VICKERY EXTENSION PROJECT

ENVIRONMENTAL IMPACT STATEMENT

APPENDIX B

SURFACE WATER ASSESSMENT

WHITEHAVEN COAL

Vickery Extension Project

Surface Water Assessment

August 2018

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North Sydney NSW 2060
Australia

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Abbreviations

ACARP	Australian Coal Association Research Program
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
Al	Aluminium
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
As	Arsenic
AWBM	Australian Water Balance Model
AWD	Available Water Determinations
B	Boron
BFI	Baseflow Index
BoM	Commonwealth Bureau of Meteorology
CCWD	Coal Contact Water Dam
CHPP	Coal Handling and Preparation Plant
cm	Centimetres
CRZ	Core Riparian Zone
CSIRO	Commonwealth Scientific & Industrial Research Organisation
DD	Diversion Dam
DEC	NSW Department of Environment and Conservation (currently OEH)
DECC	NSW Department of Environment and Climate Change (currently OEH)
DoI-Water	NSW Department of Industry - Water
DPI-Water	NSW Department of Primary Industries – Water (formerly NOW – NSW Office of Water) (currently DoI-Water)
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPA	NSW Environment Protection Authority
EP&A Act	NSW Environmental Planning and Assessment Act, 1979
EPBC Act	Commonwealth Environment Protection and Biodiversity Conservation Act, 1999
EPL	Environment Protection License
ERA	Environmental Risk Assessment
FMP	Floodplain Management Plan
FSL	Full Supply Level
Hg	Mercury
IESC	Independent Expert Scientific Committee
km	Kilometres
km^2	Square kilometres
LOOCV	Leave-One-Out Cross Validation
L/t	Litres per tonne
m	Metres
MHRDC	Maximum harvestable right dam capacity
mm	Millimetres
ML	Mega Litres
MNES	Matter of National Environmental Significance

Mo	Molybdenum
Mtpa	Million tonnes per annum
MWD	Mine Water Dam
MWSS	Mine Water Surge Storage
NAF	Non-Acid Forming
NHMRC	National Health and Medical Research Council
NOW	NSW Office of Water (currently DoI-Water)
NRAR	Natural Resources Access Regulator
NSW	New South Wales
NTU	Nephelometric Turbidity Units
NWQMS	National Water Quality Management Strategy
OEH	NSW Office of Environment and Heritage
PAF	Potentially Acid Forming
PoEO Act	*NSW Protection of the Environment Operations Act 1997*
RCP	Representative Concentration Pathway
ROM	Run-of-mine
Sb	Antimony
SD	Sediment Dam
Se	Selenium
SEARs	NSW Secretary's Environmental Assessment Requirements
SILO	Scientific Information for Landowners
SO_4	Sulfate
SWMOP	State Water Management Outcomes Plan
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
µS/cm	Microsiemens per centimetre
VB	Vegetated Buffer
WAL	Water Access Licence
WQO	Water Quality Objective
WSP	Water Sharing Plan

1 Introduction

1.1 Background

This Surface Water Assessment has been prepared by Advisian on behalf of Whitehaven Coal Limited (Whitehaven). The Surface Water Assessment forms part of an Environmental Impact Statement (EIS) that has been prepared to accompany a Development Application made for the Vickery Extension Project (the Project) in accordance with Part 4 of the New South Wales (NSW) *Environmental Planning and Assessment Act, 1979* (EP&A Act).

The former Vickery Coal Mine and the former Canyon Coal Mine are owned by Whitehaven and are located approximately 25 kilometres (km) north of Gunnedah, in NSW (Figure 1.1). Open cut and underground mining activities were conducted at the Vickery Coal Mine between 1986 and 1998. Open cut mining activities at the former Canyon Coal Mine ceased in 2009. The former Vickery and Canyon Coal Mines have been rehabilitated following closure.

1.2 Approved Mine

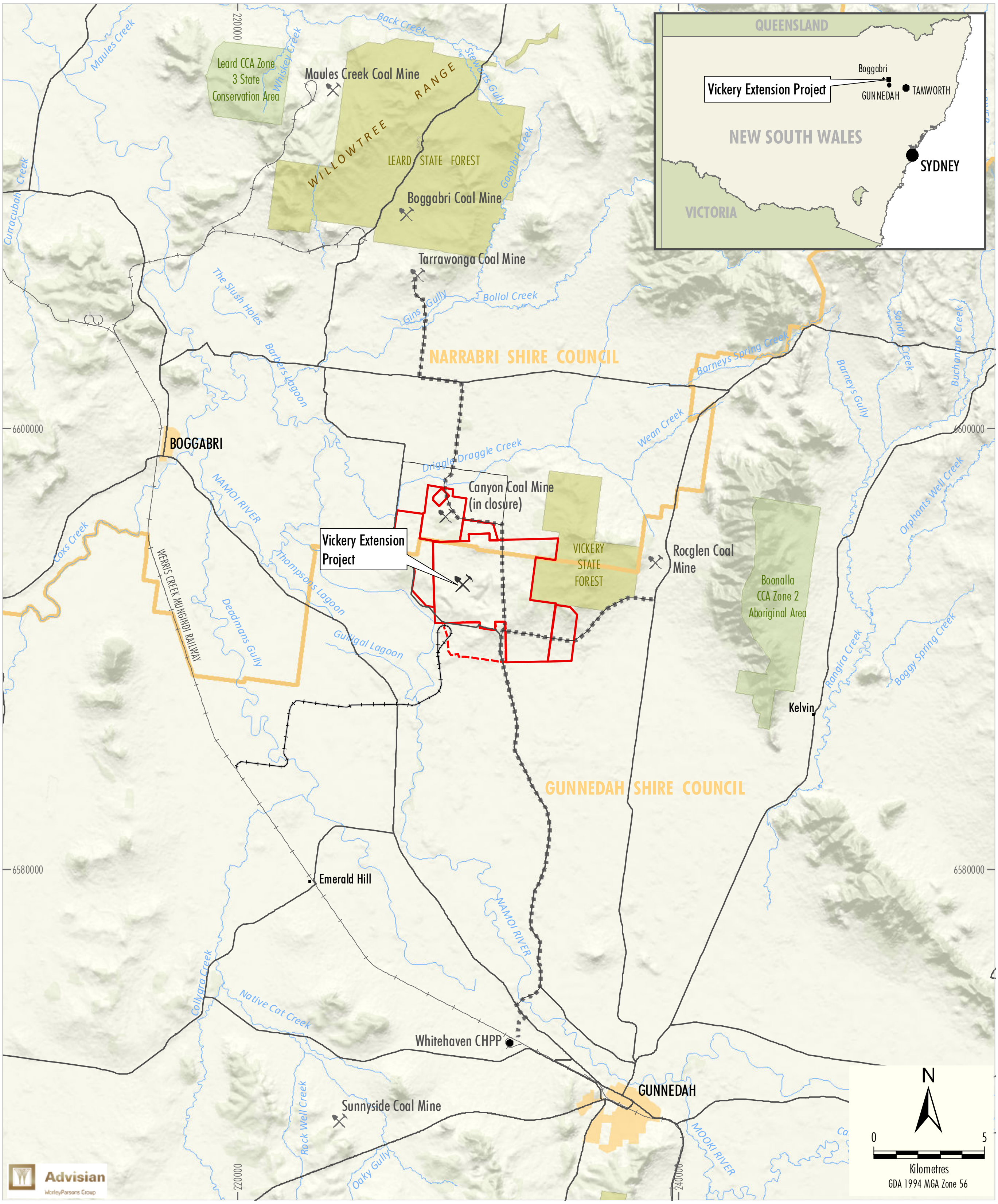
The approved Vickery Coal Project (herein referred to as the Approved Mine) is an approved, but yet to be constructed, project involving the development of an open cut coal mine and associated infrastructure and would facilitate a run-of-mine (ROM) coal production rate of up to approximately 4.5 million tonnes per annum (Mtpa) for a period of 30 years.

1.3 Project Description

Whitehaven is seeking a new Development Consent for extension of open cut mining operations at the Approved Mine (herein referred to as the Project). The Project would include a physical extension to the Approved Mine footprint to gain access to additional ROM coal reserves, an increase in the footprint of waste rock emplacement areas, an increase in the approved ROM coal mining rate and construction and operation of a Project Coal Handling and Preparation Plant (CHPP), train load-out facility and rail spur (Figure 1.2 and Figure 1.3). This infrastructure would be used for the handling, processing and transport of coal from the Project, as well as other Whitehaven mines.

ROM coal would be mined by open cut methods at an average rate of 7.2 Mtpa over 25 years, with a peak production of up to 10 Mtpa.

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



LEGEND

- Mining Tenement Boundary (ML and CL)
- Mining Lease Application (MLA)
- Local Government Boundary
- NSW State Forest
- State Conservation Area, Aboriginal Area
- Major Roads
- Railway
- Approved Road Transport Route
- Indicative Project Rail Spur

Source: LPMA - Topographic Base (2010); NSW Department of Industry (2015)

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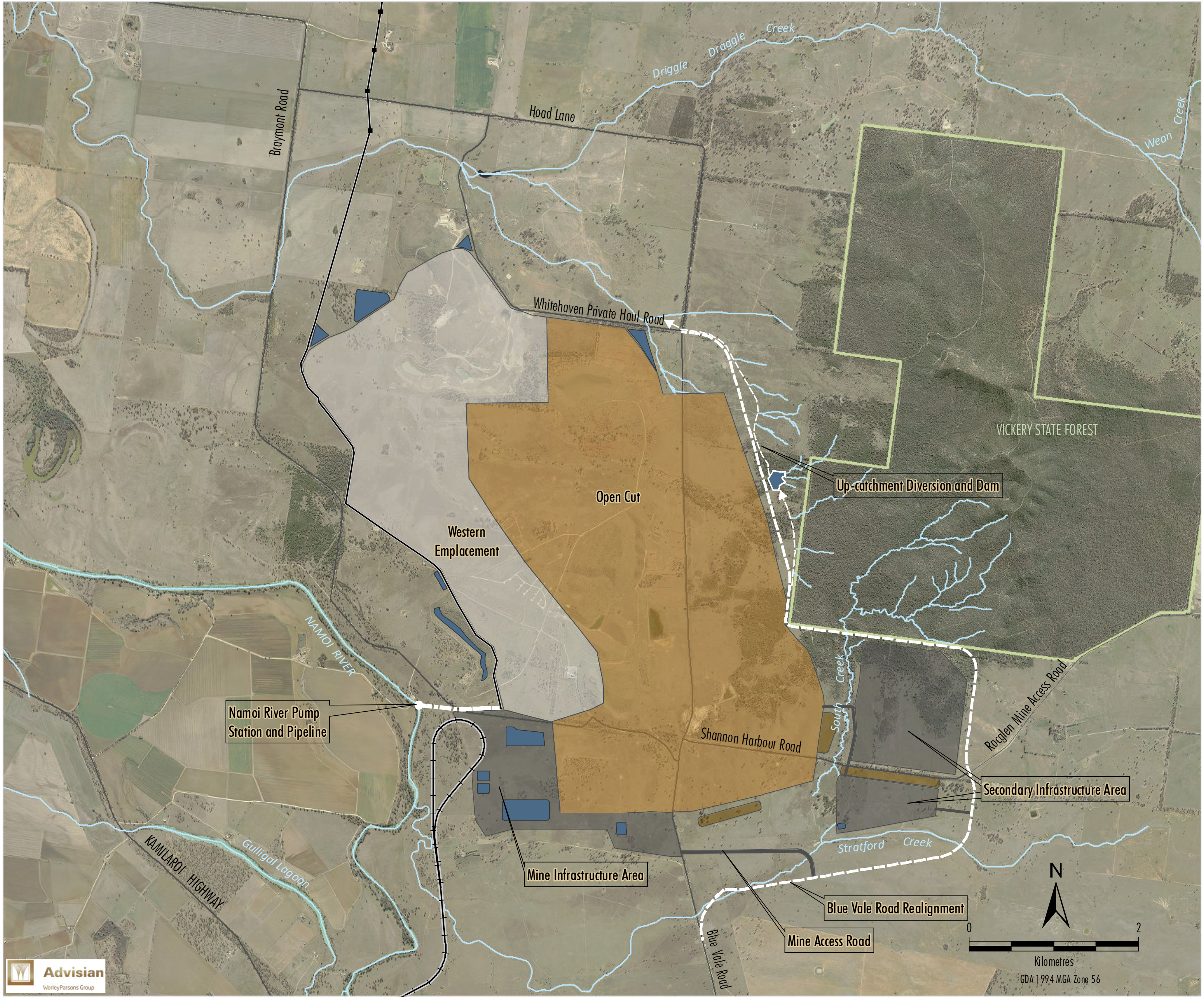
VICKERY EXTENSION PROJECT

Project Location

Figure 1.1



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LEGEND

State Forest

Project Components

- Indicative Extent of Open Cut
- Indicative Extent of Out of Pit Waste Rock Emplacement
- Indicative Extent of Infrastructure Area
- Indicative Extent of Soil Stockpile
- Indicative Extent of Water Storage
- Indicative Mine Access Road Alignment
- Indicative Namoi River Pump Station and Pipeline
- Indicative Road Realignment
- Indicative Up-catchment Diversion and Dam Location
- Indicative Rail Spur Alignment
- Indicative Location of Groundwater Bores and Pipeline

Source: Orthophoto - Department of Land and Property Information, Aerial Photography (July 2011); Department of Industry (2015); Essential Energy (2015)

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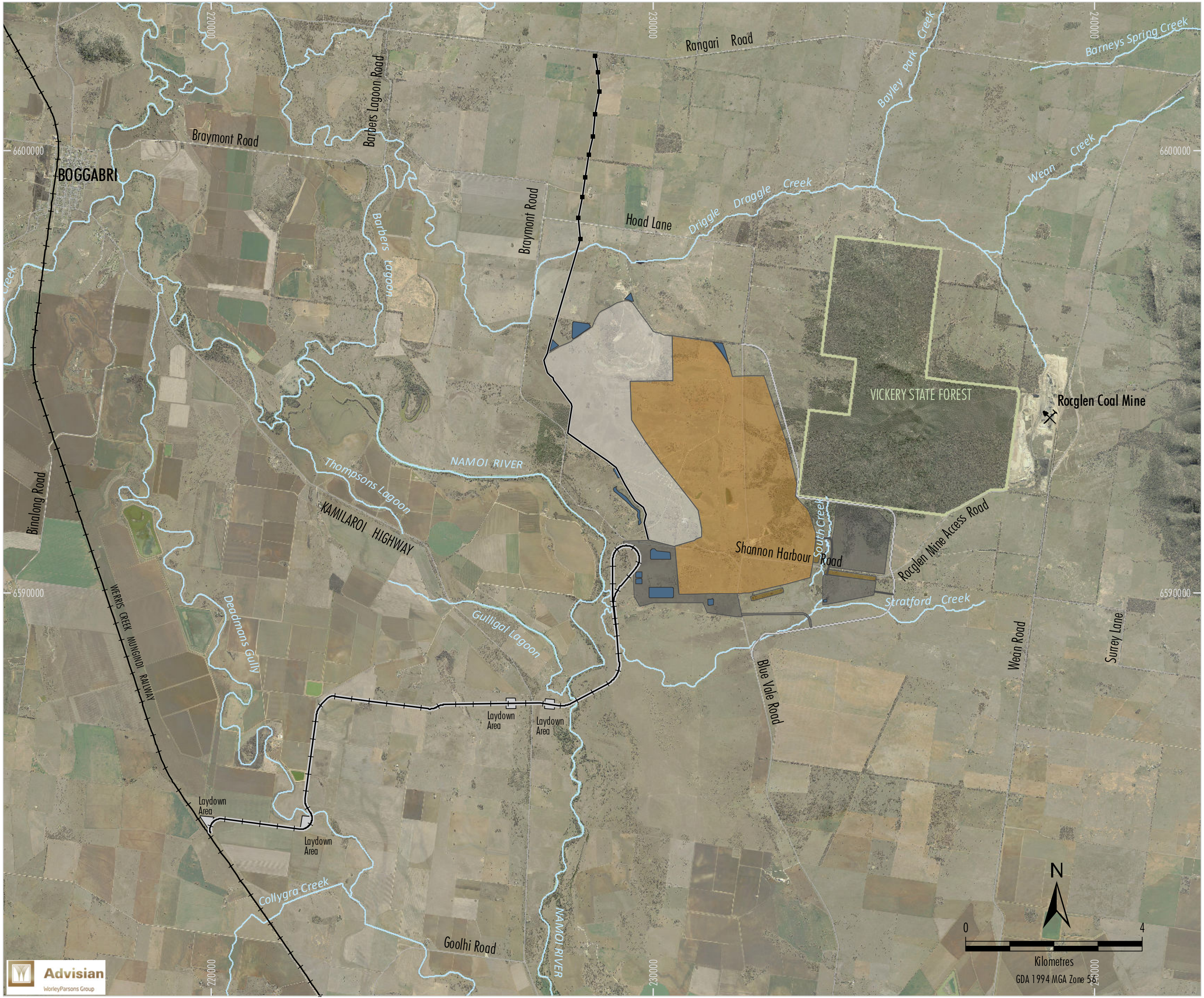
VICKERY EXTENSION PROJECT

Project General Arrangement - Project Mining Area

Figure 1.2



LEGEND

- State Forest
- Railway

Project Components

- Indicative Extent of Open Cut
- Indicative Extent of Out of Pit Waste Rock Emplacement
- Indicative Extent of Infrastructure Area
- Indicative Extent of Soil Stockpile
- Indicative Extent of Water Storage
- Indicative Mine Access Road Alignment
- Indicative Rail Spur Alignment
- Indicative Location of Groundwater Bores and Pipeline
- Indicative Road Realignment

Source: Orthophoto - Department of Land and Property Information, Aerial Photography (July 2011); Department of Industry (2015)

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Indicative Rail Spur Alignment and Groundwater Bore Locations

Figure 1.3

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1.4 Objectives

The objectives of this Surface Water Assessment are to:

- document the existing catchment conditions and the flow regime and water quality in the creeks draining from the Project area;
- assess the impacts of any changes in the flow and water quality resulting from the Project, and the mitigation actions necessary to minimise these impacts;
- identify appropriate monitoring and management measures necessary to verify the predicted impacts of the Project and initiate any additional mitigation measures; and
- assess the adequacy of the water management system to provide a secure water supply for the life of the Project.

1.5 Key Risks

An Environmental Risk Assessment (ERA) has been prepared and is documented in *Vickery Extension Project – Environmental Risk Assessment* (Operational Risk Mentoring, 2018), which is included as Appendix O to the EIS.

Table 1.1 summarises the identified risks relating to surface water and provides an outline of the consideration given to the issue in this Surface Water Assessment, together with any relevant mitigating factors or proposed actions and the assessed risk after taking account of the proposed mitigation actions. Note that the wording in the first column corresponds to the risks identified in the ERA, but the second column provides specific explanation in the context of this report.

Table 1.1: Surface Water Related Environmental Risks and Mitigation Proposals

Issue	Consideration of Issue and Mitigation Factors / Proposals	Risk
Insufficient site water flow/use monitoring data to enable model calibration which could cast doubt over predictions of water excess or shortfall.	Water balance modelling based on published data from other mines and benchmarked against observations at Rocglen Coal Mine. Mitigated by sufficient water licences held by Whitehaven (to make up any shortfall), ability to temporarily transfer water allocations between Whitehaven's operations, availability of harvestable rights, adequate sizing of storages (using the open cut voids as a backup) and conservatism in modelling. Any excess of mine water would be managed by adequate sizing of storages (using the open cut voids as a backup), and conservatism in modelling.	Low
Adverse impacts on downstream water quality parameters that could have consequential effects on ecology or beneficial use.	Mitigated through design and management of erosion and sediment control structures in accordance with the guidelines; and sizing of mine water dams to retain mine affected water on-site.	Low
Changes to flooding characteristics due to construction of the Project rail spur.	A *Flood Assessment* has been prepared by WRM for the Vickery Extension Project and is included as Appendix C to the EIS (WRM, 2018). The *Flood Assessment* considered the potential for the Project rail spur to exacerbate flooding impacts. Mitigated by incorporation of flood mitigation into the rail design (e.g. inclusion of appropriately sized culverts).	Moderate

Issue	Consideration of Issue and Mitigation Factors / Proposals	Risk
Licensed extraction from the Namoi River.	Mitigated by water extraction in accordance with licence conditions.	Low
Mine water discharge in the event of extreme weather events.	Mitigated by appropriate design/maintenance of erosion/sediment controls and sediment and mine water dams.	Low
Seepage/runoff from mine disturbance areas bypassing water management systems and migrating off-site with possible downstream contamination.	Assessment considers the likely contaminants present in runoff from disturbed areas. Any potential impact would be mitigated by appropriately handling potentially acid forming (PAF) and sodic material (as recommended in the Geochemistry Assessment – Appendix M to the EIS [Geo-environmental Management (GEM), 2018]). Mitigation would also be provided by a suitably sized water management system and regular monitoring.	Low

1.6 Report Structure

The assessment of potential impacts on surface water is closely related to other physical processes within the catchment particularly interaction with the groundwater system. Accordingly, this report draws on information provided in the following related reports:

- *Vickery Extension Project - Groundwater Assessment* prepared by HydroSimulations (2018) (Appendix A to the EIS);
- *Fluvial Geomorphological Assessment* for the Vickery Coal Project (for the Approved Mine) prepared by Fluvial Systems (2012);
- *Vickery Extension Project - Geochemistry Assessment of Overburden, Interburden and Coal Rejects* prepared by GEM (2018) (Appendix M to the EIS);
- *Vickery Extension Project - Biodiversity Assessment Report and Biodiversity Offset Strategy* prepared by Resource Strategies (2018) (Appendix F to the EIS); and
- *Vickery Extension Project - Flood Assessment* prepared by WRM (2018) (Appendix C to the EIS).

This Surface Water Assessment has been structured in the following manner:

- **Sections 2 to 6** provide a background of the regulatory and physical context;
- **Sections 7** and **8** describe the proposed water management systems within the Project area and the performance of the system in terms of the reliability of water supply and the frequency and volume of discharge under a wide range of possible climate scenarios;
- **Section 9** describes proposals for management of runoff from external catchments that drain into the Project area;
- **Section 10** provides a summary of the mitigation and management measures to be employed at the Project for impacts on surface water resources;
- **Section 11** describes the proposed Water Management Plan and provides a summary of the monitoring, licensing and approvals in respect of surface water resources necessary for the Project; and
- **Section 12** provides a list of references for the report.

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2 Secretary's Environmental Assessment Requirements

Table 2.1 details the requirements of the Secretary's Environmental Assessment Requirements (SEARs) for the Project relating to surface water and indicates where specific issues have been addressed within this document. The SEARs are provided in Attachment 1 of the EIS.

Table 2.1: Secretary's Environmental Assessment Requirements

	Requirement	Reference
Specific Issues: Water	The EIS must address the following specific issues: • **Water**- including: an assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's and DPI's requirements and recommendations (see Attachment 2);	Sections 7, 8 and 10
	an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users; and	Sections 9 and 10
	an assessment of the potential flooding impacts of the development	Section 7.12 and Appendix C to the EIS

2.1 Assessment Requirements relevant to the EPBC Act

Table 2.2 details the Assessment Requirements relevant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) relating to surface water resources and indicates where the specific issues have been addressed within this document.

Table 2.2: Assessment Requirements relevant to the EPBC Act (Water Resources)

Requirement		Reference
12.	The EIS should provide a description of the location, extent and ecological characteristics and values of the identified water resources potentially affected by the project.	Sections 4, 5 and 6
13.	The assessment of impacts should include information on: • any substantial and measurable changes to the hydrological regime of the water resource, for example a substantial change to the volume, timing, duration or frequency of ground and surface water flows;	No significant changes anticipated – refer Section 9
	• the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the water resource being seriously affected; and	Section 4.9, Appendices F and N to the EIS
	• substantial and measurable change in the water quality and quantity of the water resource—for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland; or water temperature that may adversely impact on biodiversity, ecological integrity, social amenity or human health.	No significant changes anticipated – refer Section 9
14.	The EIS must provide adequate information to allow the project to be reviewed by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, as outlined in *the Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals (2015)*.	This report addresses the specific information needs, where applicable, identified in the Guidelines.

Further information relating to water resources to be assessed under the EPBC Act is provided in Section 3.1.3.

2.2 Other Agency Comments

Comments on the SEARs were provided by the NSW Environment Protection Authority (EPA), NSW Office of Environment and Heritage (OEH) and NSW Department of Primary Industries (DPI) (via DPI Water) (now the Department of Industry [DoI] - Water). The relevant comments provided by these agencies relating to surface water are summarised in Table 2.3 and Table 2.4.

Table 2.3: NSW Environment Protection Authority and Office of Environment and Heritage Comments

	Comment	Reference
NSW EPA Comments	**6.2 Water** **Describe Proposal** 6.2.1 Describe the proposal including position of any intakes and discharges, volumes, water quality and frequency of all water discharges.	Sections 1.4, 7, 8 and 9
	6.2.2 Demonstrate that all practical options to avoid discharge have been implemented and environmental impact minimised where discharge is necessary.	Sections 7, 8, 9 and 10
	6.2.3 Where relevant include a water balance that models water management through the life cycle of the mine and that includes water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options.	Sections 7 and 8
	Background Conditions 6.2.4 Describe existing surface and groundwater quality. An assessment needs to be undertaken for any water resource likely to be affected by the proposal.	Section 6 and HydroSimulations (2018)
	6.2.5 State the Water Quality Objectives for the receiving waters relevant to the proposal.	Section 3
	6.2.6 State the indicators and associated trigger values or criteria for the identified environmental values.	Sections 3 and 6.4
	6.2.7 State any locally specific objectives, criteria or targets which have been endorsed by the NSW Government.	Sections 3 and 6
	Impact Assessment 6.2.8 Describe the nature and degree of impact that any proposed discharges will have on the receiving environment.	Section 9
	6.2.9 Assess impacts against the relevant ambient water quality outcomes.	Section 9
	6.2.12 Describe how stormwater will be managed both during and after construction.	Sections 7 and 8
	6.2.13 Any discharges from the site must be characterised with respect to their location, frequency, volume and likely water quality.	Sections 7, 8 and 9
	Monitoring 6.2.14 Describe how predicted impacts will be monitored and assessed over time.	Section 11
OEH Comments	**Water and soils** 5. The EIS must map the following features relevant to water and soils including a. Rivers, streams, wetlands, estuaries (as described in Appendix 2 of the Framework for Biodiversity Assessment). b. Proposed intake and discharge locations.	Sections 5 and 7
	6. The EIS must describe background conditions for any water resource likely to be affected by the Vickery Extension Project, …	Sections 5 and 6
	7. The EIS must assess the impacts of the Vickery Extension Project on water quality	Section 9
	8. The EIS must assess the impact of the Vickery Extension Project on hydrology, …	Section 9

	Comment	Reference
OEH Comments (continued)	**Flooding and coastal erosion** 9 The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) …	Section 7.12 and Appendix C to the EIS
	10 The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, …	
	11 The EIS must model the effect of the proposed Vickery Extension Project (including fill) on the flood behaviour …	
	13 The EIS must assess the impacts on the proposed Vickery Extension Project on flood behaviour, …	

Table 2.4: Department of Primary Industries Comments

Comment	Reference
It is recommended that the EIS be required to include: • Annual volumes of surface water and groundwater proposed to be taken by the activity …	Sections 7.5, 8.2.6, 8.4, 8.5, and Appendix A to the EIS
• Assessment of any volumetric water licensing requirements …	Sections 3.2.4, 7.10, 11.2 and Appendix A to the EIS
• The identification of an adequate and secure water supply for the life of the project.	Sections 7 and 8
• An updated detailed and consolidated site water balance for the expansion.	Sections 7 and 8
• Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, wetlands, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.	Sections 8, 9, 10 and 11
• Full technical details and data of all surface and groundwater modelling …	Sections 7 and 8, and Appendix A to the EIS
• Proposed surface and groundwater monitoring activities and methodologies.	Section 11 and Appendix A to the EIS
• Proposed management and disposal of produced or incidental water.	Sections 7,8, 9 and 10
• Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts.	Section 9
• Consideration of relevant policies and guidelines.	Section 3
• Assessment of whether the activity may have a significant impact on water resources, with reference to the Commonwealth Department of Environment *Significant Impact Guidelines*.	Sections 2.1, 7 and 8
• If the activity may have a significant impact on water resources, then provision of information in accordance with the *Information Guidelines for Independent Expert Scientific Committee* advice on coal seam gas and large coal mining development proposals, including completion of the information requirements checklist.	Section 2.1 and Attachment 2 to the EIS
• A statement of where each element of the SEARs is addressed in the EIS (i.e. in the form of a table).	Table 2.1
The EIS should take into account the objects and regulatory requirements of the *Water Act 1912* (WA 1912) and *Water Management Act 2000* (*WMA 2000*), and associated regulations and instruments, as applicable. *Water Management Act 2000 (WMA 2000)* *Water Act 1912 (WA 1912)* *Water Management (General) Regulation 2011* *Water Sharing Plans* – these are considered regulations under the *WMA 2000* *Access Licence Dealing Principles Order 2004 Harvestable Rights Orders*	Section 3

Comment	Reference
Licensing Considerations The EIS is required to provide: • Identification of water requirements for the life of the project • Explanation of how the required water entitlements will be obtained … • Information on the purpose, location, construction and expected annual extraction volumes including details on all existing and proposed water supply works which take surface water, (pumps, dams, diversions, etc.). • Details on existing dams/storages (including the date of construction, location, purpose, size and capacity) and any proposal to change the purpose of existing dams/storages. • Details on the location, purpose, size and capacity of any new proposed dams/storages. Applicability of any exemptions under the *Water Management (General) Regulation 2011* to the project.	Sections 3, 7, 8, 9, 10 and 11.2
Water allocation account management rules, total daily extraction limits and rules governing environmental protection and access licence dealings also need to be considered.	Sections 3.2.4 and 11.2
Dam Safety Where new or modified dams are proposed, or where new development will occur below an existing dam, the NSW Dams Safety Committee should be consulted in relation to any safety issues that may arise. Conditions of approval may be recommended to ensure safety in relation to any new or existing dams.	Section 3.1.4
Surface Water Assessment The predictive assessment of the impact of the proposed project on surface water sources should include the following: • Identification of all surface water features including watercourses, wetlands and floodplains transected by or adjacent to the proposed project. • Identification of all surface water sources as described by the relevant WSP (Water Sharing Plan) Detailed description of dependent ecosystems and existing surface water users within the area, including basic landholder rights to water and adjacent/downstream licensed water users.	Sections 3, 4 and 5 and Appendix A to the EIS
• Description of all works and surface infrastructure that will intercept, store, convey, or otherwise interact with surface water resources. • Assessment of predicted impacts on the following: – flow of surface water (including floodwater), sediment movement, channel stability, and hydraulic regime, – water quality, – flood regime, – dependent ecosystems, – existing surface water users, and planned environmental water and water sharing arrangements prescribed in the relevant water sharing plans.	Sections 1.3, 3.2.4, 7, 8, 9 and 10
Watercourses, Wetlands and Riparian Land • The EIS should address the potential impacts of the project on all watercourses likely to be affected by the project, existing riparian vegetation and the rehabilitation of riparian land. …	Sections 9, 10 and 11
Drill Pad, Well and Access Road Construction Any construction activity within 40m of a watercourse, should be designed by a suitably qualified person, consistent with the NSW *Guidelines for Controlled Activities on Waterfront Land* (NSW Office of Water, 2012). …	Sections 3.1, 3.3 and 9.2 and Appendix A to the EIS
Landform rehabilitation (including final void management) Where significant modification to landform is proposed, the EIS must include: • Justification of the proposed final landform with regard to its impact on local and regional surface and groundwater systems; • …Outline of proposed construction and restoration of topography and surface drainage features if affected by the project; …	Sections 7, 8, 9 and 10

3 Relevant Legislation, Policy and Guidelines

3.1 Legislation

3.1.1 Water Management Act 2000

The aim of the *Water Management Act 2000* is to provide for the sustainable and integrated management of water sources in NSW for the benefit of both present and future generations. The *Water Management Act 2000* contains provisions for the licensing of water capture and use. If any dams are proposed as part of the Project water management system, consideration must be given to whether the dams need to be licensed.

A controlled activity approval under the *Water Management Act 2000* is typically not required for surface mining activities approved as State Significant Developments.

3.1.1.1 Harvestable Rights

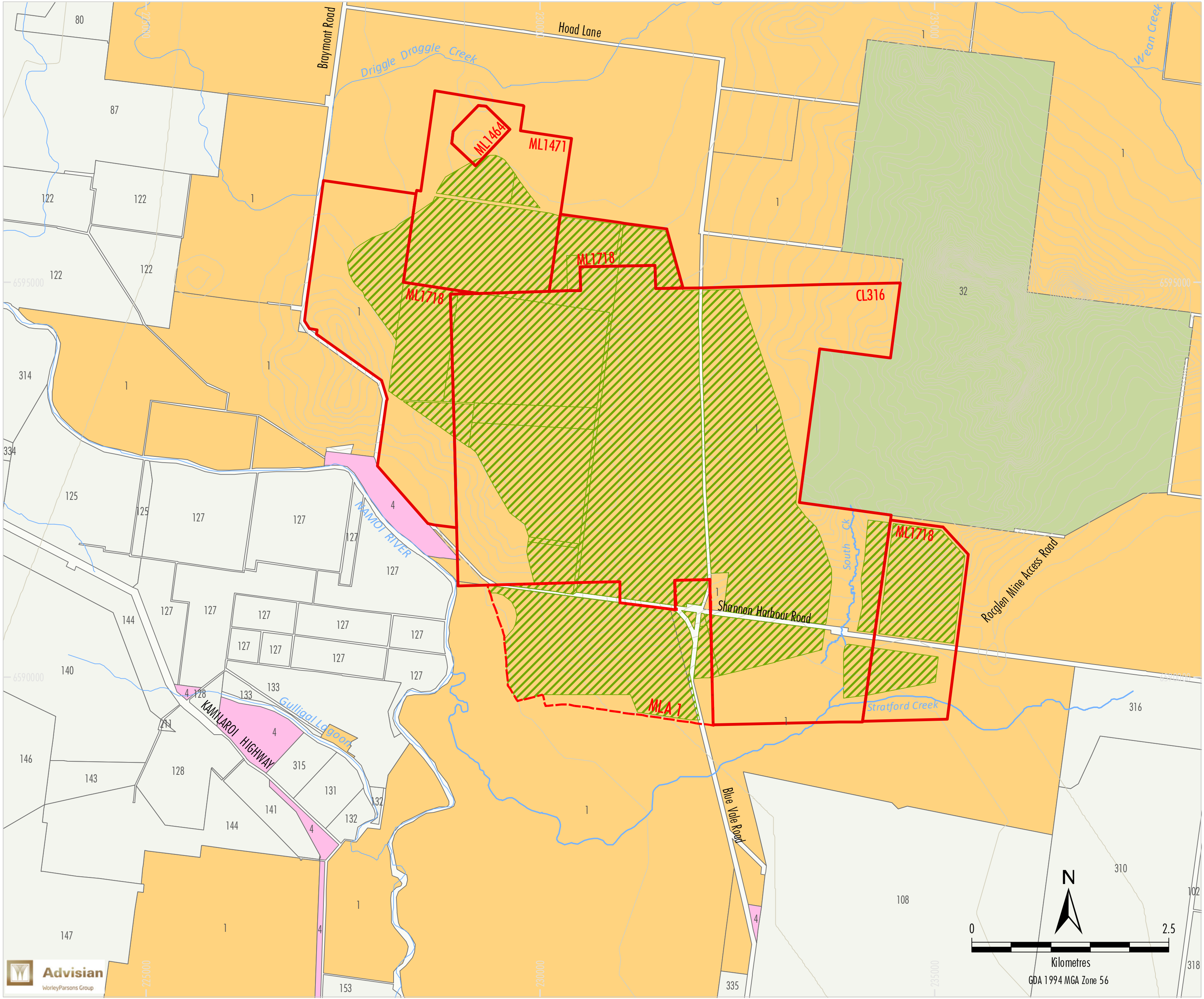
Harvestable rights orders made by the Minister under section 54 of the *Water Management Act 2000* give a landholder the right to capture 10% of the average regional rainwater runoff on their land by means of a dam or dams having not more than the total capacity calculated in accordance with Schedule 1 of the orders, providing such structures are located on minor streams only (i.e. first and second order streams). This water can, in most cases, be used for any purpose.

The maximum harvestable right dam capacity (MHRDC) for a landholding is calculated by multiplying the area of the land holding by a location specific multiplier value, available from online maps on the NSW DPI Water website.

The multiplier for the Project area is 0.065. The landholding owned by Whitehaven, as shown on Figure 3.1, that is attributable to the Project for purposes of harvestable rights, is 2,699 hectares (ha). Accordingly, the MHRDC is 175 megalitres (ML).

Note that the MHRDC, as calculated from the multiplier values, implies that the storage capacity is equal to 10% of the average annual rainfall runoff from the land, but does not specifically nominate how much water can be harvested annually, although the *Water Management Act 2000* specifies 10% of the average annual rainfall runoff.

Table 3.1 lists the identified water storage dams located within the Whitehaven landholding shown on Figure 3.1. The existing capacity of all water storage dams (as opposed to sediment dams solely for sediment control purposes) is approximately 37 ML which is significantly less than the harvestable right of 175 ML. Accordingly, if dams totalling an additional 138 ML were constructed on first or second order streams (not including excluded works), no licence would be required.



LEGEND

- Mining Tenement Boundary (ML and CL)
- Mining Lease Application (MLA)
- State Forest
- Crown Land
- Whitehaven Owned Land
- Privately Owned Land and Other Land
- Assessment of Harvestable Right Area

Source: Department of Land and Property Information (2014); Department of Industry (2015)

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Landholding Attributable to the Assessment of Harvestable Right

Figure 3.1

WHC-15-33_EIS SW_201D

Table 3.1: Identified Water Storage Dams within the Landholding shown on Figure 3.1

Dam	Location	Volume (ML)
SD-1 Dam	North of intersection of Shannon Harbour Road and Blue Vale Road	20
Triangle Dam	North-east of intersection of Shannon Harbour Road and Blue Vale Road	5
SD-1 (Canyon)	Inside north-west corner of Canyon Coal Mine lease boundary	<1
SD-2 (Canyon)	Outside the mid-point of western boundary of Canyon Coal Mine lease boundary	~1
SD-3 (Canyon)	East of the Canyon Coal Mine access road on the north side of the Canyon Coal Mine	<1
SD-4 (Canyon)	South-east of SD-2, inside the mid-point of western boundary of Canyon Coal Mine lease boundary	<1
SD-5 (Canyon)	Slightly south-east of SD-4	~1
SD-6 (Canyon)	South of SD-4 and west of SD-5	<1
SD-7 (Canyon)	North of the easternmost point of Canyon Coal Mine.	<1
SD-8 (Canyon)	East of the mid-point of the southern boundary of Canyon Coal Mine lease boundary	<1
Canyon Pit West	West on the southern stretch of the Canyon Coal Mine	~1
Canyon Pit East	East on the southern stretch of the Canyon Coal Mine	~1
Green Dam	West of L Dam	~1
Other minor storage dams	Scattered throughout Project area	<1
Total		**~37**

The *Water Management (General) Regulation 2011 (Schedule 1)* excludes certain types of water storage structures from Harvestable Rights considerations:

1. Dams solely for the control or prevention of soil erosion:

a. from which no water is reticulated (unless, if the dam is fenced off for erosion control purposes, to a stock drinking trough in an adjoining paddock) or pumped, and

b. the structural size of which is the minimum necessary to fulfil the erosion control function, and

c. that are located on a minor stream.

…

3. Dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a public authority (other than Landcom or the Superannuation Administration Corporation or any of their subsidiaries) to prevent the contamination of a water source, that are located on a minor stream.

The DPI (Water) Guideline *Dams in NSW - Do you need a licence* (2015) indicates that the following dams do not require a licence:

- dams that capture water under a harvestable right;
- dams built before 1999;
- dams up to 1 ML on small properties; and
- dams without a catchment, including turkey nest dams which operate to store water only.

The Guideline states that landholders may construct and use a dam to store different kinds of water taken under different rights and licences in addition to their harvestable right, providing the landholder holds:

- a licence for the volume of water that exceeds the MHRDC, unless the water is taken under a domestic and stock right or native title right;
- a water supply work approval for a dam which exceeds the MHRDC.

The Guideline also states that special dams which are not included in harvestable right calculations include:

1. dams for the control or prevention of soil erosion (gully control structures);
2. dams for flood detention and mitigation;
3. dams for the capture, containment and recirculation of drainage;
4. dams endorsed by the Minister for specific environmental management purposes;
5. dams without a catchment; and
6. dams licensed under the *Water Act 1912* before 1 January 1999.

Therefore, any mine water dams that collect runoff from the open cut, haul roads, coal stockpiles and infrastructure areas are defined under provision three above and are not included in harvestable rights calculations. They also apply to sediment dams constructed to control runoff from the waste rock emplacement areas until such time as the vegetation has established to the point when sediment runoff is minimal. There are no restrictions on the use of water from dams that comply with these provisions.

3.1.2 Protection of the Environment Operations Act 1997

The NSW *Protection of the Environment Operations Act 1997* (PoEO Act) and the *NSW Protection of the Environment Operations (General) Regulation 2009* set out the general obligations for environmental protection. The PoEO Act is relevant to the Project as it contains requirements relating to the prevention of the pollution of waters.

The discharge of water from the Project site must be controlled to an agreed standard to reduce the potential for pollution of the receiving waters. The Project will require an Environment Protection Licence (EPL) under the PoEO Act. All runoff from waste rock emplacement areas would be captured in sediment dams. Any overflow or controlled release to restore a dam's capacity would only occur in accordance with the relevant guidelines (i.e. in the event of a storm that exceeds the design rainfall criteria). All mine affected water (e.g. exposed to coal) would be re-used within the site.

3.1.3 Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)

The EPBC Act is the Australian Government's central piece of environmental legislation.

The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places - defined in the EPBC Act as Matters of National Environmental Significance (MNES).

The water related MNES to which the EPBC Act applies are:

- wetlands of international importance (called 'Ramsar' wetlands after the international treaty under which such wetlands are listed);
- nationally threatened species and ecological communities; and
- a water resource, in relation to coal seam gas development and large coal mining development.

The last water-related MNES listed above is commonly referred to as the *water trigger*. As the Project (the Action) is a large coal mining development, it has been referred to the Commonwealth Department of the Environment and Energy. The Action has been deemed a controlled action by the Minister for the Environment (Commonwealth) and, accordingly, the Action will require approval under the EPBC Act.

3.1.3.1 Independent Expert Scientific Committee and Bioregional Assessments

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) is a statutory body under the EPBC Act. The IESC's key legislative function, as it relates to the Project, is to provide scientific advice to the Commonwealth Minister for the Environment and relevant State Ministers in relation to coal seam gas or large coal mining developments that are likely to have a significant impact on water resources (the *water trigger*).

The IESC's *Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals* (IESC, 2018) outline the information considered necessary to enable the IESC to provide robust scientific advice to government regulators.

The Commonwealth Government is also undertaking a programme of bioregional assessments in order to better understand the potential impacts of coal seam gas and large coal mining developments on water resources and water-related assets (Commonwealth of Australia, 2017).

A Bioregional Assessment has been undertaken for the Namoi subregion of the Northern Inland Catchments bioregion, where the Project is located. As at July 2018, the Bioregional Assessment for the Namoi subregion has developed the following products relevant to this report:

- 1.1 Context Statement for the Namoi subregion;
- 1.2 Resource assessment for the Namoi subregion;
- 1.3 Water-dependent asset register for the Namoi subregion;
- 1.5 Current water accounts and water quality for the Namoi subregion; and
- 1.6 Data register for the Namoi subregion.

3.1.4 Dam Safety Act, 2015

The *Dam Safety Act 2015* establishes the role of Dams Safety NSW (replacing NSW Dams Safety Committee that was established under the *Dam Safety Act 1978*) to achieve objectives relating to the safety of dams, including ensuring that any risks that may arise in relation to dams (such as any risks to public safety and to environmental and economic assets) are of a level that is acceptable to the community. Dams Safety NSW can declare a dam or proposed dam to be a 'declared dam' under the *Dams Safety Act 2015*.

