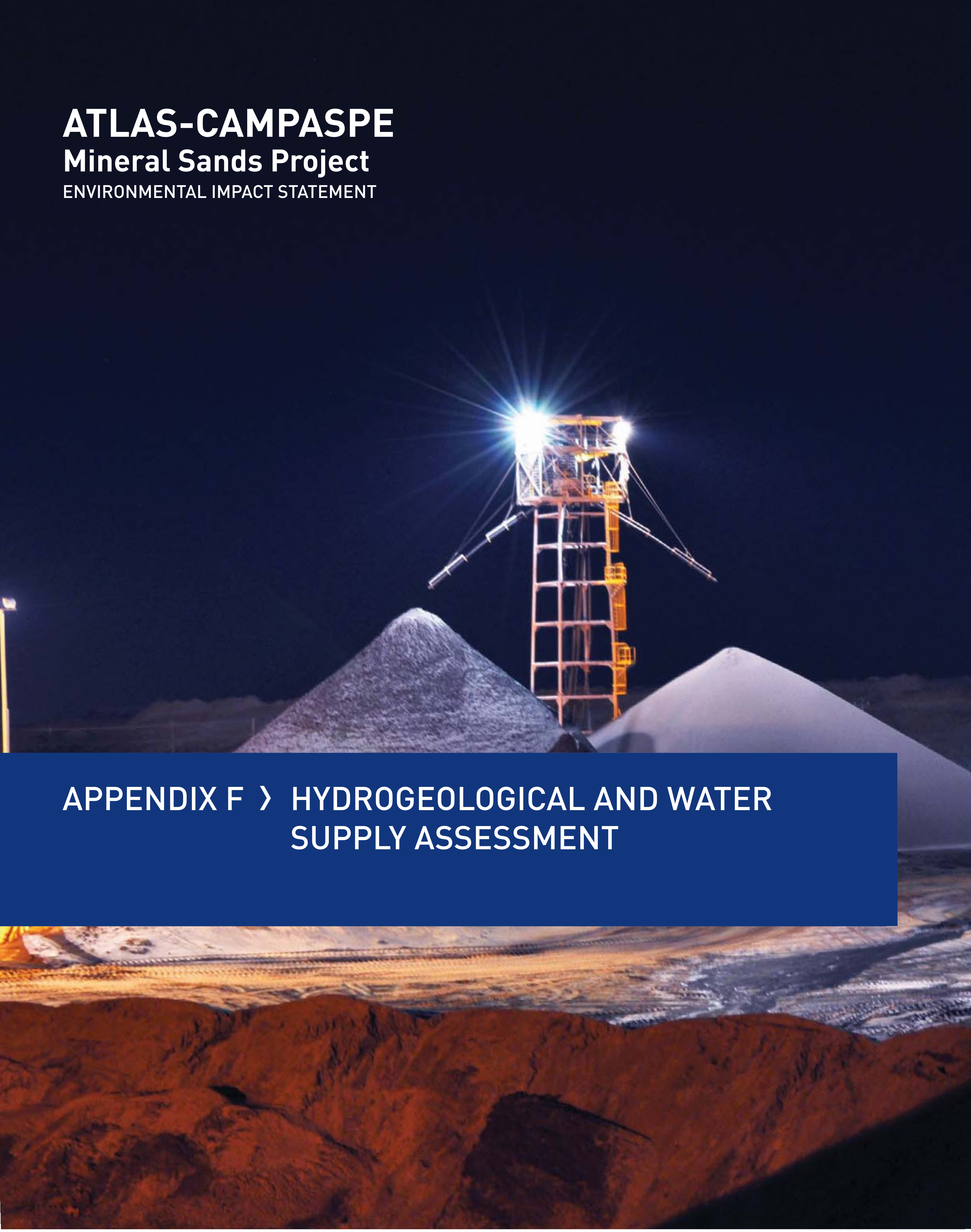
ATLAS-CAMPASPE
Mineral Sands Project
ENVIRONMENTAL IMPACT STATEMENT



APPENDIX F › HYDROGEOLOGICAL AND WATER SUPPLY ASSESSMENT

CRISTAL

Resource Strategies

ATLAS-CAMPASPE MINERAL SANDS PROJECT

APPENDIX F - HYDROGEOLOGICAL AND WATER SUPPLY ASSESSMENT

MAY 2013
Project No. BMX-11-25
Document No. 00520808.doc

1112G

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1 INTRODUCTION

The Atlas-Campaspe Mineral Sands Project (the Project) involves the construction and operation of a mineral sands mine located approximately 80 kilometres (km) north of Balranald, New South Wales (NSW), and 270 km south-east of Broken Hill, NSW (Figure 1). The Project is also proposed to involve the construction and operation of a rail facility at Ivanhoe (the Ivanhoe Rail Facility) approximately 135 km north-east of the Project site and approximately 270 km south-east of Broken Hill (Figure 1).

The proposed Atlas-Campaspe Mine involves the extraction of mineral sands from two deposits that are located approximately 7 km and 13.5 km, south of Boree Plains Station in western NSW, respectively. The proposed mining would involve sequential development and operation of two separate mineral sands ore extraction areas orientated in south-east to north-west direction. A 12 km section of the Atlas deposit (typically less than 100 metres [m] wide), and a 14 km section of the Campaspe deposit (typically less than 300 m wide) is proposed to be mined by the Project. A full description of the Project is provided in Section 2 in the Main Report of the Environmental Impact Statement (EIS).

This report provides a groundwater and water supply assessment of the proposed mining operation.

1.1 SCOPE OF WORK

In accordance with the NSW Department of Planning and Infrastructure Director-General's Requirements (DGRs) for the Project, this assessment is required to address the following specific issues (including groundwater components):

Water Resources - *including:*

- *detailed assessment of potential impacts on the quality and quantity of existing surface and ground water resources, including:*
  - *detailed modelling of potential groundwater impacts;*
  - *impacts on affected licensed water users and basic landholder rights; and*
  - *impacts on riparian, ecological, geomorphological and hydrological values of watercourses, including environmental flows;*
- *a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures;*
- *an assessment of proposed water discharge quantities and quality/ies against receiving water quality and flow objectives; - identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000;*
- *demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP);*

- *a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo; and*
- *a detailed description of the proposed water management system(including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts;*

The surface water components of the assessment are discussed separately in the Surface Water Assessment (Evans & Peck, 2012) (Appendix G of the EIS). Site sewage management is described separately in Section 2 in the Main Report of the EIS.

As part of the assessment process an Environmental Risk Assessment (ERA) (Appendix O of the EIS) was undertaken. This included a facilitated risk-based workshop involving experts across a range of disciplines, and experienced Cristal Mining Australia Limited (Cristal Mining) personnel. The objective of the assessment was to identify key potential environmental issues for further assessment in the EIS. The key potential groundwater related issue identified in the ERA (Appendix O of the EIS) was:

- Changes to groundwater gradients and consequential impacts on surface water features.

Based on the above, the assessment included the following stages:

(i) Data Collection

The following sources of data were reviewed to provide information on the hydrogeological character of the local and regional groundwater aquifers:

- Murray Basin Hydrogeological Map Series;[1]
- Lachlan Fan/Ivanhoe Block Steady State Groundwater Model;[2]
- Lower Lachlan Groundwater Model;[3]
- NSW Office of Water (NOW) PINNEENA Groundwater Database;[4]
- Victorian Water Resources Data Warehouse[5];
- Cristal Mining Exploration Drilling Database;

1. Australian Geological Survey Organisation (AGSO) and Bureau of Mineral Resources, Geology and Geophysics (BMR) (1991-1994) Murray Basin Hydrogeological Map Series 1:250,000 *Map Sheets, Mildura, Balranald, Pooncarie, Manara, Hay and Booligal*
2. Kellet, J. R. (1997) *Lachlan Fan / Ivanhoe Block Steady State Groundwater Model*. Australian Geological Survey Organization, Canberra.
3. Mampitiya, D. (2010) *Lower Lachlan Groundwater Model*. NSW Office of Water, April 2010.
4. NOW (2012) PINNEENA 3.2, NOW 10_294.
5 Victorian Department of Sustainability and Environment (DSE) (2012) Victorian Water Resources Data Warehouse. Website: www.vicwaterdata.net/vicwaterdata/home.aspx

- existing water management records (including groundwater licensing) from the Ginkgo and Snapper Mines;
- previous hydrogeological assessments and water level and quality data from monitoring programmes at the Ginkgo and Snapper Mines (Golder Associates, 2001[6]; 2007[7]);
- other hydrogeological investigation testwork undertaken by Cristal Mining (e.g. bore installation and pumping tests at the Atlas deposit and shallow geological logs); and
- other regional topographic data.

(ii) Model Development

As the existing Lachlan Fan/Ivanhoe Block Steady State Groundwater Model covers the area of interest, it was used as the basis for developing a more detailed groundwater model centred around the proposed mining area. Calibration of the groundwater model was carried to a level appropriate to the level of available data accuracy. Model development was carried out in accordance with the Murray Darling Basin Commission (MDBC)'s *Groundwater Flow Modelling Guideline*,[8] and the *Australian Groundwater Modelling Guidelines*.[9]

(iii) Hydrogeological Assessment

The groundwater model created for the Atlas-Campaspe Mine was used to predict groundwater impacts due to the borefield pumping, pit dewatering and water infiltration from sand deposition areas over the period of mining and subsequently for a period of 50 years post-mining (i.e. recovery). Recommendations for future groundwater monitoring (for model validation) and impact mitigation measures were also considered.

(iv) References

In accordance with the DGRs for the Project, this assessment has been prepared in consideration of the following groundwater-related technical policies, guidelines and plans:

- *National Water Quality Management Strategy: Guidelines for Groundwater Protection in Australia* (Agriculture and Resource Management Council of Australia and New Zealand and Australian and New Zealand Environment and Conservation Council, 1995).

6 Golder Associates (2001) Hydrogeological Assessment of the Ginkgo Mineral Sands Project.

7 Golder Associates (2007) Snapper Mineral Sands Project Hydrogeological Assessment.

8. Aquaterra (2001) *Groundwater Flow Modelling Guideline*. Murray Darling Basin Commission.

9. Sinclair Knight Merz and National Centre for Groundwater Research and Training (2012) *Australian Groundwater Modelling Guidelines*. Waterlines Report Series No. 92, June 2012.

- *NSW State Groundwater Policy Framework Document* (NSW Department of Land and Water Conservation [DLWC], 1997).
- *NSW State Groundwater Quality Protection Policy* (DLWC, 1998a).
- *Draft NSW State Groundwater Quantity Management Policy* (DLWC, 1998b).
- *NSW State Groundwater Dependent Ecosystems Policy* (DLWC, 2002).
- *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources, 2011*.
- *Murray-Darling Basin Groundwater Quality Sampling Guidelines: Technical Report No 3* (MDBC, undated).
- *MDBC Groundwater Flow Modelling Guideline* (Aquaterra, 2001).
- *Guidelines for the Assessment and Management of Groundwater Contamination* (NSW Department of Environment and Conservation, 2007).
- Any relevant Water Sharing Plan for groundwater and surface water resources.

2 PROJECT OVERVIEW

The Project would involve two main development components (Figure 1):

1. Construction and development of infrastructure for mining operations at the Atlas and Campaspe deposits (the proposed Atlas-Campaspe Mine).
2. Construction and operation of the Ivanhoe Rail Facility (the proposed Ivanhoe Rail Facility).

The proposed life of the Project is approximately 20 years, commencing approximately 1 July 2013 or upon the grant of all required approvals.

The Project general arrangements are shown on Figures 2 and 3. A detailed description of the Project is provided in Section 2 in the Main Report of the EIS.

The activities associated with the two main development components of the Project are summarised below.

2.1 ATLAS-CAMPASPE MINE

The main activities associated with the development of the Atlas-Campaspe Mine would include:

- ongoing exploration activities;
- sequential development and operation of two separate mineral sands ore extraction areas within the Mining Lease Application 1 area;
- use of conventional mobile equipment to mine and place mineral sands ore into dry mining unit(s)[10] (DMU) at a maximum ore production rate of up to 7.2 million tonnes per annum;
- mineral processing infrastructure including the primary gravity concentration unit, salt washing facility and a wet high intensity magnetic separation circuit;
- mineral concentrate stockpiles and materials handling infrastructure (e.g. towers and stackers);
- progressive backfilling of mine voids with overburden behind the advancing ore extraction areas or in overburden emplacements adjacent to the mine path;
- placement of sand residues and coarse rejects (and Broken Hill Mineral Separation Plant [MSP] process wastes)[11] following mineral processing to either the active mining area (behind the advancing ore extraction area) or in sand residue dams;

10. Mining would use conventional open pit methods and would not involve dredge mining.

11. Following cessation of operations at the Ginkgo and Snapper Mines (approximately Year 12 of the Project).

- development of a groundwater borefield at the Atlas deposit and localised dewatering systems (bores, spearfields and trenches) at both the Atlas and Campaspe deposits, including associated pump and pipeline systems;
- reverse osmosis (RO) plant to supply the salt washing facility and potable water;
- progressive development of water storage dams, sediment basins, pumps, pipelines and other water management equipment and structures;
- administration/office buildings, car parking facilities, workshop and stores;
- on-site accommodation camp;
- sewage treatment plant;
- diesel powered generators, electricity distribution station and associated internal electricity transmission lines;
- site access road, internal access roads and haul roads;
- roadworks along the proposed mineral concentrate transport route to the Ivanhoe Rail Facility;
- transport of mineral concentrates along the mineral concentrate transport route to the Ivanhoe Rail Facility;
- road transport of MSP process waste[12] in sealed storage containers from the Ivanhoe Rail Facility to the Atlas-Campaspe Mine for subsequent unloading, stockpiling and placement behind the advancing ore extraction areas;
- development of soil stockpiles and laydown areas;
- monitoring and rehabilitation; and
- other associated minor infrastructure, plant, equipment and activities.

Potable water would be supplied by the RO plant (<1 litres per second [L/s]) and reticulated via pipeline to the administration/office buildings (including ablutions) and accommodation camp at the Atlas-Campaspe Mine.

12. Following cessation of operations at the Ginkgo and Snapper Mines (approximately Year 12 of the Project).

2.2 IVANHOE RAIL FACILITY

The main activities associated with the construction and operation of the Ivanhoe Rail Facility located approximately 4.5 km south-west of Ivanhoe, would include:

- development of a rail siding for:
  - loading of train wagons with mineral concentrate for rail transport to the MSP via the Orange – Broken Hill railway; and
  - unloading of MSP process waste in sealed storage containers (transported via the Orange – Broken Hill railway) from train wagons[13];
- site access road and internal haul roads/pavements;
- hardstand areas for mineral concentrate and MSP process waste[13] unloading, stockpiling/sealed container storage and loading;
- a retention basin, drains, pumps, pipelines and other water management equipment and structures;
- site office and car parking facilities;
- extension to existing 11 kilovolt powerline;
- monitoring, landscaping and rehabilitation; and
- other associated minor infrastructure, plant, equipment and activities.

Potable water would be provided from either the Ivanhoe town water supply or the Atlas-Campaspe Mine water supply, and delivered by truck for use at the site office buildings.

13. Following cessation of operations at the Ginkgo and Snapper Mines (approximately Year 12 of the Project).

3 HYDROGEOLOGICAL SETTING

3.1 TOPOGRAPHY AND DRAINAGE

The Atlas-Campaspe Mine is located within the Benanee basin of the lower Murray River system in NSW. The Benanee basin borders the upstream effluent creeks of the Lachlan River basin, Darling and Murrumbidgee River basins and the downstream Murray River basin. The Benanee basin is made up of a number of ill-defined creeks, streams and ephemeral lakes that contribute negligible inflows to the Murray River (NOW, 2012a).

The western Riverine Plain includes several effluent creeks extending westward from the Lachlan Alluvial Fan, which do not return to the Lachlan River (Figure 4). The northernmost channel is Willandra Creek, which under flood conditions can flow to the typically dry Willandra Lakes Region World Heritage Area to the west (Figure 4). The area in which the Atlas-Campaspe Mine is located is dominated by two generally north-south trending topographic reflections of basement ridges (Iona Ridge and Neckarboo Ridge) which are on average 40 m higher than the land surface of the adjacent western Riverine Plain (to the east), and are characterised by stabilised sand dunes and mallee vegetation (Kellet, 1997). The Willandra Lakes Region World Heritage Area occupies a series of dry lake depressions about 20 km wide between the two ridges (Figures 4 and 5).

The topographic high in the region is Manfred Mountain at 171 m Australian Height Datum (AHD) to the north of the Atlas-Campaspe Mine and the lowest elevation is about 45 m AHD along the Murray River to the south (Figure 6). The Atlas-Campaspe Mine is located at elevations ranging from approximately 60 m AHD to 120 m AHD.

The Willandra Lakes Region World Heritage Area dry lake depressions (i.e. Willandra Trough) to the west and north-west of the Atlas-Campaspe Mine, are at approximately 50 m AHD to 70 m AHD.

Between the two deposits is a topographic low at 75 m AHD, which occasionally has ponded water. Water levels in the test bore indicate that the local water table is at 45 m AHD, approximately 30 m below this topographic low.

3.2 RAINFALL AND EVAPORATION

The climate is semi-arid with low and sporadic rainfall and high evaporation. Annual rainfall in the Atlas-Campaspe Mine area is both low (average 292 millimetres [mm]) as well as highly variable (minimum 110.7 mm and maximum 734.4 mm) (Appendix G).

Long-term rainfall residual mass curves (RRMC) were created for four sites that had long-term continuous records (Balranald [RSL], Euston [Turlee], Hatfield [The Vale] and Ivanhoe Post Office) [14] (Figure 4). The RRMCs are overlain on the hydrographs for the shallow aquifers (Attachment A).

The western and southern sites (Euston [Turlee] and Balranald [RSL]) are similar, showing below average (negative slope) rainfall from 1995 to 2009. The two northerly sites (Hatfield [The Vale] and Ivanhoe Post Office), show a decline in rainfall from 2000 to 2009.

Average areal actual evapotranspiration has been estimated by the Bureau of Meteorology (BOM) website to be about 328 millimetres per year (mm/year) for data obtained from 1961 to 1990.[15] The rainfall statistics in Table 1 are calculated for the same period for comparison purposes.

Table 1
Rainfall and Evapotranspiration Statistics [1961-1990]

Month	**Average Monthly Rainfall (mm)**				**Average Areal Actual Evapotranspiration**
	Balranald (RSL) [49002]	Euston (Turlee) [49111]	Hatfield (The Vale) [49047]	Ivanhoe Post Office [49019]	
January	30.8	29.1	33.4	45.1	35
February	20.4	17.8	17.8	19.2	22
March	29.2	27.3	30.1	36.7	25
April	33	27	28.7	27.3	25
May	36.1	30.8	29.4	33.8	32
June	25.7	19.5	20.8	21.8	23
July	27	25.7	22.3	23.3	25
August	36.1	29.2	28.3	28.2	29
September	34.5	24.1	24.6	24.1	30
October	31.7	29.1	29.3	30.5	29
November	26.6	21.2	20.6	20.9	25
December	28	22.9	24.6	28.5	28
Yearly Average	**359.1**	**303.7**	**309.9**	**339.4**	**328**

Source: BOM (2012).
Note: Yearly average totals vary due to rounding.

14. Cumulative deviation from the full-record average rainfall was calculated for each year, starting at a value of zero in 1980.
15. BOM (2012) *Average Annual and Monthly Evapotranspiration*.
Website: <http://www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp?maptype=1&period=an>

Locally, evapotranspiration varies as a function of the vegetation cover and surficial geology. The vegetation of the Ivanhoe Block is indicated to be an extremely efficient interceptor of rainfall, while infiltration past the vegetation of the western Riverine Plain is expected to be higher (Kellet, 1997). Infiltration is expected to increase along the depression of the Willandra Lakes Region World Heritage Area and across the more intense agricultural areas along the Murray, Murrumbidgee and Lachlan Rivers.

The thin Quaternary surficial sediments are quite variable in terms of infiltration potential including both clayey and sandy layers. The Shepparton Formation tends to be clayey, reducing the potential for infiltration, while the Loxton-Parilla Sands are more permeable.

3.3 REGIONAL CATCHMENTS AND SURFACE WATER RESOURCES

The only permanent surface water bodies in the region are the Murrumbidgee and Murray Rivers approximately 60 km and 80 km to the south-east and south of the Atlas-Campaspe Mine site respectively. Since 2012, rainfall has been significantly above average and has resulted in ephemeral water ponding in low-lying areas at the Atlas-Campaspe Mine site.

A description of the regional catchment and surface water resources is presented in the Surface Water Assessment (Appendix G of the EIS) prepared by Evans & Peck (2012).

3.4 LAND USE

The Atlas-Campaspe Mine occurs within the central-eastern portion Lower Murray Darling Catchment Management Authority (LMDCMA) area. The tenure of the land in the region is primarily Crown Land, mostly leased for the purpose of grazing in perpetuity under the NSW *Western Lands Act, 1901*. Sheep grazing is the primary grazing pursuit, although some properties (including Boree Plains) graze cattle (Ogyris Ecological Research, 2012).

Only approximately 5 percent (%) or 315,000 hectares of the land area of the LMDCMA has been cleared, primarily for cropping purposes (Ogyris Ecological Research, 2012).

3.5 STRATIGRAPHY AND LITHOLOGY

A number of large scale ridges and basins (likely fault bounded blocks) form the pre-Tertiary basement profile, over which the relatively flat lying Tertiary and Quaternary sediments of the Murray Basin have formed, and within which the Atlas-Campaspe Mine is located[16] (Figure 5).

The stratigraphy of the Atlas-Campaspe Mine area is described below in descending order.

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16. Brown, C.M. and Stephenson, A.E. (1991). *Geology of the Murray Basin, Southeastern Australia*. Bureau of Mineral Resources, Australia. Bulletin 235.

Surficial Quaternary sediments range from the sands of the Coonambidgal Formation found along the river channels, to the silty clays and evaporite deposits of the flood plain lakes. The Woorinen Formation is found as extensive east-west oriented sand dunes, but also includes clayey zones. More recent aeolian sand deposits are found as low dunes and lunettes around the larger dry lakes.

The Tertiary-Quaternary Shepparton Formation (TQs) is a thin fluvio-lacustrine deposit comprising clay, silty clay and sand with lenses of coarse sand and gravel, and minor aeolian reworked material. The Shepparton Formation is the water table aquifer to the north, east and south-east of the mining area.

The Loxton-Parilla Sands (Tps) is primarily a shallow-marine, beach to estuarine deposit, with overlying fluvial and fluvio-lacustrine layers. It grades vertically upwards and laterally landward (east) into the fluvio-lacustrine Calivil Formation (Tpc). Both of these Pliocene aquifers are comprised primarily of fine to medium grained quartz sand, with coarser zones in the beach deposits of the Loxton-Parilla Sands, which also hosts wave concentrated beach strand lines of heavy minerals. Some fine grained silt, micaceous sand and clay layers are also present. The Atlas and Campaspe deposits are located in the Loxton-Parilla Sands which hosts the water table at the Atlas-Campaspe Mine site. High permeability 'surf-zones' are commonly found in the off-shore direction from the beach deposition of the mineral strands, and the ore-zone itself has a higher permeability than the average for the Loxton-Parilla Sands.

The Tertiary Renmark Group comprises three aquifers: The Upper, Middle and Lower Olney Formations.

The Upper Olney Formation (Ter3) is a medium to fine grained sand with interbedded silt and micaceous sands, and is commonly directly hydraulically connected to the overlying Loxton-Parilla or Calivil Aquifer.

The Middle Olney Formation (Ter2) is indicated to be fluvio-lacustrine in origin. It is more clay than sand with some productive aquifer zones.

The Lower Olney Formation (Ter1) is primarily sand with some silt and carbonaceous zones. The Warina Sands (Tew) is found in the deeper seaward troughs at the base of the Renmark Group composed of coarse grained sands to gravel.

To the south and west, the Upper Olney Formation grades into the silty sand and sandy clay of the Geera Clay Equivalents (Tmge). Similarly, the Middle Olney Formation grades into the silts and clay of the Geera Clay (Tmg).

The basement rock includes sandstones and metasediments, with the Pitarpunga granite intrusion occurring to the north of Balranald.

3.6 STRUCTURAL GEOLOGY

Figures 7 to 10 show cross-sections from the AGSO regional hydrogeological mapping, showing the geological profile and the influence of basement structure on the overlying basin sediments (AGSO and BMR, 1991-1994). The section locations are provided on Figure 4.

Two digit values (e.g. 6,2) are shown on the AGSO cross-sections to indicate the salinity and potential groundwater yield of the aquifers as described in Table 2.

Table 2
Salinity / Yield Matrix

Salinity (mg/L TDS)	Bore Yield (L/s)			
	<0.5	0.5-5	5-50	>50
<500	1,1	1,2	1,3	1,4
500-1,000	2,1	2,2	2,3	2,4
1,000-1,500	3,1	3,2	3,3	3,4
1,500-3,000	4,1	4,2	4,3	4,4
3,000-7,000	5,1	5,2	5,3	5,4
7,000-14,000	6,1	6,2	6,3	6,4
14,000-35,000	7,1	7,2	7,3	7,4
35,000-100,000	8,1	8,2	8,3	8,4
>100,000	9,1	9,2	9,3	9,4

Mg/L = milligrams per litre.
TDS = total dissolved solids.

The main structural feature of the area in which the Atlas-Campaspe Mine site lies is the Ivanhoe Block, which is defined by the south-west to north-east trending Iona and Neckarboo basement ridges (Figure 4). The Willandra Trough is a basement low between the ridges and continues to the north-east as the Willandra Creek Depression. To the north of the Ivanhoe Block is the Darnick High and to the east is the Balranald Trough. The uplifted basement ridges truncate the Lower Olney Formation and parts of the Middle Olney Formation Aquifers, redirecting westerly flow in the lower aquifers to the south.

The Pitarpunga granite intrusion is another bedrock high running to the south-east from the southern end of the Iona Ridge (Figure 4), partially cutting the Lower Olney Formation (Figures 7 and 11). The Tyrrell Trough to the east of the Tyrrell Fault connects the southern end of the Willandra Trough to the deep Renmark Group Aquifers to the south.

The Tyrrell Fault runs from Robinvale to the north and west, where it intersects the Neckarboo Ridge (Figure 4). To the south-west of the fault the geological profile has been uplifted, creating a significant discontinuity in the aquifers.

3.7 LICENSING

The Atlas-Campaspe Mine is located within the Western Murray Porous Rock Groundwater Source as defined in the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* under the NSW *Water Management Act, 2000*.

Relevant to the Project, the Western Murray Porous Rock Groundwater Source includes groundwater contained in all shallow unconsolidated geological layers (Shepparton Formation to Renmark Group Units).

The long-term annual extraction limit stipulated in the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* for the Western Murray Porous Rock Groundwater Source, in addition to basic landholder rights, is 530,486 million litres per annum (ML/annum). It was estimated at the time of commencement of the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* on 16 January 2012, that only approximately 21,780 unit shares had been authorised to take water from the Western Murray Porous Rock Groundwater Source.

Cristal Mining currently holds a combined total of 21,442 share components (units or million litres in the Western Murray Porous Rock Groundwater Source for the Ginkgo and Snapper Mines, authorised by the following water access licences (WALs):

- WAL 27918 (60AL582836) – 14,000 shares;
- WAL 27915 (60AL582832) – 7,402 shares; and
- WAL 27912 (60AL582834) – 40 shares.

As the groundwater is saline, there is no significant demand for water from this source in the region, and the aquifers are indicated to be under allocated. Approvals for trading of water allocation between the mine sites would be requested from the Office of Water.

3.8 MONITORING AND TEST PUMPING

The NOW maintains a number of multi-level monitoring bores in the region, which are typically read four times each year. One monitoring bore from the Victorian Water Resources Data Warehouse (DSE, 2012) was also available for use in the assessment (located on the boundary of the model extent) as it provides additional information for the lower aquifers.

Groundwater levels are generally stable, with evidence of a small decline in some shallow aquifer water levels during the drought up to 2010. Since 2010, rainfall has been above average, however, the current edition of the NOW database does not extend beyond early 2010, and thus assessment of the effects of the increased rainfall has not been undertaken. Groundwater hydrographs are presented in Attachment A.[17] The monitoring bores are grouped into aquifers and general locations. Trends in the water levels are discussed in Section 3.11.

Cristal Mining has installed one test pumping bore (AB1) and four monitoring bores (AM1-4) adjacent to the Atlas Mine area (Figure 4). The bore is screened in the coarse sand at the base of the high-energy surf-zone (related to the beach strand deposition mechanism) in the Loxton-Parilla Sands. Three monitoring bores (AM1-3) are 10 m, 20 m and 72 m from the test bore (AB1), while the fourth (AM4) was 4.5 km to the west (Figure 4). Geological logs for the bores are included in Attachment B.

The test bore location was moved approximately 70 m from the preferred bore site to avoid interference with proposed mining infrastructure and, as a result, produced a much lower yield than planned. The water level response to pumping indicated significant vertical flow restriction, due to the clay layers above the screened zone.

The clay layers are not present towards the strandline and the formation is thus a mixed confined/unconfined aquifer. The best curve fit was obtained using the unconfined method of Tartakovsky-Neuman which accounts for three dimensional (3D) unsaturated flow and partial penetration (Attachment B).[18] The analysis indicates a hydraulic conductivity (K) of about 31 metres per day (m/d) and a vertical anisotropy of about Kv/Kh = 0.0002. Due to the confining effect of the clay layer, the calculation of Specific Yield (Sy) and the Gardner Unsaturated Parameter (kD) were insensitive in the analysis. The Specific Storage (Ss) is estimated to be about 4e-7 m^{-1}.

Additional proposed monitoring bores AM5-9 (Section 10.2) are recommended to be progressively installed around the Atlas-Campaspe Mine site during the life of the Project. Monitoring should also be carried out at the privately owned Boree Plains bore (GW063606) and supplemented with available groundwater monitoring data from government monitoring bores GW036790, GW036674 and GW036875.

17. The hydrographs presented are adjusted for salinity as described in Section 3.11.

18. Analysis carried out using AqtesolvPro Version 5.40, <www.aqtesolv.com>

3.9 GROUNDWATER BORE CENSUS

A review of the NOW groundwater database indicated seven bores drilled in the local area. Three (GW036790, GW036674 and GW036875) are multi-level government installations, and are monitored on a quarterly basis. Site reconnaissance in May 2011 identified only one location out of the remaining four private bores (GW063606 [Boree Plains] to the north of the Campaspe deposit), with the others being destroyed or buried. Two large diameter shallow wells were found at Carrawatha near to GW036674, however, these do not appear to intersect the water table and the upper aquifers are not present due to the basement ridge. The Boree Plains bore (GW063606) had a broken pump in the bore at the time of the site visit and could not be investigated.

The lack of active bores in the region is understandable given the poor quality of the groundwater (Section 3.12).

3.10 GROUNDWATER DEPENDENT ECOSYSTEMS

There are currently no high priority groundwater dependent ecosystems identified in the Western Murray Porous Rock Groundwater Source defined in the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* under the *Water Management Act, 2000,* within which the Atlas-Campaspe Mine is located.

Notwithstanding, *NSW State Groundwater Dependent Ecosystems Policy* (DLWC, 2002) recognises the four Australian groundwater dependent ecosystem types (Hatton and Evans, 1998) that can be found in NSW, namely:

- terrestrial vegetation;
- baseflows in streams;
- aquifer and cave ecosystems; and
- wetlands.

The Flora Assessment (Appendix A of the EIS) concludes that there is no groundwater dependent terrestrial vegetation known to occur within the Atlas-Campaspe Mine site. There are no permanent surface water features at the proposed Atlas-Campaspe Mine (i.e. no groundwater window lakes fed by the deep underlying saline groundwater aquifer) and therefore no groundwater dependent baseflows in streams and wetlands. The potential groundwater impacts on aquifer ecosystems (i.e. stygofauna) are described in Section 4 in the Main Report of the EIS.

A review of the regional water level indicates that the groundwater table is at least 10 m below ground level in the Benanee basin, apart from the southern and south-western boundaries along the Murray River and Murrumbidgee River to the south-west. The water table was measured to be approximately 36 m below surface at the test bore (AB1) at the Atlas-Campaspe Mine. The groundwater table is estimated to be at least 20 m below surface at Lake Mungo to the west of the Atlas-Campaspe Mine. There is no evidence of any groundwater dependent ecosystems that would be affected by the Atlas-Campaspe Mine.

3.11 BASELINE GROUNDWATER LEVEL DATA

The most recent available data for the majority of government monitoring bores (from the PINNEENA Groundwater Database) was from early 2010, and thus this date was used as a baseline for this assessment. A water level contour map for the Tps/Tpc layer is shown as Figure 12.[19] Groundwater flow is generally from east to west, with gradients ranging from 1 vertical (V):8,000 horizontal (H) in the east to 1V:2,000H across the Iona Ridge, to 1V:16,000H in the west.

Hydrographs for all monitoring bores used in the assessment (calibration bores and boundary bores) subdivided into geological layers and general localities, are included in Attachment A. In general there is a small downwards trend in levels for most bores over the last 20 years. Some large jumps in level are believed to be due to changes in the collar measuring point position (e.g. GW036740 in Tp-SouthWest2). Monitoring bores near to Lake Benanee (GW087105, GW087111, GW087116) appear to be affected by pumping in 1992/93 (Tp-SouthWest1). Monitoring bores that showed anomalous rising or falling trends (possibly due to pipe failure) were not used in the modelling.

3.11.1 Salinity Correction

There are large variations in salinity across the region and between aquifers, and the effect of density difference can be significant in the calculation of hydraulic head gradients. Density variations can be modelled directly using flow and solute modelling, however, this adds an additional complexity and cost to the analysis. A common technique is to adjust measured water level heads to an equivalent freshwater or average salinity head by adjusting for the density of the fluid in the monitoring bores. The average salinity for the aquifers is summarised in Table 3.

19. The contoured values are salinity corrected (see Section 3.11.1).

Table 3
Average Aquifer Salinity

Layer	Name	Unit	Average Salinity (mg/L)
1	Shepparton Formation	TQs	16,000
2	Loxton-Parilla Sands/Calivil	Tps/Tpc	19,500
3–4	Upper Olney	Ter3	23,800
5–7	Middle Olney	Ter2	9,400
8–9	Lower Olney/Warina Sands	Ter1/Tew	7,100

Mg/L = milligrams per litre

Salinity in the Lower Olney and Warina Sands Aquifers shows a significant increase in salinity from east to west (Figures 7 to 10).

Salinity corrections are normally applied as a product of the height of the water column by the increase in density relative to freshwater. One problem with this approach is that different correction would result for standpipes of different depths in the same aquifer with the same salinity. Considering a pair of standpipes in an upper and lower aquifer, the correction for the lower aquifer standpipe relative to the upper aquifer standpipe should be the difference in density multiplied by the height of the lower standpipe water column above the layer contact.

The salinities for many locations can only be approximated from the indicated trends on the hydrogeological maps (AGSO and BMR, 1991-1994), and the position of layer contacts is variable and uncertain in many locations. Therefore, a simplified approach is recommended, that minimises the potential for errors while addressing the most significant salinity variation between and within the most significant aquifers (i.e. between the Lower Olney Aquifer and the upper water table aquifers [TQs and Tps/Tpc]).

For the groundwater model (Section 7), the height of water column used in the correction has been standardised for each layer as the average depth to the top of the layer (no correction was made for the shallowest layer [TQs]). Corrections were also made to the average salinity of the water table aquifers (18,500 mg/L), rather than to freshwater to reduce the correction (and potential errors) in the upper aquifers.

The salinity correction for the aquifers is as follows:

$$SWLa = SWL+(\rho-\rho_{ua})/(\rho_{ua})*(Hc)$$

where:

SWLa = adjusted standing water level (AHD);

SWL = measured standing water level (AHD);

ρ = density of measured water (function of salinity);

ρ_{ua} = average density of water in the unconfined aquifers, based on a salinity = 18,500 mg/L; and

Hc = average depth to top of layer.

The range of correction is from -3.92 m to +4.11 m. The maximum correction in the unconfined aquifer ranged from -0.03 m to +0.15 m. All of the hydrograph plots (Attachment A) show salinity adjusted values.

3.11.2 Temperature Correction

Measured water temperatures indicate a significant temperature gradient with depth with deep bore (300 m) temperatures being measured at 30 degrees Celsius (°C) at the Snapper Mine to the east of Pooncarie, compared to shallow bore water temperatures of about 15°C. However, measured water levels are typically taken in static monitoring bores, which would have equilibrated in temperature to the surrounding strata and would not fully reflect the higher temperature of the source aquifer.

A review of available monitoring bore records indicated very few locations where there has been any temperature measurements taken. Given the lack of temperature data, focus on the upper layers and significant permeability barrier between the upper and lower aquifers, it was considered unnecessary to include any model modification or correction for temperature.

3.11.3 Groundwater Trends versus Rainfall

The long-term RRMC was compared to water levels in the shallow monitoring bores (Tps/Tpc and TQs hydrographs – Attachment A) in the model area (Section 7). The monitoring bores are grouped in similar levels to minimise the graph range, so that small trends are more apparent. The earliest water level records for the modelled area are from 1981. The graphs show a mixed response with some monitoring bore levels responding to the decline in rainfall from about 1995, while others have shown minimal response.

The most responsive water levels to rainfall are from shallow bores along the southern borders of the model area, namely, Cumbung Swamp (36721-1) and Boundary Bend (36724-1 and 2). The shallow monitoring bores in the southern half of the model (near Lake Benanee 87116 and 87111), near Prungle Lakes (36646-1, 36648, 36649 and 36650) and further east at 36673, all show a moderate decline in water level from the early 1990s to 2009.

In contrast there was no response at 87105 along the south-west boundary of the model, which may indicate that the bore screen is blocked or is sited in a clayey zone below the upper aquifer.

In the northern half of the model, monitoring bore levels have been steady at Garnpung Lake (36671-1) and there has been minimal change in level to the north and east of Hatfield (36672-1, 36675-1, 36800-1, 36803-1).

3.12 BASELINE GROUNDWATER CHEMISTRY DATA

Groundwater salinity mapping of the region (Murray Darling Basin Authority, 2008) indicates generally saline conditions.

Water sampling from the test bore at the Atlas-Campaspe Mine site indicates a salinity of approximately 32,000 mg/L and is dominated by Sodium and Chloride (Table 4).

Table 4
Groundwater Quality – Atlas-Campaspe Mine Site Test Bore

Parameter	Reading
Salinity	31,728 mg/L
Iron Filtered	710 µg/L
Iron Total	1,300 µg/L
Calcium	240 mg/L
Magnesium	970 mg/L
Potassium	46 mg/L
Sodium	9,000 mg/L
Chloride	18,000 mg/L
Bicarbonate	68 mg/L
Carbonate	<5 mg/L
Sulphate	3,400 mg/L
Nitrate	0.008 mg/L

µg/L = micrograms per litre

This chemistry is typical of the region, and indicates that the groundwater has a low value for any use apart from industry.

Groundwater associated with localised concentrated infiltration (due to higher permeability surface soils and local topographic concentration) is expected to form freshwater lenses of water at the groundwater table surface, due to the density contrast. No specific evidence of such freshwater lenses have been identified in the Atlas-Campaspe Mine area, but have been found at other locations.

4 PROJECT GROUNDWATER INTERACTION

4.1 GENERAL

Water is required for creating a slurry of the dry feed sand placed into the DMU. This slurry is pumped to the wet plant concentrator, where the heavy mineral concentrate (HMC) is separated over gravity spirals. The HMC is pumped to a hydro-cyclone stacker which dewaters the sand, with the overflow water being recirculated back into the system. Sand residues are pumped as a slurry to either hydro-cyclone stackers (to dewater the sand) or open piped discharge. Sand residues would initially be placed off-path in a purpose built facility (off-path sand residue dam), until they can be placed behind the mining operation in the mined-out void. Excess water from the sand residues would be decanted from the off-path sand residue dams and in-pit cells and recycled back through the system.

The amount of water lost to re-infiltration back to the aquifer from the in-pit cells would be dependent on the management of the process wastes (including sand residues), which can aim to maximise water recovery (to limit water requirements); or to minimise water recovery (to reduce the amount of re-circulating slimes in the water, which can reduce mineral recovery, and to dispose of excess water).

A conceptual mine/groundwater interaction cross-section of the pre-mine and during mining conditions is shown in Figures 13a and 13b.

4.2 MINING RATE AND PARAMETER ASSUMPTIONS

The two deposits at the Atlas-Campaspe Mine would be mined in sequence, with mining at the Atlas strand indicated to be for approximately 3 years at 500 tonnes per hour (tph), followed by mining at the wider Campaspe strand at 1,000 tph for approximately 14 years.

The feed slurry is planned to be at approximately 45% solids, requiring between 170 L/s and 340 L/s of added water for the indicated throughput rates. Sand residue pumping is likely to be at about 50% solids, while the underflow from hydro-cyclone stackers is expected to be about 70% solids.

The off-path sand residue dams would be lined with clayey materials, or constructed in-ground in clayey surficial materials, and it is not expected to have any significant infiltration to the ground. The in-pit cell walls would be primarily constructed from clayey overburden, which would limit the amount of potential infiltration. Sand overburden can be used to line the cell walls to increase the amount of infiltration by creating drainage path to the base of the pit.

Losses to process wastes (including sand residues) would include loss to pore space (porosity of 30%), infiltration and evaporation.

4.3 WATER BALANCE

The water demand for the Project (i.e. new water requirement) considers the following inputs and outputs to the water management system:

- water required for the DMUs (for slurry);
- water retained in the process wastes (i.e. sand residues including clays);
- water seepage (to groundwater table);
- water consumed in the HMC treatment facility including RO plant feed and moisture transported off-site in mineral concentrate;
- dust suppression and road maintenance works; and
- water gained from the direct rainfall and lost to evaporation.

Water pumped from the groundwater aquifer and re-infiltrated to the aquifer through the sand residues are the major factors in the site water balance.

Water losses would occur in the sand residues as storage in the pore spaces with some infiltration to the underlying aquifer. Pore space losses would be about 35 L/s (during mining of the Atlas deposit) and 70 L/s (during mining of the Campaspe deposit). Small-scale modelling of a series of generic in-pit cells indicated that infiltration from sand residues into the aquifer would typically vary from approximately 5 L/s to 75 L/s (during mining of the Atlas deposit) and 10 L/s to 100 L/s (during mining of the Campaspe deposit). The large variations are dependent on how the tailings are placed, and the mining staff would be able to use this to their advantage to accommodate higher or lower requirements for infiltration/water recovery. Therefore it is not expected that any off-path water disposal will be required.

After sand residue losses, evaporation from ponded areas would be the largest water loss and would depend on the surface area of wet sand residue areas and storage ponds. This loss is estimated to range from 5 L/s at Atlas to about 10 L/s at Campaspe.

There would also be some water lost with the stockpiled HMC and water used for dust suppression, which is estimated, based on experience at the Ginkgo and Snapper Mines, to be in the range of 5 to 10 L/s.

Minor quantities of potable water would also be produced by the RO plant for site use.

Besides sand residue losses and dust suppression, the total average water loss to other requirements (primarily evaporation) is estimated to be 5 L/s (during mining of the Atlas deposit) and 10 L/s (during mining of the Campaspe deposit).

The water balance will be primarily controlled by the management of the sand residue, and the operation staff will have the ability to adjust the water loss rate by changing the sand placement methods (by adding sand drains, or placing slimes layers) and by adjusting the sand residue pumping density. These methods would potentially allow for a wide range of water disposal/recovery rates to manage the water balance.

The average new water requirements has been advised by Cristal Mining to be up to about 115 L/s during mining of the Atlas deposit and 180 L/s during mining of the Campaspe deposit, targeting a near maximum infiltration rate, with minimal water recovery in the sand residue disposal cells, to reduce the amount of fine material being recycled through the water supply system. This new water would come from bores and from any in-pit dewatering. These numbers are conservative, with respect to the new water requirements, and may decrease with increased water recovery from the sand disposal system.

