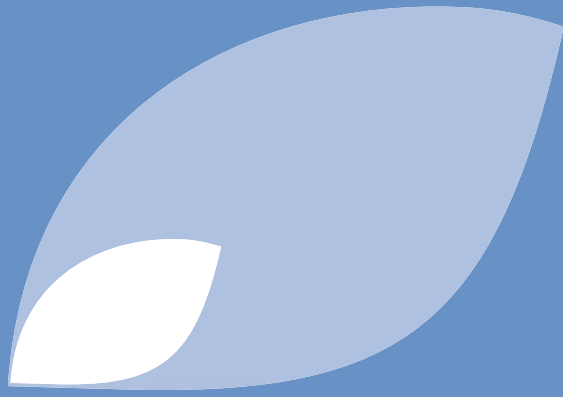




APPENDIX E

Surface water assessment







Cobbora Holding Company Pty Limited

Cobbora Coal Project Surface Water Assessment

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September 2012



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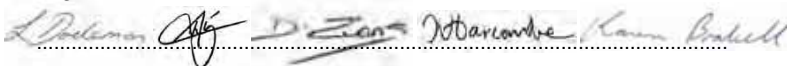
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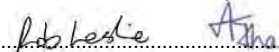
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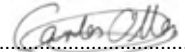
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Contents

	Page number
Executive summary	v
1. Introduction	1
1.1 Cobbora Coal Project	1
1.1.1 General overview of Project	1
1.1.2 Open-cut mine	3
1.1.3 Coal-handling and preparation plant	3
1.1.4 Train-loading facility and rail spur	3
1.1.5 Mine infrastructure area	4
1.1.6 Supporting infrastructure	4
1.1.7 Workforce and operating hours	4
1.2 Scope of assessment	5
1.3 Report structure	5
1.4 Terms of engagement	6
2. Planning and legislation	7
2.1 Director General's requirements	7
2.2 Relevant legislation	8
2.2.1 Water Act 1912	8
2.2.2 Water Management Act 2000	8
2.2.3 Dams Safety Act 1978	9
2.2.4 Protection of the Environment Operations Act 1997	9
2.3 NSW water policies, guidelines and plans	9
2.3.1 Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source	9
2.3.2 Draft Water Sharing Plan for the Macquarie-Bogan Unregulated and Alluvial Water Sources	9
2.3.3 Other relevant policies, plans and guidelines	10
3. Existing environment	11
3.1 Assessment area	11
3.2 Regional context	11
3.3 Topography and land use	11
3.4 Soils	13
3.5 Dryland salinity	13
3.6 Climate	13
3.6.1 Local weather stations	13
3.6.2 Rainfall and evaporation	13
3.6.3 Climate change	13
3.7 Local surface water bodies	15

	Page number
3.8 Baseline hydrologic conditions	15
3.8.1 Stream gauge information	15
3.8.2 Water level gauging	16
3.8.3 Baseline flood hydrology	16
3.9 Baseline water quality	17
3.9.1 Objectives and guidelines	18
3.9.2 Flow ranges during water quality monitoring	18
3.9.3 Surface water quality monitoring findings	18
3.10 Baseline geomorphology	20
3.11 Groundwater – surface water interaction	21
4. Water management system	23
4.1 Water management strategy	23
4.1.1 Clean water system	23
4.1.2 Overburden water system	24
4.1.3 Pit, infrastructure and process water systems	24
4.1.4 Staging of water management system	25
4.2 Site water balance model	25
4.2.1 Modelling approach	25
4.2.2 Water inputs	25
4.2.3 Water demands	26
4.2.4 Results of water balance modelling	27
4.3 Water supply	28
4.3.1 The Macquarie and Cudgegong Regulated Rivers Water Source	28
4.3.2 Existing water entitlements	30
4.3.3 Basic water rights — harvestable rights dams	31
4.3.4 Water source protection criteria of the WSP	31
4.4 Licensing requirements	32
5. Potential impacts	33
5.1 Construction phase	33
5.2 Operational phase	33
5.2.1 Water quality	33
5.2.2 Downstream flow impacts	35
5.2.3 Flood impacts	36
5.2.4 Project water demand	37
5.3 Post-mining phase	39
5.3.1 Final landform	39
5.3.2 Final void water balance modelling	39
5.3.3 Potential impacts	39
6. Mitigation measures	41
6.1 Construction phase	41
6.1.1 Erosion and Sediment Control Plan	41

	Page number
6.1.2 Creek crossings	42
6.1.3 Hazardous materials and effluent management	42
6.2 Operational phase	42
6.2.1 Water supply security	42
6.2.2 Sedimentation dam performance	43
6.2.3 Flood protection levees	43
6.2.4 Scour protection measures	44
6.2.5 Dry detention basin	44
6.2.6 Temporary diversion channels	44
6.2.7 Wastewater management	45
6.2.8 Flood emergency management plan	45
6.3 Post mining phase	45
7. Monitoring and management	47
7.1 Site Water Management Plan	47
7.2 Surface water monitoring program	48
7.2.1 General principles	48
7.2.2 Monitoring recommendations	49
8. Conclusions	51
9. References	53

List of tables

Table 2-1	Director General's requirements	7
Table 3-1	Flood frequency analysis results for the Talbragar River at Elong Elong	17
Table 3-2	Design flood flow estimates for Sandy Creek	17
Table 4-1	Water demand summary	27
Table 4-2	Summary of imported water requirement for dry-, median- and wet-year climate conditions	27
Table 5-1	Percentage change in peak flood event flows	36
Table 6-1	Proposed sedimentation dam release limits	43

List of figures

Figure 1-1	Site location	2
Figure 3-1	External water resources environment	12
Figure 3-2	Weather stations and baseline surface water monitoring locations	14
Figure 3-3	Existing 100 year ARI flood extent (Sandy Creek catchment)	19
Figure 5-1	Proposed 100 year ARI flood extent	38
Figure 5-2	Final landform (Year 21)	40
Figure 7-1	Recommended surface water quality monitoring locations	50

Appendices

Appendix A	Cobbora Coal Project – Baseline Hydrological Environment
Appendix B	Cobbora Coal Project – Downstream Water Quality Impact Assessment
Appendix C	Cobbora Coal Project – Downstream Flow Impact Assessment
Appendix D	Cobbora Coal Project – Flood Impact Assessment
Appendix E	Cobbora Coal Project – Water Balance and Surface Water Management System
Appendix F	Cobbora Holding Company water entitlements

Executive summary

This report assesses the potential surface water impacts associated with the proposed Cobbora Coal Project (the Project). Parsons Brinckerhoff has prepared this report for Cobbora Holding Company Pty Limited (CHC) for the purpose of informing the environmental assessment for the Project.

The Project comprises a new open-cut coal mine that will supply thermal coal, primarily to power stations in NSW. In addition, some coal will be produced for a combination of export and spot domestic markets. The Project is located approximately 5 km south of Cobbora, 22 km south-west of Dunedoo, 64 km north-west of Mudgee and 60 km east of Dubbo in the central west of NSW.

The Project's main elements are an open-cut mine, a coal-handling and preparation plant (CHPP), a train-loading facility and rail spur, a mine infrastructure area, and supporting infrastructure, including access roads, water supply and storage, and electricity supply. It is envisaged that construction activities will commence in mid-2013, with coal supplied to customers from the first half of 2015. The mine life will be 21 years.

The scope of the surface water assessment was developed to address the Director General's Requirements, as they apply to surface water. The assessment has therefore focussed on the following three key technical areas:

- site water management
- flood impacts
- downstream water quality and flow impacts.

A brief summary of the findings from each technical area is provided below.

Site water management

The proposed water management system has been designed to segregate clean runoff and mine water, and provide flexibility to ensure the site can operate over the proposed 21 year mine-life under a range of climatic conditions.

Clean water from undisturbed catchments will be diverted around the mine to Sandy Creek and Laheys Creek as much as practical. This will assist to maintain flows in the creek system. Runoff from disturbed areas, such as overburden emplacement areas, will be directed to a number of sedimentation dams strategically placed throughout the mine to allow settling. Captured water will be either reused on-site to satisfy site water demands or returned to Sandy Creek and Laheys Creek when water quality criteria have been met.

Runoff and groundwater seepage captured in-pit will be pumped to mine water dams. Infrastructure runoff from the CHPP, mine infrastructure area, coal stockpiles and rail loading facilities will be captured in storage dams. This water will be used to meet site demands as a priority over raw water and will not be released to the creek system under any circumstances.

Water balance modelling predicted that the surface water flow regime downstream of the site will slightly decrease for dry and median years, but will generally increase for wet years. During wet years more water captured in sedimentation dams will be released to downstream creeks because it will not be required to supplement on-site demands.

The final landform has been designed to backfill two mining voids and minimise the size of the third void. Due to economic constraints on the Project, a void lake is unavoidable in the south eastern end of mining area B. This void will not overtop and will act as a groundwater sink which will therefore not impact on the surface water environment.

The water balance modelling suggests that site demands cannot be met just by harvesting on-site runoff. Water deficits will occur throughout the life of the mine under median climatic conditions, and imported water will be required to make-up this deficit. The requirement for imported water peaks in Year 20, when production rates and demands are high but groundwater make is relatively low.

CHC's current water entitlements of 3,311 ML/a from the Cudgegong/Macquarie Regulated River system are adequate to meet requirements for a 10th percentile dry rainfall year, assuming most of its allocation of high security entitlements is available. In Year 20, current entitlements may not be adequate to meet demands in three out of the last 111 years of records. If these very dry climatic conditions are experienced, there would be a nominal water shortage and the mine would have to rely on a hierarchy of additional water supply or consumption strategies.

Flood impacts

A detailed flood investigation, including hydrologic and hydraulic modelling gave an understanding of the existing flooding behaviour of Sandy Creek and Laheys Creek and how it affects the main mining area. The modelling also determined how the proposed mine and associated infrastructure will affect flood behaviour in the catchment. Areas outside the mine, such as Flyblowers Creek, north of Sandy Creek catchment and the proposed rail spur waterway crossings, were assessed separately using other methods.

It was found that flows in Laheys Creek would increase slightly due to the progressive diversion of the northern part of the catchment (which naturally flows into Sandy Creek) into Laheys Creek. However, this will be counteracted by the loss of catchment area to the mine, so changes in peak flows will be minimal.

The northern boundary of the mine is approximately 2 km from the Talbragar River, and the catchment containing the mine is up to 45 m above the banks of the river. For all events analysed, including the 2,000-year average recurrence interval (ARI) event, flood levels in the Talbragar River will not be affected by the mine due to the distance and difference in elevation between the mine and the river.

Overall, the hydraulic modelling shows no significant change in flood levels along Sandy Creek and Laheys Creek, both upstream and downstream of the main mining area. Therefore, no mitigation measures are required in the Sandy Creek catchment to reduce flooding impacts.

However, there would be an impact on Flyblowers Creek, north of Sandy Creek. During Years 12–20, mitigation measures would be required to reduce the peak flow in Flyblowers Creek. A dry detention basin with a capacity of 70 ML is recommended. The detention basin can be accommodated within the Project Application Area, and should be close to the disturbed area. With this detention basin, peak flows reaching the Golden Highway should be close to those of the existing scenario, thereby avoiding adverse impacts on the highway.

In the rail corridor, the proposed rail spur will cross local waterways at 21 locations, including Fords Creek, Lambing Yard Creek and Tallawang Creek. Because some of the rail spur will be located on embankments up to 6 m high, local flooding impacts upstream of the embankments could be significant. Therefore, waterway crossings, cross-drainage culverts and rail corridor longitudinal drainage will need to be detailed at the design stage so that local flooding can be managed and impacts to the local environment and rail infrastructure minimised.

Downstream water quality and flow

Potential water quality and flow impacts on local watercourses were assessed against customised water quality and flow objectives developed from relevant Australian guidelines.

Water quality was assessed with a mass-balance model to predict potential changes in local watercourses over several operational stages of the mine. These changes were generally localised to Sandy Creek, with elevated levels of nutrients and TDS predicted in Years 1 to 16 of the Project. Impacts on the Talbragar River were minor due to the larger catchment size and greater flows.

The flow assessment demonstrated that Sandy Creek and Laheys Creek do not significantly influence flows in the Talbragar or Macquarie Rivers, due to their relatively small catchment areas and annual flow contributions. Impacts of the Project on local flows were found to be minor in the Talbragar River system but the mining operation will modify the flow regime such that low flows will increase in the Sandy Creek system, where semi-permanent pools along the creek were likely to receive more regular surface water flow and therefore less frequent drying. However, some pools that are potentially groundwater dependent will be adversely affected by groundwater drawdown during mining. Of a total of 14 refuge pools assessed within or adjacent to the main mining areas, two will definitely be adversely affected by the drawdown – one on Sandy Creek and one on Laheys Creek – while there is potential for a further two on Sandy Creek to be affected. Groundwater levels will fully recover at these sites within 20 to 50 years post mining; therefore, the groundwater inflows to the affected pools will recover in the long term.

The potential cumulative impacts of the Project on water quality and flows in the Talbragar River will be negligible, because existing mines upstream of the Talbragar River have already augmented water quality and flows in the river.

1. Introduction

The Cobbora Coal Project (the Project) is a new open-cut coal mine proposed by Cobbora Holding Company Pty Limited (CHC). The Project is located approximately 5 kilometres (km) south of Cobbora, 22 km south-west of Dunedoo, 64 km north-west of Mudgee and 60 km east of Dubbo in the central west of NSW (see Figure 1.1).

A Major Project application under Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) was submitted to the NSW Department of Planning in January 2010. The Director General's Environmental Assessment Requirements (DGRs) for the Project were issued in March 2010 and revised requirements were subsequently provided that responded to project changes and altered Government policies.

This report describes the surface water assessment that Parsons Brinckerhoff undertook for the Project's environmental assessment report.

1.1 Cobbora Coal Project

1.1.1 General overview of Project

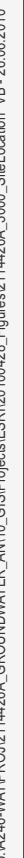
The Project will be developed near Dunedoo in the central west of New South Wales (NSW). The Project Application Area is approximately 274 square kilometres (km²). The primary purpose of the Project is to provide coal for five major NSW power stations.

The mine will extract around 20 million tonnes per annum (Mt/a) of run-of-mine (ROM) coal. From this, approximately 9.5 Mt/a of product coal will be sold to Macquarie Generation, Origin Energy and Delta Electricity under long-term contract. In addition, approximately 2.5 Mt/a will be produced for export or the spot domestic market.

The Project's key elements are:

- an open-cut mine
- a coal-handling and preparation plant (CHPP)
- a train-loading facility and rail spur
- a mine infrastructure area
- supporting infrastructure, including access roads, water supply and storage, and electricity supply.

Construction is expected to commence in mid-2013, with coal being supplied to customers from the first half of 2015. The mine life will be 21 years.



- Figure 1-1** Site location

1.1.2 Open-cut mine

Multiple open-cut mining pits will be developed in three mining areas:

- mining area A north of the infrastructure area
- mining area B south of the infrastructure area
- mining area C north-east of the infrastructure area.

There will be three out-of-pit waste rock emplacements:

- AC-OOP between mining areas A and C
- B-OOP E adjacent to mining area B on the east side of Laheys Creek
- B-OOP W adjacent to mining area B on the west side of Laheys Creek.

Over the mine life, operations will encompass approximately 4,350 hectares (ha), including associated infrastructure (e.g. haul roads), out-of-pit waste rock emplacements and rehabilitated areas. The mining areas and out-of-pit waste rock emplacements have been designed and placed to maximise the efficient extraction of the coal resource, while avoiding or minimising impacts on creeks and ecologically significant vegetation.

1.1.3 Coal-handling and preparation plant

The CHPP will treat ROM coal so that product coal meets customers' sizing and coal quality requirements. Subject to the level of impurities (rejects) in the coal and washability characteristics, the ROM will be either crushed and bypassed or treated (washed) in the preparation plant. The rejects will typically include waste rock from above, below and within the coal seam, as well as mineral matter dispersed throughout the coal.

The CHPP will be typical of those used by most coal mines in NSW and will be capable of treating up to 20 Mt/a of ROM coal. The CHPP will separate washed product coal from rejects in a series of coal-cleaning circuits (including heavy media separation). The CHPP will include a truck dump station, crushing plants, coal stockpiles and infrastructure to move and stockpile coal. Rejects from the CHPP will be returned back to the operating mine.

1.1.4 Train-loading facility and rail spur

Coal will be transported by rail to the Project's customers, including Bayswater and Liddell power stations in the Upper Hunter Valley, and Eraring, Vales Point and Munmorah power stations on the NSW Central Coast. Coal will also be transported to other domestic customers or to a ship-loading facility in Newcastle for export.

Product coal will be loaded onto trains from an overhead train-loading bin located on a rail spur balloon loop. Approximately four trains will be loaded each day. The rail spur will be approximately 28 km long (including the loop) and will join the Dunedoo-Gulgong rail line near Tallawang. A locomotive-provisioning facility will be located adjacent to the balloon loop.

1.1.5 Mine infrastructure area

An infrastructure area will be located adjacent to the mining areas. It will include workshops, hardstand and lay-down areas, bulk storage buildings, bulk fuel storage and a fuelling station, office buildings, an operations building and change-house, parking, an explosives magazine and vehicle washdown bays.

1.1.6 Supporting infrastructure

1.1.6.1 Access road

The main access to the mine will be from the Golden Highway to the north of the operations, via a road diversion that will replace an existing section of Spring Ridge Road. There will be limited light vehicle access from the south via Spring Ridge Road. Internal roads will connect the mine entrance to the workshop, administration buildings and the mine infrastructure area. Internal roads will also connect the various mine areas.

1.1.6.2 Water supply

The Project will require water, primarily for the CHPP and for dust suppression. Water will be sourced by extracting surface water, by pumping groundwater that enters the mine area, and by harvesting and reusing water on-site in accordance with the relevant permits and licences. The primary source of external water will be the Cudgegong River. Water will be supplied via approximately 26 km of pipeline from a pump station on the Cudgegong River to a primary raw-water dam south-east of the mining area. Pre-existing high-security water access licences have been purchased to allow up to 3.311 gigalitres (GL) of water to be extracted from the river.

1.1.6.3 Electricity supply

The Project will require 20 megawatts (MW) of electrical power. The mine will be connected to the grid at a small switching yard adjacent to the Castlereagh Highway. A power line, generally running parallel to the rail spur, will deliver electricity to a substation in the mine infrastructure area. An 11 kV powerline will supply the Cudgegong River pump station from the existing grid approximately 2 km south of the pump station site.

1.1.7 Workforce and operating hours

The proposed mine construction workforce will average approximately 350 persons, peaking at approximately 550 persons between the third quarter of 2013 and the second quarter of 2016.

The operational workforce is estimated to be 300 persons during the first two years of full production in 2016 and 2017. This will increase steadily over the next 10 years to peak at approximately 590 persons between 2027 and 2030.

Mine construction is expected to occur up to 10 hours a day. However, construction may occur up to 24 hours a day at times, such as during major concrete pours. Mining will occur up to 24 hours a day, 7 days a week, 52 weeks a year.

1.2 Scope of assessment

Parsons Brinckerhoff was commissioned by CHC to assess potential surface water impacts from the construction and operation of the Project, as described in Section 1.1 of this report.

The key objectives of the assessment were:

- to identify and assess potential impacts on surface water from the development of the Project
- to satisfy the DGRs relevant to surface water impacts
- to inform the wider community about the Project and its potential impacts on the local and regional surface water environment.

To achieve these objectives, the surface water impact assessment had to:

- cover a geographical area where any impacts may potentially occur
- address all surface water issues identified in the DGRs
- describe government legislation and policy relevant to surface water aspects of the Project
- describe assessment methods used, including any fieldwork
- provide the results of fieldwork and any modelling
- describe the existing surface environment, including regional and local hydrology, regional and local catchments, flooding, local water bodies, surface water quality and other surface water users
- describe the proposed water management system and mine water balance, including proposed site water demands, water disposal methods, water supply infrastructure and water storage structures
- describe the potential impacts on surface water during construction, operation and post-closure, including flooding, interception of surface water and disposal of excess water. This includes an assessment of potential cumulative impacts
- recommend measures to avoid or mitigate impacts
- recommend an appropriate surface water monitoring program.

This report has been prepared to meet the objectives and satisfy the list of requirements described above.

1.3 Report structure

The structure of this report is as follows:

- **Section 1** introduces the surface water assessment, providing an overview of the Project, and the objectives and scope of the surface water assessment.

- **Section 2** summarises the DGRs relating to surface water for the Project and the relevant legislation, policies and guidelines.
- **Section 3** describes the existing surface water environment, including local and regional hydrology, regional and local catchments, flooding, local water bodies, surface water quality and other surface water users.
- **Section 4** details the proposed water management system and mine water balance, including site water demands, water disposal methods, water supply infrastructure and water storage structures.
- **Section 5** discusses the Project's potential impacts on surface water during construction, operations and post closure, including flooding, interception of surface water, surface water extraction and disposal of excess water. This includes an assessment of potential cumulative impacts.
- **Section 6** describes recommended mitigation measures and response plans.
- **Section 7** outlines a recommended surface water monitoring program, including monitoring requirements, procedures and recommendations.
- **Section 8** provides the conclusions of the surface water assessment.
- **Section 9** provides the list of references used in the assessment.

1.4 Terms of engagement

This commission was carried out under the contract between Parsons Brinckerhoff and Cobbora Holding Company. It assesses existing conditions and proposes measures to mitigate impacts from the proposed mine on surface water. As further information becomes available and detailed designs are carried out, those mitigation measures can be optimised.

The investigations had the benefit of two years of site-specific monitoring data, together with more than a century of nearby weather information. The nature and extent of that monitoring are described in the report. The monitoring and measurements of site conditions are believed to be representative of conditions during those two years and were performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. The recommended monitoring program will add further information that will increase the understanding of surface water regimes at the site.

In preparing the report, Parsons Brinckerhoff received information from a variety of reputable sources, including CHC, other specialist consultants, published papers and other environmental assessments. While it reviewed the data before using it, the information was accepted in good faith and it was not verified in detail for accuracy or completeness.

The report is for the use of Cobbora Holding Company and regulators in the determination of a development application for the Cobbora Coal Project and no responsibility will be taken for its use by other parties. If any other party seeks to rely on this report, they should seek their own independent advice to ensure that it is relevant to their own needs. Any losses or damage that they suffer as a result of failing to make their own enquiries will not be the responsibility of Parsons Brinckerhoff.

2. Planning and legislation

2.1 Director General's requirements

On the 14 October 2011, the Director General of the NSW Department of Planning and Infrastructure (DP&I) issued a set of requirements for the Project in accordance with the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The Director General Requirements (DGRs) included specific requirements from the NSW Office of Water (NOW).

The DGRs relating to surface water are listed in Table 2-1 and include the section of this report where they are addressed.

Table 2-1 Director General's requirements

Director General's requirements		Sections
General requirements	A description of the existing environment, including sufficient baseline data.	3, Appendix A
	An assessment of the potential impacts of the Project, including any cumulative impacts, taking into consideration any relevant guidelines, policies, plans and statutory provisions.	5
	Description of the measures that would be implemented to avoid, minimise and, if necessary, offset potential impacts of the Project, including detailed contingency plans for managing any significant risks to the environment.	6 & 7
Key issues	Detailed modelling of the potential surface water impacts of the Project.	5
	A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of the volume and frequency of any water discharges), water supply infrastructure and water storage structures.	4.1 and 4.2, Appendix E
	A demonstration that water supplies for the construction and operation of the mine can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant water sharing plan (WSP) and/or requirements of the <i>Water Act 1912</i> for water sources outside of any relevant WSP.	4.3
	A description of the measures proposed to ensure the Project can operate in accordance with the proximity and water source protection criteria of the relevant WSP.	4.3
	Identification of any licensing requirements under the <i>Water Act 1912</i> or <i>Water Management Act 2000</i>.	4.4, Appendix F
	- A detailed assessment of the potential impacts on: - the quality and quantity of existing surface water resources - affected, licensed water users and basic landholder rights - the riparian, ecological, geomorphological and hydrological values of water courses resulting from any proposed diversion works, including environmental flows.	5, Appendices B and C
	A detailed description of the proposed water management system and water-monitoring program for the Project and other measures to mitigate surface water impacts.	7
	A detailed flood impact assessment identifying the impact of the Project on flooding and the measures proposed to mitigate potential flood impacts.	5.2, Appendix D

2.2 Relevant legislation

The two key pieces of legislation for water management in NSW are the *Water Act 1912* and the *Water Management Act 2000*.

2.2.1 Water Act 1912

The *Water Act 1912* (WA 1912) has historically been the main legislation managing NSW water resources. While some provisions of WA 1912 are still in force, WA 1912 is being progressively phased out and replaced by the *Water Management Act 2000* (WMA 2000).

Water sharing plans (WSPs) are statutory plans under WMA 2000 that apply to individual water source areas and contain rules for sharing and managing the water resources of NSW. These plans are progressively being developed for all water source areas across NSW.

CHC has obtained external water for the Project by purchasing regulated river (high-security) water access licences from the Macquarie and Cudgong Regulated Rivers Water Source. These licences are described in detail in Section 4.3.

The mine is located in the Sandy Creek catchment, a sub-catchment of the Talbragar River. This system is not yet covered by a WSP for surface water; however, CHC holds WA 1912 entitlements in this catchment. Further information regarding these entitlements is provided in Section 4.3. A WSP is currently being developed for the Macquarie-Bogan Unregulated and Alluvial Water Sources that will cover the Project Application Area. This WSP is expected to commence during 2012. Refer to Section 2.3.2 for further information.

The existing conditions of CHC's current WA 1912 licences will be carried over when the licence is converted under WMA 2000, which will come into effect at the commencement of the WSP.

2.2.2 Water Management Act 2000

The *Water Management Act 2000* (WMA 2000) and associated WSPs are the major water management and planning instruments in NSW. WMA 2000 established a new statutory framework for managing water in NSW, although WA 1912 continues to apply in areas not yet covered by WSPs.

For the purposes of this Project, WMA 2000 requires any development taking or using water to:

- assess whether the development will adversely impact the river or aquifer and its dependent ecosystems
- protect basic landholder rights.

WMA 2000 outlines the requirements for taking and trading water through water access licences, water supply works and water use approvals.

CHC currently holds WMA 2000 entitlements from the Macquarie and Cudgong Regulated Rivers Water Source. These entitlements are a key component for ensuring the Project has an adequate and secure water supply. Further information regarding these entitlements is provided in Section 2.3.1 and Section 4.3.

2.2.3 Dams Safety Act 1978

The *Dams Safety Act 1978* is the key instrument in NSW for the safe management of dams. The Act authorises the Dams Safety Committee to be the statutory body representing the Crown in administering the Act.

The Dams Safety Committee is therefore responsible for determining appropriate dam safety arrangements for dams. In particular it focuses on 'prescribed' dams, which are listed under Schedule 1 of the Act.

The final configuration of the mine and associated dams will be determined during detailed design, but some of the water management system dams are likely to meet the criteria for 'prescribed' dams under the Act. They will therefore need to be referred to the Dams Safety Committee before they can be built.

2.2.4 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is the main environmental protection legislation that controls how developments operate in NSW. The Act and associated Regulations are administered by the NSW Office of Environment and Heritage.

The Project is likely to require the periodic release of treated water to Sandy Creek and Laheys Creek during mining operations. These releases will need to be licensed under the POEO Act.

2.3 NSW water policies, guidelines and plans

2.3.1 Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source

The Macquarie and Cudgegong Rivers are managed as one water source in the Central West Water Management Area prescribed under WMA 2000. Water access and trading rules for these rivers are provided in the Water Sharing Plan (WSP) for this water source.

This WSP commenced on 1 July 2004 and will apply until 2014. The plan provides water for the environmental needs of the Macquarie and Cudgegong Regulated Rivers Water Source and directs how water available for extraction is to be shared. The WSP also sets rules that affect the management of water access licences, water accounts, water trading, dam operations and flow management.

CHC holds water entitlements to extract 3,311 ML or 3.311 GL of regulated river (high-security) water, together with water supply works approvals to extract from the Cudgegong River. Further details of these water access licences are provided in Section 4.3.

2.3.2 Draft Water Sharing Plan for the Macquarie-Bogan Unregulated and Alluvial Water Sources

A draft WSP for the Macquarie-Bogan Unregulated and Alluvial Water Sources is currently being developed. The draft WSP area is understood to comprise 30 surface water and four groundwater sources in the Macquarie-Bogan River catchment.

The Project lies within the Lower Talbragar River Water Source. This flows into the Macquarie Regulated River. There are 14 licensed water entitlements on the Lower Talbragar covering 897 ML/a. About 92% of the total entitlement is for irrigation and the remaining 8% is for stock and domestic purposes.

Given the non-perennial nature of the stream, the proposed access rules include a 'cease to pump' condition on licences — that is, pumping is not permitted from natural pools when the water level in the pool is lower than its full capacity as defined in the draft WSP. Water requirements for persons entitled to basic landholder rights (i.e. domestic and stock rights) are estimated to total 308 ML/a for the Lower Talbragar River Water Source.

CHC does not currently hold any licences to extract water from the main stream of the Lower Talbragar River, but it does hold two WA 1912 entitlements that authorise extraction from existing water supply dams. The existing licence conditions for these dams will be carried over when the licences are converted under WMA 2000 when the WSP begins. Further details about the existing dam licences are provided in Section 4.3.

The draft WSP for the Macquarie-Bogan Unregulated and Alluvial Water Sources was placed on public exhibition from 1 September to 21 October 2011. A final WSP is expected to come into effect sometime during 2012. This will specify water access and management arrangements for the nominated water sources and replace any WA 1912 entitlements. Trading will also be permitted within this water source and from the Upper Talbragar River Water Source in accordance with the WSP trading rules.

2.3.3 Other relevant policies, plans and guidelines

The following policies, plans and guidelines have been reviewed in preparing this report:

- Draft Murray Darling Basin Plan (Murray Darling Basin Authority 2011).
- Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).
- Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (NSW EPA 2004).
- Australian Rainfall and Runoff — A Guide to Flood Estimation (Engineers Australia 2001).
- Australian Runoff Quality (Engineers Australia 2006).
- Managing Urban Stormwater — Soils and Construction, Volume 1 (Landcom 2004).
- Managing Urban Stormwater — Soils and Construction, Volume 2E, Mines and Quarries (DECCW 2008).
- Central West Catchment Action Plan 2006–2016 (Central West Catchment Management Authority 2007).
- Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region (DIPNR 2005).
- Strategic Water Management in the Minerals Industry – A Framework (MCMR 2006).
- Water Management — Leading Practice Sustainable Development Program for the Mining Industry Department of Resources, Energy and Tourism 2008).
- Macquarie-Bogan Water Quality and River Flow Objectives (Department of Environment, Climate Change and Water 2006).

3. Existing environment

This section summarises baseline surface water conditions that have been used to assess potential impacts from the Project. Further details of how baseline conditions were defined are contained in Appendix A.

3.1 Assessment area

For the purpose of the downstream water quality and flow impact and water balance assessments (Appendices B, C and E respectively), the relevant assessment area was limited to include potential surface water receptors defined as those watercourses that drain the proposed mining areas and/or could be impacted by proposed mining activities. These receptors generally included Sandy Creek and Laheys Creek, and the downstream system of the Talbragar River through to the Macquarie River and Macquarie Marshes.

For the purposed of the flood impact assessment (Appendix D), the relevant assessment area was expanded to include additional surface water receptors that could potentially be affected by the construction of ancillary mine infrastructure (e.g. road, pipeline and rail crossings). These receptors included Flyblowers Creek, Tallawang Creek, Fords Creek, Lambing Yard Creek and Tucklan Creek.

3.2 Regional context

The Project is located approximately 5 km south of Cobbora in the central west of NSW. Figure 3-1 shows its location in relation to regional surface water resources.

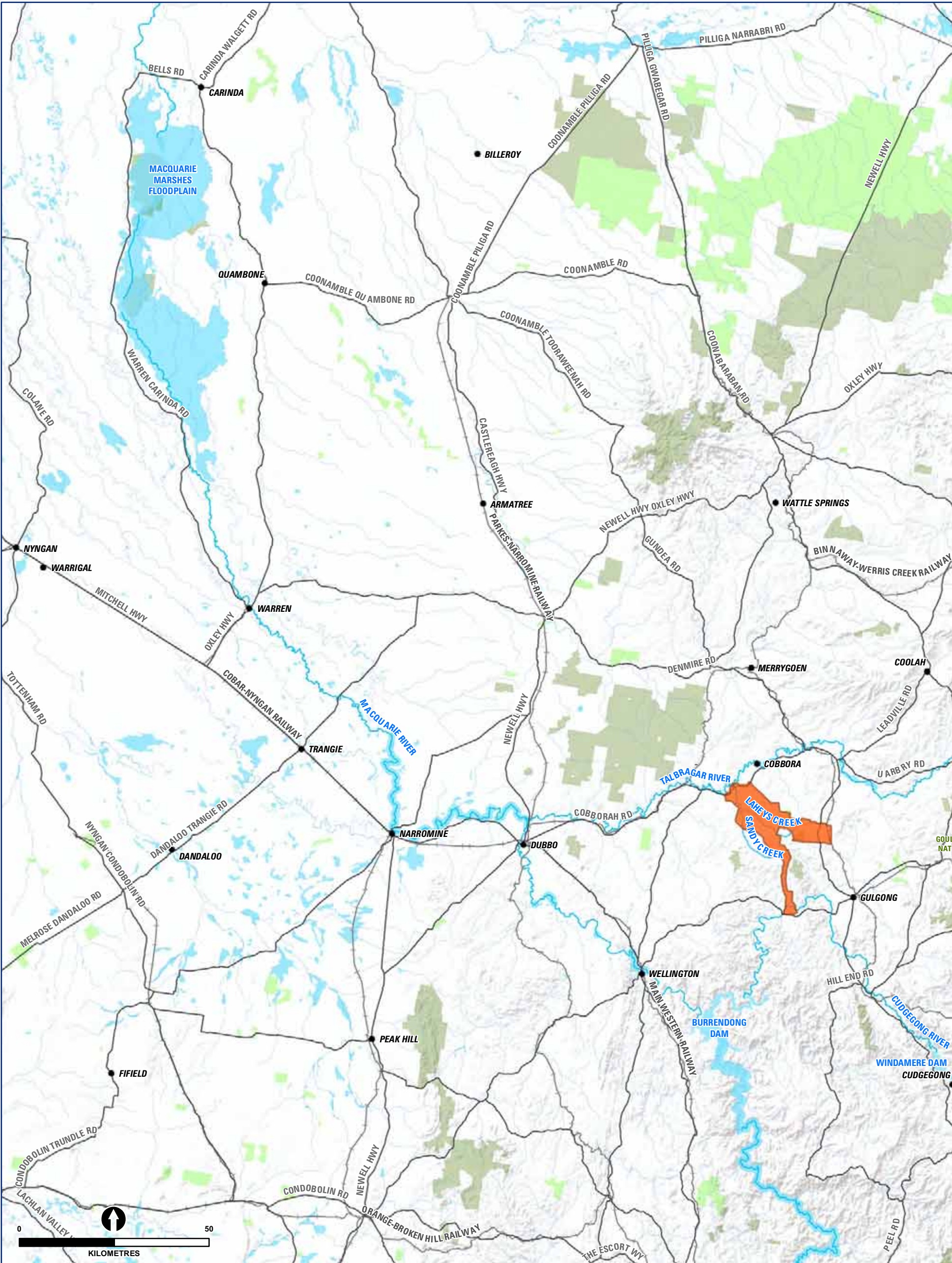
Rivers in the greater Cobbora area include the Talbragar River and Cudgegong River, which are tributaries of the Macquarie River. The Macquarie River is formed near Bathurst, at the junction of the Fish River and Campbells River, and extends north-west to the Barwon River upstream of Brewarrina. The river flows through the Macquarie Marshes, which are one of the largest semi-permanent wetlands in south-eastern Australia, covering more than 150,000 ha.

Cudgegong River rises in the Great Dividing Range above Rylstone and drains an area of 3,880 km². It is a major tributary of the Macquarie River and flows into Windamere Dam upstream of its confluence with the Macquarie River. A section of the Cudgegong River is located within the Project Application Area and is located approximately 17 km south of the proposed mining area.

Talbragar River is the closest major water body to the proposed mining area. It separates from the Coolaburragundy River at Dunedoo and runs south-west, joining the Macquarie River just north of Dubbo.

3.3 Topography and land use

The topography of the assessment area covered by the Project is gently undulating to hilly, with elevations varying between 320 and 620 m Australian Height Datum (AHD). It is mostly cleared and used for farming, including grazing sheep and cattle, cultivating cereal crops and forestry.



— Drainage lines	■ Project application area
— Major roads	■ Waterbodies
— Railway	■ State forest/ natural reserve

Figure 3-1 Existing water resources environment

3.4 Soils

The predominant soil type in the assessment area is unit Qb17, which occurs in undulating country with gravelly or stony ridges comprising hard and friable neutral red soils. Along the Talbragar River, the soil unit is Gb11, occurring on river terraces and floodplains and comprising dark porous loamy soils with some cracking clays.

3.5 Dryland salinity

The *Salinity Risk Assessment of the Central West Catchment* (Humphries 2000) describes the salinity hazard rating of the Lower Talbragar River catchment as 'very high'. However, the Sandy Creek sub-catchment has relatively low salinity compared to more salinised catchments to the west. The Project targets only Triassic and Permian strata within the sub-catchment and not the Lachlan Orogen metasediments, which are generally associated with saline soils. The salinity risk is therefore much lower in this particular part of the catchment.

3.6 Climate

3.6.1 Local weather stations

There are no Bureau of Meteorology (BoM) weather stations operating in the assessment area. However, there are two nearby weather stations that have been used to understand local weather patterns and generate a long-term dataset. These include BoM Station 064009 at Dunedoo Post Office and BoM Station 062013 at Gulgong Post Office. The closest station with long-term evaporation observations is the Wellington Research Centre (BoM Station 065035), about 60 km south-west of the assessment area.

Two additional meteorological gauging stations were installed by CHC in the assessment area between 2009 and 2011. These have been used to supplement long-term records obtained from the BoM stations, and provide rainfall information specific to the assessment area. The locations of these weather stations are shown in Figure 3-2.

3.6.2 Rainfall and evaporation

Annual rainfall is very similar at both BoM gauging stations. Average annual rainfall at Gulgong and Dunedoo between 1961 and 1990 was approximately 667 mm/a and 630 mm/a respectively.

A cumulative rainfall departure assessment for the Dunedoo station shows that this area recorded frequent below-average rainfall from 1910 to 1945 and frequent above-average rainfall after 1945. Since 2000, annual rainfall has continued to be above long term averages.

Rainfall is generally greater in the summer months than in winter, and evaporation is higher than rainfall. This is typical of Australian environments. The winter months of June and July are the exception, where rainfall and evaporation are comparable.

3.6.3 Climate change

Climate change is projected to have a marked impact on many climate variables, including temperature and rainfall, as the century progresses. However, the predicted changes over the lifetime of the Project are low, with approximately 1% change in average annual rainfall and approximately 1°C change in average annual temperature. The Project will therefore not need to implement adaptation strategies to account for climate change.

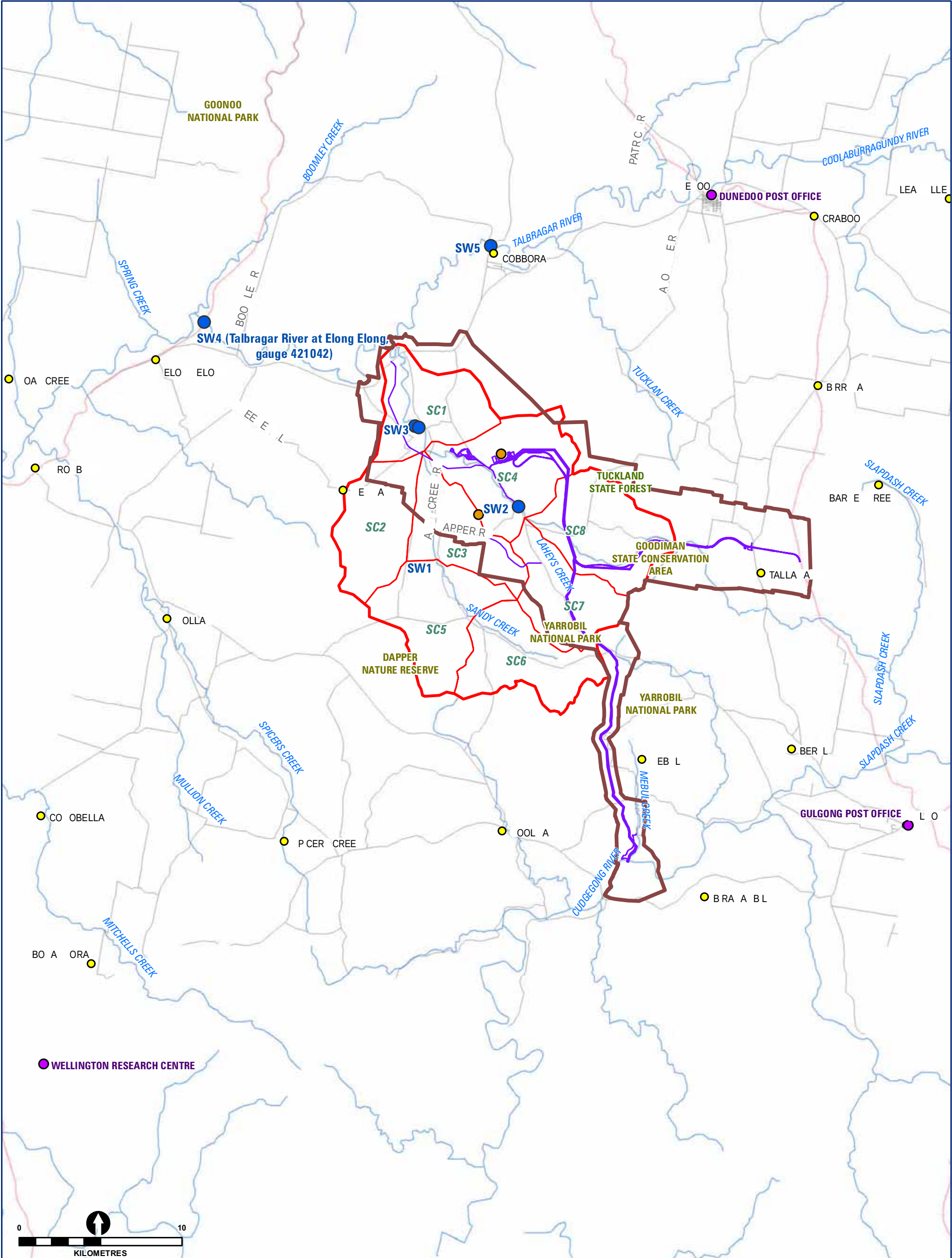


Figure 3.2 Weather stations and baseline surface water monitoring locations

- Surface water monitoring locations

●

 BOM weather station

●

 Project weather stations

●

 Towns
- Existing contours (20m)

—

 Drainage

—

 Railway

—

 Main roads
- Project application area

—

 Project area catchment boundary

—

 Sub-catchments

—

 Mine infrastructure

Topographic map source: NSW Department of Lands, 1989

3.7 Local surface water bodies

The proposed mining area is predominantly located in the Sandy Creek catchment, a sub-catchment of the Talbragar River. Sandy Creek, Laheys Creek (a tributary of Sandy Creek) and Blackheath Creek (a tributary of Laheys Creek) flow in a general north-westerly direction through the proposed mining area.

The Talbragar River, Sandy Creek and Laheys Creek are naturally ephemeral waterways that cease to flow during dry periods. There are no headwater storages to regulate flows, so all flows directly reflect rain events, groundwater baseflows and evapotranspiration processes.

Flyblowers Creek is a small creek catchment located north-west of the Sandy Creek catchment. This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek.

Fords Creek is a tributary of Laheys Creek and lies in the upper catchment. Fords Creek flows west and captures runoff from the forested areas near the Goodiman State Forest. Many small drainage channels and gullies drain into it. The proposed rail corridor runs along Fords Creek and crosses a number of these channels and gullies.

The remainder of the Project Application Area covers catchments of minor tributaries and small creeks in the south and part of the tributary system draining to Tallawang Creek in the east. Tallawang Creek flows south into the Wyaldra Creek, which eventually flows into the Cudgegong River west of Gulgong.

Two farm dams have been constructed on Blackheath Creek, a tributary of Laheys Creek. These were constructed by the landowner approximately 30 years ago to service the property's irrigation needs and are generally referred to as the west 'Woolandra' farm dams. The larger of the two dams has a capacity of approximately 1,470 ML. The upstream smaller dam (referred to as the 'sausage dam') receives inflow from groundwater springs higher in the catchment and has a capacity of approximately 15 ML.

Tucklan Creek flows in a northerly direction from the site into the Talbragar River, approximately 10 km upstream of the Sandy Creek – Talbragar River confluence. Tucklan Creek has a similar catchment area to Laheys Creek, but only approximately 1 km of its headwaters lie within the assessment area. No infrastructure will be constructed in the Tucklan Creek catchment. It was therefore not necessary to consider Tucklan Creek further in this assessment.

3.8 Baseline hydrologic conditions

3.8.1 Stream gauge information

There are no NSW Office of Water (NOW) gauging stations currently in operation within the assessment area or the broader Sandy Creek catchment. However, Station 421042 is located on the Talbragar River at Elong Elong, approximately 10 km north-west and downstream of the assessment area (shown on Figure 3-2 as SW4). Additional stream flow records are available from discontinued NOW stream gauges on the Talbragar River at Cobbora (close to SW5 on Figure 3-2) and on Sandy Creek at Medway (close to SW3 on Figure 3-2).

The Talbragar River is characterised by a seasonal discharge pattern, with lower flows during summer and autumn, and floods throughout winter and spring.

Based on available recorded data from NOW, the median annual discharge at Elong Elong is 21,509 ML/a, with a maximum recorded annual discharge of 264,366 ML in 1998 and a minimum recorded annual discharge of 653 ML in 2005.

The flow duration curve developed from the Elong Elong gauge shows that although the highest recorded mean daily flow was 40,835 ML/d (in December 2010), for 50% of the time flows were less than 11.9ML/d and for 32% of the time there was no flow.

The flow record from Sandy Creek at Medway shows that for the period of record (1966–1985), the highest mean daily flow was 8,937 ML/d, which occurred in February 1971. The flow duration curve for Sandy Creek at Medway shows that for 50% of the time flows were less than 0.04 ML/d and for 46% of the time there was no flow. Refer to Appendix A for further details.

3.8.2 Water level gauging

As part of Parsons Brinckerhoff's ongoing baseline surface water monitoring program, four water level gauging stations have operated on the Talbragar River, Sandy Creek and Laheys Creek since November 2009 at locations SW1, SW2, SW3 and SW5 (see Figure 3-2).

These data have been used in the water quality impact assessment (Appendix B) to identify the flow regimes that occurred during the surface water quality sampling program.

3.8.3 Baseline flood hydrology

3.8.3.1 Flood history

Limited flooding information is available for the assessment area and no flood studies have been carried out for the Talbragar River, Sandy Creek or Laheys Creek. Consultation with local councils indicated that major floods in the Talbragar River coincide with floods in the Macquarie River. The coincidence of high flows in both the Macquarie and Talbragar Rivers, however, rarely imposes a flood risk to Dubbo, which is located near the confluence.

The February 1955 flood was the only known occasion where both rivers flooded together and the Talbragar River 'backed up' the Macquarie River, causing extensive inundation in central and northern Dubbo.

The Dubbo Local Flood Plan suggests that the Talbragar River floods 'every few years', with only the events of 1870, 1920, 1926, 1950 and 1955 known to have broken banks and entered the surrounding floodplain. The 1955 flood is believed to be the most severe and was estimated to have a 200-year average recurrence interval (ARI). In contrast, the floods of 1920 and 1950 (the next highest) only resulted in backwater flooding in low spots along the Talbragar River.

3.8.3.2 Design flood estimation

To estimate baseline design flood conditions, a combination of flood frequency analysis and hydrologic and hydraulic modelling was undertaken. The relatively long 41 year flow record for Elong Elong was the key dataset used to estimate peak flows at Medway on Sandy Creek, by using a method that correlated flow records to transpose flood frequency analyses at Elong Elong to Medway. The flood frequency analyses for the two gauge sites are given in Tables 3-1 and 3-2.

Table 3-1 Flood frequency analysis results for the Talbragar River at Elong Elong

Storm event	Estimated flow (m ³ /s)	Estimated 95%ile lower bound flow (m ³ /s)	Estimated 95%ile upper bound flow (m ³ /s)
2 year ARI	43	27	68
5 year ARI	169	104	306
50 year ARI	893	469	2113
100 year ARI	1234	624	3103

Table 3-2 Design flood flow estimates for Sandy Creek

Event	Estimated range of Sandy Creek peak flow (m ³ /s)			WBNM modelled peak flow (m ³ /s)
	Estimated flow	95%ile lower bound flow	95%ile upper bound flow	
2 year ARI	17	11	28	29
5 year ARI	74	44	137	78
100 year ARI	599	291	1,584	429

Refer to Appendix D for further details on how the Sandy Creek analysis and design flow estimates were developed.

3.8.3.3 Hydraulic model

A hydraulic model for Sandy Creek was developed to assess baseline and future flood conditions near the mine. The model determined flood levels, extents and velocities in the watercourses. It was also used in the preliminary design of access and haul road crossings, and flood protection levees for mine infrastructure.

The model simulated flood conditions for the 2, 5, 100 and 2000 year ARI events, with the 2000 year ARI event included as an upper limit for assessing flood risk.

3.8.3.4 Baseline flood behaviour

The baseline 100 year ARI flood extent is illustrated in Figure 3-3. Overall, the 100 year ARI flood is contained within channel in the upper tributaries of Sandy Creek and Laheys Creek. Once the catchment flattens out in the middle to lower reaches of Sandy Creek and Laheys Creek, there is some floodplain flow in the left and right overbanks due to the meandering nature of these watercourses.

Existing 2 year and 5 year ARI events are mainly conveyed in-channel for the middle to lower reaches, with higher flows going out of bank in localised areas. The 2000 year ARI event produces mainly overbank flow, but flows are still contained by the shape of the valley in the lower reaches.

3.9 Baseline water quality

Baseline surface water quality was assessed by:

- defining objectives and guidelines
- reviewing and analysing baseline water-sampling data

- comparing baseline water quality against relevant guidelines
- assessing surface water quality processes in the assessment area.

Baseline water sampling data were reviewed for gauge locations SW1, SW2, SW3, SW4 and SW5 (see Figure 3-1). Samples were collected and analysed each month from August 2009 to September 2011 (inclusive). They were analysed for physical parameters (electrical conductivity, pH, turbidity, temperature, dissolved oxygen), major ions, nutrients and a suite of metals.

3.9.1 Objectives and guidelines

ANZECC (2000) guidelines and DECCW (2006) water quality objectives were used to assess baseline water quality conditions. The ANZECC guidelines were also used to develop customised or project-specific water quality objectives to assess the Project's potential impacts on surface water quality (see Appendix B for details).

To determine baseline water quality, parameters were assessed against the 'Condition 2' category, defined as *'slightly to moderately disturbed systems'*, as the Talbragar River, Sandy Creek and Laheys Creek catchments are dominated by agriculture and pastoralism.

3.9.2 Flow ranges during water quality monitoring

Appendix A contains a detailed analysis of the flow conditions that occurred during the surface water quality monitoring carried out between August 2009 and June 2011. In summary, the following observations were made:

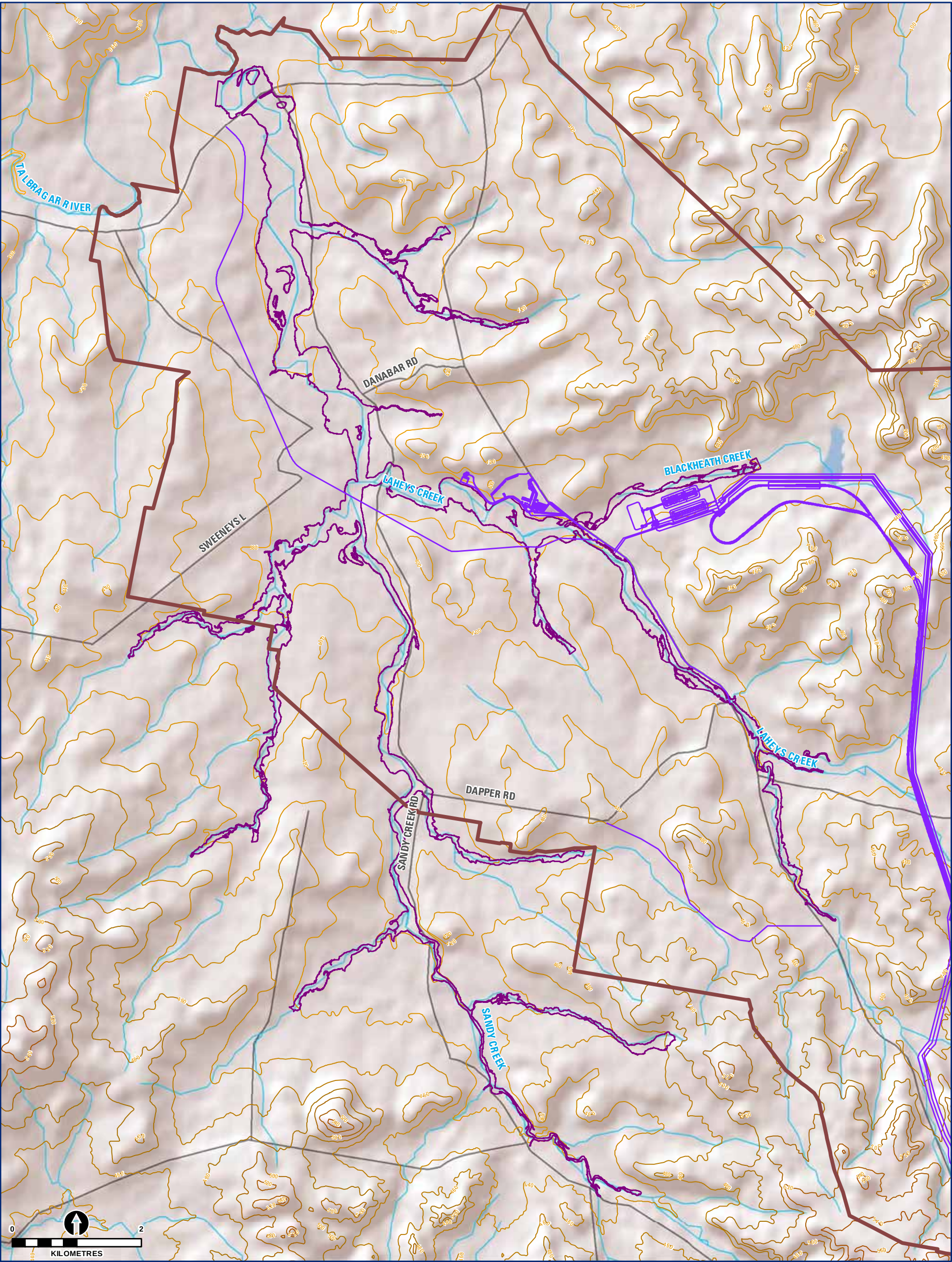
- Samples taken were predominantly collected during 'nil' or 'low' flow conditions. 'Medium' and 'high' flow conditions were not represented as frequently as the lower flows.
- Due to the ephemeral nature of Sandy Creek and Laheys Creek, low flow is the normal catchment condition and therefore the sampling undertaken to date is representative of average conditions in these creeks.

3.9.3 Surface water quality monitoring findings

Surface water quality monitoring results were compared against ANZECC water quality guidelines and water quality objectives. Full details are provided in Appendix A. The following sections summarise baseline water quality findings.

3.9.3.1 Salinity

Salinity in upstream locations of Sandy Creek (SW1) and Laheys Creek (SW2) were relatively high. This is likely to be due to saline soils and the effect of evaporation in isolated, semi-permanent pools, increasing the concentration of dissolved ions.



100 year existing flood extent	Drainage lines
Elevation (m)	Roads
Mine infrastructure	Project application area

Figure 3.3 Existing 100 year ARI flood extent (Sandy Creek catchment)

3.9.3.2 Nutrients

Elevated nutrients were also found and are likely to have been caused by local land uses and river flows. The land surrounding Sandy Creek and Laheys Creek and the Talbragar River is mainly used for cattle and sheep grazing on improved pastures, and dryland cropping.

Sediment sources will also contribute to the nutrient load in these watercourses and include overland erosion, especially along tracks which provide a conduit for surface water runoff, bank erosion during high-flow conditions and re-suspension of in-channel bed sediments. Watercourse crossings provide a mechanism to deliver and re-suspend sediment in creeks, with plumes of sediment caused by vehicle traffic.

Ephemeral streams such as Laheys and Sandy creeks also retain large amounts of particulate organic matter in the dry channel that may be carried downstream during storms.

3.9.3.3 Metals

Some metals were above the protection threshold for 99% of species in aquatic ecosystems, including aluminium, arsenic, boron, copper, manganese, nickel and zinc. Except for aluminium and boron, these metals also exceeded the threshold for the protection of 95% of species. This is commonly associated with *slightly to moderately disturbed ecosystems*, which is the existing condition of the assessment area.

Because there are no industrial discharges upstream of the site, these levels are naturally occurring, reflecting local soils and geology. In semi-permanent pools like those recorded in Laheys Creek and Sandy Creek, toxicants can also accumulate.

3.10 Baseline geomorphology

Talbragar River, Sandy Creek, Laheys Creek and other minor catchments near the site are dominated by valley fills of Quaternary alluvium. The alluvium is characterised by gravels and sands interspersed with clays, and varies in thickness from 0 to 28 m. These soils retain runoff and release it slowly, particularly when vegetation is intact. They are also long-term sediment stores.

In the Sandy Creek upper catchment, alluvial deposits are interspersed with short, bedrock-controlled sections where the longitudinal creek bed profile drops down, providing an overall stepped, longitudinal profile. The upstream Sandy Creek reach is confined with bedrock control as it steps down from the Tannabutta Group (shale, slate and thick-bedded volcanoclastic sandstone) that rims the catchment.

Downstream of those sections in Sandy Creek and Laheys Creek, water floods out into the broader valley floors of the higher order watercourses. Energy conditions are generally low in the broad valley floors where flows are dispersed. Many of these valley floors have been altered to allow cultivation and cropping. They have been channelised, often by excavation at a valley margin to reduce saturation and increase agricultural productivity. The downstream reaches of Sandy Creek and Laheys Creek are alluvial discontinuous with either chain-of-ponds or valley fill features.

The Talbragar River is in a broad valley floor with a valley fill that has been altered by cultivation. The channel has moderate sinuosity and gravel/sand bed. However, channel development is still minimal and flows are largely unconfined. The Talbragar River is an alluvial continuous channel with channelised fill.

3.11 Groundwater – surface water interaction

A key feature of groundwater – surface water interaction in the catchments is the presence of ecological refuge pools that persist during prolonged dry periods, several of which have been observed on Sandy and Laheys Creeks. Pools that persist during sustained dry periods are likely to be groundwater fed rather than reliant on surface water runoff. Other pools that dry out shortly after rainfall events are likely to be surface water fed and do not receive significant groundwater inflow. It is also likely that some pools and habitats are reliant on a combination of surface and groundwater inflows; however, given that the creeks are ephemeral, groundwater inflows will govern levels in persistent pools rather than short duration surface water inflows.

14 pool sites that have been documented in the aquatic ecology assessment (Cardno 2012) were reviewed against the groundwater modelling results and the following characteristics were identified:

- Pool site 1 on the Talbragar River is potentially groundwater dependent.
- Pool sites 2 and 3 on Sandy Creek downstream of its confluence with Laheys Creek are potentially groundwater dependent.
- Pool site 5 on Sandy Creek downstream of its confluence with Laheys Creek is likely to be groundwater dependent.
- Pool site 6 on Sandy Creek upstream of its confluence with Laheys Creek is potentially groundwater dependent.
- Pool sites 10 and 13 on Laheys Creek upstream of its confluence with Blackheath Creek are potentially groundwater dependent.
- The remaining seven pools are not groundwater dependent.

The groundwater modelling results indicate that groundwater levels will fully recover within 20 to 50 years post mining. Therefore, there will be a recovery of groundwater inflow to the affected pools in the long term.

4. Water management system

This section summarises the Project's proposed mine water balance and surface water management system, including predicted site water demands and proposed mine water storages and associated structures. It also describes the proposed water supply and licensing strategy for the Project. Please refer to Appendix E for a more detailed description of the above.

4.1 Water management strategy

The water management strategy proposed for the mine aims to segregate water according to its quality to minimise the volume of stored water affected by mining. This will allow treatment to settle suspended sediment and to divert clean water away from mining activities.

Five water classifications have been nominated for the mine site:

- **Clean water** — runoff from undisturbed areas that are expected to have pre-mining water quality and that can be diverted to the creek system.
- **Overburden water** — runoff from overburden emplacements, topsoil stockpiles and other disturbed areas. This water contains elevated suspended solids, which will be settled in sedimentation dams before release to the creek system or on-site reuse.
- **Pit water** — runoff from the open pits and groundwater seepage into the mine. This water can potentially contain suspended solids, salts and heavy metals etc. This water will be stored on-site and will be reused.
- **Infrastructure water** – runoff from the areas around the CHPP, stockpiles and infrastructure. This water will be directed to the process water circuit.
- **Process water** —water that is utilised in the CHPP, including return water from the reject emplacement areas and refuse disposal ponds. This water is continuously recycled within the system.

A brief summary of the water management systems being proposed to manage water at the mine is provided below. Refer to Appendix E for additional details on these systems.

4.1.1 Clean water system

The clean water system will generally comprise the following components:

- Clean water catch drains to divert minor catchments around the mine site, where practical.
- Clean water highwall dams and levees upslope of active mine pits to reduce peak flow rates and velocities from undisturbed catchments.
- A pump and pipeline system to pump clean water stored in clean water highwall dams to the creek system.
- A raw water dam to store water imported to the mine from the Cudgegong/Macquarie Regulated River system.

- A pump and pipeline system from the raw water dam to deliver stored water to either the process water dam (CHPP), truck fill stations (dust suppression) or water treatment plant (potable water).
- Flood mitigation works, such as levees along the edge of mining areas.

4.1.2 Overburden water system

The overburden water system will generally comprise the following components:

- A drainage system to convey runoff from the overburden emplacements, topsoil stockpiles and other disturbed areas to sedimentation dams.
- Several sedimentation dams strategically located throughout the mine site to capture water from the above sources.
- A pump and pipeline system to transfer water stored in sedimentation dams to either the mine water system for reuse at the mine site or to the creek system at nominated licensed points.

4.1.3 Pit, infrastructure and process water systems

For the purpose of this assessment, the pit, infrastructure and process water systems have been combined into a single system, referred to as the mine water system.

The mine water system will generally comprise the following components:

- Small sumps in the pit floor to collect and contain local surface water runoff from the pit floor, high wall, low wall and end walls, as well as groundwater seepage.
- Pit dewatering pumps and associated dewatering pipelines to transfer pit water to the nearest mine water dam, if necessary via a small staging dam.
- Treated effluent from the on-site wastewater treatment plant.
- A drainage system to convey runoff from disturbed areas to the nearest water storage dam.
- Mine water dams to store and contain water from the above sources.
- A return water pump and pipeline system from each dam to deliver stored water to either the CHPP (coal washing), mine infrastructure area (for vehicle wash, workshop and dust-suppression sprayers), and truck fill stations (for haul road dust suppression).

It is important to note that there will be no releases of water captured in the mine water system to the natural creek system. This system will be used as a priority to meet on-site water demands and imported raw water will only be used when there is a water deficit or high quality water is required for uses such as potable applications.

During extended wet periods, surplus mine water will be stored in-pit once the mine water dams have reached their capacity. The scale of the mine with multiple pits allows pit water to be pumped between individual open cuts. This gives good flexibility, allowing the mine to continue to operate without flooding active workings or relying on unscheduled releases of surplus water.

4.1.4 Staging of water management system

The water management system will evolve as the Project expands, to be compatible with the mine landform and schedule.

Development of the water management system concepts over the mine's 21-year life have been illustrated through snapshots at five mine stages, corresponding to Year 1, 4, 12, 16 and 20 mine landforms. For the purpose of the surface water assessment, the five mine stages selected provide a reasonable representation of how the mine will be developed. The five mine stages also illustrate the design flow paths of different classes of water and locations of water management dams during respective stages of the mine's development.

Nine mine water dams, 38 sedimentation dams, one raw water dam and nine highwall dams are proposed to manage the surface water runoff and water supply of the mine over its 21-year life.

Detailed mine stage plans and schematic diagrams showing the general connectivity between water sources, demands and storages are provided in Appendix E.

4.2 Site water balance model

A water balance model has been developed to simulate the Project's water management system. It was used to assess the performance of the system and estimate potential annual runoff volumes and water requirements. The water balance model has also been used to assess the potential for dam overflows during a range of climatic conditions.

4.2.1 Modelling approach

The water balance model was developed using GoldSim software, a widely used and industry standard platform for mine site water balance studies.

Separate GoldSim models were developed for Year 1, 4, 12, 16 and 20 mine landforms to assess the site water balance over the life of the mine. The site water balance was simulated for each mine year using 111 years of climate data based on a daily time step. The climate data were statistically analysed to present potential water balances for 10th (dry), 50th (median) and 90th (wet) percentile years. Each year of the mine was modelled for 111 years of climatic data, with water stored in all dams carried forward from one year to the next.

Treated water stored in sedimentation dams that cannot be reused or stored on-site would be returned to the creek system in accordance with relevant licensing requirements.

Catchment boundaries for the water management system were delineated using conceptual mine staging plans and reasonable assumptions about the likely destination of runoff across the site. The model was also based on other assumptions in relation to dam sizes, stage-storage relationships, pump rates and general system operating rules. Please refer Appendix E for further details on model setup and assumptions.

4.2.2 Water inputs

The water balance model was configured for the following water inputs:

- surface water runoff
- groundwater seepage to the open pits
- imported water.

Surface water runoff includes runoff from undisturbed, disturbed and rehabilitated catchments. The Australian Water Balance Model (AWBM) was incorporated into the GoldSim model to generate a daily time series of runoff from undisturbed, disturbed and rehabilitated catchments.

Groundwater includes natural groundwater seepage into the pits without pre-mining dewatering. Groundwater seepage rates over the life of the mine have been referenced from the Project's groundwater assessment report (Parsons Brinckerhoff 2012).

Raw water will be imported to meet part of the demands of the mine and provide a high quality source for potable water. This water will be pumped from the Macquarie and Cudgong Regulated River system and stored in a raw water dam. CHC currently holds 3,311 unit shares of high security water access licences (WALs) from this system, which equates to 3,311 ML/a of imported water. Refer to Section 4.3 for further details.

For the purposes of this assessment, the existing west 'Woolandra' farm dams have been included in the baseline model, that is, their combined runoff capture capacity contributes to reductions in flow in the downstream waterways. However, these farm dams have been excluded from the water balance model and proposed water management system for the Project. It is assumed that runoff from their catchments will be returned to Laheys Creek.

Treated wastewater effluent was not included in the water balance model, as the quantity will be nominal and relatively insignificant when compared to other sources.

The water balance presented in this report assumes full availability of high-security WALs. Further optimisation to minimise water consumption from the Macquarie and Cudgong Regulated River system may be possible and will be assessed during detailed design.

4.2.3 Water demands

Water demands for the Project comprise:

- CHPP make-up water
- mine infrastructure areas, such as workshops and vehicle washdown areas
- haul road dust suppression
- potable water
- miscellaneous uses, such as construction water.

Water demands for the Project are summarised in Table 4-1. The peak demand is estimated to be 3,656 ML/a.

Table 4-1 Water demand summary

Year	Product coal (Mt/a)	CHPP make-up water (ML/a)	Mine infrastructure area demand (ML/a)	Haul road dust suppression (ML/a)	Potable water demand (ML/a)	Total site demand (ML/a)
Construction (peak)	—	—	—	—	46.5	47
1	0.7	151	9	61	2.4	223
4	11.2	2,340	140	936	5.0	3,421
12	12.0	2,500	150	1,000	6.1	3,656
16	12.0	2,500	150	1,000	6.2	3,656
20	12.0	2,500	150	1,000	3.0	3,653

Refer to Appendix E for further details on how water demands for each activity were estimated.

4.2.4 Results of water balance modelling

Site water balances were obtained by assuming that runoff captured in sedimentation dams will be available for reuse. The water balance shows that the mine will generally need imported water to meet its total water demands. The estimated imported water requirements for typical dry (10th percentile), median (50th percentile) and wet (90th percentile) rainfall years are summarised in Table 4-2.

Table 4-2 Summary of imported water requirement for dry-, median- and wet-year climate conditions

Year	Total site demand (ML/a)	Groundwater seepage (ML/a)	Imported water for a dry year (ML/a)	Imported water for a median year (ML/a)	Imported water for a wet year (ML/a)
1	223	38	0	40	0
4	3,421	886	2,360	1,720	520
12	3,656	1,549	1,700	1,100	0
16	3,656	1,341	1,880	1,200	0
20	3,653	248	2,960	2,180	220

It is estimated that 2,960 ML/a of imported water will be required for a typical 10th percentile dry year and 220 ML/a for a typical 90th percentile wet year. By reusing water captured by the sedimentation dams, the Project's peak imported water demand is expected to reduce by 120 ML/a for the modelled dry year. The requirement for imported water peaks to about 3,380 ML/a in Year 20, and exceeds the 3,311 ML/a WAL limit for 3 years out of the 111 years simulated, or less than 3% of time.

The model predicts that the pit dewatering system will generally be able to maintain dry pits, but during extended wet periods mining may be interrupted by in-pit flooding. The model also predicts that there will be no releases of mine water from the water management system over the life of the Project. Mine runoff will be reused on-site and stored in-pit during extended wet periods until the mine water dams have regained their capacity to store water.

4.3 Water supply

The water balance modelling predicts that make-up water will need to be sourced from an external supply source. This external supply is referred to as imported water in Section 4.2 and is discussed in more detail below. CHC has obtained entitlements to this imported water to ensure it has an adequate supply to construct and operate the mine.

4.3.1 The Macquarie and Cudgegong Regulated Rivers Water Source

In NSW, there currently is an embargo on new WALs. Water for any new developments must therefore be sourced by the purchase of existing WALs from willing sellers via the water trading market. That means that new users can only gain access to water by purchasing entitlements from existing licence holders. This approach is consistent with the objectives of the National Water Initiative.

To provide the necessary level of water security for the Project, CHC purchased regulated river (high-security) WALs from the Macquarie and Cudgegong Regulated Rivers Water Source. CHC began buying WALs in late 2009 in accordance with the WSP and obtained 3,311 ML of regulated river (high-security) WALs from willing sellers in the system. This included 1,000 ML of authorising extraction from upstream of Burrendong Dam on the Cudgegong River and 2,311 ML from downstream of Burrendong Dam on the Macquarie River.

Purchase of this water was conditional upon receiving approval from the NSW Office of Water (NOW) for:

- Changing the extraction zone from downstream to upstream of Burrendong Dam, but still within the same water source.
- Works Approval for a pump site on the Cudgegong River some 2 km upstream from Yamble Bridge.

Changes to the extraction zone and the water supply works were subject to a detailed impact assessment by NOW, as required by WMA 2000, prior to its determination. Each of these approvals is discussed further below.

4.3.1.1 Approval to change water extraction zone

There are two extraction zones in the Macquarie and Cudgegong Regulated Rivers Water Source — upstream of Burrendong Dam on the Cudgegong River and downstream of the dam on the Macquarie River.

A change of extraction zone is permitted if the environmental and third-party user impacts are not significant and if the total extraction potential in the upstream zone does not exceed 40,000 ML. Potential extraction in this case was less than 27,000 ML.

WMA 2000 requires that the impact will not be significant. This involves an assessment by NOW on the potential environmental and third party impacts, including hydrological changes. For an approval to be granted, the Minister needs to be satisfied that the transfer of entitlement will not have adverse consequences.

Applications to change the authorised extraction zone were submitted in June 2010. Following NOW's determination that the impact will not be significant, the change of extraction zone for WALs associated with 2,311 ML was approved by the Minister under Section 71S of WMA 2000 in June 2011.

NOW also confirmed that as the extraction zone for the other 1,000 ML is located upstream of Burrendong Dam, it did not require further assessment by NOW nor approval from the Minister.

On this basis, CHC now holds 3,311 ML of regulated river (high security) WALs in the extraction zone upstream of Burrendong Dam in the Cudgegong River.

Access to this water is determined by the WSP for the regulated Macquarie and Cudgegong Rivers Water Source and will vary from year to year, depending on water in storage, climatic conditions and the associated Available Water Determination. Water availability under these types of WALs is generally very secure with the full allocation being available every year in all but the driest year on record.

The average long-term extraction factor for high-security WALs for the Macquarie Regulated River Valley published in the document *Water availability in New South Wales Murray-Darling Basin Regulated Rivers* (DWE 2009) is 0.95. This suggests a high degree of certainty about the availability of high-security WAL allocations in this system.

Regulated river (high security) WALs have priority of allocation over regulated river (general security) WALs. High security entitlements, however, cannot carryover water from one year to the next, but as specified in the WSP, 100% is allocated to high security prior to general security water being made available each year.

In all but the driest year on record, the Project will have access to 3,311 ML of water from its high security entitlements. Under extreme prolonged dry weather conditions, however, town water supply and domestic/stock uses will always take priority over other consumptive uses.

High security WALs associated with the Project do not receive an allocation before all town water supply requirements are met. This means that critical human water needs must be fully catered for before any water is allocated for other uses.

State Water is responsible for ensuring water is delivered to the authorised extraction points, in accordance with the WSP. State Water will generally require four day forward orders on water from CHC to ensure there is sufficient water in the system to deliver it to the authorised extraction point.

4.3.1.2 Authorised water extraction point

CHC required a Works Approval to build a pumping station at Lot 39 DP 750780 to extract water from the water source. Development consent for these works is required under Section 92 of WMA 2000 and the Determining Authority is NOW.

A development application was submitted by CHC in early 2010. The application was advertised and placed on public exhibition in accordance with statutory requirements, closing on 28 June 2010. No objections were lodged with NOW about the application.

NOW assessed the potential impacts of the proposed Works Approval. The site was also inspected by NOW to confirm potential impacts. The Works Approval was granted in September 2011.

A condition of the Works Approval is that CHC must provide an Extraction Strategy Agreement to State Water before the start of each water year. The main purpose of the Agreement is to assist State Water in river operational efficiencies by “mopping-up” operational surplus flows. Operational surpluses mean flows higher than the Yamble Bridge target averaging 25 ML/day.

Operational surplus arises primarily from rain-rejection of ordered water, but can also result from operator error and infrastructure failure, such as pump breakdowns. The preference of upstream licence holders to extract entitlements primarily during off-peak power periods is another significant and typically more regular source of operational surplus.

Given the strategic location of CHC's pump site in the Cudgegong River System, which is about 2 km upstream of Yamble Bridge, and that CHC will be the last major water user prior to the Cudgegong River entering the upper reaches of Burrendong Dam, CHC has a unique ability to assist river operators minimise operational surplus. Any reductions in the operational surplus will benefit the Cudgegong River delivery and water supply operations and in turn enhance the security of supply from Windamere Dam to downstream users.

Negotiations between CHC and State Water are underway so the Extraction Strategy Agreement can meet the imported water requirements of the Project as well as assist with operational efficiencies of the system. The Agreement will include a statement of intent, purpose, water order requirements, infrastructure capacity, communications protocol, information exchange, real-time monitoring and end of year reporting.

It is understood that the Extraction Strategy Agreement is currently being reviewed by State Water and is expected to be finalised before the end of 2012. The Extraction Strategy Agreement could set constraints or requirements on extraction that may need to be considered in future versions of the mine's operating water balance model. Suitable water supply security options are available to manage mine water requirement shortfalls should they be identified. These options are discussed in Section 6.2.1.

4.3.2 Existing water entitlements

A full listing of all water entitlements held by CHC is provided in Appendix F. This table includes both surface water and groundwater entitlements held under WA 1912 and WMA 2000.

Further information regarding each of the surface water entitlements listed in Appendix F is provided below. For information regarding the groundwater entitlements, refer to the relevant section in the Project's groundwater assessment report (Parsons Brinckerhoff 2012).

4.3.2.1 Approvals under the Water Management Act 2000

CHC has approval to extract water from an existing set of pumps upstream of Lot 39 DP 750780, near Gulgong at Lot 3 DP 854204 (80WA702573). This approval is associated with the 1,000 ML of water that CHC purchased in the extraction zone upstream of Burrendong Dam as part of the high security WAL. CHC holds water entitlements as part of a Joint Water Supply Works Approval.

The pipeline from the authorised extraction point to the Project site is described in more detail in the main Environmental Assessment volume.

4.3.2.2 Water Access Licences under the Water Management Act 2000

CHC holds a total of 3,311 shares of regulated river (high security) WALs to extract from the zone upstream of Burrendong Dam in the Macquarie and Cudgegong Regulated River Water Source.

4.3.2.3 Licenses under the Water Act 1912

There are four dams located on properties owned by CHC that are currently licensed under Part II of WA 1912.

These dams have recently been converted to an annual volumetric entitlement as a requirement of the draft WSP for the unregulated Macquarie-Bogan River System, which is currently being prepared. Conditions on water access under each of these licences are outlined below:

80SL095816 — Lot 1 DP 209396 ‘Rockleigh’

The current conditions attached to this licence allow CHC to divert from this structure up to 43 ML of water per year for irrigation uses. The licence conditions allow CHC to divert up to twice this amount in any one year (up to 86 ML), provided the total diversions do not exceed three times the licensed volume in any three year period. This means the maximum that can be diverted in a three year period is 129 ML.

80SL095852 — Lot 22 DP 754289 and Lot 41 DP 754289 ‘Woolandra’

This licence includes three dams. Two are situated at west ‘Woolandra’ (Lot 41 DP 754289), which lies at the headwaters of Blackheath Creek. The larger dam has a volume of 1,470 ML.

The small dam (referred to as the ‘sausage dam’) has a volume of approximately 15 ML. The dam on Lot 22 DP 754289 is situated at the headwaters of a Tucklan Creek tributary and has a volume of 548 ML.

The current licence allows CHC to divert from the structures up to 1,269 ML of water per year for irrigation. CHC can divert up to twice this amount in any one year (up to 2,538 ML), provided the total diversions do not exceed three times the licensed volume in any three year period. The maximum that can be diverted in a three year period is 3,807 ML.

When the WSP for the unregulated Macquarie-Bogan River System commences in 2012, the volume assigned to the licence will automatically convert to an unregulated access licence. This access licence can be then used for any purpose, including mining.

4.3.3 Basic water rights — harvestable rights dams

Harvestable rights allow landholders in most rural areas to collect a proportion of the runoff on their property and store it in one or more farm dams up to a certain size, without requiring a licence. This harvestable right water is generally intended for essential stock and household use but can be used for any purpose.

The harvestable right is the total amount of water that owners are entitled to capture and store, pursuant to the harvestable rights order made under Part 1 of Chapter 3 of the *Water Management Act 2000*. The maximum harvestable right dam capacity (MHRDC) is the total dam capacity allowed under the harvestable right for a property.

The total area of CHC holdings is approximately 104,006 ha. The total capacity of existing unlicensed farm dams on the CHC property is estimated at just under 2,100 ML. The calculated MHRDC allowed under the harvestable right for CHC holdings is approximately 6,760 ML. CHC has no intention of accessing water from the MHRDC for mine purposes.

4.3.4 Water source protection criteria of the WSP

The WSP for the Macquarie and Cudgong Regulated River Water Source includes specific environmental water rules to protect the water source and its dependent ecosystems.

These are designed to:

- Ensure there is no erosion of the long-term average volume of water available to the environment during the life of the Plan.
- Provide more natural flows in the upper reaches of the Cudgegong River immediately below Windamere Dam.
- Establish an environmental water allowance, which is to be released:
 - ▶ to provide more natural flows downstream of Burrendong Dam during autumn, winter and spring months, and
 - ▶ when needed for specific environmental purposes in the Macquarie River or Macquarie Marshes.

As outlined in Section 4.3, CHC has entitlements to extract from the Macquarie and Cudgegong Regulated Rivers Water Source. These were subject to detailed review and assessment by NOW prior to determination.

On the basis of NOW's positive determination and subsequent approval by the Minister, the environmental and source protection criteria set for the Macquarie and Cudgegong Regulated River Water Source will be met by the Project.

4.4 Licensing requirements

CHC proposes to construct a new dam to store water extracted from the Macquarie and Cudgegong Regulated River Water Source. This raw water dam will require a licence under WA 1912 or WMA 2000, when the relevant WSP commences. CHC will consult with NOW to obtain the necessary licences and approvals prior to construction.

The water balance modelling (Section 4.2) included groundwater seepage during the life of mine. CHC will be required to net-off this incidental take of groundwater by purchasing corresponding groundwater entitlements for the Project. Further information on this requirement is provided in the groundwater assessment report (Parsons Brinckerhoff 2012).

No further licencing requirements under the WA 1912 or WMA 2000 have been identified to source surface water for the site.

The water management system described in Section 4.2 includes the return of treated water from sedimentation dams to Sandy Creek and Laheys Creek. These are likely to be regulated by an Environment Protection Licence (EPL) issued by the NSW Office of Environment and Heritage (OEH) under the provisions of the *Protection of the Environment Operations Act 1997*.

Preliminary locations of up to three licensed points have been identified in Section 7. The final number and location of these points may be refined during detailed design in consultation with OEH.

5. Potential impacts

This section discusses the potential surface water impacts of the Project during the construction, operational and post-mining phases of the Project.

5.1 Construction phase

In general, construction phase impacts associated with mining infrastructure have been assessed with operational impacts of the Project. Key construction impacts are related to erosion and sedimentation issues, which have been considered in the site water management and water quality assessments.

The Project includes a number of watercourse crossings where access roads, haul roads and rail lines cross natural creeks and drainage lines. Preliminary design of major crossings was undertaken as part of the flood impact assessment (Appendix D). These designs determined clearances above flood levels, afflux criteria and main dimensions and invert levels of bridge and culvert openings.

During the construction of these crossings, there is potential for significant erosion unless appropriate mitigation measures are implemented. Typical construction activities will generally include the following:

- Temporary obstruction of main flow channels and/or temporary diversions to build bridge piers and abutments, or install culverts.
- Excavation in channels and floodplains to construct foundations for culverts, bridge piers and abutments.
- Placement and compaction of fill over channels and across floodplains to raise road and rail embankments at crossing structures.

If not properly controlled, these activities could have the following potential impacts:

- Disturbance of creek beds and floodplain soils which could lead to erosion of the disturbed areas and/or sedimentation in downstream channels where the eroded material will be deposited.
- During rainfall or high flow events, construction materials could be carried into creeks.
- Obstruction of flow channels or floodplains with temporary works could reduce flow conveyance leading to elevated flood levels upstream during floods. This could flood upstream land or infrastructure during construction.

Mitigation measures while constructing watercourse crossings are discussed in Section 6.1.

5.2 Operational phase

5.2.1 Water quality

The methodology used to assess water quality involved the following key tasks (refer to Appendix B for details):

- Potential surface water users and water quality objectives (WQOs) relevant to the system were reviewed.

- Project-specific or customised WQO trigger levels were developed based on published guidelines.
- Potential water quality changes downstream of the Project were assessed quantitatively using a mass-balance water quality model.
- Suitable mitigation measures were identified to minimise potential impacts.
- Potential cumulative impacts on water quality in the Talbragar River were assessed.

The assessment referred to the *Macquarie-Bogan River Water Quality and River Flow Objectives* (DECCW 2006) and ANZECC (2000) Guidelines.

Data collected by the surface water monitoring program (see Appendix A) were compared against ANZECC water quality triggers to characterise baseline water quality. These were found to exceed ANZECC guidelines for a number of water quality parameters. For this reason, and due to the ephemeral nature of the affected watercourses, it was necessary to develop customised or project-specific WQO trigger levels to assess future water quality.

A mass-balance water quality model determined customised WQO trigger levels and assessed potential impacts from sedimentation dams on water quality in Sandy Creek and the Talbragar River.

The key findings of the water quality impact assessment were:

- No apparent changes in ionic concentrations in the Talbragar River due to mining. The results indicate some improvement in TN, TP and TSS water quality parameters. All parameters modelled were below trigger levels defined by the customised WQOs in the Talbragar River.
- In Sandy Creek, all parameters were below customised WQO trigger levels, apart from TDS and TN.
- In Sandy Creek, water quality remains acceptable for irrigation.
- In Sandy Creek, water quality remains acceptable for contact recreation and livestock, apart from elevated TDS levels.
- In Sandy Creek, water quality remains acceptable for aquatic ecosystems apart from elevated TN levels.

Model predictions for TN and TP levels in Sandy Creek were based on groundwater bore concentrations, in the absence of measured data from surface runoff. Since the Project will change the existing land use from livestock pasture to mining, nutrient loads are likely to significantly reduce over the life of the mine. These parameters should therefore be viewed as conservative and are expected to decrease over time.

A cumulative assessment considered combined water quality impacts from the Project and Ulan Coal Mine, which is upstream of the confluence of Sandy Creek and the Talbragar River. Ulan Coal Mine is committed to meeting prescribed discharge limits for TDS to ensure there are no adverse impacts on the river. The Project assessment predicted a maximum 5% increase in TDS values in the Talbragar River above the baseline case, which is still well below the default WQO trigger level set for the Macquarie-Bogan catchment. The cumulative impact of the Project on the Talbragar River will therefore be acceptable.

5.2.2 Downstream flow impacts

Downstream flows are summarised in this section. Refer to Appendix C for full details of this assessment. The flow impact assessment involved the following tasks:

- Estimation of baseline catchment flows to understand the contribution of the Sandy Creek catchment to downstream flows in the Talbragar and Macquarie Rivers.
- Identification of River Flow Objectives for the wider Macquarie-Bogan catchment.
- Development and analysis of flow duration curves for Sandy Creek at Medway gauge and the Talbragar River at Elong Elong gauge.
- Analysis of the mine water balance model outputs to understand the impact of mining on flow regimes in Sandy Creek and the Talbragar River.
- Assessment of the potential cumulative impacts on flow in the Talbragar River.

The water balance for the Project (Appendix E) indicates that annual average flows will be similar to, but slightly less than baseline conditions, with a worst-case decrease of around 5% during average and dry years (with increases in annual flow volumes during wet years). Flow impacts were assessed at the confluence of Sandy Creek and Talbragar River and further downstream near the Elong Elong gauge.

Estimates in Sandy Creek were based on flows produced by the AWBM model developed for the mine water balance. For the baseline scenario, baseline flows were calibrated with data recorded at the Medway gauge on Sandy Creek. During mining, flows were taken from the water balance model outputs and assigned to specific reporting points on Sandy Creek and the Talbragar River, following the procedure described in Appendix C.

Key findings of the assessment were:

- Downstream flow impacts on the Talbragar River are minor, with the annual average flow volume at the Elong Elong gauge being reduced by less than 1% during average and dry years, and magnitudes of flow in the low and high mean daily flow categories increasing by about 20% and 4% respectively.
- Annual average flow volumes in Sandy Creek will reduce by up to 5% during average and dry years, and magnitudes of flow in the low and high mean daily flow categories increase by about 90% and 25% respectively. These changes in flow volumes could affect the semi-permanent pools that occur within the Sandy Creek and Laheys Creek catchments. However, while the overall flow volume is likely to decrease in average and dry years, potential increases in the frequency of low and very low flow events will mean that these pools will be fed more regularly from surface water flows and will dry out less frequently.
- Groundwater drawdown will also affect the semi-permanent pools. Groundwater modelling suggests that there will be no adverse impacts related to groundwater drawdown up to Year 12. However, from Year 12 onwards drawdowns will result in loss of groundwater inflow and potential loss of persistent groundwater fed pools at one site on Sandy Creek and one on Laheys Creek. Two other sites on Sandy Creek may also be affected; however, the magnitude of drawdown at these other locations is relatively low and within the margin of error of the groundwater modelling and the ground level data. Groundwater levels will fully recover at these sites within 20 to 50 years post mining; therefore, the groundwater inflows to the affected pools will recover in the long term.

The mine will contribute more surface water to the Talbragar River during wet years, but there will be minor reductions in annual flow volumes of at most 0.5% in average and dry years at the Elong Elong gauge. Given the minor changes caused by of the Project and the management actions proposed at Ulan Mine to release treated surplus mine water, it can be concluded that the cumulative impact of the Project on Talbragar River flows will be negligible.

5.2.3 Flood impacts

Appendix D gives full details of the flood impact assessment. This was based on the catchment breakdown prescribed by the Year 20 mine plan, which is the critical case for flooding. At Year 20, approximately 1,270 ha of catchment area is lost to the pits or diverted to catchments outside Sandy Creek.

Instead of this water flowing west into Sandy Creek, it is diverted north to a small tributary which joins the Talbragar River less than 1 km upstream of Sandy Creek.

Hydraulic models were constructed using the HEC-RAS software to represent baseline conditions and mining operations at Year 20. Of the eight existing sub-catchments delineated for the flood model, only four will have changed catchment characteristics. Most of these changes will be in two of the catchments.

Impervious areas will increase in most of the affected sub-catchments. The percentage changes in peak flood flows just upstream of the confluence of Sandy Creek and the Talbragar River are presented in Table 5.1.

Table 5-1 Percentage change in peak flood event flows

Event	Peak flow (m ³ /s)	Percentage Change (%)
2 year ARI	31	+7
5 year ARI	83	+6
100 year ARI	432	+1
2000 year ARI	1,355	0

Flyblowers Creek, a minor tributary of the Talbragar River, will also be affected by the Project. During Years 12 to 20, a portion of the upper eastern Sandy Creek catchment will be diverted north into the eastern arm of Flyblowers Creek. This diverted catchment reaches 86 ha at Year 12 of the mine plan.

The hydrological assessment found that peak flows in this tributary will increase by around 30% across a range of ARIs (2 year, 5 year and 100 year) due to the diverted catchment. This could affect the existing watercourse crossings at Spring Ridge Road and a further 1.2 km downstream at the Golden Highway.

While Spring Ridge Road will be closed as a result of the mining development, flood mitigation is required so that land not owned by the mine is not impacted and flows at the Golden Highway are not significantly modified. Measures to mitigate flows in this tributary are proposed in Section 6.2.

The hydraulic model at Year 20 found that much of the mine workings and infrastructure are located significant distances away from creek lines and generally out of the wider floodplain. Therefore, there are only isolated effects on flood behaviour.

The 100 year ARI flood extent in Year 20 is illustrated in Figure 5-1. This shows that mining infrastructure has relatively little interaction with the floodplain. However, there are some parts of the mine that are located on the edge or just inside the 100 year ARI flood envelope. These include part of the workshop area, northern access road and the out of pit emplacements along the upper reaches of Laheys Creek near mining area B.

Parts of the mine footprint are within the 2000 year ARI flood. These are the northern bank of the mid reaches of Laheys Creek adjacent to the workshop area; the western edge of Laheys Creek along mining area B; and the southern edge of Blackheath Creek near the CHPP.

Appendix D demonstrates that flooding behaviour is relatively unaffected by the mine. In some localised areas, there is a small increase in flood levels – in particular Laheys Creek and the lower reaches of Blackheath Creek – but flood levels in the lower reaches of Sandy Creek are similar to baseline and worst-case developed conditions.

Overall, flooding behaviour in the upper and lower reaches of Sandy Creek do not change. There is slightly more out of channel flow in the mid to lower reaches near the junction with Laheys Creek but this impact diminishes further downstream.

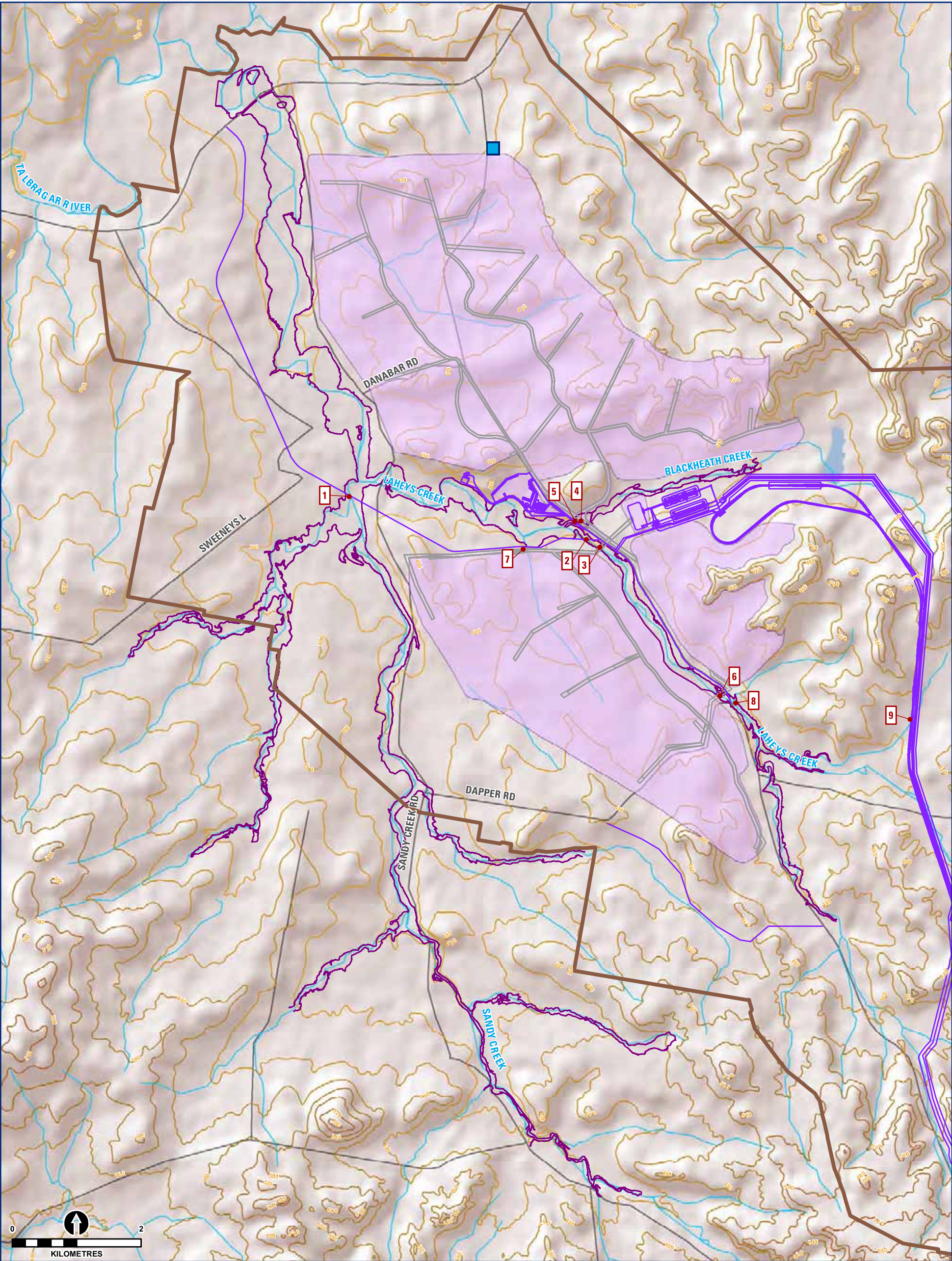
Average peak velocities for Sandy and Laheys Creeks for the worst-case developed scenario are generally similar to the range of baseline flow velocities. There are localised areas where velocities higher than 3 m/s occur in the Laheys Creek channel, but these are near proposed structures and standard mitigation measures will be required to either reduce velocities or provide erosion protection to ensure channel stability.

5.2.4 Project water demand

The water balance confirms that an external water source is needed for the Project (Section 4.2.4). Site runoff and groundwater inflows generated during mining will not be sufficient to meet the water demands of the Project under normal climatic conditions.

As outlined in Section 4.3.1, CHC has 3,311 shares of regulated river (high security) WALs to extract from the zone upstream of Burrendong Dam. These entitlements and associated extraction points were assessed by NOW during the WAL application process and were found to have no significant impact on the Macquarie and Cudgegong Regulated Rivers Water Source and associated downstream users.

It is estimated that 2,960 ML/a of imported water will be required for a 10th percentile dry rainfall year at Year 20 of the mine plan. The water balance indicates that imported water entitlements will be sufficient for all except three years in the past 111 years modelled. If the driest year on record coincided with Year 20, water savings of about 2% will be needed.



1 Waterways crossings	Drainage lines	Proposed spoil protection
Proposed detention basin site	Haul roads	Proposed levees
Proposed 100 year flood extent	Roads	Project application area
Elevation (m)	Maximum mine footprint	
Mine infrastructure		

Figure 5-1 Proposed 100 year ARI flood extent

5.3 Post-mining phase

A detailed assessment of the potential surface water impacts following the completion of mining activities is provided in Appendix E. This is summarised below.

5.3.1 Final landform

The final rehabilitated landform (Year 21) is shown in Figure 5-2. The landform comprises a single final void corresponding to former mining area B. The design of the final landform backfills final voids at former mining areas A and C through considerable investment in spoil rehandling and rehabilitation. Backfilling the entire mining area B is not economically feasible; however, the final landform design requires filling of almost half of the area of the active mine void.

Rainfall falling on the final void and groundwater seepage will partially fill the void to form a lake. The water level in the void will be influenced by the balance between inflows from rainfall and groundwater, and outflow due to evaporation.

5.3.2 Final void water balance modelling

A water balance model estimated the long term behaviour of the final void following the completion of mining. The model was developed using Microsoft Excel software to calculate the volume of water in the final void at the end of each month accounting for monthly rainfall-runoff inflow, groundwater inflows/outflows and evaporation. The model was also used to estimate potential salinity in the void. The model simulations used 1,000 years of synthetic rainfall and evaporation data.

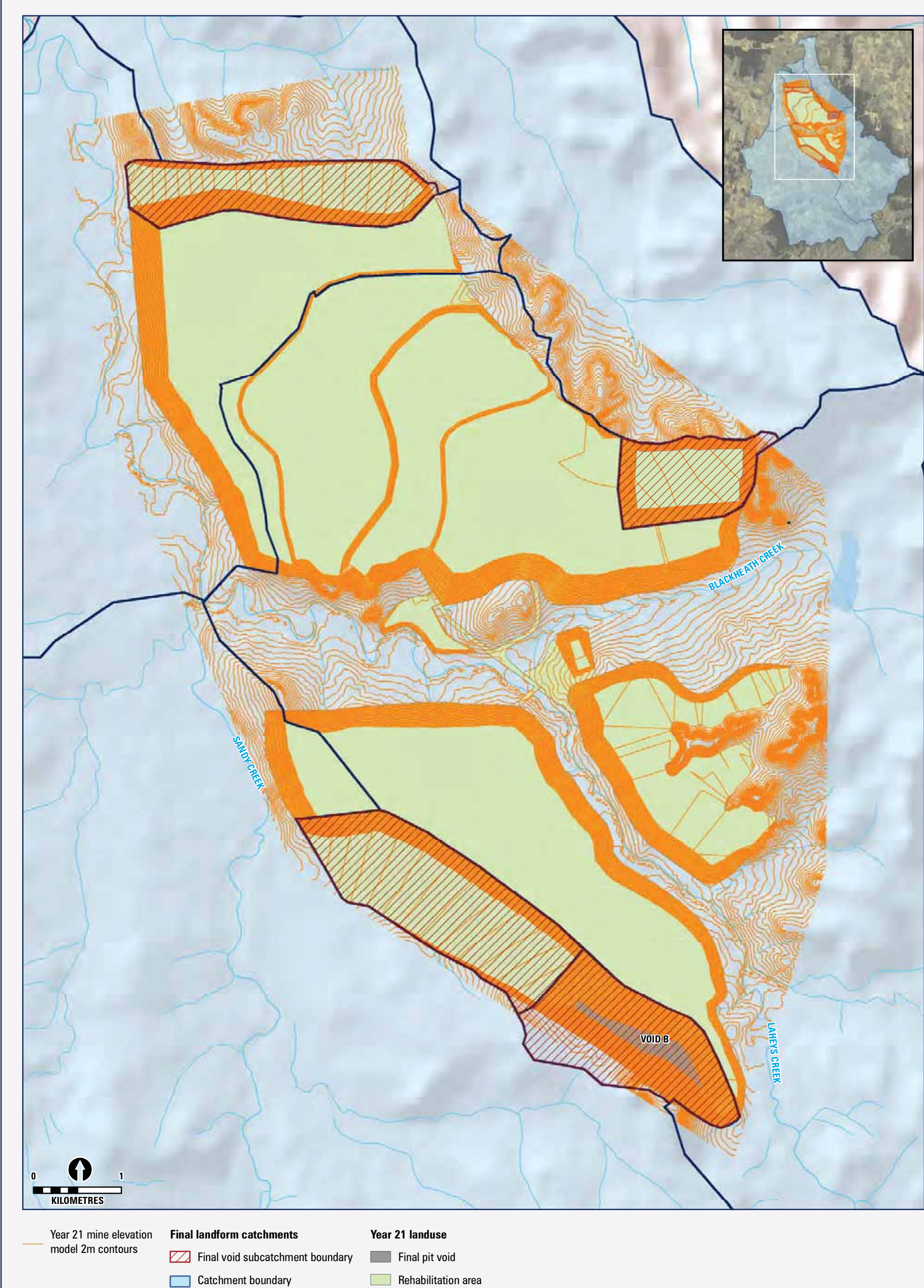
Refer to Appendix E for a detailed description of model methodology, assumptions and output results.

5.3.3 Potential impacts

The final void water balance indicates that the water level will initially rise steeply, but reach an average equilibrium over time. The void lake will not overtop and will act as a groundwater sink that will not impact nearby surface water bodies.

The salinity in the lake will increase over time. No groundwater will flow from this lake towards the creek, which offers benefit in terms of not increasing salinity in Sandy Creek. However, the void may potentially develop into a stratified lake which may lead to anoxic conditions. Water quality issues related to a confined stratified hypersaline lake have not been assessed at this stage because this would be undertaken as part of a detailed mine closure plan.

The final landform has been designed to eliminate two voids and minimise the scale of the third mining void. An unavoidable impact will be the formation of an isolated saline lake that cannot be eliminated at an economically viable cost. As no saline groundwater will migrate from that lake, the final void impacts are considered acceptable for the local surface water environment.



6. Mitigation measures

This section describes mitigation measures and response plans that are recommended for different stages of the Project. It is noted that many of the measures are an integral part of the operation of the mine so only a brief description is provided below, with more specific details provided in the respective appendices to this report.

6.1 Construction phase

6.1.1 Erosion and Sediment Control Plan

An Erosion and Sediment Control Plan (ESCP) should be prepared and implemented during the construction of all mine infrastructure. Erosion and sediment controls should be established to a standard consistent with the following guidelines:

- *Managing Urban Stormwater – Soils and Construction – Volume 1* (Landcom 2004).
- *Managing Urban Stormwater – Soils and Construction – Volume 2E Mines and Quarries* (DECCW 2008).

Erosion and sediment controls should include:

- minimising forward clearing, particularly areas around flow lines, drainage lines and watercourses
- minimising site disturbance by containing machinery access to areas required for approved construction works, access tracks or material stockpiles
- staging construction activities where practical, so that land disturbance is confined to the minimum possible area
- completing work and rehabilitating disturbed areas quickly and progressively
- minimising erosion from drainage lines that can be vulnerable to the erosive effects of concentrated flow
- intercepting and diverting clean water runoff from undisturbed areas so that it does not flow onto disturbed areas
- passing clean water through the site without mixing it with runoff from disturbed areas
- treating highly dispersive soils with gypsum to reduce the potential for tunnel erosion and surface rilling of disturbed areas
- limiting erosion potential within earthworks areas by managing runoff fetches and velocities, with measures such as diversion banks
- locating sediment traps, such as silt fences and check dams, downstream of disturbed areas
- treating runoff from large construction areas (greater than 2,500 m²) in sedimentation basins or dams, before water is displaced to watercourses
- providing shaker ramps and rock pads at construction exits to remove excess mud from truck tyres and under bodies.

6.1.2 Creek crossings

A number of reasonably large creek crossings are required as part of the proposed mine infrastructure. As discussed in Section 5.1, these crossings have been initially sized to ensure minimal impact on upstream flood levels.

Crossings should be constructed during dry periods, where possible, and generic best practice stormwater/erosion control measures should be implemented. During wet weather, work zones should be isolated to avoid flooding working areas.

It is essential that erosion protection measures be incorporated into the detailed design of these crossings. Such measures may include rock revetments and scour protection for bridge abutments and approaching channels designed to withstand extreme flow velocities. Where temporary works or obstructions are required in creek channels or in floodplains, temporary flow diversions or bypass channels should be provided with capacity equal or similar to existing flow paths to avoid temporary flooding of upstream lands during construction.

All creek crossing designs and construction methods should be developed in consultation with Fisheries NSW and the Project's aquatic ecologist to ensure the designs and construction methods being proposed comply with relevant guidelines and regulations and take into consideration the ecological constraints of the watercourses being crossed.

6.1.3 Hazardous materials and effluent management

The risk of accidental spillages of hazardous materials during construction should be reduced by having designated storage facilities with appropriate handling practices and safeguards, in accordance with relevant Australian Standards and guidelines. This should include the provision of localised bunding and spill kits. Stormwater from construction sites should be diverted to nearby sedimentation dams, where containment and treatment of any incidents will be possible.

For the lifetime of the construction camp, raw sewage will be pumped from storage tanks by a licensed contractor and delivered under contract to a local government authority for disposal in an existing town sewage treatment facility.

6.2 Operational phase

6.2.1 Water supply security

During worst-case climatic conditions, CHC has a number of alternate options available to ensure the mine continues to operate. These options are summarised as follows, in decreasing order of priority:

- Implementation of additional water conservation measures to reduce mine water demand. These include minimising make-up water demands by implementing further water conservation measures in the CHPP process water system and reducing water demands from dust suppression with environmentally safe additives that help to bind dust particles to reduce airborne dust potential.
- Purchasing of 'General' WALs from the open water market, if they are available, to meet the additional demand, and selling them back to the market when no longer required.
- Reducing coal production rates to match available water supplies. This is a worst-case scenario and assumes that the above three options are either not available or not effective at providing additional water or reducing water demands.

6.2.2 Sedimentation dam performance

In accordance with the proposed water management strategy, surplus water from sedimentation dams will be returned to Sandy Creek and Laheys Creek if it is not needed in the mine. During these events, it will be necessary to ensure treated water from these dams complies with specific concentration limits designed to protect the water quality of receiving watercourses.

Performance criteria were set using customised water quality objectives developed as part of this assessment (see Appendix B). Proposed concentration limits applicable to all sedimentation dam releases are shown in Table 6-1.

Table 6-1 Proposed sedimentation dam performance criteria

Parameter	Concentration limit (100 th -ile in mg/L)	
	50 th %ile	100 th %ile
Aluminium	N/A	0.5
Iron	N/A	1.5
Manganese	N/A	2.0
pH	N/A	6.5 -8.5
TDS	350	1400
TN	N/A	0.9
TP	N/A	0.5
TSS	N/A	200

Compliance with the concentration limits provided in Table 6-1 will ensure water quality in receiving watercourses is not adversely affected.

6.2.3 Flood protection levees

Flood protection levees are proposed at two key locations in the Laheys Creek and Blackheath Creek catchments. Although there are no proposed open-mining areas along the waterways where floodwaters can enter, there are areas that require flood protection to prevent flooding from disrupting operations.

The first location is the area along the southern edge of Blackheath Creek where a flood protection levee equal to the 2,000-year ARI flood level (or other suitable, extreme-event flood level, to be determined during detailed design) will protect the coal stockpile. Alternatively, the coal stockpile platform on the southern bank of Blackheath Creek could be built above the 2,000-year ARI event (or other suitable extreme event), with a suitable freeboard allowance.

The second location extends along the edge of the workshop area on the northern bank of the lower reaches of Laheys Creek. It is assumed that this area is required to have flood protection up to the 2,000-year ARI event (or other suitable extreme event), plus a freeboard allowance. Alternatively, the embankment for the workshop and access road could be designed to be above the 2,000-year ARI event, with scour protection added to the embankment as it will be located on a bend of Laheys Creek where scour erosion could occur.

It should be noted that the 2,000-year ARI flood event was chosen as a reasonable upper limit reference event to protect critical infrastructure and is not proposed as a strict design requirement. The appropriate standard of flood protection for critical infrastructure will be confirmed during detailed design.

6.2.4 Scour protection measures

The flood impact assessment identified that one of the out of pit emplacement areas will be located on or just within the boundary of a 100-year ARI flood extent and will thus require scour protection to protect it from erosion.

It is recommended that instead of providing a dedicated levee, the toe of the out of pit emplacement itself be engineered similarly to a levee. During construction, a suitable material should be used to construct the bottom section of the out of pit emplacement up to the level of the 100-year ARI flood level plus a freeboard of 600 mm.

In addition to engineering the toe of the out of pit emplacement, erosion and sediment control measures should be installed along the embankment to ensure sediment laden runoff does reach the creek.

It is understood that any structure that has the potential to modify flood behaviour up to the 100 year ARI event may need to be licensed by NOW. Licensing requirements associated with the design and construction of spoil emplacement protection measures should be determined during detailed design.

6.2.5 Dry detention basin

The flood impact assessment found that flows could increase in Flyblowers Creek north of Sandy Creek which flows north underneath the Golden Highway. The assessment noted that during Years 12 to 20, flood mitigation measures will be required to maintain existing peak flows in this tributary at the Golden Highway.

It is recommended that a dry detention basin be constructed to reduce peak flows at the Golden Highway culvert to baseline conditions. It is estimated that a dry detention basin with a capacity of approximately 70 ML will be required to achieve this. Further details on the features and location of the detention basin are provided in Appendix D.

The conceptual basin design presented in Appendix D should be investigated further during detailed design, in consultation with NOW, to determine any potential licensing requirements.

6.2.6 Temporary diversion channels

Diversion channels will be required to temporarily redirect existing minor tributaries and drainage lines around the mine working areas during certain stages of mining.

In the early mining stages, the upstream portion of these tributary/drainage lines will generally be unaffected by the mine while the downstream section will need to be temporarily diverted around a mining area. As the mine workings expand, the particular tributary/drainage line should be incorporated into the active mine workings and the temporary diversion will no longer be required.

The intention of these temporary diversion channels is to prevent clean water from unaffected upstream catchments from flowing into the mine. Three locations have been identified where temporary diversions are required. See Appendix D for more details.

Basic feasibility calculations have been undertaken to ensure these diversions will be practical to construct. Initial calculations indicate that the diversions are feasible and will likely maintain similar average channel slopes and velocities for the length of the diversion. This should minimise impacts to downstream receiving channels.

Appropriate tie-in works and erosion protection structures may also be required at the ends of the diversions to minimise downstream erosion.

6.2.7 Wastewater management

For the duration of mining operations, wastewater from on-site facilities such as workshops, process and administration buildings will be managed by an on-site sewage treatment system. The basic sewerage system infrastructure will generally comprise:

- transfer pumps and mains
- storage tanks
- proprietary secondary treatment plant
- tertiary treatment and disinfection
- effluent transfer system.

Sewage will be pumped to the secondary treatment plant from ablution facilities located at the CHPP, administration and workshop areas, and amenity blocks. Following transfer to the treatment plant, the effluent will undergo secondary treatment and subsequent tertiary treatment and disinfection to achieve effluent quality for reuse with the potential for human contact, in accordance with relevant guidelines. The treated effluent will then be transferred to the mine water system for beneficial reuse on-site.

6.2.8 Flood emergency management plan

The flood impact assessment found that parts of the mine's access and haul road network could be affected during very extreme floods. These vulnerable areas should be identified in a Flood Emergency Management Plan for the site, which should also consider flood risk to external public roads that may be used by staff travelling to and from the site. The Plan should include instructions for staff both on and off the site on actions to take during a flood, with clearly identified communication protocols. It is also recommended that site inductions include a review of the Flood Emergency Management Plan to maximise staff awareness of flood risk and appropriate actions.

6.3 Post mining phase

The water balance assessment of the final landforms concluded that catchment modifications caused by the mine will not have a regionally significant impact on the broader Talbragar River or Macquarie River catchments. Impacts should be mitigated through long-term remediation of the catchment in the Project area, including reinstatement of naturalistic landforms, gullies and drainage lines, to minimise the final disturbance of the catchment.

The final landform has been designed to minimise the formation of void lakes at the mining areas. Due to economic constraints on the Project a void lake is unavoidable in the south eastern end of mining area B. This void will not overtop and will act as a groundwater sink and therefore will not impact on the surface water environment. Given that the final landform has been designed to minimise void lake formation as far as economically practical, further mitigation measures are not considered necessary.

7. Monitoring and management

This section outlines the recommended actions to manage and monitor the surface water aspects of the Project.

7.1 Site Water Management Plan

It is recommended that a comprehensive Site Water Management Plan (SWMP) be developed for the Project prior to commencement. The objective of this Plan is to ensure the operational performance of the mine, with respect to water, meets all relevant regulatory requirements.

The provisions of the SWMP would cover management of both surface water and groundwater sources at the mine site.

The SWMP should:

- Identify all relevant legislative and regulatory approvals relating to water management at the site.
- Identify relevant site-specific performance benchmarks, guidelines and criteria in relation to water management.
- Identify potential impacts on local water users and water-dependent ecosystems, upstream and downstream of the mine.
- Identify and assess water sources and their context, including groundwater and surface water.
- Identify operational water demands, reuse and disposal needs using a comprehensive mine water balance for the entire mining operation.
- Identify accountabilities and responsibilities to manage water resources at the mine site.
- Identify opportunities to maximise water conservation and reuse in lieu of using imported water.
- Include procedures to treat and control the release of water to the natural environment in accordance with regulatory requirements.
- Include a comprehensive monitoring program that includes both surface water and groundwater monitoring.
- Establish contingency measures and emergency procedures should adverse conditions or impacts be encountered during the operation of the mine.
- Establish a framework of continual improvement, auditing and reporting that is consistent with regulatory requirements and industry best practice.

The SWMP should be developed in consultation with relevant stakeholders and regulatory authorities, such as local community groups and water users, State Water, the Office of Water, the Office of Environment and Heritage, and the Central West Catchment Management Authority.

The Plan should also include a set of operational procedures that clearly articulate how different aspects of the mine's water management system are to be operated and maintained.

These include:

- Water supply management
- Stormwater management
- Mine water management
- Wastewater management
- Mine dewatering
- Dust suppression control
- Rehabilitation performance monitoring.

7.2 Surface water monitoring program

7.2.1 General principles

As discussed in Section 4.4, releasing treated water from sedimentation dams to Sandy Creek or Laheys Creek is likely to be regulated by an Environment Protection Licence (EPL).

The EPL would be developed following Project Approval and prior to the commencement of mining and would specify operating conditions. One of these conditions will include specific concentration limits that will need to be complied with by the mine for all points nominated in the EPL. The EPL will also specify minimum monitoring and reporting requirements, amongst other requirements.

The following are general principles that should be considered in the development of any surface water monitoring program:

- The management of the site should engage a responsible person to coordinate and implement the surface water monitoring program, in accordance with the responsibility matrix specified in the SWMP.
- All licensed points should be monitored, recorded and reported in accordance with the relevant EPL conditions.
- Should an exceedance of the licensed criteria be recorded, the responsible person should notify the OEH of the exceedance as soon as possible. Investigations should then be undertaken to determine the cause of the exceedance and possible mitigation actions that could either prevent or minimise the chance of reoccurrence.
- The surface water monitoring program should also include monitoring points that are upstream and downstream from the licensed releases to monitor potentially adverse trends in water quality that could warrant further investigations and/or preventative actions.

7.2.2 Monitoring recommendations

Three licenced points and five monitoring points have been selected on the basis of the existing surface water monitoring program, which has been in operation since 2009 and was used to establish the baseline water quality conditions for the environmental assessment. Refer to Figure 7-1 for details.

The following surface water monitoring network has been recommended for the Project.

- SD1, SD2 and SD3 - Sedimentation dams where water is released to a receiving watercourse. These points could potentially be specified as the licensed points in the EPL for the Project.
- SW01 (Sandy Creek), SW02 (Laheys Creek) and SW05 (Talbragar River) – This would be established as the control points (monitoring only), upstream from the Project site.
- SW03 (Sandy Creek) and SW04 (Talbragar River at Elong Elong) – This would be established as control points (monitoring only) downstream from the Project site.

The location of the above monitoring points, in particular SD1, SD2 and SD3, are preliminary and may be refined as the mine water management system and associated infrastructure is confirmed during detailed design.

Equipment to be included at each monitoring point

Each monitoring point should have the capacity to monitor water quality and quantity to enable testing for compliance against relevant water quality criteria. This should include a flow gauging weir to estimate flow volume and an outlet pit to sample representative water quality at the point of sampling.

Sample collection and analysis

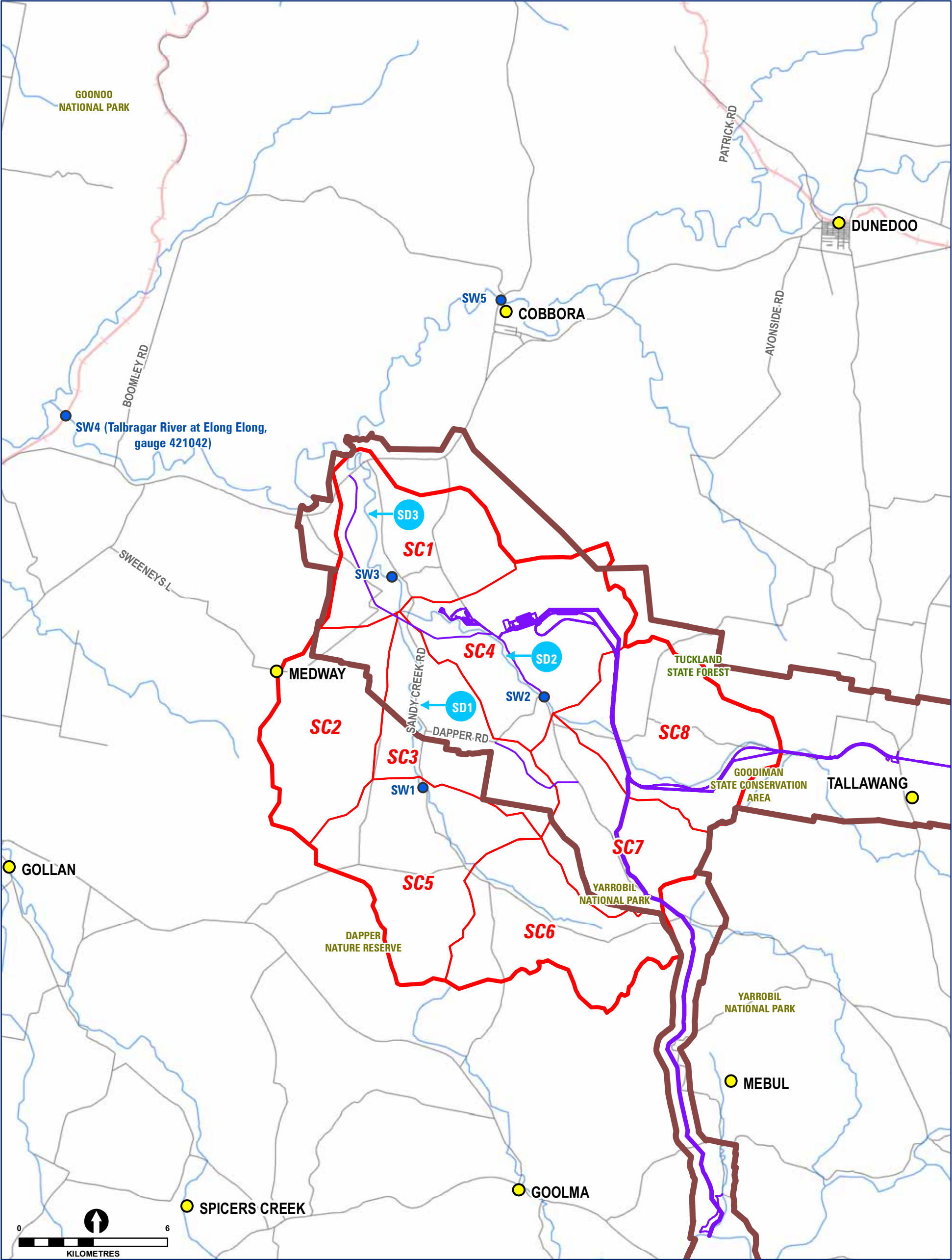
Samples should be collected by qualified professionals in accordance with *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (DEC 2004). Any laboratory used must be National Association of Testing Authorities (NATA) registered for each analysis required.

Training and equipment use

Personnel who undertake environmental monitoring must be appropriately trained in the technical and administrative aspects of sample collection, equipment calibration and use, field reporting requirements and EH&S aspects of field work. All analytical equipment should be calibrated to manufacturer's recommendations. Records of all calibrations should be kept as part of the Project monitoring file.

Reporting

The recording, reporting and assessment of monitoring results against prescribed criteria should be undertaken in accordance with the relevant provisions of the Project Approval and EPL for the Project.



● Surface water monitoring locations	— Existing contours (20m)	▭ Project area catchment boundary
● Preliminary licensed release points	— Drainage	▭ Sub-catchments
● Towns	— Railway	— Project application area
	— Main roads	— Mine infrastructure

Figure 7.1
Recommended surface water
quality monitoring locations

Topographic map source: NSW Department of Lands, 1989

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8. Conclusions

This report and its associated appendices have been prepared to assess the impacts of the proposed Cobbora Coal Mine on surface water. It considered:

- An overview of the Project, and the objectives and scope of the surface water assessment.
- The DGRs relating to surface water for the Project and the relevant legislation, policies and guidelines.
- The existing surface water environment of the Project area, including the local and regional hydrology, regional and local catchments, flooding, local water bodies, surface water quality and other surface water users.
- The proposed water management system and mine water balance, including a description of site water demands, water disposal methods, water supply infrastructure and water storage structures.
- The Project's potential impacts on surface water during construction and operation and post-closure, including flooding, interception of surface water, surface water extraction and disposal of excess water. This includes an assessment of potential cumulative impacts.
- The recommended mitigation measures and response plans for the Project.
- A recommended surface water monitoring program for the Project, including monitoring requirements, procedures and recommendations.

It has been found that the conceptually designed water management system will function effectively under a wide range of climatic conditions and stages of mine development. These ranged from some of the driest years in 111 years through to some of the wettest periods on record.

Detailed flood modelling demonstrated that the mine can be appropriately safeguarded against major floods, while the mine itself and associated infrastructure will not materially affect downstream properties.

The water management system is a robust one that can allow the mine to operate within contemporary environmental standards, so that CHC can comply with its anticipated licensing and statutory obligations.

Finally, based on current information, a post mining design has been developed that can provide a sustainable landform that will not impose unacceptable legacy issues on future generations.

9. References

ANZECC 2000, Australia and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council 2000.

ASRIS 2010, Australian Soil Resource Information System. Available online at: http://www.asris.csiro.au/index_other.html.

AWA 2000, Australian Guidelines for Water Quality Monitoring and Reporting. Australian Water Association. ISBN: 09578245-1-3. October 2000.

BoM 2011, Seasonal Rainfall Outlook Archive. Available online at: <http://www.bom.gov.au/climate/ahead/archive/rainfall/index.shtml>.

Boulton AJ & Lake PS 1990, The ecology of two intermittent streams in Victoria, Australia. I. Multi-variate analysis of physiochemical features. *Freshwater Biology*, 24, 123-141.

Cardno Ecology Lab 2012, Cobbora Coal Project: Aquatic ecology environmental assessment. Job number EL1112020A. Prepared for EMM.

CWMA 2007, Central West Catchment Action Plan 2006–2016, Central West Catchment Management Authority 2007.

CSIRO and BoM 2007, Climate Change in Australia – Technical Report, CSIRO and Bureau of Meteorology.

CSIRO 2009, Unpublished extreme temperature modelling results provided to Parsons Brinckerhoff, CSIRO 2009.

CSIRO 2010, Unpublished 'Climate futures' data provided to Parsons Brinckerhoff, CSIRO 2010.

Cuffney TF & Wallace JB 1989, Discharge-export relationships in headwater streams: The influence of invertebrate manipulations and drought. *Journal of North American Benthological Society*, 8, 33-341.

DECCW 2006, Macquarie-Bogan Water Quality and River Flow Objectives. Available online at: <http://www.environment.nsw.gov.au/ieo/MacquarieBogan/report-02.htm>, Department of Environment, Climate Change and Water 2006.

DECCW 2008, Managing Urban Stormwater – Soils and Construction – Volume 2E Mines and Quarries, Department of Environment, Climate Change and Water 2008.

Dent CL, Grim NB, Fisher SG 2001, Multi-scale effects of surface-subsurface exchange on streamwater nutrient concentrations. *Journal of North American Benthological Society*, 20, 162-181.

DIPNR 2005, Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region, Department of Infrastructure, Planning and Natural Resources 2005.

DRET 2008, Water Management — Leading Practice Sustainable Development Program for the Mining Industry, Department of Resources, Energy and Tourism 2008.

DWE 2009, Water availability in New South Wales Murray-Darling Basin Regulated Rivers, NSW Government Department of Water and Energy April 2009.

Engineers Australia 2001, Australian Rainfall and Runoff - A guide to Flood Estimation, Institute of Engineers Australia 2001.

Engineers Australia 2006, Australian Runoff Quality, Institute of Engineers Australia 2006.

GeoTerra 2012, Cobbora Coal Project - Acid and Metalliferous Drainage Assessment.

Humphries 2000, Report Summary Salinity Risk Assessment of the Central West Catchment. A joint initiative of the Central West Catchment Management Committee, the Department of Land and Water Conservation and the Natural Heritage Trust. Central West Catchment Management Committee.

Landcom 2004, Managing Urban Stormwater – Soils and Construction – Volume 1.

MCMPR 2006, Strategic Water Management in the Minerals Industry, Ministerial Council on Mineral and Petroleum Resources 2006.

MDBA 2011, Draft Murray Basin Plan, Murray Darling Basing Authority 2011.

McLuckie, D, Lord D, and Gibbs J 2006, Climate Change – the Future is Uncertain, Practical Consideration of Climate Change in Flood Risk Management in NSW, 46th Annual FMA Conference, Lismore, March 2006.

Murphy DV, Sparling GP & Fillery IRP 1998, Stratification of microbial biomass C and N and gross N mineralisation with soil depth in two contrasting Western Australian agricultural soils. Australian Journal Soil Research, 36, 45-55.

NSW EPA 2004, Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales, Department of Environment and Conservation 2004.

NSW Government 2006, Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source 2003.

NOW 2011, Draft Water Sharing Plan – Macquarie-Bogan Unregulated and Alluvial Water Sources – Order, NSW Office of Water 2011.

Parsons Brinckerhoff 2012, Cobbora Coal Project- Groundwater Assessment, Report No PR_5716A-2162570A dated June 2012.

Smith R, Jeffree R, John J, Clayton P 2004, Review of methods for water quality assessment of temporary stream and lake systems, Australian Centre for Mining Environmental Research September 2004.

Thompson JR, Taylor MP, Fryirs KA, Brierley GJ 2001, A geomorphological framework for river characterization and habitat assessment. Aquatic Conservation: Marine and Freshwater Ecosystems, 11, 373-389.

Appendix

A

Cobbora Coal Project

Baseline Hydrological Environment

PR_5754A-2162570C_Appendix A



Revision	Details	Date	Amended By
A	Draft for EMM/CHC review	5 March 2012	DE
B	Final draft for Adequacy Review	31 August 2012	DE, RL
C	Final for Public Exhibition	6 September 2012	RL

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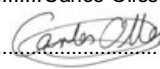
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Signed: 

Date: 18 September 2012

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Contents

	Page number
Glossary	iiiiii
1. Introduction	1
2. General catchment features	3
2.1 Topography and land use	3
2.2 Soils	3
2.3 Dryland salinity	3
3. Climate	5
3.1 Local weather stations	5
3.2 Rainfall and evaporation	5
3.3 Climate change	9
4. Surface water features	11
4.1 Regional surface water bodies	11
4.2 Local surface water bodies	13
5. Baseline hydrologic conditions in local surface water bodies	15
5.1 Stream gauge information	15
5.2 Water level gauging stations and associated data limitations	20
5.3 Stage-discharge relationships used in the assessment	22
5.4 Baseline flood hydrology	22
6. Water uses and local guidelines	23
7. Baseline water quality in local surface water bodies	25
7.1 Objectives and guidelines	25
7.2 Flow ranges relating to the surface water quality monitoring dataset	25
7.3 Surface water quality monitoring findings	27
7.4 Discussion of baseline water quality monitoring results	29
7.4.1 Flow	29
7.4.2 Salinity	29
7.4.3 Nutrients	30
7.4.4 Metals	30

	Page number
8. Baseline geomorphology of local surface water bodies	37
8.1 Geomorphic characterisation of watercourses	37
8.2 Implications of stream types for hydrological functioning	37
9. Groundwater – surface water interaction	39
9.1 Overview	39
9.2 Refuge pools	39
10. Summary	41
11. References	43

List of tables

Table 5-1	NSW Office of Water stream flow gauges	15
Table 5-2	Stream flow gauging data available	18
Table 5-3	Discharge measurement summary	20
Table 7-1	Comparison between water level data and water quality sampling occasions	26
Table 7-2	Comparison of water quality monitoring data against ANZECC water quality guidelines	31

List of figures

Figure 3-1	Weather station and surface water monitoring locations	7
Figure 3-2	Rainfall and evaporation data for the Project Application Area	8
Figure 4-1	Watercourse classification in the Macquarie–Bogan catchment (DECCW 2006)	12
Figure 5-1	Flow duration curve for Talbragar River at Elong Elong	16
Figure 5-2	Flow duration curve for Sandy Creek at Medway	16
Figure 5-3	Stage-discharge regression plots for SW1, SW2, SW3 and SW5	21
Figure 8-1	Fluvial geomorphology river styles	38

List of photographs

Photo 4-1	Catch water dam on Blackheath Creek	14
Photo 4-2	Sausage dam on Blackheath Creek	14

Appendices

Appendix A.1	Temporal variations in water level during sampling events

Glossary

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
BoM	Bureau of Meteorology
CRD	Cumulative rainfall departure
DECCW	Department of Environment, Climate Change and Water
EC	Electrical conductivity
km	Kilometres
mg/L	Milligrams per litre
ML	Megalitres
NOW	New South Wales Office of Water
NTU	Nephelometric turbidity unit
OEH	Office of Environment and Heritage
RFO	River Flow Objective
SW	Surface water monitoring point
WQO	Water Quality Objective

1. Introduction

This document describes the baseline hydrological environment in the surface water catchments relevant to the assessment area.

This document provides information on the baseline surface water environment used by the technical reports that comprise the surface water assessment of the Project. These are listed as follows:

- *Cobbora Coal Project - Downstream Water Quality Impact Assessment.*
- *Cobbora Coal Project - Downstream Flow Impact Assessment.*
- *Cobbora Coal Project - Flood Impact Assessment.*
- *Cobbora Coal Project - Water Balance and Surface Water Management System.*

2. General catchment features

2.1 Topography and land use

The topography of the area covered by the Project is gently undulating to hilly, with elevations varying between approximately 320 and 620 metres Australian Height Datum (mAHD). The area is mostly cleared and used for agricultural purposes, including grazing sheep and cattle, cultivating cereal crops and forestry.

2.2 Soils

The Australian Soil Resource Information System (ACLEP 2010) provided information on soils within the assessment area. The predominant soil type is unit Qb17, which occurs in undulating country with gravelly or stony ridges comprising hard and friable neutral red soils. Along the Talbragar River, the soil unit is Gb11, occurring on river terraces and floodplains and comprising dark porous loamy soils with some cracking clays.

2.3 Dryland salinity

The *Salinity Risk Assessment of the Central West Catchment* (Humphries 2000) describes the salinity hazard rating of the Lower Talbragar catchment as 'very high'.

However, the Sandy Creek sub-catchment has relatively low salinity compared to more salinised catchments to the west. The Project targets only Triassic and Permian strata within the sub-catchment and not the Lachlan Orogen metasediments, which are generally associated with saline soils. The salinity risk is therefore much lower in this particular part of the catchment.

3. Climate

3.1 Local weather stations

There are no Bureau of Meteorology weather stations with complete long-term data sets within the assessment area. The nearest weather stations with long-term observation data are:

- Bureau of Meteorology Station 064009: Dunedoo Post Office (BoM 2011a), approximately 20 km north-east of the Project and in operation since 1912.
- Bureau of Meteorology Station 062013: Gulgong Post Office (BoM 2011b), approximately 20 km south-east of the Project and in operation since 1881.

Rainfall data from these sites has been analysed to understand local weather patterns. An operational Bureau of Meteorology Station 064026 is located at Cobbora (Ellismayne), however, the data set is incomplete. The closest station to the assessment area with long-term evaporation observations is located at Wellington Research Centre (BoM Station 065035) about 60 km to the south-west of the assessment area.

Two additional meteorological gauging stations were installed by CHC in the assessment area between 2009 and 2011. These have been used to supplement long-term records obtained from the BoM stations, and provide rainfall information specific to the assessment area. The locations of these weather stations are shown in Figure 3-1.

3.2 Rainfall and evaporation

Annual rainfall follows very similar patterns at each Bureau of Meteorology station. The historical average annual rainfall, however, was slightly higher at Gulgong station than at Dunedoo station.

The average annual rainfall at Gulgong station, measured between 1881 and 2011, was 651.6 mm/a. Average annual rainfall at the Dunedoo station, measured between 1912 and 2011, was 616.4 mm/a, a difference of approximately 35 mm/a. This may be mainly attributed to 14 years of above-average rainfall that occurred between 1881 and 1912, before the Dunedoo station operated. A comparison of annual rainfall at each station is shown in Figure 3-2

Average monthly rainfall and evaporation data is shown in Figure 3-2. Generally the average monthly rainfall recorded at Gulgong and Dunedoo stations is very similar. In the period of record from November 2010 to November 2011 (inclusive), rainfall recorded by the on-site meteorological stations was for half of the year well above the average monthly rainfall for the Dunedoo and Gulgong stations. This is the result of above-average rainfall, which was also experienced at Dunedoo and Gulgong.

The long-term (1889–2011) cumulative mean deviation (CMD) was calculated using rainfall data sourced from the Data Drill database to show the long-term trends in rainfall patterns (Figure 3-2). Data Drill accesses grids of data derived by interpolating the Bureau of Meteorology 's station records.

The CMD graph shows a negative gradient after the start of 2000 up to the end of 2009, indicating the area was in drought with below-average rainfall for the past 10 years. Since the beginning of 2010 the graph shows a positive trend, indicating above-average rainfall conditions.

The average annual evaporation from 1965 to 2005 (inclusive) recorded at the Wellington station was approximately 1,800 mm (BoM 2006) (which is reduced to 1,440 mm after applying the pan correction factor of 0.8 for surface water bodies in the central west region).

Overall, the records indicate that rainfall is generally greater in the summer months than in the winter months and there is a high level of evaporation in comparison to rainfall. The winter months of June and July are the exception, where rainfall and evaporation are relatively equal.

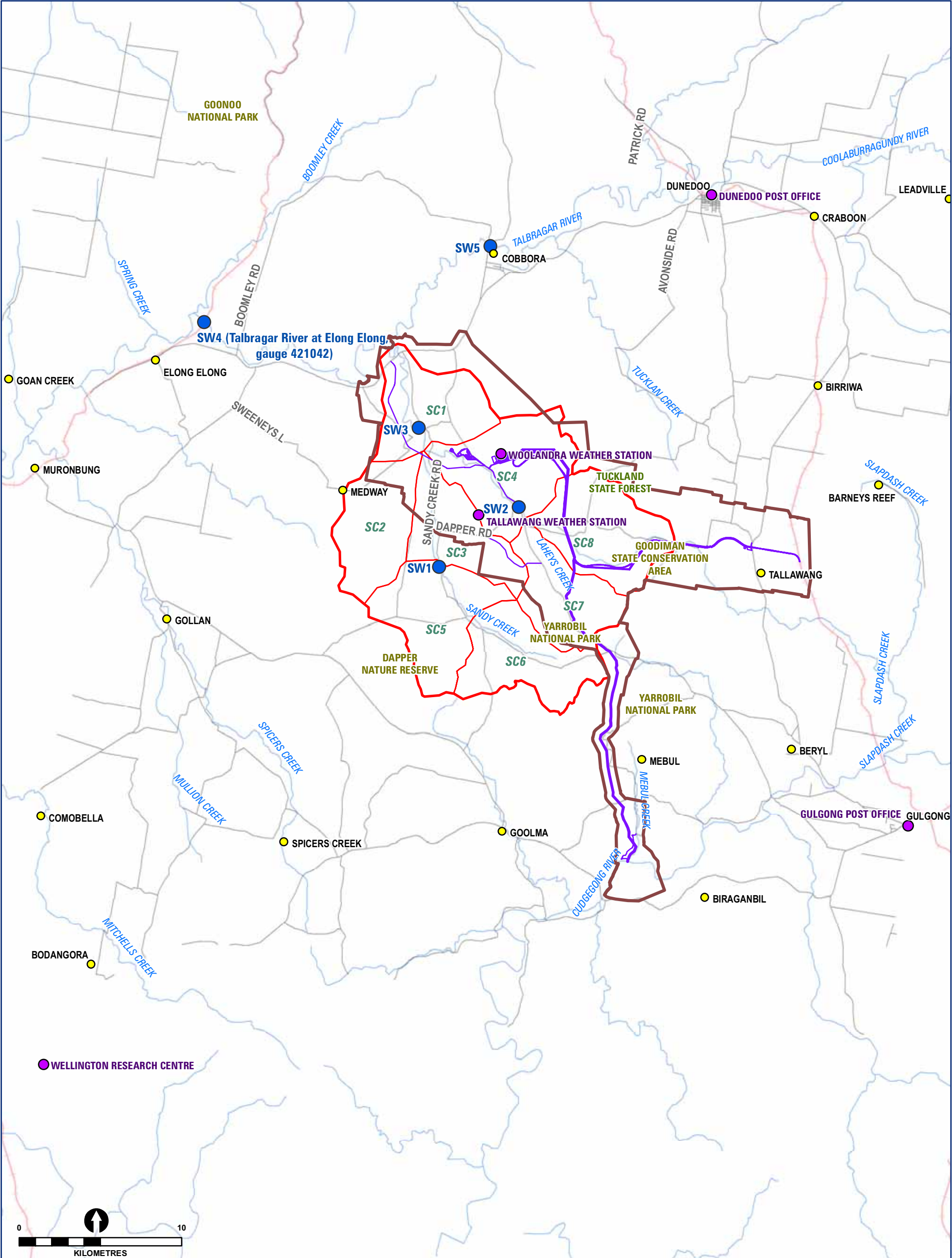


Figure 3.1 Weather stations and surface water monitoring locations

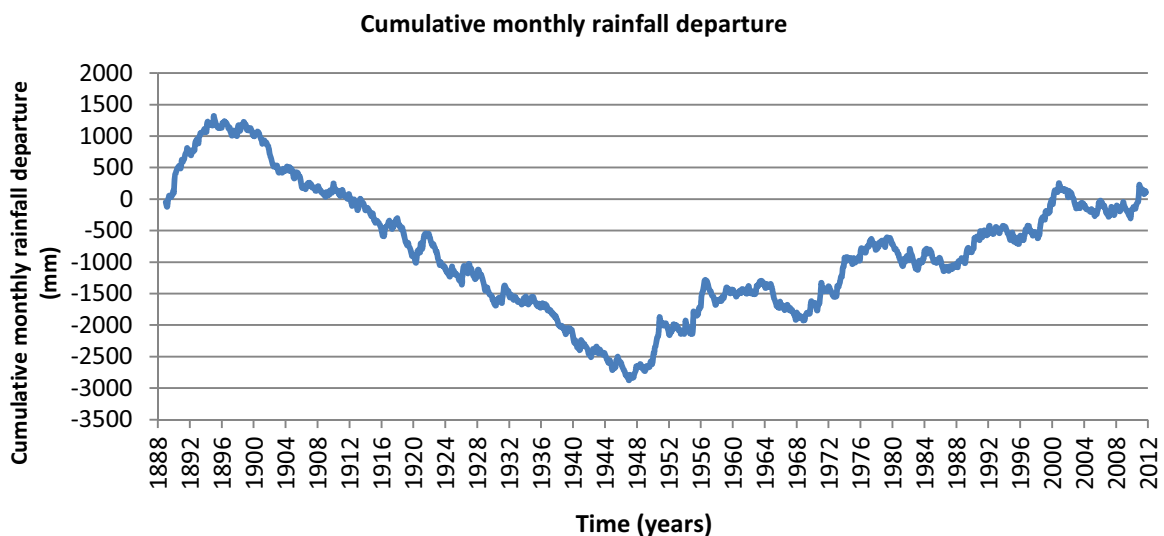
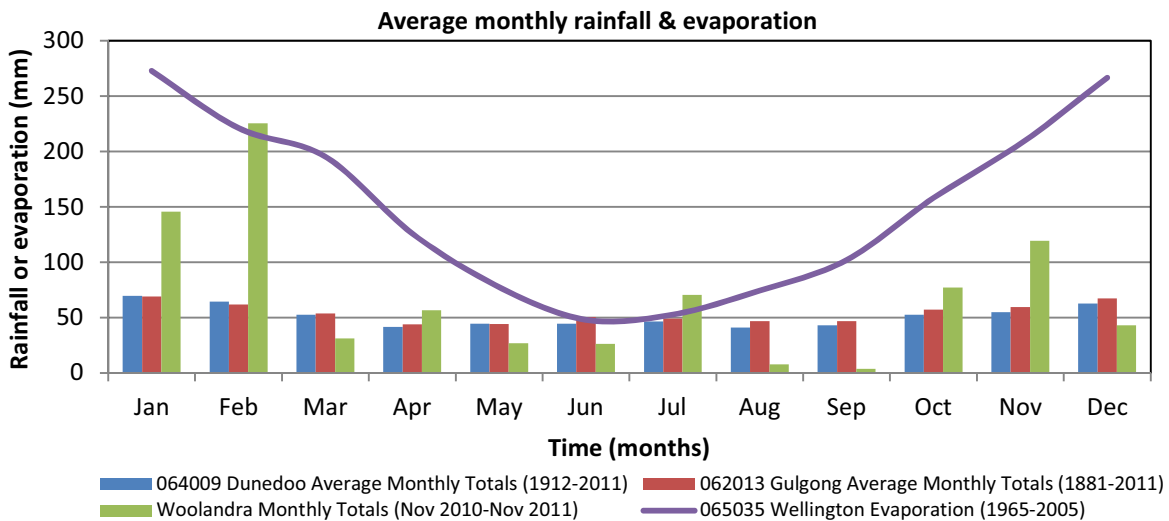
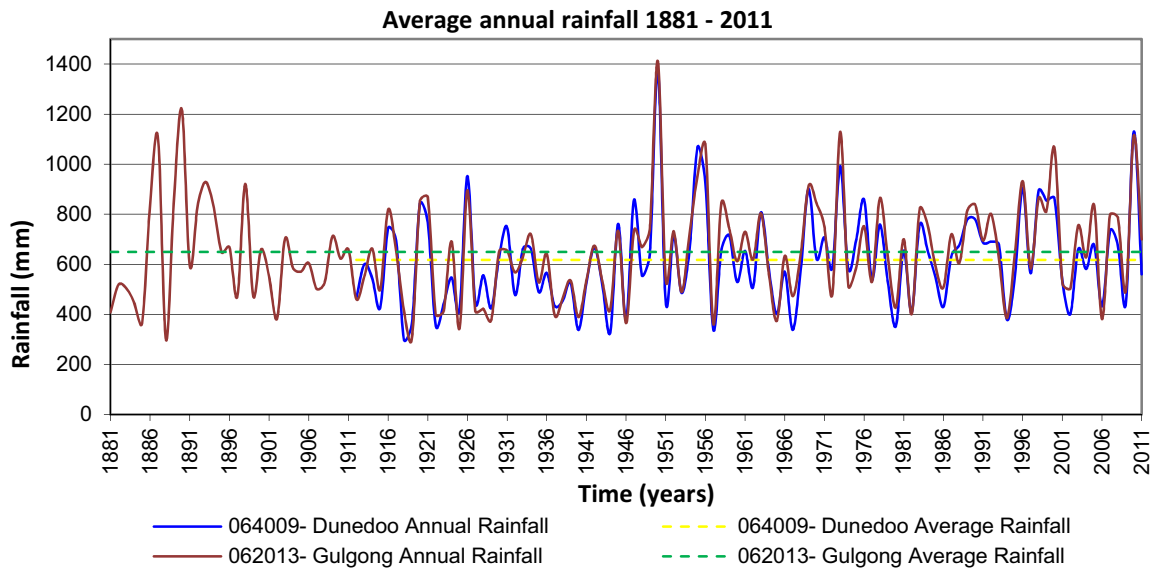


Figure 3.2 Rainfall and evaporation data for the Project Application Area

3.3 Climate change

Climate change is predicted to have a marked impact on many climate variables, including rainfall and evaporation. The effects of climate change are already being detected in Australia, and it is predicted that these changes will intensify as the century progresses (CSIRO and BoM 2007).

The following changes in climate are predicted for NSW by 2030 (CSIRO 2009, 2010), which covers the Project's 21-year lifetime:

- decrease in average annual rainfall by approximately 1%
- increase in average annual temperature by approximately 1°C
- increase in the number of very hot days (> 35°C) per year from an average of 26 days to 36 days
- increase in the number of extremely hot days (> 40°C) per year from an average of 2 days to 4 days
- increase in evapotranspiration by 2% to 4%.

Because predicted changes in climate variables over the Project lifetime are very low, the Project will not be required to implement adaptation strategies to account for climate change.

4. Surface water features

4.1 Regional surface water bodies

Rivers in the greater Cobbora area include the Talbragar River and Cudgegong River, which are tributaries of the Macquarie River. The Macquarie River is formed near Bathurst, at the junction of the Fish River and Campbells River, and extends north-west to the Barwon River upstream of Brewarrina. It flows through the Macquarie Marshes, which are one of the largest semi-permanent wetlands in south-eastern Australia, covering more than 150,000 ha. Refer to Figure 4-1 for further details.

Parts of the Cudgegong and Macquarie rivers upstream from the Macquarie Marshes are regulated under the *Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source*, which directs how the water available for extraction is to be shared and provided for environmental needs. Due to river regulation, and the construction and operation of Windamere Dam on the Cudgegong River and Burrendong Dam on the Macquarie River to supply downstream water users, the volume and pattern of flows in the watercourses have been significantly altered.

Traditionally, natural river flows were highest between June and October and lowest in late-summer and autumn. However, flows in much of the system are now at their highest during the irrigation season, which extends from October to March. In particular, the frequency, extent and duration of inundation in the Macquarie Marshes have been reduced since regulation of the Macquarie River.

The assessment area lies within the catchment of the unregulated Talbragar River (see Figure 4-1). The Talbragar River separates from the Coolaburragundy River at Dunedoo, and runs south-west, joining the Macquarie River just north of Dubbo.

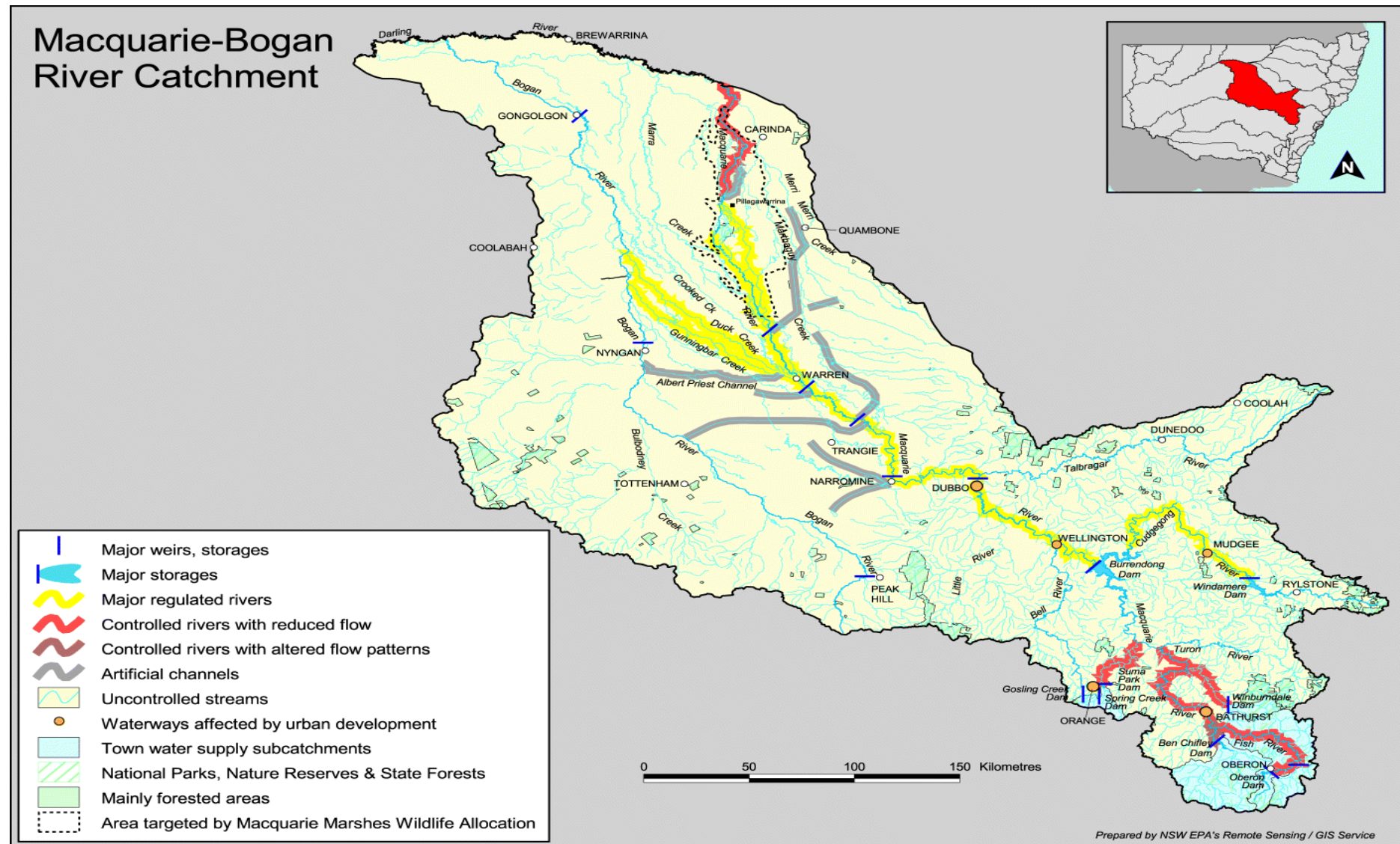


Figure 4-1 Watercourse classification in the Macquarie–Bogan catchment (DECCW 2006)

4.2 Local surface water bodies

The assessment area lies within the catchment of Sandy Creek, a tributary of the Talbragar River. Sandy Creek, Laheys Creek (a tributary of Sandy Creek) and a number of minor tributaries flow through the proposed mine area.

The Talbragar River, Sandy Creek and Laheys Creek are naturally ephemeral waterways and cease to flow during dry periods. There are no headwater storages to regulate flows, and therefore all flows directly reflect rain events, groundwater baseflows and evapotranspiration processes.

When observed during multiple site visits during 2009 and 2010, Sandy Creek and Laheys Creek were dry, apart from isolated stagnant pools. During the site visits in October, November and December 2011, running water was present in Sandy Creek, with stagnant pools at some locations; Laheys Creek was also flowing at most locations.

Laheys Creek is a small, densely vegetated channel over most of its length. Upstream of its confluence with Laheys Creek, Sandy Creek is a sandy, grassed channel showing evidence of bank erosion. Downstream of the confluence, Sandy Creek widens to become a broad, flat channel that is heavily vegetated with grasses and reeds.

Two farm dams have been constructed on Blackheath Creek, a tributary of Laheys Creek. These were constructed by the landowner approximately 30 years ago to service the property's irrigation needs. The larger of the two dams is shown in Photo 4-1. A recent survey of the dam determined its capacity to be about 1,470 ML. The upstream smaller dam (referred to as the 'sausage dam') receives inflow from groundwater springs higher in the catchment and has a capacity of approximately 15 ML (see Photo 4-2).

Flyblowers Creek is a small creek catchment located north-west of the Sandy Creek catchment. This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek.

Fords Creek is a tributary of Laheys Creek and lies in the upper catchment. Fords Creek flows west and captures runoff from the forested areas near the Goodman State Forest. Many small drainage channels and gullies drain into it.

The remainder of the Project Application Area covers catchments of minor tributaries and small creeks in the south and part of the tributary system draining to Tallawang Creek in the east. Tallawang Creek flows south into the Wyaldra Creek, which eventually flows into the Cudgegong River west of Gulgong.

Tucklan Creek flows in a northerly direction from the site into the Talbragar River, approximately 10 km upstream of the Sandy Creek – Talbragar River confluence. Tucklan Creek has a similar catchment area to Laheys Creek, but only approximately 1 km of its headwaters lie within the assessment area.



Photo 4-1 Catch water dam on Blackheath Creek



Photo 4-2 Sausage dam on Blackheath Creek

5. Baseline hydrologic conditions in local surface water bodies

5.1 Stream gauge information

No NSW Office of Water (NOW) gauging stations are currently operational within the assessment area or within the broader Sandy Creek catchment. However, Station 421042 is located on the Talbragar River at Elong Elong, approximately 10 km north-west and downstream of the assessment area (shown on Figure 3-1 as SW4).

Additional stream flow records are available from discontinued NOW stream gauges on the Talbragar River at Cobbora (close to SW5 on Figure 3-1) and on Sandy Creek at Medway (close to SW3 on Figure 3-1). Details of these gauges are provided in Table 5-1.

Table 5-1 NSW Office of Water stream flow gauges

Location	Gauge number	Period of record
<i>Operational gauges</i>		
Talbragar River at Elong Elong	421042	1964–present
<i>Discontinued gauges</i>		
Talbragar River at Cobbora	421028	1950–1954
Talbragar River at Naranmore	421037	1955–1976
Sandy Creek at Medway	421064	1966–1985

Source: PINEENA database

The Talbragar River is characterised by a seasonal discharge pattern, with lower flows during summer and autumn, and floods throughout winter and spring. Based on available recorded data from NOW, the median annual discharge at Elong Elong is 21,509 ML/a, with a maximum recorded annual discharge of 264,366 ML in 1998 and a minimum recorded annual discharge of 653 ML in 2005.

The flow duration curve developed from the Elong Elong gauge shows that although the highest recorded mean daily flow was 40,835 ML/d (in December 2010), for 50% of the time flows were less than 11.9ML/d and for 32% of the time there was no flow.

The flow record from Sandy Creek shows that for the period of record (1966–1985), the highest mean daily flow was 8,937 ML/d, which occurred in February 1971. The flow duration curve for Sandy Creek at Medway shows that for 50% of the time flows were less than 0.04 ML/d and for 46% of the time there was no flow.

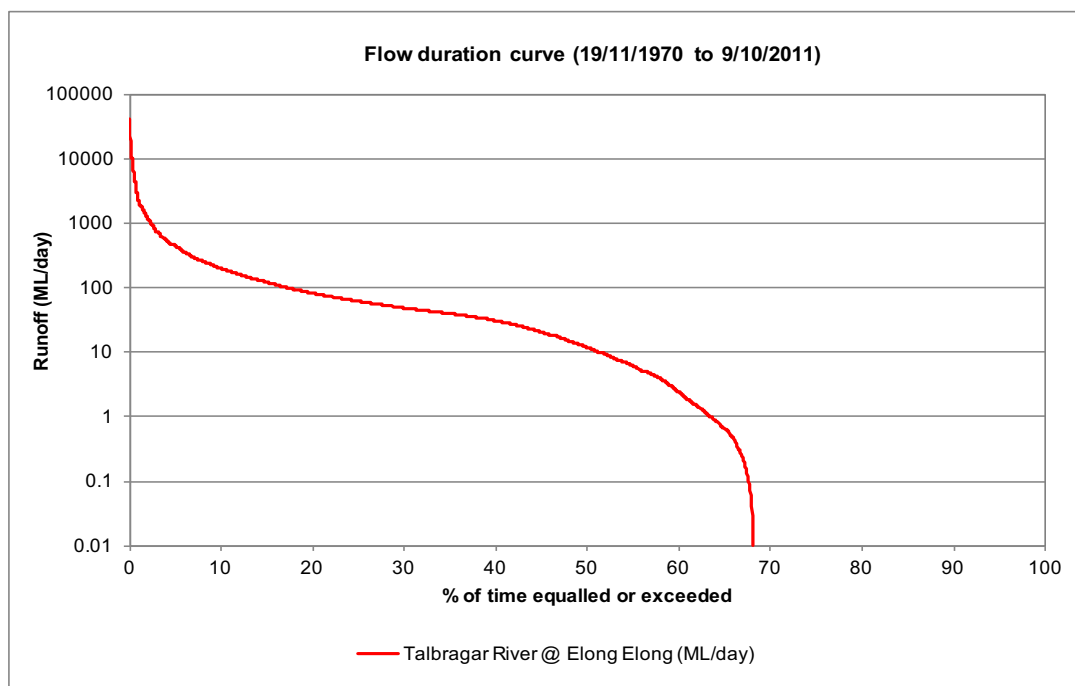


Figure 5-1 Flow duration curve for Talbragar River at Elong Elong

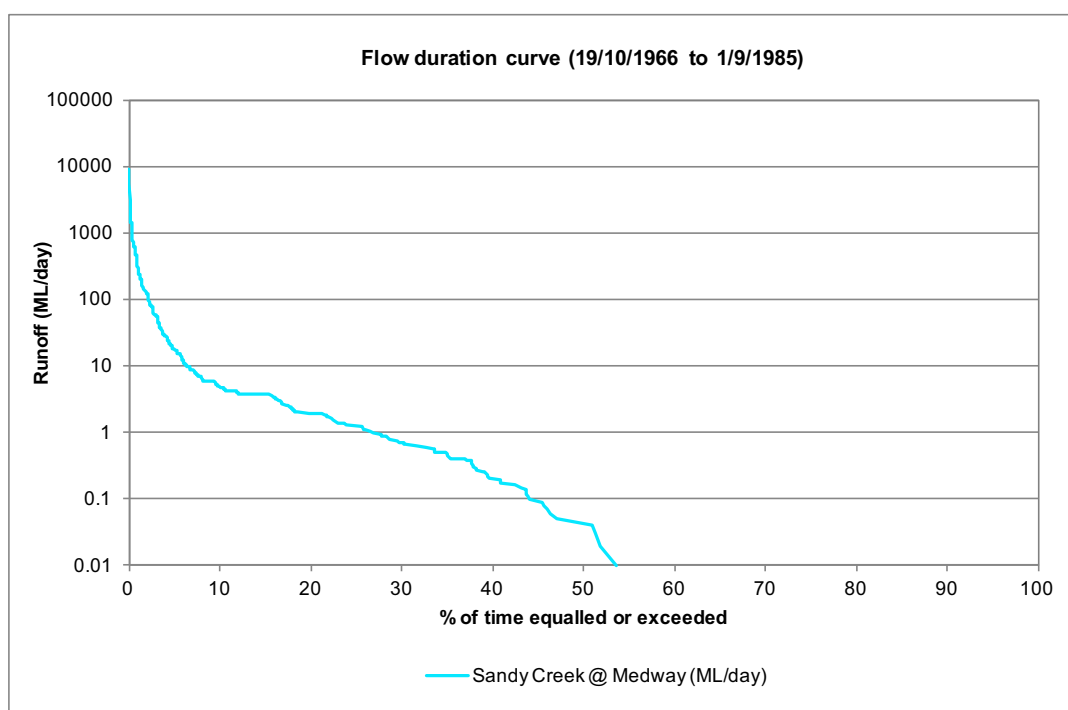


Figure 5-2 Flow duration curve for Sandy Creek at Medway

As part of Parsons Brinckerhoff's ongoing baseline surface water monitoring program, four water level gauging stations have operated on the Talbragar River, Sandy Creek and Laheys Creek since November 2009. The locations of the gauges are shown on Figure 3-1 and are described as follows:

- **SW1** - Located approximately 5 km upstream of the confluence with Laheys Creek at the intersection between Sandy Creek Road and Dapper Road.

- **SW2** – Located approximately 10 km upstream of the confluence with Sandy Creek, located on the upstream side of the intersection of Dapper and Spring Ridge roads.
- **SW3** – Located approximately 1.5 km downstream of the confluence with Laheys Creek.
- **SW5** – Located approximately 15 km upstream of the confluence of the Talbragar River and Sandy Creek, near Martin Street Cobbora.

Following a review of the baseline stream gauging data, including the water level data from the four installed gauges (SW1, SW2, SW3, and SW5) and NOW gauging records for nearby discontinued and active gauging stations (including SW4), the following observations were made:

- Water level data is available at stream gauges SW1, SW2, SW3 and SW5. These data were collated, reviewed and used to identify the water level and flow regimes that occurred during the water quality sampling occasions (see Section 7.2 for further discussion).
- Water level, daily discharge, a recent cross-section and a rating curve developed by NOW are available at the Elong Elong station 421042.
- Daily discharge data from three discontinued NOW gauges within the vicinity of the assessment area are also available and have been collated for the purposes of the *Downstream Flow Impact Assessment*. These data were converted to instantaneous flows at one of the sites (Sandy Creek at Medway) and used to supplement recently recorded data.

Table 5-2 summarises the stream gauging data that is currently available.

Table 5-2 Stream flow gauging data available

Gauge name	Gauge location/ description	Start date	End date	Duration (days)	Type of data	Time step	Data gaps	Comments/actions
SW1	Sandy Creek u/s of Laheys Creek (41010A)	19/11/2009	28/06/2011	586	Water level	4 times a day	Data gap from between 1/01/2010 and the 16/2/2010 due to Thiess installation	Gilbert & Associates site visit flagged that the gauge was not in the most suitable location (stilling well located in stagnant area, silted cross-section just downstream ponding water). Relocation to more appropriate cross-section was required.
SW2	Laheys Creek u/s of Sandy Creek (410103A)	19/11/2009	28/06/2011	586	Water level	Every 4 hours	A few small gaps between 20/1/2010 and 1/2/2010; 26/3/10 to 23/4/10; 25/5/2010 to 19/11/2010	Pipe underneath the road crossing is occasionally blocked by debris and creates an artificially high level in the recording pool – removal of debris is frequently required.
SW3	Sandy Creek d/s of Laheys Creek (410103A)	20/11/2009	28/06/2011	585	Water level	Every 4 hours	Gap between 25/05/2010 and 15/11/2010	
421064 (discontinued NOW gauge) at same location as SW3	Sandy Creek @ Medway 2 (421064)	02/10/1966	26/02/1998	11470	Water level	Daily	Some significant gaps	This record can supplement SW3 records.
421064 (discontinued NOW gauge) at same location as SW3	Sandy Creek @ Medway 2 (421064)	02/10/1966	26/02/1998	11470	Discharge	Daily	Some significant gaps	This record can supplement SW3 records.
SW4 (421042)	Talbragar River at Elong Elong (421042) – NOW gauge	20/11/1970	22/08/2011	14885	Average water level	Daily	Very minor gap between 28/12/2009 and 30/12/2009	Download data to current date came from NOW website: http://waterinfo.nsw.gov.au/water.shtml?ppbm=SURFACE_WATER&rs&3&rskm_url
SW4 (421042)	Talbragar River at Elong Elong (421042) – NOW gauge	01/12/1964	07/09/2011	17081	Discharge ML/d	Daily	Can easily covert this ML/d flow to m ³ /s flow	Download data to current date came from BoM website. Data from 1/4/11 is from BoM station 64010.

Gauge name	Gauge location/ description	Start date	End date	Duration (days)	Type of data	Time step	Data gaps	Comments/actions
SW5	Talbragar River @ Cobbora	10/12/2009	28/06/2011	565	Water level	Daily	Few small gaps: 14/01/10 to 1/2/10; 25/05/10 to 1/6/10	
421028 (discontinued NOW gauge) at same location as SW5	Talbragar River @ Cobbora (421028) – discontinued	02/03/1949	01/10/1954	2039	Water level	Daily	Some significant gaps (e.g. some of 1950)	This record can supplement SW5 records.
421028 (discontinued NOW gauge) at same location as SW5	Talbragar River @ Cobbora (421028) – discontinued	02/03/1949	10/10/1954	2048	Discharge	Daily	Some significant gaps (e.g. some of 1950)	This record can supplement SW5 records.
421037 (discontinued NOW gauge)	Talbragar River @ Naranmore (421037) – discontinued	02/01/1956	01/06/1976	7456	Water level	Daily	Some gaps (e.g. 1956)	
421037 (discontinued NOW gauge)	Talbragar River @ Naranmore (421037) – discontinued	08/12/1955	01/06/1976	7481	Discharge	Daily	Some gaps (e.g. 1956)	

5.2 Water level gauging stations and associated data limitations

To develop reliable stage discharge rating curves for water level gauging station sites, accurate surveyed cross-sections of the creek cross-section at each gauge site are required. During the baseline review, no detailed cross-section survey information was found for water level gauges at SW1, SW2, SW3 and SW5.

For gauges located at SW1, SW2, SW3 and SW5, cross-sectional survey information and manual flow measurements were collected during November 2011 in order to develop stage discharge rating curves at these locations. Discharge volumes were measured using a SonTek FlowTracker Acoustic Doppler Velocimeter and the mid-section computation method. Table 5-3 summarises these discharge measurements.

Table 5-3 Discharge measurement summary

Site	Start date and time	Total width (m)	Total area (m ²)	Total discharge (m ³ s ⁻¹)
SW1	23/11/2011 08:33 hours	6.000	0.430	0.0169
SW2	24/11/2011 08:50 hours	3.400	0.366	0.0227
SW3	24/11/2011 11:00 hours	2.100	0.601	0.0089
SW5	22/11/2011 11:42 hours	4.700	1.412	0.1000

Low flow manual measurements were required as a minimum to confirm the low flow portion of the rating curve and are more accurate than hydraulic calculations for lower flows.

Comparing the total discharge given in Table 5-3 at SW3 against the Sandy Creek flow duration curve in Figure 5-2 demonstrates that the flow gauging undertaken on 22/11/2011 and 23/11/2011 was conducted in conditions relating to the 90th percentile exceedance above the cease-to-flow condition. For the intermediate and higher flow portion of the rating curve, local hydraulic models of the gauge sites were constructed using hydraulic modeling software (HEC-RAS). These models were used to estimate the water level versus flow relationship. The stage-discharge plots generated from these analyses are shown in Figure 5-3.

The stage-discharge plots are presented in terms of water surface (WS) elevation rather than mAHD because the water levels were measured above temporary benchmarks established for each site. An investigation to convert the dataset to mAHD is continuing, including the possibility of undertaking further gauging during intermediate and high-flow conditions to refine the current rating curve regression equations.

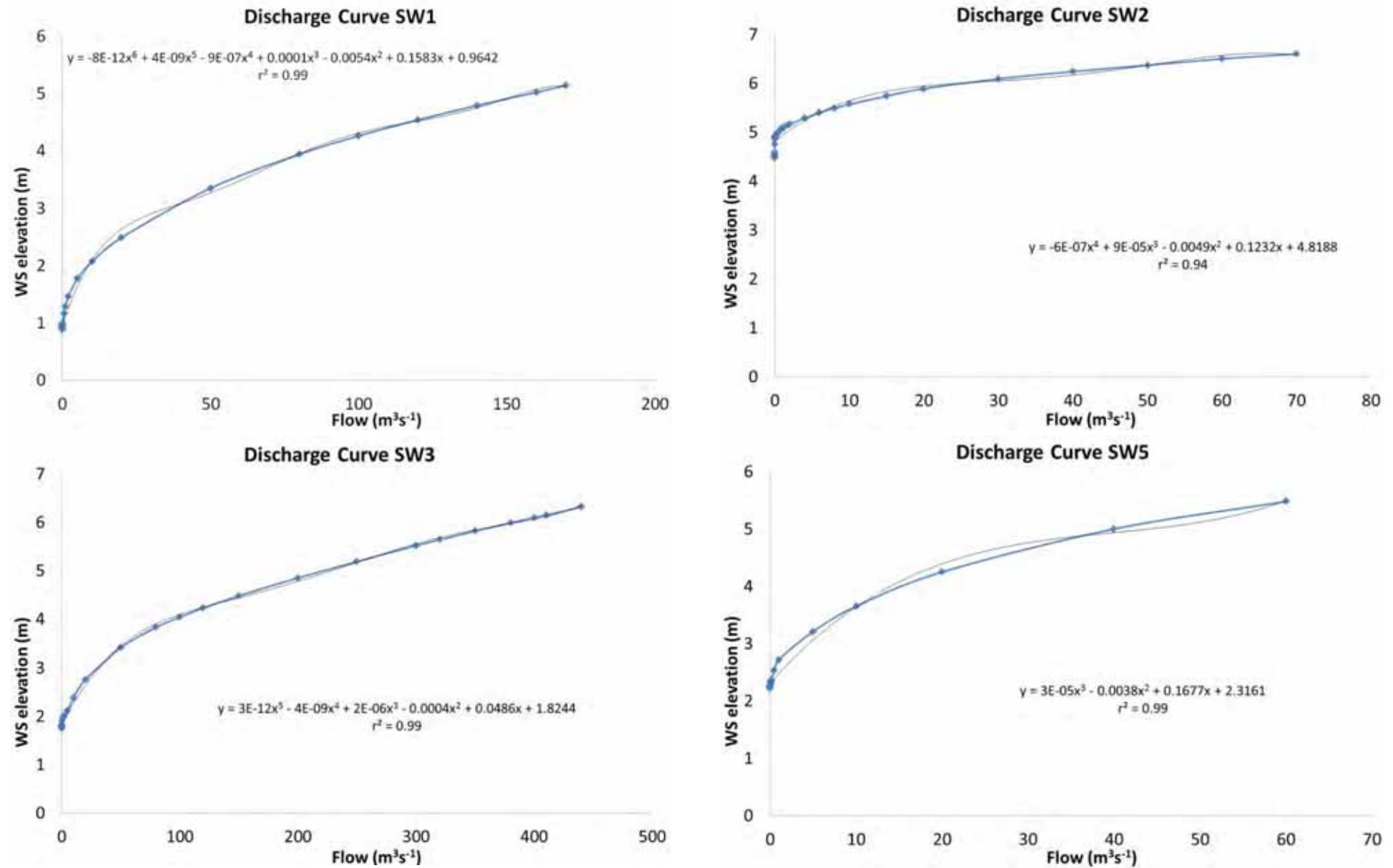


Figure 5-3 Stage-discharge regression plots for SW1, SW2, SW3 and SW5

5.3 Stage-discharge relationships used in the assessment

In the absence of stage-discharge relationships in mAHD at the water level gauging sites, rating curves were instead developed using the hydraulic model developed for the *Flood Impact Assessment*. The flood model includes cross-sections based on light detection and ranging (LiDAR) data, which is not as accurate as ground survey but can be accurate to a level of +/- 150 mm, depending on the data capture method and land cover.

The rating curves developed using the flood model were also used for the *Downstream Flow Impact Assessment*. It should be noted that these rating curves, while reasonably accurate for high flows, may be inaccurate for low-flow volume estimation and could underestimate low-flow volumes, due to the lack of detail on the bottom of the creek bed captured in the LiDAR data.

5.4 Baseline flood hydrology

Baseline hydrologic and hydraulic conditions in the local surface water bodies are described in detail in the *Flood Impact Assessment*, which provides estimates of peak flows, water levels and flood extents for a range of extreme flood events.

6. Water uses and local guidelines

Watercourses within the assessment area have been defined as ‘uncontrolled streams’ where the flow remains largely natural (DECCW, 2006). Regional Water Quality and River Flow Objectives have been developed for the Macquarie–Bogan uncontrolled rivers system by the Office of Environment and Heritage (OEH), formerly Department of Environment, Climate Change and Water (DECCW), in order to guide plans and actions to achieve healthy waterways.

Eleven Water Quality Objectives (WQOs) apply. Each is based on providing the right water quality for the environment and the different uses people have for water in the river system. They are based on measurable environmental values for:

- aquatic ecosystems
- visual amenity
- secondary recreational contact
- primary recreational contact
- livestock water supply
- irrigation water supply
- homestead water supply
- drinking water — disinfection only
- drinking water — clarification and disinfection
- drinking water — groundwater
- aquatic foods.

There are also six inland River Flow Objectives (RFOs), which deal with how water moves down rivers and streams. Each objective aims to improve river health by recognising the importance of natural river flow patterns. The RFOs are based on achieving improved environmental results by managing the river system. They are as follows:

- protect pools in dry times
- protect natural low flows
- protect important rises in water levels
- maintain wetland and floodplain inundation
- manage groundwater ecosystems
- minimise effects of weirs and other structures.

Local water quality and quantity vary naturally due to a number of factors, including the type of land the waters are draining (e.g. soils, slope), or rainfall and runoff patterns e.g. ephemeral or permanent streams). Therefore, regional objectives have been used in the downstream water quality and flow impact assessments in preference to generic guidelines.

7. Baseline water quality in local surface water bodies

The baseline surface water quality within the assessment area, including the Talbragar River, Sandy Creek and Laheys Creek catchments, was assessed by:

- defining objectives and guidelines
- reviewing and analysing baseline water sampling data
- comparing baseline water quality against relevant guidelines
- assessing surface water quality processes in the assessment area.

Baseline water sampling data were reviewed for each of the gauge locations SW1, SW2, SW3, SW4 and SW5 (see Figure 3-1). The samples were collected and analysed monthly by ALS Environmental from August 2009 to September 2011 (inclusive). Samples were analysed for physical parameters (electrical conductivity, pH, turbidity, temperature and dissolved oxygen), major ions, nutrients and a suite of metals.

7.1 Objectives and guidelines

ANZECC (2000) guidelines and DECCW (2006) water quality objectives (WQOs) were used to assess the baseline surface water quality. The ANZECC (2000) guidelines can be tailored to three different categories of ecosystems, depending on the level of disturbance of the ecosystem:

- Condition 1: high conservation/ecological value systems — effectively unmodified or other highly-valued ecosystems, typically occurring in national parks, conservation reserves or remote and/or inaccessible locations.
- Condition 2: slightly to moderately disturbed systems — ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. Typical examples include rural streams receiving runoff from land disturbed by agriculture.
- Condition 3: highly disturbed systems — measurably degraded ecosystems of lower ecological value.

For the purposes of determining baseline water quality conditions, water quality parameters have been assessed against Condition 2, as the Talbragar River, Sandy Creek and Laheys Creek catchments can be classified as *slightly to moderately disturbed systems* due to land uses in the catchments being dominated by agriculture and pastoralism.

7.2 Flow ranges relating to the surface water quality monitoring dataset

This section examines whether samples collected as part of the baseline monitoring program were representative of the range of flow conditions observed in the assessment area.

In the absence of site-specific flow gauging over an extended time, automatic water level measurements recorded at each site were used to examine whether variation in flow conditions was adequately captured.

The timing of water quality sampling events in relation to the water level record can be seen in the plots shown in Appendix A.1. The water quality samples were categorised into five water depth classes based on exceedances of the following nominal percentile water levels:

- < 25%ile = very low
- 25–50%ile = low
- 50–75%ile = medium
- 75–95%ile = high
- >95%ile = very high.

This provided a common basis for comparison across the monitoring sites, in terms of water depth classes. A summary of the results that compare between water level recordings and water quality sampling events is provided in Table 7-1.

Table 7-1 Comparison between water level data and water quality sampling occasions

Sampling location	Number of samples (number of no samples)	Sampling flow classification (based on water level measurements)				
		Very low	Low	Medium	High	Very high
SW1	14	5	3	4	2	0
SW2	18 (3)	5	4	4	0	2
SW3	18 (5)	4	3	4	2	0
SW4	18	6	2	6	3	1
SW5	15	6	7	0	2	0

Key: ■ = sufficient samples; ■ = more samples desirable; ■ = more samples required

The comparison shows that, in general, the dataset sufficiently covers the 'very low', 'low' and 'medium' water level conditions, but the 'high' and 'very high' water level conditions are under-represented. In summary, it was found that:

- No flows were observed in 3 out of 18 samples at SW2, and 5 out of 18 samples at SW3.
- No very high flow conditions were observed at SW1, SW3 or SW5.
- Only 2 out of 18 samples at SW2 and 1 out of 18 samples at SW4 were found to occur during high-flow conditions.
- No sampling was conducted during the period of very high flow in December 2010.
- The following observations are made for the 31 August 2009 to 28 June 2011 water quality sampling dataset:

- Samples taken were predominantly collected during 'nil' or 'low' flow conditions. 'Medium' and 'high' flow conditions were not represented equally in the sampling regime.
- Due to the ephemeral nature of Sandy Creek and Laheys Creek, 'low flow' is the 'normal' catchment condition for these creeks (see flow duration curve in Figure 4-2) and therefore the sampling undertaken to date can be considered representative of average conditions in the creeks.

Flow in the monitored reaches of the Talbragar River, Sandy Creek and Laheys Creek varied over the 25 -month monitoring period.

Throughout 2009, stagnant pools were observed at all sites and this situation only changed in January 2010 following heavy rainfall throughout December 2009. During most of 2010, SW1, SW2 and SW3 experienced low flows and SW4 and SW5 experienced medium to low flows. Flows then increased due to flood events that occurred during December 2010 to January 2011.

All monitoring sites recorded very high flows during the December 2010 monitoring event but no samples were collected during this period. Flows reduced slightly in February 2011 to low to medium at all sites.

The high-flow conditions monitored by the gauging stations were under-represented in the current water quality dataset. This is a common issue in routine water quality sampling and can result in the following estimation problems when using such data to understand the water quality within the system:

- Overestimation of total dissolved solids (TDS) and soluble metal/nutrient chemical concentrations by underestimating the dilution of water quality parameters that occurs during high-flow events.
- Under estimation of concentrations of total suspended solids and particulate-bound metals and nutrients by not taking high-magnitude or low-frequency storm events into account; such events deliver the majority of particulate matter to the channel via overland flow, increased bank erosion and increased capacity to entrain channel sediments.

These factors are important to consider when using routine sampling data as the basis for an assessment of the impacts of development on water quality.

7.3 Surface water quality monitoring findings

The results of the surface water quality monitoring were compared to the Condition 2 ANZECC water quality guidelines defined in Section 7.1. The detailed comparison is shown in Table 7-2.

Overall it was found that surface waters at SW1, SW2 and SW3 were dominated by chloride and sodium, with the highest value of chloride found at SW1 (2,640 mg/L during December 2009). Chloride and sodium concentrations recorded in the creeks (SW1, SW2 and SW3) were relatively high compared to ANZECC (2000) guidelines for irrigation water. SW1 and SW2 had similar magnesium concentrations, SW3 was slightly lower, and SW4 and SW5 had the lowest magnesium concentrations. SW4 and SW5 were typically dominated by magnesium and bicarbonate.

The pH measurements collected from Sandy Creek and Laheys Creek indicate neutral to slightly alkaline surface water, with an overall average of 7.77 for all sites. Upstream Sandy Creek (SW1) had an average pH of 7.86 and the lower reaches a pH of 7.54 (SW3). Laheys Creek had an average pH of 7.62. Sites along the Talbragar River had a similar average pH of 7.9 (SW4 and SW5).

Alkalinity concentrations were similar for sites SW2 and SW3, whereas SW1 had higher concentrations. Alkalinity concentrations at SW4 and SW5 had a greater range but were generally lower, except from January 2011 to May 2011 when SW4 and SW5 experienced higher levels of alkalinity.

Total nitrogen concentrations at all sites exceeded the ANZECC (2000) trigger level of 0.25 mg/L for the protection of aquatic ecosystems for all of the monitoring time, but the concentrations were below the long-term trigger value (5 mg/L) recommended for irrigation supply. Total phosphorus levels were also exceeded for the protection of aquatic ecosystems during 2011 at SW4 and SW5, these levels were also exceeded on numerous occasions at all sites during the monitoring period. The reactive phosphorus ANZECC guideline threshold for aquatic protection was also frequently exceeded, more often at SW4 and SW5 than the other three sites.

The majority of metals were generally below the guideline thresholds for livestock watering and irrigation, but exceeded the threshold for aquatic ecosystems during some of the sampling events.

Aluminum levels were above the threshold value for aquatic ecosystems 95% of the time, and elevated copper levels were recorded at all sites.

Dissolved iron levels were mostly below the threshold value; however, total iron was much higher. Manganese levels exceeded the guideline threshold for aquatic ecosystems most of the time at SW3, and, except at SW4 and SW5, exceeded the threshold for long-term irrigation on most occasions.

Zinc levels exceeded the ANZECC (2000) guideline threshold for the protection of aquatic ecosystems 40% of the time, but they were below the threshold for livestock watering and long-term irrigation.

Total suspended solids have no guideline levels under ANZECC (2000), but concentrations were generally either low (< 20 mg/L) or elevated (> 100 mg/L). The highest value of 992 mg/L at SW4 in December 2010 suggests that transport capacity in high-flow events, rather than source material, is the main control on sediment transport.

Turbidity levels mirrored suspended-solid concentrations with values generally below 10 nephelometric turbidity units (NTU) and the peak of 940 NTU also occurring at SW4 in December 2010. Levels frequently exceeded the 25 NTU guideline for aquatic ecosystems at all sites during high flow conditions.

A comprehensive table of results of each measured parameter is given in Table 7-2.

7.4 Discussion of baseline water quality monitoring results

7.4.1 Flow

Flows in the monitored reaches of the Talbragar River, Sandy Creek and Laheys Creek were variable over the 25-month monitoring period.

Flows during the 2009 monitoring events were nil too low for sites on Sandy Creek and Laheys Creek (SW1, SW2 and SW3), where large non-flowing pools were observed. The two sites on the Talbragar River (SW4 and SW5) were dry until significant rainfall in late December 2009, after which pools were present but not flowing.

Given the dry conditions in the region during the end of 2009, it is possible that the water present at SW1, SW2 and SW3 was a result of a combination of gradually evaporating surface water and limited groundwater baseflows. This is supported by the occasionally elevated metal concentrations detected at these locations.

Historical stream flow data from a site near SW3 are available for 1966–1999 (PINEENA NSW Department of Water & Energy 2008, gauge 421064). The historical flow data suggests a stream level of around 0.4–0.5 m occurs even at times of very low to no flow, which could indicate there is baseflow, at least in part, along Sandy Creek. This has also been noted following recent groundwater pump tests of shallow bores adjacent to the channel (refer to the *Groundwater Assessment* report).

Rainfall at the Dunedoo and Gulgong rain gauges was measured at 149 mm and 164.7 mm respectively for the month of December 2009. Over the Christmas period of 2009, 187.5 mm of rainfall was recorded at the on-site meteorological stations.

During 2010, nil to low flows were recorded at SW1, SW2 and SW3, and low to medium flows were recorded at SW4 and SW5. Flood events occurred during December 2010 to January 2011. However, there was a four-month gap between the monitoring event on 28 July 2010 and that on 20 December 2010.

The BoM states that 2010 began with El Niño conditions but was followed by a rapid transition into La Niña during autumn, resulting in the second half of the year (July to December) being the wettest on record for Australia (BoM 2011). It was noted in Section 7.2 that high flows have been under-represented during monitoring events.

La Niña conditions subsided in May 2011, and the remainder of the monitoring events in 2011 recorded low to medium flow in SW1, SW2 and SW3, and medium flows at SW4 and SW5.

7.4.2 Salinity

Salinity levels measured in the upstream locations of Sandy Creek (SW1) and Laheys Creek (SW2) were elevated. The high levels of salinity may be due to the soil and geological landscapes: Ballimore red earths at SW1, and Laheys Creek and Dapper Hill yellow soloths and solodic soils at SW2, which are characterised by saline soils, particularly in drainage depressions (Murphy et al 1998).

Salinity measurements in the creeks were also likely to be influenced by evaporation in the isolated stagnant pools, increasing the concentration of dissolved ions (Smith et al. 2004). In the upper reaches of Sandy Creek (SW1), the salinity has generally decreased from the beginning of the monitoring program in August 2009, when flows were very low to nil, to September 2011, when salinity levels were nearly half their original level.

Laheys Creek (SW2) and Talbragar River sites (SW4 and SW5) all follow a similar trend. However, salinity levels at SW3 in the lower reaches of Sandy Creek have generally increased. This could be due to gradual ponding of water at this site, caused by the collapse of a river bank in the December 2010 storm event with subsequent deposition of fine material and gradual cut-off of this creek channel.

7.4.3 Nutrients

Elevated concentrations of nutrients in the surface water are likely to be a result of the local land uses and river flows (Smith et al. 2004). The land surrounding Sandy Creek and Laheys Creek and the Talbragar River comprises agricultural enterprises, consisting for the most part of cattle and sheep grazing on improved pastures and dryland cropping.

Livestock waste and soil fertilisers may be transported through surface water runoff, dust movement from paddocks to the creek area, or stock movement within the riparian zone, potentially contributing to the concentrations of nitrogen and phosphorus in the surface water. In addition, periods of low flow, especially in 2009, might have led to increases in hyporheic upwelling (Dent et al 2001), supplying high nitrogen and phosphorus loads from the shallow groundwater system.

Sources of sediment that contribute to the nutrient load in these watercourses include overland erosion, especially along tracks that provide a conduit for surface water runoff, bank erosion during high-flow conditions and re-suspension of significant in-channel bed sediments. Watercourse crossings provide a mechanism for delivery and re-suspension of sediment to the creeks, with significant plumes of sediment resulting from vehicle traffic.

Ephemeral streams such as Laheys Creek and Sandy Creek will also retain large amounts of particulate organic matter in the dry channel that may be exported downstream during storm events (Cuffney et al 1989).

7.4.4 Metals

Some metals analysed were above the threshold for the protection of 95% of species in aquatic ecosystems, including aluminum, copper, cadmium, silver, manganese and zinc at all sites. Nickel was exceeded on a few occasions at SW4 and SW5. Chromium was exceeded regularly at SW4 and SW5. The protection of 95% of species, commonly associated with *slightly to moderately disturbed ecosystems* is considered relevant to the existing condition of the assessment area (see Section 7.1).

As no industrial discharges occur upstream of the assessment area, these levels are considered a natural reflection of the local soils/geology. In stagnant pools, such as those that occur in Laheys Creek and Sandy Creek, toxicants can also accumulate (Boulton et al 1990).

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines

Sample Location	Description of site	Sample Date	Aluminium _mg/L	Arsenic _mg/L	Boron _mg/L	Cadmium _mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total mg/L	Copper mg/L	Dissolved Oxygen %sat	Electrical Conductivity μS/cm - field	Fluoride _mg/L	Iron mg/L	Lead mg/L	Manganese mg/L	Mercury _mg/L	Molybdenum _mg/L	Nickel mg/L	Nitrates mg/L N	Nitrites mg/L N	pH - field	Phosphorus - total mg/L	Selenium _mg/L	Silver mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen mg/L N	Turbidity _ NTU	Zinc mg/L	
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008	
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000				20
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5			2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25			5
SW1	Sandy Creek, upstream of confluence with Laheys Creek	31-Aug-09	0.21	0.002	0.05	<0.00005	159	1790	<0.001	0.003	96	6940	0.4	0.7	0.0006	1.300	<0.0001	<0.001	0.007	<0.01	<0.01	8.0	0.05	<0.001	<0.001	972	458	4200	0.9	14.0	<0.005	
		21-Sep-09	0.24	0.0015	0.05	<0.00005	146	1820	0.001	0.002	91	6800	0.5	0.5	0.0007	1.900	<0.0001	<0.001	0.006	<0.01	<0.01	8.2	0.12	<0.001	<0.001	964	466	4100	1.4	28.0	<0.005	
		21-Oct-09	0.73	0.003	0.07	<0.00005	122	1860	0.002	0.004	126	7210	0.5	1.6	0.0026	1.300	<0.0001	0.001	0.011	<0.01	<0.01	8.4	0.28	<0.001	<0.001	1020	457	4500	2.4	96.0	0.01	
		20-Nov-09	0.57	0.0013	0.08	<0.00005	118	2240	<0.001	0.003	80	7810	0.6	1.4	0.0022	1.600	0.0001	<0.001	0.009	<0.01	<0.01	8.4	0.23	<0.001	<0.001	1275	467	5000	2.6	52.0	0.11	
		11-Dec-09	0.15	0.0028	0.11	<0.00005	113	2640	0.001	0.003	84	4800	0.7	0.5	0.0009	1.400	<0.0001	0.002	0.011	<0.01	<0.01	8.1	0.15	<0.001	<0.001	1460	582	6000	2.2	2.6	<0.005	
		7-Jan-10	0.18	0.003	0.06	<0.00005	30	202	<0.001	0.005	50	1350	0.5	1.1	0.0007	0.920	<0.0001	0.002	0.006	0.04	<0.01	7.7	0.11	<0.001	<0.001	148	91	690	1.9	6.6	0.008	
		18-Feb-10	0.09	0.0018	0.06	<0.00005	49	411	<0.001	0.001	89	2100	0.4	1.2	<0.0002	1.400	<0.0001	<0.001	0.004	<0.01	<0.01	7.6	0.08	<0.001	<0.001	268	63	1200	1.5	5.9	0.011	
		26-Mar-10	0.07	0.0014	0.08	<0.00005	49	1030	<0.001	0.001	79	4270	0.5	0.3	<0.0002	0.66	<0.0001	<0.001	0.005	<0.01	<0.01	7.9	0.04	<0.001	<0.001	545	269	2700	1.0	6.0	0.006	
		22-Apr-10	0.05	<0.001	0.05	<0.0001	72	691	<0.001	0.001	83	3190	0.4	0.2	<0.001	0.686	<0.0001	<0.001	0.003	<0.01	<0.01	7.7	0.08	<0.01	<0.001	532	133	1800	0.9	6.3	<0.005	
		25-May-10	0.25	<0.001	0.06	<0.0001	83	727	<0.001	0.001	114	2730	0.3	0.4	<0.001	0.265	<0.0001	<0.001	0.001	0.08	<0.01	8.1	<0.01	<0.01	<0.001	274	58	1470	0.3	11.5	<0.005	
		29-Jun-10	0.06	<0.001	<0.05	<0.0001	55	798	<0.001	0.001	67	3270	0.5	0.4	<0.001	0.23	<0.0001	0.001	0.002	<0.01	<0.01	7.4	0.02	<0.01	<0.001	504	74	1680	0.6	3.3	0.006	
		28-Jul-10	0.07	<0.001	<0.05	<0.0001	44	539	<0.001	<0.001	79	2420	0.3	0.3	<0.001	0.241	<0.0001	<0.001	0.002	0.04	<0.01	7.7	0.01	<0.01	<0.001	360	60	1170	1.6	3.5	<0.005	
		20-Dec-10	0.40	0.002	<0.05	<0.0001	35	206	0.001	0.002	96	950	0.2	1.3	<0.001	0.142	<0.0001	<0.001	0.004	0.3	0.03	7.7	<0.01	<0.01	<0.001	107	27	522	3.1	16.8	<0.006	
		24-Jan-11	0.08	0.001	0.05	0.0002	63	461	<0.001	0.002	112	2130	0.4	0.7	<0.001	0.33	<0.0001	0.001	0.002	0.01	<0.01	8.0	<0.01	<0.01	<0.001	276	76	1220	0.6	4.8	0.006	
		25-Feb-11	0.03	0.001	0.05	<0.0001	61	567	<0.001	<0.001	85	2490	1.7	0.9	<0.001	0.477	<0.0001	0.001	0.002	0.03	<0.01	7.8	0.08	<0.01	<0.001	326	62	1310	0.5	4.7	<0.005	
		24-Mar-11	0.08	0.001	0.06	<0.0001	80	762	<0.001	<0.001	72	3130	0.6	0.8	<0.001	0.754	<0.0001	0.001	0.002	0.02	<0.01	7.6	0.02	<0.01	<0.001	434	92	1680	0.6	4.4	<0.005	
		20-Apr-11	0.04	0.001	<0.05	<0.0001	70	780	<0.001	<0.001	90	3220	0.5	0.8	<0.001	0.589	<0.0001	0.001	0.002	0.02	<0.01	7.8	0.04	<0.01	<0.001	407	119	1860	0.6	4.2	<0.005	
		31-May-11	0.09	<0.001	<0.05	<0.0001	67	588	<0.001	<0.001	91	2640	0.4	0.8	<0.001	0.505	<0.0001	<0.001	0.002	0.57	<0.01	7.9	0.11	<0.01	<0.001	288	66	1470	1.3	11.4	0.012	
		28-Jun-11	0.02	<0.001	<0.05	<0.0001	149	727	<0.001	0.002	101	2960	0.4	0.9	<0.001	0.618	<0.0001	<0.001	0.002	0.72	<0.01	8.2	<0.01	<0.01	<0.001	78	87	1550	1.2	7.5	0.01	
		30-Aug-11	0.08	<0.001	<0.05	<0.0001	61	631	<0.001	<0.001	92	2770	0.5	0.7	<0.001	0.541	<0.0001	<0.001	0.002	0.01	<0.01	7.8	<0.01	<0.01	<0.001	317	74	1330	0.4	5.6	<0.005	
		26-Sep-11	0.32	0.010	<0.05	<0.0001	66	709	<0.001	<0.001	97	3210	0.5	0.9	<0.001	0.741	<0.0001	<0.001	<0.001	0.02	<0.01	8.0	<0.01	<0.01	<0.001	397	83	1640	0.4	14.1	<0.005	
		27-OCT-2011	0.32	0.002	0.05	0.00005	61	581	0.0005	0.001	79	2470	0.6	0.7	0.0005	0.779	5E-05	0.0005	0.002	0.005	0.005	5.0	0.04	0.005	5E-04	300	45	1310	0.5	9.5	0.008	
		28-NOV-2011	0.28	0.0005	0.025	0.00005	47	503	0.0005	0.0005	86	2320	0.5	0.8	0.0005	0.199	5E-05	0.0005	0.002	0.02	0.005	8.0	0.005	0.005	5E-04	287	10	1180	0.8	9.4	0.003	

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems																															
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality																															
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)																															
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)																															
	notes																															
	exceed all EV trigger values																															
	exceed at least one EV trigger value																															
	exceed no EV trigger values																															
	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3																															
	2000 is the maximum TDS tolerance for sensitive livestock																															
	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and cattle is 1)																															
	maximum concentration for sensitive crops																															
	lower limit valie																															

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total mg/L	Copper mg/L	Dissolved Oxygen %sat	Electrical Conductivity μS/cm - field	Fluoride _ mg/L	Iron mg/L	Lead mg/L	Manganese mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel mg/L	Nitrates mg/L N	Nitrites mg/L N	pH - field	Phosphorus - total mg/L	Selenium _ mg/L	Silver mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen mg/L N	Turbidity _ NTU	Zinc mg/L
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000			20
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5		2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25		5
SW2	Laheys Creek	31-Aug-09	0.05	0.002	0.04	<0.00005	171	1880	<0.001	0.003	89	7480	0.2	2.7	<0.0002	1.500	<0.0001	<0.001	0.008	<0.01	<0.01	7.0	0.09	<0.001	<0.001	963	1120	4900	1.4	17.0	<0.005
		21-Sep-09	0.05	0.0012	0.04	<0.00005	134	1580	<0.001	0.002	55	6250	0.2	1.3	<0.0002	0.690	<0.0001	<0.001	0.006	<0.01	<0.01	7.3	0.03	<0.001	<0.001	838	874	4000	1.0	6.0	<0.005
		21-Oct-09	0.04	0.0015	0.04	<0.00005	140	1860	<0.001	0.003	92	7360	0.3	1.6	<0.0002	0.490	<0.0001	<0.001	0.007	<0.01	<0.01	7.3	0.11	<0.001	<0.001	943	920	4900	2.1	21.0	<0.005
		20-Nov-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		11-Dec-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7-Jan-10	0.21	0.003	0.05	<0.00005	50	347	<0.001	0.003	56	2140	0.3	0.8	0.0003	1.300	<0.0001	<0.001	0.004	0.01	<0.01	7.3	0.09	<0.001	<0.001	197	216	1000	1.5	7.2	0.014
		18-Feb-10	0.33	0.0026	0.06	<0.00005	51	546	<0.001	0.002	88	2590	0.3	1.5	0.0003	1.200	<0.0001	<0.001	0.003	<0.01	<0.01	7.4	0.09	<0.001	<0.001	320	217	1700	1.2	10.0	0.006
		26-Mar-10	0.04	0.0025	0.06	<0.00005	29	624	0.002	0.001	53	2780	0.3	1.1	<0.0002	0.25	<0.0001	<0.001	0.004	<0.01	<0.01	7.6	0.09	<0.001	<0.001	339	210	1800	1.2	6.6	0.023
		22-Apr-10	0.11	0.002	<0.05	<0.0001	61	652	<0.001	0.001	52	2990	0.3	1.1	<0.001	0.562	<0.0001	<0.001	0.001	<0.01	<0.01	7.6	0.19	<0.01	<0.001	496	229	1760	1.8	8.1	<0.005
		25-May-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		29-Jun-10	0.48	<0.001	<0.05	<0.0001	61	922	<0.001	0.002	59	3750	0.2	0.8	<0.001	0.113	<0.0001	<0.001	0.001	0.03	<0.01	7.5	0.06	<0.01	<0.001	520	271	1930	0.8	11.9	0.007
		28-Jul-10	0.03	<0.001	<0.05	<0.0001	130	964	<0.001	0.003	72	5310	0.2	0.5	<0.001	0.210	<0.0001	<0.001	<0.001	0.04	<0.01	7.6	0.09	<0.01	<0.001	671	797	3230	1.0	6.4	<0.005
		20-Dec-10	1.64	0.002	<0.05	<0.0001	30	113	0.001	0.006	93	660	0.1	2.4	0.001	0.155	<0.0001	<0.001	0.004	0.16	0.02	7.2	0.17	<0.01	<0.001	62	103	354	1.1	51.4	0.01
		24-Jan-11	0.18	<0.001	0.06	0.0013	161	673	<0.001	0.004	90	3920	0.3	0.5	0.001	0.315	<0.0001	<0.001	0.002	<0.01	<0.01	8.0	<0.01	<0.01	<0.001	382	999	2780	1.0	2.9	0.01
		25-Feb-11	0.12	0.001	0.06	<0.0001	170	858	<0.001	0.003	76	4650	1.4	0.1	<0.001	0.580	<0.0001	0.001	0.002	0.07	<0.01	7.6	0.07	<0.01	<0.001	499	1190	3390	0.7	3.2	0.006
		24-Mar-11	0.17	0.002	0.06	<0.0001	171	975	<0.001	0.003	68	5040	0.4	0.1	<0.001	0.573	<0.0001	0.001	0.002	0.01	<0.01	7.7	0.04	<0.01	<0.001	565	1060	3450	0.8	4.6	<0.005
		20-Apr-11	0.64	0.001	0.05	<0.0001	161	1060	<0.001	<0.001	82	4990	0.4	0.8	<0.001	0.428	<0.0001	0.002	0.003	0.04	<0.01	8.1	<0.01	<0.01	<0.001	521	883	3530	1.1	13.0	<0.005
		31-May-11	0.38	<0.001	<0.05	<0.0001	194	1060	<0.001	0.006	84	5200	0.3	0.7	<0.001	0.322	<0.0001	<0.001	0.002	0.09	<0.01	7.8	0.06	<0.01	<0.001	532	1040	3710	1.1	11.8	0.009
		28-Jun-11	0.07	<0.001	<0.05	<0.0001	207	1260	<0.001	0.003	89	6290	0.3	0.3	<0.001	0.279	<0.0001	<0.001	0.002	0.02	<0.01	8.0	<0.01	<0.01	<0.001	763	1390	4240	0.5	4.9	0.006
		30-Aug-11	0.18	<0.001	<0.05	<0.0001	182	957	<0.001	0.003	93	5040	0.2	0.3	<0.001	0.341	<0.0001	<0.001	0.001	<0.01	<0.01	8.0	<0.01	<0.01	<0.001	536	1160	3080	0.7	3.6	<0.005
		26-Sep-11	0.31	0.011	0.05	0.0001	171	1100	0.001	0.004	87	5550	0.3	0.6	0.001	0.553	<0.0001	0.001	0.002	<0.01	<0.01	7.8	<0.01	<0.01	<0.001	613	1250	3640	0.7	11.8	<0.005
		27-OCT-2011	1.33	0.002	0.05	0.00005	106	780	0.0005	0.003	62	3390	0.3	1.3	0.001	0.574	5E-05	0.0005	0.002	0.005	0.005	7.9	0.06	0.005	5E-04	352	445	2210	0.6	14.6	0.003
		28-NOV-2011	0.50	0.0005	0.025	0.00005	80	468	0.0005	0.002	57	2690	0.3	0.6	0.0005	0.102	5E-05	0.0005	0.002	0.36	0.005	7.7	0.01	0.005	5E-04	252	407	1610	1.3	15.6	0.007

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems																															
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality																															
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)																															
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)																															
	notes																															
		exceed all EV trigger values																														
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		exceed no EV trigger values																														
	blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3																														
	green	2000 is the maximum TDS tolerance for sensitive livestock																														
	orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and cattle is 1)																														
	red	maximum concentration for sensitive crops																														
	purple	lower limit valie																														

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total_ mg/L	Copper_ mg/L	Dissolved Oxygen %sat	Electrical Conductivity µS/cm - field	Fluoride _ mg/L	Iron mg/L	Lead_ mg/L	Manganese_ mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel_ mg/L	Nitrates_ mg/L N	Nitrites_ mg/L N	pH - field	Phosphorus -total_ mg/L	Selenium _ mg/L	Silver_ mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen _mg/L N	Turbidity _ NTU	Zinc_ mg/L	
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008	
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000				20
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5			2
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25			5
SW3	Sandy Creek, downstream of confluence with Laheys Creek	31-Aug-09	0.41	0.001	0.05	<0.00005	54	404	<0.001	0.001	91	1990	0.2	1.0	0.0006	2.500	<0.0001	<0.001	0.003	<0.01	<0.01	7.7	0.07	<0.001	<0.001	241	161	1100	0.9	15.0	<0.005	
		21-Sep-09	0.39	0.0012	0.05	<0.00005	59	408	0.001	0.001	91	1970	0.2	1.0	0.0009	3.100	<0.0001	<0.001	0.003	<0.01	<0.01	8.0	0.06	<0.001	<0.001	275	181	1100	0.9	31.0	<0.005	
		21-Oct-09	0.78	0.0017	0.07	<0.00005	62	461	0.001	0.002	92	2300	0.2	2.1	0.002	3.400	<0.0001	<0.001	0.005	<0.01	<0.01	7.8	0.09	<0.001	<0.001	260	225	1300	1.2	75.0	<0.005	
		20-Nov-09	0.87	<0.001	0.08	<0.00005	77	553	0.001	0.003	79	2620	0.3	1.5	0.0016	2.500	<0.0001	<0.001	0.006	<0.01	<0.01	8.1	0.12	<0.001	<0.001	324	230	1600	1.8	54.0	0.063	
		11-Dec-09	0.64	0.0014	0.1	<0.00005	81	695	<0.001	0.005	86	3290	0.3	1.2	0.013	2.600	<0.0001	0.003	0.007	<0.01	<0.01	7.3	0.12	<0.001	<0.001	420	369	1900	1.8	1.8	0.005	
		7-Jan-10	0.18	0.003	0.06	<0.00005	34	241	<0.001	0.002	70	1400	0.2	2.1	0.0005	2.200	<0.0001	<0.001	0.006	<0.01	<0.01	7.3	0.07	<0.001	<0.001	139	147	720	1.3	9.2	0.013	
		18-Feb-10	0.31	0.001	0.07	<0.00005	39	206	<0.001	0.001	66	1210	0.2	1.4	0.0005	1.400	<0.0001	<0.001	0.004	<0.01	<0.01	7.1	0.04	<0.001	<0.001	121	96	720	0.9	19.0	<0.005	
		26-Mar-10	0.3	0.002	0.07	<0.00005	19	174	<0.001	0.001	87	1130	0.2	0.9	0.0006	1.5	<0.0001	<0.001	0.004	<0.01	<0.01	7.4	0.04	<0.001	<0.001	104	75	640	0.8	21	0.008	
		22-Apr-10	0.26	<0.001	0.06	<0.0001	40	167	<0.001	0.001	83	1140	0.2	0.9	<0.001	1.060	<0.0001	<0.001	0.002	<0.01	<0.01	7.4	0.06	<0.01	<0.001	113	71	608	0.8	14.8	<0.005	
		25-May-10	0.02	<0.001	<0.05	<0.0001	40	220	<0.001	<0.001	72	1220	0.2	3.3	<0.001	1.450	<0.0001	<0.001	0.003	0.02	<0.01	7.5	0.07	<0.01	<0.001	123	81	629	<0.1	16.2	0.021	
		29-Jun-10	0.31	<0.001	0.06	<0.0001	38	198	<0.001	<0.001	75	1200	0.2	1.7	<0.001	1.200	<0.0001	<0.001	0.003	0.02	<0.01	7.2	0.02	<0.01	<0.001	129	139	556	0.6	12.6	<0.005	
		28-Jul-10	0.28	<0.001	<0.05	<0.0001	40	213	0.001	<0.001	94	1290	0.1	0.9	<0.001	1.510	<0.0001	<0.001	0.002	0.04	<0.01	7.4	0.1	<0.01	<0.001	128	142	638	0.8	12.2	0.006	
		20-Dec-10	0.90	0.001	<0.05	<0.0001	32	149	<0.001	0.004	88	690	<0.01	1.5	<0.001	0.123	<0.0001	<0.001	0.003	0.29	0.05	7.2	0.04	<0.01	<0.001	65	48	412	1.2	40.4	0.006	
		24-Jan-11	0.34	<0.001	0.08	0.0004	92	659	<0.001	0.002	99	2930	0.3	0.9	<0.001	0.551	<0.0001	0.001	0.003	0.01	<0.01	7.7	<0.01	<0.01	<0.001	354	222	1760	0.7	4.6	0.006	
		25-Feb-11	0.16	<0.001	0.07	<0.0001	93	822	<0.001	0.001	89	3420	0.3	0.5	<0.001	0.676	<0.0001	0.001	0.002	0.03	<0.01	7.6	<0.01	<0.01	<0.001	454	213	1980	0.3	3.6	<0.005	
		24-Mar-11	0.08	0.001	0.07	<0.0001	94	922	<0.001	0.001	86	3500	0.4	0.4	<0.001	0.868	<0.0001	0.001	0.001	<0.01	<0.01	7.5	0.01	<0.01	<0.001	492	160	1930	0.4	3.7	<0.005	
		20-Apr-11	0.22	<0.001	0.06	0.0002	89	886	<0.001	<0.001	91	3450	0.3	0.6	<0.001	1.090	<0.0001	<0.001	0.002	0.02	<0.01	7.6	0.25	<0.01	<0.001	415	152	1970	0.6	5.4	<0.005	
		31-May-11	0.10	<0.001	0.05	<0.0001	89	975	<0.001	0.001	89	3690	0.3	0.6	<0.001	0.418	<0.0001	<0.001	0.001	0.02	<0.01	7.8	0.07	<0.01	<0.001	455	188	2220	0.5	4.3	<0.005	
		28-Jun-11	0.04	<0.001	<0.05	<0.0001	94	939	<0.001	<0.001	91	3600	0.3	0.8	<0.001	0.526	<0.0001	0.001	0.002	0.02	<0.01	7.8	<0.01	<0.01	<0.001	538	211	2070	0.4	4.6	<0.005	
		30-Aug-11	0.16	<0.001	0.05	<0.0001	94	780	<0.001	0.001	101	3670	0.4	0.4	<0.001	0.554	<0.0001	<0.001	0.002	<0.01	<0.01	8.0	<0.01	<0.01	<0.001	427	396	2000	0.3	2.5	<0.005	
		26-Sep-11	0.23	0.008	0.06	0.0001	99	904	0.001	0.002	104	4030	0.3	0.7	<0.001	0.654	<0.0001	0.001	0.001	<0.01	<0.01	7.9	<0.01	<0.01	<0.001	491	418	2290	0.4	9.8	<0.005	
		27-OCT-2011	0.54	0.0005	0.06	0.00005	72	603	0.0005	0.002	69	2610	0.4	0.8	0.0005	0.978	5E-05	0.0005	0.002	0.02	0.005	6.4	0.03	0.005	5E-04	295	256	1500	0.5	4.4	0.006	
		28-NOV-2011	0.52	0.0005	0.025	0.00005	71	532	0.0005	0.0005	74	2760	0.3	0.8	0.0005	0.182	5E-05	0.0005	0.002	0.005	0.005	7.7	0.02	0.005	5E-04	295	321	1650	0.7	24.9	0.007	

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)
notes	
	exceed all EV trigger values
	exceed at least one EV trigger value
	exceed no EV trigger values
blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3
green	2000 is the maximum TDS tolerance for sensitive livestock
orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and cattle is 1)
red	maximum concentration for sensitive crops
purple	lower limit valie

Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total_ mg/L	Copper_ mg/L	Dissolved Oxygen %sat	Electrical Conductivity µS/cm - field	Fluoride _ mg/L	Iron_ mg/L	Lead_ mg/L	Manganese_ mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel_ mg/L	Nitrates_ mg/L N	Nitrites_ mg/L N	pH - field	Phosphorus - total_ mg/L	Selenium _ mg/L	Silver_ mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen_ mg/L N	Turbidity _ NTU	Zinc_ mg/L		
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008		
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000				20	
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5			2	
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25			5	
SW4	Elong Elong gauging station on Talbragar River	31-Aug-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		21-Sep-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		21-Oct-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		20-Nov-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		11-Dec-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7-Jan-10	32.00	0.002	0.07	<0.00005	16	39	0.063	0.032	64	300	0.2	39.0	0.006	0.790	<0.0001	<0.001	0.063	1.1	0.07	7.6	1.1	<0.001	<0.001	21	2	280	3.4	940.0	0.055		
		18-Feb-10	6.50	0.001	0.04	<0.00005	27	32	0.013	0.01	101	380	0.2	8.5	0.0016	0.320	<0.0001	<0.001	0.019	1.2	0.04	7.6	0.59	<0.001	<0.001	22	<2	290	2.8	300.0	0.015		
		26-Mar-10	1.20	0.001	0.04	<0.00005	25	110	0.002	0.003	74	810	0.2	1.5	0.0002	0.21	<0.0001	<0.001	0.01	<0.01	<0.01	7.8	0.14	<0.001	<0.001	52	5	480	1.2	29	0.008		
		22-Apr-10	1.05	0.001	<0.05	<0.0001	48	110	0.002	0.002	69	830	0.2	1.6	<0.001	0.683	<0.0001	<0.001	0.008	<0.01	<0.01	7.7	0.18	<0.01	<0.001	68	<2	448	1.8	27.8	<0.005		
		25-May-10	1.69	<0.001	<0.05	<0.0001	44	113	0.002	0.003	104	770	0.2	1.8	<0.001	0.981	<0.0001	<0.001	0.009	0.04	<0.01	8.3	0.13	<0.01	<0.001	58	<2	410	0.9	19.4	<0.005		
		29-Jun-10	5.20	<0.001	<0.05	<0.0001	36	106	0.008	0.004	54	740	0.2	5.8	<0.001	0.442	<0.0001	<0.001	0.013	0.12	0.02	7.5	0.19	<0.01	<0.001	61	4	308	2.1	71.5	0.01		
		28-Jul-10	10.20	0.001	<0.05	<0.0001	24	53	0.017	0.012	85	440	0.1	11.6	0.002	0.185	<0.0001	<0.001	0.022	0.76	0.03	7.7	0.68	<0.01	<0.001	29	2	252	3.1	179.0	0.018		
		20-Dec-10	9.62	0.001	<0.05	<0.0001	44	106	0.016	0.011	86	830	0.1	11.3	0.002	0.501	<0.0001	<0.001	0.021	0.23	0.02	7.9	0.39	<0.01	<0.001	61	26	444	0.8	183.0	0.02		
		24-Jan-11	2.81	<0.001	<0.05	<0.0001	76	149	0.004	0.004	92	1180	0.1	2.6	<0.001	0.151	<0.0001	<0.001	0.008	<0.01	<0.01	8.1	0.23	<0.01	<0.001	77	19	636	0.6	4.0	0.007		
		25-Feb-11	1.18	0.001	<0.05	<0.0001	76	188	0.002	0.003	77	1410	0.7	1.4	<0.001	0.127	<0.0001	<0.001	0.005	0.03	<0.01	8.0	0.13	<0.01	<0.001	107	28	768	<0.1	4.8	<0.005		
		24-Mar-11	1.07	<0.001	<0.05	<0.0001	79	198	0.002	0.002	89	1410	0.2	1.2	<0.001	0.145	<0.0001	<0.001	0.004	<0.01	<0.01	8.0	0.19	<0.01	<0.001	102	19	738	0.2	20.5	<0.005		
		20-Apr-11	0.63	<0.001	<0.05	0.0017	76	230	<0.001	<0.001	93	1510	0.2	0.9	<0.001	0.171	<0.0001	<0.001	0.004	<0.01	<0.01	8.3	0.24	<0.01	<0.001	108	37	878	0.4	8.0	<0.005		
		31-May-11	0.92	<0.001	<0.05	<0.0001	80	330	0.001	0.002	85	1800	0.2	1.0	<0.001	0.130	<0.0001	<0.001	0.003	<0.01	<0.01	7.8	0.23	<0.01	<0.001	149	50	1520	0.5	19.4	<0.005		
		28-Jun-11	5.83	<0.001	<0.05	<0.0001	38	89	0.009	0.008	97	670	0.1	6.4	<0.001	0.195	0.0002	<0.001	0.014	0.47	<0.01	8.0	0.39	<0.01	<0.001	48	6	458	1.4	36.1	0.012		
		30-Aug-11	1.49	<0.001	<0.05	<0.0001	70	177	0.003	0.003	99	1310	0.2	1.9	<0.001	0.130	<0.0001	<0.001	0.005	<0.01	<0.01	8.2	0.11	<0.01	<0.001	84	24	658	0.3	9.9	<0.005		
		26-Sep-11	1.85	0.006	<0.05	<0.0001	65	170	0.004	0.003	96	1290	0.2	2.2	<0.001	0.182	<0.0001	<0.001	0.006	<0.01	<0.01	8.2	0.1	<0.01	<0.001	85	20	676	0.5	37.0	<0.005		
		27-OCT-2011	2.13	0.001	0.025	0.00005	56	195	0.003	0.004	66	1130	0.2	2.3	0.0005	0.165	5E-05	0.0005	0.007	0.005	0.005	7.6	0.22	0.005	5E-04	93	31	632	0.8	33.0	0.014		
		28-NOV-2011	36.40	0.002	0.025	0.00005	34	53	0.056	0.047	45	650	0.2	44.2	0.01	2.440	5E-05	0.0005	0.082	0.68	0.08	7.6	2.93	0.005	5E-04	36	13	340	3.8	1400.0	0.071		

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems																															
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality																															
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Table 7-2 Comparison of water quality monitoring data against ANZECC water quality guidelines (continued)

Sample Location	Description of site	Sample Date	Aluminium _ mg/L	Arsenic mg/L	Boron _ mg/L	Cadmium _ mg/L	Calcium - total mg/L	Chloride mg/L	Chromium - total mg/L	Copper mg/L	Dissolved Oxygen %sat	Electrical Conductivity μS/cm - field	Fluoride _ mg/L	Iron mg/L	Lead mg/L	Manganese mg/L	Mercury _ mg/L	Molybdenum _ mg/L	Nickel mg/L	Nitrates mg/L N	Nitrites mg/L N	pH - field	Phosphorus - total mg/L	Selenium _ mg/L	Silver mg/L	Sodium - total mg/L	Sulfates mg/L	Total Dissolved Solids @ 180°C_	Total Nitrogen mg/L N	Turbidity _ NTU	Zinc mg/L		
Aquatic Ecosystems			0.06	0.024	0.37	0.0002			0.001	0.0014	90-110	30			0.0034	1.9	0.0006		0.011		0.7	6.5-8	0.02	0.011	5E-05				0.25	2.0	0.008		
Livestock			5.00	0.5	5	0.01	1000		1	5			2		0.1	-	0.002	0.15	1	400	30			0.02			1000	2000				20	
Irrigation LTV			5.00	0.1	0.5	0.01			0.1	0.2		650	1	0.2	2	0.2	0.002	0.01	0.2				0.05	0.02					5			2	
Irrigation STV			20.00	2	0.5	0.05		175	1	5			2	10	5	10	0.002	0.05	2				0.8	0.05		115			25			5	
SW5	Talbragar River at Cobbora	31-Aug-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		21-Sep-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		21-Oct-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		20-Nov-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		11-Dec-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7-Jan-10	15.00	0.001	0.04	<0.00005	10	25	0.026	0.016	69	210	0.2	17.0	0.0046	0.290	<0.0001	<0.001	0.027	1.1	0.04	7.3	0.64	<0.001	<0.001	14	<2	240	3.1	460.0	0.041		
		18-Feb-10	8.70	<0.001	0.04	<0.00005	28	18	0.017	0.015	100	340	0.2	11.0	0.0023	0.420	<0.0001	<0.001	0.027	1	0.08	7.6	0.98	<0.001	<0.001	16	<2	250	3.1	420.0	0.021		
		26-Mar-10	1.50	0.001	0.04	<0.00005	13	25	0.004	0.004	63	340	0.2	2.2	0.0003	0.360	<0.0001	<0.001	0.012	<0.01	<0.01	7.6	0.38	<0.001	<0.001	18	<2	220	1.6	40	0.019		
		22-Apr-10	2.81	0.001	<0.05	<0.0001	25	18	0.005	0.004	79	330	0.2	3.8	<0.001	0.490	<0.0001	<0.001	0.011	<0.01	<0.01	7.6	0.37	<0.01	<0.001	18	<2	192	1.7	76.2	0.007		
		25-May-10	2.47	<0.001	<0.05	0.0006	26	28	0.004	0.004	92	340	0.1	3.3	<0.001	0.818	<0.0001	<0.001	0.011	<0.01	<0.01	7.6	0.35	<0.01	<0.001	18	<2	184	1.1	50.4	<0.005		
		29-Jun-10	2.02	<0.001	<0.05	<0.0001	19	28	0.003	0.004	65	340	0.1	2.9	<0.001	0.523	<0.0001	<0.001	0.009	0.03	<0.01	7.5	0.17	<0.01	<0.001	19	<2	120	1.8	42.2	<0.005		
		28-Jul-10	7.17	0.001	<0.05	<0.0001	26	39	0.012	0.009	82	440	<0.1	7.9	<0.001	0.132	<0.0001	<0.001	0.016	0.75	0.03	7.7	0.64	<0.01	<0.001	23	<2	250	4.2	131.0	0.016		
		20-Dec-10	4.90	<0.001	<0.05	<0.0001	44	60	0.008	0.006	89	690	0.1	5.4	0.002	0.190	<0.0001	<0.001	0.013	0.22	0.02	8.1	0.37	<0.01	<0.001	40	<2	394	0.2	84.1	0.009		
		24-Jan-11	3.81	<0.001	<0.05	<0.0001	74	92	0.005	0.004	91	1020	0.1	3.1	<0.001	0.132	<0.0001	<0.001	0.009	<0.01	<0.01	8.2	0.16	<0.01	<0.001	55	<2	536	0.5	4.0	0.01		
		25-Feb-11	0.47	<0.001	<0.05	0.0002	70	124	<0.001	0.003	76	1140	0.7	0.5	<0.001	0.108	<0.0001	<0.001	0.005	0.05	<0.01	8.0	0.24	<0.01	<0.001	72	2	620	<0.1	7.0	<0.005		
		24-Mar-11	3.28	<0.001	<0.05	<0.0001	67	120	0.005	0.004	84	1060	0.2	3.4	<0.001	0.123	<0.0001	<0.001	0.008	<0.01	<0.01	8.0	0.27	<0.01	<0.001	60	<2	590	0.3	20.6	0.006		
		20-Apr-11	0.59	<0.001	<0.05	0.0001	72	142	<0.001	<0.001	94	1240	0.2	0.7	<0.001	0.123	<0.0001	<0.001	0.005	0.01	<0.01	8.3	0.25	<0.01	<0.001	68	5	710	0.5	12.8	<0.005		
		31-May-11	1.07	<0.001	<0.05	<0.0001	73	149	0.002	0.002	91	1230	0.2	1.0	<0.001	0.127	<0.0001	<0.001	0.004	0.04	<0.01	8.2	0.3	<0.01	<0.001	69	6	702	0.7	20.3	<0.005		
		28-Jun-11	1.48	<0.001	<0.05	<0.0001	45	74	0.002	0.005	94	710	0.1	1.5	<0.001	0.164	0.0002	<0.001	0.007	0.28	<0.01	8.2	0.37	<0.01	<0.001	38	<2	452	4.8	19.1	0.006		
		30-Aug-11	1.83	<0.001	<0.05	<0.0001	64	106	0.003	0.004	95	1040	0.1	1.9	<0.001	0.146	<0.0001	<0.001	0.006	<0.01	<0.01	8.2	0.18	<0.01	<0.001	49	<2	456	0.3	26.7	<0.005		
		26-Sep-11	3.16	0.006	<0.05	<0.0001	64	117	0.005	0.004	97	1160	0.2	3.2	<0.001	0.174	<0.0001	<0.001	0.008	<0.01	<0.01	8.2	0.2	<0.01	<0.001	60	6	602	0.3	49.6	0.025		
		27-OCT-2011	2.67	0.0005	0.025	0.00005	63	149	0.004	0.004	68	1020	0.2	2.8	0.0005	0.178	5E-05	0.0005	0.008	0.06	0.005	8.9	0.24	0.005	5E-04	64	3	538	0.7	30.9	0.008		
		28-NOV-2011	25.90	0.0005	0.025	0.00005	20	21	0.041	0.026	45	340	0.1	29.4	0.003	0.567	5E-05	0.0005	0.052	0.49	0.04	7.3	1.42	0.005	5E-04	15	2	370	1.8	159.0	0.033		

Aquatic Ecosystems	ANZECC 2000 Guidelines for Aquatic Ecosystems																															
Livestock	ANZECC 2000 Guidelines for Livestock Drinking Water Quality																															
Irrigation LTV	ANZECC 2000 Guidelines for Irrigation Water Supply- LTV (Long Term Trigger Value)																															
Irrigation STV	ANZECC 2000 Guidelines for Irrigation Water Supply- STV (Short Term Trigger Value)																															
	notes																															
	exceed all EV trigger values																															
	exceed at least one EV trigger value																															
	exceed no EV trigger values																															
	blue	applied 95% protections levels from table 3.4.1 of ANZECC guidelines chapter 3																														
	green	2000 is the maximum TDS tolerance for sensitive livestock																														
	orange	5 is low risk trigger for poultry and pigs lower for other livestock (sheep 0.4 and cattle is 1)																														
	red	maximum concentration for sensitive crops																														
	purple	lower limit valie																														

8. Baseline geomorphology of local surface water bodies

A baseline geomorphology review was conducted to provide a snapshot of current geomorphic condition. Fluvial geomorphology classifications have been assigned according to the RiverStyles™ system (Thompson et al. 2001).

8.1 Geomorphic characterisation of watercourses

The watercourses of Talbragar River, Sandy Creek, Laheys Creek and other minor catchments in or near the assessment area are dominated by valley fills of Quaternary alluvium. The alluvium is characterised by gravels and sands interspersed with clays, and varies in thickness from 0 to 28 m (refer to the *Groundwater Assessment* report for details). These soils retain runoff and release it slowly, particularly when vegetation is intact. They are also long-term sediment stores.

In the Sandy Creek upper catchment, alluvial deposits are interspersed with short, bedrock-controlled sections where the longitudinal creek bed profile drops down, providing an overall stepped, longitudinal profile. The upstream Sandy Creek reach is confined with bedrock control as it steps down from the Tannabutta Group (shale, slate and thick-bedded volcanoclastic sandstone) that rims the catchment.

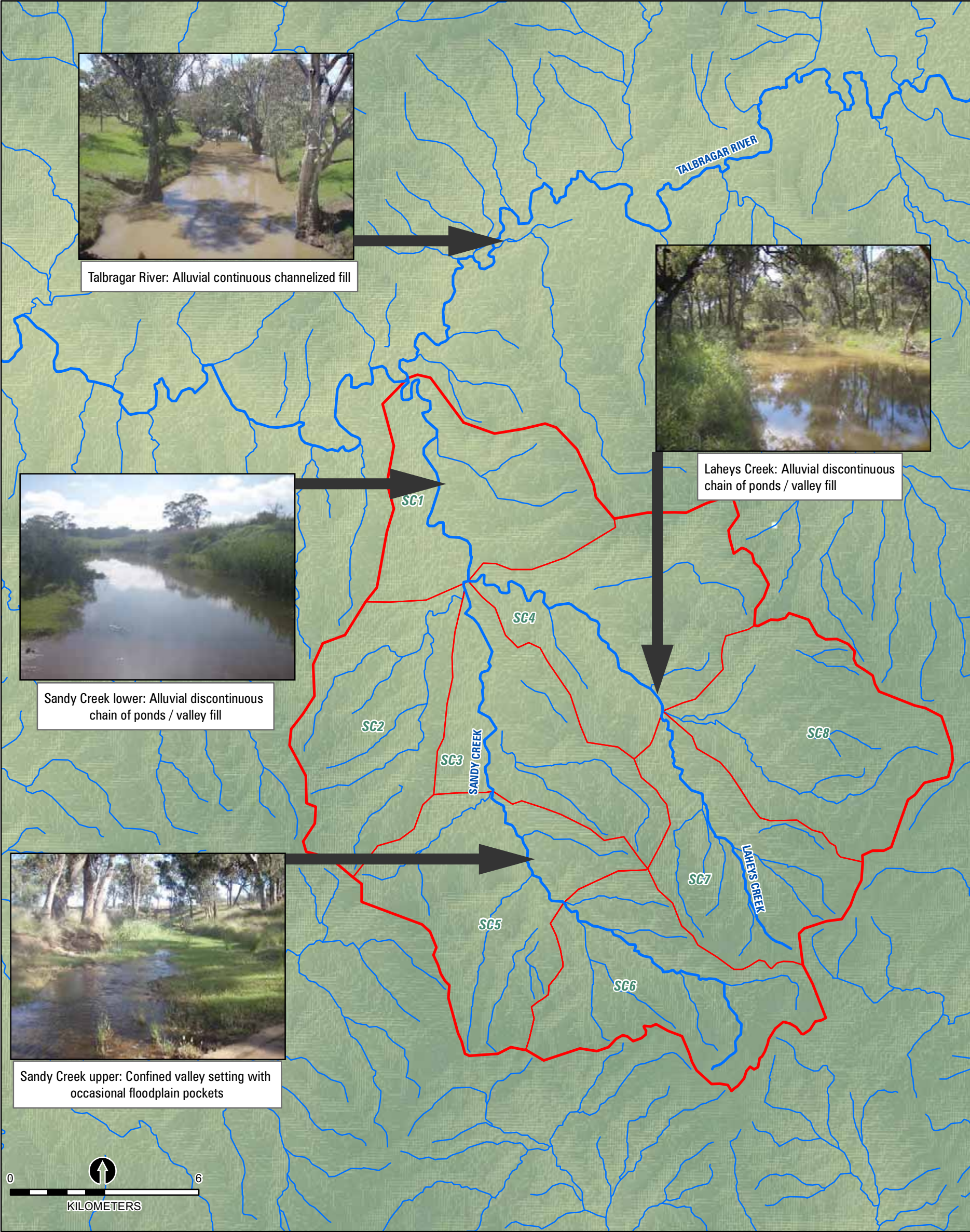
Downstream of those sections in Sandy Creek and Laheys Creek, the watercourses flood out into the broader valley floors of the higher order watercourse. Energy conditions are generally low in the broad valley floors where flows are dispersed. Many of these valley floors have been altered to allow cultivation and cropping. The valley floors have been channelised, often by excavation at one valley margin, to reduce saturation and increase agricultural productivity. The downstream reaches of Sandy Creek and Laheys Creek are alluvial discontinuous with either chain-of-ponds or valley fill features.

The Talbragar River is in a broad valley floor with a valley fill that has been altered by cultivation. The channel has moderate sinuosity and gravel/sand bed. However, channel development is still minimal and flows are largely unconfined. The Talbragar River is an alluvial continuous channel with channelised fill. The locations and typical appearance of these three channel types are shown in Figure 8-1. The implications of these stream types are summarised in Section 8.2.

8.2 Implications of stream types for hydrological functioning

The confined upper reach of Sandy Creek will be dry for large periods of time, with limited connection to the floodplain. However, episodic flushing is predicted during high rainfall events. By contrast, the lower reaches of Sandy Creek and Laheys Creek will be inundated for a larger proportion of time, with slower flow velocities and associated larger residence times. Because of this, accretion of fine sediment will occur.

Connectivity to the floodplain at these reaches means that, during periods of high flow, water will overtop the banks and sediment deposition will occur. The Talbragar River will be inundated for longer periods than Sandy Creek and Laheys Creek, with intermediate flow velocities transporting fine sediment through the reach rather than depositing it. Its partial connectivity to the floodplain allows a removal mechanism for fine sediment onto the banks, but this connectivity is expected to be much less than the channel–floodplain interaction in the Sandy Creek catchment.



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- Drainage
- Project area catchment boundary
- Sub-catchment

Figure 8.1 Fluvial geomorphology river styles

9. Groundwater – surface water interaction

9.1 Overview

A brief summary of the groundwater system's relationship to the surface water environment is included here. The *Groundwater Assessment* report describes the system in detail.

Groundwater flow direction appears to mimic the topography, with a flow direction consistent with surface water flows. Available groundwater level data in the unconfined alluvium aquifer indicate an inferred groundwater flow direction north towards the Talbragar River.

Groundwater interaction with surface water across the assessment area takes the form of groundwater discharges, such as springs and seeps, including baseflows to Sandy Creek, Laheys Creek and the Talbragar River.

Discharge also occurs from the deeper fractured systems, probably along geological structures. The conceptual model developed for the groundwater assessment describes recharge to the groundwater system as occurring via direct rainfall infiltration in areas of unconsolidated alluvium, exposed sedimentary rock and fractured rock outcrop in the elevated areas. Recharge also occurs via vertical leakage to the underlying strata, during flood inundation of surrounding lands.

9.2 Refuge pools

During dry periods Sandy Creek and Laheys Creek retain persistent pools which, in some cases, can sustain in-channel aquatic habitats and provide refuge for fish and other biota. Full details of these habitats are provided in the *Aquatic Ecology Environmental Assessment* (Cardno, 2012). Pools that persist during sustained dry periods are likely to be groundwater fed rather than reliant on surface water runoff. Other pools that dry out shortly after rainfall events are likely to be surface water fed and do not receive significant groundwater inflow. It is also likely that some pools and habitats are reliant on a combination of surface and groundwater inflows; however, given that the creeks are ephemeral, groundwater inflows will govern levels in persistent pools rather than short duration surface water inflows.

The baseline groundwater modelling results were reviewed to identify the likely degree of groundwater dependency of pools within and adjacent to the main mining area identified in the aquatic ecology assessment (Cardno, 2012). Pool sites were deemed to be groundwater dependent where the modelled water table was found to be above the general ground level within the creek, allowing for the combined margin of error of the groundwater modelling and the aerial survey of ground levels. For this purpose a combined error of 1 metre was adopted; therefore, the groundwater dependency, or otherwise, of the pools was identified as follows:

- If the water table elevation is higher than the creek bed level by more than 1 metre the pool site was deemed to be groundwater dependent.
- If the water table is within +/- 1 metre of the creek bed level the pool site was deemed to be potentially groundwater dependent.

- If the water table elevation is lower than the creek bed level by more than 1 metre the pool site was deemed to be independent of groundwater and instead reliant on surface water. It should be noted that such sites would not be persistent pool sites as the surface water flow would only sustain them for a short duration at the start of prolonged dry periods.

The results of this review are provided in Table 9-1 for 14 pool sites within and adjacent to the main mining area. The exact locations and characteristics of these sites are given in the aquatic ecology assessment (Cardno, 2012).

Table 9-1 Groundwater dependency of refuge pools within the main mining area

Site	Location	Channel bed elevation (mAHD)	Groundwater surface elevation (mAHD)	Groundwater dependent?
1	Talbragar River upstream of Sandy Creek confluence	354.2	355.2	Potentially
2	Sandy Creek downstream of Laheys Creek confluence	347.0	346.5	Potentially
3	Sandy Creek downstream of Laheys Creek confluence	347.0	346.9	Potentially
4	Sandy Creek downstream of Laheys Creek confluence	353.5	352.4	No
5	Sandy Creek downstream of Laheys Creek confluence	361.0	362.3	Yes
6	Sandy Creek upstream of Laheys Creek confluence	373.0	373.4	Potentially
7	Laheys Creek downstream of Blackheath Creek confluence	365.0	361.2	No
8	Laheys Creek at Blackheath Creek confluence	378.0	374.3	No
9	Laheys Creek at Blackheath Creek confluence	378.0	374.6	No
10	Laheys Creek upstream of Blackheath Creek confluence	395.2	395.0	Potentially
11	Laheys Creek upstream of Blackheath Creek confluence	406.0	405.0	No
12	Laheys Creek upstream of Blackheath Creek confluence	428.8	427.2	No
13	Laheys Creek upstream of Blackheath Creek confluence	436.1	435.8	Potentially
14	Fords Creek	481.7	478.9	No

10. Summary

This report has reviewed general catchment features and climate relevant to the assessment area. It has focused on local surface water features (i.e. Sandy Creek, Laheys Creek and the Talbragar River) and reviewed hydrologic conditions, water users and associated local guidelines.

The assessment found that creeks were typically ephemeral and with limited flow volume monitoring data available. A range of environmental values, based on water uses in the Macquarie–Bogan unregulated river system, were identified. Key values include aquatic ecosystem, irrigation and livestock-watering use.

Water quality baseline data were also reviewed. Due to the ephemeral nature of the creeks in the assessment area, most samples were taken during low-flow conditions, which could overestimate salinity and dissolved metal/nutrient concentrations and underestimate concentrations of total suspended solids.

Finally, geomorphologic conditions were assessed, which identified three main geomorphological units (with two subsets) in watercourses located in the assessment area.

11. References

ANZECC 2000, *An Introduction to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Australian Collaborative Land Evaluation Program 2010, Australian Soil Resource Information System, viewed 2010, <<http://www.asris.csiro.au/>>

Bureau of Meteorology 2011, Seasonal Rainfall Outlook Archive, available online at <http://www.bom.gov.au/climate/ahead/archive/rainfall/index.shtml>.

Boulton, AJ & Lake, PS 1990, 'The ecology of two intermittent streams in Victoria, Australia. I. Multi-variate analysis of physiochemical features', *Freshwater Biology*, vol. 24, pp. 123–141.

Cardno Ecology Lab 2012, Cobbora Coal Project: Aquatic ecology environmental assessment. Job number EL1112020A. Prepared for EMM.CSIRO and BoM 2007, *Climate Change in Australia – Technical Report*, CSIRO and Bureau of Meteorology.

CSIRO (2009), Unpublished extreme temperature modelling results provided to Parsons Brinckerhoff, CSIRO.

CSIRO (2010), Unpublished 'Climate futures' data provided to Parsons Brinckerhoff, CSIRO.

Cuffney, TF & Wallace, JB 1989, 'Discharge–export relationships in headwater streams: the influence of invertebrate manipulations and drought', *Journal of North American Benthological Society*, vol. 8, pp. 33–341.

Department of Environment, Climate Change and Water 2006, Macquarie–Bogan River. Water Quality and River Flow Objectives, Department of Environment, Climate Change and Water, NSW Government. Available online at <http://www.environment.nsw.gov.au/ieo/MacquarieBogan/report-02.htm>.

Dent, CL, Grim, NB & Fisher, SG 2001, 'Multi-scale effects of surface–subsurface exchange on streamwater nutrient concentrations', *Journal of North American Benthological Society*, vol. 20, pp. 162–181.

Humphries, EJ 2000, *Report Summary Salinity Risk Assessment of the Central West Catchment. A joint initiative of the Central West Catchment Management Committee, the Department of Land and Water Conservation and the Natural Heritage Trust*, Central West Catchment Management Committee.

Morgan K 2005, 'Evaluation of salinisation processes in the Spicers Creek Catchment, central west region of NSW, Australia', PhD thesis, University of New South Wales, Sydney.

Murphy, DV, Sparling, GP & Fillery, IRP 1998, 'Stratification of microbial biomass C and N and gross N mineralisation with soil depth in two contrasting Western Australian agricultural soils', *Australian Journal of Soil Research*, vol. 36, pp. 45–55.

PINNEENA, New South Wales Surface Water Data Archive, NSW Department of Water & Energy 2008.

Smith, R, Jeffree, R, John, J & Clayton, P 2004, *Review of Methods for Water Quality Assessment of Temporary Stream and Lake Systems*, Australian Centre for Mining Environmental Research.

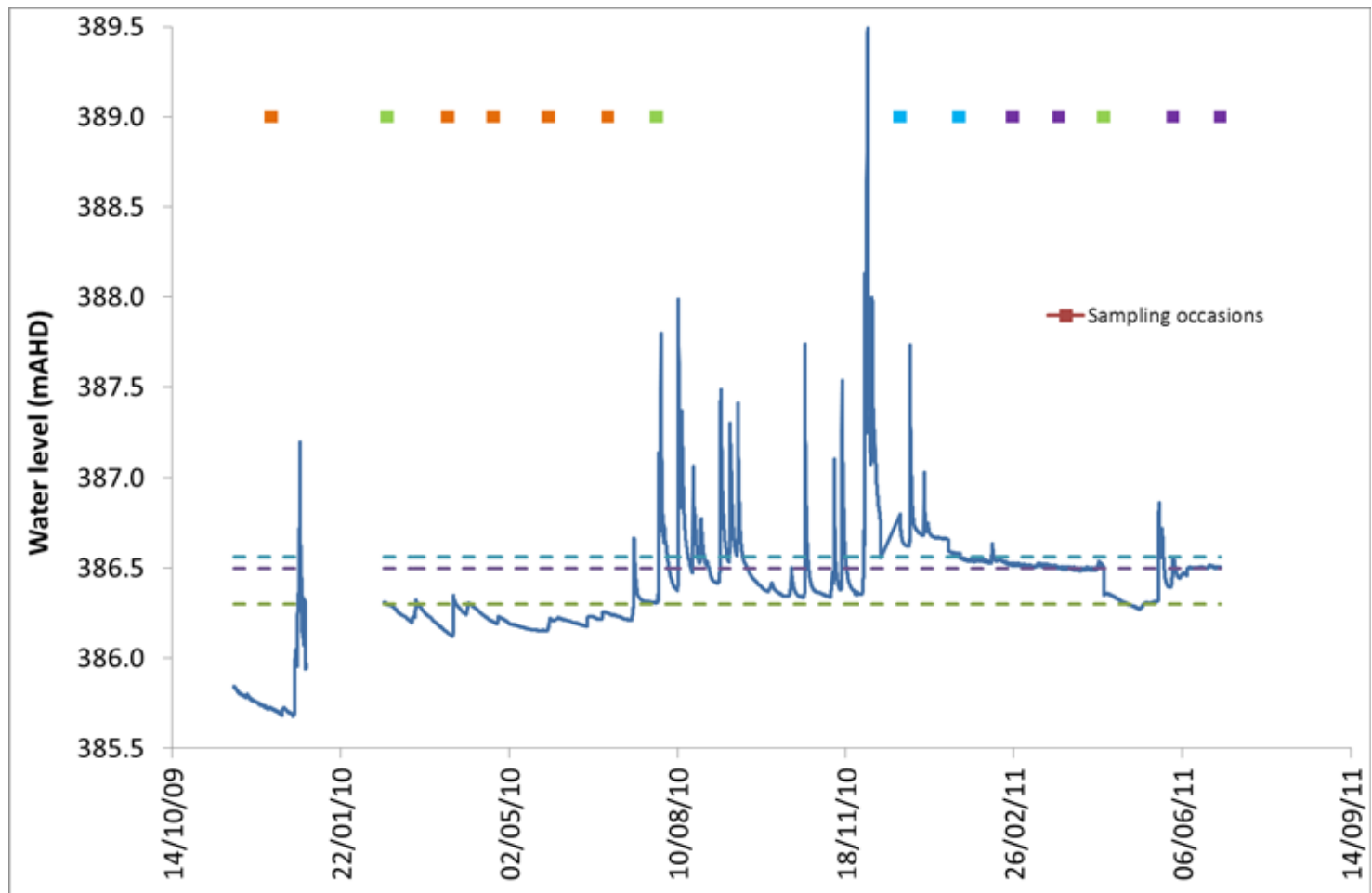
Smithson, A & Ackworth, RI 2005, 'An Investigation of unconsolidated sedimentary units and their role in the development of salinity in the Snake Gully Catchment, Central New South Wales', The University of New South Wales Water Research Laboratory, research report no. 214.

Thompson, JR, Taylor, MP, Fryirs, KA, & Brierley, GJ 2001, 'A geomorphological framework for river characterization and habitat assessment', *Aquatic Conservation: Marine and Freshwater Ecosystems*, vol. 11, pp. 373–389.

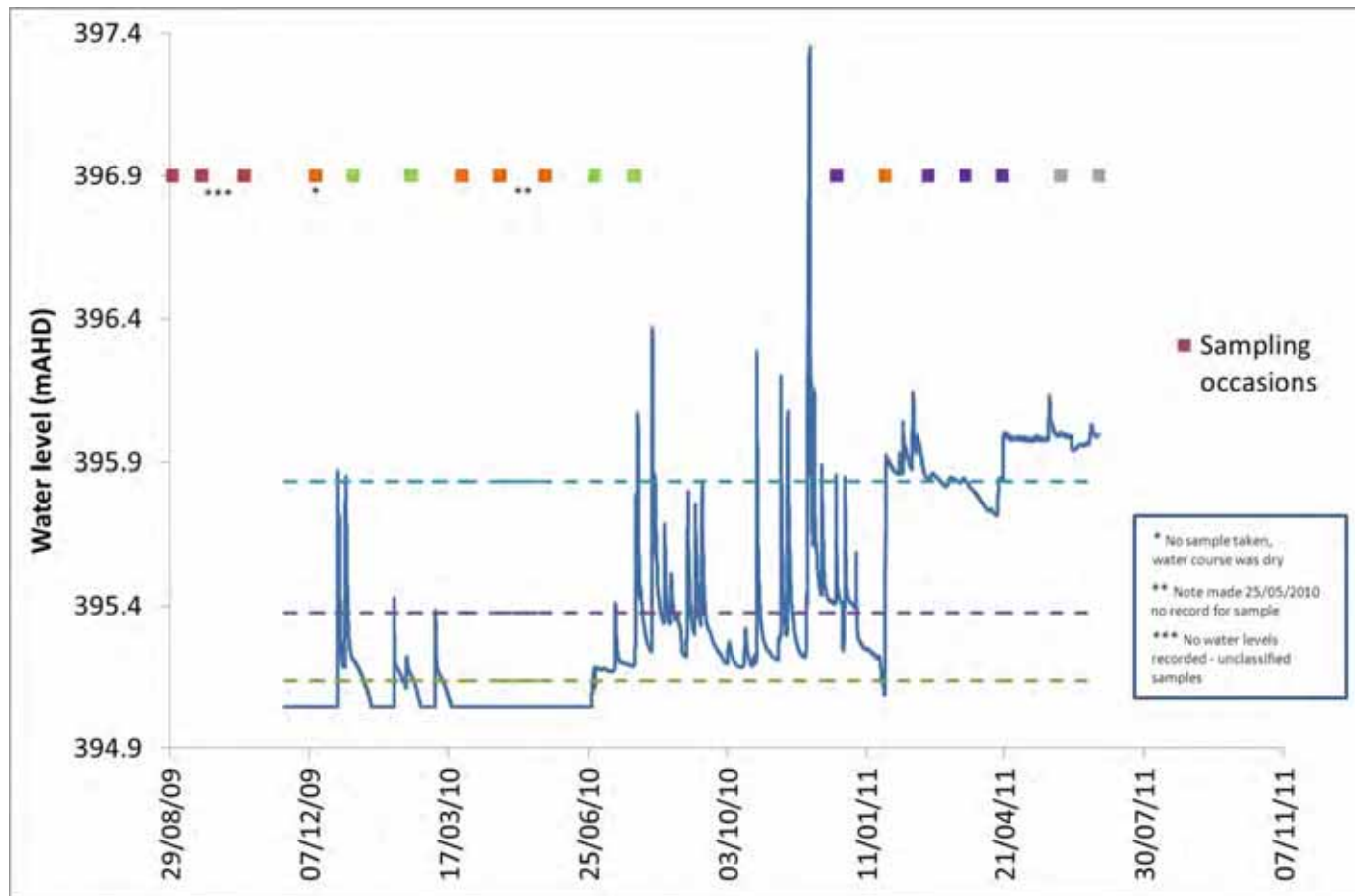
Appendix A.1

Temporal variations in water level
during sampling events

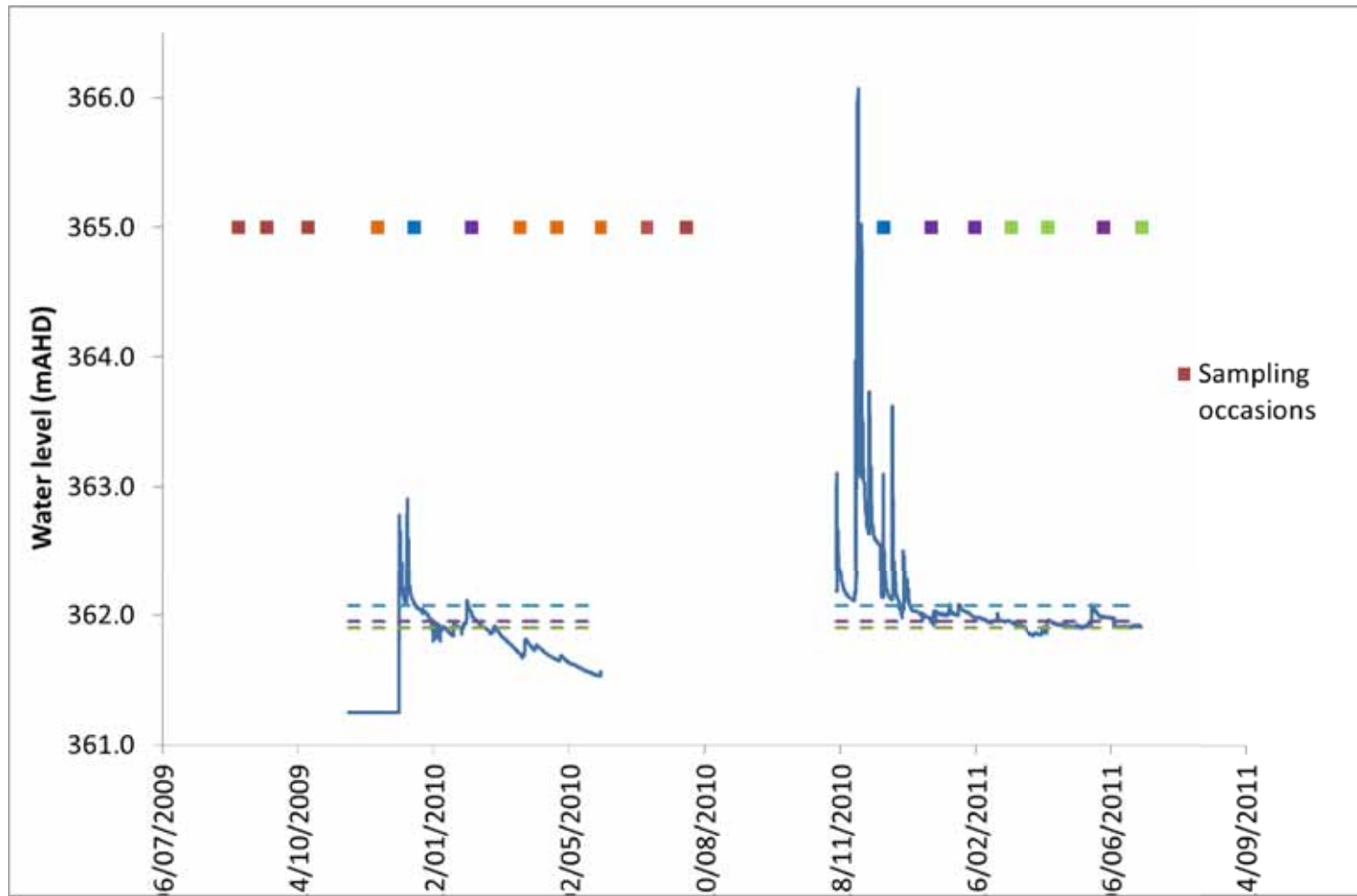
Sandy Creek upstream (SW1)

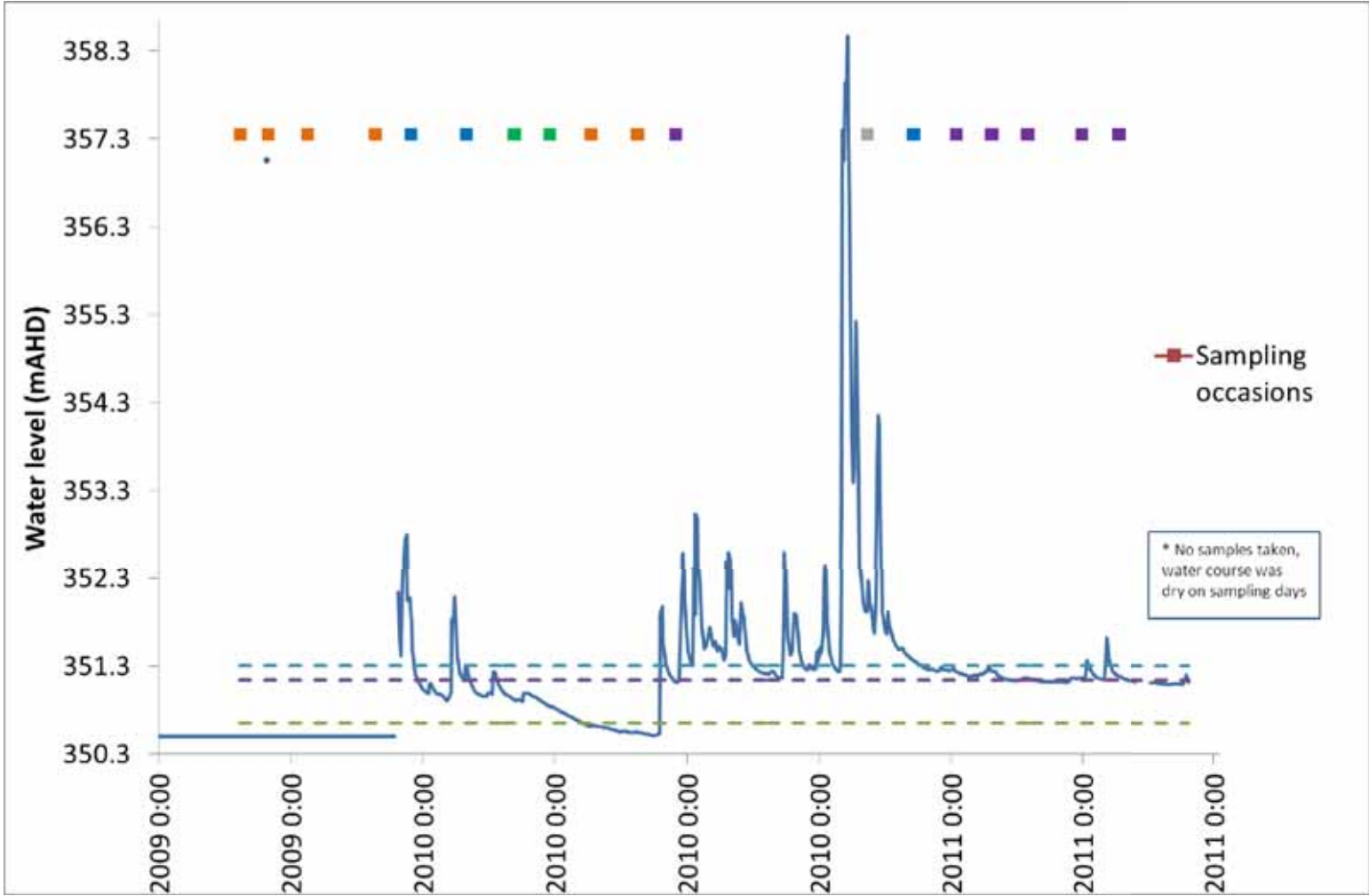


Laheys Creek (SW2)

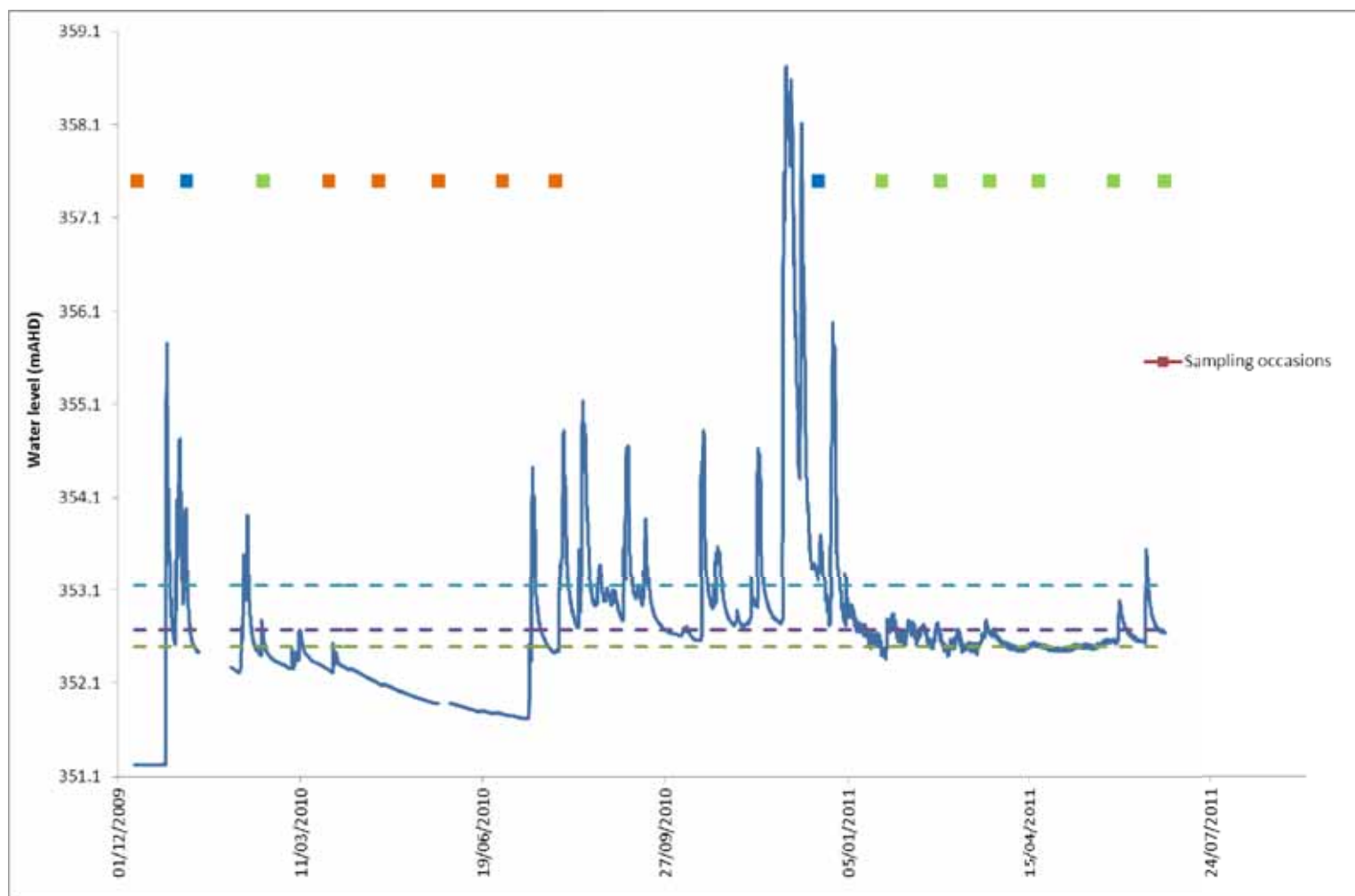


Sandy Creek Downstream (SW3)





Talbragar River at Cobbora (SW5)



Appendix

B

Cobbora Coal Project

Downstream Water Quality Impact Assessment

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Revision	Details	Date	Amended By
A	Draft for EMM/CHC review	5 March 2012	DE
B	Final draft for Adequacy Review	31 August 2012	RL
C	Final for Public Exhibition	6 September 2012	RL

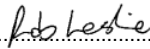
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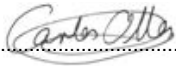
Author: Dan Evans

Signed:

Reviewer: Rob Leslie

Signed:

Approved by: Carlos Olles

Signed:

Date: 18 September 2012

Distribution: 1 x pdf to CHC as technical appendix to EA Report; Parsons Brinckerhoff

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Contents

	Page number
Glossary	iii
1. Introduction	1
1.1 Scope of assessment	1
2. Water quality objectives	3
2.1 Environment Values	3
2.2 Development of Project-specific Water Quality Objectives	4
2.2.1 Overview	4
2.2.2 Default Water Quality Objectives	4
2.2.3 Customised water quality objectives	6
3. Assessment of potential impacts	9
3.1.1 Modelling objectives	9
3.1.2 Model setup	9
3.1.3 Modelling results	14
4. Mitigation measures	17
4.1 General mitigation measures	17
4.2 Sedimentation dam performance criteria	17
5. Cumulative impacts	19
5.1 Ulan project overview	19
5.2 Potential impacts	19
6. Conclusions	21
7. References	23

List of tables

		Page number
Table 2-1	Environmental Values for the uncontrolled river segment within the Macquarie-Bogan catchment	3
Table 2-2	Macquarie-Bogan Uncontrolled Rivers Water Quality Objectives	5
Table 2-3	Selected toxicant water quality objectives	5
Table 2-4	Approximate factors to apply to soft water quality objectives for selected metals in freshwaters of varying hardness	6
Table 3-1	Customised WQOs for SW3 and SW4	15
Table 4-1	Modelled baseline TDS concentrations	17
Table 4-3	Proposed sedimentation dam performance criteria	18

List of figures

Figure 2-1	Approach to development of site specific water quality trigger values (grey shading indicates proposed approach)	7
Figure 3-1	Model schematic for Baseline and Operational Scenarios	11
Figure 3-2	Flow versus water quality regression plots at SW4	12
Figure 3-3	Model-predicted changes in chemical concentration at SW3 (Sandy Creek) and SW4 (Talbragar River) during the Project	16

Appendices

Appendix B.1	Water quality model data sources and assumptions
Appendix B.2	Model results of chemical concentration

Glossary

AWBM	Australian Water Balance Model
BL	Baseline load
EAP	Environmental Action Plan
EVs	Environmental Values
LTV	Long Term Value
NOW	NSW Office of Water
OL	Operational load
STV	Short Term Value
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WQO	Water Quality Objective

1. Introduction

This report presents the assessment of potential impacts associated with the operation of the Project on the water quality of natural receptors within the assessment area and further downstream.

1.1 Scope of assessment

For the purposes of the assessment, the assessment area includes all potential receptors defined as those watercourses that drain the assessment area i.e. Sandy Creek and Laheys Creek, and those that are likely to receive discharges from the proposed mined areas, which include Sandy Creek, Laheys Creek and the Talbragar River.

The Macquarie River, which receives tributary inflow from the Talbragar River, was not included in the assessment due to the relatively insignificant contributions of discharges from Sandy Creek and Laheys Creek to flows in the broader Macquarie River system. Refer to the *Downstream Flow Impact Assessment* report for further details.

The methodology used to assess the potential water quality impacts of the Project involved the following sequence of tasks:

- Reviewed potential surface water users within the receptor area and local water quality objectives (WQOs) relevant to the system.
- Developed project-specific or customised WQOs based on published guidelines.
- Quantitatively assessed the potential impacts of the Project on water users.
- Identified potential mitigation measures to minimise assessed impacts.
- Assessed the potential cumulative impacts of this Project, in relation to other projects in the vicinity of the assessment area on water quality in the Talbragar River.

2. Water quality objectives

2.1 Environment Values

Environmental values (EVs) are values that the community considers important for a healthy ecosystem for public benefit, welfare, safety or health.

Environmental values for an uncontrolled river segment within the Macquarie-Bogan catchment have been identified under the *Macquarie-Bogan River Water Quality and River Flow Objectives* by the Office of Environment and Heritage (formerly Department of Environment, Climate Change and Water).

The relevant environmental values and corresponding objectives adopted for the receiving waters downstream of the Project are listed in Table 2-1.

Table 2-1 Environmental Values for the uncontrolled river segment within the Macquarie-Bogan catchment

Environment Value	Objective
Aquatic ecosystems	Maintaining or improving the ecological condition of water bodies and their riparian zones over the long term.
Visual amenity	Maintaining aesthetic qualities of waters.
Secondary contact recreation	Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed.
Primary contact recreation	Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.
Livestock water supply	Protecting water quality to maximise the production of healthy livestock.
Irrigation water supply	Protecting the quality of waters applied to crops and pasture.
Homestead water supply	Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing.
Drinking water	Maintaining or improving the quality of drinking water drawn from the raw surface and groundwater sources before any treatment.
Aquatic foods (cooked)	Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities. (Note: The ANZECC 2000 Guidelines lists this environmental value as Aquaculture and human consumption of aquatic foods).

Source: *Macquarie-Bogan River Water Quality and River Flow Objectives* (Department of Environment, Climate Change and Water 2006).

2.2 Development of Project-specific Water Quality Objectives

2.2.1 Overview

Water quality data collected by the baseline surface water monitoring program were compared against ANZECC water quality triggers to characterise the baseline water quality conditions. Refer to Section 7 in the *Baseline Hydrological Environment* report for details.

The baseline water quality conditions indicate that customised or project-specific water quality objectives (WQOs) need to be developed and used as the basis for assessing the potential water quality impacts of the Project for the following reasons:

- ANZECC trigger values are based on steady-state conditions that by definition do not occur in ephemeral streams such as Sandy Creek, Laheys Creek and the Talbragar River.
- The nature of the Project area (distinct geology and ephemeral headwater creeks) means it was not possible to define a reference site with 2 years contiguous data.
- The baseline chemical concentrations were found to exceed the ANZECC guidelines in many cases.

The customised WQOs were developed using a procedure generally accepted in NSW which is based on a variation from the standard ANZECC assessment procedure (DEC 2006). The Project's impacts were then modelled and assessed against customised water quality objectives to determine the potential significance of these impacts.

Sections 2.2.2 and 2.2.3 describe the process for establishing the customised WQOs for the Project. Section 3 presents the modelling and impact assessment results.

2.2.2 Default Water Quality Objectives

As a first step towards the development of customised WQOs for the Project, default WQOs were identified, consisting of a collation of indicators that are common to all EVs and the stringent triggers among the sets of values recommended by the *Macquarie-Bogan Water Quality and River Flow Objectives* (DECCW 2006). These default WQOs are presented in Table 2-2.

Default values for toxicants that were not included in the DECCW (2006) document were developed based on ANZECC 2000 toxicant guidelines. The ANZECC 2000 default values for freshwater species providing a 95% level of protection was adopted for toxicants. These values are considered appropriate to assess '*slightly to moderately disturbed systems*' such as those encountered in an area used for stock grazing. The ANZECC guidelines (2000a) indicate that it is appropriate to compare dissolved concentrations of metals to the water quality objectives. Default WQOs for specific toxicants are outlined in Table 2-3. Similar to physical and chemical stressors, aquatic ecosystem triggers are the most stringent of the EV(s) and therefore form the basis for values in Table 2-3.

Table 2-2 Macquarie-Bogan Uncontrolled Rivers Water Quality Objectives

Parameter	Minimum constraint	EV source
Total phosphorus	50 µg/L (rivers in the Murray-Darling Basin)	Aquatic ecosystems
Total nitrogen	500 µg/L (rivers in the Murray-Darling Basin)	Aquatic ecosystems
Chlorophyll-a	5 µg/L *	Aquatic ecosystems
Turbidity	5 NTU	Homestead water use
Salinity (electrical conductivity)	30-350 µS/cm (upland rivers**)	Aquatic ecosystems
Dissolved oxygen	> 6.5 mg/L (> 80% saturation)	Drinking water
PH	6.5-8.5	Drinking water
Temperature	15°-35°C for prolonged exposure.	Primary contact
Chemical toxicants	Refer to ANZECC 2000 guidelines	
Faecal coliforms	95% of samples should be 0 coliforms/ 100 mL throughout the year. Up to 10 coliform organisms may be accepted occasionally in 100 mL. Coliform organisms should not be detected in 100 mL in any two consecutive samples.	Drinking water
Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour.	Visual amenity
Total dissolved solids	500-1000 mg/L is acceptable based on taste.	Homestead water supply
Suspended solids	<40 µg/L (freshwater)	Aquatic foods

Note:

* In absence of an upland rivers guideline the lowland rivers guideline was applied

**>250m AHD

Table 2-3 Selected toxicant water quality objectives

Group	Parameters	Unit	ANZECC freshwater water quality objectives	Level of protection
Dissolved Metals and Metalloids	Aluminium	(mg/L)	0.055 (pH>6.5) NE [*] (pH<6.5)	95%
	Arsenic	(mg/L)	0.024	95%
	Boron	(mg/L)	0.37	95%
	Cadmium	(mg/L)	0.0002	95%
	Chromium	(mg/L)	0.001	95%
	Copper	(mg/L)	0.0014	95%
	Lead	(mg/L)	0.0034	95%
	Manganese	(mg/L)	1.9	95%
	Nickel	(mg/L)	0.011	95%
	Zinc	(mg/L)	0.008	95%

* Not established

WQOs outlined in the ANZECC guidelines (2000a) for 95% level of protection for freshwater species are soft water quality objectives (hardness <60 mg/L as CaCO₃). Table 2-4 summarises the conversion factors that should be applied at each sampling event to determine an appropriate specific WQO for selected metals depending on the hardness of the water (adopted from Table 3.4.4 ANZECC Guidelines, 2000a).

Table 2-4 Approximate factors to apply to soft water quality objectives for selected metals in freshwaters of varying hardness

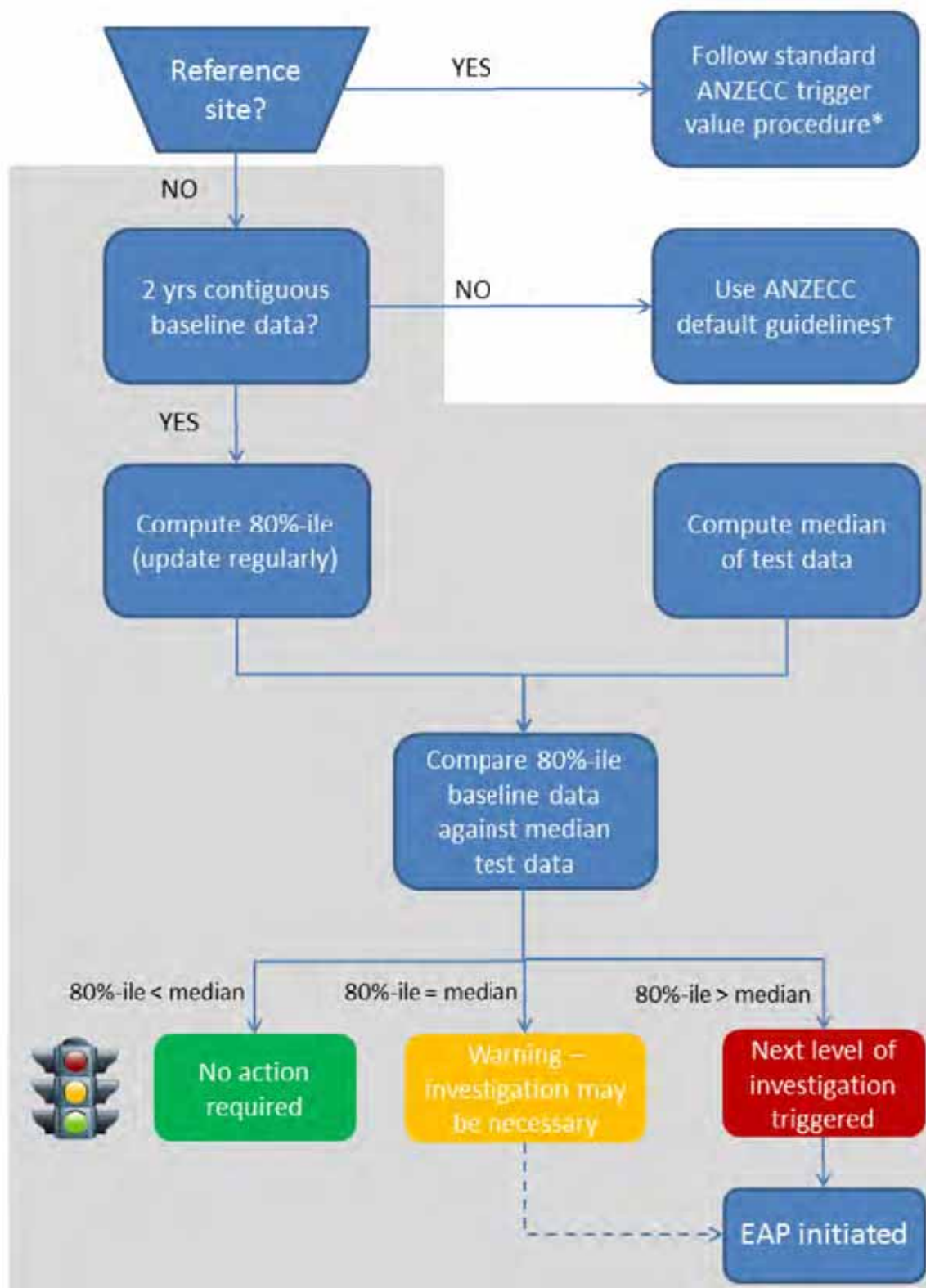
Category	Mean hardness (mg/L of CaCO ₃)	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Soft (0 – 59)	30	No adjustment – use water quality objectives above					
Moderate (60 – 119)	90	X 2.7	X 2.5	X 2.5	X 4.0	X 2.5	X 2.5
Hard (120 – 179)	150	X 4.2	X 3.7	X 3.9	X 7.6	X 3.9	X 3.9
Very hard (180 – 240)	210	X 5.7	X 4.9	X 5.2	X 11.8	X 5.2	X 5.2
Extremely hard (400)	400	X 10.0	X 8.4	X 9.0	X 26.7	X 9.0	X 9.0

2.2.3 Customised water quality objectives

Development of site-specific trigger values, based on background data, was adopted for this Project according to a procedure outlined in ANZECC (2000a) and summarised in Figure 2-1. This approach is recognised in both NSW and QLD state procedures as a legitimate variation from the standard ANZECC assessment procedure (DEC 2006).

The minimum data requirements specified in ANZECC (2000a) have been satisfied – 25 data points from August 2009 to September 2011. The ANZECC (2000a) guideline also recommends 24 monthly data points over a 2 year period. It has been demonstrated that these samples have been collected from a representative range of flow conditions, based on comparison to 25, 50, 75 and 95 percentile automatic water level recordings for the 2 year period (refer to the *Baseline Hydrological Environment* report for details).

The customised WQOs were set using a mass-balance model to compute the 80th percentile concentrations of the relevant water quality parameters for the baseline condition, and then by comparing these 80th percentile concentrations to the default WQOs. For parameter concentrations that exceeded the default WQOs, the baseline 80th percentile concentrations were adopted as the customised WQOs for the Project. The results of this process and the customised WQO trigger values are presented in Section 3.



(*ANZECC, 2000a; †ANZECC, 2000b; EAP = Environmental Action Plan)

Figure 2-1 Approach to development of site specific water quality trigger values (grey shading indicates proposed approach)

3. Assessment of potential impacts

This section presents the findings of an assessment of the potential downstream water quality impacts associated with the operation of the Project using a customised mass-balance model method.

3.1.1 Modelling objectives

The purpose of the water quality modelling was to provide a quantitative assessment of the impacts on water quality in the main streams near the proposed mine site over the life of the Project. This was achieved by firstly analysing the existing water quality in the main streams to identify the baseline loads and concentrations of key water quality parameters. As part of this assessment, customised WQOs were developed for the watercourses, in accordance with the procedure described in Section 2.2.

Five mine stages were selected to be consistent with other elements of the surface water assessment, namely mine stages associated with year 1, 4, 12, 16 and 20. The mass balance model was run for all five mine stages. Model predictions of loads and concentrations for the key water quality parameters were compared against baseline conditions and customised WQOs to assess the potential significance of any impacts.

The model results were then used to determine whether the water quality of the natural watercourses within the assessment area remain within the customised WQOs throughout the mine life and inform the development of project-specific water quality criteria that would need to be applied to any discharges from the mine site (e.g. sedimentation dam discharges) to ensure no long-term adverse environmental impacts.

3.1.2 Model setup

A mass balance model was set up in Microsoft Excel. A series of linked worksheets were designed to calculate baseline load (BL), baseline concentration, operational load (OL) and operational concentration, for comparison against customised WQOs.

The model was set up for the period 20/11/1970 to 01/01/2011 with a daily time-step to coincide with flow data availability. Chemical concentrations from 31/08/2009 – 28/06/2011 were matched to the flow data record using 50th percentile concentrations.

The following parameters were included in the pre-mining or BL water quality model:

- Metals (Aluminium, Arsenic, Cadmium, Chromium, Copper, Iron, Manganese, Nickel, Selenium, Zinc [all dissolved form])
- Total dissolved solids
- Total nitrogen
- Total phosphorus
- Total suspended solids.

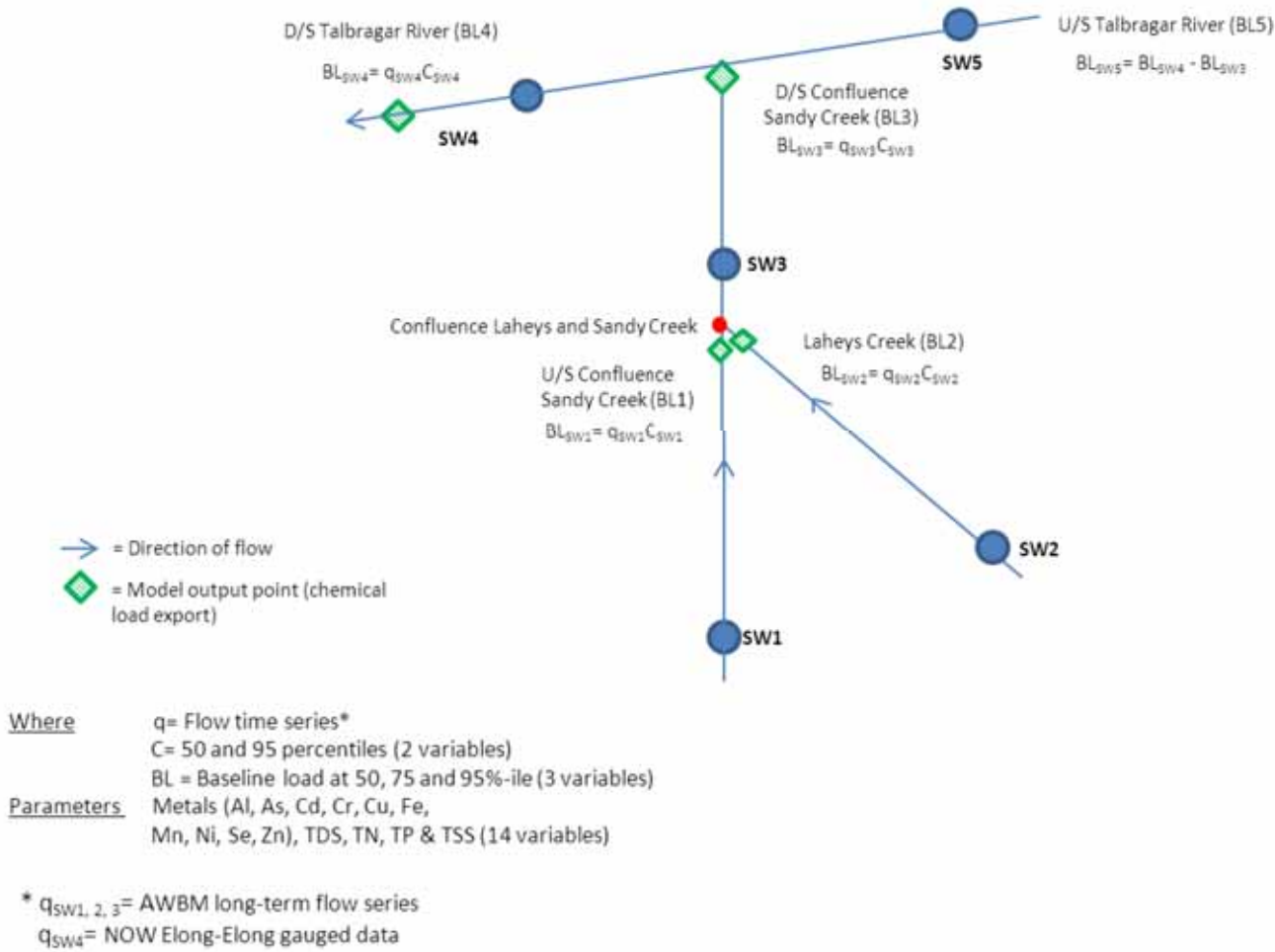
These parameters were selected on the basis of previously collected baseline monitoring data, guideline WQOs and professional judgements about the potential water quality impacts of mining, based on previous studies.

For the OL calculations, releases from the sedimentation dams were assumed to occur when there was need for a controlled discharge or overflow due to excess water at the mine site.

The mass balance model mixes the water released from the proposed water management system with the unregulated water in the stream and calculates water quality concentrations of the water quality indicators. This calculation does not include any form of physical or geochemical processes within the watercourse and thus predicts conservative concentration values.

Sections 3.1.2.1 and 3.1.2.2 describe the detailed approach towards generating BL and OL concentrations, respectively. A model schematic is shown in Figure 3-1. The data sources and assumptions for this water quality mass-balance model are summarised in Appendix B.1.

Baseline Chemical Loads (BL)



Baseline Chemical Loads (BL)

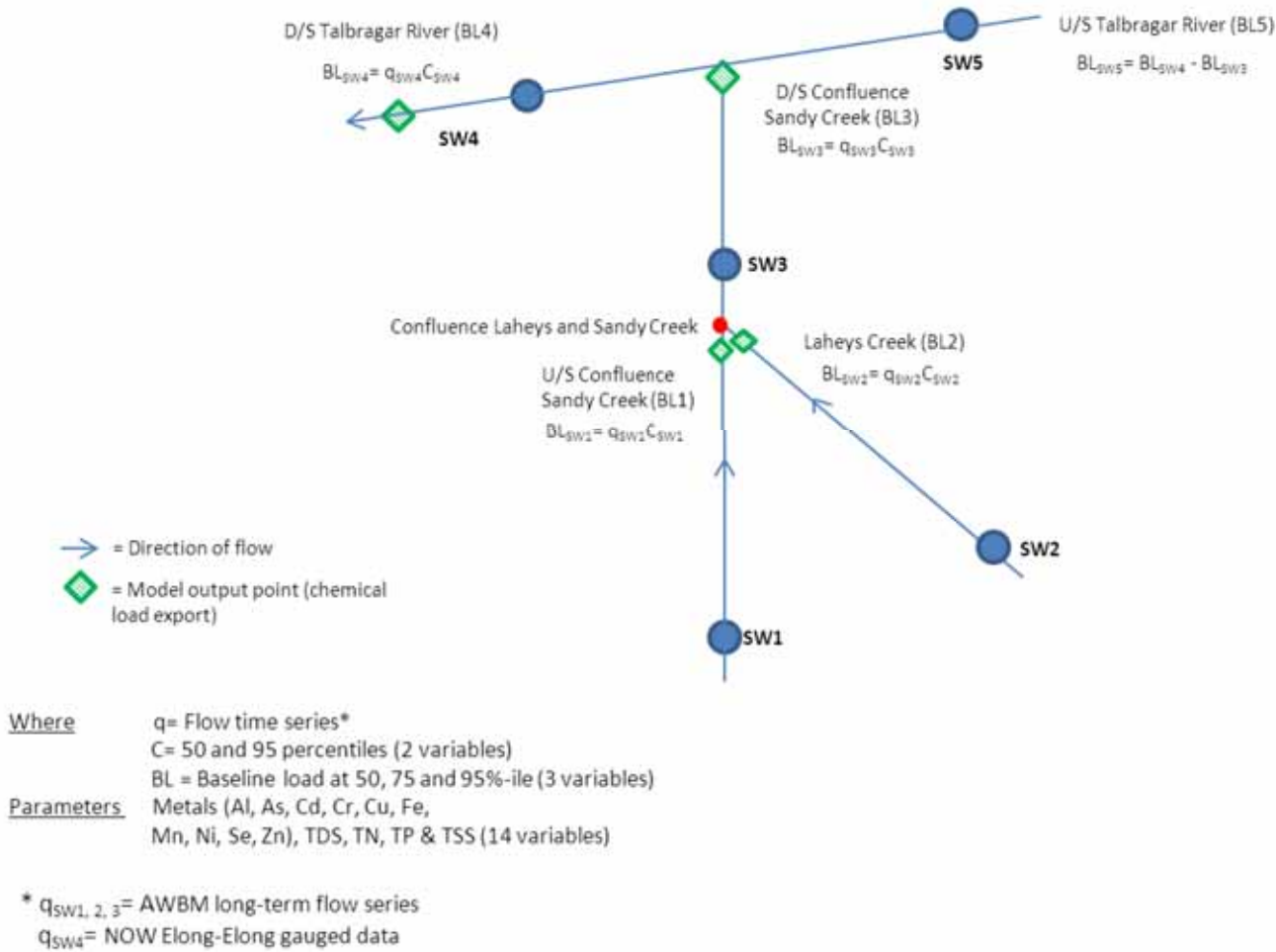


Figure 3-1 Model schematic for Baseline and Operational Scenarios

3.1.2.1 Baseline scenario

For the baseline scenario (pre-mining case), chemical loads were estimated for sites SW1, SW2, SW3, SW4 and SW5 as illustrated on the schematic in Figure 3-1. The chemical load at each stream was compiled on a daily time step over the period of 20/11/1970-01/01/2011 as this was the period of common data from the Australian Water Balance Model (AWBM) developed for the *Water Balance and Surface Water Management System Report* and NSW Office of Water (NOW) flow gauge at modelling point SW4.

The temporal representativeness of chemical sampling data was assessed in the *Baseline Hydrological Environment* report. This indicated that high flow events were under-represented in the sampling programme. Nevertheless, captured data from the high flow events suggested lower concentrations for parameters of concern than during low and intermediate flow conditions. To investigate whether flow could be used as a surrogate for water quality variability, regression plots for all sites were constructed. The indicative regression relationships between measured flow at SW4 and concentrations of Zn, TP, TDS and TSS are shown in Figure 3-2.

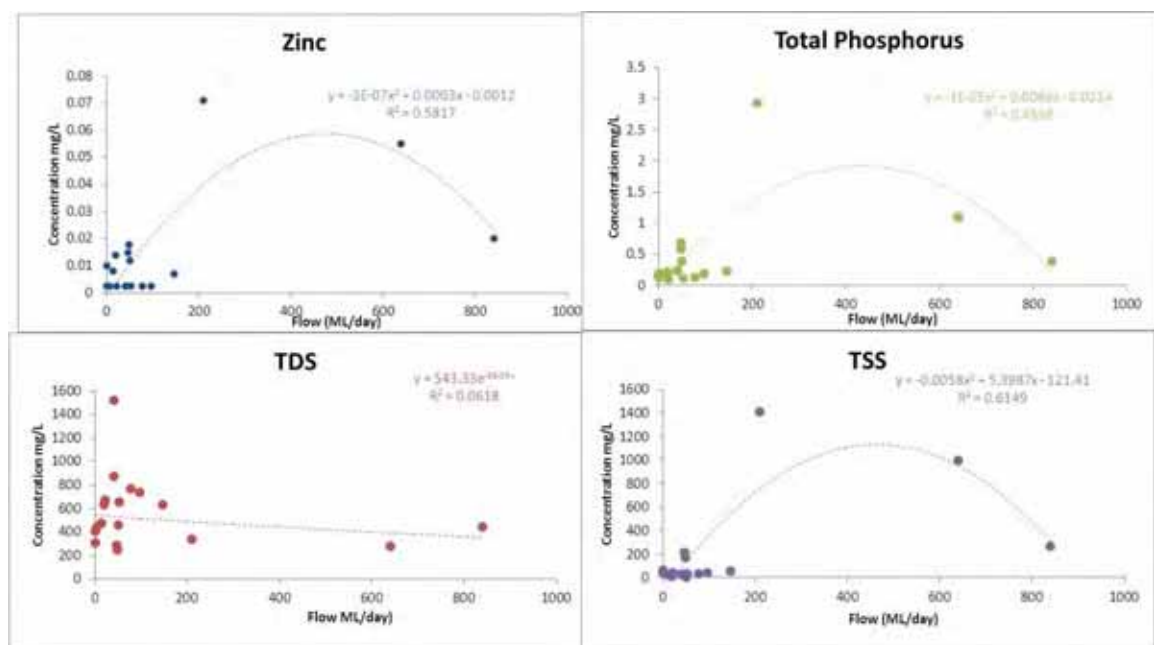


Figure 3-2 Flow versus water quality regression plots at SW4

Polynomial trend lines were fitted to zinc, phosphorus and TSS and an exponential trend line was fitted to TDS. None of these regression relationships showed strong correlation, as measured by the r^2 value. The pattern of scatter was similar for zinc, phosphorus and TSS, suggesting TSS is correlated with phosphorus and zinc. These plots show low concentrations at low flows (due to lack of source inputs) and high flows (due to volumetric dilution) and high concentrations in intermediate flows (due to first flush inputs from rapid surface water pathways).

Conversely, large variability in TDS during low flow conditions (due to a balance between low inputs but more ion-rich baseflow inputs from sub-surface flow pathways and evaporation of water in semi-permanent pools) and similar values of approximately 400 mg/L at flows >200 ML/day indicate a less variable source of water with similar composition, probably from surface water runoff.

For mass balance modelling, concurrent time series of concentrations of assessed water quality parameters were required. The measured data points were only available for 24 months from August 2009 to June 2012. Had the regression relationships been strongly correlated with the flows, these could have been used to develop a flow varying concentration time series. In the absence of this correlation, constant concentrations corresponding to the 50th percentile based on monthly sampling data were used instead.

The AWBM model simulated flows for SW1, SW2 and SW3 and NOW gauge data for SW4 were used in the mass balance modelling. Flows at SW5 on the upstream Talbragar River reach were estimated by subtracting the AWBM model estimates for SW3 from NOW gauged flows at SW4.

The BL was estimated by multiplying the daily discharge at each location by the 50th percentile concentration at each location for each parameter (Figure 3-1). This load was determined for upstream of the confluence Sandy Creek (BL1); Laheys Creek (BL2); downstream of the confluence of Sandy Creek (BL3); and downstream of the Talbragar River (BL4). BL5 (upstream Talbragar River) was calculated as BL4-BL3. Once the daily load was calculated it was converted to the 50th percentile for each of the parameters.

3.1.2.2 Operational scenario

The operational scenario includes the effect of sedimentation dam discharges on the watercourses in the assessment area. These sedimentation dam inputs were treated as 'lumped discharges' based on the location of release into the receiving watercourse (refer to the *Water Balance and Surface Water Management System Report*), and therefore the inputs vary on both a temporal (due to land changes in the different phases of the Project) and spatial scale (due to different volume and concentration input values).

The concentrations of chemicals entering the sedimentation dams were based on a previous geochemical investigation (Geoterra, 2010), hydrogeological monitoring (PB, 2012) and baseline TSS values in cease to flow conditions.

Elutriate testing data (1:5 deionised water extract) from overburden wastes was deemed to provide the highest representation of chemical composition of runoff into the sedimentation dams and was considered a worst-case representation of potential chemical inflows to the sedimentation dams (Geoterra, 2010). No nutrient leachate testing was conducted as part of the Geoterra report so the 50th percentile total nitrogen and total phosphorus concentrations from shallow bores closest to the sedimentation dams were used as inputs to the model.

The sedimentation dams were sized according to Blue Book recommendations (refer to the *Water Balance and Surface Water Management System*), which assumes a settling efficiency of 95%. It is clear that this will not remove the finest fraction of particulate matter or low density material. To estimate potential TSS concentrations from the sedimentation dams, cease to flow values in the adjacent Sandy Creek and Laheys Creek watercourses were used (19mg/L, n = 21).

The concentration of chemicals discharged from the sedimentation dams are likely to increase slightly when compared to the inputs described above due to evaporation. Water loss estimates for each sedimentation dam were calculated using the water balance model (refer to the *Water Balance and Surface Water Management System Report*) and converted to volumes based on the surface area of each sedimentation dam and the residence time.

The total load at the confluence was based on the sum of the BL plus the total sedimentation dam load. This gave the OLs for each of the mine years. BL4 was derived using the sum of the BL5 (assumed to be a constant throughout the Project life) and OL3 for each of the operational years.

3.1.3 Modelling results

Resulting chemical concentrations from the model simulations are described below for both baseline and operation scenarios. Appendix B.2 contains all tabulated outputs from the modelling runs together with comparisons to WQOs, using the 'RAG' (Red, Amber, Green) colour coding system.

3.1.3.1 Baseline scenario results and development of customised WQOs

The following observations are made from comparison of the BL3 (Sandy Creek) chemical concentration data to default WQOs:

- For primary contact, arsenic, cadmium, chromium, copper, nickel, selenium and zinc are all below the default WQO but aluminium, iron and TDS exceed the default WQO.
- For livestock water supply all parameters are below the default WQO reflecting that the pre-mining water quality is suitable for this EV.
- For irrigation all parameters are below the default WQO for Short Term Value (STV) but iron and manganese are approximately 5 times higher than the default WQO for Long Term Value (LTV).
- For aquatic ecosystems TP and TN are above the default WQO value. There is no default WQO set for TSS but the baseline value is 16 mg/L.
- This suggests that untreated water in Sandy Creek is only suitable for livestock water supply and irrigation (short term).

The following observations can be drawn from comparison of the BL4 (Talbragar River) chemical concentration data to default WQOs:

- For primary contact, arsenic, cadmium, chromium, copper, nickel, selenium, TDS and zinc are all below the default WQO but as for Sandy Creek, aluminium and iron exceed the default WQO.
- TDS in the Talbragar River is approximately a third of the concentration of that in Sandy Creek. This discrepancy is significant and shows that the Talbragar River is supported by larger flows which dilute the ion-rich baseflow and lead to less evaporative loss and subsequent concentration of salts.
- For livestock water supply all parameters are below the default WQO. For irrigation all parameters are below the default WQO for STV and LTV except iron which is approximately 10 times higher than the default WQO for LTV and TP, which is approximately 5 times higher than the default WQO for LTV.
- For aquatic ecosystems TP and TN are both above the default WQO value. These observations suggest that the Talbragar River has potential to become eutrophic and develop algal blooms during low flow periods.

TP concentrations in Sandy Creek are lower and as phosphorus is the limiting nutrient in this water type, there is a lower risk of algae generation. There is no default WQO set for TSS but the baseline concentration is 40 mg/l, 2.5 times higher than the concentration in Sandy Creek.

These observations suggest that untreated water in the Talbragar River is only suitable for irrigation (short term). However, with basic treatment it could be suitable for livestock water supply and irrigation long term.

The procedure for using this baseline concentration data generated from the model to set customised WQOs is detailed in Section 2. The summary above shows that arsenic, cadmium, chromium, copper, nickel, selenium and zinc do not require customised WQOs, as baseline concentrations are below the default WQOs for all EVs. However, aluminium, iron, total nitrogen and TSS require customised WQOs for both the SW3 (Sandy Creek) and SW4 (Talbragar River) sites because default WQOs are exceeded for these parameters. In addition, customised WQOs are required for manganese and TDS at SW3 and total phosphorus at SW4. The customised WQOs are given in Table 3-1.

Table 3-1 Customised WQOs for SW3 and SW4

Parameter	Customised Water Quality Objectives (mg/L)	
	SW3	SW4
Total suspended solids (TSS)	34	202
Total dissolved solids (TDS)	1,978	- *
Total nitrogen	0.9	2.7
Total phosphorus	- *	0.5
Aluminium	0.5	8.4
Iron	1.5	10.2
Manganese	2.1	- *

* Default WQO values were used

3.1.3.2 Operational scenario results and impact assessment

Estimated chemical concentrations at SW3 (Sandy Creek) and SW4 (Talbragar River) during the five mine stages are shown in Figure 3-3. Six parameters were selected for in-depth analysis because they exceeded the default WQOs during baseline modelling and experience suggests that these have the potential to increase during mine operation.

The main observations made from the modelling results of chemical concentration change due to mining operations are:

- A maximum increase in concentrations of 5% above baseline conditions for Al, Mn, and TDS are predicted for SW4, as shown in Figure 3-3. Modelled concentrations show some improvement in water quality with respect to TN, TP and TSS during mining. Also note that these parameters are well below the customised WQOs at SW4.
- The variation between mining years is much larger at SW3 than at SW4 for TDS concentration (e.g. 41 and 5%, respectively).
- There is no change in compliance with customised WQOs apart for TDS and TN for SW3 for years 1, 4, 12 and 16.
- Concentrations of Mn, TDS and TN are consistently lower in the Talbragar than in Sandy Creek. Conversely aluminium, TP and TSS are higher in the Talbragar.

Comparing these estimated concentrations with the customised WQOs (see Appendix B.2):

- SW3 is below the customised WQOs for irrigation (both STV and LTV) uses.
- SW3 is below the customised WQOs for contact recreation and livestock apart from the elevated TDS.
- SW3 is below the customised WQO's for aquatic ecosystems a part from TN for years 12-20, SW4 is below the customised WQOs for all EVs.

Model predictions suggest that SW3 (Sandy Creek) will be impacted to a larger degree than SW4 (Talbragar River), particularly in relation to elevated concentrations of TDS, TN and TP. Note that TN and TP values used for the analyses were based on groundwater bore concentrations in the absence of measured data from surface runoff. Since the Project will change the land use from livestock pasture to mining, nutrient loads in the form of TN and TP concentrations are likely to significantly reduce over the life of the mine.

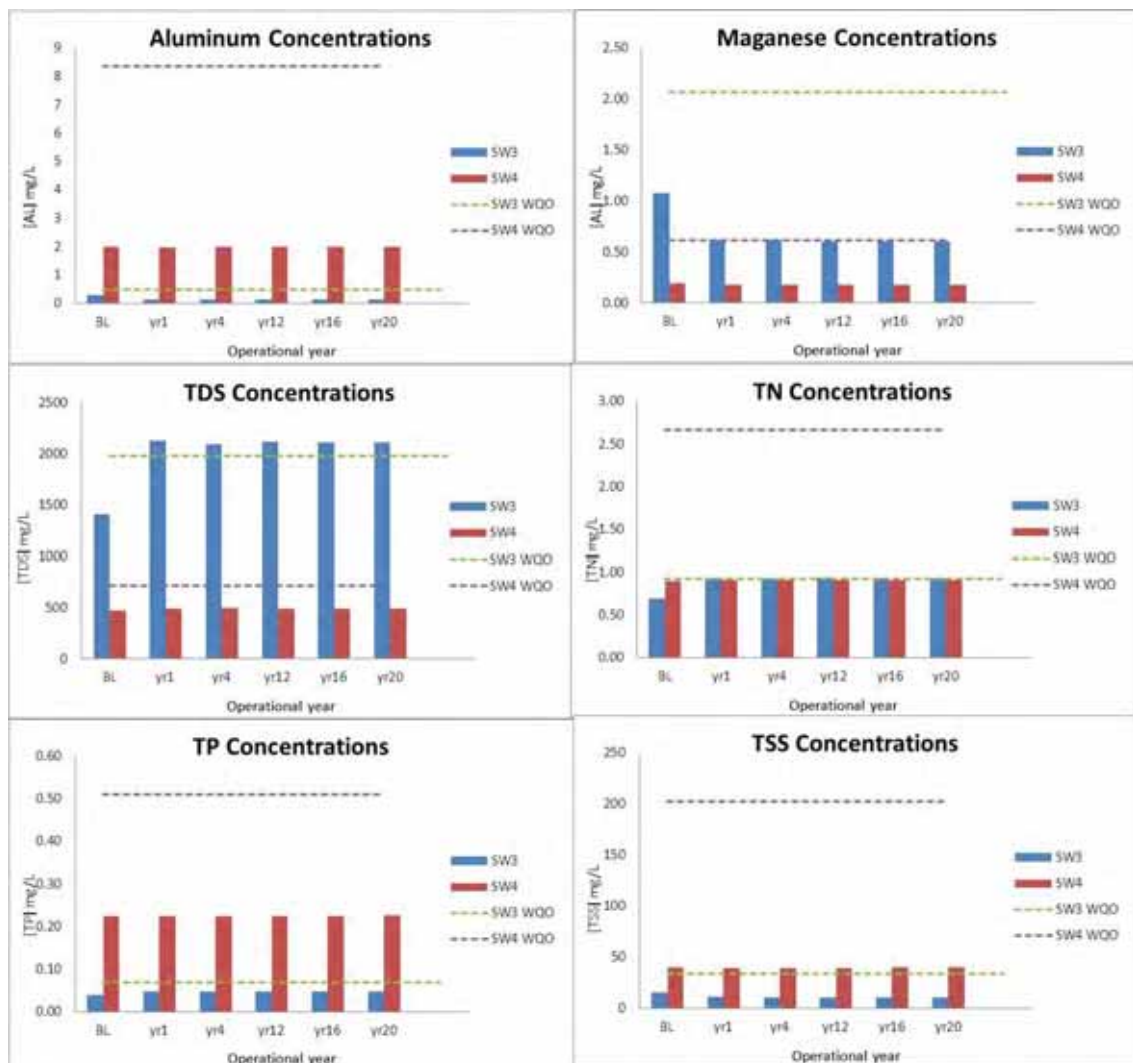


Figure 3-3 Model-predicted changes in chemical concentration at SW3 (Sandy Creek) and SW4 (Talbragar River) during the Project

4. Mitigation measures

4.1 General mitigation measures

A number of general or industry best practice mitigation measures have been recommended to minimise or avoid potential impacts of the Project on the surrounding surface water environment. These measures are discussed in detail in the *Water Balance and Surface Water Management System Report* and *Surface Water Assessment* reports.

A more specific mitigation measure relates to the application of project-specific discharge criteria to any water discharged from the Project to the surrounding environment. A discussion of the water quality discharge criteria recommended for the Project, as applied to sedimentation dam discharges, is provided below.

4.2 Sedimentation dam performance criteria

In accordance with the *Water Balance and Surface Water Management System Report*, sedimentation dams will return treated surplus water to the adjacent creeks. During discharge events, it will be necessary to set performance criteria to protect water quality conditions in the receiving watercourses.

A goal seek function in Microsoft Excel was used to assess the response of Sandy and Laheys Creeks to increases/decreases in sedimentation dam contributions. By increasing the sedimentation dam chemical loads to a level whereby the customised WQOs for that watercourse were reached, a 'tolerable' load was determined.

This sensitivity analysis process found that there was a 1:1 relationship between input and response, possibly because the composition of water from the sedimentation dams was similar to that of the receiving watercourses. On this basis, the most stringent customised WQOs have been recommended as the Project discharge limits, rounded to the nearest significant figure (Table 4-1).

Exceptions to this approach were made for TSS and TDS. For TSS the most stringent customised WQO would require a discharge limit of 30 mg/L, which is not considered feasible. Instead a limit of 200 mg/L is proposed, which would maintain baseline conditions in the Talbragar River.

Due to the sensitivity of salt loads in the catchment, more detailed consideration was given to TDS. Baseline TDS concentrations determined from the water quality mass-balance model were reviewed and are presented in Table 4-1.

Table 4-1 Modelled baseline TDS concentrations

Site	TDS concentrations (mg/L)		
	Minimum	Median	Maximum
SW1	522	1510	6000
SW2	354	3230	4900
SW3	412	1400	2290
SW4	252	469	1520
SW5	184	423	710

The modelled baseline concentrations were used to set proposed performance criteria for TDS for sedimentation dams as follows:

- The minimum baseline concentration is adopted as a 50th percentile value.
- The median baseline concentration is adopted as a 100th percentile value.

This approach would result in the TDS performance criteria given in Table 4-2.

Table 4-2 Potential reach-specific sedimentation dam performance criteria for TDS

Sedimentation dam location	TDS concentrations (mg/L)	
	50 th %ile limit	100 th %ile limit
Sandy Creek upstream of Laheys Creek confluence	500	1500
Laheys Creek	350	3200
Sandy Creek downstream of Laheys Creek confluence	400	1400

To facilitate compliance monitoring during operations, the most stringent limits in Table 4-2 are proposed as site-wide criteria on all sedimentation dams, i.e. 350 mg/L for the 50th percentile and 1400 mg/L for the 100th percentile.

Overall, compliance with the recommended criteria shown in Table 4-3 should ensure water quality conditions in the receiving watercourses are not adversely affected.

Table 4-3 Proposed sedimentation dam performance criteria

Parameter	Concentration limits (mg/L)	
	50 th %ile	100 th %ile
Aluminium	N/A	0.5
Iron	N/A	1.5
Manganese	N/A	2.0
pH*	N/A	6.5 -8.5
TDS	350	1400
TN	N/A	0.9
TP	N/A	0.5
TSS	N/A	200

(* based on default local EV, Section 2.2.2)

Tests for pH, TDS and TSS can be performed rapidly on-site with portable equipment. The testing for these parameters should therefore be undertaken to confirm performance adequacy during storms when dams reach full capacity. For more involved analysis, a quarterly sample should be sufficient, but this should be reviewed based on the first sample sets. This testing is only required when water is displaced to Sandy Creek, Laheys Creek or the Talbragar River.

5. Cumulative impacts

Cumulative impacts arise due to the influence of other construction and development activities in the local area. Any such activities have the potential to compound or exacerbate the specific impacts of the Project, thereby forming a cumulative impact.

Other projects in the region include Ulan, Moolarben and Wilpinjong Mines. Moolarben and Wilpinjong Mines are located within catchments that drain east into the Goulburn River, hence are not relevant to this assessment.

The Ulan Mine, however, is located on top of the Great Dividing Range and runoff from this mine flows in both directions, eastwards to the Goulburn River but also northwards into both Mona and Cockabutta Creeks. These two creeks subsequently flow into the Talbragar, approximately 35 and 25 km upstream, respectively, of the Sandy Creek confluence with the Talbragar River.

The Ulan Coal Mine was therefore considered as a potential contributor to cumulative impacts in combination with this Project.

5.1 Ulan project overview

The Ulan Mine Complex is one of the most established coal mining operations in the western coalfields of NSW (Xstrata, 2012). The Ulan Mine Complex lies within the Mid-Western Regional Council (MWRC) Local Government Area, located near the village of Ulan in the central west of NSW, approximately 45 kilometres north-north-east of Mudgee and 25 kilometres north-east of Gulgong. The Ulan Mine Complex covers an approximate area of 17,959 hectares and is located at the headwaters of the Goulburn and Talbragar River catchments.

In November 2010, Ulan Coal Mining Limited was granted Project Approval (08_0184) from the NSW Department of Planning, for the continuation of existing and new underground longwall mining and open cut activities to produce up to 20 Mtpa of product coal from its mining operations for the next 21 years (Xstrata, 2012).

5.2 Potential impacts

The water quality impact assessment for the Ulan Mine focussed on changes to TDS in the Talbragar River. The statement concluded that the project would have a negligible effect on the river due to the implementation of a wastewater treatment process to meet prescribed discharge standards. The baseline surface water monitoring program implemented as part of this assessment (refer to the *Baseline Hydrological Environment* report) included almost one year's worth of data that would have taken into account any effects associated with the operation of the Ulan Mine, since project approval was awarded. The water quality model for the OL case predicted a maximum 5% increase in TDS values in the Talbragar River above the baseline case, which is still below the default WQO set for the Macquarie-Bogan catchment. The cumulative impact of the Project on the Talbragar River is therefore deemed insignificant.

6. Conclusions

This report has assessed the impact of mine operation on water quality within the Sandy Creek catchment and further downstream in the Talbragar River. The relevant environmental values and default water quality objectives for the Macquarie-Bogan Catchment were reviewed. This resulted in the development of customised water quality objectives for the Project for those parameters where baseline concentrations exceeded the default water quality objectives.

The potential impacts of the Project were assessed using a mass-balance model to predict potential changes in the water quality of local watercourses over several operational stages of the mine. The main impacts were localised to Sandy Creek, with elevated levels of nutrients and TDS predicted in years 1 to 16 of the Project. The impacts on these parameters in the Talbragar River were assessed to be minor due to the larger catchment size and flows. The potential cumulative impacts of the Project on the water quality in the Talbragar River, considering the operation of the existing Ulan Mine upstream of the confluence of Sandy Creek with the Talbragar River, were deemed to be negligible.

7. References

ANZECC, 2000a. Applying Guideline Trigger Values to Sites. Section 3.4.3 of *An Introduction to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

ANZECC, 2000b. Monitoring and assessment. Chapter 7 in Volume 1 of *An Introduction to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

DECC (2010) Mines and quarries. Volume 2E in Soils and Construction. Managing Urban Stormwater. NSW Department of Environment and Climate Change. ISBN: 978-1-74122-816-8.

DEC, 2006. Using the ANZECC Guidelines and Water Quality Objectives in NSW. Available online at: <http://www.environment.nsw.gov.au/water/usinganzeccandwqos.htm>. Department of Environment and Conservation NSW. June 2006.

DECCW 2006 Macquarie-Bogan Water Quality and River Flow Objectives. Available online at: <http://www.environment.nsw.gov.au/ieo/MacquarieBogan/report-02.htm>. Department of Environment, Climate Change and Water 2006.

Geoterra (2010) Geochemical Assessment. Cobbora Coal Mine Project. Draft version. September 2010.

NSW (2006) Macquarie-Bogan River Water Quality and River Flow Objectives. In: NSW Water Quality and River Flow Objectives. Available online at: <http://www.environment.nsw.gov.au/ieo/MacquarieBogan/report-02.htm>.

PB (2012) Cobbora Coal Mine Project. Groundwater Assessment. February 2012.

Smith R, Jeffree R, John J, Clayton P, 2004. *Review of Methods for Water Quality Assessment of Temporary Stream and Lake Systems*. Australian Centre for Mining Environmental Research. September 2004.

Appendix B.1

Water quality model data sources
and assumptions

B1 Data Sources

- Daily Flow data along Sandy Creek and Laheys Creek was supplied by AWBM model described in the Water Balance and Surface Water Management system Technical Report.
- Daily flow from sedimentation dams into streams was supplied by AWBM model.
- Flow data along the Talbragar River at SW4 was supplied by Office of Water gauge 421042 (Talbragar at Elong Elong).
- Baseline metals and nutrient concentrations in the streams were supplied by ALS monthly routine monitoring over the period of September 2009-November 2011 at SW1, SW2, SW3, SW4 and SW5.
- Metal concentrations entering sedimentation dams were supplied by a previous geochemical report (Geoterra, 2010).
- Nutrient concentrations entering the sedimentation dams were supplied by groundwater monitoring (PB, 2012).

B2 Assumptions

The following assumptions have been made in constructing this water quality model:

- The chemical concentration over the sampling period of September 2009-November 2011 was taken to be representative of the total range in baseline concentrations for low flow to high flow events.
- Chemical concentration percentiles of 50 and 80 were determined from the 2nd year of monthly sampling data and represent the expected ranges in concentration.
- Concentrations that were below the limit of detection were taken to be half of what the value was that they were less than (i.e. <0.01 became 0.005).
- Minor tributaries were assumed to have no significant impact to the water quality of Laheys creek, Sandy Creek and the Talbragar River.
- The west Woolandra farm dams with a combined capacity of approximately 1,460 ML in the Laheys Creek catchment were included in the baseline flow and calculation of baseline load for BL2.
- Flow data for SW5 did not exist therefore it was found using SW4 (office of water gauge data) subtracted by SW3 (AWBM downstream confluence sandy creek data).
- The chemical load at upstream Talbragar River BL5 was calculated by subtracting the downstream chemical load at the Talbragar River (BL4) by the downstream of the confluence of Sandy Creek (SW3). Where the case occurred that $BL3 > BL4$ and a negative load was found the load for BL5 was assumed to be the same as BL4.
- From BL4 load assumption a new flow was found at SW4. This was found using the daily peak flow from the modelled parameters excluding manganese and TDS.
- The new SW4 flow resulted in a new loading at BL4 and BL5.

- Sedimentation dams entering the same stream were combined for volume, surface area and discharge.
- There is no mixing in the sedimentation dams between the settling zone and the sediment zone.
- Chemical concentrations entering the sedimentation dams was considered to be the same as chemical loads found in overburden runoff from elutriate testing in Geoterra (2010). Land use was not taken into consideration.
- Inflow into the sedimentation dams is unknown. Therefore, the volume of the settling zone in the sedimentation dam was used to determine the outflow concentration of the chemicals.
- TSS from the sedimentation dams was found using the average concentration from baseline creek data during 'no flow' periods.
- For the operational case $OL4 = \text{baseline BL5} + \text{operational OL3}$.
- Sedimentation dams can discharge 1/5 of the settlement zone volume.

Appendix B.2

Model results of chemical
concentration

Table B2.1 Fitness for use for primary/secondary contact recreation at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
secondary/Primary contact recreation	0.20	0.0500	0.0050	0.050	1.000	0.30	0.1000	0.010	5.000	1000
BL3 median	0.29	0.0005	0.00005	0.001	0.001	0.89	0.0025	0.005	0.003	1400
diff from ANZECC	out	0.0500	0.0050	0.050	1.000	out	0.1000	0.010	5.000	out
WQO	0.50	0.0500	0.0050	0.050	1.000	1.46	0.1000	0.010	5.000	1978
OL3 median yr1	0.15	0.0016	0.0001	0.001	0.002	0.78	0.0021	0.005	0.078	2122
OL3 median yr4	0.14	0.0015	0.0001	0.001	0.002	0.78	0.0020	0.005	0.003	2086
OL3 median yr12	0.14	0.0014	0.0001	0.001	0.002	0.77	0.0020	0.005	0.003	2117
OL3 median yr16	0.13	0.0014	0.0001	0.001	0.002	0.77	0.0020	0.005	0.003	2106
OL3 median yr20	0.13	0.0014	0.0001	0.001	0.002	0.77	0.0020	0.005	0.003	2105

Table B2.2 Fitness for use for livestock water supply at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
Livestock water supply	5.00	0.5000	0.0100	1.000	5.000	1.000	0.020	20.000	2000
BL3 median	0.29	0.0005	0.00005	0.001	0.001	0.0025	0.005	0.003	1400
diff from ANZECC	5.00	0.5000	0.0100	1.000	5.000	1.000	0.020	20.000	2000
WQO	5.00	0.5000	0.0100	1	5.000	1.000	0.020	20.000	2000
OL3 median yr1	0.15	0.0016	0.0001	0.001	0.002	0.002	0.005	0.078	2122
OL3 median yr4	0.14	0.0015	0.0001	0.001	0.002	0.002	0.005	0.003	2086
OL3 median yr12	0.14	0.0014	0.0001	0.001	0.002	0.002	0.005	0.003	2117
OL3 median yr16	0.13	0.0014	0.0001	0.001	0.002	0.002	0.005	0.003	2106
OL3 median yr20	0.13	0.0014	0.0001	0.001	0.002	0.002	0.005	0.003	2105

Legend

Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Table B2.3 Fitness for use for irrigation STV at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation STV	20	2	0.05	1	5	10	10	2	0.05	5	25	0.8
BL3 median	0.29	0.0005	0.00005	0.0005	0.001	0.89	1.075	0.0025	0.005	0.0025	0.7	0.04
diff from ANZECC	20	2	0.05	1	5	10	10	2	0.05	5	25	0.8
WQO	20	2	0.05	1	5	10	10	2	0.05	5	25	0.8
OL3 median yr1	0.146	0.002	0.000	0.001	0.002	0.780	0.618	0.002	0.005	0.078	0.928	0.048
OL3 median yr4	0.141	0.001	0.000	0.001	0.002	0.776	0.616	0.002	0.005	0.003	0.926	0.047
OL3 median yr12	0.136	0.001	0.000	0.001	0.002	0.772	0.598	0.002	0.005	0.003	0.935	0.047
OL3 median yr16	0.135	0.001	0.000	0.001	0.002	0.772	0.599	0.002	0.005	0.003	0.935	0.047
OL3 median yr20	0.135	0.001	0.000	0.001	0.002	0.772	0.599	0.002	0.005	0.003	0.934	0.047

Table B2.4 Fitness for use for irrigation LTV at SW3 (Sandy Creek)

SW3	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation LTV	5.00	0.1000	0.01000	0.100	0.200	0.20	0.20	0.200	0.020	2.000	5.00	0.05
BL3 median	0.29	0.0005	0.00005	0.001	0.001	0.89	1.08	0.003	0.005	0.003	0.70	0.04
diff from ANZECC	5.00	0.1000	0.01000	0.100	0.200	out	out	0.200	0.020	2.000	5.00	0.05
WQO	5.00	0.1000	0.01000	0.100	0.200	1.46	2.06	0.200	0.020	2.000	5.00	0.05
OL3 median yr1	0.15	0.0016	0.00005	0.001	0.002	0.78	0.62	0.002	0.005	0.078	0.93	0.05
OL3 median yr4	0.14	0.0015	0.00005	0.001	0.002	0.78	0.62	0.002	0.005	0.003	0.93	0.05
OL3 median yr12	0.14	0.0014	0.00005	0.001	0.002	0.77	0.60	0.002	0.005	0.003	0.94	0.05
OL3 median yr16	0.13	0.0014	0.00005	0.001	0.002	0.77	0.60	0.002	0.005	0.003	0.93	0.05
OL3 median yr20	0.13	0.0014	0.00005	0.001	0.002	0.77	0.60	0.002	0.005	0.003	0.93	0.05

Legend

Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Table B2.5 Fitness for use for aquatic ecosystems at SW3 (Sandy Creek)

SW3	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
Aquatic Ecosystems	0.20	0.02	
BL3 median	0.70	0.04	16
diff from ANZECC	out	out	out
WQO	0.93	0.07	34
OL3 median yr1	0.93	0.05	11
OL3 median yr4	0.93	0.05	11
OL3 median yr12	0.94	0.05	11
OL3 median yr16	0.93	0.05	11
OL3 median yr20	0.93	0.05	11

Legend

Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Table B2.6 Fitness for use for primary / secondary contact recreation at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
secondary/Primary contact recreation	0.20	0.050	0.0050	0.050	1.000	0.30	0.100	0.010	5.000	1000
BL4 median	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	469
diff from ANZECC	out	0.050	0.0050	0.050	1.000	out	0.100	0.010	5.000	1000
WQO	8.37	0.050	0.0050	0.050	1.000	10.18	0.100	0.010	5.000	1000
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	2.22	0.008	0.005	0.018	489
OL4 median yr4	1.99	0.001	0.0001	0.004	0.004	2.23	0.008	0.005	0.008	493
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	488
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	487
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	2.23	0.009	0.005	0.008	489

Table B2.7 Fitness for use for livestock water supply at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	TDS (mg/L)
Livestock water supply	5.00	0.500	0.0100	1.000	5.000	1.000	0.020	20.000	2000
BL4 median	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	469
diff from ANZECC	5.00	0.500	0.0100	1.000	5.000	1.000	0.020	20.000	2000
WQO	5.00	0.500	0.0100		5.000	1.000	0.020	20.000	2000
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	0.008	0.005	0.018	489
OL4 median yr4	1.99	0.001	0.0001	0.004	0.004	0.008	0.005	0.008	493
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	488
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	487
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	0.009	0.005	0.008	489

Legend

Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Table B2.8 Fitness for use for irrigation STV at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation STV	20.00	2.000	0.0500	1.000	5.000	10.00	10.00	2.000	0.050	5.000	25.00	0.80
BL4 median	1.99	0.001	0.0001	0.004	0.004	2.23	0.19	0.009	0.005	0.008	0.90	0.23
diff from ANZECC	20.00	2.000	0.0500	1.000	5.000	10.00	10.00	2.000	0.050	5.000	25.00	0.80
WQO	20.00	2.000	0.0500	1.000	5.000	10.00	10.00	2.000	0.050	5.000	25.00	0.80
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	2.22	0.18	0.008	0.005	0.018	0.91	0.23
OL4 median yr4	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.008	0.005	0.008	0.91	0.23
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.008	0.91	0.23
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.008	0.91	0.23
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.008	0.91	0.23

Table B2.9 Fitness for use for irrigation LTV at SW4 (Talbragar River)

SW4	Aluminium (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Zinc (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Irrigation LTV	5.00	0.100	0.0100	0.100	0.200	0.20	0.20	0.200	0.020	2.00	5.00	0.05
BL4 median	1.99	0.001	0.0001	0.004	0.004	2.23	0.19	0.009	0.005	0.01	0.90	0.23
diff from ANZECC	5.00	0.100	0.0100	0.100	0.200	out	0.20	0.200	0.020	2.00	5.00	out
WQO	5.00	0.100	0.0100	0.100	0.200	10.18	0.20	0.200	0.020	2.00	5.00	0.51
OL4 median yr1	1.98	0.001	0.0001	0.004	0.004	2.22	0.18	0.008	0.005	0.02	0.91	0.23
OL4 median yr4	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.008	0.005	0.01	0.91	0.23
OL4 median yr12	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.01	0.91	0.23
OL4 median yr16	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.01	0.91	0.23
OL4 median yr20	1.99	0.001	0.0001	0.004	0.004	2.23	0.17	0.009	0.005	0.01	0.91	0.23

Legend

Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Table B2.10 Fitness for use for aquatic ecosystems at SW4 (Talbragar River)

SW4	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
secondary/Primary contact recreation	0.20	0.02	
BL4 median	0.90	0.225	40
diff from ANZECC	out	out	out
WQO	2.66	0.51	202
OL4 median yr1	0.91	0.23	40
OL4 median yr4	0.91	0.23	40
OL4 median yr12	0.91	0.23	40
OL4 median yr16	0.91	0.23	40
OL4 median yr20	0.91	0.23	40

Legend

Concentration within custom water quality objective guidelines
Concentration equal to custom water quality objective guidelines
Concentration outside custom water quality objective guidelines
Unable to compare concentration to NOW water quality objective guidelines

Appendix

C

Cobbora Coal Project **Downstream Flow Impact Assessment**

PR_5754A-2162570C_Appendix C



Revision	Details	Date	Amended By
A	Draft for EMM/CHC review	5 March 2012	DE, RL
B	Final draft for Adequacy Review	31 August 2012	RL
C	Final for Public Exhibition	6 September 2012	RL

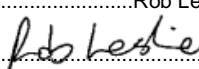
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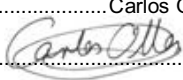
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Approved by: Carlos Olles

Signed: 

Date: 18 September 2012

Distribution: 1 x pdf to CHC as technical appendix to EA Report; Parsons Brinckerhoff

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Contents

	Page number
Glossary	ii
1. Introduction	1
1.1 Scope of assessment	1
2. Catchment overview	3
3. Catchment flow contributions	5
3.1 Water budget for the Cudgegong-Macquarie River System	5
3.2 Estimation of flows from ungauged catchments	5
3.3 Water budget findings	6
4. Water flow objectives	9
5. Assessment of potential impacts	11
5.1 Mine water balance model results	11
5.2 Flow impact assessment	11
5.3 Summary of impacts and potential mitigation measures	15
5.4 Impacts on refuge pools	16
6. Cumulative impacts	19
6.1 Ulan Coal Mine project overview	19
6.2 Potential cumulative impacts	19
7. Conclusion	21
8. References	23

List of tables

Table 3-1	Gauging station catchment details and flows	5
Table 4-1	Baseline condition flow objective values	10
Table 5-1	Summary of expected changes to Sandy Creek baseline creek flows (ML/yr)	11
Table 5-2	Flow impacts for Sandy Creek at outlet to Talbragar River	13
Table 5-3	Flow impacts for Talbragar River at Elong Elong	13

List of figures

Figure 3-1	Macquarie System Water Regulation Schematic	7

Glossary

AWBM	Australian Water Balance Model
FDC	Flow Duration Curve
NOW	NSW Office of Water
WSP	Water Sharing Plan

1. Introduction

This report assesses the impact of mine operation on creek flows in the Sandy Creek catchment where the mining areas are located and downstream in the Talbragar River system, which receives flow from the Sandy Creek catchment.

1.1 Scope of assessment

For the purposes of the assessment, the assessment area includes all potential receptors defined as those watercourses that drain the proposed mining areas and are likely to receive discharges from these areas, i.e. Sandy Creek and Laheys Creek, and the downstream system of the Talbragar River through to the Macquarie River and Macquarie Marshes.

The assessment also reviews the significance of the watercourses in the mining areas in terms of their relative flow contributions to the downstream river system.

It is important to note that the raw water supply for the Project will include licensed river extraction from the Macquarie and Cudgegong Regulated Rivers system. Cobbora Holding Company Pty Limited (CHC) has purchased (high security) Water Access Licences (WALs) from this water source in accordance with the relevant Water Sharing Plan.

To secure these WALs, a detailed impact assessment was prepared by the NSW Office of Water (NOW) before approval for the WALs was granted by the Minister in June 2011. This assessment considered potential flow impacts in the Macquarie and Cudgegong Regulated Rivers and concluded that the proposed extraction would not adversely affect downstream water users. No further discussion or analysis of this matter has therefore been included in this assessment. Please refer to Section 4.3 of the *Surface Water Assessment* report for further details.

2. Catchment overview

This section provides an overview of the broader catchment within which the Project is located. More detailed descriptions of the regional catchments and water bodies are provided in *Baseline Hydrological Environment*.

The Project is located within the upper catchment of the Macquarie River, which flows into the Macquarie Marshes, a region of national environmental significance, approximately 600 km downstream of the Project area.

The Macquarie Marshes are one of the largest semi-permanent wetlands in south-eastern Australia. Parts of the marshes are listed:

- under the Ramsar Convention, as a National Trust Landscape Conservation Area
- on the Australian Heritage Commission's Register of the National Estate
- in the Directory of Important Wetlands in Australia.

The marshes are fed by the Macquarie River. The Macquarie River and its largest tributary, the Cudgegong River, are regulated rivers. The volume and pattern of flows are largely controlled by a series of man-made structures including Windamere Reservoir on the upper Cudgegong River and Burrendong Reservoir on the Macquarie River. These structures have altered the frequency, extent and duration of inundation in the Macquarie Marshes.

The regulation of these rivers is governed by the *Water Sharing Plan (WSP) for the Macquarie and Cudgegong Regulated River Water Source 2003*. The WSP provides water for environmental needs and directs how much water is available for extraction and how it is to be shared. While the Macquarie Marshes are not part of the WSP area, the WSP includes rules about the release of flows to improve environmental outcomes for the marshes.

The WSP limits the long term annual average extraction from the Macquarie-Cudgegong system to 391 GL/year. All flows above this are reserved for the environment. In the long-term, approximately 73% of the average annual flow is protected for environmental health. Water extraction is managed to ensure that these long-term environmental flows are protected.

The mining area will be adjacent to Sandy Creek and its tributary, Laheys Creek. In the absence of appropriate controls, the Project has the potential to impact these two ephemeral creeks and smaller tributaries flowing into them. Sandy Creek flows into the Talbragar River on the western side of the assessment area. After approximately 60 km, the Talbragar River flows into the Macquarie River approximately 8 km downstream of Dubbo. The Macquarie River flows into the Macquarie Marshes 540 km downstream of this confluence.

3. Catchment flow contributions

3.1 Water budget for the Cudgegong-Macquarie River System

In order to assess the significance of surface water runoff in Sandy and Laheys Creeks to the regional waterbodies, a water budget was prepared for the regulated segment of the Cudgegong-Macquarie River system. This is shown diagrammatically in Figure 3-1. This figure presents mean (or average) and 50th percentile (or median) daily flow rates along the Macquarie River from Burrendong Reservoir to the Macquarie Marshes. The daily flows for the ungauged catchments were obtained from average yield per unit area measured at the reference gauging stations as summarised in Table 3-1.

Table 3-1 Gauging station catchment details and flows

Station	Watercourse	Location	Catchment area (km ²)	Start of record	End of record	50 th ile exceedance flow (ML/day)	Mean flow (ML/day)
421064	Sandy Creek	Medway	260	21/09/1966	01/09/85	1	17
421042	Talbragar River	Elong Elong	3050	10/11/1964	none	41	160
421001	Macquarie River	Dubbo	19600	01/06/1885	none	1520	3050
421031	Macquarie River	Gin Gin	26940	10/11/1964	none	900	2370
421004	Macquarie River	Warren Weir	26570	01/01/1898	none	610	1870
421090	Macquarie River	Marebone Weir	not reported	17/09/1976	none	210	750
421022	Macquarie River	Oxley Station	reported as 3565 – likely to be erroneous	01/01/1941	none	330	800
421147	Macquarie River	Pillicawarrina	not reported	23/06/1987	none	150	550

The approach taken to estimate the runoff yield from ungauged catchments is described in the Section 3.2. Key findings of the water budget are discussed in Section 3.3.

3.2 Estimation of flows from ungauged catchments

To estimate flows for the ungauged catchments, the following steps were completed:

- Catchment areas were calculated using geospatial software analysis of available topographic contour and stream network data. The following should be noted with respect to the catchment area calculations:
 - ▶ Contour data was used to delineate Laheys and Sandy Creeks only. Talbragar and Macquarie Rivers were delineated using stream network and basin polygon data.
 - ▶ The Macquarie River catchment downstream of Dubbo is difficult to define because of the large number of diversions and relatively flat topography. The catchment calculation for this area was based on professional judgement.
- Long term historical flow data for a number of streamflow gauge locations were obtained from:
 - a) NSW Office of Water (NOW) website for current active gauges.
 - b) PINNEENA DVD database for discontinued gauges.

- Recorded mean flow values were used to calculate the flow duration curve at each gauged location.
- The flow duration curve at each site was divided by its catchment area to obtain unit flow rates.
- The unit flow duration curves were multiplied by the ungauged catchment areas to estimate the flow duration curve at the ungauged locations. It should be noted that only single flow gauges were used and no regression analysis was carried out on multiple gauges.

3.3 Water budget findings

The Sandy Creek sub-catchment is approximately 8% of the Talbragar River catchment to the Sandy Creek and Talbragar River confluence; and approximately 1% of the Macquarie River catchment to the Talbragar River and Macquarie River confluence. Therefore, the Sandy Creek sub-catchment is a very small portion of the broader Macquarie River catchment system.

Daily mean and 50th percentile (or median) flow rates are shown on the watercourse schematic in Figure 3-1, depicting flows and extraction below the two storages – Burrendong and Windamere Dams. Other data were sourced from the WSP (NSW Government, 2006) and Dam Storage Records (NSW Government WaterInfo website, 2011). Different units for flow and extracted water volumes are presented based on standard unit conventions. The flow data show the estimated flow for the entire sub-catchment, derived from the recorded flow data at the most appropriate gauging station on the watercourse.

The mean daily flow of Sandy Creek (at Medway below its confluence with Laheys Creek) is 17 ML/day. In comparison:

- The mean daily flow of the Talbragar River above its confluence with the Macquarie River at Elong Elong is estimated to be 160 ML/day based on long-term gauging station records.
- The mean daily flow of the Macquarie River at the Dubbo Gauging Station (upstream of its confluence with the Talbragar River) is estimated to be 3,050 ML/day.
- The mean daily flow of the Macquarie River at Warren Weir is estimated to be 1,870 ML/day, 61% of mean daily flow at Dubbo gauging station and lower than at Dubbo due to water extraction between these two points.
- The mean daily flow of the Macquarie River at Oxley Station is estimated to be 800 ML/day, 26% of mean annual flow at Dubbo gauging station, lower than at Warren Weir due to further water extraction between these two points.

The flow values show that the mean daily flow in Sandy Creek is approximately 11% of the mean daily flow in the Talbragar River at Elong Elong, 0.9% of the mean daily flow in the Macquarie River at Warren Weir and 2% of the mean daily flow in the Macquarie River at Oxley Station.

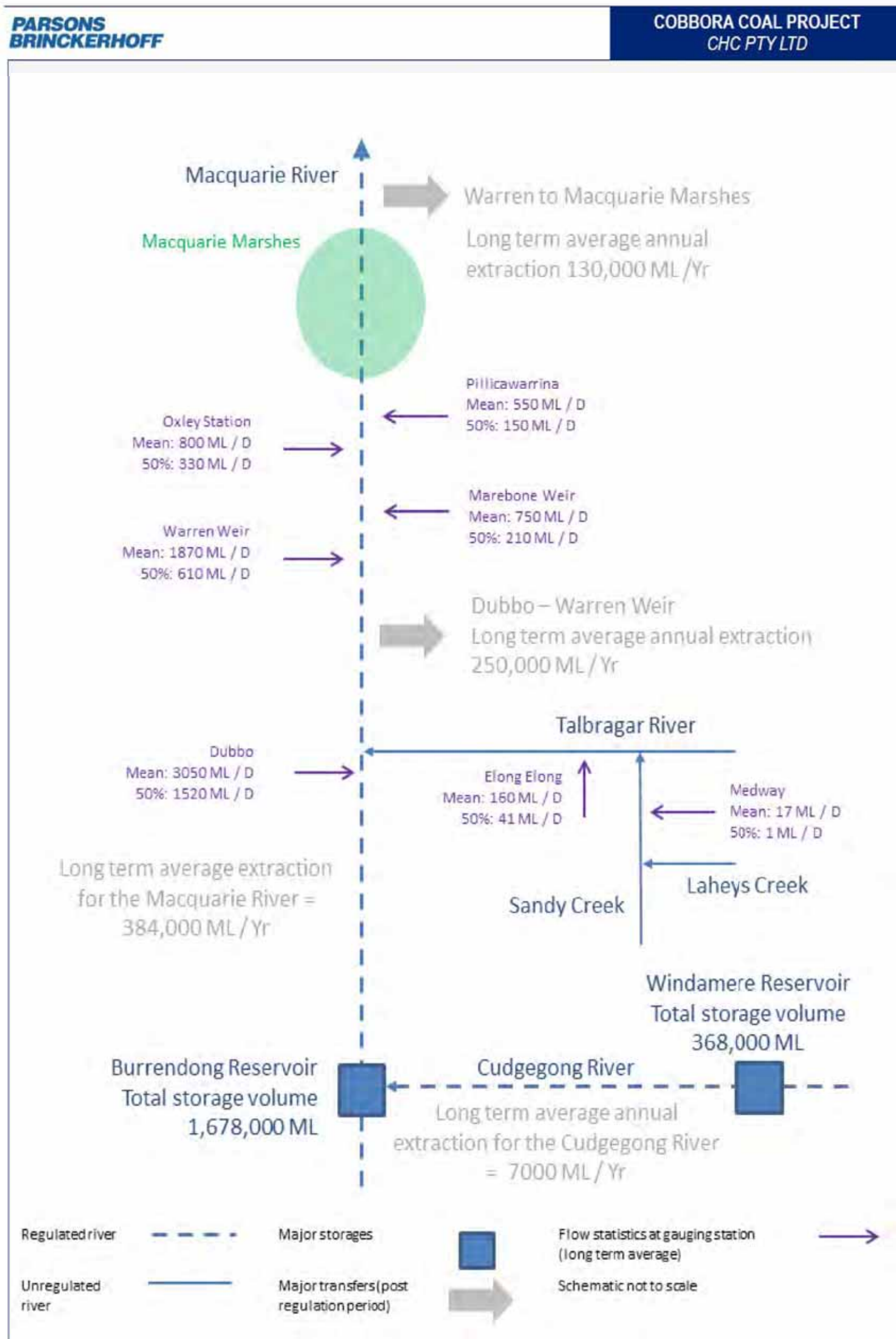


Figure 3-1 Macquarie System Water Regulation Schematic

4. Water flow objectives

The Talbragar River, Laheys Creek and Sandy Creek are within the Macquarie-Bogan River catchment. The NSW Government has developed a list of flow objectives to be used for this catchment. This Project will not extract any water from Sandy Creek, Laheys Creek or the Talbragar River but will restrict or capture a proportion of the runoff contributions from the assessment area into these watercourses. By meeting the flow objectives described for each stream, potentially adverse impacts on flows in the downstream catchments can be minimised.

Sandy Creek, Laheys Creek and the Talbragar River are all defined as 'uncontrolled streams' in that their flow pattern remains largely natural (NSW Government, 2006). NSW Government guidelines stress the importance of protecting pools in dry times, natural low flows and important rises in water levels.

Objectives for 'uncontrolled rivers' in the Macquarie-Bogan catchment can be summarised as follows:

- During periods of 'no flow' (flows exceeded 100% of the time) it is important to protect water levels in pools as these may act as refuges for aquatic plants and animals. Reduction in water levels under these conditions may make it difficult for a species to recover after a drought. The objectives state that during a period of no flow, extraction from the streams is not permitted in order to protect these pools.
- Extraction during 'very low flow' (flows exceeded 95% of the time) or 'low flows' (flows exceeded 80% of the time) imposes long artificial droughts that increase stress on aquatic plants and animals. The objectives state that extraction during very low and low flow conditions cannot be more than 30-50% of the available flow on a daily basis.
- It is important to protect 'high flows' (flows exceeded 20% of the time). Height, duration, frequency and season are all important in protecting shape of channel, water quality and reproduction of plants and animals. The objectives state that extraction during these flow conditions cannot be more than 30-50% of the available flow on a daily basis.

To identify how these quantifiable objectives translate to flows for Sandy Creek and the Talbragar River, flow duration curves (FDCs) of these two watercourses were examined. The derivation and details of these curves are described in the *Baseline Hydrological Environment* report.

Table 4-1 sets out the baseline condition flow objective values, based on the NSW Government guidelines and the Sandy Creek and Talbragar River FDCs.

Table 4-1 Baseline condition flow objective values

Flow objective	Sandy Creek		Talbragar River	
	Flow percentile/ percentile range (from FDC)	Flow/flow range (ML/day)	Flow percentile/ percentile range (from FDC)	Flow/flow range (ML/day)
No flow	>54%	0.006	>68%	0.030
Very low flow (Below 95% of all days with flow)	51%	0.010	65%	0.650
Low flow (Below 80% of all days with flow)	43%	0.046	54%	7.090
Extraction during low flow	30-50% of available flow	0.014-0.023	30-50% of available flow	2.127-3.545
High flow (Above 20% of all days with flow)	11%	6.795	14%	132.660
Allowable extraction during high flow	30-50% of available flow	2.039-3.398	30-50% of available flow	39.798-66.330

The following key points summarise the flow objectives:

- The no flow, very low flow, low flow and high flows for Sandy Creek are 0.006, 0.010, 0.046 and 6.795 ML/day, respectively.
- The no flow, very low flow, low flow and high flows for Talbragar River are 0.030, 0.650, 7.090 and 132.660 ML/day, respectively.
- During no flow and very low flow in both Sandy Creek and Talbragar River no extraction is permitted.
- During low flow and high flow in Sandy Creek the maximum permissible extraction would be 0.014 to 0.023 and 2.039 to 3.398 ML/day, respectively.
- During low flow and high flow in the Talbragar River the maximum permissible extraction would be between 2.127 to 3.545 and 39.798 to 66.330 ML/day, respectively.

5. Assessment of potential impacts

5.1 Mine water balance model results

The water balance assessment for the Project (refer to the *Water Balance and Surface Water Management System* report) found that the yield from Sandy Creek will increase during the wet years, but decrease for the average climate condition. The order of decreases in yield for the average climate is from 0.7% to 4.6% during mining years 4 to 20.

The yield from Sandy Creek is expected to decrease by 0.6% post-mining after year 21. The post mining decrease of 0.6% in Sandy Creek equates to around 0.02% at the Oxley Station, based on mean flow relationships given in Figure 3-1.

The water balance model results in terms of changed to baseline annual flow volumes in Sandy Creek are given in Table 5-1.

Table 5-1 Summary of expected changes to Sandy Creek baseline creek flows (ML/yr)

Year	10 th percentile dry year	50 th percentile median year	90 th percentile wet year
1	+46	+82	+404
4	-11	-34	+34
12	-25	-12	+174
16	-17	-42	+173
20	-19	-86	+1

5.2 Flow impact assessment

The water balance assessment for the Project (refer to the *Water Balance and Surface Water Management System* report) indicates that Project will result in annual average flow volumes similar, but slightly less than the baseline conditions, with a worst case decrease in flow volume of around 5%.

This report assesses the detailed impact on the daily flow regime at the downstream Sandy Creek point (confluence of Sandy Creek and Talbragar River) and downstream at the Talbragar River point near the Elong Elong flow gauge.

Flows in Sandy Creek are based on the flows produced by the AWBM that was developed for the mine water balance analysis. For the baseline scenario, baseline flows were calibrated to actual data recorded at the Medway gauging station on Sandy Creek (refer to the *Water Balance and Surface Water Management System* report).

For the mining scenario, flows were taken from the water balance model outputs and assigned to specific reporting points on Sandy Creek and Talbragar River, following the procedure described in the *Downstream Water Quality Impact Assessment* report. The mining scenario flows included controlled releases to the creek from sedimentation dams.

Predicted variations in flows from baseline conditions for a number of mining stages are given in Table 5-2 and 5-3. The model results show that:

- Flows are increased across the percentile ranges in Sandy Creek and the Talbragar River, reflecting the overall impact of increased flow (and reduced frequency of 'no flow' days) due to releases from the mining areas.
- There are more significant changes to the low flow conditions than the high flow conditions.
- Flow increases are highest at year 1 and mostly significant for low flow rather than high flow conditions.
- In general, flow impacts downstream of the assessment area are minor for high flows, i.e. <5% increase in the Talbragar River.
- Low and very low flows will be less frequent, especially in Sandy Creek.
- There will be larger percentage flow increases in Sandy Creek than Talbragar River.

Table 5-2 Flow impacts for Sandy Creek at outlet to Talbragar River

Objective	Flow percentile (from FDC)	Baseline (ML/day)	Year 1 (ML/day)	Year 1 change	Year 4 (ML/day)	Year 4 change	Year 12 (ML/day)	Year 12 change	Year 16 (ML/day)	Year 16 change	Year 20 (ML/day)	Year 20 change
No Flow	54%	0.0057	0.0175	+206%	0.0064	+12%	0.0106	+85%	0.0102	+79%	0.0068	+20%
Very Low Flow	51%	0.0103	0.0315	+206%	0.0116	+13%	0.0196	+91%	0.0190	+85%	0.0125	+22%
Low Flow	43%	0.0459	0.1298	+183%	0.0544	+19%	0.0897	+96%	0.0869	+90%	0.0593	+29%
High Flow	11%	6.7947	8.4184	+24%	6.8869	+1%	8.4779	+25%	8.2962	+22%	7.1969	+6%

Table 5-3 Flow impacts for Talbragar River at Elong Elong

Objective	Flow percentile (from FDC)*	Baseline* (ML/day)	Year 1 (ML/day)	Year 1 change	Year 4 (ML/day)	Year 4 change	Year 12 (ML/day)	Year 12 change	Year 16 (ML/day)	Year 16 change	Year 20 (ML/day)	Year 20 change
No Flow	>80%	0.0008	0.0027	+227%	0.0009	+7%	0.0012	+41%	0.0011	+35%	0.0009	+8%
Very Low Flow	76%	0.0084	0.0321	+283%	0.0091	+9%	0.0131	+56%	0.0127	+52%	0.0093	+12%
Low Flow	64%	1.0820	1.4989	+39%	1.1474	+6%	1.3180	+22%	1.3170	+22%	1.1818	+9%
High Flow	16%	115.0632	119.8025	+4%	118.8875	+3%	119.3890	+4%	119.3377	+4%	119.0232	+3%

**Note that the mass balance water quality model used to determine flow impacts modified the FDC for the Talbragar River at Elong Elong to address data inconsistencies in chemical load. This modified FDC was used in the flow impact assessment rather than the original FDC which is discussed in Section 4 and Table 4.1. Therefore, the baseline FDC flow values used in the flow impact assessment differed from the FDC derived from the Elong Elong gauge record. However, the modified values adopted are suitable for assessment of flow impacts across a range of flow categories.*

5.3 Summary of impacts and potential mitigation measures

The potential impacts of the Project on flows in Sandy Creek and the Talbragar River can be summarised as follows:

- In terms of annual average flow volume, there is a reduction in the yield of the Sandy Creek system during average and dry years of up to 5% but an increase in yield during wet years. A 5% maximum yield reduction in Sandy Creek equates to approximately a 0.5% reduction in yield in the Talbragar River at Elong Elong based on the mean flow relationship between the Medway and Elong Elong gauges (see Figure 3.1). This impact in the Talbragar catchment reduces further downstream as the influence of the Sandy Creek sub-catchment is reduced.
- In terms of impacts on mean daily flow, the Project will increase flows within the ranges defined by the NOW flow objectives due to the periodic releases of water from the mine.
- The difference in flow impacts when assessed at the annual and daily timescales can be explained by the more frequent flow in Sandy Creek (and consequently in Talbragar River) due to more regular flow from the mining areas than would occur under existing conditions. This effectively distorts the flow duration curve by increasing the frequency of flow, so that flow statistics (such as the 50th percentile flow) are increased in magnitude; however, there remains an overall decrease in annual flow volume passing through the systems.
- The general increase in mean daily flow will reduce the ephemeral characteristics of Laheys and Sandy Creeks, and to a lesser extent the Talbragar River. The mean daily flow increases are most significant for Sandy Creek, and most significant for low flows.

The impacts on downstream flow in the Talbragar River are considered minor, given that the impacts on the annual average flow volume at the Elong Elong gauge would be less than 1%. Releases from the mine could affect the ephemeral nature of the Talbragar River to some extent by reducing the number of no-flow days and increasing the magnitude of flows within the low flow range, however, impacts on the high flow range are in the order of 4%, which are negligible. The minor impact on the river's ephemeral characteristics and on the low flow regime would reduce further downstream as the characteristics of the broader Talbragar River catchment govern the flow regime. For this reason, no mitigation measures are deemed necessary to address potential impacts of the Project on the Talbragar River.

The impacts on Sandy Creek are more significant, with up to a 5% reduction in annual average flow volumes in average and dry conditions, but increased annual flow volumes during wet years and large increases in mean daily flow magnitude, particularly in the low to very low flow regime. These changes could affect the semi-permanent pools that occur within the Sandy Creek and Laheys Creek catchments.

While the overall flow volume is likely to decrease in average and dry years, potential increases in the frequency of low and very low flow events will mean that these pools will be fed more regularly and will dry out less frequently.

5.4 Impacts on refuge pools

Section 9.2 of the *Baseline Hydrological Environment* presented an assessment of the groundwater dependence of ecological refuge pools within and adjacent to the main mining area. Given the ephemeral nature of the creeks, pools that persist during prolonged dry periods are reliant on groundwater inflows rather than surface water flows,

The downstream flow impact assessment concluded that the changes to the surface water flow regime will not have adverse impacts on the pools, and will instead increase the frequency of low flows to the pools. However, it is important to also consider the impact of groundwater drawdown on the pools that depend on groundwater inflows to sustain them during prolonged dry periods,

Table 5-4 presents the predicted reductions in groundwater elevation due to drawdown for the later stages of mining and identifies which pools will no longer receive groundwater inflows as a result. As for the baseline assessment, the groundwater dependency of the pools during mining operations was determined as follows:

- If the water table elevation is higher than the creek bed level by more than 1 metre the pool site was deemed to be groundwater dependent.
- If the water table is within +/- 1 metre of the creek bed level the pool site was deemed to be potentially groundwater dependent.
- If the water table elevation is lower than the creek bed level by more than 1 metre the pool site was deemed to be independent of groundwater.

The impacts of the drawdown on the refuge pools during mining operations are as follows:

- No adverse impacts related to groundwater drawdown up to Year 12.
- From Year 12 large drawdown at sites 6 and 10 will result in loss of groundwater inflow and potential loss of persistent groundwater fed pools at these sites.
- From Year 20 drawdown may also cause loss of persistent groundwater fed pools at sites 2 and 3; however, it should be noted that the predicted drawdown at these sites is close to the combined margin of error in ground level and groundwater modelling data.

The groundwater modelling results indicate that groundwater levels will fully recover within 20 to 50 years post mining. Therefore, there will be a recovery of groundwater inflow to the affected pools in the long term.

Table 5-4 Groundwater drawdown impacts on refuge pools
(adverse impacts highlighted in bold text)

Site	Location	Channel bed elevation (mAHD)	Baseline groundwater surface elevation (mAHD)	Groundwater fed under baseline conditions?	Year 12 groundwater surface elevation (mAHD)	Groundwater fed at Year 12?	Year 16 groundwater surface elevation (mAHD)	Groundwater fed at Year 16?	Year 20 groundwater surface elevation (mAHD)	Groundwater fed at Year 20?
1	Talbragar River upstream of Sandy Creek confluence	354.2	355.2	Potentially	355.2	Potentially	355.2	Potentially	355.2	Potentially
2	Sandy Creek downstream of Laheys Creek confluence	347.0	346.5	Potentially	346.4	Potentially	346.0	Potentially	345.5	No
3	Sandy Creek downstream of Laheys Creek confluence	347.0	346.9	Potentially	346.7	Potentially	346.2	Potentially	345.6	No
4	Sandy Creek downstream of Laheys Creek confluence	353.5	352.4	No	344.3	No	347.0	No	349.7	No
5	Sandy Creek downstream of Laheys Creek confluence	361.0	362.3	Yes	362.1	Yes	362.1	Yes	362.2	Yes
6	Sandy Creek upstream of Laheys Creek confluence	373.0	373.4	Potentially	354.9	No	364.2	No	367.3	No
7	Laheys Creek downstream of Blackheath Creek confluence	365.0	361.2	No	356.5	No	357.8	No	358.9	No
8	Laheys Creek at Blackheath Creek confluence	378.0	374.3	No	372.2	No	372.1	No	372.2	No
9	Laheys Creek at Blackheath Creek confluence	378.0	374.6	No	371.4	No	371.5	No	371.6	No
10	Laheys Creek upstream of Blackheath Creek confluence	395.2	395.0	Potentially	391.6	No	387.8	No	385.7	No
11	Laheys Creek upstream of Blackheath Creek confluence	406.0	405.0	No	404.7	No	404.4	No	402.8	No
12	Laheys Creek upstream of Blackheath Creek confluence	428.8	427.2	No	427.2	No	426.8	No	426.0	No
13	Laheys Creek upstream of Blackheath Creek confluence	436.1	435.8	Potentially	435.7	Potentially	435.6	Potentially	435.6	Potentially
14	Fords Creek	481.7	478.9	No	478.9	No	478.9	No	478.9	No

6. Cumulative impacts

Cumulative impacts arise due to the influence or impacts of other construction and development activities in the local area. Any such activities have the potential to compound or exacerbate the specific impacts of the Project, thereby forming a cumulative impact.

Other projects in the region include Ulan, Moolarben and Wilpinjong Mines. Moolarben and Wilpinjong Mines are located within catchments that drain east into the Goulburn River, hence are not relevant to this assessment.

The Ulan Mine, however, is located on top of the Great Dividing Range and runoff from this mine flows in both directions, eastwards to the Goulburn River but also northwards into both Mona and Cockabutta Creeks. These two creeks subsequently flow into the Talbragar, approximately 35 km and 25 km upstream, respectively, of the Sandy Creek confluence with the Talbragar.

The Ulan Coal Mine was therefore considered as a potential contributor to cumulative impacts in combination with this Project.

6.1 Ulan Coal Mine project overview

The Ulan Mine Complex is one of the most established coal mining operations in the western coalfields of NSW (Xstrata, 2012). The Ulan Mine Complex lies within the Mid-Western Regional Council (MWRC) Local Government Area, located near the village of Ulan in the central west of NSW, approximately 45 kilometres north-north-east of Mudgee and 25 kilometres north-east of Gulgong. The Ulan Mine Complex covers an approximate area of 17,959 hectares and is located at the headwaters of the Goulburn and Talbragar River catchments.

In November 2010, Ulan Coal Mine Limited was granted Project Approval (08_0184) from the NSW Department of Planning, for the continuation of existing and new underground longwall mining and open cut activities to produce up to 20 Mtpa of product coal from its mining operations for the next 21 years (Xstrata, 2012).

6.2 Potential cumulative impacts

Increases in baseflow losses of 0.18-0.21 ML/day may result in the Talbragar River system due to the Ulan Coal Mine (Umwelt, 2009). Baseflow losses are predicted to increase to 0.38 ML/day after cessation of mining. Ulan Coal Mine Limited proposes to offset these losses by discharge of treated surplus mine water.

The Cobbora Project will result in a net gain of surface water in the Talbragar River during wet years, but minor losses of at most 0.5% in average and dry years at the Elong Elong gauge (based on the mean flow relationship between the two systems). Given the minor impacts of the Project and the management actions proposed at Ulan to offset baseflow impacts, it is concluded that there is negligible cumulative impact of both mining operations on the Talbragar River.

It should also be noted that for all flow objective categories, there will be an increase in flow magnitude in both Sandy Creek and the Talbragar River because the Project will reduce the ephemeral characteristics of Sandy Creek by introducing more regular flow into the system.

7. Conclusion

This report has demonstrated that Sandy Creek and Laheys Creek do not influence flows in the Talbragar or Macquarie Rivers to a significant degree, based on their small catchment area and annual flow contributions to the downstream systems. NSW Government flow objectives for the Macquarie-Bogan catchment were reviewed on the basis of flow volumes in Sandy Creek and the Talbragar River. This showed that cease to flow, very low flow, low flow and high flow conditions require protection. The impact of the Project on these flow conditions was assessed and found to be minor in the Talbragar River system and significant in the Sandy Creek system, where isolated semi-permanent pools would experience more regular low flows and less frequent drying. However, groundwater drawdown may result in the loss of persistent groundwater fed pools at up to 4 sites during operations. Recovery of groundwater levels at these sites will occur within 20 to 50 years post mining. Finally, cumulative impacts from this Project and the Ulan Coal Mine Project on the Talbragar River were assessed and found to be negligible.

8. References

Cardno Ecology Lab 2012, Cobbora Coal Project: Aquatic ecology environmental assessment. Job number EL1112020A. Prepared for EMM.

NSW Government (2006) Water Sharing Plan for the Macquarie and Cudgegong Regulated Rivers Water Source 2003. Available online at: <http://www.water.nsw.gov.au/Water-management/Water-sharing-plans/Plans-commenced/Water-source/Macquarie-and-Cudgegong-Regulated-Rivers/default.aspx>.

NSW Government (2006) Macquarie-Bogan River Water Quality and River Flow Objectives. In: NSW Water Quality and River Flow Objectives. Available online at: <http://www.environment.nsw.gov.au/ieo/MacquarieBogan/report-02.htm>.

NSW Government (2011) NSW Water Information. Available online at <http://waterinfo.nsw.gov.au/>.

Umwelt (2009) Surface Water Impacts and Mitigation. Section 5 in Surface Water Assessment. Ulan Coal – Continued Operations. Umwelt (Australia) PTY Ltd. October 2009.

Xstrata (2012) Ulan Coal. Available online at: <http://www.ulancoal.com.au/EN/Pages/default.aspx>.

Appendix

D

Cobbora Coal Project **Flood Impact Assessment**

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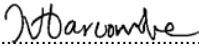
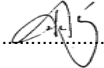


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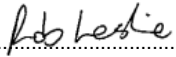
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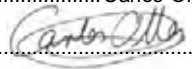
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Contents

	Page number
Glossary	v
1. Introduction	1
1.1 Background	1
1.2 Study area	1
1.3 Catchment description	2
2. Scope, approach and limitations	5
2.1 Scope of the assessment	5
2.2 Assessment approach	5
2.2.1 Existing flood conditions	5
2.2.2 Impacts and mitigation measures	6
2.3 Limitations of the assessment	7
3. Available data	9
3.1 Topography and aerial photography	9
3.2 Design rainfall intensity data	9
3.3 Pluviograph records	10
3.4 Stream gauge records	10
3.5 Water level data	12
3.6 Other data	12
4. Flood frequency analysis and flood history	13
4.1 Flood frequency analysis	13
4.2 Flood history	14
5. Hydrologic analysis	17
5.1 Overview	17
5.2 Runoff routing model	17
5.2.1 Catchment area	17
5.2.2 Design rainfall loss rates	19
5.2.3 Estimation of design rainfall	19
5.2.4 2,000-year ARI event	19

	Page number
5.3 Model validation	20
5.3.1 Fitting to flood frequency analysis	20
5.3.2 December 2010 flood event analysis	21
5.3.3 Conclusion	23
5.4 Existing case design flows	23
5.5 Proposed case design flows	24
6. Hydraulic analysis	27
6.1 Hydraulic models	27
6.1.1 Cross-section geometry development	27
6.1.2 Boundary conditions	27
6.1.3 Roughness	30
6.2 Modelled scenarios	30
6.2.1 Sandy Creek catchment model	30
6.2.2 Fords Creek and Tallawang Creek models	30
6.3 Modelled structures	31
6.3.1 Existing scenario	31
6.3.2 Proposed scenario	31
6.4 Model results	38
6.4.1 Existing scenario	38
6.4.2 Proposed scenario	45
7. Findings and mitigation measures	51
7.1 Flooding impacts	51
7.1.1 Sandy Creek, Laheys Creek and Talbragar River (Zone 1)	51
7.1.2 Flyblowers Creek (Zone 2)	51
7.1.3 Rail corridor (Zone 3)	52
7.1.4 Waterway crossings (construction)	52
7.2 Mitigation measures	53
7.2.1 Sandy Creek, Laheys Creek and Talbragar River (Zone 1)	53
7.2.2 Flyblowers Creek (Zone 2) flood detention basin	53
7.2.3 Rail corridor (Zone 3)	56
7.3 Mine safety	57
7.3.1 Crossing 1 — northern access road	57
7.3.2 Flood protection levees	57
7.3.3 Spoil emplacement protection	58
7.3.4 Temporary diversion channels	59
8. Conclusions and recommendations	61
9. References	63

List of tables

	Page number
Table 4-1	Flood frequency analysis — Talbragar River at Elong Elong 13
Table 5-1	Adopted loss values 19
Table 5-2	Sandy Creek catchment IFD parameters 19
Table 5-3	Sandy Creek PMP calculation parameters 20
Table 5-4	Model validation summary 21
Table 5-5	Peak flows at outlet of Sandy Creek (existing case) 23
Table 5-6	Proposed case peak flows at outlet of Sandy Creek 25
Table 6-1	Design flows for Fords Creek and Tallawang Creek rail crossings 28
Table 6-2	Adopted roughness values for Sandy Creek 30
Table 6-3	Preliminary design of key waterway crossings 34
Table 6-4	Proposed waterway crossings within rail corridor 35
Table 6-5	Existing and proposed flood levels at key locations 41
Table 6-6	Existing and proposed average velocities at key locations 42
Table 7-1	Flood impacts for preliminary design of Fords Creek and Tallawang Creek crossings 56
Table 7-2	Lengths of cut and fill along proposed rail spur 56

List of figures

Figure 1-1	Study zones 3
Figure 3-1	Comparison of Sandy Creek and Talbragar River average daily flow during the February 1971 event 11
Figure 3-2	Relationship between Sandy Creek daily flow and Talbragar River instantaneous flow during annual peak events 12
Figure 4-1	Annual series flood frequency analysis — Talbragar River at Elong Elong 14
Figure 5-1	Sandy Creek sub-catchments 18
Figure 5-2	Relationship between estimated Sandy Creek peak flow and Talbragar River instantaneous peak flow during annual peak events 21
Figure 5-3	Daily rainfall recorded at on-site meteorological weather stations 22
Figure 6-1	Sandy Creek model extent and cross section 29
Figure 6-2	Waterway crossings along rail spur 33
Figure 6-3	Existing 100-year ARI flood extent 40
Figure 6-4	Existing longitudinal water level profile for Sandy Creek (HEC-RAS model output), 100-year ARI 43
Figure -6-5	Existing longitudinal water level profile for Laheys Creek (HEC-RAS model output), 100-year ARI 44
Figure 6-6	Proposed 100-year ARI flood extent 46
Figure 6-7	Proposed longitudinal water level profile for Sandy Creek (HEC-RAS model output), 100-year ARI 47
Figure 6-8	Proposed longitudinal water level profile for Laheys Creek (HEC-RAS model output), 100-year ARI 48
Figure 7-1	100-year ARI peak flow and stage—storage relationship for the detention basin 54
Figure 7-2	Proposed detention basin layout 55

List of photographs

		Page number
Photo 1-1	Lower reaches of Sandy Creek	4
Photo 1-2	Lower reaches of Laheys Creek	4

Appendices

Appendix D.1	HEC-RAS results – existing scenario
Appendix D.2	HEC-RAS results – proposed scenario
Appendix D.3	Waterway crossing schematics from HEC-RAS
Appendix D.4	Temporary diversion channel locations

Glossary

Annual exceedence probability (AEP)	Chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m ³ /s has an AEP of 5%, there is a 5% chance (that is, a one-in-20 chance) of a 500 m ³ /s or larger event occurring in any one year (see 'average recurrence interval').
Australian Height Datum (AHD)	Reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of channels and water levels.
Average recurrence interval (ARI)	Long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20-year ARI flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	Land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital elevation model (DEM)	Digital representation of ground surface topography or terrain. It is also widely known as a digital terrain model (DTM).
Discharge	Rate of flow of water measured in terms of volume per unit time — for example, cubic metres per second (m ³ /s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving — for example, metres per second (m/s).
Flood	Relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam; and/or local overland flooding associated with major drainage before it enters a watercourse; and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences, excluding tsunamis.
Floodplain	Area of land that is subject to inundation by floods up to and including the probable maximum flood event — that is, flood-prone land.
Freeboard	Factor of safety used for setting floor levels, levee crest levels, etc. to provide reasonable certainty that the correct risk exposure has been selected when a particular flood has been chosen as the basis for design.
Hydrologic Engineering Centre River Analysis System (HEC-RAS) model	Software package that allows modellers to perform one-dimensional steady and unsteady flow river hydraulics calculations, sediment transport – mobile bed modelling and water temperature analysis.
Hydrologic Engineering Centre's Statistical Software Package (HEC-SSP)	Software package that allows modellers to perform statistical analysis of hydrological data. HEC-SSP can perform flood flow frequency analysis, volume frequency analysis, duration analysis and a curve combination analysis.
Hydraulics	Study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	Graph that shows how the discharge or flood level at a particular location varies with time during a flood.

Hydrology	Study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Light detection and ranging (LiDAR)	Optical remote-sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light (often pulses from a laser).
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m ³ /s	Cubic metres per second. A unit of measurement for flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Model	Mathematical representation of the physical processes involved in runoff generation and stream flow. Models are often run on computers, due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Peak discharge	Maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	Largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood-producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land — that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study.
Probable maximum precipitation (PMP)	Greatest depth of precipitation for a given duration that is meteorologically possible over a given size of storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends. It is the primary input to PMF estimation.
Root mean square (RMS) error	Frequently used measure of the differences between values predicted by a model or an estimator and the values actually observed from the thing being modelled or estimated. RMS is a good measure of accuracy.
Runoff	Amount of rainfall that actually ends up as stream flow; also known as rainfall excess.
Velocity	Speed of floodwaters, usually in m/s (metres per second).
Water surface profile	Graph showing the flood level at any given location along a watercourse at a particular time.
Watershed Bounded Network Model (WBNM)	Integrated software package for flood hydrograph studies on natural and urban catchments. WBNM is an event-based hydrologic model and calculates flood hydrographs from storm rainfall hyetographs. It can be used to model sub-catchments, reservoirs, on-site detention and other local drainage structures.
XP-RAFTS	Software package used for runoff routing for hydrologic and hydraulic analysis of drainage and conveyance systems.

1. Introduction

Parsons Brinckerhoff has been commissioned by Cobbora Holding Company Pty Limited (CHC) to prepare a flood impact assessment for the Cobbora Coal Project (the Project).

This report contributes to the surface water assessment that Parsons Brinckerhoff undertook for the Project's environmental assessment (EA) report.

The assessment of potential impacts of the Project on the dominant flow regime in the catchments (i.e. normal to low flows) is addressed in the *Downstream Flow Impact Assessment* report, which forms Appendix C to the *Surface Water Assessment* report.

1.1 Background

The Project will be developed near Dunedoo in the central west of New South Wales (NSW). The Project Application Area is approximately 274 square kilometres (km²). The primary purpose of the Project is to provide coal for five major NSW power stations.

The mine will extract around 20 million tonnes per annum (Mt/a) of run-of-mine (ROM) coal. From this, approximately 9.5 Mt/a of product coal will be sold to Macquarie Generation, Origin Energy and Delta Electricity under long-term contract. In addition, approximately 2.5 Mt/a will be produced for export or the spot domestic market.

The Project's key elements are:

- an open-cut mine
- a coal-handling and preparation plant (CHPP)
- a train-loading facility and rail spur
- a mine infrastructure area
- supporting infrastructure, including access roads, water supply and storage, and electricity supply.

Construction is expected to commence in mid-2013, with coal being supplied to customers from the first half of 2015. The mine life will be 21 years.

1.2 Study area

The study area generally covers the entire Project Application Area, with special focus on three zones where flood impacts could be significant. The three zones are listed below and shown in Figure 1-1.

- **Zone 1:** Sandy Creek Main Mining Area. This zone comprises the channel and floodplains of Sandy Creek from its headwaters to the confluence with the Talbragar River, and includes Laheys Creek and its alluvial floodplain. A hydraulic model was set up to assess the impacts in this zone since most of the mining areas and mine infrastructure lie in this catchment. This hydraulic model includes Blackheath Creek, one of the main tributaries of Laheys Creek. Flooding in this zone is associated with flows in Sandy Creek and Laheys Creek (the main tributary of Sandy Creek), and in the tributaries and gullies draining to these watercourses.

- **Zone 2:** Flyblowers Creek. This zone contains a small creek and its catchment (which is adjacent to the Sandy Creek catchment). This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek. The natural drainage line of part of this catchment will need to be diverted to accommodate the mining area.
- **Zone 3:** Proposed rail spur corridor. This zone contains the proposed rail spur and rail corridor that generally run along the top of small tributary catchments but cross a number of waterways and gullies, including Fords Creek, Lambing Yard Creek and Tallawang Creek.

1.3 Catchment description

The majority of the study area is located in the lower Talbragar River sub-catchment of the mid-Macquarie River catchment. For most of its length, the Talbragar River valley is broad and flat, and bordered by undulating hills that become less apparent as the Talbragar River progresses towards Dubbo. Due to excessive clearing in its upper catchment, the Talbragar River is highly salinised. Native vegetation only remains on the rocky sandstone hills formed by the inliers of the coarse Pilliga Sandstone.

Sandy Creek is a tributary of the Talbragar River, and Laheys Creek is a tributary of Sandy Creek. The upper reaches of each creek flow parallel to one other in a northerly direction through the study area. Laheys Creek merges with Sandy Creek approximately 7 km upstream of the confluence with the Talbragar River (refer to Figure 1-1). Sandy Creek and Laheys Creek are both ephemeral waterways — that is, they are usually dry for part of the year. Land within the Sandy Creek catchment is mainly rural, with some areas of native vegetation in the upper reaches of the catchment.

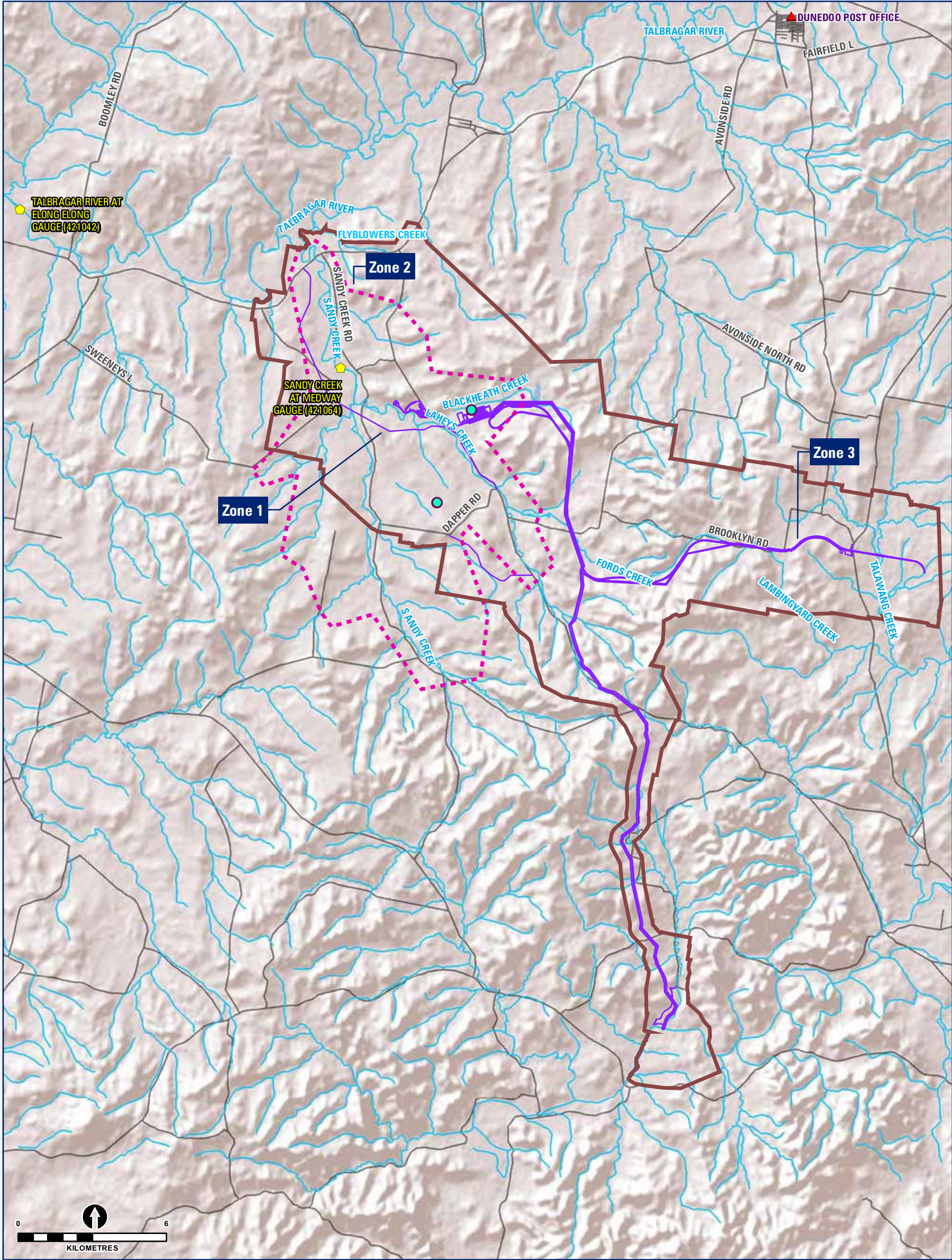
Photo 1-1 and 1-2 were taken during a site visit in September 2011. Photo 1-1 shows a section of the lower reaches of Sandy Creek. The creek channel reveals a low-flow area through which the lower flows can meander. The lower parts of the banks are steep and less vegetated. The creek channel also contains a high-flow area where the banks are gentler and more vegetated.

Photo 1-2 shows the lower reaches of Laheys Creek just upstream of its confluence with Sandy Creek. This channel also shows a low-flow channel with a less vegetated and steeper bank. The higher flow part of the creek bed has wider, gently sloping banks and sections of sandstone and conglomerate outcropping.

Flyblowers Creek is a small creek catchment located north-west of the Sandy Creek catchment. This creek flows into the Talbragar River upstream of Sandy Creek and downstream of Tucklan Creek (Zone 2).

Fords Creek is a tributary of Laheys Creek and lies in the upper catchment. Fords Creek flows west and captures runoff from the forested areas near the Goodiman State Forest. Many small drainage channels and gullies drain into it. The proposed rail corridor runs along Fords Creek and crosses a number of these channels and gullies (Zone 3).

The remainder of the study area covers the catchments of minor tributaries and small creeks in the south and part of the tributary system draining to Tallawang Creek in the east (Zone 3). Tallawang Creek flows south into the Wyaldra Creek, which eventually flows into the Cudgong River west of Gulgong.



Flow gauges	Project application area	Mine infrastructure
Project weather station	Drainage lines	Sandy Creek hydraulic model extent
BOM weather station	Roads	

Figure 1-1 Study zones



Photo 1-1 Lower reaches of Sandy Creek



Photo 1-2 Lower reaches of Laheys Creek

2. Scope, approach and limitations

2.1 Scope of the assessment

As part of the Project's environmental assessment, a flood impact assessment is required to meet the Director General's Environmental Assessment Requirements (DGRs) and support the application for Project Approval.

The brief received from CHC described the scope of works required to complete a surface water impact assessment, including flooding. The CHC brief requested that Parsons Brinckerhoff:

- Conduct a hydraulic analysis to determine flood extent and flood velocities in the study area and downstream as far as the Project could affect flooding.
- Consider the impacts of flooding in Sandy Creek and Laheys Creek on the safety of the mine under a range of annual exceedence probabilities up to a 2,000-year event.
- Determine the need for levees to protect the mine under a range of events.

Parsons Brinckerhoff has interpreted the DGRs and the CHC brief to define the scope of works for this flood impact assessment as follows:

- Describe the existing flood conditions, including the history of flooding, and the extent, level and frequency of flooding in the affected catchments for a range of annual exceedence probabilities (where data permit).
- Assess the flood impacts of the Project, particularly for scouring, erosion, and changes to flooding levels and frequencies upstream and downstream of the study area.
- Identify appropriate mitigation measures for minimising impacts of flooding behaviour upstream and downstream of the study area.
- Identify appropriate mitigation measures for minimising impacts of flooding in and adjacent to the proposed railway corridor.
- Identify appropriate flood mitigation infrastructure required for safety of the mine.

2.2 Assessment approach

2.2.1 Existing flood conditions

The following methodology was used to determine the existing flood conditions in the study area:

- The magnitude and frequency of historical flood flows in the Talbragar River were estimated based on a Log-Pearson Type III flood frequency curve fitted to the peak annual flow series from the Talbragar River flow gauge at Elong Elong, which is located downstream of the study area.

- The magnitude and frequency of historical flood flows in Sandy Creek were estimated by developing relationships between Sandy Creek maximum daily flow and Talbragar River maximum daily flows, and using the Talbragar River flood frequency curve at Elong Elong.
- The magnitude of peak flood flow rates of Sandy Creek and Laheys Creek and in minor tributaries within the study area for a range of extreme flood events were estimated using a Watershed Bounded Network Model (WBNM) hydrologic model developed for this assessment.
- Flood levels, extents and velocities within the Sandy Creek and Laheys Creek catchments for a range of extreme flood events were estimated using a one-dimensional (1D) hydraulic model (HEC-RAS) developed for this assessment.
- An inundation plan for the 100-year average recurrence interval (ARI) event was developed using the results of the HEC-RAS model to identify existing areas affected by extreme event flooding in the Sandy Creek and Laheys Creek catchments.

2.2.2 Impacts and mitigation measures

The following methodology was used to determine the potential impacts on existing flood conditions and suitable mitigation measures:

- The mine plans at different stages of development were analysed to determine the worst-case, future, modified catchment condition that would have most significant adverse impacts on flooding within the catchments upstream and downstream of the Project.
- Hydrologic (WBNM) and hydraulic (HEC-RAS) models were developed to represent a worst-case future condition by modifying the existing conditions models.
- The existing and future case HEC-RAS model results were compared to identify areas where flood behaviour changed as a result of the proposed mine and infrastructure.
- The HEC-RAS model results were used to assess vulnerable infrastructure that would require protection from the 100-year and 2,000-year ARI flood events. Vulnerable infrastructure included the active-mining areas, out-of-pit emplacement areas, coal stockpiles, mine infrastructure area and workshop area.
- Protection was assumed to be flood protection levees around open mine pit areas, coal stockpile areas and the workshop area for the 2,000-year ARI event, as well as erosion protection for the base of the spoil emplacement for the 100-year flood level (with freeboard allowance applied for both design events).
- The 2,000-year ARI flood event was chosen as a reasonable upper limit reference event for protection of critical infrastructure; however, this will be confirmed at the design stage based on a detailed risk assessment for the Project.
- The HEC-RAS model results were used to assess the impacts of proposed waterway crossings for mine access and haul roads on flood levels and flow rates. Preliminary design of the crossings was undertaken in consultation with CHC to meet specific design criteria, including flood immunity for the roads and afflux limits.

- Hydrologic modelling (using WBNM and XP-RAFTS) was used to size a temporary flood detention basin for the diverted portion of the Flyblowers Creek catchment, where mitigation is required to avoid downstream impacts for nine years of operation.
- The proposed rail spur corridor was assessed and waterway crossing locations identified. Indicative types and sizes of openings were determined based on the catchment area and channel shape determined from topographic data.
- Drainage requirements for the proposed rail spur corridor were assessed based on the proposed horizontal and vertical rail alignment and areas of cut and fill. Appropriate longitudinal drainage measures were identified for the corridor.

2.3 Limitations of the assessment

Detailed hydraulic analyses were undertaken for Sandy Creek and Laheys Creek; these analyses were represented by the hydraulic model shown in Figure 1-1 (Zone 1). The hydraulic model simulates flooding in the Sandy Creek catchment from its headwaters to its confluence with the Talbragar River (over a channel length of approximately 24 km).

The majority of the mining areas, mine infrastructure and coal-handling and preparation plant (CHPP) lie within this zone. Also modelled was the main portion of Laheys Creek (i.e. where a clearly defined channel is evident) from its confluence with Sandy Creek to approximately 13 km upstream, and the lower 3 km of Blackheath Creek.

The lower portions of minor tributaries and gullies where the topographic data define a clear, incised channel were also included in the hydraulic model.

Zones 2 and 3 include several areas outside the Sandy Creek main mining area/hydraulic model extent but still within the study area where potential flood impacts could occur. Flood impacts within these zones were assessed separately from the hydraulic model using other suitable assessment methods. These are:

- The potential for changed flooding behaviour and peak flows of Flyblowers Creek, north of the Sandy Creek catchment, during mine stages Year 12 to Year 20 (Zone 2).
- Proposed rail crossings along the rail spur that lie in the eastern portion of the study area and include Crossing 9 to Crossing 29 (Zone 3). These crossings were assessed using estimation methods based on catchment area and channel shape rather than detailed hydraulic modelling.

Flooding impacts of the power easement and water pipeline have not been considered significant because impacts on flooding will only occur during construction, and these will be addressed as part of the design for this infrastructure.

3. Available data

Section 3 details relevant data sourced and relied on for the assessment. In each case, the data were appraised for accuracy and suitability.

3.1 Topography and aerial photography

The following topographic and aerial photography data were used:

- For the Watershed Bounded Network Model (WBNM) hydrologic model catchment definition, 1:100,000 topographic maps (Cobbora 8733) and other topographic information supplied from the online Cobbora GIS portal were used.
- For hydraulic models, a digital terrain model was prepared using the 12D software, as follows:
 - ▶ CHC provided light detection and ranging (LiDAR) data prepared by AAM Hatch. The data were obtained from aerial laser survey of the study area between June and August 2009. The data were supplied as thinned ground points in ASCII format, and a triangulated irregular network was created with the LiDAR thinned points to form the digital terrain model. LiDAR data acquisition was controlled to achieve a vertical accuracy within 0.15 m root mean square (RMS) error. Horizontal coordinates were referenced to MGA zone 55, and elevations were reduced to Australian Height Datum (AHD).
 - ▶ CHC also provided 1 m contour data that were used to define topography in areas outside the extent of the LiDAR digital terrain model.
 - ▶ Cross-section surveys were undertaken in November 2011 at three locations within the Sandy Creek catchment for low-flow measurement purposes and these cross-section surveys were included in the hydraulic model for the December 2010 verification flood event.
- Aerial photography supplied from the online Cobbora GIS portal was used to estimate channel and floodplain roughness in the hydraulic model.

In addition, CHC provided the following design data sourced from the Cobbora GIS online portal:

- details of all proposed infrastructure for the mine
- details of mine layout during the various stages of the 21 years of active mining.

3.2 Design rainfall intensity data

Design rainfall intensity estimates were derived using *Australian Rainfall and Runoff* (Engineers Australia 2001). While these estimates are based on the statistical assessment of rainfall depths by the Bureau of Meteorology (BoM) in the mid-1980s, in the absence of more recent data, they remain the best available.

Intensity frequency duration (IFD) input parameters determined for the Sandy Creek catchment area are provided in Section 5 of this report.

3.3 Pluviograph records

Although there are no BoM rainfall stations operating within the Sandy Creek catchment, two on-site meteorological stations were installed by CHC in the study area between 2009 and 2011 (shown on Figure 1-1). An analysis of the daily rainfall data recorded by these stations between November 2010 and November 2011 matched well with nearby BoM rainfall gauges (Cobbora and Tallawang) and were therefore considered reliable.

The rainfall data received during the December 2010 flood event was captured by the on-site gauging stations and was used to verify the hydrologic and hydraulic models. This is discussed in Section 5.3 of this report.

3.4 Stream gauge records

A number of NSW Office of Water (NOW) stream gauges have previously operated near the Sandy Creek catchment. The Sandy Creek gauging station (421064) ceased to operate in 1985 and there is currently no active gauge station operating within the Sandy Creek catchment. Two other gauging stations along the Talbragar River have also ceased to operate. However, station 421042 'Talbragar River at Elong Elong' is an active station. It is located on the Talbragar River approximately 20 km downstream of the confluence of Sandy Creek and the Talbragar River, which is the downstream limit of the hydraulic model. Gauges 421042 and 421064 were both used in this flooding assessment and their locations are shown on Figure 1-1.

The flow record from Sandy Creek shows that for the period of record (1966–1985) the highest recorded mean daily flow was 8,937 ML/d, which occurred in February 1971. The highest maximum daily flow recorded at the Talbragar River flow gauge was 65,246 ML/d, which occurred in February 1971, and the highest mean daily flow recorded was 40,835 ML/d, which occurred in December 2010. Flow duration curves developed from these gauge records are presented and discussed in the *Baseline Hydrological Environment* report (which forms Appendix A to the surface water assessment report).

Flows recorded at the gauge on the Talbragar River at Elong Elong and at the gauge on Sandy Creek at Medway have been analysed for the period when these data records overlap (1970–1985). This analysis showed very little correlation between concurrent daily flows recorded at the Sandy Creek Medway gauge and the flows recorded at the Talbragar River Elong Elong gauge. However, detailed analysis of the recorded flows at these two gauges during annual peak events resulted in the following observations:

- Double-peak flow events were recorded at Elong Elong for most of the major events.
- In general, the first peak tends to be smaller and is recorded at the gauge one to two days earlier than the second higher peak.
- Events on Sandy Creek are generally single-peak; the peak tends to occur around the same time and be of similar magnitude to the first peak recorded at Elong Elong.
- For events where double peaks are not observed at the Elong Elong gauge, the recorded flow at Elong Elong is still comparable to the Sandy Creek peak flow within one day of the peak flow occurring in Sandy Creek.

The February 1971 flood event flows plotted in Figure 3-1 provide a typical example of this observation. The magnitude of the first peak at Elong Elong (shown in red on 01/02/1971) is comparable to the peak at Sandy Creek (shown in blue on 01/02/1971).

From this typical observation it can be concluded that:

- The first significant flow response at Elong Elong (which occurred on 01/02/1971) is mainly due to flow from the Sandy Creek catchment passing through Elong Elong on the Talbragar River.
- The peak flow at Elong Elong (which occurred on 03/02/1971) represents peak flows from the Talbragar River catchment upstream of the confluence with Sandy Creek.
- The trends described above generally occur following prolonged dry conditions when the Talbragar River and Sandy Creek are at baseflow or low-flow conditions. Following initial rainfall and onset of wet conditions, a double-peak pattern at Elong Elong is less evident due to high flows occurring in both systems and the higher flow in the Talbragar River dominating the flow record at Elong Elong.

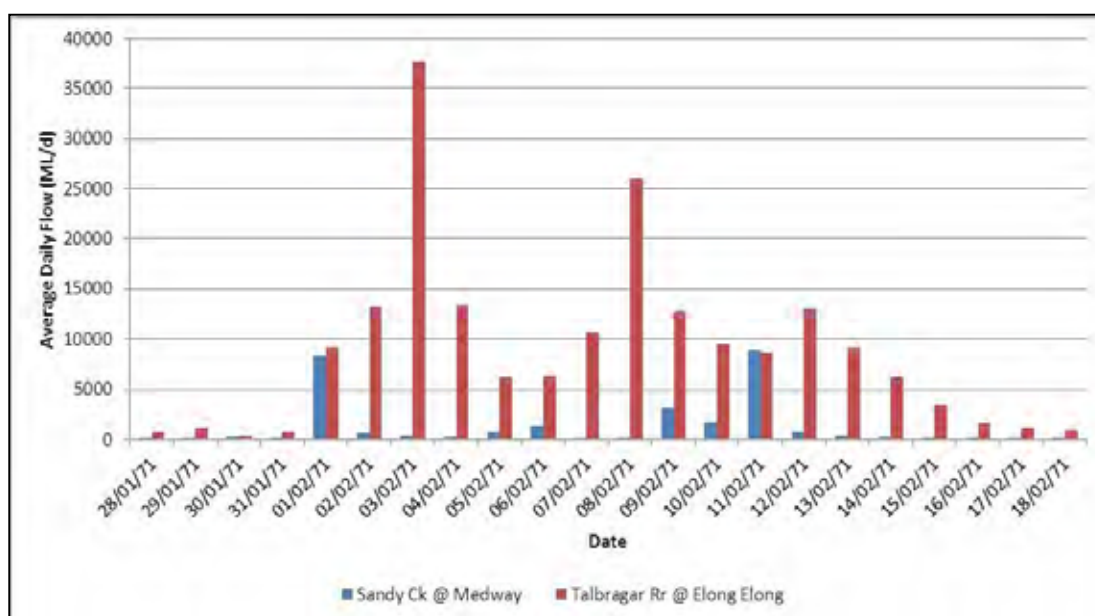


Figure 3-1 Comparison of Sandy Creek and Talbragar River average daily flow during the February 1971 event

The above observations suggest that the initial peak flows registered at Elong Elong during an event record the discharge from the smaller Sandy Creek catchment before the response from the larger Talbragar catchment, particularly for events occurring after prolonged dry conditions. Therefore, the instantaneous flows recorded at the Elong Elong gauge can be transposed to estimate instantaneous flows in Sandy Creek, where only mean daily flows are recorded.

Figure 3-2 presents the relationship between average daily flow at Sandy Creek and instantaneous peak flow in the Talbragar River on the same day that Sandy Creek peaks for reliable periods of overlapping records at both gauges. This comparison was made to identify patterns in the average daily flow record at Sandy Creek and the daily peak flows at Talbragar River.

Of the overlapping 15-year record, only 11 years of data were used in the comparison due to the potential unreliability of the remaining data. Figure 3-2 confirms that a reasonable correlation can be established between the daily flow at Sandy Creek and the instantaneous peak flow in the Talbragar River at Elong Elong for those years where the data are considered reliable.

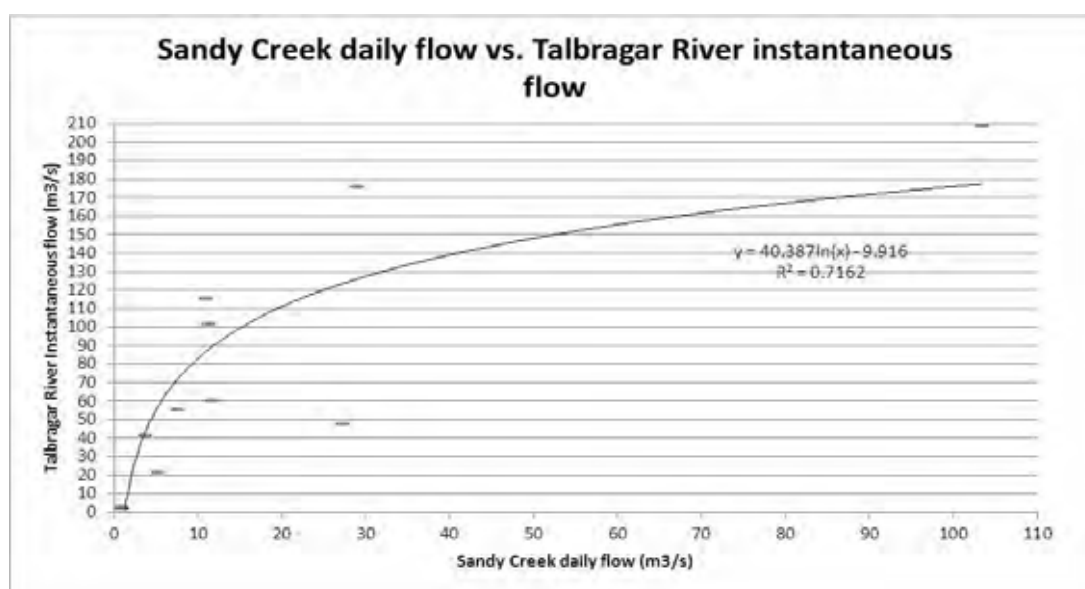


Figure 3-2 Relationship between Sandy Creek daily flow and Talbragar River instantaneous flow during annual peak events

3.5 Water level data

Water level gauges were established within the study area. Data were collected to obtain an understanding of the existing baseflow conditions when we identified that there were no flow records for the study area.

Three gauges (SW1, SW2 and SW3) were installed in the Sandy Creek catchment and have been operational since November 2009. Only water level data, not flow data, were collected at the gauging stations and one low flow measurement was taken at the three sites in November 2011.

While this information would be useful for a low-flow analysis, the data are of limited use for flooding assessment due to the short duration of record (November 2009 to February 2012) and data gaps. The data therefore do not provide an understanding of high-flow or flooding behaviour at these sites. However, the water levels recorded at the three gauges during the December 2010 flood event were used to verify the hydrologic and hydraulic models, as discussed in Section 5.3.

3.6 Other data

In addition to the above, the following data were used in the flood impact assessment:

- aerial photography, vegetation, terrain and waterways topographic information reviewed from the online GIS portal
- photographs and site understanding developed during a number of site inspections during 2010 and 2011.

4. Flood frequency analysis and flood history

4.1 Flood frequency analysis

Where sufficient flood records are available, the relationship between flood magnitude and flood frequency can be obtained through flood frequency analysis. Flood frequency analysis provides a statistical analysis of recorded stream flows, allowing us to estimate the magnitude of floods of a selected probability of exceedence. For long-duration records, Book IV of *Australian Rainfall and Runoff* (Engineers Australia 2001) recommends that the 1-in-100 annual exceedence probability (AEP) flood is the largest event that should be estimated by direct frequency analysis for important work, and that the maximum flood that should be estimated by this means under any circumstances is the 1-in-500 AEP event.

Flow has been recorded at the Talbragar River gauge at Elong Elong (421042) for 41 years (from 1970 to 2011). This is a relatively long period of record and is acceptable for flood frequency analysis. A log-Pearson type III (LPIII) distribution was fitted to the data using the flood frequency analysis software HEC-SSP. The analysis was based on the method described in Book VI, Section 2.7.2 of *Australian Rainfall and Runoff* (Engineers Australia 2001).

The results are summarised in Table 4-1 and Figure 4-1. The design peak 100-year average recurrence interval (ARI) discharge at Elong Elong was estimated to be 1,234 m³/s. This estimated flow relates to the second flow response of the Talbragar River observed during historical flood events that is governed by flows from the wider Talbragar catchment, rather than the first, and lower, flow response that is related to outflow from the Sandy Creek catchment to the Talbragar River. Refer to Section 3.5 for further discussion.

Table 4-1 Flood frequency analysis — Talbragar River at Elong Elong

Storm event	Estimated flow (m ³ /s)	Estimated 95%-ile lower bound flow (m ³ /s)	Estimated 95%-ile upper bound flow (m ³ /s)
2-year ARI	43	27	68
5-year ARI	169	104	306
50-year ARI	893	469	2,113
100-year ARI	1,234	624	3,103

A flood frequency analysis for the Sandy Creek gauge at Medway (421064) was also considered; however, given the shorter period of record available (i.e. 15 years) and lack of maximum daily flow data, statistical analysis of this data was considered to be less reliable and was not carried out. An alternative method was developed to overcome this issue by translating flows estimated for the Talbragar River from flood frequency analysis of the Elong Elong record to Sandy Creek. This analysis is discussed in Section 5.3.1.

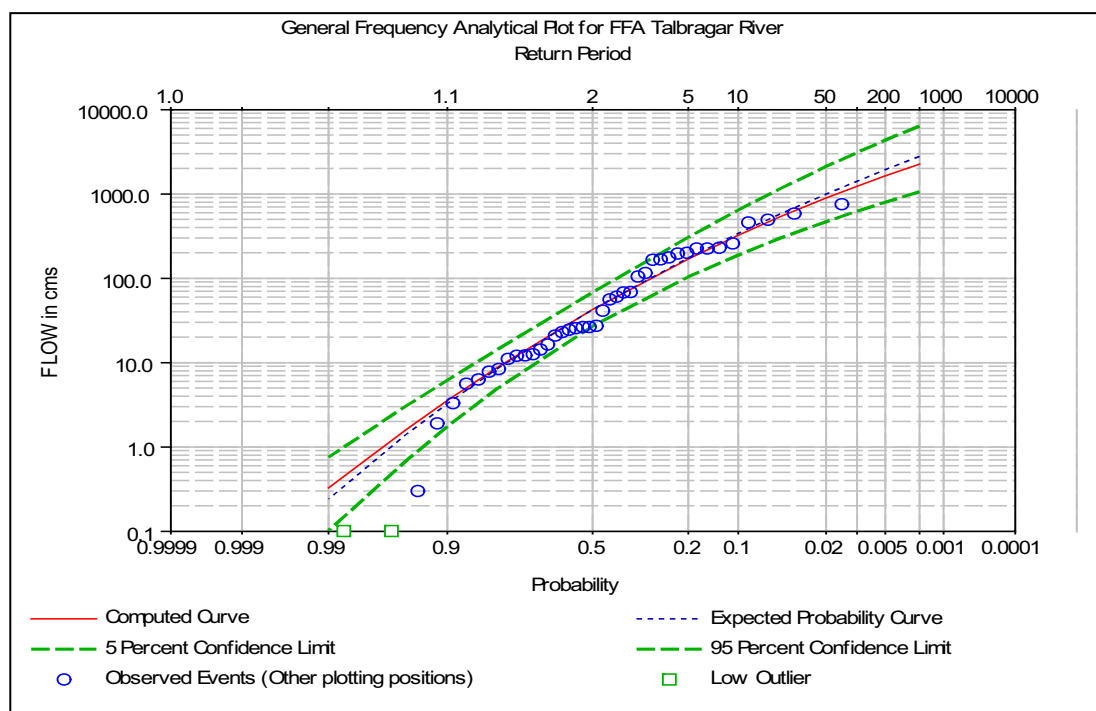


Figure 4-1 Annual series flood frequency analysis — Talbragar River at Elong Elong

4.2 Flood history

Flood information is limited in the study area and no flood studies are available for the Talbragar River, Sandy Creek or Laheys Creek. Dubbo City Council commissioned a *Talbragar River Flood Study* (Rust PPK 1995); however, this study only considered the reach of the Talbragar River immediately upstream from Dubbo.

Warrumbungle Shire Council indicates there is no flood information available for the Talbragar River in the vicinity of Cobbora (P Southwell 2009, pers. comm.). Further communication with Warrumbungle Shire Council and the Dubbo State Emergency Service office (A Luzuriaga 2009, pers. comm.) indicates that flood information for the Talbragar River at Cobbora is very limited.

It was suggested the major periods of flood concern for the Talbragar River are when the Macquarie River is also flooding. However, coinciding high flows in the Macquarie and Talbragar rivers rarely cause a flood risk for Dubbo, which is located near the confluence. The February 1955 flood reflected such conditions — the Talbragar River ‘backed up’ the Macquarie River, causing extensive inundation of parts of central and northern Dubbo (A Luzuriaga 2009, pers. comm.).

In December 2010, the Talbragar River experienced its biggest flood since 1955, and again water backed up in the Macquarie River because the Talbragar River was flowing at a higher level. As a result, the Macquarie River flooded parts of the Dubbo central business district (*Daily Liberal* 2011).

The Dubbo Local Flood Plan suggests that the Talbragar River floods ‘every few years’, with only the floods of 1870, 1920, 1926, 1950 and 1955 known to have flows that have risen above bank level and entered the surrounding floodplain.

The 1955 flood is stated to be the most severe, estimated to be a 200-year ARI event (Department of Natural Resources 2006). High rainfall in the upper catchment also produced high-velocity flows across the catchment, removing large areas of topsoil and damaging houses. The township of Ballimore was inundated with depths over 1 m. However, Ballimore is approximately 30 km downstream of Cobbora and the depths there cannot be correlated to the study area.

Since the Dubbo Local Flood Plan was prepared, the December 2010 flood event caused extensive damage and losses to agriculture, infrastructure and households in the lower Macquarie River. The December 2010 floods were the largest recorded since 1955 in the Talbragar River and the largest recorded since 1990 for the Macquarie River at Dubbo (*Daily Liberal* 2011). In contrast, the floods of 1920 and 1950 (the next highest) were known to result only in backwater flooding in low spots along the Talbragar River.

5. Hydrologic analysis

5.1 Overview

Hydrologic modelling is the process of determining runoff generated from rainfall on a catchment. The runoff estimates are then used by the hydraulic analysis, as described in Section 6. Factors affecting the volume and peak of runoff generated include:

- size and slope of the catchment and adjoining channels
- level of development (fraction impervious) and type of catchment land use
- condition of the catchment (dry or saturated) when the rainfall starts
- intensity and temporal pattern of rainfall
- ability of the catchment and other features to store runoff.

Simplistic methods exist for estimating the amount of runoff from a catchment (i.e. peak flow methods like the Rational Method). However, modelling software is necessary to accurately predict the response of large and complex catchments to rainfall over time, and the interaction between sub-catchments. For this assessment, a hydrologic model of the Sandy Creek catchment was developed using the Watershed Bounded Network Model (WBNM) software program.

5.2 Runoff routing model

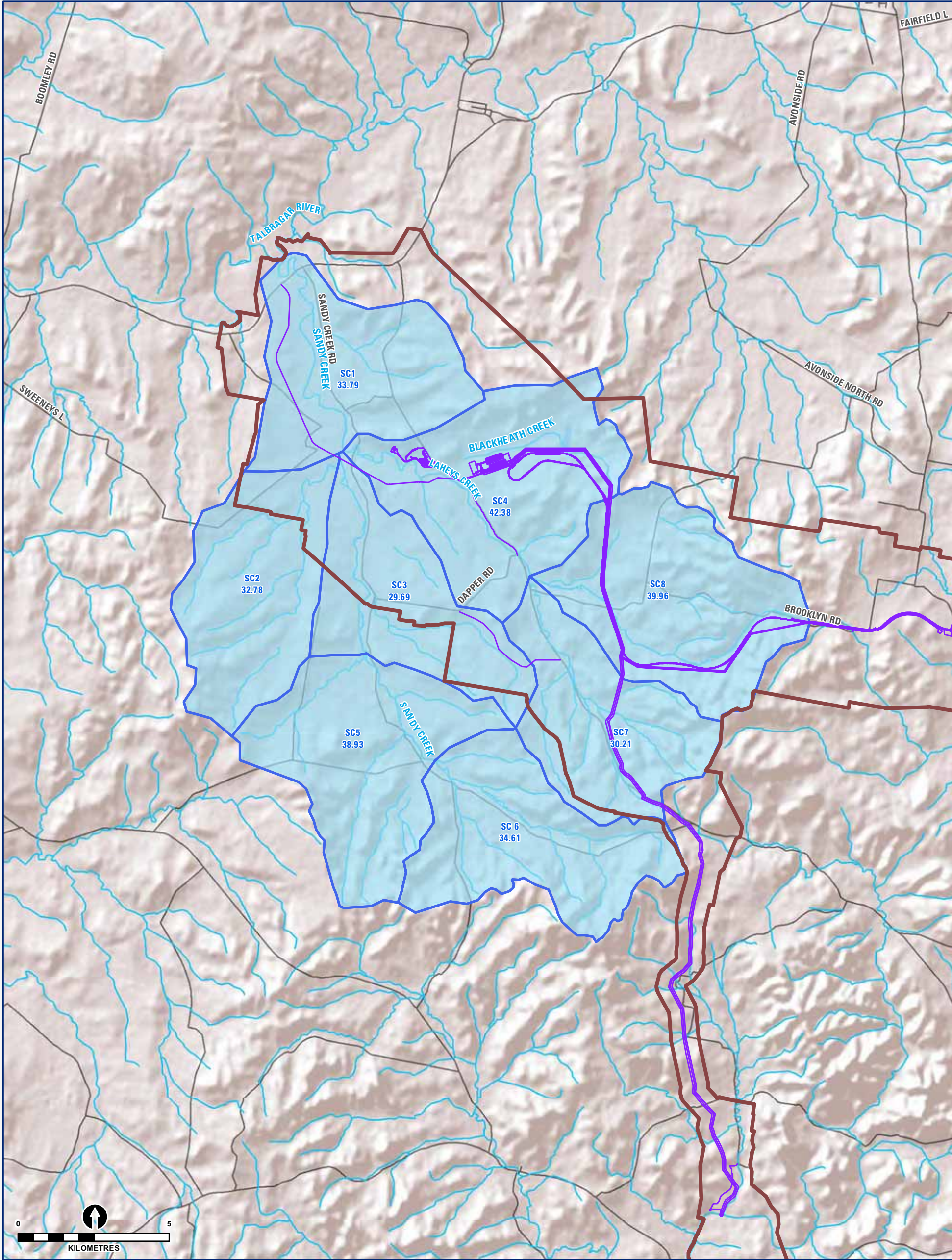
WBNM has been used extensively across NSW for urban and rural flood investigations. WBNM is an event-based hydrologic model that calculates flood hydrographs from either recorded storm rainfall hyetographs or design storm rainfall parameters. The catchment is represented in the model as a series of sub-catchments for which factors affecting runoff, such as land use (proportion of pervious versus impervious land surfaces), rainfall losses, and runoff routing through the catchment and channels, are defined.

Details of how WBNM was used to represent the Sandy Creek catchment are provided below. The model of the Sandy Creek catchment developed for this study was used to estimate flow generated from the catchment for the 2-, 5-, 100- and 2,000-year average recurrence interval (ARI) design storm events to represent a reasonable range of extreme event flood conditions.

5.2.1 Catchment area

The Sandy Creek catchment has a total area of 282.35 km². The catchment was divided into eight sub-catchments for greater definition of catchment parameters within the WBNM model. The sub-catchment breakdown is illustrated in Figure 5-1.

Catchment parameters, such as sub-catchment area, percentage imperviousness, sub-catchment links and channel definition within the catchment, were defined using available topographic contour data and a review of aerial photography of the area. The catchment was assumed to be completely pervious based on a review of aerial photography and knowledge of the catchment.



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- Project application area
- Mine infrastructure
- Drainage lines
- Roads
- Subcatchments

Figure 5-1 Sandy Creek subcatchments

5.2.2 Design rainfall loss rates

Design rainfall loss rates adopted to represent initial and continuing losses were based on recommendations within *Australian Rainfall and Runoff* (Engineers Australia 2001). Adopted loss values are given in Table 5-1.

Catchment lag parameters and stream lag factors were based on recommendations within WBNM Theory (Boyd et al. 2007). The lag parameter for all sub-catchments was adopted as 1.8. A stream lag factor of 1 was adopted for the natural channels in the catchment.

Table 5-1 Adopted loss values

Storm event	Initial loss (mm)	Continuing loss (mm/h)
2-year ARI	30	2.5
5-year ARI	30	2.5
100-year ARI	20	2.5
2,000-year ARI	0	0

5.2.3 Estimation of design rainfall

Estimation of the design flood hydrographs, using the runoff-routing modelling technique, involves the application of the design rainfall event data. Rainfall-based design flood estimation assumes the probability of the design flood event is the same as the associated design rainfall event.

Design rainfall depths of storm events were calculated by WBNM by proportioning from storm data derived from the intensity frequency duration (IFD) method, as defined in Chapter 2 of *Australian Rainfall and Runoff*, Volume 2 (Engineers Australia 1987, 2001). The IFD parameters adopted for this study and input into the WBNM model developed for the Sandy Creek catchment are shown in Table 5-2.

Table 5-2 Sandy Creek catchment IFD parameters

Variable	Symbol	Value
Rainfall intensity (mm/h) (2-year ARI; 1-hour storm duration)	$^2I_1$	26.6
Rainfall intensity (mm/h) (2-year ARI; 12-hour storm duration)	$^2I_{12}$	4.7
Rainfall intensity (mm/h) (2-year ARI; 72-hour storm duration)	$^2I_{72}$	1.18
Rainfall intensity (mm/h) (50-year ARI; 1-hour storm duration)	$^{50}I_1$	50.3
Rainfall intensity (mm/h) (50-year ARI; 12-hour storm duration)	$^{50}I_{12}$	8.9
Rainfall intensity (mm/h) (50-year ARI; 72-hour storm duration)	$^{50}I_{72}$	2.3
Average coefficient of skewness	G	0.32
Geographical factor (2-year ARI)	F2	4.33
Geographical factor (50-year ARI)	F50	15.65

5.2.4 2,000-year ARI event

5.2.4.1 Probable maximum precipitation design rainfall

To estimate the 2,000-year ARI design rainfall, the probable maximum precipitation (PMP) rainfall depths need to be calculated. Depths were calculated using the procedures outlined in *The Estimation of Probable Maximum Precipitation in Australia: generalized short duration method* (the GSDM) (Bureau of Meteorology 2003).

Parameters used in the PMP calculations are detailed in Table 5-3. The moisture adjustment factor was determined based on Figure 3 in the GSDM. The elevation adjustment factor was adopted as 1, as the site elevation is below 1,500 mAHD. The roughness parameter used in PMP calculations is a measure of how steep the catchment is. Topographic maps were used to determine this parameter.

Table 5-3 Sandy Creek PMP calculation parameters

Parameter	Value
Moisture adjustment factor	0.71
Elevation adjustment factor	1
Percentage defined as 'rough'	95%

The temporal rainfall distribution for the PMP event was adopted from procedures outlined in the GSDM.

5.2.4.2 2,000-year ARI design rainfall

The 2,000-year ARI rainfall depths were calculated based on procedures documented in *Australian Rainfall and Runoff* (Engineers Australia 2001), which are based on log relationships between the 50-year ARI, 100-year ARI and PMP rainfall depths. The temporal rainfall distribution for the PMP was adopted for the 2,000-year ARI event.

5.3 Model validation

5.3.1 Fitting to flood frequency analysis

To assess the reasonableness of the WBNM estimates, 2-year, 5-year and 100-year ARI peak flows at Sandy Creek were estimated based on the available (albeit limited) stream flow data.

Although the preferred approach for estimating peak flow in Sandy Creek would be to carry out a flood frequency analysis, the flow record at the Medway gauge was considered unsuitable, as it only recorded average daily flows and not daily maximum flows. It was therefore necessary to develop an alternative analysis method that would use the available peak flow data, as estimated from the flood frequency analysis carried out on the Elong Elong gauge data, to validate the Sandy Creek WBNM model outputs.

To correlate a peak flow recorded in the Talbragar River to a peak flow in Sandy Creek, a relationship between annual peak flows in the Talbragar River and Sandy Creek was established. This relationship was based on the key assumption that a peak flow in Sandy Creek would be approximately equivalent to the first peak flow recorded at the Elong Elong gauge during an annual peak flow event. The relationship between first and second peaks at Elong Elong could then be used to derive annual maximum peak flow estimates in Sandy Creek. Figure 5-2 shows that a reasonable correlation can be achieved for this relationship. This relationship was used to estimate peak flows in Sandy Creek.

It should be noted that this approach would tend to overestimate peak flow in Sandy Creek, as the Talbragar River was assumed to experience negligible base flow at the time the flood peak at Sandy Creek would pass the Elong Elong gauge. Overestimation will occur when the gap between the two peaks is narrow, which would mean that flow in the Talbragar River is likely to be higher than baseflow. The shorter the gap between the two peaks, the greater the overestimation.

Thus, in addition to flow estimates using flows obtained from the flood frequency analysis curve at Elong Elong, lower bound estimates using the lower bound 95%ile confidence envelopes of the flood frequency analysis curve were also calculated for comparison. It is expected that the true peak flow in Sandy Creek would be between these two values and was likely to be lower than the estimated value.

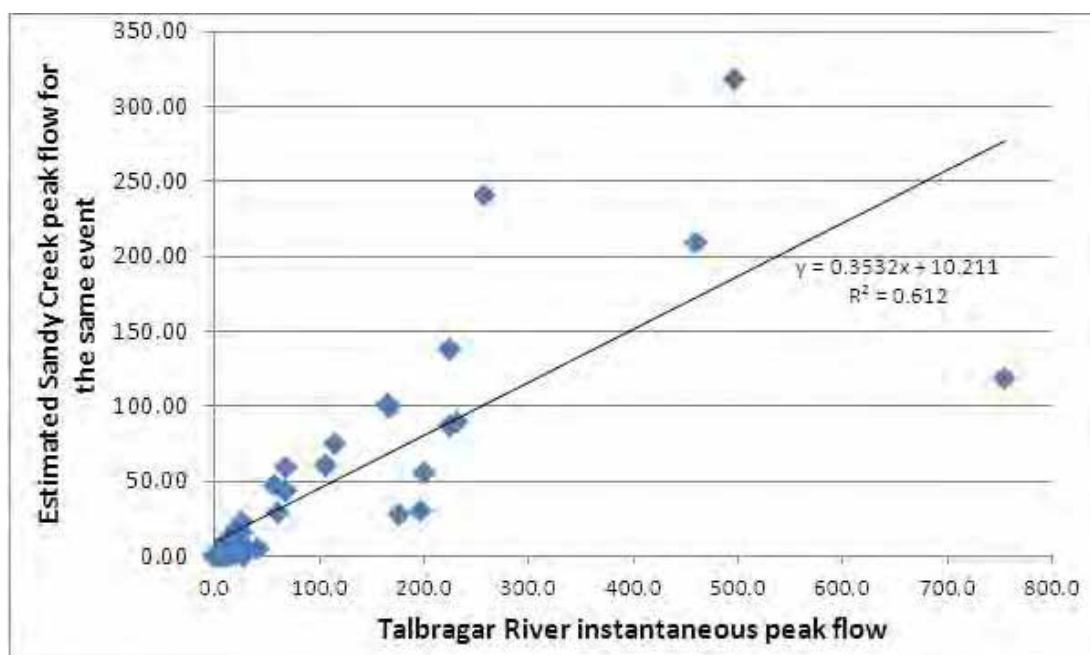


Figure 5-2 Relationship between estimated Sandy Creek peak flow and Talbragar River instantaneous peak flow during annual peak events

The model validation results are summarised in Table 5-4. The modelled peak flows are within the range of estimated peak flows from FFA of the recorded data on the Talbragar River transposed to Sandy Creek.

Table 5-4 Model validation summary

Event	Estimated range of Sandy Creek peak flow m ³ /s (by translation from Talbragar flood frequency analysis)			WBNM modelled peak flow m ³ /s
	Estimated value	95%ile lower bound	95%ile upper bound	
2-year ARI	25	20	34	29
5-year ARI	93	47	118	78
100-year ARI	446	231	1,106	429

5.3.2 December 2010 flood event analysis

Water level data was collected at three sites in the Sandy Creek catchment to obtain an understanding of the existing baseflow conditions. As discussed in Section 3.4, the use of these data for high-flow/flooding assessment is limited due to the type of data (i.e. water level, not flow data) and the relatively short time span of the record (November 2009 to February 2012).

The water level gauges at these sites did, however, capture a significant flood event that occurred in December 2010. Using the pluviograph records from the on-site meteorological stations, an attempt was made to verify the hydrologic and hydraulic models against this event.

The Bureau of Meteorology states that 2010 was the third wettest year on record for NSW and had the highest rainfall recorded in the state in over 50 years, following the very strong La Niña events in 1956 and 1950 and slightly higher than the rainfall recorded during strong La Niña events in the 1970s (Bureau of Meteorology 2011). Over the three-day period from 29 November to 1 December 2010, the total rainfall recorded at the on-site meteorological station was 217 mm, with 89 mm recorded on 1 December 2010 (see Figure 5-3).

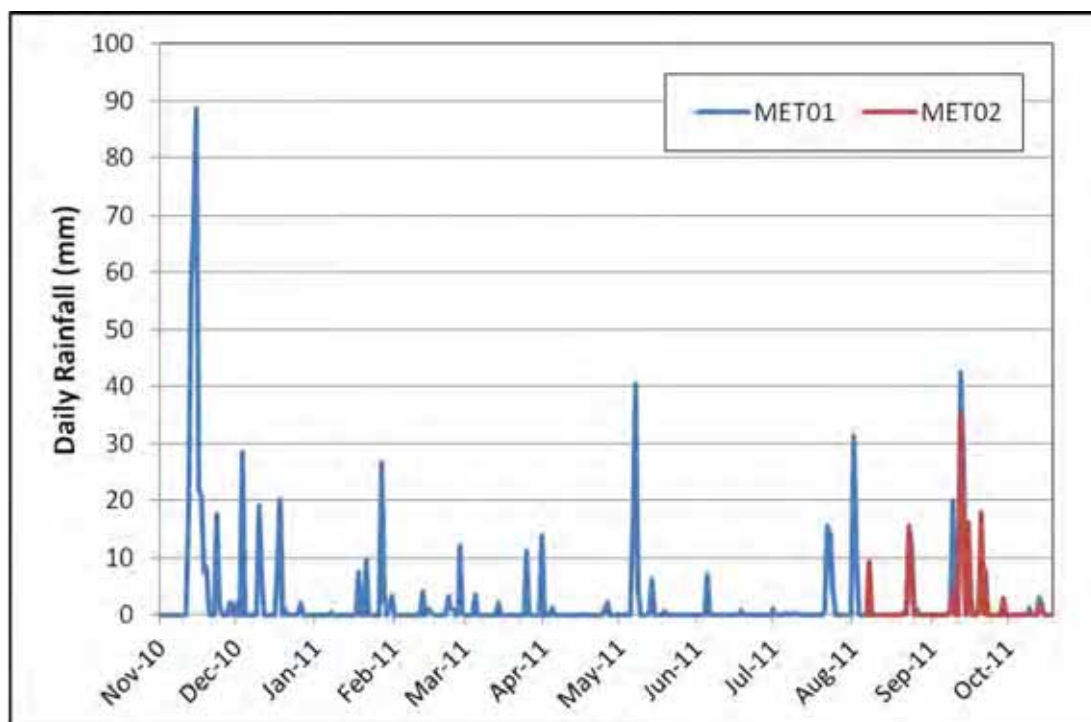


Figure 5-3 Daily rainfall recorded at on-site meteorological weather stations

An analysis of the rainfall recorded at the on-site meteorological stations for the period from 28 November to 6 December 2010 was carried out using the Wollongong University IFD Program. The analysis found that for a duration of 18 hours (which is the critical duration for the Sandy Creek catchment predicted by the WBNM model) the December 2010 event had an intensity comparable to a 20 to 50-year ARI design event. For durations longer than 36 hours and up to 72 hours, the rainfall intensity was in excess of a 100-year ARI design event.

When the WBNM model was run using the December 2010 recorded rainfall, the peak flow predicted at the outlet of the Sandy Creek catchment for this event was reasonably close to the 50-year ARI design flow estimated by the model (i.e. 374 m³/s predicted for the December 2010 event compared with 340 m³/s estimated for the 50-year ARI design event).

When the hydraulic model was run using the December 2010 rainfall recorded at the on-site meteorological station, the model over-predicted water levels by 0.8 m at SW2 but was within +/- 0.5 m at SW1 and SW3 compared with the recorded water levels at the gauge sites. The reasons for the model overestimation of peak flood level have not been identified, but are likely to be due to a combination of the following:

- The LiDAR data, which define channel topography in the flood model, have a vertical accuracy of +/- 0.15 m. The LiDAR data also do not always capture a detailed resolution of the low-flow portion of the channel due to the presence of vegetation or a steeply incised low-flow channel.

- The channel surveys at the water level recording stations were surveyed to temporary benchmarks. The survey data were converted to mAHD using an estimation procedure that involved correlating the survey to LiDAR contours; this method is significantly uncertain.

5.3.3 Conclusion

A flood frequency analysis was carried out for the data recorded in the Talbragar River at Elong Elong. It was not possible to perform a flood frequency analysis on the Sandy Creek recorded data due to a very short flow record and lack of suitable data. Since no suitable data are available for peak/maximum flows in Sandy Creek for model calibration (only average daily flows are available), a number of relationships were developed to relate the recorded Talbragar River instantaneous flows to the daily average flows at Sandy Creek, and to relate the first and second peaks recorded during annual flood events in the Talbragar River to the Sandy Creek gauge. It was then possible to relate the flood frequency analysis results at Talbragar River to Sandy Creek.

The WBNM model peak flow estimates lie within the range of the translated flood frequency analysis estimates. This provides a reasonable validation of the WBNM model and confirms that the model is reliable for flood flow estimation in Sandy Creek.

This conclusion is supported by the analysis undertaken for the December 2010 flood event, for which the WBNM model estimated a flow return period comparable to the return period estimated by Bureau of Meteorology based on rainfall records.

Verification of the hydraulic model to the peak water levels recorded during the December 2010 flood event was inconclusive. The model overestimated the peak flood level; however, this could be due to the combined errors in several sources: the LiDAR data used to define topography in the hydraulic model, the channel survey and the measured water level data.

Because the hydrological model has been validated and verified satisfactorily, the flood model was considered to be a reliable tool for estimating flood parameters within the modelled portion of the Sandy Creek catchment.

5.4 Existing case design flows

Peak flows generated within the Sandy Creek catchment are shown in Table 5-5. These flows have been taken from the outlet of the model (i.e. the downstream end of Sandy Creek, immediately before the junction with the Talbragar River).

Table 5-5 Peak flows at outlet of Sandy Creek (existing case)

Event	Critical duration minutes (hours)	Peak flow (m ³ /s)
2-year ARI	1,080 min (18 h)	29
5-year ARI	1,080 min (18 h)	78
100-year ARI	1,080 min (18 h)	429
2,000-year ARI	360 min (6 h)	1,354

5.5 Proposed case design flows

The proposed case hydrology was based on the surface water catchments contained in the surface water management plan developed as part of the *Water Balance and Water Management System* report (refer to Appendix E of *Surface Water Assessment* report).

The surface water management plans for Year 1, Year 4, Year 12, Year 16 and Year 20 were compared in relation to disturbed areas, active-mining area, catchment area lost, number of diversions and overflow from clean-water dams. Year 21 represents the final rehabilitated landform. In particular, the latter stages of the active mine — Years 12, 16 and 20 — were closely analysed.

Based on this assessment, it was concluded that the Year 20 mine plan represents the maximum disturbed catchment area during active mining since it has the largest area of catchment diverted from Sandy Creek into Laheys Creek and the largest rehabilitated areas.

At Year 20, parts of the lower catchment of Sandy Creek will be diverted upstream of the junction of Laheys Creek with Sandy Creek. The catchment area of the lower Sandy Creek will be decreased by this diversion and by the removal of catchment due to open-mining areas. As a result, the catchment area discharging into the middle section of Laheys Creek will be increased. However, overall the total catchment area of the Sandy Creek catchment will be decreased due to the active-mining areas and areas draining into the mine.

At Year 20, approximately 1,270 ha of catchment area will be lost to active-mining areas or diverted outside the Sandy Creek catchment. For 86 ha of the diverted catchment, surface water will be diverted north along the edge of mining area C to the catchment of Flyblowers Creek which joins the Talbragar River less than 1 km upstream of the Sandy Creek confluence. This is discussed in further detail in Section 7.1.2.

Year 20 was identified as the critical mine stage for flooding since it will have the highest flows entering the creeks due to the catchment diversions described above.

Catchment losses were adjusted based on the portion of disturbed areas, which included rehabilitated spoil, coal stockpiles, out-of-pit emplacements and cleared areas. Percent impervious levels were also calculated based on the area of haul roads, rail spur and paved mine infrastructure areas in each of the eight existing sub-catchments.

Of these eight, only four sub-catchments experienced changes to catchment characteristics. Only two of the sub-catchments (SC1 and SC4) experienced major changes in catchment characteristics. Percent impervious increased in most of the affected sub-catchments.

Table 5-6 summarises the peak flows at the outlet of Sandy Creek based on the Year 20 catchments. It was found that the critical duration for the 2-year ARI event at some locations around the mine infrastructure area differs from the critical storm duration of 1,080 minutes under existing conditions.

The local critical duration is 360 minutes and the flows corresponding to this storm duration were used at these locations for the hydraulic analysis in parts of Laheys Creek. The overall critical duration in the Sandy Creek catchment remains the same as existing conditions (i.e. the 1,080-minute storm). For other ARI events, the critical duration for the proposed case was the same as the existing case.

Table 5-6 Proposed case peak flows at outlet of Sandy Creek

Event	Critical duration in minutes (hours)	Peak flow (m³/s)
2-year ARI	1,080 min (18 h)	31
5-year ARI	1,080 min (18 h)	83
100-year ARI	1,080 min (18 h)	432
2,000-year ARI	360 min (6 h)	1,355

6. Hydraulic analysis

6.1 Hydraulic models

The main hydraulic model used in the assessment was a HEC-RAS model developed for Sandy Creek including its main tributaries — Laheys Creek and Blackheath Creek — as well as numerous smaller unnamed tributaries. The model extends from near the junction of Sandy Creek and the Talbragar River, about 25 km upstream along Sandy Creek and includes approximately 15 km of Laheys Creek. The model extent is shown in Figure 6-1.

In addition, two smaller localised HEC-RAS models were developed for significant creek crossings of Fords and Tallawang Creeks along the rail spur outside of the Sandy Creek catchment.

HEC-RAS is a one-dimensional hydraulic model that can simulate steady or unsteady flow in rivers and open channels. The river channel and floodplain is represented in HEC-RAS as a series of topographic cross-sections. The model can assess the effects of obstructions, such as bridges, culverts, weirs, and structures in the channel and floodplain.

6.1.1 Cross-section geometry development

6.1.1.1 Sandy Creek catchment model

A digital terrain model covering the extent of the hydraulic model was constructed using LiDAR data and 1 m contours provided by CHC (see Section 3.1).

Cross-sections of the river channel and floodplain were extracted from the digital terrain model every 300 m to 400 m along the 25 km length of Sandy Creek, Laheys Creek and minor tributaries. Cross-sections varied in width from about 300 m to 700 m depending on the depth and size of the channel and width of floodplain. Figure 6-1 shows the modelled reaches in red and model cross-sections in pink.

Cross-sections at three gauging locations (SW1, SW2 and SW3) were surveyed in November 2011. For each of the three locations, cross-section surveys were undertaken at the control (i.e. the road causeway) and at the pool where the gauge is located. These cross-section surveys aim to measure low- to medium-range flow, so their applicability to flood modelling is limited. However, the cross-sections at each of the surface water gauge locations were added into the HEC-RAS model for the purposes of model verification (see Section 5.3).

6.1.1.2 Fords Creek and Tallawang Creek models

For the localised models of the rail crossings of Fords Creek and Tallawang Creek, the cross-sections of the channels and floodplains were extracted from the same digital terrain model at intervals of 100 to 250m, with closer cross section intervals in the areas of the proposed crossing structures.

6.1.2 Boundary conditions

6.1.2.1 Sandy Creek catchment model

Inflows were assigned to reaches of the hydraulic model for each stream/tributary, based on the flow outputs of the hydrologic model.

The downstream limit of the hydraulic model is located at the confluence of Sandy Creek with the Talbragar River, approximately 600 m north-west of the Golden Highway. The model was run using a normal-depth boundary based on a downstream bed slope of 0.32%.

The use of a normal-depth boundary to create a rating curve was based on the assumption that when the Sandy Creek peak reaches the Talbragar River, the Talbragar River is flowing under normal baseflow conditions. This assumption can be justified by the observation that peak flows at the Talbragar River tend to reach the confluence of the two water bodies about one to two days after the Sandy Creek peak flow has passed through the confluence.

A sensitivity analysis was undertaken using a high water level of 348 mAHD, which generates a high water depth of 6.5 m at the downstream boundary. Under these conditions, which test the scenario of extreme flooding in the Talbragar River, it was found that water levels in the lower 2.7 km of Sandy Creek only are affected by the Talbragar River level. This indicates that flooding in the Talbragar River does not affect water levels in the middle and upper reaches of Sandy Creek. Thus, the scenario of flooding in the Talbragar River was not considered further for this study.

6.1.2.2 Fords Creek and Tallawang Creek models

The catchment area of Fords Creek draining to the rail crossing is approximately 23 km²; this includes the Fords Creek system that flows east to west along the northern edge of the proposed railway. Although this is a significant creek system, the topography shows that there is no defined channel shape in this location. It is expected that multiple cross-drainage culverts will be required at this location depending on the extent of the floodplain in this area. Given the relatively flat topography, it is envisaged that standard box/pipe culverts and associated scour protection measures will be suitable for the cross-drainage system. A preliminary design for this crossing is presented in Section 6.3.2.

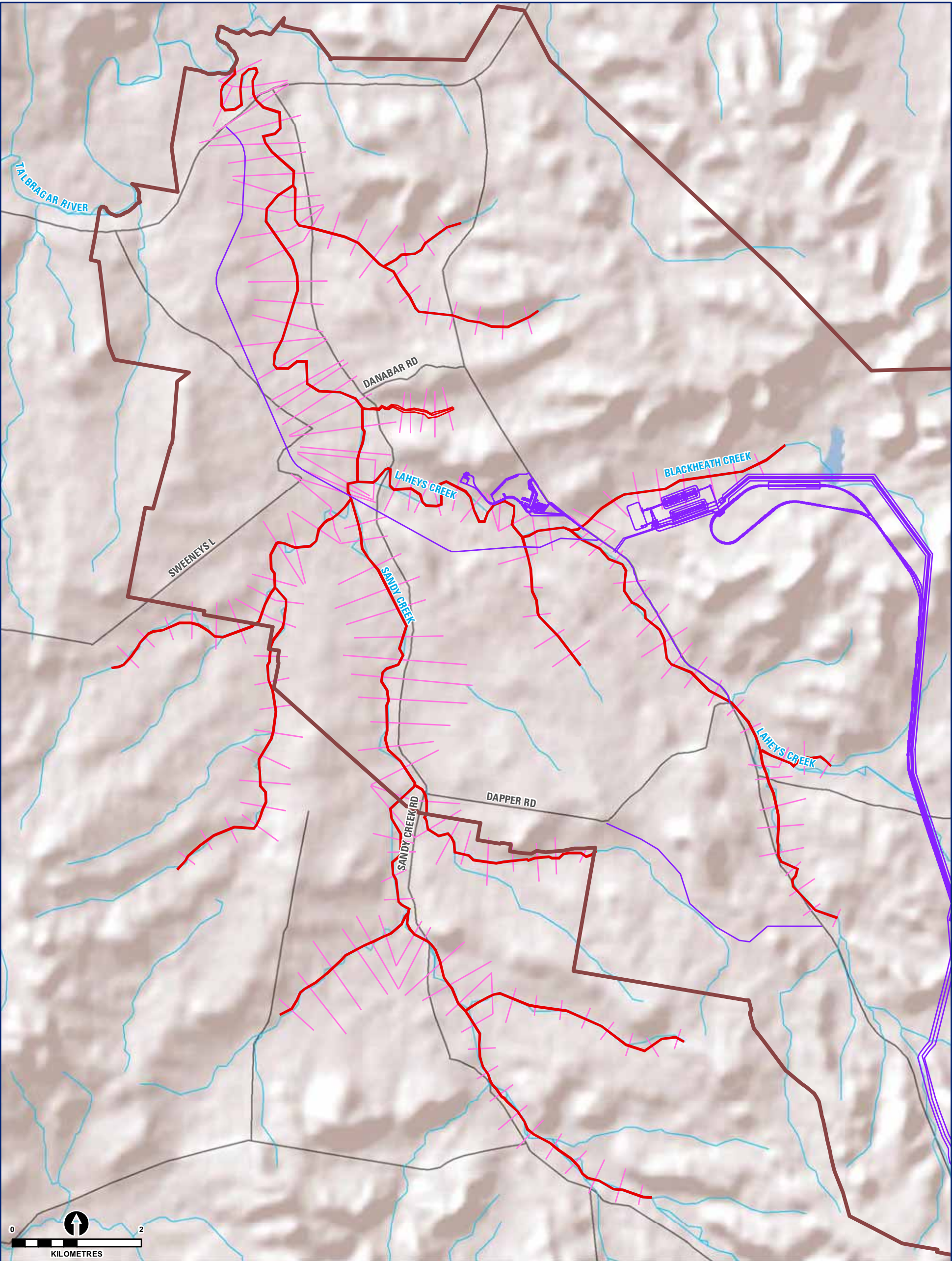
The Tallawang Creek crossing is located approximately 2 km west of the location where the proposed rail spur ties into the existing railway line. At this location, the rail spur is proposed to cross Tallawang Creek and one of its tributaries about 400 m upstream of their confluence. The total upstream catchment area draining to this location is about 44 km². There are two deeply incised channels at this crossing location, each with a channel depth of 4–5 m and a width of 40–50 m. Two separate bridges spanning each of the channels will be required at this location. A preliminary design for this crossing is presented in Section 6.3.2.

Design flows for Fords and Tallawang Creeks were estimated using rainfall runoff models (XP-RAFTS) and design parameters recommended in Australian Rainfall and Runoff (Engineers Australia 2001) and Bureau of Meteorology (BoM 2003). The estimated design flows are shown in Table 6-1.

Table 6-1 Design flows for Fords Creek and Tallawang Creek rail crossings

Catchment	Design peak flow (m ³ /s)	
	100 year ARI	PMF
Fords Creek	53	909
Tallawang Creek west channel	40	640
Tallawang Creek east channel	45	735
Tallawang Creek total	85	1375

Downstream boundary conditions were set using a normal depth boundary at sufficient distance downstream of the crossing location so that water levels at the boundary did not affect those computed by the models at the crossing locations.



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Modelled reaches	Project application area
HEC-RAS cross sections	Drainage lines
Mine infrastructure	Roads

Figure 6-1 Sandy Creek model extent and cross sections

6.1.3 Roughness

Manning's n roughness parameters are used to represent the type of channel and varying land cover across a floodplain to allow the model to simulate changes in flow behaviour as water crosses different surfaces. Each cross-section is assigned Manning's n roughness values based on the channel characteristics and land cover across the floodplain. The Manning's n values adopted for the modelled channels and floodplain sections were based on knowledge of the site developed during site inspections, aerial photograph interpretation and engineering judgement and experience.

The predominant Manning's n values adopted in the hydraulic model for the main channel and floodplain are given in Table 6-2.

Table 6-2 Adopted roughness values for Sandy Creek

Terrain type	Manning's n
Floodplain, short grass, meandering	0.054
Floodplain, medium grass, shrubs, trees, meandering	0.09
Existing creek channel, reeds, shrubs, meandering	0.05 to 0.08

6.2 Modelled scenarios

6.2.1 Sandy Creek catchment model

The model was run for the 2-, 5-, 100- and 2,000-year average recurrence interval (ARI) events for two catchment scenarios:

- The existing scenario, which represents the current state of the Sandy Creek catchment based on LiDAR data collected in July 2009.
- The proposed scenario, which incorporates worst-case mine development for flooding (i.e. Year 20) and associated mitigation measures. The proposed scenario represents the mine infrastructure area, mining areas and out-of-pit emplacement areas. The proposed scenario model has taken into account areas where levees and erosion protection will be needed to protect vulnerable infrastructure from inundation and erosion during extreme flood events.

6.2.2 Fords Creek and Tallawang Creek models

These models were run for the 100 year ARI and PMF events for:

- The existing scenario, which represents the current state of the catchments based on the LiDAR data.
- The proposed scenario, which incorporates the rail spur embankment and associated creek crossing structures.

6.3 Modelled structures

6.3.1 Existing scenario

For the existing scenario, no structures were included in the HEC-RAS hydraulic model. Although aerial photographs and site inspections indicate that structures currently do exist where waterways cross roads, these are generally low-level causeways. There is limited survey information on the location, size and height of these low-level causeways and other crossing structures, such as culverts.

During flood events it is expected that the causeways and culverts will be fully submerged and small culverts will be blocked with debris and vegetation. Therefore, the hydraulic influence of these structures under extreme flood events will be insignificant, and the existing HEC-RAS model has not included them.

6.3.2 Proposed scenario

6.3.2.1 Waterway crossings

The proposed scenario has included bridges that will be required where the proposed mine access roads and haul roads cross waterways within the Sandy Creek catchment, and rail crossings of significant size in Fords Creek and Tallawang Creek catchments. All potential crossings have been identified and are numbered with their locations given below. Of these, all of the Zone 1 crossings and two of the Zone 3 crossings (crossings 11 and 28) have been subject to hydraulic assessment and design.

Locations of the waterway crossings are indicated in Figure 6-6 for the Sandy Creek catchment (Zone 1) and in Figure 6-2 for the rail corridor (Zone 3). There are no waterway crossings in Zone 2.

Appendix D.3 contains schematics, taken from the hydraulic models, of each of the waterway crossings that were sized and modelled hydraulically.

Sandy Creek Mining Area (Zone 1)

1. Northern access road crossing Sandy Creek.
2. Northern access road crossing Laheys Creek.
3. Haul road crossing Laheys Creek (north) and Spring Ridge Road.
4. Haul road crossing Blackheath Creek.
5. Upgrade of existing Spring Ridge Road crossing Blackheath Creek.
6. Haul road crossing Laheys Creek (south) (Year 4 only).
7. Northern access road crossing diverted tributary of Laheys Creek (temporary structure).
8. Upgrade of existing Spring Ridge Road crossing Laheys Creek.

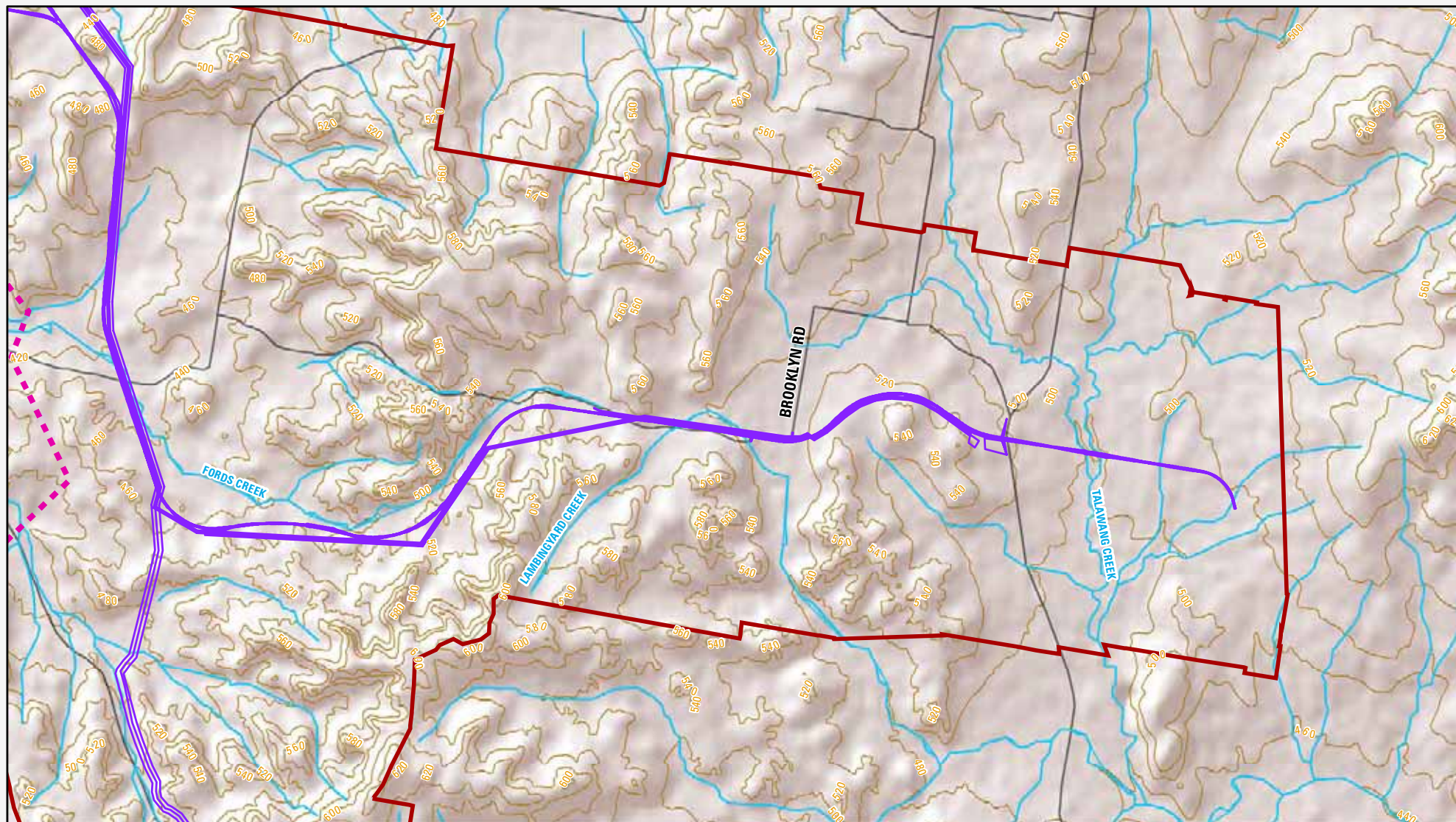
Rail corridor (Zone 3)

1. Rail crossing minor gully/drainage line running south-east.
2. Rail crossing tributary draining into Fords Creek running south-west.

3. Rail crossing Fords Creek, which flows along the northern edge of the proposed railway.
4. Rail crossing small gully draining north to Fords Creek.
5. Rail crossing existing dam capturing flow from small gully draining north to Fords Creek.
6. Rail crossing small gully draining north to Fords Creek.
7. Rail crossing existing dam capturing flow from small gully draining north to Fords Creek.
8. Rail crossing small gully draining north to Fords Creek.
9. Rail crossing small gully draining north to Fords Creek.
10. Rail crossing small gully draining north to Fords Creek, and crossing existing dam capturing flow from small gully draining north to Fords Creek.
11. Rail crossing existing dam capturing flow from small gully draining north to Fords Creek.
12. Rail crossing small gully draining north-west to Fords Creek.
13. Rail crossing small gully draining north-west to Fords Creek.
14. Rail crossing small gully draining north-west to Fords Creek, and crossing existing dam capturing flow from small gully draining north-west to Fords Creek.
15. Rail crossing small gully draining north-west to Fords Creek.
16. Rail crossing the upper reach of Lambing Yard Creek when it flows north-east.
17. Rail crossing Lambing Yard Creek after it loops around underneath the rail spur to then flow south-east (approximately 700 m east of crossing 25).
18. Rail crossing local low point where overland flow running north-east from upstream ridge line needs to be conveyed across the rail corridor.
19. Rail crossing small tributary running north into Tallawang Creek system.
20. Rail crossing Tallawang Creek, spanning two deeply incised channels that run close to each other and drain south.
21. Rail crossing small tributary running south into Tallawang Creek.

An iterative process was undertaken in consultation with the CHC infrastructure team to develop preliminary designs of some of the key crossings in the catchments in terms of crossing type, dimensions and invert levels of openings, clearance above flood levels and other roads, and levels of approach roads across floodplains.

Bridge spans and openings for the access roads were sized to avoid excessive afflux under the 100-year average recurrence interval (ARI) event. The three haul road bridges cross not only waterways but also over the top of the northern access road and Spring Ridge Road. The haul road crossings have been sized to allow a minimum clearance of 5 m from the road underneath to the soffit of the bridge to allow traffic to pass freely beneath the structure. The openings for the haul road crossings were sized to provide sufficient freeboard above the 2,000-year ARI event flood level because these roads are critical infrastructure and require a high standard of flood protection.



- 1 Waterway crossings
- Project application area
- Mine infrastructure
- Drainage lines
- Roads
- Elevation

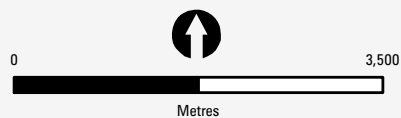


Figure 6-2 Waterway crossings along rail spur

For the rail crossings the following preliminary design criteria were adopted:

- All structures are to be designed to pass 100 year ARI flood without overtopping of the rail embankment.
- Afflux under the 100 year ARI event to be limited to no more than 500 mm immediately upstream of the crossing, and reducing to no more than 100 mm within a distance of 200 m upstream of the crossing.
- Soffit of bridge structures to be a minimum of 600 mm above the 100yr ARI flood level.

Although afflux was minimised as much as possible through the preliminary design of the crossings, some degree of afflux was accepted since any increased flooding was limited to land within the mine ownership and could therefore be managed through appropriate flood mitigation measures, such as levees and scour protection.

Table 6-3 outlines waterway crossing details and the assumptions for those included in the hydraulic model.

Table 6-3 Preliminary design of key waterway crossings

Crossing number	Description	Assumed dimensions	Total opening width	Key levels i.e. culvert invert, soffit level, deck level
1	Bridge with piers	4 x spans	57 m	Soffit 367.6 mAHD Deck 369.1 mAHD
2	Bridge with piers	7 x spans	55 m	Soffit 383.7 mAHD Deck 386.0 mAHD
3	Arch bridge	5 x arches plus 1 x high-flow arch	67 m plus 11 m arch	Soffit 389.9 mAHD Deck 392.0 mAHD
4	Arch bridge	2 x arches	50 m total	Soffit 384.7 mAHD Deck 392.0 mAHD
5	Bridge with piers	3 x spans	36 m	Soffit 382.0 mAHD Deck 383.5 mAHD
6	Arch bridge	4 x arches plus 1 x high-flow arch	55 m	Soffit 402.4 mAHD Deck 406.0 mAHD
7	Structure not included in hydraulic model as it is a temporary structure and not present in Year 20 landform			
8	Bridge with piers	3 x spans	32 m	Soffit 397.8 mAHD Deck 399.3 mAHD
11	Pipe culverts	7 x 2.55m dia culverts	32 m	Soffit 427.7 mAHD Deck 431.8 mAHD
28	Bridge with piers	7 x spans	109 m	Soffit 478.7 to 479.4 mAHD Deck 481.0 to 481.7 mAHD

Table 6-4 lists the crossings identified along the proposed rail corridor, including a description and an indicative type of crossing structure. A crossing structure is required at most locations where the proposed rail spur is constructed in fill over a topographic depression to avoid flooding impacts in drainage lines and overland flow paths upstream of the rail embankment. Table 6-4 also indicates the average height of fill required at each crossing location, based on the proposed rail spur design levels.

At least two of the crossings (Crossing 20 and Crossing 21) may require special drop structures at the outlets to reduce scour impacts in the downstream channel due to the large drops across the rail corridor and associated high outlet velocities.

The remainder of the crossings are located where the proposed rail spur crosses small creeks or gullies/drainage lines. These crossings have not been modelled hydraulically as the crossings are located within small catchments and are expected to be minor crossings that can be achieved by standard box/pipe culverts. Flood flows in these areas are likely to be relatively low, with high velocity and low flow depth. Typical scour protection measures will be required at culvert inlets and outlets at these locations.

Table 6-4 Proposed waterway crossings within rail corridor

Crossing number	Description	Type of structure required	Average height of fill (above ground level)	Additional comments/observations
9	Minor crossing of gully draining small catchment.	Standard culvert with associated erosion protection measures.	5 m	Very small farm dam located about 30 m downstream of proposed rail spur; may need to be removed.
10	Minor crossing of tributary catchment draining to Fords Creek.	Standard culvert with associated erosion protection measures.	5 m	Due to the flat topography a relatively wide and shallow floodplain may result at this location. Erosion and scour are evident at this location (based on aerial photography).
11	Crossing of Fords Creek.	Multiple cross-drainage culverts will be required to convey flow across the rail corridor in this area due to the relatively flat topography.	7 m	Due to the flat topography a relatively wide and shallow floodplain may result at this location.
12	Minor crossing of gully draining small catchment to Fords Creek.	Standard culvert with associated erosion protection measures.	1.5 m	Narrow channel, so small floodplain width and high velocities are expected at this location.
13	Rail spur located downstream of existing farm dam (within study area) draining small catchment. Dam overflows to Fords Creek.	Existing dam may need to be replaced by a standard culvert to convey flows across the rail corridor so that flows do not build up behind the rail embankment.	0.4 m	Erosion is evident downstream of the dam (based on aerial photography).
14	Minor crossing of gully draining small catchment to Fords Creek.	Multiple cross-drainage culverts are likely to be required to convey flow across the rail corridor in this area due to the relatively flat topography.	3 m	Due to the flat topography, a relatively wide and shallow floodplain may result at this location.
15	Rail spur located downstream of existing farm dam (within study area) draining small catchment; dam overflows to Fords Creek	Existing dam may need to be replaced by a standard culvert to convey flows across the rail corridor so that flows do not build up behind the rail embankment.	2 m	

Crossing number	Description	Type of structure required	Average height of fill (above ground level)	Additional comments/observations
16	Minor crossing of gully tributary draining to Fords Creek.	Standard culvert with associated erosion protection measures.	5 m	Narrow channel, so small floodplain width and high velocities are expected at this location.
17	Minor crossing of gully tributary draining to Fords Creek.	Standard culvert with associated erosion protection measures.	1.5 m	Narrow channel, so small floodplain width and high velocities are expected at this location.
18	Rail spur located upstream of existing farm dam (within study area) draining small catchment. Dam overflows to Fords Creek.	Standard culvert with associated erosion protection measures.	1 m	Existing dam may need to be removed so that flows don't build up behind the rail embankment upstream of the dam.
19	Rail spur located downstream of existing farm dam (within study area) draining small catchment. Dam overflows to Fords Creek.	Existing dam may need to be replaced by a standard culvert to convey flows across the rail corridor so that flows do not build up behind the rail embankment.	6 m	
20	Crossing of creek, with scoured banks draining small catchment to Fords Creek.	Standard culvert design may not be adequate. A drop structure may be required to reduce velocities and erosion.	0.5 m	Catchment is steep (3.5%) and velocities are expected to be high. Erosion and scour are evident at this location (based on aerial photography).
21	Crossing of creek, with scoured banks draining small catchment to Fords Creek.	Standard culvert design may not be adequate. A drop structure may be required to reduce velocities and erosion.	1.5 m	Catchment is steep (5.5%) and velocities are expected to be high. Erosion is evident at this location with cut-out gully shape (based on aerial photography).
22	Rail spur located upstream of existing farm dam (within study area) draining small catchment. Dam overflows to Fords Creek.	Standard culvert with associated erosion protection measures.	2 m	Existing dam may need to be removed so that flows don't build up behind the rail embankment upstream of the dam.
23	Minor crossing of gully draining small catchment to Fords Creek.	Multiple cross-drainage culverts are likely to be required to convey flow across the rail corridor in this area due to the relatively flat topography.	2 m	Due to the flat topography a relatively wide and shallow floodplain may result at this location.

Crossing number	Description	Type of structure required	Average height of fill (above ground level)	Additional comments/observations
24	Minor crossing of Lambing Yard Creek.	Multiple cross-drainage culverts are likely to be required to convey flow across the rail corridor in this area due to the relatively flat topography.	1.5 m	Due to the flat topography a relatively wide and shallow floodplain may result at this location.
25	Minor crossing of Lambing Yard Creek.	Multiple cross-drainage culverts are likely to be required to convey flow across the rail corridor in this area due to the relatively flat topography.	7 m	Due to the flat topography a relatively wide and shallow floodplain may result at this location.
26	Local low point.	Multiple cross-drainage culverts are likely to be required to convey flow across the rail corridor in this area due to the relatively flat topography.	2 m	This crossing will be required, to prevent local build-up of overland flow from upstream ridge line behind rail embankment.
27	Minor crossing of tributary draining to Tallawang Creek system.	Standard culvert with associated erosion protection measures.	1 m	
28	Major crossing of Tallawang Creek system.	West:3x15m spans East:4x15m spans	5 m	Two bridges will be required, with a rail embankment in between.
29	Minor crossing of small tributary draining to Tallawang Creek.	Standard culvert with associated erosion protection measures.	3 m	

6.3.2.2 Proposed mining infrastructure and mining areas

The proposed scenario hydraulic model represents a worst-case scenario. It adopted the maximum envelope of floodplain encroachment of all stages of the mine plan from spoil emplacements, access roads, haul roads and coal stockpiles. If the impacts are to be assessed based on this worst-case, then it can be assumed that during each stage of the mine plan, impacts will be equal to or less than those predicted for the worst-case scenario.

During certain stages of mining, temporary diversion channels will be required to redirect tributaries and creeks around the mine workings. Diversion channels were considered conceptually for the impact assessment but were not included in the hydraulic model. Diversion channels are discussed in Section 7.3.4.

Some reaches of Laheys Creek and Blackheath Creek will require flood protection levees to prevent flooding and damage to vulnerable infrastructure, such as coal stockpiles, infrastructure areas and spoil embankments. For the proposed scenario it has been assumed that flood levees will be provided in areas where the edge of the active-mining void is located on or within the boundary of the 2,000-year flood extent. This event was chosen as a reasonable upper limit reference event for protection of critical infrastructure. The standard of protection for critical infrastructure will be confirmed at the design stage based on a detailed risk assessment for the Project.

Based on previous experience of levee protection works, the design for the flood levee has been assumed to have a 3 m top width, with 1:3 sides and a height equal to the 2,000-year flood level plus 600 mm freeboard. This represents a design guideline only, as the levees will be subject to detailed geotechnical design during the Project's later stages.

While it is important that the proposed model accounts for floodplain lost to dirty-water channels and flood protection works such as levees, it has been assumed that the cleared area footprint around the active-mine void during the worst-case scenario will contain the levee and any dirty-water channels.

For areas where the spoil footprint is located on or within the boundary of the 100-year ARI flood extent, scour protection will be required to protect spoil emplacements from erosion. The hydraulic model was used to estimate the height of the scour protection required to resist erosion up to the 100-year ARI event (with 600 mm freeboard allowance). Typically, this scour protection would be achieved using dumped hard rock material sourced from the Project site. A potential source of suitable material for this purpose is the rail cutting. As with the flood protection levees, this represents a design guideline only, as the scour protection scheme will be subject to detailed geotechnical design during the Project's later stages.

6.4 Model results

The approach detailed in the previous sections was used to assess the flood behaviour and impacts of the mine in the Sandy Creek catchment. This section summarises the outcomes of these flooding investigations.

6.4.1 Existing scenario

6.4.1.1 Flood levels

The existing scenario, 100-year ARI flood extent is shown in Figure 6-3. The 100-year ARI event is contained within the channel in the upper tributaries of Sandy Creek and the upper reach of Laheys Creek under existing conditions. Once the catchment flattens out in the middle to lower reaches of both Sandy Creek and Laheys Creek, there is some floodplain flow in the left and right overbanks due to the meandering nature of the creeks. The existing 2-year and 5-year ARI events are mainly conveyed in-channel for the middle to lower reaches, with higher flows going out of bank in some localised areas. The 2,000-year ARI event produces mainly overbank flow, but flows are still contained by the shape of the valley in the lower reaches.

In the upper reaches of Sandy Creek, all events up to the 2,000-year ARI event are contained within the channel. As the catchment area increases and small tributaries join, the 100-year ARI event flows just over bank-full and the 2,000-year ARI event flows in the channel and floodplain. The difference in flood level between the 100-year and 2,000-year ARI events in the upper reaches of Sandy Creek is around 1–2 m. In the lower reaches of Sandy Creek there is around 1 m difference in flood levels between the 100-year and 2,000-year ARI events.

Laheys Creek experiences similar flooding behaviour. In the upper reaches, up to the 100-year ARI event, the flow is just over bank-full. As the catchment area increases and the lower parts of the catchment become flatter and the channel wider, Laheys Creek experiences floodplain flow in the 100-year ARI event in both the left and right overbanks due to its meandering nature. For the 2,000-year ARI event, the lower reaches of Laheys Creek are completely flooded and there are some interactions with flows from other tributaries (for example, Blackheath Creek). There is a 1–1.5 m difference in flood levels between the 100-year and 2,000-year ARI events.

Table 6-6 shows the existing and proposed flood levels at key locations. Existing flows and flood levels at each cross-section in the hydraulic model are given in Appendix D.1.

Water level profiles for the 100-year ARI event for the existing scenario along the modelled reaches of both Sandy Creek and Laheys Creek are shown in Figure 6-4 and Figure -6-5. The creek chainage indicated on these charts has been measured from the downstream end of each of the creeks.

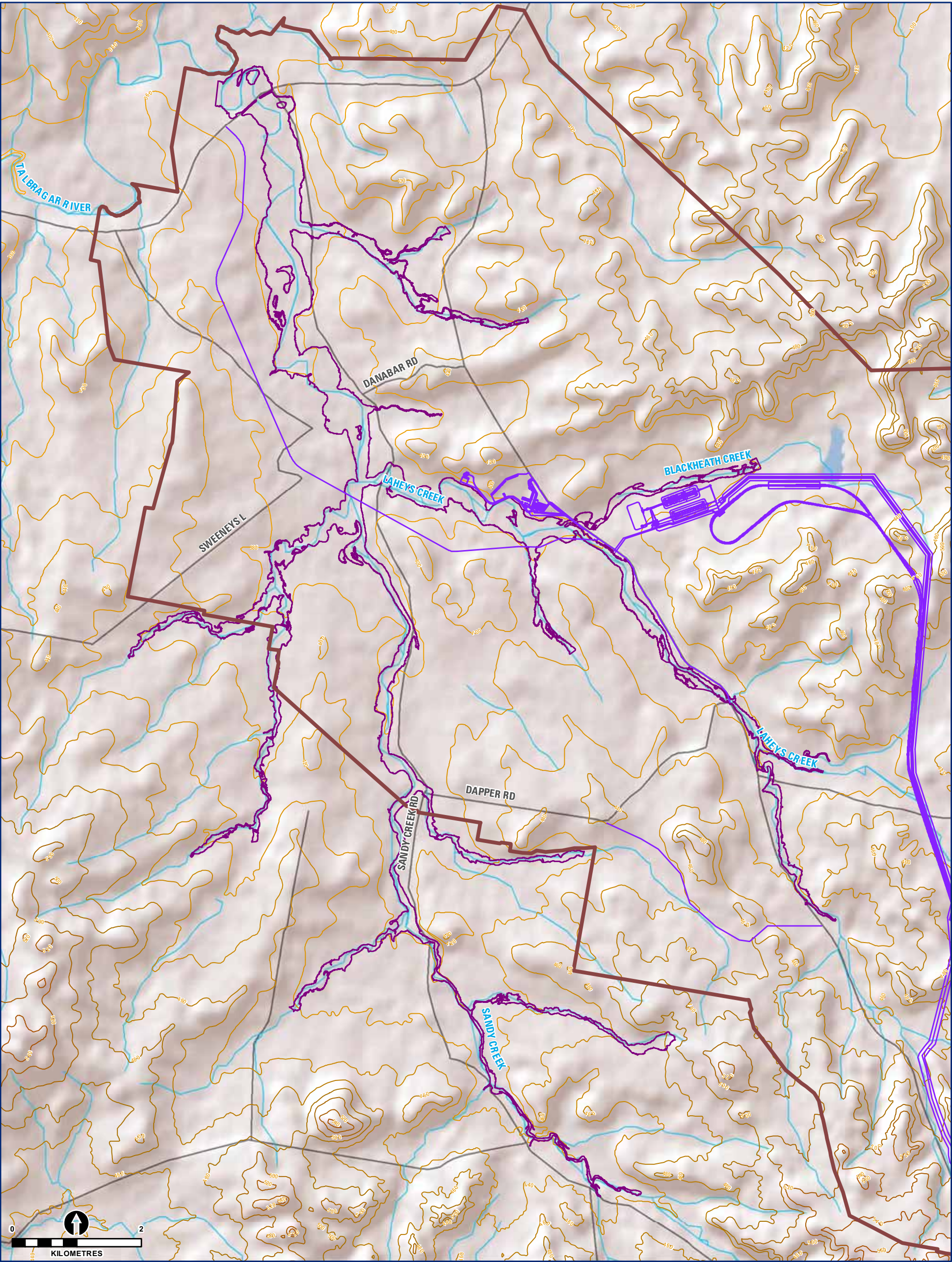
6.4.1.2 Peak velocities

Average peak velocities along Laheys Creek are generally less than 2 m/s for the 100-year ARI event, with an average velocity of 1.4 m/s. For the 100-year event, the main channel experiences a velocity range from 0.7 m/s to 2.5 m/s in the channel, and a slightly lower range of 0.1 m/s to 1.4 m/s in the floodplain. For the 2-year ARI event, peak velocities are within a range of 0.4 m/s to 2.1 m/s, with an average of 0.8 m/s.

Sandy Creek experiences a range of velocities throughout its creek system but these are lower on average than Laheys Creek due to its wider floodplain and flatter areas in its downstream reaches. For the 100-year event, Sandy Creek experiences a velocity range of 0.7 m/s to 2.3 m/s in the main channel and 0.2 m/s to 1.8 m/s in the floodplain. For the 2-year event, the velocity ranges from 0.3 m/s to 2.3 m/s and flow is mainly in-channel.

Blackheath Creek experiences lower velocities than Sandy Creek and Laheys Creek due to smaller flows. Velocities range from 0.6 m/s to 1.3 m/s for the 100-year ARI event and from 0.3 m/s to 0.8 m/s for the 2-year event.

Table 6-6 shows the existing and proposed average velocities in three key locations. Velocities stated here are averaged values across the creek cross-section. Slightly higher values will occur in the middle of the channel, and lower values near each of the overbanks.



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100 year existing flood extent	Drainage lines
Elevation (m)	Roads
Mine infrastructure	Project application area

Figure 6.3 Existing 100 year ARI flood extent (Sandy Creek catchment)

Table 6-5 Existing and proposed flood levels at key locations

Location (cross-section ID)	2-year ARI (mAHD)			5-year ARI (mAHD)			100-year ARI (mAHD)			2,000-year ARI (mAHD)		
	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
Lower reach of Sandy Creek just before confluence with Talbragar River (3672)	350.79	350.86	+0.07	351.37	351.42	+0.05	352.33	352.33	0.00	353.89	353.89	0.00
Lower reach of Sandy Creek (6066)	354.49	354.63	+0.14	355.56	355.59	+0.03	356.63	356.64	+0.01 ²	357.72	357.72	0.00
Sandy Creek downstream of junction with Laheys Creek (10294)	362.75	362.93	+0.18	363.95	364.01	+0.06	365.82	365.84	+0.02	366.97	366.97	0.00
Sandy Creek upstream of Laheys Creek junction (12447)	369.35	369.35	0.00	370.42	370.41	-0.01 ²	372.53	372.55	+0.02	373.75	373.77	+0.02
Laheys Creek just upstream of junction with Sandy Creek (1207)	367.89	368.21	+0.32	368.62	368.69	+0.07	369.34	369.36	+0.02	370.16	370.17	+0.01 ²
Lower reaches of Blackheath Creek (4159)	385.76	385.93	+0.17 ¹	385.85	385.96	+0.11	386.12	386.27	+0.15	386.45	386.62	+0.17
Laheys Creek mid-reach upstream of Blackheath Creek confluence (6761)	386.30	386.34	+0.04	387.02	387.06	+0.04	388.41	388.44	+0.03	389.34	389.51	+0.17
Laheys Creek upper reach (9208)	396.31	396.60	+0.29 ¹	396.95	397.19	+0.24	398.36	398.75	+0.39	399.67	400.07	+0.40

¹ The critical duration for the 2-year ARI is different for existing and proposed conditions, so the percent increase in water level is more significant.

² The model's accuracy is ± 0.01 , so changes in water level of less than ± 0.02 should be considered negligible.

Table 6-6 Existing and proposed average velocities at key locations

Location (cross-section ID)	2year ARI (m/s)			5-year ARI (m/s)			100-year ARI (m/s)			2,000-year ARI (m/s)		
	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
Sandy Creek (6066)	1.02	1.04	+0.02	0.94	0.93	-0.01	1.23	1.23	0.00	1.06	1.06	0.00
Laheys Creek (1207)	0.56	0.62	+0.06	0.68	0.68	0.00	1.10	1.12	+0.02	1.81	1.81	0.00
Blackheath Creek (4159)	0.50	0.51	+0.01	0.62	0.53	-0.09	0.89	0.64	-0.25	1.35	0.94	-0.41

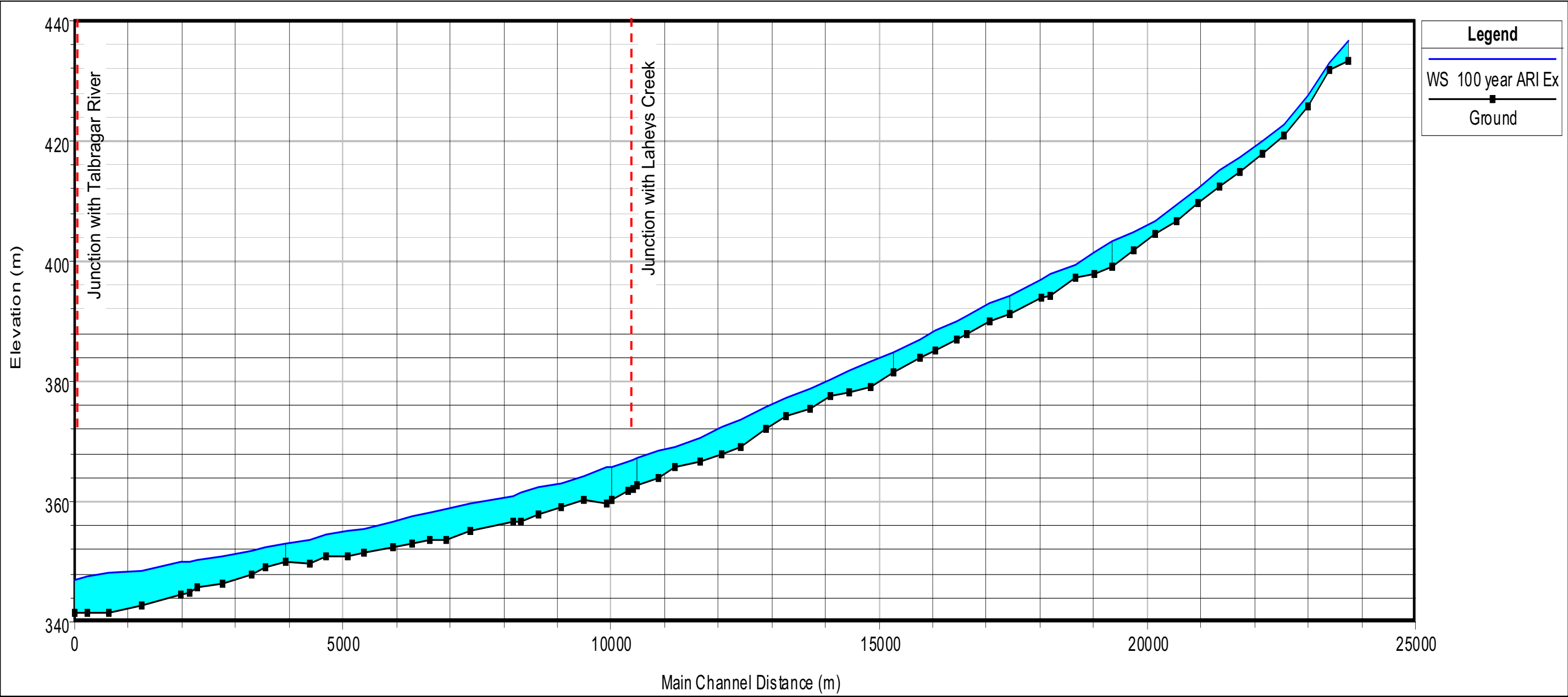


Figure 6-4 Existing longitudinal water level profile for Sandy Creek (HEC-RAS model output), 100-year ARI

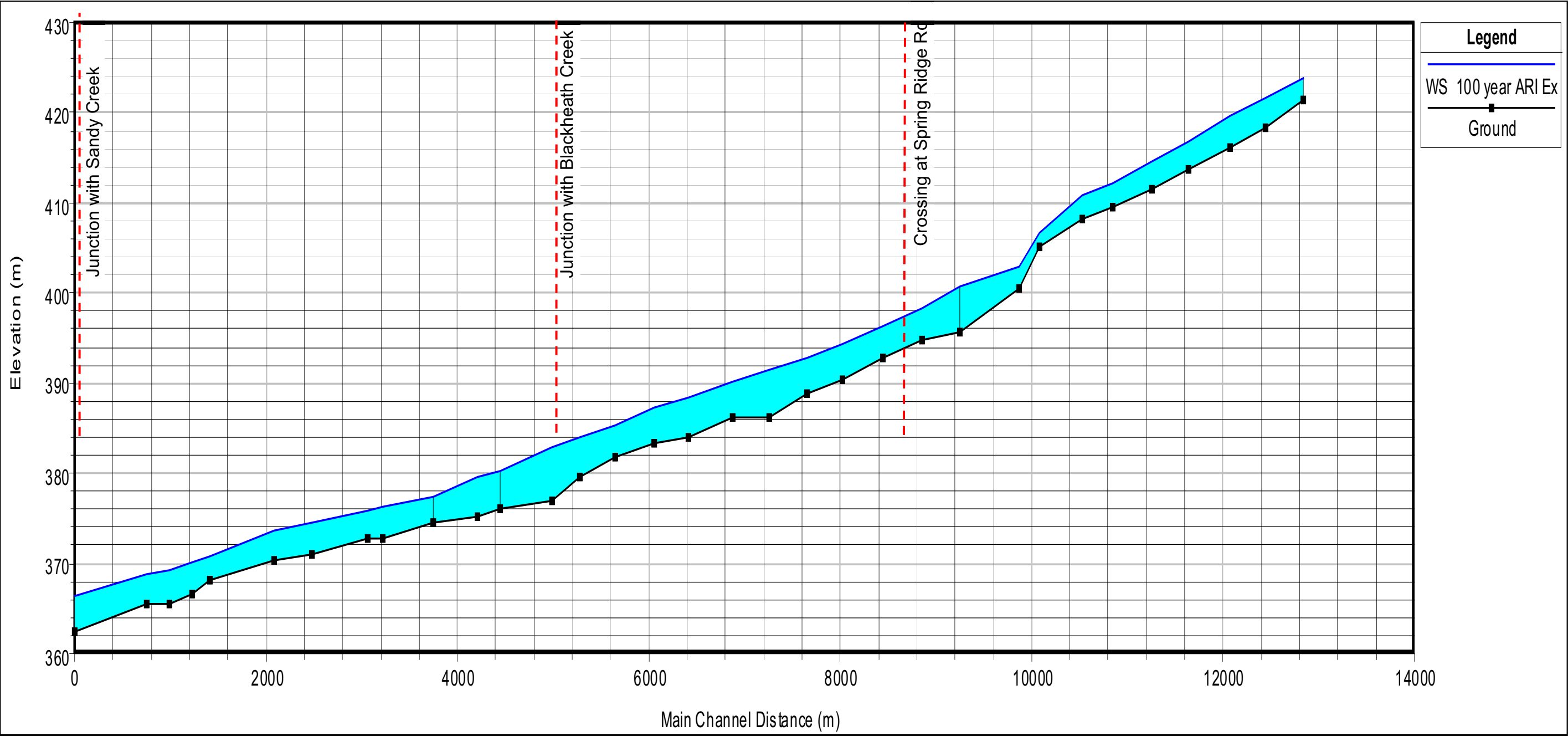


Figure -6-5 Existing longitudinal water level profile for Laheys Creek (HEC-RAS model output), 100-year ARI

6.4.2 Proposed scenario

6.4.2.1 Flood levels

The proposed scenario 100-year ARI flood extent is shown in Figure 6-6. This figure shows that flooding in Sandy Creek and Laheys Creek is similar to the existing scenario even with the worst-case mine configuration in place. In some localised areas flood levels increase — in particular, Laheys Creek and the lower reaches of Blackheath Creek — but flood levels in the lower reaches of Sandy Creek are similar for existing and proposed scenarios.

The results show that the mine footprint is mostly out of the 100-year ARI flood extent of Sandy Creek and Laheys Creek for the proposed scenario. However, some parts of the mine footprint near the workshop area, northern access road and the out-of-pit emplacement area along the upper reaches of Laheys Creek near mining area B lie on the edge of or just within the 100-year ARI flood extent for the proposed scenario.

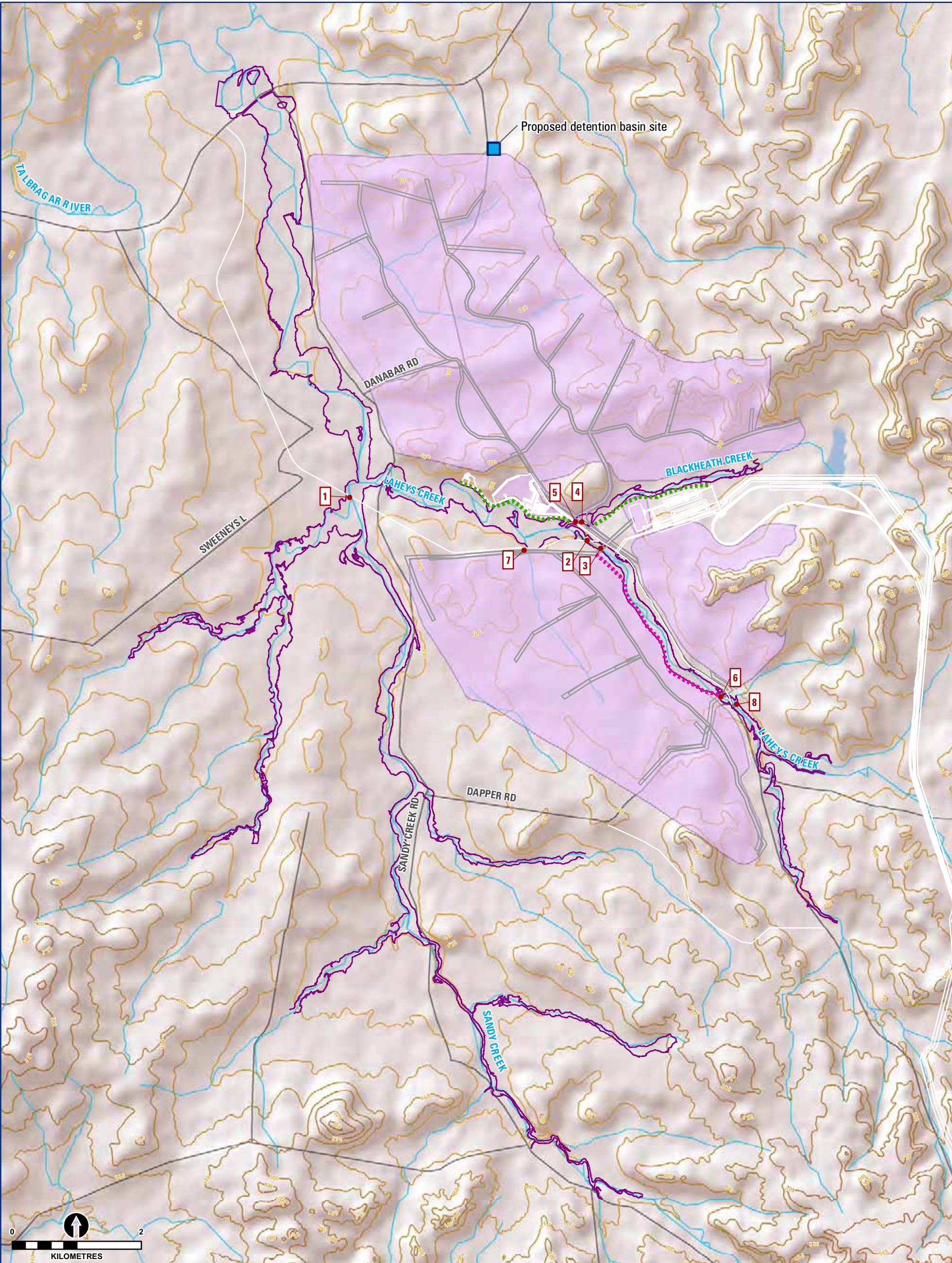
In addition to these areas, parts of the mine footprint are within the 2,000-year ARI flood extent for the proposed scenario. They are the northern bank of the mid-reaches of Laheys Creek adjacent to the workshop area, the western edge of Laheys Creek along mining area B, and the southern edge of Blackheath Creek near the coal-handling and preparation plant (CHPP).

Table 6-5 shows a small increase in flood levels in the middle to lower reaches of Laheys Creek and an increased flood level in Blackheath Creek due to the mine. This is expected, as there is an increased flow due to a larger catchment inflow and different timing of peak flows. The table also shows a notable increase in flood level (390 mm in the 100-year ARI event) at the upstream end of Laheys Creek near the crossing of Spring Ridge Road (Crossing 8) and the proposed haul road bridge crossing (Crossing 6). However this impact diminishes within 600 m further upstream in Laheys Creek.

Table 6-5 also shows small increases in flood levels in Sandy Creek just downstream of its junction with Laheys Creek. This is due to a slight increase in peak flow in Laheys Creek. However, by the time the peak reaches the lower section of Sandy Creek and its confluence with the Talbragar River, flood behaviour in the existing and proposed scenarios for the 100-year and 2,000-year ARI events is the same.

It can be assumed that, as there is little impact to flooding behaviour for the 100-year ARI event, there is less impact to the mid-range flood events such as the 20-year and 50-year ARI events. For the lower order events (2-year and 5-year ARI events) flood levels are slightly higher at the Talbragar River confluence. Overall, the upper and lower reaches of Sandy Creek experience similar flooding behaviour in the existing and proposed scenarios. There is slightly more out-of-channel flow in the middle to lower reaches near the junction with Laheys Creek, but this impact diminishes further downstream.

Water level profiles for the 100-year ARI event for the proposed scenario along the modelled reaches of both Sandy Creek and Laheys Creek are shown in Figure 6-7 and Figure 6-8. It is noted that in Figure 6-8 a high point just upstream of the proposed access road crossing (chainage 5600) has been picked up by the LiDAR data. This area will need to be verified by site survey at the design stage to confirm whether this is the bottom of the channel or sediment build-up or an inaccuracy in the LiDAR data due to vegetation coverage. For the flood modelling, the LiDAR cross-section geometry has been used as this provides a more conservative assessment in this area. Proposed flows and flood levels at each cross-section in the hydraulic model for the proposed scenario can be viewed in Appendix D.2.



1 Waterways crossings	Drainage lines	Proposed spoil protection
Proposed 100 year flood extent	Haul roads	Proposed levees
Elevation (m)	Roads	Proposed detention basin site
Mine infrastructure	Maximum mine footprint	

Figure 6-6 Proposed 100 year ARI flood extent

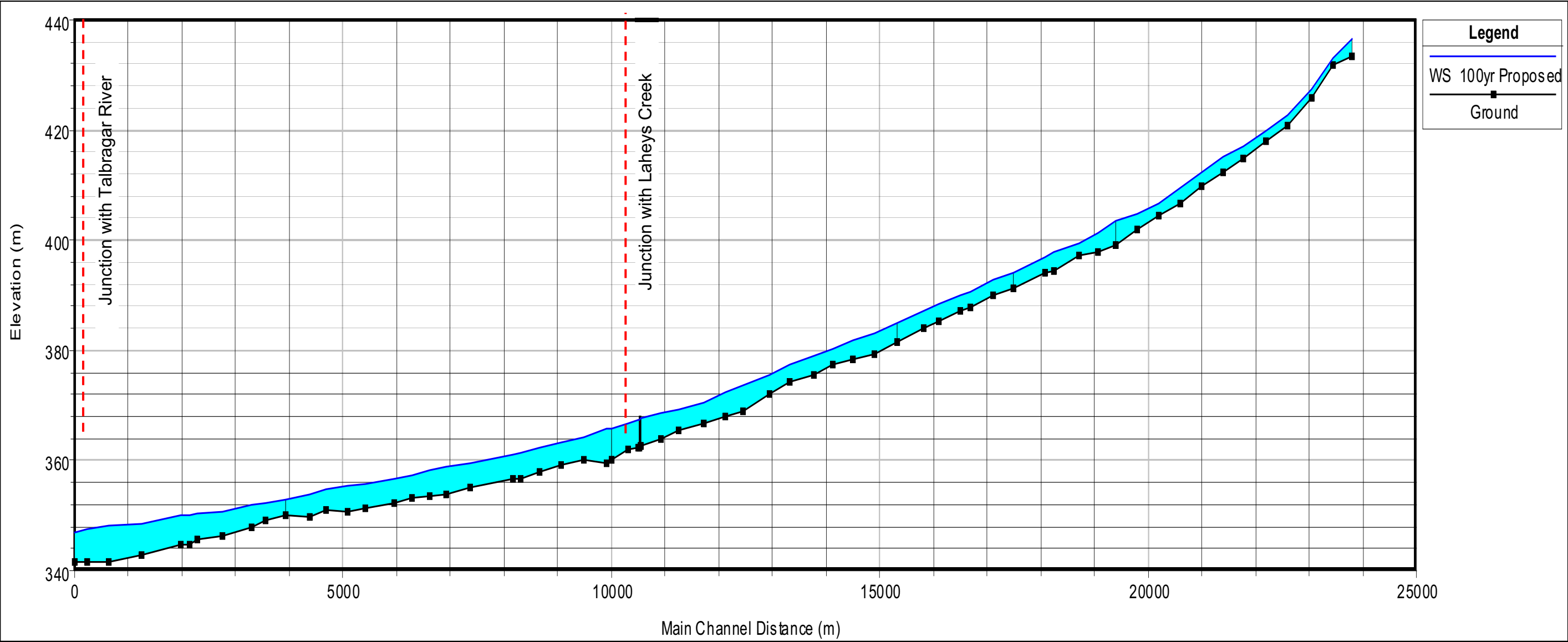


Figure 6-7 Proposed longitudinal water level profile for Sandy Creek (HEC-RAS model output), 100-year ARI

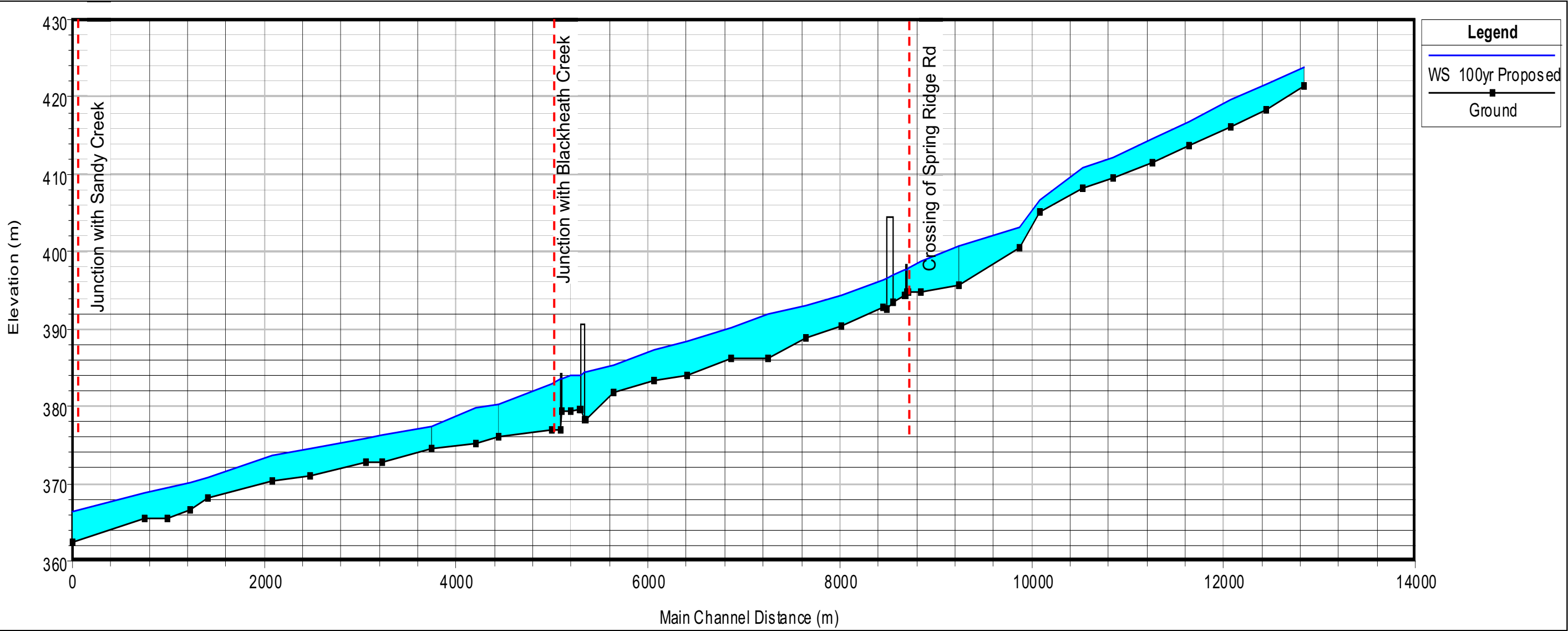


Figure 6-8 Proposed longitudinal water level profile for Laheys Creek (HEC-RAS model output), 100-year ARI

6.4.2.2 Peak velocities

Average peak velocities along Laheys Creek for the proposed scenario are similar to the range of existing velocities of 0.7 m/s to 2.5 m/s in the main channel and 0.1 m/s to 1.4 m/s in the floodplain for the 100-year ARI event. There are localised areas where the velocity in the channel reaches 3.3 m/s. These occur near proposed structures, and mitigation measures will be required in these locations to either reduce velocities or provide erosion protection to ensure channel stability.

For the 2-year ARI event, peak velocities are slightly higher than the existing velocities. The velocities are within a range of 0.4 m/s to 2.3 m/s, with the same average velocity as the existing average of 0.8 m/s.

Sandy Creek experiences the same range of velocities when compared with the existing scenario — from 0.7 m/s to 2.3 m/s in the main channel and 0.2 m/s to 1.8 m/s in the floodplain for the 100-year ARI event. For the 2-year ARI event the velocity ranges from 0.3 m/s to 2.3 m/s and flow is still mainly in-channel.

Blackheath Creek overall experiences lower velocities than the existing scenario for the 100-year ARI event, with a range of 0.6 m/s to 1.2 m/s. This could be the result of more flows in the floodplain that travel slower than the in-channel flows. This is evident by the increased flood levels shown in Table 6-5.

However, velocities at the downstream end of Blackheath Creek are slightly increased due to the presence of structures. For the 2-year ARI event, velocity ranges are slightly higher than the existing case for Blackheath Creek, with a range of 0.5 m/s to 1.4 m/s. Velocity increases in the 2-year ARI event but decreases in velocity for the 100-year ARI event because in the 2-year ARI event flow is contained in-channel resulting in higher velocities, whereas in the 100-year ARI event, flow spills out to the floodplain and has a lower velocity due to higher roughness in the overbanks.

Table 6-6 shows the existing and proposed peak velocities in three key locations. Overall, velocities are slightly increased in Laheys Creek, slightly decreased in Blackheath Creek and generally unchanged in Sandy Creek.

7. Findings and mitigation measures

7.1 Flooding impacts

7.1.1 Sandy Creek, Laheys Creek and Talbragar River (Zone 1)

Changes in flood extent and level within Sandy Creek and Laheys Creek as a result of the proposed mine are generally minor, with some localised changes in flooding due to increased flows and proposed waterway crossing structures. Flooding impacts due to the proposed mine are isolated to Laheys Creek and the lower reaches of Blackheath Creek around the mine footprint inside the study area. However, these are highly localised effects and do not affect any lands outside the study area.

Flows in Laheys Creek have increased slightly overall due to the progressive diversion of the northern part of the catchment into Laheys Creek, which naturally flows into Sandy Creek. This increase in catchment area flowing to Laheys Creek is somewhat offset by the loss of catchment area to the open mining areas and so changes in peak flows are minimal.

There has been a change in the times the creeks take to peak locally around the mine footprint — namely, the disturbed catchments within the Laheys Creek and Blackheath Creek. However, by the time the peak flow reaches Sandy Creek, peak flows become closer to the existing peaks. Modelling showed only minor changes to flood levels in Sandy Creek just downstream of its junction with Laheys Creek, but these changes diminish further downstream and there is negligible change to flood levels at the downstream end of Sandy Creek. Overall, the hydraulic modelling has shown no significant change in flood levels upstream or downstream of the Sandy Creek catchment where the majority of mining area is located.

The northern boundary of the mining area is approximately 2 km away from the Talbragar River, and the top of the catchment containing the mine area is approximately 45 m above the banks of the Talbragar River. The hydraulic model shows that for all events analysed up to the 2,000-year average recurrence interval (ARI) event, water levels in the Talbragar River will not be affected by the mine because of the distance and difference in level between the mine and the river.

There will be local increases in velocities and changes to flood levels at structures where the flooding behaviour is altered; however, these impacts are highly localised. Areas where high velocities are experienced will require mitigation in the form of scour protection.

7.1.2 Flyblowers Creek (Zone 2)

Other potentially affected areas outside the Sandy Creek hydraulic model extent were assessed hydrologically or qualitatively. It was found that there would be a notable impact on the peak flow of Flyblowers Creek, north of the Sandy Creek catchment. During Year 12 to Year 20 of the mine, a significant portion of the upper, eastern Sandy Creek catchment is diverted north into the eastern arm of Flyblowers Creek. This diverted catchment reaches a maximum of 86 ha during Year 12 of the mine, as seen in the mine staging plans provided in the *Water Balance and Water Management System* report (Appendix E to the *Surface Water Assessment* report).

A hydrological assessment found that the peak flow in this creek would be increased by around 30% across a range of events (2-, 5- and 100-year ARI events) due to the diverted catchment. This increase in peak flow will have an impact on the existing waterway crossing of the upper parts of Flyblowers Creek at Spring Ridge Road. However, this section of road will be closed and no longer in use during mining, so treatment of the road and culvert to protect them from flood damage or overtopping is not required.

The increase in peak flow also has the potential to impact on the culvert underneath the Golden Highway, which lies about 1.2 km away at the bottom of the local catchment. Mitigation of this impact would be required to ensure land not owned by CHC is unaffected and flow conditions reaching this culvert are not significantly modified. Mitigation measures at this location are recommended in Section 7.2.2.

7.1.3 Rail corridor (Zone 3)

Much of the proposed rail spur will be located on a 6 m high embankment. This has the potential to cause flooding upstream of the rail embankment. Towards the western end of the proposed rail spur, the rail corridor crosses a number of small tributaries and gullies draining into Fords Creek. Minor and localised increases to flooding at these locations may be acceptable as the entire catchments of these small tributaries lie within the study area. Towards the eastern end of the rail spur, however, where the rail line would tie into the existing rail line, the rail corridor crosses a significant channel of Tallawang Creek, where the proposed rail embankment could alter flooding behaviour.

At all of these locations, mitigation measures in the form of bridges and culverts with appropriate flow capacity would be required to prevent flows from building up behind the rail embankment and causing flooding impacts upstream. Waterway crossings and longitudinal drainage along the rail corridor are discussed in Section 7.2.3.

7.1.4 Waterway crossings (construction)

Waterway crossings are required where access roads, haul roads and rail lines cross waterways within the study area. Preliminary designs of some of the key crossings in the Sandy Creek catchment (including estimates of dimensions and invert levels of openings and clearance above flood levels) were developed as part of this assessment.

Bridge spans and openings for the access roads were sized to avoid excessive afflux under the 100-year ARI event. The openings for the haul road crossings were sized to provide sufficient freeboard above the 2,000-year ARI event flood level, on the basis that these roads are critical infrastructure and require a high standard of flood protection. Other crossings outside the Sandy Creek catchment, such as the rail spur waterway crossings, have not been modelled hydraulically but have been identified and given an indicative type and size based on channel shape, slope and catchment area.

The impacts of building the crossings have not been specifically assessed due to the preliminary nature of the design; however, a qualitative assessment has been considered. During construction of the waterway crossings, flood flows could be temporarily diverted around the construction works, which could have a localised impact on flood levels and sediment movement.

Standard flood mitigation measures during construction would apply at these locations. Typically, these include provision of temporary diversion channels with sufficient capacity (i.e. depending on the duration of the construction works) to convey flood flows that could occur during the construction period around works areas.

7.2 Mitigation measures

7.2.1 Sandy Creek, Laheys Creek and Talbragar River (Zone 1)

Since the impacts of the Project on flooding within Sandy Creek and Laheys Creek are negligible, no mitigation measures are proposed in these catchments.

Erosion protection would be required at all structures and bridges, particularly for access roads where extreme events may overtop the bridge and local roads leading up to the structure. The appropriate erosion protection would be determined during the design phase. Typically, it would include rock revetment and scour protection to bridge piers and abutments. It is essential that erosion protection measures for both the construction and operational phases of the Project be incorporated into the detailed design of these crossings.

7.2.2 Flyblowers Creek (Zone 2) flood detention basin

There would be a notable impact of increased peak flows in Flyblowers Creek (Zone 2), north of Sandy Creek. During Years 12 to 20, mitigation measures would be required to reduce the peak flow in this creek and avoid impacts on the Golden Highway further downstream in the catchment. It is recommended that a dry detention basin be constructed to reduce peak flows at the Golden Highway culvert to those that occur under the existing scenario.

7.2.2.1 Conceptual design

XP-RAFTS software was used to size a detention basin at this location. XP-RAFTS accurately models a detention basin with an outlet orifice and allows flexible adjustment of a range of modelling parameters and conditions. XP-RAFTS is also useful for demonstrating the feasibility of the mitigation measure.

For this catchment, the flows predicted by XP-RAFTS match reasonably well the flows predicted by Watershed Bounded Network Model (WBNM), and only minor adjustments were required. The hydrologic analysis found that a detention basin with a volume of 70,000 m³ (70 ML) would be required to mitigate the increase in peak flow and restore peak flow at the Golden Highway culvert to the levels that occur for the existing scenario. With the dry detention basin in place, potential adverse flood impacts on the Golden Highway would be avoided.

The basin has been designed to capture the 100-year ARI flow from the diverted catchment without spilling. For the diverted catchment, the critical duration for the 100-year ARI event is 180 minutes. Figure 7-1 shows the 100-year ARI peak flow for the diverted catchment entering the detention basin. The detention basin has been designed to have a maximum depth of 3 m. During the 100-year ARI event the depth (stage) in the basin reaches 2.3 m.

With an allowance for freeboard giving an approximate total depth of 3 m, the flood level in the basin needs to exceed 401 mAHD before it spills. For events above the 100-year ARI, the spillway would need to be designed to spill safely and to minimise erosion to the embankment and the downstream areas.

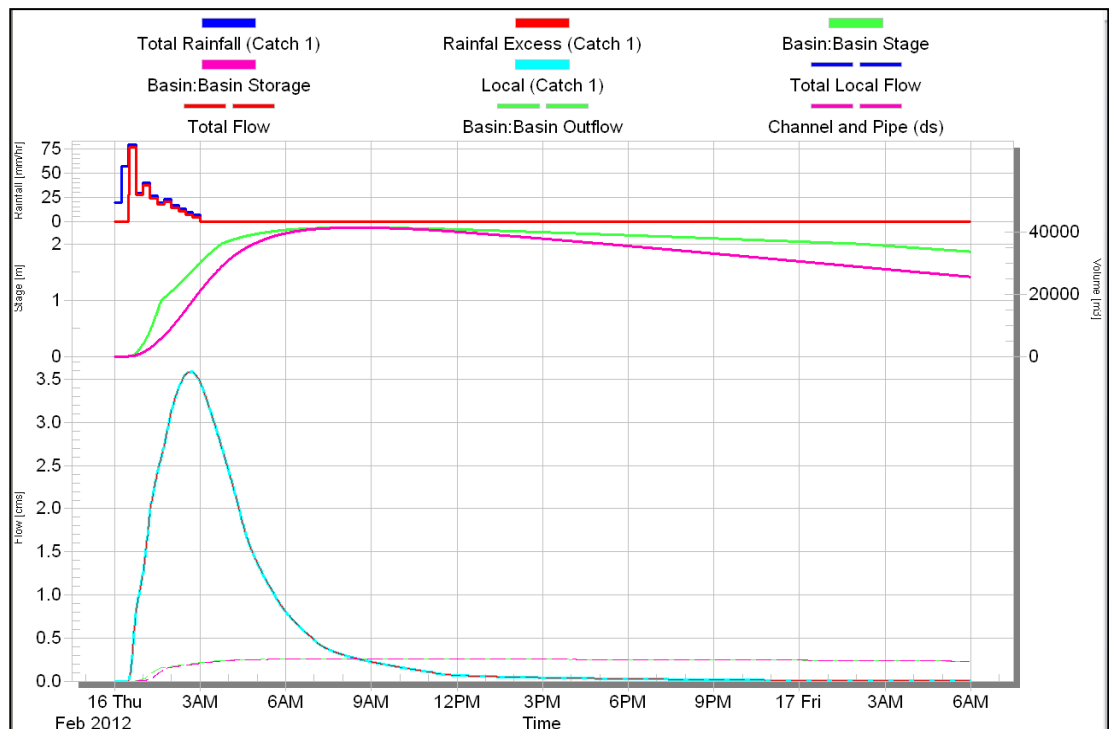


Figure 7-1 100-year ARI peak flow and stage-storage relationship for the detention basin

In the conceptual sizing exercise, a 0.3 m orifice outlet structure was modelled that allows the basin to drain slowly during and after a storm event. To test the feasibility of smaller basin sizes, a larger outlet and smaller volume basin was also tested. However, the alternative configurations did not sufficiently attenuate the flow downstream at the Golden Highway. The conceptual basin design proposed above should be investigated further at the detailed design stage in consultation with NOW to determine any potential licensing requirements.

7.2.2.2 Location

The 70,000 m³ basin can be accommodated within the study area. The proposed location for the detention basin is indicated in Figure 6-6. Although the topography in this location is relatively flat, it was chosen as it is close to the disturbed area and is further from the highway. Other locations for the detention basin were investigated, such further downstream on Flyblowers Creek, but this would disturb an area that is otherwise unaffected by mining and could have significant impacts on local ecology.

The shape of the basin has been fitted to the approximate topographic contours in the area. At this location the bottom of the detention basin would sit at 398 mAHD. The detention basin would require a 3 m embankment about 600 m in length around three edges. The 3 m embankment would tie into the top of the basin on the eastern side at 401 mAHD.

The layout and footprint of the basin is shown in Figure 7-2. This figure shows the full basin and the total footprint of the detention basin, including the embankment. An embankment top width is 3 m and 1:3 side slopes has been assumed in the figure representation of the basin.



- Culvert
- ➔ Basin outlet
- ➔ General direction of flow
- Detention basin embankment
- Project application area
- Detention basin maximum extent
- Diverted catchment

Figure 7-2 Detention basin layout

7.2.3 Rail corridor (Zone 3)

The proposed rail corridor will cross 12 waterways and has the potential to affect local flooding behaviour at these locations. Section 6.3.2 describes the crossings and proposed structure types.

Minor waterway crossings along the rail spur have not been designed at this stage of the Project since the flood immunity and design of the rail spur crossings depends on mine access requirements, safety requirements and other operational requirements for the rail spur. The flood design criteria for this rail spur may also have to conform to local design guidelines, which should be considered during the detailed design phase.

As a general guide, it is recommended that the rail embankment be structurally sound up to at least the 100-year ARI event, to avoid environmental impacts should the embankment fail during extreme flood events. Preliminary designs for the two significant rail line crossings of Fords Creek and Tallawang Creek are presented in Section 6.3.2 based on suggested design criteria of safe operation under 100 year ARI flood conditions and suggested limits on afflux in land upstream of the crossings. Table 7-1 summarises the flood impacts of these structures on adjacent land based on hydraulic models of these preliminary designs.

Table 7-1 Flood impacts for preliminary design of Fords Creek and Tallawang Creek crossings

Location	100 year ARI afflux (m)	
	Fords Creek	Tallawang Creek
Approx. 200m upstream of crossing	0.14	0.01
Approx. 100m upstream of crossing	0.27	0.02
Just upstream of crossing	0.40	0.03
Just downstream of crossing	0.00	0.00

Additional rail embankment treatments, such as riprap or gabions, may be needed on approaches to the crossings on the upstream and downstream faces of the embankment. Embankment treatments should protect the embankment from damage and/or reduce the extent of damage during an extreme flood event.

All cross drainage structures should be assessed for scour and appropriate scour protection measures (typically in the form of dumped rock or concrete pads) should be provided at the inlets and outlets of the crossing structures.

Table 7-2 provides preliminary estimates of the lengths of rail spur that expected to be in cut and fill sections.

Table 7-2 Lengths of cut and fill along proposed rail spur

Section type	Length (km)
Fill sections	12.52
Cut sections	9.03
Total length of rail spur	21.55

The rail spur is 21.55 km long. This includes the rail line from the eastern end where it ties in to the existing rail line at the western end near the coal-handling and preparation plant (CHPP), but excludes the rail loop near the CHPP. The extent of cut and fill along the rail line has been assessed for the full 21.55 km length.

A typical longitudinal drainage system would be needed along the alignment of the rail spur to convey runoff intercepted by cut/fill slopes to the cross-drainage structures. The longitudinal system should be designed to drain intercepted flows as close to natural conditions as possible. Where steep gradients are unavoidable in the system, appropriate scour protection measures in the form of rock or concrete lined channel should be provided.

In addition, all drainage structures crossing creeks that have active fish movement should be fish-friendly and designed in accordance with *Policy and Guidelines for Fish Friendly Waterway Crossing* (NSW Fisheries 2003) and *Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull & Witheridge 2003).

7.3 Mine safety

This discussion of the mine's safety considers how flooding external to mining areas and workings affects the mine, mine infrastructure and mining operations. The proposed mine plan, as discussed above, will be located predominantly outside the 2,000-year ARI floodplain. This means that flooding in the Sandy Creek and Laheys Creek catchments will have little impact on the mine, except for very extreme low probability events larger than the 2,000-year ARI event. However, at several areas of the mine the 2,000-year ARI floodplain does encroach on the mine and mine infrastructure. These areas are discussed below.

7.3.1 Crossing 1 — northern access road

Crossing 1 is above the 100-year ARI design event with a freeboard allowance. However, hydraulic modelling of Crossing 1 indicates that the 2,000-year ARI event will overtop the road. The overtopping potential for events exceeding the 100-year ARI will need to be considered when designing the access road and waterway crossing.

Additional access road embankment treatments, such as riprap or gabions, would need to be placed on both approaches to the crossing on the upstream and downstream faces of the embankment. Embankment treatments should protect the embankment from damage and/or reduce the extent of damage during an extreme flood event.

At the eastern end of the northern access road near its intersection with Spring Ridge Road, the proposed road lies within the 100-year ARI flood extent. At this location, it is recommended that the access road be built above the 100-year ARI flood level, with freeboard allowance. The embankment should be designed to protect the road from erosion and damage.

The mine's site emergency plan should point out the low risk that this access road will be submerged during an extreme flood event.

7.3.2 Flood protection levees

Flood protection levees have been proposed at two key locations in the Laheys Creek and Blackheath Creek catchments. Although there are no proposed open-mining area along the waterways where floodwaters can enter, there are areas that require flood protection to prevent flooding from disrupting operations and potentially causing loss of life and/or damage to working areas and equipment.

The first of the key locations is the area along the southern edge of Blackheath Creek where a flood protection levee equal to the 2,000-year ARI flood level (or other suitable, extreme-event flood level, to be determined at the design stage) would be required to protect the coal stockpile. Alternatively, the coal stockpile platform on the southern bank of Blackheath Creek could be built above the 2,000-year ARI event (or other suitable extreme event), with freeboard allowance, to protect this from flooding.

The second location extends along the edge of the workshop area located on the northern bank of the lower reaches of Laheys Creek. It is assumed that this area is required to have flood immunity up to the 2,000-year ARI event (or other suitable extreme event), plus freeboard allowance. Alternatively, the embankment for the workshop and access road could be designed to be above the 2,000-year ARI event, with scour protection added to the embankment as it would be located on a bend of Laheys Creek where scour erosion may be significant. At the design stage the levee/embankment design at this location needs to allow for the potentially very high extreme-event flood velocities at this location.

The 2,000-year ARI flood event was chosen as a reasonable upper limit reference event for protection of critical infrastructure and is not proposed as a strict design requirement. The appropriate standard of flood protection for critical infrastructure will be confirmed at the design stage based on a detailed risk assessment for the Project.

The total length of these levees is 3.2 km, which includes a 2.2 km stretch along Blackheath Creek and 1 km stretch along Laheys Creek (see Figure 6-6). As the edge of mining area A is significantly higher than the 2,000-year ARI event level plus 600 mm freeboard, levees along this location are not required.

For the purpose of this assessment, flood levees have been assumed to have a 3 m top width with 1:3 sides and a height equal to the 2,000-year ARI flood level plus 600 mm freeboard. These parameters are proposed as an initial guide and should be reviewed at the design stage of the Project. There should also be an allowance on the inside edge at the toe of the levee for a collection drain to collect runoff from the embankments. The levees should be designed to prevent localised failure points and have a surface that minimises erosion.

7.3.3 Spoil emplacement protection

One of the spoil emplacement areas is to be located on or within the boundary of the 100-year ARI flood extent. It would require scour protection to protect it from erosion. It is proposed that instead of providing a levee, the toe of the spoil emplacement itself be engineered similarly to a levee. During the area's formation, a suitable hard rock material sourced locally from the site (e.g. from the rail cutting) should be used to construct the bottom section of the emplacement up to the level of the 100-year ARI flood level, plus a freeboard of 600 mm. The area is located along the western edge of the upper reaches of Laheys Creek, adjacent to mining area B.

The 100-year ARI flood levels are presented in Appendix D.1, but these levels should be checked after detailed design of the spoil emplacements. In addition to engineering the toe of the spoil emplacement, erosion and sediment control measures would be required to ensure that, during a flood event, sediment-laden runoff does not enter any downstream waterways.

It is understood that any structure that has the potential to modify flood behaviour up to the 100-year ARI event may need to be licensed by NOW. Licensing requirements associated with the design and construction of spoil emplacement protection measures should be determined during the detailed design stage of the Project.

7.3.4 Temporary diversion channels

As indicated earlier, mining areas and infrastructure are predominately out of the floodplain in both the existing and proposed scenarios. In the proposed scenario, however, the mine plan requires temporary and permanent diversion/removal of some of the smaller tributaries. In some cases the upstream portion of an existing creek will be unaffected by the mine but the downstream section will need to be temporarily diverted. As the mine expands, the entire creek will be incorporated into the mining area and the temporary diversion no longer required.

A review of the proposed mine plan shows that three temporary diversions of existing waterways are required. For this assessment, basic feasibility calculations were undertaken to ensure these diversion channels could be provided. It is recommended that these diversion channels be designed to follow the shape of the existing channel as closely as possible, with a low-flow channel and a high-flow channel above the low-flow channel. The average channel slope of the proposed diversion channels should be similar to that of the existing channel, and hydraulic checks of the channel should be completed to ensure velocities in the channel are not greater than 2 m/s to reduce the erosion potential in the diverted channel.

These diversion channels are intended to prevent clean water from the unaffected catchment flowing into the northern tailings dam (site 1, Years 1–4), mining area B (site 2, Years 1–4) and mining area B (expanded) (site 3, Years 4–8).

The capacity, and therefore the size, of the diversion channels should be sufficient for the 5-year ARI event flow in the low-flow channel and for the 100-year ARI event flow in the high-flow channel. The total length of these temporary diversions is around 3.7 km, with 2.6 km required during years 1–4 and 1.1 km required in years 4–8. If these minimum design considerations are followed, the mining areas and infrastructure will not be affected during regular and relatively extreme flood events in the catchment. The indicative locations of these channel diversions can be found in Appendix D.4.

8. Conclusions and recommendations

A detailed flood investigation was undertaken to assess the impacts of the proposed mine on flooding of the waterways within, upstream and downstream of the study area. Three crucial zones were identified where flooding impacts could be significant. The Sandy Creek catchment was subject to hydrologic and hydraulic modelling so that the impacts of the mine on Sandy Creek and Laheys Creek could be quantified. Areas outside the Sandy Creek catchment were assessed separately.

A detailed flood investigation, including hydrologic and hydraulic modelling, was undertaken to understand the existing flooding behaviour of Sandy Creek and Laheys Creek and how it affects the main mining area (Zone 1), and to determine how the proposed mine and associated infrastructure will affect flood behaviour in the catchment. Investigations were also undertaken to identify whether flooding within Sandy Creek and Laheys Creek would affect the Project, the proposed mine development and its operation.

Areas outside the Sandy Creek mining area, such as Flyblowers Creek (Zone 2) north of Sandy Creek catchment and the proposed rail spur (Zone 3) waterway crossings, were assessed separately using other methods.

It was found that flows in Laheys Creek would increase slightly overall due to the progressive diversion of the northern part of the catchment (which naturally flows into Sandy Creek) into Laheys Creek. However, this increase in catchment area flowing to Laheys Creek would be counteracted by the loss of catchment area to the mine, so changes in peak flows overall would be minimal.

A change in the timing of peaks would occur locally around the mine footprint, but by the time the peak flow reaches Sandy Creek, the flood behaviour would remain very similar to the existing scenario. The minor changes to flood levels in Sandy Creek just downstream of its junction with Laheys Creek would be negligible at the downstream end of Sandy Creek.

The northern boundary of the mining area is approximately 2 km from the Talbragar River, and the top of the catchment containing the mine area is approximately 45 m above the banks of the Talbragar River. For all events analysed, including the 2,000-year average recurrence interval (ARI) event, flood levels in the Talbragar River will not be affected by the mine due to the distance and difference in elevation between the two locations.

There will be local increases in velocities and changes to flood levels at structures where the flooding behaviour is changed, but these impacts will be highly localised. Areas experiencing high velocities will require channel erosion protection measures.

A feature of the mine infrastructure is the crossing of waterways through the stages of the mine workings. These crossings have undergone preliminary sizing to ensure minimal impact on design flood levels. It is essential that erosion protection measures for both the construction and operational phases of the Project be incorporated into the detailed design of these crossings. Such measures include rock revetments and scour protection for bridge piers and abutments.

In areas where the mine footprint encroaches on the 2,000-year ARI flood extent, flood protection works will be required to protect critical infrastructure, such as the workshop area on Laheys Creek, the northern access road and the stockpile along the southern edge of Blackheath Creek.

Where the spoil emplacement encroaches on the 100-year ARI flood extent, spoil protection will be required, to prevent erosion and collapse of spoil embankments. Small diversion channels will be required temporarily throughout the earlier stages of the mine; however, the catchments of these tributaries slowly decrease as the mine progresses.

Overall, the hydraulic modelling shows no significant change in flood levels along Sandy Creek and Laheys Creek and upstream and downstream of the main mining area. Therefore, no mitigation measures are required in the Sandy Creek catchment to reduce flooding impacts within the catchment or downstream in the Talbragar River.

However, there would be an impact on Flyblowers Creek (Zone 2), north of the Sandy Creek catchment. During years 12–20, mitigation measures would be required, to reduce the peak flow in Flyblowers Creek and avoid impacts to the Golden Highway. A dry detention basin with a capacity of 70,000 m³ is recommended to mitigate this impact. The detention basin can be accommodated within the study area, and should be close to the disturbed area. With this detention basin, it is estimated that peak flows reaching the Golden Highway should be close to those of the existing scenario, thereby avoiding adverse impacts on the highway.

In the rail corridor, the proposed rail spur will cross local waterways at 21 locations, including Fords Creek, Lambing Yard Creek and Tallawang Creek. Because some of the rail spur will be located on a 6 m high embankment, local flooding impacts, particularly on the upstream side of the embankment, could be significant. Therefore, waterway crossings, cross-drainage culverts and rail corridor longitudinal drainage need to be designed so that local flooding can be managed and impacts to the local environment and rail infrastructure minimised.

9. References

Boyd MJ Rigby EH, Van Drie R & Schymitzek I 2007, *Watershed Bounded Network Model: Details of the Theory used in WBNM*, January 2007.

Bureau of Meteorology 2003, *The Estimation of Probable Maximum Precipitation in Australia: generalised short duration method*, BOM hydrometeorological advisory service, June.

Bureau of Meteorology 2011, *New South Wales in 2010: La Niña brings wettest year in half a century*, Australian Government, Bureau of Meteorology, accessed 1 March 2012, <<http://www.bom.gov.au/climate/current/annual/nsw/archive/2010.summary.shtml>>.

Daily Liberal 2011, 'Flooding fears', Fairfax Media, accessed 7 March 2012 <<http://www.dailyliberal.com.au/news/local/news/general/flooding-fears/2339740.aspx?storypage=0>>.

Department of Natural Resources 2006, *Draft Macquarie River Floodplain Management Plan October 2006 Narromine to Oxley Station*, NSW Government.

Engineers Australia 2001, *Australian Rainfall and Runoff*, Engineers Australia 2001.

Fairfull S & Witheridge G 2003, *Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*, NSW Fisheries, Cronulla.

NSW Fisheries 2003, *Policy and Guidelines for Fish Friendly Waterway Crossings*, NSW Fisheries, NSW Department of Primary Industries, Sydney.

Rust PPK Environment & Infrastructure 1995, *Talbragar River Flood Study*, prepared for Dubbo City Council, December.

Appendix D.1

HEC-RAS results – existing
scenario

HEC-RAS results – existing scenario

Hydraulic results for 2-, 5-, 100- and 2,000-year ARI design rainfall event for all creeks and tributaries

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
T9	5076.31	2.2	420.97	5	421.06	20	421.31	63.5	421.64
T9	4691.95	2.2	416.72	5	416.8	20	417	63.5	417.24
T9	4272.49	2.2	411.03	5	411.12	20	411.35	63.5	411.4
T9	3882.82	2.2	403.85	5	404.02	20	404.5	63.5	404.97
T9	3477.03	2.2	401.98	5	402.11	20	402.47	63.5	403.02
T9	3037.1	2.2	399.29	5	399.37	20	399.6	63.5	399.95
T7	3634.5	2.2	468.87	5	468.97	20	469.29	63.5	469.75
T7	3195.38	2.2	453.71	5	453.81	20	453.99	63.5	454.24
T7	2804.41	2.2	445.16	5	445.26	20	445.5	63.5	445.82
T7	2391.43	2.2	437.99	5	438.1	20	438.41	63.5	438.81
T7	2003.62	2.2	431.14	5	431.24	20	431.53	63.5	432.02
T7	1596.85	2.2	425.09	5	425.38	20	425.8	63.5	426.28
T7	1198.37	2.2	418.61	5	418.77	20	419.19	63.5	419.58
T7	810.58	2.2	415.23	5	415.31	20	415.52	63.5	415.82
T7	400.38	2.2	410.78	5	410.95	20	411.16	63.5	411.41
T6	3554.34	3.7	415.61	9.9	415.75	32	416.06	102.3	416.54
T6	3085.28	3.7	411.33	9.9	411.48	32	411.74	102.3	412.18
T6	2803.38	3.7	408.4	9.9	408.54	32	408.87	102.3	409.41
T6	2397.17	3.7	404.53	9.9	404.93	32	405.52	102.3	406.29
T6	1991.35	3.7	400.95	9.9	401.08	32	401.35	102.3	401.62
T6	1603.5	3.7	396.64	9.9	397.07	32	397.58	102.3	398.15
T6	1197.85	3.7	394.43	9.9	394.57	32	394.66	102.3	395.15

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
T6	804.92	3.7	390.84	9.9	391.13	32	391.76	102.3	392.28
T6	340.67	3.7	387.87	9.9	388.08	32	388.1	102.3	388.54
T4	1210.26	8.9	408.91	20.3	409.29	81.7	410.17	259.6	412.05
T4	798.94	8.9	406.48	20.3	406.79	81.7	407.62	259.6	407.63
T4	383.84	8.9	402.41	20.3	402.65	81.7	403.41	259.6	404.6
T3	6530	4.1	402.43	9.4	402.73	38.1	403.05	120.9	403.38
T3	6129.97	4.1	398.97	9.4	399.13	38.1	399.64	120.9	400.21
T3	5742.66	4.1	396.35	9.4	396.58	38.1	397.04	120.9	397.44
T3	5322.14	4.1	393.88	9.4	394.06	38.1	394.46	120.9	394.98
T3	4908.86	4.1	390.24	9.4	390.39	38.1	390.87	120.9	391.51
T3	4564.44	4.1	388.14	9.4	388.32	38.1	388.66	120.9	389.12
T3	4159.99	4.1	385.76	9.4	385.85	38.1	386.12	120.9	386.45
T3	3728.48	4.1	382.91	9.4	383.04	38.1	383.38	120.9	383.89
T3	3600	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
T3	3536.64	4.1	380.85	9.4	380.96	38.1	381.46	120.9	382.06
T2	5247.05	1	401.54	2.3	401.61	9.3	401.88	29.5	401.93
T2	4832.14	1	394.37	2.3	394.47	9.3	394.53	29.5	395.09
T2	4428.3	1	388.89	2.3	388.95	9.3	389.24	29.5	389.34
T2	4039.51	1	383.54	2.3	383.63	9.3	383.67	29.5	384.18
T2	3636.26	1	377.58	2.3	377.66	9.3	378.17	29.5	378.27
T2	3188.01	1	372.49	2.3	372.62	9.3	372.66	29.5	372.8
T2	2826.34	1	366.93	2.3	367	9.3	367.23	29.5	367.29
T2	2383.54	4	362.92	9	362.7	31.3	363.27	113.4	363.82
T2	2017.59	4	360.25	9	360.35	31.3	360.76	113.4	360.99
T2	1622.68	4	357.62	9	357.78	31.3	357.89	113.4	358.45
T2	1278.99	4	354.72	9	354.79	31.3	355.25	113.4	355.3

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
T2	1056.59	4	353.71	9	353.8	31.3	353.86	113.4	354.65
T2	825.92	4	352.59	9	352.67	31.3	353.21	113.4	354.61
T2	627.51	4	352.07	9	352.54	31.3	353.16	113.4	354.59
T1	1186.85	2	377.39	4.5	377.53	17.8	377.63	56.7	377.75
T1	789.36	2	371.52	4.5	371.38	17.8	372.12	56.7	373.03
T1	398.39	2	367.34	4.5	367.78	17.8	367.95	56.7	368.06
SC	24396.1	8.1	435.21	18.3	435.85	72.6	436.54	231.2	437.88
SC	24007.48	8.1	432.53	18.3	432.66	72.6	432.93	231.2	433.5
SC	23590.68	8.1	426.31	18.3	426.65	72.6	427.47	231.2	428.18
SC	23210.61	8.1	421.67	18.3	422.02	72.6	422.76	231.2	423.91
SC	22791.34	8.1	418.88	18.3	419.24	72.6	419.94	231.2	420.91
SC	22393.29	8.1	415.8	18.3	416.14	72.6	417.18	231.2	418.53
SC	22000.34	8.1	413.53	18.3	413.96	72.6	415.05	231.2	416.08
SC	21594.63	8.1	410.73	18.3	411.14	72.6	412.2	231.2	413.22
SC	21198.78	8.1	407.69	18.3	408.2	72.6	409.45	231.2	410.71
SC	20800.59	8.1	405.52	18.3	405.88	72.6	406.78	231.2	408.14
SC	20397.18	8.1	402.87	18.3	403.43	72.6	404.89	231.2	406.57
SC	20002.84	9.6	400.59	24.4	401.52	114	403.4	362.7	405.19
SC	19608.18	9.6	399.38	24.4	399.84	114	401.38	362.7	403.09
SC	19193.98	9.6	397.9	24.4	398.34	114	399.4	362.7	400.84
SC	18799.33	9.6	395.87	24.4	396.75	114	397.87	362.7	398.84
SC	18575.84	9.6	395.11	24.4	395.9	114	397.06	362.7	397.79
SC	17995.23	10	392.62	26.4	393.07	127.8	394.15	406.5	395.31
SC	17620.46	10	391.18	26.4	391.74	127.8	392.97	406.5	394.19
SC	17191.31	10	389.27	26.4	389.89	127.8	390.78	406.5	391.8
SC	16799.9	10	388.69	26.4	389.14	127.8	390.01	406.5	391.03

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
SC	16394.36	10	386.3	26.4	386.79	127.8	388.35	406.5	389.62
SC	16300	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	16131.95	10	385.25	26.4	385.83	127.8	387.04	406.5	387.96
SC	15628.48	10.4	382.53	27.9	383.53	144.3	384.92	457.1	385.75
SC	15208.91	10.4	380.96	27.9	381.98	144.3	383.21	457.1	384.32
SC	14819.5	10.4	380.4	27.9	381.21	144.3	381.88	457.1	382.73
SC	14444.44	10.4	378.56	27.9	379.39	144.3	380.25	457.1	380.97
SC	14079.1	10.4	376.96	27.9	377.69	144.3	378.85	457.1	379.71
SC	13642.13	10.4	375.6	27.9	376.26	144.3	377.38	457.1	378.31
SC	13251.15	10.7	373.06	29.3	373.75	160.8	375.7	507.7	376.97
SC	12789.38	10.7	370.31	29.3	371.29	160.8	373.6	507.7	375.17
SC	12447.42	10.7	369.35	29.3	370.42	160.8	372.53	507.7	373.75
SC	12044.6	10.7	368.48	29.3	369.36	160.8	370.55	507.7	371.55
SC	11560.14	10.7	366.76	29.3	367.9	160.8	369.24	507.7	370.33
SC	11222.89	10.7	365.85	29.3	367.07	160.8	368.45	507.7	369.48
SC	10856.9	18.5	364.71	46.9	365.94	230.2	367.24	729.1	368.41
SC	10745.43	18.5	364.37	46.9	365.65	230.2	367.01	729.1	368.24
SC	10595.95	18.5	363.79	46.9	365.17	230.2	366.58	729.1	368.06
SC	10294.08	30.1	362.75	81.7	363.95	417.2	365.82	1315.9	366.97
SC	10032.72	30.1	362.63	81.7	363.72	417.2	365.67	1315.9	366.56
SC	9613.45	30.1	362.01	81.7	362.99	417.2	364.26	1315.9	365.19
SC	9193.18	30.1	360.97	81.7	362	417.2	363.15	1315.9	364.52
SC	8774.07	30.1	359.67	81.7	360.93	417.2	362.31	1315.9	363.52
SC	8431.69	30.1	358.85	81.7	359.88	417.2	361.46	1315.9	362.46
SC	8290.61	30.1	358.61	81.7	359.61	417.2	360.9	1315.9	362.2
SC	7497.25	30.1	356.58	81.7	357.87	417.2	359.61	1315.9	361.06

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
SC	7046.07	30.1	356.06	81.7	357.11	417.2	358.82	1315.9	360.21
SC	6742.61	30.1	355.74	81.7	356.67	417.2	358.15	1315.9	359.22
SC	6406.71	30.1	355.16	81.7	356.2	417.2	357.43	1315.9	358.34
SC	6066.35	30.1	354.49	81.7	355.56	417.2	356.63	1315.9	357.72
SC	5524.29	30.1	353.74	81.7	354.52	417.2	355.57	1315.9	357.05
SC	5203	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	5202.72	30.1	353.41	81.7	354.2	417.2	355.27	1315.9	356.77
SC	4814	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	4813.22	30.1	352.44	81.7	353.46	417.2	354.63	1315.9	355.97
SC	4499.5	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	4499.48	30.1	352.11	81.7	352.92	417.2	353.74	1315.9	355.09
SC	4062.73	28.5	351.75	77.8	352	429	352.92	1354.4	354.38
SC	3672.02	28.5	350.79	77.8	351.37	429	352.33	1354.4	353.89
SC	3418.04	28.5	349.97	77.8	351.17	429	351.96	1354.4	353.55
SC	2875.94	28.5	348.35	77.8	349.36	429	350.83	1354.4	352.72
SC	2398.41	28.5	347.6	77.8	348.95	429	350.21	1354.4	352.32
SC	2270	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	2262.77	28.5	347.54	77.8	348.91	429	350.11	1354.4	352.21
SC	2000	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	1963	28.5	347.43	77.8	348.8	429	349.97	1354.4	352.07
SC	1400	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	1213.63	28.5	345.13	77.8	346.1	429	348.53	1354.4	350.8
SC	1100	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	767.56	28.5	344.2	77.8	345.36	429	348.05	1354.4	350.17
SC	500	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	412.38	28.5	343.77	77.8	344.92	429	347.69	1354.4	349.61

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
SC	350	28.5	343.22	77.8	344.27	429	347.03	1354.4	348.92
LC	13198.68	2.4	421.83	16.7	422.51	64.9	423.76	207.4	425.17
LC	12806.65	2.4	419.06	16.7	420.4	64.9	421.72	207.4	422.88
LC	12424.45	2.4	417.19	16.7	418.67	64.9	419.6	207.4	420.53
LC	11995.3	2.4	414.46	16.7	415.62	64.9	416.76	207.4	417.23
LC	11629.37	2.4	412.07	16.7	413.07	64.9	414.49	207.4	415.49
LC	11211.95	2.4	410.15	16.7	410.99	64.9	412.13	207.4	412.49
LC	10825.65	2.4	408.81	16.7	409.63	64.9	410.78	207.4	412.33
LC	10440.81	2.4	406.12	16.7	406.39	64.9	406.6	207.4	407.18
LC	10236.23	2.4	400.94	16.7	401.5	64.9	403.01	207.4	404.27
LC	9608.36	16.3	397.99	36.9	398.87	146.6	400.73	466.6	401.78
LC	9208.76	16.3	396.31	36.9	396.95	146.6	398.36	466.6	399.67
LC	8811.17	16	394.1	37	394.73	151.8	396.37	482.8	397.4
LC	8377.35	16	392.36	37	393.13	151.8	394.34	482.8	395.4
LC	7992.23	16	390.44	37	391.31	151.8	392.85	482.8	394
LC	7639.78	16	389.24	37	389.95	151.8	391.5	482.8	392.57
LC	7204.96	16	388.04	37	388.64	151.8	390.18	482.8	390.86
LC	6761.61	16	386.3	37	387.02	151.8	388.41	482.8	389.34
LC	6420.26	16	385.25	37	386.01	151.8	387.26	482.8	388.19
LC	6004.29	16	383.05	37	383.56	151.8	385.25	482.8	386.43
LC	5644.39	16	381.29	37	382	151.8	383.97	482.8	385.16
LC	5352.7	16	380.15	37	380.94	151.8	382.93	482.8	383.75
LC	4808.16	15	378.22	37.3	378.93	172.4	380.21	547.9	381.07
LC	4571.76	15	377.63	37.3	378.32	172.4	379.65	547.9	379.89
LC	4103.04	13.9	376.28	37.6	377.02	193.1	377.4	612.9	378.32
LC	3586.81	13.9	374.92	37.6	375.68	193.1	376.33	612.9	377.13

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
LC	3424.42	13.9	374.47	37.6	375.24	193.1	375.93	612.9	376.77
LC	2838.58	13.9	373.13	37.6	373.68	193.1	374.49	612.9	375.36
LC	2440.29	13.9	372.51	37.6	372.87	193.1	373.59	612.9	374.54
LC	1771.3	13.9	369.06	37.6	369.81	193.1	370.82	612.9	371.62
LC	1592.37	13.9	368.29	37.6	369.08	193.1	370.09	612.9	371.02
LC	1207.16	13.9	367.89	37.6	368.62	193.1	369.34	612.9	370.16
LC	967.02	13.9	367.4	37.6	368.02	193.1	368.76	612.9	369.62
LC	216.38	13.9	363.48	37.6	364.76	193.1	366.33	612.9	367.9
12	2022.95	2.3	398.62	5.3	398.68	21.4	399.12	68	399.2
12	1656.23	2.3	395	5.3	395.15	21.4	395.16	68	395.66
12	1242.83	2.3	390.02	5.3	390.3	21.4	390.97	68	391.01
12	789.38	2.3	385.1	5.3	385.25	21.4	385.29	68	386.15
12	700	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
12	379.26	2.3	380	5.3	380.08	21.4	380.95	68	380.71
11	5219.22	3.9	401.19	8.8	401.42	34.7	401.93	110.7	402.49
11	4811.29	3.9	398.17	8.8	398.32	34.7	398.65	110.7	399.07
11	4399.31	3.9	394.29	8.8	394.43	34.7	394.71	110.7	395.09
11	3971.94	3.9	390.48	8.8	390.61	34.7	390.93	110.7	391.33
11	3575.7	3.9	386.14	8.8	386.32	34.7	386.7	110.7	387.2
11	3195.69	3.9	383.55	8.8	383.65	34.7	383.87	110.7	384.23
11	2763.45	3.9	380.05	8.8	380.11	34.7	380.29	110.7	380.6
11	2443.27	3.9	378.23	8.8	378.39	34.7	378.76	110.7	379.22
11	2168.85	7.8	376.84	17.7	376.96	69.4	377.27	221.4	377.74
11	1544.85	7.8	373.95	17.7	374.12	69.4	374.46	221.4	374.83
11	1230.99	7.8	372.17	17.7	372.24	69.4	372.48	221.4	372.94
11	1200	Lat Struct		Lat Struct		Lat Struct		Lat Struct	

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
11	701.66	7.8	369.51	17.7	369.82	69.4	370.2	221.4	370.66
11	700	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
11	347.2	7.8	368.46	17.7	368.54	69.4	368.67	221.4	369.33
10	5220.59	3.9	424.46	8.8	424.59	34.7	425.02	110.7	425.67
10	4804.14	3.9	421.07	8.8	421.24	34.7	421.68	110.7	422.07
10	4389.26	3.9	413.66	8.8	413.84	34.7	414.2	110.7	414.58
10	3960.26	3.9	406.95	8.8	407.14	34.7	407.43	110.7	407.88
10	3651.41	3.9	402.28	8.8	402.69	34.7	403.56	110.7	404.24
10	3229.31	3.9	398.98	8.8	399.31	34.7	399.77	110.7	400.45
10	2805.48	3.9	396.3	8.8	396.39	34.7	396.71	110.7	397.21
10	2410.96	3.9	392.61	8.8	392.88	34.7	393.46	110.7	394.2
10	2010.26	3.9	390.66	8.8	390.78	34.7	391.12	110.7	391.63
10	1606.27	3.9	388.11	8.8	388.25	34.7	388.56	110.7	389.1
10	1197.16	3.9	385.63	8.8	385.76	34.7	386.06	110.7	386.38
10	1000	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
10	617.5	3.9	381.39	8.8	381.54	34.7	381.93	110.7	382.36
10	300	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
10	287.64	3.9	379.71	8.8	379.79	34.7	379.99	110.7	380.25
Trib 2b	1426.4	1.82	380.16	4.1	380.25	16.2	380.53	51.6	380.88
Trib 2b	1207.62	1.82	373.38	4.1	373.64	16.2	374.39	51.6	375.4
Trib 2b	1016.35	1.82	371.32	4.1	371.52	16.2	372.19	51.6	373.16
Trib 2b	810.24	1.82	369.05	4.1	369.35	16.2	370.08	51.6	371.25
Trib 2b	682.16	1.82	368.1	4.1	368.36	16.2	369.29	51.6	370.45
Trib 2b	422.21	1.82	365.31	4.1	365.67	16.2	366.07	51.6	366.9
Trib 2b	207.45	1.82	362.3	4.1	362.47	16.2	363.56	51.6	364.75
Trib 2b	0.1	1.82	361.35	4.1	362.35	16.2	363.55	51.6	364.76

Appendix D.2

HEC-RAS results – proposed
scenario

HEC-RAS results – proposed scenario

Hydraulic results for 2-, 5-, 100- and 2,000-year ARI design rainfall event for all creeks and tributaries

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
T9	5076.31	2.2	420.97	5	421.06	20	421.31	63.5	421.64
T9	4691.95	2.2	416.72	5	416.8	20	417	63.5	417.24
T9	4272.49	2.2	411.03	5	411.12	20	411.35	63.5	411.4
T9	3882.82	2.2	403.85	5	404.02	20	404.5	63.5	404.97
T9	3477.03	2.2	401.98	5	402.11	20	402.47	63.5	403.02
T9	3037.1	2.2	399.29	5	399.37	20	399.6	63.5	399.95
T7	3634.5	2.2	468.87	5	468.97	20	469.29	63.5	469.75
T7	3195.38	2.2	453.71	5	453.81	20	453.99	63.5	454.24
T7	2804.41	2.2	445.16	5	445.26	20	445.5	63.5	445.82
T7	2391.43	2.2	437.99	5	438.1	20	438.41	63.5	438.81
T7	2003.62	2.2	431.14	5	431.24	20	431.53	63.5	432.02
T7	1596.85	2.2	425.09	5	425.38	20	425.8	63.5	426.28
T7	1198.37	2.2	418.61	5	418.77	20	419.19	63.5	419.58
T7	810.58	2.2	415.23	5	415.31	20	415.52	63.5	415.82
T7	400.38	2.2	410.78	5	410.95	20	411.16	63.5	411.41
T6	3554.34	4.5	415.62	7.9	415.71	30.3	416.04	96.6	416.53
T6	3085.28	4.5	411.35	7.9	411.44	30.3	411.73	96.6	412.15
T6	2803.38	4.5	408.41	7.9	408.5	30.3	408.85	96.6	409.39
T6	2397.17	4.5	404.61	7.9	404.82	30.3	405.5	96.6	406.25
T6	1991.35	4.5	400.96	7.9	401.05	30.3	401.32	96.6	401.62
T6	1603.5	4.5	396.72	7.9	396.94	30.3	397.56	96.6	398.12
T6	1197.85	4.5	394.44	7.9	394.54	30.3	394.64	96.6	395.13

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
T6	804.92	4.5	390.92	7.9	391.05	30.3	391.74	96.6	392.25
T6	340.67	4.5	387.91	7.9	388.04	30.3	388.08	96.6	388.52
T4	1210.26	8.9	408.91	20.3	409.29	81.7	410.17	259.6	412.05
T4	798.94	8.9	406.48	20.3	406.79	81.7	407.62	259.6	407.63
T4	383.84	8.9	402.41	20.3	402.65	81.7	403.41	259.6	404.6
T3	6530	10.89	402.8	12.8	402.85	39.5	403.09	108.3	403.37
T3	6129.97	10.89	399.13	12.8	399.17	39.5	399.58	108.3	400.11
T3	5742.66	10.89	396.67	12.8	396.72	39.5	397.11	108.3	397.46
T3	5322.14	10.89	394.04	12.85	394.09	39.49	394.39	108.27	394.86
T3	4908.86	10.89	390.49	12.85	390.55	39.49	391.08	108.27	391.64
T3	4564.44	10.89	388.31	12.85	388.35	39.49	388.57	108.27	388.93
T3	4159.99	10.89	385.93	12.85	385.96	39.49	386.27	108.27	386.62
T3	3728.48	10.89	383.19	12.85	383.22	39.49	383.47	108.27	383.99
T3	3700	10.89	382.74	12.85	382.77	39.49	383.08	108.27	383.92
T3	3650	10.89	382.42	12.85	382.45	39.49	382.9	108.27	383.8
T2	3649	Bridge		Bridge		Bridge		Bridge	
T2	3600	10.89	381.36	12.85	381.42	39.49	381.95	108.27	383.02
T2	3540	10.89	381.21	12.85	381.26	39.49	381.74	108.27	382.88
T2	3539	Bridge		Bridge		Bridge		Bridge	
T2	3536.64	10.89	380.67	12.85	380.69	39.49	381.41	108.27	381.91
T2	5247.05	0.1	401.42	0.1	401.42	0.1	401.42	0.1	401.42
T2	4832.14	0.1	394.19	0.1	394.2	0.1	394.2	0.1	394.19
T2	4428.3	0.1	388.68	0.1	388.65	0.1	388.65	0.1	388.68
T2	4039.51	0.1	383.42	0.1	383.39	0.1	383.39	0.1	383.42
T2	3636.26	0.1	377.45	0.1	377.49	0.1	377.49	0.1	377.45
T2	3188.01	0.1	372.3	0.1	372.25	0.1	372.25	0.1	372.3

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
T2	2826.34	0.1	366.85	0.1	366.9	0.1	366.9	0.1	366.85
T2	2383.54	0.1	362.33	0.1	362.25	0.1	362.25	0.1	362.32
T2	2017.59	0.1	360.05	0.1	360.09	0.1	360.09	0.1	360.05
T1	1622.68	0.1	357.31	0.1	357.24	0.1	357.24	0.1	357.31
T1	1278.99	0.1	354.56	0.1	354.65	0.1	354.65	0.1	354.57
T1	1056.59	0.1	353.45	0.1	353.39	0.1	353.39	0.1	354.57
SC	825.92	0.1	352.41	0.1	352.53	0.1	353.14	0.1	354.57
SC	627.51	0.1	352.08	0.1	352.53	0.1	353.14	0.1	354.57
SC	1186.85	0.1	377.25	0.1	377.3	0.1	377.3	0.1	377.25
SC	789.36	0.1	371.16	0.1	371.12	0.1	371.12	0.1	371.16
SC	398.39	0.1	367.16	0.1	367.21	0.1	367.21	0.1	367.16
SC	24396.1	8.1	435.21	18.3	435.85	72.6	436.54	231.2	437.88
SC	24007.48	8.1	432.53	18.3	432.66	72.6	432.93	231.2	433.5
SC	23590.68	8.1	426.31	18.3	426.65	72.6	427.47	231.2	428.18
SC	23210.61	8.1	421.67	18.3	422.02	72.6	422.76	231.2	423.91
SC	22791.34	8.1	418.88	18.3	419.24	72.6	419.94	231.2	420.91
SC	22393.29	8.1	415.8	18.3	416.14	72.6	417.18	231.2	418.53
SC	22000.34	8.1	413.53	18.3	413.96	72.6	415.05	231.2	416.08
SC	21594.63	8.1	410.73	18.3	411.14	72.6	412.2	231.2	413.22
SC	21198.78	8.1	407.69	18.3	408.2	72.6	409.45	231.2	410.71
SC	20800.59	8.1	405.52	18.3	405.88	72.6	406.78	231.2	408.14
SC	20397.18	8.1	402.87	18.3	403.43	72.6	404.89	231.2	406.57
SC	20002.84	9.6	400.59	24.4	401.52	114	403.4	362.7	405.19
SC	19608.18	9.6	399.38	24.4	399.84	114	401.38	362.7	403.09
SC	19193.98	9.6	397.9	24.4	398.34	114	399.4	362.7	400.84
SC	18799.33	9.6	395.87	24.4	396.75	114	397.87	362.7	398.84

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
SC	18575.84	9.6	395.11	24.4	395.9	114	397.06	362.7	397.79
SC	17995.23	10	392.62	26.4	393.07	127.8	394.15	406.5	395.31
SC	17620.46	10	391.18	26.4	391.74	127.8	392.97	406.5	394.19
SC	17191.31	10	389.27	26.4	389.89	127.8	390.78	406.5	391.8
SC	16799.9	10	388.69	26.4	389.14	127.8	390.01	406.5	391.03
SC	16394.36	10	386.3	26.4	386.79	127.8	388.35	406.5	389.62
SC	16300	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	16131.95	10	385.25	26.4	385.83	127.8	387.04	406.5	387.97
SC	15628.48	10.4	382.53	27.8	383.53	143.5	384.92	454.1	385.75
SC	15208.91	10.4	380.96	27.8	381.98	143.5	383.21	454.1	384.31
SC	14819.5	10.4	380.4	27.8	381.17	143.5	381.88	454.1	382.73
SC	14444.44	10.4	378.56	27.8	379.46	143.5	380.24	454.1	380.96
SC	14079.1	10.4	376.96	27.8	377.81	143.5	378.85	454.1	379.71
SC	13642.13	10.4	375.6	27.8	376.25	143.5	377.38	454.1	378.3
SC	13251.15	10.7	373.06	29.1	373.74	159.1	375.69	501.7	376.95
SC	12789.38	10.7	370.31	29.1	371.28	159.1	373.59	501.7	375.15
SC	12447.42	10.7	369.35	29.1	370.41	159.1	372.55	501.7	373.77
SC	12044.6	10.7	368.48	29.1	369.35	159.1	370.51	501.7	371.48
SC	11560.14	10.7	366.76	29.1	367.88	159.1	369.27	501.7	370.79
SC	11222.89	10.7	365.85	29.1	367.03	159.1	368.73	501.7	370.52
SC	10856.9	18.6	364.77	46.8	366.03	228.7	367.56	723	369.9
SC	10837	Bridge		Bridge		Bridge		Bridge	
SC	10745.43	18.6	364.67	46.8	365.93	228.7	367.4	723	368.41
SC	10595.95	18.6	363.92	46.8	365.19	228.7	366.59	723	368.06
SC	10294.08	34.5	362.93	86	364.01	422.8	365.84	1317.5	366.97
SC	10032.72	34.5	362.8	86	363.78	422.8	365.68	1317.5	366.57

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
SC	9613.45	34.5	362.17	86	363.03	422.8	364.26	1317.5	365.19
SC	9193.18	34.5	361.08	86	362.08	422.8	363.16	1317.5	364.52
SC	8774.07	34.5	359.81	86	361.03	422.8	362.31	1317.5	363.52
SC	8431.69	34.5	358.97	86	359.93	422.8	361.47	1317.5	362.46
SC	8290.61	34.5	358.72	86	359.65	422.8	360.92	1317.5	362.2
SC	7497.25	34.5	356.75	86	357.93	422.8	359.63	1317.5	361.07
SC	7046.07	34.5	356.19	86	357.16	422.8	358.84	1317.5	360.21
SC	6742.61	34.5	355.85	86	356.72	422.8	358.16	1317.5	359.22
SC	6406.71	34.5	355.29	86	356.24	422.8	357.44	1317.5	358.34
SC	6066.35	34.5	354.63	86	355.59	422.8	356.64	1317.5	357.72
SC	5524.29	34.5	353.86	86	354.55	422.8	355.58	1317.5	357.06
SC	5203	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	5202.72	34.5	353.51	86	354.23	422.8	355.29	1317.5	356.78
SC	4814	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	4813.22	34.5	352.61	86	353.52	422.8	354.64	1317.5	355.97
SC	4499.5	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	4499.48	34.5	352.22	86	352.97	422.8	353.75	1317.5	355.09
SC	4062.73	31.4	351.81	82.6	351.94	431.5	352.92	1355.3	354.38
SC	3672.02	31.4	350.86	82.6	351.42	431.5	352.33	1355.3	353.89
SC	3418.04	31.4	350.05	82.6	349.58	431.5	351.96	1355.3	353.55
SC	2875.94	31.4	348.43	82.6	349.43	431.5	350.84	1355.3	352.72
SC	2398.41	31.4	347.71	82.6	349.09	431.5	350.22	1355.3	352.32
SC	2270	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	2262.77	31.4	347.66	82.6	349.07	431.5	350.12	1355.3	352.21
SC	2000	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
SC	1963	31.4	347.54	82.6	349.03	431.5	349.98	1355.3	352.07

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
SC	1400	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
LC	1213.63	31.4	348.04	82.6	348.07	431.5	348.81	1355.3	350.77
LC	1100	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
LC	767.56	31.4	348.03	82.6	348.05	431.5	348.51	1355.3	350.12
LC	500	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
LC	412.38	31.4	348.03	82.6	348.04	431.5	348.3	1355.3	349.53
LC	350	31.4	348.03	82.6	348.03	431.5	348.03	1355.3	348.03
LC	13198.68	2.4	421.83	16.7	422.51	64.9	423.76	207.4	425.17
LC	12806.65	2.4	419.06	16.7	420.4	64.9	421.72	207.4	422.88
LC	12424.45	2.4	417.19	16.7	418.67	64.9	419.6	207.4	420.53
LC	11995.3	2.4	414.46	16.7	415.62	64.9	416.76	207.4	417.23
LC	11629.37	2.4	412.07	16.7	413.07	64.9	414.49	207.4	415.49
LC	11211.95	2.4	410.15	16.7	410.99	64.9	412.13	207.4	412.49
LC	10825.65	2.4	408.81	16.7	409.65	64.9	410.78	207.4	412.33
LC	10440.81	2.4	406.12	16.7	406.38	64.9	406.6	207.4	407.18
LC	10236.23	2.4	400.94	16.7	401.53	64.9	403.08	207.4	404.41
LC	9608.36	16.3	397.97	36.9	398.84	146.6	400.62	467	401.68
LC	9208.76	17.3	396.6	37.9	397.19	152	398.75	479	400.07
LC	8920	17.3	395.98	37.9	396.44	152	397.95	479	399.77
LC	8910	Bridge		Bridge		Bridge		Bridge	
LC	8900	17.3	395.54	37.9	396.13	152	397.57	479	399.6
LC	8870	17.3	394.91	37.9	395.56	152	397.01	479	399.08
LC	8850	Bridge		Bridge		Bridge		Bridge	
LC	8820	17.3	394.31	37.9	394.9	152	396.5	479	397.91
LC	8811.17	17.3	394.18	37.9	394.75	152	396.39	479	397.76
LC	8377.35	17.3	392.48	37.9	393.15	152	394.3	479	395.65

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
LC	7992.23	17.4	390.53	38.1	391.34	154.6	392.97	486.9	394.3
LC	7639.78	17.4	389.31	38.1	389.98	154.6	391.91	486.9	392.79
LC	7204.96	17.4	388.11	38.1	388.67	154.6	390.1	486.9	391.15
LC	6761.61	17.6	386.34	38.3	387.06	157.3	388.44	494.7	389.51
LC	6420.26	17.6	385.51	38.3	386.17	157.3	387.32	494.7	388.14
LC	6004.29	18.2	382.64	39	383.2	165.4	385.27	518.2	386.85
LC	5660	18.2	381.42	39	382.15	165.4	384.41	518.2	386.5
LC	5659	Bridge		Bridge		Bridge		Bridge	
12	5644.39	18.2	381.14	39	381.9	165.4	384.07	518.2	385.83
12	5500	18.2	380.94	39	381.77	165.4	383.91	518.2	385.75
12	5400	Bridge		Bridge		Bridge		Bridge	
12	5352.7	18.2	380.27	39	381.01	165.4	383	518.2	384.05
12	4808.16	19.6	378.4	40.5	379	184.2	380.23	573	381.1
12	4571.76	19.6	377.83	40.5	378.39	184.2	379.73	573	379.91
11	4103.04	19.7	376.56	40.7	377.07	186.8	377.29	580.9	378.27
11	3586.81	19.7	375.15	40.7	375.76	186.8	376.31	580.9	377.09
11	3424.42	19.7	374.7	40.7	375.32	186.8	375.91	580.9	376.72
11	2838.58	19.7	373.36	40.7	373.71	186.8	374.47	580.9	375.31
11	2440.29	19.7	372.7	40.7	372.9	186.8	373.58	580.9	374.51
11	1771.3	19.9	369.36	40.9	369.88	189.5	370.79	588.7	371.57
11	1592.37	19.9	368.63	40.9	369.15	189.5	370.1	588.7	371.02
11	1207.16	20.7	368.21	41.7	368.69	200.3	369.36	620	370.17
11	967.02	20.7	367.68	41.7	368.13	200.3	368.78	620	369.63
11	216.38	20.7	363.74	41.7	364.85	200.3	366.35	620	367.91
11	2022.95	0.1	398.48	0.1	398.48	0.1	398.52	0.1	398.48
11	1656.23	0.1	394.77	0.1	394.77	0.1	394.69	0.1	394.77

Reach	Chainage	2-year		5-year		100-year		2,000-year	
		Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)	Peak flow (m ³ /s)	Flood level (mAHD)
11	1242.83	0.1	389.59	0.1	389.59	0.1	389.74	0.1	389.59
11	789.38	0.1	384.79	0.1	384.79	0.1	384.75	0.1	384.79
11	700	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
10	379.26	0.1	379.81	0.1	379.81	0.1	381.02	0.1	379.81
10	5219.22	3.9	401.19	8.8	401.42	34.7	401.93	110.7	402.49
10	4811.29	3.9	398.17	8.8	398.32	34.7	398.65	110.7	399.07
10	4399.31	3.9	394.29	8.8	394.43	34.7	394.71	110.7	395.09
10	3971.94	3.9	390.48	8.8	390.61	34.7	390.93	110.7	391.33
10	3575.7	3.9	386.14	8.8	386.32	34.7	386.7	110.7	387.2
10	3195.69	3.9	383.55	8.8	383.65	34.7	383.87	110.7	384.23
10	2763.45	3.9	380.05	8.8	380.11	34.7	380.29	110.7	380.6
10	2443.27	3.9	378.23	8.8	378.39	34.7	378.73	110.7	379.23
10	2168.85	7.8	376.84	17.7	376.96	69.4	377.33	221.4	377.73
10	1544.85	7.8	373.95	17.7	374.12	69.4	374.44	221.4	374.83
10	1230.99	7.8	372.17	17.7	372.24	69.4	372.55	221.4	372.92
10	1200	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
10	701.66	7.8	369.51	17.7	369.82	69.4	370.12	221.4	370.67
10	700	Lat Struct		Lat Struct		Lat Struct		Lat Struct	
Trib 2b	No flow								

Appendix D.3

Waterway crossing schematics from
HEC-RAS

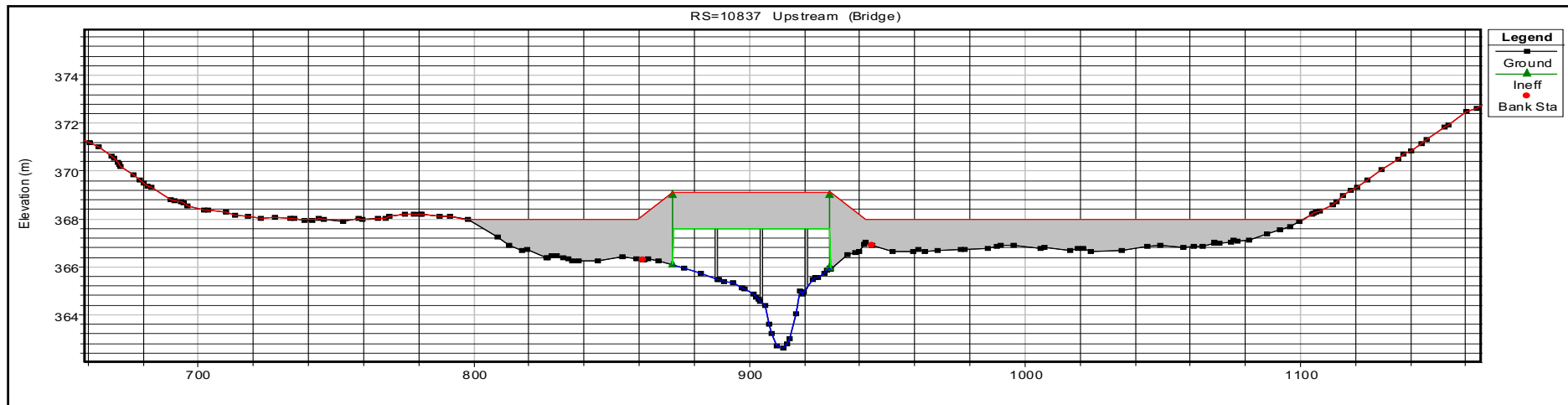


Figure D3.1 Crossing 1 schematic

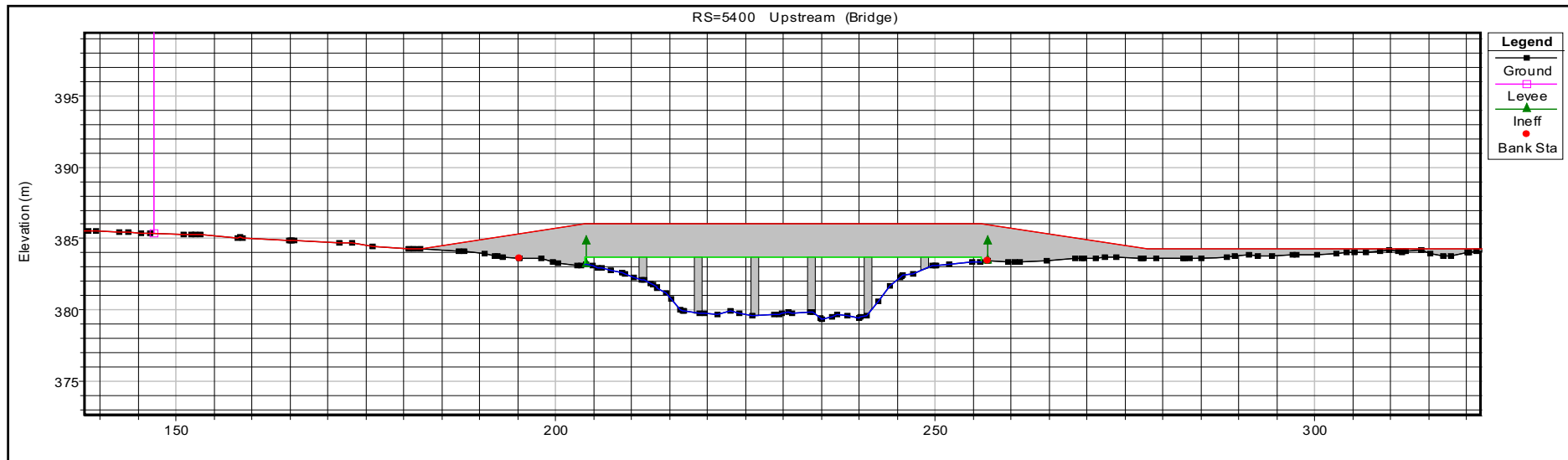


Figure D3.2 Crossing 2 schematic

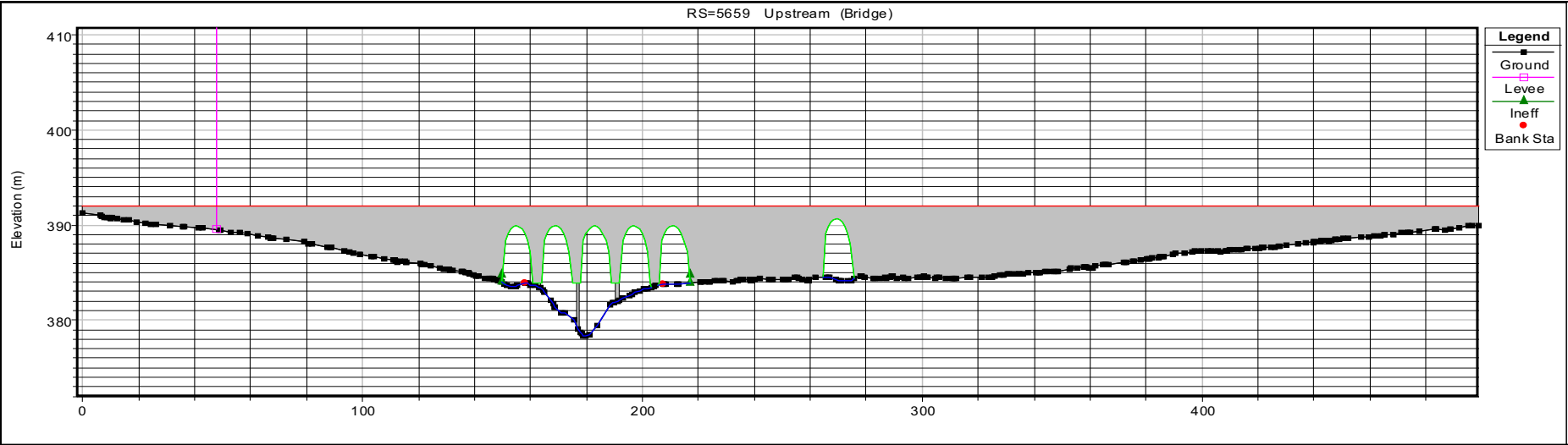


Figure D3.3 Crossing 3 schematic

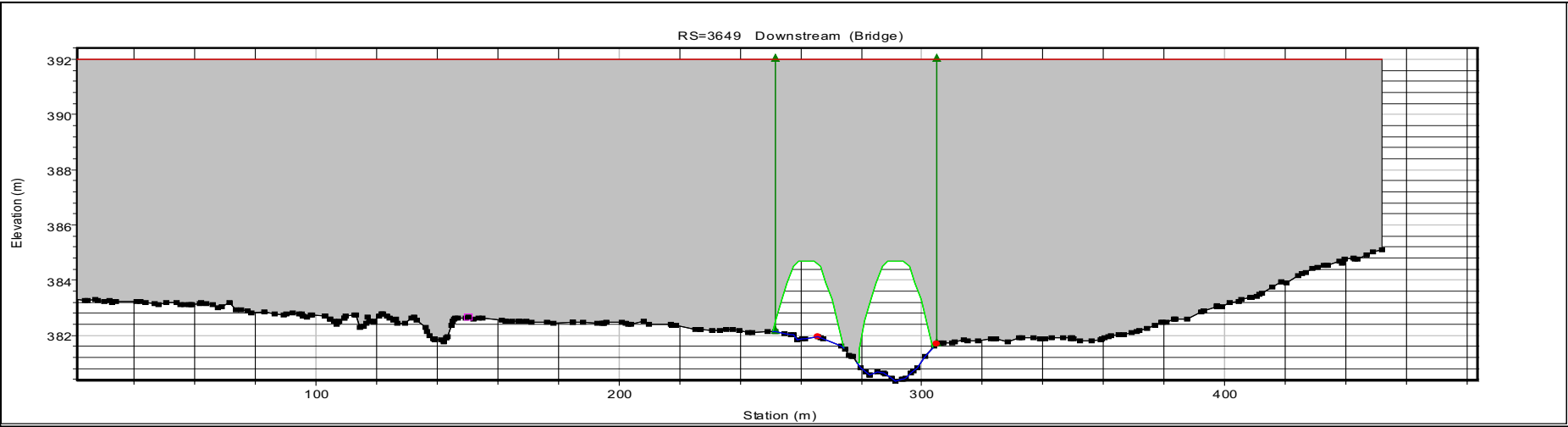


Figure D3.4 Crossing 4 schematic

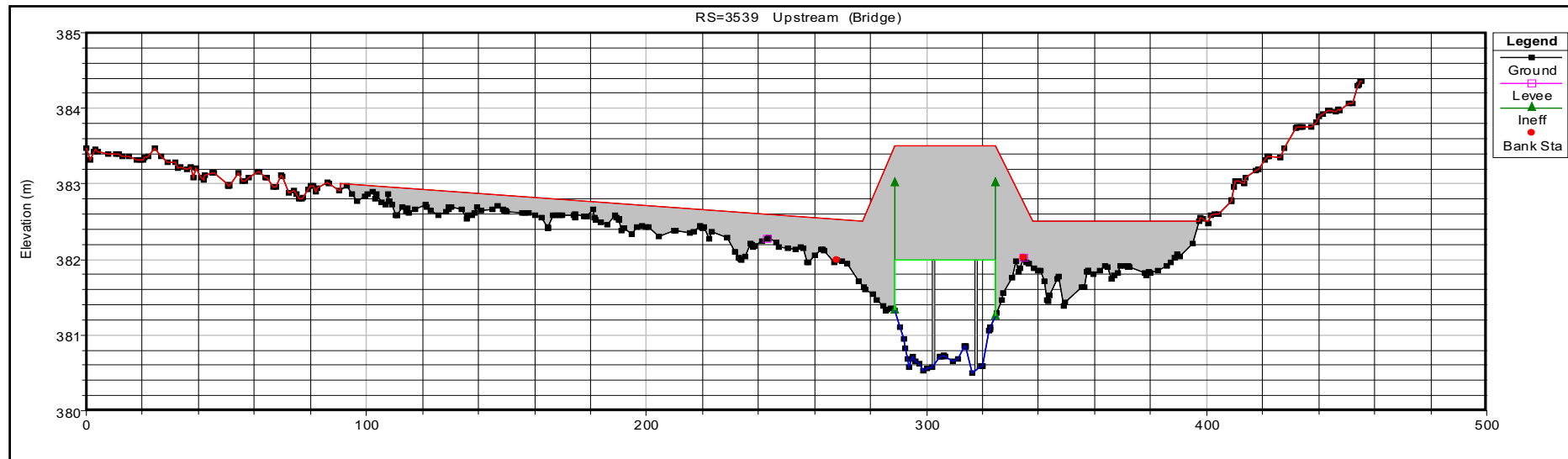


Figure D3.5 Crossing 5 schematic

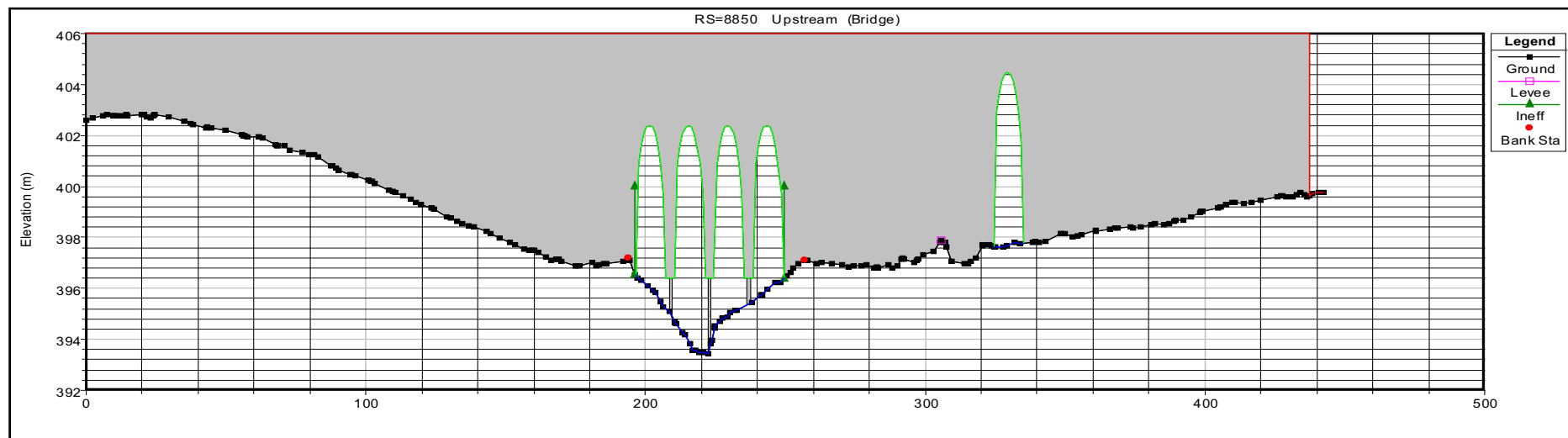


Figure D3.6 Crossing 6 schematic

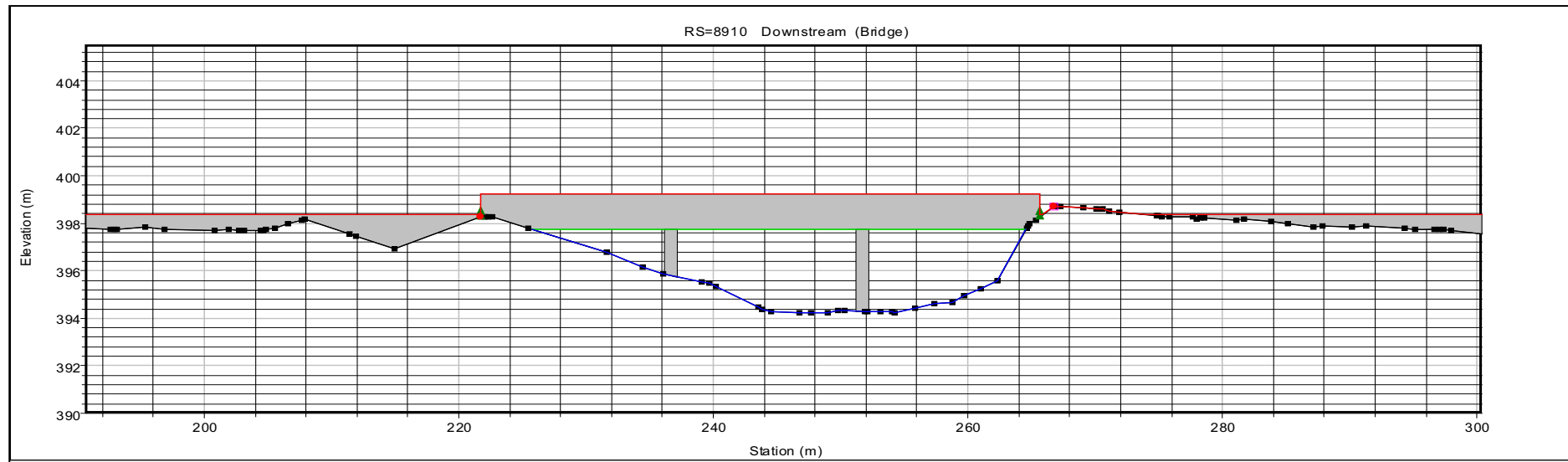


Figure D3.7 Crossing 8 schematic

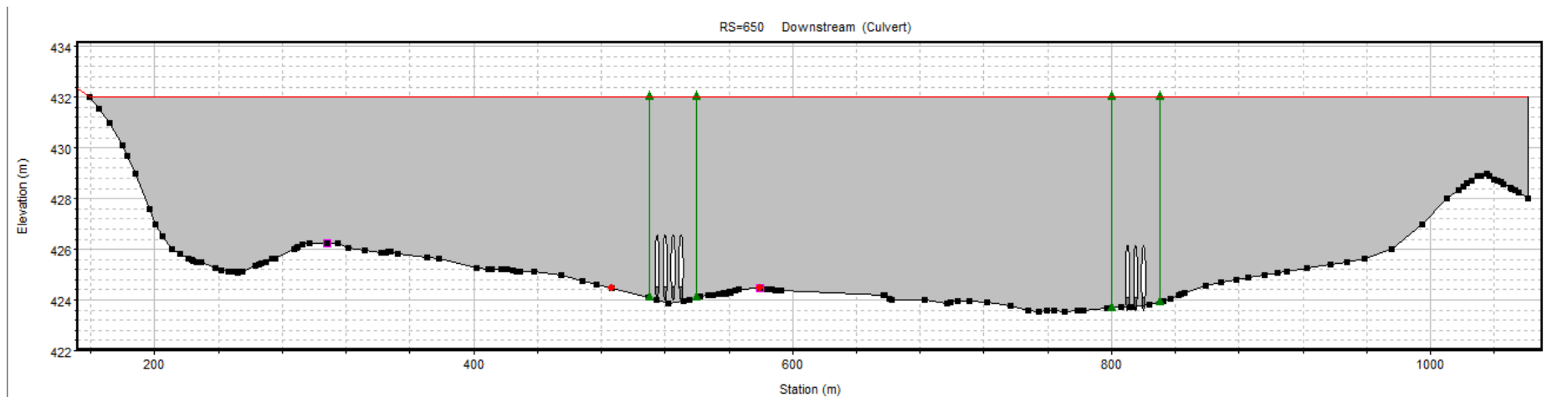


Figure D3.8 Crossing 11 schematic

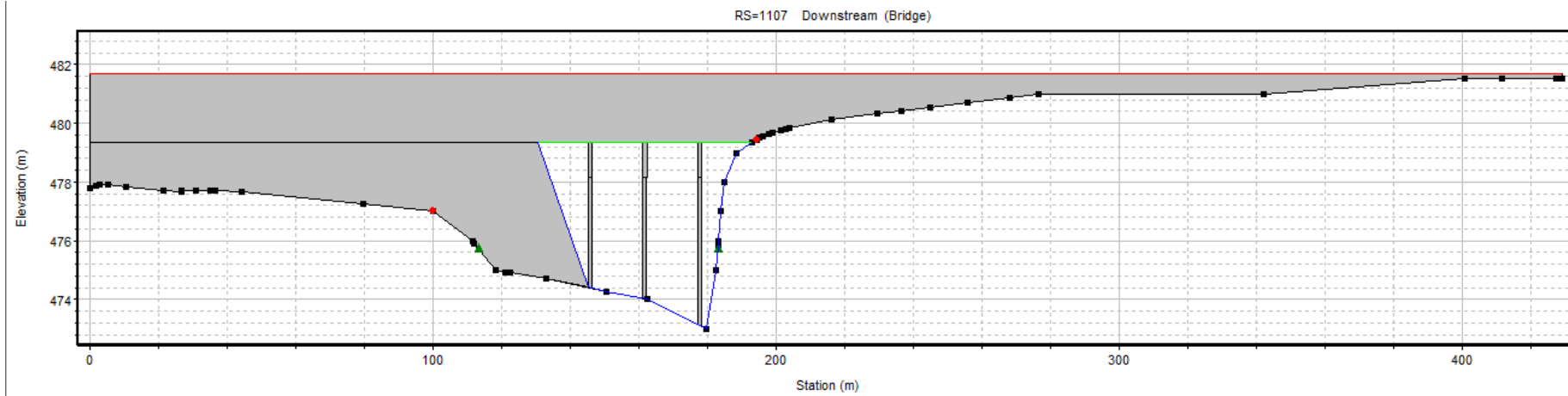


Figure D3.9 Eastern channel of Crossing 28 schematic

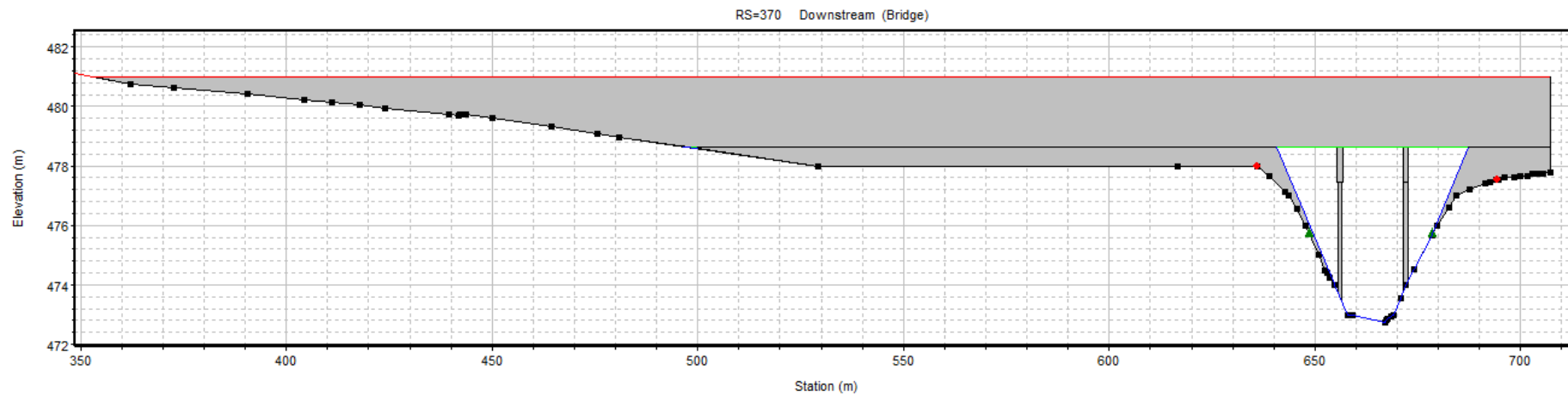
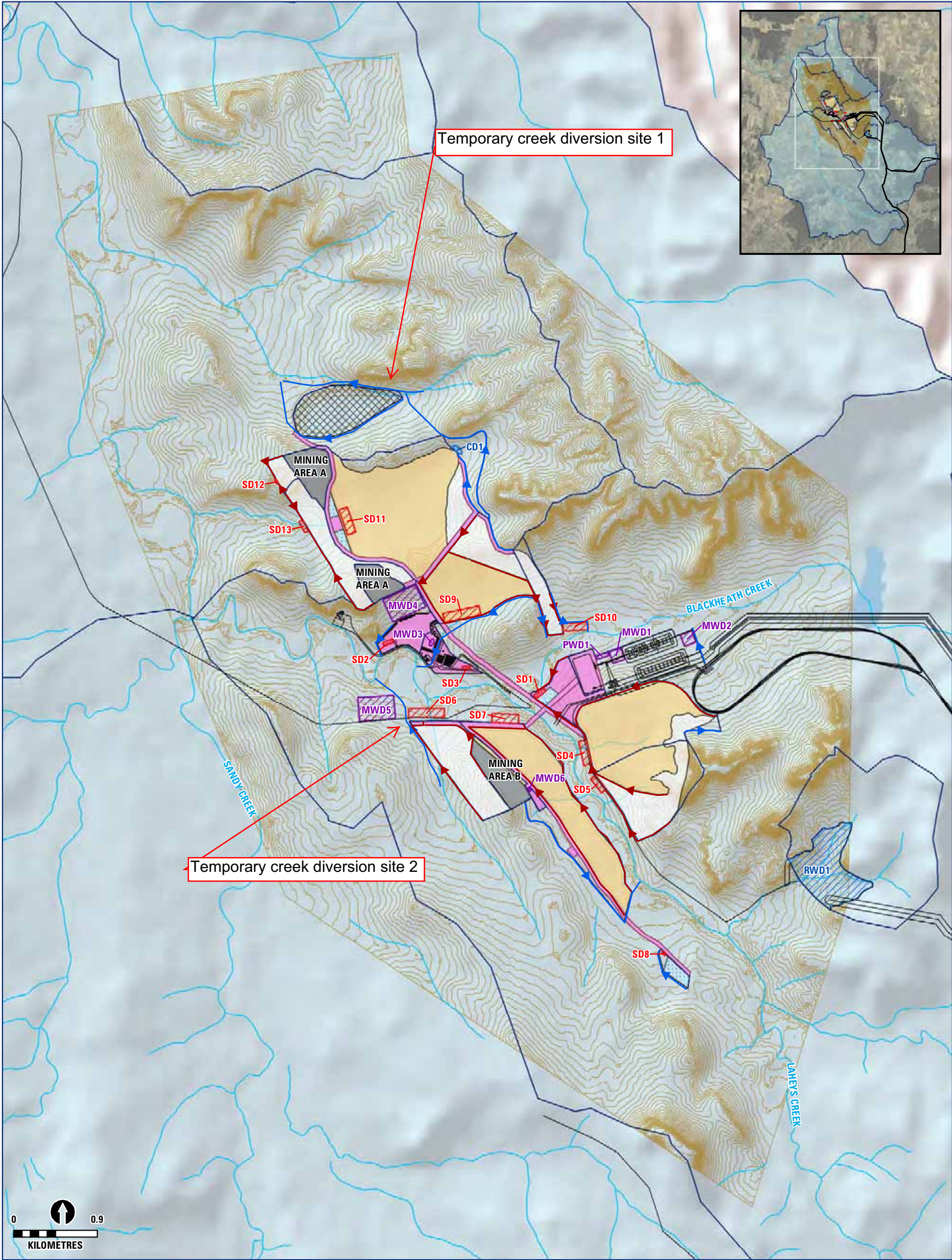


Figure D3.10 Western channel of Crossing 28 schematic

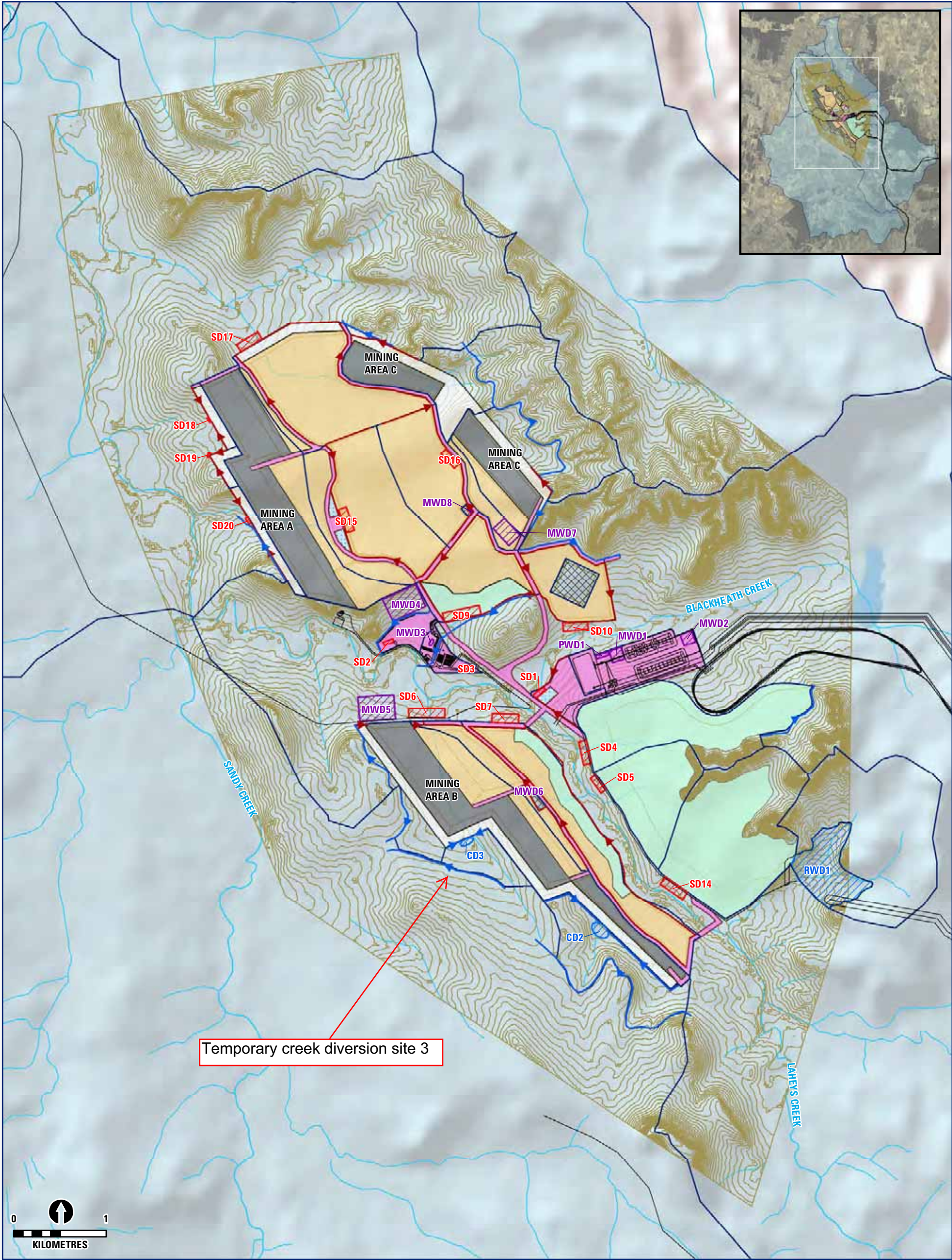
Appendix D.4

Temporary diversion channel
locations



Year 1 surface water drainage	Year 1 catchment boundary	Year 1 mine landuse	Haul road / infrastructure
Clear water diversion drain	Year 1 dams	Active dump	Reject emplacement area
Dirty water diversion drain	Highwall / clean water dam	Active mine	Topsoil stockpile
Year 1 mine elevation model 2m contours	Sediment dam	Cleared area	
Proposed infrastructures	Mine water dam		

Figure 4-1 Water management system concept for year 1



Year 4 surface water drainage	Year 4 catchment boundary	Year 4 mine landuse	Haul road / infrastructure
Clear water diversion drain	Year 4 catchment boundary	Active emplacement	Rehabilitated emplacement area
Dirty water diversion drain	Highwall / clean water dam	Active mine	Reject emplacement area
Year 4 mine elevation model 2m contours	Mine water dam	Cleared area	Topsoil stockpile
Proposed infrastructures	Sedimentation dam		

Figure 4-2 Water management system concept for year 4

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Appendix

E

Cobbora Coal Project

Water Balance and Surface Water Management System

PR_0082D-2162570C_Appendix E



Revision	Details	Date	Amended By
A	Draft for EMM/CHC review	24 February 2012	LD
B	Final draft for Adequacy Review	31 August 2012	RL
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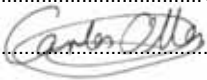
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Date: 18 September 2012

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Contents

	Page number
Glossary	v
1. Introduction	1
1.1 Background	1
1.2 Scope of works	1
2. Design objectives and criteria	3
2.1 Water management system design objectives	3
2.2 Geochemical characteristics of overburden and washery waste materials	3
2.3 Adopted design criteria	4
2.3.1 Sedimentation dams	4
2.3.2 Mine water dams	5
2.3.3 Clean water highwall dams	6
2.3.4 Prescribed dams	6
3. Existing environment	7
3.1 Catchment description	7
3.2 Climate data	9
3.3 Design rainfall data	11
3.3.1 Rainfall intensity-frequency-duration data	11
3.3.2 Five-day rainfall depths	11
3.4 Stream gauge data	11
3.5 Surface runoff	14
3.5.1 Australian Water Balance Model	14
4. Proposed site water management system	19
4.1 Water segregation	19
4.2 Clean water system	19
4.3 Overburden water system	20
4.4 Pit, infrastructure and process water systems	21
4.5 Staging of the water management system	22
4.6 Erosion and sediment controls during construction	23
5. Site water balance modelling	35
5.1 Modelling approach	35
5.1.1 GoldSim model	35
5.1.2 Proposed operating scenario	35

	Page number
5.2 Model assumptions	36
5.3 Model data	37
5.3.1 Catchments	37
5.3.2 Dam sizes	39
5.3.3 Pump rates	43
5.3.4 Operating rules	44
5.4 Water inputs	45
5.4.1 Surface water runoff	45
5.4.2 Groundwater seepage	45
5.4.3 Imported water	46
5.5 Water demands	47
5.5.1 Coal-handling and preparation plant	47
5.5.2 Mine infrastructure area	48
5.5.3 Haul road dust suppression	48
5.5.4 Potable water	48
5.5.5 Demand summary	49
5.6 Other losses	50
5.6.1 Evaporation	50
5.6.2 Seepage from dams	50
6. Results of water balance assessments	51
6.1 Modelling results for proposed operating scenario	51
6.1.1 Adequacy of CHC's existing water entitlements	58
6.1.2 Dam performance	59
6.1.3 Frequency of in-pit flooding	59
6.1.4 Mining impacts on surface water flow regime	63
7. Potential impacts and mitigation measures	65
7.1 Impact of imported water supply on mining	65
7.2 Wet weather impacts on mining	66
7.3 Impacts of mining to the surface water regime	67
8. Post mining	69
8.1 Final landform	69
8.1.1 Catchment areas	69
8.2 Final void water balance	71
8.2.1 Model data	71
8.2.2 Water inputs	71
8.2.3 Water outputs	73
8.2.4 Results	73
8.3 Final void salt balance	76
8.3.1 Modelling approach	76
8.3.2 Results	76

	Page number
8.4 Potential impacts	78
9. Conclusions	79
10. References	81

List of tables

Table 3-1	Existing catchment areas	7
Table 3-2	Summary climate statistics for Cobbora site (1889 to 2010)	10
Table 3-3	Five-day rainfall depths for Cobbora site	11
Table 3-4	NOW streamflow gauges	11
Table 3-5	Description of AWBM parameters	15
Table 3-6	Calibrated AWBM parameters for pre-mining 'undisturbed' Sandy Creek at Medway catchment	15
Table 3-7	Summary of calibrated parameters published in ACARP study	17
Table 3-8	Adopted AWBM parameters	17
Table 3-9	Calculated average runoff coefficients from adopted AWBM parameters for modelled land uses (1900 to 2010)	18
Table 4-1	Dam staging over life of the Project	22
Table 5-1	Change in disturbed area over life of the Project	37
Table 5-2	Catchment areas over life of Project	38
Table 5-3	Sedimentation dam capacities	40
Table 5-4	Dam capacities	41
Table 5-5	Clean water highwall dam capacities	42
Table 5-6	Stage-storage relationship for proposed raw water dam	43
Table 5-7	Groundwater seepage rate estimates	45
Table 5-8	CHPP make-up water demand estimates (net of tailings return water)	47
Table 5-9	Mine infrastructure area demand estimates	48
Table 5-10	Haul road dust-suppression demand estimates	48
Table 5-11	Potable water demand estimates	49
Table 5-12	Water demand summary	49
Table 6-1	Annual site water balance — 10 th percentile dry year	52
Table 6-2	Annual site water balance — 50 th percentile median year	54
Table 6-3	Annual site water balance — 90 th percentile wet year	56
Table 6-4	Summary of imported water requirement for dry, median and wet year climate conditions	58
Table 6-5	Maximum in-pit storage volumes	59
Table 6-6	Median annual flow in Sandy Creek, Flyblowers Creek, Isbester Gully and Unnamed Tributary 1	64
Table 6-7	Summary of expected changes to pre-mining creek flows during mining	64
Table 7-1	Imported water requirement for a 10 th percentile dry year	66
Table 8-1	Final landform catchment areas	69
Table 8.2	Estimated reduction to groundwater inflow to void B	72

List of figures

	Page number
Figure 3.1	Existing study catchment 8
Figure 3.2	Annual rainfall for Cobbora site — Data Drill (1889 to 2010) 9
Figure 3.3	Annual lake evaporation for Cobbora site — Data Drill (1889 to 2010) 10
Figure 3.4	Flow duration curve for Sandy Creek at Medway (no. 421064) 12
Figure 3.5	Flow duration curve for Talbragar River at Elong Elong (no. 421042) 13
Figure 3.6	Comparison of Sandy Creek and Talbragar River flow duration curves 13
Figure 3.7	Schematic layout of the AWBM rainfall-runoff model (source: CRC for Catchment Hydrology 2004) 14
Figure 3.8	Comparison of predicted and observed flow duration curves 16
Figure 4.1	Water management system concept for Year 1 24
Figure 4.2	Water management system concept for Year 4 25
Figure 4.3	Water management system concept for Year 12 26
Figure 4.4	Water management system concept for Year 16 27
Figure 4.5	Water management system concept for Year 20 28
Figure 4.6	Schematic of water management system concept for Year 1 29
Figure 4.7	Schematic of water management system concept for Year 4 30
Figure 4.8	Schematic of water management system concept for Year 12 31
Figure 4.9	Schematic of water management system concept for Year 16 32
Figure 4.10	Schematic of water management system concept for Year 20 33
Figure 5.1	Plot of groundwater seepage estimates 46
Figure 6.1	Annual imported water requirement over the 111-year water balance simulation for Year 20 58
Figure 6.2	Stored volume in mining area A over the 111-year water balance simulation for Year 16 60
Figure 6.3	Stored volume in mining area B over the 111-year water balance simulation for Year 16 60
Figure 6.4	Stored volume in mining area C over the 111-year water balance simulation for Year 16 61
Figure 6.5	Frequency of in-pit flooding for mining area A over the 111-year water balance simulation for Year 16 61
Figure 6.6	Frequency of in-pit flooding for mining area B over the 111-year water balance simulation for Year 16 62
Figure 6.7	Frequency of in-pit flooding for mining area C over the 111-year water balance simulation for Year 16 62
Figure 7.1	Comparison of annual imported water requirements over the 111-year water balance simulation for Year 20 65
Figure 8.1	Final landform 70
Figure 8.2	Stage-area-volume relationship for final void B 71
Figure 8.3	Final void B net groundwater inflow estimates over 1000 year water balance simulation 73
Figure 8.4	Final void B stored volume estimates over 1000 year water balance simulation 74
Figure 8.5	Final void B water level estimates over 1000 year water balance simulation 74
Figure 8.6	Sensitivity test net groundwater inflow over 1000 year water balance simulation (assuming no inflow reduction and no outflow) 75

Glossary

AEP	Annual exceedance probability
AMD	Acid and metalliferous drainage
ARI	Average recurrence interval
BOM	Bureau of Meteorology
CHPP	Coal-handling and preparation plant
DERM	Department of Environment and Resource Management (Queensland)
DSC	Dams Safety Committee
EA	Environmental assessment
ESCP	Erosion and Sediment Control Plan
MIA	Mine infrastructure area
NOW	NSW Office of Water
ROM	Run of mine
WMS	Water management system

1. Introduction

Parsons Brinckerhoff has been commissioned by Cobbora Holding Company Pty Limited (CHC) to prepare a site water balance and surface water management system concept for the Cobbora Coal Project (the Project).

This report contributes to the surface water assessment that Parsons Brinckerhoff undertook for the Project's environmental assessment (EA) report.

1.1 Background

The Project comprises a new open-cut coal mine to be developed near Dunedoo in the central west of New South Wales (NSW). The Project Application Area is approximately 274 square kilometres (km²). The primary purpose of the Project is to provide coal for five major NSW power stations.

The mine will extract around 20 million tonnes per annum (Mt/a) of run-of-mine (ROM) coal. From this, approximately 9.5 Mt/a of product coal will be sold to Macquarie Generation, Origin Energy and Delta Electricity under long-term contract. In addition, approximately 2.5 Mt/a will be produced for export or for the spot domestic market.

The Project's key elements are:

- an open-cut mine
- a coal-handling and preparation plant (CHPP)
- a train-loading facility and rail spur
- a mine infrastructure area
- supporting infrastructure, including access roads, water supply and storage, and electricity supply.

Construction is expected to commence in mid-2013, with coal being supplied to customers from the first half of 2015. The mine life will be 21 years.

1.2 Scope of works

This report is based on the following scope of works:

- Develop surface water management system concepts that are representative of the mine's development over its 21-year life. For the purpose of this assessment, concepts were developed for five mine stages, corresponding to Year 1, 4, 12, 16, and 20 mine landforms.
- Develop a comprehensive daily site water balance model for the five water management system concepts that correspond to Year 1, 4, 12, 16, and 20 mine landforms.

- Undertake operational water balance assessments to:
 - ▶ estimate runoff volumes within the Project site and their reuse
 - ▶ identify potential overflows from proposed water management dams
 - ▶ estimate volumes of imported water required and assess the adequacy of CHC's existing water entitlements over the 21-year mine life
 - ▶ assess the likelihood of mine pits flooding from above-average wet years
 - ▶ assess changes to the surface water regime downstream from the Project site.
- Develop a water balance and water quality model to assess potential impacts to surface water resources downstream of the Project site following mine closure.

2. Design objectives and criteria

2.1 Water management system design objectives

The objectives of the surface water management system for the Project include:

- protect the environmental values of downstream watercourses and local aquifers
- maintain the quality and quantity of surface waters to protect existing beneficial downstream uses
- provide a sustainable water supply for use in the mine.

Downstream water quality will be protected by carefully managing mine water, process water, coal stockpile runoff and unrehabilitated overburden runoff. This will preserve downstream environmental values.

In line with leading industry practice, the key objectives of the water management system design for the Project are to:

- minimise the volume of mine water (surface runoff draining to pit and groundwater seepage) generated by the Project
- preferentially reuse mine water in pit and for coal washing and dust suppression
- provide sufficient on-site storage to avoid releases that could affect the quality of downstream watercourses
- treat all runoff from unrehabilitated overburden areas to settle coarse suspended solids.

2.2 Geochemical characteristics of overburden and washery waste materials

Design criteria for the surface water management system have been set with consideration to the likely geochemical characteristics of overburden and washery waste materials at the site.

A geochemical assessment was undertaken for the Project by GeoTerra in March 2012. The geochemical assessment concluded that:

- overall, overburden and the pit floor are likely to be non-acid forming and should not require any special handling for acid and metalliferous drainage control
- overburden has low salinity and neutral acidity
- mixing mining waste will mitigate isolated AMD leachate
- water coming into contact with overburden will meet relevant ANZECC criteria for protecting downstream watercourses.

Based on these conclusions, overburden runoff will need treatment for suspended solids, but not for salinity or acidity.

2.3 Adopted design criteria

2.3.1 Sedimentation dams

Sedimentation dams have been sized based on criteria recommended in the guidelines *Managing Urban Stormwater: Soils and Construction* (Landcom 2004) and *Managing Urban Stormwater: Soils and Construction — Mines and Quarries* (DECCW 2008). The guidelines recommend providing Type F/D sedimentation dams for catchments with fine or dispersible soils. These are 'wet basins', comprising a 'settling zone' for temporary treatment storage and a 'sediment zone' for storage of sediment.

The guidelines recommend that for a sensitive receiving environment, the 'settling zone' be sized to capture runoff from a 95th percentile 5-day duration storm event. This means that water with most suspended solids removed would on average flow from sedimentation dams once or twice a year.

The guidelines recommend volumetric runoff coefficients for disturbed catchments in urban areas. For design rainfall depths of 61 mm to 80 mm, the recommended runoff coefficients range from 0.37 for soils with very low runoff potential to 0.79 for soils with high runoff potential (refer to Table F2 of the guidelines). It should be noted, however, that these values relate to urban disturbed areas (e.g. urban construction sites with compacted bare soil).

For the purpose of sizing sedimentation dams at the site, a runoff coefficient of 0.4 has been adopted for overburden areas, which corresponds to the lower values in the range recommended in the guidelines. The lower value was adopted because overburden areas at the site are typically gently sloping on the top surface and uncompacted, and are expected to have lower runoff than urban disturbed areas.

A runoff coefficient of 0.7 has been adopted for the mine infrastructure and CHPP areas (i.e. SD1, SD2 and SD3). Hardstand areas typically have a runoff coefficient closer to 0.9, however, the mine infrastructure and CHPP areas comprise a mix of hardstand and open space areas, so a lower runoff coefficient was adopted to avoid overestimating runoff from these areas. The runoff coefficient for the mine infrastructure and CHPP areas may be refined during detailed design.

Typical design features of proposed sedimentation dams are as follows:

- dams configured as Type F/D dams, as described in the guidelines *Managing Urban Stormwater: Soils and Construction* (Landcom 2004)
- 'sediment zone' for sediment storage sized at 50% of 'settling zone'
- 'settling zone' for temporary treatment storage
- slotted riser and discharge pipe with valve arrangement to allow manual operation of pipe
- slotted riser sized to drawdown 'settling zone' over five days
- select clay fill embankment with 1:3 (V:H) slopes
- embankment crest 4 m wide with gravel capping and 3% cross-fall
- spillway at top water level to safely convey the 100-year average recurrence interval (ARI) peak flow

- freeboard between top water level and top of bank
- scour protection at sedimentation dam outlet
- pump and pipeline system to transfer water to downstream watercourses where a gravity-fed outlet is not practical.

The above design criteria have been based on the conclusions of the geochemical assessment (Section 2.2). Water from sedimentation dams will be reused in the mine's water management system. Surplus water that cannot be reused will be treated in the sedimentation dams before being released to downstream watercourses.

2.3.2 Mine water dams

Mine water dams are split into three categories based on the runoff source:

- infrastructure water storage dams receiving water from the CHPP, mine infrastructure area, coal stockpile and train loading facility
- pit water dams receiving water pumped from the pit. These dams are typically 'turkeys nest' dams and have minimal local catchment
- process water dam receiving a mix of water types from other site dams for reuse on-site. This dam will be located near the CHPP.

Infrastructure water storage dams receiving water from the CHPP, mine infrastructure area and train loading facility have been initially sized to capture local catchment runoff from a 100-year ARI 72-hour storm event.

For sizing purposes, a runoff coefficient of 0.7 has been adopted for the CHPP and mine infrastructure areas (comprising a mix of open space and hardstand areas). The capacity of these dams was then confirmed by water balance modelling, with the dam being sized to achieve no discharge when operated as part of the overall site water management system under historical climate conditions. In most cases, this involved increasing the capacity above the 100-year ARI 72-hour storm event to cater for extended wet periods.

Pit water dams receiving water pumped from the open cuts were sized based on water balance modelling to achieve a reasonable level of pit dewatering when operated as part of the overall site water management system under historical climate conditions.

The process water dam has been sized at a nominal capacity of 100 ML. The capacity of this dam will be confirmed during detailed design. The nominal 100 ML capacity is adequate to supply approximately 10 days of site demands at peak coal production.

All dams storing mine water will be provided with appropriate freeboard between the top water level and top of bank and will be designed not to overflow under historical climate conditions. A spillway will be provided for emergency overflow. Mine water dam volumes may need to be reassessed during detailed design when the mine dewatering plan is finalised.

2.3.3 Clean water highwall dams

Clean water highwall dams will be provided at selected locations upslope of the pit to reduce peak flow rates and velocities from undisturbed catchments. Highwall dams will capture clean runoff that will be returned to the creek system, with large storm events overflowing to the pit.

Highwall dams have been sized to capture runoff from the 100-year ARI 24-hour storm event, assuming a runoff coefficient of 0.4 for undisturbed areas.

2.3.4 Prescribed dams

'Prescribed' dams are those listed in Schedule 1 of the *Dams Safety Act 1978*. The Dams Safety Committee (DSC) can require owners of prescribed dams to implement measures that will ensure the safety of their dams.

The final configuration of the site dams will be established during later design stages, and will depend on the availability of construction materials and relative costs of excavation and embankment construction. The currently proposed water management system for the Project includes a number of dams that may meet the criteria of a prescribed dam and will therefore need to be referred to the DSC for assessment and approval before construction of these dams can commence.

3. Existing environment

This section provides an overview of the existing surface water environment at the Project site, and focuses on the climate and rainfall-runoff characteristics that are relevant to the development of the Project's water balance model and water management system.

For a more detailed description of the existing surface water environment, refer to Appendix A of the *Surface Water Assessment* report.

3.1 Catchment description

The Project is located in the catchment of Sandy Creek and Laheys Creek. Both waterways initially flow north approximately parallel to each other, until Laheys Creek joins Sandy Creek approximately 6 km upstream of the Golden Highway. Sandy Creek and Laheys Creek are both ephemeral waterways, meaning that they are usually dry for part of the year.

Sandy Creek joins the Talbragar River approximately 1 km downstream of the Golden Highway, and 7 km downstream of the confluence of Sandy Creek and Laheys Creek. The Talbragar River is a tributary of the Macquarie River, which is a tributary of the Barwon River, which in turn is a tributary of the Darling River.

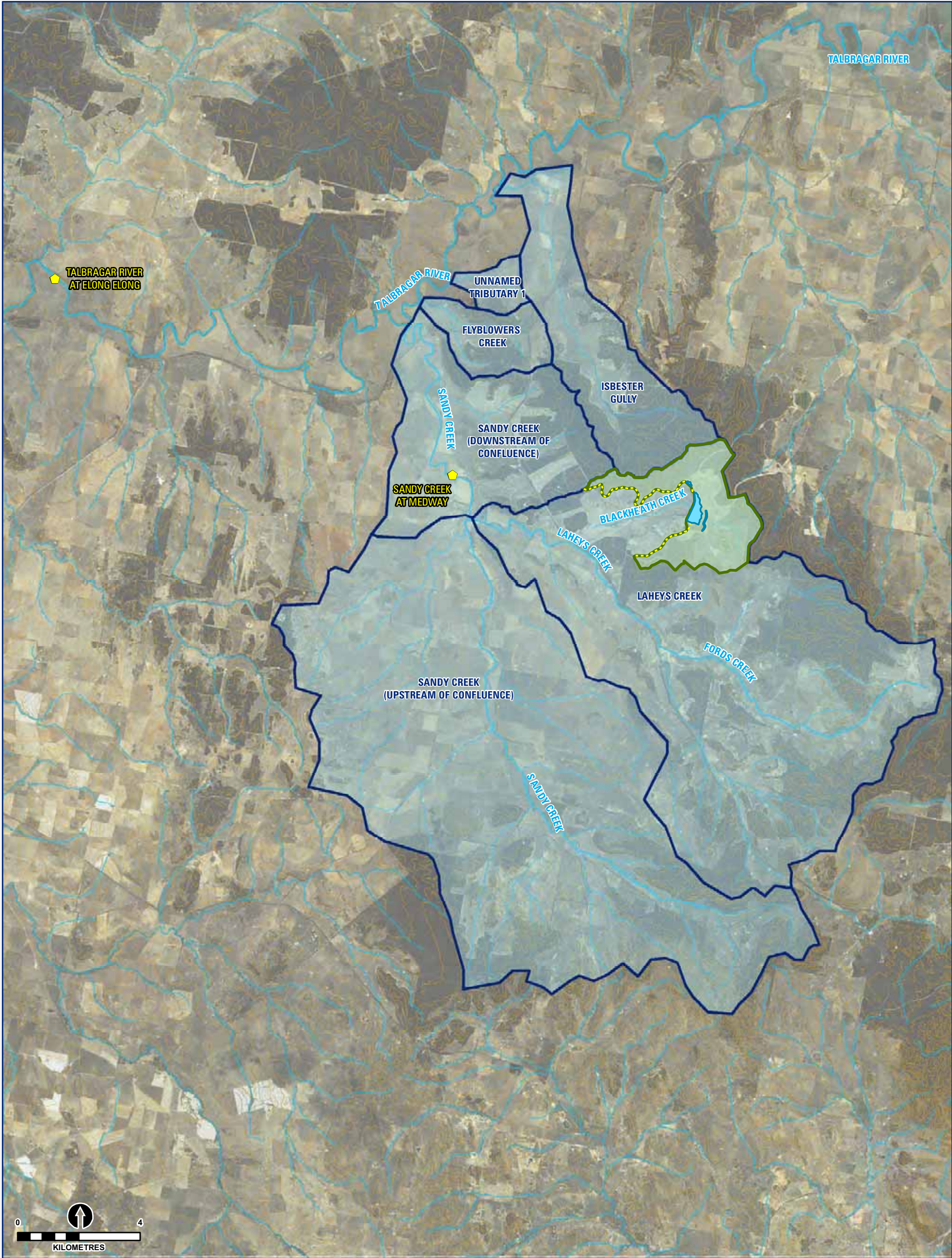
An existing catchment plan for the Project site is provided in Figure 3-1, and a summary of the sub-catchment areas is provided in Table 3-1. The total catchment area for Sandy Creek at its confluence with the Talbragar River is 28,218 ha.

Table 3-1 Existing catchment areas

Sub-catchment	Area (ha)
Sandy Creek (upstream of Laheys Creek confluence)	13,901
Sandy Creek (downstream of Laheys Creek confluence)	3,221
Laheys Creek *	11,095
Flyblowers Creek	738
Isbester Gully	2,454
Unnamed Tributary 1	278
Total	31,688

* Laheys Creek catchment area of 11,095 ha includes 1,034 ha to the existing west 'Woolandra' farm dams located in the upper reaches of Blackheath Creek.

Land use within the catchment of Sandy Creek and Laheys Creek is mainly rural, with some areas of native vegetation in the upper reaches of the catchment. Numerous small farm dams exist on drainage lines within the catchment. Two existing farm dams with a combined capacity of approximately 1,460 ML are located in the upper reaches of Blackheath Creek, which is a tributary of Laheys Creek. A network of existing contour drains diverts runoff from a catchment of approximately 1,034 ha to these two farm dams. These two farm dams are commonly referred to as the west 'Woolandra' dams.



Flow gauges	Catchment boundary
Existing contour drains	Existing farm dam subcatchment
Drainage lines	Existing farm dam (1,460ML capacity)
Topographic contours (20m interval)	

Figure 3-1 Existing study catchment

3.2 Climate data

Climate data used in the water balance model was based on 111 years (1900–2010) of daily data sourced from the Data Drill database, developed by the Queensland Department of Environment and Resource Management (DERM). The Data Drill accesses grids of data derived by interpolating the Bureau of Meteorology's station records. Interpolations are calculated by splining and kriging techniques. The data in the Data Drill are all synthetic and there are no original meteorological station data in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia (DERM 2011).

The Data Drill is considered superior to individual Bureau of Meteorology station records and site observations for water balance modelling purposes because it draws on a greater dataset, both spatially and in time. The Data Drill is also considered superior for modelling purposes as it does not contain gaps.

A plot of annual rainfall for the site is provided in Figure 3-2, and a plot of annual lake evaporation for the site is provided in Figure 3-3. Summary statistics for rainfall and evaporation are provided in Table 3-2.

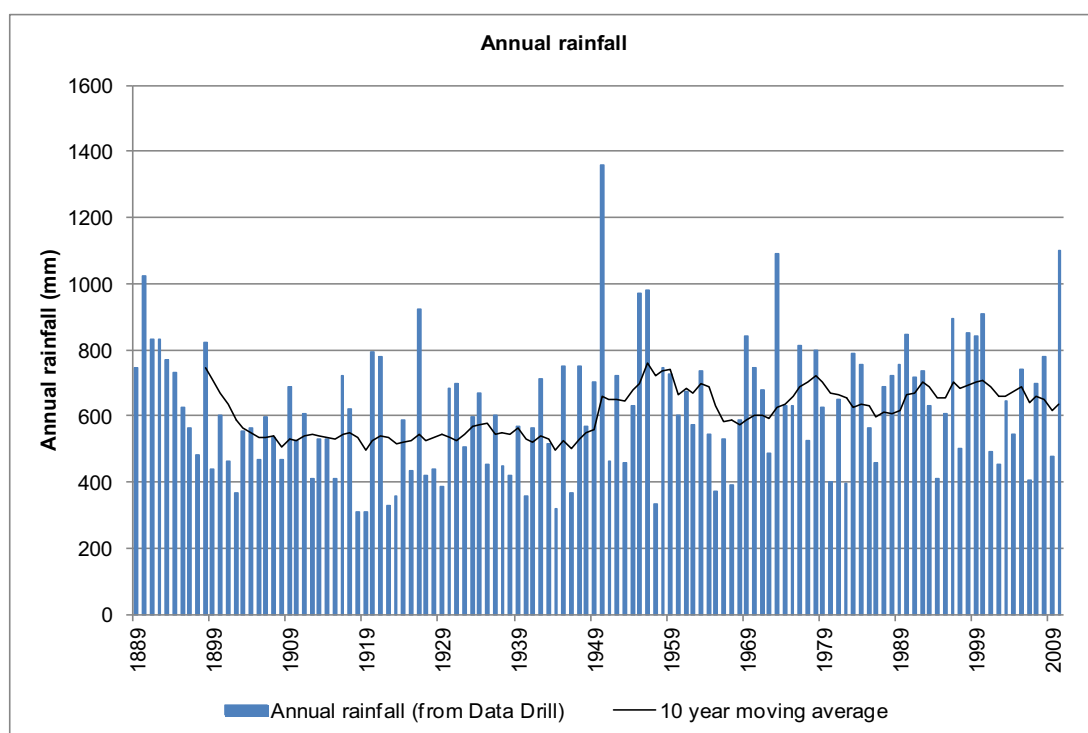


Figure 3.2 Annual rainfall for Cobbora site — Data Drill (1889 to 2010)

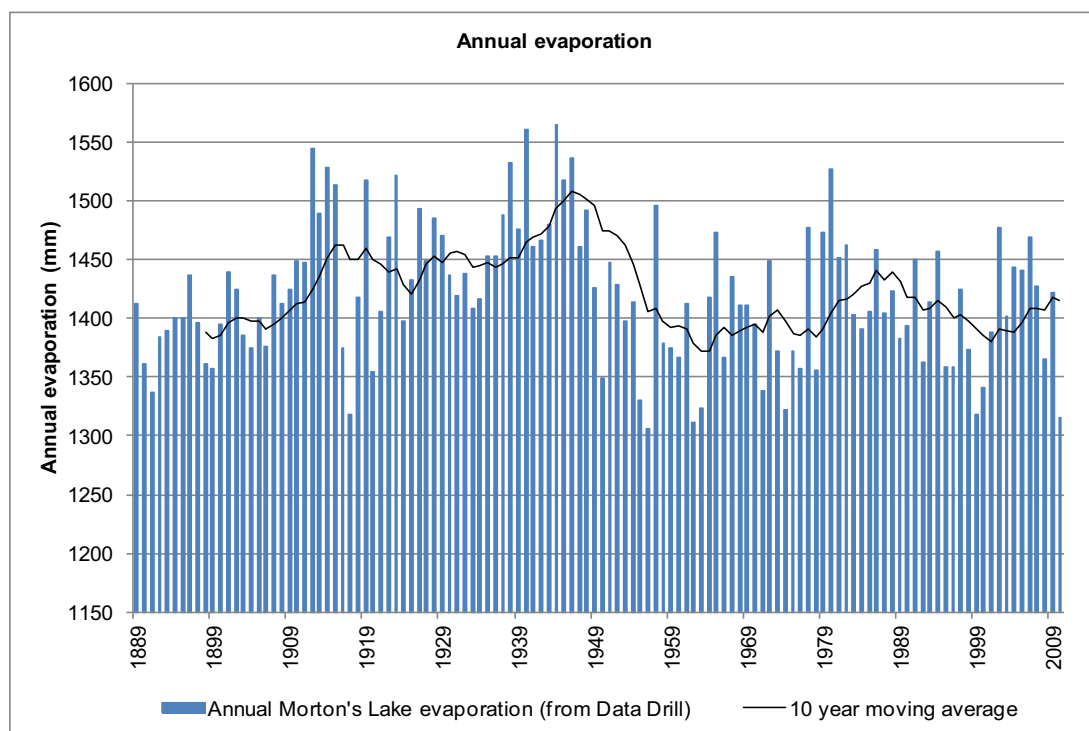


Figure 3.3 Annual lake evaporation for Cobbora site — Data Drill (1889 to 2010)

Table 3-2 Summary climate statistics for Cobbora site (1889 to 2010)

Statistic	Annual rainfall (mm)	Annual potential evapotranspiration ¹ (mm)	Annual lake evaporation ² (mm)
5 th percentile	360	1,203	1,324
10 th percentile	397	1,223	1,355
50 th percentile (median)	604	1,321	1,416
90 th percentile	839	1,422	1,493
95 th percentile	921	1,456	1,526
99 th percentile	1,099	1,489	1,557
Mean	620	1,321	1,421
Minimum	310	1,147	1,306
Maximum	1,360	1,502	1,564
Standard deviation	187	76	58

¹ Potential evapotranspiration calculated using the Penman-Monteith formula (source: Food and Agriculture Organization of the United Nations 1998).

² Lake evaporation calculated using the Morton formula for shallow lakes (source: Morton 1983).

A comparison has been made between the Data Drill rainfall data and the rainfall recorded at the two on-site meteorological stations. Quality checked rainfall data is available from November 2010. The rainfall depth recorded at the on-site meteorological stations was 645 mm for the 11-month period from November 2010 to October 2011. This compares to 649 mm for the same period obtained from the Data Drill, which is only a 1% difference and gives confidence in the Data Drill.

As discussed above, the on-site meteorological data has not been adopted for the purposes of long-term water balance modelling because of the short dataset available. However, the on-site meteorological data will be useful in the future to verify and update the water balance model during mine operation.

3.3 Design rainfall data

3.3.1 Rainfall intensity-frequency-duration data

Design rainfall intensity-frequency-duration (IFD) data was prepared for the site in accordance with the method outlined in *Australian Rainfall and Runoff* (Engineers Australia 2001). The 100-year ARI 24-hour duration rainfall depth is 157 mm. The 100-year ARI 72-hour duration rainfall depth is 200.2 mm.

3.3.2 Five-day rainfall depths

Five-day rainfall depths for the site have been estimated using a procedure outlined in the guidelines *Managing Urban Stormwater: Soils and Construction* (Landcom 2004). Five-day rainfall depths (see Table 3-3) are based on the linear relationship between five-day rainfall and average annual rainfall given in Figure 6-6 of the guidelines, and assume an average annual rainfall of 620 mm.

Table 3-3 Five-day rainfall depths for Cobbora site

Percentile	Five-day rainfall depth (mm)
75 th percentile	20.3
85 th percentile	31.1
95 th percentile	63.3

3.4 Stream gauge data

Table 3-4 provides a summary of NOW stream gauging stations in the vicinity of the study area.

Table 3-4 NOW streamflow gauges

Location	Gauge number	Period of record
Operational gauges		
Talbragar River at Elong Elong	421042	1964–present
Discontinued gauges		
Talbragar River at Cobbora	421028	1950–1954
Talbragar River at Naranmore	421037	1955–1976
Sandy Creek at Medway	421064	1966–1985

Source: NOW website and PINEENA database

Two NOW stream gauging stations have operated near the Project site (numbers 421042 and 421064), and two other NOW gauging stations have operated in the wider region (numbers 421028 and 421037).

The Sandy Creek at Medway gauging station (no. 421064) is located within the Sandy Creek catchment; however, it ceased operation in 1985 and there are no active gauging stations operating within the Sandy Creek catchment.

The Talbragar River at Elong Elong gauging station (no. 421042) is located on the Talbragar River approximately 20 km downstream of where Sandy Creek joins the Talbragar River, and is active.

Stream gauge records were obtained from NOW for Sandy Creek at Medway and Talbragar River at Elong Elong for the period of available record.

A daily flow duration curve for Sandy Creek at Medway is provided in Figure 3-4 for the period 1966 to 1985. The contributing catchment area is 260 km². The flow duration curve shows that while the highest recorded mean daily flow was 8,937 ML/d (in February 1971), for 50% of the time flows were less than 0.04 ML/d, and for 45.8% of the time there was no flow.

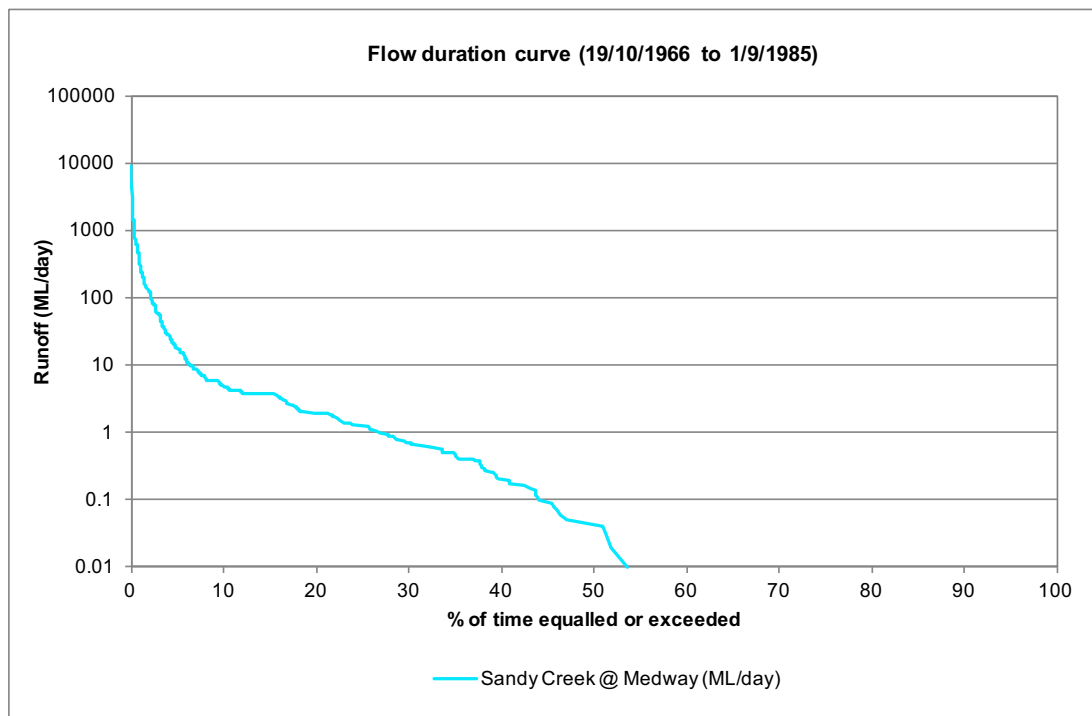


Figure 3.4 Flow duration curve for Sandy Creek at Medway (no. 421064)

A daily flow duration curve for Talbragar River at Elong Elong is provided in Figure 3-5 for the period 1970 to 2011. The contributing catchment area is 3,050 km². The flow duration curve shows the highest recorded mean daily flow was 40,835 ML/d (in December 2010), for 50% of the time flows were less than 11.9 ML/d, and for 31.8% of the time there was no flow.

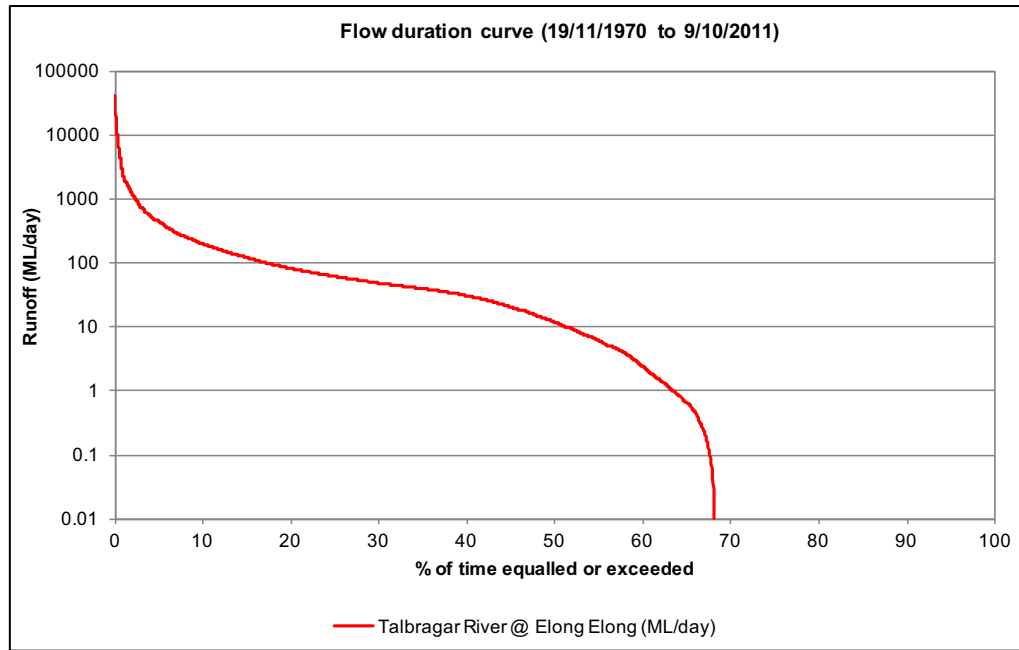


Figure 3.5 Flow duration curve for Talbragar River at Elong Elong (no. 421042)

Figure 3-6 shows a comparison of the Sandy Creek at Medway and Talbragar River at Elong Elong daily flow duration curves from 1970 to 1985, when gauging data is available for both stations (note this period is different to the plots in Figure 3-4 and Figure 3-5). Flows are given as runoff depth per unit area to allow comparison between the two gauging stations. Figure 3-6 shows that the flow duration curve for Sandy Creek at Medway has longer dry periods and higher runoff depths at the high flow end of the curve than the Talbragar River at Elong Elong, which is typical of a watercourse with significantly larger catchment area.

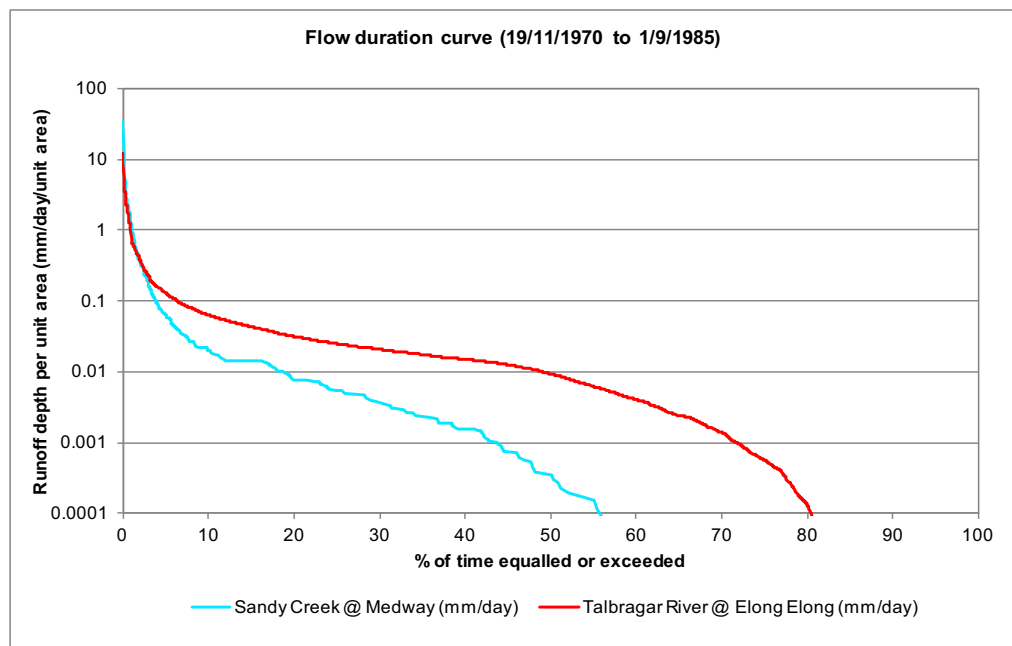


Figure 3.6 Comparison of Sandy Creek and Talbragar River flow duration curves

3.5 Surface runoff

The volume of surface water runoff has been estimated using the Australian Water Balance Model (AWBM) rainfall-runoff model that has been incorporated into the water balance model. The rainfall-runoff model has been calibrated using recorded streamflow data.

3.5.1 Australian Water Balance Model

The Australian Water Balance Method (AWBM) (Boughton 1993) was used to derive catchment runoff time series from undisturbed, disturbed and rehabilitated catchments for use in the water balance model.

The AWBM is a partial area saturation overland flow model. The use of partial areas divides the catchment into regions (contributing areas) that produce runoff during a rainfall-runoff event and those that do not. These contributing areas vary within a catchment according to antecedent catchment conditions, and allow for the spatial variability of surface storage in a catchment. The use of the partial area saturation overland flow approach is simple and provides a good representation of the physical processes occurring in most Australian catchments (Boughton 1993). This is because daily infiltration capacity is rarely exceeded, and the major source of runoff is from saturated areas. Figure 3-7 shows a schematic layout of the AWBM.

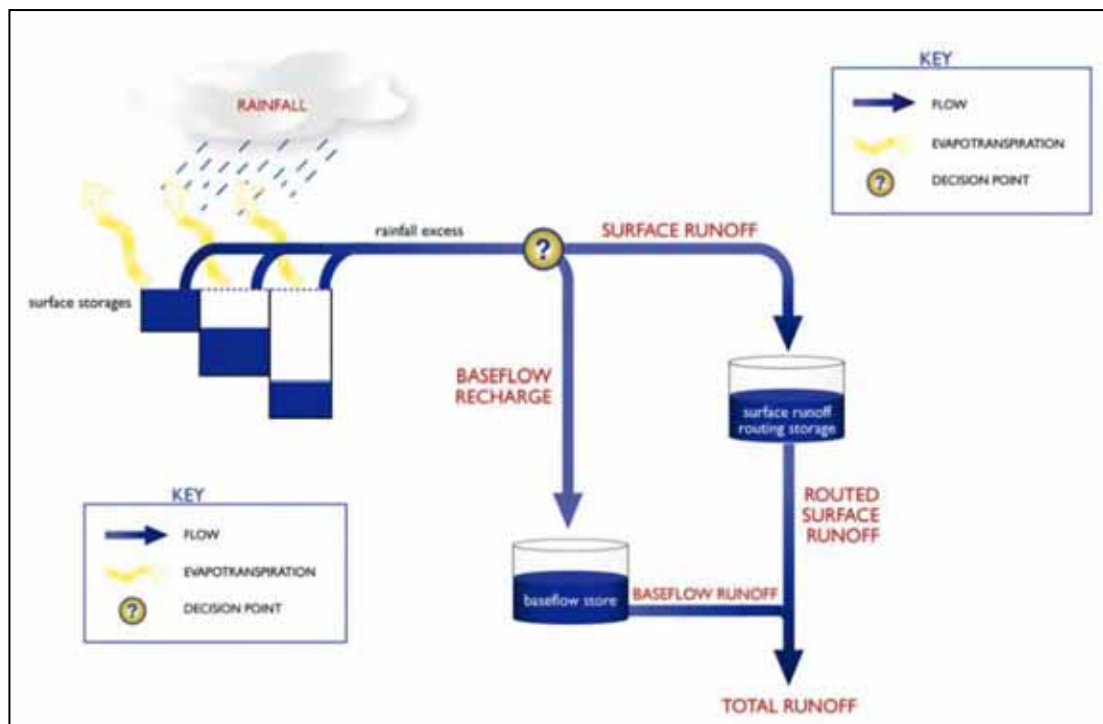


Figure 3.7 Schematic layout of the AWBM rainfall-runoff model (source: CRC for Catchment Hydrology 2004)

To implement the AWBM in a given catchment, a set of nine parameters must be defined as summarised in Table 3-5. These parameters define the generalised model for a particular catchment. The parameters are usually derived for a gauged catchment by a process of calibration where the recorded streamflows are compared with calculated streamflows.

The parameters are adjusted to produce the best match between the means and standard deviations of the daily streamflows, to match the difference in peak flow discharges.

Table 3-5 Description of AWBM parameters

Parameter	Description
A1, A2, A3	Partial areas represented by surface storages
C1, C2, C3	Surface storage capacities
Ks	Daily surface flow recession constant
BFI	Baseflow index
K _{base}	Daily baseflow recession constant

3.5.1.1 Undisturbed catchments

AWBM parameters adopted for the portions of catchments not affected by mining are provided in Table 3-6. These parameters simulated flows that closely matched the average annual volume and flow duration curve from the historically gauged Sandy Creek streamflows at Medway (no. 421064). Note that the pre-mining catchment is largely rural, however, is referred to as 'undisturbed' for the purposes of this study.

The Sandy Creek at Medway record was selected as it is located within the same catchment as the Project. While the Sandy Creek at Medway record is shorter than the Talbragar River at Elong Elong record, the Sandy Creek record is considered superior for calibration purposes as the Talbragar River catchment is significantly larger than the Sandy Creek and Laheys Creek catchments and has different runoff characteristics as demonstrated by the flow duration curve in Figure 3-8.

Table 3-6 Calibrated AWBM parameters for pre-mining 'undisturbed' Sandy Creek at Medway catchment

Catchment	AWBM parameters								
	Ks	BFI	K _{base}	A1	A2	A3	C1 (mm)	C2 (mm)	C3 (mm)
Sandy Creek at Medway	0.400	0.150	0.93	0.134	0.433	0.433	50	150	350

A comparison of predicted and observed flow duration curves is provided in Figure 3-8 for the common data period from 1970 to 1985. Flows are given as runoff depth per unit area to allow comparison between the two gauging stations and the AWBM simulated flow. The curve shows that the flow duration curve simulated from the AWBM compares reasonably well to that observed for Sandy Creek at Medway.

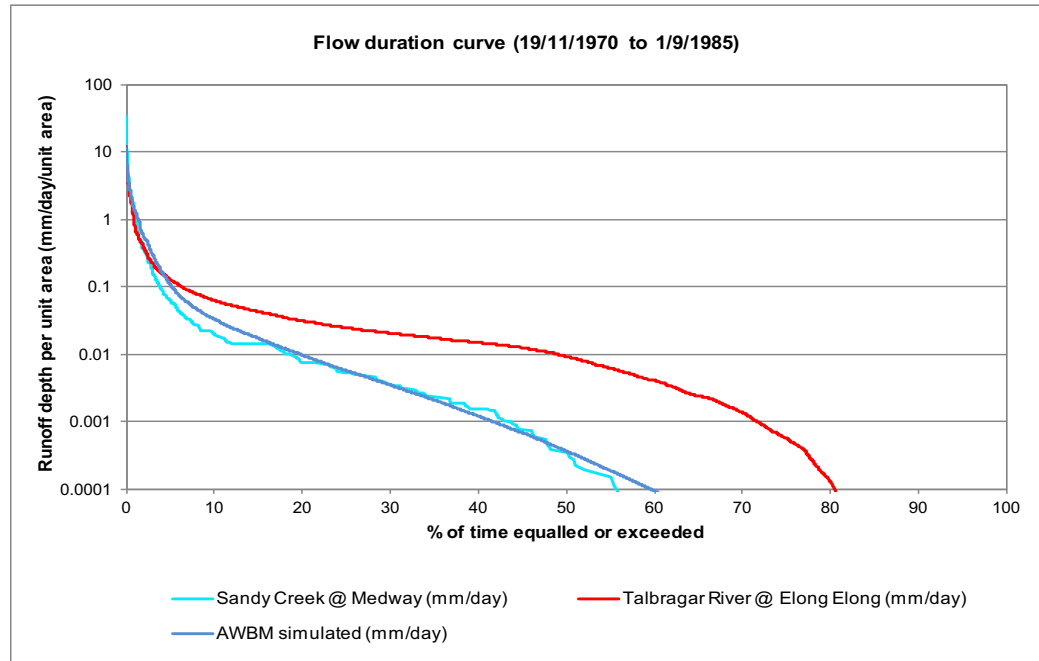


Figure 3.8 Comparison of predicted and observed flow duration curves

The mean annual runoff depth predicted by the AWBM model was 20.0 mm/a (3.0% of mean annual rainfall) for the period 1970 to 1985. The mean annual runoff depth observed at the Sandy Creek at Medway gauging station was 20.8 mm/a (3.1% of mean annual rainfall) for the period 1970 to 1985. The mean annual runoff depth observed at the Talbragar River at Elong Elong gauging station was 19.2 mm/a (2.9% of mean annual rainfall) for the period 1970 to 1985.

3.5.1.2 Disturbed catchments

AWBM parameters for mine site overburden and pit areas were estimated based on calibrated parameters published in the Australian Coal Association Research Program (ACARP) document *ACARP Project No. C7007: Water Quality and Discharge Prediction for Final Void and Spoil Catchments* (PPK Environment & Infrastructure 2001). The aim of the ACARP study was to develop a methodology, based on computer modelling and field monitoring, for predicting the hydrology and water quality of final spoil-void systems. The ACARP study included establishing a network of eight monitoring sites representing individual spoil-void catchments, including six mine sites from Queensland and two mine sites from New South Wales.

The monitoring data was used to calibrate the Spoil Hydrology Lumped Parameter Model (SHLPM) rainfall-runoff model. The SHLPM differs in some ways to the AWBM, but has the same basic structure and parameters as the AWBM. Published calibrated parameters from the ACARP study are summarised in Table 3-7. As the overburden areas at the site are typically gently sloping on the top surface, the upper range of the surface storage capacity parameters from the ACARP study were typically adopted, so as not to overestimate runoff from these areas.

Table 3-7 Summary of calibrated parameters published in ACARP study

	Parameter						
	C1 (mm) ²	C2 (mm) ²	C3 (mm) ²	A1	A2	A3	BFI
Bare dragline spoil							
Range	50–90	15–70	5	0.4–0.6	0.2–0.4	0.2	0
Average ¹	70.0	42.5	5.0	0.5	0.3	0.2	0
Vegetated dragline spoil							
Range	55–120	25–60	10–50	0.6	0.3	0.1	0–0.97
Average ¹	88.3	39.0	19.2	0.6	0.3	0.1	0.2
Rehabilitated dragline spoil							
Range	55–170	15–165	7–45	0.3–0.65	0.3–0.33	0.02–0.4	0–0.95
Average ¹	115.0	68.5	18.7	0.6	0.3	0.1	0.1
Rehabilitated truck and shovel spoil							
Range	160	60	25	0.6	0.3	0.1	0.7
Average ¹	160	60	25	0.6	0.3	0.1	0.7

Source: adapted from ACARP Project No. C7007: *Water Quality and Discharge Prediction for Final Void and Spoil Catchments* (PPK Environment & Infrastructure 2001).

Notes:

- 1 The average values presented in the table are averages of the site values and not the averages of the ranges.
- 2 As the overburden areas at the Project site are typically gently sloping on the top surface, the upper ranges of the surface storage capacity parameters C1, C2 and C3 from the ACARP study were adopted for the site to avoid overestimating runoff from these areas.

AWBM parameters for industrial areas with hardstand surfaces were estimated by modifying the storage capacity and partial area parameters to achieve a similar average annual runoff coefficient to urban catchments (around 40%).

3.5.1.3 Summary

A summary of the adopted AWBM parameters is provided in Table 3-8.

Table 3-8 Adopted AWBM parameters

Land use	AWBM parameters								
	Ks	BFI	K _{base}	A1	A2	A3	C1 (mm)	C2 (mm)	C3 (mm)
Undisturbed	0.400	0.150	0.93	0.134	0.433	0.433	50	150	350
Established rehabilitation (> 4 years)	0	0.200	0	0.100	0.300	0.600	40	100	170
Recent rehabilitation (< 4 years)	0	0.200	0	0.100	0.300	0.600	20	70	170
Active overburden	0	0.200	0	0.100	0.300	0.600	5	70	90
Pit (pit floor and in-pit overburden)	0	0	0	0.200	0.300	0.500	5	15	50
Industrial	0	0	0	0.333	0.333	0.333	2	10	40

Based on the parameters from the ACARP study, higher runoff is expected from established rehabilitation areas compared to the natural catchment. However, runoff characteristics from established rehabilitation areas are expected to move closer to the natural case over time.

The AWBM rainfall-runoff model was used to generate a daily time series of runoff from undisturbed, disturbed and rehabilitated catchments using the parameters in Table 3-8. The average runoff coefficients estimated from the AWBM rainfall-runoff model for the 111 year period from 1900 to 2010 are summarised in Table 3-9 for various modelled land uses.

Table 3-9 Calculated average runoff coefficients from adopted AWBM parameters for modelled land uses (1900 to 2010)

Land use	Volumetric runoff coefficient
Undisturbed	3.1%
Established rehabilitation (> 4 years)	4.7%
Recent rehabilitation (< 4 years)	6.9%
Active overburden	11.9%
Pit (pit floor and in-pit overburden)	27.3%
Industrial	40.0%

4. Proposed site water management system

4.1 Water segregation

Where practical, it is proposed to segregate water within the mine site according to its quality to minimise the stored volumes of water with high concentrations of dissolved ions or suspended solids. This would allow containment of water requiring treatment (e.g. settling suspended sediment) and the diversion of clean water away from mining activities (e.g. undisturbed catchments).

Five water classifications have been nominated for the mine site:

- **Clean water** — runoff from undisturbed areas that are expected to have pre-mining water quality and that can be diverted to the creek system.
- **Overburden water** — runoff from overburden emplacements, topsoil stockpiles and other disturbed areas. This water contains elevated suspended solids, which will be settled in sedimentation dams before release to the creek system or on-site reuse.
- **Pit water** — runoff from the open pits and groundwater seepage into the mine. This water can potentially contain suspended solids, salts and heavy metals etc. This water will be stored on-site and will be reused.
- **Infrastructure water** — runoff from the areas around the coal preparation plant, stockpiles and infrastructure. This water will be directed to the process water circuit.
- **Process water** — water that is utilised in the CHPP, including return water from the reject emplacement areas and refuse disposal ponds. This water is continuously recycled within the system.

Water management system concepts for the various classes of water are discussed in the following sections.

4.2 Clean water system

Clean water runoff from undisturbed catchments will be diverted around the mine site as much as practical to minimise the site water inventory and maintain pre-development releases into Sandy Creek and Laheys Creek. Clean water runoff that is not diverted around the site and is captured within the water management system will be reused on-site.

The clean water system comprises:

- Clean water catch drains to divert minor catchments around the mine site, where practical. Catch drains have been considered when delineating catchments, but have not yet been designed as part of the water management system. The size of catch drains will be considered further during detailed design.
- Clean water highwall dams and levees upslope of the pit to reduce peak flow rates and velocities from undisturbed catchments. Highwall dams will be pumped out to the creek system. Runoff from very large storm events will overtop highwall dams and flow into the pit. For the purposes of conceptual design, highwall dams have been provided at selected key locations only. However, it may be possible to provide additional highwall dams to further reduce inflows to the pit, and this will be considered during detailed design.

- A pump and pipeline system to pump clean water stored in clean water highwall dams to Sandy Creek and Laheys Creek.
- Raw water dam to store water imported to the site from the Cudgegong/Macquarie Regulated River system to supplement on-site water requirements. The proposed raw water dam is located on a drainage line within the Laheys Creek catchment, and has a maximum storage volume of 1,448 ML. The proposed raw water dam has a local natural catchment area of approximately 246 ha, and clean runoff from this catchment would also flow to this dam.
- A pump and pipeline system from the raw water dam to deliver stored water to either:
 - ▶ process water dam (for use in the CHPP and mine infrastructure area)
 - ▶ truck fill stations (for haul road dust suppression)
 - ▶ water treatment plant (for potable applications).
- Flood mitigation works. Levees will be provided along the edge of the mining areas to help control flow and prevent flood water from Sandy Creek and Laheys Creek entering the mine working area. Flood mitigation works are described in the *Flood Impact Assessment* report.

Clean water runoff from established rehabilitated overburden emplacements will be returned directly to Sandy Creek and Laheys Creek. Water from established rehabilitation areas will be returned once rehabilitation success criteria are met.

4.3 Overburden water system

Runoff from disturbed areas will be captured in sedimentation dams for environmental protection and on-site reuse, thus minimising the need to use raw water supplies when the mine is short of water.

Sedimentation dams will allow time for coarse sediments to settle and, if necessary, allow a suitable flocculent to be added to remove fine or dispersive sediment to meet licensed water quality discharge limits.

Treated runoff from large storm events will flow through sedimentation dams and typically pass to Sandy Creek and Laheys Creek. Captured water would either be released to Sandy Creek and Laheys Creek following settling, or transferred to water management dams for on-site storage and reuse.

To ensure sufficient capacity is available in the 'settling zone' for water from storm events, sedimentation dams would be maintained in a drawn-down state, as much as practical. If reuse opportunities are not available, releases would only be permitted when licence limits have been met.

The overburden water management system comprises:

- A drainage system to convey runoff from overburden emplacements, topsoil stockpiles and other disturbed areas to the nearest sedimentation dam.
- Several sedimentation dams strategically located throughout the mine site to capture water from the above sources.

- Pump and pipeline systems to transfer water stored in sedimentation dams where the dams do not allow runoff to return freely to downstream watercourses.
- Facilities to monitor water quality and quantity at nominated surface water release and monitoring points.
- Streamflow gauging stations to determine and record streamflows in Sandy Creek and Laheys Creek upstream and downstream of the site.
- A pump and pipeline system to transfer water stored in sedimentation dams to the nearest mine water management dam when the water can be reused on-site.

For the purpose of conceptual design, the majority of sedimentation dams have their own release points to the creek system. It may be possible, however, to minimise the number of such points by combining several sedimentation dam outlets into a common point. This would require additional drains and possibly pumps and pipelines and should be considered during detailed design.

4.4 Pit, infrastructure and process water systems

While water will be carefully managed to minimise the volume collected in the open mine pits, some water will make its way into the pits either by direct rainfall, groundwater seepage, runoff from and seepage through overburden emplacements, or runoff from undisturbed catchments upslope of pits that cannot be practically diverted around or captured in highwall dams.

For the purpose of this assessment, the pit, infrastructure and process water systems have been combined into a single system, referred to as the mine water system.

The mine water management system comprises:

- Small sumps in the pit floor to collect and contain local surface water runoff from the pit floor, high wall, low wall and end walls, as well as groundwater seepage.
- Pit dewatering pumps and associated dewatering pipelines to transfer pit water to the nearest mine water dam, if necessary via a small staging dam.
- Treated effluent from the on-site wastewater treatment plant.
- A drainage system to convey runoff from disturbed areas to the nearest mine water storage dam.
- Mine water dams to store and contain water from the above sources. Care has been taken in the location of storages and the layout of the drainage system to minimise the areas draining to these dams, so as to minimise storage requirements and maintain environmental compliance during rainfall events.
- A return water pump and pipeline system from each mine water dam to deliver stored water to either:
 - ▶ CHPP (for processing of run-of-mine coal into product coal)
 - ▶ mine infrastructure area (for vehicle wash, workshop and dust-suppression sprayers etc.)
 - ▶ truck fill stations (for haul road dust suppression).

There will be no releases of water captured in the mine water system to the natural creek system. This system will be used as a priority to meet on-site water demands and imported raw water will only be used when there is a water deficit or high quality water is required for uses such as potable applications.

During extended wet periods, surplus mine water will be stored in-pit once the mine water dams have reached their capacity. The scale of the mine with multiple pits allows pit water to be pumped between individual open cuts. This gives good flexibility, allowing the mine to continue to operate without flooding active workings or relying on unscheduled releases of surplus water.

4.5 Staging of the water management system

The water management system will evolve as the Project expands, to be compatible with the mine landform and schedule.

Development of the water management system concepts over the mine's 21-year life have been illustrated through snapshots at five mine stages, corresponding to Year 1, 4, 12, 16 and 20 mine landforms. For the purpose of the surface water assessment, the five mine stages selected provide a reasonable representation of how the mine will be developed.

The five mine stages also illustrate the design flow paths of different classes of water and locations of water management dams during respective stages of the mine's development. Schematic diagrams showing the general connectivity between water sources, demands and storages are provided in Figure 4-6 to Figure 4-10.

A total of nine mine water dams, 38 sedimentation dams, one raw water dam and nine highwall dams are proposed to manage surface water runoff and water supply of the mine over its 21-year life. Dam staging is summarised in Table 4-1..

Table 4-1 Dam staging over life of the Project

Year	Number of active dams			
	Mine water dam	Sedimentation dam	Raw water dam	Clean water/ highwall dam
Year 1	6	13	1	1
Year 4	8	16	1	2
Year 12	6	17	1	5
Year 16	6	14	1	1
Year 20	6	12	1	0
<i>Total no. of dams (over life of project)</i>	9	38	1	9

Note: Excludes fine and course reject disposal ponds.

It has been assumed that dams will be constructed to their maximum capacity when they are first commissioned. In practice, there may be opportunities for staging storage capacities without compromising the system's performance when catchment areas increase as the mine develops. This will be considered during detailed design.

Runoff from rehabilitation areas will be returned directly to the creek system once rehabilitation success criteria have been met. For the purposes of conceptual design of sedimentation dams and environmental impact assessment, it has been assumed that rehabilitated areas would be established four-years after final shaping, topsoil spreading and revegetation.

It is also assumed that runoff from these areas would contain low levels of suspended solids and would be suitable for direct return to the creek system (i.e. without passing through a sedimentation dam). This would be confirmed by water quality monitoring.

Where it is not practical to divert runoff from areas of active spoil or recent rehabilitation away from downstream established rehabilitation, runoff from established rehabilitation will not be included in the sedimentation dam network.

4.6 Erosion and sediment controls during construction

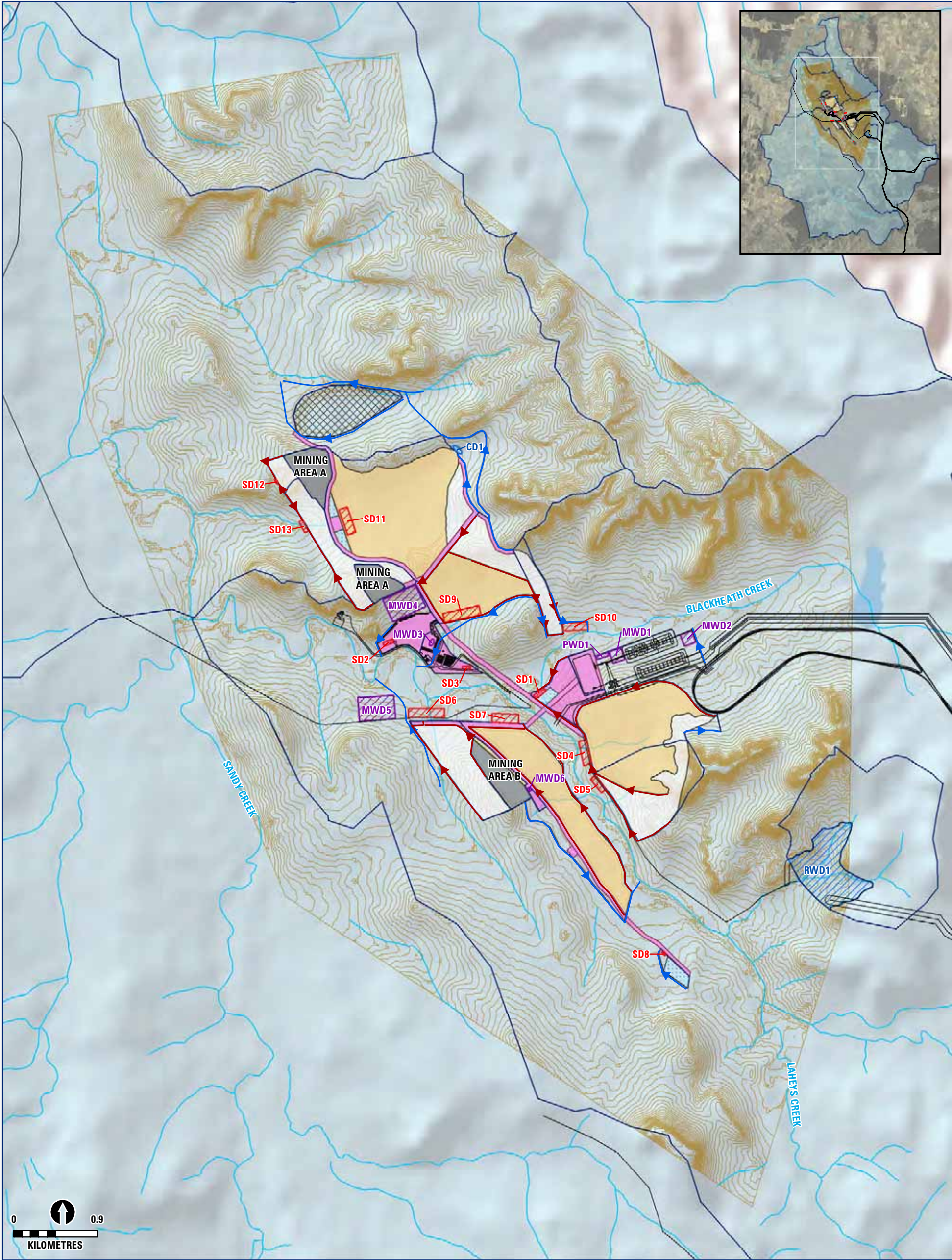
An Erosion and Sediment Control Plan (ESCP) should be prepared and implemented during the construction of all mine infrastructure. Erosion and sediment controls should be established to a standard consistent with the following guidelines:

- *Managing Urban Stormwater – Soils and Construction – Volume 1* (Landcom 2004).
- *Managing Urban Stormwater – Soils and Construction – Volume 2E Mines and Quarries* (DECCW 2008).

Erosion and sediment controls should include:

- minimising forward clearing, particularly areas around flow lines, drainage lines and watercourses
- minimising site disturbance by containing machinery access to areas required for approved construction works, access tracks or material stockpiles
- staging construction activities where practical, so that land disturbance is confined to the minimum possible area
- completing work and rehabilitating disturbed areas quickly and progressively
- minimising erosion from drainage lines that can be vulnerable to the erosive effects of concentrated flow
- intercepting and diverting clean water runoff from undisturbed areas so that it does not flow onto disturbed areas
- passing clean water through the site without mixing it with runoff from disturbed areas
- treating highly dispersive soils with gypsum to reduce the potential for tunnel erosion and surface rilling of disturbed areas
- limiting erosion potential within earthworks areas by managing runoff fetches and velocities, with measures such as diversion banks
- locating sediment traps, such as silt fences and check dams, downstream of disturbed areas
- treating runoff from large construction areas (greater than 2,500 m²) in sedimentation basins or dams, before water is displaced to watercourses
- providing shaker ramps and rock pads at construction exits to remove excess mud from truck tyres and under bodies.

Management strategies to strip, handle and respread topsoil post-disturbance, and prepare seedbeds, should also be implemented during the construction of mine infrastructure.



- Year 1 surface water drainage**

Clear water diversion drain

Dirty water diversion drain

Year 1 mine elevation model 2m contours

Proposed infrastructures
- Year 1 dams**

Highwall / clean water dam

Sediment dam

Mine water dam
- Year 1 mine landuse**

Active dump

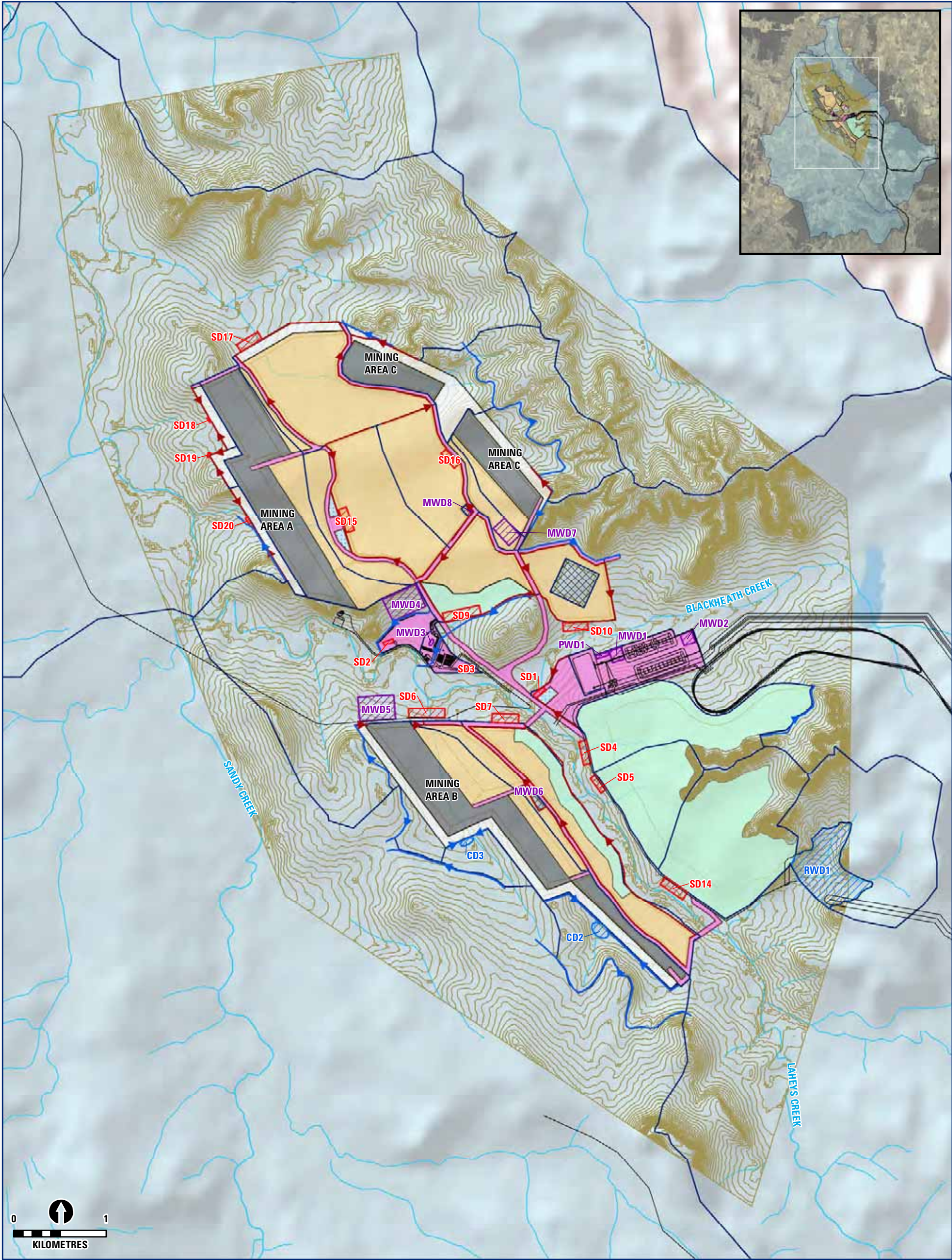
Active mine

Cleared area
- Haul road / infrastructure

Reject emplacement area

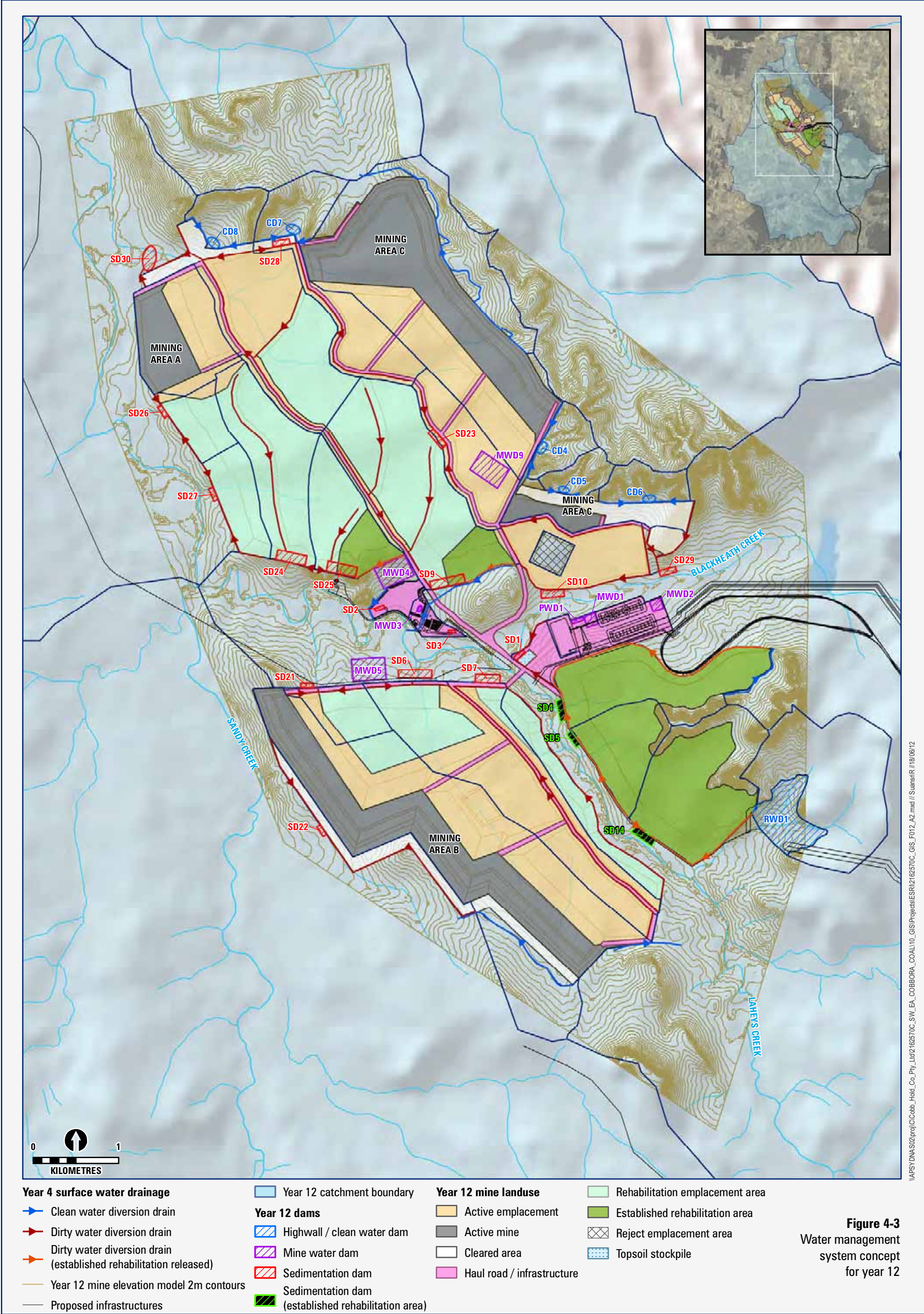
Topsoil stockpile

Figure 4-1 Water management system concept for year 1

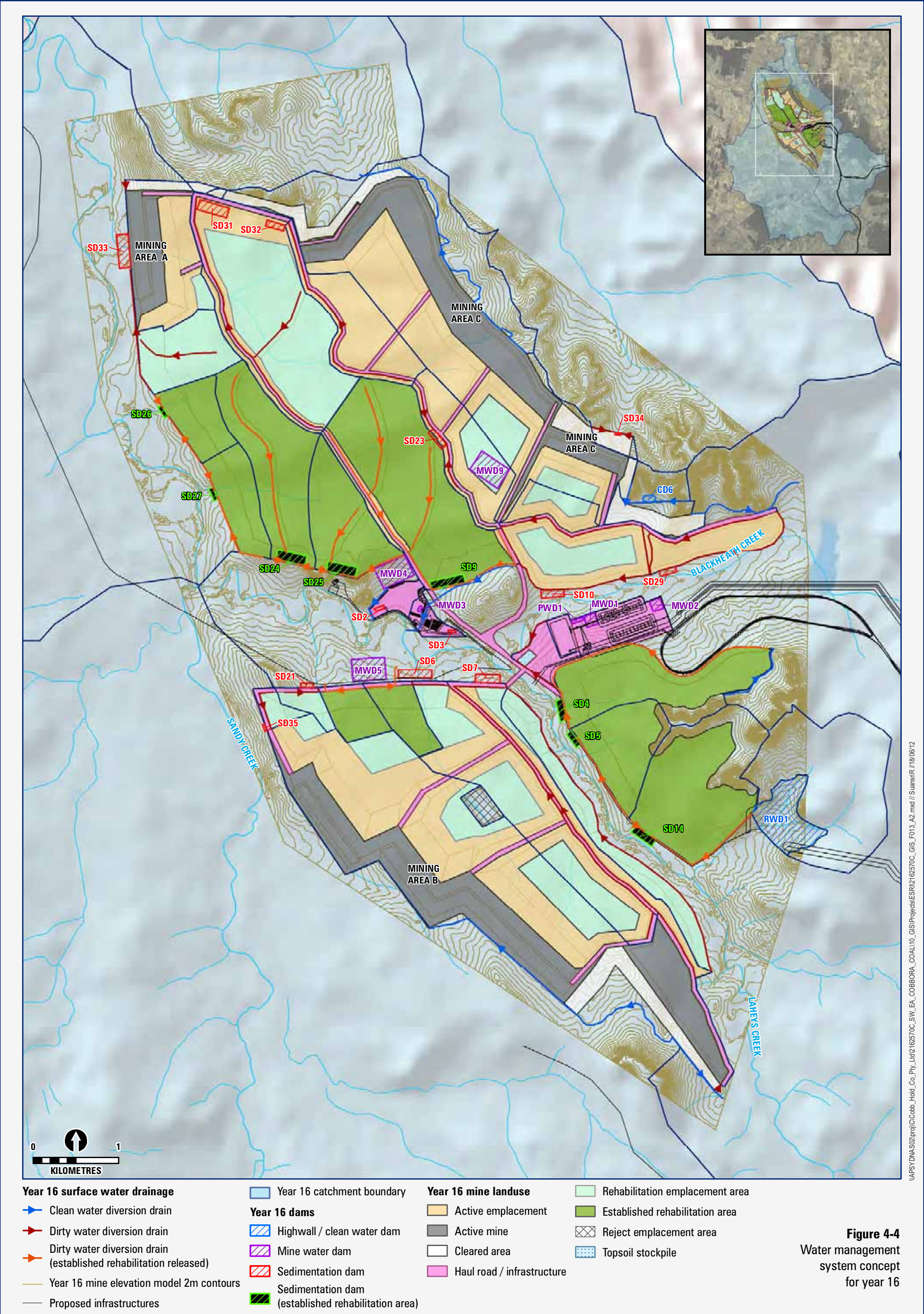


Year 4 surface water drainage	Year 4 catchment boundary	Year 4 mine landuse	Haul road / infrastructure
Clear water diversion drain	Year 4 dams	Active emplacement	Rehabilitated emplacement area
Dirty water diversion drain	Highwall / clean water dam	Active mine	Reject emplacement area
Year 4 mine elevation model 2m contours	Mine water dam	Cleared area	Topsoil stockpile
Proposed infrastructures	Sedimentation dam		

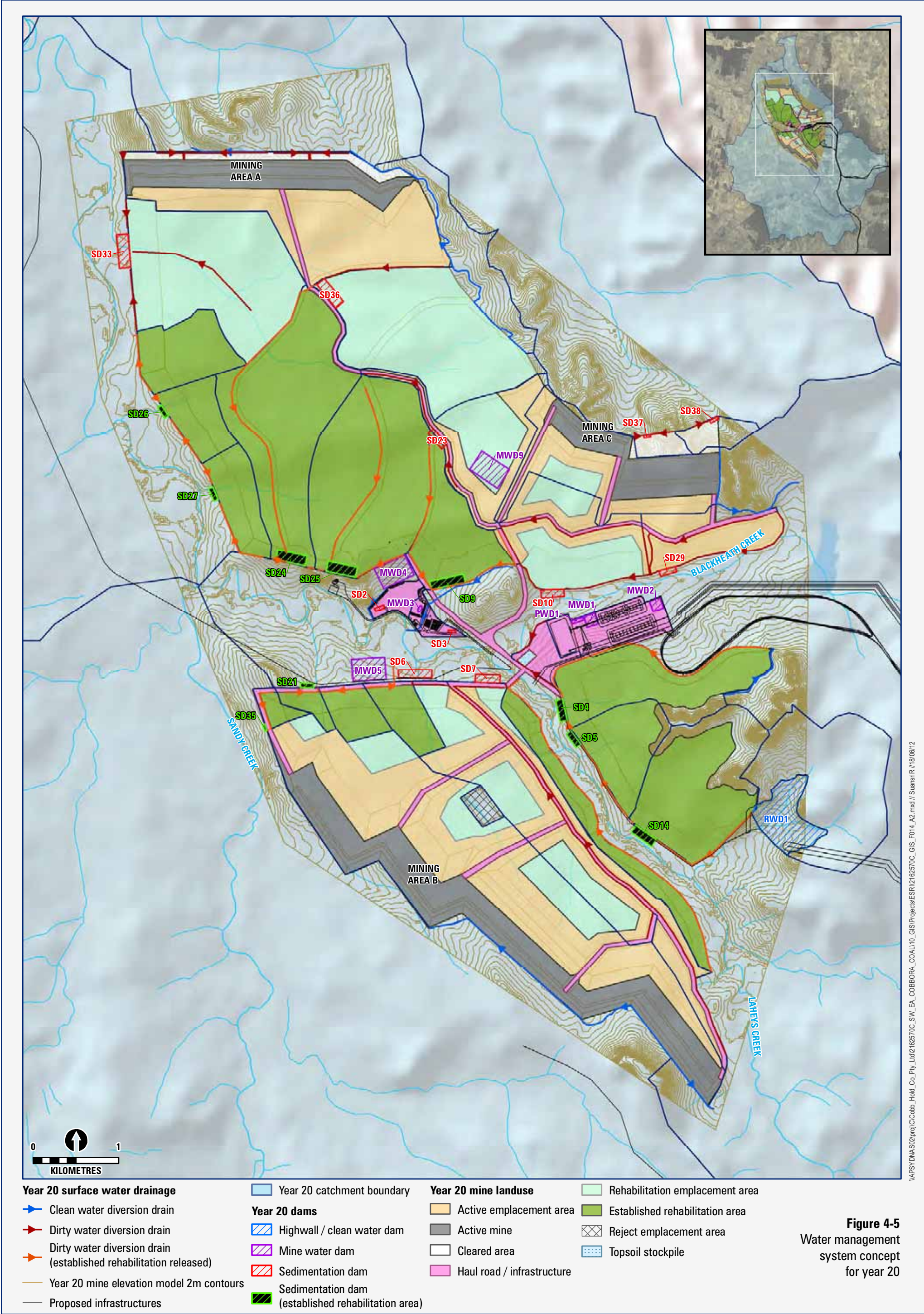
Figure 4-2 Water management system concept for year 4



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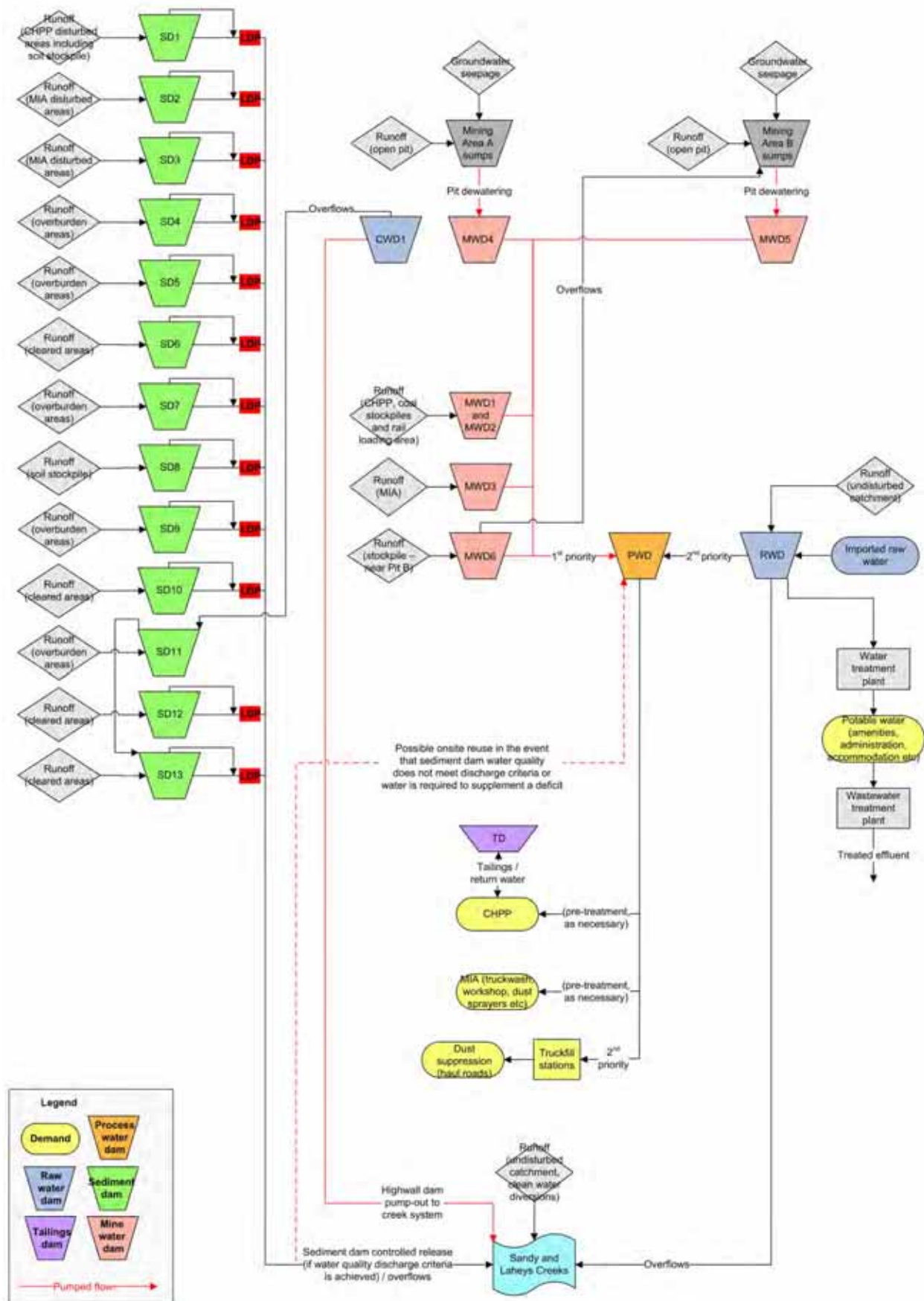


Figure 4.6 Schematic of water management system concept for Year 1



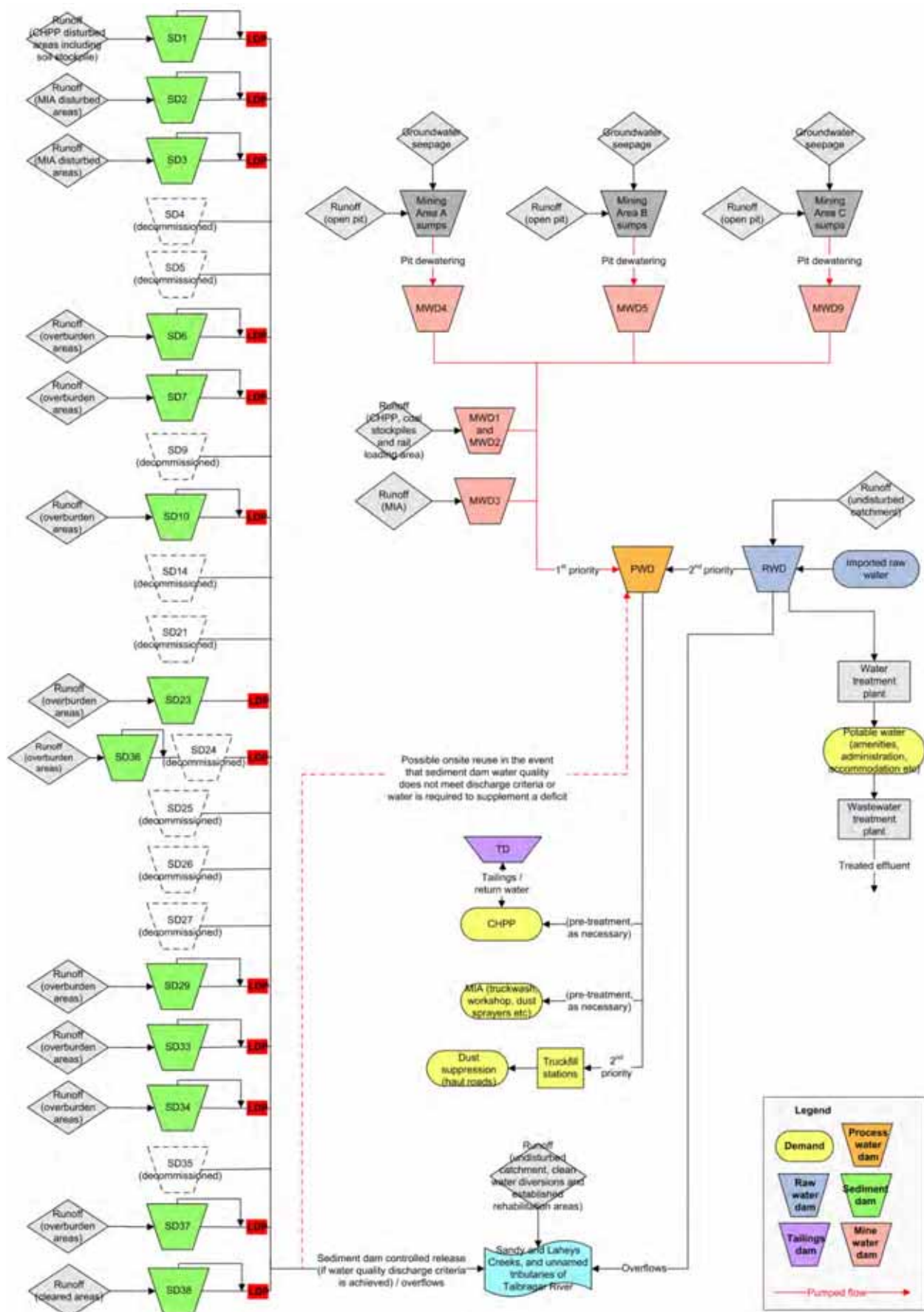


Figure 4.8 Schematic of water management system concept for Year 12

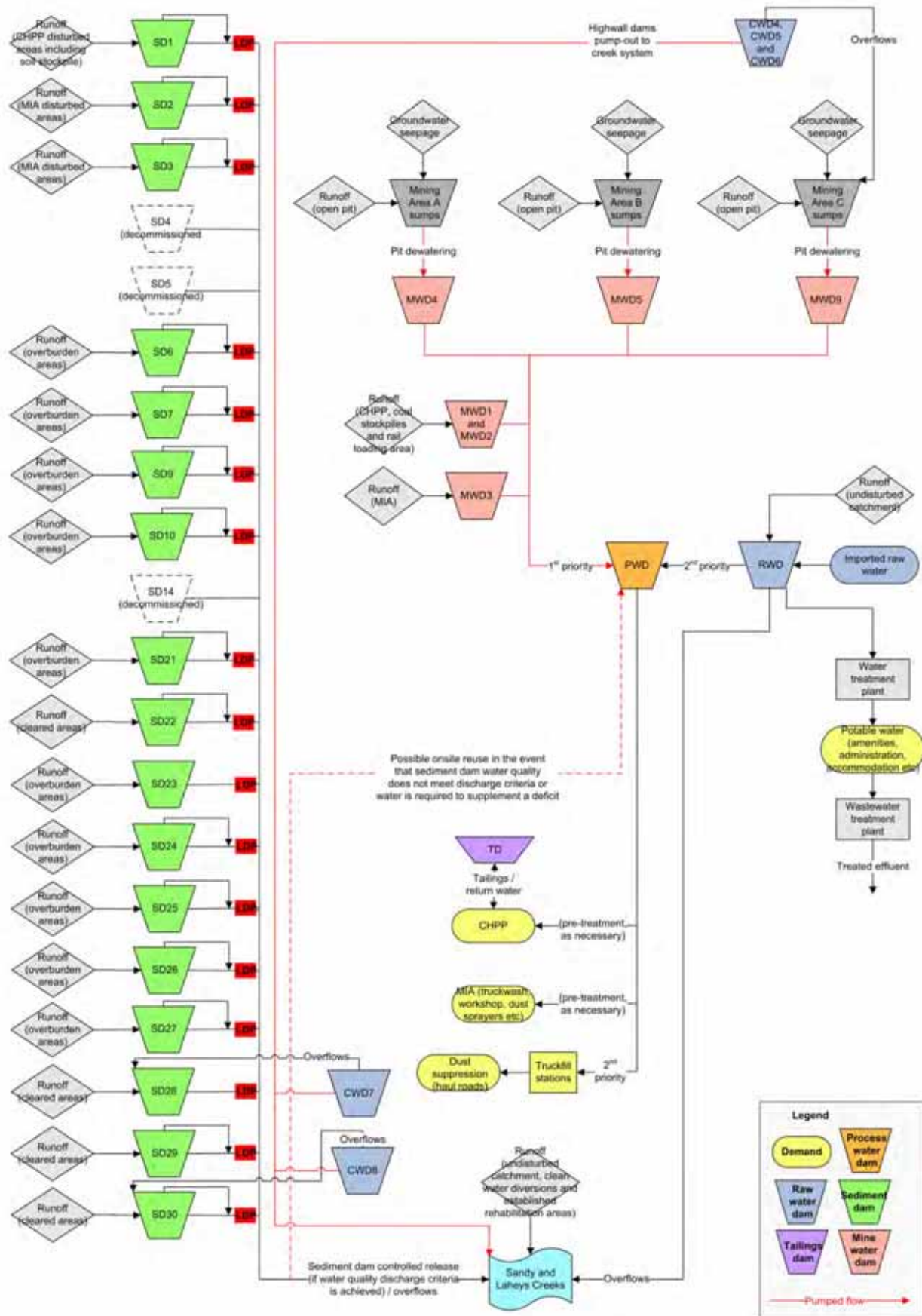


Figure 4.9 Schematic of water management system concept for Year 16

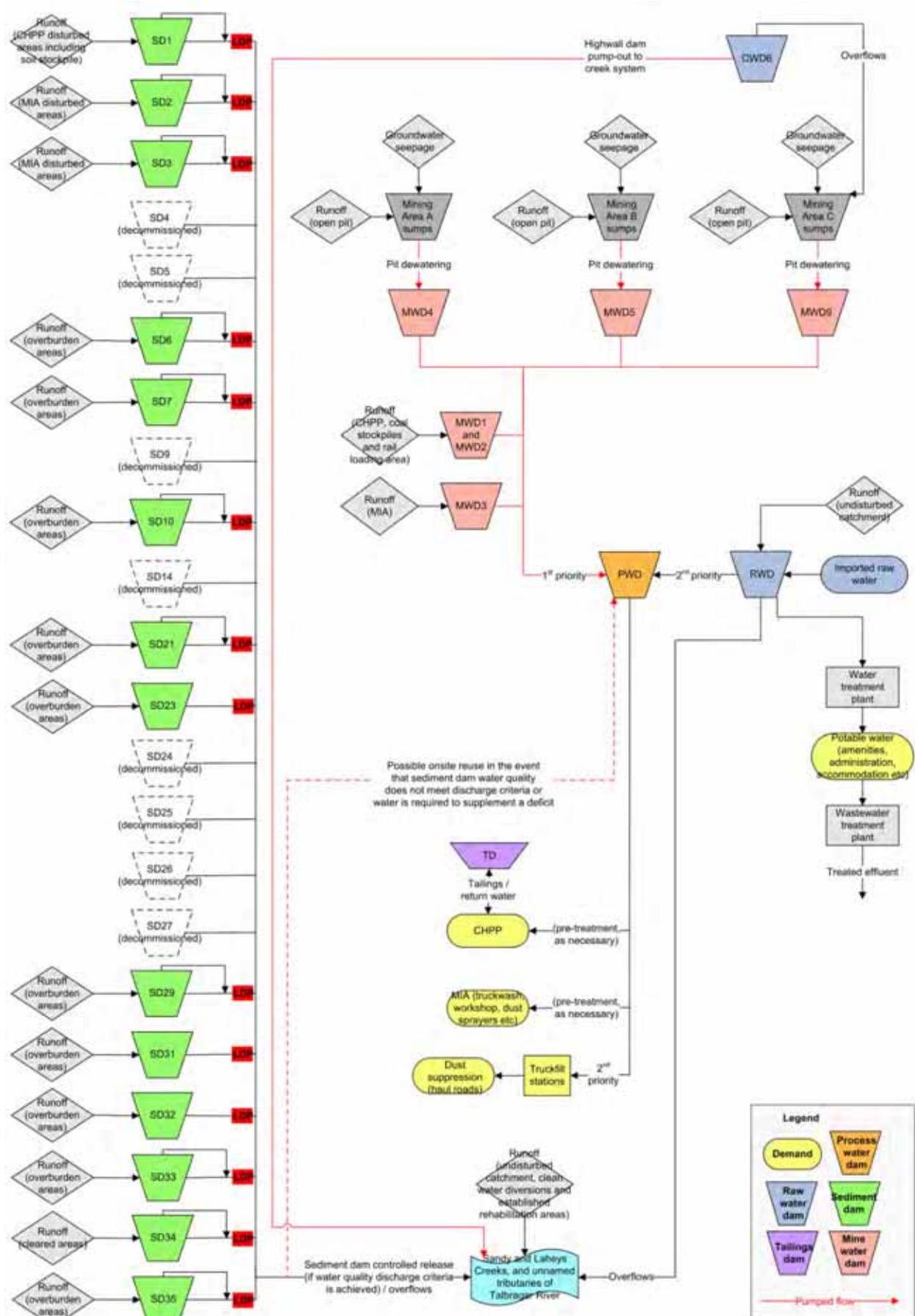


Figure 4.10 Schematic of water management system concept for Year 20

5. Site water balance modelling

5.1 Modelling approach

Water balance modelling has been undertaken to: assess the performance of the Project's water management system; estimate annual runoff volumes; potential water deficits and surpluses over the life of the mine; and confirm the preliminary sizing of water management dams.

5.1.1 GoldSim model

A water balance model of the Project was developed using GoldSim software, a widely used platform for mine site water balance studies.

The GoldSim model was used to calculate the volume of water in storages at the end of each day by taking into account daily rainfall-runoff inflow, groundwater inflow, evaporation from the storage, water usage, pumping between storages in the form of a pumping policy, and storage overflow. The network diagrams provided in Figure 4-6 to Figure 4-10 show the conceptual layout and interconnectivity of storages for the mine site.

The model logic for water transfers between storages and from their catchments to the discharge points are based on schematics of water management concepts, as presented in Figures 4-1 to 4-5.

Separate GoldSim models were developed for Year 1, 4, 12, 16 and 20 mine landforms to assess the site water balance over the life of the mine. Each model simulated 111 years of climate data (see Figure 3-2 and Figure 3-3) based on a daily time step. The climate data were statistically analysed to present potential water balances for 10th (dry), 50th (median) and 90th (wet) percentile years.

Put simply, the model took Year 1 of the mine and ran it through the first year of the meteorological data. It then ran Year 1 through the second year of meteorological data, carrying forward all water in dams stored at the end of the first year. This process was repeated for each of the 111 years of the climatic data set. This allowed an understanding of the impacts of a series of successive dry and wet years on the performance of the mine's water management system.

The above modelling sequence was subsequently repeated for Years 4, 12, 16 and 20, in each case carrying forward retained water from one year to the next.

5.1.2 Proposed operating scenario

The following two operating scenarios were considered:

- **Scenario A — release sedimentation dam water.** In this scenario, overburden runoff is displaced to the creek system in accordance with relevant licensing requirements. This is based on the assumption that the water quality of overburden runoff will be similar to pre-mining conditions (with the exception of elevated suspended solids) and that water quality criteria would be met following settling of suspended solids in sedimentation dams. Other water affected by mining is fully used in meeting the Project's water demands. Clean water is diverted from mining operations to the downstream creeks.

- **Scenario B — reuse sedimentation dam water.** In this scenario, water captured in sedimentation dams is pumped to the nearest mine water management dam if the volume stored in that dam is less than 25% capacity. Otherwise, the sedimentation dam water is displaced to the creek system in accordance with relevant licensing requirements. All other model operating rules are the same as for Scenario A.

Further analysis of the above two scenarios concluded that Scenario B would be the most appropriate scenario to be implemented for the Project. Scenario B has the advantage of reducing the volume of water from sedimentation dams released to downstream creeks and reducing the demand for raw water from the Cudgegong/Macquarie Regulated River system.

On this basis, Scenario B has been adopted as the proposed operating scenario to be used in the water balance model and water management system conceptual design presented in this report.

5.2 Model assumptions

The water balance model has been developed and refined to a level of detail suitable for conceptual design and environmental impact assessment of water management infrastructure. Some assumptions and simplifications were incorporated into the model that may need to be expanded for other applications:

- Pump rating curves have not been discretely modelled, and therefore the model does not represent delays that could occur when transporting water around the site.
- Runoff parameters have been selected using data published for other similar projects with limited quantitative data to assess the runoff characteristics of disturbed catchments at the Project site.
- The CHPP make-up demand is net of tailings return water, and as such the tailings dam did not need to be specifically included in the water balance model. This report does not assess the measures needed to avoid overflows from the tailings dam, as this is a process design issue to be addressed during detailed design.
- It has been assumed that pumping from the Cudgegong/Macquarie Regulated River system occurs at a rate of 20 ML/d, as required to maintain a storage volume of at least 25% capacity in the raw water dam. When assessing the adequacy of existing water access licences (WALs) held by CHC, it has been assumed that there is 100% allocation of high-security entitlements throughout the life of the Project. No allowance has been made to consider constraints or requirements on extraction that could be set as part of the Extraction Strategy Agreement currently being developed by CHC in consultation with State Water. This is discussed further in Section 5.4.3.
- While the model assesses the performance of the system under historical extremes that may reasonably be expected to reoccur in the future, it does not specifically quantitatively incorporate the potential impact of future climate change on runoff, given the limited influence this could have during the life of the mine.
- Groundwater seepage rates should be considered provisional only. Additional groundwater modelling during detailed design, and any potential dewatering that may be required to minimise seepage to the pit, could alter extraction rates provided in Section 5.4.2.

- The existing Sandy Creek and Laheys Creek catchments comprise numerous small farm dams, which have not been included in the water balance model. The only exceptions are the existing west 'Woolandra' farm dams located in the upper reaches of the Blackheath Creek catchment which have been included in the baseline model because of their large capacity and potential to impact on baseline flows in Laheys Creek. The west 'Woolandra' farm dams, however, have not been considered in the water balance model nor included in the proposed water management system for the Project, rather, it has been assumed that runoff from their catchments will be returned to Laheys Creek.

This report presents a conceptual water management system that will be refined and optimised as detailed design proceeds, and the quantity and quality characteristics of surface runoff and groundwater seepage are better understood.

5.3 Model data

5.3.1 Catchments

The change in the disturbed area and land use over the life of the Project is summarised in Table 5-1. Note that this table does not include undisturbed areas draining to the Project's water management system.

Table 5-1 Change in disturbed area over life of the Project

Land use	Area (ha)					
	Year 1	Year 4	Year 12	Year 16	Year 20	Year 21
Active overburden emplacement	360.4	666.4	952.8	1,072.5	959.5	
Active mine pit	50.1	295.6	562.5	504.2	442.8	
Cleared area	182.3	133.2	138.5	141.8	64.0	
Coal stockpile	13.3	14.1	11.1	11.1	11.1	
Final void						425.6
Haul road	56.9	102.6	134.5	180.2	141.4	
Infrastructure	52.9	52.2	50.7	50.7	50.7	
Rehabilitated overburden		411.6	1,212.4	1,735.1	2,234.7	
Rehabilitation area						3,587.4
Reject emplacement area	44.1	16.0	16.0	12.2	12.2	
Topsoil stockpile	10.4	6.0	2.2	2.2	2.2	
Total	770	1,698	3,081	3,710	3,919	4,013

Source: CHC

Catchment boundaries for the water management system were delineated using conceptual mine plans and reasonable assumptions about the likely destination of runoff.

Catchment boundaries are shown on the conceptual water management system plans provided in Figures 4-1 to 4-5 for Year 1, 4, 12, 16 and 20 mine landforms. A summary of catchment areas is provided in Table 5-2.

Table 5-2 Catchment areas over life of Project

Catchment	Area (ha)				
	Year 1	Year 4	Year 12	Year 16	Year 20
Surface water management system					
CWD1	16.7	0.0	0.0	0.0	0.0
CWD2	0.0	84.8	0.0	0.0	0.0
CWD3	0.0	30.3	0.0	0.0	0.0
CWD4	0.0	0.0	39.2	0.0	0.0
CWD5	0.0	0.0	29.1	0.0	0.0
CWD6	0.0	0.0	40.2	26.3	0.0
CWD7	0.0	0.0	56.8	0.0	0.0
CWD8	0.0	0.0	48.4	0.0	0.0
SD1	23.5	23.7	23.9	23.9	23.9
SD2	16.1	16.0	16.2	16.2	16.2
SD3	9.2	9.4	9.2	9.2	9.2
SD4	84.7	147.6	0.0	0.0	0.0
SD5	73.6	83.6	0.0	0.0	0.0
SD6	45.0	30.4	221.9	248.1	248.1
SD7	102.4	120.4	119.6	150.0	101.6
SD8	5.6	0.0	0.0	0.0	0.0
SD9	80.3	82.5	266.1	0.0	0.0
SD10	16.7	46.1	94.0	145.5	158.6
SD11	179.2	0.0	0.0	0.0	0.0
SD12	6.7	0.0	0.0	0.0	0.0
SD13	38.3	0.0	0.0	0.0	0.0
SD14	0.0	187.5	0.0	0.0	0.0
SD15	0.0	156.6	0.0	0.0	0.0
SD16	0.0	99.7	0.0	0.0	0.0
SD17	0.0	155.4	0.0	0.0	0.0
SD18	0.0	8.1	0.0	0.0	0.0
SD19	0.0	6.4	0.0	0.0	0.0
SD20	0.0	12.6	0.0	0.0	0.0
SD21	0.0	0.0	49.9	52.8	0.0
SD22	0.0	0.0	39.5	0.0	0.0
SD23	0.0	0.0	89.9	85.4	129.0
SD24	0.0	0.0	145.8	0.0	0.0
SD25	0.0	0.0	98.1	0.0	0.0
SD26	0.0	0.0	45.0	0.0	0.0
SD27	0.0	0.0	56.7	0.0	0.0
SD28	0.0	0.0	89.1	0.0	0.0
SD29	0.0	0.0	16.1	69.1	85.0
SD30	0.0	0.0	243.2	0.0	0.0
SD31	0.0	0.0	0.0	281.4	0.0
SD32	0.0	0.0	0.0	103.0	0.0
SD33	0.0	0.0	0.0	75.3	343.1
SD34	0.0	0.0	0.0	10.8	0.0

Catchment	Area (ha)				
	Year 1	Year 4	Year 12	Year 16	Year 20
SD35	0.0	0.0	0.0	15.1	0.0
SD36	0.0	0.0	0.0	0.0	267.7
SD37	0.0	0.0	0.0	0.0	15.1
SD38	0.0	0.0	0.0	0.0	24.8
MWD1 and MWD2	69.4	69.4	69.4	69.4	69.4
MWD3	6.0	6.0	6.0	6.0	6.0
MWD4	10.0	10.0	10.0	10.0	10.0
MWD5	10.0	10.0	10.0	10.0	10.0
MWD6	1.9	1.9	0.0	0.0	0.0
MWD7	0.0	4.0	0.0	0.0	0.0
MWD8	0.0	1.0	0.0	0.0	0.0
MWD9	0.0	0.0	10.0	10.0	10.0
RWD	245.7	243.9	243.8	243.8	243.8
Mining area A	32.1	165.5	127.4	139.8	355.9
Mining area B	20.2	236.6	485.2	700.7	684.6
Mining area C	0	187.9	492.8	590.2	193.6
Subtotal	1,093	2,237	3,293	3,092	3,006
Reject emplacement areas					
Refuse ponds	44.1	16.0	16.0	12.2	12.2
Subtotal	44	16	16	12	12
Creek systems					
Laheys Creek	10,272.4	9,269.4	9,071.8	8,774.0	8,741.0
Sandy Creek (downstream of confluence)	2,906.8	2,430.4	1,492.4	1,420.2	1,402.0
Sandy Creek (upstream of confluence)	13,901.3	14,264.5	13,839.1	13,814.6	13,808.4
Flyblowers Creek	738.4	738.4	824.4	821.1	739.0
Unnamed Tributary 1	278.4	278.4	278.4	278.4	278.4
Isbester Gully	2,454.2	2,454.2	2,454.2	2,439.2	2,389.5
Established rehabilitation returned directly to creek	0.0	0.0	419.4	1036.8	1312.2
Subtotal	30,551	29,435	28,380	28,584	28,671
Total	31,688	31,688	31,688	31,688	31,688

The catchment area draining to the water management system increases between Years 1 and 12. The catchment area draining to the system decreases after this time, as runoff from established rehabilitated areas are returned to the creek system.

5.3.2 Dam sizes

5.3.2.1 Sedimentation dams

Sedimentation dam capacities adopted in the water balance model are summarised in Table 5-3. Capacities are based on the design criteria outlined in Section 2.3.1. It may be possible to reduce the size of individual sedimentation dams by providing the required storage volume in multiple dams. This will be investigated during detailed design.

Note that SD1, SD2 and SD3 have adopted a runoff coefficient of 0.7 to account for the hardstand surfaces in the mine infrastructure and CHPP areas, whereas the other sedimentation dams capturing runoff from overburden emplacements and topsoil stockpiles have adopted a runoff coefficient of 0.4.

Table 5-3 Sedimentation dam capacities

Dam ID	Description	Maximum catchment area (ha)	Capacity (ML)		
			Settling zone	Sediment zone	Total
SD1	Sedimentation dam capturing runoff from infrastructure area west of run-of-mine stockpile pad	23.9	10.6	5.3	15.9
SD2	Sedimentation dam capturing runoff from mine infrastructure area	16.2	7.2	3.6	10.8
SD3	Sedimentation dam capturing runoff from mine infrastructure area	9.4	4.1	2.1	6.2
SD4	Sedimentation dam capturing runoff from overburden emplacement	147.6	37.4	18.7	56.0
SD5	Sedimentation dam capturing runoff from overburden emplacement	83.6	21.2	10.6	31.7
SD6	Sedimentation dam capturing runoff from overburden emplacement	248.1	62.8	31.4	94.2
SD7	Sedimentation dam capturing runoff from overburden emplacement	181.7	46.0	23.0	69.0
SD8	Sedimentation dam capturing runoff from topsoil stockpile	5.6	1.4	0.7	2.1
SD9	Sedimentation dam capturing runoff from overburden emplacement	266.1	67.3	33.7	101.0
SD10	Sedimentation dam capturing runoff from overburden emplacement	158.6	40.1	20.1	60.2
SD11	Sedimentation dam capturing runoff from overburden emplacement	179.2	45.3	22.7	68.0
SD12	Sedimentation dam capturing runoff from cleared area ahead of pit	6.7	1.7	0.8	2.5
SD13	Sedimentation dam capturing runoff from cleared area ahead of pit	38.3	9.7	4.8	14.5
SD14	Sedimentation dam capturing runoff from overburden emplacement	188.3	47.6	23.8	71.5
SD15	Sedimentation dam capturing runoff from overburden emplacement	156.6	39.6	19.8	59.4
SD16	Sedimentation dam capturing runoff from overburden emplacement	99.7	25.2	12.6	37.8
SD17	Sedimentation dam capturing runoff from overburden emplacement	155.4	39.3	19.7	59.0
SD18	Sedimentation dam capturing runoff from cleared area ahead of pit	8.1	2.1	1.0	3.1
SD19	Sedimentation dam capturing runoff from cleared area ahead of pit	6.4	1.6	0.8	2.4
SD20	Sedimentation dam capturing runoff from cleared area ahead of pit	12.6	3.2	1.6	4.8
SD21	Sedimentation dam capturing runoff from overburden emplacement	52.8	13.4	6.7	20.0
SD22	Sedimentation dam capturing runoff from cleared area ahead of pit	39.5	10.0	5.0	15.0
SD23	Sedimentation dam capturing runoff from overburden emplacement	129.0	32.6	16.3	49.0

Dam ID	Description	Maximum catchment area (ha)	Capacity (ML)		
			Settling zone	Sediment zone	Total
SD24	Sedimentation dam capturing runoff from overburden emplacement	269.7	68.2	34.1	102.4
SD25	Sedimentation dam capturing runoff from overburden emplacement	266.7	67.5	33.7	101.2
SD26	Sedimentation dam capturing runoff from overburden emplacement	50.6	12.8	6.4	19.2
SD27	Sedimentation dam capturing runoff from overburden emplacement	56.7	14.3	7.2	21.5
SD28	Sedimentation dam capturing runoff from overburden emplacement	89.1	22.5	11.3	33.8
SD29	Sedimentation dam capturing runoff from overburden emplacement	85.0	21.5	10.8	32.3
SD30	Sedimentation dam capturing runoff from overburden emplacement	243.2	61.5	30.8	92.3
SD31	Sedimentation dam capturing runoff from overburden emplacement	281.4	71.2	35.6	106.8
SD32	Sedimentation dam capturing runoff from overburden emplacement	103.0	26.1	13.0	39.1
SD33	Sedimentation dam capturing runoff from overburden emplacement	343.1	86.8	43.4	130.2
SD34	Sedimentation dam capturing runoff from cleared area ahead of pit	10.8	2.7	1.4	4.1
SD35	Sedimentation dam capturing runoff from overburden emplacement	15.1	3.8	1.9	5.7
SD36	Sedimentation dam capturing runoff from overburden emplacement	267.7	67.7	33.9	101.6
SD37	Sedimentation dam capturing runoff from cleared area ahead of pit	15.1	3.8	1.9	5.7
SD38	Sedimentation dam capturing runoff from cleared area ahead of pit	24.8	6.3	3.1	9.4

5.3.2.2 Mine water dams

Dam capacities adopted in the water balance model are summarised in Table 5-4. Capacities are based on the design criteria outlined in Section 2.3.2.

Note that no allowance has yet been made for sediment storage, but this will be considered during detailed design. For comparison purposes, estimated runoff volumes for the 100-year ARI 24-hour and 72-hour storm events are also provided in Table 5-4.

Table 5-4 Dam capacities

Dam ID	Description	Maximum catchment area (ha)	Volume (ML)		
			Adopted capacity (from water balance modelling)	100-year ARI 24-hour runoff volume	100-year ARI 72-hour runoff volume
MWD1 and MWD2	Water storage dams capturing infrastructure runoff from CHPP	69.4	175	76.3	97.2
MWD3	Storage dam capturing runoff from mine infrastructure area (mainly clean areas)	6.0	15	6.6	8.4

Dam ID	Description	Maximum catchment area (ha)	Volume (ML)		
			Adopted capacity (from water balance modelling)	100-year ARI 24-hour runoff volume	100-year ARI 72-hour runoff volume
MWD4	Mine water dam receiving water pumped from pit	–	500	–	–
MWD5	Mine water dam receiving water pumped from pit	–	500	–	–
MWD6	Infrastructure water storage dam capturing runoff from stockpile pad near mining area B	1.9	2.7	2.1	2.7
MWD7	Mine water dam receiving water pumped from pit	–	200	–	–
MWD8	Infrastructure water storage dam capturing runoff from stockpile pad near mining area C	1.0	1.4	1.1	1.4
MWD9	Mine water dam receiving water pumped from pit (replaces MWD7)	–	500	–	–

Note: Excludes sediment storage.

Mine water dams (MWD4, MWD5, MWD7 and MWD9) will have a ‘turkeys nest’ configuration and have minimal catchment area receiving mainly pumped inflows from the pit sumps. Mine water dams have therefore been sized based on the results of historical water balance modelling to achieve a reasonable level of pit dewatering when operated as part of the site water management system over the 111-year water balance simulation.

No limit has been applied in the water balance model on the volume of in-pit sump storage. As detailed in Section 4.4, CHC has considerable flexibility to transfer pit water between open cuts without needing to release surpluses during extended periods of wet weather.

5.3.2.3 Clean water highwall dams

Table 5-5 summarises the clean water highwall dam capacities adopted in the water balance model. Capacities are based on the design criteria outlined in Section 2.3. There may be an opportunity to provide additional highwall dams during detailed design to further reduce the catchment draining to the pits.

Table 5-5 Clean water highwall dam capacities

Dam ID	Description	Maximum catchment area (ha)	Capacity (ML)
CWD1	Dam capturing clean water ahead of SD11 overburden catchment	16.7	10.5
CWD2	Dam capturing clean water ahead of mining area B	84.8	53.3
CWD3	Dam capturing clean water ahead of mining area B	30.3	19.1
CWD4	Dam capturing clean water ahead of mining area C	39.2	24.6
CWD5	Dam capturing clean water ahead of mining area B	29.1	18.3
CWD6	Dam capturing clean water ahead of mining area B	40.2	25.2

Dam ID	Description	Maximum catchment area (ha)	Capacity (ML)
CWD7	Dam capturing clean water ahead of SD28 overburden catchment	56.8	35.7
CWD8	Dam capturing clean water ahead of SD30 overburden catchment	48.4	30.4

5.3.2.4 Stage-storage relationships

Stage-storage relationships for dams were included in the water balance model and were estimated based on assumed side slopes of 1:3 (V:H) and assumed depths of 2.5 m for sedimentation dams and 5.0 m for mine water dams. This assumption will be refined during detailed design once the final configuration of site dams is established.

The stage-storage relationship for the proposed 1,448 ML raw water dam was provided by CHC, and is summarised in Table 5-6. A surface area of zero was assumed for a storage volume of zero.

Table 5-6 Stage-storage relationship for proposed raw water dam

Volume (ML)	Surface area (ha)
365	12.4
726	19.0
1,095	24.5
1,448	29.7

Source: CHC

5.3.3 Pump rates

The following pump rates were adopted in the water balance model:

- pit sump to mine water dam:
 - ▶ 8.6 ML/d (100 L/s) each if current sump volume between 0 ML and 100 ML
 - ▶ 13.0 ML/d (150 L/s) each if current sump volume between 100 ML and 200 ML
 - ▶ 21.6 ML/d (250 L/s) each if current sump volume greater than 200 ML.
- mine water dam to process water dam — 10 ML/d each (116 L/s)
- low flow outlets of sedimentation dams — sized to empty 'settling zone' over five days (various sizes)
- sedimentation dams to mine water dams (for on-site reuse) — sized to empty 'settling zone' over five days (various sizes).

It has been assumed that pumping from the Cudgegong/Macquarie Regulated River system occurs as required at a rate of 20 ML/d. At the time of writing, no further constraints or requirements on pumping rates could be set because the Extraction Strategy Agreement is currently being negotiated between CHC and State Water. This is discussed further in Section 5.4.3.

5.3.4 Operating rules

Operating rules would be subject to ongoing development and refinement. The following operating rules have been assumed in the water balance model:

- Pumping from pit sumps to MD4, MD5 and MD7/MD9 stops if the dam capacity exceeds 90%. During extended wet periods, surplus mine water will either be stored in the mine pits or transferred between open cuts once mine water dams have reached their capacity.
- The 'sediment zone' of sedimentation dams is 50% of capacity throughout the simulation.
- Pumping out from sedimentation dams occurs when the water level reaches the 'settling zone'. Water captured above the 'settling zone' in sedimentation dams is pumped to the nearest mine water dam if the volume stored in that dam is less than 25% capacity. Otherwise, clarified water is released into the creek system.
- Sedimentation dam overflows are included in the model. Overflows from sedimentation dams are typically displaced to the creek (although some overflow to other sedimentation dams, or are located at low points and do not overflow).
- Other water management dams pump to the central process water dam. Water is pumped to PW1 when PW1 falls below 75% capacity, but stops when it reaches 90% capacity. When PW1 falls below 75%, but is above 25%, water is pumped from the dam with the highest current volume to capacity ratio. When PW1 drops below 25%, pumping from all mine water dams can occur if water is available in these dams.
- In Year 1, dams MWD1 and MWD2 can pump back to the mine water dams MWD4 and MWD5 when their capacity exceeds 90% in order to draw down the dam following a storm event. This is not necessary during the other modelled years, as demands are higher and water from MWD1 and MWD2 can be reused on-site.
- The CHPP, mine infrastructure area and haul road dust-suppression demands are sourced from the following dams (in order of priority):
 - ▶ process water dam (PW1)
 - ▶ raw water dam (RW1).
- Potable water demands are always sourced from the raw water dam, as high-quality water is required. Potable water demands are sourced from the raw water dam to estimate the worst-case requirement for imported water (however, potable water may be trucked to site).
- When the raw water dam falls below 25%, imported water is pumped into the dam from the Cudgegong/Macquarie Regulated River system at a rate of 20 ML/d. No further constraint has been applied in the model on the volume of imported water available to the site.
- The pump rates provided in Section 5.3.3 have been adopted in the water balance model. It has been assumed these rates would not be limited by pump/pipeline capacity.

The current model includes only the above basic operating rules (suitable for concept design and environmental impact assessment), however, it is recommended that these are refined once new groundwater, water quality and geochemistry data becomes available.

Operating rules should be developed to manage competing interests, including water retention to use around the site and maintaining spare capacity to contain storm events and pit dewatering. In particular, operating rules may need to be refined when the Extraction Strategy Agreement from the Cudgegong/Macquarie Regulated River system becomes available.

5.4 Water inputs

Water inputs for the Project comprise:

- surface water runoff
- groundwater seepage to the open pit
- imported water.

5.4.1 Surface water runoff

The AWBM rainfall-runoff model (using the Data Drill daily rainfall and evapotranspiration data) was incorporated into the GoldSim model to generate a daily time series of runoff from undisturbed, disturbed and rehabilitated catchments. The AWBM rainfall-runoff model and parameters are described in Section 3.5.1.

5.4.2 Groundwater seepage

Groundwater seepage rate estimates for the open pits are provided in the Project's groundwater assessment report (Parsons Brinckerhoff 2012), and are summarised in Table 5-7 and Figure 5-1.

The groundwater seepage rates provided in Table 5-7 are estimates of natural seepage into the pits without pre-mining dewatering. Engineered dewatering of the pits prior to the mining would change the sequence and may provide better control on groundwater. However, the water balance modelling presented in this report assumes the groundwater availability as per the natural seepage sequence provided in Table 5-7.

Table 5-7 Groundwater seepage rate estimates

Year	Seepage rate (ML/a)			
	Mining area A	Mining area B	Mining area C	Total
1	1	37	0	38
2	124	277	4	405
3	309	372	20	701
4	283	524	79	886
5	258	615	4	877
6	282	611	129	1,022
7	454	611	226	1,291
8	281	626	122	1,029
9	456	642	130	1,228
10	611	679	246	1,536
11	607	968	79	1,654
12	180	1,120	249	1,549

Year	Seepage rate (ML/a)			
	Mining area A	Mining area B	Mining area C	Total
13	276	970	304	1,550
14	20	989	357	1,366
15	94	569	313	976
16	281	734	326	1,341
17	491	962	322	1,775
18	219	242	374	835
19	109	0	166	275
20	184	0	64	248
21	186	0	162	348

Source: Parsons Brinckerhoff 2012

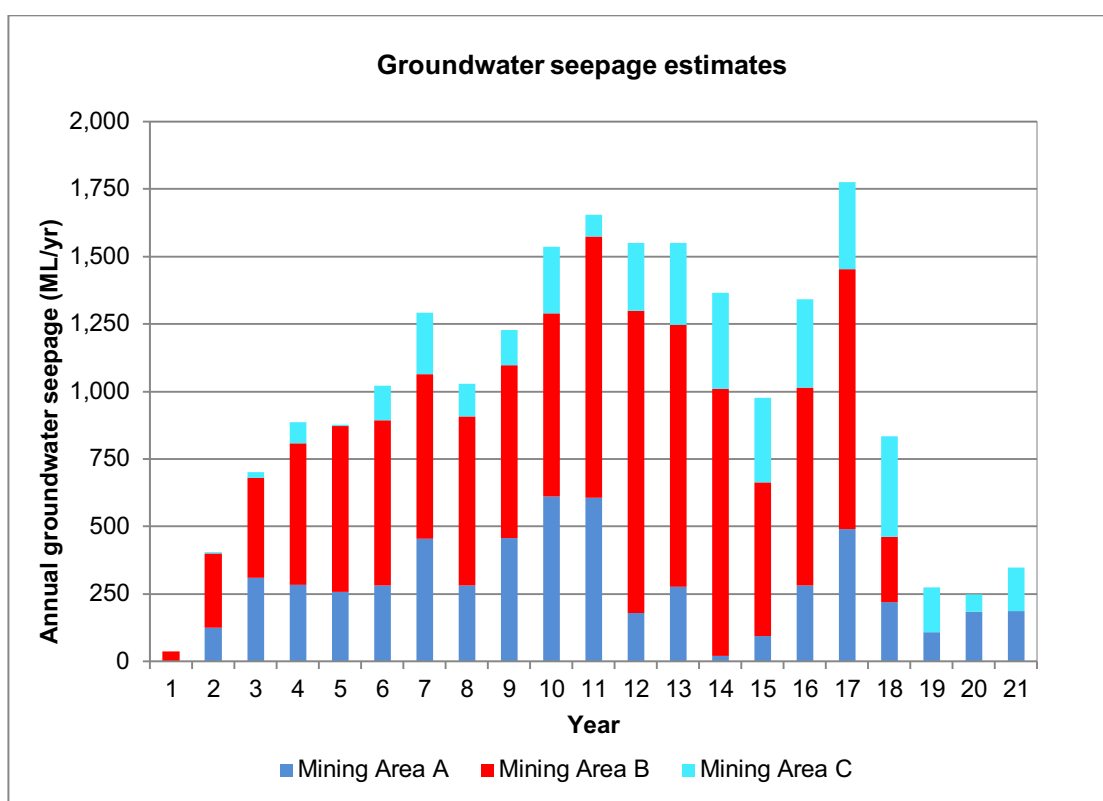


Figure 5.1 Plot of groundwater seepage estimates

5.4.3 Imported water

Raw water will be imported to the mine site to meet demands during a water deficit, and also to provide a high-quality water source (e.g. for potable applications). Imported water will be stored in the raw water dam.

Raw water will be pumped to site from the Cudgegong/Macquarie Regulated River system. CHC currently holds 3,311 unit shares of high-security water access licences (WALs) from the Cudgegong/Macquarie Regulated River system. Assuming 100% allocation of high-security WALs, this is equivalent to 3,311 ML/a.

The average long-term extraction factor for high-security WALs for the Macquarie Regulated River Valley published in the document *Water availability in New South Wales Murray-Darling Basin Regulated Rivers* (DWE 2009) is 0.95. This factor suggests a high degree of certainty in the availability of high-security WAL allocations in this system.

At the time of writing, negotiations were proceeding between CHC and State Water on the Extraction Strategy Agreement for the Project. This could set constraints on extraction based on river conditions and other demands on the system that may need to be considered in future versions of the mine's operating water balance model. Refer to Section 7.1 for further details.

For the purposes of this assessment and in consideration of the above factors, the Cudgong/Macquarie Regulated River system is a reliable source of raw water to the Project and the full entitlement of 3,311 ML/a has been assumed to be available to the Project if/when required to meet its water demands.

5.5 Water demands

Demands for the Project comprise:

- CHPP make-up water
- mine infrastructure areas, such as workshop and vehicle washdown areas
- haul road dust suppression
- potable water
- miscellaneous uses, such as construction water.

5.5.1 Coal-handling and preparation plant

Coal production rates and CHPP make-up water requirements have been provided by CHC and are summarised in Table 5-8. The CHPP demand estimate is based on a requirement of 208 ML/Mt/a product coal, and assumes that 20% of the process water requirement can be recovered from tailings.

Table 5-8 CHPP make-up water demand estimates (net of tailings return water)

Year	ROM coal (Mt/a)	Product coal (Mt/a)	CHPP make-up water (ML/a)
1	1.0	0.7	151
4	16.5	11.2	2,340
12	20.0	12.0	2,500
16	20.0	12.0	2,500
20	20.0	12.0	2,500

Make-up water for the CHPP will be sourced from mine water as a priority. It is assumed that such water will be suitable for this purpose. The CHPP make-up demand is net of tailings return water, and as such the tailings dam did not need to be specifically included in the water balance model.

5.5.2 Mine infrastructure area

Water will be required in the mine infrastructure area for vehicle washing and workshop use, as well as dust suppression for the coal stockpiles and train loading facility. Mine infrastructure area demands were provided by CHC and are summarised in Table 5-9.

Table 5-9 Mine infrastructure area demand estimates

Year	Mine infrastructure area demand (ML/a)
1	9
4	140
12	150
14	150
20	150

CHC advised that mine water will be of suitable quality for use in the mine infrastructure area. However, it is considered likely that pre-treatment would be required prior to use in the dust sprayers to prevent suspended solids from blocking the sprayer nozzles. It is also likely that pre-treatment would be required prior to use for washdown of vehicles and mining equipment. These quality requirements should be addressed during detailed design.

5.5.3 Haul road dust suppression

Mine water will be used for dust suppression on haul roads. Dust-suppression demand estimates provided by CHC are summarised in Table 5-10. Dust-suppression demand estimates are based on demands for similar sized open-cut coal mining operations in the Hunter Valley of NSW.

Table 5-10 Haul road dust-suppression demand estimates

Year	Haul road dust suppression (ML/a)
1	61
4	936
12	1,000
16	1,000
20	1,000

Water for dust suppression on haul roads will be sourced from mine water as a priority (via truck fill stations). It is assumed that such water will be of suitable quality for this purpose. The water balance analysis assumed that dust-suppression water will be applied evenly throughout the year (irrespective of rainfall depth).

5.5.4 Potable water

Potable water will be required in the administration and amenities buildings during mine operation. CHC has estimated that 50 L/d per person would be required. A summary of the workforce and potable water demand estimates for the mine operation is provided in Table 5-11.

Table 5-11 Potable water demand estimates

Year	Maximum workforce per shift (people)	Potable water demand (ML/a)
1	132	2.4
4	276	5.0
12	336	6.1
16	341	6.2
20	165	3.0

Potable water would also be required for the construction phase but this was not included in the water balance model. CHC estimated that a peak of 10 ML/a will be required for the general construction workforce (based on 50 L/d per person and 550-person workforce peak occurring in September to October 2014), and 36.5 ML/a will be required for the construction accommodation village (based on upper limit of 250 L/d per person and 400-bed village).

This is a combined peak potable water demand of 46.5 ML/a for the construction phase. Note that the demand for the construction accommodation village of 250 L/d per person is an upper limit, but would more realistically be around 100 L/d per person.

Potable water would most likely be trucked to site from the Wellington or Warrumbungle Shire Council supply during the initial construction phase. It is proposed to use raw water pumped to site from the Cudgegong/Macquarie Regulated River system for potable applications after the first six months of construction, assuming that it is treated to potable standard prior to use.

The source of potable water will be determined during detailed design. Given the small potable water demand relative to the total site demand during the operational phase, it is not expected that potable water will have a significant impact on the site water balance.

Wastewater from on-site facilities such as workshops, process and administration buildings will be managed by an on-site sewage treatment system. Treated effluent will be returned to the mine water system for onsite reuse but has not been specifically included in the water balance model, as volumes are not expected to be significant when compared to other inputs to the system.

5.5.5 Demand summary

A summary of water demands for the Project is provided in Table 5-12. The peak demand is estimated to be 3,656 ML/a.

Table 5-12 Water demand summary

Year	Product coal (Mt/a)	CHPP make-up water (ML/a)	Mine infrastructure area demand (ML/a)	Haul road dust suppression (ML/a)	Potable water demand (ML/a)	Total site demand (ML/a)
Construction (peak)	—	—	—	—	46.5	47
1	0.7	151	9	61	2.4	223
4	11.2	2,340	140	936	5.0	3,421
12	12.0	2,500	150	1,000	6.1	3,656
16	12.0	2,500	150	1,000	6.2	3,656
20	12.0	2,500	150	1,000	3.0	3,653

5.6 Other losses

5.6.1 Evaporation

Evaporation estimates for open water bodies were based on Data Drill sourced daily Morton's Lake evaporation data. The Data Drill calculates Morton's Lake evaporation using Morton's formula for shallow lakes (Morton 1983). Evaporative surface area for dams has been determined based on the stage-storage relationships provided in Section 5.3.2.

Evaporation losses from the raw water dam will be confirmed during detailed design, with consideration to the Extraction Strategy Agreement from the Cudgegong/Macquarie Regulated River system when it becomes available. NOW has suggested that the Extraction Strategy Agreement may involve seasonal pumping restrictions. If so, seasonal pumping restrictions could impact the residence time of water in the raw water dam and subsequent evaporation losses.

5.6.2 Seepage from dams

Some water will be lost from dams as a result of seepage through the foundation. Site dams should have low seepage losses and, depending on the subsoils, an engineered liner may be required. Water balance modelling has assumed seepage losses to be negligible.

6. Results of water balance assessments

This section summarises key results related to the site water balance. The results discussed here were obtained from the water balancing modelling as discussed in Section 1.

6.1 Modelling results for proposed operating scenario

The site water balances for the proposed operating scenario were obtained by assuming that runoff captured in sedimentation dams will be reused on-site to meet water demands for the Project. Water from sedimentation dams is assumed to be pumped to mine water dams for reuse on-site when these dams have sufficient spare capacity to accept additional flows.

Capacity is assumed sufficient if the stored volume is less than 25% capacity, to maintain spare capacity for pit dewatering in the event of extended wet periods. If mine water dams do not have spare capacity, then sedimentation dam water would be released to the creek system, after water quality criteria are met.

Annual summaries of water balances for the 10th (calendar year 1967), the 50th (calendar year 1906) and the 90th (calendar year 1990) percentile rainfall years were summarised from the daily water balance results. These are presented in Table 6-1 to Table 6-3. These results are representative of typical dry, average and wet years. Note that the apparent imbalance in the results tables is a result of on-site storage.

The results of the water balances are discussed in Sections 6.1.1 to 6.1.4.

Table 6-1 Annual site water balance — 10th percentile dry year

	Units	Pre- mining	Year 1	Year 4	Year 12	Year 16	Year 20	Post-mining
Catchment breakdown								
Water management system (WMS)								
▪ Raw water dam	Ha	0	246	244	244	244	244	0
▪ Clean water/highwall dams	Ha	0	17	115	214	26	0	0
▪ Sedimentation dams	Ha	0	681	1,186	1,559	1,216	1,310	0
▪ Other water dams and pits	Ha	0	149	692	1,211	1,536	1,340	384
▪ Refuse ponds	Ha	0	45	16	16	12	12	0
Existing west 'Woolandra' farm dams	Ha	1,034	—	—	—	—	—	—
Undisturbed	Ha	30,655	30,551	29,435	27,961	27,547	27,358	27,625
Established rehabilitation returned directly to creek	Ha	—	0	0	485	1,107	1,424	3,680
Total study catchment	Ha	31,688	31,688	31,688	31,688	31,688	31,688	31,688
Proportion of study catchment in WMS	%	-	3.6%	7.1%	10.2%	9.6%	9.2%	1.2%
Inflows								
Runoff								
Water management system								
▪ Raw water dam	ML/a	—	4	4	4	4	4	—
▪ Sedimentation dams	ML/a	—	172	245	278	273	217	—
▪ Other water dams and pits	ML/a	—	113	325	582	592	545	—
▪ Clean water/highwall dams	ML/a	—	1	2	4	0	0	—
Total WMS runoff	ML/a	—	290	576	869	869	766	—
Undisturbed and established rehabilitation returned directly to creek	ML/a	575	573	552	535	543	547	641
Existing west 'Woolandra' farm dams	ML/a	19	—	—	—	—	—	—
Groundwater make	ML/a	—	38	886	1,549	1,341	248	—
Imported river water	ML/a	—	0	2,360	1,700	1,880	2,960	—

	Units	Pre- mining	Year 1	Year 4	Year 12	Year 16	Year 20	Post-mining
Sedimentation dam water reused on-site	ML/a	–	50	129	141	147	123	–
Outflows								
WMS dam evaporation (net of direct rain)	ML/a	–	241	438	502	478	351	–
CHPP make-up demand	ML/a	–	151	2,340	2,500	2,500	2,500	–
Haul road dust-suppression demand	ML/a	–	61	936	1,000	1,000	1,000	–
Mine infrastructure area demand	ML/a	–	9	140	150	150	150	–
Potable water demand	ML/a	–	2.4	5	6.1	6.2	3	–
Total WMS demand	ML/a	–	223	3,421	3,656	3,656	3,653	–
Sedimentation dam returns to creek	ML/a	–	0	0	0	0	0	–
Sedimentation dam controlled releases to creek	ML/a	–	47	9	9	14	9	–
Clean water/highwall dam controlled releases to creek	ML/a	–	1	3	5	1	0	–
Raw water dam overflows to creek	ML/a	–	0	0	0	0	0	–
Existing west 'Woolandra' farm dams overflows	ML/a	0	–	–	–	–	–	–
Total flow at study catchment outlet	ML/a	575	621	564	550	558	556	641

Notes: Excludes runoff to refuse disposal ponds catchments

Table 6-2 Annual site water balance — 50th percentile median year

	Units	Pre-mining	Year 1	Year 4	Year 12	Year 16	Year 20	Post-mining
Catchment breakdown								
Water management system (WMS)								
▪ Raw water dam	Ha	0	246	244	244	244	244	0
▪ Clean water/highwall dams	Ha	0	17	115	214	26	0	0
▪ Sedimentation dams	Ha	0	681	1,186	1,559	1,216	1,310	0
▪ Other water dams and pits	Ha	0	149	692	1,211	1,536	1,340	384
▪ Refuse ponds	Ha	0	45	16	16	12	12	0
Existing west 'Woolandra' farm dams	Ha	1,034	—	—	—	—	—	—
Undisturbed	Ha	30,655	30,551	29,435	27,961	27,547	27,358	27,625
Established rehabilitation returned directly to creek	Ha	—	0	0	485	1,107	1,424	3,680
Total study catchment	Ha	31,688	31,688	31,688	31,688	31,688	31,688	31,688
Proportion of study catchment in WMS	%	—	3.6%	7.1%	10.2%	9.6%	9.2%	1.2%
Inflows								
Runoff								
Water management system								
▪ Raw water dam	ML/a	—	13	13	13	13	13	—
▪ Sedimentation dams	ML/a	—	344	498	568	541	438	—
▪ Other water dams and pits	ML/a	—	200	600	1,089	1,122	1,040	—
▪ Clean water/highwall dams	ML/a	—	2	7	13	2	0	—
Total WMS runoff	ML/a	—	559	1,117	1,682	1,678	1,491	—
Undisturbed and established rehabilitation returned directly to creek	ML/a	1,852	1,845	1,777	1,715	1,725	1,731	1,933
Existing west 'Woolandra' farm dams	ML/a	62	—	—	—	—	—	—
Groundwater make	ML/a	—	38	886	1,549	1,341	248	—
Imported river water	ML/a	—	40	1,720	1,100	1,200	2,180	—

	Units	Pre-mining	Year 1	Year 4	Year 12	Year 16	Year 20	Post-mining
Sedimentation dam water reused on-site	ML/a	–	173	337	320	347	300	–
Outflows								
WMS dam evaporation (net of direct rain)	ML/a	–	126	226	266	254	176	–
CHPP make-up demand	ML/a	–	151	2,340	2,500	2,500	2,500	–
Haul road dust-suppression demand	ML/a	–	61	936	1,000	1,000	1,000	–
Mine infrastructure area demand	ML/a	–	9	140	150	150	150	–
Potable water demand	ML/a	–	2.4	5	6.1	6.2	3	–
Total WMS demand	ML/a	–	223	3,421	3,656	3,656	3,653	–
Sedimentation dam returns to creek	ML/a	–	0	0	0	0	0	–
Sedimentation dam controlled releases to creek	ML/a	–	87	31	107	83	35	–
Clean water/highwall dam controlled releases to creek	ML/a	–	2	10	17	3	0	–
Raw water dam overflows to creek	ML/a	–	0	0	0	0	0	–
Existing west 'Woolandra' farm dams overflows	ML/a	0	–	–	–	–	–	–
Total flow at study catchment outlet	ML/a	1,852	1,934	1,818	1,840	1,810	1,766	1,933

Notes: Excludes runoff to refuse disposal ponds catchments

Table 6-3 Annual site water balance — 90th percentile wet year

	Units	Pre-mining	Year 1	Year 4	Year 12	Year 16	Year 20	Post-mining
Catchment breakdown								
Water management system (WMS)								
▪ Raw water dam	Ha	0	246	244	244	244	244	0
▪ Clean water/highwall dams	Ha	0	17	115	214	26	0	0
▪ Sedimentation dams	Ha	0	681	1,186	1,559	1,216	1,310	0
▪ Other water dams and pits	Ha	0	149	692	1,211	1,536	1,340	384
▪ Refuse ponds	Ha	0	45	16	16	12	12	0
Existing west 'Woolandra' farm dams	Ha	1,034	—	—	—	—	—	—
Undisturbed	Ha	30,655	30,551	29,435	27,961	27,547	27,358	27,625
Established rehabilitation returned directly to creek	Ha	—	0	0	485	1,107	1,424	3,680
Total study catchment	Ha	31,688	31,688	31,688	31,688	31,688	31,688	31,688
Proportion of study catchment in WMS	%	—	3.6%	7.1%	10.2%	9.6%	9.2%	1.2%
Inflows								
Runoff								
Water management system								
▪ Raw water dam	ML/a	—	184	182	182	182	182	—
▪ Sedimentation dams	ML/a	—	1,334	2,106	2,510	2,134	1,942	—
▪ Other water dams and pits	ML/a	—	425	1,641	3,158	3,502	3,278	—
▪ Clean water/highwall dams	ML/a	—	15	96	178	22	0	—
Total WMS runoff	ML/a	—	1,958	4,024	6,028	5,839	5,402	—
Undisturbed and established rehabilitation returned directly to creek	ML/a	26,087	25,985	25,031	24,416	24,940	25,229	28,790
Existing west 'Woolandra' farm dams	ML/a	871	—	—	—	—	—	—
Groundwater make	ML/a	—	38	886	1,549	1,341	248	—
Imported river water	ML/a	—	0	520	0	0	220	—

	Units	Pre-mining	Year 1	Year 4	Year 12	Year 16	Year 20	Post-mining
Sedimentation dam water reused on-site	ML/a	–	0	259	0	0	238	–
Outflows								
WMS dam evaporation (net of direct rain)	ML/a	–	199	138	343	353	201	–
CHPP make-up demand	ML/a	–	151	2,340	2,500	2,500	2,500	–
Haul road dust-suppression demand	ML/a	–	61	936	1,000	1,000	1,000	–
Mine infrastructure area demand	ML/a	–	9	140	150	150	150	–
Potable water demand	ML/a	–	2.4	5	6.1	6.2	3	–
Total WMS demand	ML/a	–	223	3,421	3,656	3,656	3,653	–
Sedimentation dam returns to creek	ML/a	–	189	339	360	336	246	–
Sedimentation dam controlled releases to creek	ML/a	–	1,119	1,466	2,113	1,778	1,432	–
Clean water/highwall dam controlled releases to creek	ML/a	–	16	104	191	24	0	–
Raw water dam overflows to creek	ML/a	–	0	0	0	0	0	–
Existing west 'Woolandra' farm dams overflows	ML/a	819	–	–	–	–	–	–
Total flow at study catchment outlet	ML/a	26,906	27,310	26,940	27,080	27,079	26,907	28,790

Notes: Excludes runoff to refuse disposal ponds catchments

6.1.1 Adequacy of CHC's existing water entitlements

The volume of imported water required depends on the rainfall that occurs during the mining period. The estimated imported water requirements for typical dry (10th percentile), median (50th percentile) and wet (90th percentile) rainfall years are summarised in Table 6-4.

Table 6-4 Summary of imported water requirement for dry, median and wet year climate conditions

Year	Total site demand (ML/a)	Groundwater seepage (ML/a)	Imported water for a dry year (ML/a)	Imported water for a median year (ML/a)	Imported water for a wet year (ML/a)
1	223	38	0	40	0
4	3,421	886	2,360	1,720	520
12	3,656	1,549	1,700	1,100	0
16	3,656	1,341	1,880	1,200	0
20	3,653	248	2,960	2,180	220

The peak annual requirement for imported water is expected to occur in Year 20 when the groundwater seepage to the pits reduces to less than 250 ML/yr but the site demand remains close to the peak at 3,653 ML/yr.

The Project is estimated to require 2,960 ML/yr of imported water under a typical 10th percentile dry year (i.e. 1967) and 220 ML/yr under a typical 90th percentile wet year (i.e. 1990) during Year 20. The estimated requirement for a dry year in Years 1, 4, 12, 16 and 20 can be met by the current entitlement of 3,311 ML/yr from the Cudgegong/Macquarie Regulated River system, assuming 100% allocation.

Figure 6-1 presents a sequence of the simulated annual requirement for imported water for Year 20. This figure shows that the requirement for imported water peaks to about 3,380 ML/yr, and exceeds 3,311 ML/yr for three years out of 111 years simulated, or less than 3% of time, for Year 20.

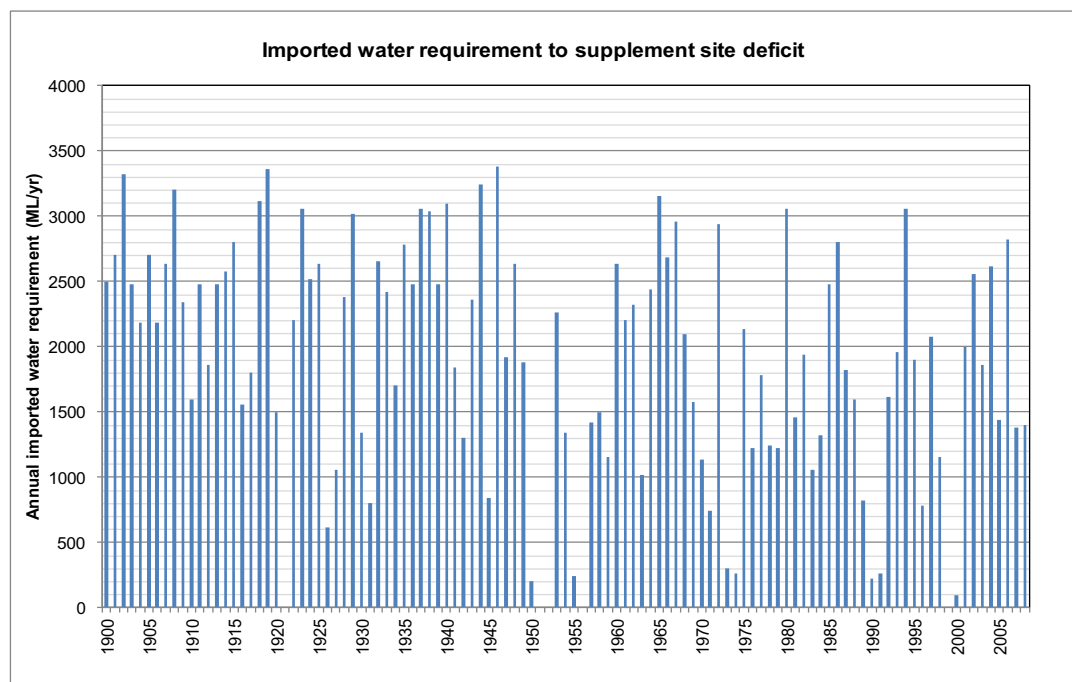


Figure 6.1 Annual imported water requirement over the 111-year water balance simulation for Year 20

6.1.2 Dam performance

Mine water dams have been sized to achieve no discharge when operated as part of the site water management system under historical climate conditions, as determined through water balance modelling.

Pumping to mine water dams from the pit will cease when a maximum operating level is achieved (refer to Section 5.3.4 for assumed operating rules). This will maintain adequate freeboard in these dams, so that small runoff events from the local catchment will not cause the dams to overflow following extended periods of pit dewatering.

The water balance results show that dams MD1, MD2, MD3 and MD8 and mine water dams MD4, MD5, MD7 and MD9 do not overflow during the 111-year water balance simulation. Mine water dam MD6, which captures runoff from the stockpile adjacent to mining area B, overflows to mining area B during extended wet periods, but does not overflow to the creek system. As such, no offsite releases of mine water, process water or infrastructure water is expected during the operating life of the Project. This water will be reused on-site in the mining process. Storage will be provided in-pit during extended wet periods, until mine water dams have capacity to receive pit water.

Although mine water dams are not expected to overflow under even extreme weather conditions (with the exception of MD6 that overflows to mining area B), dam safety requirements dictate that spillways must be provided. Spillways from MD1, MD2, MD3, MD4 and MD5 will be directed to Laheys Creek. Spillways from MD7, MD8 and MD9 will directed to sedimentation dams located at the low points of the overburden emplacement areas.

6.1.3 Frequency of in-pit flooding

Pit sumps will be able to store relatively small volumes of pit water without interruption to mining activities. However, during extended wet periods, with standard capacity dewatering systems, relatively large volumes of water will accumulate in-pit and may interrupt mining activities. The maximum in-pit storage volumes over the 111-year water balance simulation are provided in Table 6-5.

Table 6-5 Maximum in-pit storage volumes

Year	Maximum stored volume (ML/a)		
	Mining area A	Mining area B	Mining area C
1	71	57	0
4	371	417	252
12	320	2,504	1,608
16	348	2,947	1,878
20	969	2,176	390

Predicted stored volumes per mining area over the 111-year water balance simulation are provided in Figure 6-2 to Figure 6-4 for Year 16, when the mining area catchment is greatest and the estimated maximum volume stored in the combined pits is greatest. Predicted frequencies of in-pit flooding per mining area over the 111-year water balance simulation for Year 16 are illustrated by plots provided in Figure 6-5 to Figure 6-7.

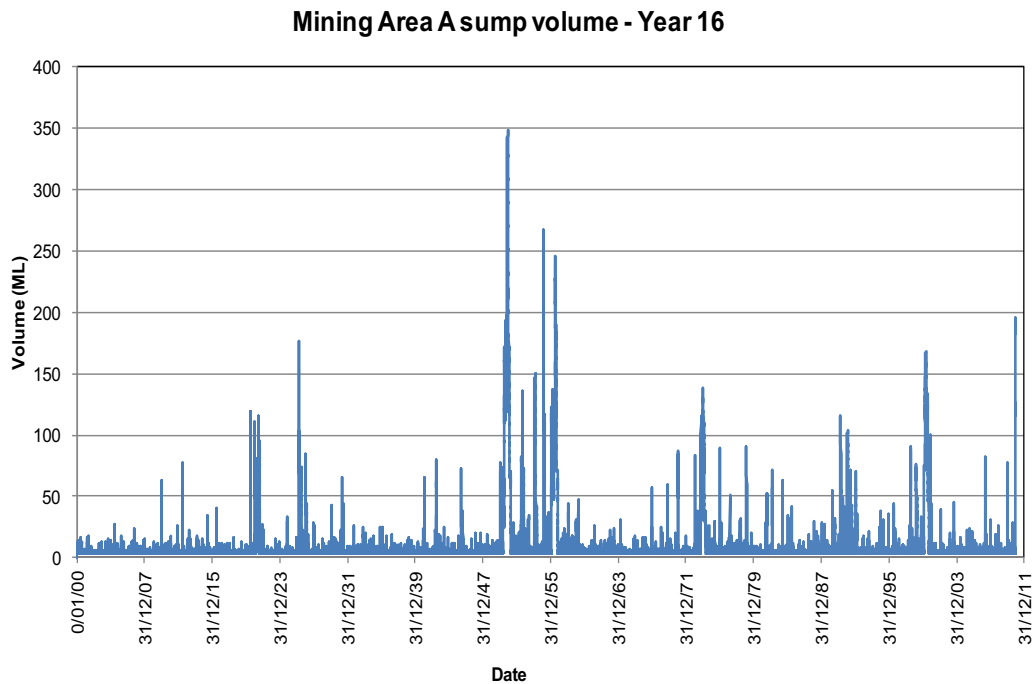


Figure 6.2 **Stored volume in mining area A over the 111-year water balance simulation for Year 16**

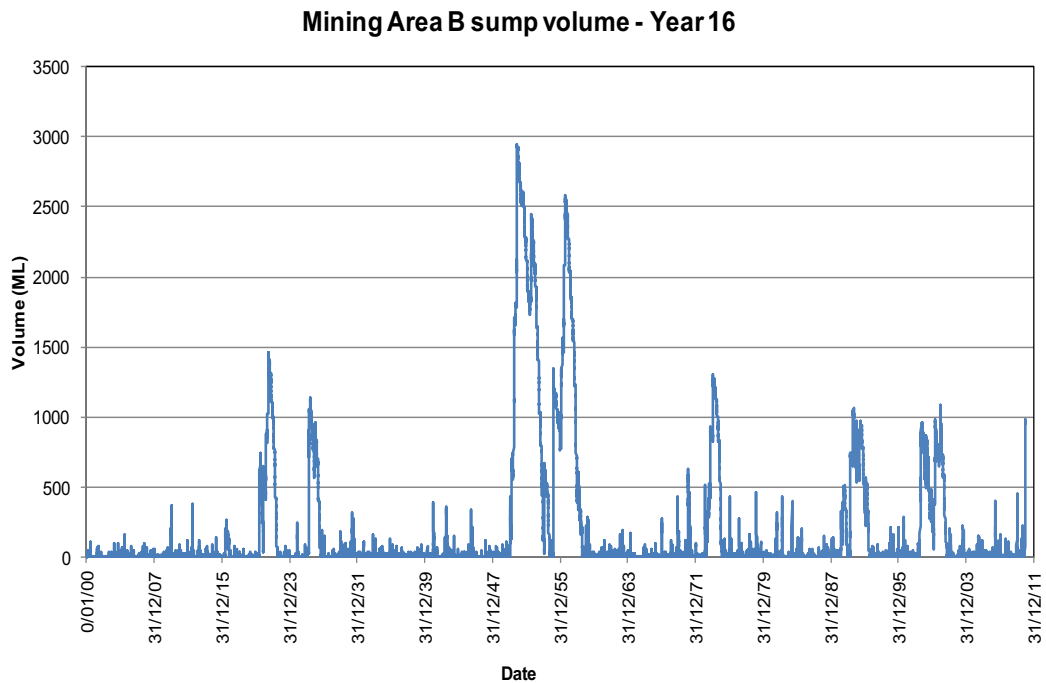


Figure 6.3 **Stored volume in mining area B over the 111-year water balance simulation for Year 16**

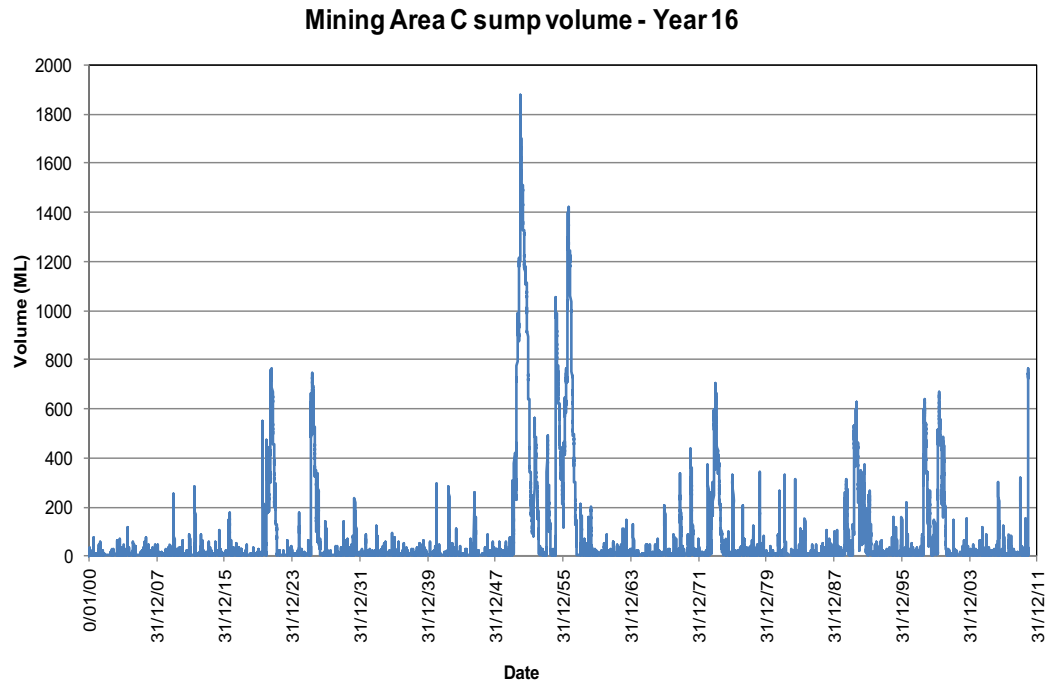


Figure 6.4 **Stored volume in mining area C over the 111-year water balance simulation for Year 16**

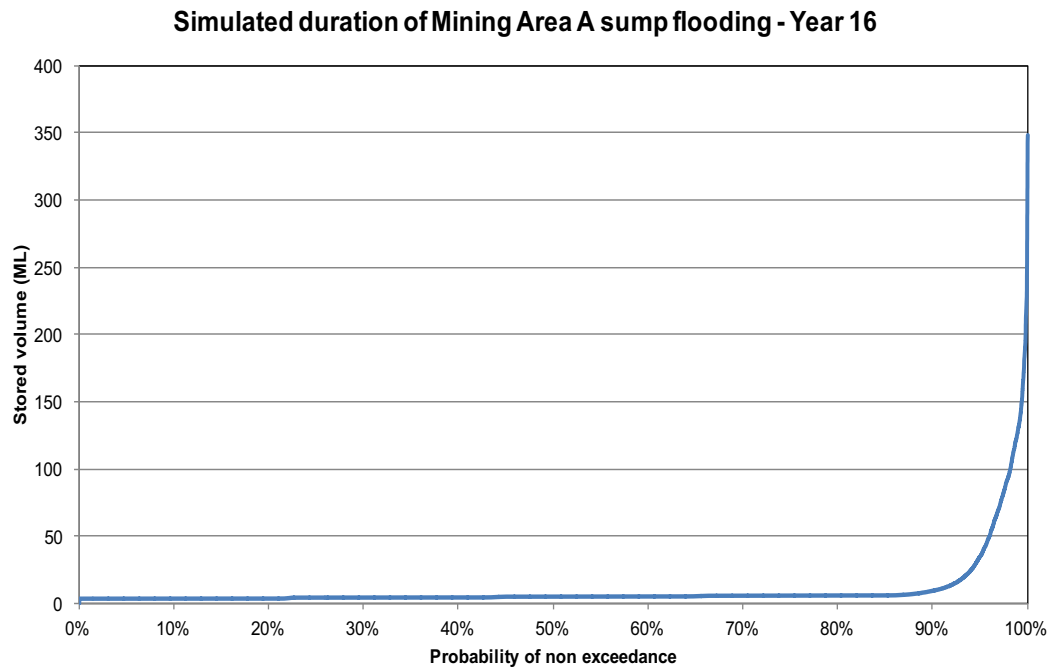


Figure 6.5 **Frequency of in-pit flooding for mining area A over the 111-year water balance simulation for Year 16**

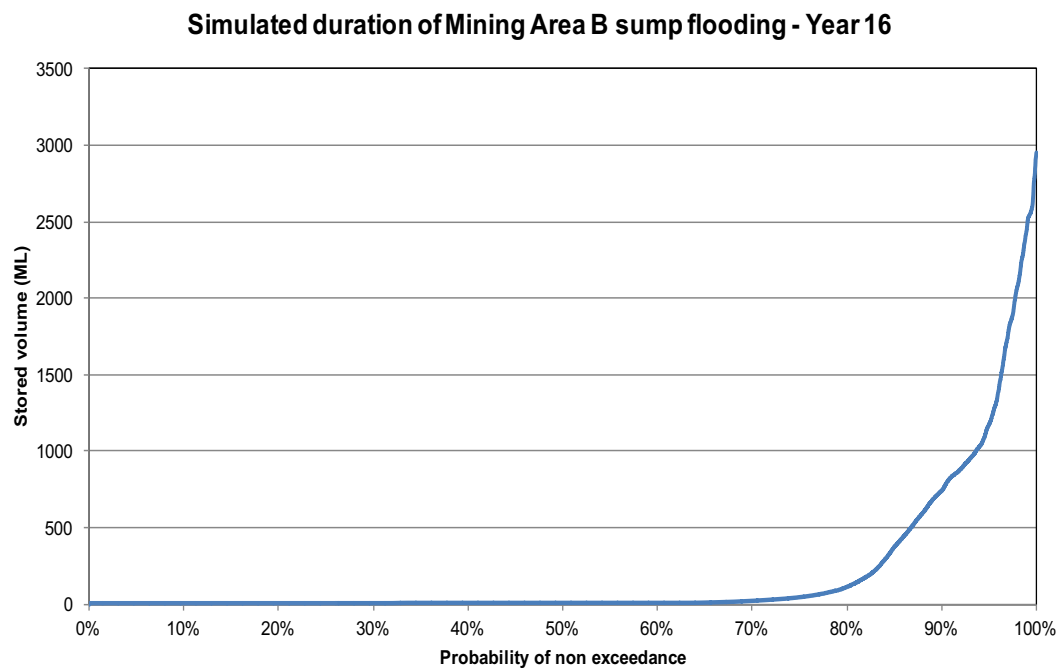


Figure 6.6 Frequency of in-pit flooding for mining area B over the 111-year water balance simulation for Year 16

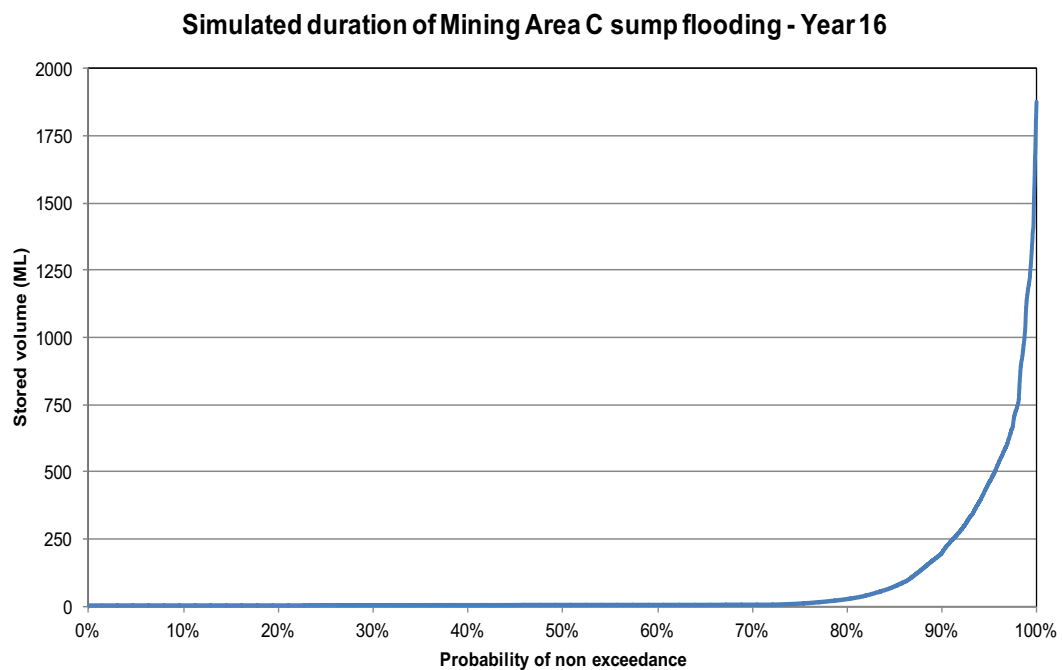


Figure 6.7 Frequency of in-pit flooding for mining area C over the 111-year water balance simulation for Year 16

The mine water dam sizes have been chosen to provide a reasonable level of pit availability over the 111-year water balance simulation. The plots from Figure 6-5 to Figure 6-7 show that although the pit dewatering system should be able to maintain dry pits, during extended wet periods mining may be interrupted by in-pit flooding.

Large volumes of water are only stored in-pit infrequently. The water balance analyses indicate that the probability of the pit water volume exceeding a combined volume of 950 ML in mining areas A, B and C sumps is less than 10% for Year 16. Should that occur, CHC would nominate one or more open cuts to receive water from the other excavations. The nominated pits would be selected to minimise overall disruption to the output of the mine.

6.1.4 Mining impacts on surface water flow regime

The water balance analyses indicate that the surface water flow regime downstream of the site will generally decrease for dry and median years. This may be attributed to the capture and on-site reuse of runoff from disturbed areas. The water balance analyses indicate that there will be an increase in downstream flows for a wet year. This may be attributed to the mine water management dams not having spare capacity to store sedimentation dam water for reuse during a wet year, so treated sedimentation dam water would be displaced into receiving watercourses.

Table 6-6 summarises estimated annual runoff volumes to the creek system for a 50th percentile median rainfall year. The median runoff volume is predicted to reduce by between -0.7% and -4.6% between Years 4 and 20. An increase in median runoff volume of +4.4% is predicted in Year 1. Table 6-7 summarises the expected change in annual creek flows downstream of the site during mining compared to pre-mining conditions.

Table 6-6 Median annual flow in Sandy Creek, Flyblowers Creek, Isbester Gully and Unnamed Tributary 1

	Units	Pre-mining	Year 1	Year 4	Year 12	Year 16	Year 20	Post-mining
Natural catchment								
Undisturbed catchment runoff and established rehabilitation runoff returned directly to creek	ML/a	1,852	1,845	1,777	1,715	1,725	1,731	1,933
Existing west 'Woolandra' farm dams catchment runoff	ML/a	62	–	–	–	–	–	–
Existing west 'Woolandra' farm dams overflows	ML/a	0	–	–	–	–	–	–
Release from water management system to creek								
Sedimentation dam returns	ML/a	–	0	0	0	0	0	–
Sedimentation dam controlled release	ML/a	–	87	31	107	83	35	–
Clean water/highwall dam controlled release	ML/a	–	2	10	17	3	0	–
Raw water dam overflows	ML/a	–	0	0	0	0	0	–
Total flow at study catchment outlet	ML/a	1,852	1,934	1,818	1,840	1,810	1,766	1,933
Percentage change from pre-mining			4.4%	-1.9%	-0.7%	-2.3%	-4.6%	4.4%

Table 6-7 Summary of expected changes to pre-mining creek flows during mining

Year	Net change from pre-mining flow (ML/yr)		
	10 th percentile (dry year)	50 th percentile (median year)	90 th percentile (wet year)
1	46	82	404
4	-11	-34	34
12	-25	-12	174
16	-17	-42	173
20	-19	-86	1

7. Potential impacts and mitigation measures

7.1 Impact of imported water supply on mining

The water balance for the Project indicates that an external water source is required for the Project. Reuse of sedimentation dam water, mine water runoff and groundwater seepage generated within the site are not adequate to meet the water demand under median climatic conditions throughout the life of the Project.

The peak annual demand for imported water is expected to occur in Year 20 when groundwater seepage to the pits reduces to less than 250 ML/a, but the Project water demand remains close to the peak at 3,653 ML/a. The simulated annual requirement for imported water for Year 20 is provided in the plot in Figure 7-1 based on the 111-year water balance simulation. The annual rainfall depth is also provided on the plot in Figure 7-1.

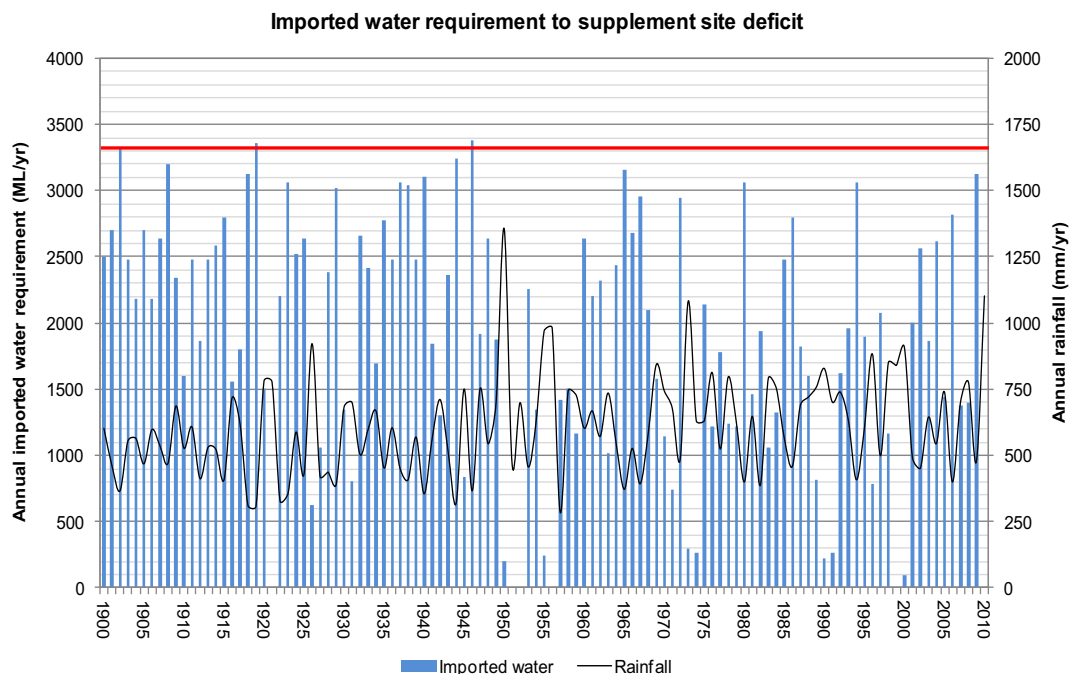


Figure 7.1 Comparison of annual imported water requirements over the 111-year water balance simulation for Year 20

It is estimated that 2,960 ML/a of imported water would be required for a 10th percentile dry rainfall year in Year 20. Figure 7-1 shows that for very dry years, the requirement for imported water exceeds 3,311 ML/a in Year 20 for three out of the 111 years modelled, reaching a maximum of 3,380 ML/a.

If very dry climatic conditions (i.e. drier than a 5th percentile rainfall year) are experienced in Year 20, appropriate mitigation measures will be required to prevent a water shortage. Mitigation measures may also be required if very dry climatic conditions are experienced in Years 18 to 19, as groundwater make to the pits reduces significantly in Year 18 due to the ongoing infilling of voids.

Table 7-1 Imported water requirement for a 10th percentile dry year

Year	Total site demand (ML/a)	Imported water (ML/a)	Groundwater seepage (ML/a)	Total WMS runoff (ML/a)	Sedimentation dam water reused on-site (ML/a)	System releases (overflows and releases) (ML/a)
1	223	0	38	290	50	48
4	3,421	2,360	886	576	129	12
12	3,656	1,700	1,549	869	141	15
16	3,656	1,880	1,341	869	147	15
20	3,653	2,960	248	766	123	9

As discussed in Section 5.4.3, the Cudgegong/Macquarie Regulated River system is a reliable source of water and the full high security WAL entitlement of 3,311 ML/a has been assumed to be available to the Project when required.

The Extraction Strategy Agreement currently being reviewed by State Water could set constraints on the volume and timing of extraction which could affect the above assumption. CHC is working with State Water to ensure as much of its licence entitlement as possible can be extracted during period of excess flows in the river, as it will assist State Water to more efficiently manage water resources in the Macquarie and Cudgegong Rivers. This approach, if implemented in the future, may need to be considered in future versions of the mine's operating water balance model to ensure the mine's operation is not adversely affected.

Should water shortages occur during worst-case climatic conditions, CHC has a number of alternate options available to ensure the mine continues to operate. These are summarised as follows, in decreasing order of priority:

- Implementation of additional operational efficiencies and water conservation measures to reduce mine water demand. These include minimising make-up water demands by implementing further water conservation measures in the CHPP process water system and reducing water demands for dust suppression with environmentally safe additives that help to bind dust particles to reduce airborne dust potential.
- Purchasing of 'General' WALs from the open water market, if they are available, to meet the additional demand, and selling them back to the market when no longer required.
- Reducing coal production rates to match available water supplies. This is a worst-case scenario and assumes that the above three options are either not available or not effective at providing additional water or reducing water demand.

7.2 Wet weather impacts on mining

There is a probability of around 10% in the mid to later years of mining (Years 12 to 16) that in-pit sumps will store significant volumes of water. A compartmentalised area would be required in-pit to store this water during wet years. Alternatively, the Project would need to provide an emergency storage for such events.

During extended wet periods, the rate of pit dewatering could exceed the rate at which water is reused on-site and dewatering ceases because mine water dams are full. During these periods, additional in-pit water storage will be provided in inactive mining areas. This would allow for the continuation of dewatering activities in active mining areas during wet periods, thus minimising significant disruptions to mining operations. Appropriate locations for these types of in-pit storages will be identified during detailed design.

7.3 Impacts of mining to the surface water regime

The water balance analyses indicate that the surface water flow regime downstream of the Project will generally decrease for dry and median years. This may be attributed to the capture and on-site reuse of runoff from disturbed areas. The water balance analyses indicate that there is an increase in downstream flows for a wet year. This may be attributed to the water management dams not having spare capacity to store sedimentation dam water for reuse during a wet year.

At the completion of mining, flows are expected to increase for dry, median and wet years. This increase may be attributed to a net increase in catchment area draining to the creek because of the decommissioning of the west 'Woolandra' farm dams.

8. Post mining

8.1 Final landform

The final rehabilitated Year 21 landform is shown in Figure 8-1. The landform comprises a single final void corresponding to former mining area B. The design of the final landform backfills the voids in former mining areas A and C through considerable investment in spoil rehandling and rehabilitation. Backfilling the entire mining area B is not economically feasible; however, almost half the area of the void at the end of mining will be backfilled.

Rainfall falling on the final void and groundwater seepage will slowly fill the void to form a lake. The water level in the void will be influenced by the balance between inflows from rainfall and groundwater, and outflows due to evaporation losses and seepage into the groundwater system. This chapter assesses the potential impacts of the final void lake in mining area B on the surface water environment. Potential groundwater impacts are discussed in the groundwater assessment report (Parsons Brinckerhoff 2012).

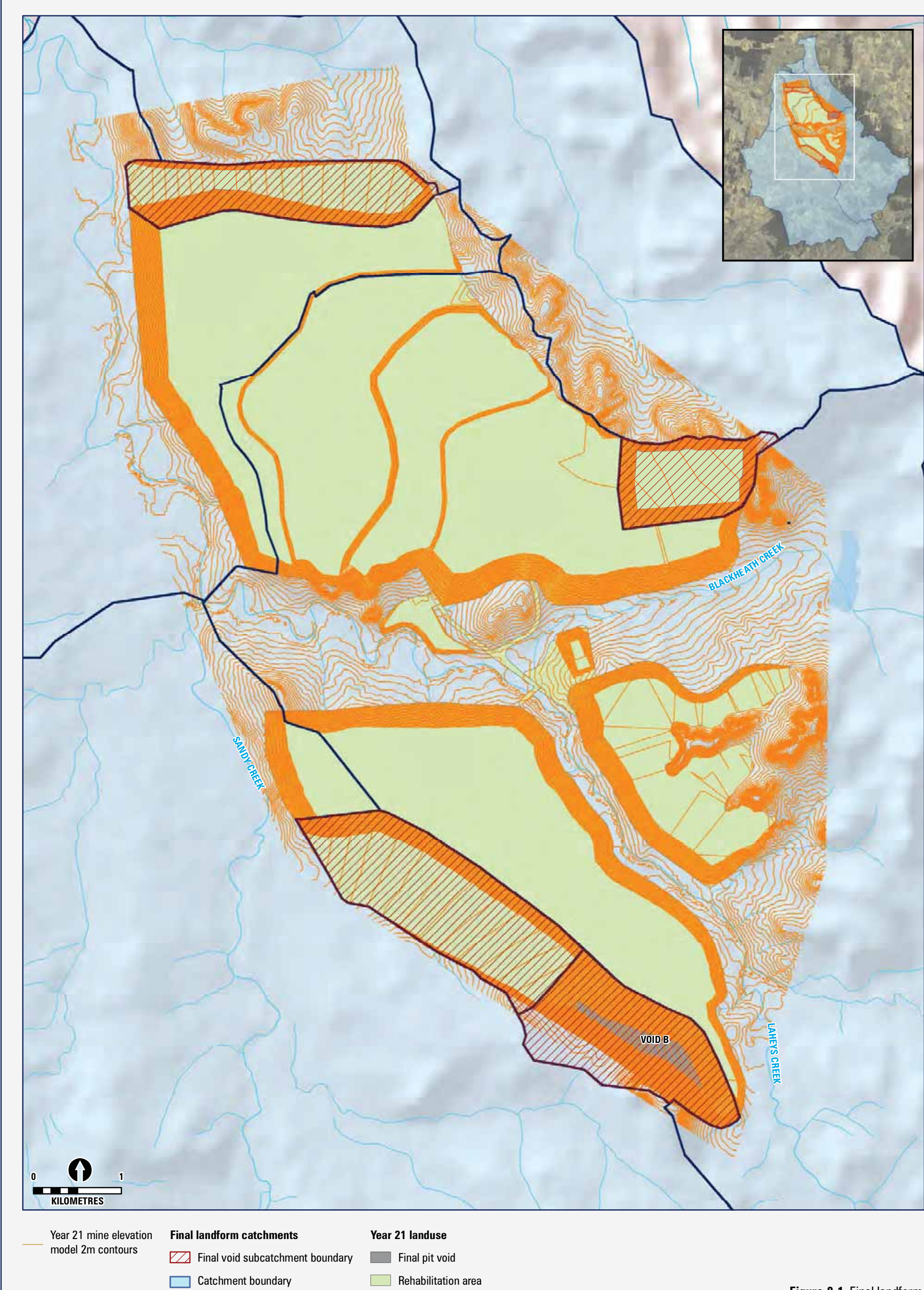
8.1.1 Catchment areas

The catchment areas for the final landform are provided in Table 8-1. The catchment boundaries are shown in Figure 8-1.

Table 8-1 Final landform catchment areas

Sub-catchment	Area (ha)
Final void	
Total area draining into void B	242
Creek system	
Sandy Creek (upstream of Laheys Creek confluence)	14,063
Sandy Creek (downstream of Laheys Creek confluence)	2,231
Laheys Creek	11,665
Flyblowers Creek	680
Isbester Gully	2,387
Unnamed Tributary 1	278
Subtotal	31,304
Total	31,688

Table 8-1 shows that the total catchment area draining to the final void B is 242 ha. The total catchment area of Sandy Creek at its confluence with the Talbragar River increases from 27,183 ha for the existing situation to 27,959 ha for the final landform (an increase of 2.9%). The catchment area for Unnamed Tributary 1 of the Talbragar River remains unchanged. The catchment area for Flyblowers Creek, however, reduces from 738 ha to 680 ha (a reduction of -7.9%), and the catchment area for Isbester Gully reduces from 2,454 ha to 2,387 ha (a reduction of -2.7%). Refer to Section 3.1 Table 3-1 for existing catchment areas.



8.2 Final void water balance

Water balance modelling has been undertaken to predict the long-term behaviour of final void B following the completion of mining. Microsoft Excel software was used for the water balance modelling. The model was used to calculate the volume of water in the final voids at the end of each month taking into account monthly rainfall-runoff inflow, groundwater inflows/outflows and evaporation. The model was simulated for 1,000 years of synthetic rainfall and evaporation data.

8.2.1 Model data

8.2.1.1 Rainfall and evaporation data

Synthetic daily rainfall and evaporation data was generated for the Project for a period of 1,000 years. This was done by repeating the 111-year daily rainfall and evaporation sequence for the period 1900 to 2010 sourced from the Data Drill (see Section 3.2 for Data Drill). The daily data was converted to monthly data.

8.2.1.2 Stage-area-volume relationship

The preliminary stage-area-volume relationships for final void B is provided in Figure 8-2. The assumed base of the final void is 342 m AHD and the assumed top of the void is approximately 407 m AHD.

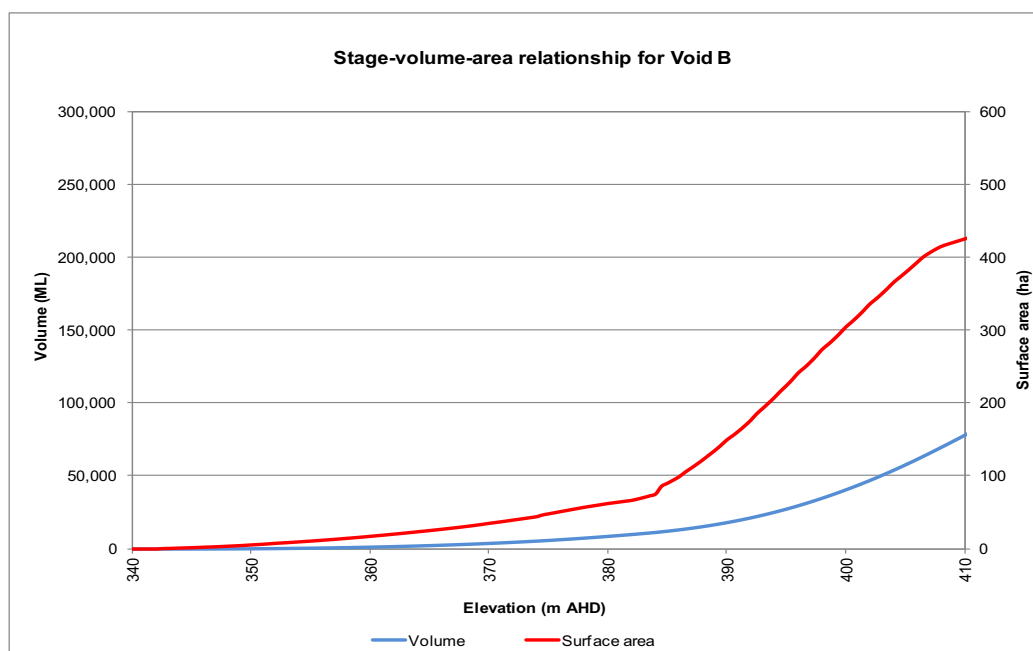


Figure 8.2 Stage-area-volume relationship for final void B

8.2.2 Water inputs

8.2.2.1 Surface water runoff

The AWBM rainfall-runoff model was incorporated into the GoldSim model to generate a daily time series of runoff from the final void catchments based on the 1,000-year synthetic rainfall and evapotranspiration data. The AWBM rainfall-runoff model and parameters are described in Section 3.5.1. The daily data was converted to monthly data.

The 'pit' AWBM parameters were adopted for the final void, and the 'established rehabilitation' AWBM parameters were adopted for rehabilitated overburden areas (see Section 3.5.1 Table 3-8).

8.2.2.2 Direct rainfall

Direct rainfall volumes for the final void were calculated based on the stage-area-volume relationship provided above in Section 8.2.1.2.

8.2.2.3 Groundwater inflows/outflows

The numerical groundwater model for the Project was used to estimate groundwater inflow and outflow rates to/from void B. The model simulated a previous final landform design that incorporated a larger void B. The groundwater model has not been re-run for the current final landform design; instead, the previously estimated inflow and outflow time series were adjusted based on void area ratios. A groundwater inflow reduction factor was determined using the following formula:

$$Q_C/Q_P = \ln(R/r_P)/\ln(R/r_C)$$

Where:

- R= Radius of influence (m)
- r= Equivalent radius of the pit (m)= (Void surface area/ π)^{1/2}
- Q= Pit inflow in ML/month
- C= Subscript for current final landform design
- P= Subscript previous final landform design

This formula was applied to the tabular relationship between elevation and groundwater inflow and outflow for the previous landform design (derived from the groundwater model) to adjust inflows to void B for the current final landform design. The applied groundwater inflow reductions are given in Table 8.2.

Table 8.2 Estimated reduction to groundwater inflow to void B

Stage (mAHD)	Equivalent radius (r _C)	LN(R/r _C)	Equivalent radius(r _P)	LN(R/r _P)	Inflow reduction ratio
385	536	2.2	949	1.7	0.74
380	445	2.4	904	1.7	0.71
375	391	2.5	853	1.8	0.69
370	334	2.7	800	1.8	0.68
365	284	2.9	751	1.9	0.66
360	235	3.1	703	2.0	0.64
355	186	3.3	655	2.0	0.62
350	133	3.6	607	2.1	0.58
348	110	3.8	559	2.2	0.57
347	99	3.9	513	2.3	0.58

Figure 8-3 gives the adjusted net groundwater inflow for void B used in the water balance model. Note that the groundwater outflow is set to zero. This is because the maximum void B water level was found to be less than the creek level of 380 mAHD (see Section 8.2.4 for simulated water levels) and less than the surrounding groundwater levels – refer to the groundwater assessment report (Parsons Brinckerhoff 2012).

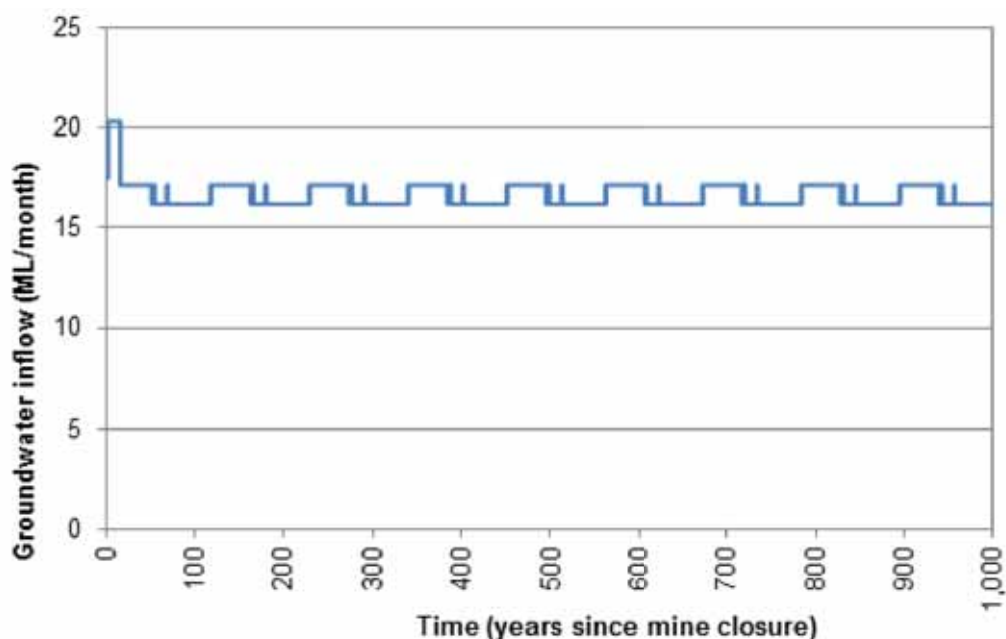


Figure 8.3 Final void B net groundwater inflow estimates over 1000 year water balance simulation

8.2.3 Water outputs

8.2.3.1 Evaporation

Evaporation estimates were based on Data Drill sourced daily Morton's Lake evaporation data (see Section 3.2 for Data Drill). The evaporative surface area for void B was determined based on the stage-area-volume relationship developed in Section 8.2.1.2.

8.2.3.2 Other outputs

Another potential output from the void could have been groundwater outflows that might have occurred concurrently to the groundwater inflows. However, as discussed above in Section 8.2.2.3, outflows were set to zero.

8.2.4 Results

Plots of simulated final void water volume and level time series are provided in Figures 8-4 and 8-5 respectively. The results indicate that water levels in the final void B will initially rise steeply, but will reach an average equilibrium level 40 years after the completion of mining. The final void will not overtop because there will be around 32.5 m freeboard between the peak water level and the top of the void. The peak simulated water level is 374.5 m AHD (Figure 8-5) which is 5.5 m below the creek level of 380 m AHD. This indicates that the void will be a groundwater sink. No groundwater outflow will occur from the void lake towards the creeks.

Since the groundwater inflow reductions were not based on numerical modelling, sensitivity analysis was undertaken to determine whether the groundwater inflow could raise the peak water level in the lake to equal the creek bed level of 380 m AHD. A simulation undertaken without any reduction in groundwater inflow and without any groundwater outflows suggests the void water level will not reach 380 m AHD. This further confirmed that the void lake will remain as a groundwater sink. The results for this sensitivity test are given in Figures 8-6 and 8-7 respectively.

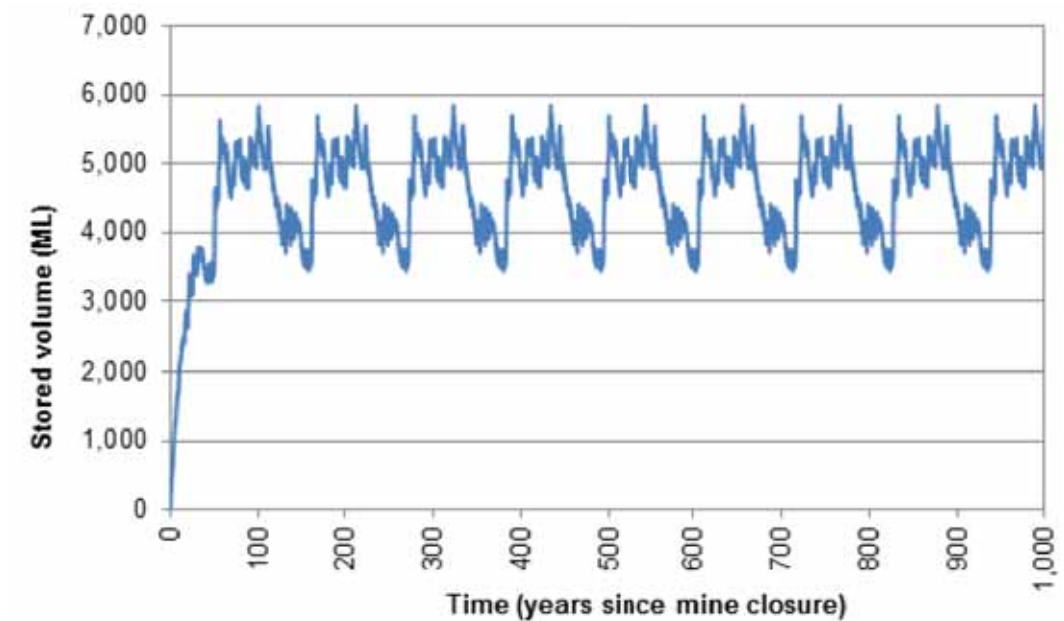


Figure 8.4 Final void B stored volume estimates over 1000 year water balance simulation

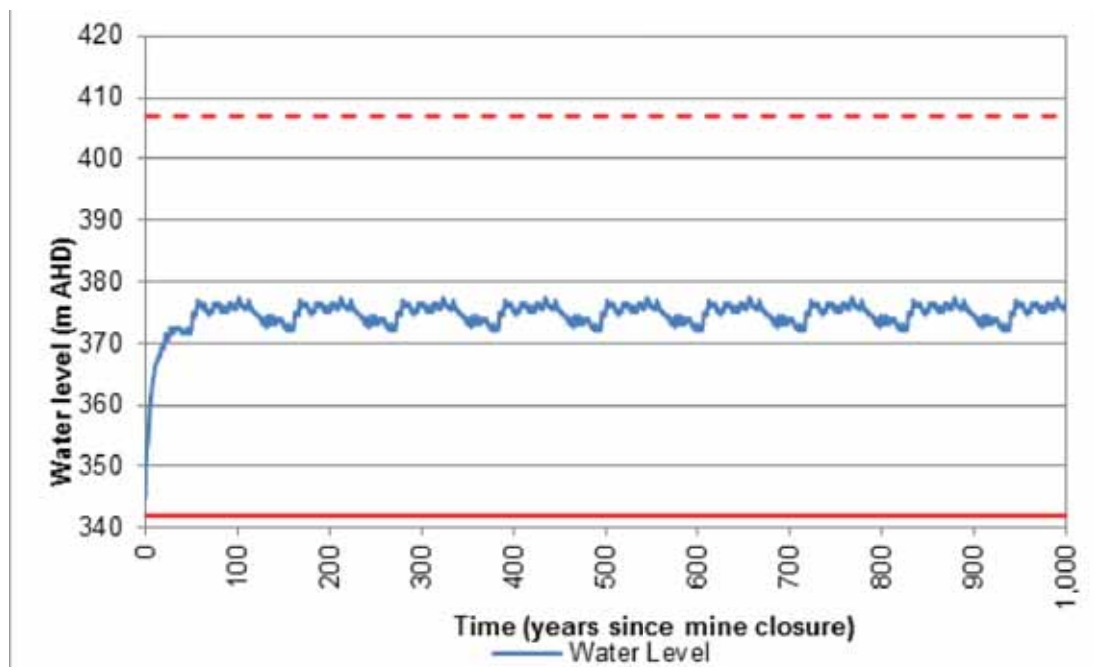


Figure 8.5 Final void B water level estimates over 1000 year water balance simulation

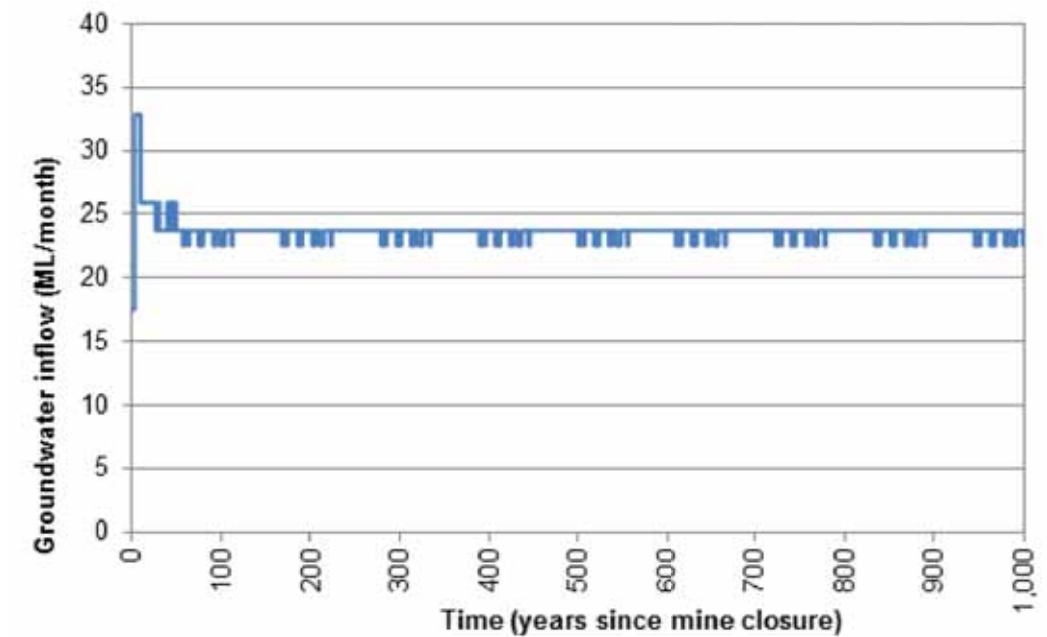


Figure 8.6 Sensitivity test net groundwater inflow over 1000 year water balance simulation (assuming no inflow reduction and no outflow)

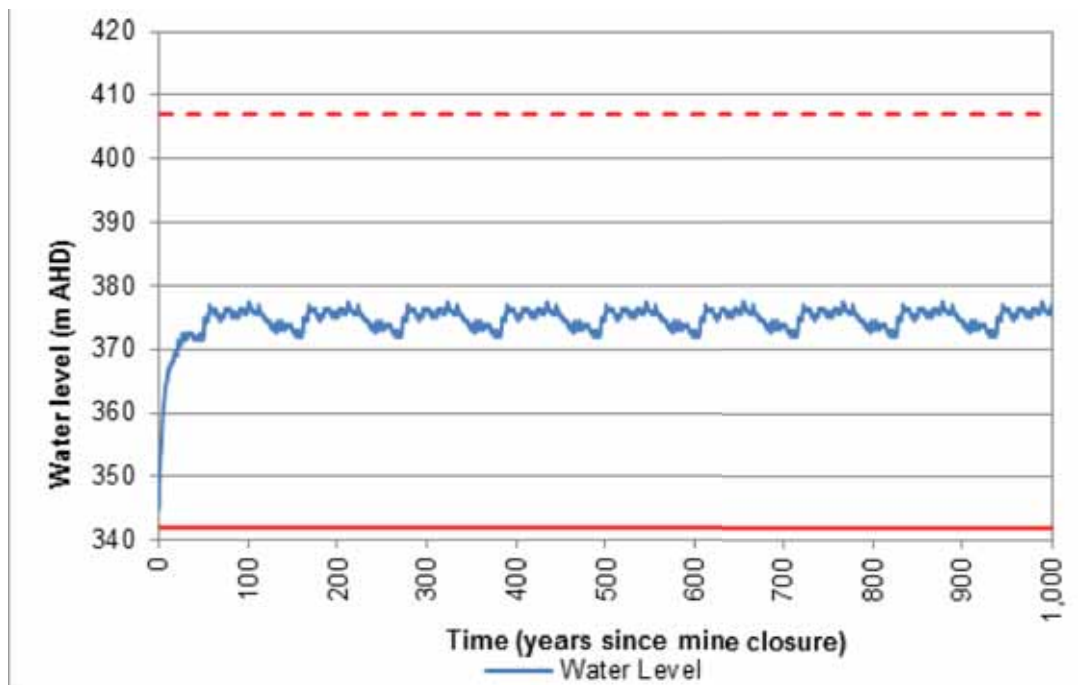


Figure 8.7 Sensitivity test final void B water level estimates over 1000 year water balance simulation

8.3 Final void salt balance

8.3.1 Modelling approach

Salt balance modelling has been undertaken to simulate salinity in final void B following the completion of mining. The salt balance was undertaken using the Microsoft Excel water balance model developed for the final void.

Salinity levels in final void B will be controlled by the salinity concentrations of rainfall falling directly on the voids, groundwater inflow, surface water runoff from rehabilitated overburden emplacement areas, and the evaporative concentration of these inflows.

The following average salinity values were assumed for the various inflows:

- **Direct rainfall falling on final voids** — assumed salinity value of 10 mg/L.
- **Groundwater inflow** — assumed salinity value of 2,806 $\mu\text{S}/\text{cm}$ (1,796 mg/L) for void B based on baseline groundwater monitoring undertaken as part of the Project's groundwater assessment (Parsons Brinckerhoff 2012). The value for void B is based on the average value for porous rock (Triassic) of 3,993 $\mu\text{S}/\text{cm}$ and the average value for porous rock (Permian) of 1,618 $\mu\text{S}/\text{cm}$, as both of these units are likely to be present in the pit.
- **Surface water runoff from rehabilitated overburden emplacement areas, void walls and natural catchment** — assumed salinity value of 238 $\mu\text{S}/\text{cm}$ (152 mg/L) based on the median salinity of overburden leachate obtained from the geochemical assessment (GeoTerra 2012). Note that it was not considered appropriate to adopt the salinity values obtained from baseline water quality monitoring in Sandy Creek and Laheys Creek, as salinity values in the creeks are likely to be elevated because of groundwater baseflow contributions and evaporative concentration effects in semi-permanent pools during dry periods.

A conversion factor of 0.64 was assumed between $\mu\text{S}/\text{cm}$ and mg/L (or ppm). This is in line with unit conversion information published on the Office of Environment and Heritage website. Note that this is an approximate conversion, rather than an absolute conversion, and is based on the fact that water chemistry is sodium chloride and carbonate dominated.

Instantaneous mixing of the various inflow types was assumed in the model, and no allowance was made for the stratification of the final void.

8.3.2 Results

Simulated final void salinity estimates are presented in Figure 8-8 for the case with reduced groundwater inflows and in Figure 8-9 for the sensitivity test case without reduced groundwater inflows based on the 1,000-year water balance simulation using synthetic rainfall and evaporation data. Results presented in both figures indicate that after 1,000 years the salinity in the void B lake will not stabilise and will keep rising due to evaporation.

The peak simulated salinity for the case with reduced groundwater inflows and without are estimated to be 103,126 mg/L and 105,296 mg/L respectively. This indicates that the peak salinity in the lake is relatively insensitive to groundwater inflows after 1,000 years.

It should be noted that these results do not take into account detailed processes such as lake stratification and mixing. In the absence of more detailed analysis, the salinity results presented here are considered to be conservative.

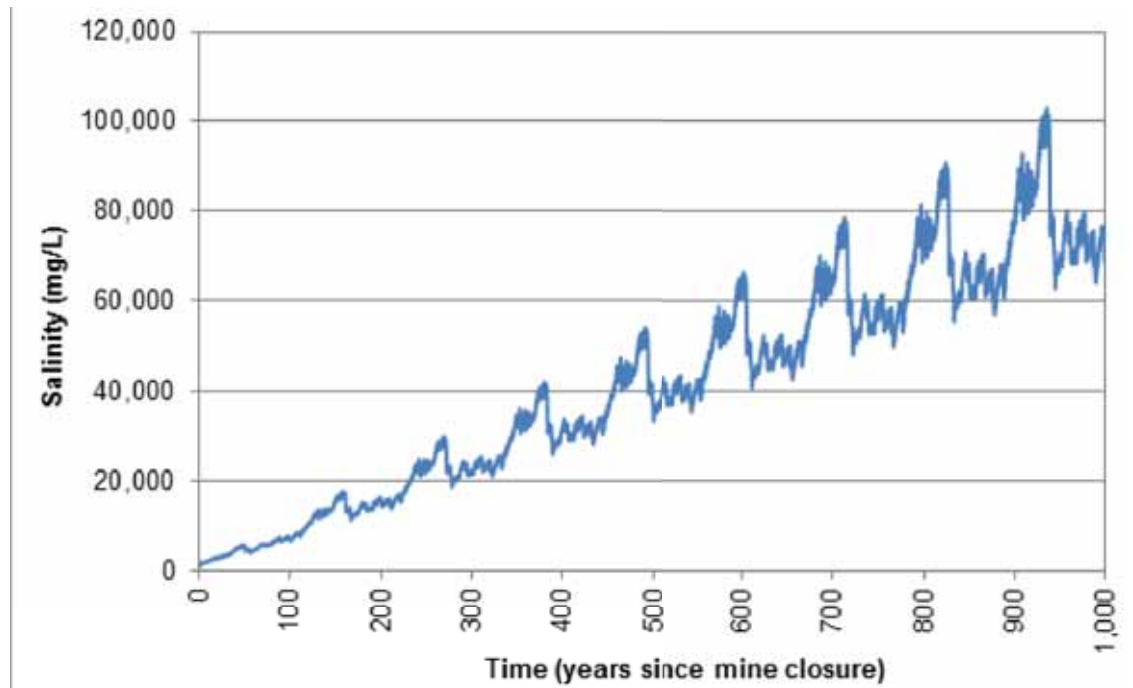


Figure 8.8 Final void B salinity estimates over 1000 year water balance simulation

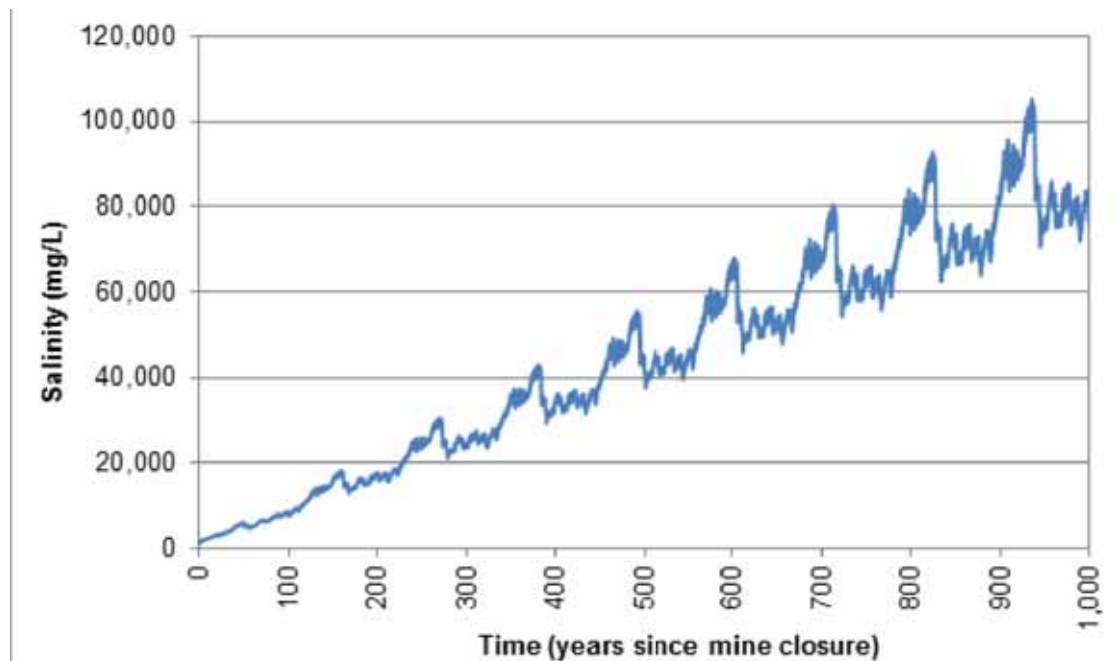


Figure 8-9 Sensitivity test final void B salinity estimates over 1000 year water balance simulation

8.4 Potential impacts

The final void water balance indicates that the water level will initially rise steeply, but reach an average equilibrium over time. The void lake will not overtop and will act as a groundwater sink, and is therefore not expected to impact nearby surface water bodies because it would be effectively isolated from the surrounding environment.

The salinity in the lake will increase over time. No groundwater will flow from this lake towards the creek, which offers benefit in terms of not increasing salinity in Sandy Creek. However, the void may potentially develop into a stratified lake which may lead to anoxic conditions. Water quality issues related to a confined stratified hypersaline lake have not been assessed at this stage as this would be appropriate as part of a detailed mine closure plan.

The final landform has been designed to eliminate two voids and minimise the scale of the third mining void. An unavoidable impact will be the formation of an isolated saline lake that cannot be eliminated at an economically viable cost. As no saline groundwater will migrate from the lake, the final void impacts are considered acceptable for the local surface water environment.

9. Conclusions

The water management system presented in this report has been designed to segregate different water types and provide operational flexibility to ensure the mine can operate over the proposed 21-year mine life under a range of climatic conditions.

Clean water from undisturbed catchments will be diverted around the mine to Sandy Creek and Laheys Creek as much as practical. This will assist to maintain flows in the creek system. Runoff from disturbed areas, such as overburden emplacement areas, will be directed to a number of sedimentation dams strategically placed throughout the mine to allow settling. Captured water will be either reused on-site to supplement a site water deficit or released to Sandy Creek and Laheys Creek when water quality criteria have been met.

Mine runoff and groundwater seepage captured in-pit will be pumped to mine water dams. Runoff from the CHPP, mine infrastructure area, coal stockpiles and rail loading facilities will be captured in infrastructure storage dams. This water potentially contains suspended solids, salts and other materials. These classes of water will be used to meet site demands as a priority over raw water and will not be released to the creek system under any circumstances.

The water balance for the Project has been analysed to predict annual runoff volumes, identify likely water deficits and surpluses, and quantify possible storage overflows. GoldSim software was used to develop a water balance model that simulated expected operations at various mine stages (Years 1, 4, 12, 16 and 20), using historical daily rainfall and evaporation data.

It is predicted that the Project will increase surface runoff compared to the pre-mining conditions. However, this increase will be offset by the capture, reuse and evaporation of runoff in the site water management system. The water balance modelling predicted that the surface water flow regime downstream of the site will generally slightly decrease for dry and median years, but generally increase for wet years. The increase in wet years may be attributed to water captured in sedimentation dams being returned to the creeks in wet years when it is not required by the mine. The median flow downstream of the site is predicted to reduce by between 0.7% and 4.6% between Years 4 and 20. An increase in median flow downstream of the site of 4.4% is predicted in Year 1.

The water balance modelling suggests that site demands cannot be met by harvesting on-site water. Water deficits would occur throughout the life of the mine under median climatic conditions, and imported water will be required to make up this deficit. Imported water requirements peak in Year 20 when production rates and demands are high but groundwater make is relatively low. CHC's current water entitlements of 3,311 ML/a from the Cudgong/Macquarie Regulated River system are adequate to meet requirements for a 10th percentile dry rainfall year throughout the life of the mine, assuming a full allocation of high security entitlements.

However, in Year 20, the current entitlements may not be adequate to meet demands for a very dry year (i.e. drier than three years in the last 111 years). If very dry climatic conditions are experienced in the final years of mining, greater water economies or alternate water supply sources would be required to maintain mining operations at full production.

The final landform has been designed to minimise the formation of void lakes at the mining areas. Due to economic constraints on the Project a void lake is unavoidable in the south eastern end of mining area B. This void will not overtop and will act as a groundwater sink and therefore will not impact on the surface water environment. Given that the final landform has been designed to minimise void lake formation as far as economically practical, further mitigation measures are not considered necessary.

10. References

Boughton 1993, A Hydrograph-based Model for Estimating the Water Yield of Ungauged Catchments.

CRC for Catchment Hydrology 2004, Rainfall Runoff Library User Guide.

DECCW 2008, Managing Urban Stormwater – Soils and Construction – Volume 2E Mines and Quarries, Department of Environment, Climate Change and Water 2008.

DERM Silo Climate Data website (February 2011)
http://www.longpaddock.qld.gov.au/silo/data_available.html.

DWE 2009, Water availability in New South Wales Murray-Darling Basin Regulated Rivers, NSW Government Department of Water and Energy, April 2009.

Food and Agriculture Organization of the United Nations 1998, Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements, Irrigation and Drainage, paper no. 56.

GeoTerra 2012, Cobbora Coal Project - Acid and Metalliferous Drainage Assessment.

Engineers Australia 2001, Australian Rainfall and Runoff - A guide to Flood Estimation, Institute of Engineers Australia 2001.

Engineers Australia 2006, Australian Runoff Quality, Institute of Engineers Australia 2006.

Landcom 2004, Managing Urban Stormwater – Soils and Construction – Volume 1.

Morton 1983, 'Operational estimates of lake evaporation', Journal of Hydrology, vol. 66.

NSW Office of Environment and Heritage website (February 2011)
<http://www.environment.nsw.gov.au/salinity/basics/units.htm>.

Parsons Brinckerhoff 2012, Cobbora Coal Project- Groundwater Assessment, Report No PR_5716A-2162570A dated June 2012.

PPK Environment & Infrastructure 2001, Australian Coal Association Research Program Project No. C7007: Water Quality and Discharge Prediction for Final Void and Spoil Catchments.

Appendix

F

Cobbora Holding Company Water Entitlements



Cobbora Holding Company water entitlements

Table F-1 Cobbora Holding Company Entitlements – Water Management Act 2000 Approvals

No	Water Act 1912 licences <i>(Status – converted)</i>	WMA Approval Number <i>(Status – active)</i>	Kind of Approval	Approval Number	Status	Water Source	Work Type	Description	No of Works	Location (Lot/DP)	Reference Number	WAL Number
1	80BL04852	80WA706213	Basic Rights	80WA706213	Current	Gunnedah - Oxley Basin Mdb Groundwater Source	Extraction Works GW	Bore	1	Lot 101 DP 754305	N/A	N/A
2	80BL13098	80WA706213									N/A	N/A
3	80BL13099	80WA706332	Basic Rights	80WA706332	Current	Gunnedah - Oxley Basin Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 31 DP 754305	N/A	N/A
4	80BL124429	80WA711150	Basic Rights	80WA711150	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore		Lot 22 DP 613344	N/A	N/A
5	80BL143580	80WA706945	Basic Rights	80WA706945	Current	Gunnedah - Oxley Basin Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 14 DP 249194	N/A	N/A
6	80BL150438	80WA711946	Basic Rights	80WA711946	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 4 DP 253275	N/A	N/A
7	80BL239595	80WA712863	Basic Rights	80WA712863	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 4 DP 253275	N/A	N/A
8	80BL241233	80WA713096	Basic Rights	80WA713096	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 37 DP 754334	N/A	N/A
9	80BL241303	80WA713130	Basic Rights	80WA713130	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 22 DP 613344	N/A	N/A
10	80BL241397	80WA713174	Basic Rights	80WA713174	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 25 DP 754334	N/A	N/A
11	80BL241474	80WA713205	Basic Rights	80WA713205	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 22 DP 613344	N/A	N/A
12	80BL242609	80WA707249	Basic Rights	80WA707249	Current	Gunnedah - Oxley Basin Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 3 DP 802679	N/A	N/A
13	80BL242883	80WA713709	Basic Rights	80WA713709	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Well	1	Lot 2 DP 1041071	N/A	N/A
14	80BL244007	80WA714127	Basic Rights	80WA714127	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 21 DP 754317	N/A	N/A
15	80BL112584	80CA715225	Water Supply Works And Water Use	80CA715225	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 6 DP 754317	80AL715224	29138
16	80BL238690	80CA715385	Water Supply Works And Water Use	80CA715385	Current	Lachlan Fold Belt Mdb Groundwater Source	Extraction Works Gw	Bore	1	Lot 68 DP 750751	80AL715384	28898
17	N/A	80WA704498	Water Supply Works	80WA704498	Current	Macquarie And Cudgegong Regulated Rivers Water Source	Diversion Works - Pumps	380mm Axial Flow Pump	2	Lot 38 DP 750780	80AL705452	27785
18	N/A	80WA702573	Joint Water Supply Works	80WA702573	Current	Macquarie And Cudgegong Regulated Rivers Water Source	Diversion Works - Pumps	Pumping Plant	1	Lot3 DP 854204	80AL702570	10438

Table F-2 Cobbora Holding Company Entitlements – Water Management Act 2000 Access Licenses

No	Water Act 1912 licence <i>(Status – converted)</i>	WMA WAL number <i>(Status – active)</i>	Category [Subcategory]	Dept. Reference No.	Status	Water Source	Tenure Type	Management Zone	Share Components (units or ML)	Extraction Times or Rates	Nominated Work Approval(s)
19	80BL112584	29138	Aquifer	80AL715224	Current	Gunnedah - Oxley Basin Mdb Groundwater Source	Continuing	GUNNEDAH-OXLEY BASIN MDB (OTHER) MANAGEMENT ZONE	188	Subject to conditions water may be taken at any time or rate	80CA715225
20	80BL238690	28898	Aquifer	80AL715384	Current	Lachlan Fold Belt Mdb Groundwater Source	Continuing	LACHLAN FOLD BELT MDB (OTHER) MANAGEMENT ZONE	82	Subject to conditions water may be taken at any time or rate	80CA715385
21	N/A	27785	Regulated River (High Security)	80AL705452	Current	Macquarie And Cudgegong Regulated Rivers Water Source	Continuing	THAT PART OF THE WATER SOURCE UPSTREAM OF THE UPPER LIMIT OF LAKE BURRENDONG	2,311	Subject to conditions water may be taken at any time or rate	80WA704498
22	N/A	10438	Regulated River (High Security)	80AL702570	Current	Macquarie And Cudgegong Regulated Rivers Water Source	Continuing	THAT PART OF THE WATER SOURCE UPSTREAM OF THE UPPER LIMIT OF LAKE BURRENDONG	1,000	Subject to conditions water may be taken at any time or rate	80WA702573

