APPENDIX F

SUPPLEMENTARY SURFACE WATER INVESTIGATIONS INCLUDING WATER BALANCE MODELLING

MOOLARBEN COAL MINES PTY LTD

MOOLARBEN COAL PROJECT – STAGE 2 PREFERRED PROJECT

Supplementary Surface Water Investigations Including Water Balance Modelling

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MOOLARBEN COAL PROJECT STAGE2 PPR
Supplementary Surface Water Investigations Including Water Balance Modelling

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Project: MOOLARBEN COAL PROJECT STAGE2 PPR
SUPPLEMENTARY SURFACE WATER INVESTIGATIONS INCLUDING WATER BALANCE MODELLING

REV	DESCRIPTION	PREPARED BY	REVIEWED BY	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
1	Draft Report – Issued for Client Review	ARM			20th April 2011		
2	Final Draft Report	ARM			17th May 2011		
3	Final Report	CRT/AM	CRT	Chris Thomas	10th June 2011		
4	Updated Final Report (incorporating revised groundwater modelling)	CRT/AM	CRT	Chris Thomas	30th August 2011		

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1. INTRODUCTION

WorleyParsons was commissioned on behalf of Moolarben Coal Mines Pty Limited (*MCM*) to undertake a Surface Water assessment for the Moolarben Coal Stage 2 Project (*Stage 2*). The purpose of this assessment is to form part of a Preferred Project Report (*PPR*) being prepared by Hansen Bailey to support the application for Project Approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (*EP&A Act*) to facilitate the development of a 24 year open cut and underground coal mine and associated infrastructure and integration with the existing Stage 1 operations.

Specifically, the Preferred Project will consist of:

- The construction and operation of an open cut (*OC*) mining operation (*OC4*) extracting up to 12 Million tonnes per annum (*Mtpa*) Run of Mine (*ROM*) coal and up to 13 Mtpa combined rate with the Stage 1 open cuts;
- The construction and operation of two underground (*UG*) mining operations (*UG1 and UG2*) extracting up to 4 Mtpa ROM coal cumulative with the Stage 1 underground;
- The construction and operations of the Stage 2 ROM coal facility;
- Extension of the life of the Coal Handling and Preparation Plant (*CHPP*) to Year 24 of Stage 2 and increased throughput of up to 17 Mtpa (*13 Mtpa open cut and 4 Mtpa underground*);
- The development of the Northern Out Of Pit (*OOP*) emplacement area;
- The construction and operation of two conveyors and associated facilities between the Stage 2 ROM coal facility and Stage 1 CHPP;
- The construction and operation of a Mine Access Road;
- The construction and operation of administration, workshop and related facilities;
- The construction and operation of water management infrastructure; and
- The installation of supporting power and communications infrastructure.

As part of the Stage 2 Environmental Assessment (*EA*), WorleyParsons undertook surface water investigations, which were documented in the report titled *'Moolarben Coal Project EA2, Surface Water Management Strategy* (*Issue No.4, November* 2008). Henceforth, this report is referred to as the *SWMS* Report.

Subsequent to the submission of the Stage 2 EA, an independent review of the *SWMS* Report was conducted by Mr Lindsay Gilbert, at the request of the Department of Planning & Infrastructure (DP&I) formerly Department of Planning. Consequently, additional investigations have been undertaken which are documented in this report.

Accordingly, this report provides further detail on the following aspects of the Moolarben Coal Project's surface water management strategy:

- Additional information related to the catchment setting, including the results of further hydraulic modelling.
- Updated dirty water balance modelling investigations, undertaken to reflect the Preferred Project's mining schedule, include the Water Sharing Agreement and incorporate estimates of water usage from Stage 1 of the MCC.
- An updated approach to the management and release of "clean" water from the Murragamba & 'Eastern' Creek catchments.
- A summary of proposed mitigation and contingency measures, including commitments to collect further data where required.

Detail of the additional investigations undertaken for this report is provided in **Chapter 2**. A summary of the relationship between the material presented in this report and the previous investigations documented in the *SWMS* Report is also included.

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2. SUMMARY OF REQUESTED INFORMATION

A summary of the information requested subsequent to submission of the Stage 2 EA is presented in **Table 1**, all of which has been considered and addressed in this report as indicated.

Table 1 INVESTIGATIONS UNDERTAKEN FOR THE PREFERRED PROJECT

TOPIC	ADDITIONAL INFORMATION REQUESTED	REFERENCE	RESPONSE
Existing Baseline Data Set	- Flow yield, flow persistence and flooding frequency on Murragamba and 'Eastern' Creek	(1)	Chapter 3
	- Information on other water users in Project drainages	(1)	Section 3.1.1
	- No water quality data for 'Eastern' Creek, upper section of Murragamba Creek, including sections to be preserved	(1)	Section 5.2
Catchment Modelling	- Outputs from hydraulic model for 1, 5 year ARI and PMP	(1)	Chapter 3, Appendix A
	- Results of sensitivity analysis from hydraulic model for 5, 100 and PMP modelling runs, involving an assessment of roughness and flow	(1)	Chapter 3, Appendix A
	- Summary of anecdotal information for past floods	(1)	N/A
	- Comparison of predicted flows to those predicted at nearby gauging stations, pro-rated for catchment areas	(1)	Section 3.1.3
Dirty Water Balance	- Plan showing all proposed water management storages, capacities, catchments and evolution, together with linkages and operating protocols	(1)	Chapter 4, Figures 1, 2 & 4
	- Description of algorithms used to simulate water balance, particularly in regard to rainfall run-off	(1)	Figure 4
	- Details of model calibration and sensitivity analysis	(1)	Section 4.5, Appendix C

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TOPIC	ADDITIONAL INFORMATION REQUESTED	REFERENCE	RESPONSE
	- List of model parameters and operation data and assumptions	(1)	Figure 4, Section4.1, Section 4.2
	- Simulated off-site discharges and spills	(1)	Section 4.4, Section 4.6
	- Provide additional information on the mine water management system	(2)	Figure 3
Management of "Clean" Water	- Treatment and release of riparian flow	(3)	Chapter 5
	- Hydrological impact of final void	(3)	Section 5.4
Existing hydraulic regime and surface water impacts	- Simulated flow duration curves for pre-mine, during mining and post mine situations for downstream Murragamba, downstream Easter Creek and Wilpinjong Ck downstream of 'Eastern' Creek confluence	(1)	Chapter 5
	- Simulated mean annual flows at these locations under these different situations. Details of the hydrologic models used	(1) / (3)	Chapter 5
Potential impacts and mitigation, monitoring and management strategies	- Provide a summary of mitigation and contingency measures	(3)	Chapter 6

References:

(1) Lindsay Gilbert, *'Preliminary Review of Moolarben Coal Project Stage 2 EA Surface Water Management Strategy & Revised Water Balance prepared by WorleyParsons'* (*undated, understood to be June 2009*).

(2) Lindsay Gilbert, *'Moolarben Coal Mine Stage 2, Review of additional data supplied by WorleyParsons'* (*September 2009*).

(3) Lindsay Gilbert, *'Review of Surface Water Assessment and Water Balance Analyses for the Environmental Assessment of the Moolarben Coal Project – Stage 2* (*December 2009*).

The following chapters have been prepared to outline the response to additional information requested, as detailed in **Table 1** above:

Chapter 3 Additional information pertaining to the existing Murragamba and 'Eastern' Creek catchments.

Chapter 4 Dirty water balance modelling investigations, which have been updated for the Preferred Project.

Chapter 5 Updated framework for release of "Clean" water from the Murragamba & 'Eastern' Creek Valleys downstream to Wilpinjong Creek.

Chapter 6 Identified impacts and proposed management and mitigation measures.

The report is intended to be read in conjunction with the *SWMS* Report. The following is noted in terms of integrating the additional data with work previously completed:

- **Chapter 3** supplements the information provided in *Chapter 3* and *Chapter 5* of the *SWMS* Report.
- The following is noted for **Chapter 4**:
  - The updated mine water demand summarised in **Section 4.1.1** and **4.1.2** replace *Section 7.1* of the *SWMS* Report.
  - Values related to the groundwater make and catchment run-off from disturbed surface water areas as summarised in **Section 4.2.1** and **4.2.2** replace the information provided in *Section 8.3* of the *SWMS* Report.
  - The results of the water balance modelling presented in **Section 4.4** replaces the information presented in *Section 8.3* of the *SWMS* Report.
- **Chapter 5** replaces the information provided in *Section 8.3.5* of the *SWMS* Report.
- **Chapter 6** summarises and expands upon information presented in *Section 7.2* and *Chapter 9* of the *SWMS* Report.

Additionally, there may be some overlap between this report and the information presented in the *Murragamba and 'Eastern' Creek Diversion Concept Design* (*2011*) (*henceforth M&ECDCD* Report).

Where necessary, this report references relevant sections of the *SWMS* Report or *M&ECDCD* Report. In addition, in some cases, the information presented in the previous report has been reproduced to assist with continuity and readability of the current report.

3. DESCRIPTION OF THE EXISTING HYDROLOGIC ENVIRONMENT

The *SWMS* Report which was prepared for the Stage 2 EA provided details of the available and reliable hydrologic data pertaining to the Murragamba and 'Eastern' Creek catchments. The analysis undertaken to support the management strategies was based on the use of this data where appropriate. The available information pertaining to the two catchments was discussed in *Chapter 3* and *Chapter 5* of the *SWMS* Report.

The information provided in this section is intended to supplement the information previously provided in the Stage 2 EA. In that regard, this chapter discusses the following issues in greater detail:

- the extent of available hydrologic, hydraulic, rainfall and water quality data and the application of this data to the surface water management strategy.
- the robustness of the hydrologic and hydraulic modelling completed for the Project.

However, in considering the above issues, the following should be kept in mind:

- Both streams are ephemeral and only carry flow during major storms over the catchment or in response to periods of rainfall extending over a number of days. The upper sections of both streams are ill-defined, reflecting the absence of regular flows and the ephemeral characteristics of the catchments. As a result, there has been very little hydrologic data collected within either valley.
- Both Murragamba and 'Eastern' Creeks drain their own self contained catchments to Wilpinjong Creek, which in turn drains to Wollar Creek. That is, both catchments are discrete sub catchments located in the upper reaches of the much larger Wollar Creek catchment. As a result, there is very little upstream contributing catchment above the area proposed for mining as part of OC4.

Therefore, the availability and suitability of quantitative data detailing the hydrologic and water quality characteristics of Murragamba and 'Eastern' Creeks should be understood in the context of their location within the overall Goulburn River catchment.

3.1 EXISTING HYDROLOGIC CHARACTERISTICS, FLOODING REGIMES AND WATER QUALITY

3.1.1 Catchment Setting

Stage 2 of the Moolarben Coal Complex (*MCC*) is located within the Wollar Creek catchment which drains an area of about 53,200 hectares (*ha*). The Wollar Creek catchment is one of twelve sub catchment management zones that comprise the water sources of the Goulburn Extraction Management Unit. The Goulburn Extraction Management Unit is one of three water sharing extraction management units covered by the Hunter Unregulated and Alluvial Water Sharing Plan. The Goulburn Extraction Management Unit drains an area of about 700,000 ha, which has an estimated annual average flow of about 204,000 Megalitres (*ML*). Of this, only 50,000 ML is licensed for extraction (*DWE, 2009a*).

The total disturbance area of Stage 2 of the MCC is approximately 1,450 ha, which is less than 3% of the total Wollar Creek catchment area. The total disturbance footprint of the MCC is less than 2,600 ha. This is less than 0.7% of the entire area covered by the Goulburn Extraction Management Unit.

The estimated annual total water demand for the MCC under full production is about 3,852 ML. This is less than 2% of the annual average flow of the Goulburn Extraction Management Unit and will be met by a combination of runoff from disturbed areas, groundwater inflows into pits, surplus water from the Ulan Coal Mine and via groundwater extraction from the Permian-age coal measures, where required.

The Stage 2 area covers a large proportion of the catchments of Murragamba Creek and 'Eastern' Creek. These catchments discharge to Wilpinjong Creek, which in turn discharges to Wollar Creek about 12 kilometres east of Stage 2. Wollar Creek discharges to the Goulburn River about 30 kilometres downstream of Stage 2 of the MCC.

The report card for the Wollar Creek water source indicates that the system has a low flow index of 0.5 ML/day (*DWE, 2009b*). This is the amount of water that discharges into the Goulburn River from the Wollar Creek catchment under low flow conditions and includes the combined discharge from Wilpinjong, Cumbo, Wollar Creeks, their tributaries and connected alluvial aquifers.

Murragamba and 'Eastern' Creeks are low order ephemeral drainage systems that only flow in response to rainfall. Both systems have insufficient baseflow to sustain surface flow in these creek lines. Hence there are no surface water discharges from these creeks into Wilpinjong Creek during periods of low or no rainfall (*refer* **Section 3.1.4**).

The Murragamba and 'Eastern' Creeks catchments cover an area of about 3,400 ha. This is approximately 6% of the total area of the Wollar Creek catchment. On a commensurate basis, 6% of the low flow component of the Wollar Creek water source is equivalent to a flow of only 0.03 ML/day.

MCM has committed to maintaining riparian flows from Murragamba and 'Eastern' Creeks for the life of the MCC. This water will be sourced from captured surface runoff from areas upstream of disturbed Stage 2 areas as well as from undisturbed catchment areas downstream of the active pit. The infrastructure required to divert clean surface water run-off is detailed in the *M&ECDCD* Report. Where required, it will be supplemented with water stored in Splitters Hollow Dam, which is an on-stream dam located along Wilpinjong Creek.

As a result, Stage 2 of the MCC will result in no net loss of riparian flow to the Goulburn River system, aside from what can be taken and stored in accordance with the Maximum Harvestable Dam Rights Criteria (*MHDRC*) (*refer* **Section 5.1**).

3.1.2 Additional Information Regarding the Existing Creek System

Flow Yield

No streamflow data is available for either Murragamba or 'Eastern' Creeks. Data available from the HYDSYS database that is managed by the Office of Environment and Heritage (*OEH*) indicates that no stream gauging has been undertaken along either stream. The nearest stream gauging station within the Wilpinjong Creek catchment is Gauge No 210082 which is located along Wollar Creek near its confluence with Wilpinjong Creek.

This gauge is about 15 kilometres east of Stage 2 of the MCC and only records streamflows from upstream of Wollar Creek. Therefore, streamflows recorded at this gauge do not define flow yield from the Murragamba and 'Eastern' Creeks catchments.

It is noted that a closer streamflow gauge is located along the upper reaches of the Goulburn River at Ulan (*Gauge No 210046*). This gauge is located about 6 kilometres from the Murragamba Creek catchment, but records flows from a completely different creek system and one which is influenced by groundwater inflows. Notably, details of the flow records from this gauge are documented in the Surface Water Management and Flood Impact Assessment Reports that were incorporated within the EA for Stage 1. These reports considered the impacts of open cut mining in areas adjacent to Moolarben Creek.

Accordingly, it is not possible to define the flow yield from either Murragamba Creek or 'Eastern' Creek without the application of predictive tools. If a predictive tool were to be applied, it should be recognised that no data at present is available to calibrate the tool and that the results so derived would be of limited value. In that regard, it should also be noted that the mining proposal will involve the relocation and reconstruction of large sections of both creeks.

Therefore, the existing flow yield for both creeks will be difficult to define given their ephemeral characteristics. In addition, runoff from both catchments makes a very limited contribution to riparian flows in the Wollar Creek system (*refer* **Section *3.1.1***).

Nonetheless, MCM has committed to installing flow monitoring devices to quantify the flow yield from both creeks. The mine plans prepared for the Preferred Project indicate that there will be a timeframe of five years to record flow yield for Murragamba Creek and 10 years to record flow yield for 'Eastern' Creek, prior to any section of the existing creeks being removed by OC4 mining. Accordingly, there exists a reasonable period of time to develop a baseline data set and define the flow yield from the existing catchments.

The specific proposal to collect and monitor streamflow is discussed further in **Section 5.2**.

Flood Frequency

As outlined above, both Murragamba and 'Eastern' Creeks are ephemeral streams. No stream gauges exist or have previously existed on either stream. Accordingly, no data is available to provide any meaningful assessment of flood frequency.

Similarly, no anecdotal evidence relating to past flooding in either creek has been identified during the study.

However, as discussed above, MCM has committed to installing flow measurement devices and collecting flow yield data for both creeks.

Rainfall Intensity

Rainfall is measured by daily-read rain gauges or by pluviometers. Daily-read rain gauges are typically manually operated and are used to record rainfall over the 24 hour period to 9 am on each day. Pluviometers record rainfall over much shorter periods, typically in the order of 6 minutes.

Reliable estimates of rainfall intensity require recorded rainfall data measured by pluviometers. *Section 3.1* of the *SWMS* Report documents the extent of available rainfall data in the vicinity of the Murragamba Creek and 'Eastern' Creek catchments. Unfortunately, there are no long term pluviometers located within a 30 kilometre radius of both catchments. Hence, there is no available data that could be used to provide a reliable measure of rainfall intensity either under average rainfall conditions or as a measure of the variation in rainfall intensity during storm events.

In this regard, it should also be noted that no daily-read rain gauges were located within the catchments of Murragamba and 'Eastern' Creeks at the time the Stage 2 EA was prepared. The nearest daily read gauge is located at Ulan Post Office (*BoM Gauge No 62036*), which is situated 5½ kilometres to the west within the adjoining catchment of Moolarben Creek. Daily read rainfall records are available for this gauge extending back to 1906.

It is noted that since the completion of the Stage 2 EA, daily read rainfall has been recorded at the MCC. This has been recorded since September 2009 and has been considered in this report.

A long term daily-read gauge is also located at Gulgong Post Office (*Gauge No 62013*), which is about 26 kilometres south-west of the Murragamba and 'Eastern' Creeks catchments. This gauge has been operational since 1881, but was more recently upgraded to a synoptic rainfall gauge.

The nearest long term pluviometer that could provide reliable information on rainfall intensity is more than 30 kilometres to the west.

Therefore, notwithstanding the data collected recently which reflects a relatively short timeframe, there is no rainfall data available for the catchments of Murragamba and 'Eastern' Creeks, or for nearby adjoining valleys, that could be interrogated to provide a reliable representation of catchment rainfall intensity.

Other Water Users

The majority of the Murragamba and 'Eastern' Creeks catchments will be given over to mining as part of Stage 2. The majority of the two valleys are owned either by MCM or by Ulan Coal Mines Limited (*UCML*). It is understood that UCML have no current or planned operations in either valley. As a result, MCM is the only existing water user in either valley.

It is acknowledged that riparian flows from Murragamba and 'Eastern' Creeks contribute, albeit in a very minor way, to the streamflows carried by Wilpinjong Creek. Although the streamflow contribution from Murragamba and 'Eastern' Creeks is small, allowance has been made within the overall water strategy to ensure that existing riparian flows are maintained and that downstream users have the potential to access water resources within Wilpinjong Creek in accordance with existing licensing.

Water Quality Data for 'Eastern' Creek and Upper Section of Murragamba Creek

Details of available water quality data are documented in *Section 3.3* of the *SWMS* Report (*November 2008*). This data was compiled from a water quality monitoring program that was developed two years prior to submission of the Stage 1 EA. The water quality monitoring program was developed to provide baseline data that could be used to characterise the water quality of streams within the Project Boundary.

It is recognised that only two water quality monitoring sites are located within the area covered by Stage 2 and that both of these are sited within the lower Murragamba Creek valley. However, the following points need to be acknowledged in understanding the reasons for the limited number of sampling points:

- Both Murragamba and 'Eastern' Creeks are intermittent and therefore rarely hold water. Water only exists along the bed of the creeks during a rainfall event or flood, except in the lower 500 metres of both creeks where shallow ponding can occur for a short period after a rainfall event.

  Hence, there is limited capacity to sample the water column under average dry weather flow conditions as the streams rarely hold water.

- The Ulan area was in severe drought during most of the period over which sampling for water quality occurred. These conditions further restricted the capacity for meaningful sampling and monitoring of stream water quality.

It should also be noted that the surface water management strategy is based on all discharges from both Murragamba and 'Eastern' Creeks meeting guideline trigger values for physical and chemical water quality as defined in the ANZECC Guidelines for upland rivers (*ANZECC 2000*). Therefore, riparian flows that enter Wilpinjong Creek and ultimately flow into Wollar Creek, will meet water quality criteria and will in all likelihood, be of better quality than the quality of runoff from the existing catchments.

3.1.3 Development Of Baseline Data Sets For Water Quality, Streamflow and Geomorphic Conditions

The surface water management strategy for Stage 2 is built around replacing most of the existing creek system and floodplain landform. The new creek system will need to function so that it distributes catchment runoff to the receiving waters both during the period of mining and post-mining. The need to ensure that the creek system can function during mining means that the alignment of the existing creek system will be substantially altered. Therefore, the surface water management strategy is about <u>designing</u> a creek system that can function under average dry and wet weather flow conditions, and not about recreating the existing system. As a result, baseline data defining existing stream characteristics has less relevance.

Notwithstanding, it is understood that all available water quality data-sets have been incorporated within the *SWMS* Report (*November 2008*) and other specialist reports that form part of the Stage 2 EA. This includes data on baseflow and surface water interactions, springs and stream gradients and geomorphic changes across the catchments. Furthermore, MCM has committed to recording flow and defining the flow yield from the two creeks.

3.1.4 Anecdotal Observations Of Creek Flow System

Classification of the Murragamba and 'Eastern' Creeks as ephemeral streams has been based on the interpretation of the prevailing surface water hydrology, which has considered the catchment characteristics relative to the recorded rainfall data. However, it is also supported by observations made during detailed field investigations.

In this regard, two separate site inspections were undertaken. The first occurred on 23rd May 2007 and involved walking the length of Murragamba Creek in the company of the aquatic and terrestrial ecologists on the project team. In the week leading up to the site visit, a total of 41 mm of rain was recorded at the Bureau of Meteorology's Gulgong Post Office Rainfall Gauge (*Gauge No. 62013*). The record shows that 36.8 mm of this rainfall fell on the 18th May 2007. The same station indicates a total of 72.6 mm of rain was recorded in the month leading up to the site visit. This can be compared with the average monthly rainfall for May at Ulan of 41.8 mm. However, during the site visit, only ponded areas of water in low lying sections of Murragamba Creek were present. Hence, there was negligible baseflow present in the system.

A second site inspection was undertaken on 29th October 2007. This site inspection involved walking along the majority of 'Eastern' Creek and documenting the morphology of the channel. In the week leading up to the site visit, a total of 56.7 mm was recorded at the Gulgong Post Office Gauge. This included 16 mm of rainfall that was recorded on the 26th October 2007 and 34 mm that was recorded on 27th October 2007. The average monthly rainfall for October at Ulan is 55.8 mm. However despite the significant rainfall leading up to the site visit there was negligible flow present in the system.

If a baseflow were present in either the creek system, it would be expected that some flow would be present following either of the rainfall events described above. However, this was not the case, with only localised ponding within depressions along both channels. Clearly both streams are intermittent and have negligible baseflow.

3.2 ADEQUACY OF THE FLOOD ANALYSIS USED TO ASSESS THE POTENTIAL IMPACTS OF THE MINE

3.2.1 Hydrologic Model Calibration

The hydrologic model that was developed to assess flood conditions along Murragamba and 'Eastern' Creeks has not been calibrated to any streamflow data. However, there is the potential to calibrate the hydrologic model to streamflow data recorded at the Ulan gauge as a result of flooding of the Goulburn River.

