Australasian Groundwater and Environmental Consultants Pty Ltd (AGE)

Appendices to the Report on

West Muswellbrook Project Gateway Application

Highly Productive Aquifer Groundwater Impact Assessment

Prepared for

Muswellbrook Coal Company Limited

Project No. G1676 November 2014

www.ageconsultants.com.au ABN 64 080 238 642

Appendix A

Groundwater and surface monitoring location summary

Table A-1 Project water monitoring locations

Bore ID	Easting (MGA 56)	Northing (MGA 56)	Ground Level mAHD survey	Ground Level from DEM mAHD	Stick Up (m)	Date Completed	Bore Desc.	Depth of drill hole (mBGL)	Dia. of Casing (mm)	Base of bore - mBGL	Top of Screen mBGL	Bottom Screen mBGL	Target Formation	Single GWL data year	Temporal GWL data year range	Field WQ Data (Y/N)	Once yearly lab. WQ analysis
CRDDH14	286849.20	6424724.40	149.5	149.9	1.00	24/01/2000	GW mon	30.5	50	30.5	19.5	25.2	Blakefield	2000	No	No	No
CRRDH22	288971.20	6429468.90	210.0	208.8	1.50	15/02/2000	GW mon	67.85	50	67.85	57.85	63.85	Blakefield / Glen Munro	2000	No	No	No
CRRDH52	291701.57	6434009.73	237.6	238.5	1.21	14/05/2002	GW mon	37	50	16.76	31	37	Heat altered coal		2003 to 2011	2003 to 2011	2011
CRRDH67	290912.40	6433195.40	208.0	208.2	1.50	14/05/2002	GW mon	36.5	50	36.5	2.5	6	Blakefield / Glen Munro	2002	No	No	No
CRLDH97	291130.90	6433832.80	224.1	224.6	1.00	15/11/2004	GW mon	30.88	125	30.88	24.88	30.88	Blakefield / Glen Munro	2004	No	No	No
CRRDH105	290674.30	6432864.43	204.0	203.5	2.12	11/03/2005	GW & SW mon	5.8	50	7.9	2.8	5.8	Alluvium Sandy Creek South		2004 to 2014	2006 to 2013	No
CRRDH106	290009.14	6433457.19	213.0	215.3	2.05	11/03/2005	GW & SW mon	4.7	50	4.6	2.7	4.7	Alluvium Sandy Creek South		2004 to 2014	2006 to 2013	No
CRRDH107	290870.20	6432412.80	201.8	198.1	1.50	12/03/2005	GW & SW mon	5.82	50	5.82	2.82	5.82	Alluvium Sandy Creek South		2007 to 2014	2006 to 2013	No
CRLDH108R	289754.20	6434186.50	225.3	225.8	0.40	30/04/2006	GW mon	127.4	150	18.3	12.3	18.3	Wambo	2013	No	No	No
CRRDH109	290352.46	6432094.78	200.6	200.5	0.60	12/05/2006	GW mon	31	150	31	13	31	Blakefield / Glen Munro	2009	No	No	No
RHDDH4	291783	6436624	257.2		0.92	24/03/1998	GW mon	84	50	40			Blakefield Seam		2000 to 2014	2000 to 2014	2011, 2012 & 2013
RHDDH20	293115.37	6439916.10	240.3	241.0	0.76	24/09/1998	GW mon	45.73	50	46.76	35.9	45.7	Blakefield / Glen Munro		2000 to 2014	2000 to 2014	2011, 2012 & 2013

Bore ID	Easting (MGA 56)	Northing (MGA 56)	Ground Level mAHD survey	Ground Level from DEM mAHD	Stick Up (m)	Date Completed	Bore Desc.	Depth of drill hole (mBGL)	Dia. of Casing (mm)	Base of bore - mBGL	Top of Screen mBGL	Bottom Screen mBGL	Target Formation	Single GWL data year	Temporal GWL data year range	Field WQ Data (Y/N)	Once yearly lab. WQ analysis
RHDDH27	291291.04	6434348.03	244.0	245.2		3/11/1998	GW mon	62.01	50	62.01	54.5	60.5	Blakefield / Glen Munro		2003 to 2011	2003 to 2011	2001
RHRDH78	292236.70	6438025.90	219.4	220.0	1.50	4/04/2002	GW mon	54	50	7.6	3.6	7.6	Alluvium Sandy Creek North	2002	No	No	No
RHRDH79	292516.70	6438469.50	214.0	214.5	1.50	4/04/2002	GW mon	24.72	50	6.15	2.65	6.15	Alluvium Sandy Creek North	2002	No	No	No
RHRDH211	292437.20	6437962.70	214.1	215.8	1.50	6/05/2005	GW & SW mon	5.2	50	5.2	2.2	5.2	Alluvium Sandy Creek North		2005 -2014	2006 -2013	No
RHRDH212	293426.10	6438850.10	201.7	202.6	1.50	6/05/2005	GW & SW mon	5.12	50	5.12	2.12	5.12	Alluvium Sandy Creek North		2007 -2014	2006 -2013	No
RHRDH213	291214.52	6438080.75	231.4	232.3	1.50	9/07/2005	GW & SW mon	3.21	50	3.21	1.21	3.21	Alluvium Sandy Creek North		2007 - 2009	2007	No
DAY1	292850.35	6441989.50	246.0	240.6	0.49		production		135				Permian Abbey Green		2003 -2011	2003 -2011	2012 & 2013
GDAY1	290818.30	6438405.69	237.6		1.12		production			5.67			Colluvium Sandy Creek North		2003 -2014	2003 -2014	2011, 2012 & 2013
JLON1	292403.50	6434331.87	259.2	272.9	0.00	1/09/1965	production	57.9	127				50m below Blakefield (Permian)		2000 -2014	2003 -2014	2011, 2012 & 2013
JLON2	292318.84	6434390.91	252.1	253.1	0.60	1/09/1965	production	39.6	127	29.48			30m below Blakefield (Permian)		1965 -2014	2003 -2014	2011, 2012 & 2013
PIT1	291243.59	6437765.25	230.1	227.7	0.27		production			6			Alluvium Sandy Creek North		2003 -2014	2003 - 2014	2011, 2012 & 2013

Bore ID	Easting (MGA 56)	Northing (MGA 56)	Ground Level mAHD survey	Ground Level from DEM mAHD	Stick Up (m)	Date Completed	Bore Desc.	Depth of drill hole (mBGL)	Dia. of Casing (mm)	Base of bore – mBGL	Top of Screen mBGL	Bottom Screen mBGL	Target Formation	Single GWL data year	Temporal GWL data year range	Field WQ Data (Y/N)	Once yearly lab. WQ analysis
PIT2	291337.60	6437735.42	229.6	226.8	0.00		production			4			Alluvium Sandy Creek North		2003 -2014	2003 -2014	2011, 2012 & 2013
SPAR2	289994.50	6433497.99	217.4	216.0	0.48		production						Alluvium Coal Creek		2003 -2011	2003 -2011	2011
SPAR4	290210.33	6433732.92	215.2	225.1	0.46		production	24.89	150	3.78			Alluvium Coal Creek		2003 - 2011	2003 -2011	2011
SPAR5	289875.92	6433546.68	217.1	218.8	0.08		production			3.95			Alluvium Coal Creek		2003 - 2011	2003 - 2011	2011
WEK2	288753.59	6434415.55		241.8			production						Alluvium Coal Creek		2003 -2006	2003 - 2006	No
WYL1	291169.47	6438494.78	243.8	248.1	0.00		production	24.4		15.7			Colluvium		1957 - 2014	2003 -2010	No
YOU1	288149.59	6434786.27	250.4	269.4	0.67		production			2			Alluvium Coal Creek		2003 - 2014	2003 -2014	2011, 2012 & 2013

Table A-2 Selected bores outside the PAA

Bore ID	Easting MGA 56	Northing MGA 56	Ground Level mAHD survey	Ground Level from DEM mAHD	Date Drilled	Depth of drill hole mBGL	Dia. of Casing mm	Target Formation (Alluvium / Permian Coal Seam)	Temporal GWL data (year range)
BRO3[1]	296022	6439457	180.0	182.9				Shallow regolith	1998 - 2013
CAD2[1]	294132	6439790	200.1	198.6				Shallow regolith	1998 - 2013
COR3[1]	293689	6439180	199.6	200.3				Alluvium Sandy Creek North	1998 -2013
WM3[1]	294773	6439840	191.7	190.0		3		Alluvium Sandy Creek North	1999 - 2014
GW012975*	297328	6440165		172.6	1948	10.7	1219	Alluvium Sandy Creek North	1953 - 1956
GW013113*	294164	6439793		198.3	1957	30.8	152	Regolith	1957 -2003
GW027311*	292056	6422787		129.1	1967	11.6	1829	Alluvium Hunter River	2004 - 2006
GW032886*	293026	6450647		227.7	1970	32.9	152	Assumed Abbey Green	1970 - 2003
GW032887*	293602	6449839		219.1	1970	37.2	152	Wambo assumed based on depth	1970 -2008
GW037397*	294914	6448097		191.0	1972	11.9	1371	Alluvium	2000[2]
GW040500*	297419	6442201		173.6		12.3	1829	Alluvium Dartbrook	1967 - 2000
GW040509*	297473	6440784		172.9		11.8	1219	Assume to be Permina regolith no depth	1953 - 1993
GW044912*	293000	6428769		221.5		15.5	152	Regolith	1975 - 1993
GW053572*	291651	6423266		127.4	1981	10.5	1200	Alluvium Hunter River	2001 - 2004
GW061636*	291981	6426129		199.1	1986	42.7	150	Below Blakefield/above Warkworth	1986 - 1993
GW067260*	297560	6443888		175.8		11.2		Alluvium	2006 - 2008
GW080074*	298120	6447511	185.4	187.0		18		Alluvium (presumed from depth)	2014[2]
GW080433*	296333	6445791	181.3	182.7	2003	14.2	203	Alluvium Dart Brook (presumed from depth)	2003 - 2014
GW080909*	287363	6425117		142.8	2004	2.66	0	Alluvium Sandy Creek South	2004[2]

Note: **NOW PINEENA database 2013, [1]AngloAmerican (2013); [2] single record only.*

Table A-3 Surface water monitoring sites

Site ID	Easting MGA 56	Northing MGA 56	Elevation m AHD	Stream/ River	Comment on the site AGE June 2014 survey
CRK1	289184	6428133	161.9819	Sandy Creek South	Perennial flow - stream 8 - 10m width underneath a main bridge flow observed between larger permanent pools.
CRK4	288155	6434860	254.8614	Coal Creek	Headwaters - surface sampling point at concrete river crossing close to the escarpment pools were low salilnity but not flowing.
DAR2	297683	6441584	166.4066	Dartbrook	Sample point under bridge, flows only in heavy rain. Dry at the time of site visit.
ROS1	294126	6439695	196.4616	Sandy Creek North	Minor tributary of Sandy Creek North. Dry only flows from large rain events.
ROS11	290780	6434457	222.0585	Sandy Creek South	Sampling point at bridge. Upper Sandy Creek South with alluvial flats and no permanent water noticeable. Only flows during rain events, dry June 2014.
ROS2	291097	6438131	232.6574	Sandy Creek North	Sandy Creek North crossing on gravel flat gravel road with adjacent raised alluvial flats. Ephemeral, appears to flow only in heavy rain events.
SCK1	287371	6427973	164.0588	Spring Creek	Adjacent bridge on Wybong Road permanent pools with no observable flow but would appear to readily flow with minimal input.
SCK2	286922	6423782	134.9469	Sandy Creek South	Road crossing with flow of water between permanent pools of water furthest south point sampled point. Water depth 0.3m June 2014.
BRA2	294928	6442979	197.8337	Dam	A stock dam 3km north of Sandy Creek North. Turbid waters from cattle.
DAN1	292946	6440242	231.9133	Dam	Stock dam adjacent VAL1. Larger body of water.
HUT1	288190	6434682		Coal Creek	Dam – not visited during AGE 2014 survey.
HUT2	288233	6434605		Coal Creek	Dam – not visited during AGE 2014 survey.
HUT3				Coal Creek	Dam – not visited during AGE 2014 survey.
VAL1	292996	6440297	227.3515	Dam	A smaller stock dam than the adjacent DAN1.
SPAR3	291440	6433548	220.8879	Well - alluvium of upper part of tributary into Sandy Creek North	Old well with beams covering the excavation. Very dilapidated and has dam nearby.

Appendix B

Bore census

Property / Landholder:		Bruce Anthony Day			
Bore name	DAY1	*Cad. Lot No:*	1	*Cad. Plan No:*	DP416437
Easting:	292849.6	*Northing:*	6441988.7	*Elevation:*	246.5
Bore located behind metal shed, next to a small water storage pond, approx. 800 m south of the unsealed road.					
Bore construction:					
Bore diameter:		20 cm (outer)			
Casing:		Black PVC, 1cm thick			
Bore equipment / use:					
Bore use:		Functional, in use, pumping to adjacent water tank located directly behind the shed (not the tank next to bore). Stock – approx 40 heads of cattle			
Bore equipment:		Windmill (non-functioning), petrol pump (behind the water tank)			
Water level measurement:					
Reference point elevation:		0.48 m			
Reference point description:		Top of the black PVC casing			
Measured depth to water:		n/a			
GWL elevation:		n/a			
GWL not measured, advised against by previous samplers (Carbon Based Environmental) due to equipment loss in bore.					
Water quality measurement:					
Temperature (°C)		11.8			
pH		6.8			
ORP (mV)		251			
EC (µS/cm)		799			
TDS (mg/l)		535			
Sampled from tank behind metal shed					
Date:		30/6/2014			
Time:		8:50			

Property / Landholder:		Rob Gordon			
Bore name	GW079026	*Cad. Lot No:*	177	*Cad. Plan No:*	DP750951
Easting:	295055.8	*Northing:*	6440427.0	*Elevation:*	189.6

Bore construction:	
Bore diameter:	120 mm (outer)
Casing:	Steel
Bore equipment / use:	
Bore use:	Functional, in use, pumping to adjacent concrete water tank located next to bore. Tank cracked, leaking. Stock – approx 60 heads of cattle
Bore equipment:	Windmill – functioning
Water level measurement:	
Reference point elevation:	0.19 m
Reference point description:	n/a
Measured depth to water:	n/a
GWL elevation:	n/a
Bore opening covered by clamp – not able to take GWL reading or sample bore. Water in the tank not safely accessible to sample.	
Water quality measurement:	
Temperature (°C)	n/a
pH	n/a
ORP (mV)	n/a
EC (µS/cm)	n/a
TDS (mg/l)	n/a
Date:	30/6/2014
Time:	9:50

Property / Landholder:		Rob Gordon			
Bore name	GW079025	*Cad. Lot No:*	177	*Cad. Plan No:*	DP750951
Easting:	295498.5	*Northing:*	6440472.9	*Elevation:*	182.0

Bore construction:	
Bore diameter:	140 mm
Casing:	steel, rusty
Bore depth:	n/a – depth not measured because of possible equipment loss (pump running), bore opening inaccessible because of pump installation.
Bore equipment / use:	
Bore use:	Functional, in use, pumping to adjacent concrete water tank and troughs. Stock.
Bore equipment:	Windmill (non-functioning), electric pump (Onga, 220V, timer)
Water level measurement:	
Reference point elevation:	approx 0.4 m
Reference point description:	Edge of steel casing
Measured depth to water:	n/a
GWL elevation:	n/a
GWL not measured, bore opening inaccessible because of the pump installation	
Water quality measurement:	
Temperature (°C)	11.5
pH	7.4
ORP (mg/l)	301
EC (µS/cm)	1498
TDS (mg/l)	1035
Sampled from adjacent water trough at location of pump outlet (pump running)	
Date:	30/6/2014
Time:	10:20

Property / Landholder:		Wilcrow Pty Ltd			
Bore name	WILCROW1	*Cad. Lot No:*	16	*Cad. Plan No:*	DP750931
Easting:	290912.9	*Northing:*	6438672.7	*Elevation:*	243.9
Bore located in the middle of paddock, approximately 300 m west from Halls Rd, Sandy Crk North alluvial flat.					
Bore construction:					
Bore diameter:	140 mm				
Casing:	10 steel				
Bore depth:	8.3 m				
Bore equipment / use:					
Bore use:	abandoned, bore opened to elements (no cap)				
Bore equipment:	none – formerly probably windmill				
Water level measurement:					
Reference point elevation (m):	0.325				
Reference point description:	Edge of steel casing				
Measured depth to water (m):	5.83				
GWL elevation (m RL):	238.36				
Water quality measurement:					
Temperature (°C)	19.2				
pH	8.3				
ORP (mV)	207				
EC (µS/cm)	2726				
TDS (mg/l)	1947				
Balier used to obtain water quality sample (3rd bailer)					
Date:	30/6/2014				
Time:	11:15				

Property / Landholder:		Wilcrow Pty Ltd			
Bore name	GW023103	*Cad. Lot No:*	28	*Cad. Plan No:*	DP750931
Easting:	290850.9	*Northing:*	6438997.4	*Elevation:*	247.0
South western corner of the property, approximately 550 m west from Halls Rd, Sandy Crk North alluvial flat.					
Bore construction:					
Bore diameter:		140 mm			
Casing:		10 steel			
Bore depth:		n/a			
Bore equipment / use:					
Bore use:		abandoned, filled up (concrete?)			
Bore equipment:		none – formerly probably windmill			
Water level measurement:					
Reference point elevation (m):		0.86			
Reference point description:		edge of steel casing			
Measured depth to water (m):		n/a			
GWL elevation (m RL):		n/a			
Water quality measurement:					
Temperature (°C)		n/a			
pH		n/a			
ORP (mV)		n/a			
EC (µS/cm)		n/a			
TDS (mg/l)		n/a			
Date:		30/6/2014			
Time:		11:25			

TUR3 not found – destroyed?

Property / Landholder:	Darryl Len Caddey, Phillip Caddey				
Bore name	CAD2, MARYVALE	*Cad. Lot No:*	178	*Cad. Plan No:*	DP750951
Easting:	294131.8	*Northing:*	6439790.2	*Elevation:*	200.1
Approximately 40 m north from Halls Rd., shallow regolith bore.					
Bore construction:					
Bore diameter:	160 mm				
Casing:	Steel				
Bore depth:	14.36 m				
Bore equipment / use:					
Bore use:	bore not used, formerly water supply for cattle				
Bore equipment:	windmill				
Water level measurement:					
Reference point elevation:	0.25 m				
Reference point description:	top of steel casing				
Measured depth to water:	11.67				
GWL elevation:	188.66				
Water quality measurement:					
Temperature (°C)	18.1				
pH	6.6				
ORP (mV)	-97				
EC (µS/cm)	4264				
TDS (mg/l)	3139				
Sampled using bailer (3rd bailer volume).					
Date:	30/6/2014				
Time:	13:00				

Property / Landholder:	Graeme Carl Sparre				
Bore name	CRRDH109	*Cad. Lot No:*	4	*Cad. Plan No:*	DP21335
Easting:	290352.5	*Northing:*	6432094.8	*Elevation:*	200.6
Source aquifer ‘burnt rock’.					
Bore construction:					
Bore diameter:	140 mm				
Casing:	PVC – white				
Bore depth:	n/a				
Bore equipment / use:					
Bore use:	bore in use – stock				
Bore equipment:	pump - petrol				
Water level measurement:					
Reference point elevation:	n/a				
Reference point description:	top of PVC casing				
Measured depth to water:	n/a				
GWL elevation:	n/a				
Not measured – pump installed and bore opening is covered.					
Water quality measurement:					
Temperature (°C)	n/a				
pH	n/a				
ORP (mV)	n/a				
EC (µS/cm)	n/a				
TDS (mg/l)	n/a				
Not sampled – pump installed and bore opening is covered.					
Date:	30/6/2014				
Time:	15:50				

Property / Landholder:	FA Wheatley and Son Pty Ltd				
Bore name	GDAY1	*Cad. Lot No:*	15	*Cad. Plan No:*	DP750931
Easting:	290818.3	*Northing:*	6438406.7	*Elevation:*	236.8
Paddock, alluvial flat (Sandy Crk North), approx 380 m west of Halls Rd.					
Bore construction:					
Bore diameter:	92 cm (inner)				
Casing:	Concrete				
Bore depth:	5.77 m				
Bore equipment / use:					
Bore use:	Functional well, not used, not equipped, previously stock water.				
Bore equipment:	n/a				
Water level measurement:					
Reference point elevation:	0.70 m				
Reference point description:	Edge of concrete casing				
Measured depth to water:	3.52 m				
GWL elevation:	234.01 m RL				
Water quality measurement:					
Temperature (°C)	15.5				
pH	6.9				
ORP (mV)	135				
EC (µS/cm)	766				
TDS (mg/l)	509				
Sampled using bailer (3rd bailer volume)					
Date:	10/7/2014				
Time:	9:30				

Property / Landholder:	FA Wheatley and Son Pty Ltd				
Bore name	WH02	*Cad. Lot No:*	15	*Cad. Plan No:*	DP750931
Easting:	290832.1	*Northing:*	6438493.8	*Elevation:*	238.3
Paddock, alluvial flat (Sandy Crk North), approx 100 m north of WH01.					
Bore construction:					
Bore diameter:	170 cm				
Casing:	Steel, concrete				
Bore depth:	n/a				
Bore equipment / use:					
Bore use:	Not used, backfilled, formerly stock water.				
Bore equipment:	Windmill (non-functioning)				
Water level measurement:					
Reference point elevation:	n/a				
Reference point description:	n/a				
Measured depth to water:	n/a				
GWL elevation:	n/a				
Bore backfilled (rubble, concrete), GWL not measured.					
Water quality measurement:					
Temperature (°C)	n/a				
pH	n/a				
ORP (mV)	n/a				
EC (µS/cm)	n/a				
TDS (mg/l)	n/a				
Bore backfilled (rubble, concrete), water quality sample not acquired.					
Date:	10/7/2014				
Time:	10:00				

Property / Landholder:		Rosella / Lawrence Edward, Sandra Robyn Holdsworth			
Bore name	ROS01	*Cad. Lot No:*	2	*Cad. Plan No:*	DP625029
Easting:	291188.9	*Northing:*	6437829.9	*Elevation:*	230.3
Well in alluvium of Sandy Creek North, approx 150 m east of Halls Rd.					
Bore construction:					
Bore diameter:		92 cm (internal)			
Casing:		concrete			
Bore depth:		6.0 m			
Bore equipment / use:					
Bore use:		Bore in use – stock (approx 20 head) water.			
Bore equipment:		Pump – petrol			
Water level measurement:					
Reference point elevation:		1.50 m			
Reference point description:		top of concrete casing			
Measured depth to water:		4.76 m			
GWL elevation:		227.04 m RL			
Water quality measurement:					
Temperature (°C)		n/a			
pH		n/a			
ORP (mV)		n/a			
EC (µS/cm)		n/a			
TDS (mg/l)		n/a			
Well covered with chicken mesh wire – water quality sample not taken.					
Date:		10/7/2014			
Time:		10:00			

Property / Landholder:	Walter John and Gwen Elizabeth Pitman				
Bore name	PIT01	*Cad. Lot No:*	1	*Cad. Plan No:*	DP625029
Easting:	291243.1	*Northing:*	6437765.5	*Elevation:*	229.3
Well in alluvium of Sandy Creek North, approx 240 m east of Halls Rd., approx 100 m south-east of ROS01					
Bore construction:					
Bore diameter:	150 x 150 cm (rectangular) well				
Casing:	timber				
Bore depth:	n/a				
Bore equipment / use:					
Bore use:	bore in use – stock (approx 50 head) water.				
Bore equipment:	pump – electric, powered directly from grid, old non-functioning windmill				
Water level measurement:					
Reference point elevation:	0.30 m				
Reference point description:	Timber edge				
Measured depth to water:	4.06 m				
GWL elevation:	225.54 m RL				
Water quality measurement:					
Temperature (°C)	15.0				
pH	6.9				
ORP (mV)	133				
EC (µS/cm)	1422				
TDS (mg/l)	971				
Bailer used to acquire water sample (3rd bailer volume)					
Date:	10/7/2014				
Time:	10:15				

Property / Landholder:	Rosella / Lawrence Edward, Sandra Robyn Holdsworth				
Bore name	PIT02/ROS02	*Cad. Lot No:*	2	*Cad. Plan No:*	DP625029
Easting:	291336.9	*Northing:*	6437732.2	*Elevation:*	229.1
Well located in the small shed at the alluvial flat of the Sandy Creek North (south-western bank of creek), approximately 360 m east of Halls Rd.					
Bore construction:					
Bore diameter:	1.0 x 1.5 m – rectangular				
Casing:	Timber				
Bore depth:	7.7 m				
Bore equipment / use:					
Bore use:	Bore in use – stock (approx 20 head) water.				
Bore equipment:	Pump – electric, 240V (Davey) – pumping!!!				
Water level measurement:					
Reference point elevation:	0.0 m				
Reference point description:	ground - Reference point approximately at ground level.				
Measured depth to water:	3.7 m				
GWL elevation:	225.4 m				
Water quality measurement:					
Temperature (°C)	18.0				
pH	6.9				
ORP (mV)	137				
EC (µS/cm)	1527				
TDS (mg/l)	1076				
Sample acquired using bailer (3rd bailer volume)					
Date:	10/7/2014				
Time:	10:30				




Property / Landholder:	Dorset / John Lawrence, Diane Gay Day, Rodney William				
Bore name	DOR01	*Cad. Lot No:*	1	*Cad. Plan No:*	DP838220
Easting:	290386.4	*Northing:*	6438064.9	*Elevation:*	251.5
Bore located south of Sandy Creek North tributary in the flat area just below the foothills. Small wire-mesh shelter with flat metal sheet roof on concrete pad.					
Bore construction:					
Bore diameter:	190 mm				
Casing:	Black PVC				
Bore depth:	27.0 m				
Bore equipment / use:					
Bore use:	Bore in use, approx 30 heads of stock				
Bore equipment:	Pump, electric (Onga)				
Water level measurement:					
Reference point elevation:	4.0 cm				
Reference point description:	Top of the black PVC casing				
Measured depth to water:	7.71 m				
GWL elevation:	243.87 m				
Water quality measurement:					
Temperature (°C)	n/a				
pH	n/a				
ORP (mV)	n/a				
EC (µS/cm)	n/a				
TDS (mg/l)	n/a				
Water quality sample not acquired, bore opening partially blocked by pump.					
Date:	10/7/2014				
Time:	11:10				

Property / Landholder:	Trevor George Woods, Karen Muriel Bates				
Bore name	GW200256	*Cad. Lot No:*	16	*Cad. Plan No:*	DP830934
Easting:	288720.2	*Northing:*	6436578.9	*Elevation:*	310.9
End of Sandy Creek Rd. R.O.W. Small mound left side of the driveway. Bore backfilled immediately after drilled – no water struck.					
Bore construction:					
Bore diameter:	n/a				
Casing:	n/a				
Bore depth:	n/a				
Bore equipment / use:					
Bore use:	No				
Bore equipment:	n/a				
Water level measurement:					
Reference point elevation:	n/a				
Reference point description:	n/a				
Measured depth to water:	n/a				
GWL elevation:	n/a				
Bore does not exist, no groundwater level measurement taken.					
Water quality measurement:					
Temperature (°C)	n/a				
pH	n/a				
ORP (mV)	n/a				
EC (µS/cm)	n/a				
TDS (mg/l)	n/a				
Bore does not exist, no groundwater quality sample taken.					
Date:	10/7/2014				
Time:	12:20				

No photos documenting this bore.

Property / Landholder:		John Howard			
Bore name	GW025631	*Cad. Lot No:*	13	*Cad. Plan No:*	DP830934
Easting:	288674.7	*Northing:*	6436034.7	*Elevation:*	284.9
Western bank of the Coal Creek (Sandy Creek South?) on the alluvial creek flat. Approx 40 m east of Sandy Creek Rd R.O.W.					
Bore construction:					
Bore diameter:	145 cm (outside)				
Casing:	Concrete				
Bore depth:	4.17 m				
Bore equipment / use:					
Bore use:	Stock				
Bore equipment:	Windmill				
Water level measurement:					
Reference point elevation:	0.32 m				
Reference point description:	Edge of the opening in the green well lid – elevation of the casing top.				
Measured depth to water:	1.67 m				
GWL elevation:	283.54 m RL				
Water quality measurement:					
Temperature (°C)	15.0				
pH	6.8				
ORP (mV)	133				
EC (µS/cm)	2035				
TDS (mg/l)	1420				
Sample obtained using bailer (3rd bailer volume)					
Date:	10/7/2014				
Time:	12:40				

Property / Landholder:	Peter Brian Watts				
Bore name	GW025626	*Cad. Lot No:*	11	*Cad. Plan No:*	DP830934
Easting:	288164.4	*Northing:*	6435243.4	*Elevation:*	262.0
NW bank of the Coal Creek, approx 80 m south of the road, well in the Coal Creek alluvium. Bore equipped with derelict windmill (easting: 288162.4; northing: 6435240.0; elevation: 261.0) about 5m away.					
Bore construction:					
Bore diameter:	150 cm – outside				
Casing:	concrete				
Bore depth:	2.45 m				
Bore equipment / use:					
Bore use:	Stock – approx 35 heads?.				
Bore equipment:	no pump.				
Water level measurement:					
Reference point elevation:	75 cm				
Reference point description:	Edge of concrete casing				
Measured depth to water:	1.10 m				
GWL elevation:	260.66 m RL				
Water quality measurement:					
Temperature (°C)	15.3				
pH	7.1				
ORP (mV)	142				
EC (µS/cm)	3110				
TDS (mg/l)	2215				
Sample obtained using bailer (3rd bailer volume)					
Date:	10/7/2014				
Time:	13:20				

Property / Landholder:		Kailana / Robert Geoffrey Gowing			
Bore name	GOW01	*Cad. Lot No:*	324	*Cad. Plan No:*	DP829973
Easting:	286554.4	*Northing:*	6430771.2	*Elevation:*	197.6
Well sunk into alluvium behind owner’s house. Reed bed covering the well, well itself not accessible.					
Bore construction:					
Bore diameter:		150 cm ??			
Casing:		Concrete			
Bore depth:		n/a			
Bore equipment / use:					
Bore use:		Domestic, stock			
Bore equipment:		no pump			
Water level measurement:					
Reference point elevation:		0.00 m			
Reference point description:		Ground			
Measured depth to water:		0.00 m			
GWL elevation:		197.60 m RL			
Groundwater level not measured – water spills over the well edge and surface water elevation in the reeds/swamp is assumed to be identical to the groundwater level. Pump taking water directly from creek.					
Water quality measurement:					
Temperature (°C)		10.2			
pH		7.7			
ORP (mV)		59			
EC (µS/cm)		4180			
TDS (mg/l)		3121			
Surface water scoop from the swampy reed bed.					
Date:		10/7/2014			
Time:		14:15			

Owner claims that the water in the well is different from the water in the creek (cca 15 m distant).
Water quality measurement of the creek water seems to confirm this – water in the creek much fresher (EC=890 µS/cm, TDS=602.2 mg/l)

Property / Landholder:		Ann Michelle Pratt			
Bore name	GOW02	*Cad. Lot No:*	37	*Cad. Plan No:*	DP750915
Easting:	286380.4	*Northing:*	6433080.7	*Elevation:*	235.3
Well in the paddock behind owner's house, approx 200 m east from Castle Rock Rd. Fenced off well in Spring Creek alluvium, small pumpshed.					
Bore construction:					
Bore diameter:		150 x 150 cm – rectangular well			
Casing:		Timber			
Bore depth:		8.40 m			
Bore equipment / use:					
Bore use:		Domestic, stock (horse, cattle)			
Bore equipment:		Electric pump			
Water level measurement:					
Reference point elevation:		0.0			
Reference point description:		ground			
Measured depth to water:		2.14 m			
GWL elevation:		233.12 m RL			
Water quality measurement:					
Temperature (°C)		17.9			
pH		7.7			
ORP (mV)		148			
EC (µS/cm)		628			
TDS (mg/l)		417			
Water quality sample obtained using bailer (3rd bailer volume)					
Date:		10/7/2014			
Time:		14:50			

Property / Landholder:	Ian Vincent Ingold, Colleen Anne Ingold				
Bore name	ING01	*Cad. Lot No:*	212	*Cad. Plan No:*	DP634465
Easting:	286632.4	*Northing:*	6429549.5	*Elevation:*	186.8
Well located in a small shed, on the paddock (Spring Creek alluvium) behind the house, approx 270 m east of the Castle Rock Rd.					
Bore construction:					
Bore diameter:	140 cm				
Casing:	Concrete				
Bore depth:	4.9 m				
Bore equipment / use:					
Bore use:	Domestic (garden)				
Bore equipment:	Pump, electric				
Water level measurement:					
Reference point elevation:	20 cm				
Reference point description:	Top/edge of the concrete casing				
Measured depth to water:	1.30 m				
GWL elevation:	185.68 m RL				
Water quality measurement:					
Temperature (°C)	12.7				
pH	7.2				
ORP (mV)	157				
EC (µS/cm)	1506				
TDS (mg/l)	1037				
Sampled from garden tap.					
Date:	10/7/2014				
Time:	15:30				

Property / Landholder:	Scott Heywood Jennar				
Bore name	JEN01	*Cad. Lot No:*	16	*Cad. Plan No:*	DP731123
Easting:	286639.9	*Northing:*	6429854.8	*Elevation:*	190.3
Well located behind machinery shed, approx 210 m east from Castle Rock Rd. Spring Creek alluvium.					
Bore construction:					
Bore diameter:	140 cm				
Casing:	Concrete				
Bore depth:	7.62 m				
Bore equipment / use:					
Bore use:	Domestic (garden)				
Bore equipment:	Pump, electric (power from grid)				
Water level measurement:					
Reference point elevation:	120 cm				
Reference point description:	Top/edge of the concrete casing				
Measured depth to water:	3.17 m				
GWL elevation:	188.32				
Water quality measurement:					
Temperature (°C)	11.5				
pH	7.2				
ORP (mV)	219				
EC (µS/cm)	1411				
TDS (mg/l)	972				
Sampled using bailer (3rd bailer volume)					
Date:	10/7/2014				
Time:	16:30				

Property / Landholder:		Maree Esther Daniels			
Bore name	DDH20	*Cad. Lot No:*	101	*Cad. Plan No:*	DP1157712
Easting:	293115.37	*Northing:*	6439916.10	*Elevation:*	240.30
Bore construction:					
Bore diameter:		50mm			
Casing:		PVC			
Bore depth:		46.76			
Bore equipment / use:					
Bore use:		Not used			
Bore equipment:		None			
Water level measurement:					
Reference point elevation:		0.76 m			
Reference point description:		Top of PVC casing			
Measured depth to water:		n/a			
GWL elevation:		n/a			
Water quality measurement:					
Temperature (°C)		n/a			
pH		6.48			
ORP (mV)		n/a			
EC (µS/cm)		12460			
TDS (mg/l)		n/a			
Date:		18/6/2014			
Time:		9:15			

