6. Groundwater modelling

A numerical groundwater model was developed to provide a quantitative assessment of impacts from the proposed mining operation. The groundwater model and a draft version of the Groundwater Model Technical Report were externally peer reviewed by Dr Merrick (Heritage Computing) in February 2012. Comments from the peer review were addressed in the final model and technical report and a second peer review was undertaken by Dr Noel Merrick. The final version of the Groundwater Model Technical Report is included in Appendix H. The peer reviews and responses to peer reviews are included in Appendix I.

The model incorporates the mine plan and is based on the current conceptual understanding of the groundwater system within the assessment area. Aquifer properties and groundwater level data collected in the period up to September 2011 have been used in model development.

The model was created using the Groundwater Vistas user interface. MODFLOW (McDonald & Harbaugh 1988), in conjunction with MODFLOW-SURFACT (version 3) were used to allow for saturated and unsaturated flow conditions.

The complexity of the groundwater model is consistent with the ‘impact assessment’ class described by the Murray Darling Basin Commission guidelines for groundwater flow modelling (MDBC 2001). New national guidelines for modelling were released in July 2012 (Barnett et al, 2101) and are largely based on the previous MDBC modelling guidelines (MDBC 2001). The modelling for this project is consistent with a Class 2 model, as described by the updated Australian groundwater modelling guidelines (Barnett et al, 2012). The guidelines state that this type of model is suitable for estimates of mine dewatering and assessments of associated impacts. A detailed description of the development and results of the groundwater model is provided in the Cobbora Coal Project – Groundwater Model Technical Report (Appendix H). A summary of this report is presented below.

6.1 Model development

A map of the assessment area, including the extent of the groundwater model, is shown in Figure 6.1. The model domain has an extent of 29 km x 50 km (1,458 km^2). The active mine area is located within the centre of the model domain and covers approximately 30 km^2. The model grid is orientated to the north-west to align the conceptualised primary groundwater flow direction in the Project catchment (north-west) with the model columns, which would simplify the numerical solutions.

The numerical groundwater model is based on the conceptual model described in this document (Section 5.9) and includes data collected during 2009–2011, as part of an extensive groundwater monitoring and testing program. The hydrogeological units of relevance to the assessment area have been simplified for incorporation into the groundwater model as discrete model layers (see Table 6.1). The simplification aims to combine formations assumed to the have similar hydraulic characteristics.

A process of model calibration was undertaken to refine estimates of aquifer properties for these units and to develop suitable boundary conditions for the model. Figure 6.2 shows the model domain and assigned boundary conditions, including the three mining areas in the proposed mine plan (mining areas A, B and C). Inactive cells have been assigned only at topographic divides and in areas where very low permeability geological units outcrop. The hydrostratigraphic units assigned to the top layer of the model are also shown in Figure 6.2.

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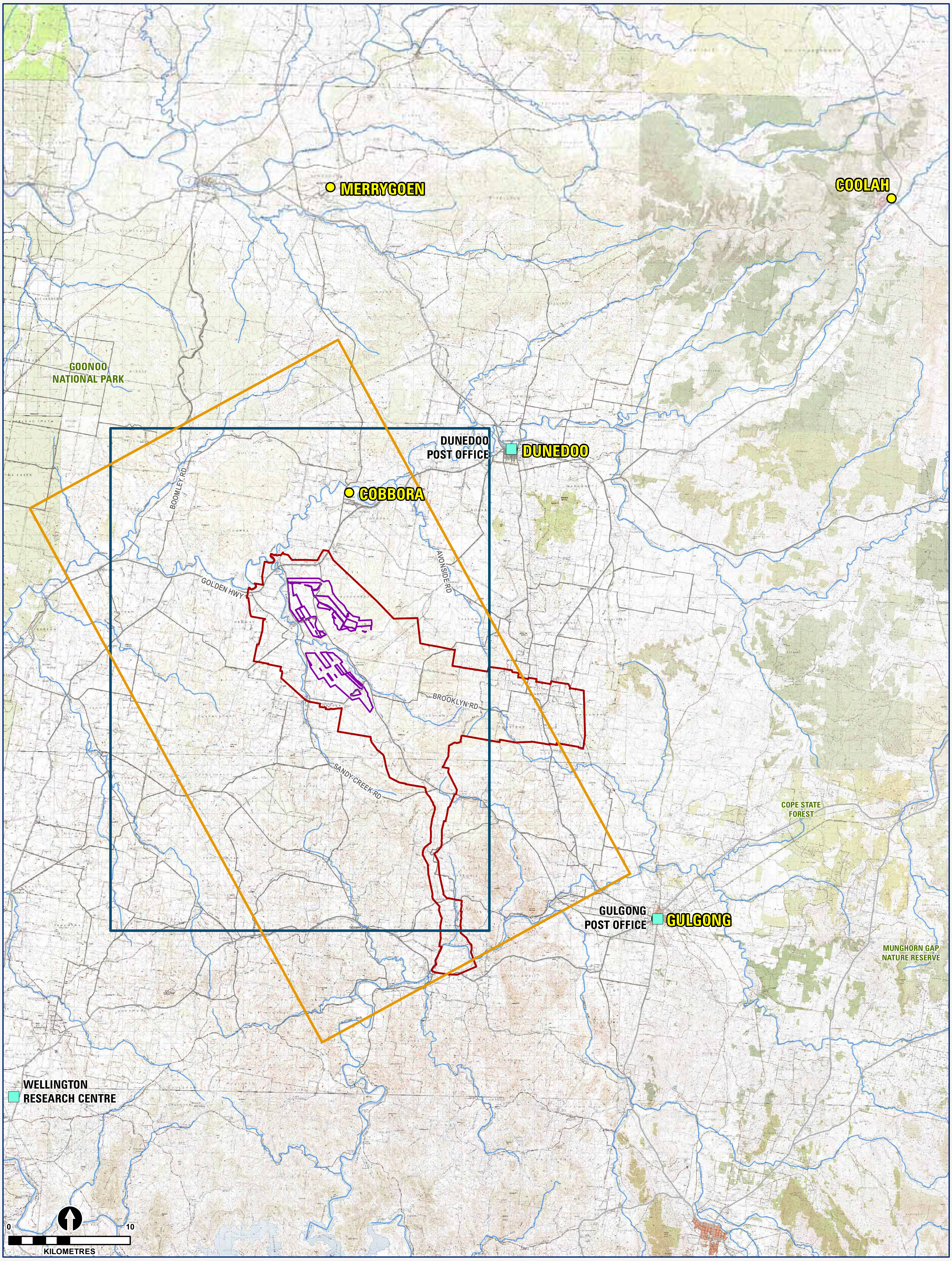

- Bureau of Meteorology station
- Assessment area
- Model extent
- Project Application Area (approximate) (as of February 2012)
- Drainage lines
- Roads
- National parks & state forests
- Proposed mining areas

Figure 6.1 Site plan and model extent

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Topographic map source: NSW Department of Lands, 1989

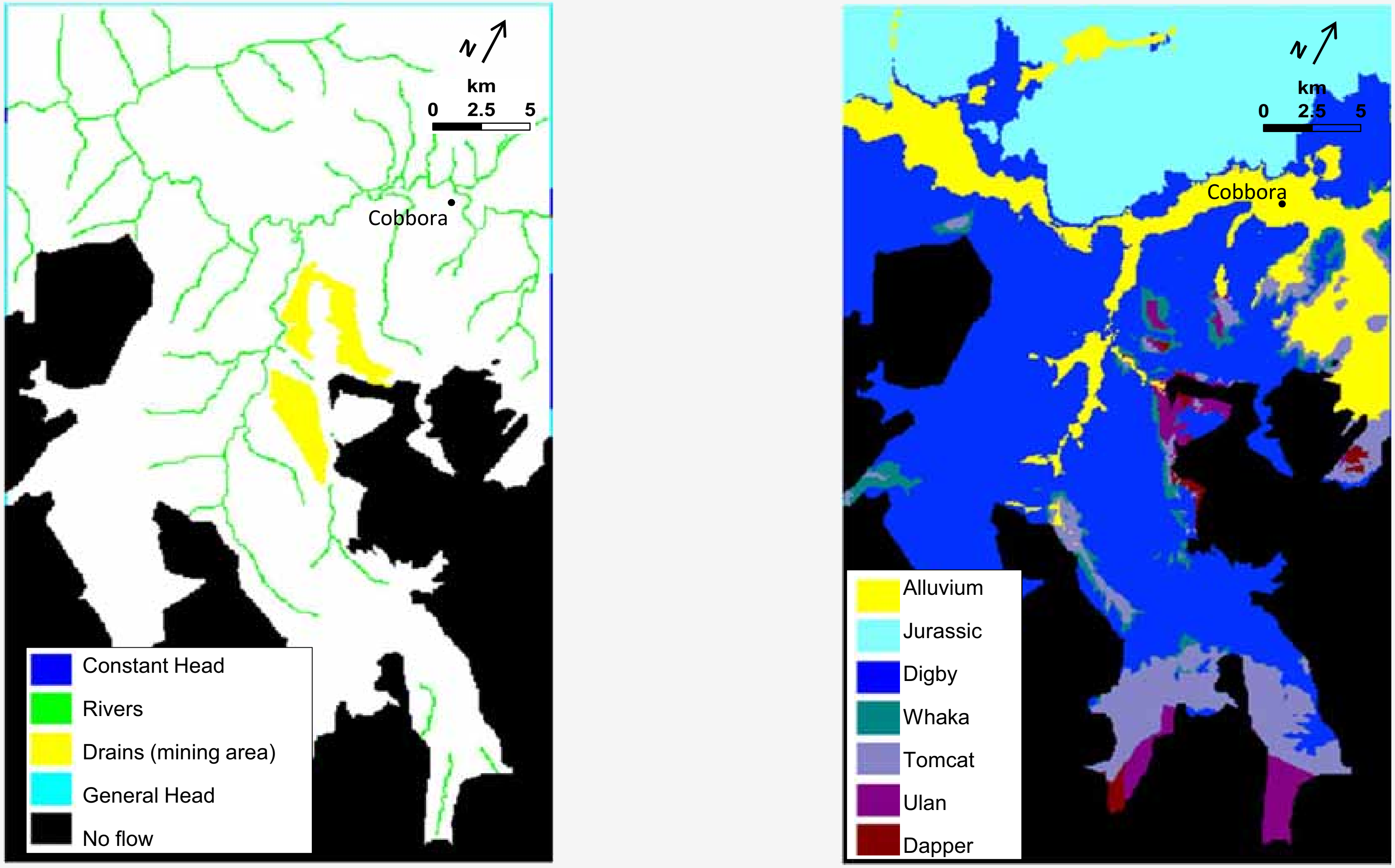


Figure 6.2 Model domain showing a) assigned boundary conditions and b) hydrostratigraphic units in layer 1

Table 6.1 Hydrostratigraphic units assigned to the groundwater model

Hydrostratigraphic unit	Geological formations
Alluvium	Alluvium
Jurassic	Pilliga Formation, Purlawaugh Formation
Digby	Napperby Formation, Digby Formation, Ellismayne Formation
Whaka	Whaka Formation, Avymore Claystone, Flyblowers Creek Seam
Tomcat	Tomcat Gully Sandstone
Ulan	Upper Ulan Seam, C-Marker Clay, Lower Ulan Seam
Dapper	Dapper Formation

6.1.1 Model calibration

Calibration is the process by which the independent variables (parameters and boundary conditions) of a model are adjusted, within realistic limits, to produce the best match between simulated and measured data. Calibration of the model to observed groundwater levels was used to refine the values of the model input parameters, including aquifer properties data and recharge to the groundwater system.

6.1.1.1 Steady state model

A steady state model was developed to simulate average long-term conditions within the assessment area. The model was calibrated to groundwater level data collected in March 2010, near the beginning of the groundwater monitoring program. A cumulative rainfall residual curve for the assessment area (Figure 6.3) indicates negligible net surplus or deficit of rainfall at this time and suggests that groundwater levels are likely to be close to their long-term average values

Calibration of the steady state model achieved a normalised root mean square (NRMS) error of 2.53%. This is well within the target value of 5% agreed with the independent reviewer, Dr Noel Merrick.

Sensitivity analysis indicates that the steady state model is not sensitive to the majority of input parameters. The model is sensitive to the horizontal conductivity of the Digby Formation, Ulan Coal Seams and Dapper Formation, with improved calibration arising from increased values of these parameters. The model was also found to be sensitive to recharge and vertical hydraulic conductivity in the Digby Formation and evapotranspiration extinction depth.

The results of sensitivity analysis were used to refine estimates of model input parameters, while ensuring that these estimates agree with the available range of data and conceptual model. Further details on the sensitivity analysis carried out are provided in Appendix H of this document.

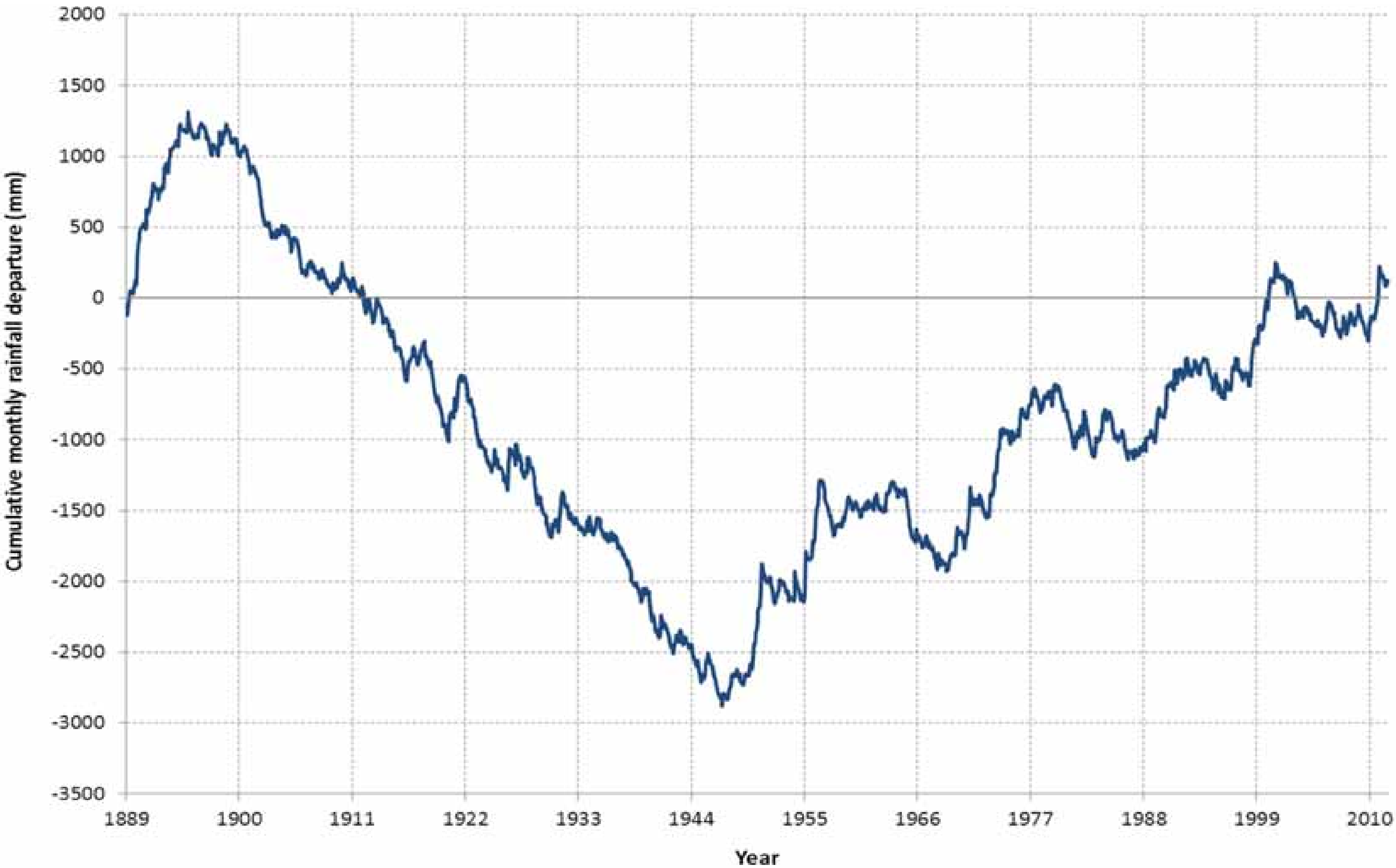


Figure 6.3 Cumulative monthly rainfall residual curve for the Project area since January 1889

6.1.1.2 Transient model

A transient model was developed to simulate the effects of changes in groundwater flows arising from variations in rainfall. The model was calibrated to groundwater level data collected between March 2010 and August 2011, as part of the groundwater monitoring program.

Calibration of the transient model achieved an NRMS error of 2.59%, which is well within the target value of 5%.

Sensitivity analysis indicates that the transient model is not sensitive to the majority of input parameters. The model was found to be most sensitive to vertical hydraulic conductivity in the Whaka Formation and vertical hydraulic conductivity, specific yield and recharge in the Digby Formation. The results were used to make further refinements to estimates of model input parameters. Further details on the transient sensitivity analysis are provided in Appendix H of this document.

The parameter values assigned to the model following completion of sensitivity analyses for both the steady state and transient models are presented in Table 6.2. For transient and predictive simulations, a long-term average rainfall of 636 mm/a was applied. The assigned evapotranspiration rate is 600 mm/a and is based on the available data (Bureau of Meteorology 2005). The depth below surface to which evapotranspiration is active in the model (i.e. evapotranspiration extinction depth) was set at 5 m, following model calibration.