As discussed, all available rainfall and streamflow data for the area has been interrogated. The only nearby streamflow gauge is located on the Goulburn River at Ulan. However, the available data shows that the gauge was only operational between 1956 and 1982. Therefore, calibration of the model to the 1955 flood of record is not possible.

In addition, the streamflow gauge data could only be used in calibration of the hydrologic model for the upper Goulburn River and would not be useful in calibrating the hydrologic models for the Murragamba Creek and 'Eastern' Creek catchments. It should be noted that this was reported on page 10 of the Flood Impact Assessment Report that was prepared for the Stage 1 EA.

Notwithstanding, the recorded data for the Ulan gauge has been reviewed and floods identified that could be used to validate (not calibrate) the hydrologic models developed for the Murragamba and 'Eastern' Creeks catchments.

Based on the data review, it appears that a number of floods occurred at Ulan between 1979 and 1982 that have the potential for use in validating the hydrologic models. However, comparison of the associated peak flows to the results of the hydrologic analysis that was completed as part of the Flood Impact Assessment for the Stage 1 EA, shows that these events were significantly smaller than the design 5 year recurrence flood.

It is generally not appropriate to base the calibration of a hydrologic model on recorded data for small floods, particularly when primary objective of the hydrologic model is to investigate larger events such as the 100 year recurrence flood. Furthermore, the results from the flood modelling that was undertaken for the Stage 2 EA for both Murragamba and 'Eastern' Creeks, show that floodwaters are retained in-channel in all events up to the design 20 year recurrence flood.

Accordingly, reliable calibration of the hydrologic model is not feasible due to the absence of reliable and relevant recorded data.

3.2.2 Flood Modelling

Results from Hydraulic Modelling for Design Flood Events

The results of simulations that were undertaken for the 5, 20 and 200 year recurrence floods and the Probable Maximum Flood (*PMF*) have been extracted from the HEC-RAS flood model. These results are summarised in tabular form in **Appendix A** for existing conditions for both Murragamba and 'Eastern' Creeks. Tributary name and cross-section references in these tables should be read in conjunction with the *Figure 6* of the *SWMS* Report, which has been reproduced and included within **Appendix A** of this report.

Hydraulic Model Calibration and Sensitivity Analysis

It is recognised that no calibration of the HEC-RAS hydraulic model that was developed and used to define flood characteristics along Murragamba and 'Eastern' Creeks has been undertaken. However, the absence of any calibration reflects the lack of recorded data for historical floods in either valley. That is, there is no recorded flood level data available for either Murragamba or 'Eastern' Creeks. Hence, it is not possible to calibrate the HEC-RAS flood models that have been developed for the valleys.

It is also suggested that there is a need for a sensitivity analysis to be undertaken on the HEC-RAS modelling results for the 5 and 100 year recurrence events and the PMF. It was suggested that the sensitivity analysis should consider the sensitivity of the flood modelling results to changes in roughness and to changes in flow.

The results of the modelling that was undertaken to assess flood conditions along Murragamba and 'Eastern' Creeks are documented in *Chapter 5* of the *SWMS* Report. The significance of flooding in the valley is best represented by the extent of the 100 year recurrence flood as shown for each creek in *Figure 9* of the *SWMS* Report. This shows that floodwaters are typically restricted to a relatively narrow corridor along either side of the creek line in both valleys. As a result, floodwaters are typically retained within the incised sections of the channels and the creeks themselves do not have extensive floodplains. This is particularly the case in the upper two-thirds of Murragamba Creek and along all but the central section of 'Eastern' Creek.

The flood extent mapping indicates that the creeks are typically incised within the respective valleys and that minor variations in in-channel roughness are unlikely to significantly alter flood extents. Furthermore, it shows that the creeks themselves primarily function as drainage corridors and that channel stability is of greater significance than peak flood level. That is, flooding is a non-issue.

In that context, it needs to be recognised that the proposal to divert the streams and construct new replacement streams post-mining, reduces the relevance of the existing flood regime. The replacement streams will be designed to carry the post-mining flood flows within a new landform. Accordingly, an analysis to assess the sensitivity of the existing system to variations in roughness and flow is not particularly relevant to the post-mining creek and valley floor landform.

Notwithstanding, an analysis has been undertaken to assess the sensitivity of flood characteristics to changes in roughness and flow. This assessment is summarised in **Appendix B** and shows the predicted increase in peak flood level and in-channel flow velocity during the 100 year recurrence flood for the following:

- a global 10% increase in in-channel roughness; and,
- a 10% increase in flow.

The results of the analysis show that 10% increases in roughness or flow will result in relatively minor increases in peak flood level in floods up to the 100 year recurrence flood. The tables presented in **Appendix B** indicate that peak flood levels increase by less than 100 mm. Increases of this magnitude will not manifest as a significant change in flood extent along either of Murragamba Creek or 'Eastern' Creek.

A 10% increase in roughness will serve to reduce peak flow velocities. The results of the analysis show that the reductions in events up to the 100 year recurrence flood are relatively minor and in all cases less than 0.3 m/s.

A 10% increase in flow will understandably increase in-channel flow velocity. The results of the sensitivity analysis show that a 10% increase in flow will lead to increases in in-channel flow velocity of less than 0.1 m/s.

The results of the additional sensitivity simulations indicate that the HEC-RAS model is not sensitive to changes in roughness characteristics and/or flow. On that basis, it is considered to be a suitable tool for use in characterising flood conditions along the existing creeks and for characterising in-channel flow velocity.

4. ADDITIONAL WATER BALANCE MODELLING INVESTIGATIONS

4.1 SUMMARY OF WATER BALANCE DEVELOPMENT FROM THE STAGE 2 EA

WorleyParsons carried out a range of water balance analyses for Stage 2, all of which are documented in the *SWMS* Report.

Subsequent to this, a number of changes have been made to the Project (*Preferred Project*). In addition, observations have been made and data collected of water usage associated with Stage 1 approval mining operations. As a consequence, parameters for the water balance model have been updated and the model used to re-simulate projected water usage at MCC.

The following section documents the findings of an updated water balance that has been completed for the Preferred Project.

4.1.1 MCC Stage 1

Since MCC began operations associated with Stage 1 mining, analysis has been completed to estimate the net water usage requirements of the CHPP. The analysis suggests that on average, 186 ML of water is used by the CHPP per 1 million tonnes (Mt) of washed *ROM* coal product.

A review has also been conducted of the requirements for dust suppression. Based on the surface area of the mine where dust suppression is currently required, it is estimated that a total of 1.1 ML/day is used for dust suppression. Since the mining approval allows operation seven days a week, this rate of water usage equates to a total volume of water of approximately 402 ML used per year for dust suppression.

MCM has advised that 4.372 Mt of coal was mined and processed by the CHPP in 2010.

The resultant estimated water demand at Stage 1 in 2010 is summarised in **Table 2** below. From the available data, the total water used for mining operations during 2010 is estimated to be 1,235 ML. When considering the volume of water used and the mass of coal mined and processed, the ROM water usage factor during 2010 can be calculated to be 282.5 Megalitres per million tonnes (*ML/Mt*) of coal.

Table 2 ESTIMATED WATER USAGE IN 2010 AT STAGE 1

AREA OF USE	WATER DEMAND (ML/year)
Coal handling and preparation plant (*4.372 Mt Coal*)	813
Dust suppression across open cut and mine infrastructure areas (*assuming 1.1 ML/day*)	402
Potable (bath-house) (*assumed*)	20
Total Demand	1,235

4.1.2 Projected Maximum Water Usage for MCC

The analysis to estimate water usage at the MCC has been used to develop a Run-of-Mine (*ROM*) factor for the combined Stage 1 and 2 operating conditions. At the maximum production rate, the MCC will mine approximately 17 Mt of ROM coal.

At year 20, the production schedule utilised for modelling purposes has assumed up to 13 Mt of Coal will be mined from OC4 and OC3, and an additional 4 Mt will be mined from UG4. Only coal that is extracted from open cut mines is proposed to be washed and processed by the CHPP. Applying the ROM factor identified from Stage 1 operations yields a total water requirement for the CHPP of 2,418 ML at maximum production.

Additionally, the total surface area of haul roads has been estimated from the mine plans and an assessment made of the potential water usage for dust suppression. This has been based on an assessment of the amount of water used for dust suppression which is lost from these surface areas as a result of evaporation and infiltration. From this assessment, the total water demand for dust suppression across the MCC will increase to 2.2 ML/day at maximum production.

The representative annual rainfall record being applied to the water balance model for "average" conditions (*refer* **Section 4.4.1**) shows that rainfall exceeding 20 mm in a 24 hour period occurring on nine separate occasions. It has been assumed that dust suppression is not required when this depth of rainfall occurs. Accordingly, for an average year, there will be a total of 356 days out of 365 days when dust suppression is required. From this, the total net water usage for dust suppression is calculated to be 783 ML/year.

The resultant water demand distribution for the MCC is listed in **Table 3**. The total volume of water required for mining equates to a ROM factor of 227 ML/Mt.

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Table 3 REVISED WATER DEMAND DISTRIBUTION AT MAXIMUM WATER USAGE

AREA OF USE	USAGE RATE UNITS	USAGE RATE (ML/unit)	QUANTITY (unit)	MAXIMUM WATER DEMAND (ML/year)
Coal handling and preparation plant (13 Mt open cut)	(ML/Mt)	186	13 Mt	2,418
Dust suppression across open cut and mine infrastructure areas	(ML/day)	2.2	356 days	783
Potable (bath-house) (*assumed*)	ML/yr	50	1 year	50
Use in underground area (*assumed*)	ML/Mt	150.25	4 Mt	601
			Total Maximum Demand	3,852
			Calculated ROM Factor for water balance (ML/Mt)	227

4.1.3 Supplementary Water Resources Available for Mining Operations

Since exhibition of the Stage 2 EA, MCM and UCML secured a formal Water Sharing Agreement (*WSA*). This agreement was formalised on 10th August 2009. Among other things, the WSA provides for the transfer of a minimum of 1,000 ML per year from the Ulan mine to the MCC.

Accordingly, the additional water available from the WSA has been included in water balance modelling completed for the Preferred Project.

4.1.4 Additional Modifications to the Water Balance

The fundamental water balance modelling philosophy which was described in *Section 8.3* of the *SWMS* Report has been retained. However, the water balance model input parameters have been modified to incorporate the predicted site water usage data (*refer* **Table 3**) and the WSA. In addition, a number of modifications have been made to the various model inputs, which include:

- Assumed groundwater inflow to the active open cut and underground mine pits has been updated to reflect groundwater modelling completed for the Preferred Project's mine pit sequence by RPS Aquaterra;
- Assumed volumes of water pumped from the northern borefield have been updated to reflect groundwater modelling carried out by RPS Aquaterra; and,

- Disturbed catchment areas, which are assumed to contribute surface water run-off used for mining, have been updated to reflect the OC1, OC2, OC3, and OC4 mine pit sequences as presented in the PPR. The contributing catchment areas are assumed to include all disturbed surface areas, including the active pit and areas undergoing rehabilitation.

4.2 WATER SOURCES FOR MINE OPERATIONS

As outlined above, water is available for use in mine operations from a number of different sources. Additional detail of the quantity of water available from these sources and the assumptions made regarding catchment areas and dam sizes is detailed below.

4.2.1 Mine Pit Inflows

Groundwater modelling has been revised by RPS Aquaterra (*2011*) to define the predicted mine pit inflows across the open cut and underground mines at the MCC. A summary of the predicted annual inflows to each open cut or underground mine is provided in **Table 4**.

4.2.2 Potential Inflows from Northern Borefield

Groundwater is stored in the Permian coal measure, which is located in the sub-strata above UG4. MCM has obtained a licence to extract this water for mining purposes. This water source is henceforth referred to as the northern borefield.

The inflows available from the northern borefield have been determined based on groundwater modelling carried out by Aquaterra for the Preferred Project. The predicted inflows reported in the Preferred Project Report for each year of mining are provided in **Table 4**.

The water balance model has been structured so that water pumped from the northern borefield is used first, together with inflows to the open cut and underground mines. This hierarchy has been adopted to maintain consistency with the groundwater modelling assumptions and provides a conservative approach to site water management.

4.2.3 Surface Water Infrastructure

A series of sediment dams will be constructed throughout disturbed catchment areas to facilitate the collection and conveyance of surface water that falls within "dirty water" catchments. Indicative dam sizings, together with catchment areas and assumed years of operation are summarised in **Table 5**.

Figure 1 provides a graphical representation of the dirty water catchment extents which have been adopted for the purposes of modelling run-off as mining progresses within OC4. The catchment extents have been based on the OC4 mine pit progression proposed for the Preferred Project, together with the rehabilitation projections. The period during which each catchment is defined as a "disturbed" catchment is based on the time interval between the commencement of mining and rehabilitation.

As described in the *SWMS* Report, and updated for the *M&ECDCD* Report, surface water infrastructure has been designed to facilitate the diversion of clean water, that is run-off from undisturbed or rehabilitated catchments, away from the active pit throughout the duration of mining in OC4. Clean water run-off has been excluded from the dirty water balance.

The storage volume given for each of the sediment dams listed in **Table 5** has been based on capturing the volume of run-off generated by the catchment area during the 20 year recurrence 1 hour duration rainfall event . This is in accordance with the guidelines for sediment dams outlined in the guideline document titled *'Managing Urban stormwater: Soils and Construction Volume 1* and *Volume 2E Mines & Quarries Guidelines'*.

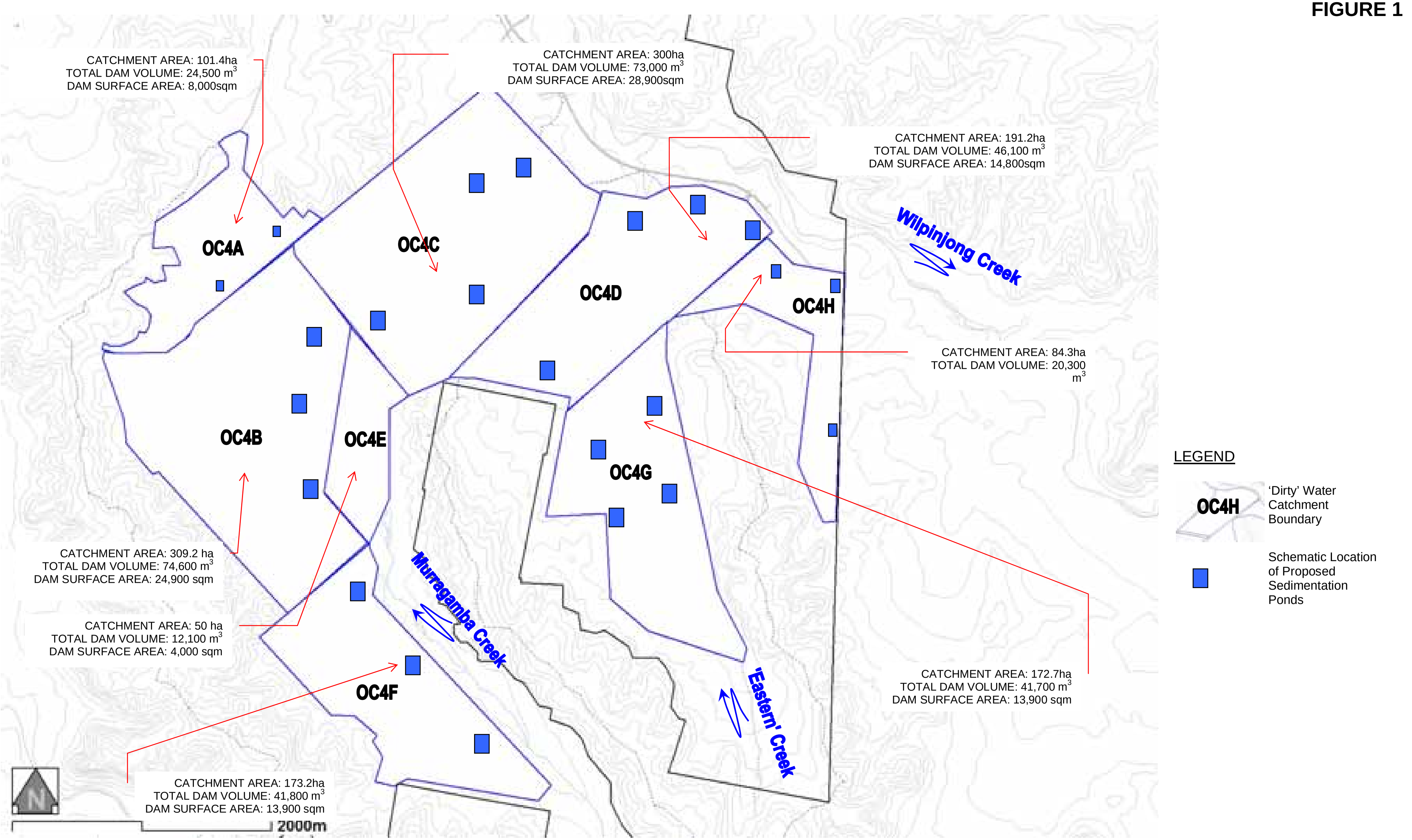
Similarly, the indicative catchments for OC1, OC2 and OC3 are shown in **Figure 2**. However, this figure is a schematic only and is intended to provide a guide for the potential dam size required to store the targeted run-off. In reality, the actual arrangement of the dams may vary subject to mining requirements.

4.2.4 Ulan Water Sharing Agreement

It is understood that water from the "East Pit" of the Ulan Mine will be delivered via a 250 mm diameter poly pipe to the CHPP Dirty Water Dam located within the rail loop of the infrastructure area of the MCC, in accordance with the WSA between UCML and MCM (*refer* **Section 4.1.3**).

Water requirements for Stage 2 of the mine will be delivered from the CHPP Dirty Water Dam via poly pipe to a range of water management structures (*tanks, reservoirs, dams, etc*) that are to be located within the Stage 2 mine area; that is, within the Murragamba and 'Eastern' Creeks valleys. A minimum of 1,000 ML/ year has been allowed for in the agreement.

FIGURE 1



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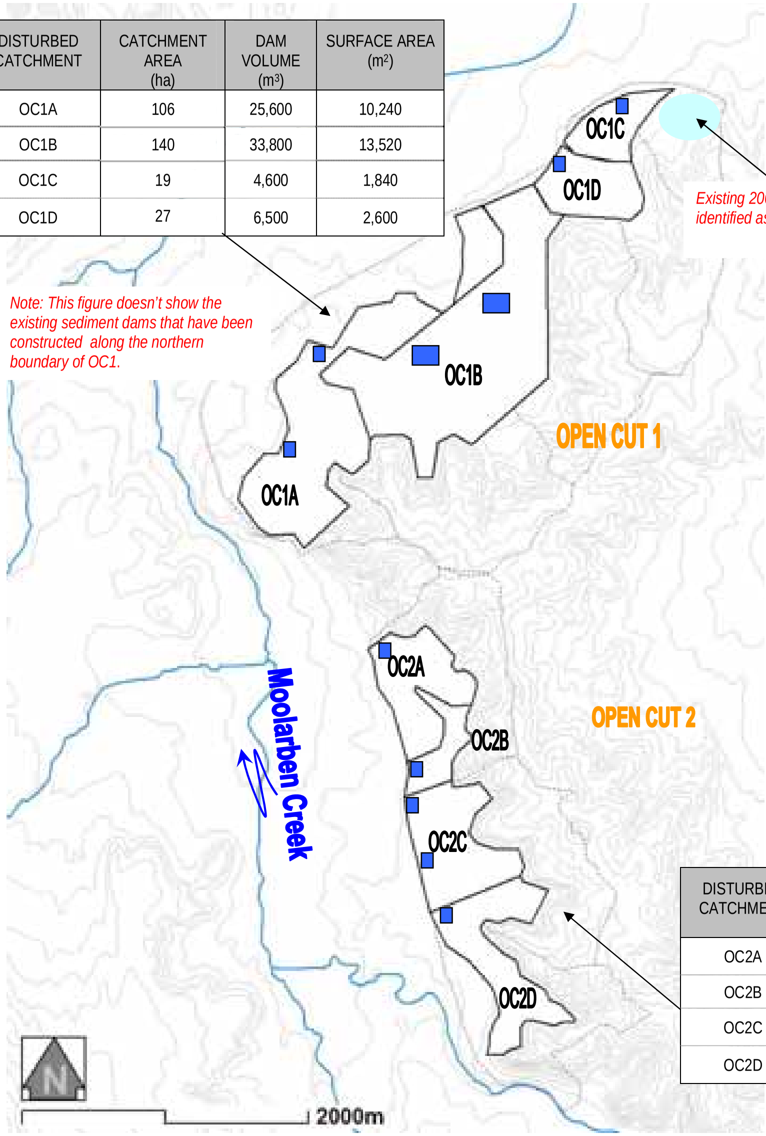
SCHEMATIC LAYOUT OF DIRTY WATER CATCHMENTS FOR THE PROGRESSION OF THE OPEN CUT 4 MINE

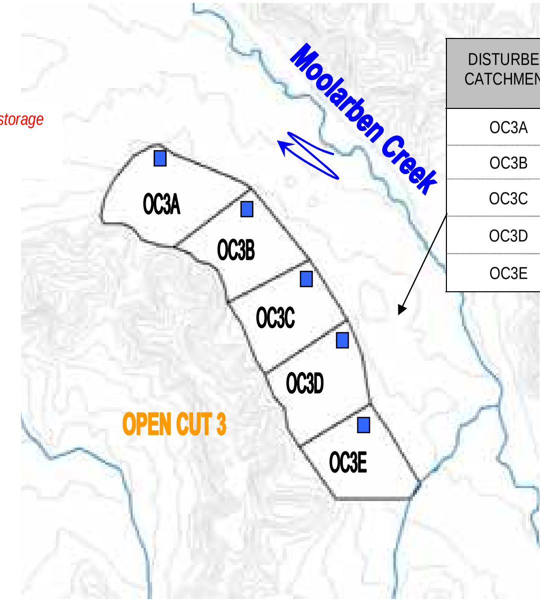
FIGURE 2

DISTURBED CATCHMENT	CATCHMENT AREA (ha)	DAM VOLUME (m^3)	SURFACE AREA (m^2)
OC1A	106	25,600	10,240
OC1B	140	33,800	13,520
OC1C	19	4,600	1,840
OC1D	27	6,500	2,600

Note: This figure doesn't show the existing sediment dams that have been constructed along the northern boundary of OC1.