Property / Landholder:		Muswellbrook Coal Company (MCC)			
Bore name	WYL1	*Cad. Lot No:*	101	*Cad. Plan No:*	DP750951
Easting:	291169.47	*Northing:*	6438494.78	*Elevation:*	243.83
Remnant of a bore, derelict windmill, not sampled by CBE					
Bore construction:					
Bore diameter:		0.12			
Casing:		PVC			
Bore depth:		15.7			
Bore equipment / use:					
Bore use:		Not used			
Bore equipment:		None			
Water level measurement:					
Reference point elevation:		0			
Reference point description:		Top of the PVS casing – approx. ground level			
Measured depth to water:		10.24			
GWL elevation:		233.59			
Water quality measurement:					
Temperature (°C)		n/a			
pH		n/a			
ORP (mV)		n/a			
EC (µS/cm)		n/a			
TDS (mg/l)		n/a			
Date:		18/6/2014			
Time:		11:15			

Property / Landholder:		Anthony Denis Lonergan			
Bore name	DDH4	*Cad. Lot No:*	101	*Cad. Plan No:*	DP1124883
Easting:	291782.68	*Northing:*	6436624.36	*Elevation:*	257.16
Exploration hole used for ground water quality sampling					
Bore construction:					
Bore diameter:		50 mm			
Casing:		White PVC			
Bore depth:		84.64			
Bore equipment / use:					
Bore use:		Monitoring - water quality sampling			
Bore equipment:		None			
Water level measurement:					
Reference point elevation:		0.92			
Reference point description:		Top of the PVC stickup			
Measured depth to water:		39.8			
GWL elevation:		218.28			
Water quality measurement:					
Temperature (°C)		n/a			
pH		7.74			
ORP (mV)		n/a			
EC (µS/cm)		3890			
TDS (mg/l)		n/a			
Date:		18/6/2014			
Time:		12:50			

Property / Landholder:		John Edward Lonergan, Johanna Lambertina Lonergan			
Bore name	JLON1	*Cad. Lot No:*	4	*Cad. Plan No:*	DP584230
Easting:	292403.50	*Northing:*	6434331.87	*Elevation:*	259.20
Bore sealed up					
Bore construction:					
Bore diameter:		n/a			
Casing:		n/a			
Bore equipment / use:					
Bore use:		stock			
Bore equipment:		Windmill			
Bore depth:		n/a			
Water level measurement:					
Reference point elevation:		n/a			
Reference point description:		n/a			
Measured depth to water:		n/a			
GWL elevation:		n/a			
Bore opening sealed					
Water quality measurement:					
Temperature (°C)		n/a			
pH		8.92			
ORP (mV)		n/a			
EC (µS/cm)		8220			
TDS (mg/l)		n/a			
Sampled from water tank					
Date:		18/6/2014			
Time:		13:50			

Property / Landholder:		Colin William Hutchinson (MCC)			
Bore name	YOU1	*Cad. Lot No:*	32	*Cad. Plan No:*	DP748710
Easting:	288149.59	*Northing:*	6434786.27	*Elevation:*	250.42
Bore construction:					
Bore diameter:		1.10 m			
Casing:		Concrete			
Bore equipment / use:					
Bore use:		n/a			
Bore equipment:		n/a			
Bore depth:		2.48			
Water level measurement:					
Reference point elevation:		0.67			
Reference point description:		Top of concrete casing			
Measured depth to water:		2.48			
GWL elevation:		248.61			
Water quality measurement:					
Temperature (°C)		n/a			
pH		n/a			
ORP (mV)		n/a			
EC (µS/cm)		5890			
TDS (mg/l)		n/a			
Date:		18/6/2014			
Time:		14:25			

Property / Landholder:		Graeme Carl Sparre			
Bore name	DDH27	*Cad. Lot No:*	2	*Cad. Plan No:*	DP136249
Easting:	291291.04	*Northing:*	6434348.03	*Elevation:*	244.04
Bore construction:					
Bore diameter:		50 mm			
Casing:		PVC			
Bore depth:		63.1			
Bore equipment / use:					
Bore use:		Monitoring			
Bore equipment:		None			
Water level measurement:					
Reference point elevation:		0.075			
Reference point description:		Top of PVC casing			
Measured depth to water:		23.56			
GWL elevation:		220.55			
Water quality measurement:					
Temperature (°C)		n/a			
pH		8.28			
ORP (mV)		n/a			
EC (µS/cm)		999			
TDS (mg/l)		n/a			
Date:		19/6/2014			
Time:		8:25			

Property / Landholder:		Graeme Carl Sparre			
Bore name	SPAR3	*Cad. Lot No:*	1	*Cad. Plan No:*	DP136249
Easting:	291439.68	*Northing:*	6433548.47	*Elevation:*	220.89
Bore construction:					
Bore diameter:		~ 1x1 m			
Casing:		Timber			
Bore depth		8.2			
Bore equipment / use:					
Bore use:		n/a			
Bore equipment:		n/a			
Water level measurement:					
Reference point elevation:		0.10			
Reference point description:		Edge of well – approximately ground level			
Measured depth to water:		2.96			
GWL elevation:		218.03			
Water quality measurement:					
Temperature (°C)		n/a			
pH		n/a			
ORP (mV)		n/a			
EC (µS/cm)		n/a			
TDS (mg/l)		n/a			
Water quality not sampled					
Date:		19/6/2014			
Time:		8:45			

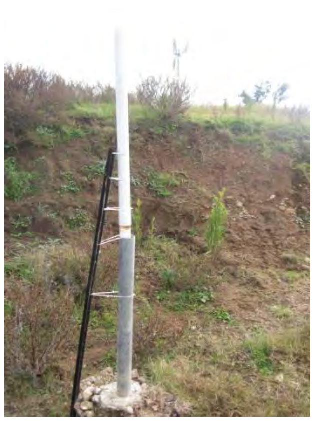
Property / Landholder:		Graeme Carl Sparre			
Bore name	CRRDH52	*Cad. Lot No:*	2	*Cad. Plan No:*	DP136249
Easting:	291701.57	*Northing:*	6434009.73	*Elevation:*	237.61
Bore construction:					
Bore diameter:		50 mm			
Casing:		PVC			
Bore depth:		16.76			
Bore equipment / use:					
Bore use:		Exploration – bore abandoned, used as sampling site			
Bore equipment:		n/a			
Water level measurement:					
Reference point elevation:		1.21			
Reference point description:		Top of PVC casing			
Measured depth to water:		16.76			
GWL elevation:		222.06			
Water quality measurement:					
Temperature (°C)		n/a			
pH		7.0			
ORP (mV)		n/a			
EC (µS/cm)		2190			
TDS (mg/l)		n/a			
Date:		19/6/2014			
Time:		9:15			

Property / Landholder:		Graeme Carl Sparre			
Bore name	SPAR4	*Cad. Lot No:*	4	*Cad. Plan No:*	DP21335
Easting:	290210.33	*Northing:*	6433732.92	*Elevation:*	215.17
Bore construction:					
Bore diameter:		150 mm			
Casing:		steel			
Bore depth:		3.78			
Bore equipment / use:					
Bore use:		n/a			
Bore equipment:		Derelict windmill			
Water level measurement:					
Reference point elevation:		0.45 m			
Reference point description:		Top of steel casing			
Measured depth to water:		3.78			
GWL elevation:		211.84			
Water quality measurement:					
Temperature (°C)		n/a			
pH		9.34			
ORP (mV)		n/a			
EC (µS/cm)		1669			
TDS (mg/l)		n/a			
Date:		19/6/2014			
Time:		9:40			

Property / Landholder:		Graeme Carl Sparre			
Bore name	SPAR2	*Cad. Lot No:*	4	*Cad. Plan No:*	DP21335
Easting:	289994.50	*Northing:*	6433497.99	*Elevation:*	217.38
Bore construction:					
Bore diameter:		1.10			
Casing:		Concrete			
Bore depth:		7.35			
Bore equipment / use:					
Bore use:		Stock, minor irrigation			
Bore equipment:		Windmill			
Water level measurement:					
Reference point elevation:		0.48			
Reference point description:		Top of concrete well			
Measured depth to water:		3.30			
GWL elevation:		214.56			
Water quality measurement:					
Temperature (°C)		n/a			
pH		7.73			
ORP (mV)		n/a			
EC (µS/cm)		2710			
TDS (mg/l)		n/a			
Date:		19/6/2014			
Time:		10:05			



Property / Landholder:		Graeme Carl Sparre			
Bore name	CRRDH106	*Cad. Lot No:*	4	*Cad. Plan No:*	DP21335
Easting:	290009.14	*Northing:*	6433457.19	*Elevation:*	213.00
Bore construction:					
Bore diameter:		50 mm			
Casing:		PVC			
Bore depth:		4.6			
Bore equipment / use:					
Bore use:		Monitoring – bore used as a stream gauge			
Bore equipment:		n/a			
Water level measurement:					
Reference point elevation:		2.05 m			
Reference point description:		Top of the PVC casing			
Measured depth to water:		3.33			
GWL elevation:		211.72			
Water quality measurement:					
Temperature (°C)		n/a			
pH		7.46			
ORP (mV)		n/a			
EC (µS/cm)		2740			
TDS (mg/l)		n/a			
Date:		19/6/2014			
Time:		10:15			


Property / Landholder:		Graeme Carl Sparre			
Bore name	SPAR5	*Cad. Lot No:*	4	*Cad. Plan No:*	DP21335
Easting:	289875.92	*Northing:*	6433546.68	*Elevation:*	217.14
Bore construction:					
Bore diameter:		150 mm			
Casing:		steel			
Bore depth:		3.95 m			
Bore equipment / use:					
Bore use:		Not used, formerly stock water			
Bore equipment:		n/a			
Water level measurement:					
Reference point elevation:		0.08 m			
Reference point description:		Top of steel casing			
Measured depth to water:		1.61			
GWL elevation:		215.61			
Water quality measurement:					
Temperature (°C)		n/a			
pH		7.78			
ORP (mV)		n/a			
EC (µS/cm)		447			
TDS (mg/l)		n/a			
Date:		19/6/2014			
Time:		10:55			

Property / Landholder:		Anthone Denis Lonergan			
Bore name	DDH4	*Cad. Lot No:*	101	*Cad. Plan No:*	DP1124883
Easting:	291782.68	*Northing:*	6436624.36	*Elevation:*	257.16
Bore construction:					
Bore diameter:		50 mm			
Casing:		PVC			
Bore depth:		84.64			
Bore equipment / use:					
Bore use:		Monitoring			
Bore equipment:		n/a			
Water level measurement:					
Reference point elevation:		0.92			
Reference point description:		Top of PVC casing			
Measured depth to water:		39.8			
GWL elevation:		218.28			
Water quality measurement:					
Temperature (°C)		n/a			
pH		7.74			
ORP (mV)		n/a			
EC (µS/cm)		3890			
TDS (mg/l)		n/a			
Date:		18/6/2014			
Time:		12:50			



Property / Landholder:		Coal & Allied Operations Pty Ltd			
Bore name	CRRDH105	*Cad. Lot No:*	3	*Cad. Plan No:*	DP998239
Easting:	290674.30	*Northing:*	6432864.43	*Elevation:*	203.95
Bore construction:					
Bore diameter:		50 mm			
Casing:		PVC			
Bore depth:		7.9 m			
Bore equipment / use:					
Bore use:		Monitoring			
Bore equipment:		n/a			
Water level measurement:					
Reference point elevation:		2.12			
Reference point description:		Top of the pvc casing			
Measured depth to water:		6.20			
GWL elevation:		199.87			
Water quality measurement:					
Temperature (°C)		n/a			
pH		7.17			
ORP (mV)		n/a			
EC (µS/cm)		962			
TDS (mg/l)		n/a			
Date:		19/6/2014			
Time:		12:40			

Property / Landholder:		John Edward Lonergan, Johanna Lambertina Lonergan			
Bore name	JLON2	*Cad. Lot No:*	4	*Cad. Plan No:*	DP584230
Easting:	292318.84	*Northing:*	6434390.91	*Elevation:*	252.07
Bore construction:					
Bore diameter:		110 mm			
Casing:		Steel			
Bore depth:		39.29			
Bore equipment / use:					
Bore use:		n/a formerly stock water			
Bore equipment:		n/a formerly windmill			
Water level measurement:					
Reference point elevation:		0.60 m			
Reference point description:		Top of steel casing			
Measured depth to water:		29.48			
GWL elevation:		228.19			
Water quality measurement:					
Temperature (°C)		n/a			
pH		6.74			
ORP (mV)		n/a			
EC (µS/cm)		7570			
TDS (mg/l)		n/a			
Date:		18/6/2014			
Time:		13:35			

Appendix C

Numerical modelling

1. Model development and calibration

1.1 Model objectives

A numerical model was developed to assess the impacts of the Proposal on the surrounding groundwater environment. During the process of model development, the requirements of the NSW AIP were considered to ensure the model would predict the:

- volume of groundwater seepage from the highly productive aquifers to pits;
- drawdown (or water take) from highly productive alluvial aquifers of Sandy Creek North, Sandy Creek South, Spring Creek, Coal Creek, Dartbrook (Middle Brook and Kingdon Ponds) and the Hunter River;
- potential for drawdown in surrounding private landholder bores within and outside of PAA, drawdown in bores within the highly productive aquifer zones; and
- potential for changes in groundwater salinity.

1.2 Model design and construction

1.2.1 Conceptualisation

A conceptual understanding of the groundwater regime developed from field measurements, observations and experience is the basis for the development of any numerical groundwater flow model. Section 3 in the main body of this report describes the conceptual groundwater model of West Muswellbrook Project (WMB). The conceptual model describes how the groundwater system operates based upon the available information and represents the natural system in an idealised and simplified way.

1.2.2 Software used

The MODFLOW SURFACT code (referred to as SURFACT for the remainder of the report) was used to simulate of groundwater flow. SURFACT is a commercial derivative of the standard MODFLOW code and has some distinct advantages over the standard MODFLOW for simulating mining projects. Unlike original MODFLOW code, SURFACT can simulate variably saturated conditions, which is beneficial when representing dewatering of strata due to mining. SURFACT also includes adaptive time-steps, and robust numerical solver that helps it converge to a numerical solution.

The MODFLOW pre- and post-processor PMWIN (Chiang and Kinzelbach, 2001) was used to generate some of the input files for the SURFACT model. Where files differ to allow for the additional capabilities of SURFACT, these changes were undertaken through manual editing of the model files.

1.2.3 Model boundaries

The extent of the numerical model boundaries were selected to be sufficiently distant from the area of the proposed mining so as to not influence the drawdown predictions. These boundaries were set as follows:

- The south western model boundary was defined along the line of Mt. Ogilvie fault (in the southern part of the boundary) and it's perceived continuation due north-west. The fault line is considered to be a barrier to groundwater flow with very low permeability.
- The eastern boundary was defined along the subcrop line of Warkworth coal seam. As the target coal seams of the West Muswellbrook Project are Abby Green and Blakefield, incorporating underlying interburden and coal seams enables the modelling of the mining impacts on those layers. The impact of mining in the WMB area is not expected to extend past the Warkworth coal seam outcrop line.

- The northern boundary is an arbitrary cut-off line set in such a distance from the Project so that the mining impacts are unlikely to reach it.
- Southern boundary was placed to the southern edge of Hunter River alluvium (between Mt. Ogilvie fault line in the west and Warkworth seam subcrop line in the east).

1.2.4 Topographic surface and drainage

A publicly available one-second smoothed digital elevation model (DEM-S) with a 30 × 30 m grid spacing (Gallant *et al*., 2011) was used to represent the ground surface throughout the model domain. This dataset was merged with a detailed LIDAR derived digital elevation model (provided by client) covering the area of the Project. Further analysis of the DEM-S was conducted (using 1 km^2 watershed) in order to extract the drainage network. Extracted drainage lines follow the line of lowest topographic surface and were used to define surface drainage and river boundary conditions in the model.

1.2.5 Model layers

The model represents following geologic layers:

- Layer 1 – topsoil and alluvium;
- Layer 2 – weathered rock (regolith) - base defined as base of weathering;
- Layer 3 – consolidated sediments of Narrabeen Formation – base at the floor of Hawkesbury Sandstone;
- Layer 4 – interburden – consolidated sediments between Hawkesbury Sandstone and top of Abby Green seam;
- Layer 5 – Abby Green seam – combined thickness of Abby Green upper and lower seams
- Layer 6 – interburden;
- Layer 7 – coal seam representing combined thickness of Whybrow, Redbank, Wambo seams. Layer base located at the base of Wambo seam;
- Layer 8 – interburden;
- Layer 9 – combined Whynot and Blakefield coal seam (target of WMP mining operations). Layer base coincident with Blakefield seam base;
- Layer 10 – interburden; and
- Layer 11 – combined thickness of Glen Munro, Woodlands Hill, Arrowfield/Bowfield and Warkworth seams. Layer base coincident with base of Warkworth seam.

Figure C 1 to Figure C 3 present the floor contours for the coal seam floors in the model. Table C 1 summarises the thickness of each model layer.

Table C 1 Overview of model layer thickness

Layer	Thickness (m)					Comment
	Min	1st quartile	Mean	3rd quartile	Max	
L01	0.5 m - topsoil; variable thickness in alluvium					topsoil / alluvium / colluvium
L02	1.0	16.8	17.9	19.3	44.7	weathered profile / colluvium
L03	2.0	188.5	244.6	317.7	455.6	Narrabeen Formation - layer base at Hawkesbury Sandstone floor
L04	2.0	132.8	248.0	360.8	427.8	*Interburden*
L05	4.5 m - combined uniform thickness					coal seam - combined Abby Green - layer base at Abby Green Lower floor
L06	2.0	41.5	53.3	66.4	99.3	*Interburden*
L07	7.0 m - combined uniform thickness					coal seam - combined Whybrow, Redbank, Wambo - layer base at Wambo floor
L08	2.0	61.3	61.1	69.6	93.9	*Interburden*
L09	5.0 m - combined uniform thickness					coal seam - combined Whynot, Blakefield - layer base at Blakefield floor
L10	2.0	117.0	134.5	155.2	265.5	*Interburden*
L11	16.0 m - combined uniform thickness					coal seam - combined Glen Munro, Woodlands Hill, Arrowfield/Bowfield, Warkworth - layer base at Warkworth floor

1.2.6 Model grid extent

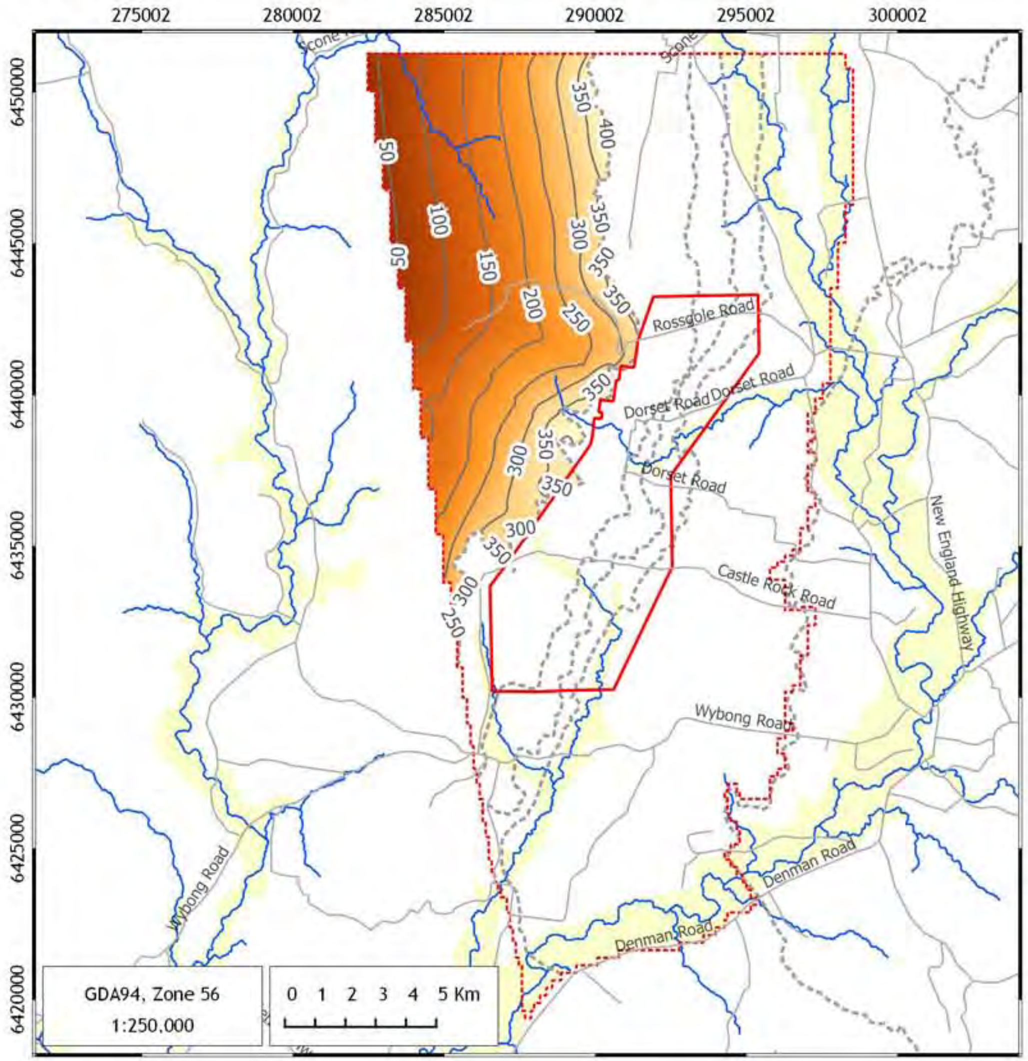
The model grid consisted of 25,132 cells per model layer (122 columns, 206 rows, 20640 active cells per layer, 11 layers). The upper left corner of the grid was set at coordinates: x = 282490, y = 6451270 (GDA94, MGA zone 56) and was not rotated. The cell size varied from a minimum of 100 × 100 m in the mining areas to a maximum of 250 × 250 m outside these zones. Figure C 4 shows the grid and active model domain, as well as the refined grid over the Project Assessment Area (PAA).

1.2.7 Time

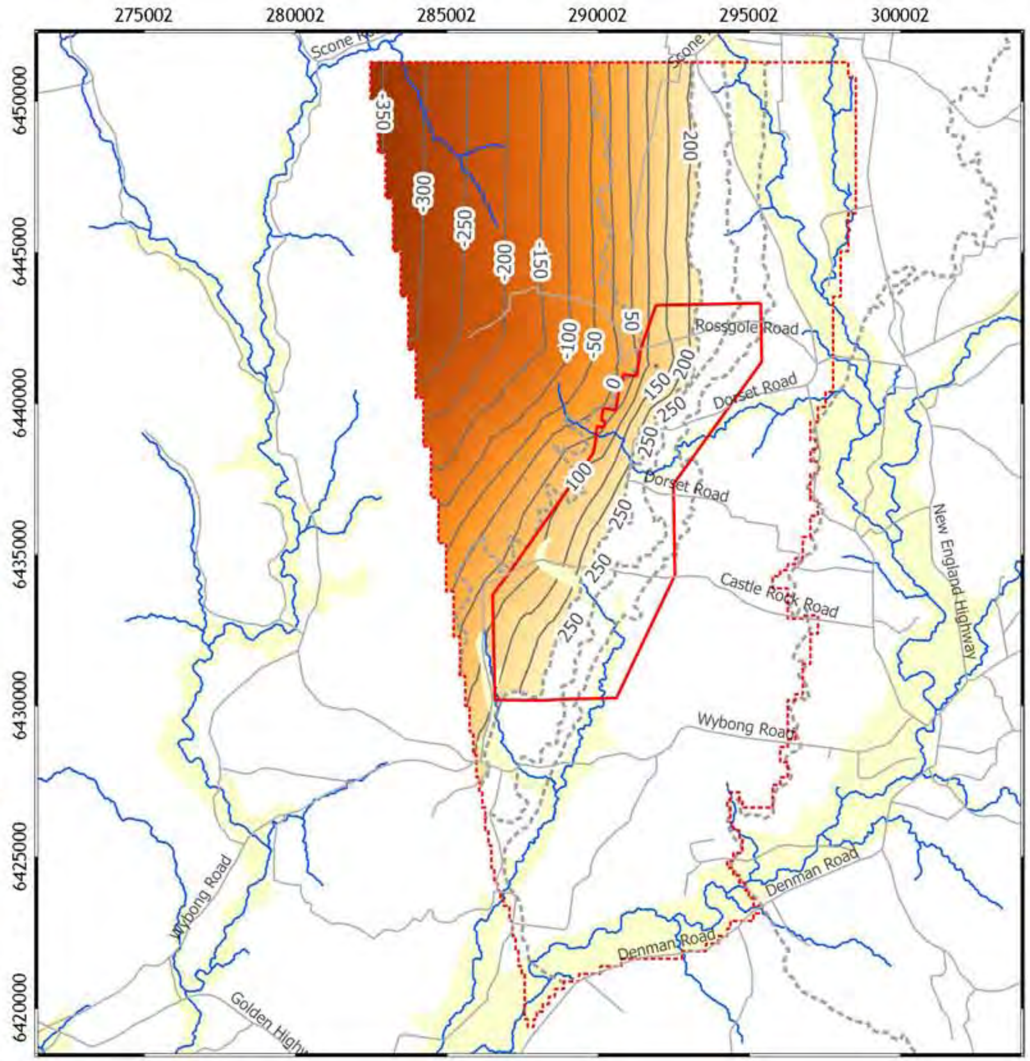
The model used days as the unit of time, and simulated the following periods of time:

- January 2004 to December 2013 - 10 years baseline period. This time period was used to calibrate the model. Once calibrated this period was used to simulate baseline conditions prior to commencement of mining. Stress period length was one month.
- 30 year mining period. Stress period length – 1 month.

Base of Layer 3 - Narrabeen Group (Hawkesbury Sandstone)



Base of Layer 5 - Abby Green



LEGEND

- Roads
- Main streams
- Layer floor subcrop lines
- Elevation contours (mAHD)
- Alluvium undifferentiated (Qa)
- Project Assessment Area
- Active model grid outline (Project Area)

West Muswelbrook (G1676)

AGE GROUNDWATER & ENVIRONMENTAL

Model layers (L03, L05)

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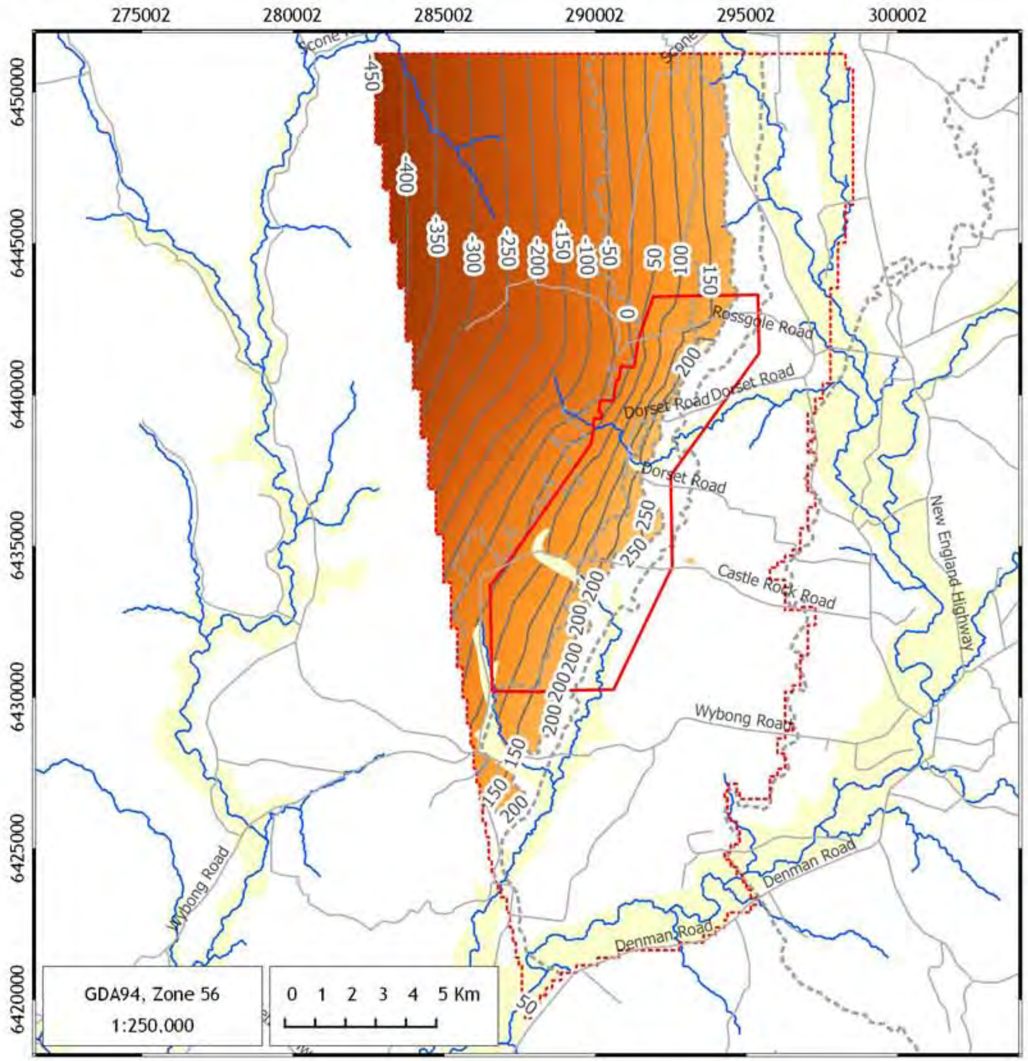
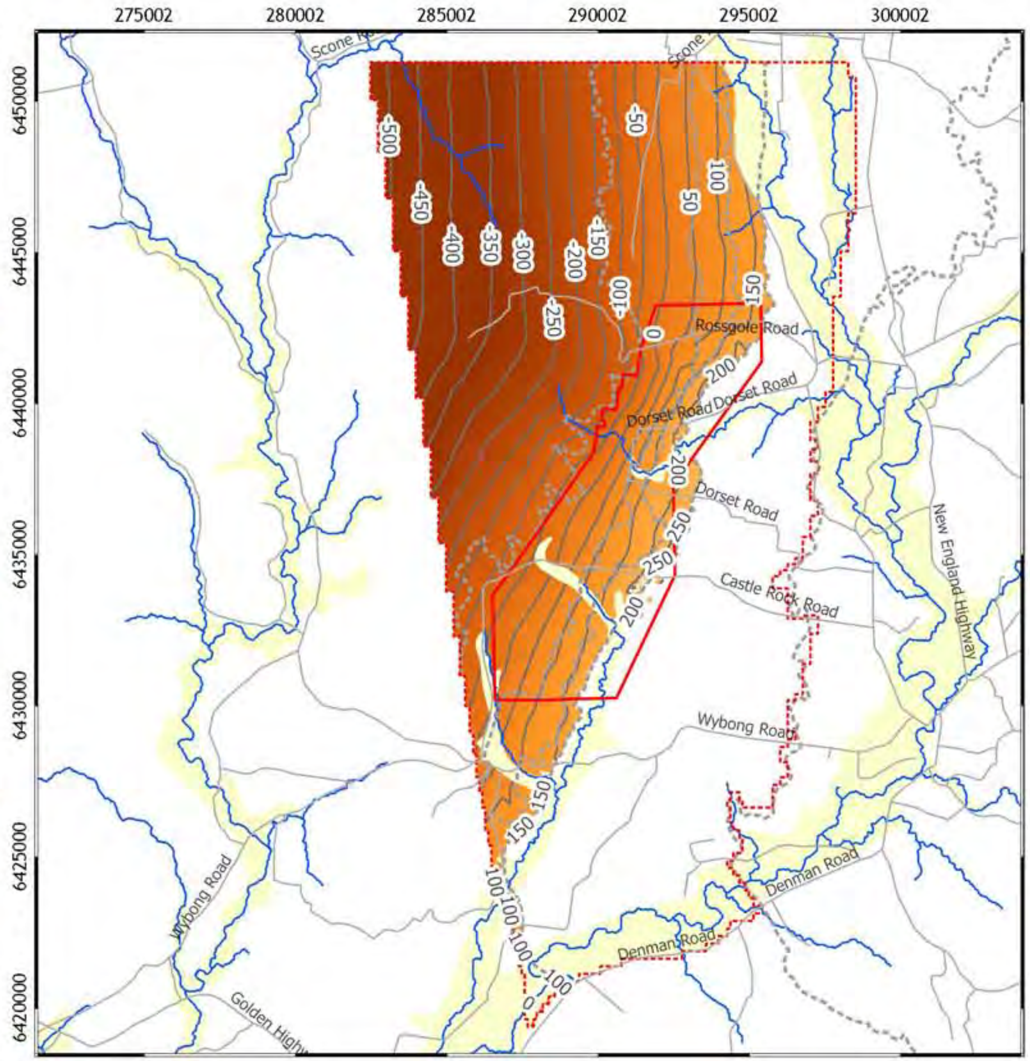
FIGURE No:
C-1

Base of Layer 7 - Wambo



Base of Layer 9 - Blakefield



LEGEND

- Roads
- Main streams
- Layer floor subcrop lines
- Elevation contours (mAHD)
- Alluvium undifferentiated (Qa)
- Project Assessment Area
- Active model grid outline (Project Area)

