APPENDIX H8

GROUNDWATER MODELLING AND ASSESSMENT OF IMPACTS OF PROPOSED INJECTION OF MINE DRAINAGE WATER 2012

ANGAS PROCESSING FACILITY

MISCELLANEOUS PURPOSES LICENSE APPLICATION 2019/0826

TERRAMIN

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9th May 2012

Mr. Matt Daniel
Environment & Community Superintendent
Terramin Angas Zinc Mine
P.O. Box 125 Strathalbyn
SA 5255

Our ref: 1122b-12-TAB

Dear Matt,

Angas Mine Modelling and Assessment of Impacts of Proposed Injection of Mine Drainage Water

In August 2011, a revised model was used by Australian Groundwater Technologies (AGT) to simulate injection into 3 wells (PN 129056, 129054, and 170448B) at total rates of 6, 8 and 12L/s in order to evaluate the impact on water pressures at the injection sites and also to determine whether the injection process has any impact on the predicted minewater discharges (AGT letter report dated 15 August 2011).

This letter report presents the results of an additional model run to predict the potential impact on flows into and out of the Angas River resulting from injecting an additional 3.4L/s into two newly drilled wells.

As indicated in our letter report dated 15 August, 2011, the initial groundwater model of the Angas Mine site was a very simple, single-layer model prepared by Australian Water Environments (AWE) and reported in the Mining and Rehabilitation Program (MARP). The MARP also contained, as an annotation to Figures 82 and 83, an estimated value of 6 L/s for summer and winter discharge from the underground workings together with a statement "Groundwater inflow progressive- modeled for mine as developed".

The initial model was reported in the AWE letter report of 20th July 2006, which estimated flows from the mine workings to range from 30 L/s at start-up to 5 L/s in the long term.

This model was revised (AWE Report, 27th September 2006) taking into account the lithology of rock units as derived from over 100 exploration drillholes at the site and the results of pumping tests on 3 water wells. This exercise resulted in a three-layer model with a thin upper aquifer to a depth of approximately 100m, a fractured rock layer extending to a depth of 380m and a less permeable layer to 600m depth. An anisotropy ratio of 3 to 1 (NS Permeability = 3xEW permeability) was applied to the two lower layers to reflect the geological structure of the fractured rock systems. The mine workings were simulated by drains, which were added to the model, at the appropriate times, positions and depths taken from the proposed mining schedule thus representing the development of the underground workings in time. The following conclusions were presented:

"The model has been run with both relatively thick and thin layer 1 configurations. It is likely that these two scenarios represent the two probable extremes as far as can be predicted based on the available data. With the initial geometry of Layer 1, the maximum predicted instantaneous mine discharge is in excess of 40 L/s whilst at later time, the (combined Layer 1 and Layer 2) flow rate is about 7.5 L/s (Figure 3). The revised Layer 1 model has an instantaneous maximum extraction rate of just over 12 L/s and a late time value of 4.5 L/s (Figure 12).

Dewatering in neither scenario was shown to impact the Angas River to any significant extent.

Owing to the natural variability inherent in the site geology it would be prudent to have in place contingency plans to cope with surplus discharge water (such as re-injection) in the event that conditions prove to be more like those in the initial model version, or to obtain additional plant water requirements from water bores should the underground workings fail to produce sufficient water to satisfy process requirements. Additional hydraulic testing would be beneficial in refining hydraulic parameters, leading to the better definition of water disposal or procurement requirements."

The model was revised again in 2007 as part of the Australian Groundwater Technologies (AGT) study into injection as a disposal method. Additional pumping test data were incorporated but there was no information available regarding discharge from underground to use as a calibration tool for the model discharge predictions.

An additional model layer was added resulting in the following vertical discretisation of the model domain:

- ground level to 35m – shallow aquifer ; 35m to 65m – weathered clayey zone ; 65m to 355m – fractured rock aquifer containing mine workings ; 355m to 570m – deeper, lower permeability fractured rocks.

Injection of surplus mine drainage water was investigated in 2007.

The *Pre-Injection Trial Report* (AGT Report, 2007/19) investigated 4 possible fracture scenarios, possibly linking the injection sites to the mine workings, which were thought could influence the behaviour of injected fluids.

