PROJECT MEMORANDUM

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DATE:	20 July 2007	**JOB NO:**	001-77636008-Rev2
TO:	Andrew Dawkins	**TASK:**	
COMPANY:	**GEOTERRA**	**PAGES:**	7
PREPARED:		**EMAIL:**	pnalecki@golder.com.au
FROM:	Przemek Nalecki	**CELL:**	0400 299 422
RE:	**GLENNIES CREEK MODELLING RESULTS**		

NUMERICAL GROUNDWATER MODEL

Introduction

The following memorandum describes the conceptualisation and set-up of a numerical groundwater model prepared to investigate the impact of developing the Glennies Creek underground extension on water levels in the Glennies Creek alluvium.

Conceptual Model

Model physical boundaries were set up along the Camberwell Anticline to the west, the contact zone between Singleton Coal Measures and Wallaringa Formation to the east and the boundary between Singleton Coal Measures and Mulbring Siltstone to the south-east. All of those boundaries were set as no-flow boundaries due to the structural and hydrogeological characteristics (typified by very low hydraulic conductivities).

Coal seams were combined into three major groups, represented by Arties Seam, Liddell Seam and combined Barrett and Hebden Seams.

Rainfall recharge is expected to occur over the alluvial sediments of the major creeks and along the coal seam outcrops. For the post-subsidence conditions, an increased recharge is also expected to occur over the area affected by surface cracking due to the subsidence.

The underground mining and consequent subsidence effects alter the hydraulic characteristics of the mined and overlying strata. The real distribution of the hydraulic conductivities within

Glennies Creek subsidence area is not known at this stage. The distribution applied in the model was based on the conceptual model of longwall mine subsidence and personal communication with Andrew Dawkins (Geoterra).

The hydraulic conductivities applied in the model are summarised in Table 1 below.

Table 1: Hydraulic conductivities adopted for the subsidence zones.

Zone	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)
Middle Liddell Seam (MLS)	1×10^{-2}	1×10^{-2}
Cavity zone (between MLS and top of Arties Seam)	1×10^{-2}	1×10^{-2}
Arties Seam to 150m above MLS	1×10^{-4}	1×10^{-6}
150m above MLS to 28 mbgl	1×10^{-7}	No change
Ground level to 28 mbgl (excluding alluvium)	1×10^{-6}	1×10^{-4}
Alluvium	No change	No change

Model Setup

The conceptual understanding of the hydrogeology of the Project Area provided a basis for a numerical groundwater model using the FEFLOW package. FEFLOW (version 5.3) is a finite element groundwater modelling package developed by WASY Institute for Water Resources Planning and Systems Research in Berlin, Germany.

FEFLOW has become an industry standard in the context of finite element models for groundwater flow and mass and contaminant transport simulations. The finite element code allows areas that involve complex structural geometry to be represented reasonably accurately, without a loss of computational efficiency.

Model mesh consists of 180,380 elements and it is shown in Figure 1. The mesh was refined along the alluvial deposits to more accurately represent any impact of mine dewatering and post-subsidence effects on alluvial groundwater systems.

The numerical model comprises 10 layers, shown in Figures 2 and 3 and structured in the following manner:

- Layer 1 represents alluvial deposits along the main creeks in the Project Area, and weathered bedrock outside the alluvial channels. The layer has an uniform thickness of 8m across the entire model;
- Layer 2 represents weathered bedrock, with a uniform thickness of 20m across the model. The base of this layer corresponds to the base of surface fracturing due to the subsidence effects;
- Layer 3 represents overburden extending from the base of surface fracturing zone to MLS + 150m;
- Layer 4 represents overburden from 150m above the MLS to Arties Seam;
- Layer 5 represents Arties Seam. The layer has a nominal thickness of 3m;
- Layer 6 corresponds to the bedrock between Arties Seam and Middle Liddell Seam;
- Layer 7 represents Middle Liddell Seam, with layer thickness set at 3m;
- Layer 8 represents the bedrock between MLS and combined Barett and Hebden Seams;
- Layer 9 represents combined Barrett and Hebden Seams of a nominal thickness of 8m; and
- Layer 10 corresponds to bedrock underlying combined Barrett and Hebden Seams. The layer has a nominal thickness of 150m.

Model Runs

The hydraulic parameters adopted for the modelling are based on available reports describing modelling investigations carried out to date for Mt Owen Open Cut (Mackie Environmental Research), Ashton Underground (Peter Dundon and Associates Pty Ltd), Glennies Creek Open Cut (Australasian Groundwater and Environmental Consultants Pty Ltd) and Camberwell Open Cuts (Mackie Environmental Research).

Three Cases have been modelled:

- Case 1, employing higher end of hydraulic conductivity and storativity values quoted in the above reports;
- Case 2, employing lower hydraulic conductivity and storativity values; and,
- Case 3, employing hydraulic conductivity values, based on the extrapolated relation between depth of the coal seam and its hydraulic conductivity, based on “Groundwater Assessment of the Proposed Glennies Creek Open Cut Coal Mine”

prepared by Australasian Groundwater and Environmental Consultants Pty Ltd, and expressed as:

$$k=0.0418*\exp^{(-0.0159*z)}$$

Where: 0.0418 – base hydraulic conductivity near surface (m/day), and

z – depth of the coal seam

The hydraulic parameters adopted for modelled Cases are presented in the Table 2, 3 and 4 below.

Table 2: Hydraulic Conductivities and Storage Parameters Adopted For Case 1

Unit	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)	Specific Yield (-) / Specific Storage (1/m)
Alluvium	5.8×10^{-5}	2.9×10^{-5}	0.25 / -
Weathered Sandstone	5×10^{-8}	5×10^{-9}	$0.03 / 1 \times 10^{-5}$
Fresh Sandstone / Shale	5×10^{-9}	5×10^{-10}	$0.03 / 1 \times 10^{-5}$
Arties and Middle Liddell Seams	6×10^{-7}	6×10^{-8}	$0.03 / 1 \times 10^{-5}$
Hebden And Barrett Seams	2×10^{-7}	2×10^{-8}	$0.03 / 1 \times 10^{-5}$

Table 3: Hydraulic Conductivities and Storage Parameters Adopted For Case 2

Unit	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)	Specific Yield (-) / Specific Storage (1/m)
Alluvium	5.8×10^{-5}	2.9×10^{-5}	0.25 / -
Weathered Sandstone	5.0×10^{-8}	5.0×10^{-9}	$0.005 / 5 \times 10^{-6}$
Fresh Sandstone / Shale	5.0×10^{-9}	5.0×10^{-10}	$0.005 / 5 \times 10^{-6}$
Arties and Middle Liddell Seams	1.0×10^{-7}	1.0×10^{-8}	$0.03 / 5 \times 10^{-6}$
Hebden And Barrett Seams	8.0×10^{-8}	8.0×10^{-9}	$0.03 / 5 \times 10^{-6}$