Existing 200ML dirty water storage identified as OC1 Dam 10





DISTURBED CATCHMENT	CATCHMENT AREA (ha)	DAM VOLUME (m^3)	SURFACE AREA (m^2)
OC3A	43.9	10,600	4,200
OC3B	35.9	8,600	3,500
OC3C	34.7	8,300	3,300
OC3D	37.5	9,000	3,600
OC3E	34.5	8,324	3,300

DISTURBED CATCHMENT	CATCHMENT AREA (ha)	DAM VOLUME (m^3)	SURFACE AREA (m^2)
OC2A	38	9,200	3,680
OC2B	14	3,400	1,360
OC2C	42	10,100	4,040
OC2D	45	10,900	4,360

LEGEND

- 'Dirty' Water Catchment Boundary
- Schematic Location of Proposed Sedimentation Ponds

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SCHEMATIC LAYOUT OF DIRTY WATER CATCHMENTS FOR THE PROGRESSION OF THE OPEN CUTS 1, 2 AND 3

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Table 4 PREDICTED GROUNDWATER INFLOWS AT DIFFERENT MINES WITHIN THE MOOLARBEN COAL COMPLEX (*Aquaterra, 2011*)

Mine Year	OC1 (ML/yr)	OC2 (ML/yr)	OC3 (ML/yr)	OC4 (ML/yr)\	UG1 (ML/yr)	UG2 (ML/yr)	UG4 (ML/yr)	TOTAL INFLOW TO MINES	VOLUME PUMPED FROM NORTHERN BOREFIELD
1	80.3	21.0	0.0	179.0	0.0	0.0	0.0	280.3	1101.0
2	102.1	6.3	0.0	95.1	0.0	0.0	0.0	203.5	1146.1
3	150.6	8.6	0.0	100.4	0.0	0.0	0.0	259.7	1037.4
4	0.0	9.8	0.0	92.2	218.1	0.0	0.0	320.2	1038.3
5	0.0	0.0	0.0	75.8	291.6	0.0	0.0	367.4	932.4
6	0.0	0.0	0.0	55.1	302.4	0.0	0.0	357.5	926.3
7	0.0	0.0	0.0	287.0	281.8	0.0	0.0	568.8	870.6
8	0.0	0.0	0.0	290.1	263.6	0.0	0.0	553.7	845.4
9	0.0	0.0	0.0	456.9	293.7	0.0	0.0	750.6	849.7
10	0.0	0.0	0.0	663.9	229.1	0.0	0.0	893.0	815.7
11	0.0	0.0	0.0	516.3	364.3	0.0	0.0	880.6	930.5
12	0.0	0.0	0.0	417.2	324.1	0.0	0.0	741.3	1032.3
13	0.0	0.0	0.0	413.0	321.6	0.0	0.0	734.6	1104.8
14	0.0	0.0	0.0	360.0	287.1	1.7	155.6	804.4	1062.9
15	0.0	0.0	0.0	321.1	0.0	8.9	275.0	604.9	1128.8
16	0.0	0.0	0.0	292.6	0.0	6.6	299.0	598.2	1135.0
17	0.0	0.0	0.0	495.2	0.0	2.6	360.7	858.5	1135.4
18	0.0	0.0	0.0	393.1	0.0	0.0	380.4	773.5	1112.3
19	0.0	0.0	0.0	309.2	0.0	0.0	443.8	753.0	1100.4
20	0.0	0.0	1.6	427.4	0.0	0.0	439.1	868.1	1106.9
21	0.0	0.0	34.0	0.0	0.0	0.0	510.0	544.1	1135.3
22	0.0	0.0	29.1	0.0	0.0	0.0	687.5	716.6	945.4
23	0.0	0.0	69.3	0.0	0.0	0.0	1176.6	1245.9	274.1
24	0.0	0.0	96.6	0.0	0.0	0.0	940.1	1036.7	856.5

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Table 5 INDICATIVE DIRTY WATER DAM CATCHMENTS AND VOLUMES ASSUMED FOR MINE WATER BALANCE

DIRTY WATER DAM IDENTIFIER	CONTRIBUTING CATCHMENT AREA (ha)	TOTAL DAM VOLUME (m^3)	DAM SURFACE AREA (m^2)	ASSUMED YEARS OF OPERATION
Open Cut 1				
OC1A	106	25,600	10,240	1 - 2
OC1B	140	33,800	13,520	2 - 8
OC1C	19	4,600	1,840	2 - 8
OC1D	27	6,500	2,600	3 - 8
Open Cut 2				
OC2A	38	9,200	3,680	1 - 5
OC2B	14	3,400	1,360	2 - 6
OC2C	42	10,100	4,040	3 - 7
OC2D	45	10,900	4,360	4 - 10
Open Cut 3				
OC3A	43.9	10,600	4,200	20 - 24
OC3B	35.9	8,600	3,500	21 - 24
OC3C	34.7	8,300	3,300	22 - 24
OC3D	37.5	9,000	3,600	23 - 24
OC3E	34.5	8,324	3,300	24
Open Cut 4				
OC4A	101.4	24,500	8,000	1 - 2
OC4B	309.2	74,600	24,900	1 - 13
OC4C	300	72,300	28,900	7 - 12
OC4D	191.2	46,100	18,400	11 - 17
OC4E	50	12,100	4,000	13 - 17
OC4F	173.2	41,800	13,900	16 - 19
OC4G	172.7	41,700	13,900	17 - 22
OC4H	84.3	20,300	6,700	20 - 23

Note:

The contributing catchment area for OC4 is the total possible area available. In some years, the assumed catchment area has been varied to account for the progression of the mine pit and the associated impact on the assumed dirty water catchment area.

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4.3 MODEL DESCRIPTION AND ASSUMPTIONS

The proposed surface water management strategy for the mine site is presented schematically in **Figure 3**.

The philosophy applied to the revised water balance analysis is presented schematically in **Figure 4**. This flow chart details the structure of the water balance model and the prioritisation of water resources in the water balance model, from the range of sources available to MCM.

The assumptions applied to the MCC water balance analysis are summarised in the following sections.

4.3.1 General Assumptions

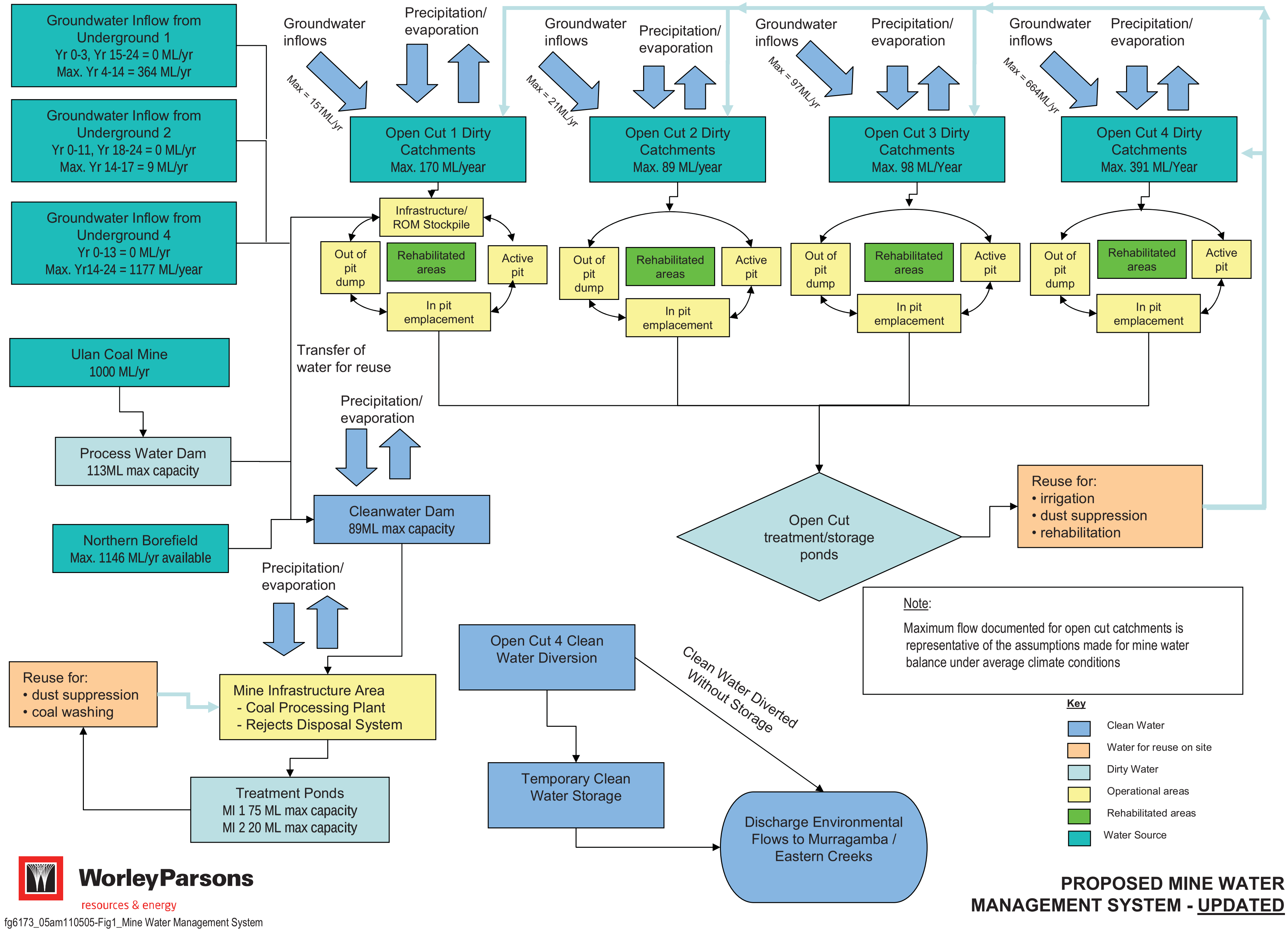
The following general assumptions have been incorporated into the water balance model.

- The water balance analysis is based on a monthly time step.
- The volume of water required by mining operations = 227x ROM Mtpa (*refer* **Section 4.1.2**).
- The volume of rainfall collected by a particular sub catchment of the mined area has been factored in order to generate the predicted run-off for the sub catchment by applying:
  - a runoff coefficient of 0.25; and,
  - an initial loss of 10 mm, applied per month.

  A review of the available literature was conducted to establish an appropriate run-off coefficient for the mine site, including investigations documented in the report titled *'Water Quality and Discharge Predictions for Final Void and Spoil Catchments'*, which was undertaken for the Australian Coal Association Research Program (*ACARP*). While there was some variation in the data presented, it is considered that a run-off coefficient between 0.2 and 0.3 may be considered representative for many overburden and mine pit areas. Accordingly, a coefficient of 0.25 has been adopted.

  It is recognised that the run-off coefficient will vary according to the material properties of the placed overburden and active mine pit, as well as the proportion of impermeable area that collects run-off from disturbed catchments. Accordingly, a sensitivity analysis of the adopted run-off coefficient has been undertaken (*refer* **Section 4.5.2**).
- Details of the rainfall data applied to the water balance for the different scenarios investigated is summarised in **Table 6** below. Additional details of these sequences can be found in the *SWMS* Report.
- Surface Water is assumed to be sourced from three areas:
  - disturbed catchments and their storage areas created through mining operations associated with OC4 (*refer* **Figure 1**);

FIGURE 3



PROPOSED MINE WATER MANAGEMENT SYSTEM - UPDATED

FIGURE 4

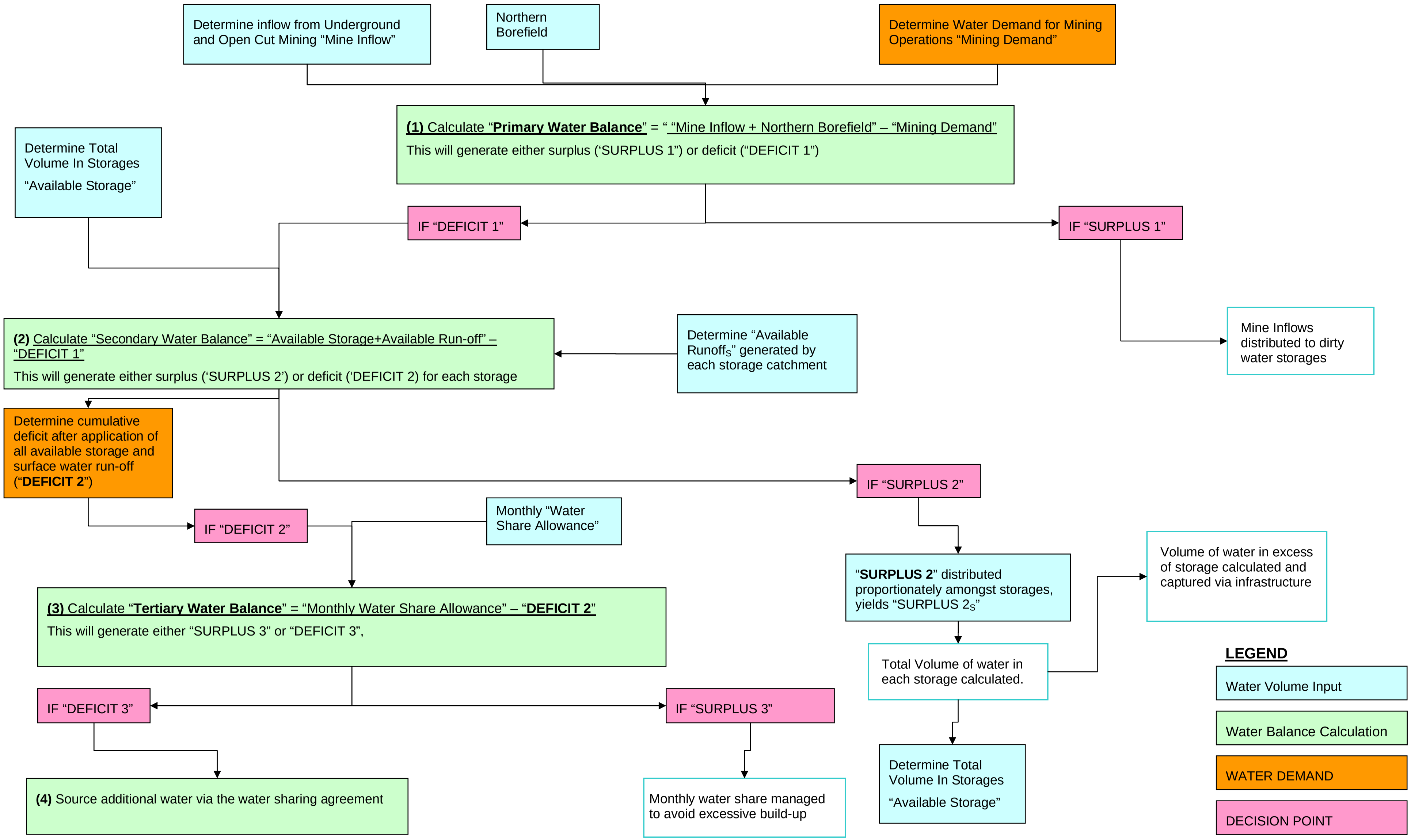


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Figure 2 –Water Balance Model Algorithm

DIAGRAMATIC REPRESENTATION OF WATER BALANCE MODELLING ALGORITHM AT A GIVEN MONTHLY TIME STEP

- the storages created to catch run-off from the mine infrastructure areas; and,
- disturbed catchments and storages created through mining undertaken as part of Stage 1 of the MCC (*i.e. OC1, OC2 and OC3*) (*refer* **Figure 2**).

4.3.2 Prioritisation of Water Sources in the Model

The following assumptions were made in developing the modelling philosophy presented in **Figure 4**.

A hierarchy was developed for the available water sources as described in **Section 4.2**. The hierarchy indicates the priority for water usage from the various sources within the mining operation. The adopted hierarchy is as follows:

(i) Groundwater inflows to the mine surface area from underground and open cut areas of the Preferred Project, together with the volume of water pumped from the northern borefield located above UG4.

(ii) Surface water captured by storages located within the mine footprint. This includes runoff from overburden areas of the mine and runoff from the active pit area. The water balance model considers:

- water available in a storage at the beginning of the month; and,
- runoff from the sub catchment draining to the storage(s) during the month.

Any excess water generated by a catchment in the monthly time step, which is not required for mining is used to fill the available dams.

As outlined in **Figure 4**, the water balance prioritises groundwater inflows from the open cut and underground mines. This step is referred to as the “Primary Water Balance”. That is, groundwater inflows from open cut and underground mines are assumed to be used first for mining processes.

Following this, run-off collected and stored at sediment dams constructed within disturbed areas is applied to the model. This includes run-off in the active pit and overburden areas. The application of these inflows from surface water catchments is referred to as the “Secondary Water Balance”.

Where a surplus of water exists after the “Secondary Water Balance” (*refer* **Figure 4**), it is distributed proportionately between all of the storages. The quantity of surplus arriving at any particular storage is based on a percentile distribution of the surplus according to storage area and dam size.

Where the model predicts a deficit to remain after the “Secondary Water Balance”, it can be made up from:

(iii) Water available from the WSA.

For a given year where the water deficit remaining after the Secondary Water Balance is less than 1000 ML, water available from the WSA will be controlled accordingly to avoid excessive build up. Water deficits in excess of 1000 ML can be managed by extracting additional water from the water sharing agreement.

4.4 RESULTS

4.4.1 Water Balance Simulations

The projected mine water demand detailed in **Section 4.1.2**, together with the available water sources identified in **Section 4.2**, have been applied to the water balance model. The results of the modelling have been used to identify the potential shortfall in water demand, which corresponds to the volume of water required from the WSA.

The model has been used to investigate the performance of the water balance for four climate sequences. The climate sequences investigated reflect the application of varying rainfall records to the water balance model and correspond to average, below average and above average rainfall series. In addition, a conservative dry weather scenario has been applied to years 6 to 16 of the water balance model. The four climate scenarios simulated by the model are summarised in **Table 6**. Further detail of the selection of the four climate scenarios is provided in *Section 8.3.1* of the *SWMS* Report.

It is recognised that evaporation from storage areas will in general vary to a small extent, as a function of the amount of rainfall during a given year, together with the number of sunny days, humidity and average temperature. In the absence of available historical data for the site, the long term average potential evapo-transpiration (*PET*) as recorded at the Ulan Post Office (*Gauge No. 62036*) has been applied to estimate losses from water storage areas due to evaporation for all four climate scenarios investigated.

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Table 6 ADOPTED WATER BALANCE RAINFALL DATA

RAINFALL SCENARIO	ADOPTED YEAR OF RAINFALL RECORD	ADOPTED ANNUAL RAINFALL (*mm*) (Gauge No. 62013)	ADOPTED ANNUAL PET (*mm*) (Gauge No. 62036)	ADOPTED AVERAGE ANNUAL RAINFALL PERCENTILE
Average Conditions	12/2006 – 12/2007	645	1,657	50%ile
"Dry Years" Scenario	Last 24 years of below average rainfall	519 [Range from 361 to 636]	1,657	28%ile
"Wet Years" Scenario	Last 24 years of above average rainfall	849 [Range from 695 to 1412]	1,657	90%ile
Conservative "Dry Years" Scenario	11 lowest rainfall years ever recorded, applied to years 6 to 16 of the water balance	358 [Range from 299 to 385]	1,657	2.5%ile

The results of the MCC water balance analyses for the climate scenarios are listed in each of **Table 7** to **Table 10**. The table numbering corresponds to Tables 16 to 19 of the *SWMS* Report that was included within the Stage 2 EA. Each table provided following effectively replaces the corresponding tables within the *SWMS* Report. Therefore, as an example, **Table 7** should be read as a replacement for *"Table 16"* within the *SWMS* Report.

The following details the information presented in each column within the tables:

• Column 4	Inflows from OC Mining	The volume of groundwater that enters the mine area as a consequence of mining coal from open cut operations. This has been based on the groundwater inflows provided by RPS Aquaterra (*refer* **Table 4**)
• Column 5	Inflows from UG Mining	The volume of groundwater that enters the mine area as a consequence of mining coal from underground operations. This has been based on the groundwater inflows provided by RPS Aquaterra (*refer* **Table 4**)
• Column 6	Northern Borefield Pumped Volumes	The volume of groundwater assumed to be pumped from the northern borefield. This has been based on modelling undertaken by RPS Aquaterra (*2011*)
• Column 7	Water Captured from Surface Water Storages within the Mine Area	The volume of surface water due to local catchment runoff and rainfall on the mine areas that is collected and used in any given year. This includes all surface water catchment areas such as open cut pits and overburden areas.
• Column 8	Deficit / Surplus	Deficit or surplus remaining after groundwater inflows to mine area, as well as captured surface water run-off is used. The year in which the greatest deficit is predicted has been highlighted in the table.

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Table 7 PPR WATER BALANCE RESULTS FOR "AVERAGE" RAINFALL CONDITIONS

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Groundwater Inflows From Open Cut Mining (ML/yr)	Groundwater Inflows from Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Captured From Mine Area Surface Water Storages (ML/yr)	Deficit / Surplus (ML/yr)
1	7.0	1589	280.3	0.0	1101.0	260	52
2	11.0	2497	203.5	0.0	1146.1	365	-782
3	11.5	2611	259.7	0.0	1037.4	453	-860
4	12.0	2724	102.0	218.1	1038.3	479	-886
5	12.3	2802	75.8	291.6	932.4	479	-1023
6	14.4	3263	55.1	302.4	926.3	457	-1522
7	15.4	3491	287.0	281.8	870.6	551	-1501
8	16.2	3685	290.1	263.6	845.4	526	-1760
9	16.3	3705	456.9	293.7	849.7	479	-1625
10	16.4	3720	663.9	229.1	815.7	332	-1679
11	15.8	3587	516.3	364.3	930.5	414	-1363
12	16.3	3710	417.2	324.1	1032.3	414	-1523
13	16.2	3681	413.0	321.6	1104.8	274	-1568
14	15.4	3485	360.0	444.3	1062.9	243	-1375
15	16.0	3638	321.1	283.9	1128.8	243	-1661
16	15.3	3462	292.6	305.6	1135.0	343	-1386
17	15.3	3481	495.2	363.3	1135.4	442	-1045
18	15.7	3567	393.1	380.4	1112.3	306	-1375
19	16.8	3821	309.2	443.8	1100.4	306	-1661
20	16.9	3829	429.0	439.1	1106.9	231	-1575
21	16.6	3768	34.0	510.0	1135.3	251	-1790
22	16.0	3635	29.1	687.5	945.4	321	-1654
23	14.7	3344	69.3	1176.6	274.1	189	-1584
24	14.2	3225	96.6	940.1	856.5	174	-1154

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Table 8 PPR WATER BALANCE RESULTS FOR "BELOW AVERAGE" RAINFALL CONDITIONS

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Groundwater Inflows From Open Cut Mining (ML/yr)	Groundwater Inflows from Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Captured From Mine Area Surface Water Storages (ML/yr)	Deficit / Surplus (ML/yr)
1	7.0	1589	280.3	0.0	1101.0	227	19
2	11.0	2497	203.5	0.0	1146.1	190	-957
3	11.5	2611	259.7	0.0	1037.4	202	-1111
4	12.0	2724	102.0	218.1	1038.3	140	-1225
5	12.3	2802	75.8	291.6	932.4	288	-1214
6	14.4	3263	55.1	302.4	926.3	271	-1708
7	15.4	3491	287.0	281.8	870.6	130	-1921
8	16.2	3685	290.1	263.6	845.4	371	-1915
9	16.3	3705	456.9	293.7	849.7	484	-1620
10	16.4	3720	663.9	229.1	815.7	190	-1821
11	15.8	3587	516.3	364.3	930.5	166	-1610
12	16.3	3710	417.2	324.1	1032.3	387	-1549
13	16.2	3681	413.0	321.6	1104.8	186	-1656
14	15.4	3485	360.0	444.3	1062.9	260	-1358
15	16.0	3638	321.1	283.9	1128.8	108	-1797
16	15.3	3462	292.6	305.6	1135.0	192	-1537
17	15.3	3481	495.2	363.3	1135.4	388	-1099
18	15.7	3567	393.1	380.4	1112.3	218	-1463
19	16.8	3821	309.2	443.8	1100.4	402	-1565
20	16.9	3829	429.0	439.1	1106.9	94	-1759
21	16.6	3768	34.0	510.0	1135.3	177	-1912
22	16.0	3635	29.1	687.5	945.4	258	-1715
23	14.7	3344	69.3	1176.6	274.1	213	-1611
24	14.2	3225	96.6	940.1	856.5	60	-1271

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Table 9 PPR WATER BALANCE RESULTS FOR "ABOVE AVERAGE" RAINFALL CONDITIONS

