employed."

Response: The drain conductance value employed for the modelling reported in the EA was derived to achieve a satisfactory calibration of the model against the historical inflow rates and drawdown impacts at Ulan.

In the modelling to assess impacts of the preferred project (Dundon, 2006b), the drain conductance value adopted for both the open cuts and the underground mines was 1000 m^2/d.

3.6 Simulation of Borefield Impacts

The Panel's concern was expressed as follows:

"It is understood that simulations of mining operations include a proposed borefield located along the entire eastern perimeter of the proposed longwall operations. It is unclear how the sustainability of this borefield would be affected in the course of seam extraction. Provision of (model) strata pressures and drawdowns for scenarios without, and with the borefield would prove useful."

Response: Refer **Section 2.12** above.

3.7 Potential Leachate Impacts

The Panel raised the following concern:

"No leachate trials appear to have been undertaken on spoils waste rock in order to geochemically characterise the solute that will reside in the open cut pit shells in the long term. The panel considers that salinity-speciation-characterisation needs to be addressed in order to understand the long term impacts of void re-saturation post mining, especially if groundwater levels rise following the current drought, or rainfall infiltrates spoils, or pits are used for storage of surplus mine water."

Response: Refer **Section 2.13** above.

4 EMAIL DATED 28 NOVEMBER 2006

Following a meeting with the Panel at the Department of Planning offices on Monday 27 November, the Panel provided additional comments relating to their outstanding concerns, which are detailed in the following sections.

4.1 Height of Failure Zone Above Goaf

"In respect of depressurisation of the Permian and Triassic strata, it would not be unreasonable to expect depressurisation of the order of metres to tens of metres if vertical drainage is established over an interval of +100m via connective cracking within a failure regime. It is therefore important to establish with a reasonable degree of certainty, geometry of the failure regime and to include same in any predictive groundwater modelling."

Response: Refer **Sections 2.10** and **3.3** above.

4.2 Model Layers to Represent the Permian and the Triassic

"It would be extremely useful to understand the vertical pressure (loss) regime above extracted panels with increased clarity. It is the shallow loss regime that clearly has the potential to impact upon features like the drip, surface drainages including the Goulburn River, and existing bores/springs. Improved clarity could be achieved by further discretising the model in a vertical sense within the Permian and Triassic zones (adding layers)."

Response: The model has been set up with the Permian Coal Measures overburden split into two layers, a lower layer of 50m (Layer 3 – representing the first 50m above the Ulan Seam) and an upper layer of 50m (Layer 2 – representing the zone between 50m and 100m above the Ulan Seam. The Triassic has been represented by a single layer (Layer 2).

The very large head differences between the Triassic groundwater levels and the Ulan Seam groundwater levels, not just within the Ulan mine vicinity, but also over much of the Moolarben Underground 4 area, indicate that the vertical permeability of the Permian and the Triassic aquifers is extremely low. Similar large head differences between the Ulan Seam and the upper parts of the Permian Coal Measures indicates similar very low vertical permeabilities in the Permian.

Modelling carried out using varying of failure zone heights with the existing model layer structure indicated limited variation in the level of impacts, such that further discretisation in a vertical sense is not justified at this time. It is considered that the current zonation is more than adequate for impact assessment purposes.

It is likely that a more detailed layer structure will be adopted for modelling to be undertaken during the project operational phase, as more information comes available.

4.3 Drain Conductance for Longwall Model Cells

"Simulation of mine panel extractions using 'drain' type cells should carefully consider the implications of using a low drain conductance. This conductance term basically provides for an impedance to free drainage within a model cell. It is understood that the low impedance employed in the 'base case' Moolarben model for underground panels is an artefact of calibration. Panel members find it difficult to comprehend how longwall mining offers such impedance when workings are exposed to vertical and relatively free gravity drainage over very large areas, and water is generally removed with some immediacy from workings. The more familiar approach to the use of drain cells in a mining or seepage face context, is to apply a very high conductance value thereby facilitating free draining conditions from strata. This approach has been widely used at other mine sites throughout the Upper Hunter region. If model calibration is the issue then perhaps it would be useful to revisit the adopted permeability and storage properties of the strata since these properties DO govern free drainage."

Response**:** Refer **Section 3.5** above.

4.4 Maintaining Drain Cells During Simulations

"Simulation of longwall panels and goaf should provide for sustained drainage of groundwaters rather then the methodology employed to date of switching panel (model) drains off after extraction. Mining operations generally do not allow a build up of water in goafed areas up dip of operations or in any intended development area (safety issues)."

Response: Refer **Section 2.9** and **Figure 5** above.

4.5 Storage Parameters in Failure Regime in Model

"Enhancement of storage properties within goaf or the failed regime should be avoided. This concept was employed in the so-called 'goaf run' presented in the EAR and is considered by the Panel to be unrealistic since it introduces a large volume of groundwater into the model (as porous and elastic storage) prior to draining that same volume of groundwater from the model. This clearly has the potential to impact upon mine water make and strata depressurisation."

Response: Refer to **Section 3.4** above.

5 MODELLING FOR PREFERRED PROJECT IMPACT ASSESSMENT

The groundwater model has been modified to incorporate many of the issues raised by the IHAP panel members, and also to incorporate the altered mine plan for the Preferred Project Proposal. A groundwater impact assessment report for this Preferred Project has been prepared (Dundon, 2006b).

The complete report detailing the modifications to the model and the results of the calibration and predictive simulations carried out with the modified model (Aquaterra Simulations, 2006b) is appended as **Attachment B**.

6 REFERENCES

Aquaterra Simulations, 2006a. *Moolarben Coal Groundwater Model ("MC1 Model").* Incorporated as Appendix F of Dundon (2006a).

Aquaterra Simulations, 2006b. *Moolarben Coal – Response to IHAP Member Comments.* Letter report dated 14 December 2006.

Coffey Geosciences Pty Ltd, 2005. *Subsidence Management Plan for Ulan Coal Mines Limited, Groundwater Impact Assessment and Recommendations for Management and Mitigation*. Supporting document to UCML (2005b).

MDBC (2001). *Groundwater flow modelling guideline.* Murray-Darling Basin Commission. (URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides)

Merrick N P, 2006. *Review of the Moolarben Coal Groundwater Modelling Study*. See **Attachment A** of this report.

Moolaben Coal Mines Pty Ltd (MCM), 2006a. *Moolarben Coal Project - Environmental Assessment*

Peter Dundon and Associates Pty Ltd, 2006a. *Moolarben Coal Project Groundwater Assessment*. Incorporated as Appendix X of the EA (MCM, 2006a).

Peter Dundon and Associates Pty Ltd, 2006b. *Moolarben Coal Project Preferred Project - Groundwater Assessment*.

SCT, 2005. *Subsidence Assessment for Longwalls 23-26 and Longwall W1 at Ulan Coal Mine*. Supporting document for UCML (2005b).

Ulan Coal Mines Limited, 2002. *2001 Annual Environmental Management Report.*

Ulan Coal Mines Limited, 2003. *2002 Annual Environmental Management Report*.

Ulan Coal Mines Limited, 2004. *2003 Annual Environmental Management Report*.

Ulan Coal Mines Limited, 2005a. *2004 Annual Environmental Management Report*.

Ulan Coal Mines Limited, 2005b. *Subsidence Management Plan Application.* Dated August 2005

Ulan Coal Mines Limited, 2006. *2005 Annual Environmental Management Report*.

ATTACHMENT A

Review of the Moolarben Coal Groundwater Modelling Study.

by

Dr N P Merrick

(dated 29 October 2006)

HERITAGE COMPUTING REPORT

REVIEW OF THE MOOLARBEN COAL GROUNDWATER MODELLING STUDY

FOR

PETER DUNDON & ASSOCIATES

ON BEHALF OF

WHITE MINING LTD

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By

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EXECUTIVE SUMMARY

A groundwater model of the proposed Moolarben underground and open cut coal mine project near Mudgee in New South Wales has been developed by Aquaterra Simulations for White Mining Ltd. The purpose of the modelling is to assess potential cumulative impacts on local aquifers and surface water bodies from Moolarben, Ulan and Wilpinjong mines, and to make a preliminary assessment of mine dewatering requirements for Moolarben.

This report provides a peer review of the model according to Australian modelling guidelines. The review is based on a checklist of 36 questions across 9 model categories.

The review finds that the model has been developed competently, and is suitable for addressing cumulative impacts from the three mines, and for estimating indicative dewatering rates. However, the modelling results are sensitive to some features that are known poorly.

There is a reasonable spread of representative groundwater level data for the Ulan seam over the three mining areas, but there are no reliable data on groundwater levels within the Goulburn River National Park. Other layers are lacking in data away from Moolarben. The data are sufficient for a first-cut steady-state modelling calibration followed by transient simulation. There is an insufficient time-varying water level record to warrant transient model calibration at this stage. This will affect the reliability of mine inflow estimates. Most piezometers have been monitored for water level for about one year, but there would be much longer records in Ulan mine bores.

A substantial number of aquifer tests provides constraints on adopted aquifer property values. This study has the advantage of existing models at the neighbouring Ulan and Wilpinjong mines, which have been used to inform material property and flux magnitudes. The two neighbouring mines would have more data than are readily available to a third party due to proprietary restrictions. Given a lack of detailed data from the neighbouring mines, and the huge effort required to simulate three mines simultaneously, one cannot expect the Moolarben model to simulate properly the groundwater processes at Ulan and Wilpinjong. Rather, the aim should be to get the offsite water levels roughly correct so that the predicted Moolarben water levels and inferred mine inflows are realistic, given that the drawdowns from the three mines are overlapping. There is particular uncertainty as to the actual longwall mine dewatering rates at the Ulan mine. For Wilpinjong, the assumption is made that mining would follow the plan at the time of approval, but the operational plan is now quite different.

The spatial agreement in groundwater levels between those simulated and those measured is acceptable. The overall fit is about 9% scaled RMS, which is quite good for a complex model and head measurements that are mixed in

time and in depth. However, there are places where observed levels cannot be replicated, with maximum residuals about 40 metres. Groundwater levels simulated at Wilpinjong are particularly good in pattern and in magnitude.

The major uncertainties in the model parameterisation are in the values allocated to vertical permeability in the interburden and horizontal permeability in each layer. Each has been explored by sensitivity analysis. The best estimate for Moolarben mine inflows at 2009 is 4.0 ML/day and 6.6 ML/day at the end of mining.

Experience with longwall mining indicates that there will be a caved zone immediately above a longwall panel with thickness up to 10 times the seam thickness, and permeabilities several orders of magnitude higher than for the unperturbed virgin rock. In all underground coal mine models, there is contention as to how this should be handled. The problem is that the most commonly used modelling software package (Modflow) does not at present permit time-varying material properties (without frequent stops and starts).

This study addresses the problem by sensitivity analysis for the extreme case of instantaneous and widespread caving. The goaf simulation has a performance that is almost as good as the base case, and is more realistic. Higher horizontal and vertical permeabilities are applied to Layer 3 above the coal seam, for all time, and drain cells representing progressively mined panels remain active. The predicted Moolarben inflow increases (over the base case) by 12% at 2009 and by 45% at 2022. Hence, there is considerable uncertainty in the long-term dewatering rates.

Of all sensitivity runs, the lowest mine inflow value (2.7 ML/day) at 2009 is about 30% lower than the base case. Hence, there is not much chance of mine inflows being significantly lower than the base case estimates, but every chance that rates could be much higher than estimated.

Mines are represented appropriately by Modflow “drain” cells. This technique has been used also in the models developed at the neighbouring mines. However, the mine drain cells are progressively deactivated, whereas it would be more realistic to keep them active permanently. There is no separate sensitivity scenario that looks at activation versus deactivation. The nearest scenario varies goaf properties at the same time. In this experiment, the Moolarben inflows increased to 4.5 ML/day at 2009 and 9.6 ML/day at the end of mining.

The impact of mining on water bodies is assessed briefly by analysis of overall reductions in simulated evapotranspiration and in simulated baseflow to Goulburn River and other creeks. It is not clear where these impacts might occur.

Until there is enough time-series data, the current model parameterisation must be regarded as preliminary. Transient calibration (yet to be done) will provide more reliable aquifer properties because there is more information content in fluctuating water levels that are responding to stresses on the aquifer system.

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INTRODUCTION

This report provides a peer review of a groundwater model of proposed mining of the Moolarben coal deposit in the Western Coal Fields of New South Wales (NSW) near the village of Ulan, 40 km north-east of Mudgee. The model has been developed by Aquaterra Simulations for Peter Dundon & Associates, who are undertaking the environmental impact hydrogeological investigations on behalf of White Mining Ltd.

The Moolarben Coal Project will comprise one underground mine and three open cut pits that will extract coal from the Ulan Seam. The project area lies between the existing Ulan Coal Mine (to the west) and the proposed Wilpinjong Coal Mine (to the east). The modelling has been done as a component of the Part 3A Environmental Assessment for the project. The purpose of the modelling is to assess potential cumulative impacts on local aquifers and surface water bodies from all three mines, and to make a preliminary assessment of dewatering requirements for the Moolarben mine.

SCOPE OF WORK

The key tasks for this peer review are:

- Read and comment on progress and draft reports produced by Aquaterra Simulations;
- Review the model as documented against the guidelines developed for the Murray Darling Basin Commission;
- Provide the review in the form of a written report.

MODELLING GUIDELINES

The review has been structured according to the checklists in the Australian Flow Modelling Guideline (MDBC, 2001). This guide, sponsored by the Murray-Darling Basin Commission, has become a *de facto* Australian standard.

The modelling has been assessed according to the 2-page Model Appraisal checklist in MDBC (2001). This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis. Not all questions are pertinent to a site-specific model.

The effort put into a modelling study is very dependent on timing and budgetary constraints that are generally not known to a reviewer. Hence, reduced performance in one aspect of the modelling effort could be the result of a conscious decision by the modelling team to get the model finished on budget and/or on time, or to apply extra focus on specific issues arising during modelling.

EVIDENTIARY BASIS

The primary documentation on which this review is based is:

1. Georgiou, J. and Middlemis, H., 2006, Moolarben Coal Groundwater Model (‘MC1 Model’). Aquaterra Simulations Report R021c [8 September 2006]

At the start of the project, the following document was provided for review:

2. Georgiou, J., 2006, Groundwater Model Design Report – Moolarben Coal Mine Project. Aquaterra Simulations Memo Report R0107a Job A37b [15 May 2006]

A progressive review was conducted on draft reports dated 21 June 2006 and 24 August 2006, and points of clarification were conveyed during several telephone discussions. Apart from the Groundwater Assessment Report by Dundon (2006), no other documents were inspected by the reviewer.

The objectives of the modelling study are stated in Document #1 as:

- *"assist in the overall hydrogeological assessment, and the design of the water supply and dewatering wellfields to support the mining operation on the Ulan Coal Seam; and,*
- *predict the cumulative potential impacts of Moolarben, Ulan and Wilpinjong mine sites, including impact of abstractions and post-mining water management plans."*

PEER REVIEW

In terms of the modelling guidelines, the Moolarben coal model is best categorised as an Impact Assessment Model of medium complexity.

The review was conducted progressively with checkpoints at the conceptualisation and model design stage (Document #2), and after calibration, sensitivity analysis, prediction and final reporting (Document #1). Written comments were conveyed to the modelling team after reviewing Document #2.

The appraisal is presented in Tables 1 and 2.

Table 1. MODEL APPRAISAL: Moolarben Coal

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
1.0	THE REPORT								Separation of Calibration and Prediction sections in the Report would have given a cleaner structure to the reporting.
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good			
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Impact Assessment Model, medium complexity
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Not done for steady state calibration. Provided in Table 4.4 for mining simulation and recovery.
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			Subject to stated limitations.
1.5	Are the model results of any practical use?			No	Maybe	Yes			Still considerable uncertainty due to complexity of the groundwater system under stress.
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			More extensive data in Groundwater Assessment Report (Dundon,2006)
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Directions are described in text. Some contours (at 2006) are shown on perspective Figure 2.1. Unknown beneath Goulburn National Park. More contours in Groundwater Assessment Report (Dundon,2006)
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Rainfall and stream stage are appropriate. Any knowledge of the weir/dam on Moolarben Creek? Probably excluded from the model.