Table 4: Hydraulic Conductivities and Storage Parameters Adopted For Case 3

Unit	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)	Specific Yield (-) / Specific Storage (1/m)
Alluvium	5.8×10^{-5}	2.9×10^{-5}	0.25 / -
Weathered Sandstone	5.0×10^{-8}	5.0×10^{-9}	0.005 / 5×10^{-6}
Fresh Sandstone / Shale	5.0×10^{-9}	5.0×10^{-10}	0.005 / 5×10^{-6}
Arties Seam	1.0×10^{-7}	1.0×10^{-8}	0.03 / 5×10^{-6}
Middle Liddell Seam	4.1×10^{-9}	4.1×10^{-10}	0.03 / 5×10^{-6}
Sandstone / Shale between Seams	1.0×10^{-9}	1.0×10^{-10}	0.005 / 5×10^{-6}
Hebden And Barrett Seams	8.4×10^{-10}	8.4×10^{-11}	0.03 / 5×10^{-6}

Rainfall recharge was assumed to occur and was applied to the model along the alluvial channels and coal seam outcrops. The applied rate of recharge was set to 8 mm/year along the alluvium and to 2 mm/year along the coal outcrops. The post-subsidence fracturing of the surface was assumed to attract the recharge of 10mm/year.

The applied recharge rates were obtained by calibrating model results to the measured water table elevation for available observation bores. Resulting recharge rates were consistent with the rates used by Australasian Groundwater and Environmental Consultants for modelling work for the proposed neighbouring Glennies Creek Open Cut.

For each of the two modelled cases, the modelling investigation was carried out in the following manner:

- Development of a model representing the best understandings of the current status of local mining and groundwater conditions. The model set up represents dewatering of the nearby mines including: Mt Owen Open Pits, Ashton Open Pit, Glennies Creek Underground and Camberwell Open Pits. The model underwent basic calibration focused on matching measured (or previously modelled) groundwater inflow rates into Glennies Creek Underground and Mt Owen Open Pit with the current model results.

- The next step involved running three predictive Cases for 5 years (from now till the end of proposed Glennies Creek Underground operation). Each Case comprised of one run with (Scenario 1) and the second run without (Scenario 2) the Glennies Creek Underground extension. The purpose of that exercise was to asses a “net” impact of the Glennies Creek Underground extension dewatering and post-subsidence effects on the surrounding hydrogeological environment. In those three models it was assumed that during the next five years Mt Owen Open Pit C will progress further south, Ravensworth Open Pit and Glennies Creek Open Pit will reach their maximum depths and the rest of the modelled operations will continue the dewatering processes at the current set up.

Model Outputs

Model generated hydrographs for observation bores located in alluvium are presented in Figures 4 to 6 for the respective Cases. The lower recharge rates applied to the alluvium created a conservative scenario for the impact assessment. At the same time, model trials indicated an insignificant impact resulting from underground dewatering on the groundwater levels in the alluvium, suggesting that for either Case, development of the Glennies Creek Underground extension would have a minor impact on the water levels in Glennies Creek alluvium.

Figures 7, 9 and 11 show model generated loss of piezometric head in Middle Liddell Seam for Scenario 1 of each of the modelled Cases. The figures show the difference between the model generated groundwater head for the current situation and the model predicted groundwater head distribution in year 2012.

Figures 8, 10 and 12 present a “net” loss of piezometric head in Middle Liddell Seam due to the development of the Glennies Creek Underground extension only.

To validate model outputs, the simulated inflow rates by year 2012 were compared to the results obtained by Mackie Environmental Research and Australasian Groundwater and Environmental Consultants Pty Ltd for Mt Owen Open Cut and Glennies Creek Open Cut respectively.

The modelled inflow rates for Case 1 were considered to be high, exceeding predictions given by the other consultants. As a consequence, Case 1 was considered to be conservative.

Case 2 inflow rates were in reasonable agreement with the reports mentioned above, and therefore this case was considered to be the more likely scenario.

Case 3 inflow rates for the “current state” model were calibrated to recently obtained measured average inflow rates into the Glennies Creek Underground operation. In conclusion, the model predicted inflow rates at the end of mining for the Case 3, would represent the most likely scenario.

The modelled long term (average) inflow rates for the respective modelled Cases are presented in Table 5 below.

Table 5. Modelled inflow rates into Glennies Creek Underground.

Case	Modelled Inflow Rates "Current State"	Modelled Inflow Rates Year 2012
Case 1	2,500 m^3/d	~10,000 m^3/d
Case 2	850 m^3/d	~1,500 m^3/d
Case 3	300 m^3/d	~500 m^3/d

It should be noted that due to the character of the fractured rock mass, the inflow rates will be primarily regulated by the fracture systems surrounding the underground void. This will result in higher inflow rates when extensive fracture systems are cut through, and declining seepage rates when mining through rock with minor fracturing (tight rock).

Attachments:

Figures - 001-077636008-Figures-Rev2.ppt

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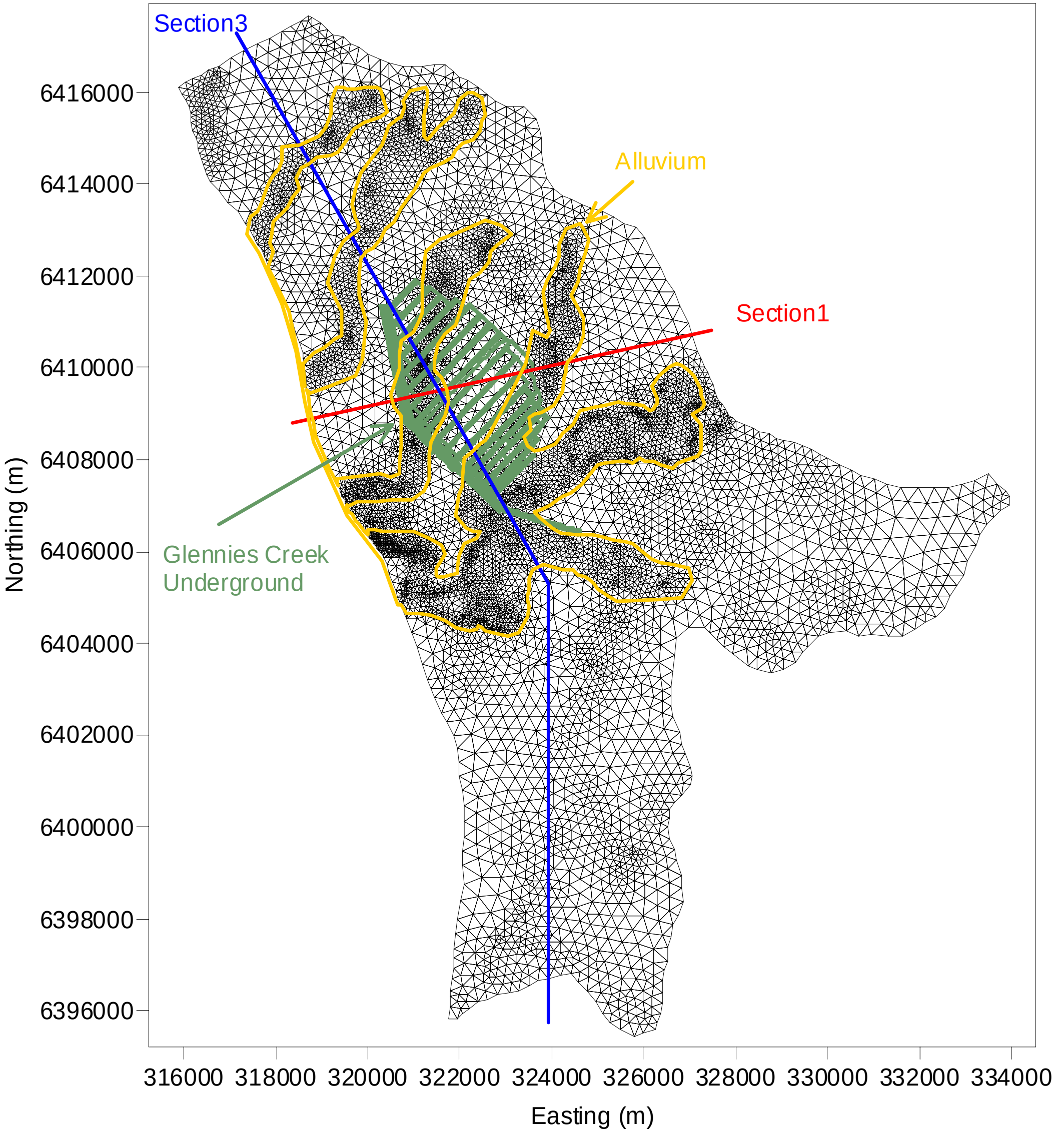