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Groundwater Inflows From Open Cut Mining (ML/yr)	Groundwater Inflows from Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Captured From Mine Area Surface Water Storages (ML/yr)	Deficit / Surplus (ML/yr)
1	7.0	1589	280.3	0.0	1101.0	428*	220
2	11.0	2497	203.5	0.0	1146.1	426	-501
3	11.5	2611	259.7	0.0	1037.4	725	-588
4	12.0	2724	102.0	218.1	1038.3	992	-374
5	12.3	2802	75.8	291.6	932.4	1272	-230
6	14.4	3263	55.1	302.4	926.3	722	-1256
7	15.4	3491	287.0	281.8	870.6	734	-1318
8	16.2	3685	290.1	263.6	845.4	720	-1566
9	16.3	3705	456.9	293.7	849.7	673	-1431
10	16.4	3720	663.9	229.1	815.7	601	-1410
11	15.8	3587	516.3	364.3	930.5	738	-1038
12	16.3	3710	417.2	324.1	1032.3	671	-1265
13	16.2	3681	413.0	321.6	1104.8	731	-1111
14	15.4	3485	360.0	444.3	1062.9	353	-1265
15	16.0	3638	321.1	283.9	1128.8	465	-1440
16	15.3	3462	292.6	305.6	1135.0	493	-1236
17	15.3	3481	495.2	363.3	1135.4	638	-849
18	15.7	3567	393.1	380.4	1112.3	452	-1230
19	16.8	3821	309.2	443.8	1100.4	375	-1592
20	16.9	3829	429.0	439.1	1106.9	440	-1414
21	16.6	3768	34.0	510.0	1135.3	471	-1618
22	16.0	3635	29.1	687.5	945.4	427	-1546
23	14.7	3344	69.3	1176.6	274.1	381	-1443
24	14.2	3225	96.6	940.1	856.5	349	-983

* The results suggest that in the order of 424 ML of surface water run-off would not be captured for the first year of operations should pumping from the borefield be sustained

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Table 10 PPR WATER BALANCE RESULTS FOR THE "CONSERVATIVE DRY WEATHER" SCENARIO

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Groundwater Inflows From Open Cut Mining (ML/yr)	Groundwater Inflows from Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Captured From Mine Area Surface Water Storages (ML/yr)	Deficit / Surplus (ML/yr)
1	7.0	1589	280.3	0.0	1101.0	260	52
2	11.0	2497	203.5	0.0	1146.1	365	-782
3	11.5	2611	259.7	0.0	1037.4	453	-860
4	12.0	2724	102.0	218.1	1038.3	479	-886
5	12.3	2802	75.8	291.6	932.4	479	-1023
6	14.4	3263	55.1	302.4	926.3	178	-1801
7	15.4	3491	287.0	281.8	870.6	142	-1909
8	16.2	3685	290.1	263.6	845.4	304	-1982
9	16.3	3705	456.9	293.7	849.7	156	-1948
10	16.4	3720	663.9	229.1	815.7	21	-1990
11	15.8	3587	516.3	364.3	930.5	33	-1743
12	16.3	3710	417.2	324.1	1032.3	121	-1815
13	16.2	3681	413.0	321.6	1104.8	60	-1781
14	15.4	3485	360.0	444.3	1062.9	99	-1519
15	16.0	3638	321.1	283.9	1128.8	82	-1822
16	15.3	3462	292.6	305.6	1135.0	120	-1609
17	15.3	3481	495.2	363.3	1135.4	442	-1045
18	15.7	3567	393.1	380.4	1112.3	306	-1375
19	16.8	3821	309.2	443.8	1100.4	306	-1661
20	16.9	3829	429.0	439.1	1106.9	279	-1575
21	16.6	3768	34.0	510.0	1135.3	299	-1790
22	16.0	3635	29.1	687.5	945.4	318	-1654
23	14.7	3344	69.3	1176.6	274.1	240	-1584
24	14.2	3225	96.6	940.1	856.5	177	-1154

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4.4.2 Discussion of Results of Water Balance Modelling for MCC

The results presented in the **Table 7** to **Table 10** show that a deficit in the water required to meet mine demands is predicted to occur for years 2 to 24 of mining, prior to consideration of the WSA. The range in the surplus/ deficit during Years 1 to 24 is summarised in **Table 11**.

Table 11 PREDICTED WATER DEFICIT RANGE FOR CLIMATE SCENARIOS

CLIMATE SCENARIO	RANGE OF SURPLUS/DEFICIT (ML)	
	MAXIMUM	MINIMUM
Average (*refer* Table 7)	52	-1790
Below Average (*refer* Table 8)	19	-1921
Above Average (*refer* Table 9)	220	-1618
"Conservative Dry –weather" (*refer* Table 10)	52	-1990

In light of the results which show that a deficit remains in all years <u>except for the first year</u> across the four climate scenarios, the potential to meet the remaining deficit through the volume of water available from the WSA was assessed. **Table 12** presents a summary of the deficit remaining after application of the WSA.

Table 12 PREDICTED DEFICIT AFTER APPLICATION OF UP TO 1000 ML FROM WSA

MINE YEAR	AVERAGE CLIMATE CONDITIONS	BELOW AVERAGE CLIMATE CONDITIONS	ABOVE AVERAGE CLIMATE CONDITIONS	CONSERVATIVE DRY WEATHER SCENARIO
1	0	0	0	0
2	0	0	0	0
3	0	-111	0	0
4	0	-225	0	0
5	-23	-214	0	-23
6	-522	-708	-256	-801
7	-501	-921	-318	-909
8	-760	-915	-566	-982
9	-625	-620	-431	-948
10	-679	-821	-410	-990
11	-363	-610	-38	-743
12	-523	-549	-265	-815
13	-568	-656	-111	-781
14	-375	-358	-265	-519
15	-661	-797	-440	-822
16	-386	-537	-236	-609
17	-45	-99	0	-45
18	-375	-463	-230	-375
19	-661	-565	-592	-661
20	-575	-759	-414	-575
21	-790	-912	-618	-790
22	-654	-715	-546	-654
23	-584	-611	-443	-584
24	-154	-271	0	-154

Water Deficit

The results documented in **Table 12** suggest that <u>in excess</u> of 1000 ML/year available from the WSA will be required in the majority of years of operation to meet maximum production levels. The maximum deficit under <u>average</u> climate conditions is equal to 790 ML and is predicted to occur in year 21.

However, it is understood that the WSA stipulates there is a minimum of 1000 ML/year which can be sourced from UCML. Accordingly, it is assumed that any predicted deficit remaining after application of the available water sharing agreement will be met by accessing extra water from the WSA.

Furthermore, MCM is investigating potential means to increase water usage efficiency at the site, particularly in regard to operation of the CHPP. This is expected to generate a reduction in rate of water usage at the site and in turn reduce the deficit predicted above in **Table 12**. One possible scenario associated with a reduction in water usage requirements has been tested below in **Section 4.5.1**.

Water Surplus

In addition, there are a number of years (*four for the above average climate scenario*) when a surplus would exist should the full 1000 ML available from the WSA be taken. The years when this occurs have been highlighted in **Table 12**. Water supply from the WSA will be monitored and controlled to avoid excessive build up and the need to discharge off site in years when modelling suggests all 1000 ML is not required.

Separate to this, the results of the modelling predict that a water surplus will be generated in the first year's operations. The predicted volume is relatively minor for average climate conditions, below average climate conditions and "conservative dry weather" scenario and could be managed even if pumping from the borefield took place as per the modelling.

However, the results of the above average climate scenario indicate that there will be an excess of surface water run-off which is not captured by the surface water infrastructure. This is because the model has assumed that volumes pumped from the borefield will be prioritised over volumes available from surface water run-off, which leads to a build-up of water in storage areas. In reality however, this represents a very conservative scenario and pumping from the borefield would be controlled to avoid excessive build-up of water at the site and the associated need to release flows off-site.

4.5 SENSITIVITY ANALYSIS

Although additional data has been collected from the Stage 1 operations, it is recognised that the water requirements associated with coal processing and related activities such as dust suppression may vary subject to a range of factors. The changes associated with these factors may result in increased or decreased water demand. Accordingly, a sensitivity analysis has been undertaken to test the robustness of the site to meet water demand in the context of varying operational conditions.

Similarly, the volume of run-off generated throughout the life of the mine may vary as a consequence of the material properties and permeability of the mining and overburden surface areas. Accordingly, an assessment has been undertaken to test the robustness of the site to meet water demand and manage water supply under varying run-off conditions.

4.5.1 Variation in ROM factor

The initial water balance undertaken for the *SWMS* Report assumed a ROM factor of 208 litres of water for every tonne of coal which is mined (*or 208 ML/Mt*). This was based on previous experience of coal mining water demands elsewhere in the Hunter Valley.

The ROM water demand has been revised to be 227 ML/Mt as a consequence of analysis of water usage for Stage 1 operations at the MCC (*refer* **Section 4.1.2**).

As outlined above, it is recognised that water demand associated with various mining operations may vary subject to a range of factors. Accordingly, a sensitivity analysis has been undertaken to determine the impact on water usage associated with variation in the adopted ROM factor. The sensitivity analysis has been based on “average” rainfall conditions and the combined Stages 1 and 2 operations.

To test the sensitivity of water demand and usage at the MCC, the ROM factor adopted from the analysis detailed in **Section 4.1.2** has been increased and decreased by 10%. This equates to the following:

- 10% increase in ROM = 249 ML/Mt
- 10% decrease in ROM = 204 ML/Mt

The results of the sensitivity analysis are documented in **Table C1** (*where the assumed ROM factor, increased by 10%*) and **Table C2** (*representing the results of modelling once ROM factor is reduced by 10%*) of **Appendix C**. The results suggest that any variation in the ROM factor can be managed through modifying the amount of water drawn from the WSA as described above in **Section 4.4.2**.

4.5.2 Variation in Run-Off Volume

The dirty water balance assessed water demands for mining operations on a month by month basis. An initial rainfall loss of 10 mm per month and a runoff coefficient equal to 0.25 was adopted to calculate the amount of surface water runoff that is captured and stored for the water balance.

It is recognised that the volume of run-off generated from the disturbed catchment areas will vary subject to a number of parameters, including the soil properties of the placed overburden and active pits, the rate of infiltration to particular soil types and the relative proportion of permeable/ impermeable surfaces at the site.

Accordingly, analysis has been undertaken to ascertain the potential to continue mining operations under modified surface water makes. This has been carried out by testing the sensitivity of the water balance to variation in the adopted run-off coefficient between 0.15 and 0.35.

The results of the sensitivity analysis are documented in **Table C3** and **Table C4** in **Appendix C**. The results demonstrate that even if surface water run-off significantly increased to a level above what is currently predicted for the site under average conditions, a deficit would still remain after the application of water available from mine inflows and surface water catchment run-off. Alternatively, if run-off is less than predicted by the water balance model, the shortfall in water availability would be sourced from the WSA to make up any shortfall and meet the projected mining demand.

In both cases, all run-off generated at the site would still be captured and used.

4.6 TREATMENT OF DIRTY WATER

Runoff from disturbed areas could potentially contain excess sediment, elevated salinity or acidity. The level of treatment which is required for runoff from the disturbed areas will vary depending on its designated re-use.

Should the quantity of dirty water from mining operations exceed the dirty water storage capacity at any stage during the life of the mine, it is proposed that the dirty water storages (*or in particular the most downstream storage*) would be suitably treated by the following measures:

- Sedimentation through the existing dams incorporated within the MCC;
- Flocculation; and/or
- Addition of gypsum to remove sediment and pollutants from the water column.

As outlined above in **Section 4.4.2**, the site will operate on a deficit of water for Years 2 to 24. However, in the event that excess water is generated on site, excess water may be used to facilitate irrigation of areas undergoing rehabilitation. Alternatively, it may be discharged offsite in accordance with the Stage 1 approval and existing Environmental Protection Licence *12932*.

Where water is used to irrigate rehabilitation areas comprised of native vegetation it will meet the guidelines outlined in chapter four of the '*Australian and New Zealand Guidelines for Fresh and Marine Water Quality'* (*ANZECC 2000*).

Any treated dirty water that is to be discharged off-site as riparian flow would be monitored and tested prior to release to ensure that the water quality was equivalent to the background levels within Wilpinjong Creek and is complying with OEH's requirements.

Any of the above actions will be subject to the relevant approvals.

4.7 CONCLUSIONS

The results from the revised water balance analysis show that for all years of operation except the first, a water deficit occurs after the application of groundwater inflows from the open cut and underground mine, groundwater sourced from the northern borefield and water captured and used from disturbed surface areas.

However, the modelling results have also demonstrated that any deficit in water requirements after the application of groundwater inflows and collected surface water can be met through the existing WSA which requires at least 1,000 ML is taken from UCML.

Furthermore, the results of the modelling have established that all surface water run-off within disturbed catchments is required for use at the site and that adequate dam sizing has been provided to avoid any requirement for discharge from Stage 2 of the MCC. The one exception to this is the first year of operation for the above average climate scenario. However, as outlined above, site water usage would be monitored and volumes sourced from the northern borefield modified to avoid excessive build-up should this scenario eventuate.

The analysis documented in the water balance represents a relatively conservative assumption in terms of site water management, since inflows from the northern borefield have been prioritised in the model. This has been adopted to reflect assumptions made for the groundwater modelling component of the project. In reality, it is understood that this water source would be controlled to avoid excessive build-up of water at the MCC.

5. MANAGEMENT & DIVERSION OF CLEAN WATER

The surface water management strategy has been developed to separate run-off from contaminated or "dirty" catchments with run-off from clean water catchments. This distinction has been achieved through the design of surface water infrastructure to facilitate diversion of clean water. This infrastructure was detailed in the Stage 2 EA and has been updated for the *M&ECDCD* Report.

Accordingly, the management of clean water has been addressed separately to management of dirty water, which is discussed in **Chapter 4**.

Since the submission of the Stage 2 EA, an updated clean water diversion strategy has been developed, which is described in the following section.

5.1 UPDATED CLEAN WATER DIVERSION STRATEGY

The results of the original clean water balance were documented in *Section 8.3.5* of the *SWMS* Report.

The clean water balance has been reviewed and certain aspects of the proposed scheme were identified as requiring refinement in order to provide a framework for flow releases which better replicates the riparian flow regime of the catchments. Most significantly, the release of a continuous riparian flow is not considered appropriate given the ephemeral nature of both creeks.

5.1.1 Updated Framework for Riparian Flow Release

A conceptual framework has been developed to ensure that adequate riparian flow generated within the Murragamba and 'Eastern' Creek catchments continues to be released downstream throughout the life of the mine. The framework has been developed through consideration of the following points:

- Murragamba and 'Eastern' Creek are ephemeral. Discharge is typically only generated in either of these catchments following a significant rainfall event.
- The impact of mining on the proportion of the combined catchment areas which will generate clean water run-off.
- The Maximum Harvestable Rights Dam Capacity (*MHRDC*) criteria, which allows a landowner to construct a storage with capacity up to 10% of the mean annual runoff generated by their land area.
- The Splitters Hollow Dam storage, an on-stream storage located on Wilpinjong Creek, is available to supplement riparian flows into Wilpinjong Creek.

- The implementation of the clean water diversion strategy, as outlined in *Figures 23 to 28* of the *M&ECDCD* Report. As shown in the figures, various drainage features are proposed to maximise the capture and storage of clean water away from the active pit and overburden areas. Where required, additional clean water drainage infrastructure will be installed.

The framework for the release of riparian flow focuses on two key components:

(i) At any particular stage in the mine life, up to approximately 15% of the runoff from the catchment will be removed due to mining operations; and,

(ii) A rainfall – runoff response relationship will be developed to determine the volume of water to be released from clean water storages following a rainfall event. This will be developed in conjunction with the collection of flow yield data for the two creeks.

These two components are addressed in detail in the following sections.

5.1.2 Estimated Reduction in Flows due to Mining Operations

There are two key reasons why the volume of flow from the catchments downstream to Wilpinjong Creek could be reduced due to mining operations in OC4.

Firstly, sections of the catchments which previously discharged to Wilpinjong Creek will be progressively transformed into the active mine pit/overburden area. Water which previously drained from this area is proposed to be captured and used for mining operations, until they are rehabilitated.

Secondly, there is potential for runoff generated across undisturbed/rehabilitated catchment areas to enter the active mine pit due to inadequate drainage infrastructure.

As discussed above, infrastructure has been proposed to facilitate capture and diversion of clean water runoff downstream for all events up to and including the 100 year ARI flood event. Therefore, changes to the catchment resulting from the mine pit/overburden area have the most potential to reduce flows.

A total of 2,580 ha of the Murragamba and ‘Eastern’ Creek catchments fall within the Stage 2 Project Boundary. A further 290 ha falls within the Stage 2 Project Boundary, located to the east of the ‘Eastern’ Creek catchment, which drains directly to Wilpinjong Creek. Together, these make a total catchment area of 2,870 ha draining to Wilpinjong Creek. However, only about 1,450 ha of the area within the Stage 2 Project Boundary will be directly affected by the OC4 mine and associated surface infrastructure throughout the life of the mine.

The progression of the active mine pit and overburden dumps at different stages of OC4 mining is outlined in *Figures 17 to 22* of the *M&ECDCD* Report. The total area of the active pit and the overburden dump was calculated for each stage of mining presented in the figures. This area was then compared with the total combined catchment area of Murragamba and 'Eastern' Creeks, and the portion of Wilpinjong Creek within the Project Boundary. It was found that for years 1 to 5 of the mine life, the area covered by the active pit and overburden emplacement represents between 3% and 10% of the combined Murragamba and 'Eastern' Creek catchment area.

The maximum disturbed catchment area occurs in year 12, where an estimated 15% of the total catchment area is disturbed due to OC4 mining. For years 15 to 24, the total disturbed area due to the active mine pit and overburden emplacement is less than 10%, as sections of the catchment affected by mining will have been rehabilitated.

The MHDRC allows a landowner to construct a storage area with a volume equivalent to 10% of the mean annual run-off, provided it is constructed on a 1st or 2nd order stream (*DWE, 2008*). Murragamba and 'Eastern' Creek would both be classed as 1st or 2nd order streams.

The MHDRC could be interpreted as being equivalent to a reduction of 10% in the area that collects runoff and release downstream from the property. In the context of the proposed OC4 mine, this would represent a reduction in the combined catchment areas of 287 ha at any one point in time.

Therefore, for approximately two thirds of the 24 year period covered by the application, the catchment area which is impacted by mining operations is less than the proportion from which runoff is permitted to be harvested under the MHRDC criteria, while for approximately one third of the mine life the criteria is exceeded by up to 5%. This additional 5% reduction in catchment area can be accounted for through releases from Splitters Hollow Dam.

5.1.3 Proposed Diversion of Clean Water Around Mining Operations

Figures 23 to 28 of the *M&ECDCD* Report outline the proposed infrastructure that will facilitate collection and diversion of clean water flows throughout the life of the mine away from the active mine pit and overburden areas. "Clean" water may be collected either from areas which have either been undisturbed by mining or from sufficiently rehabilitated areas of overburden post-mining.

The riparian flows that will be released off-site will come from two sources.

Firstly, areas that drain to the natural watercourses, whether they are the existing or rehabilitated creek lines, will continue to generate a significant proportion of the riparian flow throughout much of the mine life.

Secondly, the runoff that is collected and stored in the clean water dams will be released downstream via the proposed infrastructure.

In order to determine the volume of runoff to be released from a clean water storage following a rainfall event, the following framework is proposed:

(i) A rainfall-runoff response curve will be developed in consultation with the OEH. This response curve is intended to provide a measure of the clean water which is expected to be collected in a particular storage following a rainfall event. The rainfall response curve will be developed once an initial baseline data set has been collected from which to define the flow yield in the Murragamba and 'Eastern' Creeks (*refer* **Section 5.2**) and will be refined as more data becomes available; and,

(ii) As the rate at which clean water can be released is controlled by the capacity of the available infrastructure (*e.g., pumps, pipelines, swales, measuring weirs etc*), the total volume will typically be released over a longer period of time than if it was allowed to release through a catchment.

If required, additional water will be released from Splitters Hollow Dam to meet any shortfall in riparian flow requirements, as defined by the proposed rainfall response curve.

Notably, there is no proposal to use any clean water which is captured and stored to supplement mining operations. That is, all clean water is proposed to be released downstream.

The collection of clean water in dams and the associated controlled release of that water, together with any run-off that drains freely across undisturbed /rehabilitated catchments to the creek lines is considered to generate sufficient water such that the reduction in riparian flow resulting from the mining operations is expected to be limited to what is accepted under the MHDRC criteria, with any additional shortfall met by release from Splitters Hollow Dam.

Therefore, based on the above framework, it is expected that riparian flow will be maintained at a suitable level, i.e. at least 90% of the pre-mining run-off throughout the life of the mine.

5.2 COMMITMENT TO COLLECT ADDITIONAL SURFACE WATER DATA

Information has been provided to describe the Murragamba and 'Eastern' Creeks catchments. This description places the catchments in the context of the Wollar Creek and Goulburn River catchment areas. This information is summarised in **Chapter 3**.

Notwithstanding, MCM has committed to establish a monitoring program to quantify the streamflow and water quality characteristics within the two creeks for existing conditions. This is described in Section 5.5.6.4 of EA2 and in Chapter 9 of the *SWMS* Report and will comprise the following:

- Installation of streamflow devices along Murragamba and 'Eastern' Creeks downstream of mine disturbance areas.

- Periodic recording of streamflow. It is noted that streamflow is not expected except in response to rain. However this will support the argument regarding the ephemeral nature of the catchment.
- Periodic measurement of water quality indicators; including turbidity, pH, electrical conductivity, total suspended solids, total dissolved solids, pH and temperature.
- Regular (at least daily) streamflow recordings during rainfall events that exceed 30 millimetres in 24 hours (*or that same depth of rainfall in a shorter time period*).

In addition, streamflow gauges have been established on Wilpinjong Creek which are operated by Wilpinjong Coal Mine. MCM will seek to share streamflow and water quality data with Wilpinjong Coal Mine.

This streamflow monitoring data will be used to develop and calibrate a rainfall runoff model for the Murragamba and 'Eastern' Creeks catchments, and will enable the rainfall response curve described above to be developed. Additionally, pre and post-mining impacts on streamflow will be modelled and assessed prior to either creek being mined, once a sufficient baseline data set has been developed.

5.3 ESTIMATED CREEK FLOW IMPACT ASSESSMENT POST MINING

Previously, the 2 year ARI storm event was selected to provide an indicative estimate of the likely reduction in post-mining flows. Additional hydrologic modelling is required to assess the impact of mining on post-mining streamflow release from the Murragamba and 'Eastern' Creeks catchments.

A comprehensive assessment of the potential impact of the finished mine landscape on post-mining streamflow will be completed as part of the additional modelling proposed in **Section 5.2**, including consideration of present day climate conditions as well as potential changes in runoff due which may result from climate change impacts on rainfall and temperature.

5.4 HYDROLOGICAL IMPACT OF FINAL VOID

A final void is expected to result from mining operations which will be located at the eastern end of the Project Boundary.

The expected hydrological behaviour of the final void area has been addressed elsewhere in the documentation of the Stage 2 EA of the Moolarben Coal Project. A discussion of the expected hydrological function of the final void is provided in Section 5.4.5.6 of the report titled '*Moolarben Coal Project – Stage 2, Environmental Assessment Report*' (*March 2009)* prepared by Wells Environmental Services and Coffey Natural Systems.

With respect to hydrological impacts of the final void, the report identifies the following:

- The salinity concentration of the void lake water is predicted to be greater compared to surrounding groundwater as a result of evaporation from the surface water area.

- The lake formed by the void will act as a local hydrologic sink since "evaporation will be greater than groundwater and rainfall inflows".
- The void is not expected to impact on the quality of surrounding groundwater and surface water bodies.