Table 6.2 Summary of model input parameters

Layer(s)	Hydrogeological unit	K_h (m/d)	K_z (m/d)	S_y	S	Recharge (% of rainfall)
1	Alluvium	1	0.001	0.2	$5x10^{-4}$	2.9%
2	Jurassic	0.04	0.004	0.1	$3x10^{-4}$	0.46%
3	Digby	0.1	0.003	0.01	$5x10^{-5}$	0.64%
4	Whaka	0.004	$6x10^{-5}$	0.1	$5x10^{-4}$	0.46%
5	Tomcat Gully	0.008	$8x10^{-5}$	0.1	$5x10^{-4}$	0.46%
6	Ulan	0.3	0.003	0.1	$8x10^{-4}$	0.58%
7	Dapper	0.1	0.01	0.1	$8x10^{-4}$	0.46%

6.1.2 Predictions of mine inflows

The calibrated model was developed further, to allow a predictive simulation of mine inflow rates and changes in groundwater level over time. The following refinements were made in implementing the predictive simulation:

- The proposed mine plan was represented in the model by drain cells, which were active only during the period of excavations in that area of the mine and for 1 year afterwards, prior to backfilling taking place. The proposed mine plan comprises the mining areas A, B and C. The drain cells ensured that groundwater levels within all three mining areas were maintained at the base of the excavated area.

- The recharge and hydraulic properties assigned to the backfill (spoil) material were assigned, based on hydraulic testing data reported by Hawkins (2004), which indicates a wide range in permeability and storage characteristics for spoil material, with a geometric mean hydraulic conductivity value of 1.5 m/d. A recharge value of 3.3% of rainfall was applied to the backfill material, based on the work of Mackie (2009). This was achieved using the time-varying material properties package (TMP1) in MODFLOW-SURFACT.

- The model recorded simulated flows and groundwater levels four times each year during the life of the mine, and at yearly intervals for a further 100 years after cessation of the proposed mining operations and subsequently at decadal intervals for a further 950 years.
- The Lake boundary condition ('Lak2') was used to represent the formation of a pit lake in mining area B, following the cessation of mining operations.

6.2 Model results

6.2.1 Predicted mine inflow rates

An initial model simulation was run to provide best estimates of mine inflow rates and to investigate the potential effects on groundwater levels and river flows in the area. In this report, inflow rate is considered to be the equivalent of dewatering rate.

Predicted inflow rates during the proposed period of mining (2015 to 2035) are presented in Table 6.3 (and in Figure 6.4) for the three proposed mining areas: A, B and C. Approximately half of all dewatering is expected to occur in mining area B. The largest dewatering rates occur between 2021 and 2032, and typically exceed 2,000 ML/a during this period.

Table 6.3 Summary of estimated mine inflow rates

Year	Inflow rates (ML/a)			
	Mining area A	Mining area B	Mining area C	Total
2015	23	107	0	130
2016	192	329	23	544
2017	298	465	61	824
2018	368	600	101	1,069
2019	331	591	108	1,030
2020	446	767	183	1,396
2021	875	1,001	231	2,107
2022	733	1,325	381	2,439
2023	912	1,067	357	2,336
2024	884	1,202	369	2,455
2025	950	1,196	369	2,515
2026	453	1,444	550	2,447
2027	253	1,361	530	2,144
2028	592	1,614	596	2,802
2029	646	1,517	527	2,690
2030	637	1,237	529	2,403
2031	801	821	403	2,025
2032	1227	803	52	2,082
2033	278	633	33	944
2034	194	631	337	1,162
2035	0	31	0	31

* This table illustrates mine inflow during active mining only. Following the end of mining in area B (at year 2033) the process of groundwater recovery commences and inflow rate calculations for the recovery is presented and discussed in the *Cobbora Coal Project - Surface Water Assessment* (Parsons Brinckerhoff 2012).

It should be noted that these dewatering estimates are the theoretical pit inflow rates derived from the applied drain cells in MODFLOW. It is anticipated that active pumping from the pit may be significantly less than the predicted dewatering volume due to the effects of evaporation. Evaporative losses have been taken into account in the mine water balance presented in the surface water report (Parsons Brinckerhoff 2012b).

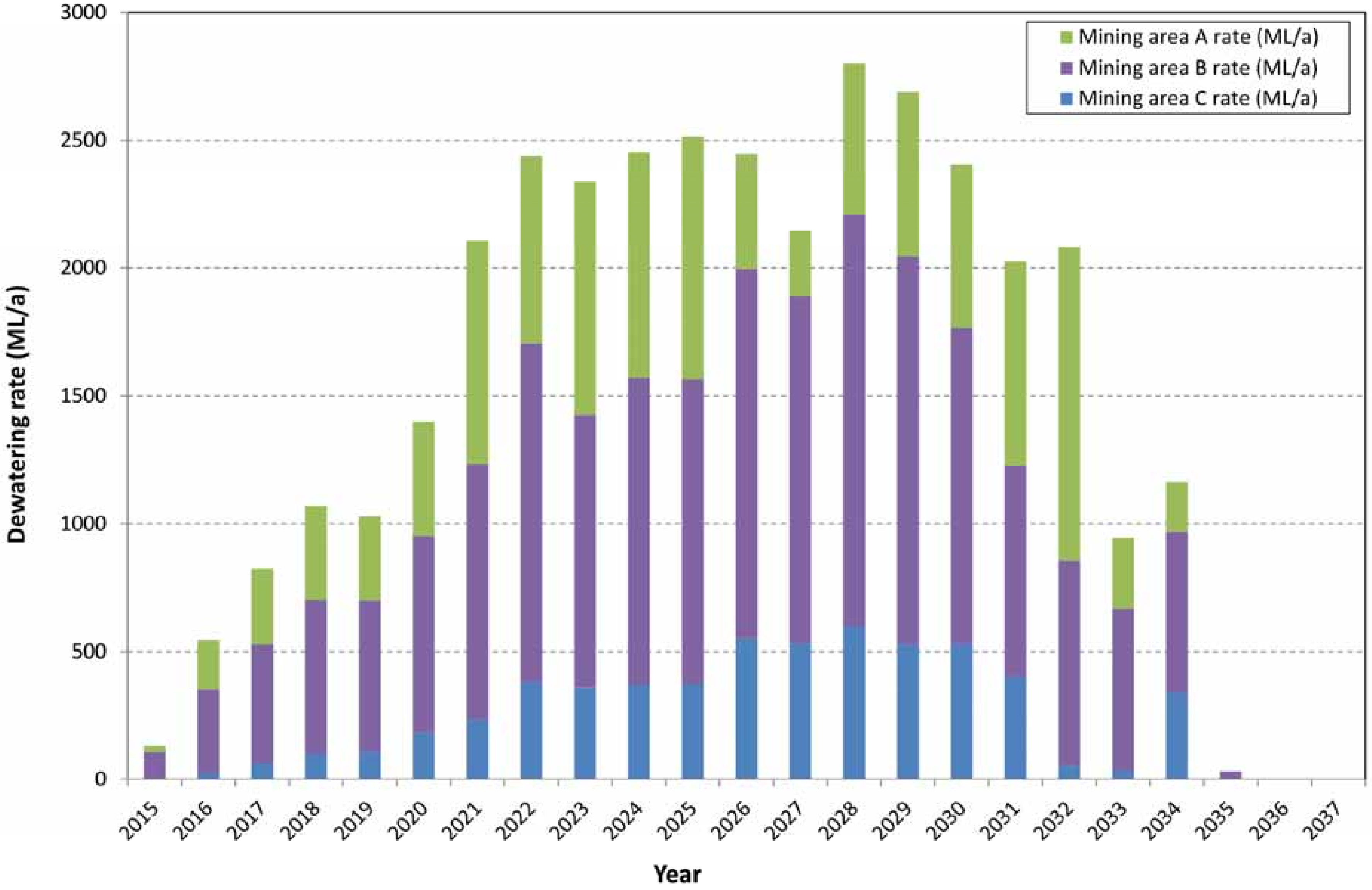


Figure 6.4 Predicted dewatering rates in each mining area

6.2.1.1 Sources of inflows

The effects of mine dewatering have been assessed based on changes in storage within each of the seven main hydrostratigraphic units in the model and the estimated reduction in river flows (the results are presented in Figure 6.5). The Ulan and Dapper hydrostratigraphic units are the biggest contributors to mine inflows in the model, with predicted cumulative storage losses of up to 6,500 ML and 6,100 ML respectively towards the end of mining.

Predicted cumulative storage losses within the alluvium reach a maximum value of approximately 720 ML. This constitutes 0.3% of the estimated 220,000 ML (220 GL) of available groundwater storage in the alluvium aquifer within the model domain (ignoring stagnant water stored in ‘dead-end’ pores).

The model results indicate a maximum reduction in river flows of approximately 480 ML/a, which occurs in 2036, following the end of mining operations. This constitutes 0.9% of the average annual flow in the Talbragar River of 54,427 ML/a.

6.2.1.2 Net groundwater usage

The placement of backfill material within the mine void is expected to increase the volume of recharge within the mining areas and contributes to the predicted dewatering rates listed in Table 6.3. River losses also contribute to the total dewatering rate. Net groundwater usage, as presented in Table 6.4 below, has been estimated based on the predicted mine dewatering rates, minus the river losses (as those losses are accounted for in surface water) and minus the contribution of enhanced recharge (which constitutes an additional use of surface water). This represents the net volume of groundwater usage as a result of mining activities.

Net groundwater usage is predicted to average approximately 1,840 ML/a between 2021 and 2030, reaching a maximum value of 2,202 ML/a in 2028. These values are slightly higher than the groundwater storage losses shown in Figure 6.5. The overall lowering of the water table within the model domain is predicted to reduce evaporation from groundwater and slightly reduce storage losses. As a conservative measure, the mitigating effects of reduced evaporation have not been included in estimating net groundwater usage. The average groundwater usage over the life of the mine is predicted to be 1,270 ML/a.

Table 6.4 Net groundwater usage during mining

Year	Dewatering rate (ML/a)	Enhanced recharge (ML/a)[1]	River losses (ML/a)	Net groundwater usage (ML/a)[2]
2015	130	31	4	95
2016	544	34	42	468
2017	824	45	80	698
2018	1,069	47	125	897
2019	1,030	49	160	820
2020	1,396	67	184	1,145
2021	2,107	84	215	1,808
2022	2,439	105	239	2,095
2023	2,336	126	265	1,946
2024	2,455	143	292	2,019
2025	2,515	161	317	2,037
2026	2,447	177	341	1,929
2027	2,144	195	364	1,585
2028	2,802	219	382	2,202
2029	2,690	239	397	2,053
2030	2,403	258	416	1,729
2031	2,025	279	431	1,315
2032	2,082	301	445	1,336
2033	944	323	459	162
2034	1,162	330	469	363
2035	31	275	474	0

Notes: [1]Enhanced recharge is the component of mine pit inflow that is attributed to additional recharge of rainfall into the adjacent spoils as a result of the high permeability and low runoff coefficient of the spoils. [2]Net groundwater usage is the theoretical groundwater inflow rate minus the enhanced recharge component, minus the estimated river losses.

6.2.2 Predicted drawdown

The maximum drawdown extent in the water table aquifer (which includes the alluvium) and Ulan Coal Seams is shown in Figure 6.6 and Figure 6.7 respectively, along with the locations of privately owned groundwater bores in the assessment area. This represents the maximum predicted drawdown in the water table at each location within the model domain and has been derived by combining predicted drawdown values across a range of time steps within the model.

Groundwater inflows to the mining areas are expected to lead to maximum lowering of the water table of up to 90 m in mining area B (with maximum lowering of the water table in mining areas A and C of 60 m and 40 m respectively). The 1 m drawdown contour is predicted to extend up to 5.5 km to the south of the mine and nearly 6 km to the west of mining area A. Drawdown to the north and east is far less extensive, with the 1 m drawdown contour predicted to lie within 4 km of the mining areas.

As the greatest lowering of water levels is expected to occur within mining area B, the largest drawdown is expected to be focused around this area. Lower values of drawdown are predicted in the vicinity of mining areas A and C as a result of lower inflow volumes.

Depressurisation is predicted to extend over a greater area in the Ulan Coal Seams than in the water table aquifer (which includes the alluvium). The 1 m depressurisation contour is predicted to lie approximately 6 km to the west of mining areas A and B. The extent of drawdown to the south, north and east of the mining areas is similar to that predicted for the water table aquifer.

The model predicts that, 20 years after the cessation of mining activity, lowering of groundwater levels will be primarily confined to within 3.5 km of the mining area boundaries, although residual drawdown is predicted to occur within 5.5 km of the void lake in mining area B.

There is continued drawdown 100 years after the cessation of mining in some areas due to evaporative losses from the pit lake and from the shallow subsurface in areas where ground levels have been lowered.

The water levels in the lake are expected to increase over time following the cessation of mining as groundwater levels recover. The water level in the lake is expected to have reached an equilibrium state 100 years after the end of mining, as evaporation from the lake is balanced by inflows from groundwater, rainfall and surface run-off (Parsons Brinckerhoff, 2012b).

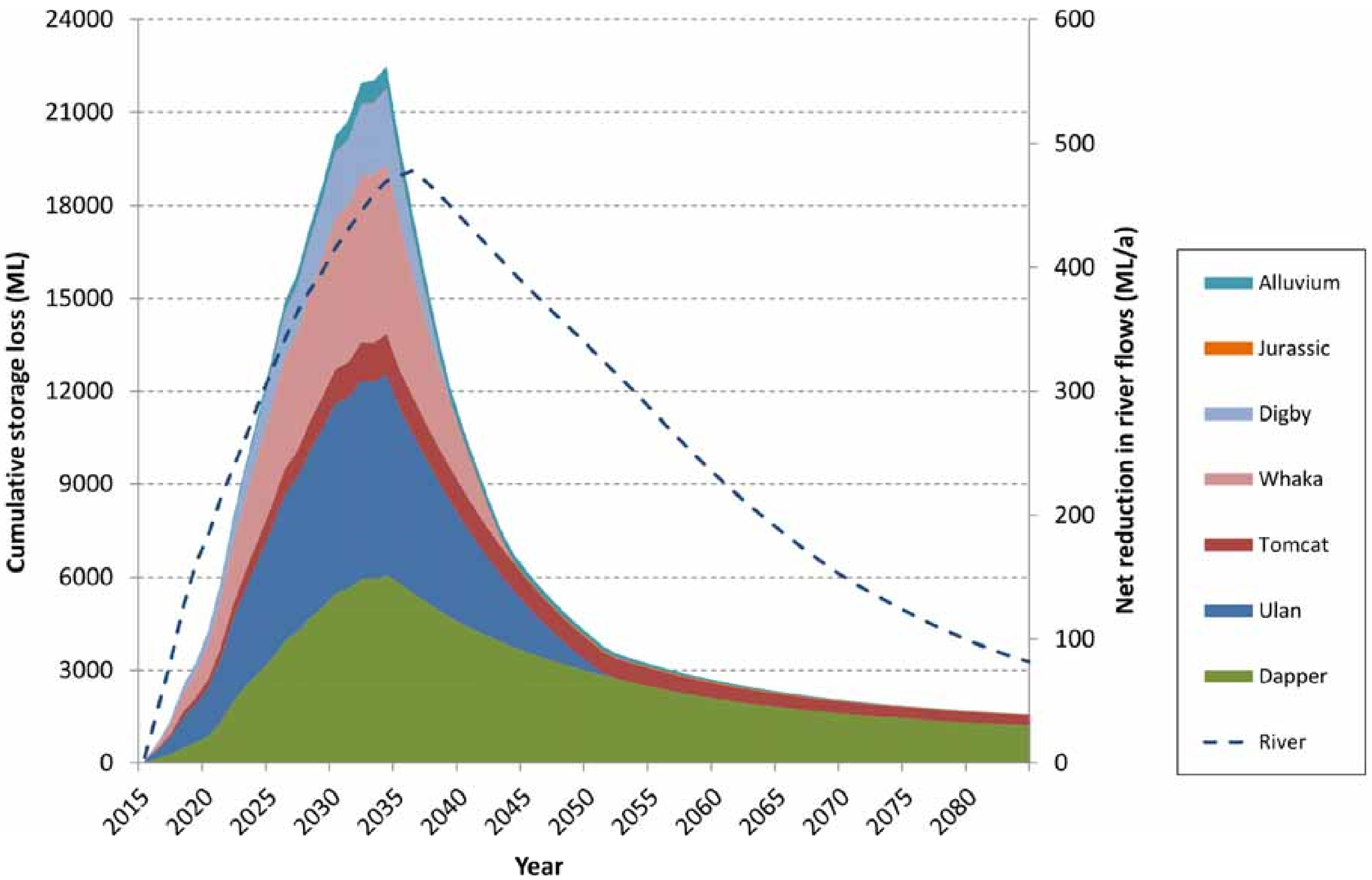
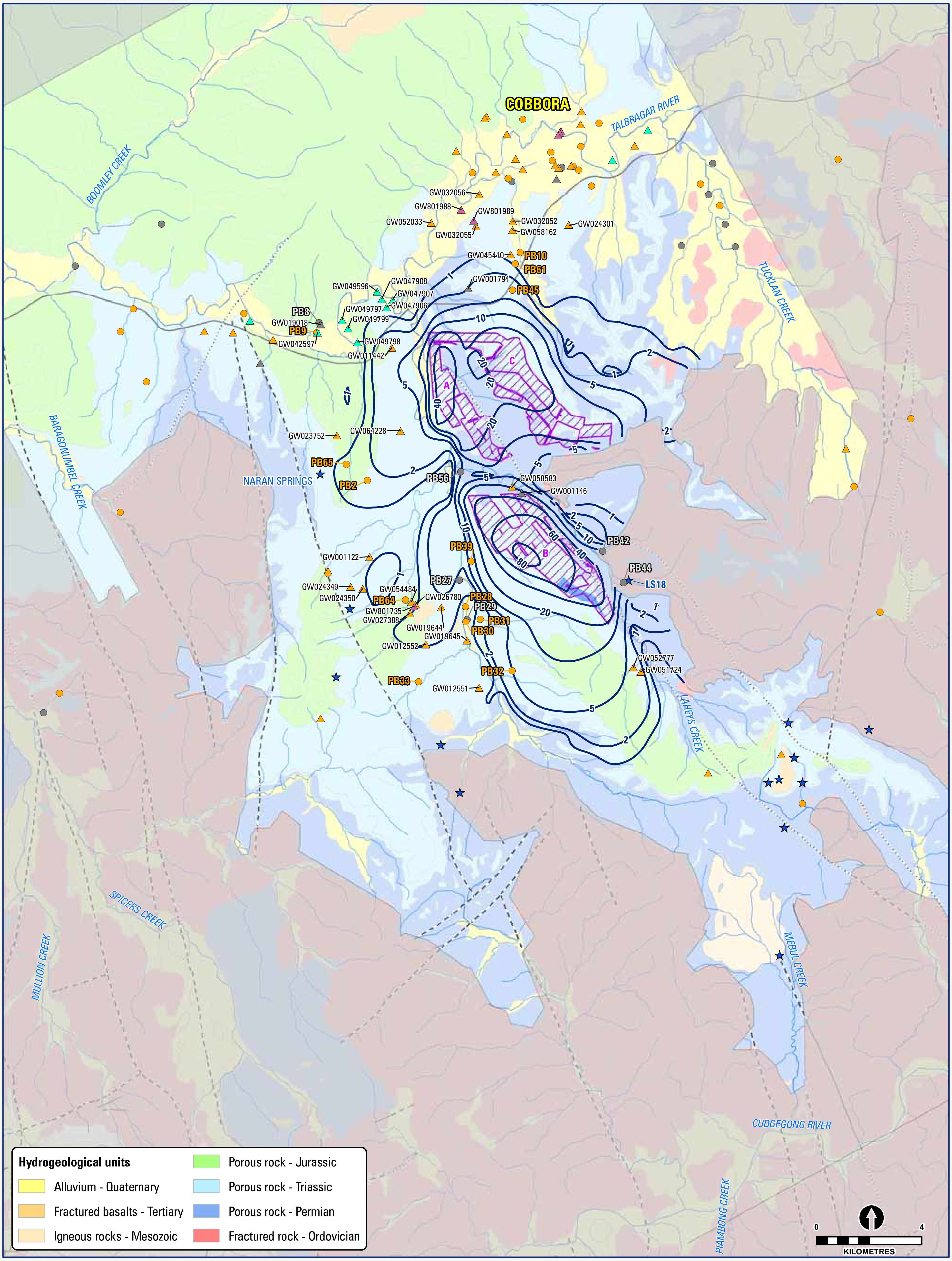


