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Carmichael Water Balance Model

Water Balance Modelling Review
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Revision	Date	Description	Author		Approver	
			FirstName LastName	Position Title	FirstName LastName	Position Title
01	04/02/2014	Draft	Dr Mohand Amghar	Principal water Engineer	Dr Ikhlef Benzenati	Manager Geotechnical, Water & Tailings
02	10/02/2014	Final	Dr Mohand Amghar	Principal water Engineer	Dr Ikhlef Benzenati	Manager Geotechnical, Water & Tailings
03	28/02/2014	Overflow statistics and clarity in figure scales	Dr Mohand Amghar	Principal water Engineer	Dr Ikhlef Benzenati	Manager Geotechnical, Water & Tailings

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1 Introduction

Adani Mining received submissions in response to the public notice of the Carmichael Coal Mine and Rail Project's Additional Environmental Impact Statement (AEIS).

These submissions included a number of comments in regards to the Project (Mine) Water Balance Assessment and outcomes, particularly in regards to the following matters:

1. The inclusion and classification of Sediment Affected Water (SAW) dams;
2. The proposed overflow / discharge regimes from SAW dams;
3. The proposed overflow / discharge regimes from process water dams (PWD);
4. Calculations of anticipated Mine Affected Water (MAW) dam discharge volumes, both annually and event wise; and
5. Consideration of mine water management practices in regards to managing MAW quality issues.

In response to these submissions, and following discussions with the Office of the Coordinator General (OCG), the Department of Natural Resources and Mines (DNRM) and the Department of the Environment and Heritage Protection (DEHP), Adani has undertaken a review of the Mine Water Balance Assessment for the following purposes:

1. To prepare submissions responses on relevant matters for inclusion in the OCG Carmichael Coal Mine and Rail Project AEIS Response Register;
2. To revisit the assessment in order to address DEHP concerns, particularly regarding the classification of SAW dams and discharges; and
3. To review operating parameters and assumptions that were inputs to the assessment, in order to identify potential opportunities to reduce associated net impacts as model outputs.

This report presents the findings of that review and the report is intended to assist the OCG in its assessment of the Carmichael Coal Mine and Rail Project AEIS, and to assist the DEHP in establishing proposed conditions for the Draft Environmental Authority for the Carmichael Coal Mine.

This report outlines the potential impacts of the Carmichael Coal Mine Project (the Project) on receiving surface waters, and the proposed mitigation measures namely "the proposed site water management system".

The report also describes the results of a site water balance model review prepared to improve the understanding of the likely magnitude, frequency, timing and duration of proposed releases of mine water to the Carmichael River. This water balance model was also used to review and assess the performance of the site water storages, for benchmarking against the DEHP guideline design criteria for sizing mine dams.

The information presented in these reports is taken from the 2013 water balance model (GHD, October 2013) and has been used in the preparation of this report. Therefore, this report should be read in conjunction with the 2013 water balance modelling report as all the input data used in this review is similar with the exception to the water management system operating rules.

Where there is a conflict between the present review and previous investigations, the current review takes precedence.

1.1 Purpose

A mine water management review was undertaken for the proposed the Project. The aim of the review was to confirm a water management strategy for the mine area to meet the following water management objectives:

- Provision of process water through maximising the use of potential contact water onsite and minimising releases;
- Achieve 95% reliability of water supply for coal processing, construction, potable use and dust suppression;
- Maximise the operability of the pit by minimising flooding in the pit; and
- Direct water from undisturbed areas away from mine operations to limit contaminations.

The review was undertaken using a water balance model developed for the operation phase using the GoldSim software modelling package.

1.2 Assumptions of the design parameters

The modelling described in this report has been reviewed and developed based on work undertaken for the Environmental Impact Statement (EIS) in 2012 and additional work conducted for the AEIS as of August 2013. It is anticipated that the Project design will continue to evolve and the water balance model will need to be updated to reflect any significant changes during the design process.

Input data for the water balance model is based on relatively long historic rainfall and evaporation records as well as input data used in the 2013 water balance model (SEIS Volume 4, Appendix K2, October 2013).

2 Model Review Development

2.1 Site Description

The Study Area of this investigation incorporates upstream elements of the Project disturbance area pertaining to the operations which is located immediately adjacent to the mine pit. This includes the mine water management as well as fresh and process water supply and storages (Figure 2-1).

Mine Water demands is required for coal processing, dust suppression, potable use and underground mine operations.

Water balance modelling undertaken in this investigation involves rainfall and flows in several surrounding catchments, including the Belyando River, the Carmichael River and the Mistake Creek. The site receives inputs of water from runoff from surrounding catchments, direct rainfall into the dams and groundwater inflow to the pit.

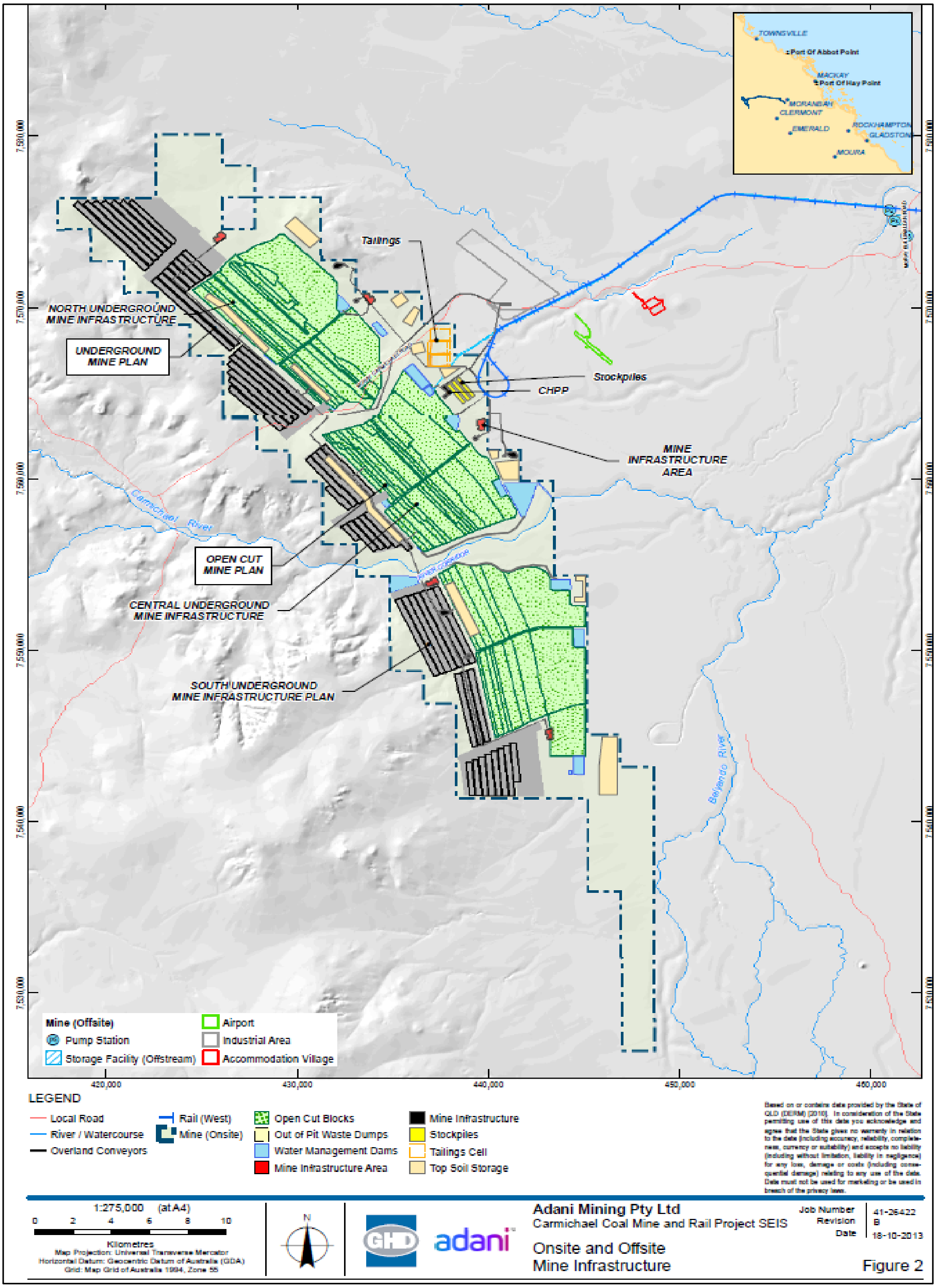


Figure 2-1 Mine layout Plan (Sourced from GHD's Water Balance Report, 2013)

2.2 Storage Design Philosophy

The design philosophy for the water storages on the site was to optimise the storage volume in consideration of cost effectiveness and site conditions. This is due to the climate variability and high construction cost.

The mine Water Management System (WMS) has been based on the following key design objectives:

- Segregation of water based on source and assumed quality;
- Minimisation of the on-site generation of MAW;
- Provision of sufficient system capacity to ensure open-cut operations are maintained by achieving the target pit availability objectives;
- Minimise excess water in the pit, so that flooding of the pit is avoided;
- Optimise the storage volume in consideration of cost;
- Provision of sufficient system capacity to ensure the uncontrolled discharge (eg. overflows) of MAW to the receiving environment is minimised to an acceptable likelihood occurrence;
- Preferential reuse of stored MAW to satisfy the mine consumptive water demands for dust suppression and plant processing; and
- Provision of water reticulation system capable of ensuring that all containment, storage and reuse requirements are met.

2.3 Controlled Release Strategy Design Philosophy

A preliminary controlled release strategy has been developed and incorporated into the water balance modelling. This strategy aims to maximise potential contact water use on site, with a view to minimising releases. The water balance model, design and sizing of dams have been based on this intention.

The controlled release strategy has two objectives:

- Minimise excess water in the pit, so that flooding of the pit is avoided; and
- Maintain an appropriate level in the PWD, Min MAW dams, such that uncontrolled releases are minimised.

As a result of high groundwater inflow coupled with size constraints of a practicable pit sump and runoff rates in the surrounding catchments, operation of the pumps will be frequently required to maintain an operable pit and to prevent uncontrolled releases. These releases will occur when the volume of water in the pit is too large to be used in the process plant within an appropriate timeframe. The excess water will pumped to the MAW Dams for discharge whenever acceptable environmental release standards are achieved.

2.4 Uncontrolled Releases

The source of uncontrolled releases are overflows from the North and South Discharge MAW dams and the process water dams. The WMS storages will be provided with an appropriate sized spillway and downstream conveyance to direct overflows to suitable receiving location. Where possible, one of these receiving locations could be the two open-cuts pits. This may be justified as follows:

- To reduce the likelihood of an uncontrolled discharge to the environment;
- The Design Storage Allowance (DSA) is shared with the open-cut pits to minimise storage requirements for each dam;
- Optimisation of construction cost for storage facilities; and
- Minimise footprint by not providing excess capacity to contain a volume of water that will only be required during an event with an extremely low probability of occurrence.

The source of uncontrolled releases will be from the MAW Dams overflows via the pit dewatering and catchment runoff. Uncontrolled releases have been minimised through the adoption of an appropriate operational volume for the process water dams and high pumping rate for excess water to the MAW Discharge dams.

2.5 Methodology

The following process has been adopted to complete the study:

- Analysis of climate data for the area;
- Use the recorded rainfall data to generate stochastic rainfall data for the planned mine life, i.e.100 realisations for the 60 year life of the mine which equal 6000 years of modelled mine life;
- Schematise the water management system to represent the water flows for the operation;
- Detail the water storage characteristics, sources of water and site water demands;
- Use the water balance model to determine operating rules for the movement of water around the site;
- Determine the reticulation system and transfer capacities required to move water around the mine WMS; and
- Assess/review the performance of the site water management system.

2.6 Key Design Criteria

The key design criteria for the water balance are as follows:

- Maintain accessibility to the pit floor to reduce pit inoperability, by maintaining stored water in the pit sump of less than 100 ML;
- Achieve 95% daily reliability of supply to the Process Plant and dust suppression;
- Achieve 95% daily reliability of potable water supply; and
- Minimise uncontrolled releases from the MAW Dams and PWD.

The combination of these criteria, along with high groundwater inflow rates and high storm rainfall events, has resulted in an operational strategy which relies on semi-continuous discharge from the MAW Dams to the PWDs (Figure 2-2).

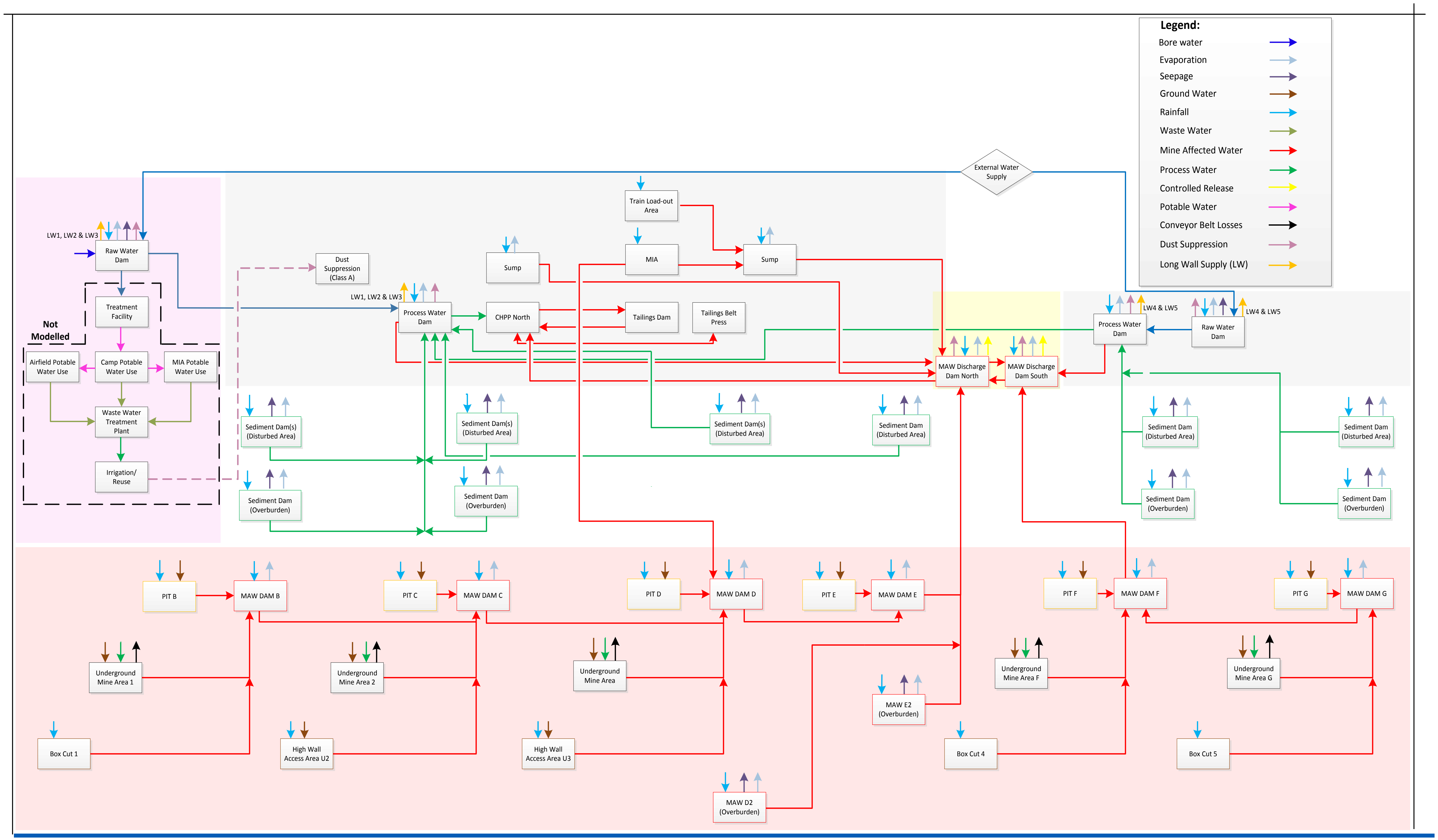


Figure 2-2 Carmichael Process flow diagram (GHD, 2013)

2.7 Summary assumptions used

Table 2-1 lists the assumptions used in the 2013 model and this revised model (2014).

Table 2-1 Summary Assumptions

2013 Model Assumptions	2014 Model Assumptions	Comments
SAW dams allowed to discharge to environment	SAW dams reclassified as MAW with no discharge to environment	SAW reclassified to MAW in consultation with DEHP, will be pumped to main North and South MAW discharge dams
Continuous pumping from pits and transfer MAWs without constraint	MAW discharge dams are limited to 90% of capacity and no pumping when transfer MAWs reach 80% capacity	The DSA is shared with the open-cut pits to minimise storage requirements for each dam
Transfer rules between storages were not optimised to optimise air space available in the shared DSA. i.e. no transfer rules between PWD and Central MAW discharge dams	Optimisation of onsite reuse of dirty and MAW water, with MAW water preferentially reused. An ability to transfer water between the mine and to optimise the use of water on site.	Uncontrolled discharge (eg. overflows) of MAW to the receiving environment is minimised to an acceptable likelihood occurrence
Only the two storages associated with the overburden area for pit D and E have a DSA.	These storages were not included in this assessment as the DSA is shared with open-cut pits	Optimisation of storage capacities and minimisation of uncontrolled discharges
Belyando River pumps directly in to Raw Water Dams at 350 ML/d	Water from Belyando River was pumped first to a sump at 350 ML/d and then up to 100 ML/d is pumped directly to the Raw Water Dam with the difference (up to 350 ML/d when Raw water dam if full) is pumped into clean water dam located near Belyando River for supply of Raw Water Dam when Belyando River cease to flow	This review has introduced an optimisation into the supply and pumping rates of clean water and minimises wastage of cost of pumping and water when raw water dam reaches its full capacity i.e. elimination of raw water dams overflowing occurring under 2013 water balance.

3 2014 Model Inputs

The input data used in this study are sourced from the 2013 GoldSim model (GHD, 2013) and reproduced in this report.