6. MANAGEMENT OF POTENTIAL SURFACE WATER IMPACTS

During the preparation of the Stage 2 EA and the subsequent investigations a number of impacts associated with the surface water were identified. **Table 13** summarises the potential impacts that have been identified and mechanisms for managing them. In addition, the table lists the recommendations in relation to further analysis and operational water management for the Preferred Project.

Table 13 SUMMARY OF IDENTIFIED IMPACTS, MITIGATION AND MANAGEMENT

ISSUE NO.	SUMMARY OF ISSUE	IDENTIFIED RESPONSE (MITIGATION OR MANAGEMENT MEASURE)
A. MURRAGAMBA/ 'EASTERN' CREEK WATER QUALITY & WATER QUANTITY IMPACTS		
A1	▪ Reduced baseflows to Murragamba and 'Eastern' Creeks, ▪ Reduced riparian flows; and, ▪ Reduced salt buffering in Wilpinjong Creek affecting riparian vegetation and related aquatic ecosystems.	▪ Murragamba and 'Eastern' creeks are ephemeral low order drainages. A run-off response only occurs following major storm events or periods of prolonged rainfall. That is, there is nil or insignificant occurrence of connected saturated alluvium to sustain baseflow in these creeks. This was described, EA Appendix 5, Chapters 3 and 5 of Appendix 6A, along with Chapter 3 of this report. ▪ MCM will maintain riparian flows in Wilpinjong Creek for the duration of Stage 2. The availability of water for riparian flow requirements was described in EA Section 5.6.3, EA Section 5.6.5, the supplementary report titled "*Concept Design for Proposed Diversions of Murragamba & 'Eastern' Creeks*" (WorleyParsons, May 2011), along with additional information provided in Chapter 5 of this report. ▪ Implement surface water monitoring of Murragamba and 'Eastern' Creek to quantify flows in the creeks and typical rainfall response mechanisms for the catchments under existing conditions. ▪ In addition to limiting dirty water catchments to within harvestable rights limits where practicable, MCM should supplement riparian flows in Wilpinjong Creek with water from its Splitters Hollow dam if required. Splitters Hollow dam is an on-stream storage on Wilpinjong Creek upstream of Stage 2 with a licensed capacity of 78 ML for stock and domestic purposes. This is sufficient to maintain at least the 80th percentile low-flow requirement of 0.5 ML/day for the Wollar Creek water source. ▪ Shallow saline groundwater, which has the potential to increase the salinity of water discharging to Wilpinjong Creek, will be removed during mining of OC4. This will have a positive impact on the quality of surface flows discharging to Wilpinjong Creek from the Stage 2 project boundary. This was described in EA Appendix 5.

Table 13 SUMMARY OF IDENTIFIED IMPACTS, MITIGATION AND MANAGEMENT

ISSUE NO.	SUMMARY OF ISSUE	IDENTIFIED RESPONSE (MITIGATION OR MANAGEMENT MEASURE)
A. MURRAGAMBA/ 'EASTERN' CREEK WATER QUALITY & WATER QUANTITY IMPACTS (cont)		
A2	Changes to catchment areas and resultant flow regimes in mine areas. Harvesting of runoff from contained mine area catchments.	▪ A commitment has been made to undertake hydrologic modeling following the collection of baseline streamflow data for Murragamba and 'Eastern' Creek. ▪ The storage at Splitters Hollow dam will be used to supplement any shortfall in clean water run-off. ▪ See response to Issue A1
A3	Increased contaminant loads (e.g. sediment and salinity) in runoff from disturbed areas to Murragamba and 'Eastern' Creeks.	▪ As much clean water as practicably possible will be diverted around mine disturbance areas. This will minimise the amount of dirty water required to be captured and managed over the life of the project. ▪ The water management strategy for Stage 2 includes the design and implementation of clean water diversions, sediment dams and erosion control structures to contain and manage dirty water on site. This was described in EA Section 5.5.6, EA Appendix 6A and Chapter 5 of this report.
A4	Modification to the manner in which baseflows are distributed to Wilpinjong Creek which could impact riparian flows.	▪ See response to Issue A2 ▪ The groundwater assessment has determined there will be negligible impact on groundwater levels (less than 1 m) within the connected alluvium on Wilpinjong Creek beyond the immediate proximity of Stage 2. Further, impacts on surficial alluvial aquifers will be temporary and will fully recover, post mining.

Table 13 SUMMARY OF IDENTIFIED IMPACTS, MITIGATION AND MANAGEMENT

ISSUE NO.	SUMMARY OF ISSUE	IDENTIFIED RESPONSE (MITIGATION OR MANAGEMENT MEASURE)
A. MURRAGAMBA/ 'EASTERN' CREEK WATER QUALITY & WATER QUANTITY IMPACTS (cont)		
A5	Increased salinity and sediment from mine area catchments during operational and remediation stages of the Project.	▪ See response to A3.

Table 13 SUMMARY OF IDENTIFIED IMPACTS, MITIGATION AND MANAGEMENT

ISSUE NO.	SUMMARY OF ISSUE	IDENTIFIED RESPONSE (MITIGATION OR MANAGEMENT MEASURE)	
B. MINE INFRASTRUTURE WATER QUALITY/QUANTITY IMPACTS			
B1	Activities within the infrastructure area including the coal handling area could adversely impact on the water quality of runoff carried by Bora Creek and subsequently on the upper reaches of the Goulburn River. Nominated contaminants include hydrocarbons, acids, salts and sediment.	▪ MCM has recently successfully upgraded its clean water diversion and erosion and sediment control structures around the infrastructure area for Stage 1. This work has being carried out in consultation with OEH and DP&I. ▪ The implementation of these measures will provide adequate water quality protection for surface water flows in Bora Creek and the Goulburn River. ▪ These measures will be extended to include additional infrastructure development areas required for Stage 2.	
B2	Potential increased sedimentation of culverts at Bora Creek crossing of the Ulan-Cassillis Road.	See response to Issue B1.	
B3	Increased yield and reduced runoff detention from the infrastructure development area leading to more rapid and increased volume of runoff to Bora Creek.	See response to Issue B1.	

7. CONCLUSIONS

The information provided above has been prepared to document the results of subsequent investigations in the Murragamba and 'Eastern' Creek catchment conditions, as well as to provide further details of the water balance modelling undertaken for the water management system at the MCC.

The discussion provided in **Chapter 3** provides further evidence that Murragamba and 'Eastern' Creek are low order, self contained catchments which represent only a small proportion of the Wollar Creek catchment and the larger Goulburn River catchment. The disturbance to the catchment area associated with mining in the Murragamba and 'Eastern' Creek valley represents only a minor proportion of flows with the Wollar Creek catchment.

The development process and the results from updated water balance modelling have been presented in **Chapter 4**. The results demonstrate that although a shortfall in water availability occurs in some years, there is understood to be adequate additional water available through the WSA to address any shortfall in demand.

Chapter 5 details the results of an updated framework for the release of riparian flows from the Murragamba and 'Eastern' catchments. The release regime recognises the ephemeral nature of the two catchments and that the provision of a consistent baseflow is not necessarily appropriate. Further water quantity and quality monitoring has been committed to by MCM to ensure adequate data is collected to define the releases.

Details of an updated framework outlining contingency, management and mitigation measures, together with commitments to provide additional information are summarised in **Chapter 6**.

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Supplementary Surface Water Investigations Including Water Balance Modelling

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Appendix A HEC-RAS Modelling Results for 5, 20, 200 and PMF floods

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Upper	M33	5 year	7.8		0.1		495.7	496.08	496.0	496.13	0.0		0.9		8.5	33.99	0.58
Upper	M33	20 year	14.0		0.1		495.7	496.19	496.1	496.25	0.0		1.1		12.4	38.99	0.64
Upper	M33	100 year	23.6	0.05	0.1	0.00	495.7	496.32	496.2	496.41	0.0	0.1	1.3	0.0	17.9	45.03	0.67
Upper	M33	200 year	28.7	0.05	0.1	0.05	495.7	496.36	496.3	496.47	0.0	0.2	1.5	0.2	19.5	46.42	0.71
Upper	M33	PMF	189.0	0.05	0.1	0.05	495.7	497.11	497.1	497.63	0.0	2.1	3.3	1.5	61.3	62.32	0.96
Upper	M32	5 year	7.8	0.05	0.0	0.05	489.5	489.67	489.7	489.74	0.0	0.2	1.2	0.6	7.6	65.94	0.93
Upper	M32	20 year	14.0	0.05	0.0	0.05	489.5	489.74	489.7	489.82	0.0	0.5	1.4	0.8	12.1	73.53	0.93
Upper	M32	100 year	23.6	0.05	0.0	0.05	489.5	489.81	489.8	489.92	0.0	0.7	1.7	0.9	17.6	83	0.97
Upper	M32	200 year	28.7	0.05	0.0	0.05	489.5	489.85	489.9	489.97	0.0	0.8	1.7	1.0	21.0	86.78	0.94
Upper	M32	PMF	189.0	0.05	0.0	0.05	489.5	490.43	490.4	490.77	0.0	1.7	3.1	1.9	81.2	120.1	1.03
Upper	M31	5 year	7.8	0.05	0.0	0.05	482.4	482.99		483.05	0.0	0.5	1.2	0.6	9.1	43.48	0.58
Upper	M31	20 year	14.0	0.05	0.0	0.05	482.4	483.11		483.18	0.0	0.6	1.4	0.7	15.0	52.67	0.59
Upper	M31	100 year	23.6	0.05	0.0	0.05	482.4	483.21		483.30	0.0	0.9	1.7	0.9	20.2	58	0.68
Upper	M31	200 year	28.7	0.05	0.0	0.05	482.4	483.25		483.36	0.0	1.0	1.9	1.0	22.7	60.08	0.72
Upper	M31	PMF	189.0	0.05	0.0	0.05	482.4	484.10		484.35	0.0	1.9	3.1	1.7	93.5	103.38	0.78
Upper	M30	5 year	7.8		0.1	0.05	478.4	479.01	479.0	479.09	0.0		1.4	0.8	6.3	34.27	0.89
Upper	M30	20 year	14.0		0.1	0.05	478.4	479.09	479.1	479.21	0.0		1.6	1.1	9.7	43.17	0.97
Upper	M30	100 year	23.6		0.1	0.05	478.4	479.23	479.2	479.33	0.0		1.6	1.1	17.3	59.72	0.82
Upper	M30	200 year	28.7		0.1	0.05	478.4	479.28	479.2	479.39	0.0		1.6	1.2	20.4	61.2	0.79
Upper	M30	PMF	189.0	0.05	0.1	0.05	478.4	479.95	480.0	480.36	0.0	1.2	3.1	2.6	68.0	83.59	0.98
Upper	M29	5 year	7.8		0.0		474.9	475.51	475.3	475.55	0.0		0.8		9.6	24.38	0.41
Upper	M29	20 year	14.0		0.0		474.9	475.66	475.4	475.72	0.0		1.0		13.5	28.22	0.48
Upper	M29	100 year	23.6		0.0		474.9	475.81	475.6	475.90	0.0		1.3		18.1	32.09	0.56
Upper	M29	200 year	28.7	0.06	0.0	0.00	474.9	475.88	475.7	475.98	0.0	0.1	1.4	0.0	20.4	34.13	0.58
Upper	M29	PMF	189.0	0.06	0.0	0.06	474.9	477.17	476.8	477.41	0.0	0.9	2.4	0.8	106.7	103.83	0.56
Upper	M28	5 year	20.7	0.09	0.1	0.09	471.2	471.57	471.5	471.63	0.0	0.4	1.1	0.6	20.4	66.6	0.58
Upper	M28	20 year	33.1	0.09	0.1	0.09	471.2	471.70	471.6	471.77	0.0	0.5	1.3	0.7	28.9	73.73	0.59
Upper	M28	100 year	52.6	0.09	0.1	0.09	471.2	471.86	471.7	471.96	0.0	0.6	1.4	0.8	41.9	80.2	0.57
Upper	M28	200 year	62.3	0.09	0.1	0.09	471.2	471.93	471.7	472.04	0.0	0.7	1.5	0.8	47.5	82.84	0.57
Upper	M28	PMF	482.0	0.09	0.1	0.09	471.2	473.29		473.71	0.0	1.8	3.3	1.8	186.9	120.81	0.73

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Upper	M27	5 year	20.7	0.08	0.1	0.08	468.4	469.05	468.9	469.09	0.0	0.6	1.0	0.5	27.3	74.69	0.43
Upper	M27	20 year	33.1	0.08	0.1	0.08	468.4	469.18	469.0	469.23	0.0	0.7	1.2	0.7	37.2	81.47	0.46
Upper	M27	100 year	52.6	0.08	0.1	0.08	468.4	469.32	469.1	469.39	0.0	0.8	1.5	0.9	49.4	92.14	0.51
Upper	M27	200 year	62.3	0.08	0.1	0.08	468.4	469.38	469.2	469.47	0.0	0.8	1.6	1.0	55.6	97.7	0.52
Upper	M27	PMF	482.0	0.08	0.1	0.08	468.4	470.83		471.06	0.0	1.7	2.8	1.9	244.6	152.52	0.57
Upper	M26	5 year	20.7	0.10	0.1	0.10	466.1	466.62	466.5	466.65	0.0	0.6	0.8	0.4	30.4	95.28	0.40
Upper	M26	20 year	33.1	0.10	0.1	0.10	466.1	466.75	466.5	466.78	0.0	0.7	0.9	0.5	43.3	105.37	0.40
Upper	M26	100 year	52.6	0.10	0.1	0.10	466.1	466.93	466.6	466.97	0.0	0.7	1.0	0.6	63.7	117.95	0.38
Upper	M26	200 year	62.3	0.10	0.1	0.10	466.1	467.00	466.7	467.04	0.0	0.8	1.1	0.7	71.9	120.63	0.38
Upper	M26	PMF	482.0	0.10	0.1	0.10	466.1	468.33	467.6	468.52	0.0	1.7	2.3	1.6	261.2	156.48	0.49
Upper	M25	5 year	20.7	0.08	0.1	0.08	459.4	460.85	460.9	461.28	0.0	1.8	3.8	1.7	8.8	10.36	1.02
Upper	M25	20 year	33.1	0.08	0.1	0.08	459.4	461.20	461.2	461.72	0.0	2.1	4.4	2.0	12.8	12.35	1.04
Upper	M25	100 year	52.6	0.08	0.1	0.08	459.4	461.57	461.6	462.25	0.0	2.4	5.2	2.3	17.7	14.41	1.12
Upper	M25	200 year	62.3	0.08	0.1	0.08	459.4	461.80	461.8	462.50	0.0	2.5	5.4	2.1	21.4	17.72	1.11
Upper	M25	PMF	482.0	0.08	0.1	0.08	459.4	464.03	463.8	464.49	0.0	2.1	6.4	2.3	198.3	128.28	0.95
Upper	M24	5 year	20.7	0.10	0.0	0.10	455.8	457.23		457.45	0.0	0.5	2.1	0.4	11.2	12.03	0.63
Upper	M24	20 year	33.1	0.10	0.0	0.10	455.8	457.57		457.89	0.0	0.6	2.6	0.5	15.5	13.52	0.68
Upper	M24	100 year	52.6	0.10	0.0	0.10	455.8	457.97		458.44	0.0	0.7	3.2	0.7	21.3	15.31	0.73
Upper	M24	200 year	62.3	0.10	0.0	0.10	455.8	458.14		458.68	0.0	0.8	3.4	0.7	23.9	16.04	0.76
Upper	M24	PMF	482.0	0.10	0.0	0.10	455.8	462.32	462.3	463.23	0.0	1.0	5.5	0.8	275.3	143.4	0.70
Upper	M23	5 year	20.7	0.08	0.1	0.08	455.0	456.05		456.22	0.0	1.0	1.9	0.8	12.1	14.64	0.60
Upper	M23	20 year	33.1	0.08	0.1	0.08	455.0	456.31		456.56	0.0	1.2	2.3	1.0	16.0	15.93	0.66
Upper	M23	100 year	52.6	0.08	0.1	0.08	455.0	456.66		457.00	0.0	1.5	2.7	1.3	21.8	17.66	0.69
Upper	M23	200 year	62.3	0.08	0.1	0.08	455.0	456.81		457.19	0.0	1.6	2.9	1.4	24.7	18.45	0.70
Upper	M23	PMF	482.0	0.08	0.1	0.08	455.0	459.22	458.3	460.51	0.0	2.1	6.4	2.0	143.3	117.57	1.00
Upper	M22	5 year	20.7	0.07	0.0	0.07	453.9	454.89	454.6	454.98	0.0	0.4	1.4	0.5	16.3	21.48	0.47
Upper	M22	20 year	33.1	0.07	0.0	0.07	453.9	455.18		455.30	0.0	0.5	1.6	0.6	22.9	23.61	0.48
Upper	M22	100 year	52.6	0.07	0.0	0.07	453.9	455.51		455.69	0.0	0.7	2.0	0.8	31.2	26.07	0.51
Upper	M22	200 year	62.3	0.07	0.0	0.07	453.9	455.64		455.85	0.0	0.7	2.1	0.8	34.5	27.01	0.53
Upper	M22	PMF	482.0	0.07	0.0	0.07	453.9	457.83		458.46	0.0	1.3	4.5	1.3	216.5	147.11	0.73

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Trib_2	S3	5 year	4.7	0.11	0.1	0.11	461.0	461.21	461.2	461.25	0.1	0.4	0.9	0.4	6.1	65.72	0.88
Trib_2	S3	20 year	8.6	0.11	0.1	0.11	461.0	461.27	461.3	461.32	0.1	0.5	1.1	0.5	9.9	70.04	0.82
Trib_2	S3	100 year	14.3	0.11	0.1	0.11	461.0	461.32	461.3	461.39	0.1	0.6	1.3	0.6	13.5	73.83	0.89
Trib_2	S3	200 year	17.2	0.11	0.1	0.11	461.0	461.33	461.3	461.42	0.1	0.7	1.5	0.7	14.3	74.62	1.00
Trib_2	S3	PMF	114.4	0.11	0.1	0.11	461.0	461.82	461.8	462.05	0.1	1.0	2.6	1.2	65.7	130.82	0.97
Trib_2	S2	5 year	4.7	0.09	0.1	0.10	456.5	456.94	456.9	457.02	0.0	0.3	1.3	0.4	3.9	13.5	0.73
Trib_2	S2	20 year	8.6	0.09	0.1	0.10	456.5	457.06	457.0	457.20	0.0	0.4	1.7	0.6	5.7	14.75	0.81
Trib_2	S2	100 year	14.3	0.09	0.1	0.10	456.5	457.23	457.2	457.42	0.0	0.4	2.0	0.7	8.8	25.18	0.81
Trib_2	S2	200 year	17.2	0.09	0.1	0.10	456.5	457.32	457.3	457.51	0.0	0.4	2.1	0.7	11.1	28.36	0.78
Trib_2	S2	PMF	114.4	0.09	0.1	0.10	456.5	458.65		458.98	0.0	1.0	3.2	0.8	71.4	73.74	0.72
Trib_2	S1	5 year	4.7	0.07	0.0	0.07	455.2	455.61	455.5	455.67	0.0	0.6	1.3	0.5	5.1	15.21	0.62
Trib_2	S1	20 year	8.6	0.07	0.0	0.07	455.2	455.80	455.6	455.88	0.0	0.8	1.5	0.6	8.0	17	0.62
Trib_2	S1	100 year	14.3	0.07	0.0	0.07	455.2	455.97	455.8	456.09	0.0	1.0	1.9	0.8	11.1	18.71	0.67
Trib_2	S1	200 year	17.2	0.07	0.0	0.07	455.2	456.03	455.9	456.17	0.0	1.1	2.1	0.8	12.2	19.25	0.72
Trib_2	S1	PMF	114.4	0.07	0.0	0.07	455.2	457.97		458.24	0.0	1.2	3.3	0.9	73.7	62.3	0.63
Middle	M21	5 year	24.0	0.09	0.0	0.09	452.4	453.25	453.2	453.60	0.0	0.9	2.7	0.7	10.1	15.47	0.97
Middle	M21	20 year	38.6	0.09	0.0	0.09	452.4	453.52	453.5	453.99	0.0	1.0	3.1	0.8	14.4	17.26	0.98
Middle	M21	100 year	60.3	0.09	0.0	0.09	452.4	453.89	453.9	454.44	0.0	1.1	3.5	0.8	22.6	27.01	0.94
Middle	M21	200 year	70.5	0.09	0.0	0.09	452.4	454.05	454.1	454.62	0.0	1.1	3.6	0.8	27.6	33.88	0.90
Middle	M21	PMF	555.0	0.09	0.0	0.09	452.4	456.42	456.4	457.17	0.0	1.4	5.6	1.5	259.1	155.46	0.90
Middle	M20	5 year	24.0	0.08	0.1	0.07	450.5	451.20	451.2	451.39	0.0	0.9	2.2	1.2	14.2	28.14	0.87
Middle	M20	20 year	38.6	0.08	0.1	0.07	450.5	451.36	451.3	451.64	0.0	1.1	2.7	1.5	18.9	29.85	0.95
Middle	M20	100 year	60.3	0.08	0.1	0.07	450.5	451.55	451.6	451.95	0.0	1.3	3.3	1.9	24.7	31.84	1.04
Middle	M20	200 year	70.5	0.08	0.1	0.07	450.5	451.65	451.7	452.08	0.0	1.4	3.4	2.0	27.8	32.87	1.04
Middle	M20	PMF	555.0	0.08	0.1	0.07	450.5	454.24	454.2	455.06	0.0	1.7	5.6	2.2	203.4	130.81	0.93
Middle	M19	5 year	24.0		0.1		449.3	450.32	450.0	450.37	0.0		1.0		24.9	49.2	0.43
Middle	M19	20 year	38.6		0.1		449.3	450.51		450.57	0.0		1.1		34.7	54.83	0.45
Middle	M19	100 year	60.3	0.06	0.1		449.3	450.72		450.80	0.0	0.2	1.3		46.5	58.44	0.46
Middle	M19	200 year	70.5	0.06	0.1		449.3	450.80		450.90	0.0	0.3	1.4		51.4	59.78	0.47
Middle	M19	PMF	555.0	0.06	0.1	0.06	449.3	452.23		452.75	0.0	1.4	3.4	1.4	200.0	156.64	0.73