2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	**Adequate**	Very Good			Ulan dewatering is the dominant current stress. This is inferred rather than exact.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		**Missing**	Deficient	Adequate	Very Good			No hydrographs are presented for analysing cause and effect. Hydrographs are presented in Groundwater Assessment Report (Dundon, 2006)
2.6	Are groundwater hydrographs used for calibration?			**No**	Maybe	Yes			Steady state calibration only.
2.7	Have consistent data units and standard geometrical datums been used?			No	**Yes**				
3.0	CONCEPTUALISATION								
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	**Yes**			
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	**Very Good**			
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	**Very Good**			Excellent perspective view in Figure 2.1. Stratigraphy is shown in Figures 3.1 and 3.2.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	**No**				Sensible number of layers, with interburden split to allow testing of goaf caving (50m thickness).
4.0	MODEL DESIGN								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	**Yes**			Very broad extent isolates boundaries from impacts, and allows cumulative effects of three mines. 100m cell size is sufficiently fine. What are the u/g panel widths for Moolarben?
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	**Adequate**	Very Good			Each boundary is justified. Concern over the southern extent of the coal seam, as it crops out and should be truncated in the model.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	**Yes**			PMWIN Pro and MODFLOW. Cannot handle time varying material properties.

Table 2. MODEL APPRAISAL – Moolarben Coal

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
5.0	CALIBRATION								
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			Several lines of evidence: scattergram, statistics, contours with spot target levels. Contours for Layer 3 not shown. Wrong layer association for last 3 targets in Table 4.1 – must be Layer 3 not Layer 4.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Calibration based on 62 head measurements, mixed in time and mixed in depth. Also informed by rough estimate of Ulan dewatering. The raw data do not give full coverage of the area, particularly for layers other than coal. Good levels simulated at Wilpinjong (inferred from prediction contours).
5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good			Steady-state only. Some alowance for dynamic water levels at Ulan mine.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Rain recharge rates in Appendix convert to 2% to 12% range - plausible. Permeability values are reasonably consistent with other studies, except for Marrangaroo Sandstone transmissivity: calibrated as 1-5 m^2/d; Wilpinjong pumptest analysis 20 m^2/d; Coffey (1991) 50 m^2/d. Sensible Kv. Comprehensive reporting of property values and distributions in Appendix. Layer 4 (Ulan Seam) Kh=1.7-3 m/d has good agreement with aquifer tests (Dundon, 2006). Storage values cannot be calibrated by steady-state simulation.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Quite good – 8.9% scaled RMS. Some extreme residuals (max 40m).

5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good			
6.0	VERIFICATION								
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			Insufficient data.
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A	Unknown	No	Maybe	Yes			
6.3	Are there good reasons for an unsatisfactory verification?	N/A	Missing	Deficient	Adequate	Very Good			
7.0	PREDICTION								
7.1	Have multiple scenarios been run for climate variability?	N/A	Missing	Deficient	Adequate	Very Good			Long term simulation requires average rain.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	Adequate	Very Good			Dewatering for one mine plan. Note that the Wilpinjong mine plan has changed since the EIS, hence any predictions for Wilpinjong behaviour are academic. Also a prediction for recovery after mine closure.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			This is a common weakness with coal mine modelling, as no transient data are used for calibration. Hence, storage parameters are uncalibrated and K values are preliminary, until the aquifer is stressed by mining.
7.4	Are the model predictions plausible?			No	Maybe	Yes			There is much uncertainty in property values that dictate mine inflows. Estimates will improve only after mining starts. Estimates are constrained a little by aquifer tests, reported Ulan flows and projected Wilpinjong flows. Very difficult to get all three mines to give the right flows simultaneously. Good discussion on percentage impacts on baseflows, evapotranspiration.

8.0	SENSITIVITY ANALYSIS								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good			Sufficiently intensive exploration of extremes for key properties (Table 4.5). Reported as SRMS% for calibration, and time-series graphs for prediction. Done for Kh, Kv, mine drain conductance, with/without goaf caving. Not done for %rain or storage parameters.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good			Significant shifts in SRMS% calibration performance indicator. Improved head performance (over base case) only for higher Kv, but Ulan inflow estimate is much worse. Goaf run is a good compromise – almost as good as base case and more realistic.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good			Wide range of mine inflow estimates for property extremes. Unlikely for mine inflow to be much lower, could be much higher.
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			Uncertainty is explored in part by sensitivity analysis, and is discussed under model limitations.
	TOTAL SCORE								PERFORMANCE:

DISCUSSION

THE REPORT

The Draft Final Report (Document #1) is a reasonable quality document of 47 pages text, including 25 figures, and 18 pages of appendices. To an external reader with no prior knowledge of the study area, the report serves well as a standalone document without need of supporting documents. However, the report could have included a better summary in Table 2.1 of aquifer test results reported by Dundon (2006). At present, the stated ranges do not always include the mean values obtained in the aquifer tests.

The report suffers from the absence of an Executive Summary and a Conclusion section, which should focus on the modelling findings in terms of the project objectives. Combining Calibration and Prediction into the same report section is not good practice.

The report has sufficient description of the modelling process and modelling results. It addresses the project objectives satisfactorily. However, the quantification of impacts is a little cryptic, with reliance on comparative water balances in Table 4.4 at different stages of mining and discussion in the text as to percentage changes. It is not always clear how the percentages or absolute differences between runs were obtained. For example, Section 4.3 dot point 7 has an increase in boundary outflows during recovery of 6 ML/day, whereas Table 4.4 appears to show 2 ML/day; dot point 8 has total predicted impacts of 3 ML/day at 2022, but Table 4.4 appears to show a much higher value. It appears that the no-mining benchmark budget figures are based on the end of recovery values, rather than a steady-state pre-development simulation. This is an appropriate approach but should be clarified.

Table 4.4 includes a budget item for Wells at 2022 that has no correspondence with Table 4.3. In the same table, the Mine Dewatering value at 2024 should be 8,620 (not 9,620) kL/day to agree with Table 4.3.

In the early stages of the report, future tense is often used when present or past tense is appropriate. This is a carryover effect from the Model Design Report.

Minor typographical corrections and suggested additions are listed in the Appendix.

DATA ANALYSIS

Even with a good set of aquifer test data, there is uncertainty in chosen hydraulic conductivity and rainfall infiltration factors, which usually are resolvable only as a ratio without supporting information (e.g. flux measurements or estimates). This is especially the case in regions away from the test areas. However, this study has the advantage of existing models at the neighbouring Ulan and Wilpinjong mines, which have been used to inform material property and flux magnitudes. For proprietary reasons, the two neighbouring mines would have more data than are readily available to a third party. Given a lack of detailed data from the neighbouring mines, and the huge effort required to simulate three mines simultaneously, one cannot expect the Moolarben model to simulate properly the groundwater processes at Ulan and Wilpinjong. Rather, the aim should be to get the offsite water levels roughly correct so that the predicted Moolarben water levels and inferred mine inflows are realistic, given that the drawdowns from the three mines are overlapping.

There is particular uncertainty as to the actual longwall mine dewatering rates at the Ulan mine. A reasonable estimate has been invoked as a calibration target. For Wilpinjong, the assumption was made that mining would follow the plan at the time of approval. The operational plan is now quite different. This will affect the detail in the Moolarben model predictions, but the order of magnitude of cumulative impacts will be satisfactory.

There is a reasonable spread of representative groundwater level data for the Ulan seam over the three mining areas, but there is no reliable data on groundwater levels within the Goulburn River National Park. Other layers are lacking in data away from Moolarben.

There is a growing data set on the time variation of groundwater levels at Moolarben, but there would be proprietary data of longer duration at Ulan that was not available for this study. Without time variations, calibration is limited to steady-state which is always inferior to transient calibration. None of the hydrographic data are presented in the modelling report, but they can be found in Dundon (2006).

CONCEPTUALISATION

The modelling team's conceptualisation is discussed in detail, and is illustrated clearly with a perspective view (Figure 2.1) and two stratigraphic cross-sections (Figures 3.1 and 3.2). The three figures together serve the purpose of a conceptual model.

A conceptual model diagram is a simplified 2D or 3D summary picture (without stratigraphic detail) that conveys the essential features of the hydrological system, denoting all recharge/discharge processes that are likely to be significant. The diagram can serve a dual purpose for displaying the magnitudes of the water budget components derived from data sources or from simulation.

The Ulan seam is represented as one layer bounded below by the Marrangaroo Sandstone and above by a lumped Illawarra Coal Measures sequence. This is in accordance with similar representations in earlier Ulan and Wilpinjong models. The overlying sequence is split arbitrarily into two model layers to allow subsequent exploration of caving above longwall panels across a 50 metre thickness. This is a sensible precaution for subsequent modelling experiments.

MODEL DESIGN

The model has been built with PMWIN Pro software and Modflow which is regarded widely as a standard, particularly by government agencies. One limitation that Modflow has for coal mining simulations is that it does not permit time-varying material properties (without frequent stops and starts). Experience with longwall mining indicates that there will be a caved zone immediately above a longwall panel with thickness up to 10 times the seam thickness, and permeabilities several orders of magnitude higher than for the unperturbed virgin rock. This situation is acknowledged in this study, and is addressed by sensitivity analysis for the extreme case of instantaneous and widespread caving.

Discretisation in space is appropriate. Model cells are 100 m square, but the numbers of rows and columns are not stated. It would have been instructive to know what the longwall panel widths[1] are to be, to judge whether 100 m was the most appropriate scale to use.

The very broad model extent isolates the boundaries from likely impacts, and reduces the need for accurate representation of boundary fluxes.

Mines are represented appropriately by Modflow "drain" cells. This technique has been used also in the models developed at the neighbouring mines. However, the mine drain cells are progressively deactivated, whereas it would be more realistic to keep them active permanently. The reason for the deactivation strategy seems to be that this gave a better representation of Ulan inflow rates, but it must be remembered that this target value is known

[1] Subsequently advised as 250 m, hence 100 m is appropriate

poorly. The subsequent goaf simulation, with higher permeabilities in the layer immediately above the Ulan seam, kept the drain cells active. This run increased the Ulan inflow at 2004 from 8.5 ML/d to 11.2 ML/d, which still is a reasonable value (subject to confirmation).
Goulburn River and several creeks are handled with appropriate Modflow features ("drain" and "river" cells). Open cut pits are represented appropriately as permanent drain cells.

CALIBRATION

Given the absence of sufficient time-varying water levels or fluxes, calibration has been limited to steady-state. However, for prediction purposes, transient simulation has been done. For transient simulation, storage properties are best estimates without calibration support.
The spatial agreement in groundwater levels between those simulated and those measured is illustrated by visual inspection of Figures 4.3.1 to 4.3.3, which show groundwater elevation contours and spot target levels for Layers 1, 2 and 4. No figure is supplied for Layer 3. Three target values in the Ulan mine lease ascribed to Layer 4 on the contour map and the Ulan Seam in Table 4.1, appear to have been allocated to Layer 3 for calibration statistics. The overall fit is about 9% scaled RMS, which is quite good for a complex model and head measurements that are mixed in time and in depth.
The scatter plot in Figure 4.1 shows no apparent bias in residuals. Some sites cannot be replicated, with maximum residuals about 40 m.
Groundwater levels simulated at Wilpinjong are particularly good in pattern and in magnitude.
Calibrated material properties and rain recharge rates are generally in accordance with values adopted for the neighbouring models and with the aquifer tests of Dundon (2006). More reliable values will have to await the collection of time-series water levels after excavation commences.

PREDICTION

Predictions are based on transient simulation for 40 years of mining followed by 40 years of recovery (to 2067). The initial 40 year period includes the end of Moolarben mining in 2022, the end of Ulan mining in 2024, and the end of Wilpinjong mining in 2027.
The stress period is two years initially (from 1987) but reduces to one year from 2006. The mining panels are assumed to be excavated instantly at the start of each period. This will cause a slight overestimation of inflows, as the model cells are "mined" in advance of what will occur in reality. The dewatering rate curve in Figure 4.2 would be more accurate if it were translated six months to the right.
On the other hand, inflows are reported (graphically) only at the end of each year when they tend to stabilise. More detailed reporting of modelling results, near the start of each stress period, would show higher inflows initially, with exponential decay to the sampled values at the end of each stress period. It is probable that the decay curve will be oscillatory due to numerical shock caused by a very sudden drop in water levels at the mine face. Therefore, the values reported annually are underestimates of the rates that occur earlier.
The two preceding issues are compensating, but it is not known if they are balancing.

SENSITIVITY ANALYSIS

A thorough sensitivity analysis has been done. This is particularly important when there is a paucity of data on material properties. The many aquifer tests done in this study (Dundon, 2006) give good information on horizontal permeabilities, but knowledge of vertical permeabilities is always weak. Substantial vertical head differences in places give qualitative indications of poor connectivity between layers. The sensitivity scenarios are documented in Table 4.5, along with performance measures in the form of scaled %RMS and mine inflow rates at Ulan and Moolarben.

The only run that gives an improved calibration statistic (based on water levels only) is the case that has high vertical permeability in Layers 3, 4 and 5, but the resulting Ulan mine inflow at 2004 is far too high.

The goaf simulation has a performance that is almost as good as the base case, and is more realistic. Higher horizontal and vertical permeabilities are applied to Layer 3 above the coal seam, for all time, and drain cells representing progressively mined panels remain active. The predicted Moolarben inflow increases (over the base case) by 12% at 2009 and by 45% at 2022. Hence, there is considerable uncertainty in the long-term dewatering rates. Of all sensitivity runs, the lowest value at 2009 is about 30% lower than the base case. Hence, there is not much chance of mine inflows being significantly lower than the base case estimates, but every chance that rates could be much higher than estimated. The report makes this uncertainty very clear.

There is some confusion as to whether the parameters adopted for the goaf run (Kh, Kv, S) and the permanent activity of drain cells are applied to Moolarben only, or Ulan as well. The header in the last section of Table 4.5 suggests that the Ulan mine is treated equally.

Sensitivity to rain recharge estimates has not been explored.

UNCERTAINTY ANALYSIS

No formal uncertainty analysis has been undertaken, but this is not unusual. This activity should not be expected unless it is called for in the project brief and is funded accordingly.

Uncertainty in predicted fluxes has been handled by sensitivity analysis.

Model limitations are discussed at length in a special section of the report. The main issues are:

- Inferred dewatering rate at Ulan mine;
- Absence of groundwater hydrographs of sufficient duration for better calibration;
- Uncertainty as to rain recharge rates;
- Absence of water levels in the Goulburn River National Park;
- Uncertainty as to permeability magnitudes and distributions (especially away from piezometer test areas);
- No calibration of aquifer storage properties.

CONCLUSION

The Moolarben Coal groundwater model has been developed competently. It is a suitable model for addressing cumulative impacts from the three mines, and for estimating indicative dewatering rates. The inflows cannot be much lower than predicted, but they could be much higher.

The report would benefit from the following actions:

- Addition of an Executive Summary;

- Addition of a Conclusion that summarises the modelling findings in terms of the project objectives;

- Separation of Calibration and Prediction sections.

The model must be considered preliminary, and improved estimates of inflows will have to await the acquisition of a longer water level monitoring record, and analysis of cause and effect between stresses (rainfall recharge, dewatering) and responses (water level fluctuations, drawdown, inflow) established through transient calibration of the model after mining commences.
The report states that the "base case predicted seepage rates and drawdowns should be regarded as rough estimates, possibly a conservatively low estimate". I concur with this.

REFERENCES

MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL:
www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

Dundon, P. J. (2006). Moolarben Coal Project Groundwater Assessment. Peter Dundon & Associates Pty Ltd Report 05-0158-R01J for Moolarben Coal Mines Pty Ltd.