3.1 Climate Data

3.1.1 Rainfall

The average annual rainfall for the mine area is approximately 530 mm/year covering the period 1889 to 2012. Climate data used in the water balance model was based on 123 years (1889-

2012) of patched-point daily data. The patched-point data was sourced from the Data Drill database, developed by Department of Science, Information Technology, Innovation and the Arts (DSITIA). Data Drill accesses grids of data interpolated (using splining and kriging techniques) from point observations by the Bureau of Meteorology (BoM). The patched-point data is considered superior to site observations for modelling purposes because it draws on a greater dataset, both spatially and in time.

The rainfall data is required as an input to the Australian Water Balance Model (AWBM) rainfall-runoff model as well as calculation of direct rainfall inputs to dams and the DSA estimation. Monthly rainfall for the site is provided in Figure 3-1. Summary statistics for rainfall and evaporation are presented in

Table 3-1

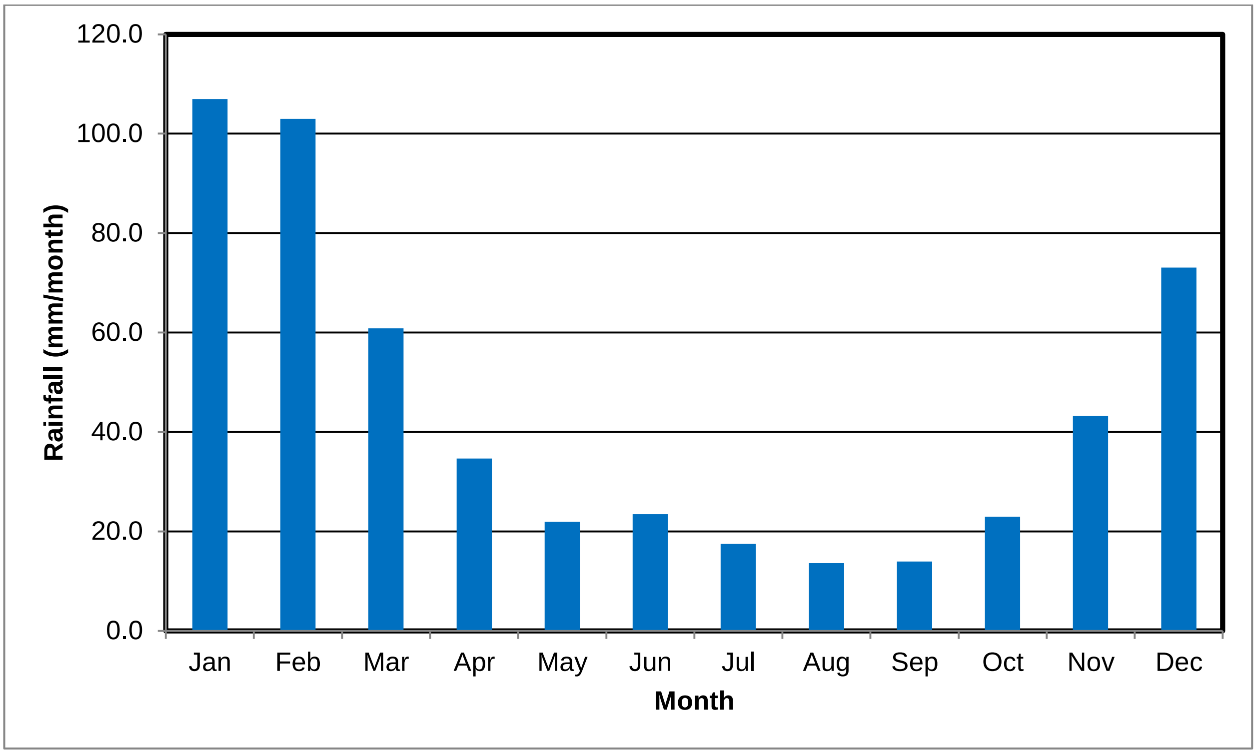


Figure 3-1 Monthly rainfall for Carmichael River site

Table 3-1 Summary climate statistics Carmichael River Site (1889 to 2012)

Statistic	Annual rainfall (mm)	Annual Class A pan evaporation (mm)	Annual potential evaporation (mm)
10th percentile	293	2,146	1,808
50th percentile (median)	507	2,247	1,896
90th percentile	791	2,403	1,984
Mean	534	2,255	1,894
Minimum	141	1,814	1,603
Maximum	1,252	2,644	2044

Standard deviation	217	109	75

A three month wet period decile analysis was undertaken for the Project site. This was done by calculating the maximum cumulative rainfall depth for any consecutive three month period within each water year (i.e. Nov to May) for the 123 year period from 1889 to 2012. A Log Pearson III probability distribution was fit to the 123 year data set. The frequency curve is provided in Figure 3-2. Rainfall depths for various annual exceedance probabilities (AEP's) are provided in Table 3-2 . The 5% AEP three month rainfall depth is 630 mm.

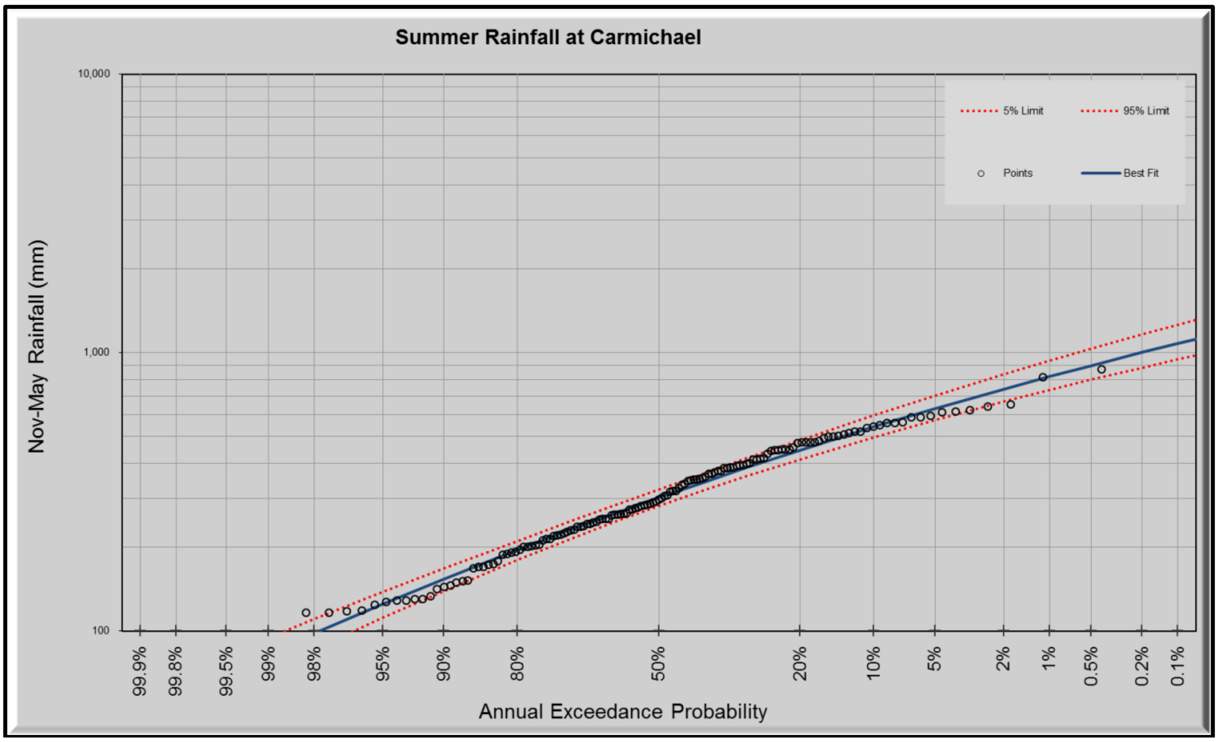


Figure 3-2 Three month wet period decile analysis data for Carmichael– Data Drill (1889–2012)

Table 3-2 Three month wet period rainfall depths for Carmichael River Site

AEP (%)	ARI (year)	Rainfall depth (mm)
10%	10	540
5%	20	630
2%	50	740
1%	100	820
0.5%	200	900
0.1%	1000	1,080

3.1.2 Evaporation

The average daily evaporation for the mine area is approximately 6.2 mm. The daily average evaporation per month is presented in Table 3-3 . The evaporation in the area varies slightly through the year, with higher evaporation observed during October to January.

Table 3-3 Average Daily Evaporation (mm/d)

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mine area	7.9	6.9	6.6	5.4	4.0	3.3	3.5	4.6	6.5	8.0	8.7	8.8

3.2 Stochastic Rainfall Generation

The purpose of the stochastic rainfall generation is to develop a wide range of climate sequences for the year mine life based on the recorded rainfall data of the area. A climate sequence is a series of daily rainfall which has the same statistical characteristics as the historical data set for a range of parameters, including mean, variance, skew, and number of wet days or dry days. Each sequence has an order in which the rainfall has occurred. For example, one sequence may have wetter years at the start of the sequence, where another sequence may have the wetter years towards the end of the sequence. Some sequences may be wetter or dryer than others in order to account for the variability of the climate which may occur during the mine life. The stochastic rainfall data replicates the seasonality of the rainfall data, although this is less of a consideration in the Project area.

The stochastic climate data for the water balance modelling was used to predict the rainfall at the site to determine the volume of water on site which needs to be managed. The stochastic rainfall sequences were produced through the use of the Stochastic bootstrapping method. 100 sequences of rainfall data were produced for the 60 year mine life. This allows a wide range of climatic conditions to be simulated. Each individual model simulation which is run using a different climatic sequence is termed a realisation. The results of the 100 realisations is aggregated to calculate various statistics (e.g. mean, median) and percentiles which are interpreted as a percentage exceedance probability (i.e. the risk of an event occurring).

3.3 Site Schematisation

The site will require a series of storages transmitting flow on demand. Process water demands will primarily be met by supply from runoff and groundwater inflow to the pit and also from runoff from the catchments surrounding the pit. During shortfall periods demands will be supplemented by supply from Belyando River flood harvesting.
A process flow diagram (PFD) of the system is presented in 2013 water balance report (GHD, 2013), as provided in Figure 2-2.

3.3.1 Catchment Areas

Catchment areas were defined on the basis of the mine layout plan, mine development data and topographical data to enable calculation of the runoff contributions into the various mine dams and pits. Catchments areas either remained fixed for the life of the mine or changed dynamically over time (e.g. open-cut pits, spoil and overburden dumps). Refer to GHD's report for further details on the catchment areas for the mine lease area.

3.4 Sources of Water

3.4.1 Groundwater

Groundwater will enter the mine operation by direct inflow to the Pit Sump due to the depth of the pit and interception with subsurface interflow. Groundwater inflow rates are expected to vary throughout the mine life and current estimates adopted in the model are based on outcomes of the report: Hydrologeology Report (GHD, 2013). These estimates, derived using a hydrogeological modelling developed by GHD (2013), were presented in the 2013 water balance report. The groundwater inflow rates vary significantly from year to year, primarily driven by the Pit development. Significant horizontal or vertical expansions in the Pit development (including the contact catchment areas) are made at the beginning of each stage, resulting in increases in groundwater inflow.

Instantaneous groundwater inflow rates based on these estimates have been adopted temporarily, as they are based on limited information and rely on several assumptions relating to the mine schedule, aquifer hydraulic parameters, recharge rates and uniformity of the problem domain (e.g. topography, potentiometric surface and aquifer heterogeneity). More detail on the development and limitations of the current estimates is provided within the groundwater report.

Hydrogeological investigations are ongoing and as the Project progresses the groundwater inflow estimates will be revised with results from more detailed numerical groundwater flow modelling.

This may have significant implications on the mine water management strategy as the model is particularly sensitive to the influence of groundwater inflows due to the large volumes of water requiring pumping from the Pit Sump.

3.4.2 Site Surface Water

Surface water will enter the operation by direct rainfall on the storages, as well as runoff captured from areas within the Site. Rainfall was applied to the model from the stochastic rainfall generation as discussed in Section 3.2.

Catchments were developed from mine area and site terrain information over the mine life. It has been assumed that all of the areas disturbed by mining are managed for the full mine life, i.e. that disturbed areas are not classed as successfully rehabilitated during the mine life and therefore runoff from these areas is not diverted off site. These areas have been assumed to have low potential for contamination. The runoff from these areas are directed to either the sediment dams or Carmichael River.

The rainfall was converted to runoff in the GoldSim model using the AWBM model as shown in Figure 3-3. This runoff can be in two forms as follows:

- Surface runoff which travels overland to the destination; and
- Subsurface (baseflow), which travels through the ground to reach the destination.

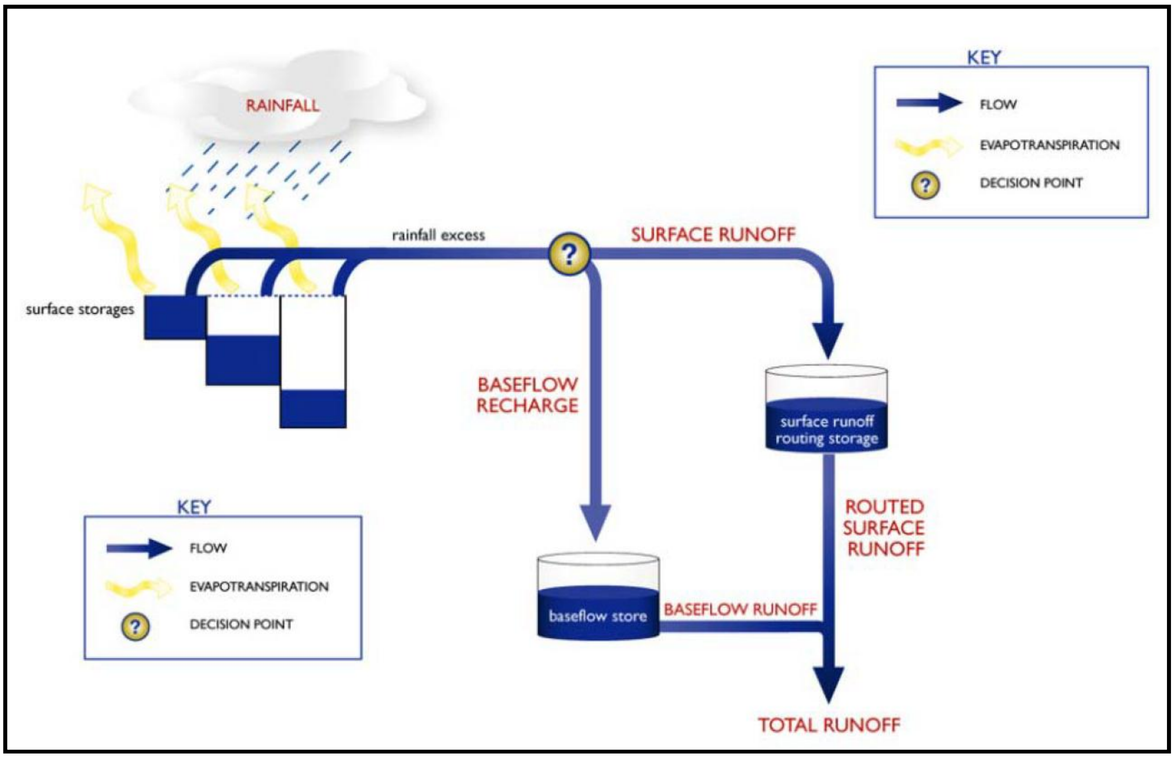


Figure 3-3 Schematic layout of AWBM runoff model (Source: CRC for Catchment Hydrology, 2004)

AWBM is a partial area saturation overland flow model. The use of partial areas divides the catchment into regions that produce runoff (contributing areas) during a rainfall-runoff event and those that do not. These contributing areas vary within a catchment according to antecedent catchment conditions, allowing for the spatial variability of surface storage in a catchment. The use of the partial area saturation overland flow approach is simple, and provides a good representation of the physical processes occurring in most Australian catchments (Boughton, 1993). This is because daily infiltration capacity is rarely exceeded, and the major source of runoff is from saturated areas.

AWBM parameters for disturbed catchment types were derived by adjusting the surface storage capacity to achieve the assumed catchment yield. The catchment yield was estimated based on typical yields observed from other mine sites around Australia and on mine sites in Central Queensland. A summary of the adopted parameters from each catchment type is provided in Table 3-6.

Table 3-4 Adopted AWBM parameters (GHD, 2013)

		Land use			
Parameter	**Description**	**Industrial**	**Open pit**	**Active spoil**	**Disturbed mining (Pre-strip)**
BFI	Baseflow index	0	0	0.103	0.103
K	Baseflow recession constant	1	1	1	1
A1	Partial area	1	0.05	0.134	0.134
A2	Partial area	0.0	0.2	0.433	0.27
A3	Partial area	0.0	0.75	0.594	0.594
C1	Surface storage capacity	5.0	5	5	13

Parameter	Description	Land use			
		Industrial	Open pit	Active spoil	Disturbed mining (Pre-strip)
C2	Surface storage capacity	0.1	10	40	23
C3	Surface storage capacity	0.1	75	100	75

3.4.3 Belyando River

The Belyando River is used to meet both fresh water demands and, as a priority, process demands in times of shortfall. The Belyando River offtake pump facility is located less than 32 km upstream of the Carmichael River junction (Figure 3-4), on the Moray Downs property.

The model assumes that all water demands will be first met by onsite water sources and any shortage will be met by Belyando River off-stream storage.