Three injection wells (6627-13985, 11529 and 11530, drilled in 2007 under PN 129053, 129054 and 129056, respectively) were initially drilled at the southern boundary of the lease. Two days injection trials were subsequently carried out in both wells 6627-11529 and 11530. The results of this program of works, which demonstrated that the well extraction Specific Capacity is similar to the injection Specific Capacity, have previously been reported in "Angas Mine Injection Testing" (AGT report 2008/7).

An additional numerical model was developed using the Modflow code, and various injection scenarios modeled as part of the investigations carried out to support an EPA authorization to undertake well injection (*Angas Mine Modelling of Possible Impacts of Injection of 2.5L/s into DH01(s)*- AGT report 2008/15.)

In late 2009 and early 2010, an additional 8 investigation drainage wells were drilled, and of these 3 had positive yields (wells PN 170446B, 170447B and 170448B). In late December 2011, an additional 2 drainage investigation wells were drilled and step discharge tested (*Drilling and Testing of Injection Wells PN 206188 (Injection well 5) and PN 206189 (Injection well 6)* – AGT 2011).

The actual performance of the Angas Mine numerical model has been a matter of conjecture since the opening of the mine because observations of discharge from the mine workings were not available and only a very limited amount of dewatering was happening via dewatering wells.

Some data did however become available in 2011 when the comparison shown in **Figure 1** showed that the model predicted mine water inflows are as accurately as can be expected in the fractured rock environment at Strathalbyn with the model-predicted discharge following the general trend of the somewhat scattered observed values and falling within the observed envelope.

