URS

Report

Yeelirrie Water Balance Study

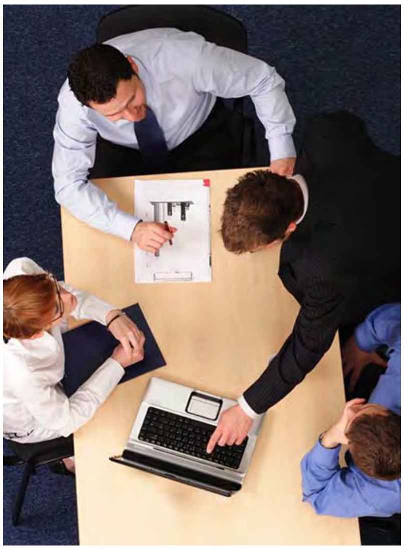
AUSTRALIA

Yeelirrie Water Balance Study

11 June 2015
42908794/BW-Wat-0175/B

Prepared for:
Cameco Australia Pty Ltd

Prepared by URS Australia Pty Ltd



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ABBREVIATIONS

Abbreviation	Description
BHP	BHP Billiton
BoM	Bureau of Meteorology
DSITIA	Department of Science, Information Technology, Innovation and the Arts
EPA	Environmental Protection Authority
ERMP	Environmental Review and Management Programme
GW	Groundnwater
LoM	life of mine
RO	Reverse Osmosis
RWP1	Raw Water Pond 1
RWP2	Raw Water Pond 2
TDS	Total Dissolve Solid
TSF	Tailings storage facility
TSS	Total Suspended Solid
URS	URS Australia Pty Ltd
WBM	water balance model
WMS	Water Management Strategy

EXECUTIVE SUMMARY

This report presents the results of the Water Balance modelling for the proposed Yeelirrie Project, which supports the Public Environmental Approval (PER) submission process, aimed to validate the performance of the Project water management strategy. The modelling results indicate the following:

- Peak water supply demand during mining period (year 4 to 18) is 8,750 kL/day.
- Groundwater Dewatering to RWP2 is estimated at 18,610 ML throughout the LoM.
- Based on the brackish water demand and operating rules adopted, in particular in maintaining four-day operational storage for RWP1 (10 ML capacity), the model estimated that 16,860 – 16,920 ML (980 – 1,110 ML/year) of brackish water is required throughout the LoM.
- Based on the saline water demand and operating rules adopted, in particular in maintaining four-day operational storage for RWP2 (25 ML capacity), the model estimated that 16,100 – 16,480 ML (510 – 1,280 ML/year) of saline water is required throughout the LoM.
- Evaporation Pond with surface area of 50 ha and 3 m deep is adequate in managing and containing the brine onsite, however, the salt within the Evaporation Pond must be emptied and transferred to a separate pond/repository to maintain the salinity below 200 g/L. During high rainfall events, transfers of saline water from the TSF to Evaporation Pond should be ceased; and the excess water should be managed through containing the water within the TSF or adhoc pumping to the open pit for temporary storage, while ceasing transfers from the borefields. It is recommended that further assessment be conducted during detailed design stage.
- The assessment showed that within the assumptions adopted in completing the water balance assessment the proposed water management strategy is adequate in containing the mine impacted water onsite.

1 INTRODUCTION

1.1 Project Background

URS Australia Pty Ltd (URS) previously completed various environmental studies including surface water and water balance study to support the Environmental Review for Yeelirrie Project for BHP Billiton (BHP) prior to acquisition by Cameco Australia (Cameco) in 2012. As part of the water balance study, URS developed a GoldSim water balance model for the Project.

Cameco continued development planning of the Project by recommencing the environment approval process in late 2014. Changes to the proposed mine plan necessitate that both the surface water and the water balance study to be updated to reflect these changes. Changes to the mine plan that are relevant to the water balance study are:

- reduction in life of mine (LOM) from 32 to 22 years;
- changes to planned rate of pit progression and associated tailings backfill and decant rate;
- increased process plant throughput and water consumption as a result of shorter LOM;
- addition of an evaporation pond; and
- changes to additional mine consumptive water demands.

The Environmental Protection Authority (EPA) Western Australia (WA) has identified key environmental objectives, relevant surface water aspects, potential risks and impacts, works required to be completed and relevant policies for the Project. As part of the EPA guidance, Cameco is required to complete the overall site water balance and management of impacted surface water to ensure onsite containment.

URS was engaged by Cameco Australia to update the surface water and water balance study for the Yeelirrie Project. This report focuses on water balance study only which supports the Public Environmental Approval (PER) submission process.

1.2 Scope of Works

The scope of works for this project was specified in URS proposal dated 16 February 2015. Key elements of the scope of works that are relevant to the water balance study were as follows:

- update the existing GoldSim model to reflect changes to the Project;
- validate the performance of the Project water management strategy such that the defined performance indicators are met; and
- preparation of a water balance study report to support the PER submission process.

2 CONCEPTUAL WATER BALANCE MODEL AND PARAMETERISATION

The water balance model (WBM) was developed by URS in 2011 using the GoldSim^{TM} software package. The model has been updated to reflect the changes to the proposed mine plan. The updated WBM schematic is shown in **Figure 2.1**.

The water balance consists of the following key components:

Climate Components:

- rainfall; and
- evaporation.

Water Demand Components:

- construction (civil earthworks and infrastructure assembly);
- dust suppression;
- vehicle wash down;
- ore processing; and
- drinking water (for site personnel after reverse osmosis treatment).

Water Supply Components:

- groundwater dewatering (groundwater abstracted during LoM);
- pit dewatering (in-pit rainfall runoff);
- brackish wellfields (groundwater abstracted from eastern, northern and western brackish wellfields);
- saline wellfields (groundwater abstracted from the palaeochannel); and
- rainfall runoff (collected from ex-pit areas within the mine site).

Water Storage and Distribution Components:

- Raw Water Pond 1 (RWP1 - collecting and distributing brackish mine water);
- Raw Water Pond 2 (RWP2 - collecting and distributing saline mine water);
- Open Pit;
- Tailings storage facility (TSF); and
- Evaporation Pond.

Water Recycling Components:

- TSF decant water (mine water pumped from a low-lying collection area at TSF).

The updated operational management-related inputs are a synthesis of information provided by Cameco through various communications, including:

- teleconference call between Cameco and URS on 24 February 2015;
- teleconference call between Cameco and URS on 28 April 2015;

- Water balance (24 March 2015).xlsx;
- 04A 11317-Mass Balance SPS Addendum RevE with Reagents.xlsx;
- Yeelirrie-water demand – supply (revised March 16 2015).xlsx;
- Fig 3.5 Indicative site-wide water balance (march 25 2015).pdf; and
- Email dated 31 March 2015, (1:31 pm), Eric Paulsen, Cameco
- Email dated 1 May 2015, (3:35 pm), Keith Berry, MWES Consulting.

2.1 Approach

In order to validate the performance of the proposed mine Water Management Strategy (WMS) under a range of historical climatic conditions, Monte Carlo i.e. multiple simulations (known as realisations) are run. The only input to vary between each realisation is the input climate data (rainfall and evaporation) which consists of 114 years (1900 to 2014) of data obtained from SILO - an enhanced climate database hosted by Science Delivery Division of the Department of Science, Information Technology, Innovation and the Arts (DSITIA).

Running on a daily timestep the first model realisation runs for a 22-year period utilising climate data from 1900 to 1921. The second realisation then utilises climate data from the period 1901 to 1922, the third from 1902 to 1923 and so on. This process allows for a total of 114 model realisations (known as a Monte Carlo simulation) to be run from the available climate data and allows for each year of the mine to be modelled for every year of available climate data.

2.1.1 Key Assumptions

The GoldSim WBM has been developed to a level of detail commensurate with the level of available data. A variety of simplifications and assumptions have been made as follows:

- no allowance was made in the model for deep percolation and seepage through the base of the storages. This is a conservative assumption and is likely to overestimate surface water volumes and frequency of runoff;
- no flood routing has been included. This is unlikely to be a significant problem due to small catchment areas;
- no restrictions have been placed on the potential supply availability of raw water supply from groundwater bores;
- groundwater bores supply is unlimited; and is stored in RWP1 and RWP2;
- emergency Pit releases outside normal operating rules or ad hoc pumping are not modelled;
- the processing plant is not specifically modelled. The water and mass balance in the process plant was completed by Cameco using SysCAD and the results is used in the GoldSim model as inputs;
- pump transfers occur at each water balance model timestep (i.e. day) and are based on specific transfer and priority rules;

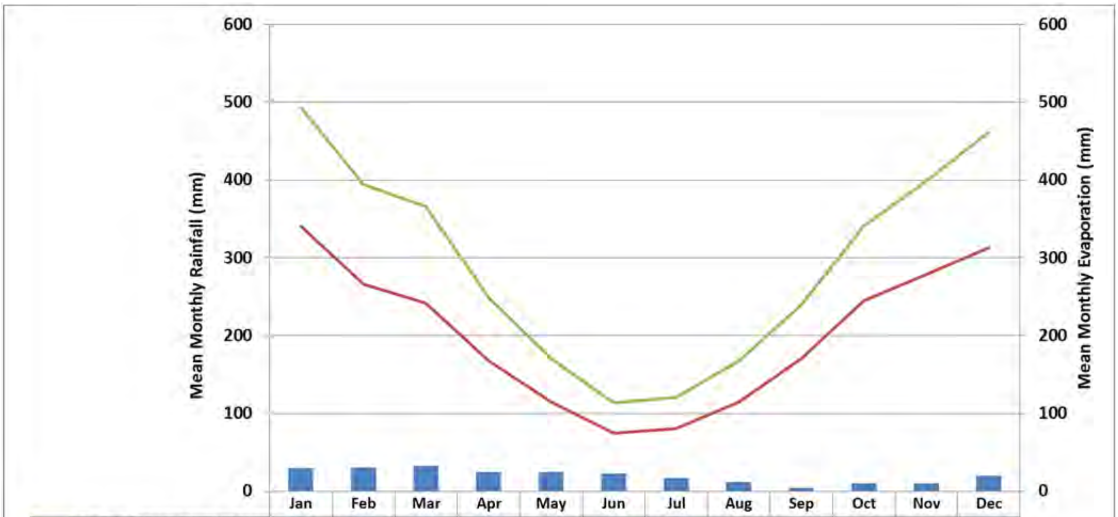
- no allowance was made for flow travel time within pipe networks (i.e. flows were assumed to be instantaneous), and pump availability was assumed to be 100% of the potential capacity for 100% of the time;
- pump capacity remains fixed irrespective of head differential from pump to water surface;
- performance of the mine Water Management Strategy was assessed on the basis of historical climate data however the potential changes to climatic extremes resulting from climate change have not been considered;
- evaporative water losses from all ponds have been estimated to be 70% of Class A Pan evaporation; and
- no loss of dam storage capacity over time due to sedimentation.

2.2 Climate Components

Two of the key inputs to the water balance numerical model are rainfall and evaporation. A thorough discussion of the climate related to the Proposed Development is presented in Section 3, Physical Environment, of the Surface Water Study Proposed Yeelirrie Development Report. The following presents additional information as appropriate with respect to the water balance-related study.

2.2.1 Rainfall and Evaporation

The average annual rainfall for Yeelirrie (BoM, Station No. 012090, 1928 to 2015) is 240 mm with recorded minimum and maximum annual rainfalls of 43 mm and 507 mm respectively. Yeelirrie receives 62% of the mean annual rainfall from November to April (see **Chart 2-1**). The highest recorded monthly rainfall of 211 mm occurred in April 1992 and the highest daily rainfall of 99.1 mm occurred in March 1931.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (012090, Yeelirrie)	29.6	30.9	32.6	24.4	25.3	22.8	17.4	12.4	4.8	9.7	10	20.2
Evap (Wiluna, 013012)	341	266	241.8	168	114.7	75	80.6	114.7	171	244.9	279	313.1
Evap (Meekatharra, 007045)	492.9	394.8	365.8	249	170.5	114	120.9	167.4	240	341	399	461.9

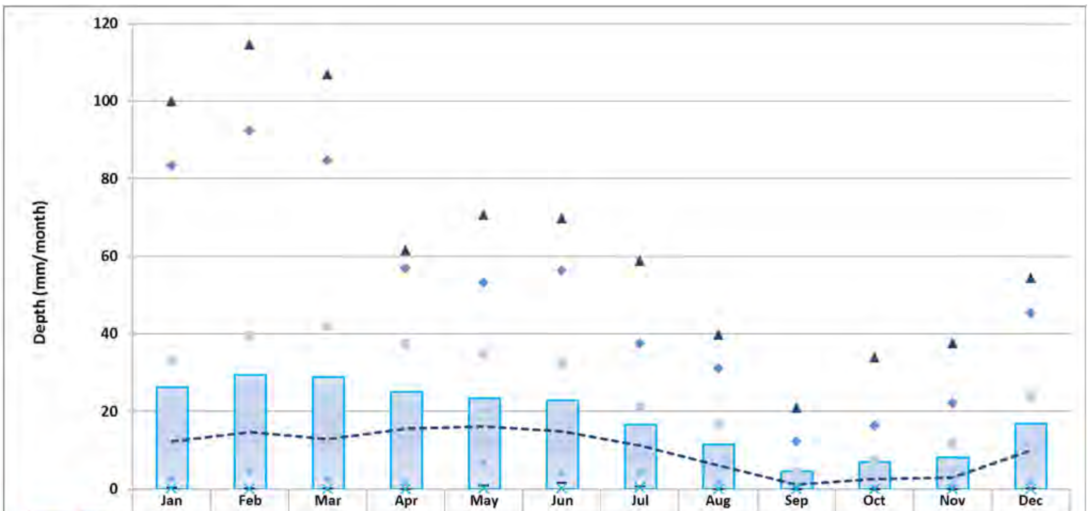
Chart 2-1 Rainfall and Evaporation (Bureau of Meteorology Weather Stations)

Due to the data shortcomings of the data from the local weather stations, long-term rainfall data for the Yeelirrie Mine site was obtained from the DSITIA SILO Data Drill system. The Data Drill rainfall is determined through accessing grids of data derived from interpolation of regional Bureau of Meteorology (BoM) station records. This provides a synthetic data set for a defined set of co-ordinates, derived from actual recorded data.

No evaporation data are recorded at the Yeelirrie BoM station. The mean annual pan evaporation at the two nearest meteorological stations (Wiluna and Meekatharra Airport) is 2,410 mm and 3,517 mm, respectively. In the absence of evaporation data at Yeelirrie, long-term (1889 – 2015) SILO Data Drill synthetic rainfall and evaporation data were generated for the Yeelirrie Catchment.

Chart 2-2 shows monthly rainfall percentiles for the SILO Data Drill derived for the Project site. Average monthly rainfall shows a distinct seasonal distribution with a defined dry season occurring from August through November and minimum average monthly rainfall occurring in September (4 mm). A defined wet season from January through June is also apparent with the maximum average monthly rainfall of 29.5 mm occurring in February.

It is also important to note the potential variability in monthly rainfall depths, particularly during the wet season as shown in **Chart 2-2**. For the months of January through March the 90th percentile totals are approximately 6 times that of the median. It can also be seen that for the dry season months of September and October the 25th percentile totals are 0.0 and 0.1 mm respectively. In summary **Chart 2-2** shows that rainfall at the Project site is distinctly seasonal with a highly variable summer wet season and a more consistent winter dry season. This distribution characterises the influence of cyclones and their remnant rain-bearing tropical lows that are the source of the majority of extreme rainfall events at the site.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	26.4	29.5	29.0	25.0	23.4	23.0	16.7	11.5	4.5	7.0	8.3	16.9
95%ile	100.1	114.7	107.0	61.6	70.7	69.8	58.9	39.9	21.0	34.0	37.7	54.4
90%ile	83.4	92.3	84.6	56.9	53.2	56.2	37.4	31.1	12.2	16.3	22.0	45.3
75%ile	33.3	39.4	42.1	37.5	35.0	32.3	21.0	16.7	4.6	7.2	11.5	24.0
Median	12.3	14.7	12.9	15.5	16.1	14.8	11.2	6.0	1.1	2.7	2.9	9.9
25%ile	2.5	4.4	2.4	1.5	6.7	4.1	4.4	1.6	0.0	0.1	0.5	1.7
10%ile	0.3	0.2	0.1	0.0	0.8	1.6	0.7	0.0	0.0	0.0	0.0	0.1
5%ile	0.1	0.0	0.0	0.0	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.0

Chart 2-2 Monthly Rainfall Percentiles (SILO Data Drill)

The long-term rainfall statistics for the Yeelirrie Mine site are shown **Table 2-1**.