CLIENT		PROJECT		
Geoterra Pty Ltd		Glennies Creek Groundwater Modelling		
DRAWN PN	DATE 07/07	TITLE **MODEL MESH**		
CHECKED EW	DATE 07/07			
SCALE Not to scale		PROJECT No 001-077636008	FIGURE No 1	REV No 1 A4

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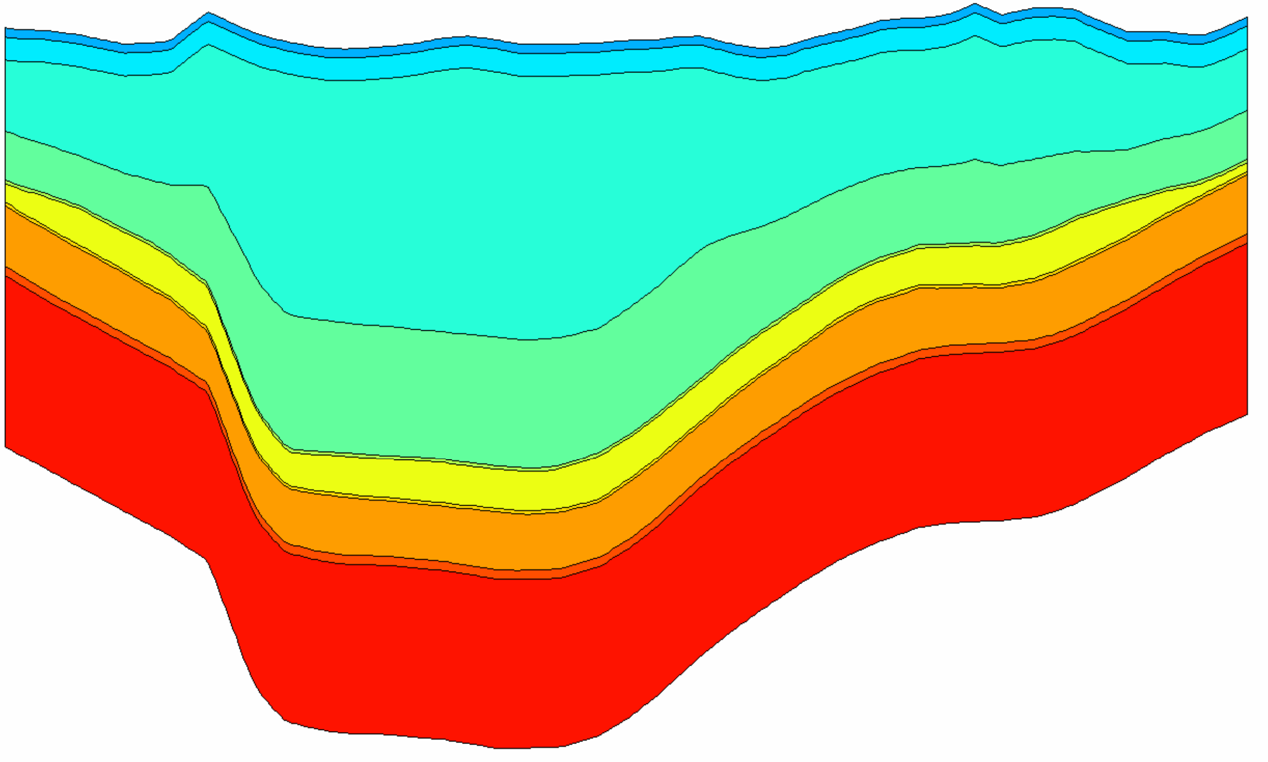

