Tarrawonga Coal Project

Environmental Assessment

APPENDIX B

SURFACE WATER ASSESSMENT

Resource Strategies

Tarrawonga Coal Pty Ltd

HYDROLOGY AND WATER MANAGEMENT CONSULTANTS

Gilbert & Associates Pty Ltd

APPENDIX B

TARRAWONGA COAL PROJECT

Surface Water Assessment

Prepared for: **Whitehaven Coal Pty Ltd**

Nov-11

AppB_SWA_GA_Oct-26

PO Box 2143
Toowong, Qld. 4066

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

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

CONTENTS Page

1	INTRODUCTION			1
	1.1	STUDY REQUIREMENTS AND SCOPE		4
		1.1.1	SURFACE WATER DIRECTOR-GENERAL'S REQUIREMENTS	4
		1.1.2	SURFACE WATER REQUIREMENTS OF NSW DEPARTMENT OF ENVIRONMENT CLIMATE CHANGE AND WATER	4
		1.1.3	SURFACE WATER REQUIREMENTS OF NEW SOUTH WALES OFFICE OF WATER	5
		1.1.4	KEY SURFACE WATER RELATED GUIDELINES	6
		1.1.5	SURFACE WATER RELATED ISSUES IDENTIFIED IN THE ERA	7
	1.2	PROJECT OVERVIEW		8
		1.2.1	PROJECT GENERAL ARRANGEMENTS	9
		1.2.2	PERMANENT GOONBRI CREEK ALIGNMENT	9
2	BASELINE SURFACE WATER HYDROLOGY			16
	2.1	GENERAL		16
	2.2	GEOLOGICAL SETTING AND SITE SOILS		16
	2.3	CLIMATE		19
		2.3.1	RAINFALL AND EVAPORATION	19
	2.4	CATCHMENTS AND SURFACE WATER RESOURCES		21
		2.4.1	GOONBRI CREEK	22
		2.4.2	BOLLOL CREEK	23
		2.4.3	NAGERO CREEK	23
	2.5	RUNOFF AND STREAMFLOW		24
		2.5.1	LOCAL WATERCOURSES	24
		2.5.2	REGIONAL WATERCOURSES	26
	2.6	FLOODING		28
	2.7	SURFACE WATER QUALITY		28
		2.7.1	WATER QUALITY CHARACTERISTICS OF REGIONAL WATER RESOURCES	30
		2.7.2	SURFACE WATER QUALITY CHARACTERISTICS OF LOCAL WATER RESOURCES	34
		2.7.3	GEOCHEMICAL CHARACTERISTICS OF MINE WASTE ROCK	45
	2.8	SURFACE WATER USERS		45
3	SURFACE WATER LICENSING			46
	3.1	EXISTING LICENCE HOLDERS		46
	3.2	WATER SHARING PLAN FOR THE UPPER NAMOI AND LOWER NAMOI REGULATED RIVER WATER SOURCES 2003		46
	3.3	DRAFT WATER SHARING PLAN FOR THE NAMOI UNREGULATED AND ALLUVIAL WATER SOURCES		46
4	OPERATIONAL SURFACE WATER MANAGEMENT			50
	4.1	EXISTING WATER MANAGEMENT SYSTEM		52
	4.2	PROPOSED PROJECT WATER MANAGEMENT SYSTEM		54
		4.2.1	APPROACH AND DESIGN CRITERIA	54
		4.2.2	PROGRESSIVE DEVELOPMENT OF THE WATER MANAGEMENT SYSTEM	55
			4.2.2.1 Year 2 Mine Layout	56
			4.2.2.2 Year 4 Mine Layout	56
			4.2.2.3 Year 6 Mine Layout	56
			4.2.2.4 Year 12 Mine Layout	57

CONTENTS (Continued)

4.2.2.5 Year 16 Mine Layout 57
4.2.2.6 Final Landform Layout 57
4.2.3 DETAILS OF WATER MANAGEMENT STORAGES 57
4.3 SYSTEM INFLOWS 62
4.4 MINE WATER STORAGE 63
4.5 WATER CONSUMPTION 63
4.6 FLOOD MANAGEMENT 63
4.7 INTERACTION WITH BOGGABRI COAL MINE SURFACE WATER MANAGEMENT SYSTEM 64
4.8 MINE WASTE ROCK EMPLACEMENT DRAINAGE MANAGEMENT 65
5 SIMULATED PERFORMANCE OF WATER MANAGEMENT SYSTEM 66
5.1 MODEL DESCRIPTION 66
5.1.1 GENERAL 66
5.1.2 RAINFALL AND EVAPORATION 66
5.1.3 RUNOFF SIMULATIONS 67
5.1.4 WATER DEMANDS 68
5.1.4.1 Crusher Demand 68
5.1.4.2 Truckfill Demand 68
5.1.4.3 Irrigation to Support Vegetation Establishment on Partially Rehabilitated Areas 69
5.1.5 LICENSED DISCHARGE POINTS 69
5.2 MODEL CALIBRATION AND VERIFICATION 70
5.3 SIMULATED PERFORMANCE 70
5.3.1 OVERALL SITE WATER BALANCE 70
5.3.2 WATER SUPPLY SECURITY 72
5.3.3 CONTAINMENT OF MINE WATER ON SITE 72
5.3.4 CONTAINMENT OF DISTURBED AREA RUNOFF AND SEDIMENT CONTROL 76
5.4 MODEL SENSITIVITY 77
5.4.1 RUNOFF SENSITIVITY 78
5.4.2 TRUCKFILL DEMAND SENSITIVITY 79
5.5 WATER MANAGEMENT IMPLICATIONS 80
6 PROPOSED PERMANENT GOONBRI CREEK ALIGNMENT 82
6.1 DESCRIPTION OF THE GOONBRI AND BOLLOL CREEK CATCHMENTS 82
6.1.1 CATCHMENT 82
6.1.2 RIPARIAN VEGETATION – GOONBRI CREEK 83
6.1.3 SOILS 84
6.2 GEOMORPHOLOGICAL CHARACTERISTICS OF GOONBRI CREEK 84
6.2.1 STREAM ORDER AND STREAM BED PROFILE 84
6.2.2 STREAM CONDITION SURVEY - GOONBRI CREEK 86
6.3 CONCEPTUAL DESIGN OF THE PERMANENT GOONBRI CREEK ALIGNMENT 88
6.3.1 CONCEPT/VISION STATEMENT 88
6.3.2 DESIGN OBJECTIVES 90
6.3.3 DESIGN CRITERIA 91
6.3.4 CONCEPTUAL DESIGN DETAILS 91
6.4 ASSESSMENT OF HYDRAULIC PERFORMANCE 96
6.4.1 DESIGN DISCHARGES 96
6.4.2 ASSESSMENT OF HYDRAULIC CONDITIONS 96
6.5 RECOMMENDATIONS FOR FUTURE DETAILED DESIGN PROCESS, MONITORING AND MANAGEMENT 98

CONTENTS (Continued)

7 ASSESSMENT OF POTENTIAL OPERATIONAL SURFACE WATER IMPACTS 101

7.1 IMPACTS ON FLOW REGIME 101
7.2 IMPACTS OF CONTROLLED RELEASE 102
7.3 IMPACTS OF RUNOFF FROM PROGRESSIVELY REHABILITATED LANDFORMS 102
7.4 IMPACTS ON LOCAL FLOOD REGIME 103
7.5 WATER LICENSING REQUIREMENTS 104

8 POST-MINING WATER MANAGEMENT 105

8.1 FINAL VOID 105
8.2 EROSION AND SEDIMENT CONTROL 108

9 EFFECTS OF CLIMATE CHANGE ON PREDICTED SURFACE WATER IMPACTS 109

9.1 FUTURE RAINFALL AND EVAPOTRANSPIRATION 109
9.2 WATER MANAGEMENT IMPLICATIONS OF CLIMATE CHANGE PREDICTIONS 110

10 RECOMMENDED MONITORING 112

10.1 CLIMATE MONITORING 112
10.2 SURFACE WATER FLOW 112
10.3 SURFACE WATER QUALITY 113
10.4 SITE WATER BALANCE 113
10.5 PERMANENT GOONBRI CREEK ALIGNMENT 113

11 BIBLIOGRAPHY 114

LIST OF TABLES

Table 1 Summary of Average Regional Rainfall and Rain Days
Table 2 Summary of Average Regional Class ‘A’ Pan Evaporation
Table 3 Design Rainfall Intensities for Goonbri Creek Catchment
Table 4 Inferred Streamflow Characteristics of Goonbri Creek at Downstream End of Permanent Goonbri Creek Alignment
Table 5 Regional Water Quality Summary
Table 6 Monitoring Data Summary - Nagero Creek
Table 7 Monitoring Data Nagero Creek from Boggabri Coal Mine
Table 8 Monitoring Data Summary - Bollol Creek
Table 9 Monitoring Data Summary - Goonbri Creek
Table 10 Summary of Metal and Nutrient Analysis Results – Nagero, Bollol and Goonbri Creeks
Table 11 Project Site Monitoring Data Summary
Table 12 Summary of Project Site Metal and Nutrient Analysis Results
Table 13 Summary of Water Quality for Licensed Discharge Points During Events
Table 14 Summary of Water Quality for Receiving Waters During Events
Table 15 Summary of Dams Included in Harvestable Right Capacity
Table 16 Summary of Water Management Storages
Table 17 Predicted Groundwater Inflows

CONTENTS (Continued)

Table 18	Water Balance Model AWBM Parameters
Table 19	Summary of Truckfill Demand Prioritisation
Table 20	Summary of Simulated Inflows and Outflows in Project Water Balance
Table 21	Simulated Water Supply Reliability
Table 22	Simulated Base Case and Low Runoff Sensitivity Water Supply Reliability
Table 23	Simulated Base Case and Low Truckfill Demand Sensitivity Water Supply Reliability
Table 24	Boggabri (Retreat) Monthly Rainfall Data Comparison Six Months Preceding Stream Condition Survey
Table 25	Typical Reach Characteristics along Goonbri Creek
Table 26	Predicted Peak Flood Discharges at Permanent Goonbri Creek Alignment Inlet – for Conceptual Design
Table 27	Project Contribution to Changes to Catchments
Table 28	Cumulative Contribution to Changes to Catchments
Table 29	Summary of Final Void Groundwater Inflow Rates
Table 30	Percentage Change in Predicted Monthly Rainfall and Evapotranspiration in 2030 and 2100 Relative to 1990 – Tarrawonga Region (from MRI-CGCM2.3.2)

LIST OF FIGURES

Figure 1	Regional Location
Figure 2	Project General Arrangement
Figure 3	Surface Water Management Plan – Year 2
Figure 4	Surface Water Management Plan – Year 4
Figure 5	Surface Water Management Plan – Year 6
Figure 6	Surface Water Management Plan – Year 12
Figure 7	Surface Water Management Plan – Year 16
Figure 8	Surface Water Management Plan – Post-Mining
Figure 9	Annual Average Rainfall Pattern and Catchments
Figure 10	Local Geology
Figure 11	Recorded Flow Duration Curve – GS 419044 – Maules Creek at Damsite Scaled by Catchment Area Ratio for Goonbri Creek
Figure 12	Recorded Streamflow Hydrograph – GS 419012 – Namoi River at Boggabri
Figure 13	Recorded Flow Duration Curve – GS 419012 – Namoi River at Boggabri
Figure 14	Surface Water Flow Paths
Figure 15	Local Surface Water Quality Monitoring Locations, Licensed Discharge Points and Land Ownership
Figure 16	Upper Namoi and Lower Namoi Regulated River Water Source
Figure 17	Project (and Existing) Water Management Schematic
Figure 18	Changes in Active Mine Pit Catchment Area over Project Life
Figure 19	Average Inflow and Outflow Components of Simulated Project Water Balance
Figure 20	Simulated Volumes in Mine Water Dam under 20th Percentile, Median and 80th Percentile Rainfall Realizations

CONTENTS (Continued)

Figure 21 Simulated Volumes in Mine Water Surge Storage under 20th Percentile, Median and 80th Percentile Rainfall Realizations
Figure 22 Simulated Volumes in Mine Pit under 20th Percentile, Median and 80th Percentile Rainfall Realizations
Figure 23 Storage Volume Exceedance Hydrographs for Mine Water Dam
Figure 24 Storage Volume Exceedance Hydrographs for Mine Water Surge Storage
Figure 25 Storage Volume Exceedance Hydrographs for Mine Pit
Figure 26 Storage Exceedance Hydrographs for Pit Inundation – Base Case and High Runoff Model Sensitivity – 95th Percentile
Figure 27 Storage Exceedance Hydrographs for MWD2 – Base Case and High Runoff Model Sensitivity – 95th Percentile
Figure 28 Distribution of Catchment Area Contributions along Goonbri Creek
Figure 29 Distribution of Catchment Area Contributions along Bollol Creek
Figure 30 Stream Bed Profile – Goonbri Creek
Figure 31 Stream Bed Profile – Bollol Creek
Figure 32 Rainfall at Boggabri (Retreat) (55044) Preceding Stream Condition Survey
Figure 33 Goonbri Creek – Stream Condition Survey Report Map Key
Figure 34 Conceptual Design Layout and Details of the Permanent Goonbri Creek Alignment
Figure 35 Plan View of Upstream Conceptual Permanent Goonbri Creek Alignment and Flood Bund Section View
Figure 36 Typical Conceptual Cross Sections of the Permanent Goonbri Creek Alignment
Figure 37 Simulated Flow Velocity Profile along the Permanent Goonbri Creek Alignment – 100 Year Design Peak Flow Conditions
Figure 38 Recommended Monitoring Locations
Figure 39 Simulated Final Void Water Levels – without partial backfilling
Figure 40 Simulated Final Void Salinity Levels
Figure 41 Simulated Final Void Water Levels – with partial backfilling

LIST OF ATTACHMENTS

Attachment A AWBM Catchment Figures

Attachment B Goonbri Creek Stream Condition Survey Report

1 INTRODUCTION

The Tarrawonga Coal Mine (TCM) is owned and operated by Tarrawonga Coal Pty Ltd (TCPL), which is a joint venture between Whitehaven Coal Mining Pty Ltd (Whitehaven) (70% ownership) and Boggabri Coal Pty Limited (BCPL) (a wholly owned subsidiary of Idemitsu Australia Resources Pty Ltd) (30% ownership). The TCM is located within Mining Lease (ML) 1579 approximately 15 kilometres (km) north-east of Boggabri, and 42 km north-northwest of Gunnedah in the Gunnedah Basin of New South Wales (NSW) (Figure 1).

The TCM commenced operations in 2006 and currently produces up to 2 million tonnes per annum (Mtpa) run-of-mine (ROM) coal. Mined coal is crushed and screened on-site and transported by road to Whitehaven's Coal Handling and Preparation Plant (CHPP), which is located approximately 35 km to the south near Gunnedah (Figure 1).

The proposed life of the Tarrawonga Coal Project (the Project) is 17 years, commencing 1 January 2013. As part of the Project, TCPL is seeking approval to extend the approved open cut boundary at the TCM further to the east and north. The mining operations would also increase the coal production rate up to 3 Mtpa. The proposed mine plan would also see the integration of mine waste rock emplacements and the final landform of the TCM and Boggabri Coal Mine (located the immediate north of the TCM). The extension would also include the development of a services corridor including a haul road linking TCM to the Boggabri Coal Mine and construction of a new mine facilities area. The approximate extent of the existing and approved surface development (including open cut, mine waste rock emplacement, soil stockpiles and infrastructure areas) at the TCM is shown on Figure 2.

This report documents the Surface Water Assessment conducted for the proposed Project including details and assessment of the proposed permanent Goonbri Creek alignment around the final void and post mine water management. The Surface Water Assessment has drawn on the results of the Geochemistry Assessment undertaken by Geo-Environmental Management Consultants (2011) and the results of the Groundwater Assessment conducted by Heritage Computing (2011).

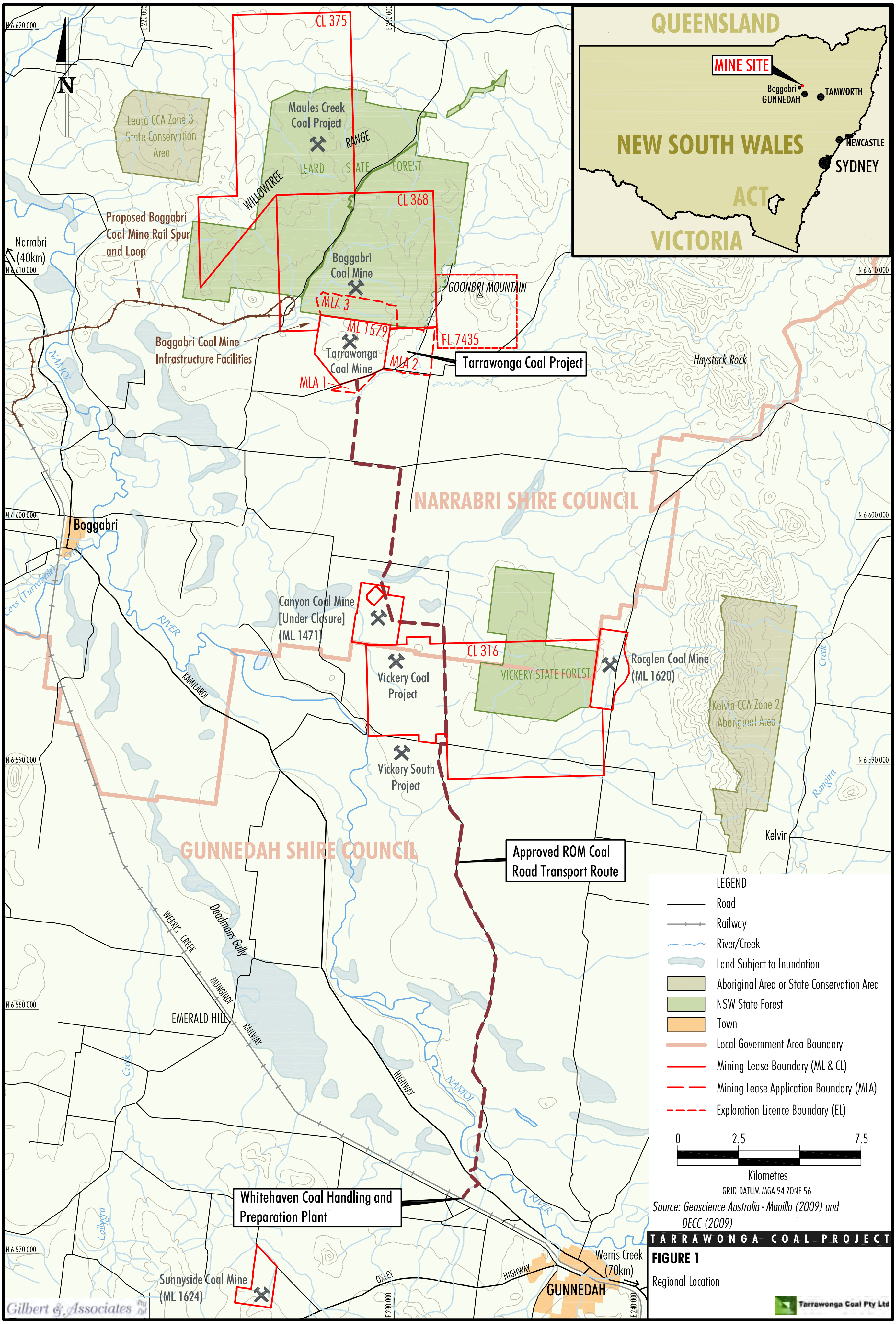
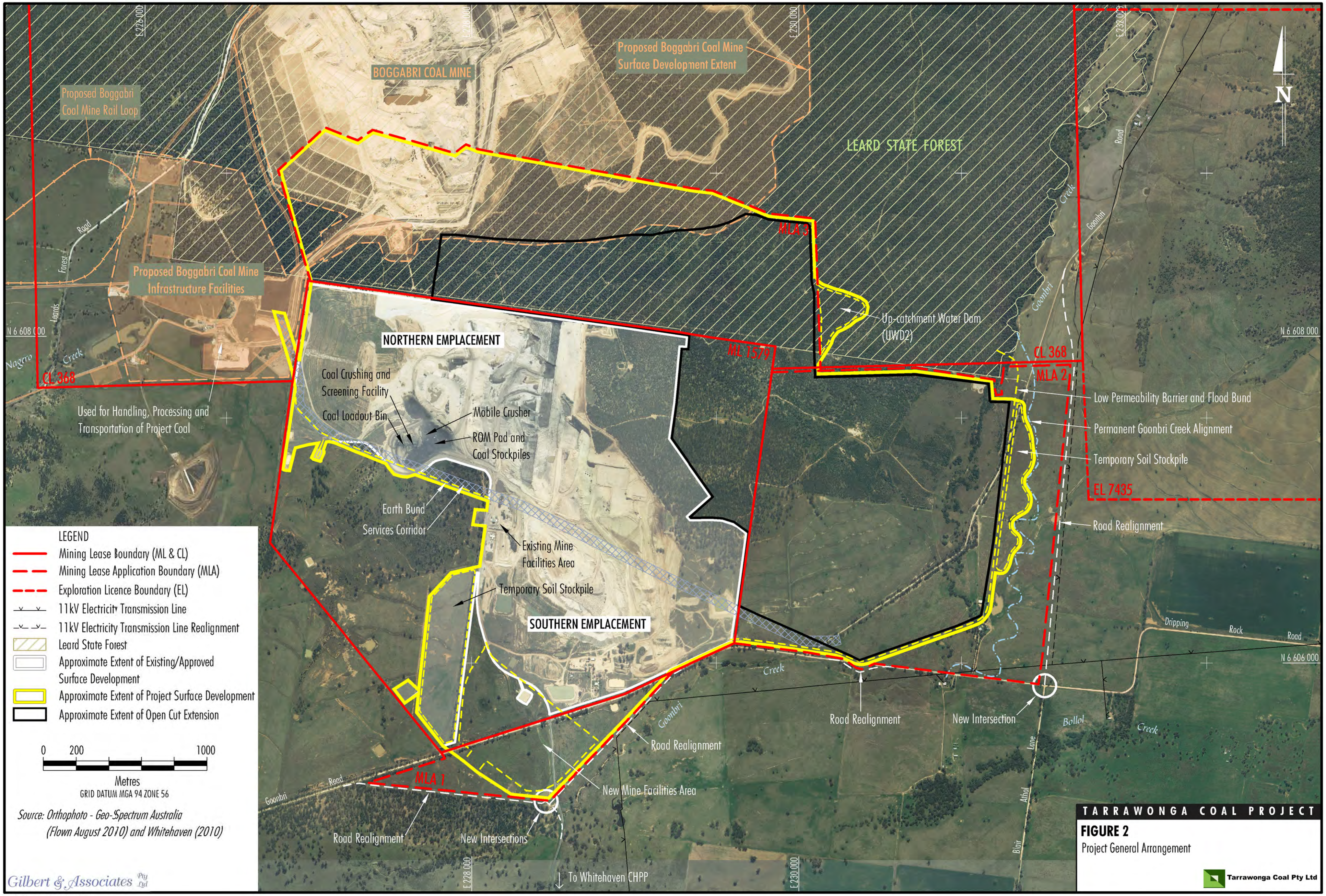


FIGURE 1
Regional Location

WHC-01-04_EA_SWA_106D



TARRAWONGA COAL PROJECT

FIGURE 2

Project General Arrangement

Tarrawonga Coal Pty Ltd

WHC-01-04_EA_SWA_107B

1.1 Study Requirements and Scope

The Surface Water 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 and Infrastructure [DP&I] in July 2011). The assessment also addresses the issues raised by other government agencies during the consultation process and the surface water related issues identified in the Environmental Risk Assessment (ERA).

1.1.1 Surface Water Director-General's Requirements

The Director-General's EARs of relevance to this surface water assessment are as follows:

Water *– including:*

- *detailed modelling of the potential surface and ground water impacts of the project, including any flooding impacts;*
- *a detailed site water balance of the project, including a description of the measures that would be implemented to minimise water use on site*
- *a detailed assessment of the potential impacts of the project on:*
  - *the quality and quantity of surface and ground water resources;*
  - *water users, including the availability of water for agricultural uses within the broader region;*
  - *the riparian, ecological, geomorphological and hydrological values of watercourses both on the site and downstream of the project; and*
  - *environmental flows;*

The groundwater components of the Surface Water Assessment are provided separately in the Groundwater Assessment (Heritage Computing, 2011) (Appendix A of the EA). The riparian and ecological components of the assessment are provided separately in the Goonbri Creek Aquatic Assessment (Cenwest, 2011) (Attachment B to Appendix E of the EA) and the Flora Assessment (FloraSearch, 2011) (Appendix F of the EA).

1.1.2 Surface Water Requirements of NSW Department of Environment Climate Change and Water

Input to the EARs was provided by the NSW Department of Environment Climate Change and Water (DECCW) (now NSW Office of Environment and Heritage [OEH]). The issues raised by the DECCW of relevance to the surface water assessment are summarised below.

1. Describe the location, water quality, volume and frequency of any water discharges.
2. Demonstrate that all practical options to prevent any discharge have been implemented and that the environmental impact of any discharge has been minimised.

3. Develop and present the results of a water balance including water requirements, stormwater and wastewater disposal, and management methods including re-use options.
4. Describe existing surface water resources including those likely to be affected by the proposal.
5. State the Water Quality Objectives for relevant receiving waters.
6. State the indicators and associated trigger values or criteria for the identified environmental values.
7. State any locally specific objectives, criteria or targets which have been endorsed by the NSW Government.
8. Describe the nature and degree of impact that any proposed discharges would have on the receiving environment.
9. Assess impacts against relevant ambient water quality outcomes.
10. Assess Project and cumulative impacts to surface waters.
11. Demonstrate how the proposal will be operated to protect the Water Quality Objectives for receiving waters.
12. Describe how predicted impacts will be monitored and assessed over time.

1.1.3 Surface Water Requirements of New South Wales Office of Water

Input to the EARs was also provided by the NSW Office of Water (NOW). The issues raised by NOW of relevance to the surface water assessment are summarised below.

- Identify sources of surface water within and adjacent to the mining area. Present baseline data for the quality and quantity of water resources within and adjacent to the mining operations area.
- Provide details of all existing surface water users within the area.
- Describe design features and measures that will be incorporated into the proposed Project to guard against long term actual and potential environmental disturbances particularly in terms of maintaining natural hydrological regime, sediment movement patterns and the identification of riparian buffers.
- Present a geomorphological assessment of Goonbri and Bollol Creeks and associated tributaries within the mining area – including stream order (using the Strahler System), river style and energy regimes both in channel and in adjacent floodplain areas.
- Provide details of any proposed diversion and other water works.
- Demonstrate that the Project has a secure water supply over the Project life which is authorised and compliant with all rules under any relevant water sharing plan.
- Provide predictions of impacts to surface water sources, basic landholder rights to water and any adjacent licensed water users and demonstrate that the proposal does not compromise basic landholder rights and any adjacent licensed water users.
- Evaluate salt migration to any surface water sources and justification for any change in salinity discharge pre to post mining.

- Describe measures to maintain flows in Goonbri Creek past the mining development which do not pose a risk to the integrity, stability and water quality of Goonbri Creek.
- Identify all works which extract or take surface water and describe purpose, location and expected extraction volumes.
- Describe and evaluate all potential impacts of proposed diversion works on sediment movement, channel stability, water quality and hydraulic regime. Describe the permanent Goonbri Creek alignment proposal including identification and justification of criteria for completion of the proposal. Present a detailed design and details of associated hydrological and hydraulic modelling. Present results of impact assessment and supporting stabilisation and rehabilitation measures. The impact assessment is to include an assessment of hydrologic energy regimes under a range of discharge scenarios, energy management and dissipation, bedload transport and biophysical maintenance of the creek.
- Describe mitigation strategies to address unavoidable impacts on surface water resources for operational and post mining phases.
- Describe the proposed and existing water management system including details of existing structures, including commissioning date and purpose.

Gilbert & Associates Pty Ltd presented the preliminary results and findings of the Surface Water Assessment to NOW representatives on 23 September 2011. No further issues requiring assessment were raised during the meeting.

1.1.4 Key Surface Water Related Guidelines

A number of key guidelines have also been used as a basis for assessing impact including:

- National Water Quality Management Strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council [ANZECC] and Agriculture and Resource Management Council of Australia and New Zealand [ARMCANZ], 2000a);
- National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ), 2000b;
- Using the ANZECC Guideline and Water Quality Objectives in NSW (NSW Department of Environment and Conservation [DEC], 2006a);
- State Water Management Outcomes Plan (NSW Department of Natural Resources, 2002);[1]
- NSW Government Water Quality and River Flow Environmental Objectives (DEC, 2006b); and
- NSW *Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources,* 2003.

[1] The State Water Management Outcomes Plan (2002) was a statutory document under the *Water Management Act, 2000* that set the overarching policy, targets and strategic outcomes for the development, conservation, management and control of NSW water sources. The Plan expired in 2007 but many of the principles and targets remain relevant.

The objects of the NSW Water Management Act 2000, which is the principal statute governing management of water resources in NSW, were also considered during the assessment. The objects of the *Water Management Act, 2000* include:

> *" to provide for the sustainable and integrated management of the water sources of the State for the benefit of both present and future generations and, in particular:*
>
> *(a) to apply the principles of ecologically sustainable development, and*
>
> *(b) to protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality, and*
>
> *(c) to recognise and foster the significant social and economic benefits to the State that result from the sustainable and efficient use of water, including:*
>
> > *(i) benefits to the environment, and*
> >
> > *(ii) benefits to urban communities, agriculture, fisheries, industry and recreation, and*
> >
> > *(iii) benefits to culture and heritage, and*
> >
> > *(iv) benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water,*
>
> *(d) to recognise the role of the community, as a partner with government, in resolving issues relating to the management of water sources,*
>
> *(e) to provide for the orderly, efficient and equitable sharing of water from water sources,*
>
> *(f) to integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna,*
>
> *(g) to encourage the sharing of responsibility for the sustainable and efficient use of water between the Government and water users,*
>
> *(h) to encourage best practice in the management and use of water."*

1.1.5 Surface Water Related Issues Identified in the ERA

In accordance with the EARs for the Project, an ERA was undertaken to identify key potential environmental issues for further assessment in the EA. The ERA was conducted on 26 July 2011, and was facilitated by a risk assessment specialist (Safe Production Solutions, 2011). The risk assessment team included representatives from Gilbert & Associates Pty Ltd.

The key potential surface water related issues identified in the ERA (Appendix O of the EA) are summarised below.

- Long term stability of the permanent Goonbri Creek alignment.
- Potential for inadequate water supply - for dust suppression and consequent impacts on dust emissions.
- Potential impacts on alluvial groundwater.

1.2 Project Overview

The main activities associated with the development of the Project would include:

- continued development of mining operations in the Maules Creek Formation to facilitate a Project ROM coal production rate of up to 3 Mtpa, including open cut extensions:
  - to the east within ML 1579 and Mining Lease Area (MLA) 2; and
  - to the north within Coal Lease (CL) 368 (MLA 3) which adjoins ML 1579;
- ongoing exploration activities;
- construction and use of a services corridor (including haul road link) directly from the Project open cut mining operation to the upgraded Boggabri Coal Mine Infrastructure Facilities[2];
- use of upgraded Boggabri Coal Mine Infrastructure Facilities for the handling and processing of Project coal and the loading of Project product coal to trains for transport on the Boggabri Coal Mine private rail spur to the Werris Creek Mungindi Railway[1];
- construction and use of a new mine facilities area including relocation of existing mine facilities infrastructure and service facilities;
- use of an existing on-site mobile crusher for coal crushing and screening of up to 150,000 tonnes (t) of domestic specification coal per annum for direct collection by customers at the mine site;
- use of an existing on-site mobile crusher to produce up to approximately 90,000 cubic metres (m^3) of gravel materials per annum for direct collection by customers at the mine site;
- progressive backfilling of the mine void behind the advancing open cut mining operation with waste rock and minor quantities of coarse reject material;
- continued and expanded placement of waste rock in the Northern Emplacement (including integration with the Boggabri Coal Mine emplacement) and Southern Emplacement, as mining develops;
- progressive development of new haul roads and internal roads, as mining develops;
- realignment of sections of Goonbri Road and construction of new intersections;
- construction of an engineered low permeability barrier to the east and south-east of the open cut to reduce the potential for local drainage of alluvial groundwater into the open cut;
- removal of a section of Goonbri Creek within the Project open cut and the establishment of a permanent Goonbri Creek alignment and associated flood bund to the east and south-east of the open cut;
- progressive development of sediment basins and storage dams, pumps, pipelines and other water management equipment and structures;
- continued development of soil stockpiles, laydown areas and gravel/borrow areas;
- ongoing monitoring and rehabilitation; and
- other associated minor infrastructure, plant, equipment and activities.

2 Subject to approvals and upgrades being in place for the transfer of Project ROM coal to the Boggabri Coal Mine Infrastructure Facilities.

A description of the Project is provided in Section 2 in the Main Report of the EA.

1.2.1 Project General Arrangements

Project general arrangements for Year 2, Year 4, Year 6, Year 12 and Year 16 are shown on Figures 3 to 7. The general arrangements are based on planned maximum production and mine progression. A final landform and rehabilitation concept for the end of the Project life is shown on Figure 8.

1.2.2 Permanent Goonbri Creek Alignment

Open cut mining will ultimately intersect the existing alignment of Goonbri Creek within MLA 2 in Project Year 15 (approximately 2027). To facilitate the open cut extension, it is proposed that Goonbri Creek be re-aligned further to the east in advance of the mine development (i.e. the permanent Goonbri Creek alignment).

The *Concept Design for the Low Permeability Barrier and Permanent Goonbri Creek Alignment* report prepared by Allan Watson Associates Pty Limited (2011) is included in Appendix R of the EA.