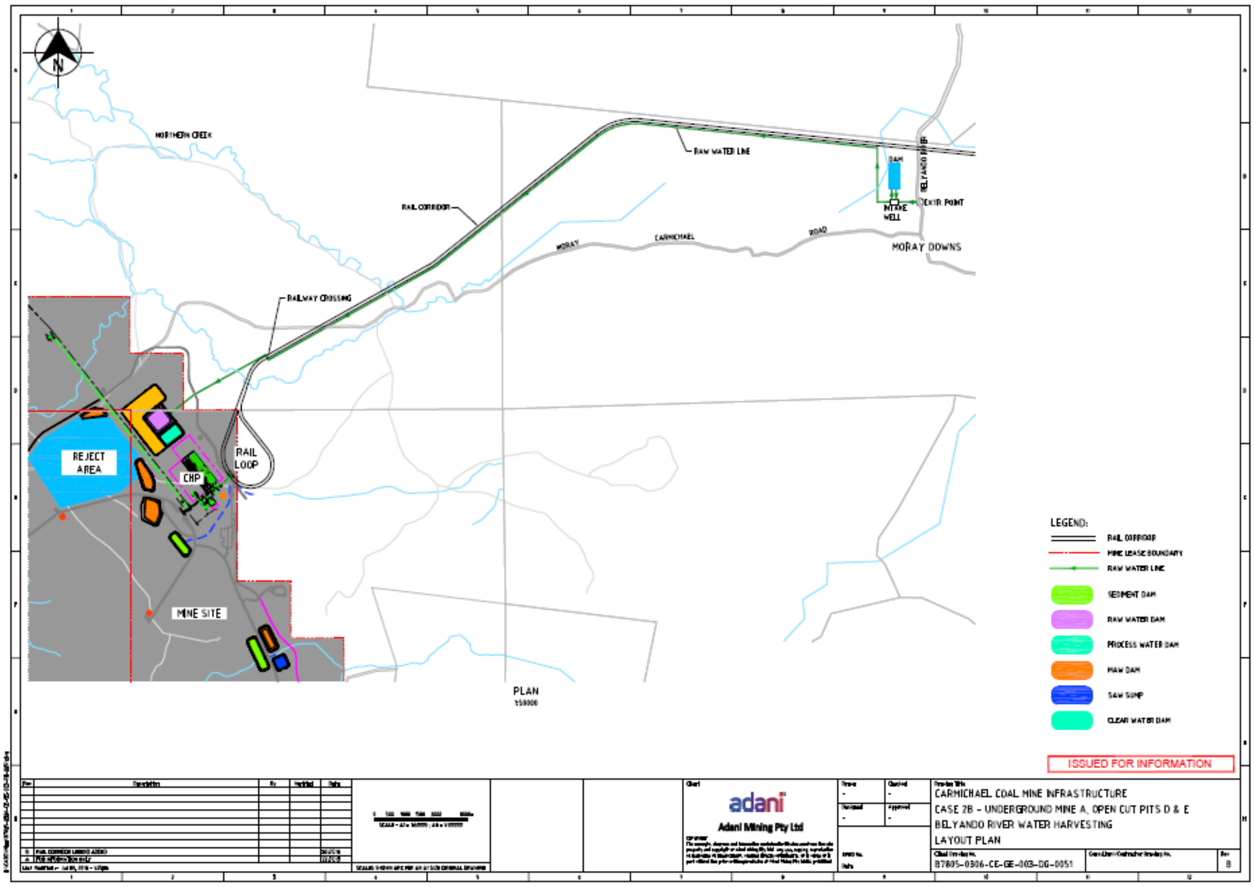


Figure 3-4 Layout Plan of Belyando River Water Harvesting

3.5 Mine Pit Sub-catchment Areas

The sub-catchment areas around the mine pits will alter through the mine life, as the pits are developed. Catchment areas are divided as follows:

- Contact diversion drainage system: represents catchments above the pit area which flow into a diversion drain system. These areas are considered to have low potential for contamination. The drainage system delivers runoff from these areas to either the sediment dam or Carmichael River;

- Spoil and overburden areas: represents catchments below the pit area which flow by gravity into sediment dam diversion drain system. These areas are considered to have low potential for contamination. These areas expected to generate mine affected runoff. The drainage system delivers runoff from these areas to the MAW dams;
- Pit catchment area: represents areas where runoff reports directly to the pit sump; these areas are considered to have high potential for contamination. The drainage system delivers runoff from these areas to the MAW dam through pumping;
- Disturbed non-mining areas – Contact catchments: represents disturbed areas which flow directly into the SAW Dam. These areas are located on the advancing highwall side of the mine; and
- Industrial areas – Coal stockpile area: represents the area of the stockpile and the Mine Industrial Areas (MIA), with runoff from the stockpile flowing directly into the CHPP Dam.

Note the process and MAW ponds are stand-alone storages which do not have an associated catchment area.

3.6 Storages

There are a number of storages proposed as part of the mine water management for the operation. These storages are depicted in the Site Water Management PFD in 2013 water balance report and summarised in Table 3-5 .

GoldSim resolves the water balance model on a daily time-step, which effectively limits the amount of water able to be drawn from a given storage to the total volume of that storage. For this reason, it is not possible to model a storage where the average residence time is less than one day (i.e. water generally flows into and out of a storage within one day). The process water ponds north and south have been modelled as a single storage of 3,000 ML and 2,000 ML to meet CHPP daily demand.

Table 3-5 Modelled Storages Summary

Dam	Purpose	Number of storages	Start Year	Capacity (ML)	Initial Volume (ML)
Pit Sumps	to manage runoff to the pit and groundwater inflow	6	2015	unlimited	0
PW Dams	to receive water from the MAW and RWD dams and provide supply for the process plant	2	2015	5,000	0
SAW Dams	to receive runoff from active disturbed areas and pumped to MAW dams	6	2015	7,700	0
MAW transfer Dams	to manage contact water and provide supply for the process water pond	8	2015	3,150	0

Dam	Purpose	Number of storages	Start Year	Capacity (ML)	Initial Volume (ML)
Discharge MAW Dams	to manage contact water and provide supply for the process water pond	2	2015	15,000	0
Overburden MAW Dams	to manage contact water and provide supply for the process water pond	4	2015	15,000	0
RW Dam	to receive water from clean water dam and provide supply for the process water pond	2	2015	2,000	1200
CPP Sumps	to receive runoff from MIA areas and pumped to PWD	2	2015	100	0
Clean Water Dam	to receive water from Belyando River and provide supply for the Raw Water Dams	1	2015	5,000	0

Although the Pit Sump has a design capacity of 100 ML when the storage capacity is exceeded excess water will fill the bottom of the pit. The Pit Sump volume is therefore modelled as an unlimited volume in order to resolve the behaviour of water within the Pit area. Conditions are included within the model which indicates that the Pit is flooded when the Pit Sump exceeds 100 ML.

3.7 Demands

The major water demand for the site arises from dust suppression and coal processing and potable water requirements. The mine water system will be configured to maximise the fit for purpose use of water on site with the aim to reduce the amount of fresh water consumed by the operation. Section 3 of the 2013 report (GHD, 2013) presents a summary of the demands for the operation of the mine and the water source in preferential order.

The process water demands are supplied from the process water dam and MAW Dams, or from the Raw Water Dam through flood harvesting at Belyando River when there is insufficient supply available from the process water dam and MAW Dams. Water from the MAW Dams is initially supplied from runoff from contact catchments surrounding the pit and from the Pit Sump. Top up volumes for the MAW Dams may be taken from the diversions around the mine pit or from the Sediment Dams, as shown in Table 3-6 .

Table 3-6 Process Water Dam – Priority of Supply Sources

Priority	Source
1	Pump from Pit Sump – surface water and groundwater captured in the mine pit
2	Pump from the MAW Dam (contains overflow from the Sediment Dam)

Priority	Source
3	Contact runoff - gravity feed from active spoil/overburden drains (runoff from contact catchments around the mine pit)
4	Flood harvesting from Belyando Off-Stream Storage (OSS)

3.8 Losses

The primary loss of water from the system will be to the seepage and to evaporation, although seepage rates will be fairly small compared to the evaporation. Seepage was included in the water balance using Darcy equation (permeability dependent). Moreton's shallow lake evaporation was used to calculate surface evaporative losses. Storage evaporative losses were calculated with each timestep (daily) and were based on the dam's current water surface area. These loss rates were applied to the dam surface areas through the period of the water balance.

3.9 Transfers and Operating Rules

A number of transfer rules have been developed for the water balance model to manage the water within the operation. A summary of the transfers are presented in **Table 3-7**.

Table 3-7 Transfer Triggers and Pumping Rates

Transfer	Transfer limit (from)		Transfer Limit (to)		Maximum Pumped rate (L/s)
	From	To	And		Maximum
Pit Sump (PS) dewatering	PS_North	North MAW Dams	PS_North >0ML	North MAW dams <80% FSL	250
	PS_South	South MAW Dams	PS_South >0ML	South MAW dams <70% FSL	250
Open-Cut Pits Dewatering	MAWB	MAWC	MAWB>2ML	MAWC <280ML	500
	MAWC	MAWD	MAWC>2ML	MAWD<480ML	725
	MAWD	MAWE	MAWD>2ML	MAWE <720ML	1250
	MAWE	MAW Disch North	MAWE>2ML	MAW_N <7600ML	1500
	MAWF	MAW Disch South	MAWF>2ML	MAW_S <6650ML	750
	MAWG	MAWF	MAWG>2ML	MAWF<585ML	650
Disturbed area (sedimentation dams)	SD1	PWD_North	SD1>2ML	PWDN<2400ML	800
	SD2	PWD_North	SD2>2ML	PWDN<2400ML	800
	SD3	PWD_North	SD3>2ML	PWDN<2400ML	800
	SD4	PWD_North	SD1>2ML	PWDN<2400ML	800

Transfer	Transfer limit (from)		Transfer Limit (to)		Maximum Pumped rate (L/s)
	SD5	PWD_South	SD5>2ML	PWDS<1600ML and OvrSD5<20ML	800
	SD6	PWD_South	SD6>2ML	PWDN<1600ML and OvrSD6<20ML	800
Overburden Area (sedimentation dams)	MAWD3	MAW_North	MAWD3>2ML	MAW_N<7520ML	800
	MAWD4	MAW_North	MAWD4>2ML	MAW_N<7520ML	800
	SD1	PWD_North	SD1>2ML	PWDN<2700ML	800
	SD2	PWD_North	SD2>2ML	PWDN<2700ML	800
	SD5	PWD_South	SD5>2ML	PWDS<1800ML	1000
	SD6	PWD_South	SD6>2ML	PWDN<1800ML	1000
MIA Area	MAWD1	MAWD	MAWD1>0ML	MAWD<590ML	100
	MIA_SP1	SUMP1	MIA_SP1>0ML	SUMP1<40ML	100
	MIA_SP2	SUMP2	MIA_SP2>0ML	SUMP2<40ML	100
	SUMP1	MAW_North	SUMP1>0ML	MAW_N<7520ML	100
	SUMP2	MAW_North	SUMP2>0ML	MAW_N<7520ML	100
Raw Water Dam (North and South	RWDN	PWD_North	RWDN>500ML	PWDN<150ML	578.7
	RWDS	PWD_South	RWDS>500ML	PWDS<150ML	578.7
PWD South	PWDS	PWDN	PWDS>1000ML	PWDN<1000ML	578.7
Clean Water Dam	CMD	RWDs	CWD>50ML	RWDN<950 ML	1157

3.10 Model Timeframe

The timeframe of the model is based on the mine schedule which shows water management requirements commencing for the 60-year period on 1 January 2015 through 31 December 2071. The model is run for 100 realisations of 60 years each.

As the model requires a ‘warm-up’ period to reach equilibrium, the first month of simulations are not considered in the model results.

4 Results of Optimisation

4.1 Storage Volume and Pumping Capacity

As discussed in Table 3.1 an alternative approach was adopted for this review which aimed to minimise the storage volumes (as presented in Table 3-5) and increase pumping capacity. A nominal operating level for the MAW dams is also incorporated in order to reduce the volume of contaminant water which could potentially spill to the environment. This resulted in an increase in the amount of time that the process water supply needed to be supplemented from the pit dewatering.

The optimum volume for the MAW dams (i.e. normal operational volume) was found to be 80% of its full supply capacity. If the dam is operated at this volume it provides a good balance between supplying water for the process demand, discharging excess water to the PWD and restricting spills to the environment by enabling sufficient spare capacity to capture runoff (uncontrolled flow) into the dam. Figure 4-1 shows pumped flows into North MAW Discharge Dam for the simulation period with 100 realisations.

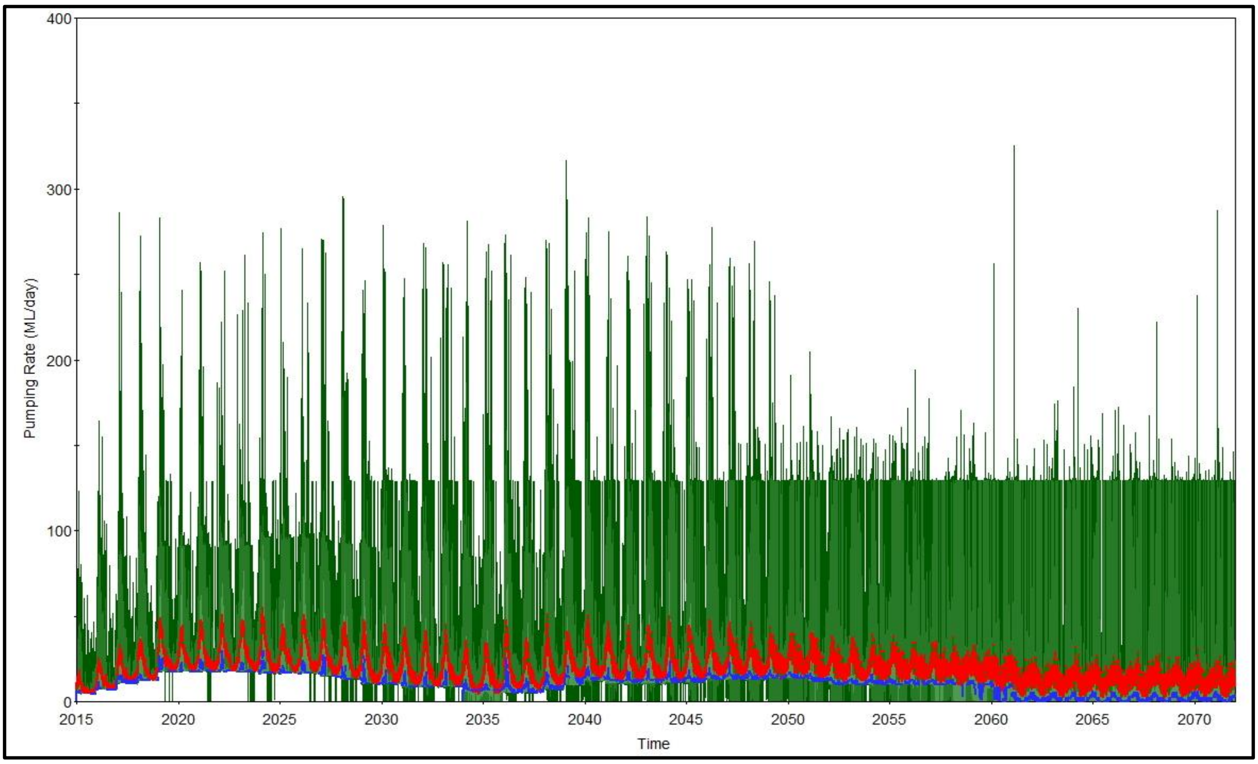


Figure 4-1 Pumped flow into North MAW Discharge Dam

4.2 Supply Reliability and Releases

This section summarises the statistical results of supply reliability and likely occurrence of uncontrolled and controlled (e.g. residual discharge) releases, based on 100 realisations of stochastic rainfall data.

The results presented do not incorporate the first month of simulation as this constitutes a 'warmup' period before the model has reached equilibrium. This period is not representative of actual results. Outputs before the model has reached equilibrium may show abnormalities due to certain parameters not yet fully propagating through the model. For example, rainfall which has fallen in the weeks or days before the model simulation begins is not represented in the system.

4.2.1 Process Water Demand

The process water demand is to be met primarily by the PWDs with supplementary supply from the Belyando River when required.

Reliability of the system, based on 100 realisations, is presented in Figure 4-1. The reliability of process water supply is very high; demand is met with 100% daily reliability in 98% of realisations, and all realisations showed a reliability of greater than 95%. This is calculated based on the number of days where supply fails for each realisation, e.g. 95 of 100 realisations showed no failures, while 5 realisations exhibited between 1 and 5 days of supply failure over the mine life.

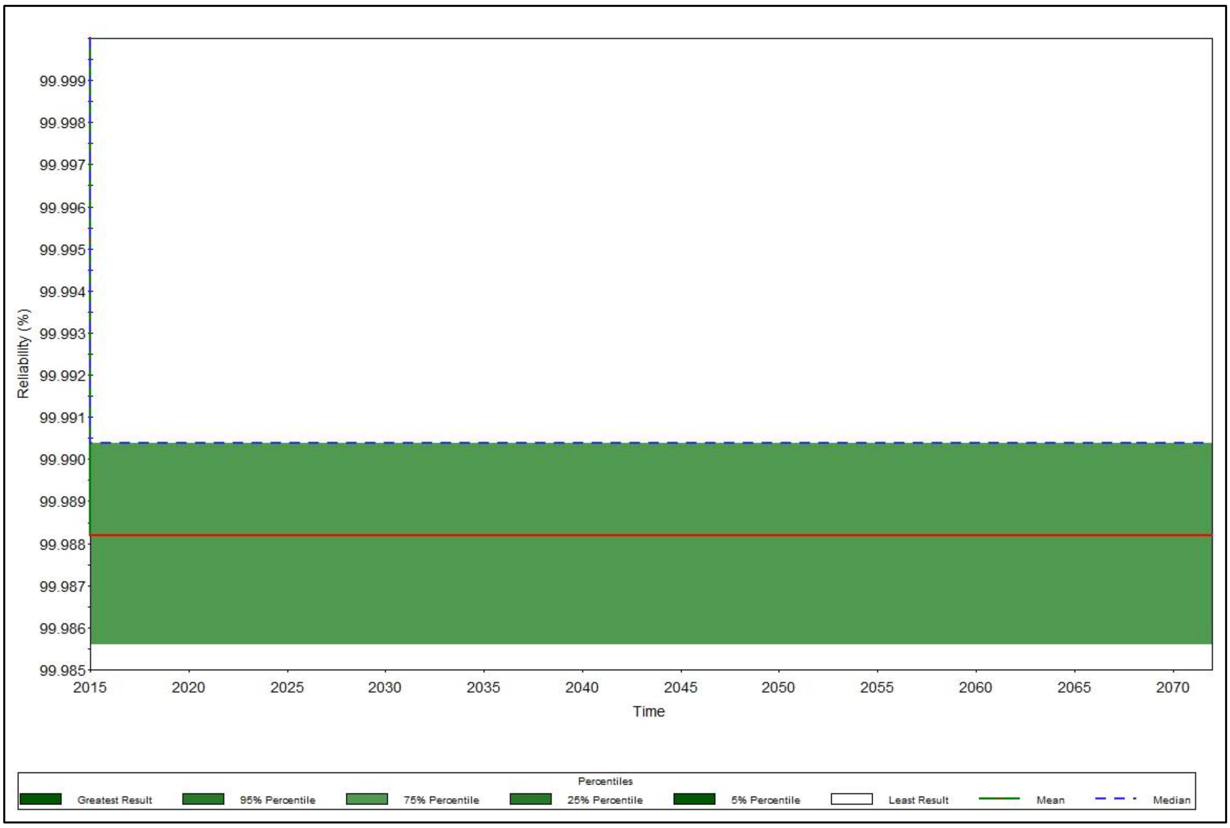


Figure 4-2 Process Water North Supply Reliability North

The maximum total period of time where demand is not being met in any given realisation was 8 days. The average period of time where demand could not be met throughout the 60 year mine life across 100 realisations was 0.5 days. This equates to an average reliability of 99.9%.