Golder Associates	CLIENT Geoterra Pty Ltd		PROJECT Glennies Creek Groundwater Modelling	
	DRAWN PN	DATE 07/07	TITLE MODEL STRUCTURE – SECTION 1	
	CHECKED EW	DATE 07/07		
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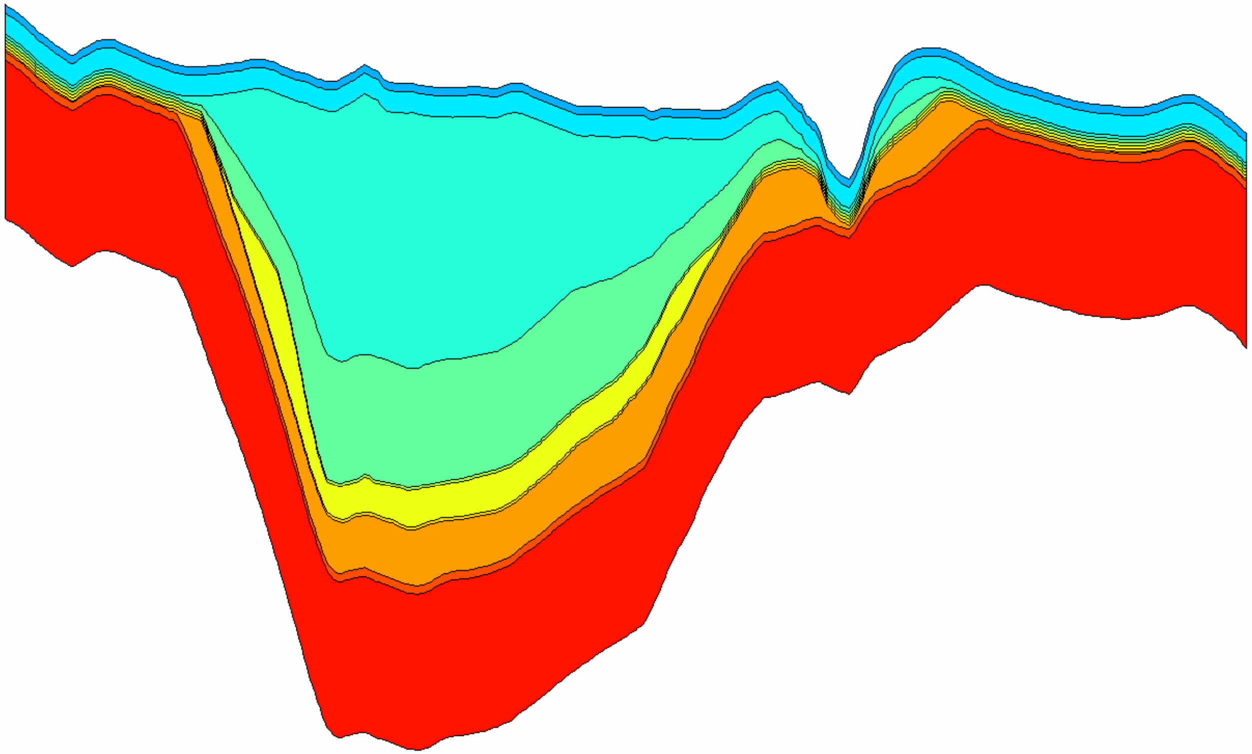

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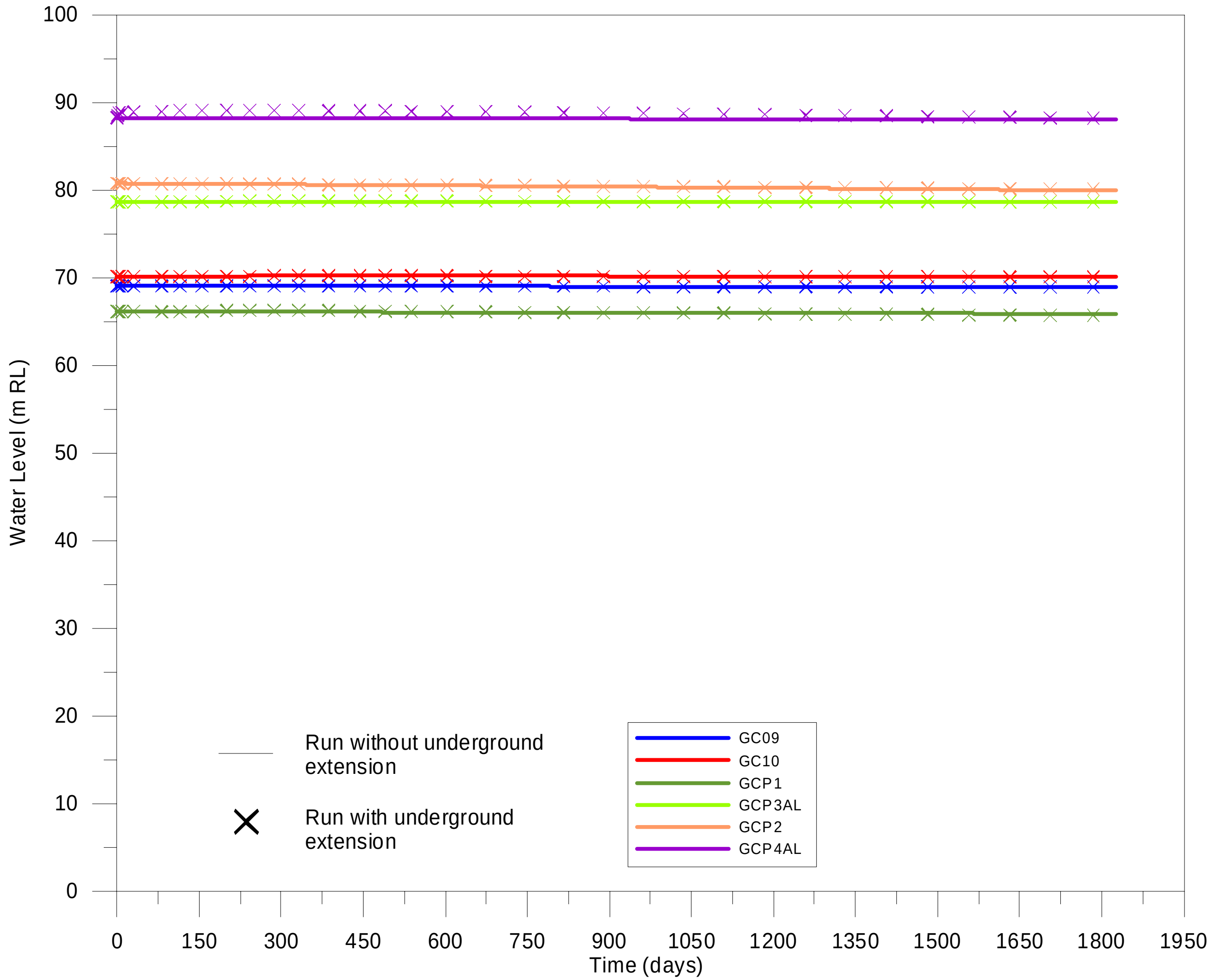