There are no surface watercourses across the Atlas-Campaspe Mine site and the surface is relatively flat. Depression in the topography would collect local surface run-off after heavy rainfall, which would eventually evaporate or infiltrate to the ground.

4.4 WATER SUPPLY

The primary source of water would be supplied from water bores pumping out of the Loxton-Parilla Sands Aquifer (which also contains the orebody). The test bore was located at the north-western end of the Atlas deposit due to the presence of a thick, coarse sand zone related to the strand beach deposition, with adequate depth below water table to allow for bore drawdown. This locality is also reasonably central to both the mine paths. Additional bores are planned to be located adjacent to the deeper sections of the mine path near to the test bore at the Atlas deposit and adjacent to the deeper sections of the Campaspe mine path to assist with pit dewatering as well as providing for mine requirements.

Based on the test bore results and water balance calculations, adequate water supply is expected to be achieved from the proposed locations. The placement and utilisation of the bores would be aimed to minimise cost in both construction, pumping and dewatering requirements.

A suitable arrangement of bores has been implemented in the model, with bores adjacent to sections of the mine paths that require dewatering. Variations to this arrangement are not expected to significantly affect the modelling results, as the overall water supply requirement would not change.

4.5 DEWATERING

The mine path is planned to drop below the natural water table level over 2.9 km at the Atlas deposit and 7.4 km at the Campaspe deposit. The maximum mining depth below the groundwater table is approximately 7 m for the deepest section of the Campaspe deposit, and up to approximately 15 m at the Atlas deposit.

Dewatering would require the installation of bores, spear points and in-pit sumps. As discussed above, water supply bores would be located to pre-dewater the deeper sections of the mine paths. A number of iterations have been carried out to approximately match the total bore pumping and in-pit dewatering to the mining water supply requirement.

During mining of the Atlas deposit there is anticipated to be some excess water from the dewatering, which would need to be disposed of through additional in-pit cells (or water disposal cells) within the mine-path. This is expected to be achievable with the area available. The total dewatering at Campaspe deposit is not expected to exceed mine water supply requirements.

4.6 OFF-PATH SAND RESIDUE DAM AREAS

Initial mining would require placement of sand residues into off-path storage dams, which would be clay-lined to contain the input water. Water would be decanted from the surface of the dams and pumped backed to the mine. The surface area of the storage dams would be the main area of evaporation during initial mining. A maximum hydraulic conductivity of 1e-7m/s for the clay lining should be achievable based on permeability test results of 1e-10m/s of compacted clay samples from the site.

4.7 PROJECT WATER STORAGE

In addition to the off-path sand residue dams, there is expected to be water storage dams created around the mine path to manage and buffer water supply. These would be constructed with compacted clayey overburden and/or cut into the natural clayey surface to minimise water loss to infiltration.

4.8 FINAL VOID

At the cessation of mining, a final void would remain at the north-western end of both the Atlas and Campaspe footprints. The final voids would be partially backfilled with overburden material pushed down from the void batters and replaced overburden.

Figure 14 shows cross-section of the two final void pits, prior to contouring of the sides to reduce the slopes. The minimum depth to water table from the floor of the final void at Atlas and Campaspe would be 5.3 m and 11.8 m, respectively. Capillary rise in sand is typically less than 1 m [Venkatramaiah 2006]. Thus these significant depths would prevent any direct evaporation from the aquifer. Incident rainfall and local surface water runoff following rainfall events would temporarily pond in the void prior to evaporating or infiltrating into the groundwater table. The rate of infiltration will be higher than normal, but over the scale of the aquifer, this will be insignificant.

5 ILUKA MINING OPERATIONS

Iluka Resources Limited (Iluka) is also currently proposing mineral sand dry-mining operations in the region (the Balranald Mineral Sands Project) at their West Balranald and Nepean deposits (Figure 1).[20] At the time of preparing this assessment, apart from the proposed mining advance rate and location of the deposits, there was limited information available regarding the potential groundwater impact of the Balranald Mineral Sands Project. It is indicated that both deposits would require significant dewatering to reach the ore-zone using lines of bores either side of the mine paths. This water would be used in the processing and sand residue placement, with any excess water re-infiltrated into the sand residue areas and/or re-injected into previously used dewatering bores, or alternative off-path injection bore locations.

The significant, but uncertain, amount of dewatering required has been considered in this assessment by a series of dewatering and re-injection bores in the groundwater model and is detailed further in Section 7.6.2.

20. EMGA Mitchel Mclennan (2012) *Balranald Mineral Sands Project, Project Scoping Report*, April 2012.

6 MODEL CONCEPTUALISATION

The conceptual understanding of the regional groundwater regime is based on the review of existing hydrogeological data and previous modelling, and the assessments described in Section 1.1, including:

- Murray Basin Hydrogeological Map Series (AGSO and BMR, 1991-1994).
- Lachlan Fan/Ivanhoe Block Steady State Groundwater Model (Kellet, 1997).
- Lower Lachlan Groundwater Model (Mampitiya, 2010).
- NOW PINNEENA Groundwater Database (NOW, 2012a).
- Victorian Water Resources Data Warehouse (DSE, 2012).
- Cristal Mining Exploration Drilling Database.
- Existing water management records (including groundwater licensing) from the Ginkgo and Snapper Mines.
- Previous hydrogeological assessments and water level and quality data from monitoring programmes at the Ginkgo and Snapper Mines (Golder Associates, 2001; 2007).
- Other hydrogeological investigation testwork undertaken by Cristal Mining (e.g. bore installation and pumping tests at the Atlas deposit and shallow geological logs).
- Other regional topographic mapping data.

The requirements of the *Water Sharing Plan for the NSW Murray Darling Porous Rock Groundwater Sources 2011* under the *Water Management Act, 2000* has also been considered (e.g. groundwater management areas).

The prior model of the regional groundwater created by Kellet (1997) for the AGSO has been used as the basis for the conceptual model. Figure 15 (Figure 38 from the AGSO model) shows groundwater flow from east to west at a low gradient in the upper Tps/Tpc Aquifer. Figure 16 also shows the discontinuous nature of flow from east to west in the Lower Olney Formation Aquifer (Figure 41 from the AGSO model).

The review of available baseline hydrogeological data indicates localised temporal surface ponding due to limited drainage, and underlying saline groundwater aquifers at moderate to significant depths.

Temporary ponding of rainfall occurs in localised topographic depressions where rainfall runoff is concentrated and the surficial soils have low permeability. These locations are isolated and do not contribute to any significant surface water system. Drainage from these locations is limited due to the low-permeability surface soils and the majority of the water eventually dissipates by evaporation. Given the limited rainfall experienced in the area historically, the frequency of surface ponding is low.

The groundwater table is associated with the underlying saline groundwater systems (ranging from approximately 10 m to 30 m below ground level) and generally sits within the shallow Shepparton Formation or underlying Loxton-Parilla Sands. The Loxton-Parilla Sands overlies the Renmark Group which is subdivided into the Upper, Middle and Lower Olney Formations and Warina Sands. At the Atlas-Campaspe Mine site there is no significant aquifer zone in the Renmark Group, due to the elevated height of basement rock and prevalence of low permeability materials. However to the west (Willandra and Wentworth Troughs) and east (Balranald Trough) significant aquifer zones have been encountered in the Renmark Group, especially in the deepest layers of the Lower Olney Formation and Warina Sands.

There are no permanent surface water features at the proposed Atlas-Campaspe Mine (i.e. no groundwater window lakes fed by the deep underlying saline groundwater aquifer).

Despite the multiple aquifer systems in the region, the Western Murray Porous Rock Groundwater Source defined in the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* includes groundwater contained in all shallow unconsolidated geological layers (Shepparton Formation to Renmark Group Units) of the basin apart from the shallow alluvial deposits around the major rivers.

All groundwater extracted for the Project is therefore considered part of the Western Murray Porous Rock Groundwater Source (i.e. one groundwater source).

7 GROUNDWATER MODEL

7.1 MODEL SOFTWARE AND COMPLEXITY

Numerical modelling has been undertaken using FEFLOW (Version 6.0), which is a 3D Finite Element Groundwater Modelling software package.[21,22] FEFLOW allows for detailed discretization around the mine areas and other locations of significant groundwater gradient change, and allows drying out and rewetting of zones within the model.

Groundwater modelling has been conducted in accordance with the MDBC *Groundwater Flow Modelling Guideline* (Aquaterra, 2001). Under the modelling guideline, the model is best categorised as an impact assessment model of medium complexity. The guide describes this model type as *"… a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies..."*

Modelling guidelines have been recently published by the National Water Commission (Sinclair Knight Merz and National Centre for Groundwater Research and Training, 2012). Based on table 2-1 (Model confidence level classification) of the guidelines, the purpose of the modelling fits into Class 1, as the model is required to provide predictions of *"long-term impacts of proposed developments in low-value aquifers"* and provide *"first pass estimates of extraction volumes and rates required for mine dewatering"*. The available data also indicates a Class 1 to Class 2 model as there is limited water level data (particularly in the mining area) and there is no significant groundwater extraction data for assessment. As discussed below useful calibration of the model is limited to steady-state conditions, which also indicates a Class 1 model.

The development of the model, as discussed below, is considered to be suitable to the requirements of the Project and environmental assessment, and would be considered to fit between Class 1 and Class 2. The confidence in model prediction is moderate, while the consequence of likely variance in those predictions is considered to be very low, given the low value of the aquifer and the significant distance to any receiving environment or groundwater use.

7.2 PRIOR MODELLING

As stated in Section 6, the prior model of the regional groundwater created by Kellet (1997) for the AGSO has been used as the basis for the conceptual model, and in development of the groundwater model for the Project.

21. Diersch, H.-J.G. (2005) *FEFLOW: Finite Element Subsurface Flow & Transport Simulation System*. DHI-WASY GmbH, Berlin.

22. FEFLOW is a highly recognized groundwater modelling software package, and is in use by a large number of hydrogeological consultants and government agencies in Australia and around the world. All parts of the FEFLOW simulation engine have passed an extensive benchmarking process where results are compared to those of other well-known simulation systems, to analytical solutions or to observations from lab experiments.

The Lachlan Fan/Ivanhoe Block area was previously modelled by the AGSO in the 1980s and 1990s (Kellet, 1997). These previous models used coarse grids (10 km x 10 km and 7.5 km x 7.5 km) and had limited accuracy, with discrepancies of up to 9 m in monitoring bores in the Western Riverine Plain (GW036721-1, eastern boundary of current model) and up to 5.8 m in the Ivanhoe Block area (GW036866).

A more recent detailed model of the Lower Lachlan Fan area was completed by the NOW (Mampitiya, 2010). The western boundary of this model was extended in subsequent modelling and has some overlap with the Project model area. Data from this recent model was used, however, there are significant difference between the models, as the Lower Lachlan Fan model simulated the Renmark Group Aquifers as a single layer and did not account for the significant vertical gradients and salinity contrasts, which occur further west in the Project area.

There is no existing available groundwater modelling for the Iluka Balranald Mineral Sands Project.

7.3 MODEL EXTENT

The extent of the Project groundwater model is shown on Figure 4. The eastern model boundary cuts through the Western Riverine Plain between monitoring bores that have good historical records and then turns south-west to the southern end of the Lachlan River at the Great Cumbung Swamp. The boundary then approximately follows the path of the Murrumbidgee River to the Murray River and along the Murray River to Robinvale. At Robinvale the model boundary trends north to north-west following the path of the Tyrrell Fault to the Neckarboo Ridge, which forms the western boundary of the model extending to the north to the town of Darnick. The northern model boundary is approximately a no-flow boundary parallel to the groundwater flow direction, between two long-term monitoring bore locations.

7.4 MODEL LAYERS

Model layers are summarised in Table 5.

Table 5
Model Layers and Estimated Hydrogeological Parameter Ranges

Layer	Name	Unit	Kh (m/d)	Sy (%)	Ss (m^{-1})
1	Shepparton	TQs	1–10	5–25	10^{-7}–10^{-5}
2	Loxton-Parilla	Tps	1–40*	10–25	10^{-7}–10^{-5}
2	Calivil	Tpc	1–10	10–20	10^{-7}–10^{-5}
3–4	Upper Olney	Ter3	0.1–5	5–15	10^{-7}–10^{-5}
3–4	Geera Clay Equivalents	Tmge	0.1–5	2–15	10^{-6}–10^{-4}
5–7	Middle Olney	Ter2	0.001–5	5–15	10^{-7}–10^{-5}
5–7	Geera Clay	Tmg	1E-6–1E-4	0.01–2	10^{-6}–10^{-4}
8	Lower Olney	Ter1	0.001–20	5–15	10^{-7}–10^{-5}
9	Warina Sands	Tew	0.001–40	5–20	10^{-7}–10^{-5}
10	Basement		1E-6–1E-3	0.01–2	10^{-9}–10^{-7}

* Locally, hydraulic conductivities up to 60 m/d are possible for the coarse sand and gravels of beach surf-zones associated with the mineral strand lines.

The estimated hydraulic conductivities presented in Table 5 are based on Kellet (1997), Mampitiya (2010) and GEO-ENG.[23] High hydraulic conductivities were calibrated by Kellet (1997) for the Loxton-Parilla Sands along the Murray River, which may be an over-estimate. Vertical anisotropy is expected to range from 1/100 to 1/10,000, due to the highly stratified layering of the sediments. Storage coefficients are based on the test bore pumping at Atlas-Campaspe Mine (Section 3.8) as well as standard estimates of porosities and compressibilities.[24]

The Upper Olney Formation (Ter3) and Geera Clay Equivalents (Tmge) were split into two layers (Layers 3-4) and the Middle Olney Formation (Ter2) and Geera Clay (Tmg) were subdivided into three layers (Layers 5-7), to improve the performance of the model with respect to vertical gradients. The lowest Renmark Group Aquifer was split into two layers to differentiate the Lower Olney Formation and the Warina Sands.

As layers are required to be continuous across the model, the intersected layers of the Renmark Group at the basement ridges are simulated by a minimal thickness of 0.1 m (Figure 11). The density of the model grid is increased at these locations of significant elevation change (Figure 17). The low vertical hydraulic conductivity of the basement layer restricts flow.

23. GEO-ENG (2010) *Bemax Resources Limited, Section 75W Modification, Snapper & Ginkgo Mines - Hydrogeological Assessment, Pooncarie, NSW*, March 2010.

24. Freeze, R.A. and Cherry, J.A. (1979) *Groundwater*, Prentice-Hall, Inc. Englewood Cliffs, NJ.

7.5 MODEL GEOMETRY

The model has a maximum east-west distance of 178 km and is 216 km north to south, with a total area of about 20,000 square kilometres. The maximum depth of the model is about 560 m. It contains approximately 220,000 elements, with about 11,200 nodes per slice (Figure 17). The element spacing along the mine path to represent the mining blocks is 100 m x 100 m. Mesh gridding is closer spaced around the model boundaries, the pumping bores and at significant elevation changes (Iona Ridge), with a wider grid (up to 8 km) over low-gradient areas, such as the Western Riverine Plain.

Layer surface data was obtained from available records (both digital and scanned drawings) from the available hydrogeological maps (AGSO and BMR, 1991-1994) and from the existing groundwater models (Kellet, 1997). The basement rock layer was simulated to be 50 m thick.

7.6 MODEL STRESSES AND BOUNDARY CONDITIONS

The model covers a large portion of the Benanee basin in NSW. As the model boundaries are a long way from the mining activity and the regional gradients are very flat, constant head boundaries can be used for the majority of the boundaries using measured monitoring bore levels along the boundaries, including measurement for the deeper aquifers.

General Head/Cauchy-type boundaries could be used, but are more difficult to apply and would effectively achieve the same result. As the rivers only interact with the shallowest aquifer, and are a long way from the mining, there is no significant advantage to using river levels for the boundary over measured monitoring bore levels.

Boundary heads were set for the primary aquifers only (Tps/Tpc and Ter1/Tew) to avoid recirculation of flow on the boundary. The heads in other layers are simulated in the model as a result of the assigned heads and vertical hydraulic conductivities. For Tps/Tpc constant head values were applied around the entire boundary except the northern segment between monitoring bore GW036913 and GW036805, effectively making this a no-flow boundary for this layer.

Boundary heads for Ter1/Tew were only assigned where these layers exist along the eastern and southern boundaries. To the west groundwater flow must travel vertically upwards to exit the model through the Tps/Tpc layer, over the Neckarboo Ridge.

Based on studies of chlorine input from rainfall, Kellet (1997) indicates that recharge varies from about 0.1 to 1% of rainfall, with the lowest infiltration over the western mallee of about 0.1 mm/year. Kellet (1997) estimated recharge across the Riverine Plain and Willandra Lakes depression to be up to 1.8 mm/year, with recharge of up to 3 mm/year along the Murray River boundary area (Kellet, 1997).

Mampitiya (2010) used a recharge rate of 1% of rainfall, which is equivalent to about 3 mm/year over the western part of the current groundwater model area, which overlaps with the Lower Lachlan Groundwater Model. Mampitiya (2010) noted that:

> *"Potential evaporation exceeds annual rainfall by a ratio of nearly 5:1 in the model area. Therefore, much of the rain received in the area is likely to evaporate before significant surface ponding, infiltration and runoff. Clay rich topsoil has a very low permeability resulting in low deep drainage from rainfall. The water table in most parts of the study area is about 25 m below ground level. All of these factors indicate that the model area is generally experiencing dry conditions and relatively low rates of rainfall recharge. Monitoring bore hydrographs do not indicate any noticeable response to rainfall, not even for sporadic high intensity events."*

Evapotranspiration boundary conditions were not required in the model, due to the significant depth of water table (apart from the southern boundary of the model which has a fixed head control).

7.6.1 Atlas-Campaspe Mineral Sands Project

Groundwater pumping from the proposed water supply bores is modelled using a series of bores (Well cells) across the thickness of the Tps/Tpc layer. The pumping rate is set to match the mine water requirements discussed in Section 4.3.

The proposed method of deposition of process wastes (including sand residues) is to construct walls from overburden across the mine path, forming discrete cells for deposition of slurry, with decanting and pumping of clean water from the surface of the created pond.

The cells and overburden walls have been modelled as alternating sections along the mine path. The amount of infiltration through the base of the cells would be dependent upon the method of sand residue placement, and whether drainage layers of sand are constructed to increase infiltration.

To simulate the variable drainage conditions Cauchy-type boundary surfaces with a rising water level have been implemented in the model to be turned on and off as the mine advances. The effect of different drainage conditions is simulated by adjustment of the transfer function rates at the base of the sand residues.

Dewatering within the ore extraction areas was simulated with the same Cauchy-type boundaries during the period of mining at the design pit floor level. The inflow parameter was set at a high value to simulate minimal inflow resistance.

7.6.2 Balranald Mineral Sands Project (Iluka)

The groundwater impact of the Balranald Mineral Sands Project has been simulated in the groundwater model by Well cells at 100 m spacing either side of the indicated mine path. Based on the projected mining advance rate the bores were turned on approximately 550 m ahead of the mining face and were left on until they were 150 m behind the mine face. At any time there are eight bores pumping on each side of the mine path (16 total), and each bore pumps for approximately 70 days. The pumping was set to a high enough rate (40 L/s) to dewater down to a few meters above the likely base of the ore-zone, with a restriction to not pump below the indicated base of the Loxton-Parilla Sands. The actual flow rate is likely to be lower, and may require additional bores or longer pumping periods. However, the end result would be similar, to achieve adequate dewatering in the ore extraction areas.

After a break of 70 days (800 m of mine advance) the bores are simulated to re-inject water into the aquifer for a further 70 days. Re-injection was similarly set to a high flow rate (40 L/s), with a restriction to a maximum water table level of approximately 5 m below the ground surface level. Again the actual infiltration would likely be at a lower rate over more bores and the sand residue area, and for a longer period, but would have a similar net effect.

There is likely to be in-pit dewatering at both of the Iluka deposits (West Balranald and Nepean), however, the effect of this water removal from the aquifer would not be significant outside the line of dewatering bores, and thus would not affect the modelled position of the advancing groundwater drawdown cone ahead of the mining face.

The re-injection simulated in the model is approximately 80% of the modelled bore pumping. A small portion of this difference would be lost to ore, evaporation and other uses, with the remainder infiltrated with the sand residues. As the sand residues infiltration has not been modelled, the analysis is conservative with respect to the likely drawdown from the Iluka operations, showing a worst case drawdown effect.

The West Balranald deposit is close to the southern boundary of the operation. A sensitivity analysis was carried out to assess the effect of changing the fixed head conditions to a no-flow condition along this boundary. The result showed minimal difference to the overall groundwater drawdown, and no effect with respect to any interaction between the Cristal Mining and Iluka operations. Therefore it was decided that this boundary is adequate for the required model purpose.

7.7 CALIBRATION

7.7.1 Calibration Options

The model was developed and calibrated under steady-state conditions against early 2010 water level data. Transient calibration against rainfall data was considered, but was assessed to not provide any meaningful information for the reasons discussed below:

- The average depth to water for the shallow monitoring bores at the Atlas-Campaspe Mine and immediate surrounds is approximately 20 m, with the shallowest recorded result of 11.2 m. A review of the hydrographs for the shallowest bores do not show any significant short-term variation that could be correlated with specific rainfall events, and the change in levels are very small and difficult to separate from variability in reading accuracy.
- The AGSO model (Kellet, 1997) was only calibrated in steady-state, while the Lower Lachlan Model (Mampitiya, 2010) was calibrated under steady-state and transient conditions. However, the transient calibration for the Lower Lachlan Model only considered flood recharge, river leakage and groundwater extraction (drawdowns of up to 8 m), none of which are significant in the Project area, while fixing the rainfall recharge at 1% of rainfall. During subsequent sensitivity analyses, only the main eastern zone of the Lower Lachlan Model was found to be sensitive to recharge rate variation, while the western part of the model (which overlaps with the Atlas-Campaspe model) was found to be insensitive to recharge rate.
- The calibration of recharge to rainfall is unlikely to be accurate, as it is likely to be a non-linear step-function (i.e. recharge is likely to be zero below a certain rainfall rate) rather than a simple percentage of rainfall.

Based on these issues it was assessed that there was no value in carrying out transient calibration for the entire model. Local transient calibration has been carried out for the pumping test, and longer-term pumping information can be used after several years of mining to better assess local storage parameters.

The model was found to be particularly sensitive to the rate of water flow across the bedrock ridges, as they represent a significant permeability barrier. The elevations of the model layers across the Iona Ridge were adjusted during development based on additional exploration drilling information to achieve a better fit to the observed monitoring bore levels.

The elevation and geometry of the Pitarpunga ridge was also varied to assess the sensitivity to the bedrock level. It was found that some improvement could be made to match the water levels at GW036673, but resulted in a poorer fit elsewhere. Without additional drilling information, further improvement in the understanding of this portion of the model area is unlikely.

Transient conditions were subsequently applied for implementing mining effects and assessment of impacts. As transient parameters have not been calibrated, apart from the single local-scale pumping test, it is necessary to carry out sensitivity analyses for hydrogeological parameters to assess the likely potential range of mine impacts.

7.7.2 Calibration Method

Manual calibration was carried out focussing on geological control due to basement level variation, material transitions within layers and high anisotropy (Kh/Kv). Lateral change in layer thickness and the uplifted basement ridges were found to exert a significant control on the groundwater flow.

Significant vertical gradients were noted at nested piezometer locations, including multiple screened zones within the same geological unit (e.g. GW036866-4 and GW036866-5, east of Pitarpunga Granite High), indicating low permeability sub-layers within the aquifers. Thus the positioning of the screen level in the model at a slice boundary is a potential source of error in the analysis. Subdividing aquifers into multiple layers, as detailed above, was used to improve the model calibration.

Automated calibration of hydraulic conductivity was subsequently carried out using the latest version of PEST.[25] Eighty pilot points were used for each layer to vary the horizontal and vertical hydraulic conductivity in each layer and the surface recharge. Regularisation (Tikhonov) and Truncated Single Value Decomposition were used. The distribution of parameters was carried out using radial basis functions, with constraints to the ranges given in Table 5. Pilot point locations are shown in Figure 18.

7.7.3 Calibration Model Properties

7.7.3.1 Rainfall

The pattern of rainfall infiltration has been based on the distribution recommended by Kellet (1997) as a function of rainfall and vegetation. As discussed in Section 7.7.1, the recharge is expected to be a non-linear function of rainfall, with minimal infiltration during drought periods. During manual calibration the recharge rates were lowered in decrements, with the best fit obtained at about 5% of the average infiltration in the AGSO model (approximately 0.05% of average rainfall).

This is considered to be reasonable due to the drought conditions prior to the steady-state calibration date of January 2010. PEST calibration varied the recharge rate further to improve the model match to water levels in the shallow monitoring bores. The calibrated distribution of infiltration is shown in Figure 18.

25. Watermark Numerical Computing, 2010, PEST 5th Edition, and addendum 2012.

7.7.3.2 *Hydraulic Conductivity*

During manual calibration, the topmost and bottom layers (TQs and Basement) were initially given a single K value.

Layer 2 (Tps/Tpc) was initially given the K value of digitized contour lines from the AGSO model (Kellet, 1997) as well as higher K values along the mine strands. These contour line values were adjusted uniformly and individually in increments, while values were interpolated between the lines.

Layers 3 and 4 were originally subdivided into two sections (south-west and north-east) along the indicated boundary between Tmge and Ter3 (AGSO and BMR, 1991-1994), with an intermediate zone between. However, the mapping does not indicate any significant difference in the hydraulic conductivities of the two units, and manual calibration runs did not indicate any significant sensitivity to dividing the layers into separate zones, therefore the hydraulic conductivities for each layer were set to a single value.

Layers 5 to 7 have a significant transition between Tmg and Ter2 as indicated in the hydrogeological sections (Figures 7 to 10) (AGSO and BMR, 1991-1994). The landward extent of Tmg is indicated to be bounded by a line from Pooncarie to Balranald. For the manual calibration major south-west and north-east zones were used with a transition between. The transition zones moves south-west with depth across the modelled layers.

Information on the geological mapping sheets (AGSO and BMR, 1991-1994) indicate that there is a decrease in the K value in the Lower Renmark Aquifer from north-east to south-west across the Pitarpunga Ridge. This appears to be confirmed by the high hydraulic head in GW036673-3, south of the ridge position. Therefore Layers 8 and 9 was initially split into two zones across this basement ridge. The difference in the modelled to observed result at GW036673-3 was one of the largest errors noted during calibration, and may indicate that the Pitarpunga Ridge extends further to the south-west than currently mapped and modelled.

Subsequent calibration using pilot points and radial basis functions in PEST varied local K values about these values to better fit the measured observed monitoring bore water levels. The distributions of horizontal hydraulic head after the PEST calibration are shown for each layer in Attachment C. Representative sectional plots are shown in Figure 11. Section line locations are shown on Figure 17.

The best fit calibrated hydraulic conductivities from the steady-state calibration are shown in Table 6.

Table 6
Calibrated Hydraulic Conductivities

Layer	Name	Unit	Kh (m/d)	Kv (m/d)
1	Shepparton	TQs	0.045–5	0.035–0.065
2	Loxton-Parilla Sands/ Calivil	Tps/Tpc	0.1–60	0.021–0.6
3–4	Upper Olney/ Geera Clay Equivalents	Ter3/Tmge	0.011–1.4	$1.2E^{-6}$–$2.1E^{-4}$
5–7	Middle Olney/ Geera Clay	Ter2/Tmg	$2.1E^{-5}$–1.0	$1.0E^{-8}$–0.0013
8	Lower Olney	Ter1	$1.0E^{-3}$–5.0	$1.0E^{-5}$–0.073
9	Warina Sands	Tew	$1.0E^{-3}$–30	$1.4E^{-3}$–0.065
10	Basement		$5.9E^{-5}$–$1.5E^{-4}$	$1.0E^{-7}$–$1.6E^{-7}$

Note: The range of horizontal conductivities across each layer is shown on figures in Attachment C.

7.7.3.3 Storage Coefficients

As the model has been limited to a steady-state calibration, no calibration of storage coefficients has been carried out apart from the analysis of the test bore pumping at the Atlas-Campaspe Mine. For predictive purposes the range of storage coefficients given in Table 5 have been used.

7.7.4 Calibration Performance

The steady-state model has been calibrated based on water levels in 48 (non-boundary) monitoring bores, with the majority (30) being in the shallow aquifers. All water level data were equally weighted. Variation of weighting could be done to discount monitoring bores that are close together at Prungle Lake, and locations that have uncertain information regarding salinity and screen position; however, it is not expected that the end results would be significantly different. Calibration statistics are provided in Table 7.

Table 7
Calibration Performance

Calibration Statistics	All Layers	Layers 1 and 2
Number of Data (n)	48	30
Root Mean Square (RMS) (m)	0.63	0.22
Scaled Root Mean Square (SRMS) (%)	3.54	1.43
Average Residual (m)	0.00	0.07
Absolute Average Residual (m)	0.29	0.16

The SRMS of 3.5% is below the target of 5% suggested in the MDBC *Groundwater Flow Modelling Guideline* (Aquaterra, 2001). The largest variance between measured and modelled groundwater level was 3.4 m at GW036790-3 in Ter2, possibly due to local isolation of the screened zone in the low permeability layer. The next largest variance was 2.2 m at GW036646-3, which may be due to an unknown geological structure related to the Pitarpunga Granite High.

For the upper water table aquifers (Layers 1 and 2), the SRMS was calculated to be 1.4%. Variances within these aquifers were all reduced to less than 0.64 m, with the average absolute residual being 0.16 m.

A scattergram plot of modelled versus measured water levels is included in Attachment C.

The accuracy of the calibration is assessed to be very good when considering the potential errors due to survey and screened-zone uncertainties, salinity corrections and the effect of vertical gradients across aquifers and sub-layers.[26] When further geological and water level data is recorded during the life of the Project, additional calibration effort should be undertaken.

The variance for each monitoring bore reading is shown on the layer information plans in Attachment C.

7.7.5 Water Balance

For the steady-state calibration the water balance is restricted to the boundary fluxes and rainfall. Boundary inflow was calculated to be 191 L/s, boundary outflow was 286 L/s and rainfall recharge was 95 L/s. The balance error was calculated to be 0.0005%.

The average rainfall infiltration is calculated to be 0.15 mm/year, which is similar to the estimated recharge rate for undisturbed mallee (0.13 mm/year), but significantly lower than the values indicated by Kellet (1997) for the Willandra Lakes Region World Heritage Area and Western Riverine Plain (1.8 mm/year) and for areas near to the Murray River (2.9 mm/year). The low recharge value is realistic given the limited rainfall over the previous years (see RRMCs in Attachment A).

7.7.6 Sensitivity Analyses

During the manual calibration phase, the model was found to be most sensitive to the position of the basement ridges and how they interrupted flow in the aquifers. Model results were moderately sensitive to both horizontal and vertical hydraulic conductivity.

26. The assigning of a monitoring bore to a specific slice (at the top or bottom of a layer) within the model can result in some error due to the significant vertical gradient across layers.

As discussed in Section 7.7.5, variations to rainfall input were modelled and found to indicate a very low recharge value, related to the drought. Calibration runs were carried out using higher rainfall inputs, which required higher hydraulic conductivities in the upper aquifers (to match the shallow aquifer gradients), which were outside the likely range of permeability for these aquifers.

8 GROUNDWATER MODELLING SCENARIO ANALYSIS

Predictive groundwater modelling has been carried out to assess the impact of the Atlas-Campaspe Mine and, in addition, the potential cumulative impact of mining with Iluka's proposed Balranald Mineral Sands Project including the Nepean and West Balranald deposits.

The model was run from the proposed start date for mining at the Atlas deposit of 1 July 2014 using the initial conditions derived from the steady-state calibration. It is expected that groundwater levels would be slightly different than what was measured in 2010, however, this would not be significant when calculating relative changes in water level due to the mining. As the impact of variations in rainfall is small, the rainfall recharge rate has also been kept at the steady-state calibration rate determined for 2010. As the calibration was carried out during a drought period the calculation of water level declines will be conservative.

8.1 CRISTAL MINING MINE SCHEDULE

The mine advance rates and water supply requirements for mining of the two deposits at the Atlas-Campaspe Mine are described in Section 4. Groundwater effects would include the groundwater pumping from the borefield, in-pit dewatering and infiltration of water through the process wastes (including sand residues). Production and dewatering bore locations are shown on Figure 19.

Mining at the Atlas deposit is scheduled to begin in mid-2014, with mining at the Campaspe deposit following a few months after the completion of mining at the Atlas deposit. Based on the planned maximum mine progression, mining of the Campaspe deposit is scheduled to be completed in approximately 2032.

8.2 BALRANALD MINERAL SANDS PROJECT (ILUKA) MINING SCHEDULE

Based on the available documentation (EMGA Mitchell Mclennan, 2012), mining at the West Balranald deposit is modelled to commence in approximately mid-2015, with mining at the Nepean deposit following a few months after completion of the West Balranald mine path. The total of the two mine paths is assumed to be completed in approximately 10 years.

8.3 WATER BALANCE

The water balance is primarily driven by the amount of water lost to sand residues (including a small proportion of clay fines). Management techniques can be used to vary the amount of water lost to infiltration by selective placement of process wastes in the emplacement cells. As discussed above, the model has been run assuming new water maximum pumping rates of 115 L/s and 180 L/s for mining of the Atlas deposit and Campaspe deposit, respectively.

Figure 20 shows a time graph of water losses to sand residues and gains due to in-pit seepage (dewatering). Other water gains and losses include rainfall, evaporation, water in the HMC and water used in dust suppression and for potable use. Evaporation will vary as the area of active sand residue disposal changes. Balancing the gains and losses is achieved by the use of bores, additional recycling of water from the sand residues and disposal of additional (excess) water through the in-pit cells. Average yearly values are summarised in Table 8.

Table 8
Mine Water Balance (Average Yearly Rates)

	Losses			Gains		Balance Requirements	
Year	**Sand Residue and HMC (L/s)**	**Evap.-Rain (L/s)**	**Dust and Potable Use (L/s)**	**Dewatering (L/s)**	**Bores (L/s)**	**Additional Recycling (L/s)**	**Additional Disposal (L/s)**
2	-11	-3	-9	-	17	6	-
3	-98	-4	-9	-	106	5	-
4	-115	-4	-9	-	113	15	-
5	-110	-4	-9	142	35	-	-54
6	-15	-1	-9	-	19	6	-
7	-50	-6	-9	-	65	-	-
8	-136	-9	-9	-	149	5	-
9	-195	-9	-9	5	178	30	-
10	-220	-9	-9	27	171	40	-
11	-196	-8	-9	71	136	6	-
12	-183	-6	-9	75	118	5	-
13	-184	-5	-9	110	85	3	-
14	-187	-8	-9	61	137	6	-
15	-119	-10	-9	22	114	2	-
16	-145	-8	-9	22	136	4	-
17	-166	-9	-9	10	165	9	-
18	-195	-9	-9	5	173	35	-
19	-145	-9	-9	-	163	-	-
20	-173	-6	-9	-	172	16	-

The bore pumping rates have been constrained to those indicated in the Project design, and bore pumping rates would be varied to suit dewatering requirements.

As can be seen from Figure 20 there would be a requirement for average dewatering of up to approximately 250 L/s and an average excess water disposal of up to approximately 120 L/s during 2017 during mining of the Atlas deposit. Dewatering of the Campaspe deposit is required from 2022 to 2030, with an average maximum rate of up to about 130 L/s.

Additional input water requirements beyond the pumping design rate of up to approximately 100 L/s (maximum yearly average 36 L/s) would be required for three periods (2015-2016, 2021-2022 and 2029-2030). This additional water is expected to be achieved by reducing losses to sand residues.

The model imbalance for the mine areas over the life of the mining was calculated to be -27.6 L/s, which compares reasonably well with the estimated non-modelled losses (porosity retention, sand residue area, and evaporation/HMC/dust suppression/ potable) of -26.6 L/s.

This comparison is sensitive to the estimate of pore space retention (water within sand residues that does not reinfiltrate to the ground) which was set at 0.10 L/s. Non-modelled losses are expected to range from 20 L/s to 30 L/s.

8.4 PREDICTED BASEFLOW CHANGES

There are no existing permanent surface water features at the proposed Atlas-Campaspe Mine (i.e. no groundwater window lakes fed by the deep underlying saline groundwater aquifer). Therefore, no impacts on any surface water baseflows are predicted.

8.5 PREDICTED GROUNDWATER DRAWDOWN

Groundwater drawdown contours during the life of the Project are shown in Figures 21 to 26. The drawdown contours include the effect of the Iluka mining operations. Based on the planned maximum mining progression, the time stages generally correspond to:

- Project Year 5 (end of mining at the Atlas deposit);
- Project Year 12 (progressive mining of the Campaspe deposit[27]);
- Project Year 20 (end of mining at the Campaspe deposit);
- 10 years post-mining;
- 20 years post-mining; and
- 50 years post-mining.

Groundwater level contours (AHD) are also shown for comparison.

[27] Approximately coincident with the end of mining of the proposed Nepean deposit at the Balranald Mineral Sands Project.

8.6 SENSITIVITY ANALYSIS

Sensitivity analyses have been carried out to assess the effect of variation in hydrogeological storage parameters, and horizontal hydraulic conductivity in the upper aquifer layers (TQs/Tps/Tpc). The model is required to assess the largest potential groundwater impact distance from the Atlas-Campaspe Mine area. As the main impact is water level drawdown, the worst case would occur with low storage coefficients and high hydraulic conductivities. To demonstrate the maximum likely variation, horizontal hydraulic conductivities in the upper aquifers were increased by 50%, Sy was reduced to 50% and Ss was reduced by an order of magnitude. Results of the analyses for the same time stages (Years 5, 12 and 20) are shown in Figures 27 to 29.

8.7 POST-MINING EQUILIBRIUM

The model results for 50 years post-mining is shown in Figure 26. The model shows some residual elevated water levels at the end of mining (i.e. commencement of post-mining scenario) at both the Atlas and Campaspe deposits, as areas of process waste deposition are above water table and do not readily drain due to adjacent unsaturated conditions. Drainage may occur more quickly than modelled, due to preferentially saturated drainage pathways. Based on the modelling results, the drawdown effect after 50 years has reduced to less than 1 m across the Atlas-Campaspe Mine site.

9 POTENTIAL IMPACTS ON HYDROGEOLOGICAL FEATURES

9.1 DEEP UNDERLYING SALINE GROUNDWATER AQUIFER – CHANGES IN HYDRAULIC PROPERTIES AND DRAWDOWN OF GROUNDWATER TABLE

Extraction of groundwater for water supply purposes from the groundwater borefield and dewatering systems (where the orebody lies below the groundwater table) would form localised groundwater sinks. As described in Section 4.5, the maximum mining depth below the groundwater table is approximately 7 m for the deepest section of the Campaspe deposit, and up to approximately 15 m at the Atlas deposit.

There would also be a change in hydraulic properties over the mine footprint where overburden and process waste is used to backfill the mine voids behind the advancing ore extraction areas. As overburden and process waste may have a different permeability than any *in-situ* material there would be associated changes in localised infiltration rates.

As discussed in Section 8.5, a reduction in groundwater head in the deep underlying saline groundwater aquifer surrounding the groundwater borefield and where dewatering of the orebody is required for mining is predicted. The model predicts maximum drawdown extents from the groundwater borefield and dewatering of the Atlas and Campaspe deposits as follows:

- Atlas deposit at the end of mining (Year 5) 1 m drawdown at approximately 2.0 km from the borefield; and
- Campaspe deposit at the end of mining (Year 20) 1 m drawdown at approximately 2.9 km from the borefield.

Based on the mine water balance results presented in Table 8, up to approximately 180 L/s (averaging approximately 120 L/s over the life of the Project) would be extracted from the groundwater borefield. The modelling also indicates maximum dewatering requirements of up to 300 L/s (from pit-side bores and in-pit dewatering) at Atlas in Year 4 and up to 160 L/s at Campaspe in Year 12 (Figure 20).

The water balance results also indicate that approximately 140 L/s (on average) of process water would be returned to the groundwater system (e.g. with in-path sand residues) over the life of the Project. Based on the current mine plan it is anticipated that water disposal of up to approximately 54 L/s would be required during mining of the Atlas deposit (Year 4) of the Project. No water disposal will be necessary at Campaspe.

As there is limited hydrogeological information for the area, there is some uncertainty in the expected extent of groundwater drawdown and sensitivity analyses have been carried out. For the worst case scenario the extent of the 1 m drawdown contour increases by 0.4 km and 2.6 km for the 5 year and 20 year cases (2.4 km and 5.5 km), with the most significant drawdown to the south. The worst case scenario drawdown 1 m contour is more than 5 km from the Mungo National Park boundary to the west.

9.2 TEMPORARY SURFACE PONDING – CHANGES IN HYDRAULIC PROPERTIES AND RAINFALL RECHARGE

As mining progresses, the ore extraction areas within the mine path would act as a localised depression. This would cause a change in water flow direction and in places a localised reversal of direction where areas of temporary surface ponding is excavated and exists adjacent to the mine path (e.g. following rainfall events).

There would also be a change in hydraulic properties over the mine footprint where overburden and process waste is used to backfill the mine voids behind the advancing ore extraction areas. As overburden and process waste may have a different permeability than the excavated material (including associated clay-based run-on depressions and gilgai), there would be associated change in localised infiltration rates.

The proposed mining of the Atlas and Campaspe deposits is expected to have a limited and localised effect on areas where temporary surface ponding occurs (i.e. through excavation). If clay materials are selectively placed in low-lying portions of the re-profiled landform within the mine path to reinstate run-on to adjacent depressions and gilgai, such limited and localised effects would also be temporary in nature.

Based on the proposed extent of mine footprints at the Atlas-Campaspe Mine, the nearest boundary of the Willandra Lakes Region World Heritage Area is approximately 10 km to the west. The nearest boundary of Mungo National Park is approximately 5 km to the west of the Atlas-Campaspe Mine. Given the intervening topography and large separation distances, excavation into local areas of temporary surface water ponding at the Atlas-Campaspe Mine would not impact on any surface water ponding or shallow groundwater systems associated with the Willandra Lakes Region World Heritage Area or the Mungo National Park.

The construction of off-path sand residue dams, in-pit cell walls, sand residue placement, in-path replacement of overburden and end-of-path mine voids would also change the geological profile and therefore alter the local rate of groundwater recharge to the deep underlying saline groundwater aquifer.

The existing unsaturated profile includes significant clay layers which limit the potential for rainfall infiltration reaching the water table. A typical geological profile (located through a topographic low mid-way along the Campaspe orebody, where there has been temporary ponding of water) is shown in Attachment D. At this location there is up to 30 m of clayey material underlying the surface, and thus downward infiltration would be negligible. The deposition of process wastes would include clay fines layers and the cell walls would be mostly constructed from clayey materials, thus the hydraulic conductivity of the replaced material would also be low.

At the cessation of mining, a final void would remain at the north-western extent of both the Atlas and Campaspe footprints. As discussed in Section 4.8 the depth to water table from the base of the final voids will be more than 5 times greater than the potential capillary rise of water in the sand, and thus no direct evaporation is expected. Incident rainfall and local surface water runoff following rainfall events would temporarily pond in the void prior to evaporating or infiltrating to the groundwater table. The final voids would be a potential location for increased infiltration. Given the limited size of the final voids, the net effect on the aquifer is expected to be negligible.

9.3 CHANGES IN GROUNDWATER QUALITY

The small increase in potential infiltration would add fresher water to the deep underlying saline groundwater aquifer. While increased evapotranspiration from the final void would increase salinity. Both of these effects would be small and would have no effect of water quality at the location of surface water ponding.

Based on the geochemical testwork undertaken by Cristal Mining (2012), overburden materials would typically be non-saline to moderately-saline and the acid-generating potential of overburden materials was assessed to be very low. Given the existing higher salinities of the deep underlying saline groundwater system, no appreciable change in groundwater salinity is expected as a consequence of mining.

In summary, there is expected to be negligible change in groundwater quality as a result of the Project.