4.2.2 Potable and Construction Water Demand

The total clean water demand for this assessment, including construction water, is up to 6.1 ML/d in the first three years and stabilises around 0.6 ML/d for most of the life of mine and will be supplied from the Belyando River.

Reliability of the system in meeting fresh water demand, based on 100 realisations, is presented in Figure 4-2. Demand is generally supplied with very high reliability; 97% reliability is achieved in 100% of the realisations. Figure 4-3 shows the storage performance for the North Raw Water Dam for the simulation period.

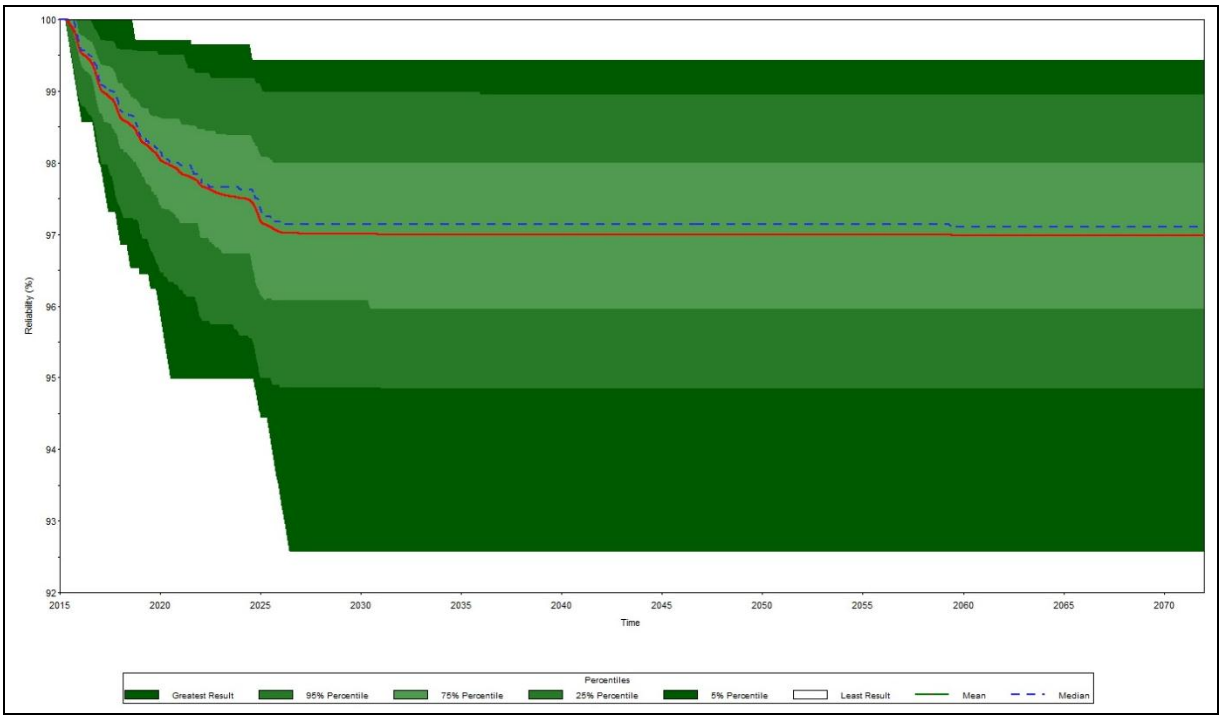


Figure 4-3 Potable and Construction Water Supply Reliability

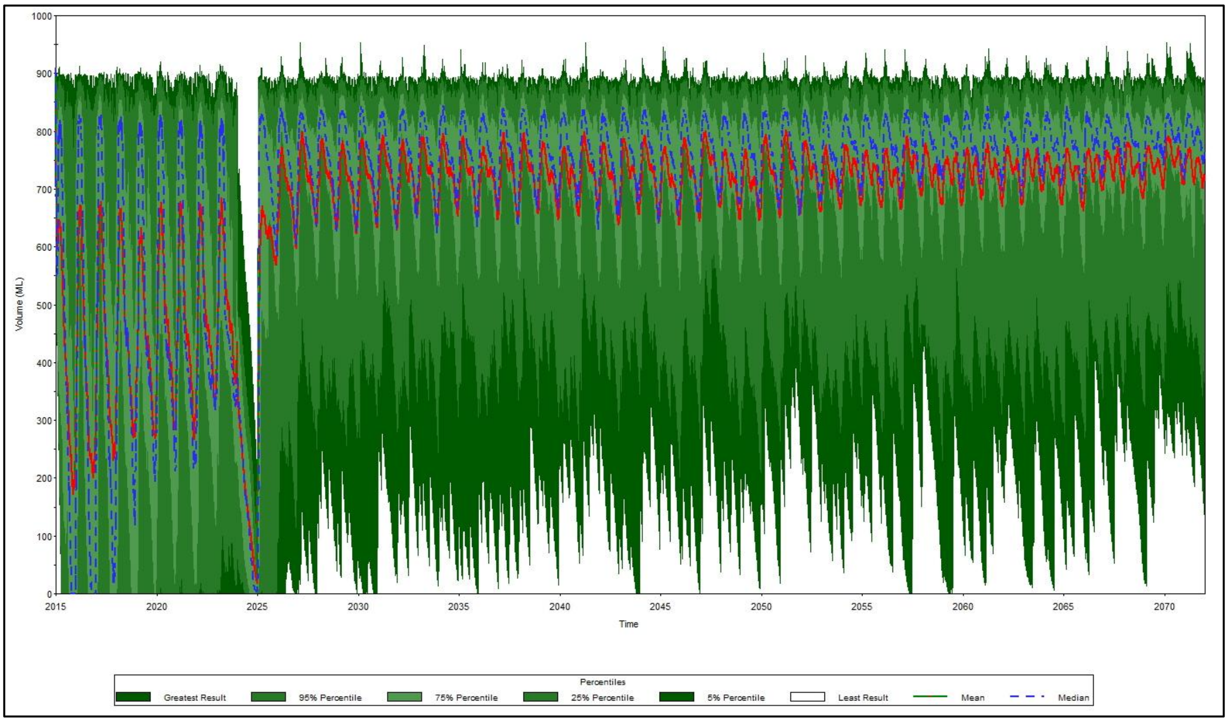


Figure 4-4 North RWD Storage Performance

Supply from the Belyando River is also used to meet process water demand as required. Potable and construction water demand is met as a priority over process water demand. This results in the reliability of potable water supply being slightly higher than the process supply, due to much lower demand rate for potable and construction water. **Figure 4-5** presents the annual water supply from flood harvesting.

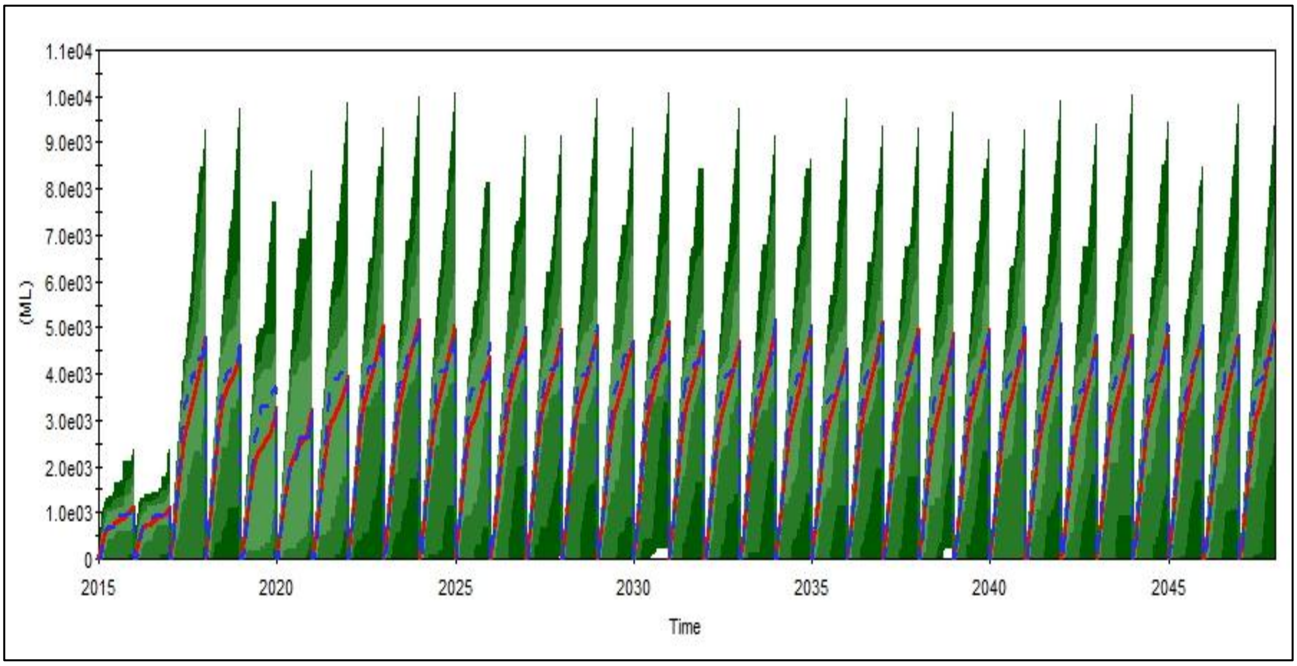


Figure 4-5 Annual water supply from Belyando River flood harvesting

4.2.3 Controlled Releases

MAW Dams will be pumped into the PWD Dams and MAW discharge Dams when capacity is available. Controlled release from MAW Dams to the receiving environment is minimised to an acceptable likelihood of occurrence as the DSA is shared with the pit to the extent that a considerable reduction in nominated storage capacity was achieved. The management objective is to keep the MAW Dams empty, as a buffer storage for overflows in order to reduce the risk of uncontrolled releases.

Controlled releases are therefore only considered to occur from the MAW Dams, where the releases flow over the dam spillway into Carmichael River. Further detail on controlled releases is provided in Section 2.3.

This analysis was conducted by assuming that if a controlled release from the PWD and or MAW dams occurred on any given day, that day was counted as a controlled release day. This is a conservative assessment as it assumes controlled release occurs over the full operating period of that day. However, as the model is run on a daily timestep, it is not possible to accurately assess the number of hours of release on each day when controlled releases occur. Figure 4-6 and Figure 4-7 show the controlled releases performance from South and North MAW discharge dams for the simulation period with 100 realisations.

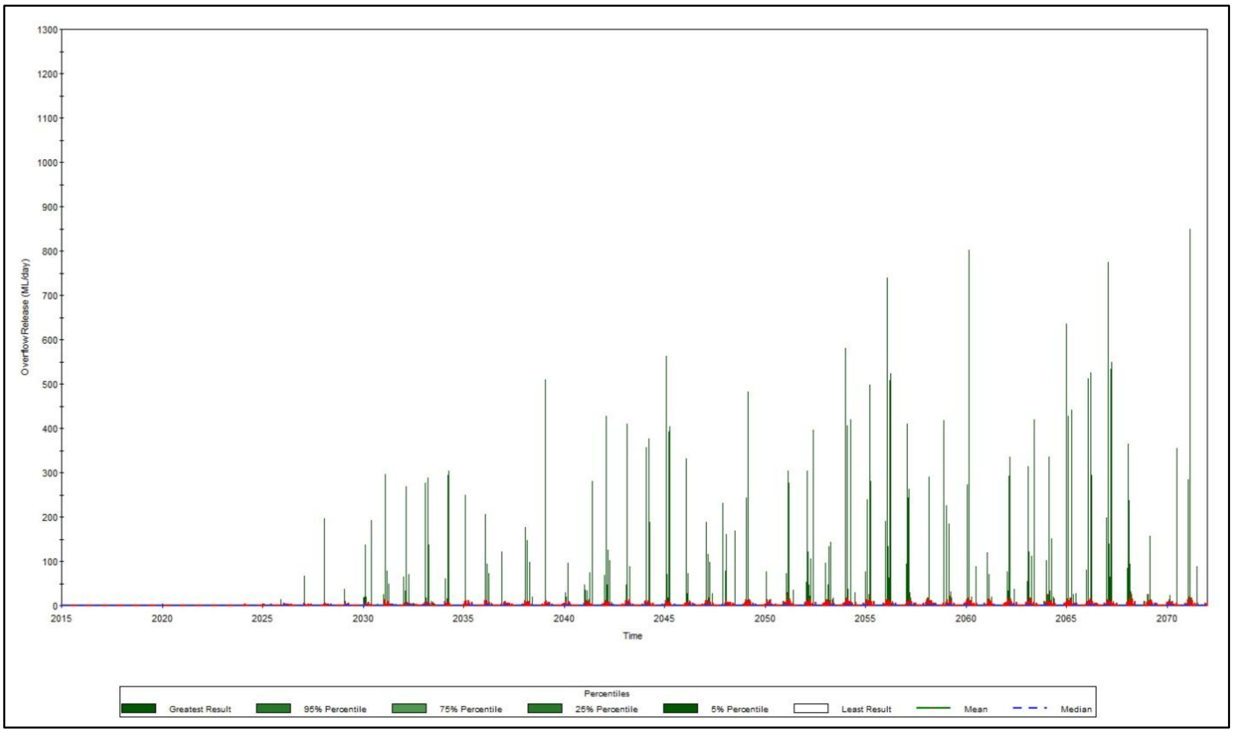


Figure 4-6 Controlled release from South MAW Discharge Dam

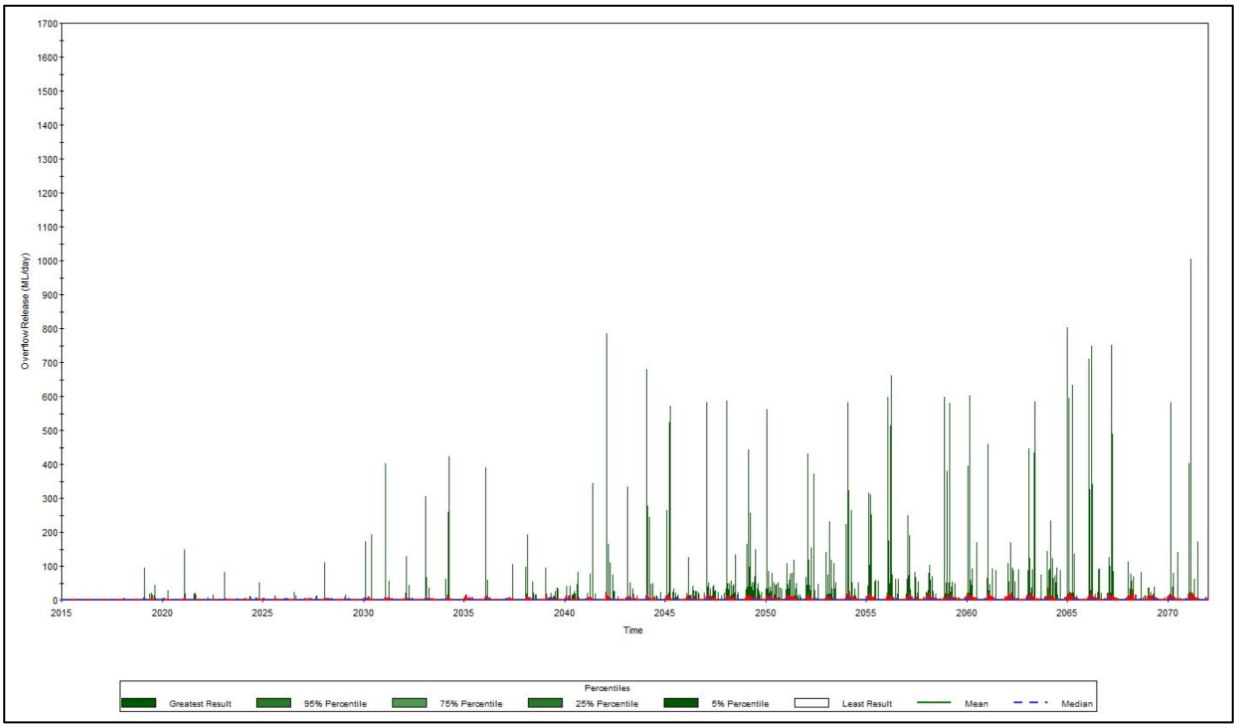


Figure 4-7 Controlled release from North MAW Discharge Dam

The significant increase in controlled release in spikes (greatest results) in 2060 correlates with a large increase in storm events and storage capacity limitation coinciding with the increase of catchment area reporting to the MAW dams. Daily percentile ranges of controlled release rates are presented by year in Figure 4-7.

Table 4-1 shows the probability of meeting the percentage of time target for controlled releases and several other statistics across the 100 realisations.