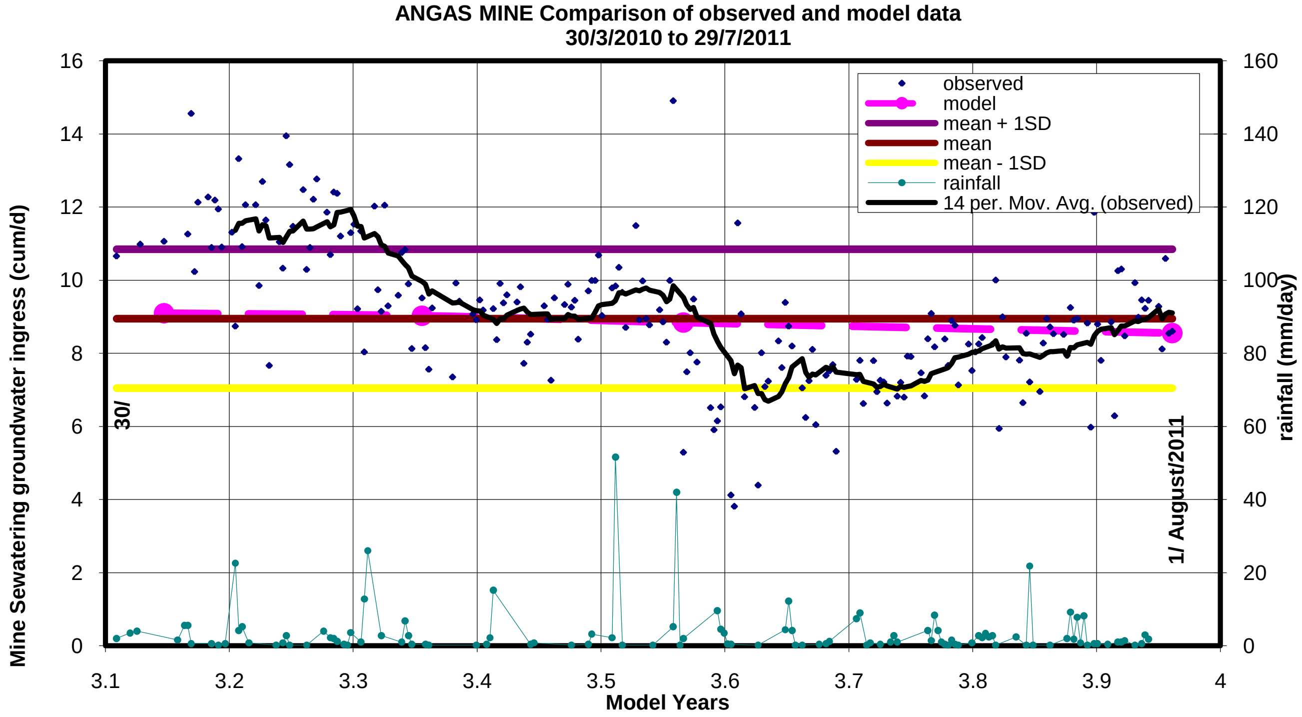


Figure 1: Comparison of Measured and Model Predicted Minewater Discharge

As previously indicated, the current modeling exercise seeks to determine the potential impact on flows into and out of the Angas River, resulting from injecting an additional 3.4 L/sec into two newly drilled wells, INJW5 (0.4 L/sec) and INJW6 (3.0 L/sec) located on the south western side of the mine lease. This is in addition to the modeled injection of 6L/s in wells PN129056 (1.5L/s), PN 129054 (0.8L/s), PN 170448B (2.6L/s) and PN 129053 (1.1L/s).

The new injection wells, whose locations can be seen in **Figure 2**, were drilled and discharge tested between November and December 2011 (AGT 2011) and were added to the 2011 version of the numerical model in Stress Period 18 (1735 days or 4.75 years elapsed time since the beginning of the model run) which corresponds with the end of May 2012.

The model was run simulating a 10 year period and model fluxes into and out of river cells were plotted in **Figure 3,** which indicates that the 4.5km reach lying within the model domain has changed from a very minor loosing-stream scenario pre-mining (at ~ 0.7L/m/day), to a very minor gaining-stream scenario (at ~0.9L/m/day) after 11 years due to small local changes in model head.

The introduction of the proposed new injection wells in year 5 has had no discernible impact on model river fluxes.

The latter are controlled by the changes to the model flow field induced by the large drawdown imposed by the mine workings in layer 3 reacting with the model boundary conditions (General Head Boundary Cells).

