ENVIRONMENTAL ASSESSMENT

Duralie Extension Project

APPENDIX A

SURFACE WATER ASSESSMENT

GLOUCESTER COAL

ResourceStrategies

HYDROLOGY AND WATER MANAGEMENT CONSULTANTS

Gilbert & Associates Pty Ltd

APPENDIX A

DURALIE EXTENSION PROJECT

Surface Water Assessment

Prepared for: **Duralie Coal Pty Ltd**

Jan-10
AppA_D.doc

PO Box 2057
Milton, Qld. 4064

Tel: (07) 3367 2388
Fax: (07) 3367 2833

A.C.N 085 419 852
A B N 62 085 419 852

CONTENTS Page

TABLES

FIGURES

PLATES

ATTACHMENTS

A1.0 INTRODUCTION

Duralie Coal Pty Ltd (DCPL) is the owner and operator of the Duralie Coal Mine (DCM). DCPL is a wholly owned subsidiary of Gloucester Coal Ltd (GCL). The DCM is located approximately 10 kilometres (km) north of the village of Stroud and approximately 20 km south of Stratford in the Gloucester Valley in New South Wales (NSW) (Figure A-1). Another GCL subsidiary, Stratford Coal Pty Ltd, owns and operates the Stratford Coal Mine, which is located some 20 km to the north of the DCM.

The Duralie Extension Project (the Project) would be an extension of the DCM and would involve open pit mining at a rate of up to 3 million tonnes per annum (Mtpa). It would also require the development of supporting infrastructure and modifications to some existing infrastructure.

The Project is described in detail in Section 2 in the Main Report of the Environmental Assessment (EA). Figures A-2 to A-6 show the general arrangements of the Project in Years 1, 3, 5 and 8 and at the end of the Project life, respectively.

This surface water assessment report has been compiled in support of the Project EA and draws on the findings of other studies including the results of groundwater modelling contained in the groundwater assessment undertaken by Heritage Computing (2009) (Appendix B of the EA), and the geochemical information in the geochemistry assessment undertaken by Environmental Geochemistry International Pty Ltd (EGi) (2009) (Appendix I of the EA).

A1.1 Study Requirements and Scope

This assessment has been prepared in accordance with the Director-General's Environmental Assessment Requirements (EARs) for the Project (issued by the NSW Department of Planning, 5 November 2009). In relation to surface water, the EARs require:

> ***Surface and Ground Water** – including:*
>
> - *detailed modelling of potential surface and ground water impacts of the project*
> - *a site water balance, salinity balance, and assessment of the suitability of minewater for irrigation use;*
> - *a detailed description of proposed final voids and their management; and*
> - *a detailed assessment (environmental, hydrogeological, and geomorphic) of the proposed final alignment of Coal Shaft Creek;*

The groundwater components of the assessment are provided separately in the groundwater assessment prepared by Heritage Computing (Appendix B of the EA).

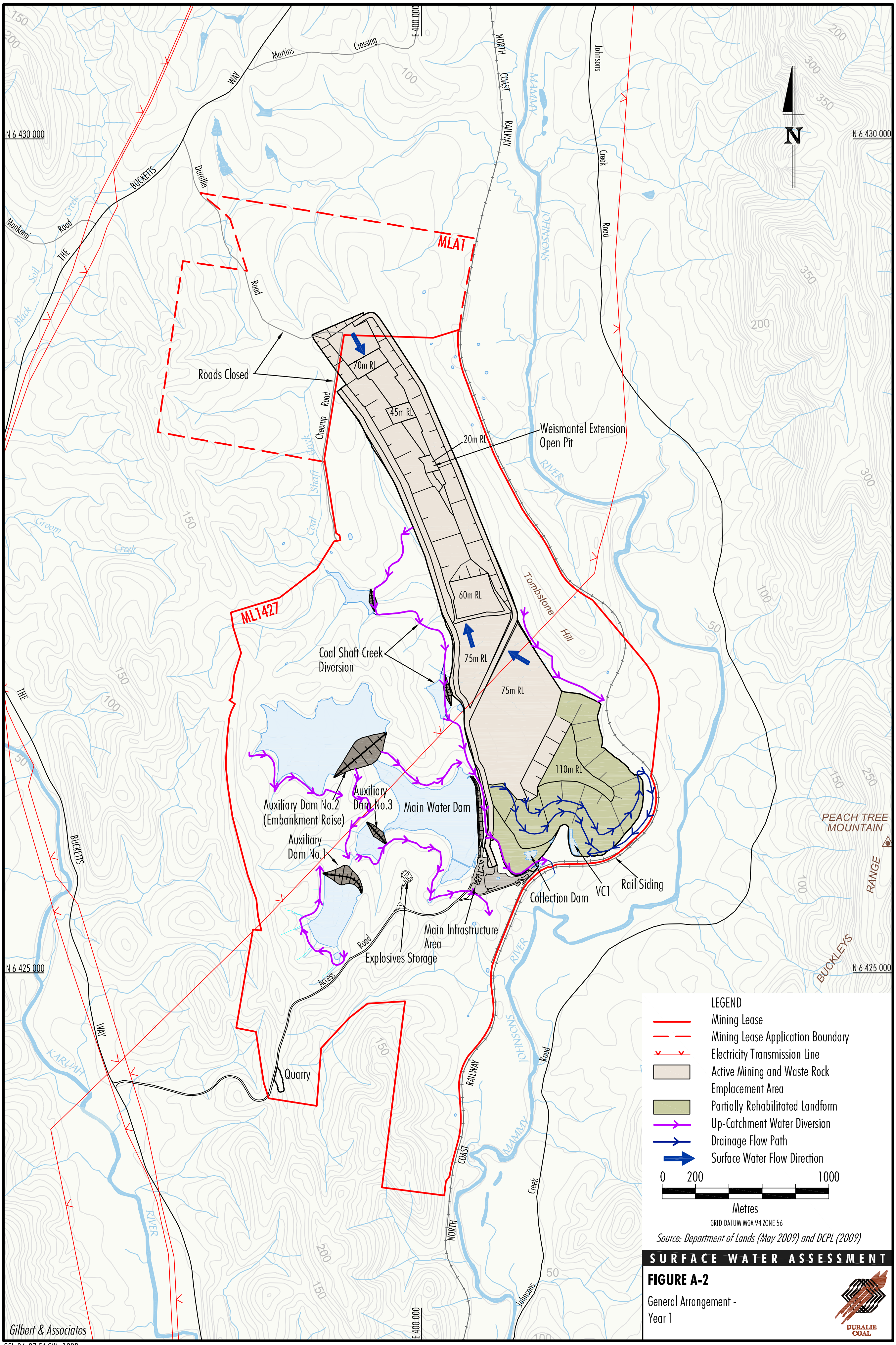
As part of the assessment process an environmental risk assessment was undertaken by SP Solutions (2009) (Appendix M of the EA). This included a facilitated, risk based workshop involving experts across a range of disciplines and experienced DCPL personnel. The objective of the assessment was to identify key potential environmental issues for inclusion in the EA. The following key potential surface water related issue were identified:

- Uncontrolled spill from the Main Water Dam (MWD) or Auxiliary Dams to Mammy Johnsons River during mine life.
- Spill of poor quality water from the final voids.

FIGURE A-1

Regional Location

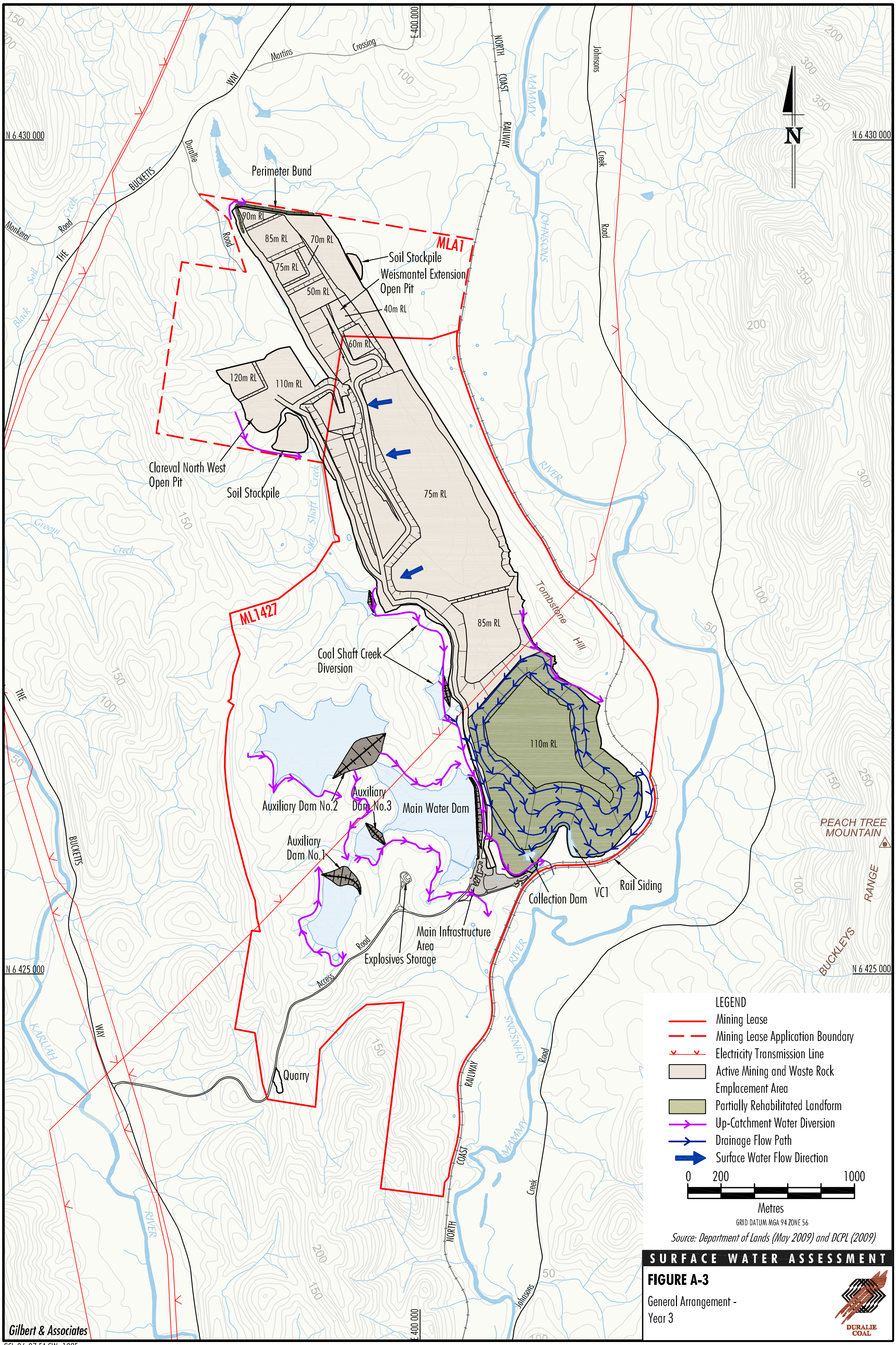
GCL-06-07 EA SW_104C



SURFACE WATER ASSESSMENT

FIGURE A-2

General Arrangement -
Year 1

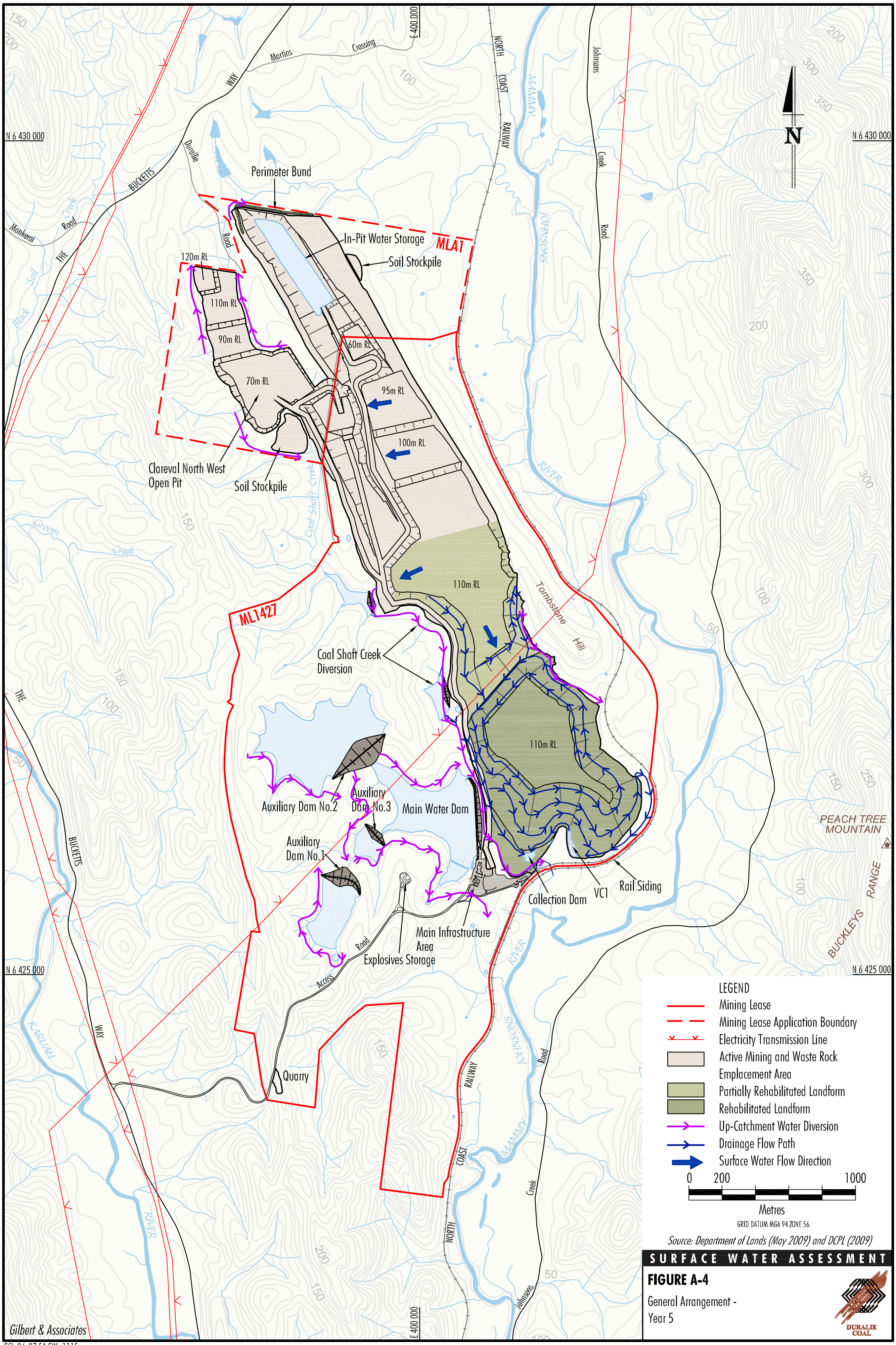


SURFACE WATER ASSESSMENT

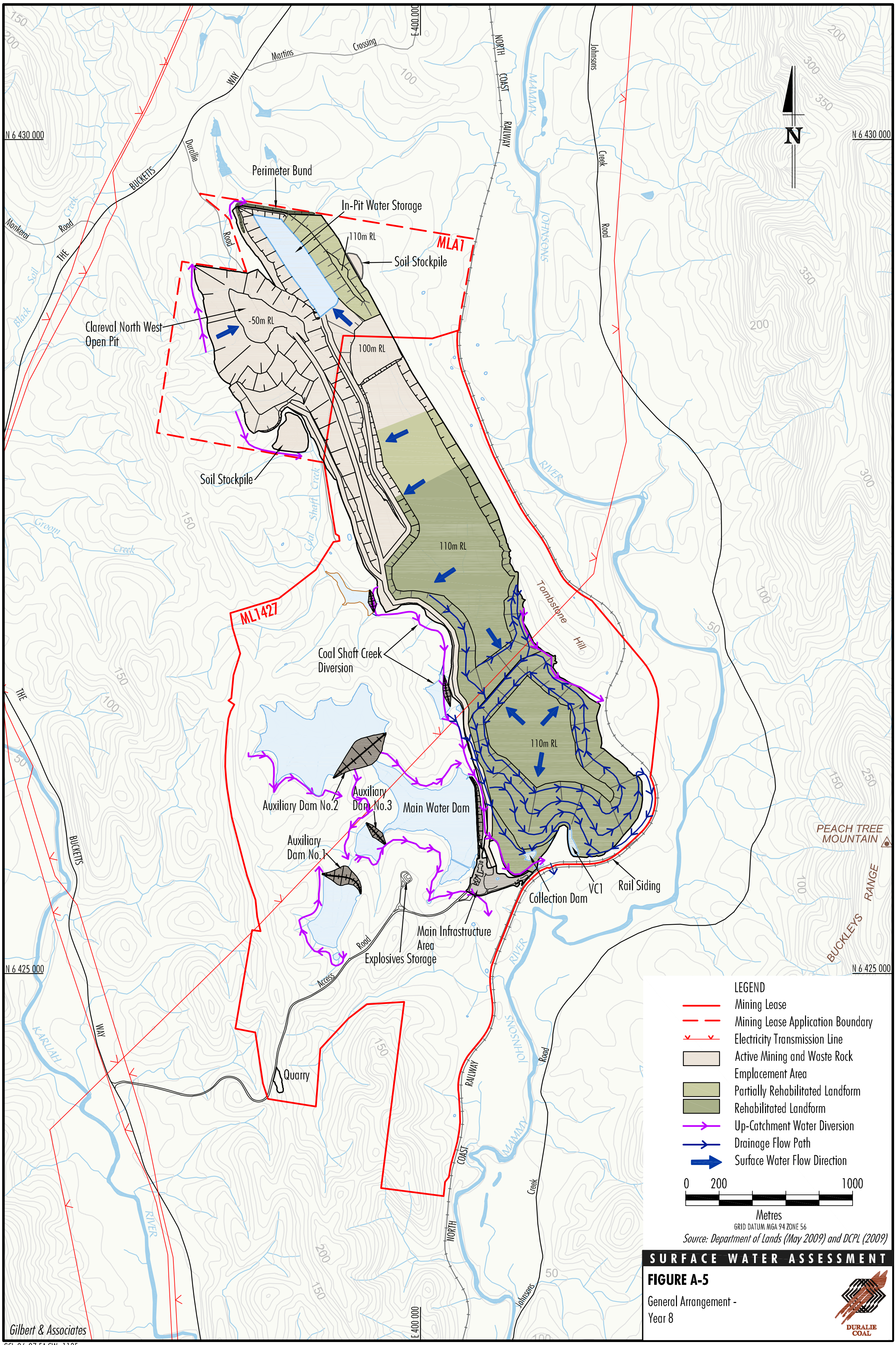
FIGURE A-3

General Arrangement -
Year 3

GCL-06-07 EA SW_109E



Perimeter Bund
In-Pit Water Storage
MLA1
Soil Stockpile
120m RL
110m RL
90m RL
60m RL
70m RL
95m RL
100m RL
Clareval North West
Open Pit
Soil Stockpile
110m RL
ML1427
Coal Shaft Creek
Diversion
110m RL
Auxiliary Dam No.2
Auxiliary
Dam No.3
Main Water Dam
Auxiliary
Dam No.1
Main Infrastructure
Area
Explosives Storage
Collection Dam
VC1
Rail Siding
Quarry
Tombstone Hill
PEACH TREE
MOUNTAIN
BUCKLEYS RANGE
N 6 430 000
N 6 425 000
E 400 000
N
LEGEND
Mining Lease
Mining Lease Application Boundary
Electricity Transmission Line
Active Mining and Waste Rock
Emplacement Area
Partially Rehabilitated Landform
Rehabilitated Landform
Up-Catchment Water Diversion
Drainage Flow Path
Surface Water Flow Direction
0
200
1000
Metres
GRID DATUM MGA 94 ZONE 56
Source: Department of Lands (May 2009) and DCPL (2009)
SURFACE WATER ASSESSMENT
FIGURE A-4
General Arrangement -
Year 5
DURALIE COAL
Gilbert & Associates



SURFACE WATER ASSESSMENT

FIGURE A-5

General Arrangement - Year 8

GCL-06-07 EA SW_113E

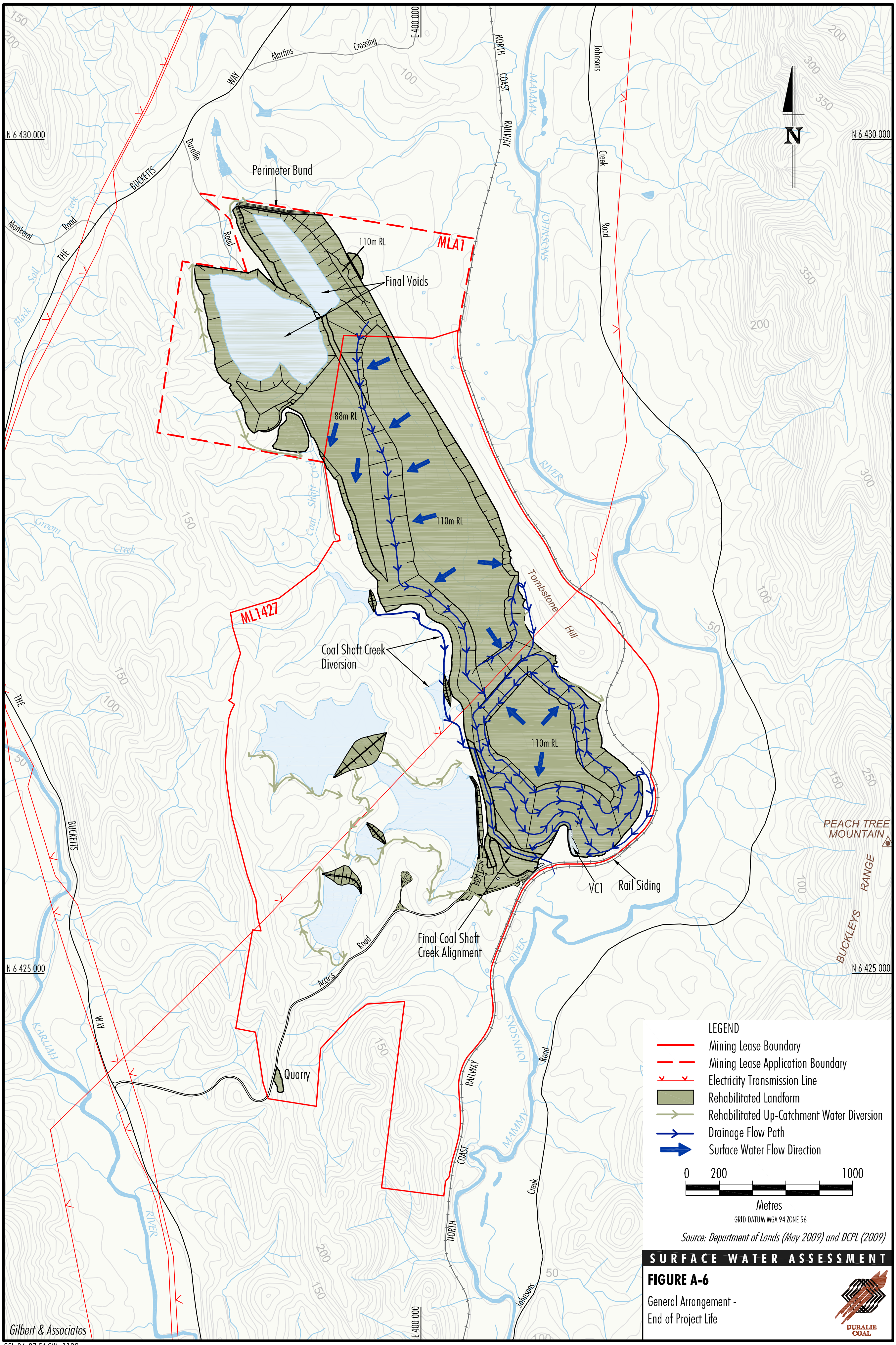


FIGURE A-6
General Arrangement - End of Project Life

GCL-06-07 EA SW_1126

- Re-mobilised irrigated solutes from irrigation areas reaching Mammy Johnsons River.
- Additional water storage – construction timing and adequacy of additional storage capacity to contain water on-site.
- Poor quality runoff from waste rock emplacement reaching Mammy Johnsons River.
- Seepage of poor quality water from final void through waste rock emplacement to Coal Shaft Creek/Mammy Johnsons River.
- Loss of base flow from Mammy Johnsons River.

The surface water assessment has been compiled to address the EARs; issues raised by government agencies during the consultation process; and the surface water related issues identified in the environmental risk assessment. A number of key guidelines have also been used as a basis for assessing impacts in this report including:

- National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand [ANZECC/ARMCANZ], 2000a).

  The surface water quality monitoring results from the existing DCM and surrounding areas have been compared to these guidelines where appropriate (Section A2.5 and Attachment AA).

- National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b).

  The surface water quality monitoring programme developed for the Project would be conducted in accordance with these guidelines (Section A8.2).

- Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (Department of Environment and Conservation [DEC], 2004).

  The surface water quality monitoring programme developed for the Project would be conducted in accordance with these guidelines (Section A8.2).

- Using the ANZECC Guideline and Water Quality Objectives in NSW (DEC, 2006a).

  The Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a) have been applied in accordance with this guideline including consideration of the NSW Government Water Quality and River Flow Environmental Objectives (DEC, 2006b).

- State Water Management Outcomes Plan.

  The assessment includes consideration of the policy developed under the State Water Management Outcomes Plan and the *Water Management Act, 2000*, including the *Water Sharing Plan for the Karuah River Water Source, 2003* (Section A2.6).

- NSW Government Water Quality and River Flow Environmental Objectives (DEC, 2006b).

  Where applicable, the Water Quality Objectives for the Karuah River have been compared to surface water quality monitoring results from the existing DCM and surrounding areas (Attachment AA).

- *Water Sharing Plan for the Karuah River Water Source, 2003.*

  This plan is discussed in Section A2.6 and is addressed in the Main Report of the EA.

The following policies, guidelines and plans referenced in the EARs, have been considered and would be used where relevant:

- Managing Urban Stormwater: Soils & Construction (Landcom, 2004).

  This guideline should be used during the design and construction of sediment control and diversion structures.

- Managing Urban Stormwater: Treatment Techniques (NSW Environment Protection Authority [EPA], 1997).

  This guideline should be used during the design and construction of sediment control and diversion structures.

- Managing Urban Stormwater: Source Control (EPA, 1998).

  This guideline should be used during the design and construction of sediment control and diversion structures.

- A Rehabilitation Manual for Australian Streams (Land and Water Resources Research and Development Corporation and Cooperative Research Centre for Catchment Hydrology [LWRRDC and CRCCH, 2000]).

  This manual should be considered, where relevant during the design and establishment of post-mining alignment of Coal Shaft Creek.

- National Water Quality Management Strategy: Australian Drinking Water Guidelines 2004 (ANZECC/ARMCANZ, 2000c).

  Water collected and used on-site is not used as drinking water, therefore this guideline is not relevant to this assessment.

- Technical Guidelines: Bunding & Spill Management (NSW Department of Environment and Climate Change [DECC]).

  This guideline should be used during the design and construction of diversion structures.

- National Water Quality Management Strategy: Guidelines for Sewerage Systems - Effluent Management (ARMCANZ/ANZECC, 1997).

  This guideline should be used during the design, construction and operation of sewerage systems on-site.

- National Water Quality Management Strategy: Guidelines for Sewerage Systems - Use of Reclaimed Water (ARMCANZ/ANZECC, 2000d).

  This guideline should be used during the design, construction and operation of sewerage systems on-site.

A2.0 BASELINE HYDROLOGY

The Project is situated in the Gloucester Valley which is bounded by Buckleys Range to the east and the Linger and Die Ridge to the west. Mammy Johnsons River flows past the eastern limit of the Project area (refer Section A2.2). The area surrounding the Project has been extensively cleared for grazing on native and improved pastures, and is also used for intensive poultry farming.

There is significant topographic relief in the Project area ranging from approximately 50 metres (m AHD[1]) along the river flats of the Mammy Johnsons River to 150 m AHD on the ridge tops to the west of the existing Mining Lease (ML) 1427. The top of Tombstone Hill, which lies between the Weismantel open pit and the Mammy Johnsons River, is approximately 130 m AHD.

The geology of the Stroud-Gloucester area is dominated by the Permian Gloucester Basin, an elongated, north-south trending syncline comprising a 4,000 m thick sequence of Permian rocks along the central axis of the syncline (DCPL, 1996).

The various sedimentary rocks in the Project area generally have low primary or intergranular porosity and permeability (DCPL, 1996). Higher permeability occurs due to fissures and fractures in the otherwise low permeability rock mass. The coal seams form the main aquifer in the Project area.

A2.1 Climate

The Project area experiences a temperate climate which is influenced locally by orographic effects of the local terrain and distance from the coast (DCPL, 1996).

Regional climate monitoring stations in the vicinity of the Project have varying periods of records (Table A-1). The Stroud Post Office (PO) and Monkerai Upper (Redleaf) stations are the closest Bureau of Meteorology (BoM) stations with reliable long-term records.

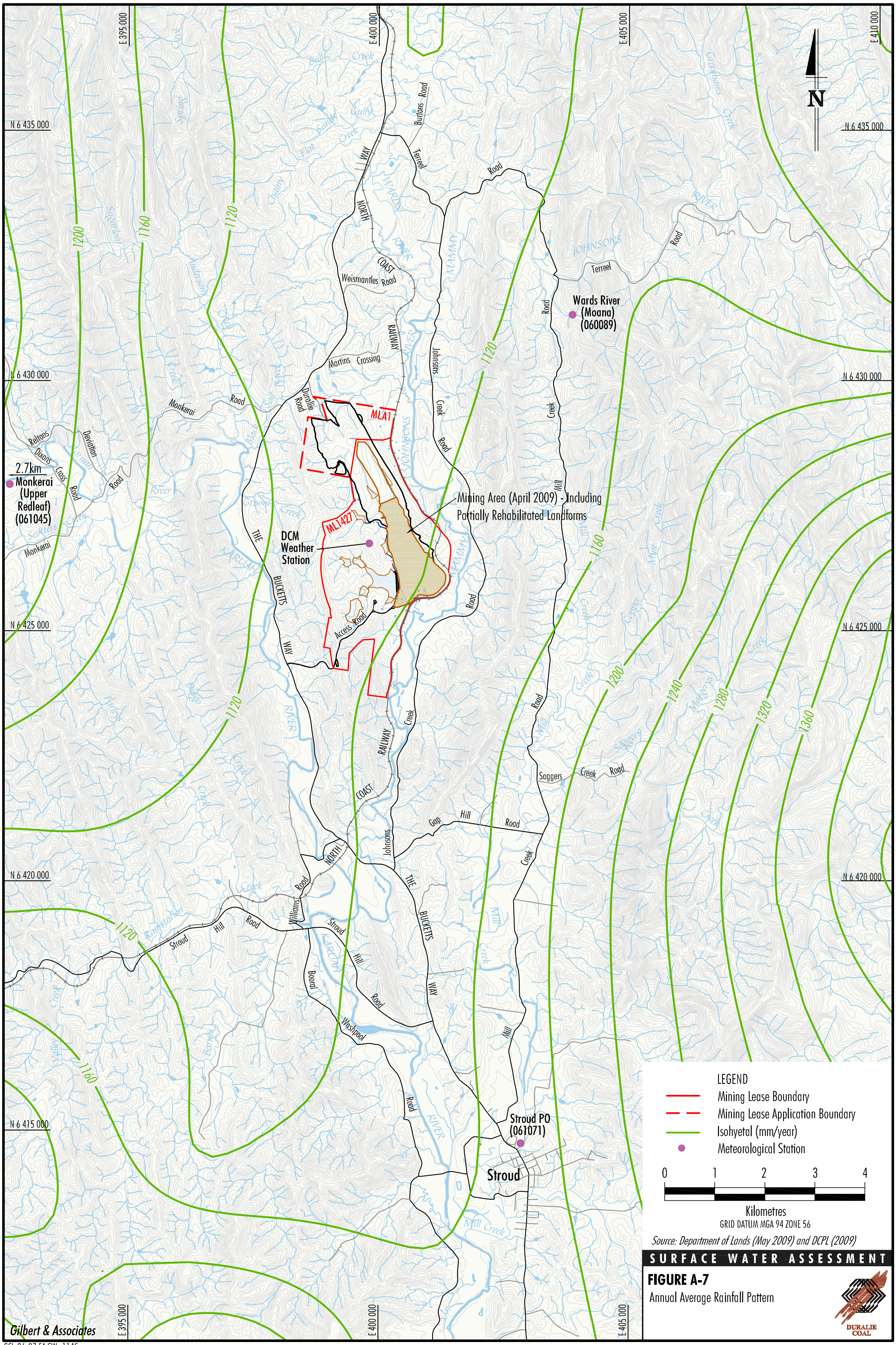
Table A-1
Summary of Regional Climate Monitoring Stations

Station Number	Station Name	Location*		Distance from DCM (km)	Elevation (m AHD)	Period of Record
		Longitude	Latitude			
061071	Stroud PO	32.40	151.97	10	44	1889 - present
060089	Wards River (Moana)	32.25	151.98	5	15	1968 - 1979
061045	Monkerai Upper (Redleaf)	32.28	151.83	8	100	1914 – 1970

* Refer to Figure A-7 for location.
Source: BoM (2009).

Meteorological conditions have also been monitored at the DCM weather station since 1995. A plot of monthly rainfall totals from the DCM and Stroud PO records is given in Figure A-8. Rainfall at Stroud PO averages 1,184 millimetres (mm) per year over the full period of available data. For the period of data in Figure A-8, rainfall at Stroud PO averages 1,132 mm per year, while at DCM the average is 1,039 mm per year.

[1] metres Australian Height Datum which approximates mean sea level.



SURFACE WATER ASSESSMENT

FIGURE A-7

Annual Average Rainfall Pattern

DURALIE COAL

GCL-06-07 EA SW_114C

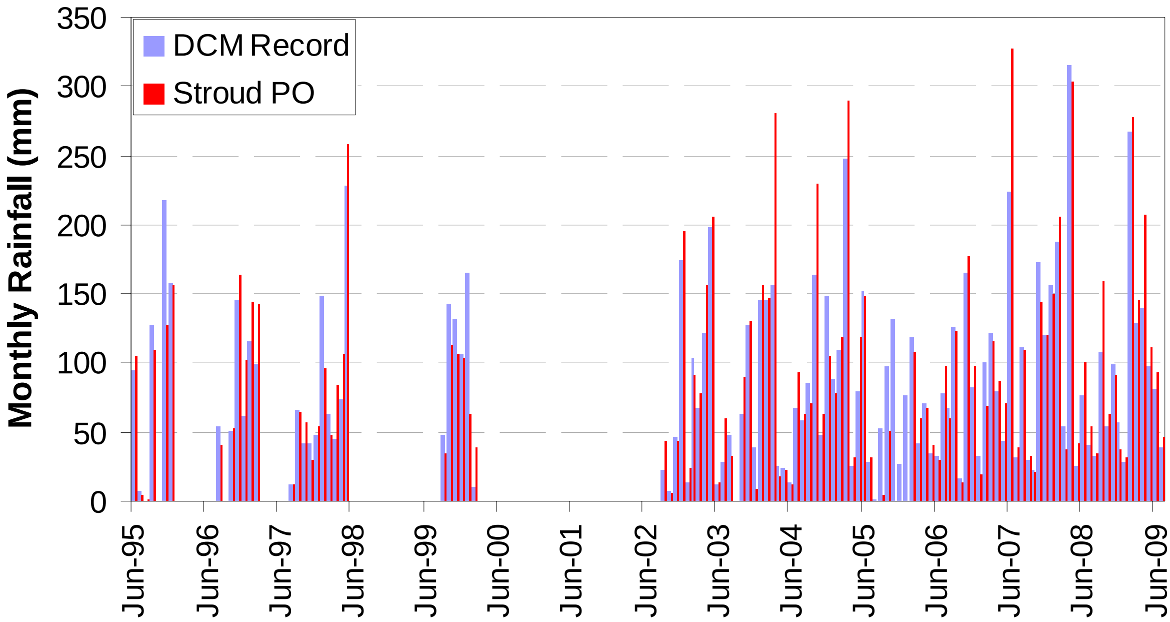


Figure A-8 Monthly Rainfall Totals

Rainfall records show an east-west variation in mean annual rainfall associated with topographic elevation but little north-south variation (Figure A-7). Rainfall experienced in the Project area can be described as moderate to high relative to rainfall across NSW.

Table A-2 presents mean monthly rainfall statistics for regional monitoring stations. Rainfall at DCM is typically lower during the winter months with maxima generally experienced during the summer months. Figure A-8 and Table A-2 show that there is a close correspondence in rainfall between the DCM weather station and the Stroud PO station for most months, although mean rainfall is lower at DCM in most months.

The nearest available BoM stations with pan evaporation records are located at Chichester Dam (BoM site 061151 – data available from 1974) located 25 km north-west of DCM and Paterson (Tocal) (BoM site 061250 – data available from 1967) located 50 km south-west of DCM.

A summary of potential (pan) evaporation for the Chichester Dam and Paterson (Tocal) stations and evaporation calculated[2] from the on-site weather station are presented in Table A-3 (for the full period of available data for each station). It is noteworthy that the Chichester Dam station is located at an elevation of 194 m AHD and is located in mountainous terrain, significantly further inland than DCM, while the Paterson (Tocal) station is located at an elevation of 30 m AHD and is a similar distance from the coast as DCM. The Chichester Dam data also contains significant gaps (data available for only 68 percent (%) of the period of record) while the Paterson (Tocal) data is more complete (data available for 91% of the period of record). Figure A-9 below shows a plot of concurrent monthly pan evaporation data from Paterson and the DCM weather station.

[2] Calculated using the Penman equation.

Table A-2
Summary of Mean Rainfall Statistics from Regional Climate Monitoring Stations

Station Name	**DCM Weather Station**		**Stroud PO**		**Monkerai Upper (Redleaf)**		**Wards River (Moana)**	
No. Years of Data	7[1]		120		56		11	
BoM Station No:	N/A		061071		061045		060089	
	Rainfall (mm)	No. of Rain Days	Rainfall (mm)[2]	No. of Rain Days[2]	Rainfall (mm)[2]	No. of Rain Days[2]	Rainfall (mm)[2]	No. of Rain Days[2]
January	77.4	11.9	119.6	8.7	156.0	14.1	182.4	8.0
February	147.6	12.3	129.7	9.1	150.4	13.6	128.9	7.5
March	117.2	11.9	153.6	9.7	146.2	14.0	167.9	7.9
April	111.1	15.9	105.5	8.5	118.1	12.8	61.3	5.1
May	71.9	14.4	94.0	8.9	79.2	11.5	68.1	6.3
June	84.3	15.4	104.7	8.5	99.6	10.6	137.8	6.1
July	44.8	12.7	76.9	8.1	71.6	10.2	31.4	3.8
August	53.1	8.8	65.8	7.7	70.7	10.4	53.7	4.0
September	80.7	11.0	63.9	7.2	75.3	10.0	46.3	6.9
October	60.5	9.0	80.7	7.8	90.2	11.8	81.2	8.0
November	112.8	10.9	84.6	8.2	92.4	11.3	108.4	10.3
December	92.7	12.4	105.1	8.3	137.0	13.3	100.8	7.2
Annual	1,054	147	1,184	101	1,287	144	1,168	81

Source: BoM (2009); DCPL (2009).
1 Summary for data collected from 2002 to 2009 only.
2 Anomalous Data tagged by BOM as quality control and considered “suspect” was removed.
N/A = Not applicable.

Table A-3
Summary of Average Evaporation Statistics (mm)

Month	DCM Weather Station	Paterson (Tocal) (Station No. 061250)	Chichester Dam (Station No. 061151)
January	179.7	192.2	139.5
February	146.4	148.4	107.4
March	123.6	130.2	93.0
April	89.9	99.0	69.0
May	73.4	74.4	46.5
June	59.7	66.0	33.0
July	73.6	77.5	40.3
August	102.9	105.4	58.9
September	142.1	132.0	84.0
October	159.5	161.2	111.6
November	163.4	177.0	123.0
December	192.5	210.8	151.9
Annual Average	1,507	1,574	1,058

From Figure A-9 and Table A-3 it may be seen that there is a close correspondence between evaporation calculated at the DCM weather station and pan evaporation recorded at the Paterson (Tocal) station for most months, although evaporation is somewhat lower at DCM from November to January.

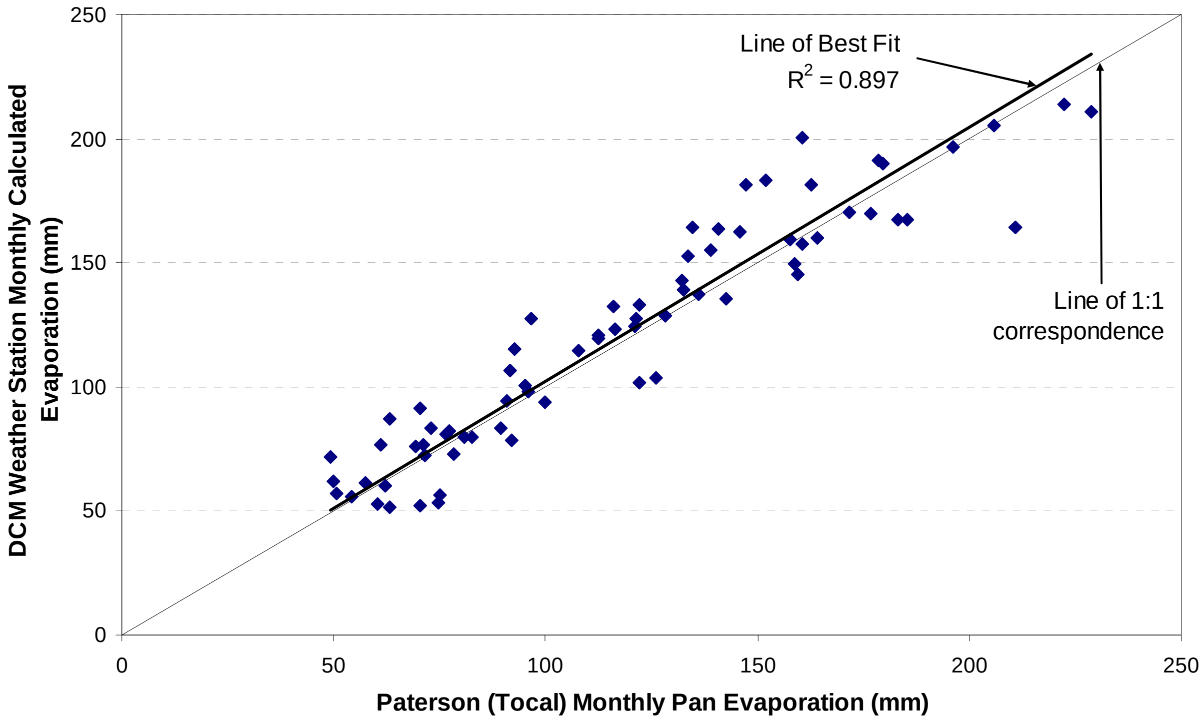


Figure A-9 Monthly Evaporation Comparison

A2.2 Catchments and Surface Water Resources

The Project area is situated within the Mammy Johnsons River catchment, a tributary of the Karuah River. The Karuah River, which rises in the Chichester State Forest, drains to Port Stephens some 40 km south of the DCM (Figure A-10). Mammy Johnsons River has a similar catchment area and length to the Karuah River above their confluence near the village of Stroud Road. The Mammy Johnsons River rises in the Myall State Forest east of the Project area and flows north out of the State Forest area and then westwards before joining the Wards River 2.5 km south-east of the township of the same name north of the Project area. The lower reaches of Mammy Johnsons River flow through an undulating landscape which has been extensively cleared for cattle grazing.

The existing DCM is situated in the catchment of Coal Shaft Creek, a small tributary which flows into the lower reaches of Mammy Johnsons River. Coal Shaft Creek has been diverted around the current DCM workings (Figure A-11). Tombstone Hill at an elevation of 130 m divides the Coal Shaft Creek catchment from the Mammy Johnsons River to the east (Figure A-11).

The Coal Shaft Creek Diversion comprises an approved, purpose-built diversion channel, which rejoins the original Coal Shaft Creek alignment near the DCM rail spur. The confluence of Coal Shaft Creek with the Mammy Johnsons River is south of the DCM rail loading infrastructure (Figure A-11) and approximately 10 km upstream of the Karuah River confluence. The existing Coal Shaft Creek Diversion is discussed further in Sections A3.1 and A3.4.

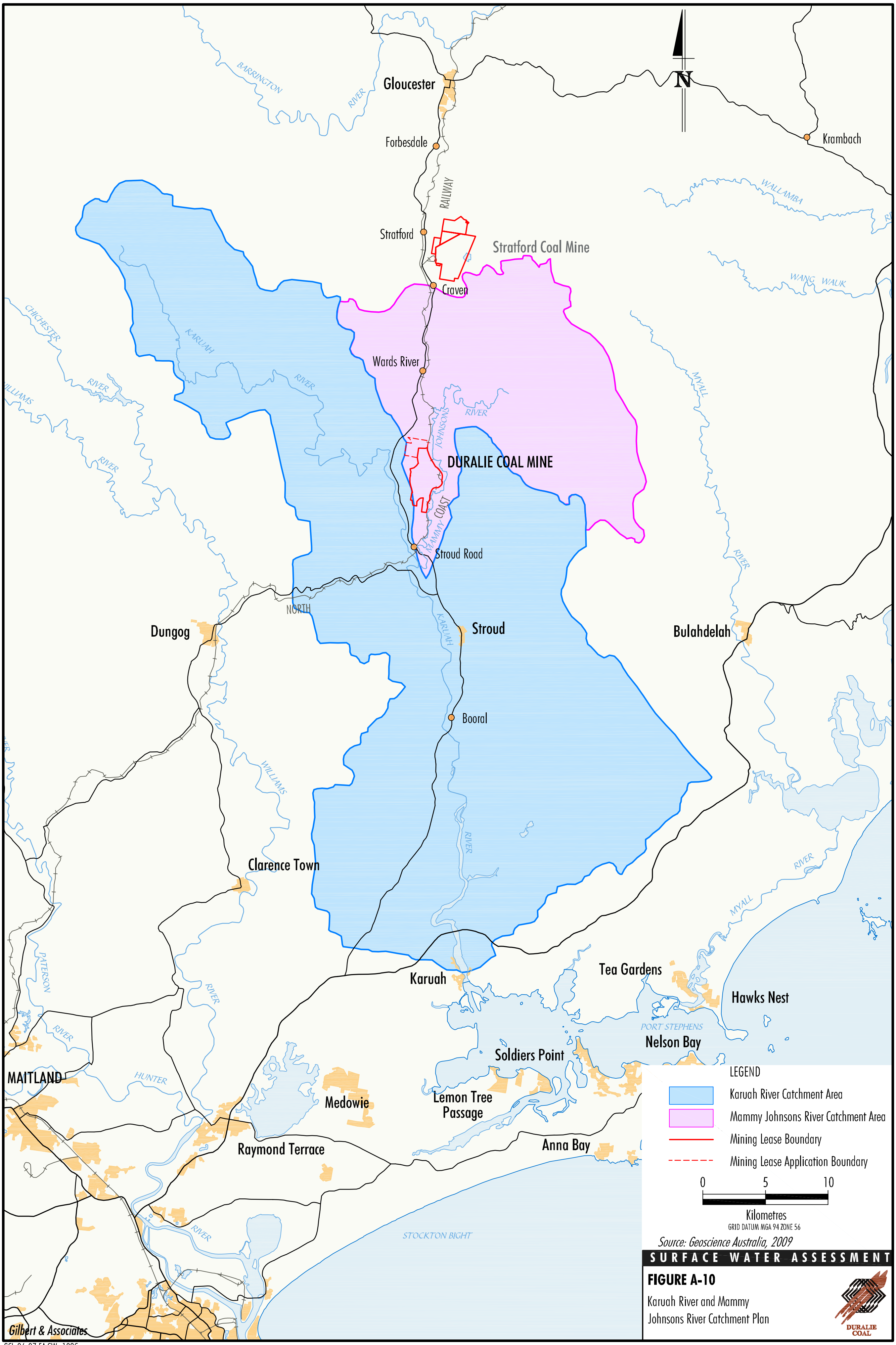
The Project would involve extension of mining into the catchment of an unnamed tributary that flows north and east to join the Mammy Johnsons River approximately 4 km upstream of the Coal Shaft Creek confluence (Figure A-11).

A summary of the catchments within the Project area and surrounds is provided in Table A-4.

Table A-4
Catchment Area Summary

Stream	Location	Catchment Area (km^2)
Coal Shaft Creek (following existing diversion [Figure A-11])	Within existing DCM disturbance area and additional Project disturbance areas	5.7
Unnamed Tributary to Mammy Johnsons River	Partly within additional Project disturbance areas	2.9
Mammy Johnsons River	To the north-east and south of the Project area	320
Karuah River	To the north-west and south of the Project area	1,470

km^2 = square kilometres.

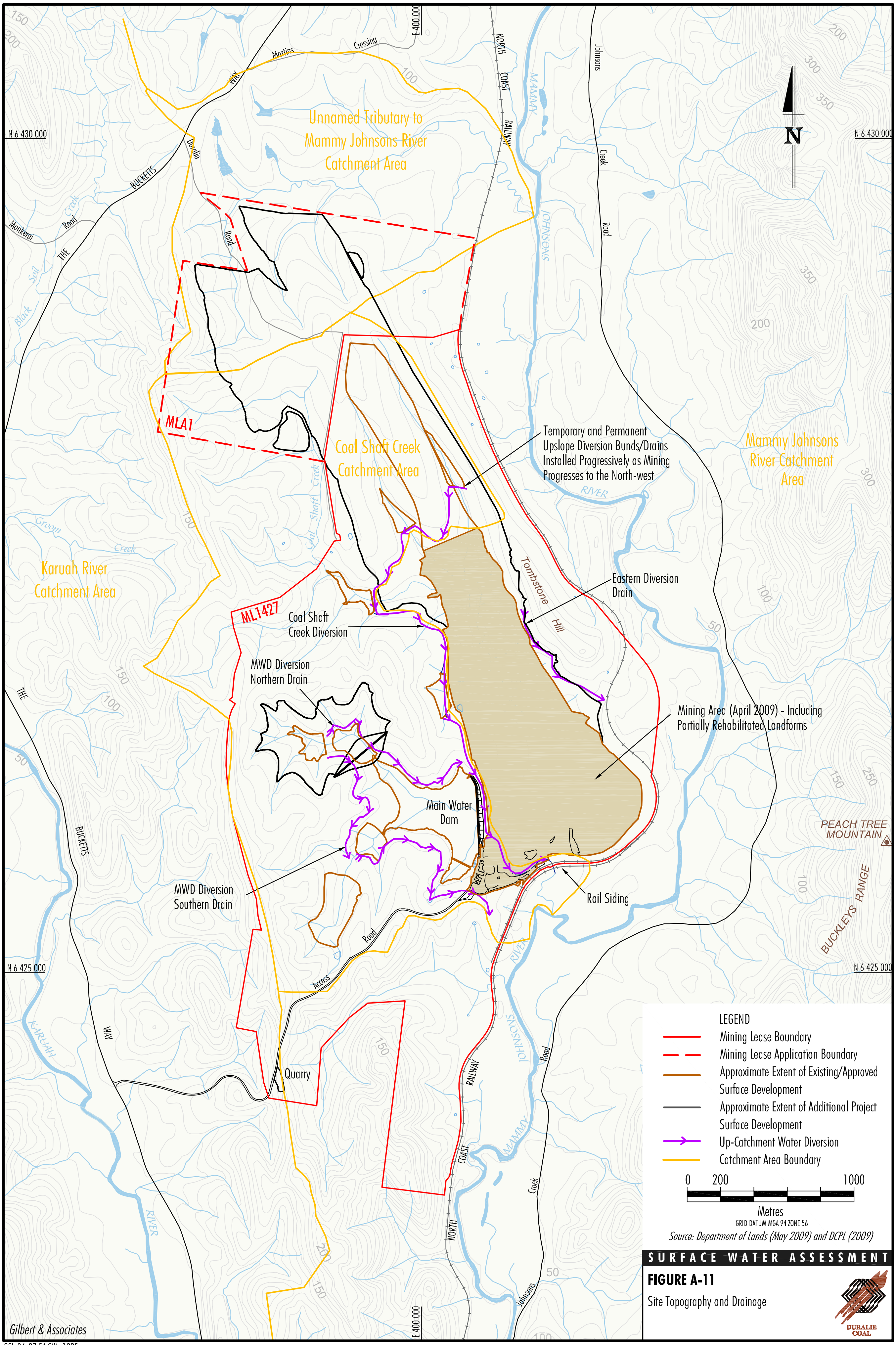


SURFACE WATER ASSESSMENT

FIGURE A-10

Karuah River and Mammy Johnsons River Catchment Plan

GCL-06-07 EA SW_102C



SURFACE WATER ASSESSMENT

FIGURE A-11

Site Topography and Drainage

A2.3 Runoff and Streamflow

The nearest operational streamflow gauging station to the Project area is on the Mammy Johnsons River known as Pikes Crossing gauging station (refer Figure A-12) – GS209002, which has operated since 1973. An operating gauging station also exists on the Karuah River (Dam Site) – GS209018, which has operated since 1979. Figure A-13 shows the recorded streamflow hydrograph for GS209002 on Mammy Johnsons River. Figure A-14 shows flow duration curves for both gauging stations, with streamflow expressed on a per unit catchment area basis for direct comparison.