9.4 POTENTIAL IMPACTS ON REGISTERED PRODUCTION BORES

The only registered bore local to the Atlas-Campaspe Mine site is at Boree Plains (GW063606), approximately 7 km to the north-east. The water quality in this bore could not be sampled during the bore census, but is expected to be poor, and is not currently used. The drawdown at this bore due to the Project is predicted to be negligible.

9.5 CUMULATIVE IMPACTS

Cumulative groundwater drawdown contours show the magnitude and water table changes caused by coincident mining of the Nepean deposit at the proposed Balranald Mineral Sands Project and mining at the Atlas-Campaspe Mine (Figures 21 to 26). The Iluka West Balranald Project is further to the south and its' impact does not extend to the Cristal Mining area. The expected effect of mining at the Nepean deposit can be seen in Figures 23 to 25, and do not overlap with the drawdown from the Atlas-Campaspe Project.

Whilst conservative for assessment purposes, the cumulative groundwater modelling results show that drawdown does not extend to the Willandra Lakes Region World Heritage Area or the Mungo National Park.

10 PROPOSED MONITORING PROGRAMME

10.1 CLIMATE MONITORING

Data should be recorded at the existing automated weather station installed at the Atlas-Campaspe Mine site (i.e. Boree Plains).

10.2 MONITORING PIEZOMETERS

In addition to the four monitoring bores installed for the pumping test (AM1-4), five additional monitoring bores (AM5-9) should be installed around the mine sites, as shown in Figure 19. Monitoring bores have not been placed on the eastern side of the mine paths, as the Loxton-Parilla Aquifer is above the water table at this location and is underlain by clayey materials, minimising the hydraulic connectivity to the east.

Groundwater monitoring should be carried out in the privately owned Boree Plains bore (GW063606) to the north and supplemented with available groundwater monitoring data from the government bore installations to the south-west and east (GW036790, GW036674 and GW036875). The modelling indicates that the likely response in these regional bores would be nil to negligible. Water levels should be collected on a quarterly basis.

10.3 GROUNDWATER QUALITY

The mining process does not introduce any chemicals to the water and groundwater contamination is unlikely. Point source contamination, for example due to fuel spills, is to be addressed in the site environmental management plan, and is unlikely to have any effect beyond the mining area. Seepage from septic absorption beds at the accommodation camp would also be limited. As the groundwater is highly saline, the impact of any point contamination is unlikely to have any regional significance.

Groundwater quality testing of water samples from the installed monitoring bores[28] and the regional government bores is planned to be carried out quarterly. Testing is recommended for Electrical Conductivity (EC), pH, standard anions and cations, and metals.

10.4 MINE WATER BALANCE

Flow meters should be installed on all bores in the groundwater supply borefield to monitor pumping rates. Flow meters would also be necessary on all transfer flows to and from the process waste (e.g. sand residues) disposal areas. The overall mine water balance should be checked on at least a yearly basis.

28. Water quality testing at the borefield area will only be required from one monitoring or production bore.

11 MANAGEMENT AND MITIGATION MEASURES

11.1 GROUNDWATER USERS – MANAGEMENT OF COMPLAINTS

In the event that a complaint is received during the life of the Project in relation to groundwater drawdown of a privately-owned bore or well, the results of the Groundwater Monitoring Programme should be reviewed by Cristal Mining as part of a preliminary evaluation to determine if further investigation notification, mitigation (bore-reconditioning), compensation (e.g. alternative water supply) or other contingency measures are required.

11.2 NUMERICAL MODEL AND WATER BALANCE REVIEW

The numerical model development as part of this assessment should be used as a management tool for the periodic review and calibration of predicted groundwater drawdown through the life of the Project.

The results of the Groundwater Monitoring Programme would inform progressive refinement of the numerical model as the mining operations are developed.

Revised outputs from the numerical model should be reported periodically over the life of the Project and used to inform the site water balance review.

Review and progressive refinement of the site water balance would be undertaken of the life of the Project to record the status of inflows, storage and consumption and to optimise ongoing water management performance.

11.3 GROUNDWATER MANAGEMENT PLAN

A Groundwater Management Plan should be prepared for the Atlas-Campaspe Mine. The plan should include a summary of the Groundwater Monitoring Programme and procedures/reporting that would be implemented over the life of the Project (e.g. responses to complaints, progressive numerical model refinement and periodic reporting to inform the site water balance review as discussed above).

The Groundwater Management Plan should also describe contingent mitigation, compensation, and/or offset options that would be enacted if, in the unlikely event, users of groundwater resources in the region are adversely affected by the Project.

For example, if drawdown of a privately-owned bore or well was materially greater than that predicted in this report and results in loss of supply to the local groundwater user, Cristal Mining’s responses could include:

- bore reconditioning; or
- provision of an alternative water supply (and appropriate licence).

11.4 GROUNDWATER LICENSING

Prior to extraction of groundwater for water supply purposes from the deep underlying groundwater aquifer and/or prior to mining in areas of temporary surface ponding (if saturated) or deep underlying saline groundwater aquifer associated with the Western Murray Porous Rock Groundwater Source; Cristal Mining would obtain and hold adequate volumetric licences in accordance with the requirements of the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011*.

Based on the results of the numerical modelling (Section 8), the predicted annual groundwater volumes required to be licensed over the life of the Project and post-mining are summarised in Table 9.

Table 9
Estimated Project Groundwater Licensing Requirements Associated with the Western Murray Porous Rock Groundwater Source* (ML/yr)

Project Year	Atlas	Campaspe	Ginkgo	Snapper	Crayfish	Total
1			2,664	3,095	5,864	11,623
2	536		2,664	3,082	5,864	12,146
3	3,343		426	2,864	5,864	12,497
4	3,564		39	2,618	5,864	12,085
5	5,582			1,311	5,864	8,279
6	66	533		1,311		1,910
7		2,050		1,311		3,361
8		4,699		1,861		6,560
9		5,771		1,607		7,378
10		6,244		1,356		7,600
11		6,528		619		7,147
12		6,086		195		6,281
13		6,150				6,150
14		6,244				6,244
15		4,289				4,289
16		4,983				4,983
17		5,519				5,519
18		5,613				5,613
19		5,140				5,140
20		5,424				5,424
21		0				0

* As defined in the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* under the *Water Management Act, 2000.*

Based on the planned mine progression at the Atlas-Campaspe Mine, continued operations at the Ginkgo and Snapper Mines and the proposed Crayfish satellite pit of the Ginkgo Mine, the existing volumetric licence allocations (21,442 ML/yr) held by Cristal Mining are considered to be adequate (Section 3.7). As the Ginkgo and Snapper Mines and Atlas-Campaspe Mine are located within the same groundwater source (i.e. Western Murray Porous Rock Groundwater Source) the appropriate licence allocations would be traded in accordance with the rules of the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011*.

Approvals for trading of water allocation between the mine sites would be requested from the Office of Water.

Based on the planned maximum mine plan progression, it is anticipated that water disposal would likely only be required during mining of the Atlas deposit (Year 4) of the Project. If required during the life of the Project, Cristal Mining would seek appropriate licences to allow for re-injection to the underlying saline groundwater aquifer.

Given the existing low value of groundwater in the region (Section 3.12), the quality of water pumped to on-path water disposal dams would not affect the beneficial use category of the underlying deep saline aquifer. The disposal of water would be undertaken in accordance with any Environment Protection Licence conditions required by the NSW *Protection of the Environment Operations Act, 1997.*

As no groundwater is proposed to be extracted at the Ivanhoe Rail Facility (i.e. from the Lower Lachlan unconsolidated alluvial sediments), the *Water Sharing Plan for the Lower Lachlan Groundwater Source 2003* would not apply to the Project.

12 GROUNDWATER MODEL LIMITATIONS

The predictive ability of groundwater modelling is generally related to the availability of geological and hydrogeological data (i.e. knowledge) of the area. Given the remote location of the Atlas-Campaspe Mine site, substantial historic datasets are not available. Notwithstanding, sensitivity variations were modelled for conservative (i.e. worse case) conditions (Section 7.7) to identify an envelope of maximum potential limit of impact. Given the conservative nature of the assessment undertaken in this report, the model accuracy is expected to be adequate for the required purpose of assessing the range of potential impacts surrounding the mining area. The proposed Groundwater Monitoring Programme (Section 10) is also aimed at increasing the knowledge of the area and validating the extent of predicted impacts.

Further away from the Atlas-Campaspe Mine area, the amount of hydrogeological knowledge is also limited and the accuracy of the modelling would therefore also be lower. Modelling accuracy of the proposed Iluka operations has also been undertaken conservatively based on the limited datasets available for the assessment.

13 CONCLUSIONS

A review of the NOW PINNEENA Groundwater Database indicated seven bores drilled within approximately 20 km of the Atlas-Campaspe Mine. Besides three multi-level government installations (GW036790, GW036674 and GW036875), a site reconnaissance by Cristal Mining in July 2011 identified only one potentially active privately-owned bore location (Boree Plains [GW036606] to the north of the Campaspe deposit). The lack of active bores in the region is understandable given the poor quality of the groundwater.

The review of available baseline hydrogeological data indicates localised temporal surface ponding due to limited drainage, and underlying saline groundwater aquifers at moderate to significant depths.

Temporary ponding of rainfall occurs in localised topographic depressions where rainfall runoff is concentrated and the surficial soils have low permeability. These locations are isolated and do not contribute to any significant surface water system. Drainage from these locations is limited due to the low-permeability surface soils and the majority of the water eventually dissipates by evaporation. Given the limited rainfall experienced in the area historically, the frequency of surface ponding is low.

The groundwater table is associated with the underlying saline groundwater systems (ranging from approximately 10 m to 30 m below ground level) and generally sits within the shallow Shepparton Formation or underlying Loxton-Parilla Sands. The Loxton-Parilla Sands overlies the Renmark Group which is subdivided into the Upper, Middle and Lower Olney Formations and Warina Sands. At the Atlas-Campaspe Mine site there is no significant aquifer zone in the Renmark Group, due to the elevated height of basement rock and prevalence of low permeability materials. However, to the west (Willandra and Wentworth Troughs) and east (Balranald Trough) significant aquifer zones have been encountered in the Renmark Group, especially in the deepest layers of the Lower Olney Formation and Warina Sands.

Despite the multiple aquifer systems in the region, the Western Murray Porous Rock Groundwater Source defined in the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* includes groundwater contained in all shallow unconsolidated geological layers (Shepparton Formation to Renmark Group Units) of the basin apart from the shallow alluvial deposits around the major rivers.

In conclusion, based on the results of this assessment (including numerical groundwater modelling), there is expected to be:

- limited, localised and temporary effects on areas where temporary surface ponding occurs at the Atlas-Campaspe Mine site (i.e. through excavation);
- no impact on any surface ponding areas or shallow groundwater systems associated with the Willandra Lakes Region World Heritage Area or Mungo National Park;

- a maximum drawdown extent of approximately 2.0 km in Year 5 of the Project (due to the groundwater borefield and dewatering of the Atlas deposit at the end of mining below the water table);

- a maximum drawdown extent of approximately 2.9 km in Year 20 of the Project (due to the groundwater borefield and dewatering of the Campaspe deposit at the end of mining below the water table);

- no drawdown of the deep underlying saline groundwater aquifer below the Willandra Lakes Region World Heritage Area or the Mungo National Park;

- negligible drawdown at the nearest privately-owned registered bore local to the Atlas-Campaspe Mine site (Boree Plains [GW063606]) due to the Project;

- no measurable changes in the quality of the temporary surface ponding areas as a consequence of the Project; and

- negligible change in groundwater quality as a result of the Project (although a small increase in potential infiltration would add fresher water to the deep underlying saline groundwater aquifer).

Whilst conservative for assessment purposes, the cumulative groundwater modelling results, including the Project and the proposed Balranald Mineral Sands Project, also show that drawdown (of the deep underlying saline groundwater aquifer) does not extend to the Willandra Lakes Region World Heritage Area or the Mungo National Park.

The potential impacts of mining on surface water resources, other than those assessed within this report, are assessed in Appendix G of the EIS.

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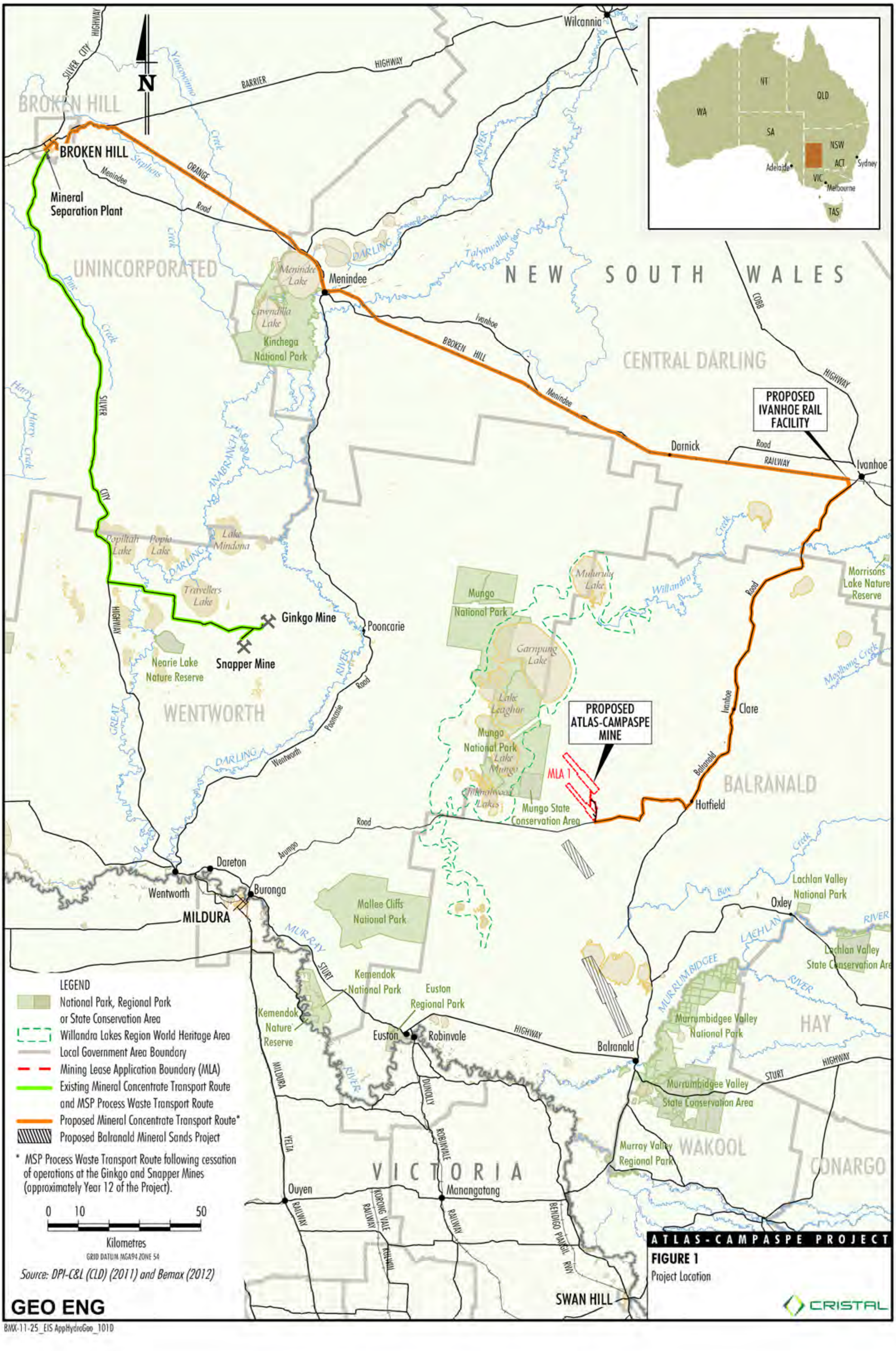
FIGURES



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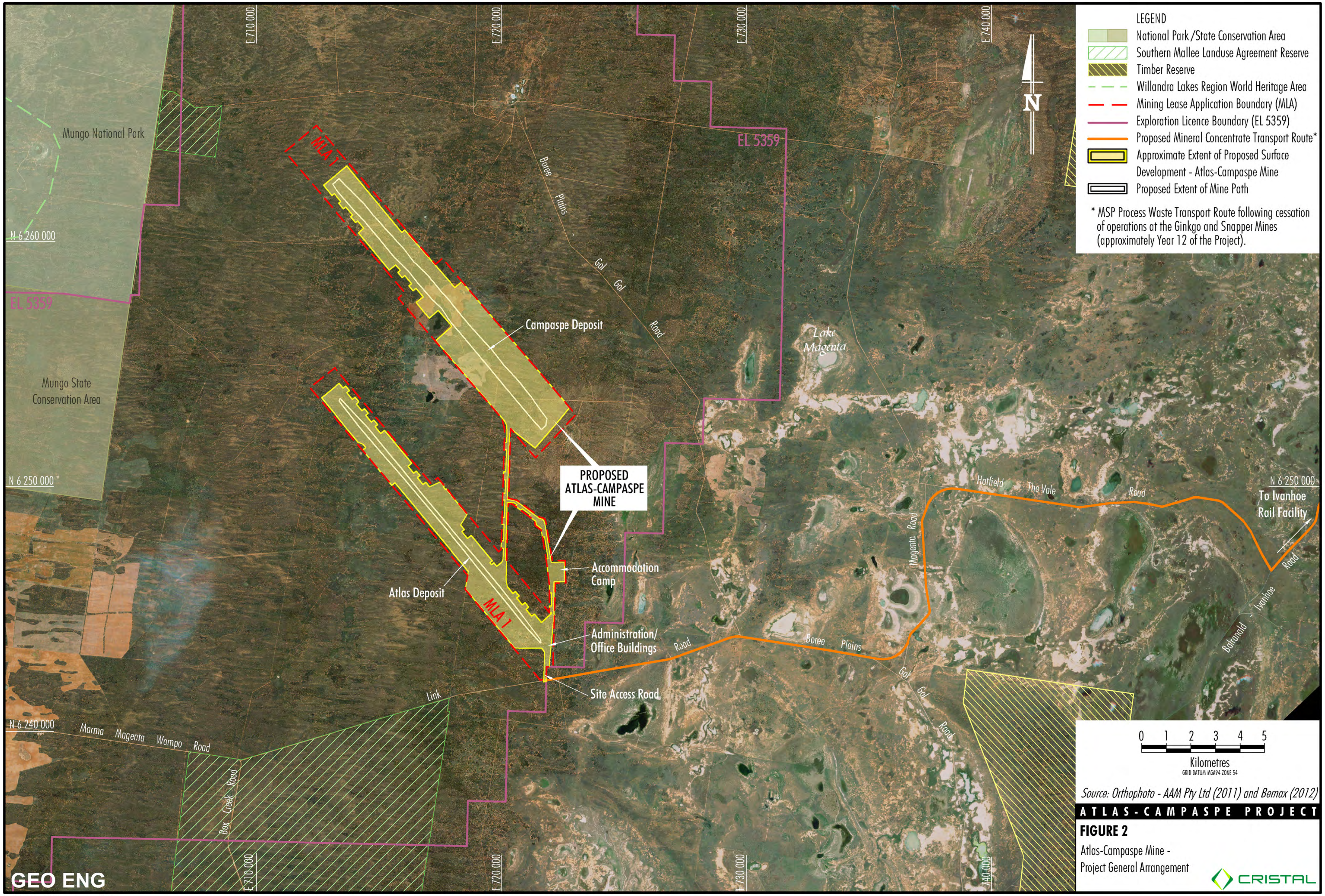

FIGURE 2
Atlas-Campaspe Mine - Project General Arrangement

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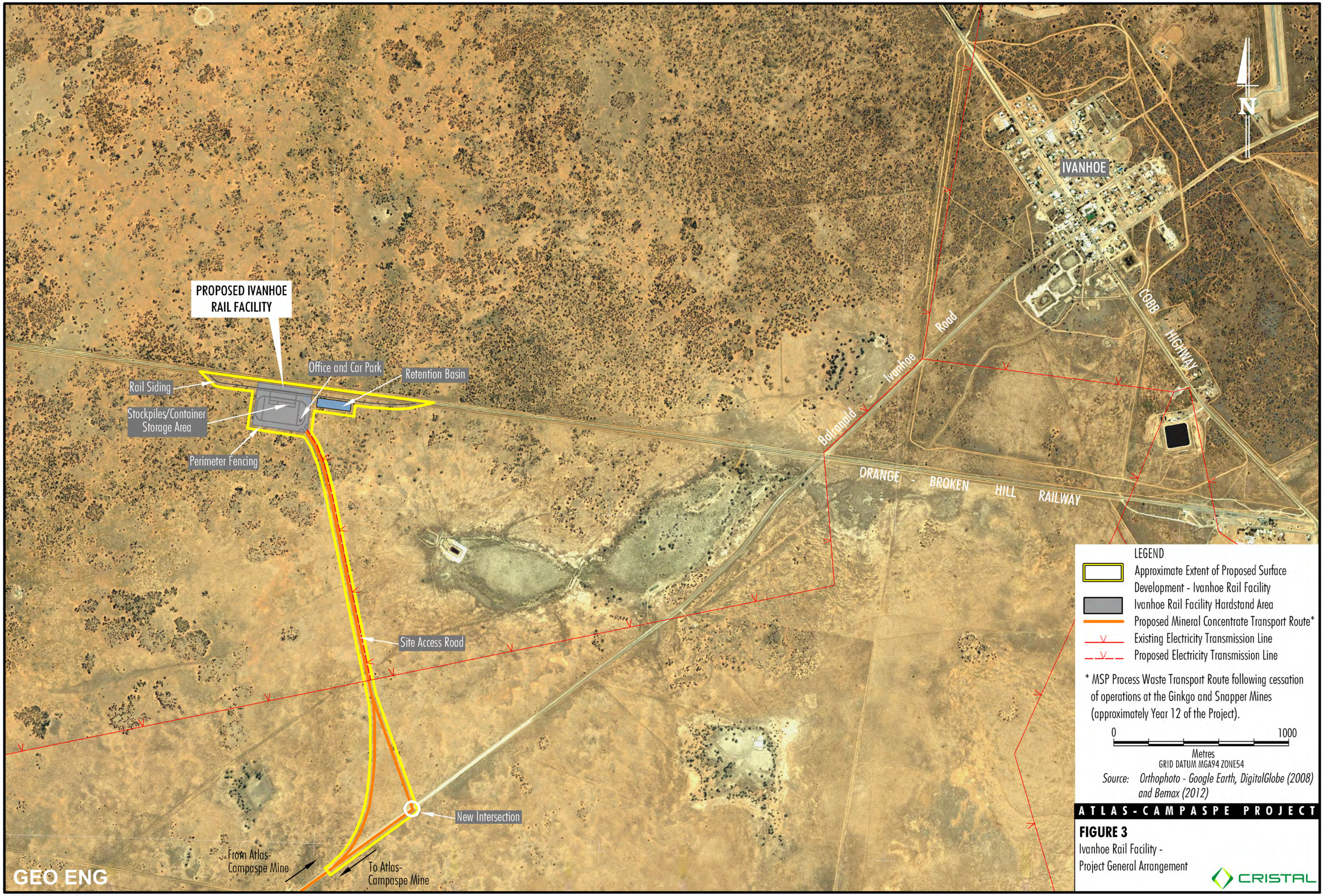

FIGURE 3
Ivanhoe Rail Facility - Project General Arrangement

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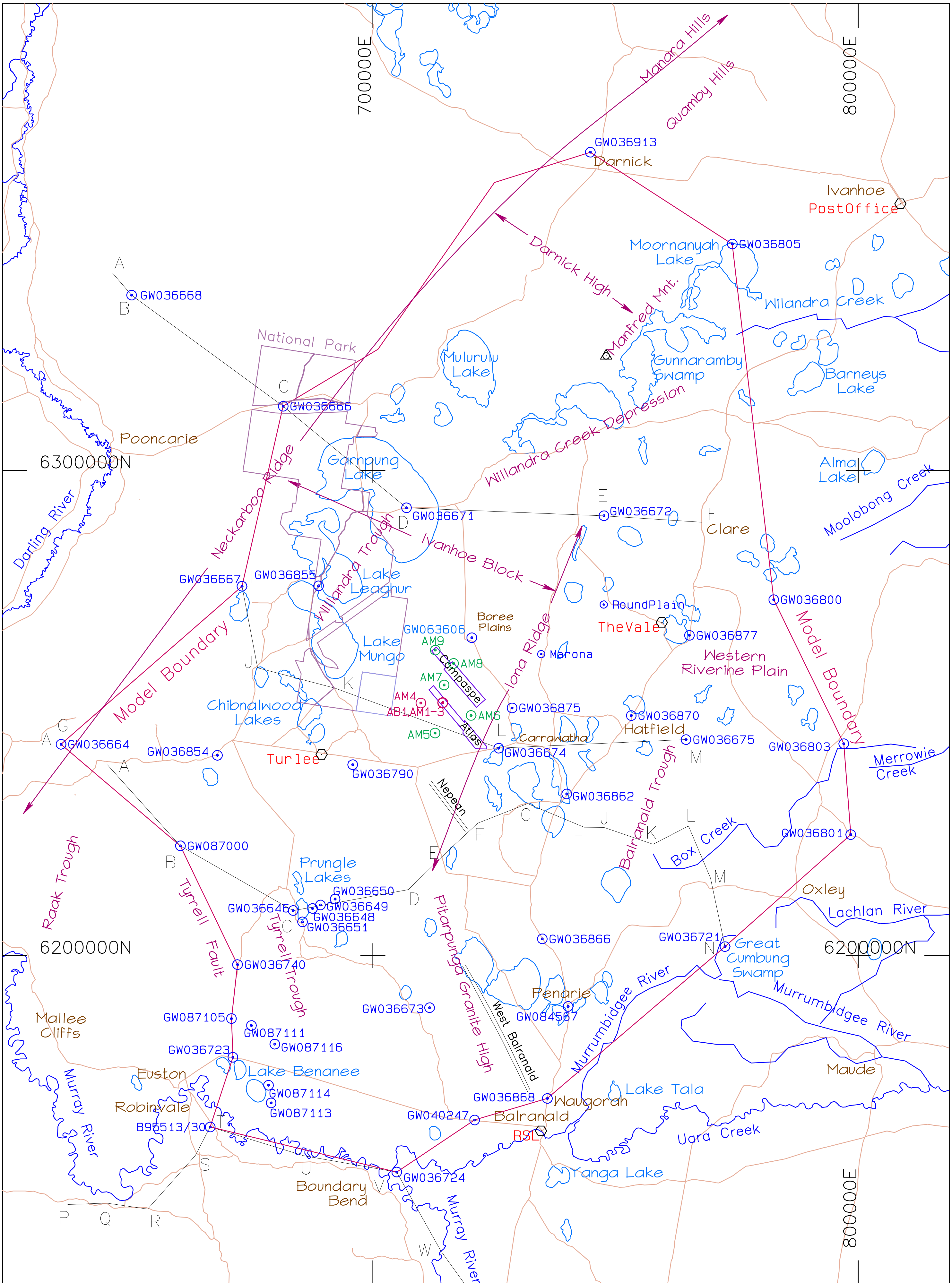

19.5 x 26.41

Note: Test & Monitoring Bores; Weather Stations; Proposed Monitoring Bores; Gov Monitoring Bores

North

Cristal Mining Australia
Atlas/Campaspe Groundwater Model

Location Plan

P Q R Cross-sections

Plotted: Oct 14 2012

Design: GEOENG

Contour int: N/A

DATUMS: Hor: GDA Z54 Ver:

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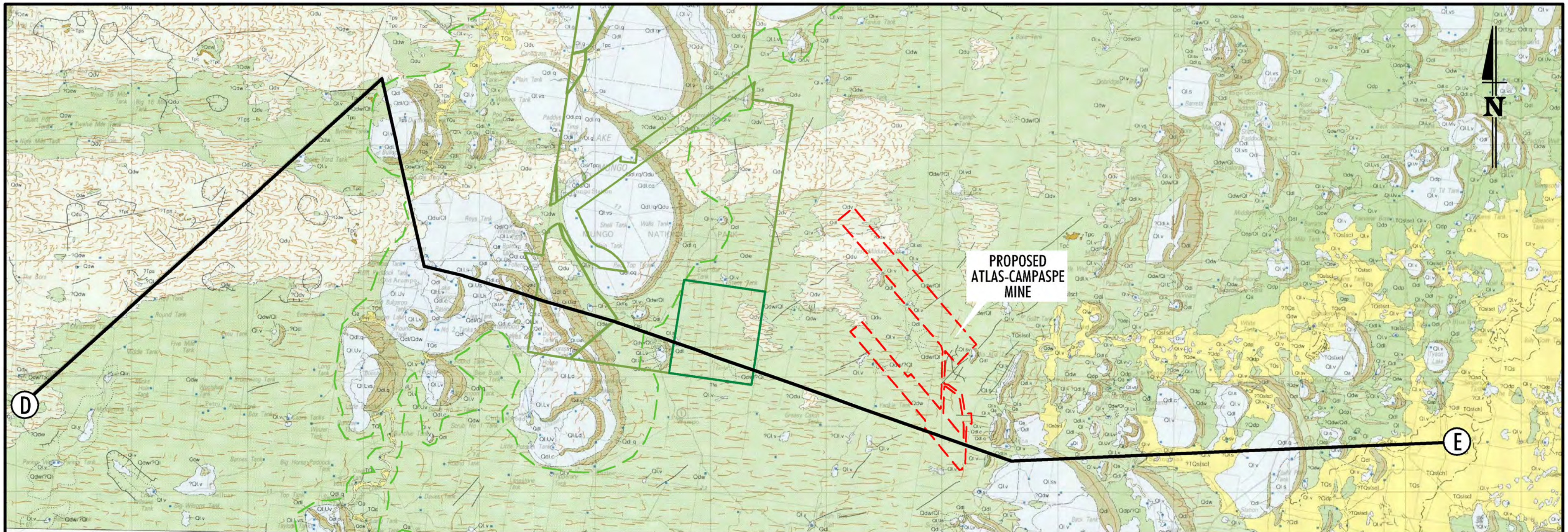
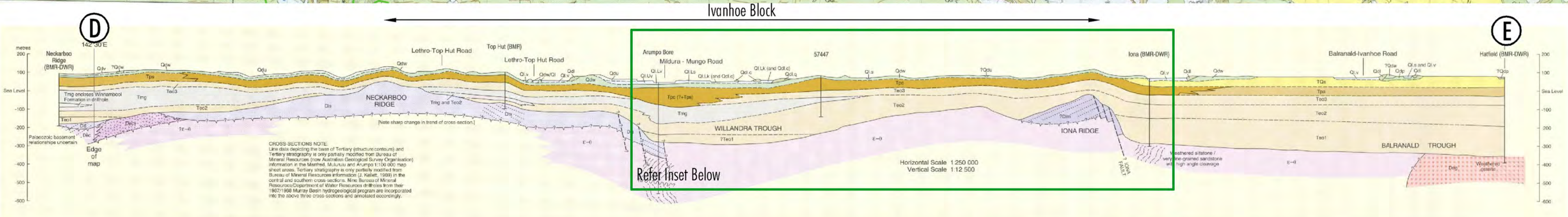
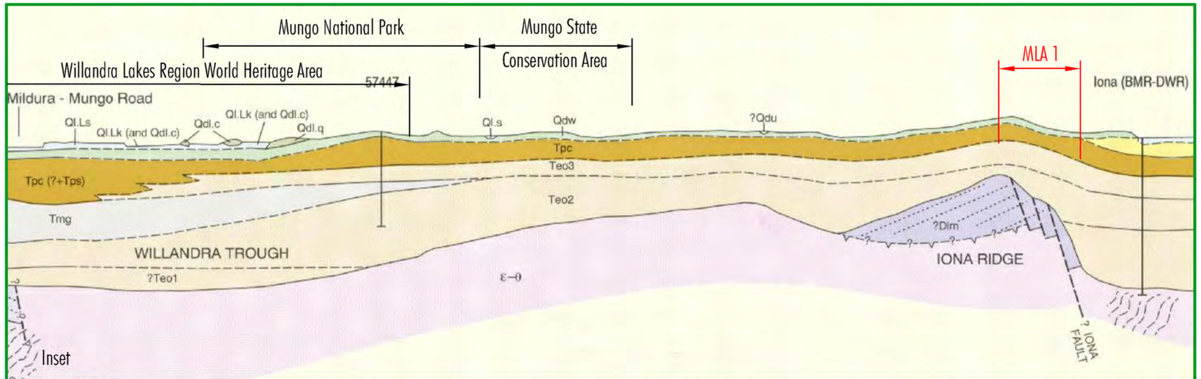
Figure 4







KEY

Qdl	Undifferentiated Lunette
Qdw	Woorinen Formation
Qdu	Lowan Sand
Ql	Lacustrine and Related Systems
TQs	Shepparton Formation
Tps/Tpc	Loxton/Parilla Sand
Teo	Olney Formation of Renmark Group
Dlm	Manfred Sandstone
ε-θ	Saint Arnaud Group Equivalent

LEGEND

- National Park /State Conservation Area
- Willandra Lakes Region World Heritage Area
- Mining Lease Application Boundary (MLA)

0 10
Kilometres
GRID DATUM MGA94 ZONE 54

Source: Department of Mineral Resources, Pooncarrie 1:250,000 (1996)

ATLAS-CAMPASPE PROJECT

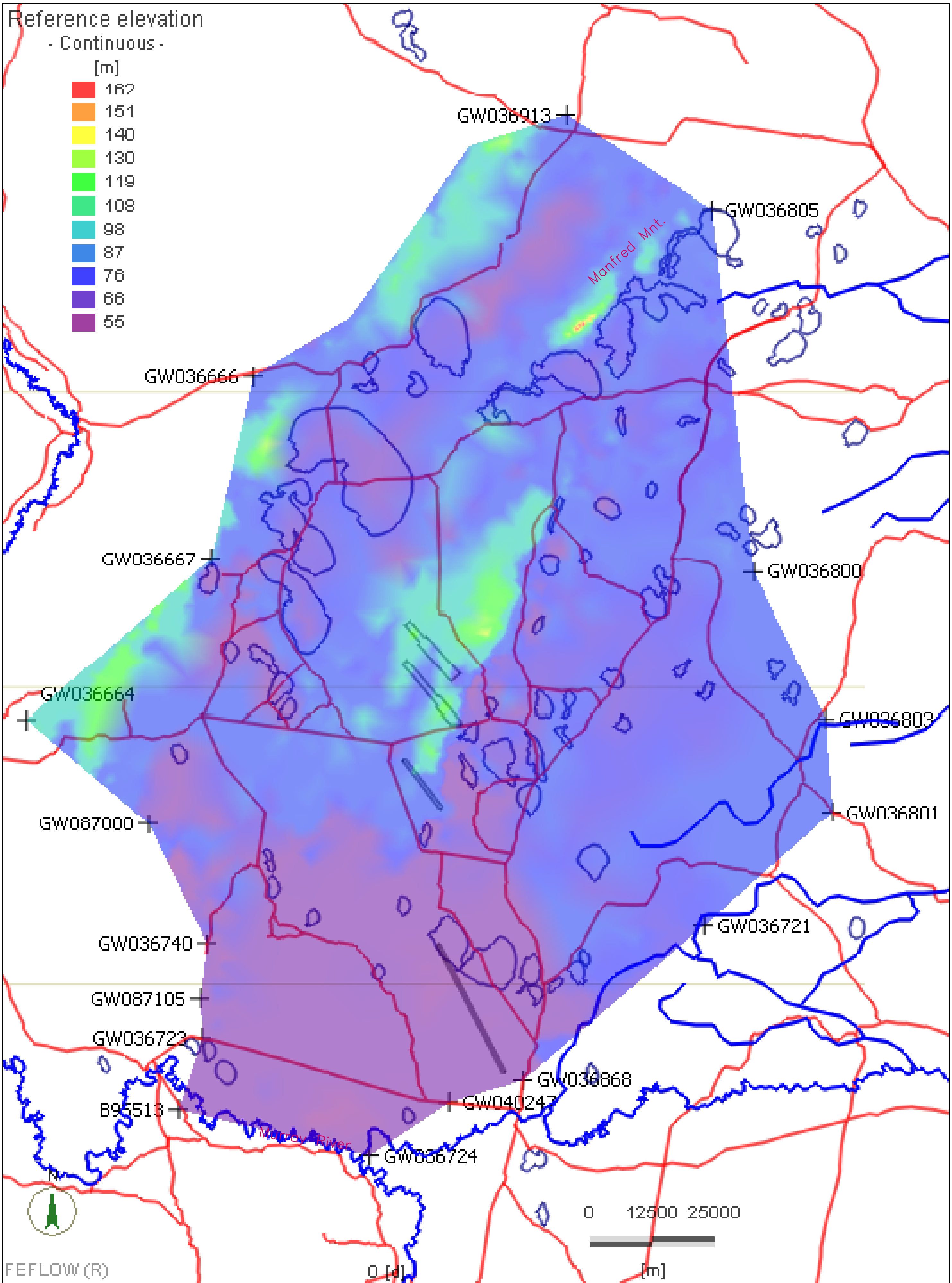
FIGURE 5

Regional Geology

GEO ENG

CRISTAL

BMX-11-25_EIS AppHydroGeo_107D



19.5 x 26.41	Note:	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Surface Topography

Plotted: Oct 14 2012	Design: GEOENG	Contour int: 1m	DATUMS: Hor: Ver: A.H.D.	A4 - 1 : 1000000
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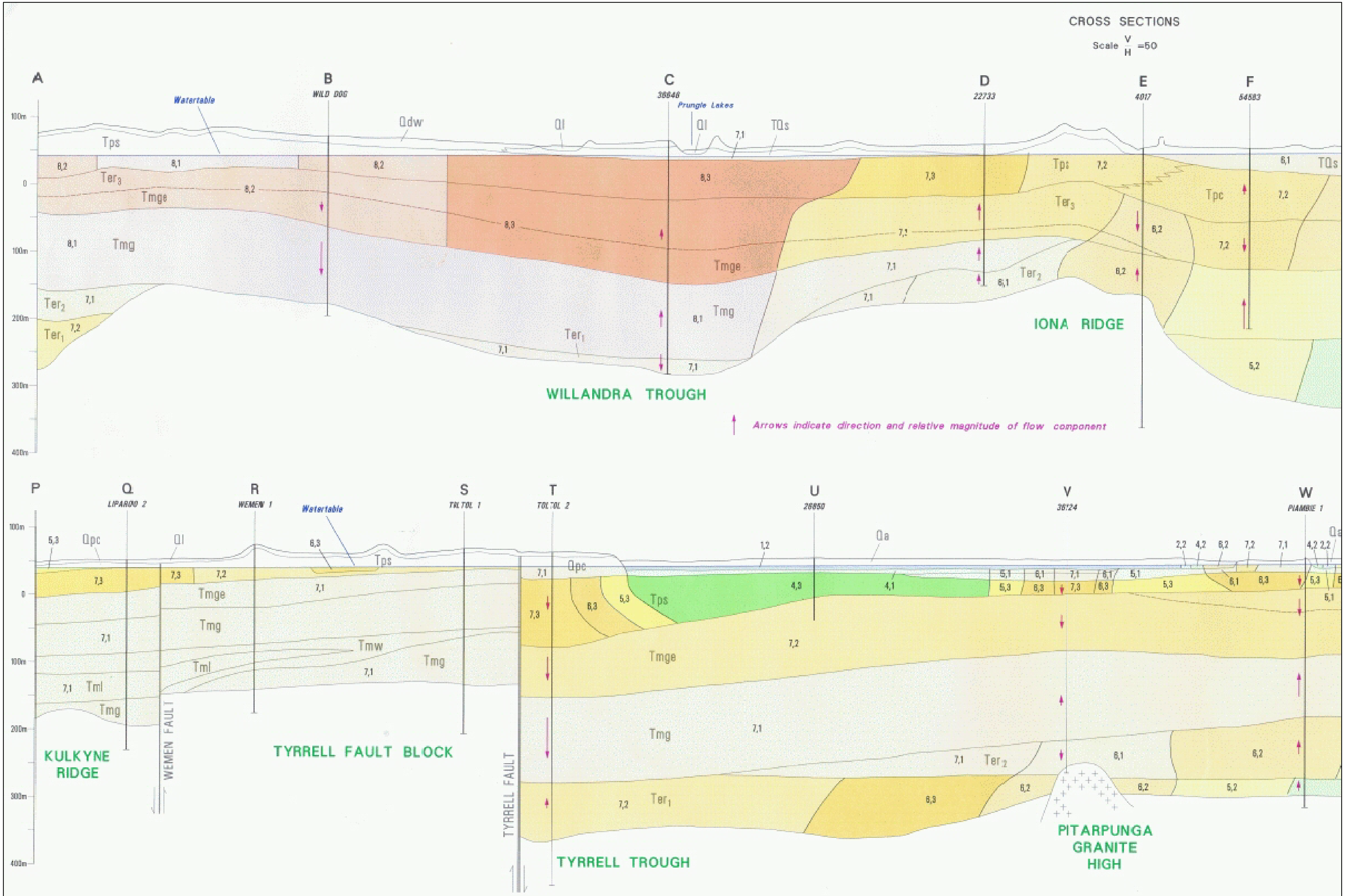

28 x 18.72	Source: Murray Basin Hydrogeological Map Series 1:250,000 Map Sheets, Balranald, AGSO, 1994	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Geological Sections Balranald Sheet West	Plotted: Oct 14 2012	See Fig 4 for Loc.	DATUMS: Hor: Ver: AHD; ORIGIN: n/a

Figure 7

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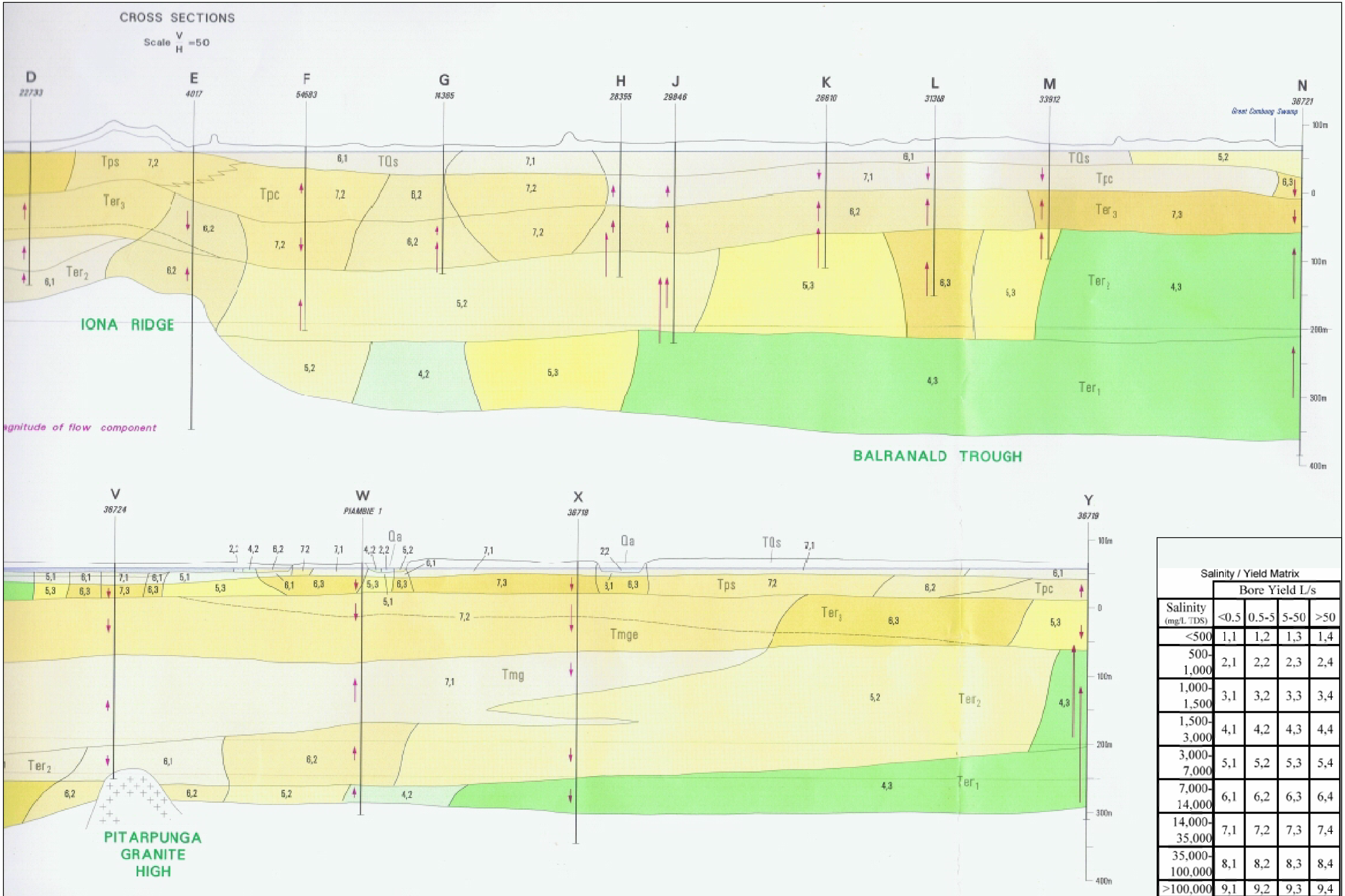

Salinity / Yield Matrix

Salinity (mg/L TDS)	Bore Yield L/s <0.5	0.5-5	5-50	>50
<500	1,1	1,2	1,3	1,4
500-1,000	2,1	2,2	2,3	2,4
1,000-1,500	3,1	3,2	3,3	3,4
1,500-3,000	4,1	4,2	4,3	4,4
3,000-7,000	5,1	5,2	5,3	5,4
7,000-14,000	6,1	6,2	6,3	6,4
14,000-35,000	7,1	7,2	7,3	7,4
35,000-100,000	8,1	8,2	8,3	8,4
>100,000	9,1	9,2	9,3	9,4

28 x 18.72

Source:
Murray Basin Hydrogeological Map Series
1: 250,000 Map Sheets, Balranald, AGSO, 1994

North

Cristal Mining Australia
Atlas/Campaspe Groundwater Model

Geological Sections
Balranald Sheet East

Plotted: Oct 14 2012

See Fig 4 for Loc.