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CLIENT Geoterra Pty Ltd		PROJECT Glennies Creek Groundwater Modelling	
DRAWN PN	DATE 07/07	TITLE **MODEL HYDROGRAPHS FOR OBSERVATION BORES IN ALLUVIUM (CASE 1)**	
CHECKED EW	DATE 07/07		
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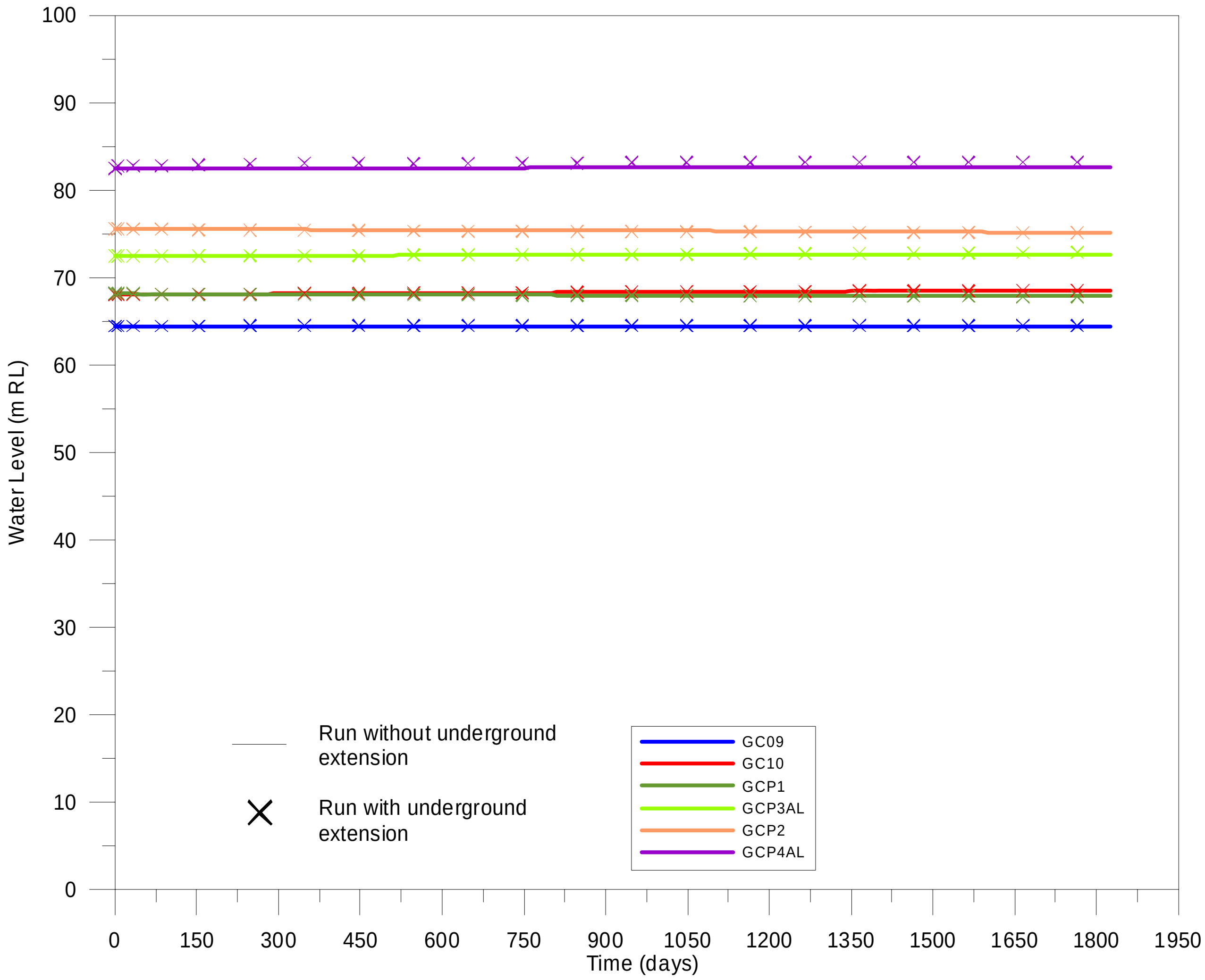

Golder Associates	CLIENT Geoterra Pty Ltd		PROJECT Glennies Creek Groundwater Modelling
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	CHECKED EW	DATE 07/07	
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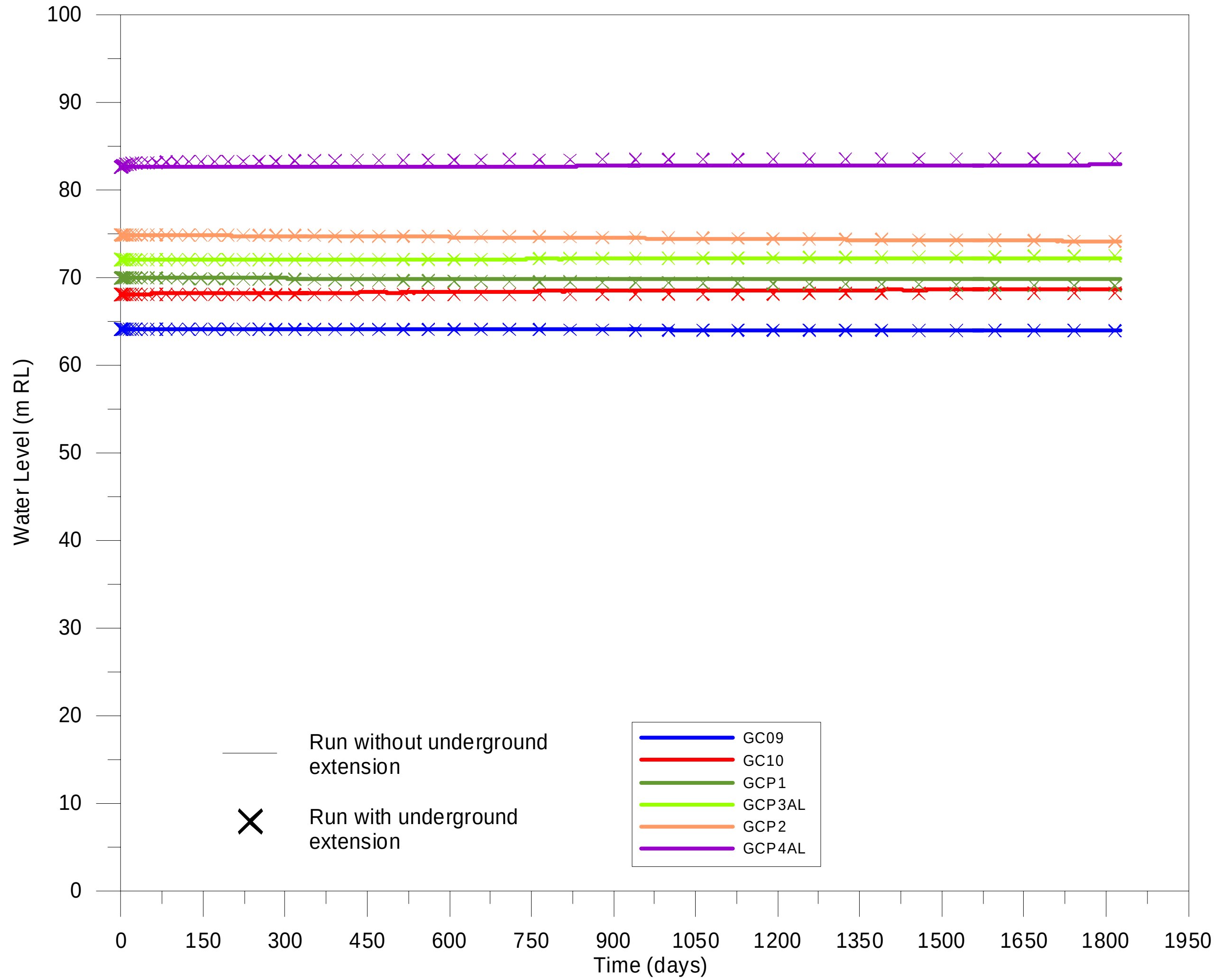