Table 2-1 Long-Term Mean Monthly Rainfall and Evaporation

Month	BoM Mean Monthly (mm)			SILO Mean Monthly (mm)	
	Rainfall (Yeelirrie Homestead)	Evaporation (Wiluna)	Evaporation (Meekatharra Airport)	Rainfall (Yeelirrie)	Evaporation (Yeelirrie)
January	29.6	341	492.9	26.4	423.4
February	30.9	266	394.8	29.5	333.7
March	32.6	241.8	365.8	29.0	303.8
April	24.4	168	249	25.0	203.7
May	25.3	114.7	170.5	23.4	137.6
Jun	22.8	75	114	23.0	96.7
July	17.4	80.6	120.9	16.7	106.2
August	12.4	114.7	167.4	11.5	147.5
September	4.8	171	240	4.5	213.5
October	9.7	244.9	341	7.0	301.3
November	10	279	399	8.3	351.4
December	20.2	313.1	461.9	16.9	406.0
Annual Mean	**240**	**2,410**	**3,517**	**221**	**3,025**
Period of Record	1928-2015	1957-1985	1967-2015	1889-2015	1889-2015

The newly extracted data drill, however, is slightly different from the data obtained and adopted in the WBM study completed in 2011. This is due to updates to the SILO database that have been implemented to improve SILO's data quality and data interpolation algorithms. In particular, the updates implemented in 2012 and 2014 have resulted in changes to the derived Data Drills. A memorandum presenting the findings of a comparison between the previous and updated SILO Data Drills to provide additional context to any results generated by the updated WBM is presented in **Appendix A**.

Yeelirrie receives 62% of mean annual rainfall in the summer months from November to April. The remaining 38% of rainfall occurs during winter, generally at low intensity, and usually these events only produce limited runoff.

Summer rains are normally of high intensity, caused by localised thunderstorm activity or much larger weather systems associated with cyclones and tropical lows. Cyclones and their remnant rain-bearing tropical lows are the source of the majority of extreme rainfall events that are likely to generate surface runoff within the Yeelirrie Catchment. BoM data indicate that 13 cyclones passed within 200 km of Yeelirrie Homestead between 1970 and 2000 and that the region has an average annual tropical cyclone frequency of between 0.4 and 0.8 (**Figure 2**).

Evapotranspiration is defined by the Bureau of Meteorology (BoM, 2010) as the transfer of water, as water vapour, to the atmosphere from both vegetated and barren land surfaces. Evapotranspiration is affected by numerous variables including climate, availability of water, vegetation, depths to shallow groundwater, water salinity and soil properties.

At Yeelirrie, the evapotranspiration is not accurately known, but is likely to be dependent on vegetation type, soil and subsurface material types and the salinity and depth to groundwater. Within the typical Yeelirrie landscapes, evapotranspiration is likely to be dominated by vegetation transpiration of soil moisture held within the unsaturated vadose zone.

The BoM has recently overseen the mapping of annual evapotranspiration parameters across Australia using Morton's complementary relationship areal evapotranspiration model. There are two products from this mapping - areal potential evapotranspiration and areal actual evapotranspiration (**Figure 3**). Mean annual areal potential evapotranspiration represents the amount of evapotranspiration that would occur based on unlimited water availability.

At Yeelirrie, the areal potential evapotranspiration is interpolated to be about 1,400 mm/year. **Figure 3** also shows the interpolated distribution of mean annual areal actual evapotranspiration. This value approximates the evapotranspiration that actually takes place under the conditions of existing water availability. This should represent the evapotranspiration which would occur over a large area of land under typical mean rainfall conditions. At Yeelirrie, the range is 200 to 300 mm/year, which suggests that most incident rainfall in the catchment is subsequently lost as evapotranspiration.

In the lower-lying valley floor portions of the Yeelirrie Catchment, evapotranspiration from shallow water table settings is considered potentially significant. The evapotranspiration would occur as evaporation from bare soils above shallow water table settings and as transpiration by phreatophytic vegetation where water table depths and groundwater salinity are suitable.

2.2.2 Effect of Salinity on Evaporation Rates

Evaporation occurs when water is converted to water vapour. The rate of evaporation is governed by the available energy at the evaporation surface; and the ease with which water vapour can diffuse into the atmosphere.

The extent to which the energy is available at the ground is used to evaporate water is determined by the process controlling vapour diffusion through the air. These can be shown to be dependent on the difference in vapour pressure and the difference in temperature between different levels in the atmosphere above the surface water.

Evaporation reaches steady state when the vapour pressure in the air immediately above the water surface is saturated. This is known as the saturated vapour pressure and is directly proportional to the temperature of the air.

The rate of evaporation is therefore proportional to the net of energy in the waterbody, the wind speed, the vapour pressure and temperature differential between the water and air.

Evaporation rates are also affected by the introduction of salt to the water body. When salt added to the water, more energy is required to remove water molecules from the surface water, less evaporation occurs and the vapour pressure above the surface is reduced. Conversely, reduced emission of molecules from the water surface means that saline waterbody will have a higher temperature than an identical freshwater body. The effect only partially compensates for the reduced evaporation induced by the introduction of salt.

Evaporation of free surface water and the effect of salinity have been applied in the water balance model for the following water storages:

- RWP1;
- RWP2;
- TSF; and
- Evaporation Pond.

The evaporation factors for RWP1, RWP2 and TSF have been modelled using a lookup table. Interpolation between tabulated factor values has been included. The adopted values are present in **Table 2-2.**

Table 2-2 Adopted Model Factors to Adjust Evaporation (0.7*Class A Pan Evaporation) for Salt Content

TDS (mg/L)	Evaporation factor
0	1
330,000	0.67
400,000	0.47
480,000	0.01

The evaporation factor presented in **Table 2-2** was not applied to the Evaporation Pond, as it was assumed that the Evaporation Pond will be emptied periodically where the brine/salt will be removed to a separate pond/repository to avoid salt build-up and maintain the salinity in the Evaporation Pond below 200 g/L. As agreed with Cameco, a constant evaporation factor of 0.88 has been assumed for the Evaporation Pond.

2.3 Water Demand Components

The water demand for the Proposed Development is divided into raw water and treated water demands, with each of the components described as follows. It should be noted that Cameco recognise that there is some flexibility in terms of the provided water quality criteria, notably for raw process water and RO feed water. The criteria and assumptions listed below represent best estimates of water quality criteria as at February 2015 for the purpose of water balance development. These criteria and requirements may change in the future as further feasibility studies are completed. Importantly, any expected changes to water quality criteria are not expected to significantly alter the volumetric water demands of the proposed development, nor the site water balance.

2.3.1 Raw Water Demand

The maximum raw water demand over the 22 years LoM is expected to be around 8,750 kL/day. The total raw water demand is supplied by RWP1 and RWP2; and made up by the following components:

- construction;
- vehicle washdown;
- process raw water (including saline water as well as the gland seal water);
- dust suppression; and
- RO plant feed.

The raw water demand over the 22 years LoM are shown in **Chart 2-3**.

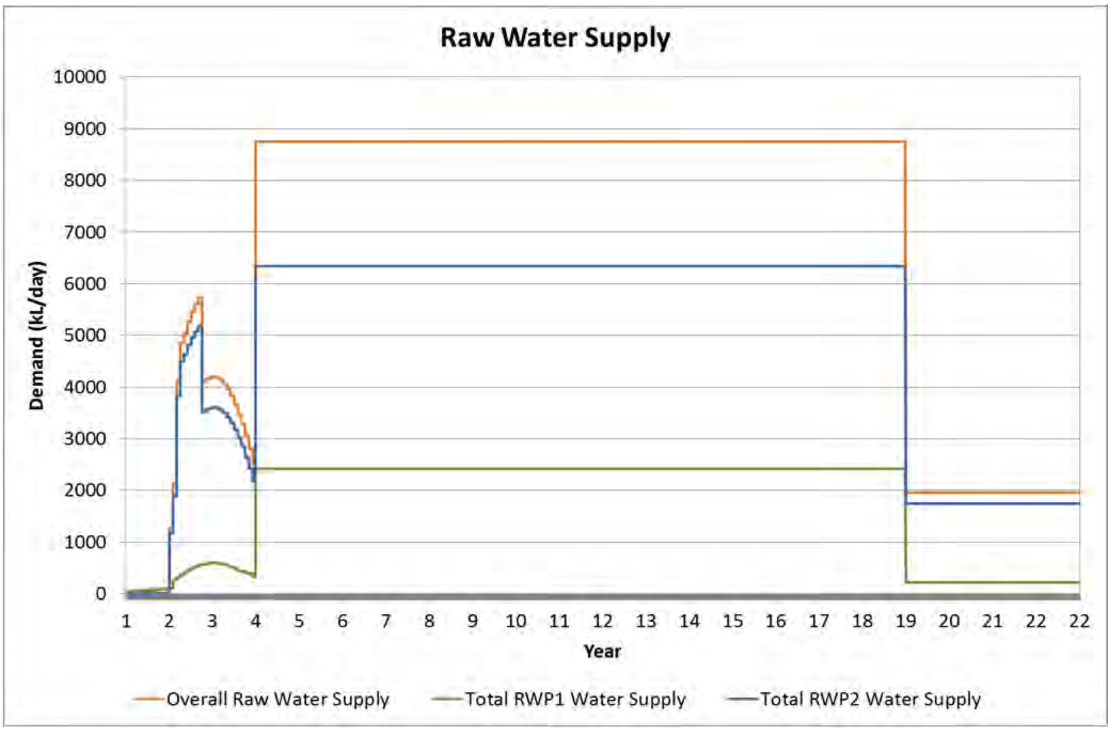


Chart 2-3 Raw Water Demand

2.3.1.1 Construction

Construction water will be used for civil earthworks such as ground compaction and construction-related dust suppression. Treated water will be used for concrete mixing and will be sourced from the RO plant (in addition to drinking water supplies).

Water demands during the construction stage of the Proposed Development will be sourced primarily from RWP2. The raw water demands for construction are described hereafter in **Sections 2.5.1** and **2.5.2**). These demands will diminish during the ramp-up stage of the Proposed Development when all of the infrastructure will be in place.

2.3.1.2 Vehicle Washdown

Vehicle washdown water is required to manage the movement of soil and particulates that adhere to vehicles that travel within the Proposed Development area. It is estimated that 36 kL/day (1.5 kL/hr) of raw water (shown in **Chart 2-7** in **Section 2.5.2**) will be required for vehicle washdown. The water will be sourced from RWP2.

2.3.1.3 Ore Processing

Water for ore processing is required to assist the disaggregation, dissolution and separation of uranium from the ore as well as reagent mixing and routine wash down and cleaning of the processing apparatus. This demand comprises a saline raw water supply to supplement the TSF decant supply and a fresh supply to mix reagents.

The demand is supplied by the following water sources:

- Raw water directly from RWP2;

- Filtered raw water from the gland seals;
- RO water; and
- TSF decant return.

The processing plant also receives water as interstitial moisture from ore and reagents, which has also been accounted for in the water balance model. The flowrates were assumed to be constant at 1,248 kL/day (52 kL/hr) and 312 kL/day (13 kL/hr) respectively. In addition, as advised by Cameco, a net gain of 72 kL/day (3 kL/hr) of water has been assumed as a result of reactions that occur in the processing plant.

In this water balance study, the processing water demand rate is expressed as a function of daily time series. The raw water demand is shown in **Chart 2-7** (**Section 2.5.2**) and the RO demand in **Chart 2-6** (**Section 2.5.1)**.

The assumed water quality criteria (maximum) for the ore processing water feeds of the Proposed Development are as follows:

- ore processing maximum TDS concentration of 40,000 mg/L;
- ore processing maximum TSS concentration of 1,000 mg/L; and
- reagent mixing maximum TDS concentration of 500 mg/L.

2.3.1.4 Dust Suppression

Water for dust suppression will be required during the entire operational phase of the Proposed Development to control the release of airborne particulates during the Proposed Development. Water for haul road and mine area dust suppression will be sourced primarily from RWP2 using saline water. This pond receives water from mine dewatering and the saline wellfields. The average raw water demand throughout the LoM is anticipated to be around 1,600 kL/day with highest demand expected to occur during construction period (2,100 kL/day), as shown in **Chart 2-7** (**Section 2.5.2**).

Water to be provided for dust suppression is assumed to meet the quality criteria of a maximum total dissolved solids (TDS) concentration of 100,000 mg/L.

2.3.2 RO Plant Water Demand

The raw water demand sourced from RWP1 to produce potable water is shown in **Chart 2-3**. The maximum total water demand is expected to be around 2,420 kL/day; and is made up by the following components:

- construction (concrete mixing);
- process potable water (reagent mixing and commissioning); and
- mine site personnel and village (drinking water at the mine and ore process plant and for domestic consumption).

The raw water feed to the RO plant from RWP1 will be passed through a particle filter before RO treatment. The particle filter is simulated by the model using the following parameters:

- filter efficiency (% of filter feed) is 92.5%;

- maximum TDS concentration and sediment concentration of 10,000 mg/L and 800 mg/L respectively; and
- backwash water containing sediment is sent to TSF.

The RO plant model parameters include:

- 93 kL/h of raw water is required for the RO plant (feed) to generate 50 kL/h and 5 kL/h of RO water for processing plant and camp respectively;
- RO plant efficiency is 59% freshwater with the remaining 41 % of the feed water to be rejected as brine to TSF, and then evaporated off in the Evaporation Pond;
- TDS concentration of treated RO water output is 500 mg/L to comply with the Australian Drinking Water Guidelines (NH&MRC, 2000). TDS concentration of the brine is calculated by the water balance model; and
- RO water will be used for construction stage of the Proposed Development as well as for personnel/camp consumption and reagent mixing within the ore processing plant.

Potable water demands from the RO Plant over 22 years LoM are shown in **Chart 2-6** and are discussed further in **Section 2.5.1**.

2.4 Supply Components

Water supply for the Proposed Development is obtained from the following sources:

- groundwater dewatering/abstraction;
- brackish and saline wellfields;
- pit dewatering; and
- stormwater runoff.

Each of the sources is described below.

2.4.1 Groundwater Dewatering/Abstraction

The predicted groundwater dewatering/abstraction rates to RWP2 for the operational phase of the Proposed Development depend on the assumed groundwater recharge rates. The groundwater dewatering rates and average TDS concentrations adopted in the WBM as provided by Cameco on 16 March 2015 (Yeelirrie-water demand – supply (revised March 16 2015).xlsx, Water balance (March 24 2015).xlsx and Yeelirrie groundwater quality memo (June 4 2014).pdf) in shown in **Chart 2-4** below.