One of the functions of Dams Safety NSW is to make recommendations on the development, implementation and modification of the dam safety standards, to keep owners of declared dams informed about dam safety standards, and to regulate compliance with those standards. Determination of whether a dam is a declared dam is based on an assessment of its consequence category, which considers potential downstream impacts of dam failure.

Under the *Dam Safety Act 2015*, a 'notification area' can be declared covering an area around the dam structure and the impoundment. Any proposal to mine within the notification area requires consultation with Dam Safety NSW. The Project is not located within the notification area of any dams identified in the *Dam Safety Act 2015*.

At the time of detailed design, all water storage and sediment dams will be reviewed against the criteria published by Dams Safety NSW and will be referred if necessary.

3.2 Policies and Plans

The following sections outline existing policies and plans relevant to the Project.

3.2.1 National Water Quality Management Strategy

The *National Water Quality Management Strategy* (NWQMS) is a joint national approach to improving water quality in Australian and New Zealand waterways.

The NWQMS aims to protect the nation's water resources by improving water quality, while supporting the businesses, industry, environment and communities that depend on water for their continued development. The main mechanism for promoting this aim has been the publication of a number of water quality guidelines, including the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council [ANZECC], 2000) (commonly referred to as the *ANZECC 2000 Guidelines*). These guidelines are reflected in the following NSW guidelines:

- *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (NSW Department of Environment and Conservation [DEC], 2006); and
- *NSW Water Quality and River Flow Objectives* (DEC, 2006).

These guidelines are discussed in Sections 3.2.2 and 3.3.1 below.

3.2.2 NSW Water Quality and River Flow Objectives

Water Quality Objectives (WQOs) were established by the NSW Government in September 1999 for the majority of NSW catchments. The WQOs are the agreed environmental values and long-term goals for NSW's surface waters and set out:

- the community's values and uses for rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water); and
- a range of water quality indicators to help assess whether the current condition of waterways supports those values and uses.

The WQOs are consistent with the agreed national framework set out in the *ANZECC 2000 Guidelines* to assess water quality in terms of whether the water is suitable for a range of environmental values, including human uses. The WQOs provide environmental values for NSW waters and the *ANZECC 2000 Guidelines* provide the technical guidance to assess the water quality needed to protect those values.

WQOs have been developed for NSW rivers and estuaries to provide guideline levels to assist water quality planning and management. The streams located within, and reporting to, the Project site are classified as "Uncontrolled Streams", which have the following WQOs relevant to the Project:

- aquatic ecosystems (maintaining or improving the ecological condition of water bodies and their riparian zones over the long term); and
- livestock water supply (protecting water quality to maximise the protection of healthy livestock).

The aquatic ecosystem WQO is consistent with the *ANZECC 2000 Guidelines* default trigger values for slightly disturbed ecosystems in south-east Australia. Further discussion of the ANZECC trigger values adopted for the Project is provided in Section 6.4.

The livestock water supply WQO is based on four key indicators. These indicators and their numerical trigger values are summarised below in Table 3.2.

Table 3.2: Livestock Water Supply Guidelines for Uncontrolled Streams in the Namoi Catchment

Indicator	Numerical Criteria (trigger values)
Algae & blue-green algae	An increasing risk to livestock health is likely when cell counts of microcystins exceed 11,500 cells per millilitre and/or concentrations of microcystins exceed 2.3 micrograms per litre expressed as microcystin-LR toxicity equivalents.
Salinity (electrical conductivity)	Recommended concentrations of total dissolved solids (TDS) in drinking water for livestock are given in Table 4.3.1 (*ANZECC 2000 Guidelines*).
Thermotolerant coliforms (faecal coliforms)	Drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 millilitres (median value).
Chemical contaminants	Refer to Table 4.3.2 (*ANZECC 2000 Guidelines*) for heavy metals and metalloids in livestock drinking water. Refer to *Australian Drinking Water Guidelines* (National Health & Medical Research Council [NHMRC] 2011) for information regarding pesticides and other organic contaminants, using criteria for raw drinking water.

The trigger values for livestock water supply are significantly higher than the trigger values for aquatic ecosystems (Section 6.4). Further consideration of the more conservative aquatic ecosystem trigger values applicable to local watercourses is provided in Sections 6.1 and 6.4.

3.2.3 State Water Management Outcomes Plan

The *Water Management Act 2000* provides for the establishment of the State Water Management Outcomes Plan (SWMOP) to set out the over-arching policy context, targets and strategic outcomes for the development, conservation, management and control of NSW's water resources.

The SWMOP promotes the objects of the *Water Management Act 2000* and its water management principles and seeks to give effect to the NSW Government's salinity strategies. The SWMOP provides for the protection and enhancement of the environmental services provided by aquatic ecosystems, while delivering a framework for the use of water to meet human needs, including more secure access licences. It details the NSW Government's commitment to manage the linkages between environment, human health, communities and industries.

The Project is consistent with the objectives of the SWMOP, both within the Project area and on downstream users, as the Project has been designed to protect the surrounding catchment from potential impacts.

3.2.4 Water Sharing Plans – Surface Water

3.2.4.1 Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2012

The *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources* (NSW Government, 2012) applies to the unregulated water sources in the Namoi Basin which comprise sources that are dependent on rainfall and natural river flows, rather than water released from dams, and associated alluvial groundwater systems.

The Water Sharing Plan (WSP) provides for the sharing of water between the environment, town water supplies, basic landholder rights and commercial uses of water. The volume of water available to meet all competing environmental and extractive needs varies on a yearly and daily basis, depending on the weather, river flows and aquifer characteristics. The WSP applies to all surface water sources in the vicinity of the Project, with the exception of the Namoi River itself.

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

The Project falls within the Lower Namoi Regulated River Water Source for the purpose of the *Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources 2016* (NSW Government, 2016). The Lower Namoi includes the regulated river sections downstream of Keepit Dam to the Barwon River.

The WSP provisions regulate water for the river's environmental needs, its ecological processes and direct how water available for extraction is to be shared. The WSP also sets rules for the management of WALs, water allocation accounts, the trading of or dealings in licences and water allocations, the extraction of water, the operation of dams and water flow management.

The WSP provides for domestic and stock rights and native title rights – both forms of basic landholder rights which allow some extraction of water from the river without a WAL. All other water extraction, other than for basic landholder rights, must be authorised by a WAL. Each WAL specifies a share component. The share components of specific purpose licences, such as local water utility and domestic and stock use, are expressed in ML/year. The share components of licences such as high security, general security and supplementary WALs are expressed as a number of unit shares.

This WSP is relevant to the Project with respect to licensed extraction from the Namoi River to meet operational demands.

3.2.4.3 Water Licences Held by Whitehaven

Table 3.3 lists Whitehaven's existing WALs that would be available for the Project to meet operation demands (total 2,147.5 shares) (excluding *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011* WALs associated with groundwater pit inflows).

Approximately 80% (1,751.5 shares) of these WALs relate to licences to take water from the Namoi River under the *Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources 2016* (NSW Government, 2016) (Section 3.2.4.2), with the remainder groundwater licences under the *Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources 2003* (NSW Government, 2003).

Table 3.3: Summary of Existing Water Access Licences

WAL No	Works Approval	Groundwater/River	Allocation (Shares)
WAL 12645	90CA806830, 90CA806981, 90WA9807004	Groundwater	35
WAL12651	90CA806845	Groundwater	52
WAL12653	90CA806850	Groundwater	166
WAL 12701	90CA806971	Groundwater	20
WAL 12715	90CA806981, 90WA807004	Groundwater	75
WAL 12724	90CA806981, 90WA807004	Groundwater	45
WAL 12731	90CA807045	Groundwater	3
		Sub-total: Groundwater	**396**
WAL 2682	90WA804771, 90CA802036	River - General Security	486
WAL 13051	90CA802398	River - General Security	96
WAL 14936	90WA801821	River - General Security	1,056
		Sub-total: River - General Security	**1,638**
WAL 16034	90WA801821	River - High Security	50
		Sub-total: River - High Security	**50**
WAL 2683	90WA804771, 90CA802036	River - Supplementary	53
WAL 13052	90CA802398	River - Supplementary	10.5
		Sub-total: River - Supplementary	**63.5**
		TOTAL:	**2,147.5**

3.2.5 Namoi Catchment Action Plan 2010 - 2020

The *Namoi Catchment Action Plan 2010 – 2020 (2013 Update)* (the Catchment Action Plan) (Namoi Catchment Management Authority, 2013) has been developed to provide the strategic framework for natural resource management in the Namoi Catchment. The Catchment Action Plan uses a new 'resilience thinking' method of catchment planning, whereby thresholds capable of changing the state of social-ecological systems are identified, and targets to avoid reaching those thresholds are established. Various actions for implementation are also listed to assist in achieving each target. The Catchment Action Plan focuses on four primary social-ecological systems: biodiversity; land; water; and people. With respect to water, the Catchment Action Plan identifies the following seven thresholds and three targets.

Catchment Action Plan Water Thresholds:

1. Surface water flow quantity is at 66% of natural (pre-development) condition with a sensitivity to natural frequency and duration.
2. Geomorphic condition is good (against benchmark condition).
3. Recruitment of riparian vegetation is higher than attrition of individual trees, shrubs or ground cover species.
4. Agricultural and urban supply aquifers do not cross into lower levels of beneficial use regarding quality.
5. Alluvial aquifers are not drawn down below long term historical maximum drawdown levels.
6. Groundwater levels do not drop below the rooting depth of groundwater-dependent ecosystems.
7. Wetland is not drained, dammed or otherwise physically modified.

Catchment Action Plan Water Targets:

1. By 2020, there is an improvement in the condition of those riverine ecosystems that have not crossed defined geomorphic thresholds as at the 2010 baseline.
2. By 2020, there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses.
3. By 2020, there is an improvement in the condition of regionally important wetlands and the extent of those wetlands is maintained.

3.2.6 NSW State Rivers and Estuaries Policy

The *NSW State Rivers and Estuaries Policy* (NSW Water Resources Council, 1993) contains state-wide objectives for the protection and enhancement of watercourses. The proposed surface water management should be consistent with the *NSW State Rivers and Estuaries Policy* objectives. The key aspect of this would be to demonstrate that there is no degradation of Driggle Draggle Creek or the Namoi River as a result of mining activities.

3.2.7 NSW Farm Dams Policy

The *NSW Farm Dams Policy* was introduced in 1999. Under this policy it is not necessary to obtain a licence or other consent from DoI-Water for a farm dam provided:

- they are not collecting flow from a major stream; and
- the combined capacity does not exceed the MHRDC for the property.

The MHRDC for the Project is 175 ML (Section 3.1.1.1).

3.2.8 Floodplain Management Plan

The Flood Assessment prepared for the EIS (WRM, 2018) addresses aspects of the Project relevant to flood management including consideration against the draft Floodplain Management Plan (FMP) for the Upper Namoi Valley Floodplain.

The currently gazetted FMP is the *Carroll to Boggabri Floodplain Management Plan* (Webb McKeown, 2006, on behalf of the Department of Natural Resources), which outlines management measures for the floodplain that are hydraulically, environmentally and economically sustainable as well as being accepted and supported by the community. For the purposes of this report, the main management consideration relates to the management of riparian zones identified on Figure 2 in the FMP, which include:

- Stratford Creek, a minor tributary of the Namoi River, which drains in a westerly direction to the south of the mine disturbance area;
- a tributary of Stratford Creek (designated 'South Creek' for the purposes of this report) which drains in a southerly direction from the Vickery State Forest; and
- a tributary of Driggle Draggle Creek (designated 'North-West Drainage Line' for the purposes of this report) which drains in a westerly direction from the Vickery State Forest.

Sections 9.1 and 9.2 provide further consideration of riparian zone protection for the watercourses.

The FMP notes *'It is recommended in the Management Study that a riparian buffer zone be established and maintained along the main water courses to help maintain the integrity of the banks and the general health of the creeks and the adjacent cultivated land'*. This recommendation is consistent with the subsequent requirements set out in the *Guidelines for Controlled Activities on Waterfront Land - Riparian Corridors* (NRAR, 2018) which are referenced in Section 3.3 below.

3.3 Technical and Policy Guidelines

The SEARs provide a list of guidelines identified by the NSW Department of Planning and Environment that should be considered for the preparation of the Surface Water Assessment. Where appropriate these guidelines have been referred to. In particular the following have been used:

- *Managing Urban Stormwater: Soils & Construction – Volume 1* (Landcom, 2004) taken into account in the design of the sediment dams;
- *Managing Urban Stormwater: Soils & Construction – Volume 2E: Mines and Quarries* (NSW Department of Environment and Climate Change [DECC], 2008) taken into account in the design of the sediment dams;
- *Environmental Guidelines: Use of Effluent by Irrigation* (DEC, 2004) for the design of the effluent irrigation system at the mine infrastructure area;
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) to determine water quality 'trigger' values;
- *ANZECC Guidelines and Water Quality Objectives in NSW* (DEC, 2006) to determine water quality 'trigger' values; and
- *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals* (IESC, 2018).

In NSW, the most relevant and comprehensive guidelines for the design of stormwater controls relating to mines is contained in *Managing Urban Stormwater: Soils and Construction Vol 2E – Mines and Quarries* (DECC, 2008) in conjunction with the references to Volume 1 (Landcom, 2004). The principles of surface water control, including the design of erosion and sediment control structures, have been adopted where applicable in this Surface Water Assessment.

In accordance with Division 2 of the *Water Management (General) Regulation* 2011, a controlled activity approval under the *Water Management Act 2000* is typically not required for surface mining activities approved as State Significant Development under the EP&A Act. However, the general standards used by DoI-Water in implementing the *Water Management Act 2000* still need to be adhered to. Consideration of the following guidelines has been included in this Surface Water Assessment:

- *Guidelines for Controlled Activities on Waterfront Land - Riparian Corridors (NRAR, 2018);*
- *Guidelines for Instream Works on Waterfront Land (DPI Water, 2012a);*
- *Guidelines for Laying Pipes and Cables in Watercourses on Waterfront Land (DPI Water, 2012b);*
- *Guidelines for Outlet Structures on Waterfront Land (DPI Water, 2012c);*
- *Guidelines for Vegetation Management Plans on Waterfront Land (DPI Water, 2012d);* and
- *Guidelines for Watercourse Crossings on Waterfront Land (DPI Water, 2012e)*.

3.3.1 ANZECC Guidelines for Fresh and Marine Water Quality 2000

The *ANZECC 2000 Guidelines* set out a range of water quality criteria for assessment of the suitability of water for protection of ecosystem health, recreational amenity, drinking water, irrigation and stock water use, and potential effects on aquatic fauna.

The main aspects of the *ANZECC 2000 Guidelines* that relate to matters covered in this report concern the default trigger values for which there is minimal risk of ecosystem harm based on 20^{th} and 80^{th} percentile data derived for appropriate reference systems (as set out in Tables 3.3.2 and 3.3.3 of the Guidelines). It is important to note that the default trigger concentrations are frequently misinterpreted as water quality targets. As noted in Section 3.3.2.3 of the *ANZECC 2000 Guidelines*:

> *'The guideline trigger values are the concentrations (or loads) of the key performance indicators, below which there is a low risk that adverse biological effects will occur. The physical and chemical trigger values are not designed to be used as 'magic numbers' or threshold values at which an environmental problem is inferred if they are exceeded.'*

The guideline *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (DEC, 2006) specifically notes that trigger values are not 'pass/fail' compliance criteria.

The *ANZECC 2000 Guidelines* recognise that the water quality values quoted in Tables 3.3.2 and 3.3.3 for south-eastern Australia are default values to be used in the absence of local data for a particular watercourse, and provide the following advice (Section 3.3.2.4 of the guidelines) in relation to the derivation of locally specific data:

> *'For naturally occurring stressors, use data for appropriate reference systems to determine the low-risk trigger value for each key indicator. For these Guidelines, data collected after two years of monthly sampling are regarded as sufficient to indicate ecosystem variability and can be used to derive trigger values'.*

Further discussion relating to the water quality data in the watercourses in the vicinity of the Project is contained in Section 6.

A further aspect of the *ANZECC 2000 Guidelines* relates to the use of trigger values for regulatory purposes. Section 2.2.1.9 of the *ANZECC 2000 Guidelines* provides the following advice in relation to the use of the trigger values for regulatory purposes:

> *'The Guidelines have not been designed for direct application in activities such as discharge consents, recycled water quality or stormwater quality, nor should they be used in this way. (The exception to this may be water quality in stormwater systems that are regarded as having some conservation value.) They have been derived to apply to the ambient waters that receive effluent or stormwater discharges, and protect the environmental values they support.'*

This advice is reflected in the guideline *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (DEC, 2006), which notes:

> *'The NSW WQOs [Water Quality Objectives] are the environmental values and long-term goals for consideration when assessing and managing the likely impact of activities on waterways. They are not intended to be applied directly as regulatory criteria, limits or conditions but are one factor to be considered by industry, the community, planning authorities or regulators when making decisions affecting the future of a waterway.'*

3.3.2 Namoi Catchment Water Study

A Ministerial Oversight Committee was established in 2009 to oversee the preparation of the *Namoi Catchment Water Study – Independent Expert Final Study Report* (Schlumberger, 2012) (the Study). The Ministerial Oversight Committee included representation from the local community, agriculture, mining and coal seam gas extraction industries as well as relevant NSW government agencies.

In August 2010, Schlumberger Water Services (Australia) Pty Ltd was appointed as the Independent Expert for the Study. The Study involved the collation of existing and new data to investigate the risks and to support the construction of a three-dimensional physical based numerical model (the Model) of the catchment water resources that could be used to develop scenarios of mining and gas development and predict their effects. The Model considers all the important physical processes relating to surface water and groundwater aquifers, the interactions between flow and water quality between them and the processes relating to coal and gas development.

The Study was submitted to the Ministerial Oversight Committee in July 2012. Relevant findings of the study, as set out in the Executive Summary, are:

> *"At a project scale, mining and CSG activities both have the potential to negatively impact groundwater and surface water resources via localised pathways. These local scale pathways, conditions and effects cannot be determined with any degree of accuracy by a catchment-scale study or predicted by a model designed to assess catchment-wide, long-term and cumulative impacts. This highlights the importance of project-specific detailed investigations, supplemented by comprehensive monitoring and appropriate operational management."*

And:

"The severity or seriousness of an impact can be reduced by mitigation. Prevention of an impact is generally preferable to mitigation and many prevention measures exist to minimise local-scale impacts (spills, discharges etc.). These should be included in the approvals and environmental management plan for each particular development project. On a sub-regional scale, impact prevention options are more limited, potentially placing greater reliance on mitigation.

Effective impact mitigation is reliant on establishing the impact source and having a comprehensive baseline dataset for both water quantity and quality so that impacts can be defined, tracked and mitigation implemented in time. Trigger levels for both water quantity and quality components should be set which define at what magnitude of impact the mitigation measures are activated."

The Project and the proposed surface water mitigation and monitoring actions conform to these recommendations.

4 Surface Water Environment

4.1 Rainfall/Climate

The Project is situated in the Namoi River Valley between tropical and temperate climatic zones and between the belts of subtropical highs and mid-latitude westerlies. The climate in the area is characterised by mild to hot summers and cool winters. The highest temperatures occur throughout December, January and February, with the coolest temperatures occurring in July. Autumn and spring are generally mild, while winters are cool to cold with overnight lows reaching close to an average of 0^{o}C.

Climate data representative of the Project area and the Maules Creek drainage line catchment (which has long-term streamflow records) have been collated, assessed and used for modelling of runoff from natural catchments (see Section 5). The Bureau of Meteorology (BoM) stations for which historic climate data was obtained are listed in Table 4.1 below. The locations of these stations are shown on Figure 5.1

Table 4.1: Climate Stations used for Calibration/Validation and Project Area Modelling

Station Number	Station Name	Start Date	End Date	Mean Annual Rainfall (mm)
54021	Barraba (Mount Lindsay)	1 Jan 1886	31 Mar 2012	979.4
54024	Barraba (Log Cabin)	1 Jan 1966	open	667.1
55044	Boggabri (Retreat)	1 Mar 1899	open	591.2
55076	Boggabri (Kanownda)	1 Jan 1899	open	575.7
55024	Gunnedah Resource Centre	1948	open	636.9

Note: mm = millimetres

4.1.1 Rainfall

The daily rainfall records for Boggabri (Retreat) (Station 55044), the closest station to the Project, were obtained from the Scientific Information for Landowners (SILO) climate database. SILO is an online database of historic daily climate records for Australia launched in 1997, developed by the BoM and the Queensland Government. The SILO database is currently hosted by the Qld Science Delivery Division of the Department of Science, Information Technology and Innovation, and contains Australian climate data from 1889 to present. Datasets are constructed from climate data collected by the BoM with interpolation where there are data gaps as follows:

- 'Patched Point' Datasets are observed data with missing or suspect values 'patched' with interpolated data; and
- 'Data Drill' datasets access grids of data interpolated from point observations by the BoM. The data in the Data Drill are all synthetic.

The patched data record for Boggabri (Retreat) (Station 55044) for the period 1 July 1889 – 30 June 2017 was obtained from SILO for the analysis of runoff from natural catchments in the immediate vicinity of the Project and as the basis for the site water balance assessment. The record comprised 92% historical station data. Missing data in this record was infilled with interpolated daily observations.

Table 4.2 contains the monthly and annual rainfall statistics for the patched data record for Boggabri (Retreat).

Table 4.2: Rainfall Statistics (mm) for Boggabri (Retreat)

Month	Mean	Min	10th Percentile (dry)	Median	90th Percentile (wet)	Max
Jan	74.1	0.0	15.4	64.1	148.4	234.3
Feb	61.8	0.0	7.5	43.1	137.0	254.9
Mar	45.8	0.0	1.8	34.6	102.6	271.7
Apr	34.8	0.0	0.6	28.6	80.8	148.5
May	38.8	0.0	1.4	31.2	89.7	146.0
Jun	45.5	0.0	9.5	40.9	86.3	196.2
Jul	42.0	0.0	7.2	34.8	83.4	147.5
Aug	37.5	0.0	6.1	31.0	72.3	158.8
Sep	40.7	0.0	4.0	36.8	87.8	138.6
Oct	50.1	0.0	10.6	46.1	92.1	239.4
Nov	58.5	0.0	12.9	47.7	113.9	250.0
Dec	61.6	0.0	11.1	55.4	118.9	181.6
Annual	591.2	255.4	400.4	562.7	808.3	1098.0

Based on the analysis of rainfall statistics in Table 4.2, rainfall is reasonably well distributed throughout the year. Summer rainfall is generally 1.5 times that of the other nine months of the year. January is usually the wettest month of the year and April is usually the driest. The wetter months of January, February and December also have a reasonably low number of mean rain days, suggesting the higher volumes of rainfall are associated with higher intensity storms falling over shorter periods of time. Consideration of such events is important when designing appropriate surface water management structures.

Climate variability, which needs to be considered in relation to shortage or excess of mine water, is illustrated by the data in Table 4.3. This data shows, for instance, that the minimum and maximum rainfall over five years has been -26% and +39% of the long-term average respectively.

Table 4.3: Consecutive Rainfall Total (mm/year) for Boggabri (Retreat)

	Consecutive Rainfall Total (mm/year)					
	1 Year	2 Years	3 Years	4 Years	5 Years	10 Years
Average	591	588	588	587	587	584
Minimum	255	344	393	432	433	486
10th Percentile	400	466	467	491	495	526
Median	563	571	582	585	587	580
90th Percentile	808	720	719	697	687	645
Maximum	1,098	958	795	819	823	695

A further indication of the variability of the climate is shown in the cumulative departure of annual rainfall from the long-term average, as shown in Figure 4.1. Figure 4.1 shows that the area has experienced extended drought periods (graph sloping downwards to the right), particularly an extended drought in 1935 – 1948 and other significant droughts in 1979 – 1983 and 1992 – 1996. Although it contained some drier years, the period 1948 – 1978 was predominantly wetter than the long-term average.

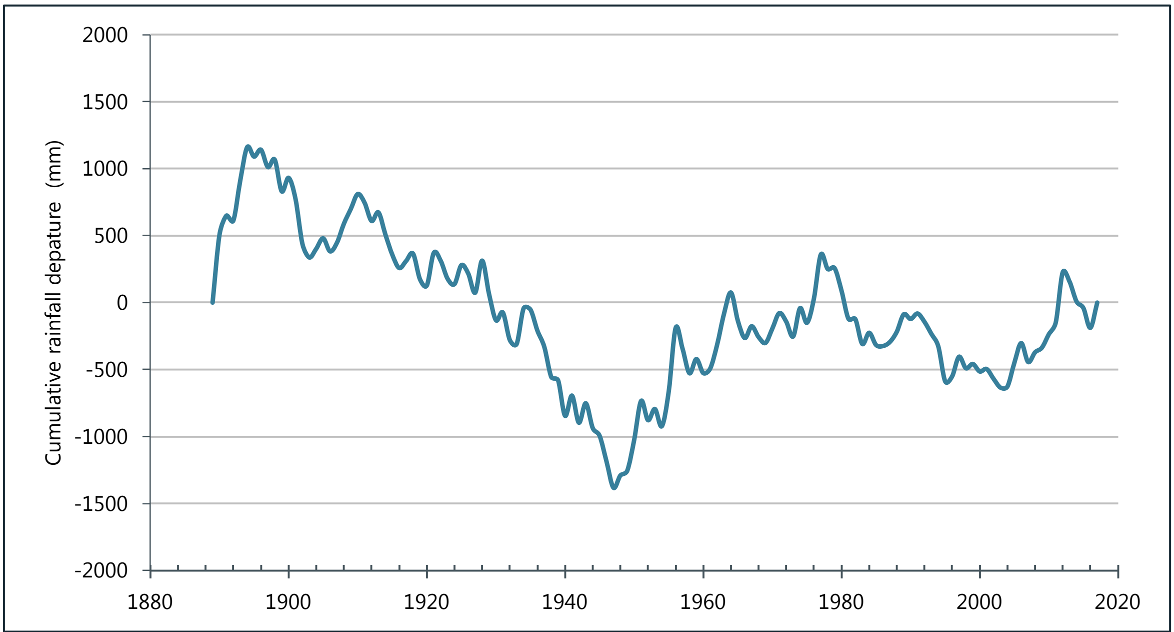


Figure 4.1: Cumulative Departure from Long-term Average Annual Rainfall – Boggabri (Retreat)

Table 4.4 summarises the average distribution of daily rainfall depths for Boggabri (Retreat).

Table 4.4: Distribution of Daily Rainfall for Boggabri (Retreat)

Rainfall	Average Days per Year	Percentage of Time
Days with rainfall <0.1 mm or zero	303	83.2%
Days with rainfall >0.1 mm	62	16.8%
Days with 0.1 – 2 mm	14	3.8%
Days with 2 – 5 mm	13	3.6%
Days with 5 – 10 mm	14	3.8%
Days with 10 – 20 mm	12	3.3%
Days with 20 – 50 mm	8	2.1%
Days with > 50 mm	1	0.2%

Rainfall for AWBM calibration

In the absence of any flow monitoring on the ephemeral creeks in the immediate vicinity of the Project, the flow regime pre, during and post-mining has been estimated using a rainfall-runoff model with parameters derived from the Maules Creek drainage line (catchment area 171 km2, located about 20 km north of the Project area) (see Sections 5.3 and 8.2.5). For the analysis of the relationship between rainfall and runoff for Maules Creek, a composite daily rainfall record representative of the centroid of the catchment (based on a Theissen polygon analysis) was prepared from rainfall stations Boggabri (Kanownda) (Station 55076) (60%) and Barraba (Mount Lindesay) (Station 54021) (40%). There were no missing data in the records for the modelling period however some disaggregation of data was required and was based on Boggabri (Kanownda) (Station 55076), Barraba (Mount Lindesay) (Station 54024) and Barraba (Log Cabin) (Station 54021).

4.1.2 Evaporation

SILO patched pan evaporation data for Boggabri (Retreat) (55044) for the period 1 July 1889 to 30 June 2017 was obtained for the analysis of runoff from natural catchments in the immediate vicinity of the Project and as the basis for the site water balance assessment. The data comprised long-term daily average data (by month) from 1889 to the end of 1969 and daily data from 1970 to 2017. Prior to 1969, only daily average evaporation data by month are available from BOM/SILO. The data record comprised 63% interpolated long-term average data and 37% interpolated daily observations.

Statistics for the patched pan evaporation data for Boggabri (Retreat) are provided in Table 4.5.

Table 4.5: Pan Evaporation Statistics (mm) for Boggabri (Retreat)

Month	Mean	Min	10th Percentile	Median	90th Percentile	Max
Jan	250	172	205	249	297	327
Feb	204	142	167	206	237	268
Mar	187	136	158	189	215	250
Apr	130	82	107	129	150	177
May	85	65	74	83	97	108
Jun	58	46	52	58	67	72
Jul	64	45	55	64	76	88
Aug	92	67	76	91	110	120
Sep	130	91	108	124	161	194
Oct	182	131	150	175	225	245
Nov	214	149	176	212	261	304
Dec	253	167	214	247	299	363
Annual	1851	1503	1687	1849	2075	2285

Evaporation for AWBM calibration

For the purposes of modelling catchment runoff, Boughton (2010) recommends the use of areal potential evapotranspiration data. Areal potential evapotranspiration is the evapotranspiration that would take place, if there was an unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average.

Monthly potential evapotranspiration specifically for the Project area was derived by interpolation of the spatial data from the digital version of the Climatic Atlas of Australia: Evapotranspiration (Version 1.0, BoM, 2002).

4.2 Climate Change

In 2014, the NSW and Australian Capital Territory (ACT) Regional Climate Modelling Project (a multi-agency research partnership between the NSW and ACT governments and the University of NSW) prepared high spatial resolution climate projections for NSW and the ACT. The *New England North West Region Climate Change Snapshot* (NSW OEH, 2014) provided information about predicted climate change effects on temperature and rainfall in the north-west slopes region where the Project is located. No predictions relating to evaporation were provided.

In 2015, the Commonwealth Scientific & Industrial Research Organisation (CSIRO) updated the 2014 predictions in *Climate Change in Australia Projections for Australia's Natural Resource Management Regions*. These reports present projections of future climate for various natural resource management regions which are grouped into 'clusters', one of which is the Central Slopes cluster, which includes the Namoi catchment (CSIRO, 2015). The projections are based on current understanding of the climate system, historical trends and model simulations of the climate response to changing greenhouse gas and aerosol emissions.

The Global Climate Model simulations presented in the report represent the full range of emission scenarios, as defined by the Representative Concentration Pathways (RCPs) used by the International Panel on Climate Change. Projects for three RCP scenarios are provided:

- RCP2.6 – representing a low emission scenario;
- RCP4.5 - representing a pathway consistent with intermediate emissions, which stabilise the carbon dioxide concentration at about 540 parts per million (ppm) by the end of the 21st century; and
- RCP8.5 - representing a high-emission scenario, for which the carbon dioxide concentration reaches about 940 ppm by the end of the 21st century.

Projections are given for two 20-year time periods: the near future 2020–2039 (referred to as 2030) and 2080–2099 (referred to as 2090). The spread of model results is presented as the range between the 10th and 90th percentile in the model output. For each time period, the model spread can be attributed to three sources of uncertainty: the range of future emissions, the climate response of the models, and natural variability.

The key predictions for the Central Slopes relevant to this Surface Water Assessment are:

- average temperatures will continue to increase in all seasons (very high confidence);
- more hot days and warm spells are projected with very high confidence;
- average winter rainfall is projected to decrease with high confidence. There is only medium confidence in spring decrease. Changes in summer and autumn are possible but unclear;
- increased intensity of extreme rainfall events is projected, with high confidence;
- on annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly for rainfall in the next 20 years.

Table 4.6 below summarises the CSIRO's seasonal rainfall and evapotranspiration projections for the near future and far future for the three RCP scenarios. The table provides the 10th and 90th percentile predictions as well as the median (50th percentile).

Table 4.6: Seasonal Rainfall and Evapotranspiration Projections as a Result of Climate Change for the Central Slopes Region

Season	Near Future (2020–2039)						Far Future (2080–2099)					
	RCP2.6		RCP4.5		RCP8.5		RCP2.6		RCP4.5		RCP8.5	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Rainfall (% change)												
Summer DJF	2	-13 to 17	1	-9 to 16	2	-12 to 23	-5	-23 to 13	0	-14 to 17	10	-14 to 29
Autumn MAM	-2	-25 to 19	-5	-22 to 19	-2	-17 to 14	-10	-26 to 17	-4	-28 to 23	-4	-35 to 27
Winter JJA	-3	-18 to 14	-3	-20 to 11	-2	-27 to 15	-4	-24 to 11	-10	-24 to 9	-17	-39 to 15
Spring SON	-2	-21 to 19	-2	-18 to 12	-1	-23 to 12	-1	-25 to 12	-8	-26 to 12	-14	-40 to 11
Annual	-1	-11 to 8	-2	-11 to 7	-1	-13 to 8	-3	-18 to 8	-4	-16 to 6	-6	-23 to 18

Season	Near Future (2020–2039)						Far Future (2080–2099)					
	RCP2.6		RCP4.5		RCP8.5		RCP2.6		RCP4.5		RCP8.5	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Evapotranspiration (% change)												
Summer DJF	3.9	1.7 to 5.1	2.8	1.3 to 6.2	3.1	1.2 to 6.6	5.3	2 to 7.7	7.1	4.3 to 11.5	13.5	8.9 to 20.8
Autumn MAM	4.6	-0.9 to 6.6	3.2	1 to 7.2	4.7	2.3 to 7.2	5.3	2.3 to 7.7	7.8	5 to 12.5	16.9	11 to 23.8
Winter JJA	4	1.5 to 8.2	3.7	0.5 to 8	4.5	1.1 to 7.4	4.3	1.5 to 6.8	7.7	4.4 to 13.5	16.3	9.9 to 26.8
Spring SON	3.3	0.5 to 5.6	3	0.8 to 4.6	2.2	0.5 to 4.9	2.5	0.2 to 5.5	5.1	1.5 to 9.4	8	4.3 to 14.6
Annual	3.6	2.5 to 4.8	3.3	1.6 to 4.8	3.6	1.8 to 5.8	4.2	2.3 to 6.9	6.8	4.2 to 10.8	12.5	9.8 to 18.1

Source: CSIRO, 2015

4.3 Topography

The Project area is divided by a ridgeline that runs diagonally from the north-east to the south-west. The highest point along this line is roughly located in the middle of Vickery State Forest at approximately 479 metres (m) Australian Height Datum (AHD).

The ridge tops and mid-slopes of Vickery State Forest above 360 m AHD are moderately sloped, with gradients fairly consistent at approximately 25-30%. Slopes then tend to flatten out below this level, with gradients ranging from 0% to 5% across much of the Project area.

4.4 Vegetation

The majority of the Project area has been cleared for agricultural and mining purposes and mainly consists of dry sclerophyll woodland and forest with dominant species of White Box, White Cypress Pine, Narrow-leaved Ironbark and Silver-leaved Ironbark, and derived native grasslands of these communities (FloraSearch, 2018).

4.5 Land Use

The Project is located within a rural area. With the exception of the Vickery State Forest, the surrounding land is primarily utilised for a combination of livestock grazing and crop cultivation.

The majority of the Project area is grazing land, some of which is rehabilitated land from mining activities associated with the former Vickery Coal Mine (Figure 4.2) and the former Canyon Coal Mine, which ceased mining in 2009.

Figure 4.2: Example of Rehabilitated Land within the Project Area

4.6 Soils

A *Soil Resource Assessment* for the Project has been prepared by SESL (2018) and forms a component of the *Agricultural Impact Statement* for the EIS. The *Soil Resource Assessment* identifies that the main soil types within the Project area are Dermosols and Sodosols.

The *Soil Resource Assessment* provides a preliminary material balance to determine the available soil resource for rehabilitation. The results of the material balance indicate there would be sufficient soil available to meet the rehabilitation concepts for the Project. The *Soil Resource Assessment* concludes the topsoil would be suitable for use in rehabilitation, with treatment if necessary (SESL, 2018).

4.7 Fluvial Geomorphology

A *Fluvial Geomorphological Assessment* was prepared for the Approved Mine (Fluvial Systems, 2012). The assessment found that the majority of the drainage lines in and around the vicinity of the Project are classified as Valley-Fill type. Drainage lines of this categorisation generally exhibit:

- highly episodic ephemeral flow;
- indistinct and discontinuous channel form;
- cohesive fine-grained bed material;
- no large woody debris (unless situated within a woody area); and
- low energy.

Occasional shallow knick-points (i.e. vertical drops in channel bed) are present in the drainage lines but only demonstrate a downstream scoured channel length less than 20 m. Headwater streams have a well-defined channel of flow in bedrock with course-grained bed material. Moderate amounts of large woody debris are evident in the headwaters within Vickery State Forest which are of low to moderate energy. The downstream end of Driggle Draggle Creek is sufficiently large enough to form a defined meandering channel.

The *Fluvial Geomorphological Assessment* for the Approved Mine (Fluvial Systems, 2012) included an assessment of the potential impacts of changes to the contributing catchment areas associated with diversion of the North-West Drainage Line along the eastern boundary of the Project area, as well as the reduction in the catchment areas of the West Drainage Line and North-West Drainage Line as a result of mining. The report concluded that the catchment changes would not impact the geomorphic functioning in the affected creeks. The catchment changes associated with the Project are similar to those for the Approved Mine, and accordingly no impacts on the fluvial geomorphic characteristics of the creek lines are expected.

4.8 Riparian Vegetation

Riparian vegetation is described in detail in the *Vickery Extension Project Baseline Flora Report* (FloraSearch, 2018). The assessment identified that River Red Gum Riparian Tall Woodland occurs in the riparian zone of the Namoi River and some of its smaller tributaries within the Project area. It also occurs on the active flood terraces above the river. Furthermore, it identified a thin patch of Narrow-leaved Ironbark – cypress pine – White Box shrubby open forest along South Creek, just north of Shannon Harbour Road.

4.9 Aquatic Ecology

An *Aquatic Ecology Assessment* has been prepared by Eco Logical (2018) as part of the EIS (Appendix N) for the Project.

The Project mining area contains a number of first and second order (Strahler classification) drainage lines, although none are named watercourses and most are within low lying areas with no defined channel or creek bed. The drainage lines are ephemeral, only holding water following flooding events, as occurred in February 2012.

Based on physio-chemical data, macro-invertebrate assemblages and the absence of native fish, the drainage lines within the Project mining area were classed as having limited aquatic habitat opportunities.

The *Aquatic Ecology Assessment* (Eco Logical, 2018) provides further detail on the condition of the drainage lines within the Project mining area and surrounds, including the drainage lines traversed by the Project rail spur as well as the Namoi River itself.

4.10 Geochemistry

4.10.1 Geochemical Characteristics of Overburden, Interburden and Coal Rejects

A *Geochemistry Assessment* (Appendix M to the EIS), prepared by GEM (2018), extends the analysis of overburden, interburden and coal rejects material originally undertaken for the Approved Mine (GEM, 2012). Key findings of the *Geochemistry Assessment* of relevance to this assessment are:

- Overburden and interburden material:
  - The overburden and interburden material, comprising predominantly non-acid forming (NAF) material with a small proportion of PAF material, will be emplaced within the Western Emplacement and the footprint of the open cut void. Based on this assessment, blending of this material during excavation, transport and dumping is expected to produce an overall NAF material. In order to ensure that no areas of concentrated PAF material are exposed on the surface of the waste rock emplacement an undertaking would be made to ensure that the final lift of the waste rock emplacement does not contain any PAF material.
  - In order to ensure long-term stability and erosion control for the waste rock emplacement, any areas of the final face that exhibit erosion would be treated with gypsum. In general, as part of the mine's rehabilitation strategy, soil that has been stripped from the site in advance of mining would be used to cover the waste rock emplacement faces to facilitate rehabilitation.
- Coal reject:
  - Coal reject materials from the open cut are expected to be non-to-slightly saline and to be NAF.
  - Rejects from the Whitehaven CHPP are slightly enriched in As, B, Sb and Se. One of the reject samples was found to be significantly enriched in As, B, Hg and Se.
  - Coal rejects from the open cut are expected to be significantly enriched in Ag, As, Hg and Se. Additionally, Mo and Se were found to be readily soluble under the prevailing neutral pH conditions of the Whitehaven CHPP samples.
  - Based on the quantity and low acid capacity (i.e. <5 kg H2SO4/t) of this material, the co-disposed material is expected to be overall NAF. No coal reject materials would be placed within 30 m of the edge of the Western Emplacement, and coal reject materials would be covered with at least 5 m of inert material on the outer surfaces of the waste rock emplacement.
- GEM (2018) recommended that water quality monitoring for the Project should consider the following parameters in the sediment dams pH, EC, total suspended solids, total alkalinity/acidity, SO_4, Al, As, Mo and Se.

Proposed measures to manage overburden, interburden and coal rejects in a safe manner are outlined in Section 7.7.

4.11 Water Quality

The outcomes of the *Geochemistry Assessment* for the Project are consistent with the outcomes of the geochemical test-work undertaken at the Tarrawonga Coal Mine that identified the potential for As, Mo and Se in mine waste rock to be slightly soluble under near-neutral pH conditions (GEM, 2012). Accordingly, Whitehaven monitors these solute concentrations in mine water storages at the Tarrawonga Coal Mine as part of the Surface Water Monitoring Program. Whitehaven also monitors for Al, As, Mo and Se in the mine water storages at the nearby Rocglen Coal Mine and in the former Canyon Coal Mine final void waterbodies.

A summary of these water quality monitoring results, including a comparison to ANZECC/Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) (2000) guideline trigger values for livestock and irrigation and NHMRC (2011) drinking water guideline values for human health, is provided in Table 4.7.

Comparison to the aquatic ecosystem guideline values is not considered warranted given measured concentrations of key water quality indicators for the Namoi River are already elevated relative to these values (Section 6).

Al, As, and Se concentrations in mine water storages, sediment dams and final void waterbodies at the former Canyon Coal Mine, Rocglen Coal Mine and Tarrawonga Coal Mine are within ANZECC/ARMCANZ (2000) guideline trigger values for livestock and irrigation and NHMRC (2011) drinking water guideline values for human health.

All Mo concentrations are also within these guideline values with the exception of average Mo concentrations at the Rocglen Coal Mine that exceed the guideline trigger value for irrigation. Figure 4.3 is a plot of Mo concentrations for samples from the Rocglen Coal Mine that exceeded the guideline trigger value for irrigation (Whitehaven Coal Limited, 2017) together with the monthly rainfall residual mass curve for Boggabri. Figure 4.3 indicates that these exceedances generally occurred during extended dry periods. It is noted that releases from sediment dams during extended dry periods are unlikely, so runoff with elevated Mo levels would be unlikely to impact the receiving environment.