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS -
MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Middle	M18	5 year	26.3		0.1		446.8	447.69	447.7	447.95	0.0		2.3		11.7	22.45	1.00
Middle	M18	20 year	42.3		0.1		446.8	447.91	447.9	448.22	0.0		2.5		17.0	27.48	1.01
Middle	M18	100 year	66.0		0.1		446.8	448.16	448.2	448.52	0.0		2.7		24.6	33.67	1.00
Middle	M18	200 year	77.3		0.1		446.8	448.25	448.3	448.64	0.0		2.8		28.0	36.08	1.00
Middle	M18	PMF	561.0	0.05	0.1	0.05	446.8	450.63		451.10	0.0	1.4	3.2	1.4	207.8	126.83	0.62
Middle	M17	5 year	26.3	0.11	0.0	0.11	441.7	443.06	442.8	443.26	0.0	0.4	2.0	0.5	14.7	15.5	0.62
Middle	M17	20 year	42.3	0.11	0.0	0.11	441.7	443.48		443.74	0.0	0.5	2.3	0.6	21.6	17.13	0.60
Middle	M17	100 year	66.0	0.11	0.0	0.11	441.7	444.01		444.33	0.0	0.6	2.6	0.6	31.2	19.2	0.58
Middle	M17	200 year	77.3	0.11	0.0	0.11	441.7	444.23		444.58	0.0	0.6	2.7	0.7	35.5	20.04	0.58
Middle	M17	PMF	561.0	0.11	0.0	0.11	441.7	448.26	448.3	449.32	0.0	0.8	5.4	0.8	276.8	154.63	0.69
Middle	M16	5 year	26.3	0.10	0.0	0.10	439.3	441.17	440.9	441.52	0.0	0.8	3.0	0.7	15.2	13.22	0.70
Middle	M16	20 year	42.3	0.10	0.0	0.10	439.3	441.67	441.3	442.12	0.0	1.0	3.5	0.9	22.5	15.9	0.73
Middle	M16	100 year	66.0	0.10	0.0	0.10	439.3	442.20		442.79	0.0	1.1	4.2	1.0	31.6	18.73	0.79
Middle	M16	200 year	77.3	0.10	0.0	0.10	439.3	442.43		443.06	0.0	1.2	4.4	1.1	36.1	20	0.79
Middle	M16	PMF	561.0	0.10	0.0	0.10	439.3	445.74	445.7	446.54	0.0	1.3	7.1	1.4	321.8	172.33	0.89
Middle	M15	5 year	26.3		0.0		436.5	438.16	437.9	438.41	0.0		2.2		11.7	11.23	0.70
Middle	M15	20 year	42.3		0.0		436.5	438.52	438.3	438.87	0.0		2.6		16.1	12.88	0.75
Middle	M15	100 year	66.0		0.0	0.07	436.5	438.98	438.7	439.42	0.0		2.9	0.2	22.6	19.59	0.76
Middle	M15	200 year	77.3	0.07	0.0	0.07	436.5	439.11	438.9	439.61	0.0	0.2	3.2	0.3	25.9	31.18	0.80
Middle	M15	PMF	561.0	0.07	0.0	0.07	436.5	441.07	441.1	441.79	0.0	1.6	5.1	1.7	223.0	146.4	0.86
Middle	M14	5 year	26.3	0.07	0.0		434.1	435.00		435.15	0.0	0.7	1.8		15.8	26.71	0.70
Middle	M14	20 year	42.3	0.07	0.0		434.1	435.20	435.0	435.41	0.0	0.5	2.1		22.9	44.74	0.74
Middle	M14	100 year	66.0	0.07	0.0	0.07	434.1	435.36	435.4	435.68	0.0	0.7	2.6	0.3	31.6	59.87	0.84
Middle	M14	200 year	77.3	0.07	0.0	0.07	434.1	435.45	435.5	435.78	0.0	0.8	2.7	0.4	36.9	64.04	0.84
Middle	M14	PMF	561.0	0.07	0.0	0.07	434.1	437.01	437.0	437.73	0.0	2.0	4.8	1.6	202.4	141.7	0.95
Middle	M13	5 year	29.5		0.0		432.4	433.25	433.0	433.28	0.0		0.9		34.7	86.28	0.43
Middle	M13	20 year	47.4		0.0		432.4	433.38	433.1	433.43	0.0		1.0		46.9	94.54	0.46
Middle	M13	100 year	73.8	0.00	0.0		432.4	433.59	433.3	433.65	0.0	0.0	1.1		67.5	107.05	0.44
Middle	M13	200 year	86.3	0.07	0.0	0.07	432.4	433.65	433.3	433.72	0.0	0.1	1.2	0.1	74.9	115.47	0.44
Middle	M13	PMF	720.0	0.07	0.0	0.07	432.4	435.64		435.83	0.0	0.8	2.1	0.7	450.0	268.28	0.41

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Trib_1	T6	5 year	3.9		0.0		457.9	458.07	458.1	458.10	0.0		0.8		4.9	72.07	0.97
Trib_1	T6	20 year	7.3		0.0		457.9	458.10	458.1	458.15	0.0		1.0		7.5	80.16	1.02
Trib_1	T6	100 year	11.9		0.0		457.9	458.14	458.1	458.20	0.0		1.1		10.5	83.91	1.02
Trib_1	T6	200 year	14.1		0.0		457.9	458.15	458.2	458.23	0.0		1.2		11.8	84.5	1.02
Trib_1	T6	PMF	62.3		0.0		457.9	458.40	458.4	458.57	0.0		1.9		33.7	98.55	1.01
Trib_1	T5	5 year	3.9		0.0		449.8	449.96	449.9	449.99	0.0		0.8		4.9	38.32	0.71
Trib_1	T5	20 year	7.3		0.0		449.8	450.01	450.0	450.07	0.0		1.0		7.2	44.23	0.80
Trib_1	T5	100 year	11.9		0.0		449.8	450.07	450.1	450.15	0.0		1.2		9.9	50.22	0.86
Trib_1	T5	200 year	14.1		0.0		449.8	450.10	450.1	450.18	0.0		1.2		11.4	53.27	0.85
Trib_1	T5	PMF	62.3	0.05	0.0	0.05	449.8	450.41	450.4	450.62	0.0	0.9	2.1	0.7	31.3	74.09	0.93
Trib_1	T4	5 year	3.9	0.05	0.0	0.05	444.8	445.01	445.0	445.05	0.0	0.8	1.0	0.6	5.3	67.07	0.96
Trib_1	T4	20 year	7.3	0.05	0.0	0.05	444.8	445.06	445.1	445.10	0.0	0.8	1.1	0.7	9.1	87.14	0.91
Trib_1	T4	100 year	11.9	0.05	0.0	0.05	444.8	445.11	445.1	445.15	0.0	0.9	1.2	0.7	13.3	102.61	0.90
Trib_1	T4	200 year	14.1	0.05	0.0	0.05	444.8	445.12	445.1	445.17	0.0	1.0	1.3	0.8	14.8	107.03	0.93
Trib_1	T4	PMF	62.3	0.05	0.0	0.05	444.8	445.32	445.3	445.44	0.0	1.6	2.0	1.3	42.0	175.9	1.10
Trib_1	T3	5 year	3.9		0.0	0.05	440.7	441.08	441.1	441.14	0.0		1.2	0.4	4.4	41.78	0.76
Trib_1	T3	20 year	7.3		0.0	0.05	440.7	441.15	441.2	441.22	0.0		1.4	0.6	7.7	57.6	0.82
Trib_1	T3	100 year	11.9	0.05	0.0	0.05	440.7	441.21	441.2	441.29	0.0	0.2	1.5	0.7	11.6	78.54	0.86
Trib_1	T3	200 year	14.1	0.05	0.0	0.05	440.7	441.24	441.2	441.31	0.0	0.3	1.5	0.8	13.9	90.87	0.84
Trib_1	T3	PMF	62.3	0.05	0.0	0.05	440.7	441.49	441.5	441.57	0.0	0.8	1.8	1.0	59.2	257.69	0.81
Trib_1	T2	5 year	3.9	0.05		0.05	438.3	438.08	438.0	438.10	0.0	0.6		0.3	6.7	67.61	0.00
Trib_1	T2	20 year	7.3	0.05		0.05	438.3	438.13	438.1	438.16	0.0	0.7		0.4	10.7	86.12	0.00
Trib_1	T2	100 year	11.9	0.05		0.05	438.3	438.19	438.1	438.22	0.0	0.7		0.6	16.2	119.26	0.00
Trib_1	T2	200 year	14.1	0.05		0.05	438.3	438.21	438.2	438.24	0.0	0.8		0.6	18.6	130.73	0.00
Trib_1	T2	PMF	62.3	0.05	0.0	0.05	438.3	438.35	438.4	438.46	0.0	1.5	0.5	1.1	43.5	218.42	0.76
Trib_1	T1	5 year	3.9		0.0		432.6	432.97	433.0	433.08	0.0		1.5		2.7	12.95	1.01
Trib_1	T1	20 year	7.3		0.0		432.6	433.08	433.1	433.23	0.0		1.7		4.4	15.9	1.02
Trib_1	T1	100 year	11.9		0.0		432.6	433.20	433.2	433.38	0.0		1.9		6.3	18.15	1.01
Trib_1	T1	200 year	14.1		0.0		432.6	433.25	433.3	433.44	0.0		2.0		7.2	19.08	1.01
Trib_1	T1	PMF	62.3	0.05	0.0	0.05	432.6	435.20		435.21	0.0	0.2	0.4	0.2	234.0	261.9	0.09

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Lower	M12	5 year	36.2		0.1		430.5	431.37	431.0	431.41	0.0		0.9		42.4	75.15	0.36
Lower	M12	20 year	57.4		0.1		430.5	431.62	431.2	431.66	0.0		0.9		62.7	89.21	0.35
Lower	M12	100 year	88.1	0.07	0.1		430.5	431.80	431.3	431.86	0.0	0.1	1.1		80.4	99.49	0.39
Lower	M12	200 year	102.5	0.07	0.1		430.5	431.88	431.4	431.95	0.0	0.2	1.2		88.4	103.17	0.39
Lower	M12	PMF	1024.0	0.07	0.1	0.07	430.5	434.23		434.53	0.0	1.1	2.6	1.1	475.9	236.2	0.47
Lower	M11	5 year	36.2	0.06	0.0	0.06	428.2	428.91	428.8	429.00	0.0	0.8	1.5	0.5	30.0	68.07	0.62
Lower	M11	20 year	57.4	0.06	0.0	0.06	428.2	429.01	428.9	429.16	0.0	1.1	1.9	0.7	36.9	71.29	0.74
Lower	M11	100 year	88.1	0.06	0.0	0.06	428.2	429.24	429.1	429.41	0.0	1.2	2.0	0.8	54.1	78.75	0.69
Lower	M11	200 year	102.5	0.06	0.0	0.06	428.2	429.32	429.1	429.50	0.0	1.3	2.1	0.9	60.5	81.35	0.69
Lower	M11	PMF	1024.0	0.06	0.0	0.06	428.2	431.46		432.14	0.0	2.4	4.7	2.2	337.2	174.76	0.84
Lower	M10	5 year	36.2	0.06	0.1	0.06	426.1	426.67	426.5	426.80	0.0	1.7	1.2	0.5	24.1	59.54	0.56
Lower	M10	20 year	57.4	0.06	0.1	0.06	426.1	426.96	426.7	427.06	0.0	1.5	1.3	0.7	44.4	82.51	0.49
Lower	M10	100 year	88.1	0.06	0.1	0.06	426.1	427.09	426.9	427.24	0.0	1.8	1.7	0.9	56.1	95.49	0.59
Lower	M10	200 year	102.5	0.06	0.1	0.06	426.1	427.16	427.0	427.31	0.0	1.9	1.8	1.0	62.7	99.11	0.60
Lower	M10	PMF	1024.0	0.06	0.1	0.06	426.1	428.92		429.54	0.0	3.7	4.2	2.9	301.7	161	0.82
Lower	M9	5 year	36.2	0.06	0.1		424.5	425.03	424.8	425.06	0.0	0.2	0.7		52.8	143.34	0.36
Lower	M9	20 year	57.4	0.06	0.1		424.5	425.08	424.9	425.13	0.0	0.3	1.0		60.3	145.89	0.47
Lower	M9	100 year	88.1	0.06	0.1	0.06	424.5	425.25	425.0	425.31	0.0	0.4	1.1	0.2	84.9	152.39	0.44
Lower	M9	200 year	102.5	0.06	0.1	0.06	424.5	425.31	425.0	425.37	0.0	0.4	1.1	0.3	93.5	154.49	0.44
Lower	M9	PMF	1024.0	0.06	0.1	0.06	424.5	427.11		427.42	0.0	1.3	2.6	1.2	440.5	229.72	0.53
Lower	M8	5 year	36.2		0.1		423.3	423.95	423.8	424.00	0.0		1.0		37.6	115.8	0.54
Lower	M8	20 year	57.4	0.07	0.1		423.3	424.21	423.9	424.25	0.0	0.2	0.8		69.9	131.79	0.35
Lower	M8	100 year	88.1	0.07	0.1		423.3	424.29	424.0	424.35	0.0	0.3	1.1		80.6	136.61	0.44
Lower	M8	200 year	102.5	0.07	0.1		423.3	424.35	424.1	424.42	0.0	0.4	1.2		89.2	140.36	0.45
Lower	M8	PMF	1024.0	0.07	0.1	0.07	423.3	426.08		426.46	0.0	1.6	2.9	1.2	406.9	223.16	0.59
Lower	M7	5 year	36.2	0.07	0.1	0.07	420.4	422.42		422.53	0.0	0.2	1.5	0.2	27.2	69.29	0.50
Lower	M7	20 year	57.4	0.07	0.1	0.07	420.4	422.33	422.3	422.69	0.0	0.2	2.7	0.3	22.1	45.24	0.94
Lower	M7	100 year	88.1	0.07	0.1	0.07	420.4	422.69	422.7	422.92	0.0	0.6	2.3	0.6	58.4	146.55	0.69
Lower	M7	200 year	102.5	0.07	0.1	0.07	420.4	422.75	422.8	422.99	0.0	0.7	2.4	0.6	67.7	155.25	0.70
Lower	M7	PMF	1024.0	0.07	0.1	0.07	420.4	424.09	424.1	424.74	0.0	2.5	5.2	1.7	353.5	254.44	1.03

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Lower	M6.6	5 year	36.2	0.05	0.0	0.05	419.2	422.49	420.7	422.49	0.0	0.1	0.3	0.1	219.5	217.45	0.06
Lower	M6.6	20 year	57.4	0.05	0.0	0.05	419.2	422.57	421.1	422.57	0.0	0.2	0.4	0.1	236.8	223.19	0.09
Lower	M6.6	100 year	88.1	0.05	0.0	0.05	419.2	422.68	421.5	422.69	0.0	0.3	0.6	0.2	261.3	235.62	0.12
Lower	M6.6	200 year	102.5	0.05	0.0	0.05	419.2	422.74	421.7	422.75	0.0	0.3	0.6	0.2	276.4	244.11	0.13
Lower	M6.6	PMF	1024.0	0.05	0.0	0.05	419.2	424.12	423.1	424.28	0.0	1.5	2.6	1.1	649.5	299.5	0.42
Lower	M6.4	5 year	36.2		0.1		418.9	420.42	420.4	420.85	0.0		2.9		12.6	15.24	1.01
Lower	M6.4	20 year	57.4	0.04	0.1	0.04	418.9	420.81	420.8	421.20	0.0	0.4	2.8	0.5	20.9	29.37	0.99
Lower	M6.4	100 year	88.1	0.04	0.1	0.04	418.9	421.13	421.1	421.54	0.0	1.1	2.9	1.2	32.4	42.95	0.88
Lower	M6.4	200 year	102.5	0.04	0.1	0.04	418.9	421.30	421.3	421.66	0.0	1.1	2.8	1.3	41.8	73.48	0.79
Lower	M6.4	PMF	1024.0	0.04	0.1	0.04	418.9	423.35		423.61	0.0	2.2	2.7	1.6	468.6	272.89	0.47
Lower	M6	5 year	36.2		0.0		416.0	417.39	417.4	417.89	0.0		3.2		11.5	11.26	1.00
Lower	M6	20 year	57.4		0.0		416.0	417.85	417.9	418.38	0.0		3.2		17.9	17.26	1.01
Lower	M6	100 year	88.1		0.0		416.0	418.23	418.2	418.87	0.0		3.5		24.9	19.64	1.00
Lower	M6	200 year	102.5		0.0		416.0	418.39	418.4	419.07	0.0		3.7		28.0	20.6	1.00
Lower	M6	PMF	1024.0	0.04	0.0	0.04	416.0	421.86	421.9	422.71	0.0	2.5	4.4	1.8	271.5	163.05	0.88
Lower	M5	5 year	36.2		0.0		414.6	415.98		416.10	0.0		1.6		23.0	28.81	0.56
Lower	M5	20 year	57.4		0.0		414.6	416.15	415.9	416.36	0.0		2.0		28.2	30.22	0.67
Lower	M5	100 year	88.1		0.0		414.6	416.46		416.74	0.0		2.3		37.9	32.7	0.69
Lower	M5	200 year	102.5		0.0		414.6	416.61		416.90	0.0		2.4		42.9	33.91	0.68
Lower	M5	PMF	1024.0	0.06	0.0	0.06	414.6	419.85	419.9	420.79	0.0	1.0	4.5	1.2	293.1	197.24	0.81
Lower	M4	5 year	36.2		0.0		412.5	413.84	413.8	414.19	0.0		2.6		13.9	16.35	0.90
Lower	M4	20 year	57.4		0.0		412.5	414.35		414.67	0.0		2.5		23.0	19.17	0.73
Lower	M4	100 year	88.1		0.0		412.5	414.83		415.20	0.0		2.7		32.9	21.84	0.70
Lower	M4	200 year	102.5		0.0		412.5	415.00		415.40	0.0		2.8		36.6	22.77	0.70
Lower	M4	PMF	1024.0	0.05	0.0	0.05	412.5	418.45	418.5	419.23	0.0	1.1	4.8	1.3	430.2	273.16	0.73
Lower	M3	5 year	36.2		0.1		410.9	413.05		413.11	0.0		1.1		32.2	20.26	0.28
Lower	M3	20 year	57.4		0.1		410.9	413.47		413.56	0.0		1.4		42.0	28.44	0.36
Lower	M3	100 year	88.1		0.1		410.9	413.88		414.01	0.0		1.6		56.2	39.97	0.42
Lower	M3	200 year	102.5		0.1		410.9	414.01		414.15	0.0		1.7		61.4	43.16	0.45
Lower	M3	PMF	1024.0	0.06	0.1	0.06	410.9	416.76		416.93	0.0	1.0	2.2	1.4	621.9	293.54	0.36

Table A1: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - MURRAGAMBA CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
Lower	M2.1	5 year	36.2	0.06	0.0		409.0	411.04	411.0	411.60	0.0	0.2	3.3		11.0	10.17	1.00
Lower	M2.1	20 year	57.4	0.06	0.0		409.0	412.03		412.28	0.0	0.8	2.3		28.3	25.03	0.60
Lower	M2.1	100 year	88.1	0.06	0.0	0.06	409.0	413.25		413.34	0.0	0.4	1.5	0.1	92.2	120.4	0.32
Lower	M2.1	200 year	102.5	0.06	0.0	0.06	409.0	413.57		413.63	0.0	0.4	1.3	0.2	136.5	157.63	0.27
Lower	M2.1	PMF	1024.0	0.06	0.0	0.06	409.0	416.59		416.64	0.0	0.7	1.7	0.7	1279.2	483.72	0.23
Lower	M2.05	5 year	36.2		0.0		409.0	411.25	410.5	411.34	0.0		1.4		26.3	22.82	0.41
Lower	M2.05	20 year	57.4	0.06	0.0	0.06	409.0	412.15	410.9	412.22	0.0	0.3	1.2	0.3	52.9	36.22	0.26
Lower	M2.05	100 year	88.1	0.06	0.0	0.06	409.0	413.28	411.2	413.33	0.0	0.3	1.1	0.3	111.5	102.97	0.19
Lower	M2.05	200 year	102.5	0.06	0.0	0.06	409.0	413.57	411.4	413.63	0.0	0.2	1.1	0.3	145.8	129.26	0.19
Lower	M2.05	PMF	1024.0	0.06	0.0	0.06	409.0	416.55	415.1	416.63	0.0	0.7	2.0	0.7	1188.2	470.51	0.26
Lower	M2	5 year	37.9		0.0		408.9	410.67		410.81	0.0		1.7		22.6	19.14	0.49
Lower	M2	20 year	59.7	0.06	0.0	0.06	408.9	411.38		411.50	0.0	0.2	1.6	0.2	38.3	23.62	0.39
Lower	M2	100 year	92.2	0.06	0.0	0.06	408.9	412.30		412.42	0.0	0.3	1.6	0.4	61.2	25.81	0.31
Lower	M2	200 year	108.0	0.06	0.0	0.06	408.9	412.72		412.84	0.0	0.2	1.6	0.4	73.1	45.59	0.28
Lower	M2	PMF	1191.0	0.06	0.0	0.06	408.9	416.54		416.62	0.0	0.7	2.1	0.8	1320.2	486.15	0.26
Lower	M1.6	5 year	37.9	0.07	0.1		408.7	410.71	409.5	410.76	0.0	0.1	1.0		37.7	23.51	0.25
Lower	M1.6	20 year	59.7	0.07	0.1	0.07	408.7	411.41	409.8	411.47	0.0	0.2	1.0	0.2	71.9	97.96	0.22
Lower	M1.6	100 year	92.2	0.07	0.1	0.07	408.7	412.36	410.2	412.39	0.0	0.2	0.8	0.2	213.5	205.37	0.14
Lower	M1.6	200 year	108.0	0.07	0.1	0.07	408.7	412.79	410.3	412.81	0.0	0.2	0.7	0.1	327.5	365.87	0.12
Lower	M1.6	PMF	1191.0	0.07	0.1	0.07	408.7	416.58	413.4	416.60	0.0	0.5	1.1	0.6	2119.8	568.65	0.13
Lower	M1.4	5 year	37.9		0.1		408.7	409.99	409.5	410.14	0.0		1.7		22.2	19.92	0.52
Lower	M1.4	20 year	59.7		0.1		408.7	410.29		410.51	0.0		2.1		28.3	21.27	0.58
Lower	M1.4	100 year	92.2		0.1		408.7	410.61		410.96	0.0		2.6		35.5	22.75	0.66
Lower	M1.4	200 year	108.0	0.07	0.1		408.7	410.73	410.3	411.14	0.0	0.2	2.8		38.2	23.7	0.70
Lower	M1.4	PMF	1191.0	0.07	0.1	0.07	408.7	413.38	413.4	413.94	0.0	1.7	4.9	1.4	561.8	415.82	0.75
Lower	M1	5 year	37.9		0.0	0.06	407.7	408.55	408.4	408.62	0.0		1.8	1.0	36.0	79.95	0.70
Lower	M1	20 year	59.7		0.0	0.06	407.7	408.72	408.5	408.81	0.0		2.0	1.1	51.5	105.38	0.72
Lower	M1	100 year	92.2		0.0	0.06	407.7	408.93	408.7	409.02	0.0		2.2	1.1	79.0	148.06	0.74
Lower	M1	200 year	108.0		0.0	0.06	407.7	408.99	408.8	409.09	0.0		2.2	1.1	87.5	149.25	0.74
Lower	M1	PMF	1191.0		0.0	0.06	407.7	410.94	410.3	411.35	0.0		2.3	2.9	421.8	212.47	0.77