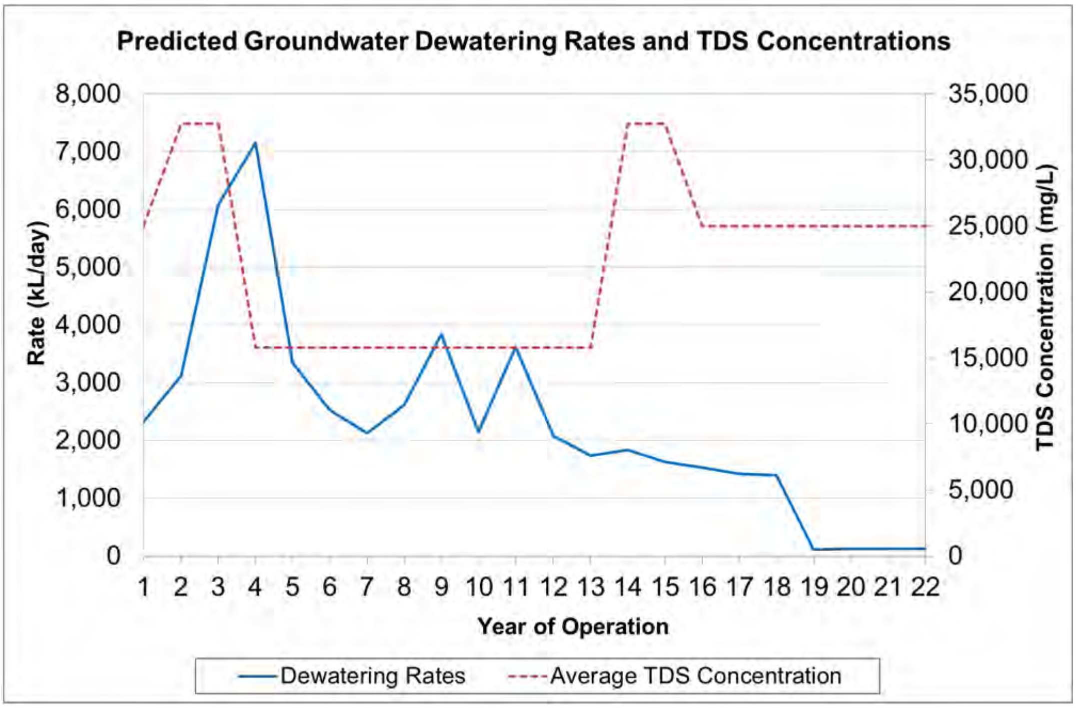


Chart 2-4 Groundwater Dewatering Rates and TDS Concentrations

The data suggest that higher groundwater dewatering rates is expected during the first five years of the mine life, peaking at 2,611,864 kL per annum in Year 4. Between Year 6 to Year 18 the average annual dewatering rate is about 801,000 kL per annum and the volume reduces to around 43,400 kL per annum during the closure period.

2.4.2 Brackish and Saline Wellfields

Groundwater supplies will be available from three brackish wellfields (northern, eastern and western) located along the Yeelirrie valley flanks and saline wellfields located along the floor of the Yeelirrie valley in superficial and palaeochannel aquifers (URS, 2011b). The brackish and saline water characteristic are as follows:

- brackish wellfields (or groundwater abstracted from the alluvium) have an average TDS and sediment concentration of 2,267 mg/L and 150 mg/L respectively; and
- saline wellfields have an average TDS and sediment concentration of 37,947 mg/L and 150 mg/L respectively.

The brackish wellfields will supply water to RWP1, which will feed the RO Plant. The saline wellfield will supply RWP2, which supplies the water for ore processing and other saline demands. The supply capacities is simulated by the GoldSim WBM based on RWP1 and RWP2 storage volume, RO plant, processing plant and other miscellaneous water demands. One of the key objectives is to ensure that RWP1 and RWP2 are maintained at 100% and 80% full at all time (i.e. transfers from the wellfields stop when RWP1 is 100% and RWP2 is 80% full).

The result is discussed in **Section 3**.

2.4.3 *Pit Floor Dewatering*

Pit floor dewatering is largely rainfall runoff captured in a series of dewatering trenches within the pit after a rainfall event and then abstracted by pumps to RWP2. The dewatering rates will be dependent on the size of the active mining area, which will vary over the life of the mine. The mining schedule as per the Cameco PER Section 9.4 Proposed Development Description has been adopted and the active mining area per year is outlined in **Chart 2-5**.

It is assumed that sediment contained within the dewatering discharge will be removed by settlement before it is pumped to RWP2.

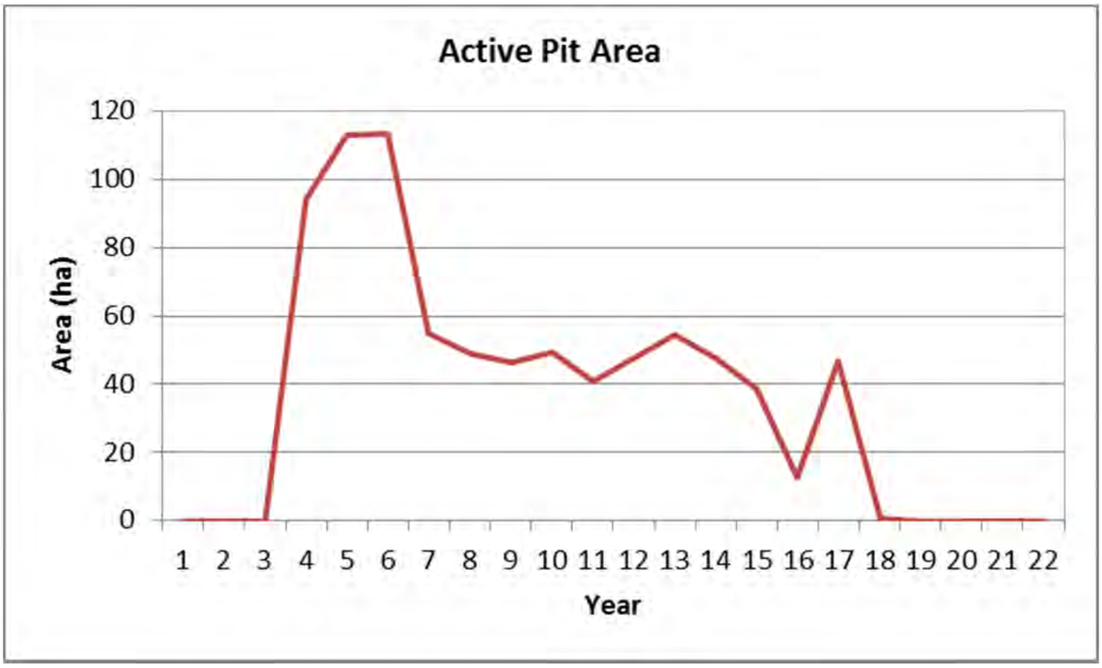


Chart 2-5 Active Open Pit Areas per Year

For the purpose of the water balance it is assumed that rainfall runoff into the inactive pits is not captured by the pit floor dewatering system, and therefore excluded as a water source. This represents a reasonably conservative approach to water availability.

The TDS concentration of pit floor water depends on the intensity and duration of the rainfall event causing pit floor runoff. The assumed values for TDS concentration for the pit floor and other mine site land-use categories are shown in **Table 2-4** (**Section 2.4.3**).

For the purpose of the WBM, the following initial conditions and operating rules were adopted:

- Initial volume: 0 m^3
- Initial TDS concentration: 0 mg/L
- Initial sediment concentration: 0 mg/L
- Pump transfer capacity (to RWP2): 66 l/s (excluding groundwater dewatering/abstraction rates to RWP2)
- Minimum volume to initiate transfer to RWP2: 5,800 m^3 (stops when volume reduces to 110 m^3)

2.4.4 Stormwater Runoff

Stormwater runoff from the mine site will be collected in seven stormwater ponds located at the natural low points within each of the sub-catchments within the mine site. However, these stormwater turnoff ponds have not been represented in the GoldSim model for the reasons discussed below.

Runoff Volume

The runoff volume and quality has been assessed during the surface water study (URS, 2011a). It is based on four main land uses within the mine site that relate to the water balance study:

- Natural undisturbed areas;
- Hardstand areas (including the process plant area and the haul roads);
- Calcrete stockpiles (including very high grade, high grade and medium grade ore stockpiles);
- Clayey stockpiles (including low grade ore, waste material, top soil and bund areas); and
- Pit floor.

Stormwater Ponds

The conceptual design of the stormwater pond capacities for each of the mine site sub-catchments depends on the design rainfall event to be captured before (hypothetical) discharge of excess water occurs. The estimated stormwater pond capacities for the mine site sub-catchments to contain water associated with 1:5, 1:20, 1:100 and 1:1,000 year ARI rainfall events are shown in **Table 2-3**.

Table 2-3 Estimated Stormwater pond Capacities for Mine Site Sub-catchments

Minesite Sub-catchment	Total Stormwater Pond Capacity (m^3) Design Rainfall Event		
	20(year ARI)	100 (year ARI)	1,000 (year ARI)
Stage 1	850,000 (28 ha)	1,830,000 (61 ha)	2,830,000 (94 ha)
Stage 2	1,165,000 (39 ha)	2,500,000 (83 ha)	3,870,000 (129 ha)

Runoff Quality

The water quality characteristics of stormwater runoff from natural undisturbed ground, hardstand areas, stockpiles and pit floor areas used in the water balance model vary depending on the intensity and duration of the rainfall event causing the runoff.

- shorter duration, higher intensity rainfall events are expected to dissolve more salts in a relatively smaller runoff volume that will result in higher TDS concentrations; and
- longer duration, lower intensity rainfall events are expected to dissolve a similar load of salts in a larger volume of runoff. The dilution will result in lower TDS concentrations.

The stormwater runoff quality has been simulated using predicted runoff volumes and solute source terms for a range of storm events (SRK, 2011). The simulated TDS concentrations for the main mine site land-use categories are shown in **Table 2-4**.

Table 2-4 Estimated TDS Concentrations for Mine Site Land-use Categories

Mine site Landuse Component	Rainfall Events					
	5 year ARI			20 year ARI		
	Rainfall Duration					
	1 hr	6 hrs	48 hrs	1 hr	6 hrs	48 hrs
	TDS Concentration (mg/L)					
Natural	65	65	65	65	65	65
Hardstand	94,900	52,100	27,100	68,900	34,000	17,200
Calcrete Stockpiles	82,100	44,200	23,100	58,800	29,400	14,800
Clayey Stockpiles	95,200	51,300	26,800	68,200	34,100	17,500
Pit Floor	78,200	34,900	18,200	62,400	29,750	12,800

Table 2-4 shows that:

- short duration rainfall is predicted to result in runoff with relatively high TDS concentrations (greater than 35,000 mg/L);
- longer duration rainfall is predicted to result in runoff with relatively lower TDS concentrations. (less than 35,000 mg/L);
- RWP2 is expected to have a maximum TDS concentration of 35,000 mg/L for only the longer (duration greater than 48 hrs) rainfall events, and will yield stormwater runoff suitable for use in the mine process. Runoff from short duration rainfall events is predicted not to be suitable in the mine process; and
- the water quality in the mine site stormwater ponds for different rainfall events was simulated by blending the runoff from the different land-use categories for each mine site catchment. The predictive results of this analysis are shown in **Table 2-5**.

Table 2-5 Simulated TDS concentrations in Mine Site Stormwater Ponds

URS

Mine Site Sub-catchment	Rainfall Events					
	5 year ARI			20 year ARI		
	Rainfall Duration					
	1 hr	6 hrs	48 hrs	1 hr	6 hrs	48 hrs
	TDS Concentration (mg/L)					
a	30,800	16,800	3,150	22,700	11,600	6,200
b	23,600	13,400	2,700	17,200	9,000	5,400
c	41,300	24,400	5,700	29,600	15,400	9,200
d	37,200	22,300	5,200	26,500	13,800	8,500
e	9,800	5,700	1,050	7,120	3,700	2,200
f	28,600	17,350	4,050	20,300	10,600	6,600
g	43,100	25,600	7,000	30,600	15,800	9,400
Pit	78,200	34,900	18,200	62,400	29,750	12,800

Table 2-5 confirms that, after blending runoff from the mine site, the runoff from the short duration events are less likely to be suitable for use as raw water sources than stormwater runoff from longer duration events.

The efficiency of use of stormwater to supplement the raw water supply is further constrained by evapo-concentration in the stormwater ponds. Evaporation from the stormwater ponds will increase the TDS concentration in the pond and render it increasingly less suitable for use on the mine site, other than for dust suppression.

Based on this assessment, it was assumed that use of stormwater to supplement the raw water supply is not feasible; hence it has been excluded in the WBM.

2.5 Water Storage and Distribution Components

The two major storage ponds (RWP1 and RWP2), TSF and Evaporation Pond represent conceptual storage facilities required for the development of the numerical water balance model. The capacity of actual ponds will be further defined in future feasibility studies.

2.5.1 Raw Water Pond 1 (RWP1)

RWP1 will collect the water supply from the brackish wellfields and provide a four-day operational buffer capacity to the RO plant. The pond will supply water via a filter to the RO plant to meet the potable water demands of the Proposed Development. The total demand to be supplied from RWP1 over the 22 year period, excluding any transfer to RWP2, is shown in **Chart 2-6**. The storage capacity for RWP1 is assumed at 10,000 kL. This represents in the order of for four days of operational demand, which is a reasonable period in which to reinstate supply in case of failure without disrupting operations. A larger pond capacity will provide more insurance but will be subject to higher evaporation losses.

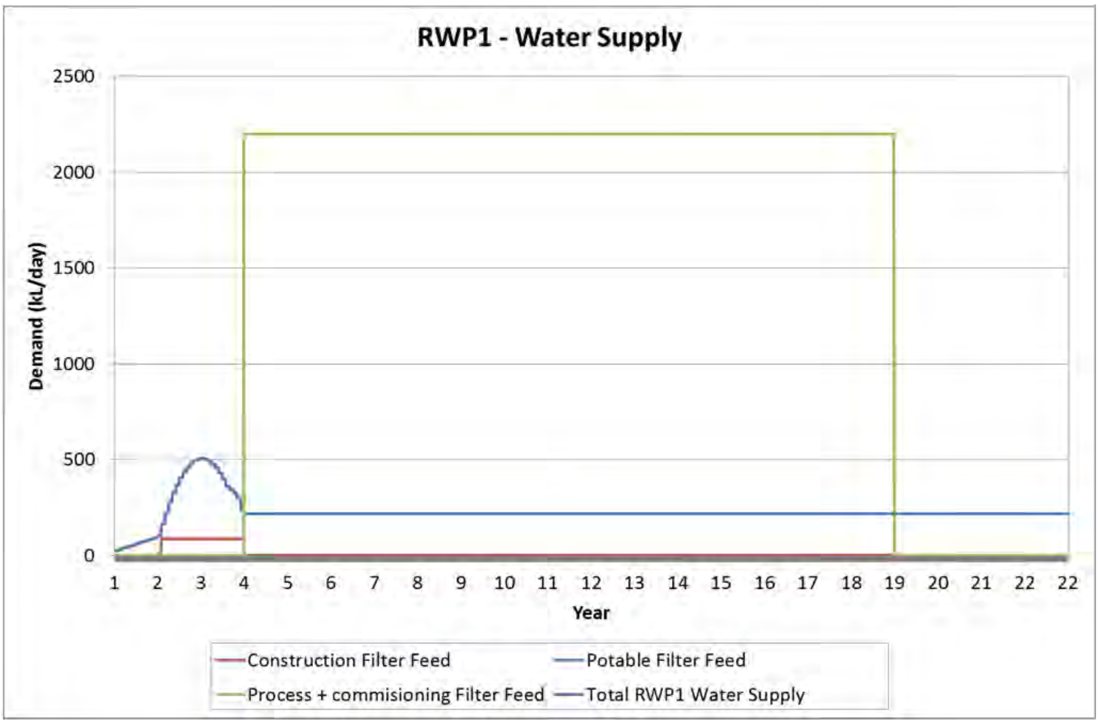


Chart 2-6 Raw Water Pond 1 - Water Supply

The efficiency of the particulate filters for the RO plant is expected to be 92.5% of the raw water feed. The remaining 7.5% consumed as backwash water to clear the filter will be discharged to the TSF.

The water quality criterion for the RO filter feed is a maximum TDS and TSS concentration of 10,000 and 800 mg/L respectively. The quality of the filter backwash is predicted to be the same as the filter removes suspended solids but not dissolved solids.

The efficiency of the RO Plant is expected to be 59% of the RO Feed. The remaining 41% will be rejected as brine and discharged to TSF (see **Section 2.5.4**).

The process driven water quality criterion for the RO Feed is a maximum TDS and TSS concentration of 10,000 and 800 mg/L respectively. The quality of the RO brine is simulated by the water balance model, The RO feed is supplied by the brackish wellfields with a TDS concentration of 2,267 mg/L (as provided by Cameco in the Water balance (March 24 2015).xlsx spreadsheet). The RO brine is expected to have a TDS concentration of less than 5,000 mg/L.