Table 4.7: Summary of Mine Water Storage Monitoring at the Rocglen, Canyon and Tarrawonga Coal Mines

Location	Parameter (mg/L)			
	Al	As	Mo	Se
Canyon Coal Mine Final Void Waterbodies				
Number of Samples	8	8	8	8
Minimum	0.25	0.003	0.003	<0.01
Average	0.50	0.005	0.003	<0.01
Maximum	0.85	0.006	0.005	<0.01
Rocglen Coal Mine Water Storages and Void				
Number of Samples	6	79	69	61
Minimum	0.27	<0.001	<0.001	<0.01
Average	0.79	0.009	0.020	<0.01
Maximum	2.18	0.042	0.195	<0.01

Location	Parameter (mg/L)			
	Al	As	Mo	Se
Tarrawonga Coal Mine Water Storages				
Number of Samples	0	106	99	102
Minimum	N/A	<0.001	<0.001	<0.01
Average	N/A	0.006	0.011	<0.01
Maximum	N/A	0.200	0.101	<0.01
Guideline Values				
ANZECC/ARMCANZ (2000) Guideline Trigger Value for Irrigation (long-term)	5	0.1	0.01	0.02
ANZECC/ARMCANZ (2000) Guideline Trigger Value for Livestock	5	0.5	0.15	0.02
Guideline value for human health (NHMRC, 2011)	N/A*	0.01	0.05	0.01

Notes:
* *No health-based guideline value can be established currently (NHMRC, 2011).*
mg/L = milligrams per litre

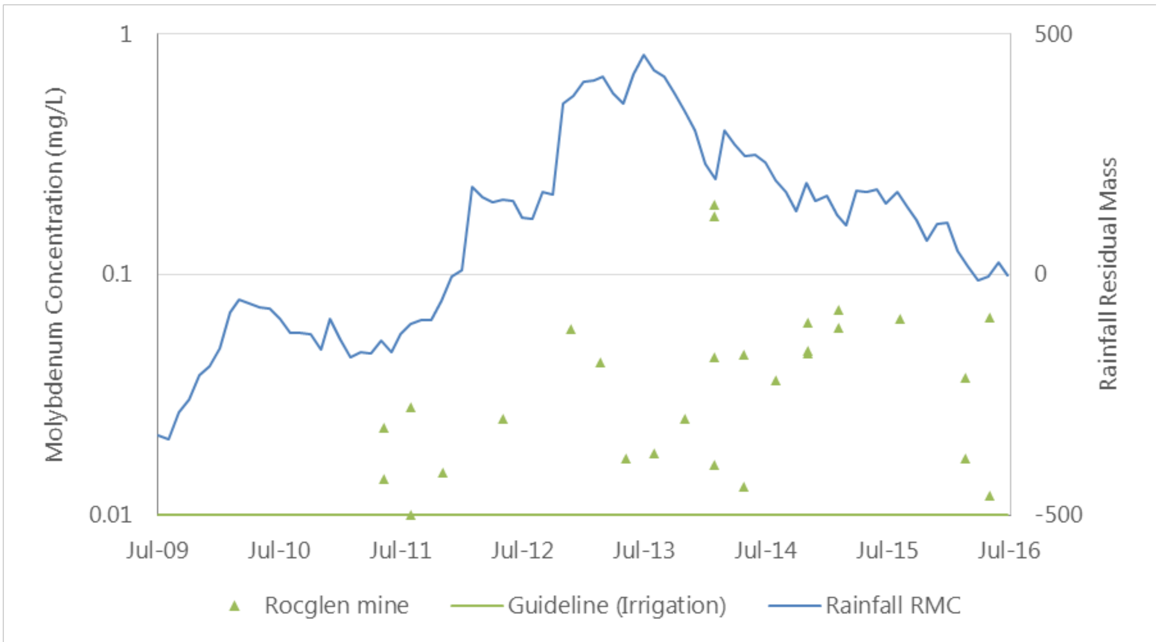


Figure 4.3: Comparison of Rocglen Coal Mine Molybdenum Concentrations in relation to monthly rainfall

Al, As, Mo and Se concentrations in the Project sediment dams to be established to collect runoff from the Project waste rock emplacement areas are expected to be lower than the already low observed concentrations in some of the Rocglen mine water storages that capture water that has been in contact with coal or coal reject material. The risk of contaminants in water released from Project sediment dams impacting downstream waters is considered to be very low given:

- overflows from sediment dams would only occur following significant rainfall (i.e. concentrations of these metals would be heavily diluted by fresh rainwater);
- water released following heavy rainfall would represent a very small portion of the flow in receiving watercourses (e.g. Namoi River, Driggle Draggle Creek, North Drainage Line and Stratford Creek);

- controlled releases from sediment dams to restore their capacity following rainfall events exceeding design capacity would allow time for runoff to settle and would occur in accordance with appropriate discharge criteria (Section 7.1);
- under median climatic conditions, controlled releases from sediment dams would only occur on an average two days per year (Section 8.7); and
- under median climatic conditions, sediment dam overflows (i.e. when rainfall exceeds sediment dam design criteria) would only occur on an average of one day in every 3 years (Section 8.7).

5 Surface Hydrology

The Project lies within the Namoi River catchment with all areas of the Project ultimately draining to the Namoi River. The Namoi River at Gunnedah has a catchment of 17,000 square kilometres (km^2), of which 5,700 km^2 is regulated by Keepit Dam. The catchments of the Mooki River, Cox's Creek and the Namoi River between Keepit Dam and Boggabri form the region known as the Liverpool Plains, which has an area of approximately 12,000 km^2. Between Gunnedah and Boggabri, the Namoi River is characterised by a wide floodplain and gentle catchment slopes.

5.1 Regional Hydrology

The *Surface Water Assessment - Tarrawonga Coal Proje*ct (Gilbert & Associates, 2011) describes the regional flow regime of the Namoi River.

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

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

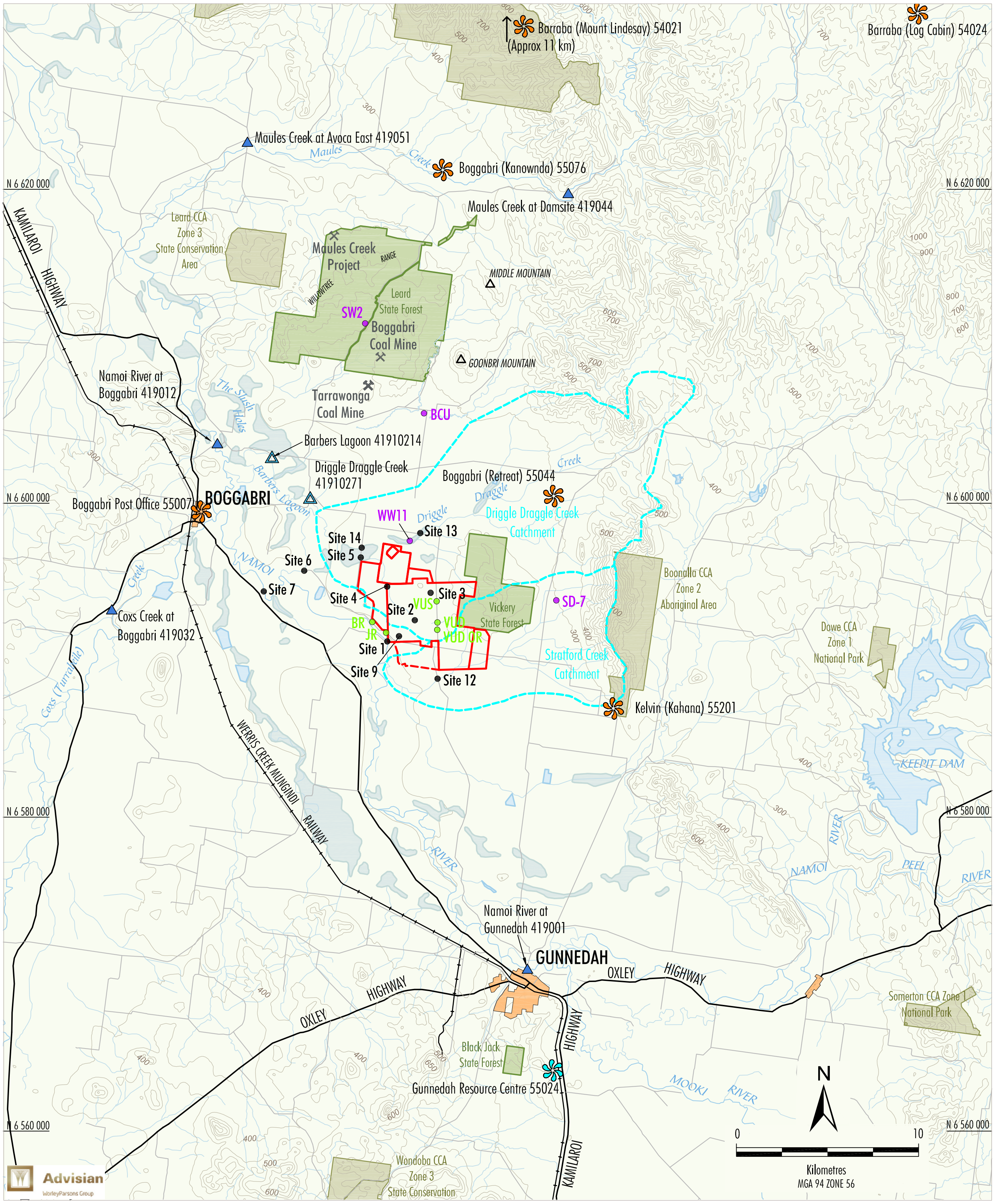
Water is released from these major water storages for irrigation, for industrial and domestic/urban requirements in the Namoi River catchment, and as environmental flows. The closest gauging station to the Project on the Namoi River is located at Boggabri (419012), just upstream of the Bollol Creek confluence with the Namoi River (Figure 5.1).

The Boggabri gauging station has a catchment area of 22,600 km^2. Flows at this gauging station exceeded 1.6 ML/day on 95% of days in the record. Zero flow was recorded on 1.4% of days in the record. Over the period of data analysed (22/02/1979 -10/10/2012), streamflow in the Namoi River at Boggabri had a median flow of 403 ML/day and an average flow of 1,695 ML/day.

Additional operational gauging stations have also operated in the region to the north of the Project (Maules Creek drainage line gauging stations [419044 and 419051]) and to the west of the Project (Coxs Creek gauging station [419032]) (Figure 5.1).

5.2 Local Hydrology

A number of intermittent streams drain across or rise within the Project area. These streams are highly ephemeral and only flow for short periods after prolonged or heavy rain and can be dry for extended periods.



LEGEND

- Mining Tenement Boundary (ML and CL)
- Mining Lease Application (MLA)
- State Conservation Area, Aboriginal Area
- State Forest
- NOW Water Quality Monitoring Locations
- NOW Gauging Station
- BOM Weather Station (Rainfall)
- BOM Weather Station (Rainfall and Evaporation)
- Surface Water Catchment Boundary
- Railway
- Major Roads
- Nearby Coal Mine Monitoring Site
- 1986 EIS Monitoring Site
- Project Monitoring Site

Source: Topographic Base Geoscience Australia (2011); DECC (2009); NSW Department Primary Industries(2011) ; Gilbert & Associates (2011)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Regional Surface Water Monitoring Sites

Figure 5.1

For the purposes of this report, the creeks and drainage lines that convey runoff into and within the Project area (Figure 1.2 and Figure 9.1) have been designated as follows:

- **'Driggle Draggle Creek'**, which runs in an east – west direction to the north of the Project area, has a catchment of about 170 km^2 at a location where it is joined by a tributary that drains from the Project area (North Drainage Line – see below). Tributaries that drain into Driggle Draggle Creek upstream of the Project area include Bayley Park Creek to the north, Glenrock Creek and Barneys Spring Creek to the north-east, and Wean Creek to the east, all of which drain into Driggle Draggle Creek north of Vickery State Forest. These creeks collectively drain from the southern sides of Haystack Rock and Rioters Hill in the north-east and the western sides of Round Hill, Mount Surprise and the main ridgeline running north-south through the Kelvin State Forest. Closer to the Project area, the North Drainage Line, the North-West Drainage Line and West Drainage Line all join Driggle Draggle Creek to the north of the Project area. Downstream of the Project area, Driggle Draggle Creek mostly flows in a south-westerly direction and drains into Barbers Lagoon and eventually the Namoi River to the west. In the area of relevance to this report, Driggle Draggle Creek is a fifth order stream according to the Strahler classification system.
- **'Stratford Creek'** comprises two main drainage lines that flow in a westerly direction and join shortly before draining into the Namoi River. The northern drainage line runs in an east – west direction just south of the proposed secondary infrastructure area and drains the south-eastern portion of the Project area (via South Creek) and the western side of the main ridgeline that runs north-south through the Kelvin State Forest (the eastern side is drained via the southern branch of the creek). At the junction with South Creek, Stratford Creek is a fourth order stream and has a catchment area of approximately 65 km^2.
- **'South Creek'** mostly drains from a southern portion of the Vickery State Forest and flows in a southerly direction between the open cut to the west and the secondary infrastructure area to the east. At the point where it joins Stratford Creek just south-west of the secondary infrastructure area, South Creek is a fourth order stream with a catchment area of 4.3 km^2.
- The **'West Drainage Line'** drains from the central portion of the Project area, including a large part of the proposed open cut area. The drainage line conveys runoff in a north-westerly direction until it joins the North-West Drainage Line to the north-west of the Project. At the point where it joins the North-West Drainage line before leaving the area to be affected by mining, the drainage line is a third order stream and has a catchment area of 5.9 km^2.
- The **'North-West Drainage Line'** drains in a north-westerly direction from the northern portion of the Project area, including the northern part of the open cut area. The West Drainage Line drains into the North-West Drainage Line shortly before it joins Driggle Draggle Creek near Braymont Road. At the point where it leaves the area to be affected by mining, the drainage line is a third order stream and has a catchment area of 23.4 km^2.
- The '**North Drainage Line**' drains from the north-eastern portion of the Project area, including the north-eastern tip of the open cut area. It drains in a north-westerly direction until it joins Driggle Draggle Creek to the north-west of the Project area (upstream of where the West Drainage Line joins Driggle Draggle Creek). At the point where it joins Driggle Draggle Creek, the North Drainage Line is a third order stream and has a catchment area of 9.9 km^2.

5.3 Flow Modelling

There are no flow gauges located on any of the streams in the vicinity of the Project area which would allow direct analysis of the existing flows. Therefore, in order to characterise the flows in the local creeks, modelling has been undertaken for the Project area using the Australian Water Balance Model (AWBM).

The AWBM modelling for the Project area was based on calibration of data from Gauging Station 419044 on the Maules Creek drainage line, located approximately 28 km north of the Project area. Station 419044 is the nearest gauging site with comparable climatic and catchment characteristics to the Project area. Twenty-four years of daily flow records are available for this station. The rainfall and evaporation data used for the modelling are described in Section 4.1.

The parameters derived from the calibration of the data from Station 419044 were then applied to the Project area. Rainfall and evaporation data were used to estimate runoff from catchments in the vicinity of the Project and within the disturbance area for estimation of flows from catchments unaffected by mining.

Further details of the approach to the AWBM modelling are provided in the sections below.

5.3.1 Australian Water Balance Model

The AWBM (Boughton, 1984; Boughton & Chiew, 2003; Boughton, 2010) is a rainfall-runoff model which uses daily rainfall and areal potential evapotranspiration to estimate the runoff depth from land surfaces with different runoff generating characteristics. The AWBM was developed for Australian catchments and has the advantage of maintaining a relatively simple structure (and relatively few parameters), whilst adequately representing the key runoff processes.

The model uses rainfall and potential evapotranspiration data together with a representation of the hydrologic processes to generate an estimate of daily runoff from the land surface. Figure 5.2 is a schematic diagram of the model structure which uses three different capacities of surface storage covering partial areas of the catchment. The water balance of each surface store is calculated independently of the others. The model calculates the moisture balance of each soil store at daily time steps. At each time step, rainfall is added to each surface store and effective evapotranspiration is subtracted from each store. If the value of moisture retained in any of the three stores exceeds its capacity, the excess moisture becomes runoff.

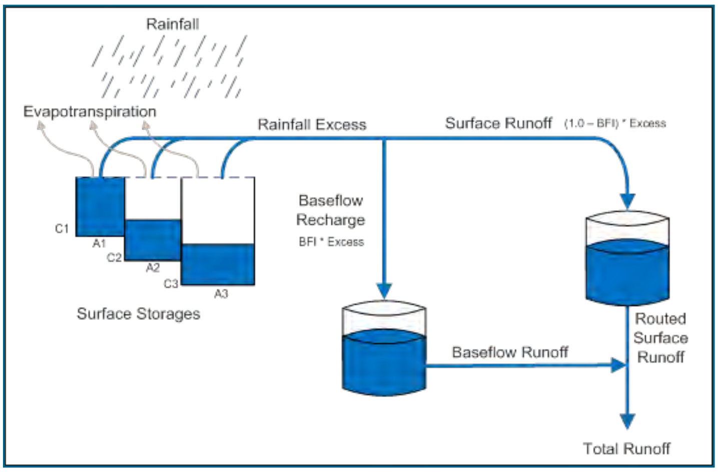


Figure 5.2: Schematic Diagram of the Structure of the AWBM

As illustrated in Figure 5.2, the AWBM utilises the following parameters to characterise the runoff characteristics of the land:

- the fraction of the catchment area represented by three soil stores (where A1 + A2 + A3 = 1);
- the soil moisture holding capacity (expressed in mm) of each of the stores (C1, C2, C3);
- a baseflow index (BFI) which sets the proportion of runoff directed to baseflow;
- a baseflow recession constant (K_{base}) which governs the rate at which water discharges from the baseflow store; and
- a recession in the rate of surface runoff (K_{surf}) to reflect the lag effect observed in large catchments.

Experience of the use of AWBM over a number of years (Boughton, 2006; 2010) has shown that the volume of runoff can be adequately characterised by a single parameter that represents the average soil moisture capacity of the land surface (AveCap), which is the sum of the product of the soil storage area fraction (A) and the soil moisture holding capacity (C) of each store.

5.3.2 Gauging Station 419044 Model Calibration and Validation

The AWBM was used to generate a set of parameters describing the flow characteristics for the Maules Creek drainage line catchment using the streamflow data from Station 419044 and climate data (Sections 4.1.1 and 4.1.2). The Leave-One-Out Cross Validation (LOOCV) procedure was applied to the model to guide the selection of the model parameters most representative of the actual flows. The calibration involved a three staged process:

1. Calculate repeated derivations of the AWBM model parameters using the automatic calibration function of the AWBM, leaving out one year at a time.
2. Apply each set of parameters to the year of data that was left out of the calibration using the manual version of the AWBM and calculate the Nash-Sutcliffe Coefficient of Efficiency for that year.
3. Using the full data set and manual version of the AWBM, select the model parameters based on the calculated Nash-Sutcliffe Coefficient of Efficiency (E) values and assessment of the flow duration curve as a guide.

5.3.2.1 Leave One Year Out Calibration

The LOOCV procedure was used to provide a validation process that utilises all available data. The model was calibrated N times, where N represents the number of years of data (for GS 419044 this equates to 24 years). For i = 1 to N, the data for year (i) was omitted from the calculations. The model was fitted to the remaining points, daily flow figures estimated and a set of model parameters derived (Ave Cap(i), BFI(i), $K_{base(i)}$, $K_{surf(i)}$). The LOOCV procedure produced N estimates of the model parameters.

The automatic calibration component AWBM was used for this procedure. This enables identification of parameters that describe the hydrological process when daily rainfall, monthly potential evapotranspiration and daily runoff are entered into the model.

All daily values were entered directly into the model except potential evapotranspiration, which was scaled by a factor of 0.85 (to account for the reduction of actual evapotranspiration as the soil dries out) for use in the calculation of the daily water balance.

The model selects a warm up period at the start of the data record and then runs the calibration for the remaining record. Default values are adopted for the baseflow parameters and the surface runoff constant during the preliminary calibration of surface storage capacity. The average surface storage capacity is scaled up and down until the calculated runoff equals the actual runoff for the assessment period. After this preliminary calibration, the BFI, K_{base} and K_{surf} parameters are calibrated in that order, then again in the same order, using a measure of differences between calculated and actual daily runoff hydrographs. The square root of the absolute difference between daily lows is summed over the period of calibration data with trial and error adjustment of the parameters to minimise the error function. In this way, the runoff generating parameters are calibrated against the amount of runoff and the parameters that affect the temporal pattern of runoff are calibrated against that pattern (Boughton, 2010).

The default values of 0.134, 0.433 and 0.433 were adopted for parameters A1, A2 and A3, respectively.

5.3.2.2 Cross Validation (excluded year)

AWBM was used to calculate the predicted runoff for the excluded year (year (i)) using the parameter set generated when year (i) was omitted (as outlined in Section 5.3.2.1 above). This method of model cross validation allows all data to be used, which is highly beneficial, particularly for sites where there is limited availability of data.

As adopted by Boughton (2006), the Nash-Sutcliffe Coefficient of Efficiency (E) was used as a measure of model performance. Boughton (2006) notes that E is based on monthly runoff and is the most common measure for comparing modelled and recorded monthly runoff. It is a normalised statistic used to determine the relative magnitude of the residual variance compared to the measured data variance to indicate the predictive accuracy of the model (Nash & Sutcliffe, 1970, Moriasi et al., 2007). The value measures how closely the modelled results fit the 1:1 line. The efficiency value can range from $-\infty$ to 1, where 1 indicates a perfect match of modelled data to observed data (Nash & Sutcliffe, 1970, Moriasi et al., 2007).

Table 5.1 identifies the results for the excluded year with the highest Nash-Sutcliffe Coefficient of Efficiency (1973 – 1974), when modelled using the parameters generated using all of the other years. Table 5.1 also contains R2, actual and calculated runoff, which also provides an indication of model accuracy. The mean, minimum and maximum values from the test sample calibration are also provided in Table 5.1.

Table 5.1: Station 419044 LOOCV Calibration Results

Characteristic	Min	Mean	Max	Highest E
Annual Rainfall (mm/y)	469.0	775.5	967.5	925.0
Annual Areal Potential Evapotranspiration (mm/y)	1,306.5	1,307.7	1,311.2	1,306.5
Period (July to June)	-	-	-	1973 – 1974
Average Capacity (mm)	261.0	272.4	299.4	270.4
BFI	0.010	0.010	0.010	0.010
K_{base}	0.806	0.806	0.806	0.806
K_{surf}	0.300	0.422	0.450	0.430
E (monthly totals)	-31.423	-4.036	0.991	0.991

Characteristic	Min	Mean	Max	Highest E
R^2 (monthly totals)	0.000	0.451	0.995	0.995
Actual Runoff (mm)	1.6	40.9	222.6	68.4
Calculated Runoff (mm)	11.9	40.6	139.9	69.1

5.3.2.3 Calibration of Full Data Set

AWBM was then run using the highest Nash-Sutcliffe Coefficient of Efficiency (E) LOOCV parameter set for the complete historic rainfall and evaporation data set ("Full Record") for the 24 (N) years of recorded daily flow data from gauging Station 419044.

The model was also run for the minimum and maximum parameter values presented in Table 5.1. Table 5.2 sets out the results of these models runs. Table 5.2 reproduces these parameter sets and the statistical analysis which was used as a basis for adopting a parameter set that best describes its flow characteristics. The Nash-Sutcliffe Coefficient of Efficiency, based on monthly totals, provided a guide to the model performance. The LOOCV highest E result from Table 5.1 is also included in Table 5.2 for comparison purposes.

Daily runoff and corresponding Nash-Sutcliffe Coefficient of Efficiency values, flow duration curves, cumulative runoff curves and scatter plots for these parameters were also calculated.

The final model parameters adopted for the calibration of the Maules Creek runoff data for the analysis in this Surface Water Assessment are listed in Table 5.2. These parameters were identified through manual adjustment to improve the fit of the flow duration curves and cumulative runoff curves.

It is noted that Boughton (2010) (Table 5.2) adopts a value of 0.05 for BFI for the Maules Creek catchment, compared with 0.3 adopted for the Vickery model. It is considered that the difference may be due to the use of different rainfall sequences by Boughton compared to those used in the current study in the calibration of BFI. The lower BFI value will result in a reduction of baseflow and an increase in surface flow. Therefore most of the flow will occur on the day of rain but the total runoff will remain the same.

Figure 5.3 contains the flow duration curve, cumulative runoff curve plot and x-y plot for the modelled daily flows generated with the adopted parameters as listed in Table 5.2, and actual flow.

Table 5.2: AWBM Parameters for Station 419044 Catchment

Input Parameters and Analysis	Full Record	Min	Max	LOOCV (highest E)	Adopted
Inputs					
Average Capacity (mm)	270.7	261.0	299.4	270.4	**269.0**
C1 (mm)	20.2	19.5	22.3	20.2	**20.2**
C2 (mm)	206.3	198.9	228.2	206.1	**205.0**
C3 (mm)	412.7	397.9	456.3	412.2	**410.0**
BFI	0.010	0.010	0.010	0.010	**0.300**
K_{base}	0.806	0.806	0.806	0.806	**0.830**
K_{surf}	0.430	0.300	0.450	0.430	**0.250**

Input Parameters and Analysis	Full Record	Min	Max	LOOCV (highest E)	Adopted
Outputs					
E (monthly data)	0.754	0.758	0.725	0.754	0.764
R^2 (monthly data)	0.800	0.794	0.800	0.799	0.813
Actual Runoff (mm)	40.9	40.9	40.9	40.9	40.9
Calculated Runoff (mm)	40.7	42.2	37.2	40.7	40.9

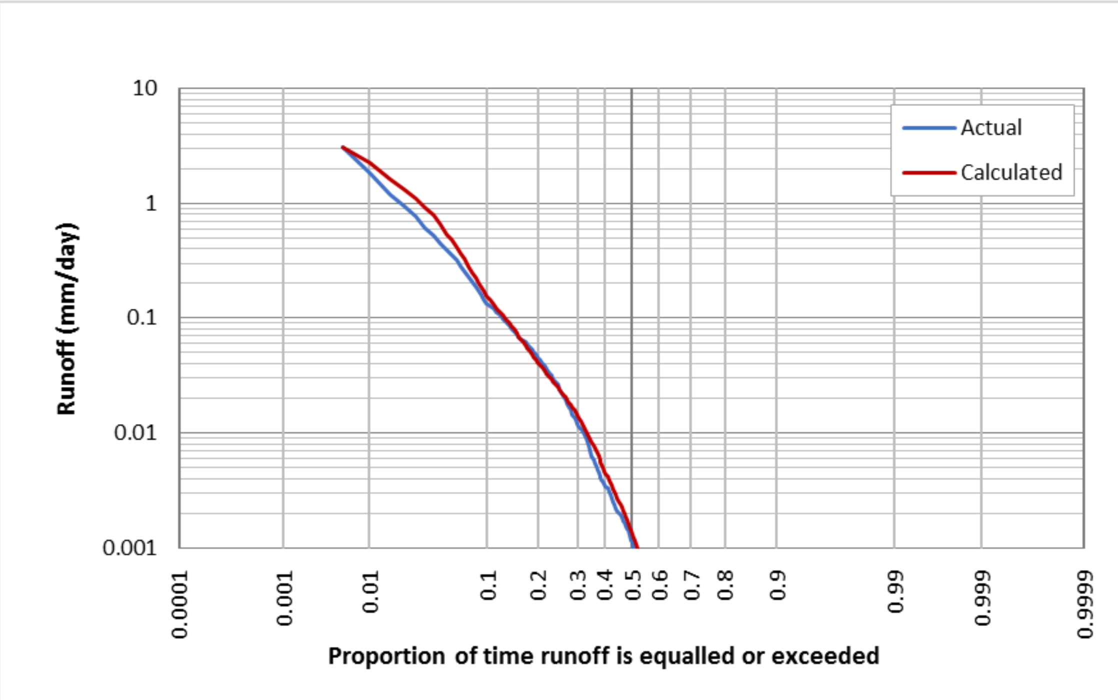


Figure 5.3: Calculated vs Actual Flow Duration Curves

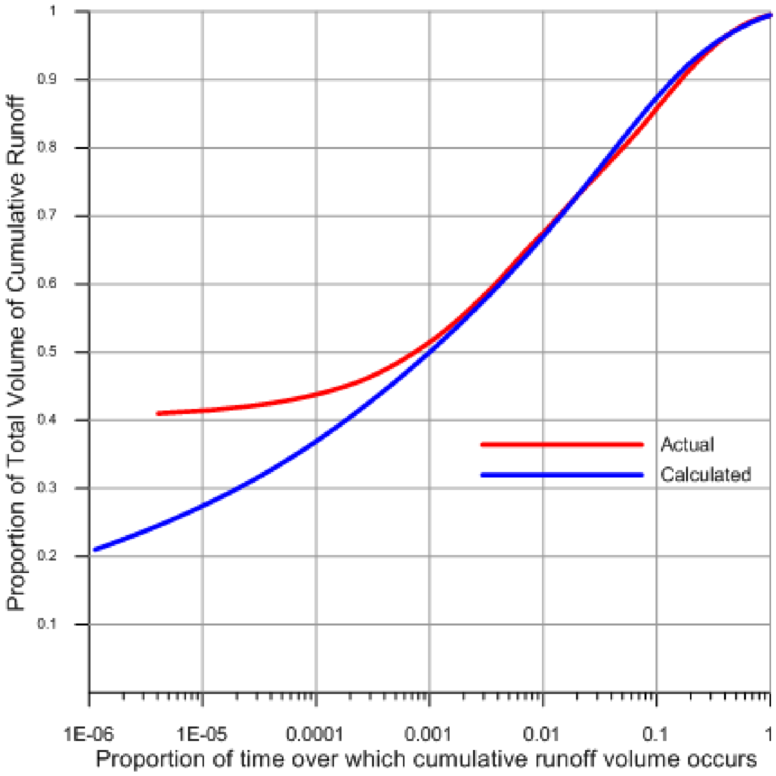


Figure 5.4: Calculated vs Actual Cumulative Runoff

5.3.3 Runoff for Natural Catchments Draining into the Project Area

The adopted model parameters identified in Table 5.2 were then applied to the Project area rainfall and evaporation data (refer Section 4.1) to estimate runoff from the catchments in the vicinity of the Project and within the disturbance area.

Table 5.3 summarises the statistics, based on the adopted AWBM modelling using the parameters in Table 5.2, for the two creeks of interest:

- South Creek, where it exits Vickery State Forest; and
- North-West Drainage Line, where it exits Vickery State Forest.

Table 5.3: Modelled Runoff for the Catchments Draining into the Project Area

Statistic	South Creek	North-West Drainage Line
Average Runoff (mm/year)	22.1	
Runoff as % of Rainfall	3.7	
Model Duration	1/7/1889 – 30/6/2017	
Catchment Area (km^2)	3.6	0.93
Average Runoff (ML/year)	79	21
10th Percentile Year – 1915/1916 Water Year (ML/year)	31	8
Median Year –1958/1959 Water Year (ML/year)	71	18
90th Percentile Year – 1917/1918 Water Year (ML/year)	141	36

6 Surface Water Quality

This section summarises surface water quality information for both the region and the creeks and drainage lines in the vicinity of the Project. All creeks in the area are highly ephemeral and water samples can only be collected on rare occasions when there is water in the creek. Baseline data has been drawn from the following sources:

- DoI-Water database records for regional monitoring sites;
- surface water quality monitoring conducted by Whitehaven in the immediate vicinity of the Project;
- monitoring of mine water storages, sediment dams and final void waterbodies at other Whitehaven operated mines;
- the *Namoi Valley Coal Project Environmental Impact Statement* (Vickery Joint Venture, 1986) (1986 EIS) for the original Vickery Coal Mine; and
- publicly available documentation containing details of water quality monitoring conducted at nearby mine sites (only monitoring sites with negligible upstream mining activity has been considered).

Detailed water quality data is provided in Annexure A.

6.1 Regional Water Quality

Regional water quality data is available for the Namoi River at Gunnedah (Station 419001), and further downstream at Barbers Lagoon (downstream of Bollol Creek) (Station 41910214) and Driggle Draggle Creek at Boggabri (Station 41910271). Regional surface water quality monitoring sites are also located on Maules Creek at Damsite (Station 419044) and Avoca East (Station 419051). Maules Creek flows into the Namoi River some 25 km to the north-west of the Project. Figure 5.1 shows the location of the water quality monitoring sites while Table 6.1 summarises the average water quality at these locations.

Water quality of the Namoi River and Maules Creek is generally characterised by moderate alkalinity and elevated electrical conductivity (EC) relative to the default trigger values for ecosystem protection in upland rivers (>150 m altitude) in the *ANZECC 2000 Guidelines*. EC values in the Namoi River at Gunnedah (Station 419001) have ranged between 200 microSiemens per centimetre (µS/cm) and 900 µS/cm every year since 2001 and there is no significant trend to the data (Schlumberger Water Services, 2011).

Average total nitrogen and total phosphorous concentrations have also been elevated relative to default trigger values for aquatic ecosystem protection. Phosphorous and nitrogen are sourced from effluent, agricultural runoff and in stream processes (Schlumberger Water Services, 2011).

Table 6.1: Summary of Regional Average Water Quality Data

Location (refer Figure 5.1)	Parameter					
	pH	EC (µS/cm)	Alkalinity (mg/L)	Turbidity (NTU)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Namoi River (and Lagoons)						
Gunnedah (419001)	8.06	497	204	67.3	0.72	0.14
Barbers Lagoon (downstream of Bollol Creek) (41910214)	7.70	348	-	304	-	-
Driggle Draggle Creek at Boggabri (41910271)	6.99	117	-	-	-	-
Coxs Creek at Boggabri (419032)		495		98.7		
Maules Creek						
Damsite (419044)	7.70	537	-	21	-	-
Avoca East (419051)	7.56	351	141	13.5	0.43	0.15
ANZECC 2000 Guidelines Default Trigger Values						
Aquatic Ecosystems [Default] (Upland Rivers)	6.5-7.5	30-350	-	2	0.25	0.02
Primary Industries [Default]	5.0-9.0	-	-	-	-	-
Livestock Drinking Water [Default]	-	3,125	-	-	-	-

Source: Gilbert & Associates (2011) and ANZECC (2000)

Notes: NTU = Nephelometric turbidity units
- = data not available

Highest turbidities have been recorded in the lower sections of the Namoi River (Schlumberger Water Services, 2011). Most sediment is derived from disturbance within catchments, stream bed and bank erosion, or direct access by livestock (Thoms *et al*., 1999). As stated in Schlumberger Water Services (2011):

> *"In summary the early studies, including Nancarrow (1998), concluded that prior to 2000, the chemical water quality of the Namoi River system was generally moderate to poor, with high levels of nutrients, areas contaminated by agricultural chemicals, and areas with on-going salinity problems. While trends for parameters such as salinity, turbidity and nutrients varied in the short term, longer term trends showed little signs of a decline through time."*

As also reported in Schlumberger Water Services (2011), surface water quality data between 2002 and 2007 has been analysed in a study carried out by the former NSW Office of Water in the Namoi catchment (Mawhinney, 2011), with the following conclusions:

- EC values typically exceeded trigger levels for the protection of aquatic ecosystems, but were suitable for irrigation;
- turbidity levels increased with distance down the catchment and are predicted to fall as beds and banks are stabilised; and
- high total phosphorous and nitrogen were detected, although there was no corresponding significant growth of blue/green algae.
- High phosphorous and nitrogen in the Peel River below Tamworth were attributed to sewage treatment discharges and urban runoff.

6.2 Project Area and Surrounds

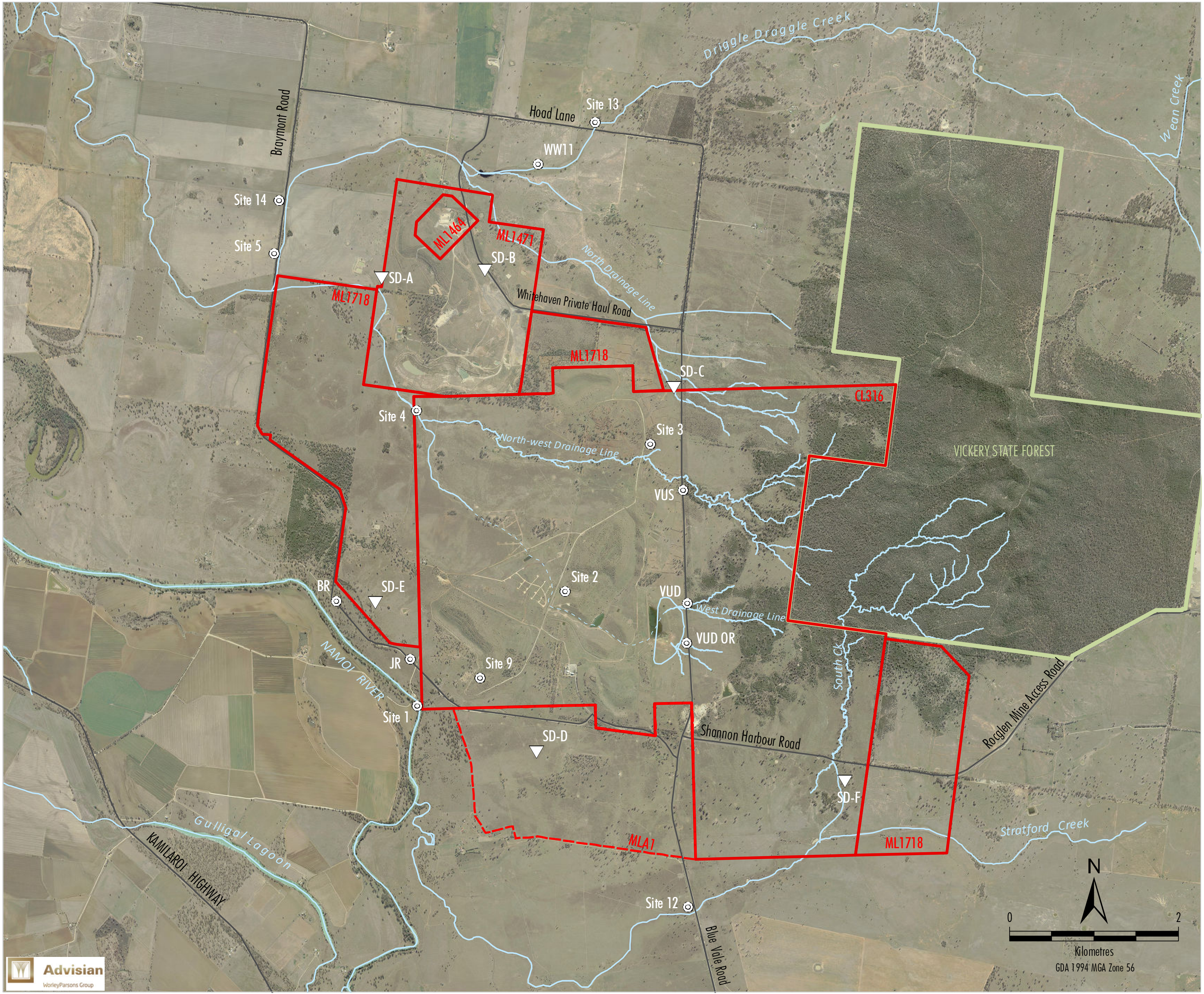
In addition to the regional water quality monitoring described above, water quality monitoring has been undertaken by a number of mining companies. Figure 5.1 shows the location of these sites in the broad regional context, while Figure 6.1 provides greater detail for the monitoring sites in the immediate vicinity of the Project mining area and Table 6.2 summarises the relative position of the various monitoring sites along the creeks.

Table 6.2: Relative Positioning of Water Quality Monitoring Sites with Respect to Local Drainage Lines

Water Body	Location	Monitoring Site	Data Source
Nagero Creek	Upstream of mining	SW2	Boggabri Coal Mine
Bollol Creek	Upstream of mining-	BCU	Tarrawonga Coal Mine
Driggle Draggle Creek	Upstream ↓ Downstream	Site 13	1986 EIS Monitoring
		WW11	Canyon Coal Mine
		Site 14	1986 EIS Monitoring
		Site 5	1986 EIS Monitoring
		Site 6 (Barbers Lagoon)	1986 EIS Monitoring
North-West Drainage Line	Upstream ↓ Downstream	VUS	Project Monitoring Site
		Site 3	1986 EIS Monitoring
		Site 4 (intersection of North-west Drainage Line and Western Drainage Line)	1986 EIS Monitoring
West Drainage Line	Upstream ↓ Downstream	VUD and VUD OR	Project Monitoring Site
		Site 2	1986 EIS Monitoring
		Site 4 (intersection of North-west Drainage Line and Western Drainage Line)	1986 EIS Monitoring
Stratford Creek	-	Site 12	1986 EIS Monitoring
Just off Namoi River	Upstream ↓ Downstream	Site 9	1986 EIS Monitoring
		Site 1	1986 EIS Monitoring
		JR	Project Monitoring Site
		BR	Project Monitoring Site
		Site 7	Project Monitoring Site

The available water quality data is provided in Annexure A and a summary of the monitoring to date, including data for the sites listed in Table 6.2, is provided in Table 6.3, together with the default *ANZECC 2000 Guidelines* 'trigger values' for ecosystem protection on upland rivers in south-eastern Australia and recommended limits for irrigation water and domestic stock.

Annexure A includes the 75 water quality samples collected by Whitehaven for the Project area. The 1986 EIS provided surface water quality monitoring data at 11 sites in the general vicinity of the Project but did not identify the number of samples collected or the duration of the sampling program.



LEGEND

- Mining Tenement Boundary (ML and CL)
- Mining Lease Application (MLA)
- State Forest
- Drainage Path
- Modified Drainage Path
- Surface Water
- Sedimentation Dam Discharge Monitoring Site

Source: LPMA - Topographic Base (2010) and Orthophoto (Boggabri 2011); Department of Industry (2015)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Surface Water Monitoring Sites in the Vicinity of the Project Mining Area

Figure 6.1

WHC-15-33_EIS SW_212D

Table 6.3: Surface Water Quality Monitoring Results – Project Area and Surrounds

	EC (lab) (µS/cm)	pH (lab)	TSS[1] (mg/L)
ANZECC Default 'Trigger Values' for Ecosystem Protection[2]	**30 – 350**	**6.5 – 7.5**	**-**
ANZECC Limits for Irrigation Water[3]	**<1,100**	**6 – 8.5**	**-**
ANZECC Limits for Stock Water[4]	**<3,700**	**-**	**-**
Project Monitoring Data (Sites BR, JR, VUD, VUD-OR, VUS)			
Number of Samples	75	75	75
20th Percentile	39	6.9	10
Average	73	7.0	42
80th Percentile	96	7.2	43
1986 EIS Report Data			
Number of Samples	11	11	9
20th Percentile	151	7.7	36
Average	456	8.1	77
80th Percentile	511	8.5	116
Site WW11			
Number of Samples	29	29	29
20th Percentile	67	6.7	31
Average	96	7.1	109
80th Percentile	122	7.3	134
Site BCU			
Number of Samples	13	13	13
20th Percentile	124	6.8	39
Average	169	7.0	164
80th Percentile	192	7.3	210
Site SW2			
Number of Samples	6	6	6
20th Percentile	56	7.0	42
Average	98	7.1	95
80th Percentile	160	7.4	110
Site SD7			
Number of Samples	28	28	28
20th Percentile	154	7.5	14
Average	220	8.0	52
80th Percentile	231	8.4	74
Dataset			
Number of Samples	162	162	160
20th Percentile	55	6.9	14
Average	137	7.3	69
80th Percentile	178	7.6	82

Notes:
1. TSS = Total Suspended Solids
2. Default 'trigger values' for slightly disturbed upland ecosystems (>150 m AHD)
3. Maximum or range for most sensitive field crops on clay soils
4. Maximum for most sensitive domestic stock (dairy cattle)

For reference purposes it should be noted that, with the exception of site WW11 (which has a very small area of the Rocglen Coal Mine within its catchment), sites BCU, SW2 and SD7 have no mining activity in their associated upstream catchments and can be considered to be appropriate indicators of local water quality. Further details of the catchment conditions upstream of these monitoring sites are provided in Table 6.4.

Table 6.4: Characteristics of Surface Water Quality Monitoring Sites Representative of Catchments Unaffected by Mining

Site Name	Relevant Mine Site	Creek Name	Location	Upstream Catchment Characteristics	Distance from Project	No. of Samples
WW11	Canyon Coal Mine	Driggle Draggle Creek	Approximately at the midpoint of the 'Gundawarra', 'Merton' and 'Whitehaven' properties, downstream of the unnamed track running east-west. Downstream on flat terrain.	Predominantly rural farms collecting upstream waters from Wean Creek, Barneys Spring Creek, Glenrock Creek and Bayley Park Creek (including Bayley Park Dam). Headwaters mostly generated from Vickery State Forest, Kelvin State Forest and Haystack Rock.	5 km north of Project	29
BCU	Tarrawonga Coal Mine	Bollol Creek	Just west of the 'Matong' property, downstream of the unnamed track running north-south. Slightly downstream of foot-slopes.	Some rural farms but mostly forested areas collecting upstream waters from Dripping Rock Creek, Nihi Creek, The Well Gully and Mihi Creek. Headwaters mostly generated from Goonbri Mountain, Dripping Rock and Haystack Rock.	13 km north of Project	13
SW2	Boggabri Coal Mine	Nagero Creek	Just upstream of approximately the midpoint of the main unnamed track running southwest to northeast within Leard State Forest boundary (amongst forested mid-slopes).	Predominantly collecting only from the southern headwaters of Nagero Creek within Leard State Forest.	19 km north of Project	6
SD7	Rocglen Coal Mine	Unnamed drainage line	Upstream (east) of Rocglen Coal Mine.	Predominantly rural farms lying in the foothills of the Kelvin State Forest, in the upper catchment of Stratford Creek.	6 km east of Project	28

6.3 Assessment

Whilst the data in Table 6.3 indicate some variation between the monitoring sites, common features include:

- Generally low EC indicating negligible sources of salt in the catchments. The average EC for the 1986 EIS data (Vickery Joint Venture, 1986) appears anomalous and is possibly due to concentration of salt in a pool as a result of evaporation during an extended period of no rainfall or flow.
- pH is generally consistent with the *ANZECC 2000 Guidelines* default trigger ranges (with some exceptions in each of the differently sourced sets of data).
- Generally low TSS but with occasional significantly higher values reflecting the episodic nature of sediment transport.