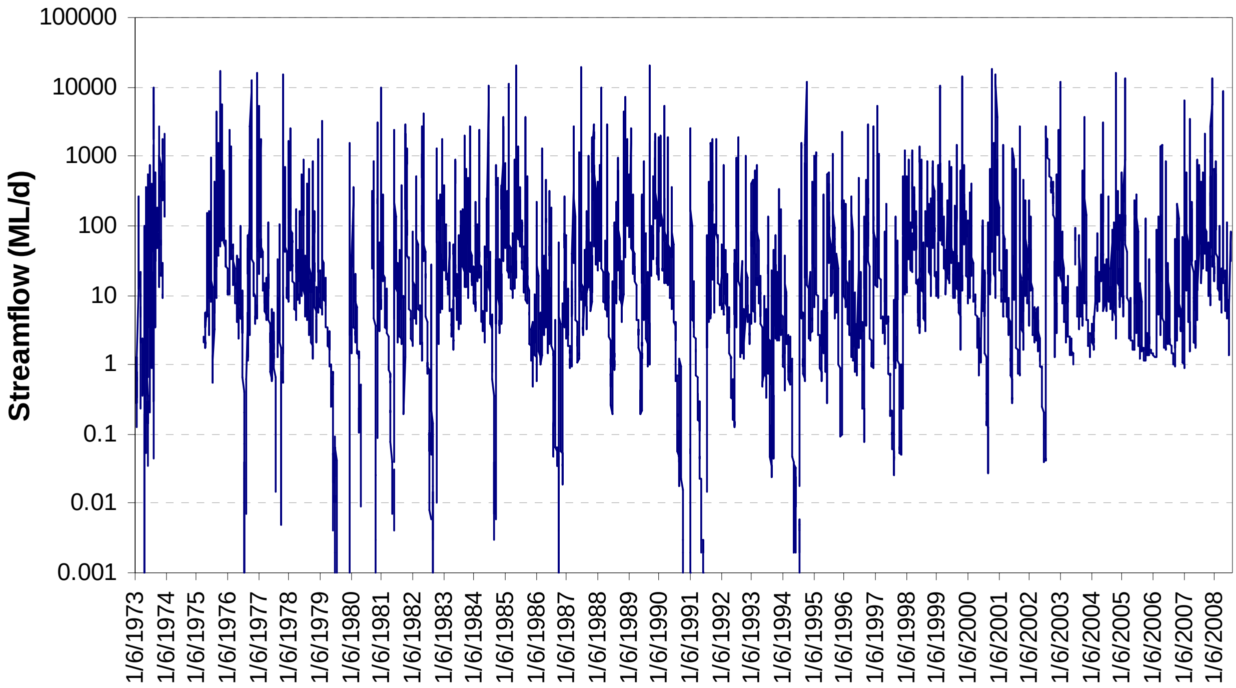
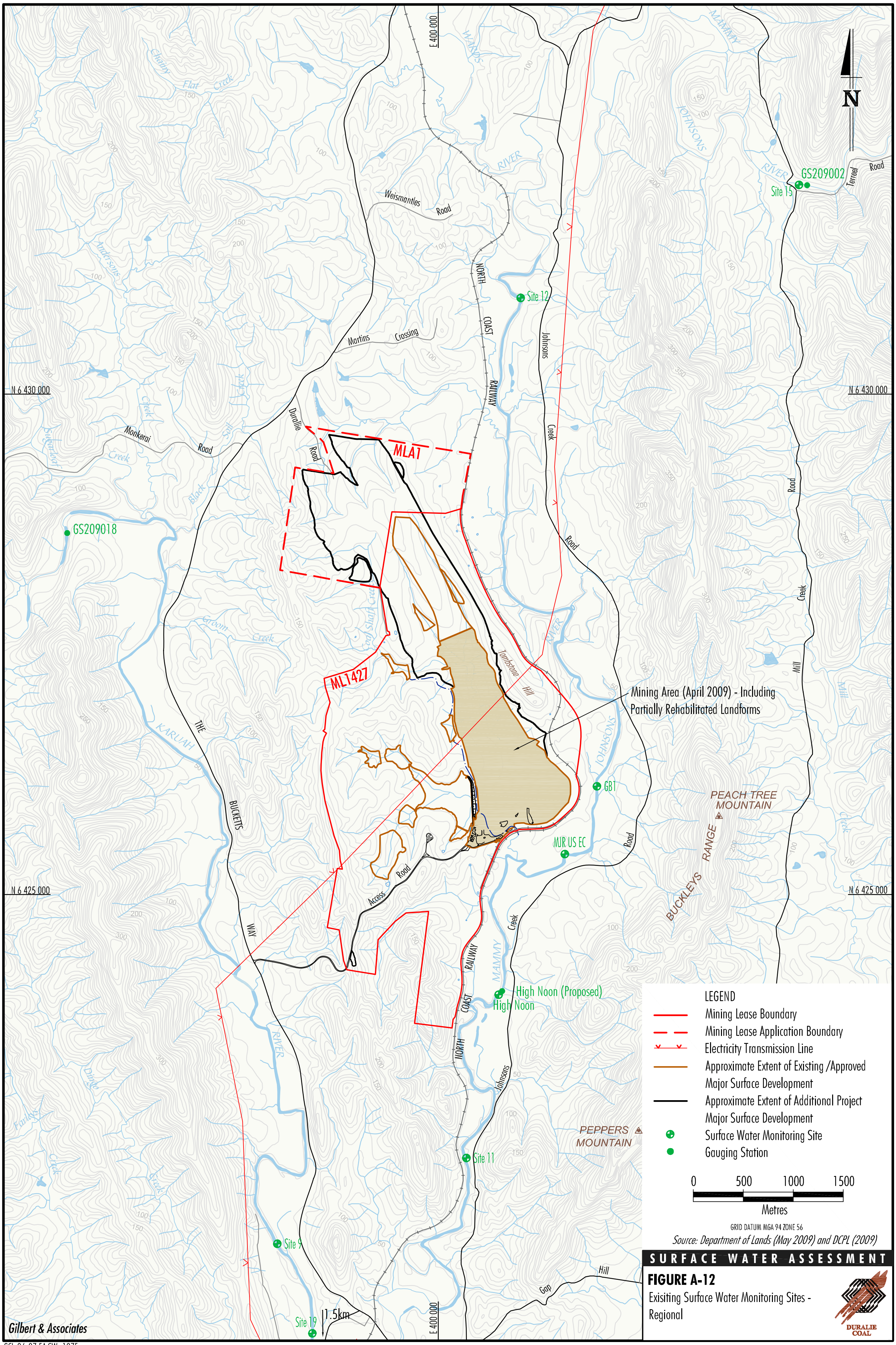


Figure A-13 Recorded Streamflow Hydrograph – GS209002 – Mammy Johnsons River at Pikes Crossing Gauging Station



SURFACE WATER ASSESSMENT

FIGURE A-12
Exisiting Surface Water Monitoring Sites - Regional

DURALIE COAL

GCL-06-07 EA SW_107E

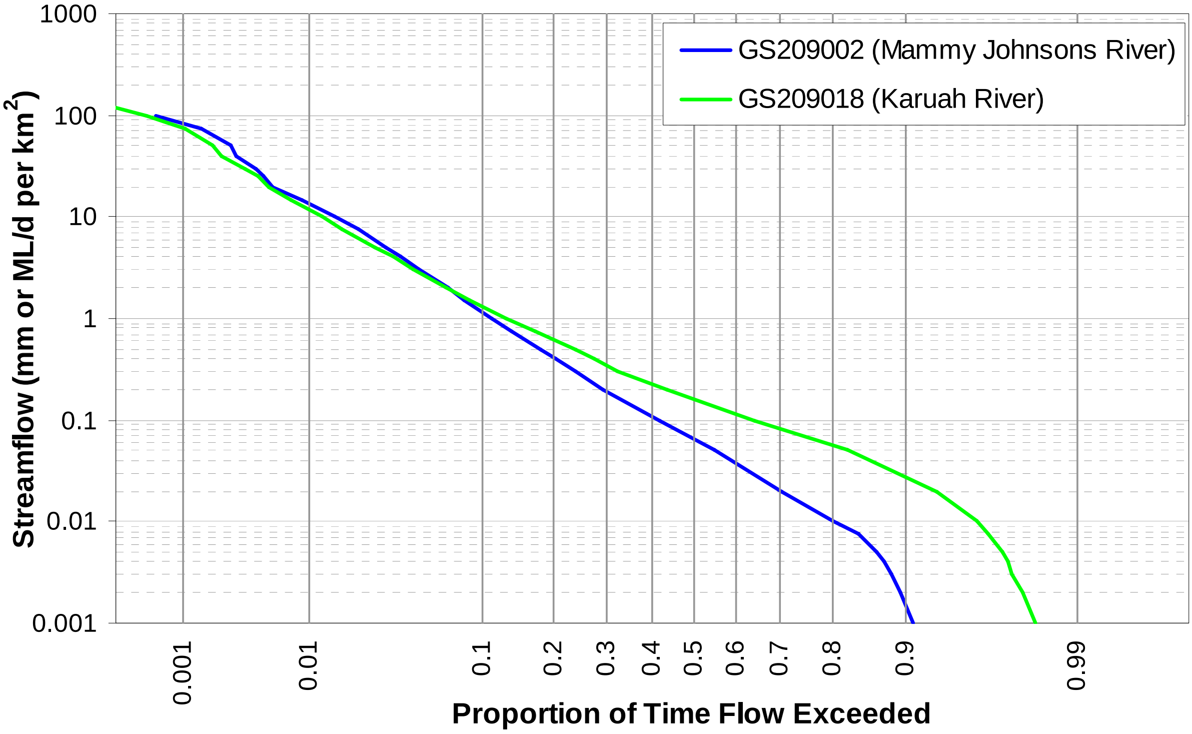


Figure A-14 Recorded Flow-Duration Curves – GS209002 (Mammy Johnsons River) and GS209018 (Karuah River)

Streamflows are characterised by low to moderate flows for long periods, with periods of higher discharge following heavy rains. Such rainfall response is typical of small and medium sized upland catchments. The Karuah River appears to have stronger low flow persistence than Mammy Johnsons River, with zero flow recorded only on 0.8% of days, compared to 5.3% of days for the Mammy Johnsons River.

Averaged over the full period of available data, streamflow in Mammy Johnsons River is estimated to amount to some 28% of rainfall.

The flow characteristics of Coal Shaft Creek are likely to be similar to Mammy Johnsons River due to the similar catchment conditions and climatic regime. Runoff rates are likely to be slightly higher (due to the greater proportion of cleared catchment compared with the forested cover of the upper Mammy Johnsons River) and is estimated to average about 30% of rainfall. Anecdotally (based on site observations of flow in the diverted Coal Shaft Creek), flow persistence in Coal Shaft Creek is less than Mammy Johnsons River, with greater periods of zero flow. The runoff coefficient of 30% is similar to the typical average for NSW coastal streams[3]. It is consistent with what would be expected in catchments with rugged topography, low permeability soils and extensive pasture cover.

The upper reaches of Coal Shaft Creek are ephemeral and baseflow contributions in these portions of the creek are likely to be small.

[3] c.f. average of 27% reported in Peel *et al*. (2000).

A2.4 Flooding

The Mammy Johnsons River flows through a relatively confined strata bound valley. The valley has variable areas of fringing floodplain comprising gently sloping pockets of alluvium. In the vicinity of the Coal Shaft Creek confluence, floodplains have formed on both sides of Mammy Johnsons River which in places extend some 600m from the river banks. In other areas the floodplains are less well developed and are absent in some areas where the Mammy Johnsons River is locally confined by hills. Flood levels during extreme flood events in the vicinity of the Coal Shaft Creek are likely to be controlled by a confinement downstream of DCM near Site 11. There are no official records of flooding along the lower reaches of Mammy Johnsons River and there is no known flood study having been conducted along this section of the river.

The proposed Project area is located predominantly in the upper reaches of Coal Shaft Creek. Coal Shaft Creek commands a relatively small (approximately 6 km^2) catchment upstream of the Project area and has been extensively diverted around the DCM. The diversion has been designed to safely pass flows up to the 1 in 100 year average recurrence interval (ARI) and the majority of the diversion would be retained during the proposed Project life.

The Mammy Johnsons River in the vicinity of the Project is located at approximately relative level (RL) 45 m, while the extent of the floodplain is at approximately RL 52 m. The North Coast Railway line (Figure A-2) follows the western (right) bank side valley of the Mammy Johnsons River next to the DCM including near the confluence of Coal Shaft Creek. The railway embankment was constructed in the 1890s and is some 10 m above the bed of Coal Shaft Creek (which is approximately at RL 46 m). There is no record of the railway embankment being overtopped in this time which suggests that areas higher than this are unlikely to be affected by flooding in Mammy Johnsons River.

The proposed mining areas associated with the Project are located further away from Mammy Johnsons River and at a higher level (approximately RL 75 m) than the existing mining area and therefore are very unlikely to be exposed to flooding in Mammy Johnsons River.

A2.5 Local and Regional Surface Water Quality

The *Duralie Coal Environmental Impact Statement* (the Duralie Coal EIS) (DCPL, 1996) indicated that water quality in Mammy Johnsons River was variable, but was generally good. It was also found that the salinity of the stream was higher during periods of low flow and generally showed a relative reduction in electrical conductivity (EC) during higher flow periods (Gilbert, 1997). The pre-mining EC levels in Coal Shaft Creek were markedly higher than the EC levels recorded in Mammy Johnsons River (*ibid.*).

DCPL monitors surface water quality on and surrounding the mine site by manual sampling from a series of selected locations, including both streams and water storage structures. Surface water samples are tested for a range of parameters including pH, EC, turbidity, total suspended solids (TSS), total dissolved solids (TDS), acidity/alkalinity, aluminium (Al), calcium (Ca), chloride (Cl), dissolved iron (Fe), magnesium (Mg), manganese (Mn), sulphate (SO_4), zinc (Zn), sodium (Na), bicarbonate (HCO_3), carbonate (CO_3), nitrogen (N), phosphorus (P), arsenic (As), boron (B), cadmium (Cd), copper (Cu), lead (Pb), chromium (Cr), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), barium (B), uranium (U), molybdenum (Mo), fluoride (F) and ammonia (NH_3). DCPL also maintains continuous EC sensors/loggers on Mammy Johnsons River upstream and downstream of the DCM – at MJR US EC and High Noon (shown on Figure A-12).

Table A-5 summarises surface water monitoring conducted at the DCM. The locations of surface water monitoring sites are shown on Figures A-12 and A-15.

Table A-5
Summary of Surface Water Quality Monitoring

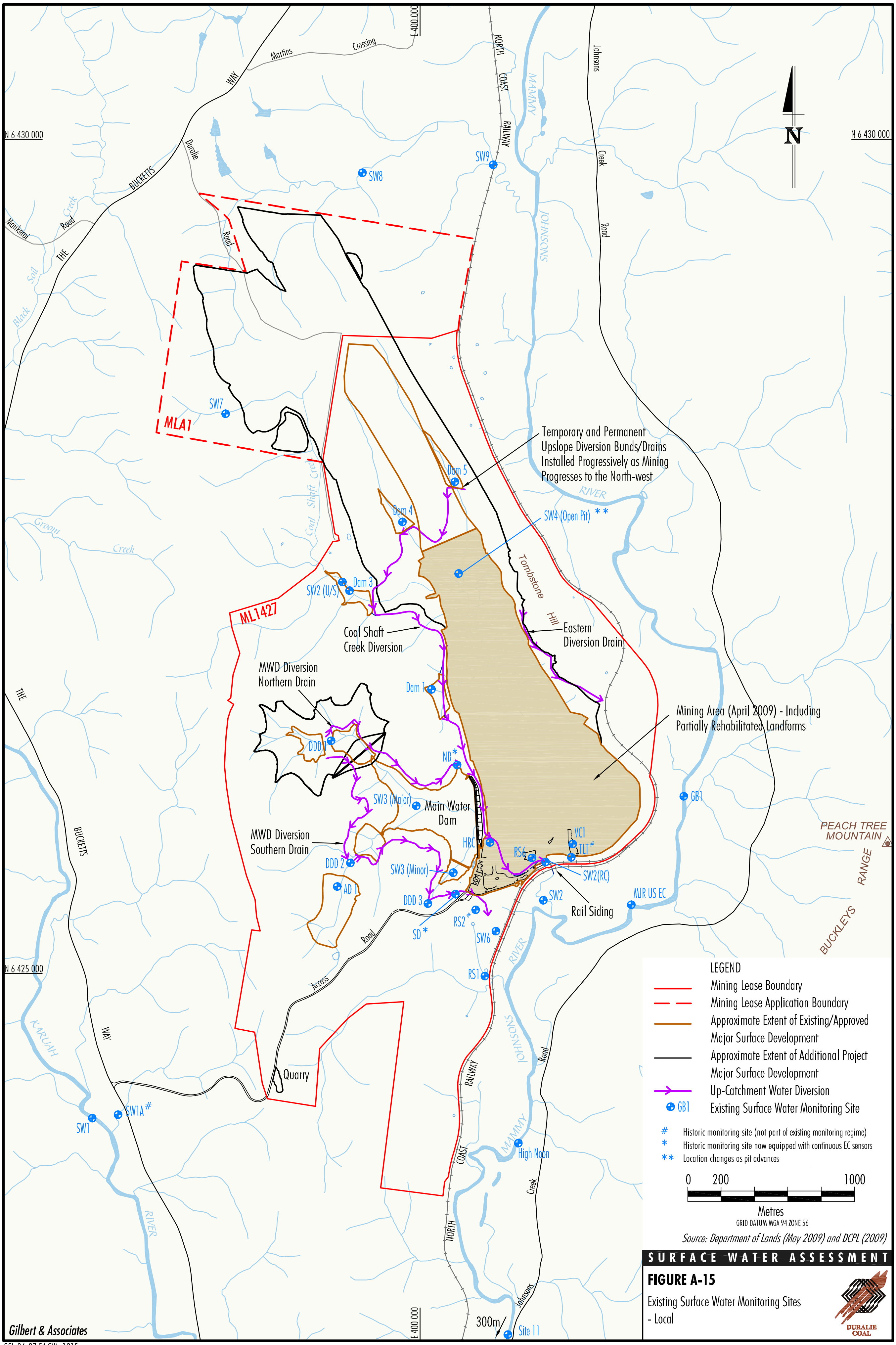
Site Name	Site Description	Frequency[1]	Current Suite of Parameters	Period of Record[2]
SW1	Karuah River (Mine Entrance)	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl.	30/08/2002 – 31/08/2009
SW1A	Mine Entrance	Spot	TSS, turbidity.	26/05/2003 – 18/03/2005
SW2	Coal Shaft Creek (lower)	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl.	30/08/2002 – 31/08/2009
SW2 (RC)	Coal Shaft Creek (rail culvert)	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	22/03/2004 – 31/08/2009
SW2 (U/S)	Coal Shaft Creek (upstream)	Weekly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	26/05/2003 – 27/10/2008
SW3 (Major)	MWD	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	30/04/2003 – 31/08/2009
SW3 (Minor)	MWD	Spot	pH, EC.	4/04/2003 – 15/08/2008
SW4	Open Pit	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Na, Cl.	28/03/2003 – 14/09/2009
SW6	Culvert at Rail Siding	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Na, Cl.	21/11/2003 – 31/09/2009
SW7	Holmes	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Na, Cl.	10/12/2007 – 31/08/2009
SW8	Zulumovski	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Na, Cl.	10/12/2007 – 11/02/2009
SW9	FisherWebster	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	20/04/2009 – 31/08/2009
GB1	Mammy Johnsons River (upstream)	Weekly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	1/10/2008 – 14/09/2009
Site 9	Karuah River (Stroud Road)	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	30/08/2002 – 31/08/2009
Site 11	Mammy Johnsons River (downstream)	Weekly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	24/09/2002 – 14/09/2009
Site 12	Mammy Johnsons River (Relton)	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	30/08/2002 – 31/08/2009

Table A-5 (Continued)
Summary of Surface Water Quality Monitoring

Site Name	Site Description	Frequency[1]	Current Suite of Parameters	Period of Record[2]
Site 15	Mammy Johnsons River (Tereel)	Monthly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	30/08/2002 – 31/08/2009
Site 19	Karuah River (Washpool)	Weekly and Event	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl, TDS, bicarbonate, carbonate, N, Na, P, As, B, Cd, Cu, Pb, Cr, Hg, Ni, Se, Ag, Ba, Mo, U, F, NO_2, NO_3, NH_3.	24/09/2002 – 14/09/2009
RS1	Rail Siding Sediment Dam	Spot	pH, EC, turbidity, TSS.	10/12/2002 - 1/4/2009
RS2	Rail Siding Sediment Dam	Spot	pH, EC, turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Na, Cl.	28/07/2003 – 21/11/2003
RS6	Rail Siding Sediment Dam	Spot	pH, EC.	5/9/2003 - 28/9/2009
VC1	Out-of-pit Waste Emplacement Dam	Spot	pH, EC. Turbidity, TSS, acidity/alkalinity, SO_4, Mn, Fe, Zn, Al, Ca, Mg, Cl (one sample).	23/3/2004 - 28/9/2009
DDD1	MWD Diversion Drain	Spot	pH, EC, turbidity. TSS, SO_4 (one sample).	2/4/2004 - 2/10/2009
DDD2	MWD Diversion Drain	Spot	pH, EC, turbidity. TSS, SO_4 (one sample).	2/4/2004 - 1/10/2009
DDD3	MWD Diversion Drain	Spot	pH, EC. Turbidity, TSS, SO_4 (one sample).	25/9/2003 - 31/3/2009
SD	MWD Diversion Southern Drain	Spot	pH, EC, turbidity, TSS, SO_4.	30/10/2004 – 13/02/2007
ND	MWD Diversion Northern Drain	Spot	EC.	21/10/2004 – 13/02/2007
Dam 1	Coal Shaft Creek Diversion Dam	Spot	pH, EC, TSS, turbidity (one sample).	12/4/2005 – 1/10/2009
Dam 3	Coal Shaft Creek Diversion Dam	Spot	pH, EC.	9/8/2006 – 1/10/2009
Dam 4	Coal Shaft Creek Diversion Dam	Spot	pH, EC, SO_4.	31/10/2005 – 1/10/2009
Dam 5	Coal Shaft Creek Diversion Dam	Spot	pH, EC, SO_4.	25/10/2005 – 1/10/2009
HRC	Haul Road Culvert	Spot	pH, EC, turbidity, TSS.	30/10/2004 – 2/12/2005
TLT	Train Leachate Tray	Spot	pH, EC.	2/04/2003 – 4/06/2008
AD1	Auxiliary Dam No. 1	Spot	pH, EC (one sample).	1/10/2009

1 A maximum of one event sample is taken in any 21 day period.
An event is defined as a runoff-producing rainfall event (i.e. 20 mm or greater of rainfall in a 24-hour period).
2 Represents total period of record of monitoring at site. Not all parameters have been monitored for the complete period of record.

A summary of salinity (EC) monitoring results for Coal Shaft Creek, unnamed tributary to Mammy Johnsons River, Mammy Johnsons River and Karuah River are provided in Table A-6.



Source: Department of Lands (May 2009) and DCPL (2009)

SURFACE WATER ASSESSMENT

FIGURE A-15

Existing Surface Water Monitoring Sites - Local

DURALIE COAL

Gilbert & Associates

GCL-06-07 EA SW_101F

Table A-6
Summary of Electrical Conductivity Monitoring Results

Watercourse	Sites	No. of Samples	Minimum[1]	Median[1]	Maximum[1]	Percentage Exceedance (%)[2]
Coal Shaft Creek (including diversion)	SW2, SW2 (U/S), SW2 (RC), SW7, HRC	193	40	**370**	**1,840**	57.51
Unnamed Tributary to Mammy Johnsons River	SW8, SW9	11	70	170	**740**	36.36
Mammy Johnsons River	GB1, Site 11, Site 12, Site 15	329	80	290	**600**	44.1
Karuah River	SW1, Site 9, Site 19	237	70	190	**790**	5.9

1 Bolded values are above the upper limit of the aquatic ecosystem guideline (300 microSiemens per centimetre [µS/cm]) for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).
2 Percentage of samples that are above the upper limit of the aquatic ecosystem guideline (300 µS/cm) for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

The monitoring data show that Coal Shaft Creek is generally more saline than Mammy Johnsons River and the Karuah River (Table A-6). The EC data presented in the Duralie Coal EIS show similar trends and results to the data collected since operations began at the DCM. It is considered that Coal Shaft Creek is generally more saline due to its ephemeral nature and the outcropping/sub-cropping of coal seams within the catchment.

Five separate TDS samples were collected from Coal Shaft Creek pre-mining in 1995 by Pells Sullivan Meynink (Woodward-Clyde, 1996). Using the relationship between TDS and EC in ANZECC/ARMCANZ (2000a), it was determined that four of the samples (80%) exceeded the aquatic ecosystem guideline of 300 µS/cm.

Figure A-16 shows a plot of recorded EC at the continuous EC sensors/loggers on Mammy Johnsons River at MJR US EC and High Noon (shown on Figure A-12) and concurrent flow rate recorded at GS209002 further upstream. Figure A-16 generally shows a typical EC response to streamflow, with EC rising gradually during streamflow recession. Over the monitoring period there has been a gradual reduction in the salinity downstream of the DCM (High Noon), relative to the upstream site (MJR US EC) (Figure A-16). This could be attributed to the progressive removal of outcropping coal for the contributing catchment of Coal Shaft Creek and the effectiveness of the first flush protocol in capturing elevated salt runoff from DCM irrigation areas during rainfall events.

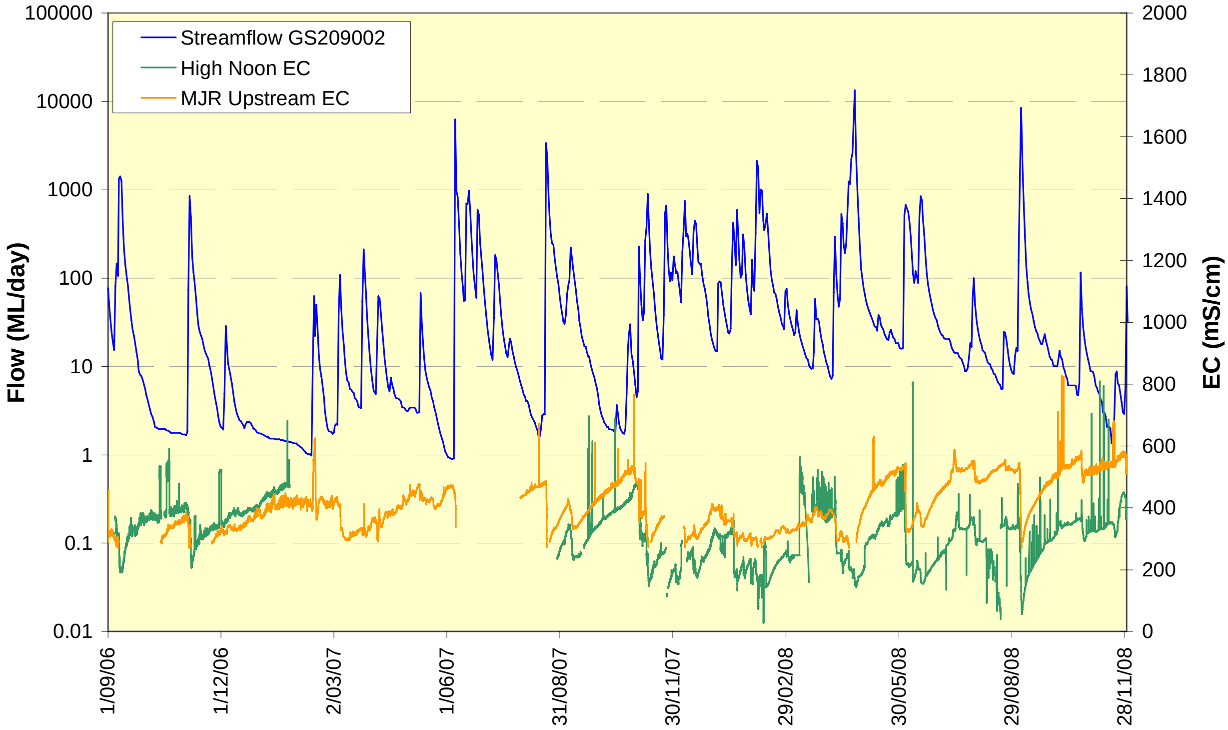


Figure A-16 EC and Streamflow in Mammy Johnsons River

Table A-7 provides a summary of pH monitoring data in the watercourses surrounding the Project area. Near neutral to slightly alkaline pH has been recorded at Coal Shaft Creek, Mammy Johnsons River and Karuah River.

Table A-7
Summary of pH Monitoring Results

Watercourse	Sites	No. of Samples	Minimum[1]	Median[1]	Maximum[1]	Percentage Exceedance (%)[2]
Coal Shaft Creek (including diversion)	SW2, SW2 (U/S), SW2 (RC), SW7, HRC	191	**5.9**	7.5	**8.5**	10
Unnamed Tributary to Mammy Johnsons River	SW8, SW9	11	7.1	7.4	7.8	0
Mammy Johnsons River	GB1, Site 11, Site 12, Site 15	329	**6.3**	7.5	**8.9**	5
Karuah River	SW1, Site 9, Site 19	236	**6.1**	7.6	**8.9**	12

1 Bolded values are outside the aquatic ecosystem guideline of pH 6.5-8.0 for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).

2 Percentage of samples that are outside the aquatic ecosystem guideline of pH 6.5-8.0 for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).

Graphs showing the water quality results for a number of key parameters versus time are provided in Attachment AA.

Elevated aluminium and zinc concentrations are regularly recorded in the Karuah River, Mammy Johnsons River, Coal Shaft Creek and the unnamed tributary to Mammy Johnsons River (SW8 and SW9), including sites both upstream and downstream of DCM. The elevated aluminium concentrations recorded may be a function of the colloidal fraction rather than the metal in solution. Concentrations of copper and chromium have also been recorded on occasions above the ANZECC/ARMCANZ aquatic ecosystems guideline in these watercourses.

The majority of the other metals monitored were below the detection limit on most sampling occasions.

A2.6 Karuah River Water Sharing Plan

The Mammy Johnsons River and its tributaries (Figure A-10) fall within Management Zone Four of the *Water Sharing Plan for the Karuah River Water Source, 2003* (the Karuah River Water Sharing Plan) made under section 50 of the *Water Management Act, 2000*. The plan commenced on 1 July 2004 and applies to 30 June 2014.

The vision for the Karuah River Water Sharing Plan is:

> *… to achieve a progressive, discernible and sustainable improvement in the quality of the Karuah River and its tributaries to deliver greater benefits in health, biodiversity, recreational attractiveness and economic productivity, achieved through implementation of a balanced water management plan.*

The plan defines access conditions for water extraction and rules for extracting water, including limiting the long-term average extraction of water and the amount of water that can be extracted on a daily basis from different flow classes.

DCPL hold Approval Number 20WA202053 under the Karuah River Water Sharing Plan for the Coal Shaft Creek Diversion. Requirements relating to the Karuah River Water Sharing Plan are discussed in the Main Report of the EA.

A3.0 SURFACE WATER MANAGEMENT

The existing water management system would be progressively augmented as water management requirements change over the life of the Project.

Section A3.1 provides a description of the existing water management system, while Section A3.2 describes the proposed changes to the water management system as part of the Project. The Project water management schematic is shown on Figure A-17a. Information sources considered in the calibration and analysis of the water management system are shown on Figure A-17b.

A predictive assessment of the performance of the Project water supply system (including the proposed changes to the site water management system under a range of different climatic scenarios) is presented in Section A4.

A3.1 Existing Water Management System

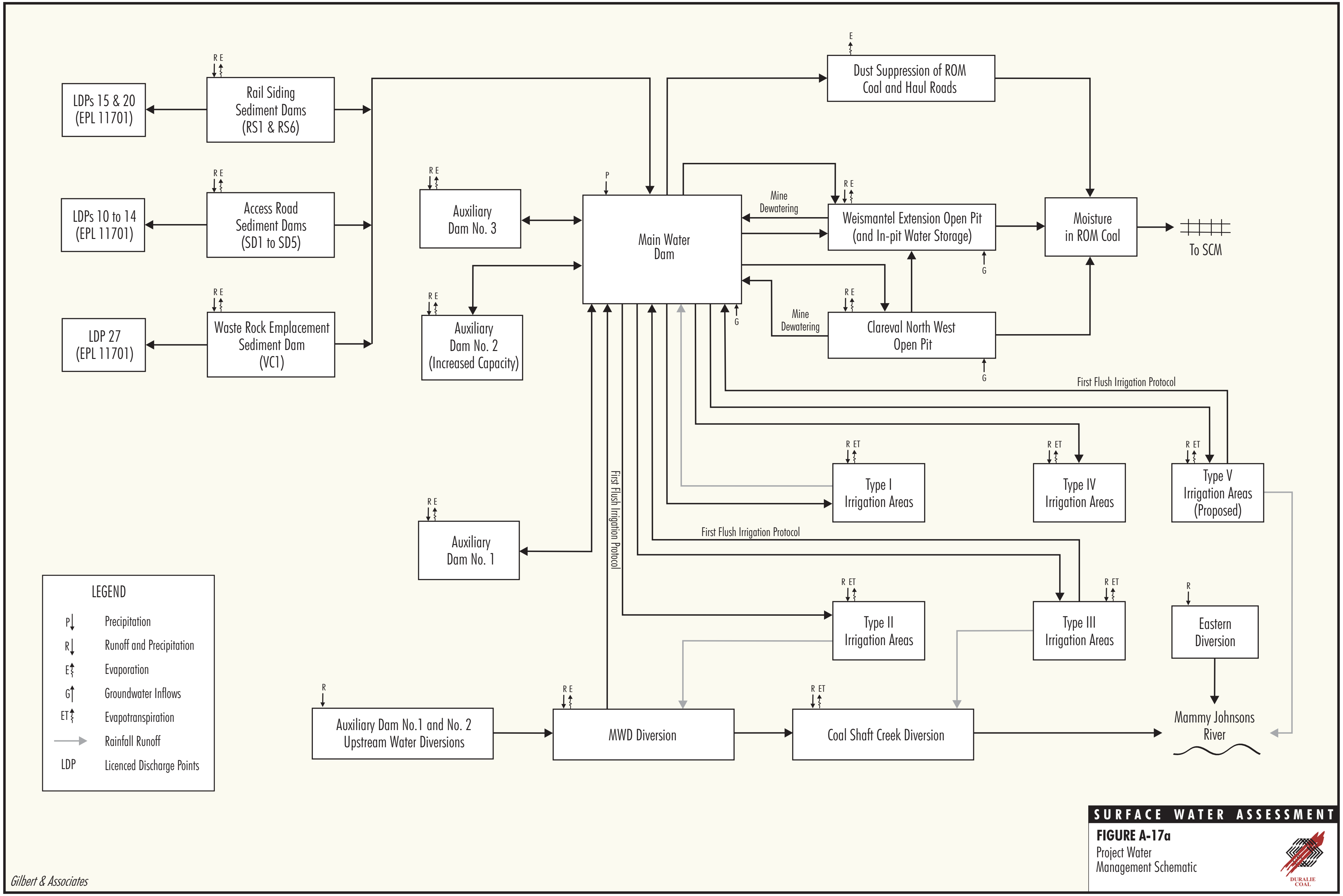
The existing water management system at the DCM is based on the management of four separate components namely upslope diversions/runoff, mine-water, sewage and water carrying sediments from areas disturbed by the DCM project activities. It includes the following:

- water management storages including the MWD and Auxiliary Dams (No. 1, No. 2 and No. 3) – although as at October 2009 only MWD and Auxiliary Dam No. 1 have been constructed;
- diversion of runoff from catchment areas upstream of the mine disturbance area;
- runoff control on disturbed and rehabilitated areas at the mine;
- runoff control on infrastructure areas;
- sedimentation control;
- open pit dewatering;
- disposal of excess water through on-site agricultural irrigation; and
- sewage treatment and disposal of effluent.

The DCM is subject to an existing Environment Protection Licence (EPL) 11701, issued by the NSW Department of Environment, Climate Change and Water (DECCW). The EPL includes conditions pertaining to environmental monitoring and release of waters off-site.

Dust suppression represents the only significant water requirement at the DCM, and as a result the water balance at the DCM is generally in surplus. The excess water is used for controlled irrigation in accordance with the approved DCM Irrigation Management Plan (IMP) (DCPL, 2008a), discussed further below.

The existing DCM water management system does not release mining-related water off-site, in accordance with the EPL and Development Consent.



SURFACE WATER ASSESSMENT

FIGURE A-17a

Project Water Management Schematic

DURALIE COAL

Gilbert & Associates

GCL-06-07 EA SW_001F

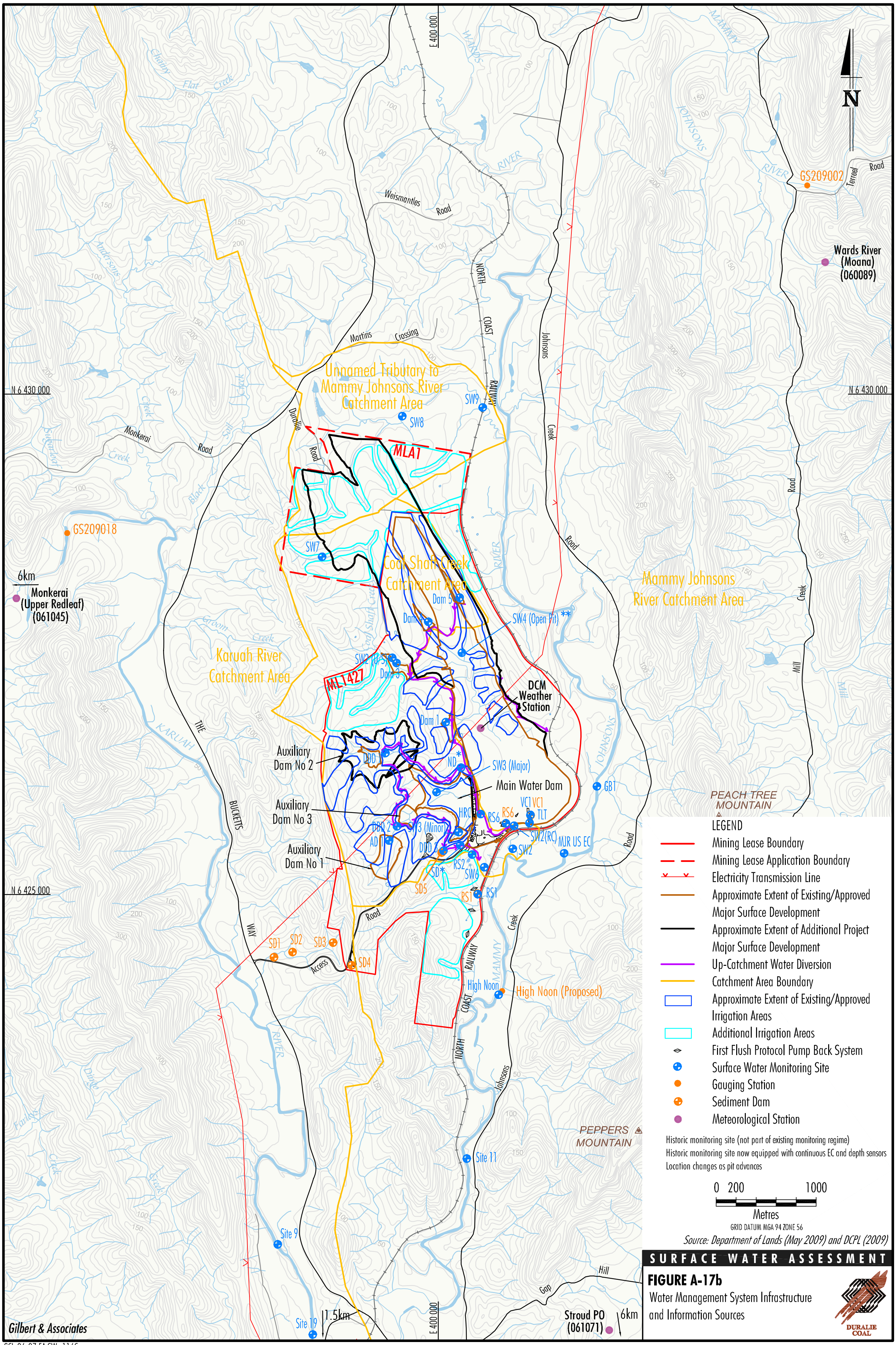


FIGURE A-17b
Water Management System Infrastructure and Information Sources

GCL-06-07 EA SW_116C

A3.1.1 Water Management Storages

Water collected for storage on-site includes incident rainfall on mine disturbance areas and groundwater inflows into the DCM. Water pumped from sumps in the open pit is stored in the MWD. The MWD is located to the north-west of the main infrastructure area (Figure A-2) and has a capacity of approximately 1,405 megalitres (ML).

The MWD has been operated to maintain freeboard below its spill level. This has been achieved by irrigation of excess water, cessation of mine dewatering operations during periods of low freeboard levels in the MWD and by maintaining freeboard in MWD by transferring excess water to Auxiliary Dam No. 1 and the Weismantel open pit. A 1 ML/hour transfer pump and pipeline, and 200 mm diameter gravity fed transfer pipeline are installed between the MWD and Weismantel open pit. The above system is designed and managed to transfer water in excess of the capacity of the MWD to the open pit.

The MWD is also used to store water pumped from selected sediment dams and runoff from the main infrastructure area. Water pumped to the MWD is first discharged into a smaller bunded area (previously known as the Upper MWD), located in the south of the MWD, adjacent to the main infrastructure area (Figure A-2). Relative to the MWD, the water quality of the smaller bunded area is more saline and is therefore preferentially used for dust suppression on-site.

Auxiliary Dam No. 1 is located upslope of the MWD (to its south-west) and upslope of the MWD diversions (refer Section A3.1.2 below). Auxiliary Dam No. 1 has been approved to a capacity of 500 ML. An upslope diversion channel/bund has been constructed around the perimeter of the dam to limit the catchment area of the storage – flow in this diversion reports to the MWD diversion. A spillway has been constructed from Auxiliary Dam No. 1 to the MWD diversion. Water is pumped from the MWD to Auxiliary Dam No. 1 in order to increase the available freeboard in the MWD for storage of mine water. As the volume stored in the MWD is reduced in dry weather (due to water use for haul road dust suppression and irrigation), water is gradually returned to the MWD from Auxiliary Dam No. 1 via a gravity pipeline.

Auxiliary Dam No. 2 has been approved to a capacity of approximately 270 ML. The approved Auxiliary Dam No. 2 would be located entirely within the MWD diversion (i.e. overflow from the dam would flow directly to the MWD). Water would be pumped from the MWD to Auxiliary Dam No. 2 and gravity discharged back to the MWD in a similar manner to Auxiliary Dam No. 1. As part of the Project, it is proposed to increase the capacity of Auxiliary Dam No. 2 (refer Section A3.2.3).

Auxiliary Dam No. 3 has been approved to a capacity of approximately 110 ML, but has not yet been constructed. Auxiliary Dam No. 3, if required to provide additional storage, would be constructed entirely within the MWD diversion (i.e. overflow from the dam would flow directly to the MWD) during the life of the Project.

A3.1.2 Runoff Control

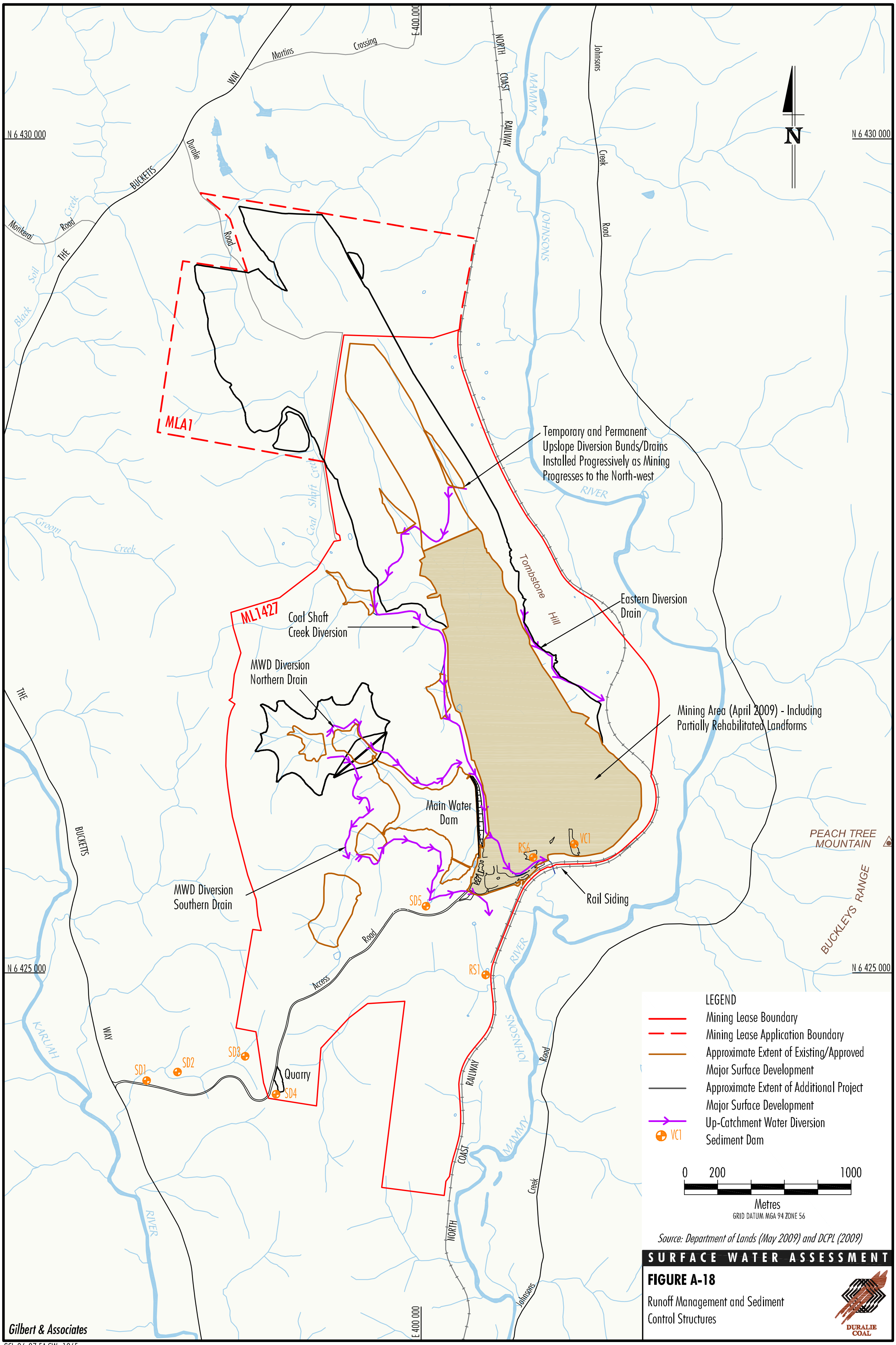
Surface water runoff controls aimed at preventing up-catchment runoff water from entering the open pit and waste rock emplacement areas have been constructed where practicable.

The main runoff water control structures at the DCM are:

- MWD diversions – Two diversion drains were approved as part of the original Duralie Coal EIS and have been constructed upslope of the MWD (northern and southern drains), to the west of the open pit and waste rock emplacement (Figure A-18). The MWD diversions intercept runoff from the catchments upstream of the MWD and divert the up-catchment runoff water to Coal Shaft Creek (northern drain) and Mammy Johnsons River (southern drain). The MWD diversion is also a component of the irrigation first flush protocol and is discussed further below.
- Coal Shaft Creek Diversion – The Coal Shaft Creek Diversion channel allows for the flow of up-catchment runoff reporting to Coal Shaft Creek to traverse the DCM site and avoid the open pit, waste rock emplacement and infrastructure areas (Figure A-18). The diversion is required until the watercourse is re-established at the cessation of mining (Section A6). The diversion was approved by Approval Number 20WA202053 under the Karuah River Water Sharing Plan (Section A2.6) and has a design capacity to safely pass the 100-year ARI peak flow event.
- Eastern Diversion – A diversion drain located along the ridgeline to the east of the existing open pit to intercept runoff from upslope catchments and divert it to Mammy Johnsons River (Figure A-18). This structure was also part of the original Duralie Coal EIS approvals.
- Flood control embankments have also been constructed to prevent inundation of open pit areas.
- A series of temporary diversion dams were also approved as part of the original Duralie Coal EIS approvals to capture runoff from the small drainage line to the north of the Weismantel open pit extent as mining progresses. These structures which have been constructed in accordance with the original approval, divert water (via pumping) to the Coal Shaft Creek Diversion (Figure A-18).

The existing Coal Shaft Creek Diversion comprised a series of diversion dams (Dams 1 to 5), connected with open channels and flowing in a general north to south direction. The open channels are constructed as cut-to-fill channels and bunds. In the upper reaches of the diversion, the channels are generally grassed or lined with rockfill (with grass and shrubs now established through the rockfill). In the lower reaches of the diversion, channels are either excavated in rock or are lined with rockfill mattresses. Most of the diversion (upper reaches) is constructed at higher levels than the original Coal Shaft Creek. This necessitated the construction of three drop structures on the lower reaches of the diversion, in the form of engineered stepped cascades, to dissipate flow energy and lower the elevation of the diversion back down to the elevation of the original Coal Shaft Creek channel into which the diversion discharges near the rail siding at the southern end of the DCM.

Plates A-1 to A-3 below show sections of the constructed diversion.



SURFACE WATER ASSESSMENT

FIGURE A-18

Runoff Management and Sediment Control Structures

DURALIE COAL

Gilbert & Associates

GCL-06-07 EA SW_106E

Plate A-1 – Drop Structure During Flow Event

Plate A-2 – Typical Rockfill Mattress-Lined Channel Shortly After Construction

Plate A-3 –Upper Reaches of Diversion Shortly After Construction

Plate A-4 –Diversion Channel Looking Downstream to Dam 1 (November 2009)

Plate A-5 –Diversion Channel Looking Upstream to Dam 3 (November 2009)

A3.1.3 Sedimentation Control

Erosion and sediment control structures currently in use at the DCM include (Figure A-18):

- five access road sediment dams (SD1, SD2, SD3, SD4 and SD5);
- two rail siding sediment dams (RS1 and RS6); and
- one waste rock emplacement sediment dam (VC1).

All erosion and sediment control structures are designed and operated in accordance with the approved DCM Erosion and Sediment Control Plan (ESCP).

A3.1.4 Open Pit Dewatering

Water reporting to the open pit is pumped via in-pit sumps to the MWD. DCPL holds an existing Bore Licence (20BL168404) issued by the DECCW, that allows for up to 300 ML of groundwater to be extracted from “works” in any 12 month period.

A3.1.5 On-site Irrigation System

An on-site irrigation system of pumps, piping and water distribution equipment is used to supply water from the MWD to the DCM irrigation areas, and comprises the following:

- five electrically powered centrifugal pumps;
- nine travelling irrigators, each delivering some 18 litres per second (L/sec) of water; and
- approximately 200 fixed sprays.

Operation of the irrigation areas is managed in accordance with the IMP (DCPL, 2008a). Five irrigation areas are currently operated/approved (Figure A-19), as follows:

- Type I – Irrigation areas located between the MWD diversions and the water storage inundation area of the MWD.
- Type II – Irrigation areas located upslope of the MWD diversions within ML 1427.
- Type III – Irrigation areas located upslope of the northern extent of the Weismantel open pit, including the upper reaches of Coal Shaft Creek.
- Type IV – Irrigation areas located on partially rehabilitated and rehabilitated areas of the waste rock emplacement.
- Type V – Irrigation areas located on inactive (but not yet topsoiled or rehabilitated) areas of the waste rock emplacement.