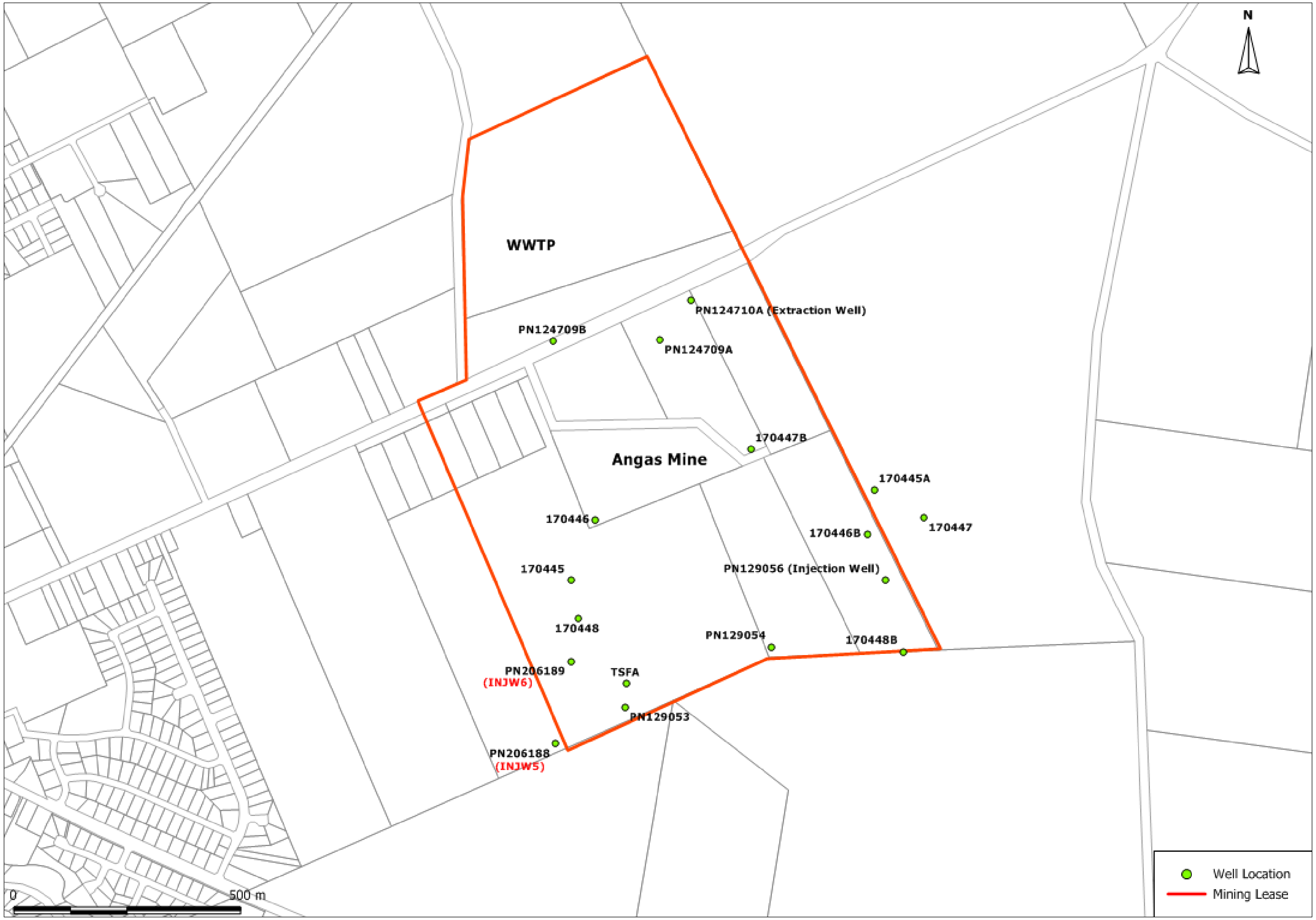
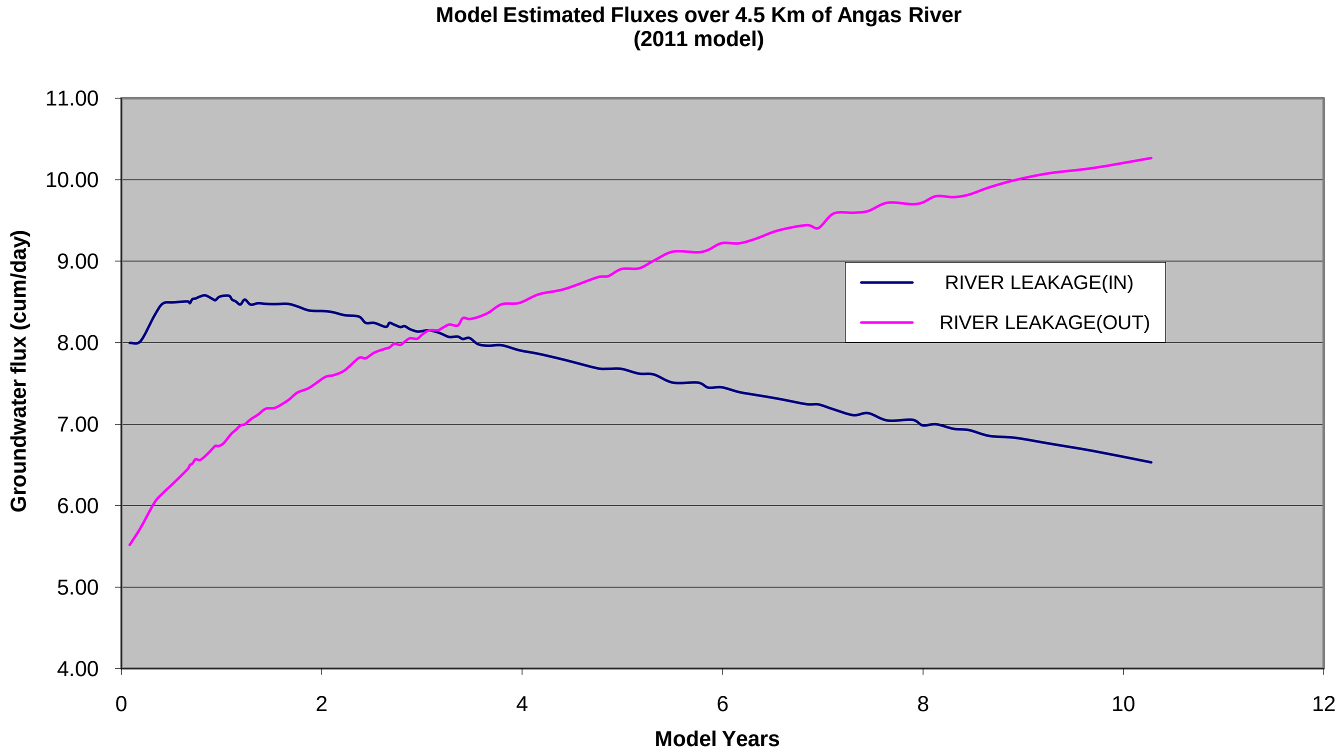