APPENDIX – Corrections and Suggestions

Table of Contents: Section 4.4 has sub-sections labelled 4.3.x.
Page 4, last paragraph: Figure 2.1 → Figure 1.1; Figure 1 → Figure 1.1
Page 6, first paragraph: Figure 2.1 → Figure 1.1
Page 6, end of second paragraph: refer Wilpinjong EIS (2005)
Page 7 onwards: lots of “will be”
Page 8: overly → overlie
Page 16, last paragraph: 63 → 62; all → 3 of 5
Page 17, Table 4.1: R680, R755, R756 not Ulan Seam?.
Page 19, Table 4.2: Kv for Layer 1 is no longer a range
Page 35, Table 4.4: check Wells figure (5,860); Mine dewatering 9,620 → 8,620
Figure 4.4: residual drawdown relative to 1987?
Figure 4.8: MC12 → MC1.3

ATTACHMENT B

Moolarben Coal – Response to IHAP Member Comments.

by

Aquaterra Simulations

(dated 14 December 2006)

Suite 3, 17 Hackney Road, Hackney
South Australia, 5069
Tel: (08) 8363 9455
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Memo

To:	Peter Dundon	**Company:**	Peter Dundon & Associates
From:	Hugh Middlemis	**Job No:**	A37-B1
Date:	14th December, 2006	**Doc No:**	R028_b

Subject: **Moolarben Coal – Response to IHAP member comments**

1. INTRODUCTION

This brief report presents information on updates and refinements to the groundwater flow model for the Moolarben Coal project, in response to issues raised by the Independent Hearing and Assessment Panel.

The issues were raised by the IHAP following submission of the report documentation on the Moolarben groundwater studies (Aquaterra, 2006; Peter Dundon and Associates, 2006; Moolarben Coal Mines, 2006), the subsequent IHAP hearing in Mudgee on November 8th and 9th, 2006, and a subsequent meeting with IHAP members Prof. Galvin and Mr Mackie on November 27th, 2006. The issues were summarised by Mr Mackie in an email on October 18th, an email dated November 15th, and an email on November 28th, 2006. Responses to the issues raised have included an email from Peter Dundon on October 27th, an email on November 23rd (which outlined the proposed approach on model refinements), and the meeting with the IHAP on November 27th.

This report describes the application of alternative groundwater modelling approaches to evaluate the potential inflows to the Moolarben Coal mine, combined with the (existing) Ulan coal mine and (proposed) Wilpinjong coal mine. The alternative approaches were applied to demonstrate:

a) that the standard and accepted best practice impact assessment modelling approaches that were applied to prepare the Environmental Assessment Report (Moolarben Coal Mines, 2006) are valid in terms of an hydrological impact prediction assessment of the Moolarben Coal mine, by benchmarking the standard Modflow model application against the specialised Surfact model, and
b) that an alternative modelling approach (as suggested by the IHAP), which involves a more detailed analysis of the potential hydrological impacts, results in predictions that are very similar to the results from the best practice impact assessment modelling approaches mentioned above (ie. the differences are within the range of the normally accepted accuracy of modelling predictions of 20%).

2. APPROACH

In summary, the more detailed approaches were applied to directly address all the issues raised by the IHAP, and involved:

- initially benchmarking the standard Modflow model application against the specialised Surfact model,
- subsequent more detailed application of the Surfact modelling package (Hydrogeologic, 2006), which allows for de-saturation of model cells subject to dewatering, and for detailed simulation of seepage faces in a mining context,
- updating the model for the revised mine plan involved in the Preferred Project proposal,
- allowing for a failure regime within and above the underground at Ulan and Moolarben (by increasing aquifer hydraulic conductivity parameters in the model),
- changing model parameters for hydraulic conductivity with time as mining progresses and the failure zones expand at Ulan and Moolarben,
- invoking very high drain conductance parameter values for the underground mine areas at Ulan and Moolarben, and maintaining those model drain features throughout the mining period.

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3. BENCHMARKING MODELLING APPLICATIONS USING MODFLOW AND SURFACT

The Environmental Assessment Report (Moolarben Coal Mines, 2006) was prepared on the basis of a groundwater flow model development, calibration and prediction that used the industry-standard Modflow package in an approach entirely consistent with the de-facto Australian best practice guideline for groundwater modelling (MDBC, 2001). Although the Modflow package has been used in a large number environmental assessment projects, including open cut and underground coal mines (and notably for Ulan and Wilpinjong), the IHAP expressed concern that the Modflow application to Moolarben may have been subject to numerical instability, or that the results may have been affected by model cells drying out due to dewatering and thus affecting groundwater flow paths in an unrealistic manner. Aquaterra agrees that such problems can potentially occur and can be quite significant in some cases, but confirms that they did not affect the Moolarben Modflow model application.

We understand that the IHAP agreed that an application that used the Surfact model should not be affected by these potential problems, so a benchmarking run was undertaken to demonstrate that the standard Modflow application is valid for the Moolarben case. The benchmark run was based on the Moolarben Coal model version MC1.3 that was used to prepare the environmental assessment report. MC1.3 utilises the Processing Modflow software (IES, 2006), which does not support Surfact, so the MC1.3 model was transferred into the Vistas groundwater modelling software (ESI, 2006), which does support Surfact. No changes were made to any model parameters, nor to any hydrological stresses nor mine plan details, and the Surfact model was run with the “pseudo-soil” function active to prevent dry cell problems.

Figures 3.1 to 3.3 show the predicted Moolarben mine dewatering rates and the predicted groundwater level contours for the Modflow and the Surfact applications of the MC1.3 model version. Very slight differences (less than 5% in dewatering rates) are apparent between the two model results, which are due to the very slight differences between the pattern of dry cells in the Modflow case and the pattern of unsaturated cells in the Surfact case. These differences are within the range of the normally accepted accuracy of modelling predictions of 10% to 20%. **The Surfact benchmarking run has therefore confirmed the validity of the Modflow model application in the Moolarben case, as reported in the environmental assessment and subsequent presentations to the IHAP.**

Figure 3.1 Predicted Moolarben Mine Dewatering Rates (MC1.3 base case) – Modflow and Surfact
(may be compared to Figure 4.2 of Aquaterra, 2006)

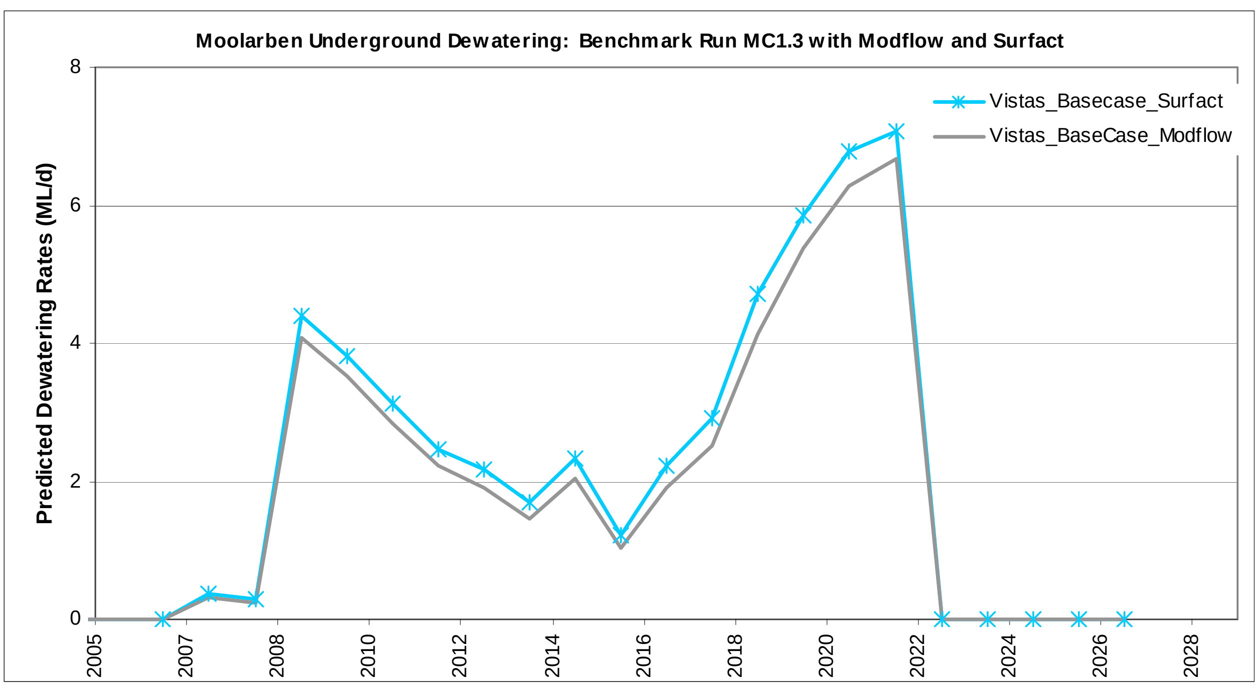


Figure 3.2
MC1.3 piezometric contour plan for Ulan seam (Layer 4) at 2022 – Modflow benchmark result
(piezometric water level contours in mAHD of cumulative impacts)
(may be compared to Figure 4.4.3 of Aquaterra, 2006, but noting that this contour plan was prepared from Vistas-Modflow, whereas the Figure 4.4.3 was prepared from PM-Modflow)

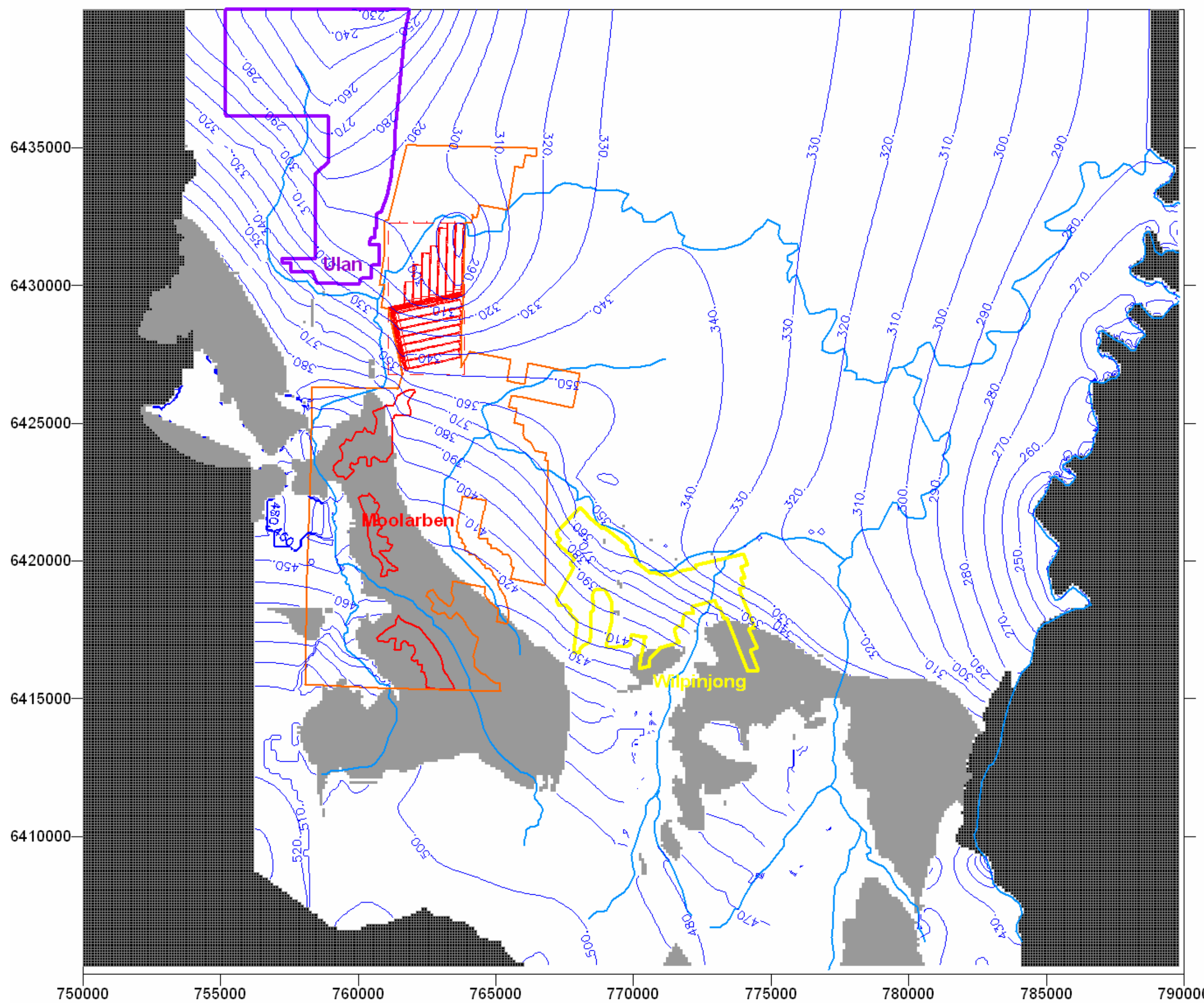
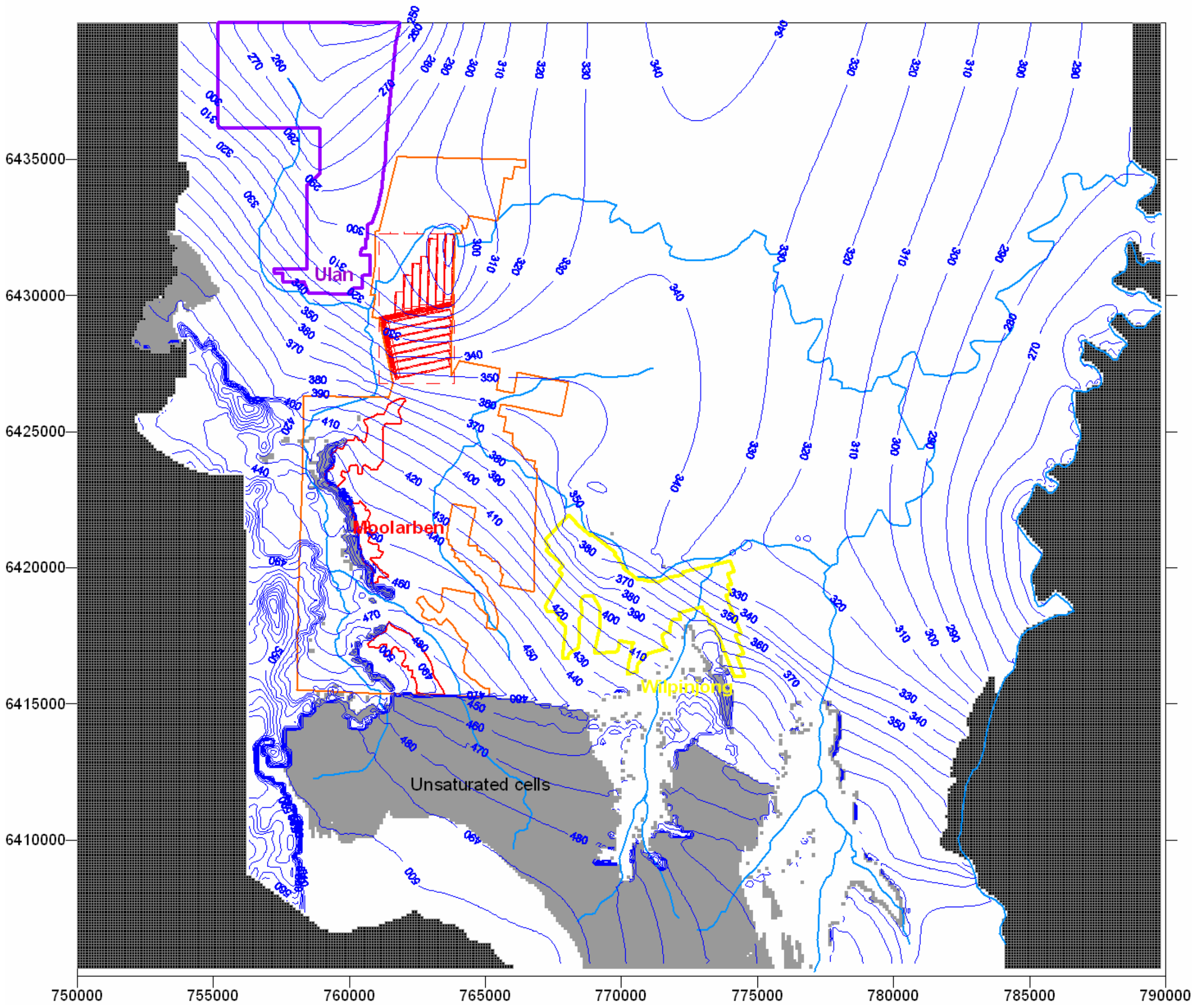


Figure 3.3
MC1.3 piezometric contour plan for Ulan seam (Layer 4) at 2022 – Surfact benchmark result
(piezometric water level contours in mAHD of cumulative impacts)
(may be compared to Figure 4.4.3 of Aquaterra, 2006)



4. MODEL REFINEMENTS (MC1.4 model version)

4.1 Modelling Approaches

The modelling approach that was applied to prepare the Environmental Assessment Report (Moolarben Coal Mines, 2006) is consistent with the Australian best practice groundwater flow modelling guidelines (MDBC, 2001) for impact assessment. We understand that the approaches applied are also consistent with most recent coal mine project environmental assessments. The IHAP suggested, however, that a further detailed investigation of the depressurisation of the extracted panels of the underground workings would be helpful.