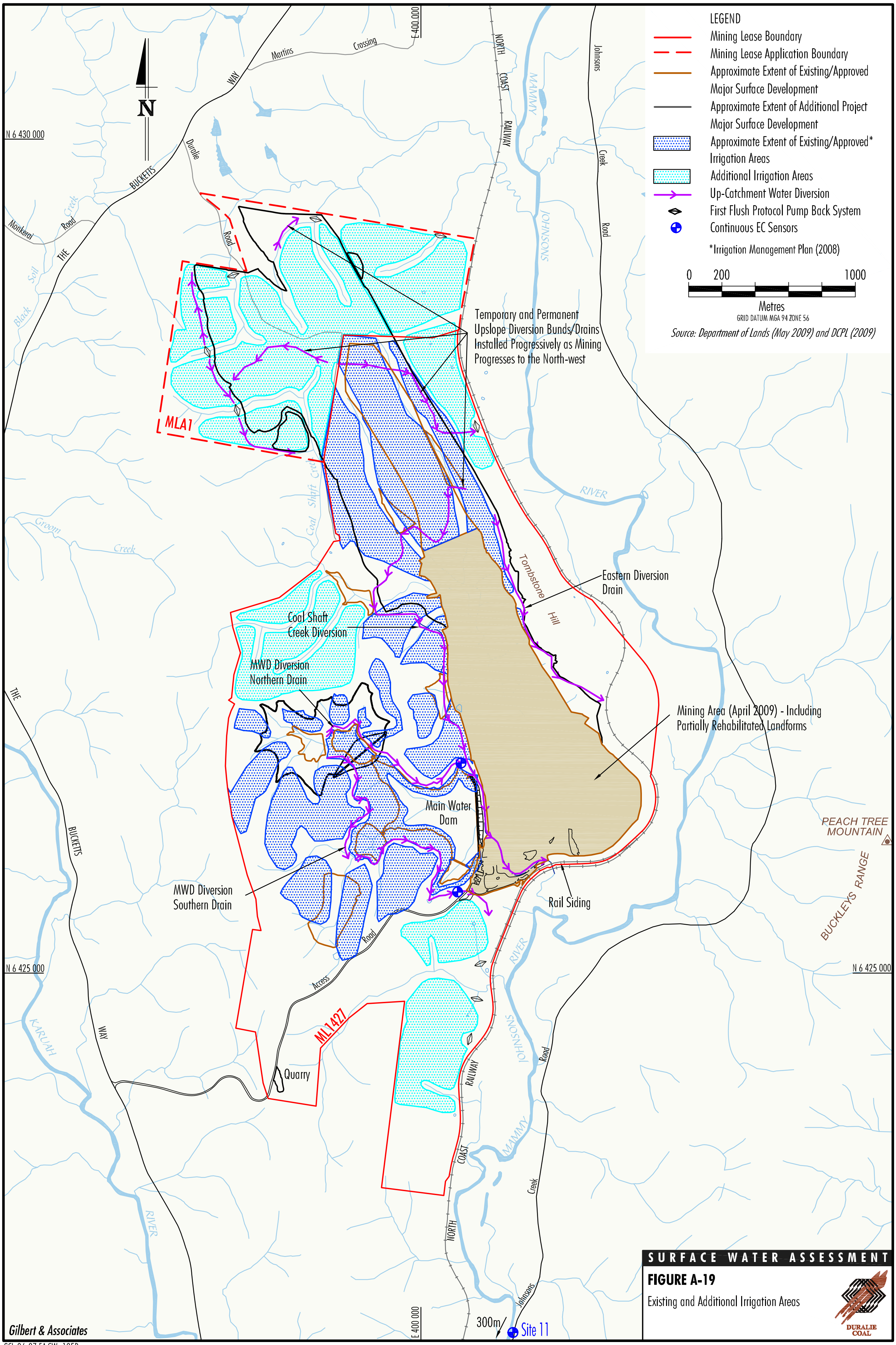
A mixture of pasture, woodland and cropping occur within the irrigation areas.

A3.1.6 First Flush Protocol

The IMP (DCPL, 2008a) includes a first flush protocol. The first flush protocol is designed to collect initial (or "first flush") rainfall runoff from irrigation areas which drain to Coal Shaft Creek or Mammy Johnsons River (i.e. Type II and Type III only) following prolonged dry spells, if this runoff contains high salinity as a result of salt build-up in irrigated soils.

Sensors measuring EC have been installed in the MWD diversion southern and northern drains (Figure A-19) to monitor runoff from the Type II irrigation areas. The first flush system for the Type II irrigation areas generally operates as follows:

- When EC readings in the MWD diversion drain sumps are equal to or greater than 1,326 μS/cm, or if the EC reading at Site 11 in the Mammy Johnsons River (Figure A-19) is equal to or greater than 400 μS/cm, motorised butterfly valves in pipelines at the downstream end of the MWD diversion northern and southern drains open, directing runoff from the irrigation areas to the MWD.
- When the EC readings in the MWD diversion drain sumps are below 1,326 μS/cm and the EC reading in the Mammy Johnsons River (at Site 11) is below 400 μS/cm, the valves close, allowing the runoff in the MWD diversion to report to the Coal Shaft Creek Diversion and Mammy Johnsons River downstream of the DCM.



GCL-06-07 EA SW_105D

A field EC meter is used following rainfall events for checking EC levels in the northern diversion dam as part of the first flush system for Type III irrigation areas. The first flush system for the Type III irrigation areas generally operates the same as the Type II irrigation areas, as described below:

- When the EC reading in the northern diversion dam is equal to or greater than 1,326 μS/cm, a valve in the base of the diversion dam is opened, directing runoff from the irrigation areas to the Weismantel open pit sumps where it is then pumped to the MWD.
- When the EC reading in the northern diversion dam is below 1,326 μS/cm, the EC reading in the Mammy Johnsons River (at Site 11) is equal to or greater than 400 μS/cm and the dam is not full (i.e. there is a low risk of spill to the Coal Shaft Creek Diversion), no action is taken and the EC levels are checked following the next rainfall event.
- When the EC reading in the northern diversion dam is below 1,326 μS/cm, the EC reading in the Mammy Johnsons River (at Site 11) is equal to or greater than 400 μS/cm and the dam is near capacity (i.e. there is a high risk of spill to the Coal Shaft Creek Diversion), a valve in the base of the diversion dam is opened, directing runoff from the irrigation areas to the Weismantel open pit sumps where it is then pumped to the MWD.
- When the EC reading in the northern diversion dam is below 1,326 μS/cm and the EC reading in the Mammy Johnsons River (at Site 11) is below 400 μS/cm, the water contained in the northern diversion dam is pumped to the Coal Shaft Creek Diversion.

A first flush protocol is not implemented on Type I irrigation areas as these are within the catchment area of the MWD or on Type V irrigation areas as these areas drain to the mine workings. A first flush protocol would be implemented for Type IV areas as part of the Project (Section A3.2.5).

A3.2 Proposed Project Water Management System

The proposed Project water management system (Figure A-17a) would be based on the existing water management system with augmentations undertaken as required over the life of the Project, including:

- Raising the embankment of Auxiliary Dam No. 2 to approximately RL 101 m, for the storage and management of water on-site (Section A3.2.3). The dam would be designed with a capacity of approximately 2,900 ML and would inundate approximately 27 ha when full.
- Development of new irrigation areas, progressively on an as required basis (i.e. as determined by periodic reviews of the site water balance), as new rehabilitated areas become available and mining extends into existing irrigation areas (Section A3.2.5).
- Progressive installation of up-catchment diversion drains and downslope sediment dams to effectively manage runoff from disturbance areas (Section A3.3).

Components of the proposed Project water management system are described in the sub-sections below.

A3.2.1 Approach and Design Criteria

The objectives of the water management on-site throughout the Project would be to:

- protect the integrity of local and regional water resources;
- operate such that there was no release of mining-related water off-site;
- maintain separation between runoff from undisturbed areas and water generated within active mining areas; and
- provide a reliable source of water for on-site mining and processing.

The water management system aims to maintain separation between water generated in undisturbed areas and water generated within active mining areas.

Water captured and diverted around active mining areas comprises surface runoff from catchment areas unaffected by the mining operations, and includes surface areas on which irrigation is undertaken excluding water collected under the first flush protocol (Section A3.1.6).

Water captured from mining related areas would include:

- rainfall within the open pits mixing with particulate matter and relatively saline groundwater;
- groundwater seeping into the open pits;
- rainfall induced runoff and seepage from active sections of the waste rock emplacement;
- rainfall induced runoff from the main infrastructure area;
- rainfall induced runoff from haul roads;
- rainfall induced runoff from areas stripped of topsoil (typically exposing clays);
- rainfall induced runoff from areas yet to adequately revegetate within sediment dam catchments; and
- direct rainfall falling on sediment dams and water management storages.

Water collected from these mining related areas would be stored for re-use on-site or irrigation and would not be directly discharged off-site.

A3.2.2 System Inflows

Sources of water from within mining related areas are listed in Section A3.2.1.

Rainfall induced runoff from active mining areas would vary with climatic conditions and the extent of current disturbance throughout the Project life. Runoff to active mining areas would be minimised through the use of upstream diversions, for example the Coal Shaft Creek Diversion, MWD diversion, the upstream clean water diversions for Auxiliary Dams No. 1 and No. 2 and diversions upslope of the Clareval North West open pit. Sediment laden runoff generated during rainfall events from the waste rock emplacement, main infrastructure and rail siding area and the haul road would be captured in open pits or sediment dams (Section A3.3).

The open pit workings would become collection points for incident rainfall, infiltration through mine waste rock emplacements and rainfall runoff. Sumps would be excavated in the floor of the active open pits as part of routine mining operations to facilitate efficient dewatering operations and to minimise interruption to mining.

Groundwater inflows to the open pits have been modelled by Heritage Computing and are presented in Table A-8.

Table A-8
Predicted Groundwater Inflows

Project Year	Average Predicted Groundwater Inflow (ML/day)
1	0.9
2	0.6
3	0.6
4	0.5
5	0.2
6	0.2
7	0.3
8	0.4
9	0.4

Source: Heritage Computing (2009).

Water that accumulates in the open pit sumps would be transferred to the MWD and may be used for dust suppression over Project haul roads and active waste rock emplacement surfaces (Section A3.2.4).

Where the potential for high groundwater inflows is identified during the life of the Project, advance dewatering may be conducted using temporary bores ahead of the open pit mining operation. Water from any such bores would be pumped to the MWD via open pit sumps.

A3.2.3 Water Storages

Water storages at the Project would include the MWD and Auxiliary Dams No. 1, No. 2 and No. 3 (refer Figure A-2). As part of the Project the embankment of Auxiliary Dam No. 2 would be raised from approximately RL 81 m to approximately RL 101 m to increase the capacity of the dam to a total of approximately 2,900 ML. This would result in an increase in the inundation area of Auxiliary Dam No. 2 from approximately 3.3 ha to approximately 27 ha. An emergency spillway would be constructed from the enlarged Auxiliary Dam No. 2 to the MWD diversion.

Auxiliary Dam No. 2 would be managed and operated for no release to downstream watercourses. This would involve operating the structure with a maximum operating level to provide freeboard for storm runoff storage. The freeboard for storm storage would be maintained by transferring excess water via a gravity pipeline to the MWD.

Once mining in the Weismantel Extension open pit is complete (scheduled for mid-2014), the remaining void would be used as a water storage, with water preferentially pumped to it from the Clareval North West open pit instead of to the other storages, until it is filled. The storage capacity of the Weismantel Extension open pit has been estimated at approximately 1,900 ML.

Water would be transferred between the storages and the open pits to minimise the disruption to mining and to maintain storm runoff storage capacity needed to achieve a low (negligible) risk of off-site release. The performance of the water management system and risks of off-site releases have been assessed as part of the water management system modelling discussed in Section A4.0. The MWD would also be managed and operated such to maintain freeboard for storm runoff and a consequent low (negligible) risk of off-site release – refer Section A4.3.

A3.2.4 Water Consumption

Water would be required for washdown of mobile equipment, dust suppression on haul roads and on ROM coal stockpiles and conveyor systems. Some water would also be used for fire fighting and other minor non-potable water uses.

The water consumption requirements and the water balance of the system would fluctuate with climatic conditions and as the extent of the mining operation changes over time. Fluctuations in water consumption have been accounted for in the site water balance model (Section A4). Some of the excess mine water would continue to be utilised through irrigation (Section A3.2.5).

A3.2.5 Irrigation

The Project would involve continued utilisation of the approved DCM irrigation areas (Figure A-19), as well as the development of new irrigation areas. A minimum of approximately 300 ha would be irrigated as part of the Project as shown on Figure A-19. Areas within the major surface development area (i.e. areas ahead of the advancing open pit and on available waste rock emplacement areas) would be irrigated in addition to the approximate 300 ha (Figure A-19).

The development and operation of additional irrigation areas would be consistent with the approved IMP, including the continued implementation of the first flush protocol (Section A3.1.6). Type VI irrigation areas would have runoff collection drains constructed downslope, directing runoff from the areas to constructed sumps or small dams. These dams would be monitored for EC following rainfall events and dewatered to the MWD by pumping based on a protocol consistent with that used for the Type II areas (Section A3.1.6), *viz.*:

- When EC readings in the sumps are equal to or greater than 1,326 μS/cm, or if the EC reading at Site 11 in the Mammy Johnsons River is equal to or greater than 400 μS/cm, the sumps would be pumped out to the MWD.
- When the EC readings in the sumps are below 1,326 μS/cm and the EC reading in the Mammy Johnsons River (at Site 11) is below 400 μS/cm, the sumps would be allowed to overflow and/or be pumped out to downstream drainage lines.

As discussed above, as the waste rock emplacement areas expand and are rehabilitated, irrigation would occur on these areas (Type IV irrigation areas). Runoff from these areas would be collected in a collection dam in the south-west corner of the waste rock emplacement. Where the measured EC in the collection dam is equal to or greater than 1,326 μS/cm, or if the EC reading at Site 11 in the Mammy Johnsons River is equal to or greater than 400 μS/cm, the accumulated water in the collection dam would be pumped out to the MWD.

A3.2.6 Operational Management and Objectives

The water management system would operate predominately as a closed self-contained system. The water balance of the system would fluctuate with climatic conditions and as the extent and status of the mining operation evolves over time.

The successful performance of the water management system (as with any mine water management system) would involve having a combination of adequate water infrastructure and the necessary management and monitoring procedures in place to achieve the performance objectives.

The broad objectives of the water management system on-site would be to:

- minimise the generation of water from mining related areas;
- minimise storage requirements by maximising re-use of water from active mining areas;
- remove potential impacts on downstream water resources by provision of secure containment on-site, adequate freeboard in water storages and maximising irrigation re-use;
- continue and expand the system of directing spills from the MWD to the Weismantel Extension open pit via pipelines to avoid uncontrolled release;
- implement a system of maintaining adequate freeboard in Auxiliary Dams No. 1 and No. 2, to avoid uncontrolled release;
- prevent sediment laden water with an elevated suspended solids concentration being discharged off-site; and
- capture first flush runoff and retain on-site if required in accordance with the approved IMP.

A3.3 Drainage Management for Undisturbed Catchments and Project Areas

The Project water management system would control waters generated from surface development areas while minimising the capture of surface water runoff by diverting upslope water around such areas. The water management system would include a combination of permanent structures that may continue to operate post closure and temporary structures that would only be required until the completion of rehabilitation works (e.g. sediment control structures).

Temporary and permanent upslope diversion bunds/drains and temporary interception dams would continue to be constructed over the life of the Project to divert runoff from undisturbed areas around the open pit and waste rock emplacement. The Project surface water management system would include continued diversion of runoff via the Coal Shaft Creek Diversion (Figures A-2 to A-6).

Permanent upslope diversion bunds/drains would remain around final voids. Isolation bunds would be constructed around the perimeter of any significant areas disturbed by mining to collect and convey drainage from these areas to containment storages.

Upslope diversion works would be designed in consultation with DECCW. The design capacity of these upslope diversion works would depend on:

- the size of the upslope catchment;
- the design life of the upslope diversion; and
- the potential consequences of a breach.

Depending on the above, the design capacity would range from the peak flow generated by the 1 in 2 year ARI event through to that generated by the 1 in 100 year ARI event.

Upslope diversions would be designed to be stable (non-eroding) at the design flows. Stabilisation of the upslope diversion works would be achieved by design of appropriate channel cross-sections and gradients and the use of channel lining with grass or rock fill as required.

The eastern toe of the backfilled waste rock emplacement would be designed to abut the Tombstone Hill ridgeline. Sediment dams would be constructed on the eastern flank of the Tombstone Hill ridgeline for sediment control whilst the eastern waste rock emplacement batters are undergoing rehabilitation/revegetation. The top surface of the waste rock emplacement would be graded away from the eastern batter and therefore only runoff from the eastern batters of the waste rock emplacement would drain to these sediment dams. The dams would be retained post-mining for stock watering and to provide stormwater runoff detention from the slightly increased catchment reporting eastwards, such that peak flow rates in culverts under the North Coast Railway line would not be increased.

Water structures (including the Coal Shaft Creek Diversion and MWD diversion) are inspected on a regular basis. For example, the Coal Shaft Creek Diversion is inspected for structural integrity, blockages or other faults after a rain event of >50 mm in seven days or at least every three months. The MWD diversion drain is inspected at least twice per year or following a significant rain event (typically of the order of 100 mm). Inspections would continue for the duration of the Project.

A3.4 Coal Shaft Creek Water Control System

Prior to the commencement of mining, Coal Shaft Creek traversed a large proportion of the DCM deposit. The staged construction of the Coal Shaft Creek Diversion has allowed the DCM to be developed. The diversion was completed in three stages. A re-established creek channel corridor bulk earthworks specification was prepared in January 2007 and in-pit waste placement in the southern end of the Weismantel open pit area is occurring in such a manner as to facilitate the ultimate construction of the re-established Coal Shaft Creek through this area (DCPL, 2008b).

The majority of the Coal Shaft Creek Diversion would remain for the Project life. The upper (northern) reaches of the diversion would be consumed by the advancing mine open pits and waste rock emplacement areas (refer Figures A-2 to A-6). Small tributaries in the very upper reaches of Coal Shaft Creek would be diverted around the Clareval North West open pit and waste rock emplacement, directing runoff back into the remnant Coal Shaft Creek upstream of the Coal Shaft Creek Diversion (refer Figures A-3 to A-6).

Hydrogeological, environmental and geomorphic considerations of Coal Shaft Creek post-closure are discussed in Section A6.2.

A3.5 Waste Rock Drainage Management

The Duralie Coal EIS Geochemical Assessment (EGi, 1996) was based on 112 rock samples collected and analysed in 1982 and collection and analysis of an additional 236 samples of overburden, roof rock and floor rock in 1995 and 1996.

The assessment indicated that the bulk of the overburden at the DCM would be non-acid forming (NAF) (EGi, 1996). However, a small percentage of the material to be mined was identified as potentially acid forming (PAF). The PAF units identified at the DCM included:

- high capacity and fast reacting PAF materials in overburden within 4 to 6 m of the roof of the coal seam;
- high capacity PAF material in areas of the coal seam floor; and
- lower capacity discontinuous PAF material in the upper overburden (5 to 20 m).

Leach column testwork conducted by EGi between December 1995 and August 2003 identified suitable limestone treatments for operational control of PAF roof and floor rock and demonstrated that long-term acid rock drainage (ARD) control of low capacity PAF material could be achieved by blending at not less than 2:1 with NAF overburden material (EGi, 2004).

ARD management at the DCM is managed in accordance with the Potential Acid Forming Material Management Plan (PAFMMP). This plan comprises of the following components:

- PAF material separation procedures;
- PAF material storage procedures; and
- monitoring of surface water and groundwater to monitor the control of PAF materials.

Monitoring results from the open pit sump indicate that the waste rock management methods have been successful in controlling acid release from the open pit floor and waste rock emplacement (Appendix I of the EA).

Geochemical investigation undertaken in Appendix I of the EA for the proposed Project concluded that:

> *Weismantel Seam overburden appears to be mainly NAF, except for a PAF horizon within 5 m (perpendicular to bedding) immediately above the coal seam. The Weismantel Seam floor rock is likely to be mainly PAF. Results from the EIS Geochemical Assessment testing suggest the PAF zone above the coal seam, the overlying thicker NAF zone, and the PAF floor rock are continuous and predictable, which is supported by more recent testing and operational experience.*
>
> *…*
>
> *Results indicate that PAF and NAF materials from Weismantel Seam overburden and Clareval Seam overburden are geochemically similar, and hence the existing management approaches used for Weismantel Seam overburden at the current DCM (Section 9) are expected to be applicable to Clareval Seam overburden. However, some modifications would be required to account for the greater complexity in the distribution of PAF and NAF in Clareval Seam overburden.*

Based on these results it is expected that use of the existing mine waste segregation and handling practices would be sufficient to maintain adequate control over acid mine drainage risk on-site. The existing PAFMMP would be revised as part of the Project to account for the greater complexity in the distribution of PAF and NAF in Clareval Seam overburden.

A4.0 SIMULATED PERFORMANCE OF WATER MANAGEMENT SYSTEM

A water balance model of the Project water management system has been developed to simulate the behaviour of the water management system over the nine years of mining operations. The model structure is generally as per the schematic in Figure A-17a. Information sources considered in the calibration and analysis of the water management system are shown on Figure A-17b.

The structure of this section is as follows:

- A description of the model structure, set-up data and assumptions (Section A4.1).
- An outline of the model calibration using monitoring data sourced from DCPL for the first six years of DCM operations (Section A4.2).
- Details of model predictions for the nine years of mining (Section A4.3).
- A discussion of model sensitivity to key water balance parameters (Section A4.4).
- A description of the salinity balance simulation undertaken for the MWD and Auxiliary Dams (Section A4.5).
- A summary of implications of the model and assumptions in regard to ongoing management of the system at DCM (Section A4.6).

A4.1 Model Description

A4.1.1 General

The model simulates daily changes in stored volumes of water at DCM in response to inflows (rainfall and groundwater) and outflows (evaporation, dust suppression use, irrigation loss and spill [if any]). Modelling includes simulation of storage in the MWD, open pits, in-pit waste rock emplacements (pore water storage), Auxiliary Dams and the minor dams (RS6 and VC1) (refer Figure A-17a). For each storage, the model simulates:

Change in Storage = Inflow – Outflow

Where:

Inflow includes rainfall runoff (for surface storages), seepage (from waste rock emplacements), groundwater inflow (for open pits), first flush capture and all pumped inflows from other storages.

Outflow includes evaporation, seepage and all pumped outflows to other storages or to a water use.

Runoff from most mine areas is assumed to report to the open pits. Infiltration through waste rock emplacement areas is assumed to report to the open pits, however runoff from rehabilitated waste rock emplacement areas at the southern end of the Weismantel open pit waste rock emplacement is assumed to report to a 60 ML capacity collection dam at the south-west corner of the waste rock emplacement.

A4.1.2 Rainfall

The model operates on a daily time step and has been developed to simulate the nine year Project life. The model utilises a long-term (10,000 year) stochastic rainfall data set as input. The stochastic rainfall data set was developed[4] using a "seed" of 120 years of rainfall data sourced from the Data Drill system[5]. The Data Drill rainfall data was compared with the DCM rainfall data record (for the period from 2002 to 2009) and found to be well correlated – refer Figure A-20 below which shows a plot of monthly rainfall totals from the DCM record versus monthly rainfall totals from Data Drill. The line of best fit on Figure A-20 shows that, on average, the Data Drill may slightly over-estimate rainfall at DCM.

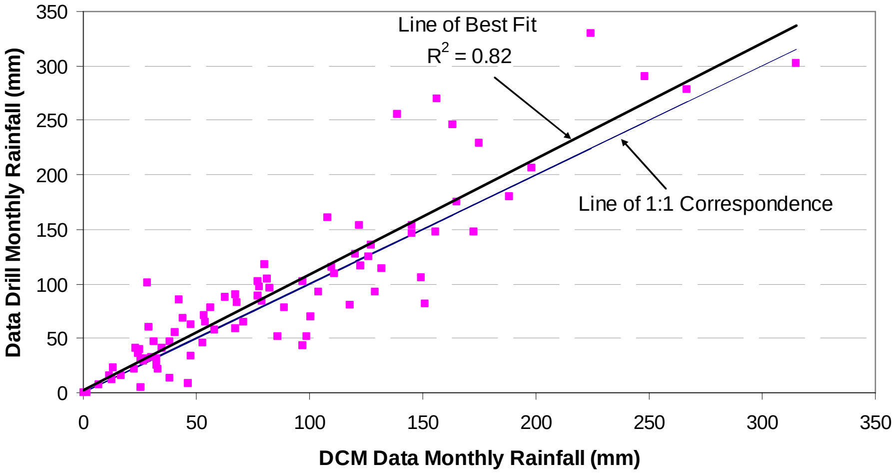


Figure A-20 Monthly Rainfall Comparison – DCPL Weather Station and Data Drill

In developing the 10,000 year stochastic rainfall data set from the Data Drill rainfall, the model parameters in the stochastic generation model were selected (A = 8.743, F = 1.196) to provide a fit to both annual rainfall totals and to the maximum daily rainfall in the Data Drill. Tables A-9, A-10 and A-11 below provide a comparison of daily, monthly and annual statistics of the 120 years of Data Drill and the 10,000 years generated stochastic rainfall data broken into 83 non-overlapping time series each of 120 years. In general the parameters indicate a good fit between the Data Drill and the stochastic data, particularly the means and standard deviations. The stochastic data exhibits a generally lower lag one serial correlation, particularly in annual totals. The effect on the water balance due to the lag one serial correlation in annual Data Drill is likely to be small because the observed lag one serial correlation of 0.219, corresponds to an R^2 value (coefficient of determination) of 0.05 in the regression of each year's total rainfall to the previous year's total rainfall. This indicates that about 5% of the variation in the Data Drill's annual total rainfall record is accounted for by this regression.

The model was run repeatedly, simulating 1,000 possible mine life "sequences", each nine years in length, to generate overall water balance, storage spill and open pit inundation statistics.

---

4 The stochastic rainfall generation model used was based on the DAYRNGEN model described in Boughton (1999).

5 The Data Drill is a system which provides synthetic data sets for a specified point by interpolation between surrounding point records held by the BoM. It is based on Jeffrey *et al*. (2001).

Table A-9
Statistical Comparison of Daily Rainfalls – Data Drill and Stochastic Rainfall Data

Month	Mean			Std Deviation			Lag One Serial Correlation			Maximum			Minimum		
	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation
Jan	3.59	3.7	0.2	10.12	10.24	0.59	0.396	0.227	0.027	254.7	146.7	33.8	0	0	0
Feb	4.40	4.5	0.3	12.81	13.19	0.92	0.313	0.215	0.030	319.3	203.6	49.5	0	0	0
Mar	4.72	4.8	0.3	14.38	14.52	1.07	0.357	0.180	0.026	438.1	239.2	57.2	0	0	0
Apr	3.60	3.4	0.2	10.94	10.19	0.71	0.310	0.257	0.032	364.4	159.0	36.0	0	0	0
May	3.11	3.0	0.2	10.01	9.79	0.68	0.351	0.264	0.033	365.4	168.3	43.2	0	0	0
Jun	3.30	3.4	0.2	10.22	10.34	0.69	0.361	0.282	0.033	356.8	152.3	40.5	0	0	0
Jul	2.61	2.5	0.2	8.82	8.46	0.77	0.331	0.232	0.037	257.1	142.9	38.0	0	0	0
Aug	2.17	2.1	0.2	7.58	7.42	0.56	0.338	0.269	0.037	278.2	124.6	29.9	0	0	0
Sep	2.18	2.2	0.1	7.61	7.55	0.55	0.267	0.203	0.033	219.8	125.1	30.2	0	0	0
Oct	2.43	2.5	0.2	8.14	8.26	0.69	0.268	0.195	0.030	232.6	140.2	32.1	0	0	0
Nov	2.68	2.7	0.2	7.71	7.59	0.44	0.214	0.171	0.023	233.3	111.1	26.6	0	0	0
Dec	3.17	3.3	0.2	9.28	9.51	0.50	0.285	0.206	0.032	223.7	137.3	31.5	0	0	0

Table A-10
Statistical Comparison of Monthly Rainfalls – Data Drill and Stochastic Rainfall Data

Month	Mean			Std Deviation			Lag One Serial Correlation			Maximum			Minimum		
	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation
Jan	114.9	113.8	7.2	91.9	76.5	6.3	0.248	0.023	0.094	529.5	395.1	65.7	2.4	6.4	3.7
Feb	124.1	127.6	8.4	97.8	93.1	7.9	0.006	0.053	0.082	493.2	488.3	96.1	0	4.9	2.8
Mar	145.9	147.6	9.2	121.5	103.7	9.9	0.071	0.052	0.084	523.5	532.6	87.9	4.7	8.2	4.6
Apr	100.1	102.2	6.9	90.3	77.2	7.3	0.111	0.055	0.088	528	399.8	68.6	5.6	4.7	2.9
May	93.0	93.7	6.2	76.2	75.9	7.6	0.055	0.034	0.081	378.7	395.4	66.8	1.1	3.5	2.1
Jun	100.3	101.2	7.3	87.2	80.4	6.7	-0.010	0.066	0.086	513.5	393.9	59.0	0	2.8	2.1
Jul	75.3	76.5	6.8	62.6	63.5	7.2	-0.054	0.051	0.085	289.8	334.8	67.5	0.9	2.6	1.8
Aug	65.1	66.0	4.8	68.4	56.2	6.2	0.251	0.039	0.095	490.7	292.8	60.4	0	2.3	1.7
Sep	63.2	64.9	4.4	52.1	53.3	5.9	0.047	0.031	0.090	244.1	283.2	62.0	0	2.4	1.9
Oct	77.6	77.4	5.5	68.3	58.5	5.7	0.077	0.038	0.095	346.7	316.4	56.6	0.9	4.6	2.5
Nov	82.4	81.2	5.2	53.4	51.4	5.0	0.157	0.041	0.095	248.9	267.7	42.8	5.3	6.8	3.6
Dec	101.5	100.9	5.8	66.6	68.6	6.0	0.009	0.030	0.098	300	359.9	56.4	6.4	7.0	4.1

Table A-11
Statistical Comparison of Annual Rainfalls – Data Drill and Stochastic Rainfall Data

Mean			Std Deviation			Lag One Serial Correlation			Maximum			Minimum		
Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation	Data Drill	Stochastic	Std. Deviation
1143	1153.061	24.60446	284.5	298.0	22.4	0.219	-0.006	0.1	1889	2055	160.5	533.8	498.5	94.9

A4.1.3 Irrigation Area First Flush Protocol Capture

The model simulates capture of first flush runoff from Types II, III, IV and VI irrigation areas, by simulating the actual protocols used on-site (Sections A3.1.6 and A3.2.5). As described in these sections, the two key triggers for first flush capture are:

i) the EC value in the irrigation area runoff reporting to the first flush monitoring point (with an EC greater than or equal to 1,326 µS/cm requiring first flush capture); and

ii) the EC value in the Mammy Johnsons River (with an EC value equal to or greater than 400 µS/cm requiring first flush capture).

Irrigation Area Runoff EC

Rather than attempting to explicitly model salinity in irrigation area runoff, a correlation between antecedent rainfall and runoff EC (measured in the MWD southern diversion drain) was developed for use in the water balance model.

DCPL has operated continuously recording EC sensors in the MWD diversion drain sumps (refer Section A3.1.6) since mid-2006. EC data from the sensors in the southern drain (on days when flow occurred) was compared with DCM daily rainfall for the previous 28 days. Rather than using 28 day rainfall totals, individual daily rainfalls for each of the preceding 28 days were used and different “weights” used to multiply each day’s rainfall, with the “weights” generally decreasing with duration back from the current day. The “weighted” rainfalls for 28 days were then summed – a sum of weighted rainfalls greater than one meant runoff EC was less than 1,326 µS/cm and when the sum was less than one, runoff EC was greater than 1,326 µS/cm. The “weights” were optimised (by linear discriminant analysis) to best distinguish between EC values above and below 1,326 µS/cm. Figure A-21 below shows a plot of recorded daily average EC in the southern MWD diversion versus the sum of weighted rainfalls over the period of available monitoring data. This method successfully predicted 86% of days with recorded EC above 1,326 µS/cm and 91% of days with recorded EC below 1,326 µS/cm.

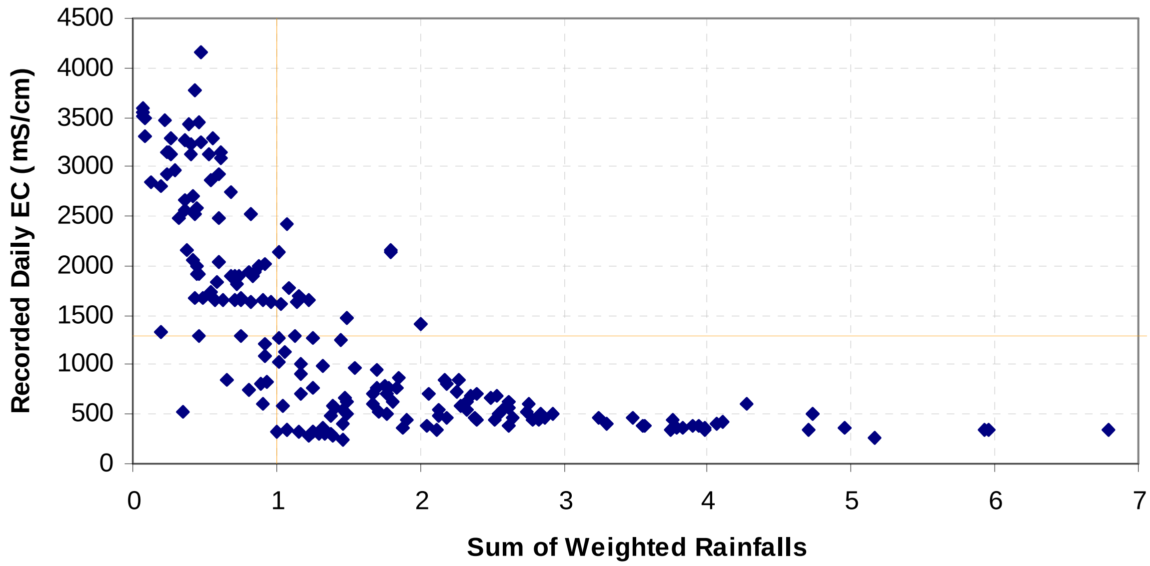


Figure A-21 Results of Linear Discriminant Analysis for Prediction of Irrigation Area Runoff EC in the Main Water Dam Southern Diversion Drain

Mammy Johnsons River EC and Flow

Prediction of EC in Mammy Johnsons River was undertaken by developing a correlation between river flow rate in Mammy Johnsons River at Site 11 and EC monitored at Site 11. EC data from a former gauging station[6] located at Stroud Road township was also included to expand the available data set. The correlation developed is shown in Figure A-22 below.

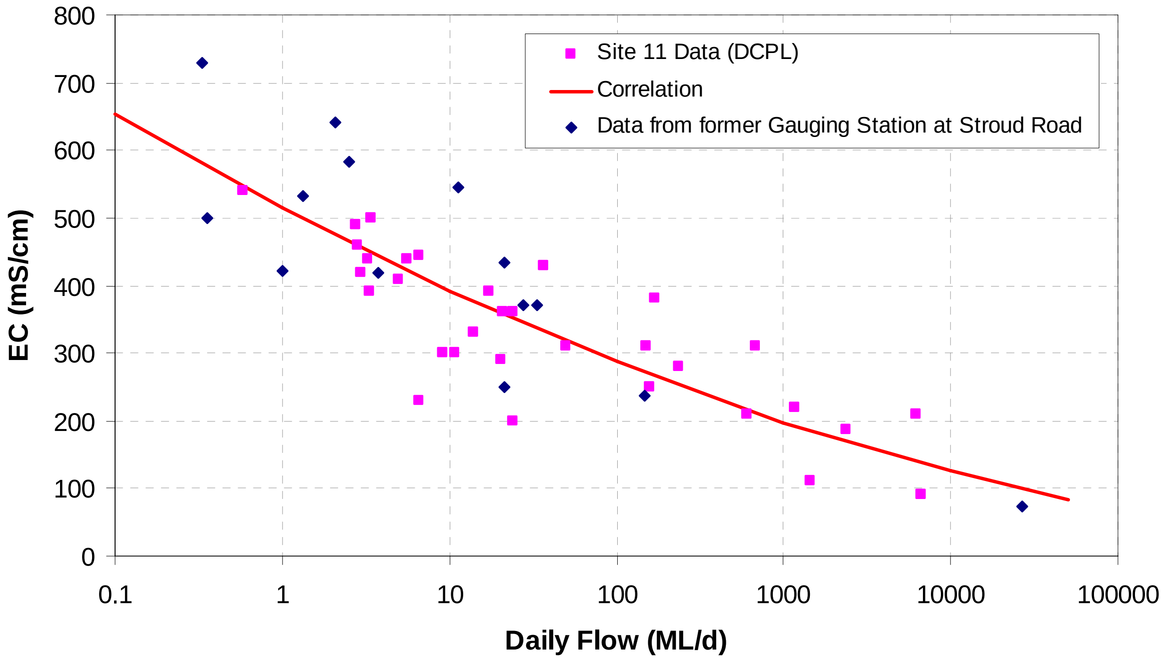


Figure A-22 Mammy Johnsons River EC-Flow Correlation

[6] GS209004 operated from 1968 to 1980.

The flow correlation equation developed is as follows:

$EC^{1/2} = 22.681 – 1.249 \times \text{Ln (Flow)}$ ($r^2 = 0.72$)

Where:

EC is in µS/cm.

Flow is in megalitres per day (ML/d).

Upper bound and lower bound EC values were set at 730 and 72 µS/cm, respectively, based on recorded data limits.

Streamflow data for Mammy Johnsons River at Site 11 was developed in two stages. Firstly a rainfall-runoff model was developed to simulate flows at GS209002 (Pikes Crossing). The model used was based on the nationally recognised Australian Water Balance Model (AWBM) – Boughton (2004). The AWBM is a catchment-scale water balance model that estimates streamflow from rainfall and evaporation. Figure A-23 below shows flow duration curves of monitored and AWBM predicted flows at GS209002 and indicates a good model fit to monitored daily flows.

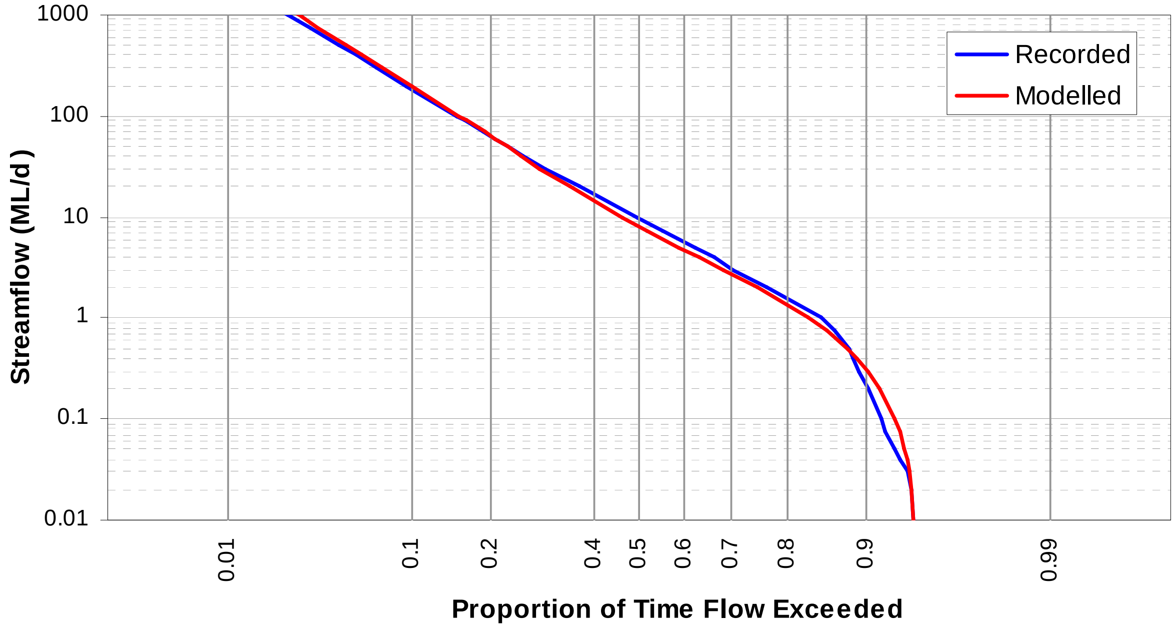


Figure A-23 Flow Duration Curve – Monitored and Modelled Flow Mammy Johnsons River at GS209002

Secondly, it was recognised that the streamflow at Site 11 would vary from that at GS209002 due to increased catchment area. An attempt was made to calibrate an AWBM for the former gauging station at Stroud Road (GS209004) which is located a short distance downstream of Site 11 (and was deemed to be representative of flows at Site 11), however the calibration was poor – likely due to lack of reliable rainfall data in the catchment for the period of operation of that gauging station. Instead a correlation between streamflow at the two gauging stations was developed using 5½ years of available concurrent data. The following correlation was developed using daily discharges:

For flows at GS209002 less than 1,000ML/d:

$Flow_{GS209004} = Flow_{GS209002} \times 2.16$ ($r^2 = 0.77$)

For flows at Pikes Crossing greater than 1,000ML/d:

$Flow_{GS209004} = Flow_{GS209002} \times 1.86$ ($r^2 = 0.68$)

In summary, EC in Mammy Johnsons River (used in determining first flush capture conditions) is modelled using a three step process:

1) Streamflow at GS209002 (Pikes Crossing) is calculated using the calibrated AWBM;
2) Streamflow at Site 11 is calculated from the flow calculated in (1) using the above correlation relationship; and
3) EC at Site 11 is calculated from the flow calculated in (2) using the correlation presented in Figure A-22.

A4.1.4 Other Data

Other key data and assumptions used in the model include the following:

- Average monthly pan evaporation data taken from monthly averages from the Paterson (Tocal) (BoM Station No. 061250) record (refer Table A-3).
- Future mine catchment areas measured from "snapshot" plans provided by DCPL (refer Figures A-2 to A-6).
- Groundwater inflow rates to the Clareval North West and Weismantel Extension open pits derived from groundwater modelling by Heritage Computing (Appendix B of the EA) (Section 3.2.2).
- Rainfall events in excess of the 100 year ARI design capacity of the MWD diversion and Coal Shaft Creek Diversion would result in overtopping of the diversions and flow into the MWD or Weismantel Extension open pit. On days where the rainfall was above the design capacity, inflow to the MWD was calculated as half the total runoff reporting to the diversion on that day.
- Progressive development of additional Type IV irrigation areas and commissioning of new Type VI irrigation areas early during the Project life. Progressive removal of Type III areas as the Weismantel Extension open pit advances.
- Commissioning of the enlarged Auxiliary Dam No. 2 (2,900ML capacity) at the start of 2011.
- The capacity of Auxiliary Dam No. 1 has been modelled as 440 ML (as built).
- Commissioning of the Weismantel Extension open pit as a water storage upon completion of mining in mid-2014.
- No pumping from either open pit to the MWD when the volume held in the MWD is above 1,200 ML.
- Pumped transfer from the MWD to the Weismantel open pit at 24 ML/day when the volume held in the MWD rises above 1,200 ML.

- The following key triggers for transfer between the MWD and Auxiliary Dams No. 1 and No. 2 to minimise the risk of disruption to mining:

	Auxiliary Dam No. 1	Auxiliary Dam No. 2
Trigger volume in MWD for pumping to begin to Auxiliary Dam from MWD (pending Auxiliary Dam freeboard requirements below).	900 ML	900 ML
Trigger volume in MWD for pumping to begin from Auxiliary Dam to MWD	800 ML	800 ML
Auxiliary Dam minimum freeboard for pumping from MWD	43 ML	130 ML
Transfer rate from MWD to Auxiliary Dam	10 ML/day	10 ML/day
Transfer rate from Auxiliary Dam to MWD	58 ML/day	58 ML/day

- Transfer from Auxiliary Dam No. 1 to the MWD (at 58 ML/d rate) occurs when either:
  - MWD volume falls below 800 ML; or
  - Remaining Auxiliary Dam No. 1 freeboard is less than 43 ML and the MWD volume is less than 1,295 ML (water below inlet of pipeline to pit).
- Transfer from Auxiliary Dam No. 2 to the MWD (at 58 ML/day rate) occurs when either:
  - MWD volume falls below 800 ML; or
  - Remaining Auxiliary Dam No. 2 freeboard is less than 130 ML and the MWD volume is less than 1,295 ML (water below inlet of pipeline to pit).
- Auxiliary Dam No. 3 has not been included in the model – as conservative assumption although not overly so, given that this dam is likely to be quite small compared to the other storages.
- Project simulations commence on 1st July 2010, with an assumed total stored surface water volume at DCM of 1,250 ML.

A4.2 Model Calibration

DCPL has provided the following data for use in model calibration:

- Daily estimated volumes of water pumped from/to mine storages, the Weismantel open pit and MWD.
- Daily rainfall at DCM.
- Daily site evaporation data, calculated from the DCPL weather station.
- MWD level (generally weekly).
- Monitored haul road water usage.
- Daily recorded hours of irrigation to travelling irrigators and fixed sprays.
- Soil moisture (gypsum block) measurements for the Type II irrigation area.

Data has been provided for the period since mine commissioning in 2003.

Model calibration (carried out for the period 2003-2009) has been split into three component parts, focusing on:

1. the existing Weismantel open pit;
2. the Type II irrigation areas upslope of the MWD; and
3. the MWD.

A4.2.1 Weismantel Open Pit

The existing Weismantel open pit receives runoff from the mine area, waste rock emplacement and surrounding remnant natural surface, as well as groundwater inflow and seepage from the in-pit waste rock emplacement.

Figure A-24 below shows a plot of cumulative volume of water pumped from the open pit (based on data supplied by DCPL[7]), together with predicted volume obtained using time-varying catchment areas (based on plans provided by DCPL) and the following calibrated parameters:

- Weismantel open pit catchment area varying from 10 ha in mid-2003 to 133 ha in mid-2009.
- Runoff coefficients for mine area, waste rock emplacement and residual (undiverted) undisturbed catchments of 0.45, 0.09 and 0.24, respectively.
- Groundwater inflow rates varying linearly between the values and dates below:

Date:	1/3/2003	1/10/2003	1/9/2004	2/9/2004	1/1/2006	1/7/2006	1/11/2008
ML/day	0	0.45	0.5	0.06	0.04	0.01	0.15

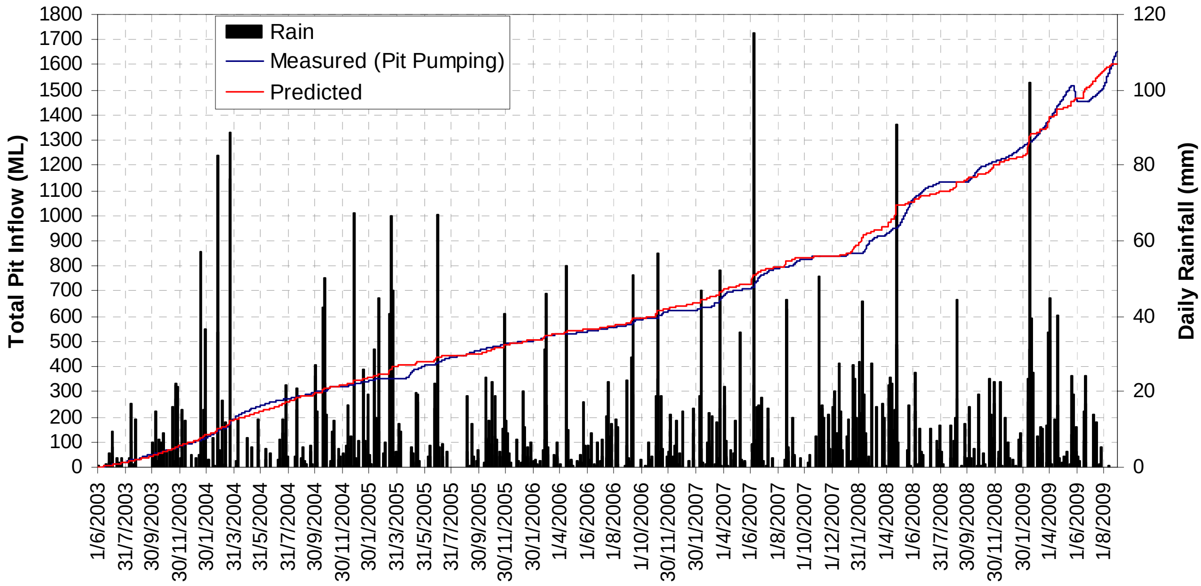


Figure A-24 Recorded and Predicted Water Volumes – Open Pit

[7] Supplied pumping data were not available on a daily basis, but as either weekly or monthly totals.

The above groundwater inflow rates are significantly lower than the median 0.68 ML/day predicted as part of Duralie Coal EIS studies. It was found that the recent groundwater inflow rate could be increased by decreasing the pit area runoff coefficient and still obtain a similarly good match between predicted pit inflow and monitored water pumped from the pit. The net effect on the overall pit water balance is likely to be small – i.e. whether water originates from groundwater or surface runoff.

Waste rock emplacement rehabilitation has not been in place for a long enough period of time to enable estimates of runoff rates to be derived from monitored data from rehabilitated waste rock emplacement areas. A runoff coefficient of 0.24 was used for these areas, equal to the value for natural surface areas (no distinction was made between direct runoff and seepage in the model).

The above (calibrated) runoff coefficients were used in predictive water balance model simulations.

A4.2.2 Type II Irrigation Areas

Soil Moisture

The Type II irrigation areas have been extensively instrumented with soil moisture sensors, in the form of gypsum blocks (MEA[8] Gbugs). The Gbugs measure soil potential which is converted to soil matrix potential – the higher the soil potential, the drier the soil. Gbug readings are understood to be used as a guide by DCM personnel to decide upon where and when to irrigate.

Recorded data from several Gbugs (8 centimetres [cm] in length to a depth of 20 cm) were used to develop a simple soil moisture balance model. The model was set up as a simple single surface store with recharge by rainfall and irrigation, loss to evapotranspiration, runoff and deeper infiltration. Figure A-25 shows a plot of data from one of the Gbugs, together with the simple structure of the soil moisture balance model and model results plotted against time, while Figure A-26 shows an x-y plot of daily monitored and simulated daily Gbug readings.

[8] Measurement Engineering Australia Pty Ltd.

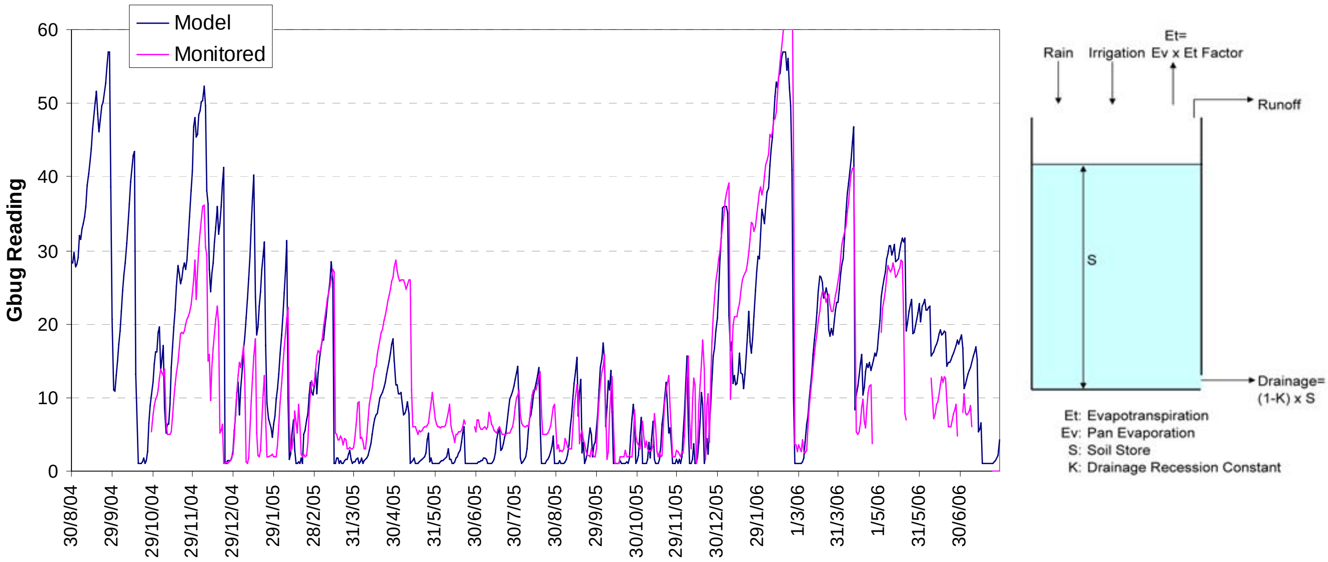


Figure A-25 Soil Moisture Monitoring and Modelling Predictions (Irrigation Run 16)

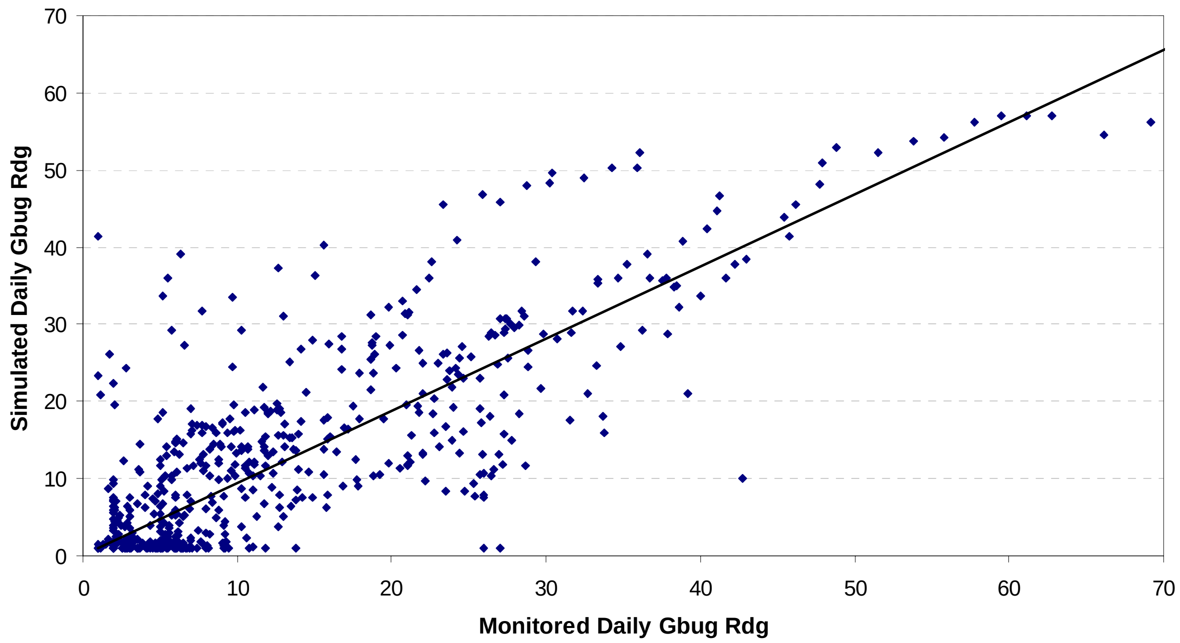


Figure A-26 Comparison of Monitored and Simulated Soil Moisture (Irrigation Run 16)

Table A-12 below summarises regression coefficients of daily simulated to recorded Gbug readings.