Figure 2: Locations of INJW5 and INJW6



RIVER LEAKAGE (IN) represents flow from the model river calls into the shallow aquifer.

RIVER LEAKAGE (OUT) represents flow from the shallow aquifer into the river via the river cells.

Figure 3: Model Groundwater Fluxes in/out of 4.5km of the Angas River close to Angas Mine

The model water level changes at a point on the river in layer 1 (shallow aquifer) are shown in **Figure 4**.

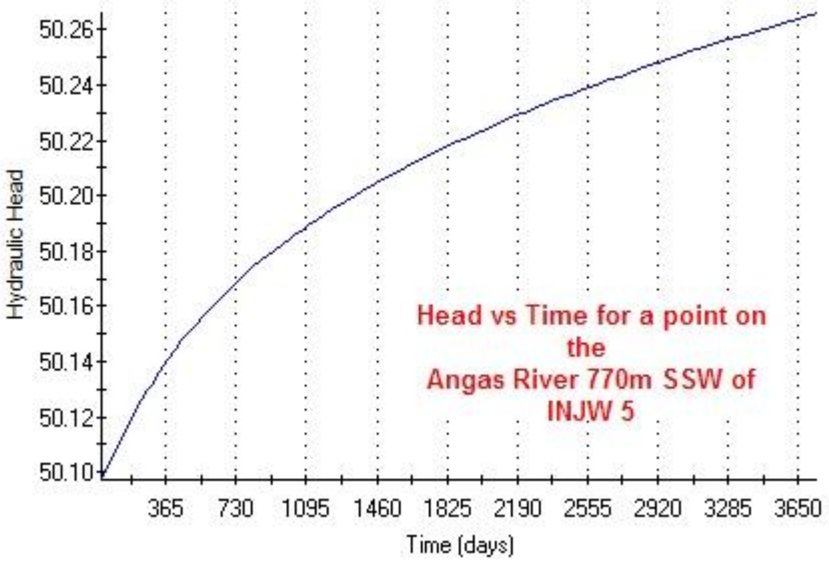


Figure 4: Model Shallow Aquifer Head versus Time close to INJW5

Figure 4 indicates a gradual head rise in the shallow aquifer totaling approximately 16 cm over 10 years with no evidence of steepening after the introduction of INJW5 and INJW6 after 1735 days.