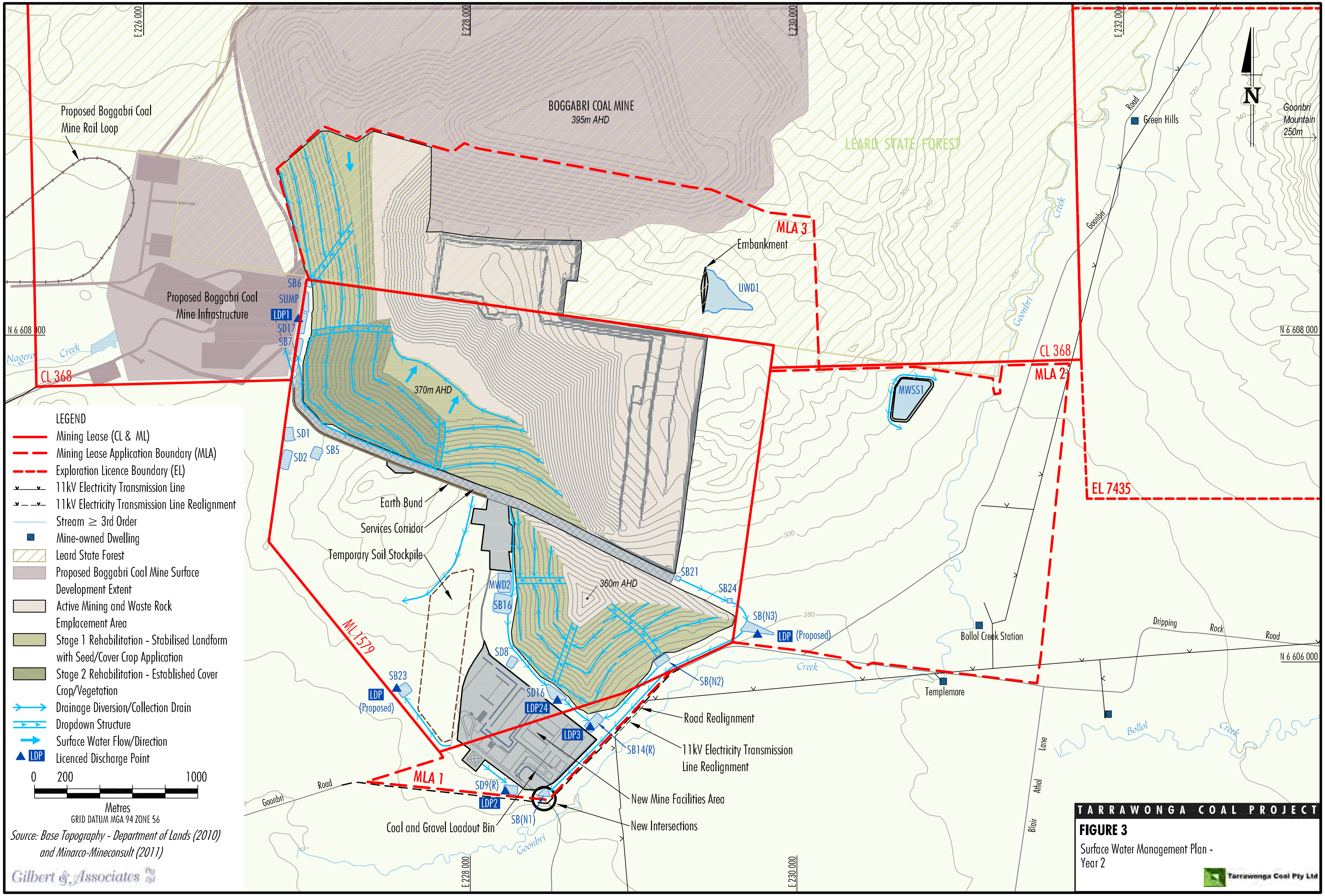
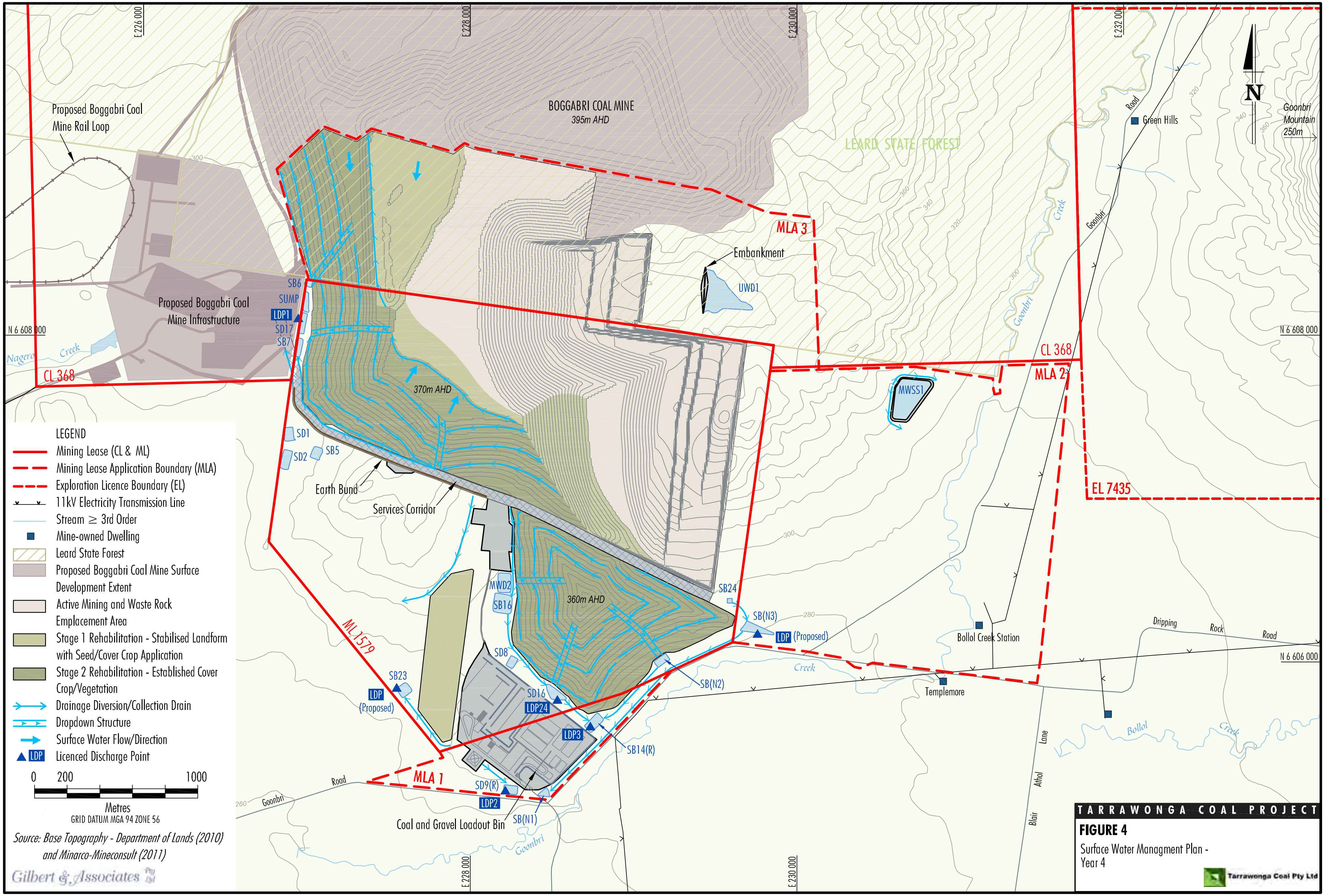
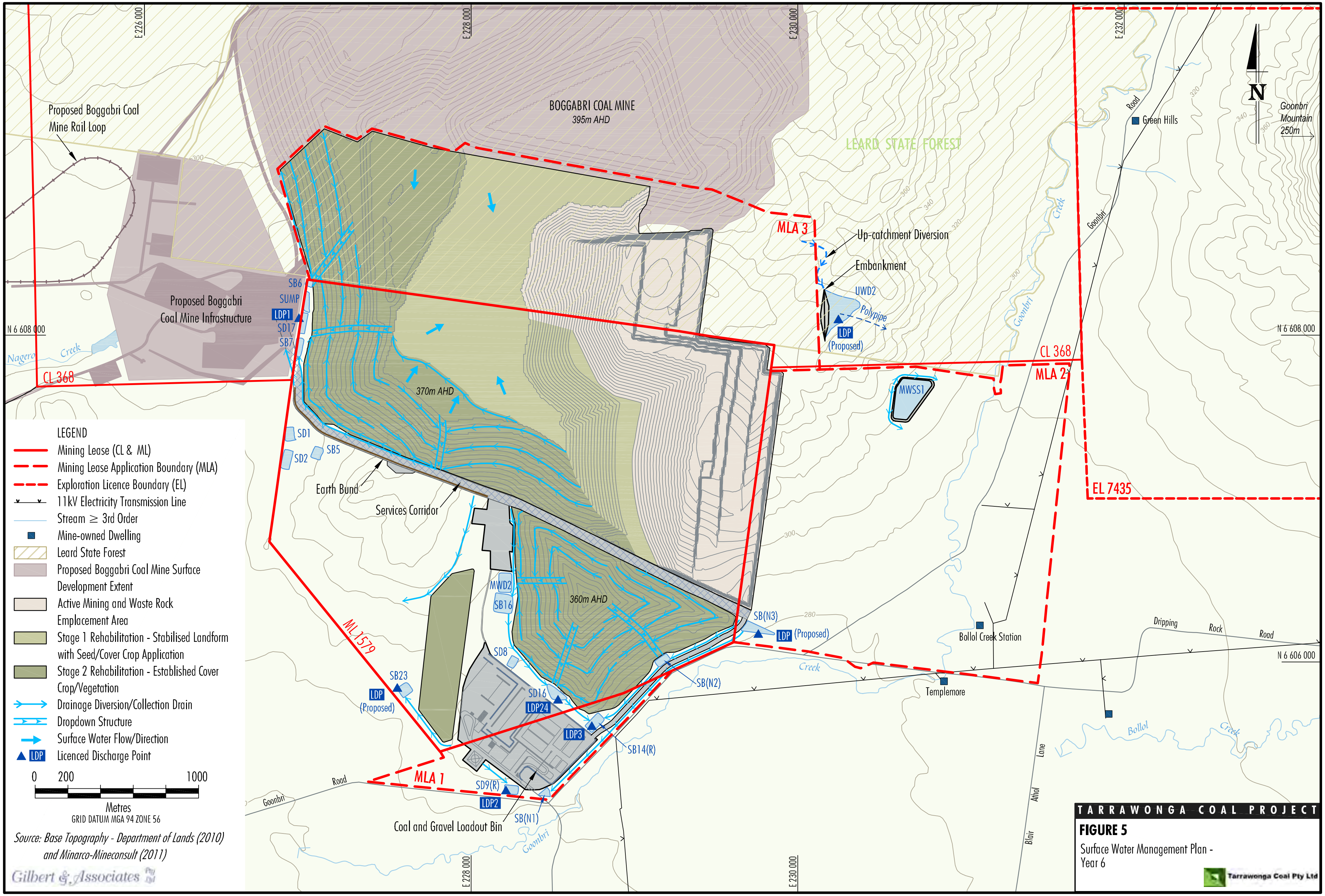


FIGURE 3
Surface Water Management Plan - Year 2

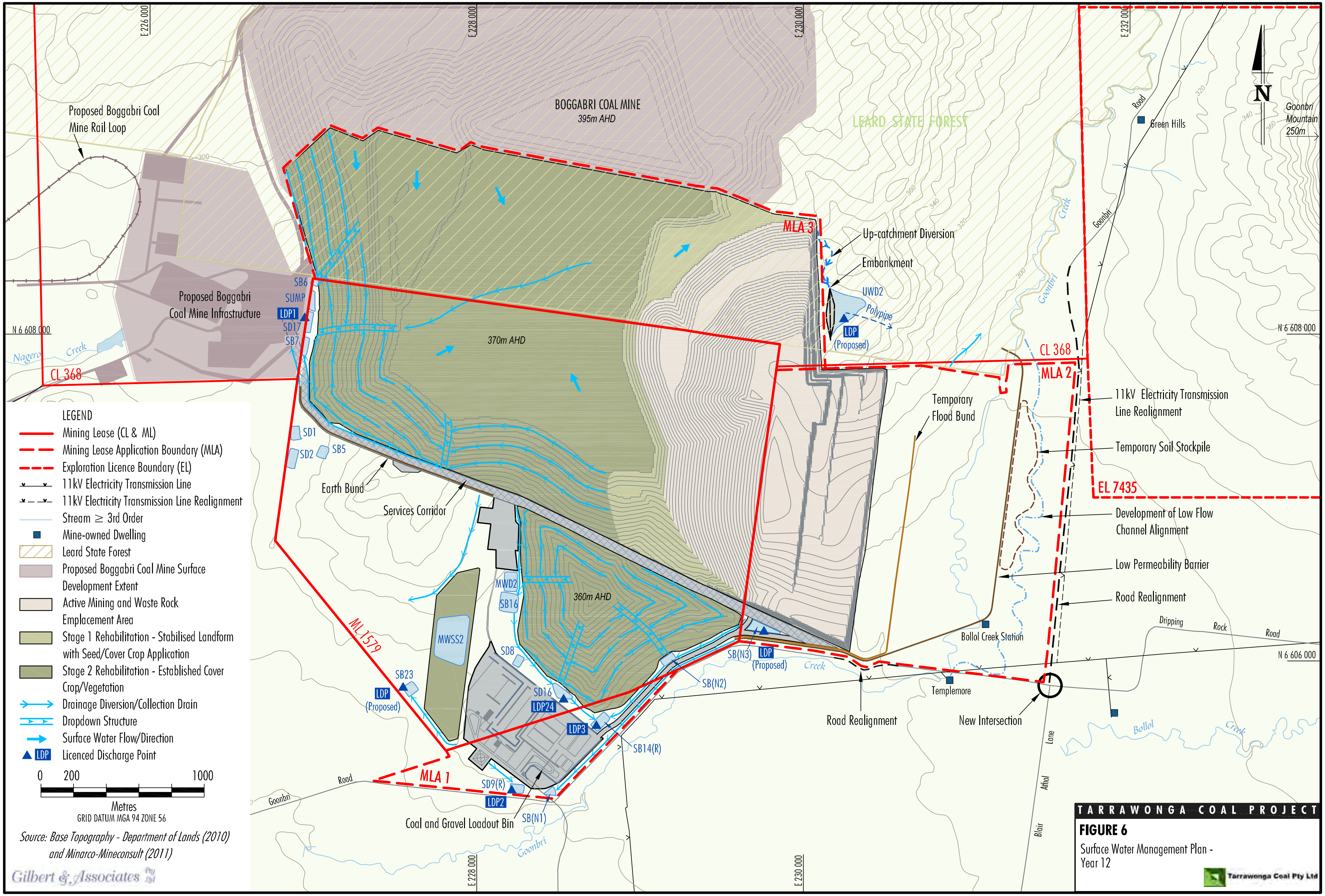
WHC-01-04_EA_SWA_101L



WHC-01-04_EA_SWA_1020



WHC-01-04_EA_SWA_115G



WHC-01-04_EA_SWA_103J

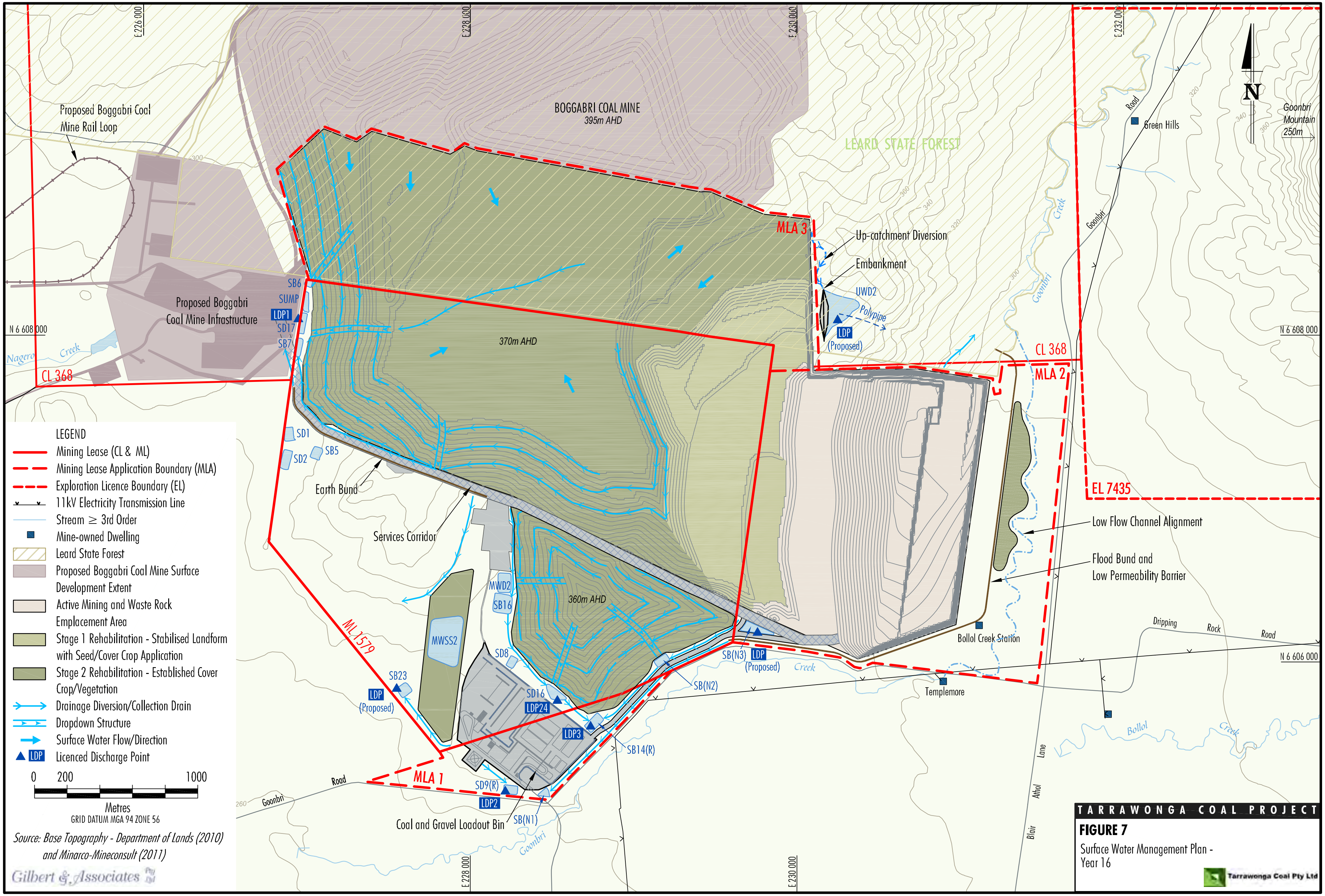


FIGURE 7
Surface Water Management Plan - Year 16

WHC-01-04_EA_SWA_104K

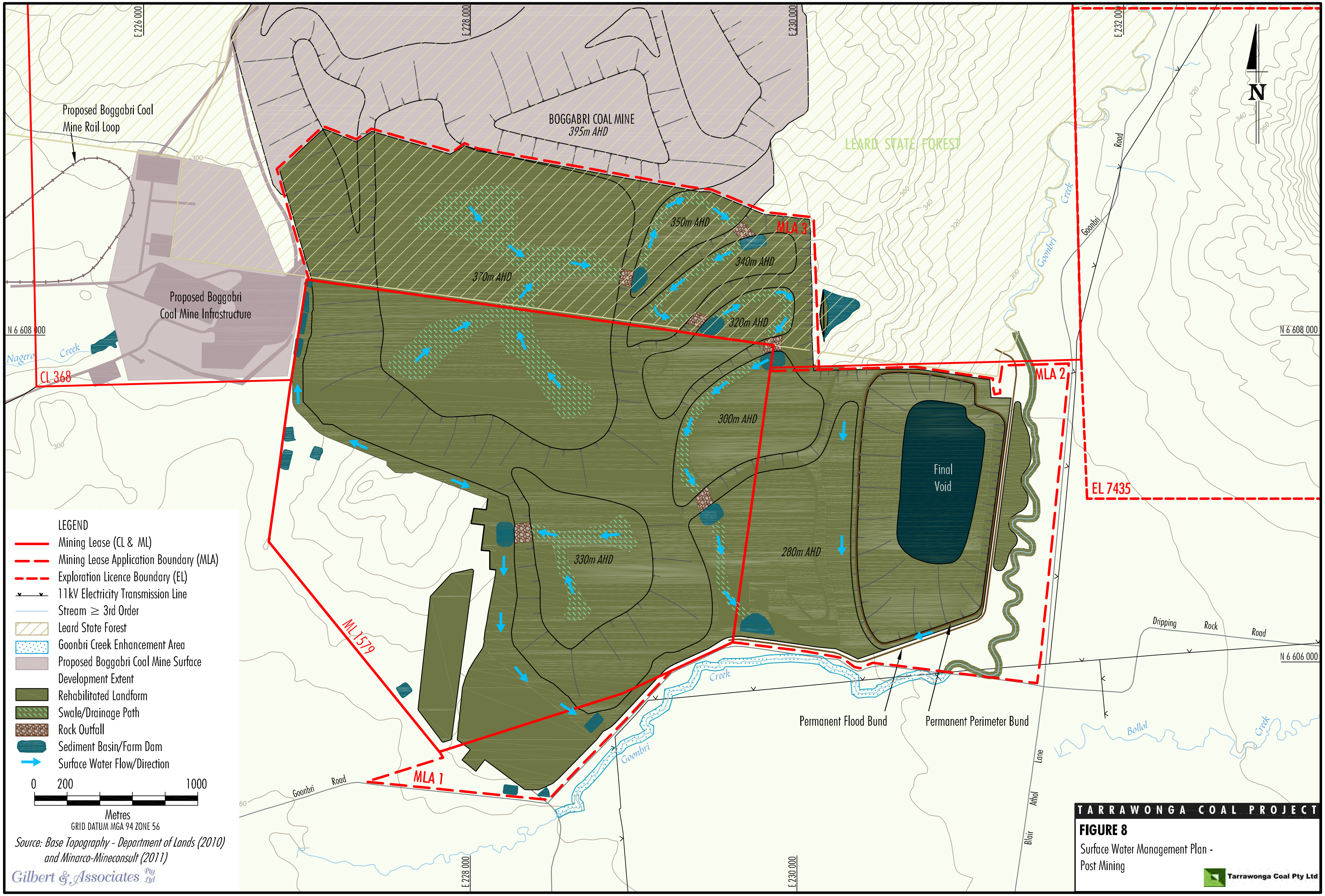


FIGURE 8

Surface Water Management Plan - Post Mining

2 BASELINE SURFACE WATER HYDROLOGY

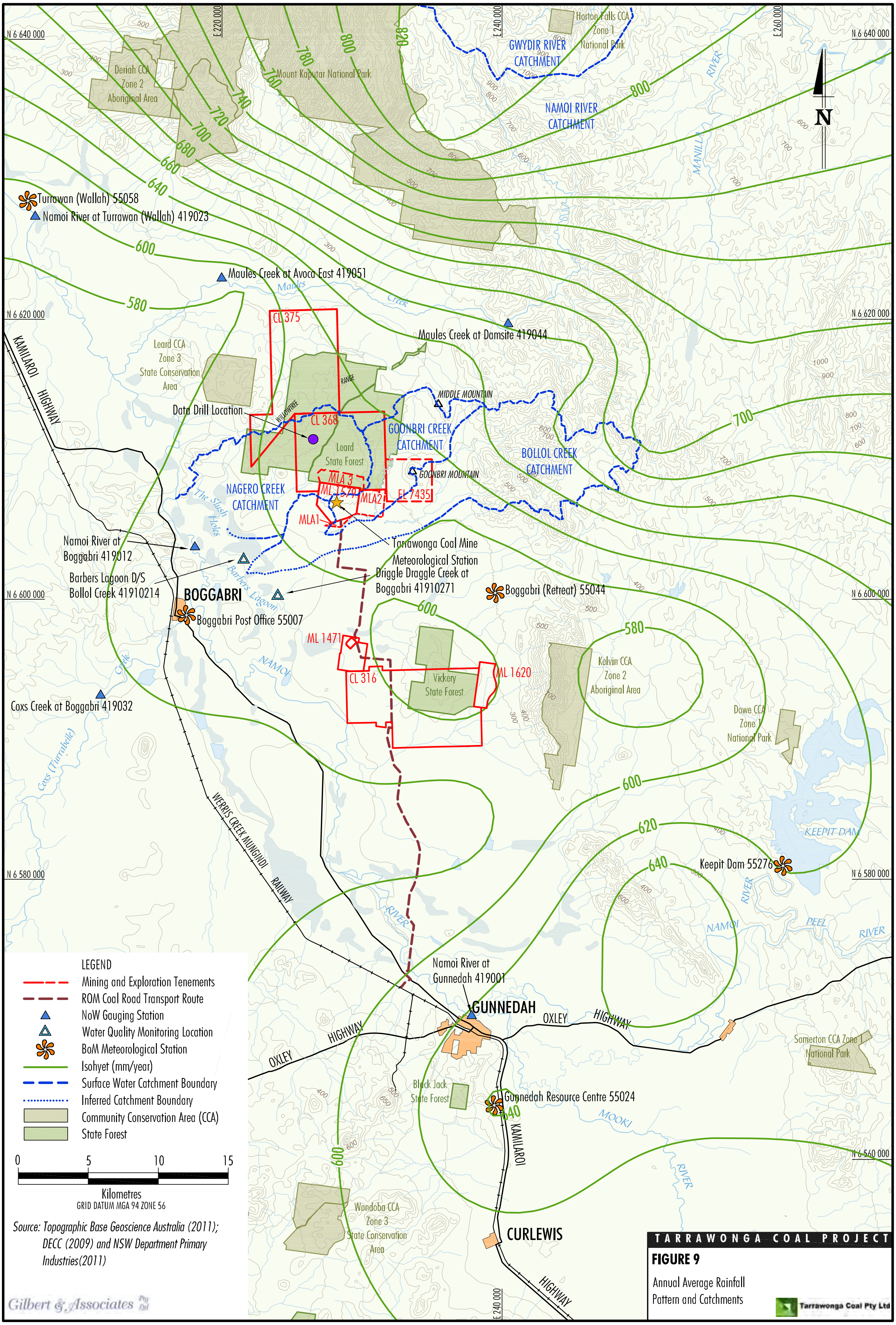
2.1 General

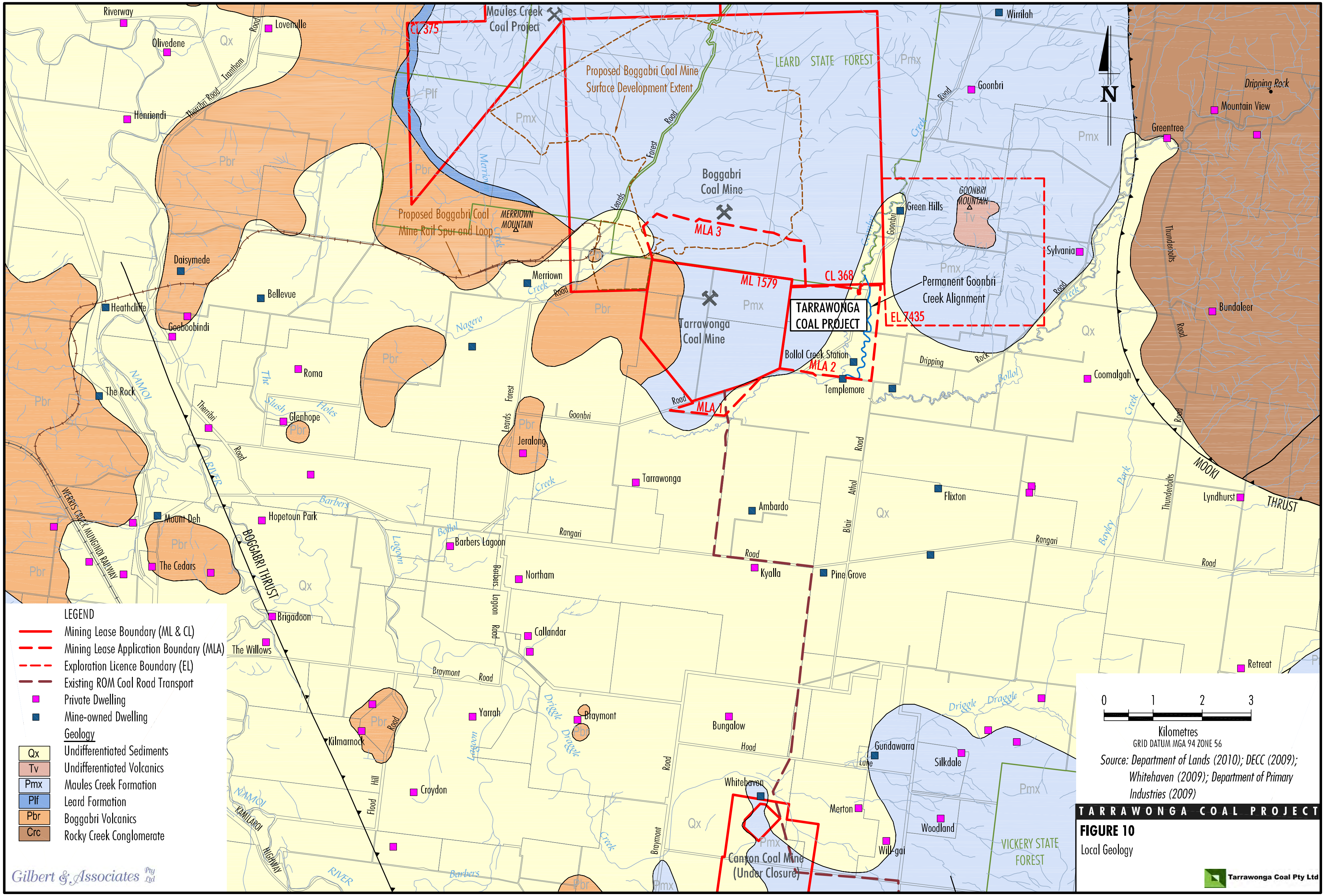
The Project site is situated predominantly on the hills and foot slopes of the Leard State Forest. The southern and eastern extremities of the site are situated on the floodplains of Goonbri and Bollol Creeks.

The Project area is situated entirely within the Namoi River catchment (refer Figure 9). The Namoi River drains an area of approximately 42,000 square kilometres (km^2) extending from Woolbrook in the east to Walgett in the west. It is bounded by the Gwydir River catchment to the north, the Macleay and Manning River catchments to the east, the Hunter River catchment to the south-east and the Macquarie and Castlereagh River catchments to the south. The Namoi is a tributary of the Barwon River which ultimately flows into the Murray-Darling System. The slopes and upland areas of the Project site and its surrounds are drained by a series of ephemeral streams which rise in the Willow Tree Ranges (refer Figure 9). The main local drainage systems associated with the Project area are Nagero Creek, Goonbri Creek and Bollol Creek.

2.2 Geological Setting and Site Soils

The Project site is located within the Maules Creek sub-basin, and contains coal seams, sedimentary and volcanic rocks of predominantly Permian age. Minor undifferentiated volcanic and igneous rocks of younger age are located in isolated outcrops in the area (RCA Australia, 2005). The Maules Creek Formation directly overlies the Boggabri Ridge Volcanics and contains approximately 15 coal seams with an average thickness of 1.5 metres (m). The approved open-cut mining operations at the TCM target the upper 8 coal seams from the sequence. These upper sequences are separated from the lower seams by a thick (approximately 40 m) interburden unit. The upper catchment of Goonbri Creek comprises moderate relief, rounded ridges and hills (including Goonbri Mountain) which are composed of Permian aged Maules Creek volcanics. The outflow plain areas which merge with the floodplain of the Namoi River further downstream comprise predominantly low lying undifferentiated alluvial sediments (refer Figure 10). These extensive plains are Cainozoic aged deposits which contain Holocene alluvial channels and overbank deposits of sand, silt and clay. Occasional outcrops of sandy conglomerates with minor amounts of interbedded sandstone, siltstone and mudstone are also present in some creek channels. The mapped alluvial deposits are shown on Figure 10 and extend in a 'tongue' upstream along Goonbri Creek to past the upstream end of the permanent Goonbri Creek alignment.


TARRAWONGA COAL PROJECT
FIGURE 9
Annual Average Rainfall Pattern and Catchments
Tarrawonga Coal Pty Ltd
LEGEND
Mining and Exploration Tenements
ROM Coal Road Transport Route
NoW Gauging Station
Water Quality Monitoring Location
BoM Meteorological Station
Isohyet (mm/year)
Surface Water Catchment Boundary
Inferred Catchment Boundary
Community Conservation Area (CCA)
State Forest
0 5 10 15
Kilometres
GRID DATUM MGA 94 ZONE 56
Source: Topographic Base Geoscience Australia (2011); DECC (2009) and NSW Department Primary Industries(2011)
Gilbert & Associates Pty Ltd
Turrawan (Wallah) 55058
Namoi River at Turrawan (Wallah) 419023
Maules Creek at Avoca East 419051
Maules Creek at Damsite 419044
GWYDIR RIVER CATCHMENT
NAMOI RIVER CATCHMENT
GOONBRI CREEK CATCHMENT
BOLLOL CREEK CATCHMENT
NAGERO CREEK CATCHMENT
Mount Kaputar National Park
Deriah CCA Zone 2 Aboriginal Area
Horton Falls CCA Zone 1 National Park
Leard CCA Zone 3 State Conservation Area
Leard State Forest
Data Drill Location
CL 375
CL 368
MLA 3
ML 1579
MLA2
MLA1
EL 7435
MIDDLE MOUNTAIN
GOONBRI MOUNTAIN
Tarrawonga Coal Mine Meteorological Station
Driggle Draggle Creek at Boggabri 41910271
Namoi River at Boggabri 419012
Barbers Lagoon D/S Bollol Creek 41910214
BOGGABRI
Boggabri Post Office 55007
Boggabri (Retreat) 55044
ML 1471
CL 316
ML 1620
Vickery State Forest
Kelvin CCA Zone 2 Aboriginal Area
Dowe CCA Zone 1 National Park
Coxs Creek at Boggabri 419032
KEEPIT DAM
Keepit Dam 55276
Namoi River at Gunnedah 419001
GUNNEDAH
OXLEY HIGHWAY
KAMILAROI HIGHWAY
WERRIS CREEK MUNGINDI RAILWAY
Black Jack State Forest
Gunnedah Resource Centre 55024
Somerton CCA Zone 1 National Park
Wondoba CCA Zone 3 State Conservation Area
CURLEWIS
N 6 640 000
N 6 620 000
N 6 600 000
N 6 580 000
N 6 560 000
E 220 000
E 240 000
E 260 000
WHC-01-04_EA_SWA_108E



WHC-01-04_EA_SWA_117C

The main soil types are Stratic Rudosols (44%), Tenosols (17%) and Sodosols (16%). The Stratic Rudosols are characterised by alluvial depositional layers (Mackenzie Soil Management, 2011). The Tenosols are shallow stony soils and the Sodosols have a strong texture contrast between topsoil and sodic subsoils.

Site soils were generally found to have a strong potential to disperse, to have topsoil acidity and had major nutrient deficiencies (Mackenzie Soil Management, 2011).

2.3 Climate

The Project area experiences a temperate climate which is influenced locally by orographic effects of the terrain to the north and east of the Project. Average monthly maximum temperatures at the Gunnedah Resource Centre (Bureau of Meteorology [BoM] Station # 55024) vary from 16.1 degrees Celsius (ºC) in July and 31.9 ºC in January. Average monthly minimum temperatures vary from 4.7 ºC in July to 18.9 ºC in January. The dominant wind directions based on standard 9 am observations are from the east, southeast, northwest and the northeast.

2.3.1 Rainfall and Evaporation

The distribution of annual average precipitation across the Project and regional areas is shown on Figure 9. Average annual rainfall is highest in elevated areas associated with the Willowtree Ranges and the volcanic highlands associated with Mount Kaputar further to the north. Average annual rainfall is relatively lower on the floodplains of the Namoi River and areas to the south and east of the Project site.

The average monthly rainfall and potential evaporation statistics from regional stations are summarised in Tables 1 and 2 respectively. Rainfall is reasonably evenly distributed throughout the year but tends to be highest in the summer season months. Similarly, evaporation has been measured to be highest during the months of November, December, January and February when average solar radiation, temperature and vapour pressure deficit are higher.

Table 1 Summary of Average Regional Rainfall and Rain Days

	Data Drill[3] North Tarrawonga		Boggabri PO (55007)*		Boggabri (Retreat) (55044)*		Turrawan (Wallah) (55058)*	
	Rainfall (mm)	Rain Days	Rainfall (mm)	Rain Days	Rainfall (mm)	Rain Days	Rainfall (mm)	Rain Days
	1889 - 2011		1884 - 2011		1889 - 2011		1910 - 2011	
Jan	79.4	10.1	71.0	5.6	71.5	5.2	81.1	5.6
Feb	67.0	8.4	64.4	5.0	61.4	4.6	61.2	4.6
Mar	49.9	7.2	45.5	4.1	42.2	3.6	42.5	3.6
Apr	37.0	6.2	33.7	3.6	35.4	3.1	33.4	3.1
May	44.4	7.0	41.8	4.4	38.0	3.6	41.9	3.5
Jun	42.5	8.5	43.5	5.4	43.7	4.6	43.0	4.5
Jul	44.2	8.4	41.4	5.4	42.8	4.8	42.3	4.7
Aug	39.7	8.0	38.1	5.1	37.3	4.4	34.8	4.2
Sep	38.9	8.0	38.0	4.7	39.9	4.4	37.2	3.8
Oct	53.2	9.3	51.1	5.6	50.3	5.2	50.9	4.8
Nov	58.3	9.8	58.5	5.8	56.9	5.3	57.6	5.4
Dec	64.0	9.8	64.1	5.9	61.7	5.1	65.3	5.4
Annual	**618.5**	**100.7**	**591.1**	**60.6**	**581.1**	**53.9**	**591.2**	**53.2**
Monthly Mean	51.5	8.4	49.3	5.1	48.4	4.5	49.3	4.4
*Data from BoM (2009).								

Table 2 Summary of Average Regional Class 'A' Pan Evaporation (millimetres [mm])

Site	Keepit Dam (55276)*	Gunnedah Resource Centre (55024)*
Operation	**1972 - 2006**	**1971 – 2010**
Jan	255.7	248.4
Feb	204.5	202.1
Mar	182.1	196.4
Apr	124.1	138.2
May	80.6	90.4
Jun	56.1	61.7
Jul	63.9	64.8
Aug	89.2	91.8
Sep	129.3	127.4
Oct	172.7	174.9
Nov	207.7	206.1
Dec	259.4	250.5
Annual	**1825.3**	**1852.7**
Note: As measured by Class A evaporation Pan		
*Data from BoM (2009).		

[3] 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.

Rainfall intensities representative of a number of Average Recurrence Interval (ARI) events for different durations for the Goonbri Creek catchment are summarised in Table 3 below.