Table A-12
Soil Moisture Balance Model Regression Coefficients

Run No:	2	3	5	9	11	12	16	26
Regression Slope	0.689	0.782	1.12	0.680	0.931	0.565	0.936	0.686
r^2	0.39	0.44	0.57	0.37	0.39	0.44	0.64	0.49

Although direct daily regression coefficients are well below one, given that the model reproduces the general pattern/trend of observed soil moisture, the simple model was incorporated into the mine water balance model to predict when irrigation runs are able to be irrigated (to achieve a Gbug reading of 10 or more). Adopted soil moisture model parameters are summarised in Table A-13 below (averaged over the eight modelled irrigation runs).

Table A-13
Adopted Soil Moisture Balance Model Parameters

Parameter:	S_{max}	K	Et Factor (Summer)	Et Factor (Winter)
Value:	80.7	0.999	0.60	0.48

<u>Irrigation Area Runoff</u>

Modelling of runoff from the Type II irrigation areas was undertaken using the AWBM. All of the travelling irrigator runs were simulated separately as was the un-irrigated portion of the catchment. Irrigation was simulated over each run according to recorded hours provided by DCPL, as well as rainfall recorded at the DCM meteorological station. The following AWBM parameters were used.

Store:	1	2	3
Surface Storage Capacity (C):	5.6	118	118
Partial Areas (A):	0.33	0.335	0.335
Baseflow Index (BFI):		0.23	
Baseflow Recession Constant (K_b):		0.823	
Surface Flow Recession Constant (K_s):		0.0	

The parameters were adapted from those used for GS209002 on Mammy Johnsons River, with lower surface store values used to reflect the cleared nature of the catchment. The average surface store was equal to the S_{max} of the soil moisture balance model described above. The model was unable to be calibrated directly, given there is no measurement of total flow rate from the catchment. However, modelled flows were used as input to the water balance calibration of the MWD (refer Section A4.2.3).

An effective yield (runoff coefficient) of 45% of rainfall for the total Type II irrigation area was predicted by the model for the 2003-2009 period. The higher runoff coefficient is considered to be as a result of the higher antecedent moisture conditions in the irrigated soils.

A4.2.3 Main Water Dam

The MWD receives runoff from the residual catchment between the storage area and the MWD diversion, direct rainfall, water pumped from the open pit and other dams at DCM, seepage from the MWD diversion and first flush capture from the Type II irrigation area.

Figure A-27 shows a plot of monitored MWD storage volume (based on recorded levels and volume-level relationship developed from as-built topographic contours), together with predicted volume obtained using the calculated dam catchment area and the following calibrated parameters:

- Runoff coefficients of 0.22 for undisturbed areas[9] and 0.75 for Type I irrigation areas (within the MWD catchment). The calibrated runoff coefficient for Type I irrigation areas is higher than the Type II irrigation areas (Section A4.2.2), which is considered to be because these areas are irrigated more heavily compared to the other areas as the runoff reports back to the MWD.
- Pan factors (used as a multiplier on evaporation data to convert to open water evaporation) of 1.05 and 0.82 for summer and winter respectively.
- First flush collection was simulated by calculating flow rates in the MWD diversion from the Type II irrigation area moisture store model described in Section A4.2.2 and assuming a maximum first flush capture rate of 37 L/s (rate determined as a calibration parameter and scaled back from the theoretical maximum pipeline capacity due to changes to the configuration of the pipeline inlet pit).
- Seepage from the small dams that form part of the MWD diversion was also modelled. Water volumes in these dams were modelled by simulating inflow rates to the dams using the Type II irrigation area moisture store model described in Section A4.2.2, allowing for evaporation and a seepage rate of 7.5 mm/day (rate determined as a calibration parameter and applied to the wetted surface area of each dam).

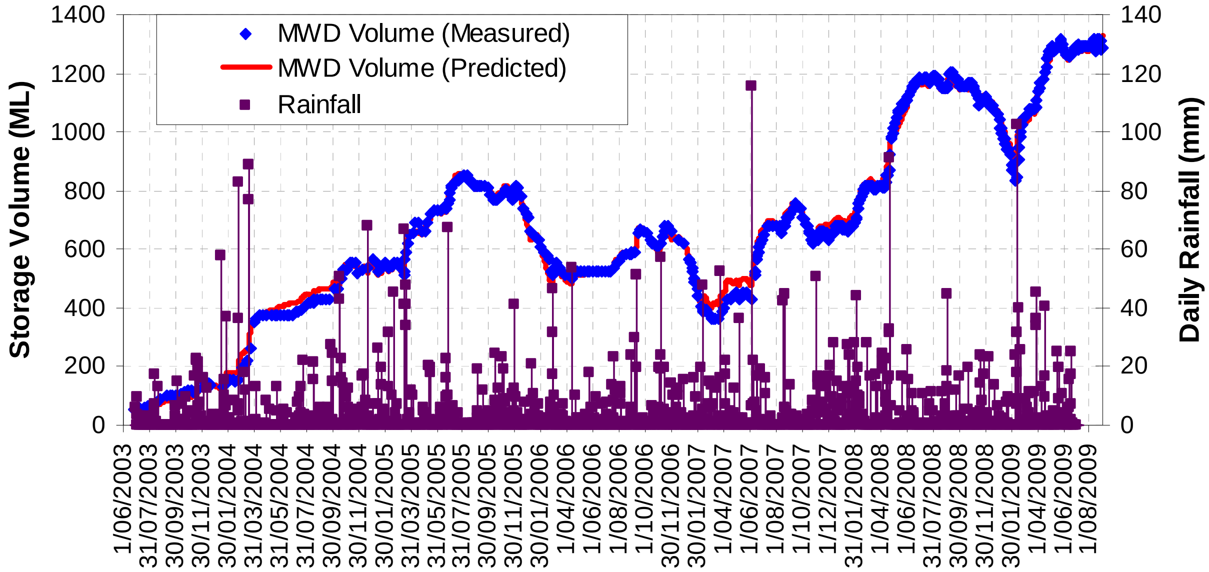
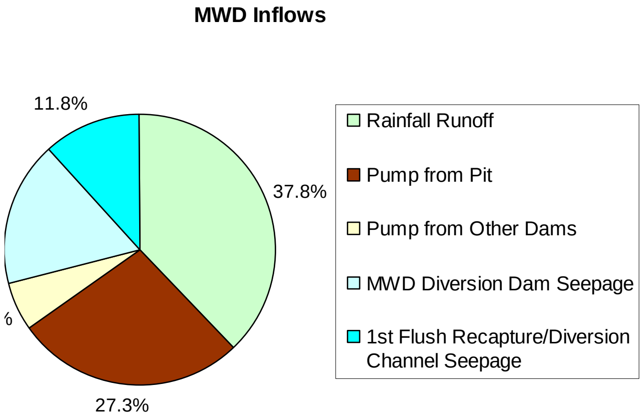


Figure A-27 Recorded and Predicted Water Volumes - Main Water Dam

Calibrated proportions of component inflows and outflows for the MWD for the period from mid-2003 to the mid-2009 are shown in Figure A-28 below.

[9] Note that this differs from the runoff coefficient obtained for the undiverted open pit area undisturbed catchment (refer Section A4.2.1) – this is attributed to the flatter, somewhat more vegetated nature of the pit area undisturbed catchment.



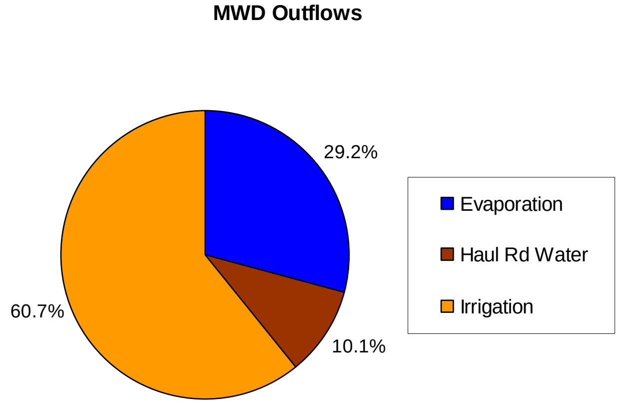


Figure A-28 Main Water Dam Water Balance 2003-2009

A4.3 Simulated Performance

A4.3.1 Overall Water Balance

The predicted average water balance for the Weismantel Extension and Clareval North West open pits for the nine years of mining, averaged over all 1,000 mine life sequences is summarised in Table A-14.

Table A-14
Predicted Average Water Balance for Open Pits

	Average Inflows (ML/year)
Groundwater	172
Rainfall-runoff	724
Transfer from MWD to Weismantel Extension open pit	23
Seepage from Clareval North West in-pit waste rock emplacement	63
Pump from rehabilitated waste rock emplacement capture dam to Weismantel Extension open pit	58
	Average Outflows (ML/year)
Pump to MWD	411
Evaporation	65
Seepage to Weismantel Extension in-pit waste rock emplacement	408
Average Change in Storage (ML/year)	*156*

The predicted average water balance for the MWD and Auxiliary Dams for the Project life, averaged over all 1,000 mine life sequences is summarised in Table A-15.

Table A-15
Predicted Average Water Balance for Mine Water Storages*

	Average Inflows (ML/year)
Rainfall-runoff	807
Pump from open pits	411
Pump from other dams	46
Seepage from upslope of MWD diversion	91
First flush collection	167
	Average Outflows (ML/year)
Irrigation	769
Evaporation	599
Haul road use	74
Transfer to Weismantel Extension open pit	23
Spill off-site	0
Average Change in Storage (ML/year)	*57*

* Includes MWD, Auxiliary Dams No. 1 and No. 2.

The water balance for the nine year mining period for rainfall totals corresponding to the median, 10 percentile (%ile) (dry) and 90%ile (wet) are given in Tables A-16 and A-17 for the open pits and mine water storages respectively.

Table A-16
Predicted Water Balance for Open Pits for Given Rainfall Totals

Average Inflow (ML/year) from:	*10%ile Rainfall*	*Median Rainfall*	*90%ile Rainfall*
Groundwater	172	172	172
Rainfall-runoff	821	691	782
Transfer from MWD to Weismantel Extension open pit	0	0	0
Seepage from Clareval North West in-pit waste rock emplacement	60	63	69
Pump from rehabilitated waste rock emplacement capture dam to Weismantel Extension open pit	53	65	59
Average Outflow (ML/year) to:			
Pump to MWD	357	260	416
Evaporation	58	60	69
Seepage to Weismantel Extension in-pit waste rock emplacement	383	395	409
Average Change in Storage (ML/year):	*308*	*276*	*188*

Table A-17
Predicted Water Balance for Mine Water Storages* for Given Rainfall Totals

Average Inflow (ML/year) from:	*10%ile Rainfall*	*Median Rainfall*	*90%ile Rainfall*
Rainfall-runoff	664	762	888
Pump from open pits	357	260	416
Pump from other dams	41	46	51
Seepage from upslope of MWD diversion	83	92	98
First flush collection	160	205	194
Average Outflow (ML/year) to:			
Irrigation	835	756	730
Evaporation	487	635	641
Haul road use	76	74	73
Transfer to Weismantel Extension open pit	0	0	0
Spill off-site	0	0	0
Average Change in Storage (ML/year):	*-93*	*-100*	*203*

* Includes MWD, Auxiliary Dams No. 1 and No. 2.

A4.3.2 Overall System Performance

DCPL would maintain their policy of no release of mining-related water off-site. The policy of no uncontrolled release would be achieved through:

- the use of controlled irrigation of excess water;
- transfer of water between the MWD and Auxiliary Dam water storages and the open pits;
- maintaining adequate freeboard for large rainfall events; and
- ensuring adequate pump capacity is installed to transfer water between the water storages and to the open pits.

The water balance simulation modelling showed that there were no simulated releases of mine related from the MWD or the Auxiliary Dams in any of the 1,000 sequences simulated. This reflects a negligible risk of uncontrolled spill risk if the assumed operational conditions are adhered to.

The consequence of exceeding the design capacity of the water management system would be the transfer of water to the open pits with consequential disruption to mining operations. The risk of disruption to mining operations is an operational risk and would have no environmental consequences.

The existing DCM is operated with the operational risk of disruption to mining as a result of exceedance of the design capacity of the water management systems (Table A-18). The operational risk to the Project as a result of the water management system has been assessed using the water balance modelling in conjunction with 1,000 sequences each 9 years in length and has been determined to be an economically and operationally acceptable risk.

Table A-18
Predicted Pit Inundation Statistics

Pit Inundation Statistic		Probability for Rest of Mine Life			
		50%	10%	2%	1%
Weismantel Extension Open Pit	Total No. Days>200 ML	0	0	0	0
	Max. Consecutive Days>200 ML	0	0	0	0
	No. Events>200 ML for >30 days	0	0	0	0
Clareval North West Open Pit	Total No. Days>200 ML	0	67	211	362
	Max. Consecutive Days>200ML	0	50	169	240
	No. Events>200 ML for >30 days	0	1	2	2

A4.4 Model Sensitivity

The water balance model is well calibrated against the available past observations which cover a six year period (Figures A-24 and A-27). Forward predictions may however be sensitive to uncertainty in components of the water balance which would change significantly compared to their current magnitudes.

The sensitivity of model was tested by varying model catchment runoff coefficients evaporation rates and groundwater inflow rates by +/- 10% (Table A-19).

Table A-19
Sensitivity Analysis Results

Parameter	Variation	Predicted Spill Risk over Project Life	Probability of Event >200ML in Clareval North West Open Pit for >30 days
Base Case (no variation)		<0.1%	16%
Runoff Coefficients (all storages)	+10%	0.3%	32%
	-10%	<0.1%	7%
Evaporation Rates (all storages)	+10%	<0.1%	12%
	-10%	0.4%	27%
Groundwater Inflows	+10%	0.1%	18%
	-10%	<0.1%	14%

The sensitivity analysis indicates that model predictions are relatively insensitive to changes in groundwater inflows but are more sensitive to changes in runoff coefficients and evaporation – particularly to reduced evaporation and increased runoff coefficient.

A4.5 Salinity Balance – Main Water Dam and Auxiliary Dams

A salt balance simulation has been undertaken for the MWD and Auxiliary Dams. The balance involved tracking the movement of salt[10] into and out of the MWD and Auxiliary Dams and estimating changes in salt concentration (EC) in the dam over average, and unusually wet and unusually dry periods. The salinity balance used simulated water inflows, outflows and changes in storage generated from the water balance model simulation for three different climatic sequences. Salt loads and concentrations were then calculated by applying salt concentrations to the salt sources (inflows) to the MWD and Auxiliary Dams based on DCM records for these sources. Salt outflows (with irrigation water and other water outflows) were calculated by multiplying the outflows by the salt concentration of the three storages which was tracked on a daily basis via the salt load and water volume in the storages. The assumed salt concentrations in the inflows to the storages are summarised in Table A-20 below (generally based on DCM monitoring data).

Table A-20
Assumed Electrical Conductivity in Inflows to the MWD and Auxiliary Dams

Salt Inflow Source	Electrical Conductivity (µS/cm)
Internal catchment runoff	100*
First flush capture and seepage	670
Weismantel Extension open pit	3,530#
Clareval North West open pit	3,530#
First flush return (Type II and VI Irrigation Areas)	692
Rail siding sediment dam (RS6)	1,445

* Assumed value - the majority of runoff comprises direct rainfall on the stored water surface.
# Assumed value based on monitoring data in the Weismantel open pit sump.

The simulated EC levels in the MWD and Auxiliary Dams over the three simulated climatic sequences are shown in Figures A-29, A-30 and A-31.

[10] Because the bulk of the available data on salinity is in the form of field measurements of electrical conductivity, which is an indirect measure of total dissolved solids, the model has been set-up to simulate changes in electrical conductivity.

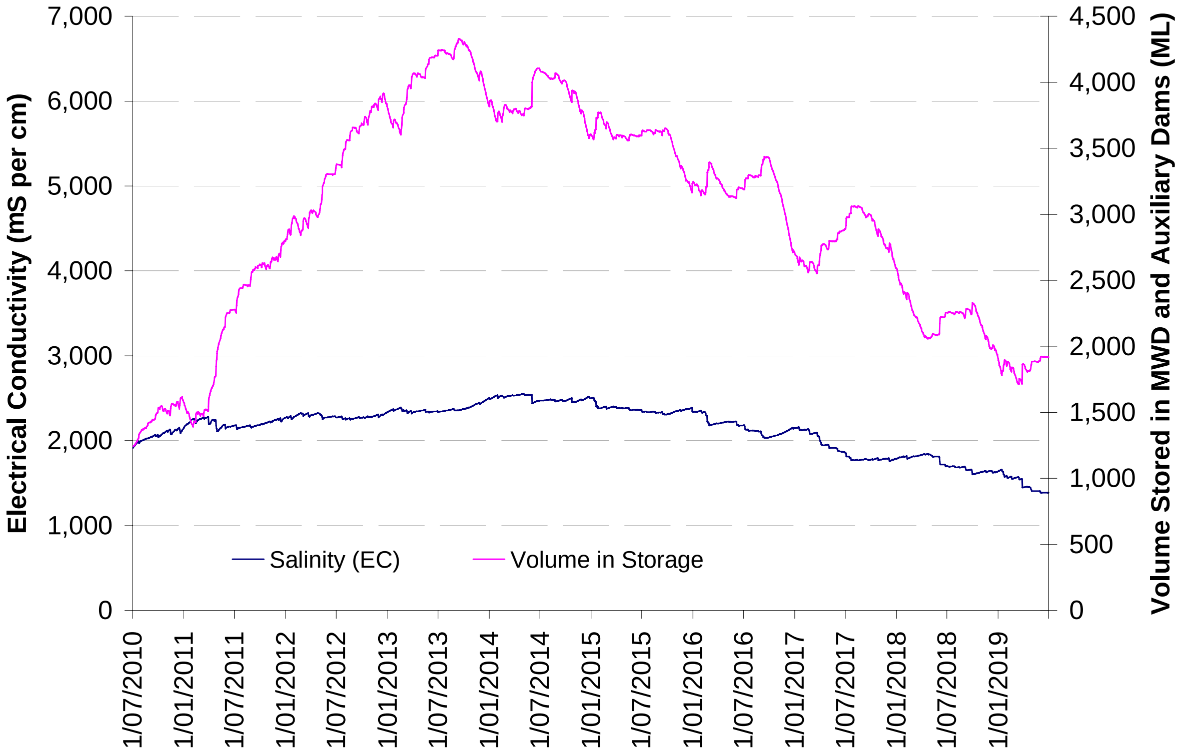


Figure A-29 Simulated Salinity and Storage Volumes in Main Water Dam and Auxiliary Dams – Median Rainfall Sequence

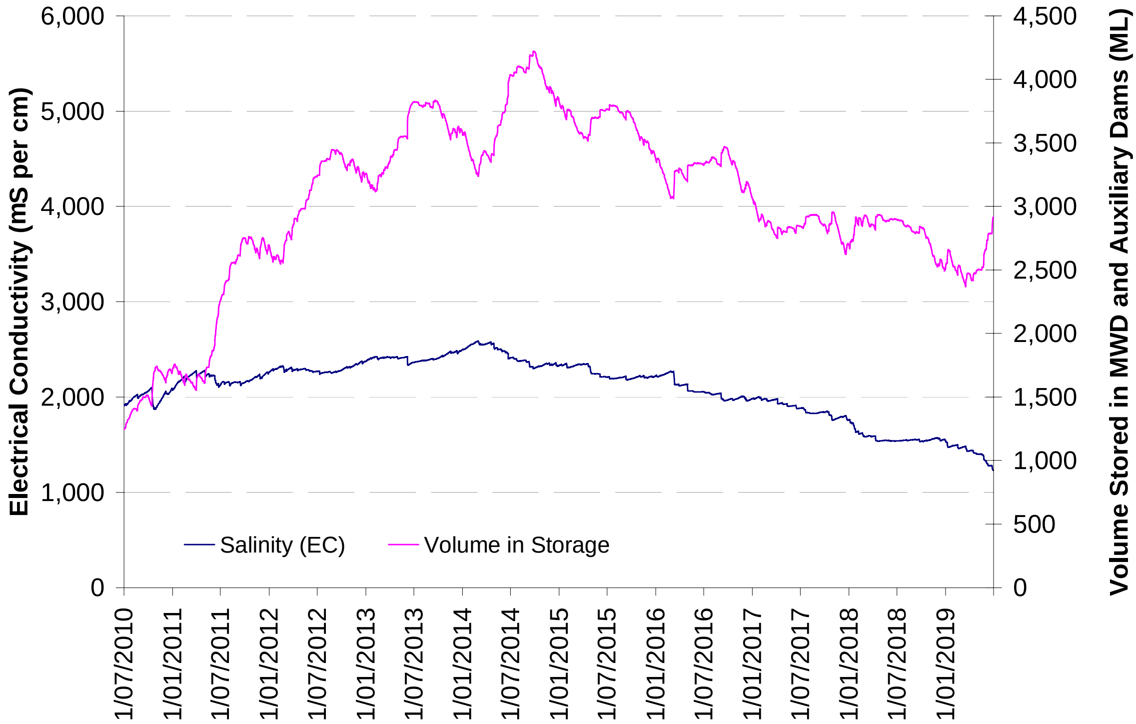


Figure A-30 Simulated Salinity and Storage Volumes in Main Water Dam and Auxiliary Dams – 10 Percentile Exceedence (Wet) Rainfall Sequence

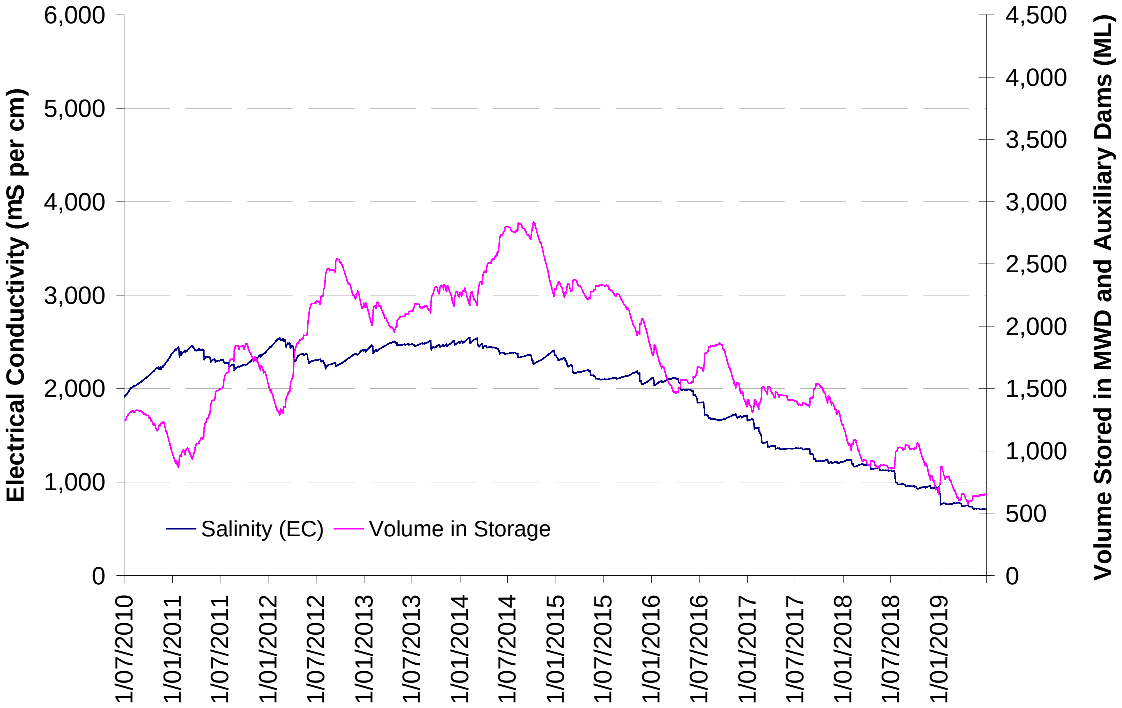


Figure A-31 Simulated Salinity and Storage Volumes in Main Water Dam and Auxiliary Dams – 90 Percentile Exceedence (Dry) Rainfall Sequence

The simulated salinity (EC) of water in the MWD is typically between 700 and 2,600 µS/cm. The average simulated EC of water in the MWD for the median, dry and wet rainfall sequences is 2,144 µS/cm, 1,940 µS/cm and 2,091 µS/cm, respectively.

An assessment of the suitability of mine water for irrigation use was conducted by Agricultural Water Management based on the average salinity of irrigation water for the median rainfall sequence and is presented in Attachment AB. The potential impacts of irrigation are discussed in Section A5.3.

A4.6 Water Management Implications

The results of the water balance model are contingent upon the assumptions given in Section A4.1 and A4.2 relating to how stored water is managed and the timing of future proposed works. In summary these are as follows:

- Commissioning of Auxiliary Dam No. 2 in early 2010 and raising the embankment of Auxiliary Dam No. 2 by the start of 2011.
- Use of the Weismantel Extension open pit as a water storage from mid-2014.
- Commissioning of additional (Type VI) irrigation areas from mid-2010 onwards.
- Progressive commissioning of additional irrigation areas on the waste rock emplacement as additional waste rock emplacement areas become available, from mid-2010 onwards.
- Commissioning of additional pumps for all irrigation areas to enable at least a third of all irrigation areas to be irrigated on any one day.
- Maintenance of adequate freeboard in and transfer rates between all water storages (refer Section A4.1.4).

- Extension of the overflow pipeline, between the MWD and Weismantel Extension open pit, northwards as the pit advances.
- Maintaining a 24 ML/day transfer pump and pipeline to transfer water from the MWD to the Weismantel Extension open pit.
- Ensuring a stored water volume at DCM of no more than 1,250 ML at 1st July 2010.

The distribution of the water between the storages at the start of the Project , even if it was all in the MWD, does not affect the water balance or the negligible risk of uncontrolled spill, as long as the operating procedures in Section A4.1.4 are followed.

A5.0 ASSESSMENT OF POTENTIAL OPERATIONAL SURFACE WATER IMPACTS

The potential operational impacts of the Project on local and regional surface water resources are:

- Changes to flows in local creeks due to expansion and subsequent capture and re-use of drainage from mine catchment areas.
- Potential for export of contaminants (principally sediments and soluble salts) in mine area runoff and accidental spills from containment storages (principally sediments, soluble salts, oils and greases), causing degradation of local and regional watercourses.
- Additional runoff generated from irrigation areas due to higher antecedent soil moisture.
- Potential for more saline runoff from irrigation areas to local drainage lines.
- Changes to flows in the Mammy Johnsons River and Karuah River as a result of runoff and flow changes in contributing catchments and groundwater drawdown.
- Potential for migration of contaminants through groundwater or direct runoff to the Mammy Johnsons River as a result of irrigation and on-site water storage (including in-pit water storage).

A5.1 Impacts on Flow Regime in Local Creeks

The effect of runoff capture on flows in local drainages as a result of the expanded area affected by mining as part of the Project is summarised in Table A-21.

Table A-21
Changes to Contributing Catchment of Local Creeks

Catchment	Total Pre-mining Catchment Area (km^2)	Area Captured in Water Management System (km^2)	
		Existing	Maximum
Coal Shaft Creek	9	3.3	5.2
Unnamed Tributary to Mammy Johnsons River	2.9	0	0.8

The catchment of these creeks would be progressively reinstated as the waste rock emplacements are rehabilitated and become free draining. However, as discussed in Section A3.2.5, while the rehabilitated waste rock emplacement is being irrigated where the measured EC in the collection dam is equal to or greater than 1,326 µS/cm, or if the EC reading at Site 11 in the Mammy Johnsons River is equal to or greater than 400 µS/cm, the accumulated water in the collection dam would be pumped out to the MWD. Following the completion of rehabilitation post-mining, only the catchment areas of the final voids would remain excised from the catchment (total of 0.75 km^2) (Section A6.1).

As part of development of the Weismantel open pit waste rock emplacement, waste rock would be placed against the Tombstone Hill ridgeline to the east of the waste rock emplacement area (refer Figure A-6). Drainage from the eastern batter of the rehabilitated waste rock emplacement (total batter area 0.4 km^2) would drain eastwards towards Mammy Johnsons River.

A5.2 Release of Contaminants in Drainage Off-site

Sediment dams and other containment storages would be sized to contain runoff from rainfall events between a 1 in 20 year and 1 in 100 year ARI, depending on the function of the storage and the potential consequences of the spill. Sediment dams would be constructed downslope of the eastern batter of the Weismantel open pit waste rock emplacement (Figures A-3 to A-6).

The risk of spill from the MWD and the open pits has been evaluated as part of the site water balance (Section A4.3). There were no spills simulated during the 1,000 climatic sequences simulated and subject to adherence with the operational protocols and other assumptions inherent in the modelling – refer Section A4.6, there is a negligible risk of spill occurring from the MWD or the Auxiliary Dams over the Project life to downstream receiving waters including Mammy Johnsons River.

A5.3 Potential Impacts of Irrigation

The continued and expanded irrigation would be undertaken generally in accordance with the currently implemented IMP (DCPL, 2008a). It is expected that runoff rates from irrigation areas would increase as a result of higher antecedent moisture conditions in the irrigated soils. Direct runoff of irrigation water would be avoided by strict management of irrigation including the continued use of soil moisture monitors.

Agricultural Water Management (2009) conducted an assessment of the suitability of mine water for irrigation use at the Project and this is included in Attachment AB. Agricultural Water Management concluded there was no evidence that irrigation with water from the MWD would significantly affect soil properties and their suitability for future agricultural use. Accordingly water from the MWD is considered suitable for irrigation, under an irrigation system conducted in accordance with the IMP moisture deficit strategy (Attachment AB).

The first flush protocol would continue to be implemented during the use of irrigation throughout the Project (Section A3.2.5). Therefore runoff which is not captured is expected to be of similar quality to the pre-mining water quality of Coal Shaft Creek, which minimises impacts on the water quality (specifically salinity) of receiving waters i.e. the Mammy Johnsons River and its downstream users.

A5.4 Impacts on Mammy Johnsons River

Changes to flows and flow regimes in the Mammy Johnsons River may potentially occur as a result of:

- runoff and flow changes in contributing catchments; and
- groundwater migration as a result of irrigation and on-site water storage (including in-pit water storage).

The existing catchment areas of Coal Shaft Creek and the unnamed tributary to Mammy Johnsons River contribute approximately 2.7% of the total catchment area of Mammy Johnsons River. The loss of a further 2.7 km^2 total catchment as part of the Project (refer Table A-21 above), represents approximately 0.8% of the total catchment of Mammy Johnsons River. The cumulative loss (with the existing DCM) of 6 km^2 total catchment represents approximately 1.9% of the total catchment of Mammy Johnsons River and approximately 0.4% of the catchment of the Karuah River. Given this, and the likely increased runoff rates from the irrigation areas (Section A5.3), the impacts on flow in Mammy Johnsons River are likely to be insignificant.

Following the completion of rehabilitation post-mining, only the catchment areas of the final voids would remain excised from the catchment (approximately 0.75 km^2, or 0.2% of the total catchment of Mammy Johnsons River and approximately 0.05% of the catchment of the Karuah River).

The Groundwater Assessment (Appendix B of the EA) concluded that the impact on flows in the Mammy Johnsons River as a result of the Project is considered to be negligible, with a maximum predicted reduction in baseflow over the nine years of mining operations of approximately 0.00014 megalitres per day per square kilometre ($ML/day/km^2$) of catchment area.

Potential impacts on surface water quality in the Mammy Johnsons River would result from changes in the water quality of runoff in contributing catchments and the potential for migration of contaminants through groundwater as a result of irrigation and on-site water storage (including in-pit water storage). As discussed above, the impact on flows in Mammy Johnsons River is considered to be negligible and there is not expected to be any changes in the quality of groundwater as a consequence of mining (Appendix B of the EA), therefore there would be negligible impact on water quality in the Mammy Johnsons River.

A range of measures would be implemented as part of the Project to minimise the potential for impacts on surface water quality including:

- the continued implementation of the first flush protocol from irrigated areas throughout the life of the Project;
- the construction of upslope diversion bunds/drains and temporary interception dams over the life of the Project to divert runoff from undisturbed areas around the open pit and waste rock emplacement;
- the provision of secure containment on-site, adequate freeboard in water storages and maximised irrigation re-use to prevent sediment laden water with an elevated suspended solids concentration being discharged off-site; and
- the implementation of a comprehensive monitoring programme to monitor the effectiveness of the above measures.

The implementation and adherence to these measures would result in the Project having a negligible risk of water quality impacts on the Mammy Johnsons River.

A6.0 POST-MINING WATER MANAGEMENT

The post-mining water management strategy presented in the Duralie Coal EIS proposed re-establishing the original alignment of Coal Shaft Creek which would incorporate the final void as a permanent lake and construction of a channel linking the void to the river (DCPL, 1996). The current post-mining water management strategy is shown on Figure A-6.

The final water management strategy for the Project would be finalised through the NSW Department of Industry and Investment's (DII's) Mining, Rehabilitation and Environmental Management Process (MREMP).

A6.1 Final Void Water Management

At the cessation of mining, final voids would remain in the Clareval North West open pit and Weismantel Extension open pit (Figure A-6). The approximate depths and areas of final voids are provided in Table A-22.

Table A-22
Project Final Voids

Final Void	Depth (m)	Area (ha)	Catchment Area (ha)
Clareval North West Open Pit	190	47	47
Weismantel Extension Open Pit	90	10	28

The surface catchment area of the final voids would be reduced to a practicable minimum (refer Figure A-6) by the use of upslope diversions, contour drains around their perimeter and maximising backfilling of voids. Calculated final void catchment areas are given in Table A-22.

Inflows to the final open pit voids comprise incident rainfall over the void lake surface, runoff and seepage from the sides of the voids and their adjacent contributing catchment and seepage from coal seam groundwater and waste rock emplacement infiltration. A final void water balance model has been developed for the combined final voids to predict the long-term behaviour of the final void water bodies.

Post recovery groundwater seepage rates (including overburden infiltration) to the voids were advised by Heritage Computing. Inflow rates were estimated for different final void water levels (reducing with rising water level).

Rainfall runoff from the void catchments was estimated using runoff coefficients applied to the final void sub-catchments (in a manner similar to the mine water balance model – refer Section A4), with an allowance for long-term infiltration through the rehabilitated waste rock emplacement equal to 2% of incident rainfall. Daily rainfall data used in the model was the same stochastic data set developed for the mine water balance model (refer Section A4.1.2) with evaporation equal to monthly average values (refer Section A4.1.4) multiplied by a pan factor of 0.9.

Interchange of stored water between the pit void and surrounding waste rock emplacement was simulated using Darcy's Law and an assumed waste permeability of 10^{-4} m/s. Storage of water was modelled in the waste rock emplacement interstitial void space with an assumed void ratio of 0.25 (DCPL, pers. comm.).

Spill between the two voids was modelled as occurring at RL 50 m, while the perimeter of the final voids was assumed to be at RL 88 m. An initial stored water level to RL 40 m was assumed for the Weismantel Extension open pit void, corresponding to approximately 1,100 ML stored water. The Clareval North West open pit was assumed to be initially empty, with the pit floor at approximately RL -100 m.

Model results are shown in Figure A-32 below in terms of predicted final void water levels versus time.

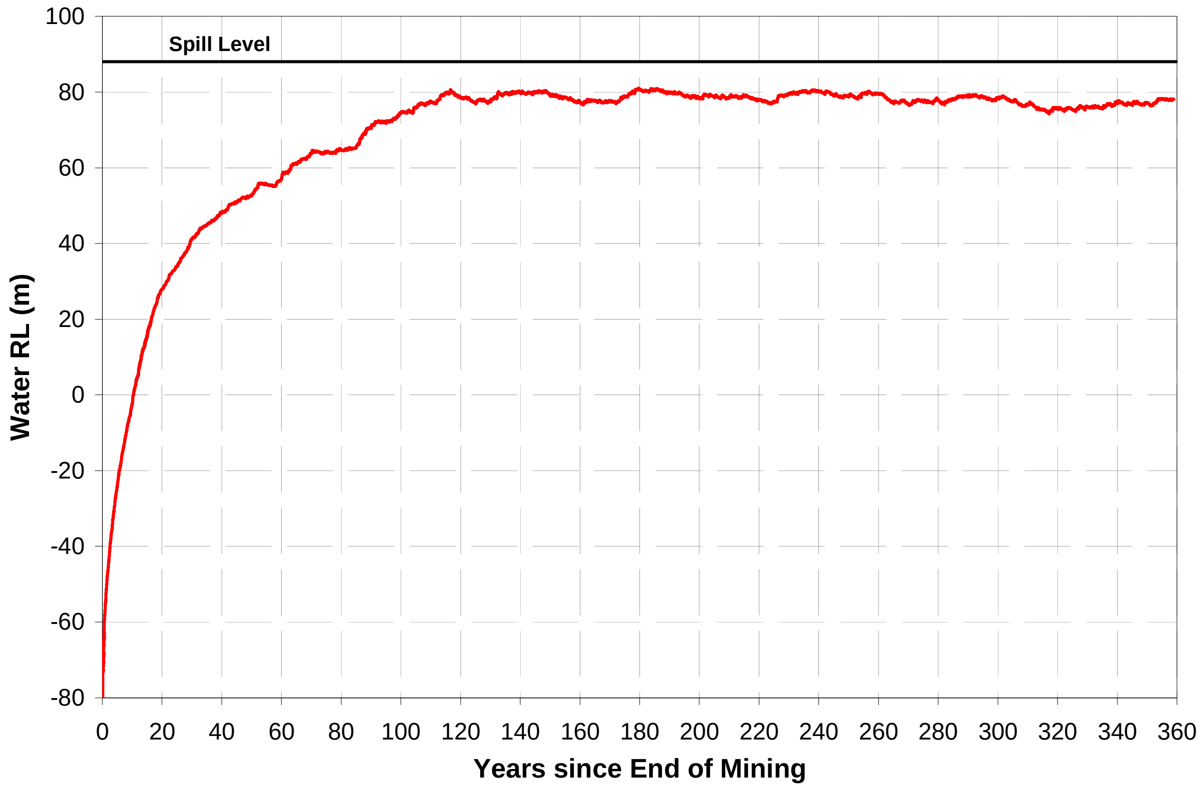


Figure A-32 Predicted Final Void Water Levels

Figure A-32 shows that predicted water level in the final voids would stabilise after about 120 years at a level approximately 8 m below spill level. No spill is predicted in the long-term from the final voids.

The sensitivity of model predictions on filling characteristics to key parameters was tested. Table A-23 summarises the results of the analysis.

Table A-23
Final Void Water Balance Sensitivity Results

Parameter	Variation	Approximate Predicted Duration to Reach RL 80 m
Base Case	-	120 years
Surface Runoff Coefficients	+20%	110 years
	-20%	180 years
Rehabilitation Infiltration Rate	x 0.5 (to 1%)	Does not reach this level
	x 2 (to 4%)	110 years
Evaporation Rate	+20%	Does not reach this level
	+10%	Does not reach this level
	-10%	100 years
	-20%	90 years

Results of the sensitivity analysis indicate that the void filling rate is most sensitive to evaporation rates however void filling rate is still relatively slow being approximately 90 years to reach RL 80 m under the low evaporation rate scenario. The final void level will ultimately depend on the climatic conditions which prevail in the future (i.e. over the next 100 to 130 years). There is significant uncertainty in the prediction of future climate conditions, however, as outlined in Section A7 below, most projections are for significantly lower rainfall and higher evaporation rates. As discussed below this would have the effect of reducing the rate of filling and of lowering the final void water levels below those shown on Figure A-32.

The final void water balance model was also used to simulate salinity levels in final void waters. The balance involved tracking the movement of salt (EC) into the final void and estimating changes in salt concentration (EC) in the void over time. Assumed salt concentrations used in inflows to the final void are as follows:

- Rainfall runoff from remnant surface catchment (void perimeter): 400 µS/cm.
- Groundwater inflow: 2,568 µS/cm.
- Seepage from waste rock emplacements: 670 µS/cm.

Figure A-33 shows predicted final void salinity (EC) versus time. Final void salinity is predicted to generally slowly increase with time, reaching 5,000 µS/cm in 310 years.

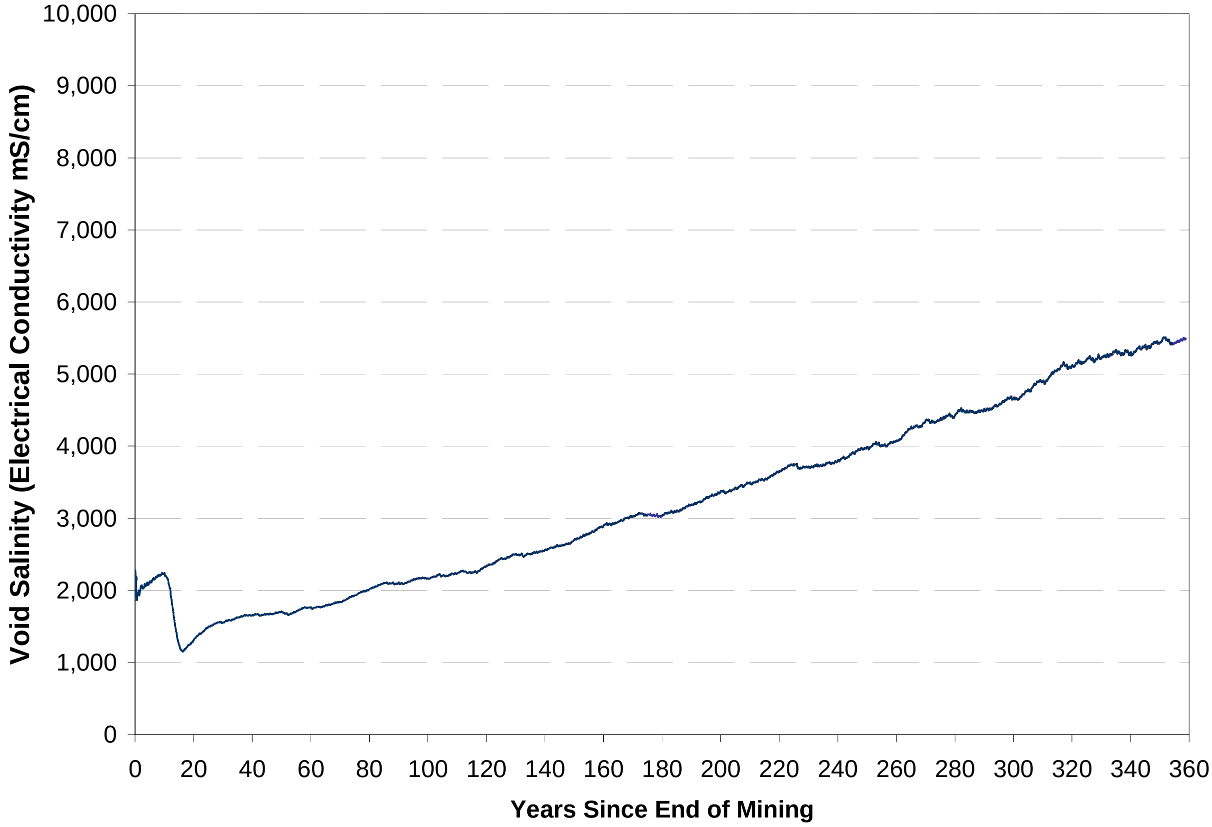


Figure A-33 Predicted Final Void Salinity

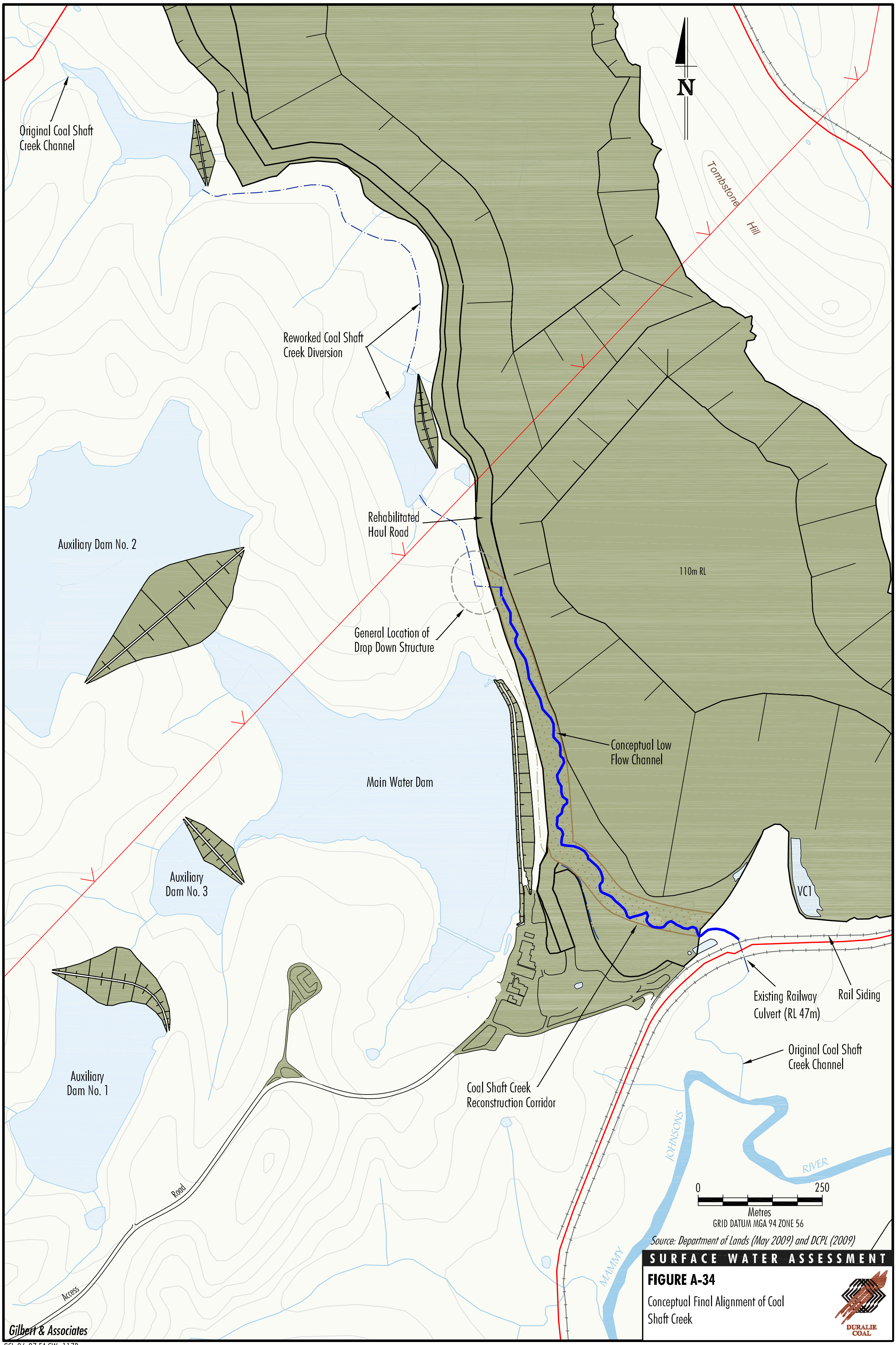
A6.2 Coal Shaft Creek

Following the completion of mining activities at the DCM, a final alignment of Coal Shaft Creek would be established, stabilised and revegetated prior to lease relinquishment.

The proposed design concept for the post-mining alignment of Coal Shaft Creek would comprise a reworked section of the existing Coal Shaft Creek Diversion channel, a drop-down section outside the in-pit waste rock emplacement, and reconstructed section of the creek within a corridor within the in-pit waste rock emplacement at the southern end of the Weismantel open pit extent (Figure A-34). The design of the reconstructed Coal Shaft Creek would be based on geotechnical, hydrological and hydraulic characteristics of similar natural drainage systems with particular emphasis on stream channel and bank stability, seepage management and habitat creation.

Analyses into the post-mining alignment and reconstruction of Coal Shaft Creek would collect information from similar natural features surrounding the Project area to inform the final design of the channel, including:

- stream energy, stream power and critical tractive stress;
- energy relationships at bankfull stage and at peak flow;
- channel long profiles and cross-sections;
- upstream and downstream controls;
- bed and bank material, including critical entrainment and destabilisation thresholds;



SURFACE WATER ASSESSMENT

FIGURE A-34

Conceptual Final Alignment of Coal Shaft Creek

GCL-06-07 EA SW_117B

- changes in energy profiles and constriction and resultant changes in afflux through, past and over structures; and
- nature of bedload transport and mechanisms to permit bedload transport.

The final design of the post-mining alignment of the Coal Shaft Creek would be documented in a Coal Shaft Creek Reconstruction Plan as part of the overall site water management reporting process. Consultation would continue to be conducted with the NSW Office of Water within DECCW (NOW) regarding the final post-mining alignment and design of the reconstructed Coal Shaft Creek.

The Coal Shaft Creek Reconstruction Plan would include acceptance criteria and monitoring requirements such as bed and bank stability, movement of bed sediment, changes to flow path geometry, vegetation and habitat establishment and water quality.

A description of the components of the proposed design for the reconstructed Coal Shaft Creek is provided below.

Reworked Section of Existing Diversion Channel

Following the completion of mining, the upper section of the existing Coal Shaft Creek Diversion channel would be reworked, if required, to improve its longer-term stability (e.g. minor reinforcement and other maintenance) and geomorphologic and ecological function. The objective of the reworking would be to transform the existing engineered diversion channel into a more natural form which has geomorphologic and hydraulic characteristics consistent with other watercourses and features in the surrounding area. The main elements of the upper section of the Coal Shaft Creek Diversion would be retained as a primarily engineered structure, depending on the outcome of the geomorphic, hydraulic and geotechnical analyses. Sediments and vegetation would establish within the channel over time. The banks of the diversion would continue to be revegetated and maintained throughout the mine life and following the completion of mining to enhance stability and create fauna habitat. The performance of the diversion channel would continue to be assessed following significant flood events.

Drop-Down Section

A drop-down section, to lower the level of the diversion approximately 20 m, would be constructed between the reworked section of the existing Coal Shaft Creek Diversion channel and the re-established alignment within the in-pit waste rock emplacement. The drop-down section would be constructed from the diversion channel through the ridgeline north of the existing MWD. The aim would be for excavation into hard rock to facilitate long-term stability and to minimise ongoing maintenance. Long-term maintenance and monitoring of the drop-down section would be conducted if required.

DCPL would undertake a study into the long-term geotechnical stability and maintenance requirements of the proposed drop-down section of the reconstructed Coal Shaft Creek. The study would seek input from hydrologists and geotechnical engineers and would be conducted in consultation with the NOW. The results of this study would be incorporated into the final design and post-mining alignment of the reconstructed Coal Shaft Creek as a component of the Coal Shaft Creek Reconstruction Plan. The design objective and proposed acceptance criteria would be based on developing a drop-down system with similar hydraulic performance and geological/geotechnical stability (including rock strength and resistance to weathering) as natural cascades and rock shelves in comparable natural creeks of comparable size to Coal Shaft Creek.

Reconstructed Section of Coal Shaft Creek

The creek would be designed with a meandering channel contained within a reconstructed 50 m wide corridor, which would generally replicate the original meandering geometry. The reconstructed creek design would aim to be similar to pre-mining (surveyed) creek cross-sections as far as practicable and adopt a design with a “main” flow channel, with overbank areas for large flows, with the main channel sized appropriately to drain expected catchment yields such that stability is not compromised, habitat is created and seepage is managed (Figure A-35).