DATUMS: Hor: Ver: AHD

ORIGIN: n/a

Figure 8

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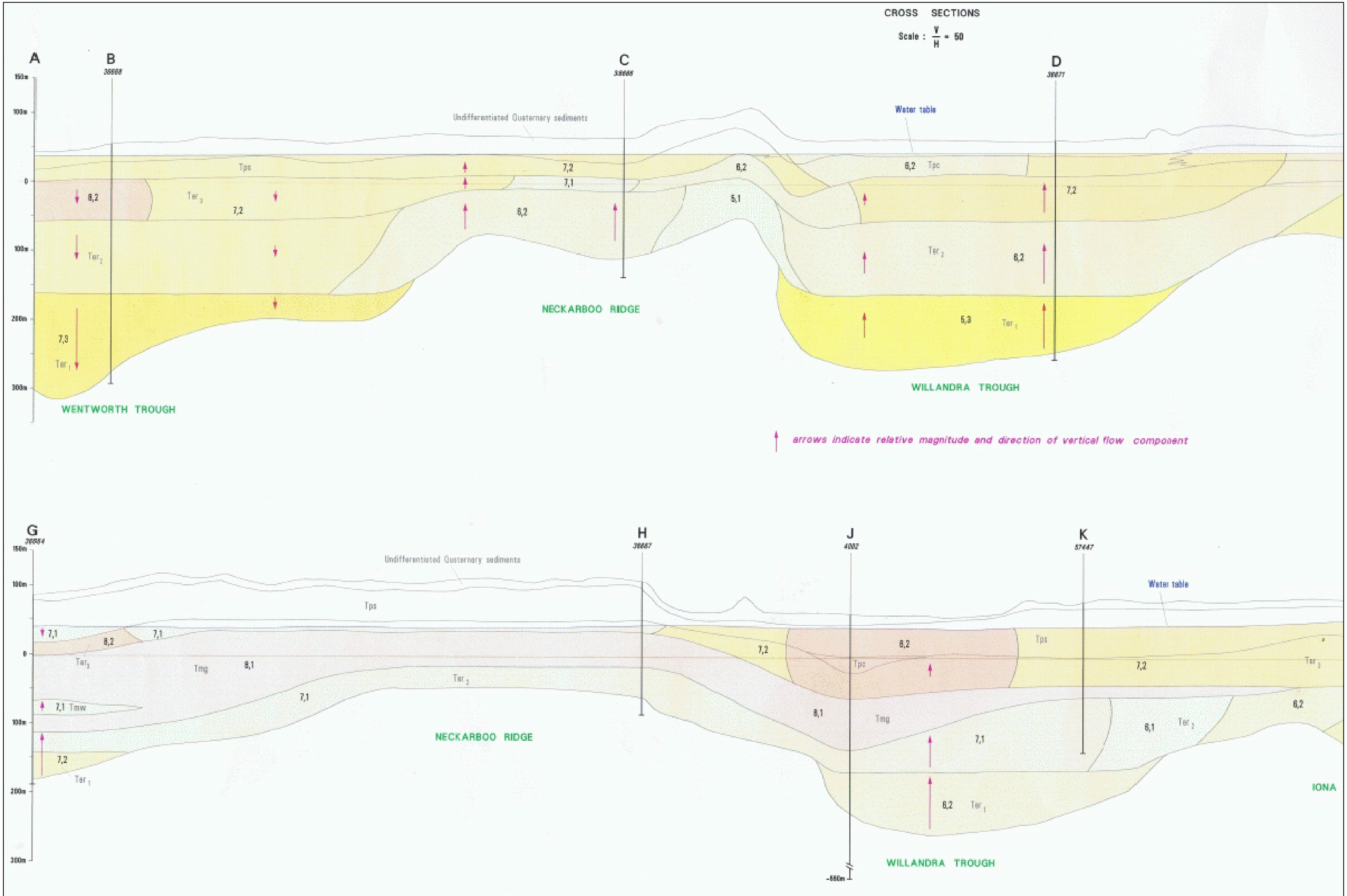
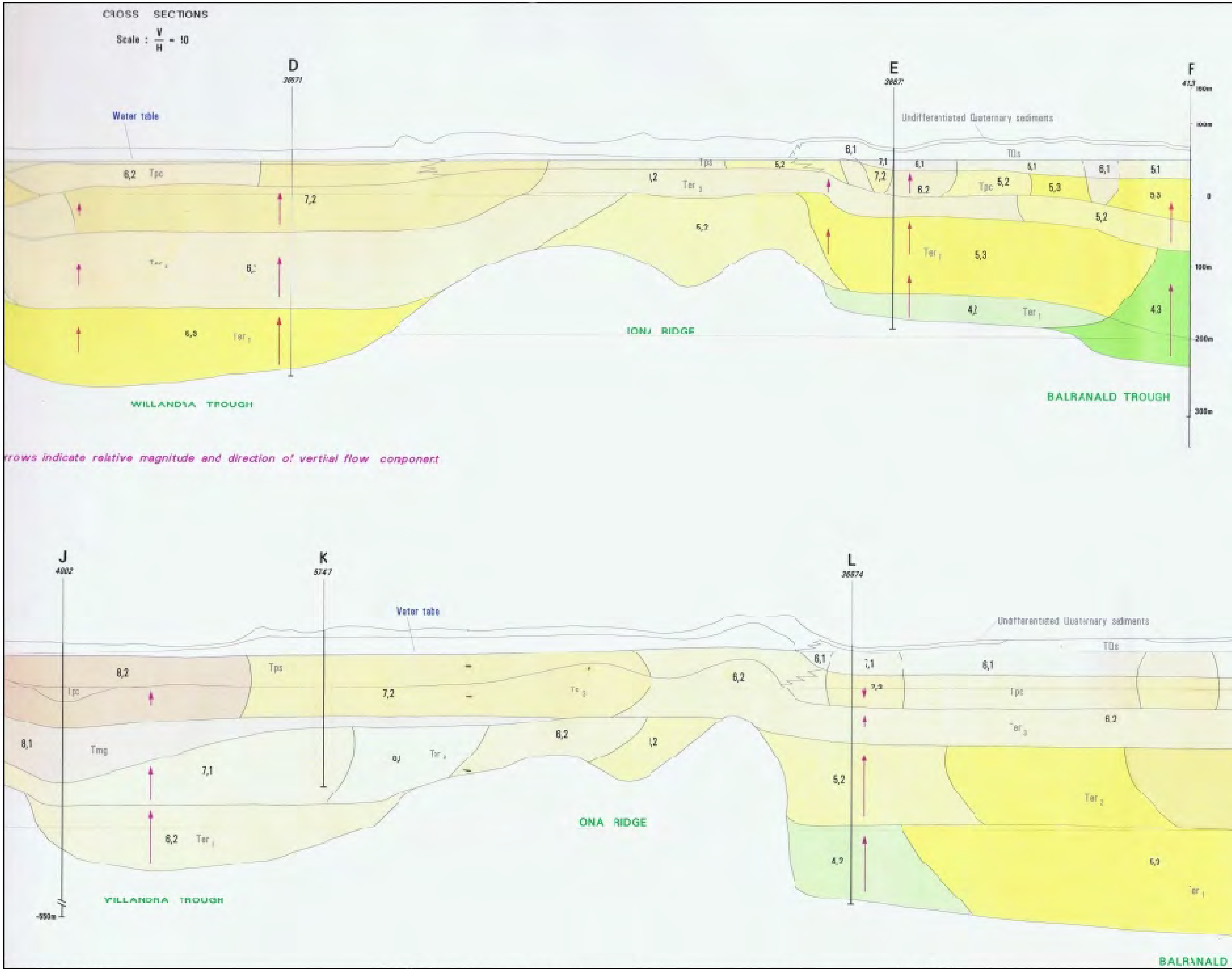
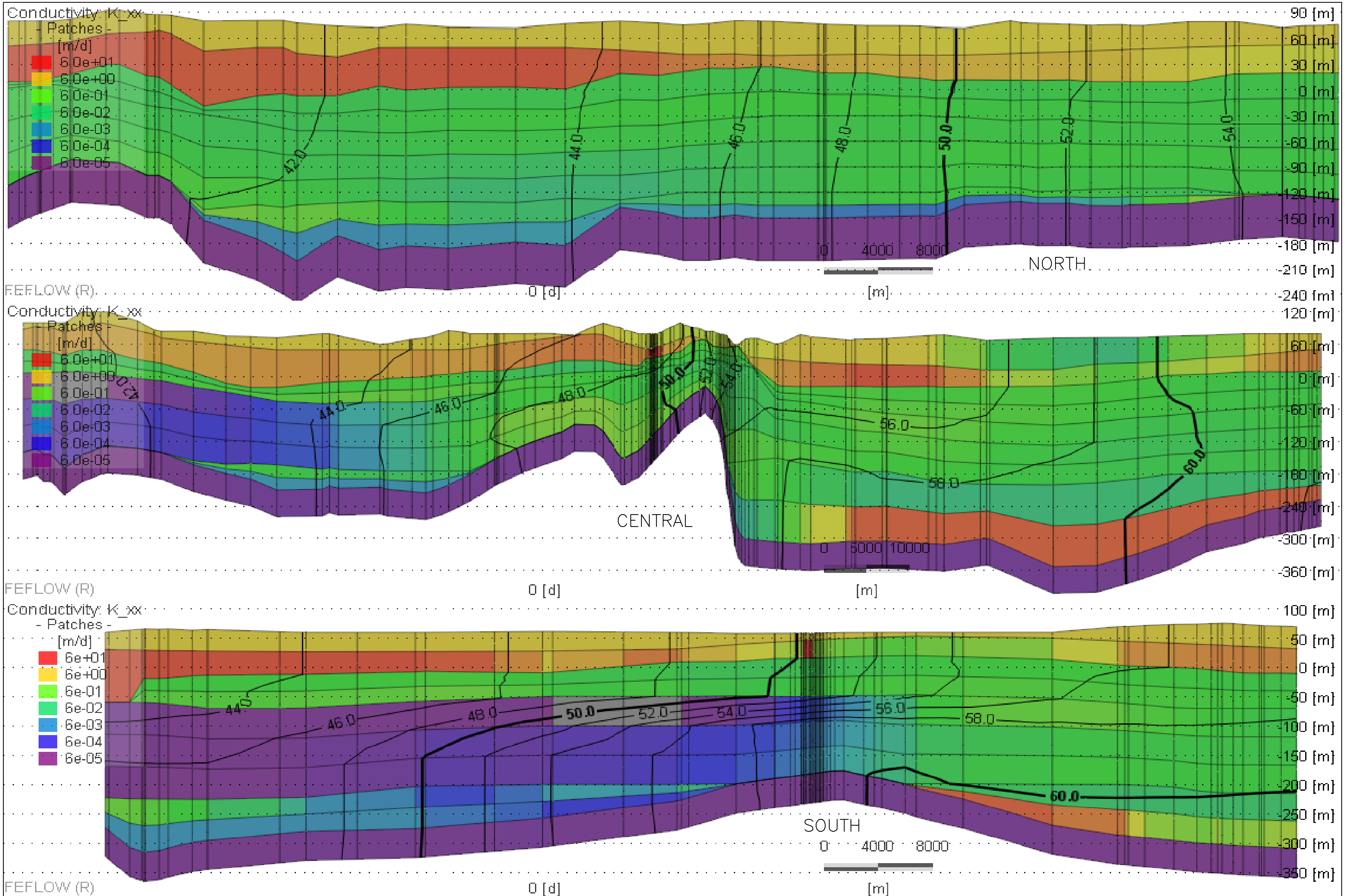


28 x 18.72	Source: Murray Basin Hydrogeological Map Series 1: 250,000 Map Sheets, Pooncarie, BMR, 1991	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Geological Sections Pooncarie Sheet West	Plotted: Oct 14 2012	See Fig 4 for Loc.	DATUMS: Hor: Ver: A.H.D. ORIGIN: n/a	Figure 9 File no.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro

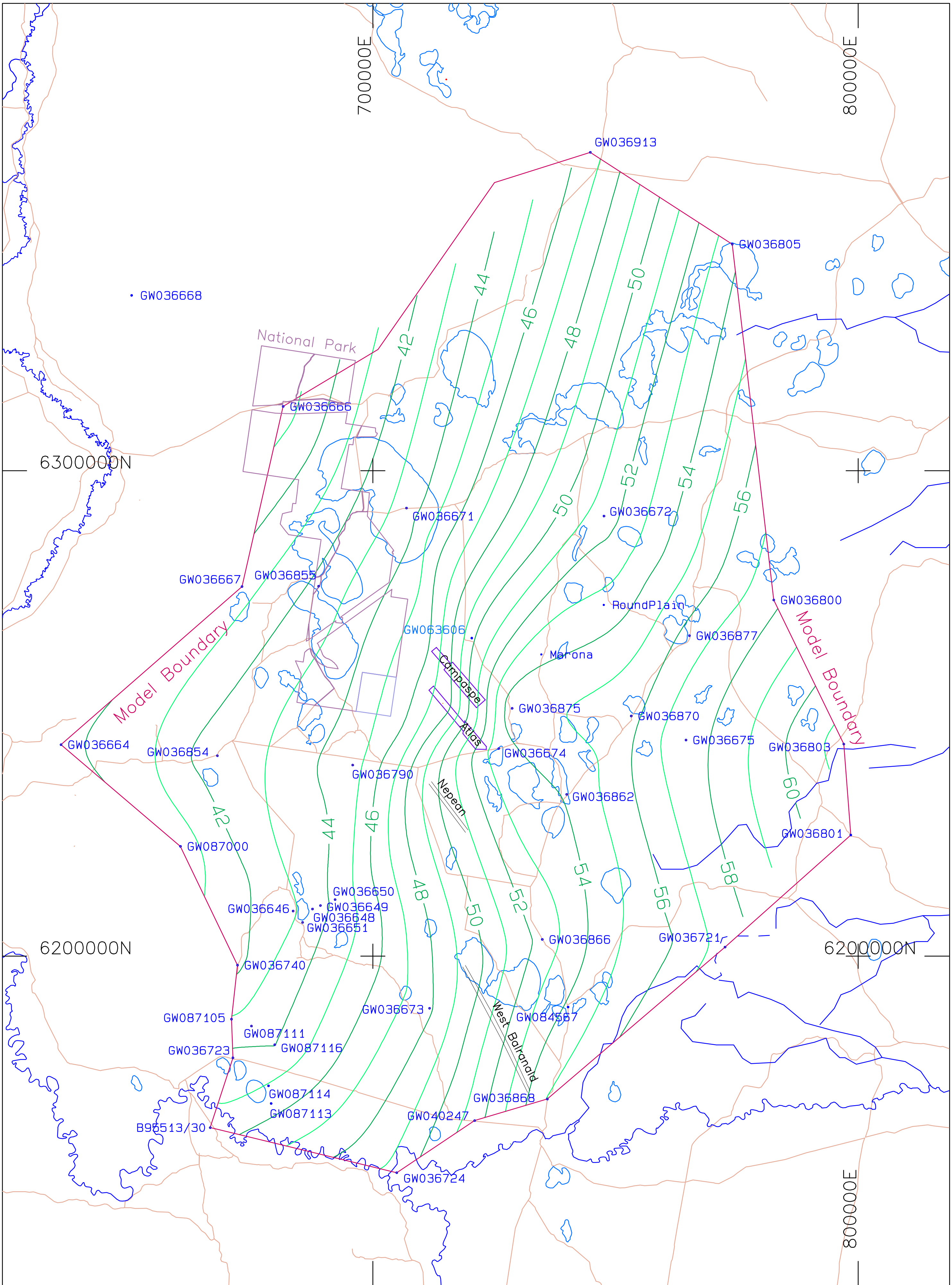


	Bore Yield L/s			
Salinity mg/L TDS	<0.5	0.5-5	5-50	>50
<500	1,1	1,2	1,3	1,4
500-1,000	2,1	2,2	2,3	2,4
1,000-1,500	3,1	3,2	3,3	3,4
1,500-3,000	4,1	4,2	4,3	4,4
3,000-7,000	5,1	5,2	5,3	5,4
7,000-14,000	6,1	6,2	6,3	6,4
14,000-35,000	7,1	7,2	7,3	7,4
35,000-100,000	8,1	8,2	8,3	8,4
>100,000	9,1	9,2	9,3	9,4

28 x 18.72	Source: Murray Basin Hydrogeological Map Series 1:250,000 Map Sheets, Pooncarie, BMR, 1991	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Geological Sections Pooncarie Sheet East	Plotted: Oct 14 2012	See Fig 4 for Loc.	DATUMS: Hor: Ver: A.H.D. ORIGIN: n/a	Figure 10



28 x 18.72	Legend:	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model West - East Sections South, Central and North	Plotted: Mar 9 2013	Design: GEO-ENG	See Fig. 17 for Section Lines Locations	DATUMS: Hor: Ver: AHD ORIGIN:	Figure 11 File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro



19.5 x 26.41	*Note:* Contours From Layer 2 (Tp)	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Upper Aquifer Water Levels (m AHD) Measured 2010 - Salinity Corrected

⊙ Groundwater Bore

Plotted: Oct 30 2012 | Design: GEOENG | Contour int: 1m | DATUMS: Hor: GDA Z54 Ver: AHD | A4 - 1 : 172000

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Figure 12

Pre-Mine Geology and Water Table

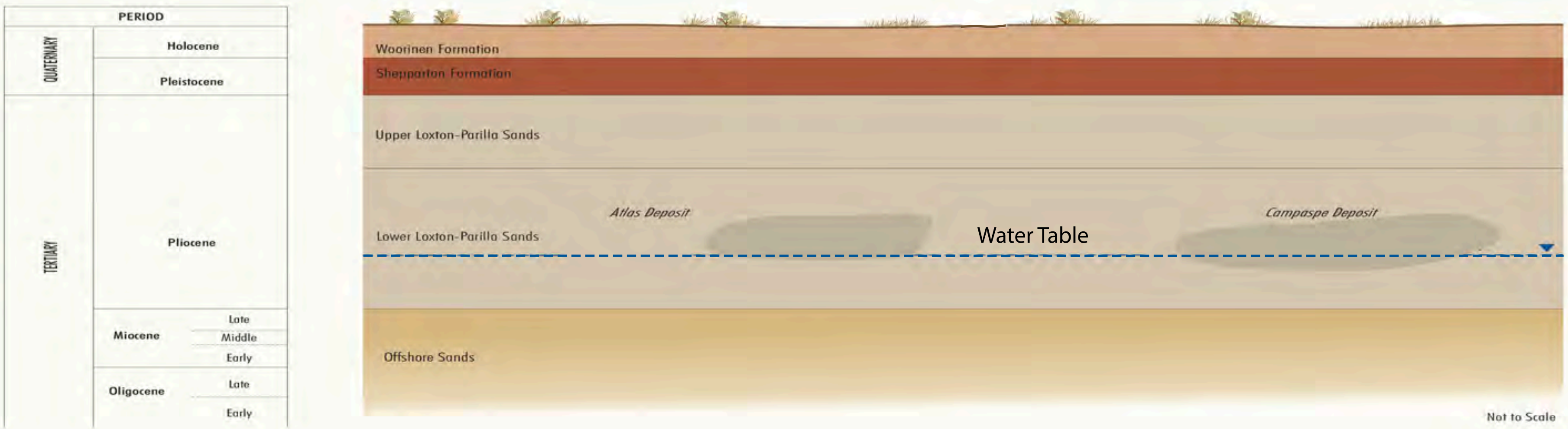


Figure 13a

Mine/GDW Interaction - Atlas Completed, Mining at Campaspe

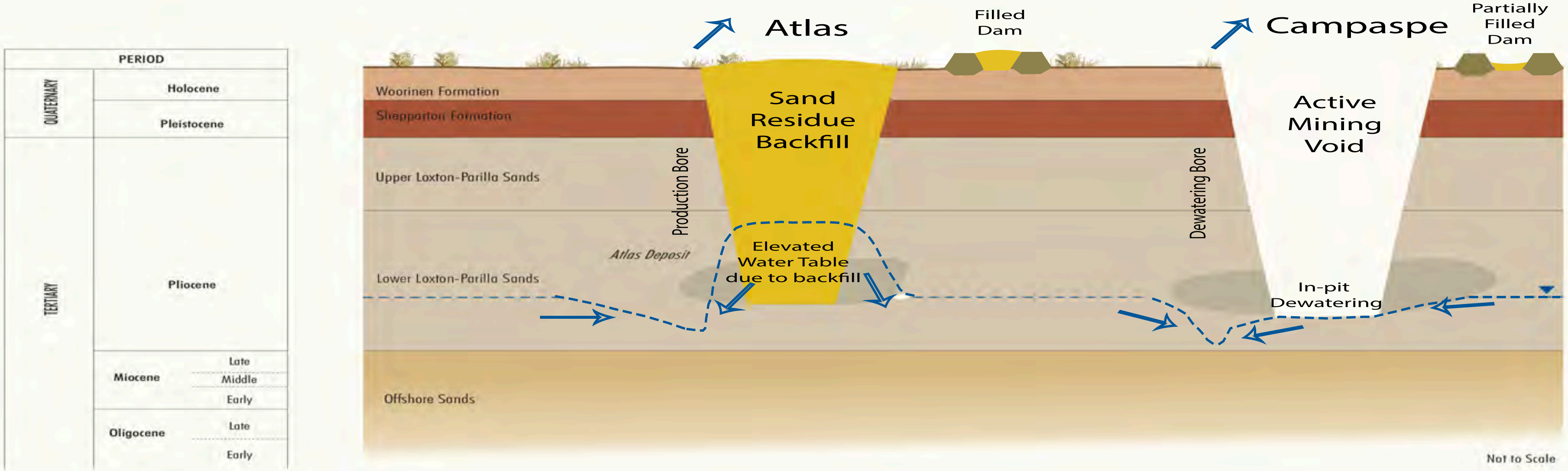
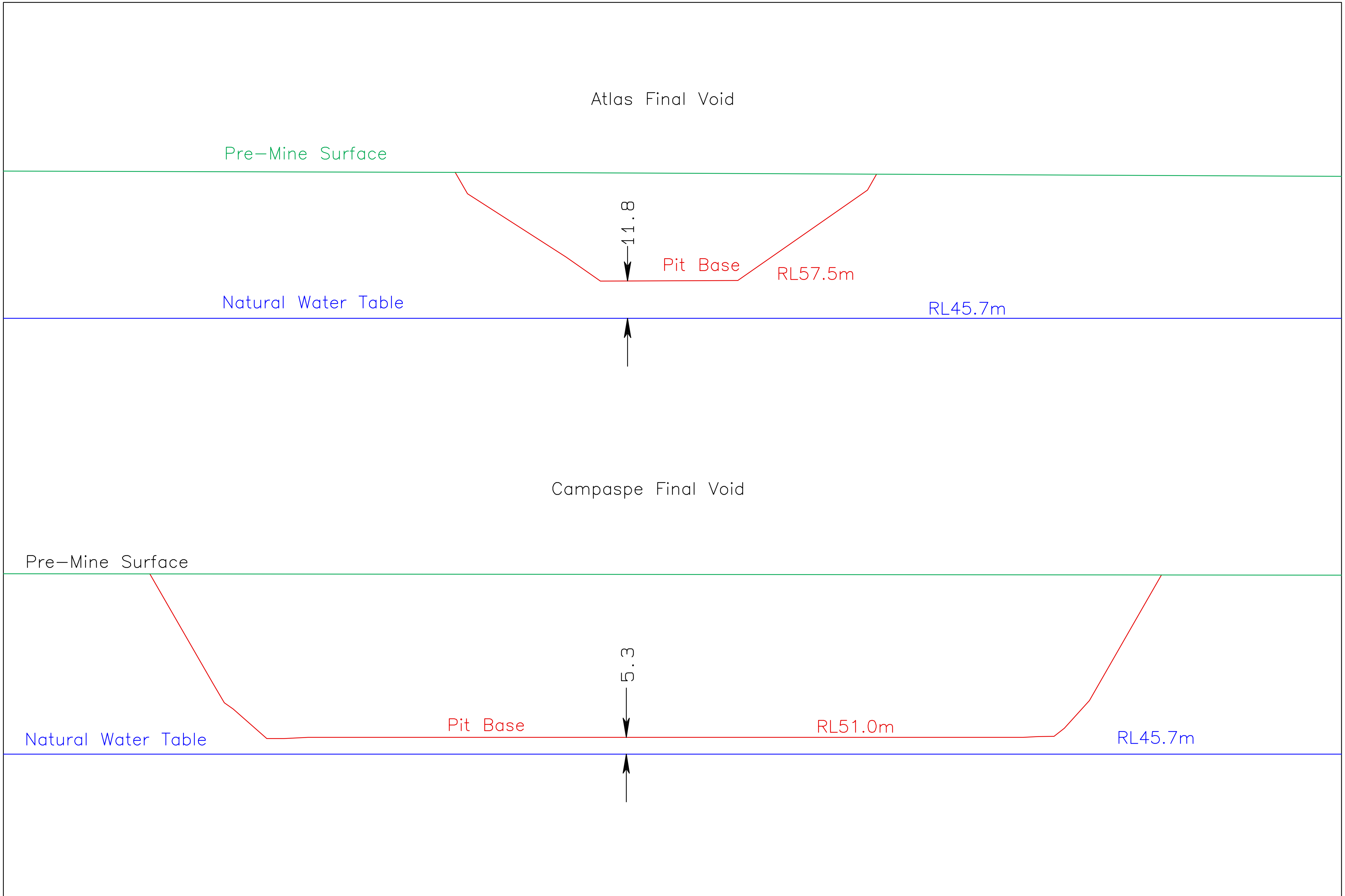


Figure 13b



28 x 18.72	*Legend:*	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Final Voids Depth to Water Table	Plotted: May 2 2013	Design: GEO-ENG	Surveyed: Cristal	Contour int: NA Index contour: NA	DATUMS: Hor: Ver: AHD Plan Scale - 1 : 1500	Figure 14 File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro

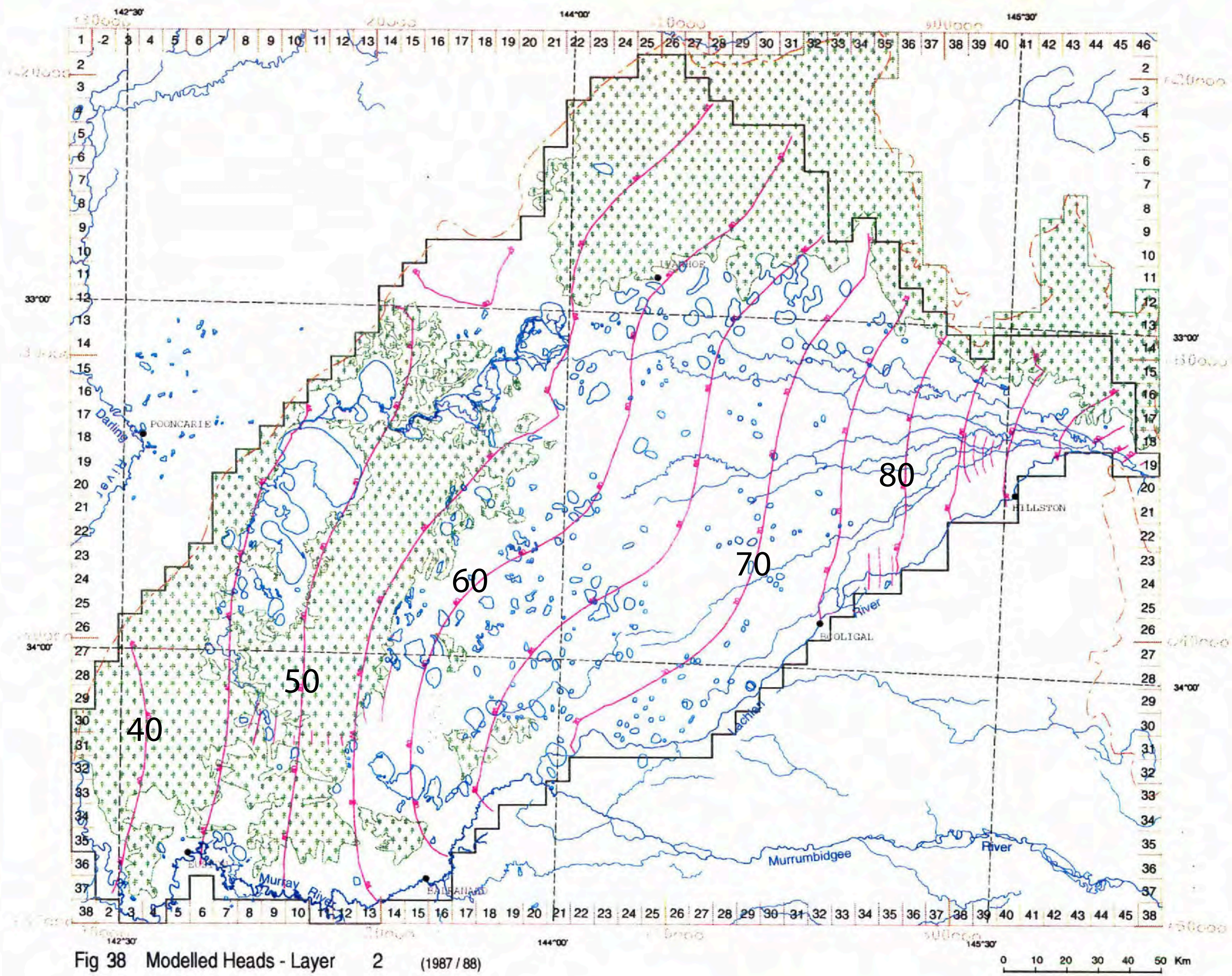


Fig 38 Modelled Heads - Layer 2 (1987 / 88)

From Kellet 1997, Ivanhoe Block Model Tps/Tpc Layer Heads (m AHD)

Figure 15

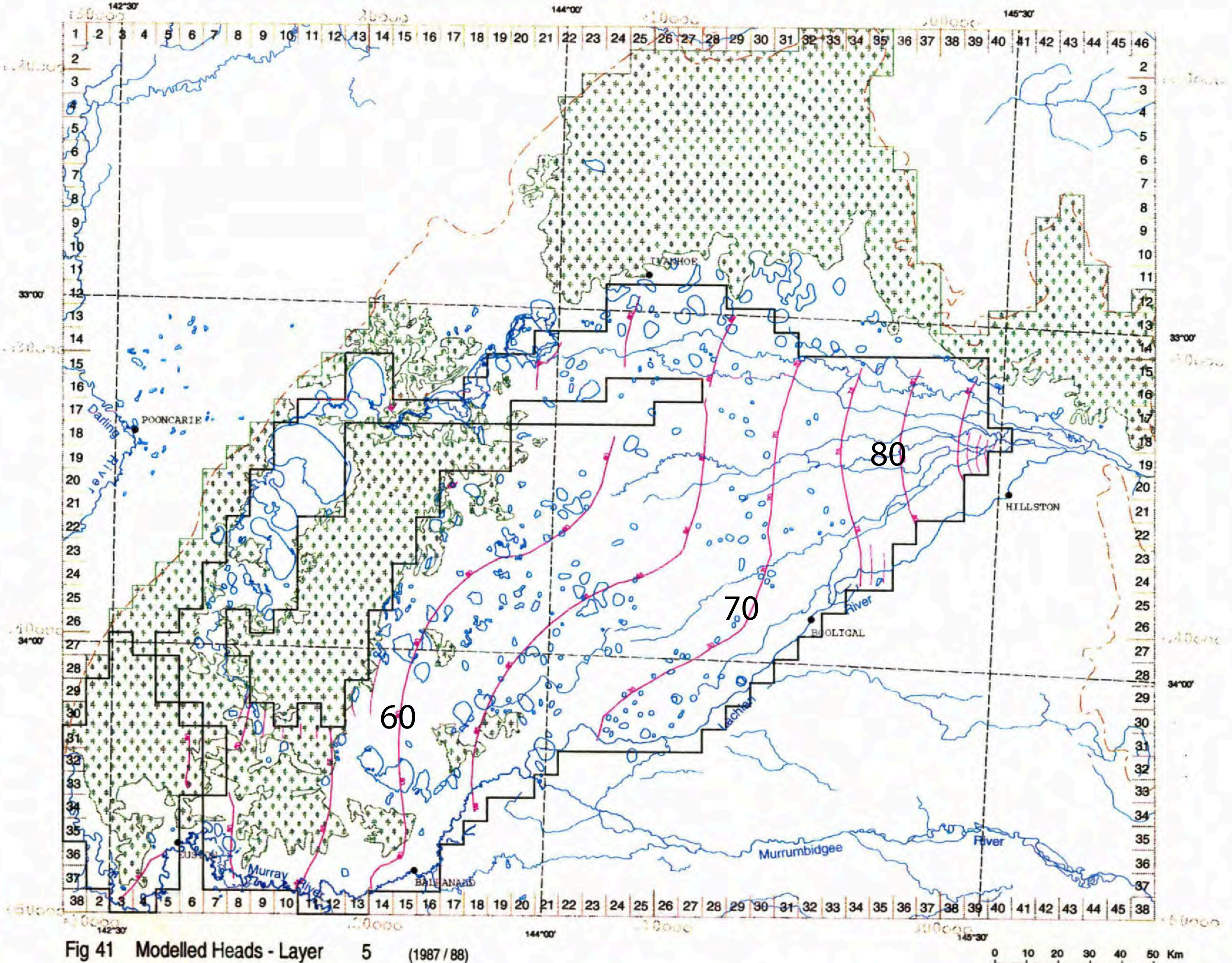
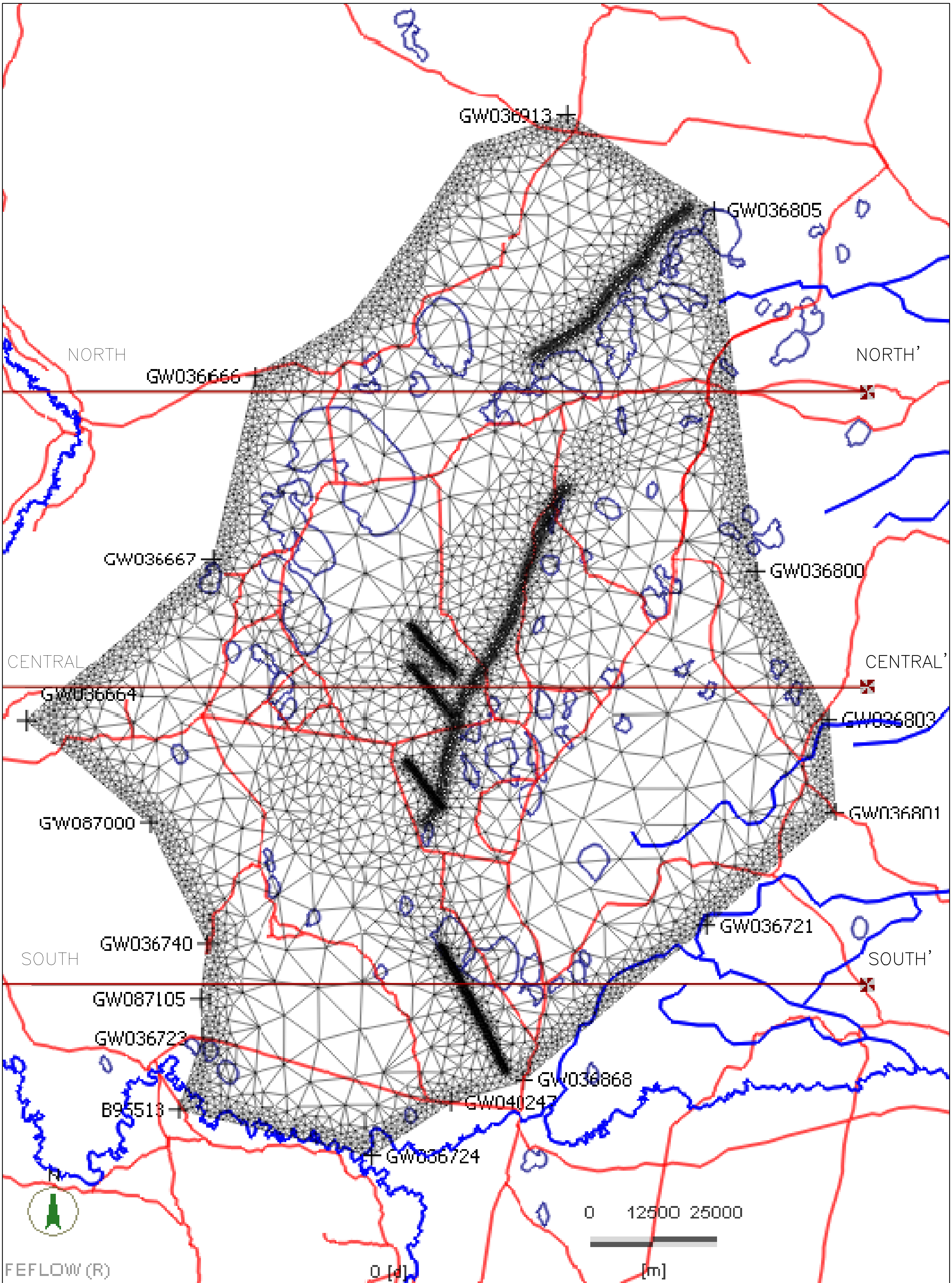


Fig 41 Modelled Heads - Layer 5 (1987 / 88)

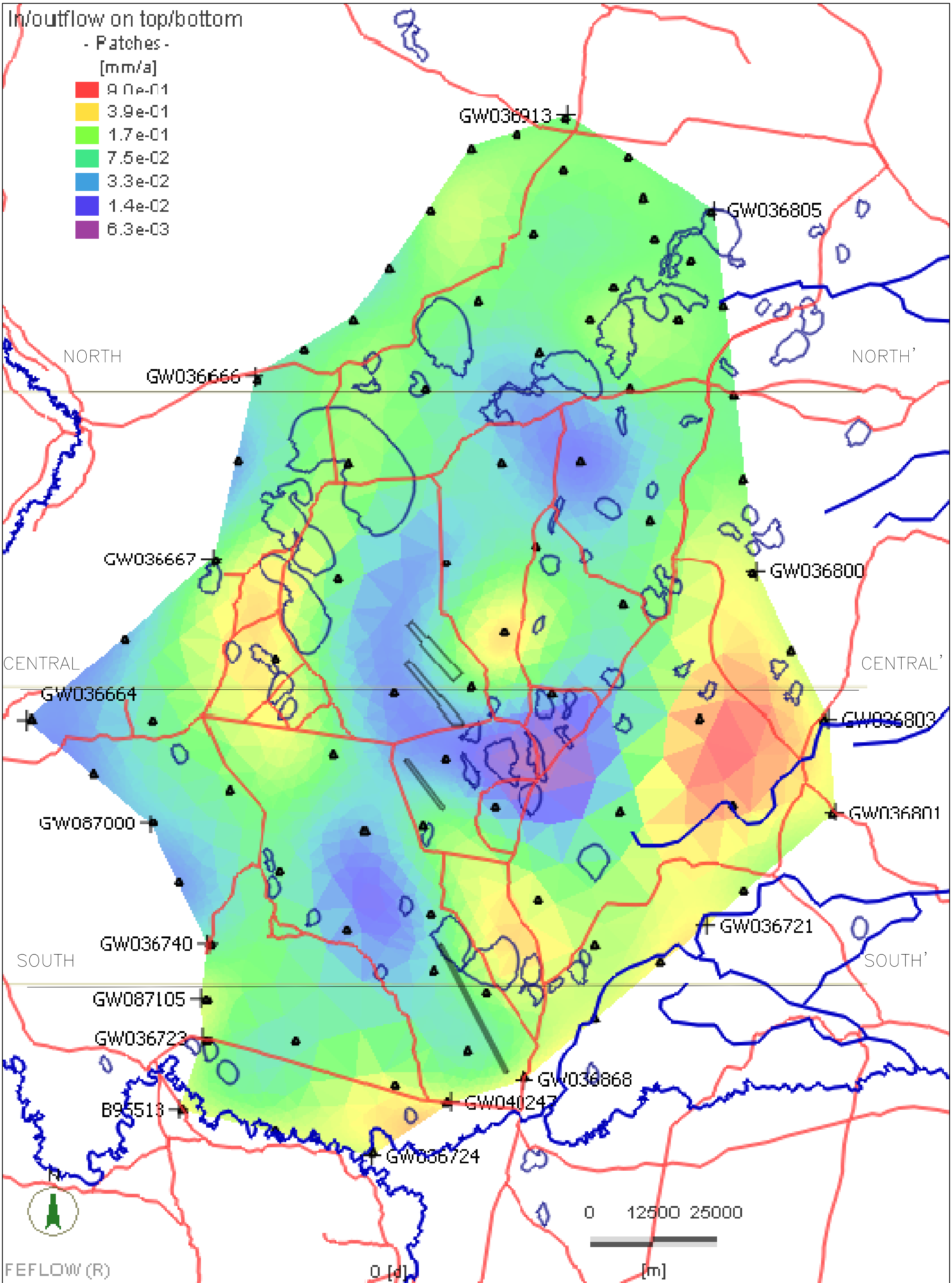
From Kellet 1997, Ivanhoe Block Model Ter1 Layer Heads (mAHD)

Figure 16



19.5 x 26.41	Note: Cross-section location for Figure 11	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Mesh Design
Plotted: May 28 2013	Design: GEOENG	Contour int: 1m DATUMS: Hor: Ver: A4 - 1 : 172000	Figure 17

C:\GE\TM\Current\Bemax\Campaspe\c10.pro



19.5 x 26.41	Note: ▲ Pilot Point Location	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Pilot Point Locations and Calibration Infiltration Rate

Plotted: Apr 30 2013	Design: GEOENG	Contour int: 1m	DATUMS: Hor: Ver: AHD	A4 - 1 : 172000