Table 3 Design Rainfall Intensities for Goonbri Creek Catchment*

Duration (hours)	Rainfall Intensity (mm/hour)				
	1 in 5 year ARI	1 in 10 year ARI	1 in 20 year ARI	1 in 50 year ARI	1 in 100 year ARI
1	37.5	43.4	51.0	63.0	72.0
2	22.9	26.6	31.5	38.4	43.9
3	17.1	19.8	23.5	28.6	32.7
4.5	12.7	14.8	17.5	21.3	24.3
6	10.3	12.0	14.2	17.2	19.7
9	7.7	8.9	10.6	12.8	14.7
12	6.3	7.2	8.6	10.4	11.9
18	4.8	5.5	6.5	8.0	9.1
24	3.9	4.5	5.4	6.5	7.5

*Data from BoM (2009).

2.4 Catchments and Surface Water Resources

Flow in the Namoi River is regulated by three major water storages:

- Keepit Dam was constructed on the Namoi River upstream of the Peel River confluence in 1960 with a storage capacity of 427,000 megalitres (ML).
- Split Rock Dam was constructed on the Manilla River in 1988 with a storage capacity of 397,000 ML.
- Chaffey Dam was constructed on the Peel River upstream of Woolomin in 1979 with a storage capacity of 62,000 ML.

Water is released from these storages for environmental, irrigation, industrial and domestic/urban requirements.

The slopes and upland areas of the Project site and its surrounds are drained by a series of ephemeral streams which rise in the Willowtree Range. The local drainage catchments associated with the Project area are Nagero Creek, Goonbri Creek and Bollol Creek. In their headwater and mid reaches these streams comprise small confined channels with occasional pockets of adjoining floodplain.

As they descend onto the expansive alluvial flats below the Project area, they transition into relatively poorly defined drainage paths which become expansive ponded overland flow areas during and following heavy rainfall. The overland flow moves slowly down-gradient (west and southwest) toward the Namoi River itself.

The alluvial flats are traversed by several local public roads which influence the pattern of flow – either by damming the movement of flow where roads form barriers to shallow flow or by providing preferred flow paths where the shoulder and table drains of a roadway are aligned such as to form pathways for overland flow. The pattern of overland flow is also influenced by cropping activities conducted in the area. In the past, drainage works (diversion channels and swales) and flood protection works (flood levees) have been constructed to divert flood waters away from inhabited areas. Farm dams have also been constructed on some of the more dominant flow paths for stock watering. These works also influence the movement of water across the alluvial flats.

2.4.1 Goonbri Creek

Goonbri Creek rises on the eastern slopes of the Willowtree Range (Figure 9). It flows generally southward along the eastern boundary of the Leard State Forest and is flanked on its eastern side by Middle Mountain and Goonbri Mountain which form a discontinuous line of hills. Downstream of the Project area, Goonbri Creek flows generally westward and south-westward, crossing the TCM ROM coal road transport route near the TCM site access road and ultimately disperses as overland flow on the adjacent alluvial flats and the Namoi River floodplain.

Goonbri Creek is an ephemeral stream. Goonbri Creek comprises a low capacity channel which is confined on its western bank by the lower slopes of the Willowtree Range. It comprises a relatively shallow low capacity channel which overflows out onto the adjacent plains on its eastern bank during moderate and high flows. Downstream of the Dripping Rock Road crossing, Goonbri Creek has a relatively incised channel with sufficient capacity to contain moderate flood flows. Flows from the creek ultimately disperse onto the alluvial flats as its flow energy is dissipated across the nearly flat alluvial plains south and west of Project area.

The alluvial flats have very low natural slopes which are difficult to discern. The slopes generally fall in a westerly and south-westerly direction at between 0.15 % and 0.40 %. The flatness of the terrain on the alluvial flats and the effect of ongoing cropping and cultivation have prevented the formation of well-defined drainage features.

Goonbri Creek commands a catchment of some 35 km^2 above the Dripping Rock Road crossing (Figure 10). The valley is more than 500 m wide and has gently sloping sides. The channel slope is 0.003 m/m (Lampert & Short, 2004).

The dominant land uses in the Goonbri Creek catchment are forestry in the higher elevations comprising the Leard State Forest, and agricultural land uses including grazing and cropping on the alluvial floodplains. Several rural residences (including those owned by Whitehaven) are located within the catchment.

The TCM is subject to an Environment Protection Licence (EPL) No. 12365, which includes licensed wet weather discharges into the Goonbri Creek catchment.

Further detail regarding the hydrology and geomorphology of Goonbri Creek, with specific consideration to the permanent Goonbri Creek alignment, is provided in Section 6.

2.4.2 Bollol Creek

Bollol Creek rises in the hills north-east of Goonbri Mountain (Figure 9). It initially flows south and westward through a confined valley before dispersing out onto the alluvial flats south of the lower reaches of Goonbri Creek. Bollol Creek then flows south and westward as sheetflow in several pathways associated with shallow, discontinuous swales and divots before eventually reaching Barbers Lagoon to the south and into a series of lagoons to the west known as the Slush Holes, which are relic river channels of the Namoi River. Local anecdotal evidence indicates that the bulk of the flow heads southwest to Barbers Lagoon, and ultimately to the Namoi River.

Bollol Creek has an inferred catchment area of approximately 119 km^2, although the actual catchment area contributing flow at different points on the floodplain varies with changing patterns of local cropping and vegetation. The dominant land use in the Bollol Creek floodplain is mixed agricultural including cropping and livestock grazing.

The Bollol Creek valley is flat and up to 2 km wide. The channel slope is 0.006 m/m (Lampert & Short, 2004). Bollol Creek is characterised as a meandering gravel river. Typical characteristics for this category are long pools separated by short riffles. The river may run dry or have isolated pools during periods of no flow. Riparian vegetation includes River Oaks and Tea Tree. The floodplain is continuous with flood channels and supports pasture and crops (Lampert & Short, 2004).

2.4.3 Nagero Creek

Nagero Creek drains the western and south-western slopes of the Willowtree Range on the western side of the Project area (Figure 9). It flows in a westerly and south-westerly direction ultimately flowing into the Slush Holes. Nagero Creek has a catchment area of approximately 78 km^2 at the confluence with the Slush Holes. During large flood events the Slush Holes become backwater areas of the Namoi River. At other times they become isolated billabongs.

Nagero Creek is an ephemeral stream. It has a well defined incised channel with well vegetated banks. The creek bed comprises sand and/or rock. The bed slope varies between approximately 2 % at the top of the catchment to 0.8 % downstream of the Boggabri Coal Mine (Parsons Brinckerhoff, 2010).

The dominant land uses in the Nagero Creek catchment include mining (i.e. Boggabri Coal Mine and a small portion of the existing TCM), agriculture (sheep and cattle grazing, mixed cropping) and rural settlement.

The NSW OEH licences discharges into NSW rivers and creeks under the NSW Protection of the Environment Operations Act, 1997 (POEO Act). The Boggabri Coal Mine is subject to an existing EPL No. 12407, which includes licensed wet weather discharges into the Nagero Creek catchment. The TCM is also subject to an EPL No. 12365 which includes licensed wet weather discharges into the Nagero Creek catchment.

2.5 Runoff and Streamflow

2.5.1 Local Watercourses

Casual observation and anecdotal evidence from mine site staff and local landholders indicate that the local streams in their upper reaches are highly ephemeral, respond quickly to rainfall, flow for relatively short periods after rainfall and exhibit little flow persistence following rainfall due to limited interaction between shallow alluvial aquifers and the bed of the streams.

Water ponding is more prevalent and persistent in the lower alluvial floodplain areas due to the slow moving nature of flows and the relatively low seepage loss (groundwater recharge) rates in these areas. Flow in these areas is associated with larger, less frequent events.

Whilst there are no gauged flow data available for any of the local watercourses, a quantitative insight into the likely hydrological characteristics of Goonbri Creek (and the other local ephemeral drainages) can be obtained by assessing the flow records from the Maules Creek gauging station (GS 419044) which is the closest gauged catchment likely to have similar hydrological characteristics to Goonbri Creek (refer Figure 9). There is also a second gauging station on Maules Creek further downstream in the area of alluvial flats (GS 419051). Streamflow records are available for Maules Creek GS 419044 for the period 1968-1992. The catchment upstream of GS 419044 (which is similar to the Goonbri Creek catchment) has a contributing catchment area of some 171 km^2. The average annual runoff yield per unit catchment area, over the gauged period, was 40.3 mm/annum - the equivalent of about 6.45 % of rainfall.

Inferred streamflow characteristics for Goonbri Creek have been derived by scaling the observed flows at Maules Creek gauging station (GS 419044) by the ratio of the catchment areas at the downstream end of the permanent Goonbri Creek alignment to the catchment area above the Maules Creek gauging station - refer Table 4.

Table 4 Inferred Streamflow Characteristics of Goonbri Creek at Downstream End of Permanent Goonbri Creek Alignment

Statistic	Inferred Value
Mean Annual Flow (ML)	1338
Standard deviation in annual flow (ML)	38.44
Average number of no flow days per annum	201
80 percentile daily flow (ML)	1.42
50 percentile (median) flow (ML)	0.03
20 percentile flow (ML)	0
Mean Flow in January (ML)	169.4
Mean Flow in February (ML)	419.3
Mean Flow in March (ML)	53.5
Mean Flow in April (ML)	35.9
Mean Flow in May (ML)	72.0
Mean Flow in June (ML)	76.8
Mean Flow in July (ML)	164.3
Mean Flow in August (ML)	113.8
Mean Flow in September (ML)	89.1
Mean Flow in October (ML)	56.8
Mean Flow in November (ML)	96.1
Mean Flow in December (ML)	33.8

A flow duration curve calculated from the recorded streamflow at Maules Creek (GS 419044) and scaled to reflect flows at Goonbri Creek (at the downstream end of the permanent Goonbri Creek alignment) is shown in Figure 11.

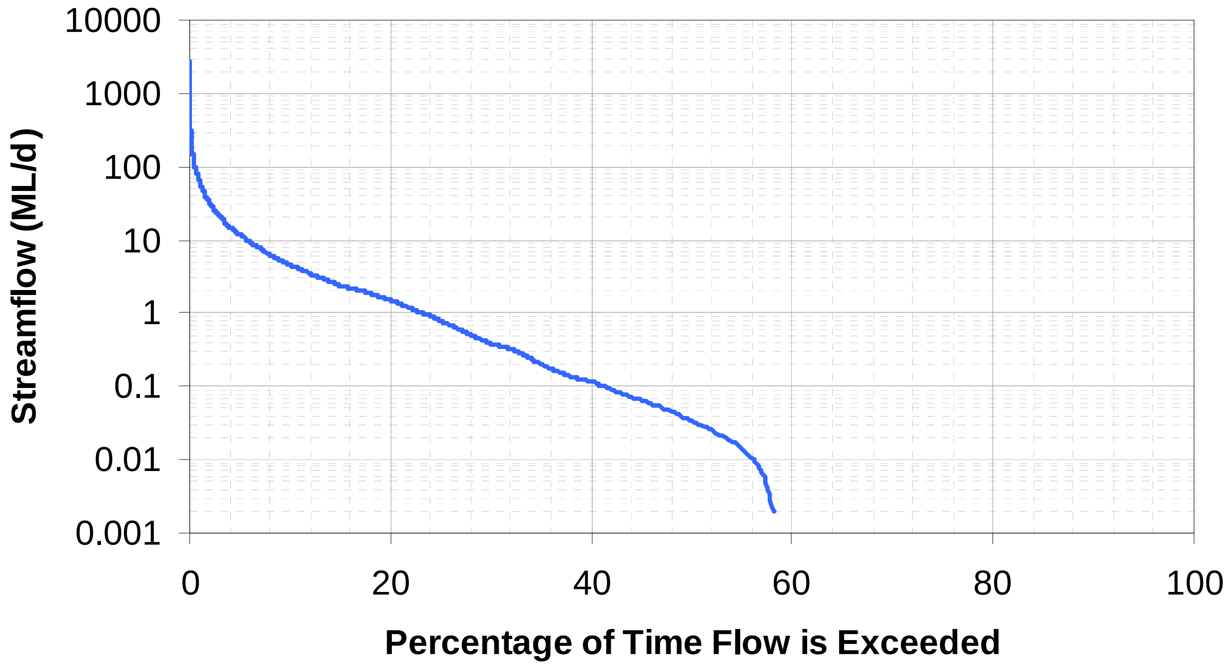


Figure 11 Recorded Flow Duration Curve – GS 419044 – Maules Creek at Damsite Scaled by Catchment Area Ratio for Goonbri Creek

Figure 11 shows that Maules Creek has moderate flow persistence flowing on about 58 % of days compared with about 27 % of days with rainfall on average. It is expected that flows in Goonbri Creek would exceed 1 ML/day (11.6 litres per second) on about 25 % of days.

2.5.2 Regional Watercourses

The closest gauging station on the Namoi River to the Project site is located at Boggabri (GS 419012), just south (upstream) of the Bollol Creek confluence with the Namoi River (Figure 9). The Boggabri gauging station commands a catchment area of 22,600 km^2 and has an estimated mean annual flow of 836,209 ML (NSW Water Info Website, 2011) - equivalent to about 35.4 mm of runoff per annum or 6 % of the average annual rainfall at Boggabri. Figure 12 shows the recorded daily streamflow hydrograph for the Namoi River gauging station at Boggabri with flows (obtained from all data available on the NSW Water Info Website, 2011) plotted on a logarithmic scale. Figure 13 shows the daily flow duration curve again with the same flows plotted on a logarithmic scale[4].

[4] Streamflow is often plotted on a logarithmic scale because of its extreme variability which makes it difficult to see low and moderate flows if it is plotted on a linear scale.

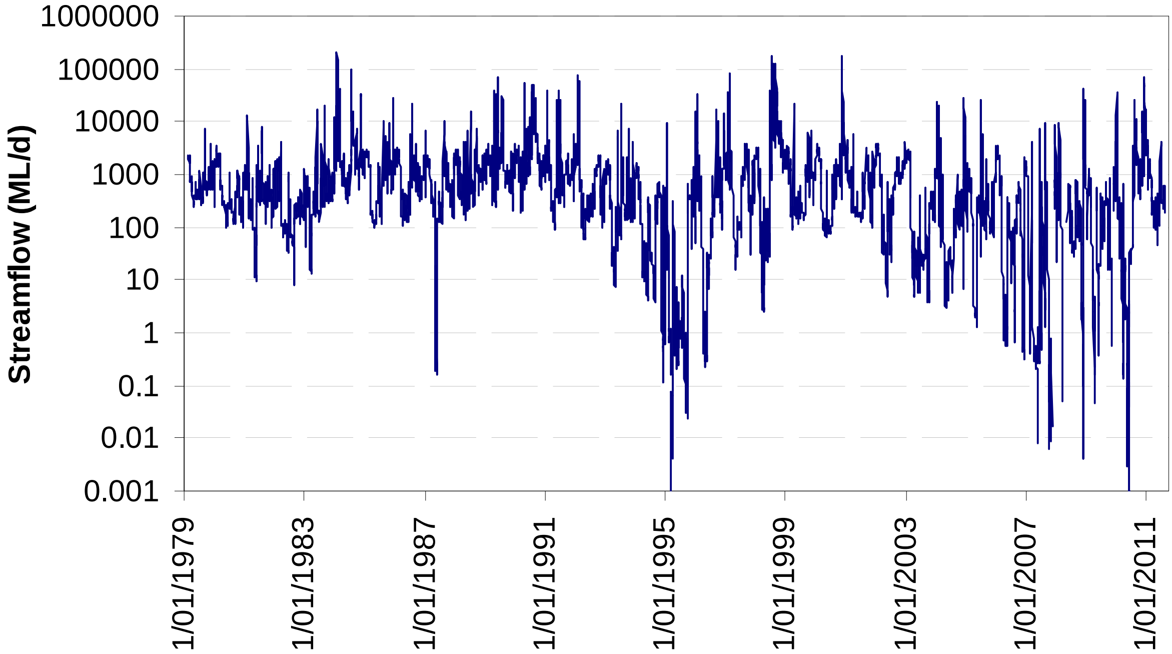


Figure 12 **Recorded Streamflow Hydrograph – GS 419012 – Namoi River at Boggabri**

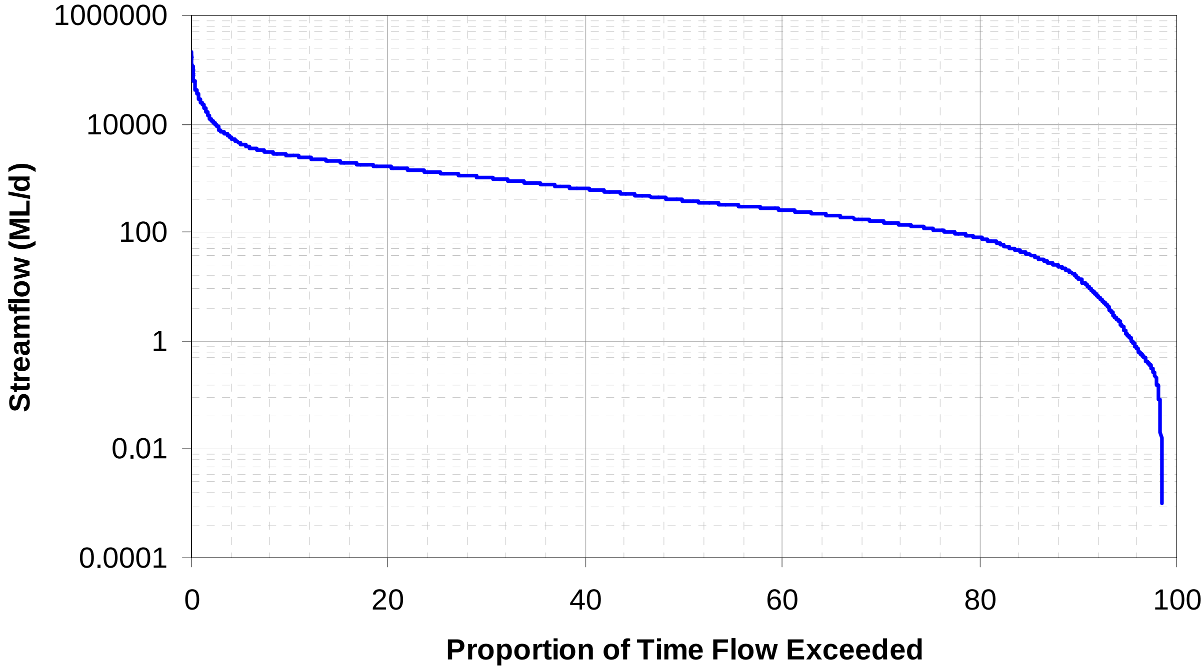


Figure 13 **Recorded Flow Duration Curve – GS 419012 – Namoi River at Boggabri**

Streamflow in the Namoi River is characterised by strong flow persistence with flows exceeding 1.3 ML/day on 95 % of days. Zero flow has been recorded on 1.5 % of days. Averaged over the full period of available data, streamflow in the Namoi River at Boggabri is estimated to amount to 1,643 ML/day. These flow characteristics are typical of large regulated catchments.

2.6 Flooding

The Namoi River valley has experienced a number of significant floods. The largest confirmed flood occurred in February 1955, with significant floods also being recorded in January 1971, February 1984 and November 2000 (NSW Department of Land and Water Conservation, 2003). Flooding along the reaches of the Namoi River nearest to Boggabri is characterised by outbreaks from the main channel, and associated inundation of the extensive floodplain areas on both sides of the river channel. Floodplain flow is dominated by flow in flood runners (i.e. preferential flow paths during flood events). Flow patterns are also affected by a series of relic channels which form semi-permanent lagoons between floods (NSW Department of Land and Water Conservation, 2003).

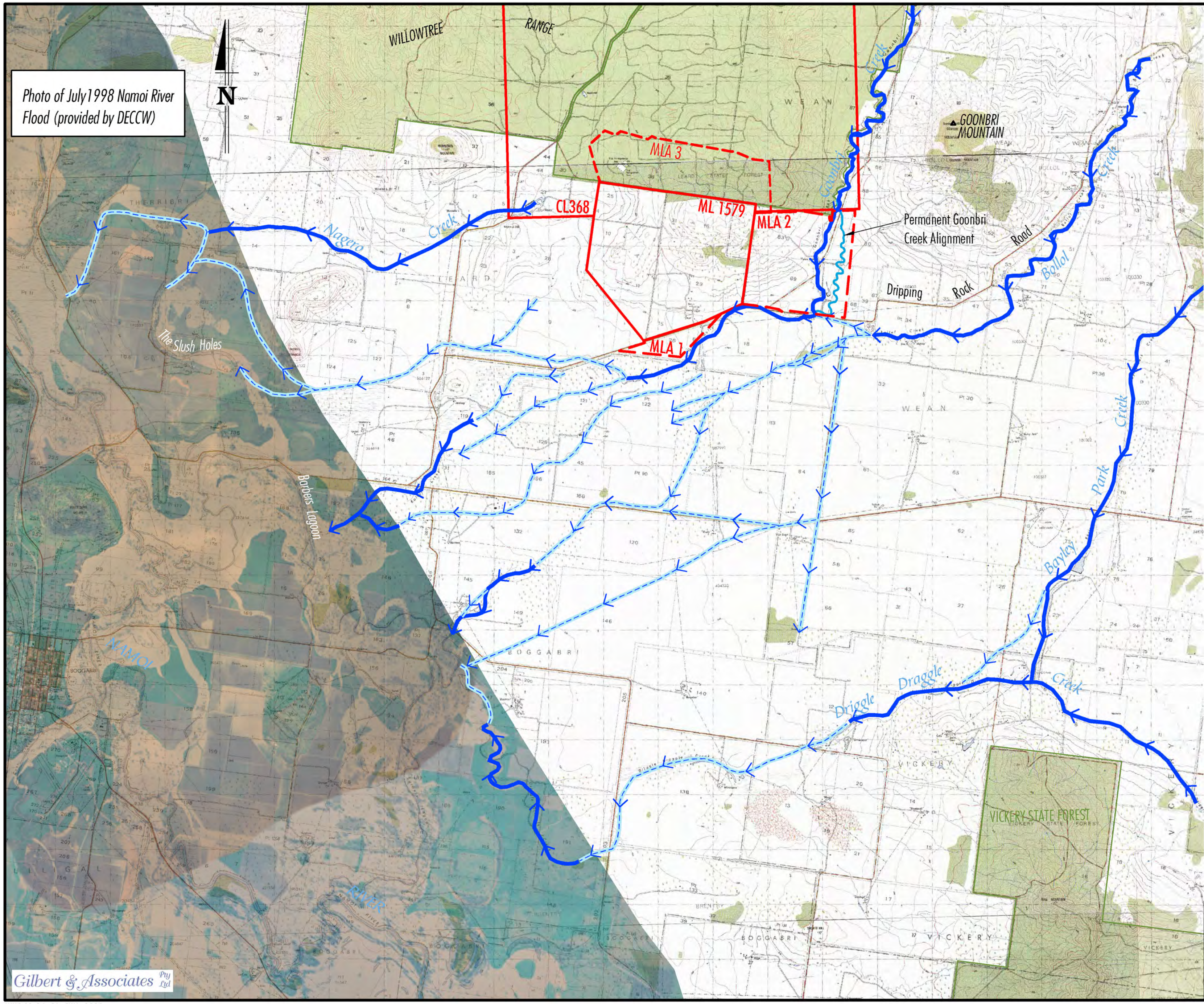
During intense and prolonged rainfall events, such as occurred in July 1998, February 2003 and February 2007, large areas of the alluvial flats become inundated forming large slow moving sheets of water which slowly dissipate by evaporation and seepage into the alluvial plains and by slow drainage into the Namoi River via the relic lagoons on the edges of the River. During these periods, flows from the various source streams follow a number of overland flow paths on the alluvial flats which have been identified by local landholders and are reproduced on Figure 14. The dominant flow paths follow shallow natural swales and subtle depressions in the terrain.

The Project area is predominantly on elevated land and would be above any conceivable flooding of the Namoi River. The maximum water level reached in the Namoi River at Gunnedah (upstream of the mine site) in the 1955 flood was 264.5 m Australian Height Datum (AHD). The lowest level on the Project area site is about 271 m AHD. Lower sections of the site along Goonbri Creek could however be affected by extreme flooding from Goonbri Creek and possibly Bollol Creek and would be protected by a flood bund as described in Section 4.2.2.4.

2.7 Surface Water Quality

The surface water quality characteristics of local and regional water resources reflect the catchment geology, soils, vegetation and land use. Data available to characterise surface water quality and its spatial and temporal variability is scarce in local (i.e. Project area) catchments – being limited to monitoring data collected by the local mining companies during the periods when the local ephemeral systems have flowed and when access to collect samples was possible. More extensive data sets are available for the Namoi River because monitoring has been conducted over a much longer time span and which, due to the effect of flow regulation, is effectively a perennial system. The water quality characteristics of water held on site in the existing mining operations has also been characterised as a baseline of the existing water management system.

The characterisation of water quality has been undertaken using statistically based analyses. Results of these analyses have been interpreted using reference values from the ANZECC Guidelines (2000a) for different environmental values for comparison.



Notes

1. The flow paths depicted on the attached figure have been developed from aerial photography taken during the 1998 flood event, information on drainage paths shown on 1 : 25,000 scale topographical mapping, field observations made during several ground reconnaissance inspections of the area and from information provided by local landholders.

2. The overland flow paths shown depict the main pathways for water movement across the alluvial flats and flood plain areas during periods of high runoff in the contributing catchments and coincidental flooding in the Namoi River.

3. Overland flow paths also reflect the subtle topography - including shallow depressions and divots that have formed on the surface of the alluvial flats.

4. The rates of flow and its relative distribution across the various flow paths will be affected by the status and distribution of vegetation - principally pasture grasses and crops on the alluvial flats.

5. Overland flow is also affected by the existing and any changes to the road network on the alluvial flats and flood plains. Flow can be impeded by the damming effect of road embankments which block overland flow paths. Preferential flow paths can also form along table drains and road verges where roads are aligned in directions sympathetic to overland flow paths.

6. Flood levees, farm dam embankments and diversion bunds have been constructed in some areas which also locally affect the movement of water.

LEGEND

- Mining Lease Boundary (ML & CL)
- Mining Lease Application Boundary (MLA)
- Overland Flow
- Channel Flow

0 1 2 3
Kilometres
GRID DATUM MGA 94 ZONE 56

Source: Department of Lands (2010)

TARRAWONGA COAL PROJECT

FIGURE 14

Surface Water Flow Paths (Developed in Consultation with Local Landholders and NSC)

Tarrawonga Coal Pty Ltd

Gilbert & Associates Pty Ltd

WHC-01-04_EA_SWA_109C

2.7.1 Water Quality Characteristics of Regional Water Resources

The Namoi River, and its associated floodplains and fringing lagoons, are the regional surface water resources of relevance to this Project. Water quality data is available for the Namoi River at Gunnedah and a relatively small amount of data is available for Barbers Lagoon and Driggle Draggle Creek which are Namoi River lagoons downstream of the Project site. Some limited data is also available for Maules Creek – a tributary of the Namoi River north of the Project site. A summary of the available data from these sites is provided in Table 5 below.

The water quality of Maules Creek and the Namoi River are characterised by moderate alkalinity and elevated levels of salinity (electrical conductivity) relative to guideline values (Table 5). Average and 80th percentile Total Nitrogen and Total Phosphorous concentrations in both the Namoi River and Maules Creek have also been elevated relative to guideline trigger values for aquatic ecosystems.

Table 5 Regional Water Quality Summary

Parameter	Units	ANZECC Guidelines		BARBERS DOWNSTREAM AT BOLLOL CK (Station Number 41910214)			DRIGGLE DRAGGLE CK AT BOGGABRI (Station Number 41910271)			MAULES CREEK AT DAMSITE (Station Number 419044)			MAULES CREEK AT AVOCA EAST (Station Number 419051)			NAMOI RIVER AT GUNNEDAH (Station Number 419001)		
		Aquatic Ecosystems	Primary Industries	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile
pH		6.5 to 7.5	5.0 to 9.0	7	7.70	ID	1	6.99	ID	42	7.7	8.0	132	7.56	7.90	627	8.06	8.30
Electrical Conductivity	µS/cm	30 to 350	-	7	348	ID	1	117	ID	44	537	635	133	351	380	819	497	647
Dissolved Oxygen	mg/L	-	-	6	3.85	ID	1	5.84	ID	0	ID	ID	19	3.79	6.34	159	7.12	8.20
Turbidity	NTU	2 to 25	-	6	304	ID	0	ID	ID	35	21	14.2	124	13.5	13.0	692	67.3	50.0
Alkalinity (as Bicarbonate)	mg/L	-	-	0	ID	ID	0	ID	ID	0	ID	ID	7	141	ID	158	204	238
Ammonia as N (Total)	mg/L	2.3	0.03	0	ID	ID	0	ID	ID	0	ID	ID	0	ID	ID	138	0.05	0.05
Boron	mg/L	1.3	5	0	ID	ID	0	ID	ID	0	ID	ID	5	0.04	ID	17	0.08	0.12
Calcium	mg/L	-	1000	0	ID	ID	0	ID	ID	0	ID	ID	7	29	ID	89	37	45
Chloride	mg/L	-	-	0	ID	ID	0	ID	ID	0	ID	ID	7	24	ID	158	40	54

Table 5 Regional Water Quality Summary (Continued)

Parameter	Units	ANZECC Guidelines		BARBERS DOWNSTREAM AT BOLLOL CK (Station Number 41910214)			DRIGGLE DRAGGLE CK AT BOGGABRI (Station Number 41910271)			MAULES CREEK AT DAMSITE (Station Number 419044)			MAULES CREEK AT AVOCA EAST (Station Number 419051)			NAMOI RIVER AT GUNNEDAH (Station Number 419001)		
		Aquatic Ecosystems	Primary Industries	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile
Fluoride	mg/L	-	-	0	ID	ID	0	ID	ID	0	ID	ID	0	ID	ID	16	0.25	0.33
Iron	mg/L	-	0.01	0	ID	ID	0	ID	ID	0	ID	ID	1	0.05*	ID	21	0.07*	0.05*
Magnesium	mg/L	-	15	0	ID	ID	0	ID	ID	0	ID	ID	7	11.0	ID	89	23.2	28.3
Nitrate as N	mg/L	17	50	0	ID	ID	0	ID	ID	0	ID	ID	7	0.29	ID	90	0.44	0.42
Total Nitrogen	mg/L	0.25	-	0	ID	ID	0	ID	ID	0	ID	ID	48	0.43*	0.55*	381	0.72*	0.90*
Total Phosphorus	mg/L	0.02	-	0	ID	ID	0	ID	ID	0	ID	ID	53	0.15*	0.17*	526	0.14*	0.17*
Potassium	mg/L	-	-	0	ID	ID	0	ID	ID	0	ID	ID	7	1.71	ID	158	2.83	3.70
Silica	mg/L	-	-	0	ID	ID	0	ID	ID	0	ID	ID	2	16.0	ID	61	3.1	4.7

Table 5 Regional Water Quality Summary (Continued)

Parameter	Units	ANZECC Guidelines		BARBERS DOWNSTREAM AT BOLLOL CK (Station Number 41910214)			DRIGGLE DRAGGLE CK AT BOGGABRI (Station Number 41910271)			MAULES CREEK AT DAMSITE (Station Number 419044)			MAULES CREEK AT AVOCA EAST (Station Number 419051)			NAMOI RIVER AT GUNNEDAH (Station Number 419001)		
		Aquatic Ecosystems	Primary Industries	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile	*Count*	Average	80th Percentile
Sodium	mg/L	-	-	0	ID	ID	0	ID	ID	0	ID	ID	7	29	ID	158	37	46
Sulphate (SO_4)	mg/L	-	1000	0	ID	ID	0	ID	ID	0	ID	ID	7	17	ID	158	43	59
Zinc	mg/L	0.031	0.005	0	ID	ID	0	ID	ID	0	ID	ID	1	0.02	ID	3	0.015	ID

* Apparently erroneous values which are both isolated and inconsistent with all other observations (i.e. orders of magnitude higher) were not used in the statistical calculations.

µS/cm = microSiemens per centimetre.

mg/L = milligrams per litre.

NTU = nephelometric turbidity unit.

2.7.2 Surface Water Quality Characteristics of Local Water Resources

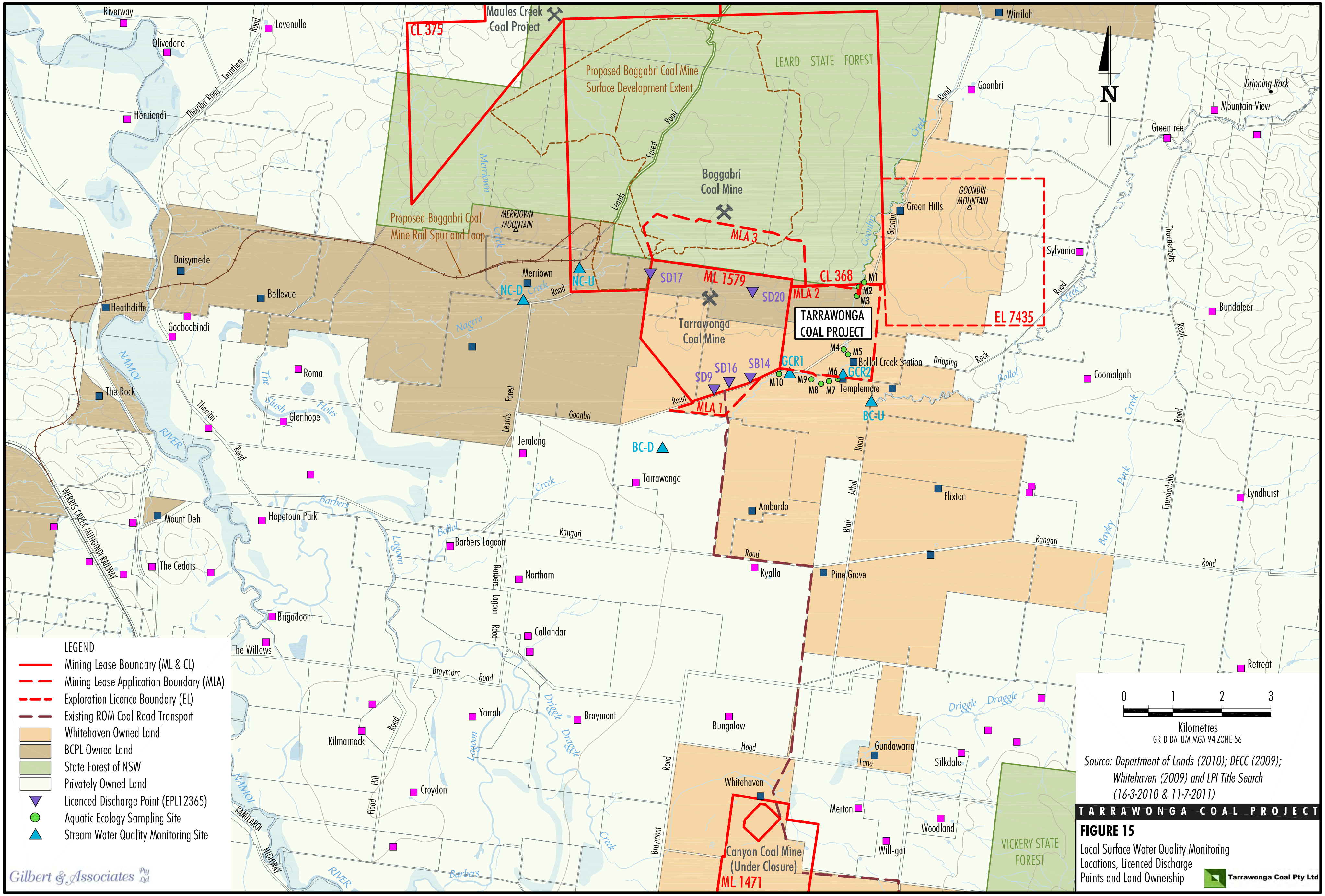
Water quality sampling has been conducted on Nagero and Bollol Creeks upstream and downstream of past mining activities. The monitoring site locations are shown on Figure 15. Both Nagero Creek and Bollol Creek have been predominantly dry since mining commenced due to drought and there have been relatively few opportunities to collect samples during the period since monitoring was initiated. Results of the water quality monitoring for these creeks are summarised in Tables 6, 7, 8 and 9 below.