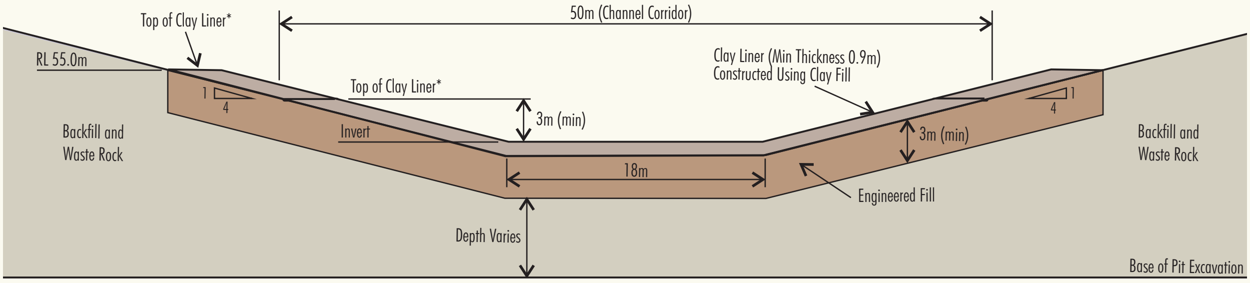
The design channel profile would comprise a regular form which oscillates between right and left hand dominant profiles with right and left bends transitioning to a symmetrical profile in the straight sections between meander bends (Figure A-35). The design bed slope would involve a regular pattern of flatter sections in bend areas and steeper sections in straighter sections between bends. The channel would be designed with similar hydraulic and geomorphic characteristics as the southern reach of the original creek channel. For example, the channel would have a similar stream power as the modelled stream power for the original Coal Shaft Creek, which had an average stream power of 29.1 Newtons per metre per second (N/ms), a minimum of 2.7 N/ms and a maximum of 65.0 N/ms at a flow rate of $10 m^3/s$ (Gilbert & Associates, 2006a).

The stability of the original creek was dependent on relatively dense vegetation along the creek banks and it is envisaged that short-term stability of the outer banks of the reconstructed channel would be enhanced by selective armouring using rocky backfill or large timber debris. The maximum design cross-section batter slopes would also be designed somewhat flatter than the surveyed natural creek sides to enhance stability.

The geotechnical requirements for the bulk fill and engineered fill (Figure A-35) would be determined as part of further analyses and would include waste rock material of a specified particle distribution with specific placement and compaction requirements.

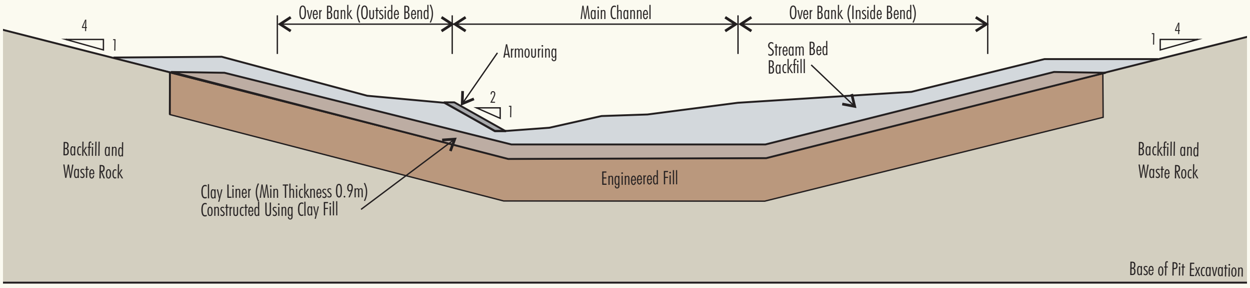
The channel would include an engineered low permeability liner (Figure A-35) which would restrict the movement of water between Coal Shaft Creek and the waste rock emplacement. An analysis of the movement of water through the in-pit waste rock emplacement and its potential movement into the reconstructed creek has previously been simulated using the SEPP/W modelling package (Gilbert & Associates, 2006b). The modelling determined that to be effective in reducing the salt flux into the reconstructed channel to a low level a liner should be selected with a effective saturated permeability of less than 10^{-9} m/s, an effective thickness of 1 m and extension of 10 m above the channel or to the top of the waste rock emplacement (which ever is lower). As part of the final detailed design, seepage analysis, geotechnical testing and modelling would be undertaken to confirm an appropriate liner material, thickness and extension above the channel invert.

Whilst the design concepts are based on characteristics of the original creek, the reconstructed creek is expected to be dynamic and to evolve into a more natural system over time. This would inevitably result in preferential erosion and deposition in some sections which may (depending on the pattern of flows experienced post commissioning) be initially greater than might be expected in the natural creek. Selection of final form and alignment would be subject to a detailed hydraulic analysis, as part of final design, together with an assessment of the likelihood of bed/bank erosion on the outside of bends under a range of flow conditions.

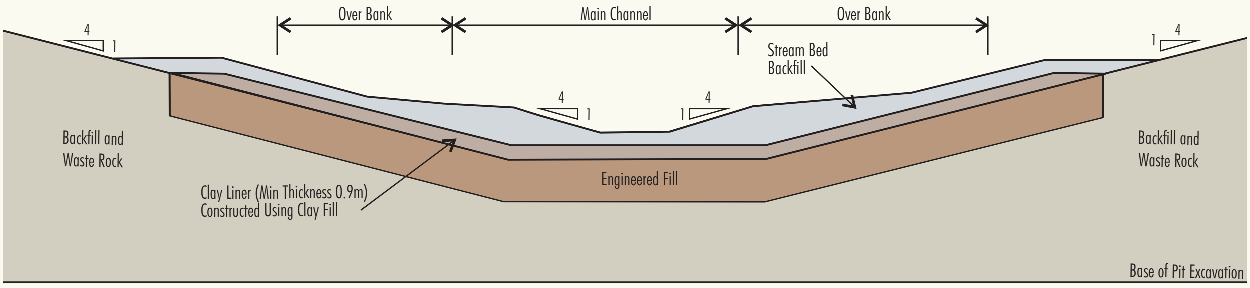


*Channel Corridor Clay Liner to extend up batters to RL 55m or
3m(min) vertically from corridor invert (whichever is greater).

Typical Channel Corridor Section



Typical Section - Reconstructed Creek (Bend)



Typical Section - Reconstructed Creek (Straight)

Source: Allan Watson Associates (2006)

SURFACE WATER ASSESSMENT

FIGURE A-35

Coal Shaft Creek Reconstruction
(Typical Sections)

DURALIE COAL

The conceptual longitudinal channel profile would also include habitat creation initiatives such as the provision of irregular pool and riffle sequences, use of material recovered from the existing channel or some other suitable source, placement of large boulders and/or timber to form pools upstream and promote aquatic habitat and planting of riverine vegetation on banks to enhance stability.

The channel would be formed progressively from south to north and creek flows would not be reinstated until the completion of mining and/or when vegetation was well established throughout. In concept, the creek would be constructed by:

- forming the 50 m wide corridor in the waste rock material;
- constructing the clay liner to control leakage from the reconstructed creek to the waste rock and seepage from the waste rock emplacement to the creek;
- forming the channel and banks using material recovered from the existing channel or some other suitable source;
- placement of large boulders and/or timber to form pools upstream and promote aquatic habitat; and
- planting of riverine vegetation on banks to enhance stability.

It is proposed that acceptance criteria would be based on demonstrating substantial achievement of equivalent stability and geomorphic and ecological function as exist in other comparable creeks systems to the original Coal Shaft Creek.

A6.3 Erosion and Sediment Control

Erosional stability would be a key requirement of site rehabilitation and closure works design. The operational sediment and erosion control works would be retained and maintained during the revegetation establishment phase. Following the establishment of self-sustaining stable final landforms, key elements of the operational sediment control structures would either be left as passive water control storages if practicable or would be removed if they could not be left without an ongoing maintenance commitment.

A7.0 EFFECTS OF CLIMATE CHANGE ON PREDICTED SURFACE WATER IMPACTS

Recent (post 1950) changes to temperature are evident in many parts of the world including Australia. The Intergovernmental Panel on Climate Change (IPCC) (2007) has, in its most recent assessment, concluded that:

> *most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Discernible human influences now extend to other aspects of climate, including ocean warming, continental average temperatures, temperature extremes and wind patterns.*

Predicting future climate using global climate models is now undertaken by a large number of research organizations around the world. In Australia much of this effort has been concentrated in the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and BOM. CSIRO has recently published a comprehensive assessment of future climate change effects on Australia (CSIRO, 2007). CSIRO has included assessments based on the predictions from 23 selected climate models from research organisations around the world. Model predictions were made for a range of different future greenhouse emission scenarios adopted by the IPCC.

CSIRO has used predictions of future climate from these various models to formulate probability distributions for a range of climate variables including temperature, rainfall potential evaporation, snow cover and drought. The model predictions are made relative to 1990 conditions for 2030, 2050, 2070 and 2100. Predictions for 2030 are relatively insensitive to future emission scenarios because they largely reflect greenhouse gases that have already been emitted. Longer-term predictions become increasingly sensitive to future emission scenarios.

A7.1 Future Rainfall

There is large variability inherent in rainfall in Australia and predictions of future rainfall also vary significantly between the models used in the CSIRO study. Predictions of future precipitation in southern eastern Australia are generally for decreased rainfall but increases in rainfall per day and for the number of dry days (defined as days with less than 1mm of rainfall). Future seasonal rainfall predictions for the Project area have been obtained using the CSIRO's OzClim[11] system for the medium impact (Max Planck: ECHAM5/MPI-OM) Global Climate model, with medium climate sensitivity and the A1B[12] emission scenario for years 2030 and 2100 – refer Table A-24 below.

[11] http://www.csiro.au/ozclim/home.do

[12] A1B emission scenario refers to expected emissions for a future characterised by very rapid economic growth, a global population that peaks in mid-century and declines thereafter and a substantial reduction in regional differences in per capita income. It assumes rapid introduction of new and more efficient technologies and a balance between fossil fuel and non-fossil energy sources.

Table A-24
Percentage Change in Seasonal Rainfall
Relative to 1990– Duralie Coal Mine Area
(from Max Planck: ECHAM5/MPI-OM)

Season	2030	2100
Summer	-4.2	-13.7
Autumn	-0.3	-0.9
Winter	-9.1	-29.6
Spring	-8.5	-27.6

As noted above however there is a large variability in the prediction of future rainfall of between the various models and the simulated results above are considered to reflect the “middle ground”.

Based on these predictions there would be reduced rainfall in all seasons with particularly large reductions in winter and spring by 2100.

A7.2 Future Potential Evapotranspiration

Predictions of future potential evapotranspiration are more closely aligned to temperature change predictions. In the Gloucester region the median of the model predictions for the A1B emission scenario are for a slight increase by 2030 (about 1%) increasing to between 3 and 4% by 2100.

Overall there would also be a tendency for reduced overall runoff particularly in winter and spring. The predictions of change to future rainfall and potential evaporation by 2100 would be expected to translate into a significant reduction in yield from local catchments.

A7.3 Water Management Implications of Climate Change Predictions

The implications of climate change predictions on water management are unlikely to be significant over the Project life because they are small compared to the natural climatic variability. In the long-term however they have implications on the final void behaviour. In this regard the currently most accepted scenarios would see a reduction in overall rainfall and an increase in evaporation. This would translate to reduced surface water runoff inflows to the void and reduced incident rainfall over the void surface. There would also be increased evaporation loss from the void surface and as a consequence lower average water levels in the void.

A8.0 RECOMMENDED MONITORING

DCPL have established a climate station near the centroid of the site which provides short interval data including rainfall, temperature and solar radiation. The existing surface water quality and flow monitoring programme is shown on Figures A-12 and A-15.

DCPL also monitor a range of operational water management indicators including data on pumped water transfers, storage levels and water quality in water management storages, water volumes applied to the different irrigation areas and the moisture levels in soils in these areas using gypsum blocks. The following recommendations to expand the current monitoring are provided on the basis of the expanded mining activities.

A8.1 Surface Water Flows

A gauging station on the Coal Shaft Creek Diversion should be installed, commissioned and rated. Data from this station in combination with water quality data would be used to assess changes to the quantity and quality of water generated from the Coal Shaft Creek catchment during the remaining Project life and into the post-mining closure stages of the Project.

Rating of the streamflow gauging station at High Noon should be conducted and streamflow gaugings should take place at least monthly for a two year period and be reviewed thereafter, particularly to check for any change to the hydraulic control. The DECCW gauging station on Mammy Johnsons River known as the Pikes Crossing gauging station should be maintained, if DECCW decommission the station, DCPL should take over the maintenance of the station for the life of the Project and/or provide an alternative gauging station.

A8.2 Surface Water Quality

The existing water quality monitoring programme described in Section A2.5 should be expanded to include monitoring of water quality in new mine water dams (Auxiliary Dams No. 2 and No. 3). Water quality monitoring sites should also be established in sediment dams constructed to control runoff draining from the expanded waste rock emplacement area coincident with the Tombstone Hill ridgeline that would drain to Mammy Johnsons River. Water quality monitoring should also occur in first flush capture dams downslope of proposed Type VI irrigation areas. Water quality monitoring would be undertaken in accordance with the Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b) and Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC, 2004).

A8.3 Irrigation Monitoring

The current irrigation monitoring protocols which are contained in the IMP should be expanded to cover the new irrigation areas as they are developed. In accordance with the IMP, the monitoring would include recording the volume and salinity of water applied to the various irrigation areas, the salinity and volumes of water draining off irrigation areas and the soil moisture and salinity in actively irrigated areas.

In addition to the above, the existing irrigation monitoring protocols should be expanded to include the following (Attachment AB):

- Water quality samples from the MWD should be analysed for residual sodium carbonate (RSC) and sodium adsorption ratio (SAR).
- Fixed soil sampling sites should be established to provide consistent locations for taking soil samples.
- Two to five soil samples should be taken at each soil sampling site to account for sample variation.
- Soil samples should be taken from a constant depth (sampling from 0 to 30 cm is recommended).
- Soil chemical testing should be expanded to include EC.
- Soil monitoring incorporating the above sampling and testing recommendations should be conducted at an additional two reference sites. These reference sites should be matched with irrigation areas with similar soil types before irrigation commences.

A8.4 Site Water Balance and Salinity Monitoring

The site water balance and salt balance should be monitored and reviewed periodically to check that it is behaving within the bounds projected by the current modelling. These reviews would also enable corrective actions to be implemented. This would require monitoring of water levels and conductivity/pH in site storages on a weekly basis (initially). Monitoring should also include quantities of water transferred to the MWD, volume of water stored in the MWD and irrigation system area, operating hours and quantity of water irrigated. This information should be reviewed and compared with model predictions on an annual basis. Results of this and other monitoring activities should be reported in the Annual Environmental Management Report. The frequency and parameters monitored should be reviewed on an annual basis.

A9.0 REFERENCES

Agricultural Water Management (2009). “Duralie Extension Project Irrigation Water – Suitability Assessment”.

ANZECC/ARMCANZ (1997). “Guidelines for Sewerage Systems - Effluent Management, National Water Quality Management Strategy”, Australian and New Zealand Environment and Conservation Council.

ANZECC/ARMCANZ (2000a). “Australian Water Quality Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy”, Australian and New Zealand Environment and Conservation Council, October.

ANZECC/ARMCANZ (2000b). “Australian Guidelines for Water Quality Monitoring and Reporting, National Water Quality Management Strategy”, Australian and New Zealand Environment and Conservation Council, October.

ANZECC/ARMCANZ (2000c). “Australian Drinking Water Guidelines 2004”, Australian and New Zealand Environment and Conservation Council.

ANZECC/ARMCANZ (2000d). “Guidelines for Sewerage Systems – Use of Reclaimed Water, National Water Quality Management Strategy”, Australian and New Zealand Environment and Conservation Council.

BoM (2009). “Climate Data Online”, Accessed September 2009, <http://www.bom.gov.au/climate/averages/>.

Boughton, W.C. (1999). “A Daily Rainfall Generating Model for Water Yield and Flood Studies”. CRC for Catchment Hydrology, Report 99/9, June.

Boughton, W.C. (2004). “The Australian Water Balance Model”. Environmental Modelling & Software, Vol. 19, pp 943-956.

CSIRO (2007). “OzClim”, Accessed June 2009, <http://www.csiro.au/ozclim/home.do>.

DEC (2004). “Approved Methods for the Sampling and Analysis of Water Pollutants in NSW”, March.

DEC (2006a). “Using the ANZECC Guideline and Water Quality Objectives in NSW”, June.

DEC (2006b). “NSW Government Water Quality and River Flow Environmental Objectives”, Accessed September 2009, <http://www.environment.nsw.gov.au/ieo/index.htm>.

DCPL (1996). “Duralie Coal Project Environmental Impact Statement”, September 1996. Report prepared for DCPL.

DCPL (2008a). “Duralie Coal Mine Irrigation Management Plan”.

DCPL (2008b). “Duralie Coal Mine Annual Environmental Management Report“. September 2008.

EGi (1996). “Duralie Coal Project Environmental Geochemistry of Mine Rock and Coal Reject - Implications for Mine Operation and Waste Management”. Report prepared for DCPL.

EGi (2004). “ARD Management at Duralie Coal Mine - Review Report”. Report prepared for DCPL.

EGi (2009). “Duralie Extension Project Geochemistry Assessment”, Report prepared for DCPL.

EPA (1997). “Managing Urban Stormwater: Treatment Techniques”, November.

EPA (1998). “Managing Urban Stormwater: Source Control”, December.

Gilbert & Associates (2006a). “Duralie Coal Mine – Coal Shaft Creek Reconstruction Conceptual Hydraulic Design”. Report prepared for DCPL.

Gilbert & Associates (2006b). “Duralie Coal Mine Hydraulic Design of Low Permeability Liner for Coal Shaft Creek Reconstruction”. Report prepared for DCPL.

Gilbert, L. (1997). “Surface Water Hydrology Background – Submission to the Duralie Project Commission of Inquiry”, January 1997.

Heritage Computing (2009). “Duralie Extension Project Groundwater Assessment”, Report prepared for DCPL.

IPCC (2007). “IPCC Assessment Report 4”, Accessed June 2009, <http://www.ipcc.ch>.

Jeffrey, S.J., Carter, J.O., Moodie, K.M and Beswick, A.R. (2001). "Using spatial interpolation to construct a comprehensive archive of Australian climate data", *Environmental Modelling and Software*, Vol 16/4, pp 309-330.

Landcom (2004). “Managing Urban Stormwater: Soils & Construction”, 4th Edition, March.

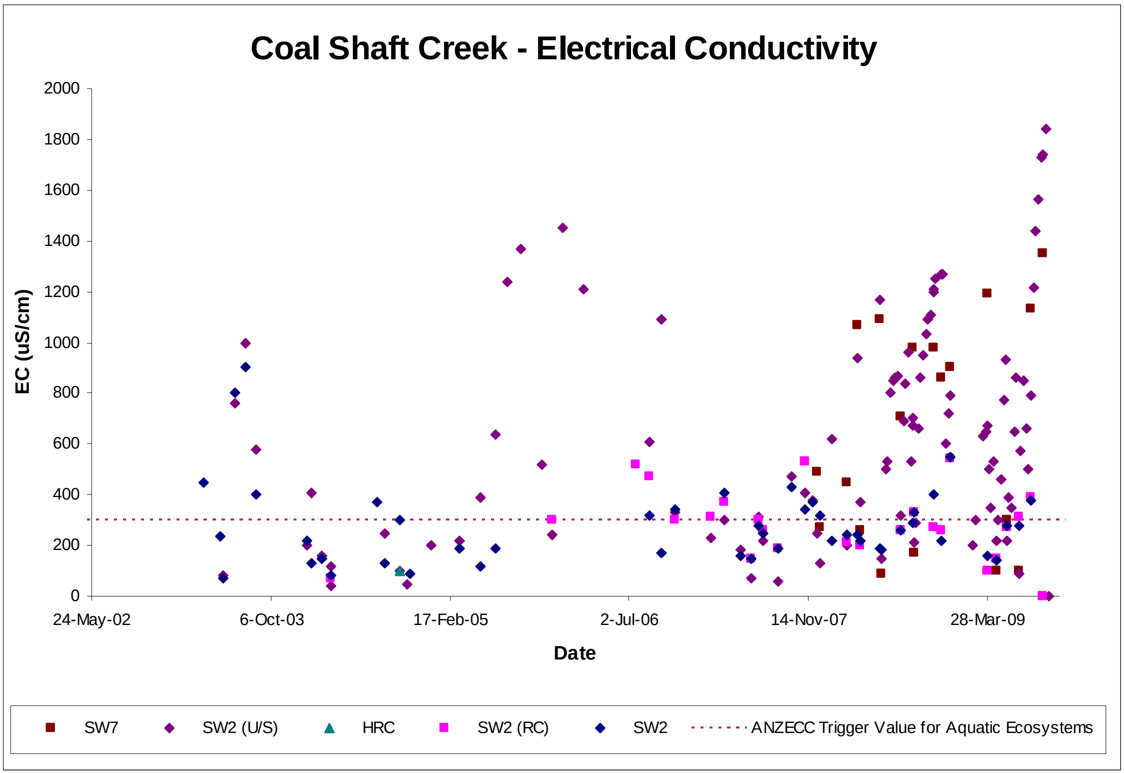
LWRRDC and CRCCH (2000). “A Rehabilitation Manual for Australian Streams”, March.

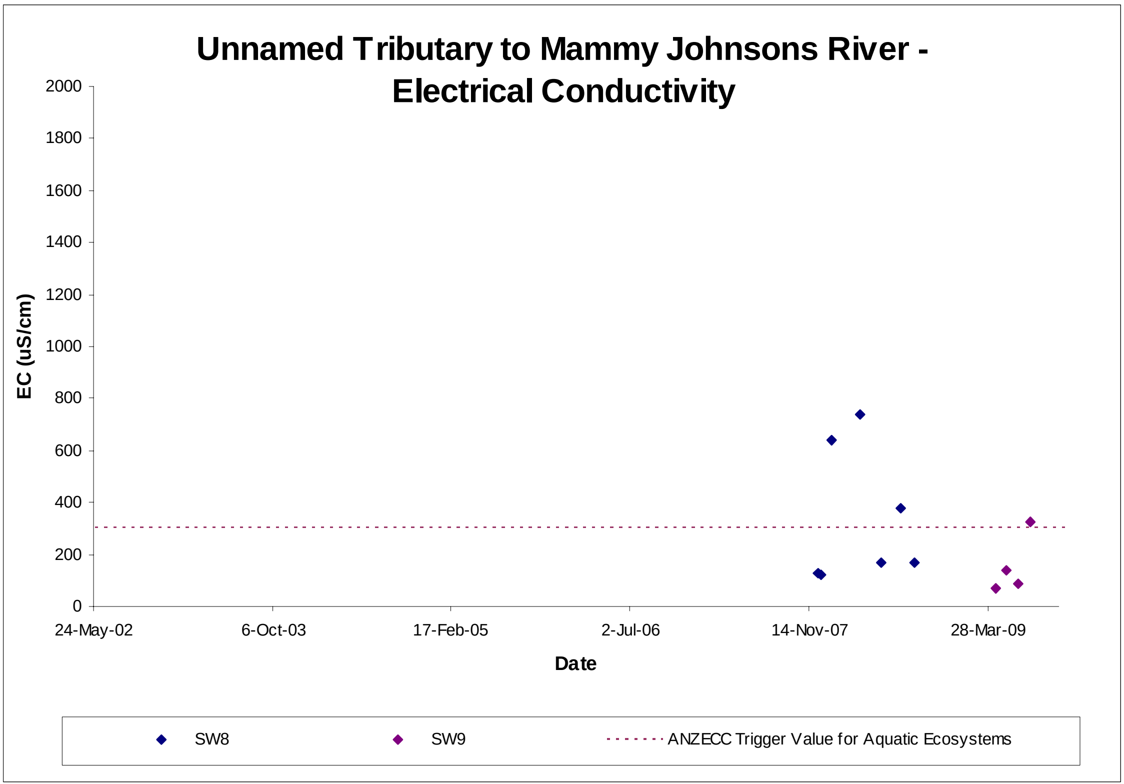
Peel M.C., Chiew F.S.H, Western A.W. and McMahon T.A. (2000). “Extension of Unimpaired Monthly Streamflow Data and Regionalisation of Parameter Values to Estimate Streamflow in Ungauged Catchments”. Centre for Environmental Applied Hydrology, University of Melbourne, July.

SP Solutions (2009) “Duralie Extension Project Environmental Risk Assessment”. Report prepared for DCPL.

Woodward-Clyde (1996). “Duralie Coal Project Surface Water Resources”, September 1996. Report prepared for DCPL.

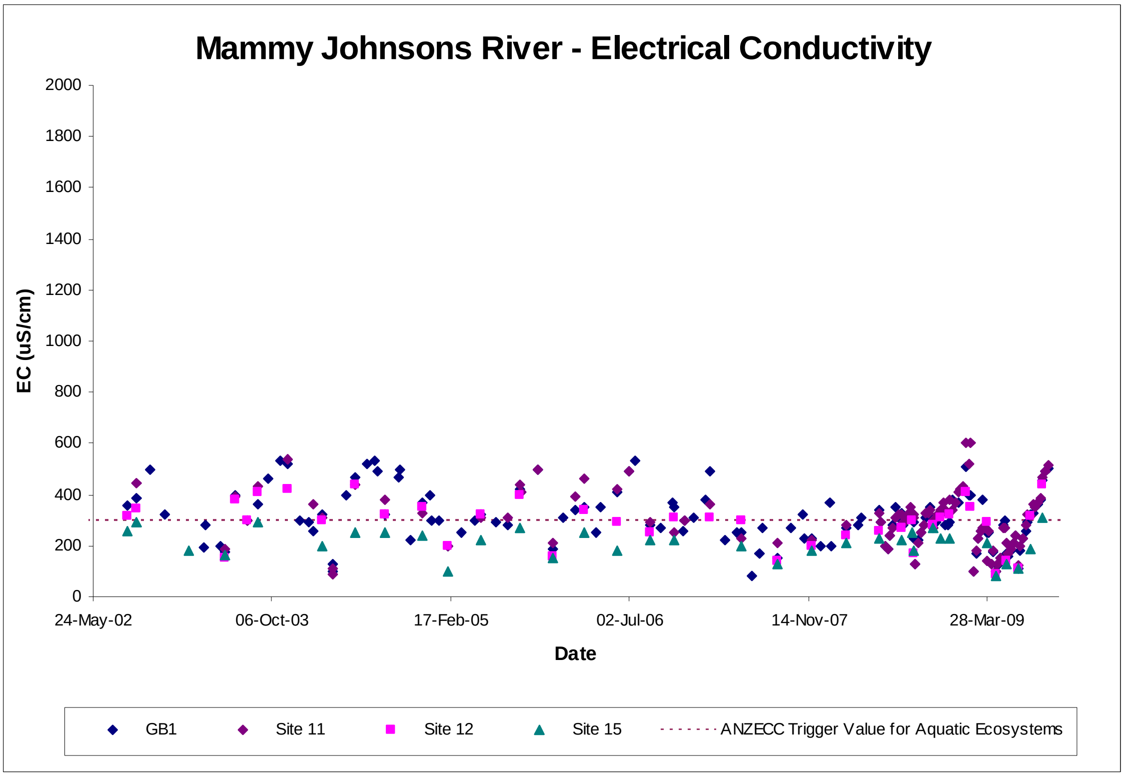
ATTACHMENT AA
WATER QUALITY MONITORING DATA

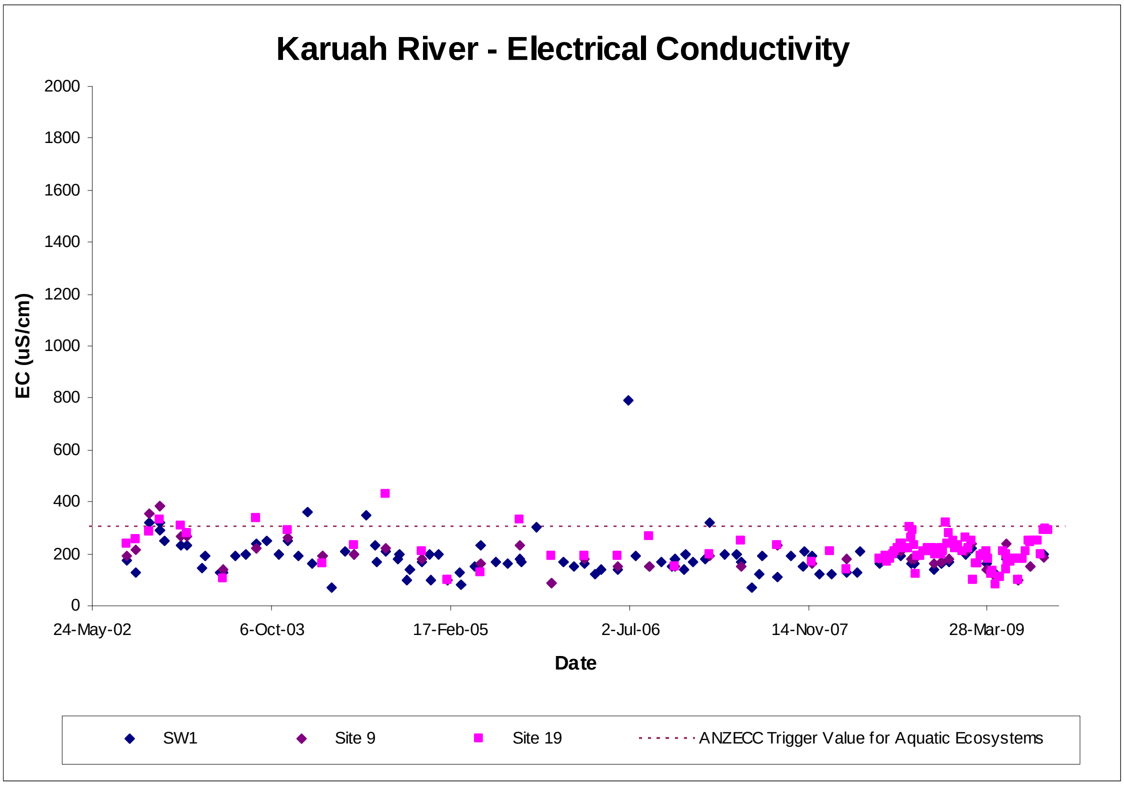




Electrical Conductivity Monitoring Results

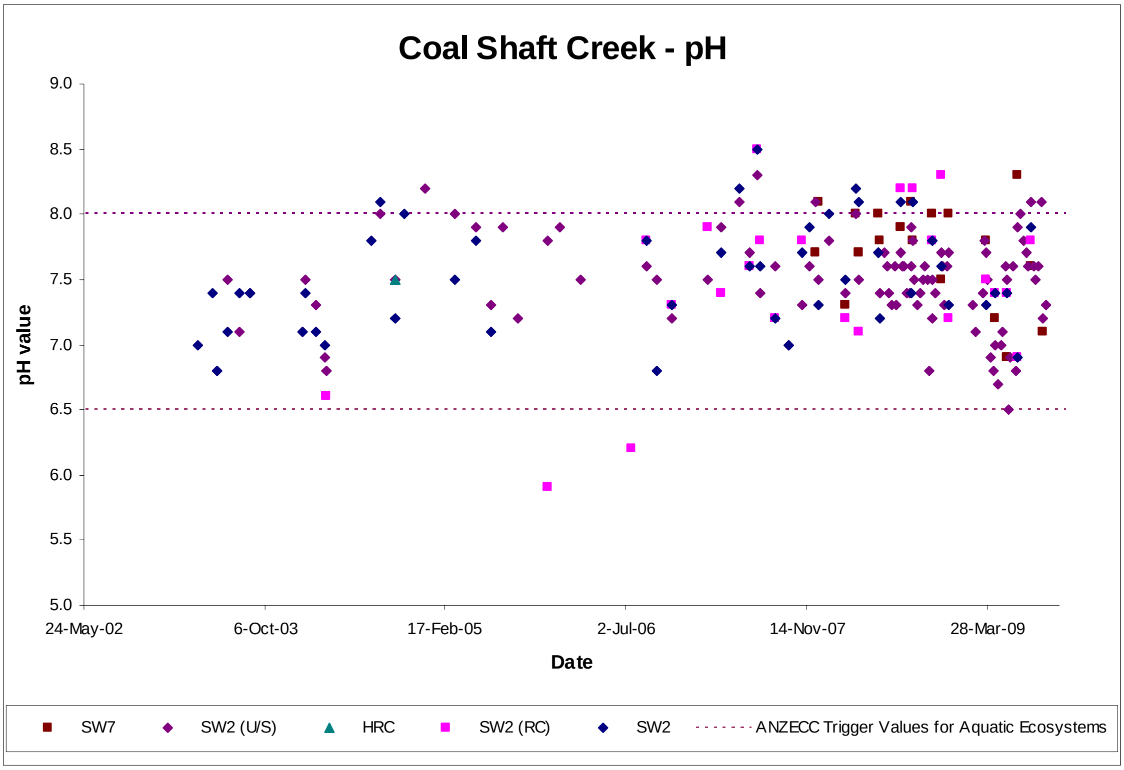
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

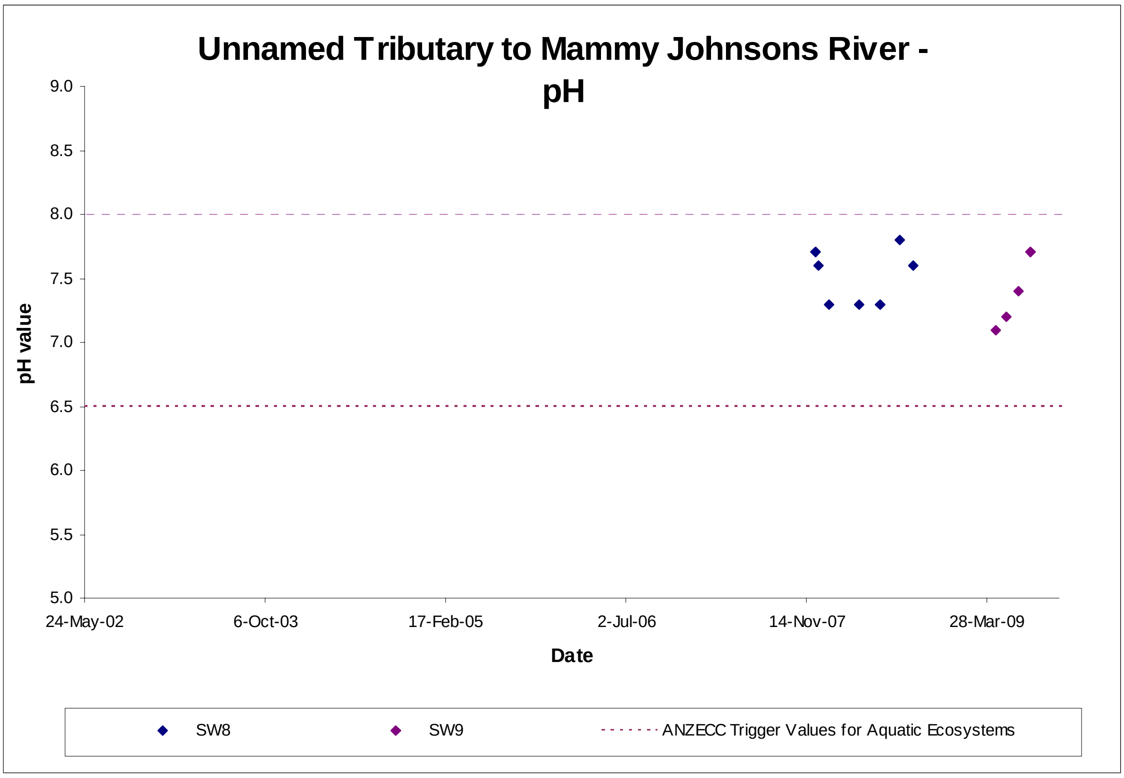




Electrical Conductivity Monitoring Results (continued)

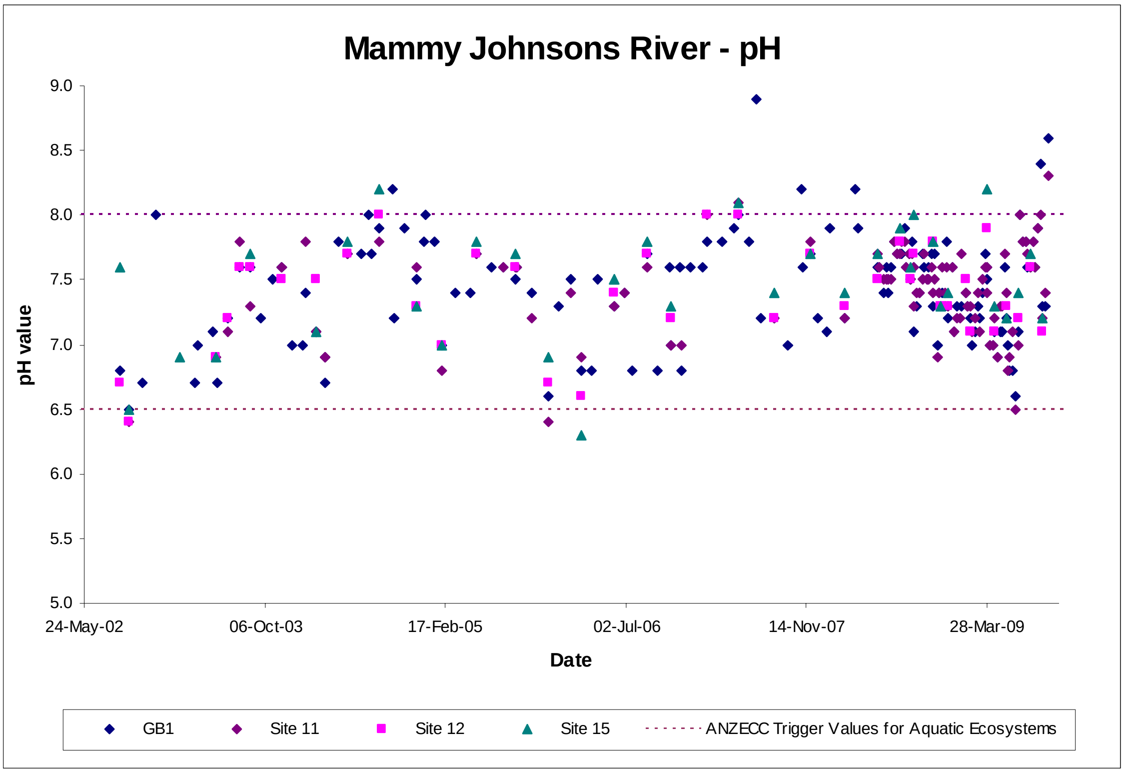
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed NSW coastal rivers (ANZECC/ARMCANZ, 2000a).

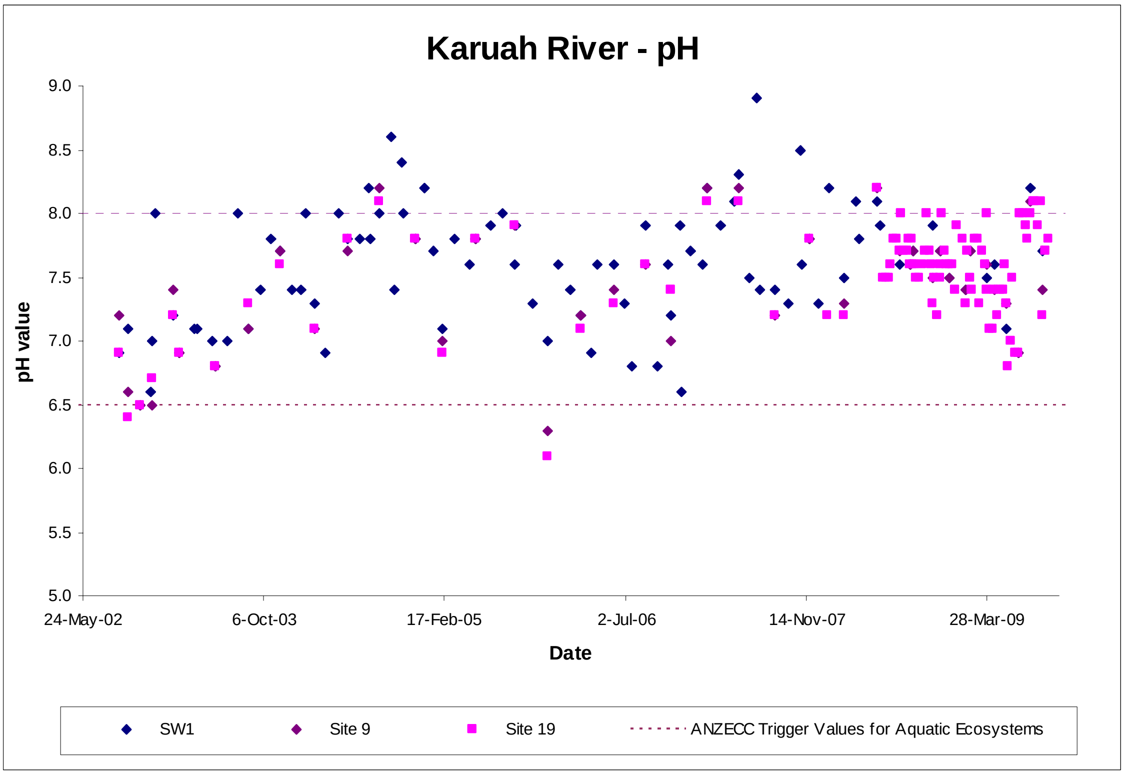




pH Monitoring Results

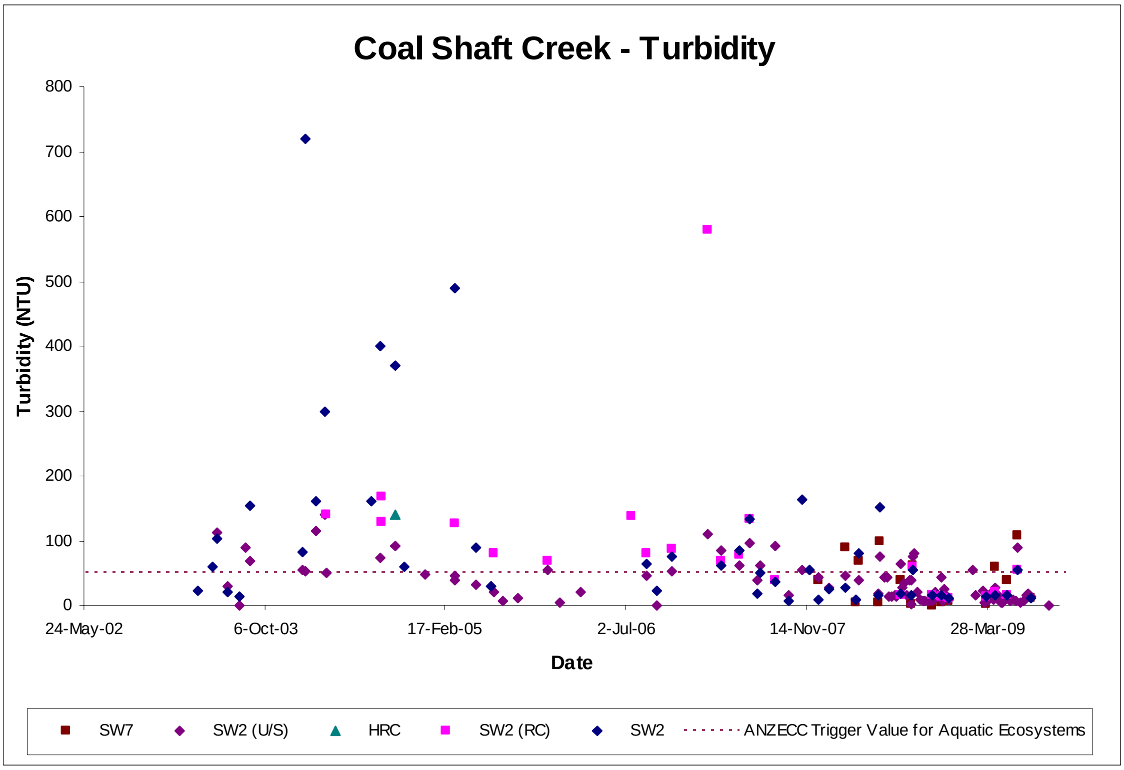
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).

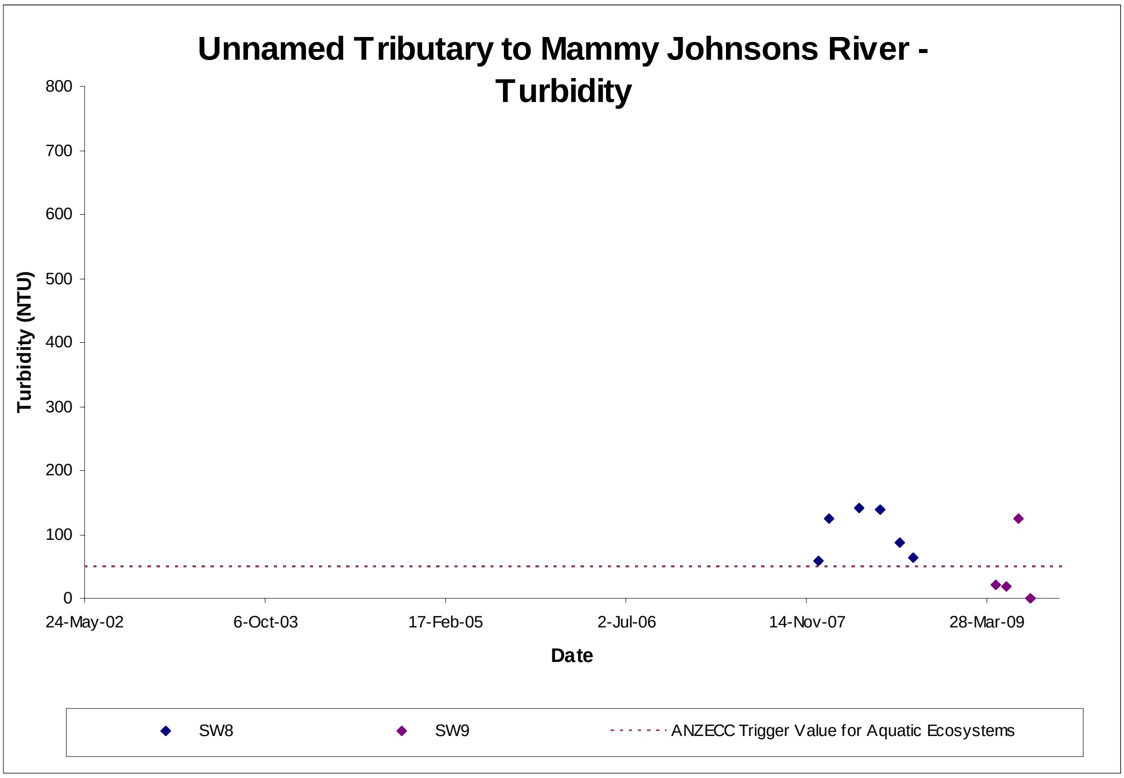




pH Monitoring Results (continued)

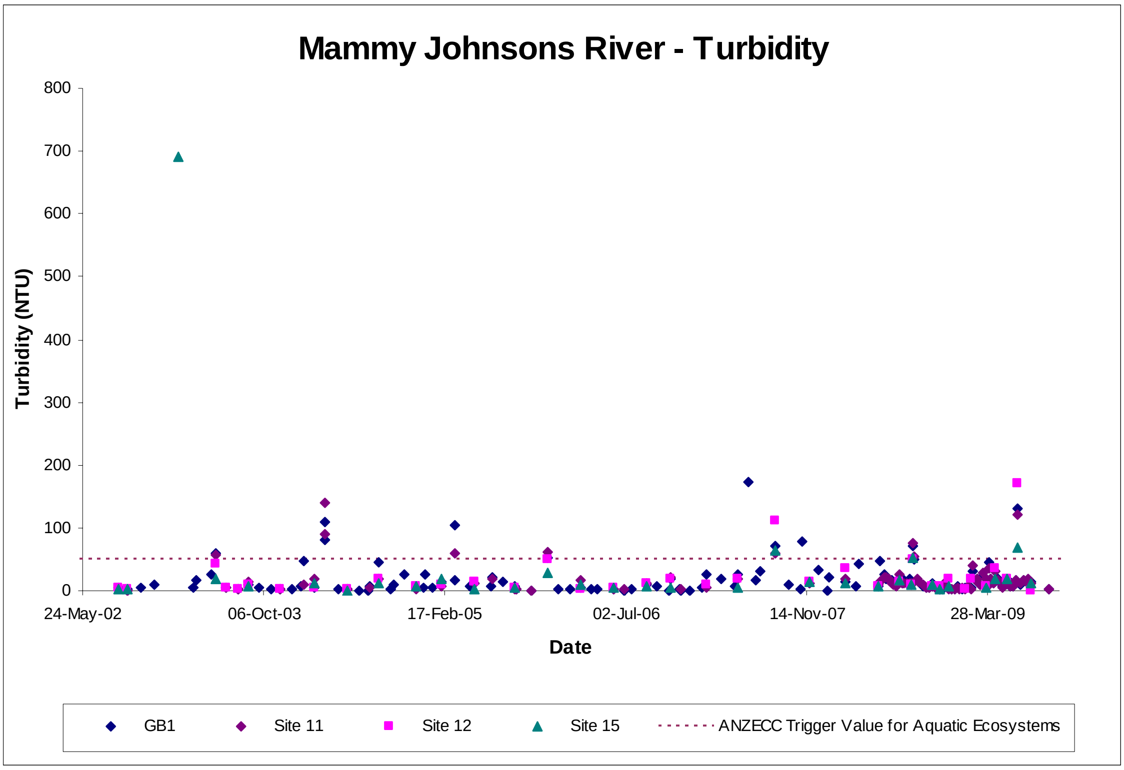
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).

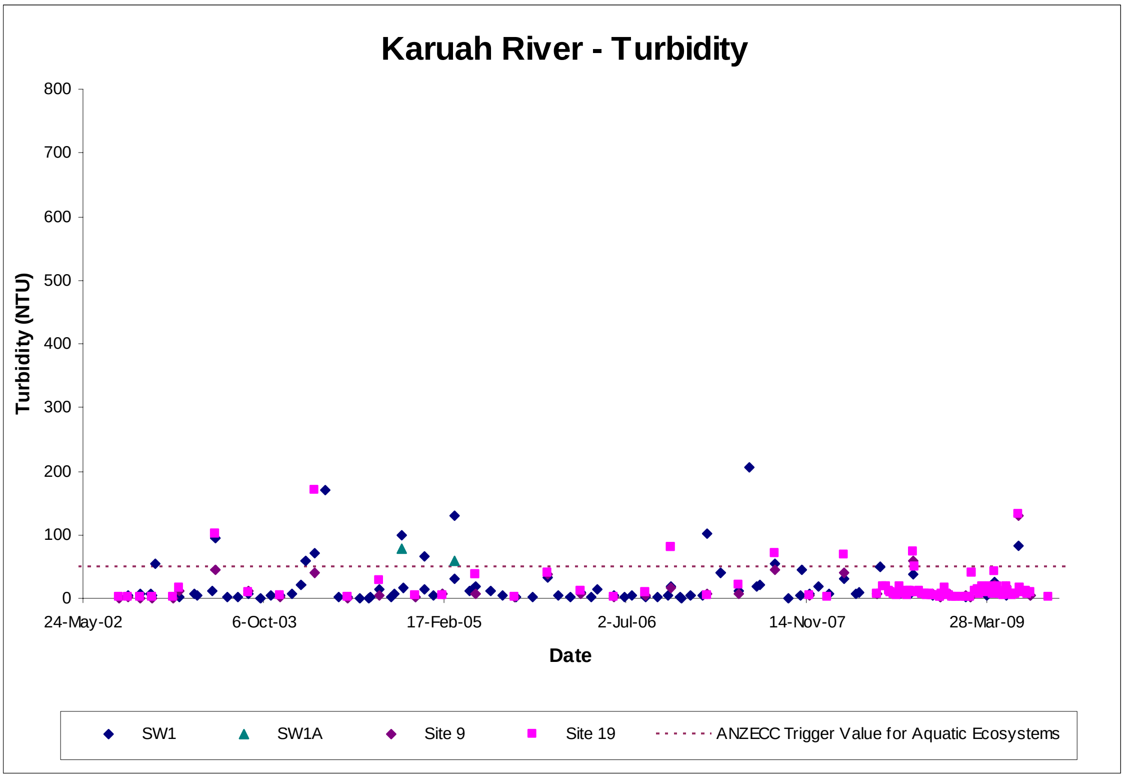




Turbidity Monitoring Results

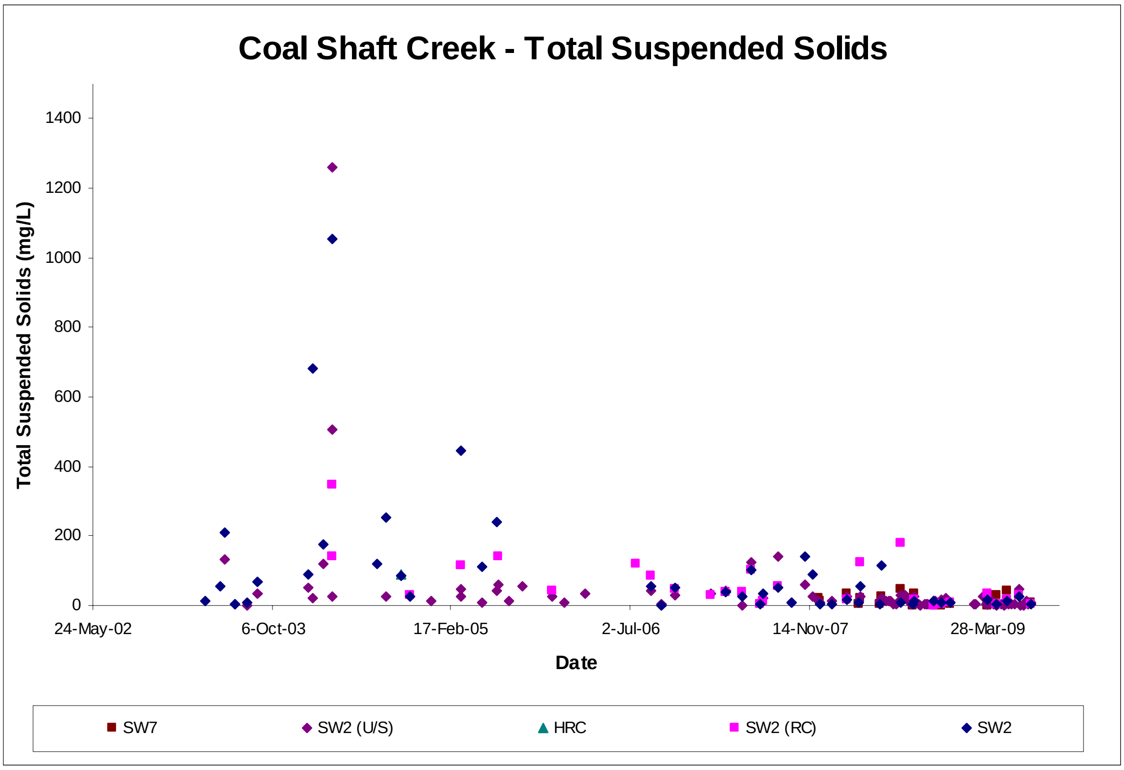
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).