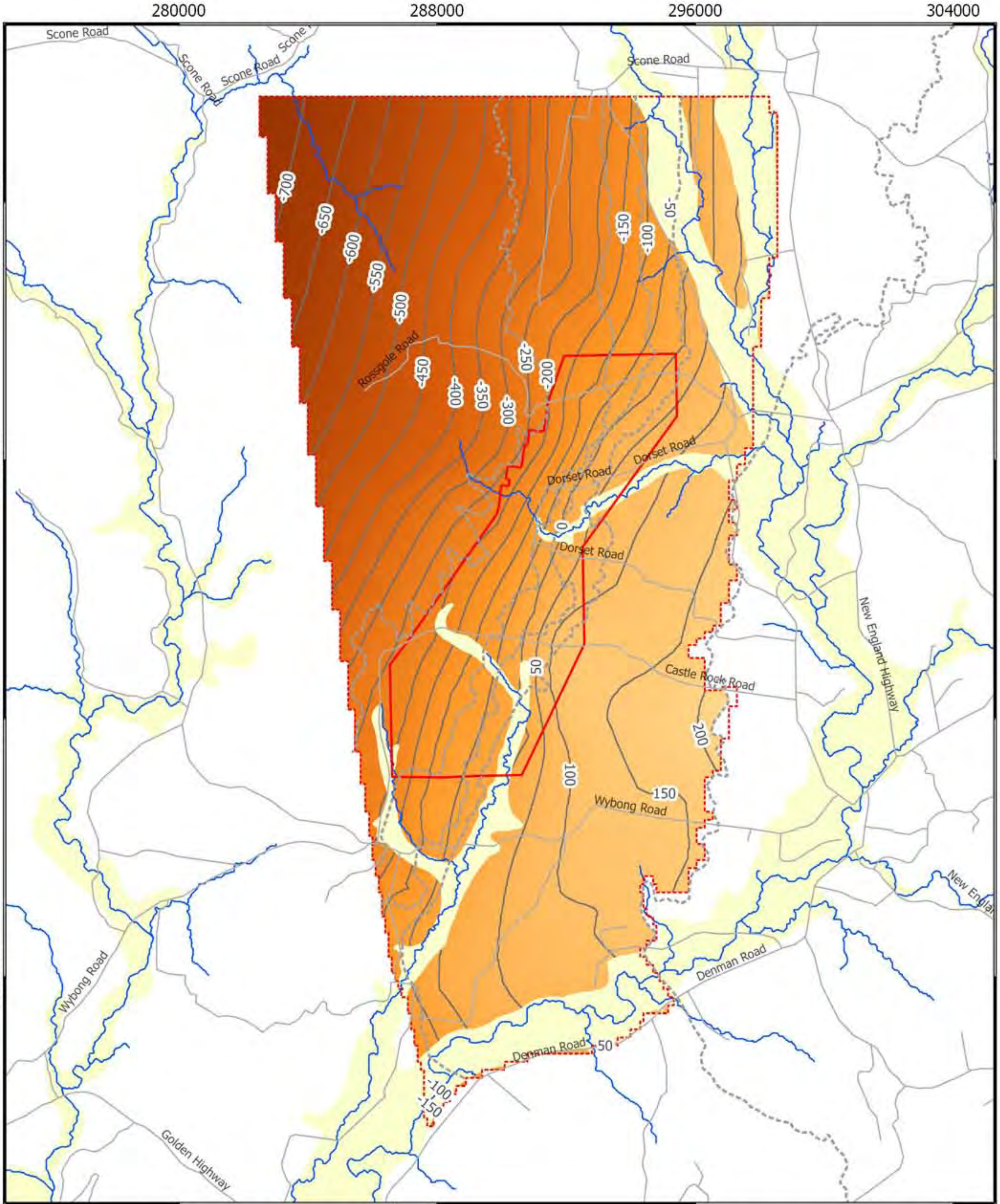
West Muswelbrook (G1676)

AGE GROUNDWATER & ENVIRONMENTAL

Model layers (L07, L09)

DATE
8/10/2014

FIGURE No:
C-2



GDA94, Zone 56 1:175,000	1 0 1 2 3 4 km

West Muswellbrook (G1676)

Model Layer 11 - Warkworth

- Roads
- Main streams
- Layer floor subcrop lines
- Elevation contours (mAHD)
- Alluvium undifferentiated (Qa)
- Project Assessment Area
- Active model grid outline (Project Area)

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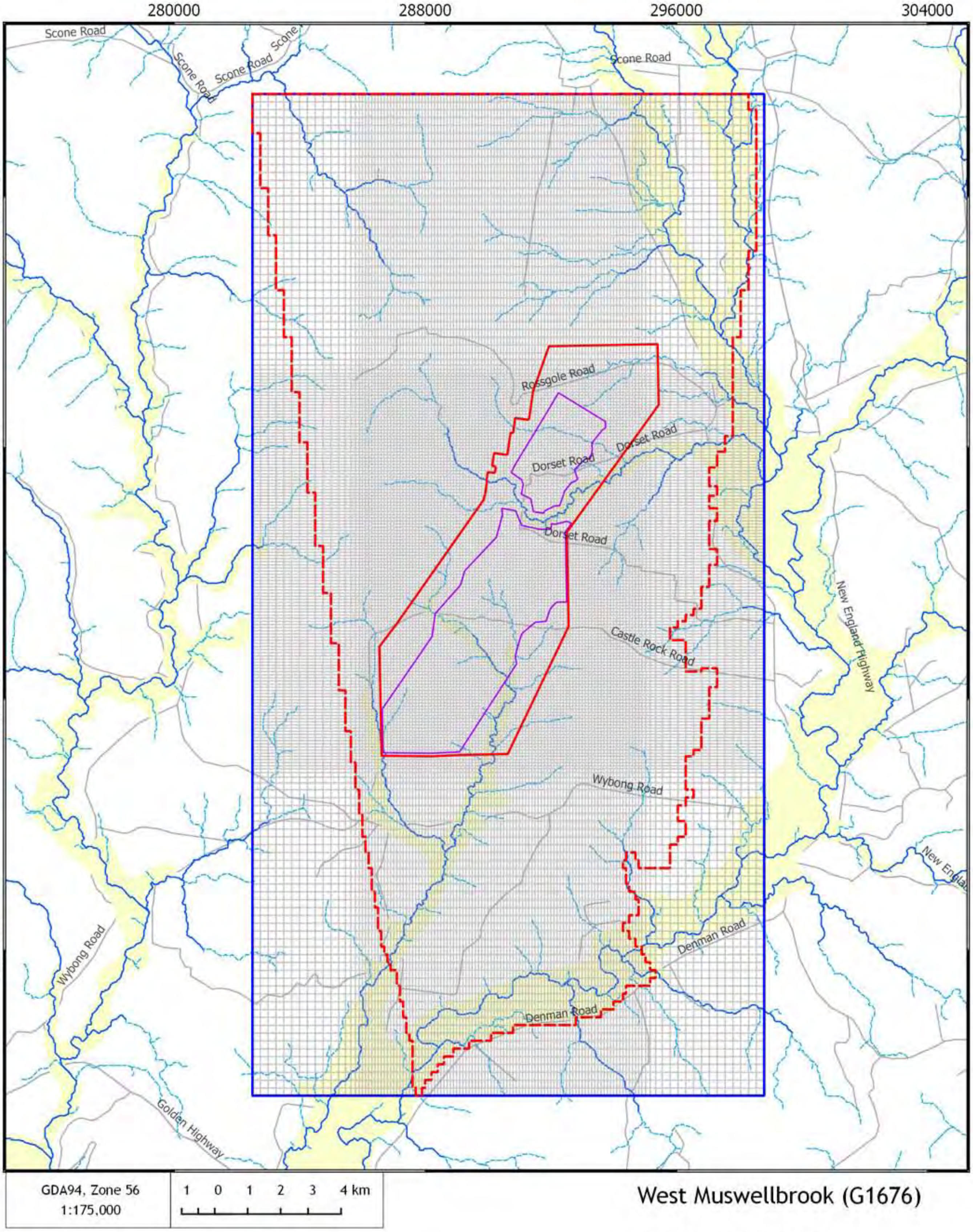
FIGURE No: C-3



West Muswellbrook (G1676)

Model grid extent

- Model grid lines
- Model grid - full extent
- Streams - main
- Streams - ephemeral
- Roads
- Pit outlines
- Project Assessment Area
- Active model grid outline (Project Area)
- Alluvium undifferentiated (Qa)

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FIGURE No: C-4

1.2.8 Boundary conditions - river and streams

The SURFACT RIV (river) package was used to represent the surface drainage (both permanent rivers and ephemeral streams) within the active model domain. The river package was set as a transient boundary with variable stage in multiple river/stream reaches. See Table C 4 for the overview of stage elevation change for individual reaches of the stream network during the lead-in (calibration) model period.

Drainage reaches were defined using the available stream gauge data or alluviual groundwater table elevation in designated bores. Refer

Figure C 5 for the location of river cells/reaches:

- *Reach 1* – ephemeral streams – river cells dry; 'drain' mode – stage always 0.0 m, elevation of head defined for each cell identical to elevation of stream bed.
- *Reach 2* – Sandy Creek North (middle) – river stage derived from the groundwater level measurement in piezometer RHRDH211. All stage data below 0.12 m considered to be below the ground surface (stream dry, stage set to 0.0 m).
- *Reach 3* – Sandy Creek North (lower).
- *Reach 4* – Sandy Creek South (middle) – river stage derived from the groundwater level measurement in piezometer CRD107. All stage data below 0.12 m considered to be below the ground surface (stream dry, stage set to 0.0 m).
- *Reach 5* – Sandy Creek South (lower) – derived from stage in Reach 4 (added 0.1 m)
- *Reach 6* – Dart brook.
- *Reach 7* – Kingdon Ponds.
- *Reach 8* – Hunter River.

Stream bed elevation for individual cell was acquired from DEM-S analysis (see Section 1.2.4 above) and then rectified using the DGPS survey data. See Table C 2 for the overview of stream bed elevation error.

Table C 2 RIV cells stream bed elevation error

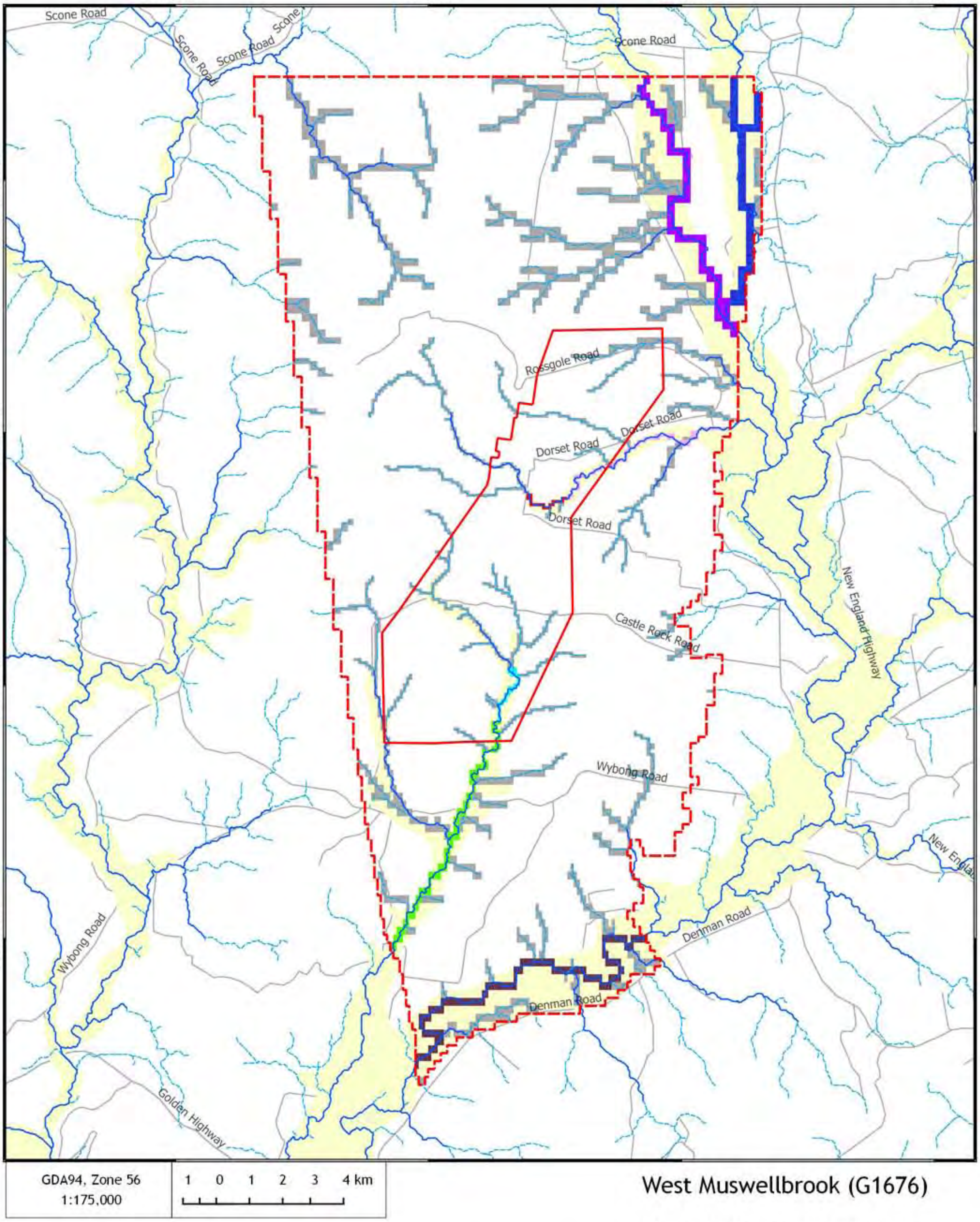
Stream catchment	Stream reach	Cell row	Cell column	Bed elevation DEM (m RL)	Bed elevation surveyed (m RL)	Bed elevation error (m)
Dartbrook	1	45	118	168.9	166.4	-2.5
Sandy Creek North	1	64	98	195.4	196.3	0.9
Sandy Creek North	1	67	90	206.4	205.6	-0.8
Sandy Creek North	1	80	67	233.2	230.7	-2.5
Sandy Creek North	1	80	68	232.1	232.7	0.6
Sandy Creek North	1	94	97	220.4	220.5	0.1
Sandy Creek North	1	96	99	229.7	222.5	-7.2
Sandy Creek North	2	84	70	226.8	228.6	1.8
Sandy Creek North	3	60	115	173.9	170.1	-3.8

Stream catchment	Stream reach	Cell row	Cell column	Bed elevation DEM (m RL)	Bed elevation surveyed (m RL)	Bed elevation error (m)
Sandy Creek South	1	113	38	250.8	252.1	1.3
Sandy Creek South	1	117	64	221.2	220.5	-0.7
Sandy Creek South	1	122	53	221.8	222.7	0.9
Sandy Creek South	1	127	56	215.3	213.6	-1.7
Sandy Creek South	1	133	61	204.1	200.6	-3.5
Sandy Creek South	4	147	59	185.5	186.6	1.1
Sandy Creek South	5	171	48	157.7	156.8	-0.9
Sandy Creek South	5	189	26	133.4	134.0	0.6
Spring Creek	1	121	21	251.3	252.4	1.1
Spring Creek	1	137	19	229.7	225.5	-4.2
Spring Creek	1	172	30	165.3	164.1	-1.2

Stream bed conductance for individual river is cells is calculated using the stream length within particular cell (derived from GIS analysis), width of the stream, stream bed thickness and stream bed vertical conductivity. River cell parameters are presented in Table C 3.

Table C 3 RIV boundary condition – parametres

Stream reach	Stream width (m)	Stream bed thickness (m)	Stream bed vert. conductivity (m/day)
Reach 1 - ephemeral streams / other drains	5.00	1.00	0.10
Reach 2 - Sandy Crk N – middle	5.00	2.00	0.10
Reach 3 - Sandy Crk N – lower	7.00	2.00	0.10
Reach 4 - Sandy Crk S – middle	5.00	2.00	0.10
Reach 5 - Sandy Crk S - lower	7.00	2.00	0.10
Reach 6 - Dartbrook	7.00	2.50	0.10
Reach 7 - Kingdon Ponds	7.00	3.00	0.10
Reach 8 - Hunter River	10.00	4.00	0.10



West Muswellbrook (G1676)

River boundary condition - river cells

Active model grid outline (Project Area)
Streams - main
Streams - ephemeral
Roads
Project Assessment Area
Alluvium undifferentiated (Qa)

1 - Ephemeral streams
2 - Sandy Creek North - middle reach
3 - Sandy Creek North - lower reach
4 - Sandy Creek South - middle reach
5 - Sandy Creek South - lower reach
6 - Dartbrook
7 - Kingdon Ponds
8 - Hunter River

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FIGURE No: C-5

Table C 4 RIV Reaches – transient stage during model calibration period

Stress period	Date	Stage for stream reach (m)							
		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8
1	Jan 2004	0.000	0.000	0.000	0.979	1.079	0.184	0.114	1.023
2	Feb 2004	0.000	0.000	0.000	0.979	1.079	0.224	0.153	0.957
3	Mar 2004	0.000	0.000	0.000	0.979	1.079	0.330	0.387	0.862
4	Apr 2004	0.000	0.000	0.000	0.979	1.079	0.221	0.410	0.823
5	May 2004	0.000	0.000	0.000	0.979	1.079	0.178	0.420	0.826
6	Jun 2004	0.000	0.000	0.000	0.979	1.079	0.160	0.420	0.788
7	Jul 2004	0.000	0.000	0.000	0.979	1.079	0.159	0.428	0.830
8	Aug 2004	0.000	0.000	0.000	0.979	1.079	0.159	0.411	0.860
9	Sep 2004	0.000	0.000	0.000	0.979	1.079	0.215	0.411	0.884
10	Oct 2004	0.000	0.000	0.000	0.979	1.079	0.220	0.415	1.022
11	Nov 2004	0.000	0.000	0.000	0.979	1.079	0.247	0.410	0.881
12	Dec 2004	0.000	0.000	0.000	0.979	1.079	0.189	0.419	1.057
13	Jan 2005	0.000	0.000	0.000	0.959	1.059	0.181	0.410	1.061
14	Feb 2005	0.000	0.000	0.000	0.938	1.038	0.172	0.407	0.949
15	Mar 2005	0.000	0.000	0.000	0.919	1.019	0.166	0.362	0.936
16	Apr 2005	0.000	0.000	0.000	0.897	0.997	0.158	0.341	0.895
17	May 2005	0.000	0.000	0.000	0.897	0.997	0.157	0.345	0.929
18	Jun 2005	0.000	0.000	0.000	0.877	0.977	0.166	0.345	0.891
19	Jul 2005	0.000	0.000	0.000	0.858	0.958	0.290	0.345	0.891
20	Aug 2005	0.000	0.000	0.000	0.834	0.934	0.250	0.342	0.808
21	Sep 2005	0.000	0.000	0.000	0.817	0.917	0.202	0.339	0.863
22	Oct 2005	0.000	0.000	0.000	0.819	0.919	0.246	0.325	0.924
23	Nov 2005	0.000	0.000	0.000	0.796	0.896	0.209	0.317	0.999
24	Dec 2005	0.000	0.000	0.000	0.776	0.876	0.204	0.300	1.028
25	Jan 2006	0.000	0.000	0.000	0.756	0.856	0.167	0.290	1.114
26	Feb 2006	0.000	0.000	0.000	0.748	0.848	0.160	0.274	1.145
27	Mar 2006	0.000	0.000	0.000	0.779	0.879	0.159	0.294	1.120
28	Apr 2006	0.000	0.000	0.000	0.773	0.873	0.155	0.322	1.101
29	May 2006	0.000	0.000	0.000	0.792	0.892	0.150	0.340	1.043
30	Jun 2006	0.000	0.000	0.000	0.613	0.713	0.151	0.345	0.876

Stress period	Date	Stage for stream reach (m)							
		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8
31	Jul 2006	0.000	0.000	0.000	0.535	0.635	0.153	0.346	0.966
32	Aug 2006	0.000	0.000	0.000	0.392	0.492	0.161	0.352	0.948
33	Sep 2006	0.000	0.000	0.000	0.247	0.347	0.167	0.327	0.928
34	Oct 2006	0.000	0.000	0.000	0.135	0.235	0.076	0.117	0.951
35	Nov 2006	0.000	0.000	0.000	0.964	1.064	0.094	0.110	0.972
36	Dec 2006	0.000	0.000	0.000	0.323	0.423	0.017	0.085	0.759
37	Jan 2007	0.000	0.000	0.000	0.927	1.027	0.007	0.089	0.768
38	Feb 2007	0.000	0.000	0.000	0.183	0.283	0.011	0.088	0.694
39	Mar 2007	0.000	0.000	0.000	0.285	0.385	0.013	0.085	0.665
40	Apr 2007	0.000	0.294	0.294	0.342	0.442	0.013	0.082	0.687
41	May 2007	0.000	0.295	0.295	0.293	0.393	0.011	0.107	0.696
42	Jun 2007	0.000	0.328	0.328	0.293	0.393	0.445	0.529	1.302
43	Jul 2007	0.000	0.328	0.328	0.243	0.343	0.299	0.469	0.709
44	Aug 2007	0.000	0.472	0.472	0.167	0.267	0.296	0.447	0.766
45	Sep 2007	0.000	0.343	0.343	0.675	0.775	0.217	0.421	0.544
46	Oct 2007	0.000	0.356	0.356	0.625	0.725	0.174	0.404	0.532
47	Nov 2007	0.000	0.334	0.334	0.452	0.552	0.186	0.422	0.663
48	Dec 2007	0.000	0.327	0.327	0.479	0.579	0.413	0.682	1.102
49	Jan 2008	0.000	0.335	0.335	0.377	0.477	0.311	0.480	0.760
50	Feb 2008	0.000	0.329	0.329	0.485	0.585	0.328	0.478	0.976
51	Mar 2008	0.000	0.336	0.336	0.536	0.636	0.234	0.454	0.746
52	Apr 2008	0.000	0.348	0.348	0.453	0.553	0.228	0.449	0.748
53	May 2008	0.000	0.391	0.391	0.944	1.044	0.214	0.434	0.547
54	Jun 2008	0.000	0.384	0.384	0.927	1.027	0.411	0.558	0.978
55	Jul 2008	0.000	0.398	0.398	0.763	0.863	0.282	0.513	0.672
56	Aug 2008	0.000	0.385	0.385	0.684	0.784	0.248	0.515	0.661
57	Sep 2008	0.000	0.355	0.355	0.639	0.739	0.464	0.575	1.254
58	Oct 2008	0.000	0.328	0.328	0.864	0.964	0.312	0.492	0.756
59	Nov 2008	0.000	0.346	0.346	0.600	0.700	0.259	0.473	0.690
60	Dec 2008	0.000	0.364	0.364	0.437	0.537	0.309	0.505	0.869
61	Jan 2009	0.000	0.362	0.362	0.151	0.251	0.188	0.468	0.615

Stress period	Date	Stage for stream reach (m)							
		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8
62	Feb 2009	0.000	0.322	0.322	0.126	0.226	0.415	0.540	1.052
63	Mar 2009	0.000	0.139	0.139	0.129	0.229	0.371	0.485	0.537
64	Apr 2009	0.000	0.000	0.000	0.126	0.226	0.319	0.475	0.780
65	May 2009	0.000	0.000	0.000	0.000	0.100	0.290	0.474	0.773
66	Jun 2009	0.000	0.000	0.000	0.000	0.100	0.267	0.481	0.938
67	Jul 2009	0.000	0.000	0.000	0.000	0.100	0.256	0.480	0.605
68	Aug 2009	0.000	0.000	0.000	0.000	0.100	0.212	0.490	0.548
69	Sep 2009	0.000	0.000	0.000	0.000	0.100	0.180	0.519	0.599
70	Oct 2009	0.000	0.000	0.000	0.000	0.100	0.170	0.554	0.661
71	Nov 2009	0.000	0.000	0.000	0.000	0.100	0.182	0.556	0.756
72	Dec 2009	0.000	0.000	0.000	0.000	0.100	0.157	0.515	0.824
73	Jan 2010	0.000	0.000	0.000	0.000	0.100	0.241	0.478	0.774
74	Feb 2010	0.000	0.000	0.000	0.000	0.100	0.175	0.459	0.679
75	Mar 2010	0.000	0.000	0.000	0.496	0.596	0.181	0.447	0.770
76	Apr 2010	0.000	0.000	0.000	0.293	0.393	0.274	0.477	1.028
77	May 2010	0.000	0.000	0.000	0.525	0.625	0.175	0.489	1.038
78	Jun 2010	0.000	0.000	0.000	0.744	0.844	0.311	0.494	0.879
79	Jul 2010	0.000	0.000	0.000	0.715	0.815	0.398	0.544	0.851
80	Aug 2010	0.000	0.286	0.286	0.683	0.783	0.399	0.638	1.187
81	Sep 2010	0.000	0.279	0.279	0.589	0.689	0.355	0.575	0.731
82	Oct 2010	0.000	0.286	0.286	0.454	0.554	0.393	0.593	0.715
83	Nov 2010	0.000	0.283	0.283	0.536	0.636	0.476	0.707	1.119
84	Dec 2010	0.000	0.256	0.256	0.669	0.769	0.436	0.609	0.987
85	Jan 2011	0.000	0.292	0.292	0.727	0.827	0.320	0.541	0.590
86	Feb 2011	0.000	0.145	0.145	0.834	0.934	0.222	0.516	0.626
87	Mar 2011	0.000	0.292	0.292	0.434	0.534	0.195	0.513	0.657
88	Apr 2011	0.000	0.363	0.363	0.373	0.473	0.201	0.518	1.137
89	May 2011	0.000	0.448	0.448	0.177	0.277	0.216	0.531	0.623
90	Jun 2011	0.000	0.458	0.458	0.000	0.100	0.405	0.570	1.374
91	Jul 2011	0.000	0.442	0.442	0.000	0.100	0.262	0.532	0.963
92	Aug 2011	0.000	0.455	0.455	0.000	0.100	0.291	0.540	1.145

Stress period	Date	Stage for stream reach (m)							
		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8
93	Sep 2011	0.000	0.484	0.484	0.000	0.100	0.285	0.569	1.104
94	Oct 2011	0.000	0.542	0.542	0.000	0.100	0.306	0.618	0.866
95	Nov 2011	0.000	0.535	0.535	0.198	0.298	0.397	0.682	0.975
96	Dec 2011	0.000	0.488	0.488	0.129	0.229	0.397	0.606	0.921
97	Jan 2012	0.000	0.466	0.466	0.195	0.295	0.253	0.582	0.720
98	Feb 2012	0.000	0.437	0.437	0.167	0.267	0.507	0.666	1.389
99	Mar 2012	0.000	0.417	0.417	0.131	0.231	0.458	0.653	1.164
100	Apr 2012	0.000	0.444	0.444	0.000	0.100	0.302	0.553	0.654
101	May 2012	0.000	0.456	0.456	0.128	0.228	0.293	0.546	0.591
102	Jun 2012	0.000	0.452	0.452	0.122	0.222	0.379	0.530	0.852
103	Jul 2012	0.000	0.351	0.351	0.000	0.100	0.447	0.583	1.106
104	Aug 2012	0.000	0.155	0.155	0.000	0.100	0.309	0.528	0.873
105	Sep 2012	0.000	0.000	0.000	0.179	0.279	0.260	0.520	0.556
106	Oct 2012	0.000	0.000	0.000	0.494	0.594	0.221	0.497	0.553
107	Nov 2012	0.000	0.000	0.000	0.132	0.232	0.209	0.483	0.607
108	Dec 2012	0.000	0.000	0.000	0.396	0.496	0.204	0.478	0.635
109	Jan 2013	0.000	0.450	0.450	0.313	0.413	0.325	0.526	0.887
110	Feb 2013	0.000	0.449	0.449	0.293	0.393	0.640	0.571	0.809
111	Mar 2013	0.000	0.423	0.423	0.184	0.284	0.575	0.678	1.150
112	Apr 2013	0.000	0.268	0.268	0.277	0.377	0.368	0.592	0.514
113	May 2013	0.000	0.629	0.629	0.331	0.431	0.348	0.582	0.654
114	Jun 2013	0.000	0.000	0.000	0.374	0.474	0.375	0.563	0.656
115	Jul 2013	0.000	0.545	0.545	0.713	0.813	0.425	0.555	0.643
116	Aug 2013	0.000	0.441	0.441	0.449	0.549	0.334	0.545	0.552
117	Sep 2013	0.000	0.000	0.000	0.449	0.549	0.309	0.561	0.588
118	Oct 2013	0.000	0.000	0.000	0.449	0.549	0.320	0.595	0.692
119	Nov 2013	0.000	0.000	0.000	0.449	0.549	0.346	0.579	0.862
120	Dec 2013	0.000	0.000	0.000	0.449	0.549	0.274	0.506	0.637

1.2.9 Boundary condition - recharge

The SURFACT recharge package (RCH) was used to simulate the recharge boundary condition. The rate of recharge was calculated using two SILO daily rainfall datasets, processed to provide monthly transient data:

- Aberdeen Main Road (station no: 61000) – measured daily rainfall; and
- Aberdeen Rossgole (interpolated daily rainfall – datadrill location latitude: -32.10°, longitude: 150.75°, elevation: 524 m)

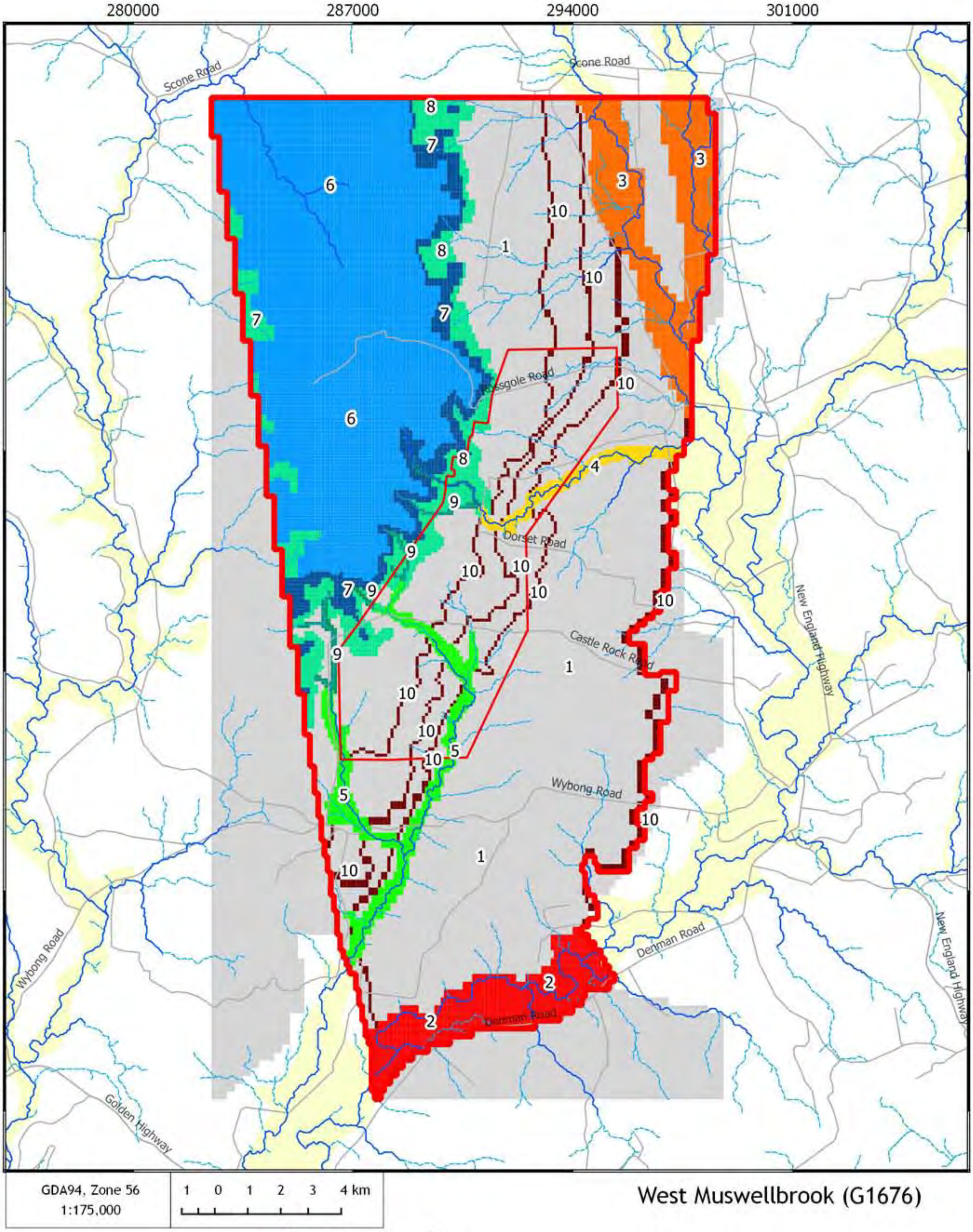
Each of the rainfall datasets were used as an input for simple soil moisture/recharge model (see Section 3.5.1 of this document) and three transient base recharge datasets were calculated:

- Base RCH 1 – for top of the Rossgole plateau (basalts, sandstones);
- Base RCH 2 – for slope colluvium; and
- Base RCH 3 – for downslope areas (topsoil, regolith, alluvium zones).

Additionally, ten recharge zones (Figure C 6) were used to distribute the recharge spatially. The model applied recharge over the calibration period as a fixed proportion (recharge factor for individual recharge zone) of one of the three the base recharge datasets, as described above. See Table C 5 for list of recharge zones and associated base recharge datasets and recharge factors. See Table C 6 for the actual transient base recharge values.