In addition to aforementioned criteria, the following are the initial conditions and operating rules were adopted in the WBM:

- assumed pond depth is 2 m;
- initial storage volume is 5,000 kL (50% of capacity)
- initial TDS concentration is assumed to be 2,200 mg/L.
- initial sediment concentration is assumed to be 150 mg/L.
- minimum volume below which the transfer to RWP2 is stopped is assumed at 3,500 kL;
- maximum transfer rate from RWP1 to RWP2 is assumed at 1,700 kL/day.

2.5.2 *Raw Water Pond 2 (RWP2)*

RWP2 will collect the saline water supply from pit, groundwater dewatering and the saline. RWP2 will supply water for the following demands:

- ore processing make-up water;
- dust suppression;
- vehicle washdown; and
- construction (during the initial stage of the Proposed Development).

To provide for four-day operational storage, RWP2 will need to have a minimum capacity of 25,000 kL. The total demand to be supplied from RWP2 over the 22 year period of operation is shown in **Chart 2-7**.

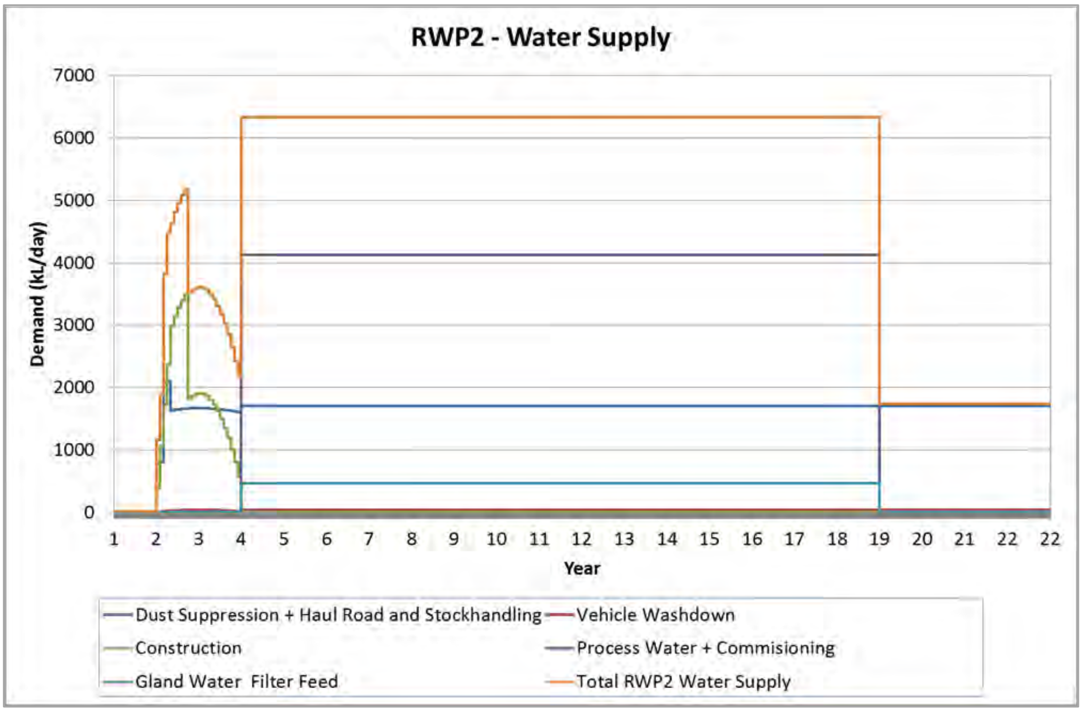


Chart 2-7 Raw Water Pond 2 - Water Supply

The supply for the gland seals from RWP2 will be passed through a separate particle filter before it is used by ore processing machinery in the plant. The efficiency of the particulate filter is expected to be 92.5% of the raw water feed. The remaining 7.5% consumed as backwash water to clear the filter will be discharged to the TSF.

The water quality criterion for the RO filter feed is a maximum TDS and TSS concentration of 40,000 and 800 mg/L respectively. The quality of the filter backwash is predicted to be the same as the filter removes suspended solids but not dissolved solids.

In addition to aforementioned criteria, the following are the initial conditions and operating rules were adopted in the WBM:

- assumed pond depth is 3 m;
- initial storage volume is 12,500 kL (50% of capacity);

- initial TDS concentration is assumed to be 20,000 mg/L;
- initial sediment concentration is assumed to be 150 mg/L;
- maximum volume above which the transfer to RWP1 is stopped is assumed at 22,500 kL;
- maximum transfer rate from RWP1 to RWP2 is assumed at 1,700 kL/day; and
- the overflow volume is reinjected into the groundwater.

2.5.3 RWP1 to RWP2 Transfer

In the event that the total supply to RWP2 cannot meet the objective of maintaining the storage volume at 80% full, the supply will be supplemented by drawing water from RWP1, which is supplied by the brackish wellfields. The rate and total volume of brackish wellfield water to be supplied over the operational life of the mine is simulated by the GoldSim WBM (refer to **Section 3** of this report).

2.5.4 Tailings Storage Facility (TSF) Decant

The TSF receives water from the following sources:

- processing plant;
- filters backwash; and
- brine rejects from RO Plant.

The TDS concentration of the tailings exiting the processing plant is assumed at 106,546 mg/L (email from Cameco dated 31 march 2015). With addition of backwash water from filters and brine from RO plant, the TDS concentration in the TSF is expected to reach 350,900 mg/L (04A 11317-Mass Balance SPS Addendum RevE with Reagents.xlsx). Due to the high salinity, Cameco advised that only 10% (853 kL/day) of the water entering the TSF can be recycled and reused in the processing plant. The remaining water is send to Evaporation Pond to be evaporated off as part of the brine management strategy.

The following are the initial conditions and operating rules adopted for the TSF in the WBM:

- TSF surface area is 154.5 ha, however, 20% (maximum) of the area (30.9 ha) is use as Decant Pond;
- the TSF is assumed to be the shape of an inverted cone with 1% beach slope;
- the decant pond operating volume is 321,348 kL (~3.1 m depth of water);
- initial volume is 0 kL;
- initial TDS concentration is 0 mg/L;
- initial sediment concentration is 0 mg/L;
- decant return to the processing plant is calculated as 10% of the daily inflows to the TSF;
- as recommended by Cameco, runoff on the beach occurs only when the total rainfall depth in 7 consecutive days is greater than 25 mm; with runoff coefficient of 0.7;
- as recommended by Cameco, evaporation rate from the TSF beach is assumed at 1.6 mm/day;

- minimum volume below which the transfer from TSF to Evaporation Pond is stopped is assumed at 321,348 kL (~3.1 m depth of water); and
- transfer rate from TSF to Evaporation Pond is simulated by the GoldSim WBM, however, the maximum rate is capped at 1,000 l/s.

2.5.5 Evaporation Pond

As aforementioned in Section **2.5.4**, only 10%of the water entering the can be recycled/reused in the Processing Plant due to high salinity. The remaining water in the TSF is transferred to the Evaporation Pond to be evaporated off as part of the brine/saline water management strategy. For the purpose of the WBM, it is assumed that the brine will be stored in a single solar evaporation pond and to the salinity is maintained below 200 g/L.

The WBM is used to model the size of evaporation required to store and manage the brine/saline water assuming no discharge to the environment.

The following are parameters adopted to size the Evaporation Pond:

- no constrained on area available to construct the Evaporation Pond;
- no overflows to the environment;
- transfer rates from the TSF to Evaporation Pond is capped at 1,000 l/s;
- TSF to maintain storage volume of 321,348 kL (~3.1 m depth of water);;
- assumed pond depth is 3 m; and
- the pond surface area is allowed to dynamically change throughout simulation (by fixing the pond depth at 3 m);

It is noted that single solar evaporation is considered as one of the most uneconomical method for brine management involving large volume of saline water with high salinity. The accumulation of salt in the pond increases the salinity hence reduced the evaporation rate. A more advanced brine management system e.g. combination of evaporation and crystallisation ponds and removal of precipitated salt to a separate repository would reduce the footprint; however, this is not part of the current scope of works and the assessment conducted herein is considered as appropriate.

2.6 Summary of Model Parameterisation

A summary of the model parameters and values adopted for water quantity and quality criteria in the WBM is given in **Table 2-6** through **Table 2-10** and then discussed thereafter.

- **Table 2-6** presents the model parameters for the water demand components;
- **Table 2-7** presents the model parameters for the water sources;
- **Table 2-8** presents the model parameters for the water supply and treatment components;
- **Table 2-9** presents the water quality input data that were adopted from the ERMP Proposed Development Description, Cameco, or assumed by URS.

- **Table 2-10** presents the water quality input data that were calculated from the results of the concurrent surface water and groundwater studies (URS, 2011a and 2011b), and recommended by Cameco.

Note that values in black have been defined, verified and/or derived from BHP Billiton (2011) and/or Cameco data or assumed by URS from comparable studies. Values in blue were assigned in the model.

Table 2-6 Water Balance Model Parameters - Demands

Component	Element	Type	Value	Unit
Processing Plant	Total Raw Water	Time Series	variable	kL/day
	Filtered Gland Water	Time Series	variable	kL/day
	Potable (RO) Water	Time Series	variable	kL/day
Miscellaneous Raw Water	Dust Suppression	Time Series	variable	kL/day
	Vehicle Washdown	Time Series	variable	kL/day
	Construction Raw Water	Time Series	variable	kL/day
Miscellaneous Potable	Construction	Time Series	variable	kL/day
	Personnel/Camp	Time Series	variable	kL/day

Table 2-7 Water Balance Model Parameters - Sources

Component	Element	Type	Value	Unit
Climate	Daily Rainfall	Time series	variable	mm/day
	Daily Evaporation	Time series	variable	mm/day
	Pan Evaporation Factor	Data	0.7	
Groundwater Dewatering	Daily dewatering rate	Time series	variable	kL/day
Pit Floor Dewatering	Active Pit Area	Time series	variable	m^2
	Pump Capacity Pit	Data	66	l/s
	Pit Storage: Pump ON	Data	5,800	m^3
	Pit Storage: Pump OFF	Data	110	m^3
	Pit Storage: Initial Volume	Data	0	m^3

Table 2-8 Water Balance Model Parameters - Water Supply and Treatment

Component	Element	Type	Value	Unit
RWP1	Capacity	Data	10,000	m^3
	Pond Depth	Data	2	m
	Initial Volume	Data	5,000	m^3
	Transfer to RWP2 Capacity	Data	1,700	kL/day
	Transfer to RWP2 ON Capacity	Data	3,500	m^3
	Transfer to RWP2 OFF Capacity	Data	3,000	m^3
RWP2	Capacity	Data	25,000	m^3
	Pond Depth	Data	3	m

Component	Element	Type	Value	Unit
	Initial Volume	Data	12,500	m^3
	Transfer from RWP1 ON Capacity	Data	80	%
	Transfer from RWP1 OFF Capacity	Data	90	%
Filtering Process	Filtering Efficiency	Data	92.5	%
RO Plant	Filtrate Efficiency	Data	59	%
TSF	Decant Pond Capacity	Data	321,348	m^3
	Decant Pond Operating Capacity	Data	321,348	m^3
	Initial Volume	Data	0	m^3
	Transfer to Evaporation Pond ON	Data	321,348	m^3
Evaporation Pond	Depth	Data	3	m

Table 2-9 Defined Water Balance Water Quality Constraints

Description		TDS Criteria (mg/L)	TSS Criteria (mg/L)
Process Plant	Process Raw Water	Max 40,000	Max 1,000
Miscellaneous Mine Site	Dust Suppression	Max 100,000	Max 1,500
	Construction	Max 40,000	Max 1,000
	Vehicle Washdown	Max 40,000	Max 1,000
RO Plant	RO Feed	Max 10,000	Max 800
	RO Filtrate	Max 500	0
Personnel/Camp	Water supply	Max 500	0

Table 2-10 Adopted water Quality Constraints from Concurrent Yeelirrie Water Studies

Description		Likely TDS Concentration (mg/L)	Likely TSS Concentration (mg/L)
Wellfield Supply	Brackish Wellfields	2,267	-
	Saline Wellfields	37,947	-
Groundwater Dewatering	Groundwater Dewatering	22,220	-
Minesite Runoff	Natural Runoff	65	553
	Hardstand Runoff	27,000	400

	Calcrete Stockpile Runoff	22,400	500
	Clayey Stockpile Runoff	26,800	500
Pit Floor Dewatering	Pit Floor Runoff	18,200	500
	Initial Pit water	0	0
Raw Water Ponds	RWP1 Initial	2,200	150
	RWP2 Initial	20,000	150
RO Plant	RO Plant Filtrate	500	0
Processing Plant	Tailings	106,546	-

3 WATER BALANCE MODELLING RESULTS

This section presents the results of the Monte Carlo water balance numerical modelling to validate the Project WMS described in **Section 2**.

Results are presented as percentile distributions e.g. represent the volume of water in the storages for a range of possible historical climate conditions at each model timestep (i.e. day). It should be noted that results presented under each percentile result may not occur within a single realisation and are a function of the total distribution of all results from the modelling realisations (114 in total). The plots may be read as follows:

- the lightest red areas represent the range of values between:
  - the maximum and 95th percentile result; and
  - the minimum and 5th percentile result.
- the 2nd lightest red area represents the range of values between:
  - the 95th and 90th percentile result; and
  - the 5th and 10th percentile result.
- the next darkest red area represents the range of values between:
  - the 90th and 75th percentile result; and
  - the 10th and 25th percentile result.
- the darkest red area represents the range of values between:
  - the 25th and 75th percentile results.
- The solid black line represents the median result and the dashed red the mean result.

3.1 Modelling Results

The WBM was used to simulate the operation of the mine under 114 sets of climate conditions (based on 114 years of historical climate data), without the inclusion of stormwater pond recovery (considered to be a reasonable case in the absence of rainfall inputs into the water balance).

The results outlined below indicate that the proposed infrastructure was able to meet the containment objective presented in **Section 2**.

3.1.1 Brackish Wellfields Supply Rates to RWP1

Chart 3-1 shows the simulated transfer rates from the brackish wellfields to RWP1 to meet the objectives and assumed operating rules specified in **Section 2.4.2** and **2.5.1**.

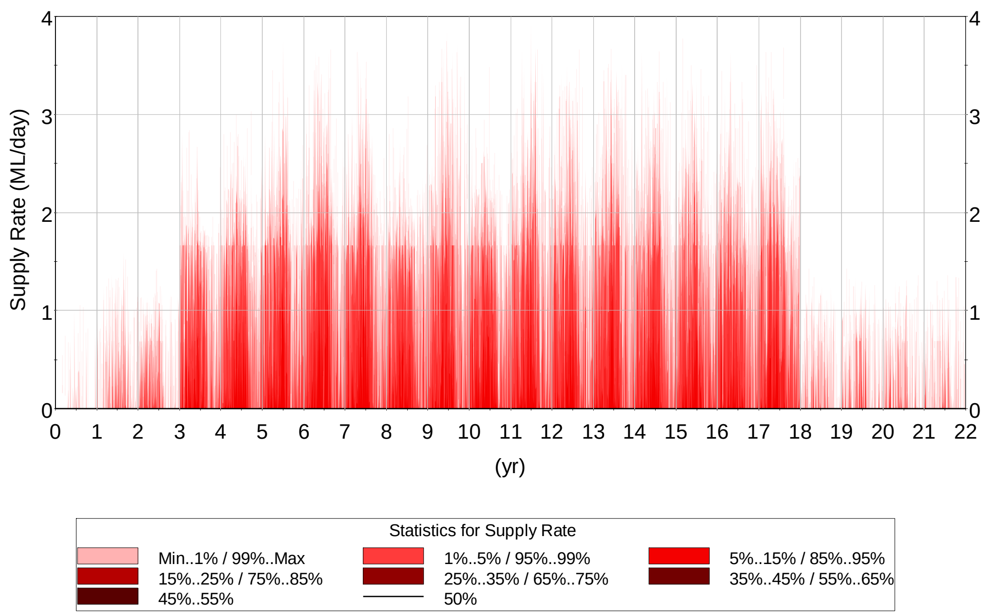


Chart 3-1 Brackish Wellfields Transfer Rates to RWP1

The model estimates that 1 to 3.9 ML/day (when supply is required) of brackish water is required to meet the potable water demand and maintain RWP1 at almost 100% full. During the mining period (Year 4 to 18), the brackish water demand is expected to be between 980 – 1,110 ML annually; and 16,860 – 16,920 ML throughout the LoM.