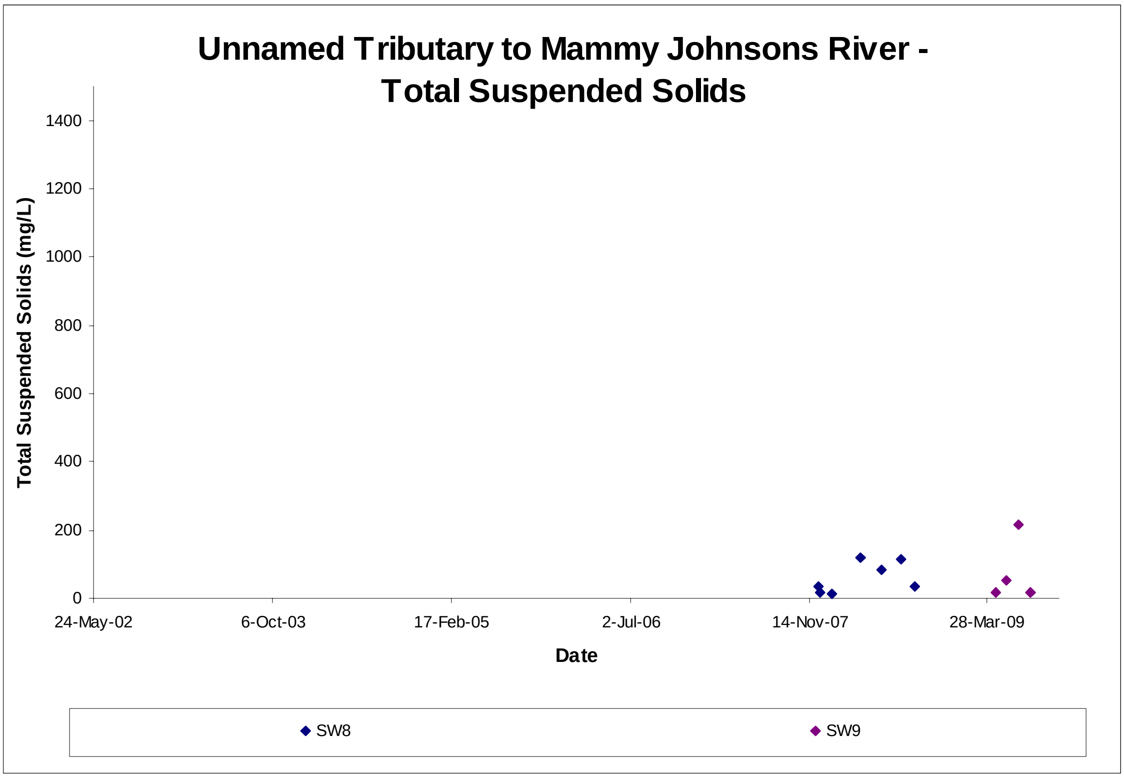




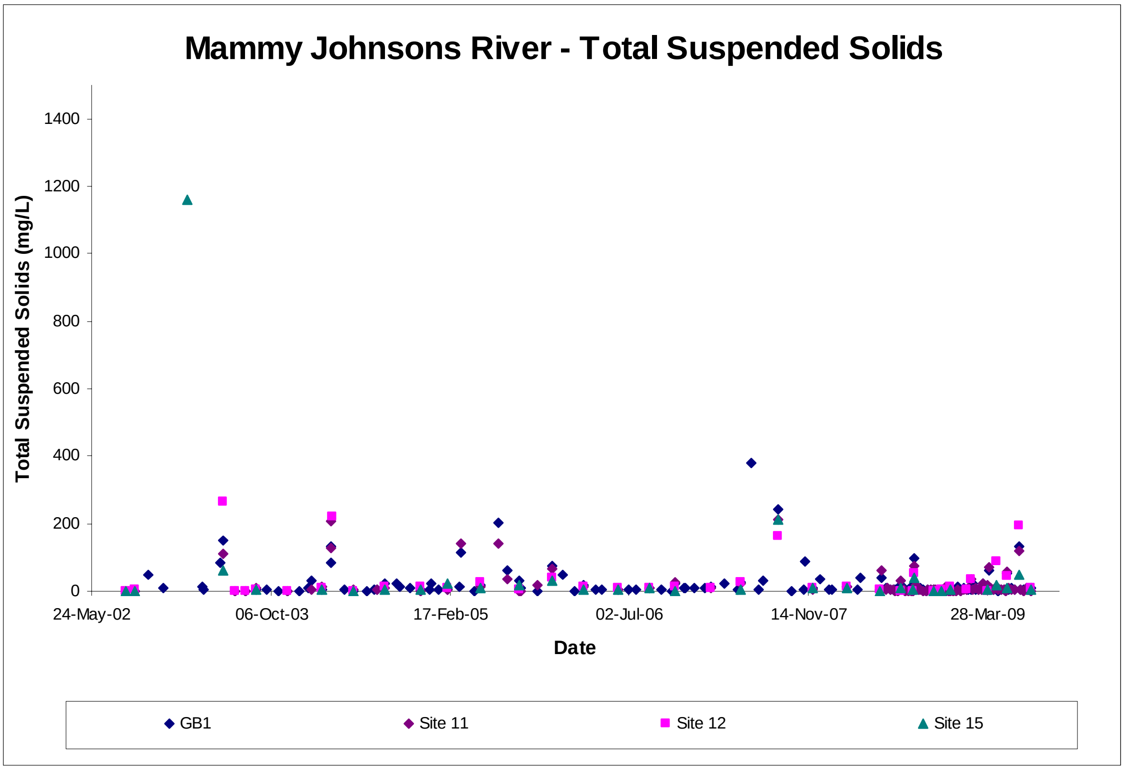
Turbidity Monitoring Results (continued)

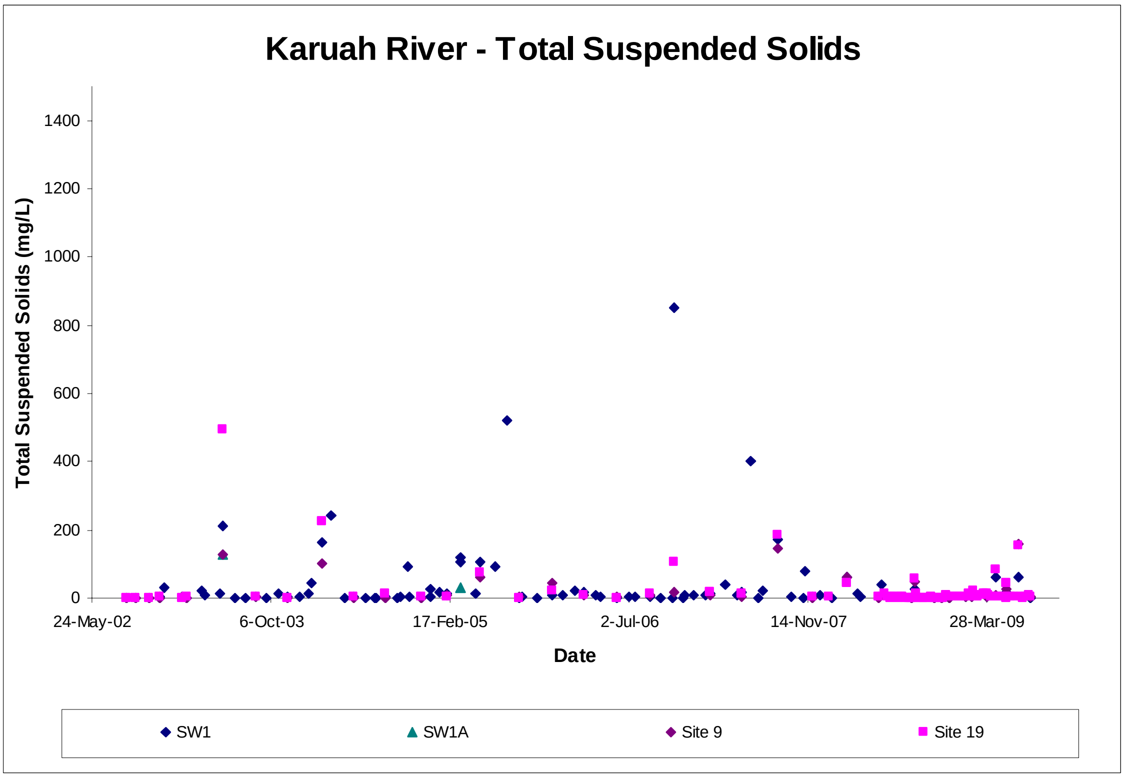
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly disturbed lowland rivers in south-east Australia (ANZECC/ARMCANZ, 2000a).



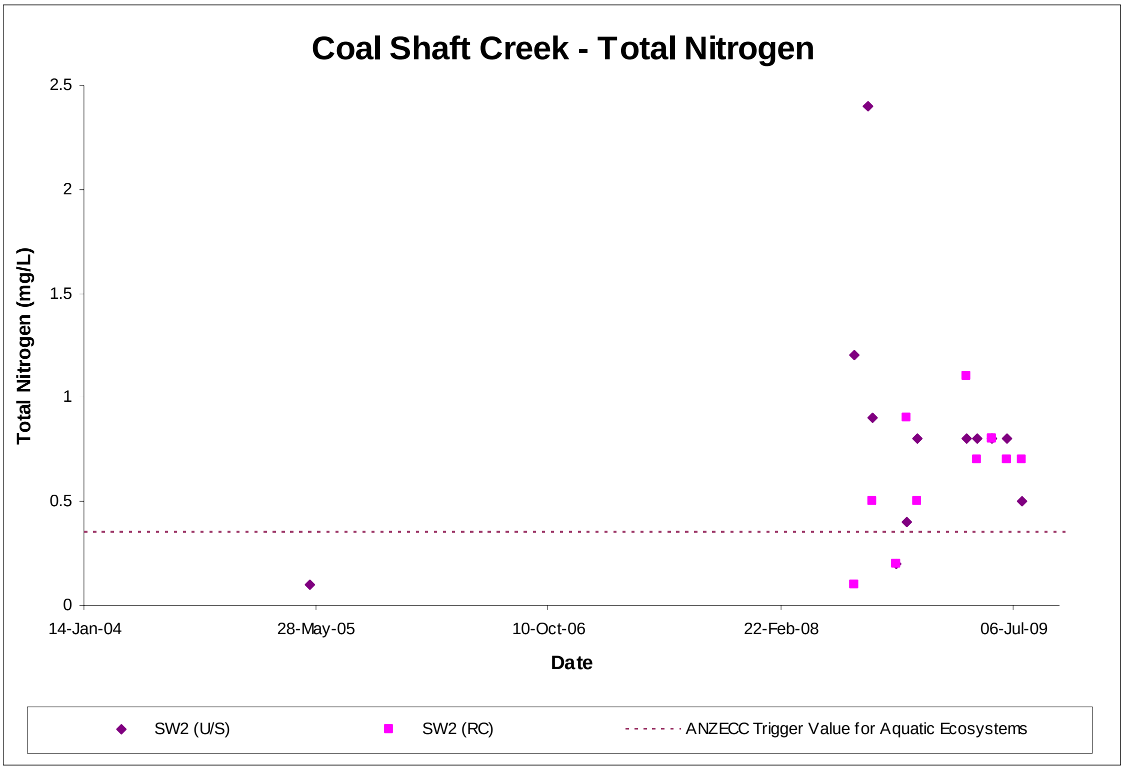


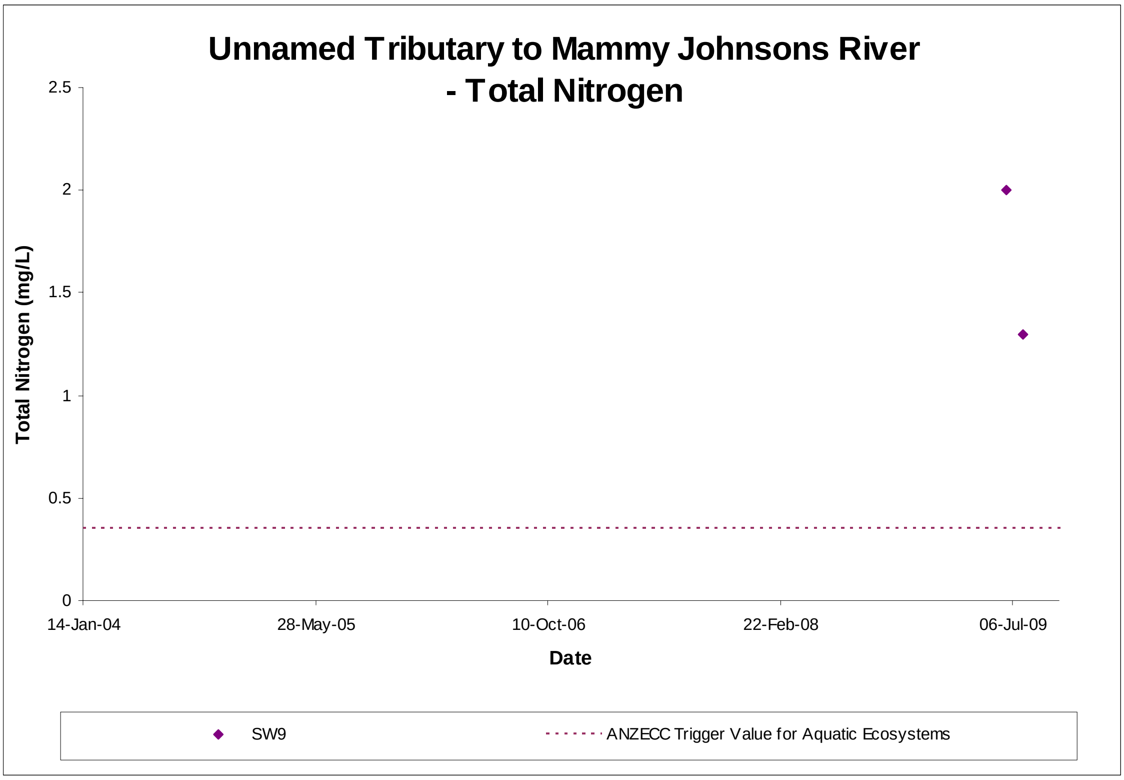
Total Suspended Solids Monitoring Results





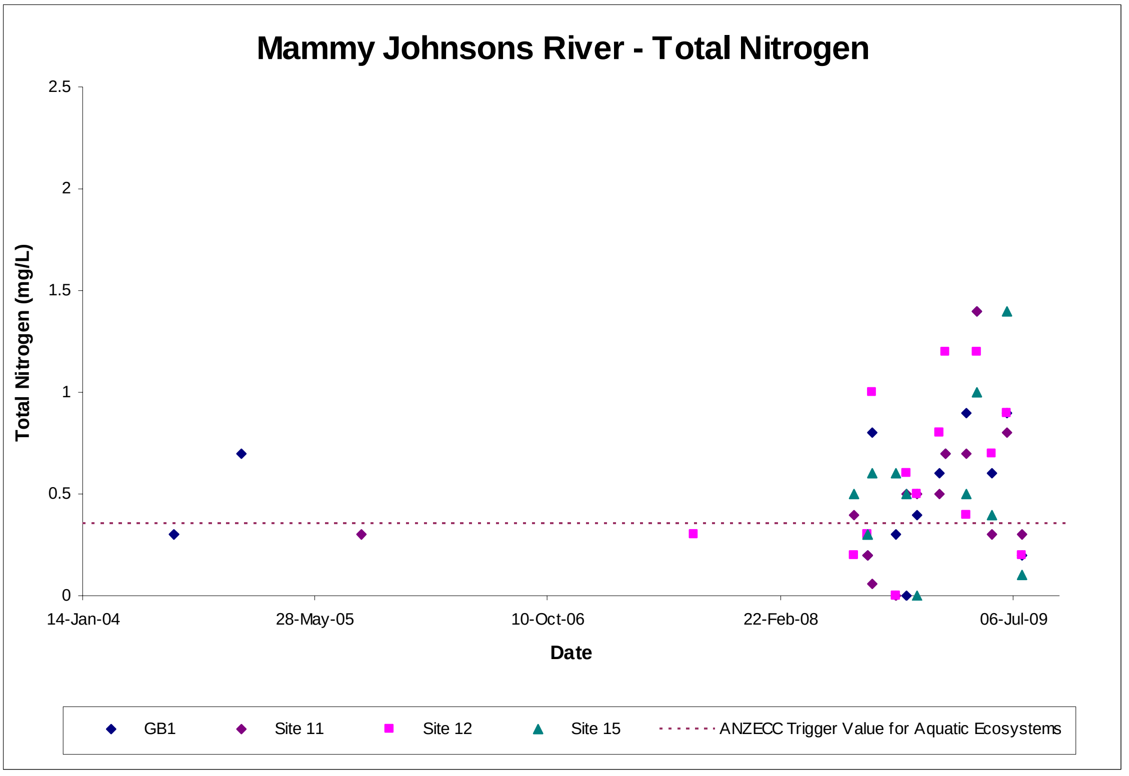
Total Suspended Solids Monitoring Results (continued)

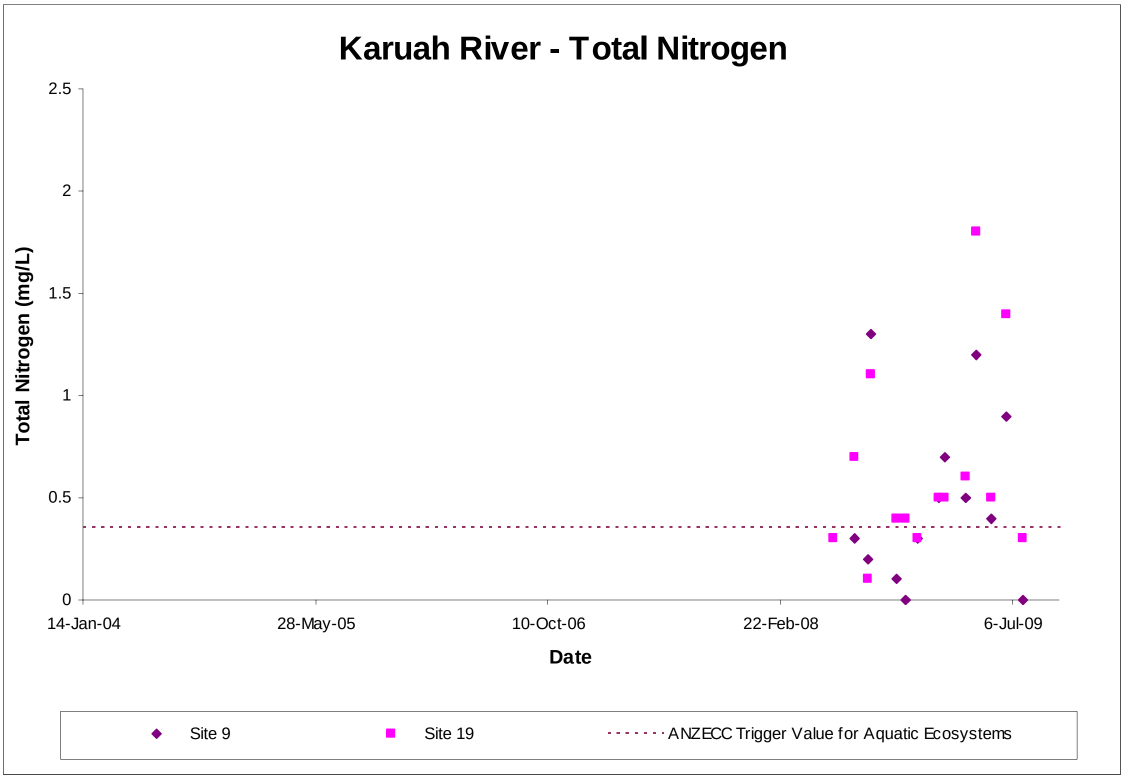




Total Nitrogen Monitoring Results

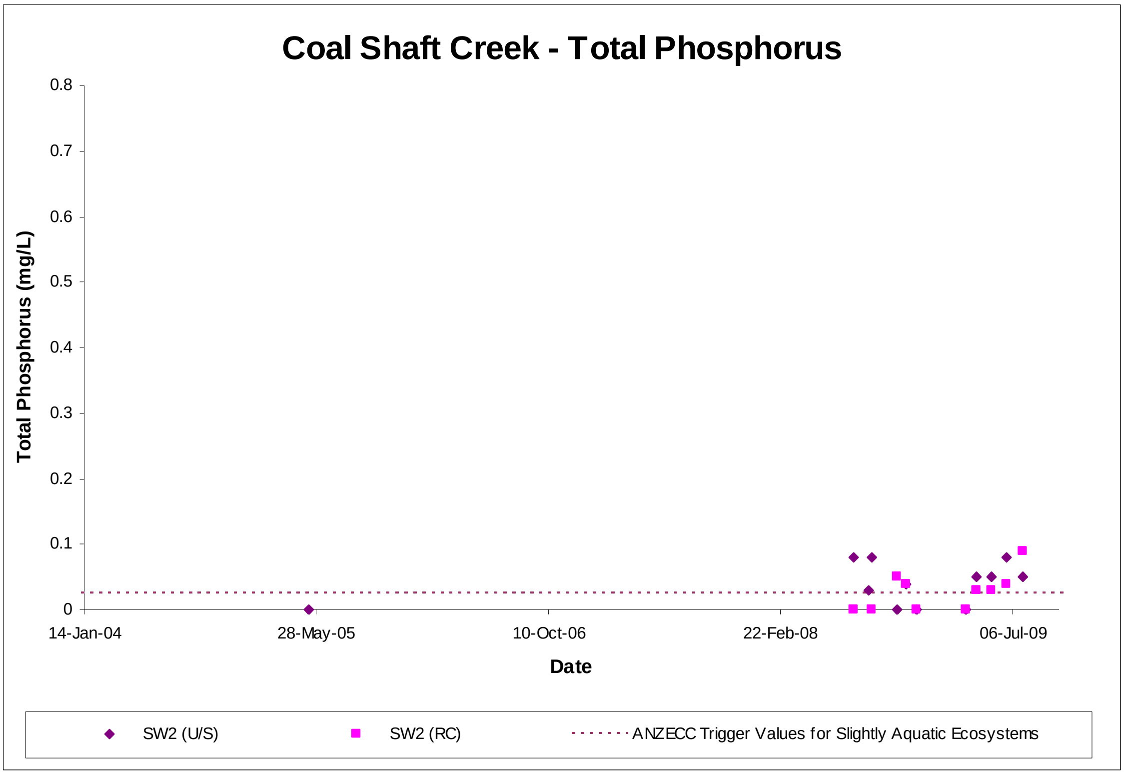
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline given for aquatic ecosystems in the Water Quality Objectives for the Karuah River and Great Lakes catchment (DEC, 2006b).

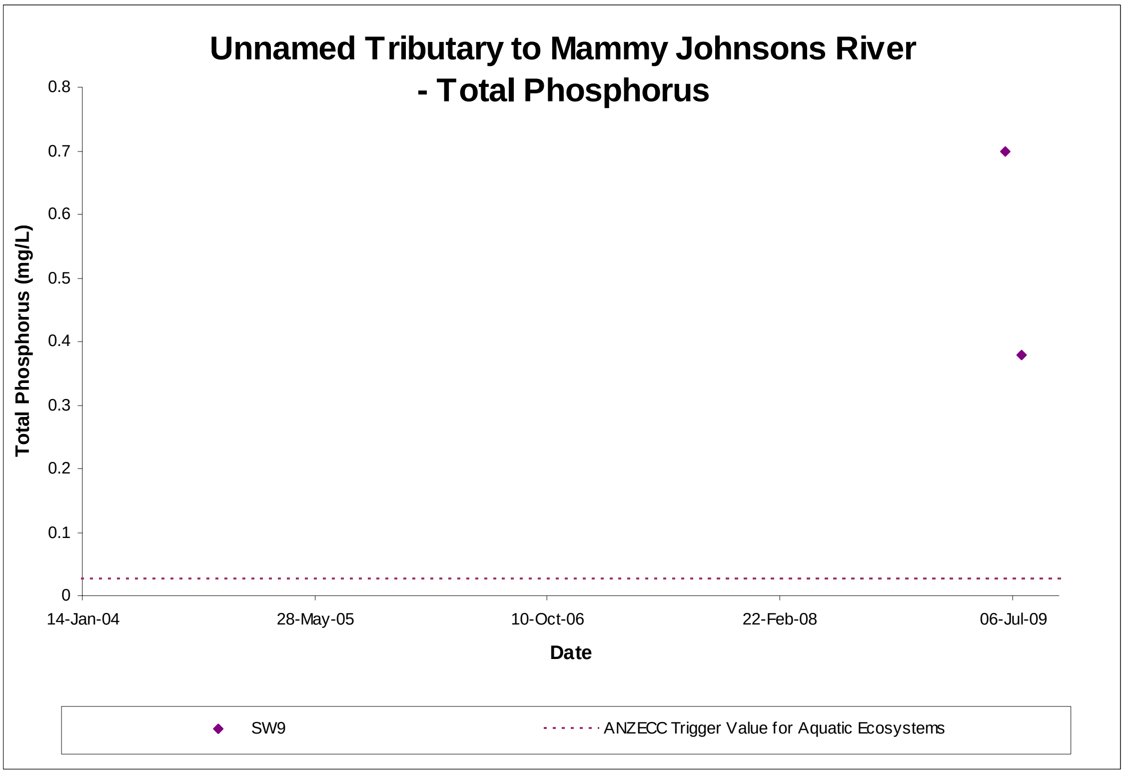




Total Nitrogen Monitoring Results (continued)

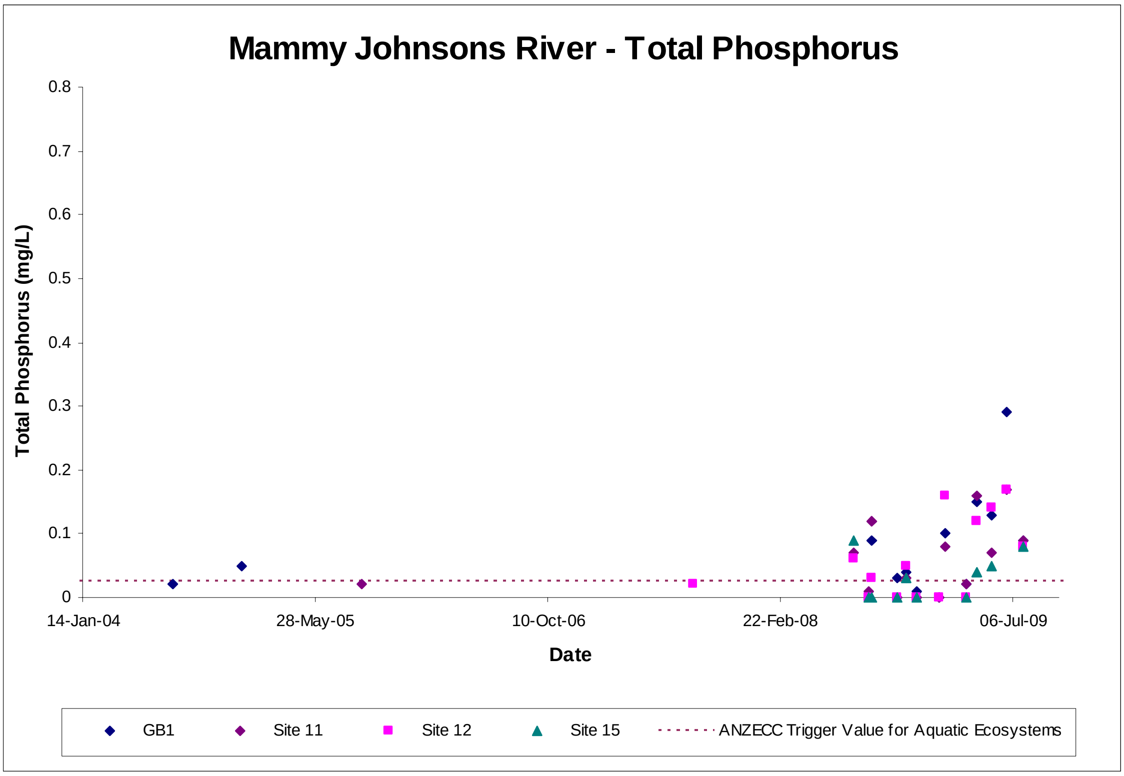
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline given for aquatic ecosystems in the Water Quality Objectives for the Karuah River and Great Lakes catchment (DEC, 2006b).

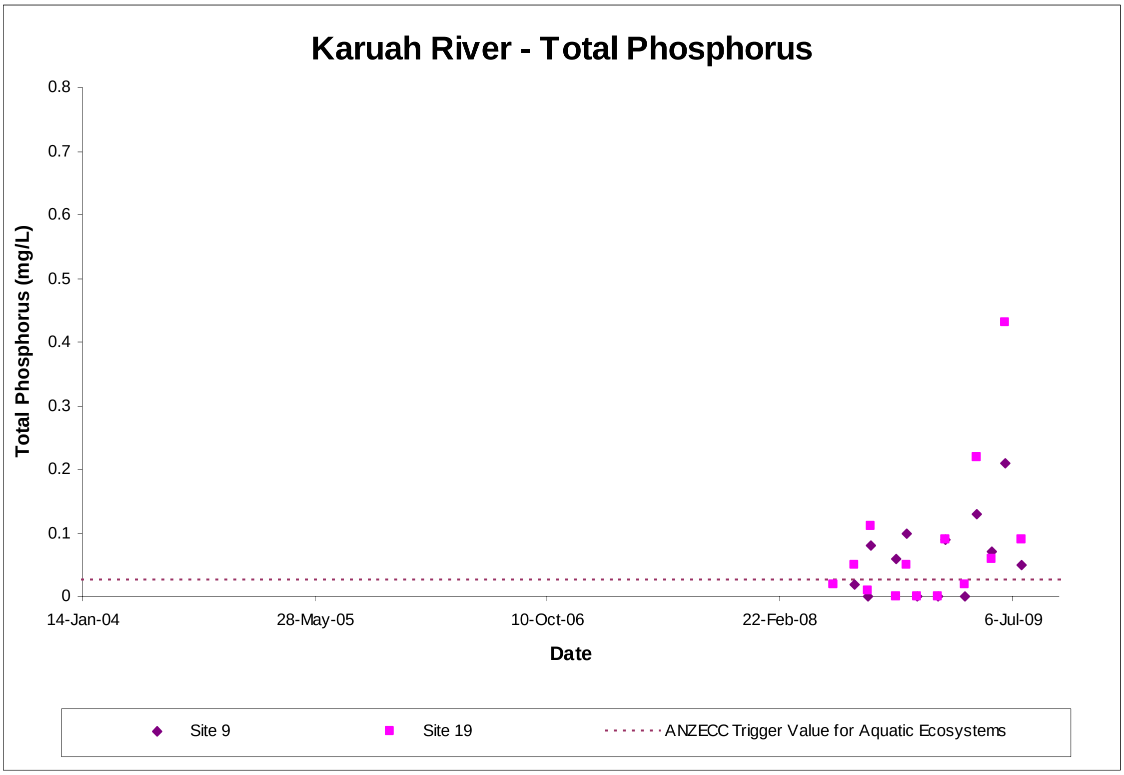




Total Phosphorus Monitoring Results

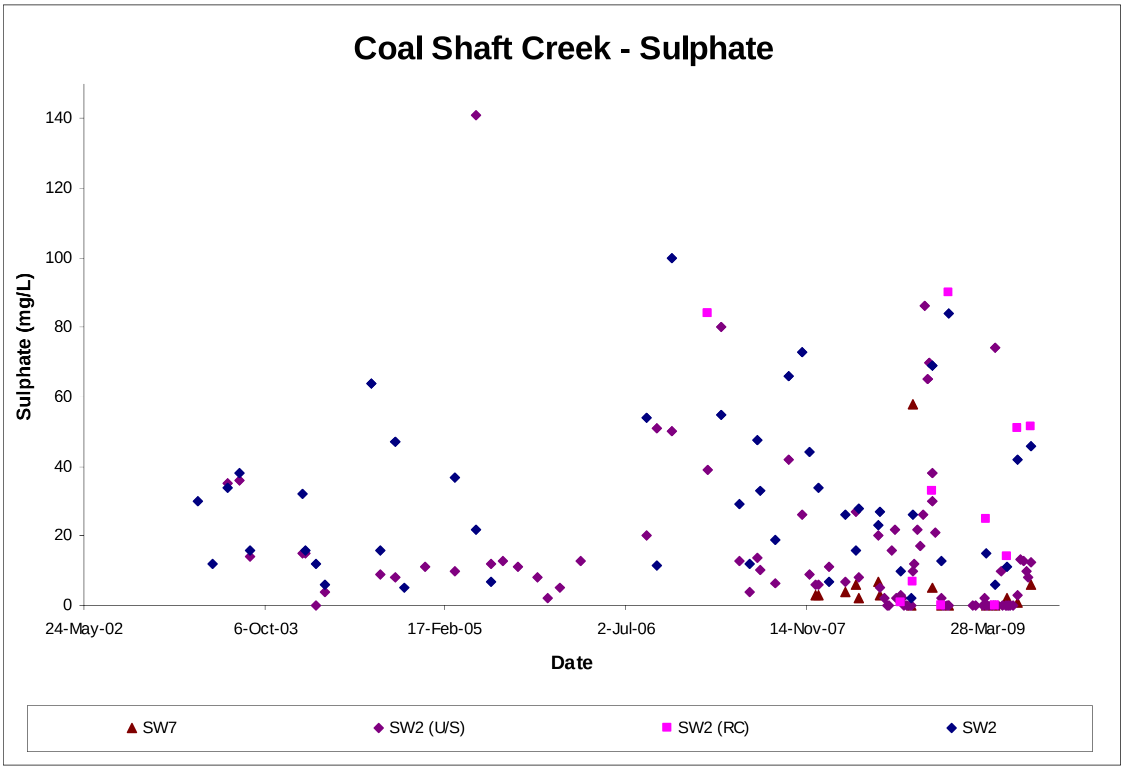
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline given for aquatic ecosystems in the Water Quality Objectives for the Karuah River and Great Lakes catchment (DEC, 2006b).

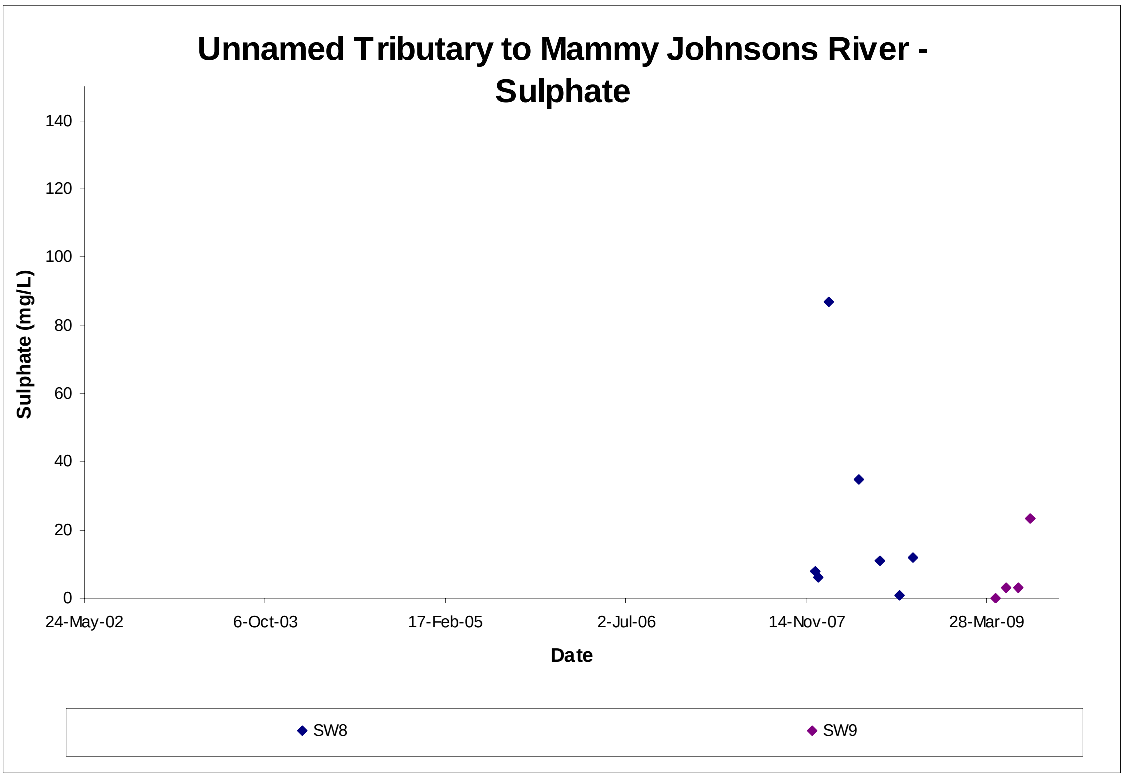




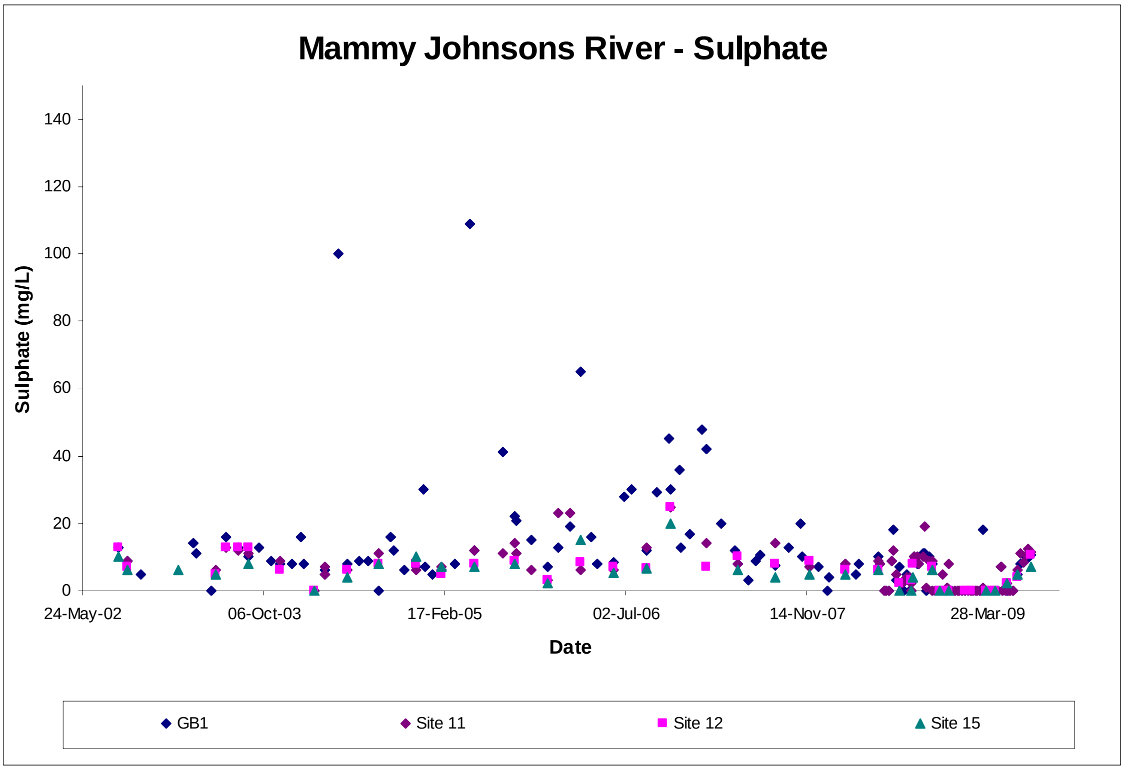
Total Phosphorus Monitoring Results (continued)

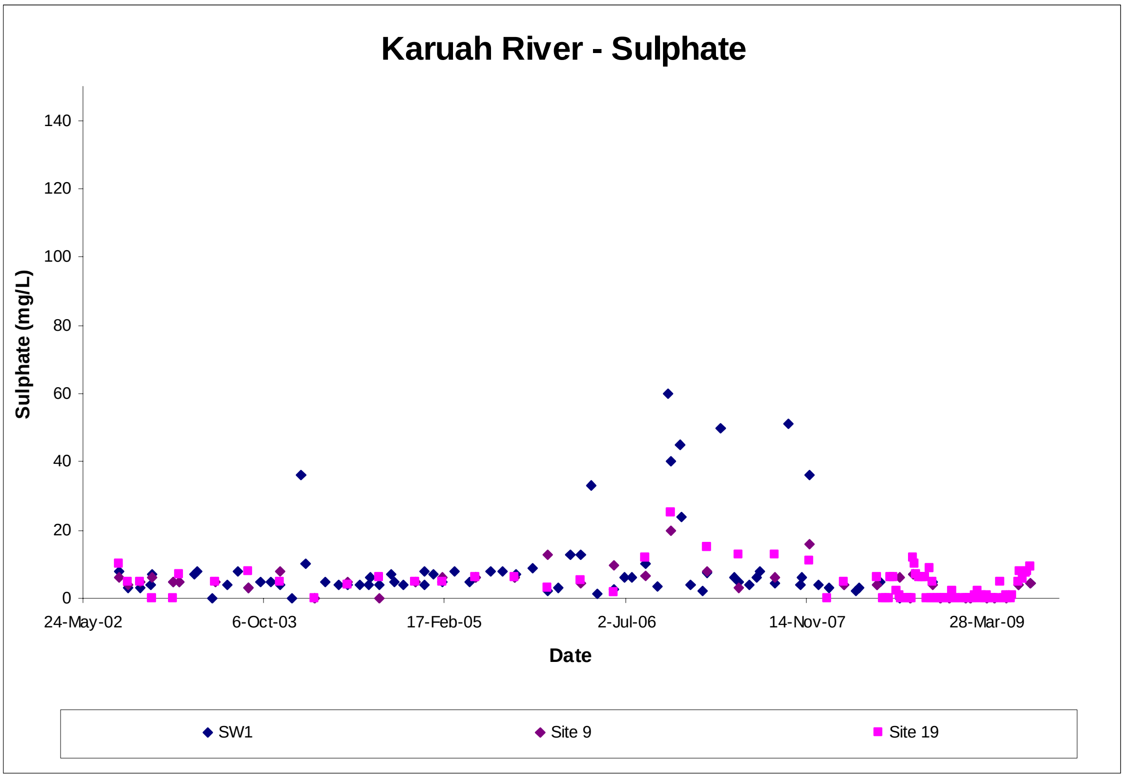
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline given for aquatic ecosystems in the Water Quality Objectives for the Karuah River and Great Lakes catchment (DEC, 2006b).



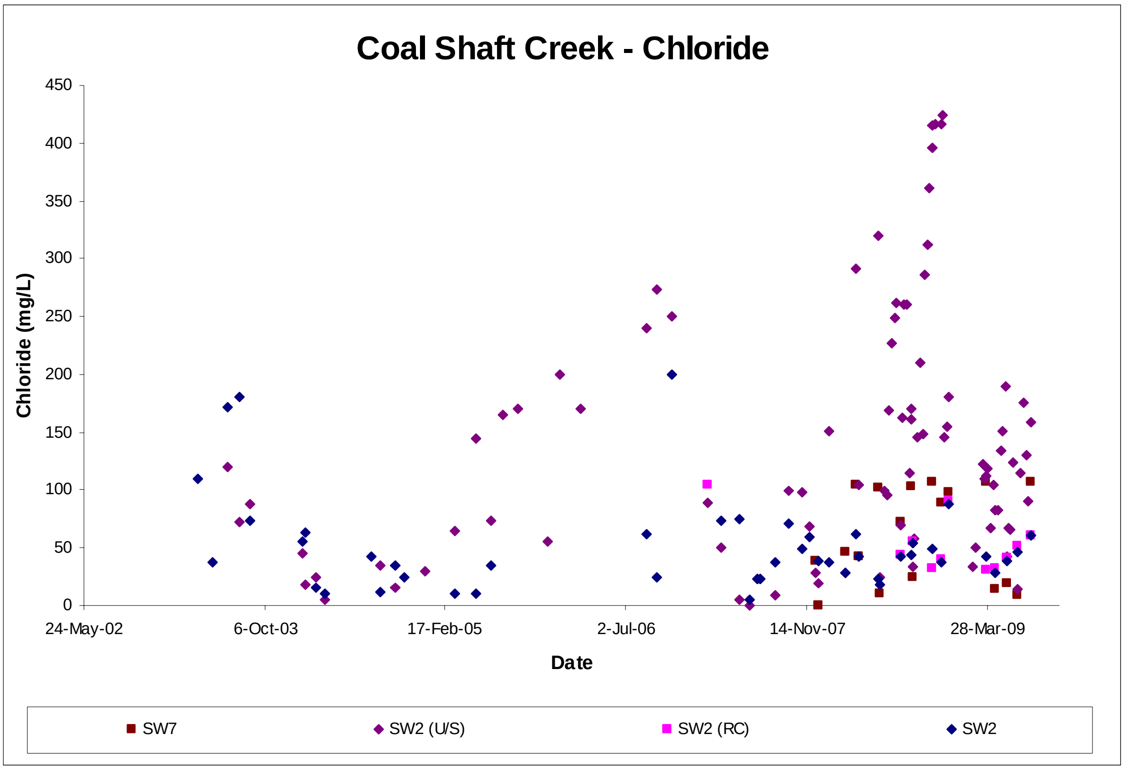


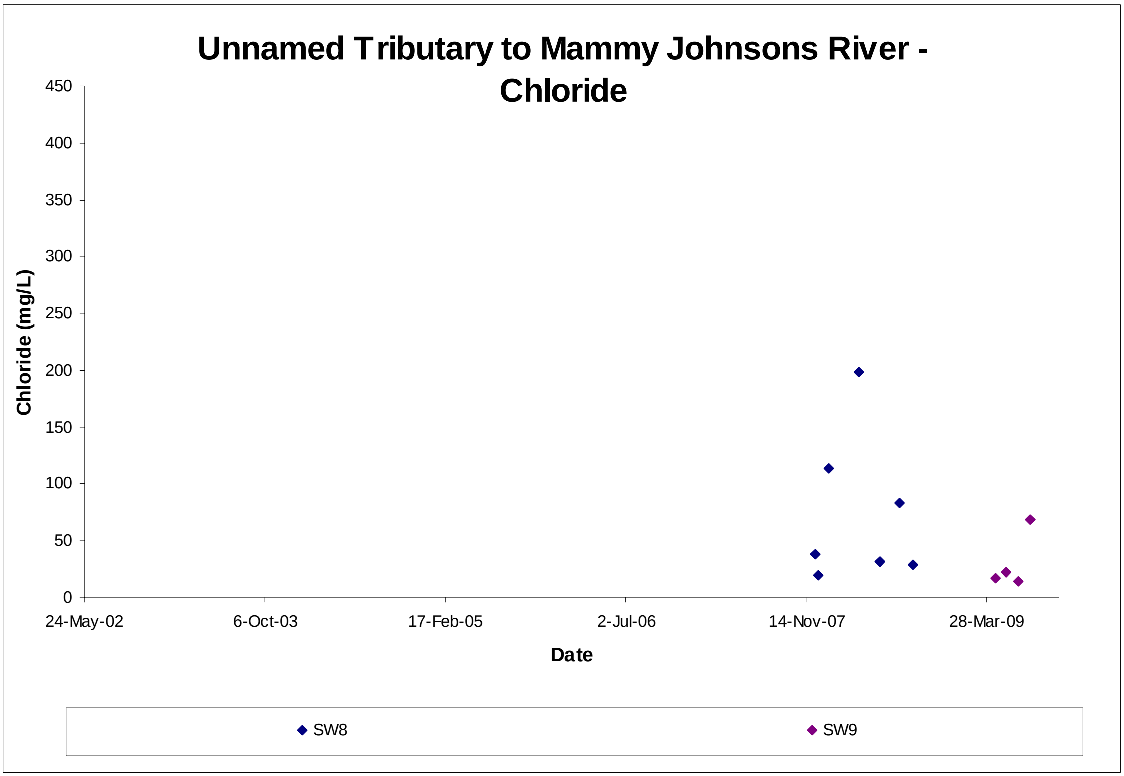
Sulphate Monitoring Results



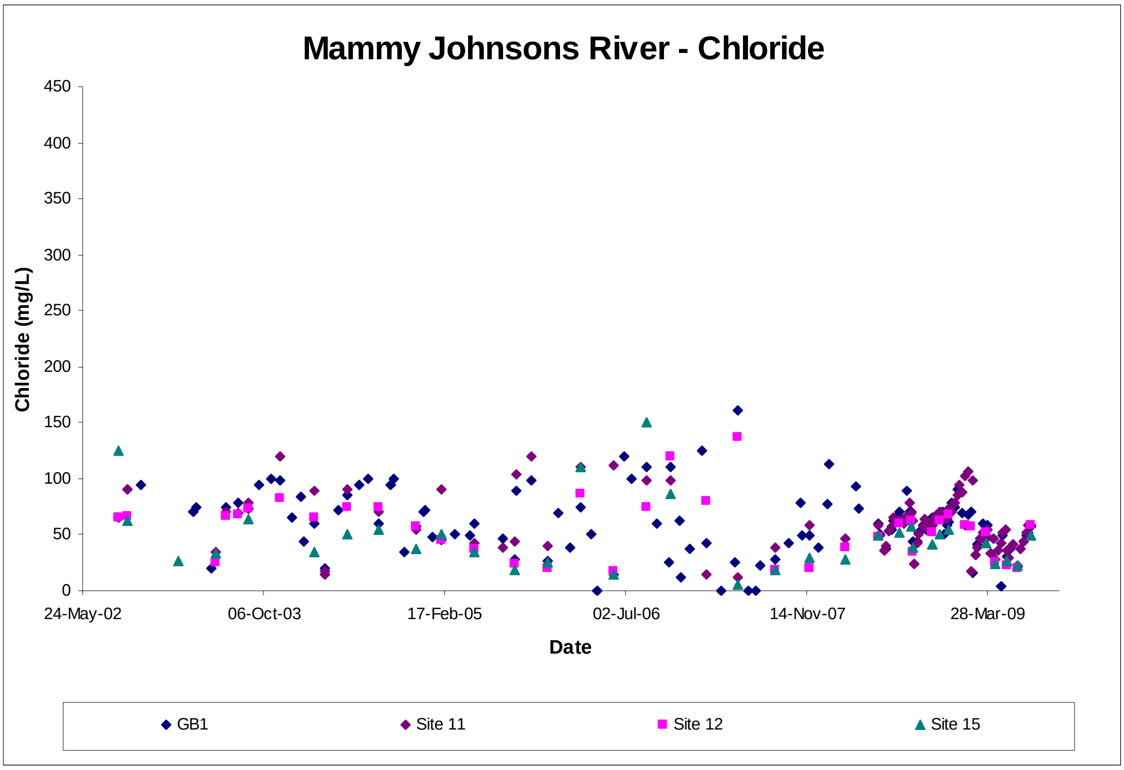


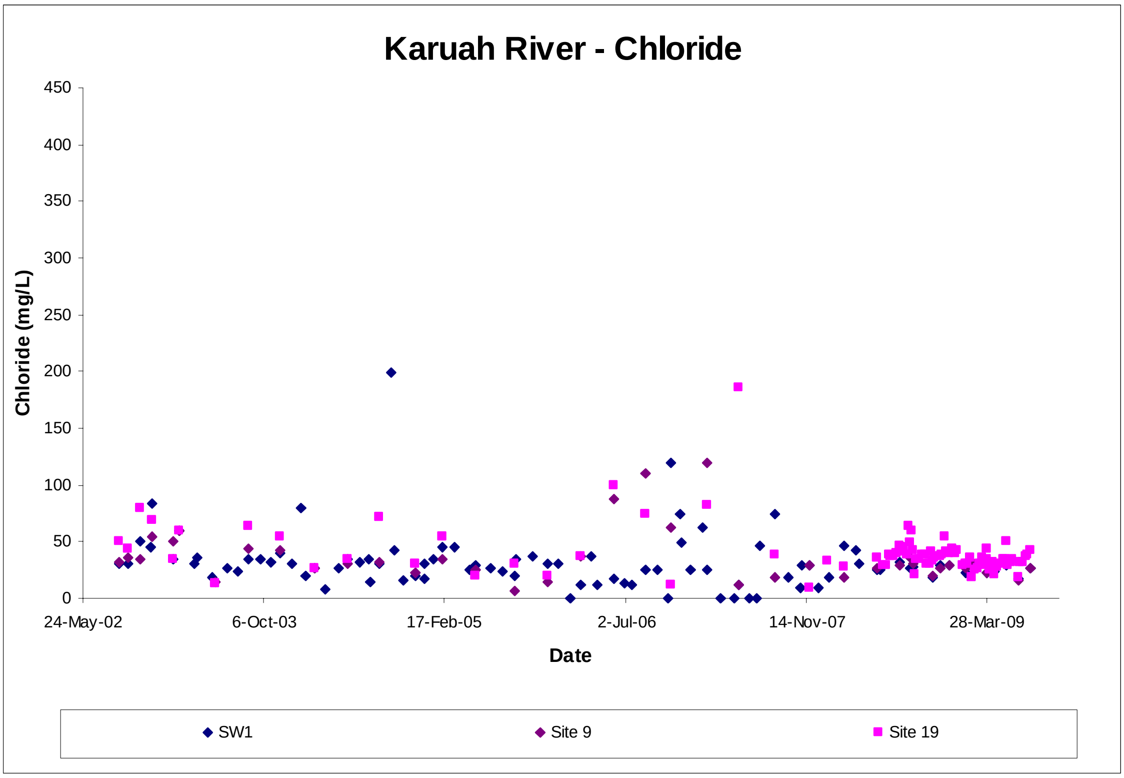
Sulphate Monitoring Results (continued)