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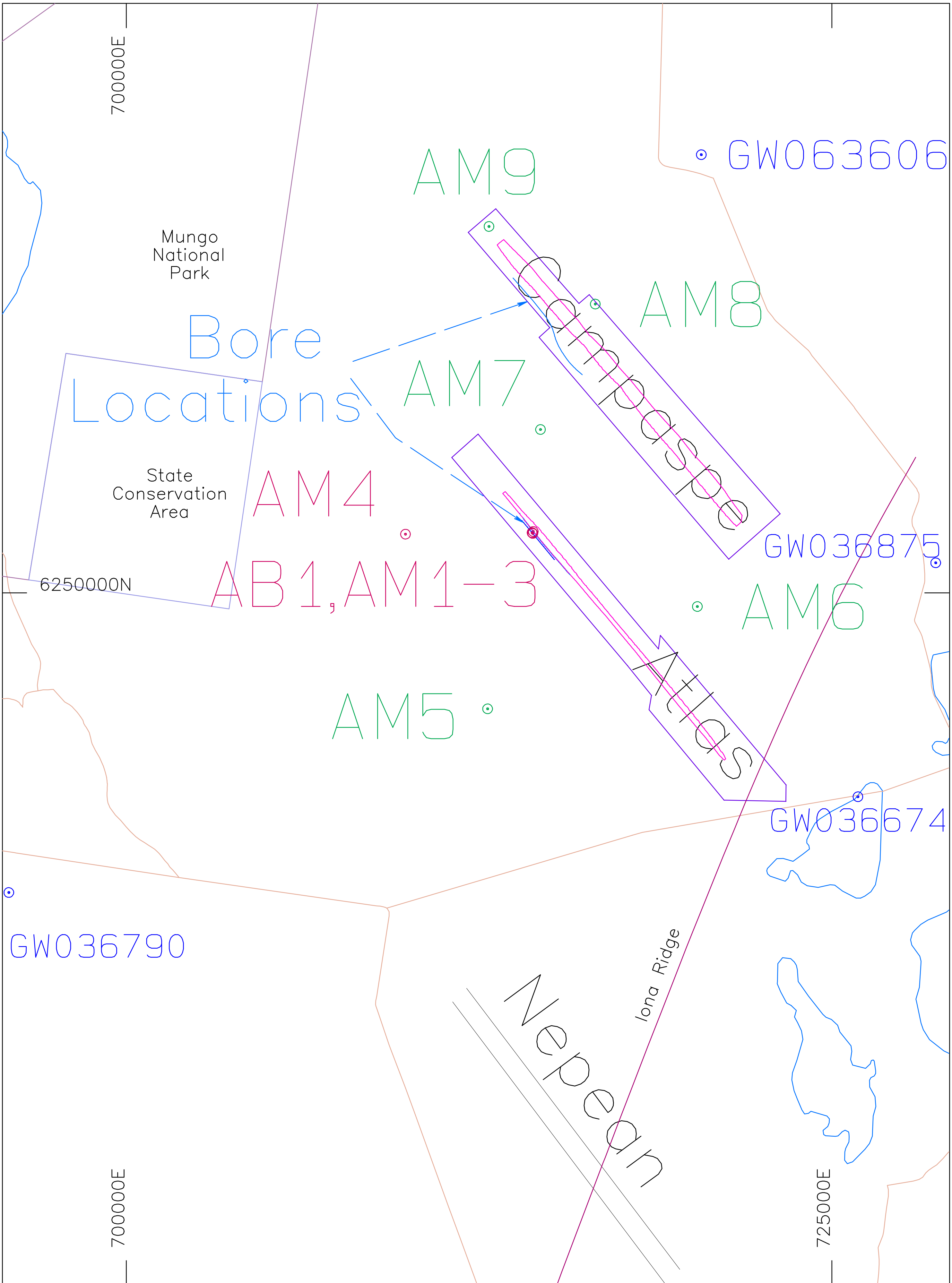
Figure 18



19.5 x 26.41

Note:
⊙ Proposed Bores
⊙ Existing Cristal Bores
⊙ Existing Government Bores

North

Cristal Mining Australia
Atlas/Campaspe Groundwater Model

Groundwater Monitoring Locations

Plotted: Mar 9 2013

Design: GEOENG

DATUMS: Hor: Ver: AHD

A4 - 1 : 172,000

File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro

Figure 19

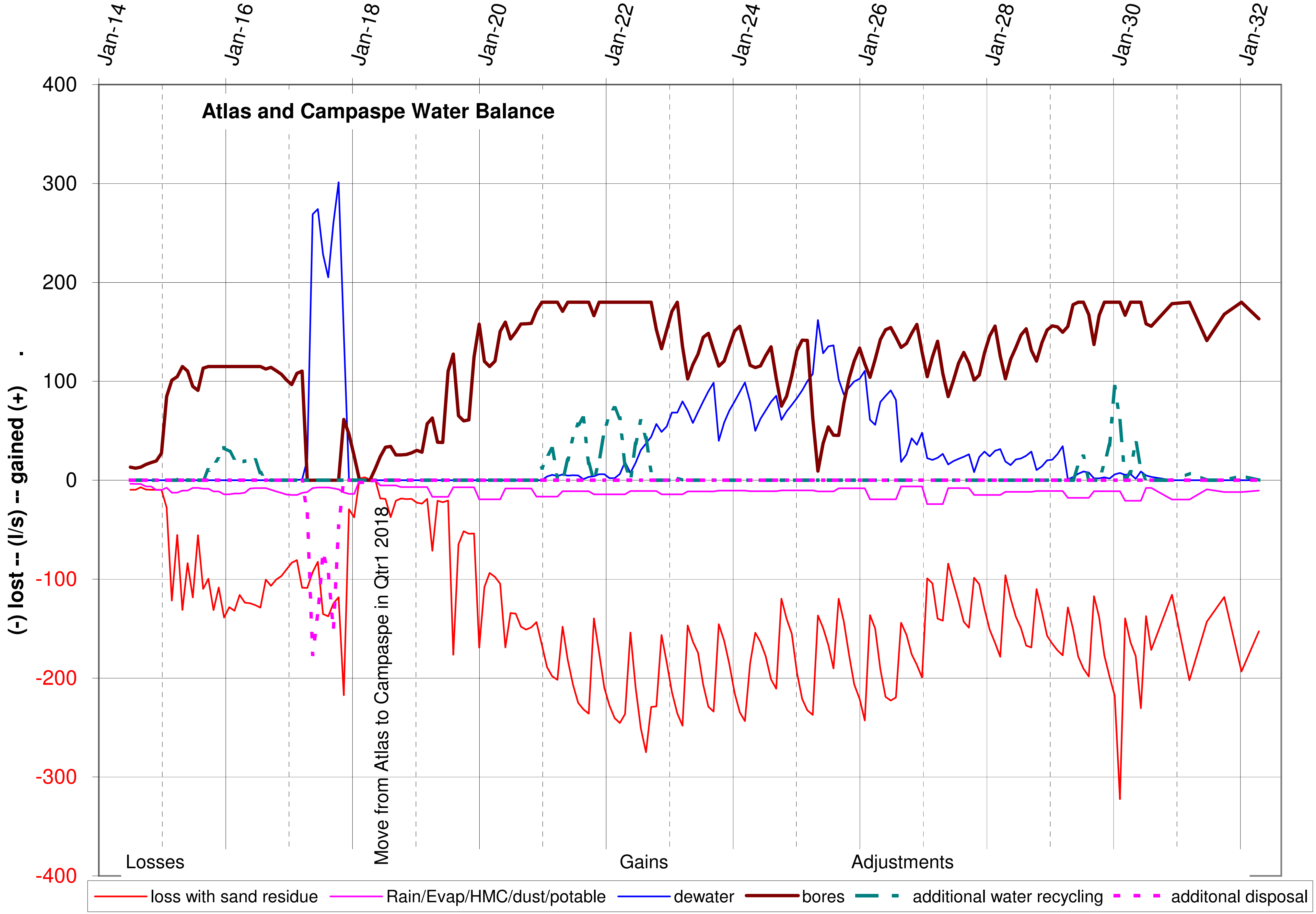
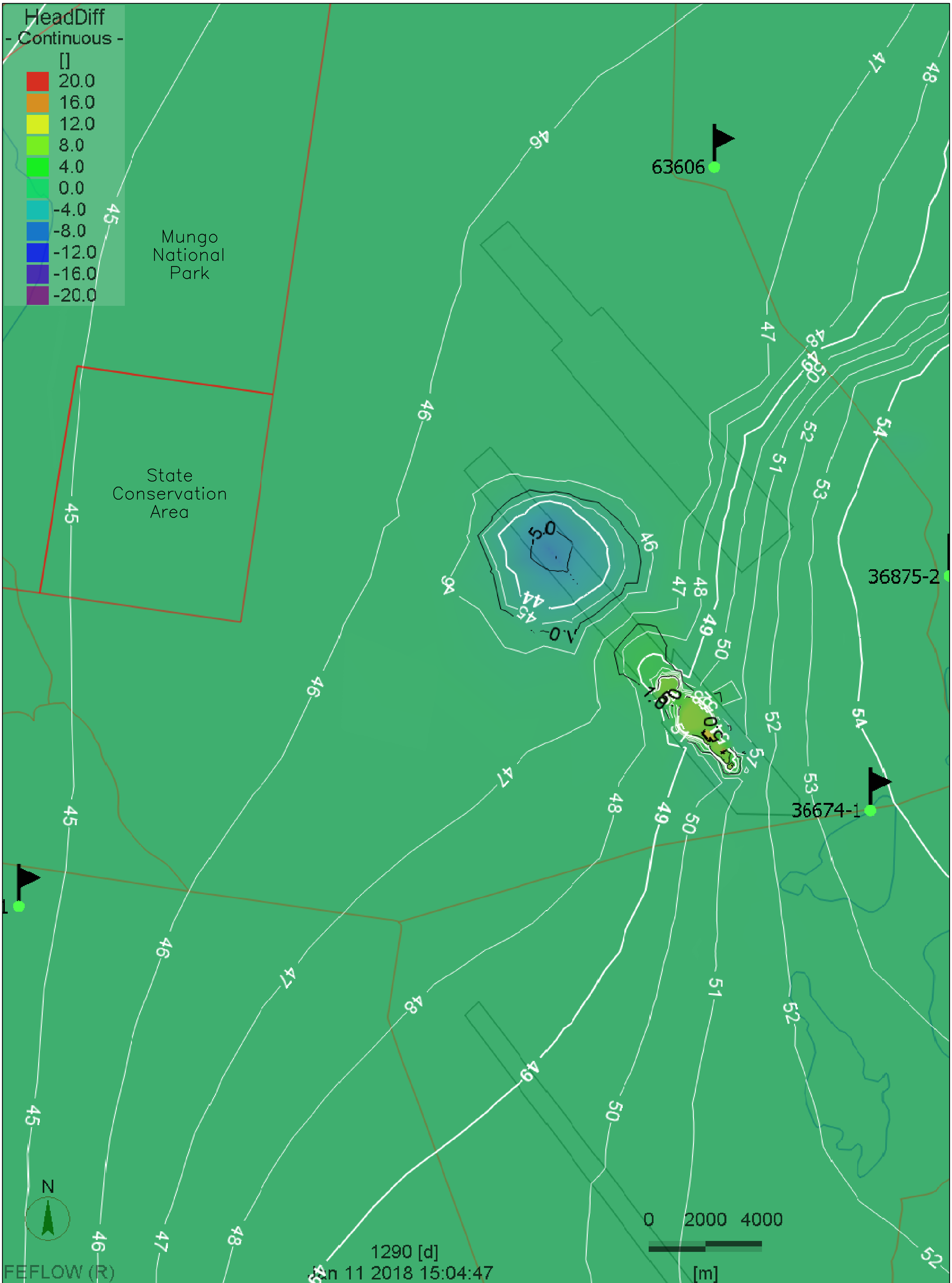
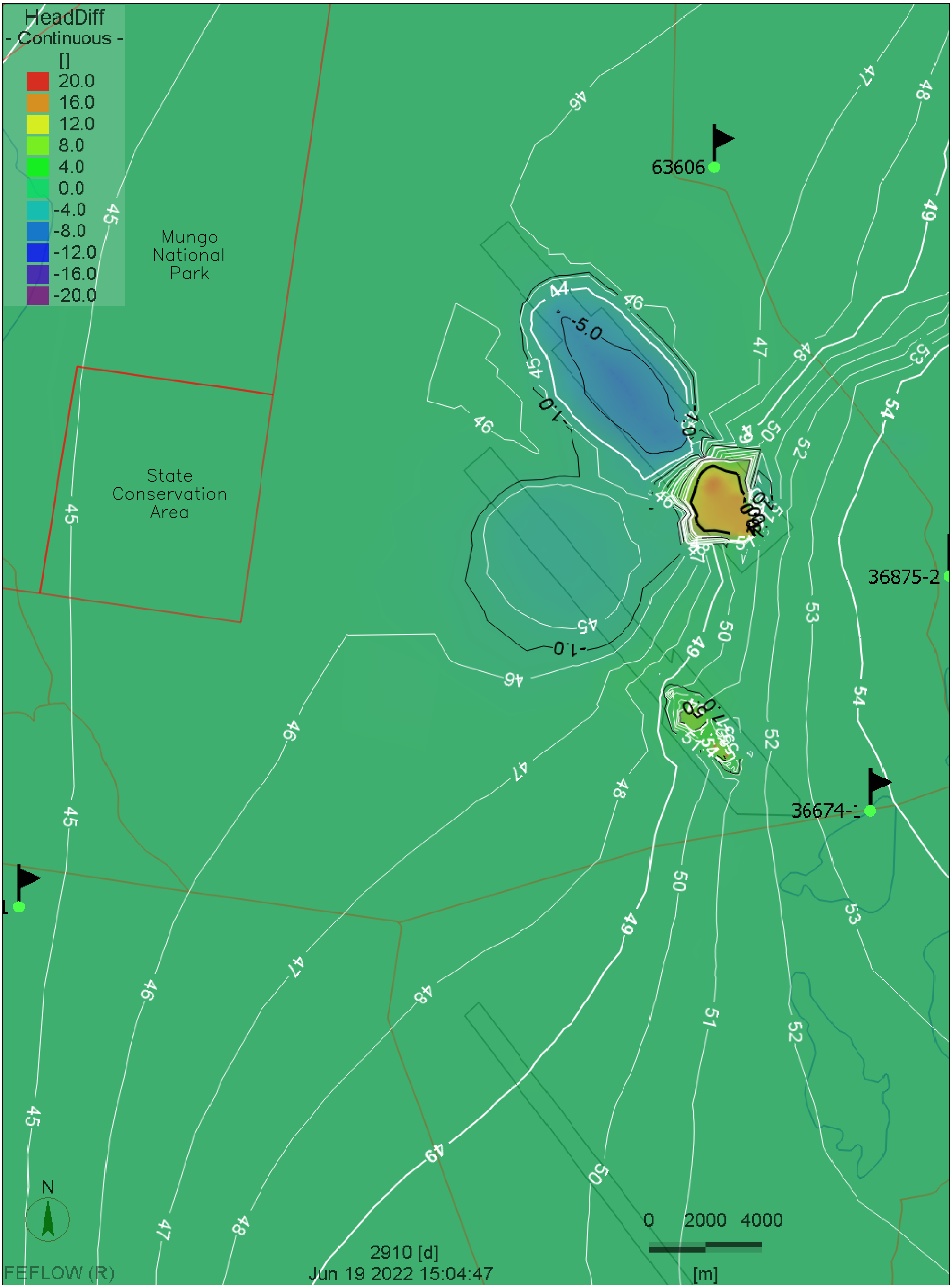

Atlas and Campaspe Water Balance
Jan-14
Jan-16
Jan-18
Jan-20
Jan-22
Jan-24
Jan-26
Jan-28
Jan-30
Jan-32
400
300
200
100
0
-100
-200
-300
-400
(-) lost -- (l/s) -- gained (+)
Move from Atlas to Campaspe in Qtr1 2018
Losses
Gains
Adjustments
loss with sand residue
Rain/Evap/HMC/dust/potable
dewater
bores
additional water recycling
additonal disposal

Figure 20

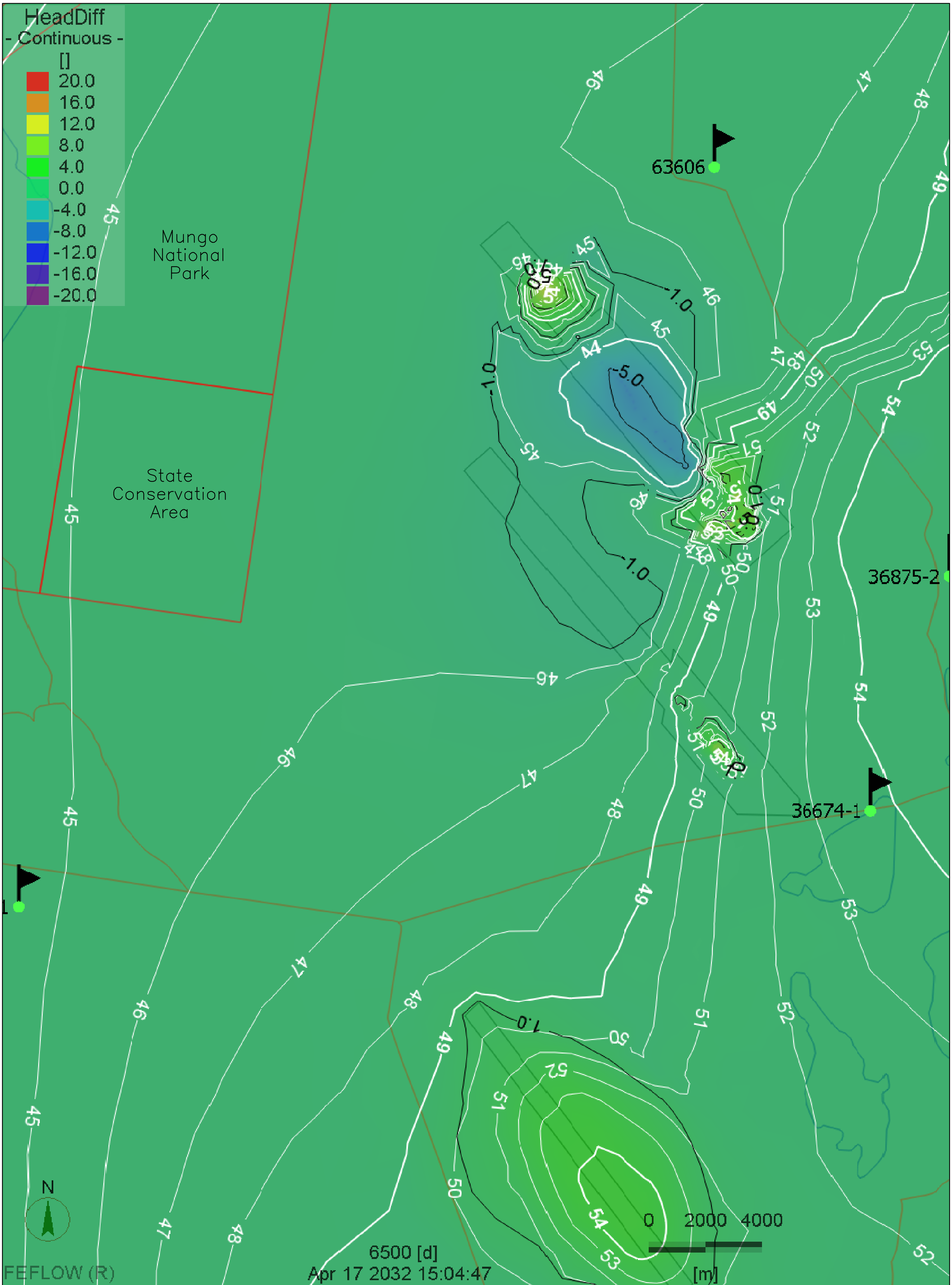


19.5 x 26.41	Note: Base (Calibrated) Case Parameters Layer 2 (Tp)	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Drawdown and Water Level (m AHD) Project Year 5 (End of Atlas)

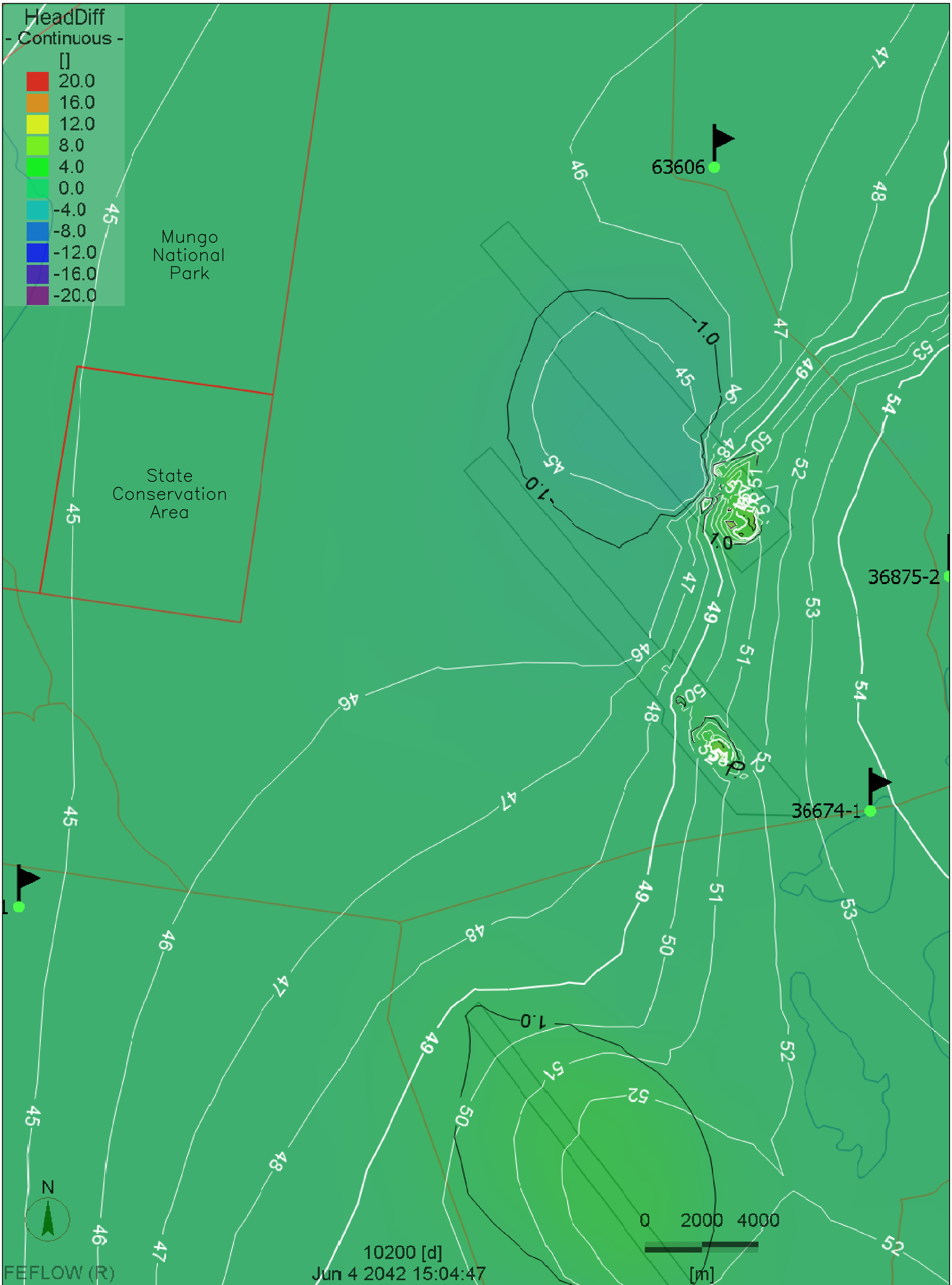
Plotted: Mar 9 2013	Design: GEOENG	File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro	DATUMS: Hor: Ver: AHD	A4 - 1 : 172,000	Figure 21



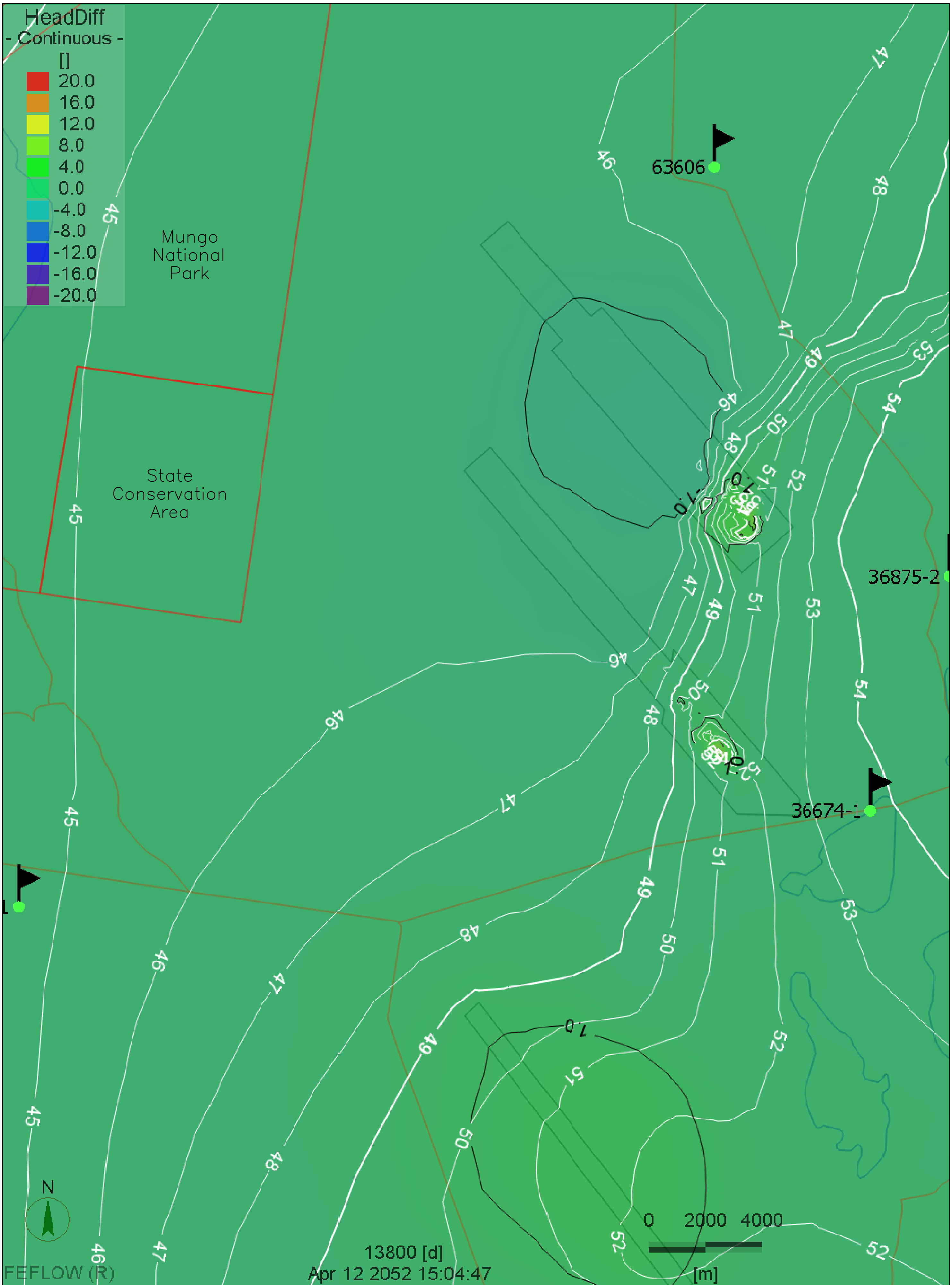
19.5 x 26.41	Note: Base (Calibrated) Case Parameters Layer 2 (Tp)	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Drawdown and Water Level (m AHD) Project Year 12
	Plotted: Mar 9 2013	Design: GEOENG	File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro	DATUMS: Hor: Ver: AHD A4 - 1 : 172,000 Figure 22



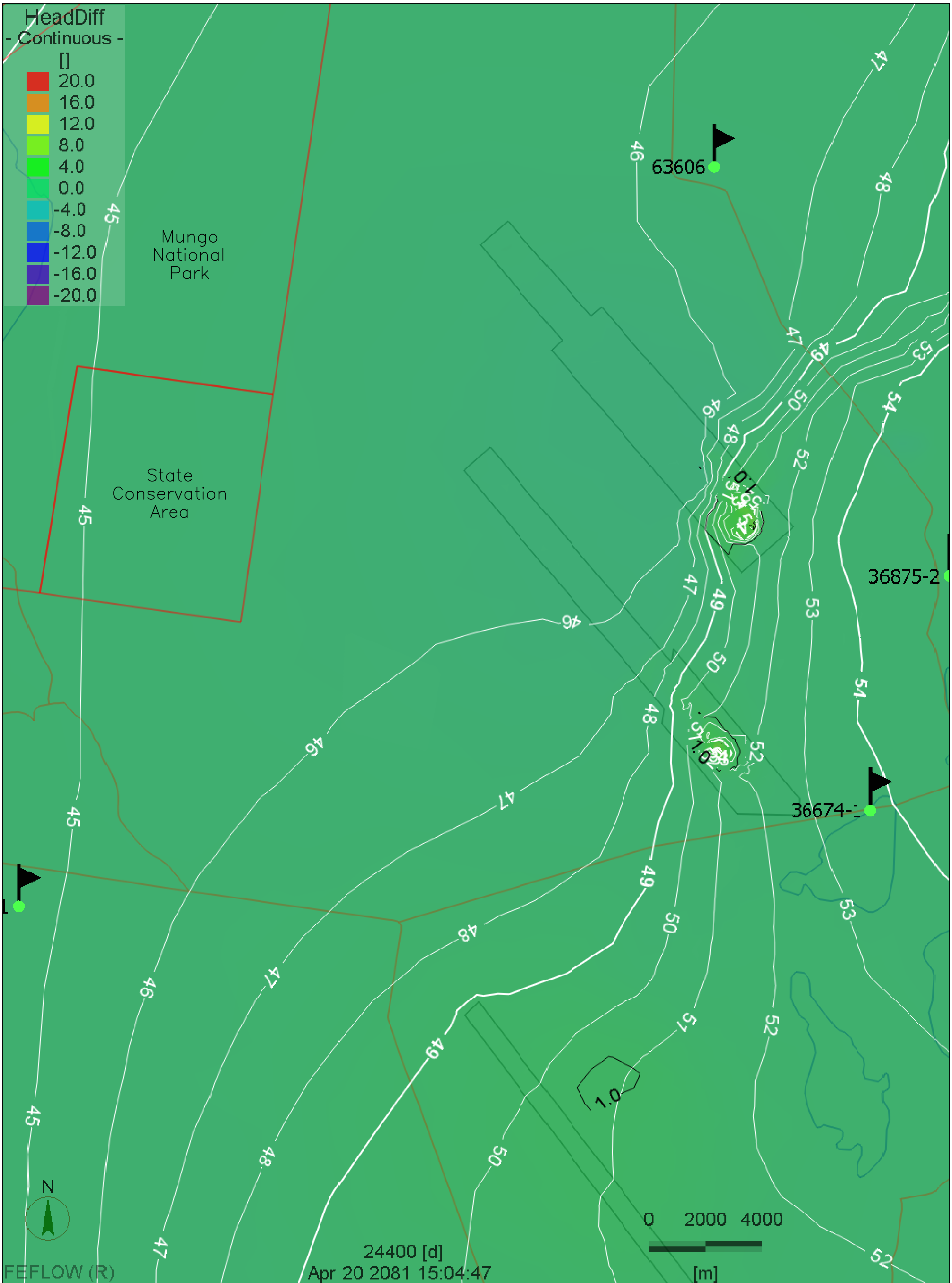
19.5 x 26.41	Note: Base (Calibrated) Case Parameters Layer 2 (Tp)	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Drawdown and Water Level (m AHD) Project Year 20 (End of Campaspe)
Plotted: Mar 9 2013	Design: GEOENG	DATUMS: Hor: Ver: AHD	A4 - 1 : 172,000
File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro			Figure 23



19.5 x 26.41	Note: Base (Calibrated) Case Parameters Layer 2 (Tp)	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Drawdown and Water Level (m AHD) Post-mining + 10 YR
Plotted: Mar 9 2013	Design: GEOENG	File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro DATUMS: Hor: Ver: AHD	A4 - 1 : 172,000 Figure 24



19.5 x 26.41	Note: Base (Calibrated) Case Parameters Layer 2 (Tp)	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Drawdown and Water Level (m AHD) Post-mining + 20 YR
	Plotted: Mar 9 2013	Design: GEOENG	File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro	DATUMS: Hor: Ver: AHD A4 - 1 : 172,000 Figure 25



19.5 x 26.41

Note: Base (Calibrated) Case Parameters
Layer 2 (Tp)

North

Cristal Mining Australia
Atlas/Campaspe Groundwater Model

Drawdown and Water Level (m AHD)
Post-mining + 50 YR

Plotted: Mar 9 2013

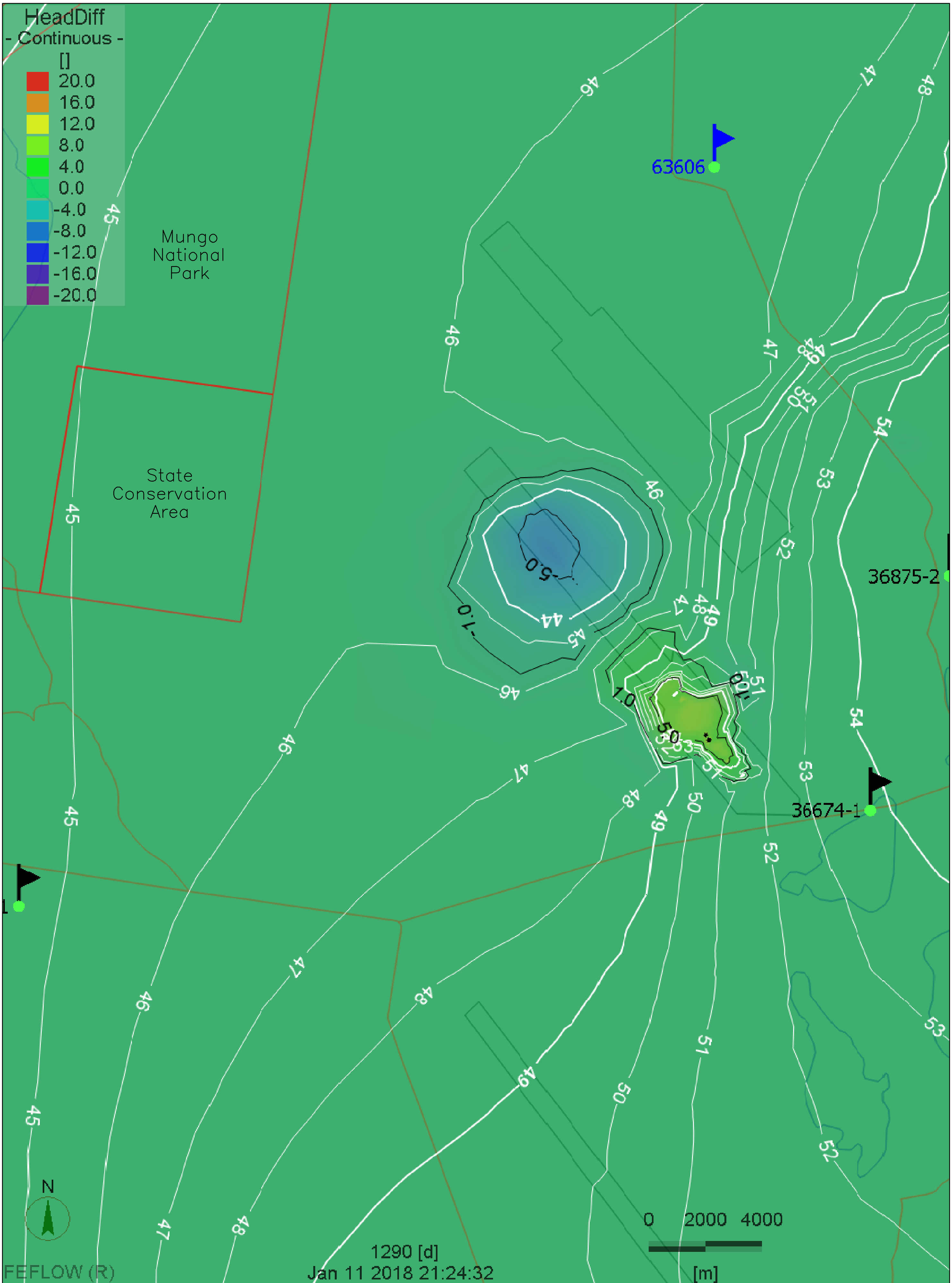
Design: GEOENG

File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro

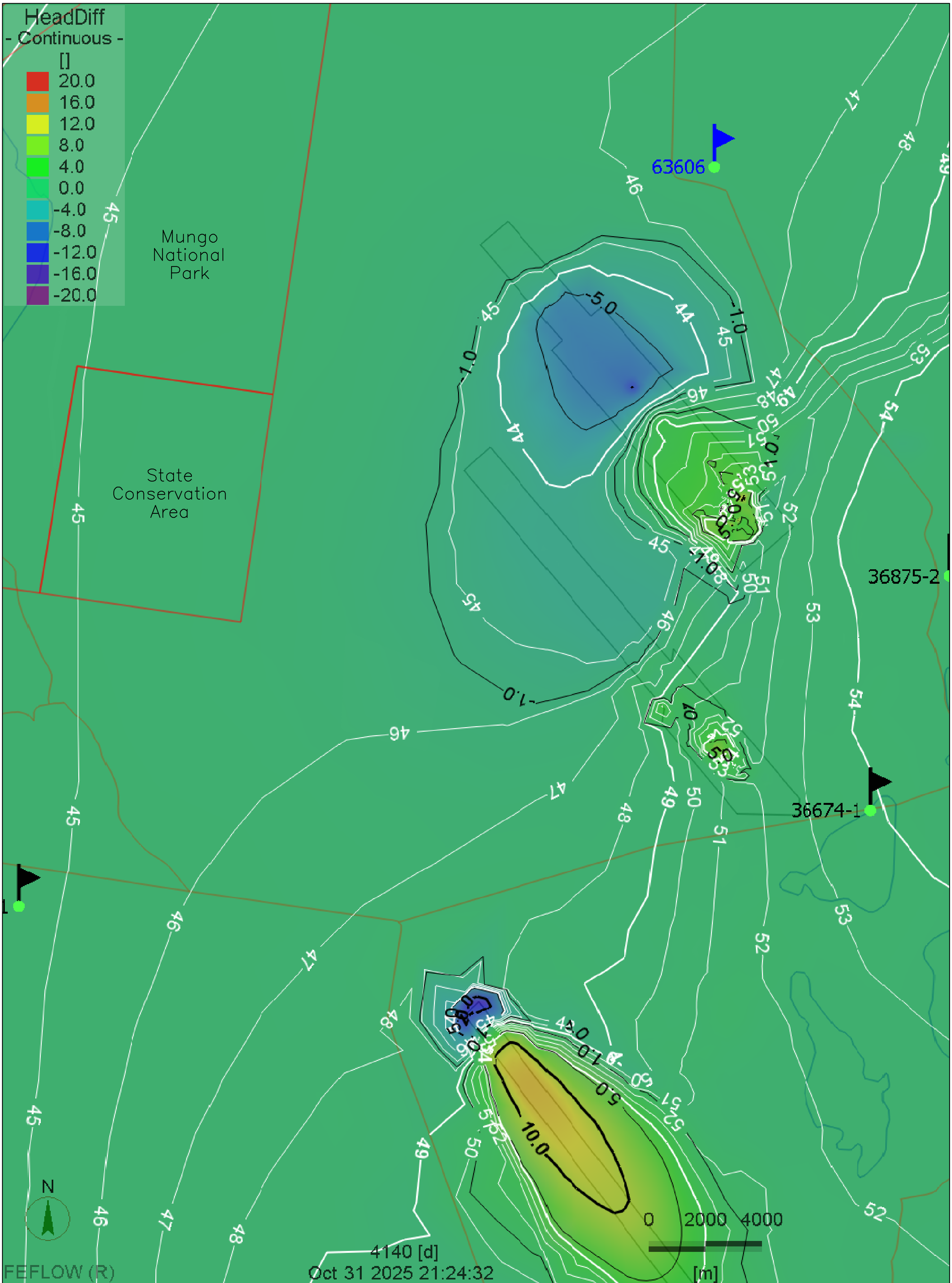
DATUMS: Hor: Ver: AHD

A4 - 1 : 172,000

Figure 26



19.5 x 26.41	*Note:* Worst Case Parameters Layer 2 (Tp)	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Drawdown and Water Level (m AHD) Project Year 5 (End of Atlas)
Plotted: Mar 9 2013	Design: GEOENG	C:\GE\TM\Current\Bemax\Campaspe\c10.pro	DATUMS: Hor: Ver: AHD · A4 - 1 : 172,000 · Figure 27



19.5 x 26.41

Note: Worst Case Parameters
Layer 2 (Tp)

Cristal Mining Australia
Atlas/Campaspe Groundwater Model

Drawdown and Water Level (m AHD)
Project Year 12

Plotted: Mar 9 2013

Design: GEOENG

DATUMS: Hor: Ver: AHD

A4 - 1 : 172,000

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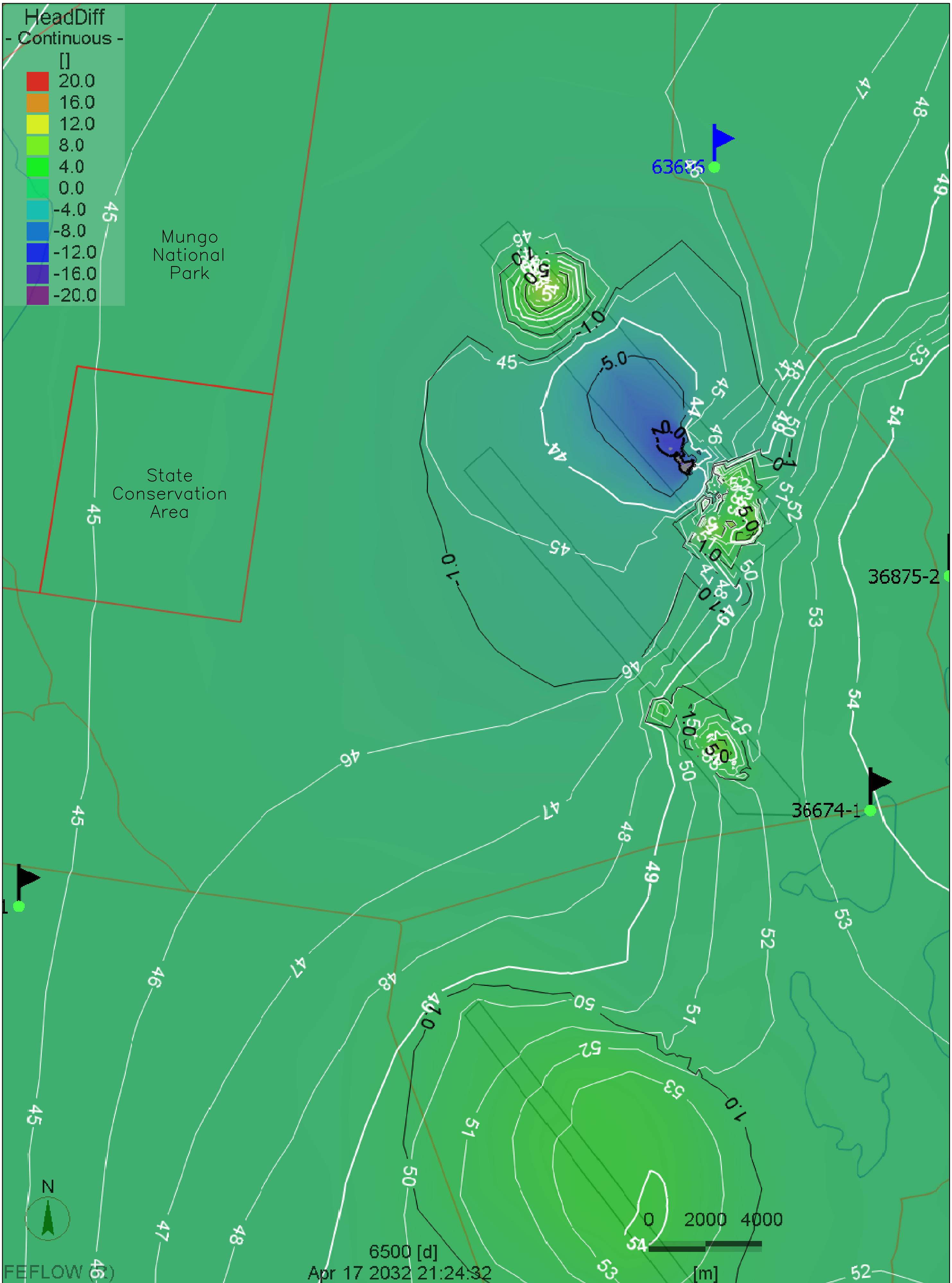
Figure 28