3.1.2 Saline Wellfields Supply Rates to RWP2

Chart 3-2 shows the simulated transfer rates from the saline wellfields to RWP2 to meet the objectives and assumed operating rules specified in **Section 2.4.2** and **2.5.2**.

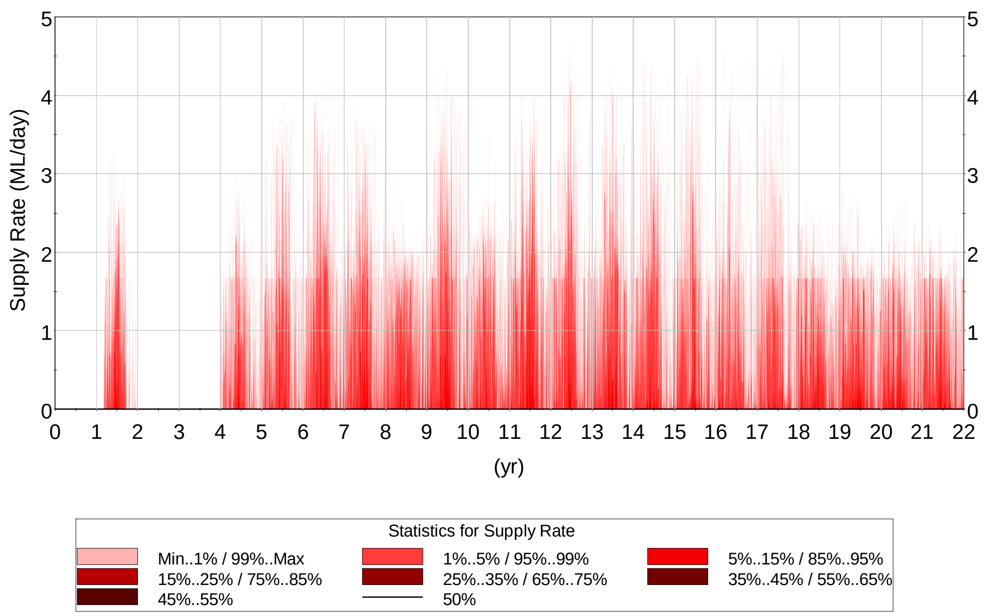


Chart 3-2 Saline Wellfields Transfer Rates to RWP2

The model estimates that 1.7 to 4.8 ML/day (when supply is required) of saline water is required to meet the saline water demand and to maintain RWP2 at almost 80% full. During the mining period (Year 4 to 18), the saline water demand is expected to be between 510 – 1,280 ML annually; and 16,100 – 16,480 ML throughout the LoM.

3.1.3 Pit Floor Dewatering

Chart 3-3 to **Chart 3-6** shows the open pit storage volume, TDS concentration and pit floor dewatering rate to RWP2 to meet the objectives and assumed operating rules specified in **Section 2.4.3**.

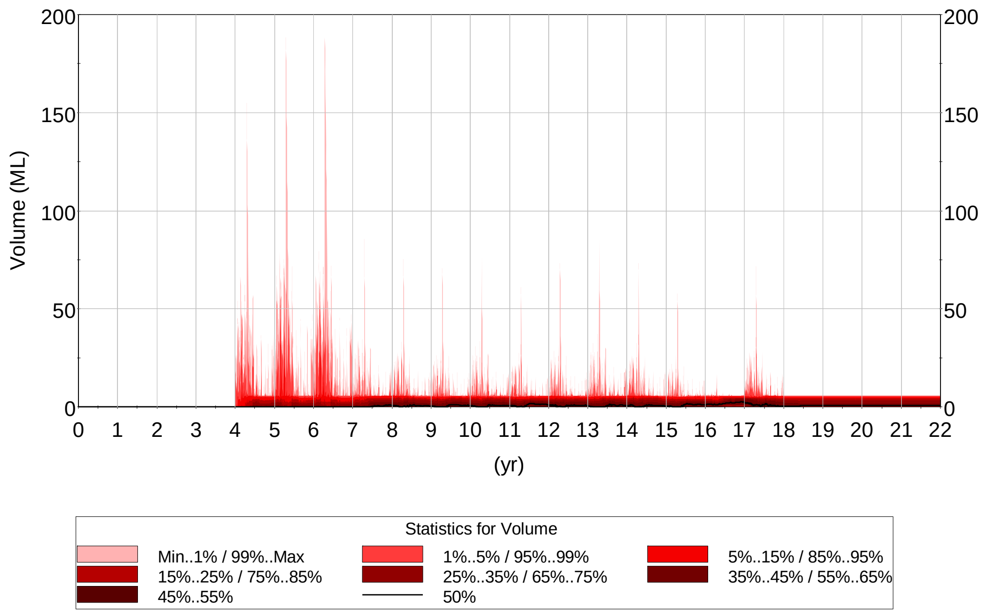


Chart 3-3 Open Pit – Storage Plot

On average, the volume of water accumulate in the pit floor is around 2 ML, with TDS concentration of ~40,000 mg/L.

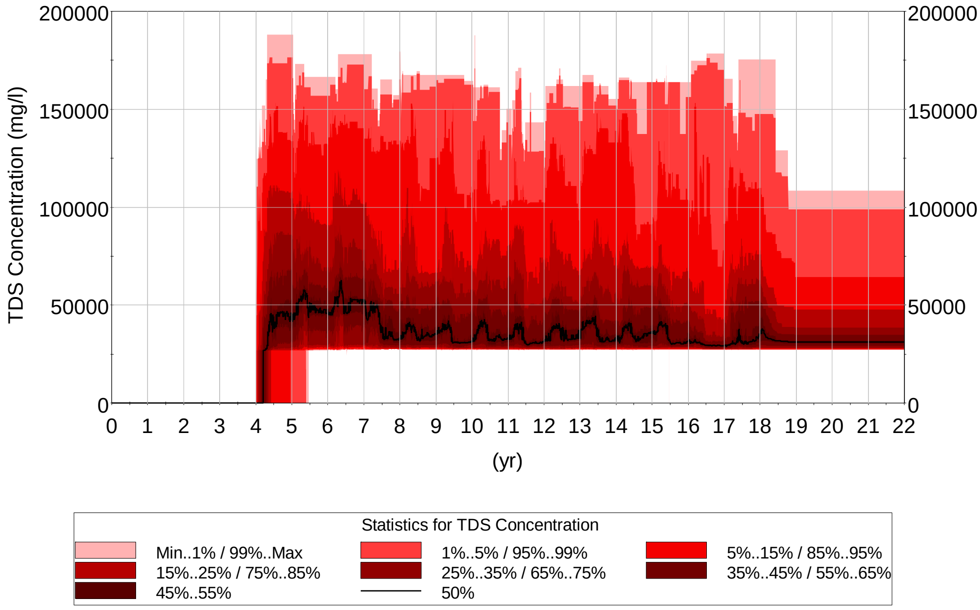


Chart 3-4 **Open Pit Water Quality – TDS**

Chart 3-5 and **Chart 3-6** shows the dewatering rates from the Open Pit to RWP2 during the mining period (Year 4 to 18). The model estimates that throughout that period, 175 to 830 ML of water is transferred from the Open Pit to RWP2; with annual average dewatering rate of 55 ML.

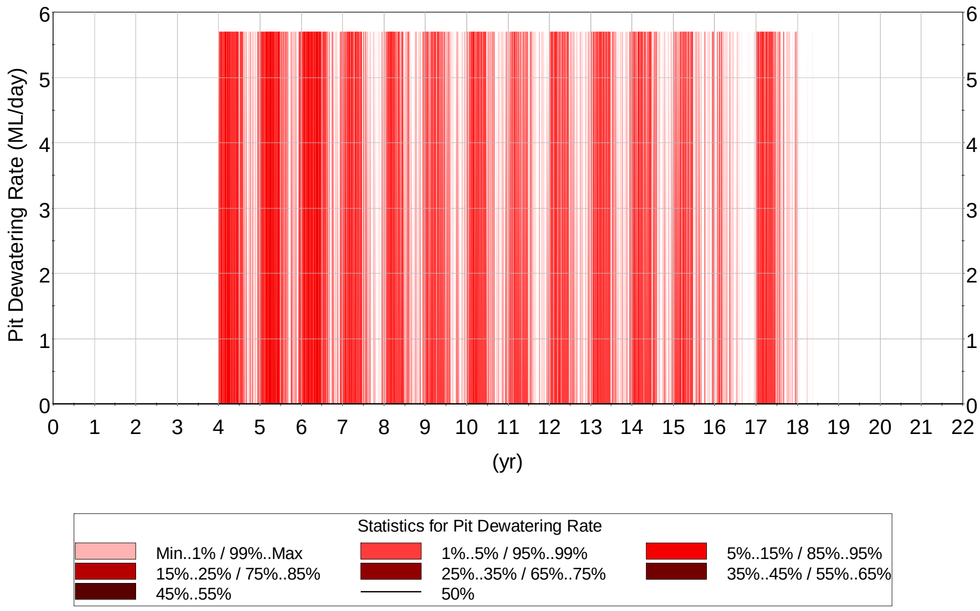


Chart 3-5 **Pit Floor Dewatering to RWP2**

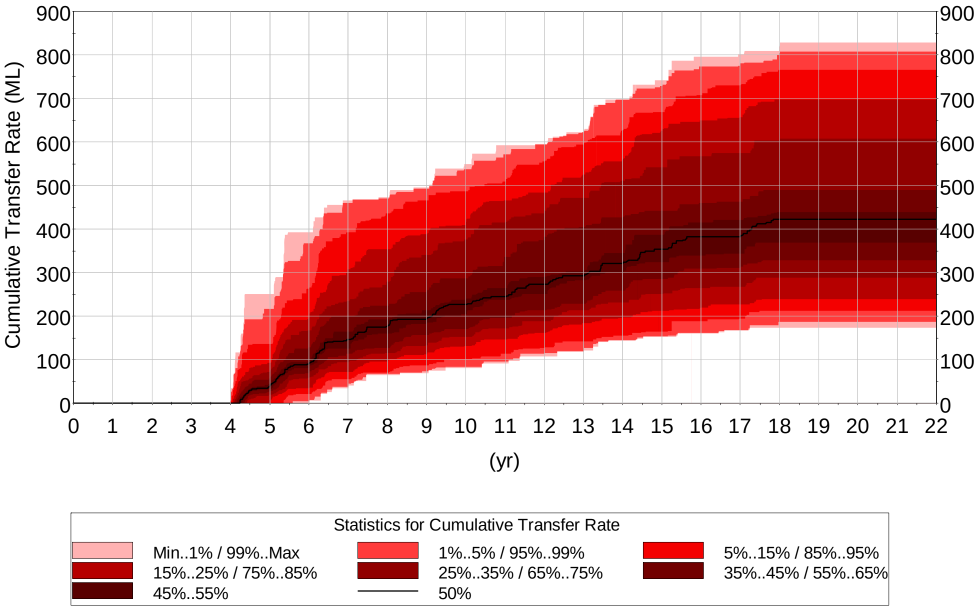


Chart 3-6 **Cumulative Pit Floor Dewatering to RWP2**

3.1.4 RWP1

The RWP1 storage volume throughout the LoM is presented in **Chart 3-7** below. The result indicated that the minimum storage volume is ~6.5 ML with average storage volume during operational period maintained at around 8.2 ML.

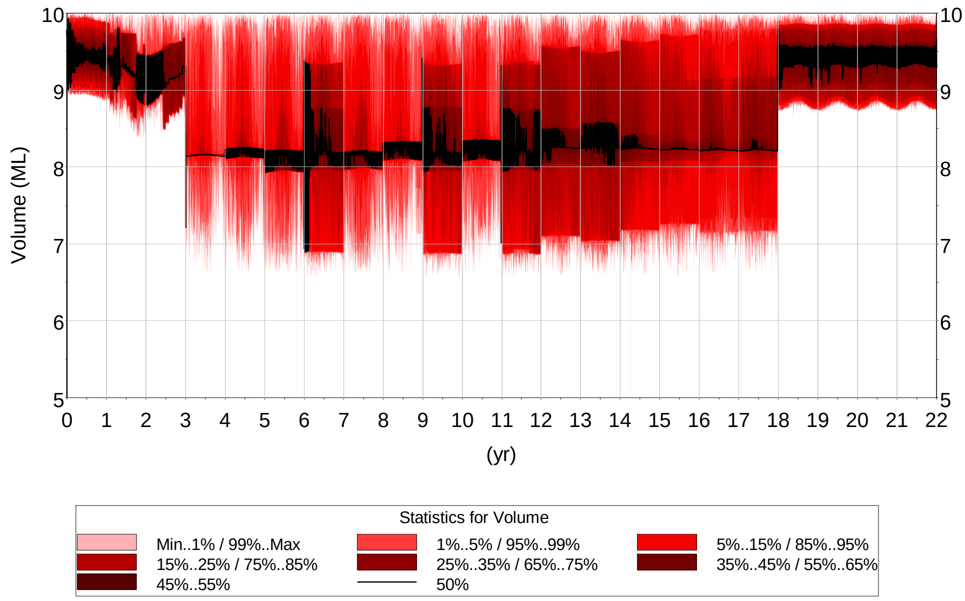


Chart 3-7 **RWP1 - Storage Plot**

RWP1 TDS concentration throughout the LoM is presented in **Chart 3-8** below. The result indicated that during the mining period, the TDS concentration in maintained at approximately 2,300 mg/L, which is well below the RO plant feed water quality criteria described in **Section 2.3.2.**

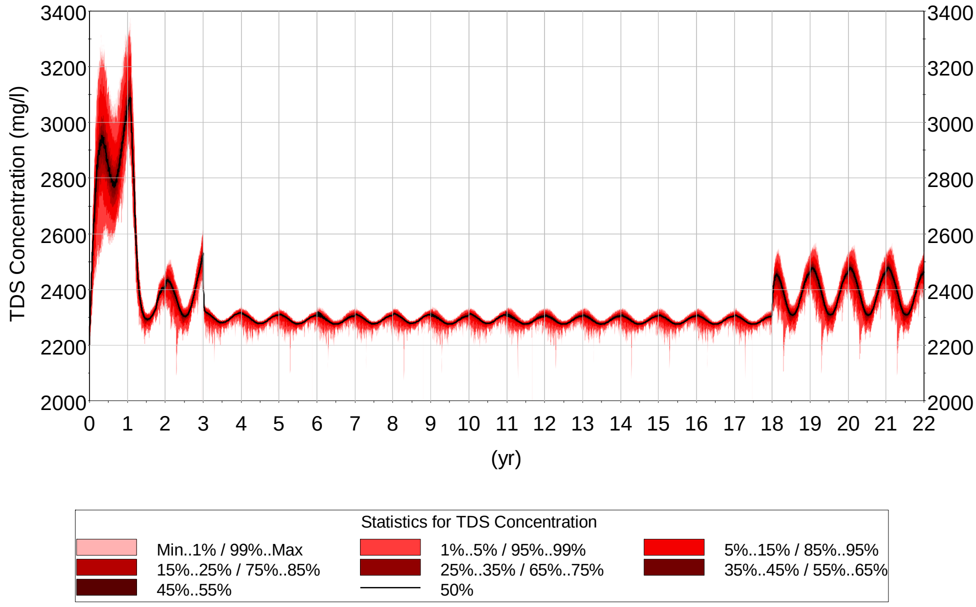


Chart 3-8 RWP1 Water Quality - TDS

3.1.4.1 RWP1 to RWP2 Transfer

Chart 3-9 shows the simulated transfer rates from RWP1 to RWP2 when supply from the saline bores, groundwater dewatering and pit floor dewatering to RWP2 cannot meet the objective of maintaining RWP2 storage volume at 80% full.