Golder Associates	CLIENT Geoterra Pty Ltd		PROJECT Glennies Creek Groundwater Modelling	
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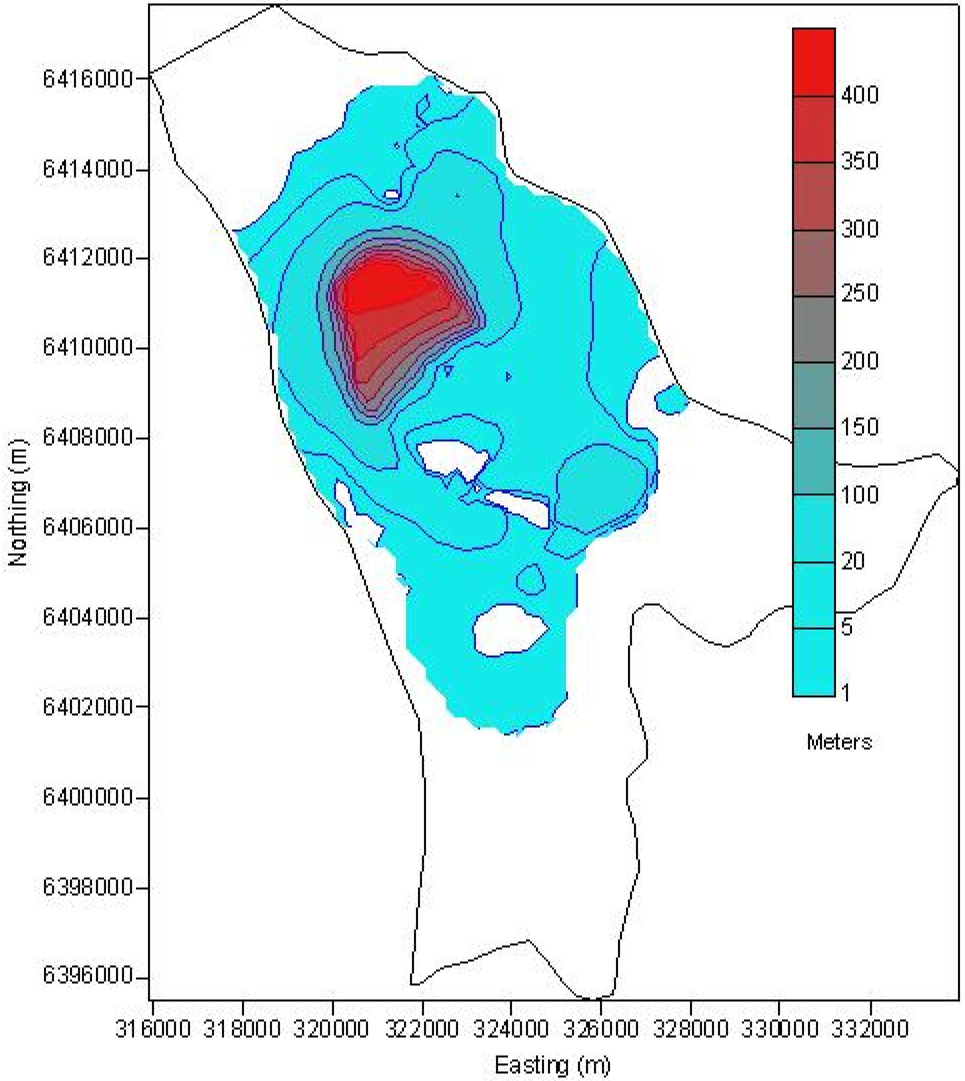

CLIENT	Geoterra Pty Ltd		PROJECT	Glennies Creek Groundwater Modelling		
DRAWN	PN	DATE 07/07	TITLE	**MODELLED CUMULATIVE LOSS OF PIEZOMETRIC HEAD AT YEAR 2012 (MIDDLE LIDDELL SEAM, CASE 1)**		
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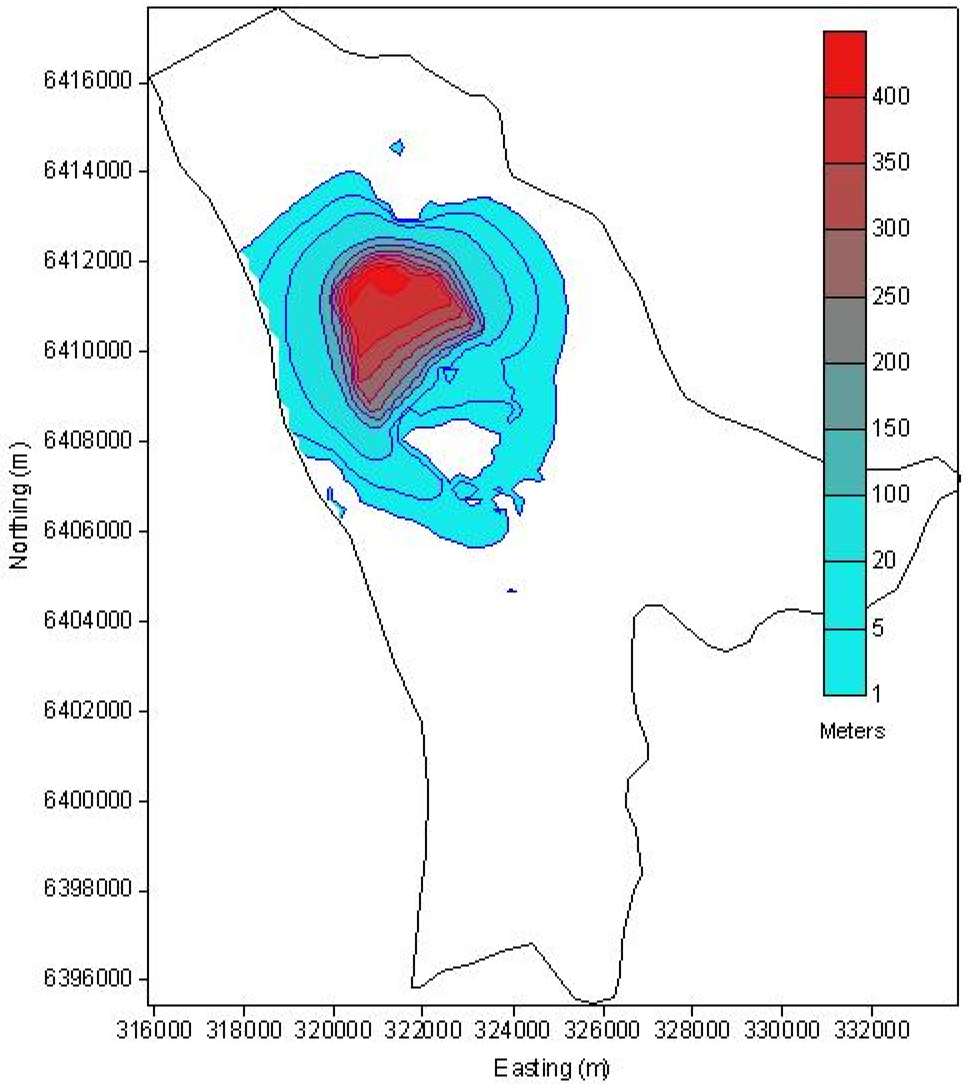