Section 3 above has shown that the best practice approaches are valid in terms of a more detailed assessment, by benchmarking the standard Modflow model application against the specialised Surfact model, using the MC1.3 model version. Section 4.2 below documents an alternative modelling approach, consistent with suggestions by the IHAP regarding a more detailed representation in the model of vertical drainage above the extracted panels due to connective cracking within the failure regime through the overlying Permian strata, and expansion of the failure zone with time as mining progresses. The previous modelling work did consider failure zone processes, but the processes were implemented in just one sensitivity run for the environmental assessment. Later, during the IHAP process, further model runs were undertaken to address these issues, and the results were used as the basis for discussions with the IHAP, but they have not been formally documented.

4.2 Detailed Representation of Underground Mining (using Surfact)

While the standard Modflow approach is appropriate for environmental assessment purposes, the Surfact modelling package (Hydrogeologic, 2006) does allow for more detailed simulations of underground mining,. While these may be required for operational design and optimisation purposes, they are usually not necessary for environmental assessment purposes. Surfact allows for drainage of model cells subject to dewatering (usually without causing model stability problems), and it also allows for detailed simulation of seepage faces in a mining context. Surfact has the benefit that it is an enhanced version of the Modflow code, which enables simple transfer of the existing MC1.3 Modflow model into Surfact, using the Vistas software package (Vistas is a good interface for Surfact).

Upon transfer of the MC1.3 model into Surfact, some of the aquifer hydraulic conductivity parameters for the MC1.3 model were rationalised, as suggested by the IHAP, and the calibration period simulation to 2006 was re-run. Given the changes involved, the new model setup is now referred to as the MC1.4 model version. The model calibration performance is good in terms of a history match to dewatering rates and aquifer water levels at Ulan in 2006, as will be discussed later.

The model parameters were rationalised in the MC1.4 model version to address concerns by the IHAP regarding the spatial distribution of parameters in the MC1.3 model, notably abrupt changes across a north-south alignment between Wilpinjong and Moolarben, and an east-west alignment with the palaeochannel and Wilpinjong Creek, which were not rationalised during the MC1.3 model calibration process. The abrupt changes have now been removed in the MC1.4 model, or greatly reduced to slight changes, with the exception of the area south of the east-west alignment.

The area south of the east-west alignment covers the area of the Moolarben and Murragamba Creeks, where the geology comprises mainly Illawarra Coal Measures outcrop, with less extensive outcrops of the Narrabeen Group, and where there are also several occurrences of basalt intrusions. This area is bounded on the west by Carboniferous granite outcrop, giving an overall geological distribution that differs markedly from other parts of the model area, and thus warrants different parameters. During the parameter refinement process for the MC1.4 model, it was found that changes to the hydraulic conductivity parameters in this area perturbed the model simulations, causing poor solution convergence. Similarly, attempts were made to render more uniform parameters within layer 3, but convergence problems again affected the results. Further modelling work in time may allow a greater consistency in parameters in this southern area, as the aquifer responses to actual mine dewatering become known.

Table 4.1 summarises the model parameters applied to the MC1.4 model, showing that the abrupt changes of concern to the IHAP have been removed or greatly reduced. The most notable parameter changes include the reduction in the Kh value for the Ulan and Moolarben areas from 3 to 1.7 m/d (to achieve a reasonable match to Ulan inflows), and more uniform parameters for the basement units.

Table 4.1
MC1.4 model aquifer parameters (Surfact)

Main Layer	Aquifer/Aquitard	K_h (m/d)	K_v (m/d)	Uncon-fined S_y (-)	Confined S (-)
1 & 2	Alluvial deposits (Goulburn River and other minor creeks)	1.0 to 1.5	1.e-3 to 7.e-3	0.20	n/a
4	Alluvial Dep's (Moolarben Ck)	0.7	7.e-2		
2	Palaeochannels	1.0	5.e-5	0.05	5.e-5
1	Narrabeen Group (Triassic)	0.1	1.e-3 to 5.e-3	0.05	5.e-5
2	Illawarra Coal Measures (undisturbed)	0.5 to 0.8 in Ulan & Moolarben areas, and elsewhere, except: 0.06 Murragamba Ck area	7.e-4	0.05	5.e-5
3	Illawarra Coal Measures (undisturbed)	0.8 Ulan+Moolarben area 0.01 to 0.05 generally	2.5e-5 1.e-4 Murrag.Ck area	0.05	5.e-5
4	Ulan Coal Seam (undisturbed)	1.7	2.e-4 2.5e-2 Murrag.Ck area	0.05	5.e-5
5	Marrangaroo Sandstone and Nile Sub-Group	1.0	1.e-5	0.05	5.e-5
4 & 5	Basement (granites and metamorphics)	0.001	1.e-5	0.05	5.e-5

The parameter values for vertical hydraulic conductivity are conservatively high, which should have the effect of over-estimating the drawdown due to pumping. Results from the 42-day pumping test that was undertaken adjacent to Wilpinjong Creek for the Wilpinjong project (WCPL, 2005) gave a vertical leakance parameter of 1.e-6 d^{-1}, which is equivalent to a vertical hydraulic conductivity (Kv) value of about 5.e-5 m/d for a 50 metre thick unit, which is lower than most values in Table 4.1.

Although Surfact does not allow for changing of hydraulic conductivity parameters with time to represent the development of the failure regime as underground mining progresses at Ulan and Moolarben, a simplified modelling approach was adopted. The simplified approach involves running the model in short time frames (3-5 years), applying the final water level conditions from the previous run as the initial conditions for the subsequent run, and adjusting the hydraulic conductivity parameters at the start of each run. The time "slices" are shown later in Table 4.3. The parameters were changed with time and space as the Ulan underground mine developed for the runs covering calibration period up to 2006, and also to represent the future development of the Ulan and Moolarben mines for the predictive runs going forward from 2006. Note that only the horizontal and vertical hydraulic conductivity parameters were changed in Layer 4 (Ulan Coal seam), and also in the overlying layers 2 and 3 (Permian overburden) to represent the 50m to 100m failure zones. The aquifer storage parameters were not changed.

The parameters that were applied to the Ulan and Moolarben underground areas for failure zones extending up to 100m above the goaf are summarised in Table 4.2 (see below). A sensitivity run has also been undertaken to extend the failure zone more than 100m (ie. to the surface), with the results indicating inflow rates less than 1% higher than for a 100m failure zone, and groundwater levels changing imperceptibly.

The opportunity was also taken to update the MC1.4 model for the latest mine plan. Mine plan changes have been made during the IHAP process, as described in accompanying reports. The updates notably affected the UG4 layout and schedule, with mining ceasing in 2021 (rather than 2022 in the previous plan).

As suggested by the IHAP, a very high drain conductance parameter value was applied to the underground mine areas at Ulan and Moolarben, to facilitate free drainage conditions from strata, and with the model drain features being maintained throughout the underground mining periods. A drain conductance parameter value of 1,000 m^2/d was applied, consistent with the value applied to the open cut areas. This results in almost complete de-saturation of the Ulan Coal Seam (ie. water levels at 1m above the base of the seam in

Layer 4, which is approximately 10 metres thick, as shown in plots presented later), while the shallow water table is shown to remain in the Triassic aquifer of Layer 1 (subject to some drawdown).

The previous model (MC1.3) applied a drain conductance parameter ("C") of 4 m^2/d to the underground areas, based on the following calculation: $C=K_vLW/M$, where K_v is the vertical hydraulic conductivity for Layer 4 (2.e-4 m/d), L is the length of the cell (100 m), W is the width of the mined panels (approx. 250 m), and M is the nominal thickness of a permeable layer in the "bed" of the drain (assumed to be 1 m). The calculated conductance amounted to 5 m^2/d, and this was subsequently adjusted during the calibration process to 4 m^2/d to obtain a better match to the reported Ulan inflows, while achieving a good match to the measured water levels. This approach resulted in simulated water levels (MC1.3 model) in the Ulan seam below the top of layer 4, but not quite to the base of layer 4, and is thus physically realistic for the purposes of environmental assessment. Adopting a drain conductance value of 1,000 m^2/d for the underground areas for the Surfact model (MC1.4 model) is equivalent to applying a vertical hydraulic conductivity value of 4.e-2 m/d to the drain conductance calculation, or 200 times higher than the background K_v value for layer 4, and 20 times the K_v value applied to the failure zone (see Table 4.2). Clearly, such an approach does not artificially limit potential drain inflows.

Table 4.2
MC1.4 model aquifer hydraulic conductivity parameters applied to underground failure zones

Layer	Aquifer/Aquitard	K_h (and mult. factor)	K_v (and mult. factor)
1	Triassic aquifer (**sensitivity run** of 100+m failure zone)	0.2 (factor 2X background)	1.e-3 (no factor applied)
2	Illawarra Coal Measures (50 to 100m failure zone)	1.6 (factor 2X background)	1.4e-3 (factor 2X background)
3	Illawarra Coal Measures (0 to 50m failure zone)	8.0 (factor 10X background)	2.5e-4 (factor 10X background)
4	Ulan Coal Seam (goaf zone)	17 (factor 10X background)	2.e-3 (factor 10X background)

(Note that aquifer storage parameters are unchanged, and that the failure zone parameters apply to the Ulan underground and Moolarben UG4 footprints only in Layers 4, 3 and 2. Note also that a thin transition zone of two cells wide was applied with intermediate values between the background parameter value and the failure zone parameter value to ensure model stability).

4.3 Model History Match to Ulan Operations

With the parameter changes described above, the MC1.4 model was run for the calibration period to 2006, with the Ulan dewatering operation active and the progressive failure zones invoked in the model. In summary, and as shown in the figures below, an acceptable history match was achieved in terms of:

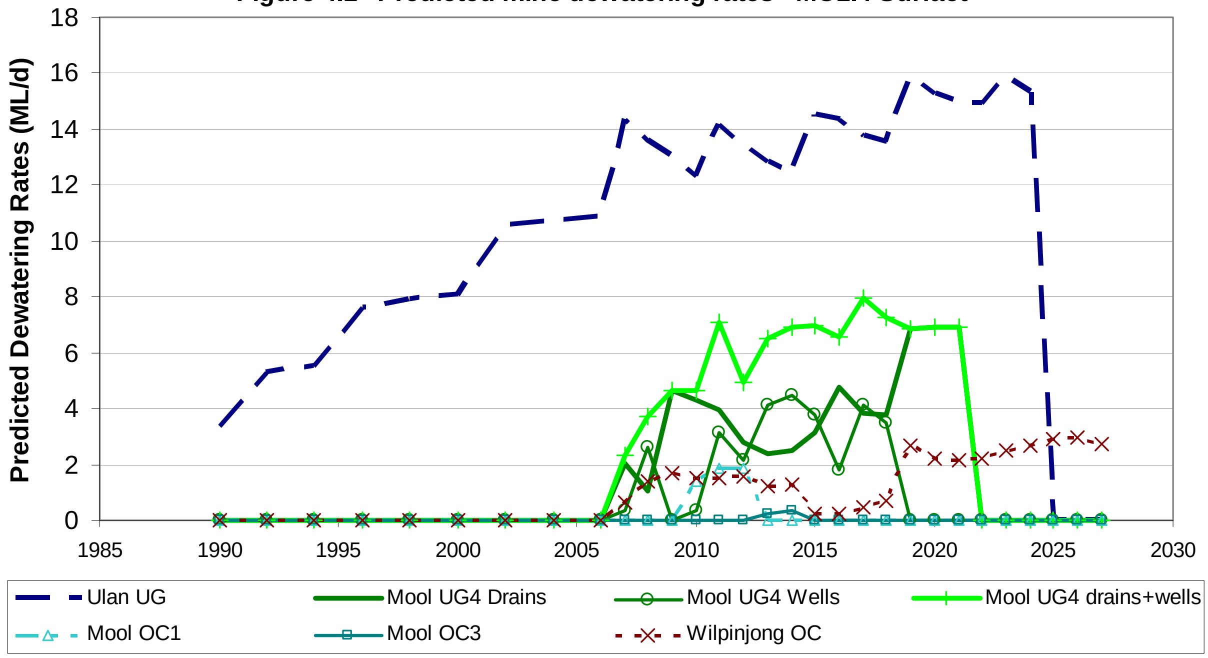
- Ulan dewatering at 1987 was reportedly about 3 ML/d, compared with the MC1.4 model result of just over 3 ML/d (Figure 4.1).
- Ulan dewatering at 2004 was reportedly about 10 ML/d, while the MC1.4 model result is just over 10 ML/d (Figure 4.1).
- The scaled RMS error is 10%, which is higher than the 8.9% achieved for the MC1.3 model (Aquaterra, 2006), but is marginally within the nominal target range of 5% to 10%.
- The Ulan Seam (Layer 4) is dewatered to 1m above the base of Layer 4 across the entire Ulan underground (Figures 4.6 and 4.12), while the Permian aquifer (Layer 3) has "perched" water levels more than 170m higher at Ulan in 2006, and about 50m higher at Moolarben in 2006, which we understand to be consistent with observations in the area.
- The Triassic aquifer directly above the Ulan underground has water levels affected by drawdown of up to 8 m, but the natural hydraulic gradients result in drawdown impacts of around 1m in areas near the Goulburn River. This is higher than but generally consistent with available data from UCML monitoring bores, which are located outside the Ulan footprint, and most of which show no drawdown in the Triassic aquifer to date, the possible exception being PZ04A with 0.9m drawdown to end 2005 (Dundon and Associates, 2006). Note that the model parameter values for vertical hydraulic conductivity are believed to be conservatively high, which should have the effect of over-estimating the drawdown due to pumping

4.4 Predictions of Mine Dewatering

Using the results at 2006 as the initial conditions, the Surfact model (MC1.4) was run in a series of 4-year timeframes or "slices" for the period 2006 to 2027 (the end of Wilpinjong mining), as shown in the schedule in Table 4.3. For the new Moolarben mine plan, mining ceases at 2021, while Ulan is assumed to continue until 2024. The water level conditions for the end of each run were specified as the starting conditions for the next run, and the underground failure zone parameters were invoked at the start of each timeframe as mining progresses. Following the cessation of mining, pit void parameters were invoked for the residual open cut areas at Wilpinjong and Moolarben, and the model was run for a further 40 years to simulate the recovery of the groundwater systems post-decommissioning.

The predicted mine inflow rates are shown graphically in Figure 4.1, and are listed in Table 4.3, along with the Moolarben mine water demand, the assumed dewatering well pumping rates, and the residual surplus or deficit. There is interaction between the dewatering wells and the drain features, and additional runs may need to be undertaken to absolutely optimise the well pumping rates (as was done for the environmental assessment prior to the IHAP process), but the results available from these runs are more than adequate for impact prediction purposes. In other words, the nominal "surplus" shown for some years is artificially high due to an excessively high assumed pumping rate for the bores in the model. Likewise, minor "deficits" shown in some years are due to slightly insufficient dewatering well pumping in the model. These nominal rates would be corrected during actual operations to maintain optimal water balances, by only pumping when there is an <u>actual</u> shortfall between <u>actual</u> inflows and <u>actual</u> demand.