Table 6 Monitoring Data Summary - Nagero Creek

Reference Guideline		**pH**	**Electrical Conductivity (µS/cm)**	**Total Suspended Solids (mg/L)**	**Grease and Oil (mg/L)**
EPL No. 12365		6.5 to 8.5	n/a	Median <20mg/L, Maximum <50mg/L	10
ANZECC (2000a) Default Aquatic Ecosystem Triggers		6.5 to 8.0	30 to 350^	n/a	n/a
ANZECC (2000a) Default Livestock Drinking Water		n/a	<2,500 (TDS [mg/L])	n/a	n/a
Monitoring Site	**Date**	**pH**	**Electrical Conductivity (µS/cm)**	**Total Suspended Solids (mg/L)**	**Grease and Oil (mg/L)**
NCU	29/12/2009	6.8	95	34	n/a
NCD	22/12/2009	7.8	137	164	19
NCD	29/12/2009	6.7	143	32	n/a

TDS = total dissolved solids.
^ Guideline Limit NSW Upland Rivers.

Results of monitoring on Nagero Creek reported by Parsons Brinkerhoff (2010) are summarised in Table 7 below.



WHC-01-04_EA_SWA_105D

Table 7 Monitoring Data Nagero Creek from Boggabri Coal Mine

Sampling Site	Sampling Date	pH	Electrical Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)
SW1 (Downstream of Mine)	23/9/08	6.7	231	2,070	3.8	0.38
SW1 (Downstream of Mine)	6/10/08	7.4	127	169	3.1	0.29
SW1 (Downstream of Mine)	13/12/08	7.7	174	158	1.2	
SW1 (Downstream of Mine)	17/2/09	7.3	59	160	1.9	0.12
SW2 (Upstream of Mine)	23/9/08	5.9	56	99	0.7	0.19
SW2 (Upstream of Mine)	6/10/08	7.0	72	32	0.6	0.13
SW2 (Upstream of Mine)	13/12/08	7.8	86	66	0.8	
SW2 (Upstream of Mine)	17/2/09	7.1	33	110	0.5	0.11

The available data for Nagero Creek indicate that it has been characterised by near neutral pH and low salinity. There have been a few samples which have had elevated suspended solids and one with elevated oil and grease concentration compared to the EPL limit values.

Table 8 Monitoring Data Summary - Bollol Creek

Reference Guideline		pH	Electrical Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Grease and Oil (mg/L)
EPL No. 12365		6.5 to 8.5	n/a	Median <20mg/L, Maximum <50mg/L	10
ANZECC (2000a) Default Aquatic Ecosystem Triggers		6.5 to 8.0	30 to 350^	n/a	n/a
ANZECC (2000a) Default Livestock Drinking Water		n/a	<2500 (TDS)	n/a	n/a
Monitoring Site	**Date**	**pH**	**Electrical Conductivity (µS/cm)**	**Total Suspended Solids (mg/L)**	**Grease and Oil (mg/L)**
BCU	23/09/2008	6.8	95	92	<2
BCU	22/12/2009	7.32	150	220	n/a
BCD	5/09/2008	7.2	75	150	<2
BCD	23/09/2008	6.7	115	107	<2
BCD	15/12/2008	6.9	135	30	<2
BCD	22/12/2009	7.04	146	32	n/a
BCD	29/12/2009	6.88	75	47	n/a

^ Guideline Limit NSW Upland Rivers.

The available data for Bollol Creek indicate that it has been characterised by near neutral pH and low salinity. It has been moderately elevated in suspended solids compared to the EPL limit values.

Table 9 Monitoring Data Summary - Goonbri Creek

Reference Guideline		pH	Electrical Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Grease and Oil (mg/L)
EPL No. 12365		6.5 to 8.5	n/a	Median <20mg/L, Maximum <50mg/L	10
ANZECC (2000a) Default Aquatic Ecosystem Triggers		6.5 to 8.0	30 to 350^	n/a	n/a
ANZECC (2000a) Default Livestock Drinking Water		n/a	<2500 (TDS)	n/a	n/a
Monitoring Site	**Date**	**pH**	**Electrical Conductivity (µS/cm)**	**Total Suspended Solids (mg/L)**	**Grease and Oil (mg/L)**
GCR1	29/12/2009	7.02	60	38	n/a
GCR2	12/5/2011	7.27	531	904	<5
M1	3/1/2011	6.5	174	n/a	n/a
M2	3/1/2011	6.4	168	n/a	n/a
M3	3/1/2011	6.4	181	n/a	n/a
M4	3/1/2011	6.5	187	n/a	n/a
M5	3/1/2011	6.4	180	n/a	n/a
M6	3/1/2011	6.3	209	n/a	n/a
M7	3/1/2011	6.3	372	n/a	n/a
M8	3/1/2011	6.2	180	n/a	n/a
M9	3/1/2011	6.4	198	n/a	n/a
M10	3/1/2011	6.4	191	n/a	n/a

^ Guideline Limit NSW Upland Rivers.

The available data for Goonbri Creek indicate that it has also been characterised by near neutral pH and variable but generally low salinity. There has been one moderately high electrical conductivity reading and one high suspended solids concentration recorded relative to the EPL limit values.

Samples collected from Nagero, Bollol and Goonbri Creeks were also analysed for metals and bulk nutrients. Results of these analyses are summarised in Table 10 below.

Apart from Total Aluminium, metal concentrations were below ANZECC default guideline values for protection of aquatic ecosystems. Nutrients however were high relative to the default guideline values.

Table 10 Summary of Metal and Nutrient Analysis Results – Nagero, Bollol and Goonbri Creeks

Chemical Constituent	Monitoring Location	GCR2	NC-U	NC-U	NC-D	NC-D	BC-U	BC-D	BC-D
	Date	12/5/11	4/1/10	15/2/10	4/1/10	15/2/10	15/2/10	4/1/10	15/2/10
	ANZECC (2000a) Default Aquatic Ecosystem Triggers at 95% of Species Protection								
As (mg/L)	0.024	0.008							
Al (mg/L)	0.055 (pH >6.5)		6.01	5.99	4.4	36.5	2.16	0.57	2.53
Mn (mg/L)	1.9		0.34	0.042	0.648	0.368	0.045	0.106	0.129
Se (mg/L)	0.011	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe (mg/L)	n/a		6.17	4.22	3.94	23.2	1.68	0.64	1.79
Nitrates (mg/L)	0.7		2.82	0.1	<0.01	0.42	0.2	<0.01	0.02
TKN (mg/L)	n/a		2.4	1.2	3.2	2.6	1.2	3	1.5
TN (mg/L)	0.25*		5.2	1.3	3.2	3	1.4	3	1.5
TP (mg/L)	0.02*		0.18	0.16	0.41	0.78	0.36	0.65	0.22
Sb (mg/L)	n/a	<0.001							
Mo (mg/L)	n/a	<0.01							

* Guideline Limit NSW Upland Rivers.

Water quality has also been monitored in site water management storages in accordance with the TCM sampling program. The available data from this program, which are summarised in Tables 11 and 12 below, illustrates the characteristics of mine site water quality. Results of the monitoring indicate that mine and sediment dam water has generally been slightly alkaline and characterised by variable and sometimes elevated salinity in relation to ANZECC default guideline values. Mine water (water which has contacted active mine areas – refer Section 4.2.1) and storages affected by mine water have tended to have higher salinity (average 2,396 – 2,719 µS/cm) than storages receiving runoff from mine waste rock and other disturbed areas (average 363 – 983 µS/cm). Results of laboratory analysis for metals indicate mine waters have generally been low or similar to the ANZECC default guideline values for protection of aquatic ecosystems.

Water quality monitoring is undertaken during rainfall events, the results of which are summarised in Tables 13 and 14 below.

Table 11 Project Site Monitoring Data Summary

Reference Guideline		pH				Electrical Conductivity (µS/cm)				Total Suspended Solids (mg/L)				Grease and Oil (mg/L)			
EPL No. 12365		6.5 to 8.5				n/a				Median <20mg/L, Maximum <50mg/L				10			
ANZECC (2000a) Default Aquatic Ecosystem Triggers		6.5 to 8.0				30 to 350*				n/a				n/a			
ANZECC (2000a) Default Livestock Drinking Water		n/a				<2500 (TDS)				n/a				n/a			
Monitoring Site	**# Samples**	**Min**	**Max**	**Ave**	**Med**	**Min**	**Max**	**Ave**	**Med**	**Min**	**Max**	**Ave**	**Med**	**Min**	**Max**	**Ave**	**Med**
Pit Water^	11	7.1	8.9	8.1	8.2	78	3970	2445	2420	10	293	86	27	<2	30	6.5	3.5
SD1	3	7.5	8.6	ID	ID	540	990	ID	ID	23	524	ID	ID	<2	<5	ID	ID
SD2	2	7.8	8.5	ID	ID	395	610	ID	ID	102	290	ID	ID	<2	2	ID	ID
SB4	1	8.7				1980				31				<2			
SB5	10	7.8	8.9	8.4	8.6	531	1210	983	1070	7	77	35	29	<2	13	5	2
SD5	5	6.5	8.7	8.1	8.4	930	3750	2396	2620	8	144	50	35	<2	<2	<2	<2
SB7	8	7.5	8.7	8.2	8.3	197	560	363	352	10	387	103	50	<2	13	6	5
SD8	14	6.8	8.9	8.4	8.5	190	1450	734	750	5	173	37	25	<2	6	2	2
SB16	7	7.2	9.2	8.9	8.7	674	1440	1064	1085	6	24	15	14	<2	<5	4	5
SD6	1	7.5				310				104				<2			

^Receives mine water.
ID Insufficient data.
* Guideline Limit NSW Upland Rivers.

Table 12 Summary of Project Site Metal and Nutrient Analysis Results

Chemical Constituent	Monitoring Location		SD1	SB5	MV1	SD8	SD9	SD5	Pit Water	SD16	SD14	SD17	SB16	Pit
	Date		25/7/07	25/7/07	25/7/07	25/7/07	25/7/07	25/7/07	8/9/10	4/8/11	4/8/11	4/8/11	4/8/11	4/8/11
	ANZECC (2000) Default Aquatic Ecosystem Triggers at 95% of Species Protection	ANZECC (2000) Default Livestock Drinking Water Triggers at a Low Risk Level												
Cl (mg/L)	0.03	n/a	170	195	656	21	21	603	256					492
SO_4 (mg/L)	n/a	1000	67	82	271	17	3	198						
Ca (mg/L)	n/a	1000	18	20	83	7.9	7	31						
Mg (mg/L)	n/a	n/a	8.3	14	54	9.7	8.8	46						
Na (mg/L)	n/a	n/a	186	197	481	49	53	641	362					621
K (mg/L)	n/a	n/a	5.4	8.4	34	13	13	30						
As (mg/L)	0.024	0.5	0.005	0.007	<0.001	0.007	0.005	0.001	0.009	0.002	0.001	0.002	0.002	0.015
Cd (mg/L)	0.0002	0.01	0.00009	0.00038	0.00009	0.00017	0.00006	<0.00005						
Cr (mg/L)	0.001	1	0.002	0.001	<0.001	0.017	0.011	<0.001						
Cu (mg/L)	0.0014	0.4 (Sheep) 1 (Cattle) 5 (Pig) 5 (Poultry)	0.003	0.002	0.002	0.012	0.009	0.001						
Hg (mg/L)	0.0006	0.002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001						
Ni (mg/L)	0.011	1	0.004	0.004	0.014	0.021	0.014	0.005						
Pb (mg/L)	0.0034	0.1	0.0006	0.0006	0.0003	0.0078	0.0057	<0.0002						
Zn (mg/L)	0.08	20	<0.005	0.009	0.012	0.033	0.018	<0.005						
Al (mg/L)	0.055 (pH >6.5)	5							0.35					0.97
Mn (mg/L)	1.9	Not sufficiently toxic							0.078					34
Se (mg/L)	0.011	0.02								<0.01	<0.01	<0.01	<0.01	
Fe (mg/L)	n/a	Not sufficiently toxic							0.08					0.33
Sb (mg/L)	n/a	n/a								<0.001	<0.001	<0.001	0.004	
Mo (mg/L)	n/a	0.15								0.011	0.003	0.006	0.028	

Table 13 Summary of Water Quality for Licensed Discharge Points During Events

Reference Guideline		pH				Electrical Conductivity (µS/cm)				Total Suspended Solids (mg/L)				Grease and Oil (mg/L)**			
EPL No. 12365		6.5 to 8.5				n/a				Median <20mg/L, Maximum <50mg/L				10			
ANZECC (2000a) Default Aquatic Ecosystem Triggers		6.5 to 8.0				30 to 350*				n/a				n/a			
ANZECC (2000a) Default Livestock Drinking Water		n/a				<2500 (TDS)				n/a				n/a			
Monitoring Site	**# Samples**	**Min**	**Max**	**Avg**	**Med**	**Min**	**Max**	**Avg**	**Med**	**Min**	**Max**	**Avg**	**Med**	**Min**	**Max**	**Avg**	**Med**
SD9 (dp)^	6	7.1	7.8	7.3	7.3	55	220	118	113	22	78	52	54	<2	5	4	5
SB14 (dp)^	10	6.8	8.4	6.8	7.6	74	570	245	255	30	2630	458	139	<2	33	8	5
SD16 (dp)^	9	7.3	8.8	8.0	8.0	633	857	761	748	6	263	70	45	<5	9	6	5
SD17 (dp)^	4	7.3	7.9	ID	ID	232	425	ID	ID	152	1020	ID	ID	<2	5	ID	ID
SD20 (dp)^	0	ID				ID				ID				ID			

(dp)^ EPL Licensed discharge point

* Guideline Limit NSW upland rivers

** Reported concentration taken as maximum

Table 14 Summary of Water Quality for Receiving Waters During Events

Reference Guideline		pH				Electrical Conductivity (µS/cm)				Total Suspended Solids (mg/L)				Grease and Oil (mg/L)**			
EPL No. 12365		6.5 to 8.5				n/a				Median <20mg/L, Maximum <50mg/L				10			
ANZECC (2000) Default Aquatic Ecosystem Triggers		6.5 to 8.0				30 to 350*				n/a				n/a			
ANZECC (2000) Default Livestock Drinking Water		n/a				<2500 (TDS)				n/a				n/a			
Monitoring Site	**# Samples**	**Min**	**Max**	**Avg**	**Med**	**Min**	**Max**	**Avg**	**Med**	**Min**	**Max**	**Avg**	**Med**	**Min**	**Max**	**Avg**	**Med**
NCU	6	6.6	8.1	7.2	7.2	26	181	76	56	24	1940	510	130	4	5	5	5
NCD	7	6.5	7.6	7.1	7.0	65	379	150	132	29	314	133	79	<2	5	5	5
BCU	6	6.7	7.2	6.9	6.8	63	275	145	143	20	616	167	70	<2	5	3	2
BCD	13	6.2	8.3	7.0	6.7	77	152	113	110	5	85	39	39	<2	22	6	5

* Guideline Limit NSW upland rivers

** Reported concentration taken as maximum

2.7.3 Geochemical Characteristics of Mine Waste Rock

An investigation of the environmental geochemical characteristics of the mine waste rock at the TCM and for the Project was conducted by Geo-Environmental Management Consultants (2011) and is reported in Appendix N of the EA. Results of these investigations indicate that the overburden from the proposed eastern and northern pit extension areas are generally expected to be non-acid forming and present a low salinity risk. The investigations conducted by Geo-Environmental Management Consultants led to the conclusion that a relatively high proportion of the overburden from the proposed extension areas is likely to be moderately or highly sodic and therefore dispersive. If these materials were left exposed on the waste rock emplacement surfaces (or final pit walls) they may become highly dispersive causing problems with increased erosion and impacting water quality due to increased total suspended solids. Geo-Environmental Management Consultants also reported that arsenic (As), molybdenum (Mo) and selenium (Se) in overburden materials was likely to be slightly soluble under the prevailing near-neutral pH conditions.

Based on these findings the following recommendations were made in relation to water management Geo-Environmental Management Consultants, 2011):

1. It was recommended that in order to ensure long-term waste rock emplacement stability and erosion control, and to help with maintaining the quality of the site water, the final waste rock emplacement surfaces (top and batter slopes) will need to be treated with gypsum and/or constructed of material that is known to be non-sodic or only have low sodicity. It is therefore recommended that a sufficient quantity of suitable material be identified prior to completion of the waste rock emplacements which can either make-up the final lift of each waste rock emplacement or can be placed as a cover over the completed waste rock emplacements.
2. It was recommended that the water quality monitoring program for the potentially impacted areas include the following parameters: pH, electrical conductivity, total suspended solids, total alkalinity/acidity, SO_4, As, Se, and Mo.

2.8 Surface Water Users

Water in Nagero Creek is currently used by property owners along Therribri Road, Manilla Road, and Leard State Forest Road for stock water purposes (Parsons Brickerhoff, 2010).

Overland flow on the alluvial flats is also used opportunistically by local landholders for stock watering under basic landholder rights and the water harvesting limits applied to landholders in the region.

3 SURFACE WATER LICENSING

3.1 Existing Licence Holders

Information provided by NOW confirms that, at the time of writing, there had been no records of water extraction or access licences having been issued on Nagero, Bollol or Goonbri Creeks. There are however extensive water access licences in force on the Namoi River under the Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources as discussed below.

3.2 Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources 2003

A water sharing plan (the Plan) for the Namoi River regulated water sources has been enacted under the NSW *Water Management Act 2000*. The Plan was implemented by the then Department of Infrastructure, Planning and Natural Resources and is administered by NOW.

The Plan provides the detailed rules by which water is preserved for basic landholder uses and the environmental needs of the river, and by which the water available for extraction is shared amongst access licence holders. The Plan contains the rules for managing water allocation accounts, trading of licences and the making of water allocations under the different classes of licence.

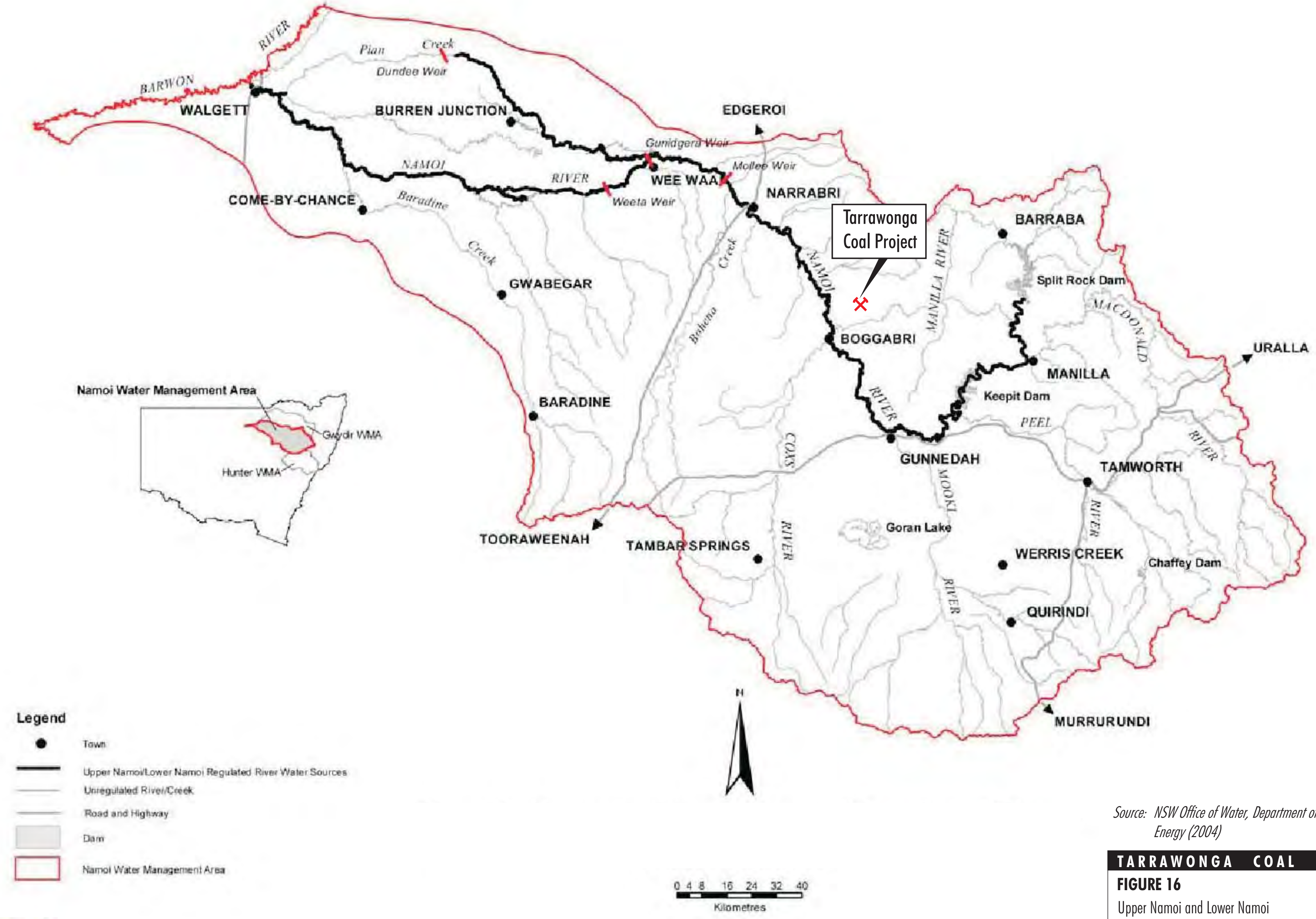
The Plan applies to two water sources – the Upper Namoi Regulated River Water Source and the Lower Namoi Regulated River Water Source. The Lower Namoi includes the regulated river sections downstream of Keepit Dam to the Barwon River, including the regulated sections of the Namoi River downstream of the TCM (Figure 16). The Plan however does not explicitly cover the unregulated tributaries which flow from the mine site area (Nagero, Goonbri or Bollol Creeks). Because the Project would not involve extraction between the banks of any regulated rivers, the Upper Namoi and Lower Namoi Regulated River Water Sharing Plan is not applicable to the Project.

3.3 Draft Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources

The Project is located within the Maules Creek Tributaries Management Zone defined in the Draft Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2011.

The Draft Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2011 is currently on public exhibition until 2 December 2011 and is anticipated to be commenced in mid-2012 (NOW website, 2011).

The Project would involve capture and use of water from on site dams. Until such time that a Water Sharing Plan is commenced for these activities, they come under the *Water Act 1912*. Pursuant to Section 22BA of the *Water Act, 1912* an embargo on any further applications for water licences for works to which Part 2 of the *Water Act, 1912* extends was declared on 16 March 2006 for the Murray-Darling Basin.



Source: NSW Office of Water, Department of Water and Energy (2004)

Gilbert & Associates Pty Ltd

TARRAWONGA COAL PROJECT

FIGURE 16

Upper Namoi and Lower Namoi Regulated River Water Source

Tarrawonga Coal Pty Ltd

WHC-10-04 EA SWA_002A

The following were declared works to which Part 2 of the *Water Act, 1912* does not extend on 23 March 2011 pursuant to section 5(1) of the *Water Act, 1912*:

a) *Dams solely for the control or prevention of soil erosion, provided no water is reticulated or pumped from such dams and the size of the structure is the minimum necessary to fulfil the erosion control function, and provided such dams are not located on a river (as defined in Part 2 of the* Water Act 1912 *as amended from time to time) or a lake…*

…

c) *Dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a Government agency or Local Government Council to prevent the contamination of a water source, provided such dams are not located on a river (as defined in Part 2 of the* Water Act 1912 *as amended from time to time) or a lake.*

…

h) *Works authorised under section 54 of the* Water Management Act 2000 *for the capture and use of the harvestable right.*

The existing and proposed sediment control dams are consistent with works described in Section 5(1) (a) and the proposed mine water dams are consistent with works described in Section 5(1) (c) of the *Water Act, 1912*.

An assessment of water capture and re-use on site in relation to the NSW harvestable rights policy is provided below.

Whitehaven owns a total of 3,354 hectares (ha) of land in the Nagero, Goonbri and Bollol catchments (509 ha in Nagero catchment and 2,845 ha in Goonbri/Bollol catchment). Applying the NOW's method for calculating the maximum harvestable right (NOW, 2011b), a harvestable right multiplier value of 0.07 ML/ha is applicable to the Project location. This results in a total maximum harvestable right of 235 ML for Whitehaven (36 ML for Nagero catchment and 199 ML for Goonbri/Bollol catchment).

Table 15 below details the capacities for each storage (existing and proposed) as well as whether or not that storage is to be included in the harvestable right capacity as a result of exemptions in Section 5(1) of the *Water Act, 1912*.

Table 15 Summary of Dams Included in Harvestable Right Capacity

Storage	Capacity (ML)	Storage included in Harvestable Right Capacity – where not excluded under Section 5(1) of the *Water Act, 1912*	Contribution to Harvestable Right Capacity (ML)
MWD2	21.4	×(Dam for contaminant capture)	0
MWSS (East)	1050.0	×(Dam for contaminant capture)	0
(West)	580.0	×(Dam for contaminant capture)	0
SB(N1)	59.1	×(Dam for contaminant capture)	0
SB(N2)	6.4	× (Sediment dam not used for water extraction)	0
SB(N3)	15.3	× (Dam for contaminant capture)	0
SB6	0.8	× (Sediment dam not used for water extraction)	0
SB7	4.6	× (Sediment dam not used for water extraction)	0
SB14(R)	30.4	× (Sediment dam not used for water extraction)	0
SB21(R)	1.6	× (Dam for contaminant capture)	0
SB23	29.5	× (Sediment dam not used for water extraction)	0
SB24	1.6	× (Dam for contaminant capture)	0
SD8	3.9	× (Dam for contaminant capture)	0
SD9(R)	24.3	× (Dam for contaminant capture)	0
SD16	21.0	× (Sediment dam not used for water extraction)	0
SD17	62.8	× (Sediment dam not used for water extraction)	0
UWD	191	✓ (Capture and use of catchment runoff)	191
TOTAL	**2103.7**		**191**

4 OPERATIONAL SURFACE WATER MANAGEMENT

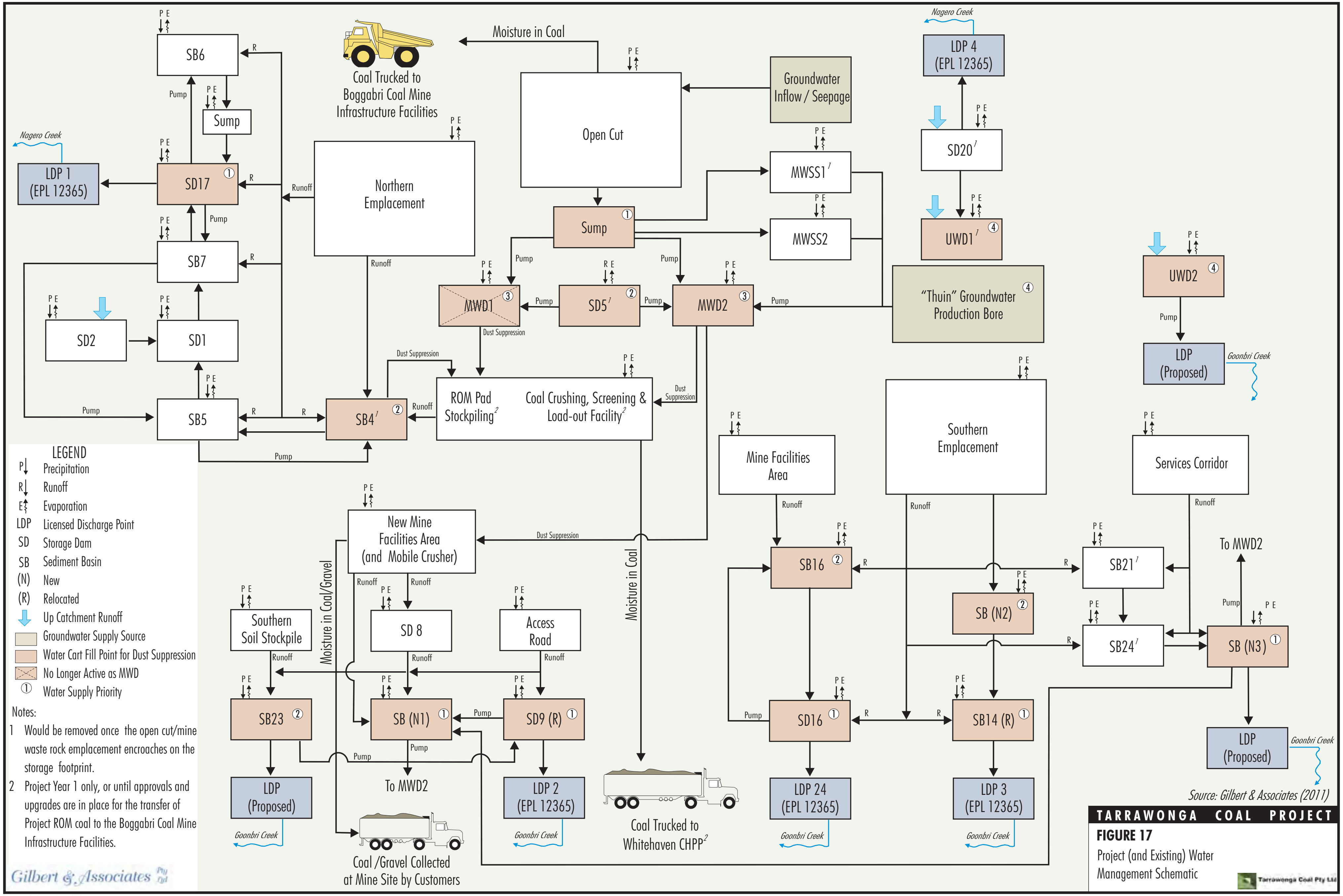
Accepted best practice principles for mine site water management have been applied to the development of the water management system covering the Project life. These principles include avoiding, to the maximum extent practical, the contamination of water as a result of mining activities, minimising the use of imported water and minimising changes to the flow regimes of downstream waters. Integration of these principles to the water management system has resulted in:

- minimising the disturbance of land to the maximum extent practical and progressive and ongoing isolation and diversion of clean water runoff around mine disturbed areas to downstream receiving waters;
- containment and preferential use of mine water and disturbed area runoff from the project site to meet dust control and crusher operational requirements; and
- management protocols which see rapid progressive rehabilitation activities on mine waste rock emplacement areas and other areas disturbed by mining and the passive management of runoff (i.e. allowing runoff to drain off site from sediment dams which are not actively dewatered between rainfall events) after they have become stabilised by vegetation. Runoff from rehabilitated areas that have been reshaped, topsoiled and seeded, but where vegetation has not yet become sufficiently well established to enable uncontrolled release, would be actively managed via sediment control storages.

These initiatives are consistent with the existing water management system.

Section 4.1 provides a description of the existing water management system, while Section 4.2 describes the proposed changes to the water management system as part of the Project. A schematic of the Project water management system is shown in Figure 17.

The permanent Goonbri Creek alignment is detailed in Section 6 while Section 4.8 addresses drainage management associated with the mine waste rock emplacements.



LEGEND

- P Precipitation
- R Runoff
- E Evaporation
- LDP Licensed Discharge Point
- SD Storage Dam
- SB Sediment Basin
- (N) New
- (R) Relocated
- Up Catchment Runoff
- Groundwater Supply Source
- Water Cart Fill Point for Dust Suppression
- No Longer Active as MWD
- ① Water Supply Priority

Notes:

1 Would be removed once the open cut/mine waste rock emplacement encroaches on the storage footprint.

2 Project Year 1 only, or until approvals and upgrades are in place for the transfer of Project ROM coal to the Boggabri Coal Mine Infrastructure Facilities.

Gilbert & Associates Pty Ltd

WHC-10-04 EA SW_003D

Source: Gilbert & Associates (2011)

TARRAWONGA COAL PROJECT

FIGURE 17

Project (and Existing) Water Management Schematic

Tarrawonga Coal Pty Ltd

4.1 Existing Water Management System

The existing water management infrastructure comprises a mine water dam and a series of sediment dams, sediment basins and drains used for controlling sediment-laden runoff from the Project area. Drainage works have been constructed to divert 'clean' water around the site or away from mine disturbed areas. Runoff from mine disturbed areas is collected in sediment basins where suspended sediments are allowed to settle out of the water column. Mine water is stored in a mine water dam. Water which accumulates in these storages is used for dust suppression or coal crushing and screening activities on-site. During extended wet periods controlled discharge occurs from Licensed Discharge Points (LDPs) at sediment dams SD20, SD17, SD16, SD9, and sediment basin SB14 – refer Figure 17.

The main components of the existing water management system are:

- A 'dirty' water collection drain along the northern perimeter of ML 1597 intercepts drainage from disturbed areas in the northern part of the mine site. The drain conveys this water in a westerly direction to SB6 which is located in the north-western corner of ML 1597. SB6 overflows to a sump and then to SD17 which is a LDP.
- Runoff from the rehabilitated western flank of the northern out-of-pit overburden emplacement is conveyed via a series of drains and a drop structure to SB7 and SD17. SB7 overflows to SD17 which is a LDP.
- A dirty water drain has been constructed on the western side of the main internal access road. The drain intercepts runoff from the road and channels it in a southerly direction to SD9 which is a LDP.
- A system of 'dirty' water banks and drains at the toe of the western slopes of the southern overburden emplacement are used to intercept runoff from overburden emplacements and direct it to SB16 and SB14 and ultimately to SD16, which is a LDP. Runoff intercepted from the southern slopes of the southern overburden emplacement is directed to SD16 or SB14 which are both LDPs.

Under the approved, revised Site Water Management Plan (Whitehaven, 2011), all drainage management structures are to be constructed prior to the commencement of surface disturbance activities in the particular area. Design of these structures is to be based on Landcom (2004) guidelines. All sediment control structures have been designed to accommodate a minimum of a 10 year ARI rainfall event (Whitehaven, 2011).

Water for dust suppression is sourced from 'dirty' water runoff collected on-site. Any shortfall is supplemented with 'clean' water. The main source of water for crushing operations and dust suppression is from the mine water dam and SB4.

Water captured in the open cut originates from coal seam inflows and contributing catchment runoff. Captured water is allowed to settle in an in-pit collection sump which has a nominal capacity of about 5 ML. Water which collects in the sump is pumped (if necessary) to the existing mine water dam, which is located near the coal crusher.

Alternatively, if in-pit water can be retained in in-pit sumps without impacting on mining operations, it will remain in pit for collection by water carts and subsequent use for haul road dust suppression. Make-up water if required is sourced from surface water collection and a licensed production bore.

As a result of an approval to modify the TCM in October 2010, the following drainage and sediment and erosion controls have been approved and are being implemented as the mine progresses:

- Sediment Basin SB22 east of the open cut;
- Sediment Basin SB21 to be constructed to collect runoff from the north-eastern portion of the expanded southern emplacement;
- construction of additional contour banks and the extension of the ‘dirty’ water collection drain along the northern perimeter of the ML 1597 boundary;
- Sediment Basin SB23 has been constructed south of the topsoil stockpile to collect runoff from the stockpile area catchment;
- a new mine water dam is being constructed south of the existing mine facilities and adjacent to the western side of the southern emplacement;
- Sediment Basin SB24 to capture overflow from SB21 to enhance solids settling prior to offsite licensed discharge; and
- Sediment Dam SD18 north of SB24 to capture clean water from the clean water diversion drain.

4.2 Proposed Project Water Management System

The proposed Project water management system would retain most of the elements of the existing system. Additional components would be constructed and some elements of the existing system would be decommissioned as they became redundant during the life of the Project. The following additional components would be required:

- sediment dams and drains to manage runoff from relocated Mine Facilities Area (i.e. SD9(R) and SB(N1));
- progressive installation of diversions to direct runoff from both the Northern and Southern Emplacements to sediment dams/basins;
- construction of two[5] Up-catchment Water Dams (UWDs) during the mine life such that runoff upslope of the pit is captured and either pumped to Goonbri Creek or used for water supply if required;
- construction of a Mine Water Dam and two Mine Water Surge Storages (MWSSs) or an in-pit storage during the mine life such that the mine pit can be efficiently dewatered and mine water securely contained on site;
- construction of a temporary flood bund along Goonbri Creek to ensure pit protection prior to the development of the permanent Goonbri Creek alignment; and
- development of the permanent Goonbri Creek alignment (refer to Section 6).

4.2.1 Approach and Design Criteria

Objectives of site water management are:

- protect the integrity of local and regional water resources;
- operate such that there are no releases of mine water off-site;
- maintain separation between runoff from undisturbed, rehabilitated and mining related areas; and
- provide a reliable source of water for dust suppression and crushing operations.

Based on the results of past monitoring and the results of the environmental geochemical assessments, water on the site has been classified into one of the following 4 types:

1. Undisturbed area runoff – being runoff from catchments which are undisturbed by mining activities and which are, to the maximum extent possible, allowed to flow unhindered to their natural receiving waters downstream. Where these areas have to be intercepted they would be diverted to downstream receiving waters.