Table C 5 Recharge zones, associated recharge factors and corresponding base RCH dataset

Recharge zone	Recharge factor	Applied to base RCH dataset
zone 01 - topsoil/regolith	0.050	3
zone 02 - alluvium - Hunter River	1.000	3
zone 03 - alluvium - Dartbrook, Middle Brook, Kingdon Ponds	1.000	3
zone 04 - alluvium - Sandy Crk North	1.000	3
zone 05 - alluvium - Sandy Crk South	1.000	3
zone 06 - basalts, sandstone - top of the plateau	1.000	1
zone 07 - cliff face	0.000	1
zone 08 - slope colluvium - general	0.800	3
zone 09 - slope colluvium to alluvium feed-in	1.000	2
zone 10 - coal seam subcrop/outcrop	0.100	3



West Muswellbrook (G1676)

Recharge

AGE GROUNDWATER & ENVIRONMENTAL

DATE 8/10/2014

FIGURE No: **C-6**

Table C 6 Base transient recharge rates

Date	SP	Base RCH1 (mm/day)	Base RCH2 (mm/day)	Base RCH3 (mm/day)	Date	SP	Base RCH1 (mm/day)	Base RCH2 (mm/day)	Base RCH3 (mm/day)
Jan 2004	*1*	0.000000	0.000000	0.000000	*Jan 2009*	*61*	0.000000	0.000000	0.000000
Feb 2004	*2*	0.000000	0.000000	0.000000	*Feb 2009*	*62*	0.561765	1.796345	1.375168
Mar 2004	*3*	0.000000	0.000000	0.000000	*Mar 2009*	*63*	0.000000	0.000000	0.000000
Apr 2004	*4*	0.000000	0.000000	0.000000	*Apr 2009*	*64*	0.000000	0.000000	0.000000
May 2004	*5*	0.000000	0.000000	0.000000	*May 2009*	*65*	0.000000	0.000000	0.000000
Jun 2004	*6*	0.000000	0.000000	0.000000	*Jun 2009*	*66*	0.000000	0.000000	0.000000
Jul 2004	*7*	0.000000	0.000000	0.000000	*Jul 2009*	*67*	0.000000	0.000000	0.000000
Aug 2004	*8*	0.000000	0.000000	0.000000	*Aug 2009*	*68*	0.000000	0.000000	0.000000
Sep 2004	*9*	0.000000	0.000000	0.000000	*Sep 2009*	*69*	0.000000	0.000000	0.000000
Oct 2004	*10*	0.000000	0.000000	0.000000	*Oct 2009*	*70*	0.000000	0.000000	0.000000
Nov 2004	*11*	0.000000	0.000000	0.000000	*Nov 2009*	*71*	0.000000	0.000000	0.000000
Dec 2004	*12*	0.000000	0.193464	0.000000	*Dec 2009*	*72*	0.000000	0.123444	0.000000
Jan 2005	*13*	0.000000	0.000000	0.000000	*Jan 2010*	*73*	0.000000	0.987049	0.343783
Feb 2005	*14*	0.000000	0.000000	0.000000	*Feb 2010*	*74*	0.000000	0.000000	0.000000
Mar 2005	*15*	0.000000	0.000000	0.000000	*Mar 2010*	*75*	0.000000	0.000000	0.000000
Apr 2005	*16*	0.000000	0.000000	0.000000	*Apr 2010*	*76*	0.000000	0.219219	0.000000
May 2005	*17*	0.000000	0.000000	0.000000	*May 2010*	*77*	0.000000	0.000000	0.000000
Jun 2005	*18*	0.000000	0.000000	0.000000	*Jun 2010*	*78*	0.000000	0.000000	0.000000
Jul 2005	*19*	0.000000	0.499721	0.000000	*Jul 2010*	*79*	0.000000	0.070126	0.000000
Aug 2005	*20*	0.000000	0.000000	0.000000	*Aug 2010*	*80*	0.000000	0.137881	0.000000
Sep 2005	*21*	0.000000	0.000000	0.000000	*Sep 2010*	*81*	0.000000	0.000000	0.000000
Oct 2005	*22*	0.000000	0.000000	0.000000	*Oct 2010*	*82*	0.000000	0.000000	0.000000
Nov 2005	*23*	0.000000	0.000000	0.000000	*Nov 2010*	*83*	0.000000	0.000000	0.000000
Dec 2005	*24*	0.000000	0.000000	0.000000	*Dec 2010*	*84*	0.000000	0.202934	0.000000
Jan 2006	*25*	0.000000	0.000000	0.000000	*Jan 2011*	*85*	0.000000	0.000000	0.000000
Feb 2006	*26*	0.000000	0.000000	0.000000	*Feb 2011*	*86*	0.000000	0.000000	0.000000
Mar 2006	*27*	0.000000	0.000000	0.000000	*Mar 2011*	*87*	0.000000	0.000000	0.000000
Apr 2006	*28*	0.000000	0.000000	0.000000	*Apr 2011*	*88*	0.000000	0.000000	0.000000
May 2006	*29*	0.000000	0.000000	0.000000	*May 2011*	*89*	0.000000	0.000000	0.000000
Jun 2006	*30*	0.000000	0.000000	0.000000	*Jun 2011*	*90*	0.695452	2.002900	1.938632
Jul 2006	*31*	0.000000	0.000000	0.000000	*Jul 2011*	*91*	0.000000	0.000000	0.000000
Aug 2006	*32*	0.000000	0.000000	0.000000	*Aug 2011*	*92*	0.000000	0.000000	0.000000

Date	SP	Base RCH1 (mm/day)	Base RCH2 (mm/day)	Base RCH3 (mm/day)	Date	SP	Base RCH1 (mm/day)	Base RCH2 (mm/day)	Base RCH3 (mm/day)
Sep 2006	*33*	0.000000	0.000000	0.000000	*Sep 2011*	*93*	0.000000	0.000000	0.000000
Oct 2006	*34*	0.000000	0.000000	0.000000	*Oct 2011*	*94*	0.000000	0.000000	0.000000
Nov 2006	*35*	0.000000	0.000000	0.000000	*Nov 2011*	*95*	0.204872	1.369663	0.724536
Dec 2006	*36*	0.000000	0.000000	0.000000	*Dec 2011*	*96*	0.000000	0.000000	0.000000
Jan 2007	*37*	0.000000	0.000000	0.000000	*Jan 2012*	*97*	0.000000	0.000000	0.000000
Feb 2007	*38*	0.000000	0.000000	0.000000	*Feb 2012*	*98*	0.000000	0.377910	0.000000
Mar 2007	*39*	0.000000	0.000000	0.000000	*Mar 2012*	*99*	0.000000	0.000000	0.000000
Apr 2007	*40*	0.000000	0.000000	0.000000	*Apr 2012*	*100*	0.000000	0.000000	0.000000
May 2007	*41*	0.000000	0.000000	0.000000	*May 2012*	*101*	0.000000	0.000000	0.000000
Jun 2007	*42*	2.665852	3.485639	2.803082	*Jun 2012*	*102*	0.000000	0.000000	0.000000
Jul 2007	*43*	0.000000	0.000000	0.000000	*Jul 2012*	*103*	0.000000	0.442747	0.000000
Aug 2007	*44*	0.000000	0.000000	0.000000	*Aug 2012*	*104*	0.000000	0.000000	0.000000
Sep 2007	*45*	0.000000	0.000000	0.000000	*Sep 2012*	*105*	0.000000	0.000000	0.000000
Oct 2007	*46*	0.000000	0.000000	0.000000	*Oct 2012*	*106*	0.000000	0.000000	0.000000
Nov 2007	*47*	0.000000	0.000000	0.000000	*Nov 2012*	*107*	0.000000	0.000000	0.000000
Dec 2007	*48*	0.000000	1.193605	0.000000	*Dec 2012*	*108*	0.000000	0.000000	0.000000
Jan 2008	*49*	0.000000	0.000000	0.000000	*Jan 2013*	*109*	0.000000	1.029487	0.702650
Feb 2008	*50*	0.000000	0.000000	0.459404	*Feb 2013*	*110*	0.366924	0.424340	0.342232
Mar 2008	*51*	0.000000	0.000000	0.000000	*Mar 2013*	*111*	0.844275	1.172817	0.456392
Apr 2008	*52*	0.000000	0.000000	0.000000	*Apr 2013*	*112*	0.000000	0.000000	0.000000
May 2008	*53*	0.000000	0.000000	0.000000	*May 2013*	*113*	0.000000	0.000000	0.000000
Jun 2008	*54*	0.000000	1.573260	0.000000	*Jun 2013*	*114*	0.000000	0.000000	0.000000
Jul 2008	*55*	0.075179	0.090007	0.000000	*Jul 2013*	*115*	0.000000	0.000000	0.000000
Aug 2008	*56*	0.000000	0.000000	0.000000	*Aug 2013*	*116*	0.000000	0.000000	0.000000
Sep 2008	*57*	0.499164	0.499164	0.000000	*Sep 2013*	*117*	0.000000	0.000000	0.000000
Oct 2008	*58*	0.000000	0.000000	0.000000	*Oct 2013*	*118*	0.000000	0.000000	0.000000
Nov 2008	*59*	0.000000	0.000000	0.000000	*Nov 2013*	*119*	0.492079	1.530593	1.790232
Dec 2008	*60*	0.000000	0.000000	0.000000	*Dec 2013*	*120*	0.000000	0.000000	0.000000

1.2.10 Boundary condition - evapotranspiration

Transient EVT rate was adopted directly from SILO interpolated dataset. A FAO56 daily EVT rate was processed to produce monthly EVT rate for Aberdeen Rossgole datadrill location (lat: -32.10°, lon: 150.75°, elev: 524 m; see Table C 8 for actual monthly EVT rates).

Similarly to the spatial distribution of recharge, zones were used to apply different EVT rates to different areas of the model. The EVT zones were defined as follows:

- Zone 01 – plateau – basalts and sandstones, identical to recharge Zone 06;
- Zone 02 – exposed cliff face – identical to recharge Zone 07; and
- Zone 03 – lowland area – identical to combined recharge Zones 01-05 and 08-10.

Because SILO data is available for both main zones, a comparison between actual FAO56 EVT rates at Zone 01 and Zone 03 was undertaken and a relation between the 'base' EVT rate (Zone 01 – Aberdeen Rossgole) and the EVT rate in Zone 03 was established. The EVT rate for Zone 03 could be then calculated as a percentage (factor) of the base EVT rate.

See Figure C 6 for the recharge zonation overview and Table C 7 for the EVT factors applied to individual EVT zones.

Table C 7 EVT factors for individual zones

Zone	EVT factor
Zone 01 – Rossgole plateau - basalts, sandstones	1.000
Zone 02 - steep cliffs	1.000
Zone 03 - lowland area	1.070

Table C 8 Base transient evapotranspiration rate

Date	SP	EVT rate (mm/mth)	Date	SP	EVT rate (mm/mth)	Date	SP	EVT rate (mm/mth)
Jan 2004	1	169.1	*May 2007*	41	64.4	*Sep 2010*	81	83.0
Feb 2004	2	155.9	*Jun 2007*	42	31.4	*Oct 2010*	82	98.8
Mar 2004	3	105.5	*Jul 2007*	43	44.0	*Nov 2010*	83	115.4
Apr 2004	4	88.7	*Aug 2007*	44	65.8	*Dec 2010*	84	128.1
May 2004	5	65.4	*Sep 2007*	45	93.3	*Jan 2011*	85	157.0
Jun 2004	6	45.3	*Oct 2007*	46	143.5	*Feb 2011*	86	136.6
Jul 2004	7	46.2	*Nov 2007*	47	124.0	*Mar 2011*	87	107.9
Aug 2004	8	67.5	*Dec 2007*	48	130.6	*Apr 2011*	88	77.9
Sep 2004	9	91.3	*Jan 2008*	49	134.5	*May 2011*	89	54.2
Oct 2004	10	124.9	*Feb 2008*	50	101.7	*Jun 2011*	90	37.5
Nov 2004	11	147.9	*Mar 2008*	51	119.4	*Jul 2011*	91	44.2
Dec 2004	12	160.4	*Apr 2008*	52	68.2	*Aug 2011*	92	60.8
Jan 2005	13	164.3	*May 2008*	53	60.2	*Sep 2011*	93	95.7
Feb 2005	14	145.5	*Jun 2008*	54	35.0	*Oct 2011*	94	100.2
Mar 2005	15	117.5	*Jul 2008*	55	44.4	*Nov 2011*	95	132.0
Apr 2005	16	94.9	*Aug 2008*	56	57.9	*Dec 2011*	96	122.4
May 2005	17	60.8	*Sep 2008*	57	88.5	*Jan 2012*	97	138.2
Jun 2005	18	41.9	*Oct 2008*	58	120.2	*Feb 2012*	98	110.5
Jul 2005	19	48.1	*Nov 2008*	59	117.7	*Mar 2012*	99	101.3
Aug 2005	20	69.5	*Dec 2008*	60	149.8	*Apr 2012*	100	76.4
Sep 2005	21	85.9	*Jan 2009*	61	172.8	*May 2012*	101	61.7
Oct 2005	22	114.6	*Feb 2009*	62	128.2	*Jun 2012*	102	35.1
Nov 2005	23	129.9	*Mar 2009*	63	119.6	*Jul 2012*	103	41.1
Dec 2005	24	198.4	*Apr 2009*	64	68.8	*Aug 2012*	104	74.7
Jan 2006	25	159.7	*May 2009*	65	51.0	*Sep 2012*	105	107.1
Feb 2006	26	145.0	*Jun 2009*	66	39.1	*Oct 2012*	106	145.8
Mar 2006	27	122.0	*Jul 2009*	67	45.1	*Nov 2012*	107	150.7
Apr 2006	28	93.0	*Aug 2009*	68	82.9	*Dec 2012*	108	168.4
May 2006	29	61.4	*Sep 2009*	69	103.7	*Jan 2013*	109	174.3
Jun 2006	30	41.4	*Oct 2009*	70	122.4	*Feb 2013*	110	118.8

Date	SP	EVT rate (mm/mth)	Date	SP	EVT rate (mm/mth)	Date	SP	EVT rate (mm/mth)
Jul 2006	31	44.5	*Nov 2009*	71	168.1	*Mar 2013*	111	109.5
Aug 2006	32	71.7	*Dec 2009*	72	164.7	*Apr 2013*	112	84.1
Sep 2006	33	102.9	*Jan 2010*	73	166.8	*May 2013*	113	60.1
Oct 2006	34	141.3	*Feb 2010*	74	120.7	*Jun 2013*	114	32.3
Nov 2006	35	160.2	*Mar 2010*	75	115.1	*Jul 2013*	115	44.3
Dec 2006	36	157.8	*Apr 2010*	76	80.2	*Aug 2013*	116	77.3
Jan 2007	37	184.6	*May 2010*	77	55.1	*Sep 2013*	117	115.2
Feb 2007	38	138.5	*Jun 2010*	78	36.9	*Oct 2013*	118	158.0
Mar 2007	39	116.2	*Jul 2010*	79	36.7	*Nov 2013*	119	142.8
Apr 2007	40	84.8	*Aug 2010*	80	59.0	*Dec 2013*	120	175.5

1.2.11 Starting heads

Initially, a steady state model was run before the beginning of the lead-in calibration period, however the resulting heads did not conform to our conceptual understanding of the interconnectivity of the groundwater flow system, namely the disconnect between the Hawkesbury Sandstone and underlying Permian strata. Starting heads for the calibration period were combined from the steady state model final heads as follows:

- Heads for layer 1 and 2 were adopted without change.
- Heads for layer 3 to 11 were adopted from the steady state model outputs for the area eastwards from the outcrop of individual seams/layers; an elevation of the layer 5 roof was used for starting head value for all the layers westwards of the outcrop line of individual model layer.

In order to accommodate the change of starting heads due to change of hydraulic parameters during the calibration process, the heads at the end of individual calibration run were used as starting heads for the next iteration in the calibration process.

1.3 Model calibration

Calibration of a groundwater flow model is a process that demonstrates that a model is capable of replicating observed field data. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes that match field measured values within an acceptable range of error.

1.3.1 Calibration method

The model calibration method was primarily driven by adjusting selected parameters within realistic ranges to match transient groundwater levels. The calibration strategy initially involved manual testing and adjusting parameters to obtain an initial fit against the observation data. The final calibration was completed using PEST (independent Parameter Estimation tool; Doherty, 2006) to refine the manual calibration.

The calibration period lasted from January 2004 to December 2013 (10 years, monthly stress periods), a time interval for which the transient observations of groundwater table (29 bores), stream flow (stream stage), evapotranspiration and rainfall are available. The calibration run does simulate the behaviour of the hydrogeologic systems under historical (observed) climatic conditions and represents the antecedent state of the system prior the commencement of mining activities.

There were two main objectives of the calibration process: (1) create a set of starting heads that would be as close to physical reality as possible and (2) replicate the trends (recharge/discharge) observed in the transient groundwater level datasets. The automatic calibration process was partially guided by changing weights of individual observations so that the 'starting head' observation dataset had initially higher weights than the 'transient trends' observation dataset. Weights were also used to exclude some (erroneous or unreliable) of the observations from the calibration.

The only parameters adjusted during the calibration process were those associated with hydraulic properties (horizontal and vertical hydraulic conductivity, specific yield, specific storage). Parameters associated with recharge, EVT and vertical conductivity of the stream beds were not being calibrated. Due to the lack of actual field measurements specific for individual hydrostratigraphic units, some of the parameters were tied to another parameter; this process prevented the tied parameters to move independently and aided with the calibration process. The following parameter groups were tied together: all interburden units, all coal seams, all coal seam subcrop zones. Slope colluvium properties were tied to Sandy Creek North, Sandy Creek South and Spring Creek alluvium properties. All parameters were only adjusted within realistic parameter bounds, and were not allowed to move to extremes just to meet statistical objectives.

1.3.2 Calibration targets

Groundwater level information for transient calibration was collated from multiple sources. Mainly, publicly available records (NSW Office of Water – Pineena database) and records provided by client (groundwater data from the exploration drilling program) were used. Where the target aquifer information was not available, it was estimated based on additional background information (bore construction, bore depth, bore location). Records with water level data but with no other information were ultimately removed from calibration dataset.

In total, measurements from 93 private bores, exploration bores and wells were used to compile the 'starting head' observation dataset. Out of these, 29 bores had at least two field measurements and could be used to compile the 'transient trends' observation dataset. All observation bores used during the calibration process are shown on the map (Figure C-7) as well as presented in Table C 9.

Table C 9 Observation bores used during the calibration process

Bore ID	Easting	Northing	Dataset*)	Bore ID	Easting	Northing	Dataset*)
BRO3	296022.07	6439457.32	SH, TT	**CRRDH6**	287992.15	6427104.05	SH
CAD2	294131.81	6439790.20	SH, TT	**CRRDH67**	290912.40	6433195.40	SH
COR3	293689.07	6439180.32	SH, TT	**CRRDH77**	290920.37	6433498.98	SH
CRRDH105	290674.30	6432864.43	SH, TT	**CRRDH9**	287678.76	6426077.69	SH
CRRDH106	290009.14	6433457.19	SH, TT	**CRRDH90**	290746.94	6432984.87	SH
CRRDH107	290870.20	6432412.80	SH, TT	**GW012975**	297328.12	6440165.15	SH
CRRDH52	291701.57	6434009.73	SH, TT	**GW032886**	293025.75	6450646.97	SH
DAY1	292850.35	6441989.50	SH, TT	**GW032890**	289728.68	6433755.22	SH
GDAY1	290818.30	6438405.69	SH, TT	**GW037397**	294913.86	6448096.98	SH
GW024561	290209.06	6433726.36	SH, TT	**GW040500**	297418.55	6442200.53	SH
GW027311	292056.03	6422787.41	SH, TT	**GW040509**	297473.03	6440784.28	SH
GW032887	293602.07	6449839.06	SH, TT	**GW040566**	297535.66	6441586.64	SH
GW067260	297559.55	6443887.60	SH, TT	**GW044912**	293000.48	6428769.28	SH
GW080433	296333.03	6445791.20	SH, TT	**GW053572**	291175.82	6438530.47	SH
PIT1	291243.59	6437765.25	SH, TT	**GW080074**	296435.04	6430363.39	SH
PIT2	291337.60	6437735.42	SH, TT	**GW080907**	287273.03	6425261.40	SH
RHDDH20	293115.37	6439916.10	SH, TT	**GW080908**	297568.08	6440763.31	SH
RHDDH27	291291.04	6434348.03	SH, TT	**GW080909**	287363.03	6425117.40	SH
RHDDH4	291782.68	6436624.36	SH, TT	**RHDDH105**	293030.48	6437111.57	SH
RHRDH211	292437.20	6437962.70	SH, TT	**RHDDH116**	292587.58	6439229.02	SH
RHRDH212	293426.10	6438850.10	SH, TT	**RHDDH216**	292704.03	6435859.82	SH
RHRDH213	291214.52	6438080.75	SH, TT	**RHDDH217**	292690.30	6436869.88	SH
SPAR2	289994.50	6433497.99	SH, TT	**RHDDH22**	291695.37	6434266.24	SH
SPAR4	290210.33	6433732.92	SH, TT	**RHDDH23**	292831.56	6437261.06	SH
SPAR5	289875.92	6433546.68	SH, TT	**RHDDH28a**	291346.31	6433733.46	SH
WEK2	288753.59	6434415.55	SH, TT	**RHDDH48**	292677.46	6435440.76	SH
WM3	294773.07	6439840.32	SH, TT	**RHDDH49**	292981.47	6437565.30	SH
WYL1	291169.47	6438494.78	SH, TT	**RHRDH114**	293280.65	6439687.63	SH
YOU1	288149.59	6434786.27	SH, TT	**RHRDH115**	292792.31	6439123.99	SH
CRDDH14	286849.20	6424724.40	SH	**RHRDH117**	293195.10	6439773.34	SH
CRDDH15	286962.15	6425364.98	SH	**RHRDH121**	293244.84	6440010.05	SH
CRDDH16	286807.07	6425603.09	SH	**RHRDH155**	292285.00	6434895.59	SH
CRDDH24	288880.91	6429021.45	SH	**RHRDH159**	293524.79	6440517.62	SH

Bore ID	Easting	Northing	Dataset*)	Bore ID	Easting	Northing	Dataset*)
CRDDH25R	289913.95	6431714.88	SH	**RHRDH162**	293643.96	6440688.71	SH
CRDDH3	287353.71	6423209.92	SH	**RHRDH163**	293026.41	6439612.93	SH
CRDDH46	287195.77	6422650.89	SH	**RHRDH164**	292975.12	6439625.25	SH
CRLDH108R	289754.20	6434186.50	SH	**RHRDH165**	292771.74	6439430.57	SH
CRLDH97	291130.90	6433832.80	SH	**RHRDH166**	292768.11	6439173.68	SH
CRRDH102	290637.00	6432788.31	SH	**RHRDH167**	292643.22	6439144.13	SH
CRRDH109	290352.46	6432094.78	SH	**RHRDH169**	292590.03	6438795.42	SH
CRRDH12	288449.70	6428009.07	SH	**RHRDH202**	292666.69	6435561.68	SH
CRRDH19	288809.54	6428523.64	SH	**RHRDH31**	291942.56	6434532.65	SH
CRRDH22	288971.20	6429468.90	SH	**RHRDH42**	292797.73	6439483.15	SH
CRRDH28	290461.85	6432650.04	SH	**RHRDH78**	292236.70	6438025.90	SH
CRRDH38	289580.14	6430796.92	SH	**RHRDH79**	292516.70	6438469.50	SH
CRRDH44	289232.26	6430068.48	SH	**RHRDH80**	292456.70	6438493.36	SH
CRRDH59	291277.13	6433610.38	SH				

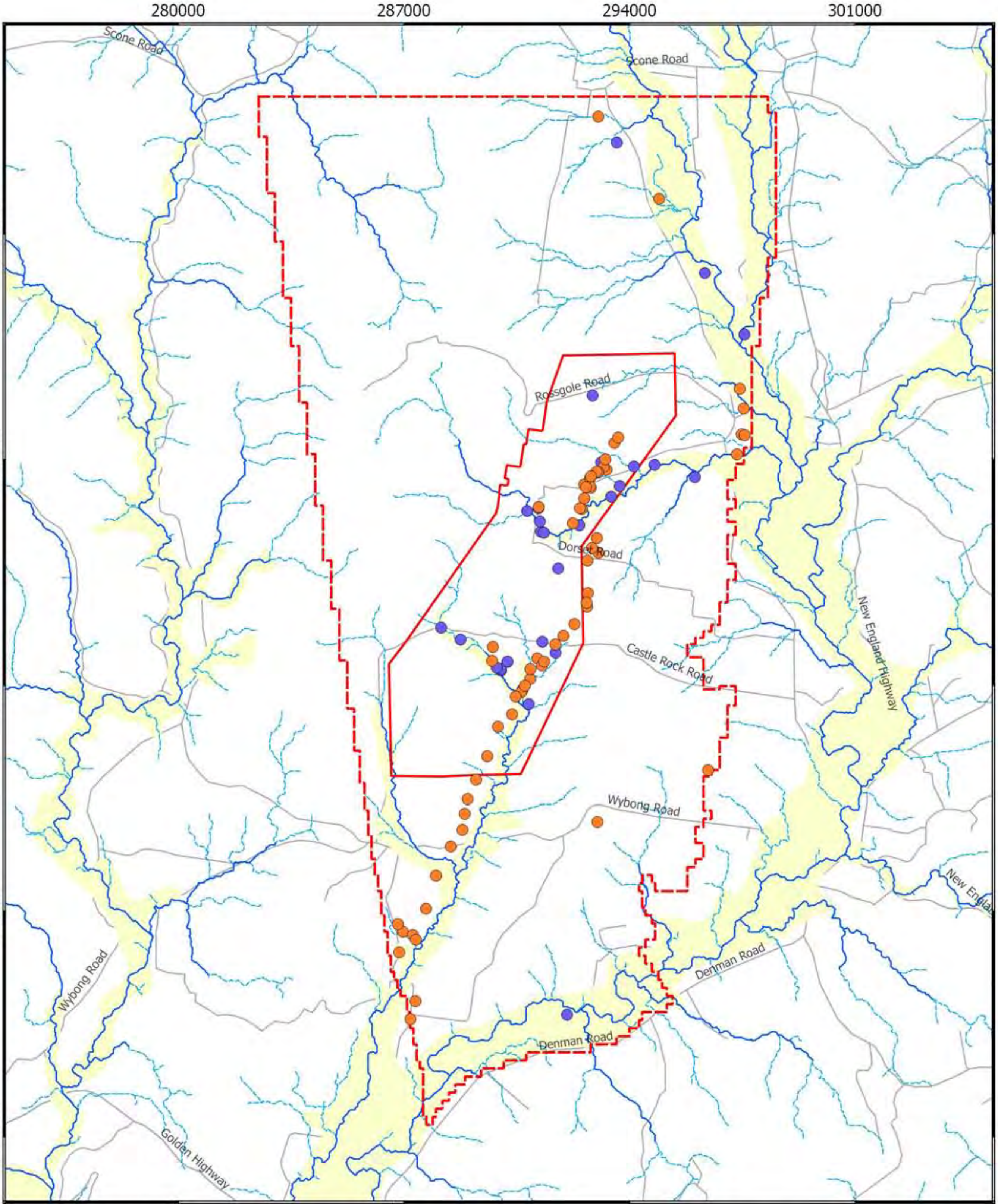
Note: **) Dataset type: SH – starting head, TT – transient trend*

1.3.3 Data exclusions

Two types of groundwater table data were used: manual measurements (bores ‘dipped’ by electronic meter) and automatic measurements (data recorded by automatic loggers). Given the model stress period length (one month for both calibration and predictive part of the model run), the use of the high density (15 minutes intervals) data for the transient calibration was not practical and did not contribute to the quality of the calibration. The dataset was thus resampled from the 15 minutes intervals to monthly intervals in order to speed up the processing of the modelled results.

During the calibration process, several bores with detrimental influence on the calibration process were identified. These observations were either not relevant to the performance of model in critical areas or identified as faulty and/or unreliable. Such observations were removed from the calibration entirely or weighted out by setting their contribution towards the objective function to zero.

Bores removed entirely out of the calibration in spite of the existence of groundwater observation data and target aquifer unit were JLON1 and JLON2. These bores were removed because the model conceptualization did not allow a match of measured and modelled heads to acceptable degree - the aquifer in which these bores are located was not modelled as a separate hydrostratigraphic unit.



GDA94, Zone 56
1:175,000

1 0 1 2 3 4 km

West Muswellbrook (G1676)

Observation bores

- Project Assessment Area
- Active model grid outline (Project Area)
- Streams - main
- Streams - ephemeral
- Alluvium unconsolidated (Qa)
- Road major
- Road

- SH - startring heads dataset
- SH, TT - both starting heads and transient datasets

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FIGURE No: C-7

Bores removed partially from calibration by weighting were COR3 and DAY1. Some of the observations for these bores were preserved, the observations noted as unreliable by data collectors were weighted out. In spite of zero weighting, these observations were included in the final statistical overview.

1.3.4 Calibration run - results

The groundwater flow model was calibrated as an inverse problem where model parameters (hydraulic properties of aquifer) were adjusted in order to achieve the best possible fit between measured and calculated observations. PEST and BeoPEST (Doherty, 2006; Doherty, 2010; Doherty, 2011) were used to aid the calibration process.

Adjustable parameters for all model layers within the calibration process were:

- horizontal hydraulic conductivity (HC);
- vertical hydraulic conductivity (VHC) converted to vertical conductance term (VCONT); and
- specific yield and specific storage.

The first two model layers were divided into multiple zones representing regolith and weathered regolith zone, alluviums of individual streams and rivers, slope colluvium, subcrops of coal seams. All other model layers comprised of a single zone. The hydraulic properties of individual zones of layers 1, 2 (weathered regolith, alluvium, coal seam subcrops), 3 (Hawkesbury Sandstone), 4, 6, 8, 10 (interburden) were assigned uniform values. The horizontal hydraulic conductivity of the coal seams were set to decrease with depth according to Equation 1.

$$HC = HC_0 \times e^{(-0.022*depth)} \qquad \text{(Eq. 1)}$$

Where: *HC* is horizontal hydraulic conductivity at specific depth

HC_0 is horizontal hydraulic conductivity at depth of 0 m (surface)

depth is depth of the floor of the coal seam

The Equation 1 was derived from the data collected during the previous field campaigns. The assumed decrease of hydraulic conductivity of all the modelled coal seams is shown in Figure C 8.

The vertical hydraulic conductivity (VHC) is derived from the horizontal hydraulic conductivity using the value of VHC factor according to Equation 2. Because of this relationship between HC and VHC, the value of VHC varies with depth together with value of HC.

$$VHC = HC \times VHC_{factor} \qquad \text{(Eq. 2)}$$

Heads at the end of the calibration run and beginning of the prediction run for model layer 1 (unconfined aquifer – alluvium and weathered regolith) and model layer 9 (Blakefield – deepest targeted coal seam) are presented in Figure C 9. Estimated values of base hydraulic parameters are presented in Table C 10.

Although the site-specific values for alluvial areas are not known (see main report, Section 3.3.1), the calibrated values of hydraulic conductivities (~ 0.5 to 5.0 m/day) and specific yield (~ 3.0 to 7.5%) for alluvium and colluvium are within bounds expected for unconsolidated unconfined aquifer. Calibrated values of hydraulic properties for coal seams and interburden correspond to the permeability data collected during previous work in and around the Study Area (see Figure C 8).

Table C 10 Calibrated hydraulic properties

Layer	Zone	Description	HC, HC_0 (*) (m/day)	VHC factor (-)	SS (-)	SY (-)
1	1	topsoil/regolith	2.0554×10^{-01}	8.9198×10^{-01}	1.0000×10^{-05}	1.0013×10^{-03}
	2	alluvium - Hunter River	$5.0859\times10^{+00}$	1.8162×10^{-03}	1.2498×10^{-04}	3.1451×10^{-02}
	3	alluvium - Middle Brook / Kingdon Ponds	$5.1129\times10^{+00}$	5.9466×10^{-03}	1.0000×10^{-04}	7.5416×10^{-02}
	4	alluvium - Sandy Crk North	$1.0007\times10^{+00}$	6.8974×10^{-03}	3.0485×10^{-04}	7.5785×10^{-02}
	5	alluvium - Sandy Crk South	$1.0007\times10^{+00}$	6.8974×10^{-03}	3.0485×10^{-04}	7.4561×10^{-02}
	6	basalts, sandstone - top of the plateau	1.0000×10^{-01}	9.0000×10^{-01}	1.0000×10^{-04}	1.0000×10^{-03}
	7	cliff face	1.0000×10^{-01}	5.0000×10^{-03}	5.0000×10^{-06}	5.0000×10^{-03}
	8	slope colluvium	8.6769×10^{-01}	6.2125×10^{-03}	3.0485×10^{-04}	3.7893×10^{-02}
	9	slope colluvium - Sandy Crk North feed-in	8.6789×10^{-01}	5.8473×10^{-03}	3.0485×10^{-04}	3.7893×10^{-02}
	10-12	slope colluvium - Coal Crk, Sandy Crk South, Spring Crk feed-in zone	8.6769×10^{-01}	6.2125×10^{-03}	3.0485×10^{-04}	3.7281×10^{-02}
	13-16	coal seam subcrops	$3.0656\times10^{+00}$	6.0410×10^{-01}	1.0000×10^{-03}	7.2057×10^{-03}
2	1	layer 02 - weathered regolith	8.6810×10^{-02}	4.9554×10^{-02}	5.0001×10^{-05}	5.0065×10^{-03}
	2	coal seam subcrops	$3.0656\times10^{+00}$	6.0410×10^{-01}	1.0000×10^{-03}	7.2057×10^{-03}
3	1	Hawkesbury Sandstone (Narrabeen Grp)	1.0000×10^{-01}	5.0000×10^{-03}	5.0000×10^{-06}	5.0000×10^{-03}
4	1	interburden	3.3884×10^{-04}	9.9873×10^{-03}	5.0890×10^{-06}	2.1742×10^{-03}
5	1	coal seam - combined Abby Green	*5.7079×10^{-02}*	1.0013×10^{-03}	1.7640×10^{-06}	2.2421×10^{-03}
6	1	interburden	4.2578×10^{-04}	9.9874×10^{-03}	1.0010×10^{-06}	2.0628×10^{-03}
7	1	coal seam - combined Whybrow, Redbank, Wambo	*5.7079×10^{-02}*	1.0013×10^{-03}	1.7640×10^{-06}	2.2421×10^{-03}
8	1	interburden	4.2578×10^{-04}	9.9874×10^{-03}	1.0010×10^{-06}	2.0628×10^{-03}
9	1	coal seam - combined Whynot, Blakefield (target seam)	*5.7079×10^{-02}*	1.0013×10^{-03}	1.7640×10^{-06}	2.2421×10^{-03}
10	1	interburden	4.2578×10^{-04}	9.9874×10^{-03}	1.0010×10^{-06}	2.0628×10^{-03}
11	1	coal seam - combined Woodlands Hill, Arrowfield, Bowfield, Warkworth	*5.7079×10^{-02}*	1.0013×10^{-03}	1.7640×10^{-06}	2.2421×10^{-03}

Note: *(*)(*) HC represents actual horizontal hydraulic conductivity value for model layer – used for L1-L4, and L6, L8, L10. HC_0 represents horizontal hydraulic conductivity at depth 0 m (intercept value, in italics) and is applied to the coal seams layers (L5, L7, L9, L11). Actual hydraulic conductivity of the coal seams is decreasing with depth (see Section 3.3.4)*