Figure 4.1 Predicted mine dewatering rates - MC1.4 Surfact



The predicted dewatering rates shown in Figure 4.1 and Table 4.3 are consistent with historical information, and forward projections at Ulan, and with the predicted rates for Moolarben and Wilpinjong as reported in the environmental assessment (Aquaterra, 2006; Peter Dundon and Associates, 2006; Moolarben Coal Mines, 2006). The combination of Moolarben dewatering wells and drains reaches a maximum of about 7.2ML/d in 2011 and 2017, compared to the previous combined total prediction of 7.3 ML/d in 2017 (note that the nominal combined maximum of 8.9 ML/d in 2011 is due to surplus pumping of 2.7 ML/d, giving an effective maximum of about 7.2 ML/d). Therefore, the water balance for the revised predictions is consistent with the existing water management arrangements, as previously reported.

Figures 4.2 to 4.11 present contour plans of predicted water levels in the four main model layers:

- Layer 1 = Triassic aquifer
- Layer 2 = upper Permian aquifer
- Layer 3 = lower Permian aquifer

- Layer 4 = Ulan Seam.

Table 4.3: Predicted Mine Dewatering Rates (MC1.4 Surfact)

Mine Year	Stress Period	Time Slice	Year	Moolarben Mine Water Inflows (m3/d)				Moolarben Water Demand	Moolarben Dewatering Wells	Surplus (minus sign shows Deficit)		
				UG4	OC 1	OC 3	Total Inflow	(m3/d)	(m3/d)	(m^3/d)	Ulan UG and OC	Wilp. OC
	1	1	1987-90								3,371	
	2	1	1990-92								5,296	
	3	1	1992-94								5,522	
	4	2	1994-96								7,609	
	5	2	1996-98								7,922	
	6	2	1998-00								8,086	
	7	3	2000-02								10,540	
	8	3	2002-04								10,764	
	9	3	2004-06								10,861	
1	10	4	2006-07	2,009	-	0	2,009	570	330	1,769	14,316	631
2	11	4	2007-08	1,055	-	0	1,055	2,740	2,640	955	13,595	1,383
3	12	4	2008-09	4,666	-	0	4,666	3,995	-	672	12,994	1,664
4	13	4	2009-10	4,296	1,406	0	5,702	4,137	330	1,895	12,320	1,536
5	14	5	2010-11	3,922	1,884	0	5,806	6,277	3,135	2,664	14,140	1,511
6	15	5	2011-12	2,770	1,871	0	4,641	6,849	2,145	-63	13,452	1,547
7	16	5	2012-13	2,386	-	239	2,625	6,849	4,125	-99	12,860	1,202
8	17	5	2013-14	2,472	-	370	2,842	6,849	4,455	447	12,424	1,278
9	18	6	2014-15	3,163	-	0	3,163	6,849	3,795	109	14,534	252
10	19	6	2015-16	4,746	-	0	4,746	6,849	1,815	-288	14,360	205
11	20	6	2016-17	3,826	-	0	3,826	6,849	4,125	1,101	13,746	457
12	21	6	2017-18	3,803	-	0	3,803	6,849	3,465	419	13,544	686
13	22	7	2018-19	6,878	-	0	6,878	2,567	-	4,311	15,902	2,677
14	23	7	2019-20	6,889	-	0	6,889	2,282	-	4,606	15,293	2,226
15	24	7	2020-21	6,915	-	0	6,915	2,282	-	4,633	14,960	2,123
16	25	7	2021-22	-	-	0	-	-	-	0	14,921	2,225
17	26	8	2022-23	-	-	0	-	-	-	0	15,906	2,468
18	27	8	2023-24	-	-	0	-	-	-	0	15,313	2,686
19	28	8	2024-25	-	-	0	-	-	-	0	-	2,894
20	29	8	2025-26	-	-	0	-	-	-	0	-	2,946
21	30	8	2026-27	-	-	0	-	-	-	0	-	2,726

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Figures 4.6 and 4.11 show a zoomed-in view of the Ulan and Moolarben areas, with the base elevation for the Ulan Seam plotted with the predicted Ulan Seam water levels, to demonstrate that the Ulan Seam has been effectively dewatered.

The plots for 2021 show that the head differences between the Ulan Seam (layer 4) and the overlying lower Permian (layer 3), are about 30 to 80 metres across the Moolarben footprint (greater in the down-dip direction to the north-east). The predicted head differences are about 50 to 150 metres across the Ulan footprint. There is a head difference of about 40 m between the lower and upper Permian aquifers. There is almost no head difference between the upper Permian and Triassic in most areas, mainly because of the similarity of the K_v parameters for these two units, noting that we have adopted conservatively high K_v values that would not under-estimate the drawdown effects on the shallow units.

Figures 4.12 to 4.15 show the predicted drawdown in the main aquifer layers for the period from 2006 to 2021 (the Moolarben mining period). These results are consistent with the previous predictions (Aquaterra, 2006; Peter Dundon and Associates, 2006; Moolarben Coal Mines, 2006).

Table 4.4 presents a summary of the water balance components throughout the simulations, showing that the predicted impacts due to mining are very similar to the previous predictions, especially in relation to changes in predicted river and creek flows (Table 4.4 of Aquaterra, 2006). The individual values are slightly different than the previous values due to the different way that Surfact deals with dry/unsaturated cells, and hence different recharge rates and evaporation rates.

A sensitivity run was undertaken to extend the failure zone to more than 100 metres above the underground workings, by increasing the Kh value for the shallow Triassic aquifer (layer 1) by a factor of two for the

Moolarben and Ulan underground footprints (Table 4.2). As the results indicated changes to inflow rates of less than 1%, and the groundwater levels were imperceptibly different, plots of these results are not presented. In other words, due to the similarity of aquifer parameter values in layers 1 and 2, the drawdown effects are already conservatively over-estimated in the model, and the model results are insensitive to further increases in parameter values.

Table 4.4

MC1.3 model water balances

(may be compared to Table 4.4 of Aquaterra, 2006

MC1.4 Model Water Balance Component volumes (kL/d)	Rainfall Recharge	Head-dependent Flow	Goulburn River	Minor Creeks	Evap'n	Wells	Mine dewatering	Storage replenishment	Storage depletion	**Total**
2006 (Ulan o/c & u/g active; stress period 9)										
Into model	99,880	265,440	43,615	-	-	-	-	-	15,855	424,790
Out of model	-	284,955	64,920	3,420	58,120	-	10,860	3,025	-	425,300
2022 (End Moolarben mining; stress period 25)										
Into model	99,880	266,225	43,770	-	-	-	-	-	25,355	435,230
Out of model	-	283,365	64,540	2,865	53,275	6,555	17,145	7,515	-	435,260
2024 (End Ulan mining; stress period 27)										
Into model	99,880	266,035	43,790	-	-	-	-	-	22,530	432,235
Out of model	-	283,890	64,510	2,845	52,855	-	18,000	9,920	-	432,020
2027 (End Wilpinjong mining; stress period 30)										
Into model	99,880	265,980	43,800	-	-	-	-	-	16,450	426,110
Out of model	-	284,130	64,505	2,825	52,485	-	2,725	19,000	-	425,670
2067 (End Recovery Run; stress period 31)										
Into model	99,880	265,845	43,530	-	-	-	-	-	3,180	412,435
Out of model	-	284,730	65,385	3,025	56,235	-	-	3,095	-	412,470

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5. SUMMARY

The Moolarben model has been refined to address concerns raised by the IHAP, and the predicted impacts from the refined approach are very consistent with the previous predictions, as reported in the environmental assessment.

Regards,
Aquaterra

Hugh

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Figure 4.2
MC1.4 (Surfact) piezometric contour plan for Triassic aquifers (Layer 1) at 2006 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

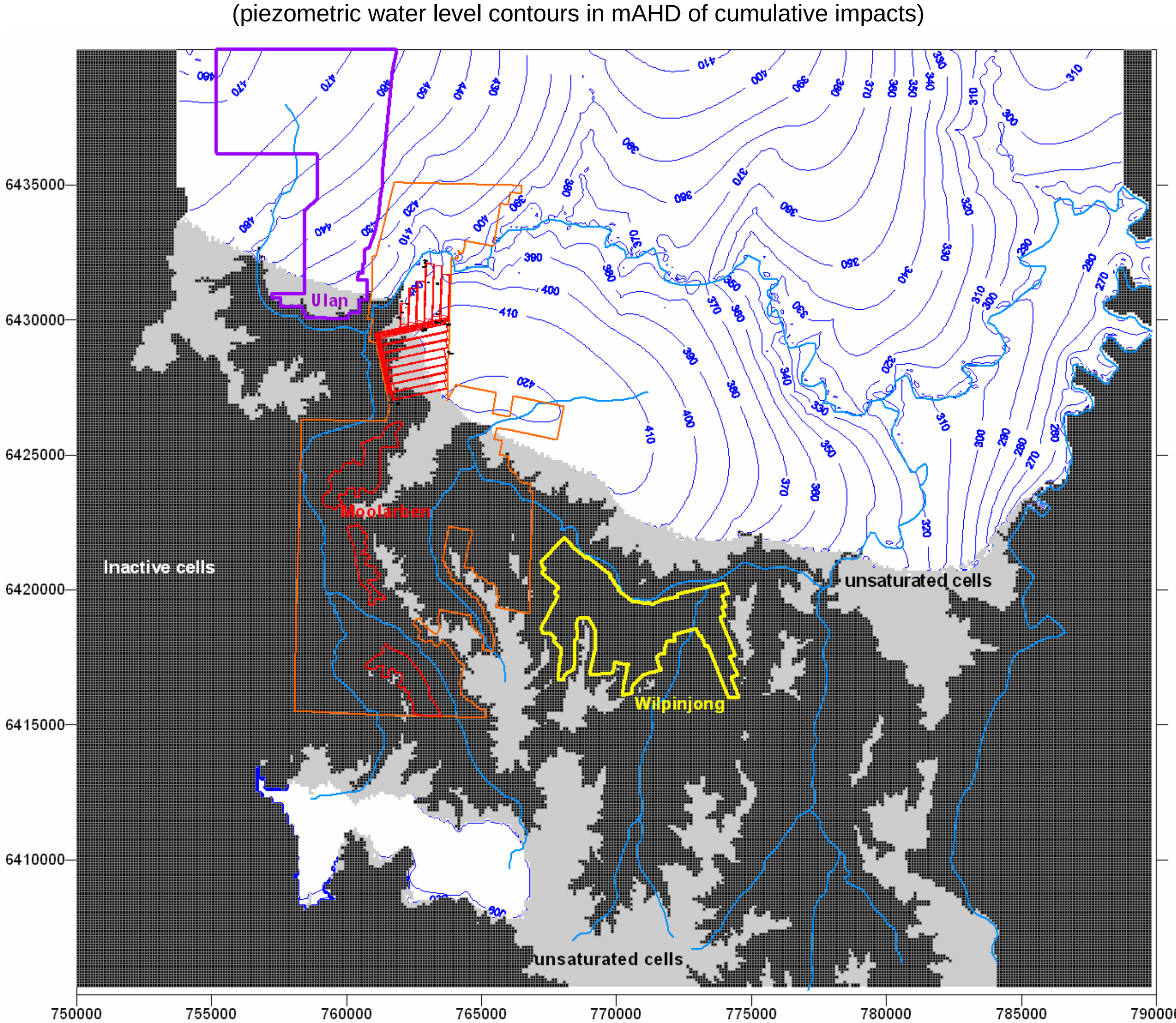


Figure 4.3
MC1.4 (Surfact) piezometric contour plan for upper Permian aquifers (Layer 2) at 2006 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

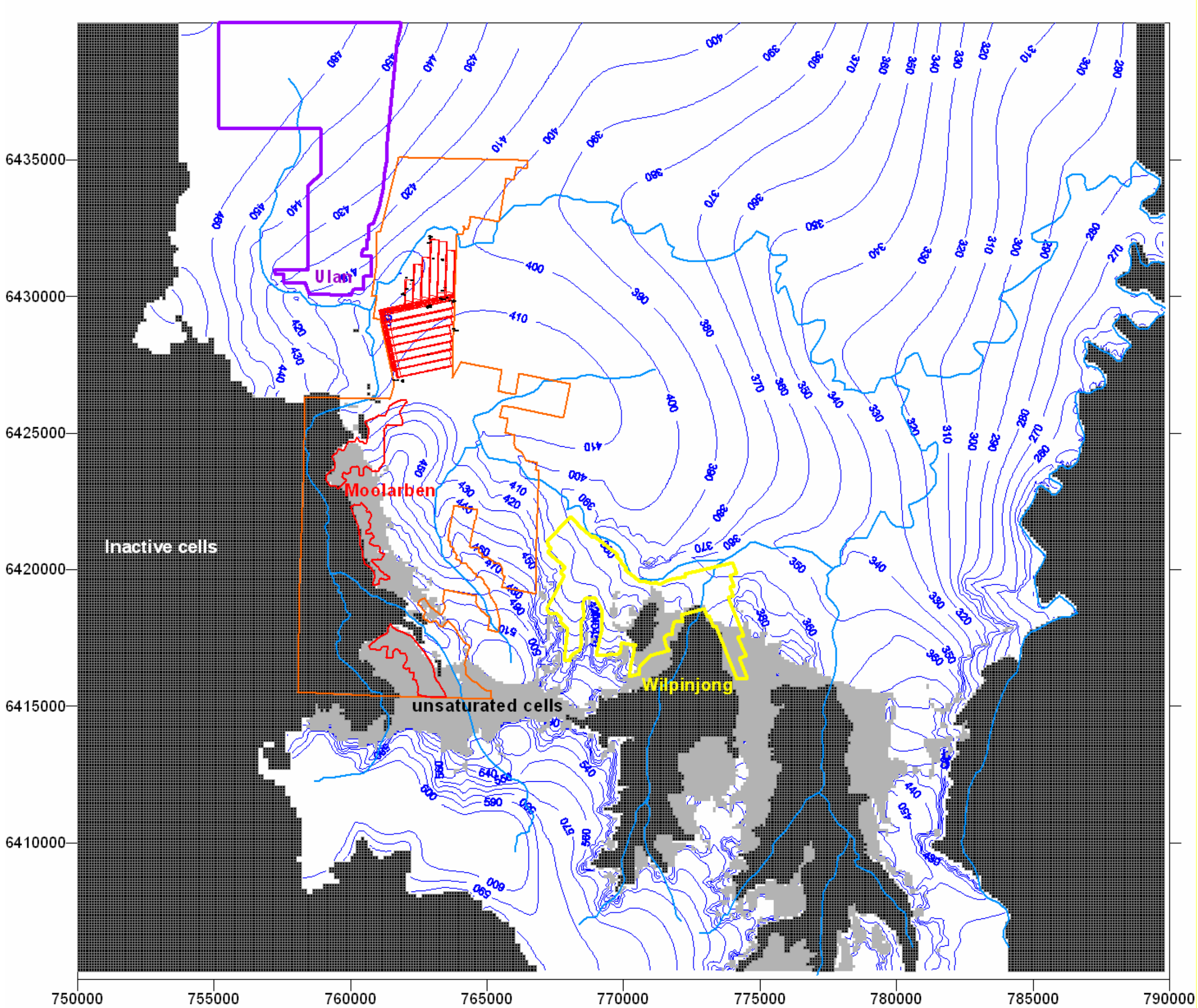


Figure 4.4
MC1.4 (Surfact) piezometric contour plan for lower Permian aquifers (Layer 3) at 2006 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