Table A2: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - EASTERN CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
1	E17	5 year	8.6	0.05	0.0	0.05	465.5	465.72	465.7	465.80	0.0	0.2	1.3	0.2	6.8	43	1.01
1	E17	20 year	13.9	0.05	0.0	0.05	465.5	465.78	465.8	465.89	0.0	0.5	1.5	0.5	9.6	46.35	0.99
1	E17	100 year	22.3	0.05	0.0	0.05	465.5	465.87	465.9	466.01	0.0	0.7	1.7	0.7	13.7	50.73	0.97
1	E17	200 year	26.2	0.05	0.0	0.05	465.5	465.90	465.9	466.06	0.0	0.7	1.8	0.7	15.5	52.45	0.96
1	E17	PMF	168.0	0.05	0.0	0.05	465.5	466.63	466.6	467.05	0.0	1.7	3.1	1.6	63.2	79.68	0.95
1	E16	5 year	8.6	0.06	0.0	0.06	458.1	458.82	458.7	458.94	0.0	0.9	1.6	0.5	6.3	16.12	0.71
1	E16	20 year	13.9	0.06	0.0	0.06	458.1	458.96	458.9	459.13	0.0	1.0	2.0	0.7	8.8	18.66	0.76
1	E16	100 year	22.3	0.06	0.0	0.06	458.1	459.12	459.1	459.36	0.0	1.2	2.4	0.9	11.9	21.42	0.85
1	E16	200 year	26.2	0.06	0.0	0.06	458.1	459.18	459.1	459.45	0.0	1.3	2.6	1.0	13.2	22.44	0.88
1	E16	PMF	168.0	0.06	0.0	0.06	458.1	460.51	460.5	460.95	0.0	1.4	4.0	1.6	79.9	87.35	0.86
1	E15	5 year	8.6		0.0		451.5	452.09	452.1	452.25	0.0		1.8		4.8	15.12	1.01
1	E15	20 year	13.9	0.05	0.0		451.5	452.22	452.2	452.42	0.0	0.2	2.0		7.0	17.99	1.01
1	E15	100 year	22.3	0.05	0.0	0.05	451.5	452.38	452.4	452.64	0.0	0.6	2.3	0.5	10.1	20.99	0.98
1	E15	200 year	26.2	0.05	0.0	0.05	451.5	452.44	452.4	452.72	0.0	0.7	2.4	0.6	11.5	22.23	0.96
1	E15	PMF	168.0	0.05	0.0	0.05	451.5	453.76	453.8	454.33	0.0	1.7	3.7	1.4	59.7	59.62	0.86
1	E14	5 year	15.0	0.04	0.0	0.04	445.0	445.32	445.3	445.39	0.0	0.1	1.1	0.4	13.5	75.86	0.84
1	E14	20 year	24.3	0.04	0.0	0.04	445.0	445.37	445.4	445.47	0.0	0.3	1.4	0.5	17.6	79.79	0.92
1	E14	100 year	37.7	0.04	0.0	0.04	445.0	445.44	445.4	445.58	0.0	0.5	1.7	0.7	22.8	83.05	0.99
1	E14	200 year	44.6	0.04	0.0	0.04	445.0	445.47	445.5	445.63	0.0	0.6	1.8	0.7	25.7	84.74	0.99
1	E14	PMF	305.0	0.04	0.0	0.04	445.0	446.27	446.3	446.74	0.0	1.5	3.2	1.5	108.6	119.1	0.96
1	E13	5 year	15.0	0.09	0.1	0.09	438.1	438.57	438.5	438.67	0.0	0.6	1.7	0.6	13.9	48.23	0.82
1	E13	20 year	24.3	0.09	0.1	0.09	438.1	438.71	438.6	438.83	0.0	0.7	1.9	0.7	21.4	57.96	0.79
1	E13	100 year	37.7	0.09	0.1	0.09	438.1	438.88	438.8	439.01	0.0	0.8	2.1	0.7	33.6	83.05	0.77
1	E13	200 year	44.6	0.09	0.1	0.09	438.1	438.95	438.8	439.09	0.0	0.8	2.1	0.7	39.6	90.73	0.76
1	E13	PMF	305.0	0.09	0.1	0.09	438.1	439.98	439.8	440.33	0.0	1.3	3.9	1.6	158.6	137.96	0.92
1	E12	5 year	15.0		0.0		432.5	433.21	433.1	433.31	0.0		1.4		10.8	23.37	0.65
1	E12	20 year	24.3		0.0		432.5	433.37	433.2	433.51	0.0		1.6		14.9	27.08	0.70
1	E12	100 year	37.7	0.07	0.0	0.07	432.5	433.54	433.4	433.72	0.0	0.1	1.9	0.1	19.7	37.33	0.76
1	E12	200 year	44.6	0.07	0.0	0.07	432.5	433.60	433.5	433.81	0.0	0.2	2.1	0.2	22.3	49.4	0.79
1	E12	PMF	305.0	0.07	0.0	0.07	432.5	434.62	434.6	435.06	0.0	1.2	3.6	1.1	156.3	180.57	0.87

Table A2: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - EASTERN CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
1	E11	5 year	15.0	0.07	0.0	0.07	429.0	429.19	429.2	429.29	0.0	0.5	1.4	0.5	11.5	63.14	0.99
1	E11	20 year	24.3	0.07	0.0	0.07	429.0	429.27	429.3	429.39	0.0	0.6	1.6	0.6	16.1	66.15	0.99
1	E11	100 year	37.7	0.07	0.0	0.07	429.0	429.35	429.4	429.52	0.0	0.7	1.9	0.7	22.1	69.84	0.99
1	E11	200 year	44.6	0.07	0.0	0.07	429.0	429.39	429.4	429.58	0.0	0.7	2.0	0.7	25.0	71.56	0.99
1	E11	PMF	305.0	0.07	0.0	0.07	429.0	430.21	430.2	430.49	0.0	0.9	2.9	0.9	193.6	311.95	0.83
1	E10	5 year	15.0	0.07	0.0	0.07	422.0	422.39	422.3	422.46	0.0	0.4	1.2	0.4	14.3	42.73	0.60
1	E10	20 year	24.3	0.07	0.0	0.07	422.0	422.49	422.4	422.60	0.0	0.5	1.5	0.5	18.8	46.03	0.68
1	E10	100 year	37.7	0.07	0.0	0.07	422.0	422.63	422.5	422.78	0.0	0.6	1.8	0.6	25.3	50.47	0.71
1	E10	200 year	44.6	0.07	0.0	0.07	422.0	422.70	422.6	422.86	0.0	0.7	1.9	0.7	28.9	52.7	0.72
1	E10	PMF	305.0	0.07	0.0	0.07	422.0	423.84	423.8	424.49	0.0	1.5	4.1	1.5	109.9	89.7	0.96
1	E9	5 year	15.0		0.0		418.9	419.49	419.5	419.77	0.0		2.3		6.4	11.62	1.01
1	E9	20 year	24.3		0.0		418.9	419.79	419.7	420.09	0.0		2.4		10.0	12.42	0.87
1	E9	100 year	37.7	0.07	0.0	0.07	418.9	420.11	420.0	420.47	0.0	0.2	2.7	0.2	14.4	17.96	0.82
1	E9	200 year	44.6	0.07	0.0	0.07	418.9	420.24	420.1	420.63	0.0	0.4	2.8	0.3	17.0	23.47	0.81
1	E9	PMF	305.0	0.07	0.0	0.07	418.9	422.71		422.98	0.0	1.0	3.1	0.9	209.6	132.31	0.52
1	E8	5 year	23.1	0.07	0.0	0.07	417.0	418.67		418.77	0.0	0.3	1.5	0.3	21.4	31.09	0.38
1	E8	20 year	36.2	0.07	0.0	0.07	417.0	418.95		419.09	0.0	0.4	1.8	0.4	31.5	40.41	0.42
1	E8	100 year	54.3	0.07	0.0	0.07	417.0	419.24		419.41	0.0	0.6	2.1	0.6	44.6	49.96	0.46
1	E8	200 year	63.2	0.07	0.0	0.07	417.0	419.36		419.54	0.0	0.6	2.2	0.6	50.8	53.9	0.47
1	E8	PMF	504.0	0.07	0.0	0.07	417.0	421.50		421.98	0.0	1.6	4.7	1.3	259.2	148.73	0.71
1	E7	5 year	23.1		0.0		417.0	417.37	417.4	417.56	0.0		1.9		12.2	33.12	1.00
1	E7	20 year	36.2		0.0		417.0	417.50	417.5	417.75	0.0		2.2		16.4	33.5	1.00
1	E7	100 year	54.3		0.0		417.0	417.66	417.7	417.98	0.0		2.5		21.7	33.97	1.00
1	E7	200 year	63.2		0.0		417.0	417.72	417.7	418.08	0.0		2.6		24.0	34.17	1.01
1	E7	PMF	504.0	0.07	0.0	0.07	417.0	419.65	419.7	420.36	0.0	1.1	4.2	1.1	195.9	161.99	0.83
1	E6	5 year	23.1		0.0		413.0	413.76	413.7	413.92	0.0		1.8		12.9	23.13	0.76
1	E6	20 year	36.2		0.0		413.0	413.98	413.8	414.17	0.0		2.0		18.4	26.64	0.76
1	E6	100 year	54.3	0.07	0.0	0.07	413.0	414.20	414.0	414.45	0.0	0.3	2.2	0.3	25.0	34.18	0.75
1	E6	200 year	63.2	0.07	0.0	0.07	413.0	414.29	414.1	414.56	0.0	0.4	2.3	0.4	28.3	37.48	0.75
1	E6	PMF	504.0	0.07	0.0	0.07	413.0	416.19	416.2	417.13	0.0	1.3	4.9	1.5	166.7	115.86	0.91

Table A2: HEC-RAS MODELLING RESULTS FOR EXISTING CONDITIONS - EASTERN CREEK

REACH	MODEL CROSS-SECTION	PROFILE	Q Total	Mann Wtd Left	Mann Wtd Chnl	Mann Wtd Rght	Min Ch El	W.S. Elevation	Crit W.S.	E.G. Elevation	E.G. Slope	Vel Left	Vel Chnl	Vel Right	Flow Area	Top Width	Froude # Channel
			(m3/s)				(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m/s)	(m/s)	(m2)	(m)	
1	E5	5 year	23.1		0.0		411.0	411.70	411.5	411.84	0.0		1.7		13.8	20.4	0.65
1	E5	20 year	36.2		0.0		411.0	411.90	411.7	412.11	0.0		2.0		17.9	20.8	0.70
1	E5	100 year	54.3	0.07	0.0	0.07	411.0	412.12	411.9	412.41	0.0	0.2	2.4	0.2	23.2	33.67	0.74
1	E5	200 year	63.2	0.07	0.0	0.07	411.0	412.21	412.0	412.54	0.0	0.3	2.6	0.3	26.7	43.5	0.76
1	E5	PMF	504.0	0.07	0.0	0.07	411.0	413.85	413.9	414.53	0.0	1.3	4.7	1.8	200.1	136.09	0.89
1	E4	5 year	23.1		0.0		408.5	408.98	409.0	409.21	0.0		2.2		10.7	22.95	1.01
1	E4	20 year	36.2		0.0		408.5	409.14	409.1	409.46	0.0		2.5		14.5	23.28	1.01
1	E4	100 year	54.3		0.0		408.5	409.34	409.3	409.75	0.0		2.8		19.2	23.68	1.01
1	E4	200 year	63.2		0.0		408.5	409.43	409.4	409.88	0.0		3.0		21.3	23.85	1.01
1	E4	PMF	504.0	0.07	0.0	0.07	408.5	411.67		412.18	0.0	1.5	4.0	1.3	220.6	120.67	0.71
1	E3	5 year	23.1		0.0		406.6	407.47		407.56	0.0		1.4		17.1	20.48	0.47
1	E3	20 year	36.2	0.07	0.0		406.6	407.71		407.84	0.0	0.1	1.6		22.5	28.53	0.51
1	E3	100 year	54.3	0.07	0.0		406.6	407.98		408.16	0.0	0.3	1.9		33.0	48.51	0.53
1	E3	200 year	63.2	0.07	0.0	0.07	406.6	408.10		408.28	0.0	0.4	2.0	0.1	38.9	53.66	0.53
1	E3	PMF	504.0	0.07	0.0	0.07	406.6	409.78	409.8	410.60	0.0	1.6	4.9	1.3	184.2	118.62	0.88
1	E2	5 year	26.2		0.0		406.5	407.14	407.0	407.31	0.0		1.8		14.6	23.28	0.73
1	E2	20 year	41.3		0.0		406.5	407.34	407.2	407.58	0.0		2.1		19.3	23.69	0.76
1	E2	100 year	61.7	0.07	0.0	0.07	406.5	407.57	407.4	407.89	0.0	0.2	2.5	0.2	25.2	35.89	0.78
1	E2	200 year	71.7	0.07	0.0	0.07	406.5	407.66	407.5	408.02	0.0	0.3	2.6	0.3	29.2	51.19	0.80
1	E2	PMF	565.0	0.07	0.0	0.07	406.5	409.26	409.3	409.85	0.0	1.3	4.5	1.5	265.6	225.14	0.87

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Appendix B HEC-RAS Modelling Sensitivity Analysis for 100 Year Recurrence Flood Event

Table B1: HEC-RAS ROUGHNESS AND FLOW SENSITIVITY ANALYSIS FOR MURRAGAMBA CREEK

			Adopted in EA2		Roughness Sensitivity (+10%)				Flow Sensitivity (+10%)			
REACH	MODEL CROSS-SECTION	PROFILE	W.S. Elevation	Vel Chnl	W.S. Elevation	Increase	Vel Chnl	Increase	W.S. Elevation	Increase	Vel Chnl	Increase
			(m)	(m/s)	(m)	(m)	(m/s)	(m/s)	(m)	(m)	(m/s)	(m/s)
Upper	M33	5 year	496.08	0.91	496.11	0.03	0.8	-0.1	496.1	0.02	1.0	0.0
Upper	M33	100 year	496.32	1.32	496.34	0.02	1.3	-0.1	496.33	0.01	1.4	0.1
Upper	M33	PMF	497.11	3.28	497.24	0.13	2.9	-0.4	497.19	0.08	3.4	0.1
Upper	M32	5 year	489.67	1.17	489.67	0	1.2	0.0	489.68	0.01	1.2	0.0
Upper	M32	100 year	489.81	1.67	489.83	0.02	1.5	-0.1	489.83	0.02	1.7	0.0
Upper	M32	PMF	490.43	3.09	490.43	0	3.1	0.0	490.48	0.05	3.2	0.1
Upper	M31	5 year	482.99	1.22	483.01	0.02	1.1	-0.1	483.01	0.02	1.3	0.0
Upper	M31	100 year	483.21	1.74	483.22	0.01	1.7	-0.1	483.21	0	1.9	0.1
Upper	M31	PMF	484.1	3.06	484.2	0.1	2.8	-0.3	484.18	0.08	3.1	0.0
Upper	M30	5 year	479.01	1.41	479.01	0	1.4	0.0	479.02	0.01	1.4	0.0
Upper	M30	100 year	479.23	1.57	479.26	0.03	1.4	-0.2	479.27	0.04	1.5	-0.1
Upper	M30	PMF	479.95	3.1	479.95	0	3.1	0.0	479.99	0.04	3.3	0.2
Upper	M29	5 year	475.51	0.81	475.52	0.01	0.8	0.0	475.54	0.03	0.8	0.0
Upper	M29	100 year	475.81	1.31	475.83	0.02	1.3	-0.1	475.83	0.02	1.4	0.1
Upper	M29	PMF	477.17	2.4	477.27	0.1	2.2	-0.2	477.28	0.11	2.4	0.0
Upper	M28	5 year	471.57	1.1	471.61	0.04	1.0	-0.1	471.6	0.03	1.1	0.0
Upper	M28	100 year	471.86	1.43	471.91	0.05	1.3	-0.1	471.92	0.06	1.4	0.0
Upper	M28	PMF	473.29	3.28	473.38	0.09	3.1	-0.2	473.37	0.08	3.4	0.2
Upper	M27	5 year	469.05	1.02	469.07	0.02	1.0	0.0	469.07	0.02	1.1	0.0
Upper	M27	100 year	469.32	1.47	469.34	0.02	1.4	-0.1	469.34	0.02	1.6	0.1
Upper	M27	PMF	470.83	2.76	470.97	0.14	2.5	-0.2	470.96	0.13	2.8	0.0
Upper	M26	5 year	466.62	0.83	466.66	0.04	0.8	-0.1	466.64	0.02	0.9	0.0
Upper	M26	100 year	466.93	1.03	466.98	0.05	0.9	-0.1	466.98	0.05	1.0	0.0
Upper	M26	PMF	468.33	2.25	468.37	0.04	2.2	0.0	468.39	0.06	2.4	0.2
Upper	M25	5 year	460.85	3.82	460.85	0	3.8	0.0	460.92	0.07	3.9	0.1
Upper	M25	100 year	461.57	5.16	461.57	0	5.2	0.0	461.58	0.01	5.6	0.5
Upper	M25	PMF	464.03	6.41	464.25	0.22	5.5	-0.9	464.23	0.2	6.2	-0.3
Upper	M24	5 year	457.23	2.13	457.29	0.06	2.0	-0.1	457.29	0.06	2.2	0.1
Upper	M24	100 year	457.97	3.17	458.07	0.1	3.0	-0.2	458.06	0.09	3.3	0.1
Upper	M24	PMF	462.32	5.51	462.32	0	5.5	0.0	462.47	0.15	5.7	0.2
Upper	M23	5 year	456.05	1.85	456.12	0.07	1.7	-0.1	456.1	0.05	1.9	0.1
Upper	M23	100 year	456.66	2.74	456.74	0.08	2.6	-0.2	456.74	0.08	2.8	0.1
Upper	M23	PMF	459.22	6.39	459.32	0.1	5.9	-0.5	459.71	0.49	5.0	-1.4
Upper	M22	5 year	454.89	1.37	454.93	0.04	1.3	-0.1	454.94	0.05	1.4	0.0
Upper	M22	100 year	455.51	1.95	455.61	0.1	1.8	-0.1	455.59	0.08	2.0	0.1
Upper	M22	PMF	457.83	4.48	458.04	0.21	4.0	-0.5	457.97	0.14	4.5	0.1
Trib_2	S3	5 year	461.21	0.92	461.21	0	0.9	0.0	461.23	0.02	0.9	-0.1
Trib_2	S3	100 year	461.32	1.31	461.37	0.05	1.0	-0.3	461.33	0.01	1.4	0.0
Trib_2	S3	PMF	461.82	2.56	461.82	0	2.6	0.0	461.85	0.03	2.7	0.1
Trib_2	S2	5 year	456.94	1.3	456.97	0.03	1.2	-0.1	456.94	0	1.4	0.1
Trib_2	S2	100 year	457.23	2	457.2	-0.03	2.1	0.1	457.26	0.03	2.1	0.1
Trib_2	S2	PMF	458.65	3.2	458.75	0.1	2.9	-0.3	458.74	0.09	3.3	0.1

Table B1: HEC-RAS ROUGHNESS AND FLOW SENSITIVITY ANALYSIS FOR MURRAGAMBA CREEK

			Adopted in EA2		Roughness Sensitivity (+10%)				Flow Sensitivity (+10%)			
REACH	MODEL CROSS-SECTION	PROFILE	W.S. Elevation	Vel Chnl	W.S. Elevation	Increase	Vel Chnl	Increase	W.S. Elevation	Increase	Vel Chnl	Increase
			(m)	(m/s)	(m)	(m)	(m/s)	(m/s)	(m)	(m)	(m/s)	(m/s)
Trib_2	S1	5 year	455.61	1.28	455.63	0.02	1.2	-0.1	455.65	0.04	1.3	0.0
Trib_2	S1	100 year	455.97	1.87	456.1	0.13	1.6	-0.3	456.01	0.04	1.9	0.1
Trib_2	S1	PMF	457.97	3.27	458.17	0.2	2.9	-0.4	458.11	0.14	3.3	0.0
Middle	M21	5 year	453.25	2.68	453.3	0.05	2.5	-0.2	453.29	0.04	2.8	0.1
Middle	M21	100 year	453.89	3.48	453.89	0	3.5	0.0	453.98	0.09	3.6	0.1
Middle	M21	PMF	456.42	5.58	456.42	0	5.6	0.0	456.55	0.13	5.7	0.1
Middle	M20	5 year	451.2	2.19	451.23	0.03	2.1	-0.1	451.24	0.04	2.3	0.1
Middle	M20	100 year	451.55	3.26	451.59	0.04	3.1	-0.1	451.61	0.06	3.4	0.1
Middle	M20	PMF	454.24	5.62	454.24	0	5.6	0.0	454.38	0.14	5.7	0.1
Middle	M19	5 year	450.32	0.97	450.37	0.05	0.9	-0.1	450.36	0.04	1.0	0.0
Middle	M19	100 year	450.72	1.3	450.78	0.06	1.2	-0.1	450.77	0.05	1.4	0.1
Middle	M19	PMF	452.23	3.43	452.33	0.1	3.2	-0.2	452.33	0.1	3.5	0.1
Middle	M18	5 year	447.69	2.26	447.69	0	2.3	0.0	447.73	0.04	2.3	0.1
Middle	M18	100 year	448.16	2.68	448.16	0	2.7	0.0	448.22	0.06	2.7	0.0
Middle	M18	PMF	450.63	3.23	450.83	0.2	2.9	-0.3	450.82	0.19	3.2	0.0
Middle	M17	5 year	443.06	2.01	443.12	0.06	1.9	-0.1	443.13	0.07	2.1	0.1
Middle	M17	100 year	444.01	2.6	444.12	0.11	2.5	-0.1	444.14	0.13	2.7	0.1
Middle	M17	PMF	448.26	5.43	448.26	0	5.4	0.0	448.42	0.16	5.6	0.2
Middle	M16	5 year	441.17	2.98	441.27	0.1	2.8	-0.2	441.27	0.1	3.1	0.1
Middle	M16	100 year	442.2	4.17	442.29	0.09	4.0	-0.2	442.34	0.14	4.3	0.1
Middle	M16	PMF	445.74	7.07	445.74	0	7.1	0.0	445.88	0.14	7.3	0.2
Middle	M15	5 year	438.16	2.24	438.22	0.06	2.1	-0.1	438.22	0.06	2.3	0.1
Middle	M15	100 year	438.98	2.94	439.11	0.13	2.7	-0.3	439.05	0.07	3.1	0.1
Middle	M15	PMF	441.07	5.05	441.13	0.06	4.9	-0.2	441.19	0.12	5.2	0.1
Middle	M14	5 year	435	1.75	435.04	0.04	1.6	-0.1	435.04	0.04	1.8	0.1
Middle	M14	100 year	435.36	2.61	435.37	0.01	2.6	0.0	435.41	0.05	2.7	0.1
Middle	M14	PMF	437.01	4.82	437.01	0	4.8	0.0	437.13	0.12	4.9	0.1
Middle	M13	5 year	433.25	0.85	433.27	0.02	0.8	0.0	433.27	0.02	0.9	0.0
Middle	M13	100 year	433.59	1.09	433.63	0.04	1.0	-0.1	433.63	0.04	1.1	0.0
Middle	M13	PMF	435.64	2.09	435.78	0.14	2.0	-0.1	435.79	0.15	2.1	0.0
Trib_1	T6	5 year	458.07	0.79	458.07	0	0.8	0.0	458.07	0	0.8	0.0
Trib_1	T6	100 year	458.14	1.13	458.14	0	1.1	0.0	458.15	0.01	1.2	0.0
Trib_1	T6	PMF	458.4	1.85	458.4	0	1.9	0.0	458.42	0.02	1.9	0.0
Trib_1	T5	5 year	449.96	0.8	449.96	0	0.8	0.0	449.97	0.01	0.8	0.0
Trib_1	T5	100 year	450.07	1.2	450.07	0	1.2	0.0	450.09	0.02	1.2	0.0
Trib_1	T5	PMF	450.41	2.06	450.46	0.05	1.9	-0.2	450.44	0.03	2.1	0.1
Trib_1	T4	5 year	445.01	1.01	445.03	0.02	0.9	-0.2	445.02	0.01	1.1	0.1
Trib_1	T4	100 year	445.11	1.18	445.13	0.02	1.0	-0.1	445.11	0	1.2	0.1
Trib_1	T4	PMF	445.32	1.98	445.32	0	2.0	0.0	445.34	0.02	2.0	0.0
Trib_1	T3	5 year	441.08	1.16	441.08	0	1.2	0.0	441.1	0.02	1.1	0.0
Trib_1	T3	100 year	441.21	1.51	441.21	0	1.5	0.0	441.23	0.02	1.5	0.0
Trib_1	T3	PMF	441.49	1.84	441.52	0.03	1.6	-0.2	441.5	0.01	1.9	0.1