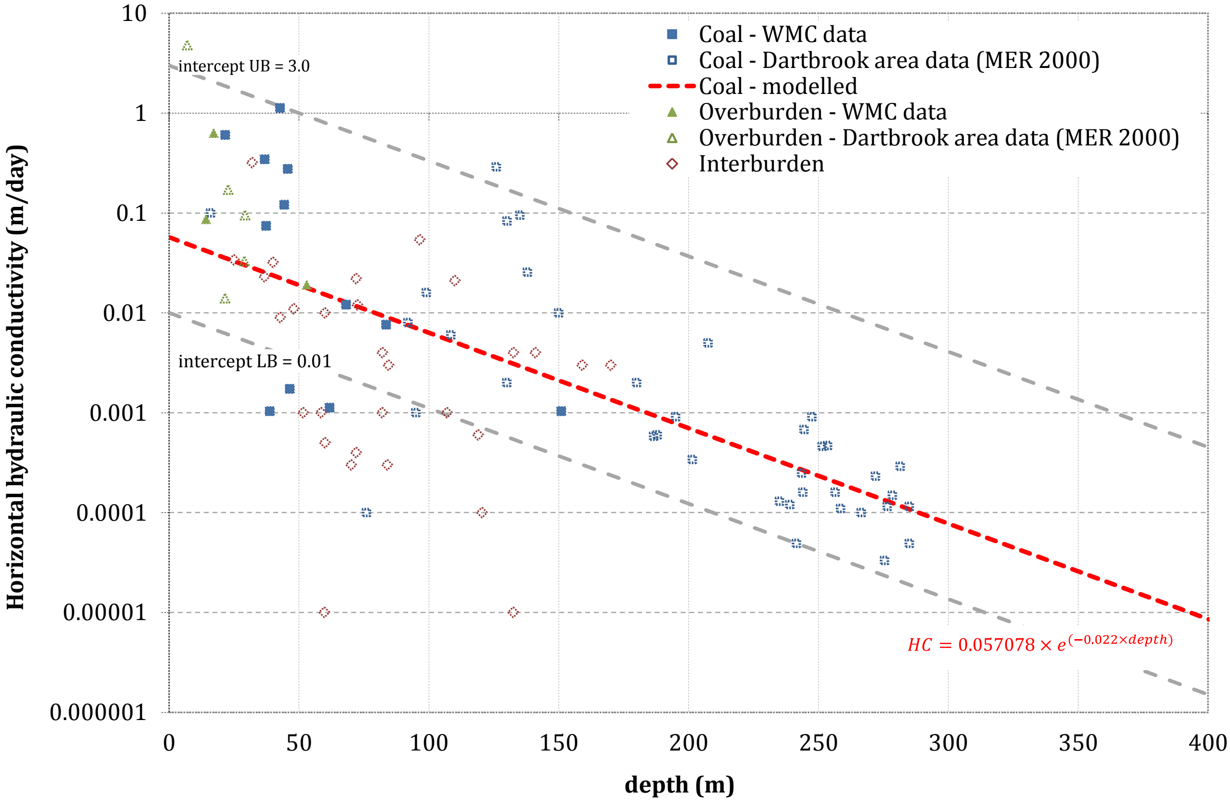
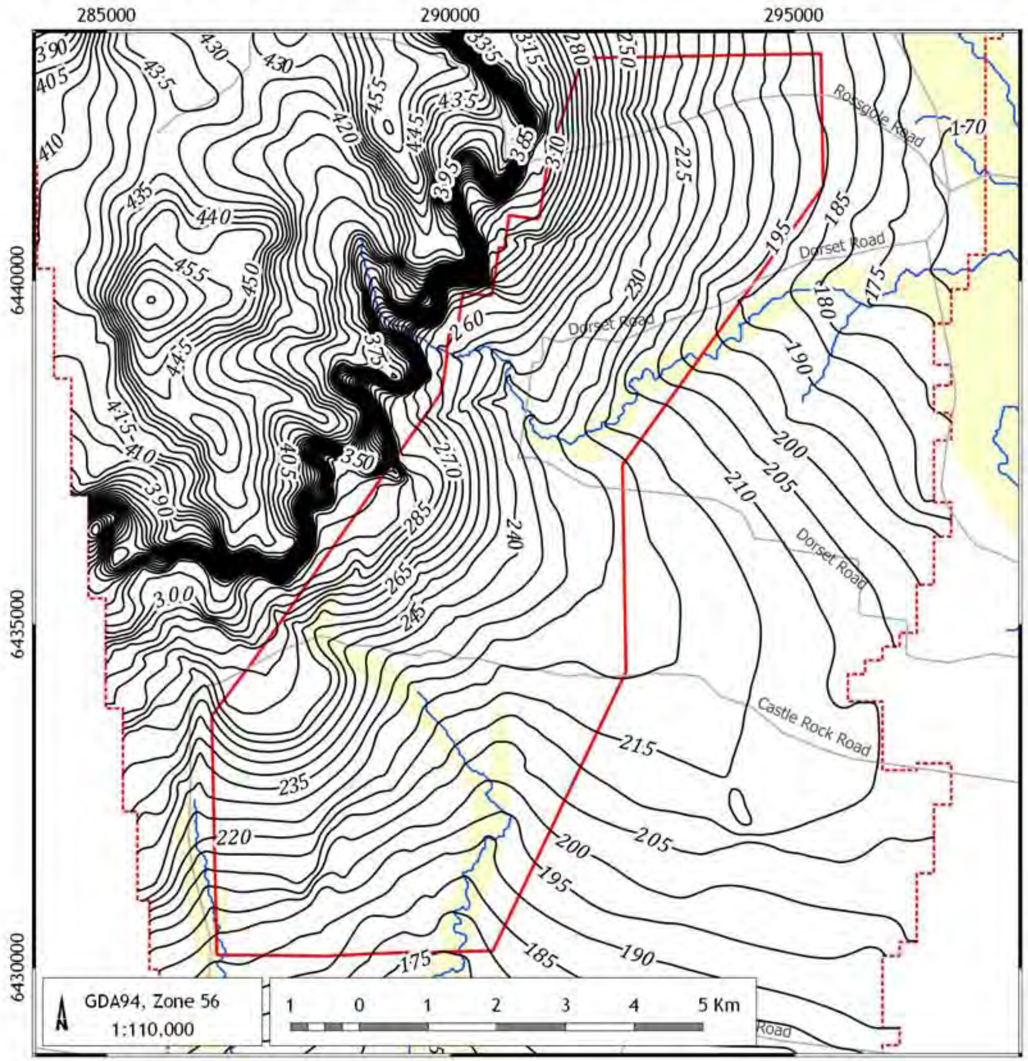
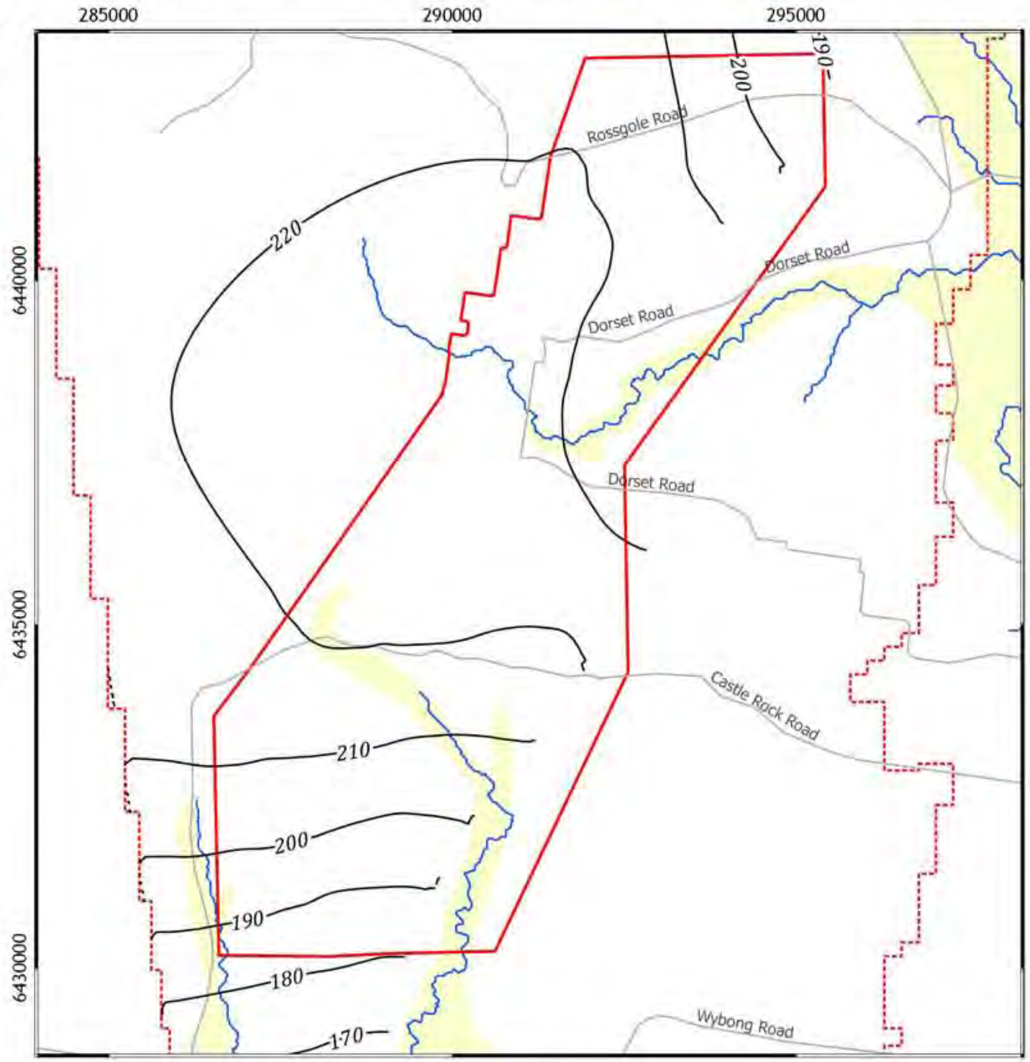


Figure C 8 Change of hydraulic conductivity with depth – field and model data

Hydraulic head - L01 - weathered regolith, alluvium



Hydraulic head - L09 - Permian coal seam (Blakefield)



LEGEND

- Groundwater head contour (mAHD)
- Project Assessment Area
- Active model grid outline (Project Area)
- Streams - main
- Alluvium unconsolidated (Qa)
- Roads

West Muswellbrook (G1676)

Hydraulic heads, layers 1 and 9 end of model calibration

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FIGURE No:
C-9

1.3.5 Calibration run - volumetric budget

Quantifying flow processes within the groundwater model, the water budget is often used as an important measure of model quality. The budget is by default calculated for the whole model domain and presented in a regular model output file, however the calculated and recorded cell-by-cell flows can be used to quantify intra- and inter-aquifer flows within the model domain. Although zone-based budgets were not calculated for the lead-in calibration period, they form a basis for evaluation of mining impacts (model prediction) and are discussed later in Section 1.4.

In terms of the water budget for the whole model domain, the inflow terms are: river and recharge. Correspondingly, the outflow terms are: river and evapotranspiration.

The budget error (water balance error) is one of the measures of the quality of model setup. The water balance error for the calibration period varies between -0.18% and 0.12%, the average value is 0.0007% (Figure C 10). The value of water balance error is safely below maximum recommended value of 1% for every time step of the model run (Barnett *et al,* 2012).

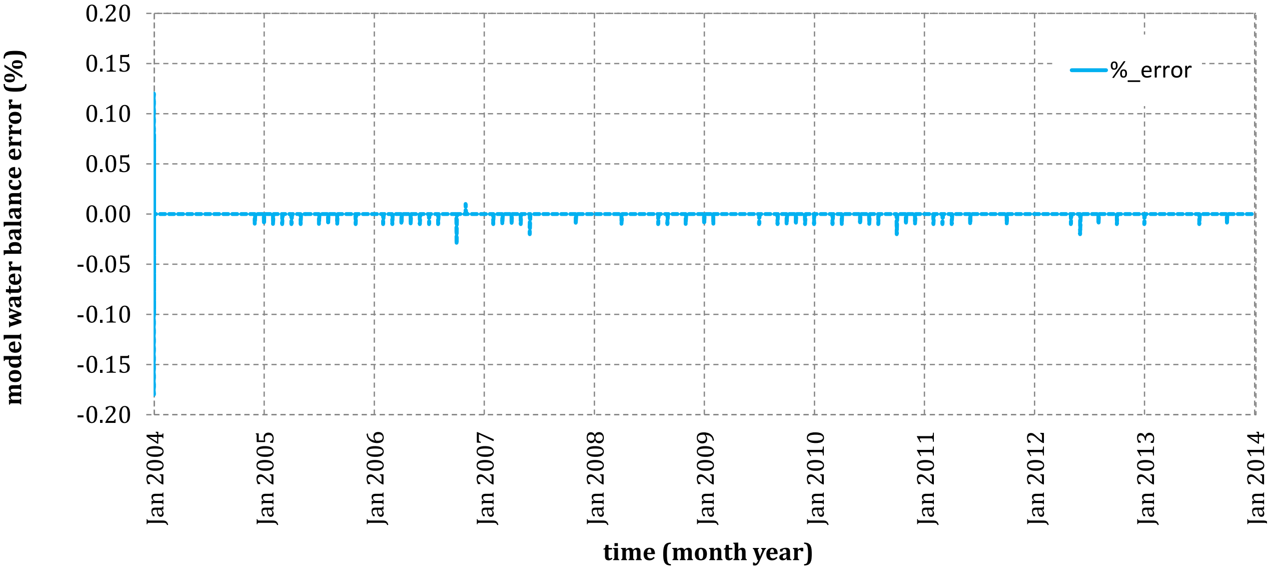


Figure C 10 The water balance error for the calibration period

With respect to model inputs, the recharge represents 42% and rivers represent 8% of the volumetric inflows. River boundary condition also represents the largest sink; about 31% of the overall volume is extracted by baseflow, followed by 19% of volume lost to evapotranspiration. The cumulative water budget for individual types of boundary conditions is summarized in Table C 11 and Figure C 11.

Table C 11 Water budget overview - cumulative volume and average rates

	cumulative volume		average rate *)	
	(m³)	(ML)	(m³/day)	(ML/month)
RCH (in)	41993163	41993.2	11497	349.9
RIV (in)	8443566	8443.6	2312	70.4
EVT (out)	18837622	18837.6	5158	156.9
RIV (out)	30988850	30988.9	8484	258.2

Note: **)the average rates were calculated over the period of the whole calibration run (10 years).*

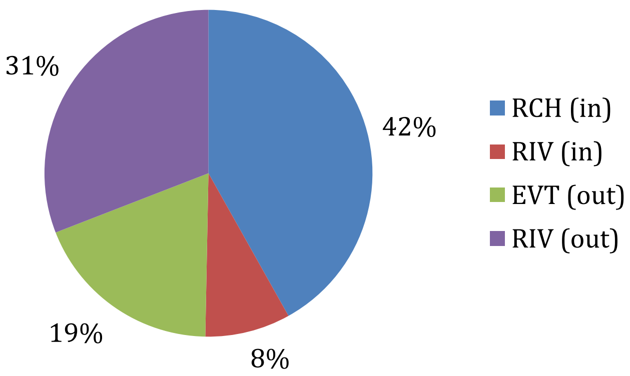


Figure C 11 Water budget overview – representation of individual boundary conditions

1.3.6 Quality of model calibration

The quality of the calibration can be assessed by checking the model performance measures against the specific calibration criteria. The recommended performance measures (Hill and Tiedeman, 2007) include:

- Water balance error – discussed in previous Section 1.3.5;
- Qualitative measures (representing goodness of fit between the calculated/modelled and measured groundwater heads). This assessment was undertaken by analysis of scatter diagrams comparing modelled and measured heads as well as visual check of hydrographs presenting modelled and measured heads; and
- Quantitative measures – assessment undertaken by calculating the calibration statistics.

The goodness of fit between the modelled and observed groundwater heads was examined with respect to 'starting heads' and 'transient trends' observation datasets as discussed in Section 1.3.1. For these purposes scatter diagrams as well as spatial distribution of residuals for both datasets were analysed.

See Figure C 12 for the comparison of the 'starting heads' measured and modelled data. See Figure C 13 for the map of the 'starting heads' observations in unconfined (weathered regolith or alluvium) and confined (Permian coal measure) aquifer.

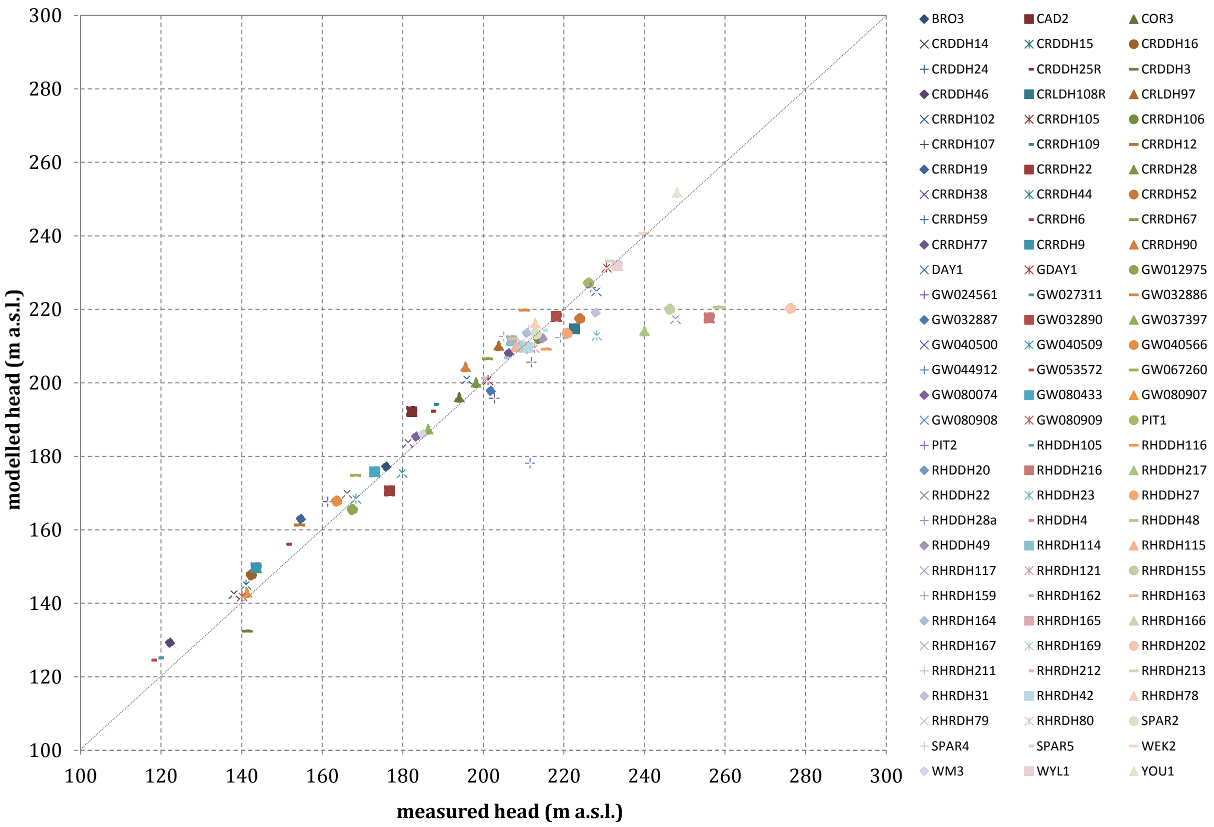
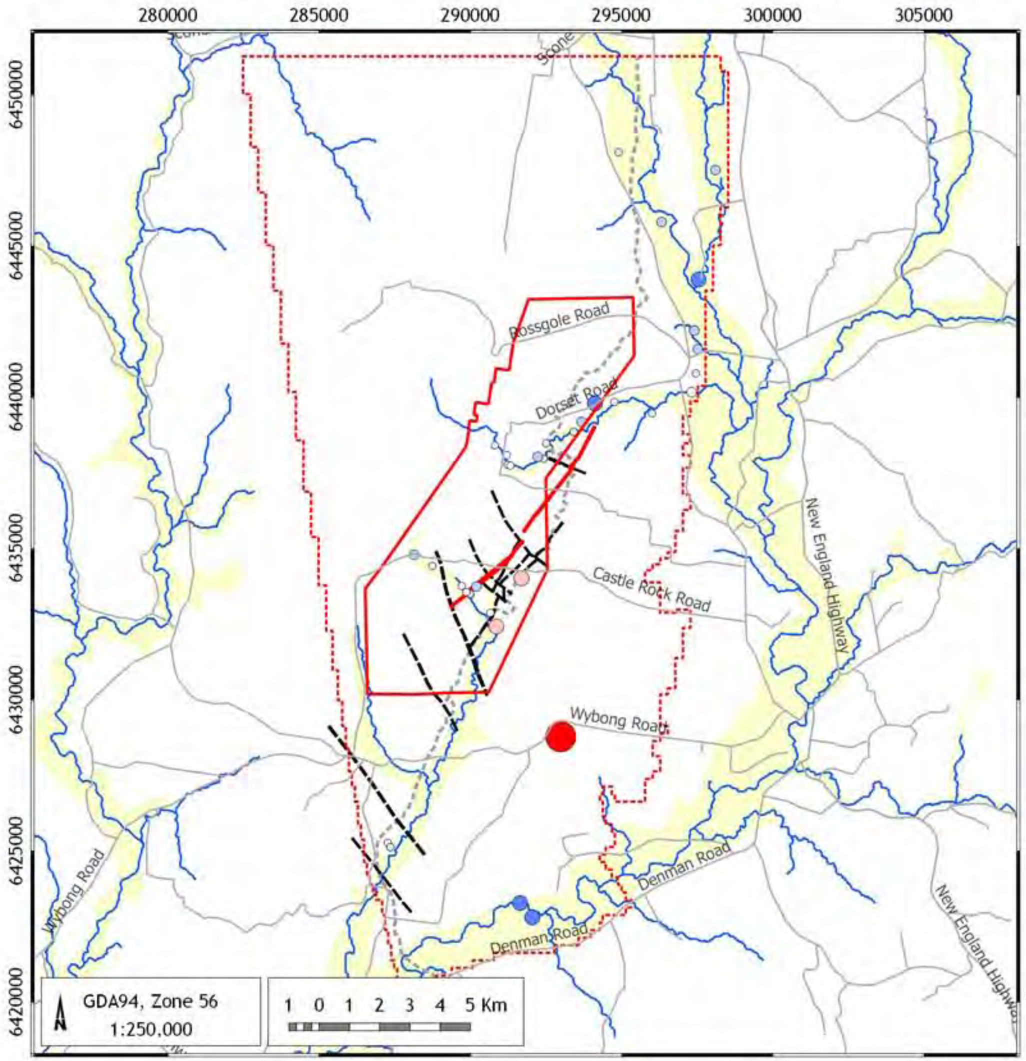
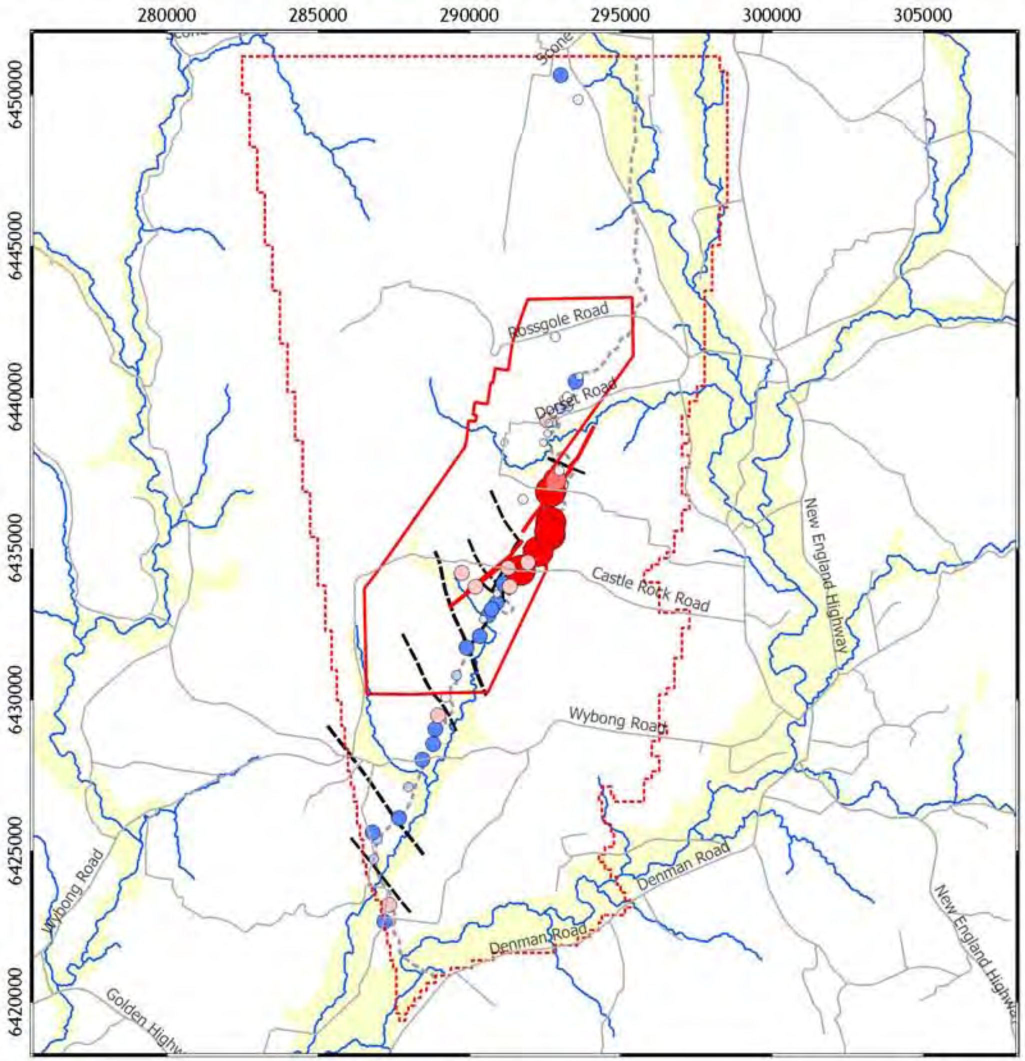


Figure C 12 Scatter diagram – 'starting heads' dataset – all bores

Residuals - 'starting heads' dataset - L01-02 - weathered regolith, alluvium



Residuals - 'starting heads' dataset - L05-11 - Permian coal seams



LEGEND

- Active model grid outline (Project Area)
- Project Assessment Area
- Alluvium undifferentiated (Qa)
- Blakefield floor subcrop
- Dartbrook Dyke
- Faults

- -60 to -20 (m)
- -20 to -10 (m)
- -10 to -05 (m)
- -05 to -02 (m)
- -02 to 00 (m)
- 00 to +02 (m)
- +02 to +05 (m)
- +05 to +10 (m)
- +10 to +20 (m)
- +20 to +60 (m)

- Roads
- Streams - main

West Muswellbrook (G1676)

Spatial distribution of residuals

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FIGURE No:
C-13

With respect to the 'starting head' target dataset, most of the data points show acceptable fit; however, the scatter diagram (Figure C 12) and the map (Figure C 13) identifies a group of bores in which the model under predicts the groundwater head – see Table C 12.

Table C 12 Bores with 'starting heads' residual greater than 10 m

Bore	Easting	Northing	Hydrostrat. unit	Measured head (m a.s.l.)	Modelled head (m a.s.l.)	Residual *) (m)
RHRDH202 (L9)	292666.69	6435561.68	Blakefield coal seam	276.300	220.199	-56.101
RHDDH216 (L9)	292704.03	6435859.82	Blakefield coal seam	256.100	217.666	-38.434
RHDDH48 (L9)	292677.46	6435440.76	Blakefield coal seam	258.300	220.574	-37.726
RHDDH22 (L9)	291695.37	6434266.24	Blakefield coal seam	247.700	217.446	-30.254
RHRDH155 (L9)	292285.00	6434895.59	Blakefield coal seam	246.300	220.038	-26.262
RHDDH217 (L9)	292690.30	6436869.88	Blakefield coal seam	240.000	214.110	-25.890
RHDDH23 (L9)	292831.56	6437261.06	Blakefield coal seam	228.200	212.849	-15.352
GW044912 (L2)	293000.48	6428769.28	weathered regolith	211.600	178.107	-33.493

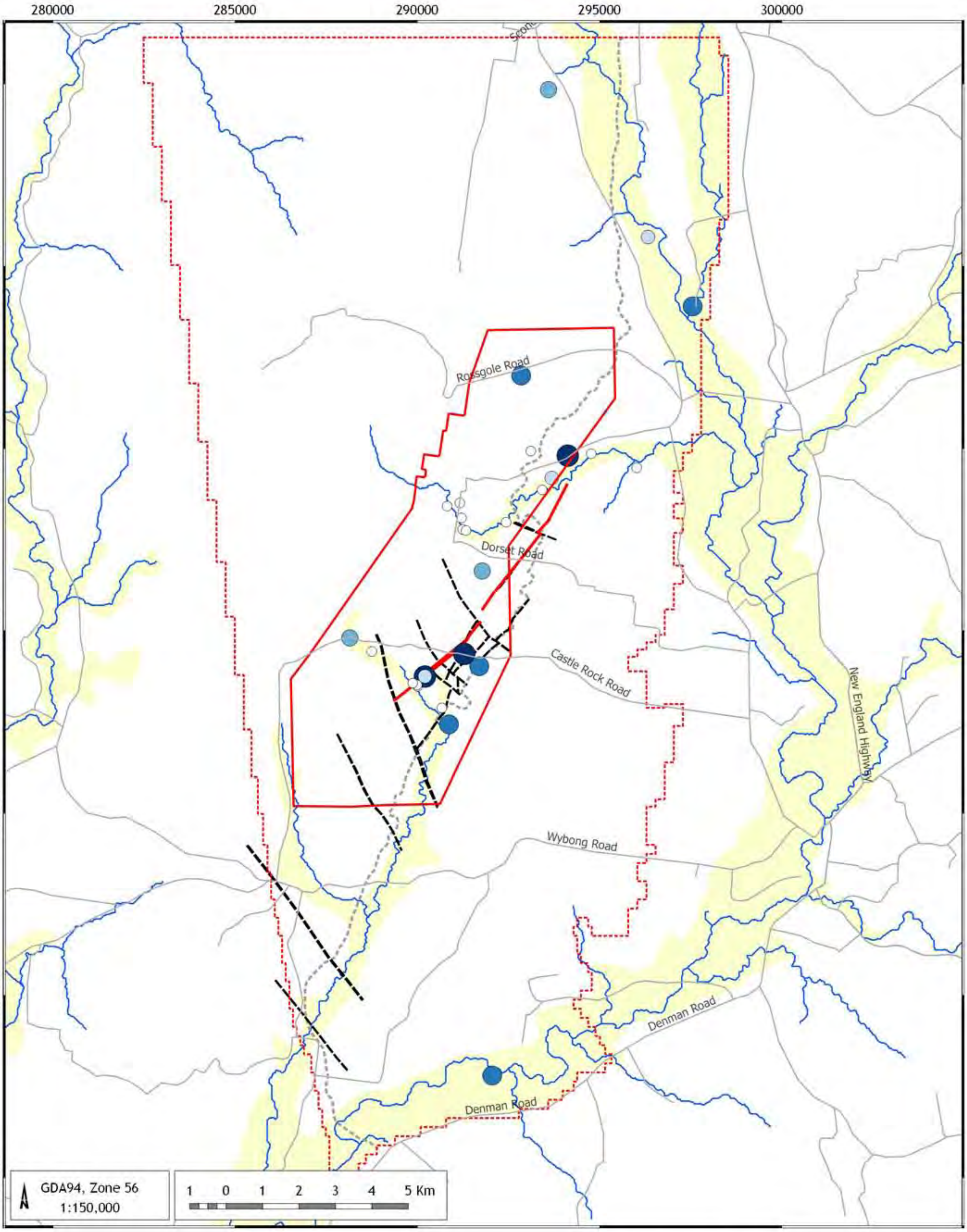
Note: **) Residual calculated as 'modelled – measured' head. Negative residual means model is underpredicting in the particular location (modelled heads are lower than measured heads), positive residual means model is overpredicting (modelled heads are higher than measured heads).*

Most of the identified bores are measuring groundwater level in Blakefield coal seam (model layer 9). These bores are all clustered in one area, between Sandy Creek North and Coal Creek alluvium, just west of the Blakefield coal seam subcrop line. This area appears to be structurally complex and is divided into disparate blocks bounded by various splays of the Lyndale and W220 faults. Based on the field observation, the groundwater head in the area seems to be at least partially disconnected (the groundwater flow is restricted) from the wider groundwater system. Given the simplified nature of the model, these observations could not be properly fitted without compromising the model calibration.

The reason for the misfit of the observations in the weathered regolith bore GW044912 is not clear and the bore should be visited and the observation data verified.

The 'transient trends' dataset shows mostly an acceptable fit. Because the transient dataset could not be evaluated simply based on the residuals of individual observations (there are multiple observations for each bore, thus collated into *observation group*), an approach of examining the weighted contribution of individual observation groups towards the objective function was chosen. As every bore (observation group) contains variable amount of measurements (individual observations), a bore with good fit but more observations might contribute more to the objective function than poorly fitting bore with less observations. A contribution of every observation group is therefore weighted using the number of individual observations. See Table C 13 for the overview of all the bores of 'transient trends' dataset and Figure C 14 and Table C 13 to see the spatial distribution of the calibration fit and scatter diagram respectively. Figure C 15 shows the transient scatter and Figure C 16 presents all the hydrographs comparing observed and modelled data.

In terms of the quantitative calibration measures (calibration statistics), the model shows overall good fit with the RMS value of 4.34 (m) and SRMS value of 2.7%. See Table C 14 for the full overview of statistical measures.