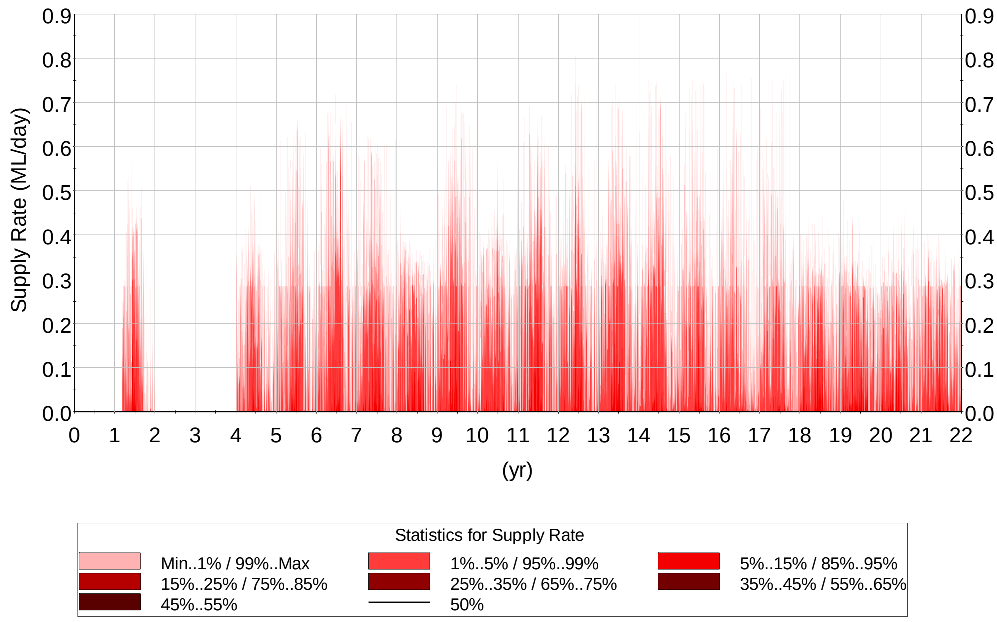
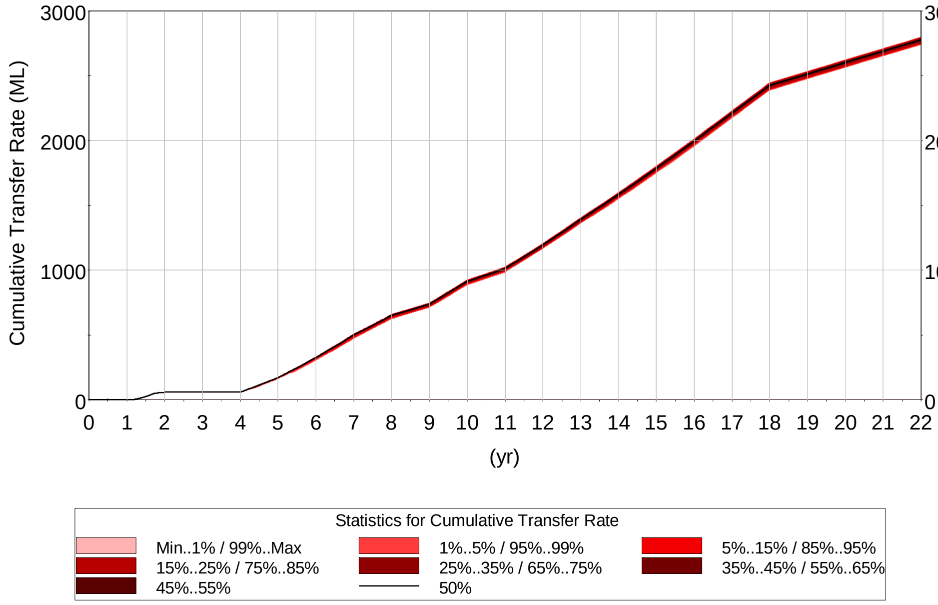


Chart 3-9 RWP1 to RWP2 Transfer Rate



The model estimates that throughout the LoM 2,740 to 2,800 ML of water is transferred from RWP1 to RWP2; with approximately 2,400 ML is transferred to RWP2 during the mining period.

3.1.5 RWP2

The RWP2 storage volume throughout the LoM is presented in **Chart 3-10** below. The result indicated that the minimum storage volume is ~16.2 ML with average storage volume during operational period maintained at around 21 ML.

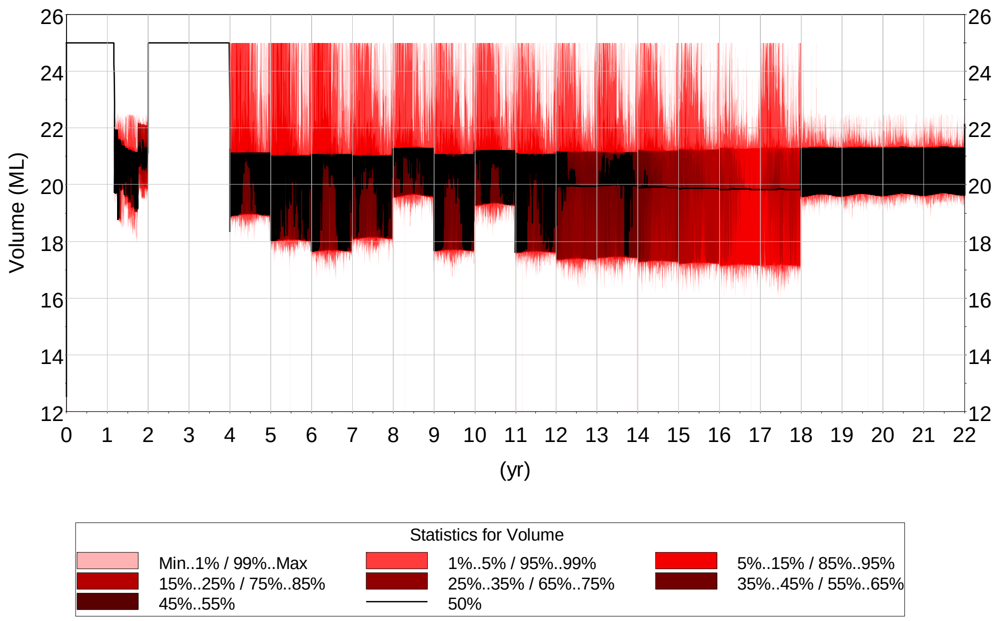


Chart 3-10 RWP2 - Storage Plot

RWP2 TDS concentration throughout the LoM is presented in **Chart 3-11** below. The result indicated that during the mining period, the TDS concentration in maintained at approximately between 20,000 and 33,000 mg/L, which are below the 40,000 mg/L processing plant water quality criteria described in **Section 2.3.1.**

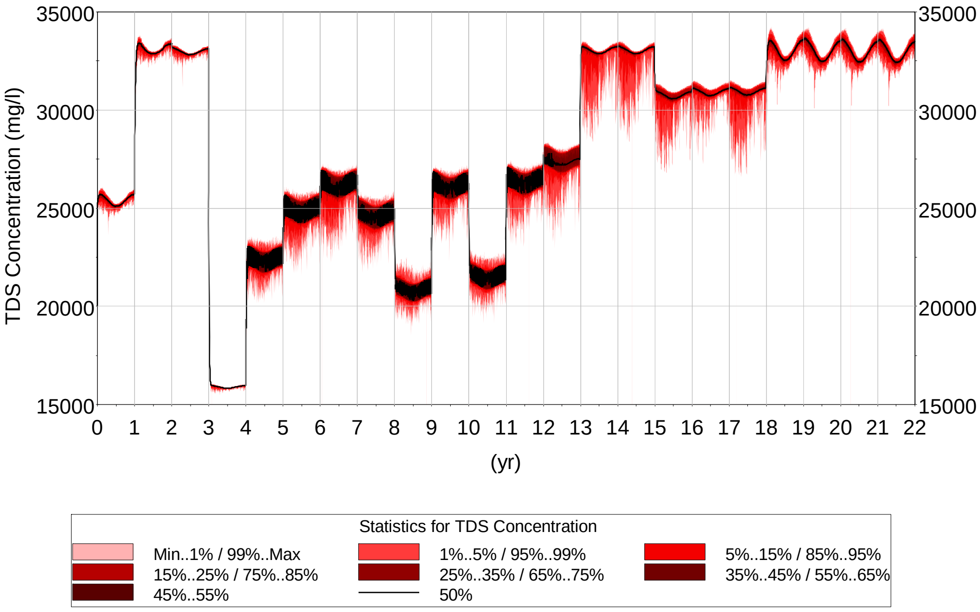


Chart 3-11 RWP2 Water Quality - TDS

3.1.5.1 Reinjection into the Groundwater

As aforementioned in **Section 2.5.2**, overflows from the RWP2 is modelled as reinjection rates into the groundwater. The estimated groundwater reinjection rates are shown in **Chart 3-12** below.

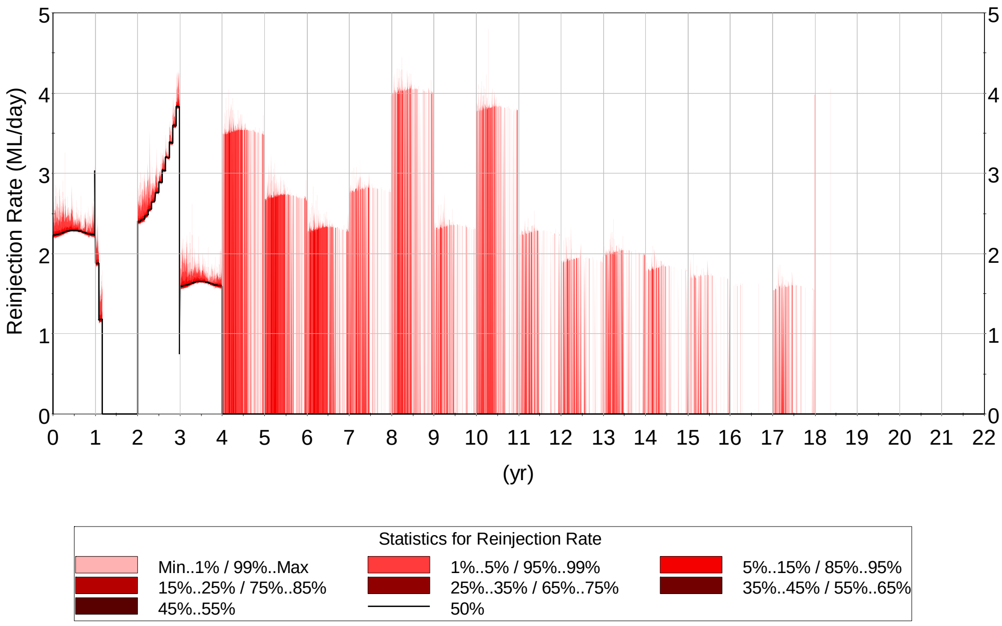


Chart 3-12 RWP2 Overflows/Reinjection Rates into the Groundwater

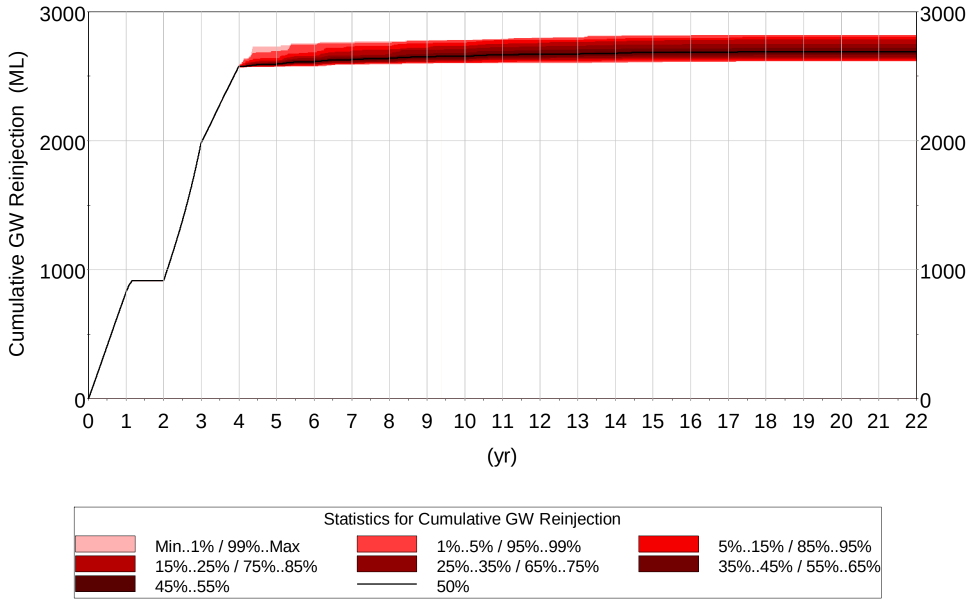


Chart 3-13 Cumulative Groundwater Reinjection Rate throughout LoM

The model estimates that throughout the LoM 2,620 – 2,820 ML of water is reinjected into the groundwater. As shown in **Chart 3-13**, the bulk of the water is reinjected during the first 4 years of mine life. Once the processing plant commences, the reinjection rates diminishes to an average of ~5 ML/year.

3.1.6 TSF

The TSF storage volume and water depth throughout the LoM is presented in **Chart 3-14** and **Chart 3-15** below. As described in **Section 2.5.4,** during the mining period, the storage volume and depth is maintained at 320 ML and 3.2 m respectively (minimum volume below which the transfer from TSF to Evaporation Pond is stopped).

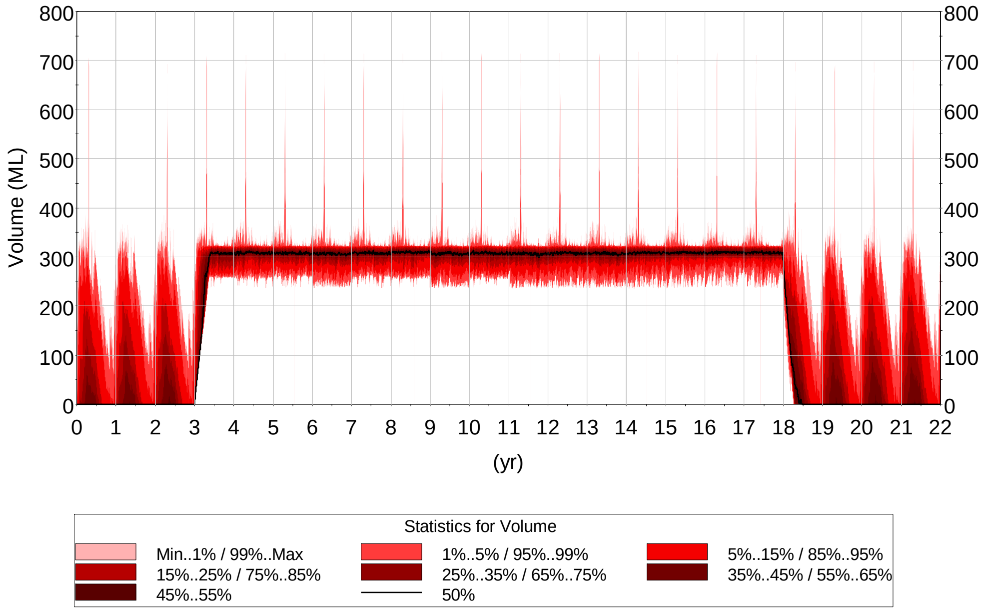


Chart 3-14 TSF - Storage Plot

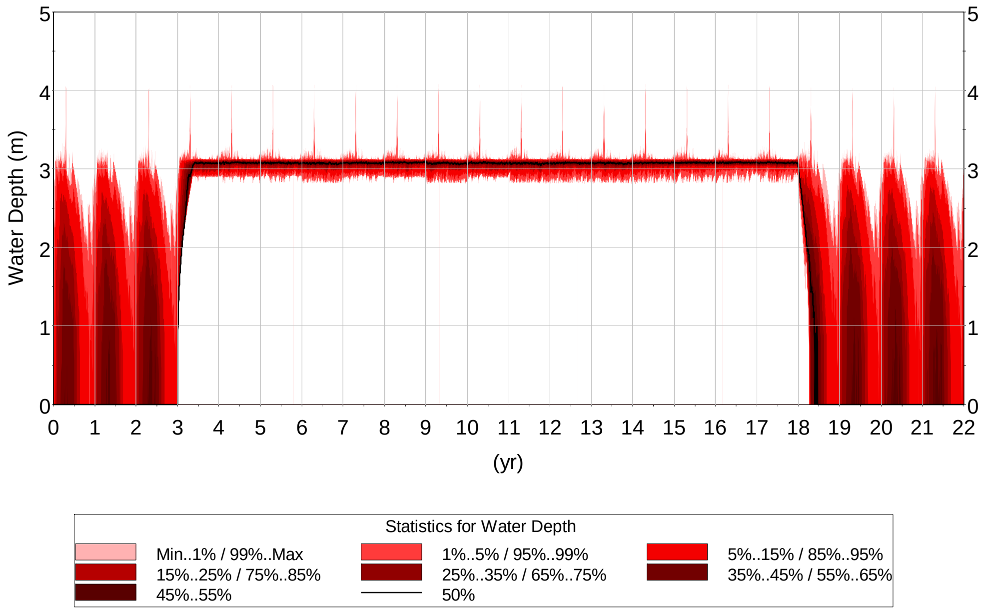


Chart 3-15 TSF - Storage Depth

TSF TDS concentration throughout the LoM is presented in **Chart 3-16** below. The result indicated that during the mining period, on average the TDS concentration in maintained at between 230,000 and 340,000 mg/L, which are within the expected concentration estimated by Cameco, as discussed in **Section 2.5.4**.