Figure 6.5 Predicted storage and river water losses from mine dewatering



Registered Groundwater Bores (NOW, 2011)
- Stock/domestic
- Irrigation
- Other
- Not known

Surveyed Groundwater Users
- Stock/domestic
- Not known

- Springs
- Drainage lines
- Fault - approximate
- Fault - concealed

- Proposed mining areas
- No flow boundary of numerical groundwater model
- Predicted pit lake location

- Maximum predicted drawdown (m)

Geologic map source: Geological Survey of New South Wales, 1999

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Figure 6.6 Maximum predicted drawdown in the water table aquifer

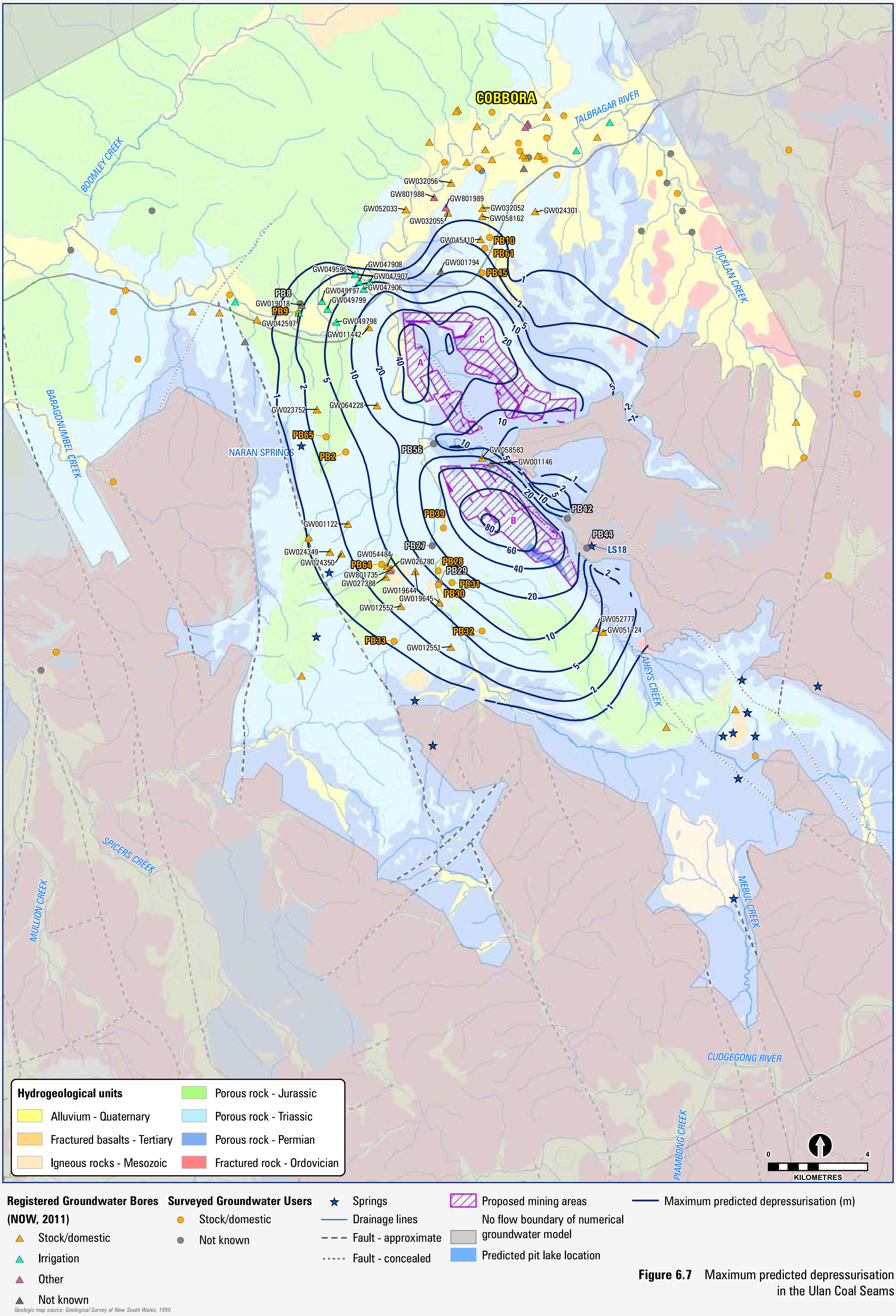

Figure 6.7 Maximum predicted depressurisation in the Ulan Coal Seams

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6.2.2.1 Predicted impacts on local groundwater bores

Existing groundwater bores identified as part of a hydrocensus in the assessment area are shown in Figure 4.1, along with the locations of other privately owned registered bores. A threshold of > 2 m drawdown has been applied for assessment purposes, in line with the Aquifer Interference Policy (DTIRIS 2012), which defines a maximum drawdown of less than 2 m as 'minimal impact'.

Model hydrographs for surveyed bores with a maximum predicted drawdown of more than 2 m as a result of mine dewatering are shown in Figure 6.8, with further details on these bores in Table 6.5 below. The privately owned registered bores (not surveyed) likely to experience drawdown > 2 m are also included in Table 6.5.

Table 6.5 List of potentially impacted groundwater bores

Bore	Owner-ship	Coordinates (MGA Zone 55)		Predicted maximum drawdown (m)	Approximate bore depth (mBGL)	Likely screened unit
		Easting (m)	Northing (m)			
PB32*	Private	710912	6431760	5.1	44.7	Triassic (porous rock aquifer)
PB39*	CHC	709354	6435914	30	100	Permian (porous rock aquifer)
PB45*	CHC	710921	6446204	3.4	unknown	Triassic (porous rock aquifer)
PB56*	CHC	708965	6439307	3.1	18	Triassic (porous rock aquifer)
GW001146	CHC	711270	6438510	30	18.8	Permian (porous rock aquifer)
GW001794	CHC	09254	6446255	2.1	32.3	Triassic (porous rock aquifer)
GW011442	CHC	706349	6444003	3.4	14.6	Triassic (porous rock aquifer)
GW012551	Private	709649	6431117	2.4	36.8	Triassic (porous rock aquifer)
GW058583	CHC	710907	6438733	21	53.3	Permian (porous rock aquifer)
GW051724	CHC	715790	6431728	4.5	77.5	Triassic (porous rock aquifer)
GW052777	CHC	715506	6431888	5.5	77.5	Triassic (porous rock aquifer)
GW064228	CHC	706679	6440854	3.7	64	Triassic (porous rock aquifer)
GW801735	Private	707198	6434204	2.2	120	Triassic (porous rock aquifer)

* registered bore number unknown
MGA = Map Grid Australia

Ten of the 13 bores with predicted drawdowns > 2 m are owned by Cobbora Holding Company Pty Ltd. Of the other bores, PB32 shows a maximum drawdown of 5.1 m, GW012551 shows a maximum drawdown of 2.4 m and GW801735 shows a maximum drawdown of 2.2 m.

Most private registered bores and bores identified during the hydrocensus show predicted drawdown values of less than 2 m throughout the period of mining activities and beyond.

6.2.3 Final void and post-mining recovery

The recovery in groundwater levels following mining will be influenced by the presence of the pit lake in mining area B and the presence of backfill material, which is expected to be significantly more permeable than the original geology. This increased permeability is expected to reduce groundwater levels in the vicinity of mining area C, where groundwater levels currently rise steeply away from nearby creeks.

The pit lake in mining area B is expected to receive groundwater inflows following the cessation of mining activity. The predicted groundwater inflows for a range of lake stage values during post-mining recovery are presented in Table 6.6 below. These were used to inform the surface water impact report, where further modelling was undertaken to assess the effects of rainfall, surface runoff and evaporation on lake stage (Parsons Brinckerhoff 2012b). The calculated inflows increase as the lake stage increases which seems counterintuitive. However this is a function of the differential recovery of the groundwater relative to the filling of the pit lake. The model predicts that initial inflows will be low because there will be a broad cone of drawdown related to mining that will take several decades to recover. As the groundwater levels recover, there will be in increase in the lake-ward gradient and therefore inflow, despite the gradual filling of the lake.

The lake is predicted to reach a steady state when the stage reaches 373.9 m AHD (i.e. inflows from groundwater, average rainfall and surface runoff are equal to average evaporative losses). The estimated groundwater inflow to the void lake at equilibrium (approximately 270 ML/a) will be ongoing and should be taken into account in groundwater licence provisions.

Table 6.6 Groundwater inflow rates to pit lake

Lake stage (m AHD)	Groundwater inflow rate (ML/a)
348	5
353	45
358	104
363	172
368	218
373	268

6.2.4 Uncertainty analysis of mine inflows

An analysis was conducted to assess the model response to changes in the most sensitive input parameters. The most significant parameters with respect to mine inflow and drawdown are in relation to the Ulan Coal Seams and the properties of the backfill material. The largest component of dewatering occurs in the Ulan unit and the groundwater system was found to be sensitive to the hydraulic conductivity of this unit during calibration. The permeability and storage characteristics of the spoil material are not well quantified at this stage and there is potential for some heterogeneity. Accordingly, the hydraulic conductivities of the Ulan Coal Seams and the backfill material were changed by +/- 50% in four sensitivity runs.

The analysis indicates that mine dewatering rates and groundwater usage may vary by up to 12% as a result of the above parameter variations. As a conservative approach, estimates of groundwater inflow into the final void are assumed to have a coefficient of variation of 15%. That is, for the purpose of the stochastic modelling of the filling of the final void (Parsons Brinckerhoff 2012b), the groundwater inflow component has been applied in a probabilistic manner, with a standard deviation of 15% of the estimate.

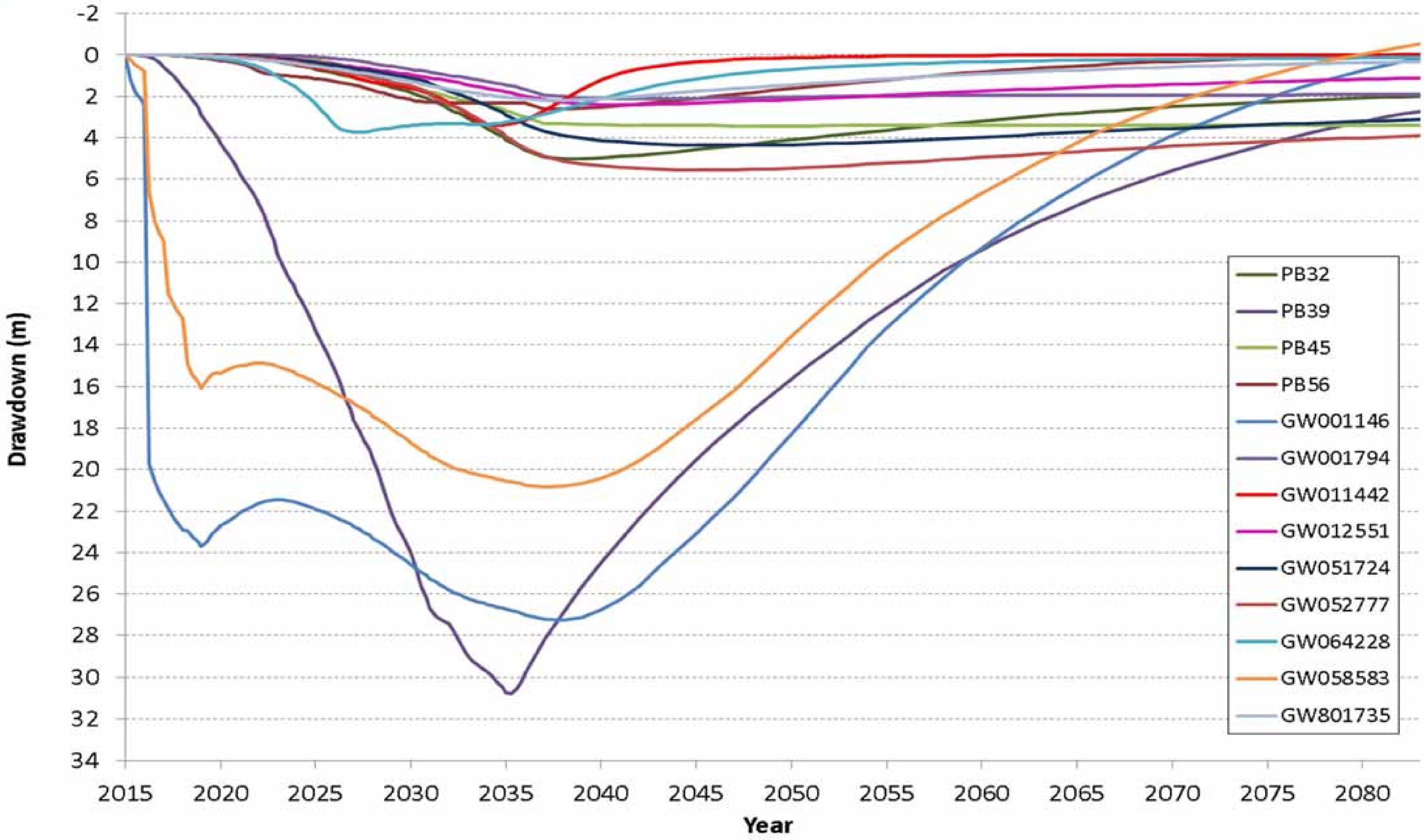


Figure 6.8 Hydrographs of groundwater bores with >2 m drawdown

6.2.5 Areas of potential groundwater availability to ecosystems

Groundwater is potentially available to ecosystems in the following environments:

- springs/seeps
- semi-permanent pools (non-flowing) within the creeks supporting aquatic species
- shallow groundwater in alluvium.

All identified springs, including the priority groundwater dependent ecosystem, Naran Springs, are shown on the maps of maximum drawdown at the water table and depressurisation in the Ulan Coal Seam (Figure 6.6). All identified springs are located well outside the predicted 1 m drawdown. Depressurisation in the Ulan Coal Seam will extend further than the predicted drawdown in the water table such that approximately 1 m head decline may occur in the Permian rocks at Naran Springs, located 5.25 km to the west of the mining areas.

Groundwater investigations (groundwater levels, quality and isotope studies) indicate that springs are not associated with the regional flow systems and do not discharge from the Permo-Triassic aquifer. In addition, all springs are located outside of areas where artesian pressures are observed or predicted to occur. Therefore, our investigations indicate that depressurisation in the Ulan Coal Seam will not impact the identified springs, including Naran Springs.