LEGEND

- Active model grid outline (Project Area)
- Project Assessment Area
- Alluvium undifferentiated (Qa)
- Blakefield floor subcrop
- Dartbrook Dyke
- Streams - main
- Faults
- Roads

Contribution to phi

- 0 - 5 (m2)
- 5 - 10 (m2)
- 10 - 20 (m2)
- 20 - 40 (m2)
- 40 - 60 (m2)

West Muswellbrook (G1676)

Transient 'trend' dataset - weighted contribution to objective function (phi)

DATE 8/10/2014

FIGURE No: **C-14**

Table C 13 Weighted contribution towards objective function for individual observation groups (bores) – 'transient trends' dataset

Bore	Easting	Northing	Contrib to phi (m^2)	No of observations	Wghtd contrib to phi (m^2)
BRO3 (L1)	296022.1	6439457.3	108.82	37	2.94
CAD2 (L2)	294130.0	6439790.0	1650.58	34	48.55
COR3 (L1)	293689.1	6439180.3	321.29	36	8.92
CRRDH105 (L1)	290674.3	6432864.4	109.54	80	1.37
CRRDH106 (L1)	290009.1	6433457.2	137.46	96	1.43
CRRDH107 (L1)	290870.2	6432412.8	3188.98	93	34.29
CRRDH52 (L2)	291701.6	6434009.7	1049.74	28	37.49
DAY1 (L5)	292850.4	6441989.5	1179.37	31	38.04
GDAY1 (L1)	290818.3	6438405.7	36.07	28	1.29
GW024561 (L9)	290209.1	6433726.4	200.73	5	40.15
GW027311 (L1)	292056.0	6422787.4	65.75	3	21.92
GW032887 (L7)	293602.1	6449839.1	91.14	7	13.02
GW067260 (L1)	297559.6	6443887.6	61.27	2	30.63
GW080433 (L1)	296333.0	6445791.2	699.93	110	6.36
PIT1 (L1)	291243.6	6437765.3	53.95	39	1.38
PIT2 (L1)	291337.6	6437735.4	41.95	39	1.08
RHDDH20 (L9)	293115.4	6439916.1	95.57	49	1.95
RHDDH27 (L9)	291290.0	6434348.0	1496.56	27	55.43
RHDDH4 (L9)	291782.4	6436622.6	431.96	39	11.08
RHRDH211 (L1)	292437.2	6437962.7	69.83	86	0.81
RHRDH212 (L1)	293426.1	6438850.1	101.56	70	1.45
RHRDH213 (L1)	291214.5	6438080.8	16.05	27	0.59
SPAR2 (L1)	289994.5	6433498.0	57.59	26	2.22
SPAR4 (L1)	290210.3	6433732.9	165.31	25	6.61
SPAR5 (L1)	289875.9	6433546.7	26.22	26	1.01
WEK2 (L1)	288753.6	6434415.6	14.99	10	1.5
WM3 (L1)	294773.1	6439840.3	75.25	37	2.03
WYL1 (L5)	291169.5	6438494.8	113.47	37	3.07
YOU1 (L1)	288149.6	6434786.3	411.58	36	11.43

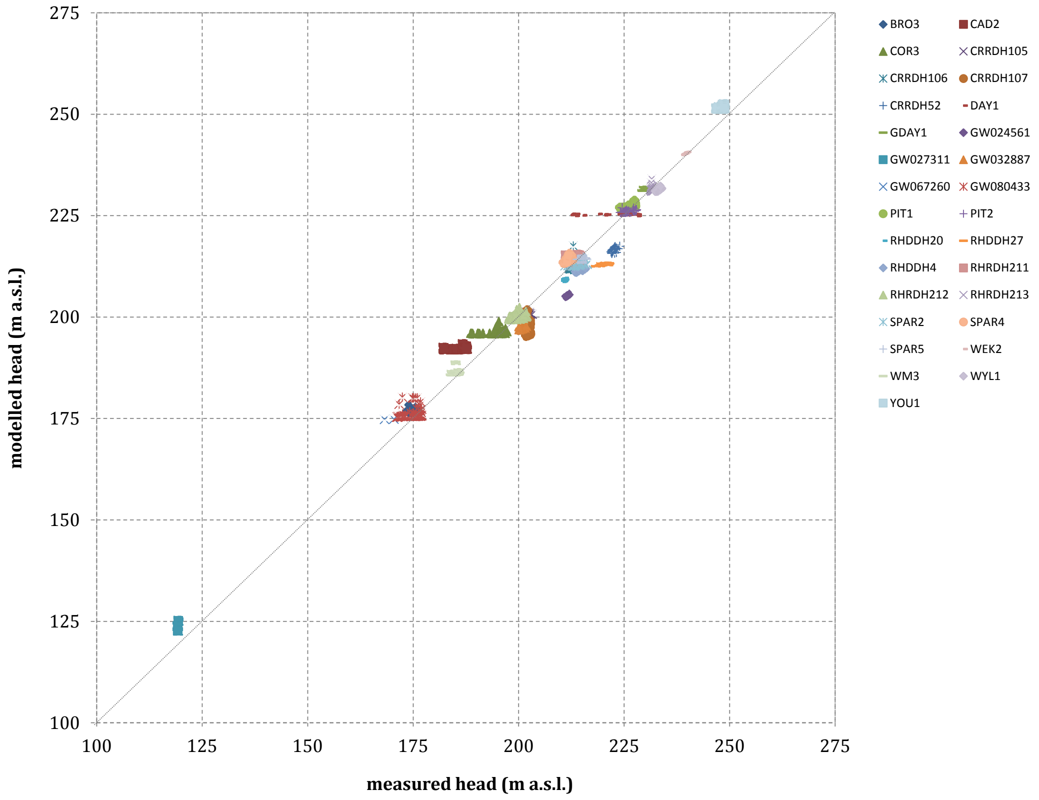


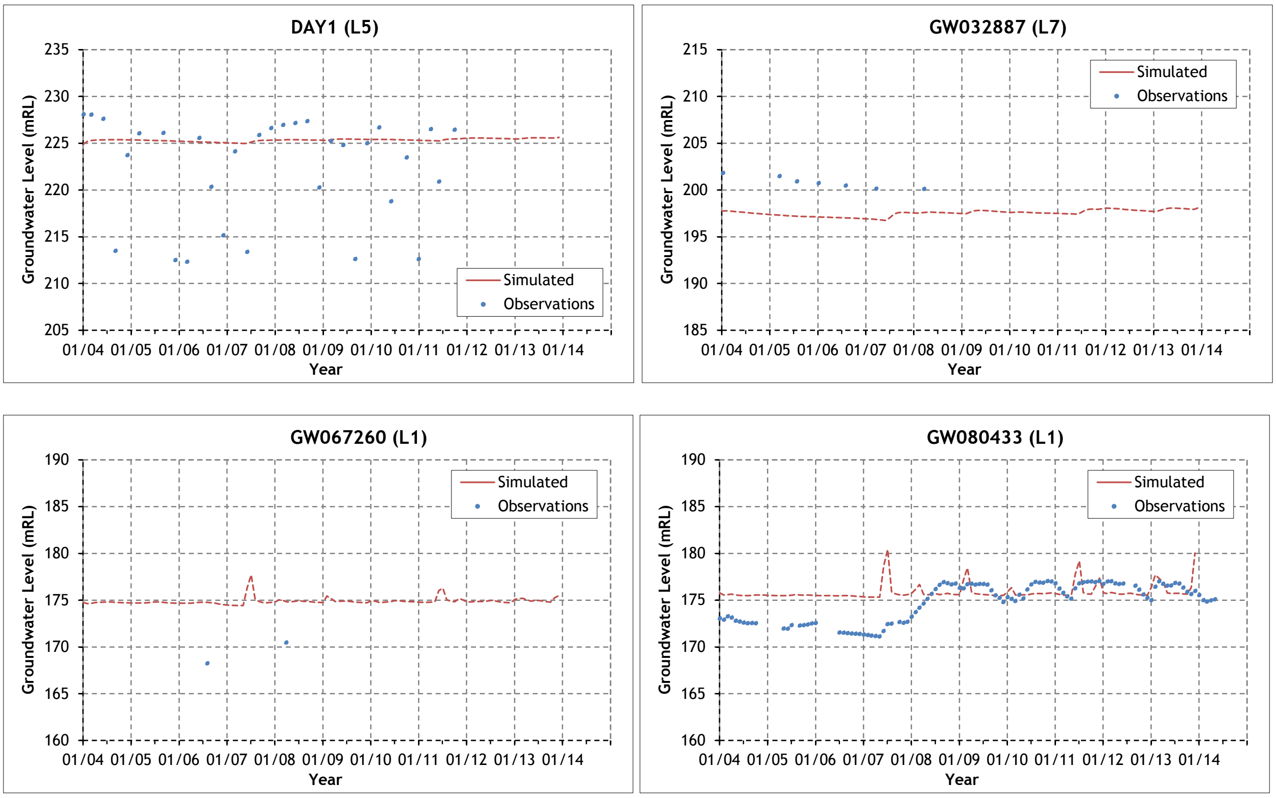
Figure C 15 Scatter diagram – 'transient trends' dataset – selected bores

Table C 14 Overall calibration statistics

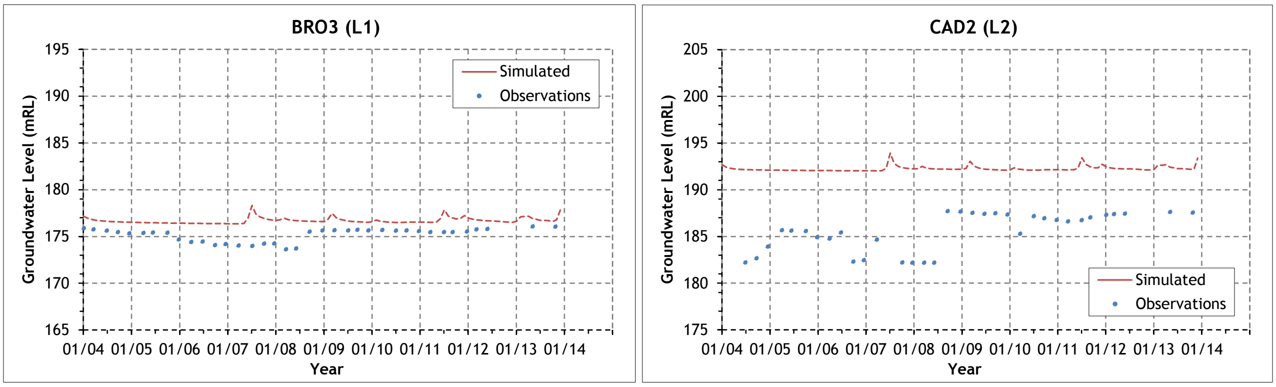
Calibration measure		Value
sum of residuals (SR):	[m]	3142.10
mean sum of residuals (MSR):	[m]	2.56
scaled mean sum of residuals (SMSR):	[%]	1.62
sum of squares (SSQ):	[m2]	23085.39
mean sum of squares (MSSQ):	[m2]	18.81
root mean square (RMS):	[m]	4.34
root mean fraction square (RMFS):	[m]	2.00
scaled RMFS (SRMFS):	[%]	2.61
scaled RMS (SRMS):	[%]	2.74

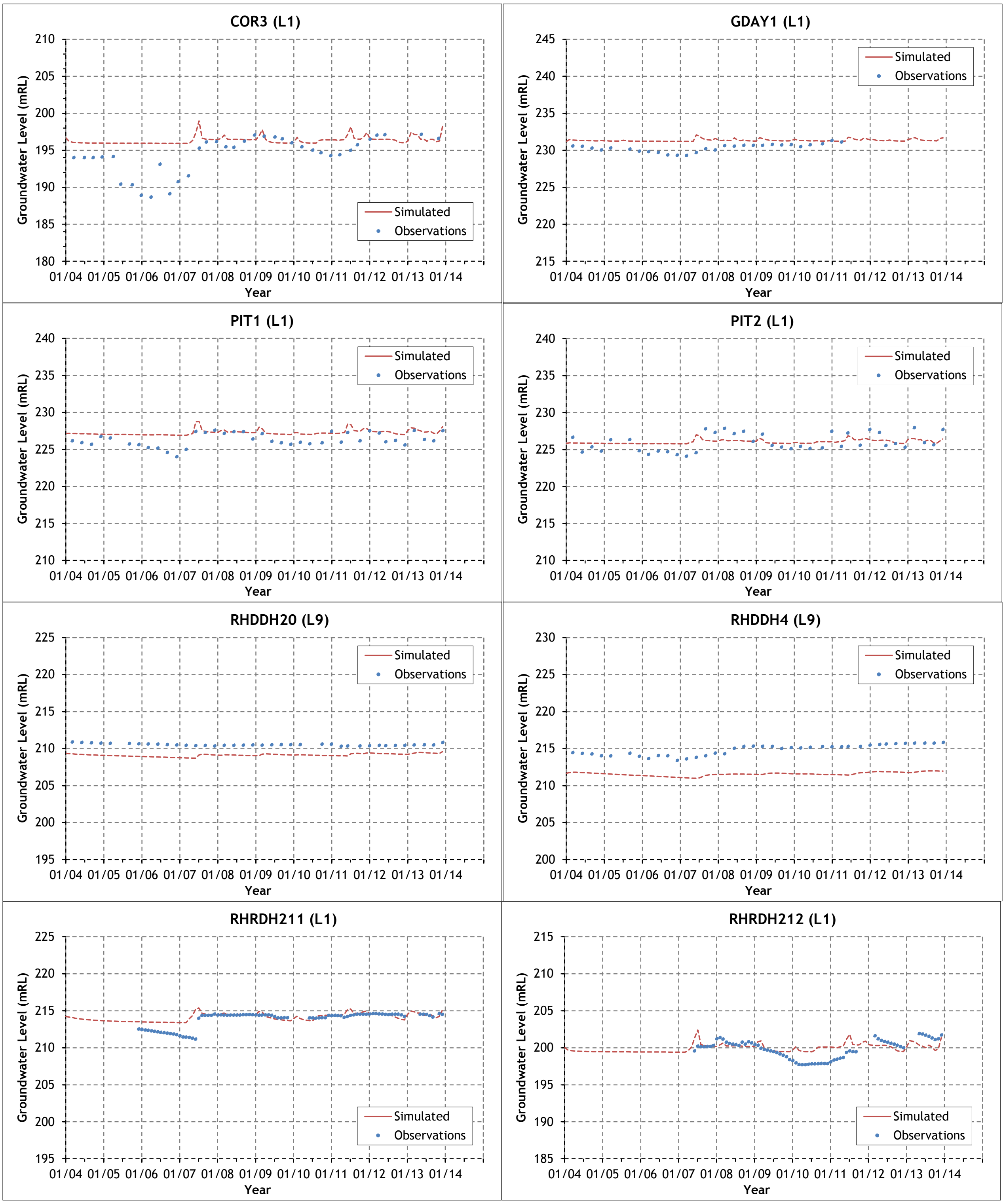
Figure C 16 Hydrographs – observed vs. modelled heads – 'transient trend' observation bores (below)

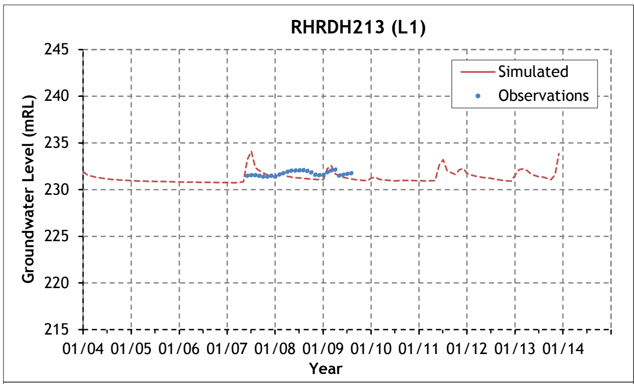
Dartbrook, Middle Brook, Kingdon Ponds catchment area

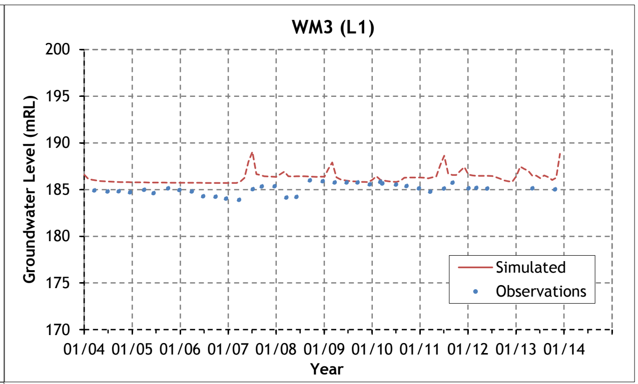


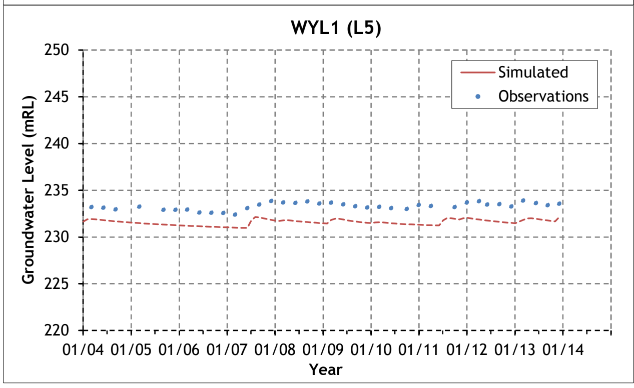
Sandy Creek North catchment area



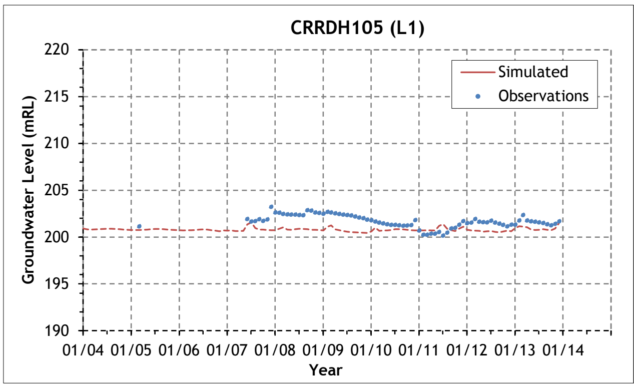

COR3 (L1)
GDAY1 (L1)
PIT1 (L1)
PIT2 (L1)
RHDDH20 (L9)
RHDDH4 (L9)
RHRDH211 (L1)
RHRDH212 (L1)
Groundwater Level (mRL)
Year
01/04 01/05 01/06 01/07 01/08 01/09 01/10 01/11 01/12 01/13 01/14
Simulated
Observations

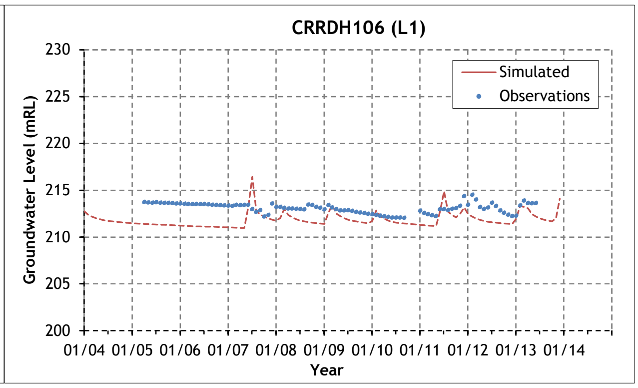


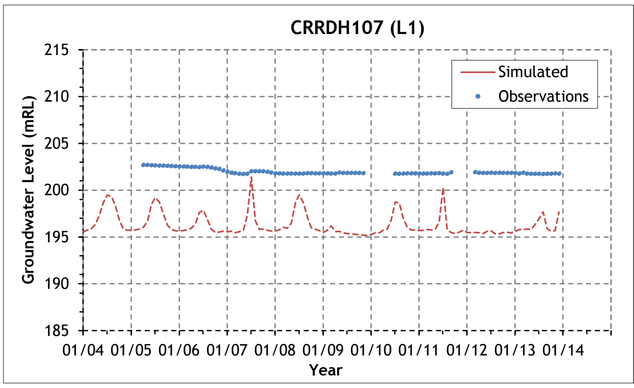


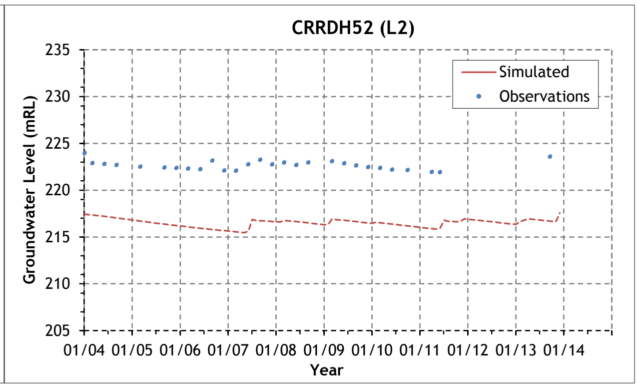


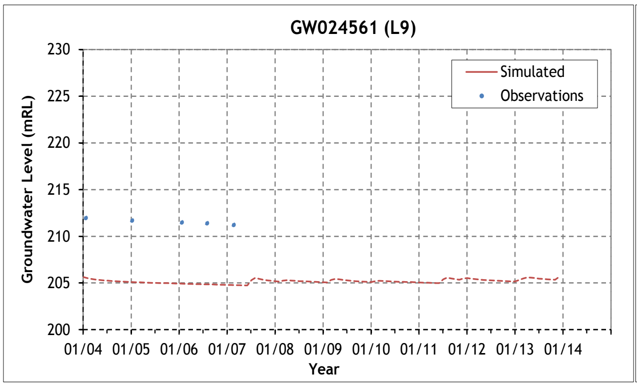
Coal Creek, Sandy Creek South



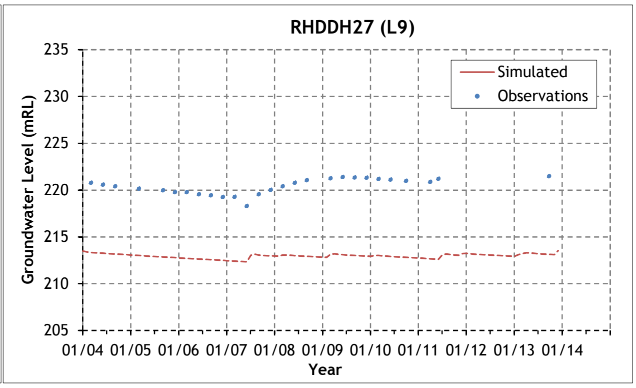




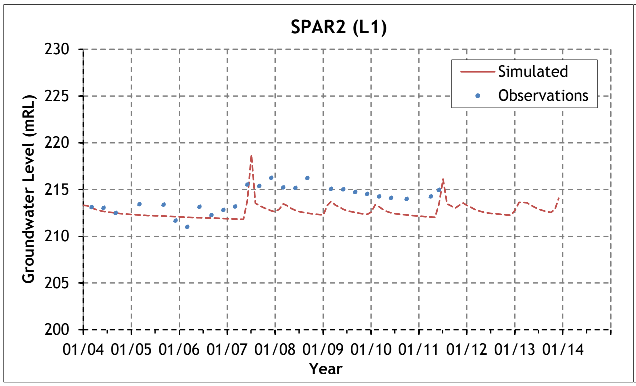




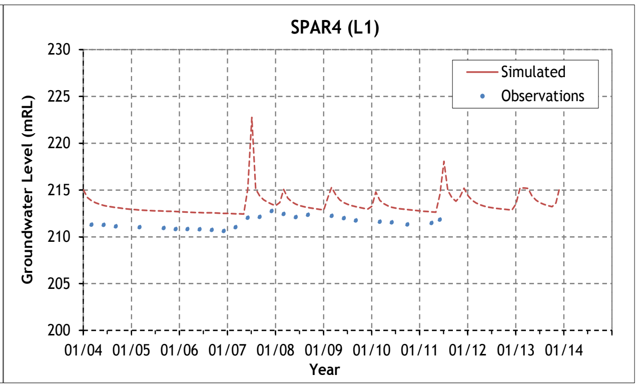
GW024561 (L9)
Groundwater Level (mRL)
Year
Simulated
Observations



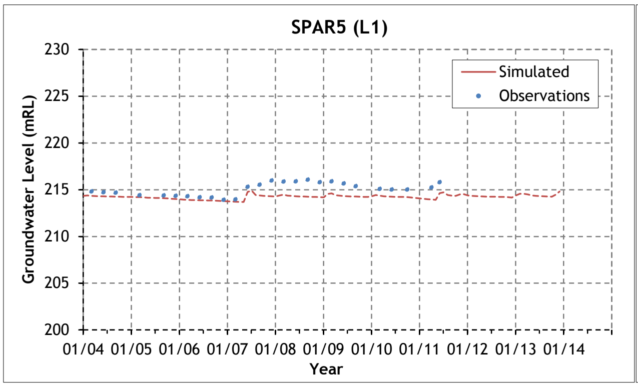
RHDDH27 (L9)
Groundwater Level (mRL)
Year
Simulated
Observations



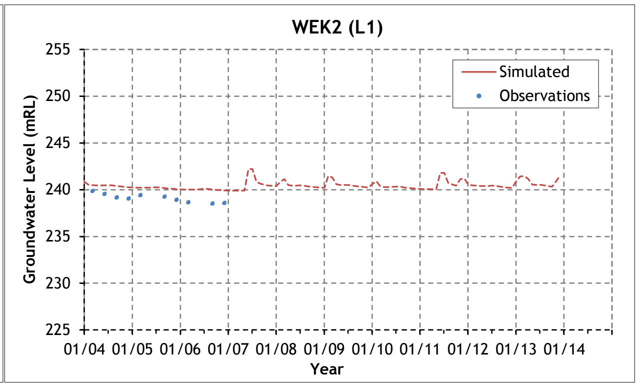
SPAR2 (L1)
Groundwater Level (mRL)
Year
Simulated
Observations



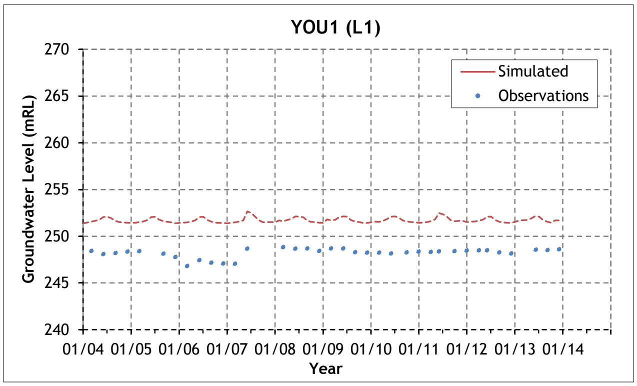
SPAR4 (L1)
Groundwater Level (mRL)
Year
Simulated
Observations



SPAR5 (L1)
Groundwater Level (mRL)
Year
Simulated
Observations

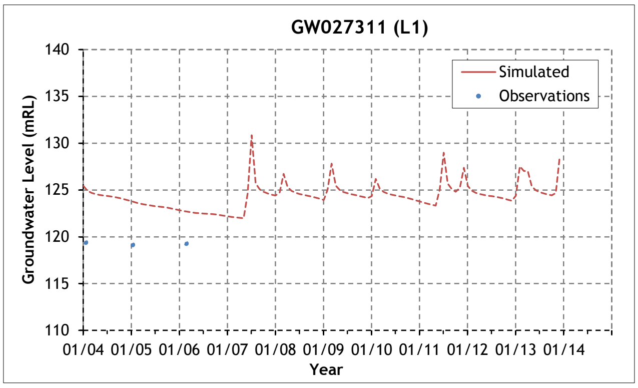


WEK2 (L1)
Groundwater Level (mRL)
Year
Simulated
Observations



YOU1 (L1)
Groundwater Level (mRL)
Year
Simulated
Observations

Hunter River alluvium



1.4 Model predictions

1.4.1 Prediction goals

As specified earlier in Section 1.1, the AIP requires analysis of the following:

- volume of groundwater seepage from the highly productive aquifers (HPA) to pits;
- drawdown (or water take) from highly productive alluvial aquifers of Sandy Creek North, Sandy Creek South, Spring Creek, Coal Creek, Dartbrook (Middle Brook and Kingdon Ponds) and the Hunter River; and
- potential for drawdown in surrounding private landholder bores within and outside of PAA, drawdown in bores within the highly productive aquifer zones; and

The prediction goals are addressed by examination of model outputs, mainly by analysis of the volumetric budgets (and their change expressed as comparison of mine and no-mine scenario runs) and drawdown contours and hydrographs, again expressed as a comparison between mine and no-mine scenario runs.

1.4.2 Mining progression, location of drain cells

The open cut mining was simulated using SURFACT drain (DRN) package. The cells were located to the floors of individual model layers. Mining progression was defined as a progression of strips going down to the base of Wambo and Blakefield coal seams, moving in north-to-south direction (Figure C 17 and Figure C 18) in annual timesteps. A conductance term of 100 m/day was applied to all drain cells. The mine was simulated using a simple transient model, the hydraulic properties within model layers were not changed to simulate the emplacement of spoil.

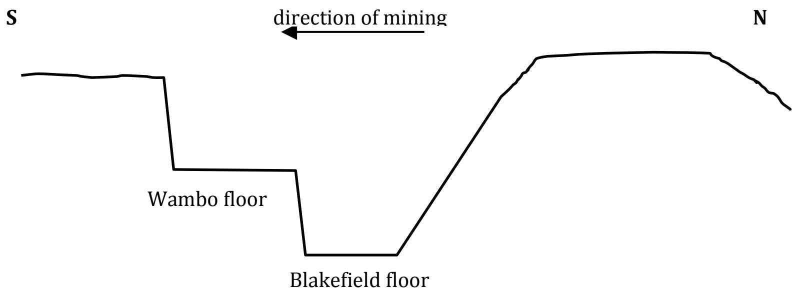
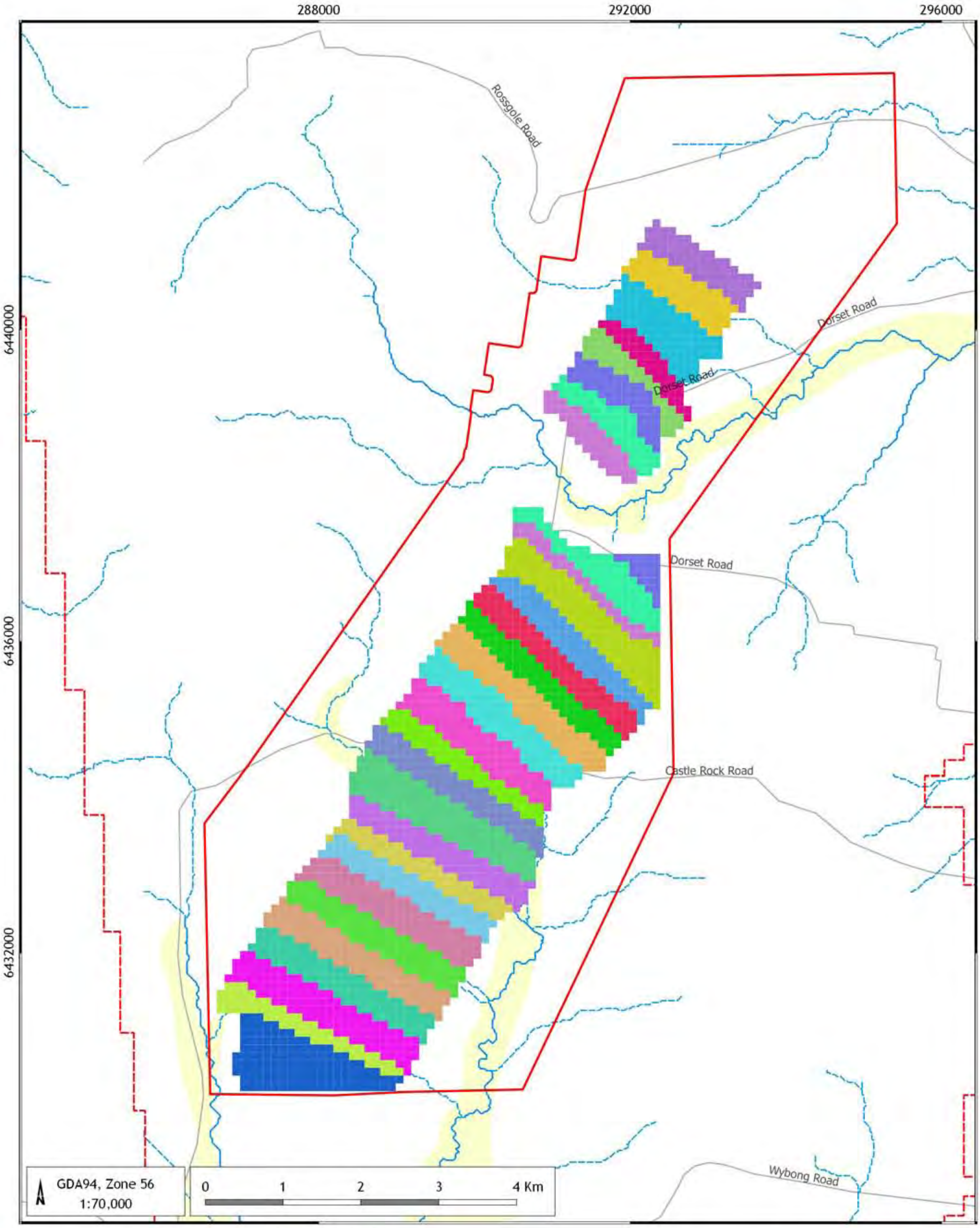


Figure C 17 Mining progression - simplified cross section



LEGEND

- Project Assessment Area
- Active model grid outline (Project Area)
- Streams - minor / ephemeral
- Streams - main
- Roads
- Alluvium undifferentiated (Qa)

Mining progression

Year 3	Year 10	Year 17	Year 24
Year 4	Year 11	Year 18	Year 25
Year 5	Year 12	Year 19	Year 26
Year 6	Year 13	Year 20	Year 27
Year 7	Year 14	Year 21	Year 28
Year 8	Year 15	Year 22	Year 29
Year 9	Year 16	Year 23	Year 30

West Muswellbrook (G1676)

Drain cells progression
Blakefield seam (L09)

DATE 8/10/2014

FIGURE No: **C-18**

1.4.3 Predictive run - volumetric budget

Similarly to the calibration period, the volumetric water balance was calculated. Globally, the inflow terms are: river and recharge. The outflow terms are: river, drains (simulating mining progression) and evapotranspiration. In terms of the inter-aquifer processes, the flows were calculated between alluvial zones of Dartbrook (Middle Brook, Kingdon Ponds), Sandy Creek North, Sandy Creek South, Spring Creek, Hunter River and weathered regolith. Also investigated were the RIV boundary condition flow terms , which define either baseflow (water removed from the model domain) or recharge through the stream bed (water added into the model domain).

The water balance error for the mining period varies between -0.06% and 0.01%, the average value is -0.0012% (Figure C 19). The value of water balance error is below maximum recommended value of 1% for every time step of the model run (Barnett *et al,* 2012).

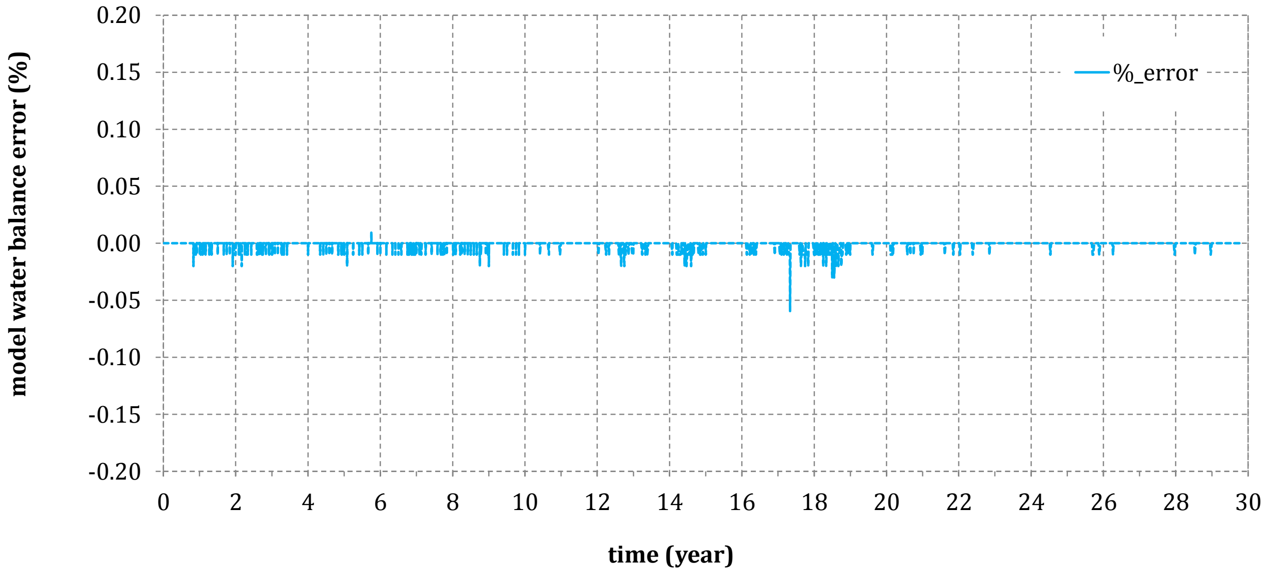


Figure C 19 The water balance error for the prediction (mining) period

With respect to model inputs, the recharge represents 42% and rivers represent 9% of the volumetric inflows. River boundary condition also represents the largest sink; about 31% of the overall volume is extracted by baseflow, followed by 18% of volume lost to evapotranspiration. The volume of water taken out by the proposed mine is about 1% of the overall water budget. The cumulative water budget for individual types of boundary conditions is summarized in Table C 15 and Figure C 20.