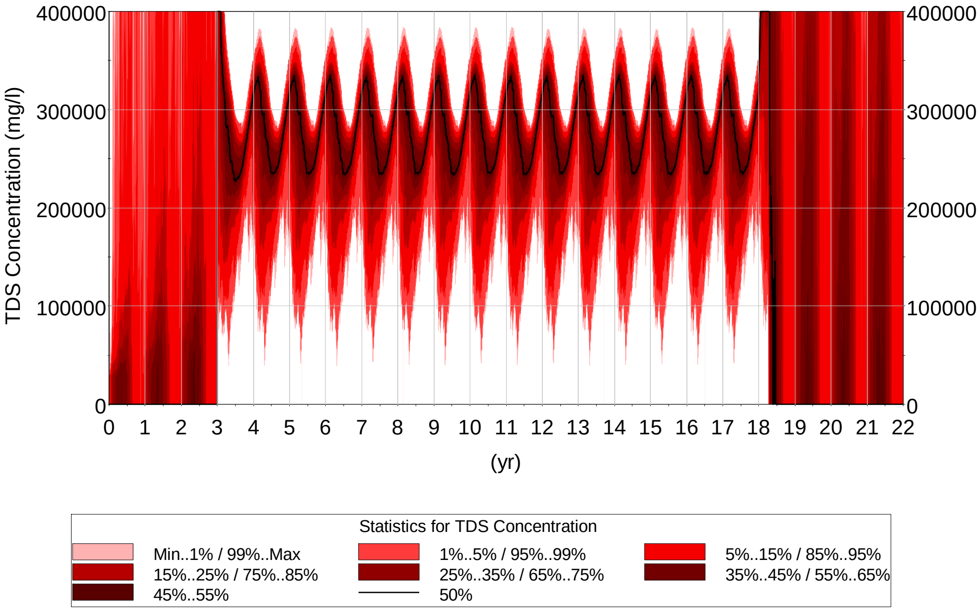


Chart 3-16 TSF Water Quality - TDS

3.1.7 Evaporation Pond

High level assessment of Evaporation Pond size required to evaporate/manage the saline water/brine was completed as part of the water balance study. As aforementioned in **Section 2.5.5**, it was assumed that the brine will be stored in a single solar evaporation pond, and the salinity is maintained below 200 g/L. Salt removal (if necessary to maintain Salinity below 200 g/L)has not been explicitly modelled, however, the salinity factor that effect the evaporation rate from the Evaporation Pond has been limited to 0.88 (refer to **Section 2.2.2**).

In assessing the Evaporation Pond's capacity and surface area required to contain the brine with zero discharge to the environment, the following three scenarios were assessed:

- inclusion of direct rainfall; no constraint on Evaporation Pond surface area, with pond depth fixed at 3 m;
- exclusion of direct rainfall; no constraint on Evaporation Pond surface area, with pond depth fixed at 3 m; and
- constrain Evaporation Pond surface area at 50 ha, with pond depth fixed at 3m, to assess the impact on TSF water level during extreme rainfall events.

The Evaporation Pond storage volume and surface area required to manage/evaporate the saline water/brine throughout the LoM is presented in **Chart 3-17** to **Chart 3-20** below. **Chart 3-17** and **Chart 3-18** shows the capacity and surface area required to manage brine and direct rainfall onto the Evaporation Pond; while **Chart 3-19** and **Chart 3-20** shows the capacity and surface area required to contain and evaporate the saline water/brine without the influence of direct rainfall.

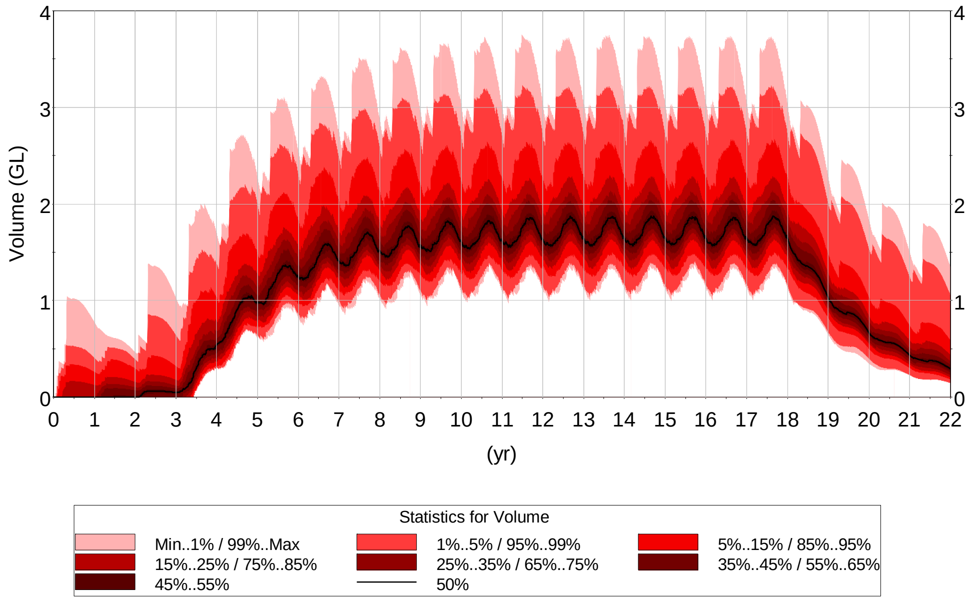


Chart 3-17 Evaporation Pond - Storage Plot (with Direct Rainfall)

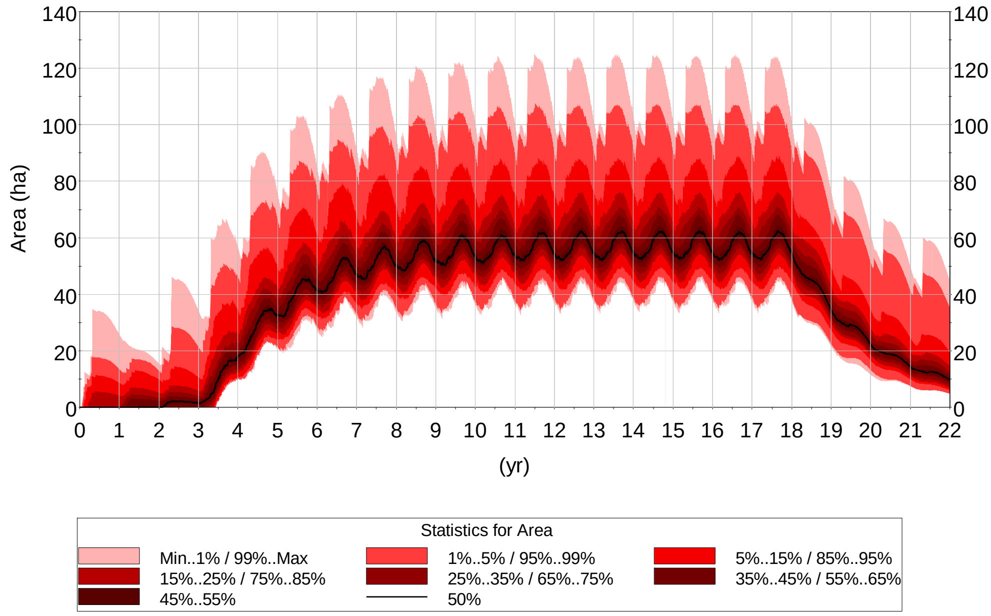


Chart 3-18 Evaporation Pond Surface Area (with Direct Rainfall)

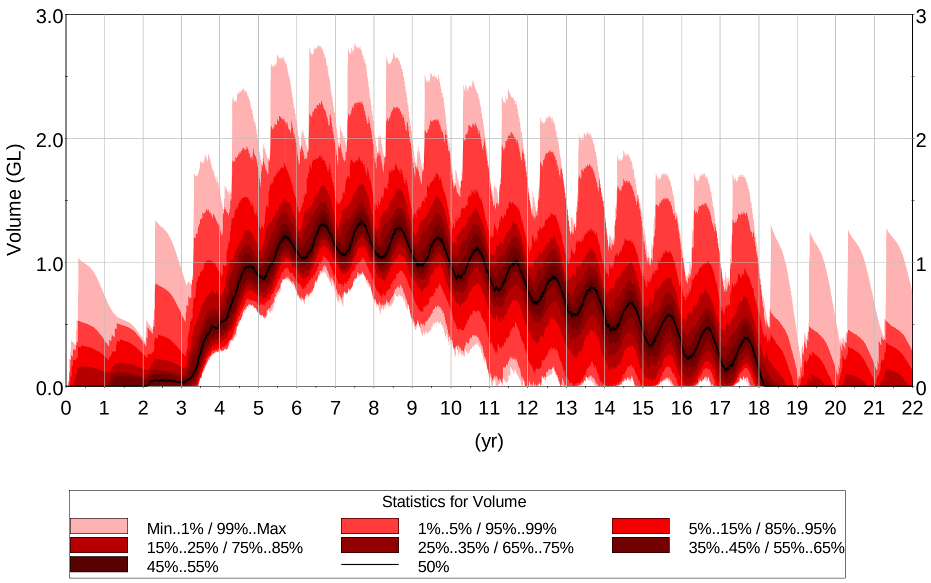


Chart 3-19 Evaporation Pond - Storage Plot (without Direct Rainfall))

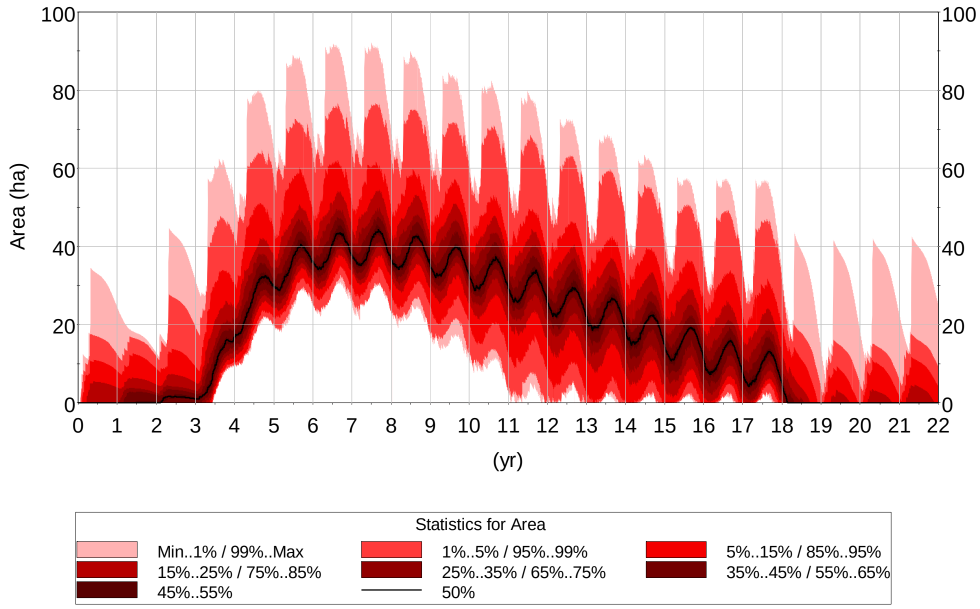


Chart 3-20 Evaporation Pond Surface Area (without Direct Rainfall)

The modelling results indicated that on average 45 ha (3 m plus freeboard to manage direct rainfall) to 65 ha (3 m including freeboard) of area is required to manage the brine while maintaining TSF water level at ~3.2 m.

During extreme or high rainfall events, the model estimate that up to 125 ha (3 m plus freeboard) or 90 ha (3 m including freeboard) is required to contain the brine within the Evaporation Pond while maintaining TSF water level at ~3.2 m. However, typically in mine water management, Evaporation Pond is not sized to manage extreme rainfall event, as the excess water is normally contain within the TSF or transferred to the open pit for temporary

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storage. As such, it is estimated that an Evaporation Pond with 50 ha surface area with an operating depth of 3 m is adequate to manage the brine.

To verify that the Evaporation Pond size is adequate to prevent uncontrolled discharge to the environment and to assess the impact on TSF water level during extreme rainfall events, a separate water balance simulation was completed by constraining the Evaporation Pond surface area and capacity to 50 ha and 1.5 GL respectively. Transfers from TSF to Evaporation Pond is triggered only if the Evaporation Pond volume is less than 80% and stopped when the Evaporation Pond storage volume reaches 90% of its capacity to avoid overflows to the environment. The results are presented in **Chart 3-21** to **Chart 3-23** below.