To assess the potential impacts to shallow groundwater in alluvium and semi-permanent pools along Sandy Creek and Laheys Creek, simulated drawdown hydrographs have been generated for representative aquatic ecology sites (semi-permanent pools). These are shown in Figure 6.9. The site location numbers refer to sites sampled and characterised by the Project ecologist (Figure 5.17). The hydrographs indicate that significant but temporary drawdown will likely occur within the alluvium or exposed Permo-Triassic rocks at some of those locations. In particular, drawdown in the order of 2.7 m to 12.9 m is predicted to occur at sites 4, 6 and 9. Relatively minor drawdown (≤0.7 m) is predicted at sites 3, 13 and 28.

There is potential for drawdown at these locations to cause leakage from the alluvium which may lead to a decline in groundwater seepage in semi-permanent pools that are reliant on groundwater discharge. It is noted that the predicted drawdown is unlikely to lead to permanent loss of semi-permanent pools due to the episodic rapid recharge of the alluvium aquifers during high rainfall and high stream flow events.

Some additional calculations and a more detailed assessment of the overall impacts to semi-permanent pools (to consider the impacts from groundwater dewatering and also the increased low flow frequency for the surface water system) is contained in the Cobbora Coal Project - Surface Water Assessment (Parsons Brinckerhoff 2012).

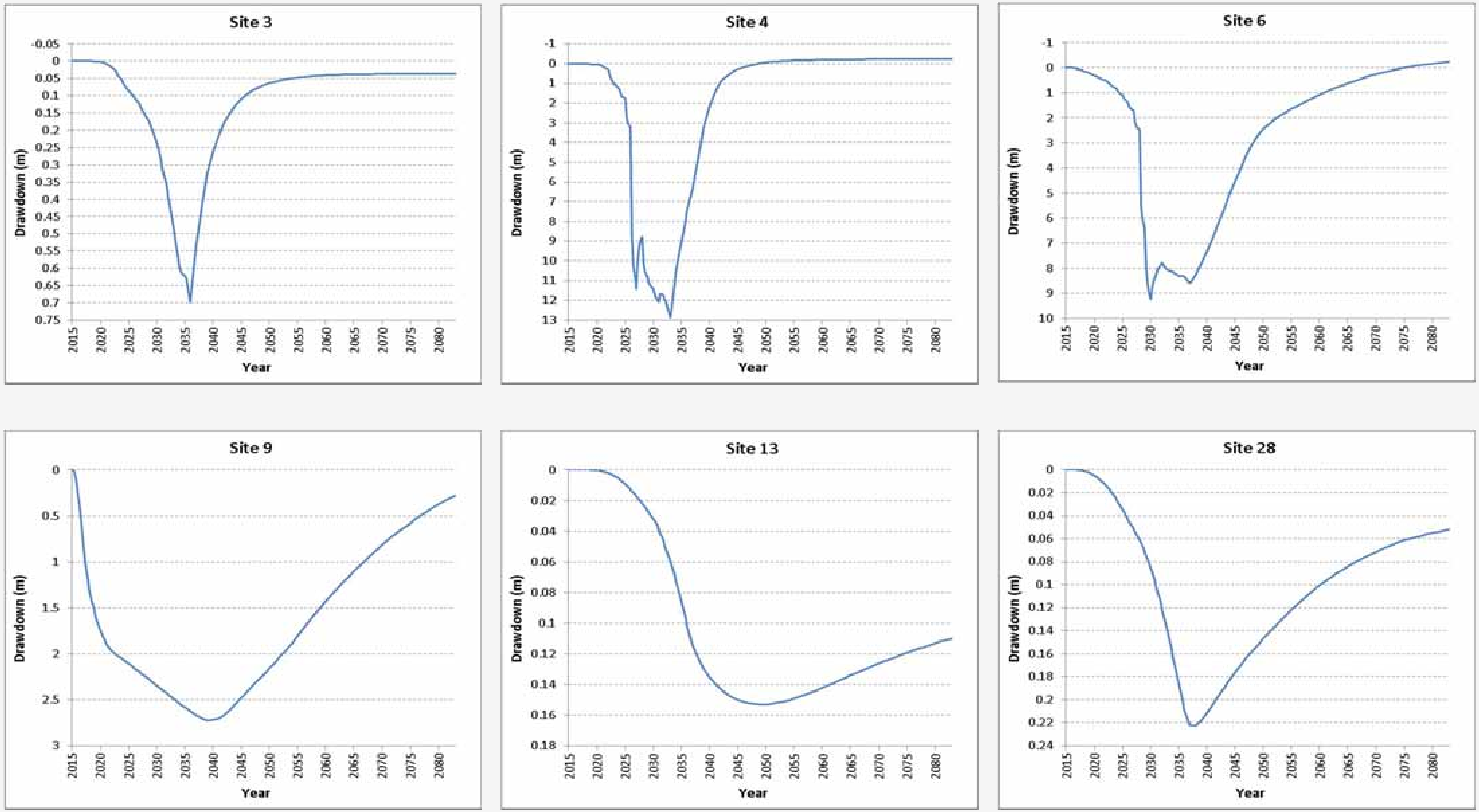


Figure 6.9 Simulated hydrographs at aquatic ecology sites

7. Potential groundwater impacts

Coal mining operations will involve stripping of overburden and interburden units of the Permo-Triassic succession using excavators, and mining of the economic coal seams. Overburden stripping and mining will be carried out in a series of mining strips and blocks which together define three mining areas; A, B and C.

The deepest target seams are the Ulan seams which dip towards the west in the areas designated as mining areas A and B such that those mining areas will reach a total depth of 110 metres below the surface. Mining of those areas will therefore be below the water table and moderate amounts of groundwater inflow will occur. Within mining area C, the Ulan seams occur at shallower depths and the water table is considerably deeper (as it is located along a ridge) such that groundwater inflows will be considerably less than in mining areas A and B.

It is anticipated that in most areas of mining, inflows will be low and dewatering will be achieved through the use of in-pit sumps and pumps. However, active mining blocks, where they are below the water table, may need to be dewatered to allow safe operation of vehicles and machinery where higher inflows are encountered. It may be necessary to install a number of dewatering bores (either inside the proposed pit or just outside the pit perimeter) to depressurise the coal measures prior to and during active mining. A small number of dewatering bores may need to be installed during mining of mining areas A and B. However, mining at mining area C will likely only require minor sump pumping when inflows are encountered or during periods of high rainfall.

All mining areas will receive inflow of surface water runoff from local catchments and direct rainfall during larger rainfall events which will be managed using surface pumping equipment.

Mine inflow and dewatering will result in depressurisation of coal measures in the vicinity of the mining areas, which in turn will cause leakage from overlying units and lowering (drawdown) of the water table in affected areas. Section 6 of this report discusses the likely leakage volumes from surrounding Permo-Triassic and alluvium aquifers within the cone of depressurisation. There is also potential for minor induced leakage from surface water systems which is also discussed in Section 6. The extent of drawdown and potential impacts associated with the Project are assessed further using numerical modelling (Section 6).

Broken waste rock will be back-filled into the mined pit voids. The broken waste rock piles will be more permeable and produce less surface runoff than the pre-existing ground surface, causing significantly higher rates of infiltration and recharge to groundwater in those backfilled areas. This will result in localised groundwater mounding in those areas (to some extent enhancing recovery of the mine induced drawdown) and also some increase in the initial rate of groundwater inflows to mine Pit B.

If waste rock contains acid-forming materials (e.g. sulfides), there is potential for acid mine drainage to develop. Acid mine drainage (AMD) occurs due to the oxidation of sulfide minerals (if present) in the presence of infiltrating water, producing dilute sulphuric acid which, in turn, can leach and mobilise metals in the leachate and groundwater.

In 2012, the consultant Geoterra carried out an AMD assessment as part of this program of investigations and the potential for AMD was assessed to be low at this location. The AMD report is provided in a separate volume of the environmental assessment report and AMD risk is assessed as low for this project.

The final landform has been designed to minimise impacts to groundwater and surface water due to changes to the flow regime and potential salinisation of water that accumulates in the final pit void. The final landform is presented in map and cross section format and Figure 7.1 shows a 3D rendering of the final landform and the location of the cross section lines. Pit A has been backfilled to be 3 metres above the current groundwater table and free draining for surface water, thereby allowing the natural processes of rainfall and groundwater discharge to occur freely (Figure 7.2). Pit B has been designed to minimise impacts to the surface and groundwater systems while also considering the economic feasibility of fully backfilling of this deep narrow pit. The final landform is largely backfilled to 3 metres above the current water table but with a small section of the pit to remain as a lake (Figure 7.3). Pit C will be backfilled to a minimum of 5 metres above the current groundwater table and will also allow surface water to drain freely to the south east into Blackheath Creek a tributary of Laheys Creek (Figures 7.1 and 7.2). Groundwater levels for the current situation, end of mining, and following recovery to equilibrium levels after mining ceases are illustrated on two cross sections (Figures 7.2 and 7.3).

The calculated final equilibrium groundwater levels and the pit void lake quality for Pit B is determined by water and mass balance modelling, as discussed in the Cobbora Coal Project - Surface Water Assessment (Parsons Brinckerhoff 2012).

The potential impacts the Project will have on the groundwater system include:

- drawdown of groundwater levels and pressures within the alluvium and porous rock aquifers in the assessment area during mining
- reduction in available groundwater for one existing third party groundwater user within the assessment area during mining
- reduced groundwater discharge to creeks and loss of potential groundwater availability to ecosystems during mining
- development of a saline lake that will be isolated from the surrounding environment post mining.

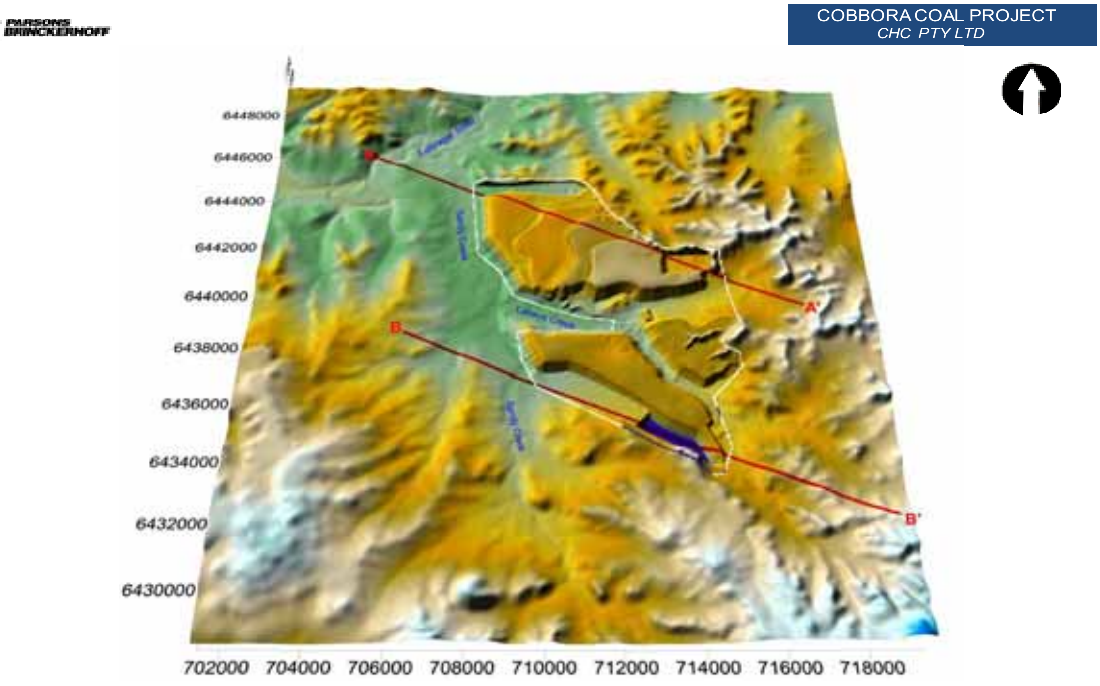


Figure 7.1 Final landform and cross section locations

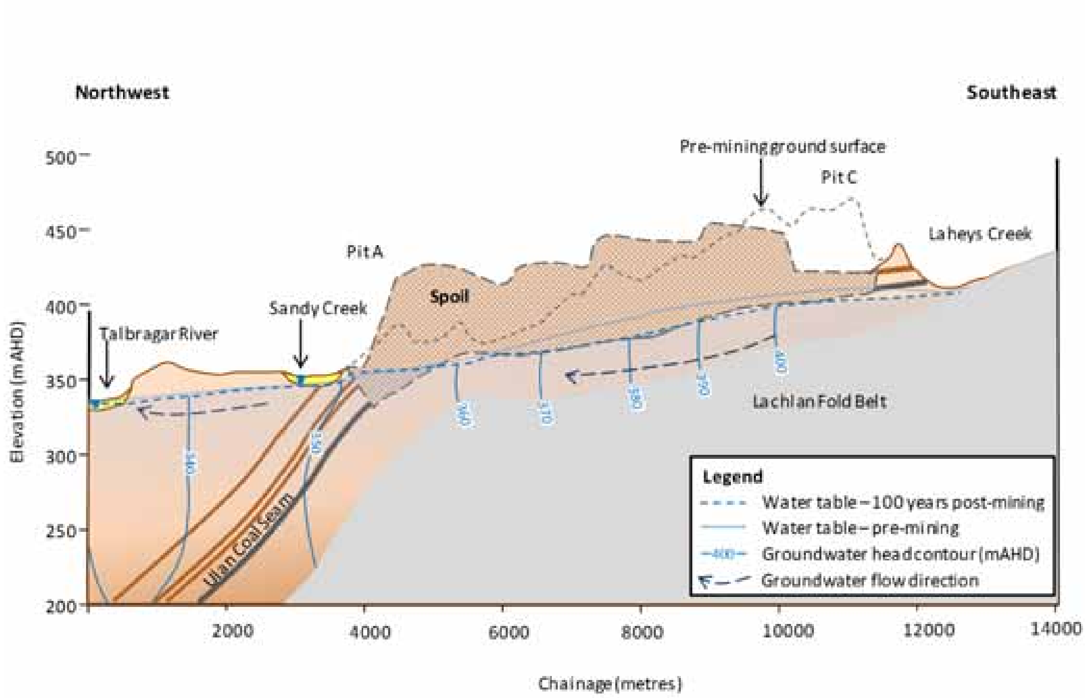


Figure 7.2 Hydrogeological Cross Section - Final landform, Pits A and C

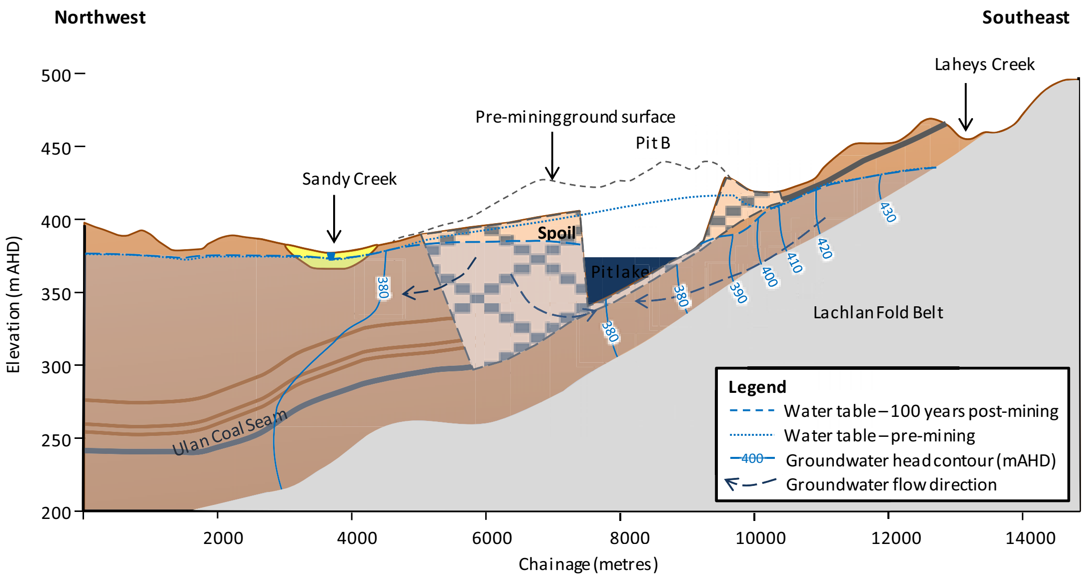


Figure 7.3 Hydrogeological Cross Section - Final landform, Pit B

7.1 Groundwater levels

The numerical model, described in Section 6, has been used to predict changes in groundwater levels as a result of mining. Mine inflow will result in depressurisation of coal measures in the vicinity of the mining areas which, in turn, will cause leakage from overlying units and lowering (drawdown) of the water table in affected areas. The maximum induced drawdown in the porous rock aquifer is predicted to be approximately 90 m. This is expected to occur beneath mining area B during active mining.

The maximum drawdown adjacent to the alluvium is predicted to be approximately 20 m, enhancing leakage from the alluvium (maps indicating water table drawdown include the alluvium). The location of this maximum drawdown is expected to occur approximately 0.5 km to the west of mining area B within the alluvium associated with Sandy Creek, between 14 and 15 years after the commencement of mining activity. The predicted cumulative storage losses within the alluvium reach a maximum value of approximately 720 ML, which constitutes only 0.3% of the estimated 220,000 ML (220 GL) of available groundwater storage in the alluvium aquifer within the model domain (ignoring stagnant water stored in 'dead-end' pores).

Groundwater drawdown of more than 1 m in the water table is expected to extend up to 5.5 km to the south of the mining area and nearly 6 km to the west of mining area A. The 1 m drawdown contour is predicted to remain within 4 km of the mining areas to the north and east. The maximum extent of drawdown is expected to occur at the end of the proposed mining activities. Depressurisation of the Ulan Coal Seam is likely to extend further than drawdown at the water table such that the 1 m drawdown contour in the Ulan Coal Seam may extend approximately 6 km to the west of the proposed mining areas A and B.