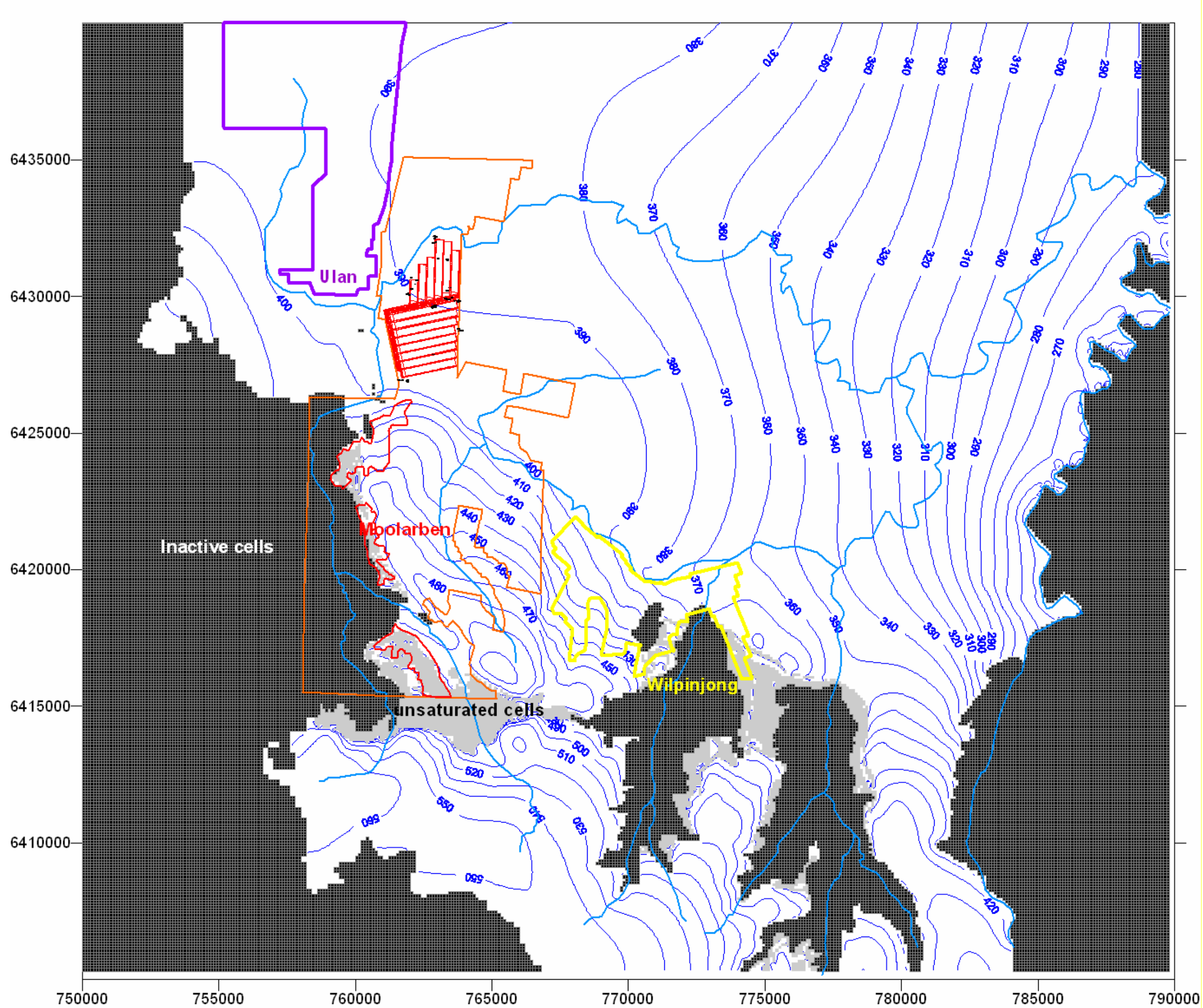


Figure 4.5
MC1.4 (Surfact) piezometric contour plan for Ulan Seam (Layer 4) at 2006 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

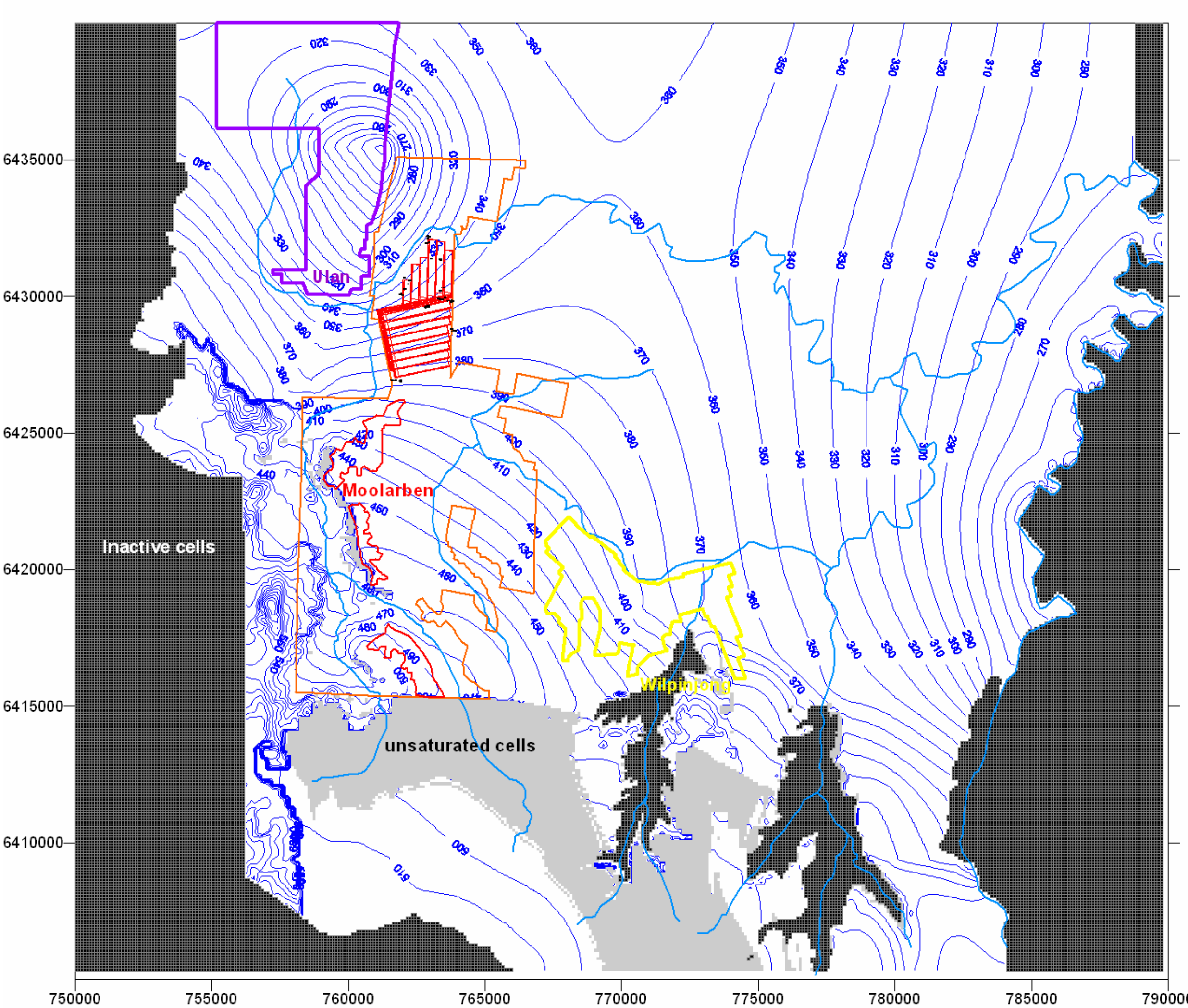


Figure 4.6
MC1.4 (Surfact) piezometric contour plan (blue lines) for Ulan Seam (Layer 4) at 2006 (cumulative impacts), and contours on base of Layer 4 (black lines)
(contours in mAHD)

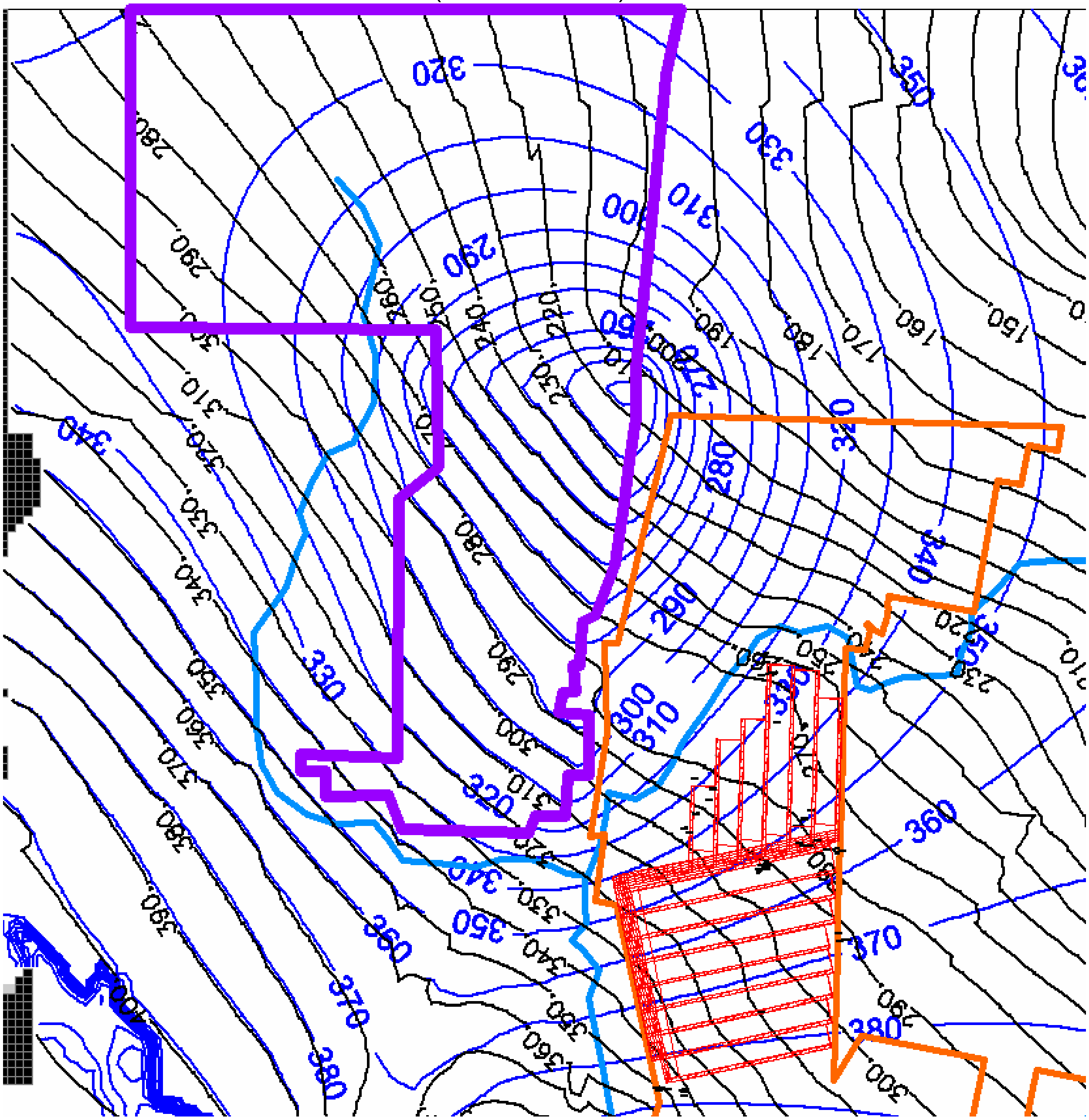


Figure 4.7
MC1.4 (Surfact) piezometric contour plan for Triassic aquifers (Layer 1) at 2021 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

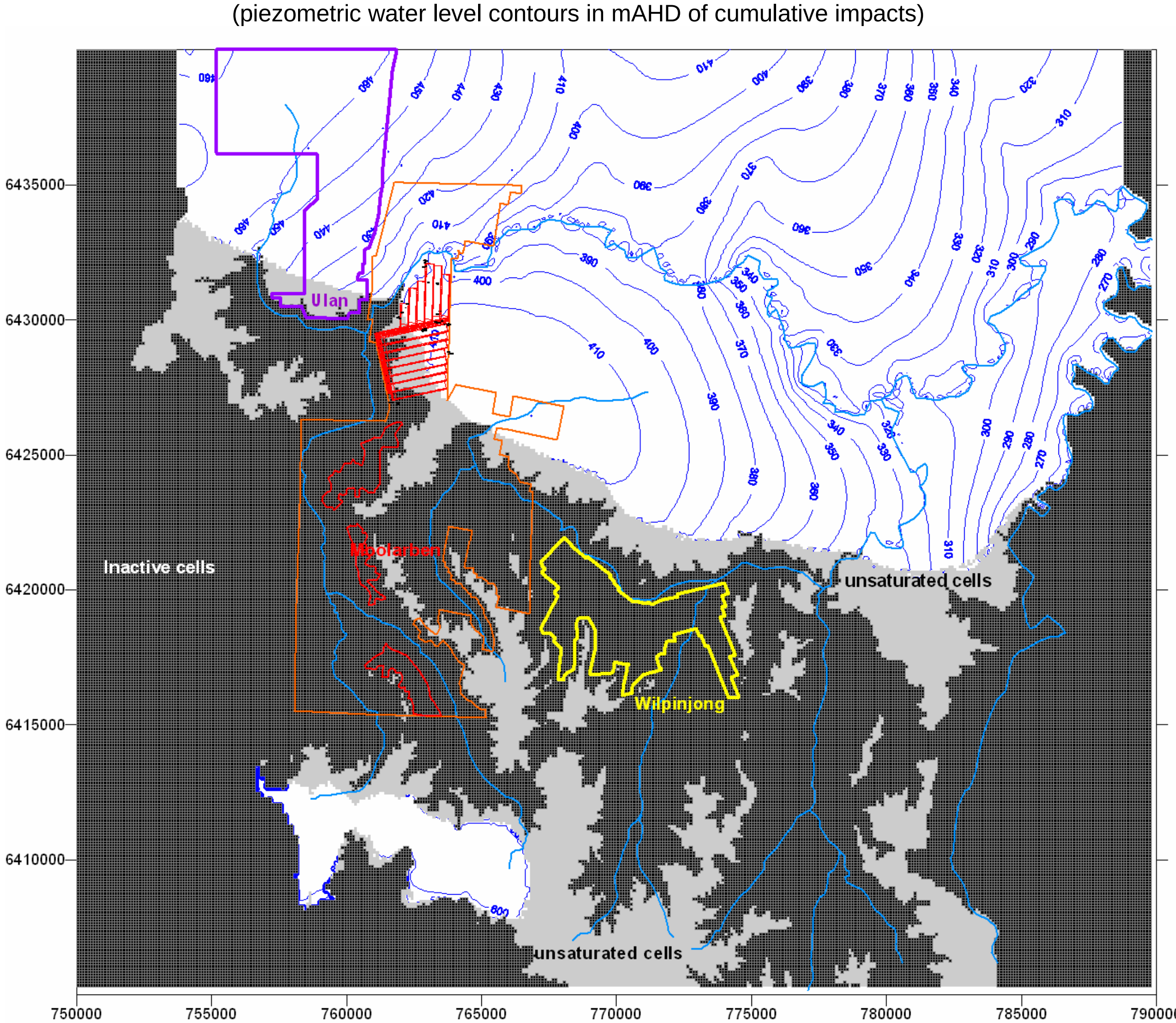


Figure 4.8
MC1.4 (Surfact) piezometric contour plan for upper Permian aquifers (Layer 2) at 2021 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