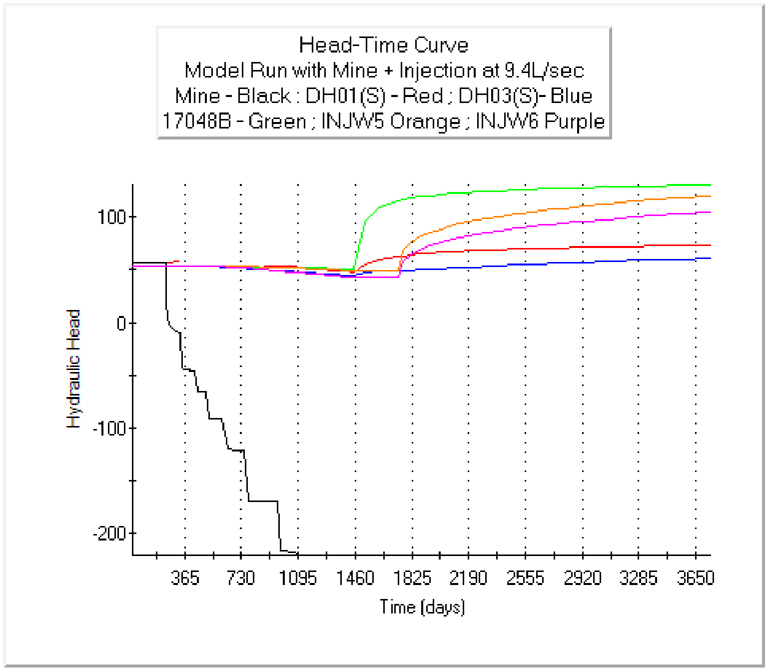


Figure 5: Heads versus Time with INJW5 and INJW6

The heads versus time plot for layer 3 is shown in **Figure 5** in which the new injection wells can be seen to give rise to fairly large head increases, as predicted from the injection test results.

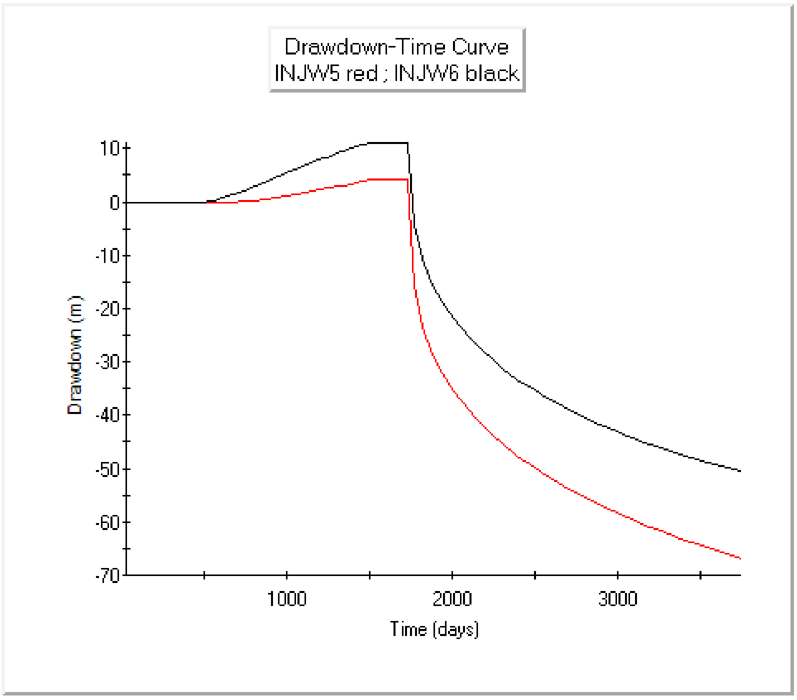


Figure 6: Model Drawdown in INJW5 and INJW6

The model drawdown for the two new injection wells is given in **Figure 6**. Positive drawdown (water level drop) can be seen before the onset of injection which leads to significant negative drawdowns (water level rises).