Table 4-1 Statistics of controlled releases

Statistics	Result
Reliability of meeting DEHP guideline (minimisation to less 5% of time)	100%
Average % of time controlled spills	1.65%
South MAW Dam Discharge	
Maximum Total Release Volume over 60 years (ML) South MAW Dams	1,033
Average Release Volume over 60 years (ML)	463
Minimum Total Release Volume over 60 years (ML)	0
Maximum Release Volume (on a spill day) (ML) at 95% confidence	59.4
Minimum Release Volume (on a spill day) (ML) at 95% confidence	0
Average Release Volume (on a spill day) (ML) at 95% confidence	0.1
Maximum Annual Release Volume (ML/a)	256
North MAW Dam Discharge	
Maximum Total Release Volume over 60 years (ML) North MAW Dams	750
Average Release Volume over 60 years (ML)	281
Minimum Total Release Volume over 60 years (ML)	0
Maximum Release Volume (on a spill day) (ML) at 95% confidence	16
Minimum Release Volume (on a spill day) (ML) at 95% confidence	0
Average Release Volume (on a spill day) (ML) at 95% confidence	0.1
Maximum Annual Release Volume (ML/a)	385

4.2.4 Uncontrolled Releases

An analysis was also conducted to characterise uncontrolled releases activity. It was assumed that if an overflow discharge occurred on any given day, that day was counted as an uncontrolled release day.

The maximum overflow rate from the MAW and PWD Dams to the mine lease area or Carmichael tributaries is 11 ML/d for the first half of the mine life (2015-2045) and 24 ML/d for the second half of the mine life (2046-2071).

There are four periods, 2034, 2045, 2056 and 2060, where the uncontrolled discharge is elevated for a period of time. These periods coincide with increased groundwater flow rates into the mine pit and also correlates with a large increase in storm events and storage capacity limitation coinciding with the increase of catchment area reporting to the MAW dams. Table 4-2 shows the probability of meeting the percentage of time target for uncontrolled releases and several other statistics across the 100 realisations.

Table 4-2 Statistics of uncontrolled releases

Statistics	Result
Reliability of meeting DEHP guideline (minimisation to less 5% of time)	100%
Average % of time controlled spills	0.95%
South Dams (MAWs, SAWs and PWD)	
Maximum Total Release Volume over 60 years (ML) South MAW Dams	256
Average Release Volume over 60 years (ML)	95
Minimum Total Release Volume over 60 years (ML)	0
Maximum Release Volume (on a spill day) (ML) at 95% confidence	16
Minimum Release Volume (on a spill day) (ML) at 95% confidence	0
Average Release Volume (on a spill day) (ML) at 95% confidence	0.06
Maximum Annual Release Volume (ML/a)	18
North Dams (MAWs, SAWs and PWD)	
Maximum Total Release Volume over 60 years (ML) North MAW Dams	258
Average Release Volume over 60 years (ML)	87
Minimum Total Release Volume over 60 years (ML)	0
Maximum Release Volume (on a spill day) (ML) at 95% confidence	1.7
Minimum Release Volume (on a spill day) (ML) at 95% confidence	0
Average Release Volume (on a spill day) (ML) at 95% confidence	0
Maximum Annual Release Volume (ML/a)	5

4.2.5 Pit Flooding

The pit is assumed to be ‘flooded’ if the volume in the sump exceeds 100 ML, with the pit assumed to be ‘unworkable’ if the volume in the Sump remains above 100 ML for more than one day. An analysis was conducted to characterise pit flooding and consequent number of unworkable days.

The volume of water entering the pit increases over the course of the mine life due to increasing catchment area reporting to the pit. Consequently, the risk of flooding also increases through the mine life. Figure 4-8 shows the daily percentiles of Pit Sump volume through the course of the mine life, with increasing occurrences of volumes over the Pit Sump limit of 100 ML.

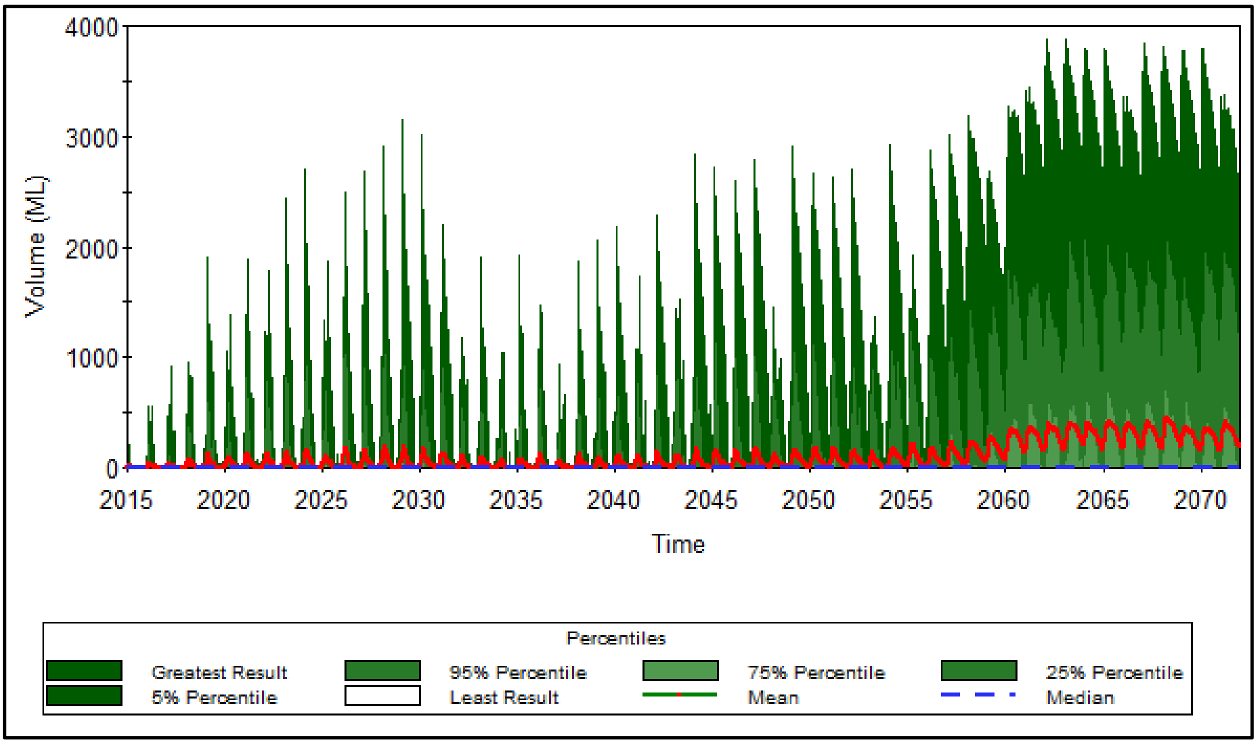


Figure 4-8 Pit Storage Performance for Pit D

5 Conclusions and Recommendations

A review of the 2013 water balance modelling was undertaken to optimise transfer rules, pumping requirements and controlled release frequency and pump rate. The study also assesses the reliability of dust suppression, process and potable water supply and incidence of uncontrolled release.

The current mine water management configuration is driven by three main factors:

- Groundwater inflow to the mine pit;
- Challenging limited water available for water supply; and
- Potential contaminated runoff which needs to be managed.

Dam storage volumes are constrained by storage losses in the Carmichael area as well as the water supply options. The approach adopted to determine storage and pumping capacity aimed to limit storage requirements while optimising pumping around the Site.

Several areas around the mine pit have been identified as having the potential to generate contaminated runoff. This runoff cannot be released into the environment without being treated to an appropriate standard. It is proposed that this runoff is directed into the SAW Dam via a gravity drain system where it will be preferentially used for the process water demand. Water in excess of the process demand will be released into the receiving environment after being treated to an acceptable standard (referred to as a controlled release). A diversion drain system will isolate runoff from clean catchments and will direct this runoff first sediment sump and overflows into Carmichael River.

The need to minimise the potential for uncontrolled releases has led to an operational level in the MAW dams of 80% of its capacity. If the dam is operated at this volume it provides a good balance between supplying water for the process demand, discharging excess water to the environment.

Groundwater inflows to the pit were found to make a significant contribution to the mine water balance. Due to groundwater inflows and runoff reporting directly to the pit, high levels of pumping are required on a significant number of days in order to keep the mine pit accessible. The adopted pumping rates were determined as the pump rates required to feasibly limit the total average number of days of flooding in the pit. On average across the simulation, an unworkable pit due to flooding occurs on 2 days per year.

Water supply reliability is considered to be extremely high: 95% reliability is highly probable under this water management strategy, although the system may still fail given a rare dry period.
However, it is not realistic to expect any system to be 100% reliable under every possible climatic scenario. Designing a strategy to achieve this would require the system to be able to handle very rare, extreme dry events. This would be extremely cost-inhibitive and even without the current site constraints very cost-ineffective due to maximum storage requirements being vastly in excess of normal daily operation. A balance is always required between reliability of a system and cost effectiveness.

The main recommendations from this review are as follows:

1. Streamflow records were not available for the 2013 water balance model and it is recommended that these inputs are reviewed and updated as further information becomes available in the future.
2. More detailed investigations will be required to update the model inputs for the Basic design phase of the Project.

6 Limitation of the model

This report presents a revised Mine Water Management strategy at the Site which provides acceptable levels of reliability, estimates feasible storage and pumping capacity requirements and addresses potential flooding of the pit, and occurrences of uncontrolled releases and also developed in line with the hazard category assessment of the regulated dams carried out by GHD (2014). This strategy will continue to develop as the project progress, particularly with data updates and modifications to process design and infrastructure.
As the basis for the strategy, the mine water balance model has been reviewed on currently available information; however, several parameters in the model remain uncertain and are subject to change with ongoing investigations. Data which requires ongoing monitoring and/or investigation include:

1. Rainfall data via ongoing meteorological monitoring around the Site;
2. Streamflow data via ongoing streamflow gauging in relevant streams; and

3. Ongoing groundwater investigations, to which the model is particularly sensitive.

Model inputs which remain subject to change and may require modification include:

1. Process design modifications, in particular, process and raw water demands;
2. Changes to the mine plan which may affect available storage area and pumping requirements; and
3. Mine schedule and timing.

Additionally, several issues have been flagged which require further investigation, including:

- Uncertainties in water quality from various sources which may have implications for acceptable end-uses of water supply; and
- Climate variability and flow requirements may limit pumping from the Belyando River and subsequently affect reliability of process and fresh water supply.
- Only basic operating rules, suitable for conceptual design. Operating rules should be upgraded when further water quality, groundwater and geochemistry data becomes available. Operating rules should be developed to manage competing interests including water retention for use around site, water retention for dilution and maintaining spare capacity for containment of storm events.

The proposed water management system should be refined and optimised as detailed design proceeds, and water quality, groundwater and geochemistry characteristics are confirmed from ongoing monitoring programs.

7 Reference Cited

Boughton, 2004, Australia Water Balance Model

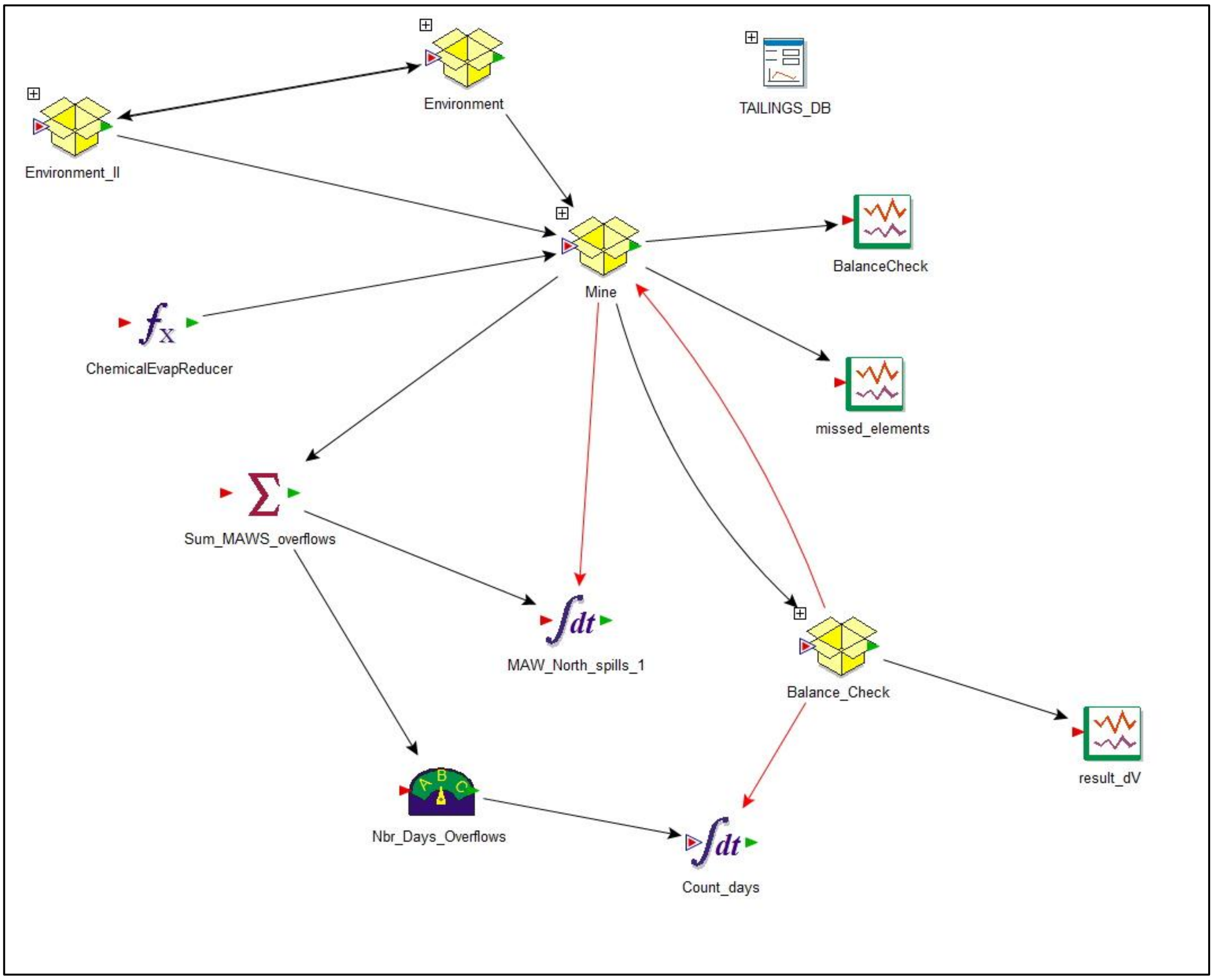
Boughton, W. C, 1993, *A Hydrograph-based Model for Estimating the Water Yield of Ungauged Catchments.*

CRC for Catchment Hydrology, 2004, *Rainfall Runoff Library User Guide*.

The Institution of Engineers Australia, 2001, *Australian Rainfall and Runoff*.

GoldSim Software, 2013, GoldSim Technology Group, 2013

Appendix 1 – GoldSim Schematic



GoldSim Layout for Carmichael River Water Balance

Appendix 2 – Modelling Data Input and Results

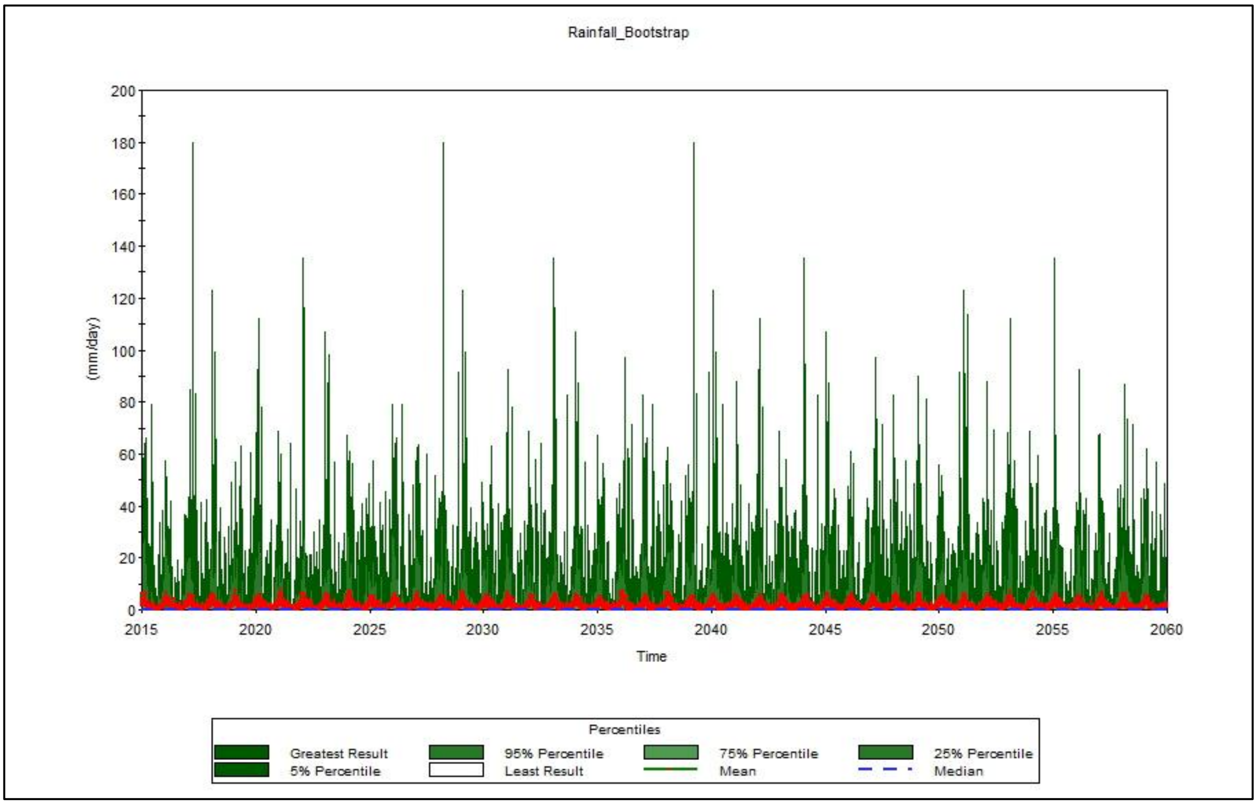


Figure A2- 1 Time Series of Rainfall Data (Stochastic data)