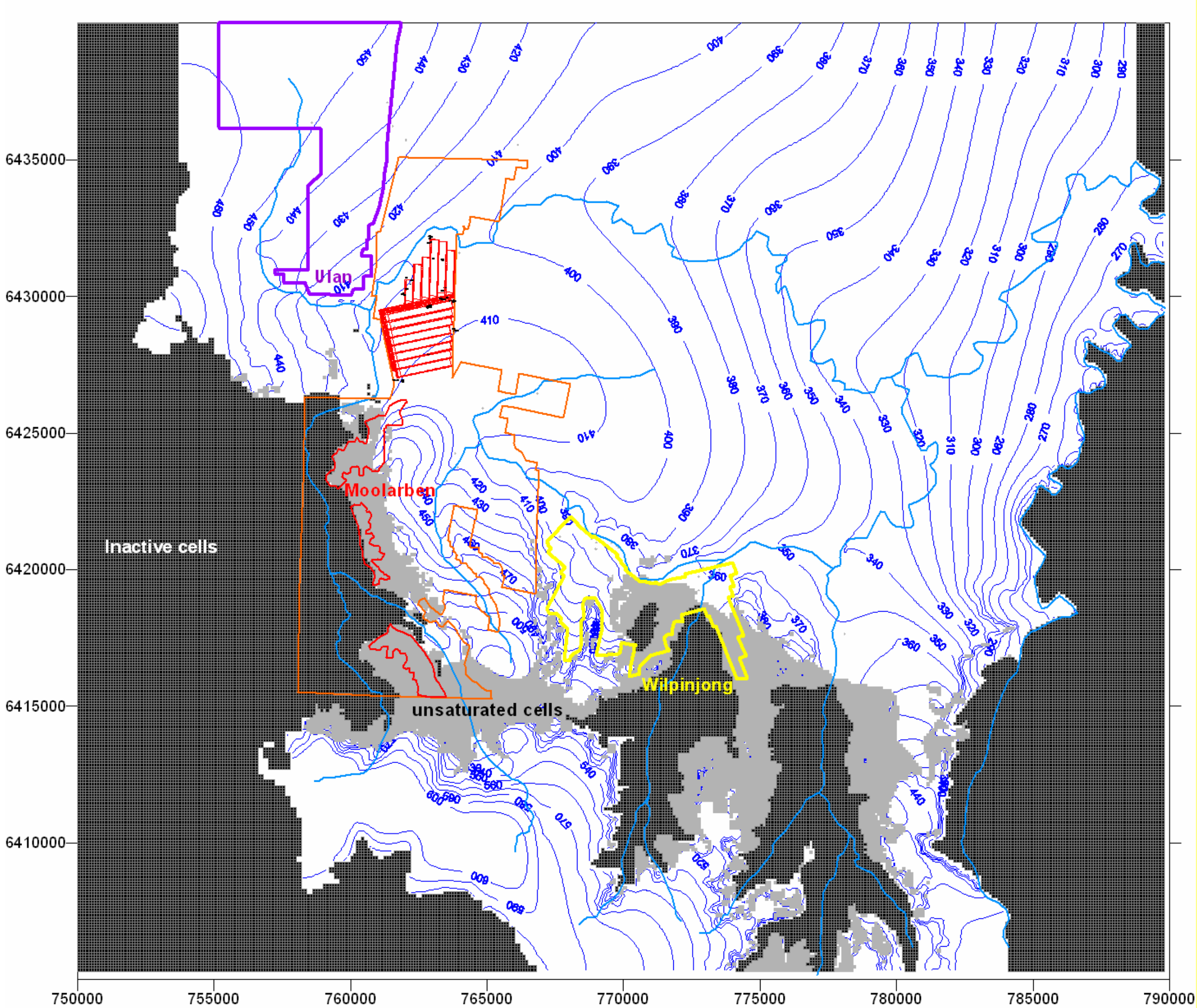


Figure 4.9
MC1.4 (Surfact) piezometric contour plan for lower Permian aquifers (Layer 3) at 2021 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

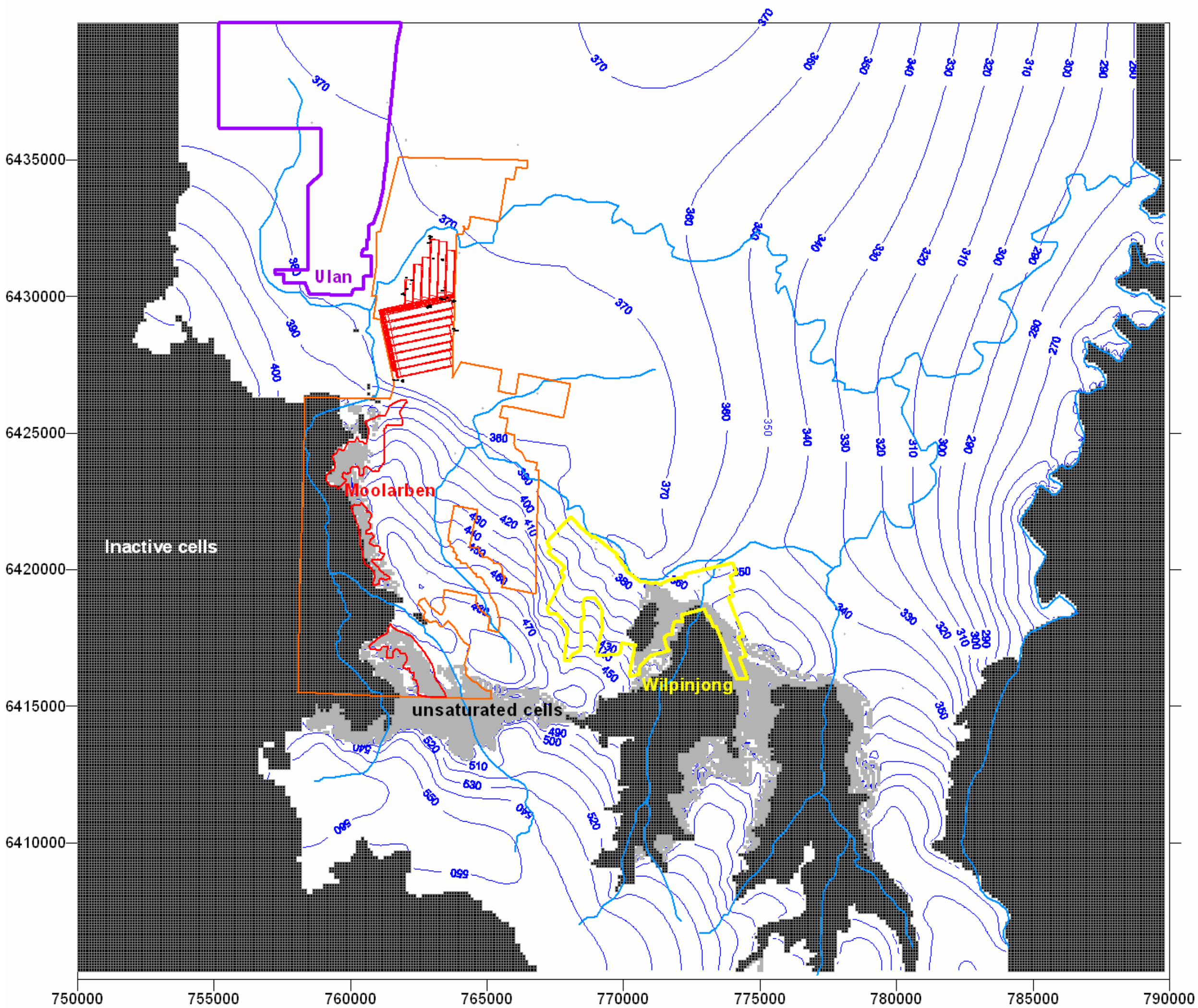


Figure 4.10
MC1.4 (Surfact) piezometric contour plan for Ulan seam (Layer 4) at 2021 (cumulative impacts)
(piezometric water level contours in mAHD of cumulative impacts)

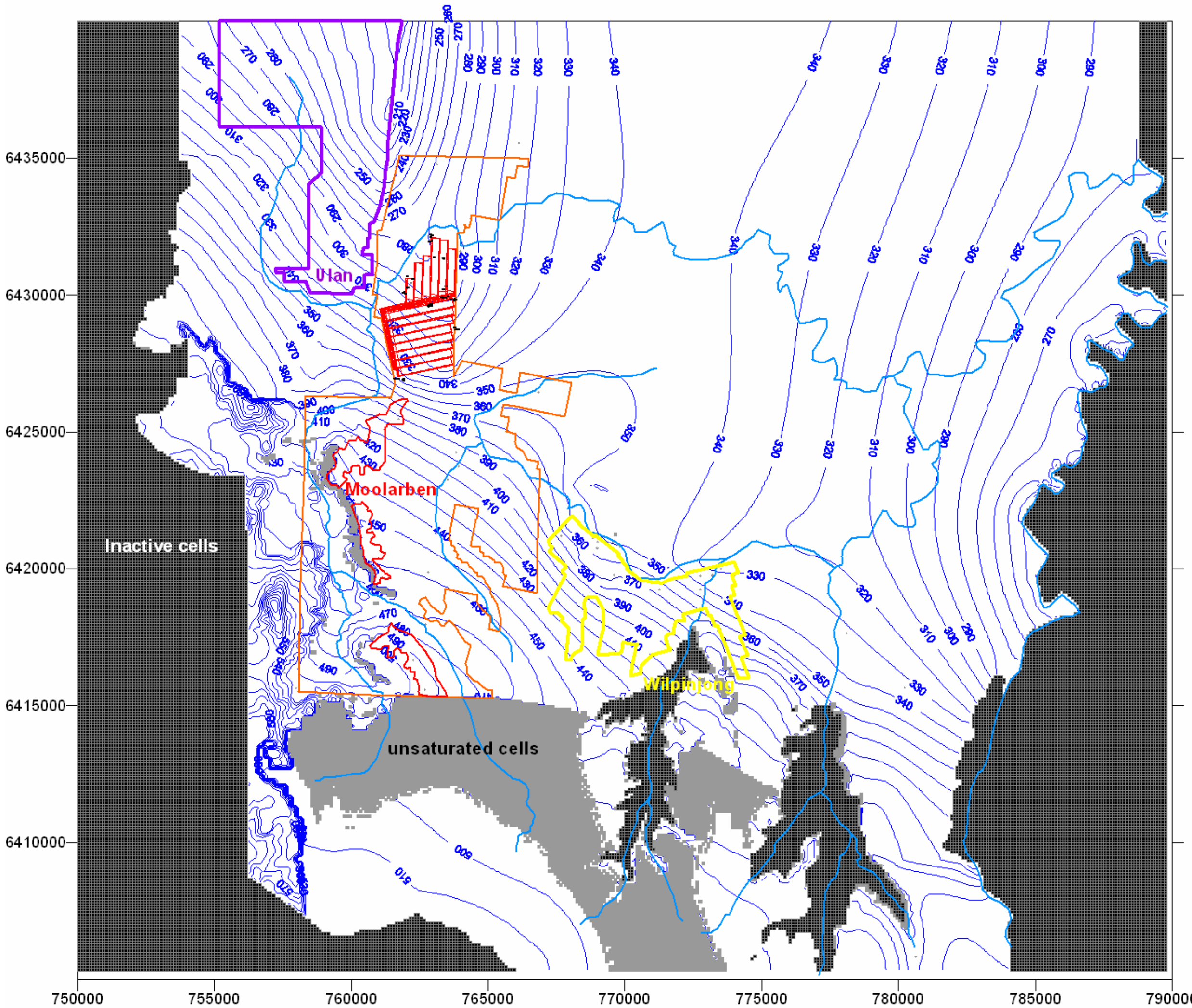


Figure 4.11
MC1.4 (Surfact) piezometric contour plan (blue lines) for Ulan Seam (Layer 4) at 2021 (cumulative impacts), and contours on base of Layer 4 (black lines)
(contours in mAHD)

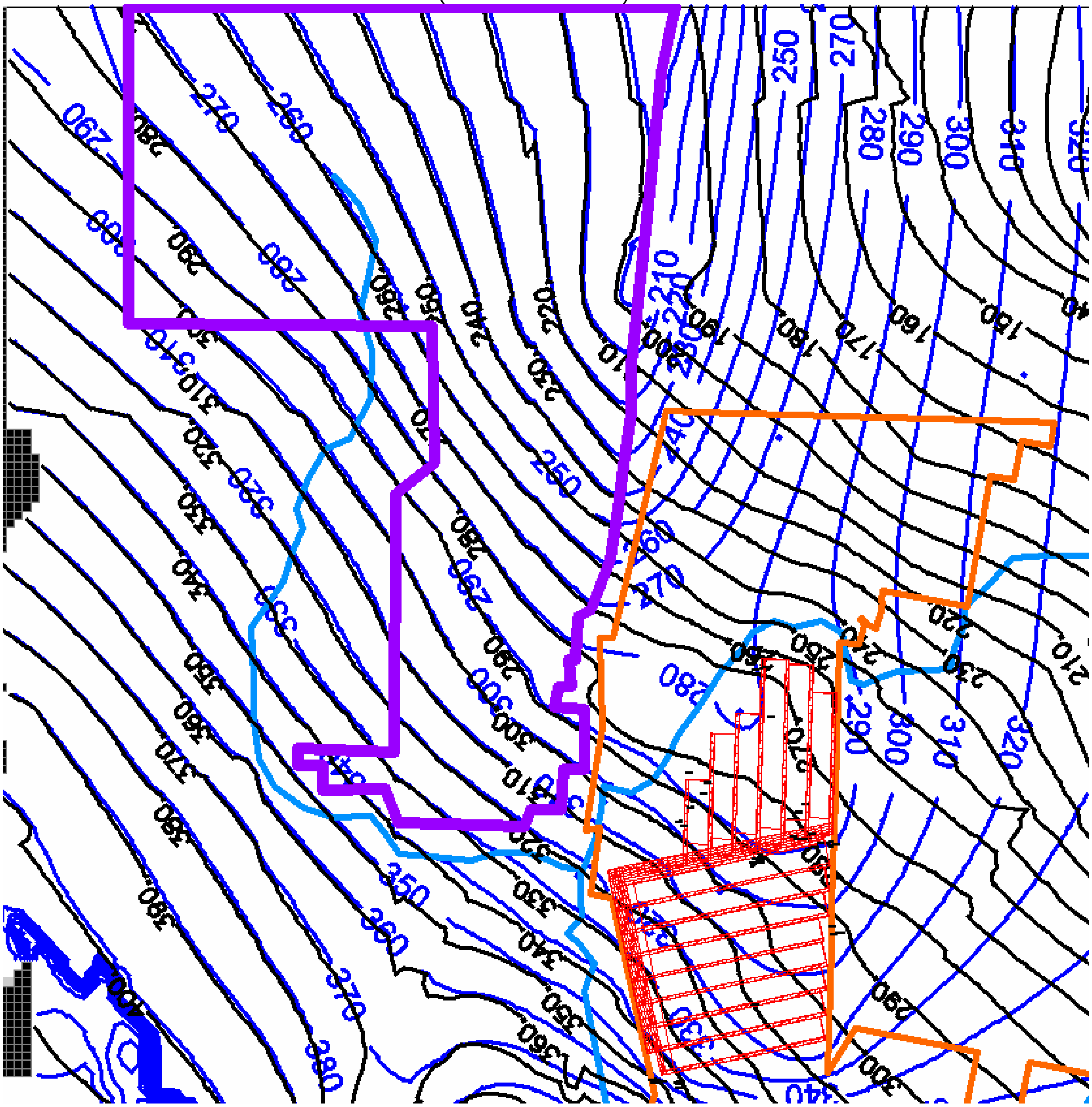


Figure 4.12
MC1.4 (Surfact) cumulative impacts drawdown contour plan for Triassic aquifers (Layer 1) 2021-2006
(drawdown contours in metres of cumulative impacts)