[5] It is proposed that an initial UWD would be replaced by a second dam as mining progresses.

Drainage management for undisturbed catchments includes a combination of permanent structures that may continue to operate post closure and temporary structures (e.g. sediment control structures). Temporary upslope diversion drains would continue to be constructed over the life of the Project to divert runoff from undisturbed areas around the open pit. Permanent upslope diversion drains would be constructed around the final void. The project surface water management system would include diversion of runoff via the permanent Goonbri Creek alignment (refer Section 6).

2. Runoff from stabilised rehabilitated mine areas – being runoff from rehabilitated mine areas that have established stable vegetation cover and where runoff has similar water quality characteristics to areas that are undisturbed by mining activities. The water management system is based on managing the runoff from these areas in the same way as runoff from undisturbed areas.

3. Disturbed area runoff including inactive and partially rehabilitated areas. These include haul roads, hardstand and partially rehabilitated areas in the process of achieving vegetation stability. The water quality characteristics from these areas are assumed to meet the appropriate requirements of a discharge licence (EPL) following active management in the sediment control system. Runoff from the mine infrastructure area would be treated via an oil-water separator. Water quality data from storages collecting runoff from partially rehabilitated areas of the existing operations indicates that it is likely to have low salinity and be near neutral in pH but may have elevated sediment concentrations. Water captured from partially rehabilitated areas would be stored in receiving sediment dams/basins until suspended solids have settled out. Sediment dams/basins are designed to capture runoff from a 90th percentile rainfall event with a duration of 5 days (Landcom, 2004 and DECCW, 2008), after which time it is assumed water can be pumped out via the nominated LDP.

4. Mine and mine affected water – would comprise water extracted from the pit and water from active mine waste rock areas. Based on results of site water quality monitoring conducted to date, mine pit water and (to a lesser degree) runoff from active mine waste rock is likely to have elevated salinity levels and is unlikely to be suitable for uncontrolled release. The water management plan is based on containing and re-using this water on site.

4.2.2 Progressive Development of the Water Management System

Figure 3 to Figure 8 show the proposed progressive development of the Project. Water management structures such as dams and drains are detailed on each figure and how these vary over the mine life in order to allow for the development of both the pit and progressive rehabilitation of waste rock areas.

4.2.2.1 Year 2 Mine Layout

Figure 3 shows the proposed development as at 2014 (Year 2). At this stage the mine pit would be advancing eastwards with runoff from rehabilitated and partially rehabilitated mine waste rock catchment areas directed to SB6, SB7 and SD17 in the west via batter drains and drop structures. Runoff from active waste rock emplacement areas, including the southern batter of Boggabri Coal's mine waste rock emplacement would be directed back towards the mine pit, where practicable. For the purposes of this assessment, it has been assumed that runoff reporting to SB6, SB7 and SD17 would be used for dust suppression or, at times when stored water exceeded those requirements, would be discharged off-site following settling in the sediment dams via a LDP. UWD1 would have been constructed and would capture clean water upslope of the mine pit. Water in UWD1 would be either used for dust suppression or pumped out to Goonbri Creek via a LDP. Water ponding against Boggabri Coal's mine waste rock emplacement to the north of UWD1 would be managed by Boggabri Coal. A MWSS would be located east of the mine pit or an in-pit storage which will store mine affected water during extended wet periods. Runoff from the eastern portion of the services corridor (i.e. east of the Mine Water Dam [MWD2]) would be captured in SB21(R) and SB24. Runoff from the southern emplacement would be captured in a number of sediment dams/basins via batter drains and drop structures. Runoff from a topsoil stockpile located to the west of the new Mine Facilities Area would be captured in SB23. Storage SB(N1) and SD9R would capture runoff from the new Mine Facilities Area. SB(N1) would also capture overflow from SD8 and SB(N3). Water captured in sediment dams would be used for dust suppression or at times when there was excess over the demand, it would be discharged following settlement via a LDP.

4.2.2.2 Year 4 Mine Layout

Figure 4 shows the proposed development as at 2016 (Year 4). The mine pit continues to progress to the east with all runoff from active waste rock (including the southern batter of Boggabri Coal's mine waste rock emplacement) being directed toward the mine pit. Catchments reporting to SB6, SB7 and SD17 would be fully rehabilitated. Runoff captured in SD17 would be passively managed and allowed to release via the LDP. Similarly the southern waste rock emplacement catchments reporting to SB16, SD16, SB(N2) and SB14(R) would be fully rehabilitated and passively managed (i.e. allowed to release via LDPs). Runoff from a portion of partially rehabilitated mine waste rock emplacement east of SB6, would be directed to the abutting Boggabri Coal mine waste rock emplacement via a batter drain.

4.2.2.3 Year 6 Mine Layout

Figure 5 shows the proposed development as at 2018 (Year 6). Over this period the mine would continue to progress eastward with runoff from fully rehabilitated areas being passively managed via LDPs associated with sediment dams. Runoff from active mine waste rock emplacement areas would be directed toward the mine pit. UWD1 would have been decommissioned ahead of the advancing pit and replaced by a new dam (UWD2) located further upslope to the east. The topsoil stockpile area reporting to SB23 would have been reclaimed and the topsoil stockpile area rehabilitated. SB23 would then be servicing only undisturbed and rehabilitated catchment areas and runoff would be passively managed via a LDP.

4.2.2.4 Year 12 Mine Layout

Figure 6 shows the proposed development as at 2024 (Year 12). A central drain would have been developed to direct runoff from the rehabilitated area on top of the mine waste rock emplacement westwards towards SD17. The mine pit would have progressed further east towards Goonbri Creek, mining through the MWSS which would be relocated to west of the Mine Facilities Area or an in-pit storage. Mine progression also means a temporary flood bund would have been constructed to protect the pit against inundation risk during large floods. The permanent Goonbri Creek alignment, which incorporates a long-term flood bund and low permeability sub-surface barrier, would be under construction to the east of the temporary flood bund.

4.2.2.5 Year 16 Mine Layout

Figure 7 shows the proposed development as at 2028 (Year 16). Further rehabilitation of the backfilled northern emplacement would have been completed increasing the catchment area reporting to SD17 which would be passively managed. The mine pit would have intersected the original Goonbri Creek alignment and the associated temporary flood bund. The permanent Goonbri Creek alignment would have been commissioned and would receive flows from the upper Goonbri Creek catchment.

4.2.2.6 Final Landform Layout

Figure 8 shows the post mine landform. The final mine void would occupy an area at the eastern extremity of the workings. The void would form a permanent contained lake with a minimal contributing catchment defined by the Permanent Goonbri Creek flood bund on the eastern side and a runoff drain and permanent flood bund on the western side of the void. Further details on the void water balance are provided in Section 8.1.

The rehabilitated mine landform would comprise an elevated landform comprising gently sloping upper plateau areas and outer batters sloping at 1 vertical to 5 horizontal. The top surface plateau areas comprise seven plateau areas which would drain via a network of wide swale drains to a series of drop structures over the internal and outer batters.

4.2.3 Details of Water Management Storages

Table 16 summarises the capacity, function, inflows, outflows and active life of water management storages.

Table 16 Summary of Water Management Storages

Storage Name	Design Capacity (ML)	Function/Purpose	LDP Period	Rehabilitated Period *(allowed to flow off site)*	End Date	Inflows *(all storages receive Rainfall/Runoff)*	Outflows *(all storages lose water to Evaporation)*
MWD2	21.4	Receive mine water pumped out of the pit, supply the Crusher, Truckfill point	-	-	-	Inflow from SD17 (only if SD17 is unable to pump to LDP) Inflow from Thuin Bore Inflow from mine pit Inflow from MWSS	Crusher Demand Truckfill Demand Irrigation of revegetated areas on Mine Waste Rock Emplacement Outflow to MWSS
MWSS (eastern)*	1050	To provide surge storage store for mine pit dewatering	-	-	31/12/2019	Inflow from mine pit	Outflow to MWD2
MWSS (western)*	580	To provide surge storage store for mine pit dewatering as replacement for MWSS(eastern)	-	-	1/1/2030	Inflow from mine pit	Outflow to MWD2
SB(N1)*	17.3	Capture mine facilities area runoff, Truckfill point	-	-	-	Inflow from SD9(R) Overflow from SD8 Overflow from SB(N3)	Truckfill Demand Overflow to Goonbri Creek
SB(N2)*	7.4	Capture runoff from the Southern Waste Rock Emplacement	-	-	-	-	Overflow to SB14(R)

* New storage.

Table 16 Summary of Water Management Storages (Continued)

Storage Name	Design Capacity (ML)	Function/Purpose	LDP Period	Rehabilitated Period *(allowed to flow off site)*	End Date	Inflows *(all storages receive Rainfall/Runoff)*	Outflows *(all storages lose water to Evaporation)*
SB(N3)*	24.3	Capture runoff from Services Corridor and Northern Waste Rock Emplacement	1/1/2016 To End of mine life	-	-	Inflow from SB24 Overflow from SB24	Overflow to SB(N1)
SB6+	14.7	Capture runoff from the Northern Waste Rock Emplacement	-	-	-	-	Overflow to SD17
SB7+	13.4	Capture runoff from the Northern Waste Rock Emplacement	-	-	-	-	Overflow to SD17
SD17+	21.5	Capture runoff from the Northern Waste Rock Emplacement	1/1/2014 To 1/1/2016	1/1/2016 To End of mine life	-	Overflow from SB6 Overflow from SB7	Outflow to LDP Outflow to MWD2 Overflow to Nagero Creek
UWD*	191.0	Prevent clean water runoff from entering mine pit, truckfill point	Entire mine life	-	-	-	Truckfill Demand Outflow to LDP Overflow to mine pit

* New storage.

\+ The combined capacity of these three storages is currently 12.2 ML. The combined capacity would be increased progressively to 49.6 ML in order to capture runoff from the increased catchment of the Northern Waste Rock Emplacement.

Table 16 Summary of Water Management Storages (Continued)

Storage Name	Design Capacity (ML)	Function/Purpose	LDP Period	Rehabilitated Period *(allowed to flow off site)*	End Date	Inflows *(all storages receive Rainfall/Runoff)*	Outflows *(all storages lose water to Evaporation)*
SB14(R)^	3.1	Capture runoff from the Southern Waste Rock Emplacement	1/1/2016 To 1/1/2018	1/1/2018 To End of mine life	-	Inflow from SB(N2) Overflow from SB(N2) Overflow from SD16	Outflow to LDP Overflow to Goonbri Creek
SB16	8.5	Capture runoff from the Southern Waste Rock Emplacement	-	-	-	-	Outflow to SD16
SB21(R)^	15.7	Capture runoff from Services Corridor and Northern/Southern Waste Rock Emplacements	-	-	1/1/2015	-	Outflow to SB24
SB23	14.6	Capture runoff from Temporary Soil Stockpile	1/1/2016 To 1/1/2018	1/1/2018 To End of mine life	-	-	Outflow to SD9(R) Outflow to LDP Overflow to Goonbri Creek
SB24	18.6	Capture runoff from Services Corridor and Northern/Southern Waste Rock Emplacements	-	-	1/1/2017	Inflow from SB21(R) Overflow from SB21(R)	Outflow to SB(N3) Overflow to SB(N3)

^ Existing storage relocated.

Table 16 Summary of Water Management Storages (Continued)

Storage Name	Design Capacity (ML)	Function/Purpose	LDP Period	Rehabilitated Period *(allowed to flow off site)*	End Date	Inflows *(all storages receive Rainfall/Runoff)*	Outflows *(all storages lose water to Evaporation)*
SD8	2.9	Capture runoff from hardstand area	-	-	-	-	Overflow to SB(N1)
SD9(R)^	14.6	Capture mine facilities area runoff, Truckfill point	-	-	-	Inflow from SB23	Truckfill Demand Outflow to SB(N1) Overflow to Goonbri Creek
SD16	9.3	Capture runoff from the Southern Waste Rock Emplacement	1/1/2016 To 1/1/2018	1/1/2018 To End of mine life	-	Inflow from SB16 Overflow from SB16	Outflow to LDP Overflow to SB14(R)

^ Existing storage relocated.

* New storage.

4.3 System Inflows

Rainfall induced runoff from active mining areas would vary with climatic conditions and the extent of disturbance throughout the Project life. Sediment laden runoff generated during rainfall events from mining areas would be captured in the mine pit or sediment dams/basins.

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 mine pit have been modelled by Heritage Computing (2011) and are presented in Table 17.

Table 17 Predicted Groundwater Inflows

Project Year	Average Predicted Groundwater Inflow Rate (ML/d)
1*	0.40
2	0.55
3	0.60
4	0.63
5	0.60
6	0.50
7	0.46
8	0.60
9	0.69
10	0.69
11	0.57
12	1.11
13	0.91
14	0.85
15	0.97
16	0.89
17	1.03

* Project Year 1 commencing in 2013.
Source: Heritage Computing (2011).

Water that accumulates in mine pit sumps would be accessed by water carts directly, or be transferred to MWD2, and used for dust suppression over Project haul roads. Water for vegetation establishment on partially rehabilitated areas would also be supplied from MWD2.

Water can be sourced from the Thuin groundwater production bore, which has an annual extraction limit of 50 ML, if required to maintain supply during protracted dry weather. Bore water would be pumped directly into MWD2.

4.4 Mine Water Storage

MWD2 would be located near the mine infrastructure area or in advance of the open cut. It would be used to store water from pit dewatering operations and would be used as the priority supply for water used in the crusher and dust suppression water for application to haul roads.

The MWSS would be established by excavating a void in the overburden in the advance mine area to enable the pit to be rapidly dewatered if prolonged or intense rainfall occurs which cannot otherwise be quickly removed from the pit without exceeding the capacity of MWD2.

4.5 Water Consumption

Water generated on site would be used to meet crusher demand and dust suppression requirements. The water consumption requirements and the water balance of the system would fluctuate with climatic conditions and as the mining operation changes over time. Fluctuations in water consumption have been accounted for in the site water balance model (refer Section 5) in accordance with the production schedule. Water would also be used to aid in the establishment of vegetation in areas that can be supplied by surface storage by maintaining soil moistures at levels which support plant growth.

4.6 Flood Management

A temporary flood bund would be required from Year 12 on the western bank of Goonbri Creek to protect the advancing pit against the risk of inundation during floods in Goonbri Creek. At this time, the permanent Goonbri Creek alignment would be under construction to the east of the existing section of Goonbri Creek. A flood protection bund would also be required on the eastern bank of Goonbri Creek to protect the construction works of the permanent Goonbri Creek alignment, and particularly the low permeability barrier.

A preliminary hydrological assessment has been undertaken to assess the indicative flood bund size that would be needed to ensure that the flood bunds are suitably designed to protect both the advancing pit in the west and the construction of the low permeability barrier in the east for the peak flow resulting from a 1 in 100 year ARI rainfall event.

A rainfall-routing model for Goonbri Creek was set up to generate estimates of peak flows for a 1 in 100 year ARI event. An estimated peak flow of approximately 190 cubic metres per second (m^3/s) was determined. The hydraulic conditions which are expected to occur in Goonbri Creek during the peak 1 in 100 year ARI flood event were estimated using the HECRAS model (USACE, 2010) – refer Section 6.4.2.

Modelling results indicate that a bund height of 1.5 m above natural surface would be required for the eastern bund and a bund about 2.5 m above natural surface would be required for the western bund.

Modelled flow velocities at the bund locations indicate that the batters should be vegetated with a dense grass cover to provide resistance against erosion.

4.7 Interaction with Boggabri Coal Mine Surface Water Management System

The Project mine waste rock emplacement would merge with and form a continuous landform with the proposed Boggabri Coal Mine waste rock emplacement to the north. The integration provides overall benefits in terms of reduced mine waste rock emplacement footprint and individual benefits to both operations. The single landform would result in a reduction in runoff from the mine waste rock emplacement reporting to the Nagero Creek catchment and an increase in the area reporting to Goonbri and Bollol Creeks. The total length of batters on the merged mine waste rock emplacement would also be reduced by some 4 km compared to the batter length of both waste rock emplacements (Boggabri and Tarrawonga) if they were not integrated. This reduces exposure to potential batter erosion and consequential sediment load to the downstream environment. It is expected that under low and average climatic conditions there would be a low risk of elevated turbidity and suspended solids affecting downstream water courses at levels that are higher than those from other landuse activities. Under high and extreme rainfall conditions the risk of elevated turbidity would be higher but consistent with other land use activities such as cropping which are conducted in downstream catchment areas.

The TCM water management system has been designed to operate independently of the Boggabri Coal Mine water management system – i.e. water supply and containment components of the TCM water management system have been designed to meet the Project requirements independently of the Boggabri Coal Mine and its water management infrastructure. There may however be opportunity to share water management infrastructure and to transfer water from one site to the other where this is mutually beneficial. Such infrastructure sharing arrangements and transfers would be subject to separate assessment and approval.

4.8 Mine Waste Rock Emplacement Drainage Management

Results of geochemical characterisation testing of mine waste rock and experience of drainage management on the existing mine waste rock emplacements on site confirm that mine waste rock drainage is likely to be neutral to slightly alkaline and to represent a relatively low salinity risk. Waste rock materials are however sodic and dispersive and therefore present a risk of accelerated erosion if not adequately managed. The proposed mine waste rock emplacement design involves the creation and rehabilitation of the final batters on the western side of the emplacement in the early years of the operations (refer Figure 4). The mine waste rock emplacement design also provides for the integration with the Boggabri Coal Mine waste rock emplacement to the north which will optimise waste rock emplacement capacity and reduce the overall footprint and length of final batters. During the operational phase runoff from most active mine waste rock emplacement areas would report to the mine pit where it would be actively managed as mine water through containment and re-use on site.

The final design of the top of the mine waste rock emplacement involves the creation of seven sub-catchment areas. Runoff from these areas would be drained via a series of gently graded swales (on the top surface of the waste rock emplacement) and drop structures located at batter locations which minimise individual fall heights. This drainage strategy will be implemented progressively as the mine waste rock emplacement is constructed and progressively rehabilitated. A key requirement for completion of the mine waste rock emplacement will be to ensure that there are no dispersive or erodible materials left exposed at the surface.

This will be achieved by selective placement of waste rock so that all sodic material is either buried at least 1 m beneath non-dispersive waste rock or the top 1 m of material is stabilised by gypsum treatment. The drainage design on mine waste rock emplacement catchments would incorporate measures to prevent any dispersive materials being placed within 2 m of all final drainage surfaces. The proposed design provides for all drainage surfaces on the top of the waste rock emplacement (comprising gently graded swales) to be underlain by a low permeability layer comprising a compacted layer of (non-dispersive or gypsum stabilised) spoil to limit water contact and movement through underlying dispersive spoils and to maintain near surface moisture to enhance plant growth.

5 SIMULATED PERFORMANCE OF WATER MANAGEMENT SYSTEM

A water balance model of the Project water management system has been developed to simulate its behaviour over the 17 years of mining operations.

5.1 Model Description

5.1.1 General

The model simulates daily changes in the volumes of mine water in response to inflows (rainfall and groundwater) and outflows (evaporation, dust suppression use and spill [if any]).

For each mine water storage the model simulates:

Change in Storage = Inflow – Outflow

Where:

Inflow includes rainfall runoff, groundwater inflow (for mine pit) and all pumped inflows from other storages.

Outflow includes evaporation, spill and all pumped outflows to other storages or for consumption on site (e.g. crusher, truckfill) or controlled release.

Storages included in the model were the mine pit, MWD2, MWSS and the UWD.

5.1.2 Rainfall and Evaporation

The model operates on a daily time step and simulates the 17 year Project life using the full period of available climatic data for the region from 1889 to 2010 (sourced from the Data Drill system – refer Section 2.3). The model simulates 122 possible mine life “realizations”, each of 17 years. Realization 1 uses climatic data from 1889 to 1905; realization 2 uses data from 1890 to 1906; realization 3 uses data from 1891 to 1907 and so on. In order that recent climate be included in as many realizations as all other years in the record, climate data was “wrapped” with data from 1889 to 1903 added to the record after 2010. In this way, historically representative climatic realizations are produced which can be used to test the water management system over a wide range of climatic conditions. By ranking simulated outcomes, the model can be used to estimate the probability and consequences of different water management outcomes occurring – such as uncontrolled spills or water supply shortfalls.

Daily pan evaporation data was also sourced from the Data Drill system covering the same period as the rainfall sequence (1889 – 2010). The pan evaporation data was converted to estimates of open water evaporation by applying a pan factor of 0.8.

5.1.3 Runoff Simulations

The Australian Water Balance Model (AWBM) (Boughton, 2004) was used to simulate runoff from rainfall on the various catchments and landforms across the Project area. The AWBM is a nationally-recognised catchment-scale water balance model that estimates streamflow from rainfall and evaporation. Modelling of the following six different sub-catchment types was undertaken (as shown in the figures presented in Attachment A):

- Natural Surface/Undisturbed;
- Active Waste Rock Emplacements;
- Partially Rehabilitated Areas;
- Rehabilitated Areas;
- Hardstand; and
- Open Pit.

AWBM parameters for undisturbed areas were taken from model calibrations undertaken for Maules Creek[6]. Parameters for the remaining sub-catchments were taken from literature-based guideline values or experience with similar projects. Table 18 gives the AWBM parameters used in the model.

Table 18 Water Balance Model AWBM Parameters

Parameter	Natural Surface	Active	Partially Rehabilitated	Rehabilitated	Hardstand	Open Pit
C1 (mm)	13	10	10	13	2	2
C2 (mm)	127	90	65	85	-	20
C3 (mm)	255		65	85	-	-
A1	0.13	0.2	0.15	0.13	1	0.1
A2	0.43	0.8	0.60	0.43	0	0.9
A3	0.44	0	0.25	0.44	0	0
BFI	0.23	0.8	0.1	0.1	0.0	0.1
K_{base}	0.98	0.98	0.95	0.95	0.96	0.9
K_{surf}	0.5	0.2	0.2	0.2	0.1	0.2

Note: An AWBM evaporation factor of 0.85 was used in the model as recommended by Boughton (2006).

Catchment and sub-catchment areas were calculated from current and future mine layout plans provided by Whitehaven. The total catchment area reporting to the mine pit varied over the mine life as is shown on Figure 18 below.

[6] Maules Creek gauging station (GS 419044).

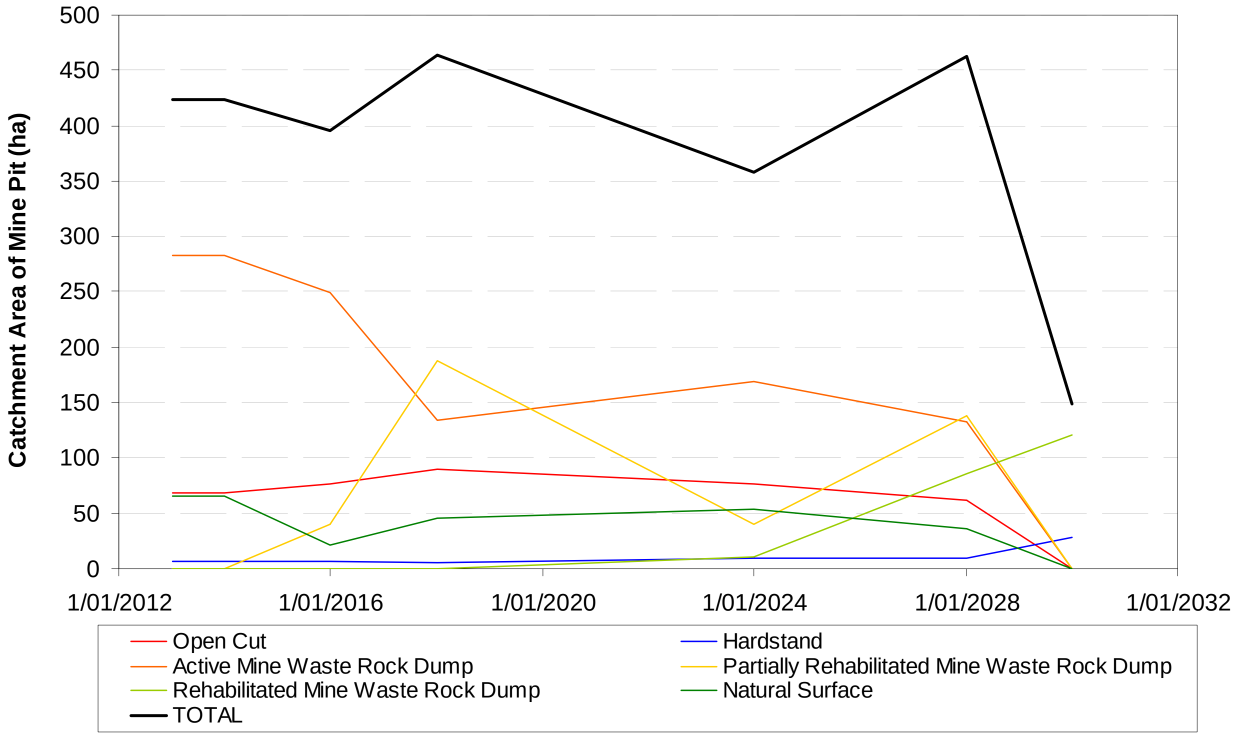


Figure 18 Changes in Active Mine Pit Catchment Area over Project Life

5.1.4 Water Demands

5.1.4.1 Crusher Demand

A crusher is used to pre-process ROM coal at TCM prior to its transport to Whitehaven's CHPP near Gunnedah. The crusher uses a relatively small quantity of water which it sources from the water management system. The crusher water demand was estimated from historical Annual Environmental Management Reports (AEMRs) and adjusted according to estimates of future usage (as advised by Whitehaven). This resulted in estimates of 33 ML/annum (0.1 ML/d) for the first year of the simulation and 7 ML/annum (0.02 ML/d) for the remainder of the simulation.

5.1.4.2 Truckfill Demand

Demand for haul road water for dust suppression was estimated from haul road lengths and widths (estimated from future mine layout plans allowing for haulage of coal to the CHPP and mine waste rock to emplacements) multiplied by pan evaporation and a pan factor of 1.2 to allow for the higher evaporation losses that occur on active haul roads used by large haul trucks.

The assumed order of priority for sourcing water for dust suppression is based on using mine water in preference to disturbed area runoff and sediment dam water. The priorities used for the Project water management system are summarised in Table 19.

Table 19 Summary of Truckfill Demand Prioritisation

Truckfill Demand Priority	Source Water Storage	Reasoning for Priority Assignment
1	MWD2	Receives mine water pumped inflow however stops sourcing before spill with direct spill to Goonbri Creek to be avoided. During periods when water in MWD2 is at elevated levels – excess mine water transferred to the Mine Water Surge Storage
2	SB(N1)	Receives runoff from the mine infrastructure area for the duration of the mine life
3	SD9(R)	Similar to SB(N1) except overflows to SB(N1)
4	UWD	Clean water dam, only sourced as a final option

5.1.4.3 Irrigation to Support Vegetation Establishment on Partially Rehabilitated Areas

The demand for water for irrigation of revegetated areas on partially rehabilitated mine waste rock emplacement areas has been calculated based on the partially rehabilitated catchment area on site (estimated from future mine layout plans) multiplied by pan evaporation (minus rainfall) and a pan factor of 0.5 to allow for crop factor and irrigation inefficiency.

5.1.5 Licensed Discharge Points

A number of existing and proposed LDPs have been included in the water balance model. These LDPs are associated with the following storages; SD17 (LDP 1), SD9(R) (LDP 2), SB14(R) (LDP 3), SD16 (LDP 24), SB23 (Proposed), SB(N3) (Proposed) and UWD (Proposed). It was assumed that water in sediment storages would only be pumped out to a LDP if runoff reporting to that storage was from inactive and partially rehabilitated mine waste rock emplacement areas. The water management system has been developed such that if a storage is receiving runoff from active mine and mine waste rock emplacement areas then it was assumed that water would be suitable for controlled release via a LDP following settling in a sediment dam.

Water which accumulates within sediment control dams would be pumped out via a LDP if there has been no rainfall/runoff for the previous 5 days. This timeframe allows sediment to settle out and corresponds to the rainfall duration for which sediment dams are sized under Landcom guidelines (refer Landcom (2004), Sections 6.3.4(f) and (i)).

5.2 Model Calibration and Verification

Based on the available/existing monitoring datasets/records, model calibration was not conducted as part of this assessment. The proposed monitoring (as detailed in Section 10) would allow calibration and model verification following the first full year of monitoring with ongoing verification and calibration checks through the Project life as part of the annual water balance and environmental performance assessments.

5.3 Simulated Performance

The simulated performance of the water management system has been assessed against its design objectives and criteria. The water volumes which need to be managed by the system will vary widely because of the large range of different weather conditions which can be experienced on site. The aspects of the system which would enable it to operate effectively during drought are different to those that would accompany prolonged wet periods. The system will also need to cope with short term as well as long term climatic patterns and trends. The ability of the system to meet its design objectives in the face of this variability has been assessed by simulating the system over all rainfall conditions that have been recorded in the area.

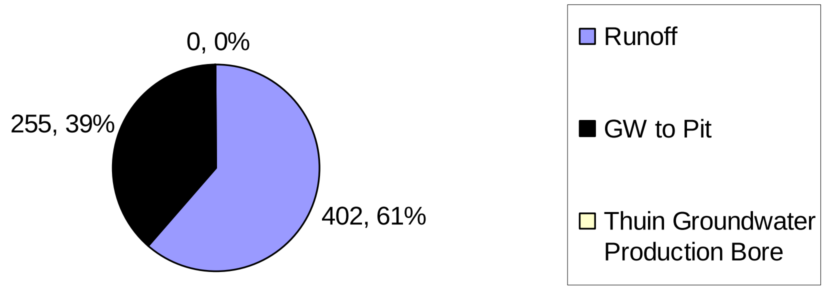
5.3.1 Overall Site Water Balance

The average water balance has been calculated by averaging inputs and outputs over the mine life sequence in all simulated sequences. The overall water balance provides a rapid initial appreciation of the relative contribution made by the various components and therefore which components of the balance are most significant. A summary of the simulated water balance is presented in Table 20 and is also shown pictorially in Figure 19.

Table 20 Summary of Simulated Inflows and Outflows in Project Water Balance

		Simulated Results (ML/yr)		
		25th percentile	Average	75th percentile
Inflows	Rainfall/Runoff	325	402	480
	Thuin Groundwater Production Bore	0	0	0
	Groundwater Inflow to Mine Pit	255	255	255
Outflows	Pond Evaporation	118	130	141
	Mine Water Spill to Environment	0	0	0
	Supplied to Crusher	8	8	8
	Supplied to Truckfill	389	394	399
	Supplied to Irrigation	64	125	193

Average Inflows (ML/yr)



Average Outflows (ML/yr)

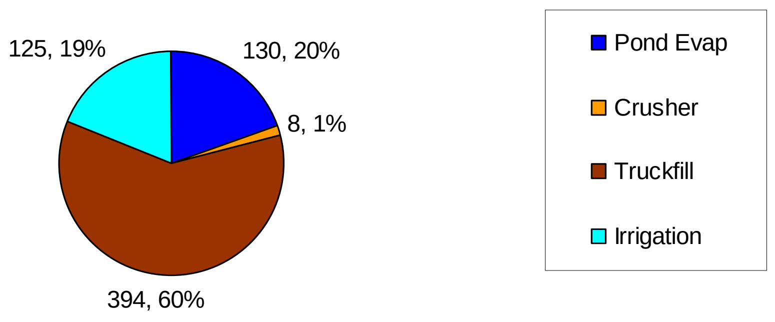


Figure 19 Average Inflow and Outflow Components of Simulated Project Water Balance

5.3.2 Water Supply Security

One of the objectives of the water management system is to provide water for dust suppression on haul roads and for use in the crusher. The security of the water supply has been assessed in terms of volumetric reliability which is defined as the total volume of water that was able to be supplied in the simulated mine life divided by the total water demand over the same period. The lowest reliability in any simulated mine life realization has been calculated along with the average over all realizations – refer Table 21 below.

Table 21 Simulated Water Supply Reliability

Statistic	Crusher	Haul Road Dust Suppression
Average volumetric reliability	99.9%	98.4%
Minimum volumetric reliability	99.5%	93.4%

The simulated volumetric reliabilities are based on use of mine water only and do not include use of water in sediment dams. The reliability levels are considered to be high by industry standards. In reality it is common practice to use synthetic dust suppressant during periods of water shortfall. The volumetric reliabilities for the crusher have been obtained from the model simulations undertaken without including supply drawn from the Thuin Groundwater Production Bore. They therefore represent supply reliability without recourses to use of external water sources. The water allocation associated with the Thuin Groundwater Production Bore is more than 3 times the estimated average annual crusher water demand.

5.3.3 Containment of Mine Water on Site

Another objective of the site water management system is to contain mine water on site and to minimise the risk of it from being discharged to receiving waters off site. This would be achieved by the provision of a dedicated mine water storage for containment of water pumped from the active mining operations and through management of pit water. If there are periods of extended pit inflows when the pit dewatering operations would be limited by the capacity of the mine water dam excess water would be diverted to a MWSS such that the mine pit could be returned to active production quickly. There are a number of different ways that the results from a large number of model simulations can be presented. To illustrate how containment storages are likely to perform under different climatic conditions plots of simulated storage volumes (hydrographs of storage volumes) over the mine life for three climatic realizations chosen to include low, average and high rainfall periods have been developed. The simulated performance of MWD2, the MWSS and the mine pit over these three realizations are shown in Figures 20, 21 and 22, respectively.