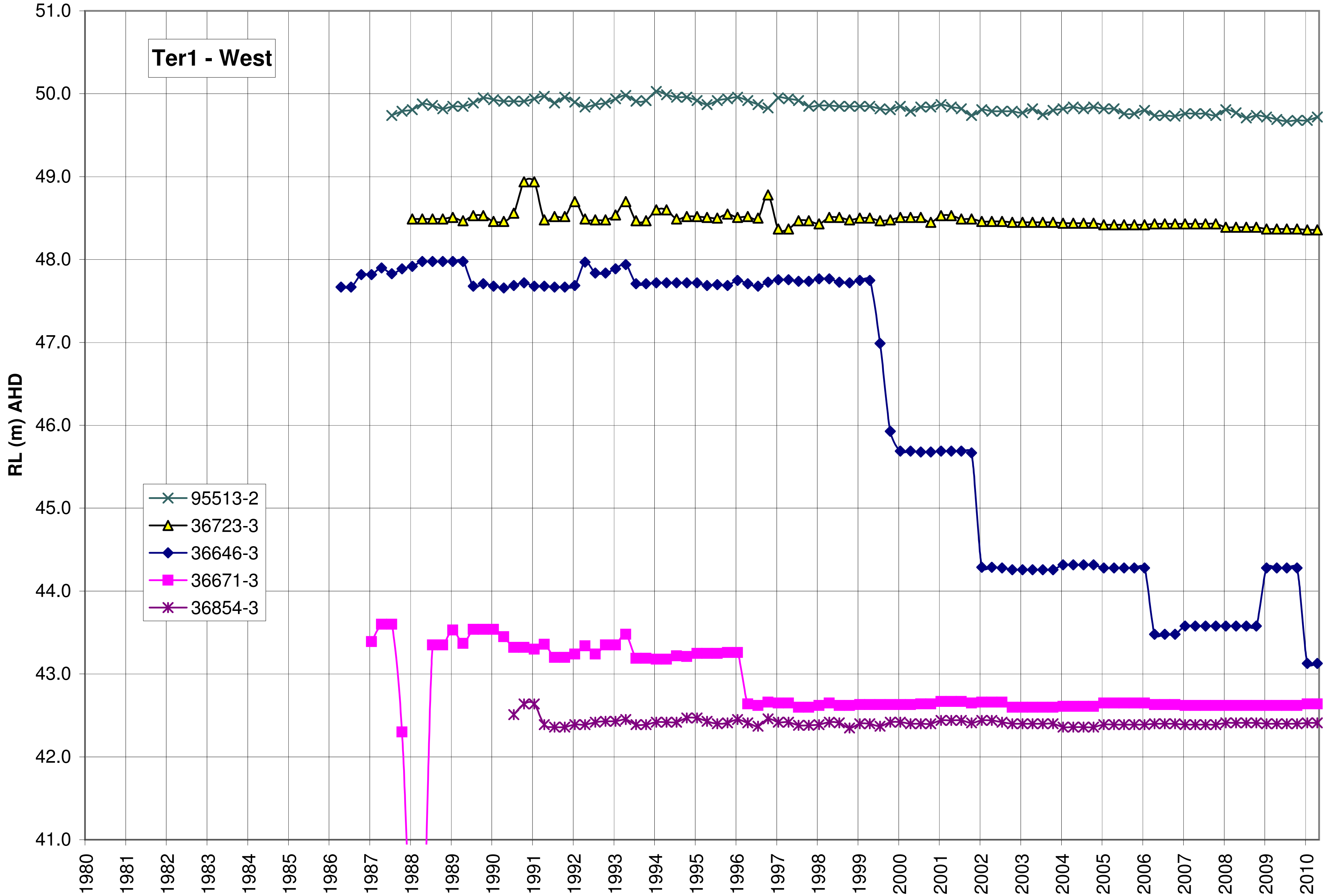


19.5 x 26.41	*Note:* Worst Case Parameters Layer 2 (Tp)	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Drawdown and Water Level (m AHD) Project Year 20 (End of Campaspe)

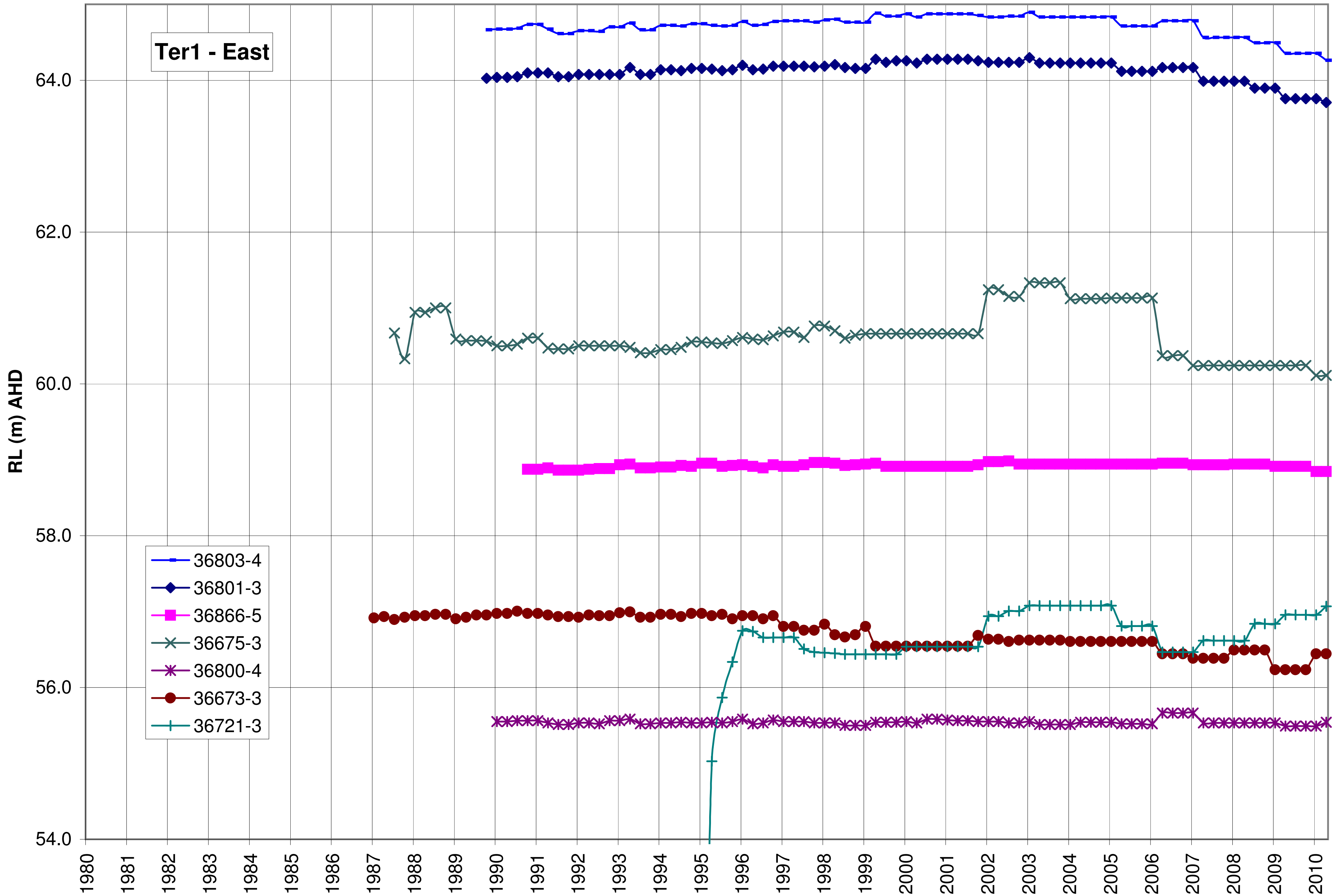
Plotted: Mar 9 2013	Design: GEOENG	File No.: C:\GE\TM\Current\Bemax\Campaspe\c10.pro	DATUMS: Hor: Ver: AHD	A4 - 1 : 172,000	Figure 29

ATTACHMENT A

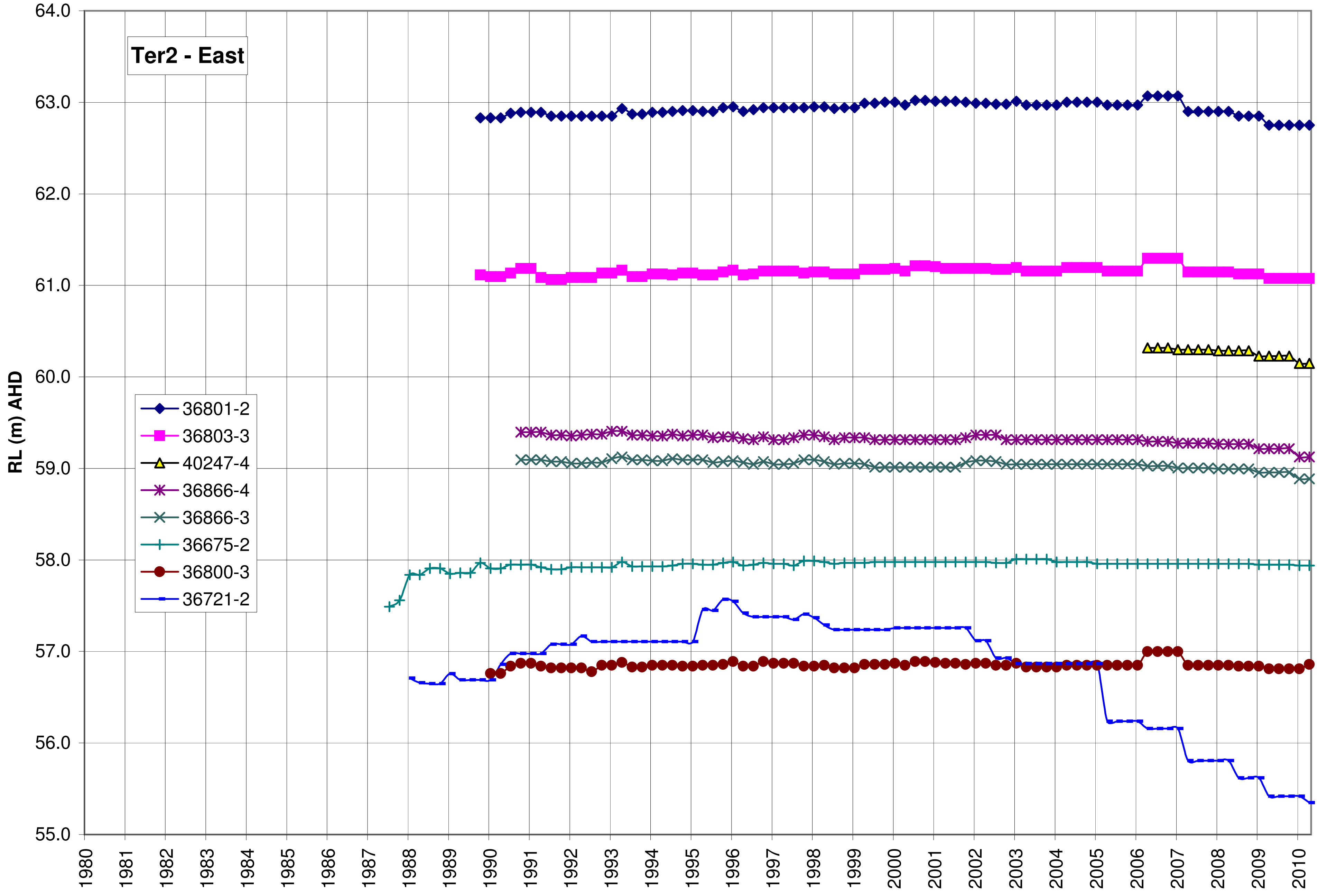
MONITORING BORE HYDROGRAPHS AND RAINFALL RESIDUAL MASS CURVES



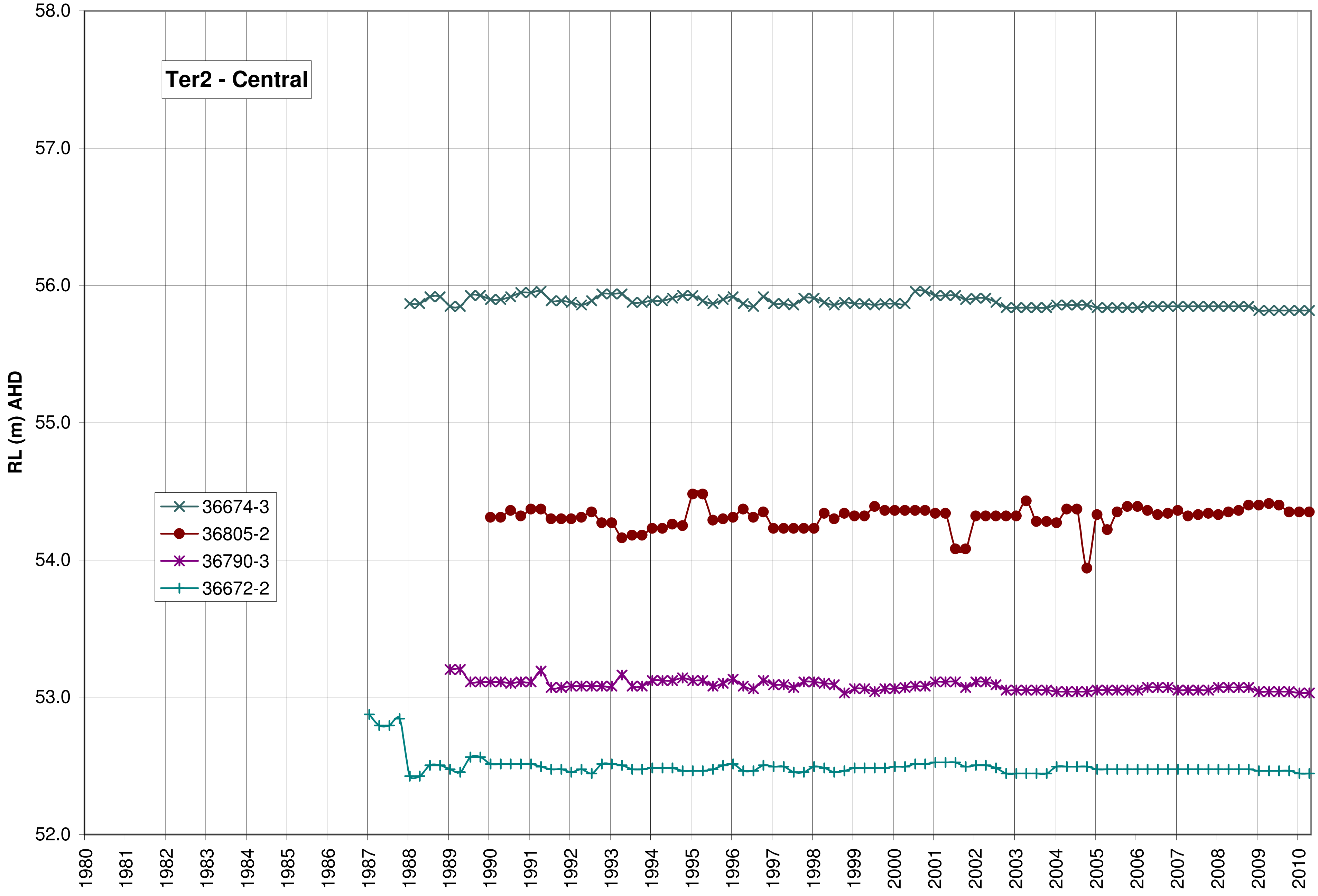
Ter1 - West
RL (m) AHD
95513-2
36723-3
36646-3
36671-3
36854-3
51.0
50.0
49.0
48.0
47.0
46.0
45.0
44.0
43.0
42.0
41.0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010



Ter1 - East
RL (m) AHD
64.0
62.0
60.0
58.0
56.0
54.0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
36803-4
36801-3
36866-5
36675-3
36800-4
36673-3
36721-3



Ter2 - East
RL (m) AHD
64.0
63.0
62.0
61.0
60.0
59.0
58.0
57.0
56.0
55.0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
36801-2
36803-3
40247-4
36866-4
36866-3
36675-2
36800-3
36721-2



Ter2 - Central
RL (m) AHD
58.0
57.0
56.0
55.0
54.0
53.0
52.0
36674-3
36805-2
36790-3
36672-2
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
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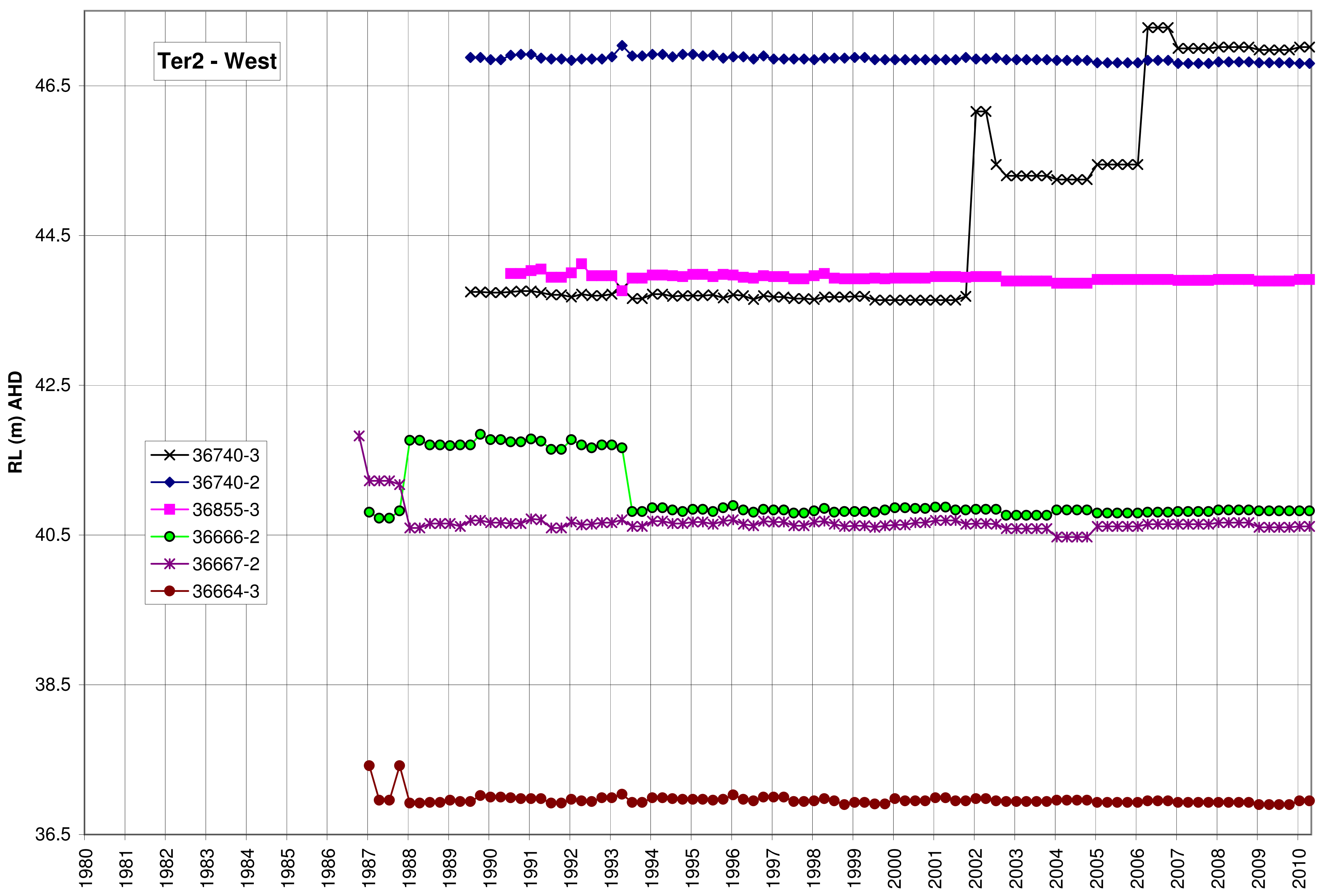
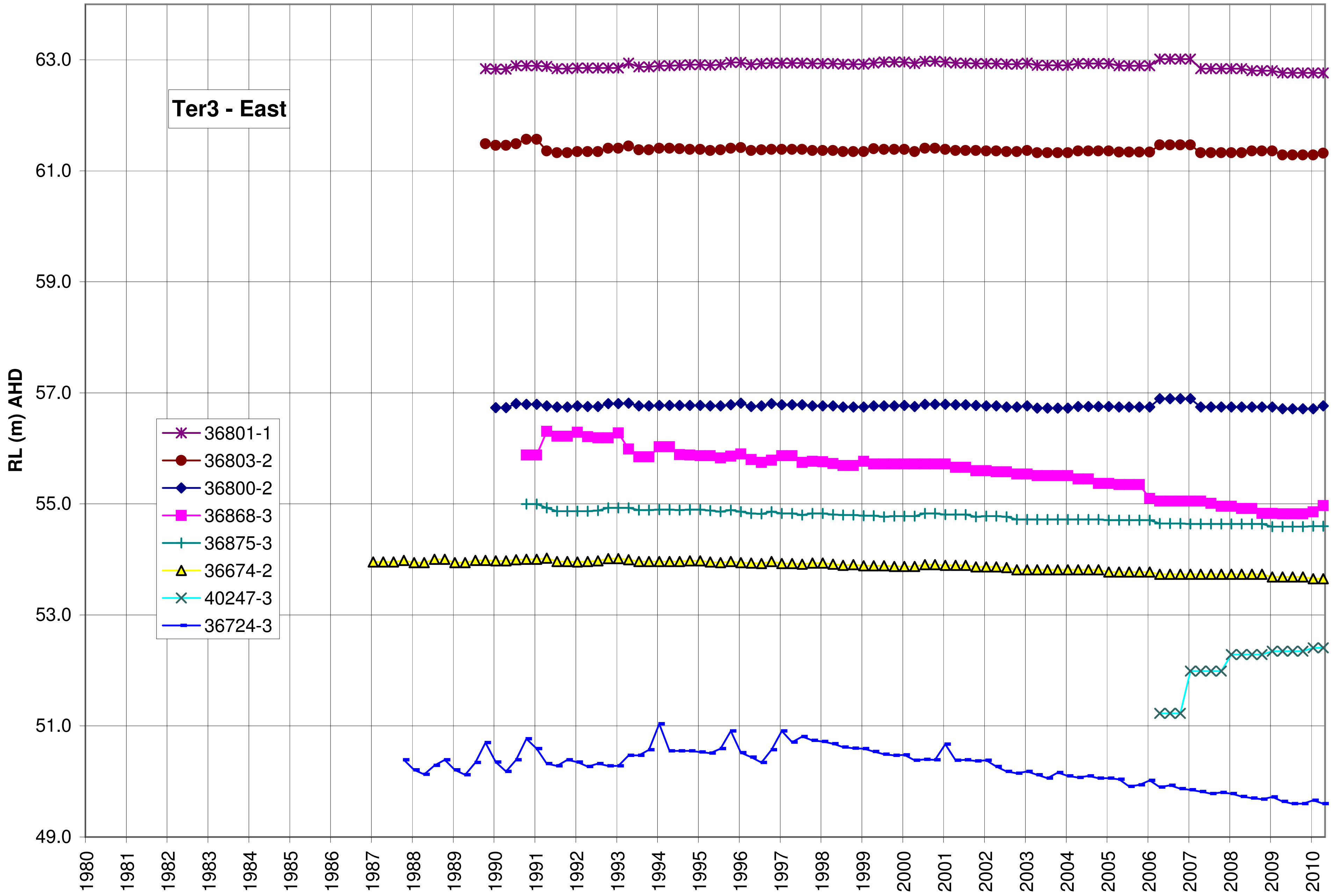
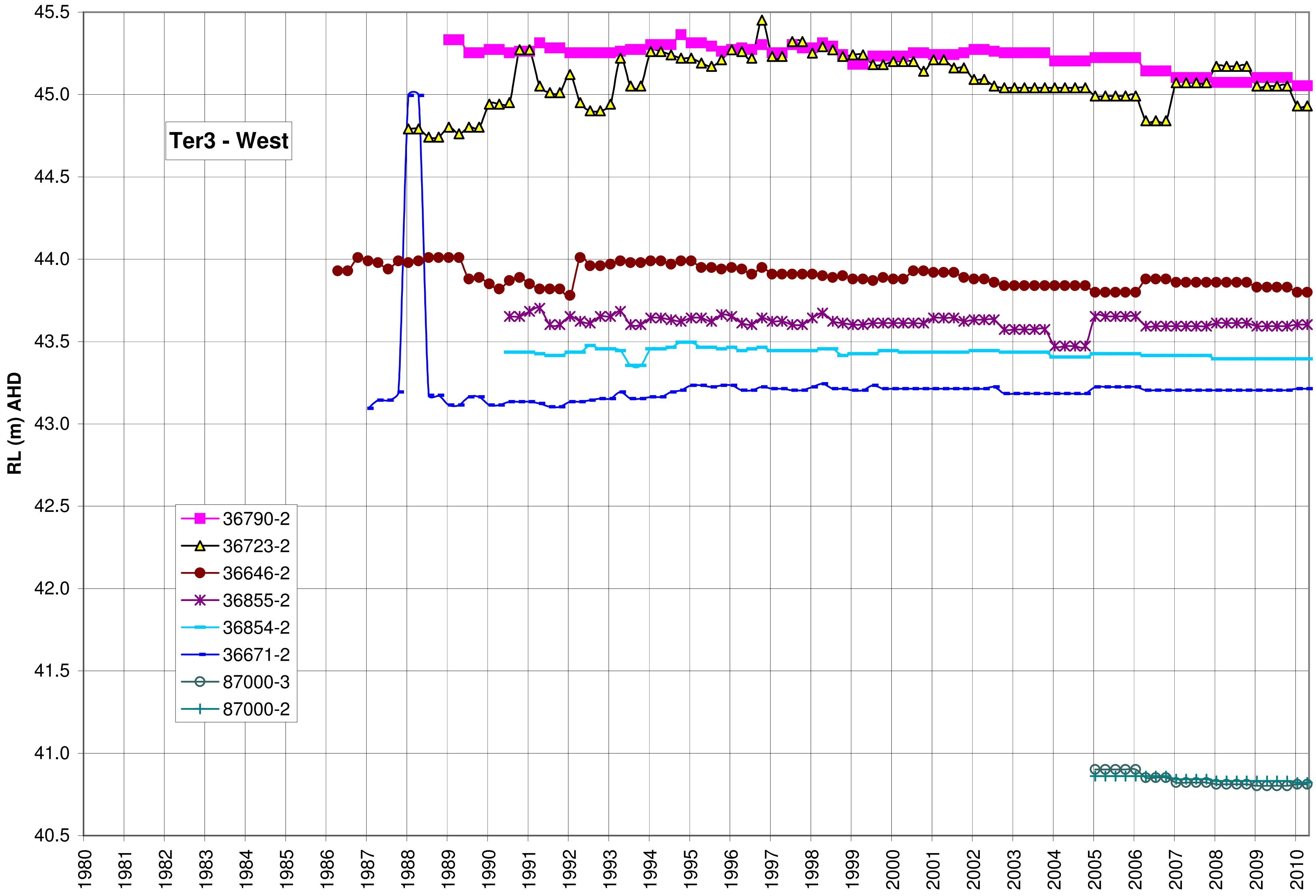
2003
2004
2005
2006
2007
2008
2009
2010

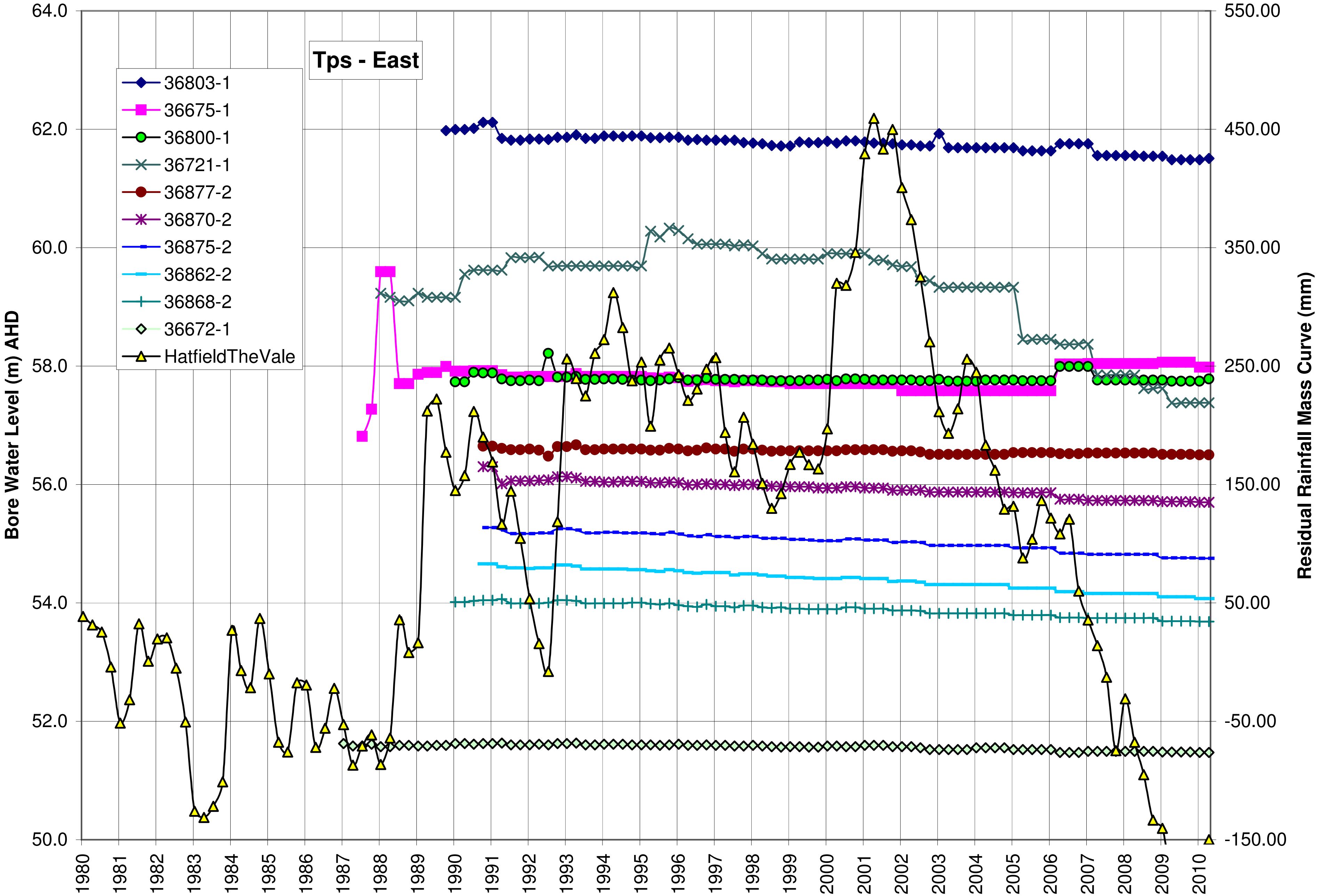

Ter2 - West
RL (m) AHD
46.5
44.5
42.5
40.5
38.5
36.5
36740-3
36740-2
36855-3
36666-2
36667-2
36664-3
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010



Ter3 - East
RL (m) AHD
63.0
61.0
59.0
57.0
55.0
53.0
51.0
49.0
36801-1
36803-2
36800-2
36868-3
36875-3
36674-2
40247-3
36724-3
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010



Ter3 - West
RL (m) AHD
45.5
45.0
44.5
44.0
43.5
43.0
42.5
42.0
41.5
41.0
40.5
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
36790-2
36723-2
36646-2
36855-2
36854-2
36671-2
87000-3
87000-2



Tps - East
36803-1
36675-1
36800-1
36721-1
36877-2
36870-2
36875-2
36862-2
36868-2
36672-1
HatfieldTheVale
Bore Water Level (m) AHD
Residual Rainfall Mass Curve (mm)
64.0
62.0
60.0
58.0
56.0
54.0
52.0
50.0
550.00
450.00
350.00
250.00
150.00
50.00
-50.00
-150.00
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
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1999
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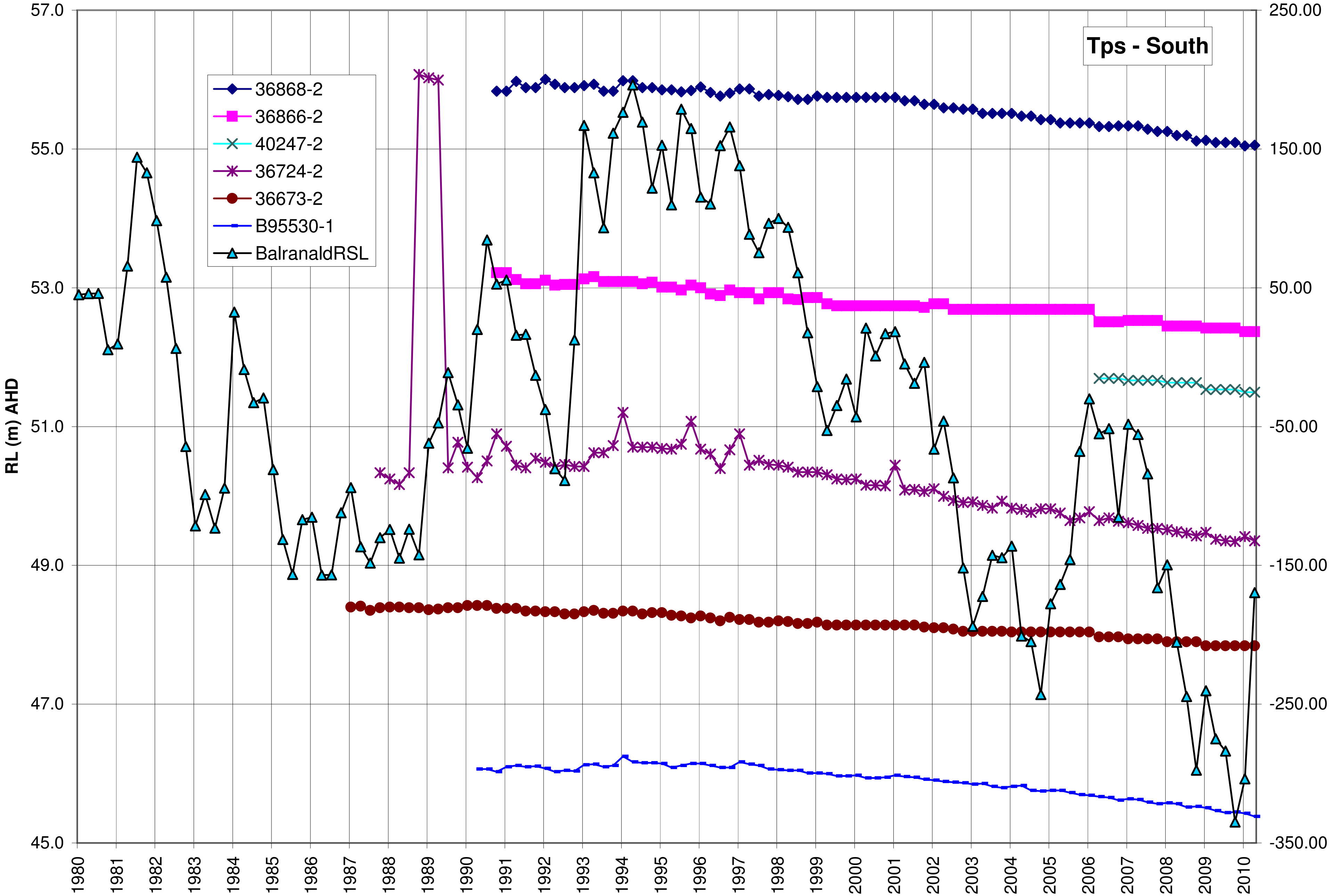
2004
2005
2006
2007
2008
2009
2010


Tps - South
36868-2
36866-2
40247-2
36724-2
36673-2
B95530-1
BalranaldRSL
RL (m) AHD
57.0
55.0
53.0
51.0
49.0
47.0
45.0
250.00
150.00
50.00
-50.00
-150.00
-250.00
-350.00
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
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1999
2000
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2004
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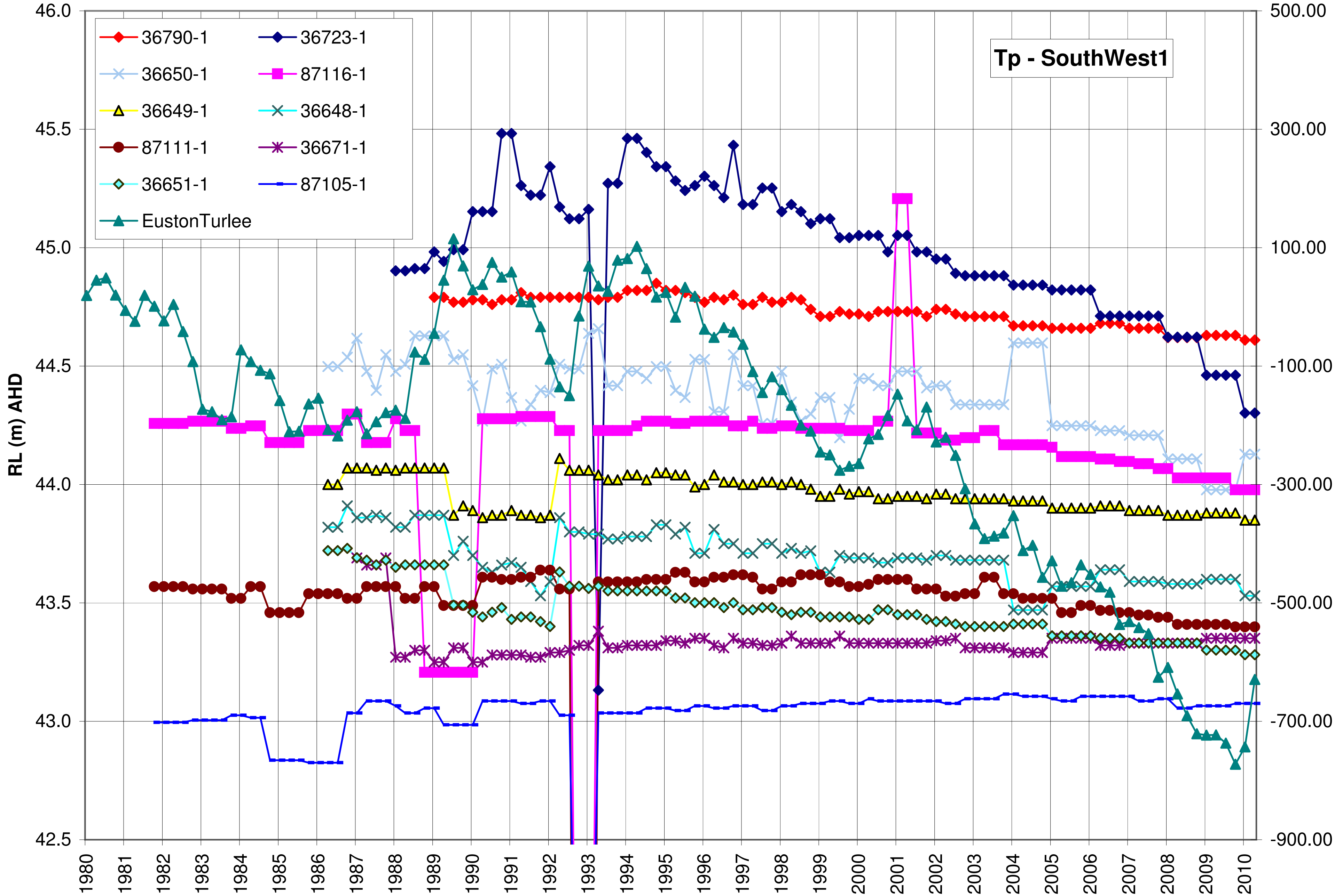
2006
2007
2008
2009
2010


Tp - SouthWest1
36790-1
36723-1
36650-1
87116-1
36649-1
36648-1
87111-1
36671-1
36651-1
87105-1
EustonTurlee
RL (m) AHD
46.0
45.5
45.0
44.5
44.0
43.5
43.0
42.5
500.00
300.00
100.00
-100.00
-300.00
-500.00
-700.00
-900.00
1980
1981
1982
1983
1984
1985
1986
1987
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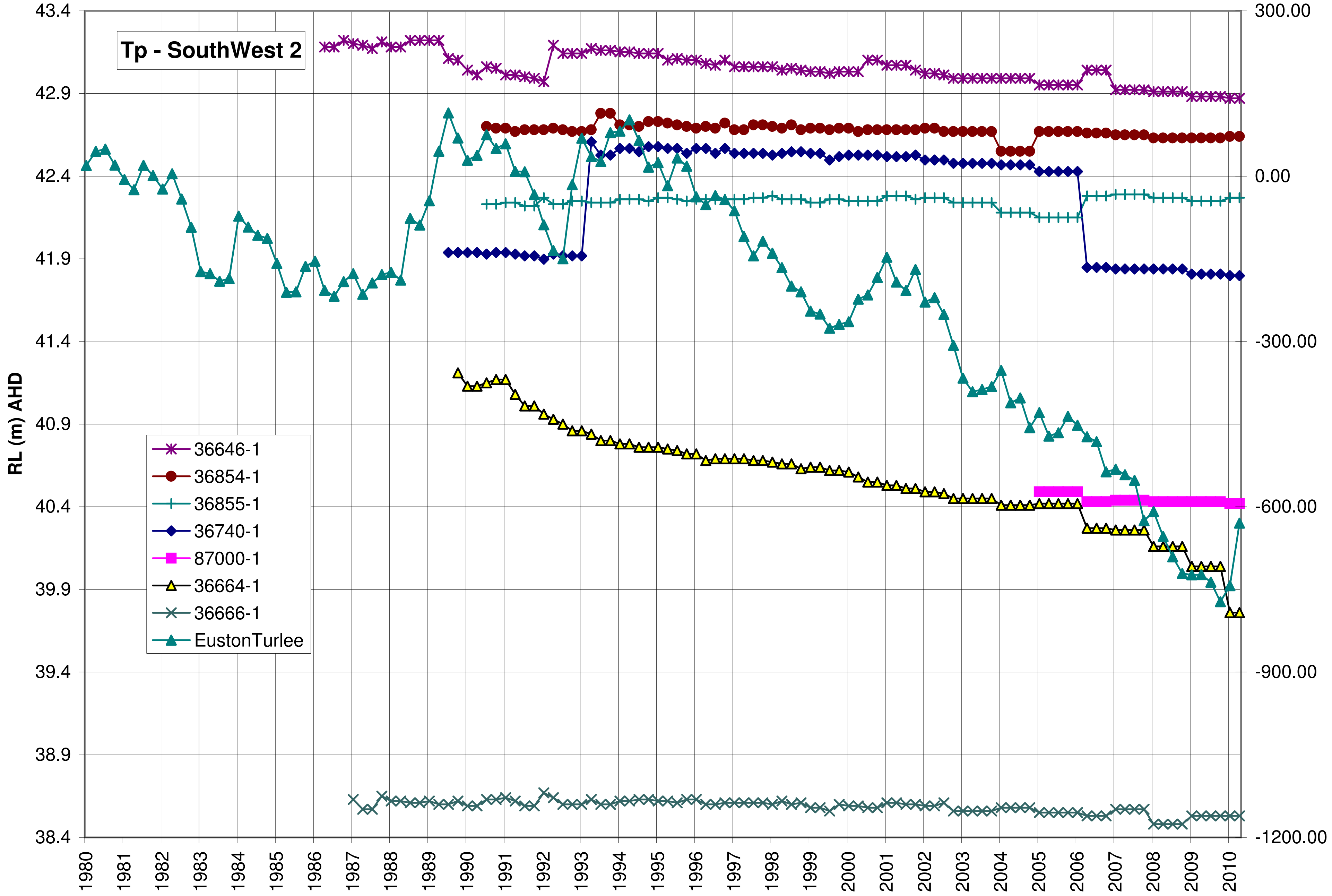
2007
2008
2009
2010