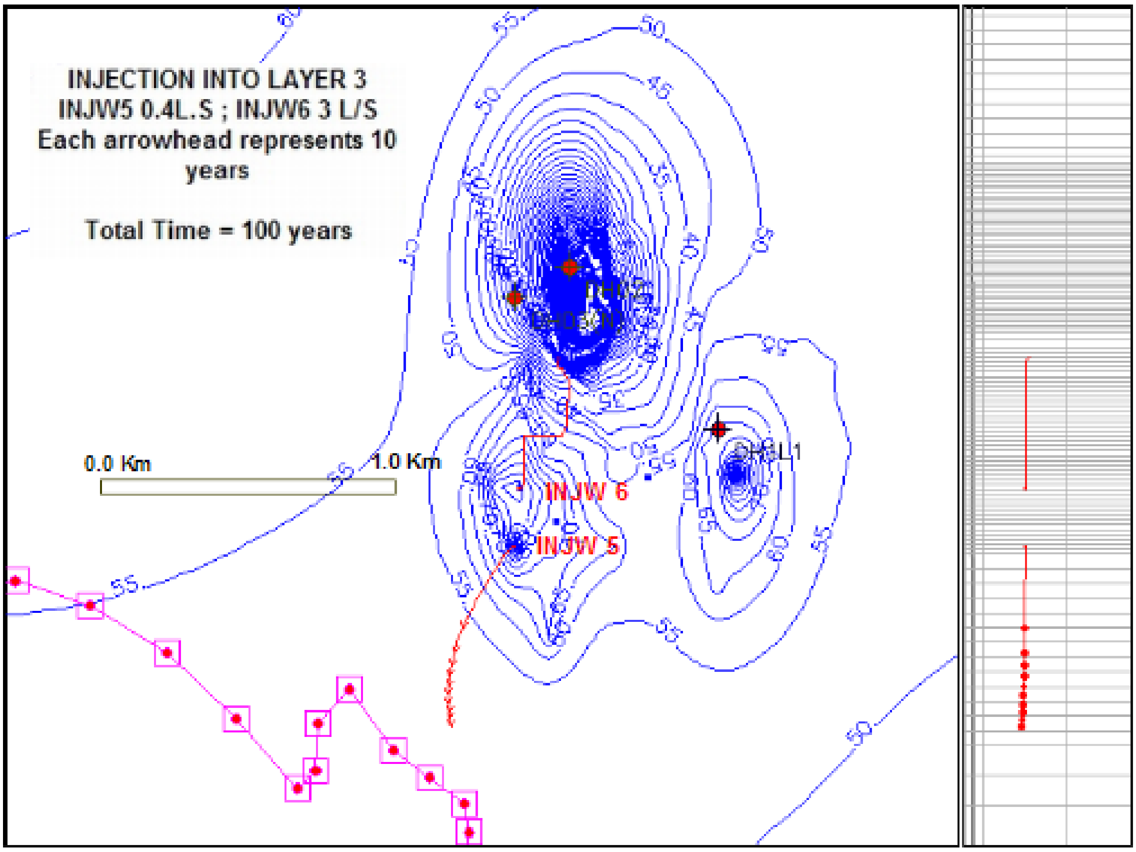


Figure 7: Model Heads after 10 years with flow paths from new injection wells

The water entering the Angas River (represented by the pink squares in figure 7) will be native groundwater. The flow paths shown in **Figure 7** were calculated by the PMPATH module in PMWIN for the maximum layer 3 heads (at the end of the model mining phase) which were maintained for 100 years. The red arrows represent flow paths of injected water with each ten years marked by a small arrowhead.

The “front” of a plume from INJW5 clearly remains within layer 3 (see cross sectional view at right side) and reaches only some 200m from the river after 100years and is 375m from the river after 10 years.

Water injected into INJW6 reports to the cone of depression around the underground workings within 10 years and cannot reach the river at any time.

The scenario represented by **Figure 6** is considered to be extremely conservative because the steep hydraulic gradients driving the migration of injected water will only persist as long as injection is operating. Thereafter the gradients will flatten and the flow will revert to the pattern exhibited by the native groundwater, of extremely slow movement in a general south direction.

As confirmation of the flow path information the model was run as a solute transport model using MT3D.

Injected water was allocated a value of 100 units (or 100% injected water) and native groundwater was assumed to have a value of zero thus any value between 1 and 100 indicates the percentage of injected water at a given point in the model plume.