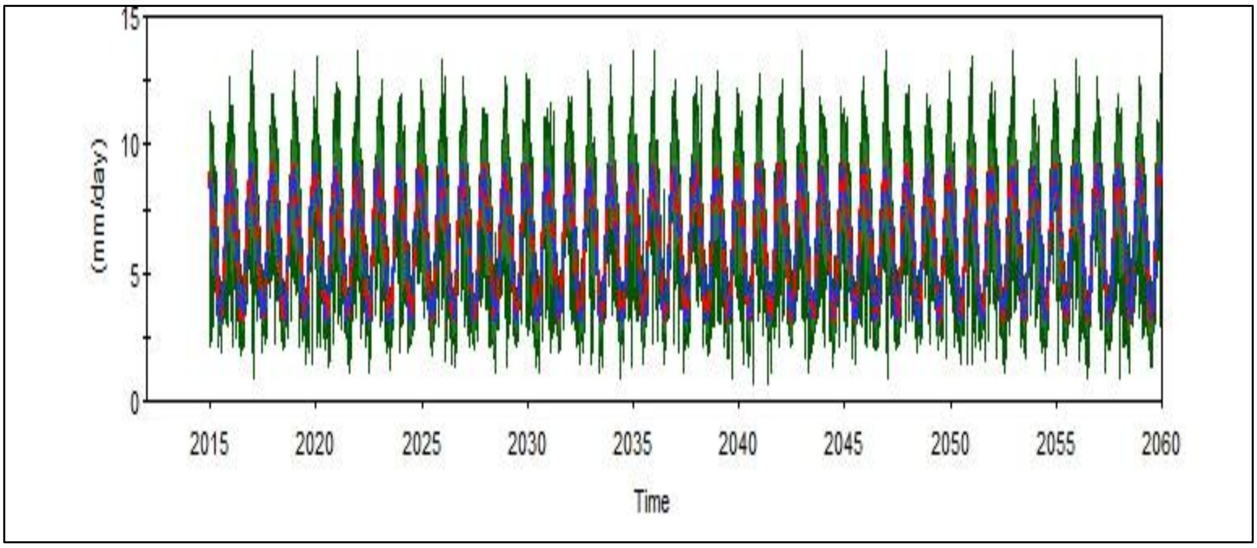


Figure A2- 2 Time Series of evaporation Data (Stochastic data)

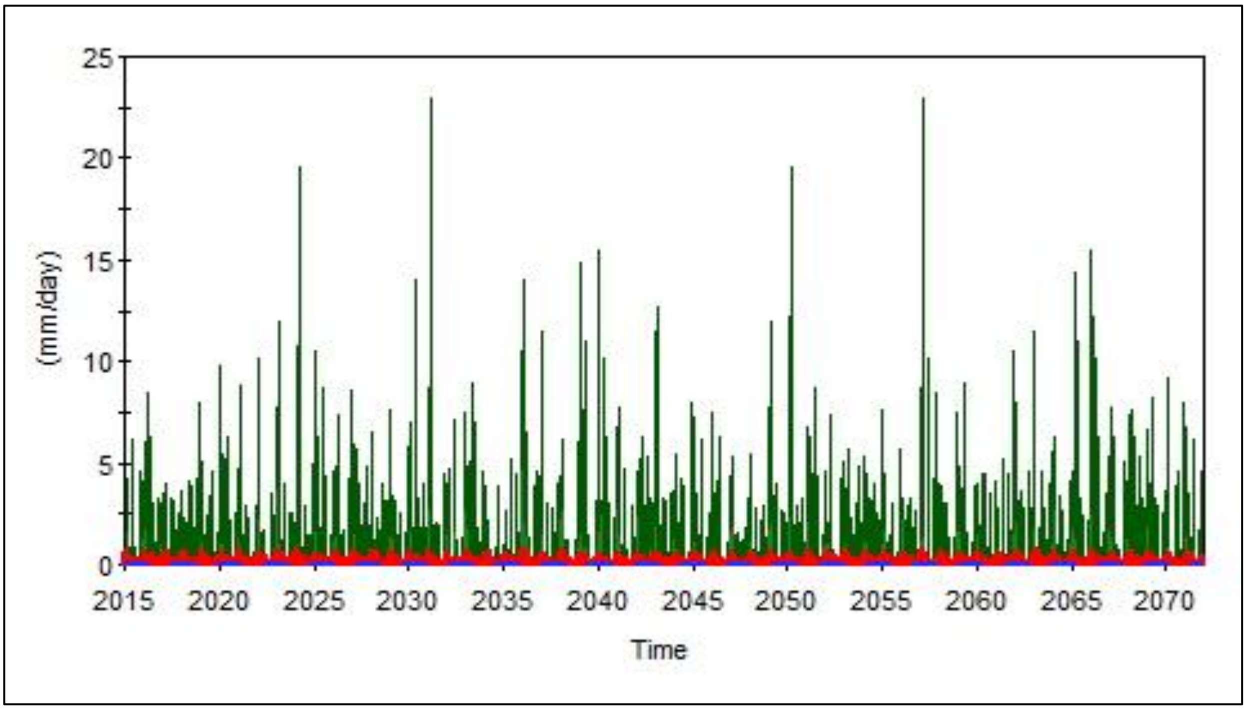


Figure A2- 3 Time Series of Runoff depth (Stochastic data)

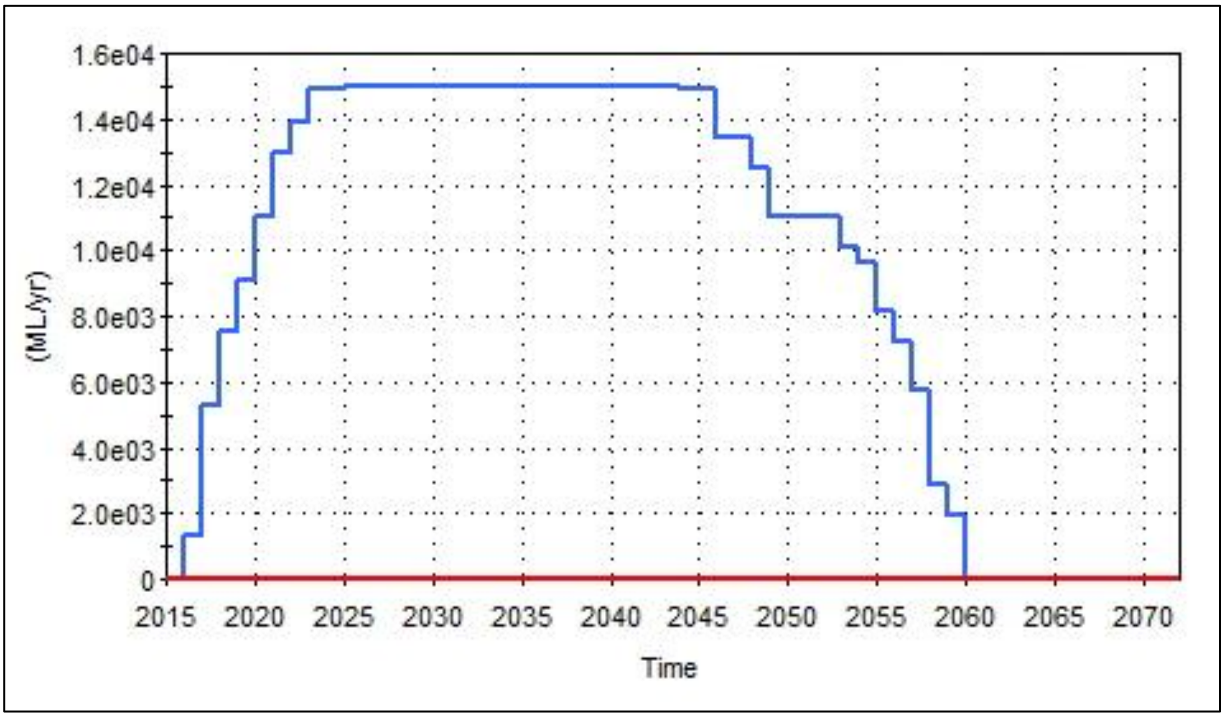


Figure A2- 4 Time Series of CHPP demand

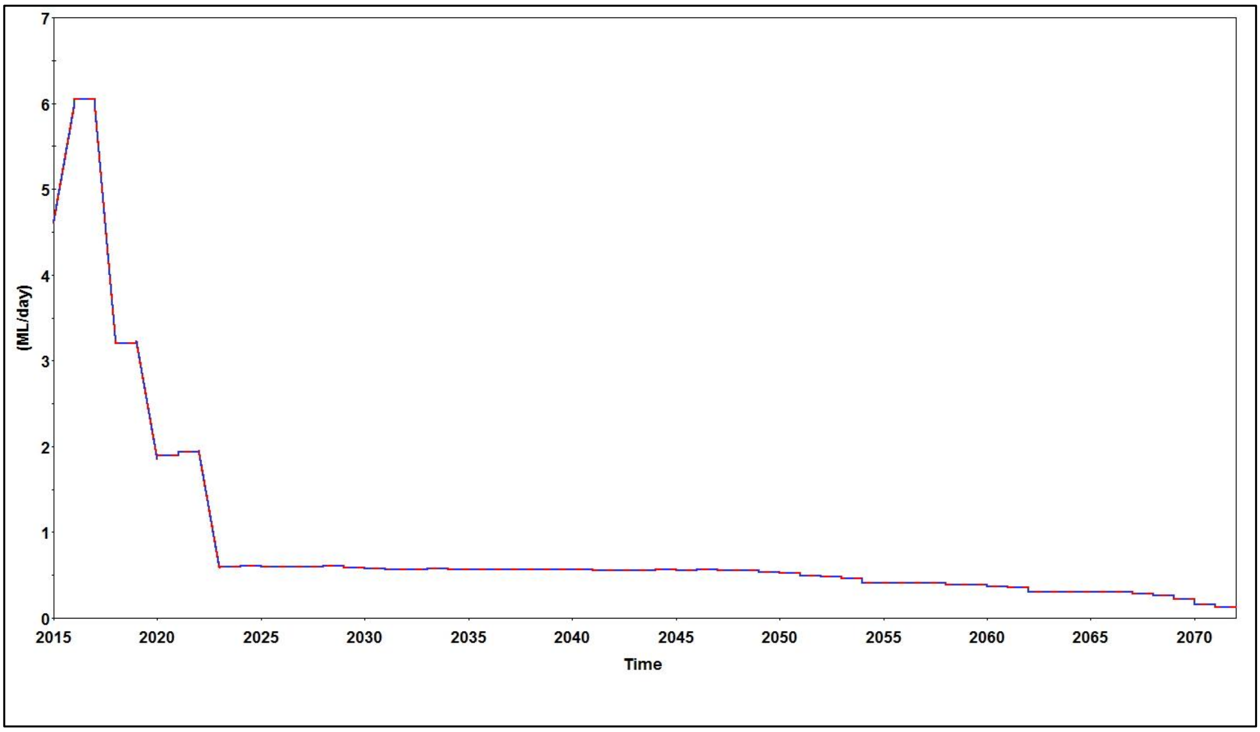


Figure A2- 5 Time Series of potable and construction water demand

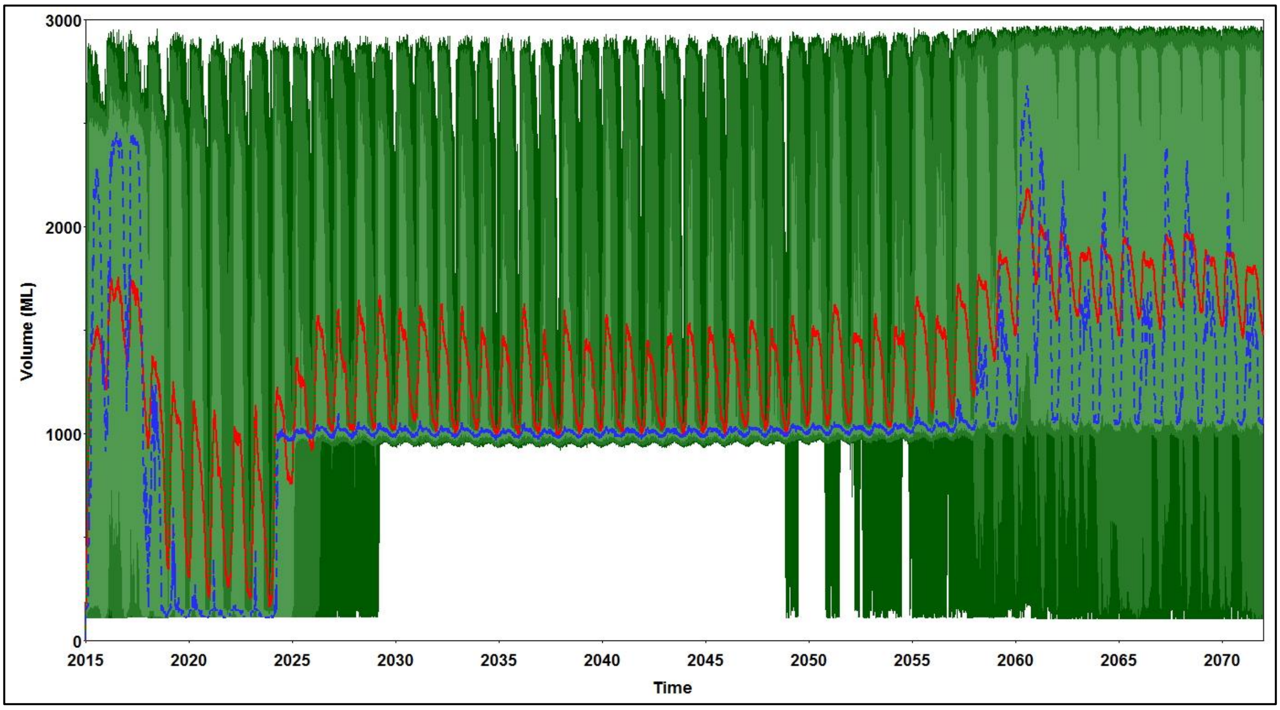


Figure A2- 6 Process water dam north storage performance for the simulation period

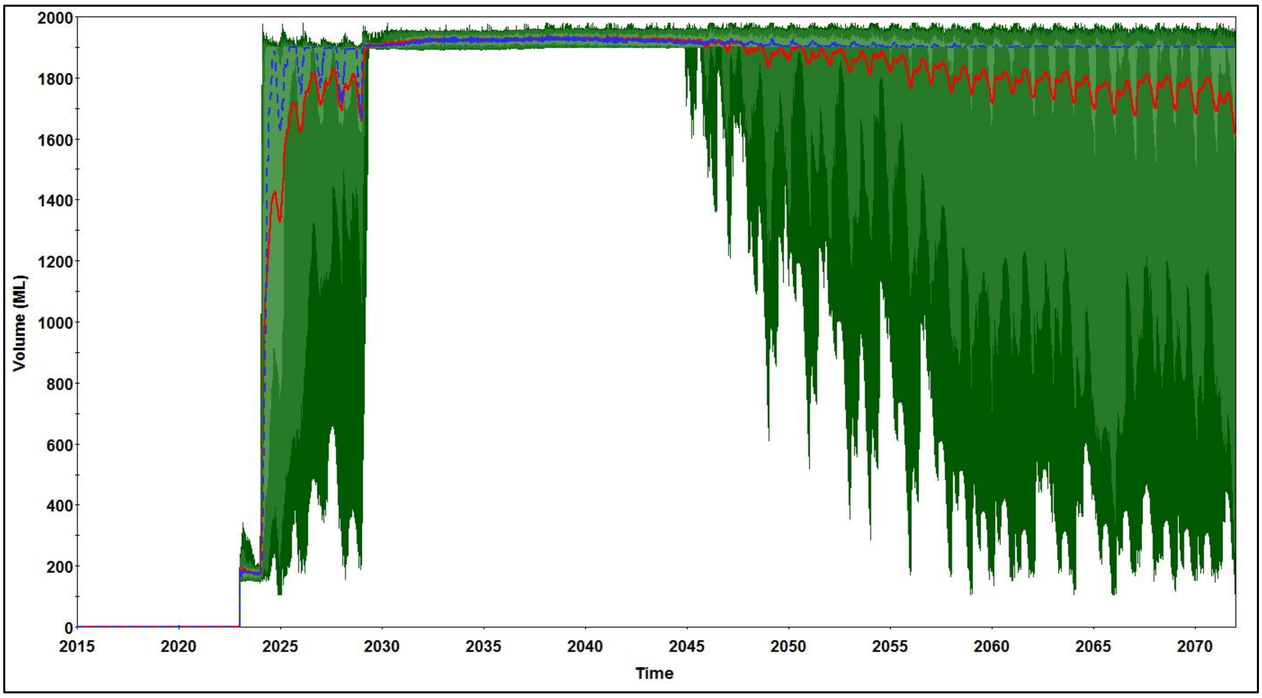


Figure A2- 7 Process water dam south storage performance for the simulation period

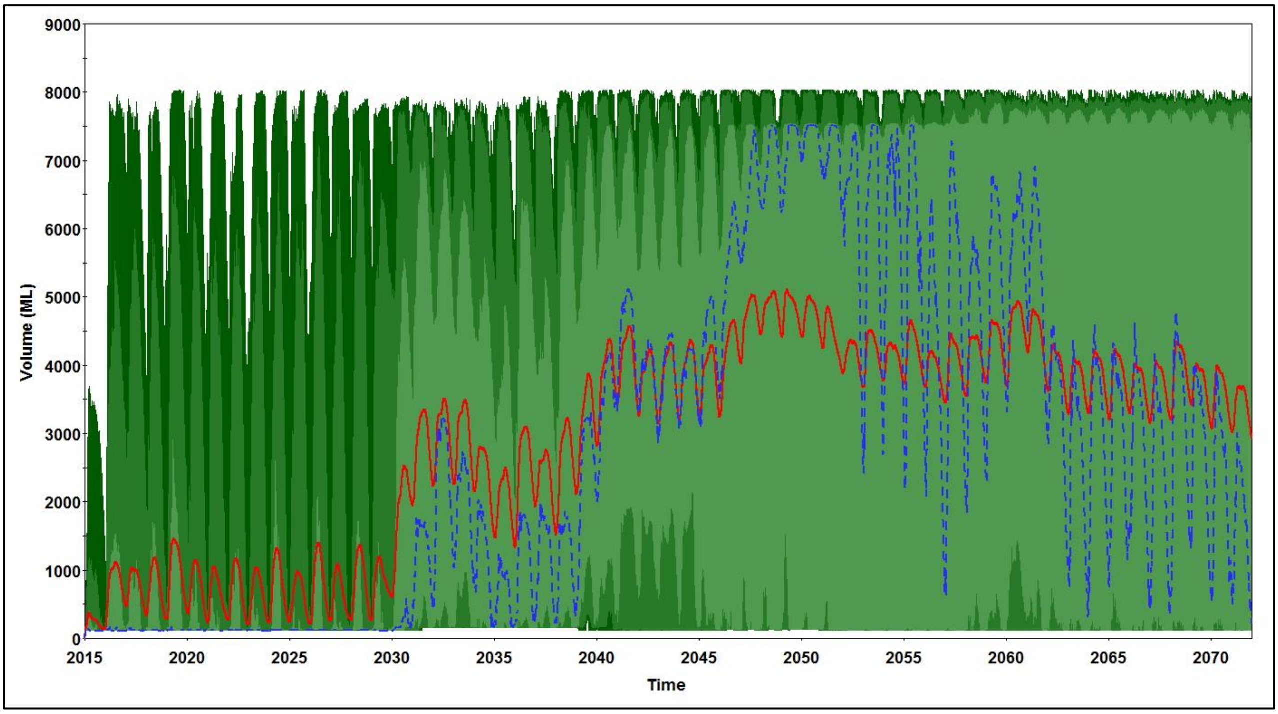


Figure A2- 8 MAW discharge north storage volume performance for the simulation period