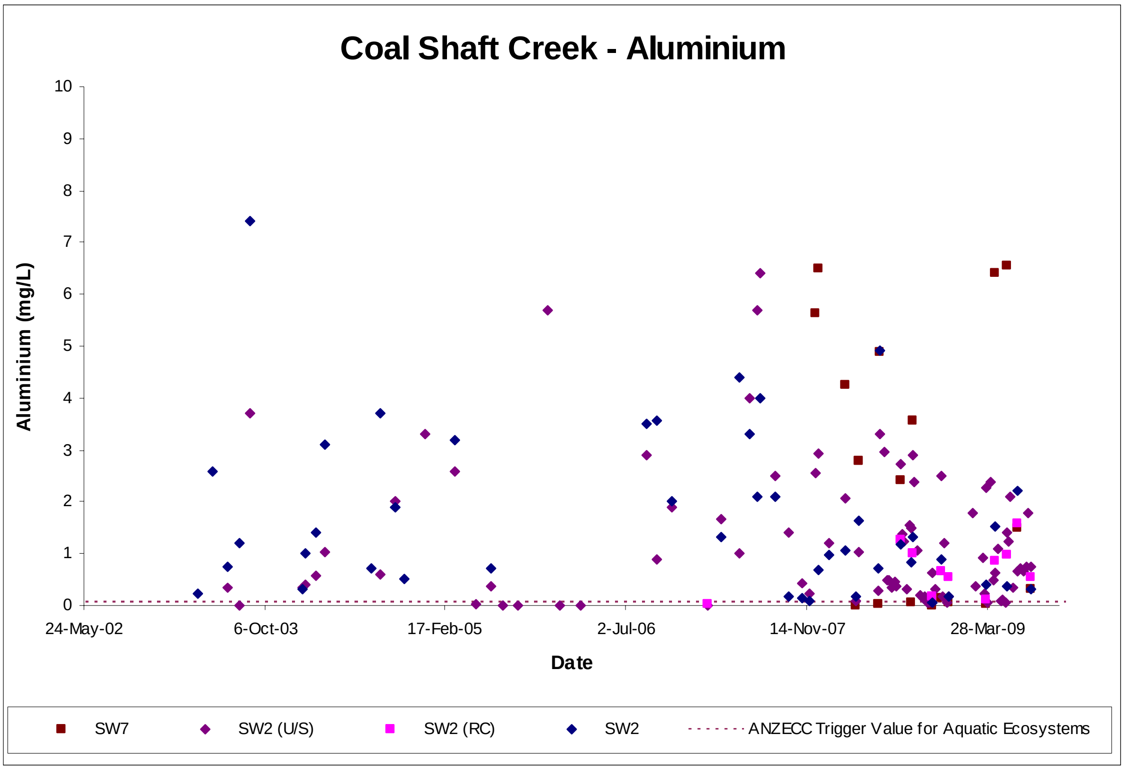


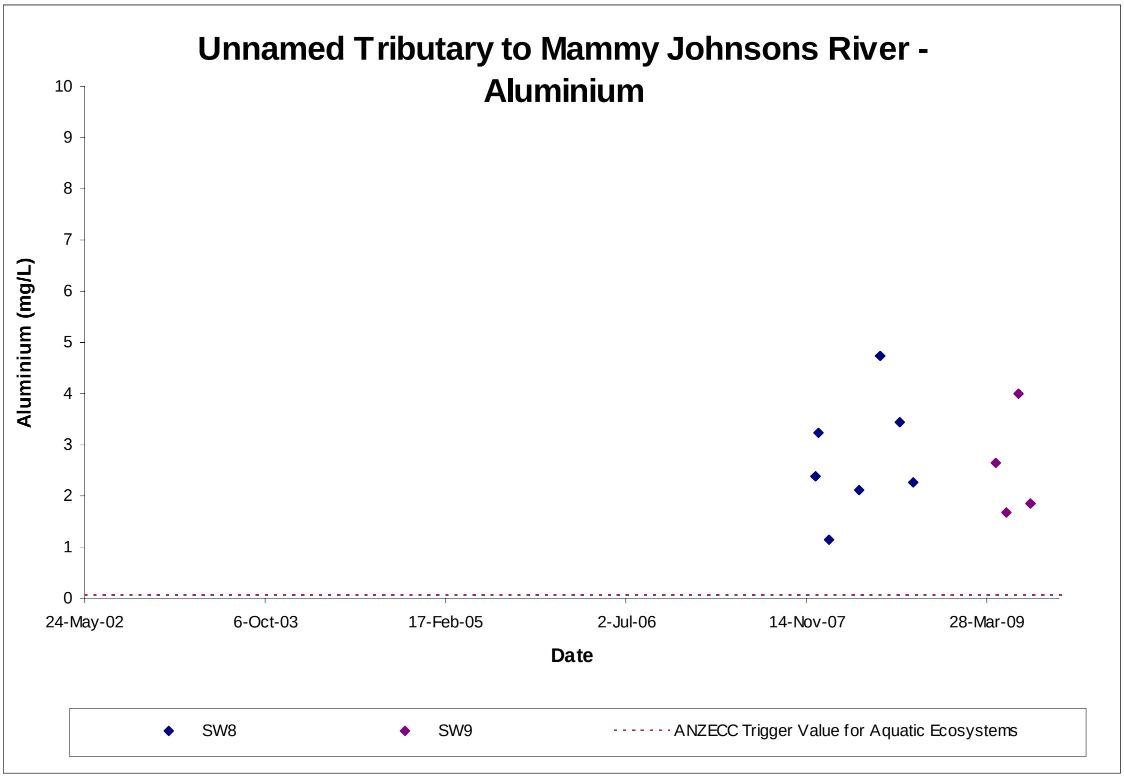
Chloride Monitoring Results





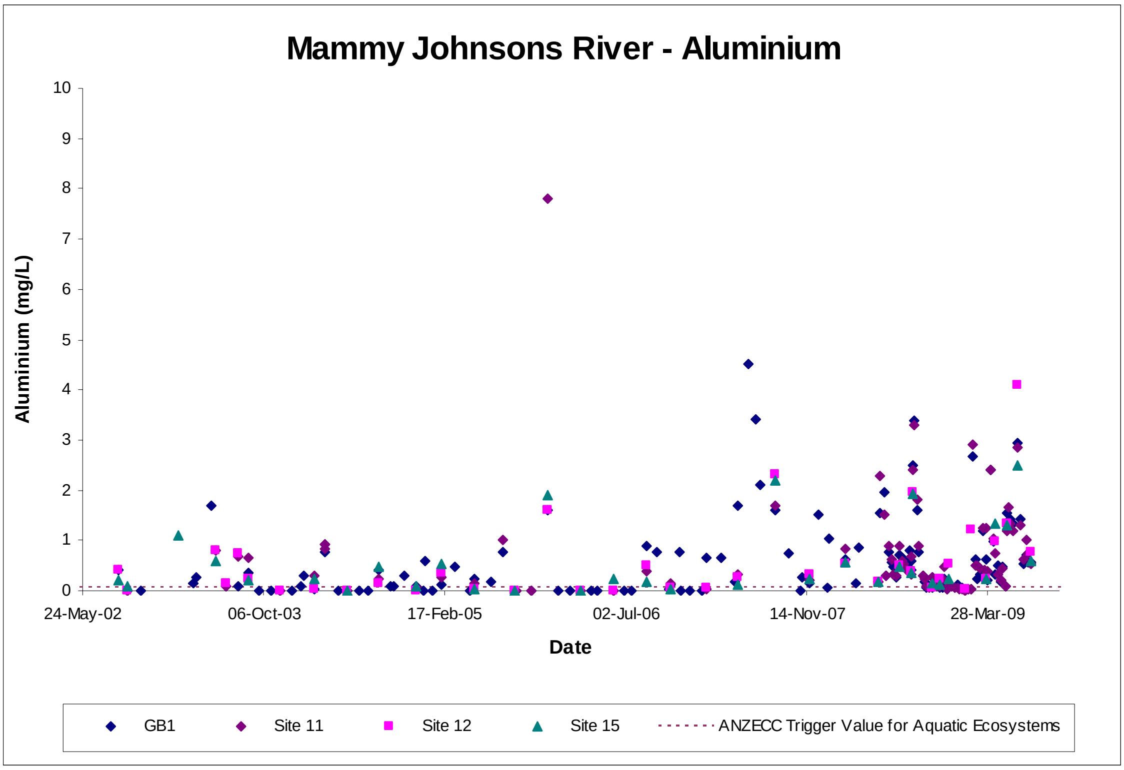
Chloride Monitoring Results (continued)

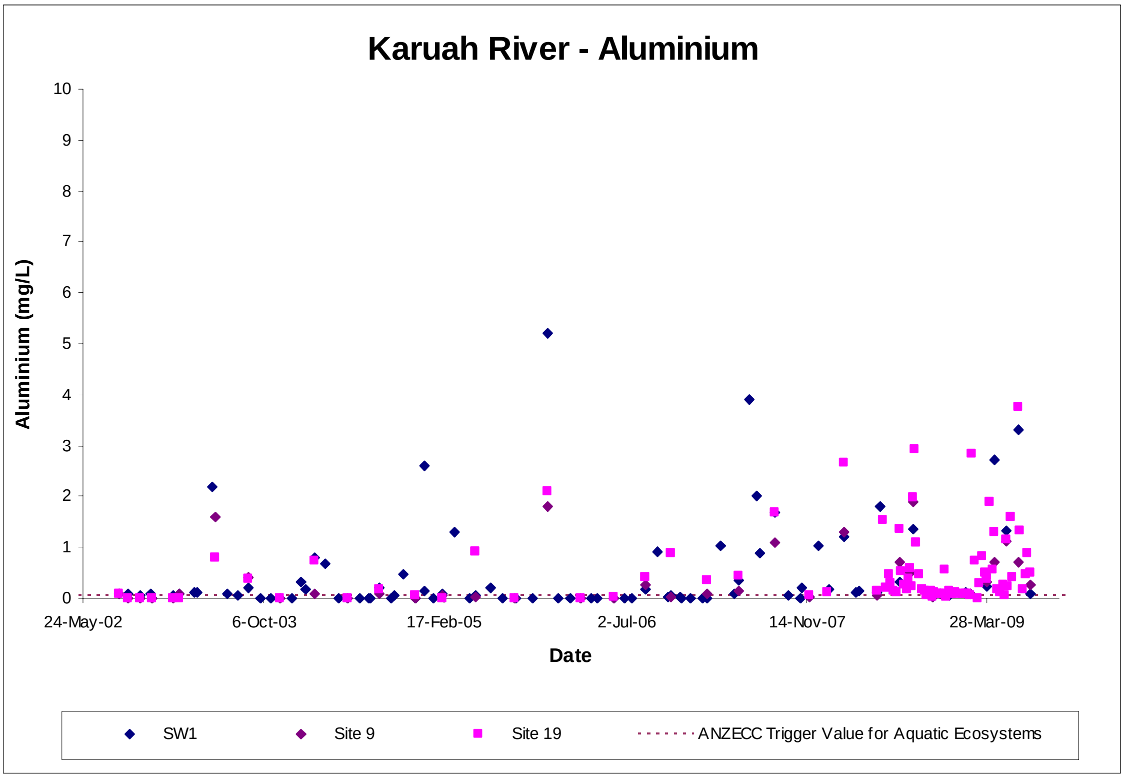




Aluminium Monitoring Results

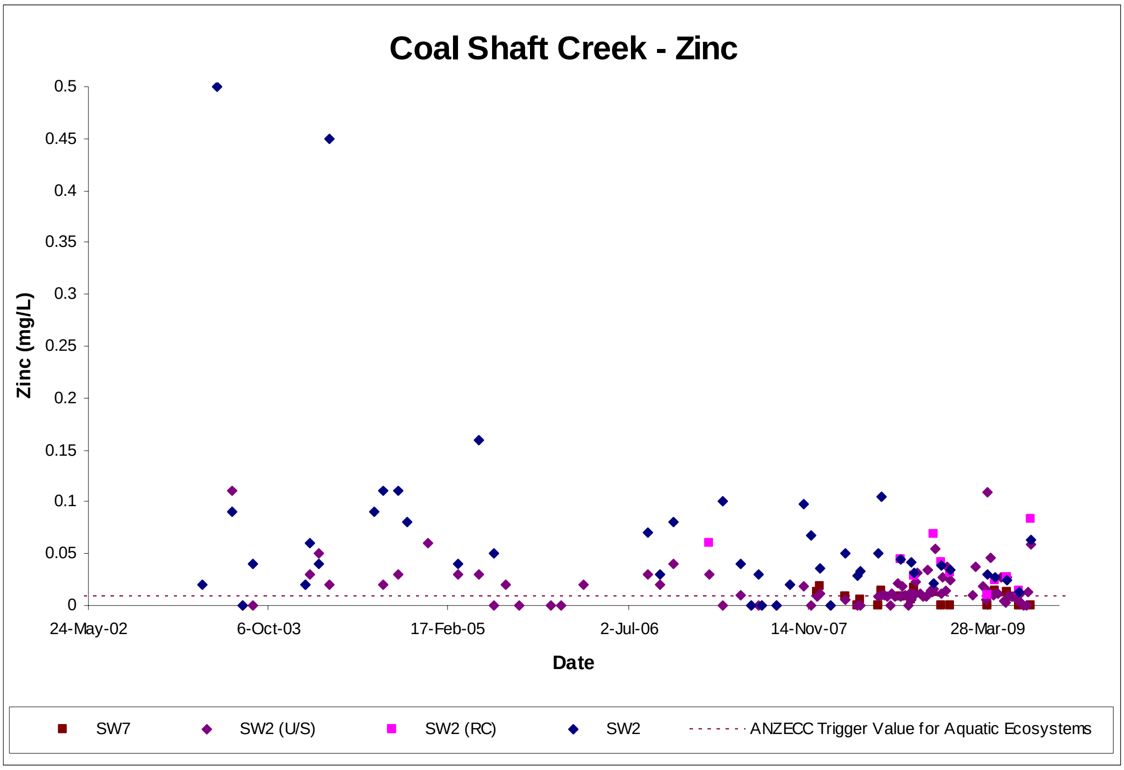
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).

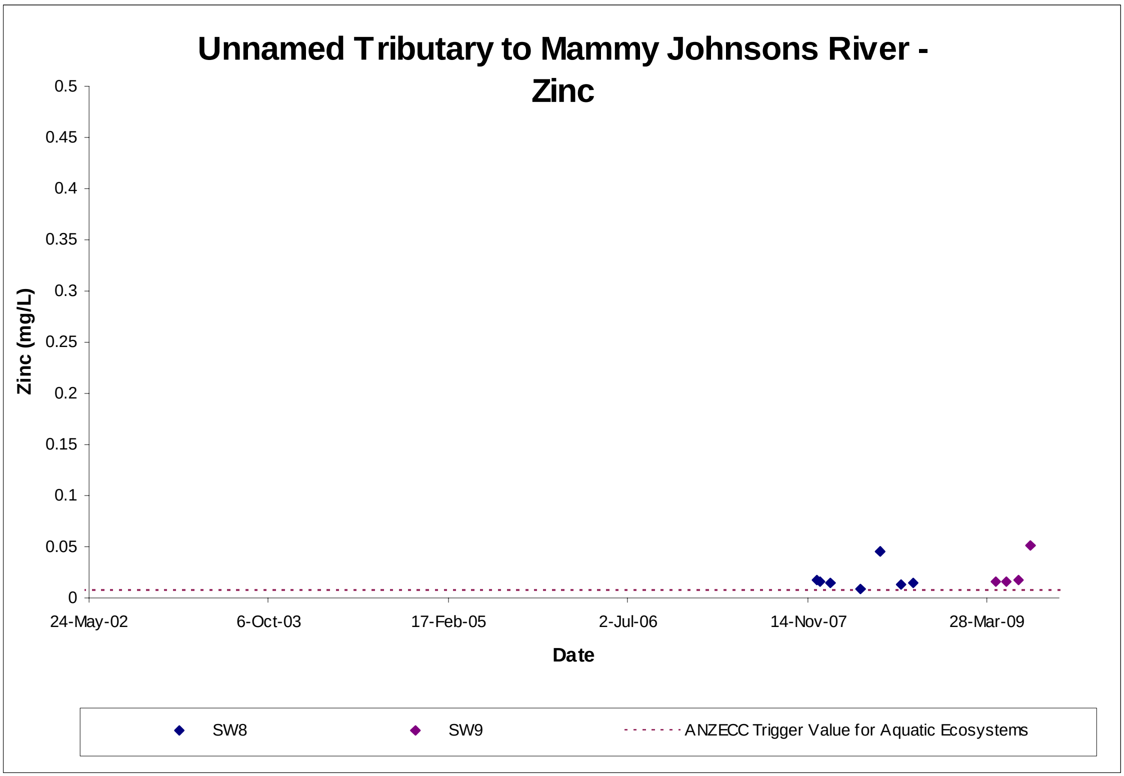




Aluminium Monitoring Results (continued)

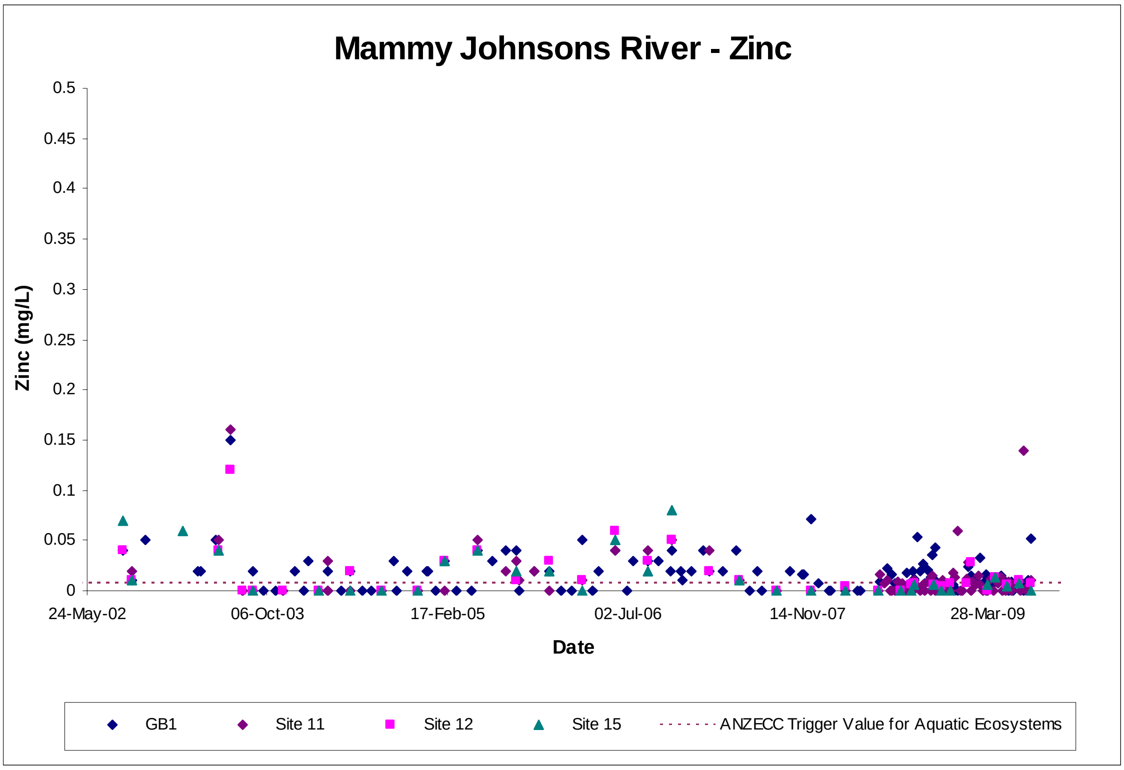
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).

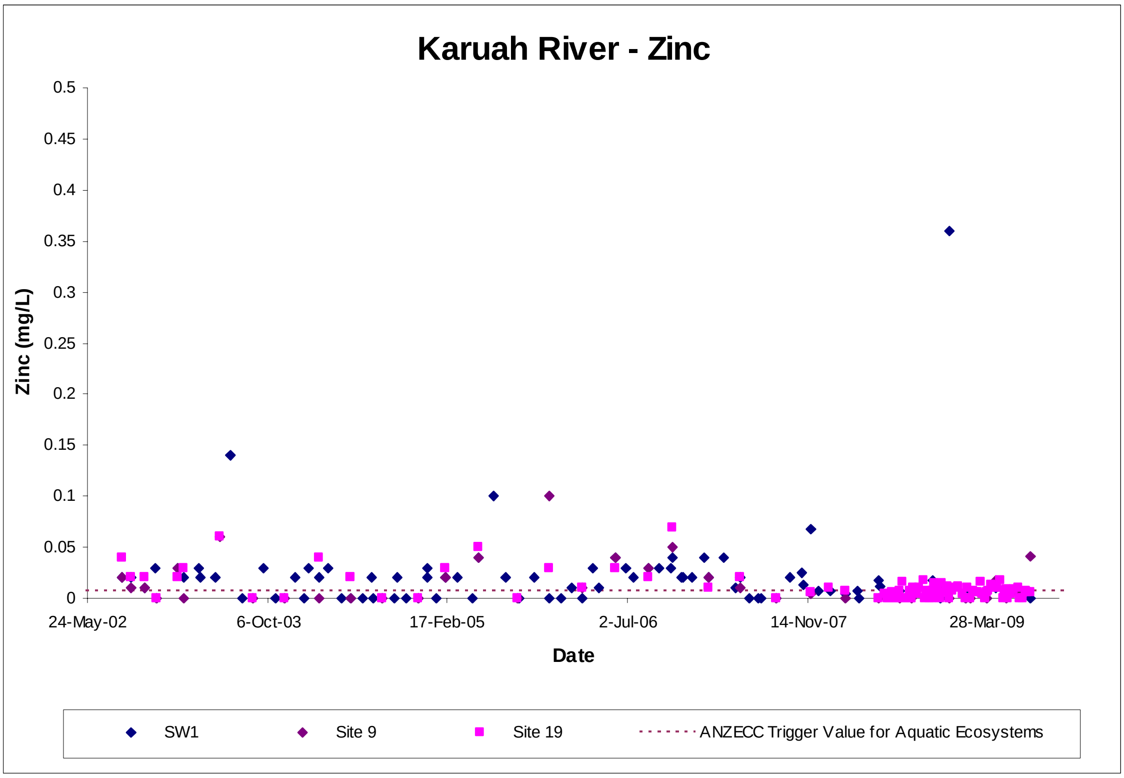




Zinc Monitoring Results

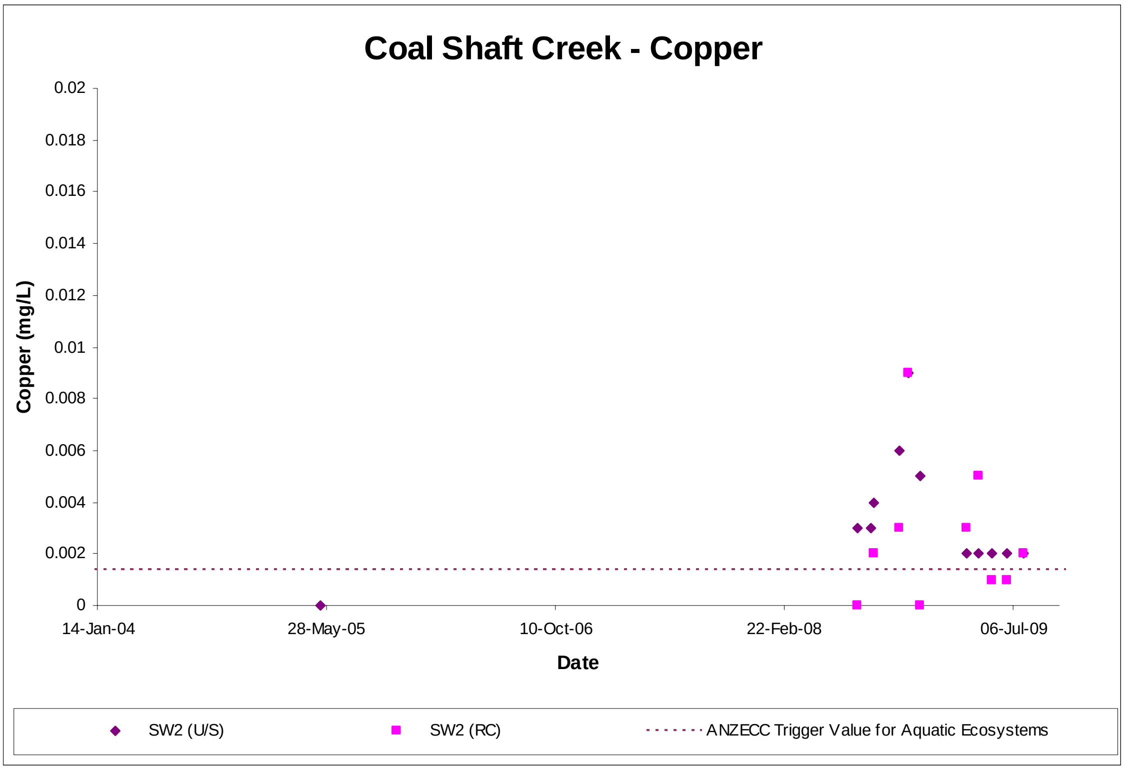
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).

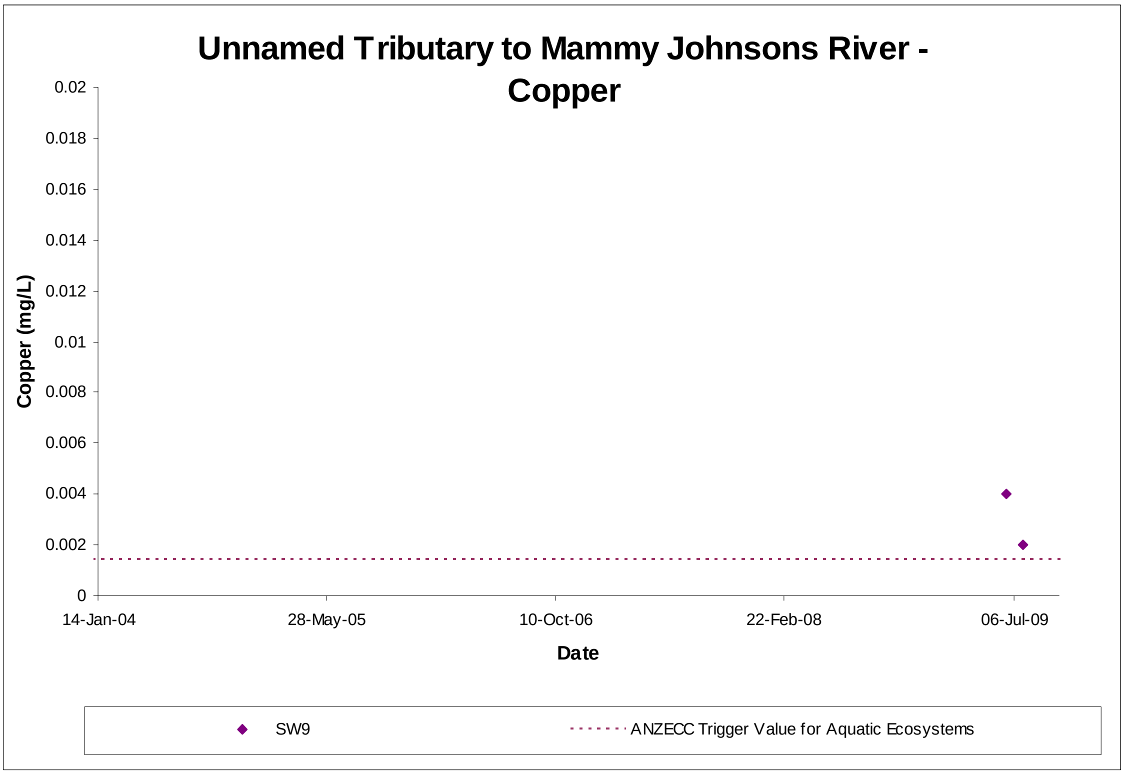




Zinc Monitoring Results (continued)

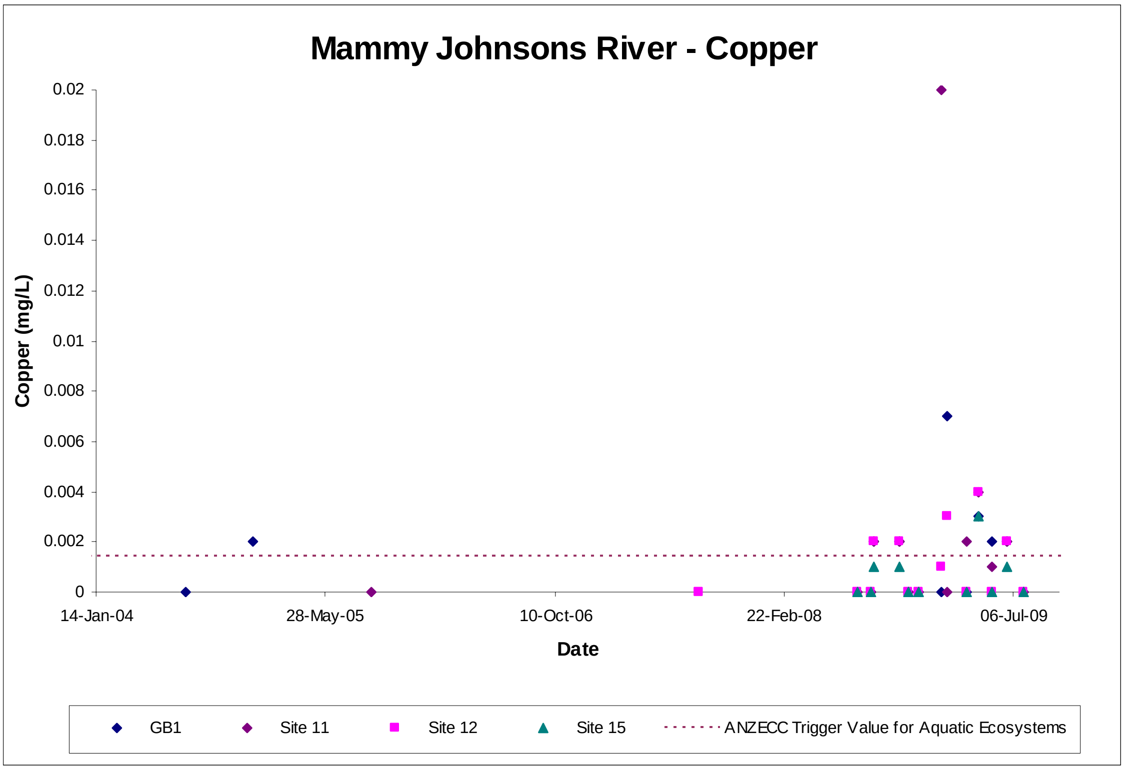
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).

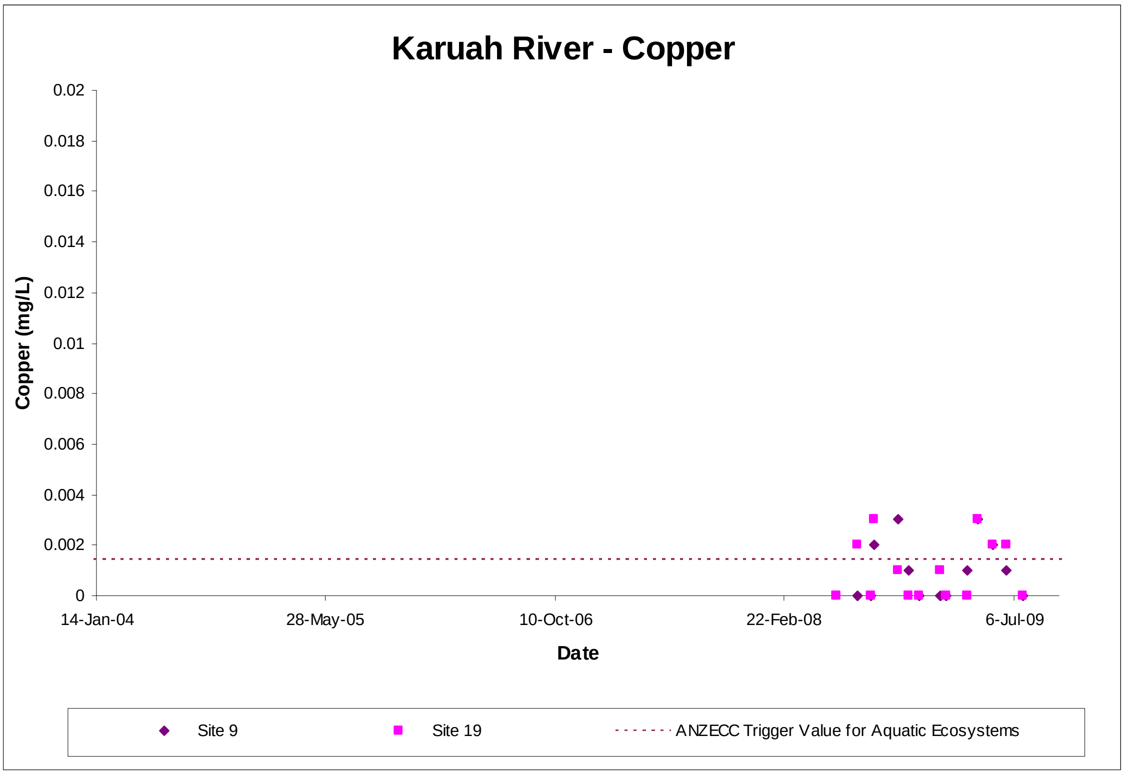




Copper Monitoring Results

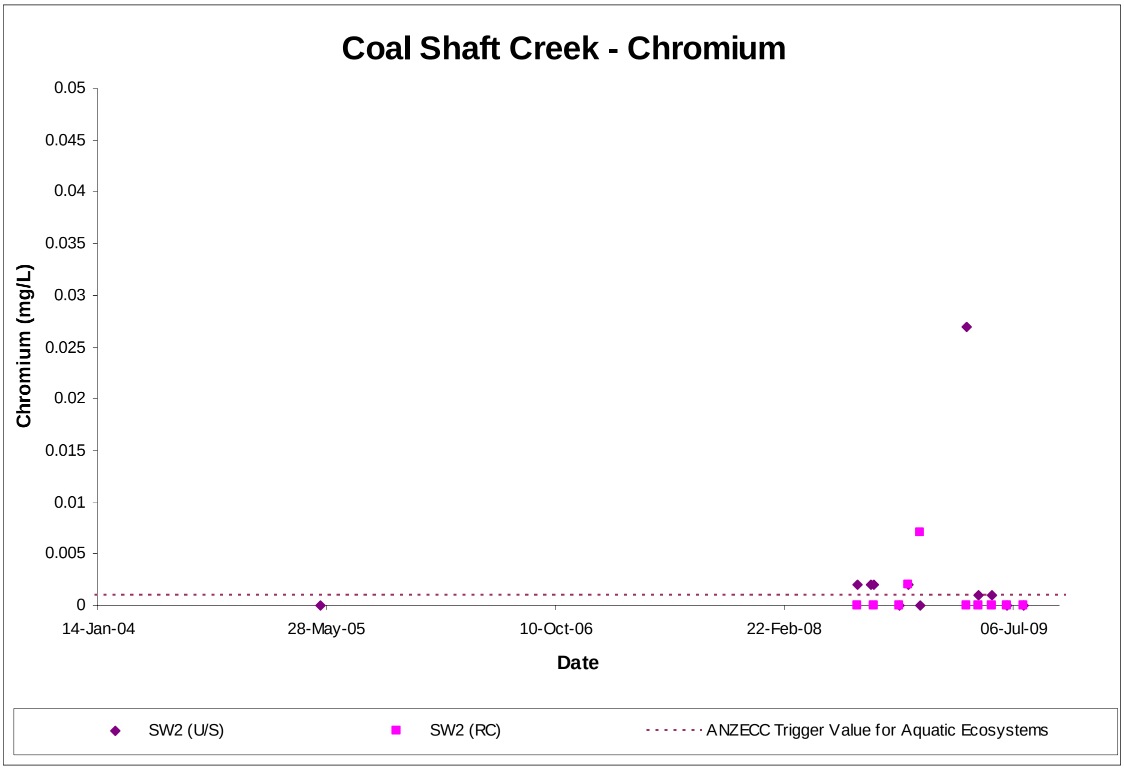
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).

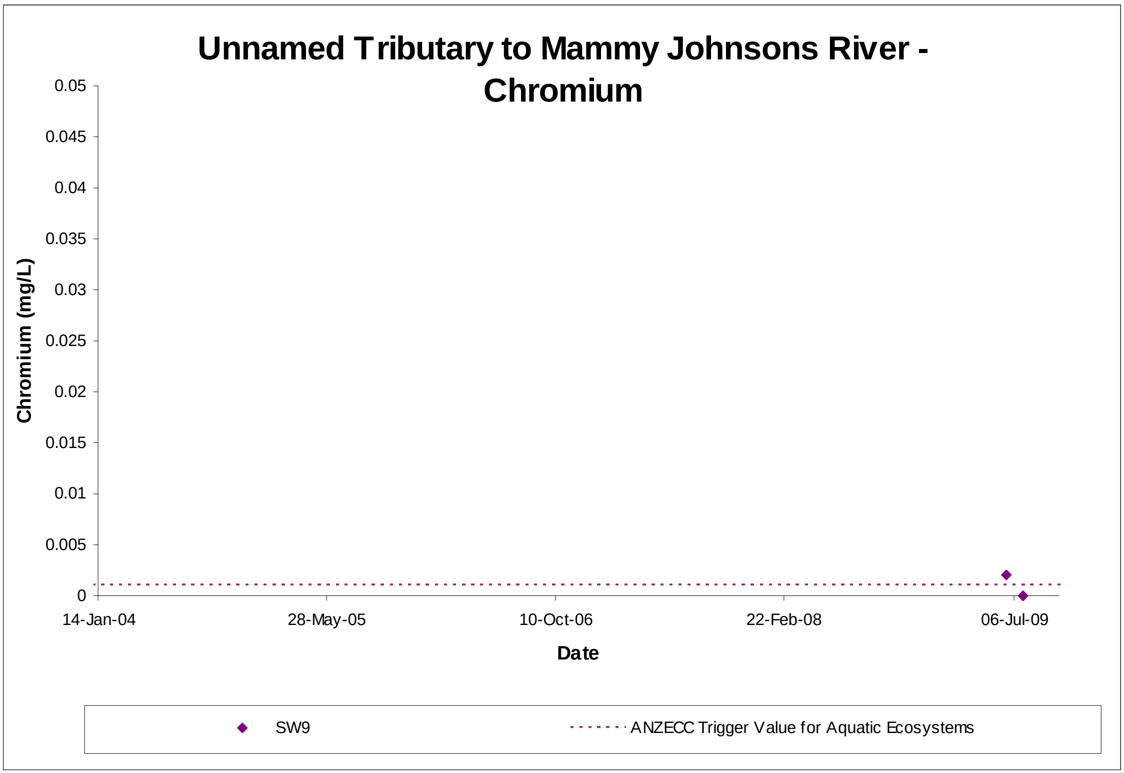




Copper Monitoring Results (continued)

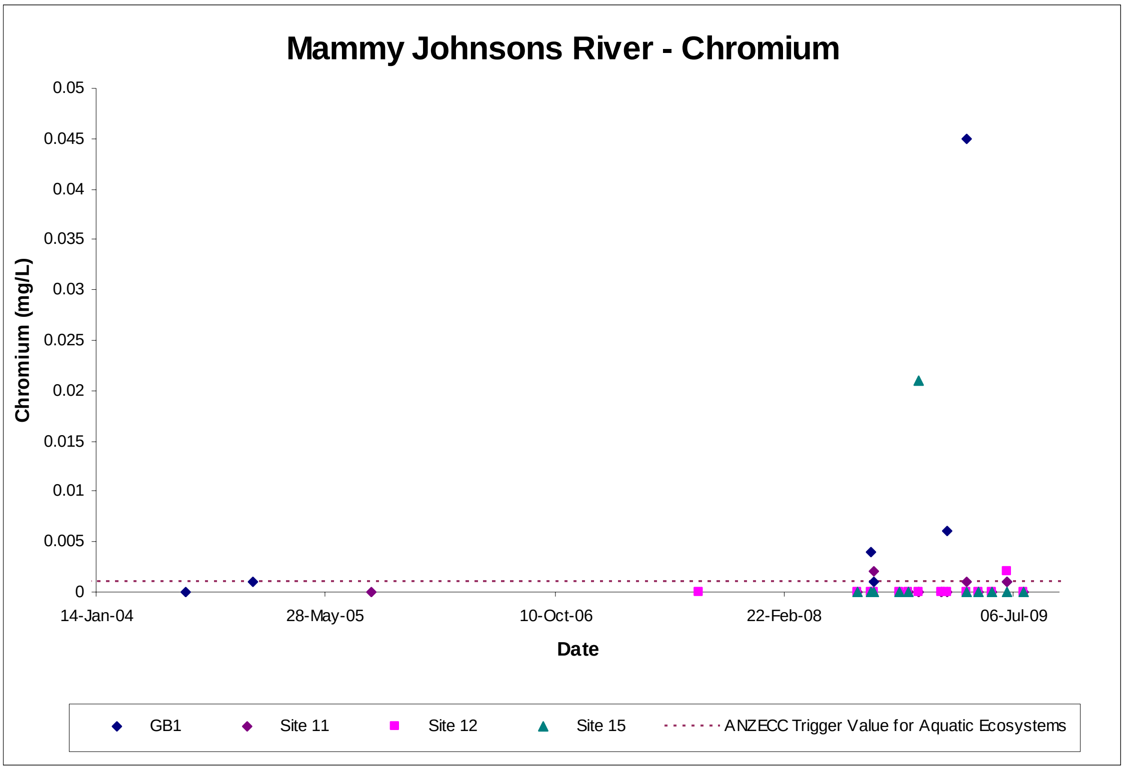
Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).

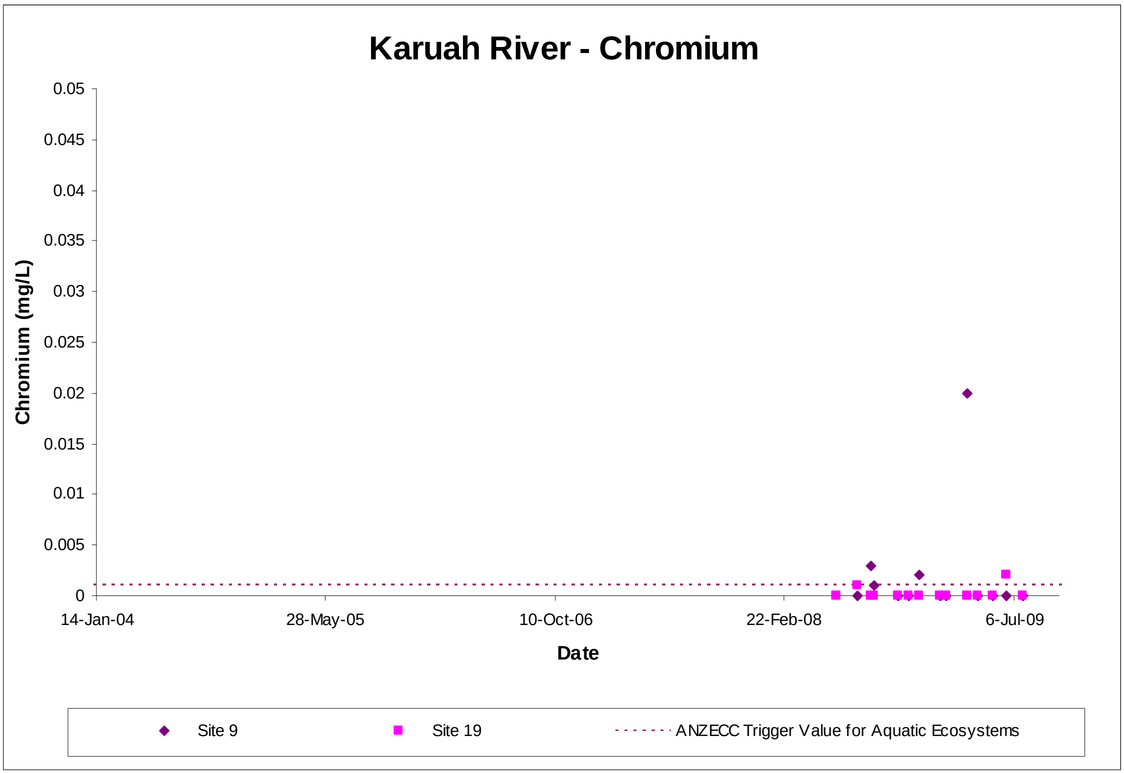




Chromium Monitoring Results

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).





Chromium Monitoring Results (continued)

Note: ANZECC/ARMCANZ Trigger Value for Aquatic Ecosystems is the guideline for slightly to moderately disturbed freshwater systems (ANZECC/ARMCANZ, 2000a).

ATTACHMENT AB
IRRIGATION WATER – SUITABILITY ASSESSMENT

ATTACHMENT AB
DURALIE EXTENSION PROJECT

IRRIGATION WATER – SUITABILITY ASSESSMENT

Prepared for Duralie Coal Pty Ltd

by

AGRICULTURAL WATER MANAGEMENT
49 Pebble Beach Drive
Runaway Bay
QLD 4216

January 2010

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF APPENIDICES

DISCLAIMER

This report was prepared by LanSci Management Pty Ltd trading as Agricultural Water Management for Duralie Coal Pty Ltd. LanSci Management Pty Ltd cannot accept responsibility or liability for problems that occur because the report does not consider issues of which LanSci Management Pty Ltd was not informed. No responsibility is accepted to any other party who may use or rely on the whole or any part of the contents of the report.

The report should be read in full and no attempt should be made to interpret parts thereof in isolation. The report should not be used or copied by other than Duralie Coal Pty Ltd without written authorisation from LanSci Management Pty Ltd.

AB1. INTRODUCTION

The Duralie Coal Mine (DCM) is located approximately 10 kilometres (km) north of the village of Stroud and approximately 20 km south of Stratford in the Gloucester Valley in New South Wales (NSW). The DCM is owned and operated by Duralie Coal Pty Ltd (DCPL), a wholly owned subsidiary of Gloucester Coal Ltd.

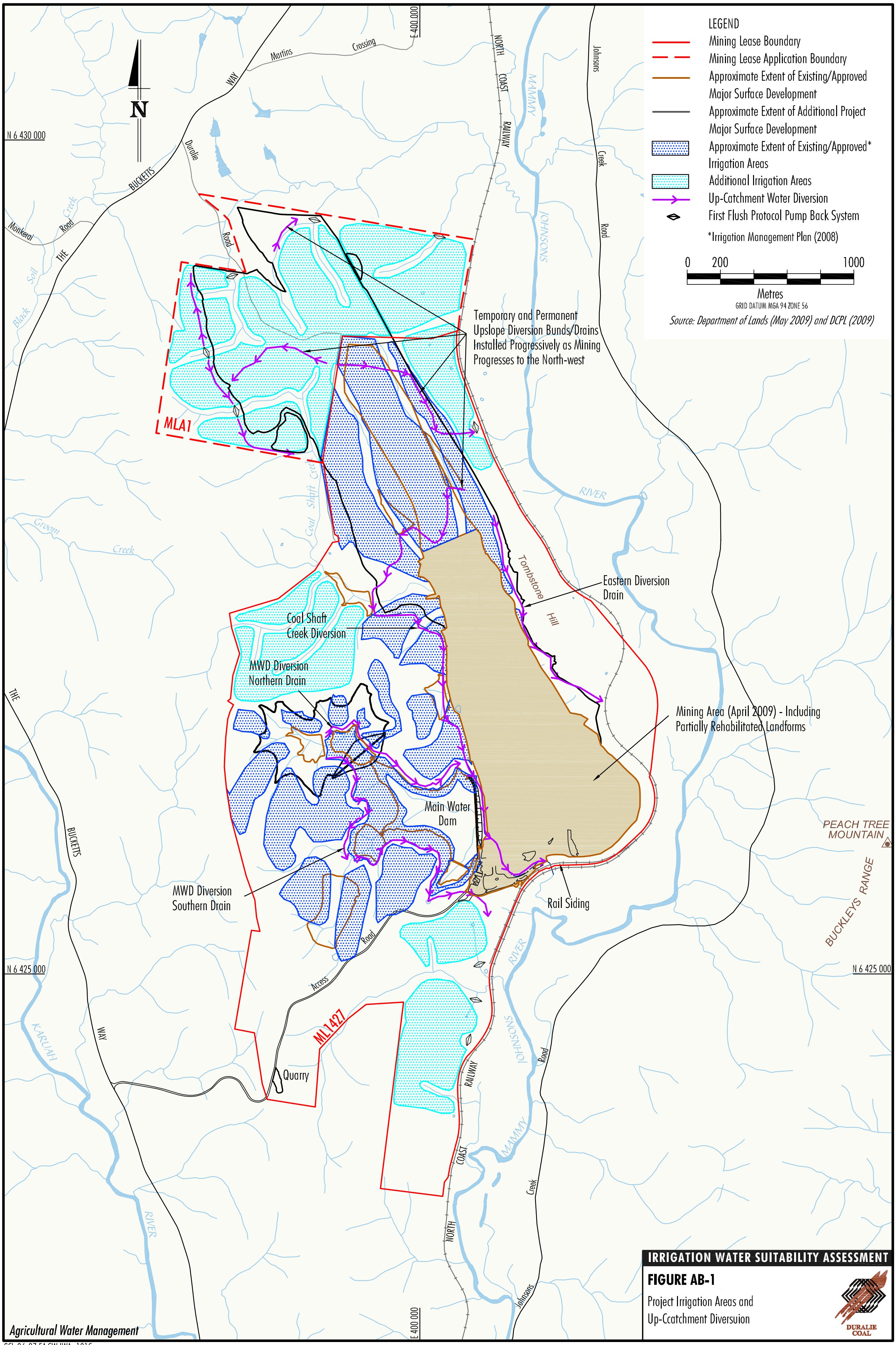
The Duralie Extension Project (the Project) would involve the continuation of open pit mining operations at the DCM. The Project would also include the continued disposal of excess water through irrigation including development of new irrigation areas within Mining Lease (ML) 1427 and Mining Lease Application 1 (Figure AB-1).

Agricultural Water Management was engaged to conduct a desk-top assessment of the suitability of water for irrigation use at the Project to address the following Director-General's Environmental Assessment Requirement for the Project:

> *Surface and Ground Water – including:*
>
> *…*
>
> - *… and an assessment of the suitability of minewater for irrigation use;*

The assessment includes an analysis of potential irrigation impacts on vegetation growth, soil quality and soil structure. This assessment includes:

- Characterisation of the existing environment, including site topography, rainfall, evaporation, soil types, soil drainage, soil depth, and geology of the proposed irrigation areas.
- Water balance analyses to estimate the irrigation demand throughout the year.
- Salt budgets to estimate the accumulation of salt in the soil and the likely effects on plant growth.
- Assessment of the potential impacts of the irrigation with water from the Main Water Dam (MWD) on soils, specifically the impacts on soil quality, structure, and suitability of the soil for future agricultural use.