The maximum drawdown extent in both the water table aquifer and the Ulan Coal Seams is shown in Figure 7.4 and 7.5 respectively, along with locations of privately owned groundwater bores in the assessment area. These figures represent the maximum predicted drawdown at each location within the model domain. Therefore, they accurately represent maximum impact at any location regardless of which year the maximum impact occurs during mining. Water level contours at the end of mining are presented for both the water table aquifer and the Ulan Coal Seam, Figure 7.6.

The model predicts that 20 years after mining ceases, lowering of groundwater levels will be primarily confined to within 3.5 km of the mining area boundaries, although residual drawdown is predicted to occur within 5.5 km of the void lake in mining area B (Figure 7.7). There is residual drawdown 100 years after the cessation of mining in some areas due to evaporative losses from the pit lake and from the shallow subsurface in areas where ground levels have been lowered (Figure 7.8). The water levels in the lake are expected to increase over time following the cessation of mining as groundwater levels recover. The water level in the lake is expected to have reached an equilibrium state 100 years after the end of mining, as evaporation from the lake is balanced by inflows from groundwater, rainfall and surface run-off (Parsons Brinckerhoff, 2012b).

7.2 Groundwater users

Within a 15 km radius of the Project area 143 registered bores were identified. During the two hydrocensus surveys, a total of 74 individual bores were surveyed, with 40 of these able to be correlated with registered bores.

The groundwater model has been used to assess the potential impacts on on privately owned groundwater bores. The model results predict that 13 bores will experience a drawdown of greater than 2 m as a result of mine dewatering (Table 6.5). Ten of these bores are on properties owned by CHC (Figure 7.1). The remaining three bores are predicted to experience maximum drawdown values of 2.2 m, 2.4 m and 5.1 m respectively.

The majority of bores show predicted drawdown values of less than 2 m throughout the period of mining activities and beyond.

Based on these results, the overall impact on groundwater users is considered low and manageable. It is noted that ten of the 13 bores that are predicted to experience drawdown >2 m are located on properties owned by Cobbora Holding Company Pty Ltd and therefore impacts to third-party bores is expected to be negligible. Should water supplies from the bore of the single property owner outside the land owned by Cobbora be adversely affected, appropriate remedial measures will be negotiated.

The maximum drawdown groundwater contours during mining are overlain with registered groundwater bore users and the current extent of the land owned by Cobbora Holding Company. The water table drawdown contours and registered bore users who obtain groundwater supply from the water table aquifer are presented in Figure 7.4.
The depressurisation of the Ulan Coal Seam is illustrated in Figure 7.5 and registered bore users who access this deeper groundwater source are illustrated on this map. It should be noted that most users obtain their groundwater supply from the shallower water table aquifer.

7.3 Baseflow to rivers/creeks

The numerical model, described in Section 6, has been used to assess the potential impacts on rivers and creeks in the assessment area as a result of mine dewatering activities.

The model results indicate a likely maximum reduction in river flow of approximately 480 ML/a, which occurs in 2036 following the end of mining operations. This constitutes 0.9% of the average annual flow in the Talbragar River of 54,427 ML/a (Parsons Brinckerhoff 2012).Many of the creeks and rivers in the assessment area are ephemeral in nature and it is likely that large stretches of the river network receive negligible groundwater flow throughout the year. During dry periods, there remain isolated semi-permanent pools within the creeks. There is no appreciable flow of surface water in these pools and it appears that groundwater inflows to these pools are balanced by evaporative losses. As mining progresses the frequency of low flow events in the surface water systems will increase and this is likely to supplement water to these pools, as further discussed in the Cobbora Coal Project - Surface Water Assessment (Parsons Brinckerhoff 2012).

The numerical model indicates that, under current pre-mining conditions, surface water bodies are a net source of water to the groundwater system. This is supported by field observations during flooding. This influx of water is expected to occur mainly during periods of high river flow, following heavy rainfall.

The predicted reduction in river flows is expected to mainly comprise increasing recharge of surface water to the underlying aquifers. Reduced flow of groundwater to surface water bodies during mining is expected to make up a much smaller component of the 480 ML/a indicated by the model. The model results predict that approximately 65% of the total reduction in surface water flows is due to increased outflows from rivers to the surrounding groundwater system, with reductions in baseflow accounting for the remaining 35%.Potential groundwater availability to ecosystems.

Groundwater is potentially available to ecosystems in various environments across the assessment area. Their occurrences, potential impact and impact level are summarised in Table 7.1.

Table 7.1 Potential impacts on groundwater availability to ecosystems

Groundwater environment	Occurrence	Potential impacts	Impact level
Springs/seeps	Seventeen springs or seeps have been identified across the assessment area (Figure 5.17). These are typically associated with localised outcrops of Tertiary basalt or Jurassic sedimentary outliers. The elevations of the springs tend to be significantly higher than the regional water table and piezometric head (confined groundwater pressures).	Hydrogeochemical and isotopic evidence indicates that springs and seeps are derived from recent meteoric recharge and not the Permo-Triassic groundwater system. They represent local perched systems that are independent of the regional aquifer system. In addition the identified springs and seeps are located beyond the area of predicted drawdown. Flow rate and water quality at the springs are therefore unlikely to be impacted by the proposed operations.	Low
Spring*	Naran Springs is identified as a high priority groundwater dependent ecosystem (GDE) in the water sharing plan for porous rock water sources. It is located approximately 5.25 km to the west of the proposed mining areas. It is located in an area where the regional water table (and piezometric surface) is greater than 20 m below the ground surface.	Naran Springs is assumed to be similar to the other springs identified in the study area and associated with outliers of Jurassic sedimentary rocks. Naran Springs is similarly unlikely to be impacted by the proposed operations.	Low
Semi-permanent pools (non-flowing) within the creeks and rivers	Semi-permanent pools occur in a number of locations along Sandy and Laheys Creeks and the Talbragar River. The pools are sustained by episodic stream flow events and minor discharge of groundwater from the alluvium and, locally, the Permo-Triassic system. Groundwater discharge is insufficient to cause permanent base flow in the Talbragar River and tributary streams in the Project area.	Modelling indicates that significant drawdown is likely to occur in the Permo-Triassic units adjacent and to the west of mining areas A and B. This may induce leakage from the alluvium and cause a decline in groundwater seepage in semi-permanent pools that are connected to those groundwater systems along Sandy Creek and Laheys Creek. Despite the predicted drawdown, temporary groundwater storage in the alluvium may continue to sustain these pools for 6 to 8 months following flood recharge events. The increased incidence of low flow events during and post mining from the surface water systems is likely to mitigate the groundwater impact to some degree as further discussed in the *Cobbora Coal Project - Surface Water Assessment* (Parsons Brinckerhoff 2012.	Moderate
Shallow groundwater in river and creek alluvium	Groundwater occurs at shallow levels within alluvium and Permo-Triassic units in a narrow (500 m) but discontinuous zone adjacent to creek and river courses in the Project area (Figure 5.17). Where groundwater is shallower than 3 m depth, it is assumed to be available to deeper rooted vegetation.	Significant drawdown is likely to occur in the Permo-Triassic units adjacent and to the west of mining areas A and B. Testing has shown that the alluvium is hydraulically poorly connected to the underlying Permo-Triassic strata and it is expected that depressurisation of the coal measures will cause some drawdown in the alluvium. Modelling suggests that the drawdown may exceed 5 m along stretches of Sandy and Laheys Creek that are adjacent to mining areas A and B. Rainfall and flood recharge will likely be sufficient to sustain the local alluvium aquifers for several months following flood events despite drawdown in the coal measures.	Moderate

* Priority groundwater dependent ecosystem as identified by the Water Sharing Plan for the MDB Porous Rock Groundwater Source (NOW 2011b)

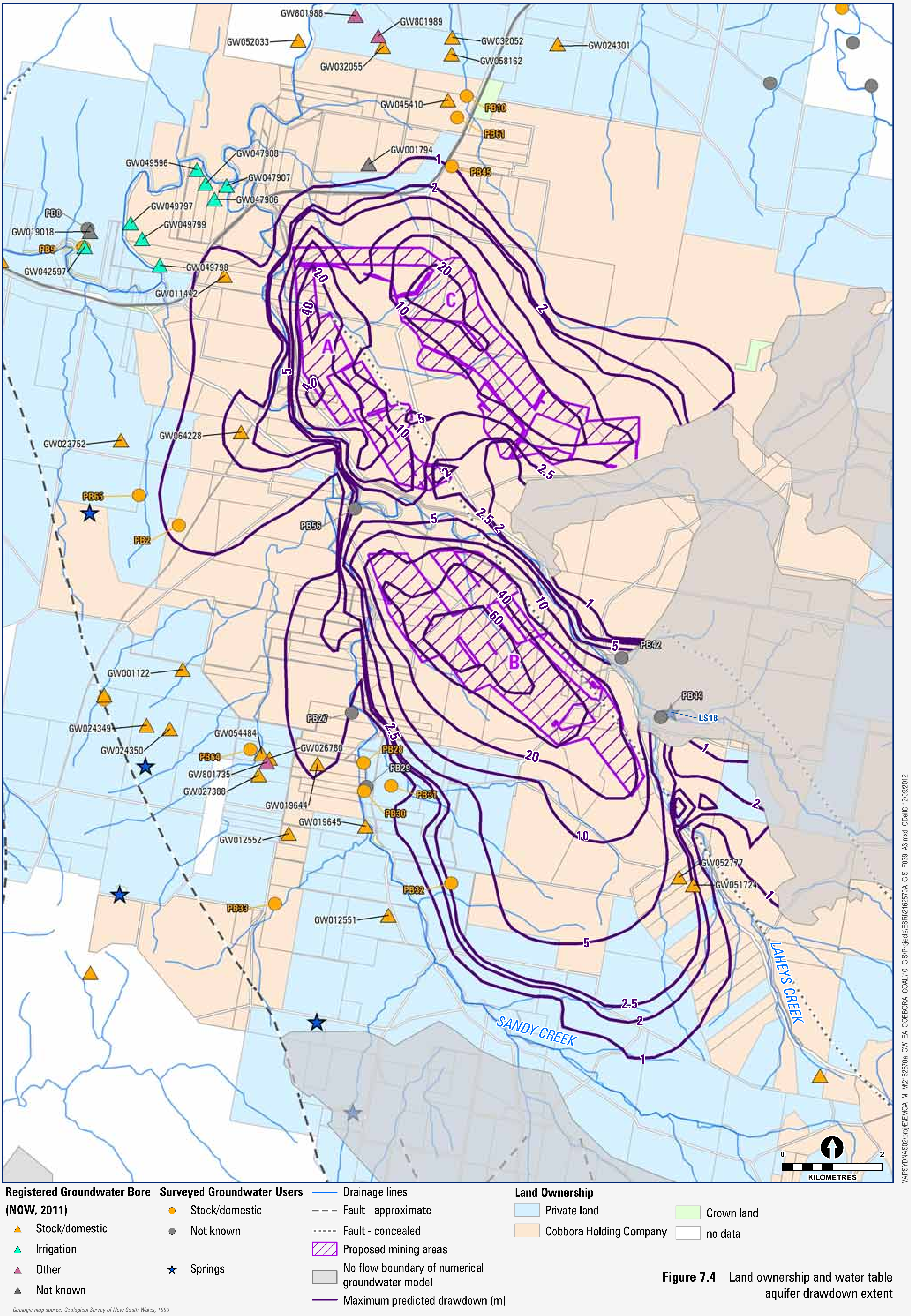


Figure 7.4 Land ownership and water table aquifer drawdown extent

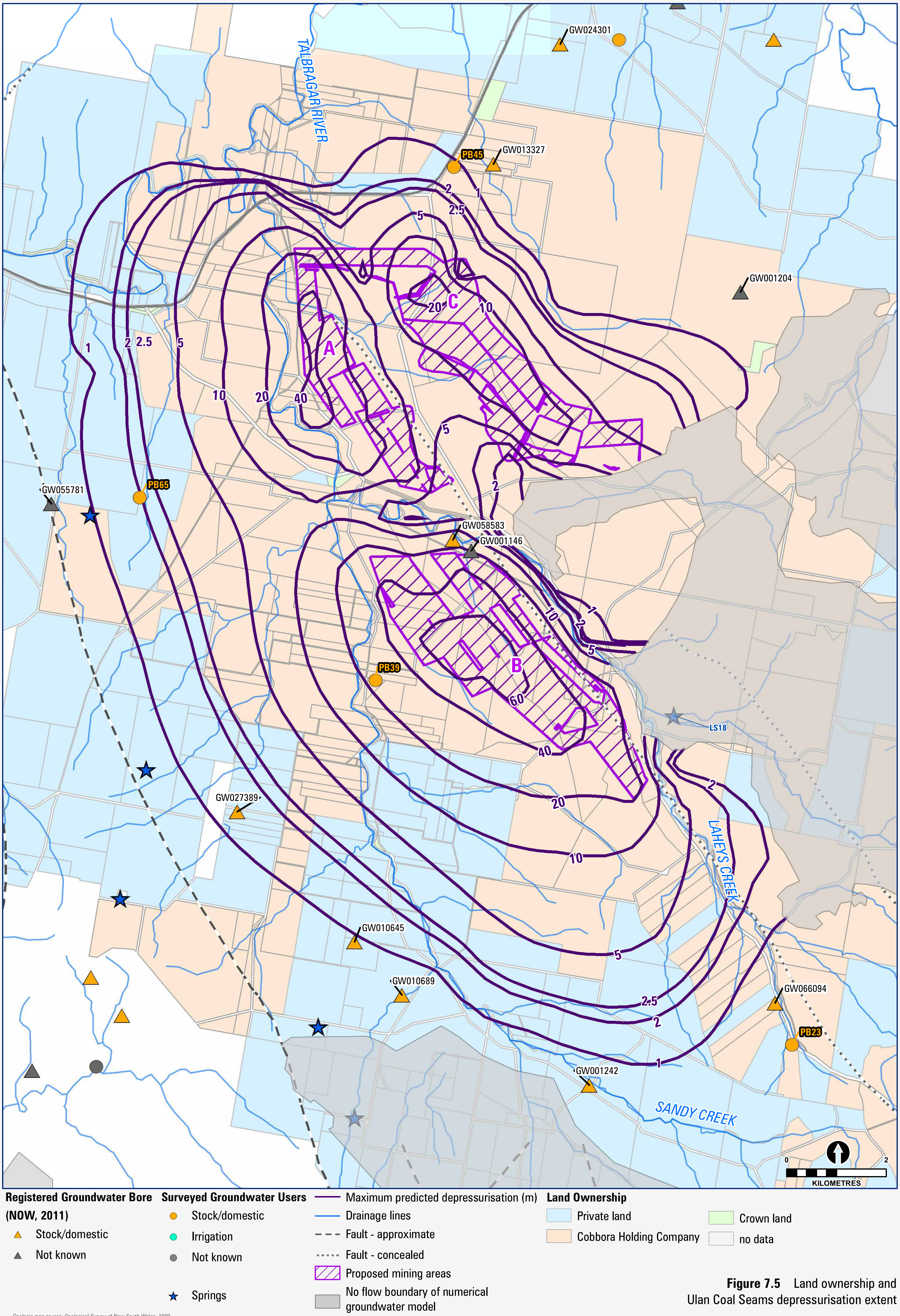
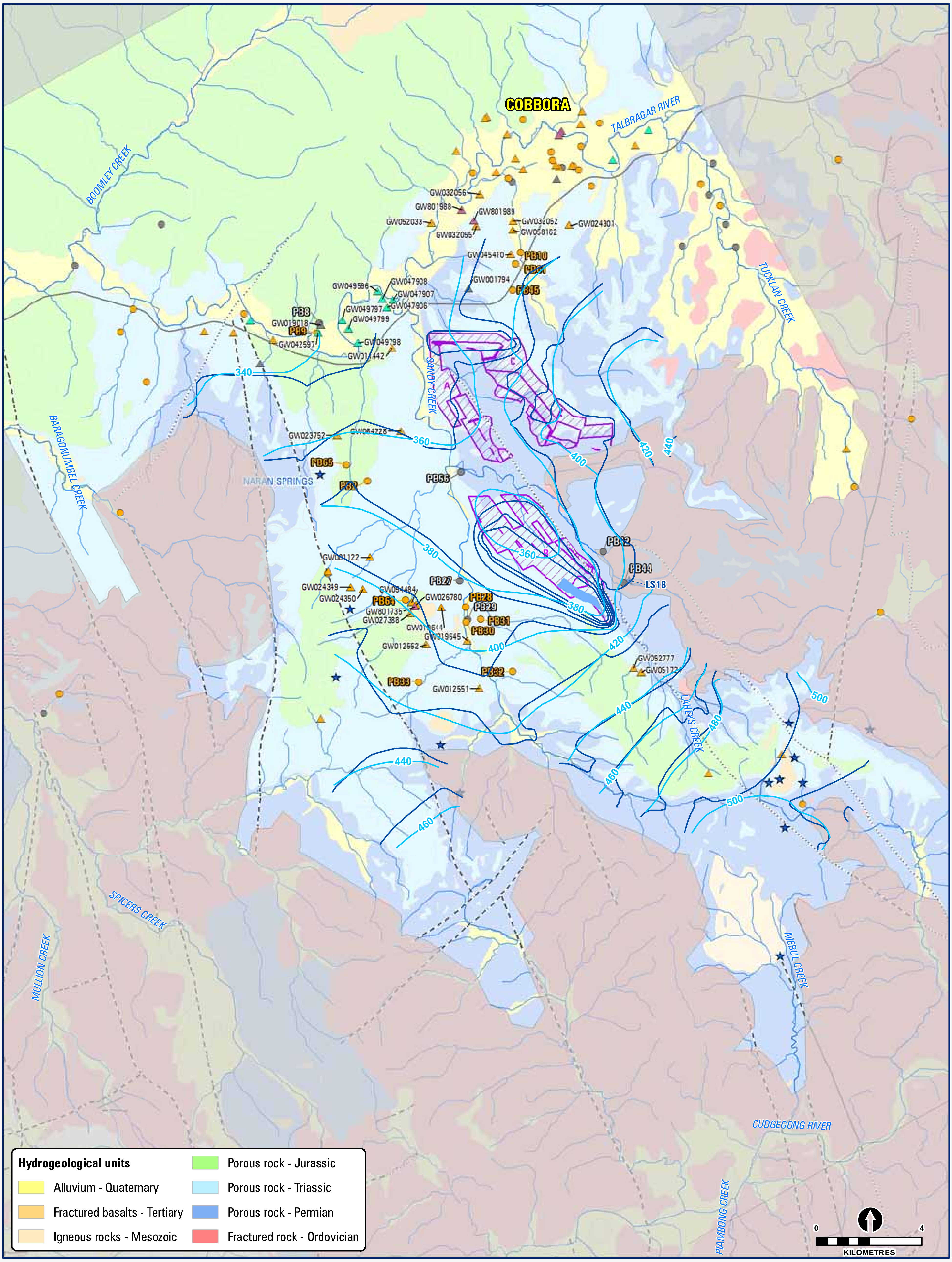