6.4 ANZECC Water Quality Criteria

For the purposes of assessing the potential impact of mine operations on water quality, the *ANZECC 2000 Guidelines* water quality criteria are a relevant consideration. The data in Table 6.3 indicate that the average pH monitoring results in drainage lines unaffected by mining complies with the default trigger values for ecosystem protection in upland rivers as set out in the *ANZECC 2000 Guidelines*, with the exception of monitoring Site SD7 and the 1986 EIS Report data. The data also indicate that the surface water in the vicinity of the Project is suitable for livestock watering and irrigation.

It should be noted that the *ANZECC 2000 Guidelines* provide default 'trigger values' for different indicators of water quality parameters as either a 'threshold value' or as a 'range of desirable values'. Where an indicator is above a threshold value or outside the range of desirable values, 'there may be a risk that the environmental value will not be protected'. The purpose of these 'trigger values' is to provide a 'trigger' for action or further investigation. They are not prescribed limits or discharge standards.

The *ANZECC 2000 Guidelines* also state that:

> *"Trigger values are conservative assessment levels, not 'pass/fail' compliance criteria. Local conditions vary naturally between waterways and it may be necessary to tailor trigger values to local conditions or 'local guidelines'."*

Furthermore, the *ANZECC 2000 Guidelines* state that two years of monthly sampling is regarded as sufficient to provide an indication of the local ecosystem variability and to provide a basis for derivation of 'trigger values' appropriate to conditions in a particular creek system. For physical and chemical stressors for slightly or moderately disturbed ecosystems, such as that surrounding the Project area, the *ANZECC 2000 Guidelines* recommend the use of either the 80th percentile upper limit or the 20th and 80th percentile range of the data obtained from an appropriate reference system as the basis for 'trigger values' appropriate to local receiving waters.

Trigger values for receiving watercourses will be prepared as part of the Water Management Plan for the Project. The development of the trigger values will consider the *ANZECC 2000 Guidelines*. The Water Management Plan will identify the requirements for any actions to be taken should parameter readings outside the adopted trigger ranges occur persistently in a particular location or show a consistent trend. These actions may include investigations to ascertain whether the cause of the exceedance is related to mining activities and, if so, what mitigation actions may need to be implemented.

7 Mine Staging and Water Management

This section describes the operational water management system throughout the life of the Project. The water management system has been developed to comply with accepted principles for mine site water management, and to satisfy the Project's specific objectives and design criteria, as summarised in Section 7.1.

7.1 Objectives and Design Criteria

The water management system has been developed to provide a solution which satisfies the Project's objectives and design criteria. The objectives and design criteria of the Project water management system are to:

- protect the integrity of local and regional water resources;
- protect the integrity of local and regional aquatic environments;
- separate runoff from undisturbed, rehabilitated and mining affected areas;
- design and manage the system to operate reliably throughout the life of the mine in all seasonal conditions, including both extended wet and dry periods;
- provide a sufficient source of water for use in mining operations, including during periods of extended dry weather;
- provide sufficient storage capacity in the system to store, treat and discharge runoff as required, including during periods of extended wet weather;
- develop facilities for the long-term functioning of the water management system as soon as practicable and to minimise the number of facilities that would be removed by mining activities during the Project life;
- ensure adequate supply of water for dust suppression and provide distributed sources for filling of water-carts;
- avoid the requirement for water to be pumped wherever possible;
- minimise the volume of water to be obtained from external water sources; and
- minimise the number of licensed discharge points.

To effectively develop a water management system that addresses the above objectives and design criteria, runoff has been classified into four distinct categories:

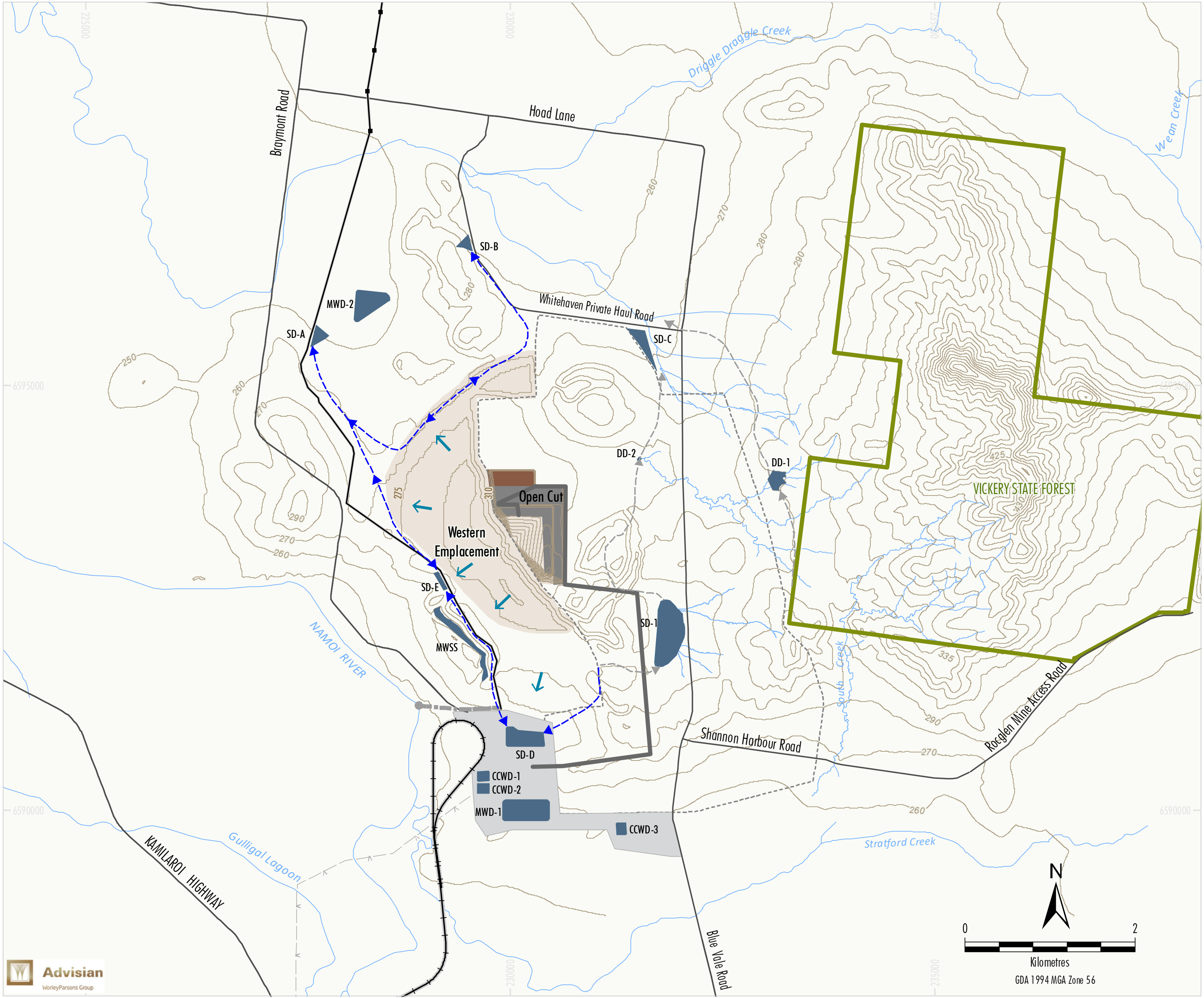
- ***Undisturbed area runoff*** – runoff from catchments that have not been disturbed by mining activities. Undisturbed area runoff may be diverted around mining activities to downstream receiving waters.
- ***Rehabilitated area runoff*** – runoff from rehabilitated mine areas that have established stable vegetation cover. This runoff is expected to have similar water quality characteristics to undisturbed area runoff. The water management system has been designed to allow runoff from these areas to be discharged without control.
- ***Disturbed area runoff*** – runoff from active waste rock emplacement areas and areas under active rehabilitation. The water management system has been designed to capture this runoff and to:
  - transfer it to the mine water management system for reuse in mine operations; or
  - discharge it off-site after retention for sufficient time to allow settlement of sediment to achieve the required water quality (TSS typically 50 mg/L).

- ***Mine Water*** – water collected in sumps in the open cut as a result of runoff from the open cut itself or active waste rock emplacement areas reporting to the open cut and runoff from the mine infrastructure area. As this water is likely to contain coal particles, the water management system is designed to contain and re-use this water on site.

7.2 Overview of Conceptual Project Water Management System

The Project water management system would be progressively developed over the life of the mine, as detailed in Section 7.2.1. A conceptual water management system has been prepared for the Project and comprises the construction and operation of interconnected sediment dams and water storage dams and other management structures as shown conceptually on Figure 7.1 to Figure 7.4, and schematically on Figure 8.1, including:

- **Sediment Dams (SD)** – a network of sediment dams (designated SD-A to SD-F) would be progressively constructed to manage runoff from the waste rock emplacement areas, and any undisturbed areas that naturally drain to the site of each dam. Runoff collected in these dams would either be transferred to the mine water dams or, if the mine water dams were at capacity, discharged in a controlled manner once the water quality meets EPL discharge quality criteria (Section 7.4).
- **Mine Water Dams (MWD)** – two mine water dams (MWD-1 and MWD-2) would be constructed. MWD-1 would accept water pumped from the open cut, existing Blue Vale void, MWD-2, the CCWDs and water transferred from the sediment dams SD-D and SD-E. MWD-2 would accept water pumped from the open cut and transferred from sediment dams SD-A, SD-B and SD-C. Water in the mine water dams would be used as required for mine operations, including for dust suppression and the Project CHPP. No water held in the MWDs would to be transferred to the sediment dams or discharged to the receiving environment.
- **Coal Contact Water Dams (CCWD)** – constructed to collect runoff from the mine and secondary infrastructure areas. All runoff collected in these dams would be transferred to MWD-1. No water held in the CCWDs would be transferred to the sediment dams or discharged to the receiving environment. The conceptual design includes CCWD-1, CCWD-2 and CCWD-3.
- **Existing Storage Dams and voids** – would be utilised in the early operation of the mine (Years 0 - 3) as a source of water for mine operations and for water management prior to the construction and commissioning of sediment dams SD-A and SD-B. The conceptual design includes the existing storage dam SD-1, Shannon Hill, Greenwood, Red Hill and Canyon voids (refer Table 3.1).
- **Diversion Dams (DD)** – would be constructed to divert runoff from undisturbed catchments and prevent it entering the open cut. The primary purpose of these dams is to raise the water level sufficiently to allow diversion across the landscape to a point where the water can drain into an existing stable drainage system. Water for mine operations may be extracted from these dams for water supply in the early Project life. The conceptual design includes diversion dams DD-1 and DD-2.
- **Blue Vale Void** – the existing Blue Vale void will be used as a water supply dam in the early stages of the Project life (Years 0-3). Once the MWDs are established, the Blue Vale void will be used as a mine water surge storage (MWSS) to provide additional capacity for storage of water pumped from the open cut, in the event that the mine water dams are near capacity due to extended wet weather.



LEGEND

- State Forest
- Existing 66kV Powerline
- Indicative Up-catchment Diversion
- Indicative Namoi River Pump Station and Pipeline
- Indicative Active Mining
- Indicative Active Waste Rock Emplacement
- Indicative Soil Stripped
- Indicative Infrastructure Area
- Indicative Extent of Water Storage
- Indicative Mine Access Road
- Indicative Main ROM Coal Haul Road
- Indicative Rail Spur Alignment
- Indicative Location of Groundwater Bores and Pipeline
- Indicative Maximum Extent of Open Cut
- Indicative Drain
- Indicative Runoff Direction

Source: Department of Land and Property Information (2014); Department of Industry (2015)

WHITEHAVEN COAL

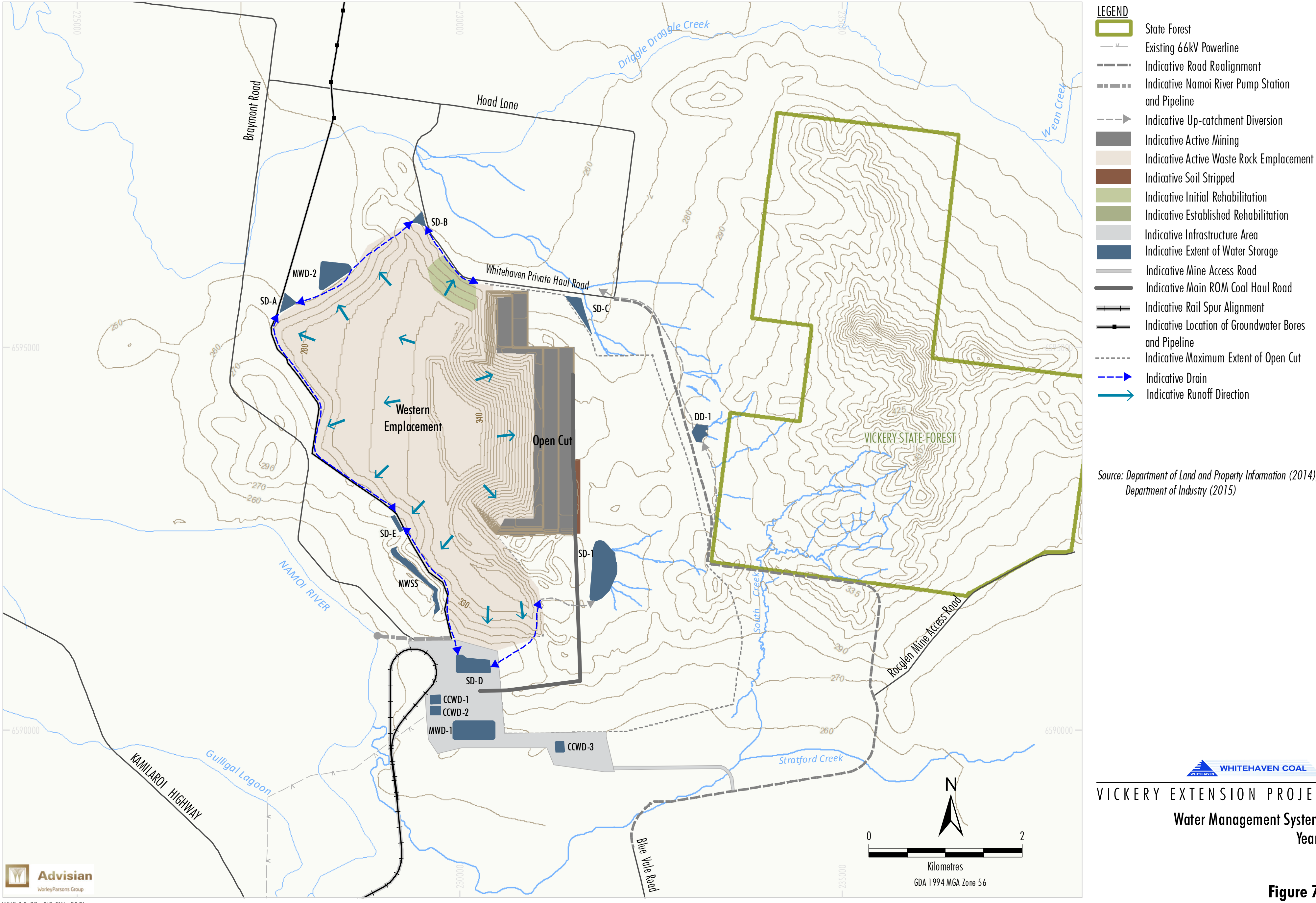
VICKERY EXTENSION PROJECT

Water Management System - Year 3

Figure 7.1

Advisian WorleyParsons Group

WHC-15-33_EIS SW_204I



Source: Department of Land and Property Information (2014); Department of Industry (2015)

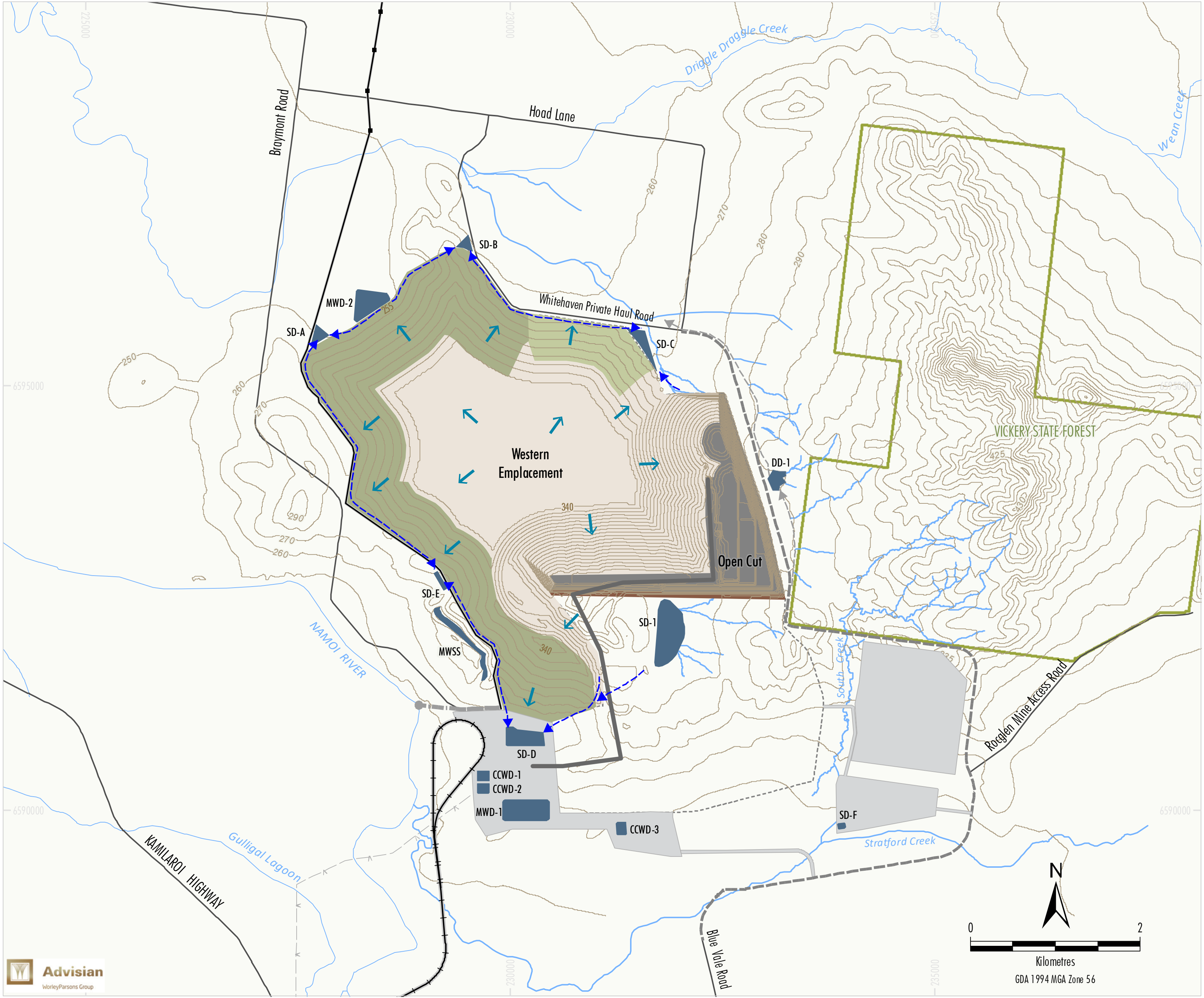
WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Water Management System - Year 7

Figure 7.2

WHC-15-33_EIS SW_205I



LEGEND

- State Forest
- Existing 66kV Powerline
- Indicative Road Realignment
- Indicative Namoi River Pump Station and Pipeline
- Indicative Up-catchment Diversion
- Indicative Active Mining
- Indicative Active Waste Rock Emplacement
- Indicative Soil Stripped
- Indicative Initial Rehabilitation
- Indicative Established Rehabilitation
- Indicative Infrastructure Area
- Indicative Extent of Water Storage
- Indicative Mine Access Road
- Indicative Main ROM Coal Haul Road
- Indicative Rail Spur Alignment
- Indicative Location of Groundwater Bores and Pipeline
- Indicative Maximum Extent of Open Cut
- Indicative Drain
- Indicative Runoff Direction

Source: Department of Land and Property Information (2014); Department of Industry (2015)

0 2 Kilometres
GDA 1994 MGA Zone 56

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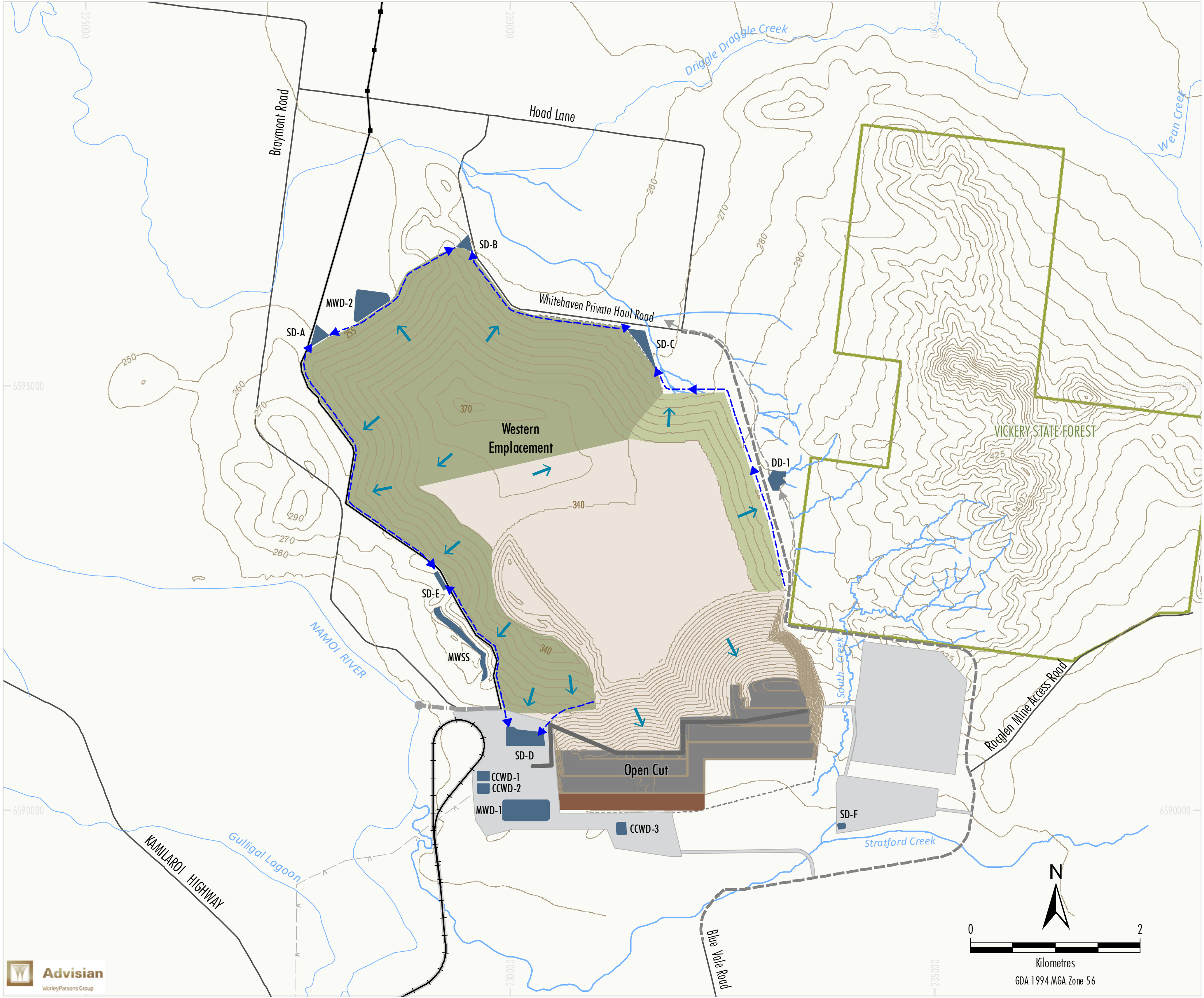
WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Water Management System - Year 13

Figure 7.3

WHC-15-33_EIS SW_206I



LEGEND
- State Forest
- Existing 66kV Powerline
- Indicative Road Realignment
- Indicative Namoi River Pump Station and Pipeline
- Indicative Up-catchment Diversion
- Indicative Active Mining
- Indicative Active Waste Rock Emplacement
- Indicative Soil Stripped
- Indicative Initial Rehabilitation
- Indicative Established Rehabilitation
- Indicative Infrastructure Area
- Indicative Extent of Water Storage
- Indicative Mine Access Road
- Indicative Main ROM Coal Haul Road
- Indicative Rail Spur Alignment
- Indicative Location of Groundwater Bores and Pipeline
- Indicative Maximum Extent of Open Cut
- Indicative Drain
- Indicative Runoff Direction

Source: Department of Land and Property Information (2014); Department of Industry (2015)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Water Management System - Year 21

Figure 7.4

Advisian WorleyParsons Group

WHC-15-33_EIS SW_207I

- **Namoi River Pump Station and Groundwater Borefield** – a surface water pump on the bank of the Namoi River and a groundwater borefield would provide raw water from licensed sources. In times of shortage of mine water, these sources would be used to provide additional supply.
- **Supporting Structures** - drains and diversions, including swale drains and possibly rock chutes, would be progressively constructed to direct waste rock emplacement area runoff into sediment dams and to divert undisturbed runoff away from active mining areas.
- **Mine Infrastructure Area Services** – potable supply would be provided by tanker truck. Water tanks would be constructed within the mine infrastructure area to store potable water and raw water. Effluent would be initially removed from site by tanker and later treated by an on-site package treatment plant and disposed of by means of an irrigation system designed and operated in accordance with the *Environmental Guidelines: Use of Effluent by Irrigation* (DEC, 2004).

The conceptual water management system design will be refined as part of detailed mine design, with the final design to be described in a Water Management Plan for the Project.

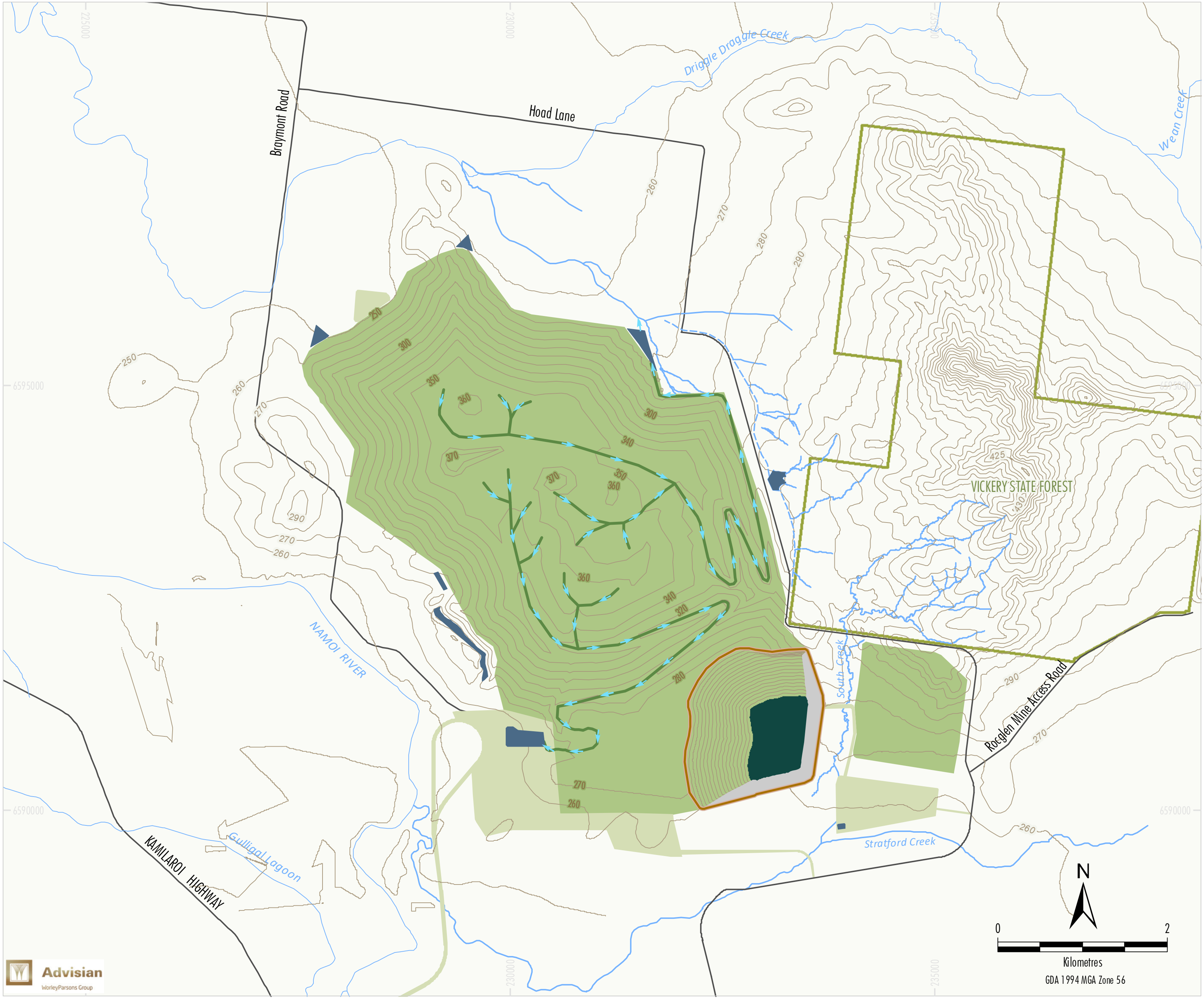
7.2.1 Progressive Development of the Mine and Water Management System

The progressive development of the water management system, as depicted conceptually in Figure 7.1 to Figure 7.4, accounts for the ongoing development of the open cut and mine areas, as well as the continuing prompt rehabilitation of sections of waste rock emplacement areas once the final level and landform have been achieved. The progressive development of the mine as depicted in Figure 7.1 to Figure 7.4 provides the basis for the final landform and associated drainage systems depicted in Figure 7.5. Water management structures, such as sediment dams, storage dams and drains, as well as indicative drainage pathways, are detailed on each Figure. Figure 7.1 summarises the expected life, catchment area and indicative storage volume for the proposed water storage structures described in Figure 7.1 to Figure 7.4 and in the following sections. The conceptual progressive development of the water management system would be refined throughout the life of the Project and documented in revisions of the Water Management Plan.

7.2.1.1 Project Year 3

The mine infrastructure area, the associated CCWDs (CCWD-1, CCWD-2 and CCWD-3) and the mine water dam (MWD-1) adjacent to the rail loop would be constructed at the commencement of the Project. By Year 3 (Figure 7.1), the open cut would be operating and waste rock emplacement would occur at the Western Emplacement.

When mining has progressed sufficiently, waste rock would be placed within the footprint of the open-cut void as well as progressively raising the level of the Western Emplacement. A series of graded drainage swales and contour banks would be progressively constructed around the emplacement to direct and capture runoff. Rock lined chutes may be required in some locations to drain steeper batters. Runoff from active emplacement areas would be directed back towards the open cut where practicable. Five sediment dams (SD-A to SD-E) would be constructed to capture the remaining disturbed area runoff from the Western Emplacement. A second mine water dam (MWD-2) would be constructed to the north of the Project. Pumps and pipelines would be constructed to allow water transfers from sediment dams and CCWDs to the mine water dams, and between the mine water dams.



LEGEND

- State Forest
- Indicative Up-catchment Diversion
- Indicative Sediment Dams
- Indicative Constructed Channels
- Indicative Pasture Area
- Indicative Woodland/Forest Area
- Indicative Final Void
- Indicative Final Void Highwall
- Final Void Perimeter Bund

Source: Department of Land and Property Information (2014); Department of Industry (2015)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Project General Arrangement - Final Landform

Figure 7.5

WHC-15-33_EIS SW_213H

Transfer of water may also be conducted by tankers. Water in the existing storage dam (SD-1), located near Hoad Lane (Figure 7.1) would be used for mine operations until it is subsumed by the open cut in Year 15.

At the time that the Blue Vale Road realignment is constructed to run along the eastern side of the mine footprint, the permanent diversion dam DD-1 would be constructed to the east of the Blue Vale Road realignment. Contour banks would be constructed to direct runoff into the dam and allow overflow to drain in a northerly direction into a minor tributary of Driggle Draggle Creek. A temporary diversion dam (DD-2) would be constructed on the North-West Drainage Line to direct natural runoff away from the open cut for the first few years until around Year 7. A drainage channel would be constructed to divert water to the north-east through a shallow ridge and into the North Drainage Line.

The existing Blue Vale void will be used as a water supply dam during Years 0-3. Once the MWDs are established, the Blue Vale void will be used as a mine water surge storage (MWSS) to provide additional capacity for storage of water pumped from the open cut, in the event that the mine water dams are near capacity due to extended wet weather.

7.2.1.2 Project Year 7

As shown in Figure 7.2, by Year 7 the open cut would have progressed as far as the northern boundary of the extraction area and ramped up to full production of ROM coal. Emplacement of waste rock would continue to raise the level of the Western Emplacement. Initial rehabilitation would commence in the northern section of the Western Emplacement where no more disturbance would occur for the remainder of the Project. DD-2 will be decommissioned at around Year 7.

7.2.1.3 Project Year 13

As shown in Figure 7.3, by Year 13 the Western Emplacement would be completed to its western extent and include areas of established rehabilitation along the western batters. Waste rock emplacement would continue in the north-east corner within the footprint of the open cut void. Mining operations would have reached the eastern extent of the open cut and would begin to progress to the south. SD-F would be constructed by Year 13 to enable collection of runoff from the secondary infrastructure area, which would also be constructed prior to Year 13.

7.2.1.4 Project Year 21

SD-1 will be subsumed by the open cut at around Year 15. As shown Figure 7.4, by Year 21 the Western Emplacement would continue to be developed into the final landform with established rehabilitation on the north-western extent. The open cut would reach the southern boundary of the open cut area By Year 21.

7.2.1.5 Final Landform

The final landform, shown in Figure 7.5, would involve rehabilitation of all the waste rock emplacement areas together with completion of the drainage systems shown on Figure 7.5.
A remnant void with a surface area of 258 ha, a contributing rehabilitated catchment of 200 ha and a highwall catchment area of 50 ha (refer Section 8.10 for further details) would remain in the south-east corner of the extraction area. Bunding would be constructed around the rim of the void to prevent inflow from the adjoining rehabilitated land and from flooding from South Creek (see Section 7.12).

The CCWDS and MWDs would be decommissioned and backfilled as part of the final landform rehabilitation. The sediment dams would also be decommissioned as part of the final landform rehabilitation once the water quality of the runoff from the emplacements is considered to be acceptable and the rehabilitation has been adequately established. The sediment dams would either be backfilled and rehabilitated or else left in place and managed as farm dams for stock watering. The decision to retain the sediment dams would be determined in consultation with the future landowner at the closure of the mine.

7.3 System Inflows

The conceptual water management system has been developed to account for all system inflows, namely, rainfall runoff, stream flow, incident rainfall and groundwater infiltration. The water balance analysis described in Section 8 quantifies these inflows.

The open cut would collect rainfall runoff, incident rainfall, groundwater and infiltration through waste rock emplacements. Water flowing into the open cut would accumulate in sumps and would be pumped to either of the two mine water dams (MWD-1 and MWD-2) or accessed directly by water carts.

Groundwater inflows to the open cut have been modelled (see *Groundwater Assessment* [HydroSimulations, 2018], Appendix A to the EIS) and are taken into account in the water balance analysis described in Section 8.

The mine water management system has been designed to minimise reliance on external water sources, however, the mine will require additional supply from licensed surface water or groundwater sources to supplement storages for dust suppression and/or coal processing in extended dry periods.

7.4 Collection and Storage

In accordance with the water management system's objectives and design criteria, the conceptual system has been designed to provide sufficient capacity to appropriately store, treat and discharge runoff as required, even in extended periods of above average rainfall. The mine plan involves a number of water storage structures for different purposes that are detailed in Table 7.1 and shown schematically on Figure 8.1:

- Diversion dams that are intended to provide a structure from which water can be diverted away from the active mining area and the flow rate controlled by means of a restricted spillway. Water for mine operations may be extracted from these dams for water supply early in the mine life.
- Sediment dams (SD-A to SD-E) from which water can:
  - be used directly for dust suppression;
  - be transferred to the MWDs to restore capacity in the sediment dams within five days of a rainfall event;

  - be discharged off-site in a controlled manner (referred to as ‘controlled discharge’ in the results tables in Section 8) within five days of the end of a storm rainfall event in excess of the design rainfall (38.4 mm over five days in accordance with Landcom (2004) - refer Section 7.8 for further details) in order to restore capacity in the dams before the next rainfall event. This would only occur on the rare occasions when there is insufficient capacity in the MWDs to receive water from the sediment dams and would be undertaken in accordance with Project EPL water quality requirements (refer Section 10.5); and
  - wet weather discharges (referred to as ‘overflows’ in the results tables in Section 8) in the event of a storm rainfall in excess of the design rainfall (38.4 mm over five days) and after all possible transfers of water to the MWDs and water carts has occurred. Wet weather discharges would be managed in accordance with the requirements of the Project EPL.
- Sediment dam SD-F would collect runoff from a secondary infrastructure area located in the south-eastern corner of the Project site that may be used to store vehicles and spoil stockpiles and would not include any coal storage or processing operations. This area, including SD-F, would be constructed and become operational between Years 7 and 13. SD-F would be a stand-alone sediment dam that only collects runoff from this area. Depending on what is stored on the secondary infrastructure area, an oil and grease separator may be provided upstream of SD-F to treat runoff before it reaches the sediment dam. Water from SD-F would not be transferred to the MWDs. In order to maintain sufficient capacity for design rainfall events, SD-F would require periodic treatment (e.g. flocculation) and controlled discharge to receiving waters once water quality is within acceptable EPL limits (typically TSS of 50 mg/L). Overflows from SD-F would be managed in accordance with Project EPL requirements.
- Three CCWDs (CCWD-1, CCWD-2 and CCWD-3) located within the mine infrastructure area. Any water collected in these dams would be transferred to MWD-1 and would not be discharged off-site.
- A mine water dam (MWD-1) located within the mine infrastructure area adjacent to the Project rail loop from which water can be used:
  - for supply to the Project CHPP and the mine infrastructure area;
  - for dust suppression in the southern portion of the mine area;
  - to receive water transferred from the open cut and Blue Vale void;
  - to receive water transferred from the CCWDs and sediment dams SD-D and SD-E; and
  - to receive additional supply from any licenced extraction from the Namoi River.
- A mine storage dam (MWD-2) located near sediment dam SD-A which would:
  - be used for additional supply for dust suppression in the northern portion of the mine area;
  - receive water transferred from sediment dams SD-A, SD-B and SD-C;
  - receive water transferred from the open cut;
  - receive additional supply from licensed extraction from groundwater bores; and
  - provide top-up water to MWD-1 if required.

In the event that the main mine water storages are at or near capacity, any excess mine water would initially be retained in the open cut while runoff collected in the sediment dams would be managed. The mine is a multi-seam mine and therefore the mining schedule may be altered to accommodate temporary storage of water in the open cut while higher level coal seams are mined. Nevertheless, if storage of excess water in the open cut persists for any length of time, the existing Blue Vale void would be used to hold the excess water. Alternatively, excess water held within the water management system may be used to irrigate land catchments that report to the mine water management system. Evaporation cannons may also be used in these areas to reduce the volume of water in the system.

Table 7.1 summarises the expected life, catchment area and indicative storage volume for the proposed water storage structures.

Table 7.1: Proposed Water Storage Structures

Dam/Location	Designation	Approximate Years of Operation during the Project[1]	Approximate Catchment (ha)	Indicative Capacity (ML) [2]
Diversion Dams				
North-East Drainage Line	DD-1	Year 1 – 25	230	80
Middle Drainage Line	DD-2	Years 1 – 7	210	10
Existing Storage Dam				
West Drainage Line	SD-1	Years 1 – 15	205	20
Sediment Dams				
Western Emplacement	SD-A	Years 1 – 25	566	110
	SD-B	Years 1 – 25	642	125
	SD-C	Years 1 – 25	422	85
	SD-D	Years 1 – 25	667	130
	SD-E	Years 1 – 25	98	28
Secondary Infrastructure Area	SD-F	Years 13 – 25	165	32
Coal Contact Water Dams				
ROM Pad, CHPP and Train Load-out	CCWD-1	Years 1 - 25	50	55
Product Stockpile	CCWD-2	Years 1 - 25	34	30
Next to office area	CCWD-3	Years 1 - 25	40	40
Mine Water Dams				
Adjacent to Rail Loop	MWD-1	Years 1 - 25	n/a	520
Adjacent to SD-A	MWD-2	Years 1 – 25	n/a	520
Blue Vale Void water supply	MWSS	Years 0 – 3	29.6	1,000
Blue Vale Void surge storage		Years 3 -25		

Notes

1: The approximate lifetime for facilities are based on the staged mine plan layouts in Figure 7.1 to Figure 7.5.

2: Runoff storage capacity for sediment dams and CCWDs includes additional 20% provided for dust suppression supply.

7.5 Water Requirements

In accordance with the Project water management system's objectives and design criteria, the system has been designed to provide a reliable source of water for use in mining operations even in extended periods of below average rainfall. Although the water consumption requirements of the Project and the system water balance would fluctuate with climatic conditions and the stage of mine development, the water management system has been designed to be adaptable. Water may be obtained from licensed external sources if additional water is required for operational use.

7.5.1 Coal Handling and Preparation Plant

The process of washing coal leads to a small increase in the moisture content of the product coal and the coarse rejects component. In addition, after mechanical dewatering, the fine rejects component typically has a moisture content of about 35% by mass. Based on a review of published water usage from other existing mines and project proposals, 120 litres per tonne (L/t) of ROM processed has been adopted as the Project CHPP water requirement. The amount of ROM coal processed year to year varies depending on ROM coal quality and market conditions, with the average over the project life of 55%. The water balance model includes provision for the daily Project CHPP use based on the projected mine production set out in Table 7.2, assuming 55% of ROM coal is processed through the Project CHPP.

Table 7.2: Schedule of Coal Production and Haul Road Length

Project Year	Mine Year	ROM Coal (Mtpa)			Active Haul Road Length (km)
		Project	Other Whitehaven Mines[1]	Total	
1		-	N/A[2]		0.0
2	1	1.0	2.7	3.7	12.0
3	2	2.7	3.4	6.1	12.0
4	3	4.3	3	7.3	12.7
5	4	5.5	3	8.5	13.3
6	5	7.2	3	10.2	14.0
7	6	8.4	3	11.4	14.6
8	7	8.5	3	11.5	14.6
9	8	9.8	3	12.8	14.6
10	9	9.3	3	12.3	14.6
11	10	8.8	3	11.8	14.6
12	11	8.6	3	11.6	14.6
13	12	8.6	-	8.6	14.6
14	13	8.3	-	8.3	14.6
15	14	9.1	-	9.1	14.2
16	15	9.9	-	9.9	13.8
17	16	9.6	-	9.6	13.3
18	17	9.7	-	9.7	12.9
19	18	9.5	-	9.5	12.5
20	19	8.9	-	8.9	12.0
21	20	9.9	-	9.9	11.6

Project Year	Mine Year	ROM Coal (Mtpa)			Active Haul Road Length (km)
		Project	Other Whitehaven Mines[1]	Total	
22	21	7.8	-	7.8	11.2
23	22	6.5	-	6.5	11.2
24	23	4.0	-	4.0	11.2
25	24	2.1	-	2.1	11.2
26	25	1.1	-	1.1	11.2
Total		**179**	**33.1**	**212.2**	

1 ROM coal rates used here are for impact assessment purposes only, reflecting Whitehaven's anticipated production schedule at the time of preparation of the EIS. Actual production rates may vary, within approved limits.

2 Prior to the commissioning of the Project rail spur and CHPP, ROM coal from other Whitehaven mines would be transported to the Whitehaven CHPP in accordance with their respective consents.

Note: Discrepancies in totals due to rounding.

7.5.2 Air Quality Management

The water requirements for dust suppression on haul roads and hardstand areas are closely related to the daily weather conditions (e.g. hot windy days can increase the potential for dust generation). Thompson and Visser (2002) studied the water requirements for dust suppression on mine haul roads and demonstrated a robust relationship between water requirements for dust suppression and the potential evaporation on the day, while taking into account any incident rainfall. An algorithm based on the work of Thompson and Visser (2002) has been benchmarked against estimated mine water use at two mines in the Hunter Valley and has been adopted for the site water balance model. The algorithm is:

$$\text{Daily volume of water (ML)} = (Eo \times (1 + F) - P) / 100 \times A$$

Where:

- A = is the area of active haul road (ha);
- P = daily rainfall (mm);
- Eo = daily open water evaporation (mm); and
- F = a factor to account for the effect of 'wheel splash' on water loss.

The modelling also takes account of the water application requirements for greater than 80% dust control efficiency, as adopted for the dust emissions analysis for the Project. An analysis of dust control for the Tarrawonga Coal Mine (Pacific Environment Ltd, 2014), which is also operated by Whitehaven, demonstrated an average dust control efficiency of about 90% (compared to the EPA's requirement for 80% efficiency). Based on the water use data from the Tarrawonga Coal Mine (average of 4.7 mm/day), a value of 0.45 for the factor 'F' with a maximum daily application of 10 mm was adopted for water balance modelling.

Active haul road lengths, derived from year-by-year mine plans, are set out in Table 7.2. Haul roads would be 40 m wide, of which 30 m is assumed to require regular watering for dust suppression purposes.

7.5.3 ROM Pad and Stockpile Dust Suppression

Water would be used as required to control dust on the ROM pad (approximately 13 ha) and the product coal stockpile (approximately 6 ha). For water balance modelling purposes, it has been assumed that water for dust suppression would be at the same rate as that for haul road dust suppression. In the case of haul roads, the water requirements derived from the work of Thompson and Visser (2002) take account of the effect of traffic movement. Clearly, such traffic movement would be absent from the stockpiles. However, the stockpiles would be more exposed to localised wind effects.

7.5.4 Mine Infrastructure Area and Facilities

In addition to the ROM pad and product coal stockpile, the mine infrastructure area contains three distinct zones:

- the mine operations area and workshops (approximately 9 ha) which is assumed to require water for dust suppression at the same rate as the haul roads;
- the train load-out facility is assumed to require 100 kilolitres per day on 250 days per year (25 ML/year) for dust suppression. The Project rail spur itself is assumed to not require any dust suppression; and
- water supply for the ablution facilities and amenities (100 L/person/day, which equates to approximately 16 ML/year) is assumed to be provided from a groundwater bore and subsequently treated before being irrigated to land.

7.5.5 External Water Sources

Whitehaven has a number of WALs for water from the Namoi River and from groundwater. As set out in Table 3.3, these WALs, which include water from sources with different reliability, total 2,147.5 shares.

For the purposes of water balance modelling, it has been assumed that access to water from these sources would only be undertaken on a 'campaign' basis in which 100 ML would be transferred into the mine water management system over a 10 day period when total water in the mine water system fell below a specified level (see Section 8.2.7 for further details).

7.6 Waste Rock Emplacement Drainage Management

The concept drainage design for the waste rock emplacement area has been developed in accordance with *Managing Urban Stormwater, Soils and Construction, Volume 2E Mines and Quarries* (DECC, 2008) and in consideration of the *Draft Guidelines for the Design of Stable Drainage Lines on Rehabilitated Minesites in the Hunter Coalfield* (DPI, 2016). The concept drainage design has been developed for the life of the mine, as shown in Figure 7.1 to Figure 7.4.

The concept drainage design for the waste rock emplacement areas involves the creation of a number of sub-catchments to be progressively developed over the life of the mine. Gently graded swales and contour banks would be constructed to drain runoff from the upper plateau and steeper batters. A typical worst-case drainage swale would have a gradient of 1 in 70, with a drop of 3 m over more than 2 km. Rock lined chutes may be required in some situations to drain steeper batter slopes. Emplacement area drainage systems and structures would be progressively constructed and rehabilitated to ensure appropriate drainage conditions at all times.

During the life of the mine, all runoff from active waste rock emplacement areas would report to either the open cut or sediment dams. As described in Section 7.4, captured runoff would be preferentially reused in mine operations, either direct from the sediment dams or by transfer to one of the mine water dams. In the event that there is insufficient capacity in the mine water dams to accept water transferred from the sediment dams, runoff collected in sediment dams would be allowed to discharge off-site once the suspended solids concentration (and other relevant parameters) has reduced to a level suitable for controlled discharge in accordance with an EPL.

The Western Emplacement would be progressively rehabilitated during the life of the mine, as depicted in Figure 7.1 to Figure 7.4.

7.7 Management of Overburden, Interburden and Coal Rejects

The *Geochemistry Assessment* (GEM, 2018) (Appendix M to the EIS) indicates that the majority of overburden and interburden has a low sulphur content and is expected to be NAF, with a low salinity risk. A small quantity of the strata contains increased sulphur concentrations which present a risk of being PAF. The identified PAF strata typically occur as non-continuous units of mixed (finely inter-bedded) layers immediately adjacent to some of the coal seams and most of these materials are expected to only have a low capacity to generate acid.

Although the majority of the overburden and interburden is expected to be non or slightly sodic a very small proportion of this material is expected to be moderately to highly sodic.

The *Geochemistry Assessment* (GEM, 2018) recommends that concentrated zones PAF material is not placed within the final lift of the waste rock emplacements.

The *Geochemistry Assessment* also recommends that, in order to ensure long-term stability and erosion control for the waste rock emplacement, any areas of the final waste rock emplacement face that exhibit some erosion would be treated with gypsum (GEM, 2018).

No reject material would be placed within 30 m of the edge of the Western Emplacement and reject material would be covered with at least 5 m of inert material on the outer surfaces of the waste rock emplacement. Dewatered reject material would be co-disposed with waste rock in locations such that any runoff or infiltration would report to the mine water management system.

7.8 Sediment Dam Design and Operation

The sizing and management of the sediment dams have been designed in accordance with the *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004) criteria for 'fine' or 'dispersive' sediments.

The indicative total sediment dam volumes (refer Table 7.1) have been calculated based on the following formulas and assumptions (parentheses indicate references to Landcom (2004)):

Dam Volume = Settling Zone + Sediment Storage Zone (p 6-22 (i))

Where:

- Sediment Storage Zone = 50% of Settling Zone (Soil Types D and F) (Table 6.1)
- Settling Zone = $10 \times C_v \times R \times A$ (p 6-22 (i)(i))

▪ Cv (volumetric runoff coefficient, defined as that portion of rainfall that runs off as stormwater over the 5-day period)	= 0.51 (overburden) = 0.85 (MIA and ROM)	(Appendix F)
▪ R (90th percentile 5-day rainfall depth for Gunnedah)	= 38.4 mm	(Table 6.3a)
▪ A (Catchment Area)	(ha)	(p 6-22 (i)(i))

In addition, all dams receiving runoff from the waste rock emplacement areas have been designed with an additional 20% capacity to the Landcom (2004) design capacity for retention of water to provide supply for water cart filling (for use in dust suppression). These sediment dams would be operated in the following manner, in accordance with the requirements of *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004):

- Within five days of the end of a rainfall event, all practical measures would be implemented to drain water from the dam in order to provide the required design freeboard for a subsequent event. Water would be transferred preferentially to the mine water dams.
- As described in Section 7.4, on the rare occasions that there is insufficient capacity in the MWDs to receive water from the sediment dams, runoff in the sediment dams would be discharged off-site in a controlled manner within five days of the end of the rainfall event. Controlled discharge would only occur once the water was of appropriate sediment concentration (TSS typically 50 mg/L) in accordance with the EPL requirements. Note that this does not apply to runoff collected in the CCWDs that receive water that has been in contact with coal. Water from these dams would only be transferred to the mine water dams and not discharged off site.
- The transfer of water from the sediment dams to the mine water dams or discharge from the site would only need to take water down to the level necessary to provide the required design freeboard for a subsequent rainfall event. This level would be designated by a permanent marker.
- A permanent marker would be placed in each dam designating the maximum sediment level. On occasions when a sediment dam is empty, the sediment level would be checked and, if necessary, sediment removed to restore the required sediment storage capacity. Sediment removed from the dams would be placed in waste rock emplacement areas.
- As described in Section 7.4, wet weather discharges from sediment dams would only occur in the event of rainfall in excess of the design rainfall (38.4 mm over five days) and after all possible transfers of water to the MWDs and water carts. Wet weather discharges would be managed in accordance with the EPL requirements.

7.9 Coal Contact Water Dam Design and Operation

The EPA's preferred criteria for the design capacity of CCWDs is for the dams to be based on a 'design storm' of 72 hour duration and a 1% annual exceedance probability (AEP). However, these criteria do not specify an operating rule and make no allowance for the transfer of water to a mine water dam. In line with current best practice for the design of mine water management systems, the water balance analysis (Section 8) involves simulation of the water balance on a daily basis for the entire life of the Project.

An initial estimate of the required capacity for the CCWDs was made using the same criteria as those set out in Section 7.8. This capacity and the associated transfer rate to the mine water dam were then assessed in the model for the full range of climate scenarios. The final CCWD capacities and associated transfer rates were adopted to ensure that the annual probability of overflow of coal contact water for the life of the mine was 1% or less for all climate sequences represented by the historic record.

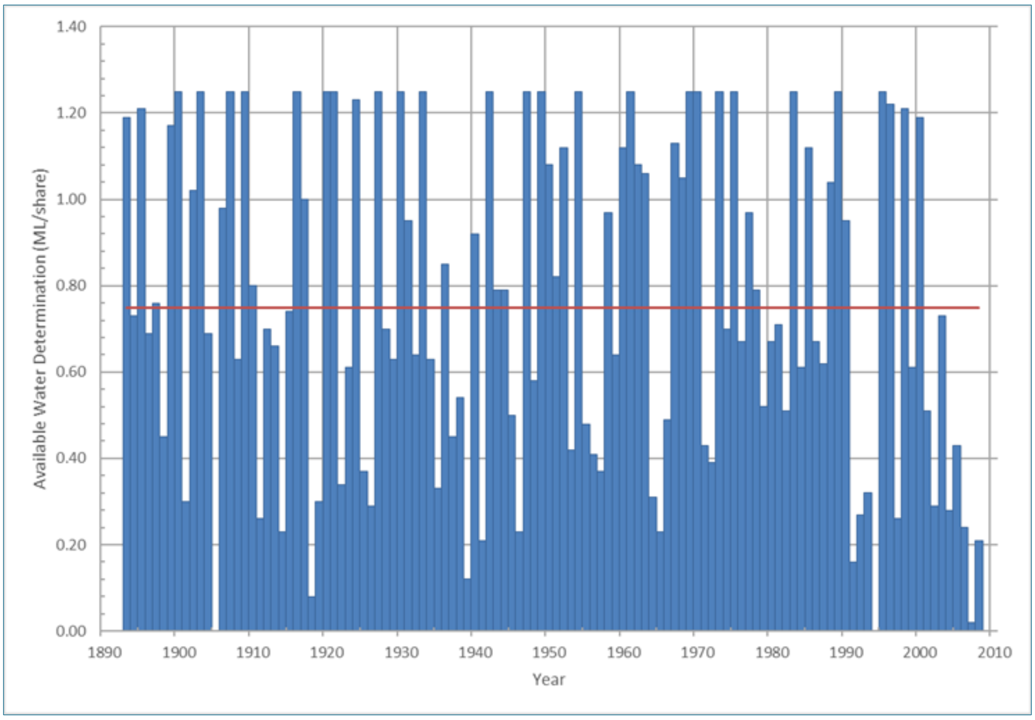
7.10 Additional Supply

The Project would utilise runoff collected in the sediment dams and the open cut as the primary source of water for operational purposes. The mine would also require additional supply from licensed external sources, the volume of which would vary from year to year depending on the stage of the Project, the water availability from internal sources and climatic conditions.

As shown in Table 3.3, the portfolio of WALs held by Whitehaven includes (in order of decreasing reliability):

- 396 unit shares from groundwater sources (equivalent to 396 ML/year);
- 50 unit shares of river high security water (equivalent to 50 ML/year);
- 1,638 unit shares of river general security water (equivalent to 1,638 ML/year when the available water determination (AWD) is 100%, or 1 ML per unit share); and
- 63.5 unit shares of river supplementary water (equivalent to 63.5 ML/year).

The long-term average cumulative AWD for General Security category water has been determined at 76% under the current Water Sharing Plan rules (Ribbons, 2009). Annual AWD for the Lower Namoi commencing in 1893 can be derived from *Water availability in NSW Murray-Darling Basin regulated rivers, Appendix of annual data* (DPI, 2013) and is shown in Figure 7.6 and Figure 7.7.



Source: DPI, 2013

Figure 7.6: Modelled Annual General Security Available Water Determination

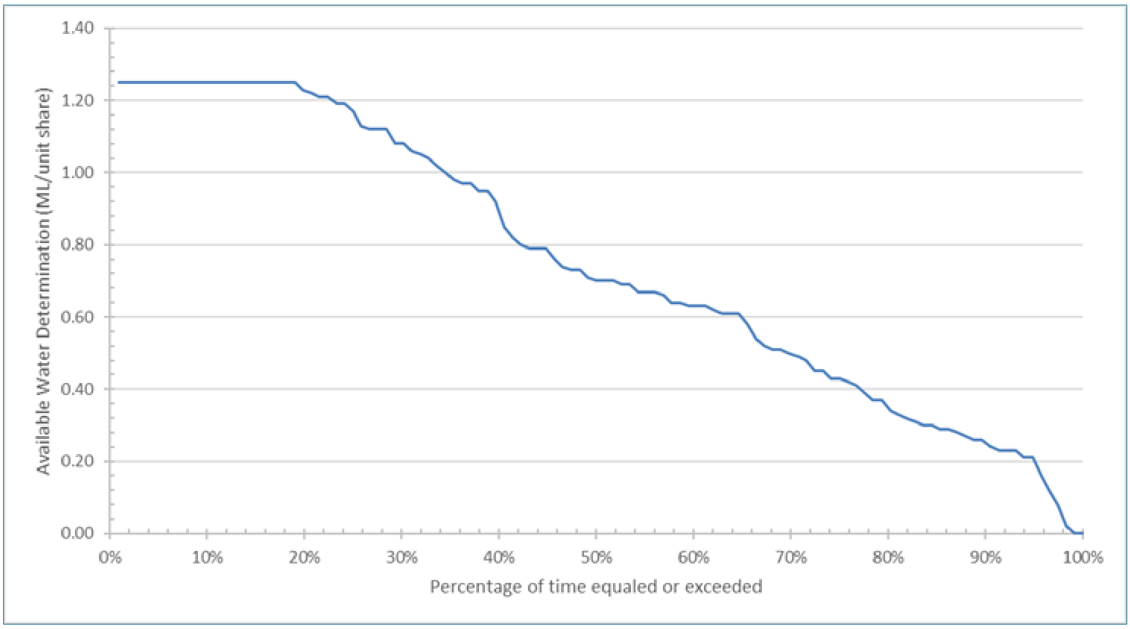


Figure 7.7: Frequency of Annual General Security Available Water Determination

For purposes of the water balance modelling, distribution of AWD announcements during the water year has been determined through analysis of announcement since the start of the Water Sharing Plan. Announcement information can be obtained through the NSW Water Register (DPI-Water, 2018), with the analysed monthly distribution of AWD announcements shown in Figure 7.8.

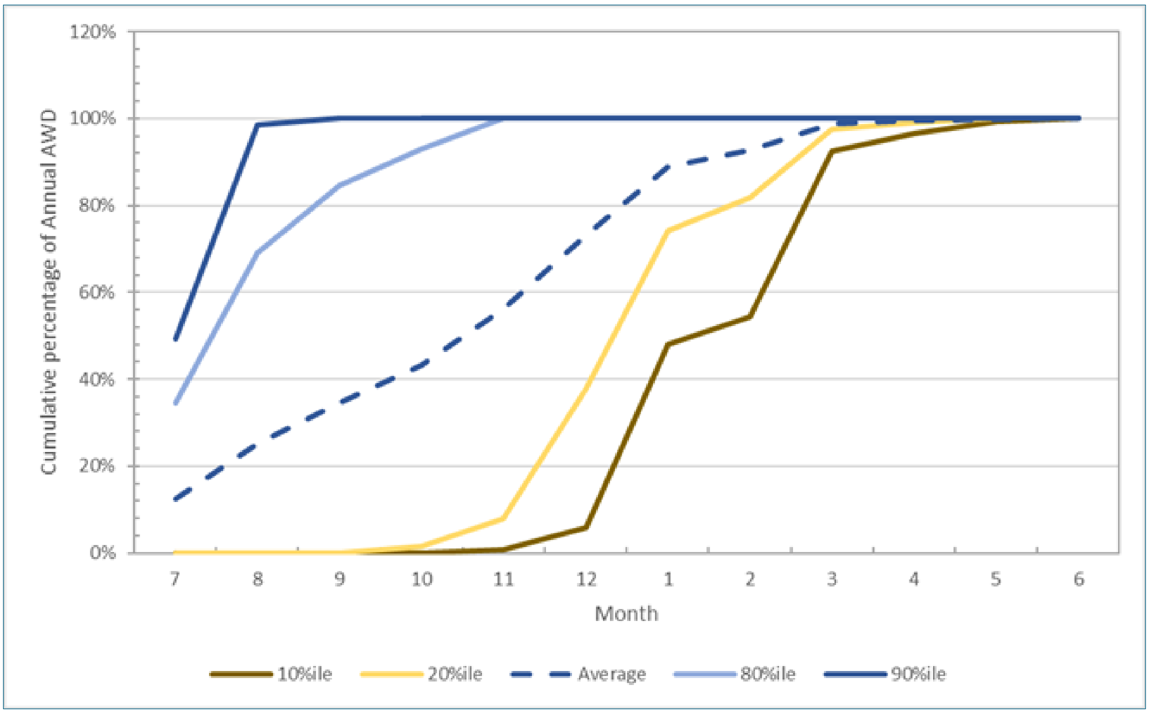


Figure 7.8: Monthly Timing of Available Water Determination Announcements during the Water Year

7.11 Water Conveyance Structures

In accordance with the requirements set out in Table 6.1 of *Managing Urban Stormwater: Soils & Construction – Volume 2E: Mines and Quarries* (DECC, 2008), all hydraulic conveyance structures such as contour banks, drainage swales and spillways will be designed to remain stable in the event of a 1% AEP rainfall event.

7.12 Flooding

A *Flood Assessment* has been prepared by WRM for the Project and is included as Appendix C to the EIS (WRM, 2018). The *Flood Assessment* considers the potential impacts of flooding from the Namoi River, Deadmans Gully, Stratford Creek, South Creek and Driggle Draggle Creek to the Project, and associated mitigation requirements (e.g. levees). The Flood Assessment also considers potential impacts of flood infrastructure to flooding characteristics.

The existing conditions flooding characteristics in the vicinity of the proposed mine area and the Project rail spur are summarised as follows (WRM, 2018):

- The disturbance areas associated with the Project (with the exception of the Project rail spur) are not located on land flooded by the Namoi River for the design 3 x 1% AEP extreme event. Therefore, flood protection levees are not required to prevent Namoi River inundation.
- The secondary infrastructure area (Figure 7.3) is affected by flooding by Stratford Creek, a minor tributary of the Namoi River. Peak 1% AEP flood depths from Stratford Creek along the southern boundary of the secondary infrastructure area are up to 1.5 m.
- The secondary infrastructure area and the south-western corner of the open cut are affected by flooding from South Creek, a minor tributary of Stratford Creek. South Creek flood depths across the infrastructure areas are shallow and generally less than 1.6 m.

Based on the above, levees are proposed to mitigate flooding along South Creek and Stratford Creek.

The Project rail spur alignment is located across the Namoi River floodplain, which would be inundated to various depths during flood events. The proposed waterway openings of the Project rail spur would be designed to satisfy the criteria/objectives of the draft FMP for the Upper Namoi Valley Floodplain. For the purposes of modelling impacts, it has been assumed by WRM (2018) that bridges will cross the Namoi River, Stratford Creek and Deadmans Gully with the superstructure located above the 1% AEP flood level as well as across the Kamilaroi Highway with appropriate road clearance.

7.13 Wastewater Treatment and Effluent Disposal

Wastewater from the ablution facilities and offices would be treated in a conventional aerated wastewater treatment system and effluent would be disposed of by irrigation onto a designated irrigation area in accordance with the requirements of *Use of Effluent by Irrigation* (DEC, 2004).

Prior to development of the wastewater treatment system, wastewater from the ablution facilities and offices would be collected on a regular basis by a licensed waste contractor.

8 Simulated Performance of the Water Management System

A water balance analysis has been undertaken to assess the performance of the conceptual operational water management system described in Section 7 in terms of:

- security of water supply for operational purposes; and
- frequency and volume of discharge from the sediment dams.

A separate water balance analysis has also been undertaken to assess the long-term water level and salinity in the final void following mine closure.

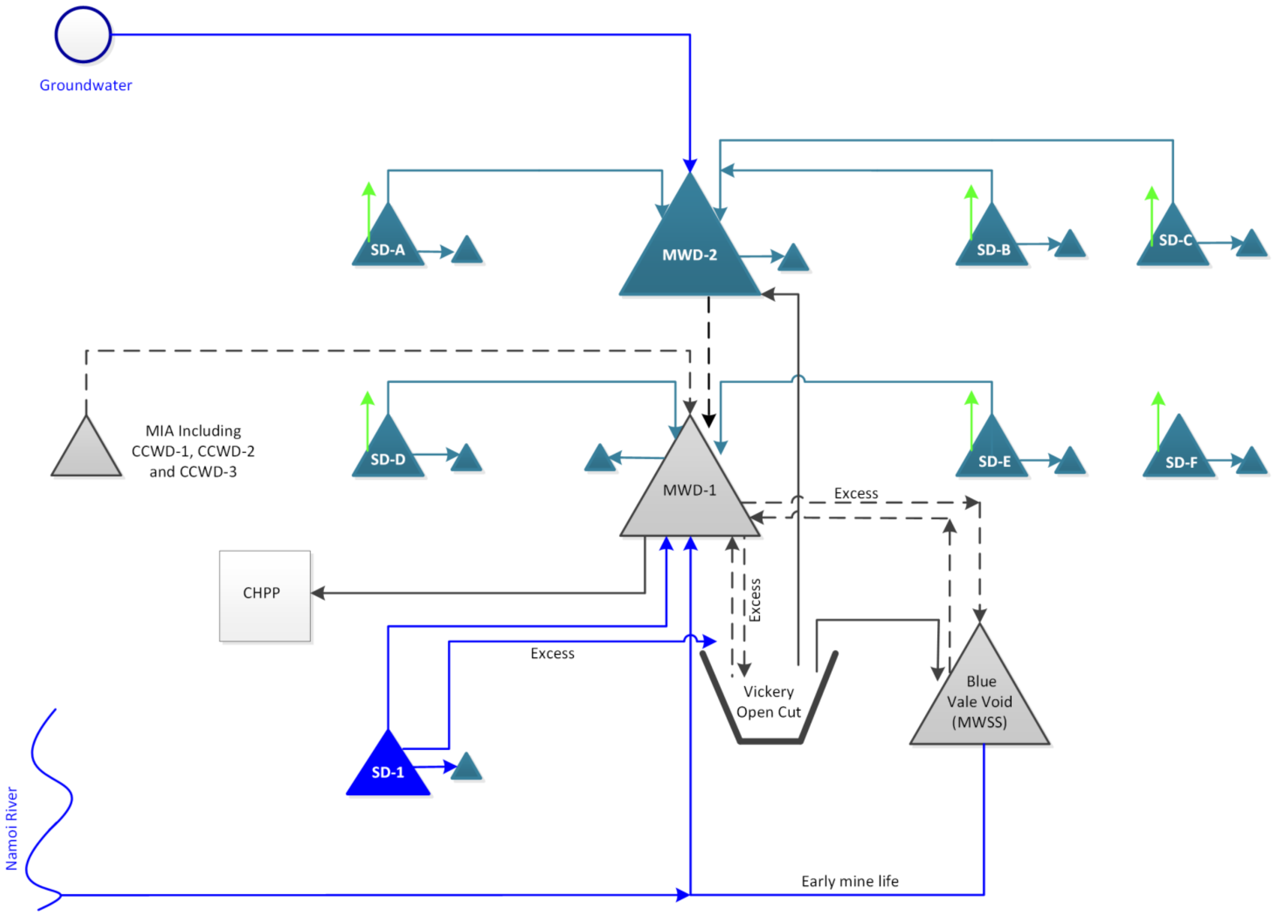
8.1 Methodology

The water management system would involve a number of water storage structures for different purposes which are described in Section 7.4 and shown schematically in Figure 8.1. Table 8.1 summarises the inflows and outflows from each of these dams as represented in the water balance model.

Table 8.1: Components of the Project Water Balance Model

Inflows and Transfers	Outflows and Losses
Catchment runoff reporting to sediment dams.	Water required for dust suppression on haul roads. Excess transferred to the mine water dams. Controlled discharge from sediment dams in accordance with relevant criteria.
Groundwater inflow and catchment runoff reporting to the open cut.	Water transferred to mine water dams when capacity is available. Water for CHPP operations. Additional supply for dust suppression.
Runoff from the mine infrastructure area reporting to CCWDs.	Water for dust suppression within the mine infrastructure area and on coal stockpiles. Excess transferred to the mine water dams.
Direct rainfall onto the surface of the mine water dam and sediment dams.	Evaporation and seepage losses from the mine water dams and sediment dams.
Raw water supply (when required) from licensed water sources.	Controlled discharge from sediment dams in accordance with relevant criteria.

The water balance model has been set up to permit an assessment of the risk of water shortfall or discharge at any stage of the mine life. This is achieved by modelling the progressive development of the mine over the 26 years of the mine life combined with the climate (rainfall and evaporation) data commencing at 1893 (year from which AWD data is available – refer Section 7.10) to 1991 (as the final year in the climate record is 2017 and therefore 1991 is the last year that 26 years of the mine life can commence to be modelled). This enabled the modelling of 98 climate scenarios.



Dirty Water (Sediment) Transfer

Coal Contact Water Transfer

Coal Contact Water from Storage

Fresh Water Transfer

Controlled Off-site Discharge or Overflow due to rainfall in excess of design storm

Dust Suppression drawn from mine infrastructure area dams and reserve storage in SDs

Notes

1: All dams are subject to direct rainfall and evaporation
2: Existing storage dam SD-1 will be used as a water source early in the mine life prior to the commissioning of the other sediment dams. Blue Vale Void will also be used as a water supply dam early in the mine life and subsequently (once the MWDs are established) as the MWSS.
3: If required, contingency actions including use of the MWSS and/or evaporation cannons and irrigation would be implemented to reduce surplus water.

Figure 8.1: Schematic Diagram - Mine Water Management System

8.2 Model Data

8.2.1 Climate Data

8.2.1.1 Historical Data

A daily water balance model has been developed for the Project. The water balance model utilises 124 years of the daily rainfall record from the BoM Boggabri (Retreat) weather station (Station 055044), which commenced recording in 1889. For purposes of water balance modelling, the following climate datasets have been used:

- daily patched rainfall data from Boggabri (Retreat): 1 July 1893 – 30 June 2017 (summarised in Table 4.2);
- daily patched pan evaporation data from Boggabri (Retreat): 1 July 1893 – 30 June 2017 (Table 4.5); and
- monthly areal potential evapotranspiration from the digital version of the *Climatic Atlas of Australia: Maps of Evapotranspiration* (Version 1.0, BoM, 2002).

The water balance model commences in 1893 as the long term AWD data is available from this time (Section 7.10).

As recommended by Boughton (2010), the monthly areal potential evapotranspiration data was used to account for evaporation and evapotranspiration losses from the contributing catchments in the rainfall:runoff component of the water balance model (see Section 8.2.5). For the purposes of accounting for evaporation from mine water dams and dust suppression water requirements (see Section 7.5.2), daily SILO data from Boggabri (Retreat) has been utilised, noting that prior to 1970 the long-term average monthly data has been used (refer Section 4.1.2).

Evaporation from all water surfaces is modelled using monthly 'pan factors' for Moree (from Table S6 in McMahon et al, 2013) to convert the pan evaporation data in Table 8.2 to open water evaporation. The average monthly factors for Moree Comparison (53048) and Moree Aero (53115) were adopted because both sites are classed as '*high quality Class-A evaporation pan*' and have an average of 14 months of data used for calculation of the pan factors. Data from the Gunnedah Resource Centre, which is also classified as having a '*high quality Class-A evaporation pan*', has only a limited number of months with adequate data for calculation while the evaporation pan at Tamworth Airport is not classified as '*high quality*'.

Table 8.2: Monthly Pan Evaporation Statistics (mm)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SILO patched data for Boggabri (Retreat)												
Average	250	204	187	130	85	58	64	92	130	182	214	253
Median	249	206	189	129	83	58	64	91	124	175	212	247
Pan Factor												
	0.800	0.803	0.791	0.795	0.822	0.870	0.901	0.915	0.878	0.852	0.827	0.800

8.2.1.2 Climate Change

The climate change projections for both rainfall and evapotranspiration described in Section 4.2 have been addressed in the water balance modelling in the following manner:

- The operational water balance over the mine life will be impacted by the 'near future' climate projections. As set out in Table 4.6, the 10th percentile to 90th percentile range for possible changes in annual rainfall for all climate scenarios in the near future (2020 to 2039) range from -13% to +8% with a median of -1% to -2%. Evapotranspiration is predicted to increase in the range of +1.6% to +5.8% with a median of +3.3% to +3.6%. (For modelling purposes, it has been assumed that the percentage change quoted for evapotranspiration also applies to open water evaporation.) The uncertainties in rainfall and evapotranspiration projections are included in the sensitivity analysis set out in Section 8.8.
- The water balance analysis for the final void (see Section 8.10) considers the long-term (1,000 year) water level and salinity in the lake that will form in the base of the void following completion of the project after 2040. In order to account for possible long-term future change in the climate, the water balance analysis assesses the impact of the 'far future' high range estimates for rainfall (-23% to +18%) and evapotranspiration (+9.8% to +18.1%) on the equilibrium water level (see Table 4.6).

8.2.2 Catchment Areas

The operational water balance model has been configured to represent the progressive development of the Project over 26 years (i.e. 1 year of construction and 25 years of mining), based on the detailed mine plans prepared for Project Years 3, 7, 13, 21 and the final landform (see Figure 7.1 to Figure 7.5). For modelling purposes, catchment areas and the state of the surface (active emplacement, initial rehabilitation, established rehabilitation, etc.) were determined for each of the six catchments based on mine layout plans for Years 3, 7, 13, 21 and the final landform. This data was supplemented by annual data showing the total area of the various land surfaces (see Figure 8.2) which was interpolated for each of the drainage catchments.

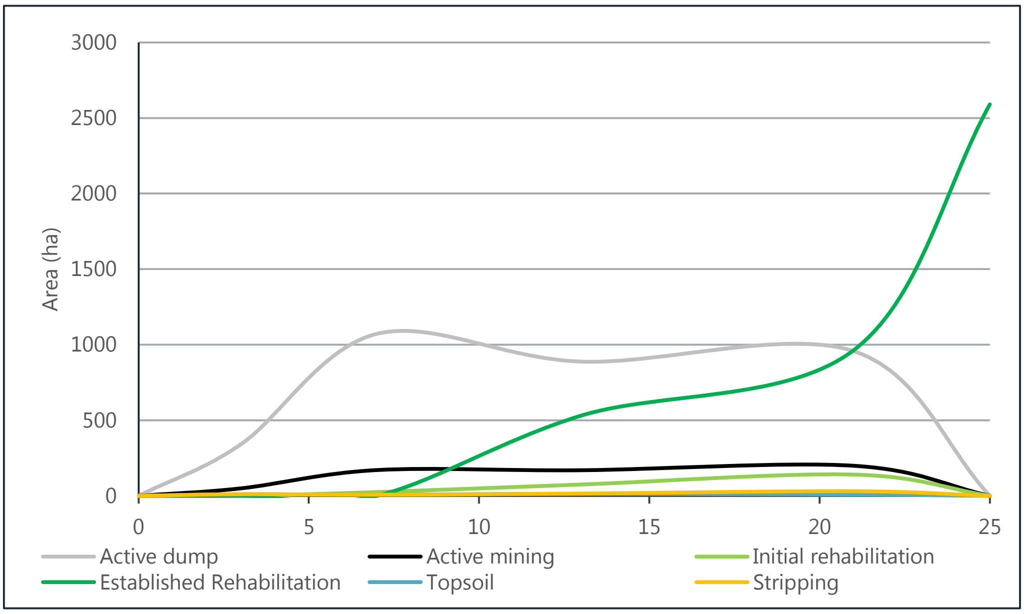


Figure 8.2: Progressive Development of Catchment Areas

8.2.3 Groundwater

Groundwater inflow to the open cut is expected to vary between 0.24 and 1.42 ML/day during the mine life (HydroSimulations, 2018). Inflow would largely occur as seepage around the perimeter of the open cut (typical dimensions shown in Table 8.3). For 'worst case' conditions with a predicted groundwater inflow of about 1.42 ML/day in Year 11, the predicted groundwater inflows would amount to:

- approximately 0.002 L/sec/m for the perimeter of the open cut
- approximately 1 mm/day over the base of the open cuts.

These inflows are significantly less than the evaporation loss from the active open cut area. Accordingly, groundwater is considered to evaporate as soon as seepage occurs. However, for accountability purposes, the predicted groundwater inflows are included in the water balance analysis.

Table 8.3: Active Open Cut Perimeter and Surface Area

Project Year	Open Cut Perimeter (km)	Open Cut Surface Area (ha)
3	4	55
7	9.3	154
13	8.1	111
21	8.6	221

8.2.4 Water Storages

The operational water balance model includes the catchment areas and water storages shown schematically in Figure 8.1, described in Section 7.4 and summarised in Table 7.1.

In the water balance model, direct rainfall onto the water surface and evaporation and seepage losses from all the water storage dams are accounted for as depth of gain or loss depending of the climate on a particular day; and are converted to a volume by multiplying by the surface area of the storage, which is a function of the volume of water held in the storage. The relationship between surface area and storage volume was established from the geometry of each storage.

8.2.5 Runoff Modelling

As discussed in Section 5.3, the AWBM has been used to estimate daily runoff volumes from the various catchments draining to the dams depicted in Figure 8.1.

For the purposes of selecting appropriate parameters to represent the runoff characteristics of the various surfaces, parameters derived from various sources were tested to determine the volume and flow distribution that would occur using the daily climate dataset compiled for this analysis. The main sources of data for this analysis were:

- parameters derived from rainfall and runoff data collected from open cut mines in the Hunter Valley and Queensland (Australian Coal Association Research Program [ACARP], 2001); and
- parameters derived from surface water assessments for mining projects including the Tarrawonga Coal Project (Gilbert & Associates, 2011), Maules Creek Coal Mine (WRM, 2011), Mt Thorley (JP Environmental), Cobbora Coal Project (Parsons Brinckerhoff, 2012), Watermark Coal Project (WRM, 2013) and Rixs Creek Continuation of Mining (JP Environmental, 2014).

Average Capacity

To establish appropriate estimates of parameters for the Project, the parameter sets representing the various surfaces types derived from the sources quoted above were used to model runoff using the full climate dataset (with BFI assumed to be zero). The results of this analysis are summarised in Figure 8.3, which shows the relationship between adopted Average Capacity (Ave Cap) and modelled runoff percentage for the different surface types. Table 8.4 summarises the statistics for the modelled total runoff for the different surface types.

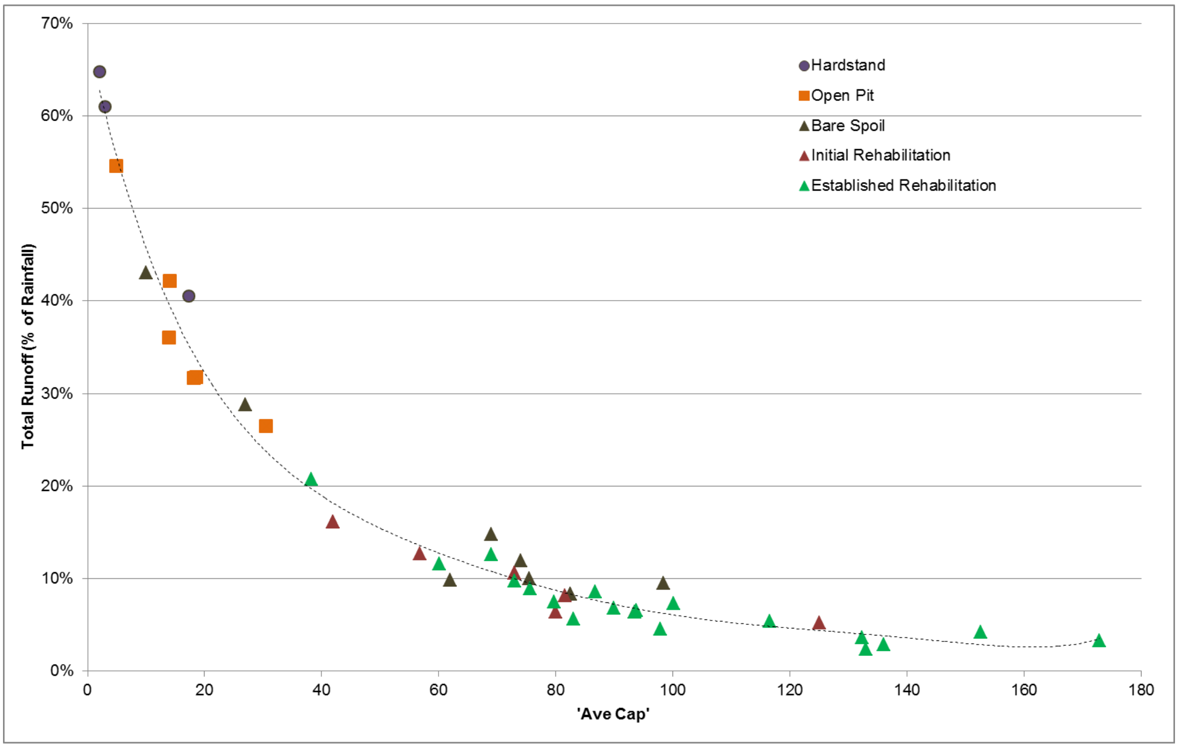


Figure 8.3: Relationship between Ave Cap and Runoff % for Different Surface Types

Table 8.4: Modelled Total Runoff Statistics for Different Surface Types (% of Rainfall)

	Hardstand	Open Pit	Bare Spoil	Initial Rehabilitation	Established Rehabilitation
Datasets	5	5	8	9	18
Minimum	36.0%	26.5%	8.3%	5.2%	2.9%
Average	47.6%	37.3%	16.8%	10.3%	7.6%
Maximum	64.8%	54.6%	43.0%	16.1%	20.8%

The values for the parameter Ave Cap adopted for this assessment for the various surface types are set out in Table 8.5, together with the resulting modelled surface runoff and baseflow rates. The values adopted for Ave Cap were those that resulted in the average total runoff identified in Table 8.4 for each surface type.

For runoff modelling purposes, the area of haul road has been included in the bare spoil area because these areas have similar characteristics and because they are constantly changing. The runoff characteristics were weighted more towards the spoil due to the larger percentage of the area that is spoil compared to haul road. After Year 1, the area of haul roads averages 5.5% of the bare spoil. After accounting for the runoff characteristics in Table 8.4, an Ave Cap of 54.7 was adopted for the combined bare spoil and haul road areas giving an average surface runoff of 12.9% and 'baseflow' to groundwater system within the emplaced waste rock of 5.5%.

Baseflow Index

Based on limited field monitoring in the Hunter Valley, Mackie (2009) modelled the effect of the soil moisture storage characteristics of the soil profile on waste rock emplacements and the resulting contribution to groundwater recharge by water that drained through the soil profile. Mackie concluded that percolation rates into the waste rock beneath a replaced surface soil typically ranged from 1% to 5% of the long-term rainfall. Intuitively, it could be expected that the higher percolation rate would occur for bare spoil with limited soil cover and no vegetation (5% of the long-term rainfall), while minimum percolation would occur for fully established rehabilitation (1% of the long-term rainfall).

Based on this premise, the BFI parameters in AWBM were tuned to the target percolation (baseflow) rates for each surface type. The adopted BFI values for the waste rock emplacement surfaces in the Project area are:

- bare spoil 0.3
- initial rehabilitation 0.2
- established rehabilitation 0.15

These BFI values are consistent with the range of BFI values provided in ACARP (2001), the Tarrawonga Coal Project (Gilbert & Associates, 2011), Maules Creek Coal Mine (WRM, 2011), Cobbora Coal Project (Parsons Brinckerhoff, 2012) and Watermark Coal Project (WRM, 2013) and Rixs Creek Continuation of Mining (JP Environmental, 2014).

The BFI values adopted for this assessment are set out in Table 8.5.

Table 8.5: Adopted AWBM Ave Cap and BFI Parameters for Project Surfaces

Surface Type	Ave Cap	BFI	Surface Runoff (%)[1]	Modelled Baseflow (%)[2]
Hardstand	9.1	0	47.8%	0%
Mine Pit	13.6	0	37.6%	0%
Bare Spoil + Haul Road	54.7	0.3	12.9%	5.5%
Initial Rehabilitation	73.0	0.2	8.5%	2.1%
Established Rehabilitation	79.7	0.15	6.3%	1.1%

Notes: [1] Runoff expressed as percentage of long-term rainfall.
[2] 'Baseflow' component from emplacement surfaces assumed to report to the groundwater within the waste rock.

8.2.6 Water Demands and Losses

Water demands included in the operational water balance model include daily accounting for:

- Water requirements for:
  - dust suppression on haul roads based on the methodology set out in Section 7.5.2 which accounts for day-to-day rainfall and open water evaporation (Section 8.2.1) and the progressive changes in active haul road length (Table 7.2) and
  - dust control on the mine infrastructure area, ROM pad and product coal stockpile based on the methodology set out in Section 7.5.2.
- Water requirements for operation of the Project CHPP as set out Section 7.5.1 for the tonnages set out in Table 7.2.
- Water 'loss' by evaporation from the water surface of each mine water dam, sediment dam and the CCWD, with the water surface area calculated from the volume of water held and the volume: area characteristics of each storage.

8.2.7 Water Transfers and Operating Rules

As described in Sections 8.2.2, 8.2.4 and 8.2.6, the Project conceptual water management system comprises a number of water sources and storages which would be interlinked with pipes and pumps. For purposes of characterising the overall water balance of the mine water management system the following operating rules and assumptions have been adopted:

- Sediment dams would be operated in accordance with the requirements of *Managing Urban Stormwater: Soils and Construction* (Landcom, 2004). With the exception of SD-F, water from the sediment dams would be pumped to the nearest MWD to restore the design capacity within five days of the end of a rainfall event. When necessary (e.g. if there is insufficient capacity in the MWDs or voids), water from the sediment dams would be treated (e.g. flocculation) and released in accordance with the EPL discharge criteria.
- Water from SD-F would not be transferred to any of the MWDs. In order to maintain sufficient capacity for rainfall events, SD-F would require periodic treatment (e.g. flocculation) and controlled discharge to receiving waters once water quality is deemed to be within acceptable EPL limits.
- The 'reserve' capacity of the sediment dams would be the priority water source for haul road dust suppression. To utilise all of the dams evenly and take advantage of the distributed water sources, supply from the individual dams has been assumed to be proportional to the catchment area. Demand in excess of the supply available from the sediment dams would be taken from the MWDs. In practice, intermediate water fill points may be located throughout the mine site which would be supplied from the MWDs. CCWDs would receive runoff from coal stockpiles and the mine infrastructure area. Any excess water from the CCWDs would be transferred to MWD-1.
- MWD-1 and MWD-2 would be operated as balancing storages with no contributing catchments of their own. Water would be transferred from MWD-2 to MWD-1 when levels in MWD-1 are less than 10%.
- MWD-1 would supply a number of water demands according to the following order of priority:
  - Project CHPP;
  - train load-out facility;
  - mine infrastructure area dust suppression;

- haul road dust suppression not met from sediment dam supplies; and
- transfer of excess water to the Blue Vale Void during wet weather.

- Water supply to MWD-1 would be sourced in the following order of priority:
  - excess water from the CCWDs;
  - excess water from the sediment dams;
  - dewatering from the open cut;
  - water stored in the existing Blue Vale void MWSS;
  - licensed extraction from the Namoi; and
  - licensed extraction from the borefield via MWD-2.
- MWD-2 would supply haul road dust suppression demand and at times additional supply to MWD-1.
- Water supply to MWD-2 would be sourced in the following order of priority:
  - Excess water from sediment dams;
  - dewatering from the open cut; and
  - licensed groundwater extraction from the borefield.
- There would be no transfer of water from the MWDs to the sediment dams.
- The existing Blue Vale Void would initially be used as the main water storage while the other dams are being constructed. After commissioning the other dams, the existing Blue Vale void would be used to temporarily store excess water during prolonged wet weather, after which time it would be returned to MWD-1. Other existing voids may also be used for mine water storage early in the mine life, prior to being subsumed.
- Water from the open cut would be pumped to either MWD or the existing Blue Vale void if there is no capacity available in either MWD.
- Excess water from MWD-1 would be transferred to the existing Blue Vale void when levels in MWD-1 are above 95%.
- Extraction from the Namoi River and the borefield is limited based on the associated licence limits over water year (July-June).

The operating rules assumed in the water balance model are summarised in Table 8.6. All transfers were assumed to occur at a maximum rate of 10 ML/day.

Table 8.6: Operating Rules

Component	Rule	Start	Stop
CCWDs	Transfer water from CCWD to MWD	CCD Volume > 5% of capacity	CCD <5% or MWD-1=100%
Sediment Dams	Utilise for dust suppression	SD Volume > 5% of capacity	
	Pump from sediment dam to mine water dam	SD Volume > 30% of capacity	SD Volume < 30% of capacity or MWD > 90% of capacity
	Controlled discharge from sediment dams to receiving waters	SD Volume > 30% of capacity and MWD > 90 % capacity	SD volume <30% or MWD <90%

Component	Rule	Start	Stop
Opencut	Pump from open cut to MWD-1	Opencut >40ML, MWD-1<70%, or MWD-1>MWD-2	Opencut <40ML, MWD-1>70%, MWD-1<MWD-2, or BVV>75%
	Pump from open cut to MWD-2	Opencut >40ML, MWD-2<70%, or MWD-2>MWD-1	Opencut <40ML, MWD-2>70%, MWD-2<MWD-1, or BVV>75%
	Pump from open cut to Blue Vale Void	MWD-1>70%, MWD-2>70% & BVV<75%	MWD-1<70% & BVV>75% MWD-2<70% & BVV>75% MWD-1>95%
Mine voids	Pump from Blue Vale, Shannon Hill and/or Greenwood Voids to MWD-1	MWD-1<70%	MWD-1>70%
	Canyon and/or Red Hill Void to MWD-2	MWD-2<70%	MWD-2>70%
Namoi River	Pumping from Namoi River to MWD-1 (initially water to be pumped to Blue Vale Void until MWD-1 commissioned)	MWD-1<10%, Namoi extraction < licence condition	100ML extracted Namoi extraction = licence conditions MWD-1>50%
Borefield	Pumping from borefield to MWD-2	Borefield extraction < licence conditions, and MWD-2<10%, or Namoi extraction = licence conditions	100ML extracted, Borefield extraction = licence conditions, or MWD-2>50%
MWDs	Pumping from MWD-2 to MWD-1	MWD-1 < 5% & MWD-2 > 5%, or MWD-1 < 70% & MWD-2 > 15%	MWD-1 > 5% & MWD-2 < 15%, or MWD-1 > 70%
	Pumping from MWD-1 to Blue Vale Void	MWD-1 > 95%	MWD-1 < 95%

8.3 Adopted Climate Sequences

Because the water balance model keeps track of all runoff, water transfers and volumes in various storages on a day to day basis for a 26 year climate sequence over the life of the Project, a large quantity of data is generated even for a single scenario. For purposes of demonstrating the long-term performance of the system under dry, median and wet conditions, the climate sequences listed in Table 8.7 were adopted for detailed analysis.

Table 8.7: Climate Sequences Adopted for Analysis

Statistic	Year Climate Sequence Commenced
10th percentile (dry)	1915
50th percentile (median)	1981
90th percentile (wet)	1946

8.4 Water Balance Accounting

Model results were used to check that the model provided satisfactory accounting for all water gains, losses and water uses over the Project life. The following tables show the results of this analysis over the 26 year life of the Project for a median climate sequence starting in 1981:

- Project water supply and demand (Table 8.8);
- site water balance (Table 8.9);
- sediment dam and CCWD water balance (Table 8.10);
- MWDs water balance (Table 8.11); and
- open cut and the existing Blue Vale Void water balance.

The results in Table 8.8 to Table 8.12 confirm that the model accounts for all water supply demands, water sources, inputs and outputs for the sediment dams, CCWDs and MWDs, the open cut and the existing Blue Vale Void over the life of the Project. Importantly, the results in Table 8.10 and Table 8.11 show that there is no overflow from the CCWDs or MWDs.

Table 8.8: Project Water Supply and Demand over 26 year Project life (Median Climate Sequence)

Demand/Supply Location	Total Volume (ML)
Demands	
Coal processing	12,271
Haul road dust suppression	19,381
Stockpile and hardstand dust suppression	10,122
Total Demand	*41,774*
Sources/Supply	
Coal Processing Sources	
Mine Water Dam 1	12,271
Dust Suppression Sources	
Mine Water Dams 1	17,891
Mine Water Dams 2	3,329
Sediment Dam SD-A	1,947
Sediment Dam SD-B	538
Sediment Dam SD-C	3,792
Sediment Dam SD-E	1,193
Sediment Dam SD-F	301
Other temporary or intermittent dams (SD-1, Canyon Void etc)	512
Dust Suppression Sources Total	**29,503**
Total supply	*41,774*
Shortfall	**0**

Table 8.9: Site Water Balance over 26 year Project life (Median Climate Sequence)

Water Source or Destination	Total Volume (ML)
Water sources	
Rainfall on water surfaces	7,939
Runoff	46,583
Namoi River	14,362
Borefield	1,641
Mine groundwater	7,550
Total sources	78,075
Use	
Haul road dust suppression	19,381
Stockpile and hardstand dust suppression	10,122
Coal Processing	12,271
Total use	41,774
Losses	
Evaporation	26,508
Controlled discharge from sediment dams (to restore capacity within 5 days of a rainfall event exceeding design criteria for sediment dams)	2,313
Overflow from sediment dams (in excess of design capacity)	3,847
Seepage	1,049
Diversion	1,197
Amenities (land disposal)	416
Total losses	**35,330**
Change in storage	971
Balance	**0**

Table 8.10: Sediment Dam Water Balance over 26 year Project life (Median Climate Sequence)

Water Sources	Units	Sediment Dams					
		SD-A	SD-B	SD-C	SD-D	SD-E	SD-F
Initial Storage	(ML)	0	0	0	0	0	0
Inflows							
Runoff	(ML)	4,618	1,822	9,408	2,876	2,558	1,286
Rainfall on water surfaces	(ML)	439	505	440	847	178	100
Total Inflows	**(ML)**	**5,057**	**2,327**	**9,848**	**3,723**	**2,736**	**1,386**
Outflow							
Evaporation	(ML)	987	899	1,128	2,062	428	230
Dust Suppression	(ML)	1,947	538	3,792	0	1,193	301
To Mine Water Dams	(ML)	1,024	229	2,167	1,131	727	0
Controlled Discharge[1]	(ML)	406	240	681	177	148	662
Overflow[2]	(ML)	675	411	2,026	324	227	184
Total Losses	**(ML)**	**5,039**	**2,317**	**9,793**	**3,693**	**2,723**	**1,377**

Water Sources	Units	Sediment Dams					
		SD-A	SD-B	SD-C	SD-D	SD-E	SD-F
Final Storage	(ML)	18	10	55	29	13	9
Balance	**(ML)**	**0**	**0**	**0**	**0**	**0**	**0**

Note [1]: To restore capacity within 5 days of a rainfall event exceeding design criteria for sediment dams (refer to Section 7.8)
[2]: Exceedance of design criteria for sediment dams (refer to Section 7.8)

Table 8.11: MWDs and CCWDs Water Balance over 26 year Project life (Median Climate Sequence)

Water Source or Destination	MWD-1 (ML)	MWD-2 (ML)	CCWDs
Initial Storage	0	0	0
Inflows			
Runoff	0	0	5,666
Rainfall on water surfaces	1,560	1,564	441
Transfer from sediment dams	1,857	3,420	-
Transfer from CCWDs	5,209	0	-
Namoi River	13,833	0	-
Borefield	0	1,226	-
Return from Blue Vale void	3,157	0	-
Mine dewatering	7,484	3,406	-
Transfer from MWD-2 to MWD-1	1,889		-
Total inflow	**34,989**	**9,616**	**6,107**
Outflows			
Coal processing	12,271	1,890	-
Dust suppression	17,891	3,329	-
Evaporation from water surfaces	4,108	4,097	891
Transfer to MWDs	-	-	5,209
Transfer to Blue Vale void	306	0	-
Overflows	0	0	0
Total outflow	**34,576**	**9,316**	**6,100**
Final storage	413	300	7
Balance	0	0	0

Table 8.12: Open Cut and Blue Vale Void Water Balance over 26 year Project life (Median Climate Sequence)

Water Source or Destination	Open cut (ML)	Blue Vale Void (ML)
Initial Storage	0	10
Inflows		
Runoff	15,970	97
Rainfall on water surfaces	964	449
Namoi River	0	529
Transfer from MWDs	0	306

Water Source or Destination	Open cut (ML)	Blue Vale Void (ML)
Groundwater	7,550	0
Open cut to Blue Vale void	-	3,704
Total inflow	**24,484**	**5,085**
Outflows		
Dust suppression	0	325
Evaporation	9,337	1,224
Transfer to MWDs	10,889	3,157
Transfer from Blue Vale void	3,704	-
Seepage	517	294
Overflow	0	0
Total outflow	**24,447**	**4,999**
Final storage	36	96
Balance	0	0

8.5 Model Results

The water balance model was used to assess water sources, use, losses and change in water storage through the mine life for 98 climate sequences. Each climate sequence is a 26 year history based on the historic rainfall and evaporation data. Sequence 1 represents the climate record from 1 July 1893 (year from which AWD data is available – refer Section 7.10) to 30 June 1919. Sequence 2 is the climate record from 1 July 1894 to 30 June 1920, through to sequence 98 which represents 1 July 1991 to 30 June 2017. The results are provided below in the form of exceedance plots over the mine life.

It should be noted that in the exceedance plots in Section 8, the outer limit of the coloured band represents the 10^{th} to 90^{th} percentile range of occurrence for the result or metric for all of the modelled climate sequences over the 26 year Project life. The median result is shown as a black line. It should be noted that the plots show the statistical probability of the results and do not correlate to a specific climate sequence (i.e. the black line in Figure 8.4 is the median result for all climate sequences not the result corresponding the median climate scenario).

8.5.1 Water Sources

As shown in Table 8.9, the main water source for the Project is runoff collected on the mine site in sediment dams, CCWDs and the open cut. As the mine expands over the Project life and sub-catchment properties change, runoff generally increases, as shown in Figure 8.4).

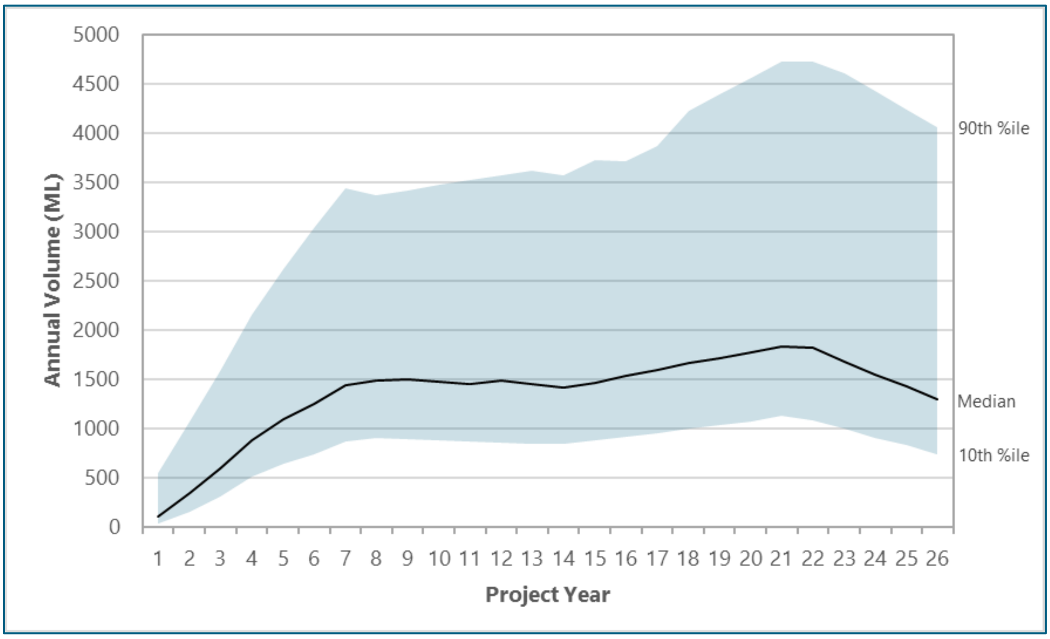


Figure 8.4: Annual Runoff Exceedance Ranges for all modelled Climate Sequences

There is a high degree of variability in the amount of runoff generated compared to the total mine demands. Onsite water storages would be used to balance the supply of water from runoff and demand for coal processing and dust suppression.

Extraction from the Namoi River and the Borefield would provide additional supply when site runoff is not adequate to supply the site demands. Extraction from these sources is limited by licence conditions, although the projected demand is well below the licence levels shown in Table 3.3 (refer also Section 8.6). As supply from site runoff increases, the amount of water required from the external sources decreases, as shown in Figure 8.5 and Figure 8.6.

Figure 8.5: Annual Extraction Exceedance Ranges for Namoi River for all modelled Climate Sequences

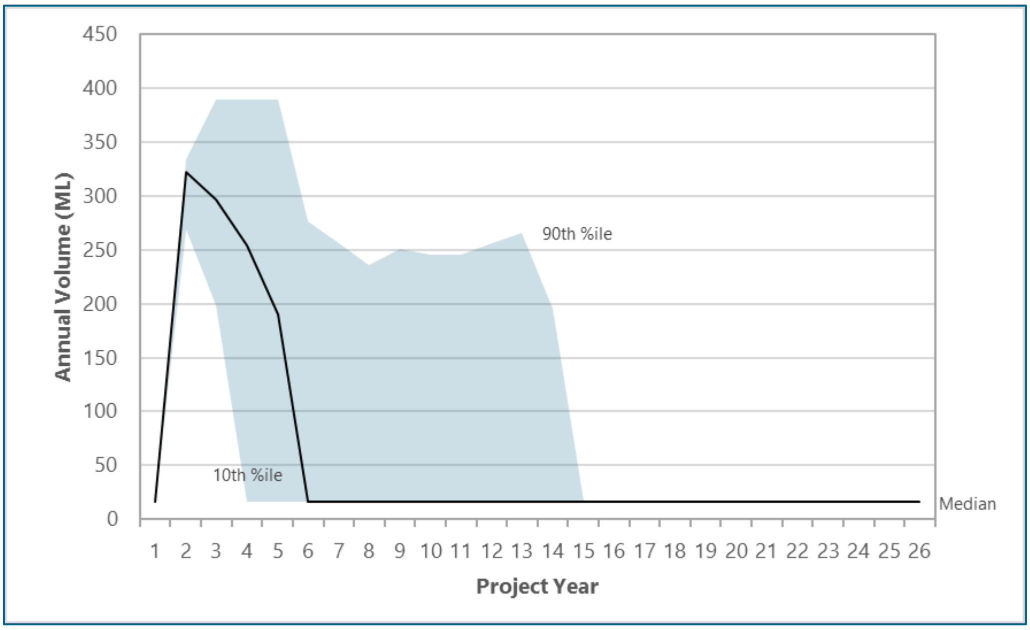


Figure 8.6: Annual Extraction Exceedance Ranges for the Borefield for all modelled Climate Sequences

Groundwater to the open cut has been included in the water balance in accordance with the annual inflows shown in Figure 8.7. Groundwater does not provide significant supply to the water management system as the majority of this inflow would evaporate before reaching the open cut sump as discussed in Section 8.2.3.

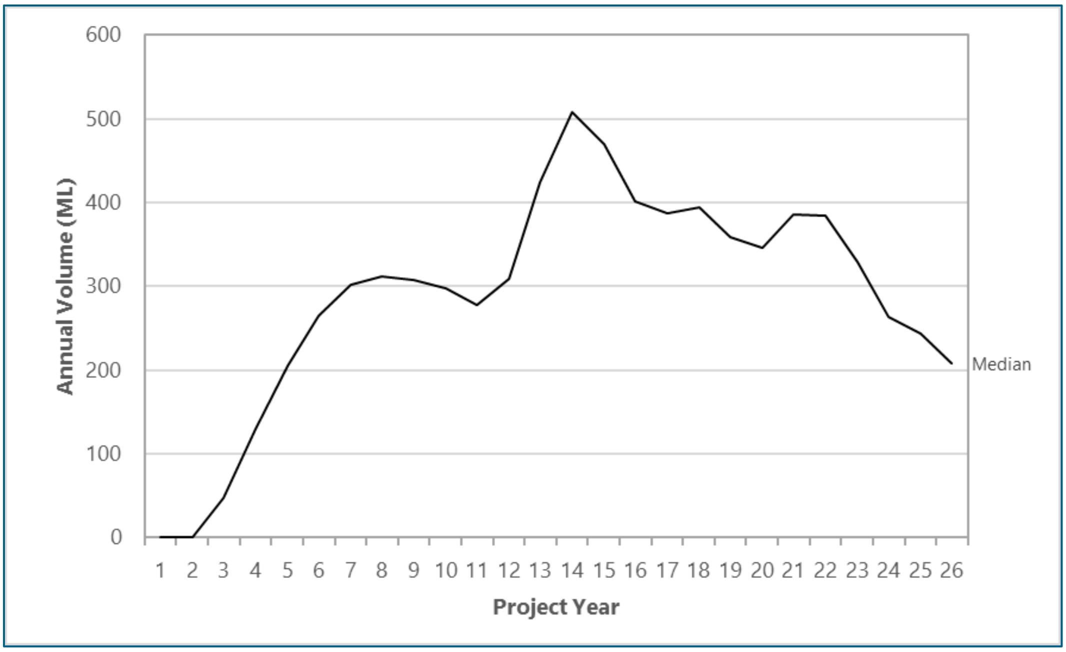


Figure 8.7: Annual Mine Groundwater Inflow over Project life

8.5.2 Water Usage

The main water usage for the Project is dust suppression, comprising approximately 75% of the total site demand. Dust suppression demand is split approximately 70:30 between haul roads and stockpile/hardstand areas. The demand for dust suppression increases in the first 6 years of the Project life as haul road distances increase (Figure 8.8), and then remains consistent until Year 12. After Year 12 the demand for dust depression begins to drop as the haul road distances start to reduce. The demand for dust suppression for stockpile and hardstand areas is very consistent after Year 3 (Figure 8.9). Demand for coal processing (Figure 8.10) follows the processing rate and is it not influenced by climatic conditions.

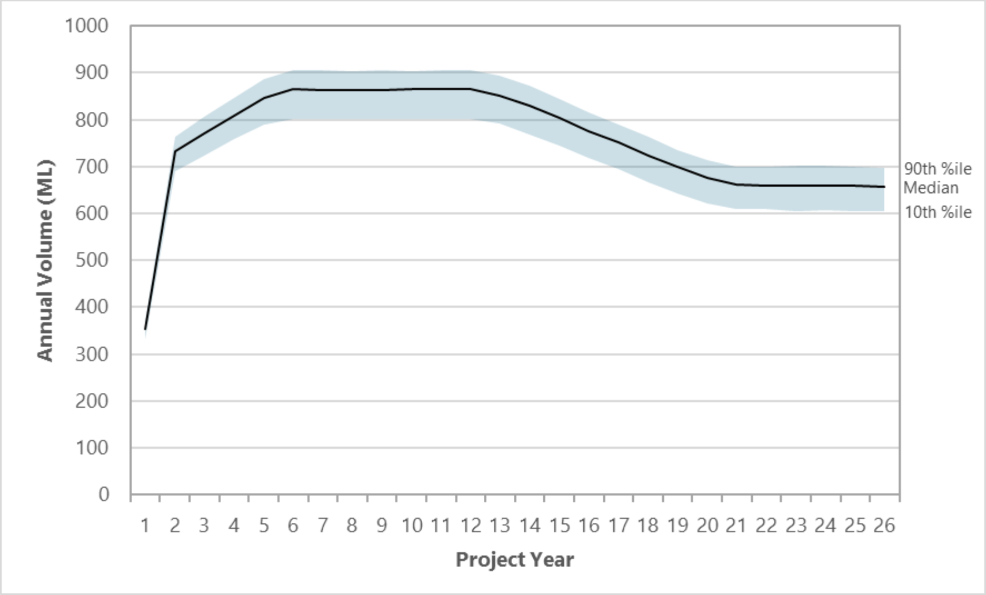


Figure 8.8: Annual Haul Road Dust Suppression Demand for all modelled Climatic Sequences

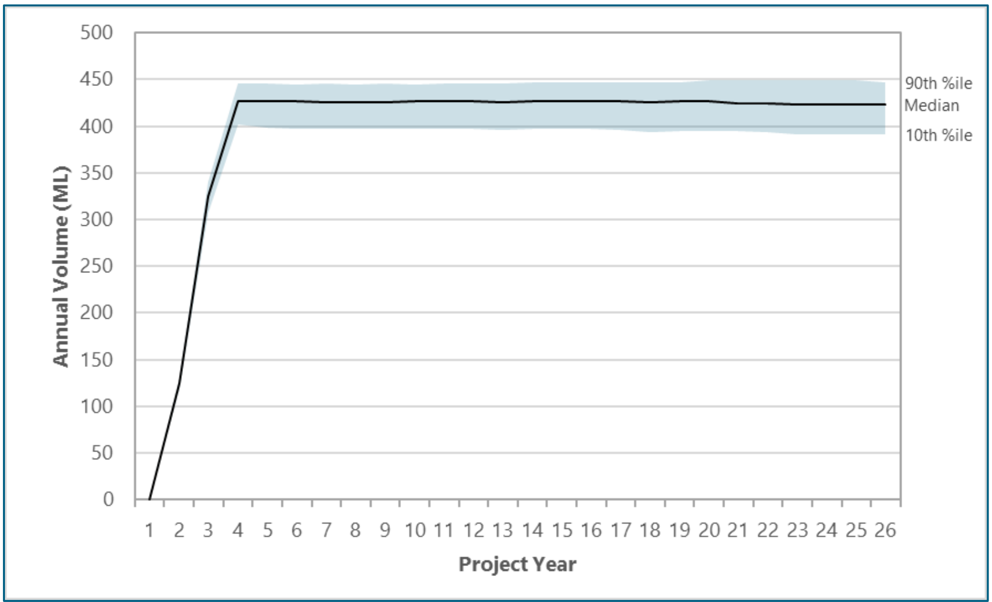


Figure 8.9: Annual Stockpile and Hardstand Dust Suppression Demand for all modelled Climatic Sequences

Figure 8.10: Annual Coal Processing Demand over the Project life

8.5.3 Water Losses

The main water loss from the site water system is through evaporation from water stored in dams, voids and sumps on the site. Evaporation generally increases over time (Figure 8.11) as both the amount of groundwater inflow to the open cut and the amount of water in storage increase. There is variability in the amount of evaporation each year as a result of the climatic conditions and some uncertainty in the amount of water in storage.

As described in Sections 7.4 and 7.8, controlled discharges from the sediment dams would only occur within five days of the end of design rainfall events and would only be undertaken if required to restore capacity in the dams before the next rainfall event if there is insufficient capacity in the MWDs and water carts to receive water transfer from the sediment dams. Controlled discharges increase towards the end of the Project (Figure 8.12) as it becomes more likely that the MWDs are full (refer Section 8.5.4), and as the contributing catchments and runoff to the sediments dams increases. Overflows (also described in Sections 7.4 and 7.8) occur when rainfall exceeds the design capacity of the sediment dams and after all possible transfer of water from the sediment dams to the mine water dams and water carts has occurred. Overflows also increase over time (Figure 8.13) as the contributing catchments from the waste emplacement increases.

Other losses to the water system include seepage to groundwater.

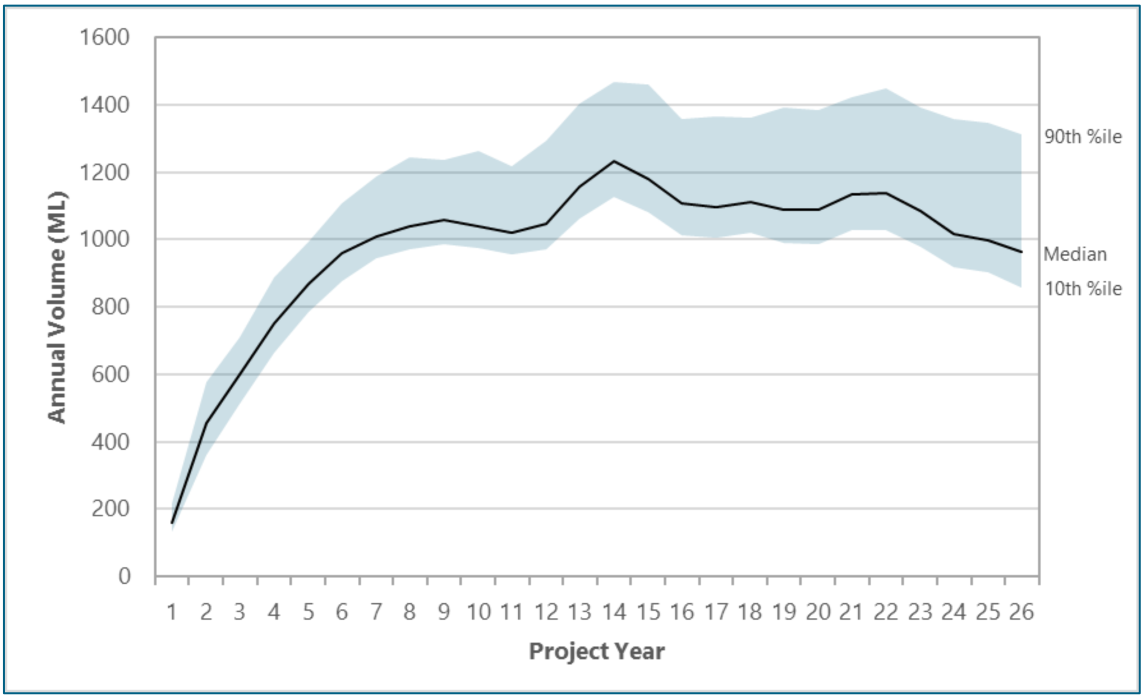
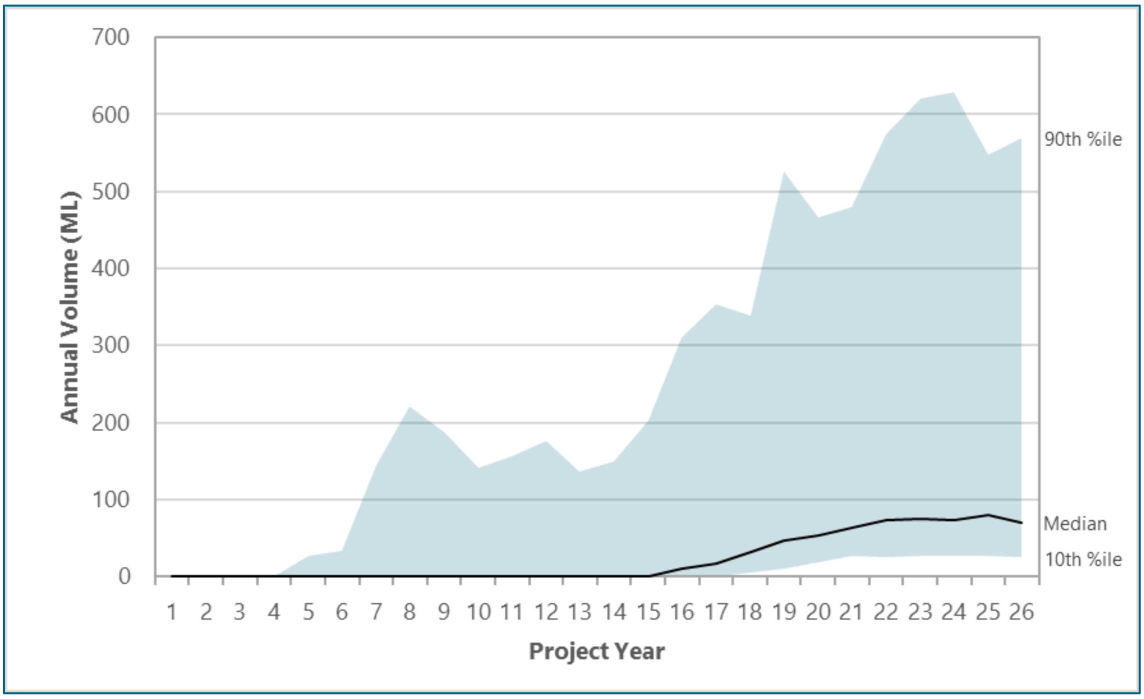


Figure 8.11: Annual Evaporation Loss Exceedances for all modelled Climatic Sequences



Note: "Controlled discharge" refers to discharge required to restore the capacity of the sediment dam within five days of the occurrence a rainfall event exceeding the design criteria of the sediment dam.

Figure 8.12: Annual Sediment Dam Controlled Discharge Exceedances for all modelled Climatic Sequences

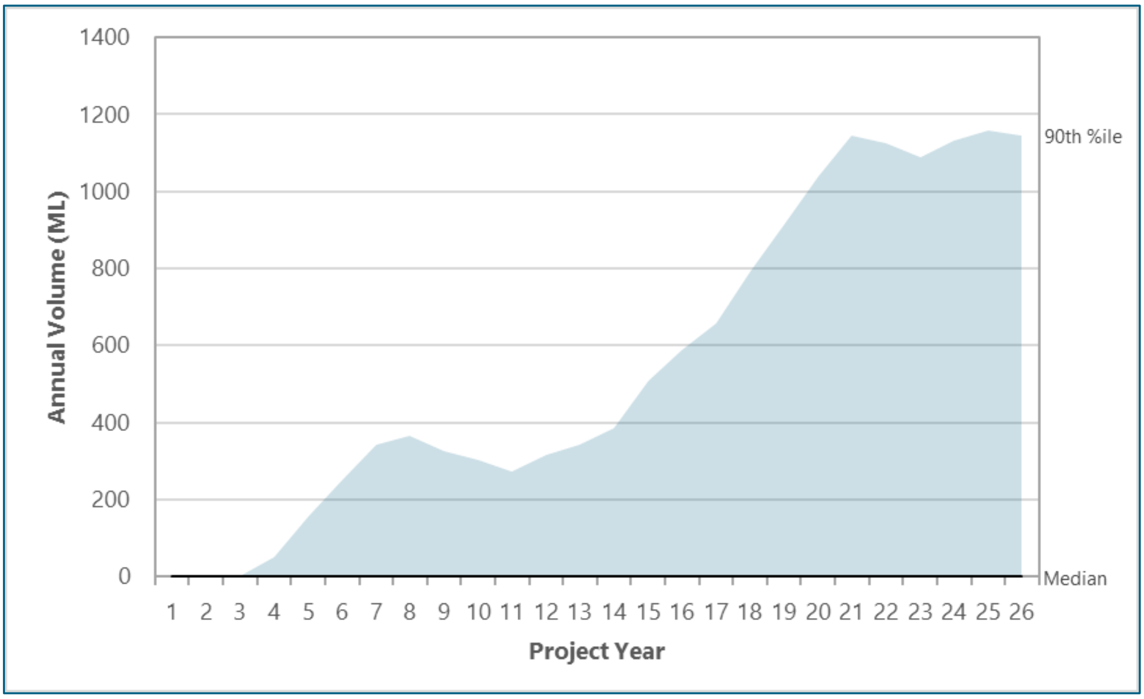


Figure 8.13: Annual Sediment Dam Overflow Exceedances for all modelled Climatic Sequences

8.5.4 Water Storage

On site water storage provides a balancing function between times of excess and times of insufficient runoff to supply site requirements. The water balance model assumes that any water in the open cut would be pumped to a MWD. In the event that the MWDs are full, the model assumes that any water from the open cut that could not be accommodated in the MWDs would be transferred to the Blue Vale Void. In practice, however, some water could be retained in the open cut while mining occurs within higher coal seams.

For purposes of assessing the probability of having an excess of water that would require retention in the open cut or transfer to Blue Vale void, the water balance model has been run for the 98 climatic sequences. Figure 8.14 to Figure 8.17 show the variability in storage and extraction throughout the mine life. Noteworthy aspects of these figures are:

- MWD-1 (Figure 8.14) fluctuates significantly throughout the mine life, with an increasing trend in volume;
- MWD-2 (Figure 8.15) has a more pronounced seasonal fluctuation, with a similarly increasing trend in volume throughout the mine life;
- The volume held in the open cut (Figure 8.16) fluctuates in relation to rainfall events leading to water being held in the open cut until it can be transferred to the MWDs or Blue Vale void; and
- The volume held in the Blue Vale void is higher in the early stages of the mine life and then drops to be consistently low, with an increasing trend towards the end of the mine life (Figure 8.17).

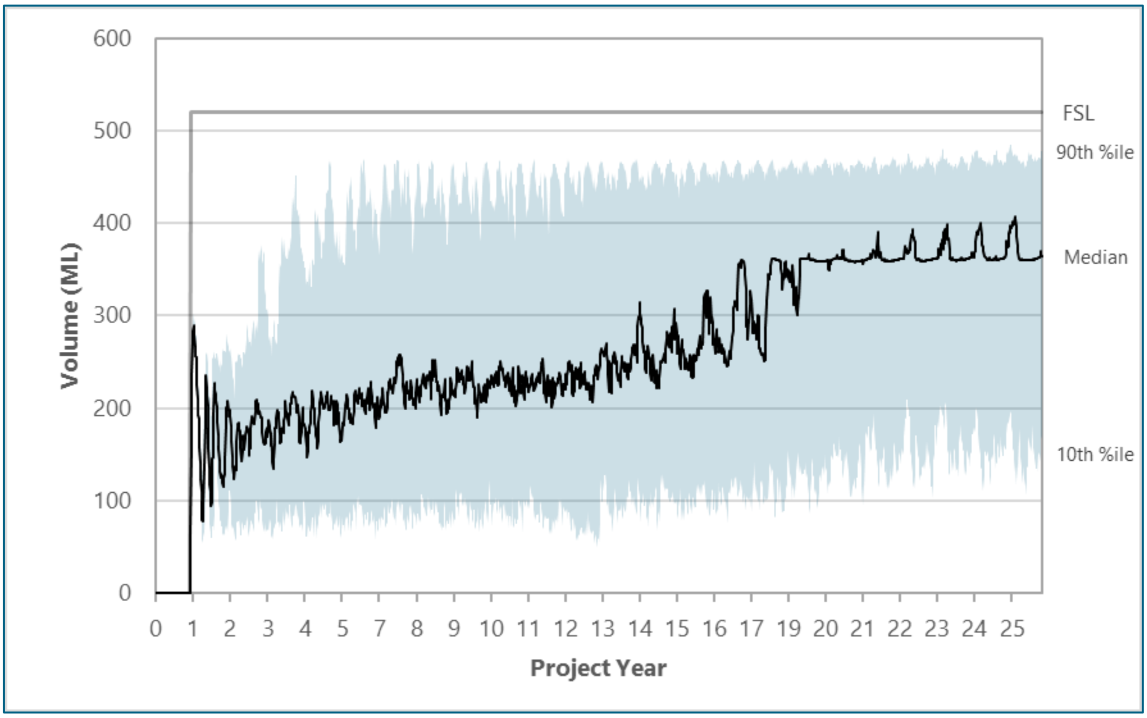


Figure 8.14: MWD-1 Storage Volume Exceedances for all modelled Climatic Sequences

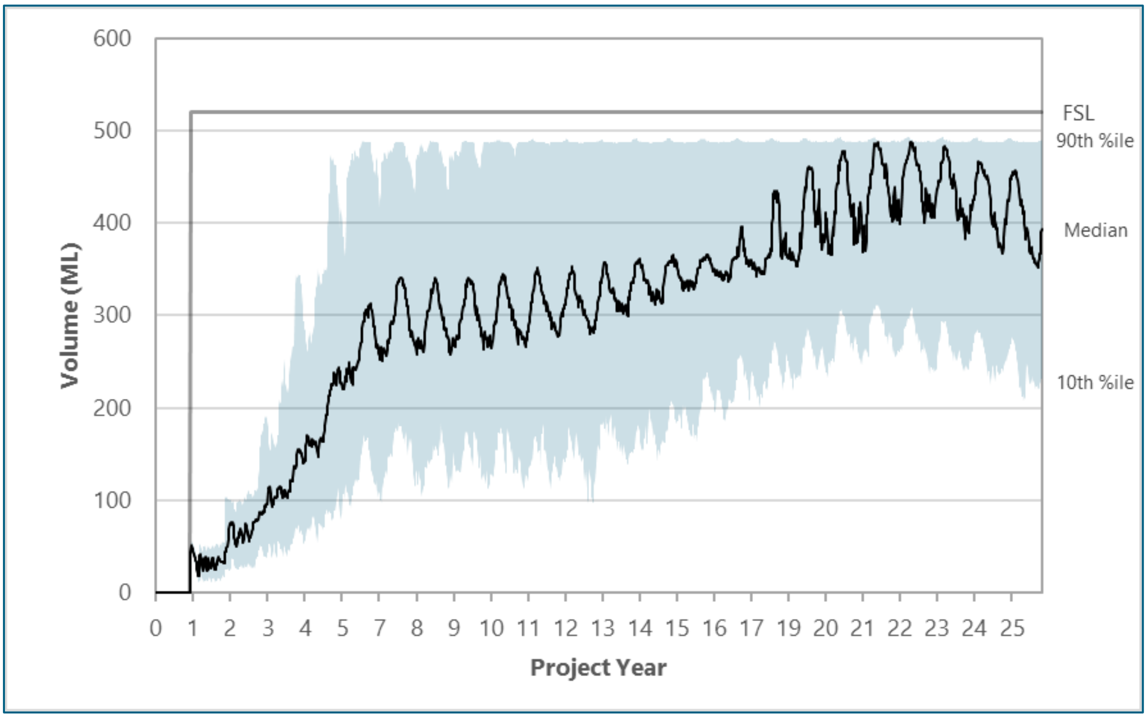


Figure 8.15: MWD-2 Storage Volume Exceedances for all modelled Climatic Sequences

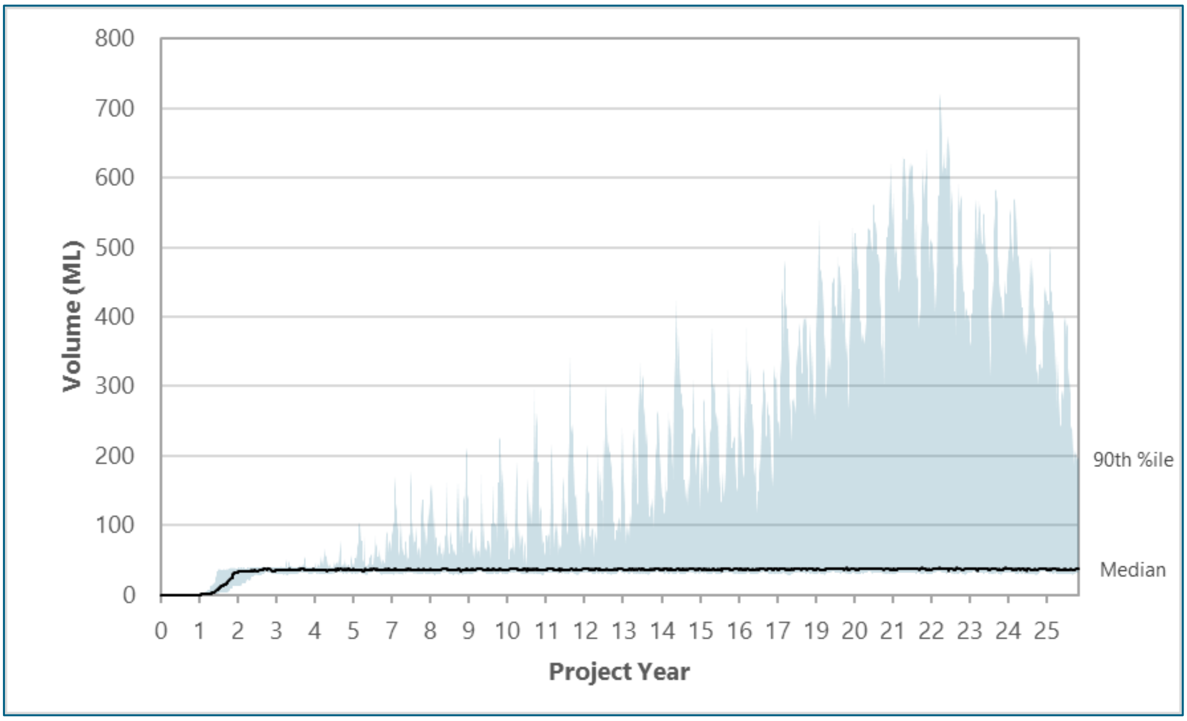


Figure 8.16: Open Cut Storage Volume Exceedances for all modelled Climatic Sequences

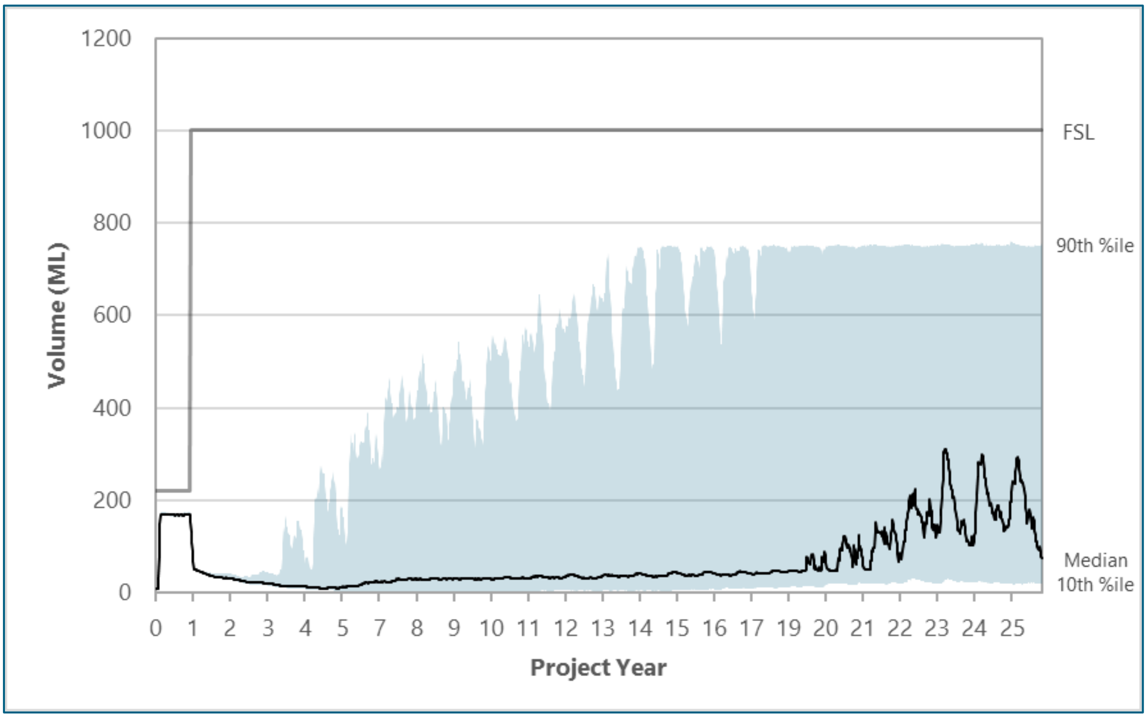


Figure 8.17: Blue Vale Void Storage Volume Exceedances for all modelled Climatic Sequences

8.6 Requirement for Additional External Water Supply

Table 8.13 summarises the probability of requirements for external supply from the Namoi River or groundwater sources and temporary transfer to the open cut and/or Blue Value void. Key features of this summary are:

- The average annual requirement for importation of water from external sources is within the volume available from the WALs held by Whitehaven (refer Table 3.3) and indicates an ability to operate even when considering low AWDs in the Namoi River (see Section 7.10).
- In dry years, the maximum requirement for imported water remains within the licensed allocation. In the event that the announced allocation is less that the required volume, Whitehaven could ensure continued operation by taking steps such as:
  - reducing the volume of water required for dust suppression by applying dust suppression chemicals, which can reduce the required water volume by up to 50%; and/or
  - obtaining temporary transfer of water on the open market.

Table 8.13: Licensed Extraction Probability

Source	Project Year	Extraction Volume (ML/year)		
		10th Percentile	Median	90th Percentile
Namoi River	3	573	1,068	1,353
	7	0	820	1,465
	13	0	469	1,207
	21	0	128	754
Groundwater Bores	3	199	297	390
	7	16	16	256
	13	16	16	274
	21	16	16	16

Figure 8.18 and Figure 8.19 show the pattern of annual additional supply required to maintain normal operations for the median and the 10th percentile dry climate sequences respectively. Note that these Figures represent different climatic sequences, with the median sequence (Figure 8.18) commencing in 1981 and the 10th percentile dry sequence (Figure 8.19) commencing in 1915 and hence the year by year results are not comparable. The Figures show that the requirement for additional supply can be expected to vary from year to year, with no or minimal requirement in about 30% of years, even in a dry climate sequence.

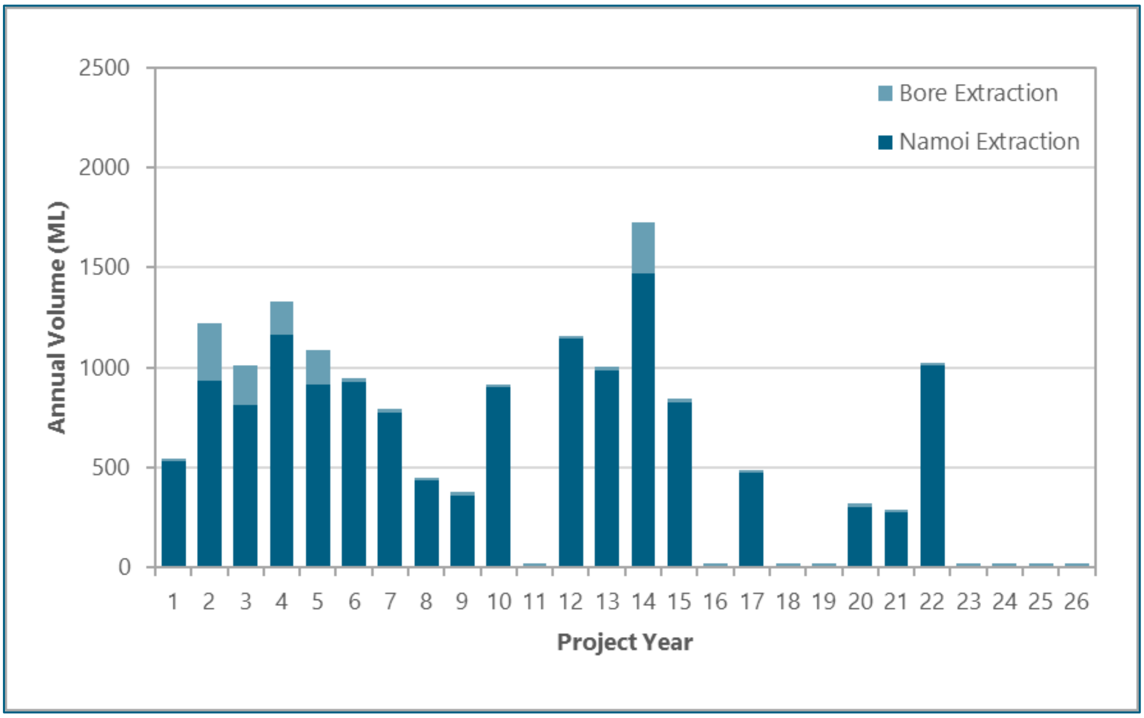


Figure 8.18: Additional Supply Requirements (Median Climate Sequence commencing 1981)

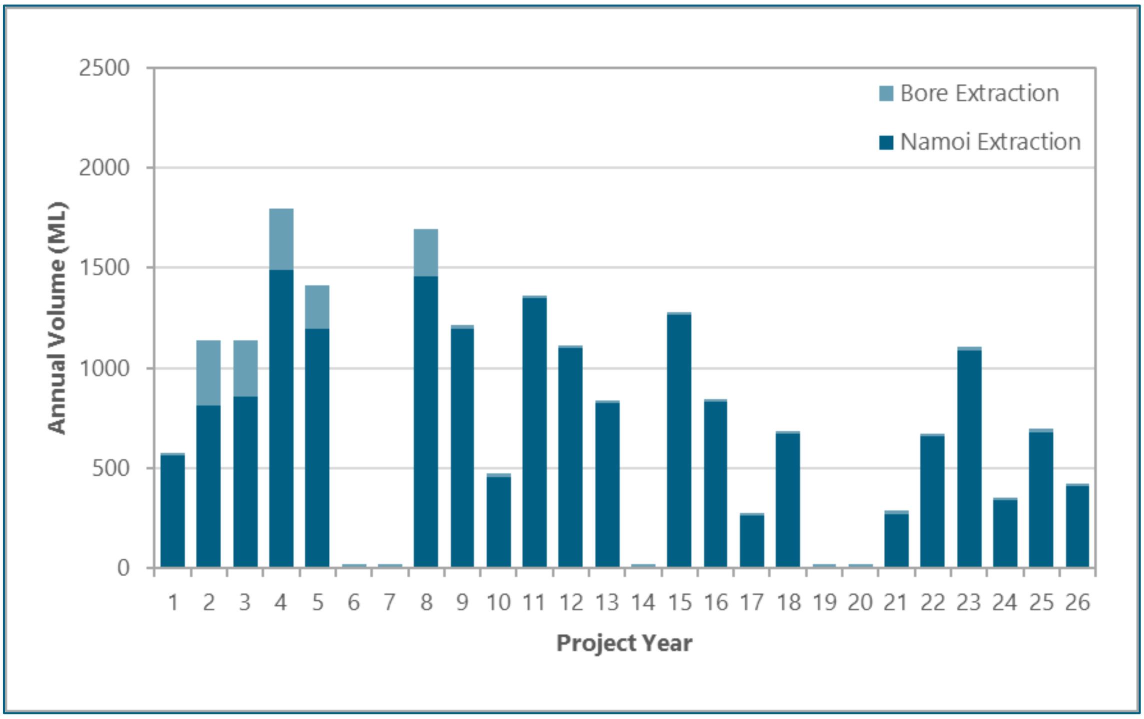


Figure 8.19: Additional Supply Requirements (10th Percentile Dry Climate Sequence commencing 1915)

8.7 Performance of Sediment Dams

Table 8.14 summarises the performance of the sediment dams over the 26 year life of the Project for a median climate sequence. Key features of the data presented in Table 8.14 include:

- approximately 9% of the runoff would be discharged as controlled discharge (i.e. to restore the capacity of the sediment dams within 5 days of a rainfall event exceeding the design criteria);
- approximately 15% of the runoff would overflow following rainfall events that exceed the design capacity of the sediment dams; and
- SD-F has a higher proportion of controlled discharges because it has no connection to the MWDs for water transfer.

It is noted that the frequency of overflow would be very low. The data shows that SD-C would experience 12 days of overflow over the 26 year life of the Project (an average of less than 1 day per year). This frequency is less than the expected frequency (two to four overflow events per year) quoted in Table 6.2 of and *Managing Urban Stormwater: Soils & Construction– Volume 2E: Mines and Quarries* (DECC, 2008).

Table 8.14: Sediment Dam Performance over Project Life (Median Climate Sequence)

	Units	Sediment Dams						
		SD-A	SD-B	SD-C	SD-D	SD-E	SD-F	Total
Inflow (rainfall and runoff)	(ML)	5,057	2,327	9,848	3,723	2,736	1,386	25,076
Dust Suppression	(ML)	1,947	538	3,792	0	1,193	301	7,771
To Mine Water Dams	(ML)	1,024	229	2,167	1,131	727	0	5,278
Controlled Discharge[1]	(ML)	406	240	681	177	148	662	2,313
	% inflow	8%	10%	7%	5%	5%	48%	9%
	Days	28	26	18	8	41	121	146
Overflow[2]	(ML)	675	411	2026	324	227	184	3,847
	% inflow	13%	18%	21%	9%	8%	13%	15%
	Days	9	7	12	5	5	4	15

Notes: [1] To restore capacity within 5 days of a rainfall event exceeding design criteria for sediment dams (refer to Section 7.8)
[2]: Exceedance of design criteria for sediment dams (refer to Section 7.8)

8.8 Sensitivity Analysis

In addition to the effect of the range of the historic climate sequences discussed in Sections 8.5 and 8.6, uncertainties in the water balance analysis relate to:

- the assumed runoff characteristics of different mine surfaces; and
- the impacts of climate change on rainfall and evapotranspiration over the life of the mine.

These uncertainties have been assessed through sensitivity analyses, as outlined below. Impacts on the external supply of water and volumes of water in the open cut and Blue Vale void have been assessed.

8.8.1 Sensitivity of results to variation in runoff

Table 8.4 shows the minimum, average and maximum runoff for different surface types based on published data expressed as a percentage of long-term rainfall. Table 8.15 shows the variation between the maximum and minimum runoff values in Table 8.4 expressed as the variation from the average. The ranges shown in Table 8.15 were used as the basis for the assessing the impacts of variations in runoff on the water management system.

Table 8.15: Variation in Estimated Runoff for Different Surface Types in Table 8.4

	Hardstand	Open Pit	Bare Spoil	Initial Rehabilitation	Established Rehabilitation
Minimum as % of Average	-24%	-29%	-51%	-50%	-62%
Maximum as % of Average	+36%	+46%	+156%	+56%	+174%

A sensitivity analysis of the impacts of variations in runoff on the external supply and volume of water stored in the open cut and the Blue Vale void was undertaken using a Monte-Carlo analysis. This involved varying the runoff for each surface type by a randomly selected amount within the ranges in Table 8.15. The water balance model was run with 100 different combinations of variations in runoff for each of the 10th percentile, median and 90th percentile climate sequences. The resulting 10th and 90th exceedance results for the analysis are shown in Table 8.16 compared to the average base case result (i.e. with the parameters adopted to produce the results in Section 8.5) for the respective climate sequence.

Table 8.16: Sensitivity Analysis of variation in Catchment Runoff

	10th %ile Climate Sequence (dry) (commencing 1915)			Median Climate Sequence (commencing 1981)			90th %ile Climate Sequence (wet) (commencing 1946)		
	10th %ile	Base Case	90th %ile	10th %ile	Base Case	90th %ile	10th %ile	Base Case	90th %ile
Average supply from Namoi River (ML/y)	431	682	746	343	547	721	222	431	566
Maximum annual supply from Namoi River (ML/y)	1,260	1,487	1,574	1,341	1,470	1,631	1,009	1,344	1,510
Average supply from GW (ML/y)	57	65	136	57	54	83	40	47	69
Maximum annual supply from GW (ML/y)	316	323	881	366	284	477	286	328	331
Max volume in Open Cut (ML)	684	853	1,451	449	588	1,246	773	1,428	2,449
Max volume in Blue Vale Void (ML)	759	773	878	773	780	939	789	843	956

Table 8.16 shows that surface runoff assumptions impact both the requirement for external water supply and the maximum amount of water stored in both the open cut and the Blue Vale void. While requirements for external supply (from the Namoi River and the borefield) are sensitive to catchment runoff assumptions, the result for the average demand over the Project life under the dry climate sequence is less than the entitlements held by Whitehaven.

8.8.2 Sensitivity of results to projected climate change effects

Table 4.6 summarises climate change projections in terms of the percentage projected change in rainfall and evapotranspiration. (For purposes of this report, the percentage change in open water evaporation is assumed to be the same as the percentage change in areal potential evapotranspiration.)

The sensitivity of the impacts of the near future projections (approximately corresponding to the life of the mine) for rainfall and evapotranspiration on the external supply and volume of water stored in the open cut and the Blue Vale void was undertaken using a Monte-Carlo analysis. This involved scaling both the rainfall and evaporation to a randomly selected percentage change within the near future range (approximately corresponding to the life of the mine) for each RCP identified in Table 4.6 over the near future period of time (20 years).

The historical AWDs were also scaled over time to incorporate the projected change in water availability from the Water Availability in the Namoi Report (CSIRO, 2007), with reducing water availability over time.

The water balance model was run with 100 different combinations of randomly selected variations in rainfall and evaporation within the ranges in Table 4.6 for the median climate sequence. The 10^{th} percentile, median and 90^{th} percentile results are shown in Table 8.17. The average results for the base case median climate sequence (i.e. with the parameters adopted to produce the results in Section 8.5) are included in Table 8.17 for comparison purposes.

Table 8.17: Sensitivity Analysis of Climate Change Projections

	Base Case	RCP 2.6			RCP 4.5			RCP 8.5		
		10^{th} %ile	Median	90^{th} %ile	10^{th} %ile	Median	90^{th} %ile	10^{th} %ile	Median	90^{th} %ile
Average supply from Namoi River (ML/y)	547	289	751	936	301	638	926	293	623	993
Maximum annual supply from Namoi River (ML/y)	1,470	1,346	1,686	1,781	1,390	1,510	1,775	1,341	1,554	1,775
Average supply from borefield (ML/y)	54	51	104	189	58	74	178	59	74	192
Maximum annual supply from borefield (ML/y)	284	369	586	916	371	382	916	374	383	917
Max volume in Open Cut (ML)	588	400	555	1,436	410	582	1,314	382	637	1,426
Max volume in Blue Vale Void (ML)	780	413	772	964	354	780	963	194	784	964

Table 8.17 shows that for the mid-range RCP scenario projections there is an increased demand from the Namoi River and groundwater components, however there is a high degree of uncertainty. For example, the average water requirement from the Namoi River under RCP 4.5 ranges from a decrease of 55% to an increase of 23%. However there is not a large variation between the different RCP scenarios as the near future projections for each scenario are not significantly different.

8.8.3 Summary

Overall, the sensitivity analysis indicates that although the different runoff assumptions and climate change projections influence the required amount of imported water, the maximum amount of water held in storage is within the capacity of the proposed water storages and entitlements held by Whitehaven. These results indicate that the conceptual water management system would be capable of operating satisfactorily even if the model assumptions outlined in Sections 7 and 8 differ significantly to those experienced in practice.

The site water balance would be reviewed and revised throughout the mine life and contingency actions implemented if required (for example construction of additional storages, irrigation of mine catchments and/or use of evaporation cannons).

8.9 Operational Water Balance Modelling Conclusion

The water balance modelling results indicate that:

- the Project would be able to operate effectively and meet the water requirements for coal processing and dust suppression in any of the range of climate sequences represented in the historical record;
- the Project would be capable of operating with no discharge of water that had been in contact with coal;
- releases from the sediment dams to restore their capacity within five days of the occurrence of a rainfall event exceeding the design capacity would occur as controlled discharge (subject to water quality constraints or as overflow in rainfall that exceeded the design guideline). Any overflow would have lower frequency than typical values quoted in the relevant guidelines; and
- the results of the water balance analysis are not very sensitive to assumptions regarding the runoff characteristics of the surfaces draining to sediment and CCWDs.

Based on the detailed assessment above, and in consideration of the IESC Information Guidelines (IESC, 2018) (refer Sections 3.1.3.1 and 3.3), the Action would not result in significant changes to the quantity or quality of surface water available to third party users or the environment. Accordingly, the Action would not have a significant impact on surface water resources.

8.10 Mine Void Water Balance Following Mine Closure

Following completion of mining the open cut would be rehabilitated to produce a final void in the south-east corner of the open cut with the following characteristics;

- void surface area (at minimum surrounding ground level) of approximately 258 ha;
- rehabilitated contributing catchment area of approximately 200 ha;
- highwall (i.e. residual open cut highwall subject to limited final landform reshaping and rehabilitation) catchment area (with open cut runoff characteristics) 50 ha;
- base level approximately 30 m AHD; and
- minimum crest level of approximately 265 m AHD.

Figure 8.20 shows the relationship between water level in the final void and the groundwater inflow rate derived from the post-mining 'recovery' scenario in the groundwater model (HydroSimulations, 2018).

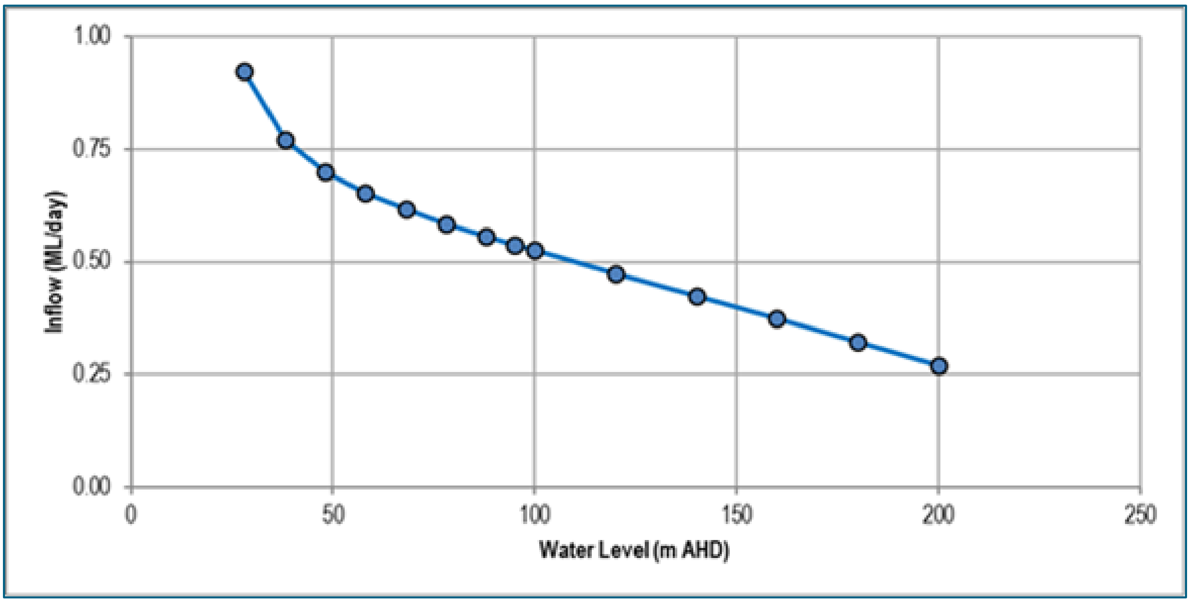


Figure 8.20: Relationship between Void Water Level and Groundwater Inflow

8.10.1 Water Balance in Mine Void

A monthly water balance analysis has been undertaken to establish the water surface areas that would achieve a balance between inputs (runoff, groundwater inflow and direct rainfall) and losses (evaporation) for the following scenarios that represent the 10th and 90th percentile values for the 'high emission' scenario for the 'far future' (see Table 4.6):

- Scenario 1: maximum rainfall reduction (-23%) + minimum evaporation increase (+9.8%);
- Scenario 2: maximum rainfall increase (+18%) + minimum evaporation increase (+9.8%);
- Scenario 3: maximum rainfall reduction (-23%) + maximum evaporation increase (+18.1%);
- Scenario 4: maximum rainfall increase (+18%) + maximum evaporation increase (+18.1%).

The water balance analysis of the void is based on the following assumptions:

- except for the highwall to the east and south of the void, the contributing catchment above the open cut lake water level would be rehabilitated and would have runoff characteristics equivalent to fully rehabilitated mine spoil used in the operational water balance analysis (see Table 8.5);
- runoff characteristics for the highwall are assumed to be the same as those for the open cut used in the operational water balance analysis (see Table 8.5);
- ACARP (2001) documents the results of an investigation of the runoff and water balance in seven remnant mine voids in Queensland and NSW. Many of these voids had a water area of the order of 1,500 m long and 80 m wide with a depth below the surrounding land ranging from 30 m to 65 m. The investigation identified an evaporation 'pan factor' of 0.5 based on the observations of the progressive decline in water level when there was no rainfall. For modelling of the water balance for the Vickery final void, a 'pit evaporation factor' of 0.7 has been applied to the open water evaporation estimated using the monthly 'pan factors' listed in Table 8.2;

- the final void may not be as shaded from the sun or protected from the wind as the long narrow mine voids assessed in the ACARP (2001) study. Accordingly, a 'pit evaporation factor' for evaporation of 1 was also tested (i.e. evaporation from the void lake would be the same as from a water body on the surface of the surrounding land;
- evaporation loss from the water surface also accounts for the reduction in evaporation as salinity increases using equation 4.7.4 from Grayson et al (1996):

  Evaporation = Evaporation (Fresh Water) / (1 + Salinity [mg/L] / 10^6); and
- the void would act as a groundwater sink and the inflow would vary according to the level of water in the void lake using the relationship shown in Figure 8.20.

The modelling accounts for the geometry of the void (depth, area, volume) as determined from the final landform plans.

For purposes of this analysis, a synthetic monthly climate and runoff sequence was generated by calculating the monthly totals for the rainfall, open water evaporation and runoff adjusted to take account of the changes in rainfall and evaporation using the factors listed above for Scenarios 1 – 4. To create a synthetic 1,000 year record, years were then selected at random from the historical record.

Figure 8.21 shows the modelled variation of water level in the void for the existing climate and climate change scenarios.

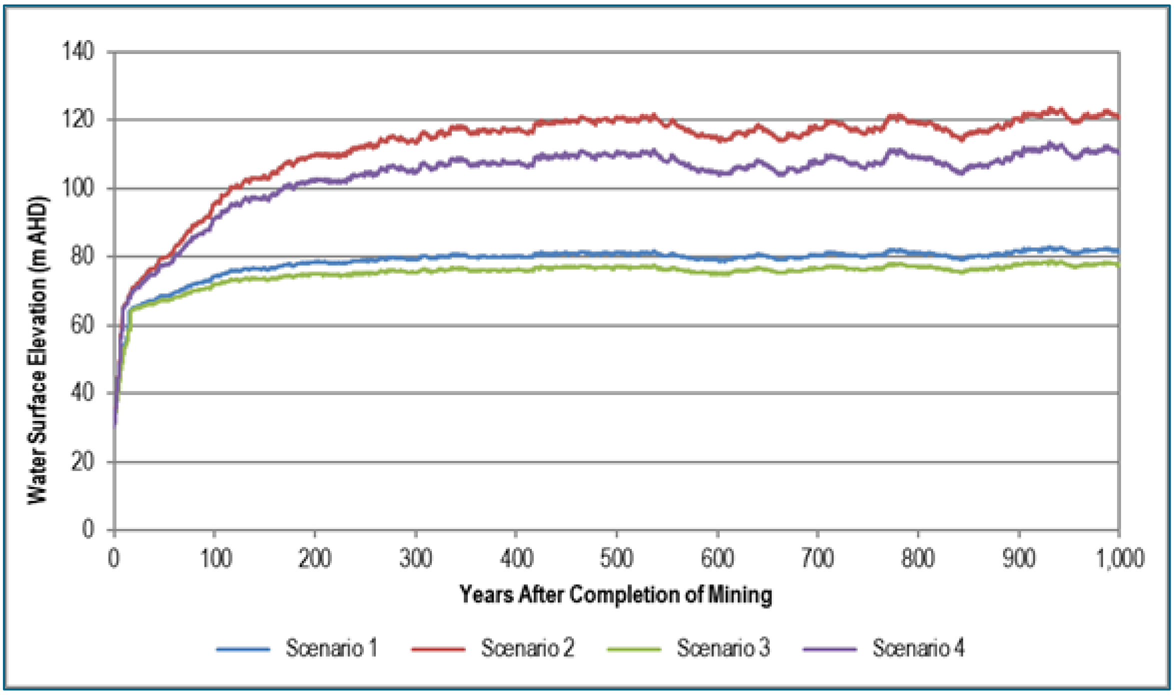


Figure 8.21: Modelled Water Level Variation under Different Climate Scenarios

Key aspects of the results shown in Figure 8.21 are:

- the water level in the void would take approximately 300 years to reach 'equilibrium';
- Scenarios 2 and 4 (increased rainfall) show an equilibrium water level about 30 m to 40 m higher than for Scenarios 1 and 3 (decreased rainfall);

- the difference in evaporation estimates (+9.8% or +18.1%) has significantly less effect on the equilibrium water level compared to rainfall;
- the equilibrium water level for all scenarios is more than 140 m lower than the spill level of the void (265 m AHD) so there is no risk of discharge to the natural environment; and
- the 'equilibrium' water level can be expected to vary depending on the year to year variation in rainfall as shown in Table 8.18. Table 8.18 also includes statistics for water level and water surface area assuming the 'pit evaporation factor' is 1.0.

Table 8.18: Variation of Final Void Water Level and Water Surface Area Post Mining

Statistic	Water Level (m AHD)				Water Surface Area (ha)			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 1	Scenario 2	Scenario 3	Scenario 4
'Pit Evaporation Factor' = 0.7								
Min	78.9	113.4	75.0	103.8	39.1	74.3	35.2	64.5
Average	80.7	118.3	76.8	108.2	41.0	79.2	37.0	69.0
Max	83.0	123.8	79.0	113.4	43.4	84.9	39.2	74.3
'Pit Evaporation Factor' = 1.0								
Min	62.6	83.8	59.7	77.6	26.1	41.9	24.2	37.1
Average	64.7	89.6	62.0	83.0	27.6	46.4	25.6	41.2
Max	67.7	96.0	64.8	89.1	29.8	51.5	27.7	46.0

The data in Table 8.18 shows that the variability between minimum and maximum water levels (and the resulting water surface area) for any scenario is proportionally similar to the difference between the scenarios. In the event that the actual 'pit evaporation factor' is 1.0 (rather than 0.7 as assumed for Figure 8.21), the effect would be that equilibrium water levels would be about 15 m lower. It follows that, for the purposes of assessing the risk of the void filling with water and discharging to the environment, a 'pit evaporation factor' of 0.7 is more conservative. For a pit factor of 0.7, the analysis indicates that the water level would reach a maximum of about 124 m AHD (140 m below the lowest point on the rim of the void). There would, therefore, be no risk of overflow.

8.10.2 Salinity in Final Void

The long-term water balance model also predicts the progressive accumulation of salt associated with the groundwater inflows and surface runoff loads into the final void, as the final void would act as a 'sink' for groundwater. The analysis includes the reduction in evaporation as salinity increases (described above) but excludes any precipitation of salt if hyper-saline conditions occur. The salinity predictions are based on the following assumed salt concentrations:

- groundwater salinity of approximately 2,700 mg/L (which is comparable to the median salinity of the Maules Creek Formation [2,666 mg/L] and the assumed salinity of waste rock [3,000 mg/L] presented in HydroSimulations (2018)); and
- average salinity of surface runoff from the rehabilitated low wall of the final void catchment would be 100 mg/L (160 µS/cm) based on typical water quality in the creek systems in the area (see Table 6.3).

The results of the salinity analysis for the climate scenarios are shown in Figure 8.22. For all scenarios, the salinity can be expected to increase progressively with the accumulation of salt, primarily from groundwater.

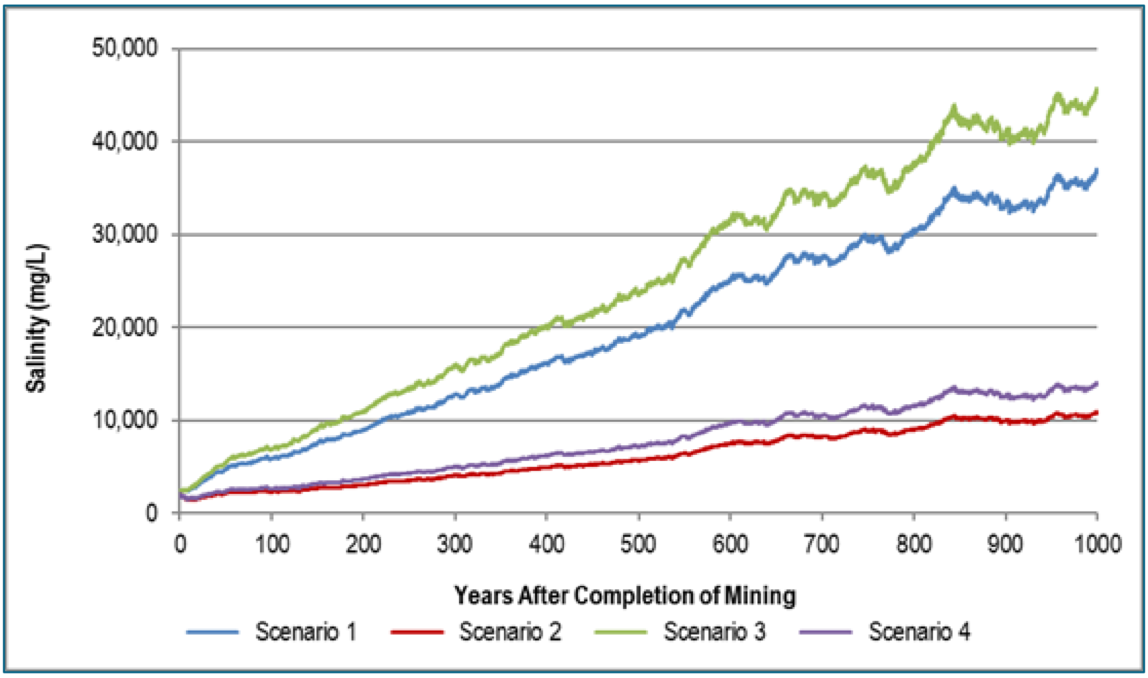


Figure 8.22: Progressive Increase in Salinity under Different Climate Scenarios

Table 8.19 summarises the maximum salinity for the four scenarios, under the two ‘pit evaporation factor’ values. The table shows that highest salinity can be expected to occur under climate scenarios with reduced rainfall (Scenarios 1 and 3) and that increasing the ‘pit evaporation factor’ from 0.7 to 1.0 leads to more than doubling of the maximum salinity.

Table 8.19: Modelled Variation of Maximum Salinity

Pit Evaporation Factor	Maximum Salinity (mg/L)			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
‘Pit Evaporation Factor’ = 0.7	36,956	10,906	45,746	14,007
‘Pit Evaporation Factor’ = 1.0	99,017	29,110	129,229	37,622

9 External Catchments

9.1 Driggle Draggle Creek

9.1.1 Changes in Catchment Area

As outlined in Section 7.2, two up-catchment diversions are proposed to minimise runoff from entering the open cut. These diversions would divert the runoff from the North-West Drainage Line into the North Drainage Line which drains in a north-westerly direction towards Driggle Draggle Creek.

The diversion dam (DD-1), shown on Table 7.1 is proposed to collect runoff from the Vickery State Forest and divert it to a drainage line which would run parallel to the Blue Vale Road realignment to the east of the open cut and discharge into the North Drainage Line. The diversion would be constructed in conjunction with the Blue Vale Road realignment and would operate as a permanent structure.

Diversion dam DD-2 would be constructed early in the Project life at a location downstream of DD-1 on the North-West Drainage Line (see Figure 7.1) to divert local runoff to the North Drainage Line. DD-2 would be designed to operate as a temporary structure, as the area occupied by DD-2 would be subsumed by the open cut sometime before Project Year 7.

Figure 9.1 shows the locations on the existing drainage system at which the progressive change in 'natural' catchment areas over the life of the Project has been assessed, including the effects of the up-catchment diversions described above. The results of this analysis are set out in Table 9.1.

Table 9.1: Catchment Areas at Project Stages

Drainage Line	Location	Existing (km^2)	Year 3 (km^2)	Year 7 (km^2)	Year 13 (km^2)	Year 21 (km^2)	Year 25 (km2)	Post Mining
South Creek	SC3	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	SC2	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	SC1	5.6	5.6	5.6	4.6	4.6	4.6	5.7
West Drainage Line	WDL3	2.9	0.0	0.0	0.0	0.0	0.0	0.0
	WDL2	8.9	0.0	0.0	0.0	0.0	0.0	0.0
	WDL1	21.2	5.0	1.9	1.9	1.9	1.9	5.5
North-West Drainage Line	NWDL4	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	NWDL3	0.6	2.3	2.3	2.3	2.3	2.3	2.3
	NWDL2	4.4	2.1	2.1	0.0	0.0	0.0	0.0
	NWDL1	6.0	0.0	0.0	0.0	0.0	0.0	0.0
North Drainage Line	NDL4	0.5	2.8	2.8	2.8	2.8	2.8	3.1
	NDL3	0.4	3.1	3.1	0.0	0.0	0.0	0.0
	NDL2	1.8	6.3	6.3	3.4	3.4	3.4	10.7
	NDL1	7.0	11.5	9.5	6.7	6.7	6.7	15.9

Drainage Line	Location	Existing (km^2)	Year 3 (km^2)	Year 7 (km^2)	Year 13 (km^2)	Year 21 (km^2)	Year 25 (km2)	Post Mining
Driggle Draggle Creek	DDC3	156.1	156.1	156.1	156.1	156.1	156.1	156.1
	DDC2	163.2	167.6	165.6	162.8	162.8	162.8	172.0
	DDC1	201.7	190.0	184.9	182.1	182.1	182.1	194.9
Stratford Creek	ST3	1.7	1.7	1.7	0.7	0.7	0.7	1.7
	ST2	2.8	2.8	2.8	2.8	0.5	0.5	0.4
	ST1	106.1	105.5	105.5	103.2	99.6	99.4	104.1
Namoi River	NR2	3.9	1.4	1.4	1.4	1.4	1.4	9.1
	NR1	3.0	2.6	2.6	2.6	2.7	2.6	4.2

At the completion of mining, runoff from the top of the waste rock emplacement would be directed via graded swales and contour banks to the Driggle Draggle Creek catchment on the eastern side of the emplacement and to the Namoi River on the western side of the emplacement (refer Figure 7.5 and Section 7.6). A perimeter bund would be constructed around the final void to prevent runoff from the surrounding landform flowing into the final void.

The drainage arrangements outlined above would result in changes to the Driggle Draggle Creek and Namoi River catchments as follows:

- 3.4% decrease in the Driggle Draggle Creek catchment area upstream of Braymont Road; and
- 0.01% reduction in the overall Namoi River catchment attributable to the internal drainage in the final void catchment.

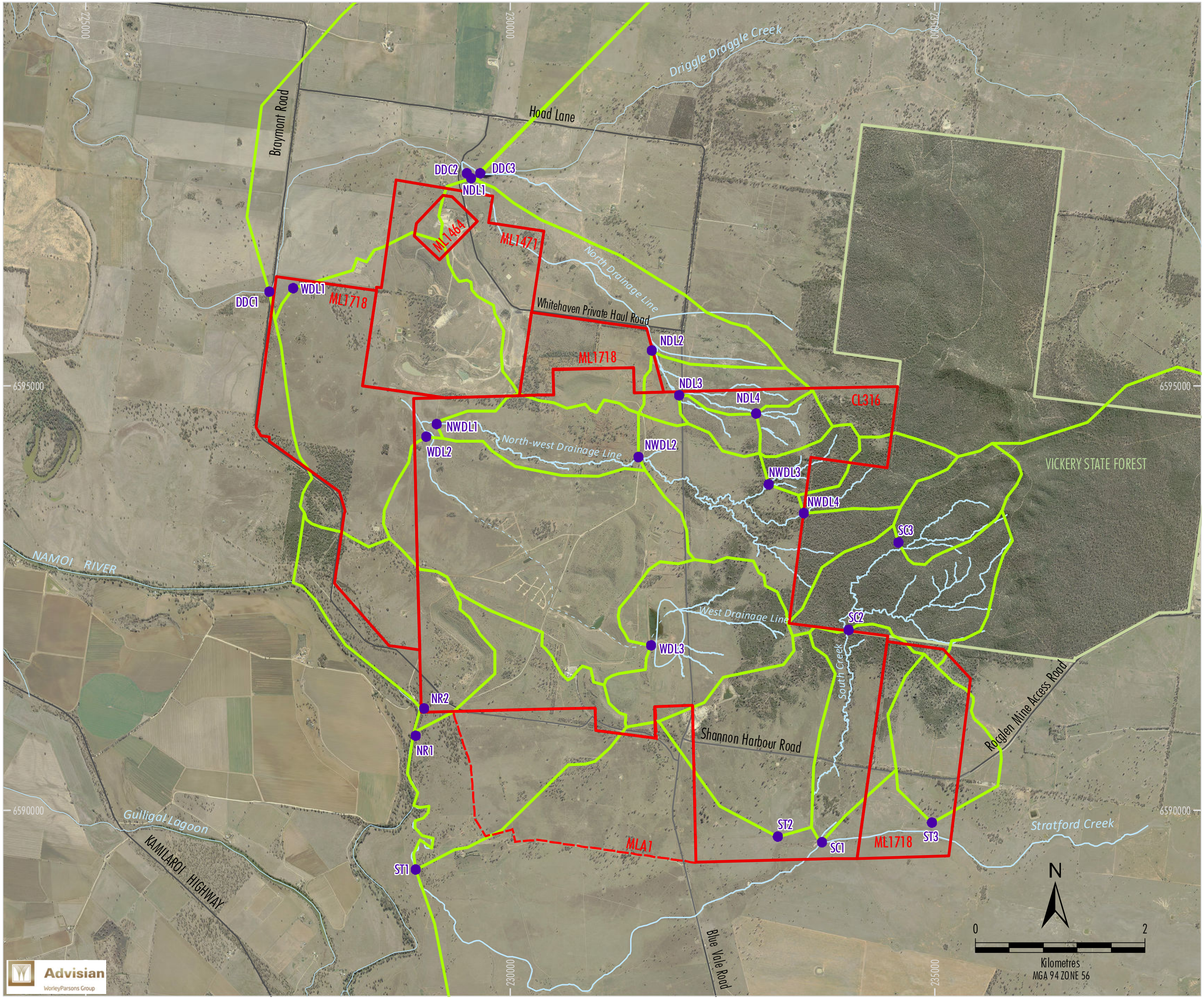
9.1.2 Impacts on Flows

The up-catchment diversions are not expected to cause any significant change to the flows in Driggle Draggle Creek. At the point where the DD-1 diversion discharges, the upstream catchment area of Driggle Draggle Creek is approximately 169.5 km^2. The contributing catchment area of DD-1 is approximately 2.5 km^2, which represents only a 1.5 % increase to the contributing catchment area at this point.

Runoff modelling has been undertaken to assess the impact of the catchment changes set out in Table 9.1 on flow in Driggle Draggle Creek at two locations:

- downstream of the confluence with the North Drainage Line (DDC2 on Figure 9.1); and
- at Braymont Road (DDC1 on Figure 9.1).

The runoff analysis was undertaken using the AWBM model, (previously described in Sections 5.3.2 and 8.2.5) using runoff characteristics derived from recorded rainfall and flow data for the Maules Creek drainage line catchment. Daily runoff volumes were calculated for Driggle Draggle Creek for existing conditions and at each stage of the Project using a 128 year daily climate dataset. The modelling assumes that during mining, all runoff from mine affected catchments would be retained within the mine water management system. For post mining conditions, the modelling assumes that the relevant sections of the final landform that drain in a northerly direction (see Figure 7.5) contribute to the flow in Driggle Draggle Creek. Modelling of runoff for rehabilitated waste rock emplacement areas used the runoff characteristics for 'rehabilitated' as set out in Table 8.5.



LEGEND

- Mining Tenement Boundary (ML and CL)
- Mining Lease Application (MLA)
- State Forest
- Drainage Path
- Modified Drainage Path

Source: Orthophoto - Department of Land and Property Information, Aerial Photography (July 2011)

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VICKERY EXTENSION PROJECT

Location for Assesment of Changes in Catchment Area

Figure 9.1

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Table 9.2 provides statistics for modelled flows in Driggle Draggle Creek downstream of the confluence with the North Drainage Line (DDC2) while Table 9.3 provides statistics for Driggle Draggle Creek at Braymont Road (DDC1). In each case the table illustrates the overall impact of the Project on the flow regime throughout the Project life and post mining (following rehabilitation).

Table 9.2: Modelled Flow Statistics for Driggle Draggle Creek Downstream of the Confluence with the North Drainage Line (DDC2)

	Pre-mining	Year 3	Year 7	Year 13	Year 21	Year 25	Post Mining
Area (km^2)	163.2	167.6	165.6	162.8	162.8	162.8	172
10^{th} Percentile Year (ML/Year)	0	0	0	0	0	0	0
Median Year (ML/Year)	15	18	18	18	18	18	19
90^{th} Percentile Year (ML/Year)	4,391	4,624	4,493	4,419	4,419	4,419	4,664

Table 9.3: Modelled Flow Statistics for Driggle Draggle Creek at Braymont Road (DDC1)

	Pre-mining	Year 3	Year 7	Year 13	Year 21	Year 25	Post Mining
Area (km^2)	201.7	190.0	184.9	182.1	182.1	182.1	194.9
10^{th} Percentile Year (ML/Year)	0	0	0	0	0	0	0
Median Year (ML/Year)	19	21	20	20	20	20	21
90^{th} Percentile Year (ML/Year)	5,427	5,225	5,009	4,936	4,936	4,936	5,278

The statistics in Table 9.2 and Table 9.3 show that Driggle Draggle Creek is a highly ephemeral creek with no flow in at least 10% of the years, only very modest flow in median years, and flow in the order of 5,000 ML/year in the wettest 10% of years.

For Driggle Draggle Creek downstream of the confluence with the North Drainage Line (DDC2), the data in Table 9.2 shows:

- an initial increase in the contributing catchment as a result of the construction of the diversions followed by a reduction as the disturbance area encroaches on the catchment of the North Drainage Line;
- a 5.4% increase in the contributing catchment area post-mining as a result of the change in the catchment boundary in the final landform;
- small changes in the median and 90^{th} percentile flows during mining that reflect the changes in the catchment areas;
- a minor increase in the median and 90^{th} percentile flows following mining attributable to a small increase in catchment area and the increased runoff expected from the rehabilitated waste rock emplacements compared to the pre-mining conditions.

For Driggle Draggle Creek at Braymont Road (DDC1) the data in Table 9.3 shows:

- an initial decrease in the contributing catchment as a result of the open cut and Western Emplacement being developed in the catchment area, with minor decreases in subsequent years as the Western Emplacement extends westwards;

- a 3.4% decrease in the contributing catchment area post-mining as a result of the change in the catchment boundary in the final landform. This decrease corresponds with an increase in the catchments that go directly into the Namoi River, changes in the catchment due to the final void and a section of the Western Drainage Line that will drain to the Namoi River;
- small changes in the median and 90th percentile flows during mining that reflect the changes in the catchment areas;
- a minor decrease in the 90th percentile flows following mining attributable to the decrease in catchment area compared to the pre-mining conditions.

The minor changes in flows in Driggle Draggle Creek as a result of the Project are not expected to have any effect on the geomorphologic characteristics or riparian values of the creek itself or the downstream receiving waters in Barbers Lagoon.

9.2 South Creek and Stratford Creek

As shown in Table 9.1:

- The catchment of South Creek will not change significantly overall as a result of the Project. The catchment for South Creek at SC1 reduces at around Year 13 due to the construction of the secondary infrastructure area. However, runoff from this area will be captured by SD-F and then be periodically released in a controlled manner (as described in Section 7.4). Runoff from this catchment will therefore be returned to the system on a regular basis with the only 'loss' being attributable to evaporation from SD-F. Accordingly, the flow regime and geomorphic characteristics would not be significantly affected by the Project.
- The catchment of Stratford Creek at ST1 gradually reduces over the life of the mine by 2 km^2 (2%). This is attributable to the internal drainage in the final void catchment. The flow regime and geomorphic characteristics would not be significantly affected by the Project.

The *Carroll to Boggabri Floodplain Management Plan* (Webb, 2006) identifies that in the vicinity of the Project, Stratford Creek, South Creek and the North-West Drainage Line have been designated as having riparian zones. These areas were defined from interpretation of aerial photography for the Liverpool Plains Region (currently held by OEH) for purposes of defining the Riparian Zones within the *Liverpool Plains Regional Vegetation Management Plan* (Department of Land and Water Conservation, 2002). The FMP recommends that riparian buffer zones be maintained to help maintain the integrity of the banks and the general health of the creeks and the adjacent cultivated land by:

- decreasing the disturbance to creek and river banks in non-flood times;
- establishing riparian buffer areas; and
- stabilising creek banks by artificial means in areas that are dangerous or place permanent infrastructure at risk.

Guidelines for the required widths for riparian corridors are set out in the Guidelines *for Controlled Activities on Waterfront Land - Riparian Corridors* (NRAR, 2018). As noted in Section 3.3, works within riparian zones require a 'controlled activity approval' under the *Water Management Act 2000*. Notwithstanding that the EP&A Act provides an exemption for separate approvals relating to works within riparian corridors for projects assessed as State Significant Development, the requirements for works within or adjacent to riparian zones have been taken into account in identifying setbacks from South Creek within the Project area.

South Creek flows southward between the open cut and the secondary infrastructure area from the Vickery State Forest to the north and drains into Stratford Creek, as shown on Figure 7.1 to Figure 7.5. The secondary infrastructure area would be constructed on the eastern side of South Creek, while the open cut would be constructed to the west of the creek.

In accordance with the Guidelines *for Controlled Activities on Waterfront Land - Riparian Corridors* (NRAR, 2018), riparian protection of South Creek would be provided by considering:

1. **Core Riparian Zone (CRZ)** – as South Creek is a 4th order Strahler watercourse, this width should be between 20 to 40 m wide or taken conservatively as 40 m (refer page 2 of guidelines).
2. **Vegetated Buffer (VB)** – recommended width is 10 m.
3. **Asset Protection Zone** – as there are no assets, this requirement is not applicable.

In addition to the total width of 50 m (CRZ + VB), the design of the secondary infrastructure areas has made provision for the construction of a bund and drainage line to convey runoff from secondary infrastructure areas into the relevant sediment dam (SD-F) outside the riparian zone.

On the western side of South Creek, a 50 m riparian zone would also be provided between the creek and the toe of a bund to protect the open cut and the final void from floodwater in South Creek.

9.3 Namoi River

During mining, the catchment area draining direct to the Namoi River would be temporarily reduced by up to about 2.5 km^2 at any time. Following completion of mining, the total catchment draining to the Namoi River would be reduced by the area of the final void (2.4 km^2) or a reduction of 0.01% in the total catchment area. An area of about 9 km^2 of rehabilitated waste rock emplacement area would drain towards the Namoi River while the remainder of the emplacement area would drain towards Driggle Draggle Creek (as described in Section 9.1). These changes would not lead to any perceptible or measurable change in flows in the river.

The measures to protect the quality of the water in the watercourses surrounding the site (see Section 9.4) would also ensure there was no change in the overall water quality of the Namoi River. Accordingly, no impacts to downstream water users on the Namoi River are predicted as a result of the Project.

9.3.1 Cumulative Changes in Catchment Area

The *Tarrawonga Coal Project Surface Water Assessment* (Gilbert & Associates, 2011) considered the potential cumulative impacts of the Tarrawonga Coal Mine, the Boggabri Coal Mine and the Maules Creek Coal Mine in the context of potential reduction in catchment area of the Namoi River. The potential cumulative interaction of the Project with the projects assessed by Gilbert & Associates (2011) is considered in Table 9.4.

Table 9.4: Catchment Areas at Each Stage of the Project

Scenario	Percentage Reduction in Namoi River Contributing Catchment (%)
Project (incorporating the Approved Mine)	
Project – Year 3	0.02
Project – Year 7	0.05
Project – Year 13	0.05
Project – Year 21	0.07
Other Mining Projects	
Tarrawonga Coal Mine	0.02
Boggabri Coal Mine	0.04
Maules Creek Coal Mine	0.04
Rocglen Coal Mine	0.01
Potential Maximum Cumulative Impact	**0.18**
Approved Mine Maximum Cumulative Impact	0.16
Incremental Change Due to the Project	**0.02**

Based on this estimate, it is considered that the maximum cumulative reduction in contributing catchments to the Namoi River during the life of the Project would be approximately 0.18% (an increase of approximately 0.02% from the Approved Mine). This conservatively assumes that the maximum reduction in contributing catchments for each individual mine was to occur at the same time.

On this basis, negligible change in flows in the Namoi River are expected as a result of cumulative changes in catchment area, particularly when considering flows in the Namoi River where it passes the Project are controlled by releases from Keepit Dam.

9.4 Potential Impacts on Water Quality in External Watercourses

All water in contact with coal in the open cuts or the mine infrastructure area would be retained on-site and would not be discharged to the environment.

Sediment laden runoff from the site would be controlled as follows:

- Runoff from the waste rock emplacement areas would report to a series of sediment dams which would be sized and operated in accordance with the guidelines in *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004). As described in Section 8.7, water balance modelling shows that the proposed sizes of the sediment dams would lead to 'wet weather discharges' (as permitted by Landcom (2004)) less frequently (typically about once every four years on average) than the expected Landcom (2004) frequency of two to four wet weather discharge events per year. Any such discharges would only occur as a result of prolonged heavy rainfall when the local watercourses would likely have elevated levels of suspended solids (unrelated to mining activities).
- In the event that controlled discharge of water from a sediment dam is required (i.e. to restore capacity), the water would be allowed to settle (with the aid of an environmentally safe flocculent if necessary) in order to ensure that any discharge had a suspended solids concentration of less than 50 mg/L.

- Wet weather discharges and discharges to restore sediment dam capacity would be undertaken in accordance with an Environment Protection Licence (EPL) issued by the EPA for the Project which would specify water quality requirements and limits, including conditions for water quality monitoring and discharge.
- As described in Section 7.7, the *Geochemistry Assessment* (GEM, 2018) recommends that, in order to ensure long-term stability and erosion control for the waste rock emplacement, any areas of the final waste rock emplacement face that exhibit some erosion would be treated with gypsum. In general, as part of the mine's rehabilitation strategy, soil that has been stripped from the site in advance of mining would be used to cover the waste rock emplacement face to facilitate rehabilitation. This would have the effect of limiting the concentration of sediment in the runoff from the waste rock emplacement reporting to sediment dams.

The *Geochemistry Assessment* (GEM, 2018) identifies that the coal reject material is expected to be generally NAF and non-saline to moderately saline. The small amount of reject material that was characterised as being PAF has a low sulphur content, so this material is expected to have only a low capacity to generate acid. To manage acid generation potential, dewatered coal reject material would be co-disposed with waste rock within the waste rock emplacement areas. Isolation of these materials from any surface runoff from rehabilitated areas would ensure that they would not affect runoff quality.

It is expected that the EPL issued for the Project would be similar to the existing EPLs for the Tarrawonga, Boggabri, Maules Creek and Rocglen mines. The approved water management systems and EPLs for these mines do not allow for any discharge of mine water. The EPLs provide for the controlled discharge of water from sediment dams in order to restore capacity within five days of rainfall events within the water quality limits specified by the EPL. The EPLs also allow for 'wet weather discharges' from sediment dams following significant rainfall events when the design capacity of the sediment dam has been exceeded and where all practical measures have been taken to restore capacity within five days of rainfall events. In such events there would be a significant dilution effect in the receiving environment due to higher river flows.

The proposed water management system for the Project is described in Section 7, mitigation and management measures are described in Section 10, and monitoring and licensing measures are outlined in Section 11. Sections 7.4, 7.8 and 10.5 provide further detail of the approach to the design and operation of the sediment dams.

The measures outlined above are designed such that any overflow or controlled discharge from the sediment dams would have low concentrations of suspended sediment, minimal salinity and close to neutral pH and would be similar to the water quality in local watercourses following prolonged heavy rainfall events.

10 Mitigation and Management Measures

10.1 Overview

The proposed water management system described in earlier sections has been designed on the basis of a number of basic principles for water management on any site (mining or industrial) to ensure minimal surface water impacts (flow or water quality) outside the site, including:

- source control of potential sources of pollution to minimise the exposure of potential pollutant sources to water;
- maintenance of separation of water of different quality; and
- recycling of site water for appropriate purposes depending on the water quality.

In accordance with the principle of maintaining separation of water of different quality, runoff from undisturbed natural catchments would be diverted around the Project disturbance area where possible.

10.2 Management of Mine Water/Coal Contact Water

'Coal contact water' is defined as any water that has been in contact with coal. For the Project, mine water would be used as the primary source to maintain the supply of processing water to the Project CHPP.

Apart from water contained in the coal rejects (after mechanical dewatering) and moisture in product coal, all water used in the Project CHPP would be recycled.

Water supply for dust suppression on the ROM pad and product coal stockpile would be preferentially drawn from the mine water dams. This source would also be used for general dust suppression and maintenance within the mine infrastructure area.

No mine water would be discharged from the site. In the event of there being excess mine water that cannot be stored in MWD-1, water would be temporarily stored in the Blue Vale void. The site water balance would be reviewed and revised throughout the mine life and contingency actions implemented if required (for example, construction of a MWSS or other storages, irrigation of mine catchments and/or use of evaporation cannons).

The operation of the system for management of mine water/coal contact water is dependent on the sizing of the two MWDs and Blue Vale void, and the ability to transfer water from the open cut and water storage dams by means of pumps and pipelines (or other mechanism). Procedures should be implemented to regularly inspect and maintain pipelines. In the event that a leak from a pipeline is detected, it should be repaired promptly to avoid inadvertent discharge of mine water in locations where the water could drain off site, either directly or via a sediment dam.

10.3 Construction and Rehabilitation of the Waste Rock Emplacement Areas

The majority of waste rock, interburden and coal reject material requiring emplacement for the Project is expected to be NAF (GEM, 2018).

The construction of the waste rock emplacement areas would include a range of measures designed to manage exposure to the small proportion of total material expected to be PAF:

- the small proportion of PAF material is expected to blend with NAF material to produce an overall NAF material during the waste rock emplacement process;
- PAF materials would not be placed within the final lift of the waste rock emplacements; and
- coal reject material would be co-disposed with waste rock within the waste rock emplacement areas. No reject material would be placed within 30 m of the edge of the Western Emplacement and reject material would be covered with at least 5 m of inert material on the outer surfaces of the waste rock emplacement.

Measures to maximise the control of erosion would include:

- batter slopes on the waste rock emplacement areas would be graded to have an appropriate slope, consistent with the requirement to minimise the footprint of the emplacements;
- contour drains would be used to break-up steeper slopes in order to minimise rill and gully erosion from concentrated flow;
- waste rock emplacement areas would be progressively shaped and revegetated; and
- the small amount of sodic material (with the potential to become dispersive if left exposed) expected to be encountered would be mixed with non-sodic material during the waste rock removal and emplacement process which would result in the waste rock emplacements having an overall low sodic nature; and any areas of the final waste rock emplacement face that exhibit erosion would be treated with gypsum.

In addition to these measures to control the volume and quality of runoff from the surface of the emplacement, all water conveyance structures would be designed and constructed to safely convey flow resulting from a 1% AEP rainfall event.

10.4 Sediment Dam Sizing and Operation

A series of sediment dams would be constructed to control runoff from the waste rock emplacement areas. Key features of the design and management of these facilities in order to minimise any off-site impacts would be:

- The sediment dams would be sized and operated in accordance with the guidelines in *Managing Urban Stormwater: Soils & Construction* (Landcom, 2004) and outlined in Section 7.8, namely:
  - sufficient capacity to retain the runoff from a 90th percentile five day rainfall event of 38.4 mm as well as provide an additional 50% for sediment storage (as well as additional capacity to provide supply for water carts); and
  - pump and pipeline facilities (or other transfer mechanisms) with sufficient capacity to transfer water to a mine water dam and restore the runoff capture capacity of the sediment dams within five days of the end of the rainfall event. In practice, transfer would commence before the end of a rainfall event and this would further limit the frequency of overflow.

- In addition to water being transferred to a mine water dam, water would also be available from the sediment dams for supply to water carts.
- The water balance modelling demonstrates that the design and operation of the sediment dams as set out above would lead to overflows (as permitted by the guidelines) less frequently than the expected frequency of two to four overflow events per year.
- Any overflows from the sediment dams would only occur as a result of rainfall in excess of 38.4 mm in five days when the local creeks would have elevated levels of suspended solids.
- In the event that controlled discharge of water from a sediment dam is required (because of limited storage capacity in a mine water dam), the water would be allowed to settle (with the aid of an environmentally safe flocculent if necessary) in order to ensure that any discharge had a suspended solids concentration of less than 50 mg/L.
- As outlined in Section 7.4, water from SD-F will not be transferred to the MWDs but will be treated prior to discharge to receiving waters.

The operation of the system for management of sediment laden water is dependent on the sizing of the sediment dams, the capacity of the mine water dams, and the ability to transfer water from the sediment dams by means of pumps and pipeline or other method. The site Water Management Plan would contain procedures to ensure that the pumps and pipelines were operational at all times. The plan would also include measures to ensure that pipelines are regularly inspected, maintained and promptly repaired so as to ensure there would be no inadvertent discharge off site.

10.5 Site Discharges from Sediment Dams

As noted in Section 10.2, all water that has been in contact with coal (i.e. mine water) would be retained on-site.

Controlled discharges from sediment dams (refer Sections 7.4 and 7.8) would only occur in order to restore sediment dam capacity for the next rainfall event and would be undertaken in accordance with an EPL for the Project under the following circumstances:

- rainfall in excess of 38.4 mm over five days has been received in the vicinity of the Project and there is insufficient capacity in the MWDs and water carts to receive water from the sediment dams;
- controlled discharges would occur within five days of the end of the rainfall event; and
- prior to controlled discharge, the water would be sampled and analysed to confirm its suitability for discharge in accordance with EPL requirements, including demonstrating a TSS concentration of less than 50 mg/L (if required, flocculation may be required prior to discharge to ensure that water quality is within acceptable EPL limits).

Overflows from sediment dams would only occur in the event of a storm rainfall in excess of the design rainfall (38.4 mm over five days) and after all possible transfers of water to the MWDs and water carts has occurred. Overflows would be managed in accordance with Project EPL requirements.

These controls, together with the control of pollutant sources summarised in Section 10.3 would result in the Project having negligible impact on water quality in the receiving creeks.

The landform that would be developed progressively during the Project would lead to changes in the catchment areas draining to creeks surrounding the Project. Section 9.1 shows that the main changes would affect catchments draining to Driggle Draggle Creek. However, the change in catchment area during the Project and post-mining would only lead to a minor decrease in the flow in the creek during conditions that were wetter than average. Any decrease in flow in Driggle Draggle Creek would not have any measurable impact on the flow in the Namoi River.

10.6 Air Quality Control

Air quality control is a key environmental management issue for any open cut mine. For the Project, the following measures have been adopted to ensure that there would be adequate water available for air quality control:

- The water requirements for dust suppression on haul roads and hardstand areas has been based on water usage and air quality control data from Tarrawonga Coal Mine which is operated by Whitehaven and is located about 12 km north of the Project area. An analysis of air quality control for the Tarrawonga Coal Mine (Pacific Environment Ltd, 2014), demonstrated an average dust control efficiency of about 90% (compared to the EPA's requirement for 80% efficiency). Water use and active haul road length data from Tarrawonga Coal Mine (January 2012 to March 2016) showed that water application for dust suppression ranged from 7.2 mm/day in February to 1.6 mm per day in June with an average over all months of 4.7 mm/day. These water usage rates have been incorporated into the water balance modelling, which demonstrates that adequate water supply would be available for all climate scenarios.
- Water cart refill points would be distributed throughout the site. The overall effect would be to maximise water cart availability, particularly on hot windy days which would be critical for dust control.
- In the event of water shortage, chemical suppressants may be used to improve dust suppression. Chemical suppressants can typically reduce the water requirement by 50%.

10.7 Water Balance and Security of Supply

The main sources of water supply for mine operations would be:

- runoff from the catchment reporting to the open cut;
- runoff from the waste rock emplacement areas;
- runoff from the mine infrastructure area, including the ROM pad and product coal stockpile;
- licensed groundwater supply for the ablution facilities and amenities; and
- additional supply from licensed groundwater and Namoi River sources.

The water balance modelling shows that the proposed water management system would be capable of meeting all operational water requirements with the following additional supply:

- life of Project average licensed extraction from the Namoi River ranges from 470 to 655 ML/year, with annual extraction ranging from 0 to 1,465 ML/year, depending on mine year; and
- life of Project average licensed extraction from groundwater bores ranges from 57 to 107 ML/year, with annual extraction ranging from 0 to 390 ML/year.

As shown in Table 8.13, the average requirement for additional supply over the life of the mine ranges from about 530 ML/year to about 740 ML/year. Table 8.13 demonstrates that the requirement for additional water supply is within the available licensed allocations (surface and groundwater) of 2,147.5 shares (Table 3.3).

In the unlikely event where the requirement for additional water supply exceeds the available licensed allocation, Whitehaven would make use of the carry-over provisions in the rules of the WSP or would seek a temporary transfer.

If these options were not available, measures such as the use of chemical dust suppressants could be used. The impacts of the use of chemical dust suppressants on the annual external water demand were assessed using the water balance model. For modelling purposes, it was assumed that demand for water for dust suppression would be reduced by 50% when monthly rainfall was less than the 25th percentile, and this would continue until monthly rainfall was greater than the 50th percentile. The results of the analysis are shown graphically for the median and 10th percentile dry climate sequences on Figure 10.1 and Figure 10.2 respectively. In these Figures the base case is the total annual extraction from the Namoi River and bore as shown in Figure 8.18 and Figure 8.19.

The model demonstrated that use of chemical dust suppressants could reduce the total external water demand by approximately 25%, as water for dust suppression accounts for approximately 70% of the total water demand for the Project.

The water balance analysis outlined below demonstrates that there would be adequate and secure water supply for the life of the Project.

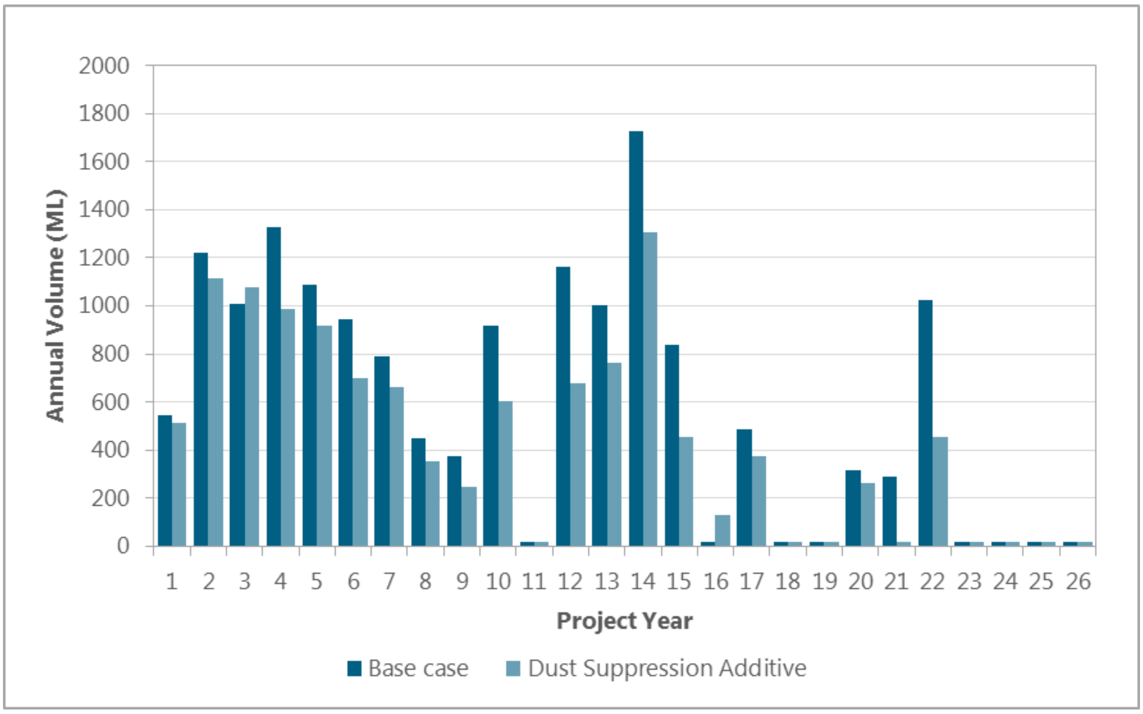

Figure 10.1: Annual External Water Source Extraction for Median Climate Sequence (commencing 1981) with Dust Suppression Additive used during Dry Periods

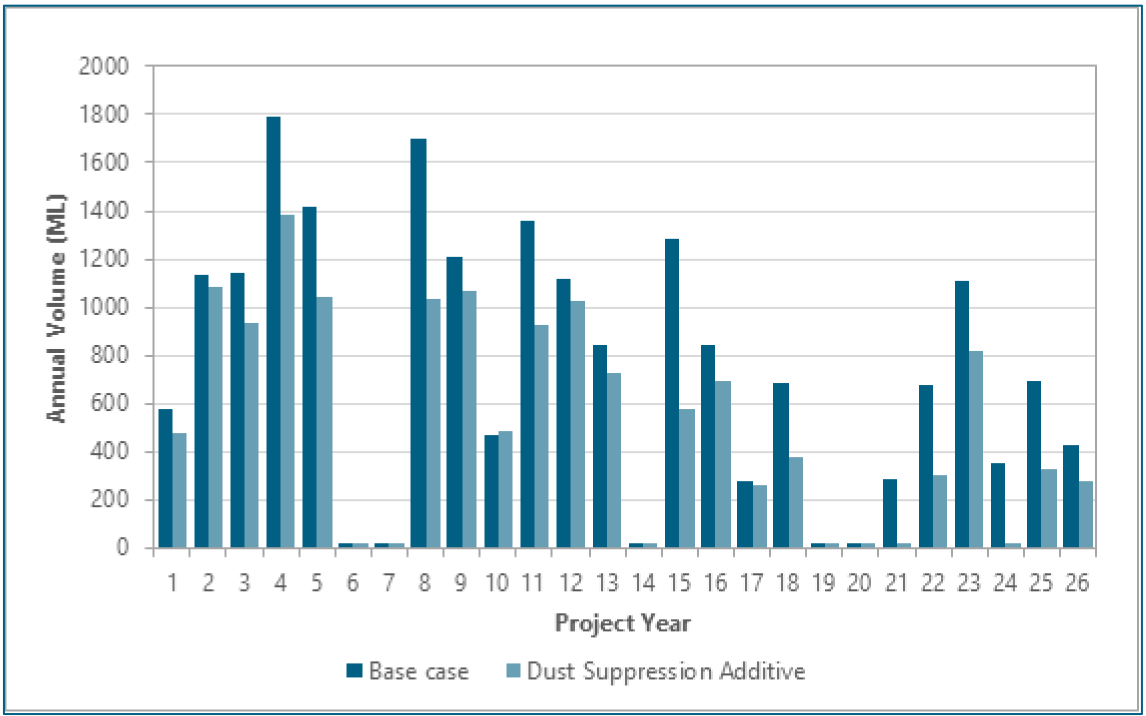

Figure 10.2: Annual External Water Source Extraction for Dry Climate Sequence (commencing 1915) with Dust Suppression Additive used during Dry Periods

10.8 Management of the Final Void

A final void with a total catchment area of 258 ha will remain at the completion of the Project. The void would have steep highwall batters on the eastern and southern sides. Bunding around the perimeter of the void would be constructed to exclude runoff from the adjacent rehabilitated waste rock emplacement areas and from floodwater from South Creek and Stratford Creek.

The required bund level on the eastern and southern boundaries of the void, necessary to exclude floodwater from South Creek and Stratford Creek has been assessed in the *Flood Assessment* (WRM, 2018).

Groundwater modelling indicates that the final void would remain a groundwater sink. The water balance modelling for the final void takes account of predicted groundwater inflows, catchment runoff and evaporation loss from the surface of the lake that would form in the final void. The modelling also takes account of current climate predictions for the 'far future'. Depending on the adopted long-term climate scenario (Section 8.10.1), the modelling indicates that an equilibrium water level would be achieved between approximately 80 m AHD (under a decreased rainfall climate scenario) and around 110 - 120 m AHD (under an increased rainfall climate scenario). This indicates that the water level would be at least 140 m below the spill level (approximately 265 m AHD). There would therefore be no risk of discharge to the environment from the void lake.

The water balance modelling also accounts for the progressive accumulation of salt in the void, primarily from groundwater inflow. The analysis indicates that the salinity would progressively increase to reach salinity comparable to seawater under a decreased rainfall climate scenario (Section 8.10.2). Increased rainfall scenarios would result in lower salinity within the void lake.

11 Monitoring and Licensing

11.1 Water Management Plan

A Water Management Plan would be developed for the Project. The Water Management Plan would include a full description of monitoring and management measures, which are summarised below and would describe the design objectives and performance criteria.

11.1.1 Climate Monitoring

From a surface water management perspective, the key factors to be monitored are rainfall and evaporation.

A meteorological monitoring station has been installed at the Canyon Coal Mine to the immediate north of the Project to obtain ongoing meteorological monitoring. Parameters measured at the station include temperature, humidity, barometric pressure, wind speed and direction, rainfall (depth and rate), solar radiation and dew point.

These parameters can be used to calculate evaporation using the Penman-Monteith equation, which is considered more representative of evapotranspiration conditions than the traditional Class A evaporation pan and can be adapted to estimate open water evaporation.

11.1.2 Site Surface Water Monitoring and Discharge

The Water Management Plan would include trigger levels for investigating any potentially adverse impacts associated with the Project including downstream surface water and groundwater quality.

Six sediment dams (SD-A to SD-F) would be constructed as necessary to control all runoff from the waste rock emplacement areas that drain away from the open cut.

Figure 6.1 shows the proposed locations at which monitoring would be undertaken for any controlled discharge from the sediment dams.

Water quality monitoring during a controlled discharge would be conducted in accordance with an EPL for the Project, and could include analysis of the following parameters:

- conductivity
- TSS
- pH
- oil and grease
- total organic carbon

Consistent with the recommendations of the Geochemistry Assessment (GEM, 2018), water quality monitoring of sediment dams could include analysis of the following parameters:

- Total alkalinity/acidity
- SO_4
- Al
- As
- Mo
- Se

11.1.3 Ambient Surface Water Quality

Ambient surface water quality monitoring should continue to be undertaken at the following sites historically monitored in the immediate vicinity of the Project as shown on Figure 5.1 and Figure 6.1:

- Driggle Draggle Creek - WW11
- Driggle Draggle Creek - Site 14
- Driggle Draggle Creek - Site 6 (Barbers Lagoon)
- Stratford Creek - Site 12
- Namoi River - Site 1
- Adjacent to the Namoi River - JR
- Adjacent to the Namoi River - BR
- Namoi River - Site 7

In addition, it is recommended that an additional monitoring site be established on Stratford Creek upstream of the secondary infrastructure area.

The creeks surrounding the site are highly ephemeral. Accordingly, monitoring at these locations would continue to be on an opportunistic basis whenever sufficient rainfall occurs to cause flow. Water quality monitoring at these locations should include the same suite of parameters specified in the EPL conditions for other mines in the vicinity:

- conductivity
- TDS
- TSS
- turbidity
- pH
- oil and grease
- total organic carbon

The monitoring locations, monitoring parameters and monitoring frequency would be described in detail in the Water Management Plan for the Project.

11.1.4 Water Balance Monitoring and Management

The water balance assessment provided in Section 8 of this report is based on the best currently available science in relation to runoff characteristics of the various types of mine surfaces. The water balance analysis provides the basis for the assessment of water security for operational purposes and the proposed staging of construction of various water storages.

However, the runoff characteristics of the open cut and waste rock emplacements exhibit significant variation depending on the local climate and geology as well as the particular characteristics of the mining operation. It is therefore proposed that sufficient monitoring of all the components of the mine water balance be conducted to permit periodic reviews of the mine water balance modelling to re-assess the required volume and timing for construction of future mine water dams. Specifically, it is recommended that this includes:

- continuous monitoring of rainfall and other meteorological variables by means of an automatic weather station. Calculation of daily rainfall, evapotranspiration and open water evaporation from the meteorological data;
- monitoring of water levels in the mine water dams;
- installation of total flow meters to monitor inflows to and outflows from the mine water dams;
- installation of total flow meters to monitor the volume of water extracted at each water cart fill point; and
- installation of total flow meters to monitor the volume of water delivered to and returned from the Project CHPP.

Prior to commencement of operations a site Water Management Plan would be prepared that reflects details of the detailed design of the mine and its water management facilities. The operating rules for the water management system would be further developed at that time and would be reviewed as part of the periodic review of the Water Management Plan to reflect operating experience and improved data relating to the runoff characteristics of the various land surfaces within the Project area.

11.2 Licensing and Approvals

Surface water related licences and subsidiary approvals required for the Project would include an Environment Protection Licence specifying conditions for water quality monitoring and discharge.

As discussed in Section 3.1.1.1, dams located on a first or second order stream solely for the capture, containment and recirculation of mine affected water consistent with best management practice to prevent the contamination of a water source are "excluded works" and do not need to be licensed under the *Water Management Act 2000*. Therefore, it is not expected that the sediment dams and mine water dams proposed for the Project (as identified in Table 7.1) would require licensing.

As outlined in Section 3.1.1.1, other dams totalling 138 ML could be constructed on first or second order streams without the requirement for a license under harvestable rights.

Water supply works approvals and controlled activity approvals under the *Water Management Act 2000* are not required for State Significant Development.

12 References

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Annexure A

Surface Water Quality Data

Mine Site	Sample Location	Date (italics indicative only)	Time	EC (µS/cm)	pH	TSS (mg/L)	Total Organic Carbon (mg/L)	Grease & Oil (mg/L)
Vickery	BR	13 September 2011	9:55	136	3.87	200	12	<5
Vickery	BR	29 September 2011	10:05	27	6.63	318	5	<5
Vickery	BR	24 November 2011	12:00	78	6.69	158	16	<5
Vickery	BR	6 February 2012	10:40	216	6.98	27	41	<5
Vickery	BR	13 July 2012	13:00	70	7.03	69	25	<5
Vickery	BR	21 April 2015	16:33	71	7.24	32	15	<5
Vickery	BR	17 June 2015	09:47	57	7.24	81	14	<5
Vickery	BR	3 August 2016	14:38	66	7.10	30	16	<5
Vickery	BR	25 August 2016	11:35	91	7.32	384	16	<5
Vickery	BR	14 September 2016	11:18	77	7.37	24	22	<5
Vickery	JR	13 September 2011	9:40	113	7.53	134	8	<5
Vickery	JR	29 September 2011	9:05	44	6.91	21	9	<5
Vickery	JR	24 November 2011	12:15	94	6.81	15	31	<5
Vickery	JR	6 February 2012	10:20	218	7.18	13	23	<5
Vickery	JR	13 July 2012	13:15	116	7.48	20	20	<5
Vickery	JR	27 August 2014	15:19	98	7.43	7	13	<5
Vickery	JR	21 April 2015	16:42	43	6.99	59	8	<5
Vickery	JR	17 June 2015	09:38	102	7.48	56	7	<5
Vickery	JR	24 June 2016	11:34	127	7.32	338	6	<5
Vickery	JR	3 August 2016	14:30	54	7.29	39	8	<5
Vickery	JR	25 August 2016	11:50	118	7.65	58	12	<5
Vickery	JR	14 September 2016	11:27	100	7.56	21	13	<5
Vickery	VUD	13 September 2011	8:15	37	6.79	34	12	<5
Vickery	VUD	29 September 2011	9:35	38	7.15	28	8	<5
Vickery	VUD	24 November 2011	12:35	72	6.48	10	21	<5
Vickery	VUD	6 February 2012	9:40	111	7.25	10	19	<5
Vickery	VUD	11 July 2012	10:00	44	6.88	16	22	<5
Vickery	VUD	29 January 2013	15:32	102	6.63	18	51	<5
Vickery	VUD	1 March 2013	12:38	57	7.06	16	14	<5
Vickery	VUD	18 June 2013	8:58	63	7.1	16	14	<5
Vickery	VUD	27 August 2014	15:39	52	7.16	18	19	<5
Vickery	VUD	1 June 2015	09:55	64	6.94	18	17	<5
Vickery	VUD	17 June 2015	10:48	38	7.02	10	13	<5
Vickery	VUD	24 June 2016	11:49	60	7.04	13	12	<5
Vickery	VUD	3 August 2016	14:07	32	6.64	10	11	<5
Vickery	VUD	23 August 2016	13:09	56	7.03	5	18	<5
Vickery	VUDOR	13 September 2011	8:00	36	7.13	42	9	<5
Vickery	VUDOR	29 September 2011	9:30	34	7.09	20	9	<5
Vickery	VUDOR	24 November 2011	12:30	92	7.09	24	20	<5
Vickery	VUDOR	6 February 2012	9:20	214	7.21	8	28	<5

Mine Site	Sample Location	Date (italics indicative only)	Time	EC (µS/cm)	pH	TSS (mg/L)	Total Organic Carbon (mg/L)	Grease & Oil (mg/L)
Vickery	VUDOR	4 June 2012	12:45	56	7.17	48	19	<5
Vickery	VUDOR	4 June 2012	12:55	47	7.12	45	14	<5
Vickery	VUDOR	13 July 2012	13:30	57	7.16	26	27	<5
Vickery	VUDOR	29 January 2013	15:21	95	6.81	11	32	<5
Vickery	VUDOR	18 June 2013	8:50	82	7.04	32	22	<5
Vickery	VUDOR	27 August 2014	15:33	62	7.38	17	15	<5
Vickery	VUDOR	21 April 2015	16:52	37	6.94	8	9	<5
Vickery	VUDOR	21 April 2015	16:59	31	6.91	7	11	<5
Vickery	VUDOR	1 June 2015	10:04	68	7.06	26	13	<5
Vickery	VUDOR	17 June 2015	10:55	49	7.08	8	13	<5
Vickery	VUDOR	3 August 2016	14:15	39	7.08	25	11	<5
Vickery	VUDOR	25 August 2016	12:00	76	7.18	14	14	<5
Vickery	VUDOR	25 August 2016	12:09	85	7.16	6	14	<5
Vickery	VUDOR	14 September 2016	11:47	72	7.29	9	18	<5
Vickery	VUDOR	14 September 2016	11:53	52	7.24	6	17	<5
Vickery	VUS	13 September 2011	8:35	35	6.8	25	13	<5
Vickery	VUS	29 September 2011	9:40	32	6.9	24	9	<5
Vickery	VUS	24 November 2011	12:45	90	7.09	35	18	<5
Vickery	VUS	6 February 2012	9:59	224	7.15	8	32	<5
Vickery	VUS	4 June 2012	13:10	39	7.05	57	19	<5
Vickery	VUS	11 July 2012	10:10	46	6.83	32	21	<5
Vickery	VUS	29 January 2013	15:40	117	6.56	14	36	<5
Vickery	VUS	1 March 2013	12:45	42	6.89	52	13	<5
Vickery	VUS	18 June 2013	9:06	40	7.01	28	15	<5
Vickery	VUS	28 June 2013	10:10	42	7.03	11	15	<5
Vickery	VUS	28 June 2013	10:56	37	7.05	20	14	<5
Vickery	VUS	27 August 2014	15:51	52	7.02	15	22	<5
Vickery	VUS	21 April 2015	17:05	26	6.76	11	9	<5
Vickery	VUS	1 June 2015	09:49	82	7.17	17	16	<5
Vickery	VUS	17 June 2015	10:42	40	7.01	7	12	<5
Vickery	VUS	24 June 2016	11:58	55	7.1	26	10	<5
Vickery	VUS	3 August 2016	13:57	37	6.92	20	13	<5
Vickery	VUS	23 August 2016	13:18	74	7.14	5	19	<5
Vickery	VUS	25 August 2016	12:18	62	7.21	17	18	8
Vickery	VUS	14 September 2016	12:08	60	7.14	10	7	<5
Vickery	Site 1	*1 January 1986*	-	511	8.0	43	-	-
Vickery	Site 2	*1 January 1986*	-	151	8.8	50	-	-
Vickery	Site 3	*1 January 1986*	-	165	8.4	32	-	-
Vickery	Site 4	*1 January 1986*	-	185	9.1	18	-	-
Vickery	Site 5	*1 January 1986*	-	154	8.4	221	-	-

Mine Site	Sample Location	Date (italics indicative only)	Time	EC (µS/cm)	pH	TSS (mg/L)	Total Organic Carbon (mg/L)	Grease & Oil (mg/L)
Vickery	Site 6	*1 January 1986*	-	273	8.5	74	-	-
Vickery	Site 7	*1 January 1986*	-	517	7.7	39	-	-
Vickery	Site 9	*1 January 1986*	-	2,489	7.4	39	-	-
Vickery	Site 12	*1 January 1986*	-	373	7.8	179	-	-
Vickery	Site 13	*1 January 1986*	-	96	6.8	-	-	-
Vickery	Site 14	*1 January 1986*	-	98	7.8	-	-	-
Canyon	WW11	26 July 2006	-	125	6.4	591	-	5
Canyon	WW11	11 July 2007	11:25	170	6.7	48	-	<2
Canyon	WW11	20 August 2007	14:10	55	7.6	280	-	<2
Canyon	WW11	6 February 2008	14:00	55	6.4	81	-	<2
Canyon	WW11	3 September 2008	16:55	100	8.1	166	-	<2
Canyon	WW11	7 October 2008	10:50	165	7.2	22	-	<2
Canyon	WW11	15 December 2008	12:50	130	6.8	12	-	<2
Canyon	WW11	17 February 2009	13:20	60	6.6	72	-	<2
Canyon	WW11	29 December 2009	14:25	61	6.96	114	8	
Canyon	WW11	4 January 2010	14:05	98	7.37	14	15	<5
Canyon	WW11	15 January 2010	13:20	76	6.77	69	5	<5
Canyon	WW11	15 February 2010	11:30	71	6.39	33	21	<5
Canyon	WW11	10 August 2010	14:30	66	7.29	54	14	<5
Canyon	WW11	20 August 2010	14:10	106	8.14	22	19	18
Canyon	WW11	2 September 2010	-	-	-	-	-	<5
Canyon	WW11	10 September 2010	13:30	81	6.88	115	18	<5
Canyon	WW11	12 November 2010	10:15	114	6.64	58	25	<5
Canyon	WW11	6 December 2010	15:00	112	6.66	45	16	<5
Canyon	WW11	9 September 2011	9:00	131	7.02	147	15	<5
Canyon	WW11	29 September 2011	10:30	58	7.09	412	7	<5
Canyon	WW11	14 November 2011	9:10	84	7.45	60	16	<5
Canyon	WW11	24 November 2011	11:35	116	7.18	34	26	<5
Canyon	WW11	1 February 2012	13:00	75	6.95	106	11	<5
Canyon	WW11	13 July 2012	12:00	117	7.4	96	24	<5
Canyon	WW11	29 January 2013	14:39	112	6.74	81	24	<5
Canyon	WW11	27 August 2014	13:32	68	7.21	221	14	<5
Canyon	WW11	21 April 2015	15:53	75	7.25	24	7	<5
Canyon	WW11	1 June 2015	9:27	134	7.03	30	7	<5
Canyon	WW11	17 June 2015	10:09	73	7.1	32	10	<5
Tarrawonga	BCU	1 March 2007	16:00	165	6.8	193	-	<2
Tarrawonga	BCU	23 August 2007	11:00	180	6.8	46	-	2
Tarrawonga	BCU	6 February 2008	15:05	120	7.1	20	-	<2
Tarrawonga	BCU	17 February 2009	14:18	275	6.8	35	-	<2
Tarrawonga	BCU	15 February 2010	14:45	63	7.22	94	-	<5

Mine Site	Sample Location	Date (italics indicative only)	Time	EC (µS/cm)	pH	TSS (mg/L)	Total Organic Carbon (mg/L)	Grease & Oil (mg/L)
Tarrawonga	BCU	10 August 2010	12:50	65	6.66	616	-	<5
Tarrawonga	BCU	23 November 2011	16:40	177	7.27	64	-	<5
Tarrawonga	BCU	31 January 2012	13:55	306	6.76	584	-	<5
Tarrawonga	BCU	29 January 2013	13:12	188	6.99	72	-	<5
Tarrawonga	BCU	28 March 2014	08:00	131	7.19	88	-	<5
Tarrawonga	BCU	4 August 2016	10:39	150	7.19	70	13	<5
Tarrawonga	BCU	14 September 2016	11:25	185	7.35	24	10	<5
Tarrawonga	BCU	14 September 2016	12:50	195	7.49	221	9	<5
Rocglen	SD7	9 August 2010	10:35	92	7.85	8	9	<5
Rocglen	SD7	8 November 2010	10:10	77	9.56	52	11	<5
Rocglen	SD7	2 March 2011	10:00	1080	9.17	236	37	<5
Rocglen	SD7	17 May 2011	9:25	159	7.45	78	23	<5
Rocglen	SD7	4 August 2011	12:25	213	7.4	290	66	<5
Rocglen	SD7	10 November 2011	9:40	173	7.61	83	15	<5
Rocglen	SD7	14 November 2011	8:00	176	7.67	88	15	<5
Rocglen	SD7	28 November 2011	15:30	154	7.01	60	11	<5
Rocglen	SD7	7 March 2012	9:00	165	7.49	16	14	<5
Rocglen	SD7	7 May 2012	11:30	192	7.61	34	14	<5
Rocglen	SD7	1 August 2012	10:00	155	7.68	23	17	<5
Rocglen	SD7	28 November 2012	10:20	199	8.99	98	20	<5
Rocglen	SD7	26 February 2013	12:10	203	7.68	14	15	<5
Rocglen	SD7	14 May 2013	9:20	233	7.86	29	21	<5
Rocglen	SD7	8 August 2013	12:00	138	8.77	14	17	<5
Rocglen	SD7	8 November 2013	9:30	199	7.82	18	19	<5
Rocglen	SD7	5 February 2014	10:50	222	7.34	52	19	<5
Rocglen	SD7	5 May 2014	11:40	200	8.14	20	12	<5
Rocglen	SD7	6 August 2014	10:40	196	8.44	10	15	<5
Rocglen	SD7	12 November 2014	11:00	244	8.42	16	20	<5
Rocglen	SD7	11 February 2015	9:55	301	8.14	26	20	<5
Rocglen	SD7	11 May 2015	10:05	146	7.52	18	9	<5
Rocglen	SD7	18 August 2015	10:30	135	7.62	5	10	<5
Rocglen	SD7	19 November 2015	11:40	200	8.05	35	15	<5
Rocglen	SD7	1 March 2016	12:00	241	7.98	29	13	8
Rocglen	SD7	21 March 2016	09:35	-	-	-	-	<5
Rocglen	SD7	11 May 2016	09:00	282	8.14	38	22	<5
Rocglen	SD7	9 November 2016	-	174	8.15	7	15	<5
Boggabri	SW2	23 September 2008	-	56	5.9	99	-	ND
Boggabri	SW2	6 October 2008	-	72	7	32	-	ND
Boggabri	SW2	13 December 2008	-	86	7.8	66	-	ND
Boggabri	SW2	17 February 2009	-	33	7.1	110	-	<5

Mine Site	Sample Location	Date (italics indicative only)	Time	EC (µS/cm)	pH	TSS (mg/L)	Total Organic Carbon (mg/L)	Grease & Oil (mg/L)
Boggabri	SW2	12 July 2012	-	183	7.4	42	-	<5
Boggabri	SW2	13 July 2012	-	160	7.2	220	-	ND