CLIENT: Geoterra Pty Ltd		PROJECT: Glennies Creek Groundwater Modelling	
DRAWN: PN	DATE: 07/07	TITLE: **MODEL NET LOSS OF PIEZOMETRIC HEAD AT YEAR 2012 (MIDDLE LIDDELL SEAM, CASE 1)**	
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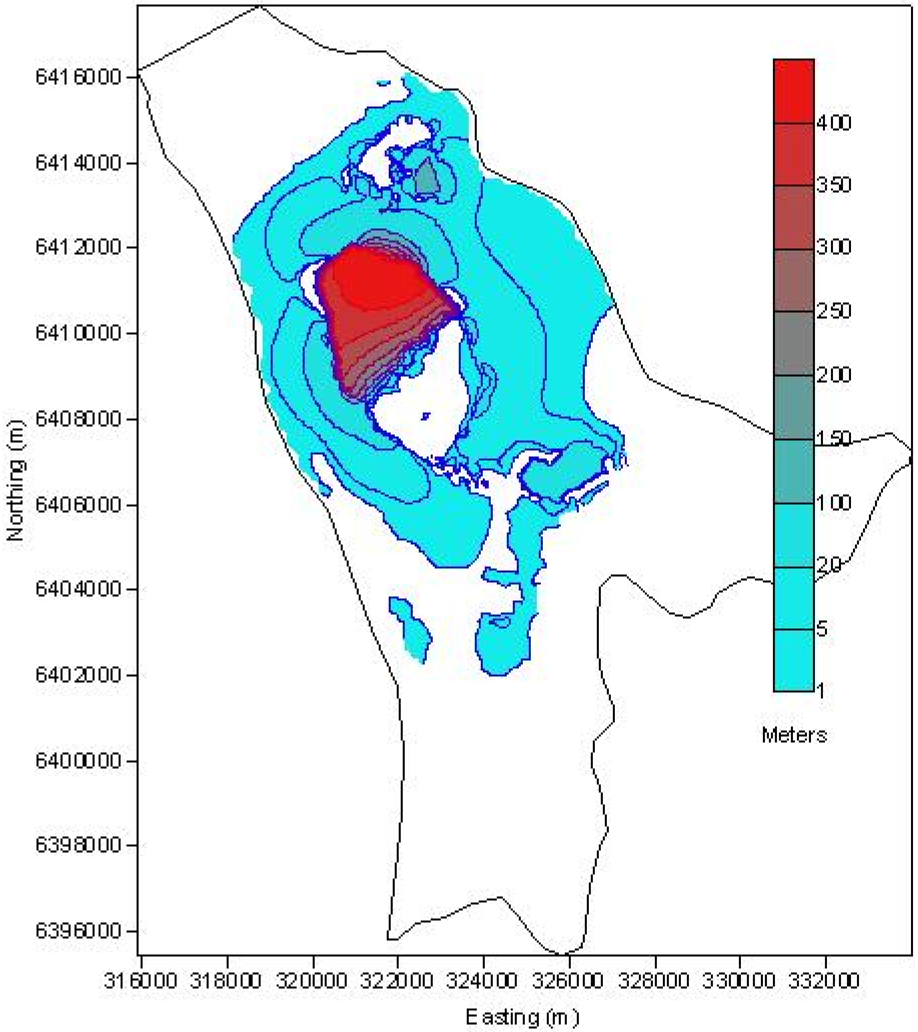

CLIENT	Geoterra Pty Ltd	PROJECT	Glennies Creek Groundwater Modelling
DRAWN PN	DATE 07/07	TITLE	**MODEL CUMULATIVE LOSS OF PIEZOMETRIC HEAD AT YEAR 2012 (MIDDLE LIDDELL SEAM, CASE 2)**
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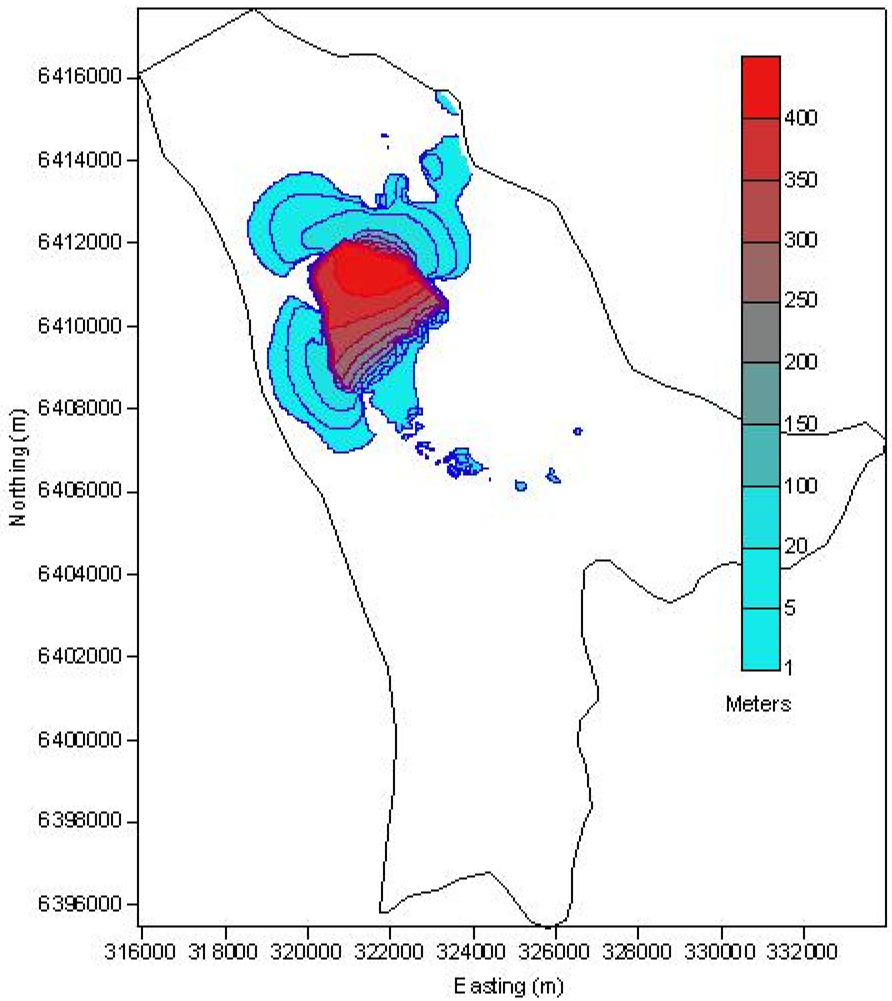