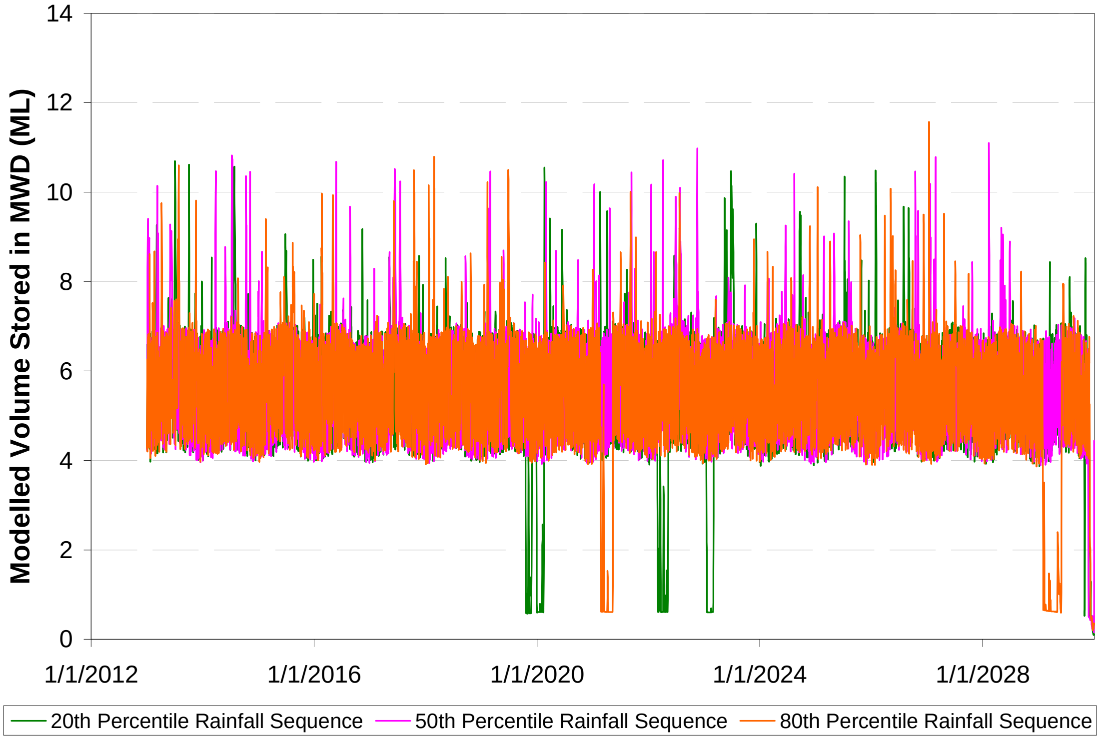


Figure 20 **Simulated Volumes in Mine Water Dam under 20th Percentile, Median and 80th Percentile Rainfall Realizations**

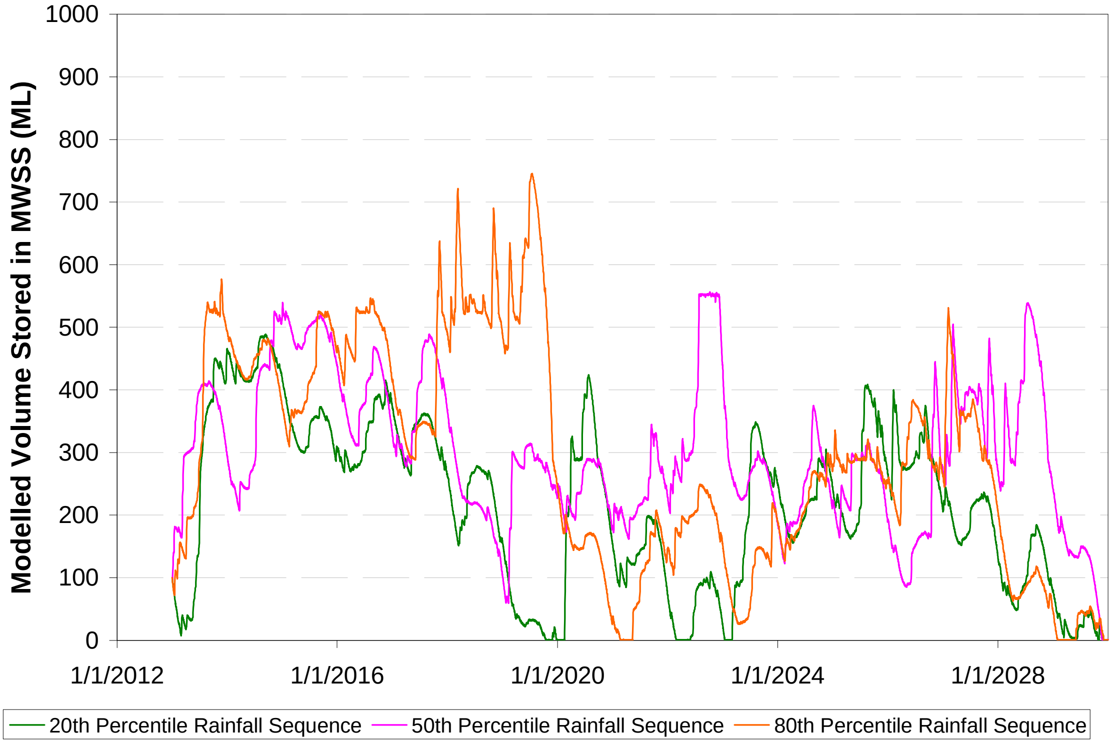


Figure 21 **Simulated Volumes in Mine Water Surge Storage under 20th Percentile, Median and 80th Percentile Rainfall Realizations**

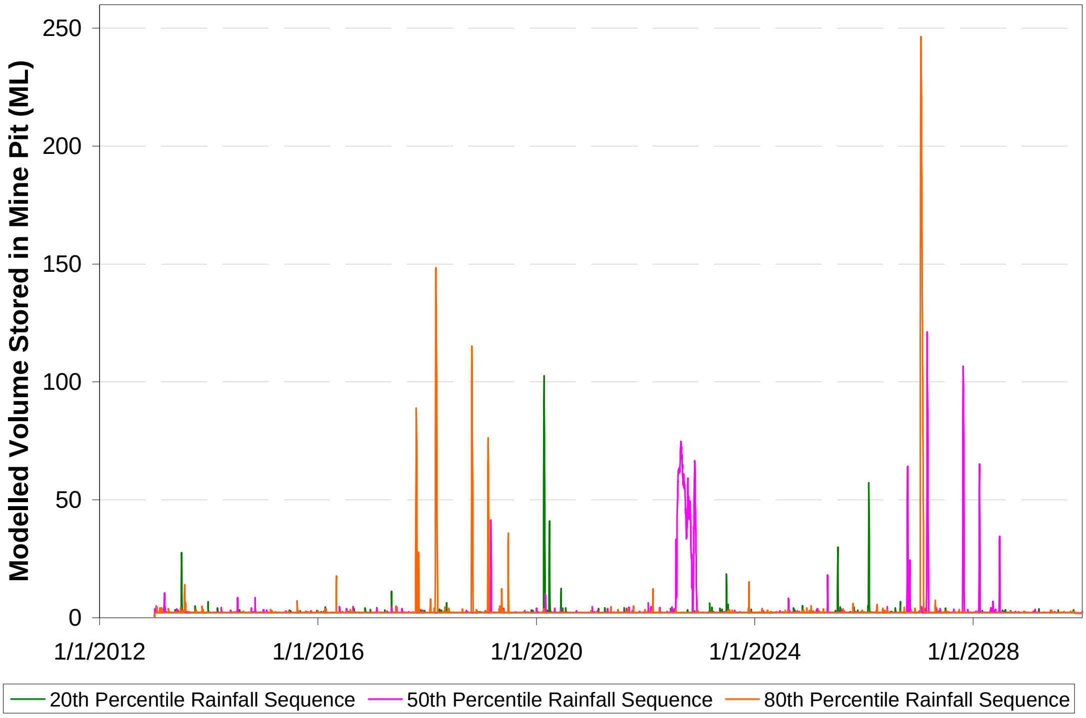


Figure 22 **Simulated Volumes in Mine Pit under 20th Percentile, Median and 80th Percentile Rainfall Realizations**

These graphs illustrate the changes in storage during the individual climatic realizations simulated. In particular they illustrate that storage volumes change over a wide range in response to rainfall variability. The transient nature of excess water in the pit reflects the capacity of the mine dewatering system and the Mine Water Surge Storage to store excess water. The simulation results also illustrate that under some conditions the MWSS would be required to provide carry-over storage for extended periods. Whilst these graphs illustrate the simulated outcomes of the three selected sequences they do not reveal the simulated behaviour of the large number of other realizations simulated or of the probability of simulated storage capacities being equalled or exceeded. The volume of water in the mine pit and mine water storages being exceeded at various levels of probability has been assessed by undertaking a statistical analysis of the simulated storage behaviour over all realizations. The results of these analyses are shown as a series of exceedance hydrographs which show storage volumes that were exceeded in 50%, 75% and 95% of Project life realizations. Figures 23, 24, and 25 show the storage exceedance hydrographs for water in MWD2, MWSS and mine pit, respectively.

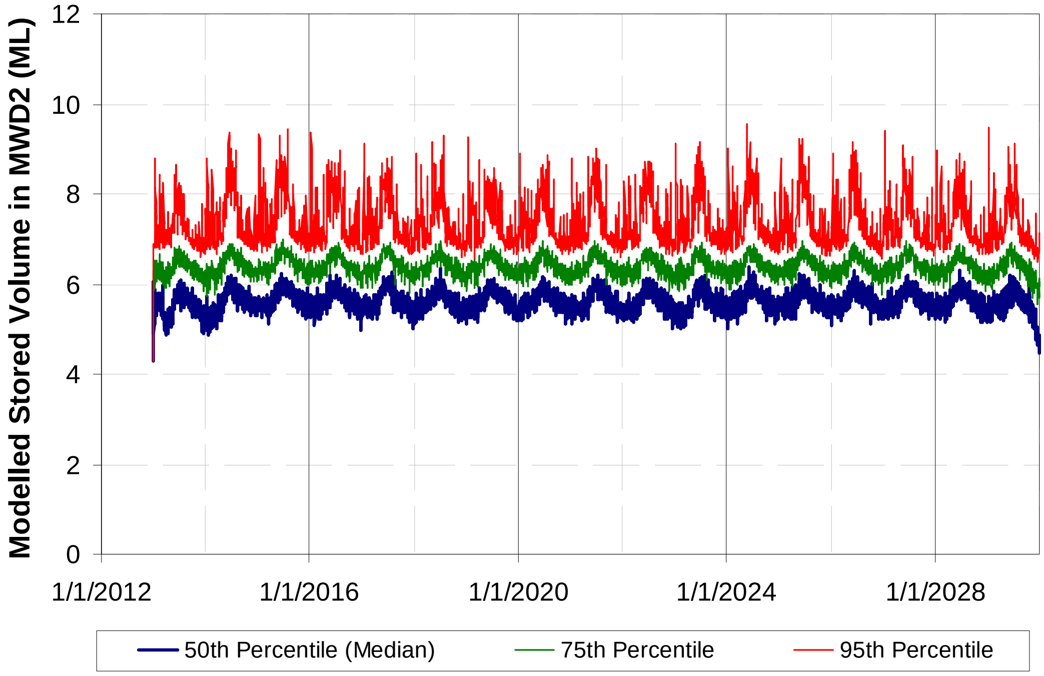


Figure 23 Storage Volume Exceedance Hydrographs for Mine Water Dam

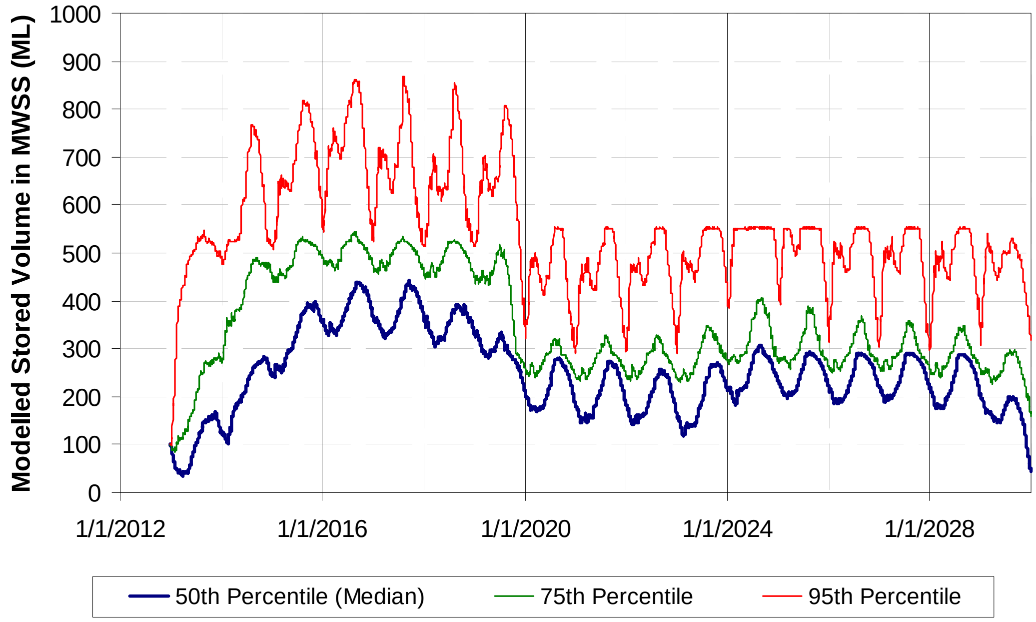


Figure 24 Storage Volume Exceedance Hydrographs for Mine Water Surge Storage

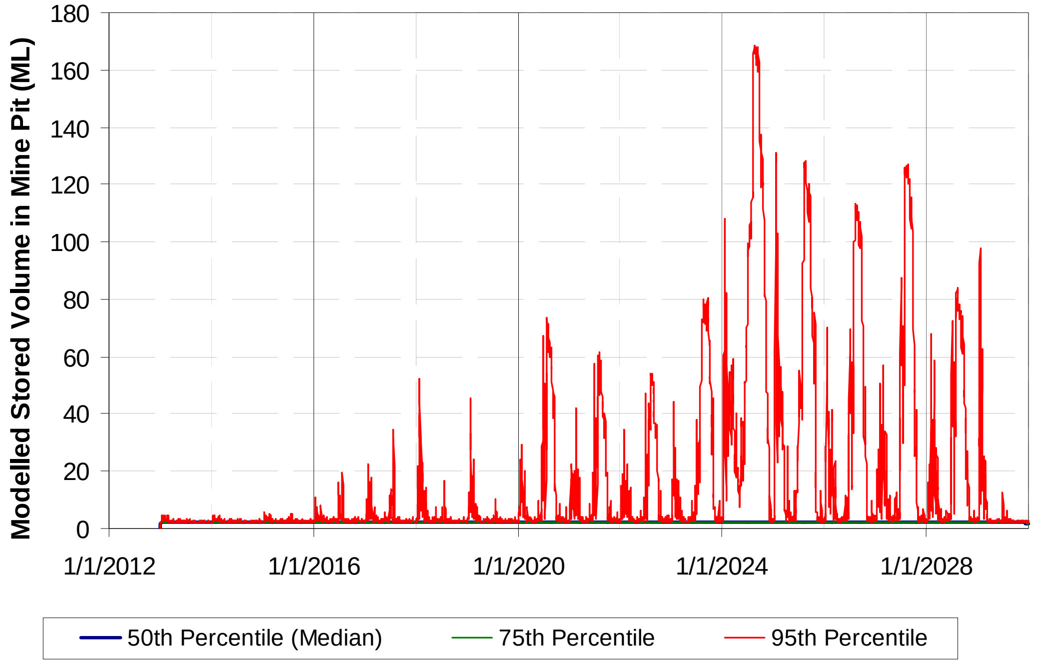


Figure 25 Storage Volume Exceedance Hydrographs for Mine Pit

5.3.4 Containment of Disturbed Area Runoff and Sediment Control

The following strategies are applied to the management of runoff from mine disturbed and rehabilitated areas:

- Runoff from fully rehabilitated and stabilised areas is passively managed such that it flows directly off site to downstream watercourses or is allowed to drain off site through passively managed sediment dams or sediment basins.
- Runoff from partially rehabilitated areas (taken to be areas that have not been fully rehabilitated and had at least 2 years for the vegetation cover to establish), is actively managed via the sediment control storages. These are operated such that water is either re-used on site (if there is insufficient mine water to meet site demands) or is released to downstream receiving waters via a LDP after settling. In accordance with the Landcom (2004) guidelines, settling has been assumed to occur in 5 days following each storm event after which water is released. Sediment Dams SD17 and SB14(R) receive runoff from partially rehabilitated areas in years 1 to 4 (i.e. prior to completion and stabilisation of the catchment areas reporting to these storages). These dams have been sized in accordance with the Landcom (2004) and DECCW (2008) guidelines.

- Runoff from hardstand areas, haul roads and other mine facilities areas also reports to sediment control storages and would be actively managed via the sediment control system as described above. Runoff from the main hardstand areas reports to SD9(R) and SB(N1). These structures have been sized in accordance with Landcom (2004) and DECCW (2008) guidelines and would be operational over the entire Project life.
- Runoff from active and recently constructed topsoil stockpile areas is also managed in sediment control storages (i.e. Sediment Basins and Sediment Dams). Runoff from the main topsoil stockpile reports to SB23. This structure would be actively managed up to approximately 2016 after which time the catchment reporting to SB23 would be fully rehabilitated and runoff allowed to flow off site uninterrupted.

5.4 Model Sensitivity

All predictive water balance modelling has inherent uncertainty associated with it. Models are simplifications of reality and rely on assumptions and selection of unknown model parameters to simulate the water balance of a system. Model sensitivity is used to test the sensitivity of model predictions to particular model assumptions and parameters. This is achieved by changing model parameter values (up and/or down) from their selected values and by changing model assumptions away from the selected values used in the original predictive runs and comparing model predictions from the sensitivity runs to those obtained from the original predictive runs. Individual model parameters are changed one at a time so that the sensitivity of particular parameters can be tested in isolation.

Whilst the absolute value of a model parameter may often be unknown there are usually physical and practical limits to the values that any parameter can take and the underlying concept behind the sensitivity analysis reported here is to test model outcomes over the range that model parameters are expected. The analysis has also been limited to model parameters and assumptions which affect the key water management objectives of site containment of mine water, specifically water supply security and control of mine pit inundation.

The key components of the model which affect these water management objectives are runoff generation from rainfall (being the principal input component of the water balance) and demand for dust suppression on haul roads (being the principal outflow component in the overall water balance) – refer Figure 19.

5.4.1 Runoff Sensitivity

The sensitivity of model predictions to changes in runoff was tested by comparing the original model prediction with predictions from model runs undertaken with runoff rates increased and decreased by 20%. Increasing runoff would have the effect of increasing the volume of water stored in the pit and of uncontrolled spill from the sediment management system.

The 95th percentile curves for mine pit inundation at the 95th percentile exceedance level for high and base case runoff parameters is shown in Figure 26 below.

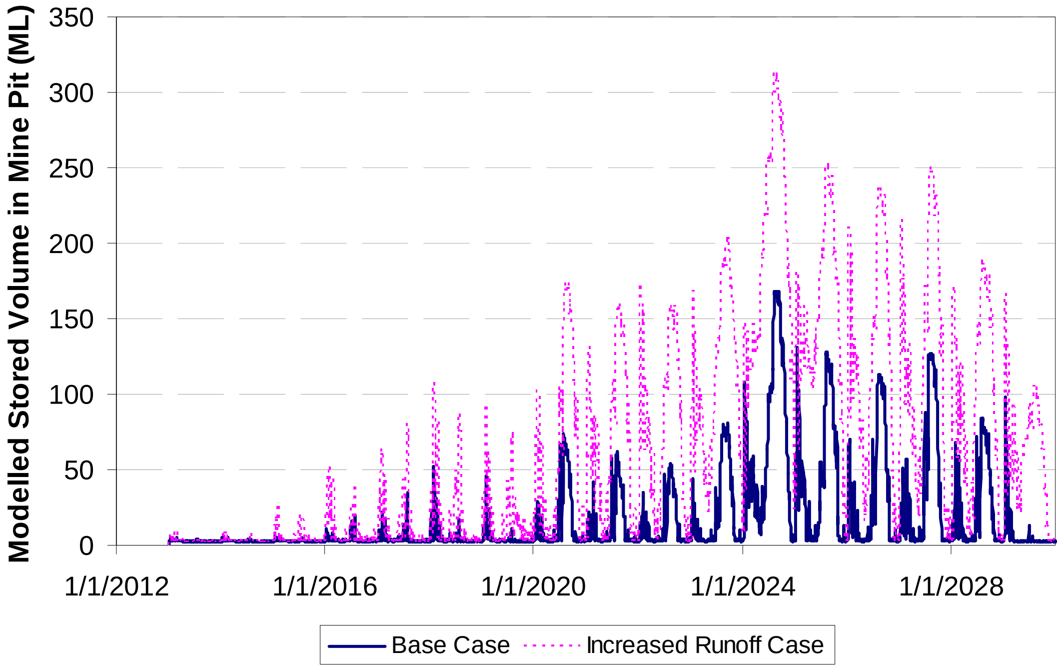


Figure 26 Storage Exceedance Hydrographs for Pit Inundation – Base Case and High Runoff Model Sensitivity – 95th Percentile

The model sensitivity run with higher runoff also resulted in increased stored water volume in MWD2 for the 95th percentile exceedance level – refer Figure 27. The effect of increased runoff is less pronounced for MWD2 when compared to the Mine Pit due to the smaller catchment area of MWD2.

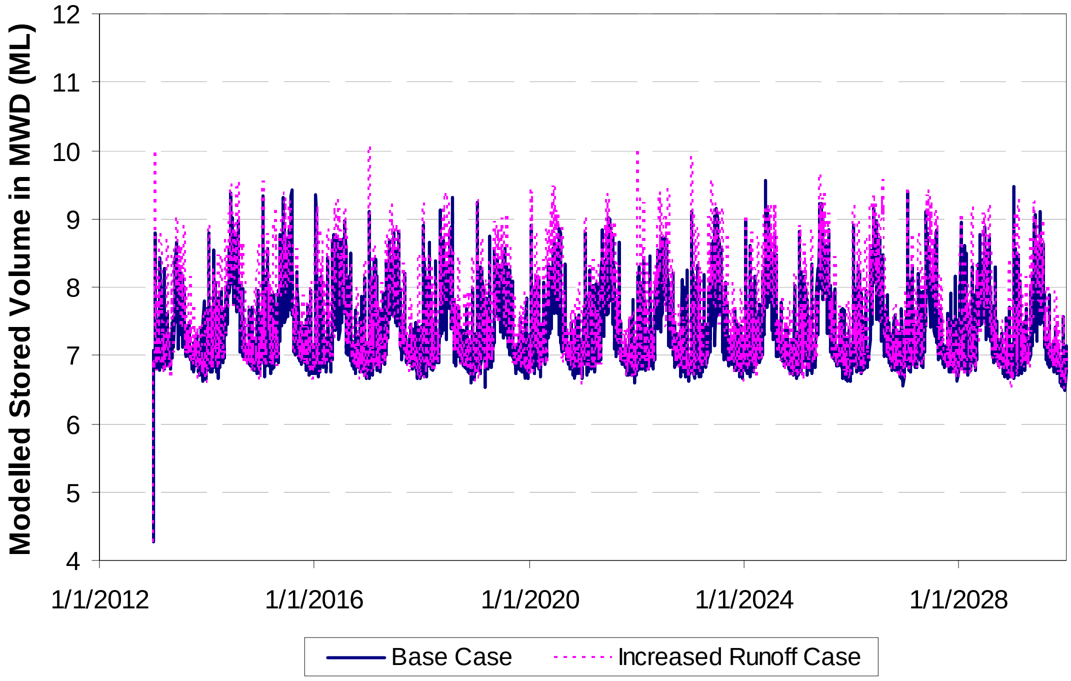


Figure 27 Storage Exceedance Hydrographs for MWD2 – Base Case and High Runoff Model Sensitivity – 95th Percentile

In comparison with the base case, decreasing runoff by 20% would reduce water availability to meet site requirements. The lowest and average reliability for the base case and low runoff sensitivity runs are summarised in Table 22 below.

Table 22 Simulated Base Case and Low Runoff Sensitivity Water Supply Reliability

Statistic	Haul Road Dust Suppression	
	Base Case	**Low Runoff**
Average volumetric reliability	98.7%	96.4%
Minimum volumetric reliability	95.5%	87.7%

5.4.2 Truckfill Demand Sensitivity

The sensitivity of model predictions to changes in truckfill demand was tested by comparing the original model prediction with predictions from model runs undertaken with truckfill demand rates increased and decreased by 20%. Increasing truckfill demand would have the effect of decreasing volumetric reliability and of decreasing overflow from the sediment management system. There was however little simulated effect on modelled volumes of water stored in the mine pit.

In comparison with the base case, decreasing truckfill demand by 20% would increase the ability of the site water management system to meet site requirements. The lowest and average reliability for the base case and low truckfill demand sensitivity runs are summarised in Table 23 below.

Table 23 Simulated Base Case and Low Truckfill Demand Sensitivity Water Supply Reliability

Statistic	Haul Road Dust Suppression	
	Base Case	Low Truckfill
Average volumetric reliability	98.7%	99.9%
Minimum volumetric reliability	95.5%	98.4%

5.5 Water Management Implications

Results of water balance simulation modelling indicate that the proposed water management system has the capacity to be operated to meet the system water management objectives. In particular the proposed sediment control storages have sufficient capacity to enable them to manage disturbed area runoff in accordance with design criteria recommended in the Landcom (2004) guidelines. The site sediment and erosion control system would be managed through erosion and sediment control plans that would be progressively developed and approved over the life of the Project. The plans would be updated periodically to meet the particular changes to the Project over the mine life. The effectiveness of the plans would also be assessed through monitoring and by a formal auditing process.

Water balance modelling also indicates that the proposed mine water management system has the capacity to be operated to meet the combined objectives of controlling water inundating the pit for prolonged periods causing disruption to mining and preventing off-site release of mine water.

The relatively low demand for water on-site and the increasing catchment area reporting to the mine pit as it progresses north and eastward mean that additional surge storage may be required to enable the pit to be dewatered effectively. Modelling indicates that peak volumes which might need to be held in the surge storage are highest in the early years of the Project when runoff from active mine waste rock emplacement areas is greatest and when demand for dust suppression water is relatively low compared to later in the Project life. Later in the mine life, changes in these factors would affect the site such that peak requirements for surge storage to cover high rainfall events would reduce. This would mean that the initially large surge storage, which would be created in the eastern mine footprint in advance of mining, could be replaced either by a smaller storage near the new mine facilities area after the topsoil stockpile in this area had been removed during progressive rehabilitation, or by in-pit storage. Modelling indicates that some 550 ML of surge storage capacity would be required to minimise disruption to mining in the latter years of the Project. This would however be confirmed during ongoing updates and refinements (including calibration) to the model prior to the mine progression necessitating the relocation of the storage.

Irrigation activities would be undertaken to maximise evapotranspiration but avoid surface runoff (due to irrigation). Irrigation areas would ultimately drain to sediment dams and storage basins where existing and/or proposed LDPs are operated. Based on the results of the Geochemistry Assessment (Appendix N) and consideration of existing water quality of on-site water storages, the risk of impacts on downstream surface water resources due to Project irrigation activity are considered to be negligible.

Implementation, management and monitoring of the Project water management system would be based around the Water Management Plan which would be developed from the currently approved Water Management Plan for the Project. The Water Management Plan would be modified and updated in accordance with the evolving requirements of the Project.

6 PROPOSED PERMANENT GOONBRI CREEK ALIGNMENT

6.1 Description of the Goonbri and Bollol Creek Catchments

6.1.1 Catchment

Goonbri Creek commands a catchment of some 35 km^2 above the Dripping Rock Road crossing and has a catchment of some 27 km^2 above the upstream end of the proposed permanent Goonbri Creek alignment (Figure 28). The proposed permanent Goonbri Creek alignment would rejoin the current alignment of Goonbri Creek approximately 3 km further downstream. The distribution of catchment area contributing to flow in Goonbri Creek is shown in Figure 28 below.

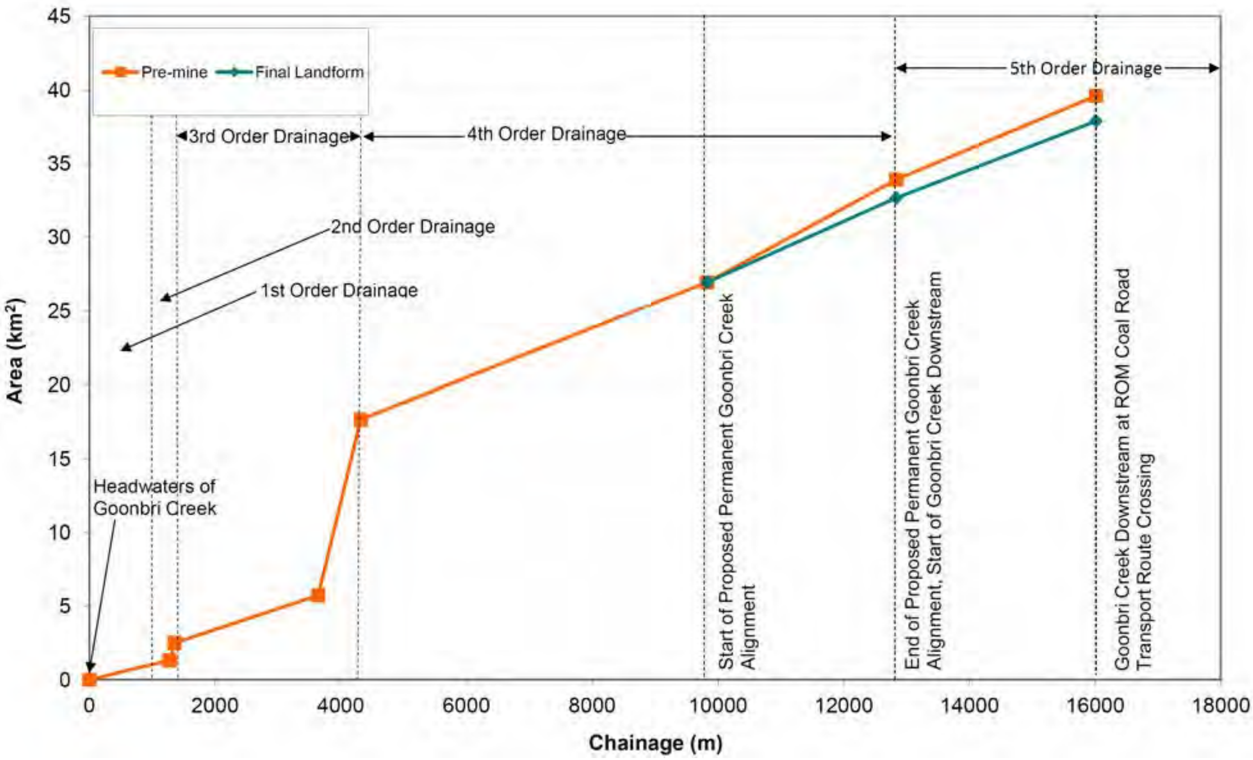


Figure 28 Distribution of Catchment Area Contributions along Goonbri Creek

The reduction in contributing catchment for the proposed post-mine final landform (shown on Figure 28) reflects the portion of the former Goonbri Creek catchment area which would consequently report to the final void (<2 km^2). The catchment reporting to the final void would be minimised by the construction of perimeter bunds and contour drains around the final extent.

Bollol Creek commands a catchment area of some 116 km^2. The distribution of the catchment and stream order are shown on Figure 29.

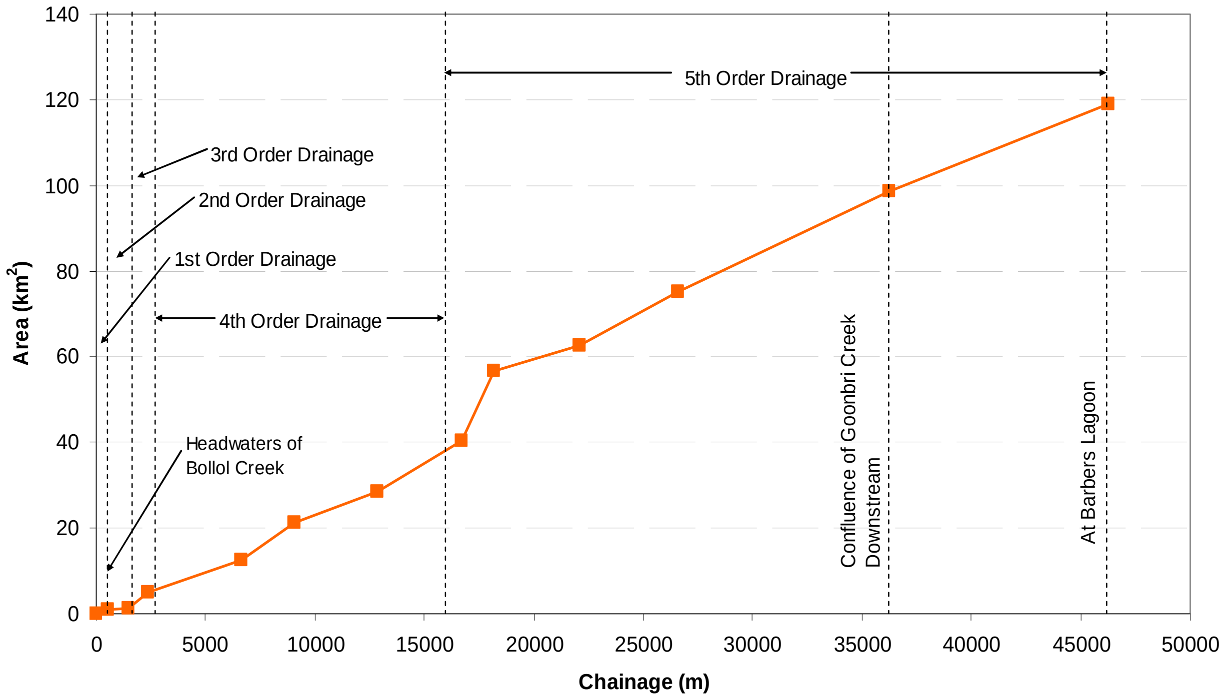


Figure 29 Distribution of Catchment Area Contributions along Bollol Creek

6.1.2 Riparian Vegetation – Goonbri Creek

Riparian vegetation along the upper reaches of Goonbri Creek (within the Leard State Forest) consists of sedges along the channel margins and White Cypress Pine and Narrow-leaved Ironbark communities in the overbank areas (Figure B-2 in Attachment B).

Riparian vegetation includes *Eucalyptus* and *Leptospermum* species. The vegetation extends over 100 m with a corridor greater than 100 m along the western banks and 20 m along the eastern banks. Beyond the riparian corridor, the floodplain consists of pasture grasses on the eastern side (Lampert & Short, 2004).

Where Goonbri Creek enters the proposed Project area, the drainage line traverses active agricultural land with some patches of remnant and regrowth forest. Sedges become increasingly prevalent along the channel margin with open grasslands on the overbank areas (Figure B-4 in Attachment B). The agriculture areas support mixed grazing and cropping activities. The riparian vegetation along the creek line in these areas is dominated by grassy overbank areas with some scattered Blakely's Red Gum, Rough Barked Apple and Paperbark trees located in the riparian corridor.

Downstream of the proposed Project area, sedges and other dense grasses are dominant on the channel margins, and large semi-permanent, in-stream scour pools are choked with various aquatic plants (Figure B-7 in Attachment B). Overbank areas in the non-active, re-colonised pastures are dominated by tussock grasses and sedges, native grasses and some scattered trees within the riparian corridor.

Photographic plates along Goonbri Creek and supporting descriptions are provided in Attachment B.

6.1.3 Soils

A soils investigation in the Project area and surrounds was conducted by Mackenzie Soil Management. The investigation found that topsoils in much of the cleared agricultural land in the vicinity of Goonbri Creek showed evidence of structural degradation through compaction.

The soils mapped in the vicinity of Goonbri Creek upstream of Dripping Rock Road are reported to include Static Rudosols and Sodosols. The depth to gravel and sand along the creek bed is generally greater than 1 m. Soil dispersion is moderate to high as is compaction severity. Much of the topsoil has a poor shrink-swell capacity, so the rate of recovery from compaction damage would be slow. Although, the clay rich subsoils in the Static Rudosols in these areas have favourable self-repair capacity via shrink and swell processes (Mackenzie Soil Management, 2011).

Soils in the downstream areas of Goonbri Creek subject to overland flow are predominantly Static Rudosols with a depth to rock and to underlying sandy gravel deposits of in excess of 2 m. Soil dispersion and compaction is also found in these soils.

6.2 Geomorphological Characteristics of Goonbri Creek

The section of Goonbri Creek in the area which flows through the Leard State Forest was classified as being representative of the "low sinuosity, fine grained" (Lampert & Short, 2004) 'River Style'.

6.2.1 Stream Order and Stream Bed Profile

The reach of Goonbri Creek within the Project area is mapped as a 4th order stream in accordance with the Strahler stream classification system (Strahler, 1952).

The longitudinal stream bed slope profile follows the classical convex curve – refer Figure 30. It is moderately flat (0.4 %) in its mid reaches where the permanent Goonbri Creek alignment is proposed.

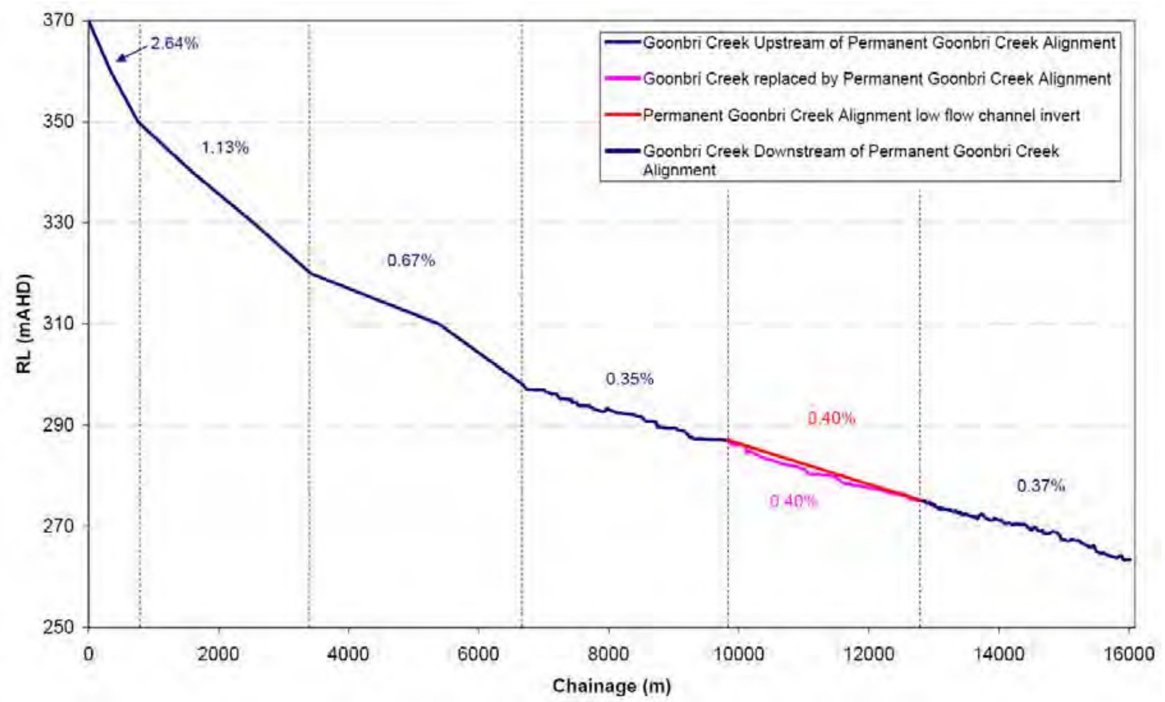


Figure 30 Stream Bed Profile – Goonbri Creek

The longitudinal profile of Bollol Creek is shown on Figure 31 below. Bollol Creek is significantly longer and is steeper in its upper reaches than Goonbri Creek. In areas close to its confluence with Goonbri Creek confluence however it has a similar longitudinal profile to Goonbri Creek – refer Figure 31.