Table C 15 Volumetric budget overview

	Cumulative volume		Average rate	
	(m3)	(ML)	(m3/day)	(ML/month)
RCH (in)	125976603	125976.6	11497	349.9
RIV (in)	25424073	25424.1	2320	70.6
DRN (out)	3276659	3276.7	299	9.1
EVT (out)	54895756	54895.8	5010	152.5
RIV (out)	89772945	89772.9	8193	249.4

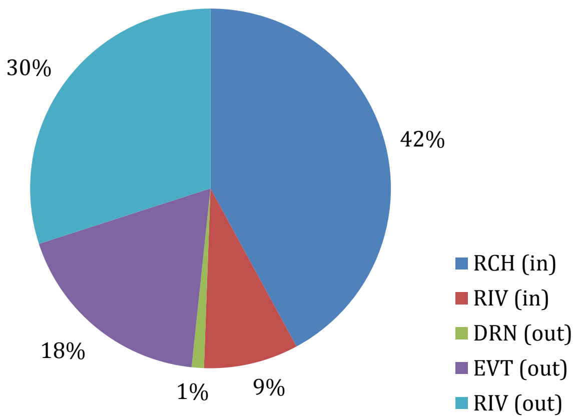


Figure C 20 Water budget overview – representation of individual boundary conditions

As the drain (DRN) boundary condition was used to simulate the mining progression, the volumetric budget of drains represents the estimate of all the water extracted from the weathered regolith (less productive aquifer), alluvium (predominantly highly productive aquifer) and Permian strata and interburden (less productive aquifer) by the Project. The only direct water-take of water from highly productive alluvium happens when the mining intersects the Coal Creek alluvium. Other parts of the highly productive alluvium aquifer systems are influenced indirectly by reduced recharge into the alluvium.

The drain output is presented in the form of two graphs: actual drain model output (Figure C 21) and summary annual water output (Figure C 22).

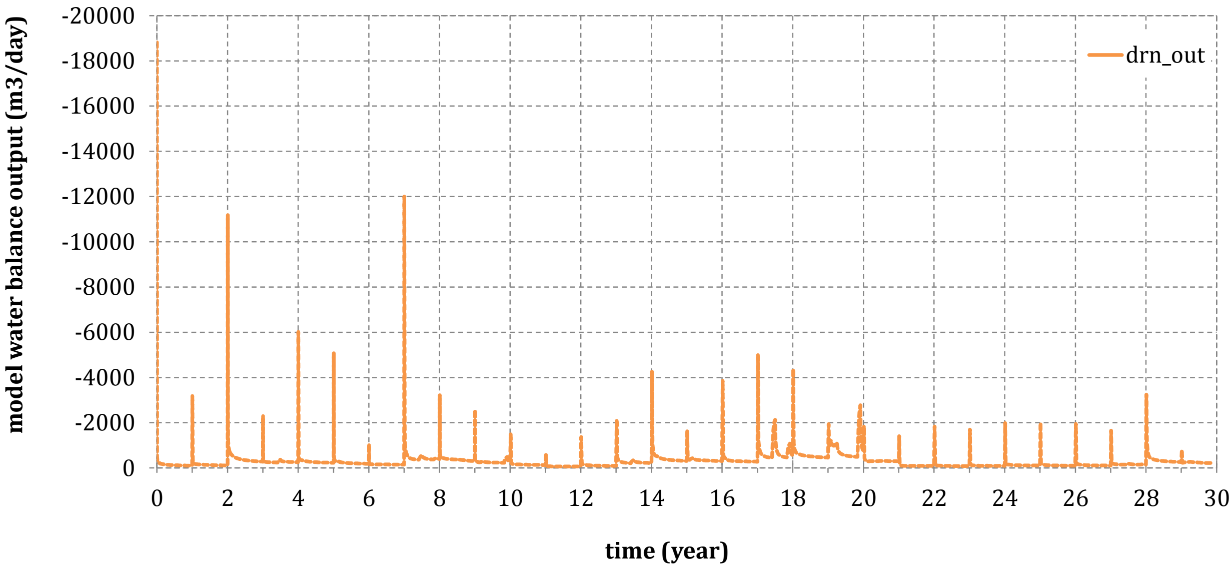


Figure C 21 Model water balance output – DRN boundary condition

The raw drain output shows inflow peaks at the moment of drain cell movement (beginning of the year). These peak inflow rates however last only for a brief period of time (hours). Then the groundwater gradients normalize and inflow rates become much more realistic. It is possible to say that the peak inflow rates are the artificial product of the annual step of drain cells emplacement and the initial peak inflow rates are not representative of actual expected inflow rates.

In order to avoid the 'peak inflow rate' issue, the inflow rates were used to calculate actual cumulative volumes for every year of mining (Figure C 22). The predicted mine inflow then fluctuates between 26 ML/year (~2.2 ML/month in year 12) and 318 ML/year (~26.5 ML/month in year 20) with average rate of 109 ML/year (~9.1 ML/month).

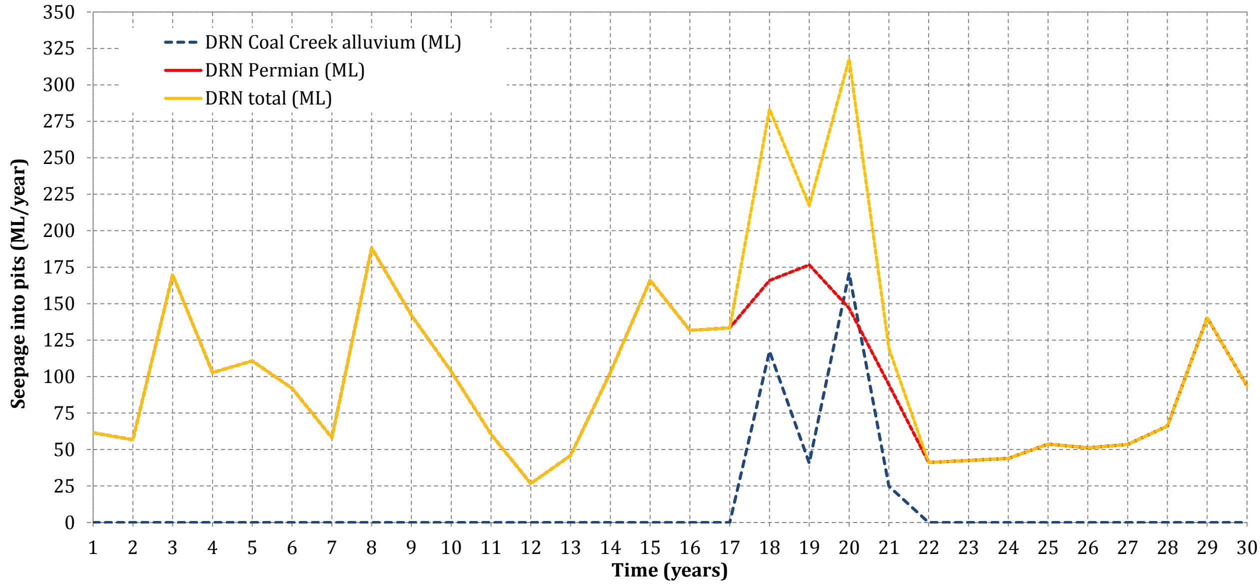


Figure C 22 DRN boundary condition – summary annual output

The peak drain outflows are happening around year 8 and 18 to 20. These time period represent times when the north pit is approaching the highly productive Sandy Creek North alluvium (years 8 and 9) and when the south pit mines through the Coal Creek (Sandy Creek South) alluvium.

The drain budget also does not account for the one-off volume of water removed by mining up the saturated alluvium sediments of Coal Creek. Based on the measured area of the mined alluvium (93.142 ha), estimated saturated thickness (2 m) and estimated specific yield (7.4%), the volume of groundwater contained in the alluvial sediments is approximately 137.9 ML.

1.4.4 Predictive run – zone budgets

Zone budgets were extracted for the individual alluvial areas of Dartbrook (Middle Brook and Kingdon Ponds), Sandy Creek North, Sandy Creek South (including Coal Creek), Spring Creek and Hunter River. The groundwater gradient mostly causes the groundwater flows from weathered regolith to alluvium, occasional periodic and short term reversals of flow are caused by rainfall events and associated higher recharge to alluvium. The flow rates into the alluvium are on average 420 m^3/day for Dartbrook and Kingdon Ponds, 280 m^3/day for Sandy Creek North, 358 m^3/day for Coal Creek, 280 m^3/day for Sandy Creek South, 133 m^3/day for Spring Creek and 233 m^3/day for Hunter River. See Table C 16 for the summary statistics of flow rates for individual alluvial zones and Figure C 23 for transient flow rates to alluvial zones surrounding the Project.

The impact of the Project on the alluvium flows (change of flow rates) were examined by comparing the water budgets of two model scenarios: scenario where the mine is implemented ('mine' run) and scenario without the mine ('no-mine' run) under otherwise unchanged conditions. The comparison of budgets for individual alluvial zones (see Figure C 24) shows several trends:

- The Sandy Creek North alluvium is not being mined, however the mining activity north and south of the alluvial zone temporarily changes the groundwater flow regime in the vicinity of the alluvium (lowered groundwater flow gradients from the outside towards alluvium) resulting in the decrease of inflows into the alluvium by approximately 180 m^3/day (1.15 ML/year) between years 7 and 9 of mining.
- Coal Creek alluvium is being mined out during mining year 17. The flow into alluvium gradually decreases from year 14, any potential inflow is lost after year 17. The loss of inflow for Coal Creek alluvium averages at approximately 255 m^3/day (93 ML/year). Due to the planned diversion of Coal Creek, the loss of inflow will likely to be lower. This option was however not addressed by modelling due to lack of available information about the diversion.
- Sandy Creek South alluvium is being affected indirectly as the mine progresses alongside the creek in a NE to SW direction. Predicted inflows into alluvium start to decrease past mining year 12 with an average decrease in inflow of 15 m^3/day (5.7 ML/year).
- As the mining activity moves towards south-west, predicted inflows into Spring Creek alluvium start to gradually decrease around mining year 25. On average, the loss of alluvial inflow represents 30 m^3/day (10.9 ML/year) peaking towards the very end of the mining at 163 m^3/day (59.6 ML/year).
- The decrease of inflows into alluvial zones of Dartbrook and Hunter River is negligible.
- The predicted combined loss of alluvial inflows due to the mining activities associated with the Project is dominated by loss of inflows into the Coal Creek alluvium. The peak value occurs towards the end of mining due to combination of effects on Spring Creek and Coal Creek alluvium. The average combined loss of seepage into all alluvial aquifers is 240 m^3/day (87 ML/year), peaking at 616 m^3/day (225 ML/year)
- The less water seeps into the alluvial aquifer, the less water is able to seep through the stream bed into the creeks in the form of baseflow. The predicted loss of recharge into alluvium then directly translates into the loss of baseflow.

Due to the simplified conceptualization imposed on the numerical model, following items that can significantly impact the model budgets were not considered:

- During the modelling of the mining progression, hydraulic properties of the mined area were not changed to simulate spoil emplacement. Spoil has usually higher hydraulic conductivity and storage than native rock and accepts more diffuse recharge. Placement of spoil will likely influence the change of flow into alluvium of Sandy Creek North as the hydraulic system will not return into pre-mining equilibrium.
- The model does not take into account the diversion of the Coal Creek. The Coal Creek diversion will impact the area of recharge at the western and southern side of the pit well as stage in Sandy Creek South and possibly Spring Creek. The details of this surface water project were not available at the time.

Table C 16 Summary of inflow rates into individual alluvial zones

Alluvium zone	Min (m3/day)	1st quartile (m3/day)	Average (m3/day)	3rd quartile (m3/day)	Max (m3/day)
Dartbrook, Kingdon Ponds	-4394.2	364.6	419.4	518.5	2564.1
Sandy Crk North	-387.1	255.6	282.4	333.0	630.3
Coal Crk *)	32.2	303.5	357.9	408.4	660.5
Sandy Crk South	-548.6	230.7	279.7	343.1	761.9
Spring Crk	-1029.7	109.4	133.2	222.6	558.9
Hunter River	-262.7	219.2	233.4	252.8	690.8

***Note:** *) Statistics for Coal Creek alluvium are calculated only up to year 17 when the drain cells intersect the alluvium. After that point, the alluvium (and all inflows into it) are removed from calculations*

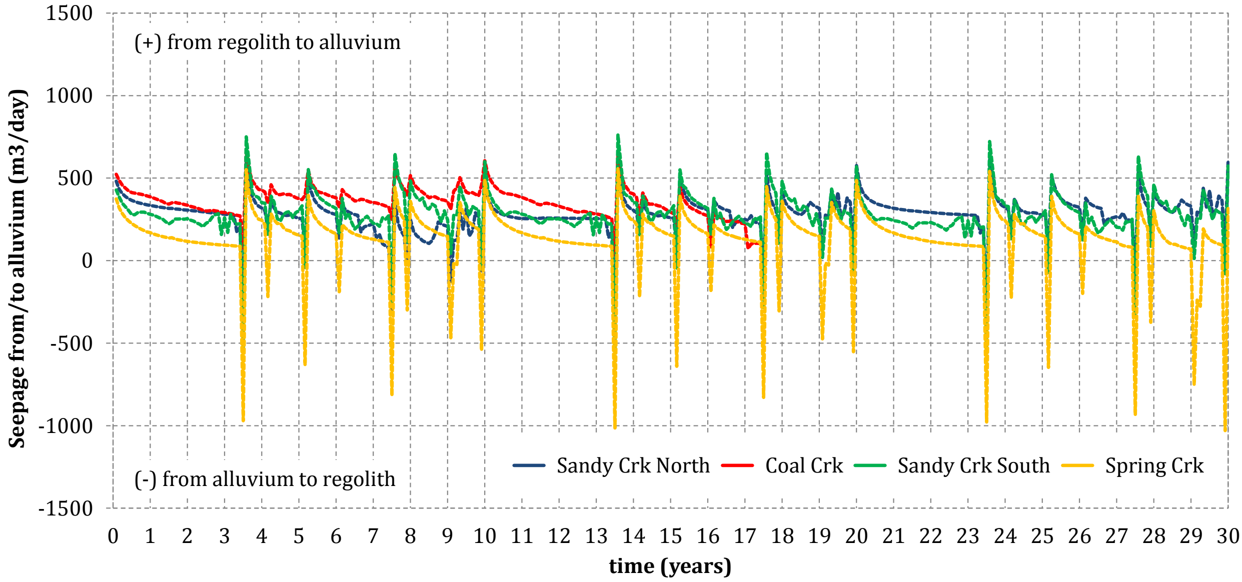


Figure C 23 Transient flow rates for alluvial zones

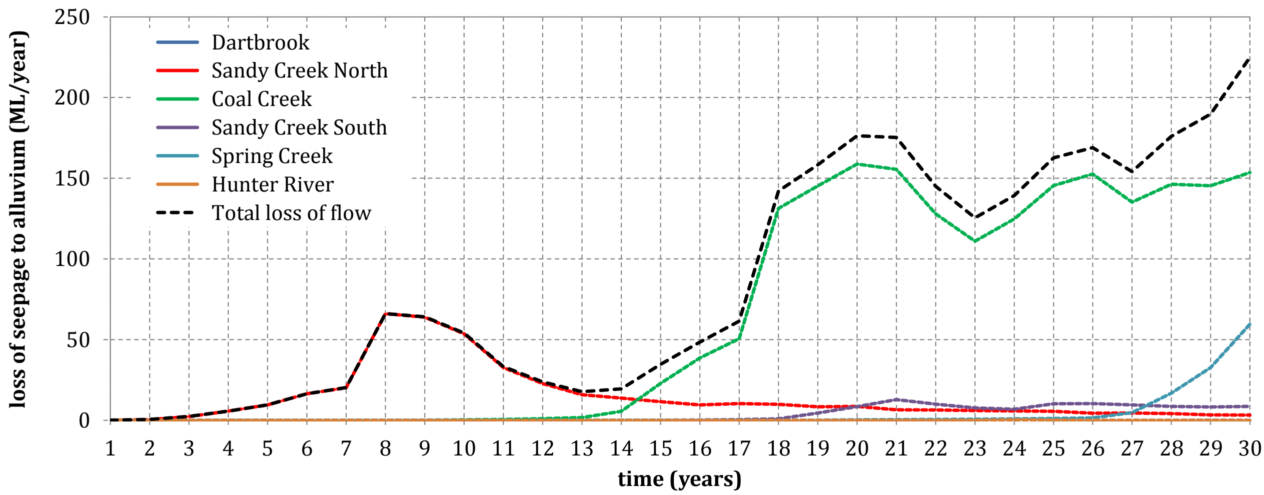


Figure C 24 Loss of recharge into alluvium due to mining

Table C 17 Summary of loss of recharge rates into affected alluvial zones

	Min (m3/day)	1st quartile (m3/day)	Mean (m3/day)	3rd quartile (m3/day)	Max (m3/day)
Sandy Creek North	0.28	13.11	39.45	41.96	180.91
Coal Creek	0.00	0.14	254.78	398.93	434.70
Sandy Creek South	0.00	0.00	14.75	25.56	35.00
Spring Creek *)	0.00	0.00	29.78	29.65	163.25
Cumulative loss of recharge +)	0.28	53.89	238.75	430.49	615.84

*) *Although the majority of Spring Creek alluvium is not classified as a highly productive alluvium, it was included for sake of completeness.*

+) *The statistics for the cumulative recharge losses are calculated from the cumulative value of recharge for the nominated alluvial areas and is not a simple sum of individual statistical parameters.*

1.4.5 Predictive run – drawdowns and impacted bores.

Drawdowns, calculated as a difference between 'no-mine' and 'mine' heads were calculated for layers 2, representing the unconfined weathered regolith and alluvial aquifers and layer 9, representing the deepest coal seam mined within the Project area. 1 m and 2 m contours of cumulative drawdown were then used to select bores impacted by the mining activity. In total, 37 bores were impacted by mining.

Table C 18 Bores impacted by drawdown greater than 1 m

Bore	Easting	Northing	Model layer	Max draw-down (m)	Max drawdown date	Mined out	HPA	PAA
GOW01	286554.4	6430771.2	1	4.1	28 years, 12 months	no	no	no
GW016279	288584.1	6434625.0	1	13.3	17 years, 5 months	yes	yes	yes
GW022292	289217.7	6434391.7	1	16.7	18 years, 11 months	yes	yes	yes
GW032889	290775.4	6433807.7	1	11.0	17 years, 7 months	yes	yes	yes
GW052617	289781.1	6433756.3	1	14.1	19 years, 11 months	yes	yes	yes
GW078457X	289728.7	6433755.2	1	14.1	19 years, 11 months	yes	yes	yes
GW200257	290635.5	6432950.7	1	9.7	20 years, 12 months	yes	yes	yes
ING01	286632.4	6429549.5	1	2.7	29 years, 1 month	no	no	no
JEN01	286639.9	6429854.8	1	4.1	29 years, 1 month	no	no	no
PIT1	291243.6	6437765.2	1	1.7	8 years, 12 months	no	yes	yes
PIT2	291337.6	6437735.4	1	2.0	8 years, 12 months	no	yes	yes
ROS01	291189.0	6437830.0	1	1.8	8 years, 12 months	no	yes	yes
SPAR2	289994.5	6433498.0	1	18.6	19 years, 11 months	yes	yes	yes
SPAR5	289875.9	6433546.7	1	16.0	19 years, 11 months	yes	yes	yes
WEK2	288753.6	6434415.6	1	16.9	18 years, 7 months	yes	yes	yes
WEK3	288701.4	6434592.8	1	18.6	17 years, 8 months	yes	yes	yes

Bore	Easting	Northing	Model layer	Max draw-down (m)	Max drawdown date	Mined out	HPA	PAA
GW011315	293175.4	6435582.6	2	2.1	23 years, 8 months	no	no	no
GW024558	289109.7	6434543.5	2	17.7	17 years, 7 months	yes	yes	yes
GW025631	288674.7	6436034.7	2	1.6	16 years, 1 month	no	yes	yes
GW029518	293482.3	6434664.5	2	1.9	23 years, 9 months	no	no	no
GW037914	287239.7	6430036.3	2	10.9	29 years, 10 months	no	no	no
GW038412	291506.7	6437736.1	2	2.6	9 years, 1 month	no	yes	yes
GW057443X	292938.7	6431787.7	2	1.1	23 years, 8 months	no	no	no
GW057600X	293230.8	6432872.2	2	1.9	23 years, 8 months	no	no	no
GW078471	291577.2	6436442.1	2	4.4	9 years, 1 month	yes	no	yes
ROS2	290848.4	6437830.8	2	3.1	8 years, 12 months	yes	no	yes
SPAR1	291428.6	6433506.5	2	5.9	21 years, 3 months	no	yes	yes
SPAR3	291439.7	6433548.5	2	5.8	21 years, 4 months	no	yes	yes
SPAR4	290210.3	6433732.9	2	15.5	19 years, 1 month	yes	yes	yes
WILCROW01	290912.9	6438672.7	2	1.1	9 years, 4 months	no	no	yes
WYL1	291169.5	6438494.8	2	5.2	9 years, 12 months	yes	no	yes
DAY1	292850.4	6441989.5	5	11.6	3 years, 1 month	no	no	yes
DOR01	290386.4	6438064.9	5	37.3	9 years, 1 month	no	no	yes
GW026995	287862.7	6432791.8	5	66.8	24 years, 4 months	yes	no	yes
GW033267	292046.3	6442091.9	5	12.9	4 years, 5 months	no	no	yes
GW200213	290444.4	6438126.0	5	37.1	9 years, 1 month	no	no	yes
GW200214	290518.1	6438166.9	5	37.7	9 years, 1 month	no	no	yes

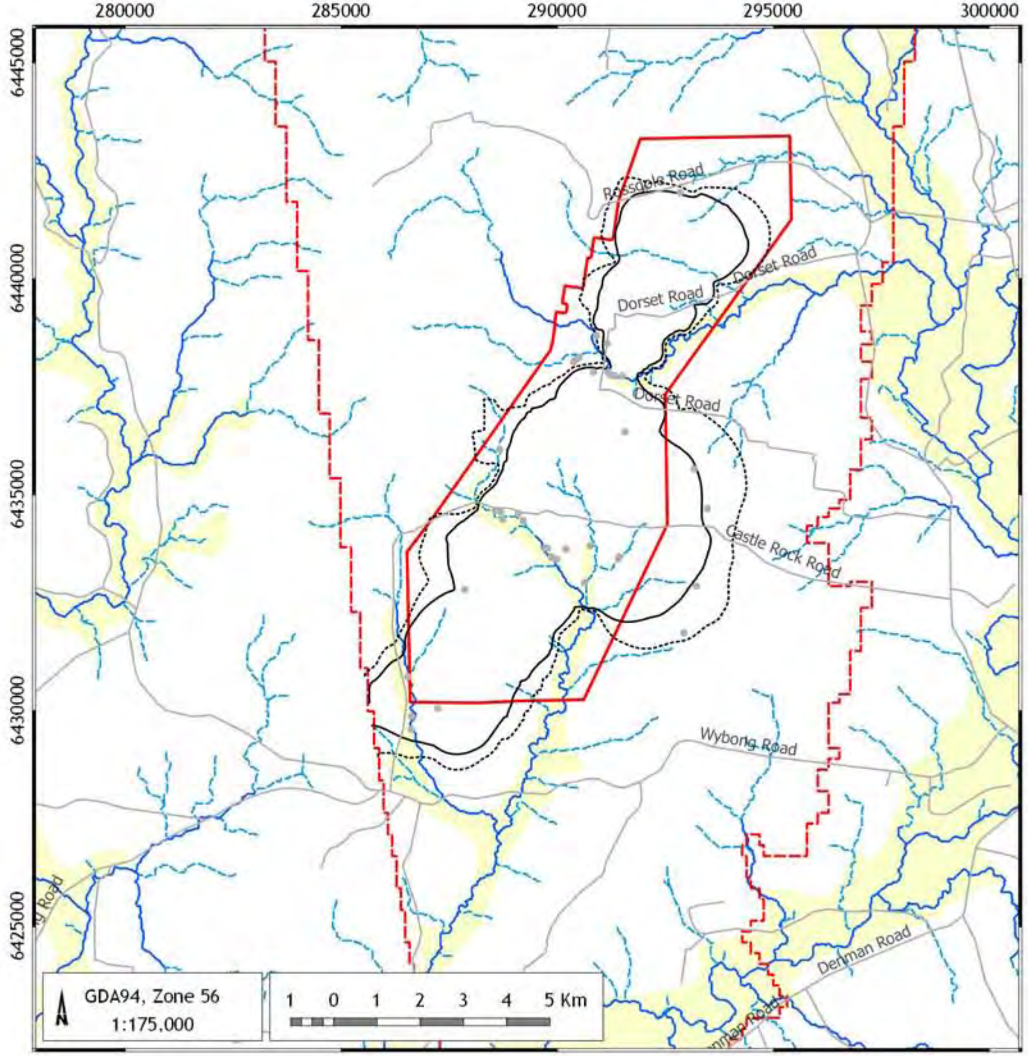
Note: PAA – Project Assessment Area, HPA – Highly productive aquifer

Out of these, 16 bores lie within the footprint of the mine and will be destroyed and 21 bores lie outside of the mine footprint and will be likely impacted by drawdown. 19 of the 37 bores are located in the highly productive aquifer (HPA) and 29 of the bores lie within the PAA. List of impacted bores is presented in Table C 18 and each of the impacted bores is shown on the map of the cumulative drawdown for layers 2 and 9 (Figure C 25).

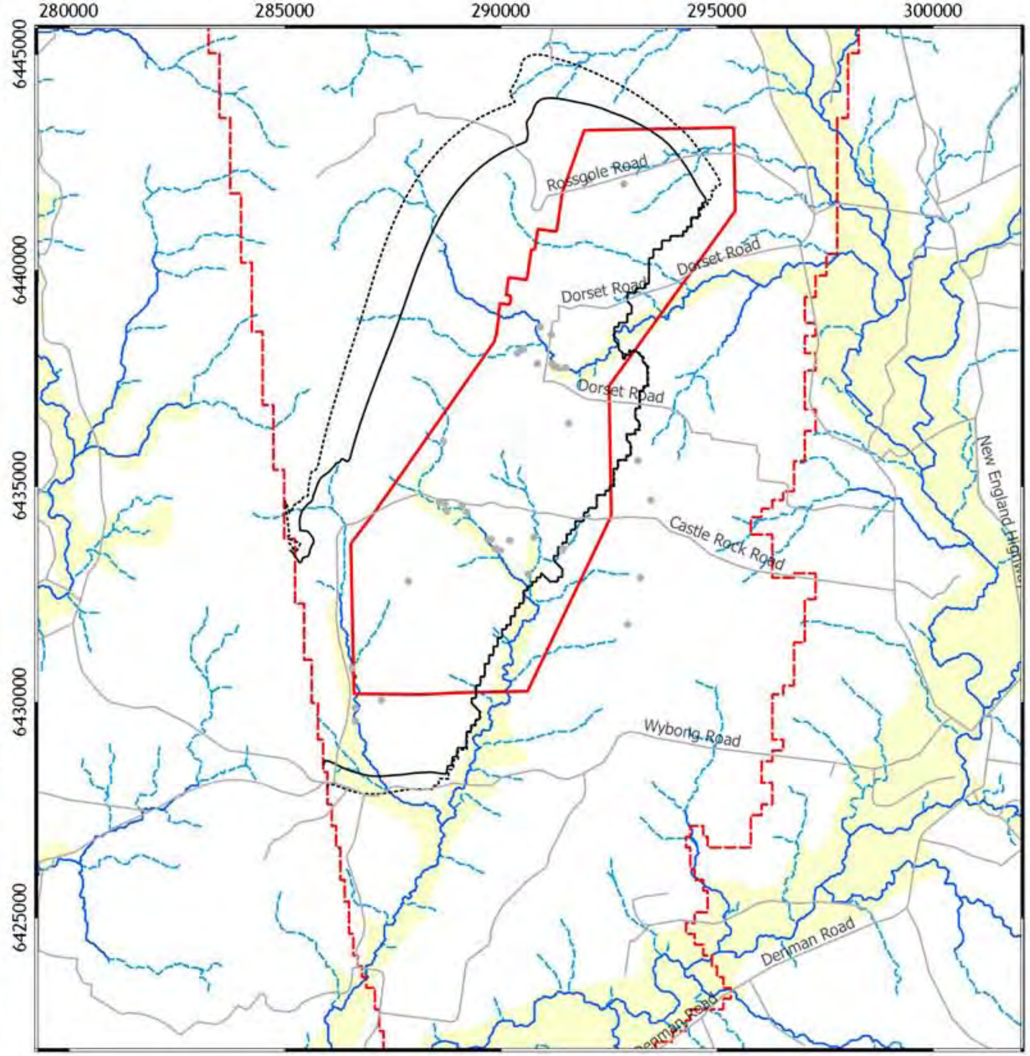
The time progression of drawdown is shown on series of the drawdown maps (again presented for model layers 2 and 9) for mining years 3 (the Blakefield seam is initially mined), year 10 (mining reaches Sandy Creek North, mining south of the Sandy Creek North alluvium starts), year 20 (Sandy Creek South alluvium was mined, approximately half way through southern pit) and year 30 (end of mining). Drawdown contours are presented in Figure C 26 to Figure C 29.

Figure 30 shows hydrographs of when predicted drawdowns will occur at private bores outside the mine footprint.