Figure 7.5 Land ownership and Ulan Coal Seams depressurisation extent



Registered Groundwater Bore (NOW, 2011)
- Stock/domestic
- Irrigation
- Other
- Not known

Surveyed Groundwater Users
- Stock/domestic
- Not known

- Springs
- Drainage lines
- Fault - approximate
- Fault - concealed

- Proposed mining areas
- No flow boundary of numerical groundwater model
- Predicted pit lake location

- Groundwater elevations: End of mining (Year 21) - Ulan Coal Seam
- Groundwater elevations: End of Mining (Year 21) - Water Table

Geologic map source: Geological Survey of New South Wales, 1999

Figure 7.6 Water levels and Ulan Coal Seams pressures at cessation of mining

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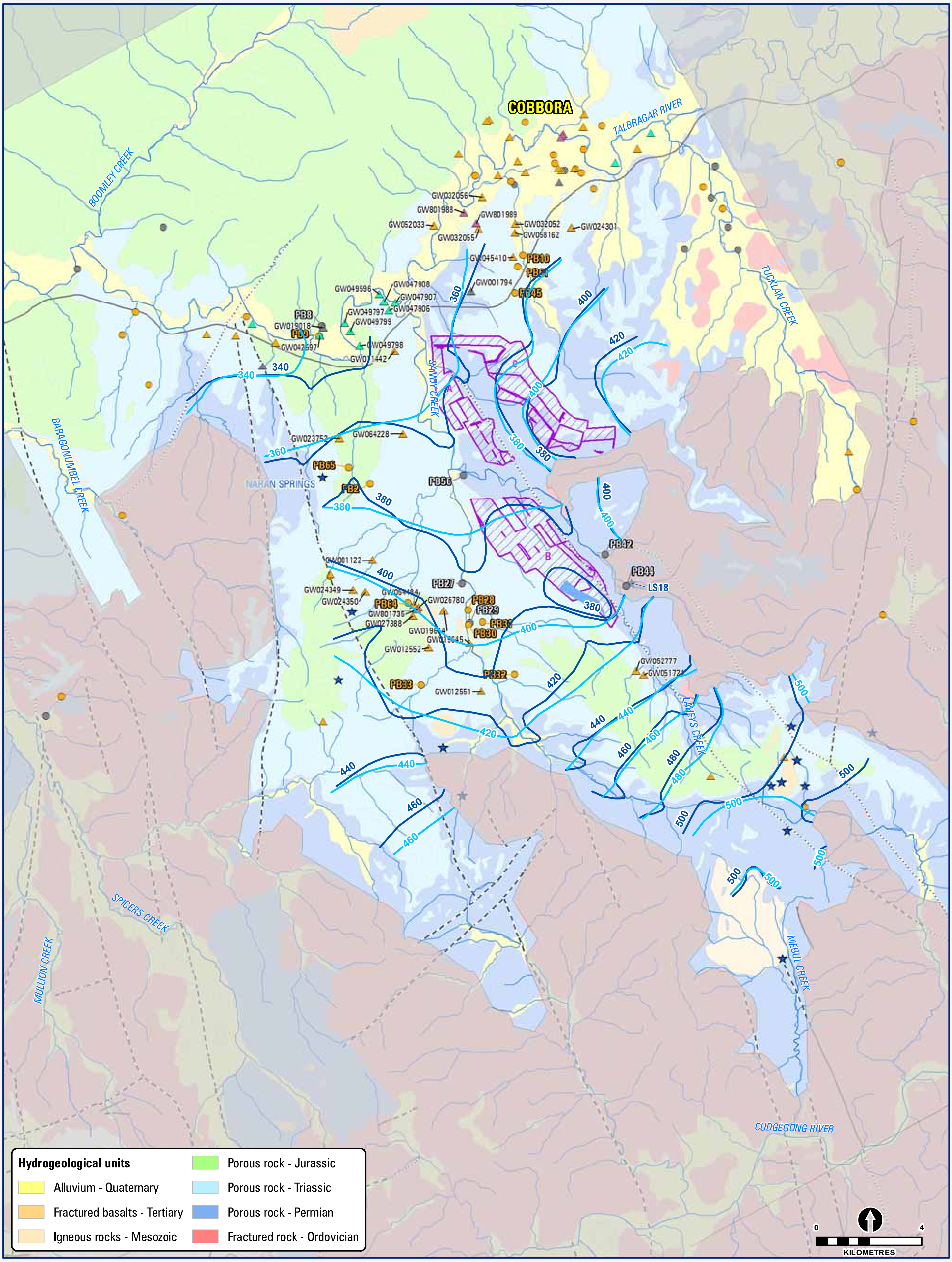

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Registered Groundwater Bore (NOW, 2011)
- Stock/domestic
- Irrigation
- Other
- Not known

Surveyed Groundwater Users
- Stock/domestic
- Not known

- Springs
- Drainage lines
- Fault - approximate
- Fault - concealed

- Proposed mining areas
- No flow boundary of numerical groundwater model
- Predicted pit lake location

- Groundwater elevation: 20 years after mining Ulan Coal Seam
- Groundwater elevation: 20 years after mining Water Table

Geologic map source: Geological Survey of New South Wales, 1999

Figure 7.7 Water levels and Ulan Coal Seams pressures 20 years after mining

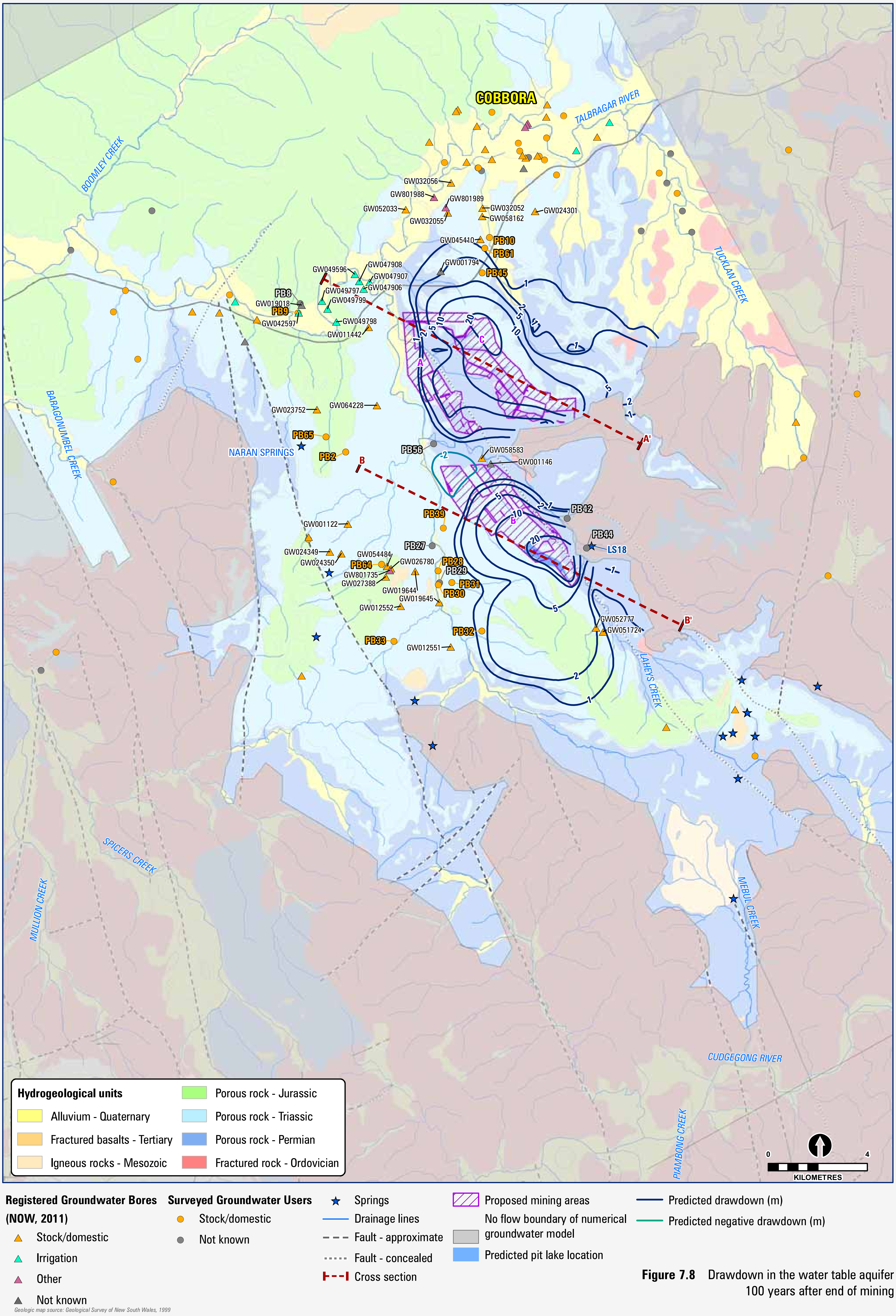


Figure 7.8 Drawdown in the water table aquifer 100 years after end of mining

7.4 Groundwater quality

Baseline groundwater quality within the alluvium aquifer is marginal to saline (averaging 3,650 µS/cm EC), with salinities generally increasing with depth. Due to the low permeability and isolated nature of the aquifer, the contribution to overall mine inflows and therefore quality is expected to be very low impact.

The western edge of mining area A is the only area planned to intersect alluvial sediments. Therefore the alluvium aquifer groundwater contribution to pit inflows will be very minor. Where leakage of groundwater from the alluvium aquifer to the underlying aquifer occurs, no degradation to the underlying groundwater is expected due to its existing quality.

Groundwater salinity within the Triassic units is 4,000 µS/cm EC, which on average is higher than the Permian units (1,600 µS/cm EC). Therefore there is likely to be some variation in quality of groundwater inflows depending on depth and location of mining. The shallower zones of mining will generally produce more saline waters, while the deeper zones of mining that intersect the fresher groundwater within the Ulan and Dapper seams is likely to improve the quality of overall inflows.

The overall groundwater quality is likely to be similar to that described for those piezometers and test production bores screened across multiple units within the porous rock aquifer (Section 5.7.2). The porous rock aquifer is typically brackish, slightly acidic to slightly alkaline, dominated by chloride and sodium, and contains elevated zinc and iron.

Mining is expected to result in increased connectivity and subsequent mixing of groundwater within the vicinity of the mining areas. However, the anticipated change in water quality as a result of increased interaction between the units will not degrade the measured water quality conditions or beneficial use at most bores.

As mining progresses, mined areas will be backfilled. Active dewatering of the mining area will cease following mining operations and the pore spaces within the backfilled area will gradually become saturated. During this saturation phase, the hydraulic gradient will initially be towards the backfilled material including Pit lake B. Due to the final lake level being lower than the surrounding recovered groundwater levels, over time the Lake in Pit B will become increasingly saline, and potentially hypersaline. This has been calculated analytically and discussed in greater detail in the Cobbora Coal Project - Surface Water Assessment (Parsons Brinckerhoff 2012). However, groundwater quality outside the lake is likely to be largely un-impacted as hydraulic gradients will continue to be towards the lake over the longer term.

Groundwater flowing through the backfill is likely to undergo slight changes in quality, as groundwater interacts with the backfill material. Minerals present in the backfill material will gradually dissolve into the groundwater until the chemical composition reaches equilibrium. Backfill material will comprise the in situ sedimentary rock removed to access the Ulan Coal Seams, which should minimise the potential for significant changes in resultant groundwater chemistry.

In March 2012, Geoterra carried out a geochemical assessment to assess the acid mine drainage (AMD) potential of the overburden, coal, floor rock and washery wastes anticipated to be produced from development of the Project. The geochemical assessment concluded that:

- overall, overburden and the pit floor are likely to be non-acid forming and should not require any special handling for acid and metalliferous drainage control

- overburden has low salinity and neutral acidity
- mixing mining waste will mitigate isolated AMD leachate.

Based on the samples analysed and interpretation undertaken by Geoterra (2012), the potential for AMD to be considered a risk to groundwater is low.

The recovery in groundwater levels following mining will be influenced by the presence of the pit lake in mining area B and the presence of backfill material, which is expected to be significantly more permeable than the original geology. This increased permeability is expected to reduce groundwater levels in the vicinity of mining area C, where groundwater levels currently rise steeply away from nearby creeks.

The pit lake in mining area B is expected to receive groundwater inflows following the cessation of mining activity. The water levels in the lake are expected to increase over time following the cessation of mining as groundwater levels recover and reach an equilibrium level of approximately 373.9 m AHD after approximately 100 years. At this elevation, the lake will continue to be a groundwater sink causing continued drawdown in the immediately surrounding area. The hydraulic gradient will be toward the pit lake and therefore groundwater flow will be from Sandy Creek towards the pit. As a consequence it is not expected that the pit lake will degrade water quality in the adjacent Sandy Creek.

7.5 Dryland salinity

The planned mining activities will result in a decrease in groundwater levels in the Project area (Section 7.1). The induced groundwater drawdown is estimated to mostly recover once mining activities cease, as mined areas will be backfilled, however the groundwater levels in some areas will be lowered over a longer timeframe due to the presence of a pit lake in Area B and the relatively high permeability of the spoil. The induced drawdown that results from mining activities reduces the likelihood of dryland salinity development, as dissolved salts are kept further away from the ground surface (Walker et al, 1999).

The potential for dryland salinity development is further alleviated by the likely increased recharge afforded by the higher permeability of the backfilled areas, decreasing shallow groundwater salinity. Also, overburden placed and stockpiled during the mine's operation is expected to be of low salinity (Geoterra 2012). Local seeps near the margins of stockpiles may form due to local mounding and/or perching of groundwater within the spoil. While these seeps are expected to be relatively fresh and derived from enhanced rainfall recharge, periodic monitoring should be undertaken as part of the overall site water management plan.

Revegetation of the site will be carried out progressively during operation and following mine closure. This is expected to minimise the potential for dryland salinity. Therefore the potential for the development of dryland salinity due to planned mining activities is likely to be low.

7.6 Groundwater licensing

Based on the numerical modelling, groundwater usage reaches a maximum of 2,202 ML/a during year 2028. By utilising the account management provisions of the Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater Sources in respect to Available Water Determinations, carryover and account limits, required aquifer access licence entitlement is 1,924 unit shares (equates to 1,924 ML when the Available Water Determination is 1 ML). The sum of enhanced in-pit recharge and induced reduction of flows in the Lower Talbragar River Water Source peaks at 799 ML/a in 2034. Licences from separate water sources will be required to offset impacts (see Table 7.2).

Table 7.2 Water licensing requirements

Water source	Water licence units required	Current water licence units held
Gunnedah-Oxley Basin MDB Groundwater Source	1,924	1,024
Talbragar River Water Source	799	1,780

The long-term groundwater inflows to the pit lake is expected to be approximately 270 ML/a at equilibrium. The long term enhanced recharge for the final rehabilitated landform is expected to be approximately 280 ML/a. Provisions should be made to hold aquifer access licences and water access licences to account for this ongoing groundwater and surface water use.

CHC currently holds more than twice the required water access licences in the Lower Talbragar River Water Source. No additional purchases are required.

Groundwater within the Gunnedah-Oxley Basin MDB Groundwater Source may be traded from any location within the Gunnedah-Oxley Basin, which extends from the Great Dividing Range in the south east (where it separates from the Sydney Basin) to the north and west where it crosses the NSW-Queensland border.

CHC require a total of 1,924 unit shares from the Gunnedah Oxley Basin MDB Groundwater Source, and currently have secured 1,024 unit shares. Purchase of a further 150 unit shares is currently in progress. . This leaves 750 unit shares to be purchased from the remaining 15,496 unit shares of current available licensed entitlement across approximately 115 aquifer access licences. CHC initiated a program of consultation in mid-2012 to assess the market depth of licence holders willing to sell entitlement. Licence holders (for whom contact details could be sourced) with a likely potential to sell more than 100 unit shares have since been approached. This process resulted in limited success, with CHC agreeing to purchase terms with all willing sellers. Consultation further revealed that the number of willing sellers is nearing exhaustion. CHC therefore may not be able to secure the entire additional 750 unit shares from the existing market.