Tp - SouthWest 2
RL (m) AHD
43.4
42.9
42.4
41.9
41.4
40.9
40.4
39.9
39.4
38.9
38.4
300.00
0.00
-300.00
-600.00
-900.00
-1200.00
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
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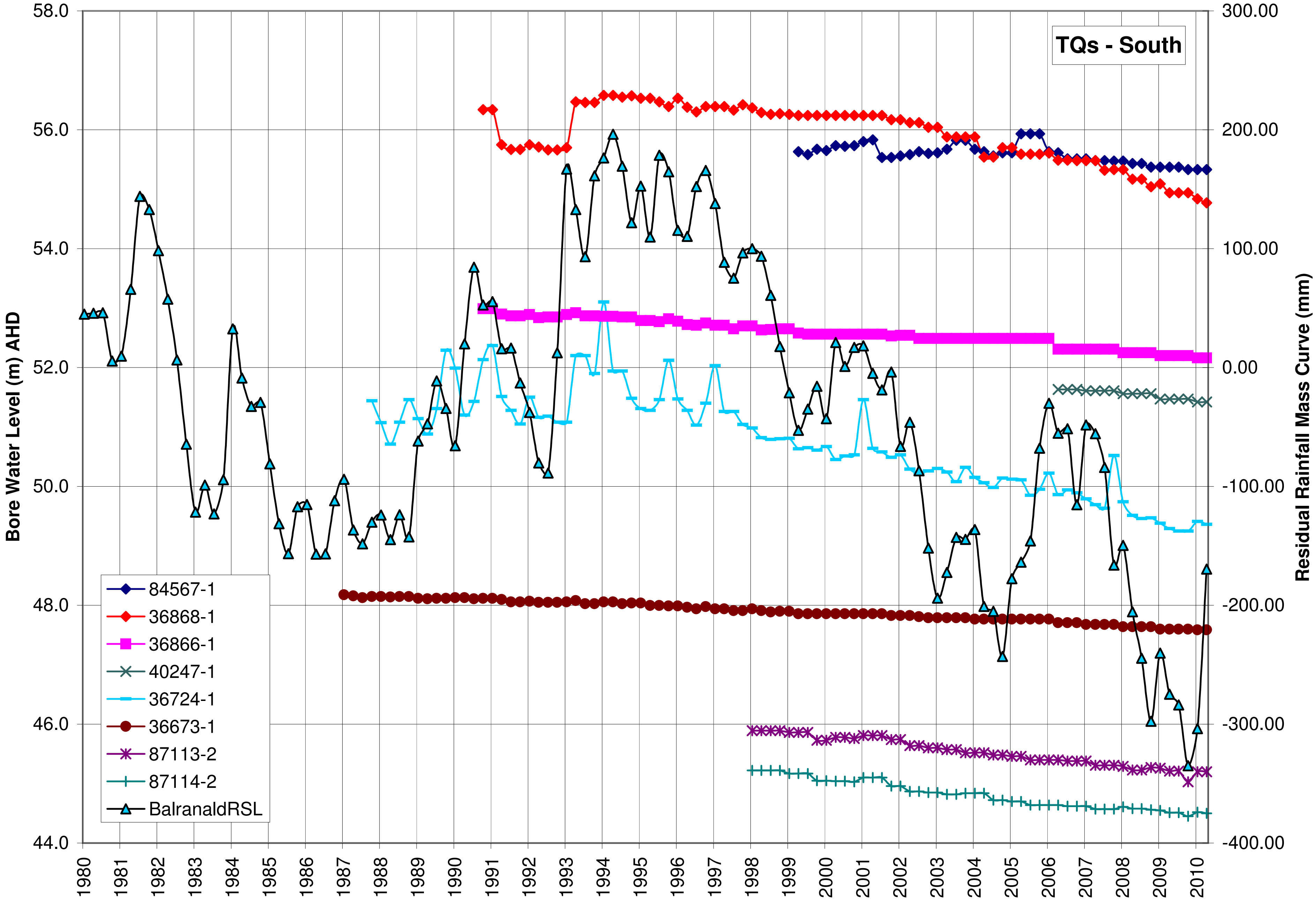
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
36646-1
36854-1
36855-1
36740-1
87000-1
36664-1
36666-1
EustonTurlee



TQs - South
Bore Water Level (m) AHD
Residual Rainfall Mass Curve (mm)
58.0
56.0
54.0
52.0
50.0
48.0
46.0
44.0
300.00
200.00
100.00
0.00
-100.00
-200.00
-300.00
-400.00
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
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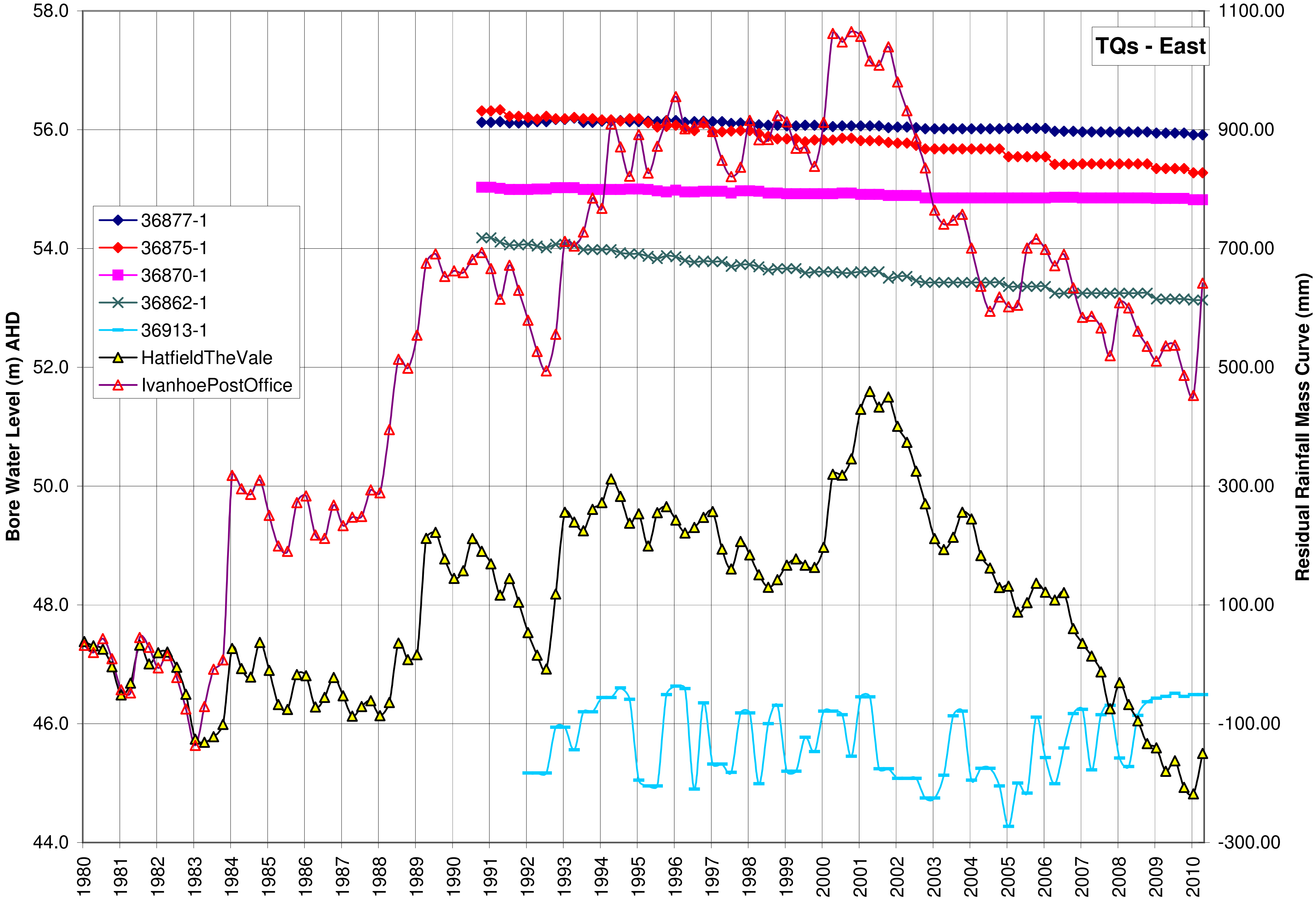
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
84567-1
36868-1
36866-1
40247-1
36724-1
36673-1
87113-2
87114-2
BalranaldRSL


TQs - East
36877-1
36875-1
36870-1
36862-1
36913-1
HatfieldTheVale
IvanhoePostOffice
Bore Water Level (m) AHD
Residual Rainfall Mass Curve (mm)
58.0
56.0
54.0
52.0
50.0
48.0
46.0
44.0
1100.00
900.00
700.00
500.00
300.00
100.00
-100.00
-300.00
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
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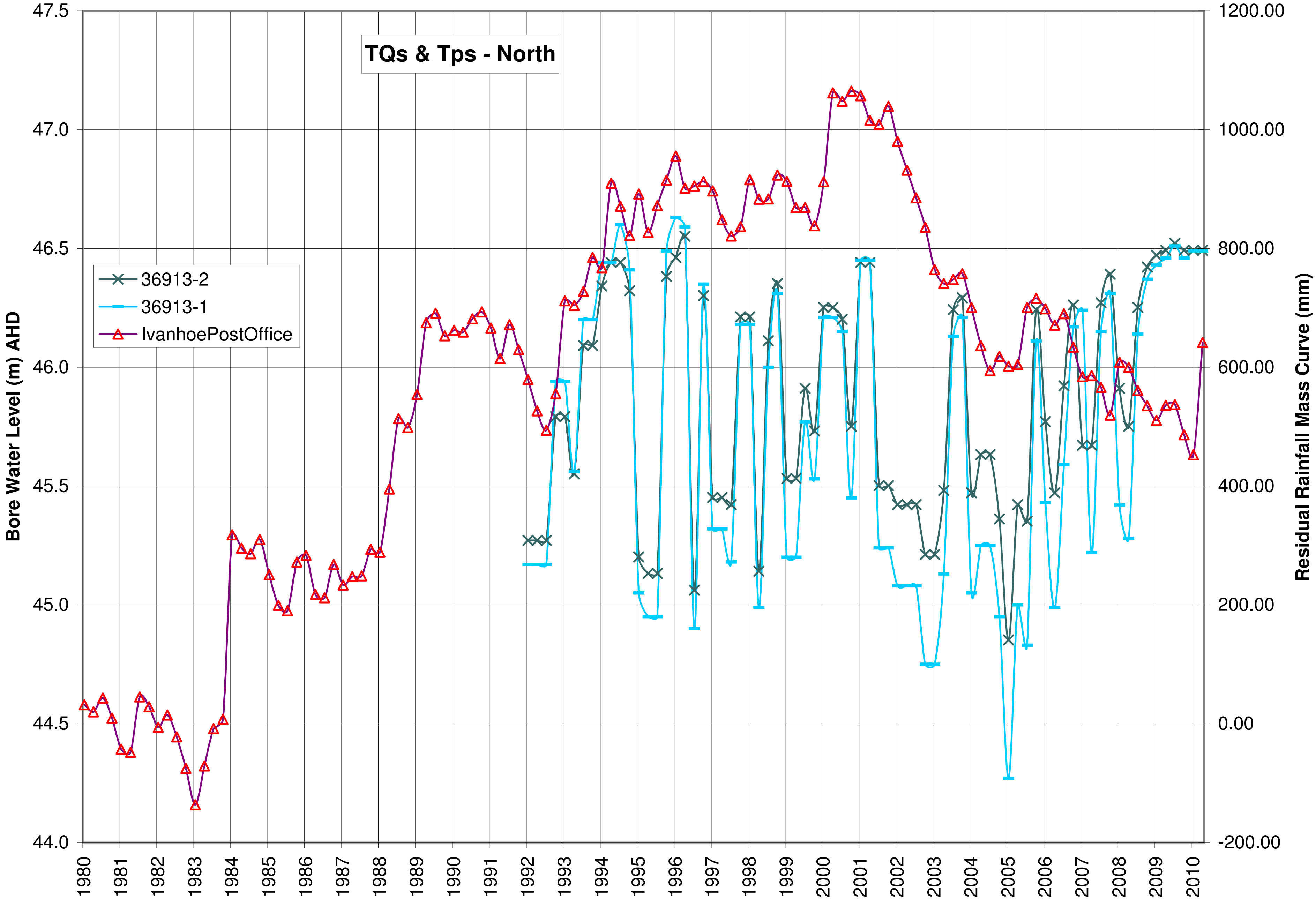
2006
2007
2008
2009
2010

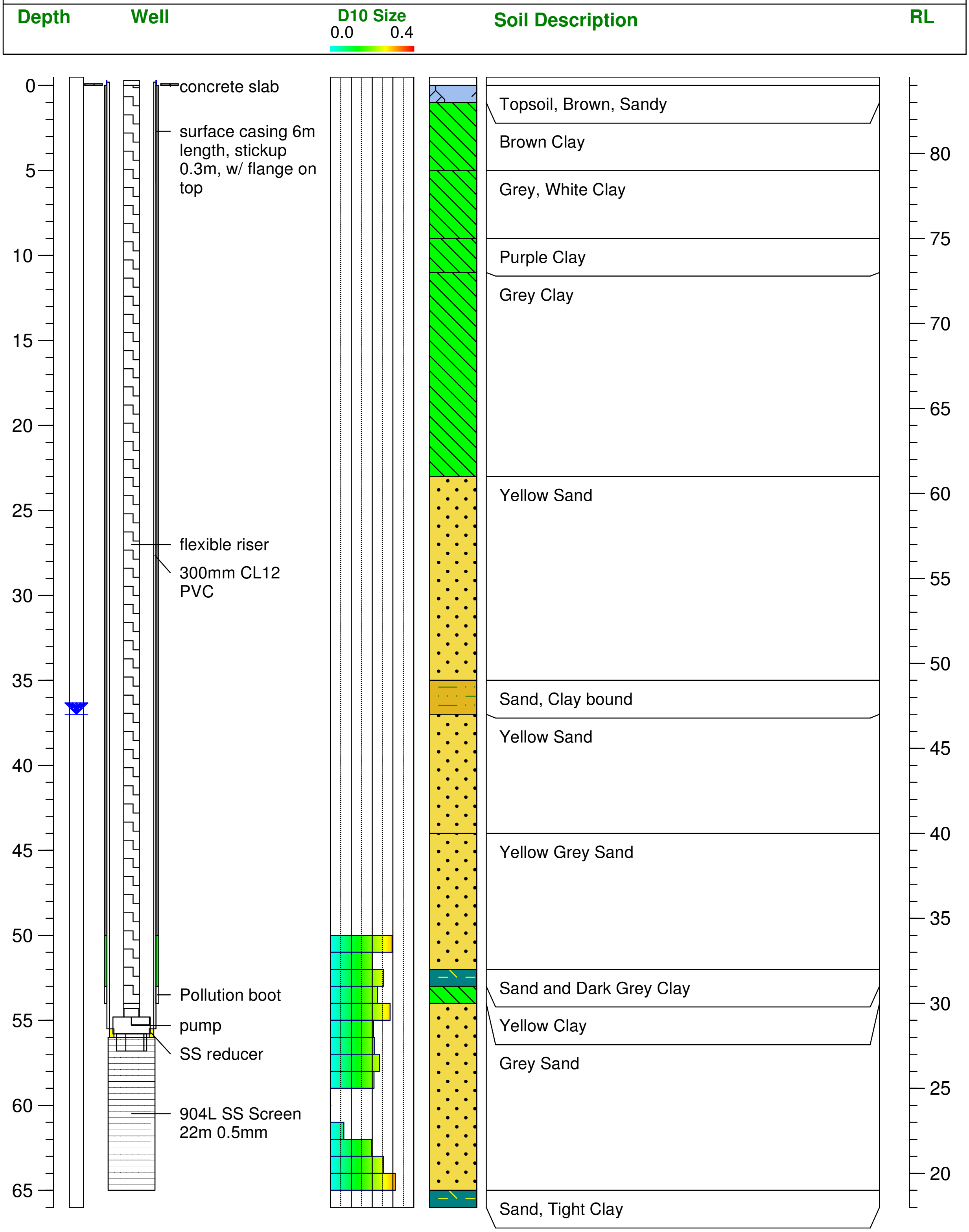


TQs & Tps - North
Bore Water Level (m) AHD
Residual Rainfall Mass Curve (mm)
36913-2
36913-1
IvanhoePostOffice
47.5
47.0
46.5
46.0
45.5
45.0
44.5
44.0
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
-200.00
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

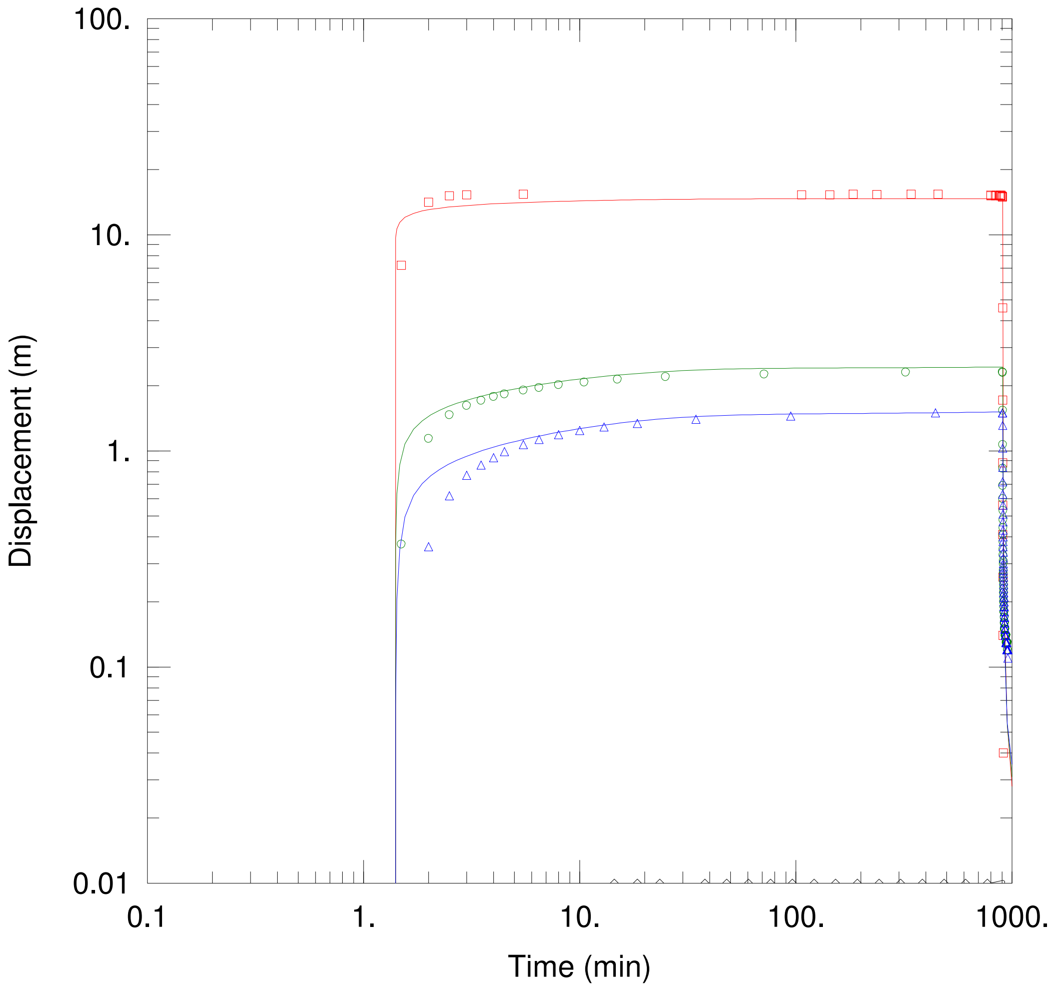
ATTACHMENT B

TEST AND MONITORING SITE BORE LOGS AND PUMPING TEST RESULT

Client:	**BEMAX Resources**	**Driller:**	Stephen Colless	**Borehole No:**	**AB1**
Project:	Atlas Test Bore	**Drill:**	Watson Drilling	**Easting:**	714402
Location:	AB1	**Method:**	Mud Rotary	**Northing:**	6252103
Date:	February 2012	**Logged by:**	JC/TS	**Elevation:**	84



Notes:



ATLAS TEST BORE

Data Set: C:\GE\curr\Cont\Bemax\CampaspeAtlas\GDW\Bores\PumpTest\AB1UTN28.aqt
Date: 07/31/12 Time: 09:03:30

PROJECT INFORMATION

Company: GEO-ENG
Client: BEMAX
Project: 1104
Location: Atlas
Test Well: AB1
Test Date: Mar 27, 2012

AQUIFER DATA

Saturated Thickness: 28. m Anisotropy Ratio (Kz/Kr): 0.0002317

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
AB1	714402	6252103.1

Observation Wells

Well Name	X (m)	Y (m)
□ AB1	714402	6252103.1
○ AM1	714388.6	6252117.6
△ AM2	714375.1	6252133
◇ AM4	709890.4	6252078.3

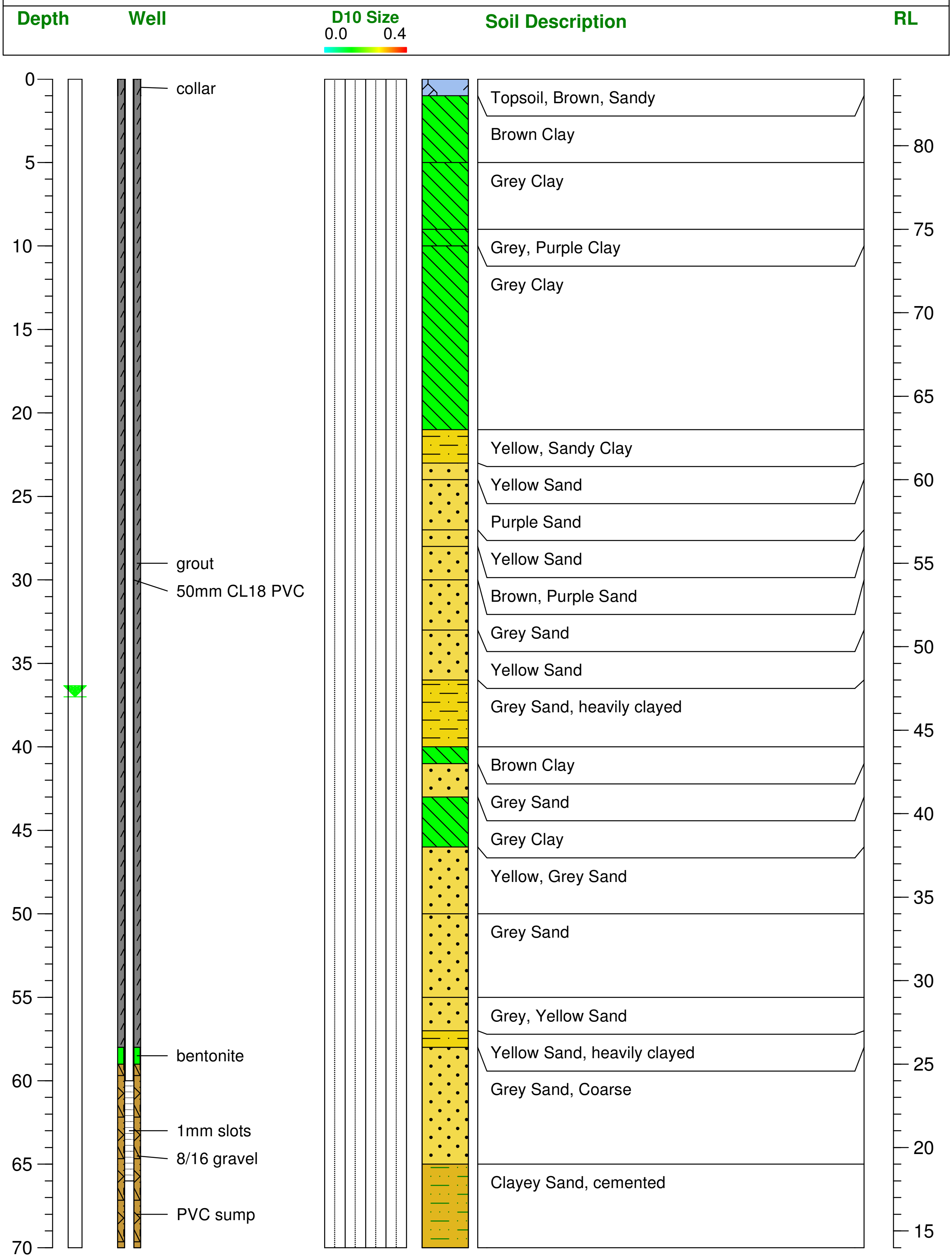
SOLUTION

Aquifer Model: Unconfined Solution Method: Tartakovsky-Neuman

T = 870.3 m^2/day
Sy = 0.05
kD = 0.2531

S = 1.134E-5
Kz/Kr = 0.0002317

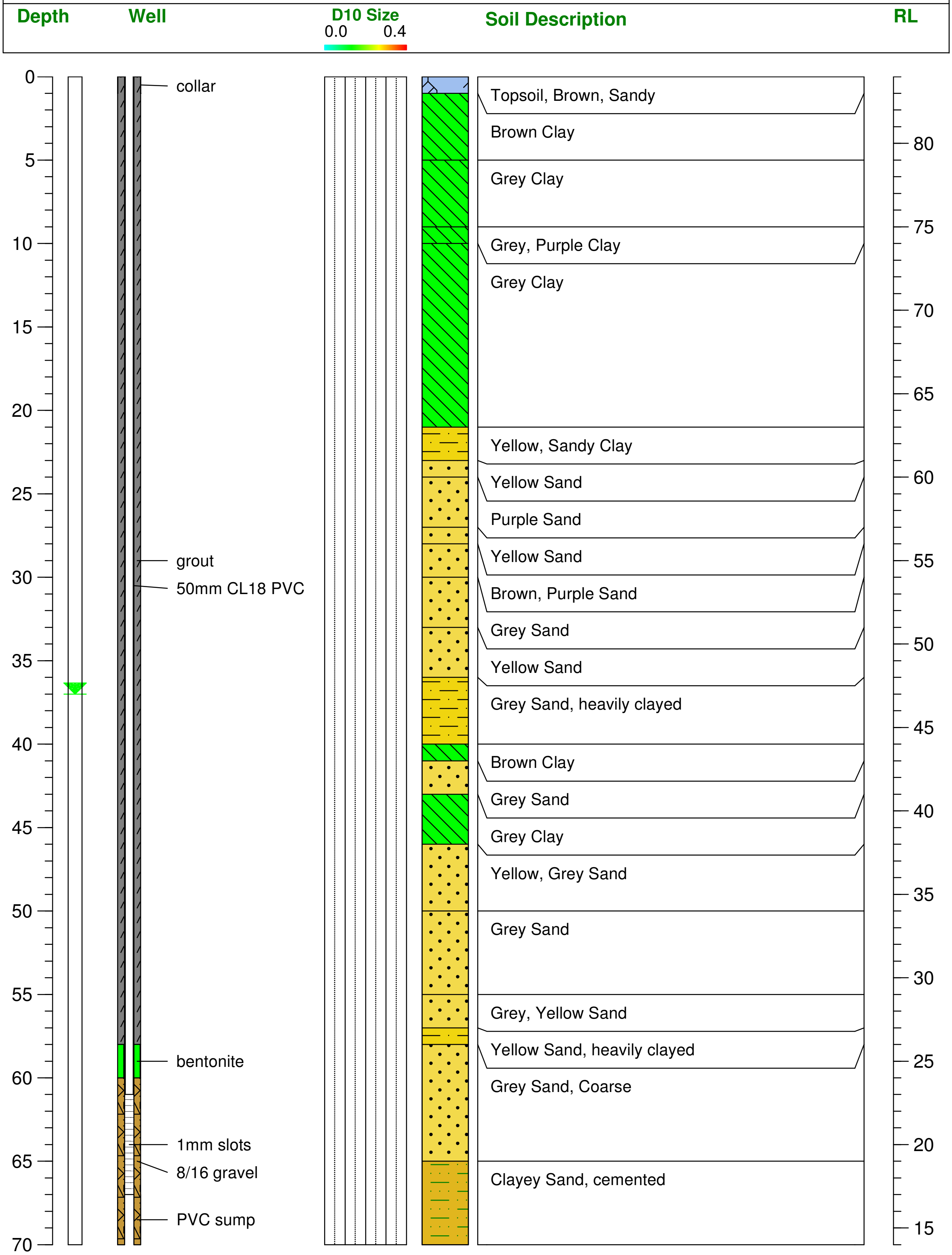
Client:	**BEMAX**	**Driller:**	Stephen Colless	**Borehole No:**	**AM1**
Project:	Atlas Mine	**Drill:**	Watson Drilling	**Easting:**	714388
Location:	AM1	**Method:**	Mud Rotary	**Northing:**	6252117
Date:	February 2012	**Logged by:**	BEMAX	**Elevation:**	~84



Notes:

GEO-ENG

Client:	**BEMAX**	**Driller:**	Stephen Colless	**Borehole No:**	**AM2**
Project:	Atlas Mine	**Drill:**	Watson Drilling	**Easting:**	714375
Location:	AM2	**Method:**	Mud Rotary	**Northing:**	6252133
Date:	February 2012	**Logged by:**	BEMAX	**Elevation:**	~84



Notes:

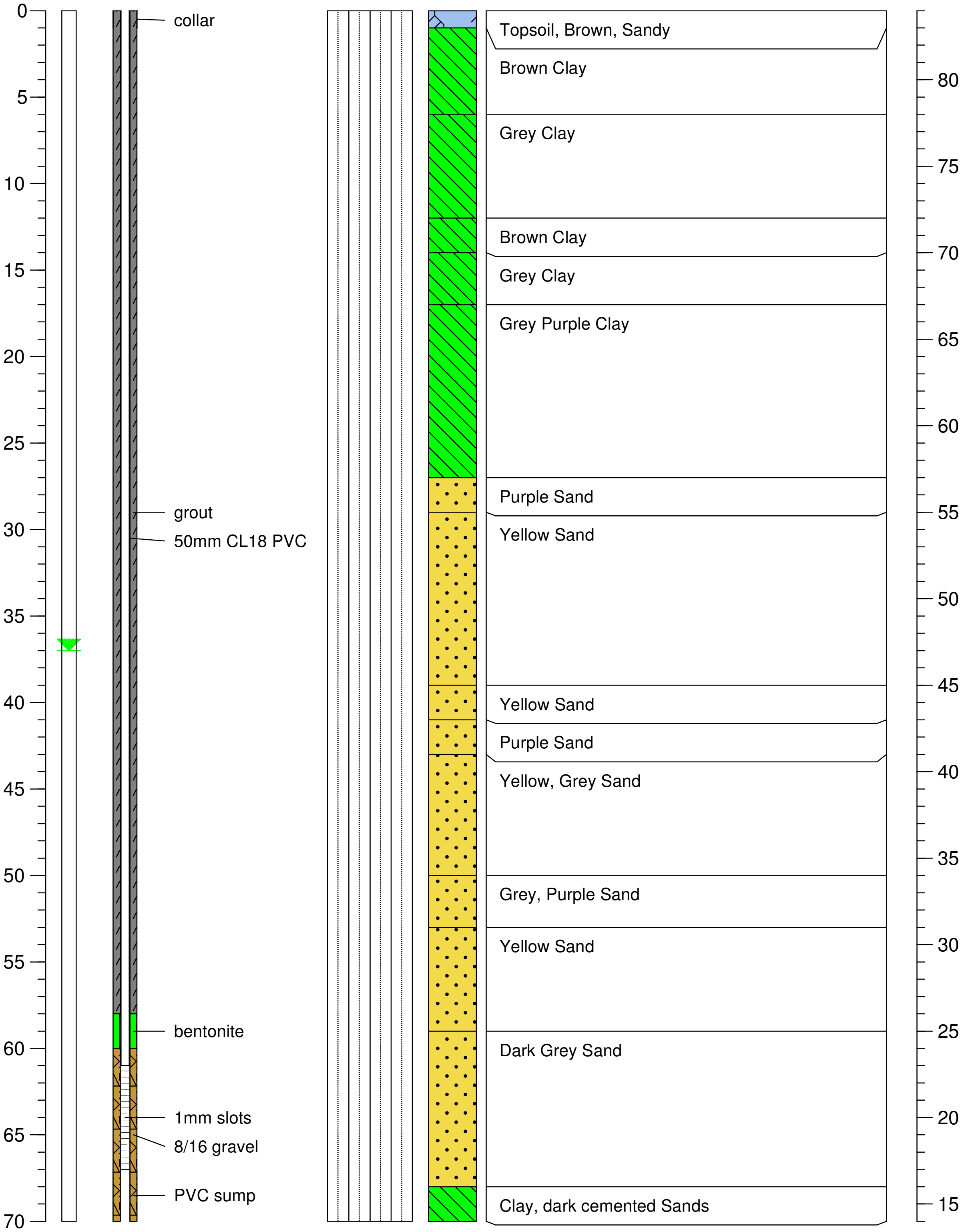
GEO-ENG

Client: BEMAX
Project: Atlas Mine
Location: AM3
Date: February 2012

Driller: Stephen Colless
Drill: Watson Drilling
Method: Mud Rotary
Logged by: BEMAX

Borehole No: AM3
Easting: 714418
Northing: 6252173
Elevation: ~84

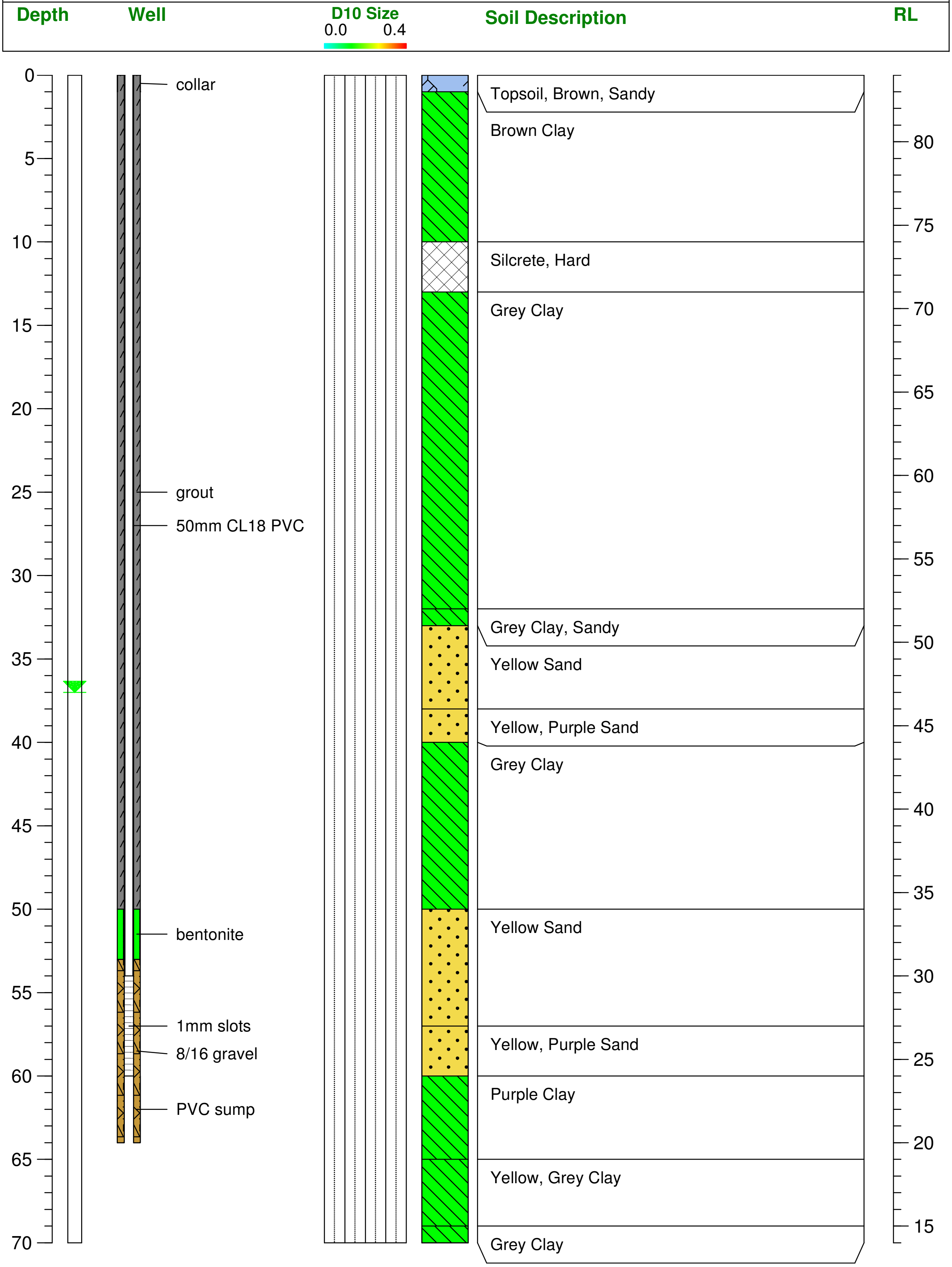
Depth	Well	D10 Size 0.0 – 0.4	Soil Description	RL



Notes:

GEO-ENG

Client:	**BEMAX**	**Driller:**	Stephen Colless	**Borehole No:**	**AM4**
Project:	Atlas Mine	**Drill:**	Watson Drilling	**Easting:**	709890
Location:	AM4	**Method:**	Mud Rotary	**Northing:**	6252078
Date:	February 2012	**Logged by:**	BEMAX	**Elevation:**	~84

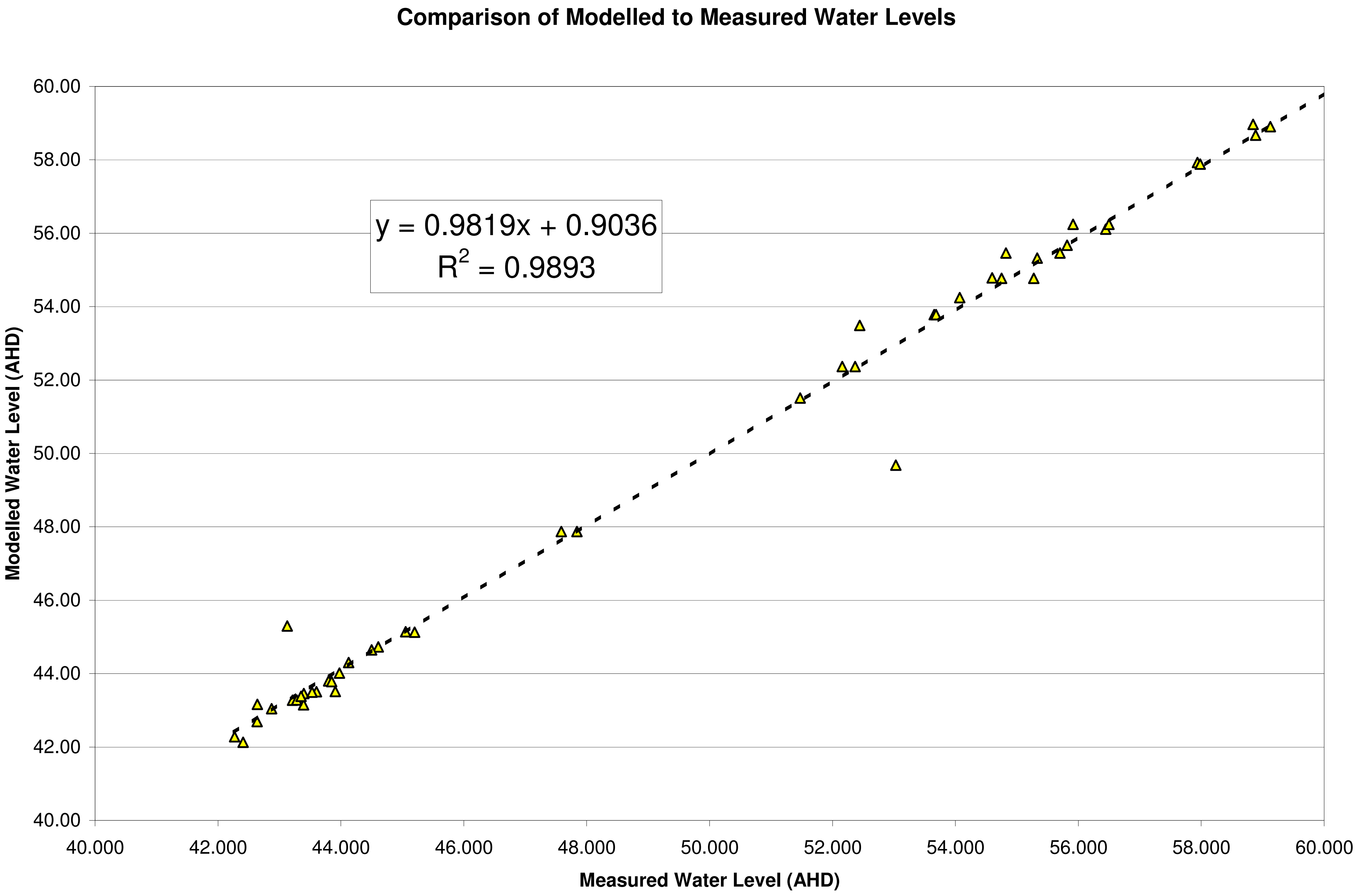


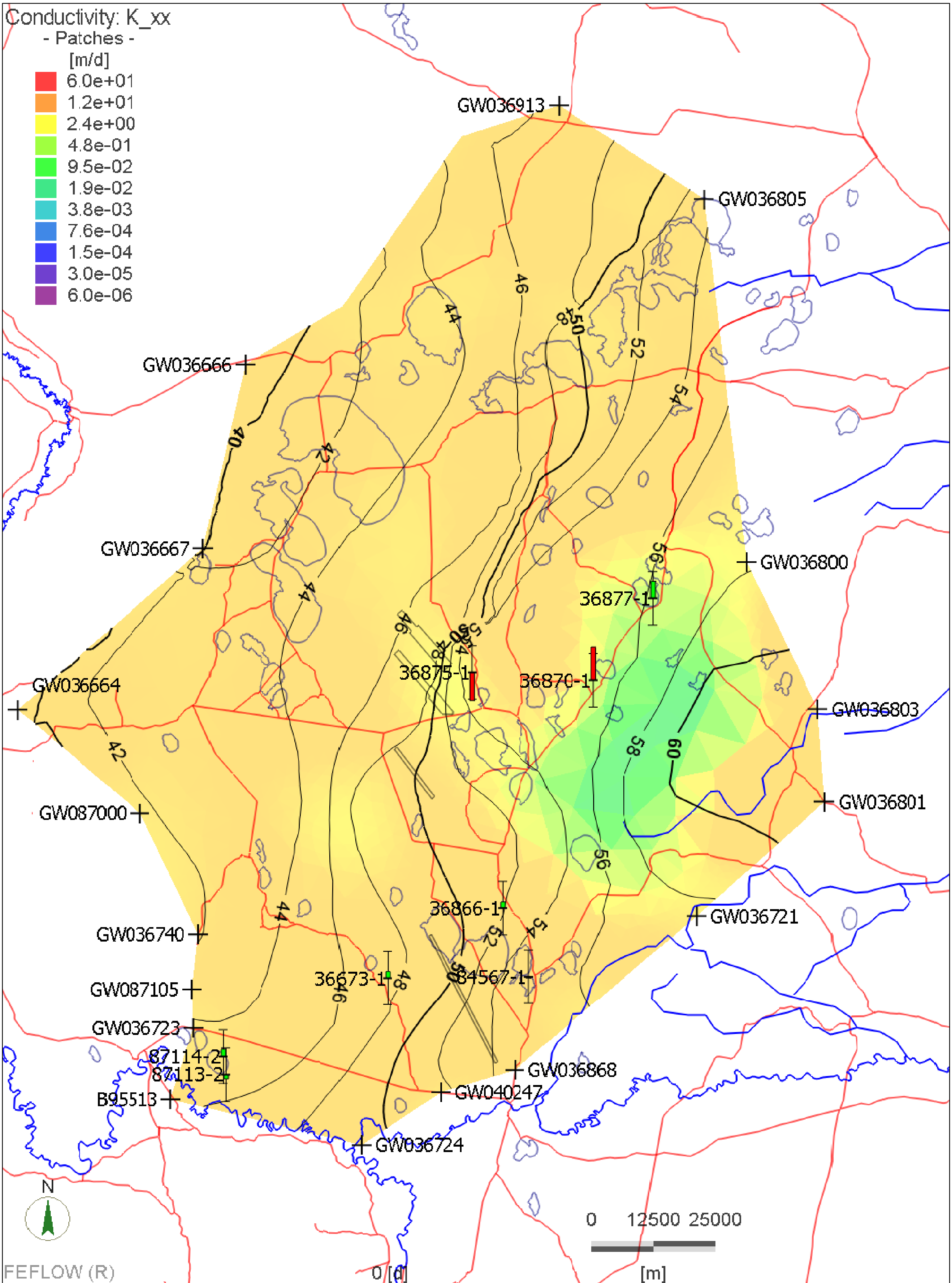
Notes:

GEO-ENG

ATTACHMENT C

HYDRAULIC CONDUCTIVITY AND STEADY-STATE HEAD CONTOURS FOR MODEL LAYERS (INCLUDING MODELLED VERSUS MEASURED BORE WATER LEVEL VARIANCE)


Comparison of Modelled to Measured Water Levels
y = 0.9819x + 0.9036
R2 = 0.9893
Modelled Water Level (AHD)
Measured Water Level (AHD)
60.00
58.00
56.00
54.00
52.00
50.00
48.00
46.00
44.00
42.00
40.00
40.000
42.000
44.000
46.000
48.000
50.000
52.000
54.000
56.000
58.000
60.000



19.5 x 26.41 | *Note:* Kh — Coloured Patches
Contours of Hydraulic Head

North

Cristal Mining Australia
Atlas/Campaspe Groundwater Model

Model Slice/Layer 1 steady-state

Monitoring Bore Water Levels (Modelled — Measured)
+/−0.5m error bars

Plotted: Oct 14 2012

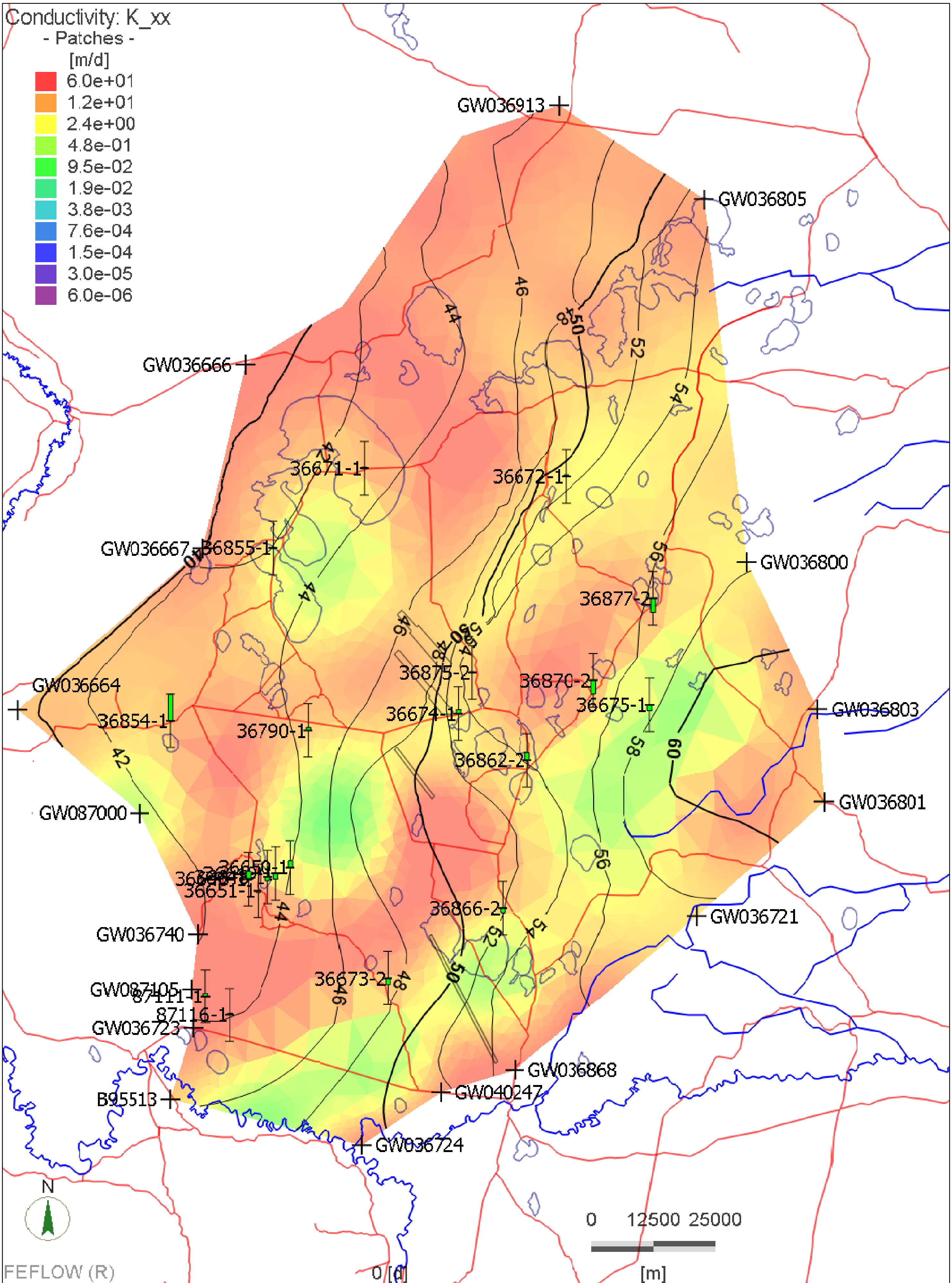
Design: GEOENG

Contour int: 2m

DATUMS: Hor: Ver: AHD

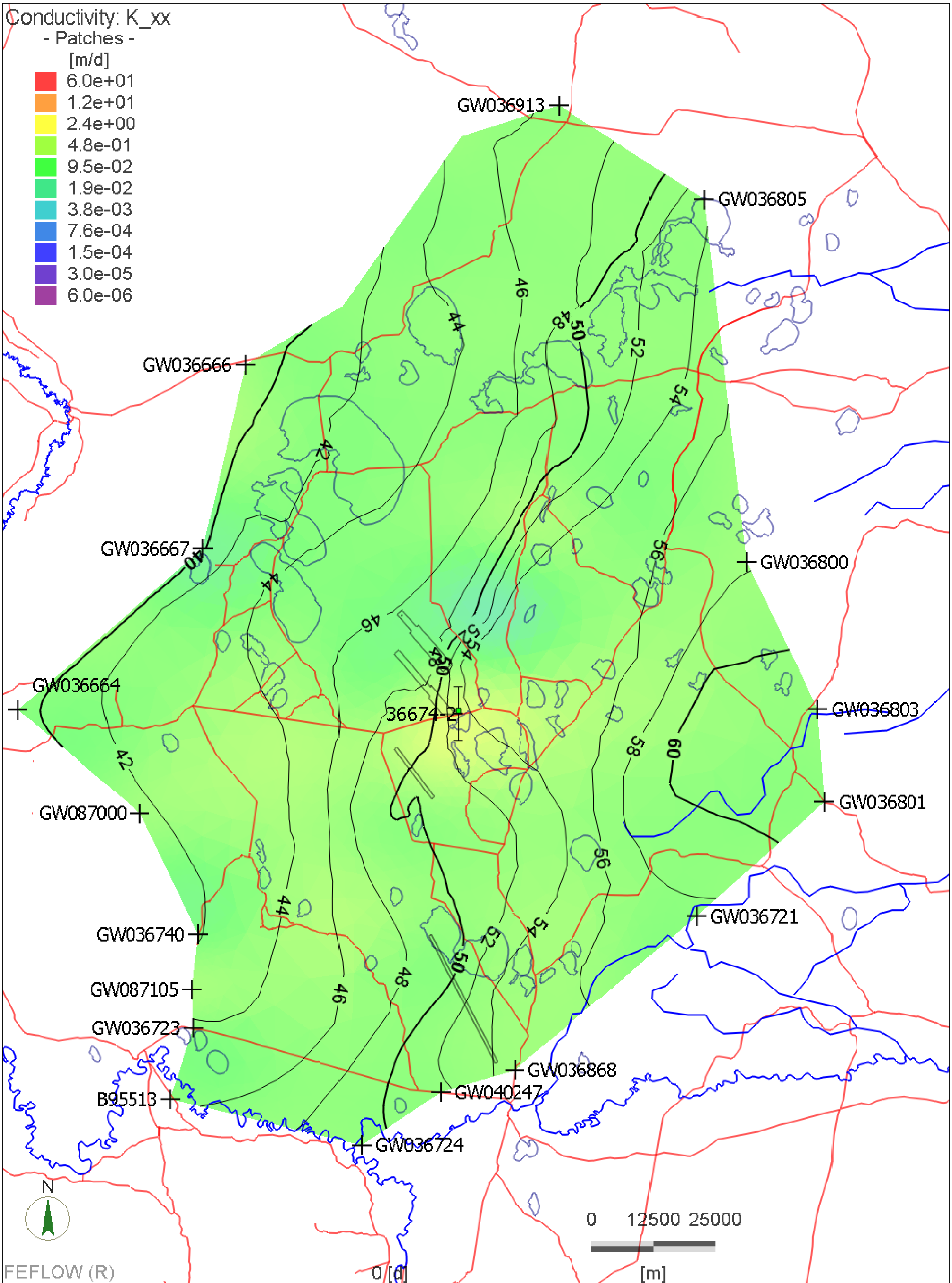
A4 - 1 : 1000000

File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro



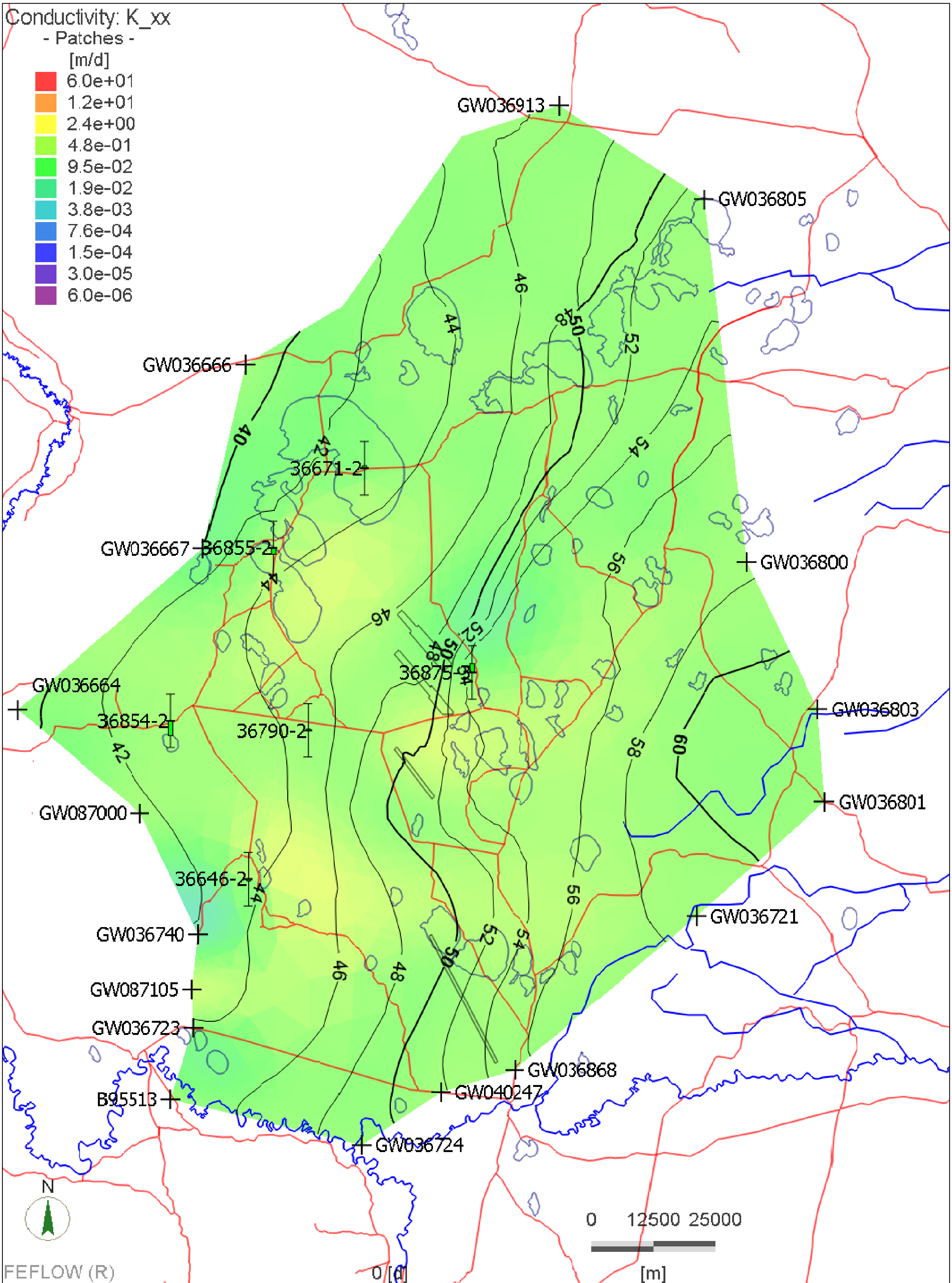
19.5 x 26.41	Note:	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 2 steady-state
Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m; DATUMS: Hor: Ver: AHD	A4 - 1 : 1000000

File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro



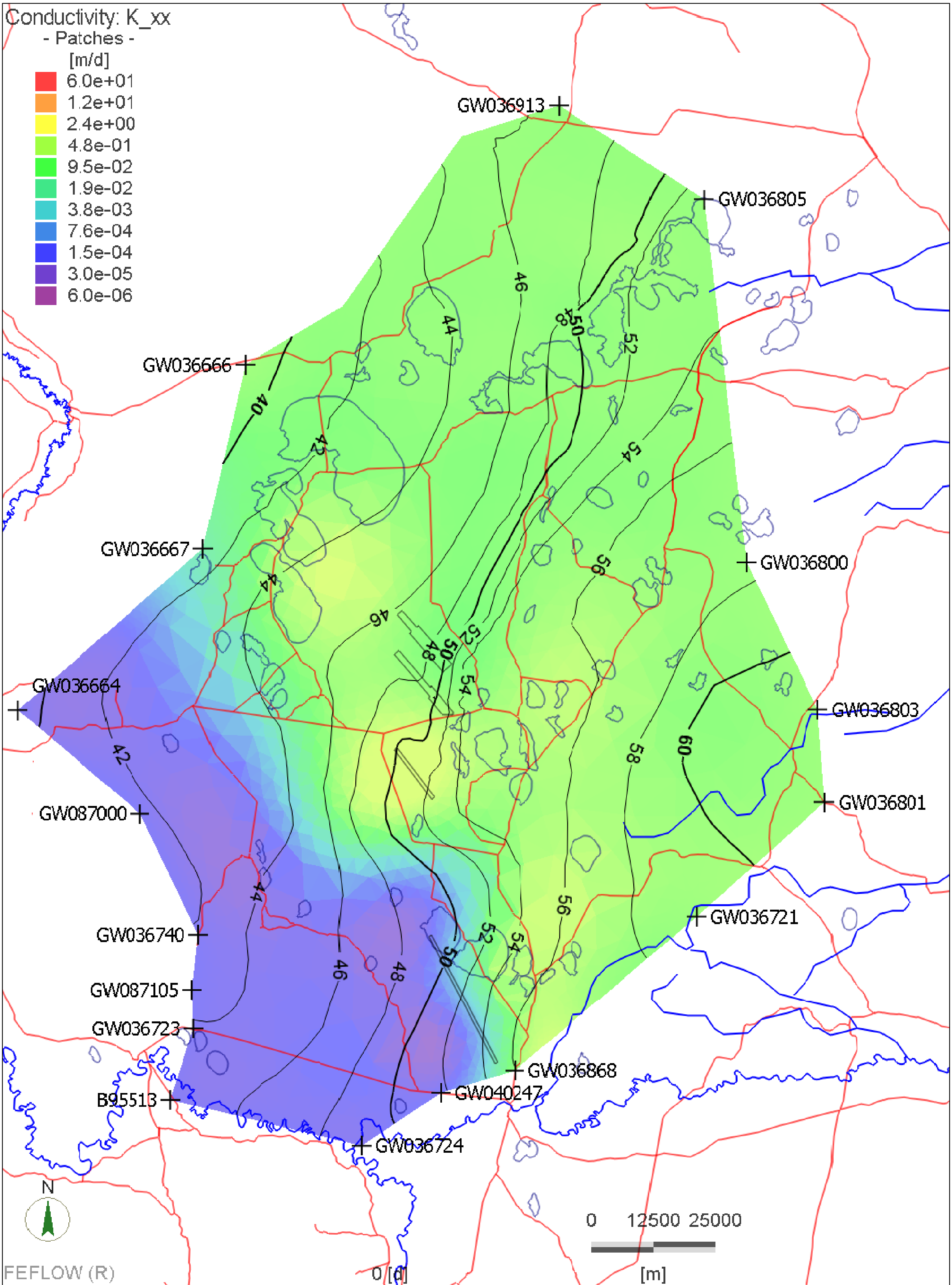
19.5 x 26.41	Note:	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 3 steady-state
Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m	DATUMS: Hor: Ver: AHD	A4 - 1 : 1000000

File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro



19.5 x 26.41	Note:	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 4 steady-state

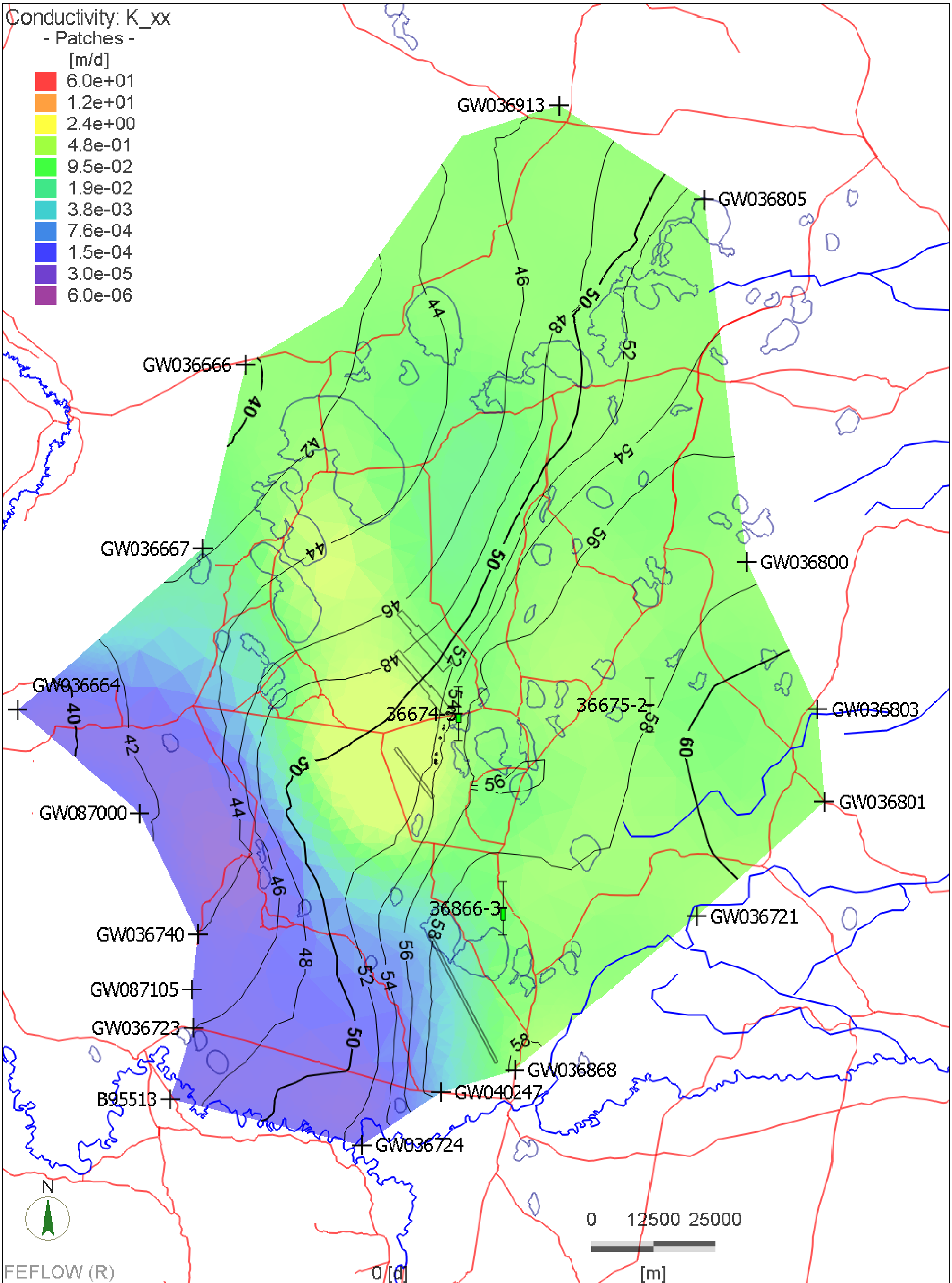
Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m	DATUMS: Hor: Ver: AHD	A4 - 1 : 1000000
		File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro		



19.5 x 26.41	Note:	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 5 steady-state

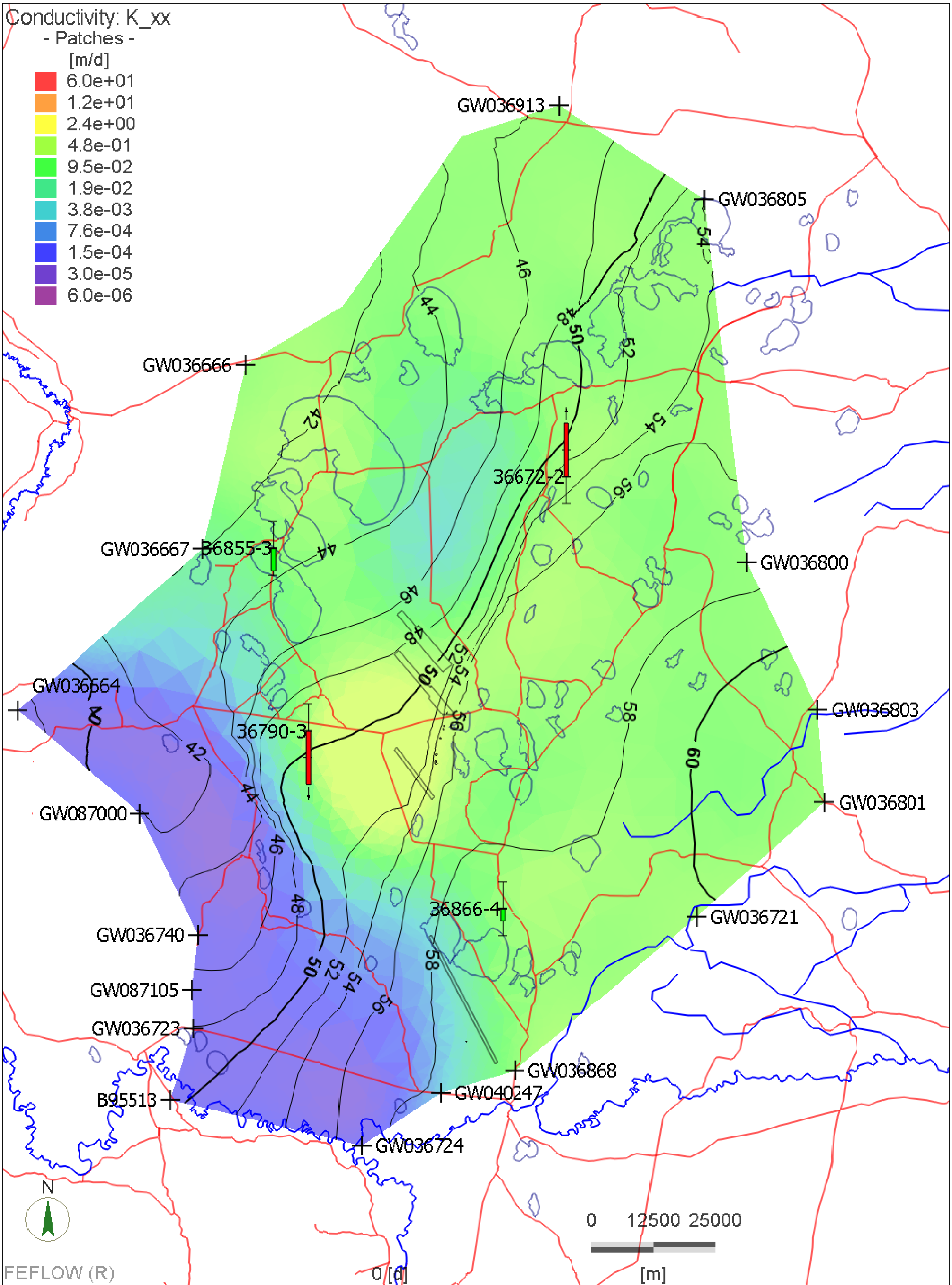
Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m	DATUMS: Hor: Ver: AHD	A4 - 1 : 1000000

File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro



19.5 x 26.41	Note:	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 6 steady-state

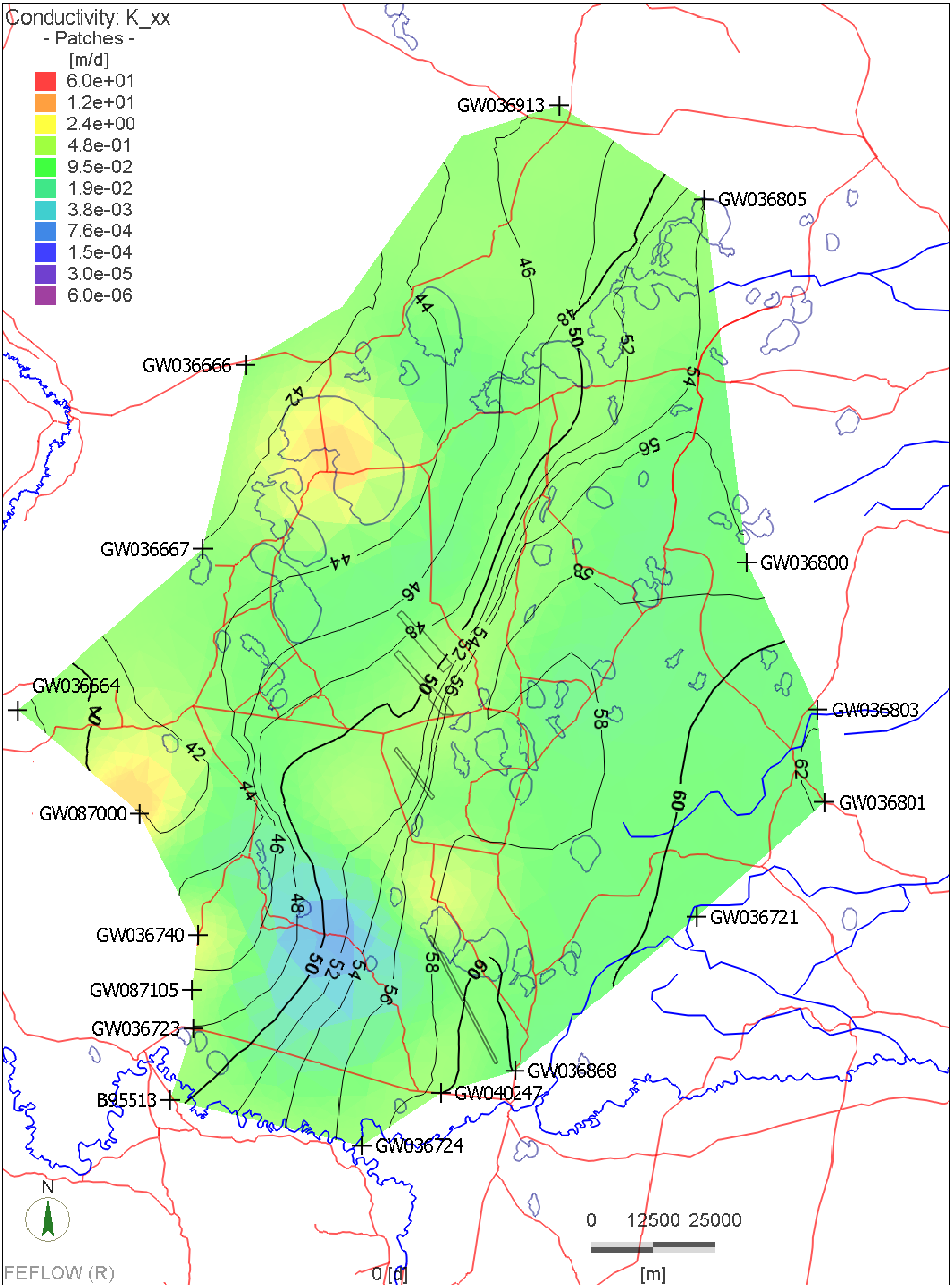
Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m	DATUMS: Hor: Ver: AHD	A4 - 1 : 1000000
		File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro		



19.5 x 26.41	Note:	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 7 steady-state

Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m	DATUMS: Hor: Ver: AHD	A4 - 1 : 1000000

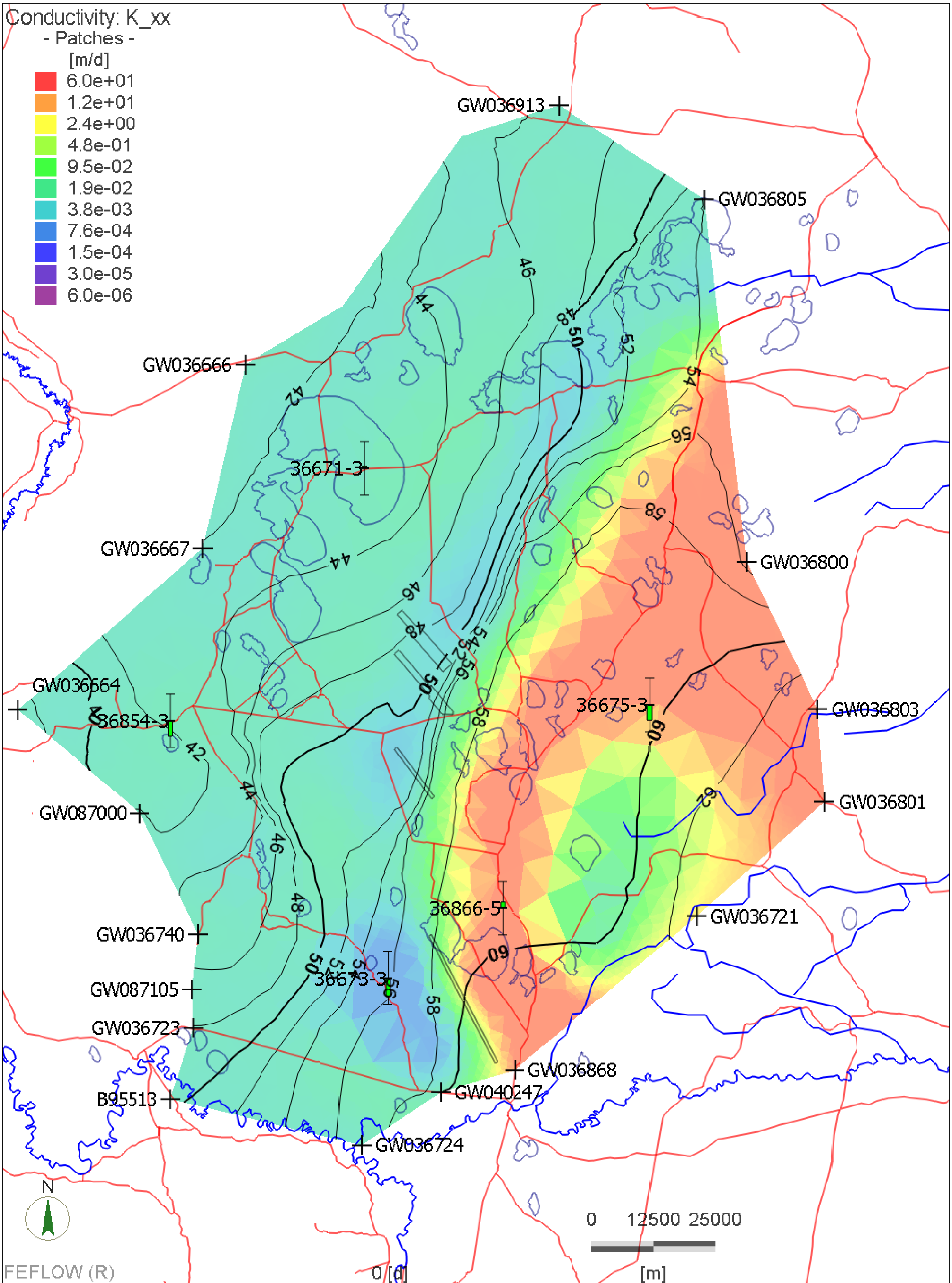
File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro



19.5 x 26.41	Note: Pale Mask indicated extent of Ter1	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 8 steady-state

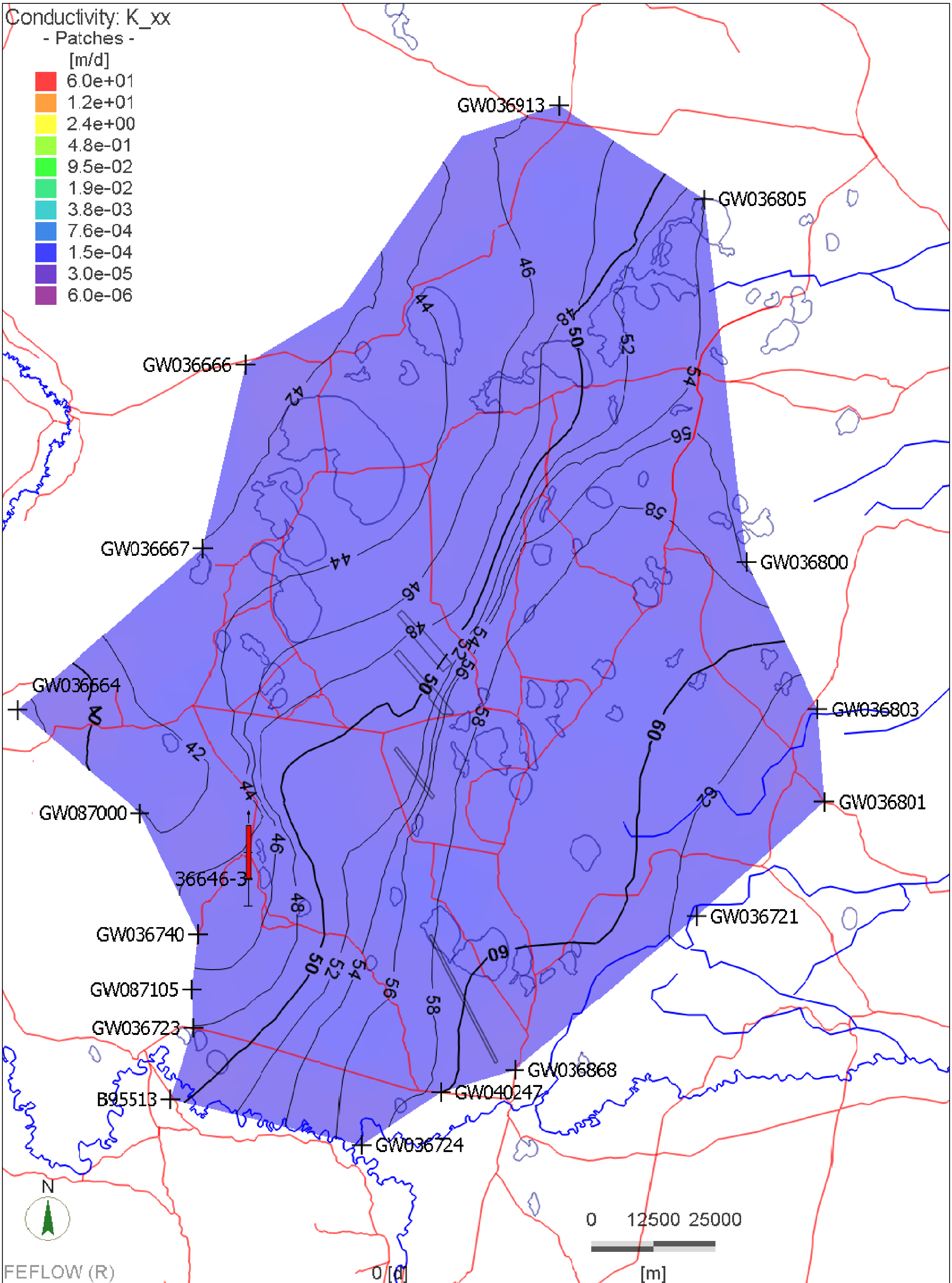
Plotted: Oct 14 2012 | Design: GEOENG | Contour int: 2m | DATUMS: Hor: Ver: AHD | A4 - 1 : 1000000

File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro



19.5 x 26.41	Note: Pale Mask indicated extent of Ter1	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 9 steady-state
	Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m DATUMS: Hor: Ver: AHD A4 - 1 : 1000000

C:\GE\TM\Current\Bemax\Campaspe\c9.pro

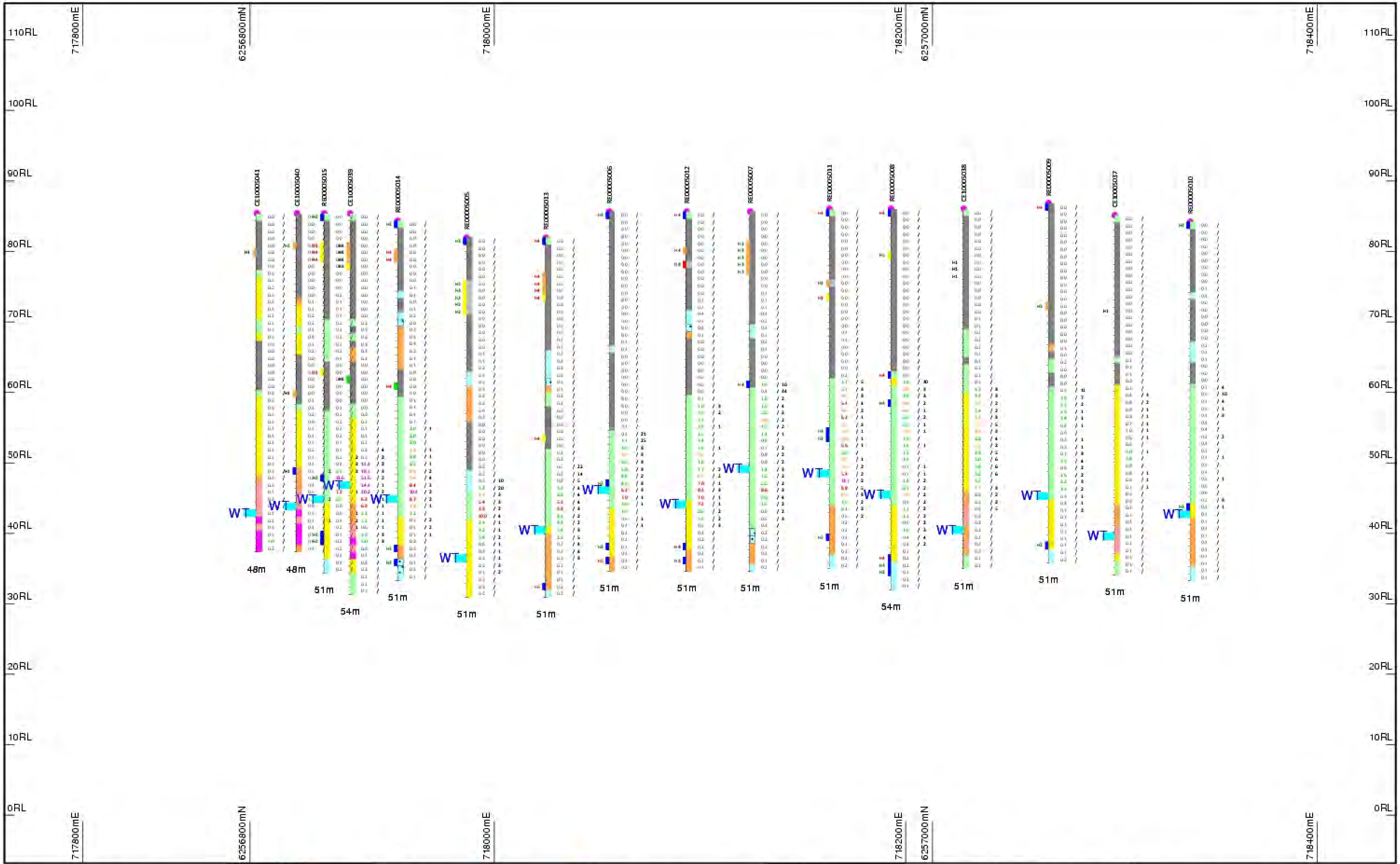


19.5 x 26.41	*Note:*	North	Cristal Mining Australia Atlas/Campaspe Groundwater Model	Model Slice/Layer 10 steady-state

	Plotted: Oct 14 2012	Design: GEOENG	Contour int: 2m	DATUMS: Hor: Ver: AHD	A4 - 1 : 1000000
			File No.: C:\GE\TM\Current\Bemax\Campaspe\c9.pro		

ATTACHMENT D

EXAMPLE OF EXPLORATION DRILL HOLE CROSS-SECTION, SHOWING THICKNESS OF UPPER CLAY LAYERS



CRISTAL MINING AUSTRALIA

Legend

0 to 1	5 to 10
1 to 3	10 to 100
3 to 5	>= 100

Clay	Fine	Coarse medium
Silt	Fine medium	Coarse
Very fine	Medium	Very coarse
		Gravel

INDURATION %

0 - 5% 10 - 25%
5 - 10% 25 - 50%
>50%

X Scale = 1 : 3000
Y Scale = 1 : 500

Plot Date 27-May-2011

Sheet 1 of 1

Plot File: CE01 sizing

50 0 50m

CAMPASPE CE01 SIZING