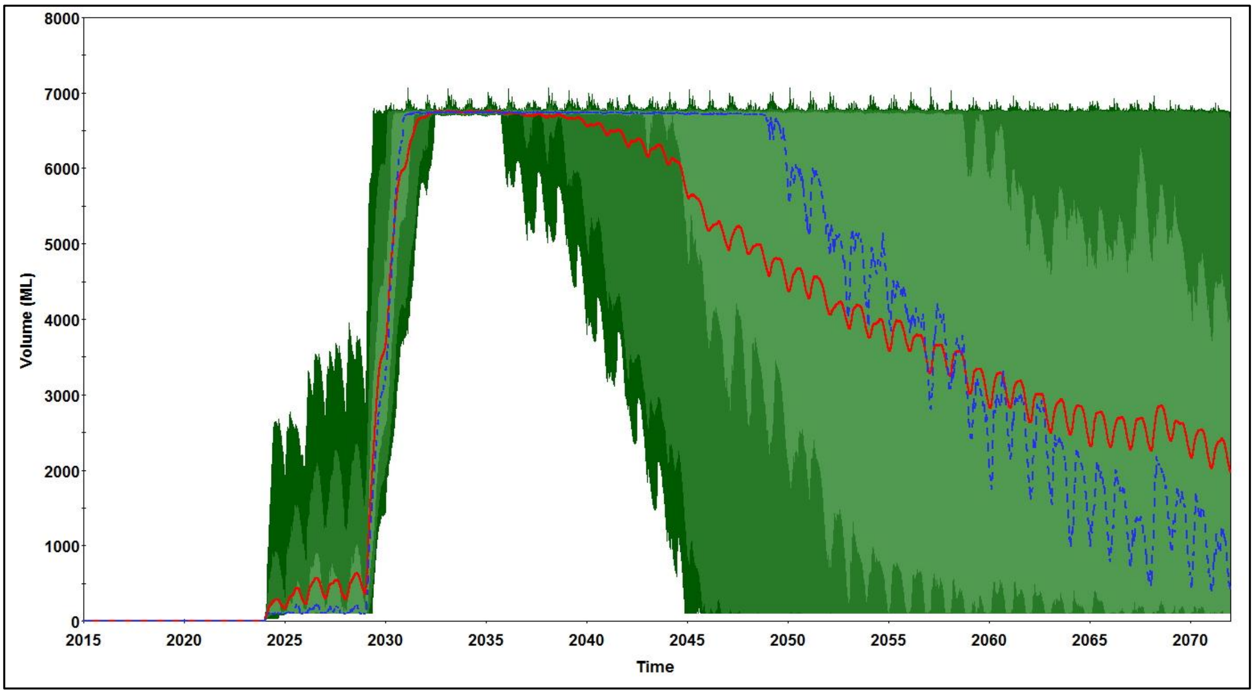


Figure A2- 9 MAW discharge south storage volume performance for the simulation period

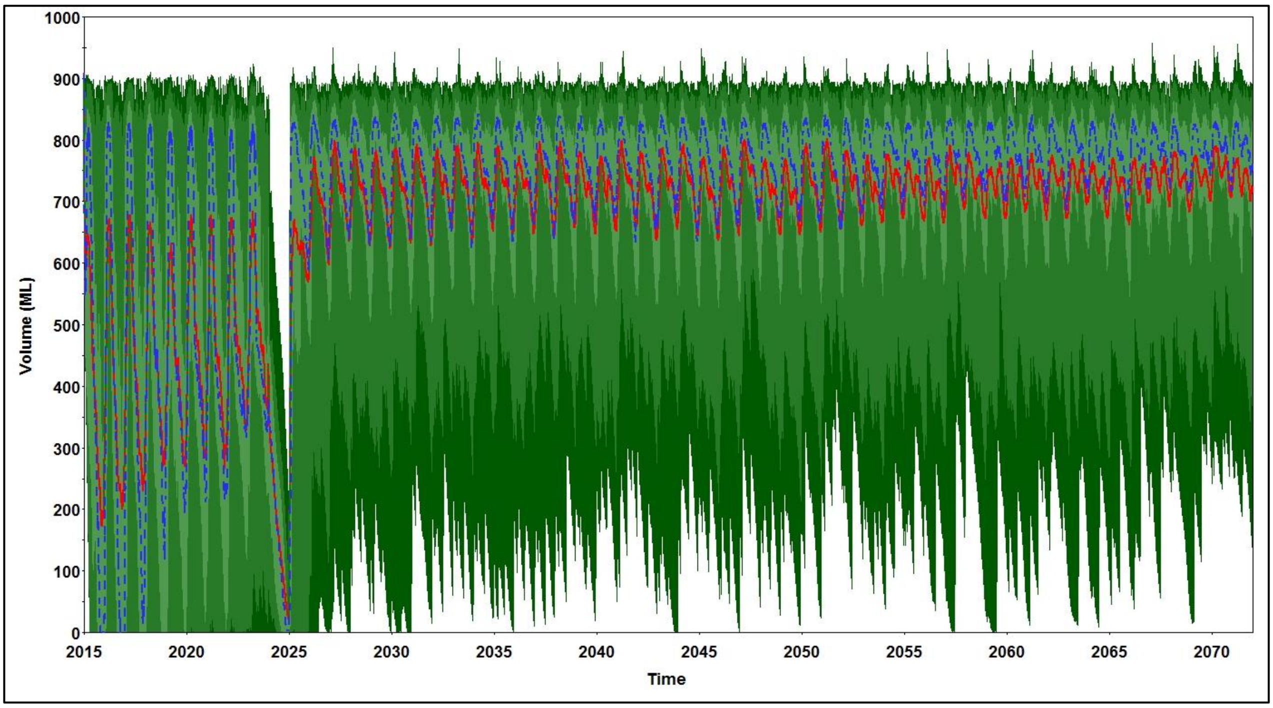


Figure A2- 10 RWD North storage performance for the simulation period

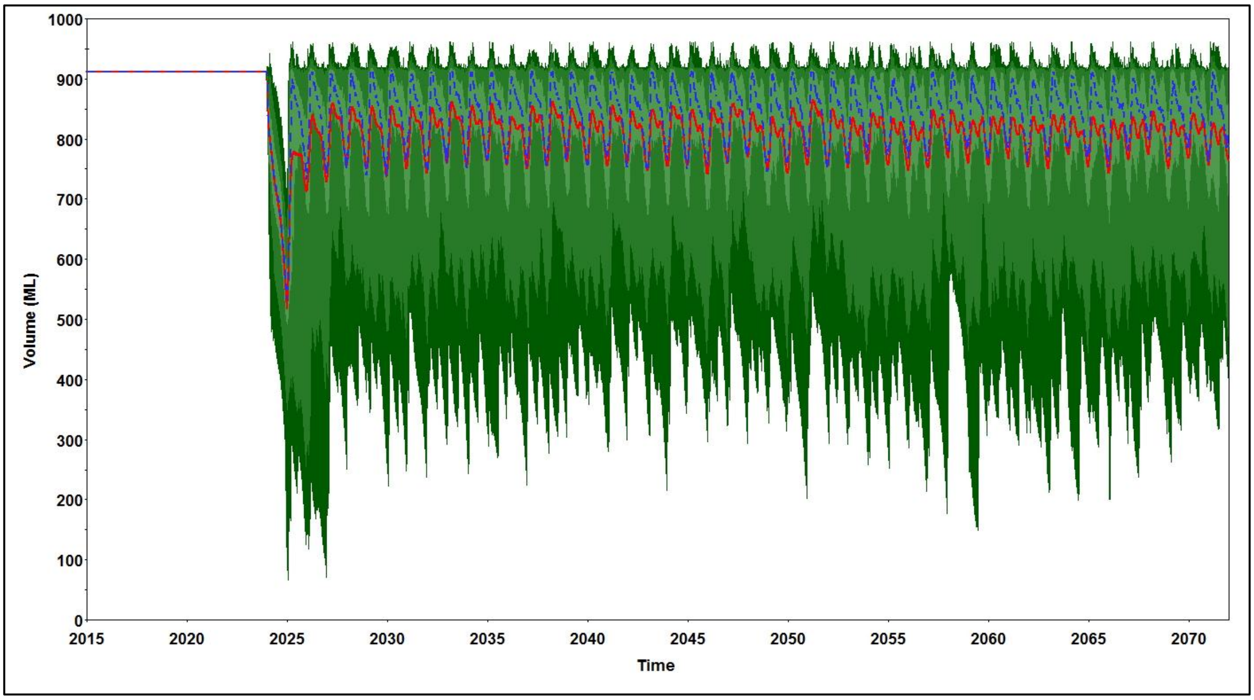


Figure A2- 11 RWD south storage performance for the simulation period

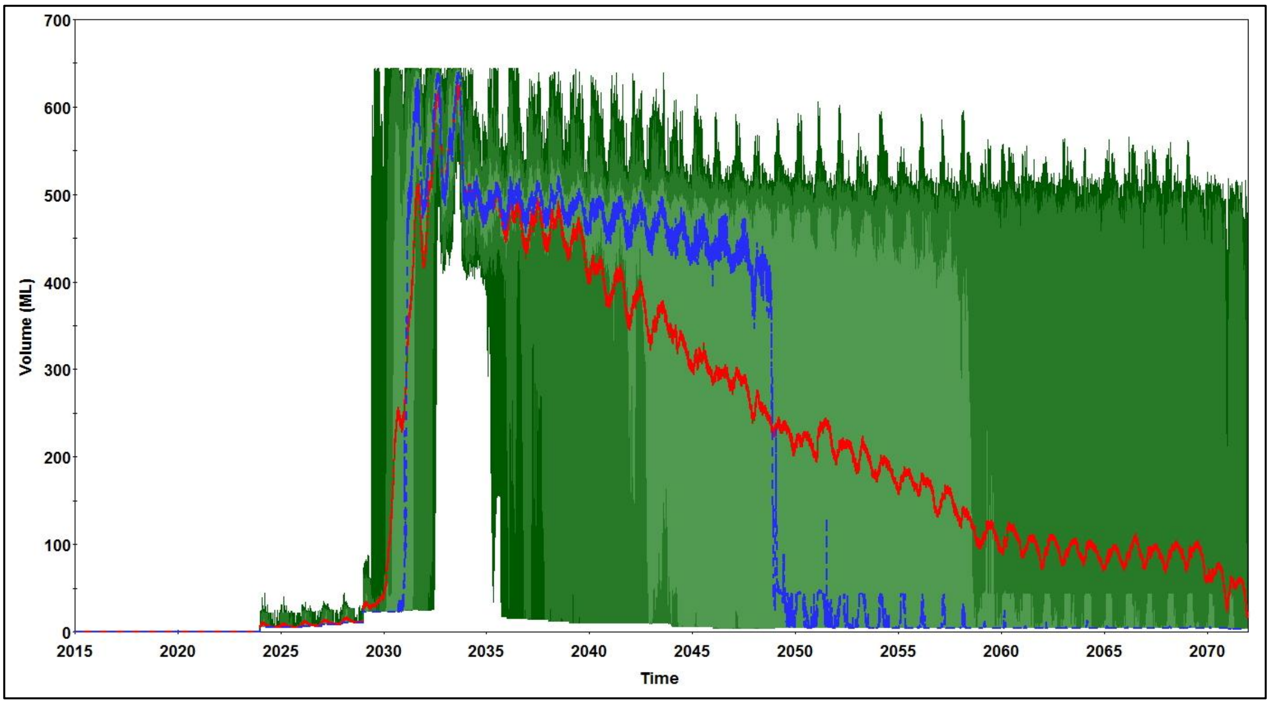


Figure A2- 12 MAWF (Pit F) storage performance for the simulation period

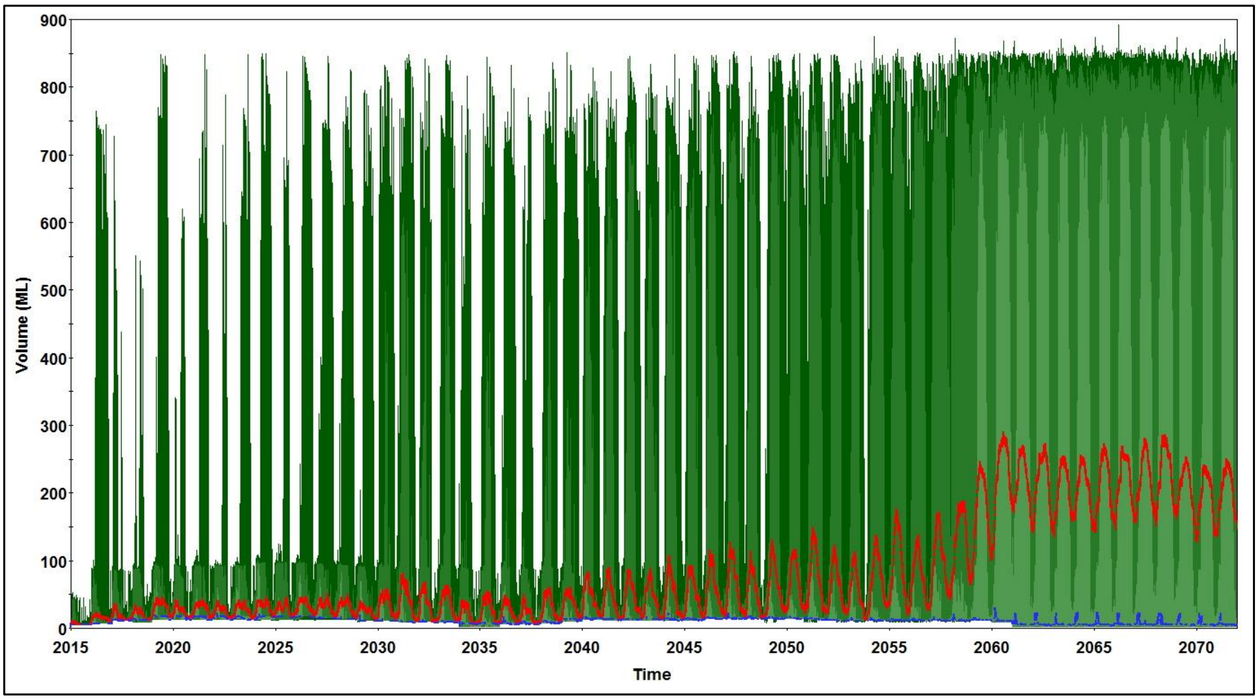


Figure A2- 13 MAWE (Pit E) storage performance for the simulation period

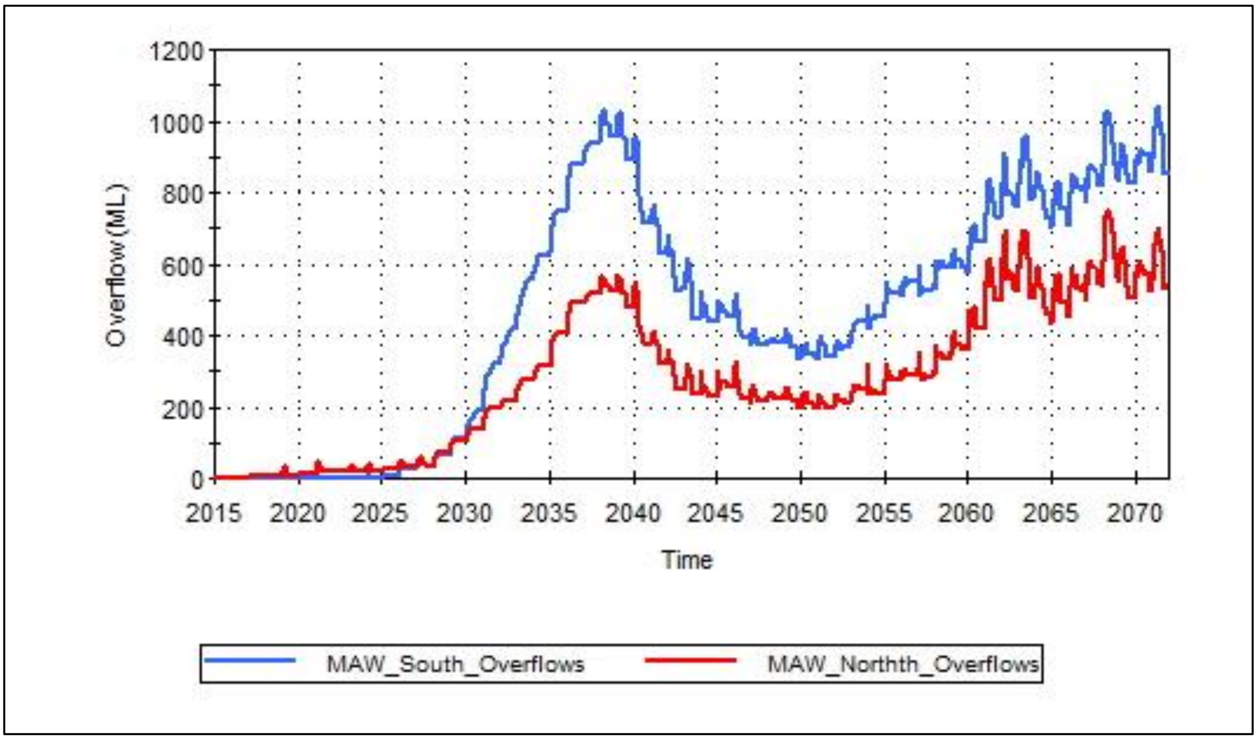


Figure A2- 14 Mean annual cumulative controlled releases for the simulation period