Table B1: HEC-RAS ROUGHNESS AND FLOW SENSITIVITY ANALYSIS FOR MURRAGAMBA CREEK

			Adopted in EA2		Roughness Sensitivity (+10%)				Flow Sensitivity (+10%)			
REACH	MODEL CROSS-SECTION	PROFILE	W.S. Elevation	Vel Chnl	W.S. Elevation	Increase	Vel Chnl	Increase	W.S. Elevation	Increase	Vel Chnl	Increase
			(m)	(m/s)	(m)	(m)	(m/s)	(m/s)	(m)	(m)	(m/s)	(m/s)
Trib_1	T2	5 year	438.08		438.09	0.01		0.0	438.09	0.01		0.0
Trib_1	T2	100 year	438.19		438.21	0.02		0.0	438.2	0.01		0.0
Trib_1	T2	PMF	438.35	0.53	438.35	0	0.5	0.0	438.37	0.02	0.6	0.1
Trib_1	T1	5 year	432.97	1.45	432.97	0	1.5	0.0	432.99	0.02	1.5	0.0
Trib_1	T1	100 year	433.2	1.88	433.2	0	1.9	0.0	433.23	0.03	1.9	0.0
Trib_1	T1	PMF	435.2	0.41	435.3	0.1	0.4	-0.1	435.34	0.14	0.4	0.0
Lower	M12	5 year	431.37	0.85	431.42	0.05	0.8	-0.1	431.42	0.05	0.9	0.0
Lower	M12	100 year	431.8	1.1	431.85	0.05	1.0	-0.1	431.85	0.05	1.1	0.0
Lower	M12	PMF	434.23	2.64	434.36	0.13	2.5	-0.1	434.39	0.16	2.7	0.1
Lower	M11	5 year	428.91	1.45	428.93	0.02	1.4	-0.1	428.93	0.02	1.5	0.1
Lower	M11	100 year	429.24	2.02	429.28	0.04	1.9	-0.1	429.29	0.05	2.1	0.1
Lower	M11	PMF	431.46	4.66	431.59	0.13	4.4	-0.3	431.6	0.14	4.8	0.1
Lower	M10	5 year	426.67	1.18	426.73	0.06	1.1	-0.1	426.73	0.06	1.2	0.0
Lower	M10	100 year	427.09	1.72	427.15	0.06	1.6	-0.1	427.13	0.04	1.8	0.1
Lower	M10	PMF	428.92	4.24	429.06	0.14	3.9	-0.3	429.04	0.12	4.4	0.1
Lower	M9	5 year	425.03	0.69	425.04	0.01	0.7	0.0	425.04	0.01	0.7	0.1
Lower	M9	100 year	425.25	1.05	425.28	0.03	1.0	-0.1	425.29	0.04	1.1	0.0
Lower	M9	PMF	427.11	2.6	427.23	0.12	2.5	-0.1	427.24	0.13	2.7	0.1
Lower	M8	5 year	423.95	0.96	423.99	0.04	0.9	-0.1	424	0.05	0.9	0.0
Lower	M8	100 year	424.29	1.11	424.35	0.06	1.0	-0.1	424.33	0.04	1.2	0.0
Lower	M8	PMF	426.08	2.88	426.23	0.15	2.7	-0.2	426.18	0.1	3.0	0.1
Lower	M7	5 year	422.42	1.49	422.42	0	1.5	0.0	422.41	-0.01	1.7	0.2
Lower	M7	100 year	422.69	2.34	422.69	0	2.3	0.0	422.73	0.04	2.4	0.0
Lower	M7	PMF	424.09	5.16	424.09	0	5.2	0.0	424.2	0.11	5.2	0.1
Lower	M6.6	5 year	422.49	0.28	422.49	0	0.3	0.0	422.5	0.01	0.3	0.0
Lower	M6.6	100 year	422.68	0.58	422.68	0	0.6	0.0	422.71	0.03	0.6	0.0
Lower	M6.6	PMF	424.12	2.57	424.12	0	2.6	0.0	424.22	0.1	2.7	0.1
Lower	M6.4	5 year	420.42	2.88	420.5	0.08	2.6	-0.2	420.52	0.1	2.8	0.0
Lower	M6.4	100 year	421.13	2.89	421.13	0	2.9	0.0	421.24	0.11	2.8	-0.1
Lower	M6.4	PMF	423.35	2.68	423.46	0.11	2.5	-0.2	423.5	0.15	2.7	0.0
Lower	M6	5 year	417.39	3.16	417.38	-0.01	3.2	0.0	417.45	0.06	3.3	0.1
Lower	M6	100 year	418.23	3.54	418.23	0	3.5	0.0	418.33	0.1	3.6	0.1
Lower	M6	PMF	421.86	4.41	421.86	0	4.4	0.0	421.97	0.11	4.6	0.1
Lower	M5	5 year	415.98	1.58	416	0.02	1.5	0.0	416.02	0.04	1.7	0.1
Lower	M5	100 year	416.46	2.33	416.54	0.08	2.2	-0.1	416.55	0.09	2.4	0.0
Lower	M5	PMF	419.85	4.49	419.93	0.08	4.3	-0.2	419.99	0.14	4.6	0.1
Lower	M4	5 year	413.84	2.61	413.94	0.1	2.3	-0.3	413.92	0.08	2.6	0.0
Lower	M4	100 year	414.83	2.68	414.96	0.13	2.5	-0.2	414.94	0.11	2.8	0.1
Lower	M4	PMF	418.45	4.81	418.43	-0.02	4.8	0.0	418.58	0.13	4.9	0.1
Lower	M3	5 year	413.05	1.12	413.14	0.09	1.1	-0.1	413.14	0.09	1.2	0.0
Lower	M3	100 year	413.88	1.57	413.99	0.11	1.5	-0.1	413.96	0.08	1.6	0.1
Lower	M3	PMF	416.76	2.2	416.83	0.07	2.1	-0.1	416.88	0.12	2.3	0.1

Table B1: HEC-RAS ROUGHNESS AND FLOW SENSITIVITY ANALYSIS FOR <u>MURRAGAMBA</u> CREEK

			Adopted in EA2		Roughness Sensitivity (+10%)				Flow Sensitivity (+10%)			
REACH	MODEL CROSS-SECTION	PROFILE	W.S. Elevation	Vel Chnl	W.S. Elevation	Increase	Vel Chnl	Increase	W.S. Elevation	Increase	Vel Chnl	Increase
			(m)	(m/s)	(m)	(m)	(m/s)	(m/s)	(m)	(m)	(m/s)	(m/s)
Lower	M2.1	5 year	411.04	3.31	411.04	0	3.3	0.0	411.15	0.11	3.3	0.0
Lower	M2.1	100 year	413.25	1.47	413.25	0	1.5	0.0	413.52	0.27	1.3	-0.2
Lower	M2.1	PMF	416.59	1.69	416.6	0.01	1.7	0.0	416.7	0.11	1.8	0.1
Lower	M2.05	5 year	411.25	1.38	411.25	0	1.4	0.0	411.41	0.16	1.3	-0.1
Lower	M2.05	100 year	413.28	1.06	413.28	0	1.1	0.0	413.53	0.25	1.1	0.0
Lower	M2.05	PMF	416.55	2.03	416.56	0.01	2.0	0.0	416.66	0.11	2.1	0.1
Lower	M2	5 year	410.67	1.68	410.68	0.01	1.7	0.0	410.8	0.13	1.7	0.0
Lower	M2	100 year	412.3	1.55	412.3	0	1.6	0.0	412.7	0.4	1.5	-0.1
Lower	M2	PMF	416.54	2.13	416.54	0	2.1	0.0	416.63	0.09	2.3	0.1
Lower	M1.6	5 year	410.71	1.01	410.72	0.01	1.0	0.0	410.84	0.13	1.0	0.0
Lower	M1.6	100 year	412.36	0.81	412.36	0	0.8	0.0	412.76	0.4	0.7	-0.1
Lower	M1.6	PMF	416.58	1.13	416.58	0	1.1	0.0	416.67	0.09	1.2	0.1
Lower	M1.4	5 year	409.99	1.71	410.05	0.06	1.6	-0.1	410.05	0.06	1.8	0.1
Lower	M1.4	100 year	410.61	2.6	410.7	0.09	2.5	-0.1	410.68	0.07	2.7	0.1
Lower	M1.4	PMF	413.38	4.86	413.38	0	4.9	0.0	413.47	0.09	5.0	0.1
Lower	M1	5 year	408.55	1.76	408.59	0.04	1.6	-0.1	408.59	0.04	1.8	0.0
Lower	M1	100 year	408.93	2.18	408.97	0.04	2.0	-0.2	408.97	0.04	2.2	0.0
Lower	M1	PMF	410.94	2.3	411.08	0.14	2.2	-0.1	411.09	0.15	2.4	0.1

Table B2: HEC-RAS ROUGHNESS AND FLOW SENSITIVITY ANALYSIS FOR EASTERN CREEK

			Adopted in EA2		Roughness Sensitivity (+10%)				Flow Sensitivity (+10%)			
REACH	MODEL CROSS-SECTION	PROFILE	W.S. Elevation	Vel Chnl	W.S. Elevation	Increase	Vel Chnl	Increase	W.S. Elevation	Increase	Vel Chnl	Increase
			(m)	(m/s)	(m)	(m)	(m/s)	(m/s)	(m)	(m)	(m/s)	(m/s)
1	E17	5 year	465.72	1.3	465.72	0.0	1.3	0.0	465.73	0.0	1.3	0.0
1	E17	100 year	465.87	1.7	465.87	0.0	1.7	0.0	465.89	0.0	1.8	0.1
1	E17	PMF	466.63	3.1	466.63	0.0	3.1	0.0	466.69	0.1	3.2	0.1
1	E16	5 year	458.82	1.6	458.87	0.05	1.5	-0.1	458.85	0.03	1.7	0.1
1	E16	100 year	459.12	2.4	459.19	0.07	2.2	-0.3	459.15	0.03	2.5	0.1
1	E16	PMF	460.51	4.0	460.51	0	4.0	0.0	460.59	0.08	4.1	0.1
1	E15	5 year	452.09	1.8	452.09	0	1.8	0.0	452.11	0.02	1.8	0.0
1	E15	100 year	452.38	2.3	452.38	0	2.3	0.0	452.41	0.03	2.3	0.1
1	E15	PMF	453.76	3.7	453.76	0	3.7	0.0	453.85	0.09	3.8	0.1
						0		0.0		0		0.0
1	E14	5 year	445.32	1.1	445.34	0.02	1.0	-0.1	445.33	0.01	1.2	0.0
1	E14	100 year	445.44	1.7	445.46	0.02	1.6	-0.1	445.46	0.02	1.8	0.1
1	E14	PMF	446.27	3.2	446.27	0	3.2	0.0	446.32	0.05	3.4	0.1
1	E13	5 year	438.57	1.7	438.58	0.01	1.6	0.0	438.59	0.02	1.7	0.0
1	E13	100 year	438.88	2.1	438.89	0.01	2.0	0.0	438.92	0.04	2.1	0.0
1	E13	PMF	439.98	3.9	440.15	0.17	3.4	-0.5	440.07	0.09	4.0	0.1
1	E12	5 year	433.21	1.4	433.26	0.05	1.3	-0.1	433.24	0.03	1.4	0.0
1	E12	100 year	433.54	1.9	433.6	0.06	1.8	-0.2	433.57	0.03	2.0	0.1
1	E12	PMF	434.62	3.6	434.62	0	3.6	0.0	434.69	0.07	3.7	0.1
1	E11	5 year	429.19	1.4	429.19	0	1.4	0.0	429.21	0.02	1.4	0.0
1	E11	100 year	429.35	1.9	429.35	0	1.9	0.0	429.38	0.03	1.9	0.0
1	E11	PMF	430.21	2.9	430.21	0	2.9	0.0	430.25	0.04	3.0	0.1
1	E10	5 year	422.39	1.2	422.41	0.02	1.1	-0.1	422.41	0.02	1.2	0.0
1	E10	100 year	422.63	1.8	422.65	0.02	1.7	-0.1	422.67	0.04	1.8	0.1
1	E10	PMF	423.84	4.1	423.99	0.15	3.7	-0.4	423.94	0.1	4.2	0.1

Table B2: HEC-RAS ROUGHNESS AND FLOW SENSITIVITY ANALYSIS FOR EASTERN CREEK

			Adopted in EA2		Roughness Sensitivity (+10%)				Flow Sensitivity (+10%)			
REACH	MODEL CROSS-SECTION	PROFILE	W.S. Elevation	Vel Chnl	W.S. Elevation	Increase	Vel Chnl	Increase	W.S. Elevation	Increase	Vel Chnl	Increase
			(m)	(m/s)	(m)	(m)	(m/s)	(m/s)	(m)	(m)	(m/s)	(m/s)
1	E9	5 year	419.49	2.3	419.52	0.03	2.2	-0.1	419.53	0.04	2.4	0.1
1	E9	100 year	420.11	2.7	420.2	0.09	2.5	-0.2	420.19	0.08	2.7	0.1
1	E9	PMF	422.71	3.1	422.82	0.11	3.0	-0.2	422.86	0.15	3.2	0.0
1	E8	5 year	418.67	1.5	418.74	0.07	1.4	-0.1	418.73	0.06	1.5	0.1
1	E8	100 year	419.24	2.1	419.33	0.09	2.0	-0.1	419.32	0.08	2.2	0.1
1	E8	PMF	421.50	4.7	421.69	0.19	4.3	-0.4	421.62	0.12	4.8	0.1
1	E7	5 year	417.37	1.9	417.37	0	1.9	0.0	417.4	0.03	2.0	0.1
1	E7	100 year	417.66	2.5	417.66	0	2.5	0.0	417.7	0.04	2.6	0.1
1	E7	PMF	419.65	4.2	419.65	0	4.2	0.0	419.77	0.12	4.3	0.1
1	E6	5 year	413.76	1.8	413.78	0.02	1.7	-0.1	413.8	0.04	1.8	0.0
1	E6	100 year	414.20	2.2	414.22	0.02	2.2	-0.1	414.25	0.05	2.3	0.1
1	E6	PMF	416.19	4.9	416.21	0.02	4.8	0.0	416.4	0.21	4.9	0.0
1	E5	5 year	411.70	1.7	411.76	0.06	1.5	-0.1	411.74	0.04	1.7	0.1
1	E5	100 year	412.12	2.4	412.21	0.09	2.2	-0.2	412.17	0.05	2.5	0.1
1	E5	PMF	413.85	4.7	413.85	0	4.7	0.0	413.94	0.09	4.9	0.2
1	E4	5 year	408.98	2.2	408.98	0	2.2	0.0	409.01	0.03	2.2	0.1
1	E4	100 year	409.34	2.8	409.34	0	2.8	0.0	409.39	0.05	2.9	0.1
1	E4	PMF	411.67	4.0	411.85	0.18	3.6	-0.3	411.83	0.16	4.0	0.1
1	E3	5 year	407.47	1.4	407.5	0.03	1.3	-0.1	407.51	0.04	1.4	0.1
1	E3	100 year	407.98	1.9	408.03	0.05	1.8	-0.1	408.05	0.07	2.0	0.1
1	E3	PMF	409.78	4.9	409.78	0	4.9	0.0	409.88	0.1	5.1	0.2
1	E2	5 year	407.14	1.8	407.18	0.04	1.7	-0.1	407.18	0.04	1.9	0.1
1	E2	100 year	407.57	2.5	407.63	0.06	2.4	-0.1	407.63	0.06	2.6	0.1
1	E2	PMF	409.26	4.5	409.3	0.04	4.4	-0.1	409.36	0.1	4.6	0.1

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Appendix C Dirty Water Balance Sensitivity Analysis

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Table C1 SENSITIVITY OF WATER BALANCE MODEL TO 10% INCREASE IN ROM FACTOR FOR AVERAGE RAINFALL CONDITIONS

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Inflows From Open Cut Mining (ML/yr)	Inflows From Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Used From Mine Area Surface Water Storages (ML/yr)	Deficit (ML/yr)
1	7.0	1743	280.3	0.0	1101.0	260	-102
2	11.0	2739	203.5	0.0	1146.1	365	-1024
3	11.5	2864	259.7	0.0	1037.4	453	-1113
4	12.0	2988	102.0	218.1	1038.3	479	-1150
5	12.3	3073	75.8	291.6	932.4	479	-1294
6	14.4	3579	55.1	302.4	926.3	457	-1839
7	15.4	3829	287.0	281.8	870.6	551	-1839
8	16.2	4042	290.1	263.6	845.4	526	-2117
9	16.3	4064	456.9	293.7	849.7	479	-1984
10	16.4	4080	663.9	229.1	815.7	332	-2039
11	15.8	3935	516.3	364.3	930.5	414	-1710
12	16.3	4069	417.2	324.1	1032.3	414	-1882
13	16.2	4038	413.0	321.6	1104.8	274	-1924
14	15.4	3823	360.0	444.3	1062.9	243	-1712
15	16.0	3991	321.1	283.9	1128.8	243	-2014
16	15.3	3798	292.6	305.6	1135.0	343	-1722
17	15.3	3818	495.2	363.3	1135.4	442	-1382
18	15.7	3913	393.1	380.4	1112.3	306	-1721
19	16.8	4191	309.2	443.8	1100.4	306	-2031
20	16.9	4200	429.0	439.1	1106.9	231	-1946
21	16.6	4133	34.0	510.0	1135.3	251	-2155
22	16.0	3987	29.1	687.5	945.4	321	-2007
23	14.7	3668	69.3	1176.6	274.1	189	-1908
24	14.2	3537	96.6	940.1	856.5	174	-1467

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Table C2 SENSITIVITY OF WATER BALANCE MODEL TO 10% REDUCTION IN ROM FACTOR FOR AVERAGE RAINFALL CONDITIONS

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Inflows From Open Cut Mining (ML/yr)	Inflows From Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Used From Mine Area Surface Water Storages (ML/yr)	Deficit (ML/yr)
1	7.0	1428	280.3	0.0	1101.0	260	213
2	11.0	2244	203.5	0.0	1146.1	365	-529
3	11.5	2346	259.7	0.0	1037.4	453	-596
4	12.0	2448	102.0	218.1	1038.3	479	-610
5	12.3	2518	75.8	291.6	932.4	479	-739
6	14.4	2932	55.1	302.4	926.3	457	-1192
7	15.4	3137	287.0	281.8	870.6	551	-1147
8	16.2	3312	290.1	263.6	845.4	526	-1387
9	16.3	3329	456.9	293.7	849.7	479	-1250
10	16.4	3343	663.9	229.1	815.7	332	-1302
11	15.8	3224	516.3	364.3	930.5	414	-999
12	16.3	3334	417.2	324.1	1032.3	414	-1147
13	16.2	3308	413.0	321.6	1104.8	274	-1195
14	15.4	3132	360.0	444.3	1062.9	243	-1021
15	16.0	3270	321.1	283.9	1128.8	243	-1293
16	15.3	3111	292.6	305.6	1135.0	343	-1035
17	15.3	3128	495.2	363.3	1135.4	442	-692
18	15.7	3206	393.1	380.4	1112.3	306	-1014
19	16.8	3433	309.2	443.8	1100.4	306	-1274
20	16.9	3441	429.0	439.1	1106.9	231	-1187
21	16.6	3386	34.0	510.0	1135.3	251	-1408
22	16.0	3266	29.1	687.5	945.4	321	-1286
23	14.7	3005	69.3	1176.6	274.1	189	-1245
24	14.2	2898	96.6	940.1	856.5	174	-827

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Table C3 SENSITIVITY OF WATER BALANCE MODEL TO INCREASE IN RUN-OFF COEFFICIENT TO C = 0.35 FOR AVERAGE RAINFALL CONDITIONS

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Inflows From Open Cut Mining (ML/yr)	Inflows From Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Used From Mine Area Surface Water Storages (ML/yr)	Deficit (ML/yr)
1	7.0	1589	280.3	0.0	1101.0	493	285
2	11.0	2497	203.5	0.0	1146.1	691	-456
3	11.5	2611	259.7	0.0	1037.4	859	-455
4	12.0	2724	102.0	218.1	1038.3	908	-457
5	12.3	2802	75.8	291.6	932.4	908	-593
6	14.4	3263	55.1	302.4	926.3	865	-1113
7	15.4	3491	287.0	281.8	870.6	1049	-1002
8	16.2	3685	290.1	263.6	845.4	1003	-1283
9	16.3	3705	456.9	293.7	849.7	914	-1191
10	16.4	3720	663.9	229.1	815.7	642	-1369
11	15.8	3587	516.3	364.3	930.5	798	-978
12	16.3	3710	417.2	324.1	1032.3	798	-1138
13	16.2	3681	413.0	321.6	1104.8	530	-1312
14	15.4	3485	360.0	444.3	1062.9	463	-1155
15	16.0	3638	321.1	283.9	1128.8	463	-1442
16	15.3	3462	292.6	305.6	1135.0	653	-1076
17	15.3	3481	495.2	363.3	1135.4	842	-645
18	15.7	3567	393.1	380.4	1112.3	581	-1100
19	16.8	3821	309.2	443.8	1100.4	581	-1386
20	16.9	3829	429.0	439.1	1106.9	529	-1324
21	16.6	3768	34.0	510.0	1135.3	568	-1521
22	16.0	3635	29.1	687.5	945.4	606	-1367
23	14.7	3344	69.3	1176.6	274.1	457	-1367
24	14.2	3225	96.6	940.1	856.5	337	-994

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Supplementary Surface Water Investigations Including Water Balance Modelling

Table C4 SENSITIVITY OF WATER BALANCE MODEL TO DECREASE IN RUN-OFF COEFFICIENT TO C = 0.15 FOR AVERAGE RAINFALL CONDITIONS

Mine Year	Total Mined ROM Coal (Mtpa)	Total Demand (ML/yr)	Inflows From Open Cut Mining (ML/yr)	Inflows From Underground Mining (ML/yr)	Groundwater Pumped From the Northern Borefield (ML/yr)	Water Used From Mine Area Surface Water Storages (ML/yr)	Deficit (ML/yr)
1	7.0	1589	280.3	0.0	1101.0	85	-123
2	11.0	2497	203.5	0.0	1146.1	119	-1029
3	11.5	2611	259.7	0.0	1037.4	147	-1167
4	12.0	2724	102.0	218.1	1038.3	155	-1210
5	12.3	2802	75.8	291.6	932.4	155	-1347
6	14.4	3263	55.1	302.4	926.3	148	-1831
7	15.4	3491	287.0	281.8	870.6	177	-1874
8	16.2	3685	290.1	263.6	845.4	170	-2117
9	16.3	3705	456.9	293.7	849.7	155	-1950
10	16.4	3720	663.9	229.1	815.7	107	-1904
11	15.8	3587	516.3	364.3	930.5	133	-1644
12	16.3	3710	417.2	324.1	1032.3	133	-1803
13	16.2	3681	413.0	321.6	1104.8	88	-1754
14	15.4	3485	360.0	444.3	1062.9	79	-1539
15	16.0	3638	321.1	283.9	1128.8	79	-1826
16	15.3	3462	292.6	305.6	1135.0	111	-1618
17	15.3	3481	495.2	363.3	1135.4	143	-1344
18	15.7	3567	393.1	380.4	1112.3	99	-1582
19	16.8	3821	309.2	443.8	1100.4	99	-1868
20	16.9	3829	429.0	439.1	1106.9	90	-1764
21	16.6	3768	34.0	510.0	1135.3	96	-1992
22	16.0	3635	29.1	687.5	945.4	103	-1870
23	14.7	3344	69.3	1176.6	274.1	77	-1747
24	14.2	3225	96.6	940.1	856.5	57	-1274