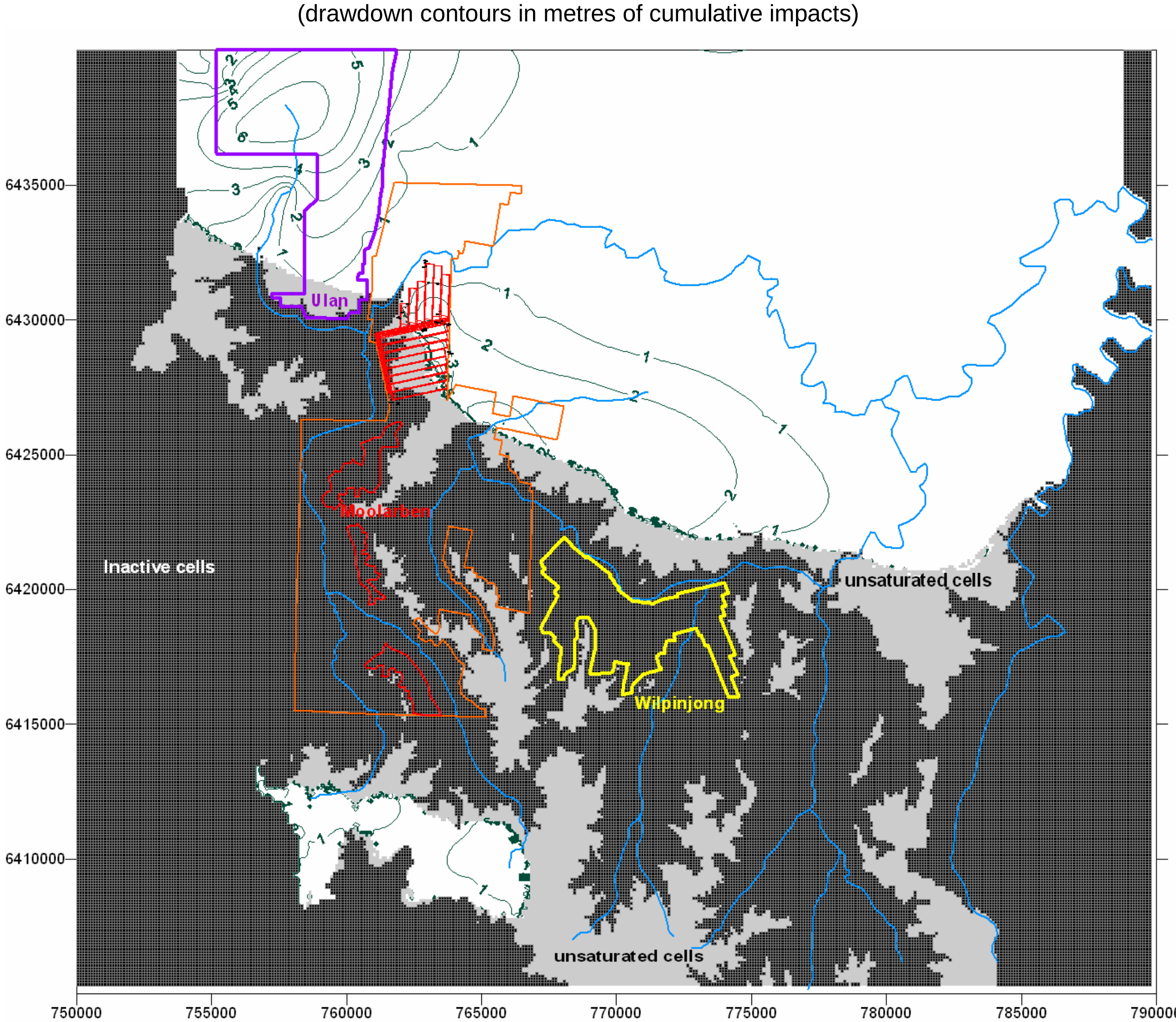


Figure 4.13
MC1.4 (Surfact) cumulative impacts drawdown contour plan for upper Permian aquifers (Layer 2) 2021-2006
(drawdown contours in metres of cumulative impacts)

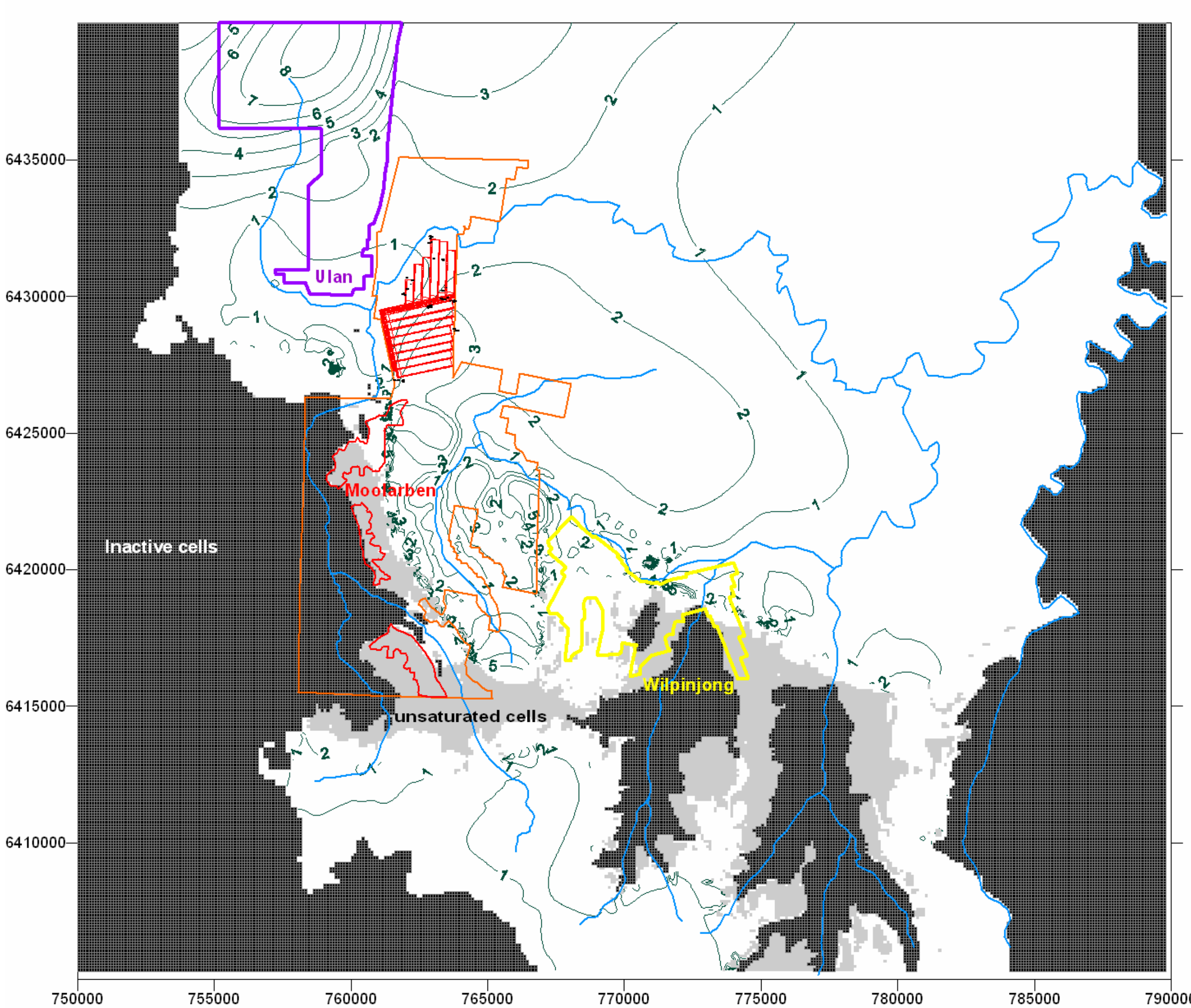


Figure 4.14
MC1.4 (Surfact) cumulative impacts drawdown contour plan for lower Permian aquifers (Layer 3)
2021-2006
(drawdown contours in metres of cumulative impacts)

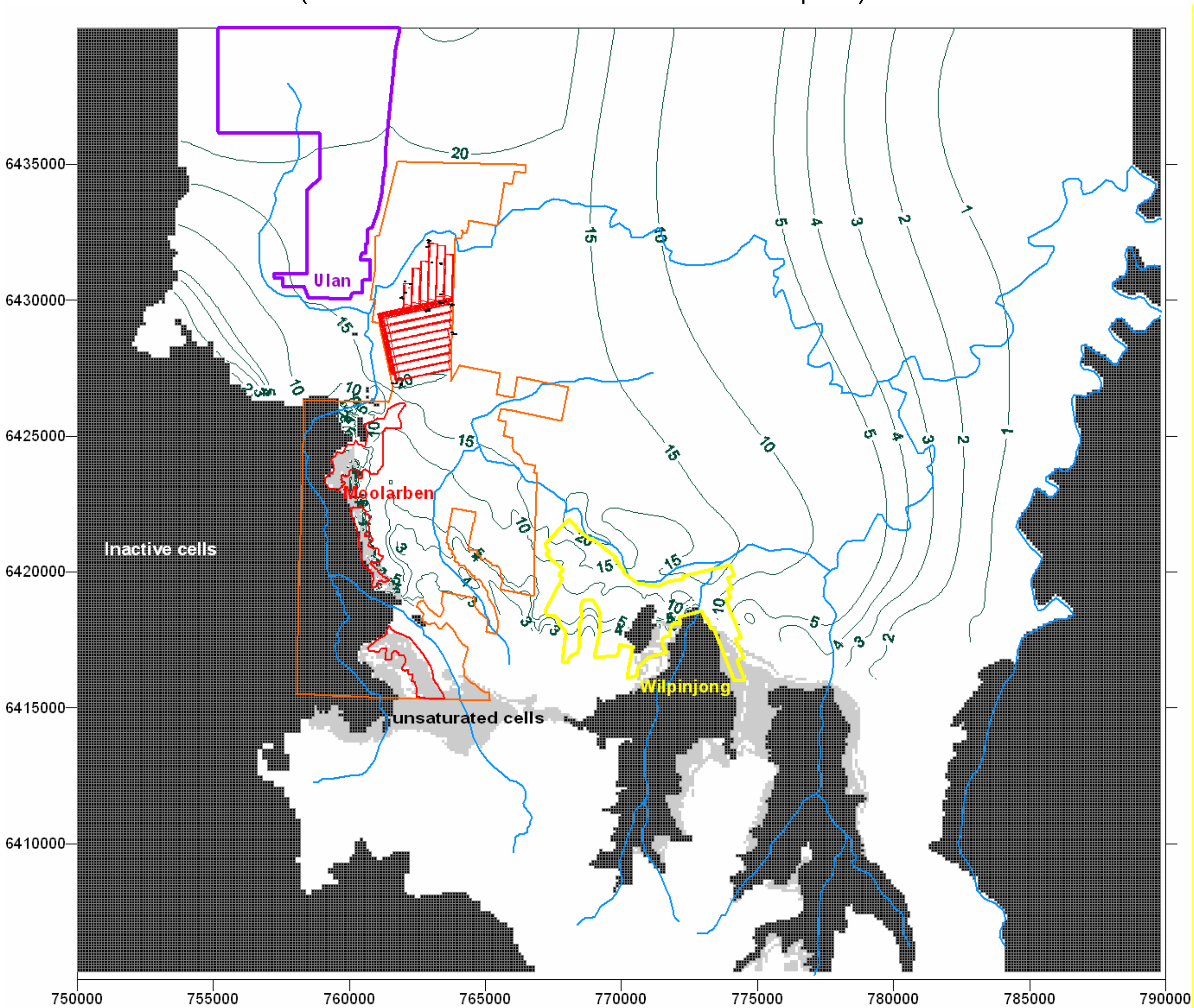
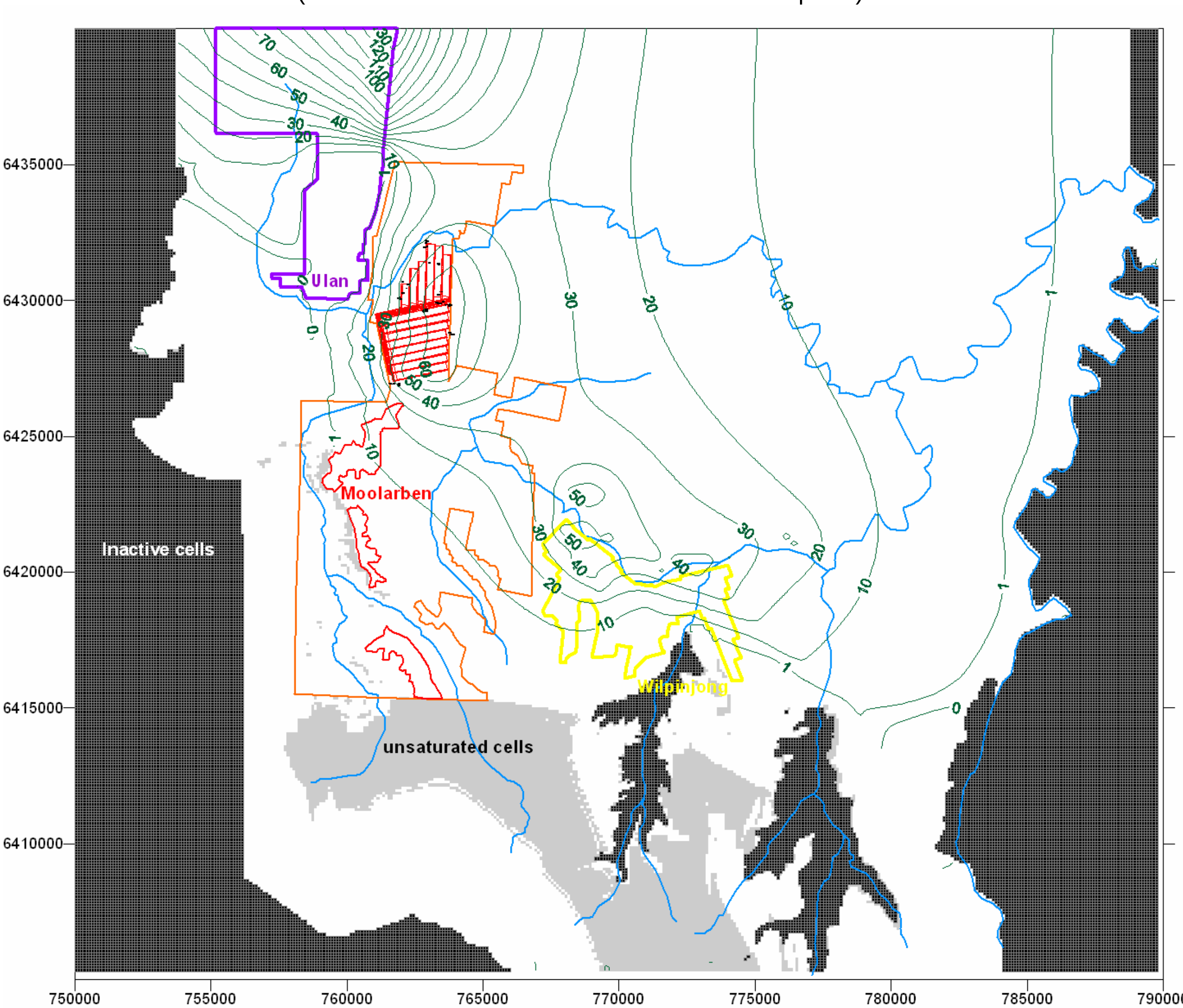


Figure 4.15
MC1.4 (Surfact) cumulative impacts drawdown contour plan for Ulan seam (Layer 4) 2021-2006
(drawdown contours in metres of cumulative impacts)



Note that the lack of drawdown contours in the southern part of the Ulan mine area is due to no change in Ulan Seam water levels for the period 2006 to 2021, as the drain features are maintained on during mining periods.

REFERENCES

Aquaterra (2006). Moolarben Coal Groundwater Model ('MC1 Model'). Report to Peter Dundon and Associates. 8th September, 2006.

ESI (2000-2004). *Groundwater Vistas. Version 4 User's Manual.* URL: www.groundwatermodels.com

Hydrogeologic (2006). *Modflow-Surfact Software (Version 2.2)*. URL: www.hgl.com.

IES (2006). *Processing MODFLOW Pro Version 7.0.15 User's Manual.*
URL: http://www.iesinet.com/products/desktop_pmwin.php

MDBC (2001). Groundwater Flow Modelling Guideline. Report by Aquaterra to the Murray-Darling Basin Commission. January, 2001.
URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

Peter Dundon and Associates (2006). Moolarben Coal Project Groundwater Assessment. Report to Moolarben Coal Mines. 8th September, 2006.

Moolarben Coal Mines Pty Ltd (2006). Moolarben Coal Project Environmental Assessment Report. September 2006.

Wilpinjong Coal Pty Ltd (2005). Environmental Impact Statement, Wilpinjong Coal Project. May 2005.