There is a large volume of “unassigned water” within the Gunnedah Oxley Basin MDB Groundwater Source with the current level of entitlement, plus estimated basic rights, accounting for only 11% of the LTAAEL. The potential exists for issue of new entitlement through a Controlled Allocations Order under section 65 of the WMA 2000. The NSW Office of Water is currently considering a Controlled Allocation Order for a number of groundwater sources in NSW with “unassigned water”, including the Gunnedah Oxley Basin MDB Groundwater Source. However the timing of any such approval and announcement is unknown. The likely implementation process for the release of any new entitlements for those systems that have a defined volume of unassigned water is a staged approach via a tender process.

7.7 Final landform

Mining area A will be backfilled to be 3 metres above the current groundwater table and will also provide a free draining surface profile. This design allows for rainfall to either recharge the underlying groundwater system and or run-off in high rainfall events to the surface water system. The backfill to 3 metres above the water table is considered to be well in excess of the capillary fringe and vegetation on these areas is also likely to be shallow rooted. Therefore this design allows the natural processes of rainfall and groundwater recharge to occur freely (Figure 7.2), and will minimise impacts to the adjacent groundwater and surface water systems.

Mining area B final landform has been designed to minimise impacts to the surface and groundwater systems while also recognising the economic feasibility of fully backfilling this deep narrow pit. The final landform is therefore largely backfilled to 3 metres above the current water table but with a small section of the pit to remain as a deep narrow lake. The backfilled area means that the final surface area of the active mining void is reduced by almost half (Figure 7.3) of the final mining area the end of mining. The backfill to 3 metres above the water table is considered to be well in excess of the capillary fringe and vegetation on these areas is also likely to be shallow rooted. The final shape and location of Pit B lake ultimately minimises the potential for saline water to impact on the surrounding groundwater systems by forming a groundwater sink. Localised groundwater flow over the longer term will be towards this lake, thereby minimising impacts over the longer term.

Pit C will be backfilled to be 3 metres above the current groundwater table and will also provide a free draining surface profile. This design allows for the majority of rainfall on this area to recharge the underlying groundwater system and in high rainfall events to run-off into to the surface water system. Excess surface water will run-off to the south east into Blackheath Creek a tributary of Laheys Creek (Figures 7.1 and 7.2), and will prevent the development of salinity in this small catchment. The backfill to 5 metres above the water table is well in excess of the capillary fringe and vegetation on these areas is also likely to be shallow rooted. Therefore this design allows the natural processes of rainfall and groundwater recharge to occur freely and will minimise impacts to the adjacent groundwater and surface water systems.

8. Monitoring and management

8.1 Groundwater monitoring network

Groundwater quality and groundwater level monitoring has been carried out on the existing network of monitoring bores on an intermittent basis since their installation for the purpose of baseline data collection (see Section 4.4). It is recommended that nominated bores be used throughout the life of the mine to monitor groundwater level and groundwater quality changes associated with mining.

8.1.1 Additional monitoring locations

Monitoring of the aquifers in the Project area has been ongoing since 2009. Currently the monitoring network consists of 56 monitoring bores. As part of the overall site water management, additional monitoring locations will be required during the operational phase of the Project.

A groundwater management plan (GMP) will be implemented as part of the overall site water management. The GMP will detail operational procedures that will ensure mining operations will not result in any unacceptable impacts on surface water and groundwater systems, and their users (including groundwater dependent ecosystems). It will detail strategies used to manage and monitor groundwater level and quality within the mine lease area and outline a monitoring and reporting program, which includes procedures for review and reporting of results. The GMP will include all relevant regulatory approvals and conditions along with strategies for compliance. A draft framework for the GMP is provided in Appendix J.

The groundwater monitoring network and program will focus primarily on the identified impacts (Section 7). Based on the predicted impacts the network will require the following additional monitoring points:

- Additional monitoring bores installed in strategic locations to monitor the identified potential impacts of the mine's operation on the surrounding groundwater environment.
- New shallow monitoring bores installed adjacent to and down gradient of sedimentation and mine water dams to detect potential leakage into underlying aquifers to address potential contamination issues.[1]
- Replacement of monitoring bores destroyed by mining operations.[2]
- Monitoring of semi-permanent pools along Sandy Creek, Laheys Creek and the Talbragar River which are likely sustained by seepage from the alluvial aquifers, and potentially also the Permo-Triassic aquifer where they outcrop in the stream beds.

The proposed locations of additional bores per site are listed in Table 8.1 and shown on Figure 8.1a and Figure 8.1b. It should be noted that the locations of the bores are indicative only, and for the shallow monitoring bores, represent the locations of dams in Year 1 of mining. The locations of additional monitoring bores will be finalised prior to the

[1] Bores shown on Figure 8.1 and in Table 8.1 are based on the Year 1 dam configuration. Bore locations to be finalised within the GMP prior to the commencement of mining.
[2] GW6A-D and GW11 destroyed in approximately Year 8.

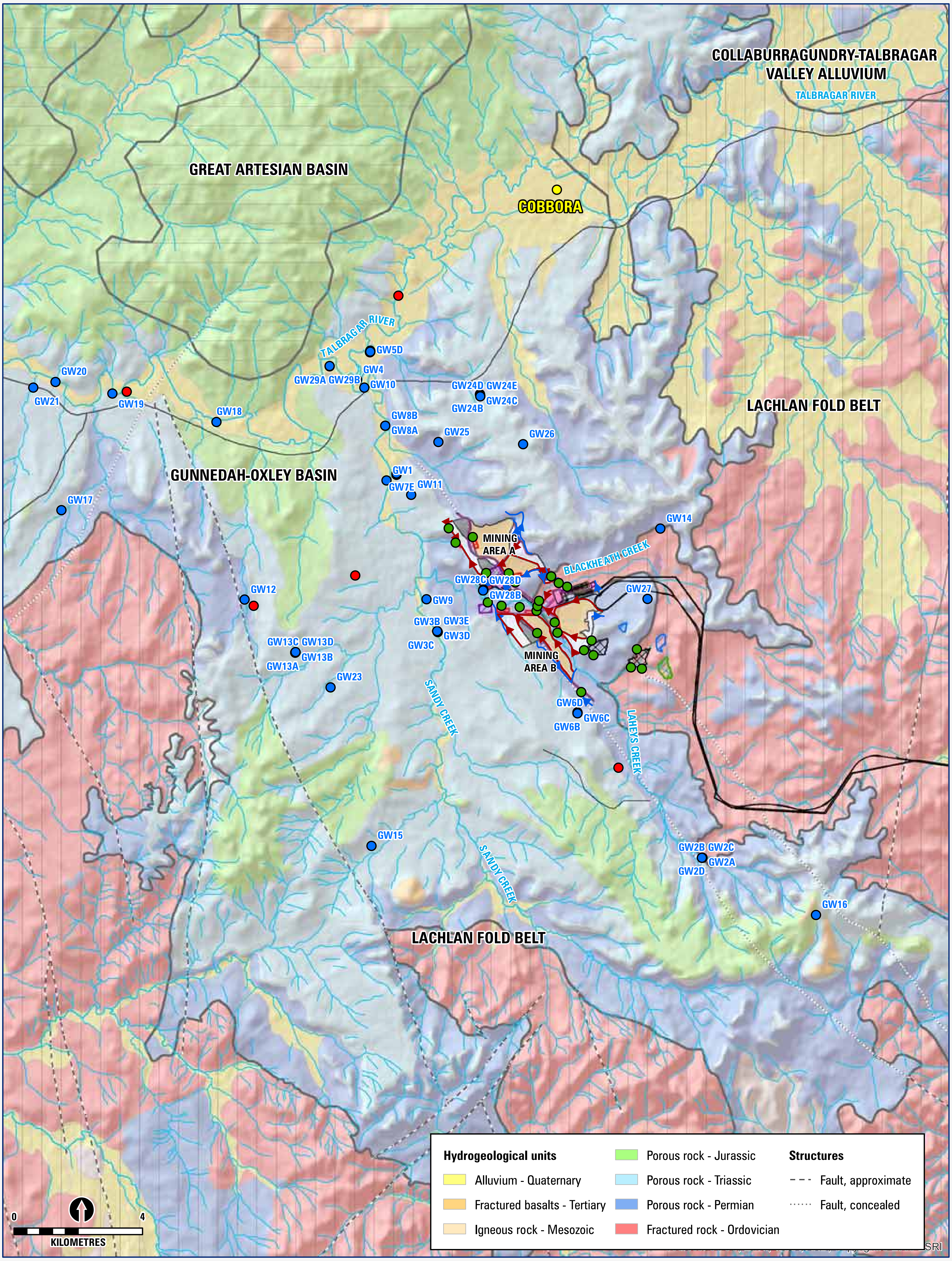
commencement of mining. At this time detailed bore locations will be determined based on the final positioning of all site works and access for all years of mining.

A licensed driller is required to drill and construct the bores with a hydrogeologist to supervise drilling, and bore licences need to be obtained from NOW prior to drilling.

Table 8-1 Proposed additional monitoring bores

Monitoring target	Proposed location
Drawdown of groundwater levels and pressures within the alluvium and porous rock aquifers in the assessment area	The alluvium aquifer between the upstream alluvium aquifer (Talbragar River alluvium) and the area of the alluvium aquifer predicted to be impacted by mining
	The Talbragar alluvium aquifer downstream of the proposed mine location (new monitoring bore adjacent to existing porous rock bore GW19)
	Additional monitoring bores to the west and south of the mine pits constructed into the Permo-Triassic units between existing private groundwater users and the mine pit
Reduced groundwater discharge to creeks and loss of potential groundwater availability to ecosystems	Naran Springs (one screened into the base of the Jurassic rock, and one into the underlying Permian Ulan Seam).
Groundwater quality (shallow)	Shallow monitoring bores adjacent to sedimentation and mine water dams and stockpiles that contain potentially poor quality water or waste rock materials, to ensure early detection of any groundwater impacts
Replacement of destroyed bores	Replacement of GW6A-D
	Replacement of GW11
Semi-permanent pools	Shallow monitoring bores adjacent to semi-permanent pools along Sandy Creek, Laheys Creek and the Talbragar River

a: Based on the assumption of approximately 1 monitoring bore per sedimentation dam; 2 monitoring bores per mine water dam, and 3 monitoring bores per tailings emplacement area in Year 1.



Year 1 surface water drainage
- Clear water diversion drain
- Dirty water diversion drain
- Proposed infrastructures

Year 1 dams
- Tailings Dam
- Highwall / clean water dam
- Raw water / diversion dam
- Sedimentation dam
- Mine water dam

Groundwater monitoring network
- Existing groundwater monitoring bore
- Proposed shallow bore (indicative location)
- Proposed regional bore (indicative location)

Year 1 mine landuse
- Active emplacement
- Active mine
- Tailings emplacement area
- Cleared area
- Haul road / infrastructure
- Topsoil stockpile

Figure 8-1a Proposed additional monitoring locations

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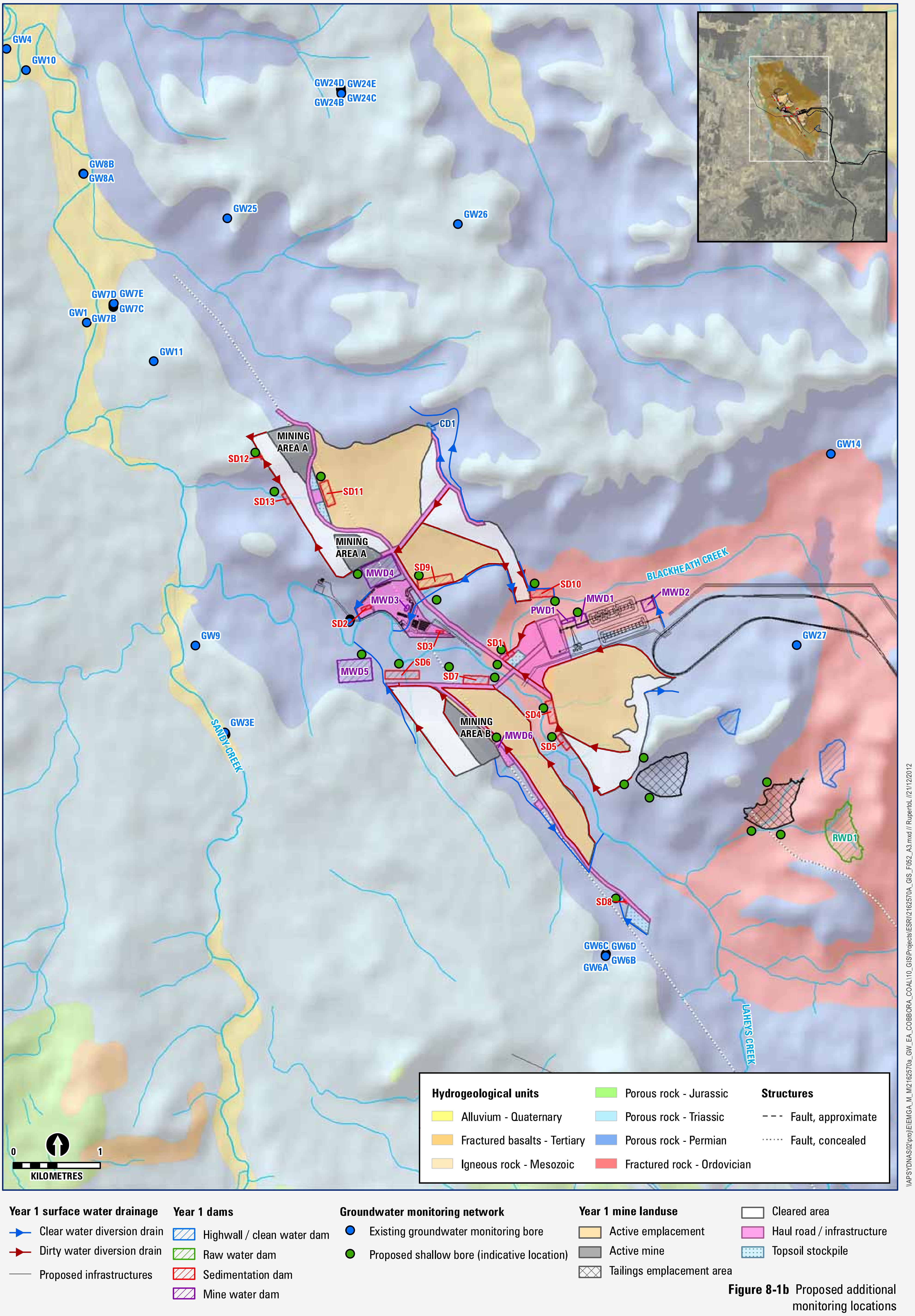

Figure 8-1b Proposed additional monitoring locations

Figure 8.2 illustrates the indicative design of monitoring bores for the Project.

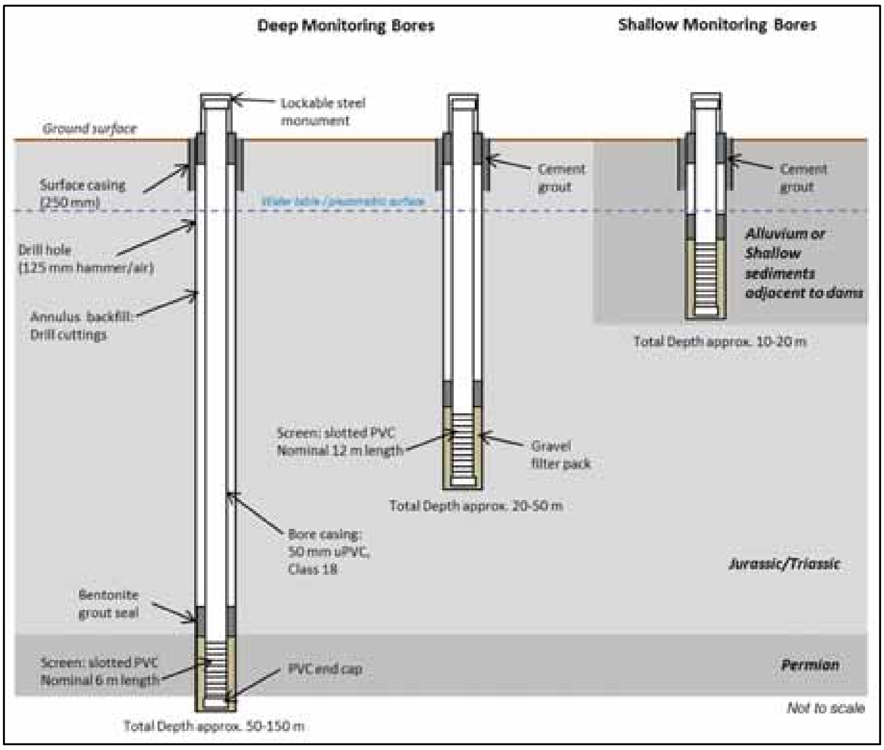

Figure 8.2 Indicative monitoring bore design

8.1.2 Groundwater level monitoring

All existing monitoring bores are fitted with groundwater level data loggers that record the groundwater level on a continuous basis. The level data is downloaded and the manual levels are recorded on a bi-annual basis.

It is recommended that this practice continues on a bi-annual basis until mining commences. Following the commencement of mining, the frequency of groundwater level monitoring should continue, but additional data downloads from bores closest to the active mining area should be increased to quarterly or monthly downloads to ensure data losses are minimised. The monitoring frequency and number of bores fitted with data loggers should be reassessed on annual basis as part of the annual monitoring report.