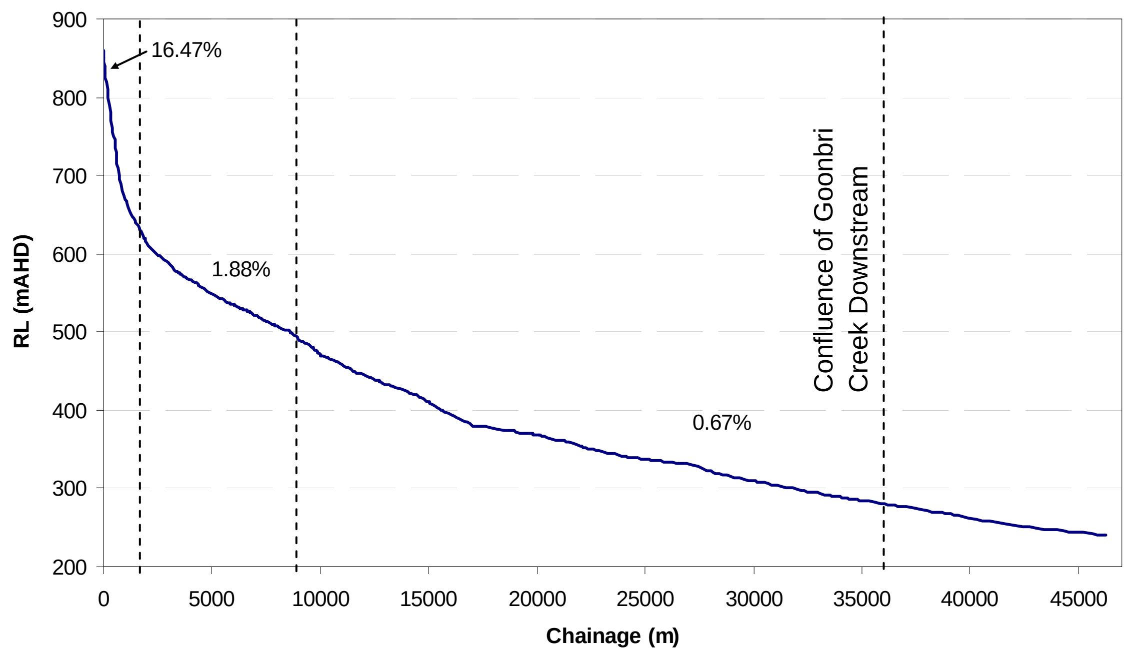


Figure 31 Stream Bed Profile – Bollol Creek

6.2.2 Stream Condition Survey - Goonbri Creek

A stream condition survey was conducted along Goonbri Creek on the 10th and 11th of March 2011 to characterise existing conditions along the drainage line upstream, downstream and within the proposed Project area. Nearby BoM station Boggabri (Retreat) (Station No. 55044) has a daily rainfall record from 1889 to 2011 (refer Table 1). Table 24 below summarises the observed rainfall six months prior to the stream condition survey, and the long-term monthly averages taken at the station. Rainfall was higher than long-term averages in October, November and December 2010. During 2011 however, rainfall was lower than long-term averages recorded at the station. The 2010 total annual rainfall was 870.7 mm, which is 34 % higher than the long-term averages recorded at this station.

Table 24 Boggabri (Retreat) Monthly Rainfall Data Comparison Six Months Preceding Stream Condition Survey

Month	Observed Monthly Rainfall (mm)	Long-Term Average Monthly Rainfall (mm)
October 2010	51.2	50.3
November 2010	99.2	56.9
December 2010	112.6	61.7
January 2011	29.0	71.5
February 2011	25.8	61.4
March 2011	55.6	42.2

A summary of daily rainfall data recorded approximately five weeks prior to the stream condition survey as recorded at nearby BoM station No. 55044 is shown in Figure 32 below.

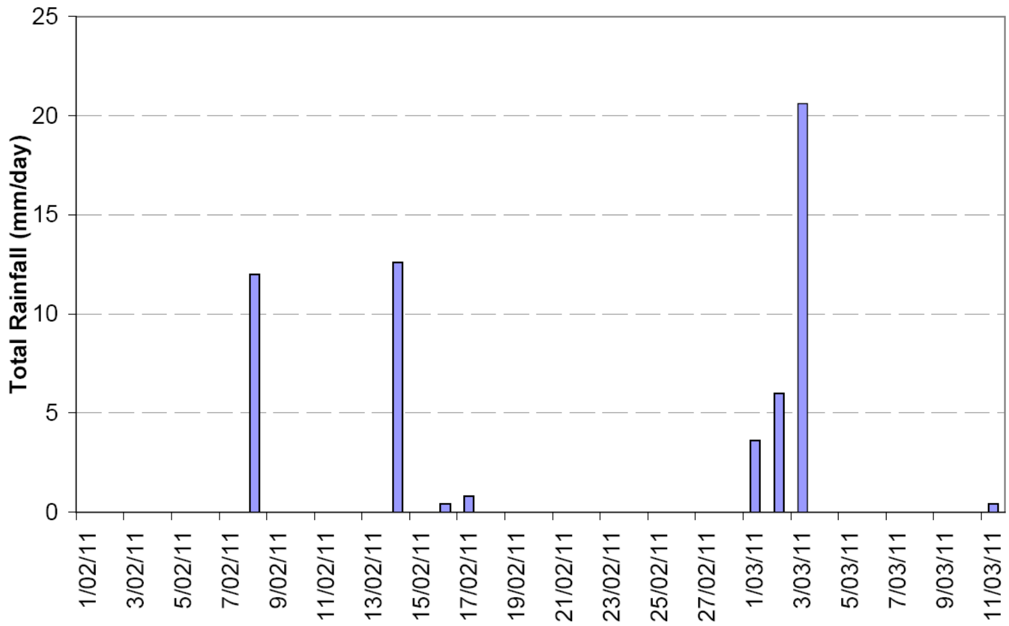


Figure 32 Rainfall at Boggabri (Retreat) (55044) Preceding Stream Condition Survey

Based on the available rainfall record at Boggabri there was 30 mm of rain (the highest daily fall of 21 mm was recorded on the 3rd of March) in the first 3 days of March leading up to the survey on the 10th and 11th but no rain recorded in the 6 days immediately prior to the survey and only a light shower was experienced on the 11th of March during the survey. These conditions are considered to be normal for this time of year. There was no flow observed in Goonbri Creek at the time of the survey, although there were a number of remnant pools.

The stream condition survey involved walking an unbroken transect along the channel of the creek from upstream of the proposed extent of proposed open cut to downstream of the ROM coal road transport route crossing. Photographs, coordinates and notes were taken of creek features. Information noted included plan form of the channel, channel geomorphology and geometry (e.g. shape and steepness of banks and other alluvial features associated with the creek channel such as flood terraces, the nature and extent of erosion or deposition features, channel profile dimensions and cross sectional form), bed materials, vegetation communities and other vegetation (including the type and distribution of bank and overbank vegetation) and adjacent land use. The information recorded during the stream condition survey is documented in Attachment B.

The characteristics of Goonbri Creek, as identified during the stream condition survey, are summarised in Table 25 below. The inspected section of Goonbri Creek was sub-divided into 4 different reach types with similar channel form, vegetation and overall condition. The location and extent of the classified reach types are shown on Figure 33. The proposed permanent Goonbri Creek alignment section would replace parts of Reach Types 1, 2 and 3.

Table 25 – Typical Reach Characteristics along Goonbri Creek

Reach*	Typical Channel Features	Typical Bed Materials	Riparian Vegetation	Adjacent Land use
I	Low sinuosity, right bank of channel confined by hill slopes of Leard State Forest; some minor lateral erosion evident	Mixed gravel and sand some silt	Sedge grasses on banks with Forest surrounding	State Forest
II	Low to moderate sinuosity, increased evidence of lateral erosion evident and increasing development of alternating bars and scour holes	Varied, from cobbles and gravel to sand and silt	Sedge grasses on banks and open grassland with scattered stands of trees on overbank areas	Past agricultural land with some regrowth
III	Low to moderate sinuosity, increasingly incised channel with increased undercutting of banks, larger scour holes, and erosional and depositional features present	Varied, predominantly sandy and silty with some grassy sections	Sedge grasses on banks and open paddock with native plains grasses and occasional trees in riparian corridor	Cropping and pastures
IV	Predominantly straight, gully-like incised channel with occasional meander, lateral instability and large scour holes with alternating permanent pools and bars	Typically silty and sandy	Aquatic plants in large permanent scour pools, sedges on banks with various grasses on overbank areas, some scattered trees in riparian corridor	Recolonised pasture

* Refer to Figure 33 and Attachment B

6.3 Conceptual Design of the Permanent Goonbri Creek Alignment

6.3.1 Concept/Vision Statement

The design concept for the permanent Goonbri Creek alignment involves mimicking the existing section of Goonbri Creek in its upper reaches where the creek flows through and along the boundary of Leard State Forest – corresponding to Reaches 1 and 2 identified on the Condition Survey – refer Section 6.2. Reach 1 has had minimal land disturbance while Reach 2 has had moderate disturbance compared to reaches downstream of the Project area. The stability of the creek channel in these reaches has been largely dependent on the intact and relatively undisturbed nature of the vegetation in the riparian corridor.

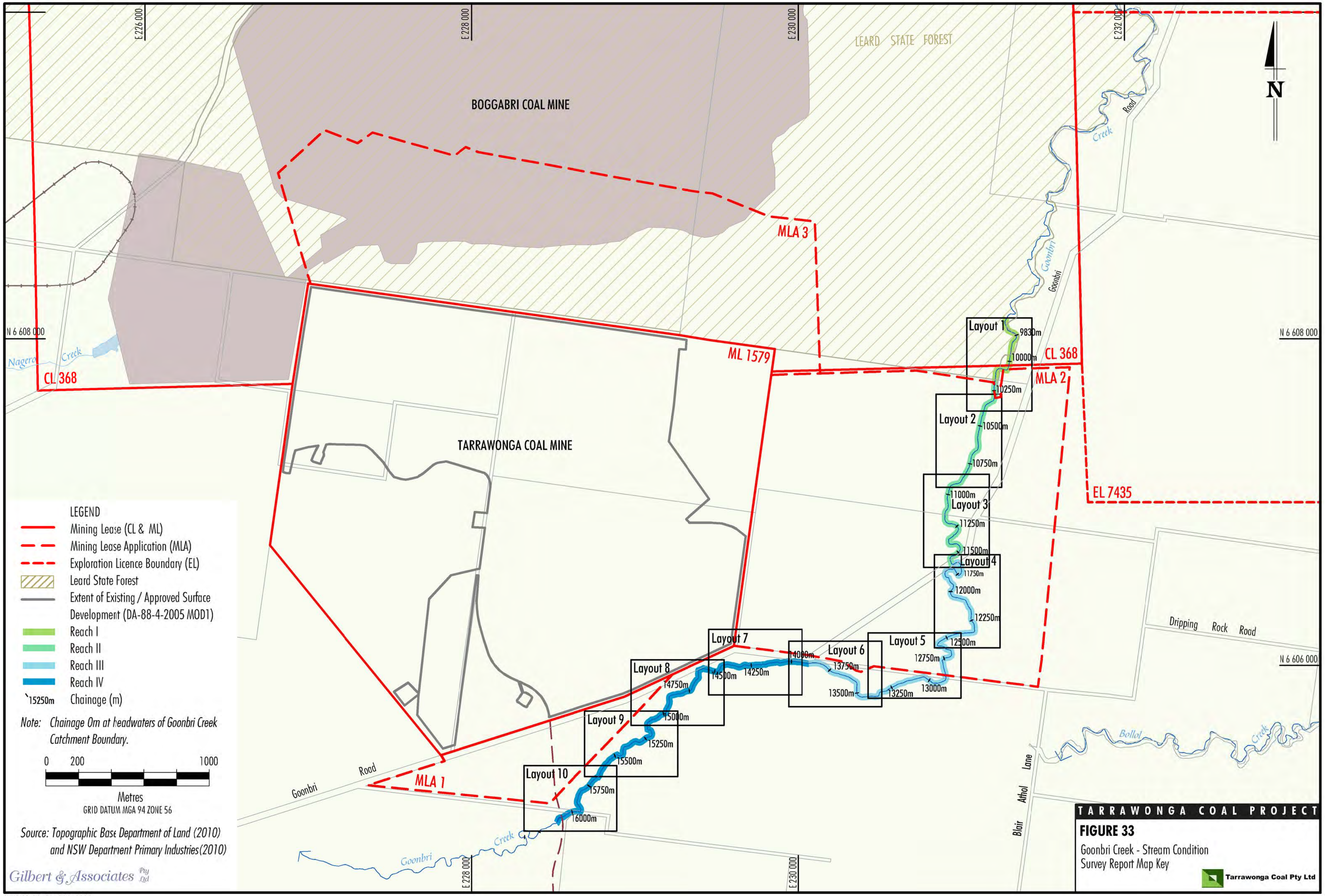


FIGURE 33

Goonbri Creek - Stream Condition Survey Report Map Key

WHC-01-04_EA_SWA_110C

The concept is to develop a wide revegetated floodway corridor, which would roughly define the inundation area of the permanent Goonbri Creek alignment. The floodway corridor would however not be confined on one side as the existing alignment of Goonbri Creek is on its western margin by the toe slopes of the Willowtree Range. Completion of the re alignment would then involve establishing a low capacity shallow channel within the revegetated floodway corridor which has a proportionately similar form and capacity as the existing Goonbri Creek channel in the Leard State Forest. The channel would be constructed to mimic the bed-slope and the width and depth variability which exists in survey Reaches 1 and 2 in Goonbri Creek.

The formation of the vegetated floodway corridor in advance of the re-alignment would provide a wide, stable corridor for the re-aligned creek. A low capacity channel can be formed within the vegetated corridor similar to that which exists in the upper reaches. The concept of a shallow low capacity channel is to provide a low energy, small capacity pathway for movement of low flows. Flows greater than the channel capacity would disperse out onto the wide revegetated floodway where it would move slowly downstream through the vegetated overbank areas. Adoption of a shallow, low capacity primary channel would mimic the typical channel form found in survey Reaches 1 and 2 and would result in limiting the flow energy in the central channel and dispersion flow energy associated with higher flows over the wide vegetated corridor.

Toward the downstream end of the permanent Goonbri Creek alignment, the channel of the realigned creek would gradually transition into the deeper more confined channel profile of Goonbri Creek which exists downstream of the outfall of the permanent Goonbri Creek alignment. The stability of the bed and banks of the reaches downstream would be improved by re-establishing bank and riparian vegetation in currently unstable areas.

6.3.2 Design Objectives

The objectives of the design of the proposed permanent Goonbri Creek alignment are as follows:

1. To provide a permanent alternative alignment for Goonbri Creek around the eastern edge of the proposed open cut extent.
2. Minimise disturbance upstream of the proposed open cut extent (i.e. upper reaches of Goonbri Creek as it flows along the boundary of the Leard State Forest).
3. Revegetate the permanent Goonbri Creek alignment and thereby extend the vegetated, higher value habitat conditions of upper reaches of Goonbri Creek through to the Bollol Creek floodplain area.
4. To provide stability with increased vegetation along the corridor within and immediately downstream of the re-aligned section to enhance stability and habitat value.
5. To provide a naturally stable creek which has equivalent hydraulic and geomorphological stability as the upper reaches of Goonbri Creek in the Leard State Forest over all flow conditions experienced in the catchment.

6. To provide a naturally stable transition back into the original alignment of Goonbri Creek which results in no significant (detectable) change to the existing (pre-alignment) hydraulic conditions (including flow rate, flow energy or distribution of flow) in the lower Goonbri Creek or the alluvial flats downstream.

6.3.3 Design Criteria

The following design criteria have been developed to meet the objectives of the design without compromising the stability of the surrounding environment and future mining activities:

1. The permanent Goonbri Creek alignment would be designed to provide similar or lower flow velocities and flow energy levels as occur in the upper reaches of Goonbri Creek over a wide range of flows.
2. The rates of flow energy dissipation, flow velocities and boundary shear stresses in the low flow channel and vegetated corridor, and 1 in 100 year ARI flood limit, would be consistent with the same parameters in the upper reaches of the creek and its floodplain over the range of design discharges. Design discharges would cover the range from the mean daily flow to the peak 1 in 100 year ARI discharge.
3. The performance of the permanent Goonbri Creek alignment would be assessed against the peak flow resulting from the Probable Maximum Precipitation rainfall event (QPMP). The re-alignment and the flood isolation bund would be designed such that QPMP would not inundate the proposed open cut mining areas with the permanent flood isolation bunds designed to be stable under these extreme/limiting flow conditions.
4. Reaches downstream of the permanent Goonbri Creek alignment would be retained in their current form to preserve the distribution of flows in the alluvial flats. However bank riparian vegetation would be maintained and improved along the lower sections of Goonbri Creek over its channelised length and remediation/stabilisation actions would be implemented in areas which show signs of bed and bank instability to ensure its overall stability and so protect the downstream end of the permanent Goonbri Creek alignment against any possible instability in the lower reaches of Goonbri Creek expanding upstream into the permanent Goonbri Creek alignment.

6.3.4 Conceptual Design Details

The conceptual design layout and details and typical cross sections are shown on Figures 34 to 36.

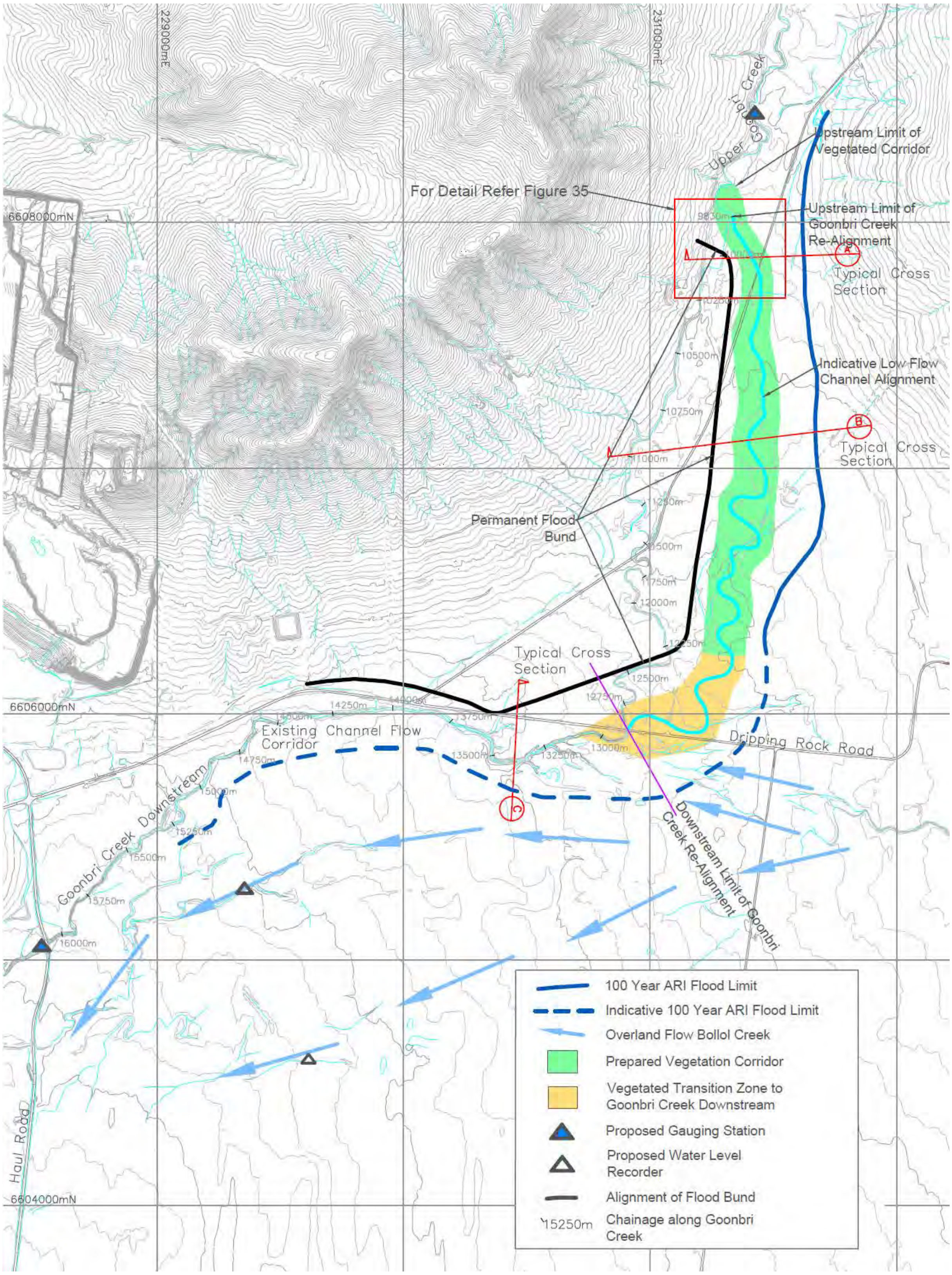
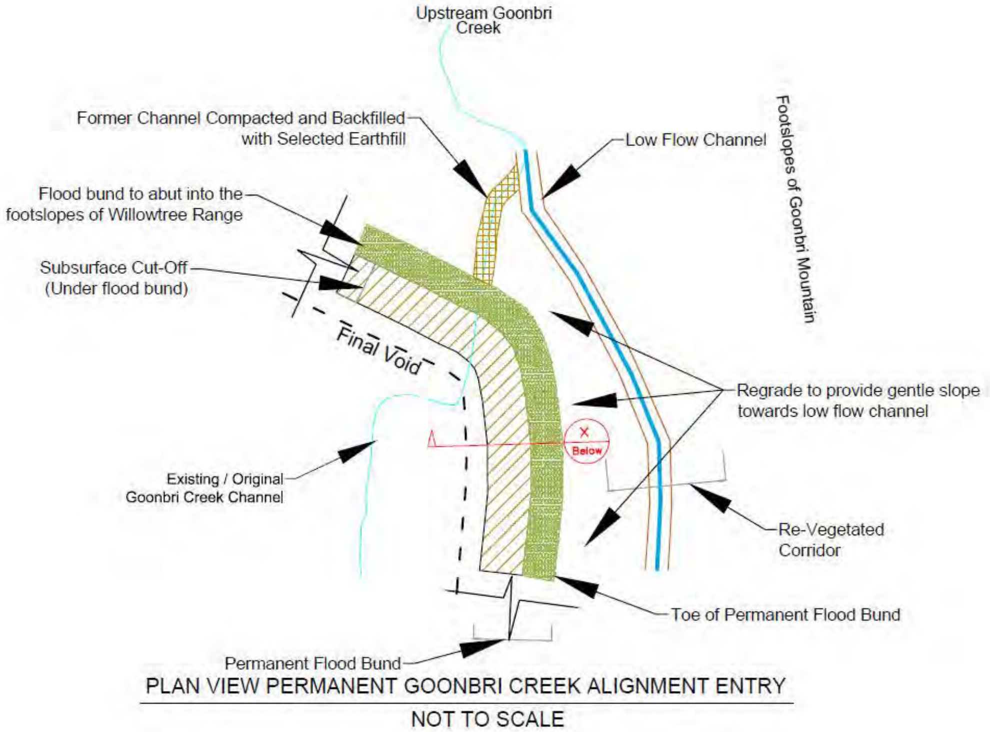


Figure 34 Conceptual Design Layout and Details of the Permanent Goonbri Creek Alignment



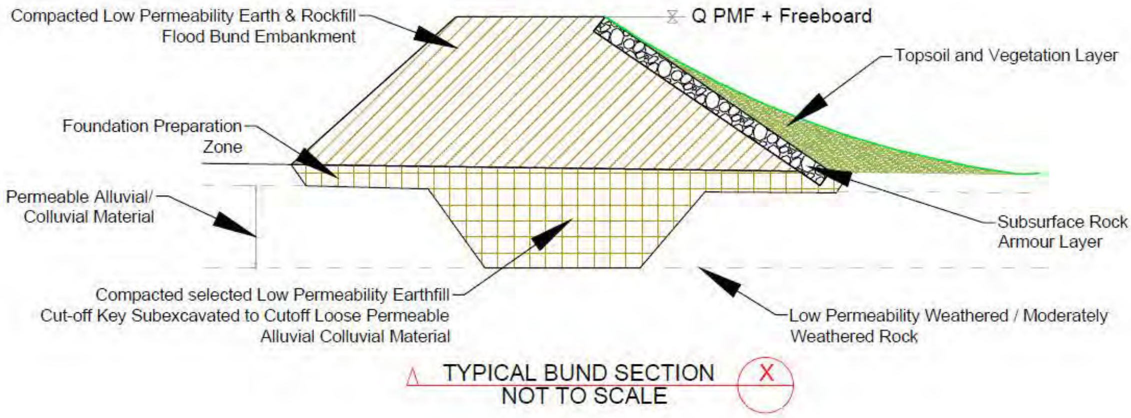


Figure 35 **Plan View of Upstream Conceptual Permanent Goonbri Creek Alignment and Flood Bund Section View**

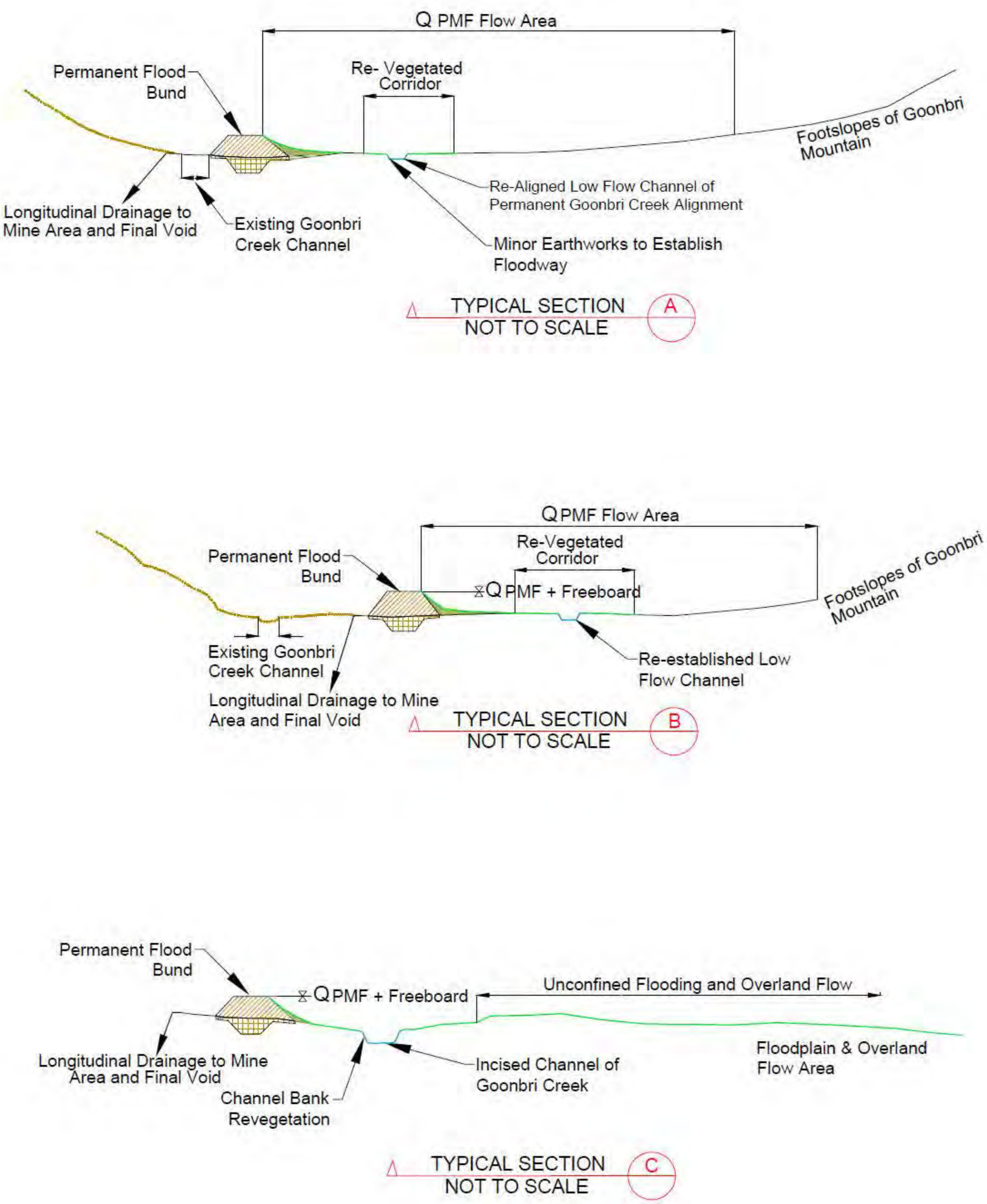


Figure 36 Typical Conceptual Cross Sections of the Permanent Goonbri Creek Alignment

The key requirement which governs the horizontal location of the permanent Goonbri Creek alignment is that it be re-aligned outside the proposed extent of the open cut. The permanent Goonbri Creek alignment corridor takes advantage of a natural depression and expansive low lying areas on the eastern side of the existing Goonbri Creek alignment. The permanent Goonbri Creek alignment commences approximately 425 m upstream of the open cut extent with a flood bund acting as a cut-off levee (refer Figure 34). The cut-off levee abutment would merge with the foot slopes of the Willowtree Range at its upstream and downstream extremities. The upstream end of the permanent Goonbri Creek alignment would be formed near the upstream abutment of the flood bund. A cut-off key would be constructed below the levee to block seepage through the more permeable near surface alluvium. From its upstream extremity and the point where the flood bund crosses the original channel, the existing channel would be backfilled, regraded and revegetated to facilitate drainage toward the inlet of the permanent Goonbri Creek alignment. The alignment of the low capacity channel that would be formed within the wider floodway corridor would follow a meandering path that mimicked the existing creek channel alignment such that its length is the same as the existing section of Goonbri Creek.

The longitudinal profile of the existing Goonbri Creek channel and invert of the permanent Goonbri Creek alignment are shown on Figure 30. The existing surface is slightly undulating however the permanent Goonbri Creek alignment would be excavated into the existing surface and have an average bed slope of about 0.4%. The bed and banks of the low flow channel would be ‘over-excavated’ to provide for placement of creek channel substrate and topsoil. The channel profile would be constructed with a variable form to allow for changes in bed depth along the alignment and for a variable cross sectional profile consistent with profile changes in the existing creek in survey Reaches 1 and 2.

Materials used in the bed and banks of the low flow channel would be selected to conform with engineering specifications relevant to erosion resistance and stability under alternating wetting and drying conditions. Dispersive soils would not be placed in the bed and banks of the low flow channel. The floodway corridor would be formed using in-situ materials with earthworks scheduled such that all topsoil in areas disturbed by earthworks during its formation would be stripped and replaced over the final surface. In areas where dispersive and/or acidic soils are encountered, these would be stabilised using amelioration techniques recommended by Mackenzie Soil Management (2011) including the addition of gypsum and lime.

Larger trees cleared from mine areas would be used to roughen sections of the vegetated corridor and would be placed in selected parts of the low flow channel to increase cross sectional diversity and enhance stability. Constructed rock bars, bank levees and riffles would also be used to provide early stability and diversity to the channel.

The formed overbank flow areas on the western bank between the flood bund and excavated low flow channel would be graded to slope towards the reformed low flow channel (refer Figure 35) at a grade compatible with the surrounding landscape. Fill material would be used to infill depressions and to affect a nominal positive slope back toward the low flow channel. This would reduce the potential for an out of channel floodway to form and for longer term loss of diversion channel and flood bund integrity. These infill areas would be topsoiled and revegetated.

The channel would transition back to the more incised profile of the downstream reaches near the end of the permanent Goonbri Creek alignment. The transition zone would commence at the end of the formal revegetated corridor – refer Figure 34, in the area where overland flows from Bollol Creek currently flow into the lower reaches during periods of high flow. The transition zone would be constructed so as to preserve the distribution of flows in areas downstream. The transition itself would also be designed to have lower velocities and lower energy flows than in representative sections of Goonbri Creek downstream.

The existing terrain along the permanent Goonbri Creek alignment is such that the earthworks required to form the vegetated floodway would be relatively minor with excavation and fill depth being generally less than a metre. The low flow channel would also involve relatively small excavations and could be undertaken using small earthmoving equipment to limit disturbance within the revegetated floodway corridor.

6.4 Assessment of Hydraulic Performance

6.4.1 Design Discharges

A rainfall-routing model for Goonbri Creek was set up using RORB (Laurenson & Mein, 1997) modelling software in order to generate preliminary estimates of likely peak design flows. The model parameters were selected based on recommendations in Australian Rainfall and Runoff (Institution of Engineers, Australia, 1998). The predicted peak design flows used in the performance assessment of the conceptual design are summarised in Table 26 below.

Table 26 Predicted Peak Flood Discharges at Permanent Goonbri Creek Alignment Inlet – for Conceptual Design

	ARI – Years			
	2	**20**	**100**	**PMF***
Estimated Peak Flow Rate (m^3/s)	18	109	192	1,379

* Probable Maximum Flow

6.4.2 Assessment of Hydraulic Conditions

A preliminary hydraulic assessment has been undertaken to assess the viability of the design concept described in Section 6.3.

The indicative hydraulic conditions likely to be experienced in the permanent Goonbri Creek alignment have been assessed using the 1-dimensional hydraulic modelling software HEC-RAS (USACE, 2010). Input used in the HEC-RAS model comprised:

- channel and natural creek cross-sections[7] to define the channel and creek geometry – obtained from available 1 m topographic contours with manual inclusion of the proposed low flow channel;
- estimates of channel and natural creek roughness/friction factors[8];
- design flow rates (refer Section 6.4.1 above), and
- estimated water levels at either end of the modelled reach.

Modelled peak flow velocities in the channel and overbank areas are indicators of the stability of the permanent Goonbri Creek alignment. Figure 37 shows the variation of velocity under peak 1 in 100 year ARI peak flow conditions in the low flow channel and overbank areas.

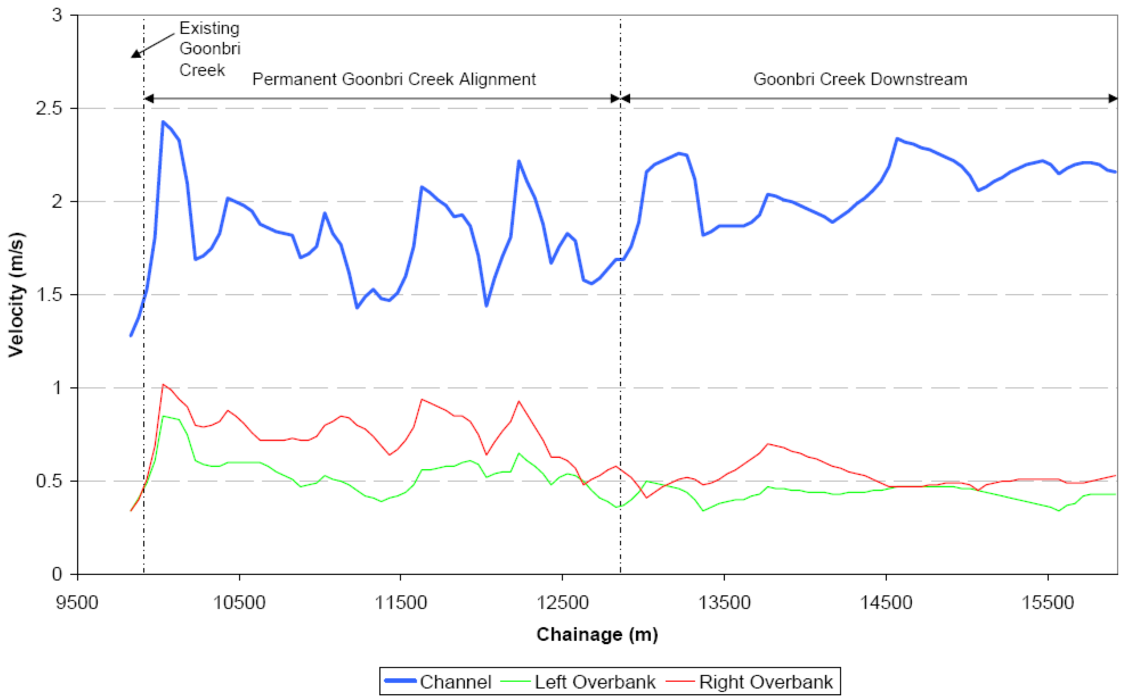


Figure 37 Simulated Flow Velocity Profile along the Permanent Goonbri Creek Alignment – 100 Year Design Peak Flow Conditions

These velocities are similar to and generally less than the corresponding velocities along the existing alignment of Goonbri Creek.