Golder Associates	CLIENT: Geoterra Pty Ltd		PROJECT: Glennies Creek Groundwater Modelling
	DRAWN: PN	DATE: 07/07	TITLE: **MODEL NET LOSS OF PIEZOMETRIC HEAD AT YEAR 2012 (MIDDLE LIDDELL SEAM, CASE 2)**
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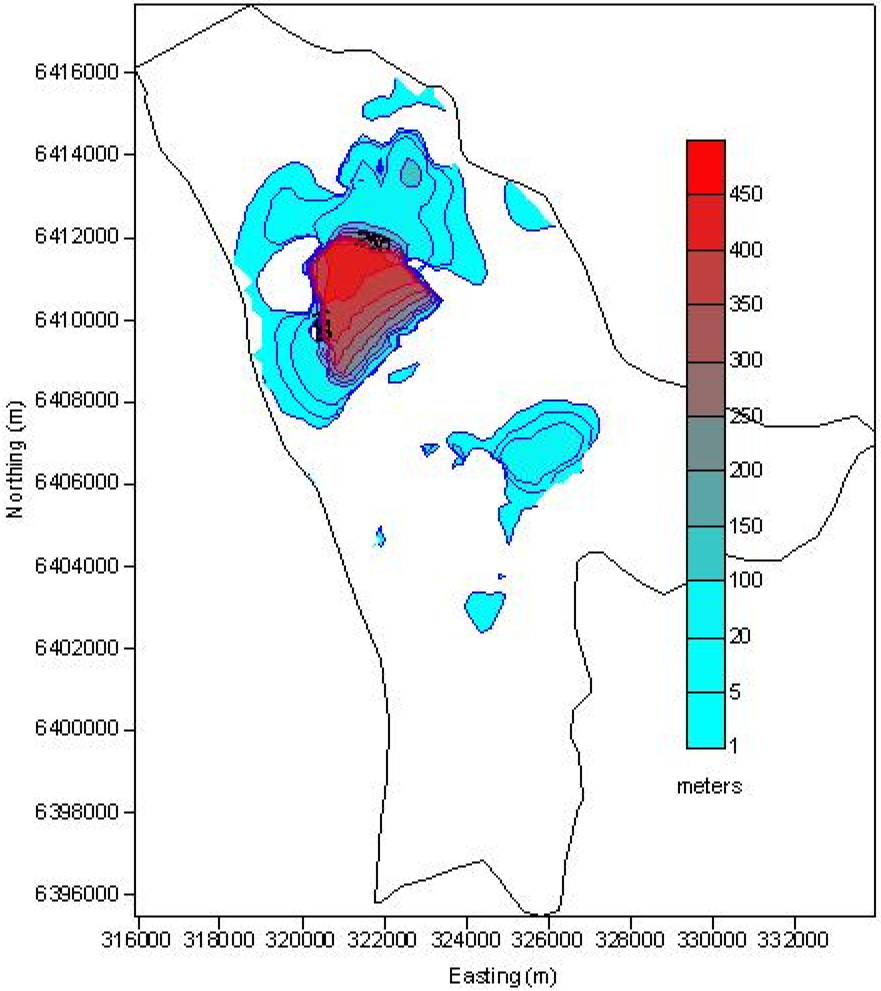

CLIENT Geoterra Pty Ltd		PROJECT Glennies Creek Groundwater Modelling
DRAWN PN	DATE 07/07	TITLE **MODEL CUMULATIVE LOSS OF PIEZOMETRIC HEAD AT YEAR 2012 (MIDDLE LIDDELL SEAM, CASE 3)**
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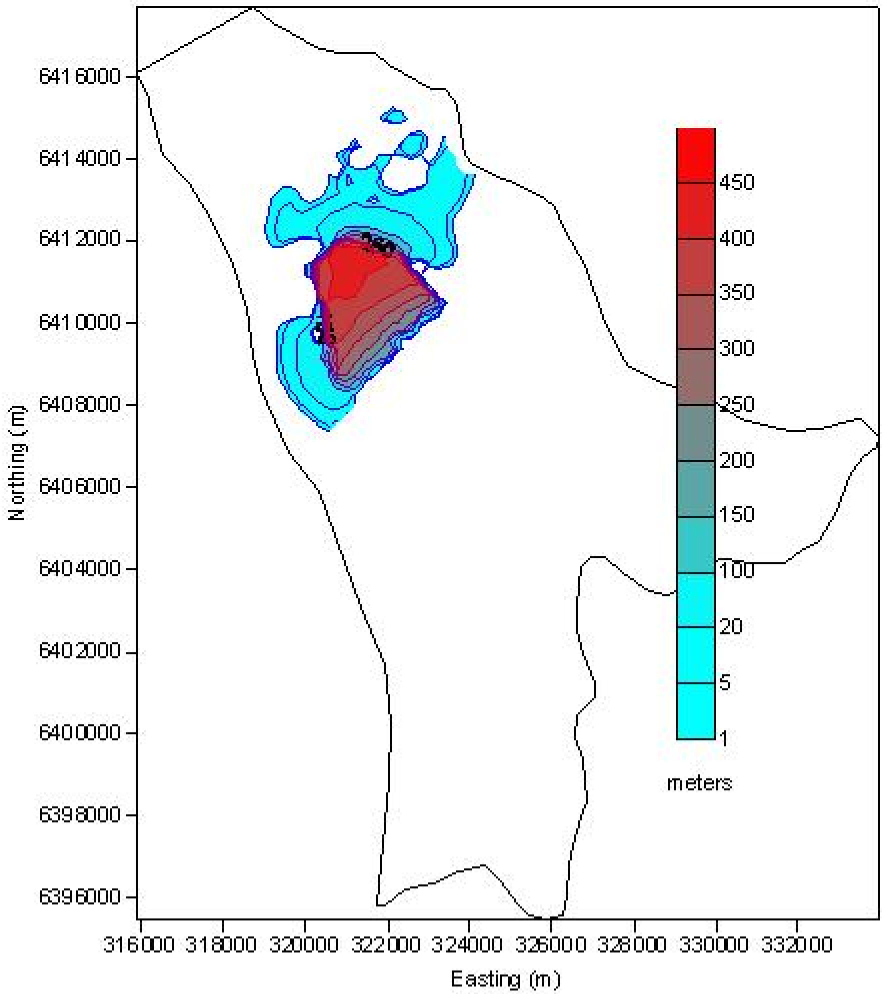

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	DRAWN: PN	DATE: 07/07	TITLE: **MODEL NET LOSS OF PIEZOMETRIC HEAD AT YEAR 2012 (MIDDLE LIDDELL SEAM, CASE 3)**		
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