8.1.3 Groundwater dewatering volumes

Rates of seepage to active mine pits during operation should be monitored. Monitoring of groundwater quality and seepage and/or groundwater levels should be undertaken at in-pit sumps and pumps and at dewatering bores if they are constructed as part of the mining operation.

8.1.4 Groundwater quality

A bi-annual groundwater quality monitoring program is ongoing at the site and this should continue until mining commences. As mining progresses, the frequency of monitoring at sites close to active mining areas should be increased to quarterly or monthly to ensure changes in the groundwater chemistry are detected as early as possible. Salinity monitoring in particular is required during mining and following the cessation of mining.

The recommended analytical suite for groundwater monitoring, based on the baseline investigations, is as follows:

- field parameters — pH, EC, redox, temperature, TDS, DO
- laboratory analytes — major ions (calcium, potassium, sodium, magnesium, chloride, total alkalinity and sulfate) and dissolved metals (aluminium, arsenic, barium, beryllium, cobalt, iron, manganese, lead, nickel and zinc).

Sampling should be undertaken by trained personnel to ensure representative samples are collected from each bore. These samples should be submitted for laboratory analysis to a NATA-accredited laboratory.

A program of routine water sampling and testing of washery wastes and overburden and/or interburden materials should also be carried out during active placement to monitor any variation in acid potential and to reconcile the low potential AMD in the overburden.

8.1.5 Existing groundwater users

A number of existing groundwater users have been identified within the predicted 1 m zone of influence. While these groundwater bores remain operational, they will be incorporated into an ongoing groundwater level and quality monitoring program for the Project.

In some situations, additional monitoring bores may need to be specifically constructed to target selected aquifers so that any impacts from the mine on existing users can be more accurately understood. This greater level of understanding can be used to better manage and target practical mitigation options for these users.

8.1.6 Potential groundwater dependent ecosystems

The identification and assessment of groundwater-dependent ecosystems will continue to be undertaken by NOW as stated in Schedule 3 of the Water Sharing Plan for the MDB Porous Rock Groundwater Sources (NOW 2011b). Where additional groundwater-dependent ecosystems are identified during the life of the mine, additional monitoring may be required.

8.1.7 Dryland salinity

Groundwater levels are an essential indicator for potential dryland salinity, and will be recorded during the life of the Project (see Section .8.1.2).

In addition, low lying areas, particularly in the northern part of the Project area, will be monitored for salt scald as part of the overall Groundwater Management Plan (see Section 8.1.1).

The primary management technique to reduce the risk of dryland salinity will be the progressive revegetation of the mining area.

8.2 Data management and reporting

Collation and review of all monitoring data should be undertaken prior to mining commencing. Annual reporting is recommended and should be carried out by an experienced hydrogeologist.

The review of all monitoring datasets should be undertaken annually and focus on identification of trends, overall adequacy of the monitoring program, identification of gaps, and to determine if measured impacts continue to be within reasonable limits of the most recent predictions.

8.2.1 Development of trigger levels

It is proposed that soft trigger levels for groundwater levels and quality be developed immediately prior to the commencement of mining, in accordance with the ANZECC (2000) guidelines.

As per the ANZECC (2000) guidelines, trigger levels should preferably be based on site specific baseline data collected prior to the commencement of mining. In addition the guidelines provide for preliminary trigger levels to be updated as additional baseline data become available. Therefore trigger levels should not necessarily be fixed for the life of the mine operation, but should be revised as further information becomes available, and should be developed in collaboration with NOW and other professionals including ecologists. Updated impact assessment model(s) with the latest datasets and mine operations data (actual mine progression, depths and inflow rates, as well as future mine plans) should also be used to ensure trigger levels are appropriate. The updated models and simulations would be used to review and update the trigger levels and mitigation and response plans, where appropriate. Trigger levels should be designed to ensure that triggers are only activated due to unpredicted impacts occurring, or at key stages of the mine operation to prompt a predetermined action (such as more frequent monitoring or sampling, visits to landholders to ensure their water supplies are being maintained, or inspection of groundwater dependent ecosystems).

Preliminary groundwater trigger levels for the alluvium and porous rock aquifers are presented in Table 9.1. In the absence of a site-specific trigger level, the appropriate default trigger level is considered to be the ANZECC (2000) freshwater guideline for aquatic ecosystems (95% level of protection), along with the guidelines for upland rivers in south-east Australia. ANZECC (2000) does not provide default guideline trigger levels for all water quality parameters analysed.

Where natural parameter levels from the baseline data set were outside of the ANZECC (2000) guidelines, or where ANZECC (2000) does not specify a level, the envelope of the baseline data set is used to establish the trigger, to reflect the ambient conditions of the Project area and its natural variation. Triggers have been categorised based on the Alluvium, Triassic and Permian aquifer water quality data from the Project area. Detailed water quality results tables for all groundwater monitoring bores are provided in Appendix D.

The trigger levels listed in Table 9.1 are preliminary in nature, and should be revised during the mine's operation. In particular, the triggers should be revised immediately prior to the commencement of mining (when the GMP is developed), using the extended baseline information available at that time. As mining progresses, the monitoring data may vary (such as over periods of extended wet or dry years) and trigger levels may need to be adjusted annually to ensure they remain relevant and useful tools for environmental management during mine operation (Parsons Brinckerhoff, 2012).

Table 8.2 Proposed preliminary groundwater level and quality triggers

Parameter	Units	ANZECC (2000)	Baseline (Alluvium)[4]	Baseline (Triassic)[4]	Baseline (Permian)[4]	Preliminary trigger (Alluvium)	Preliminary trigger (Triassic)	Preliminary trigger (Permian)
Field Parameters								
Level	mbTOC	n/a	Site dependent	Site dependent	Site dependent	Moving average	Moving average	Moving average
Conductivity	uS/cm	25 - 2200	1850-6949	827-9060	556-9030	1850-6949	827-9060	556-9030
pH	pH units	6.5-8	6.2-8.01	5.83-7.67	5.27-8.89	6.2-8.01	5.83-7.67	5.27-8.89
Dissolved Oxygen	mg/L		0.47-9.5	0.64-4.8	0.11-11.7	0.47-9.5	0.64-4.8	0.11-11.7
Temperature	°C	ID	16.3-20.6	16.4-22.5	15.4-31.0	16.3-20.6	16.4-22.5	15.4-31.0
Redox	mV	ID	-151-257.4	-124-192.8	-199.5-140	-151-257.4	-124-192.8	-199.5-140
Total Dissolved Solids	mg/L	ID	1200-4300	537-5800	80-5600	1200-4300	537-5800	80-5600
Alkalinity								
Total Alkalinity as CaCO3	mg/L	ID	90-926	84-780	14-679	90-926	84-780	14-679
Major ions								
Chloride	mg/L	ID	333-1830	185-2930	88.3-2690	333-1830	185-2930	88.3-2690
Sulfate	mg/L	ID	36.3-305	8.97-315	0.25-352	36.3-305	8.97-315	0.25-352
Calcium	mg/L	ID	22-126	18-324	0.5-332	22-126	18-324	0.5-332
Magnesium	mg/L	ID	35-203	19-298	0.5-427	35-203	19-298	0.5-427
Sodium	mg/L	ID	230-1340	103-1440	83-1020	230-1340	103-1440	83-1020

Potassium	mg/L	ID	2-19	5-57	6-236	2-19	5-57	6-236
Dissolved Metals								
Aluminium	mg/L	0.055	<0.01-0.77	<0.01-0.09	<0.01-7.92	0.77	0.09	7.92
Arsenic	mg/L	0.013 (As V)	<0.001-0.002	<0.001-0.002	<0.001-0.008	0.013	0.013	0.013
Beryllium	mg/L	ID	<0.001	<0.001-0.094	<0.001-0.002	<0.001	0.094	0.002
Barium	mg/L	ID	0.028-0.478	<0.001-0.8	0.029-0.949	0.48	0.8	0.95
Cobalt	mg/L	ID	<0.001-0.056	<0.001-0.044	<0.001-0.126	0.056	0.044	0.126
Lead	mg/L	0.0034	<0.001-0.003	<0.001-0.008	<0.001-0.093	0.0034	0.008	0.093
Manganese	mg/L	1.9	0.016-5.7	0.05-6.27	0.009-3.56	5.7	6.27	3.56
Nickel	mg/L	0.011	<0.001-0.012	<0.001-0.031	<0.001-0.156	0.012	0.031	0.156
Zinc	mg/L	0.008	<0.005-0.194	<0.005-0.126	<0.005-1.08	0.194	0.126	1.08
Iron (dissolved)	mg/L	ID	<0.05-3.2	<0.05-7.16	<0.05-91.1	3.2	7.16	91.1

Note: Metals are dissolved metal species/trigger values for upland rivers in south-east Australia (ANZECC 2000)
1 95% trigger values (ANZECC 2000)
2 n/a — no trigger value available
3 ID — insufficient data to determine trigger value
4 Range based on data assessed in the EA, collected between September 2009 and August 2011
5 Max value of pH12.24 detected on one occasion at GW24 (removed from trigger data set)

9. Mitigation measures and response plans

The groundwater assessment has highlighted potential risks associated with mine-induced drawdown for impacts to the groundwater regime and users. These include:

- loss of access to groundwater for some private bores
- mine groundwater inflows
- reduction in baseflow to the Talbragar River and associated tributaries
- reduction in water availability to potential ecosystems
- changes in groundwater quality.

The adoption of a comprehensive mitigation and response plan is required to minimise, if not eliminate, the effects of these potential impacts. A groundwater management plan (Appendix J) will be prepared, which will detail the mitigation measures and response plans.

Based on the modelled potential impacts, the following recommendations should be considered.

9.1 Groundwater levels

A groundwater management plan should be prepared detailing established trigger values for drawdown prior to the commencement of mining. The plan would allow for prompt and appropriate response actions to ensure impacts are mitigated, or responded to.
The framework of the groundwater management plan is provided in Appendix J.

9.1.1 Groundwater users

Groundwater users have been identified as likely to be impacted by mining operations due to a reduction in groundwater levels. At this stage of the assessment the modelled impacts do not require immediate action.

Where groundwater bores have been identified as likely to experience drawdowns they will be included in the routine monitoring program for groundwater levels. Each groundwater user would be assessed on a case by case basis.

Where a groundwater bore is identified as experiencing a loss in availability of water, an assessment will be undertaken investigating the loss of availability, whilst considering any mitigating factors where applicable (e.g. age, bore efficiency/construction, review of climatic conditions, and assessment of current monitoring). If further monitoring information is required, additional monitoring bores may be installed between the landholders bore and the mine site.

Where an assessment deems the impacts are a result of mining and are unacceptable, the options to mitigate the impact could include:

- Replacement bore(s) being drilled deeper on site or at other locations to compensate for the loss in yield or groundwater quality. This could require additional costs for pump replacements (upsizing) and/or expansion or upgrades to the distribution networks and additional power consumption, if any.

- The mine operator providing a replacement water supply, either via surface water licences and/or excess groundwater inflow. This option may require treatment as well as a delivery mechanism.

- Compensation for temporary or permanent retirement of operations requiring water being arranged with private bore users.

9.1.2 Mine groundwater inflows

Groundwater inflows to the mining areas will be routinely monitored and compared to modelled inflows. Where actual inflows exceed modelled inflows under drier than average conditions, a hydrogeologist should carry out a review to establish the nature of the exceedence and the possible reasons for it. An appropriate response action for should be prepared and implemented in consultation with NOW.

Based on the groundwater model, groundwater inflow to the mining areas is likely to be greatest along the western and southern perimeters of the overall mining areas. Artesian groundwater pressures are present on the boundaries of these areas, therefore mitigation measures may include installation of dewatering bores pre mining to depressurise the aquifer in this area, and reduce the inflows to the pit.

9.2 Groundwater quality

To mitigate and manage risks to groundwater quality it is recommended that the following be implemented:

- Any tailing dams to be constructed, managed and rehabilitated to best practice standards to minimise any potential impacts to groundwater sources.

- A water management strategy for end of mining that monitors the chemistry of the water in Pit B.

- A sampling and testing program for monitoring acid potential of the waste rock.

- An emergency spill and clean-up plan upon the notice of a spill or presence of contaminant. Reporting, clean-up and monitoring of all spills are required.

- Collect and store groundwater seepage to the mining areas in small sumps in the pit floor where it can be monitored, and then transfer to environmental dams.

9.3 Communication and reporting plan

Consultation will be undertaken by CHC with stakeholders and government agencies, in particular NOW, when establishing the final mitigation and response plan(s), trigger values, and reporting protocols to be implemented during mine operation. The reporting process will include a clear communications matrix identifying the organisations and personnel to be notified in the event an impact is detected.

10. Conclusions

This report and its associated appendices have been prepared to assess the impacts of the proposed Project on the local and regional groundwater environment. It considered:

- An overview of the Project, and the objectives and scope of the groundwater assessment.
- The DGRs relating to groundwater for the Project and the relevant legislation, policies and guidelines.
- The groundwater investigations undertaken for the assessment.
- The existing groundwater environment of the Project area, including the assessment of hydraulic properties; groundwater levels; groundwater flow and groundwater quality, surface water – groundwater connectivity, and potential groundwater availability to ecosystems.
- The Project's potential impacts on local and regional groundwater resources, groundwater users and potential groundwater availability to ecosystems.
- Mitigation measures and response plans for the Project.
- The future monitoring and management of groundwater for the Project, including monitoring requirements, recommendations and a groundwater management plan.

Through field investigations and assessments, and numerical groundwater modelling it can be concluded that the potential impact the Project will have on the local groundwater system is a result of the drawdown in the alluvium and Permo-Triassic porous rock aquifers, which locally reduces the groundwater levels for nearby extractive users and the environment.

Modelled groundwater inflows to the mining areas are expected to lead to maximum lowering of the water table of up to 90 m in mining area B. The 1 m drawdown contour is predicted to extend up to 5.5 km to the south of the mine and nearly 6 km to the west of mining area A. Drawdown to the north and east is far less extensive, with the 1 m drawdown contour predicted to lie within 4 km of the mining areas. For the Ulan Coal Seams the 1 m drawdown contour is predicted to lie approximately 6 km to the west of mining areas A and B. The extent of drawdown to the south, north and east of the mining areas is similar to that predicted for the water table aquifer.

Based on the numerical modelling results, net groundwater usage (for the purpose of licencing) reaches a maximum of 2,202 ML/a during year 2028. The predicted cumulative storage losses within the alluvium could reach a maximum value of approximately 720 megalitres (ML), which constitutes only 0.3% of the estimated 220,000 ML (220 gigalitres (GL)) of available groundwater storage in the alluvium aquifer within the model domain.

Groundwater drawdown levels for nearby users have been assessed and there are 13 private bores that will experience drawdown greater than 2 m. Ten of these 13 private bores are owned by CHC and therefore impacts to third-party bores is expected to be minor. Where the impact to third party bores is assessed to be directly related to mining operations, CHC will take corrective actions at its own expense.

The lowering of groundwater levels will result in some reduction in baseflow of the Talbragar River. The high permeability and low run off coefficient of placed spoil will lead to enhanced recharge and will reduce flow to the river. The induced river losses (469 ML/a) and enhanced recharge (330 ML/a) combine to peak at 799 ML/a in 2034.. The impact is considered small in relation to flows in the Talbragar River, representing only 1.5% of the average annual flow. CHC holds water access licences totalling more than twice the required entitlement, therefore the overall impact is considered low.

Ecosystems potentially relying on groundwater in the Project area can be classified into three systems: springs, semi-permanent pools and shallow alluvial groundwater.

The springs/seeps that have been identified in the assessment area represent local perched systems, independent of the regional aquifer system. Flow rate and water quality are therefore unlikely to be impacted by the Project.

The depressurisation likely to occur in the Permo-Triassic units to the west of mining areas A and B is likely to induce leakage from the alluvium and cause a decline in groundwater seepage in semi-permanent pools. Subsequently the availability of groundwater to ecosystems potentially relying on shallow groundwater and semi-permanent pools within the creeks and river may be reduced. The overall impact to both systems is considered moderate, as rainfall and flood recharge will likely sustain the local alluvium aquifers for several months following rainfall and flood recharge events. Monitoring via strategically located alluvial and Permo-Triassic outcrop monitoring bores will be undertaken to mitigate the impact.

A lake will form within the final void of mining area B due to accumulation of groundwater inflow and surface water runoff. The water levels in the lake are expected to increase over time following the cessation of mining as groundwater levels recover and reach an equilibrium level of approximately 373.9 m AHD. At this elevation, the lake will continue to be a groundwater sink causing continued drawdown in the immediately surrounding area. The hydraulic gradient will be toward the pit lake and therefore groundwater flow will be from Sandy Creek towards the pit. As a consequence it is not expected that the pit lake will degrade water quality in the adjacent Sandy Creek.

A groundwater management plan (GMP) will be prepared prior to the commencement of mining. The GMP will provide details on the monitoring of groundwater levels, mine inflows and groundwater quality, including trigger levels, procedures for review and appropriate response action plans. Mitigation measures would also be included should monitoring indicate impacts are not consistent with modelling results. The staged mine plan allows time to implement mitigation measures should there be inconsistencies with modelled impacts.

While the groundwater assessment has identified a number of potential impacts to the groundwater system, these impacts are generally considered transient and low to moderate impact with respect to downstream users and the environment. CHC is committed to implementing mitigation and management measures to monitor and manage these potential impacts throughout the life of the mine and post mining, through the GMP. The GMP will be prepared in consultation with NOW, and will assist the mine in operating within contemporary environmental standards, to ensure that CHC can comply with its anticipated licensing and statutory obligations.

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