Cumulative drawdown - alluvium/weathered regolith (L01-02)



Cumulative drawdown - Permian coal seams (L05-11)



LEGEND

- Project Assessment Area
- Active model grid outline (Project Area)
- Predicted bores affected by drawdown layer
- 1m contour
- 2m contour
- Streams - minor / ephemeral
- Streams - main
- Alluvium unconsolidated (Qa)

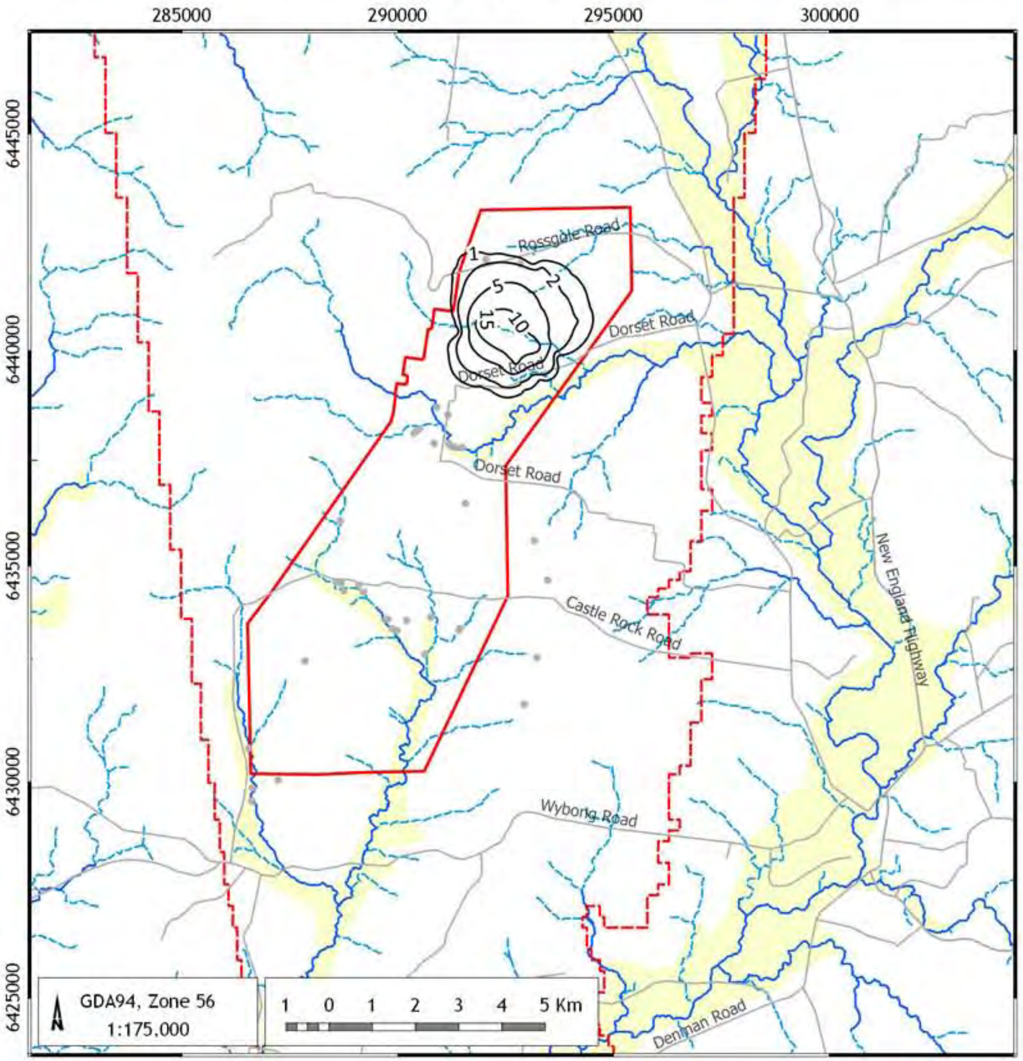
West Muswellbrook (G1676)

Cumulative drawdown
Model layers L01-L11

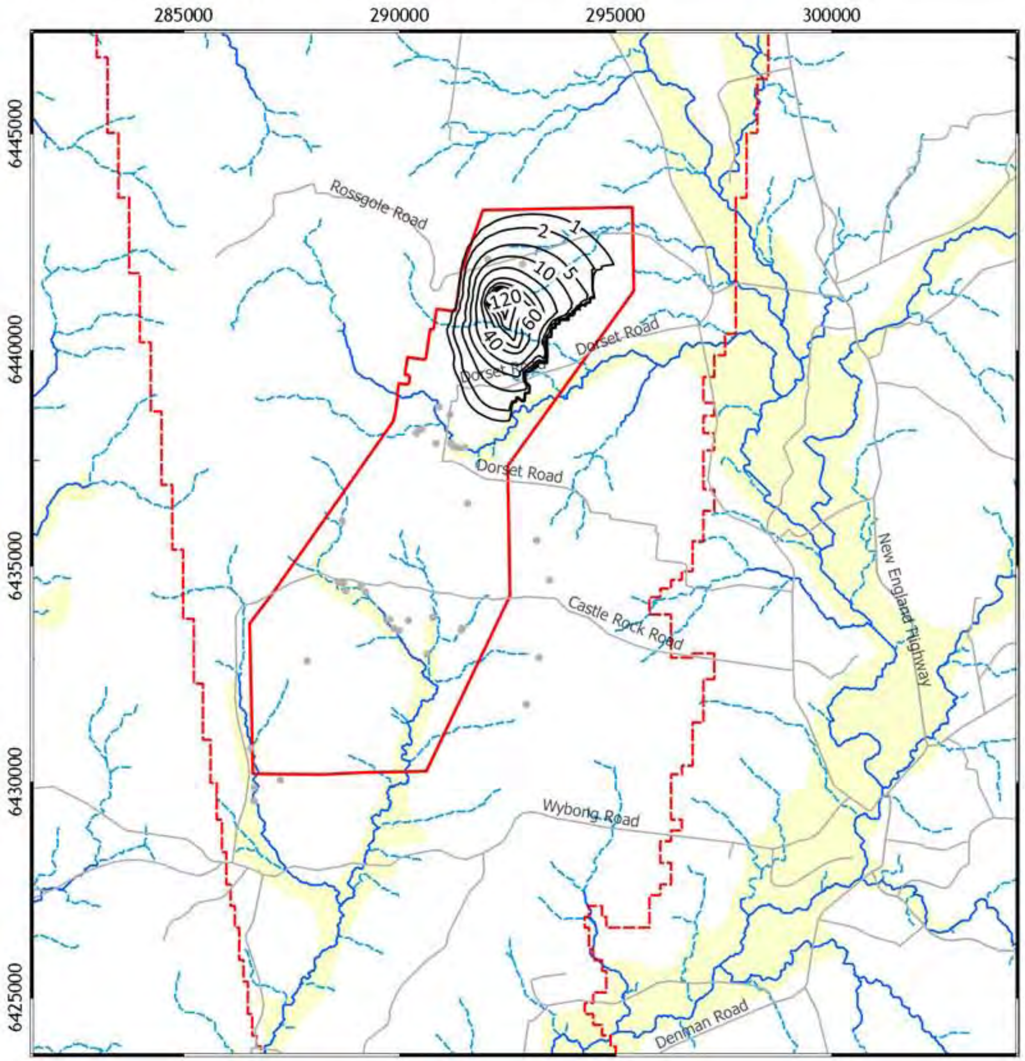
DATE
8/10/2014

FIGURE No:
C-25

Drawdown Y03 - alluvium/weathered regolith (L02)



Drawdown Y03 - Permian coal seams (L09)



LEGEND

- Project Assessment Area
- Active model grid outline (Project Area)
- Predicted bores affected by drawdown layer
- Contours
- Streams - minor / ephemeral
- Streams - main
- Alluvium unconsolidated (Qa)

West Muswellbrook (G1676)

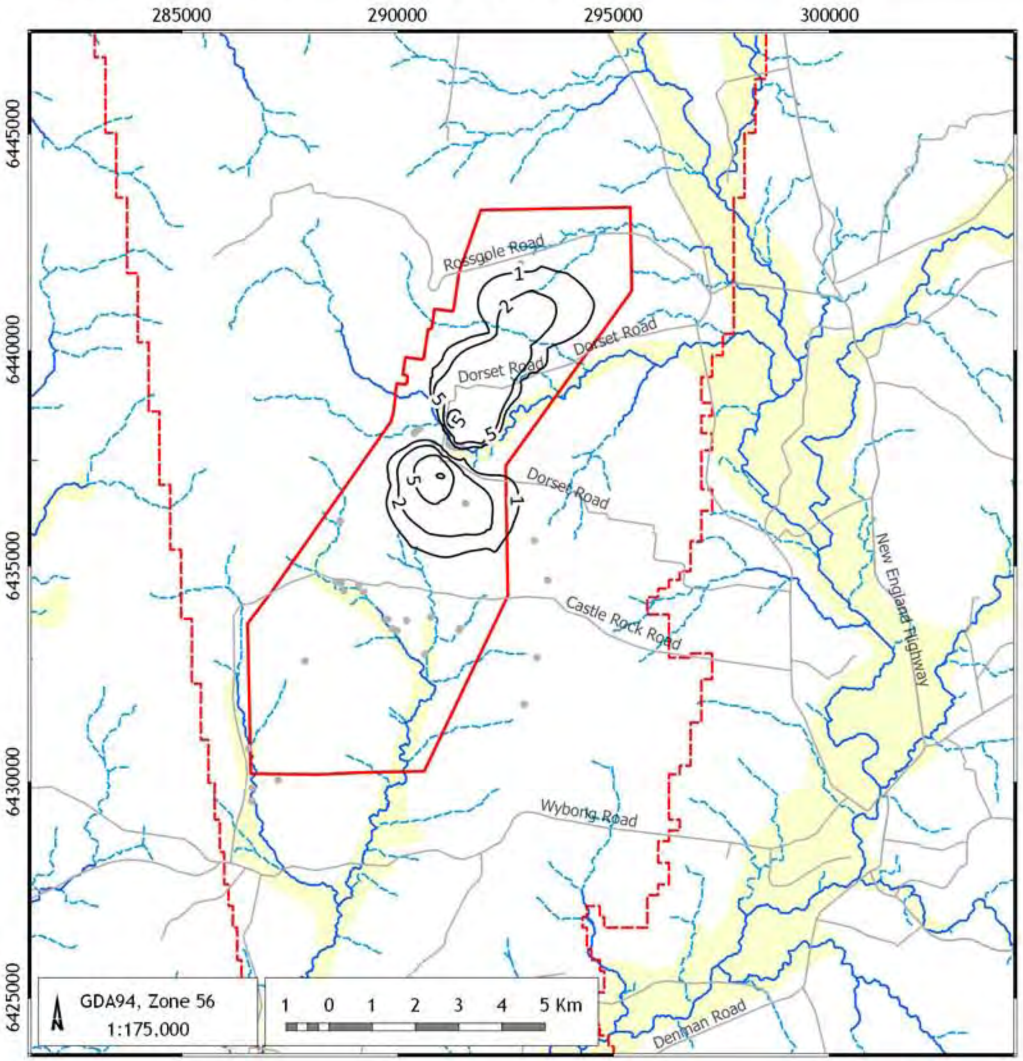
GROUNDWATER & ENVIRONMENTAL

Drawdown - year 3

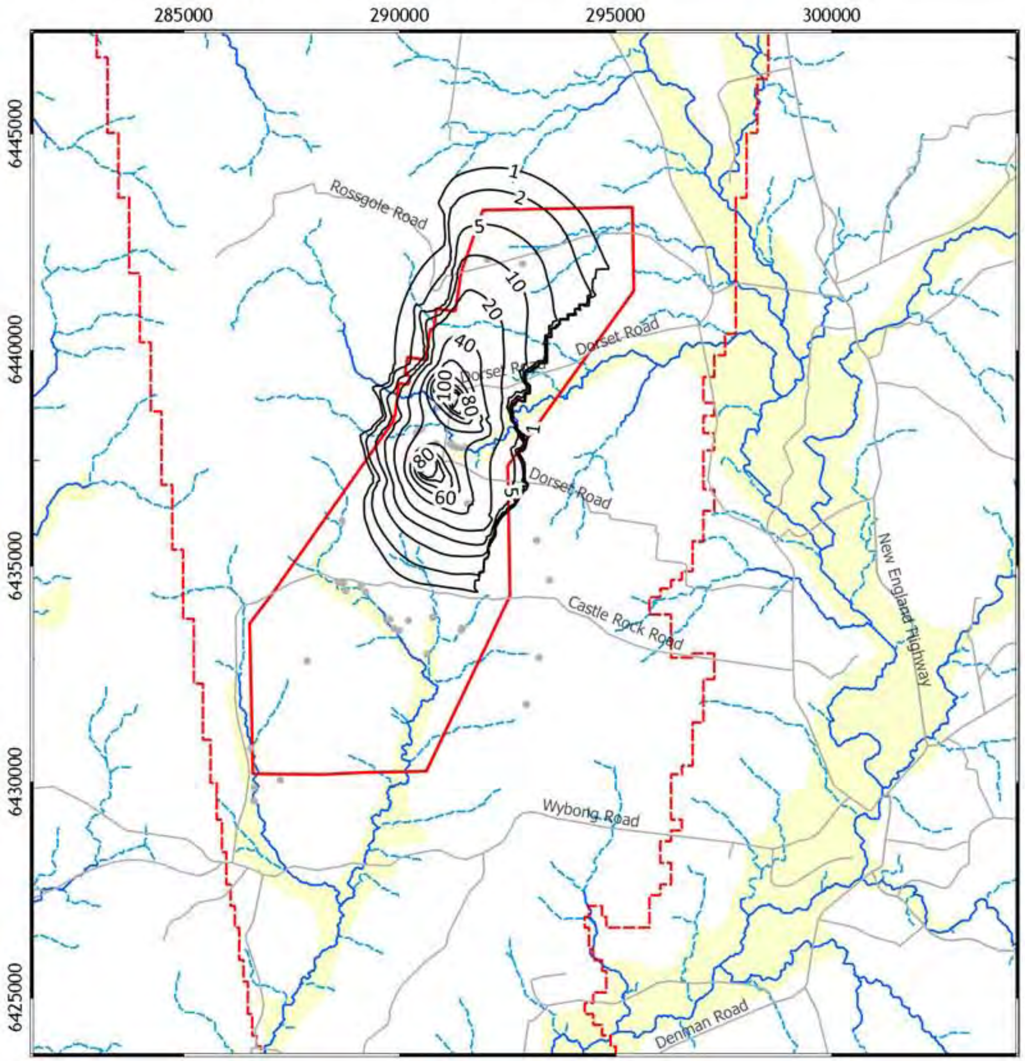
DATE
8/10/2014

FIGURE No:
C-26

Drawdown Y10 - alluvium/weathered regolith (L02)



Drawdown Y10 - Permian coal seams (L09)



LEGEND

- Project Assessment Area
- Active model grid outline (Project Area)
- Predicted bores affected by drawdown layer
- Contours
- Streams - minor / ephemeral
- Streams - main
- Alluvium unconsolidated (Qa)

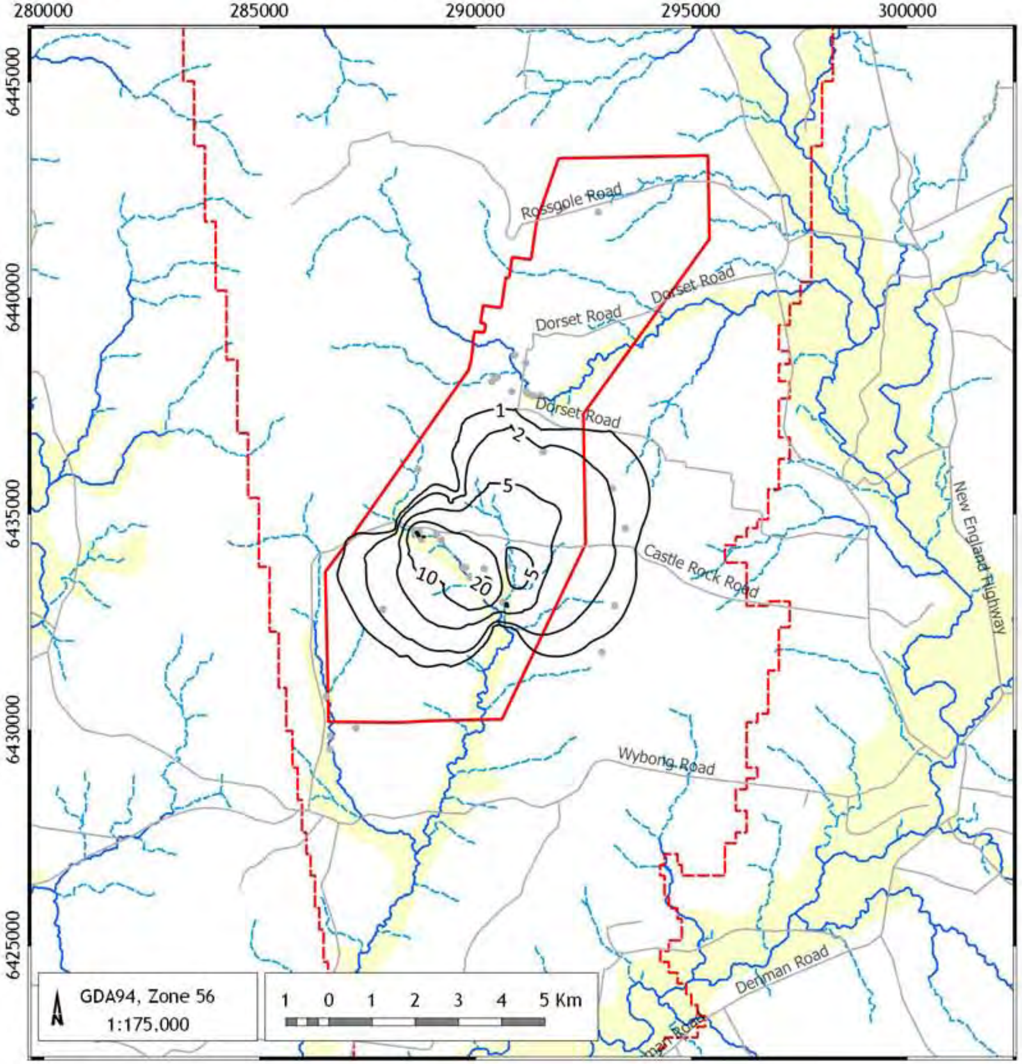
West Muswellbrook (G1676)

Drawdown - year 10

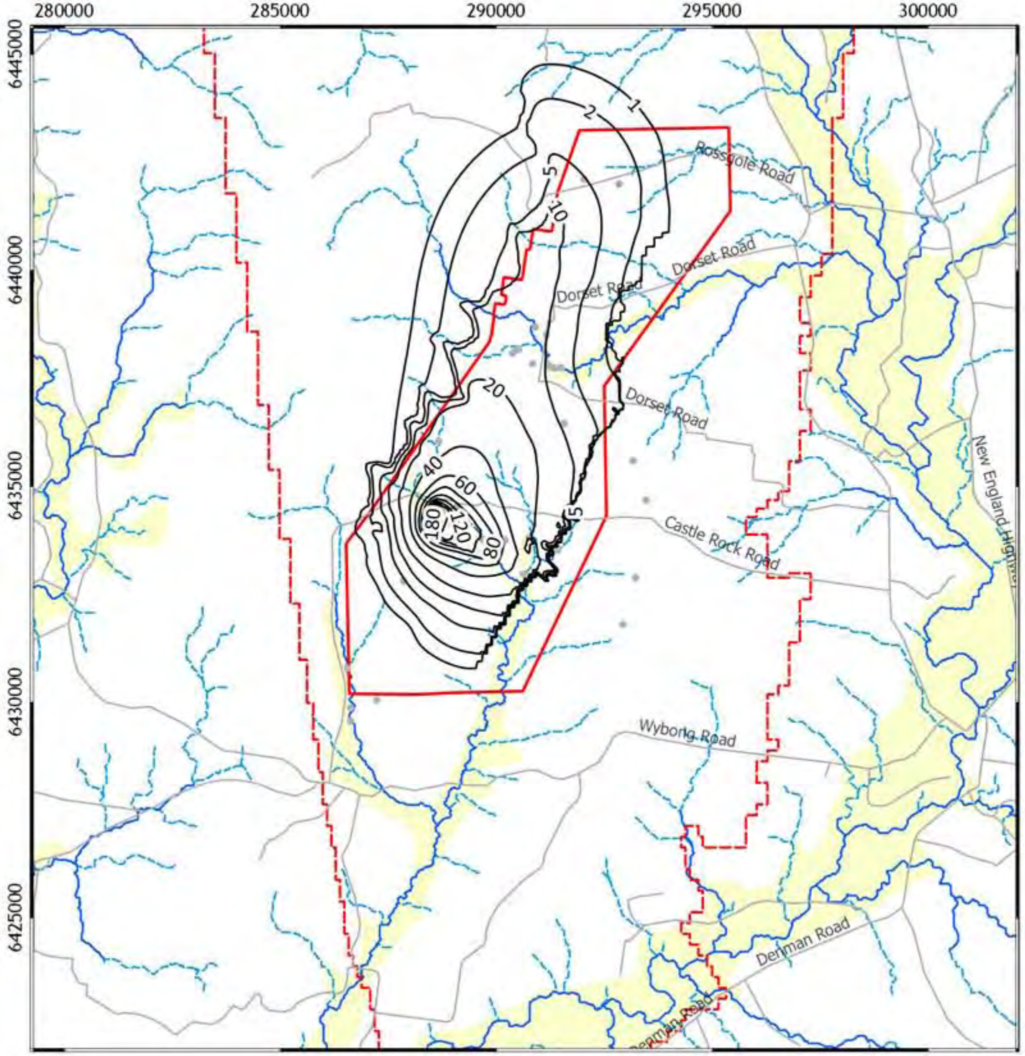
DATE
8/10/2014

FIGURE No:
C-27

Drawdown Y20 - alluvium/weathered regolith (L02)



Drawdown Y20 - Permian coal seams (L09)



LEGEND

- Project Assessment Area
- Active model grid outline (Project Area)
- Predicted bores affected by drawdown layer
- Contours
- Streams - minor / ephemeral
- Streams - main
- Alluvium unconsolidated (Qa)

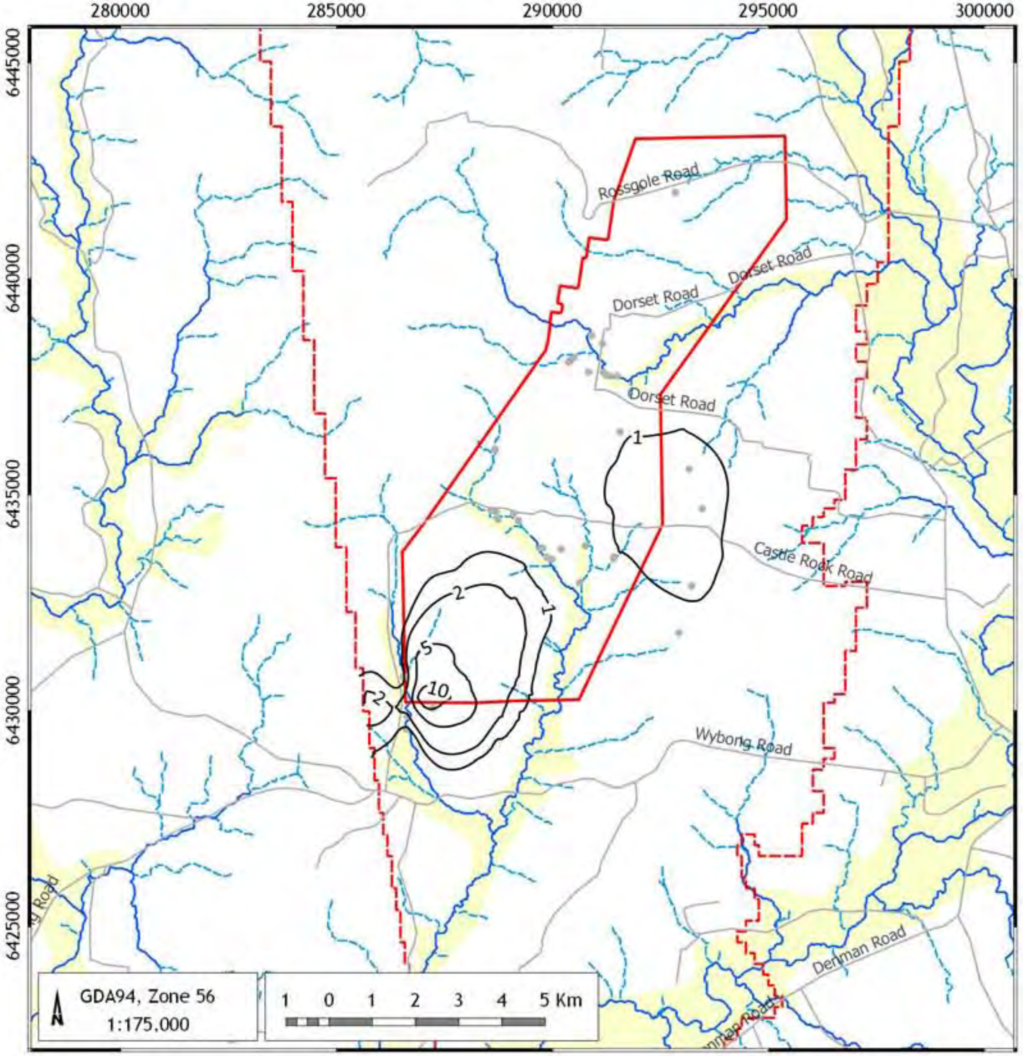
West Muswellbrook (G1676)

Drawdown - year 20

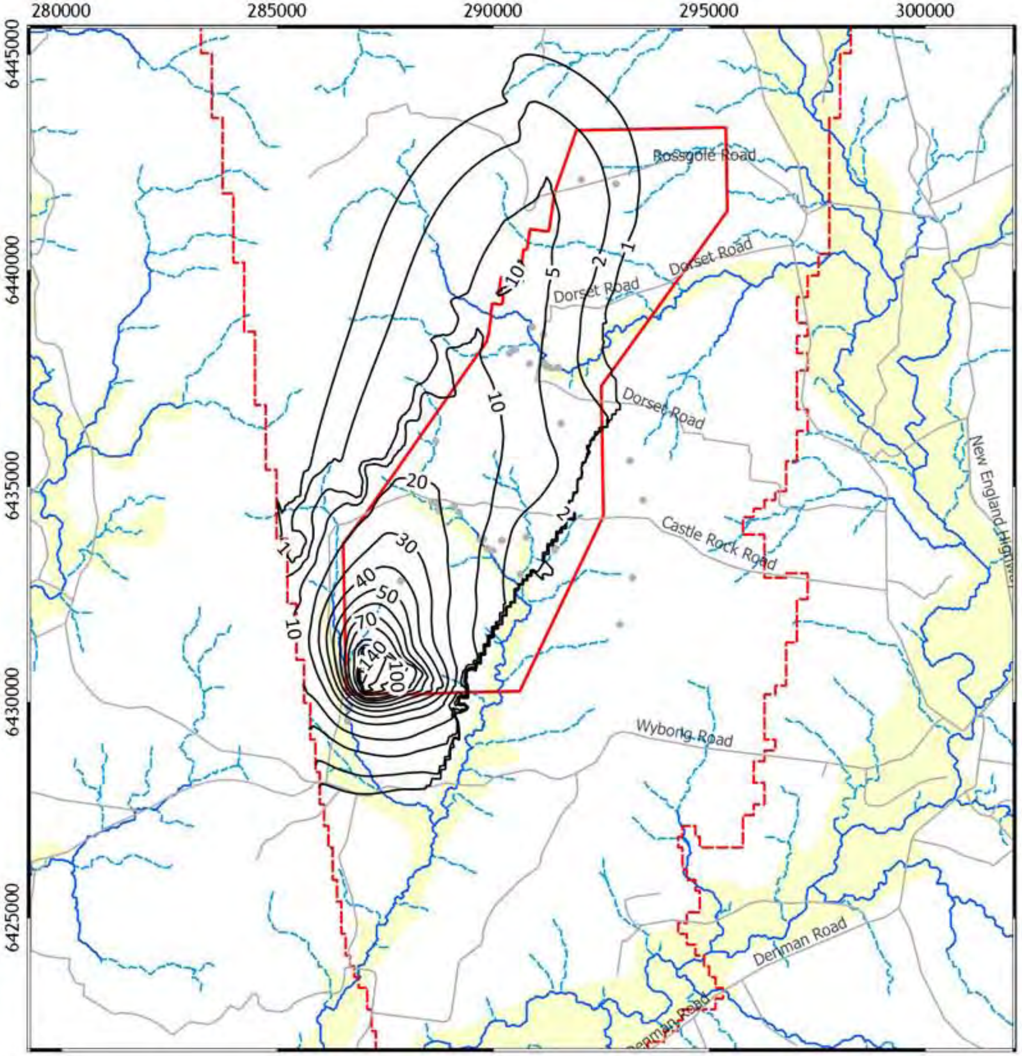
DATE
8/10/2014

FIGURE No:
C-28

Drawdown Y30 - alluvium/weathered regolith (L02)



Drawdown Y30 - Permian coal seams (L09)



LEGEND

- Project Assessment Area
- Active model grid outline (Project Area)
- Predicted bores affected by drawdown layer
- Contours
- Streams - minor / ephemeral
- Streams - main
- Alluvium unconsolidated (Qa)

West Muswellbrook (G1676)

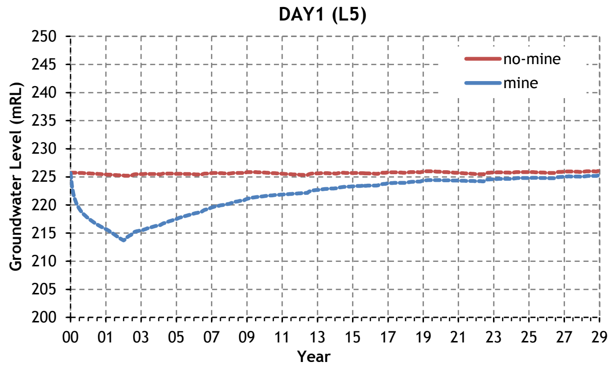
Drawdown - year 30, end of mining

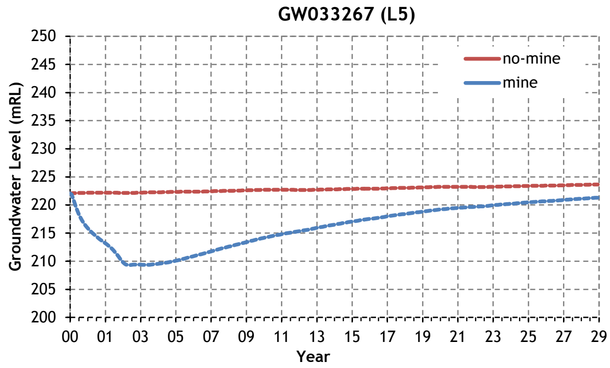
DATE
8/10/2014

FIGURE No:
C-29

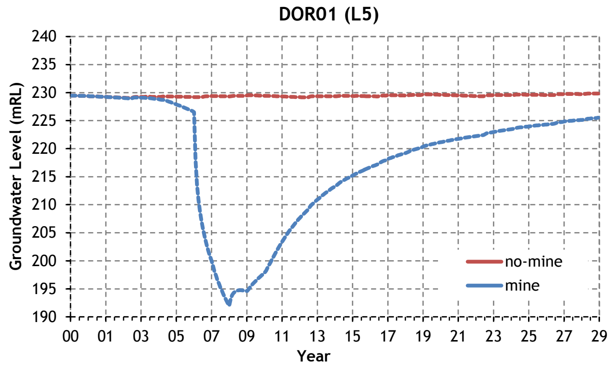
Figure C 30 Hydrographs – drawdowns on affected bores outside of mine footprint (below)

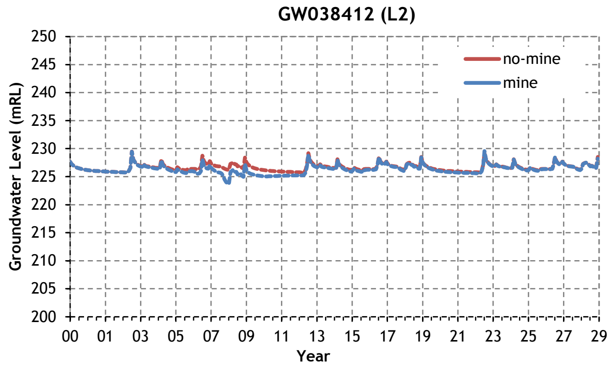
Rossgole Rd.

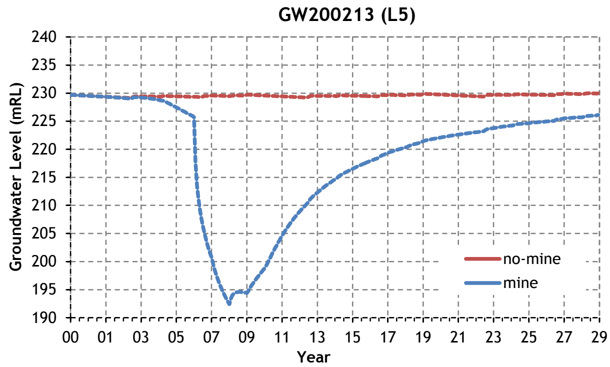


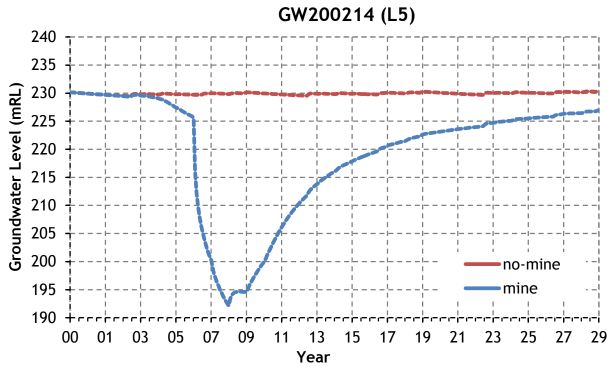


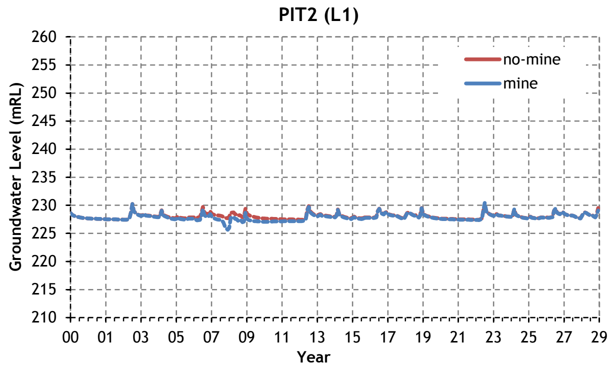
Sandy Ck. North



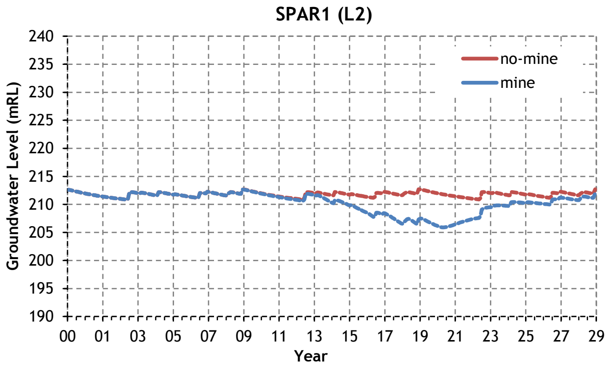


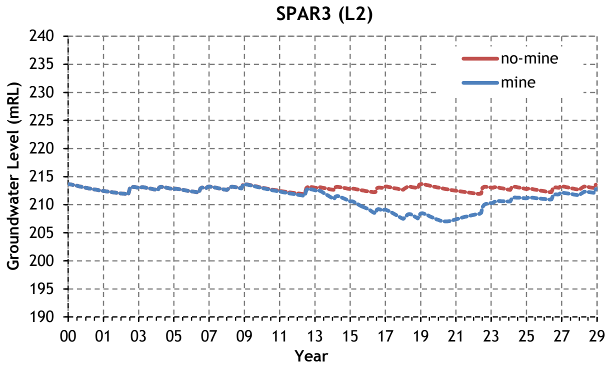




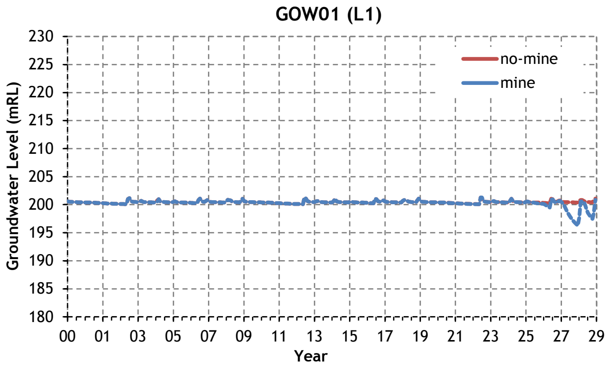


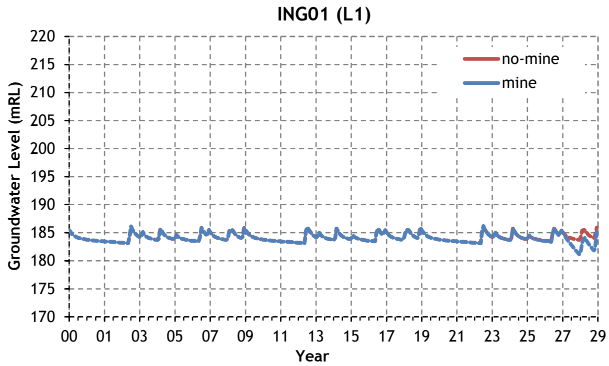
Coal Creek

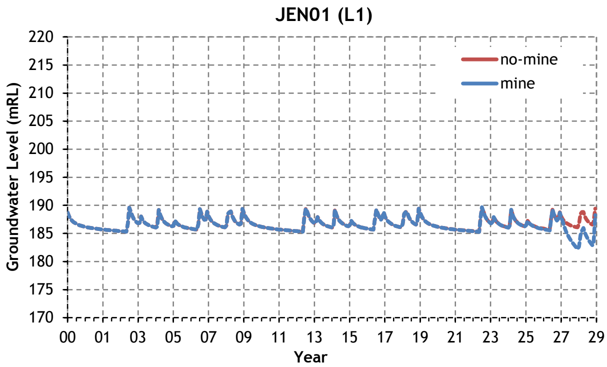




Spring Creek







Weathered regolith east of Blakefield seam subcrop: