

WATERMARK

COAL PROJECT

ENVIRONMENTAL IMPACT STATEMENT

February 2013

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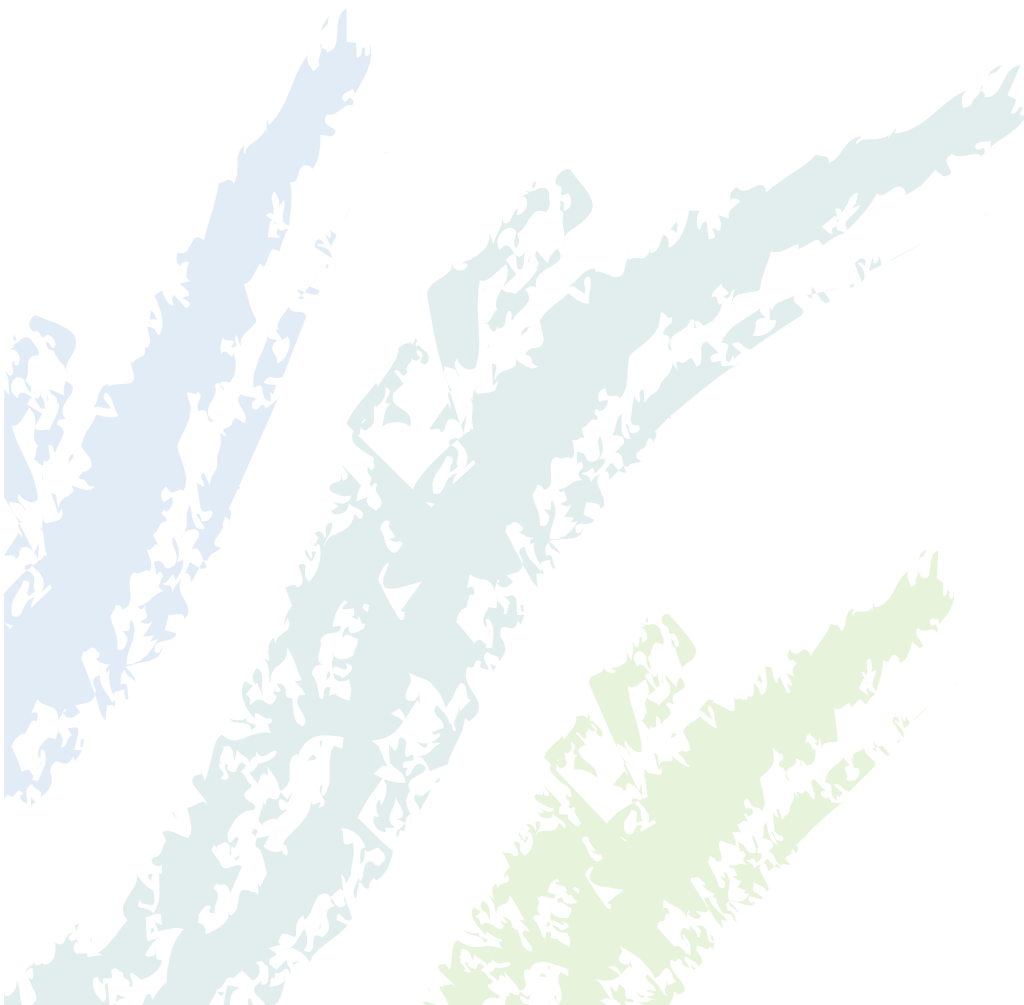
Surface Water
Impact Assessment





SHENHUA WATERMARK PROJECT – SURFACE WATER IMPACT ASSESSMENT

Hansen Bailey Pty Ltd
February 2013



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For and on behalf of
WRM Water & Environment Pty Ltd

David Newton
Director

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EXECUTIVE SUMMARY

WRM Water & Environment Pty Ltd was commissioned by Hansen Bailey Environmental Consultants, on behalf of Shenhua Watermark Coal Pty Limited, to undertake a surface water impact assessment for the Watermark Coal Project (the Project). The assessment will form part of an Environmental Impact Statement being prepared to support an application for State Significant Development Consent under Division 4.1 of Part 4 of the *Environmental Planning & Assessment Act 1979*.

The potential impacts of the Project on surface water resources include:

- Impacts on regional water availability due to the potential need to obtain water from external sources to meet operational water requirements of mining operations;
- Adverse impacts on the quality of surface runoff draining from the disturbance area to the various receiving waters surrounding the Project;
- Adverse impacts on downstream water quality in Watermark Gully associated with possible overflows from the Mine Water Management System;
- Loss of catchment area draining to Watermark Gully, Native Dog Gully and Lake Goran due to capture of runoff within onsite storages and the open cut mining; and
- Interference with flood flows along Watermark Gully and Native Dog Gully.

The water requirements of the Project have been investigated using a detailed site water balance model. The model results may be summarised as follows:

- On average, different stages of mining will operate with a net water deficit of the order of 20 to 160 ML/a (in reality, the site water balance will vary significantly from year to year, depending upon climatic conditions).
- On average, water collected onsite, such as groundwater inflow and surface runoff to mining pits and storages should be able to meet all mine water demands about 90% of the time.
- There is a 10% chance that the volume of external water supply required in any year from Year 4 to Year 19 will be of the order of 300 to 600 ML/a.
- Under extreme drought conditions (1% chance), the annual volume of external water supply could potentially be 900 ML/a.

Water required from external sources will be obtained under appropriate Water Access Licences to ensure no adverse impacts on water availability for other licensed water users.

The mine water management system will be designed and operated to minimise the impacts of the Project on downstream water quality. Wherever possible, runoff from undisturbed areas will be diverted around disturbance areas using diversion drains. This will minimise the volume of water collected in onsite storages and also minimise the impacts on downstream catchments. Sediment-laden runoff will be collected and treated in sediment dams. If the quality of this water is not suitable for release to receiving waters, it will be pumped back into the mine water management system. This water will only be released from site if water quality is acceptable, or during a rainfall event that exceeds the design capacity of the sediment control system.

The mine water management system will be operated to fully contain mine water on the mine site and to preferentially reuse this water to meet minesite demands. The results of the mine water balance modelling show that under the full range of historical rainfall conditions, the proposed mine water management system will have sufficient capacity to contain all mine water on the site without the need for offsite releases. The proposed mine site water management

strategy and infrastructure will ensure that the Project has a negligible impact on the quality of surface runoff and receiving waters.

Impacts associated with the Project will include a temporary reduction in the catchment area draining to receiving watercourses due to capture of runoff from disturbed catchment areas within the mine water management system. This reduction in catchment area will reduce the volume and peak of stormwater runoff resulting in a reduction in flood discharges. The maximum captured catchment areas represent:

- Less than 1% of the Mooki River catchment to the confluence with Watermark Gully.
- Approximately 17% of the catchment area of Watermark Gully to the Kamilaroi Highway.
- Approximately 29% of the catchment of Native Dog Gully (excluding Yarraman Creek).
- Less than 0.4% of the catchment to Lake Goran.

At the completion of mining, surface runoff from rehabilitated overburden emplacement areas will be released from the site. An area of approximately 108 ha, which originally drained to Lake Goran, will continue to drain to the mine final void. The changed topography following completion of the Project will have the following impacts on catchment areas:

- The catchment draining north via Watermark Gully to the Kamilaroi Highway will increase by 5.2 km², an increase of approximately 13%.
- The catchment draining to Lake Goran will be reduced by 6.0 km². This represents a reduction in catchment area of less than 0.5% and, in practical terms, will have no measureable impact on inflows to the lake.
- The catchment draining north to the Mooki River floodplain will be increased by 1.4 km².
- The catchment draining south to Native Dog Gully (excluding Yarraman Creek) and the Mooki River floodplain will be reduced by 1.6 km², a decrease of approximately 2%.

Water balance simulation of the final void shows that the water level is expected to reach an equilibrium water level approximately 20 to 30 m below the overflow level. The lake will take approximately 100 years to reach the equilibrium level.

A detailed flood modelling study of Watermark Gully has been undertaken to assess the flood impacts of the Project. Watermark Gully is affected by a reduction in catchment area of up to about 25%, as well as filling of the upper reaches of the main channel by a proposed overburden emplacement area. Due to the wide, shallow nature of flood flows in Watermark Gully, the filling of the main channel will not result in major impacts on flow velocities. Changes in flow velocity and flood levels will be accommodated in the detailed design of the site drainage system.

The results of a detailed flood modelling study of the Mooki River show that almost the entire area within the Disturbance Boundary will be flood free during a flood event with an average recurrence interval of 100 years. Even during an extremely rare flood event (the largest that could conceivably occur) Mooki River flood levels would not encroach significantly within the Disturbance Boundary. Hence, the Project will not impact flood behaviour on the Mooki River floodplain.

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1 INTRODUCTION

WRM Water & Environment Pty Ltd was commissioned by Hansen Bailey Environmental Consultants (Hansen Bailey), on behalf of Shenhua Watermark Coal Pty Limited (Shenhua Watermark), to undertake a surface water impact assessment for the Watermark Coal Project (the Project). The assessment will form part of an Environmental Impact Statement (EIS) being prepared by Hansen Bailey to support an application for State Significant Development Consent under Division 4.1 of Part 4 of the *Environmental Planning & Assessment Act 1979* (EP&A Act).

In October 2008, Shenhua Watermark Coal Pty Limited (Shenhua Watermark) was granted Exploration Licence (EL) 7223. Shenhua Watermark is a subsidiary of the Shenhua Corporation.

The Project is located within EL 7223, approximately 25 km south south-east of Gunnedah and to the immediate west of the village of Breeza, within the Gunnedah Local Government Area (LGA). The Project is approximately 282 km by rail from the export Port of Newcastle. Figure 1.1 illustrates the regional location of the Project in relation to the nearest town centres of Breeza and Gunnedah.

The Project generally comprises:

- The construction and operation of an open cut mining operation extracting up to 10 Million tonnes per annum (Mtpa) of Run of Mine (ROM) coal for a 30 year period;
- An open cut mining fleet of excavators and shovels, supported by haul trucks, dozers, graders, drill rigs and water carts;
- Progressive rehabilitation of all disturbed areas;
- The construction and operation of a Coal Handling and Preparation Plant (CHPP) with a throughput of 10 Mtpa ROM coal;
- The co-disposal of tailings and coarse reject within the Overburden Emplacement Areas (OEA);
- The construction and operation of a rail spur, rail loop, Kamilaroi Highway rail overpass, associated load out facility and connection to the Werris Creek - Moree Railway Line;
- The construction and operation of a Mine Access Road;
- The construction and operation of administration, workshop and related facilities;
- The construction and operation of ground and surface water management and reticulation infrastructure including pipelines, pumping stations and associated infrastructure for access to water from groundwater aquifers, the Mooki River and private dams to the north-east of the Project Boundary;
- The installation of communications and electricity reticulation infrastructure; and
- A workforce of up to approximately 600 full-time equivalent employees during construction and up to 600 full-time equivalent employees during operation of the Project.

The conceptual layout of the Project is shown in Figure 1.2.

The structure of this report is as follows:

- Section 2 provides background information on the characteristics of the existing surface water environment.

- Section 3 provides a summary of the proposed surface water management strategy and water management infrastructure for the mine.
- Section 4 describes the potential impacts of the Project on surface water resources and provides an assessment of the likely magnitude of these impacts.
- Section 5 provides the methodology and results of a study to simulate the rainfall runoff behaviour of the Mooki River catchment, in which the Project is located.
- Section 6 presents the methodology and results of a numerical simulation of the mine site water balance, including an assessment of storage behaviour and potential release volumes. Section 6 also includes an assessment of the salt load released to receiving waters prior to and during the Project, as well as an assessment of the likely long term water level and salinity behaviour of the open cut final void.
- Section 7 presents the methodology and results of a flood study of Watermark Gully, which drains a portion of the Project Area.
- Section 8 presents the methodology and results of a flood study of the Mooki River.
- Section 9 documents the proposed mitigation and management measures to minimise the risk of adverse surface water impacts from the Project.
- Section 10 is a summary of the findings of the surface water impact assessment.
- Section 11 is a list of references.

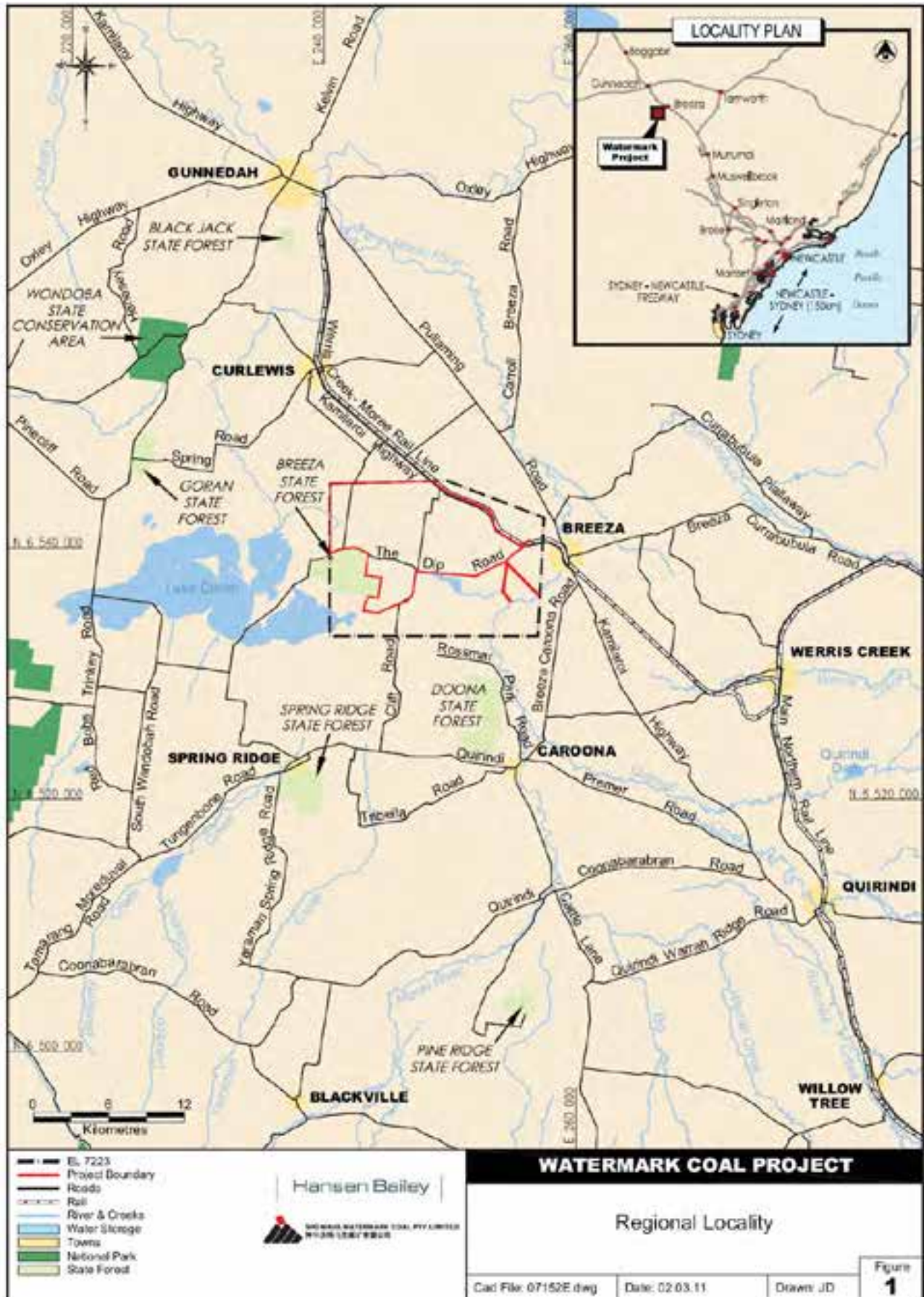


Figure 1.1 Project Locality Map

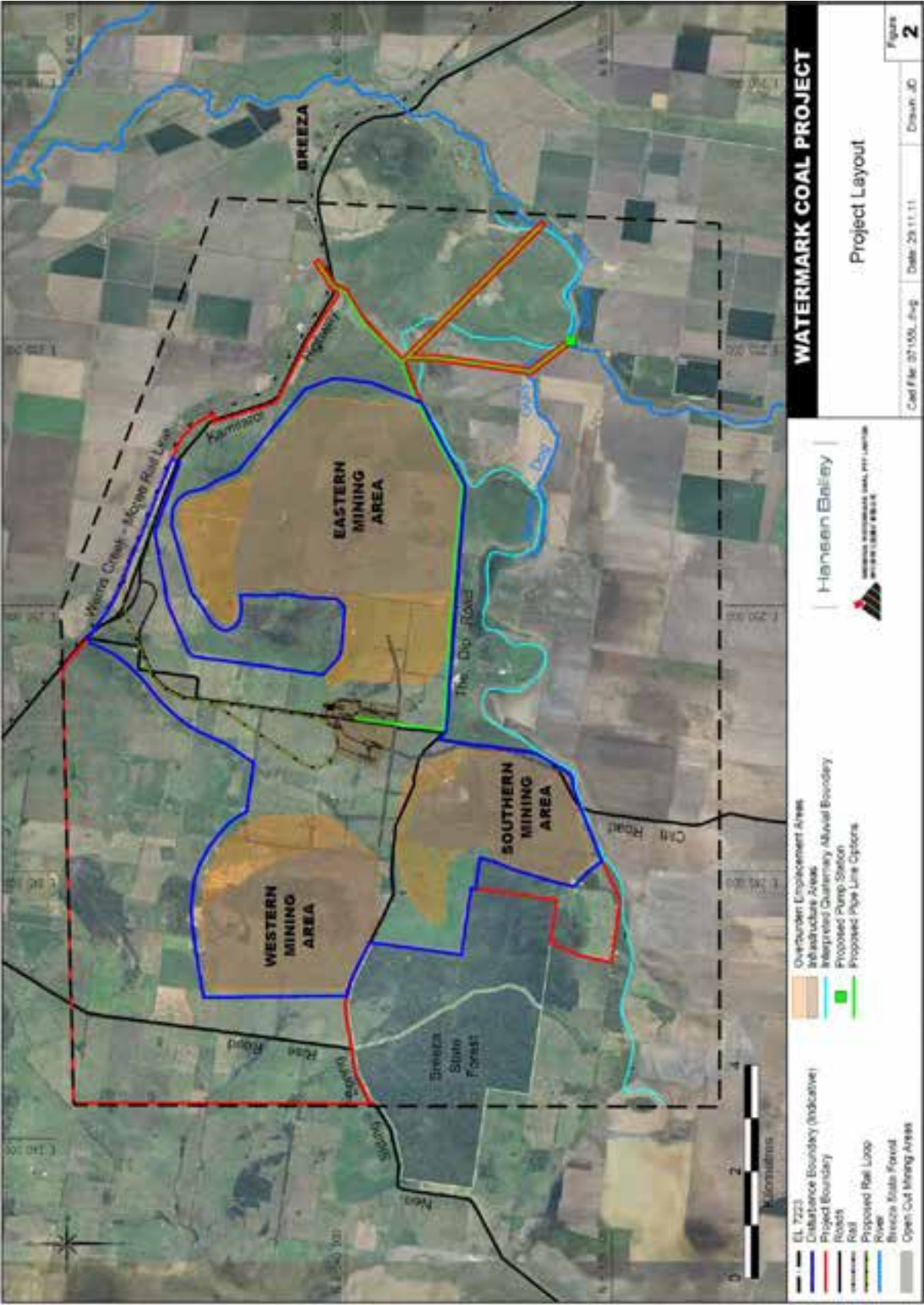


Figure 1.2 Conceptual Project Layout

2 REGULATORY FRAMEWORK

2.1 OVERVIEW

The following legislation, plans, policies and regulations are relevant to the Project for surface water management:

- *Water Management Act 2000* (WM Act) and associated water sharing plans;
- National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000);
- ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006);
- Dams Safety Act 1978;
- Managing Urban Stormwater Soils and Construction – Volume 2E Mines and Quarries (DECC, 2008); and
- Managing Urban Stormwater, Soils and Construction (Landcom, 2004).

2.2 WATER MANAGEMENT ACT 2000

The objective of the WM Act is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The WM Act provides clear arrangements for controlling land based activities that affect the quality and quantity of the State's water resources. It provides for four types of approval:

- Water use approval – which authorise the use of water at a specified location for a particular purpose, for up to 10 years;
- Water management work approval;
- Controlled activity approval; and
- Aquifer interference activity approval – which authorises the holder to conduct activities that affect an aquifer such as approval for activities that intersect groundwater, other than water supply bores and may be issued for up to 10 years.

For controlled activities and aquifer interference activities, the WM Act requires that the activities avoid or minimise their impact on the water resource and land degradation, and where possible the land must be rehabilitated.

With respect to surface water, the Project has the potential to impact on two water sources under the WM Act:

- The Mooki River Water Source identified in the Water Sharing Plan for the Phillips Creek, Mooki River, Quirindi Creek, and Warrah Creek Water Sources 2003; and
- The Lake Goran Water Source identified in the Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources (2012).

The water sharing plans allow for some extraction of water from the river without a Water Access Licence to provide basic landholder rights, which include domestic and stock rights as

well as native title rights. The Project will not rely on water associated with basic landholder rights.

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

The *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2012* underwent public exhibition in 2011 and commenced on 4 October 2012. The plan area comprises 23 unregulated water sources in the Namoi catchment and four alluvial water sources (Manilla, Curabubula, Quipolly, Quirindi) that are relatively distant from the Project Area. The Mooki River and Quirindi Creek are excluded from the water sharing plan.

The Namoi Unregulated and Alluvial Water Sources are shown in Figure 2.1. The total licensed water entitlement has a share component of 32,259 ML/a in 9 surface water licences. Almost all of this entitlement (99.7%) is for irrigation purposes with the remainder for stock and domestic. Water access from Lake Goran is limited by a cease to pump level of 294.7 mAHD.



Figure 2.1 Namoi Unregulated and Alluvial Water Sources (Source: NOW)

2.2.2 Water Sharing Plan for the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources 2003

The *Water Sharing Plan for the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources* commenced in July 2004. The plan covers the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources upstream of the junction of the Mooki River with the Namoi River at Gunnedah.

The objectives of this Plan are to:

- Implement the River Flow Objectives listed in Appendix 4, to protect, preserve, maintain or enhance the important river flow dependent environmental features, and cultural and Aboriginal heritage values of the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources, and to provide water for downstream subcatchments,
- Manage in-river water resources of the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources to ensure equitable sharing of water between all uses and

users, including basic rights, and to minimise any adverse socio-economic impacts in regard to communities and individuals in these water sources,

- Protect the water resources of the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources by ensuring that extraction minimises any adverse environmental impacts,
- Ensure water extraction from the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creeks Water Sources is managed within Murray Darling Basin Cap for the Namoi Water Management Area,
- Provide rules for market based trading of access licence share components and individual daily extraction limits in the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources, and
- Contribute to the achievement of water quality to support the environmental values of the Phillips Creek, Mooki River, Quirindi Creek and Warrah Creek Water Sources.

The Mooki River Water Source, shown in Figure 2.2, has a total area of about 836 km². Inflows to the Mooki River Water Source are highly variable and dependent upon local rainfall and inflows from the Phillips Creek, Warrah Creek and Quirindi Creek Water Sources.

At the start of the Plan, the estimated water requirement for water access licences in the Mooki River Water Source was 27,449 ML/year. Extractions from the Mooki River are subject to Total Daily Extraction Limits which limit the daily extraction volume depending upon the river flow rate. At the time of writing this report, the Project does not have any licences to extract from the Water Sources under this plan.

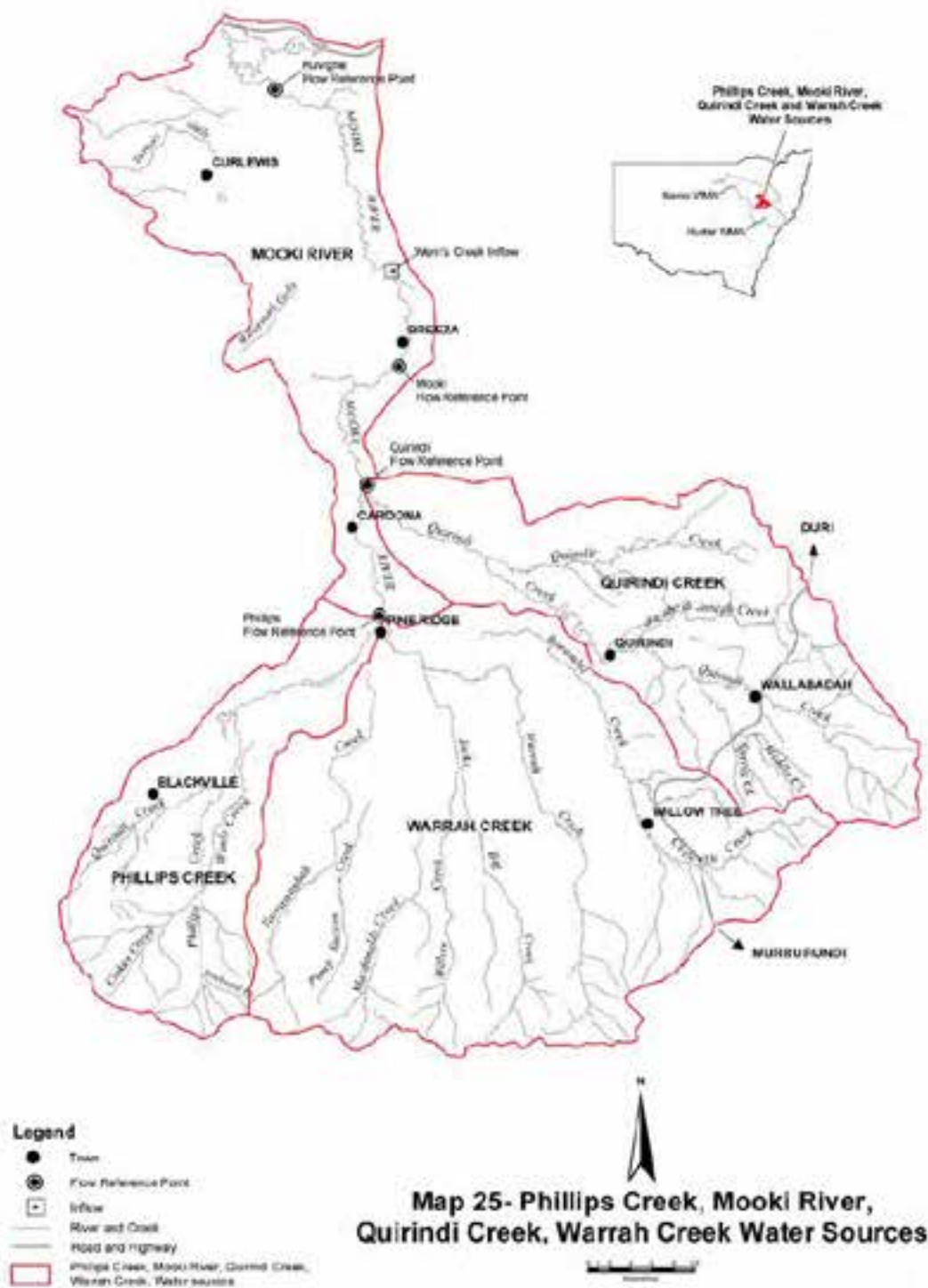


Figure 2.2 Mooki River Water Source (Source: NSW Department of Water and Energy)

2.3 DIRECTOR-GENERAL'S REQUIREMENTS

All applications for Project Approval under Division 4.1 of Part 4 of the EP&A Act must be accompanied by an EIS prepared in accordance with the Director-General's Requirements. This impact assessment, which forms part of the EIS, addresses the DGRs concerning surface water. Table 2.1 lists the DGRs that are relevant to this assessment and the sections of this report where each are addressed.

Table 2.1 Director-General's Requirements

Key Issue	Requirement	Report Section
Water	A detailed assessment of potential impacts on the quality of existing surface and ground water resources, including: - Impacts on affected licensed water users and basic landholder rights.	2.1, 5.2, 5.3 and 5.4
	A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures.	7
	An assessment of proposed water discharge quantity and quality against receiving water quality and flow objectives.	7
	Assessment of impacts of salinity from mining operations on groundwater and surface water resources, including disposal and management of coal rejects and modified hydrogeology, a salinity budget and the evaluation of salt migration to surface, near surface and groundwater sources.	7.12
	Identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000.	2 and 5.2
	Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP) or water source embargo.	5.2
	A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	4 and 10
	A detailed flood impact assessment, which identifies impacts on local and regional flood regimes, including; - an assessment of the potential for flooding to occur in the open cut pits; and - any measures proposed to mitigate potential flood impacts.	8 and 9

This report only addresses the surface water aspects of these DGRs. The groundwater aspects are addressed in the groundwater impact assessment (Appendix R of the EIS).

3

EXISTING SURFACE WATER ENVIRONMENT

3.1 DRAINAGE NETWORK

3.1.1 Overview

The Project Area is located within the catchment of the Mooki River, a tributary of the Namoi River. The drainage network in the area of interest is shown in Figure 3.1. Surface runoff from the disturbance area drains in one of three general directions:

- North to the Mooki River floodplain, either via Watermark Gully or other smaller, unnamed flow paths;
- South to Native Dog Gully, a tributary of the Mooki River; or
- West towards Lake Goran, a large ephemeral lake.

The catchment boundary and directions of surface drainage are shown in Figure 3.2.

A desktop assessment was undertaken to identify the stream order of Watermark Gully, Native Dog Gully and the Mooki River in the vicinity of the Project. Stream ordering followed the Strahler stream classification system. Waterways are given an 'order' according to the number of additional tributaries associated with each waterway (Strahler, A. N., 1952). In this report, stream order is defined by those watercourses represented on the NSW 1:25,000 topographic map series. Following this methodology:

- Watermark Gully was determined to be a 2nd order stream;
- Native Dog Gully was determined to be a 3rd order stream at the confluence with the Mooki River; and
- The Mooki River was determined to be at least a 4th order stream.

3.1.2 Mooki River

The headwaters of the Mooki River originate on the northern slopes of the Liverpool Ranges and Coolah Tops, flowing in a northerly direction to the Namoi River just north-east of Gunnedah. In the upper catchment, creek channels are typically well defined, with an incised main channel and a gravel or cobble bed (see Figure 3.3). Active bank erosion is evident at some locations. Contour banks are used extensively in the foothills of the Liverpool Ranges at the transition between the steeper upper catchment and the alluvial plains. The alluvial plains are used extensively for cropping, with few local drainage features apparent, as shown in Figure 3.4.

The Mooki River has numerous tributary creeks, including Yarramanbah Creek, McDonalds Creek, Big Jacks Creek, Werris Creek, Warrah Creek, Quirindi Creek, and Native Dog Gully. The catchment area of Mooki River to Caroonah, located about 14 km south of the Project Area, is approximately 2,540km². Quipolly Dam (5,300 ML) has a catchment area of 102km² and is located on Quipolly Creek which flows into Quirindi Creek. The Quirindi Creek catchment of approximately 814 km² flows into the Mooki River downstream of Caroonah. The Mooki River catchment area to Breeza, located approximately 5km downstream of the Project, is 3,630km². Native Dog Gully drains into the Mooki River at approximately 7km upstream of Breeza which is

located at the eastern side of the Project Area. Werris Creek and Currabubula Creek, with a total catchment area of approximately 669km², drain into the Mooki River approximately 6km downstream of Breeza.

3.1.3 Watermark Gully

The northern portion of the Project Area drains northwards to the Mooki River floodplain via Watermark Gully. The total catchment of Watermark Gully upstream of the Kamilaroi Highway is approximately 39 km². In its upper and mid reaches, Watermark Gully has a small but defined main channel within a wide floodplain (see Figure 3.5). However, near the northern portion of the Project Area, the main channel essentially disappears to become a very wide, shallow flow path.



Figure 3.1 Drainage Network

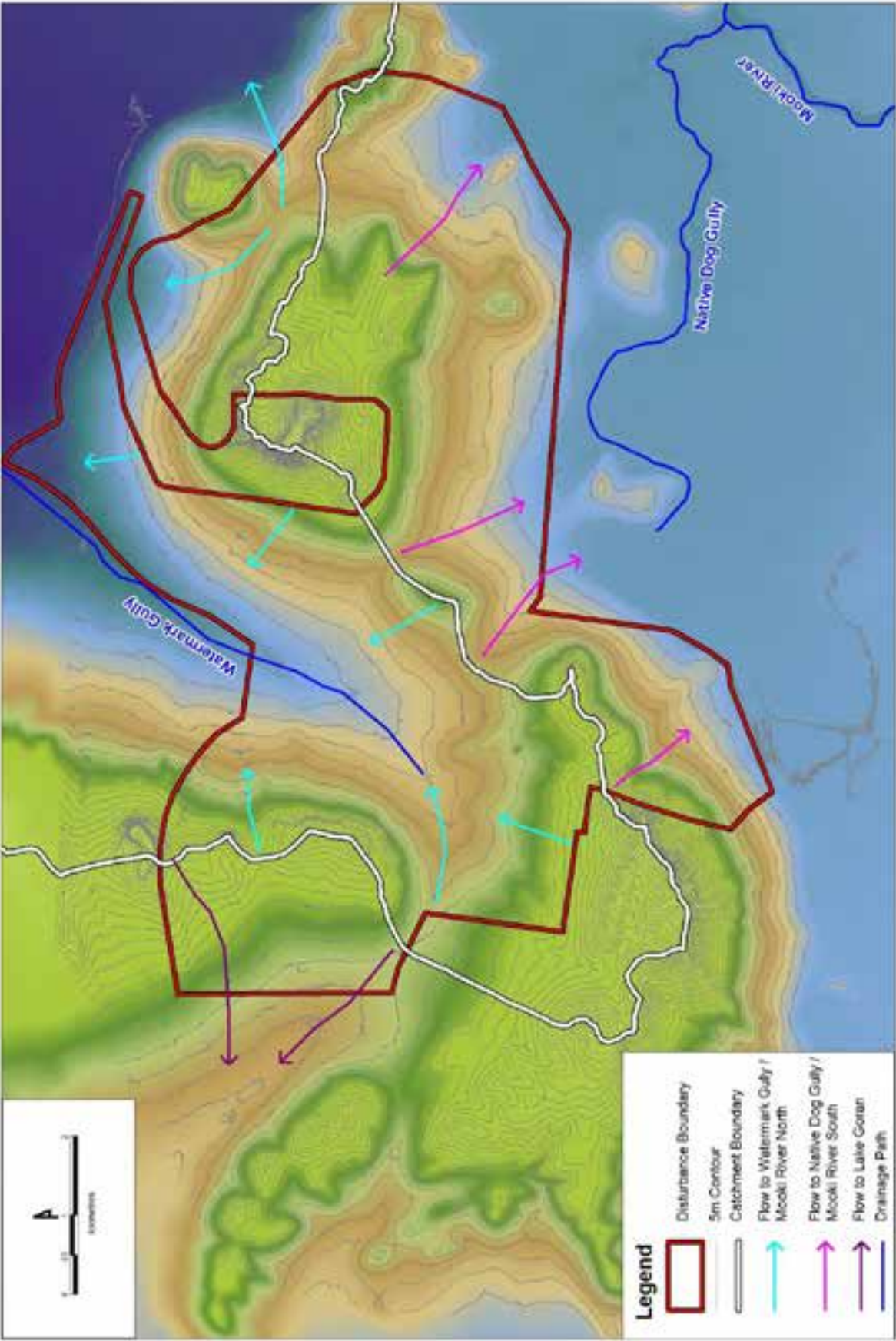


Figure 3.2 Direction of Surface Drainage Across the Project Area



Figure 3.3 Photographs showing typical creek channels in the upper Mooki River catchment



Figure 3.4 Photograph showing alluvial plains of the Mooki River catchment



Figure 3.5 Photograph showing Watermark Gully main channel within Project Boundary

3.1.4 Native Dog Gully

Native Dog Gully is a tributary of Mooki River which drains the southern portion of the Project Area. Native Dog Gully has a catchment area of approximately 72km² to the Mooki River (excluding the Lake Goran catchment area). During major flood events, Native Dog Gully is affected by backwater from the Mooki River. The floodplain area between Yarraman Creek, Native Dog Gully and Lake Goran is very flat and flow direction during flood events is affected by the relative levels and flows in the Mooki River, Yarraman Creek and Lake Goran. During low flow conditions, Yarraman Creek drains to Native Dog Gully.

3.1.5 Lake Goran

Lake Goran is a naturally occurring ephemeral lake. During periods of intense rainfall, (approximately once every 5 years) the lake overflows to the east via Native Dog Gully (Zhang L et al. 1997, pp.10). The catchment of Lake Goran is drained by Coomoo Coomoo Creek, Moreduval Hut Gully and Lever Gully from the south and some unnamed watercourses from west and north into the lake. Coomoo Coomoo Creek loses channel definition across the lower floodplain before draining into Lake Goran. The catchment area of Lake Goran is approximately 1,320km². Lake Goran stores approximately 131,000ML below the overflow level of 296.5mAHD.

3.1.6 Local Drainage

With the exception of Watermark Gully, there are few well defined watercourses across the Project Area. Surface drainage within the Disturbance Boundary has been extensively modified by agricultural activity and is dominated by overland flow, constructed contour banks and numerous small farm dams. Figure 3.6 shows photographs of typical hillslope topography across the Project Area.



Figure 3.6 Photographs of typical hillslope topography dominated by overland flow

3.2 RAINFALL AND EVAPORATION

Daily rainfalls have been recorded at Breeza (Main Road) (BoM Station No. 055008), about 1 km east of the Project Area, since 1883. Rainfall data recorded at this station would be representative of rainfall in the vicinity of the Project Area. Table 3.1 shows summary details of the rainfall station. Table 3.2 shows summary rainfall statistics for the Breeza (Main Road) station. Mean annual rainfall is 608 mm with the highest monthly rainfalls occurring in the summer. The highest annual rainfall at this station (1131 mm) was recorded in 1950.

Table 3.1 Rainfall Station Details

Station No.	Station Name	Elevation (m)	Latitude	Longitude	Distance from Site (km)	Opened	Closed
055008	Breeza (Main Road)	296	31.25° S	150.46° E	1	1883	-

Table 3.2 Monthly Rainfall Statistics, Breeza (Main Road) (Station No. 055008), 1883-2012

Statistic	Monthly Rainfall (mm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	74.0	64.0	48.5	39.5	40.5	42.9	40.5	39.7	40.0	54.2	63.6	66.9	608.1
Lowest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.8	0.0	257.5
5th %ile	9.2	2.2	0.0	0.0	2.5	3.5	4.1	2.6	2.3	6.9	6.9	8.9	351.1
10th %ile	13.8	8.1	1.3	2.5	5.2	9.1	6.7	6.9	8.3	11.0	16.1	14.1	376.4
Median	57.2	53.2	32.0	33.1	32.2	35.3	32.5	32.8	35.0	48.1	51.7	60.5	605.1
90th %ile	166.7	145.6	119.4	80.7	84.0	87.2	75.1	85.0	82.2	109.0	121.7	120.3	831.8
95th %ile	205.3	188.1	146.5	98.8	108.4	101.6	110.3	103.7	96.3	125.5	156.6	142.3	857.4
Highest	305.9	220.2	241.4	169.1	178.0	161.6	215.6	153.7	141.8	156.6	236.6	273.2	1131.1

Table 3.3 shows mean monthly evaporation (based on Class A pan evaporation) recorded by the Bureau of Meteorology at Gunnedah Resource Centre (BOM Station No. 055024), located about 20 km to the north of the Project Area. Mean annual evaporation is 1,752mm, which is nearly 3 times of annual average rainfall.

Figure 3.7 shows the annual distribution of average monthly rainfall and evaporation. Evaporation is greater than rainfall in all months, but is much greater than rainfall in the warmer months.

Figure 3.8 shows the distribution of average annual rainfall over the Mooki River catchment, based on data obtained from the Bureau of Meteorology (BOM, 2009). Average annual rainfalls are similar across the alluvial plains (of the order of 600 to 650 mm), but are significantly higher across the Liverpool Ranges that form the southern boundary of the Mooki River catchment. Average annual rainfall on the Liverpool Ranges is approximately 900 to 1100 mm.

Table 3.3 Mean Monthly Pan Evaporation, Gunnedah Resource Centre, 1948 to 2010

Month	Mean Monthly Pan Evaporation (mm)
January	239
February	190
March	186
April	129
May	84
June	57
July	59
August	84
September	117
October	164
November	201
December	242
Total	1,752

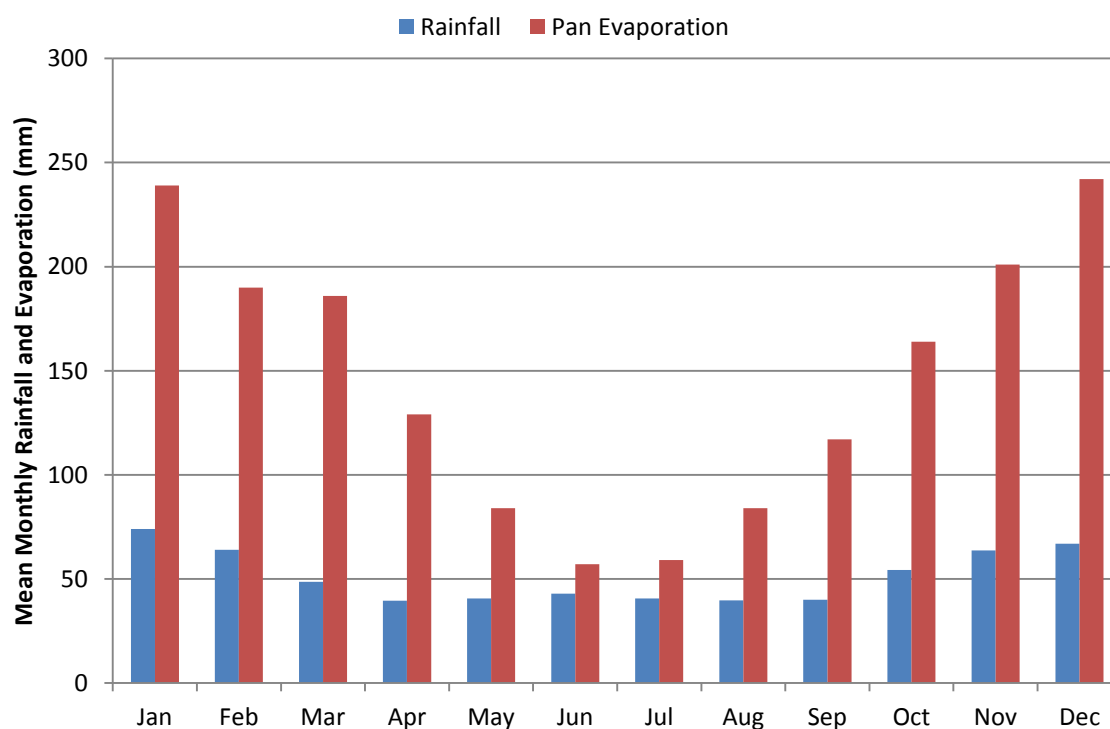


Figure 3.7 Distribution of Monthly Rainfall (Breeza, Main Road) and Evaporation (Gunnedah Resource Centre)

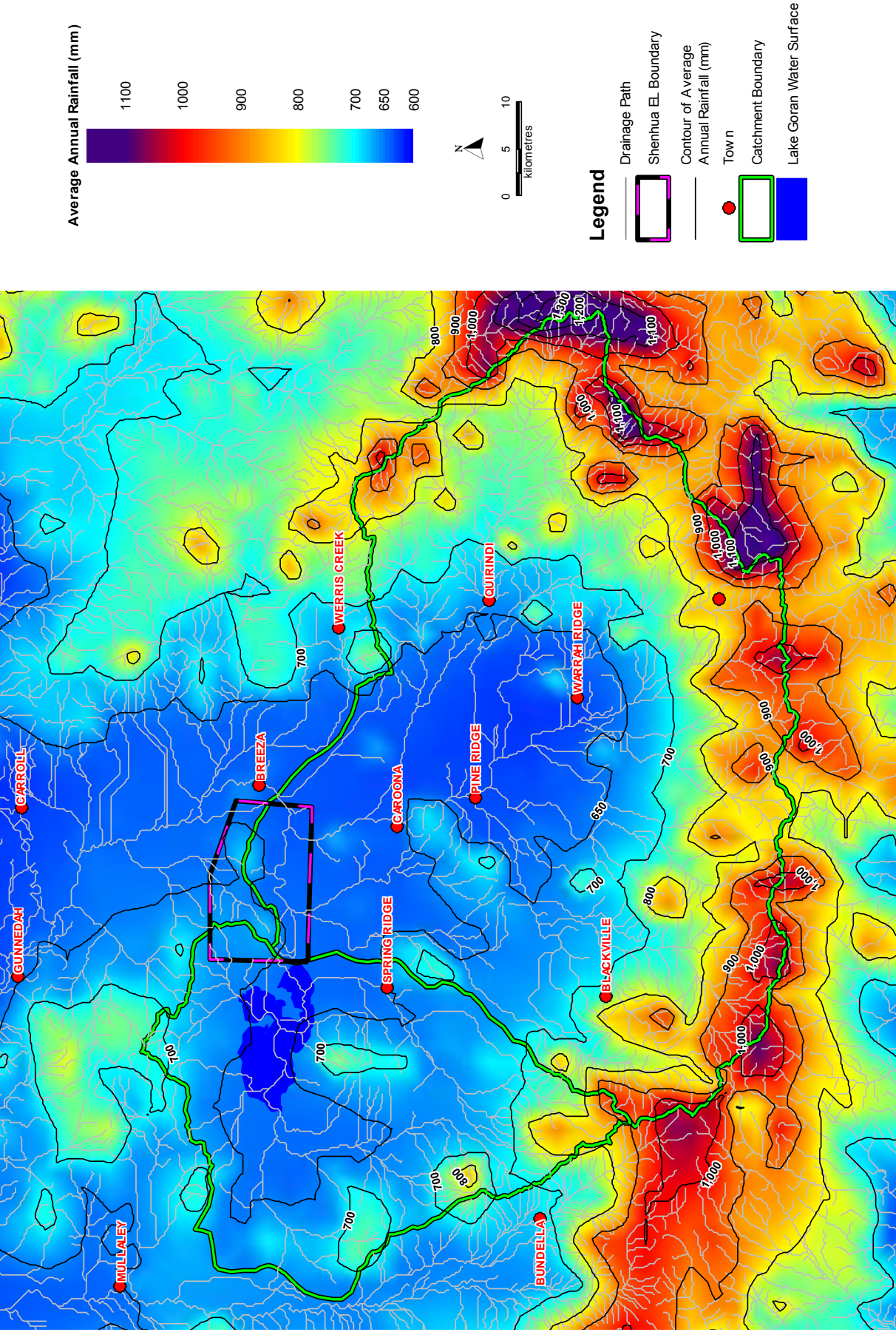


Figure 3.8 Average Annual Rainfall, Upper Mooki River Catchment

3.3 STREAMFLOW

Streamflow data for the Mooki River is available at two gauging stations: Breeza (Station No. 419027, catchment area 3,630km²) and Caroona (Station No. 419034, catchment area = 2,180km²). Data is available at Breeza from 1957-2011 and Caroona from 1965-2011. There is no streamflow data available for Native Dog Gully.

Table 3.4 shows the estimated annual runoff volume for the Mooki River catchment to the Breeza gauge. The volumetric runoff coefficient is typical of natural Australian catchments, with a mean value of approximately 4%. Figure 3.9 presents the flow-duration relationship for Mooki River at the Breeza and Caroona gauges which indicates that flow is non-zero about 85% of the time.

Figure 3.10 presents a plot of annual runoff versus rainfall for the Mooki River catchment at Breeza. Very little runoff is generated by the catchment when annual rainfall is less than about 500mm. Once annual rainfall exceeds this value, the volume of surface runoff increases substantially.

Table 3.4 Annual Rainfall and Runoff Volumes for Mooki River to Breeza Gauging Station

Year	Annual Rainfall (mm)*	Annual Runoff Volume		Volumetric Runoff Coefficient
		(GL)	(mm)	
1958	563	42	11	0.020
1959	719	25	7	0.010
1960	626	86	24	0.038
1961	710	22	6	0.008
1962	697	39	11	0.015
1963	868	110	30	0.035
1964	689	132	36	0.053
1965	376	8	2	0.006
1966	503	19	5	0.010
1967	428	8	2	0.005
1968	804	68	19	0.023
1969	804	93	26	0.032
1970	775	Missing flow data		-
1971	752	390	107	0.143
1972	576	11	3	0.005
1973	833	27	7	0.009
1974	598	306	84	0.141
1975	684	6	2	0.002
1976	897	240	66	0.074
1977	893	385	106	0.119
1978	750	130	36	0.048
1979	534	16	4	0.008
1980	332	2	0.5	0.001
1981	606	13	4	0.006
1982	360	7	2	0.005
1983	771	53	15	0.019
1984	956	360	99	0.104
1985	612	32	9	0.014
1986	522	9	2	0.005
1987	662	34	9	0.014
1988	720	23	6	0.009
1989	709	260	72	0.101
1990	881	327	90	0.102
1991	749	142	39	0.052
1992	591	137	38	0.064
1993	767	72	20	0.026
1994	366	2	1	0.002
1995	688	7	2	0.003
1996	866	Missing flow data		-
1997	640	Missing flow data		-
1998	885	575	158	0.179
1999	Missing rainfall data	57	16	-
2000	Missing rainfall data	568	156	-
2001	Missing rainfall data	23	6	-
2002	Missing rainfall data	2	1	-
2003	Missing rainfall data	3	1	-
2004	Missing rainfall data	54	15	-
2005	606	7	2	0.003
2006	Missing rainfall data	0	0	-
2007	Missing rainfall data	43	12	-
2008	Missing rainfall data	64	18	-
2009	553	Missing flow data		-
2010	Missing rainfall data	228	63	0.005
Mean	668	107	29	0.038

* Based on rainfall for the Breeza at the Park Station (Station No. 55065).

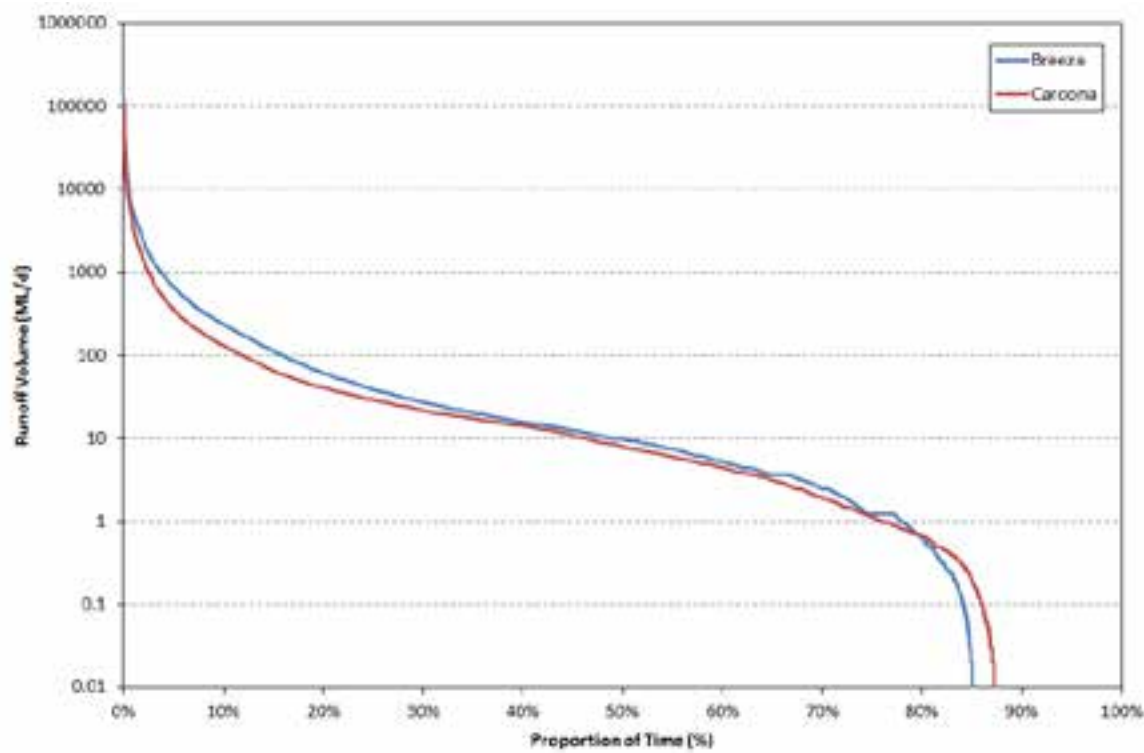


Figure 3.9 **Derived Flow-Duration Relationship for Mooki River at Breeza (1957-2011) and Caroona (1965-2011)**

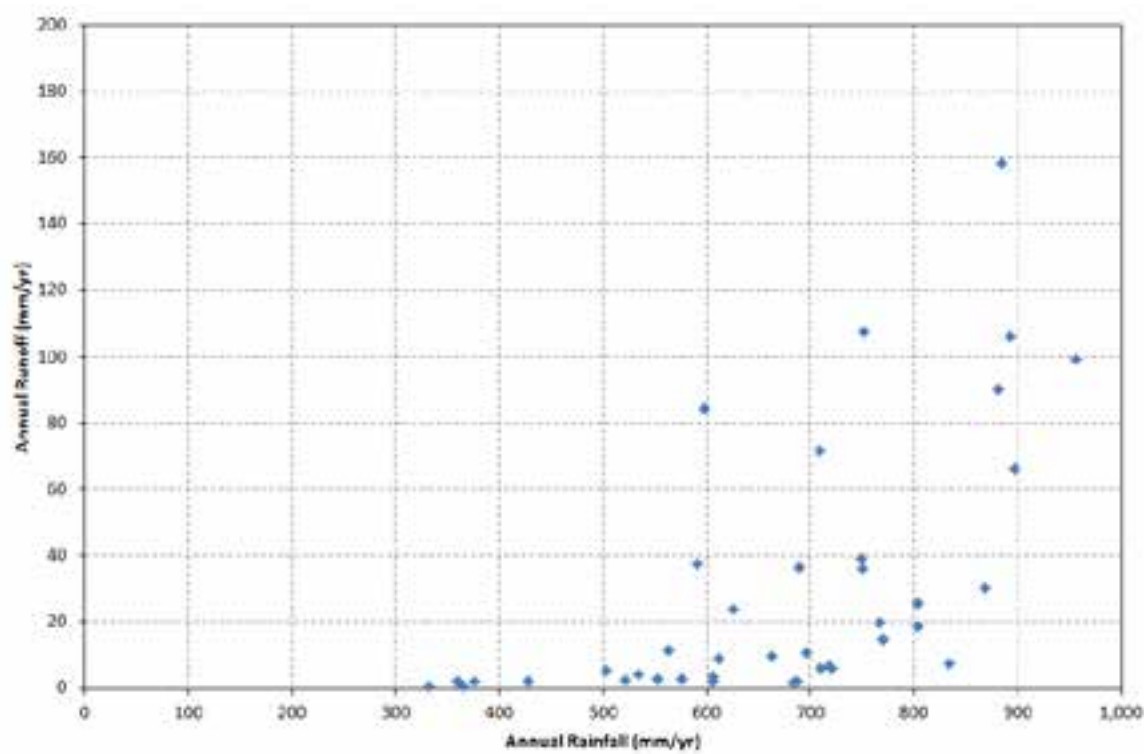


Figure 3.10 **Annual Runoff versus Rainfall for Mooki River at Breeza Gauging Station**

3.4 WATER QUALITY

3.4.1 Regional Water Quality

Water quality data has been sourced from the New South Wales Office of Water (NOW) for two locations (shown in Figure 3.11):

- Mooki River at Carroona (Station No. 419034) – opened in 1965; and
- Mooki River at Ruvigne (Station No. 419084) – opened in 1994.

The available long term water quality data for these two gauges, which included electrical conductivity and turbidity, was compared to the trigger values in the Australia and New Zealand Environment Conservation Council (ANZECC) water quality guidelines (ANZECC, 2000), shown in Table 3.5.

Table 3.5 Water Quality Trigger Values (ANZECC, 2000)

Parameter	Unit	Trigger Value			
		Irrigation	Livestock drinking	Eco-system* ^d	Recreational
pH	pH	6.0 - 9.0	-	6.5 - 8.0	6.5 - 8.5
EC (uncompensated)	µS/cm	1,000 * ^a	-	-	-
EC (25C)	µS/cm	-	-	35-350	-
DO (% Saturation)		-	-	90-110	-
Total Dissolved Solids (TDS)	mg/L	-	2,000* ^a	-	1,000
Turbidity	NTU	-	-	2-25	-
Calcium (Ca)	mg/L	-	1000	-	-
Sodium (Na)	mg/L	115* ^c	-	-	300
Magnesium (Mg)	mg/L	-	2,000* ^b	-	-
Sulphate as SO ₄	mg/L	-	1000	-	400
Chloride as Cl	mg/L	175* ^c	-	-	400
Arsenic	mg/L	0.1* ^f	0.5	0.013* ^{ae}	0.05
Barium	mg/L	-	-	-	1
Cadmium	mg/L	0.01* ^f	0.01	0.0002* ^e	0.005
Chromium	mg/L	0.1* ^f	1	0.001* ^e	0.05
Copper	mg/L	0.2* ^f	0.4* ^a	0.0014* ^e	1
Iron	mg/L	0.2* ^f	-	-	0.3
Lead	mg/L	2* ^f	0.1	0.0034* ^e	0.05
Manganese	mg/L	0.2* ^f	-	1.9* ^e	0.1
Nickel	mg/L	0.2* ^f	1	0.011* ^e	0.1
Zinc (Zn)	mg/L	2* ^f	20	0.008* ^e	5
Mercury	mg/L	0.002* ^f	0.002	0.0006* ^e	0.001
Ammonia	mg/L	-	-	0.013	-
Total phosphorus (Total P)	mg/L	0.05* ^f	-	0.02	-
Total nitrogen (Total N)	mg/L	5	-	0.25	-
Nitrate-N	mg/L	-	400	0.7* ^e	10
Nitrite-N	mg/L	-	30	-	1

Notes: - No Trigger Value recommended.

*^a Lowest recommended value.

*^b Cattle (insufficient information on other livestock)

*^c Sensitive crops

*^d Upland River

*^e 95% of species protected

*^f Long term Trigger Value

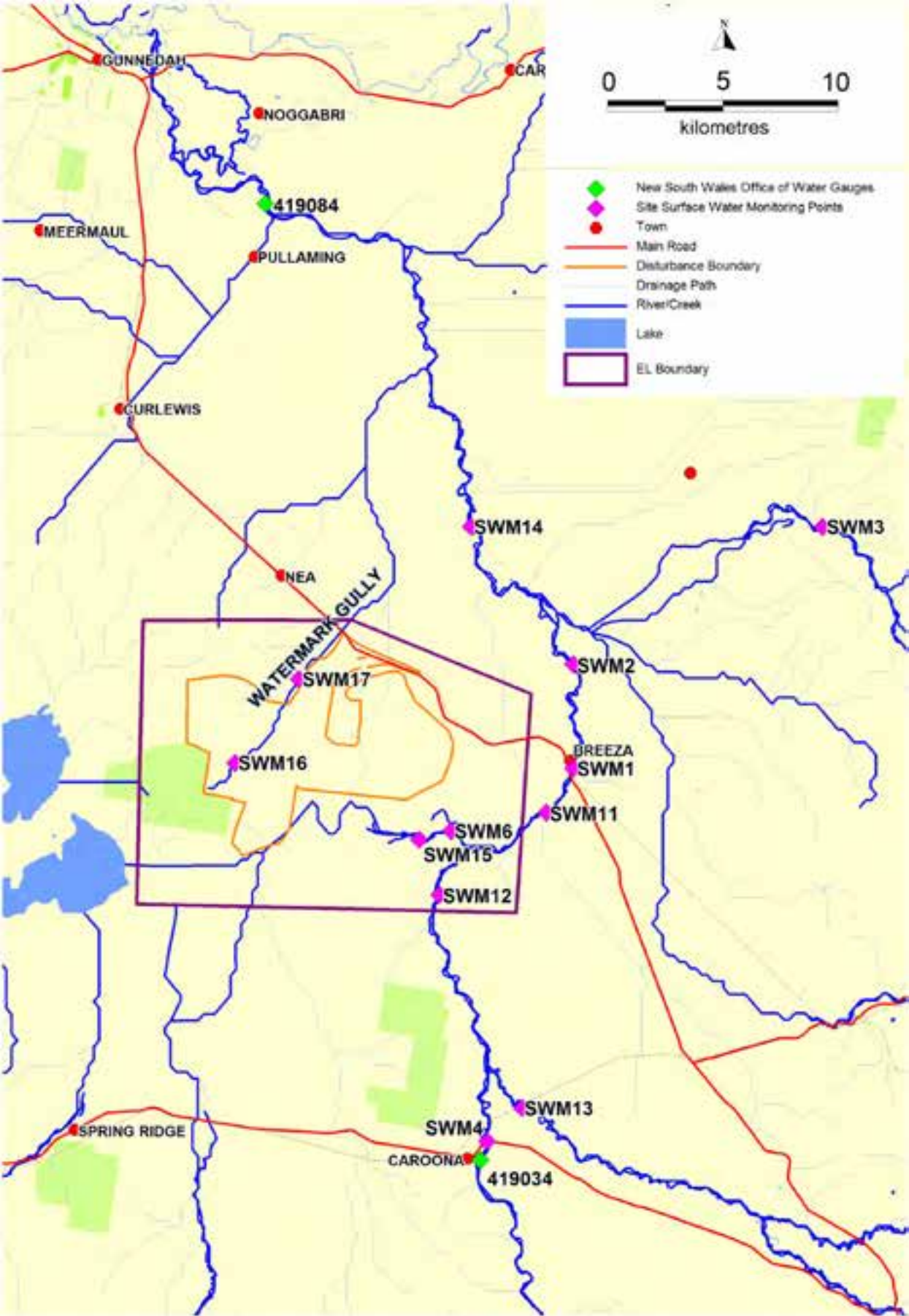


Figure 3.11 Baseline Surface Water Quality Monitoring Locations

A summary of the water quality data is provided in Table 3.6, with recorded electrical conductivity shown in Figure 3.12 and turbidity shown in Figure 3.13. The following is of note:

- The 20th percentile electrical conductivity records at both gauges exceed the ANZECC upper trigger value for ecosystem protection;
- The 80th percentile electrical conductivity records at both gauges exceed the ANZECC trigger value for irrigation purposes;
- The 20th percentile turbidity record at the Caroonna gauge exceeds the ANZECC upper trigger value for ecosystem protection;
- The median turbidity records at both gauges exceed the ANZECC upper trigger value for ecosystem protection.

Table 3.6 Mooki River Surface Water Quality Monitoring Data (1994 to 2012)

Water Quality Parameter		Sampling Site	
		Mooki River @ Caroonna 410934	Mooki River @ Ruvigne 410984
EC (uS/cm)	20 th ile	673	450
	Median	888	688
	80 th ile	1036	1030
	N	32906	243812
Turbidity (NTU)	20 th ile	37	6
	Median	76	155
	80 th ile	166	445
	N	12269	2975

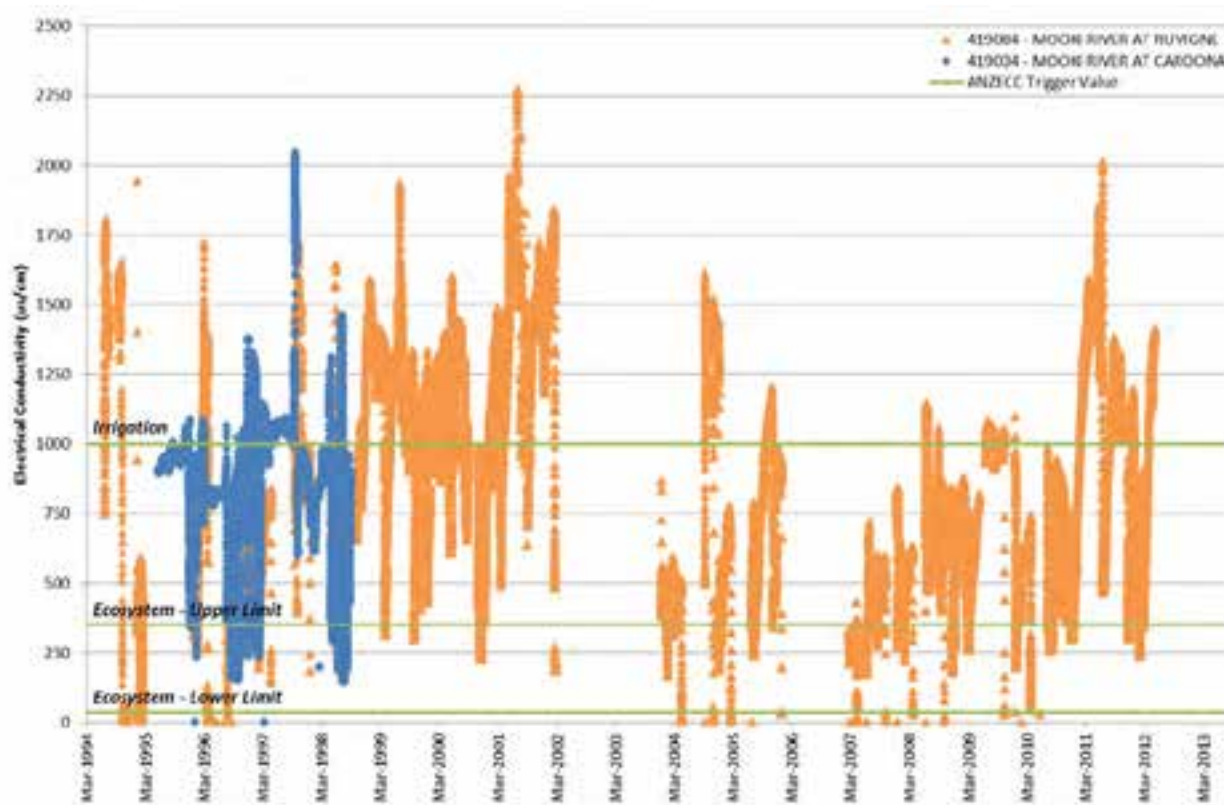


Figure 3.12 NOW Surface Water Quality Monitoring – Electrical Conductivity

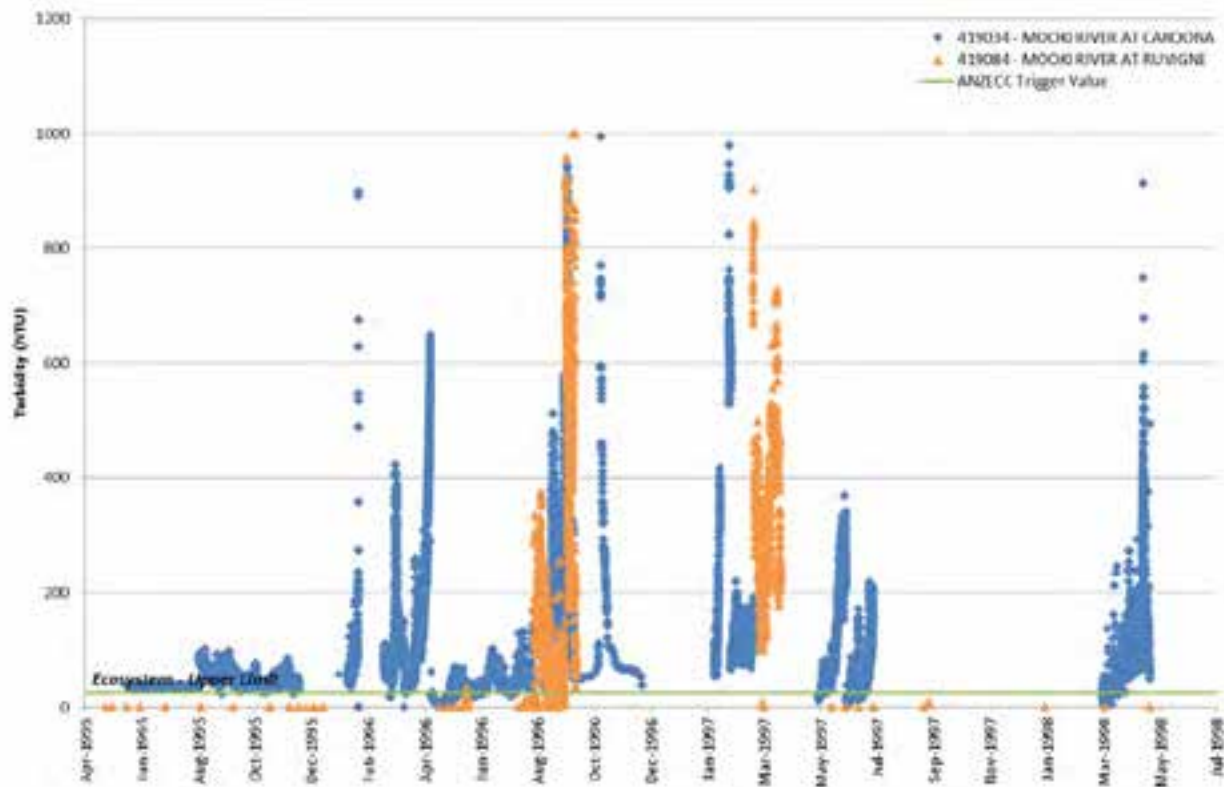


Figure 3.13 NOW Surface Water Quality Monitoring – Turbidity

3.4.2 Baseline Water Quality Monitoring

Baseline surface water quality monitoring at 12 sites has been undertaken by GHD from October 2009 to December 2010 and Carbon Based Environmental Pty Ltd from January 2011 to date on behalf of Shenhua Watermark Coal. Figure 3.11 shows the baseline surface water monitoring locations. Sampling has been undertaken on a monthly basis for salinity, pH, temperature, Dissolved Oxygen, Total Suspended Solids and Total Dissolved Solids as well as a number of metals and organic compounds. Note that sampling at Watermark Gully (SWM16 and SWM 17) occurs during rainfall events only as the gully is otherwise dry. Results are summarised in Table 3.7.

A comparison of the recorded baseline monitoring data at the Project Area with ANZECC trigger values has been undertaken in order to characterise the site water quality. Ecosystem protection trigger values used in the comparison are for Upland Rivers with a level of protection of 95% of species, provided in Table 3.6. If ANZECC indicated a range of trigger values, the lowest value has been used for comparison.

Review of this information indicates the recorded surface water quality at SWM16 and SWM17 in Watermark Gully is:

- Slightly alkaline, with pH ranging from 8.8 to 6.3 with a median pH value of approximately 7.4.
- Fresh, with electrical conductivities ranging from 14 to 266 $\mu\text{S}/\text{cm}$, with a median value between 67 and 100 $\mu\text{S}/\text{cm}$.
- Below the ANZECC trigger values for total dissolved solids, sulphate, arsenic, barium, cadmium and mercury.
- Above the phosphorous ANZECC trigger value for ecosystem and irrigation purposes on all occasions.

- Above the chromium, copper, lead and zinc ANZECC trigger values for ecosystem protection for the majority of records. The irrigation, recreation and livestock trigger values for these parameters have not been exceeded.
- Above the iron ANZECC trigger value for recreation and irrigation purposes on all occasions.
- Below the manganese ANZECC trigger value for ecosystem protection, but has exceeded the recreation and irrigation trigger values on the majority of occasions.
- Mostly below the nickel ANZECC trigger value for ecosystem protection, but has exceeded the ecosystem trigger value on several occasions. The nickel irrigation, recreation and livestock trigger values have not been exceeded.
- Below the acceptable dissolved oxygen ANZECC range for ecosystem protection on the majority of occasions. Only a few occasions exceed the specified range.
- Well above the ANZECC turbidity range for ecosystem protection.

The surface water quality at SWM6 and SWM15 in Native Dog Gully is:

- Slightly alkaline, with pH ranging from 7.7 to 9.7 with a median pH value of approximately 8.8;
- Fresh to brackish, with electrical conductivities ranging from 3 to 48,200 $\mu\text{S}/\text{cm}$, with a median value between 1,170 and 1,510 $\mu\text{S}/\text{cm}$;
- Below the ANZECC trigger values for arsenic, barium, lead and mercury;
- Above the total dissolved solids ANZECC trigger value for recreation and livestock purposes on many occasions,
- Above the sulphate ANZECC trigger values for recreation and livestock purposes on a few occasions,
- Above the phosphorous ANZECC trigger value for ecosystem and irrigation purposes on all occasions;
- Mostly below the cadmium ANZECC trigger value for ecosystem protection, exceeding the ecosystem trigger value only once. The cadmium irrigation, recreation and livestock trigger values have not been exceeded.
- Above the chromium, copper and zinc ANZECC trigger values for ecosystem protection for the majority of records. The irrigation, recreation and livestock trigger values for these parameters have not been exceeded.
- Above the iron ANZECC trigger value for recreation and irrigation purposes on most occasions
- Below the manganese ANZECC trigger value for ecosystem protection on all occasions, but has exceeded the recreation and irrigation trigger values on numerous of occasions.
- Mostly below the nickel ANZECC trigger value for ecosystem protection, but has exceeded the ecosystem trigger value on several occasions. The nickel irrigation, recreation and livestock trigger values have not been exceeded.
- Below the acceptable dissolved oxygen ANZECC range for ecosystem protection on the majority of occasions. Only a few occasions exceed the specified range.
- Above the ANZECC turbidity range for ecosystem protection for the majority of the records.

The surface water quality in the Mooki River is:

- Slightly alkaline, with pH ranging from 6 to 12.2 with a median pH value of approximately 8.5 across all Mooki River site gauges.
- Fresh to brackish, with electrical conductivities ranging from 89 to 2,200 $\mu\text{S}/\text{cm}$, with a median value between 890 and 1030 $\mu\text{S}/\text{cm}$ across all Mooki River site gauges.
- Below the ANZECC trigger values for sulphate, arsenic, barium, and mercury.

- Mostly below the total dissolved solids ANZECC trigger value for recreation and livestock purpose, only exceeding the trigger twice.
- Above the phosphorous ANZECC trigger value for ecosystem and irrigation purposes on the majority of occasions.
- Mostly below the cadmium ANZECC trigger value for ecosystem protection, exceeding the ecosystem trigger value a few times. The cadmium irrigation, recreation and livestock trigger values have not been exceeded.
- Above the chromium ANZECC trigger values for ecosystem protection for the majority of records. The recreation trigger value was exceeded only a couple of times and the irrigation and livestock trigger value has not been exceeded.
- Above the copper ANZECC trigger values for ecosystem protection for the majority of records. The recreation, irrigation and livestock values have not been exceeded.
- Above the iron ANZECC trigger value for recreation and irrigation purposes on most occasions.
- Mostly below the lead and nickel ANZECC trigger values for ecosystem protection, but has exceeded the ecosystem trigger values on a several occasions. The irrigation, recreation and livestock trigger values for these parameters have not been exceeded.
- Below the manganese ANZECC trigger value for ecosystem protection on all occasions, but has exceeded the recreation and irrigation trigger values the majority of the time.
- Below the acceptable dissolved oxygen ANZECC range for ecosystem protection on the majority of occasions.
- Above the ANZECC turbidity range for ecosystem protection for the majority of the records.

In terms of salinity, the best water quality is observed in Watermark Gully and the poorest water quality in Native Dog Gully. The high salinity in Native Dog Gully may be attributed to the significant proportion of the catchment that has been identified as having grey vertosol soils (Yarraman Soil Landscape). These soils become extremely saline with depth. In the vicinity of the Project, the Mooki River also has large proportions of catchment identified as having brown vertosol soils (Conadilly Soil Landscape) which are characterised with high salinity. However, greater dilution would occur in the Mooki River than in Native Dog Gully.

3.4.3 Groundwater Quality

Groundwater quality for the Project has been summarised by Terrenus Earth Sciences (2012). Several aquifers exist in the vicinity of the Project Area, with different aquifers contributing to the groundwater interaction in each of the mining areas.

The results of groundwater quality sampling in the immediate vicinity of the eastern, southern and western mining areas indicate that:

- Groundwater from the aquifers intersected by the eastern mining area has a Total Dissolved Solids (TDS) concentration ranging from 610 to 25,100 mg/L (910 to 37,460 $\mu\text{S}/\text{cm}$). Most groundwater in the eastern mining area is expected to have a salinity of approximately 1,000 to 3,000 mg/L (1,500 to 4,480 $\mu\text{S}/\text{cm}$).
- Groundwater from the aquifers intersected by the southern mining area has a Total Dissolved Solids (TDS) concentration ranging from 2,190 to 29,600 mg/L (3,270 to 44,180 $\mu\text{S}/\text{cm}$). Most groundwater in the southern mining area is expected to have a salinity of approximately 10,000 to 14,000 mg/L (14,900 to 20,900 $\mu\text{S}/\text{cm}$).
- Groundwater from the aquifers intersected by the western mining area has a Total Dissolved Solids (TDS) concentration ranging from 1,390 to 11,000 mg/L (2,080 to 16,420 $\mu\text{S}/\text{cm}$). Most groundwater in the western mining area is expected to have a salinity of approximately 3,000 mg/L (4,480 $\mu\text{S}/\text{cm}$).

Table 3.7 Surface Water Quality Monitoring Baseline Data (2006 to 2012)

Water Quality Parameter		Sampling Site											
		Mooki River						Native Dog Gully		Quirindi Creek	Currabubula Creek	Watermark Gully	
		SWM1	SWM2	SWM4	SWN11	SWM12	SWM14	SWM6	SWM15	SWM13	SWM3	SWM16	SWM17
pH	20%ile	7.9	7.8	8.1	8.0	8.4	8.0	8.1	8.0	7.9	8.1	6.6	7.2
	Median	8.5	8.4	8.5	8.5	8.6	8.3	8.7	9.1	8.1	8.2	7.3	8.0
	80%ile	8.8	8.8	8.8	8.8	8.9	8.7	9.1	9.4	8.4	8.4	7.4	8.3
	N	27	26	29	23	17	24	21	15	21	15	6	6
EC (µS/cm)	20%ile	561.0	501.0	520.0	537.2	885.6	568.2	35.5	667.4	534.0	507.2	38.8	87.2
	Median	891.0	921.5	896.0	992.0	1032.0	1020.0	1514.0	1168.0	780.0	953.0	66.9	100.3
	80%ile	1291.8	1274.0	1102.2	1277.6	1170.2	1281.2	9340.0	1780.2	915.0	1414.2	115.1	248.0
	N	27	26	29	23	17	24	21	15	21	15	6	6
Dissolved Oxygen ^a (%Saturation)	20%ile	66.0	40.0	57.2	37.8	68.4	44.2	61.0	80.8	40.6	47.0	11.6	20.0
	Median	84.0	54.0	74.0	69.6	79.0	65.0	88.0	84.0	71.5	63.0	35.0	67.2
	80%ile	92.0	82.1	83.6	85.2	97.4	77.9	101.1	126.8	80.0	81.0	39.8	112.0
	N	16	16	17	12	7	13	11	5	14	16	5	6
TSS (mg/L)	20%ile	28.0	42.0	14.4	16.2	20.2	36.0	16.0	7.8	14.0	4.6	98.4	20.8
	Median	43.0	60.5	23.0	37.0	44.0	50.5	23.0	62.0	31.0	8.5	162.0	43.0
	80%ile	112.0	100.0	56.0	60.4	60.8	152.0	50.2	100.8	60.0	53.6	233.4	122.8
	N	26	26	28	27	17	24	20	15	23	14	5	5
TDS (mg/L)	20%ile	411.6	467.6	462.0	422.0	457.6	418.4	582.8	377.6	411.6	400.0	257.2	153.0
	Median	540.0	534.0	584.0	572.0	564.0	527.0	2663.0	630.0	471.0	608.0	404.0	173.0
	80%ile	712.8	706.8	684.8	720.0	646.6	704.0	10540.0	994.0	520.0	849.2	556.6	229.2
	N	27	27	29	27	17	24	20	15	23	15	5	5
Sulphate (mg/L)	20%ile	12.2	12.3	7.3	12.2	12.0	14.0	28.0	1.6	19.4	33.8	0.5	0.5
	Median	17.0	17.0	11.0	19.0	14.0	21.0	246.5	23.0	37.0	66.0	0.5	0.5
	80%ile	26.8	27.6	15.4	27.2	18.8	29.0	1300.0	58.0	52.2	97.8	0.5	11.0
	N	27	28	30	27	17	26	20	16	23	15	6	6
TKN (mg/L)	20%ile	0.5	0.6	0.5	0.5	0.4	0.7	0.9	1.0	0.6	0.3	1.8	1.4
	Median	0.7	0.8	0.8	0.6	0.7	0.9	1.3	1.3	1.0	0.4	2.0	1.8
	80%ile	1.2	1.2	1.3	1.0	1.1	1.4	2.2	2.6	1.4	0.8	2.2	2.2
	N	26	26	28	27	17	25	20	16	23	14	5	5
Total Phosphorous (mg/L)	20%ile	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.3	0.1
	Median	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.2	0.1	0.3	0.2
	80%ile	0.6	0.5	0.4	0.4	0.3	0.5	0.5	0.7	0.4	0.4	0.4	0.3
	N	26	26	28	27	17	25	20	16	23	14	5	5
Turbidity ^b (NTU)	20%ile	15.0	71.9	15.5	36.6	27.4	100.5	15.1	29.7	30.4	15.3	247.9	33.5
	Median	47.4	156.0	51.0	57.8	49.3	158.0	78.6	54.0	46.3	37.4	696.0	207.0
	80%ile	519.0	672.8	351.2	498.0	68.6	285.0	258.2	80.4	66.0	65.3	792.4	218.0
	N	6	12	13	10	6	11	8	4	10	11	5	6
Alkalinity (mg/L)	20%ile	243.0	255.4	256.0	256.0	272.8	225.4	187.8	264.4	248.0	143.0	30.6	41.2
	Median	291.0	286.5	350.0	330.0	340.0	290.5	255.0	280.0	293.0	260.0	41.0	74.5
	80%ile	360.0	364.0	379.0	364.0	390.0	342.0	324.0	346.0	324.0	282.0	47.4	112.2
	N	21	20	21	19	13	20	14	14	15	6	4	4
Total Metals	Arsenic (mg/L)	20%ile	0.0005	0.0005	0.0005	0.0005	0.0010	0.0005	0.0005	0.0020	0.0028	0.0020	0.0020
		Median	0.0005	0.0010	0.0005	0.0005	0.0010	0.0020	0.0015	0.0020	0.0040	0.0035	0.0020
		80%ile	0.0018	0.0020	0.0005	0.0020	0.0020	0.0030	0.0030	0.0036	0.0052	0.0050	0.0020
		N	27	28	30	27	17	26	16	23	15	6	6
	Barium (mg/L)	20%ile	0.0492	0.0576	0.0494	0.0488	0.0524	0.0590	0.0388	0.0310	0.0334	0.0610	0.0680
		Median	0.0710	0.0740	0.0555	0.0680	0.0710	0.0765	0.0885	0.0565	0.0460	0.0530	0.0745
		80%ile	0.0868	0.1006	0.0632	0.0874	0.0890	0.1000	0.1872	0.0890	0.0796	0.1410	0.1500
		N	27	28	30	27	17	26	20	16	23	15	6
	Beryllium (mg/L)	20%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
		Median	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
		80%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
		N	26	27	29	27	17	26	20	16	23	14	6
	Cadmium (mg/L)	20%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		Median	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
		80%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001
		N	27	28	30	27	17	26	20	16	23	15	6
	Chromium (mg/L)	20%ile	0.0010	0.0020	0.0009	0.0010	0.0020	0.0020	0.0005	0.0005	0.0005	0.0070	0.0005
		Median	0.0020	0.0030	0.0020	0.0020	0.0030	0.0035	0.0020	0.0025	0.0010	0.0110	0.0035
		80%ile	0.0066	0.0062	0.0040	0.0040	0.0030	0.0110	0.0040	0.0050	0.0030	0.0170	0.0040
		N	27	28	30	27	17	26	20	16	23	15	6

Water Quality Parameter		Sampling Site												
		Mooki River						Native Dog Gully		Quirindi Creek	Currabubula Creek	Watermark Gully		
		SWM1	SWM2	SWM4	SWN11	SWM12	SWM14	SWM6	SWM15	SWM13	SWM3	SWM16	SWM17	
Total Metals	Copper (mg/L)	20%ile	0.0030	0.0034	0.0020	0.0022	0.0030	0.0030	0.0028	0.0030	0.0020	0.0009	0.0070	0.0020
		Median	0.0040	0.0040	0.0030	0.0030	0.0040	0.0040	0.0050	0.0045	0.0030	0.0020	0.0095	0.0040
		80%ile	0.0060	0.0066	0.0062	0.0040	0.0050	0.0100	0.0060	0.0080	0.0046	0.0030	0.0130	0.0050
		N	27	28	30	27	17	26	20	16	23	15	6	6
	Iron (mg/L)	20%ile	1.0000	1.4320	0.5560	0.6020	1.1560	1.6000	0.6680	0.4000	0.3940	0.1760	5.5400	1.7500
		Median	1.7400	2.6600	1.1500	1.3300	1.8000	2.2500	1.8500	2.0000	1.4200	0.3700	9.2400	2.7850
		80%ile	4.4300	5.0480	4.2400	2.7000	3.0600	6.8000	3.5800	4.3000	3.1200	0.8680	14.0000	3.4400
		N	26	27	29	27	17	26	20	16	23	14	6	6
	Lead (mg/L)	20%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0070	0.0005
		Median	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0115	0.0025
		80%ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0006	0.0140	0.0040
		N	26	28	30	27	17	26	20	16	23	15	6	6
	Manganese (mg/L)	20%ile	0.0414	0.0470	0.0260	0.0336	0.0534	0.0530	0.0326	0.0310	0.0666	0.0534	0.0770	0.1430
		Median	0.0500	0.0890	0.0390	0.0500	0.0690	0.0895	0.0920	0.0815	0.1310	0.0870	0.1700	0.1975
		80%ile	0.0898	0.1324	0.0852	0.0980	0.0980	0.1580	0.2772	0.2750	0.3712	0.1220	0.4430	0.2860
		N	27	28	30	27	17	26	20	16	23	15	6	6
	Nickel (mg/L)	20%ile	0.0040	0.0050	0.0040	0.0040	0.0050	0.0050	0.0040	0.0050	0.0034	0.0005	0.0110	0.0060
		Median	0.0050	0.0070	0.0050	0.0050	0.0060	0.0070	0.0065	0.0075	0.0050	0.0005	0.0180	0.0080
		80%ile	0.0098	0.0110	0.0188	0.0078	0.0078	0.0180	0.0114	0.0090	0.0076	0.0006	0.0230	0.0100
		N	27	28	30	27	17	26	20	16	23	15	6	6
	Vanadium (mg/L)	20%ile	0.0280	0.0284	0.0236	0.0272	0.0292	0.0290	0.0162	0.0200	0.0100	0.0050	0.0050	0.0050
		Median	0.0300	0.0310	0.0300	0.0300	0.0300	0.0325	0.0200	0.0475	0.0100	0.0090	0.0150	0.0050
		80%ile	0.0360	0.0396	0.0358	0.0348	0.0347	0.0400	0.0392	0.0710	0.0196	0.0100	0.0200	0.0100
		N	26	27	29	27	17	26	20	16	23	14	6	6
	Zinc (mg/L)	20%ile	0.0050	0.0050	0.0025	0.0042	0.0028	0.0060	0.0025	0.0025	0.0044	0.0025	0.0140	0.0070
		Median	0.0100	0.0090	0.0050	0.0060	0.0060	0.0120	0.0035	0.0065	0.0080	0.0025	0.0235	0.0110
		80%ile	0.0410	0.0382	0.0364	0.0420	0.0198	0.0340	0.0332	0.0420	0.0228	0.0208	0.0350	0.0120
		N	26	27	29	27	17	26	20	16	23	14	6	6
Mercury (mg/L)	20%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
	Median	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
	80%ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
	N	24	27	26	24	15	23	19	14	21	13	6	6	

N = Number of samples

Note: Analytes analysed in a concentration below the detection limit were replaced with half of the detection limit.

a Records from Jan 2011 onwards were recorded in ppm and have been excluded.

b Records only available until December 2010.

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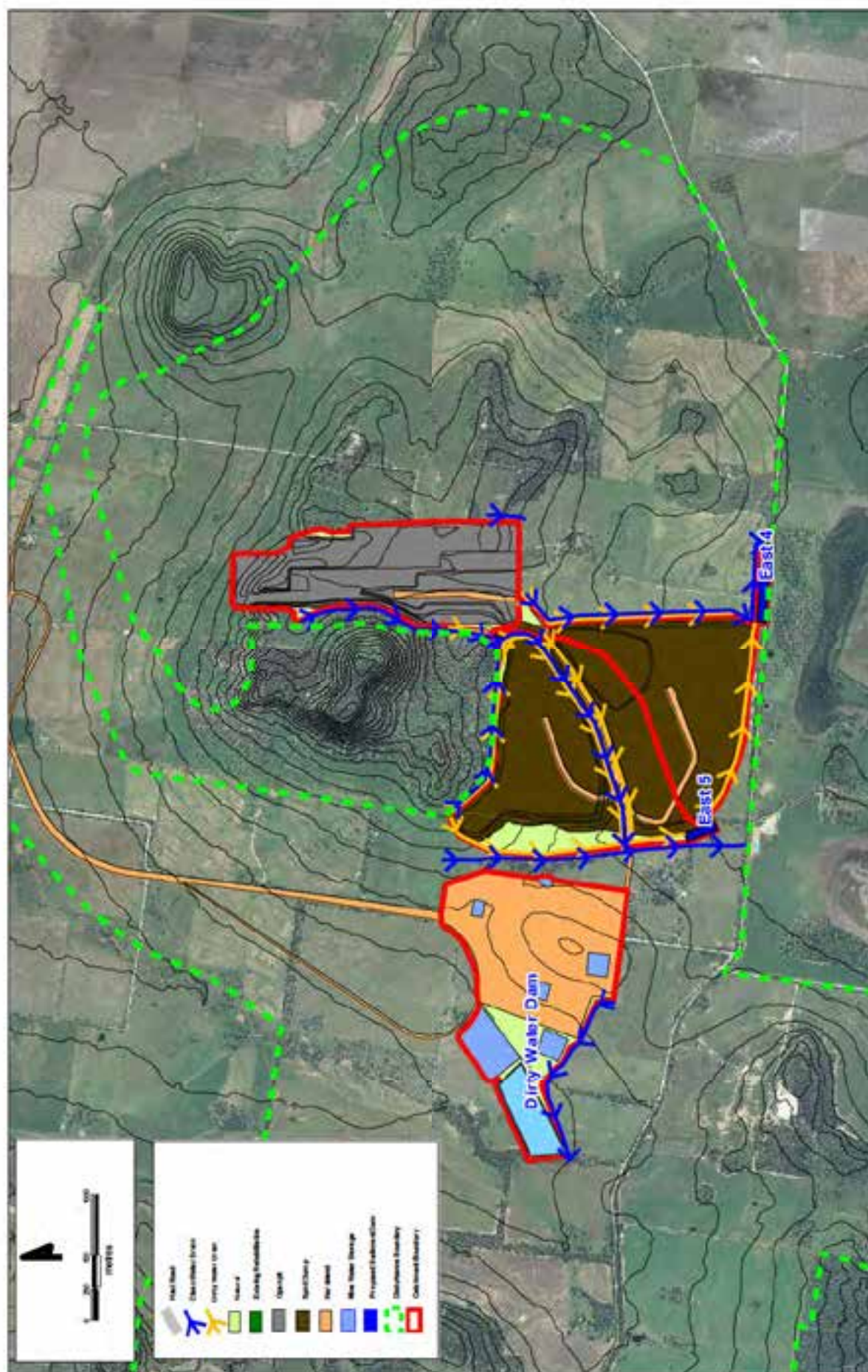
PROPOSED WATER MANAGEMENT STRATEGY AND INFRASTRUCTURE

The proposed strategy for the management of surface water at the mine is based on the separation of water from different sources based on anticipated water quality. Surface water runoff from undisturbed areas will be diverted, wherever possible, around areas disturbed by mining and released from the site, minimising the capture of clean surface runoff. Seepage, groundwater and surface runoff inflows to the open cut mining areas could potentially have elevated salinity and will be collected in onsite storages and used preferentially to satisfy mine site water demands. Surface runoff from overburden emplacement areas is likely to have high concentrations of suspended sediment and will be captured in sediment dams to improve water quality prior to release from the site, or returned to the mine water system if the water quality is not suitable for release. Further details of the mine site water management strategy are provided in Section 7.

Figures 4.1 to 4.5 show indicative locations of the key features of the mine, including infrastructure related to the management of water on the Project site for seven different stages of mining (Years 2, 5, 10, 15, 21, 25 and 30). The main components of water-related infrastructure include:

- Sediment dams to collect and treat runoff from overburden emplacement areas;
- Dirty water drains to divert sediment-laden runoff from overburden emplacement areas to sediment dams;
- Clean water drains to divert runoff from undisturbed catchments around areas disturbed by mining;
- A dirty water storage system to store water pumped out of the Open Cut Mining Areas and to collect runoff from the CHPP and coal stockpile area, as well as decant water from the tailings drying area.

Details of proposed mine site storages, including indicative storage sizes and pumping rules are provided in Section 7.



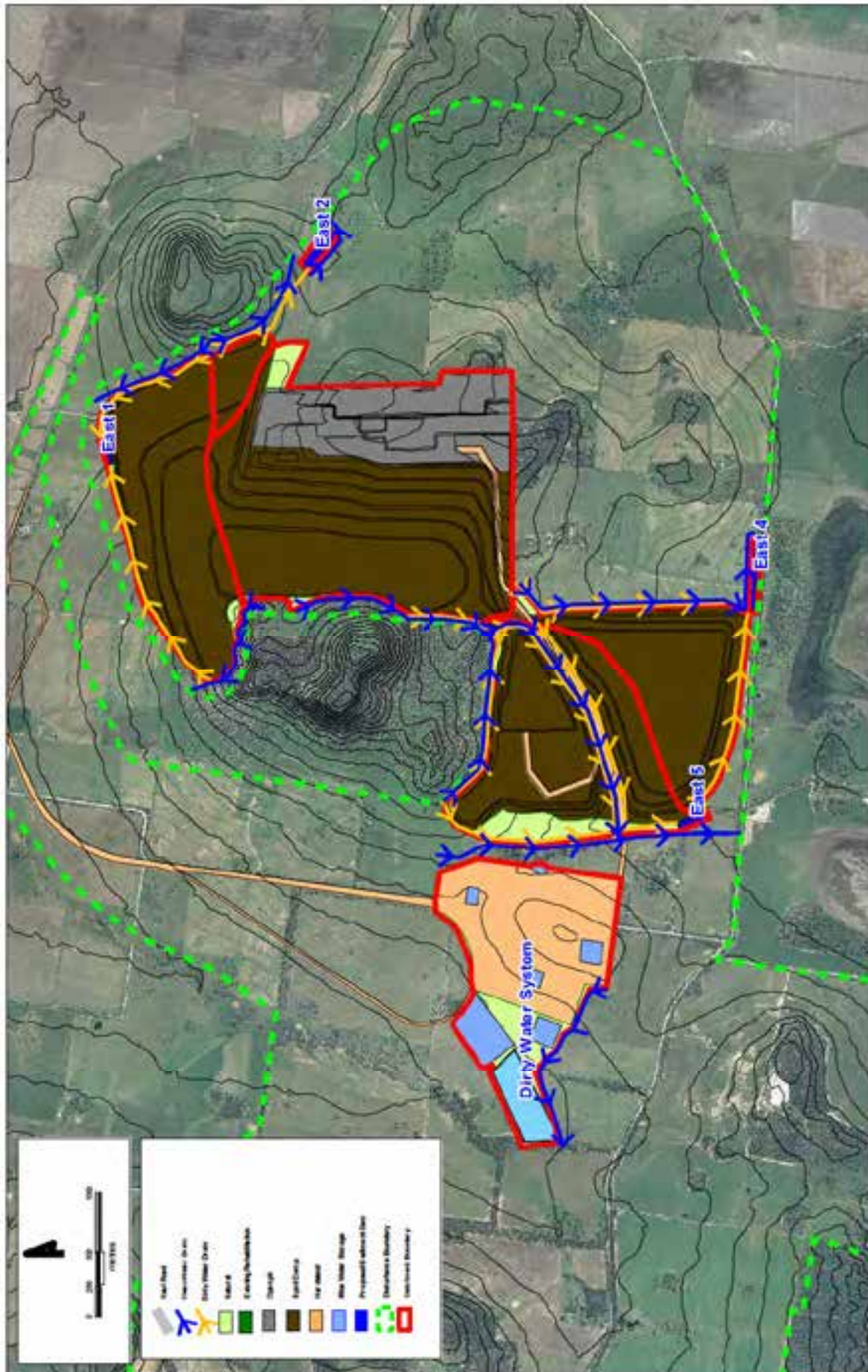


Figure 4.2 Mine Plan Showing Proposed Water Management Infrastructure, Year 5

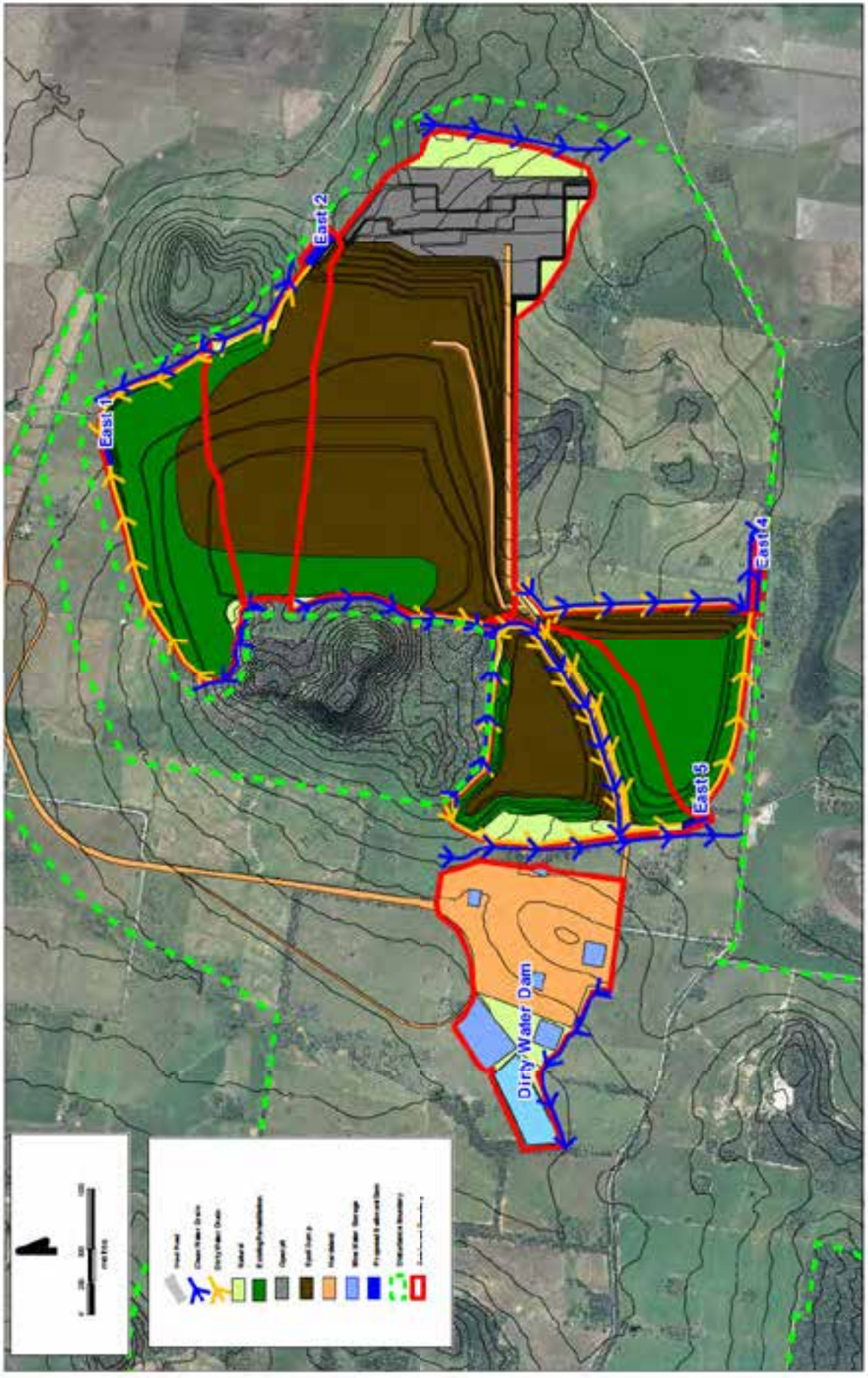


Figure 4.3 Mine Plan Showing Proposed Water Management Infrastructure, Year 10







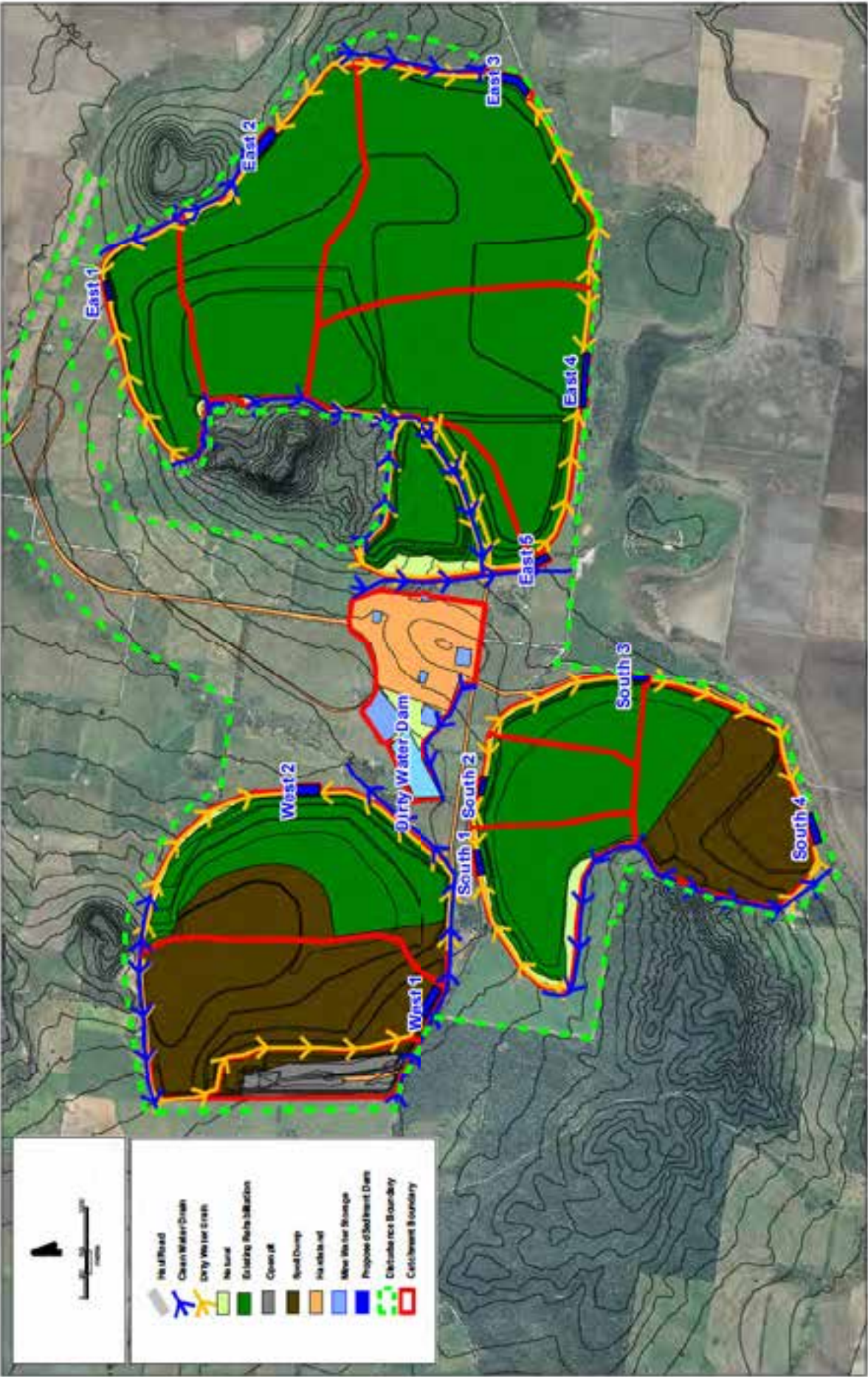


Figure 4.7 Mine Plan Showing Proposed Water Management Infrastructure, Year 30

5 IMPACT ASSESSMENT

5.1 POTENTIAL IMPACTS

The potential impacts of the proposed mining operations on surface water resources include:

- Impacts on regional water availability due to the potential need to obtain water from external sources to meet operational water requirements of mining operations;
- Adverse impacts on the quality of surface runoff draining from the disturbance area to the various receiving waters surrounding the Project;
- Adverse impacts on downstream water quality in Watermark Gully associated with possible overflows from the Mine Water Management System;
- Loss of catchment area draining to Watermark Gully, Native Dog Gully and Lake Goran due to capture of runoff within onsite storages and the Open Cut Pit;
- Interference with flood flows along Watermark Gully and Native Dog Gully.

An assessment of each of these potential impacts of the Project is provided in the following sections.

5.2 MINE SITE WATER REQUIREMENTS

Significant volumes of water are required on the mine site to meet operational water demands, such as dust suppression and coal processing. A key objective of the mine site water management system is to maximise reuse of onsite surface runoff and groundwater inflows. This onsite recycling of water will minimise the volume of water from external sources that is required to satisfy site demands. However, the volume of water captured on site is highly variable dependent upon climatic conditions. Hence, the required makeup water volume from external sources is likely to vary significantly from year to year.

A detailed daily water balance model has been prepared to estimate the likely variation in mine site water requirements over the life of the Project. Full details of the methodology and results of the water balance modelling are provided in Section 6.

The results of the water balance model show that:

- On average, different stages of mining will operate with a net water deficit of the order of 20 to 150 ML/a (in reality, the site water balance will vary significantly from year to year, depending upon climatic conditions).
- On average, water collected onsite, such as groundwater inflow and surface runoff to mining areas and storages should be able to meet all mine water demands about 90% of the time.
- There is a 10% chance that the volume of external water supply required in any year will be of the order of 300 to 500 ML/a.
- Under extreme drought conditions (1% probability), the annual volume of external water supply could potentially be 900 ML/a.

Water required from external sources will be obtained under appropriate Water Access Licences and will be accessed in accordance with the requirements of existing Water Sharing Plans, including adherence to total daily extraction limits. This will ensure no adverse impacts on water availability for other licensed water users.

5.3 SURFACE WATER QUALITY

Water on the mine site will consist of:

- Runoff from undisturbed area (clean runoff),
- Runoff from disturbed areas (sediment-laden runoff), and
- Water that has been affected by contact with coal or other potential contaminants (mine water). This includes groundwater and surface runoff inflows to open cut pits, runoff from coal stockpiles etc.

Wherever possible, clean runoff will be diverted around disturbance areas using diversion drains. This will minimise the volume of water collected in onsite storages and also minimise the impacts on downstream catchments.

Sediment-laden runoff will be collected and treated in sediment dams. If the quality of this water is not suitable for release to receiving waters, it will be pumped back into the mine water management system. This water will only be released from site if water quality is acceptable, or during a rainfall event that exceeds the design capacity of the sediment control system.

The mine water management system will be operated to fully contain mine water on the mine site and to preferentially reuse this water to meet minesite demands. The results of the mine water balance modelling show that under the full range of historical rainfall conditions, the proposed mine water management system will have sufficient capacity to contain all mine water on the site without the need for offsite releases.

The proposed mine site water management strategy and infrastructure will ensure that the Project has a negligible impact on the quality of surface runoff and receiving waters.

5.4 LOSS OF CATCHMENT AREA

5.4.1 During Active Mining Operations

During active mining operations, the mine water management system will capture runoff from areas that would have previously flowed to the receiving waters of Watermark Gully, Native Dog Gully or Lake Goran. The captured catchment area will change as the Project develops. Initially, surface runoff from the overburden emplacement areas will be collected in the proposed sediment dams and pumped into the mine water management system. However, as rehabilitation of the overburden emplacement area progresses and the quality of surface runoff improves, runoff from fully rehabilitated areas will be released back into the downstream catchment.

Table 5.1 shows the catchment area captured within the mine water management system for various stages of mine development. The catchment areas shown in Table 5.1 are the maximum catchment areas captured, assuming that no water overflows or is released from sediment dams. Rehabilitated sediment dams that are no longer pumped back to the mine

water management system are not included as captured area (details are provided in Section 7.3.2). Hence, the maximum captured catchment areas represent:

- Less than 1% of the Mooki River catchment to the confluence with Watermark Gully.
- Approximately 17% of the catchment area of Watermark Gully to the Kamilaroi Highway.
- Approximately 29% of the catchment of Native Dog Gully (excluding Yarraman Creek).
- Less than 0.4% of the catchment to Lake Goran.

Table 5.1 Catchment Area Captured Within the Mine Water Management System

Catchment	Captured Catchment Area (km ²)						
	Year 2	Year 5	Year 10	Year 15	Year 21	Year 25	Year 30
Watermark Gully/Mooki River North	1.8	5.0	6.0	4.3	7.3	9.5	6.6
Native Dog Gully	5.3	6.8	9.1	13.6	19.7	5.1	3.5
Lake Goran	0.0	0.0	0.0	0.0	0.0	2.6	4.5

5.4.2 Final Landform

At the completion of mining, surface runoff from rehabilitated overburden emplacement areas will be released from the site. An area of approximately 108 ha, which originally drained to Lake Goran, will continue to drain to the mine final void.

The catchment boundaries of the final landform are shown in Figure 5.1. The net change in catchment area draining from the site is summarised in Table 5.2. The changed topography as a result of the Project will have the following impacts on catchment areas:

- The catchment draining north via Watermark Gully to the Kamilaroi Highway will increase by 5.2 km², an increase of approximately 13%.
- The catchment draining to Lake Goran will be reduced by 6.0 km². This represents a reduction in catchment area of less than 0.5% and, in practical terms, will have no measureable impact on inflows to the lake.
- The catchment draining north to the Mooki River floodplain will be increased by 1.4km².
- The catchment draining south to Native Dog Gully (excluding Yarraman Creek) and the Mooki River floodplain will be reduced by 1.6 km², a decrease of approximately 2%.

Table 5.2 Change in Catchment Area, Final Landform

Receiving Watercourse	Change in Catchment Area (km ²)
Watermark Gully	+5.2
Mooki River North	+1.4
Native Dog Gully / Mooki River South	-1.6
Lake Goran	-6.0
Final Void	+1.1

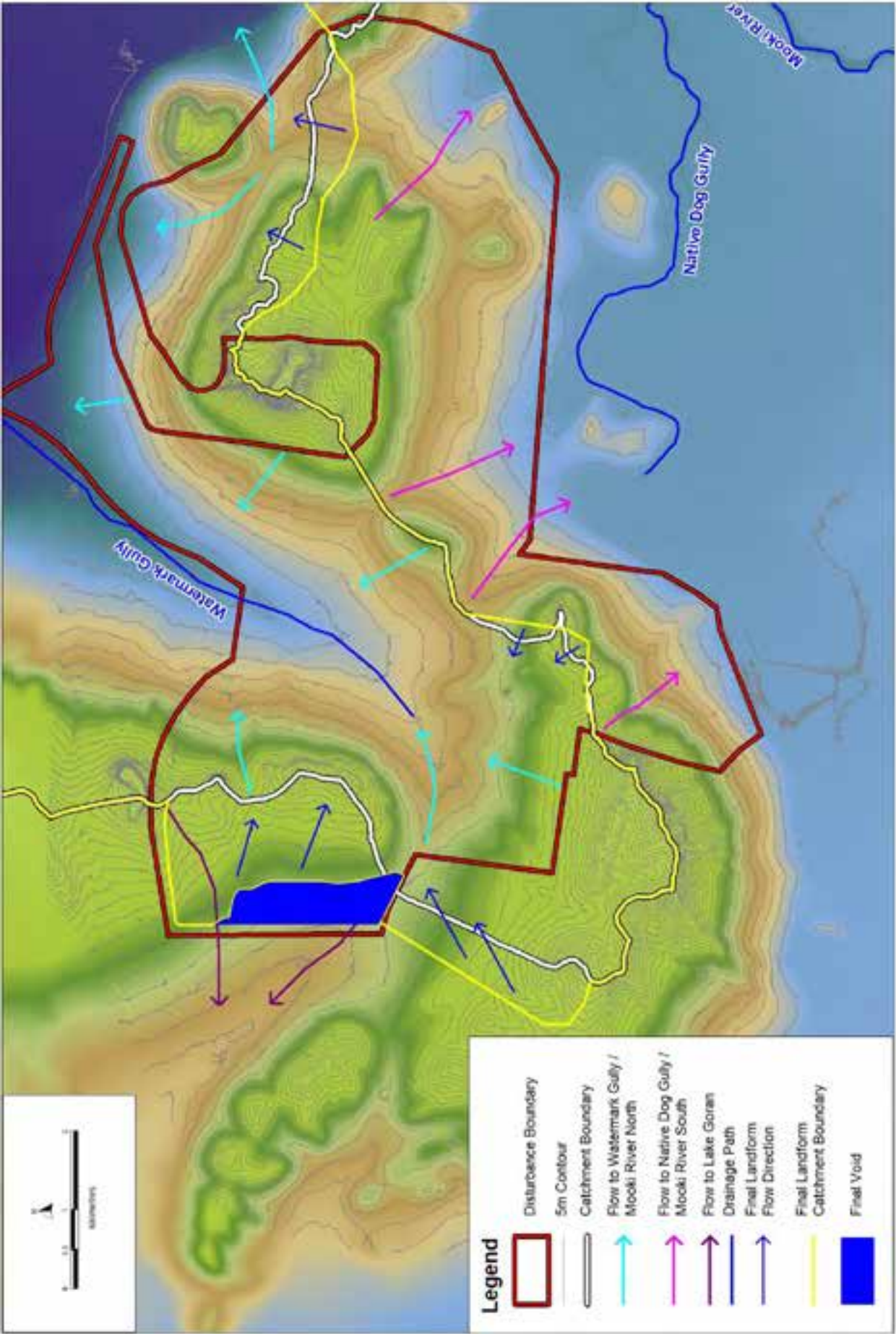


Figure 5.1 Final Landform Catchment Boundaries

5.4.3 Impacts on Flow Frequency in Watermark Gully

The changing catchment area contributing to Watermark Gully will affect the magnitude and frequency of surface runoff flows. Watermark Gully is highly ephemeral and flows only for short periods during and immediately after rainfall. A rainfall runoff model was used to assess the likely impact of the changes to contributing catchment area on the flow-duration relationship for Watermark Gully.

The model results, shown in Figure 5.2, indicate that the Project will reduce the frequency of flow during mining when the contributing catchment area is reduced. However, once mining is complete, the catchment area to Watermark Gully will be increased, generating flows slightly higher than pre-mining conditions. Further detail is provided in Section 8.4.

Whilst the hydrologic model results show a measurable change in the flow-duration relationship for Watermark Gully, given the high variability of runoff in natural watercourses in the area of interest, it is considered unlikely that these flow frequency changes will significantly alter the hydraulic characteristics of Watermark Gully which will readjust itself to the altered flow regime.

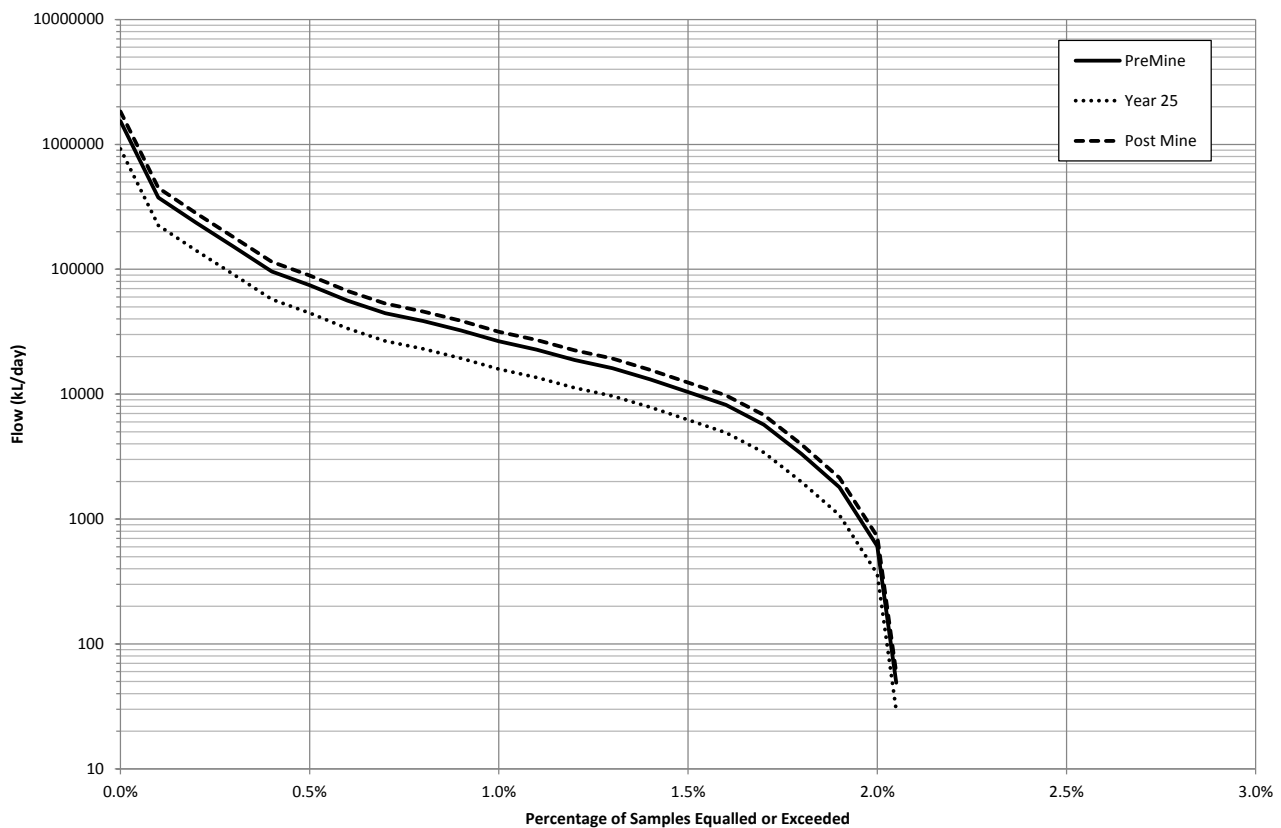


Figure 5.2 Flow Frequency Impacts, Watermark Gully

5.5 WATER LICENSING

5.5.1 Harvestable Rights Assessment

Under the Water Management Act 2000, landholders in most rural areas are permitted to collect a proportion of the rainfall runoff on their property and store it in one or more dams up to a certain size. This is known as a 'harvestable right'. A dam can capture up to 10 percent of the average regional rainfall runoff for their landholding without requiring a licence.

Based on the Project's landholding of 14,843 ha and a harvestable rights multiplier value of 0.07 ML/ha for the relevant area, the total harvestable right for the Project is 1,039 ML.

An assessment of existing farm dams on the Project's landholding has been undertaken to determine the existing dam capacity. A summary of existing farm dams is provided in Table 5.3. The total capacity of existing farm dams is estimated at approximately 79 ML. On this basis, the remaining harvestable right available to the Project is 960 ML.

5.5.2 Water Allocations

The water management system for the Project has been designed to minimise the capture of clean runoff wherever possible. Dams solely for the capture, containment and recirculation of mine affected water consistent with best management practice to prevent the contamination of a water source are "excluded works" under harvestable rights and are exempt from the requirement for water supply works approvals and Water Access Licences. On this basis, water captured in the site water management structures (listed in Table 5.4) with the exception of rainfall runoff from undisturbed natural catchments, is not subject to licensing.

The capture of runoff from undisturbed natural catchment draining to the any of the site water management dams may require a Water Access Licence (WAL). Figure 5.3 shows the undisturbed catchment areas draining to the site water management dams. For the Mooki River Water Source, the maximum undisturbed catchment captured is approximately 117 ha, occurring in the Year 21 staged mine plan. No undisturbed catchment is captured within the Lake Goran Water Source.

Table 5.5 shows the estimated maximum volume of water captured within the water management system from undisturbed catchments from both the Lake Goran and the Mooki River Water Sources. The estimated peak annual take from the Mooki River Water Source of 153 ML is less than the Project's remaining harvestable right of 960 ML.

The intercepted peak annual water take has been estimated using maximum annual rainfall of 1,194mm and a volumetric runoff coefficient of 0.11 (11%) based on the runoff coefficient utilised for harvestable rights calculations (10% of runoff = 0.07 ML/ha = 7 mm runoff. 100% of runoff = 70 mm. 70mm/639 mm average annual rainfall = 11%).

Table 5.3 Summary of Existing Farm Dam Capacities

Property No.	Property Name	Number of Dams	dimensions	Total Depth m	Size (ML)	Total ML	Comment
0	The Watermark	1			2.50	2.50	Watermark Gully - series of 3 dams 500m sth east of House
0	The Watermark	4			0.36	1.44	
1	Linavardi	1	30 m x 40m	1m	0.48	0.48	Dam. Sth of Dip Rd - front of property. Very few water points here
1	Linavardi	2			0.16	0.32	
3	Dixie	1			1.50	1.50	
3	Dixie	5			0.36	1.80	Watermark Gully - series of dams
4	part Glasgerie	1			0.20	0.20	Opposite Demeter
6	Gleneyre	1			2.00	2.00	Dam. front entrance behind shed. Exclude from LA. Part of Office/Coreshed
6	Gleneyre	3			0.36	1.08	
7	Tathra	1			0.16	0.16	
12	Carinya, Old Block etc (inc Browns Cc	12			0.24	2.88	
14	The Yarrens	1	90m x 40m	2m	2.88	2.88	Dam. just south of house
14	The Yarrens	2			0.70	1.40	
19	Stafford	1	60m x 40m	3m	2.88	2.88	Dam. Cnr of Cull & Werner Rds
19	Stafford	5			0.60	3.00	
24	Inverness	2	30m x 30m	shallow	0.36	0.72	Dam. Behind old house
24	Inverness	2	30m x 30m	2.5m	0.90	1.80	dam. Middle of pdk. Access may be no good.
24/26	Inverness	3			0.80	2.40	dam. Watermark gully
28	Springhurst	7			0.50	3.50	
29	Shar	2			1.00	2.00	Dams in Cnr of Court Lane and Hwy.
30	Lilyfield	8			0.40	3.20	
31	Gunnadoo	1	40m x 40m	2m	1.28	1.28	Dam at entrance
31	Gunnadoo	3			0.36	1.08	
32	Urubula	1			2.00	2.00	Dam. Along Werner Rd. west of Clift Rd.
32	Urubula	2			0.36	0.72	
34	Lochiel East	1			3.00	3.00	Dam. Enter from Lake Goran rd along tree line.
34	Lochiel East	2			0.80	1.60	
40	The Wilgas	3			0.36	1.08	
41	Flakenhoe	5			0.40	2.00	Dam Cnr Court & Dip rd
41	Flakenhoe	2	35m x 40m	2m	1.12	2.24	Dam behind shed + further North in trees
42	Wattlevale	2			2.20	4.40	Dam. Near house
42	Wattlevale	1			1.00	1.00	Dam. Boundary of Nea Siding Rd.
42	Wattlevale	2			0.24	0.48	
44	Tillbrook	6			0.36	2.16	
44	Moondyne	3			0.36	1.08	
46	Molonga	1			2.00	2.00	
46	Molonga	1			0.36	0.36	
48	Ashley Downs	1			1.20	1.20	Dam used as water supply for Spraying etc. Not for Exploration use!
48	Ashley Downs	1			0.20	0.20	
49	Monivae	1			1.50	1.50	2 dams located along drive way (middle of pdk)
49	Monivae	1			2.00	2.00	Boori Rd, at entrance
49	Monivae	9			0.24	2.16	
51	Santa Capri	1	20m x 20m	1m	0.16	0.16	dam at entrance.
56	Barwo	1	35m x 40m	3m	1.68	1.68	Dam in cropping pdk off Dip rd (opp entrance to cottage(ATCO) Barwo.
56	Barwo	5			0.36	1.80	
60	Demeter	2			0.50	1.00	
60	Demeter	2			0.36	0.72	
60	Demeter	1	35m x 40m	3m	1.68	1.68	2 x dams at house off hwy
					TOTAL	78.7	

Table 5.4 Schedule of Water Management Structures

Water Management Structure	Capacity (ML)	Purpose	Design Basis
Dirty Water Dam	2000	Containment of mine affected water from active mining operations and sediment dams.	Sized, in combination with other components of mine water management system, to not spill under all simulated conditions.
Turkeys Nest Dam	50	Storage of external raw water supply.	Sized, in combination with other components of contained water system, to not spill under all simulated conditions.
Sediment Dams			
East 1	43	Collection of potentially sediment-affected runoff for treatment prior to release from site or reuse in the mine water management system	Sized for a 5 day management period for sediment capture with transfer of water to containment structures.
East 2	167		
East 3	212		
East 4	179		
East 5	83		
South 1	87		
South 2	51		
South 3	37		
South 4	130		
West 1	146		
West 2	176		
Active Mining Pit			
Year 2	5700	Containment of mine affected water to prevent uncontrolled spills in the event of the mine water management system reaching capacity	As per proposed mine plan schedule and earthworks
Year 5	51000		
Year 10	83000		
Year 15	52000		
Year 21	39000		
Year 25	25000		
Year 30	51000		
Final Void	51000	Long term containment of groundwater seepage and surface runoff from the final landform.	As per proposed mine plan schedule and earthworks

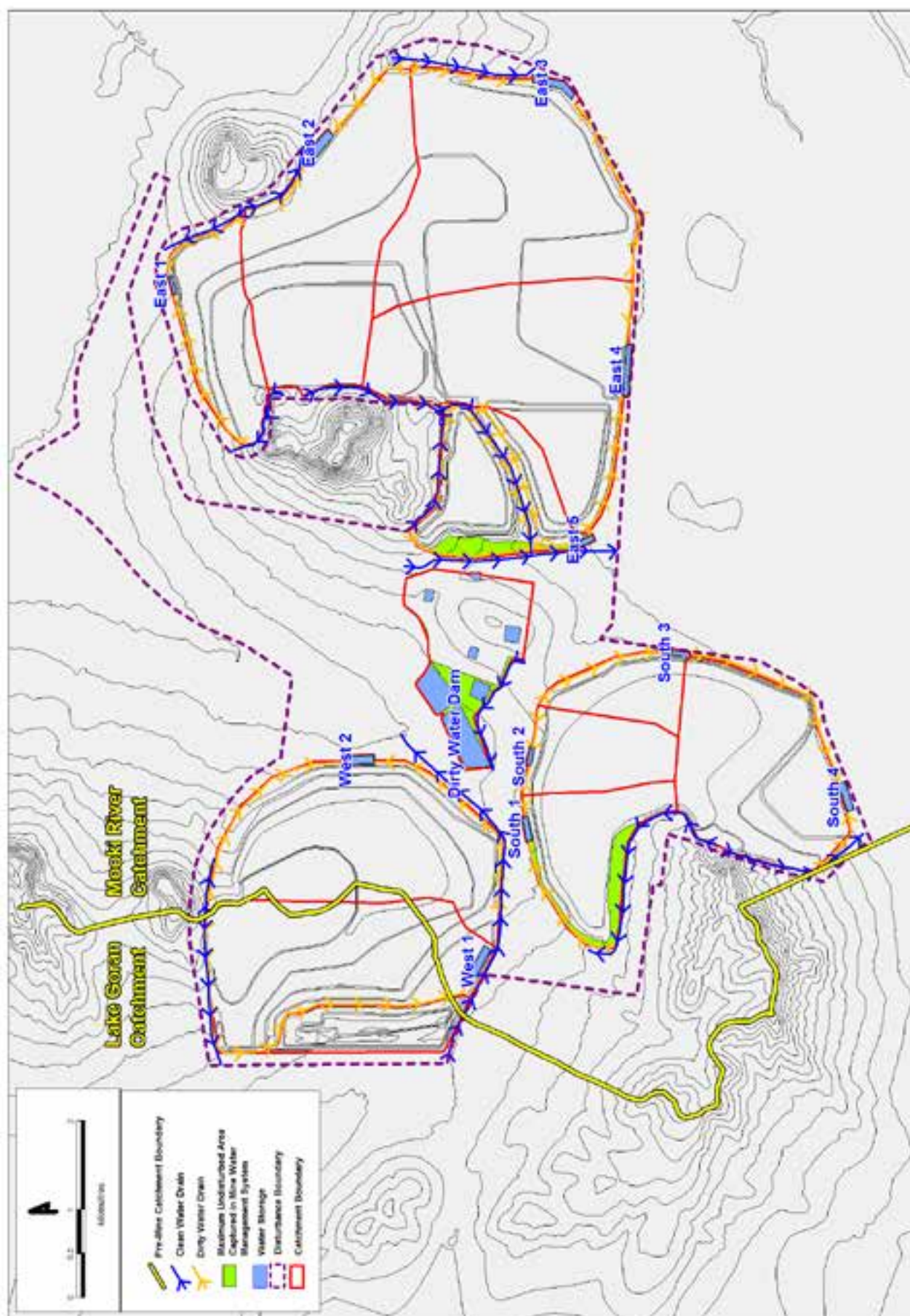


Figure 5.3 Undisturbed Catchment Areas Draining to the Mine Water Management System

Table 5.5 Surface Water Licensing Requirements

WATER SOURCE	PEAK ANNUAL TAKE (DURING MINING) (ML)	PEAK ANNUAL TAKE (AFTER MINING) (ML)	'AWD FACTOR'	SHARE COMPONENT TOTAL REQUIREMENT	TOTAL NUMBER OF LICENCES	TOTAL SHARE COMPONENT (UNITS)	LTAEL
Mooki River	153	0	1.1	168	29 unregulated river 9 domestic and stock 3 domestic and stock (stock) = 41 licences	29,589.5 unregulated river 23.5 domestic and stock (stock) 82 domestic and stock = 29,695 units	As calculated under clause 35 of the WSP
Lake Goran	0	0	1.1	0	No record found	No record found	As calculated under clause 29 of the WSP

5.6 LOCAL CATCHMENT FLOODING

With the exception of Watermark Gully, there are few well defined watercourses across the Project Area. Surface drainage within the Disturbance Boundary has been extensively modified by agricultural activity and is dominated by overland flow, constructed contour banks and numerous small farm dams. In mining disturbance areas, these minor drainage features will be replaced by mining infrastructure including open cut mining areas and overburden emplacements.

Impacts associated with the Project will include a reduction in the catchment area draining to receiving watercourses due to capture of runoff from disturbed catchment areas within the mine water management system (see Section 4.4). This reduction in catchment area will reduce the volume and peak of stormwater runoff resulting in a reduction in flood discharges.

A detailed flood modelling study of Watermark Gully has been undertaken to assess the flood impacts of the Project. Watermark Gully is affected by a reduction in catchment area of up to about 25% during mining, as well as filling of the upper reaches of the main channel by a proposed overburden emplacement area. Due to the wide, shallow nature of flood flows in Watermark Gully, the filling of the main channel will not result in major impacts on flow velocities. Changes in flow velocity and flood levels will be accommodated in the detailed design of the site drainage system. Full details of the methodology and results of the flood modelling study for Watermark Gully are provided in Section 7.

5.7 MOOKI RIVER FLOODING

The Mooki River floodplain is subject to extensive inundation during flood events. Major recent flood events occurred in 1998 and 2000.

The results of a detailed flood modelling study of the Mooki River show that almost the entire area within the Disturbance Boundary will be flood free during a flood event with an average recurrence interval of 100 years. Even during an extremely rare flood event (the largest that could conceivably occur) Mooki River flood levels would not encroach significantly within the Disturbance Boundary. Hence, the Project will not impact flood behaviour on the Mooki River floodplain. Full details of the methodology and results of the flood modelling study are provided in Section 8.

6

SIMULATION OF RAINFALL RUNOFF FOR THE MOOKI RIVER CATCHMENT

6.1 INTRODUCTION

A rainfall runoff model was used to assess the catchment water balance of the upper Mooki River catchment. The model was used to simulate the hydrologic response of the Liverpool Ranges and alluvial lands and was calibrated to recorded rainfall and runoff data. The calibrated model was used to undertake a water balance for Lake Goran, which provided an additional verification for the calibrated rainfall-runoff parameters and infiltration rates determined in the groundwater modelling. Further details of the available data and the methodology and results of the investigation are provided in the following sections.

6.2 AVAILABLE DATA

6.2.1 Overview

Data used in the hydrologic analysis of the upper Mooki River catchment included rainfall data, evaporation data, streamflow and water level data, as well as information on regional geology.

6.2.2 Rainfall

Recorded average annual rainfalls from 1961 to 1990 over the upper Mooki River catchment are presented in Figure 6.1. Rainfall is highly variable across the area of interest; with average annual rainfalls in some parts of the Liverpool Ranges almost double those across the alluvial plains.

For hydrologic modelling of the Mooki River catchment, long-term daily rainfall data was obtained from DERM using their SILO Data Drill service (Jeffrey et al. 2001). The SILO data is based on interpolated historical data and has been adjusted for data gaps and accumulated rainfall totals.

6.2.3 Evaporation

Evaporation data is required for hydrological modelling of the catchment, as well as the water balance simulation of Lake Goran. Morton's Lake evaporation, obtained from the SILO Data Drill service, was adopted as a representative evaporation time series for all of the hydrologic analyses.

6.2.4 Streamflow

There are five streamflow gauging stations in the study area, including two stations on the Mooki River and three on tributaries of the Mooki River. Summary details of the gauging stations are provided in Table 6.1. The streamflow gauging station locations are shown in Figure 6.1.

Table 6.1 Streamflow Gauging Stations

Station No.	Station Name	Lat.	Long.	Catchment Area (km ²)	Site Commence
419027	Mooki River at Breeza	-31.28°	150.46°	3,630	Sep. 1957
419034	Mooki River at Caroona	-31.66°	150.43°	2,180*	Aug. 1965
419076	Warrah Ck at Old Warrah	-31.41°	150.64°	146	Jun. 1982
419086	Bundella Ck at Bundella	-31.56°	149.99°	151	Dec. 1995
419087	Big Jack's Ck at Warrah Ridge	-31.58°	150.53°	432	Jan. 1996

*Note – NOW (2010) gives catchment area as 2,540km². Investigations found that inclusion of the Quirindi Creek catchment may account for the difference, however further inspection found that the Mooki and Quirindi Creek confluence is downstream of the gauge.

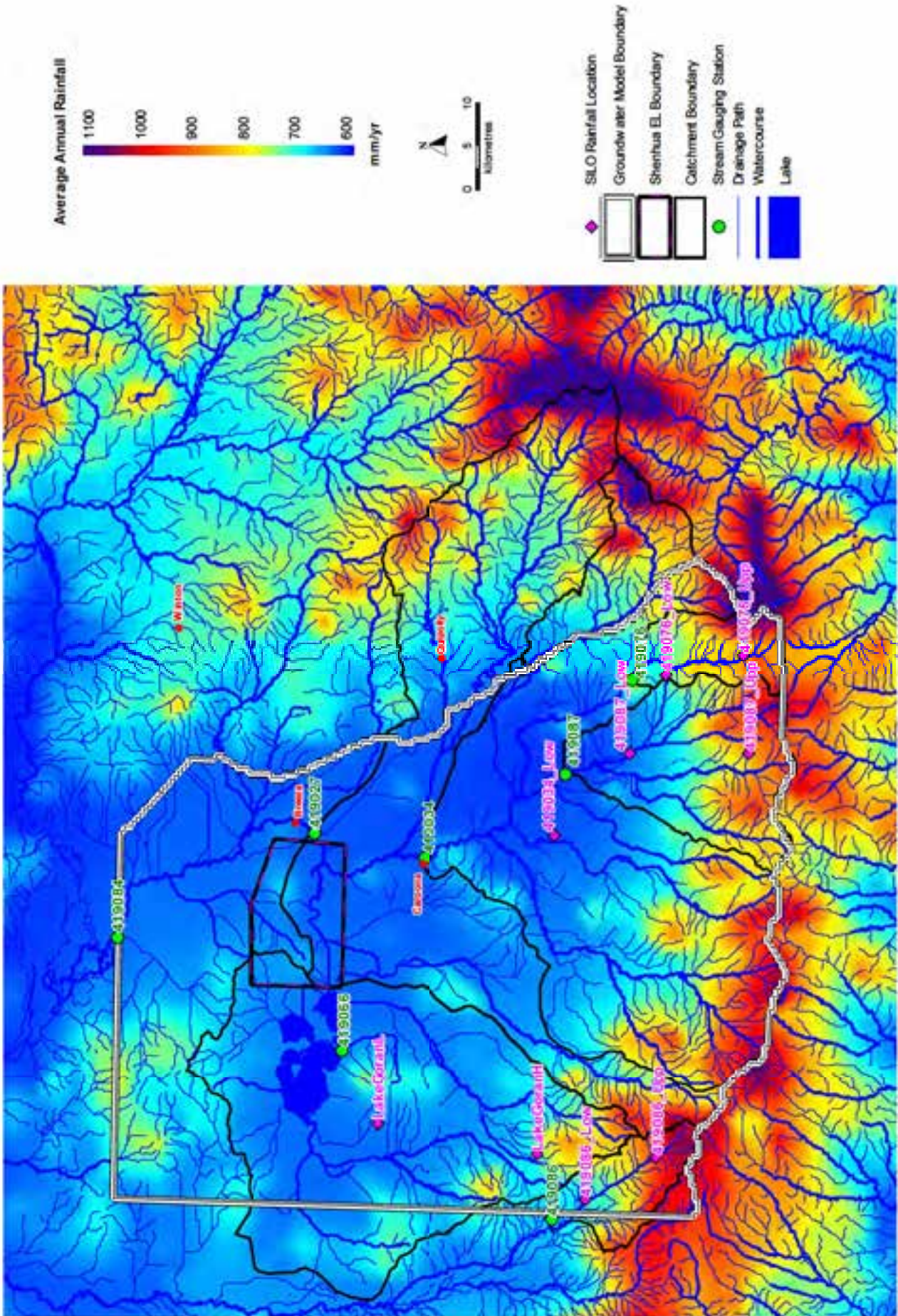


Figure 6.1 Average Annual Rainfalls (BOM 2009), SILO Rainfall Locations & Catchment Boundaries

6.2.5 Lake Goran Historical Water Levels

Recorded water levels at Lake Goran (Station No. 419066 – Goran Lake at Hokey Pokey) are available for the period January 1974 to June 2005 (NOW, 2010). The recorded water levels are presented in Figure 6.2.

Lake Goran stage-storage characteristics were derived from the reservoir rating table (NOW, 2010) and are presented in Table 6.2 and Figure 6.3.

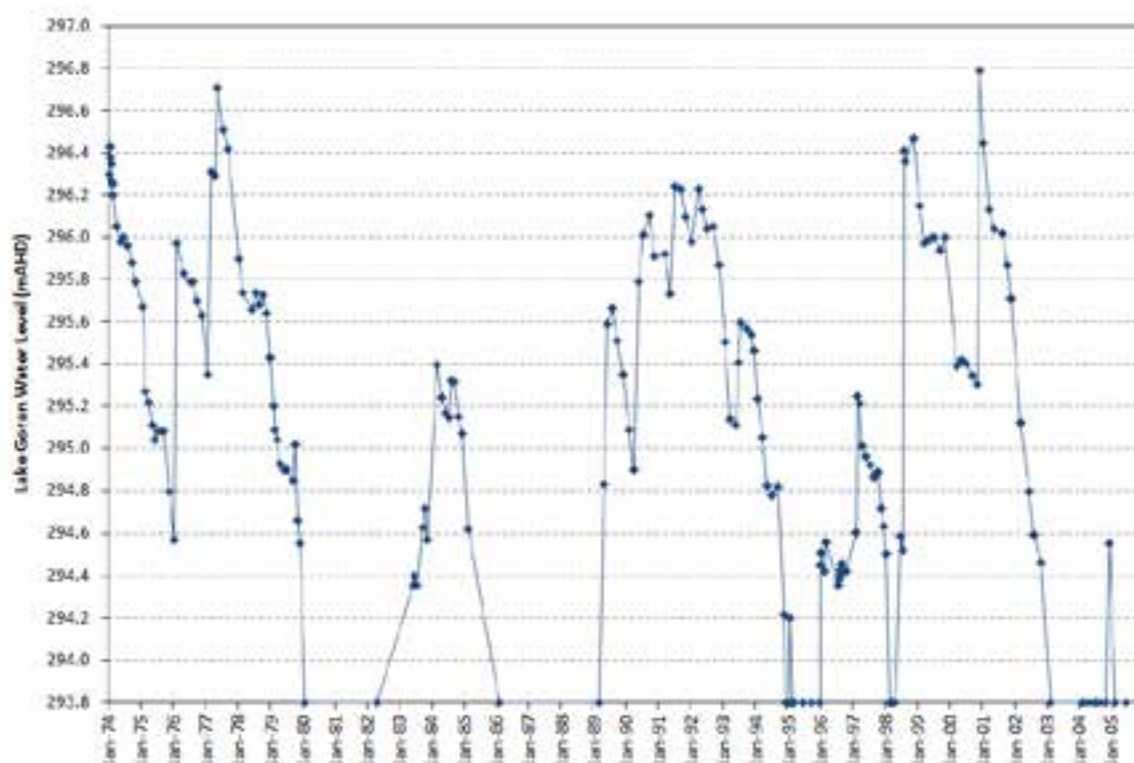


Figure 6.2 Lake Goran (Stn. No. 419066) Recorded Water Levels

Table 6.2 Lake Goran Stage Storage Characteristics (NOW, 2010)

Level (mAH)	Surface Area (ha)*	Volume (ML)
294.0	0	0
294.5	2,840	7,100
295.0	5,700	28,450
295.5	5,990	57,675
296.0	7,620	91,700
296.5 FSL	8,000	130,750
296.8	10,114	157,921
297.0	10,315	178,350
297.5	14,875	241,325
298.0	20,515	329,800
298.5	30,445	457,200
299.0	42,775	640,250

* Surface areas inferred from GIS data and level-volume information.

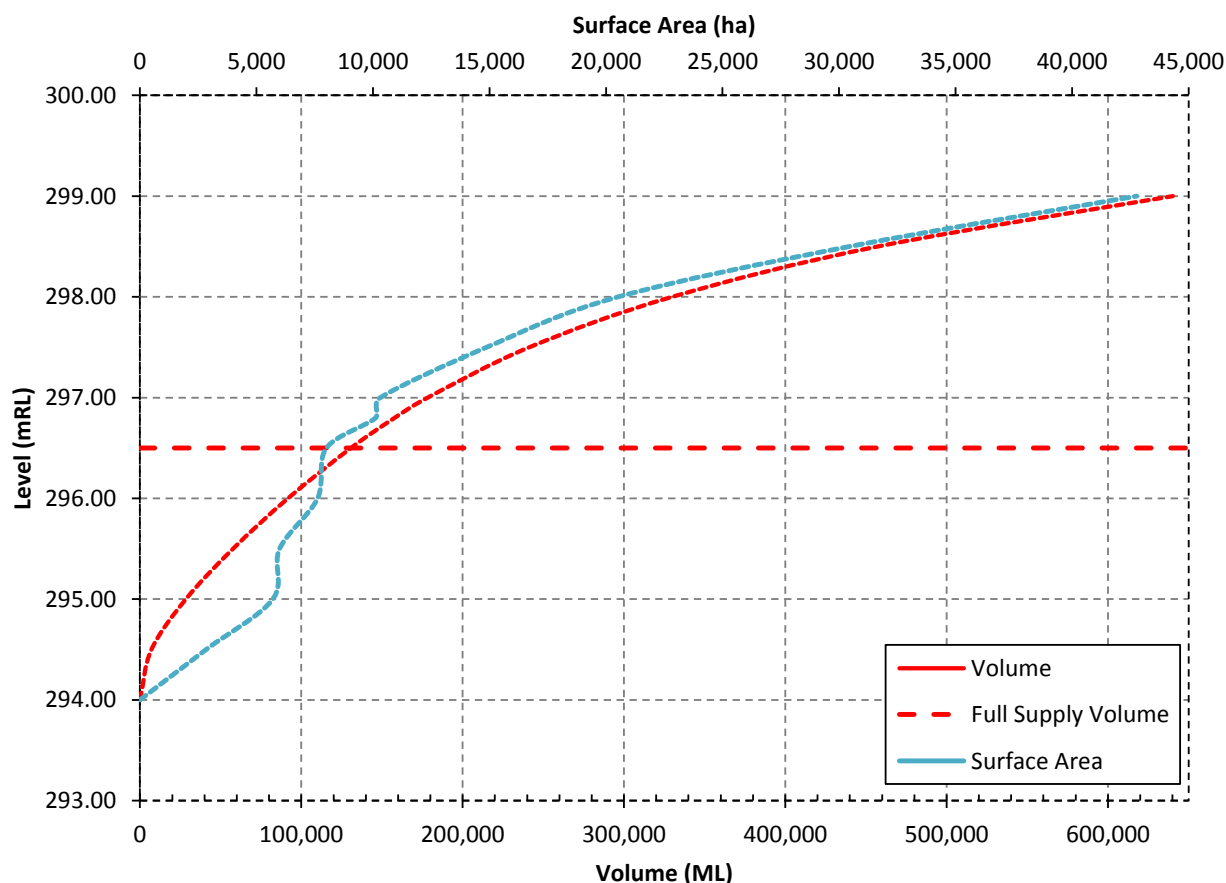


Figure 6.3 Lake Goran Stage Storage Characteristics (NOW, 2010)

6.2.6 Regional Geology

The headwaters of the Mooki River originate on the northern slopes of the Liverpool Ranges and Coolah Tops, flowing in a northerly direction to the Namoi River just north-west of Gunnedah. The regional geology is shown in Figure 6.4, depicting the basalt of the Liverpool Range beds to the south, and the undifferentiated alluvial deposits which comprise a large part of the Mooki River plains.

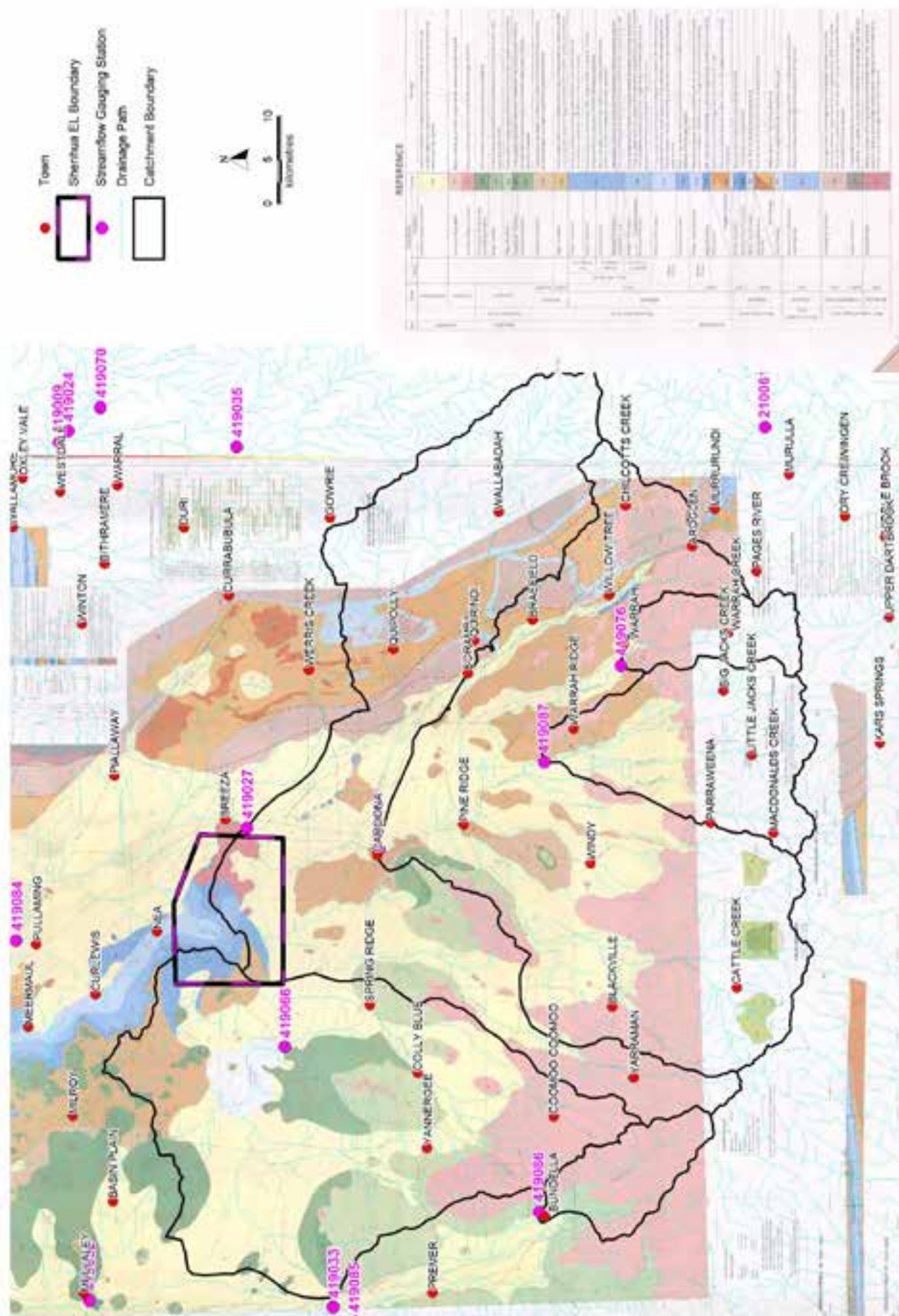


Figure 6.4 Regional Geology (AUSLIG, 1996), Streamflow Gauging Stations and Catchment Boundaries

6.3 ASSESSMENT METHODOLOGY

6.3.1 Overview

The hydrologic assessment of the Mooki River catchment included two components:

- Development and calibration of an AWBM (Boughton 2003) rainfall-runoff model to represent the hydrologic response of the Mooki River catchment; and
- Simulation of the water balance of Lake Goran to verify the rainfall-runoff parameters and the infiltration rate to groundwater as determined in the groundwater modelling (AGE Consultants).

6.3.2 Rainfall-Runoff Modelling of the Mooki River Catchment

The hydrologic response of the Mooki River catchment is potentially affected by the different soils, geology and vegetation across the catchment, as well as the significant variability in rainfall across the catchment. An initial modelling approach was developed based on using separate sets of AWBM model parameters to represent the Liverpool Ranges and the alluvial lands. However, model results indicated that the hydrologic response was much more sensitive to the adopted rainfalls than the AWBM model parameters. It was found that a similar calibration to recorded data could be achieved using the same AWBM parameters for the Liverpool Ranges and alluvial areas. Hence, the adopted modelling approach used a single set of AWBM model parameters.

It was assumed that recorded streamflow data for Warrah Creek (419076) and Bundella Creek (419086) were representative of the hydrologic response of the Liverpool Ranges. These catchments are located in the upper reaches of the Mooki River catchment and are dominated by basalt geology (see Figure 6.4). AWBM model parameters for the Liverpool Ranges were determined by calibrating the model to recorded rainfall and streamflow data for the Warrah Creek catchment (419076). The model parameters were then verified against data for the Bundella Creek catchment (419086). The adopted rainfall for the calibration and verification of the AWBM parameters was based on a representative historical daily rainfall sequence, derived by taking the average of rainfalls from the SILO Data Drill for the upper and lower portions of the catchments.

Once the AWBM parameters representing runoff from the Liverpool Ranges were determined, models of the total catchment to Big Jacks Creek at Warrah Ridge (419087), the Mooki River at Caroona (419034) and the Mooki River at Breeza (419027) were developed by setting up component AWBM models to represent runoff from the Liverpool Ranges and runoff from alluvial areas. The area of “ranges” catchment was assumed to be represented by the extent of basalt geology, as shown in Figure 6.4. The same set of AWBM model parameters was adopted for both the ranges and alluvial catchments, however, different rainfalls were used to reflect the rainfall variability across the catchment (see Figure 6.1). Using this approach, it was found that simulated runoff exceeded the recorded runoff at the downstream gauges. Hence, a simple transmission loss, modelled as a fixed proportion of surface runoff and baseflow was added to the catchment model. The transmission loss was adjusted to achieve reasonable agreement between recorded and simulated streamflows at the downstream gauges. The transmission loss would represent groundwater recharge from surface runoff, as well as water extracted for agricultural use. Previous studies (e.g. Zhang et al 1997) have indicated that significant recharge of the alluvial aquifers occurs through infiltration of runoff from the Liverpool Ranges.

6.3.3 Lake Goran Water Balance

The OPSIM (Water Solutions, 2010) water balance model was used to simulate the water balance of Lake Goran. The AWBM parameters developed for the remainder of the Mooki River catchment were applied to the Lake Goran catchment to estimate surface runoff inflows. The OPSIM model simulated direct rainfall on the lake surface, surface runoff inflows (including a transmission loss rate), evaporation (using Morton's Lake evaporation) and seepage loss. Result of the groundwater modelling investigations (AGE Consultants) found that there is very little groundwater recharge from Lake Goran. Hence, the assumed seepage losses from the lake were set to zero.

The transmission loss rate and an open water evaporation factor were determined by comparing the recorded and simulated water levels for Lake Goran for different assumed transmission loss rates and evaporation factors. This open water evaporation factor is applied only to the evaporation rates from the water surface itself. The sum of the squares of the differences of recorded and simulated water levels was adopted as an objective function. A visual comparison of the recorded and simulated rates of water level drawdown during dry periods was also used to assess the appropriateness of the adopted transmission loss rate and evaporation factor.

6.4 MODEL CALIBRATION AND VERIFICATION RESULTS

6.4.1 Adopted Model Parameters

Table 6.3 and Table 6.4 show the adopted AWBM parameters and model inputs for the different catchments.

Table 6.3 AWBM Parameters	
Parameter	Adopted Value
A1	0.134
A2	0.433
C1	40
C2	80
C3	260
BFI	0.3
K	0.98

Table 6.4 AWBM Modelling Details and Results

	Streamflow Gauging Station					Lake Goran
	Warrah Ck 419076	Bundella Ck 419086	Big Jacks Ck 419087	Mooki at Caroona 419034	Mooki at Breeza 419027	
Simulation Period	17/6/1982- 23/8/2011	8/12/1995- 23/8/2011	2/1/1996- 22/6/2004	11/8/1965- 23/8/2011	2/9/1957-23/8/2011	10/1/1974- 17/6/2005
Adopted Rainfall (refer Figure 6.1)	Average of 419076_Upp and 419076_Low	Average of 419086_Upp and 419086_Low	Ranges catchment: 419087_Upp Alluvial catchment: 419087_Low	Ranges catchment: Average of 419076_Upp and 419076_Low Alluvial catchment: 419034_Low	Ranges catchment: Average of 419076_Upp and 419076_Low Alluvial catchment: 419034_Low	Ranges catchment: LakeGoranH Alluvial catchment: LakeGoranL
Ranges (mm)	24,345	12,505	6,918	36,666	42,705	Refer Lake Goran water balance Table 6.5.
Plains (mm)	n/a	n/a	5,636	30,162	34,880	1,347
Catchment Area (km ²)	146	152	432	2,196	1,745	216
Ranges (km ²)	146	152	280	1,204	1,961	1,131
Plains (km ²)	0	0	152	992	30%	30%
Transmission Loss ^c	n/a	n/a	84%	30%	30%	30%
Outputs						
Runoff Observed (mm) [Period of Record]	1,997	754	153	1,494	1,564	Refer Lake Goran water balance Table 6.5.
Runoff Observed (mm) [1996-2004]	710	455	153	502	467	
Runoff Simulated (mm) [1889-2010]	6,544	5,221	1,633	3,378	3,432	
Runoff Coefficient ^b	8.2%	6.0%	2.4%	4.4%	4.1%	

Notes: ^a Does not include Lake Goran catchment area.

^b Based on observed runoff and spatially averaged rainfall.

^c Applies to runoff from ranges catchment only.

6.4.2 Ranges Catchments

The results of the AWBM model calibration to recorded data at Warrah Creek (419076) are shown in Figure 6.5 (flow-duration curve) and Figure 6.6 (cumulative discharge). The model provides a good representation of flow behaviour for this catchment. The results of the verification runs at Bundella Creek are shown in Figure 6.7 and Figure 6.8. The model also provides a reasonable representation of runoff behaviour for the Bundella Creek catchment.

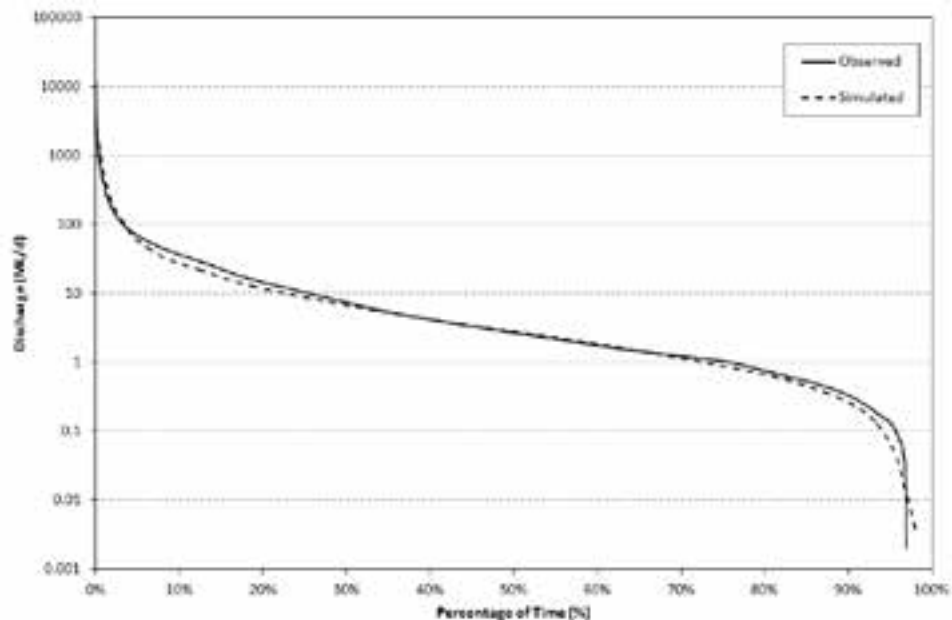


Figure 6.5 Flow Duration Curve, AWBM Model Calibration, Warrah Ck (419076), 17/6/82 – 23/8/11

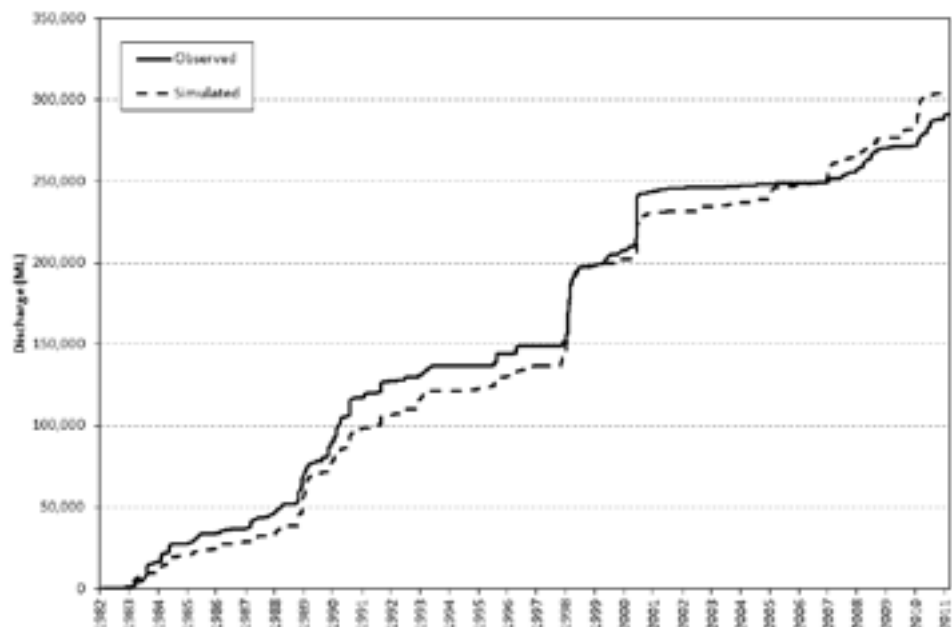


Figure 6.6 Cumulative Discharge, AWBM Model Calibration, Warrah Creek (419076)

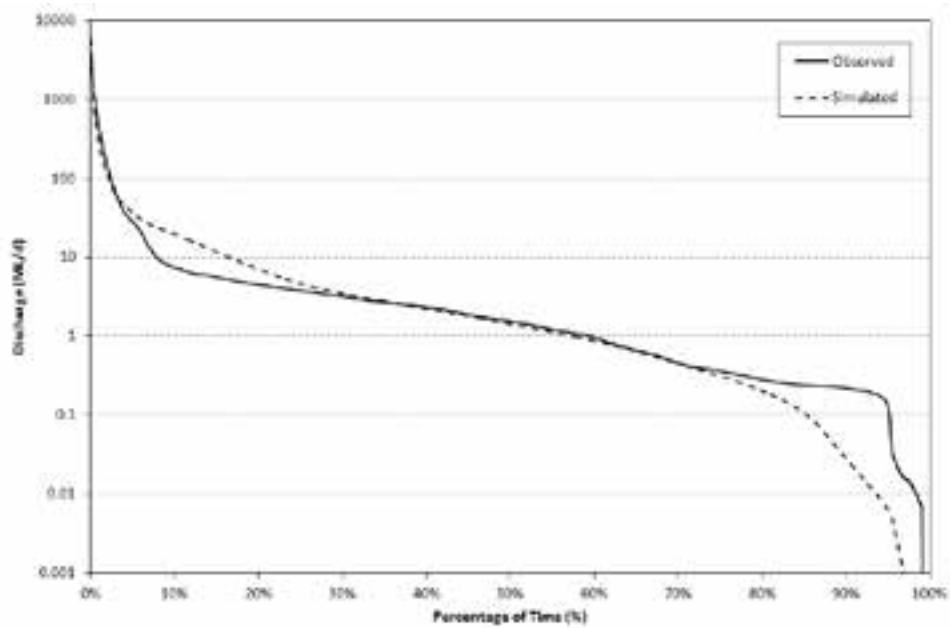


Figure 6.7 Flow Duration Curve, AWBM Model Verification, Bundella Creek (419086), 8/12/95 – 23/8/11

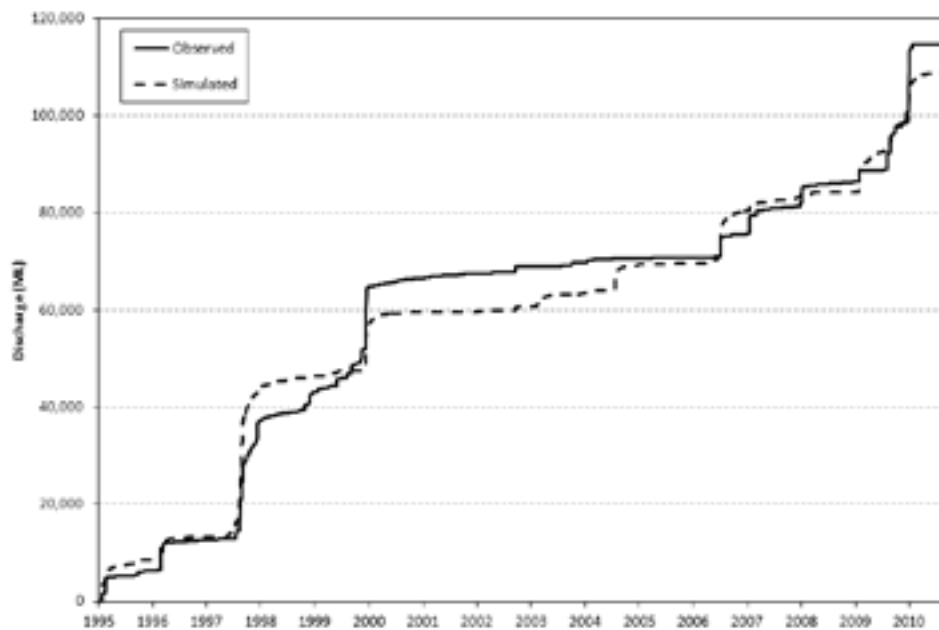


Figure 6.8 Cumulative Discharge, AWBM Model Verification, Bundella Creek (419086)

6.4.3 Alluvial Catchments

Figure 6.9 to Figure 6.14 show the results of the catchment model to the downstream gauges which include the ranges catchments, alluvial catchments and transmission losses.

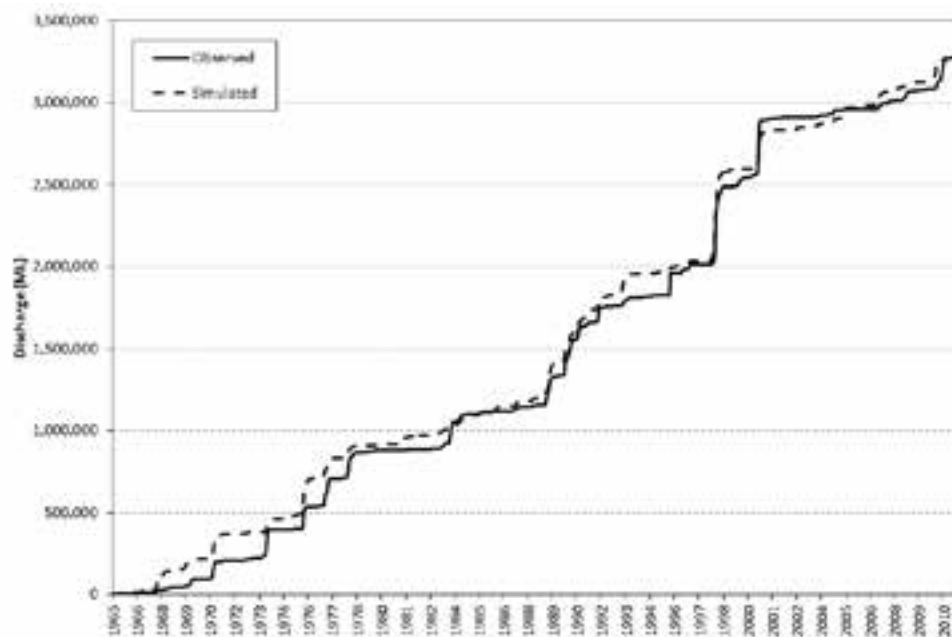


Figure 6.9 Cumulative Discharge, AWBM Model Verification, Caroona (419034)

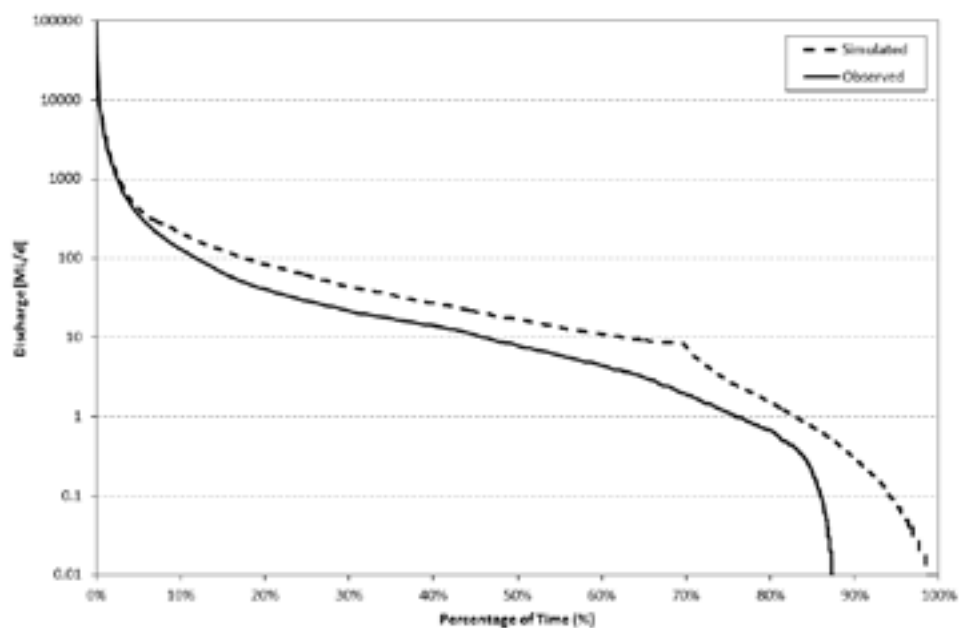


Figure 6.10 Flow Duration Curve, AWBM Model Verification, Caroona (419034) 11/8/65 – 23/8/11

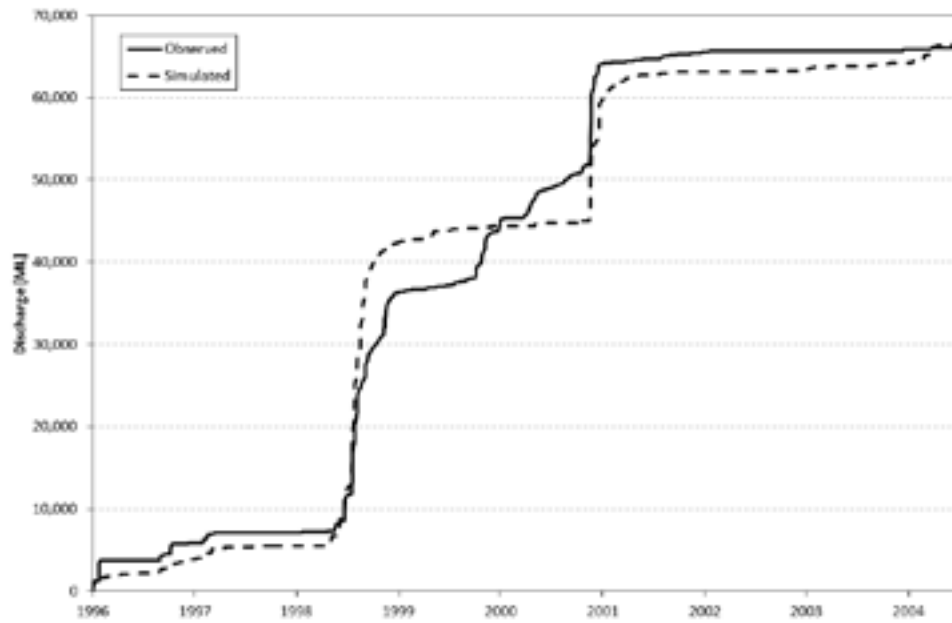


Figure 6.11 Cumulative Discharge, AWBM Model Verification, Big Jacks Creek (419087)

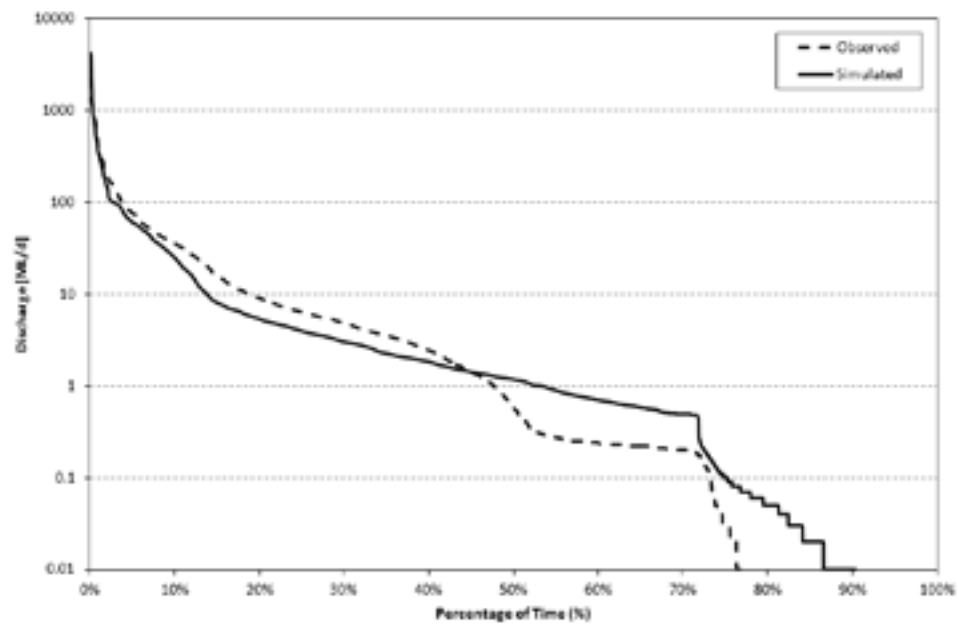


Figure 6.12 Flow Duration Curve, AWBM Model Verification, Big Jacks Creek (419087) 2/1/96 – 22/6/04

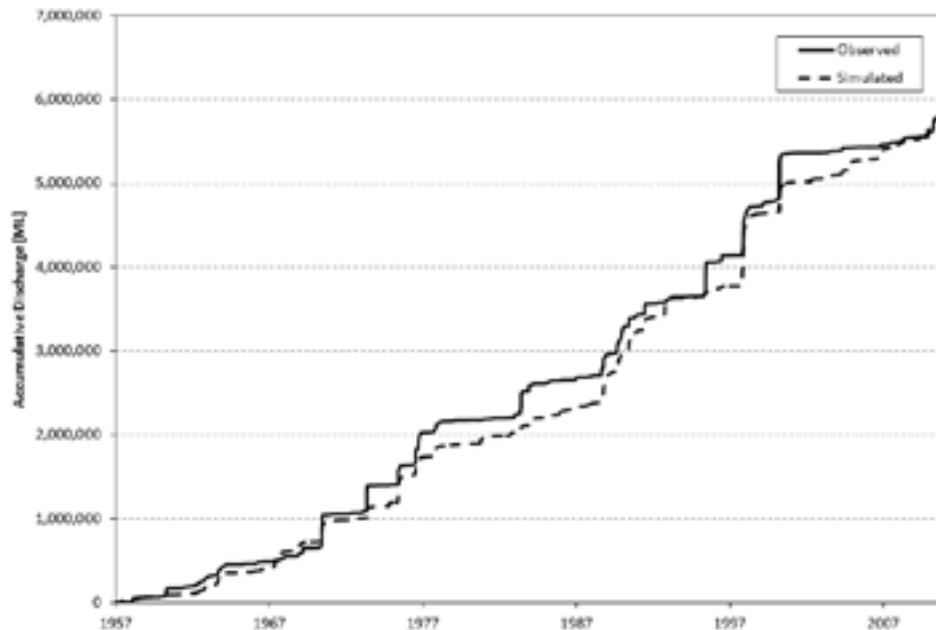


Figure 6.13 Cumulative Discharge, AWBM Model Verification, Mooki at Breeza (419027)

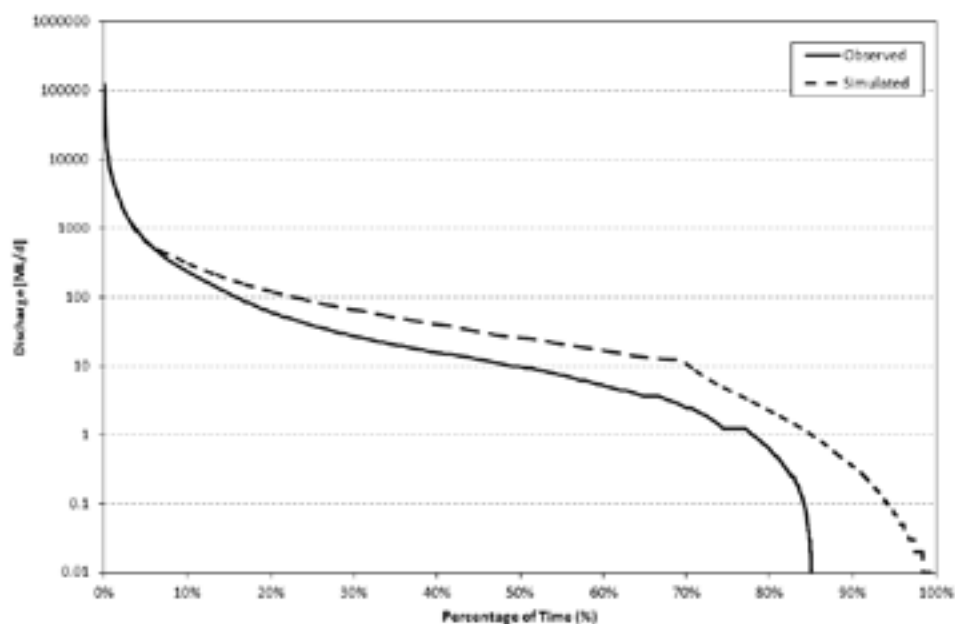


Figure 6.14 Flow Duration Curve, AWBM Model Verification, Mooki at Breeza (419027) 2/9/57 – 23/8/11

Review of the AWBM model calibration results indicates that a single set of AWBM parameters can provide a realistic representation of the rainfall runoff characteristics of the Mooki River catchment to Breeza, including the Liverpool Ranges, the alluvial plains and the Lake Goran catchment. A transmission loss of 30% for runoff from the Liverpool Ranges resulted in good agreement between simulated and observed runoff and water levels, with the exception of the Big Jack's Creek stream gauging station (#419087) for which a transmission loss of 84% was determined. Investigation into the details of this stream gauging station found that the rating curve was 'poor' (NOW 2010), which may explain the difference in the transmission loss rates.

6.5 LAKE GORAN WATER BALANCE

The results of the Lake Goran water balance simulation are shown in Figure 6.15 and Figure 6.16 for an adopted seepage rate of 0mm/d, a transmission loss rate of 30% and an open water evaporation factor of 1.1.

A range of transmission loss rates and evaporation factors were investigated and compared using the sum of the difference of squares as the objective function, as well as visual comparison with the rate of water level drawdown. Results found that a transmission loss rate of 30% and evaporation factor of 1.1 gave the lowest objective function and good agreement with the historical water levels.

Note that detailed information on water extractions from Lake Goran were not available. However, there are currently 9 surface water licences for the Lake Goran water source with a total entitlement of 32,259 ML/year (99.7% for irrigation purposes and 0.3% for stock and domestic purposes) (NOW 2011). Licence conditions include a Cease to Pump level of 294.7 mAHd (14,400ML). Hence, it is possible that the adopted evaporation factor of 1.1 is artificially high to represent water extracted from the lake for irrigation.

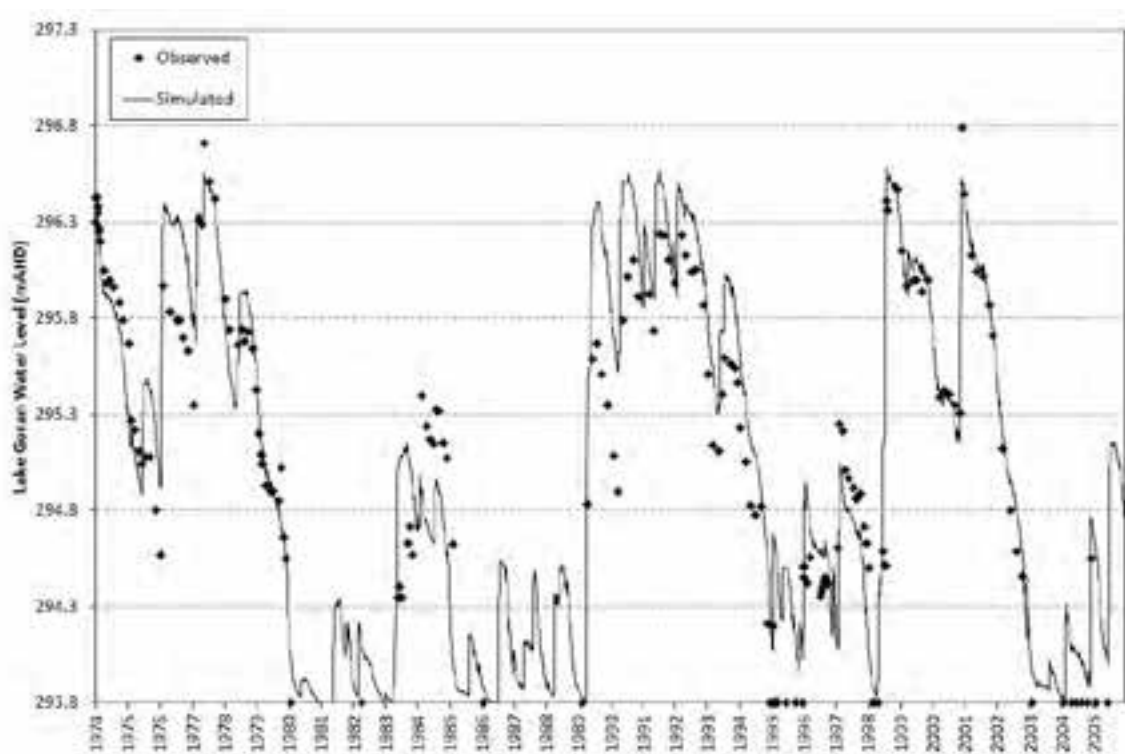


Figure 6.15 Lake Goran Observed & Simulated Water Level

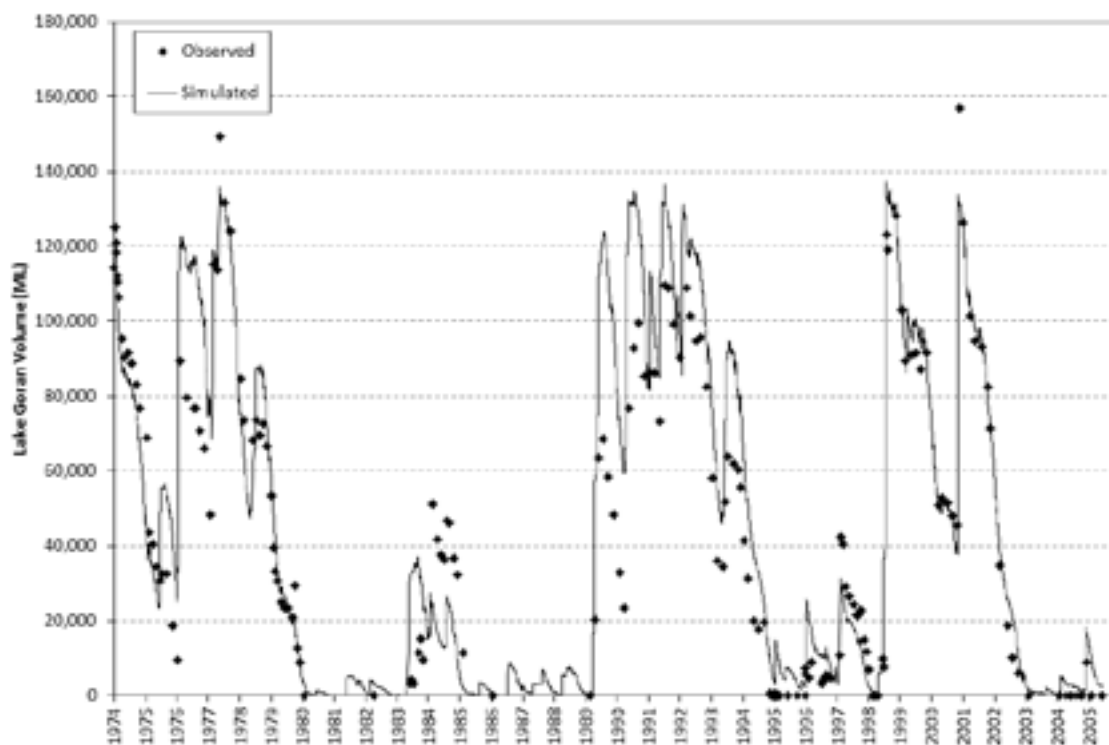


Figure 6.16 Lake Goran Observed & Simulated Volumes

Long term average annual water balance results for the Lake Goran simulation model are shown in Table 6.5. Review of the results indicates that the large surface area of the lake means that a high proportion of inflow comes from direct rainfall on the water surface, as well as very high losses due to evaporation. Spills to Native Dog Gully and transmission losses are only a small portion of the lake outflows.

Table 6.5 Lake Goran Annual Average Water Balance (1889 – 2010)

INFLOWS		ML/a
Direct Rainfall		21,370
Rainfall Runoff		34,550
Total		55,920
OUTFLOWS		
Evaporation ^a		50,300
Spills to Native Dog Gully		3,700
Transmission Loss		1,920
Infiltration to Groundwater ^b		0
Total		55,920

^a Includes irrigation extractions

^b Adopted value based on groundwater modelling results

6.6 CONCLUSIONS

Assessment of the catchment water balance for the Liverpool Ranges and Lake Goran has been undertaken using the AWBM model to determine the rainfall runoff characteristics of the Mooki River catchment.

The following conclusions have been drawn:

- A single set of rainfall runoff model parameters were calibrated, verified and adopted as representative of the rainfall runoff characteristics of the Liverpool Ranges.
- Investigations at streamflow gauges which included both Liverpool Ranges and alluvial plains catchment found that the model results were not overly sensitive to varying model parameters. Higher runoff volumes occurred from the Liverpool range catchments, but this was mostly attributed to higher rainfalls.
- The model parameters determined for the Liverpool Ranges were therefore adopted for the entire catchment.
- A transmission loss of 30% was applied as a fixed percentage to both surface runoff and baseflow runoff from the Liverpool Ranges to all streamflow gauging station analyses except for Big Jack's Creek (#419087). Investigation into the details of the Big Jack's Creek (#419087) stream gauging station found that the rating curve was 'poor' (NOW 2010), which may explain the difference in the transmission loss rates.
- The adopted rainfall runoff model provides a realistic representation of runoff volumes in the area of interest.

7 MINE WATER BALANCE

7.1 OVERVIEW

A computer-based simulation model (OPSIM) was used to assess the dynamics of the mine water balance under conditions of varying rainfall and catchment conditions throughout the development of the Project. The OPSIM model dynamically simulates the operation of the water management system and keeps complete account of all site water volumes and representative water quality on a daily time step.

The model has been configured to simulate the operations of all major components of the water management system. The simulated inflows and outflows included in the model are given in Table 7.1.

Table 7.1 Simulated Inflows and Outflows to Mine Water Management System

Inflows	Outflows
Direct rainfall on water surface of storages	Evaporation from water surface of storages
Catchment runoff	CHPP demand
Groundwater inflows	Dust suppression demand
Raw water supply	Vehicle wash down
	Offsite spills from storages

7.2 CLIMATE DATA

Synthetic historical rainfall and evaporation data for the Project Area from the SILO Data Drill service (Jeffrey et al. 2001) was adopted to simulate the behaviour of the site water management system. The key advantage of adopting the Data Drill dataset is that it has been adjusted to remove accumulated totals over multiple days and to fill periods of missing data using rainfall from nearby stations. The dataset extends from 1889, and includes open water evaporation and potential evapo-transpiration estimates using Morton's Method (Morton, 1983).

Morton's Lake evaporation was used to estimate evaporation loss from storages. Soil moisture evapotranspiration losses in the AWBM model were estimated using Morton's Lake evaporation with an evapotranspiration factor.

7.3 METHODOLOGY

The water management system was modelled using two different methodologies; static and forecast. For both the static and forecast simulations, seven different representative stages of mine life (Years 2, 5, 10, 15, 21, 25 and 30) were modelled to reflect variations over time such as

changes in catchments, ROM coal production and groundwater seepage inflows to the open cut pits. Although the catchment areas will continuously change as the Project progresses, the adopted approach of modelling discrete stages will provide a reasonable representation of conditions over the 30 year period.

The changes in the physical layout are represented in the mine stage plans given in Figure 4.1 to Figure 4.7. The operational rules at each modelled stage are summarised in Table 7.3. Catchment areas (separated by the different land use types) reporting to the mine site storages are provided in Table 7.4. Note that for the Dirty Water System, the natural catchment area includes the area occupied by the water storages.

7.3.1 Static Simulation

For the static simulation, each stage of mine development is modelled separately from the other stages. For each mine stage, the model is run for a 122 year period using the synthetic climatic dataset (1889-2010). This simulation type is useful for providing an indication of the water balance under the specific operating rules adopted for that stage of operation and allows for a comparison of inflows and outflows between the different stages.

7.3.2 Forecast Simulation

The forecast simulation allows the model configuration to change over the modelled 30 year mine life, reflecting changes in the water management system over time. The operational rules and physical layout for each representative stage of mine progression are applied to a range of years given in Table 7.2 and are then linked in the model to reflect variations over time such as catchments, ROM coal production and groundwater seepage.

Table 7.2 Application of Representative Mine Stages to Full Mine Life

Representative Mine Stage	Applied Range of Mine Life
Year 2	Year 1 – Year 3
Year 5	Year 4 – Year 7
Year 10	Year 8 – Year 12
Year 15	Year 13 – Year 17
Year 21	Year 18 – Year 22
Year 25	Year 23 – Year 26
Year 30	Year 27 – Year 30

To assess the effects of varying climatic conditions, the forecast model is run for 92 realisations (with each realisation corresponding to the 30 year mine life), using 122 years of climatic data. A different rainfall input sequence is applied to each realisation. The first realisation adopts climatic data from 1889 to 1919, the second from 1890 to 1920 and so on through the 122 years of historical climatic data available from January 1889 to December 2010. A statistical analysis of the resultant 92 realisations can then be undertaken to assess the behaviour of the various storages over extended dry and wet periods, reflecting the full range of climatic conditions experienced in the last 122 years.

Table 7.3 Watermark Water Balance Model Operational Rules

Node Name	Operational Rules
<u>Raw Water Supply</u>	
External Water Source (e.g. Local Groundwater Bores, Mooki River)	Supplies to Turkeys Nest Dam at as required.
<u>Water Demands</u>	
CPP	Demands from the Dirty Water System at a makeup rate as per Table 7.8.
Haul Road & Pit Floor Dust Suppression	Demands from the Dirty Water System at a rate as per Table 7.5.
Stockpile Dust Suppression	Demands from the Dirty Water System at a rate as per Table 7.6.
Rom Bin Dust Suppression	Demands from the Dirty Water System at a rate as per Table 7.7.
Vehicle Washdown	Demands at a rate of 150kL/d from the Dirty Water System.
<u>Operational Pits</u>	
East Pit	Continuous dewatering to Dirty Water System at variable rate. Receives pit groundwater inflows as per Table 7.10.
South Pit	Continuous dewatering to Dirty Water System at variable rate. Receives pit groundwater inflows as per Table 7.10.
West Pit	Continuous dewatering to Dirty Water System at variable rate. Receives pit groundwater inflows as per Table 7.10.
<u>Water Storages</u>	
Combined Dirty Water Dam + Coal Contact Dam	Receives pit dewatering and sediment dam transfers. Demands from the Turkeys Nest Dam as required at a maximum rate of 80L/s. Supplies to the following demands as required: - CPP - Dust Suppression (Haul Road, Stockpile, ROM Bins) - Vehicle Wash
Turkeys Nest Dam	Storage overflows to Watermark Gully. Receives inflows from external raw water source. Supplies to the Dirty Water System as required.
Sediment Dams	Transfer to Dirty Water System to maintain empty. Storages overflow to Watermark Gully & Tributary and Native Dog Gully
<u>Receiving Waters</u>	
Watermark Gully	Receives storage overflows from Dirty Water System and some sediment dams.
Watermark Gully Tributary	Receives storage overflows from some sediment dams.
Native Dog Gully	Receives storage overflows from some sediment dams.
Lake Goran Tributary	Receives storage overflows from some sediment dams.

Table 7.4 Catchment Areas and Land Use Classifications

Stage	Storage	Runoff Component	Contributing Catchment (ha)				
			Rehabilitated Spoil	Spoil	Roads/ Hardstand	Natural	Mining Pit
Year 2	Active Pit (East)	Surface & Base			4.8	9.1	139.3
	Dirty Water System	Surface & Base			133.6	160.1	
	East Sed Dam 4	Surface & Base		128.8	6.3	4.3	
	East Sed Dam 5	Surface & Base		178.8	14.9	27.4	
Year 5	Active Pit (East)	Surface		273.5	6.7	12.8	122.0
		Base		275.1	6.7	12.8	122.0
	Dirty Water System	Surface & Base			133.6	160.1	
	East Sed Dam 1	Surface		166.2		8.3	
		Base		164.5		8.3	
	East Sed Dam 2	Surface & Base		22.0		3.8	
	East Sed Dam 4	Surface & Base		133.3	1.3	4.3	
	East Sed Dam 5	Surface & Base		179.3	14.2	27.6	
Year 10	Active Pit (East)	Surface	36.6	384.5	24.0	44.9	116.7
		Base	36.6	480.4	24.0	44.9	116.7
	Dirty Water System	Surface & Base			133.6	160.1	
	East Sed Dam 1	Surface	137.4	29.5		8.3	
		Base	135.2	29.4		8.3	
	East Sed Dam 2	Surface	26.4	133.7		10.7	
		Base	28.5	37.8		10.7	
	East Sed Dam 4	Surface & Base	94.4	42.6	1.5	4.3	
	East Sed Dam 5	Surface & Base	84.4	101.6	7.7	27.4	
Year 15	Active Pit (East)	Surface	80.0	258.6	18.2	22.8	118.3
		Base	313.2	671.4	18.2	22.8	118.3
	Dirty Water System	Surface & Base			133.6	160.1	
	East Sed Dam 1	Surface	166.7			8.3	
		Base	164.5			8.3	
	East Sed Dam 2	Surface	259.6	149.0		13.2	
		Base	48.4	2.6		13.2	
	East Sed Dam 3	Surface	19.9	295.7			
		Base		29.1			
	East Sed Dam 4	Surface & Base	94.4	43.3	1.8	4.3	
	East Sed Dam 5	Surface & Base	171.1	14.9	7.5	27.4	

Stage	Storage	Runoff Component	Contributing Catchment (ha)				
			Rehabilitated Spoil	Spoil	Roads/ Hardstand	Natural	Mining Pit
Year 21	Active Pit (South)	Surface		270.8	4.7		73.4
		Base		454.3	4.7		73.4
	Dirty Water System	Surface & Base			133.6	160.1	
	East Sed Dam 1	Surface					
		Base	164.4			8.3	
	East Sed Dam 2	Surface					
		Base	50.0			13.9	
	East Sed Dam 3	Surface	184.3	374.4		16.1	
		Base	11.2	2.4		16.1	
	East Sed Dam 4	Surface	161.7	330.7			
		Base	77.5	11.5			
	East Sed Dam 5	Surface & Base	172.3	20.8	0.4	27.4	
	South Sed Dam 1	Surface		152.5		33.0	
		Base		110.5		33.0	
	South Sed Dam 2	Surface		131.9		4.6	
		Base		33.5		4.6	
	South Sed Dam 3	Surface		84.7	4.6	9.8	
		Base		41.4	4.6	9.8	
Year 25	Active Pit (West)	Surface		239.1	15.7		146.0
		Base		359.8	16.5		146.0
	Dirty Water System	Surface & Base			133.6	160.1	
	East Sed Dam 1	Surface	175.0				
		Base	172.8				
	East Sed Dam 2	Surface	429.6			13.9	
		Base	50.0			11.5	
	East Sed Dam 3	Surface	558.6			16.1	
		Base	13.6			15.5	
	East Sed Dam 4	Surface	492.3				
		Base	89.1				
	East Sed Dam 5	Surface & Base	193.1		0.4	27.4	
	South Sed Dam 1	Surface	134.0	18.4		33.0	
		Base	109.0	1.5		33.0	
	South Sed Dam 2	Surface	107.8	24.1		4.6	
		Base	33.5			4.6	
	South Sed Dam 3	Surface	55.9	32.5		10.8	
		Base	40.8	0.8		10.8	
	South Sed Dam 4	Surface & Base		346.5	2.3		
	West Sed Dam 2	Surface		334.8	3.7	23.1	
		Base		214.1		23.1	

Stage	Storage	Runoff Component	Contributing Catchment (ha)				
			Rehabilitated Spoil	Spoil	Roads/ Hardstand	Natural	Mining Pit
Year 30	Active Pit (West)	Surface		41.0	4.5		61.8
		Base	108.4	542.4	7.2		61.8
	Dirty Water System	Surface & Base			133.6	160.1	
	East Sed Dam 1	Surface	175.0				
		Base	172.8				
	East Sed Dam 2	Surface	430.5			13.1	
		Base	50.8			10.7	
	East Sed Dam 3	Surface	559.4			15.9	
		Base	13.6			16.1	
	East Sed Dam 4	Surface	492.3				
		Base	89.1				
	East Sed Dam 5	Surface & Base	193.2		0.4	27.8	
	South Sed Dam 1	Surface	152.5			33.0	
		Base	110.5			33.0	
	South Sed Dam 2	Surface	131.9			4.6	
		Base	33.5			4.6	
	South Sed Dam 3	Surface	88.3			10.8	
		Base	41.6			10.8	
	South Sed Dam 4	Surface & Base	96.9	251.9			
	West Sed Dam 1	Surface & Base		395.5			
	West Sed Dam 2	Surface	300.0	137.6	4.5	15.2	
		Base	183.9	30.3	3.1	23.0	

7.4 CONCEPTUAL WATER MANAGEMENT SYSTEM LAYOUT

The conceptual water management system layout from the Surface Water Assessment of the Feasibility Study (GHD 2011) has been adopted as a basis for the current water balance model, with the following exceptions:

- The Dirty Water Dam and Coal Contact Dam have been modelled as a combined storage (referred to herein as Dirty Water System) of 2,000 ML capacity.
- Potable water use is not included in the model as the volumes of potable water are insignificant compared to water volumes in the mine water management system.

The periods of operation of each water storage are presented in Figure 7.1. Note that once the entire catchment of a sediment dam has been rehabilitated for longer than 2 years it has been assumed that the catchment water quality is acceptable for release and the sediment basin no longer pumps water to the Dirty Water Dam but will be released offsite. The water management system is shown schematically in Figure 7.2.

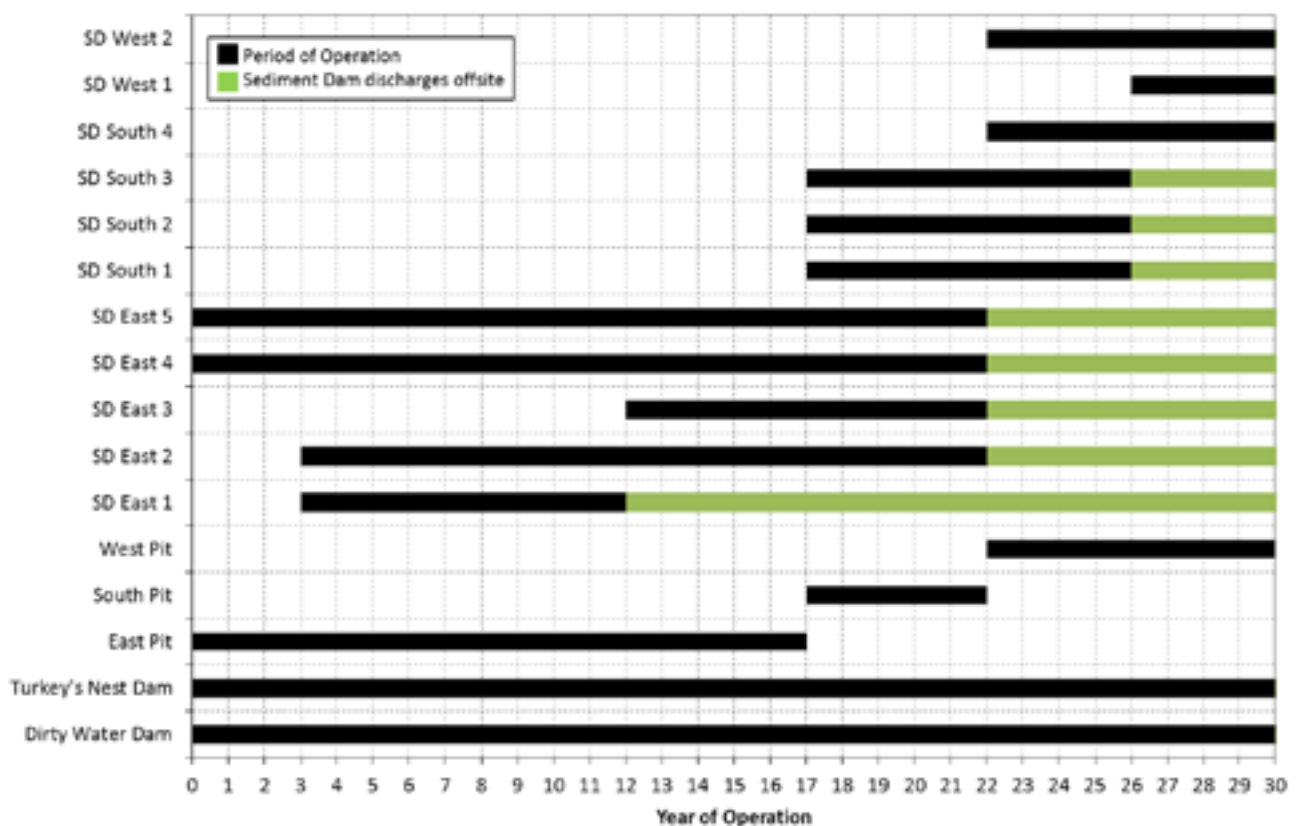


Figure 7.1 Watermark Storages and Periods of Operation

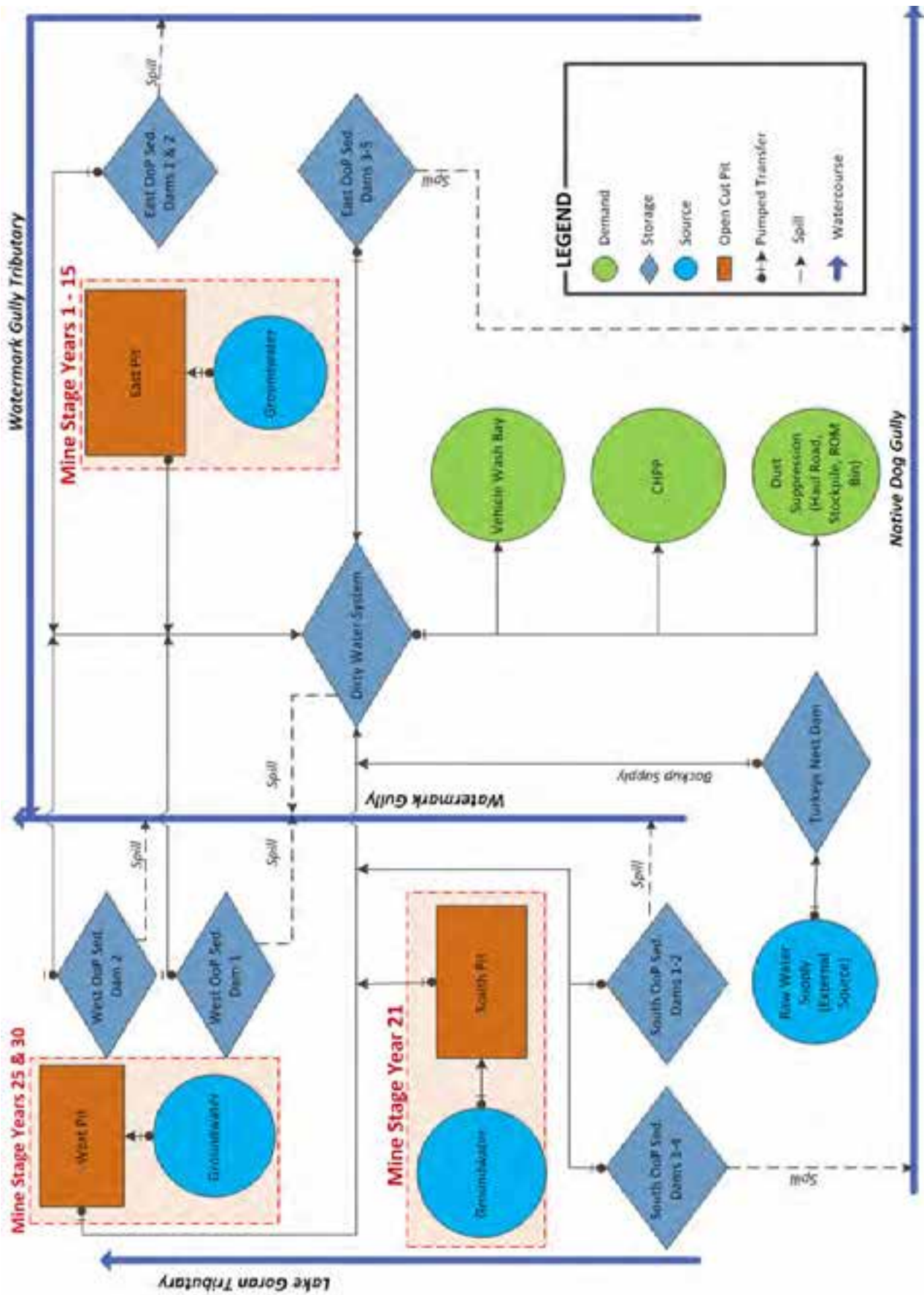


Figure 7.2 Watermark Water Management System Schematic

7.5 STORAGE CAPACITIES

The following storage capacities were adopted for the water balance modelling:

- Dirty Water Dam + Coal Contact Dam – 2,000 ML
- Turkey's Nest Dam – 50 ML

Pit capacities have been estimated from the contour information supplied with the mine plans, and are as follows:

- East Pit:
 - Year 2 – 5,700 ML
 - Year 5 – 51,000 ML
 - Year 10 – 83,000 ML
 - Year 15 – 52,000 ML
- South Pit:
 - Year 21 – 39,000 ML
- West Pit:
 - Year 25 – 25,000 ML
 - Year 30 – 51,000 ML
- Final Void – 51,000 ML

Sediment dam sizes have been based on the proposed design standards for sediment control dams (see Section 7.8). Storage surface areas have been estimated based on an assessment of required dam volumes and likely dam footprint areas.

7.6 WATER DEMANDS

7.6.1 Dust Suppression

Dust suppression is comprised of three components: haul road watering, stockpile watering and ROM bin watering. The feasibility study (GHD 2011) assumed haul road and mine pit watering were constant throughout mine life, whereas stockpile dust suppression was assumed to scale with plant throughput.

Experience from currently operational mine sites in the Hunter Valley indicates a watering rate for haul roads typically in the range of 2.5 – 3 mm/d. The evapotranspiration rate at Watermark is approximately 1500mm/a, which equates to 4.1mm/d on average. Dust suppression watering rates need to be sufficient to replace evaporative losses. Considering these factors, a dust suppression watering rate of 4mm/d has been adopted for modelling purposes.

Dust suppression watering rates are based on a daily time series dataset, consistent with the adopted rainfall dataset and methodology, as specified in Section 7.2. The adopted daily dust suppression watering time series assumes that:

- on days on which the rainfall depth is greater than 5mm/d, no dust suppression will be required;
- when daily rainfall is less than 5mm/d, the rate of 4mm/d is interpolated linearly with rainfall; and
- when there is no daily rainfall, a dust suppression watering rate of 4mm/d is applied.

This method allows for seasonal variation in dust suppression water application rates based on rainfall variability. Since the adopted dust suppression time series is linked to the long term daily rainfall, the impact on dust suppression water demand during wet and dry periods in the climate record are incorporated in the water balance assessment. The resultant average daily dust suppression watering rate of the adopted dataset (including rainfall days) is 3.4mm/d.

7.6.2 Haul Road Dust Suppression

A chemical dust suppressant agent will be applied to haul roads to minimise water usage in the middle stages of mine life (mining stages Year 5 to Year 21). The adopted haul road watering rate is 1.92 mm/day (0.08 L/m²/hr), which represents a reduction in water demand for haul roads of about 50%. The resultant average daily dust suppression watering rate of the adopted dataset (including rainfall days) is 1.63 mm/d with the use of chemical dust suppressants.

A detailed study of mine water management at 11 open cut mines in the Bowen Basin and Hunter Valley (ACARP, 2008) found a median water application rate of 2.5 mm/day and that leading practice haul road dust suppression used a water application rate of approximately 1.26 mm/day, without the assistance of chemical dust suppression agents. With the use of a chemical dust suppressant, the maximum adopted road watering rate of 1.92 mm/day should be easily achievable for the Project.

An extract from the relevant study is provided below (ACARP, 2008). Note that the average water use rates for the Hunter Region in Table C2 are heavily skewed due to the reported dust suppression water use rates of Mine Site 19, provided in Table C1. The reported usage at this mine site is an order of magnitude larger than all of the other sites. As noted in the ACARP report, Mine Site 19 has excess water and uses dust suppression as a water disposal strategy. Hence, this site is not considered representative of typical water management practice.

Mine sites considered in the ACARP (2008) report are located in the Hunter Valley and Bowen Basin. Representative annual rainfall and evaporation for the Bowen Basin, Hunter Valley and Gunnedah Basin are summarised as follows:

- Bowen Basin (Moranbah) Rainfall = 607mm, Evaporation = 2300 mm
- Hunter Valley (Singleton) Rainfall = 737 mm, Evaporation = 1640 mm
- Gunnedah Basin (Gunnedah) Rainfall = 627, Evaporation = 1750 mm.

The Watermark Project is located in an environment with average annual rainfall and evaporation between the Hunter Valley and Bowen Basin. Hence, the dust suppression rates reported in the ACARP (2008) report are likely to be indicative of values at the Watermark Project.

The staged mine plans were used to determine haul road lengths as the mine develops, as well as pit floor and stockpile areas. A watered road width of 25m has been assumed. The resultant average dust suppression of the adopted daily time series is presented in Table 7.5.

Table C 1: Dust Suppression Water Use Rates

Region		Mine Site	Volume per Length of Haul Road (ML/km/month)	Volume per Area of Haul Road (L/m ² /day) [†]
North Bowen Basin		2	2.8	2.6
		3	2.9	2.7
		4	0.9	0.8
		8	1.1	1.0
		9	4.0	3.7
South Bowen Basin		12	2.0	1.8
		13	2.7	2.5
		17	1.5	1.4
Hunter Valley		18	2.5	2.3
		19	26.7	25.0
		20	5.0	4.7

* Based on estimated road length from map, actual road length not provided

† Based on 35m road width

From this table, average regional water use rates could be derived.

Table C 2- Average Water Use Rates by Region

	Mean (ML/km/month)	Mean (L/m ² /day)
All Sites	5.8	5.4
North Bowen Basin	2.3	2.2
South Bowen Basin	2.0	1.9
Hunter Valley	12.9	12.1

Production ratios vary from site to site but there is a clear trend for mines in the South Bowen Basin to use lower rates. One mine in the Hunter Valley has a significantly higher rate. This mine has an excess of worked water. Its wet indicator is 95% for Mine 19. It uses dust suppression as a strategy to lower its worked water stocks and minimise its discharge risk.

A review of environmental impact statements submitted by various mines showed that the water use rate that is used for planning purposes is 3L/m²/day. Two-thirds of the sites have lower use rate and are thus operating below what is considered current or normal practice.

Leading practice values for dust suppression use rate were selected as the 15th percentile in the range of each data set: 1.39 ML/km/month and 1.26 L/m²/day. We selected the 15th percentiles rather than the minima of each data set to take into account some of the uncertainties attached to some of the collected data.

Table 7.5 Estimated Haul Road Dust Suppression Requirements

Mining Stage (Year)	Haul Road Length (km)	Dust Suppression Area (ha)* ¹	Maximum Daily Dust Suppression (kL/d)* ²	Yearly Average Dust Suppression (ML/a)* ³
2	11.0	27.6	1,104	342
5	10.1	25.1	483	149* ⁴
10	12.7	31.7	609	189* ⁴
15	11.7	29.3	562	174* ⁴
21	10.5	26.3	505	157* ⁴
25	12.7	31.7	608	393
30	8.6	21.5	858	266

*¹ Includes haul road and pit floor dust suppression.

*² For a non-rainfall (0mm) day.

*³ Based on long-term average including rainfall days.

*⁴ Reduced water requirement due to application of dust suppressant.

7.6.3 Stockpile Dust Suppression

Based on a ROM stockpile of 3,000m² per million tonnes of plant throughput, the stockpile dust suppression demands are presented in Table 7.6. It is assumed that washed coal stockpiles will require minimal dust suppression.

Table 7.6 Water Balance Adopted Stockpile Dust Suppression Requirements

Mining Stage (Year)	Stockpile Dust Suppression Area (m ²)	Maximum Daily Dust Suppression (kL/d)* ¹	Yearly Average Dust Suppression (ML/a)* ²
2	8,100	32	10
5	30,000	120	37
10	30,000	120	37
15	29,400	118	36
21	30,000	120	37
25	30,000	120	37
30	5,700	23	7

*¹ For a non-rainfall (0mm) day.

*² Based on long-term average including rainfall days.

7.6.4 ROM Bin Dust Suppression

Dust suppression demands for the ROM bins have adopted the estimates given in the feasibility report, which were based on 8 trucks/hr and an 80% loss rate. The net demand has been scaled in proportion with the proposed plant throughput and is presented in Table 7.7. Note that this demand is not affected by rainfall.

Table 7.7 EIS Water Balance Adopted ROM Bin Dust Suppression

Mining Stage (Year)	ROM Mtpa (wet)	ROM Bin Net Dust Suppression	
		(kL/d)	(ML/a)
2	2.7	41	15
5	10	150	55
10	10	150	55
15	9.8	147	54
21	10	150	55
25	10	150	55
30	1.9	29	10

7.6.5 Coal Preparation Plant

The adopted net CHPP demand rate is 76 L/ROM tonne, based on estimates provided by CPG Resources for a coal processing facility using belt press filters (CPG, 2012). The adopted CHPP water demand for each modelled stage is provided in Table 7.8.

Table 7.8 Adopted CHPP Water Usage

Mining Stage (Year)	ROM Mtpa (wet)	CPP Net Demand (ML/a)
2	2.7	205
5	10	760
10	10	760
15	9.8	745
21	10	760
25	10	760
30	1.9	144

7.6.6 Vehicle Washdown

The feasibility study assumed vehicle wash (light and heavy) was constant during mine life at a net rate of 55ML/a (150kL/d) with a return rate of 90% adopted (i.e. 5.5ML/a loss). These estimates were based on 50 light vehicle and 2 heavy vehicle washes per day. These values have been adopted for the current water balance.

7.6.7 Demand Summary

A summary of the Project demands is presented in Table 7.9 below.

Table 7.9 Summary of Project Demands – Net Usage

Mining Stage (Year)	Average Haul Road Dust Suppression (ML/a)	Average Stockpile Dust Suppression (ML/a)	ROM Bin Dust Suppression (ML/a)	CPP Net Demand (ML/a)	Net Vehicle Washdown (ML/a)	Average Total Site Demand (ML/a)
2	342	10	15	205	5.5	580
5	149	37	55	760	5.5	1010
10	189	37	55	760	5.5	1050
15	174	36	54	745	5.5	1010
21	157	37	55	760	5.5	1010
25	393	37	55	760	5.5	1255
30	266	7	10	144	5.5	430

7.7 WATER SOURCES

7.7.1 Groundwater Inflows

Groundwater inflows to the open cut pits over the life of the Project were adopted based on estimates provided by AGE (August 2012). The average groundwater inflow rate for each modelled stage was adopted for the water balance model, as shown in Table 7.10. Based on advice from AGE, the groundwater inflow rates provided are assumed to already account for moisture lost to evaporation and in the mined coal.

Table 7.10 Pumpable Groundwater Inflows

Mine Stage (Year)	Estimated Average Groundwater Inflow	
	ML/annum	kL/day
2	0	0
5	14	37
10	57	157
15	43	117
21	175	480
25	371	1016
30	132	362

7.7.2 Catchment Runoff

Catchment runoff from external catchments was modelled using the AWBM rainfall-runoff model. Catchments across the site have been characterised into the following land use types:

- Natural/Undisturbed
- Un-rehabilitated Spoil
- Rehabilitated Spoil
- Roads/Hardstand (including pit floor & prestrip).

For undisturbed areas, model parameters from a model calibrated to recorded streamflow data for natural catchments in the vicinity of the project were adopted (see Section 5).

AWBM model parameters for compacted areas were selected by adopting values to provide a volumetric runoff coefficient similar to typical values for urban catchments which have similar characteristics. AWBM model parameters for spoil catchments were adopted from a previous study of runoff from disturbed mine catchments in the Hunter Valley region (ACARP, 2001). Rehabilitated spoil is assumed to have the same parameters as natural land type. The parameters are shown in Table 7.11.

Table 7.11 Adopted Rainfall-Runoff Parameters – AWBM Model

Parameter	Natural/ Undisturbed	Un-rehabilitated Spoil	Rehabilitated Spoil	Roads/ Hardstand
A1	0.134	0.1	0.134	0.33
A2	0.433	0.3	0.433	0.33
C1	40	15	40	2
C2	80	50	80	10
C3	260	110	260	30
C _{AVG}	153	82.5	153	14.2
K	0.98	0	0.98	0
BFI	0.3	0.2	0.3	0
Lake to Evapotranspiration Factor	0.99	0.99	0.99	0.99
Long-term Volumetric Runoff Coefficient	3.6%	7%	3.6%	35.4%

7.7.3 Raw Water

For the purposes of current investigations, the term ‘raw water’ represents the amount of raw water imported from an external, offsite source that is required to sustain the nominated design production rate and associated operational demands for the Project. Any shortfall in mine water is made up from imported raw water – that is, during dry periods imported raw water is used to ensure that all operational demands are met. It is assumed that water collected on site is used before water is imported. Raw water, if required, will be pumped to the Turkey's Nest Dam and into the Dirty Water System.

7.8 SEDIMENT DAMS

7.8.1 Sizing

Conceptual sediment dam locations were determined as part of the feasibility studies (GHD, 2011). These dams have been moved slightly to match the current mine plans. There are a total of 5 sediment dams proposed for the East Out of Pit dump, 4 sediment dams proposed for the South Out of Pit dump, and 2 sediment dams proposed for the West Out of Pit Dump.

The sediment dams have been sized in accordance with current recommended design standards in the following guidelines:

- Managing Urban Stormwater, Soils and Construction (Landcom, 2004); and
- Managing Urban Stormwater, Soils and Construction, Mines and Quarries (DECC, 2008).

The sediment dam volumes will be based on the following design standards and methodology:

- “Type F” sediment basins consistent with SD 6-4 (page 6-19, Landcom 2004);
- Total sediment basin volume = settling zone volume + sediment storage volume. The sediment storage volume is the portion of the basin storage volume that progressively fills with sediment until the basin is de-silted. The settling zone is the minimum required free storage capacity that must be restored within 5 days after a runoff event;
- Sediment basin settling zone volume based on 90th percentile 5-day duration rainfall (38.4mm) with an adopted volumetric event runoff coefficient for disturbed catchments of 0.64; and
- Sediment storage volume = 50% of settling zone volume.

Table 7.12 provides the adopted sediment dam volumes and the associated pump requirements to restore the settling zone capacity within 5 days. Note that current design guidelines (DECC, 2008) allow for the adoption of larger dam sizes to allow for dewatering over a longer period to reduce the required pumping rate.

Table 7.12 Sediment Dam Sizing

Sediment Dam	Maximum Catchment Area (ha)	Total Volume Required (ML)	5 day Pump Requirement (L/s)
East 1	120	43	100
East 2	450	167	385
East 3	580	212	490
East 4	490	179	420
East 5	230	83	190
South 1	240	87	200
South 2	140	51	120
South 3	100	37	85
South 4	350	130	300
West 1	400	146	340
West 2	480	176	410

7.8.2 Sediment Dam Collection System – Operating Rules

The operating rules for the sediment dam collection system are based on the recommendations in the guidelines ‘Managing Urban Stormwater Soils and Construction Guideline: Mines and Quarries’ (DECCW 2008). The operating rules are as follows:

- Runoff from disturbed areas will be captured in a sediment dam and pumped to the Dirty Water Dam.

- Pump capacities will be sized to empty sediment dams in 5 days.
- Runoff from rehabilitated areas established for more than 2 years will be directed to a sediment dam and released off-site.

7.9 PUMP CAPACITIES

The following pump capacities have been adopted for the water balance model:

- Pit dewatering – staged pumping depending on water volume:
 - <100ML: 100L/s (8,640kL/d)
 - 100 – 200ML: 200L/s (17,280kL/d)
 - >300ML: 300L/s (25,920kL/d)
- Sediment Dams – as per Table 7.12 (empty in 5 days)
- Turkey's Nest Dam - 80L/s – (6,900kL/d)

7.10 WATER BALANCE MODEL RESULTS

7.10.1 Overview

The OPSIM model was used to assess the performance of the proposed water management system, including:

- Mine storage inventory;
- Raw water requirements from an external source;
- Uncontrolled spills from the mine water storages; and
- The overall water balance within the study area.

It is important to note that investigation outcomes are dependent on the accuracy of input assumptions. There is inherent uncertainty with respect to some key site characteristics (e.g. catchment yield/rainfall runoff, mining area groundwater inflows) which cannot be accurately determined prior to the commencement of operations.

7.10.2 Potential Impacts

The potential impacts on surface water for the Project include:

- Potential to run out of water for the production of coal;
- Potential for uncontrolled spills from the mine water dams; and
- Potential to impact on production as a result of in-pit inundation.

An assessment of these impacts using the OPSIM Model developed for the Project is provided below.

7.10.3 Static Simulation Results

Table 7.13 provides the long term daily average water balance for each of the 7 representative mine stages. See Section 7.3 for a description of static simulation modelling methodology. The following is of note:

- The gross water deficit is equivalent to the raw water inflow to the model;

- The average annual volume of water required from an external source, across each of the 7 representative stages, is 83 ML.
- Year 5 requires the greatest amount of raw water supplied. This stage has a total demand similar to Year 10, 15, 21 and 25, however the groundwater inflow rate during this stage is much lower than the other mine stages;
- Year 21 has the highest total rainfall runoff yield due to its large catchment areas and relative proportion of unrehabilitated to rehabilitated spoil;
- The highest groundwater inflows occur during Year 25;
- Total evaporation and off-site spills from sediment dams generally increase towards the end of mine life, due to the greater number of active sediment dams; and
- Haul road dust suppression is reduced in Year 5, 10, 15 and 21 due to the use of a chemical dust suppressant agent to reduce the required haul road watering rate.

Table 7.13 Long Term Daily Average Water Balance (ML/annum)

		Stage						
		Year 2	Year 5	Year 10	Year 15	Year 21	Year 25	Year 30
Water Inputs								
Rainfall/Runoff Yield								
	<i>Dirty Water System</i>	552	511	529	544	562	558	587
	<i>Active Pit</i>	378	485	634	629	399	606	359
	<i>Turkeys Nest Dam</i>	16	16	16	16	16	16	16
	<i>Sediment Dams</i>	239	331	309	471	830	486	508
	Total Rainfall Yield	1,185	1,342	1,487	1,660	1,807	1,666	1,470
Groundwater Inflow to Active Pits		0	14	57	43	175	371	132
Gross Water Inputs		1,185	1,356	1,545	1,702	1,982	2,037	1,602
Water Outputs								
Evaporation from Storages								
	<i>Dirty Water System</i>	472	361	404	444	486	476	554
	<i>Active Pit</i>	39	21	75	101	70	113	209
	<i>Turkeys Nest Dam</i>	37	37	37	37	37	37	36
	<i>Sediment Dams</i>	23	17	31	62	106	48	99
	Total Evaporation	570	436	548	643	699	674	898
Storage Overflows (off-site)								
	<i>Dirty Water System</i>	0	0	0	0	0	0	0
	<i>Active Pit</i>	0	0	0	0	0	0	0
	<i>Turkeys Nest Dam</i>	0	0	0	0	0	0	0
	<i>Sediment Dams</i>	55	61	56	111	307	145	224
	Total Overflows	55	61	56	111	307	145	224
Net Loss from CHPP		205	760	760	745	760	760	144
Vehicle Wash		5	5	5	5	5	5	5
ROM Bin Dust Suppression		15	55	55	54	55	55	11
Stockpile Dust Suppression		10	37	37	37	37	37	7
Haul Road Dust Suppression		342	150	189	174	156	393	266
Gross Water Outputs		1,203	1,504	1,650	1,769	2,020	2,069	1,555
Water Retained Onsite								
Net Inventory								
	<i>Dirty Water System</i>	13	13	14	14	13	12	11
	<i>Active Pit</i>	9	1	7	12	4	21	52
	<i>Turkeys Nest Dam</i>	0	0	0	0	0	0	0
	<i>Sediment Dams</i>	2	0	2	5	6	3	4
	Total	25	14	23	31	23	37	67
Gross Water Retained		25	14	23	31	23	37	67
Water Volume Required from External Source (Gross water deficit)		43	162	128	98	61	68	21

7.10.4 Forecast Simulation Results - Interpretation

The modelling methodology of a forecast simulation is provided in Section 7.3. In interpreting the results of a forecast simulation, provided in the following sections, it should be noted that this simulation type provides a statistical analysis of the water management system's performance over its 30 year mine life, based on 92 realisations with different climatic sequences (see Section 7.3.2). The 50th percentile probability represents the median results, the 1st and 10th percentile represent wetter conditions and the 90th and 99th percentile results represent dryer conditions. There is an 80% chance that the result will fall within the 10th and 90th percentiles. The 1st and 99th percentile results represent the likely upper and lower bounds of the estimate (i.e. 98% of all results will fall within this range). Importantly, note that a percentile trace shows the percentile chance of a particular value, and **does not** represent continuous results from a single model realisation e.g. the 50th percentile trace does not represent the model time series for median climatic conditions.

A single realisation can also be selected from the 92 modelled realisations in order to show the water management system's actual performance (not a statistical representation) for a particular climate sequence.

7.10.5 Mine Site Storage Inventory – Forecast Results

Figure 7.3, Figure 7.4 and Figure 7.5 show the predicted probability of the modelled out-of-pit, dirty water system and in-pit storage volume for the Project, respectively. A build-up of water in the active pits generally occurs when the out of pit storages are too full to accept additional pit water. The out-of-pit storages include the Dirty Water System, Turkeys Nest Dam and the sediment dams. The Dirty Water System is the primary out-of-pit storage and has a capacity of 2,000 ML. The sediment dam system has a total maximum capacity of approximately 1,300 ML, however, the total active volume of the sediment dams varies over time as runoff from fully rehabilitated areas is released (see Figure 7.1). The maximum operating volume (MOV) of the Dirty Water System is the volume at which pumping from the open cut pits and sediment dams into the Dirty Water System ceases. The MOV is a function of the operating rules and physical layout of each representative stage and is varied as shown in Table 7.14. The MOV is selected to provide the maximum available capacity for the dewatering of sediment dams and the active pit while providing sufficient storage to accommodate unexpected rainfall events without allowing spills from the Dirty Water System. The model representation of the MOV is controlled by fixed operational rules. In reality, the site water management system will implement adaptive management to minimise the environmental risks of the project. This approach would provide flexibility to allow, for example, the MOV to be varied on a temporary basis to reduce the risk of sediment dam overflows.

Table 7.14 Adopted Maximum Operating Volumes, Dirty Water System

Stage	Adopted MOV (ML)
Year 2	1,500
Year 5	1,600
Year 10	1,600
Year 15	1,450
Year 21	1,450
Year 25	1,450
Year 30	1,200

The minesite water balance would generally be in equilibrium when water in the Dirty Water System under median (50%) conditions does not exceed the MOV, to allow water to be pumped in from the active pits. If the Dirty Water System stored capacity exceeds the MOV, mining could be affected. The following is of note:

- There is a 50% chance that:
 - The combined out-of-pit storages will be 2,240 ML at about 29 years;
 - The Dirty Water System will reach 1,450 ML in Years 20, 21, 22, 25 and 26;
 - The active pit will not be completely dewatered at any point in time after about 26 years;
 - The in pit inundation will be at least 200ML at any point in time after about 27 years; and
 - The active pit stored water volume will reach at least 650 ML at the end of mine life.
- There is a 10% chance that:
 - The combined out-of-pit storage will be 2,880 ML at about 27 years;
 - The Dirty Water System will be at or above the MOV at any point in time after about 7 years;
 - The Dirty Water System will be at least 1,660 ML at about 6 years;
 - The active pit will not be completely dewatered;
 - The in pit inundation will be at least 480 ML after 10 years; and
 - The active pit water volume will be 2,070 ML at the end of mine life.
- There is a 1% chance that:
 - The Dirty Water System will be at least 1,890 ML at about 16 years;
 - The in pit inundation will be at least 1,780 ML after 8 years; and
 - The active pit stored water volume will be 3,000 ML at the end of mine life.

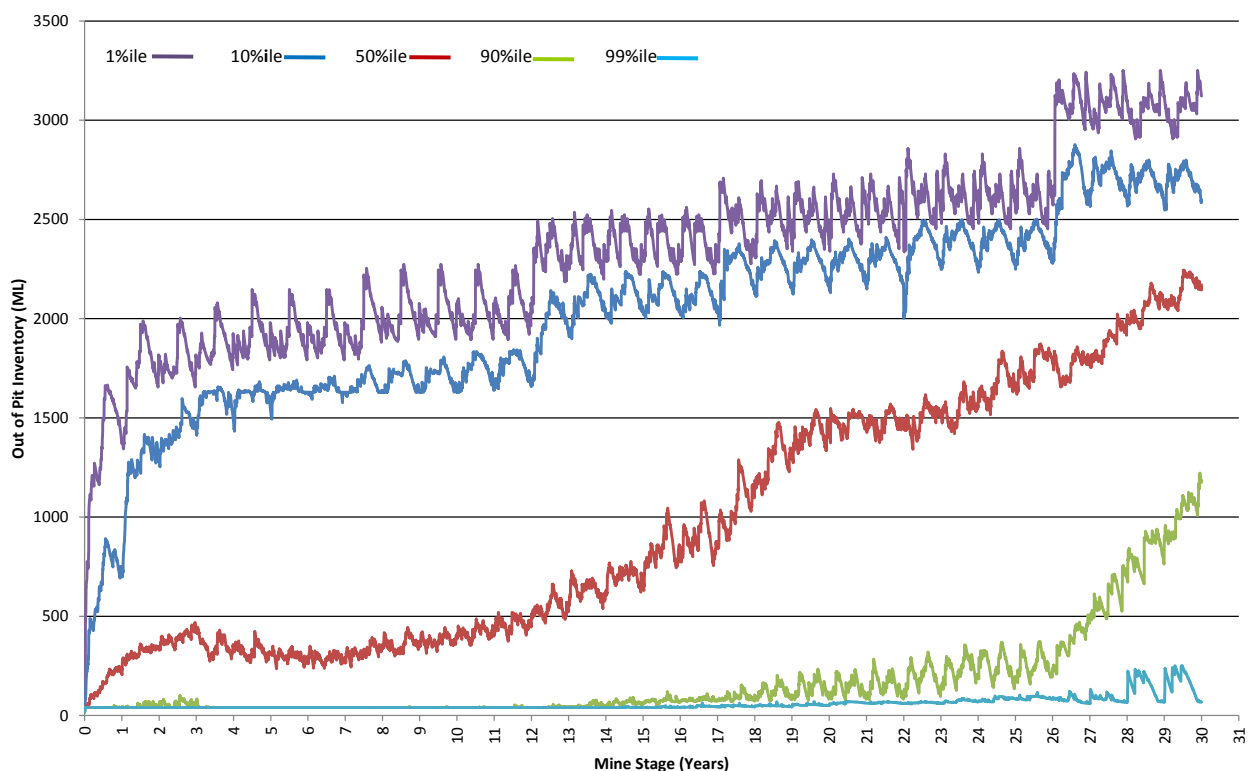


Figure 7.3 Forecast Out of Pit Inventory, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) Percentile

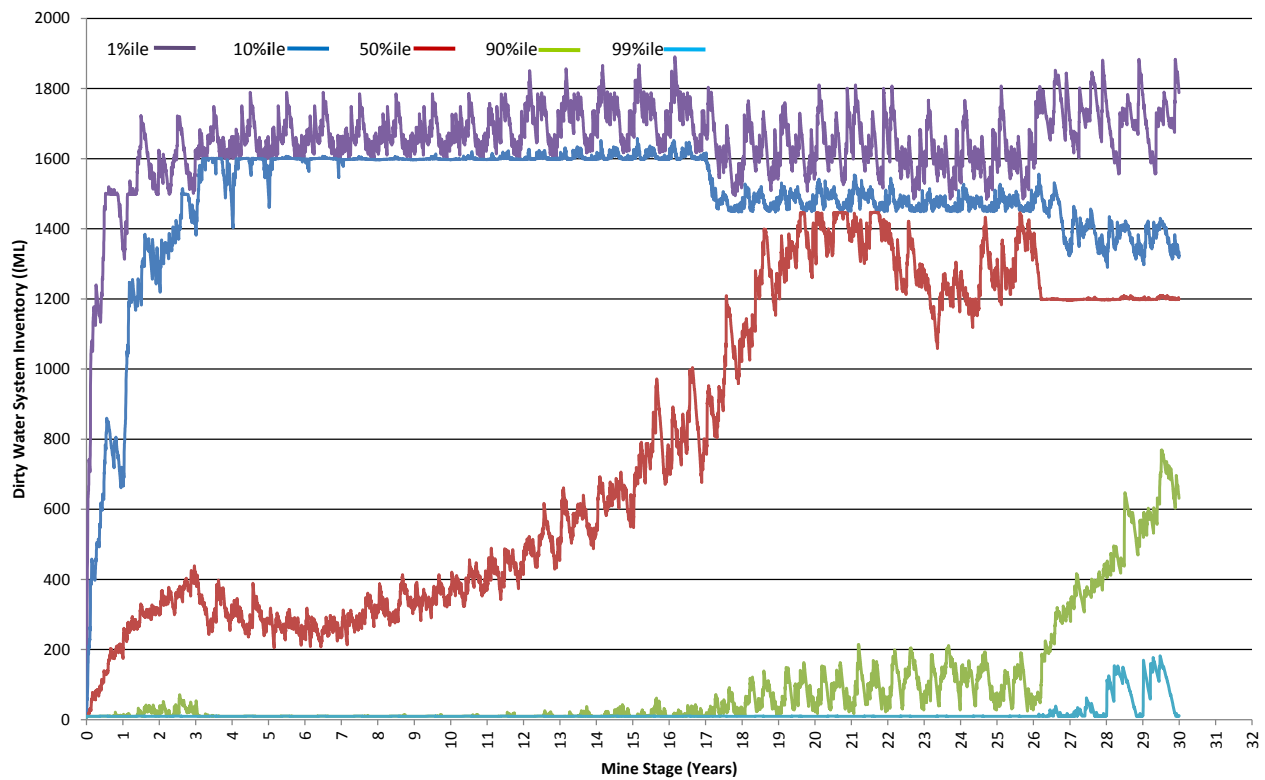


Figure 7.4 Forecast Dirty Water System Inventory, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) Percentile

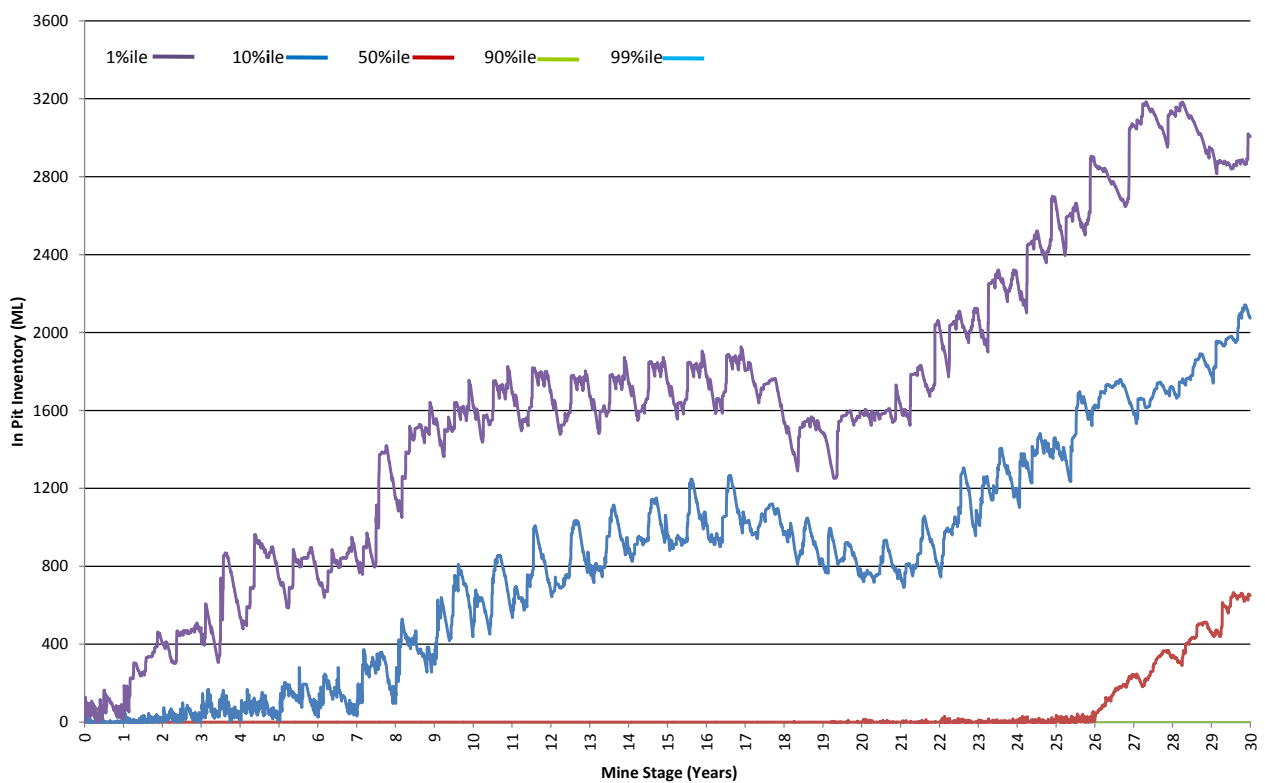


Figure 7.5 Forecast In-Pit Storage Inventory, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) Percentile

Figure 7.6 and Figure 7.7 show a ranked plot of stored volume in the Dirty Water System and the active pit, respectively, for three discrete climatic sequences. The discrete sequences were selected based on the 10%ile (wetter), median and 90%ile (drier) total catchment runoff inflows. The following is of note:

- For the discrete sequence with median catchment runoff inflows:
 - The Dirty Water System is at or above 500 ML approximately 58% of the time;
 - The Dirty Water System is at or above 1,600 ML only 2% of the time;
 - The active pit stores at least 500 ML approximately 16% of the time;
 - The active pit is fully dewatered about 57% of the time;
- For the discrete sequences with 10%ile catchment runoff inflows:
 - The Dirty Water System is at or above 500 ML approximately 71% of the time;
 - The Dirty Water System is at or above 1,600 ML less than 18% of the time;
 - The active pit stores at least 500 ML approximately 47% of the time;
 - The active pit is fully dewatered about 34% of the time;
- For the discrete sequences with 90%ile catchment runoff inflows:
 - The Dirty Water System is at or above 500 ML approximately 35% of the time;
 - The Dirty Water System is below 1,800 ML 100% of the time;
 - The active pit stores at least 500 ML approximately 3% of the time; and
 - The active pit is fully dewatered about 75% of the time.

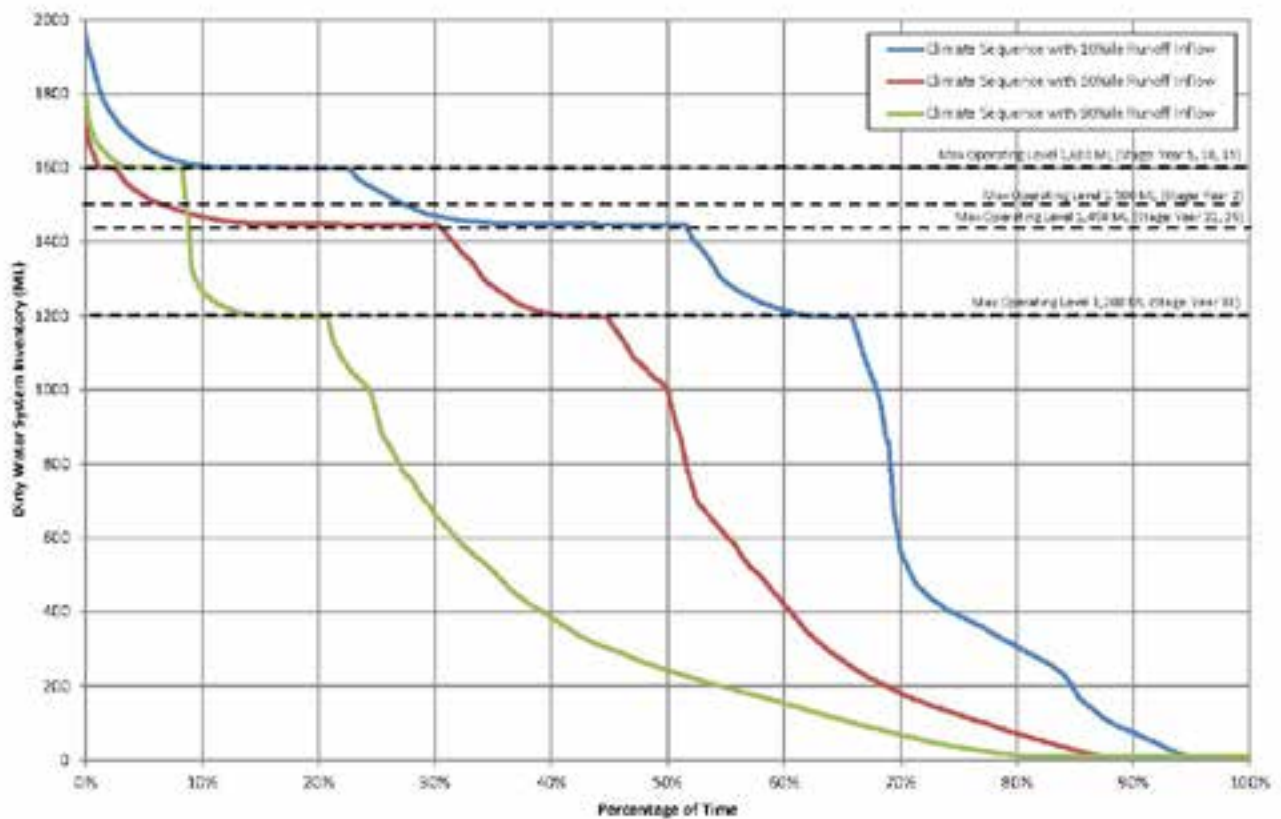


Figure 7.6 Distribution of Mine Water Dam Stored Volume Over Mine Life

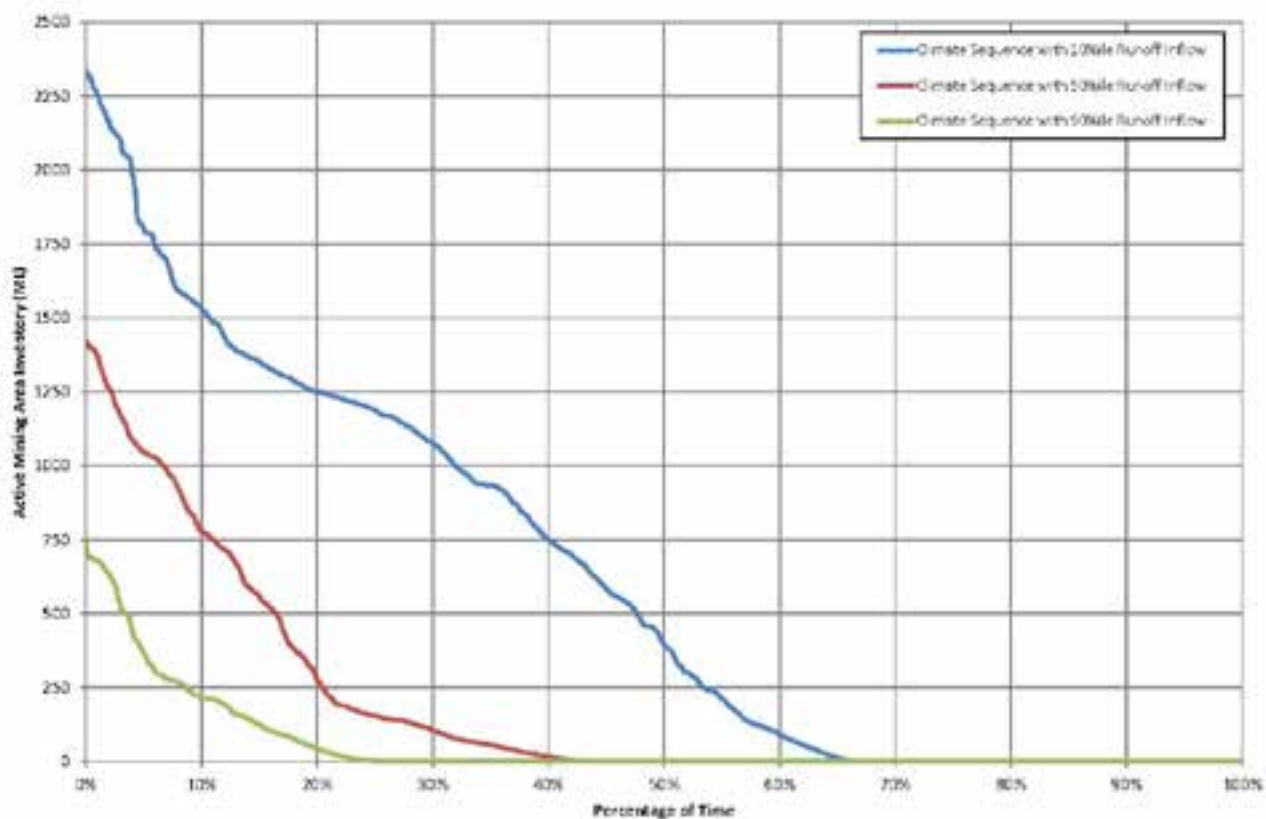


Figure 7.7 Distribution of Pit Stored Volume Over Mine Life

Figure 7.8 shows the distribution of the maximum active pit inundation volume, from any point in time, from each of the 92 discrete realisations. The following is of note:

- There is a 90% chance that the maximum pit inundation volume during the 30 year mine life will be at least 920 ML;
- There is a 50% chance that the maximum pit inundation volume during the 30 year mine life will be at least 1,690 ML; and
- There is a 10% chance that the maximum pit inundation volume during the 30 year mine life will be at least 2,330 ML.

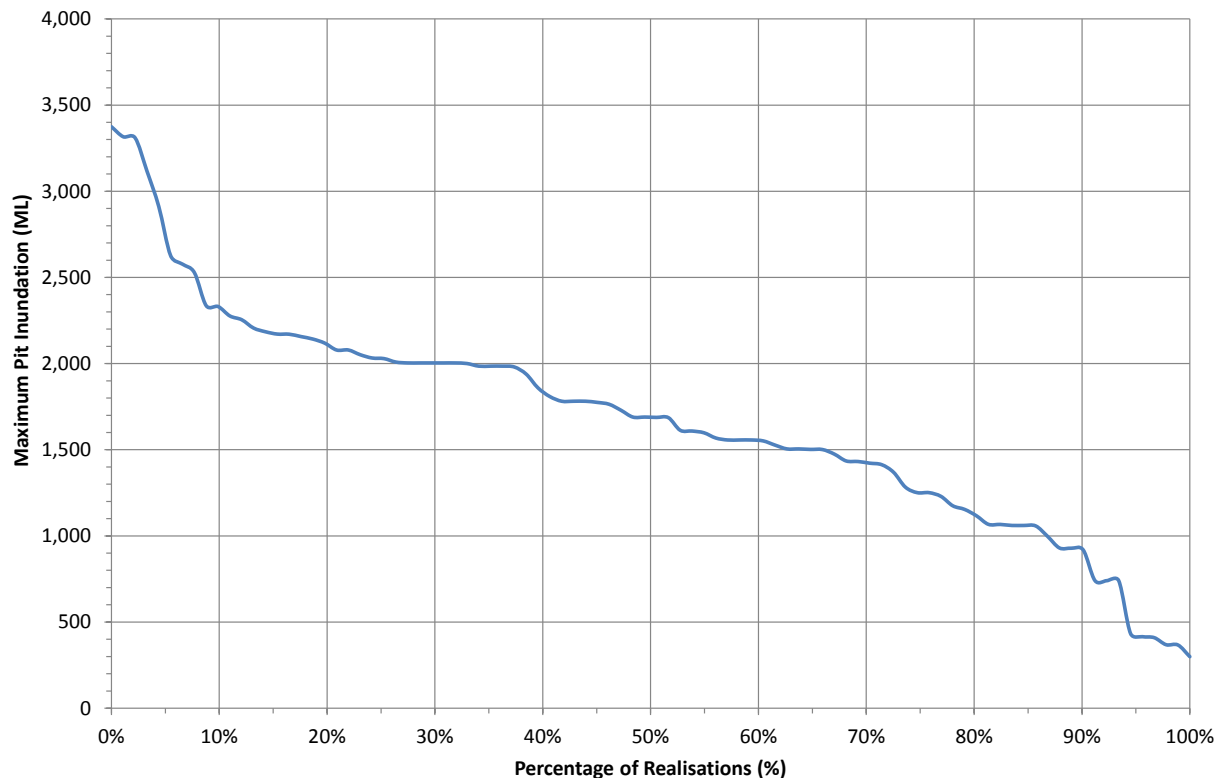


Figure 7.8 Maximum Active Pit Inundation

7.10.6 Off-site Water Requirements– Forecast Results

When the demand from the Dirty Water System and from evaporation draws the Turkey's Nest Dam below a low trigger level, water will be demanded from offsite. The following is of note:

- There is a 50% chance that:
 - a total volume of at least 170 ML of offsite supplies will be required to supply operational demand in the first year;
 - a total volume of at least 143 ML of offsite supplies will be required to supply operational demand in Year 7;
 - approximately 20-40ML of offsite supplies will be required per year in Year 2 to Year 4 and Year 11 to Year 30;
- There is at least a 10% chance (90th percentile results) that:
 - a total volume of 580 ML, at most, of offsite supplies will be required to supply operational demand in Year 5 and Year 7;
 - 30 ML, at most, of offsite supplies will be required per year at the end of mine life (Year 28 to Year 30);
- There is 1% chance (99th percentile results) that:
 - a total volume of approximately 900 ML to 920 ML of offsite supplies will be required per year to supply operational demand between Year 5 to Year 17;
 - less than 230 ML of offsite supplies will be required per year for the last 4 years of mine life;
- As a result of evaporation, offsite supplies are required even for the 10th and 1st percentile traces (wetter conditions) in order to maintain a minimum volume available in the Turkey's Nest Dam.

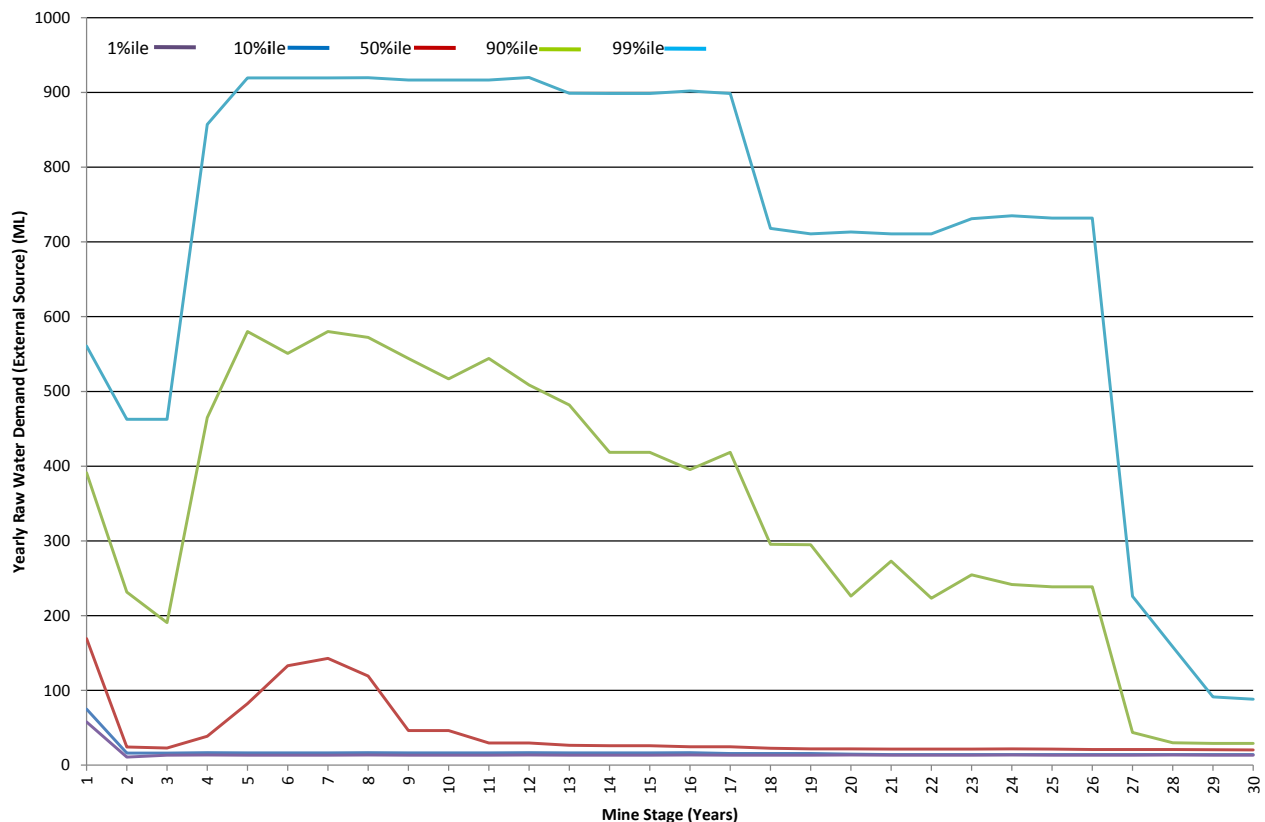


Figure 7.9 Forecast Yearly Raw Water Demand, 99th (very dry), 90th (dry), 50th (median), 10th (wet) and 1st (very wet) Percentile conditions

7.10.7 Supply Reliability – Forecast Results

An estimate of the reliability of the Watermark water management system in meeting demands was obtained by calculating a percent reliability for each of the 92 discrete realisations. The reliability was defined as the ratio of number of days that demands were fully supplied by the on-site water management system (excluding raw water inflows) to total number of simulated days. Figure 7.10 shows the distribution of the water management system's reliability from each of the 92 discrete realisations. The following is of note:

- There is a 90% chance that the reliability of the water management system will be at least 82.5%;
- There is a 50% chance that the reliability of the water management system will be at least 89%; and
- There is a 10% chance that the reliability of the water management system will be at least 97.6%.

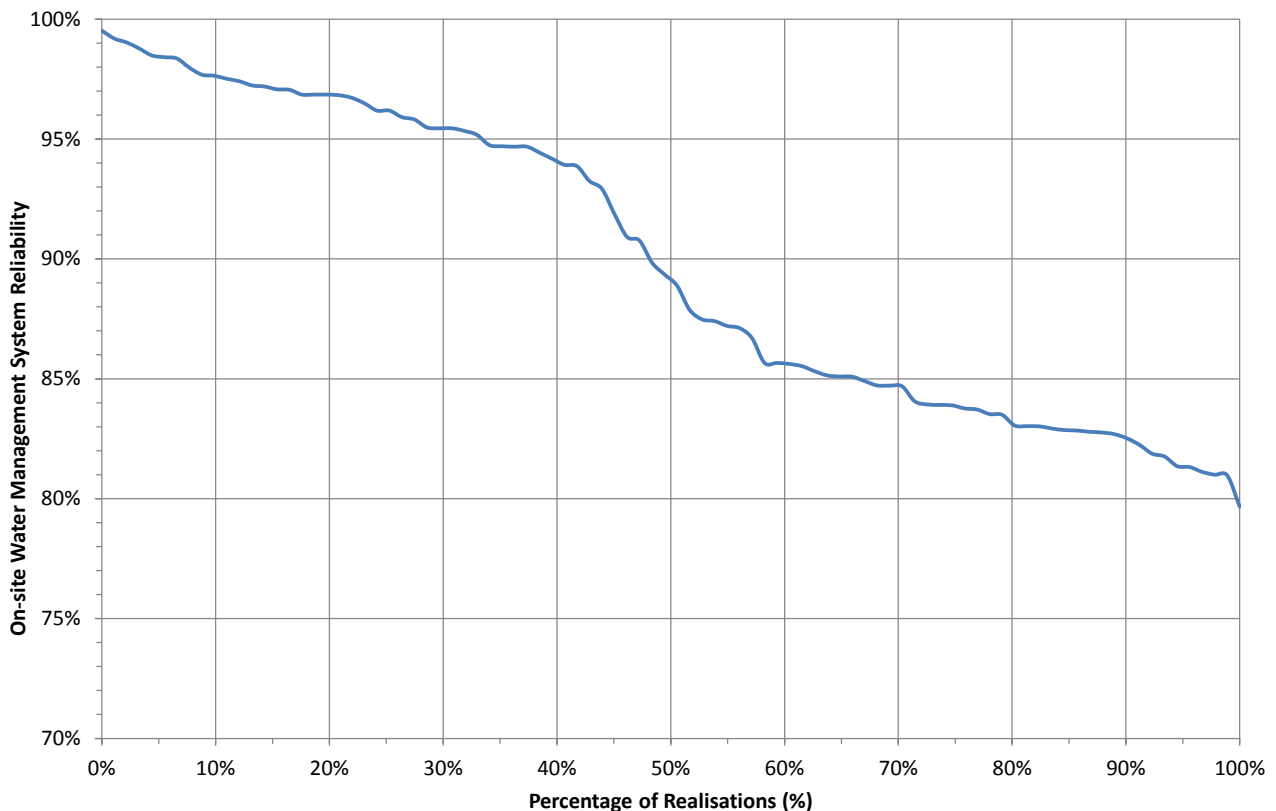


Figure 7.10 On-site Water Management System Reliability

7.10.8 Uncontrolled Spills – Forecast Results

Dirty Water System

The model of the water management system has been configured to ensure no off-site spills from mine water storages. The modelled results show no spills from the Dirty Water System.

Sediment Dams

Table 7.15 shows the predicted spills from the mine affected water storages over the 30 year period for the median result as well as the 90th and 10th percentile confidence limits of the estimate. The following is of note:

- Each of the sediment dams are active for different periods of time during the 30 year mine life (see Figure 7.1);
- The median average annual spill days is less than 10 days for East 1, East 2, East 3, South 4 and West 1 sediment dams;
- West 2 sediment dam has the highest median number of spill days, however this is likely a function of modelling, as this sediment dam is the last priority for pumping in to the Dirty Water System;
- The sediment dams which are active towards the end of mine life have a greater risk of spilling due to the likelihood of the Dirty Water System being fuller.;
- In reality, if the sediment dams are not able to be dewatered to the Dirty Water System within 5 days, excess water will be transferred to the active pit and flocculation will be used to ensure that any overflows will be within EPL limits.

Table 7.15 Predicted Spills From Sediment Dams

Sediment Dam	Years of Operation	Simulation	Average Annual Spill Volume (ML)	Average Annual Spill Days (days)
East 1	9	10%ile	44.5	18.7
		50%ile	4.7	0.2
		90%ile	0	0
East 2	19	10%ile	31.8	11.2
		50%ile	8.8	3.2
		90%ile	0	0
East 3	10	10%ile	110.9	19.9
		50%ile	27.2	7.3
		90%ile	0	0
East 4	22	10%ile	49.5	14.9
		50%ile	8.4	5.2
		90%ile	0	0
East 5	22	10%ile	42.2	45.5
		50%ile	19.7	17.5
		90%ile	0.4	0.05
South 1	9	10%ile	68.5	39.7
		50%ile	9.6	10.6
		90%ile	0	0
South 2	9	10%ile	54.2	28.6
		50%ile	9.6	10.9
		90%ile	0	0
South 3	9	10%ile	48.1	50.3
		50%ile	12.2	17.9
		90%ile	0	0
South 4	8	10%ile	144.5	22.6
		50%ile	54.5	8.3
		90%ile	0	0
West 1	4	10%ile	231.1	35.3
		50%ile	37.5	9.8
		90%ile	0	0
West 2	8	10%ile	206.1	67.6
		50%ile	73.0	23.6
		90%ile	0	0

7.11 SENSITIVITY TO ADOPTED MODEL INPUTS

The adopted values of model inputs represent an estimate of the various components of the site water balance based on available data and experience from other mining projects. Inaccuracies in the model inputs will affect how well the model represents the behaviour of the actual mine water management system and will affect the magnitude of model results. The largest uncertainty in model inputs is the magnitude of surface water runoff inflows. The sensitivity of the model results to key inputs may be summarised as follows:

- A 10% difference in the volume of surface runoff would correspond to an increase or reduction in inflows to the water management system of about 220 ML.
- If site demands are underestimated by 20%, the impact on the site water balance would be to increase site water requirements by approximately 250 ML.

Further detailed assessment of the sensitivity of the water management system performance to model inputs will be undertaken as part of detailed infrastructure design.

7.12 ADAPTIVE MANAGEMENT OF MINE WATER BALANCE

The model results presented above represent the application of the adopted mine water management system rules over the mine life, regardless of climatic conditions. In reality, there are numerous options for adaptive management of the mine water management system to accommodate climatic conditions. For example, when excess water is available on site, it may be possible to increase the application of water for dust suppression. These alternative management approaches would be used to reduce the risks to the project associated with climatic variability.

7.13 SURFACE RUNOFF SALT BALANCE

The OPSIM model was used to undertake an assessment of the likely impact of the Project on the salt load released to receiving waters as surface flow. Representative salinities (expressed as total dissolved solids - TDS) were assigned to runoff from various catchment types, as well as groundwater inflows to mining pits and raw water imported to the mine site. The adopted salinities for the different sources of water were based on an assessment of seepage water quality undertaken by Terrenus (2012). The adopted salinity concentrations for the various water sources are provided in Table 7.16.

Table 7.16 Adopted Salinity Concentrations

Salinity Source	TDS (mg/L)
Groundwater	
Eastern Mining Area	3,000
Southern Mining Area	14,000
Western Mining Area	3,000
Raw Water	550
Undisturbed/Natural Runoff	550
Industrial/Hardstand Runoff	1,500
Spoil Runoff	
Surface	1,500
Baseflow	5,000
Rehabilitated Spoil Runoff	800

To assess the impacts of the Project on the receiving water salt balance, the OPSIM model was run as a static simulation. For the static simulation, each stage of mine development is modelled separately from the other stages, over the full historical climatic data set (1889-2010).

The following receiving water catchment areas for premine catchments were adopted for the analysis:

- Lake Goran: 1365 km²;
- Watermark Gully/Mooki River North: 54 km²; and
- Native Dog Gully (excluding Yarraman Creek): 68 km².

The catchment area draining to each of the receiving water locations varied according to the changes in the mine site catchments with the progression of the mine.

Table 7.17 provides a summary of the salt balance for the pre-mine catchments and selected stages of the mine life. The model results show that the total average salt load released offsite in surface runoff is not significantly increased by the Project. The maximum total average salt load of 65.7 t/d occurs in year 30 of the Project and represents an increase in the pre-mine salt load of about 0.8%.

The salt load released to Native Dog Gully is not significantly affected by the Project. The salt load drops by about 10% in Year 15.

The salt load released to Watermark Gully (including other unnamed tributaries draining north to the Mooki River) is reduced by 4% in Year 5 and Year 15. The salt load to Watermark Gully is elevated in Year 25 and Year 30 with a modelled increase of 4% and 30% respectively. Note that this represents a likely upper limit of the salt load impact since the quality of surface runoff from rehabilitated areas is likely to improve over time.

Under normal operation, spoil runoff collected in sediment dams is pumped back for use in the mine water management system. Sediment dams would only spill following extended periods of significant rainfall. Under these conditions, it is likely that the quality of water collected in sediment dams would be improved by significant fresh runoff inflows.

Table 7.17 Long Term Average Surface Water Salt Balance (t/day)

Average Annual Salt Balance (t/day)		Existing	Year 5	Year 15	Year 25	Year 30
Watermark Gully Salt Load						
	<i>Catchment Runoff</i>	2.4	2.2	2.2	2.1	2.4
	<i>Dam Overflows</i>	0.0	0.1	0.1	0.4	0.7
	Total	2.4	2.3	2.3	2.5	3.1
Native Dog Gully Salt Load						
	<i>Catchment Runoff</i>	3.0	2.7	2.4	2.7	2.8
	<i>Dam Overflows</i>	0.0	0.2	0.3	0.2	0.2
	Total	3.0	2.9	2.7	3.0	3.0
Lake Goran Salt Load						
	<i>Catchment Runoff</i>	59.9	59.9	59.9	59.8	59.6
	<i>Dam Overflows</i>	0.0	0.0	0.0	0.0	0.0
	Total	59.9	59.9	59.9	59.8	59.6
Gross Salt Inputs		65.2	65.1	64.9	65.2	65.7

7.14 FINAL VOID STORAGE AND WATER QUALITY BEHAVIOUR

The OPSIM model was used to assess the likely long term water level behaviour and salt balance of the final void. The historical rainfall and evaporation sequences were looped numerous times to create a long term climate record. A salinity of 800 mg/L for runoff from the rehabilitated catchment area draining to the final void and a salinity of 3,000 mg/L for groundwater inflows have been adopted, as per Table 7.16. The final void configuration and contributing catchment areas are shown in Figure 7.11. Note that the majority of surface runoff catchment is diverted away from the final void and into Watermark Gully. Long term groundwater inflows to the final void were provided by AGE groundwater consultants, shown in Figure 7.12.



Figure 7.11 Final Void Mine Plan

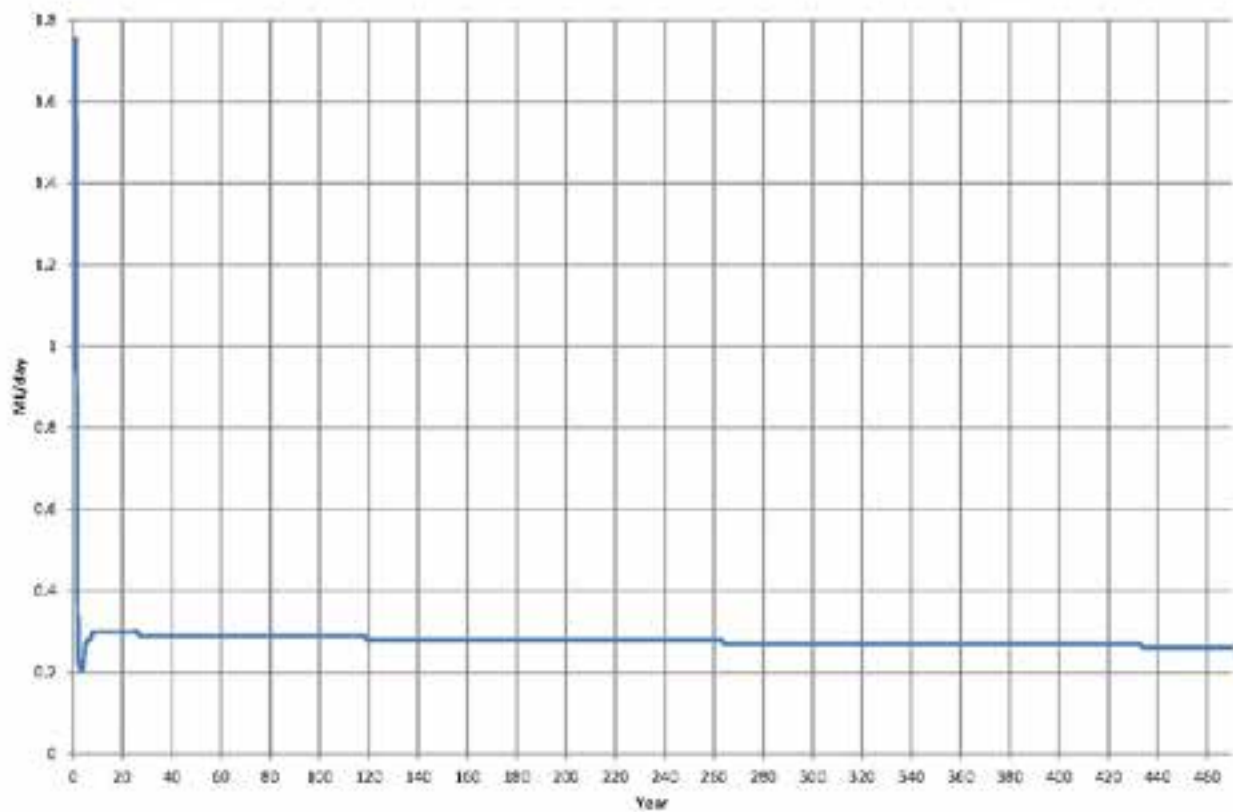


Figure 7.12 Adopted Long Term Groundwater Inflows To The Final Void

Since initial water level in the final void is likely to be more than 60 m below the surrounding ground levels, the water surface will be partially protected from sun and wind resulting in evaporation from the water surface being lower than from water in a dam at the surface. An evaporation factor was adopted to reflect the lower evaporation at the bottom of the final void. It was found that the model results were sensitive to this adopted factor, with the equilibrium water level related to the adopted evaporation factor.

Adopting an evaporation factor of 0.7 (a typical value adopted in similar studies), the simulated long term equilibrium water level was approximately 280 mAHD, which is about 30 m below the overflow level from the final void. Adopting a lower evaporation factor resulted in a higher equilibrium water level. However, as the water level rises closer to the surface, it is likely that the rate of evaporation would increase.

Figure 7.13 shows model results with three different evaporation factors:

- 0.7.
- 0.5.
- 0.5 for the first 50 years of the simulation, then 0.7.

Based on these results it is expected that the final void will reach an equilibrium water level of approximately 280 to 290 mAHD, which is approximately 20 to 30 m below the overflow level. The lake will take approximately 100 years to reach the equilibrium level.

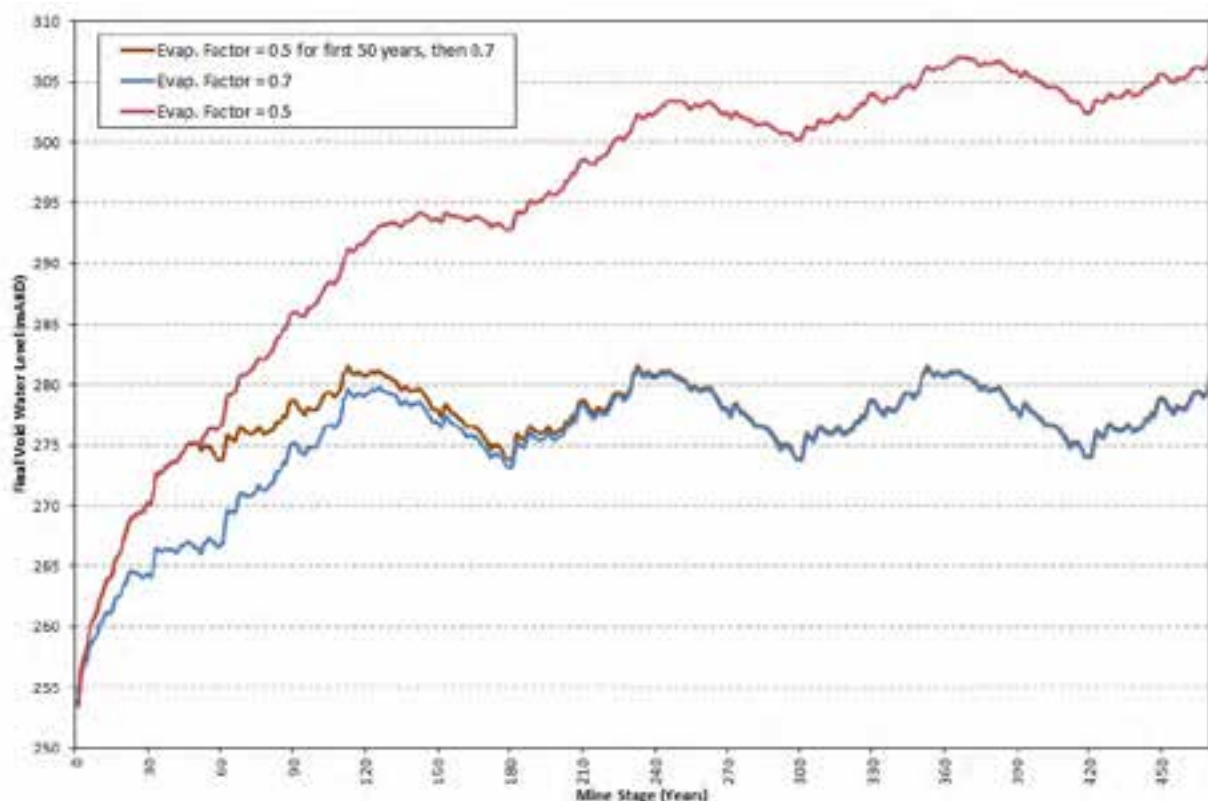


Figure 7.13 Final Void Water Level

Figure 7.14 shows the modelled salt concentration, as total dissolved solids in mg/L, over the 470 year simulation. Based on the adopted model assumptions, salinity will slowly rise over time at a rate of approximately 5,000 mg/L per 150 years. In reality, the salinity of runoff inflows is expected to decrease over time, resulting in a slower rate of salinity rise than indicated by the model results. On average, approximately 16% of the total salt load to the final void is

attributed to surface and baseflow catchment runoff, and the remainder is attributed to groundwater inflows.

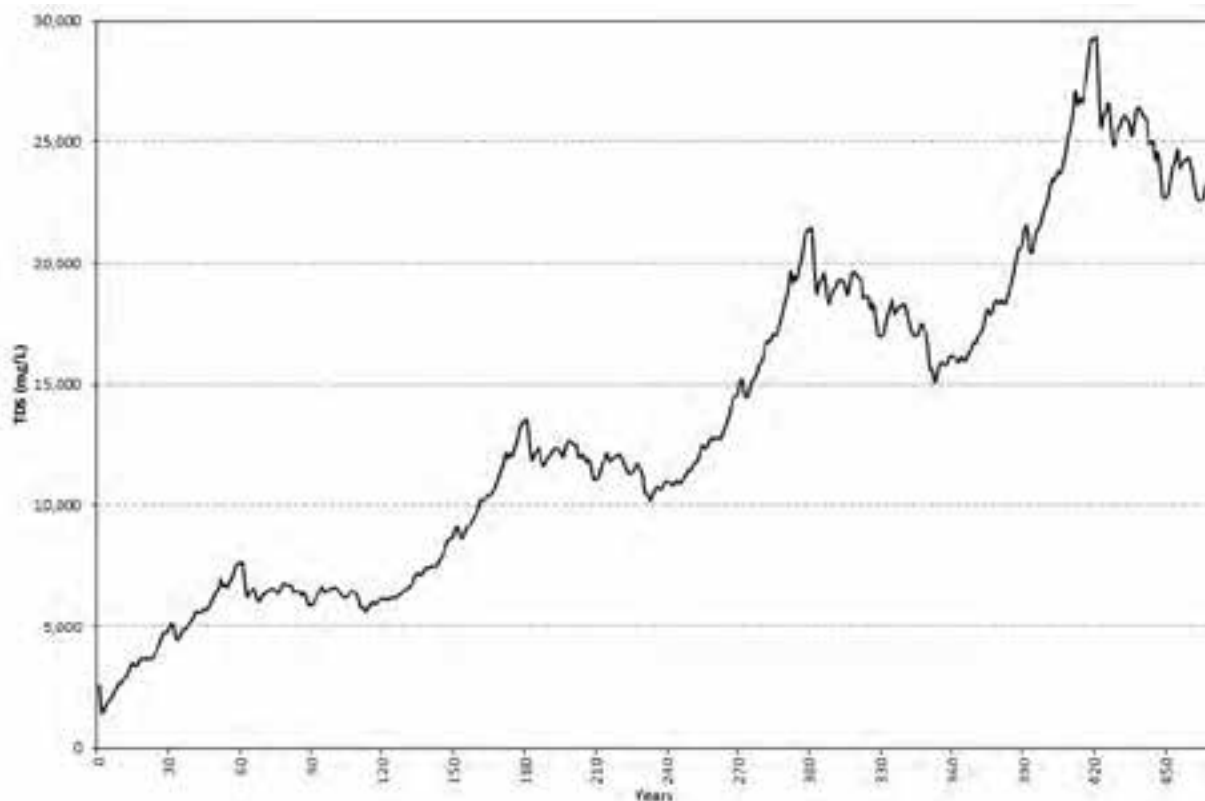


Figure 7.14 Final Void Total Dissolved Solids Concentration (Evaporation Factor of 0.7)

7.1 CLIMATE CHANGE IMPACTS ON FINAL VOID

An assessment was undertaken of the potential impacts of climate change on the behaviour of the final void. The likely impacts of climate change on key hydrologic parameters for the area of interest were estimated based on information published by the Department of Environment, Climate Change and Water (DECCW, 2010) and are summarised as follows:

- Increase in average annual evaporation of up to 20%,
- Increase in average annual runoff of up to 5%,
- Increase in average annual rainfall of up to 10%.

Table 7.18 shows the average annual value of key inputs and outputs for the final void under existing climate conditions, excluding the first 100 years when the final void water level is increasing. Table 7.18 also shows an estimate of the revised inputs and outputs based on the climate change assumptions summarised above. It has been assumed that climate change will have no net impact on groundwater inflows to the final void.

For the existing climate scenario, the inflows and outflows are close to balanced (net inflow of 7 ML per year), reflecting the equilibrium water level that is achieved after the initial 100 year period of water level rise. The adopted climate change assumptions show a net outflow of 51 ML per year. Hence, the final void water level will reduce until the smaller water surface area for evaporation balances the net inflows. Hence, under the adopted climate change assumptions,

the final void equilibrium water level will be lower than predicted for the existing climate scenario results shown in Figure 7.13.

Table 7.18 Impact of Climate Change on Fina Void Water Balance

	Average Annual Inflow (ML/a)	
	Existing Climate	With Climate Change Assumptions
Direct Rainfall	282	311
Evaporation	-452	-542
Groundwater Inflow	100	100
Baseflow	62	65
Surface Runoff	14	15
Net Inflow / Outflow	7	-51

8

WATERMARK GULLY FLOOD ASSESSMENT

8.1 INTRODUCTION

Development of the Project will impact the catchment and drainage path of Watermark Gully. A flood study was undertaken to assess flood behaviour along Watermark Gully for existing conditions, Year 30 mine conditions and post-mine conditions. A runoff-routing model was used to estimate flood design discharges along Watermark Gully and the HECRAS hydraulic model was used to estimate design flood levels and flow velocities. Details of the methodology and results of the Watermark Gully flood investigations are provided in the following sections.

8.2 ESTIMATION OF DESIGN FLOOD DISCHARGES

8.2.1 Catchment Description

Figure 8.1 shows the catchment of Watermark Gully draining to the Kamilaroi Highway. The total catchment of Watermark Gully upstream of the Kamilaroi Highway is approximately 39 km². The land use within the catchment is primarily cleared farming land with some areas of remnant vegetation.

Development of the Project will reduce the catchment area of Watermark Gully, with the maximum reduction in catchment area occurring at Year 30 of the Project. The catchment of Watermark Gully at Year 30 will be reduced to 30 km² due to capture of runoff within the mine water management system. A portion of this captured catchment area will be released once overburden emplacements are completely rehabilitated. The catchment of Watermark gully will be increased to 43 km² for the post-mine conditions. Further discussion of the impact of the Project on catchment areas is provided in Section 8.2.8 and 8.2.9.

8.2.2 Methodology

Design event flood discharges in Watermark Gully were estimated using the RAFTS runoff-routing model (XP Software, 2009). The RAFTS model was used to estimate the 2, 5, 10, 20, 50 and 100 year Average Recurrence Interval (ARI) design discharges. In the absence of historical stream gauge data, the model was calibrated by matching peak discharges with discharges estimated using the Rational Method.

Separate RAFTS models were developed for pre-mine conditions, Year 30 mine conditions and post mine conditions to represent the change in catchment area during and after the completion of the Project.

Estimates of the Probable Maximum Precipitation (PMP) event for the entire catchment were made using the Generalised Short Duration Method (GSDM) (BOM 2003a). The PMP rainfall estimates were applied to the RAFTS models to generate design discharges for the PMP design flood (PMPDF) in the catchment.

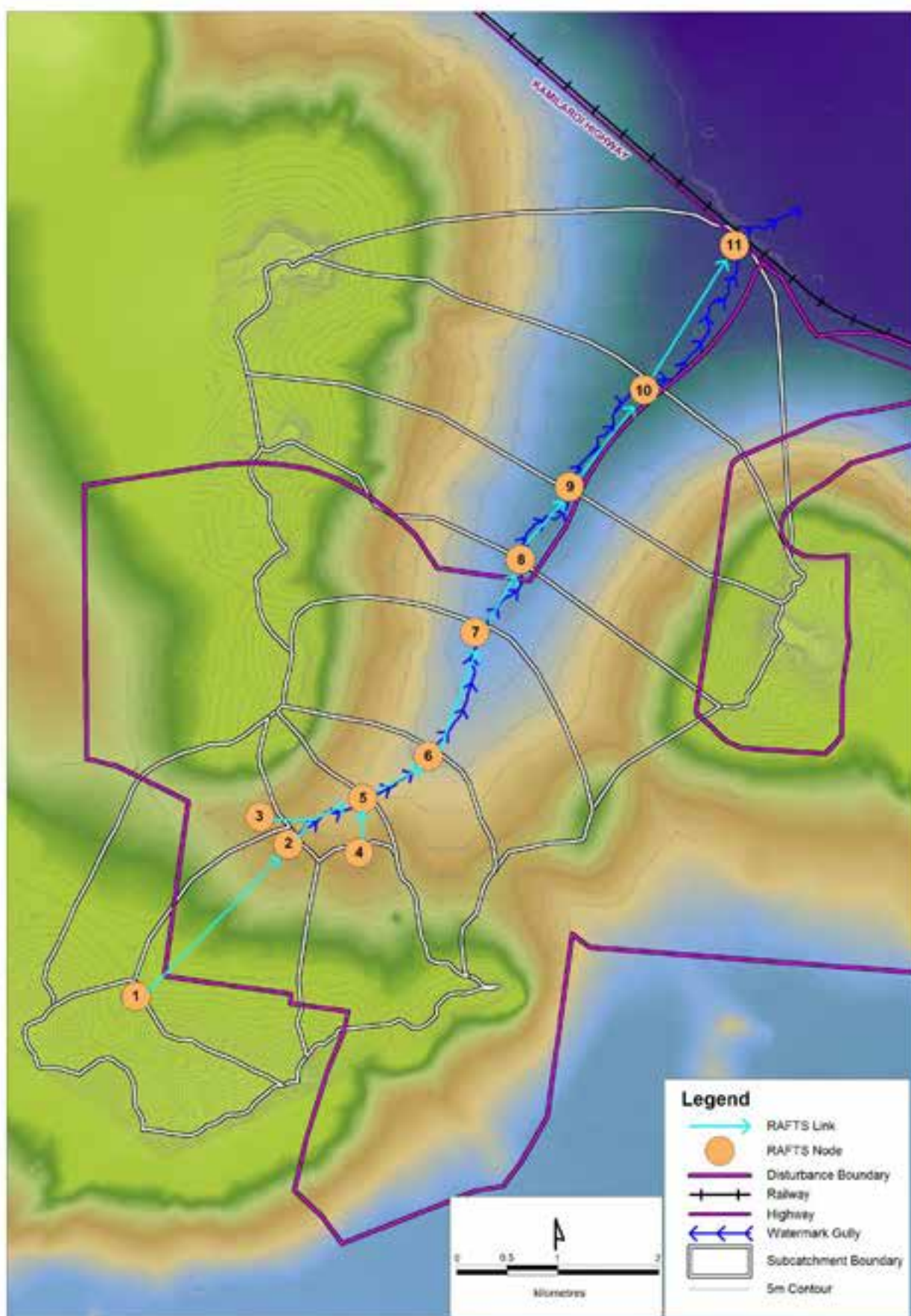


Figure 8.1 Watermark Gully RAFTS Model Configuration – Existing Conditions

8.2.3 Rational Method Peak Design Discharges

Australian Rainfall and Runoff (Pilgrim, 1998) includes separate methods for obtaining Rational Method estimates of peak discharges in eastern and western New South Wales. Since the Project Area is close to the boundary of the area where each method is applied, both methods were used to estimate peak discharges and the higher peak discharge was adopted.

The Regional Flood Frequency method of McDermott and Pilgrim (1983) was found to produce the highest discharges and was used to estimate design discharges in Watermark Gully at the Kamilaroi Highway. The peak discharge of a 2.5 year ARI event was estimated at the Kamilaroi Highway and frequency factors were applied to estimate peak design discharges up to the 50 year ARI design flood. The 100 year ARI peak discharge was extrapolated from the peak discharges of 2 to 50 Year ARI design floods as shown in Figure 8.2.

The 2.5 year ARI peak design discharge was calculated using equation $Q_{2.5} = 0.44(ASE)^{0.69}$, in accordance to the method of McDermott and Pilgrim (1983) in Australian Rainfall and Runoff (1998) for western New South Wales. Table 8.1 shows the frequency factors and adopted peak design discharges for Watermark Gully up to the 50 year ARI, as well as the extrapolated 100 year ARI design discharge.

Table 8.1 Frequency Factors and Estimated Rational Method Discharges, Watermark Gully

Average Recurrence Interval (Years)	Frequency Factor	Peak Design Discharge (m ³ /s)
2	0.84	15.3
2.5	1.00	18.2
5	1.58	28.7
10	2.33	42.3
20	3.29	59.7
50	5.00	90.8
100	-	125.0

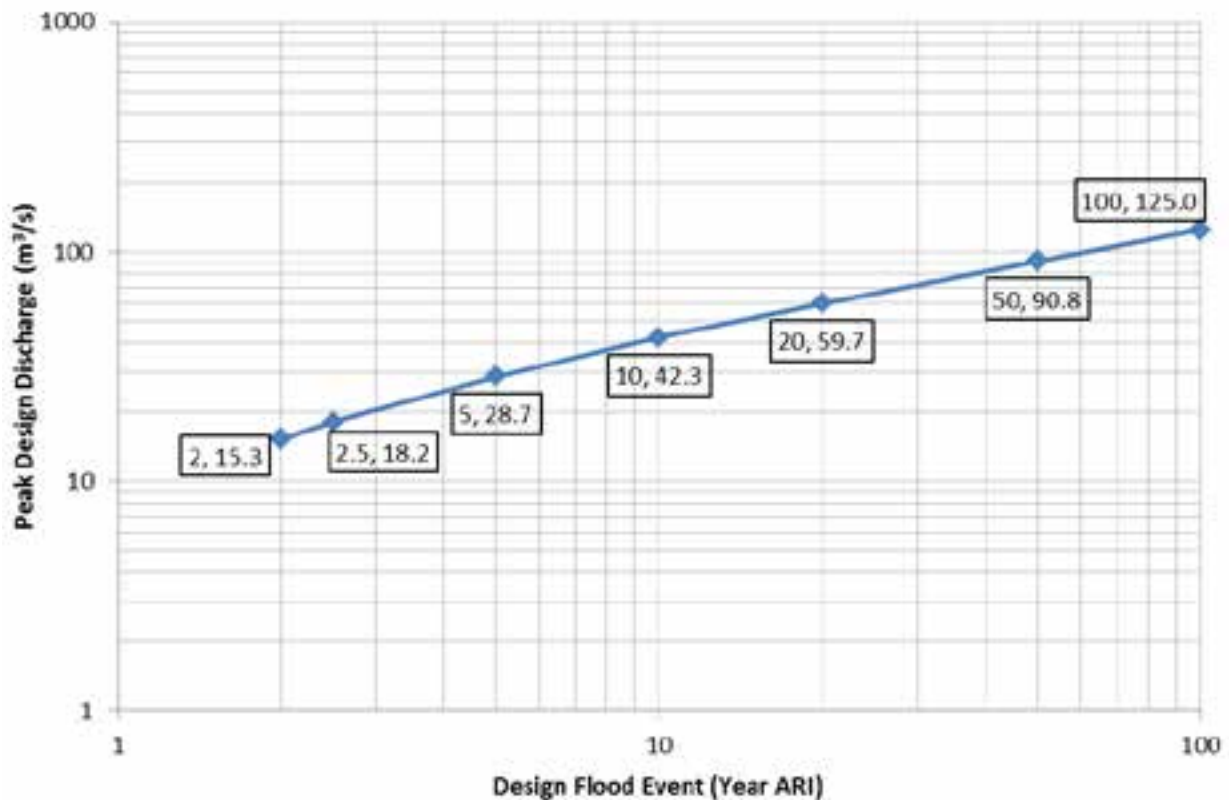


Figure 8.2 Extrapolation of 100 Year ARI Peak Design Discharge, Watermark Gully

8.2.4 RAFTS Model Configuration

The total catchment area was split into 11 subcatchments for the RAFTS model. Subcatchment area and slope were estimated from available LiDAR data provided by AAM Group and used as input data for the model. Figure 8.1 shows the model configuration including all subcatchment nodes and links.

8.2.5 Adopted Design Rainfalls

Design rainfall patterns and intensities for design events up to the 100 year ARI event were determined using standard procedures in Australian Rainfall and Runoff (Pilgrim, 1998). The RAFTS model was run for storm durations from 30 minutes to 12 hours for events up to the 100 year ARI.

PMP rainfall patterns and intensities were estimated using the Generalised Short Duration Method (GSDM) (BOM, 2003a). Table 8.2 shows the adopted PMP design rainfall intensities.

Table 8.2 Adopted PMP Rainfall Durations and Intensities

Duration (min)	PMP Rainfall Intensities (mm/hr)
15	680
30	480
45	413
60	360
90	273
120	230
150	196
180	170
240	140
360	107

8.2.6 RAFTS Subcatchment Parameters

Details of the adopted RAFTS subcatchment parameters are given in Table 8.3. The following is of note with respect to the RAFTS model:

- The percentage impervious in each subcatchment was assumed to be 0%;
- A PERN 'n' value of 0.06 was adopted for all subcatchments;
- Catchment slope in each subcatchment was determined using the available LiDAR data; and
- A value of 2.5 was adopted for the global storage coefficient "Bx".

Table 8.3 RAFTS Subcatchment Parameters

Subcatchment Number	Catchment Area (ha)			Catchment Slope (%)		
	Existing Conditions	Year 30 Conditions	Post Mine Conditions	Existing Conditions	Year 30 Conditions	Post Mine Conditions
1	176	176	176	8.0	8.0	8.0
2	298	233	233	6.4	6.4	6.4
3	273	205	205	6.2	6.0	6.0
4	217	48	48	4.1	5.5	5.5
5	93	31	31	7.3	3.5	3.5
6	215	99	113	7.5	2.8	2.8
7	415	128	128	6.5	2.5	2.5
8	486	294	291	7.2	4.2	4.2
9	516	516	516	8.1	8.1	8.1
10	703	703	703	6.2	6.2	6.2
11	550	550	550	7.5	7.5	7.5
3a	-	-	431	-	-	8.8
5a	-	-	186	-	-	6.3
6a	-	-	136	-	-	3
7a	-	-	93	-	-	3
7b	-	-	422	-	-	7.5
8a	-	-	41	-	-	3
Total Catchment Area	3942	2983	4303			

8.2.7 RAFTS Model Calibration

Table 8.4 gives the adopted RAFTS parameters for the calibration scenario. Initial and continuing losses were used as calibration parameters to match the peak RAFTS discharges to the Rational Method.

Table 8.4 Adopted Initial Loss and Continuing Loss

RAFTS Catchment & Rainfall Parameters	Existing Conditions
Initial Loss (mm)	15
Continuing Loss (mm/h)	4.9

Table 8.5 shows the estimated peak 2, 5, 10, 20, 50 and 100 year ARI, and PMP design discharges of Watermark Gully at the Kamilaroi Highway with Rational Method discharges for the calibration scenario. The following is of note concerning the calibration results:

- The critical storm duration is 150 minutes for the PMP design event and 360 minutes for all other design events.
- The RAFTS model discharges correspond well to the Rational Method discharges for the calibration scenario. The RAFTS model discharges have been adopted for this study.

Table 8.5 RAFTS Model Calibration Peak Discharges, Watermark Gully at Kamilaroi Highway

Design Storm Event	Design Discharge (m ³ /s)		% Diff
	Rational Method	RAFTS	
2 Year ARI	15.3	14.4	-6%
5 Year ARI	28.7	32.8	14%
10 Year ARI	42.3	46.7	10%
20 Year ARI	59.7	69.1	16%
50 Year ARI	90.8	97.6	7%
100 Year ARI	125.0	124.6	0%
PMP	-	1544.0	-

8.2.8 Year 30 Mine Conditions

Some areas of the Watermark Gully catchment are within the mine disturbance boundary and runoff from portions of these areas will be captured in mine site storages. The maximum area of catchment will be captured within the mine in Year 30 of the proposed mine plan.

Table 8.3 shows all subcatchment areas and slopes for Year 30 conditions compared to the existing conditions. The total catchment area of Watermark Gully upstream at the Kamilaroi Highway, for the Year 30 Conditions, is 29.8 km², which is 9.6 km² less than the catchment area for existing conditions. Figure 8.3 shows the RAFTS model configuration for Year 30 conditions.

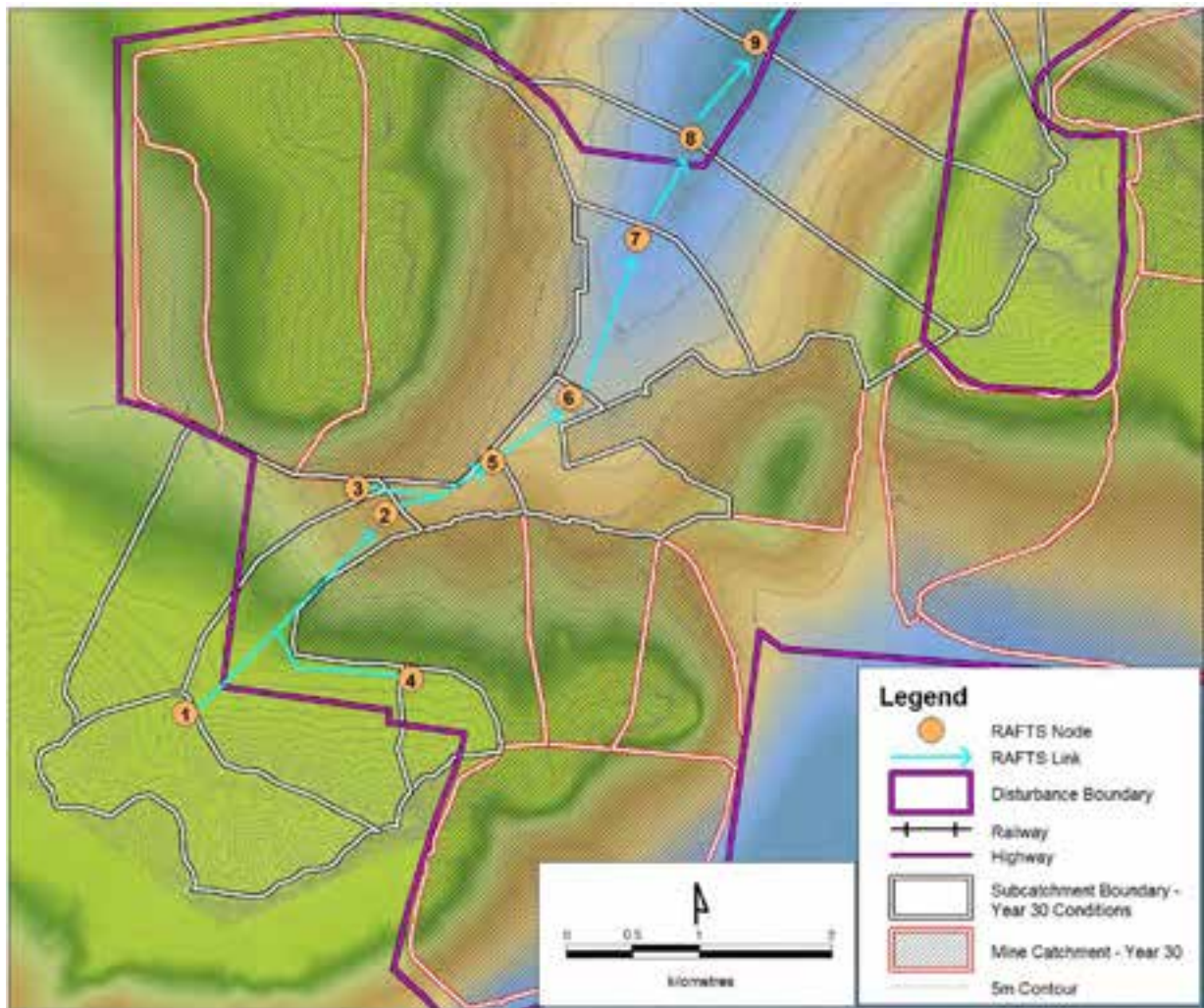


Figure 8.3 Watermark Gully RAFTS Model Configuration – Year 30 Conditions

8.2.9 Post-mine Conditions

A portion of the captured catchment area during the mine operation will be released once overburden emplacements are completely rehabilitated.

Table 8.3 shows all subcatchment areas and slopes for post mine conditions compared to the existing and Year 30 mine conditions. Six sub-catchments were added into the model to reflect the released catchment to Watermark Gully for post-mine conditions. The total catchment area of Watermark Gully upstream at the Kamilaroi Highway, for the post-mine conditions, is 43.0 km², which is 3.6 km² larger than the catchment area for existing conditions. Figure 8.4 shows the RAFTS model configuration for post-mine conditions.

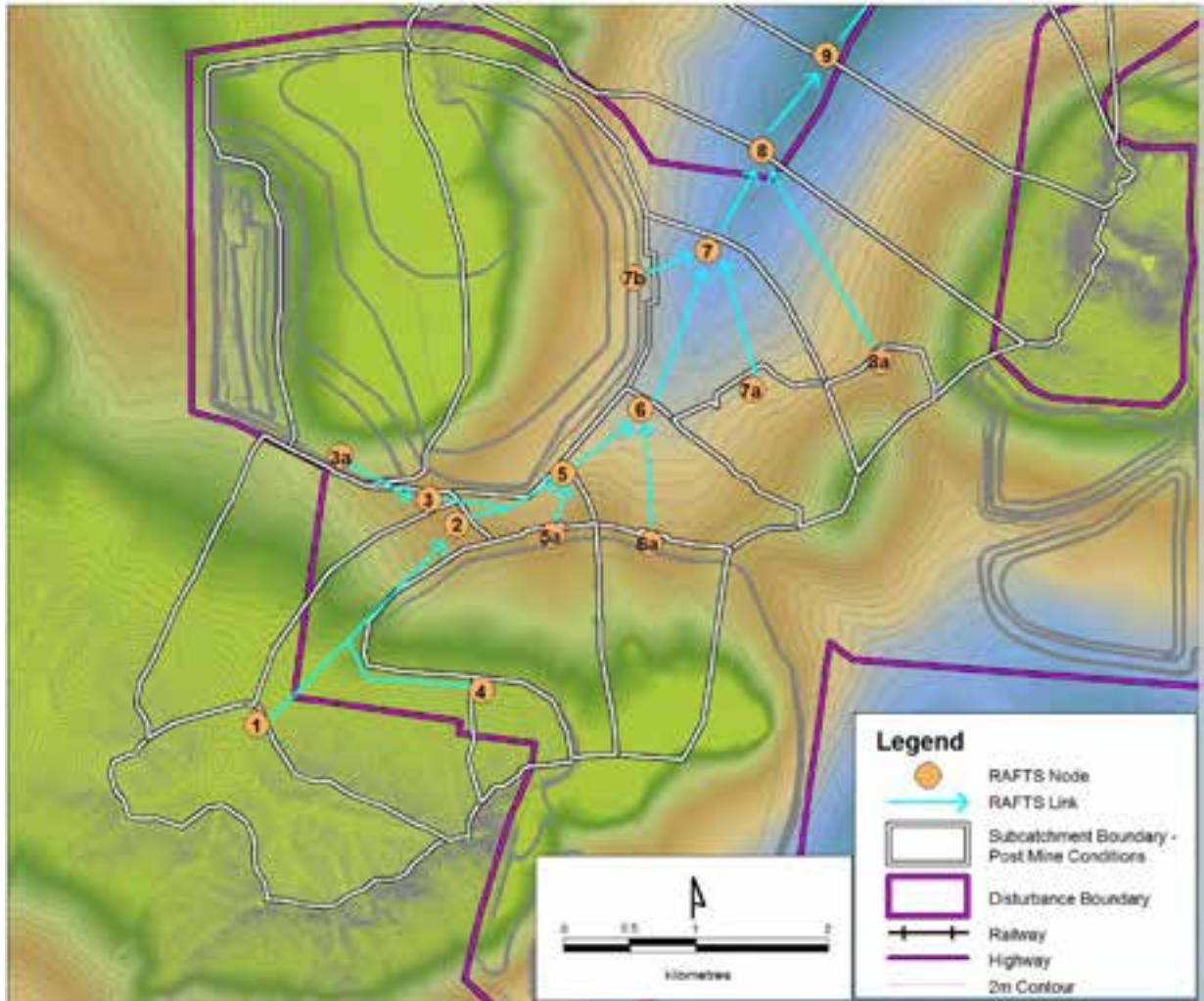


Figure 8.4 Watermark Gully RAFTS Model Configuration – Post-mine Conditions

8.3 ESTIMATION OF DESIGN FLOOD EXTENTS AND LEVELS

8.3.1 Methodology

The HEC-RAS hydraulic model (USACE, 2010) was used to estimate the design flood extents, levels and velocities along Watermark Gully to the Kamilaroi Highway for existing, Year 30 and post-mine conditions.

8.3.2 Model Configuration

Cross sections for the study were developed from survey data provided by AAM Group. Figure 8.5 shows the locations of the cross sections used in the model.

The adopted Manning's 'n' values were 0.05 for the gully and 0.06 for the overbank area. A normal depth of 0.2% was adopted as the downstream boundary condition.

Flooding in the lower reach of Watermark Gully is controlled by the railway embankment and culverts located downstream of the Kamilaroi Highway, between XS 2 and XS 3 in the model. The configuration of the railway culverts was estimated based on site visit, photos and

topographic survey data. There are three sets of culverts at the railway. Table 8.6 shows the adopted configurations of the culverts at the railway.

Table 8.6 Adopted Culvert Configuration

Location	Number of Culvert	Culvert Width (m)	Culvert Height (m)
North-West	10	1.2	0.8
Centre	3	2.4	0.8
South-East	10	1.2	0.8

8.3.3 Design Flood Extents

Figure 8.5 to Figure 8.7 show the flood extents of the 2 year ARI, 100 year ARI and PMF design floods for both existing and Year 30 conditions. Note that the area downstream of the highway and railway is influenced by regional flooding from the Mooki River (see Section 9).

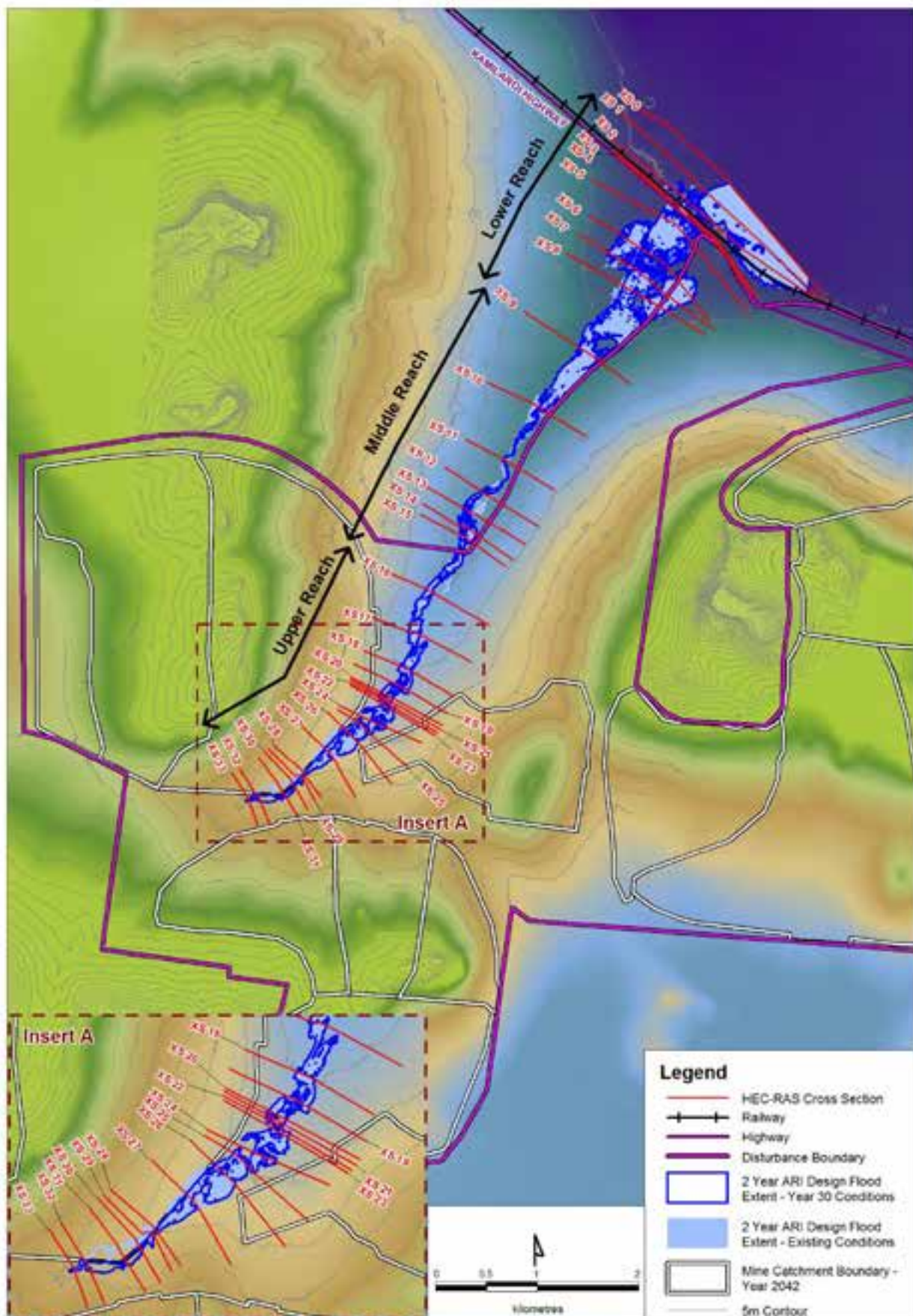


Figure 8.5 Watermark Gully HEC-RAS Model Configuration and Q2 Design Flood Extents



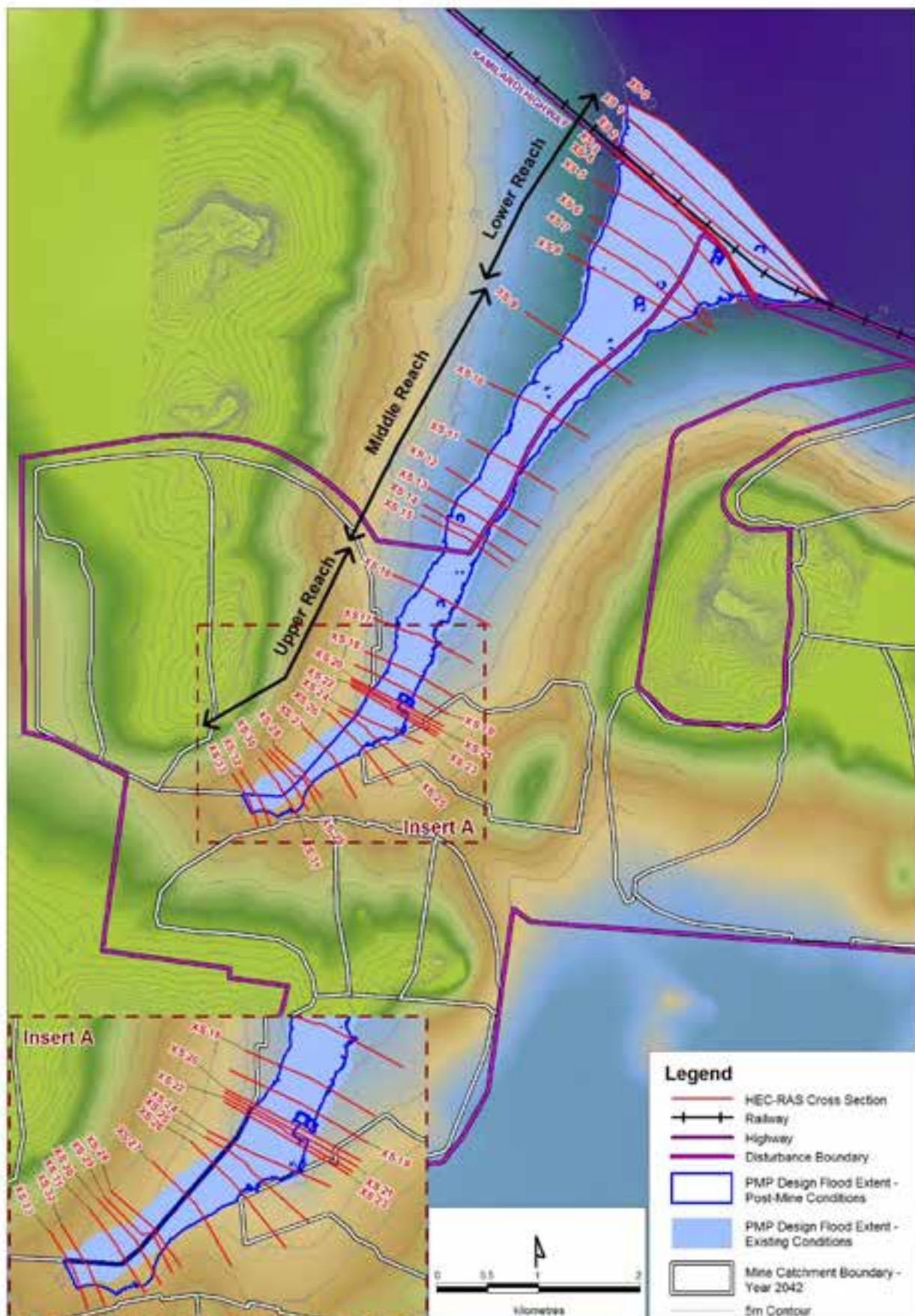


Figure 8.7 Watermark Gully HEC-RAS Model Configuration and PMP Design Flood Extents

8.3.4 Design Flood Levels

Figure 8.8 shows the 2 year ARI, 100 year ARI and PMP design flood levels longitudinal section along Watermark Gully. Table 8.7 shows the estimated 2 year ARI, 100 year ARI and PMP design flood levels at each model cross section for existing, Year 30 and post-mine conditions. Watermark Gully is characterised by wide, shallow flow.

The model results show that the 2 year ARI design flood levels for existing conditions along Watermark Gully range from:

- about 295.35m AHD to 313.87m AHD along the upper reach;
- about 285.69m AHD to 295.35m AHD along the middle reach; and
- about 278.32m AHD to 285.69m AHD along the lower reach.

The 100 year ARI design flood levels for existing conditions along Watermark Gully range from:

- about 295.81m AHD to 314.47m AHD along the upper reach;
- about 286.18m AHD to 295.81m AHD along the middle reach; and
- about 278.58m AHD to 286.18m AHD along the lower reach.

The PMP design flood levels for existing conditions along Watermark Gully range from:

- about 297.49m AHD to 315.69m AHD along the upper reach;
- about 287.62m AHD to 297.49m AHD along the middle reach; and
- about 279.51m AHD to 287.62m AHD along the lower reach.

8.3.5 Impacts on Flood Levels and Flood Extent – Year 30 Mine Conditions

The Project will impact flood levels along Watermark Gully through changes in contributing catchment area and partial filling of the main channel in the upper reaches by the proposed overburden emplacement area associated with the West Pit. The impacts of the overburden emplacement area on the Watermark Gully cross-section at three locations are shown in Figure 8.9. The proposed overburden emplacement area will cross the main channel at some locations. Hence, a diversion of the main channel further to the east will be required. Note that the upper reaches of Watermark Gully have been heavily modified by agricultural activity, including construction of farm dams and contour banks, as shown in Figure 8.10. The existing main channel of Watermark Gully is poorly defined.

Detailed design of the channel cross-section in the modified reach will be undertaken as part of the mine infrastructure design to provide a stable channel configuration. The general principles of the design will be to mimic the natural channel features as much as possible and to convey frequent flows at non-erosive velocities. The assessment of the impacts on flood flows due to the Project has been undertaken based on a preliminary concept for the Watermark Gully main channel profile in the diverted reach. The adopted main channel cross-section profile for the diverted reach was based on the shape of the existing main channel, as shown in Figure 8.11. Figure 8.12 shows the location of the conceptual diversion. Note that hydraulic modelling shows that the diversion hydraulic characteristics will be similar and therefore will behave in a hydraulically similar manner to the existing flow path. Impacts on design flood levels and velocities are shown in Table 8.7 and Table 8.8 respectively. Downstream of cross-section XS 28, the 2 year ARI, 100 year ARI and PMP design flood levels for Year 30 conditions are generally lower than existing conditions due to the reduction in catchment area. For Year 30 conditions, peak flood levels upstream of XS 28 will be increased for the 2 year ARI, 100 year ARI and PMP design events by up to 0.65m, 0.88m and 1.24m respectively compared to existing conditions.

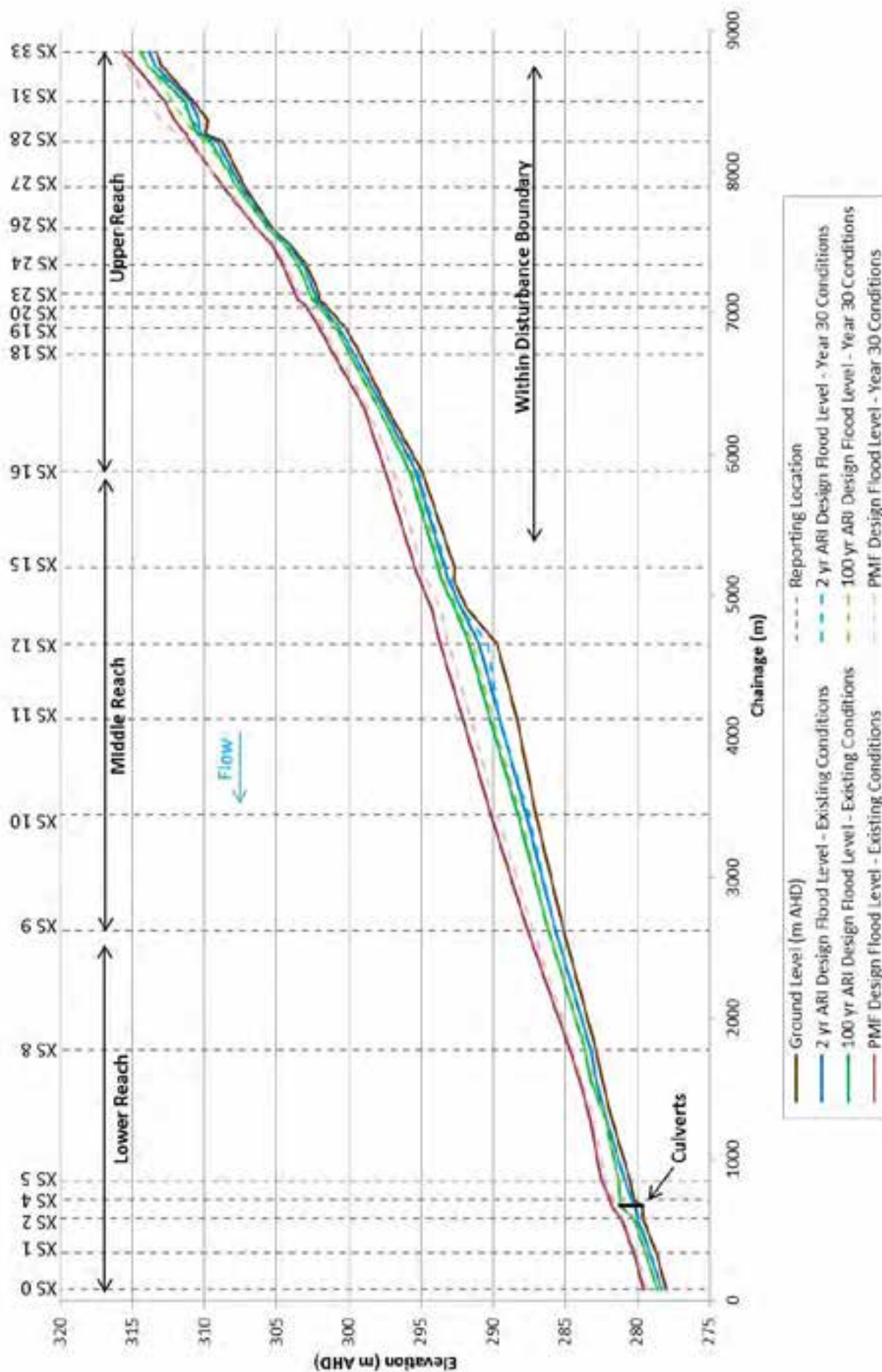


Figure 8.8 Watermark Gully Peak Water Level Longitudinal Section, 2 Year ARI, 100 Year ARI and PMP Design Flood Events

Table 8.7 Design Flood Levels of 2 Year ARI, 100 Year ARI and PMP Design Events

Reporting Location	Chainage (m)	Ground Level (m AHD)	2 Year ARI Design Flood Level (m AHD)				100 Year ARI Design Flood Level (m AHD)				PMF Flood Level (m AHD)						
			Existing Conditions	Year 30 Conditions	Diff. (m)	Post-mine Conditions	Diff. (m)	Existing Conditions	Year 30 Conditions	Diff. (m)	Post-mine Conditions	Diff. (m)	Existing Conditions	Year 30 Conditions	Diff. (m)	Post-mine Conditions	Diff. (m)
XS 0	80	277.99	278.32	278.30	-0.02	278.33	0.00	278.58	278.52	-0.06	278.60	0.02	279.51	279.33	-0.19	279.56	0.05
XS 1	340	278.67	279.11	279.12	0.01	279.11	0.00	279.39	279.32	-0.06	279.40	0.02	280.22	280.05	-0.18	280.27	0.05
XS 2	583	279.60	279.96	279.86	-0.10	279.97	0.01	280.24	280.18	-0.06	280.25	0.01	281.11	280.93	-0.18	281.16	0.05
XS 3	672	279.61	280.14	280.04	-0.09	280.16	0.02	281.16	281.08	-0.07	281.18	0.03	281.79	281.65	-0.14	281.80	0.01
XS 4	717	280.25	280.36	280.35	-0.02	280.37	0.00	281.16	281.09	-0.07	281.19	0.03	281.85	281.70	-0.15	281.87	0.02
XS 5	848	280.48	280.87	280.84	-0.03	280.88	0.01	281.31	281.20	-0.10	281.34	0.03	282.45	282.25	-0.21	282.51	0.06
XS 6	1299	281.78	282.15	282.15	0.00	282.15	0.00	282.25	282.22	-0.03	282.26	0.01	283.28	283.04	-0.24	283.34	0.06
XS 7	1561	282.41	282.82	282.82	0.00	282.83	0.01	283.20	283.11	-0.09	283.25	0.05	283.99	283.83	-0.15	284.13	0.14
XS 8	1777	282.83	283.26	283.18	-0.08	283.26	0.00	283.63	283.53	-0.10	283.67	0.04	284.63	284.48	-0.16	284.81	0.17
XS 9	2625	285.07	285.69	285.68	-0.01	285.70	0.01	286.18	286.07	-0.11	286.20	0.02	287.62	287.20	-0.42	287.65	0.03
XS 10	3447	287.06	287.75	287.57	-0.18	287.76	0.01	288.28	288.13	-0.15	288.34	0.06	290.14	289.74	-0.41	290.30	0.16
XS 11	4123	288.33	289.53	289.57	0.05	289.55	0.03	290.23	290.04	-0.19	290.26	0.04	292.09	291.53	-0.56	292.23	0.14
XS 12	4653	289.73	290.97	290.32	-0.65	291.00	0.03	291.67	291.44	-0.23	291.73	0.07	293.67	293.09	-0.58	293.85	0.18
XS 13	4910	291.85	292.25	292.24	-0.01	292.27	0.02	292.64	292.48	-0.16	292.68	0.04	294.28	293.68	-0.59	294.46	0.19
XS 14	5110	292.70	293.08	292.97	-0.11	293.09	0.01	293.59	293.40	-0.19	293.64	0.06	295.08	294.58	-0.50	295.25	0.16
XS 15	5194	292.65	293.32	293.25	-0.07	293.34	0.02	293.80	293.60	-0.20	293.86	0.06	295.40	294.88	-0.52	295.57	0.17
XS 16	5876	294.94	295.35	295.25	-0.10	295.39	0.04	295.81	295.61	-0.20	295.90	0.09	297.49	296.93	-0.56	297.75	0.26
XS 17	6334	297.43	297.63	297.62	-0.01	297.64	0.01	297.97	297.89	-0.09	298.02	0.05	298.99	298.69	-0.30	299.23	0.24
XS 18	6712	299.22	299.68	299.64	-0.04	299.71	0.02	299.99	299.91	-0.08	300.03	0.04	301.09	300.82	-0.27	301.20	0.11
XS 19	6893	300.19	300.64	300.60	-0.04	300.66	0.02	300.85	300.76	-0.09	300.91	0.05	302.04	301.71	-0.32	302.21	0.17
XS 20	7039	301.45	301.80	301.73	-0.07	301.82	0.02	302.02	301.95	-0.06	302.05	0.03	302.93	302.67	-0.26	303.08	0.14
XS 21	7075	301.84	302.02	301.99	-0.03	302.04	0.02	302.36	302.27	-0.09	302.40	0.05	303.31	303.06	-0.25	303.44	0.13
XS 22	7098	302.03	302.27	302.23	-0.05	302.29	0.01	302.52	302.44	-0.07	302.56	0.04	303.53	303.25	-0.28	303.65	0.12
XS 23	7136	302.01	302.35	302.24	-0.11	302.37	0.02	302.68	302.59	-0.09	302.73	0.05	303.74	303.45	-0.29	303.86	0.12
XS 24	7342	302.97	303.18	303.30	0.12	303.20	0.02	303.51	303.41	-0.11	303.57	0.06	304.62	304.33	-0.29	304.75	0.13
XS 25	7483	304.08	304.24	304.22	-0.02	304.27	0.03	304.46	304.41	-0.05	304.50	0.04	305.35	305.13	-0.21	305.51	0.16
XS 26	7595	305.25	305.40	305.43	0.03	305.43	0.03	305.50	305.45	-0.05	305.56	0.06	306.33	306.20	-0.13	306.60	0.27
XS 27	7894	307.23	307.48	307.39	-0.09	307.44	-0.04	307.75	307.70	-0.05	307.80	0.05	308.73	308.55	-0.18	309.00	0.27
XS 28	8218	308.77	309.14	309.71	0.57	309.81	0.67	309.57	309.89	0.32	310.13	0.56	311.00	311.30	0.30	311.90	0.90
XS 29	8265	309.96	310.30	310.03	-0.27	310.09	-0.21	310.53	310.55	0.02	310.68	0.15	311.28	311.87	0.59	312.65	1.37
XS 30	8365	309.79	310.42	310.87	0.45	310.96	0.54	310.90	311.38	0.48	311.62	0.73	312.12	312.96	0.84	313.36	1.24
XS 31	8500	310.75	310.95	311.60	0.65	311.68	0.73	311.32	312.20	0.88	312.42	1.10	312.79	314.03	1.24	314.59	1.80
XS 32	8755	313.00	313.47	313.44	-0.03	313.51	0.04	313.95	313.89	-0.06	314.07	0.12	314.84	315.27	0.43	315.80	0.95
XS 33	8850	313.34	313.87	313.87	0.01	313.99	0.12	314.47	314.51	0.04	314.64	0.17	315.69	315.83	0.14	316.33	0.65

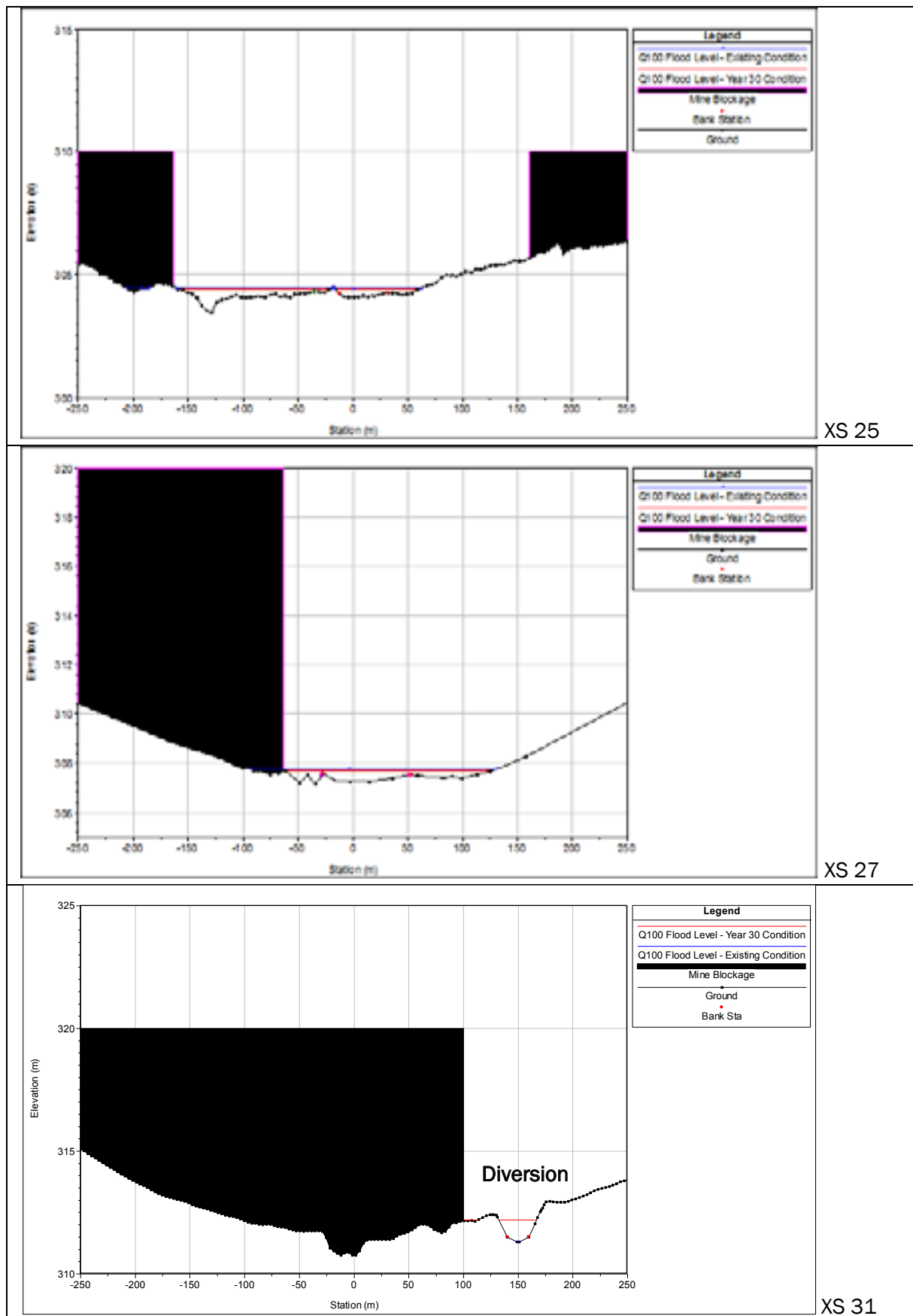


Figure 8.9 Impacts of Overburden Emplacement on Watermark Gully Cross-section



Figure 8.10 Aerial Image of Upper Reaches of Watermark Gully (Source: Google Earth)

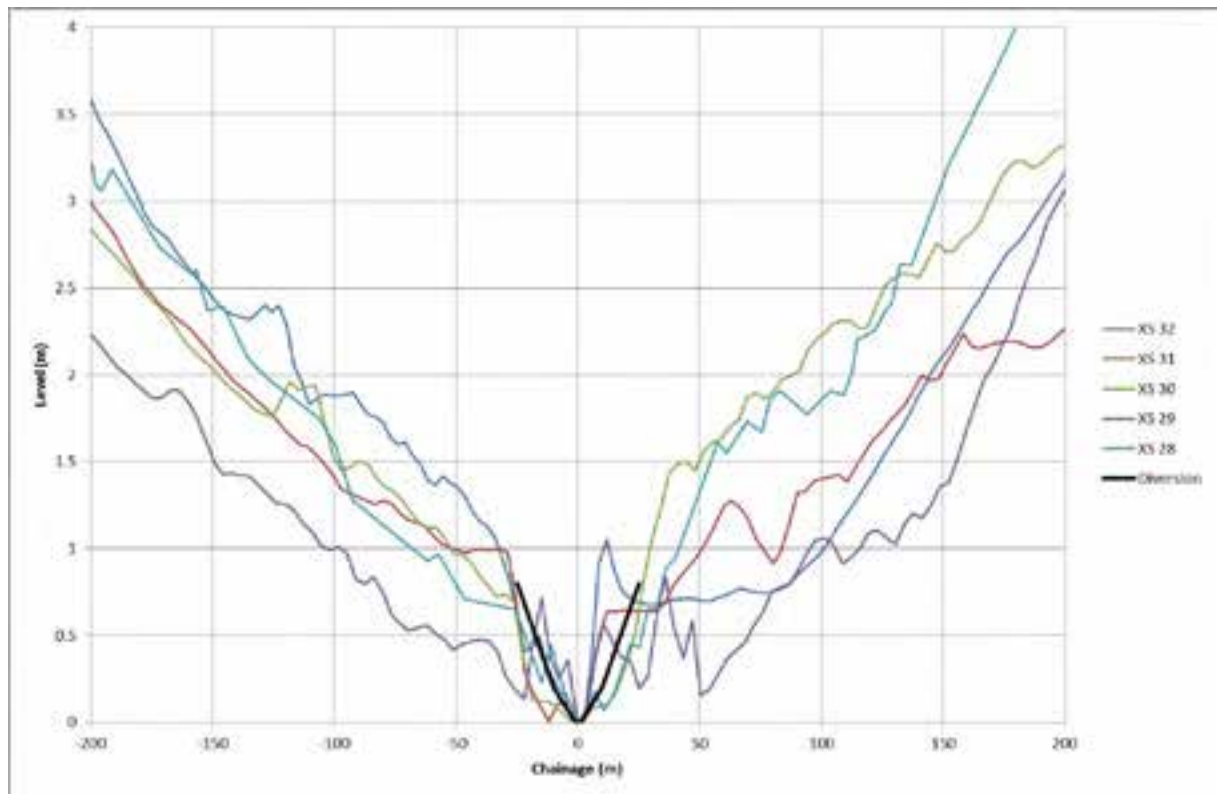


Figure 8.11 Comparison of Watermark Gully Cross-sections With Adopted Cross-section for Main Channel Division in the Impacted Reach

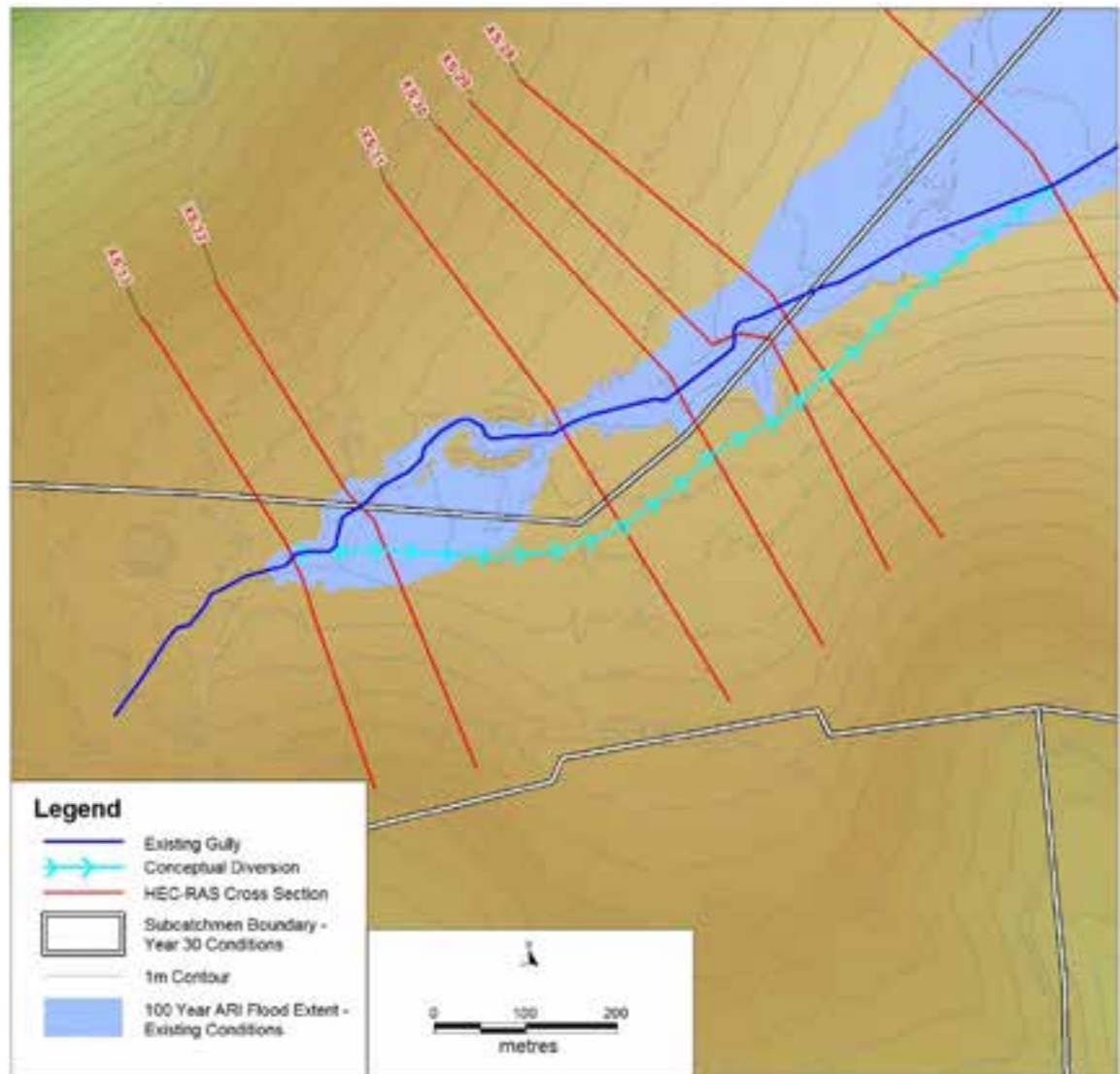


Figure 8.12 Location of Main Channel Diversion, Watermark Gully

8.3.6 Impacts on Flood Levels and Extent – Post-mine Conditions

Impacts on design flood levels for post-mine conditions are shown in Table 8.7. The following is of note:

- For the 2 year ARI design flood, the flood levels are generally slightly higher than existing conditions downstream of cross-section XS 28, with less than 0.05m increased in peak flood levels along Watermark Gully. The model result shows no increase in peak flood level downstream of the Kamilaroi Highway for the 2 year ARI design flood.
- For the 100 year ARI design flood, the increase in peak flood levels downstream of cross-section XS 28 are up to 0.09m. At the downstream of the Kamilaroi Highway, the peak flood levels for the post-mine conditions will increase by up to 0.02m. The impact on the peak flood levels downstream of Kamilaroi Highway will be reduced as floodwater flows onto the Mooki River floodplain.
- For the PMF, the increase in peak flood levels downstream of Kamilaroi Highway is up to 0.05m.

8.3.7 Flood Velocities

Figure 8.13 and Figure 8.14 show a longitudinal plot of the 2 year and 100 year ARI channel velocities along Watermark Gully for existing, Year 30 and post-mine conditions.

Table 8.8 shows these values for each model cross section.

The model results indicate that, in general, flood velocities along Watermark Gully are not high because Watermark Gully is characterised by wide, shallow flow. Hence, even though constriction of the channel reduces waterway area, the flow remains relatively wide and shallow (width of the order of 50 to 100 m and flow depth of the order of 1 m). The channel velocities for Year 30 and post-mine conditions are within the range of existing velocities.

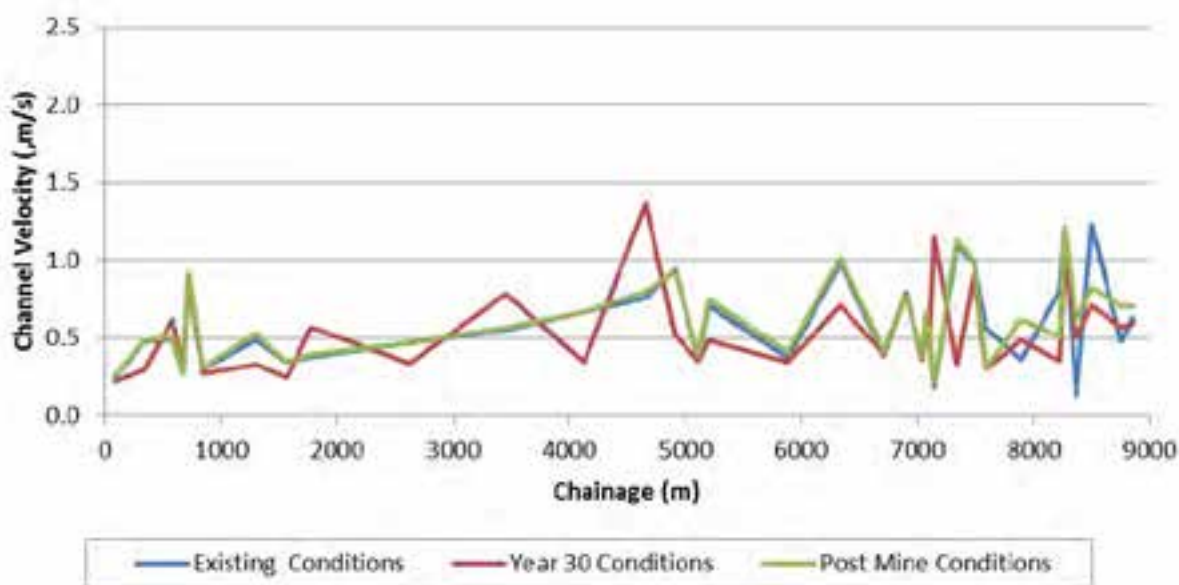


Figure 8.13 Watermark Gully Channel Velocity, 2 Year ARI Event

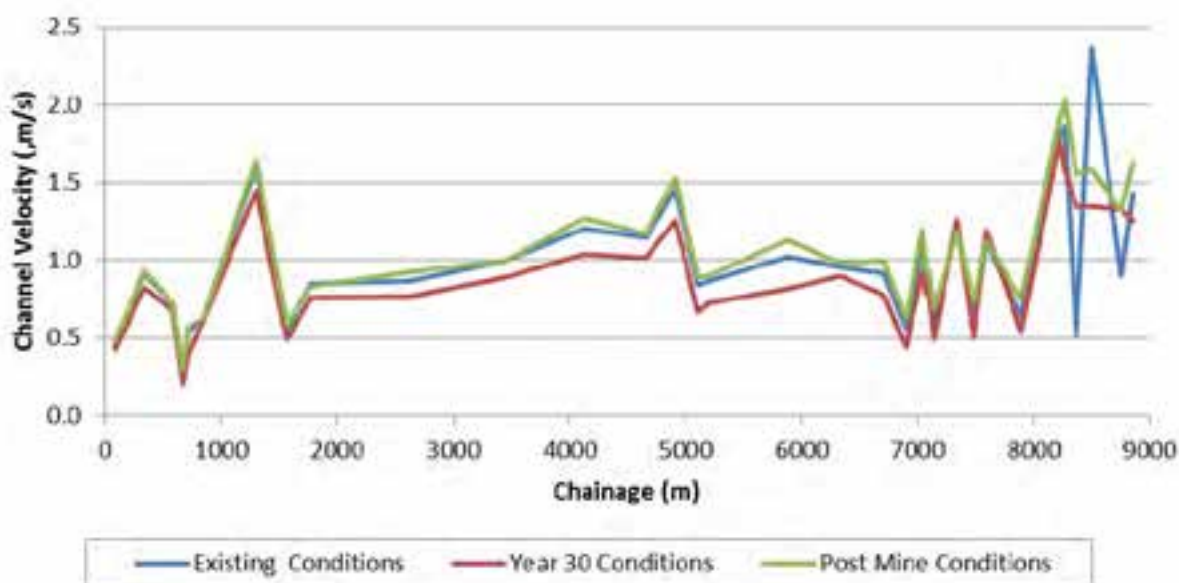


Figure 8.14 Watermark Gully Channel Velocity, 100 Year ARI Event

Table 8.8 Watermark Gully Channel Velocity, 2 Year and 100 Year ARI

Reporting Location	Chainage (m)	Channel Velocity - 2 Year ARI (m/s)			Channel Velocity - 100 Year ARI (m/s)		
		Existing Conditions	Year 30 Conditions	Post-mine Conditions	Existing Conditions	Year 30 Conditions	Post-mine Conditions
XS 0	80	0.2	0.2	0.3	0.5	0.4	0.5
XS 1	340	0.5	0.3	0.5	0.9	0.8	0.9
XS 2	583	0.5	0.6	0.5	0.7	0.7	0.7
XS 3	672	0.3	0.3	0.3	0.3	0.2	0.3
XS 4	717	0.9	0.8	0.9	0.5	0.4	0.6
XS 5	848	0.3	0.3	0.3	0.6	0.6	0.6
XS 6	1299	0.5	0.3	0.5	1.6	1.4	1.6
XS 7	1561	0.4	0.2	0.4	0.6	0.5	0.6
XS 8	1777	0.4	0.6	0.4	0.8	0.8	0.8
XS 9	2625	0.5	0.3	0.5	0.9	0.8	0.9
XS 10	3447	0.5	0.8	0.6	1.0	0.9	1.0
XS 11	4123	0.7	0.3	0.7	1.2	1.0	1.3
XS 12	4653	0.8	1.4	0.8	1.2	1.0	1.2
XS 13	4910	0.9	0.5	0.9	1.5	1.3	1.5
XS 14	5110	0.4	0.4	0.4	0.8	0.7	0.9
XS 15	5194	0.7	0.5	0.7	0.9	0.7	0.9
XS 16	5876	0.4	0.3	0.4	1.0	0.8	1.1
XS 17	6334	1.0	0.7	1.0	1.0	0.9	1.0
XS 18	6712	0.4	0.4	0.4	0.9	0.8	1.0
XS 19	6893	0.8	0.8	0.8	0.6	0.4	0.6
XS 20	7039	0.4	0.4	0.4	1.1	0.9	1.2
XS 21	7075	0.7	0.6	0.7	0.9	0.8	0.9
XS 22	7098	0.5	0.5	0.6	0.9	0.8	0.9
XS 23	7136	0.2	1.2	0.2	0.6	0.5	0.7
XS 24	7342	1.1	0.3	1.1	1.2	1.3	1.2
XS 25	7483	1.0	0.9	1.0	0.6	0.5	0.7
XS 26	7595	0.6	0.3	0.3	1.1	1.2	1.1
XS 27	7894	0.4	0.5	0.6	0.6	0.5	0.7
XS 28	8218	0.8	0.4	0.5	1.8	1.8	1.9
XS 29	8265	1.2	1.0	1.2	1.9	1.6	2.0
XS 30	8365	0.1	0.5	0.6	0.5	1.3	1.6
XS 31	8500	1.2	0.7	0.8	2.4	1.3	1.6
XS 32	8755	0.5	0.6	0.7	0.9	1.3	1.3
XS 33	8850	0.6	0.6	0.7	1.4	1.3	1.6

8.4 WATERMARK GULLY FLOW FREQUENCY ASSESSMENT

The changes in catchment area due to the progress of mining will affect the magnitude and frequency of flows in Watermark Gully. The OPSIM model was used to simulate the flow-duration relationship for Watermark Gully for pre-mine conditions, Year 25 and for post-mine conditions.

The 122 years of historical rainfall data was applied to the pre-mine, Year 25 and post-mine Watermark Gully catchment configurations (shown in Figure 8.15, Figure 8.16 and Figure 8.17). Flows in Watermark Gully are reported at three locations.

Spills will occur from the sediment dams to Watermark Gully during the mine life, however these have been excluded from the flow frequency analysis for Year 25 to maximise the excluded catchment and provide a conservatively low estimate of flow frequency.

The catchment area draining to Watermark Gully post-mine will exceed that for pre-mine due to the inclusion of contour drains redirecting surface water away from the final void.

The modelled flow frequencies at reporting locations 1, 2 and 3 are provided in Figure 8.15, Figure 8.16 and Figure 8.17 respectively. The following is of note:

- As expected, the post-mine Watermark Gully catchment configuration (which has the largest catchment draining to Watermark Gully) results in the highest flows and the Year 25 catchment configuration results in the lowest flows at each reporting location;
- For all catchment configurations, Watermark Gully is dry approximately 97.9% of the time; and
- At the downstream boundary (reporting location 3), the 1 percentile flow is 15.8 ML/day for the Year 25 Watermark Gully catchments, 26.5 ML/day for the pre-mine catchments and 31.6 ML/day for the post-mine catchments.

Whilst the hydrologic model results show a measurable change in the flow-duration relationship for Watermark Gully, given the high variability of runoff in natural watercourses in the area of interest, it is considered unlikely that these flow frequency changes will significantly alter the hydraulic characteristics of Watermark Gully which will readjust itself to the altered flow regime. A geomorphological assessment of impacts on Watermark Gully has been undertaken by GHD (GHD 2012).

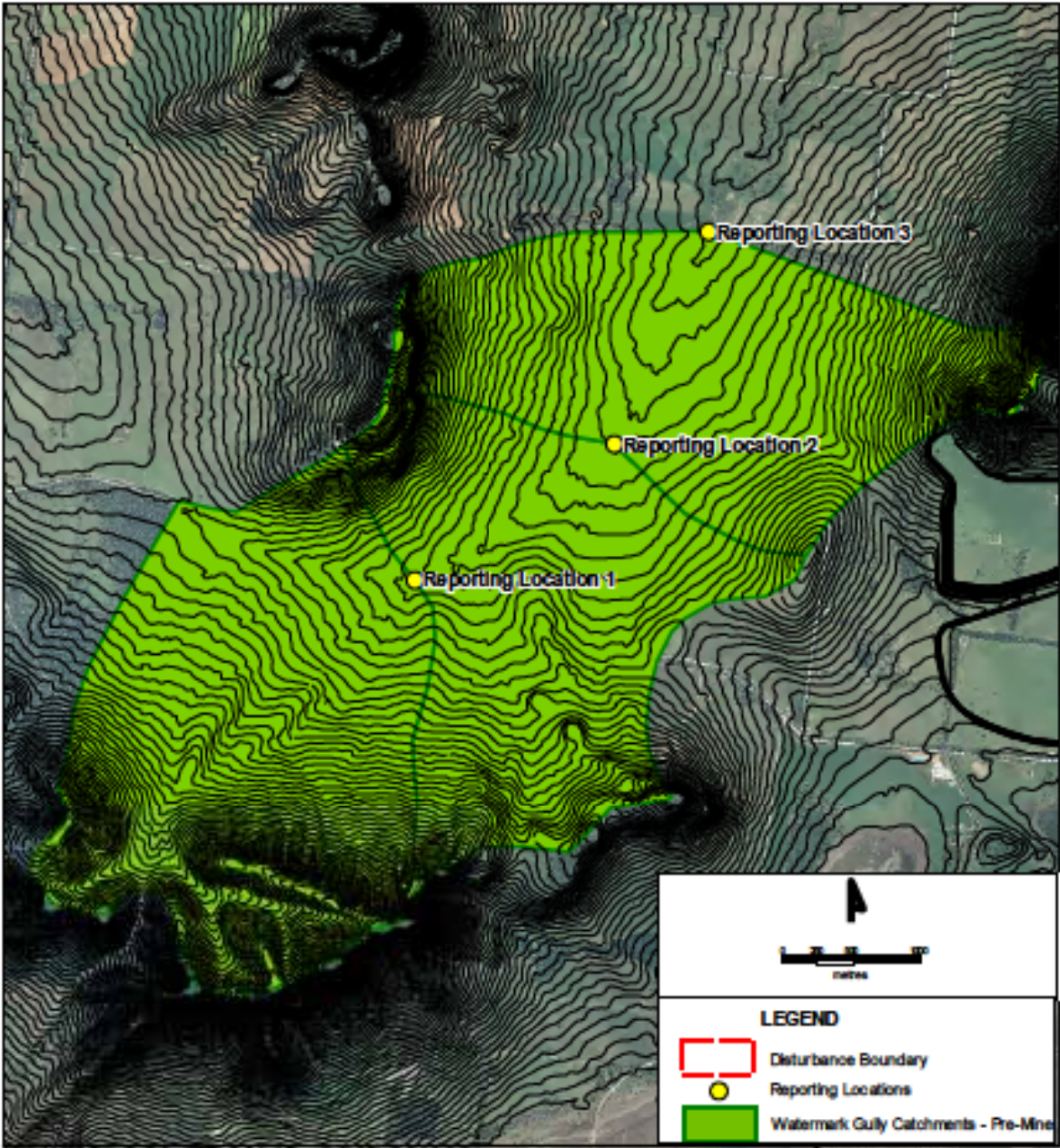


Figure 8.15 Pre-Mine Watermark Gully Catchment Configuration

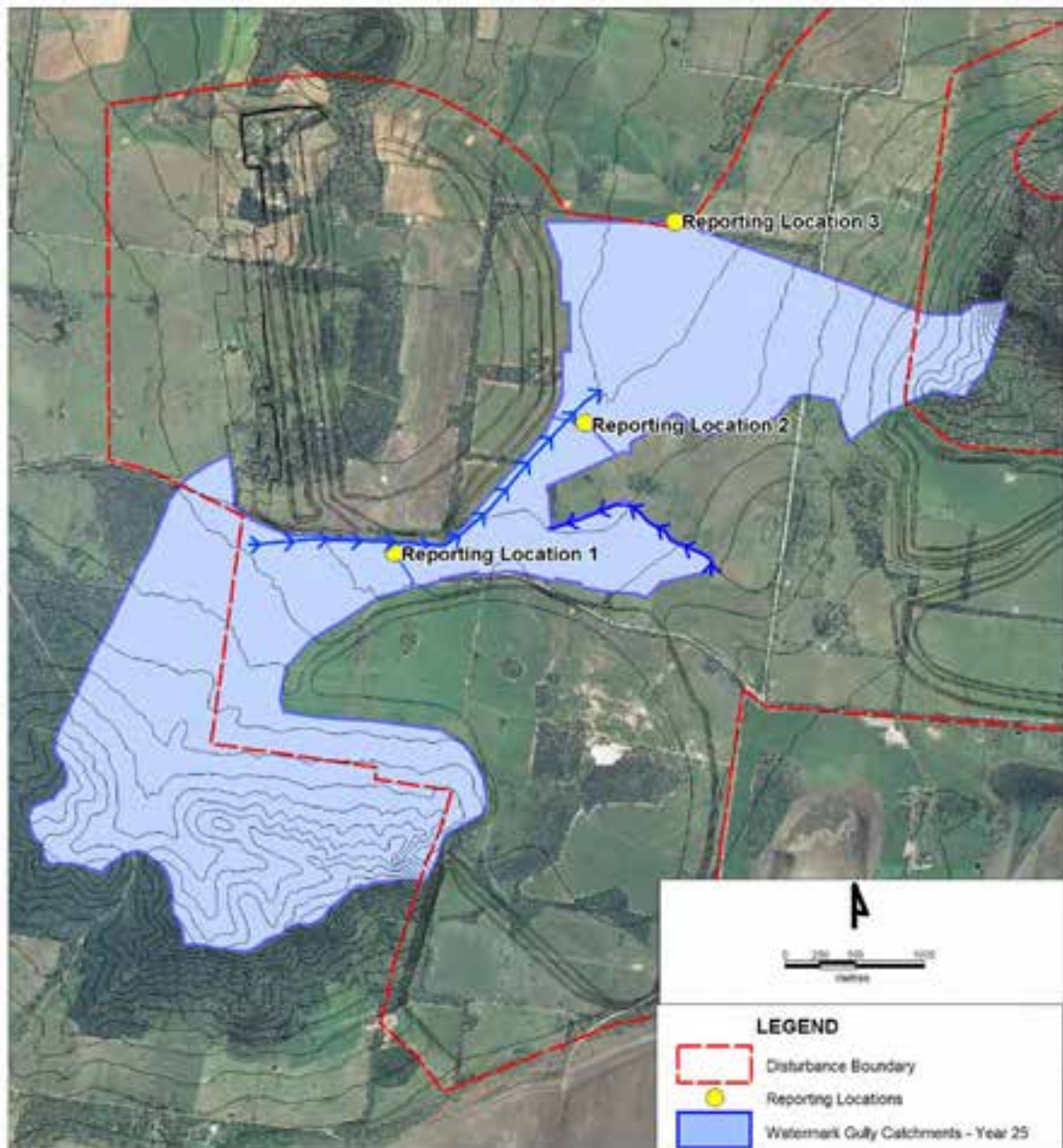


Figure 8.16 Year 25 Watermark Gully Catchment Configuration

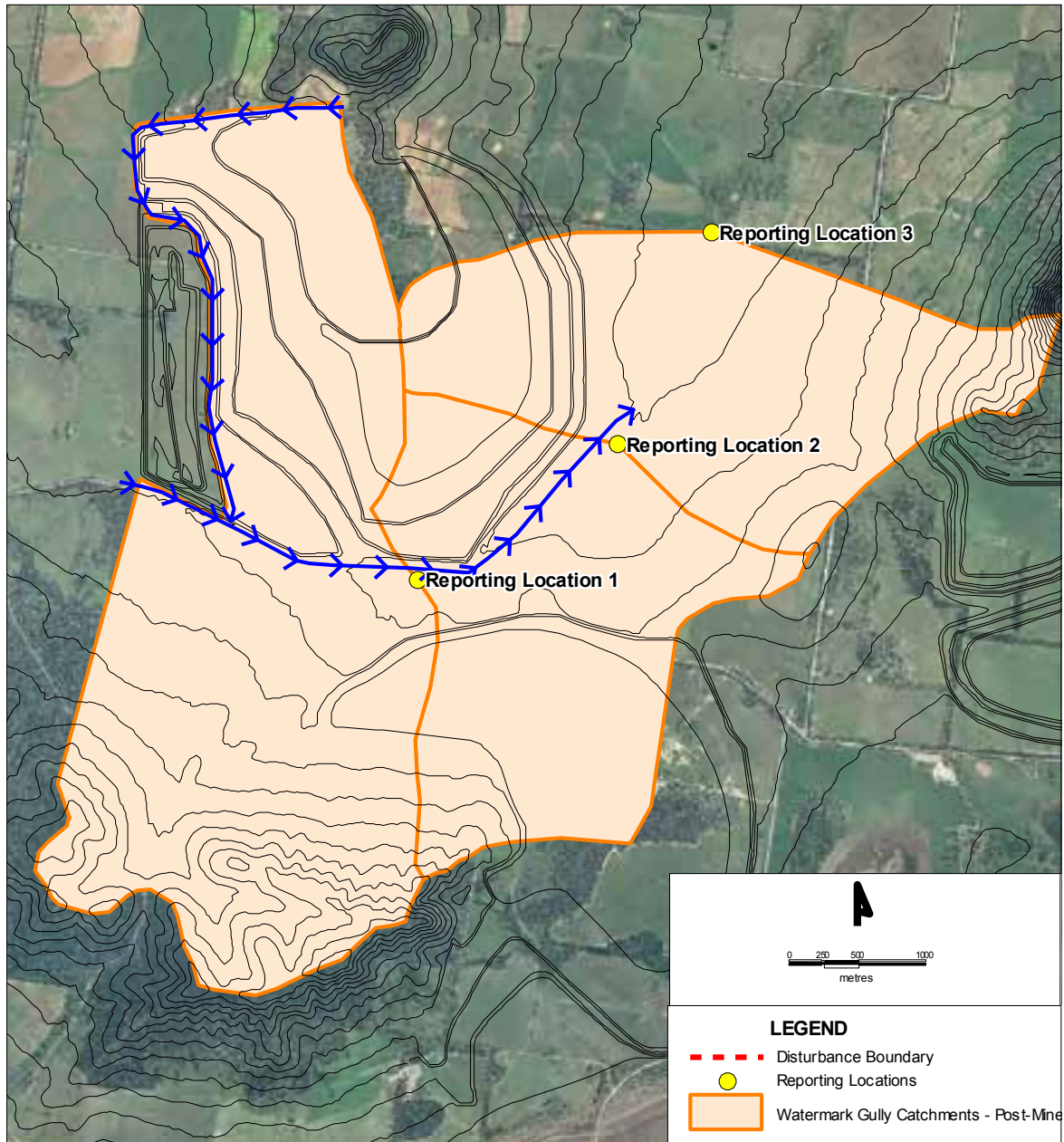


Figure 8.17 Post-Mine Watermark Gully Catchment Configuration

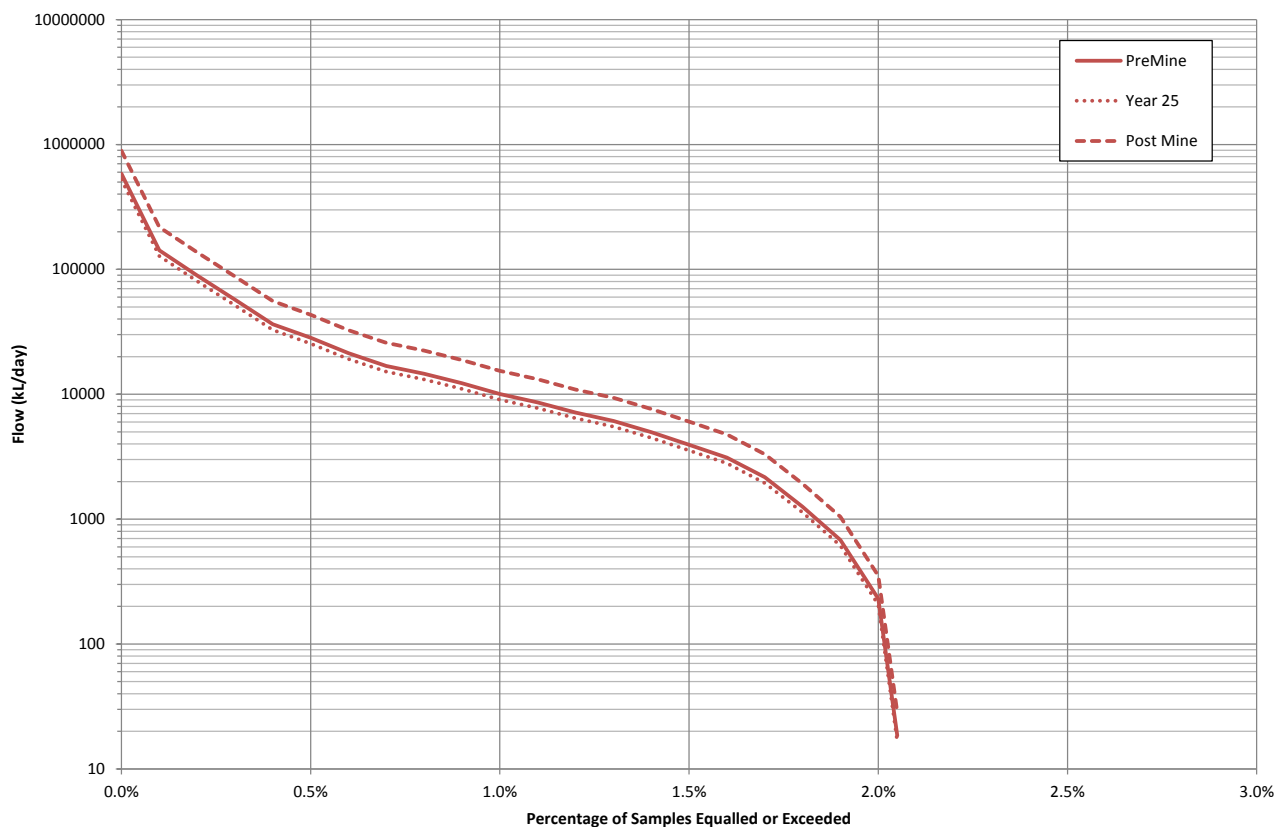


Figure 8.18 Watermark Gully Flow Frequency – Reporting Location #1

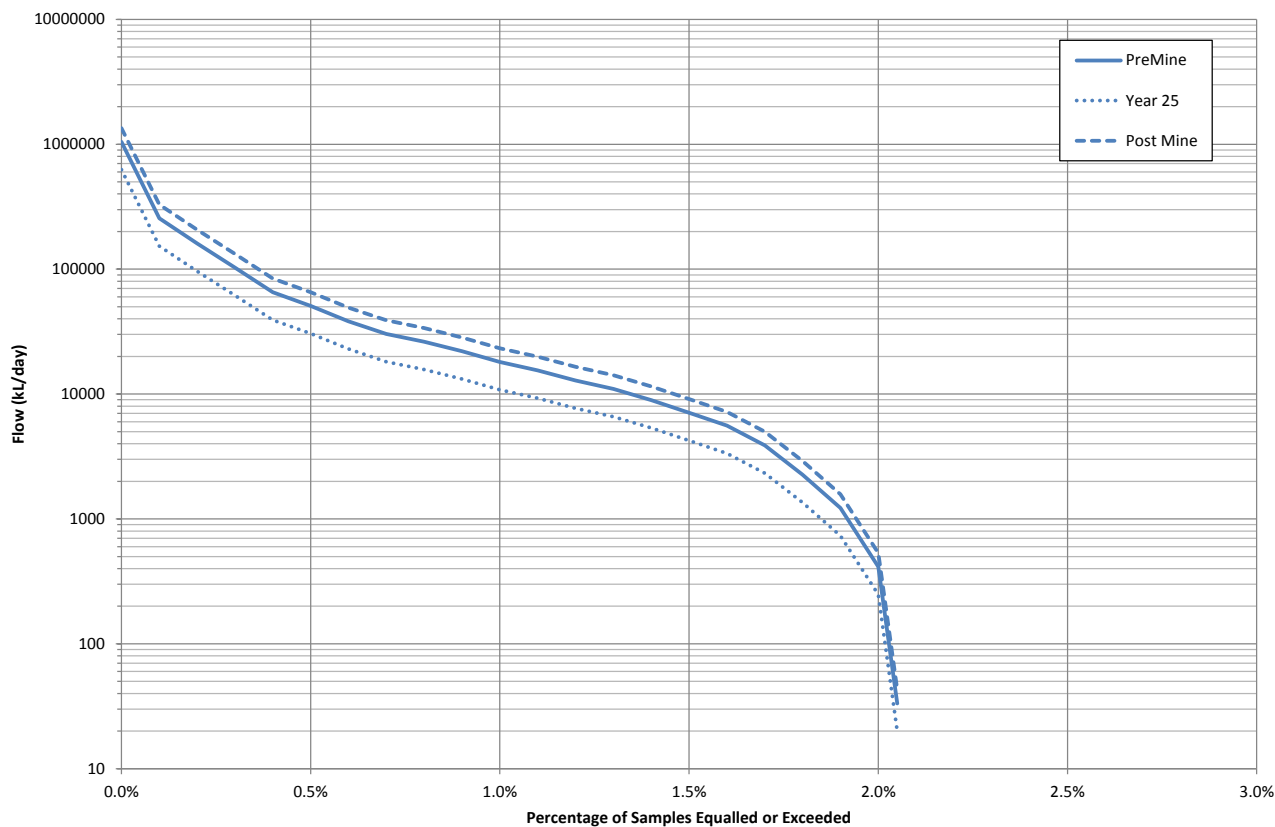


Figure 8.19 Watermark Gully Flow Frequency – Reporting Location #2

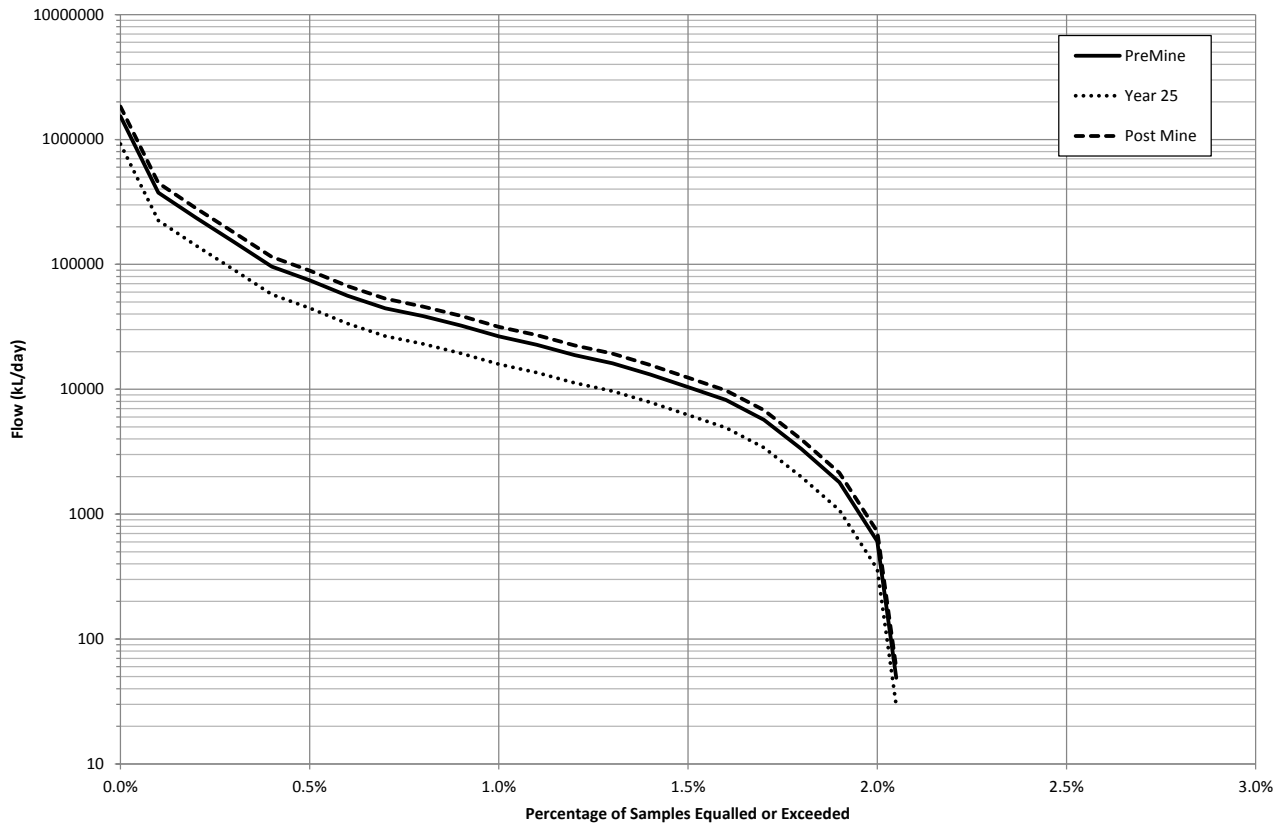


Figure 8.20 Watermark Gully Flow Frequency – Reporting Location #3

9 MOOKI RIVER FLOOD ASSESSMENT

9.1 OVERVIEW

Significant areas of the alluvial plains adjacent to the Project are inundated during major flood events in the Mooki River. A flood study of the Mooki River was undertaken to estimate design flood levels in the vicinity of the Project. The methodology for the flood study was based on the development of a runoff routing (RAFTS) model of the Mooki River catchment and a two-dimensional (TUFLOW) hydraulic model of Native Dog Gully and the the Mooki River floodplain. Further details of the methodology and results of the flood study are provided below.

9.2 CALIBRATION AND VERIFICATION EVENTS

9.2.1 Adopted Calibration and Verification Events

The two largest recent flood events (July 1998 and November 2000) at Caroona and Breeza were selected for hydrologic and hydraulic model calibration due to availability of data and the magnitude of the flood events. The January 1984 event was selected as a verification event for the hydrologic model only. The lack of sub-daily rainfall data for the January 1984 event made it unsuitable for use in the hydraulic model calibration because runoff inflows could not be accurately defined for this event.

9.2.2 Rainfall Data

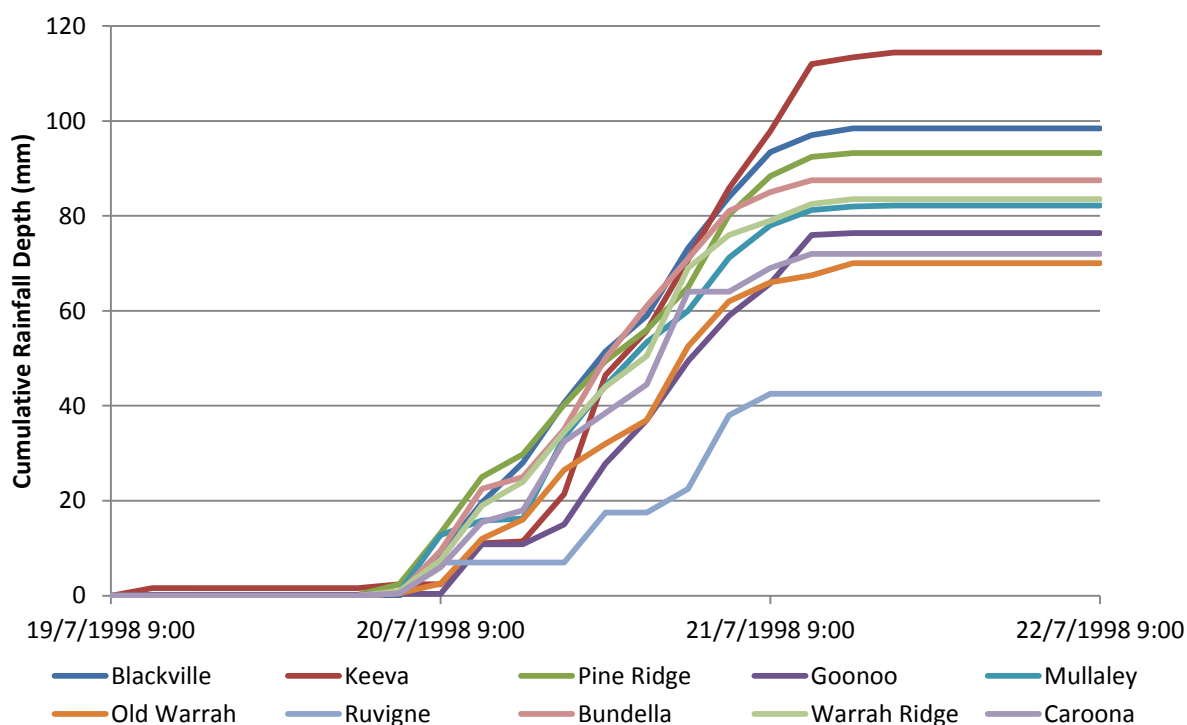
Pluviograph Data

Table 9.1 shows the available pluviograph data from rainfall stations within and adjacent to the Mooki River catchment for the selected model calibration and verification events. Figure 9.1 and Figure 9.2 show the recorded cumulative rainfalls at all stations with pluviograph data for July 1998 and November 2000 flood events. Figure 9.3 shows the locations of the pluviograph stations. The following is of note:

- There is no pluviograph data available for 1984 flood event.
- Pluviograph data is available for both 1998 and 2000 flood events at all selected stations.

Table 9.1 Pluviograph Data Availability for Mooki River Catchment

Station Name	Pluviograph Data Available			Total Rainfall (mm)	
	January 1984	July 1998	November 2000	July 1998 ^a	November 2000 ^b
Blackville	-	Y	Y	98	153
Bundella	-	Y	Y	88	121
Caroona	-	Y	Y	72	112
Goonoo	-	Y	Y	76	94
Keeva	-	Y	Y	114	127
Mullaley	-	Y	Y	82	84
Old Warrah	-	Y	Y	70	122
Pine Ridge	-	Y	Y	93	117
Ruvigne	-	Y	Y	43	46
Warrah Ridge	-	Y	Y	84	104

^a 9am 19 July to 9am 22 July^b 9am 17 November to 9am 21 November**Figure 9.1** Cumulative Rainfalls in the Mooki River Catchment, July 1998 Flood Event

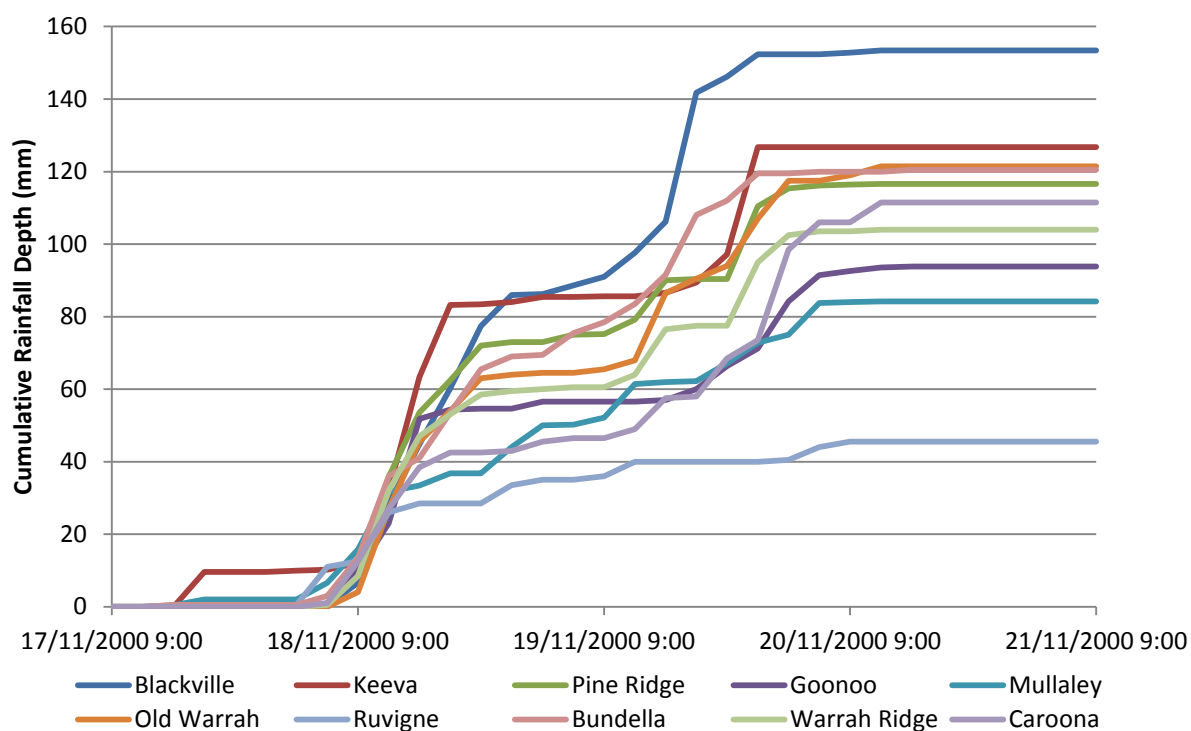


Figure 9.2 Cumulative Rainfalls in the Mooki River Catchment, November 2000 Flood Event

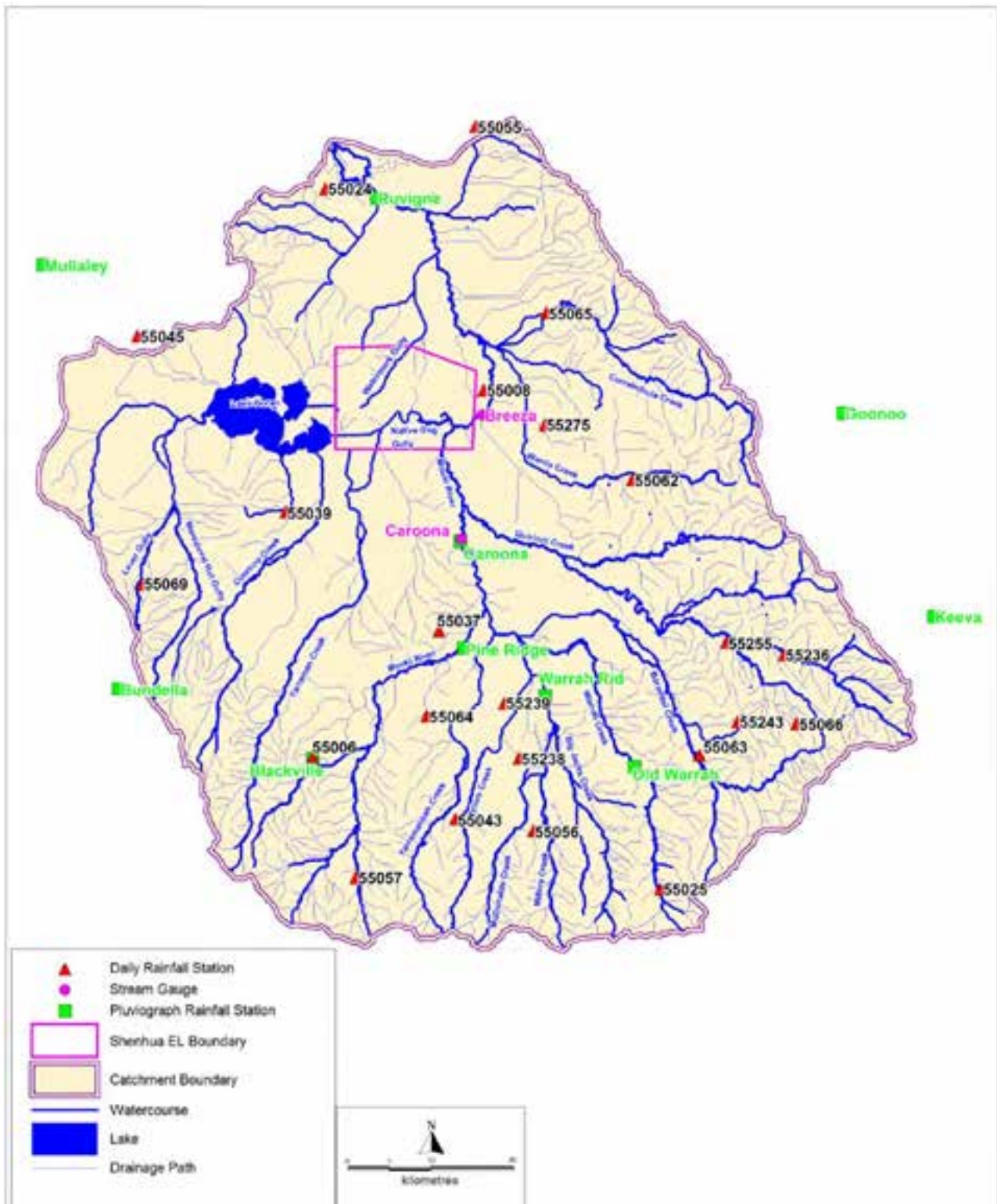


Figure 9.3 Rainfall Station and Stream Gauge Locality Map

Daily Data

Table 9.2 shows the available daily data from rainfall stations within and adjacent to the Mooki River catchment for the selected model calibration / verification events. Daily rainfall data at stations shown in Table 9.2 is available for all selected calibration and verification events. Figure 9.3 shows the locations of the daily rainfall stations.

Table 9.2 Daily Rainfall Data Availability for Mooki River Catchment

Station Number	Station Name	Total Rainfall (mm)		
		1984 Event ^a	1998 Event	2000 Event
55006	Blackville Post Office	95	96	152
55008	Breeza (Main Street)	148	129	107
55024	Gunnedah Resource Centre	131	87	59
55025	Willow Tree (Highlands)	85	115	272
55037	Pine Ridge (Mooki Springs)	80	86	117
55039	Spring Ridge	80	86	183
55043	Willow Tree (Parraweena)	84	103	136
55045	Curlewis (Pine Cliff)	87	98	134
55055	Carroll (The Ranch)	52	59	43
55056	Willow Tree (Green Hills)	81	100	168
55057	Willow Tree (Valais)	126	103	128
55062	Werris Creek Post Office	104	120	101
55063	Willow Tree (General Store)	95	101	126
55064	Pine Ridge (Windy)	86	90	136
55065	Breeza (The Park)	162	76	77
55066	Wallabadah (Woodton)	115	98	139
55069	Yannergee (Dobroyd)	75	87	34
55236	Wallabadah (Martyn St)	75	85	133
55238	Pine Ridge (Boondari)	74	92	151
55239	Pine Ridge (Round Island)	83	91	140
55243	Willow Tree (Glenora)	93	97	66
55255	Quirindi (Springvale)	63	90	118
55275	Breeza (Alpha)	96	106	102

^a 9am 29 January to 9am 30 January

Rainfall Distribution

Figure 9.4, Figure 9.5 and Figure 9.6 show the rainfall distribution in the Mooki River catchment during the 1984, 1998 and 2000 calibration/verification events respectively, based on all available pluviograph and daily rainfall data. The following is of note:

- During the January 1984 flood event, high rainfalls were recorded at Breeza and near Blackville with daily rainfalls of 162mm and 144mm respectively. Relatively low daily rainfall was recorded near Quirindi, Warrah Ridge and Spring Ridge.

- During the July 1998 flood event the highest rainfall was recorded at Breeza with a total rainfall of 129mm. More than 100mm of total rainfall was also recorded in the Werris Creek catchment and near Liverpool Range. Relatively low daily rainfall was recorded in Lake Goran catchment.
- During the November 2000 flood event, 272mm of rainfall was recorded in the upper catchment of Warrah Creek, and 183mm total rainfall was recorded at Spring Ridge, south of Lake Goran. Total rainfall recorded at Breeza was 107 mm.

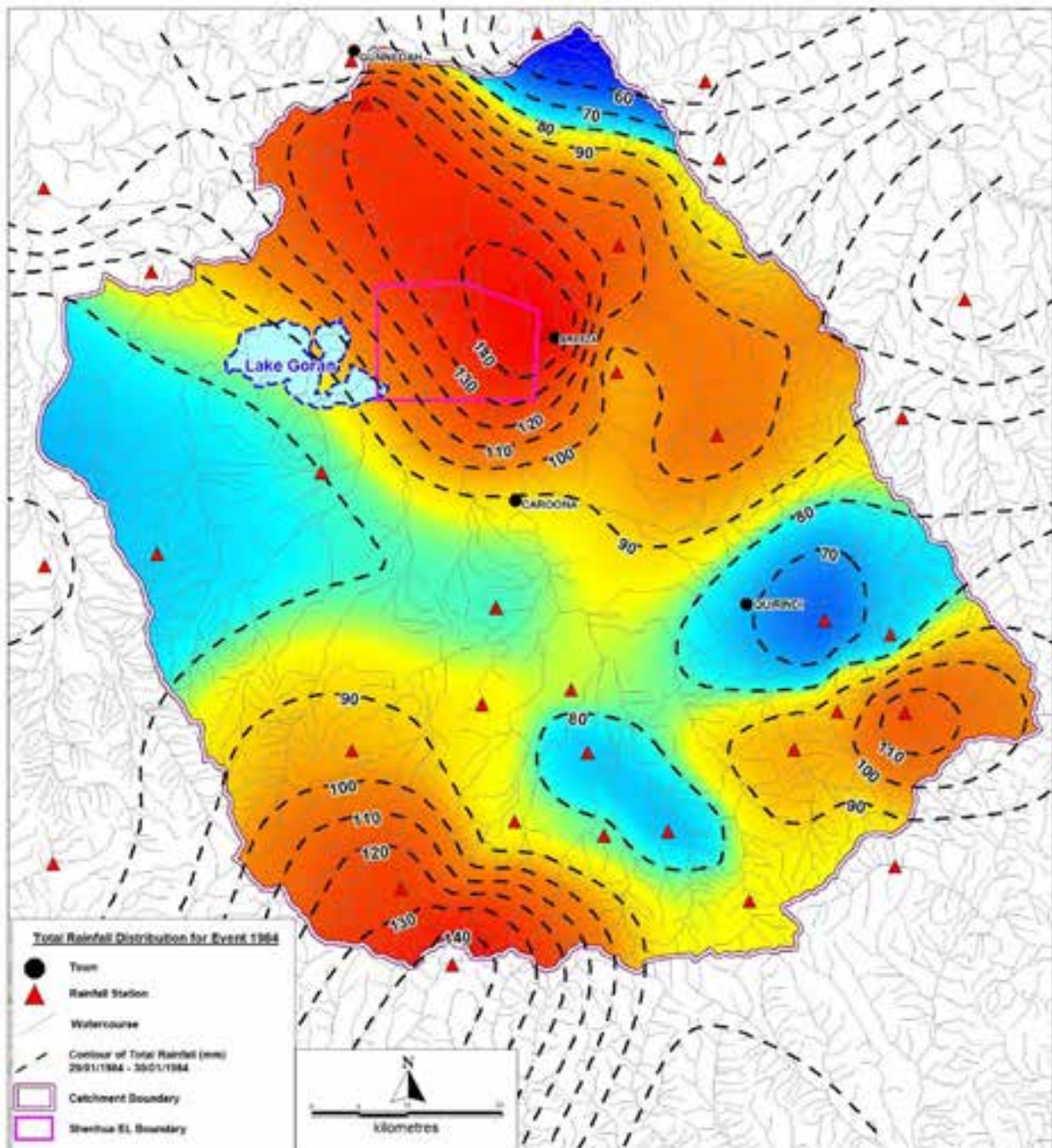


Figure 9.4 Total Rainfall Distribution in the Mooki River Catchment, January 1984 Flood Event

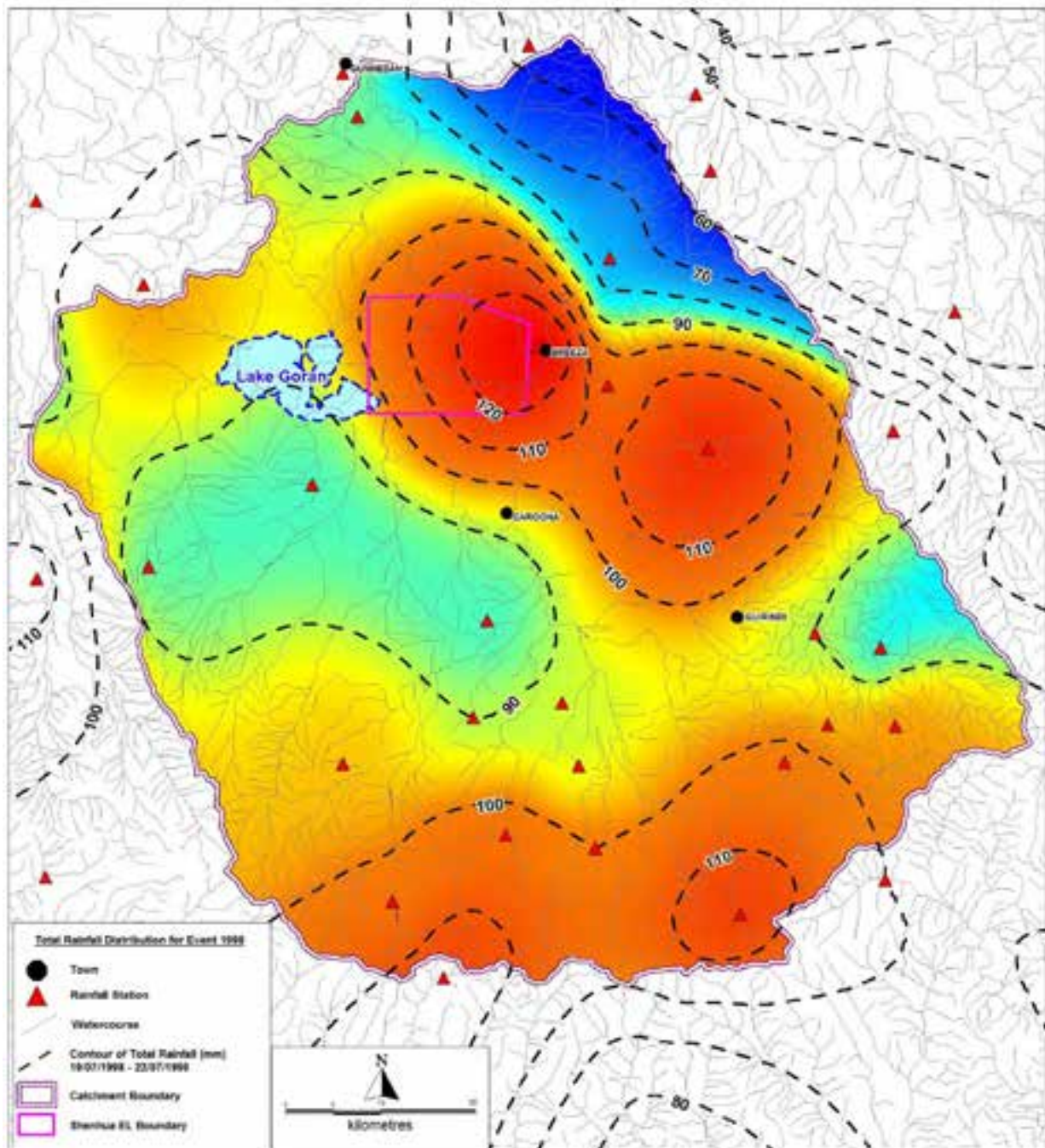


Figure 9.5 Total Rainfall Distribution in the Mooki River Catchment, July 1998 Flood Event

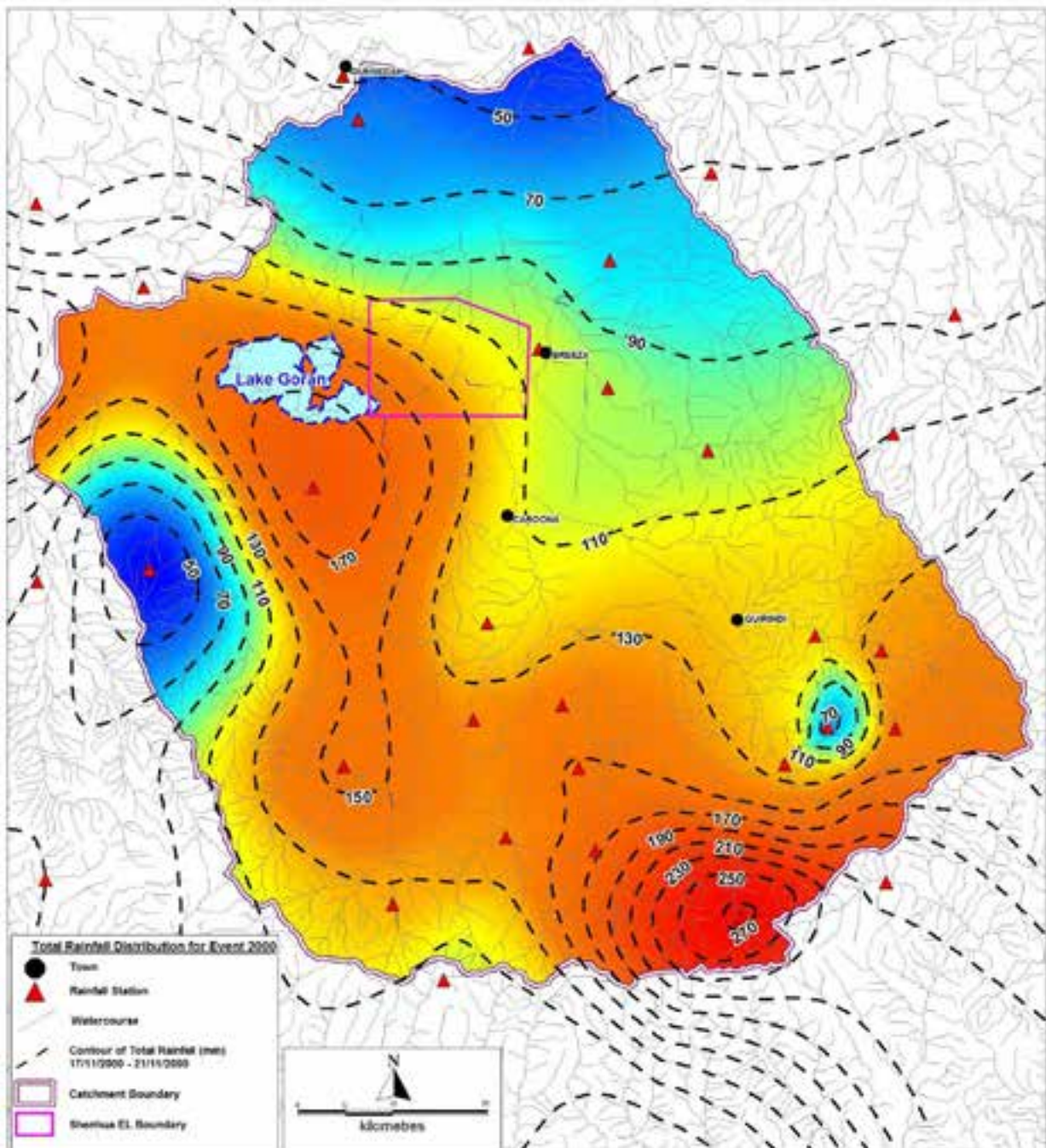


Figure 9.6 Total Rainfall Distribution in the Mooki River Catchment, November 2000 Flood Event

9.2.3 Streamflow Data

Streamflow Stations

The key stream gauging stations used for calibration of the Mooki River hydrologic and hydraulic models are Mooki River at Caroona (419034) and Mooki River at Breeza (419027).

Recorded discharges and water levels were obtained for both stations from the NSW Office of Water (NOW) Pineena database covering the selected calibration events. Figure 9.3 shows the location of these stream gauging stations.

The stream gauging stations were selected based on proximity to the Project and an extended period of available data. Mooki River at Caroona (419034) is located upstream of the project site and Mooki River at Breeza (419027) is located immediately downstream of the Project and upstream of the Kamilaroi Highway bridge.

Available Streamflow Stations

The peak annual discharges recorded at the selected gauge sites are shown in Table 9.3. A summary of the available peak series data for the gauges is given below in Table 9.4.

Figure 9.7 and Figure 9.8 show current NOW rating curves for Caroona and Breeza, and all gauged flows at both stations. The largest gauged flow at Caroona is 40,000 ML/d (462 m³/s) and the largest gauged flow at Breeza is 130,000 ML/d (1,505 m³/s). The largest flood on record at both gauges is the July 1998 event, with recorded peak discharges at Caroona and Breeza of 1573m³/s and 1831m³/s respectively.

Figure 9.9, Figure 9.10 and Figure 9.11 show the recorded water levels and discharge hydrographs at Caroona and Breeza for the January 1984, July 1998 and November 2000 flood events. The following is of note:

- During the January 1984 flood event, the peak water levels and discharges were recorded at about 1230 hours on 30 January at Caroona and at about 2100 hours on 30 January at Breeza. The recorded peak water levels at Caroona and Breeza are 305.73m AHD and 288.93 m AHD respectively. The recorded peak discharges at Caroona and Breeza are 712m³/s and 1143m³/s respectively.
- During the July 1998 flood event, the peak water levels and discharges were recorded at about 2200 hours on 21 July at Caroona and at about 0700 hours on 22 July at Breeza. The recorded peak water levels at Caroona and Breeza are 306.87m AHD and 289.80m AHD respectively. The recorded peak discharges at Caroona and Breeza were 1,573m³/s and 1,831m³/s respectively.
- During the November 2000 flood event, the peak water levels and discharges were recorded at about 1845 hours on 20 November at Caroona and at about 0030hours on 21 November at Breeza. The recorded peak water levels at Caroona and Breeza are 306.64m AHD and 289.70m AHD respectively. The recorded peak discharges at Caroona and Breeza are 1,423m³/s and 1,738m³/s respectively.
- For the November 2000 event, the recorded peak water level and discharge at Breeza are constant from 0030 hours to 0245 hours on 21 November, which corresponds with the peak of the flood event. Hence, it is possible that the Breeza gauge did not record the peak water level during the November 2000 event.

Table 9.3 Peak Annual Discharges, 1972 to Present

Year	Mooki River at Carroona (419034)		Mooki River at Breeza (419027)	
	Month of Peak	Peak Discharge (m ³ /s)	Month of Peak	Peak Discharge (m ³ /s)
1972			Nov	56
1973			Oct	126
1974			Jan	1140
1975			Jun	28
1976			Jan	1144
1977			Mar	443
1978			Jul	188
1979			Sep	55
1980	Jan	5	Jan	4
1981	Jul	9	Jul	53
1982	Mar	86	Mar	102
1983	Aug	77	Sep	223
1984	Jan	712	Jan	1143
1985	Aug	42	Dec	84
1986	Aug	5	Jul	20
1987	Aug	44	Aug	70
1988	Jun	13	Aug	24
1989	Jun	521	Jun	642
1990	Apr	505	Apr	532
1991	Jan	681	Jan	737
1992	Feb	725	Feb	775
1993	Jul	80	Oct	72
1994	Mar	1	Mar	0.4
1995	Jan	153	Jan	99
1996	Jan	838		no record
1997	Jan	159		no record
1998	July	1573	July	1831
1999	Oct	128	Oct	99
2000	Nov	1423	Nov	1738
2001	Mar	13	Mar	41
2002	Dec	3	Dec	5
2003	Aug	31	Dec	34
2004	Jan	80	Dec	87
2005	Jul	7	Jul	10
2006	Jul	0.3	Jul	0.1
2007	Jun	232	Jun	185
2008	Dec	245	Dec	213
2009	Feb	8	Feb	8
2010	Dec	238	Dec	227
2011	Nov	325	Nov	290

Table 9.4 Summary of Annual Peak Series Data

Gauging Station Name	Gauging Station No.	Period of Record	Years Without Data	Years of Available Data
Mooki River at Caroona	419034	1980-2011	0	32
Mooki River at Breeza	419027	1972-2011	2	38

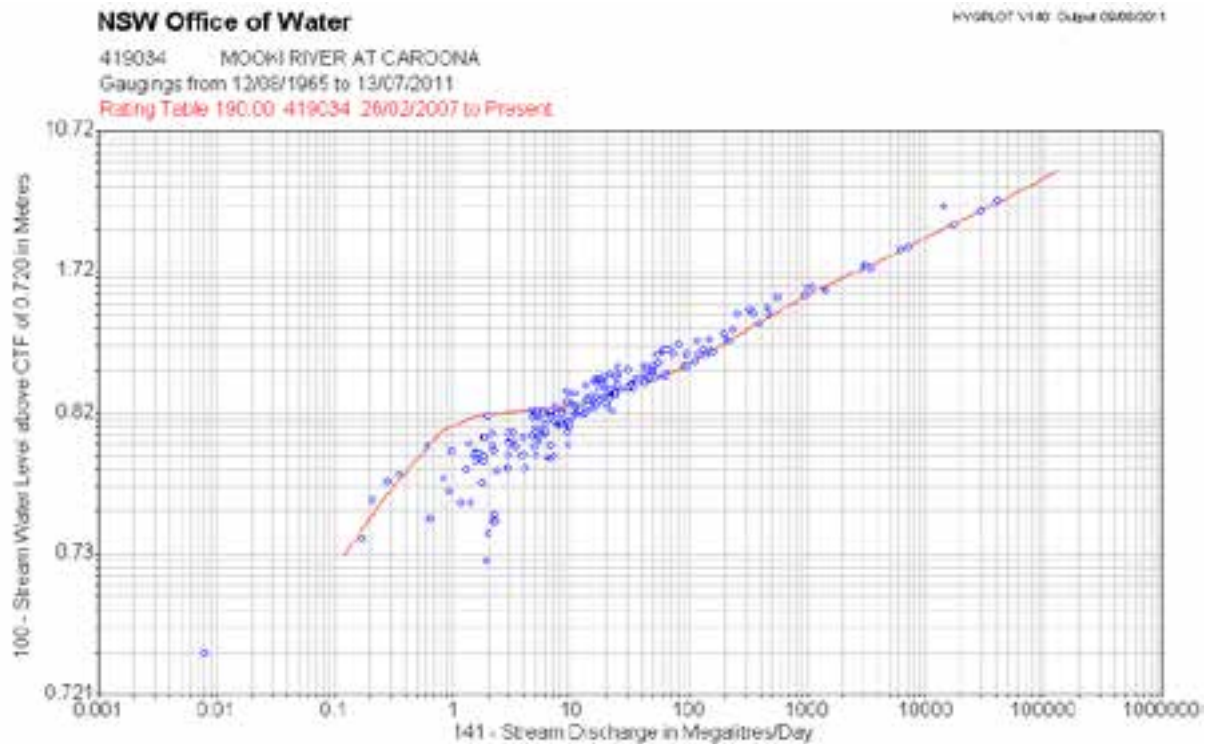


Figure 9.7 Current Rating Curve and Stream Gaugings, Mooki River at Caroona (419034)



Figure 9.8 Current Rating Curve and Stream Gaugings, Mooki River at Breeza (419027)

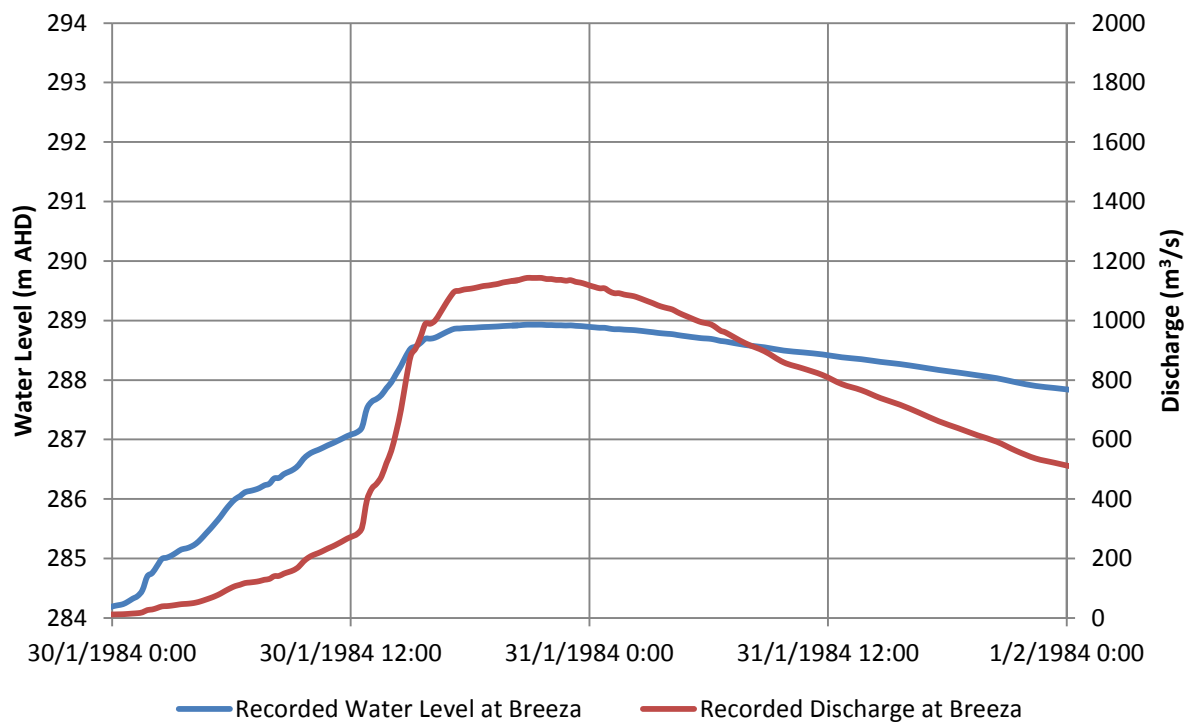
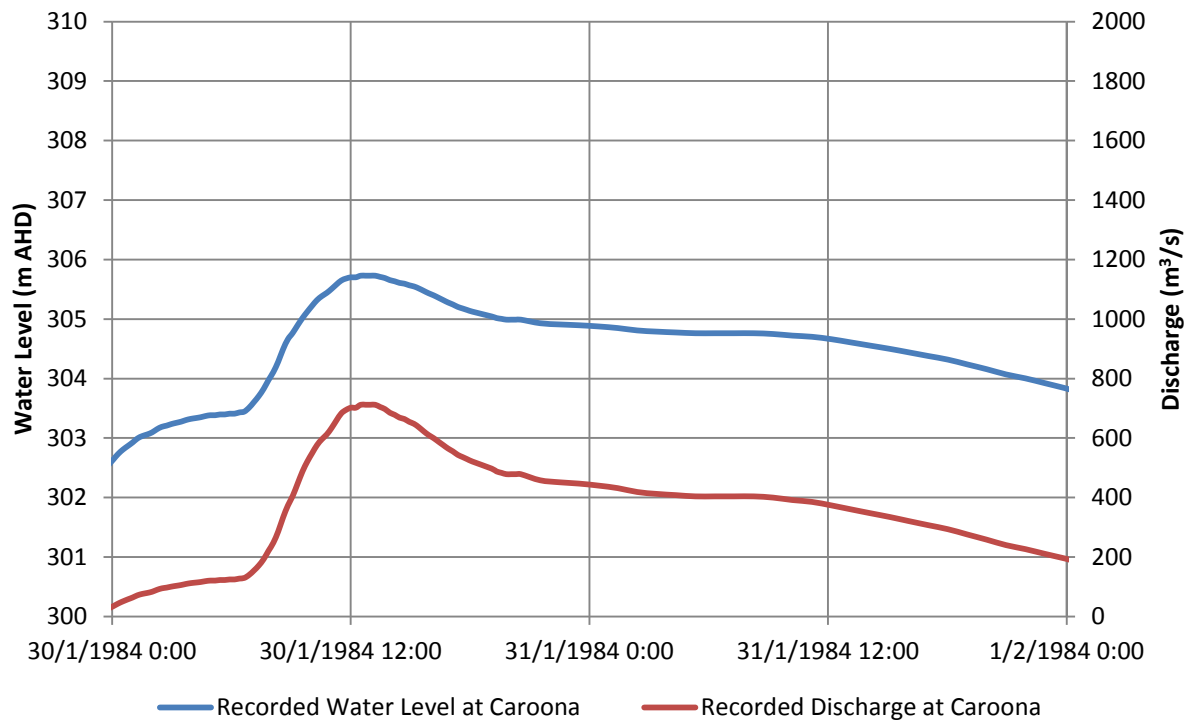


Figure 9.9 Recorded Water Level and Discharge Hydrograph at Caroona and Breeza, January 1984 Flood Event

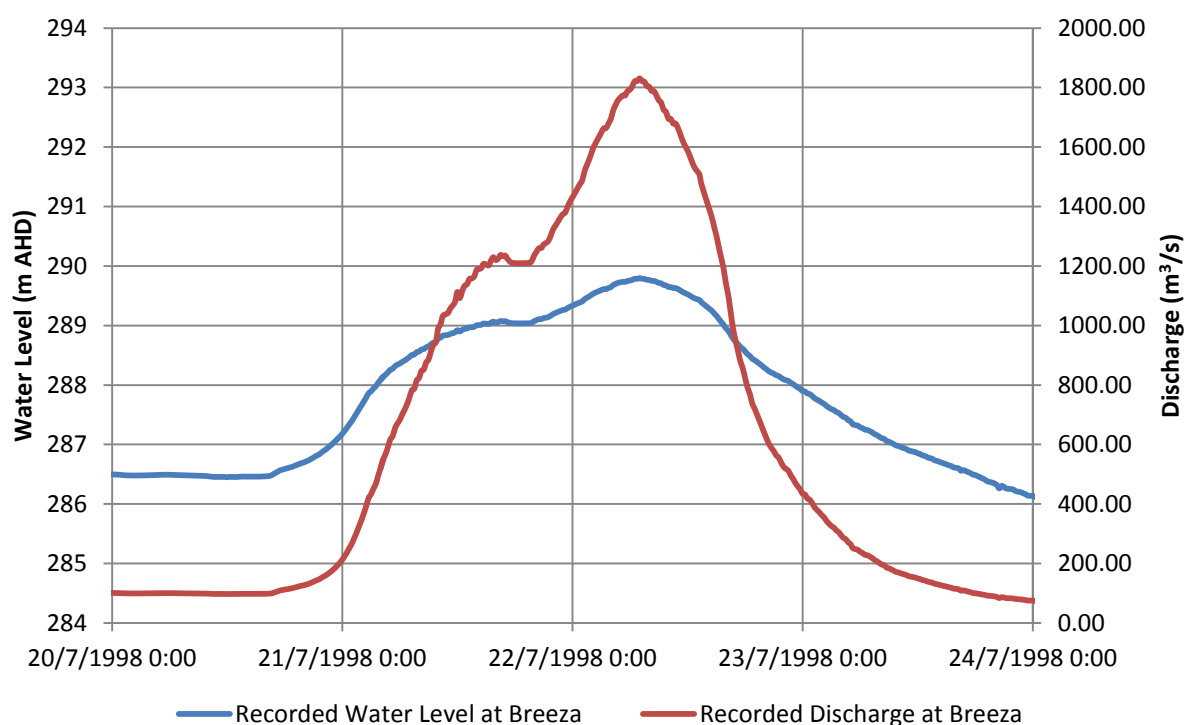
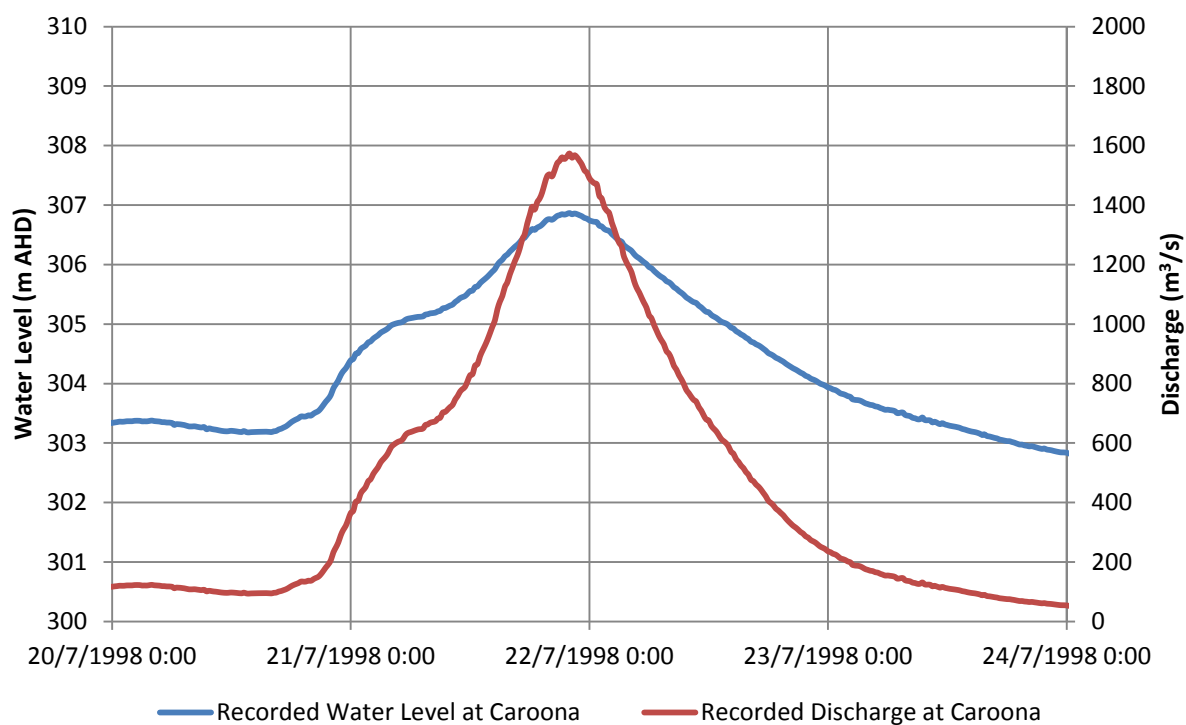


Figure 9.10 Recorded Water Level and Discharge Hydrograph at Caroona and Breeza, July 1998 Flood Event

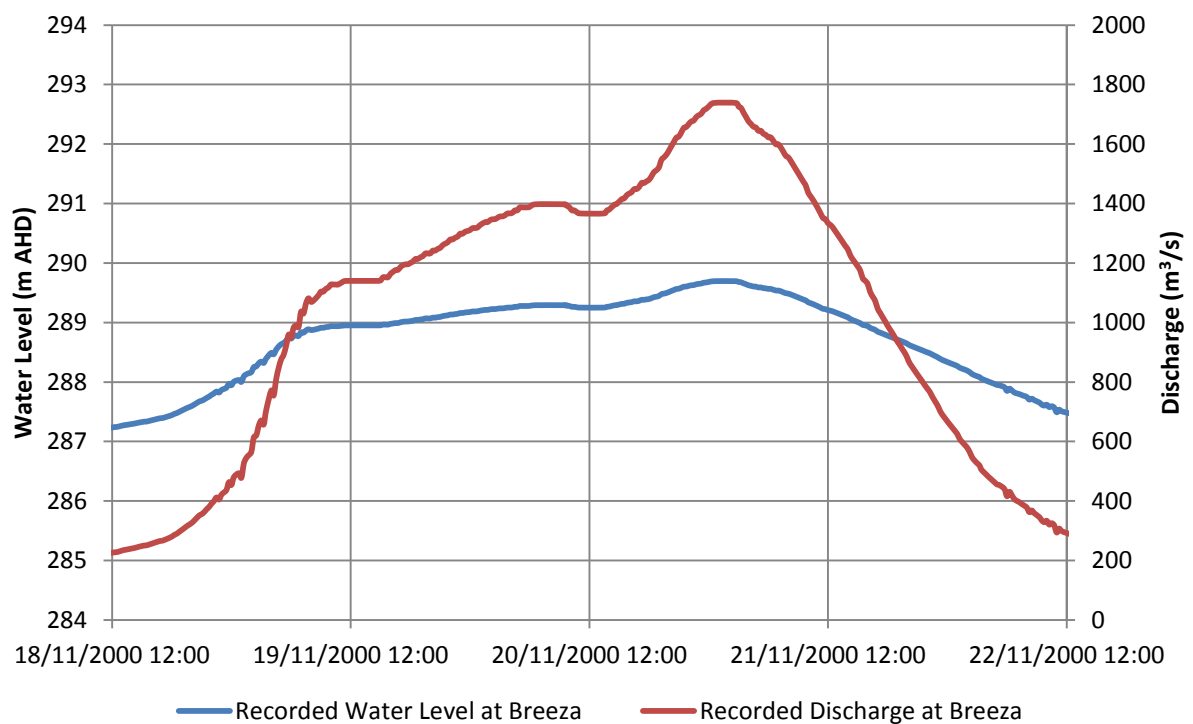
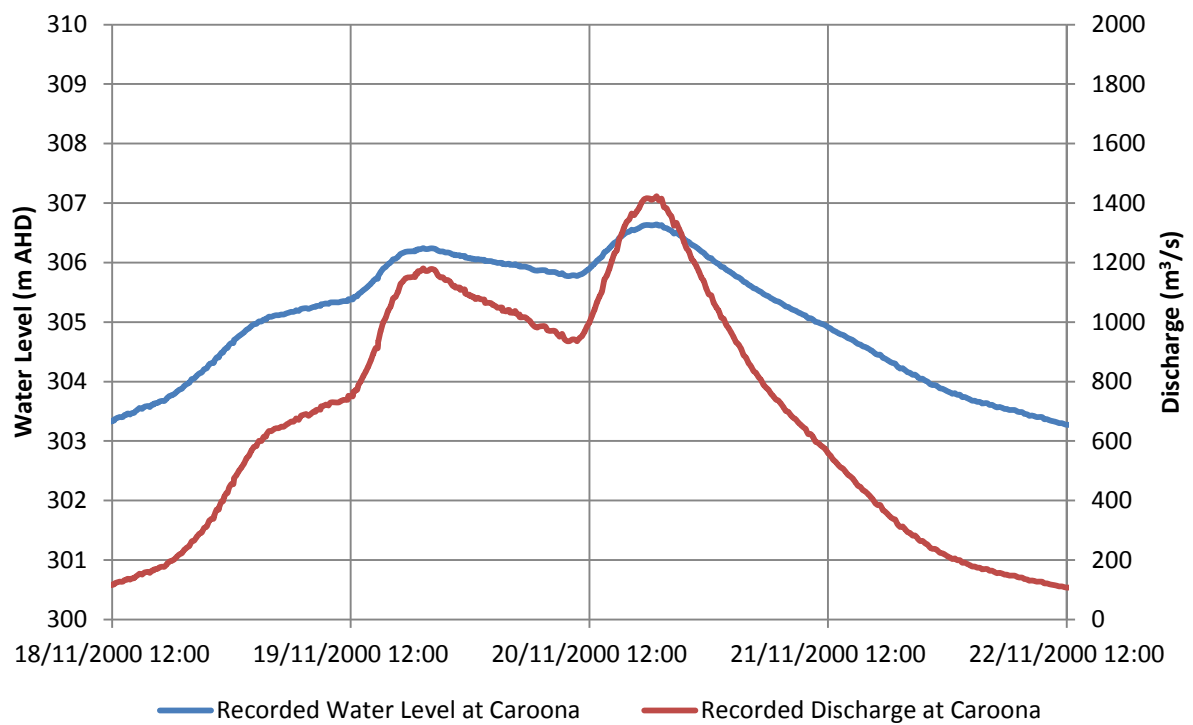


Figure 9.11 Recorded Water Level and Discharge Hydrograph at Caroona and Breeza, November 2000 Flood Event

9.2.4 Storage Data

Table 9.5 shows the adopted stage – storage relationship for Lake Goran. The elevation data for Lake Goran was obtained from the NOW Pineena Database. The Lake Goran stage–storage data was used in the development and calibration of the hydrologic and hydraulic models for the study.

Table 9.5 Adopted Stage–Storage for Lake Goran

Stage (mAHD)	Volume (ML)
294.0	0
294.5	7,100
295.0	28,450
295.5	57,675
296.0	91,700
296.5	130,750
296.8	157,921
297.0	178,350
297.5	241,325
298.0	329,800
298.5	457,200
299.0	640,250

9.2.5 Survey Peak Flood Levels

Post-flood survey peak flood levels are available downstream of the township of Breeza for the July 1998 and November 2000 flood events (SMEC 2003). These historical peak flood levels were used for the purpose of model calibration. Further discussion on survey peak flood levels is provided in Section 9.5.

9.3 HYDROLOGIC MODEL CALIBRATION AND VERIFICATION

9.3.1 Methodology

Flood discharges within the Mooki River catchment were estimated using the RAFTS runoff-routing model (XP Software, 2009). The RAFTS model extends from the Liverpool Range to approximately 20km upstream of Gunnedah, and includes Lake Goran. The RAFTS model was calibrated against the two largest recent floods at Caroona and Breeza (July 1998 and November 2000), and verified against the smaller 1984 flood event.

9.3.2 RAFTS Model Configuration

RAFTS sub-catchments

Figure 9.12 shows the Mooki River RAFTS model configuration, consisting of 53 sub-catchment areas totalling 5,909 km². Table 9.6 shows the adopted RAFTS sub-catchment parameters for the Mooki River catchment. A global storage ‘Bx’ factor of 1.2 was adopted for the model.

RAFTS sub-catchment boundaries were delineated using 5m contours. The adopted fraction impervious for each sub-catchment was 3%. A uniform catchment Manning's 'n' of 0.04 was adopted for the model. Average catchment slope was determined from the 5m contours.

Rafts links

Channel routing links have been included in the RAFTS model. The channel routing parameters were developed based on the physical channel characteristics including channel length and slope. The RAFTS channel routing links within the two-dimensional hydraulic model boundary were refined during the joint calibration with the two-dimensional model.

9.3.3 Calibration / Verification Methodology

The purpose of the model calibration is to achieve the best possible fit between the predicted and recorded discharge hydrographs at the two selected stations along the Mooki River for the selected calibration events. For these stations, the calibration attempted to match the predicted and recorded flood peaks and volumes, and also the shape of the hydrographs.

Due to the sparse coverage of pluviograph stations within the Mooki River catchment, the RAFTS model cannot be expected to accurately reproduce flood behaviour for all events at both stations. A single set of model parameters was adopted for all calibration events. The model parameters were adjusted to achieve the best calibration across both events, resulting in a compromise between model accuracy and the complexity of model parameter sets. It is noted that calibration of the models for individual events can be improved by adopting a different set of model parameters for each of the different events.

Rainfall losses were adjusted to achieve the best possible hydrograph shapes and flood volumes. A uniform initial loss and continuing loss rate were adopted for each flood event throughout the catchment. Again it is noted that calibration of the models for individual events can be improved by adopting variable initial and continuing losses across the catchment.

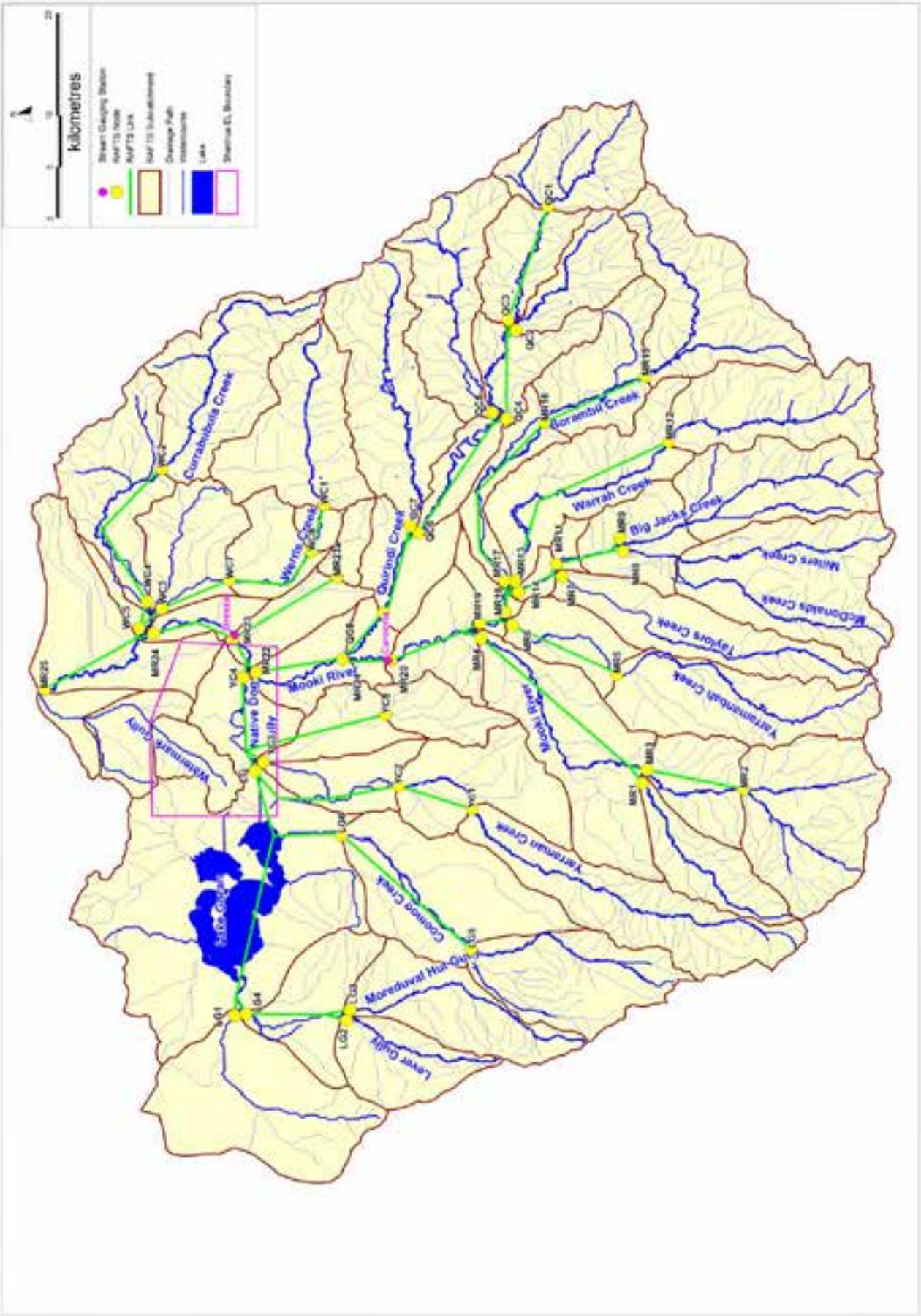


Figure 9.12 RAFTS Model Configuration

Table 9.6 Adopted RAFTS Sub-Catchment Parameters

Sub-Catchment ID	Catchment Area (km ²)	Catchment Slope (%)	Sub-Catchment ID	Catchment Area (km ²)	Catchment Slope (%)
LG	484	3.0	QC1	116	4.5
LG1	222	1.6	QC2	77	5.0
LG2	89	2.4	QC3	78	3.0
LG3	129	3.6	QC4	67	4.5
LG4	97	2.5	QC5	148	3.5
LG5	150	2.0	QC6	44	2.5
LG6	192	3.1	QC7	192	4.0
MR01	84	9.1	QC8	75	1.2
MR02	189	5.0	WC1	163	5.0
MR03	79	3.8	WC2	171	8.0
MR04	200	1.8	WC3	98	4.1
MR05	169	8.0	WC4	141	7.5
MR06	66	2.6	WC5	15	0.5
MR07	137	3.2	WC6	17	4.3
MR08	236	3.5	WC7	65	0.5
MR09	181	4.5	YC1	189	7.5
MR11	31	1.5	YC2	127	2.5
MR12	148	6.5	YC3	65	0.8
MR13	161	2.6	YC4	72	2.1
MR14	13	1.5	YC5	55	3.0
MR15	181	8.2	YC6	61	2.0
MR16	109	3.3			
MR17	56	3.1			
MR18	5	1.5			
MR19	21	0.5			
MR20	75	2.5			
MR21	30	2.5			
MR22	57	4.0			
MR23	59	0.1			
MR23_a	25	2.2			
MR24	34	0.9			
MR25	164	1.6			

9.3.4 Selection of Calibration / Verification Events

The RAFTS model was calibrated against the two largest flood events and verified against another large flood event for which suitable rainfall and stream flow data is available for two selected gauging stations. Table 9.7 shows the selected calibration events and recorded peak discharges.

Table 9.7 Recorded Peak Discharges of Calibration / Verification Events

Gauging Station Name	Gauging Station No.	Recorded Peak Discharge (m ³ /s)		
		July 1998	November 2000	January 1984
Mooki River at Caroon	419034	1573	1423	712
Mooki River at Breeza	419027	1831	1738	1143

9.3.5 Assignment of Total Rainfalls and Temporal Patterns

Total rainfalls from daily stations were assigned to the nearest sub-catchment based on the distance from stations to the centroid of sub-catchments. The nearest available pluviograph temporal pattern was applied to the daily rainfall stations. This method ensures all the available data are used, and the rainfall pattern for the nearest pluviograph is assigned to the sub-catchment. Figure 9.3 shows all available daily and pluviograph rainfall stations within the catchment.

9.3.6 Initial and Continuing Losses

Table 9.8 shows the adopted initial loss and continuing loss for each of the calibration and verification events.

Table 9.8 Adopted Initial and Continuing Losses, Calibration / Verification Events

Calibration / Verification Event	Initial Loss (mm)	Continuing Loss (mm/hr)
July 1998	0	0.4
November 2000	25	0.5
January 1984	15	1.75

9.3.7 Lake Goran Initial Water Levels

No recorded water level information is available for Lake Goran in the period immediately prior to the selected calibration and verification events. As a result the adopted initial water levels in Lake Goran were adjusted to improve the RAFTS model calibration at Breeza for each event, and to match outflows from the lake predicted by the hydraulic model, which simulates the complicated lake outlet hydraulics at a high level of detail. Table 9.9 lists the adopted Lake Goran initial water levels for each of the calibration and verification events.

Table 9.9 Adopted Lake Goran Initial Water Levels, Calibration and Verification Events

Event	Lake Goran Initial Water Level (m AHD)
January 1984	294.5
July 1998	294.5
November 2000	295.3

It should be noted that the RAFTS model cannot simulate the dynamic outlet behaviour of Lake Goran due to the complicated hydraulics affecting the lake outlet. The lake discharges to Native Dog Gully via a poorly defined overflow path which is wide, shallow and heavily affected by tailwater levels in Native Dog Gully, as well as discharges from the adjacent Coomoo and Yarraman Creeks. For this reason, the adopted starting water levels, as well as simulated water level behaviour in the lake are not directly comparable between the hydrologic and hydraulic models due to different simulation start times and the different approaches to simulating discharges from the lake outlet. The hydraulic model (described in Sections 9.4 and 9.5) will provide the most accurate assessment of the behaviour of Lake Goran during the calibration and verification events.

9.3.8 Hydrologic Model Calibration / Verification Results

July 1998 Flood Event

Figure 9.13 and Figure 9.14 show recorded and predicted discharge hydrographs at Caroona (419034) and Breeza (419027) for the July 1998 event. Table 9.10 shows a comparison of the predicted and recorded July 1998 peak discharges at Caroona and Breeza. The following comments are made with regards to the calibration results:

- The peak discharge is underestimated slightly at Caroona, and the shape of the predicted hydrograph shows more attenuation than is evident in the recorded hydrograph. The timing of the predicted is several hours later than the recorded hydrograph.
- The peak discharge is slightly overestimated at Breeza, however the timing of the peak corresponds well to the recorded hydrograph. The flood volume (the area under the hydrograph) has been overestimated at Breeza.
- Due to the limited pluviograph coverage and the adoption of uniform rainfall losses across the catchment it is not possible to improve the calibration without sacrificing the quality of the calibration at either Breeza or Caroona. For example, the volume of the flood hydrograph and peak discharge at Breeza could be improved by increasing the continuing loss, however this would reduce the predicted peak discharge at Caroona.
- Conversely, the RAFTS model can adequately match the predicted peak discharge at Caroona with the adoption of a continuing loss of 0.0mm/hr, however this results in the RAFTS model overestimating the peak discharge at Breeza by more than 20%. This indicates that the available pluviograph coverage upstream of Caroona does not adequately represent the spatial variability of rainfall in the upper catchment during the event.
- Considering the limited available rainfall data, the July 1998 calibration is considered acceptable.

Table 9.10 Comparison of Recorded and Predicted Peak Discharges, Breeza and Caroona – July 1998 Calibration Event

Gauging Station Name	Station No.	Peak Discharge (m ³ /s)		Difference (%)
		Recorded	Predicted	
Mooki River at Caroona	419034	1,573	1,390	-12%
Mooki River at Breeza	419027	1,831	1,918	5%

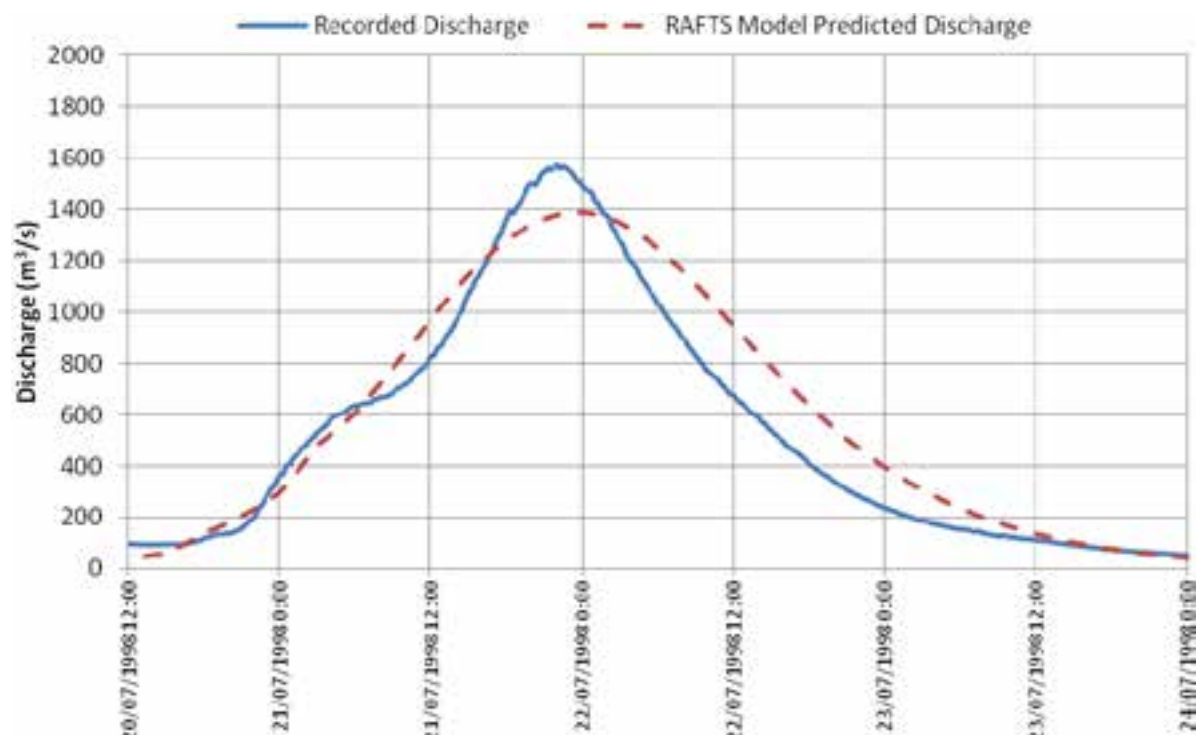


Figure 9.13 Recorded and Predicted Discharge Hydrographs at Caroona (419034), July 1998 Calibration Event

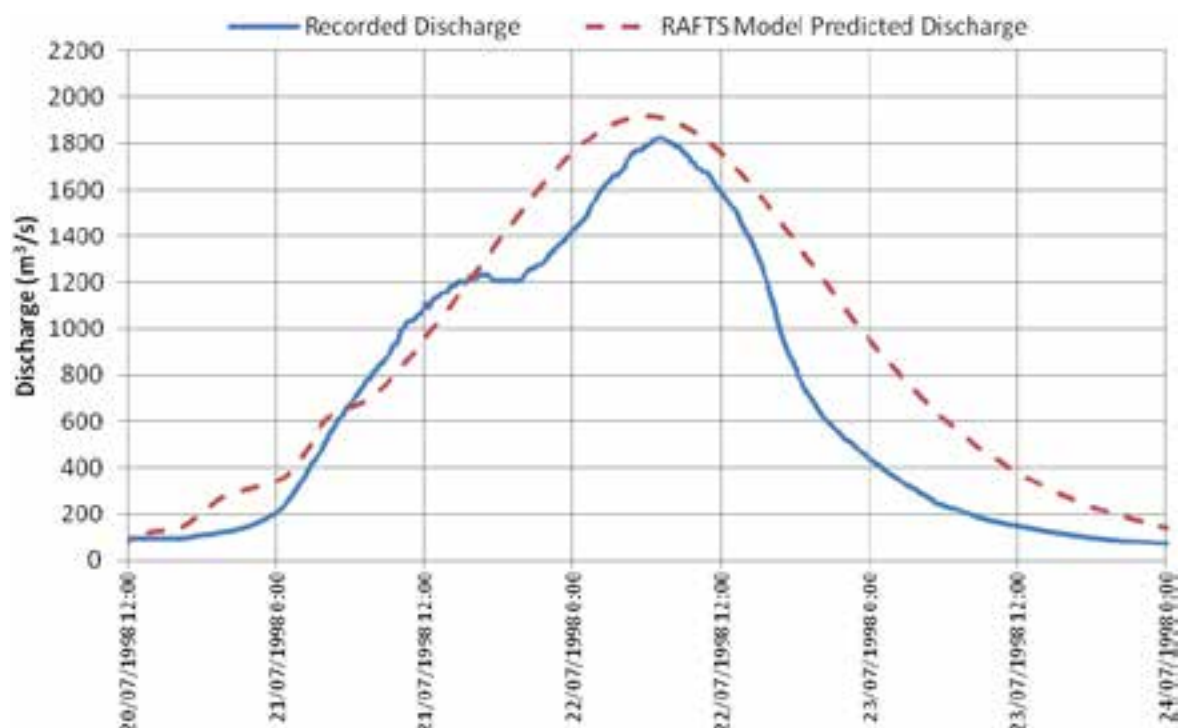


Figure 9.14 Recorded and Predicted Discharge Hydrographs at Breeza (419027), July 1998 Calibration Event

November 2000 Flood Event

Figure 9.15 and Figure 9.16 show recorded and predicted discharge hydrographs at Caroona (419034) and Breeza (419027) for the November 2000 event. Table 9.11 shows a comparison of the predicted and recorded November 2000 peak discharges at Caroona and Breeza. The following comments area made with regards to the calibration results:

- The peak discharge is underestimated at Caroona, however the two distinct peaks are evident in the predicted hydrograph. The timing of both peaks in the predicted hydrographs is slightly early.
- The peak discharge is slightly overestimated at Breeza, however the timing of the peak corresponds well to the recorded hydrograph, and the predicted flood volume adequately matches the predicted hydrograph. The timing of the rising limb in the predicted hydrograph is several hours late.
- Available pluviograph rainfalls upstream of Caroona for the November 2000 event do not appear to be representative of the actual rainfall in that part of the catchment during the event. A large RAFTS model initial loss (25mm) is necessary to reduce the magnitude of the initial flood peak predicated by the RAFTS model at Caroona. If a lower initial loss was adopted, the predicted initial flood peak at Caroona would exceed the second, larger flood peak. The adopted initial loss has an impact on predicted discharges at Breeza, delaying the rising limb of the predicted hydrograph by several hours.
- The RAFTS model can only match the second, larger flood peak act Caroona by adopting a 0.0mm initial loss and 0.0mm/hr continuing loss, however this results in an overestimation of the initial flood peak by more than 30%. This results in the initial flood peak in the predicted hydrograph becoming the larger peak, which is not reflected in the recorded hydrograph. Further, the adoption of lower losses results in a poor calibration at Breeza, with the predicted peak discharge being overestimated by more than 50% for the no losses simulation. In a similar manner to the July 1998 event, the November 2000 calibration indicates that available pluviograph data upstream of Caroona is not representative of the temporal and spatial distribution of rainfall in the upper catchment during the event.
- Considering the limited available rainfall data, the November 2000 calibration is considered acceptable.

Table 9.11 Comparison of Recorded and Predicted Peak Discharges, Breeza and Caroona – November 2000 Calibration Event

Gauging Station Name	Station No.	Peak Discharge (m ³ /s)		Difference (%)
		Recorded	Predicted	
Mooki River at Caroona	419034	1,423	1126	-21%
Mooki River at Breeza	419027	1,738	1875	8%

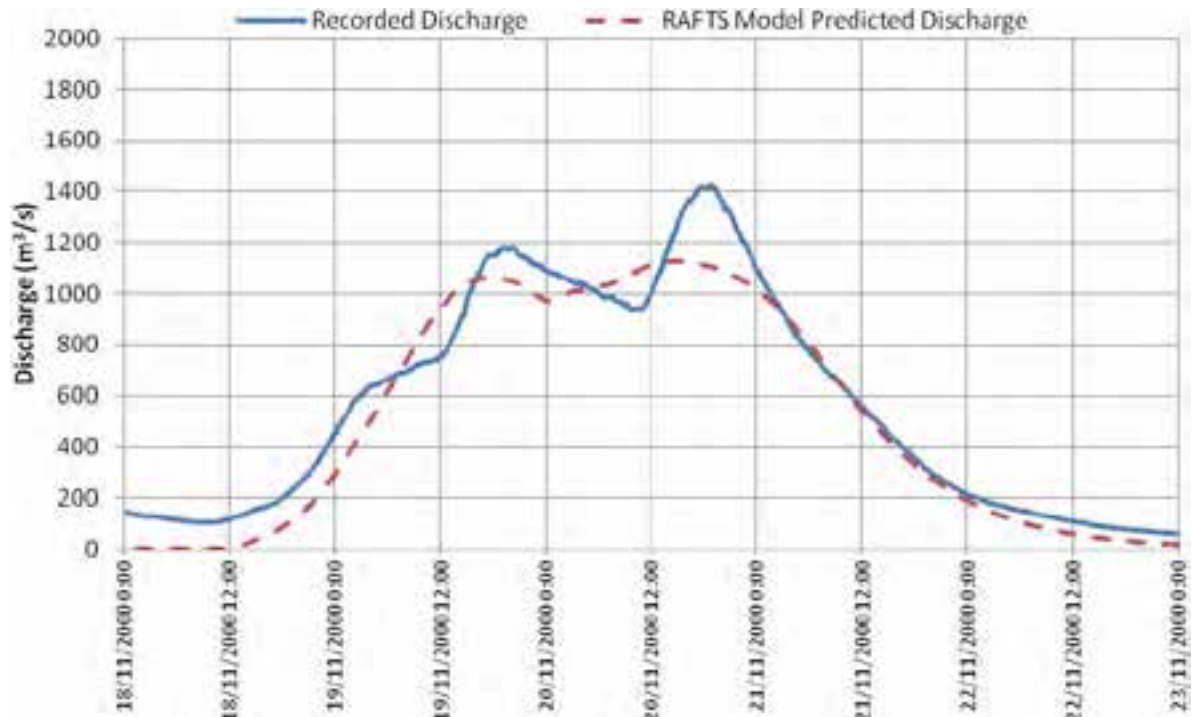


Figure 9.15 Recorded and Predicted Discharge Hydrographs at Caroona (419034), November 2000 Calibration Event

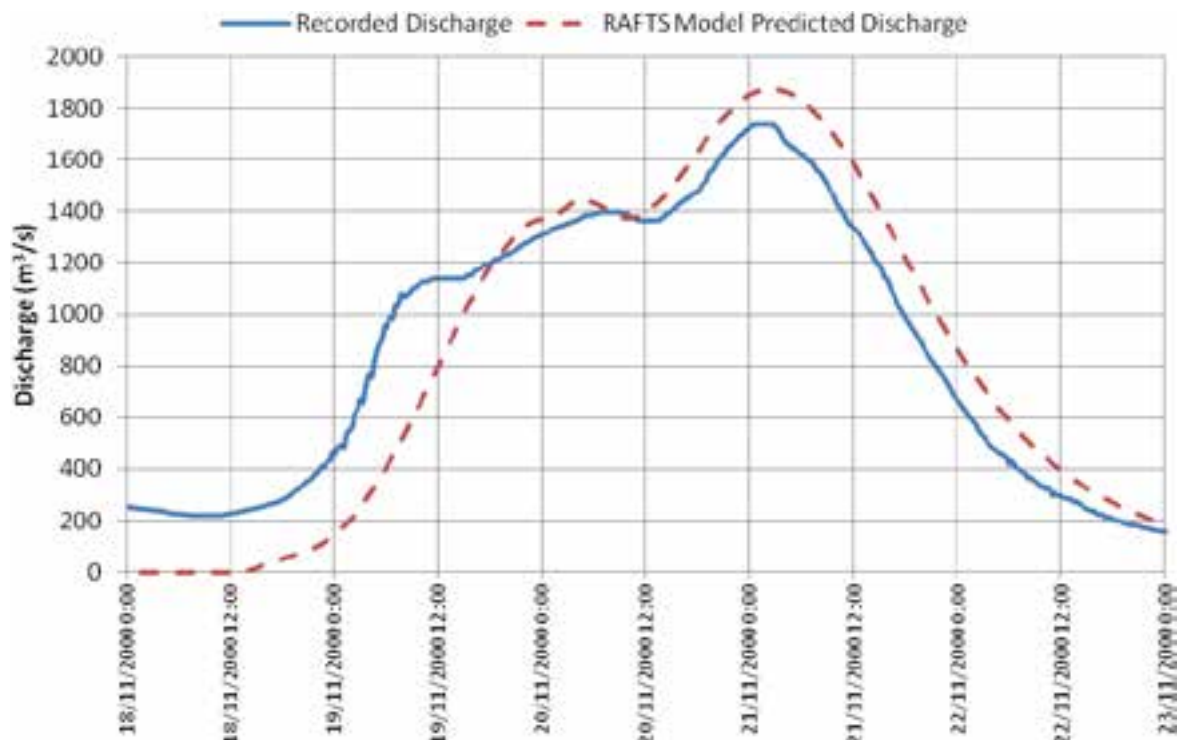


Figure 9.16 Recorded and Predicted Discharge Hydrographs at Breeza (419027), November 2000 Calibration Event

January 1984 Flood Event

Table 9.12 shows a comparison of predicted and recorded peak discharges at Caroona and Breeza for the January 1984 calibration events. Figure 9.17 and Figure 9.18 show recorded and predicted discharge hydrographs at Caroona (419034) and Breeza (419027) for the January 1984 event. The following comments are made with regards to the calibration results:

- No pluviograph data is available for the January 1984 event, so little emphasis was placed on matching the timing and shape of the recorded hydrographs. The purpose of modelling the January 1984 event was to verify that the RAFTS model could adequately predict peak discharges and flood volumes despite the coarse nature of the input rainfall data.
- The RAFTS model peak discharges at both Caroona and Breeza match very well with recorded peak discharges. The predicted flood volumes at both gauges are slightly overestimated.
- Considering the use of daily rainfall data only, the January 1984 verification is considered acceptable. The January 1984 event was used as a hydrologic model verification event only, and was not used in verification of the hydraulic model.

Table 9.12 Comparison of Recorded and Predicted Peak Discharges, Breeza and Caroona – January 1984 Verification Event

Gauging Station Name	Gauging Station No.	Peak Discharge (m ³ /s)		Difference (%)
		Recorded	Predicted	
Mooki River at Caroona	419034	712	708	-1%
Mooki River at Breeza	419027	1,143	1,142	0%

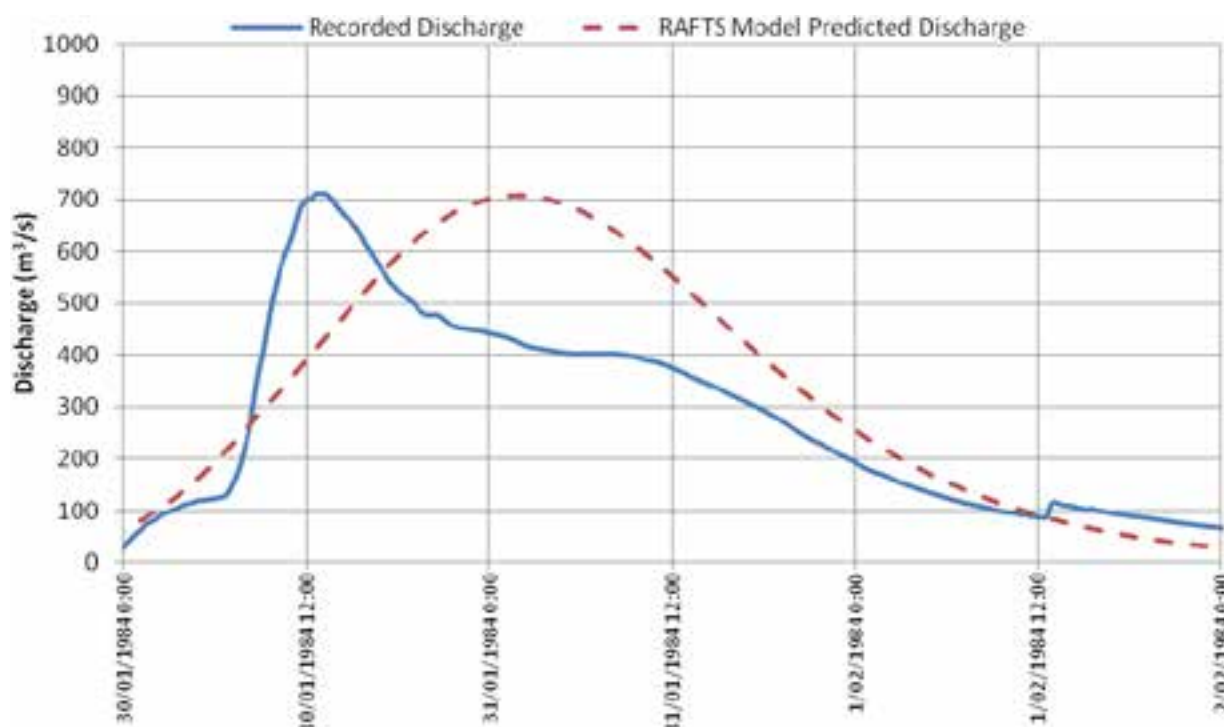


Figure 9.17 Recorded and Predicted Discharge Hydrographs at Caroona (419034), January 1984 Verification Event

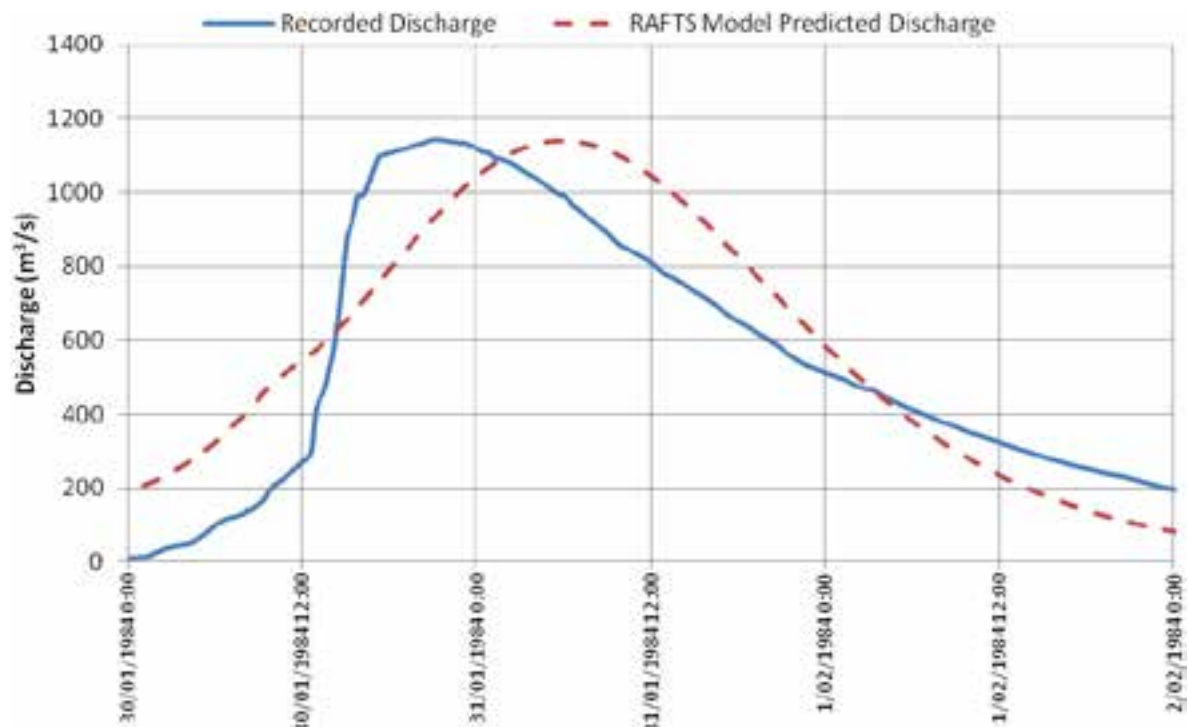


Figure 9.18 Recorded and Predicted Discharge Hydrographs at Breeza (419027), January 1984 Verification Event

9.3.9 Development of Input Hydrographs for Hydraulic Model Calibration

The upstream boundary of the hydraulic model is located immediately downstream of the Caroona gauging station. To ensure that inaccuracies in the modelled discharge at Caroona did not affect the hydraulic model calibration, the recorded discharge hydrograph at Caroona was adopted as the inflow boundary for the hydraulic model for the calibration events.

In order to generate the remaining inflows for the hydraulic model, the rainfall losses adopted for the RAFTS model downstream of Caroona were reviewed. The review ensured that the adopted inflows downstream of Caroona do not adversely affect the RAFTS model calibration at Breeza when the recorded discharge hydrograph at Caroona is adopted as the TUFLOW model inflow.

July 1998 Event

The recorded and predicted July 1998 discharge hydrographs at Breeza (following the adoption of the recorded discharge hydrograph at Caroona) are shown in Figure 9.19. The following is of note:

- When the recorded discharge at Caroona is adopted in the RAFTS model the predicted hydrograph at Breeza is significantly improved in terms of peak discharge, timing and shape when compared with the calibration plot shown in Figure 9.14. This indicates that despite the large increase in catchment area between Caroona and Breeza, flood behaviour at Breeza is significantly influenced by flows at Caroona.
- When the recorded discharge hydrograph at Caroona was adopted in the RAFTS model, the adopted continuing loss in the RAFTS model was increased to 1.25mm/hr from the 0.4mm/hr adopted for the full model calibration.

- The initial loss remained at 0mm, which is considered acceptable based on the rainfall in the Breeza area in the days leading up to the July 1998 event. The initial water level in Lake Goran was also unchanged from 294.5m AHD.
- The predicted discharge hydrographs downstream of Caroona generated from the truncated model were adopted for use in the hydraulic model calibration for the July 1998 event.

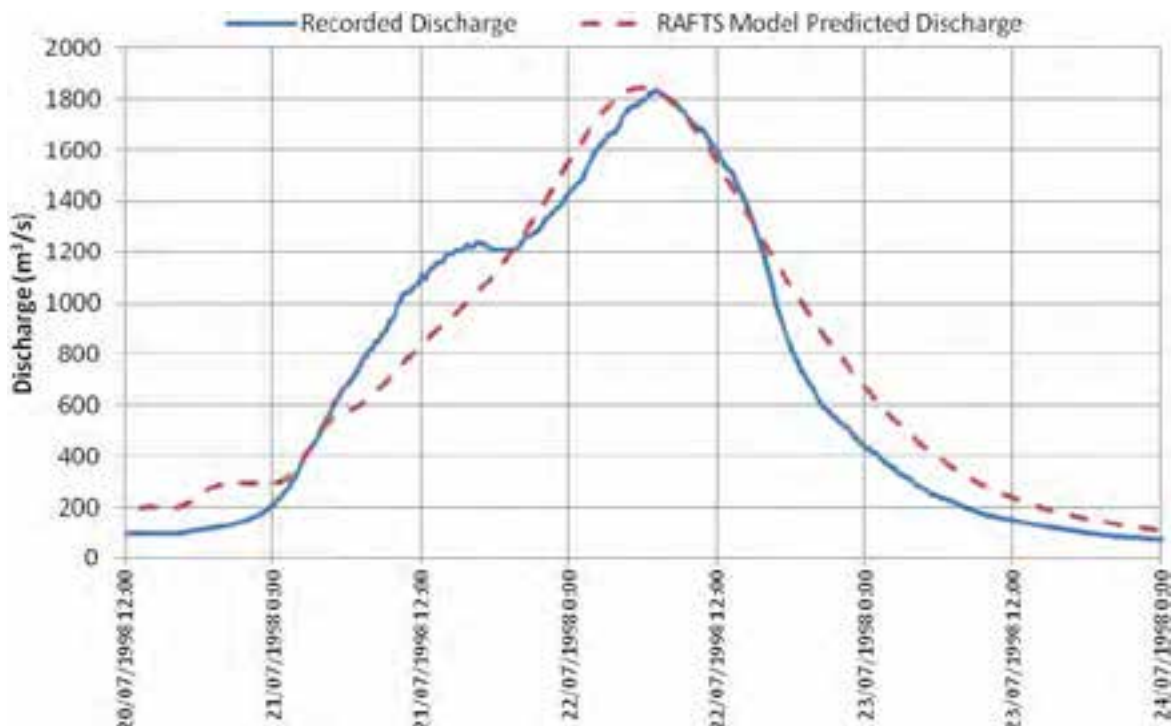


Figure 9.19 Recorded and Predicted Discharge Hydrographs at Breeza (419027), July 1998 Calibration Event (Recorded Discharge at Caroona Adopted in RAFTS Model)

November 2000 Event

The recorded and predicted November 2000 discharge hydrographs at Breeza (following the adoption of the recorded discharge hydrograph) are shown in Figure 9.20. The following is of note:

- When the recorded discharge at Caroona is adopted in the RAFTS model the predicted hydrograph at Breeza is significantly improved in terms of peak discharge, timing and shape when compared with the calibration plot shown in Figure 9.16.
- When the recorded discharge hydrograph at Caroona was adopted in the RAFTS model, the adopted continuing loss in the RAFTS model was increased to 1.6mm/hr from the 0.5mm/hr adopted for the full model calibration. The initial loss was reduced to 0mm, which is considered acceptable based on the rainfall in the Breeza area in the days leading up to the November 2000 event.
- The initial water level in Lake Goran was unchanged from 295.3m AHD.
- The predicted discharge hydrographs downstream of Caroona generated from the truncated model were adopted for use in the hydraulic model calibration.

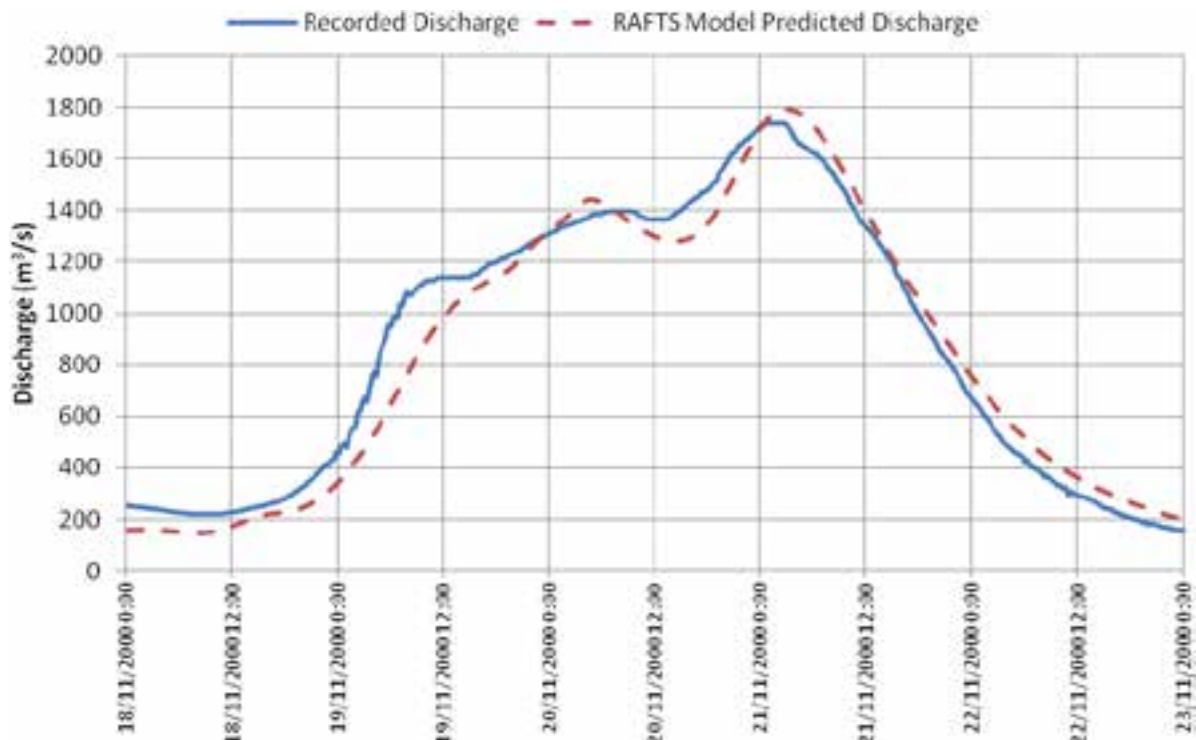


Figure 9.20 Recorded and Predicted Discharge Hydrographs at Breeza (419027), November 2000 Calibration Event (Recorded Discharge at Caroona Adopted in RAFTS Model)

9.4 HYDRAULIC MODEL DEVELOPMENT

9.4.1 Methodology

The TUFLOW fully two-dimensional hydrodynamic model (WBM, 2011) was used to estimate design flood levels and flood velocities along the Mooki River and its floodplain including Native Dog Gully in the vicinity of the Project. TUFLOW estimates flood levels and velocities on a fixed grid pattern by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. It also incorporates a one-dimensional or quasi two-dimensional modelling system (ESTRY). The one-dimensional (ESTRY) and two-dimensional (TUFLOW) schemes are solved independently, but are dynamically linked at the boundary to ensure continuity (mass) is conserved.

Results from the two-dimensional model were used to refine the channel routing parameters of the hydrologic model as part of a joint calibration process for the hydrologic and hydraulic models.

9.4.2 TUFLOW Model Configuration

Model Configuration

Figure 9.21 shows the extent of the Mooki River TUFLOW model. The hydraulic model covers approximately 620km² of the Mooki River catchment, and includes Lake Goran. Due to the large area included within the 2D model, two nested domains (coarse and fine grid sizes) were used in the hydraulic model. A fine 8m grid size and a 2.5 second time step were adopted in Native Dog Gully and the Mooki River channel. A coarse 40m grid size and a 10 second time step were adopted for the floodplain.

The western part of Lake Goran was modelled as a one dimensional storage node and linked to the eastern part of the lake which was included in the two dimensional model. The two dimensional simulation of the eastern part of Lake Goran (which includes the lake outlet point), ensures a better representation of discharge from the lake into Native Dog Gully, which is heavily affected by tailwater levels in Native Dog Gully and discharges in Coomoo and Yarraman Creeks.

Topographic Data

The data supplied by AAM Group included airborne LiDAR survey from February 2012, which covers an area from Caroonna to approximately 8km downstream of Breeza, including Lake Goran. At the time of the LiDAR survey, there was water in Lake Goran, and as a result bathymetry data is not available for the lake below 294.9m AHD. The PINEENA (NSW Water of Office, 2010) stage-storage for the lake was used to supplement the LiDAR data below this level.

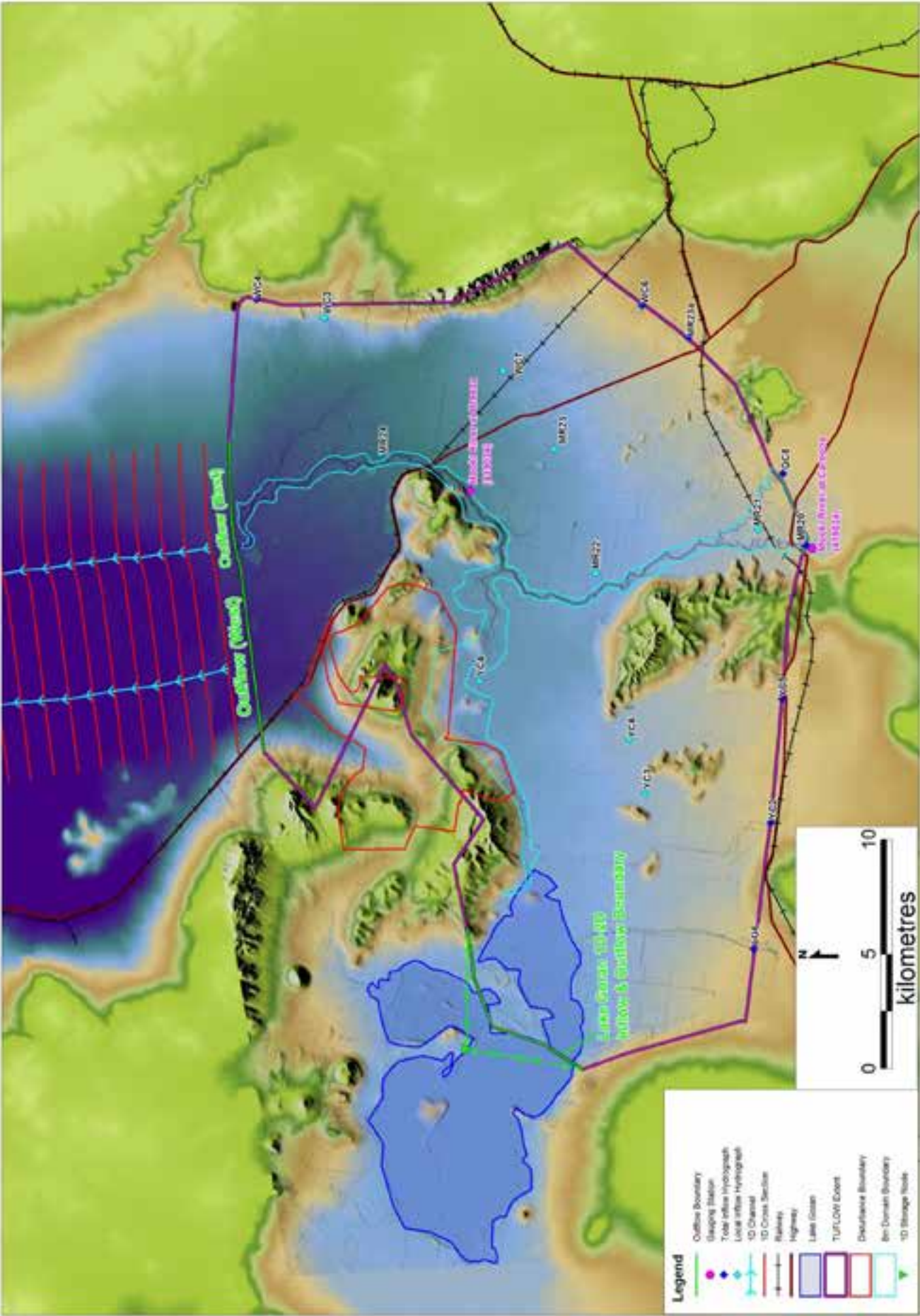


Figure 9.21 TUFLOW Model Extents and Configuration

Adopted Manning's 'n' Values

Table 9.13 shows the adopted Manning's 'n' values for the study area. Manning's 'n' was used as a hydraulic model calibration parameter.

The Manning's 'n' values for channel and floodplain were first estimated according to guidelines given in Chow (1959) and subsequently revised during model calibration.

Table 9.13 Adopted Manning's 'n' Values

Description	Manning's 'n'
Channel	0.035
Floodplain	0.040

Inflow Boundaries

Figure 9.21 shows the locations of the inflow boundaries used in the TUFLOW model. Total and local inflow boundaries were added to the TUFLOW model as 2D QT (discharge vs. time) boundaries. The TUFLOW QT inflows are named corresponding to the RAFTS node numbers (See Figure 9.12). The upstream boundary of the model is located at the Carroona gauging station.

Outflow Boundaries

The downstream 2D boundary is a HX (head from external source) boundary. The downstream HX boundary is connected to a 1D channel reach which extends approximately 20km downstream of the 2D boundary. The 1D channel approach was adopted to prevent instability occurring within the 2D model at the downstream boundary due to the flat topography of the floodplain.

The 1D channel cross sections downstream were duplicated from the 2D boundary and extended with normal depths of 0.06% for the first 10km and 0.2% for the next 10km. A rating curve was developed for use as the downstream boundary of the 1D channels. The adopted rating curve has no impact on water level within the 2D extent.

Hydraulic Structures

Twenty culvert crossings and two bridges were included in the Mooki River TUFLOW model. The culverts were modelled using the ESTRY 1D hydraulic model, a built-in feature of TUFLOW. Details of culvert configurations were obtained from Gunnedah Shire Council and ARTC. Table 9.14 shows a summary of key information for each culvert crossing.

The highway bridge and railway bridge across Mooki River was added as layered flow constriction within the 2D domain. Table 9.15 shows the adopted bridge characteristics, and Table 9.16 shows the adopted blockage factor and form loss co-efficient (FLC) within each layer at each structure. Four layers represent the flow across a bridge structure:

- Layer 1 represents the waterway area beneath the bridge deck;
- Layer 2 represents the bridge deck;
- Layer 3 represents the guard rail; and
- Layer 4 represents flow above the bridge (assumed to be unimpeded).

Table 9.14 Adopted 1D Culvert Characteristics

ID	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Culvert Dimensions
Highway Culverts			
529500	306.40	306.20	2 x 0.75m (W) x 0.3m (H)
529501	305.30	305.00	2 x 0.75m (W) x 0.3m (H)
529502	303.90	303.70	2 x 0.75m (W) x 0.3m (H)
529503	301.58	301.40	12 x 0.75m (W) x 0.3m (H)
529504	300.00	299.70	2 x 0.75m (W) x 0.3m (H)
529505	299.70	299.40	2 x 0.75m (W) x 0.3m (H)
529506	295.84	295.70	2 x 0.75m (W) x 0.3m (H)
529507	294.83	294.78	2 x 0.77m (W) x 0.32m (H)
529508	293.93	293.72	2 x 0.77m (W) x 0.32m (H)
529509	291.25	291.20	2 x 0.75m (W) x 0.3m (H)
529510	289.52	289.38	2 x 0.77m (W) x 0.32m (H)
529511	287.48	287.35	12 x 0.77m (W) x 0.3m (H)
529512	286.58	286.61	1 x 2.13m (W) x 1.52m (H)
Railway Culverts			
421.74	307.88	307.80	2 x 3.6m (W) x 1m (H)
426.31	294.31	294.10	4 x 9.5m (W) x 2.5m (H)
426.51	294.51	294.40	1 x 5m (W) x 1.2m (H)
428.84	290.08	289.96	6 x 1m dia.
431.24	287.14	286.91	4 x 2.3m (W) x 2.3m (H)
431.83	285.91	285.75	2 x 8.5m (W) x 3.5m (H)
583.61	302.01	301.95	1 x 2.4m (W) x 2.4m (H)

Table 9.15 Adopted Bridge Crossing Properties

Property	Highway Bridge	Railway Bridge
Bridge Deck Level (m AHD)	291.20	289.76
Deck Depth (m)	1.2	1.2
Approximate Bed Level (m AHD)	282.11	282.07
Guard Rail Height (m)	1.2	1.2
Approximate Bridge Length (m)	150	137.25
Number of Piers	14	14
Pier Diameter (m)	0.7	0.7
Approximate Distance between piers (m)	10	9.15

Table 9.16 Adopted TUFLOW Layered Flow Constriction Properties

Description	Highway Bridge	Railway Bridge
Layer 1 Obvert (m AHD)	290	288.56
Layer 1 Blockage	9	11
Layer 1 FLC ^a	0.2	0.2
Layer 2 Depth	1.2	1.2
Layer 2 Blockage	100	100
Layer 2 FLC ^a	1	1
Layer 3 Depth	1.2	1.2
Layer 3 Blockage	20	10
Layer 3 FLC ^a	0.2	0.1

^a The FLC (ξ_a) is a calibration factor applied as an energy loss based on the equation: $\Delta h = \xi_a \frac{V^2}{2g}$

Lake Goran

The western part of Lake Goran was modelled as an off-stream 1-D storage. Runoff from the catchments draining into Lake Goran was applied directly to the 1D storage node. The 1D storage node was connected to the 2D model domain using a HX boundary, which allows flow into and out of the 1D storage node and the 2D domain.

The stage-storage relationship adopted for the western part of Lake Goran (1D storage node) is shown in Table 9.17, and represents about 90% of the total lake storage at the level of 297m AHD. The eastern part of Lake Goran was included in the 2-D modelling study area to allow more accurate modelling of the outlet of Lake Goran, which is heavily affected by tailwater levels in Native Dog Gully and flows in Coomoo and Yarraman Creeks.

It is of note that no recorded water levels in Lake Goran were available during the calibration events. The initial water level in Lake Goran was adjusted to achieve a better calibration for each event. An initial water level of 296.3m AHD in Lake Goran was adopted for both calibration events. The initial water level is set in both the 1D and 2D domains at the start of the simulation. The Lake Goran initial water levels used in the RAFTS and TUFLOW modelling are different due to the two models having different starting times, and the different approaches to modelling of the lake outlet between the models. The TUFLOW model provides a more accurate assessment of Lake Goran water level behaviour due to detailed modelling of the lake outlet hydraulics. As a result, the adopted Lake Goran initial water levels and predicted lake water levels in two models cannot be directly compared.

Table 9.17 Stage-Storage Relationship of the Western Part of Lake Goran (1D Storage Node)

Stage (m AHD)	Volume (ML)
294.0	-
294.5	7,100
295.0	28,450
295.5	57,785
296.0	88,738
296.5	122,313
297.0	159,225
297.5	200,503
298.0	245,600
300.0	461,000

9.5 HYDRAULIC MODEL CALIBRATION

9.5.1 General

The TUFLOW hydraulic model was calibrated against the July 1998 and November 2000 flood events. Due to the inaccuracies associated with the RAFTS model calibration at Carroona, the recorded discharge hydrographs at Carroona for the July 1998 and November 2000 flood events were used as inflows to the TUFLOW model to improve the accuracy of the hydraulic model calibration. Inflows for catchments downstream of Carroona were obtained from the truncated RAFTS calibration models discussed in Section 8.3.9.

Calibration of the TUFLOW model was based on recorded water levels and discharges at Breeza (419027) stream gauge for the calibration events, as well as anecdotal evidence on flood depths and extents provided by landholders in Flood Study Landholder Interviews (Hansen Bailey, 2012), provided in Appendix A. The survey peak flood levels of the July 1998 and November 2000 are also used for model calibration. In general terms, the fit between recorded and predicted water level hydrographs at Breeza is considered acceptable, particularly considering the level of accuracy of the available survey data. The predicted flood extents adequately reflect the observed historical flood extents reported in Hansen Bailey (2012).

9.5.2 July 1998 Calibration

Figure 9.22 shows the recorded and predicted water level hydrographs at Breeza (419027) for the July 1998 calibration event. The following is of note with regards to the recorded and predicted hydrographs:

- The predicted peak water level at Breeza (419027) is 0.2m higher than the recorded peak water level at the gauge.
- The predicted hydrograph at Breeza (419027) peaks approximately 1 to 2 hours earlier than the recorded peak. The predicted flood peak from TUFLOW model matches the peak discharge recorded at the gauge well.
- Overall the calibration of the hydraulic model against the recorded water level hydrographs for the July 1998 flood event is considered to be acceptable.

A comparison of surveyed (SMEC, 2003) and predicted peak flood levels downstream of Breeza is shown in Table 9.18. The locations of the surveyed flood marks are shown in Figure 9.23. Overall the calibration of the hydraulic model against the surveyed flood levels for the July 1998 flood event is considered to be acceptable.

Figure 9.23 shows the estimated flood extent and flood depths for the July 1998 flood. The following is of note:

- Native Dog Gully was affected by breakout flows and backwater from the Mooki River. A small area at the south-east corner of the disturbance boundary would likely have been inundated during the 1998 flood event.
- The predicted extent of flooding generally reflects the observed extent and depth of flooding reported by landholders in the area (Hansen Bailey, 2012).

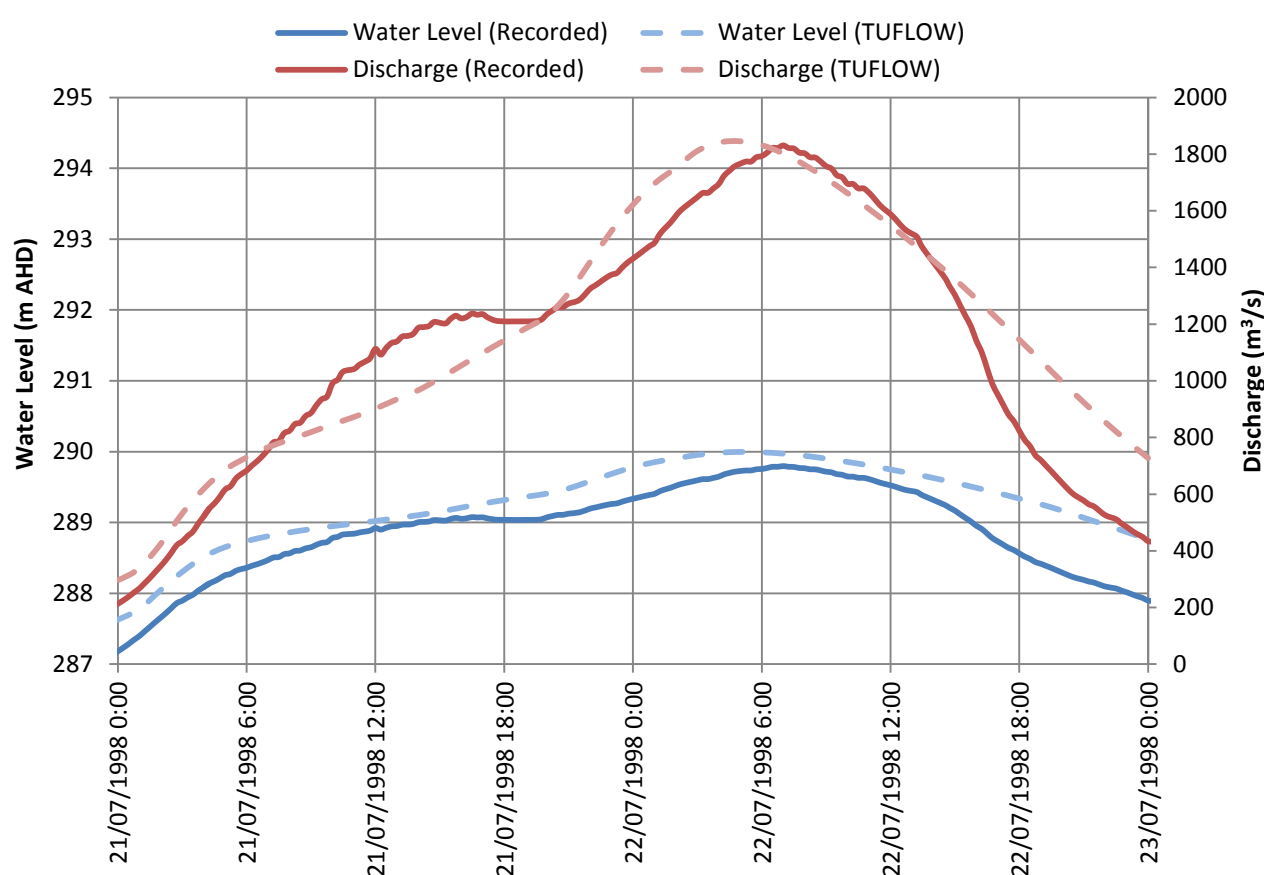


Figure 9.22 Recorded and Predicted Water Level Hydrographs at Breeza (419027), July 1998 Event

Table 9.18 **Surveyed (SMEC, 2003) and Predicted Peak Flood Level, July 1998 Event**

Point ID	Surveyed Flood Level (m AHD)	Predicted Flood Level (m AHD)	Difference (Predicted - Surveyed) (m)
1	286.43	286.35	-0.08
2	285.90	286.05	0.15
3	285.52	286.05	0.53
4	283.94	284.18	0.24
5	283.64	283.84	0.20
6	284.77	285.00	0.23
7	283.37	283.29	-0.08
8	282.28	281.92	-0.36
9	282.16	281.72	-0.44
10	279.74	280.07	0.33
11	279.50	280.01	0.50
12	280.60	280.70	0.10
13	277.18	277.08	-0.10

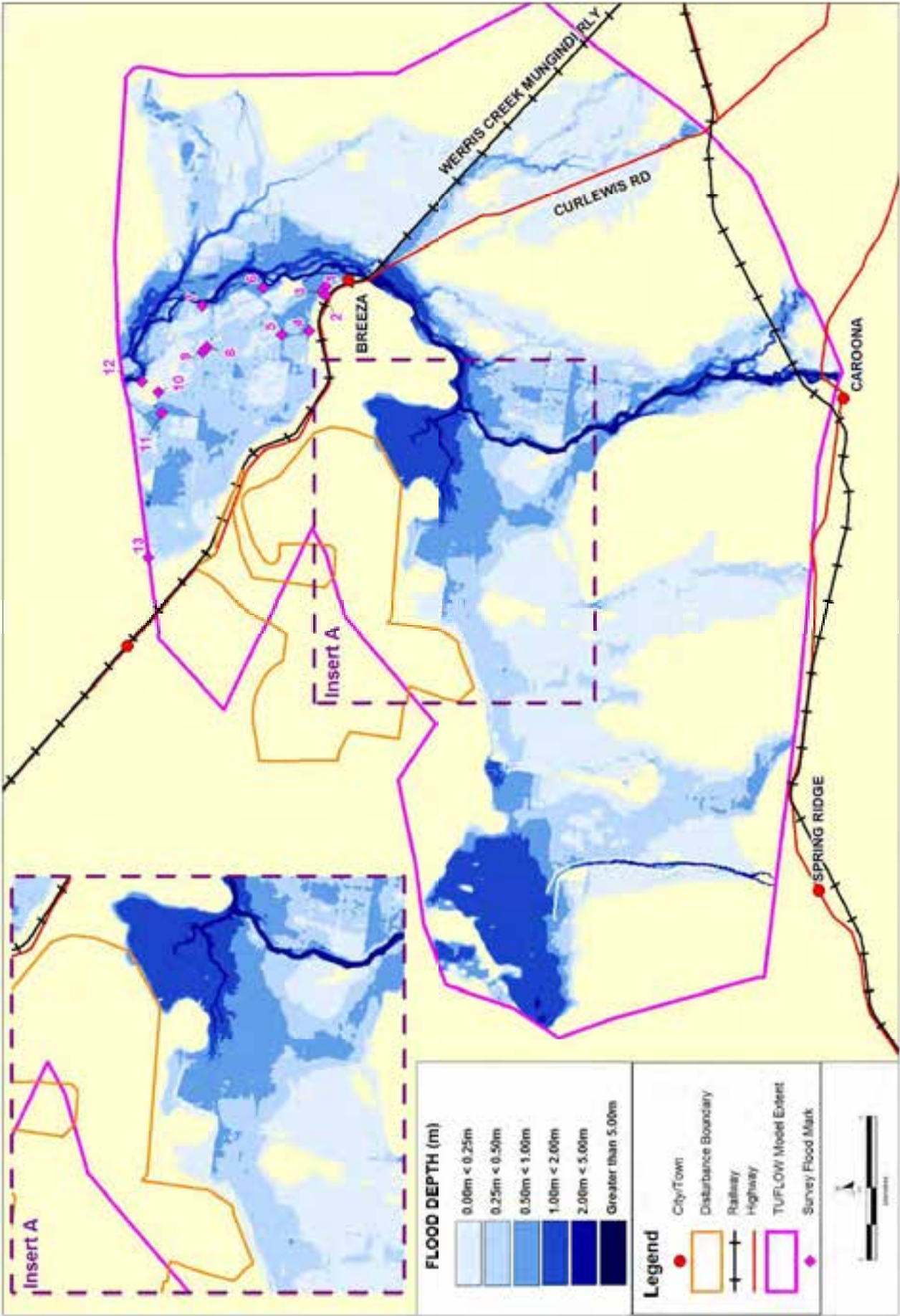


Figure 9.23 Predicted Flood Extent and Depth Profile, July 1998 Flood Event

9.5.3 November 2000 Calibration

Figure 9.24 shows the recorded and predicted water level and discharge hydrographs at Breeza (419027) for the November 2000 Flood event calibration. The following is of note with regards to the recorded and predicted hydrographs:

- The predicted peak water level at Breeza (419027) is 0.28m higher than the recorded peak water level at the gauge. The shape and timing of predicted water levels match the recorded water levels at the gauge. The difference in peak water level is considered acceptable considering that the Breeza gauge appears to have not recorded the peak water level during the November 2000 event.
- A good fit has been achieved between recorded and predicted discharges at the Breeza gauge (419027), particularly for the flood peak. The shape and timing of predicted discharges from TUFLOW model match well with the recorded discharges.
- Overall the calibration of the hydraulic model against the recorded water level hydrographs for the November 2000 flood event is considered to be good.

A comparison of surveyed (SMEC, 2003) and predicted peak flood levels downstream of Breeza is shown in Table 9.19. The locations of the surveyed flood marks are shown in Figure 9.25. Overall the predicted flood levels are in good agreement with the surveyed flood levels for the November flood event. The hydraulic model is considered to be well calibrated.

Figure 9.25 shows the estimated flood extent and flood depths for the November 2000 flood. The following is of note:

- Native Dog Gully was affected by breakout flows and backwater from the Mooki River. A small area at the south-east corner of the disturbance boundary would likely have been inundated during the 2000 flood event.
- The predicted extent of flooding generally reflects the observed extent and depth of flooding reported by landholders in the area (Hansen Bailey, 2012).

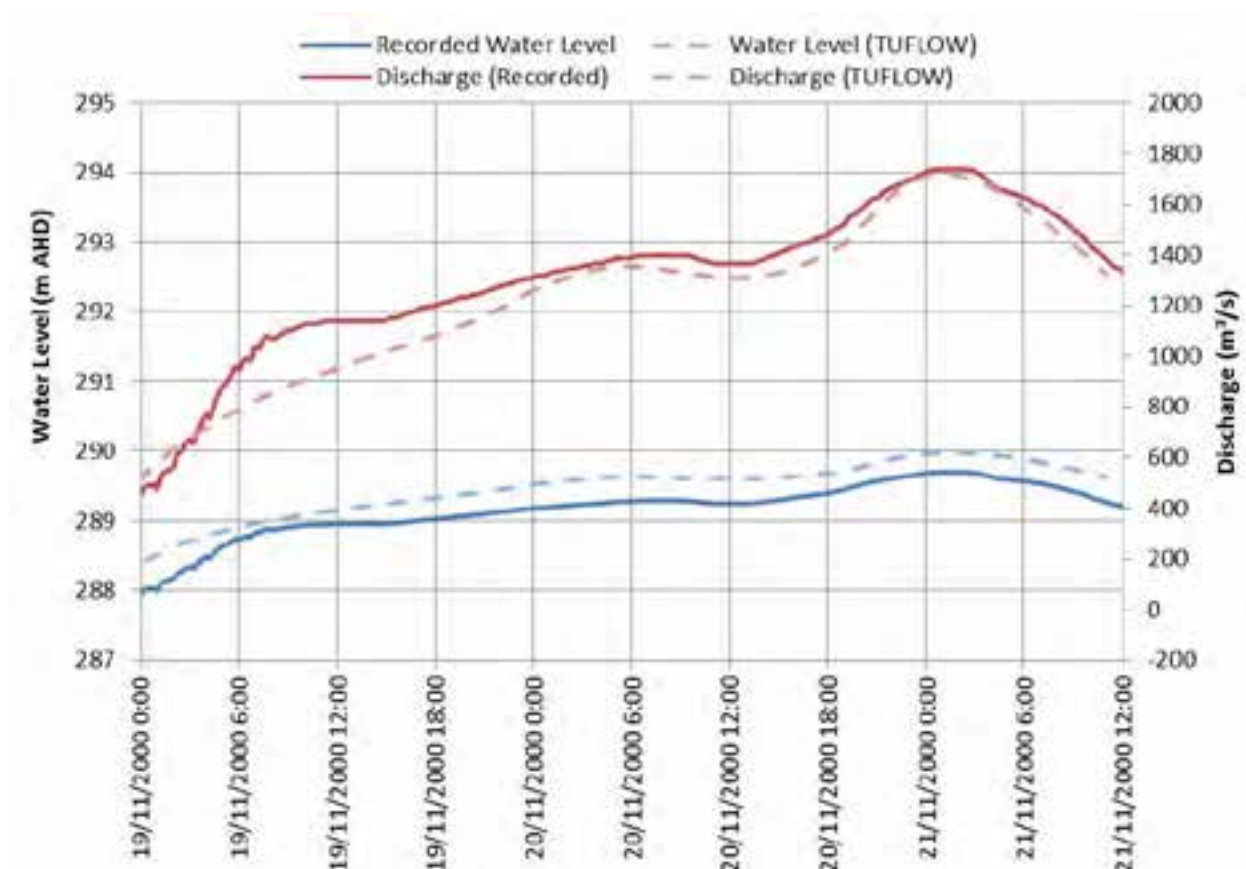


Figure 9.24 Recorded and Predicted Water Level Hydrographs at Breeza (419027), November 2000 Flood Event

Table 9.19 Surveyed (SMEC, 2003) and Predicted Peak Flood Level, November 2000 Event

Point ID	Surveyed Flood Level (m AHD)	Predicted Flood Level (m AHD)	Difference (Predicted - Surveyed) (m)
1	286.30	286.33	0.03
2	286.08	286.24	0.16
3	284.77	284.98	0.21
4	280.03	280.04	0.01

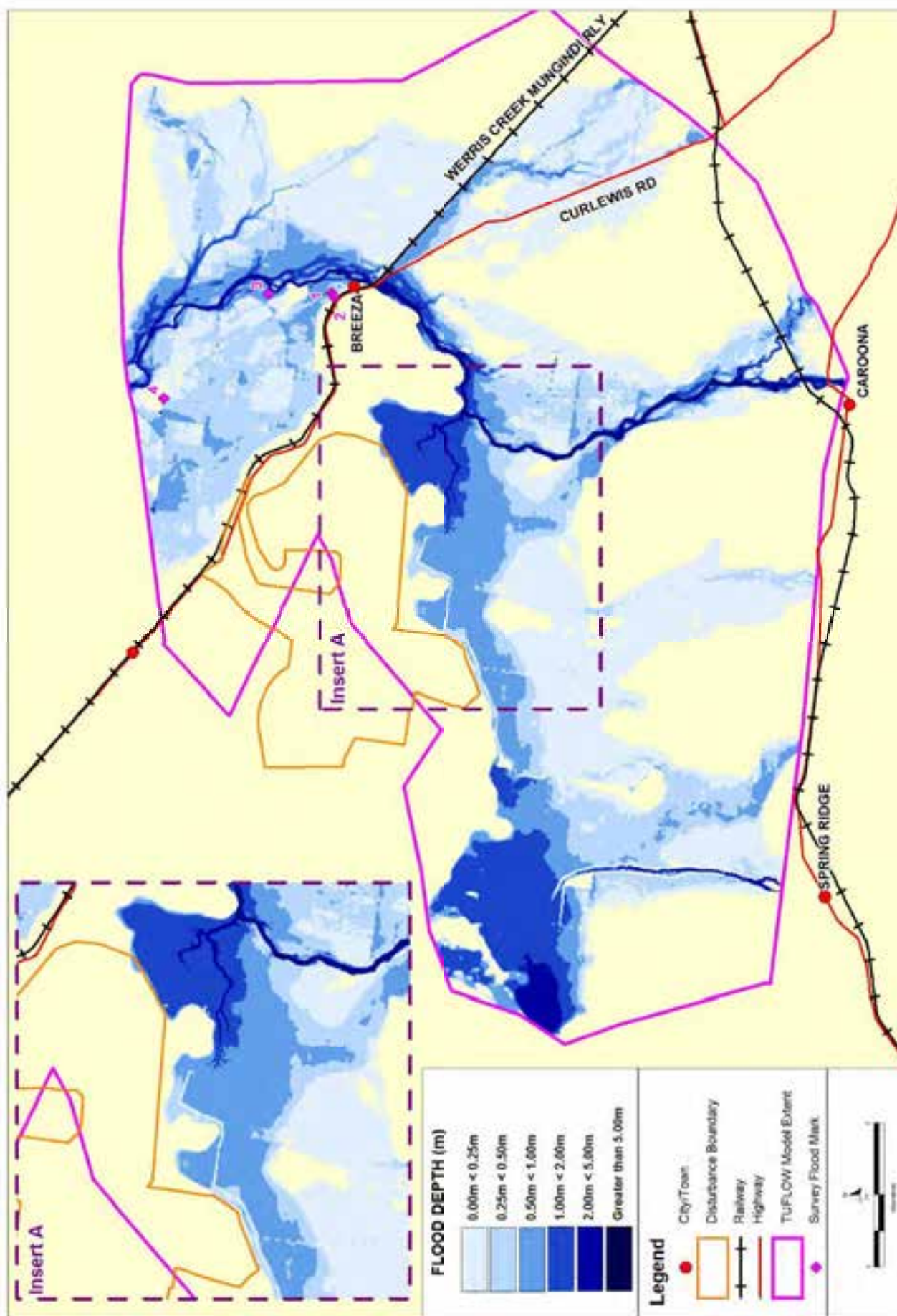


Figure 9.25 Predicted Flood Extent and Depth Profile, November 2000 Flood Event

9.6 ESTIMATION OF DESIGN FLOOD DISCHARGES

9.6.1 Methodology

The calibrated RAFTS model was used to estimate design flood discharges in the Mooki River catchment based on design rainfall Intensity–Frequency–Duration (IFD) data from Australian Rainfall and Runoff (IEAust, 1998). Design flood discharge hydrographs were estimated for a range of storm durations up to 72 hours for the 5, 10, 20, 50 and 100 year Average Recurrence Interval (ARI) events. The discharges estimated by the RAFTS model were reconciled with discharges estimated by flood frequency analyses at two gauging locations within the Mooki River catchment.

Estimates of the Probable Maximum Precipitation (PMP) flood event in the Mooki River catchment were made using the Generalised Tropical Storm Method (GTSMR) as described in BOM (2003b). The PMP rainfall estimates were applied to the RAFTS model to generate flood hydrographs for the PMP design flood (PMPDF) in the Mooki River catchment. For the purposes of this study, it has been assumed that the PMPDF is equivalent to the Probable Maximum Flood (PMF) for the Mooki River catchment.

9.6.2 Design Rainfalls and Temporal Patterns

Design Events Up to 100 Year ARI

Table 9.20 shows the adopted design rainfall intensities for the Mooki River catchment. Design rainfall patterns and intensities were determined using standard procedures given in Australian Rainfall and Runoff (ARR) (IEAust, 1998) for the 5, 10, 20, 50 and 100 Year ARI events.

Table 9.20 Adopted Design Rainfall Intensities, Mooki River Catchment

Duration (hours)	Adopted Design Rainfall Intensities, Mooki River Catchment (mm/hr)				
	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
12	6.2	7.1	8.3	9.9	11.1
18	4.8	5.4	6.3	7.6	8.6
24	3.9	4.4	5.2	6.2	7.1
36	2.9	3.4	4.0	4.8	5.5
48	2.4	2.8	3.2	3.9	4.5
72	1.7	2.0	2.4	2.9	3.3

Areal reduction factors (ARFs) for design events were estimated based on a recent ARF study in New South Wales (Jordan et al. 2011). The Jordan et al. (2011) study covered more than 6000 sites across NSW and the ACT, and provides equations to calculate ARFs for catchments up to 10,000 km² and durations between 1 hour and 120 hours for ARIs up to and including 2000 years. Table 9.21 gives the adopted ARFs for the Mooki River catchment. ARFs have been applied to the design rainfall intensities reported in Table 9.20.

Table 9.21 Adopted Areal Reduction Factors, Mooki River Catchment

Storm Duration (hour)	Areal Reduction Factor
12	0.70
18	0.73
24	0.77
36	0.81
48	0.84
72	0.87

Probable Maximum Precipitation Event

Probable Maximum Precipitation (PMP) rainfall intensities and patterns were estimated using the Generalised Tropical Storm Method (GTSMR) (BOM, 2003b). GTSMR method is designed to estimate long duration storms from 24 hours to 120 hours. It is noted that the Generalised Short-Duration Method (GSDM) is not suitable for catchments larger than 1,000km². The PMP rainfall patterns and intensities were applied into the RAFTS model to estimate the Probable Maximum Flood (PMP).

Table 9.22 shows the adopted PMP rainfall depths for the Mooki River catchment for the various storm durations analysed. For the estimation of PMP discharges, the spatial distribution of PMP rainfall across the catchment was determined in accordance with the methodology outlined in BOM (2003b).

Table 9.22 PMP Rainfalls for the Mooki River Catchment to the Upstream of Ruvigne

Event Duration (Hours)	PMP Rainfall Depth (mm)
24	600
36	700
48	790
72	960
96	1,090
120	1,150

Temporal Patterns

The temporal patterns given in Australian Rainfall and Runoff (IEAust, 1998) were applied to the 5, 10, 20, 50 and 100 year ARI design events and the BOM (2003b) GTSMR temporal patterns were applied to the PMP rainfalls.

9.6.3 Flood Frequency Analysis

Design flood discharges were estimated from a flood frequency analysis (FFA) of recorded flows at Carroona (419034) and Breeza (419027). There is 32 years of data at the Carroona gauging station and 38 years of data at the Breeza gauging station.

The methodology recommended in Australian Rainfall and Runoff (Book 4, Section 2, IEAust, 1998) was used to fit a Log-Pearson Type III distribution to an annual series of recorded peak flood discharges at these locations.

Table 9.23 shows the results of the FFA for the Mooki River at Caroona and Breeza, including the 5% and 95% confidence limits for a range of design discharges. Figure 9.26 and Figure 9.27 show the plot of the fitted frequency distributions at the site together with the 5% and 95% confidence limits. The following is of note with regards to the FFA results:

- The estimated 100 year ARI discharge at Caroona is 2,870m³/s.
- The estimated 100 year ARI discharge at Breeza is 4,230m³/s.
- The level of uncertainty associated with discharges for events of greater than 20 year ARI is large due to the relatively short period of record available at both gauging stations.

Table 9.23 Flood Frequency Analysis Results, Mooki River at Caroona and Breeza

ARI (Years)	Estimated Peak Discharge (m ³ /s)					
	Mooki River at Caroona (419034)			Mooki River at Breeza (419027)		
	5%	Q _y	95%	5%	Q _y	95%
2	70	110	190	70	120	190
5	240	430	760	270	450	750
10	390	770	1,510	480	880	1,600
20	540	1,230	2,810	730	1,520	3,160
50	700	2,050	6,020	1,080	2,810	7,310
100	790	2,870	10,400	1,350	4,230	13,300

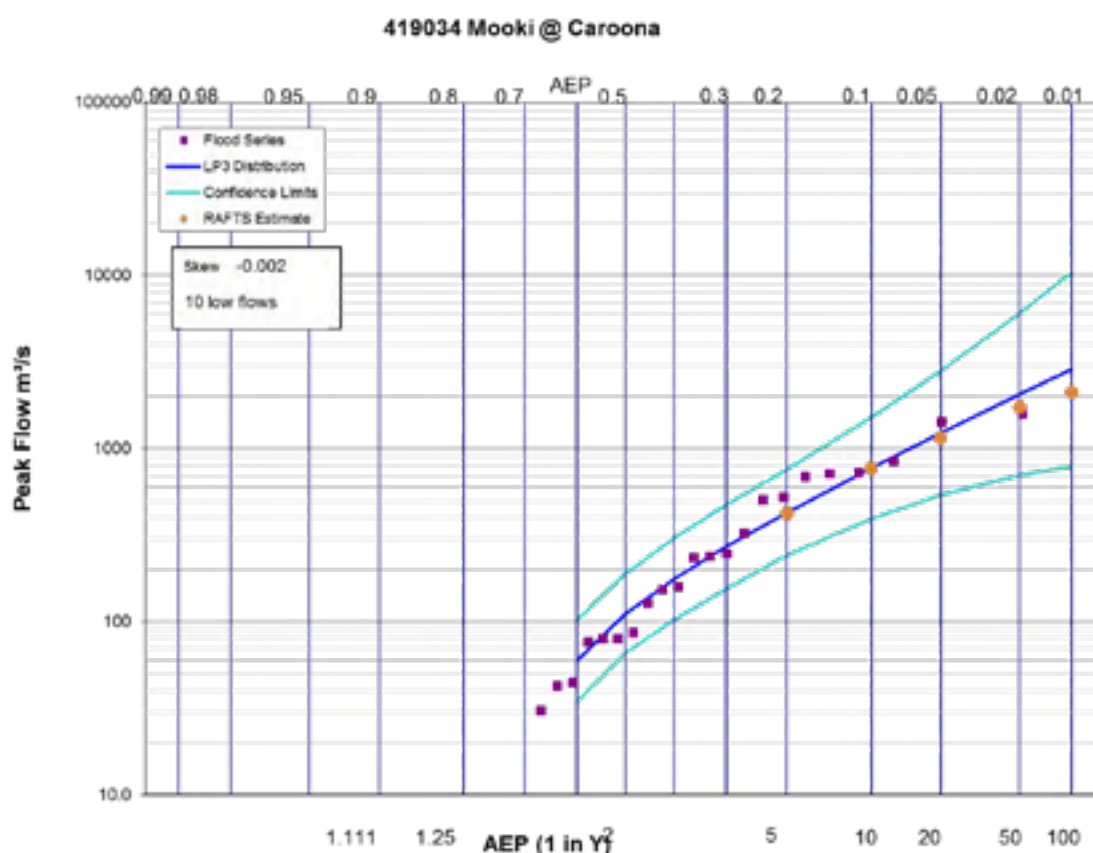


Figure 9.26 Flood Frequency Distribution, Mooki River at Caroona (419034)

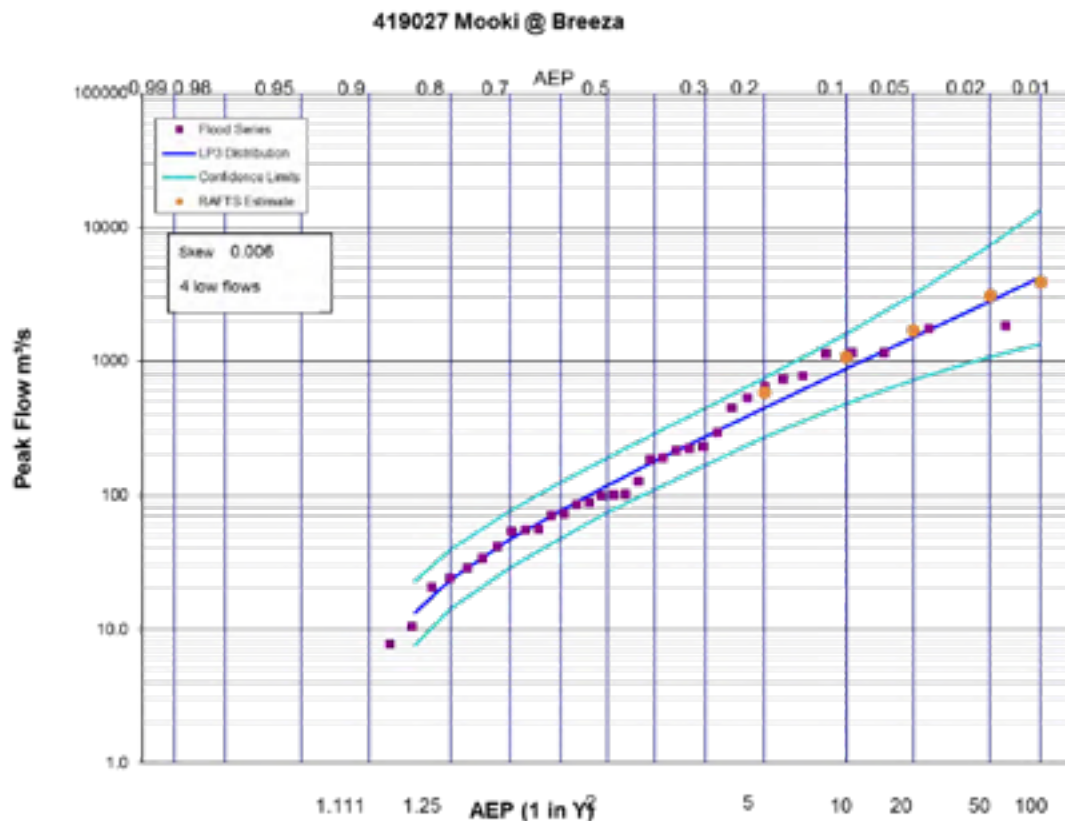


Figure 9.27 Flood Frequency Distribution, Mooki River at Breeza (419027)

9.6.4 Adopted Design Discharges

Table 9.24 shows the adopted design discharges, as estimated by the RAFTS model, at the two FFA locations for the 5, 10, 20, 50 and 100 year ARI events, and PMF. Table 9.25 shows the adopted initial losses, continuing losses and initial water levels at Lake Goran for different design events. A comparison of RAFTS model and FFA design discharges is given in Figure 9.26 and Figure 9.27. The following is of note:

- The adopted initial water levels at Lake Goran for different design events were selected based on a simulation of water levels for 122 years using the Lake Goran water balance model described in Section 5.5. The 1 percentile simulated lake water level was adopted as the starting water level for the 100 year ARI design flood event.
- The critical duration storm for all design events is the 72 hour storm.
- The peak design discharges estimated by the RAFTS model have a good agreement with FFA peak discharges.
- The PMF discharge at Mooki River at Carroona (8,500 m³/s) is approximately 4 times the estimated 100 year ARI discharge (2,110 m³/s). The PMF discharge at Mooki River at Breeza (17,000 m³/s) is between 4 and 5 times the estimated 100 year ARI discharge (3,880 m³/s).

Table 9.24 Adopted Design Discharges

Event ARI (Years)	RAFTS Model Design Discharge (m ³ /s)	
	Mooki River at Caroona (419034)	Mooki River at Breeza (419027)
5	420	590
10	770	1,070
20	1,150	1,700
50	1,730	3,110
100	2,110	3,880
PMF	8,500	17,000

Table 9.25 Adopted Rainfall Losses and Initial Water Level at Lake Goran

Event ARI (Years)	Initial Loss (mm)	Continuing Loss (mm/hr)	Initial Water Level at Lake Goran (m AHD)
5	35	2	295.1
10 and 20	25	1.5	296.1
50 and 100	15	1	296.5
PMP	0	0.5	296.6

9.6.5 Estimated Average Recurrence Interval of Historical Events

The estimated average recurrence interval of historical events was estimated by comparing recorded peak discharges for the historical flood events with the adopted design flood discharges shown in Table 9.24. The results of the comparison are shown in Table 9.26 and indicate that:

- The January 1984 flood had an ARI of approximately 10 years.
- The July 1998 flood had an ARI of between 23 and 42 years.
- The November 2000 flood had an ARI of between 21 and 34 years.

Table 9.26 Estimated ARI of Historical Flood Events

Flood Event	Mooki River at Caroona (419034)		Mooki River at Breeza (419027)	
	Recorded Peak Discharge (m ³ /s)	Estimated ARI (Years)	Recorded Peak Discharge (m ³ /s)	Estimated ARI (Years)
July 1998	1,573	42	1,831	23
November 2000	1,423	34	1,738	21
January 1984	712	9	1,143	11

9.7 ESTIMATION OF DESIGN FLOOD LEVELS AND EXTENT

9.7.1 General

The calibrated TUFLOW model was used to derive design flood levels and flood extents for the 100 year ARI design flood and Probable Maximum Flood. Design discharge hydrographs at the TUFLOW model boundaries were obtained from the calibrated RAFTS model.

9.7.2 100 Year ARI Design Flood Levels and Flood Extent

Figure 9.28 shows the extent of flooding and the flood depths for the 100 year ARI design flood. Flood velocities for the 100 year ARI event are shown in Figure 9.29. The following is of note:

- The 100 year ARI design flood level at Breeza gauging station is 290.97m AHD, which is approximately 1.2m higher than the recorded peak level during July 1998 flood event.
- Despite the significant difference in flood level at the Breeza gauge location, the predicted extent of flooding for the 100 year ARI design flood is generally only slightly larger than the 1998 flood extent.
- Native Dog Gully is heavily affected by breakout flows and backwater from the Mooki River.
- A small area at the south-east corner of the disturbance boundary would be inundated to a depth of up to 1.7m during a 100 year ARI design flood event. The area of inundation is located in a backwater area with very low flow velocities (less than 0.1 m/s). Filling of this small inundation area will not affect flood behaviour on the floodplain. The lost flood storage due to filling of this area would be approximately 235ML. This represents only about 2% of the flood storage volume in the northern Native Dog Gully floodplain during a 100 Year ARI event (approximately 11,310ML).
- It is likely that a levee embankment will be constructed within the disturbance boundary to prevent floodwaters from potentially overflowing into the open cut pit. An additional model run was undertaken with the site filled to the disturbance boundary (simulating the impacts of a levee) to assess the impact on peak flood level. The model results showed that the increase in flood levels on the adjacent floodplain was less than 5 mm.

9.7.3 PMF Flood Levels and Flood Extent

Figure 9.30 shows the extent of flooding and the flood depths for the PMF design flood. The following is of note:

- The PMF design flood level at Breeza gauging station is 293.22m AHD, which is approximately 3.4m higher than the recorded peak level during July 1998 flood event.
- The predicted extent of flooding for the PMF design flood is significantly larger than the 100 Year ARI design flood extent.
- Native Dog Gully is heavily affected by breakout flows and backwater from the Mooki River. Some areas along the southern side and at the south-east corner of the disturbance boundary would be inundated to a depth of up to 4.3m during a PMF design flood event.
- Watermark Gully is not affected by backwater flooding from the Mooki River during the PMF design flood event.

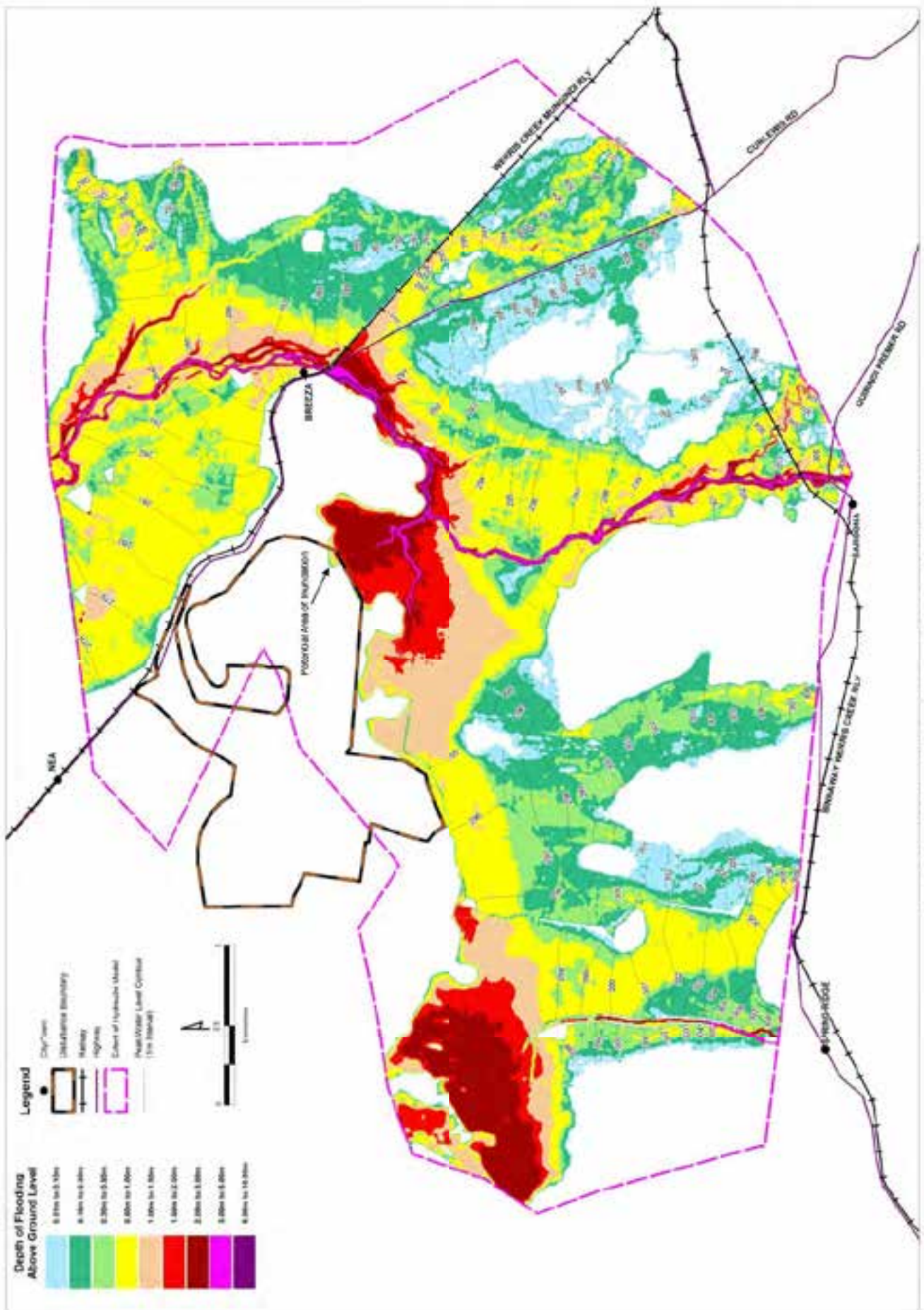
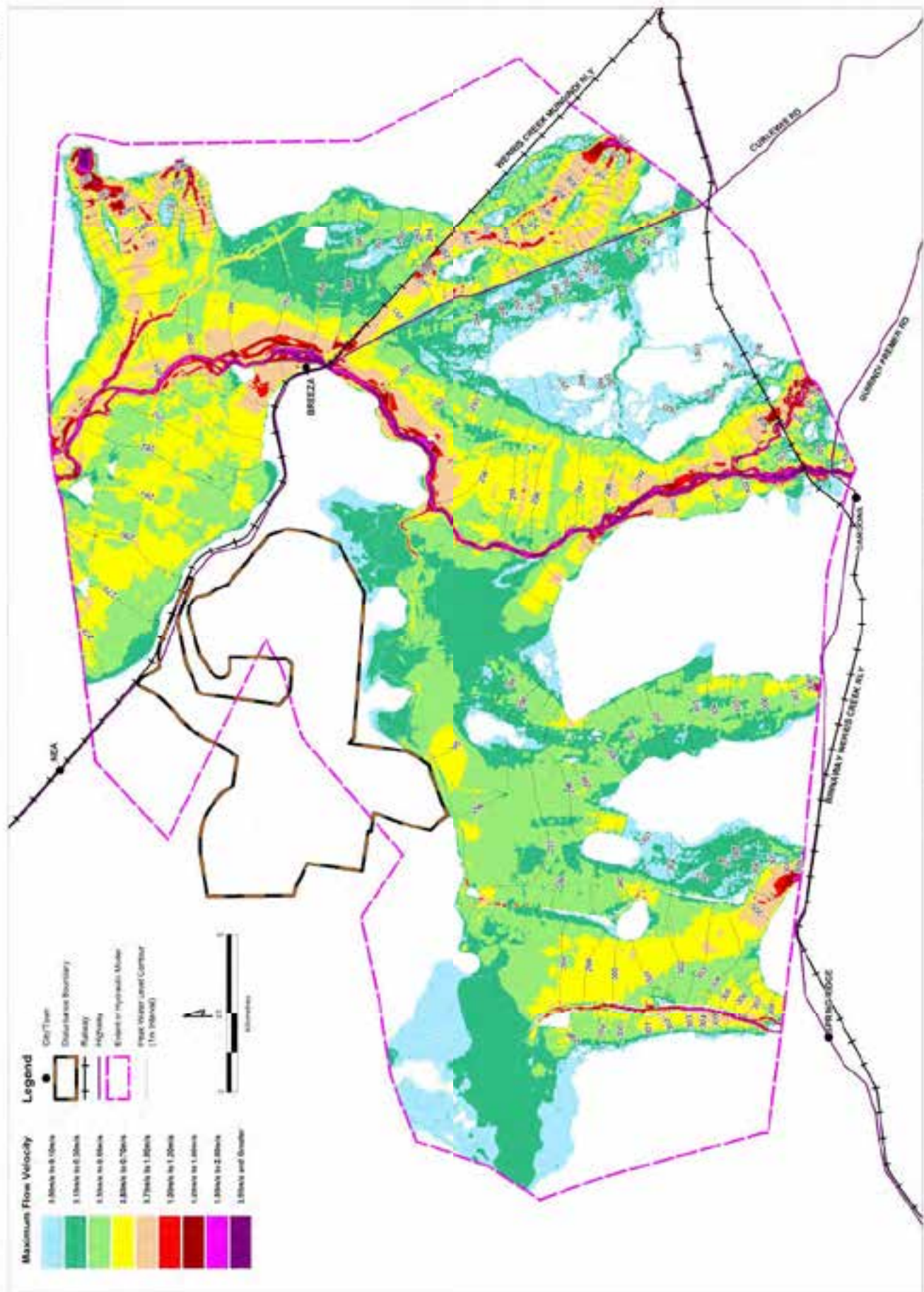


Figure 9.28 100 Year ARI Flood Extent and Peak Depth Profile, Mooki River





10

MITIGATION AND MANAGEMENT MEASURES

10.1 OVERVIEW

The impacts of the Project on surface water resources will be mitigated through the implementation of the following measures:

- A mine site water management system to control the flow and storage of water of different qualities across the site;
- A sediment control plan to reduce sediment loads from disturbed area runoff; and
- A surface water monitoring program to continually assess environmental impacts and ensure that the site water management system is meeting its objectives of minimal impact on receiving waters.

An overview of each of these management measures is provided in the following sections.

10.2 MINE WATER MANAGEMENT SYSTEM

A key objective of the mine water management system will be to minimise the risk of uncontrolled releases from mine site storages. To achieve this objective, operation of the mine water management system will be based on the following principles:

- Diversion of clean surface water runoff away from areas disturbed by mining activities;
- Operation of the mine water management system to ensure no uncontrolled releases of mine water from the site;
- Collection of potentially sediment-affected runoff in sediment dams for treatment prior to release from site or reuse in the mine water management system;
- Transfer of groundwater and seepage inflows to the open cut pits to the mine water system for reuse as a water supply;
- Collection of contaminated water from industrial areas for treatment in an oil and grease separator prior to recycling in the mine water management system; and
- Minimisation of fresh water usage by recycling water from the mine water system before taking additional water from external sources.

Details of the operation of the mine water management system are provided in Section 6.

An important component of the mine water management system will be to ensure that contingency measures are in place to accommodate either a surplus or deficit of water on site. Appropriate water licences will be obtained to meet the potential shortfall in water during dry conditions. Mine operations will also be planned to ensure that mining can continue during extended wet periods when water is likely to accumulate in the open cut mining areas.

10.3 SEDIMENT AND EROSION CONTROL PLAN

10.3.1 Overview

A sediment and erosion control plan will be developed as part of detailed design for the Project. The design of sediment control measures will be based on the principle of ensuring that runoff from disturbed areas is separated from clean area runoff and collected in sediment dams for treatment. Design of proposed erosion and sediment control measures will be based on the recommended design standards in the following guidelines:

- Managing Urban Stormwater, Soils and Construction, (Landcom, 2004); and
- Managing Urban Stormwater, Soils and Construction, Volume 2E Mine and Quarries (DECC, 2008).

Locations of proposed major sediment dams to collect and treat runoff from overburden emplacement areas are shown in Figure 4.7. Additional minor sediment traps may also be required at other locations across the site.

Sediment dams will be dewatered within 5 days after a runoff event to provide free storage capacity of at least the Settling Zone Volume. Where the total suspended solids (TSS) concentration in sediment dams after a runoff event is less than the selected water quality objective, sediment dams may be dewatered to receiving waters. Where TSS exceeds the water quality objective, water in basins must be either:

- Flocculated to reduce TSS to less than the water quality objective;
- Pumped to another water storage with available capacity; or
- Pumped in to the mine water management system.

10.3.2 Overburden Emplacement Drainage

Minimising erosion of overburden emplacements is important in establishing a stable final landform. The proposed final surface of rehabilitated overburden emplacements will include contour drains which direct runoff across the emplacement slope at non-erosive velocities, as well as rock-lined chutes to convey inflows from contour drains down the face of the emplacement. Rock chutes will discharge to a sediment basin to reduce suspended sediment concentrations. A preliminary concept design for overburden emplacement drainage has been prepared to illustrate the proposed drainage system.

Design Criteria

Design criteria for the permanent contour drains are based on recommendations in the 'Blue Book' guidelines (Landcom, 2004). Details of the adopted criteria are shown in Table 10.1. Note that the final void includes a diversion drain to minimise the contributing catchment area. A higher design standard would be appropriate for this drainage structure to ensure that it will be effective in diverting runoff away from the final void in the long term.

Table 10.1 Contour Drain Design Parameters

Parameter	Value	Comment
Design storm event	20 year ARI	Nominal, 10-year ARI minimum.
Contour Bank Spacing	80 – 100 m	Based on 10° slope angle (PEA, 2011).
Channel configuration	Trapezoidal	Shaped for stability and to reduce erosive energy levels.
Design velocity	1.5 m/s	Grass material, moderate soil erodibility.
Longitudinal gradient	1 %	As recommended (1-5%).
Batter slopes	1(V) : 2(H)	As recommended.
Minimum channel depth	300 mm	As recommended.
Minimum cut depth	150 mm	Nominal, to minimise risk of piping.
Freeboard	300 mm	Nominal, to contain 100-year ARI.
Bund crest width	4 m	To enable safe compaction of bund by mine machinery.

Methodology

The Rational Method was used to estimate design discharges for the contour drains and a sample rock chute catchment for the 20 and 100 year ARI design discharges. Table 10.2 shows the Rational Method calculations.

Manning's equation was used to estimate flow depths and velocities along the contour drains. Adopted Manning's n values for the contour drains are shown in Table 10.1.

Concept design of the rock chute was undertaken using the CHUTE software (Keller, 2003), based on a 10° slope angle of overburden emplacement. A factor of safety of 1.3 was adopted for the calculations, as recommended for a major structure where failure would threaten an asset or cause major loss.

Table 10.2 Estimation of Design Discharges

Rational Method Parameters	Units	Design Storm Event			
		Contour Drain		Rock Chute	
		20 Year ARI	100 Year ARI	20 Year ARI	100 Year ARI
Catchment Area	ha	15 ^{*1}	15 ^{*1}	175	175
C10		0.86 ^{*2}	0.86 ^{*2}	0.86 ^{*2}	0.86 ^{*2}
Time of Concentration	min	22 ^{*3}	22 ^{*3}	56 ^{*3}	56 ^{*3}
Runoff Coefficient (Cy)		0.90	1.03	0.90	1.03
Frequency Factor (Fy)		1.05	1.20	1.05	1.20
Rainfall Intensity (Iy)	mm/hr	70.8	115.6	49.3	67.9
Discharge	m ³ /s	2.5	5.0	21.6	34.1

Notes: ^{*1} Based on maximum bank spacing of 100m and maximum contour drain length of 1.5km.

^{*2} 'Group C' soil hydrologic group – moderate to high runoff potential. (Landcom, 2004)

^{*3} Pilgrim and McDermott method, time of concentration [hours] = $0.76 \times \text{Area [km}^2\text{]}^{0.38}$

Table 10.3 Contour Drain Adopted Mannings n Values

Parameter	Value	Comment
Mannings 'n', post-construction	0.03	Excavated or Dredged Channels, earth, straight and uniform, with short grass, few weeds (Chow, 1973)
Mannings 'n', final design	0.05	Excavated or Dredged Channels, channels not maintained, weeds and brush uncut, clean bottom, brush on sides (Chow, 1973)

Contour Drain Sizing

Based on the design criteria specified above, a summary of the contour drain design parameters is shown in Table 10.4. A typical cross-section is shown in Figure 10.1. An example drainage network across a portion of the overburden emplacement area adjacent to the East Pit is shown in Figure 10.2.

Table 10.4 Contour Drain Design Parameters

Parameter	Value	Comment
Channel Base Width	6 m	
Channel Depth	0.75 m	Includes 0.3 m freeboard.
Q ₂₀ Water Depth	0.44 m	
Q ₂₀ Velocity	1.46 m/s	
Q ₁₀₀ Water Depth	0.57 m	
Q ₁₀₀ Velocity	1.71 m/s	

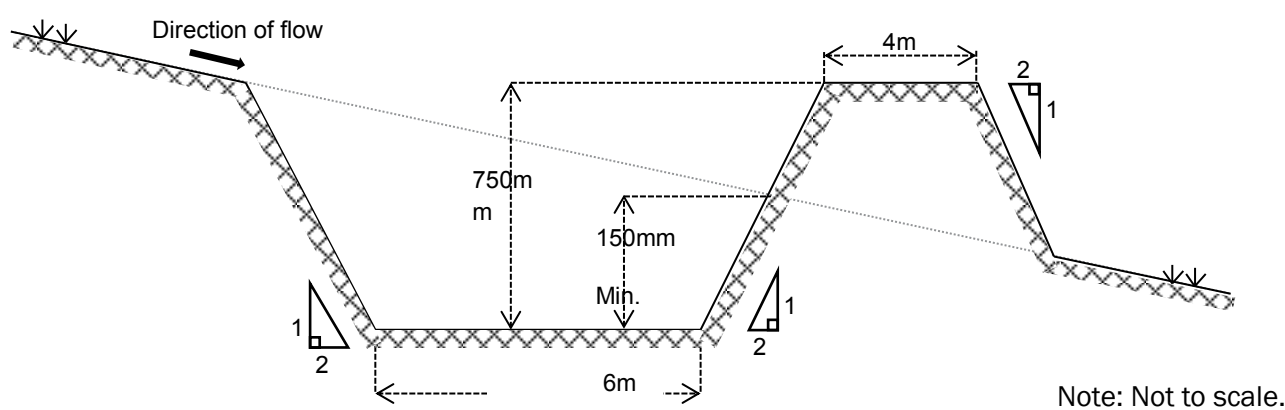


Figure 10.1 Contour Drain Typical Cross-section

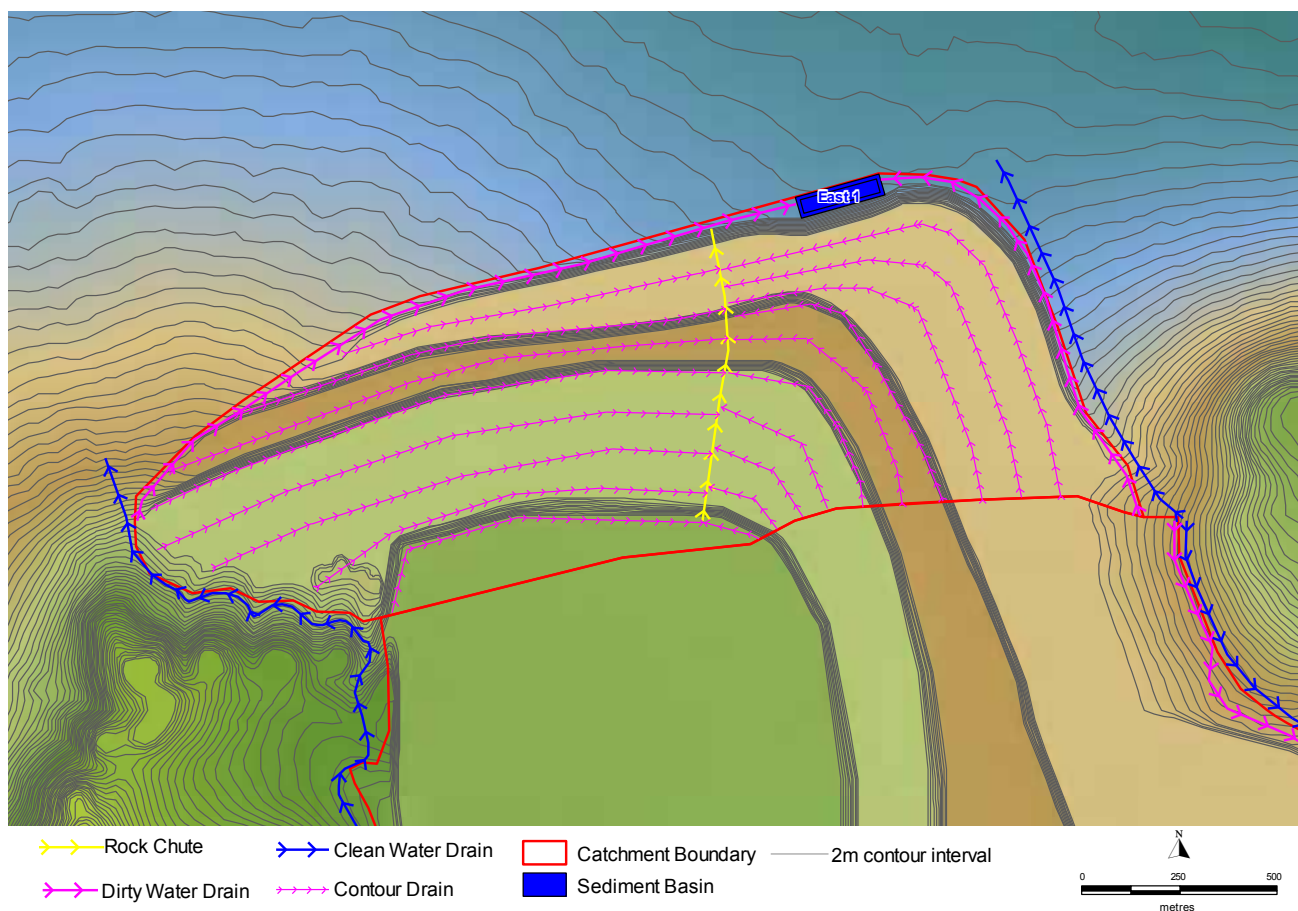


Figure 10.2 Sample of Concept Design for Overburden Emplacement Drainage

Rock Chute Design

Concept design details of an example rock chute are provided in Table 10.5. Note that the design is dependent on the catchment area reporting to the chute. A schematic of a typical rock chute is shown in Figure 10.3.

Table 10.5 Rock Chute Concept Design Parameters

Parameter	Value	Comment
Chute width	35 m	
Rock angle of repose	42°	For angular rock larger than 100mm
Specific gravity of rock	2.65	Typical of granite
Q ₂₀ rock size - d50	450 mm	
Q ₁₀₀ rock size - d50	625 mm	
Bank angle	21°	
Apron length	5 m	Hydraulic jump at 1 - 1.5 m
Apron Slope	0°	

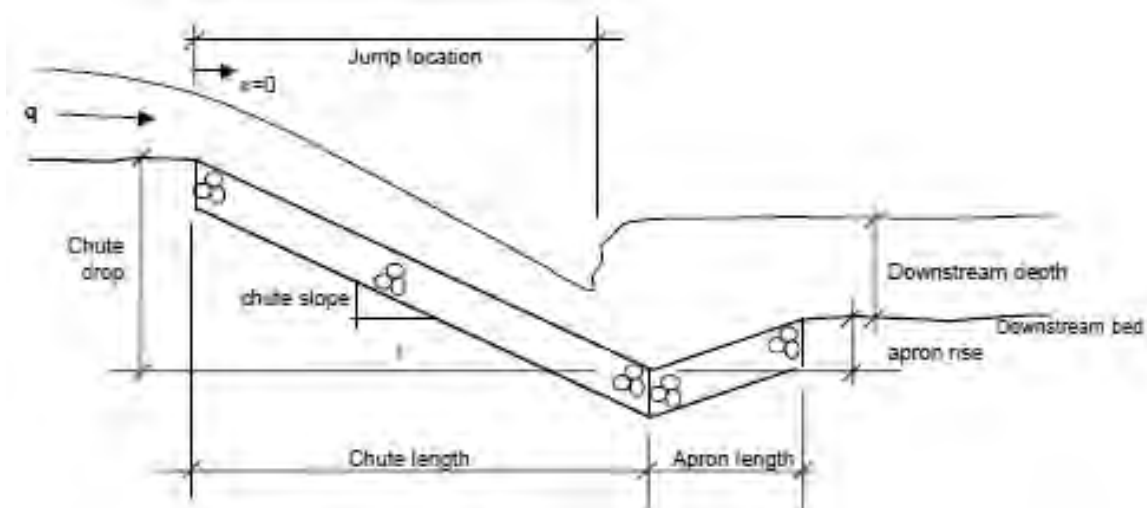


Figure 10.3 Schematic of a Typical Rock Chute (Source: Keller, 2003)

10.4 SURFACE WATER MONITORING PROGRAM

10.4.1 Overview

A detailed environmental monitoring program, including surface water sampling, is currently managed by Carbon Based Environmental Pty Ltd on behalf of Shenhua Watermark. A summary of surface water data collected to date under the program, as well as a plan showing the location of surface water monitoring sites, is presented in Section 2.5.

The surface water monitoring program includes eight river and two creek monitoring sites. Field analysis of pH, Electrical Conductivity, Dissolved Oxygen, Redox Potential and temperature is conducted monthly in the field. Comprehensive laboratory analysis is also undertaken for monthly samples. Samples are collected to the DECCW Approved Water Sampling Methods: AS/NZS5667.1 and AS/NZS 5667.6. Additional surface water sampling is undertaken following events if recorded rainfall at both of the meteorological monitoring sites exceeds 22mm/day. Event sampling is undertaken at all regular monitoring sites plus additional sites SWM16 and SWM17 on Watermark Gully. River flow rates for the Mooki River are obtained from the NSW Office of Water. Details of monitored water quality parameters and monitoring frequency are provided in Table 10.6.

The current surface water monitoring program will continue after mining commences. This will provide a comparison of baseline water quality which will allow adverse impacts, if any, to be identified. The surface water monitoring program will be expanded after mining commences to include sampling from key storages within the mine water management system, including sediment dams and the primary mine water storages. The parameter suite and sampling frequency for onsite monitoring will be identical to the current receiving water monitoring program. Once a baseline of consistent water quality data for onsite storages is established, it may be possible to reduce sampling frequency.

Regular inspection of surface drainage infrastructure will also be an important component of the surface water monitoring program. The inspections will include clean and dirty water drains, as well as sediment dams to identify any actual or potential problems with the clean or dirty water drainage system, such as areas of active erosion or sediment deposition with the potential to affect the integrity of the surface water management system.

Table 10.6 Surface Water Monitoring Program Details (Source: Carbon Based Environmental Pty Ltd)

<i>Monitoring Type</i>	<i>Parameter</i>	<i>Unit of Measurement</i>	<i>Frequency</i>
Surface Waters •10 "normal" sites •2 extra sites- rainfall events •1 Field Blank •1 field Duplicate	pH (field)	---	Monthly or Rainfall >22mm
	Electrical Conductivity (field)	µS/cm	Monthly or Rainfall >22mm
	Temperature (field)	°C	Monthly or Rainfall >22mm
	Redox Potential (field)	mV	Monthly or Rainfall >22mm
	Dissolved Oxygen (field)	ppm	Monthly or Rainfall >22mm
	Total Dissolved Solids	mg/L	Monthly or Rainfall >22mm
	Total Suspended Solids	mg/L	Monthly or Rainfall >22mm
	Sulphate	mg/L	Monthly or Rainfall >22mm
	Total Kjeldahl Nitrogen (TKN)	mg/L	Monthly or Rainfall >22mm
	Total Phosphorous	mg/L	Monthly or Rainfall >22mm
	Alkalinity	mg/L	Monthly or Rainfall >22mm
	Total Metals (As, Ba, Be, Cd, Cr, Cu, Mn, Ni, Pb, Va, Zn, Fe, Hg)	mg/L	Monthly or Rainfall >22mm
Weather Stations (x 2 sites)	Dissolved Metals (As, Ba, Be, Cd, Cr, Cu, Mn, Ni, Pb, Va, Zn, Fe, Hg)	mg/L	Monthly or Rainfall >22mm
	2m Air Temperature	°C	Continuous (10 minute average)
	10m Air Temperature	°C	Continuous (10 minute average)
	Average Wind Speed	km/hr	Continuous (10 minute average)
	Maximum Wind Speed	km/hr	Continuous (10 minute average)
	Wind Gust	km/hr	Continuous (10 minute average)
	Wind Direction	°	Continuous (10 minute average)
	Relative Humidity	%	Continuous (10 minute average)
	Rainfall	mm	Continuous (10 minute average)
	Solar Radiation	W/m²	Continuous (10 minute average)

10.4.2 Surface Water Quality Performance Criteria

As discussed in Section 3.4, background concentrations of some pollutants in receiving waters downstream of the Project are well above ANZECC trigger values. Hence, it is appropriate to develop site-specific water quality objectives based on recorded baseline data. Table 10.7 shows a preliminary assessment of trigger values for key water quality parameters for Native Dog Gully, Watermark Gully and the Mooki River. These will be refined based on further sampling to be undertaken prior to commencement of the Project.

Since no releases of mine water are anticipated, the performance criteria for Mooki River water quality will be based on a comparison of upstream and downstream water quality. Where downstream water quality is similar to upstream water quality (referenced to the baseline correlation of water quality parameters upstream and downstream), then no further investigation is required. However, where the increase in the concentration of a pollutant is outside the expected range and concentrations exceed the trigger values, then an assessment of potential reasons for the observed water quality will be undertaken to determine whether the Project may have influenced downstream water quality.

Table 10.7 Preliminary Trigger Values for Water Quality Assessment

Parameter	Unit	ANZECC Trigger Value			Recorded Baseline Data (80%ile)				Preliminary Trigger Value			Comment
		Irrigation	Livestock drinking	Eco-system ^{*d}	Recreational	Watermark Gully ^{*f}	Native Dog Gully ^{*h}	Mooki River ^{*i}	Watermark Gully	Native Dog Gully	Mooki River	
pH	pH	6.0 - 9.0	-	6.5 - 8.0	6.5 - 8.5	7.2 - 8.3	8.1 - 9.1	8.1 - 8.8	6.5-8.5	6.5-9.0	6.5-9.0	Lower bound based on ANZECC guideline for ecosystem protection, upper bound based on Baseline data.
EC	µS/cm	1,000 ^{*a}	-	35-350	-	248	9,340	1,247	250	2,000	1,250	Watermark Gully & Mooki River based on Baseline data. Native Dog Gully based on inspection of results.
DO (% Saturation)		-	-	90-110	-	20-112	60-101	57-92	20-110	60-110	60-110	Lower bound based on baseline data, upper bound based on baseline data and ANZECC guideline for ecosystem protection.
Total Dissolved Solids (TDS)	mg/L	-	2,000 ^{*a}	-	1,000	123	10,540	693	200	10,500	700	Baseline data adopted. Rounded up to nearest hundred.
Turbidity	NTU	-	-	2-25	-	218	258	362	220	260	360	Baseline data adopted.
Calcium (Ca)	mg/L	-	1000	-	-	-	-	-	1,000	1,000	1,000	Lack of baseline data, adopted lowest ANZECC guideline.
Sodium (Na)	mg/L	115 ^{*c}	-	-	300	-	-	-	115	115	115	Lack of baseline data, adopted lowest ANZECC guideline.
Magnesium (Mg)	mg/L	-	2,000 ^{*b}	-	-	-	-	-	2,000	2,000	2,000	Lack of baseline data, adopted lowest ANZECC guideline.
Sulphate as SO4	mg/L	-	1000	-	400	11	1,300	24	400	1,300	400	Mooki and Watermark Gully based on ANZECC guidelines. Native Dog Gully based on Baseline data.
Chloride as Cl	mg/L	175 ^{*c}	-	-	400	-	-	-	175	175	175	Lack of baseline data, adopted lowest ANZECC guideline.
Arsenic	mg/L	0.1 ^{*f}	0.5	0.013 ^{*ae}	0.05	0.002	0.003	0.002	0.013	0.013	0.013	Lowest ANZECC guideline adopted.
Barium	mg/L	-	-	-	1	0.15	0.1872	0.1	1	1	1	Lowest ANZECC guideline adopted.
Cadmium	mg/L	0.01 ^{*f}	0.01	0.0002 ^{*e}	0.005	0.00005 ^{*j}	0.00005 ^{*j}	0.00005 ^{*j}	0.0002	0.0002	0.0002	Based on ANZECC guideline for ecosystem protection.
Chromium	mg/L	0.1 ^{*f}	1	0.001 ^{*e}	0.05	0.004	0.004	0.005	0.004	0.004	0.005	Baseline data adopted.
Copper	mg/L	0.2 ^{*f}	0.4 ^{*a}	0.0014 ^{*e}	1	0.005	0.006	0.005	0.005	0.006	0.005	Baseline data adopted.
Iron	mg/L	0.2 ^{*f}	-	-	0.3	3.44	3.58	3.4	3.4	3.6	3.4	Baseline data adopted. Rounded up to nearest hundred.
Lead	mg/L	2 ^{*f}	0.1	0.0034 ^{*e}	0.05	0.004	0.0005 ^{*j}	0.0005 ^{*j}	0.004	0.001	0.001	Watermark Gully based on baseline data. Native Dog Gully & Mooki River based on detection limit.
Manganese	mg/L	0.2 ^{*f}	-	1.9 ^{*e}	0.1	0.286	0.2772	0.0953	0.3	0.3	0.1	Baseline data adopted. Rounded up to nearest tenth.
Nickel	mg/L	0.2 ^{*f}	1	0.011 ^{*e}	0.1	0.01	0.0114	0.0085	0.011	0.011	0.011	Lowest ANZECC guideline adopted. Also corresponds to Baseline data.
Zinc (Zn)	mg/L	2 ^{*f}	20	0.008 ^{*e}	5	0.012	0.0332	0.0343	0.02	0.04	0.04	Baseline data adopted. Rounded up to nearest tenth.
Mercury	mg/L	0.002 ^{*f}	0.002	0.0006 ^{*e}	0.001	0.00005 ^{*j}	0.00005 ^{*j}	0.00005 ^{*j}	0.0006	0.0006	0.0006	Based on ANZECC guideline for ecosystem protection.
Ammonia	mg/L	-	-	0.013	-	-	-	-	0.013	0.013	0.013	Lack of baseline data, adopted lowest ANZECC guideline.
Total phosphorus (Total P)	mg/L	0.05 ^{*f}	-	0.02	-	0.3	0.5	0.4	0.3	0.5	0.4	Baseline data adopted.
Total nitrogen (Total N)	mg/L	5	-	0.25	-	-	-	-	0.25	0.25	0.25	Lack of baseline data, adopted lowest ANZECC guideline.
Nitrate-N	mg/L	-	400	0.7 ^{*e}	10	-	-	-	0.7	0.7	0.7	Lack of baseline data, adopted lowest ANZECC guideline.
Nitrite-N	mg/L	-	30	-	1	-	-	-	1	1	1	Lack of baseline data, adopted lowest ANZECC guideline.

Notes: - No Trigger Value recommended. ^{*f} Long term Trigger Value

^{*a} Lowest recommended value.

^{*b} Cattle (insufficient information on other livestock)

^{*c} Sensitive crops

^{*d} Upland River

^{*e} 95% of species protected

^{*f} At SWM17

^{*g} At SWM6

^{*h} Average of SWM12, SWM11 & SWM1

^{*i} Many samples under detection limit.

11

SUMMARY OF FINDINGS

The potential impacts of the Project on surface water resources include:

- Impacts on regional water availability due to the potential need to obtain water from external sources to meet operational water requirements of mining operations;
- Adverse impacts on the quality of surface runoff draining from the disturbance area to the various receiving waters surrounding the Project;
- Adverse impacts on downstream water quality in Watermark Gully associated with possible overflows from the Mine Water Management System;
- Loss of catchment area draining to Watermark Gully, Native Dog Gully and Lake Goran due to capture of runoff within onsite storages and the Open Cut Pit;
- Interference with flood flows along Watermark Gully and Native Dog Gully.

The water requirements of the Project have been investigated using a detailed site water balance model. The model results may be summarised as follows:

- On average, different stages of mining will operate with a net water deficit of the order of 20 to 160 ML/a (in reality, the site water balance will vary significantly from year to year, depending upon climatic conditions).
- On average, water collected onsite, such as groundwater inflow and surface runoff to mining pits and storages should be able to meet all mine water demands about 90% of the time.
- There is a 10% chance that the volume of external water supply required in any year from Year 4 to Year 19 will be of the order of 300 to 600 ML/a.
- Under extreme drought conditions (1% chance), the annual volume of external water supply could potentially be 900 ML/a.

Water required from external sources will be obtained under appropriate Water Access Licences to ensure no adverse impacts on water availability for other licensed water users.

The mine water management system will be designed and operated to minimise the impacts of the project on downstream water quality. Wherever possible, runoff from undisturbed areas will be diverted around disturbance areas using diversion drains. This will minimise the volume of water collected in onsite storages and also minimise the impacts on downstream catchments. Sediment-laden runoff will be collected and treated in sediment dams. If the quality of this water is not suitable for release to receiving waters, it will be pumped back into the mine water management system. This water will only be released from site if water quality is acceptable, or during a rainfall event that exceeds the design capacity of the sediment control system.

The mine water management system will be operated to fully contain mine water on the mine site and to preferentially reuse this water to meet minesite demands. The results of the mine water balance modelling show that under the full range of historical rainfall conditions, the proposed mine water management system will have sufficient capacity to contain all mine water on the site without the need for offsite releases. The proposed mine site water management strategy and infrastructure will ensure that the Project has a negligible impact on the quality of surface runoff and receiving waters.

Impacts associated with the Project will include a temporary reduction in the catchment area draining to receiving watercourses due to capture of runoff from disturbed catchment areas within the mine water management system. This reduction in catchment area will reduce the volume and peak of stormwater runoff resulting in a reduction in flood discharges. The maximum captured catchment areas represent:

- Less than 1% of the Mooki River catchment to the confluence with Watermark Gully.
- Approximately 17% of the catchment area of Watermark Gully to the Kamilaroi Highway.
- Approximately 29% of the catchment of Native Dog Gully (excluding Yarraman Creek).
- Less than 0.4% of the catchment to Lake Goran.

At the completion of mining, surface runoff from rehabilitated overburden emplacement areas will be released from the site. An area of approximately 108 ha, which originally drained to Lake Goran, will continue to drain to the mine final void. The changed topography following completion of the Project will have the following impacts on catchment areas:

- The catchment draining north via Watermark Gully to the Kamilaroi Highway will increase by 5.2 km², an increase of approximately 13%.
- The catchment draining to Lake Goran will be reduced by 6.0 km². This represents a reduction in catchment area of less than 0.5% and, in practical terms, will have no measureable impact on inflows to the lake.
- The catchment draining north to the Mooki River floodplain will be increased by 1.4km².
- The catchment draining south to Native Dog Gully (excluding Yarraman Creek) and the Mooki River floodplain will be reduced by 1.6 km², a decrease of approximately 2%.

Water balance simulation of the final void shows that the water level is expected to reach an equilibrium water level approximately 20 to 30 m below the overflow level. The lake will take approximately 100 years to reach the equilibrium level.

A detailed flood modelling study of Watermark Gully has been undertaken to assess the flood impacts of the Project. Watermark Gully is affected by a reduction in catchment area of up to about 25%, as well as filling of the upper reaches of the main channel by a proposed overburden emplacement area. Due to the wide, shallow nature of flood flows in Watermark Gully, the filling of the main channel will not result in major impacts on flow velocities. Changes in flow velocity and flood levels will be accommodated in the detailed design of the site drainage system.

The results of a detailed flood modelling study of the Mooki River show that almost the entire area within the Disturbance Boundary will be flood free during a flood event with an average recurrence interval of 100 years. Even during an extremely rare flood event (the largest that could conceivably occur) Mooki River flood levels would not encroach significantly within the Disturbance Boundary. Hence, the Project will not impact flood behaviour on the Mooki River floodplain.

12

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APPENDIX A

FLOOD STUDY LANDHOLDER INTERVIEWS

WATERMARK COAL PROJECT

FLOOD STUDY LANDHOLDER INTERVIEWS

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17 May 2012

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EXECUTIVE SUMMARY

WRM Water and Environment Pty Ltd have been engaged by Hansen Bailey on behalf of Shenhua Watermark to complete a Flood Impact Assessment of the proposed Watermark Coal Project (The Project). The specific objective of this report, prepared by Hansen Bailey, is to document interviews with former landholders in the Project Boundary who have been able to provide anecdotal evidence of the nature of floods in the region, the movement of water, impacts of flood events on their properties and neighbouring properties and other related observations within the vicinity of the Project Boundary. This report has been provided to WRM Water and Environment Pty Ltd for consideration during the construction and calibration of their flood model.