IRRIGATION WATER SUITABILITY ASSESSMENT

FIGURE AB-1

Project Irrigation Areas and Up-Ccatchment Diversuion

GCL-06-07 EA SW IWA_101C

AB2. EXISTING ENVIRONMENT

AB2.1 Local Climate

The local mean monthly rainfall and potential evapotranspiration are summarised in Table AB-1. The rainfall distribution was based on measurements at Wards River (Moana) (Commonwealth Bureau of Meteorology [BoM] Station 060089), supplemented with data from Craven (Station 060042) and Stroud Post Office (Station 061071) BoM stations. The data set covered 69 years from 1940 to 2008 and included a variety of wet and dry years.

The evapotranspiration was based on the estimated pan evaporation at Dungog taken from the "Ausclim" data file supplied by Commonwealth Scientific and Industrial Research Organisation. The Dungog data was used because it referenced the closest station and the annual pan evaporation (1,525 millimetres per year [mm/yr]) was not much different to other BoM stations in the general district. The measured pan evaporation is 1,571 mm/yr at Paterson (Station 061250) and 1,607 mm/yr at Lostock Dam (Station 061288). However, pan evaporation is much less (1,059 mm/yr) at Chichester Dam (Station 061151).

Pan evaporation was converted to the potential reference crop evapotranspiration by multiplying by a pan coefficient of 0.8. The reference crop evapotranspiration was then converted to the potential evapotranspiration of extensively grazed native pasture by multiplying by a crop coefficient of 0.75 (Allen *et al*., 1998). In addition, an adjustment was made to allow for the effect of cold conditions on evapotranspiration during the cooler months.

Table AB-1 Mean Monthly Rainfall and Potential Evapotranspiration from Native Pasture.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Yr
Rain (mm/mth)	128	132	152	88	88	102	53	59	53	78	90	97	1,120
Evapotranspiration – pasture (mm/mth)	124	101	90	65	43	30	27	36	60	99	114	126	915

Note: mm/mth = millimetres per month.

Based on the BoM data set the annual rainfall distribution varied as follows:

Driest	1/10-dry	Median	1/10-wet	Wettest
557 mm	756 mm	1,106 mm	1,486 mm	1,815 mm

Note: mm = millimetres

Points of note are:

- The area receives a moderately high rainfall that averages 1,120 mm/yr.
- The mean monthly rainfall is less than the potential evapotranspiration for five months of the year (September to December). These months would have the most frequent irrigation demand but the natural variation in rainfall can create a demand in all months.

AB2.2 Geology

The Project coal resource is located within the Permian-aged Gloucester Basin in NSW. In the Project area, the DCM is located in the southern closure of the main synclinal structure of the Gloucester Basin and is associated with the coal bearing strata of the Dewrang Group. The Dewrang Group comprises three main stratigraphic units, namely: Mammy Johnsons Formation; Weismantels Formation; and Durallie Road Formation.

The Dewrang Group subcrops over a major portion of the DCM and consists of coarse and medium grained sandstones with minor siltstone, conglomerate and coal seams including the Weismantel and Clareval Seams associated with the Weismantels Formation and Durallie Road Formation, respectively. The underlying basement rocks are principally volcanics of Early Permian (i.e. Alum Mountain Volcanics) and Carboniferous age that were folded during formation of the Gloucester Basin. The Early Permian and Carboniferous volcanic rocks are typically erosion resistant and form the more prominent ridges to the east and west of the DCM.

Normal and reverse faults are characteristic of the area. The Gloucester Basin is a fault-controlled depositional trough and subsequent compression tectonics have induced folding, which has accentuated the dip of the strata and, in places, resulted in thrust-faulted repetition of the stratigraphic units. The main faulting and fracturing (joints) trend north-south, east-northeast, and west-southwest in the Project area. Generally the joint spacing in the sandstone is approximately 1 metre (m) (Kidd, 1996).

Alluvials (~ 8 to 15 m thick)

A thin, narrow and discontinuous deposit of Quaternary to Recent Age alluvial deposits occurs along the river flats of Mammy Johnsons River. The alluvium consists of silty sands and silts with lenses of gravelly sands and sandy, coarse gravel, particularly towards the base of the alluvium. The gravel lenses correspond to former channel deposits of the river and are evident in the present bed and banks of the river.

Mammy Johnsons Formation

The uppermost layer of the Mammy Johnsons Formation is thick shale. Similar to its underlying coal formations, the deeper sections of the Mammy Johnsons Formation comprise coarse grained lithic sandstones. It also hosts minor, poorly developed coal seams.

Weismantels Formation

The Weismantels Formation comprises fine to medium grained sandstones over thick shale covering the Weismantel Seam (below).

Weismantel Seam (~10 to 20 m thick)

The Weismantel Seam is currently the only seam being mined at the DCM and would continue to be mined as part of the Project. The Weismantel Seam is generally between 10 and 12 m thick. However significant reverse faulting causes repetition of the middle and lower sections of the seam resulting in coal thicknesses of up to 20 m. The Weismantel Seam is divided into working sections on a coal quality basis. The upper 3 to 4 m is generally thermal coal and the lower 7 to 8 m is a mixture of coking coal and thermal coal.

As the DCM is located at the southern closure of the regional syncline, the pit extent to date has been located at the southern-most outcrops within the axis of the syncline. The DCM Project pit extent would subsequently progress away from the axis and would be located on the western limb of the syncline.

The seam is underlain and overlain by massive medium to coarse grained lithic sandstones, conglomerates and minor siltstones. The immediate roof and floor of the Weismantel Seam have a high pyrite content.

Durallie Road Formation

The Durallie Road Formation forms the base of the Dewrang Group and comprises mostly marine sandstones in the south of the Gloucester Basin. The Durallie Road Formation hosts the Clareval Seam (below).

Clareval Seam (variable thickness)

The Clareval Seam was identified in late 2005 from seismic re-interpretation and confirmed by an exploration drilling programme. The Clareval Seam is situated at depth approximately 200 m below and parallel to the Weismantel Seam. The Clareval Seam exhibits many of the same features as the Weismantel Seam in regard to coal quality trends and seam structure. In the Project area, the Clareval Seam is typically 8 to 9 m thick, however sequences of 30 and up to 50 m thickness are known to exist in the north-west.

Alum Mountain Volcanics

The Alum Mountain Volcanics are a ryholitic rock unit, which is underlain by undifferentiated rocks of Carboniferous age.

AB2.3 Topography

The topography of the DCM site is of intermediate undulating lowlands (Organic Waste Recycling Unit [OWRU], 1996). There is a wide range of slope gradients and terrain types. The most suitable pasture irrigation areas occur on slopes of less than 10 to 12 percent (%). Areas with slopes gradients between 12 and 20% could be used for infrequent irrigation, provided there is a reasonable depth of soil and they are managed to avoid runoff during irrigation (OWRU, 1996).

Ridges, side slopes and floodplains are generally suited for irrigation. However, drainage lines and frequently waterlogged foot slopes should be avoided (OWRU, 1996).

AB2.4 Soils

Veness & Associates (1996) identified five different soil mapping units, containing soil types that coincide with the geologic boundaries. The five soil types, as described in the *Duralie Coal Environmental Impact Statement* (DCPL, 1996), were:

- Type A: Alluvial soils;
- Type B: Structured loams, yellow and gleyed podzolic soils;
- Type C: Minimal prairie soils, brown and gleyed podzolic soils;
- Type D: Structured plastic clays; and
- Type E: Structured plastic clays, minimal prairie soils.

Irrigation on alluvial soils (Type A) would not be included in the Project and therefore Type A soils were not considered in this assessment.

In addition to the soil types listed above, irrigation would also be applied to waste rock emplacements at the Project. The waste rock emplacements would generally consist of coarse and medium grained sandstones with minor siltstone and conglomerate (Section AB2.2). A layer of topsoil would be spread over the waste rock during rehabilitation.

AB2.5 Main Water Dam – Irrigation Water

Water stored on-site includes groundwater inflows to the open pit, incident rainfall and runoff from mine disturbance areas at the DCM.

Water pumped from sumps in the open pit is stored in the MWD. The MWD is located to the north-west of the main infrastructure area and has a capacity of up to approximately 1,405 megalitres (ML). The MWD is also used to store water collected from selected sediment dams and runoff from the main infrastructure area.

Water stored in the MWD would be used for irrigation.

Main Water Dam Water Quality

The mean composition of water samples taken from the MWD over the periods 6 September 2007 to 1 September 2008, and from 5 September 2008 to 24 February 2009, are given in Table AB-2. Only selected analytes that were used in the discussion are reported in Table AB-2. A large number of samples (86) contributed to the overall mean pH but smaller numbers (5 to 18) were available for the other constituents. The electrical conductivity (EC) values were restricted to those taken after 20 January 2009 because of uncertainty about data accuracy before then.

Table AB-2 The Mean Composition of Water in the Main Water Dam (2007/08 and 2008/09).

Constituent	Units	Period		
		2007/08	2008/09	Overall mean
pH		7.6	7.7	7.6
EC	dS/m	-	1.89	1.89
Sodium	mg/L	163	175	172
Calcium	mg/L	150	163	154
Magnesium	mg/L	42	47	43
Total alkalinity[1]	mg/L as $CaCO_3$	141	156	145
Bicarbonate	mg/L	172	190	177
Chloride	mg/L	208	193	204
Sulphate	mg/L	439	543	468
SAR[2]		3.03	3.11	3.15
RSC[2]	meq/L	<0	<0	<0

Source: DCPL (pers. comm., 2009).

Notes:

1. Calculated from the bicarbonate concentration on the assumption that the alkalinity was entirely due to bicarbonate ions (as indicated by two samples that were analysed in July and August 2008).
2. Calculated from the various concentration data.

dS/m: deciSiemens per metre.
mg/L: milligrams per litre.
$CaCO_3$: calcium carbonate.
SAR: sodium adsorption ratio.
RSC: residual sodium carbonate (bicarbonate).
meq/L: milliequivalents per litre.

Gilbert & Associates (2009) has prepared a MWD salt balance simulation for the Project over median, unusually wet and unusually dry periods. The predicted average EC values under these weather conditions are:

- Median Rainfall Sequence: 2.14 dS/m.
- Wet (1/10 wet) Rainfall Sequence: 2.09 dS/m.
- Dry (1/10 dry) Rainfall Sequence: 1.94 dS/m.

Gilbert & Associates (pers. comm. 11 November 2009) provided predicted mean water quality for other constituents in the MWD for the median rainfall sequence (Table AB-3).

Table AB-3 The Predicted Mean Composition of Water in the Main Water Dam (Median Rainfall Sequence).

Constituent	Units	Predicted Value
pH		7.6
EC	dS/m	2.14
Sodium	mg/L	164
Calcium	mg/L	209
Magnesium	mg/L	59
Total alkalinity	mg/L as $CaCO_3$	96
Bicarbonate[1]	mg/L	117
Chloride	mg/L	159
Sulphate	mg/L	753
SAR[2]		2.58
RSC[2]	meq/L	<0

Source: Gilbert & Associates (pers. comm., 11 November 2009).
Notes:
1. Calculated from total alkalinity on the assumption that the alkalinity was entirely due to bicarbonate ions (as indicated by two samples that were analysed in July and August 2008).
2. Calculated from the various concentration data.

The predicted average water quality provided in Table AB-3 was used to assess potential irrigation impacts for the Project.

Relevant guidelines used to characterise the predicted mean quality of the MWD water for irrigation purposes included:

- *Use of Effluent by Irrigation Environmental Guidelines* (NSW Department of Environment and Conservation [DEC], 2004).
- *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (Environment Protection Heritage Council, the National Resource Management Ministerial Council and the Australian Health Ministers' Conference, 2006).

Water quality monitoring currently conducted in the MWD includes a number of minor constituents, none of which were present in concentrations that exceeded the long-term trigger values for irrigation water in the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase1)* (Environment Protection Heritage Council, the National Resource Management Ministerial Council and the Australian Health Ministers' Conference, 2006).

The EC value of 2.14 dS/m gives the water a medium salinity rating as defined in the *Use of Effluent by Irrigation Environmental Guidelines* (DEC, 2004). As such it is suitable for use on moderately tolerant crops, and above. Most pasture grasses are included in this grouping. This general classification can be refined by conducting a more detailed analysis that considers the potential for some salts to be removed from solution by precipitation within the soil, and the effect of rainfall on leaching losses. These issues are discussed more fully in the salt budget section (Section AB3.3).

High concentrations of sodium or chloride can cause leaf scorching, but the concentrations in the irrigation water (Table AB-3) would not harm moderately tolerant, and hardier species (Environment Protection Heritage Council, the National Resource Management Ministerial Council and the Australian Health Ministers' Conference, 2006). Hence pasture grasses would not be affected.

The SAR of the irrigation water (Table AB-3) was well below critical values and would not contribute to a structural decline in the soils.

A high bicarbonate concentration can react with calcium ions to form carbonate salts that give scale deposits in pipelines, can clog soil pores, and increase the soil sodicity by reducing the calcium concentrations and thereby increasing the sodium-permeability hazard. The risk can be assessed in a number of ways:

- The bicarbonate concentration of 117 mg/L is sufficiently high to warrant assessing its concentration against the corresponding concentrations of calcium and magnesium (the RSC).
- The RSC is less than zero in the irrigation water, hence there are sufficient cations to offset the bicarbonate.
- This conclusion is supported by the fact that the adjusted SAR in the irrigation water is less than the critical threshold of 6, above which there is a risk to the soil structure through sodicity effects (DEC, 2004).

The above tests lead to the conclusion that there are ample calcium ions in solution to balance the bicarbonate and no water quality or soil amendments are required to ameliorate potential soil structure impacts.

AB3. POTENTIAL IRRIGATION IMPACTS

Potential irrigation impacts were assessed with consideration of:

- Soil types and characteristics (Section AB2.4).
- Irrigation water quality (Section AB2.5).
- A water balance analysis, which when considering the above, as well as soil permeability and DCPL irrigation management system characteristics, provided an estimate of irrigation rates over the soil types (Section AB3.1).
- An assessment of soil chemistry based on the results from the above, including an assessment of the performance of existing irrigation areas and the likely effects on the salt budget of irrigated soil types (Sections AB3.2 and AB3.3).

AB3.1 Water Balance Analyses

Water balances have been prepared to estimate irrigation rates on the soil types which account for soil type permeabilities and the DCPL irrigation management system requirements for irrigation application.

AB3.1.1 Methodology

The H2OB daily water balance model[1] was used to conduct the water balance calculations that provided estimates of the irrigation volumes and percolation rates. The model estimated daily changes in the soil moisture content, based on the day to day changes in rainfall and evapotranspiration, and irrigation was scheduled according to a deficit irrigation strategy outlined in the *Irrigation Management Plan* (IMP) (DCPL, 2008) that ensured no more water was applied than the soil could absorb.

The irrigation volumes were largely determined by the interaction of:

- The evaporative demand and its seasonal trend from low in winter to high in summer.
- The rainfall pattern and the extent to which it satisfied the evaporative demand. The variation in rainfall between years gave rise to the differences in irrigation volumes between dry and wet years. Not all the rain was effective because some was lost through runoff and deep percolation.
- The water-use characteristics of the pasture.
- The irrigation efficiency which was set at 75%. The irrigation volumes are gross values that include the net volume that reaches plants plus irrigation losses.

Following the procedures outlined in the IMP, the irrigation was scheduled to apply 20 mm per application when the soil moisture deficit was 30 mm below field capacity before irrigation commenced (termed a 20/30 irrigation strategy). The 30 mm represents the trigger deficit, and the procedure left a 10 mm soil moisture buffer should rain fall soon after irrigation.

---

1 The H_2OB daily water balance model has been used for more than one hundred water balance studies in NSW. It was reviewed by what was then the NSW Environment Protection Authority, and has been accepted by the now NSW Department of Industry and Investment, and the NSW Department of Environment, Climate Change and Water, and the NSW Department of Planning for irrigation assessments in NSW.

The IMP varies the irrigation strategy according to the general suitability, including surface slope, of various areas for irrigation. In accordance with the IMP, a 25/35 strategy is used for areas that were rated as most suitable for irrigation. A 20/30 strategy is used for areas with some limitations, and a 15/25 strategy for areas with further limitations. The IMP identifies these areas as Class 1, 2 and 3 areas. The irrigation strategies have been designed to match the ability of the various areas to fully absorb the applied water, and gave the least frequent but heaviest application rates on Class 1 areas, and the most frequent but lightest application rates on Class 3 areas.

Since the classes of the proposed irrigation areas were not available for this assessment, it was decided to generally use the middle strategy to estimate water use and percolation. As shown in the results, the 20/30 strategy gave an overestimate of water use relative to the 25/35 strategy, and an underestimate relative to the 15/25 strategy, and the overall mean was close to the water use with the 20/30 strategy. While only one irrigation strategy was used in the water balance analyses, it was recognised that in practice the strategy would be varied to suit the infiltration capacity and slope of each individual area being watered.

Separate analyses were prepared for the four soil types as identified by Veness & Associates (1996), to test the influence of soil type on drainage and hence on the irrigation volume. The four soil types were:

- Type B: Structured loams, yellow and gleyed podzolic soils.
- Type C: Minimal prairie soils, brown and gleyed podzolic soils.
- Type D: Structured plastic clays.
- Type E: Structured plastic clays, minimal prairie soils.

The water balance analyses were based on an unlimited supply of water from the MWD. Hence the irrigation volume was never affected by a limited supply of water and reflected the irrigation strategies described above.

A comment is also included on the irrigation on the top surface of the rehabilitated waste rock emplacements.

Further details of the H2OB water balance model are given in Appendix ABA.

AB3.1.2 Results

The results of the water balance analysis are provided below and are compared with results from previous studies for the DCM conducted by OWRU (1996).

The annual irrigation volumes varied with the wetness of the year (Table AB-4). The 1/10-dry year results were used to illustrate the volume in a very dry year, and the 1/10-wet year results apply to the other end of the scale in a very wet year. Eighty percent of all years would fall within these two bounds.

Since the actual size of the areas of each soil type were not considered in this assessment, the results are given in units of megalitres per hectare per year (ML/ha/yr) and the total water use can be calculated from these values once the areas are determined.

Table AB-4 The Annual Irrigation Volumes in Years of Varying Wetness.

Soil Type	Degree of Wetness (ML/ha/yr)		
	1/10-dry	Median	1/10-wet
B	5.4	3.7	2.6
C	5.7	4.0	2.7
D	5.6	3.7	2.6
E	5.7	4.0	2.7

In general, the irrigation volume increased by approximately 45% in a very dry year relative to the median, and decreased by approximately 31% in a very wet year. Also, the overall median volume of 3.9 ML/ha/yr virtually equalled the expected rate of 4.0 ML/ha/yr used in the OWRU (1996) report.

There was a small variation in the irrigation volume between soil types. This reflected how quickly each type dried down sufficiently to accept another irrigation, and represented a balance between the infiltration of rainwater into the soil and the drainage characteristics of the soil.

The effect of the irrigation strategy on the mean irrigation volume is given in Table AB-5. Note that median volumes are given in Table AB-4 to match the percentile based measures used for wet and dry conditions, whereas means are given in Table AB-5.

Table AB-5 The Mean Annual Irrigation Volumes with Three Irrigation Strategies.

Soil Type	Irrigation Strategy (ML/ha/yr)		
	15/25	20/30	25/35
B	4.1	3.8	3.5
C	4.5	4.1	3.6
D	4.3	3.8	3.1
E	4.6	4.1	3.3

The 15/25 strategy applied the smallest amount per application, but because the small amount was transpired in the shortest time, more frequent waterings were also required. This frequent watering regime could result in an application being made just before rain, whereas the longer wait for the soil to dry down to the trigger deficit with the other strategies could result in rain interrupting the irrigation sequence. Hence there was a tendency for more water to be applied with the 15/25 strategy (Table AB-5).

In addition there was a wide variation in the irrigation volume throughout a year (Figure AB-2). These results are presented to show how much the irrigation volume within a given month can vary depending on the wetness of that month. The results should not be used to describe the sequence over a series of months because the volumes were taken from separate probability distributions for each month. Hence, in statistical terms the results are independent between months and a sequence of results should not be combined to describe the expected values over a number of months. In reality, such a sequence usually includes months of varying wetness.

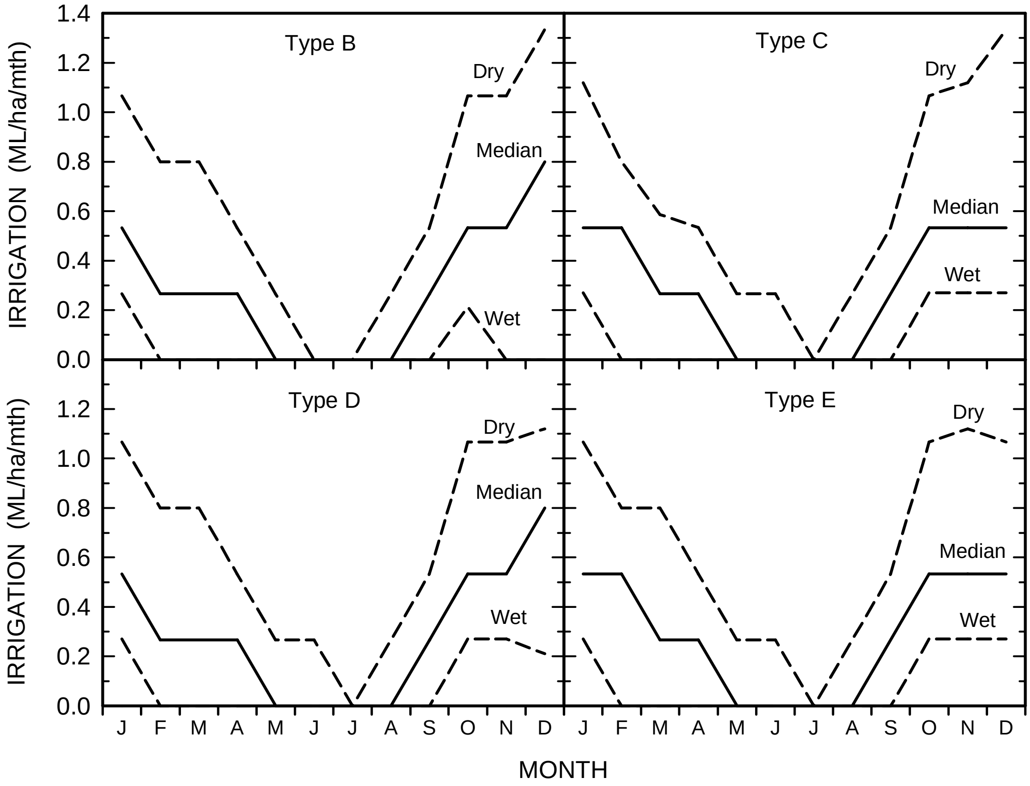


Figure AB-2 Irrigation Demand Throughout the Year in Dry, Median and Wet Months, for the Four Soil Types.

In warmer months, the irrigation demands exceeded 1.0 ML/ha/mth, but fell to very low or zero amounts during winter. Figure AB-2 illustrates how little irrigation is required during wet months. When any of the months between February and September were very wet, no irrigation was applied.

The four soil types behaved differently during wet and dry months. When it was wet, Type B soils absorbed more rain and hence required less irrigation. However, when it was dry their greater drainage losses after the infrequent rain assumed more importance and relatively more irrigation was required.

More details on these effects are given in Table AB-6 that presents the mean rates of runoff and deep percolation after rain on the four soil types. Note that these rates are given in units of mm/yr to facilitate their comparison with rainfall amounts.

Table AB-6 The Mean Annual Runoff and Percolation with the Four Soils.

Soil type	Rainfall Runoff (mm/yr)	Percolation (mm/yr)
B	245	254
C	299	229
D	397	115
E	397	137

When interpreting the results in Table AB-6 it is important to note that the deficit irrigation strategies ensured that there was no runoff or percolation immediately after an irrigation. The runoff and percolation in Table AB-6 were caused by rain.

Soil Type B has the highest infiltration capacity and hence had the least runoff of rainwater. The combination of this relatively high rate of absorption of rainwater combined with the greater drainage of these soils gave the highest percolation rate. As discussed later, this aspect is important when considering the potential to leach salts from the soil.

Irrigation on Waste Rock Emplacements

As described in Section AB2.4, the waste rock emplacements would generally consist of coarse and medium grained sandstones with minor siltstone and conglomerate. A layer of topsoil would be spread over the waste rock during rehabilitation. The waste rock emplacements would have higher permeabilities and therefore higher leaching potential than soils Types B, C, D and E.

Given the above, irrigation rates for the waste rock emplacement could be greater than any of the other soil types assessed, although more detailed analyses would be required to assess whether the higher permeabilities of the waste rock emplacements would enable more irrigation to be applied.

AB3.2 Soil Chemistry – Existing Irrigation Areas

As described in the IMP, DCPL currently irrigates the area within ML 1427 (Figure AB-1). Monitoring conducted as part of the IMP includes monitoring soil characteristics within these irrigation areas and in an unirrigated reference area immediately adjacent the irrigation areas.

Soils in the irrigation areas and in the unirrigated reference area are sampled in August each year to monitor changes in the soil chemistry in accordance with the IMP. Mean results are presented in Figures AB-3 and AB-4. Results from these areas include concentrations for calcium sodium, magnesium, bicarbonate, chloride and sulphate which provide indications of salt trends as well as indications for potential structural effects via calculated SARs.

The reference area carries native pasture and is located away from the irrigation runs where there is no risk of irrigation water or runoff from the irrigation areas entering the reference area. Both the irrigated and unirrigated areas are used as a common grazing area.

In the first instance, it should be noted that while the results from the reference site can be used to compare the time trends between the irrigated and non-irrigated areas, they do not provide an absolute contrast with the mean irrigation results. The reason stems from the fact that there are wide differences in the soil chemistry between various areas and base-line data is not available to match specific areas. Examples of the wide variation between areas are the pH range of 4.3 to 5.1 in surface samples from non-alluvial soil types which were tested by OWRU (1996) before irrigation commenced, and the variation in calcium concentration from 440 to 2,960 milligram per kilogram (mg/kg). Since the reference results came from a single area, it was not clear which of the irrigation areas provided matched sites. Hence, mean results for the irrigation areas are presented here and the results are subject to this limitation.

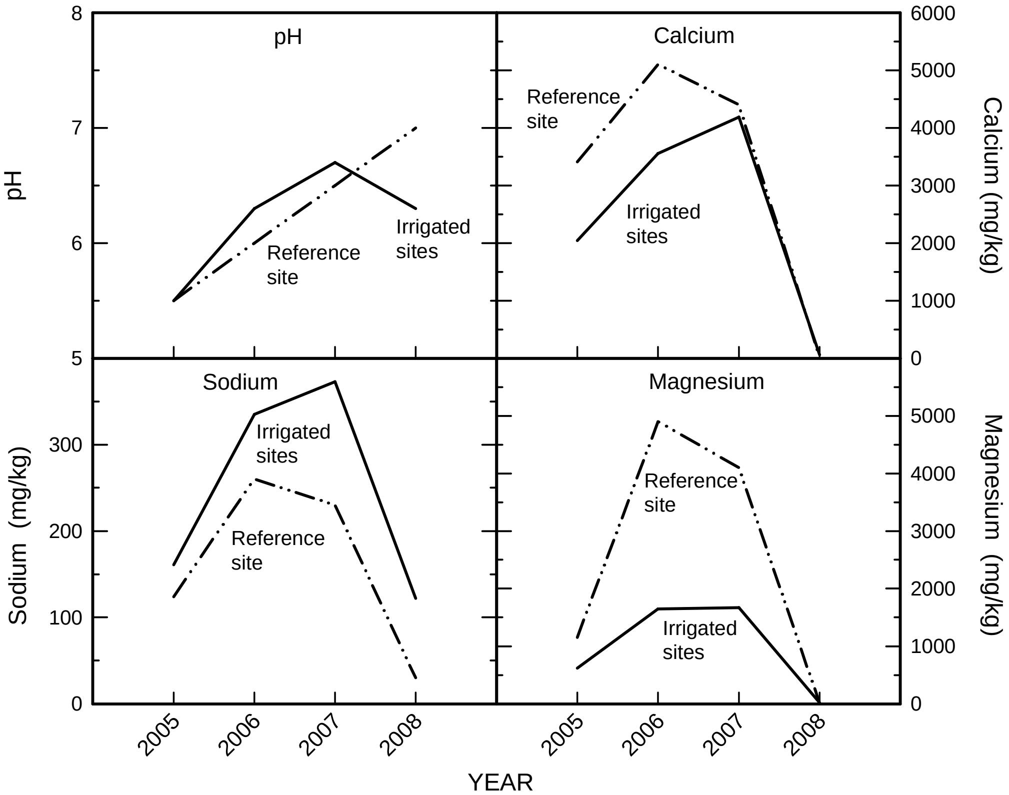


Figure AB-3 Changes in the pH and Concentrations of Calcium, Sodium and Magnesium in Soil between 2005 and 2008.

The following points should be noted:

- There was an upward trend in pH, but since it occurred on both the reference and irrigated areas, it was not attributed to irrigation.
- With irrigation, there was an approximate doubling of the calcium, sodium and magnesium concentrations between 2005 and 2007. There also was a concurrent increase in these constituents on the reference site, but the increase varied in extent and unexpectedly the calcium and magnesium concentrations were at higher levels without irrigation.
- There was an abrupt decline in the salt concentrations on all sites in 2008. Checks discounted the possibility that this resulted from laboratory errors, and since it was too precipitous to be explained through normal processes, the 2008 results were not accepted for the current study. Some explanation for the sudden decline may emerge following subsequent testing.

The results in Figure AB-3 were also used to calculate the SAR, which was at a low level and varied little between 2005 and 2007. The values were 0.3 to 0.4 on the irrigated areas, and constant at 0.2 on the reference area. Hence the sodium concentration, relative to calcium and magnesium, was at levels that were not expected to impact on soil stability.

The rainfall during the four 12 month periods preceding sampling varied markedly. Recordings from 16 August in one year to 15 August the next were:

- August 2004 – August 2005: 1,237 mm (about 100 mm above mean).
- August 2005 – August 2006: 797 mm (very dry and slightly above 1/10-dry year).
- August 2006 – August 2007: 1,060 mm (slightly below mean).
- August 2007 – August 2008: 1,319 mm (about 200 mm above mean).

While it was very dry during the 12 months preceding the 2006 sampling, there was no marked change in the trend lines in Figure AB-3 in that year.

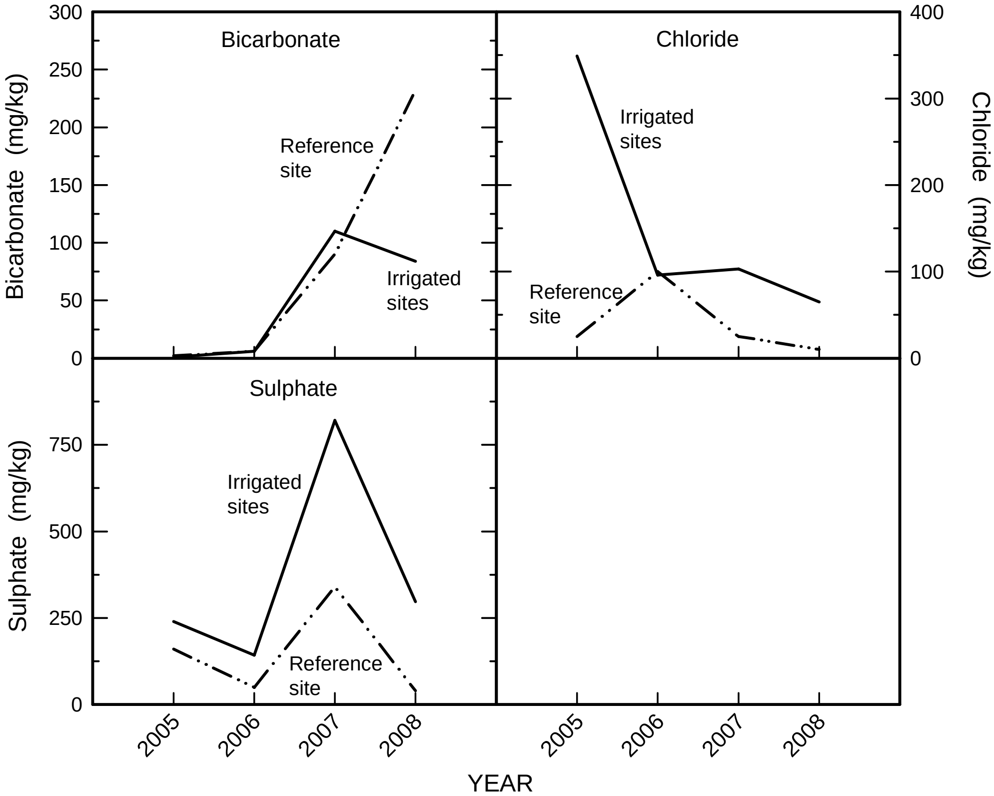


Figure AB-4 Changes in the Concentrations of Bicarbonate, Chloride and Sulphate in Soil between 2005 and 2008.

The following points should be noted:

- There was an upward trend in the bicarbonate concentration that continued into 2008 on the reference site, but reversed between 2007 and 2008 on the irrigated areas.
- The chloride concentration on the irrigated sites showed the only marked decline of all constituents. After an abrupt decline between 2005 and 2006, it stabilised thereafter.
- The sulphate concentration increased markedly in 2007, and then declined in 2008. The higher levels with irrigation suggest that the runoff from the waste rock emplacements (collected in the open pit and pumped to the MWD) may have added sulphate ions to the irrigation water.

The possibility that grazing cattle redistributed salts through their excreta from the irrigated areas to the reference site was also considered, but discounted. Because the irrigated areas represented only a relatively small proportion of the total area and the total area was subject to common grazing, the redistributed salts were spread over a wide area and would have a limited impact on specific areas such as the reference site.

Since any changes in the time trends in the above results were more or less matched between the irrigated and reference areas there was no apparent impact of irrigation on the above constituents. This is an important conclusion when considering the potential impact of irrigation on the new areas. Also, since the trends were not consistent between constituents and the doubt attached to the 2008 results, no clear reasons could be offered for the observed changes over time.

AB3.3 Salt Budgets

The salt budgets examined the likely effects of salts in the irrigation water on soil salinity. The irrigation water would apply salts to the irrigation areas and the quantity that would be retained in the soil would vary with the input/output balance. The amount applied is a function of the irrigation volume by the concentrations of salt in the irrigation water, and the amount removed is a function of both chemical reactions in the soil and leaching losses. Salt budgets were used to examine the balance, and by difference the salt accumulation.

AB3.3.1 Methodology

The annual salt loads were calculated from the annual irrigation volumes, which varied from year to year according to the rainfall (Table AB-4) and the salt concentrations in the irrigation water (Table AB-3). Annual results were calculated on the assumption that the equilibrium salinity with the prevailing rainfall and salt inputs was reached within a year.

Since the soil salinity is a function of the salts that remain in the soil solution, the salt budgets estimated how much of the salts were effectively removed from the soil solution through chemical reactions or through leaching. The methods of Rhoades *et al*. (1992) were used to estimate the removal of salt from the soil solution through precipitation reactions or ion-pair formation. Leaching losses were estimated from the leaching fraction, which is a measure of the proportion of applied water that percolates below the root zone, and was calculated from the water balance results.

The soil salinity was given in terms of the mean-annual water-uptake-weighted root zone salinity, expressed in EC terms for a saturated extract (ECE). The weighting procedure gave more emphasis to the salinity at the more shallow soil depths where plants absorb most water. In addition, expressing the salinity on a saturated extract basis gave concentrations at typical moisture contents for irrigated crops. It is quite different to the concentrations in 1:5 soil:water mixtures that are used in laboratory tests. This approach was used to obtain an estimated soil salinity that focused on the effect on plant growth.

AB3.3.2 Results

Because the amount of rainfall has such a pronounced effect on soil salinity, the salt budgets were repeated for the 1/10-dry, the median and the 1/10-wet years.

The estimated leaching fractions for each soil type are given in Table AB-7, and the estimated soil salinity in Table AB-8.

Table AB-7 The Annual Leaching Fractions in Years of Varying Wetness.

Soil type	Degree of Wetness		
	1/10-dry	Median	1/10-wet
B	0.14	0.20	0.31
C	0.14	0.19	0.30
D	0.08	0.11	0.17
E	0.09	0.13	0.19

The more poorly drained soils (i.e. Types D and E) had the smaller leaching fractions, a result that carried through to the soil salinity. Regardless, the values in Table AB-7 were within the general range of 0.10 to 0.30 for loam soils, and slightly above the 0.05 to 0.20 range for light clays (Department of Natural Resources [DNR], 1997). The drainage characteristics of both the surface soil and the subsoil influenced the leaching fraction. The surface soil partly determines the infiltration capacity and how much rain water is lost through runoff. On the other hand, the subsoil determines how quickly surplus water drains from the root zone.

Table AB-8 The Estimated Soil Salinity in Years of Varying Wetness.

Soil type	Degree of Wetness (ECE dS/m)		
	1/10-dry	Median	1/10-wet
B	1.4	1.2	1.1
C	1.5	1.4	1.2
D	2.0	1.7	1.5
E	2.0	1.7	1.5

The estimated soil salinities followed the typical pattern of being highest in the drier years. This occurred because there was more leaching of salt in the wetter years.

In all instances, the estimated soil salinity never exceeded 2.0 dS/m, a concentration which equals the upper threshold of 2.0 dS/m for salt concentrations in soil that create no or slight limitations for recycled-water irrigation systems (DEC, 2004). Only salt-sensitive and moderately sensitive crops are affected at this level of salinity and even these species would only suffer a partial reduction in growth (DEC, 2004). For instance, white clover is affected by an ECE greater than 1.5 dS/m but its growth would only be reduced by 6% by an ECE of 2.0 dS/m (DEC, 2004).

Some ECE threshold values taken from the Environment Protection Heritage Council, the National Resource Management Ministerial Council and the Australian Health Ministers' Conference (2006) are:

- Crested wheatgrass 3.5 dS/m.
- Sorghum 6.8 dS/m.
- Kikuyu 2 to 4 dS/m.
- Lovegrass 2 dS/m.
- Perennial ryegrass 5.6 dS/m.
- Rhodes grass 4 to 8 dS/m.
- River sheoak 4 to 8 dS/m.
- Spotted gum: 2 to 4 dS/m.
- Swamp mahogany 4 to 8 dS/m.

Importantly, the grasses grown on the irrigation areas would not be affected.

Irrigation on Waste Rock Emplacements

The waste rock emplacements would have a higher percolation rate than the other soil types assessed under the same rainfall and evaporation conditions.

Given the percolation rate has a strong effect on the leaching of salts, it is considered that the potential salinity impacts on the waste rock emplacement would be less than the potential impacts on the other soils assessed.

AB4. IMPACT ASSESSMENT

AB4.1 Potential Impacts of Irrigation

Two measures were used to assess the potential impact of irrigation of water from the MWD on the Project irrigation areas:

- The measured impact on existing irrigation areas.
- The expected effect on soil salinity.

Irrigation over a number of years at the DCM has not materially affected the chemical composition of the soil relative to the unirrigated reference area. Whilst there have been some changes in the pH and composition that cannot be easily explained, they were more or less matched across the two areas. The existing irrigation water has a relatively high sodium concentration of 172 mg/L and whilst this caused a small increase in the soil-sodium concentration relative to the reference area, its potential impact on soil structure was more than offset by the high calcium concentration. As a result the SAR remained at a low level of less than 0.5 and the soil sodium would not affect the stability of the soil structure.

The water balances showed that the soils and existing vegetation could accommodate irrigation volumes of 3.7 to 4.0 ML/ha/yr in a year of median wetness, rising to 5.4 to 5.7 ML/ha/yr in a 1/10-dry year, but falling to 2.6 to 2.7 ML/ha/yr in a 1/10-wet year. The potential irrigation volumes were slightly higher on soil Types C and E and reflected the combined effect of the infiltration and drainage capacities of the various soils.

For reasons given in the text, the irrigation volumes were calculated with a 20/30 irrigation strategy. The IMP uses this strategy on Class 2 areas, but recommends using smaller applications (15/25 strategy) on Class 3 areas that have more limitations for irrigation. In addition, heavier applications (25/35 strategy) are used on Class 1 areas. These applications rates should be continued on the new areas, subject to there being no surface runoff following irrigation.

With the above irrigation volumes and corresponding salt loads, the estimated soil salinity in the 1/10-dry year was 1.4 dS/m on soil Type B, ranging up to 2.0 dS/m on soil Types D and E. Lower values were obtained in wetter years when there were more leaching losses. Thus the irrigated soils are expected to remain in the low-salinity class and there should be no detrimental effect on the grass pastures.

As a consequence, there is no need to reduce the salt loads by reducing the irrigation volumes below the maximum hydraulic loads given above.

The irrigation water has a predicted mean EC of 2.14 dS/m and it is worth noting that the effect on soil salinity was moderated by precipitation reactions that removed some salts from solution. Thus the effect on soil was less than might be expected had the water EC been dominated by sodium and chloride ions.

The potential salinity impacts of irrigating on the rehabilitated waste rock emplacements are expected to be less than the potential impacts on the other soils that were assessed because of the significantly higher percolation rates in the waste rock.

In conclusion, there was no evidence that irrigation with water from the MWD would significantly affect soil properties and their suitability for future agricultural use. Accordingly water from the MWD is considered suitable for irrigation, under an irrigation system conducted in accordance with the IMP moisture deficit strategy.

AB4.2 Contingency Measures

In accordance with the above findings, under an irrigation system conducted in accordance with the IMP, there would be no immediate mitigative measures required for the irrigation areas. The current irrigation practices (i.e. retaining an appropriate moisture deficit) should be continued in the proposed irrigation areas.

The continued effective performance of the irrigation system would be influenced by the quality of water applied. Given the natural variability of rainfall and other variables (e.g. quality of open pit inflows), the quality of irrigation water would be expected to also vary. The following contingency measures should apply if the water quality in the MWD changes as indicated for an extended period.

- An increase in the pH above 8.5 could indicate that acid treatment is required to reduce the bicarbonate load.
- If the pH decreases below 6.0 the source of the acidity should be tracked and rectified via lime addition (e.g. more lime could be added to the potentially acid forming material in the open pit).
- An EC above 2.5 dS/m should initiate a review of factors that are likely to affect soil salinity, noting that some salts that contribute to the water EC may not be harmful to soils.
- A RSC above 1.5 and/or a SAR above 6.0 should initiate a review of salt budgets with particular focus on the permeability hazard and to assist in determining if treatments to reduce the bicarbonate or sodium concentrations are required. Some soil amelioration treatments that are described below could also be relevant with the prevailing water quality conditions.

In addition to the quality of the irrigation water, the soil properties would also influence the irrigation system's continued effective performance. The following contingency measures should be applied if the following soil conditions prevail for an extended period:

- An increase in the soil pH above 7.5 should be addressed by reducing the pH of the irrigation water (see above).
- A decrease in the soil pH below 5.5 should be addressed by increasing the pH of the irrigation water (see above), or by liming the soil.
- An increase in the ECE above 2.5 dS/m should be addressed by measures to reduce the soil salinity. Some options are (a) increasing leaching losses by increasing the infiltration of rainwater (cultivation-based renovation and good vegetation cover are appropriate), (b) reducing the salt load, or (c) applying leaching irrigations.
- A SAR above 6.0 should be addressed by reducing the sodium concentration in the irrigation water, or facilitating the leaching of sodium from the soil, or both. With the proposed project, it is unlikely that the soil SAR would increase to 6.0 given the low SAR of soils before irrigation commenced and the expected SAR of the irrigation water is 2.6. A common remedial treatment for a high SAR is to add gypsum to the soil, but that probably is inappropriate at the Project given the high existing levels of soil calcium on the irrigation areas.
- A decline in surface infiltration can be addressed in the short-term by a light cultivation (renovation), but a long-term solution would require an investigation as to the cause, leading to chemical amelioration of the water or soil.
- Leaf scorching is indicative of excessive sodium, chloride, or other salts in the irrigation water. It can be lessened by avoiding watering during the middle of hot days, but in the long run would require some improvement in water quality.

Note that the trigger points for remediation are often best defined in terms of composite indices such as the SAR, because these provide a balanced assessment of one ion versus another.

AB4.3 Recommended Monitoring

The existing soil monitoring program should be expanded to include the new irrigation areas, with the following refinements:

- In an attempt to add more certainty to the reference results, a minimum of two additional reference sites should be established.
- Sites on the reference and irrigation areas should be matched before irrigation commences. This can be done by testing the soils at the proposed reference sites and at a number of irrigation sites before any irrigation is applied. The test data can then be used to determine which irrigation sites are chemically matched to the reference sites.
- The chemical testing should be expanded to include a test of the EC of the soil.

Soil sampling should incorporate:

- Fixed sampling sites should be established and used to provide consistent locations for taking soil samples over time. Each site should cover about 100 square metres, and each set of samples should be taken from different positions across the sampling site.
- To minimise the effect of local variation, at least two but preferably five samples should be taken at each sampling site. The 2 - 5 samples should be bulked to provide one sample for analysis (from each sampling site).
- Samples should be taken from a constant depth, 0 - 30 centimetres is recommended. All plant material, including roots, should be removed from the samples.

Water quality samples from the MWD should be analysed in sufficient detail to document:

- pH;
- EC;
- RSC; and
- SAR.

In addition to the formal monitoring, operators should be trained to observe whether the re-use irrigation is proceeding in accordance with the IMP. Issues that can be monitored visually include over-watering that causes surface runoff after an irrigation, and foliar damage to vegetation from mine-water.

AB5. REFERENCES

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998) *Crop Evapotranspiration*. FAO Irrigation and Drainage Paper 56, FAO, Rome, 1998.

Department of Environment and Conservation (2004) *Use of Effluent by Irrigation Environmental Guidelines*. Dept. of Environment and Conservation (NSW), Sydney.

Department of Natural Resources (1997) *Salinity Management Handbook.* Queensland Department of Natural Resources, Coorparoo, 1997.

Duralie Coal Pty Ltd (1996) *Duralie Coal Environmental Impact Statement*. Report prepared by Woodward-Clyde.

Duralie Coal Pty Ltd (2008) *Duralie Coal Mine, Irrigation Management Plan*. Document No. IMP-F.

Environment Protection and Heritage Council, National Resource Management Ministerial Council and Australian Health Ministers Conference (2006) *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1*).

Gilbert & Associates (2009) *Duralie Extension Project Surface Water Assessment*.

Kidd, C. (1996) *Groundwater Hydrology Background*. *Part B, Section 2 of the Duralie Coal Mine Commission of Enquiry*.

Organic Waste Recycling Unit (1996) *Duralie Coal: Irrigation Study: Soil and Site Suitability*. Report prepared for Duralie Coal Pty Ltd. In Duralie Coal Pty Ltd (1996) *Duralie Coal Environmental Impact Statement*.

Rhoades, J.D., Kandiah, A. and Mashali, A.M. (1992) *The use of saline waters for crop production*. FAO Irrigation and Drainage Paper 48, FAO, Rome.

Veness & Associates (1996) *Soil Sampling Program: Duralie Coal*. Report prepared for Duralie Coal Pty Ltd.

APPENDIX ABA. Water Budget Methods and Parameters

Water balance analyses were conducted using the H2OB Soil Water Balance Model, version 5.2.

A major issue in water budget analyses is to estimate when recycled water can be used for irrigation. This is done by using a water balance model to estimate day-to-day changes in the soil water content according to the historical rainfall record, and initiating irrigation when the soil had dried to the trigger deficit as set by the *Irrigation Management Plan* (IMP) (Duralie Coal Pty Ltd, 2006) irrigation strategy.

A. OPERATING BASIS FOR H2OB WATER BALANCE MODEL

The H2OB water balance model uses two continuity models to balance water inputs against water outputs for the recycled water supply and the soil/plant system on a daily basis. Only the second model was used for the Project analyses as the Main Water Dam was assumed to always contain water (i.e. would not empty).

<u>Wet-weather-storage water balance</u>

RECYCLED WATER + DAM-RAIN = IRRIGATION + DAM-EVAP + EXCESS + ΔDAM

Recycled water:
Specified as a daily flow.

Dam-rain:
Equals volume of rain that falls on storage.

Irrigation:
Irrigation strategy can be varied.

Dam-evap:
Evaporation from storage. Equated to potential evaporation rate from a free-water surface.

Excess:
Equals the volume of recycled water that is discharged because the storage is full.

ΔDam:
Balancing term in continuity equation. Equals changes in stored volume.

<u>Irrigation-area water balance</u>

RAIN + IRRIGATION = EVAPOTRANSPIRATION + SURFACE RUNOFF + PERCOLATION + ΔSW

Rain:
Daily rainfall taken from long-term historical records.

Evapotranspiration:
Best available estimate of local evapotranspiration.
Crop factor used to estimate potential evapotranspiration for a given crop.
Actual evapotranspiration declines as soil dries, with function determined by crop type.
Intercepted water on canopy preferentially evaporated, at a rate that equals the reference-crop, potential rate of evapotranspiration with low growing crops, and at higher rates with well-ventilated crops, e.g. trees.

ΔSW:

Balancing term in continuity equation. Represents changes in soil water content.

Infiltration, redistribution, runoff and percolation:

Most calculations done on a daily basis, infiltration and runoff calculated 6-hourly using published models of infiltration.

The saturated hydraulic conductivity (Ksat) was estimated from soil texture and likely soil compaction.

Steps in the calculations are:

- Surface runoff calculated from rainfall volume, slope and surface conditions using the US Soil Conservation Service curve number procedure. Only important on steeper land.
- Daily rain split into two lots, and each is assumed to fall over 6 hours, with a 6-hour dry period between. This is done because functions work better on short time steps.
- Distance that wetting front will move in 6 hours is estimated, and subject to the wetting rate not exceeding the infiltration rate, the soil is allowed to fill to saturation to the depth of the wetting front. Surplus rain is allocated to runoff.
- The infiltration rate is determined by sorptivity, and the Ksat of the transmission zone.
- Water redistributes through the soil at a rate that equals the hydraulic conductivity at a nominal suction of 10 centimetres. Only the water held between saturation and field capacity will redistribute.
- A low-conductivity layer can cause water to accumulate as a perched water table.
- Interflow is estimated from Ksat, the hydraulic head and wetting front. It is usually very small on flat re-use areas.

The point of these calculations is to solve the model to estimate the new soil water content. The soil water content is then used to determine when the next irrigation is due.

A. PARAMETER VALUES

INPUT DATA

(a) Recycled water supply

Unrestricted.

(b) Crop

Grazed native pasture.

(c) Rainfall & evaporation

The rainfall distribution was based on measurements at Wards River (Moana) (Station 060089) Commonwealth Bureau of Meteorology (BoM) station, supplemented with data from Craven (Station 060042) and Stroud Post Office (Station 061071) BoM stations. The data set covered 69 years from 1940 to 2008 and included a variety of wet and dry years.

The evapotranspiration was based on the estimated pan evaporation at Dungog taken from the "Ausclim" data file supplied by Commonwealth Scientific and Industrial Research Organisation. The Dungog data was used because it referenced the closest station and the annual pan evaporation (1,525 millimetres per year [mm/yr]) was not much different to other BoM stations in the general district. The mean measured pan evaporation is 1,571 mm/yr at Paterson (Station 061250) and 1,607 mm/yr at Lostock Dam (Station 061288). However, pan evaporation is much less (1,059 mm/yr) at Chichester Dam (Station 061151). Pan evaporation was converted to the potential reference crop evapotranspiration by multiplying by a pan coefficient of 0.8. The reference crop evapotranspiration was then converted to the potential evapotranspiration of extensively grazed native pasture by multiplying by a crop coefficient of 0.75 (Allen *et al*., 1998). In addition, an adjustment was made to allow for the effect of cold conditions on evapotranspiration during the cooler months.

Mean monthly rainfall, and potential evapotranspiration from native pasture.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Yr
Rain (mm/mth)	128	132	152	88	88	102	53	59	53	78	90	97	1,120
Evapotranspiration – pasture (mm/mth)	124	101	90	65	43	30	27	36	60	99	114	126	915

(d) Soil properties

Generalised properties of the soils were:

Soil type	Horiz.	Depth (cm)	Texture	K_{sat} (mm/d)	WHC (mm)
B	A	0 to 31	Fine sandy loam	120	45
	B	31 to 70	Light-medium clay	12	46
C	A	0 to 28	Fine sandy clay loam	235	36
	B	28 to 68	Light-medium clay	12	48
D	A	0 to 35	Light clay	35	40
	B	35 to 59	Light-medium clay	12	29
E	A	0 to 20	Light clay	35	23
	B	20 to 62	Light-medium clay	12	50

Notes:

K_{sat} = saturated hydraulic conductivity.

mm = millimetres.

mm/d = millimetres per day.

WHC = total available water holding capacity within profile depth.

(e) Irrigation

Travelling gun irrigators that applied 20 mm when the soil dried to a 30 mm deficit and an application efficiency of 75%.