[7] Cross sections used in this assessment are based on cross sectional profiles measured using a tape measure during the condition surveys supplemented by the available 1 m contour plans of the site.

[8] Friction factors (Mannings "n") for the low flow channel and existing creek were set to 0.045 in accordance with the conditions observed along the bed and banks of the existing Goonbri Creek during the creek condition survey. Friction factors for the overbank areas (i.e. vegetated corridor) were set at 0.08, to reflect denser vegetation, based on literature guidelines. These conditions reflect the expected corridor condition after vegetation has been fully established.

6.5 Recommendations for Future Detailed Design Process, Monitoring and Management

The following recommendations are made for the future detailed design process, monitoring and management of the permanent Goonbri Creek alignment:

1. Detailed cross sectional and longitudinal survey should be conducted along Goonbri Creek from upstream of the realignment section to the existing TCM to Gunnedah haul road crossing. This should be supplemented with a Lidar survey to define the existing floodplain areas associated with Goonbri Creek and the Bollol Creek confluence and downstream to Barbers Lagoon and the Slush Holes.

2. A numerical hydraulic model should be developed to simulate the existing hydraulic characteristics of Goonbri Creek along the surveyed route and down to the Bollol Creek confluence. The hydraulic characteristics of the area from the Bollol Creek confluence downstream to Barbers Lagoon and the Slush Holes should also be modelled using a 2-dimensional model. This modeling would utilize the topographical survey data generated by the survey recommended in 1 above and the observations captured by the flow and water level monitoring recommended in 3 below.

3. Results of modelling should be used to provide more concise baseline characterisation of the existing geomorphologic and hydraulic characteristics of Goonbri and lower Bollol Creeks as a basis for final design of the permanent Goonbri Creek alignment.

4. Condition surveys of Goonbri Creek should be undertaken periodically during/following a range of climatic conditions (i.e. following prolonged dry periods and significant flood events) to document creek condition for a range of baseline/pre-mine conditions of the watercourse.

5. Flow gauging stations on Goonbri Creek should be established upstream and downstream of the proposed re-alignment (refer Figure 38 for recommended locations) to: (a) support the development of catchment models during the detailed design phase to confirm or adjust the design flows in this report; and (b) assist in management and performance evaluation monitoring during and post construction. Pluviometers should be established in the upstream catchment in conjunction with the gauging stations. Water level monitoring to determine the distribution of flows in the lower reaches of Bollol Creek and the alluvial flats should also be conducted to support detailed hydraulic modelling (refer Figure 38).

6. The hydraulic model(s) developed in 2 above should be re-calibrated against gauging station and water level monitoring data on Goonbri Creek (collected after completion of the initial modelling) and used to test and refine the design of the permanent Goonbri Creek alignment to meet its design objectives and criteria.

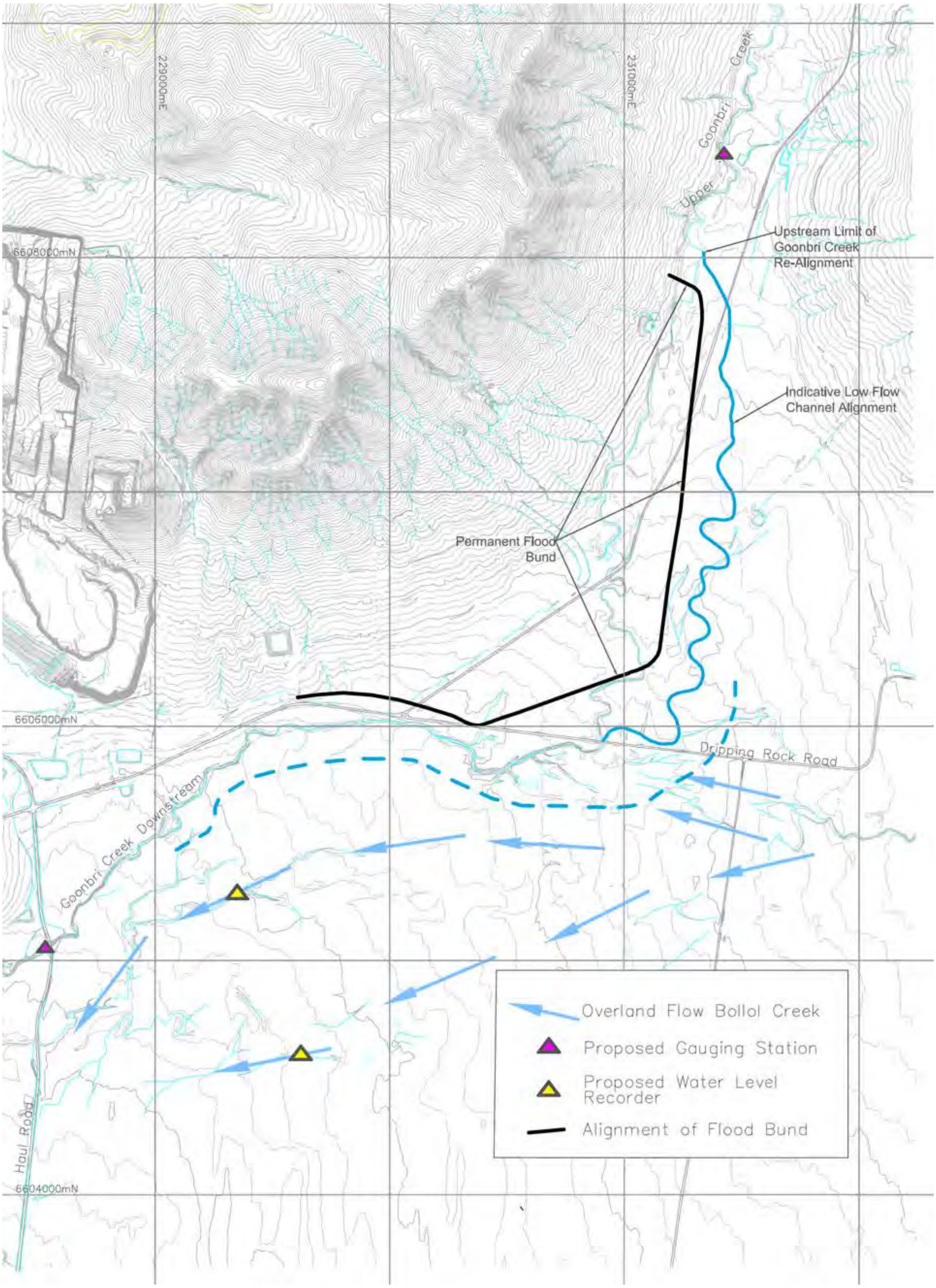


Figure 38 Recommended Monitoring Locations

7. Control or reference sites and reaches for a channel stability monitoring program should be identified and baseline topographical and geomorphic condition surveys conducted. Bollol Creek and Goonbri Creek upstream of the permanent alignment should be used to locate suitable (representative) reference reaches. The reaches should have similar characteristics to Goonbri Creek over the section being realigned and/or similar to the reach types envisaged in the permanent Goonbri Creek alignment design. Historical changes in these reaches should be assessed using historical data including aerial photography. Condition surveys should also be conducted following significant flow events to assess background responses to flow events.

8. A Permanent Goonbri Creek Alignment Design, Construction and Management Plan should be developed, in consultation with regulatory and approval authorities, to outline the formal design and predicted performance in relation to the concepts and design objectives outlined in this report (subject to acceptance and approval by the regulatory authorities). The management plan should incorporate the performance assessment and associated monitoring regime.

9. A revegetated corridor (within and immediately downstream of the proposed permanent Goonbri Creek alignment) should be established using endemic vegetation consistent with the management plan objectives. Establishment of the corridor should be timed to provide substantial vegetation establishment prior to construction of the low capacity channel and planned commissioning.

10. Geotechnical investigations will be required to support final design. These would build on the results of the soils surveys and preliminary investigation conducted for the conceptual design. The investigations should be designed to identify the physical (geomechanical) and chemical properties of materials likely to be encountered during construction of the floodway corridor and low flow channel.

11. The low flow channel should be constructed within the revegetated permanent Goonbri Creek alignment at least three years prior to planned commissioning.

12. The outlet transition zone works should be conducted at least one year prior to planned commissioning.

13. An ‘as-constructed’ report should be compiled demonstrating compliance with design objectives prior to planned commissioning.

14. A performance monitoring plan should be developed and implemented including stability monitoring in the permanent Goonbri Creek alignment and at least three control-reference sites – upstream, downstream and on other unaffected watercourse(s) such as the upper reaches of Bollol Creek. The proposed criteria against which the geomorphological functionality of the permanent Goonbri Creek alignment is judged should be based on distinguishing between the type, frequency and magnitude of geomorphological changes in the permanent Goonbri Creek alignment with those that occur in the control or reference sites.

7 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 the progressive extension and subsequent capture and re-use of drainage from active mine catchment areas.
- Changes (albeit small) to the Goonbri/Bollol Creek floodplain due to the flood bund to protect against extreme flood events entering the mine and realignments of Goonbri Road.
- Potential for export of contaminants (principally sediments and soluble salts) in mine catchment area runoff, controlled releases and accidental spills from containment storages (principally sediments, soluble salts, oils and greases), causing degradation of local and regional watercourses.

Assessment of the permanent Goonbri Creek alignment (considering the removal of a 3 km section of the existing Goonbri Creek alignment) is provided in Section 6. The associated impacts on flora and fauna (terrestrial and aquatic) are addressed in the Fauna and Flora Assessments included as Appendices E and F in the EA.

7.1 Impacts on Flow Regime

The potential impacts to downstream flow regimes has been assessed by estimating changes to mine site catchments which contribute to runoff in local and regional waters. Maximum catchment area excised from both Nagero Creek and Bollol/Goonbri Creeks by the Project are given in Table 27. Cumulative impacts associated with the Project and Boggabri Coal Mine (assuming the maximum reduction in contributing catchments for each individual mine was to occur at the same time) is given in Table 28.

Table 27 Project Contribution to Changes to Catchments

Timing	Percentage Reduction in Contributing Catchment		
	Nagero Creek	Bollol/Goonbri Creeks	Namoi River
TCM (existing/approved)	2.4%	1.8%	0.01%
Project – Year 2 (progressive)	**6.9%**	2.5%	**0.02%**
Project – Year 4 (progressive)	6.3%	2.6%	0.02%
Project – Year 6 (progressive)	4.5%	2.8%	0.02%
Project – Year 12 (progressive)	2.9%	2.3%	0.01%
Project – Year 16 (progressive)	3.0%	**3.0%**	0.02%
Post-Mining	6.0%	-2.1%*	0.004%

* A negative value indicates a gain in catchment area (as the final mine landform would result in the catchment divide extending further to the north-west).

Table 28 Cumulative Contribution to Changes to Catchments

Catchment	Maximum Percentage Decrease in Catchment Area			
	Project	Boggabri Coal Mine	Maules Creek Coal Project	Cumulative
Nagero Creek	6.9%	21.1%	0.8%	28.0%
Bollol/Goonbri Creeks	3.0%	0.9%	-	3.9%
Namoi River	0.02%	0.04%	0.04%	0.10%

7.2 Impacts of Controlled Release

The water management system has been developed such that mine water would be contained on site and that controlled release would occur from active sediment control structures following settlement. Provided the water management system is constructed and operated in accordance with its design and operational criteria it is considered that there would be a low risk of adverse water quality impacts from controlled releases. When sediment storages are only receiving runoff from fully rehabilitated and stabilised catchment areas they would be passively managed. Releases from passively managed storages are considered to have a very low risk of adversely affecting downstream waters. In part, this would be dependent on the adoption of effective monitoring and adaptive management of the sediment and erosion control scheme, including, for example, transfers to on-site surge storages if water quality is not suitable for release.

Based on the results of the Geochemical Assessment (Appendix N) and consideration of water quality monitoring data in on-site water storages receiving drainage from active and partially rehabilitated overburden emplacements (refer SD1, SD2 and SB7 in Table 11), the risks of elevated dissolved solids and other contaminants impacting downstream waters is considered to be low.

7.3 Impacts of Runoff from Progressively Rehabilitated Landforms

It is expected that the water quality of runoff from portions of the mine waste rock emplacement which have been rehabilitated and where sufficient time has elapsed for vegetation to establish, would reflect runoff water quality from similar un-mined areas. Once this has occurred, runoff would be released to the environment. Prior to the stabilisation of rehabilitated areas, runoff would be managed via the actively managed sediment and erosion control system.

The northern emplacement is to be progressively rehabilitated generally from west to east. As areas are rehabilitated, runoff would be directed towards the west via drains and drop structures into SB6, SB7 or SD17. SB6 and SB7 overflow to SD17 which is an existing LDP.

The southern emplacement is also to be progressively rehabilitated during the mine life. Runoff from rehabilitated areas would be directed to three storages: SB(N2), SD16, and SB14(R). These three storages are linked in that SB(N2) overflows to SB14(R) and SD16 overflows to SB14(R) (refer Figure 17). Once the quality of runoff reporting to the three storages reflects the quality of runoff from similar but un-mined areas, the storages would be passively managed with uncontrolled releases to Goonbri Creek via SB14(R).

Similarly, the area draining to SB23 includes a soil stockpile which would be removed by Year 4 and is planned to be rehabilitated by Year 6 (refer Figure 4 and Figure 5). Following stabilisation, runoff would be passively managed with uncontrolled release to Bollol/Goonbri Creeks.

There is a risk that runoff from some areas of the rehabilitated mine site may contain elevated suspended sediment. This risk will depend on the effectiveness of the rehabilitation works conducted on site and would reduce over time as ongoing monitoring and maintenance programs are implemented. During intense rainfall events the capacity and effectiveness of sediment control structures may be reduced resulting in increased concentrations of suspended sediments. Suspended sediment concentrations are usually higher during large rainfall events naturally. It is expected that under low and average climatic conditions there would be a low risk of elevated turbidity and suspended solids affecting downstream water courses at levels that are higher than those from other land use activities. Under high and extreme rainfall conditions the risk of elevated turbidity would be higher but consistent with other land use activities such as cropping which are conducted in downstream catchment areas.

If constructed and operated in accordance with Landcom (2004) guidelines and application of adaptive management measures (e.g. transfers to on-site surge storages if water quality is not suitable for release), runoff and subsequent releases from these catchments would meet the standards accepted for well managed erosion and sediment control schemes.

7.4 Impacts on Local Flood Regime

As described in Section 2.6, lower sections of the Project site along Goonbri Creek could be affected by extreme flooding from Bollol/Goonbri Creek and would be protected by flood bunds. The Project area is predominantly on land with an elevation greater than 275 m AHD and therefore would be above any conceivable flooding of the Namoi River.

The impacts of the flood bund and embankments of the Goonbri Road realignments on the Goonbri/Bollol Creek floodplain south of Dripping Rock Road would be minimal.

7.5 Water Licensing Requirements

Protection of the Environment Operations Act, 1997

While three of the nominated LDPs are administered in accordance with the existing EPL, an additional three LDPs are proposed. One LDP is proposed for SB23 which was approved as part of the October 2010 modification and is currently pending a variation to the existing EPL to be included as a LDP. Another LDP is proposed for UWD2 which receives runoff from undisturbed catchment only. The third LDP is proposed for SB(N3) which would be in service for the remaining mine life.

Water Act, 1912

Water may be sourced from the Thuin Groundwater Production Bore when stored volume in MWD2 is low. Bore extraction is licensed up to a maximum of 50 ML per year and there is no plan to increase the current allocation from this bore for the Project.

Water licensing requirements for groundwater inflows to the open cut and are considered separately in the Groundwater Assessment (Appendix A to the EA).

Water Management Act, 2000

Consideration of the water licensing requirements under the *Water Management Act, 2000* and applicability to the Project is discussed in Section 3.2.

8 POST-MINING WATER MANAGEMENT

8.1 Final Void

A final void would be left at the end of the Project life. TCPL propose to manage the final void and its catchment configuration by changes to the final mine plan (e.g. partial backfill) and closure works to achieve a final void water level which is close to the pre-mine level in the coal measures but ensures a groundwater sink. For the purposes of assessment and comparison, a final void water balance model has been set up to simulate the behaviour of the water body that would form in the final void (1) without partial backfill and (2) with partial backfill.

The model simulates inflow from catchment rainfall runoff (including direct rainfall) and groundwater recovery, and outflow due to evaporation. Key model assumptions included:

- A catchment area totalling approximately 155 ha based on the post mine landform plan – refer Figure 8.
- The same 122 year climatic data set used in the water management system water balance model was used in the final void model. The 122 year climatic data set was repeated twice to generate a 366-year daily time-step final void simulation.
- Groundwater inflow rates were provided by Heritage Computing (2011) and are summarised in Table 29. The groundwater inflows include re-pressurisation of the porous rock aquifers and infiltration reporting to the void via the adjacent mine waste rock emplacement.
- Open water evaporation rates were factored down according to the water surface level in the void (from 40 % when the void was empty to 80 % if the water level was to reach a spill level of 280 m AHD).

Table 29 Summary of Final Void Groundwater Inflow Rates

RL (m)	Groundwater Inflow (ML/d)
178.9	1.08
203.1	0.28
225.0	0.10
234.9	0.12
245.1	0.22
253.4	0.29

Source: Heritage Computing (2011)

Model results are shown in Figure 39 (without partial backfill) and indicate that the final void would slowly reach equilibrium water levels below the surrounding existing surface level. Salinity is predicted to increase slowly reaching some 7,000 mg/L (without partial backfill) and 5,000 mg/L (with partial backfill) at the end of the modelling simulation (after 366 years) (Figure 40).

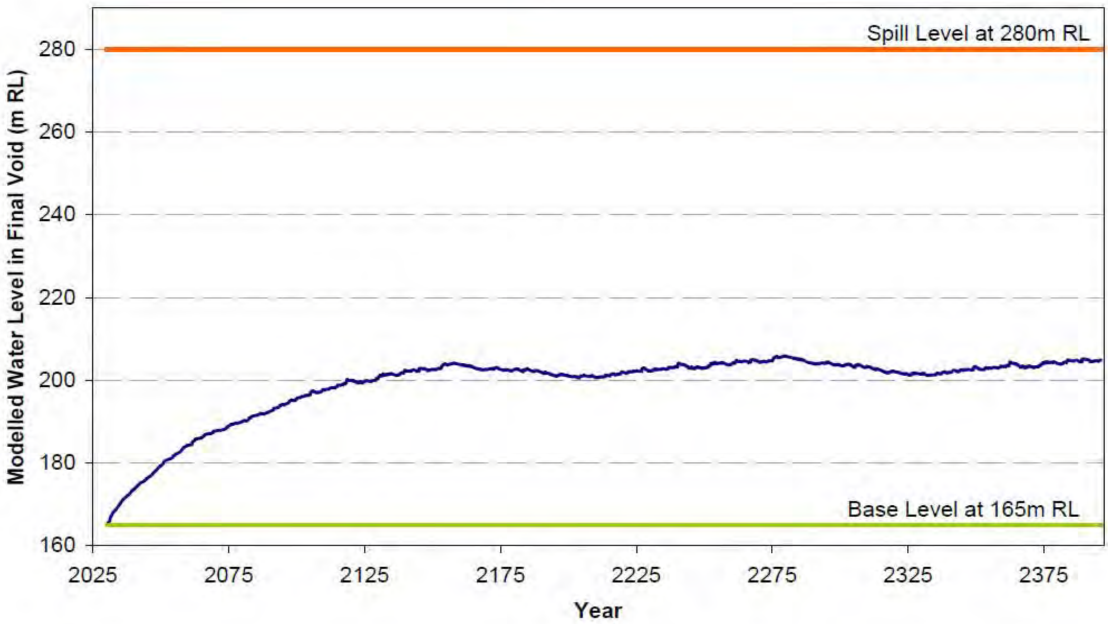


Figure 39 **Simulated Final Void Water Levels – without partial backfilling**

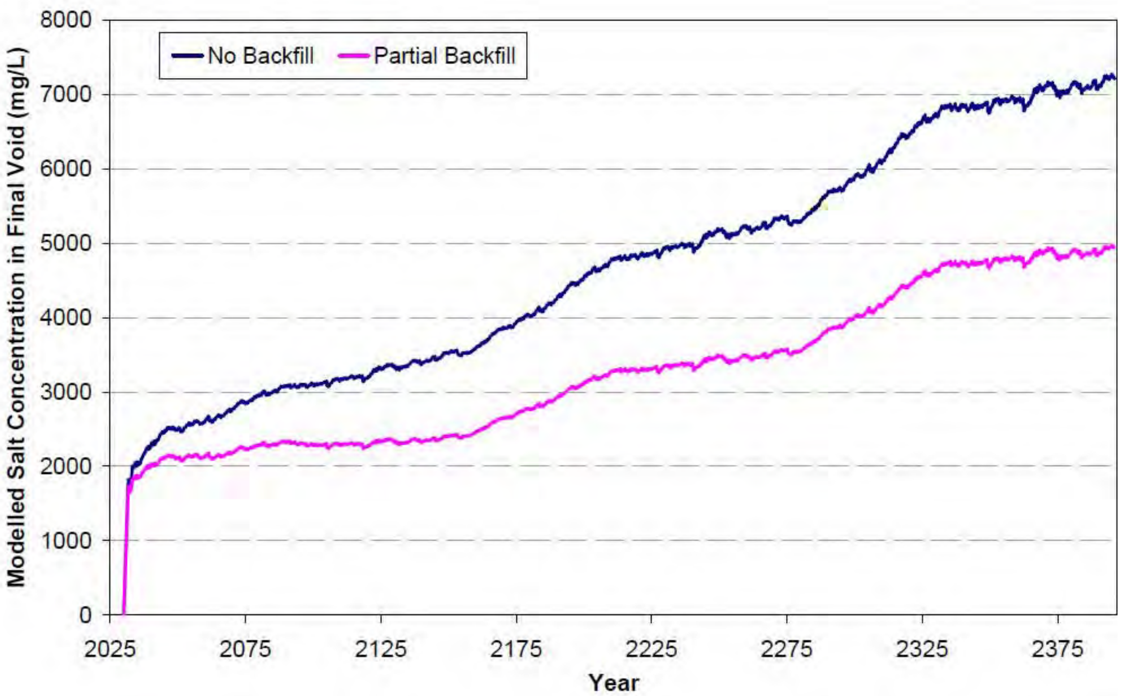


Figure 40 **Simulated Final Void Salinity Levels**

The simulated final void water levels (without partial backfill) indicate the void would reach an equilibrium level which would likely oscillate between about 200 and 210 m AHD depending on climatic variability. This is greater than 50 m below the pre-mine water levels in the area and would result in a permanent groundwater sink forming and potentially permanent lowering of local levels.

There are however several measures that can be taken to increase the final void water levels to more closely approximate pre-mine levels in the coal measures however retain a localised groundwater sink. TCPL propose to manage the final void to retain a localised groundwater sink and achieve a final void water level between 240 to 260 m AHD (i.e. more closely approximating the pre-mine water levels in the coal measures), without the final void overflowing to the downstream watercourses.

The viability of achieving this has been tested by assessing the effects of partially backfilling the void so as to reduce its evaporative surface area to approximately 55 ha (at spill level). The results of the partial void backfill scenario given in Figure 41 below indicate that partial backfilling has the potential to achieve the objective of water level recovery.

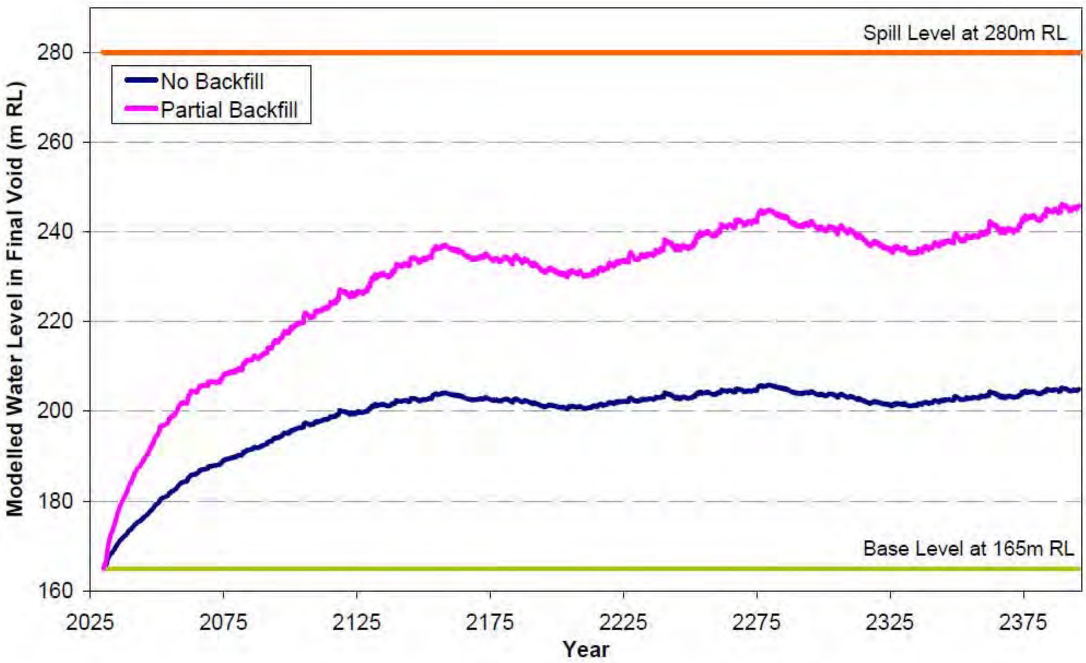


Figure 41 Simulated Final Void Water Levels – with partial backfilling

There are other options which could also be used such as changing the final catchment configuration. It is understood TCPL propose that these options would be evaluated and incorporated into mine (closure) planning as the Project is developed.

8.2 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 requirement.

9 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 conducted and co-ordinated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). 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 more sensitive to future emission scenarios.

9.1 Future Rainfall and Evapotranspiration

Predictions of future rainfall in south-eastern Australia are generally for reduced annual rainfall, but increased daily rainfall and a higher number of dry days per year. Future monthly rainfall and evapotranspiration predictions for the Project area have been obtained using the CSIRO's (2007) OzClim system for a medium impact (in terms of rainfall reduction) global climate model. The model used was the MRI-CGCM2.3.2 with low climate sensitivity, maximum rate of global warming and the A1FI emission scenario[9]. Table 30 below summarises model results.

[9] A1FI emission scenario refers to expected emissions for a future characterised by very rapid economic growth, 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 but emphasises fossil-fuel intensity.

Table 30 Percentage Change in Predicted Monthly Rainfall and Evapotranspiration in 2030 and 2100 Relative to 1990 – Tarrawonga Region (from MRI-CGCM2.3.2)

Season	Percentage Change from 2030		Percentage Change from 2100	
	Rainfall	Potential evapotranspiration	Rainfall	Potential evapotranspiration
January	-6.8	3.3	-28.8	14.0
February	-9.7	3.0	-39.0	13.2
March	0.9	3.1	4.2	13.4
April	-2.5	3.9	-11.6	16.6
May	-11.4	6.3	-44.1	24.8
June	-9.2	7.0	-37.4	26.6
July	-15.1	5.5	-54.6	21.9
August	-13.8	0.3	-51.0	1.5
September	-11.7	1.5	-45.1	6.9
October	-4.3	2.2	-19.1	10.0
November	-13.3	2.2	-49.7	9.6
December	-3.0	3.1	-13.6	13.4

As noted above however, there is a large variability in the prediction of future rainfall 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 for the majority of months. Potential evapotranspiration increases for all months with the greatest increase occurring in June.

9.2 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.

Longer term climate change predictions do however have potential implications for post mine water management and specifically the water balance of the final void. In this regard the currently most accepted scenarios would see a reduction in overall rainfall and an increase in evapotranspiration. This would translate to reduced surface water runoff inflows to the void and reduced incident rainfall over the surface of the void. There would also be increased evaporation loss for the void surface and as a consequence lower average water levels in the void.

As described in Section 8.1, TCPL propose that options would be evaluated and incorporated into mine (closure) planning as the Project is developed to increase the final void water levels to match pre-mine levels. The implications for changes to the water balance of the final void due to climate change are considered minimal.

10 RECOMMENDED MONITORING

TCM currently implement a surface water monitoring program in accordance with the requirements of Development Consent (DA-88-4-2005) and EPL No. 12365. The proposed extension would necessitate changes to this surface water monitoring program in line with the structural changes to the water management system to incorporate new on-site storages and changes to LDPs.

Due to the greater requirements to contain and manage water on-site as the mining operations areas are extended (including groundwater inflows) over the life of the Project, a progressive expansion to monitoring which will provide data sufficient to audit the performance of the mine water containment components and support ongoing water balance model calibration and verification is proposed.

Development of the permanent Goonbri Creek alignment ahead of mining toward the end of the Project life will also require specific flow and geomorphologic monitoring which should be ongoing following the completion of the realignment for verification and determination of its success/performance triggers.

Specific monitoring recommendations covering flow and water quality are summarised below.

10.1 Climate Monitoring

Rainfall and evaporation data is required to interpret surface water monitoring and as input to water balance and catchment modelling. There is currently one weather station on site which provides rainfall and other climatic data used to estimate evaporation rates. It is recommended that two additional pluviometers be established in the upper and mid reaches of the Goonbri Creek catchment. Details of these stations may be subject to land holder agreement and would be confirmed prior to establishment. Data from these devices would support catchment and associated hydraulic modelling of the permanent Goonbri Creek alignment. They would also support ongoing water balance modelling of mine areas to the east of the current weather station.

10.2 Surface Water Flow

It is proposed to establish continuous flow monitoring (gauging) stations on Goonbri Creek upstream and downstream of the proposed re-alignment and disturbance area. The stations should be established during the first 2 years of the Project and maintained over the life of the Project. The gauging stations should be designed to provide low flow accuracy and resolution. It is also recommended that a network of flood level gauges be established in the lower reaches and overflow areas of Bollol/Goonbri Creek – refer Figure 38. These monitoring sites would provide data in support of hydraulic modelling for the permanent Goonbri Creek alignment design and to demonstrate preservation of overland flow patterns on the alluvial flats downstream of the permanent Goonbri Creek alignment.

10.3 Surface Water Quality

Water quality monitoring sites should be expanded to include all new on-site storages and LDPs. Additional water quality monitoring sites should also be established on Goonbri Creek at the proposed gauging stations (refer Section 10.2).

Sampling in site storages should follow the current regime of quarterly and event based sampling. Sampling of sites on Goonbri Creek and other local surface waters should be event based.

The analysis of samples should also comply with the current regime of combined field sampling for salinity (electrical conductivity), pH and suspended solids and laboratory analysis for common cations, anions, metals (including arsenic, iron, chromium, cadmium, zinc, aluminium, molybdenum and selenium) and bulk nutrients (total nitrogen, total phosphorus).

10.4 Site Water Balance

It is recommended that the following data be monitored and recorded to provide data for calibration of the water balance model and assessment of the operational performance of the water management system over the life of the Project:

- records of pumped water volumes;
- storage levels in mine water dams and other containment storages;
- haul road water usage rates;
- crusher usage rates; and
- irrigation usage rates.

Monitoring frequency should be consistent with requirements for model calibration.

10.5 Permanent Goonbri Creek Alignment

Recommendations for monitoring associated with the permanent Goonbri Creek alignment in support of its design and construction are provided in Section 6.5. In addition it is recommended that erosion and condition surveys be conducted for the first five significant flow events post commissioning. These surveys should be conducted both along the permanent Goonbri Creek alignment itself and the control reaches on Goonbri Creek upstream and Bollol Creek. The comparative changes and responses to flow events would be used to establish compliance with performance triggers and objectives.

11 BIBLIOGRAPHY

Allan Watson Associates (2011). “Concept Design for Low Permeability Barrier and Permanent Goonbri Creek Alignment”. Report prepared by Allan Watson Associates Pty Ltd for Tarrawonga Coal Pty Ltd, September.

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 and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy”. October.

ANZECC/ARMCANZ (2000b). “Australian Guidelines for Water Quality Monitoring and Reporting, National Water Quality Management Strategy”. 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 2011. <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.

Boughton W.C. (2006). “Calibration of a daily rainfall-runoff data with poor quality data”. Environmental Modelling & Software, Vol.21, pp.1114-1128.

Cenwest (2011). “Goonbri Creek Aquatic Assessment” as Attachment [B] to “Tarrawonga Coal Project Fauna Assessment”.

CSIRO (2007). “OzClim”, Accessed September 2011. <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>.

DECCW (2008). “Managing Urban Stormwater – Soils & Construction Volume 2E Mines and Quarries”. Department of Environment and Climate Change NSW, June.

FloraSearch (2011). “Flora Assessment”, Report prepared by FloraSearch Pty Ltd for Tarrawonga Coal Pty Ltd. October.

Geo-Environmental Management Consultants (2011). “Tarrawonga Coal Project – Geochemistry Assessment Of Overburden”.

Heritage Computing (2011). “Groundwater Assessment - A Hydrogeological Assessment in Support of the Tarrawonga Coal Project Environmental Assessment”. Report prepared by Heritage Computing Pty Ltd for Tarrawonga Coal Pty Ltd, October.

Institution of Engineers, Australia (1998). “Australian Rainfall and Runoff – A Guide to Flood Estimation - Volume 1”. Institution of Engineers Australia, Barton ACT.

Intergovernmental Panel on Climate Change (2007). “Climate Change 2007”. Fourth Assessment Report.

Lampert, G and Short, A (2004), “Namoi River Styles”.

Landcom (2004). “Managing Urban Stormwater: Soils & Construction Volume 1”, 4th Edition, March.

Laurenson, E.M. and Mein, R.G. (1997) “RORB – Version 4 Runoff Routing Program User Manual”, Monash University, Clayton, Vic., January.

Mackenzie Soil Management Pty Ltd (2011). “Soil Survey and Land Resource Assessment – Tarrawonga Coal Project Boggabri NSW”. June.

New South Wales Department of Land and Water Conservation (2003). “Carroll to Boggabri Flood Study and Compendium of Data”, January.

New South Wales Department of Natural Resources (2002). “State Water Management Outcomes Plan”.

New South Wales Department of Planning and Infrastructure (2011). “Director-General’s Environmental Assessment Requirements”.

New South Wales Office Of Water (2011a). “Water Information Website”, Accessed July 2011, < http://realtimedata.water.nsw.gov.au/water.stm>.

New South Wales Office Of Water (2011b). “Harvestable Right Dams Website”, Accessed October 2011, <http://www.water.nsw.gov.au/Water-licensing/Basic-water-rights/Harvestable-right-dams>.

Parsons Brinckerhoff (2010). “Continuation of Boggabri Coal Mine Project – Surface Water Assessment”, prepared for Boggabri Coal Pty Ltd, October.

RCA Australia (2005).”Groundwater Assessment of the Proposed East Boggabri Mine”, prepared for East Boggabri Joint Venture, Carrington, May.

RW Corkery & Co Pty Ltd (2007), “Site Water Management Plan for the Tarrawonga Coal Mine”.

Safe Production Solutions (2011). “Tarrawonga Coal Project Environmental Risk Assessment”, Report prepared by Safe Production Solutions Pty Ltd for Tarrawonga Coal Pty Ltd, October.

Strahler, A. N. (1952), “Hypsometric (Area-Altitude) analysis of erosional topography”. Bulletin, Geological Society of America 63, 1117–1142

USACE (2010). “HEC-RAS River Analysis System – User’s Manual, Version 4.1”. US Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA, USA, January.

Whitehaven Coal Mining Pty Ltd (2011), “Site Water Management Plan”.