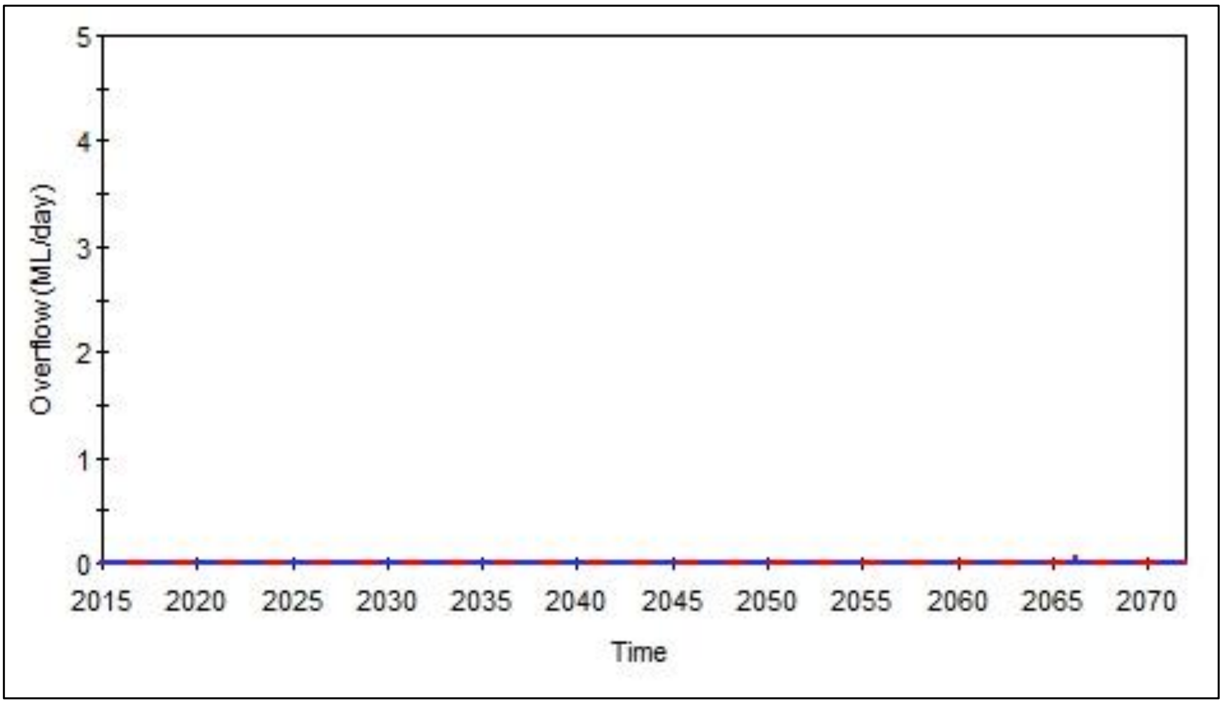


Figure A2- 15 MAWE Dam overflows for the simulation period

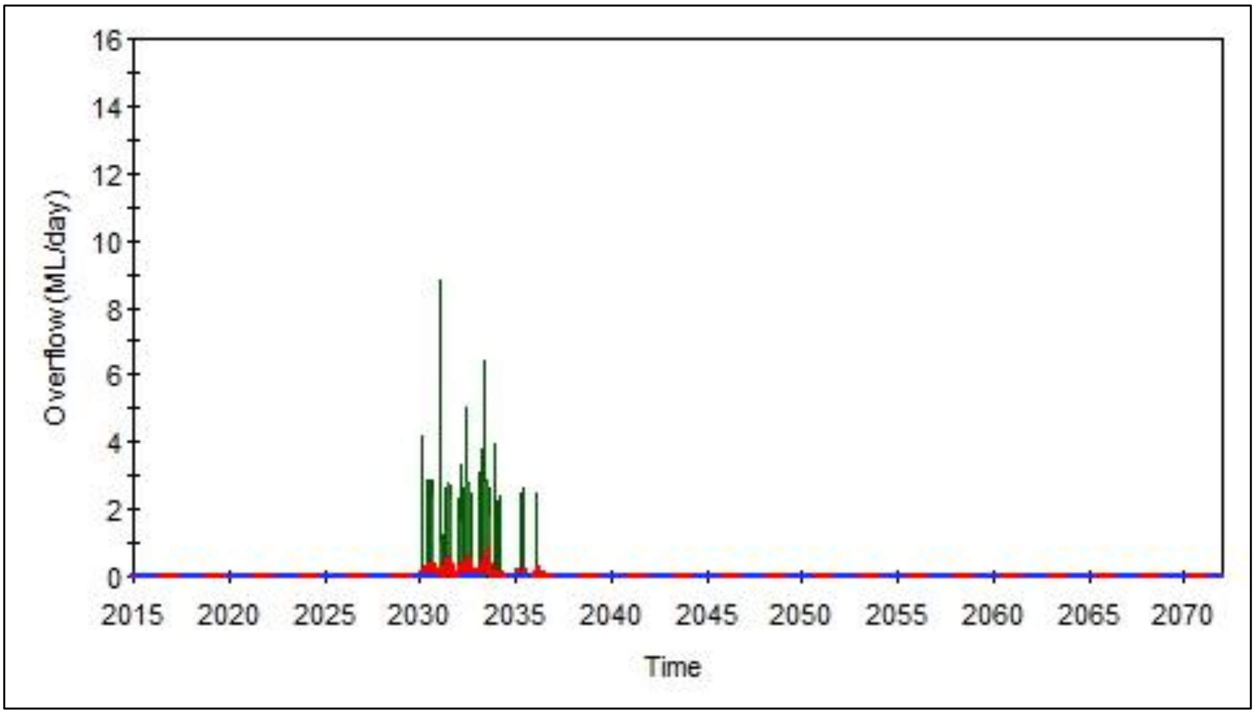


Figure A2- 16 MAWF Dam overflows for the simulation period

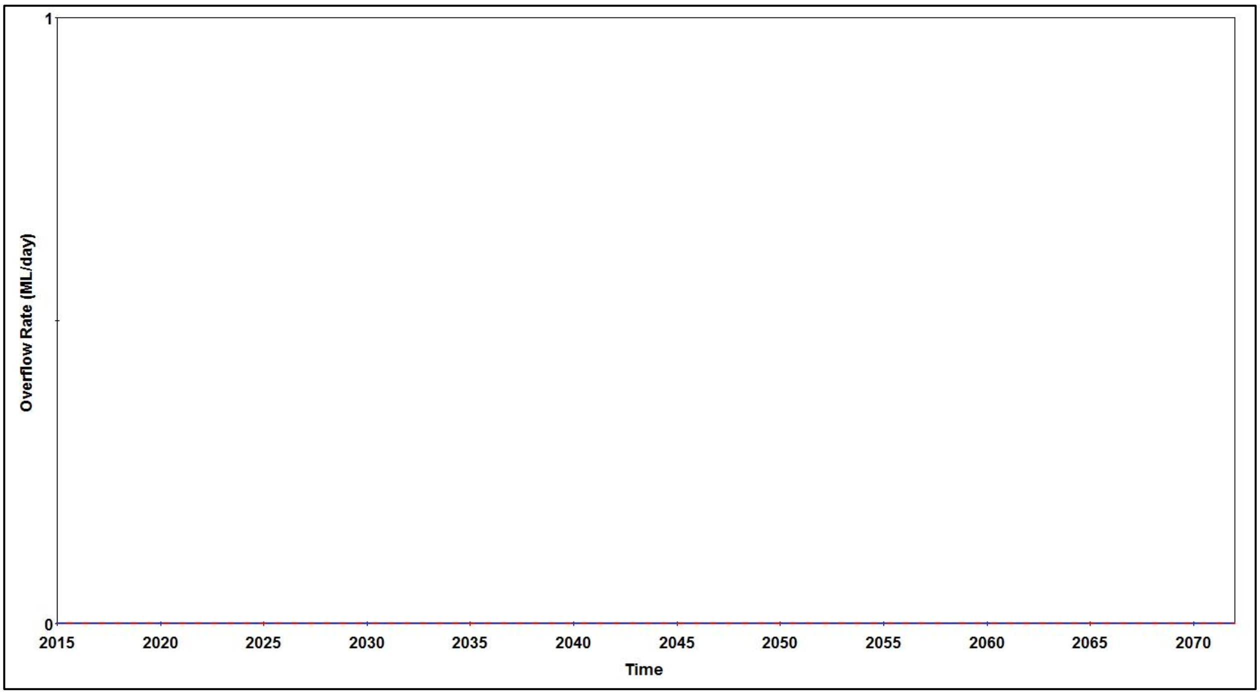


Figure A2- 17 MAWG Dam overflows for the simulation period

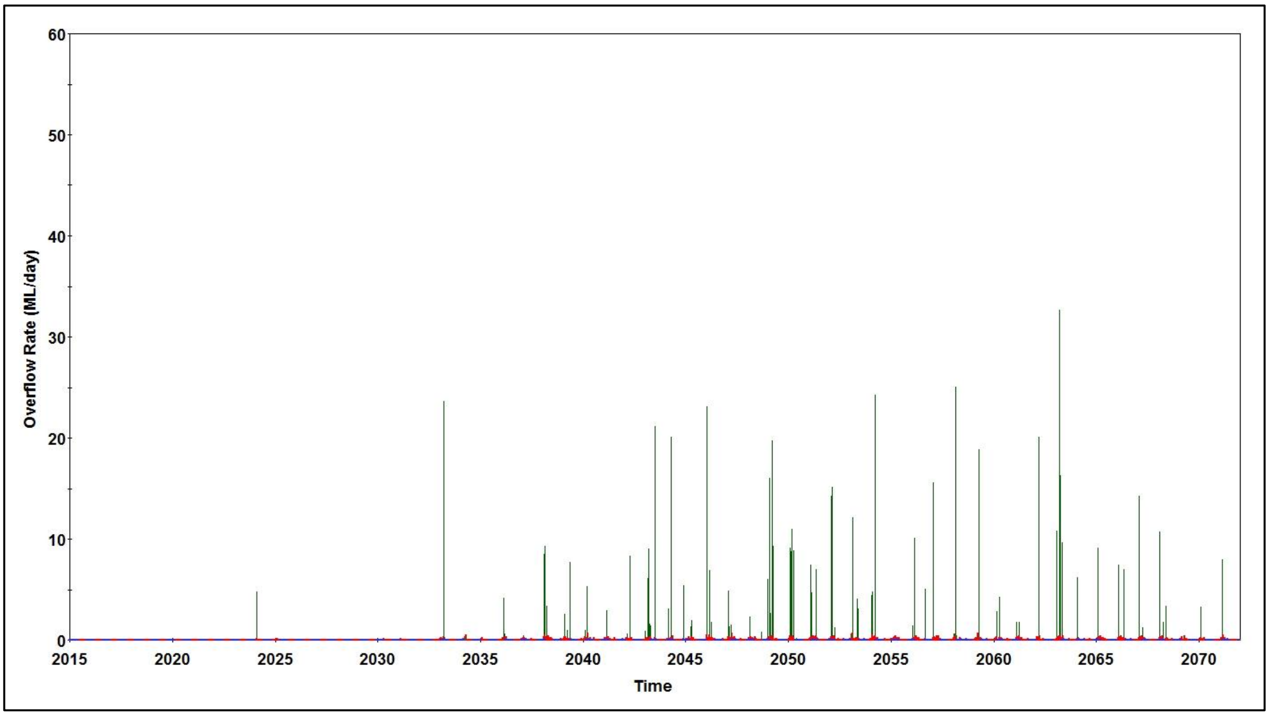


Figure A2- 18 PWD South Dam overflows for the simulation period

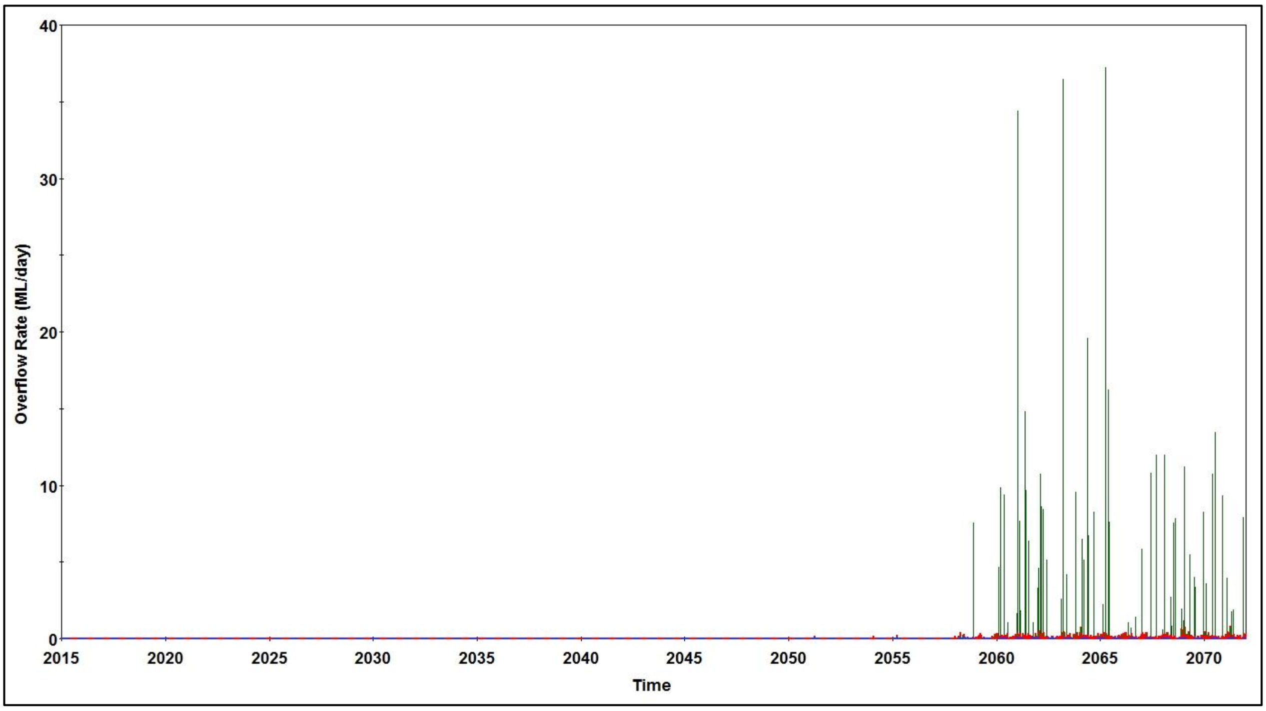


Figure A2- 19 PWD North Dam overflows for the simulation period

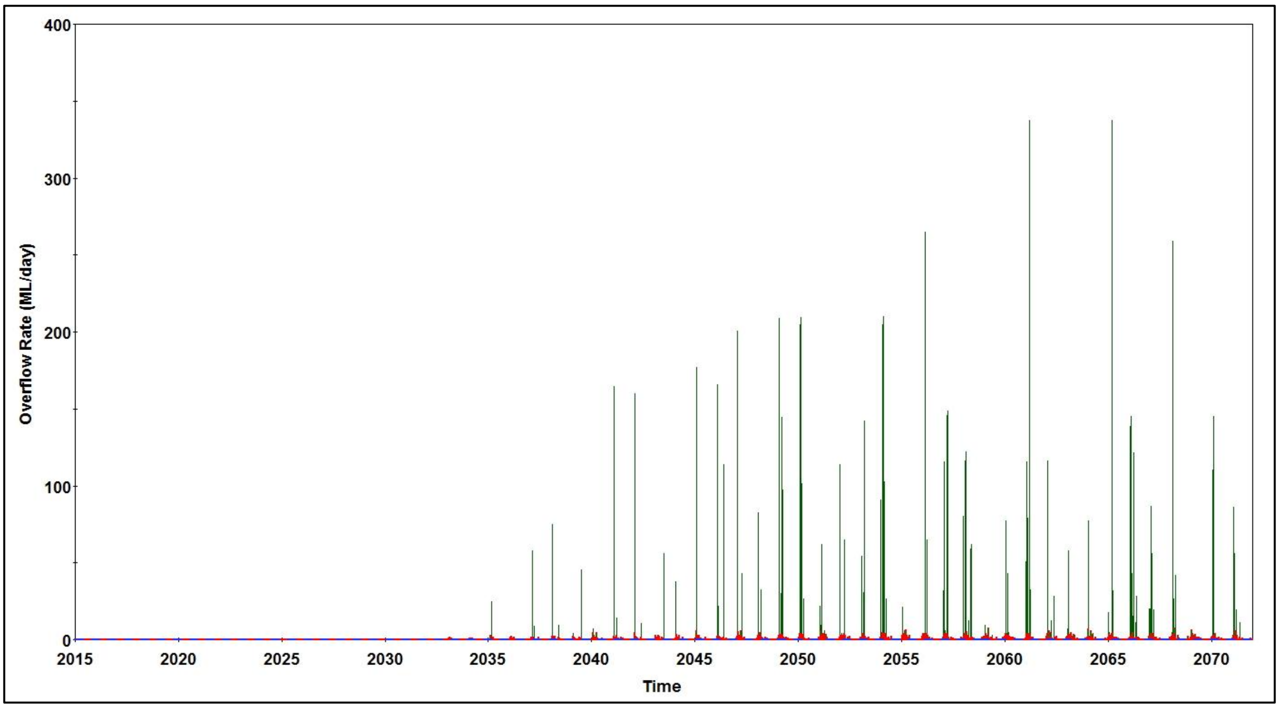


Figure A2- 20 Overburden MAW Dams overflows for the simulation period