Whilst water movements are fairly predictable during periods of inundation and flooding within and around the Project Boundary, the nature of flood events have been observed as variable over the past 50 years dependent upon cropping regimes, land contouring, dam installations, stocking rates, vegetation cover, water holding capacity of the soil and the extent of soil moisture prior to inundation.

Flooding within the Disturbance Boundary, from prior landholder observations, largely occurs around Watermark Gully. Water that does not flow to Watermark Gully on the western and southern portions of the Disturbance Boundary primarily drain to Lake Goran. Within the southern portion of the Eastern Mining Area most waters runoff to the southern black soil plains. Runoff from the north-eastern portion of the Eastern Mining Area travels across the Kamilaroi Highway, or through culverts down to the northern floodplains.

Flooding in the southern portion of the Project Boundary is a result of flows from Coomoo Coomoo and Yarraman Creeks as well as Lake Goran. Overflows from Coomoo Coomoo Creek and Lake Goran occur in moderate to high flow events while flows from Yarraman Creek flood out into the low lying floodplain in all flow events.

Significant flood events which impacted the Watermark area, as described by the landholders interviewed, occurred in 1955, 1974, 1984, 1998 and 2000. It was observed that most flood waters escape from the ridge country quite quickly, whereas waters will pool in areas of the plains for extended periods of time. It was also observed that the impact of flooding is worsened during winter due to less evaporation and evapotranspiration.

Impacts of flooding at Watermark include cutting of roads, 'washing out' of unsealed roads, erosion, breaks in contour banks and dams, loss of stock and crops and some weed propagation. Blocking of the Kamilaroi Highway due to flood waters and water covering the railway line have been mitigated by the construction of causeways and culverts in the Watermark Gully vicinity. However inundation of the Highway in the low lying areas associated with Watermark Gully can still intermittently block traffic.

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**WATERMARK COAL PROJECT
FLOOD STUDY LANDHOLDER INTERVIEWS**

for
Shenhua Watermark Coal Pty Limited

1 INTRODUCTION

1.1 BACKGROUND

In October 2008, Shenhua Watermark Coal Pty Limited (Shenhua Watermark) was granted Exploration Licence (EL) 7223. Shenhua Watermark is a subsidiary of the Shenhua Corporation, the world's largest integrated coal based Energy Company.

The Watermark Coal Project (the Project) is located within EL 7223, approximately 35 km south-east of the township of Gunnedah and to the immediate west of the village of Breeza, within the Gunnedah Local Government Area (LGA). The Project is approximately 282 km by rail from the export Port of Newcastle. **Figure 1** illustrates the regional locality of the Project in relation to the nearest town centres of Breeza and Gunnedah.

Hansen Bailey has been commissioned by Shenhua Watermark to prepare an Environmental Impact Statement (EIS) to support an application for State Significant Development Consent under Division 4.1 of Part 4 of the *Environmental Planning & Assessment Act 1979* (EP&A Act) for the Project.

1.2 THE PROJECT

The Project generally comprises:

- The construction and operation of an open cut mining operation extracting up to 10 Million tonnes per annum (Mtpa) of Run of Mine (ROM) coal for a 30 year period;
- An open cut mining fleet of excavators and shovels, supported by haul trucks, dozers, graders, drill rigs and water carts;
- Progressive rehabilitation of all disturbed areas;
- The construction and operation of a Coal Handling and Preparation Plant (CHPP) with a throughput of 10 Mtpa ROM coal;
- The co-disposal of tailings and coarse reject within the Overburden Emplacement Areas (OEA);
- The construction and operation of a rail spur, rail loop, Kamilaroi Highway rail overpass, associated load out facility and connection to the Werris Creek - Moree Railway Line;
- The construction and operation of a Mine Access Road;

- The construction and operation of administration, workshop and related facilities;
- The construction and operation of ground and surface water management and reticulation infrastructure including pipelines, pumping stations and associated infrastructure for access to water from groundwater aquifers, the Mooki River and private dams to the north-east of the Project Boundary;
- The installation of communications and electricity reticulation infrastructure; and
- A workforce of up to approximately 600 full-time equivalent employees during construction and up to 600 full-time equivalent employees during the operation of the Project.

1.3 DOCUMENT PURPOSE

The Director-General's Requirements (DGRs) issued for the Project on 19 April 2012 specifies that the EIS must include:

"A detailed flood impact assessment, which identifies impacts on local and regional flood regimes, including:

- *An assessment of the potential for flooding to occur in the open cut pits; and*
- *Any measures proposed to mitigate potential flood impacts."*

WRM Water and Environment Pty Ltd (WRM) have been engaged by Hansen Bailey on behalf of Shenhua Watermark to complete a Flood Impact Assessment to satisfy the DGRs listed above.

A key input into the calibration of the flood model prepared by WRM is anecdotal evidence from landholders within and surrounding the Project Boundary. As such, Hansen Bailey conducted interview with former and current landholders in the vicinity of the Project Boundary to understand the nature of floods in the region, local water movements, impacts of flood events and other general observations within the vicinity of the Project Boundary. The names of the properties previously owned by the prior landholders and those owned by current landholders are provided in **Table 1** with property locations provided in **Figure 2**.

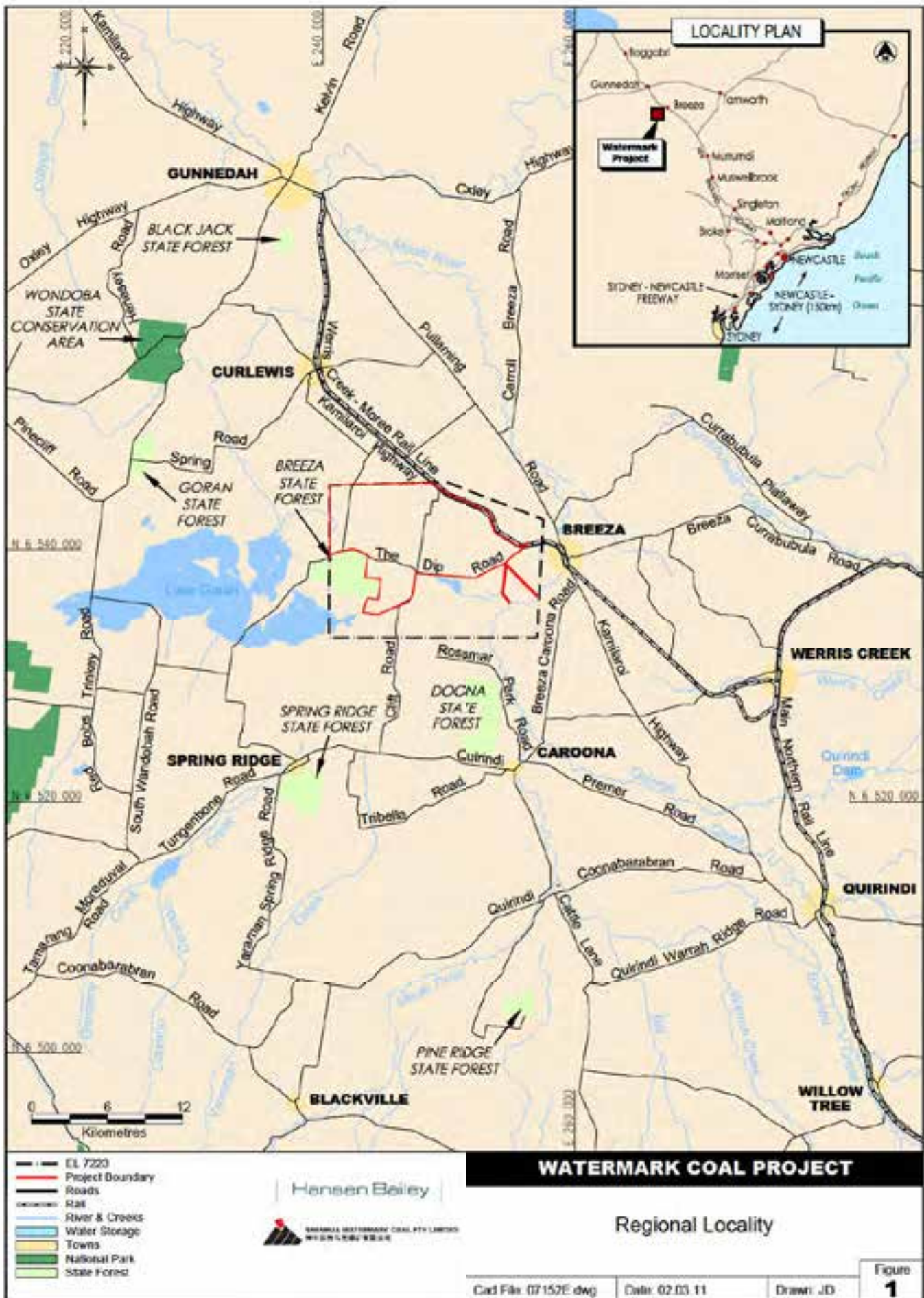
This report has been prepared by Hansen Bailey and documents the interviews with former and current landholders within the Watermark area and has been provided to WRM for consideration during the construction and calibration of their flood model.

1.4 DOCUMENT STRUCTURE

This Flood Study Landholder Interview Report is structured as follows:

- **Section 2** provides an overview of the existing environment present at Watermark;
- **Section 3** describes the method of conducting the study. The names of the prior and current landholders interviewed are detailed and the locations of the relevant properties is provided in this section;

- **Sections 4 – 12** details the observations provided by each landholder interviewed and includes observations of flood events, movements of water, impacts of flood events, how these impacts are managed and mitigated and other related observations; and
- **Section 13** provides a summary of the findings of the interviews.



2 EXISTING ENVIRONMENT

All land within the Project Boundary is owned by Shenhua Watermark. Shenhua Watermark leases the purchased land back to former landholders to continue grazing and working the land throughout the Project development.

Throughout the Project Boundary, there are numerous topographic highs associated with Mount Watermark, Black Mountain, and an unnamed topographic high referred to by locals as 'Springhurst Hill'. Smokey Point is located partly within the Southern Mining area however most of this range is located outside of the Project Boundary in the Breeza State Forest. The black soil plains are located to the south, east and north-east of the Project Boundary. Gently undulating cleared grasslands (approximately 310 m Australian Height Datum (AHD)) dominate the central and western portions of the Project Boundary.

The Watermark Project exists wholly within the Namoi River catchment. Sub-catchments related to the site include the Mooki Hills sub-catchment encompassing the Watermark Gully catchment, the Mooki Plains sub-catchment encompassing Native Dog Gully, the Yarraman sub-catchment which drains to Lake Goran and extends to Blackville, and the Currabubula and Werris Creek sub-catchments which discharge to the Breeza plains (Namoi Catchment Management Authority (CMA) 2012).

The Mooki River is an ephemeral waterway located predominately to the east of the Project Boundary. Native Dog Gully, which drains to the Mooki River, is located to the south of the Eastern Mining Area. Watermark Gully is located in the central portion of the Project Boundary between the Southern and Western Mining Areas. There are also a series of smaller unnamed and intermittently flowing watercourses within the Project Boundary.

The water bodies within the Project Boundary are primarily farm dam-type structures. The naturally occurring ephemeral Lake Goran is located to the south-west of the Project Boundary.

3 METHODOLOGY

Throughout March and April 2012 interviews were organised by Michelle Cavanagh of Hansen Bailey with current and former landholders from within and surrounding the Watermark Project Boundary. The locations of the properties referred to throughout this report are provided in **Figure 2**. Melanie Layton or Grayson Wolfgang of Shenhua Watermark were also present for these interviews.

Table 1
Prior Landholder Interviewed and Related Property

Landholder	Property	Date Interviewed
Kevin and Helen Fulwood	Springhurst	28 March 2012
Tony Clift	Stafford, Urubula, Barwo, Birrawa	29 March 2012
Bev and Ellis Watters	Kalmina	29 March 2012
Colin, Jenny and Heath Birchall	Tathra	29 March 2012
Jeff Britten	Keinghton	2 April 2012
John and Charmain Bailey	The Watermark and Dixie	2 & 26 April 2012
Len Rowarth	The Wilgas	2 April 2012
Phillip Warmoll	Nardoo, Merrigal, Maydale	3 April 2012
Andrew Pursehouse	Breeza Station	26 April 2012

During the interviews the landholders recalled which flood events had impacted their properties significantly. Photographic evidence of flood events were provided where available (**Plates 1 – 7**) or reference points for locations where flood waters had risen to were offered (**Figure 3**). Drainage channels and the directions of water flows on and off the properties were also detailed (**Figure 3**). Questions addressed are provided in **Table 2** and **Table 3**.

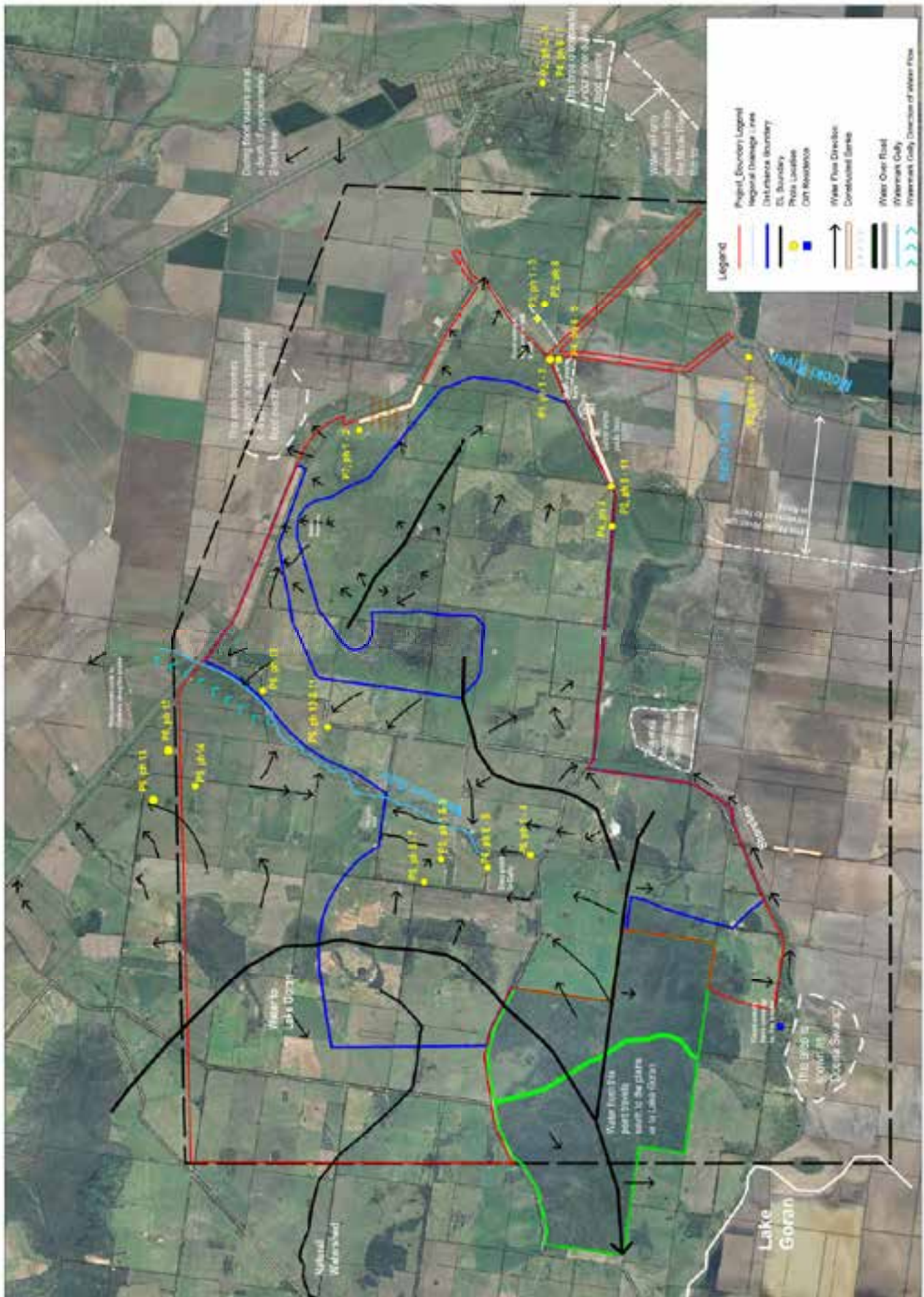


Table 2
Flood Event Questions

When	What	How
In which year and month have floods impacted your property? Which flood events impacted your property most significantly?	What area of your property was impacted most significantly?	In your experience has flooding generally occurred in the region as a result of an intense period of significant rainfall (flash flooding) or as a result of prolonged rainfall?
What is the frequency of flood events occurring on your property?	To which point did flood levels rise to? Do you have photos or historical markers?	Where did the water come from or travel to? E.g. Watermark Gully, Native Dog Gully etc
	What was the flood volume, rate of rise, rate of flow, and flood duration?	Did the floods that impacted your property come suddenly or did you have ample warning?
	Was there much vegetation in the area which was flooded?	What is the nature of drainage on your property?
		Did you notice a difference between the impacts associated with flooding after a dry period versus the impacts associated with flooding after a wet period?

Table 3
Post Flood Event Questions

Immediate Impacts	Post Flood Impacts	Management / Mitigation
Was your home or property isolated by the flood waters?	Did you observe a change to weed or insect propagation post flood?	Did you modify drainage channels or watercourses post-flood or over time?
Did the railway, highway or any roads get cut off as a result of the flooding? Was this infrastructure significantly damaged after the flood waters subsided?	How long post flood did it take for the environment to return to a more normal state?	Did you move stock to pre-empt any potential flood hazards?
Did the flood remove vegetation, cause erosion, contour or river bank failure?	Did you notice any change in the pattern or nature of flooding over time?	Any flood proofing of house / infrastructure required post flood event?
Did you complete water or soil testing whilst on your property and if so, did you notice any difference after flooding? E.g. Increased turbidity, sedimentation, salinity, etc?		Did you implement any bunding or levee banks to mitigate against flood impacts for the future?
Was there any response from soils as a result of flooding? E.g. long term improvement from sediment deposition?		Did you alter the topography of your property in an attempt to mitigate flood impacts? If so were these successful?
Did you notice a response from the land in terms of productivity?		
Did the flood waters appear polluted?		



4 SPRINGHURST

Kevin and Helen Fulwood spent 21 years on the Springhurst property which was owned prior by Kevin Fulwood's father. Half of the Springhurst property is located within the Project Boundary, north of the Western Mining Area. The Fulwood's continue to manage the land they formerly owned on behalf of Shenhua Watermark.

The following observations were noted by the Fulwood's in regard to flooding in the region.

4.1 FLOOD OBSERVATIONS

- Water running off Mount Watermark in a late 1970 flood backed up roads including the Kamilaroi Highway. The Fulwood's needed to be towed to get out of their property;
- In the mid 1980's a May flood occurred after a drought period. Approximately six inches of rain fell in 2.5 hours, measured at the Springhurst house. The neighbouring Lilyfield and Inverness properties measured more rainfall (**Figure 2**);
- The flood of 2000 impacted the bottom south-western corner of the Springhurst property;
- The short catchment of Watermark Gully has been flooded almost every four or five years recently. The local country is contoured into the gully, yet usually there is little water present;
- In November 2011 the front dam on Springhurst spilled over after prolonged rainfall;
- A storm with heavy rainfall and a fast flow will carry large volumes of water down to Watermark Gully off the Springhurst property; and
- It was suggested that the way land is stocked and cultivated can contribute to a flood event occurring and the nature of the flood event.

4.2 MOVEMENT OF WATER

- In big floods water runs straight off the Springhurst property. On Springhurst there is a natural gully which carries water down to Watermark Gully (**Figure 3**). Rapid flows come off the slope at Springhurst and the water 'roars' downhill. Despite the level of ground cover the slope of the land at Springhurst will still move water;
- Water flows off the Springhurst property in the north and travels along the highway in the direction of Curlewis;
- Gullies up to 2.5 m in depth exist within Watermark Gully;
- Overnight storms will overflow Watermark Gully; and
- Around 1955 pools began to form in Watermark Gully; now it will flow with water after prolonged rainfall.

4.3 ALTERATION TO TOPOGRAPHY

- Contour banking work commenced around the 1970's on Springhurst. The majority of contour banks were constructed in the 1980's and 1990's to prevent erosion; and
- A gully on the Goodwood property, north of Springhurst, was diverted to the plains; this is not a natural water course.

4.4 IMPACTS

- One foot of water over the Kamilaroi Highway will be enough to block traffic;
- Flooding on Springhurst has caused much erosion and caused breaks in contour banks and dam walls due to the velocity at which water travels off the hill;
- Flooding impacts were observed as worse after dry times due to a lack of vegetation and ground cover;
- Flash flooding causes the most damage to the Springhurst property, whereas prolonged rainfall causes trickles of water off the property generally;
- Boundary fences have been knocked down by flood waters;
- The Springhurst house only ever had access cut off for about an hour as the land is sloped enough for water to runoff down slope;
- Flooding has damaged the railway line in the past. This has now been mitigated by the installations of culverts which allow the water to travel through and onto the northern plains;
- Rutherglen insect, frog, mosquito and bird numbers will increase post flood, yet there is no marked difference to weed or bee populations at Springhurst; and
- Seepage occurred after the 2000 flood at the nearby Inverness house; a connection which had not been evidenced prior, nor since. The Fulwood's thought this was potentially related to the location of sandstone. The water covered an area of approximately a quarter of an acre and dried up after six months.

4.5 MANAGEMENT OF FLOOD IMPACTS

- No till farming practice has lessened the impact of flood events;
- High levels of vegetation cover mitigate the impact of erosion from flooding;
- Waterways have been constructed to slow and direct the water down off Springhurst Hill; and
- Water on the property is diverted to dams. An artificial gully was built to flow into natural channels and end at grassed areas as the natural gully was quite deep and was eroding the land. This alteration diverts water around the natural areas of flow to alleviate pressure and erosion.

4.6 GENERAL OBSERVATIONS

- There is no salinity issue on the Springhurst property. A connection between Lake Goran and salt levels has been observed by the Fulwood's. When Lake Goran dried up there was less of a salt issue;
- The Inverness property was thought to be a salt recharge zone as suggested by the Curlewis Soil Landscapes book. Water infiltrates underground at Inverness and disappears. It was suggested that the groundwater is saline at Inverness as the dams there are salty; and
- Seepage under the Springhurst Hill occurred until the land was put back to forest.

5 STAFFORD, URUBULA, BARWO AND BIRRAWA

The Clift's are a generational farming family from the Watermark-Breeza area. Stafford is located south of the Breeza State Forest whilst Urubula and Birrawa are located on the southern plains directly east of Stafford (**Figure 3**). Tony Clift also held the property, Barwo, located in between the Southern and Western Mining Areas and continues to manage property on behalf of Shenhua Watermark.

The following observations were noted by Tony' Clift's in regard to flooding in the region.

5.1 FLOOD OBSERVATIONS

- Significant flood events were observed to have occurred in 1974, 2000 and 2010;
- A significant flood occurred in 1974 in which Lake Goran filled up overnight after 10 inches of rainfall;
- In 2010 the Mooki River was backed up across the floodplains; it was a substantial flood event for the southern plains in which approximately four foot of water covered the plains;
- In 2010, 20 inches of water fell in a week;
- The southern plains will flood both after intense periods of rainfall and prolonged periods of rainfall. The extent of the impact depends on prior conditions including cropping regimes and the time of year;
- A big rain event at the top of the catchment in the past took three days to get to the southern plains, now it only takes one day. It was suggested this is potentially due to a change from Plains Grass to cultivation; and
- Water has been observed over the top of the rail line from Watermark Gully. This water takes approximately 12 hours to drain away from the gully to the northern Breeza plains.

5.2 MOVEMENT OF WATER

- Water from Mount Watermark does not run to the Mooki River. Flood water from the Mooki River joins the Watermark water heads at the Baiada poultry farm, 'Woodleigh'. Water moves slowly past 'Ranken Park' then moves across the plains to 'Gabo'. This movement of water is very visible and takes much time to drain;
- Much water runs down Watermark Gully which is black, loamy country. The soil will seal and keep water flowing down slope;
- A divide from Springhurst, down to Molonga carries water to Watermark Gully (**Figure 3**);

- 20 years ago half of the Yarraman Creek water drained to Lake Goran whilst the other half drained to the Mooki River. Bank reconstruction was completed to direct water to Native Dog Gully, thus water now flows around the Southern Mining Area as a 'shoreline'. Water lies along the 'shoreline' on the floodplains below during flood events;
- Waters from Blackville feed the Mooki River;
- In high rainfall periods the Mooki River is backed up by the Namoi River. This in turn backs tributaries up, including Native Dog Gully, and creates slow moving water;
- The CMA completed rock work along the 'shoreline' so that now the water does not "eat back up" to Yarraman Creek;
- Yarraman Creek water in the past dispersed across the southern plains. An artificial creek was constructed and the western side of the plains is now drier;
- Coomoo Coomoo Creek is located further west through the brown hills and feeds Lake Goran;
- Red Bobs and Coomoo Coomoo Creek water also go to Lake Goran. Lake Goran will overflow around Doona Swamp to Native Dog Gully;
- It was observed that if Cox's Creek rises above the Tambar Springs Bridge water will flow back through the Tally Ho property to Lake Goran;
- In the red country water will run quickly;
- In drought the soil will seal. If grass shoots prior to heavy rainfall it is preferable and will lessen the risk of a flood event occurring;
- Excess runoff to the plains from the northern ridge country will not cause much of an impact as the plains will be under water anyway. The issue is what is carried with the water; and
- Much clean water comes from the ridgeline of Breeza State Forest down to Stafford.

5.3 IMPACTS

- The black soils will swell after a period of inundation;
- Water has been observed over the bank of the Clift-Doona Road (**Figure 3**);
- It was observed that water has blocked The Dip Road near the Southern Mining Area approximately three or four times;
- Breeza State Forest Road quality is impacted by heavy rainfall and flood events;
- Flood waters have come up to Robert Clift's house (**Figure 3**) requiring sand banking work to be completed;
- Court Lane generally does not get blocked for too long by flood waters;

- Watermark Gully over the Kamilaroi Highway rarely blocks traffic for more than six hours. Some water will cross the road at the Nea-Siding silos on the Kamilaroi Highway;
- A flood event on the black soil plains can impact the plains for up to two months in winter. The extent of impact will depend on the crop species growing at the time. Flood impacts to the plains during summer are closer to three weeks;
- Approximately every five years a crop is lost to a flood;
- In the November 2000 flood all of the summer and winter crops were lost, incurring a significant financial cost;
- Prolonged rainfall in January and February 2012 caused damage including erosion however this was not a flood event;
- Flooding does little infrastructure damage on the plains;
- The flow of the Mooki River in flood will move the rail bridge with its speed and volume;
- The 1955 flood, when the plains were still stocked, caused a loss of livestock; and
- Drought impacts are softened by subsoil moisture from flooding.

5.4 MANAGEMENT OF FLOOD IMPACTS

- Block farming and resulting sheet erosion has less impact than gully erosion;
- Flood impacts are lessened with the use of zero till farming practice;
- On the eastern side of Stafford no contours have been constructed and there is no erosion issue. Contours have been constructed on the western portion of the property, south of the Breeza State Forest; and
- Contour banks on the plains create gullies, due to the depth and speed of water flow causing erosion.

5.5 GENERAL OBSERVATIONS

- Much country in Watermark Gully is farmed;
- Many dams north of the Western Mining Area are silted up and take little rainfall to spill over;
- There is unstable black soil in the proposed rail loop location, which is at present proposed close to Watermark Gully. An issue from stockpiling coal close to Watermark Gully where water will flow were noted;
- Springs are present throughout the area, primarily to the west of the Southern Mining Area. These springs will flow north or south intermittently. Springs may stop running with the planting of Lucerne which absorbs water and allows growth in saline areas. Lucerne sown in the red soil country helps slow or stop runoff and assists with salt issues. A spring located in the Eastern Mining Area holds quality water;

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- At higher elevations the springs are fresher. Lower to the plains the springs are more saline;
- Some salt scalded country exists in the Western Mining Area; and
- It was observed that black soil and sandstone will chemically react, and that sandstone may assist with filtering salt.

6 KALMINA

Bev and Ellis Watters spent seven years between 2003 and 2010 on the Kalmina property which was a cattle and grain property rotationally cropped and under sown with Lucerne. The property, located on the western side of Court Lane was owned by Lindsay Bailey prior to 2003.

The following observations were noted by the Watters in regard to flooding in the region.

6.1 FLOOD OBSERVATIONS

- The Watters only experienced one significant flood event on Kalmina during the time spent on the property. Fences from both ends of the property were damaged. Fast running water, thought to be from overnight rainfall spread out for approximately 100 m on the property yet escaped quickly.

6.2 MOVEMENT OF WATER

- Part of Watermark Gully is located on the Kalmina property on which two dams have been constructed;
- Dams overflowed at Kalmina several times however due to the drainage network the block would only flood during significant flood events. Some pooling of water was noted;
- Watermark Gully catchment would continue to run until the holes filled up for 2 – 3 days after rain. There could be 8 – 10 foot of water deep in Watermark Gully. The water will stay until it is evaporated or soaked into the soil;
- A big contour bank has been constructed on the treed lane. This contour diverts water around and into Watermark Gully (**Figure 3**);
- Cattle are run in Watermark Gully as it is natural grassland; and
- A culvert under a bend on Court Lane carries water from contour banks on the east of Court Lane under the road (**Figure 3**). Much of this water empties to the gully.

6.3 IMPACTS

- No house exists on the Kalmina property, however flood waters have cut off Colley Road at the Inverness house for a couple of days in the past.

6.4 GENERAL OBSERVATIONS

- Much rain was observed to fall in the region around November; and
- No topographic alteration to Kalmina was completed for any drainage or flood mitigant purposes however some land contouring works were completed near Court Lane.

7 TATHRA

Colin Birchall has lived on the property, Tathra, for 70 years and continues to manage the property on behalf of Shenhua Watermark. Tathra is located in a horseshoe shaped valley south of The Dip Road and to the south-east of the Eastern Mining Area. The Tathra property also encompasses Tathra North located on the northern Breeza Plains, north-east of the Eastern Mining Area (**Figure 3**).

The following observations from the Birchall family were noted in regard to flooding in the region.

7.1 FLOOD OBSERVATIONS

- Significant flood events at Tathra were noted to have occurred in 1955, 2000, and 1998;
- In the 1955 flood waters came up to within a foot of the railway line on the plains near the Merrigal property at the corner of the Dip Road and Kamilaroi Highway (**Figure 2**);
- The most significant flood event to impact Tathra occurred in 1998 as it was a quick and unexpected flood. This was the first big flood after contour banks had been constructed in 1995. After this date sheep were no longer run on the property, due to losing hundreds of stock. This event caused waters to rise to paddocks which had never before been impacted by flooding;
- In 1998 flood water levels rose above Ashley Downs' letterbox (**Plate 3, photo 8 - 11**). The water spread out a long way up the valley, with the top water level located around Browns Corner;
- In 2000 and 1998 flood waters rose to the bottom of the silos and to the bottom of the haystacks (**Plate 3, photos 1 - 2**). Water blocks the road into the property;
- In 1998 cropping machinery had been out on the plains the night before the flood. Prolonged and heavy night time rainfall in the Blackville hills caused waters to rise quickly throughout the night. Rushes of fast flowing water came off the hills unexpectedly causing damage to machinery and livestock loss;
- In the 2000 flood it rained every day for a week. In the Breeza State Forest the flood waters rose halfway up the trees. Waters lay in the southern paddocks for approximately a week post-flood;
- Water would remain for 3 to 4 days at height in 1998 and 2000. Approximately 1 m of water or more covered the road into the Keington homestead. The peak flood water level for both events is located approximately at Browns Corner;

- When Colin was young if all the land was saturated and six inches of rain fell, a flood would likely be imminent. Now, only the six inches of rain is required for land to flood;
- Tathra is located in a backwater. Flood waters enter the property fairly dirty and silt loaded;
- Flood events from Mount Watermark will bring red soil down to Tathra;
- The observed flooding frequency was averaged at 10 years;
- The prolonged rainfall in 2010 did not impact Tathra significantly;
- Water from Blackville and Carroona contribute to flooding at Tathra; and
- It was noted that essentially all the floodplains are covered by water during flood events.

7.2 MOVEMENT OF WATER

- Tathra is located in a horseshoe valley. The rain comes from elsewhere and ends up at Tathra. Water does not runoff Tathra, which is kept well grassed. Run-on to the property, however, is common;
- Impacts to the property from flood waters mainly come from water from the Mooki River backing up into Native Dog Gully and spreading out;
- Every flood is different, with water coming from and ending up in different areas. Flood impacts have worsened since banks were constructed in 1995 to divert water to Native Dog Gully on neighbouring properties;
- Flooding will cause a current along Native Dog Gully. The Mooki River pushes Native Dog Gully back, not allowing the waters to drain;
- Lake Goran in the past, prior to bank reworking, spilled into Native Dog Gully;
- Native Dog Gully is 'double ended' in that it receives water from both Lake Goran and the Mooki River. In flood events Native Dog Gully can have difficulty draining if both water bodies are filled;
- It was observed that Tathra is impacted by all flood events. Water will flow across Tathra to Keinghton. This may have implications for Tathra regarding interactions with the Eastern Mining Area;
- It was observed that water runs off Mount Watermark and also comes from seepage and the Mooki River;
- Black soils with salinity issues will leak like sand;
- Water is picked up at the top of paddocks;

- Runoff from Watermark does not come from a specific drainage line. The extent of runoff will depend on the amount of grass cover on the land. Infiltration is an issue as the water has to come out somewhere, and often this is at Tathra. Water off Hill 60 runs off onto Tathra; and
- The red hills were described as 'very leaky'.

7.3 IMPACTS

- In the winter flood of July 1998, approximately 300 sheep were lost;
- Milky components were observed in the flood water currents in the 2000 flood event;
- Flood waters can block traffic on the Kamilaroi Highway at Watermark Gully, north of Breeza. It does not take much water to cut the Breeza-Quirindi Highway;
- Weed propagation post-flooding was observed. It was postulated that the weeds come from water flows from Blackville;
- Lippia and burrs were observed post-flooding;
- River fences close to the Mooki River are taken out by flood events however there is no flow on the plains. Fences on the black soil plains will lean due to swelling and excess soil moisture;
- Millimetres of alluvium have been observed post-flood event;
- Much surface water flows to Tathra from Keington. No till with tramline down hill has worsened runoff with erosion evident;
- It takes the system about three weeks post-flood to return to normal;
- After the 1998 flood it took over two weeks to access the inundated land and assess the damage afterward; and
- Inches of water across the plains are not an issue.

7.4 ALTERATION TO TOPOGRAPHY

- The Namoi CMA created rock, drop down stair bed control structures on Native Dog Gully as the gully was growing and black soil was being cutting out. The structures are curved and achieve their purpose. A double stair at the bottom end stops the banks from ripping;
- The Birchall's wanted to slow the water down Native Dog Gully, to avoid erosion of the gully. Draining the gully as fast as possible on neighbouring properties would have implications for Tathra; and
- A drain along Duddy Road in the past carried water. This was backfilled and a gas pipeline put in the drain. This has had implications for flooding.

7.5 MANAGEMENT OF IMPACTS

- No mitigation bunding or levees have been constructed on Tathra;
- Post-flood the land is not tilled; and
- Soil texture does not change post-flood event, however soil moisture is improved. The year following a flood event many costs from flooding can be recouped due to increased soil moisture.

7.6 GENERAL OBSERVATIONS

- In 1955 there were no crops growing on the plains; the land was grazed. Sorghum cropping commenced on the southern plains around the 1970's;
- In 1985 salinity started to occur in the soil after 'endless' rain. Water pooling over salt laden soil creates a salinity issue; and
- No machinery is left on the southern plains due to the impacts of the 1998 flood.

8 KEINGHTON

Jeff Britten is the former landholder of the property Keinghton. This property is located on the northern corner of The Dip Road and the Kamilaroi Highway (**Figure 2**). The following observations were noted from the time Jeff spent on the property.

The following observations from the Jeff Britten were noted in regard to flooding in the region.

8.1 FLOOD OBSERVATIONS

- The 1971 flood was acknowledged. This flood came as a shock; there was no forewarning. No roads were blocked during this flood;
- In the early 1990's it did not take much rain to flood;
- Gates to the property on The Dip Road were under water in the 2000 flood. In the back plains of the property this flood was close to the biggest. Water came up to the gates of Browns Corner in 2000; a level to which waters had not risen before;
- There had been a fortnight's worth of rain in 2000 prior to flooding, this flood was not a result of flash flooding. Approximately seven days of rainfall in a row caused flooding on a Saturday afternoon. There was roughly a two day lag to the flood peak. This was a slow flood which peaked for approximately 18 hours. The water was not fast moving in the back areas;
- Impacts of the 2000 flood were more significant at Breeza than Gunnedah. There was more warning the flood was imminent than the 1998 flood;
- There was a fast flow of water through the Breeza Mooki River Bridge in 2000 (**Plate 2, photo 2 – 4** and **Plate 4, photo 6 - 7**). A big head of water needed to pass through a much narrower flood channel;
- Pullaming Stock Route was a waterway in 2000;
- A major flood on the plains will cover the Kamilaroi Highway. Gunnedah is generally more accessible on the Kamilaroi Highway, with more of an issue posed travelling south to Quirindi during flood events; and
- Waters over The Dip Road rose to approximately 1.2 m during the 1998 and 2000 flood events.

8.2 MOVEMENT OF WATER

- Most water runs off the Keinghton property due to the slope of the land.

8.3 IMPACTS

- Post-flood event plains weeds have been observed, especially around the edges of the plains;

- The Keington property was not ever isolated by floodwaters; however the Elsdon property (**Figure 2**), located at a lower elevation has experienced isolation;
- Water will go over the road during flood however most times the roads are still able to be driven through;
- No stock loss was experienced at Keington as a result of flooding; and
- Some fencing will get knocked down on the black soils however this is not a significant issue.

8.4 GENERAL OBSERVATIONS

- Water hitting the clay pan causes a salinity issue; and
- Contouring paddocks helps direct the movements of water.

9 THE WATERMARK AND DIXIE

The Baileys have lived and worked on The Watermark property for approximately 60 years and purchased the property from the Clift's in 1952 and continues to manage property on behalf of Shenhua Watermark. The Bailey family has lived in the valley for 150 years. John and Charmain Bailey experienced four significant floods and many smaller ones also during their time spent on The Watermark property.

The following observations were noted by the Bailey's in regard to flooding in the region.

9.1 FLOOD OBSERVATIONS

- 1974 was noted as a significant flood event on The Watermark property;
- The 1984, 1970 and 1974 floods were comparable to the 2000 flood at The Watermark;
- Army ducks came out in 1955 to Breeza from Gunnedah. Water was an inch below the railway in 1955;
- In 2000, water rose to 1.2 m at The Watermark property, which was too deep to drive through. Water was deepest at The Watermark's back gate. The house was isolated for a day and a night when it was too wet and the waters too deep to get out. Generally the entrance from Court Lane will be blocked, yet there is the option of exiting via the back entrance of the property to Nea;
- In 2000 around 12 inches of rain caused flooding of around five - six inches at The Watermark;
- At the deep point in the gully (**Figure 3**) waters rose to Mr Bailey's shoulder in 2000;
- In the past it would take weeks for water to travel due to Plains Grass in the sheep country. The water now arrives within 24 hours of rainfall periods;
- In the past the Gunnedah Shire Council would phone the Baileys to check how much water is coming down Watermark Mountain during periods of high rainfall; and
- Due to flooding of the Highway a causeway and culverts were constructed. Before culverts were constructed floodwaters flowed up to and over the railway line. The Watermark Gully causeway was doubled in size to keep the water moving through and down to the northern plains.

9.2 MOVEMENT OF WATER

- Water from the Breeza State Forest causes Watermark Gully to run;
- Water from neighbouring properties Barwon, Lilyfield, Springhurst, and Linavardi (**Figure 2**) run into Watermark Gully. Water from Lilyfield runs into a tree line on the northern boundary of The Watermark;

- Water spreads down out for a quarter of a mile either side of the gully. Between four and six feet of water will lie in Watermark Gully;
- Water will run fairly quickly off Mount Watermark and into the valley. Water runs off Mount Watermark from both sides into valley;
- Watermark Gully flows across the Kamilaroi Highway meets flood waters from the Mooki which travel north to onto the northern plains and north to Curlewis, not just straight out across the plains;
- Dams in the gully fill up with approximately two foot of water;
- Flood impacts on The Watermark property are dependent upon how much rain falls in the Breeza State Forest. Inches of rain in the forest will impact Watermark Gully;
- Water flows to The Watermark homestead in the light country seen in **Plate 6** and **Photo 6** and **7**;
- Big gullies exist outside of Lilyfield;
- Many dams exist across Watermark Gully. Water from Linavardi (**Figure 2**) flowed to Watermark Gully in the past, however much of this water now infiltrates the soil due to increased ground cover;
- Native Dog Gully backs up during periods of inundation and waters cannot escape to Lake Goran;
- Small drainage gullies will get much water running through them after heavy rainfall;
- On the corner of the Kamilaroi Highway flood waters cover the paddock to the west of Court Lane with one foot of still water. This paddock has never been cropped;
- Water rose to between Ashley Downs' gate and the mail box in 2000 (**Plate 3, photo 8 - 11**);
- All of Dixie's water flows to Watermark Gully with land also contoured to direct water into dams; and
- 'White country' on Dixie is evidence of low lying water.

9.3 IMPACTS

- Court Lane is covered in water for approximately a quarter mile at the corner of the Kamilaroi Highway during significant flood events. Court Lane will be cut by flood waters every five - six years except during drought periods;
- A culvert was constructed on the corner of Colley Road and Court Lane (**Plate 6 photo 10**). Due to the tilt of the road this culvert does not work and waters still cover the Lane at this point;
- Court Lane gets washed away by the flood waters and will need to be re-graded post-flood. Gullies down Court Lane will get washed out from flood events;

- All ground on the property is contoured, causing little sediment wash and only a little erosion. A few contour banks will break as a result of flooding but the impacts are not significant;
- In 2000 wheat crops were impacted by the rain and water logging;
- In 2000 at the Breeza Railway Bridge flood waters were lapping at the iron (**Plate 2, photo 2 – 4, Plate 4 and photo 6 -7**). The water turned the brick pylons;
- Flood waters will cut the Kamilaroi Highway. Travelling to Quirindi past the Breeza Bridge the Highway has been cut for approximately a mile;
- Fences all down Watermark Gully would be damaged from flooding;
- All flood waters are dirty brown water, but do not have an odour;
- In the 1950's a 10 foot deep gully was cut out of a paddock at Dixie as a result of flood waters. A depression in the paddock still remains despite the completion of extensive earthworks;
- No cattle have been lost as a result of flooding, only fences have been damaged; and
- More frogs are observed, yet no weed infestations are noted post-flood events.

9.4 MANAGEMENT OF FLOOD IMPACTS

- The dams on the property have been surveyed in. The tops of the dams will overflow with water during flood periods;
- Flood waters at The Dip Road near the Tathra property are generally too deep to traverse during flood;
- Any flood-damaged contours were fixed quickly, post flood event; and
- Farming over banks also helps direct water down to Watermark Gully at Dixie (**Plate 6 photo 13**). This avoids banks cracking and breaking and gullies forming as a result of flooding.

9.5 GENERAL OBSERVATIONS

- Light grasses are evidence of waterways on The Watermark and at Dixie (**Plate 6 photo 15**); and
- Dixie is 'heavy' country and will run out of water, whereas The Watermark has never run out.

10 THE WILGAS

The Rowarth's are a generational farming family. Len Rowarth has lived on the property 'The Wilgas' on Black Mountain since 1938. The Rowarth family continues to manage property on behalf of Shenhua Watermark

The following observations were noted by Mr Rowarth in regard to flooding in the region.

10.1 FLOOD OBSERVATIONS

- A significant flood event will render two - three foot of water;
- During flood events along Dip Road the tops of boundary fence post are only just visible. Water will travel over The Dip Road;
- Rainfall of 10-12 inches overnight in the elevated catchment areas will cause a flood. This water travels but also infiltrates the soil;
- The plains were under water for many months around 1980. A horse had to be ridden at times to traverse the flood waters;
- In general peak flood waters of 1 m - 1.5 m will last for about four hours;
- Waters from Piallaway Range drain to Werris Creek and the Mooki River;
- The Wilgas house has never been isolated;
- Ashley Downs could get isolated by flood waters cutting The Dip Road (**Plate 3 photo 8 – 11**); and
- The black soils can be farmed after a flood event as the water moves away fairly quickly.

10.2 MOVEMENT OF WATER

- Local water does not stay on The Wilgas for long. The main flood issue in the area is the combination of overflows from Lake Goran and the Mooki River which can build up much water below The Dip Road. Within a couple of days the water disperses;
- Soil types will dictate the movement of water and maize crops can divert the direction of water. The newer irrigation dams are causing the flood waters to travel in a different direction to the way in which they flowed in the past;
- Water moves quickly down Black Mountain. Runoff is similar at Demeter and on the properties toward Court Lane (**Figure 2**);
- Rainfall of 70-80 mm has been experienced during a storm event;
- Water from Lake Goran will travel to the Mooki under some flood circumstances;
- Tributaries off the southern area of the Liverpool Ranges flow into the Mooki River contributing to flow levels; and

- Runoff on the Wilgas property is most substantial on the north-east side. There is some runoff on the other side however the slope is less steep.

10.3 IMPACTS

- Damage from flooding includes soil erosion, dam breaks, and damage to fences. Vegetative cover helps hold water back and contour banking has helped mitigate many of these impacts;
- Flood waters in the past carried much sediment and caused much erosion however waters are now virtually clear due to changed farming practices;
- Weeds will occur along the Mooki River post-flood, and also on the sloped country. Flooding will alter the seed bank with water infiltration bringing seed up to the surface. There is little weed on the black soils except in waterways; and
- Crops can survive flood events, for example cotton survived the 1974 flood event.

10.4 MANAGEMENT OF FLOOD IMPACTS

- Chemical farming and maintaining ground cover helps mitigate against flooding impacts; and
- Contouring land has been completed in order to divert and slow water.

10.5 GENERAL OBSERVATIONS

- Springs break out on the light ridge and sandy country. They are hard to predict and will run intermittently.

11 NARDOO, MERRIGAL AND MAYDALE

Phillip Warmoll has lived and worked on the floodplains north north-west of the township of Breeza since 1962. These properties are located outside of the Project Boundary on the east north-eastern side of the EL on the Breeza Plains.

The following observations were noted by Phil Warmoll in regard to flooding in the region.

11.1 FLOOD OBSERVATIONS

- The 1984 flood was insignificant to the floodplain properties;
- The 2000 flood was similar to the 1970s floods;
- Approximately 18 – 20 inches (two foot) of water can cover the northern plains when the Mooki River bursts its banks and the water spreads out;
- Watermark may be isolated for 12-14 hours. The Kamilaroi Highway would get cut off at Watermark Gully; the flood waters are quick and can travel over high ground;
- Sometimes the volume of flood water slowly builds, other times the volume will build after intense rainfall, such as 1974. In 1974 there was approximately seven inches of quick rain overnight;
- Flooding is a result of the amount of rainfall in addition to the capacity of the soil to hold moisture;
- Waters will runoff when the soil reaches its water holding capacity;
- In the smallest flood water came up to the Maydale house on the river in 1984, but other '*larger*' floods such as the three which occurred in the 1970's did not reach this house. The pattern of flooding is largely variable;
- Ponding on the plains is evident;
- Fences create a wall for the flood waters to pass through creating a hydraulic boundary on which grass and debris accumulate; and
- Flood waters are cleaner now than in the past due to zero till farming practices.

11.2 MOVEMENT OF WATER

- The cause of flooding on the northern Breeza plains comes primarily from the Mooki River. The impact of runoff from Watermark Gully is negligible to the plains properties. Similarly a fair amount of water will come off Black Mountain onto the northern plains yet this is not significant compared to the contributions from the Mooki River;
- A sheet of water flows from the Kamilaroi Highway down to Werris Creek;
- Water lies down on the plains to the south of the Project, but travels on the northern plains;

- It now takes more rainfall for Watermark Gully to flow whereas it would run more frequently in past years. The abundance of grass in the gully means only an insignificant amount of runoff is travelling down to the plains;
- Gravity fed channels carry water for many kilometres on the plains;
- Lagoon water on the plains pools, (**Figure 3**) and takes much time to get away;
- Native Dog Gully waters cannot get into the Mooki River during flood events and these waters will spread out over the southern plains; and
- Due to the flatness of the land runoff is not a significant issue for the plains properties.

11.3 IMPACTS

- Flood events now do more damage to infrastructure channels on the northern Breeza plains as the irrigation channels are larger. In the 1970's the infrastructure was built more around the natural lay of the land on which flooding caused less of an impact. More recently, with improved infrastructure, the channels are larger and floods will gouge out more ground;
- In the 1970's when sheep were run on the plains the damage was more significant, especially to fences, whereas in 2000 the damage was more to earthworks;
- Some severe erosion and siltation have been observed as a result of flooding, but not enough to silt up dams;
- Pollution of flood waters is dependent on how the rain falls. Flash flooding such as those which occurred in the mid 1970's carried more polluted and turbid water. These floods were quick; there was stubble, erosion, and therefore silt laden waters;
- Lippia; a water spread weed, and Noogoora burr have been noted post flood events;
- Insect populations are not notably different post-flood event; and
- There is less ground cover in dry periods, thus erosion is more significant during flooding after these times.

11.4 MANAGEMENT OF IMPACTS

- No works to mitigate damage to irrigation channels are completed;
- There are many culverts between Breeza and Watermark Gully for water the flow through; and
- Irrigation channels are the only land alteration which has been completed on Phil Warmoll's properties however the purpose of these channels is not to mitigate against flood events.

12 BREEZA STATION

Andrew Pursehouse has lived and worked on the Breeza Station property since 1984. Breeza Station is located to the south-east of the Project Boundary in close proximity to the township of Breeza (**Figure 2**).

The following observations were noted by Andrew Pursehouse in regard to flooding in the region.

12.1 FLOOD OBSERVATIONS

- The 2000 flood had the most significant impact on Breeza Station;
- On Breeza Station water will only spread from the Mooki River to the black tank (**Figure 3**). This tank is within approximately 800 m of the Mooki River located to the west south-west of the river;
- The floodplains on the northern side of the Kamilaroi Highway are quite flat and flood waters will stretch out for much further than on the southern plains;
- Close to Gunnedah, north of the Project Boundary, at the point where the Mooki and Namoi Rivers meet on the plains, the water will back up as far as the Drayton property;
- The flood waters really hug the Mooki River on Breeza Station, thus impacts to the Station are minimal. Water is also able to get away to the north of the Station quite quickly;
- There is much quick runoff from Breeza Mountain to the Mooki River;
- The soil profile on the black soil plains fills from the bottom up like an empty sponge post drought. Pore spaces open up to receive water and the soil swells;
- The rise of the river will depend on the level of soil moisture at the time of the rainfall;
- It can take between one and four days for water to travel from Willow Tree to Breeza Station;
- Flood events at Breeza Station are dictated by where water is coming from. For example with the summer rainfall over 2011-2012 little came from the east; from Quirindi;
- Reference was made to a house on a neighbouring property approximately 100 m from the river, located on a high point. In 2000 the water level at this house was the highest ever experienced;

- When the plains were covered in Plains Grass it took longer for the water to reach the river. In the 1900's much of the plains were covered both in Plains Grass and Nardoo. Those areas with patches of Nardoo, a native medic water plant, suggest that those areas would have laid water for extended periods. Nardoo is a legume which sustains Plains Grass; and
- Water travels quickly down the Great Dividing Range.

12.2 MOVEMENT OF WATER

- The Breeza Mountain carries water down at a quick velocity into the Mooki River. There is a substantially sized catchment behind the Mooki which has a narrow channel for water to pass through at the Breeza Bridge;
- There is a unique stretch of the Mooki River where it crosses between Breeza and Doona in which there is a 1:800 m drop of slope. This means that flood waters will stay in relatively close proximity to the Mooki River;
- Water flows directly north, the way in which the paddocks are lain out in the land to the west of Mystery Road (lie of land is 1:800 m). To the east of Mystery Road the natural flow follows the Highway on a north north-easterly direction however this has been altered in order to create square paddocks (lie of land is 1:1, 500 m); and
- The Mooki River and Cox's Creek are the main drainage channels from the Liverpool Plains into the Namoi River. A substantial volume of water travelling from the Liverpool Catchment water must pass past Breeza Station.

12.3 IMPACTS

- In the 2000 flood event the Kamilaroi Highway to the south of Breeza was cut off at the bridge to all traffic. The water came up approximately 1 m over the road where the road verges and guide posts were damaged;
- Flood damage to structures on Breeza Station is minimal;
- No different response from soils post flood has been observed, however all crops are yield mapped and the impacts of a localised flood will be visible on the yield maps. Too much soil moisture is an issue for the crops;
- Breeza Station Road is damaged by flood waters from the runoff. The soils are hardsetting and susceptible to surface sealing. Native vegetation slows erosion runoff and erosion can be combated with changed farming practice;
- Floods caused some damage to fencing however little other infrastructure on the property is impacted; and
- No weed or insect propagation has been noted post-flood event.

12.4 MANAGEMENT OF IMPACTS

- No bunding or mitigation to flooding occurs on Breeza Station;
- Avoiding grazing of land next to the Mooki River helps alleviate flood erosion;
- The Mooki River is fenced off from stock. If it is grazed it is only '*crash grazed*' for short periods; and
- Change from farming across slope to down slope. The frequency of cropping has also been altered.

12.5 GENERAL OBSERVATIONS

- Opportunistic cropping commenced in the 1980's in response to salinity and utilising moisture in the soil for chickpeas, sorghum, etc;
- Rainfall in the region is bi-modal and slightly summer dominant;
- Surface sealing of soils occurred in the 1960's and 1970's causing water to run very quickly; and
- Lake Goran would fill up overnight in the past.

13 CONCLUSION

Flooding within the Disturbance Boundary, from prior landholder observations, largely occurs around Watermark Gully. This catchment begins in the Breeza State Forest, travels through the gully, picking up runoff water from Mount Watermark and the western ridges. Water then drains through culverts or across the Kamilaroi Highway, down to the northern floodplains, where it meets flood waters from the Mooki River and travels north to Curlewis. Water that does not flow to Watermark Gully on the western and southern portions of the Disturbance Boundary primarily drain to Lake Goran. Within the southern portion of the Eastern Mining Area most waters runoff to the southern black soil plains. The north-eastern portion of the Eastern Mining Area travels across the Kamilaroi Highway, or through culverts down to the northern floodplains.

Whilst water movements are fairly predictable during periods of inundation and flooding, the nature of flood events have been observed as variable over the past 50 years, dependent upon cropping regimes, land contouring, dam installations, stocking rates, vegetation cover, water holding capacity of the soil and the extent of soil moisture prior to inundation.

Flooding in the southern portion of the Project Boundary is a result of flows from Coomoo Coomoo and Yarraman Creeks as well as Lake Goran. Overflows from Coomoo Coomoo Creek and Lake Goran occur in moderate to high flow events while flows from Yarraman Creek flood out into the low lying floodplain in all flow events.

Significant flood events which impacted the Watermark area occurred in 1955, 1974, 1984, 1998 and 2000. The 1974 flood was significant for the southern plains in particular. The 1998 winter flood was an unexpected event which occurred due to significant rainfall inundation overnight. The 2000 summer flood occurred after prolonged rainfall and caused much crop damage, especially on the southern Breeza plains. It was observed that most flood waters escape from the ridge country quite quickly, whereas waters will pool on the plains for extended periods of time.

Impacts of flooding at Watermark include blocking of roads, '*washing out*' of unsealed roads, soil erosion, breaks in contour banks and dams, loss of stock and crops and some weed propagation. Road blocking lasts no more than half a day in most instances. Blocking of the Kamilaroi Highway and water covering the railway have been mitigated in recent years by the construction of causeways and culverts in the Watermark Gully vicinity. Few landholders experienced isolation on their properties for any extended periods of time. Erosion impacts have lessened over time with an increase in vegetative cover and changes to no till farming practices. In general it was observed that impacts of flooding are increased after a drought period due to a lack of vegetative cover and soil surface sealing resulting in amplified runoff and erosion. It was also observed that the impact of flooding is worsened during winter due to less evaporation and evapotranspiration.

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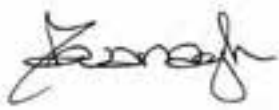
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for

HANSEN BAILEY



Michelle Cavanagh
Environmental Scientist

APPENDIX A

PLATES

Plate 1

Tathra flood level comparison; 2000 & 2012

Photo 1.



Photo 2.



Plate 2

Birchall Family Photos; December 2000

Photo 1.



Photo 2.



Photo 3.



Photo 4.



Photo 5.



Photo 6.



Photo 7.



Photo 8.



Photo 9.



Plate 3

Tathra Reference Location Photos; 2012

Photo 1.



Photo 2.



Photo 3.



Photo 4.



Photo 5.



Photo 6.



Photo 7.



Photo 8.



Photo 9.



Photo 10.



Photo 11.



Plate 4

Britten Family Photos; 1998 & 2000

Photo 1.

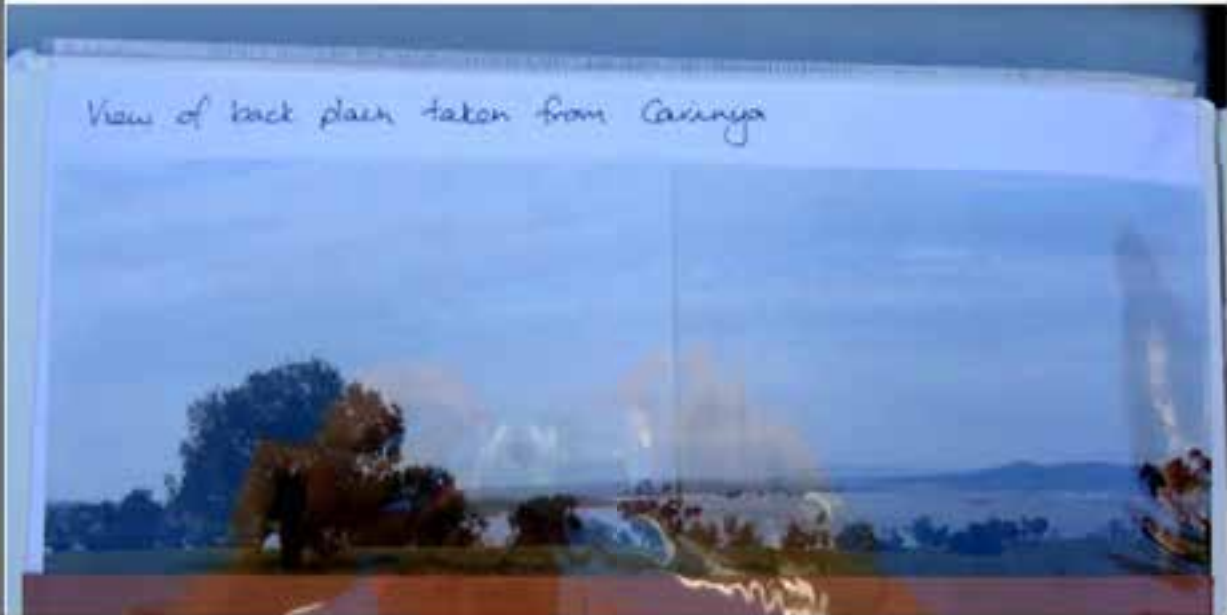


Photo 2.



Photo 3.



Photo 4.



Photo 5.



Photo 6.



19/11/00
Taken from bridge over Mackinac
at Breese. Kamilaroi Highway
closed to all traffic. Water
still rising

Photo 7.

20/11/00 -
Truck tried to get through but
didn't make it. Had to be
recovered. Water still rising.
Massive damage to rail bridge
by flood waters.



Plate 5

Bailey Family Photos; 1998

Photo 1.



Photo 2.



Photo 3.



Photo 4.



Photo 5.



Photo 6.



Photo 7.



Photo 8.



Photo 9.



Photo 10.



Photo 11.



Photo 12.



Plate 6

The Watermark & Dixie Property Reference Location Photos

Photo 1.



Photo 2.



Photo 3.



Photo 5.



Photo 6.



Photo 7.



Photo 8.



Photo 9.



Photo 10.



Photo 11.



Photo 12.



Photo 13.



Photo 14.



Photo 15.



Plate 7

Rowarth Family Photos

Photo 1.



Photo 2.



APPENDIX B

CPG REPORT



Hansen Bailey
Watermark Project
CHPP Water Usage
Project: 13973.0067
Date: 31/05/12 Rev: 0

Project Details

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Approvals

Approval / Signatures			
Action	Name	Role	Signature
Prepared by:	W Mackinnon	Consutling Manager NSW	

Revision History					
Rev	Date	Description	Prep	App 1	App 2
0	31/05/2012	Report Issued	W Mackinnon		



1. Introduction

Shenhua Watermark Coal Pty Ltd (SWC) are currently undertaking detailed study work for the development of the Watermark resource area located near Curlew to the south-east of Gunnedah. The proposed mine will target primarily Hoskissons and Melvilles seams, along with several thin seams to produce export thermal and metallurgical products.

CPG Resources - QCC Pty Ltd (QCC) have been engaged by Hansen Bailey to assist with a review of the Watermark Project CHPP design and to nominate the anticipated CHPP net water usage requirement. This information is required as an input into the Surface Water Impact Assessment for the Environmental Impact Statement (EIS) Hansen Bailey are currently preparing.

Specifically the QCC scope of work included:

- Review of the GHD Feasibility Study (in relation to CHPP facilities) to understand the proposed coal handling process, coal quality, anticipated quantum of rejects and tailings and nominated CHPP net water usage
- Document, based on experience, the anticipated CHPP net water usage for the proposed coal handling process.

2. CHPP Facilities and Water Usage

The Watermark CHPP design work has been undertaken by Shenyang Design Research Institute (SDRI), including the entire production system infrastructure. The production system includes the primary crushing station, a 100 kt raw coal storage area (with underground reclaim), secondary and tertiary crushing stations, main processing plant (CPP), two 200 kt product coal stockpiles (with underground reclaim), reject bin and train loading station.

The Watermark CHPP will process approximately 10 Mt/y of ROM coal. The ranges in coal sizing, washability and quality are described within the Gallagher Consulting Services (GCS) report, split into two groups for discussion, namely the coking coals (two product wash) and the thermal coals (single product wash). The CPP processing capacity is 1450 t/h, determined on the basis of the facility being available 7,000 hours per year for processing.

2.1 CPP Process

The proposed CPP process at Watermark can be described as:

Coarse	-50+1.4w/w mm	Two stages of dense medium cyclones (DMC)
Fine	-1.4w/w+0.125 mm	Spirals
Ultrafine	-0.125+0 mm	Tailings

SDRI have estimated product yields and product ashes for the 22 year mine plan. Overall yield ranges from 64% to 72.5%, averaging 67.5% for the life of mine. For the water balance evaluation it is total yield that is relevant to considerations, as total product (and reject) and associated moistures, determine the quantity of water

exiting the plant. Therefore, separate evaluation of two stage and single stage washing is not relevant to this review.

Review of the sizing ranges presented in the GCS report suggest the following size ranges are relevant to Watermark processing:

Size (mm)	Fine	Coarse	Typical
-50+1.4w/w	60	84	75
-1.4w/w+0.125	25	12	8
-0.125+0	15	4	8
Total	100	100	100

2.2 Washed Product Moisture

The estimation of washed coal moisture (Mwc) is subject to some uncertainty due to several factors, including product size distribution, plant dewatering efficiency, and coal quality characteristics. The different size fractions in a washed product contribute very different amounts to the total product moisture and until the plant is producing, the actual size distribution is unknown.

Air-dry moisture and moisture holding capacity data assist with the projection of ROM coal moisture, and subsequently are useful in inferring the washed product moisture. In Figure 1, it can be seen that the moisture data is variable, highlighting the need to allow for an appropriate range when projecting washed product total moisture.

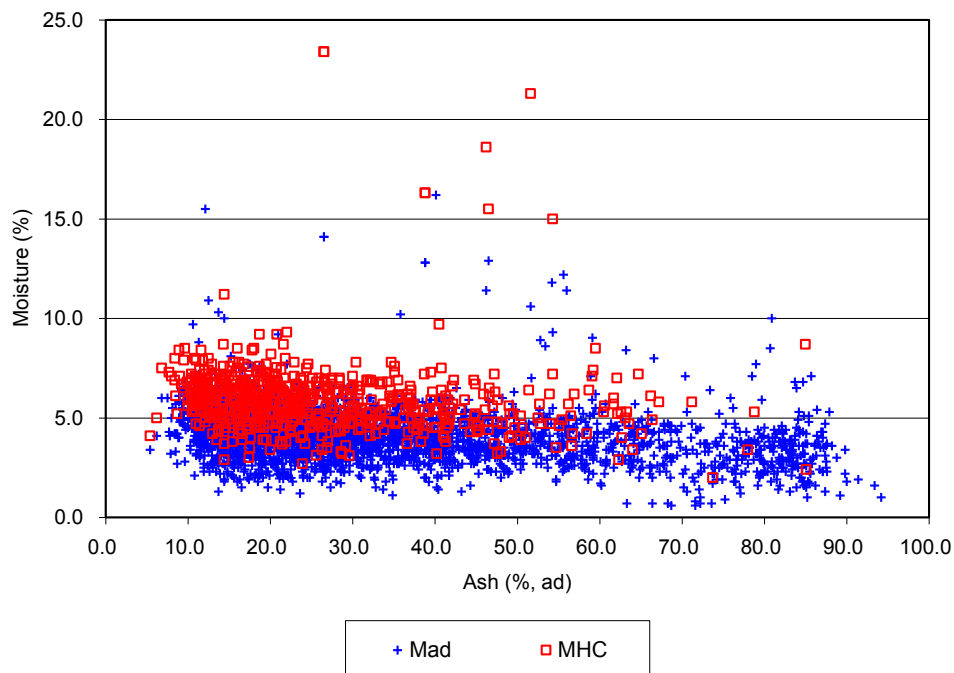


Figure 1: Watermark Bore Core Moisture Data

If material less than 30% ash is considered (i.e. “true coal”), the air-dry moisture (Mad) averages 4.5%, while the moisture holding capacity (MHC) is typically around 6% to 6.5%. In situ moisture (Mis) can be estimated as MHC+1% for this rank of coal. This leads to an expected total product moisture for washed coal built up as shown in Figure 2.

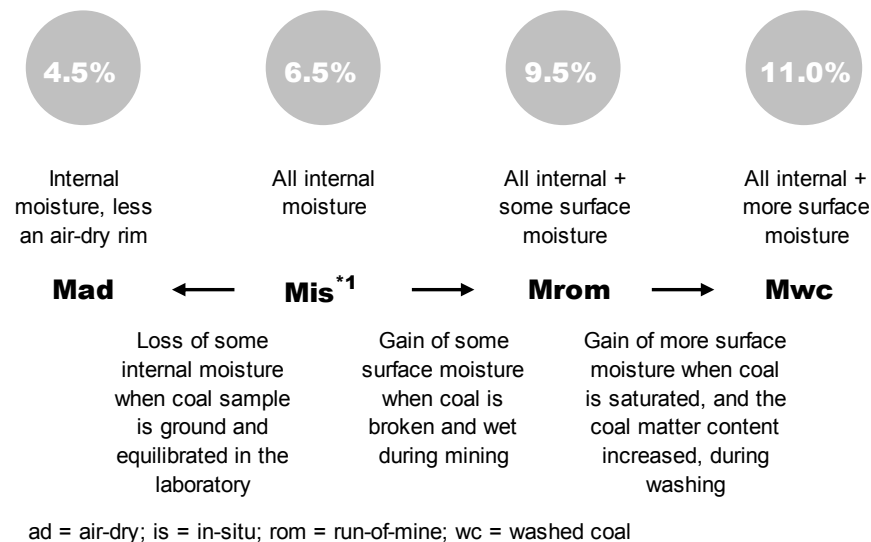


Figure 2: Typical Washed Product Moisture Projection

The underlying variability in Mad and MHC as shown in Figure 1 suggests values of 2.0% above this typical number could be expected, leading to washed total moisture levels of up to 13.0% at times. The SDRI report indicates a total moisture of around 11% is expected, which is reasonable if appropriate mine scheduling provides an average mix of coals over the life of mine. However, due to differences in size distribution which will arise from two stage washing and the manner in which fine coal will be distributed to either primary or secondary product, it is unlikely that both primary and secondary products will be at 11% total moisture as indicated by SDRI in Table G-2.

2.3 Plant Water Usage

For the proposed CPP, plant water usage will be relatively low by Hunter Valley standards due to the fact there will be no wet tailings disposal. Tailings will be mechanically dewatered via belt press filters, allowing filter cake to be dry disposed as part of a total plant reject stream.

The water demand throughout the 1450 t/h CPP will be high but the bulk of this process water is recovered for re-use via the tailings thickener. However, water will ultimately be consumed due to:

- water leaving the plant as part of the product stream
- water leaving the plant as part of the reject stream

With a traditional wet tailings disposal system, the water contained within the tailings stream would be the major single loss of water from the process. This will be avoided at Watermark, with the thickened tailings reporting to belt press filters which will

reduce the tailings total moisture significantly, from 70% (slurry) to around 35% ("filter cake"). The water removed by the belt press filters will also return to the CPP water circuit for immediate re-use.

Due to the unavoidable loss of water through the washing process, raw water make-up will be required to offset the loss of water through the plant product and reject streams. Based on the sizing and yield ranges expected for Watermark and the likely moisture parameters, water balance calculations have been undertaken. On the basis of washing 1450 t/h of ROM coal, this equates to:

- 1450 t/h wet coal at 9.5% TM, which equates to
- 1374 t/h air-dry solids, plus 76 t/h of free water, which equates to
- 1312 t/h dry solids, plus 62 t/h of air-dry "inherently bound" water, plus 76 t/h of free water

It was assumed that the Mad in the ROM material, product, reject and tailings remained unchanged at 4.5%. From the typical sizing/yield water balance calculations undertaken (Table 1), it is predicted that the plant will require 107 m³/h of make-up water per 1450 t/h of ROM coal on average. This equates to approximately 74 litres of make-up water per tonne of ROM coal processed on average. The SDRI projections for water usage range from 93 m³/h to 102 m³/h (section 5.5.2 in SDRI report) and on balance, the QCC and SDRI projections are of similar magnitude. The typical/nominal water balance assumptions and calculations are shown in Table 1.

Table 1: Water Balance For Typical Conditions

Mad	4.5								
ROM TM	9.5								
Feed Splits	Nominal		Yields (% ad)		Free Moistures (% ar)				
+2 mm	75		73		Product	Reject			
-2+0.125 mm	17		75		5.0	12.0			
-0.125 mm	8		0		14.5	22.0			
	100		67.5			35.0			
	1 mod		Product t/h		Reject t/h		BPF	Total	Trucked
Basis	ROM t/h	Make-up t/h	Coarse	Fine	Coarse	Fine	Tailings t/h	Product t/h	Reject t/h
wet	1450	107.00	792	205	316	75	169	997	560
air-dry solids	1374.1		752.3	175.2	278.3	58.4	109.9	928	447
dry solids	1312.3		718.5	167.3	265.7	55.8	105.0	886	426
free water	75.92	107.00	39.6	29.7	37.9	16.5	59.2	69	114
			67.5		20.3	4.3	8.0		32.5
	annual 10 Mt/y		Product Mt/y		Reject Mt/y		BPF	Total	Trucked
Basis	ROM Mt/y	Make-up Mt/y	Coarse	Fine	Coarse	Fine	Tailings Mt/y	Product Mt/y	Reject Mt/y
wet	10.00	0.74	5.46	1.41	2.18	0.52	1.17	6.87	3.86
air-dry solids	9.48		5.19	1.21	1.92	0.40	0.76	6.40	3.08
dry solids	9.05		4.95	1.15	1.83	0.38	0.72	6.11	2.94
free water	0.52	0.74	0.27	0.20	0.26	0.11	0.41	0.48	0.78
megalitres	524	738	273	205	262	114	408	478	783

In total, this water usage equates to around 738 megalitres per year of process make-up water being required, based on 10 Mt/y ROM processing. Figure 3 shows the process water balance for the typical hourly and annual average flows for processing 1450 t/h and 10 Mt ROM coal respectively. Note that this figure is for the CPP process only and does not include provision of wash down water, dust suppression water, potable water etc, around the CHPP area which should also be allowed. A typical additional usage for these demands would be from 1% to 3% of the process demand. Therefore, an average total CHPP water usage would be 110 m³/h or 760 megalitres per year (76 litres per ROM tonne).

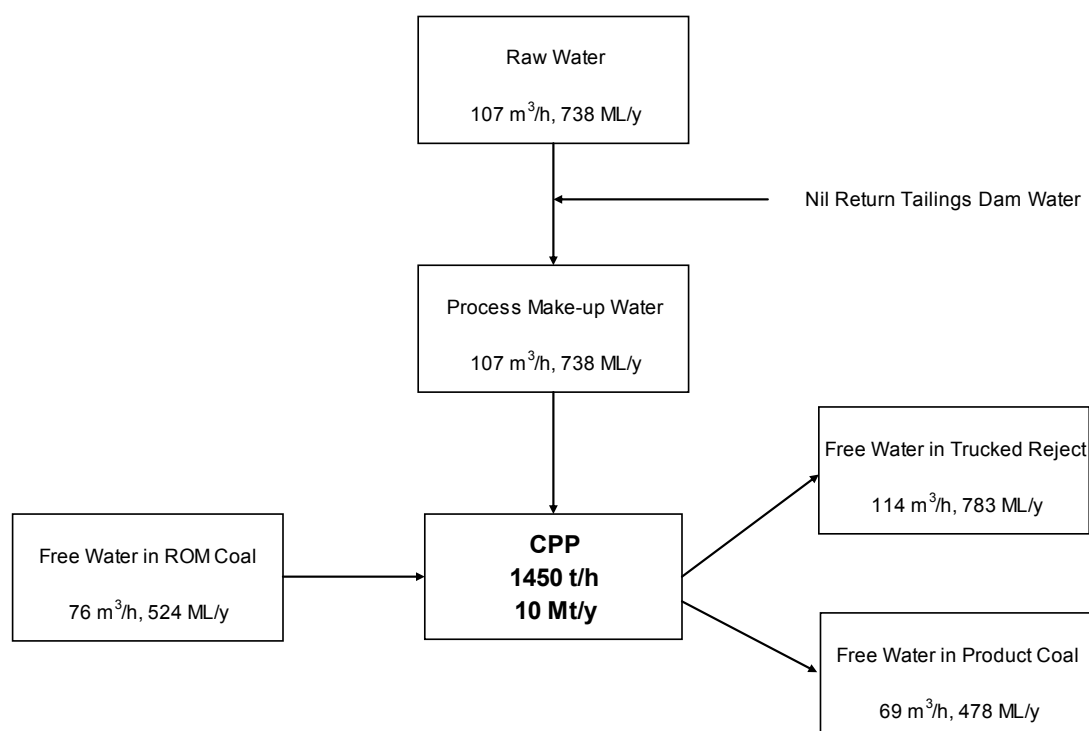


Figure 3: Watermark CPP Typical Water Balance

To allow for the observed variability in the coals to be washed, water balance calculations have also been undertaken for the finest, lowest yielding coal, which will lead to maximum water usage. From the finest sizing/yield water balance calculations undertaken (Table 2), it is predicted that the plant will require 168 m³/h of make-up water per 1450 t/h of ROM coal on average. This equates to approximately 116 litres of make-up water per tonne of ROM coal washed. Annually, around 1160 megalitres of process make-up water would be required under these conditions, based on 10 Mt/y ROM processing. Allowing for other water usage around the CHPP area leads to a total CHPP water usage would be 173 m³/h or 1195 megalitres per year (119 litres per ROM tonne).

Table 2: Water Balance For Maximum Usage Conditions (Finest/Lowest Yielding Coal)

Mad	4.5									
ROM TM	9.5									
					Free Moistures (% , ar)					
Feed Splits	Nominal		Yields (% , ad)		Product	Reject				
+2 mm	60		70		5.0	12.0				
-2+0.125 mm	25		72		14.5	22.0				
-0.125 mm	15		0			35.0				
	100		60.0							
	1 mod		Product t/h		Reject t/h		BPF	Total	Trucked	
Basis	ROM t/h	Make-up t/h	Coarse	Fine	Coarse	Fine	Tailings t/h	Product t/h	Product t/h	Reject t/h
wet	1450	168.24	607	289	281	123	317	897	721	
air-dry solids	1374.1		577.1	247.3	247.3	96.2	206.1	824	550	
dry solids	1312.3		551.1	236.2	236.2	91.9	196.8	787	525	
free water	75.92	168.24	30.4	41.9	33.7	27.1	111.0	72	172	
			60.0		18.0	7.0	15.0		40.0	
	annual 10 Mt/y		Product Mt/y		Reject Mt/y		BPF	Total	Trucked	
Basis	ROM Mt/y	Make-up Mt/y	Coarse	Fine	Coarse	Fine	Tailings Mt/y	Product Mt/y	Product Mt/y	Reject Mt/y
wet	10.00	1.16	4.19	2.00	1.94	0.85	2.19	6.18	4.98	
air-dry solids	9.48		3.98	1.71	1.71	0.66	1.42	5.69	3.79	
dry solids	9.05		3.80	1.63	1.63	0.63	1.36	5.43	3.62	
free water	0.52	1.16	0.21	0.29	0.23	0.19	0.77	0.50	1.19	
megalitres	524	1160	209	289	233	187	765	499	1185	



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3. Summary and Issues

With the inclusion of mechanical dewatering of the tailings stream at Watermark, the water usage will be relatively low by Hunter Valley standards. The expected raw water usage will be around 76 litres per ROM tonne, although this number could be as high as 119 litres per ROM for fine, low yielding coal. In practice, a long term average usage should be closer to the 76 litres per ROM tonne value, but this will ultimately depend on the product size distribution and resultant product and reject moistures achieved from each plant circuit. If higher moistures are realised than currently projected, water usage will increase by a commensurate amount.

Note that if traditional tailings dam disposal were to be employed, this water usage would be of the order of 200 litres per ROM tonne. Tailings dams will enable return of water decanted from the tailings slurry, which is typically around 30% to 40% of the water included within the tailings slurry. The majority of tailings slurry water remains bound within the desposited solids within the tailings dam, while there are some losses from seepage and evaporation also.