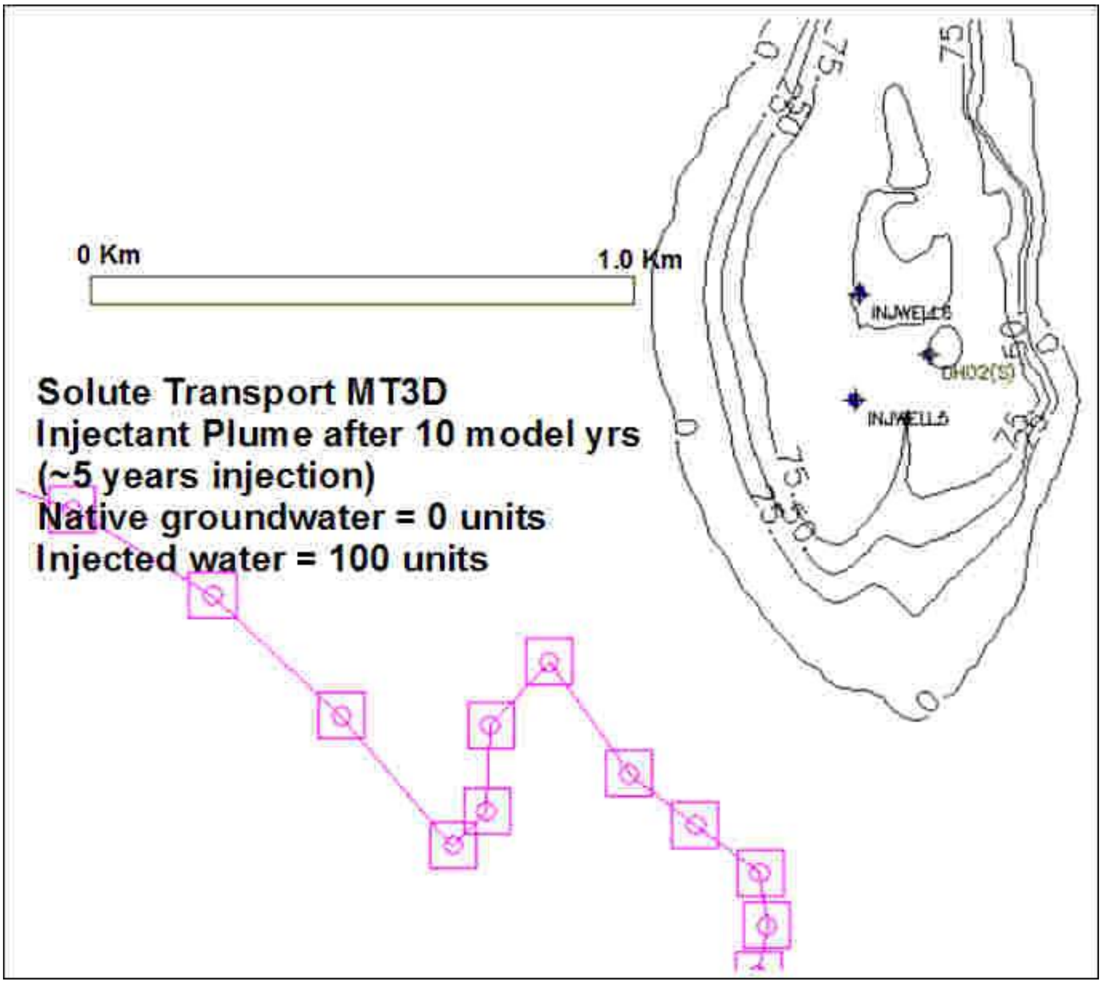


Figure 8: MT3D Model Plume of Injected Water after 10 years Model Time (Approx 5 years Injection)

The injected water plume after approximately 5 years of injection is shown in **Figure 8**.

The zero contour is 385m from the river in a direct line between INJW5 and the closest point on the river.

This is consistent with the flow path estimate of 375m after 10 years of injection.

Conclusion

The numerical model results indicate that:

1. The water injected into INJW5 moves slowly towards the Angas River.
2. Water injected into INJW6 reports to the cone of depression around the mine workings within the first 10 years.
3. Injected water remains within model layer 3 at all times.
4. Small increases in heads within model layer 1, due to dewatering in layer 3, result in a very small change in water balance in the 4.5km reach of the Angas River, which lies within the model domain. The head changes are approximately 0.16m and the overall river reach changes from a very slight loosing stream (-0.7L/m/day) to a slight gaining stream (+0.9L/m/day) after 11 years since the model run commenced.

5. A plot of the river cells water balance showed no indication of any impact due to the additional injection of mine drainage water after model year 5.

Yours sincerely,

Don Armstrong

For and on behalf of AGT Pty Ltd