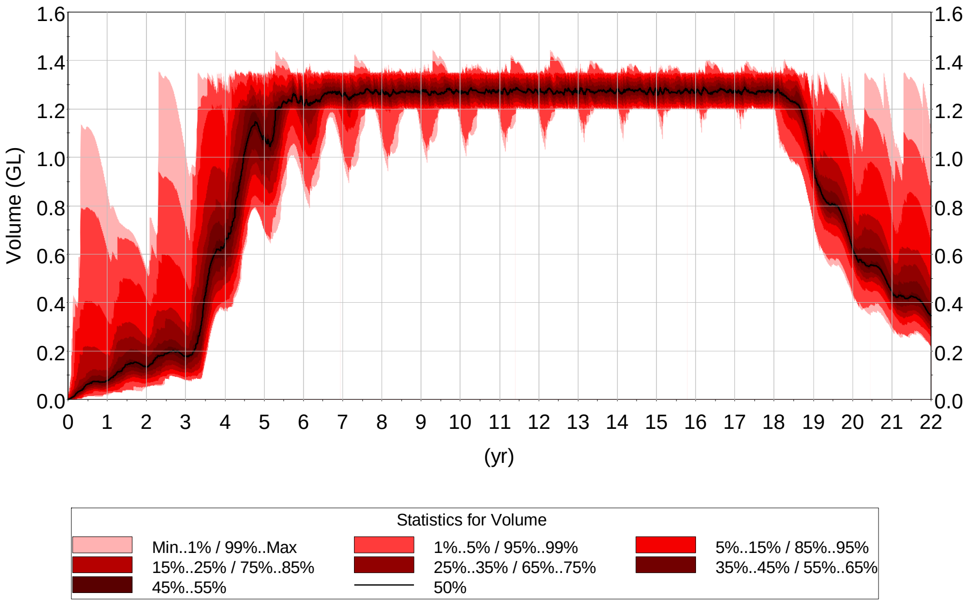

Chart 3-21 Evaporation Pond - Storage Plot (with fixed 50 ha Surface Area)

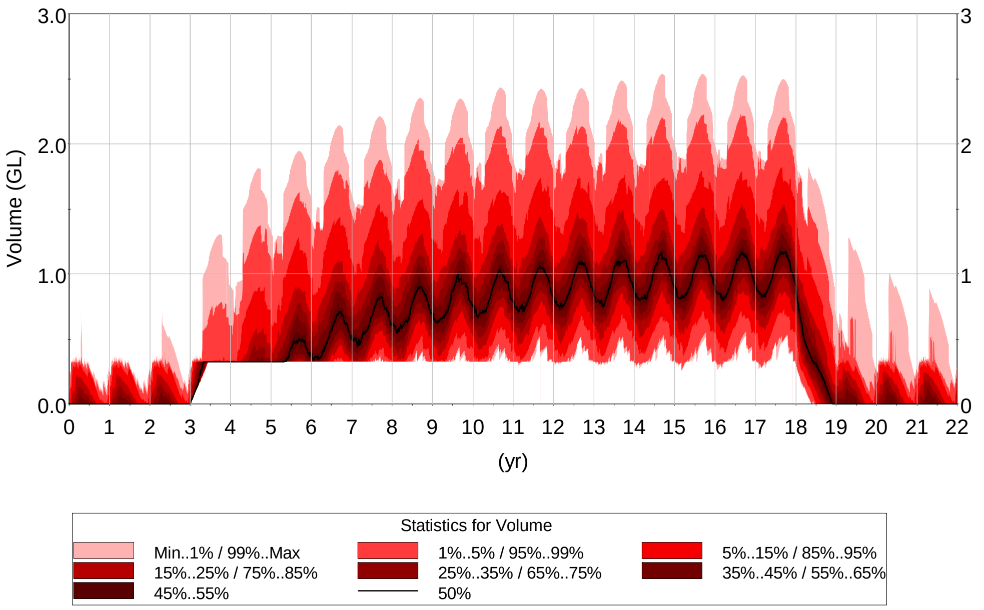

Chart 3-22 TSF – Storage Plot (with Evaporation Pond Surface Area fixed at 50 ha)

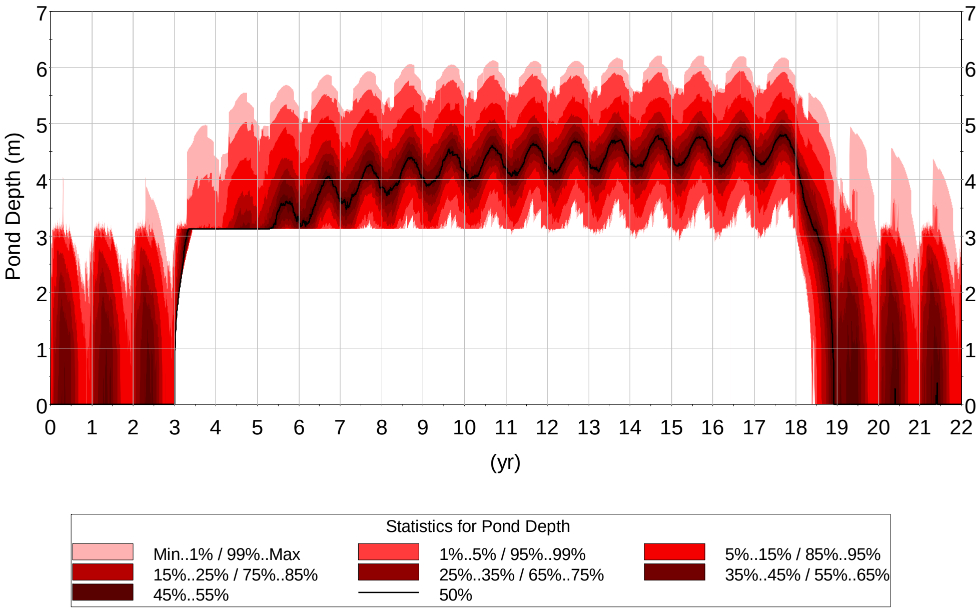

Chart 3-23 TSF – Pond Depth (with Evaporation Pond Surface Area fixed at 50 ha)

Modelling results presented in **Chart 3-21** to **Chart 3-23** above shows that Evaporation Pond with surface area of 50 ha and 3 m deep is adequate in managing and containing the brine onsite, however, the salt within the Evaporation Pond may need to be emptied and transferred to a separate pond/repository to maintain the salinity below 200 g/L. During high rainfall events, transfers of saline water from the TSF to Evaporation Pond must be ceased; and the excess water must be managed through containing the water within the TSF or adhoc pumping to the open pit for temporary storage, while ceasing transfers from the borefields.

Note that, the water level within the TSF shown in **Chart 3-23** is expected to be lesser with addition of freeboard to the Evaporation Pond to manage direct rainfall onto the pond.

3.2 Life of Mine Site Water Accounting

Estimated water balance fluxes for the WBM are presented in **Appendix B**. All water storage ponds and pit within the WBM as well as the entire model have been subjected to water mass balance checks to confirm model continuity and mass balance. The results showed that the model is balanced with 0.008% error.

4 SUMMARY AND CONCLUSIONS

This report presented the results of water balance modelling updates to reflect changes to the Proposed Development Project and to validate the performance of the Project water management strategy. The modelling results indicate the following:

- Peak water supply demand during mining period (year 4 to 18) is 8,750 kL/day.
- Groundwater Dewatering to RWP2 is estimated at 18,610 ML throughout the LoM.
- Based on the brackish water demand and operating rules adopted, in particular in maintaining four-day operational storage for RWP1 (10 ML capacity), the model estimated that 16,860 – 16,920 ML (980 – 1,110 ML/year) of brackish water is required throughout the LoM.
- Based on the saline water demand and operating rules adopted, in particular in maintaining four-day operational storage for RWP2 (25 ML capacity), the model estimated that 16,100 – 16,480 ML (510 – 1,280 ML/year) of saline water is required throughout the LoM.
- Evaporation Pond with surface area of 50 ha and 3 m deep is adequate in managing and containing the brine onsite, however, the salt within the Evaporation Pond must be emptied and transferred to a separate pond/repository to maintain the salinity below 200 g/L. During high rainfall events, transfers of saline water from the TSF to Evaporation Pond must be ceased; and the excess water must be managed through containing the water within the TSF or adhoc pumping to the open pit for temporary storage, while ceasing transfers from the borefields. It is recommended that further assessment be conducted during detailed design stage.
- The assessment showed that within the assumptions adopted in completing the water balance assessment the proposed water management strategy is adequate in containing the mine impacted water onsite.

5 REFERENCES

URS (2011a), Final Report, Surface Water Study, Proposed Yeelirrie Development, Report prepared for BHP Billiton Yeelirrie Development Company Pty Ltd, February 2011

URS (2011b), Final Report, Groundwater Study, Proposed Yeelirrie Development, Report prepared for BHP Billiton Yeelirrie Development Company Pty Ltd, February 2011

URS (2011c), Final Report, Water Balance Study, Proposed Yeelirrie Development, Report prepared for BHP Billiton Yeelirrie Development Company Pty Ltd, February 2011

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FIGURES

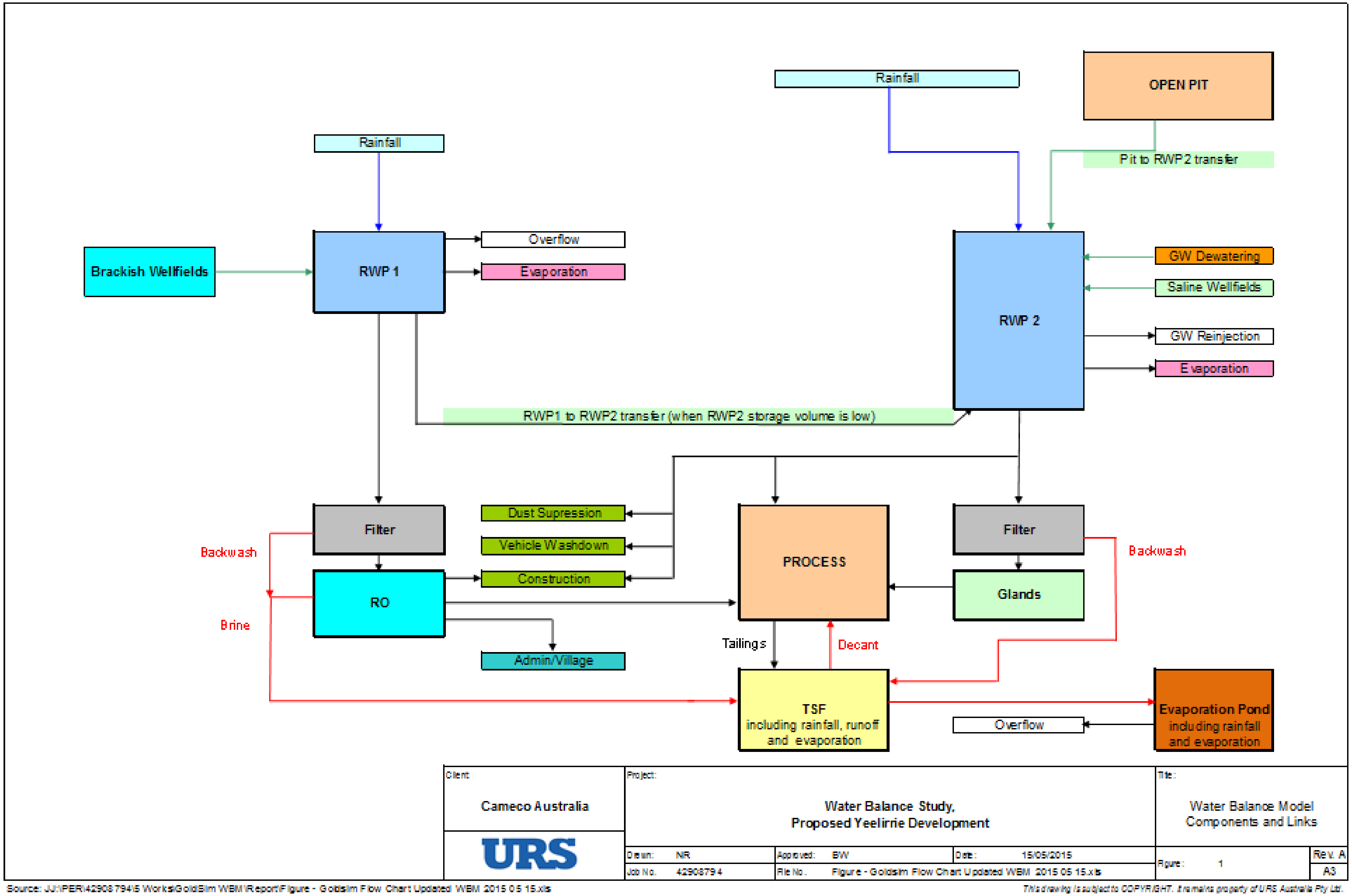
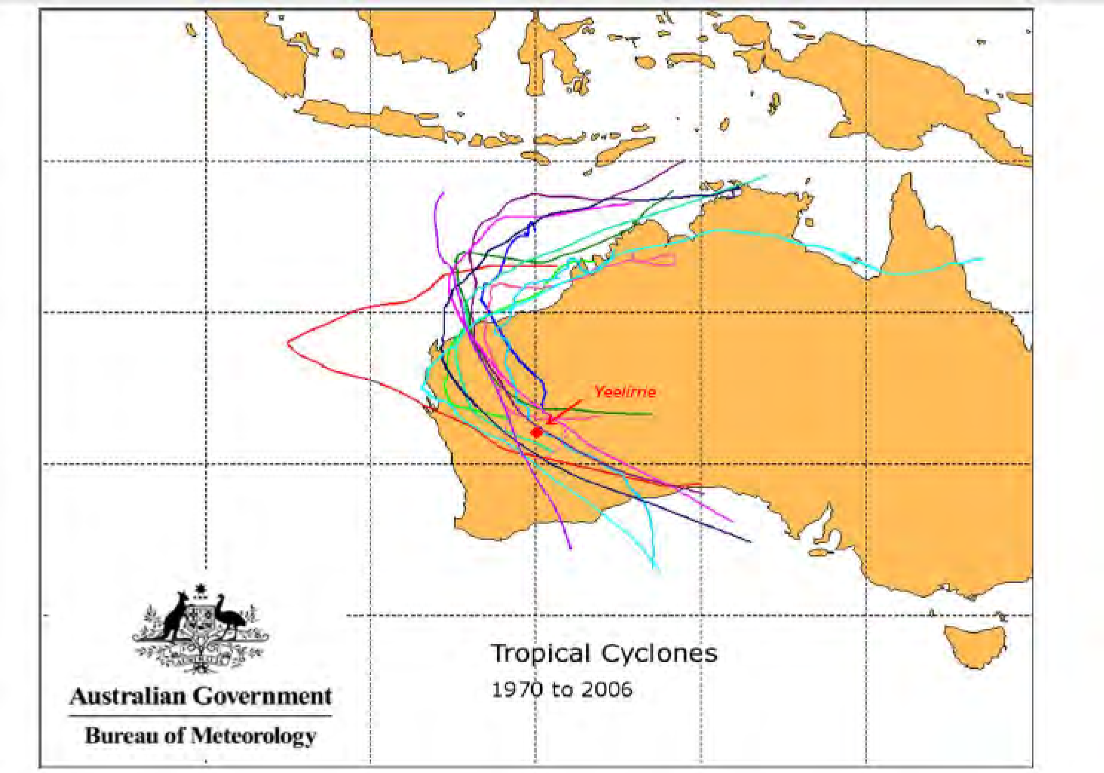


Figure 1 **Water Balance Model Schematic**



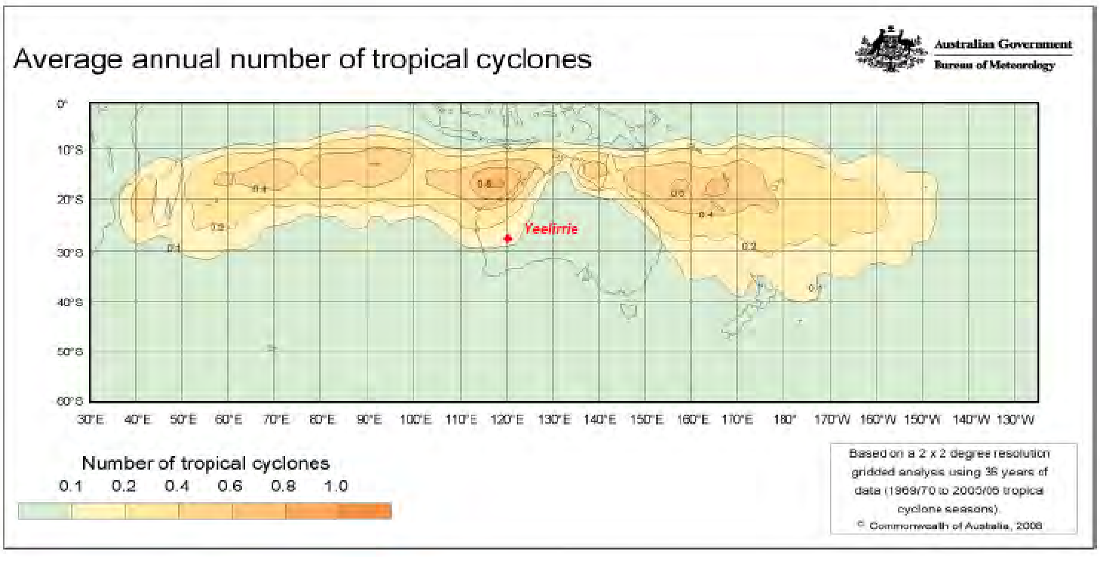


Figure 2 Cyclone Tracks and Frequency (BoM, 2010)

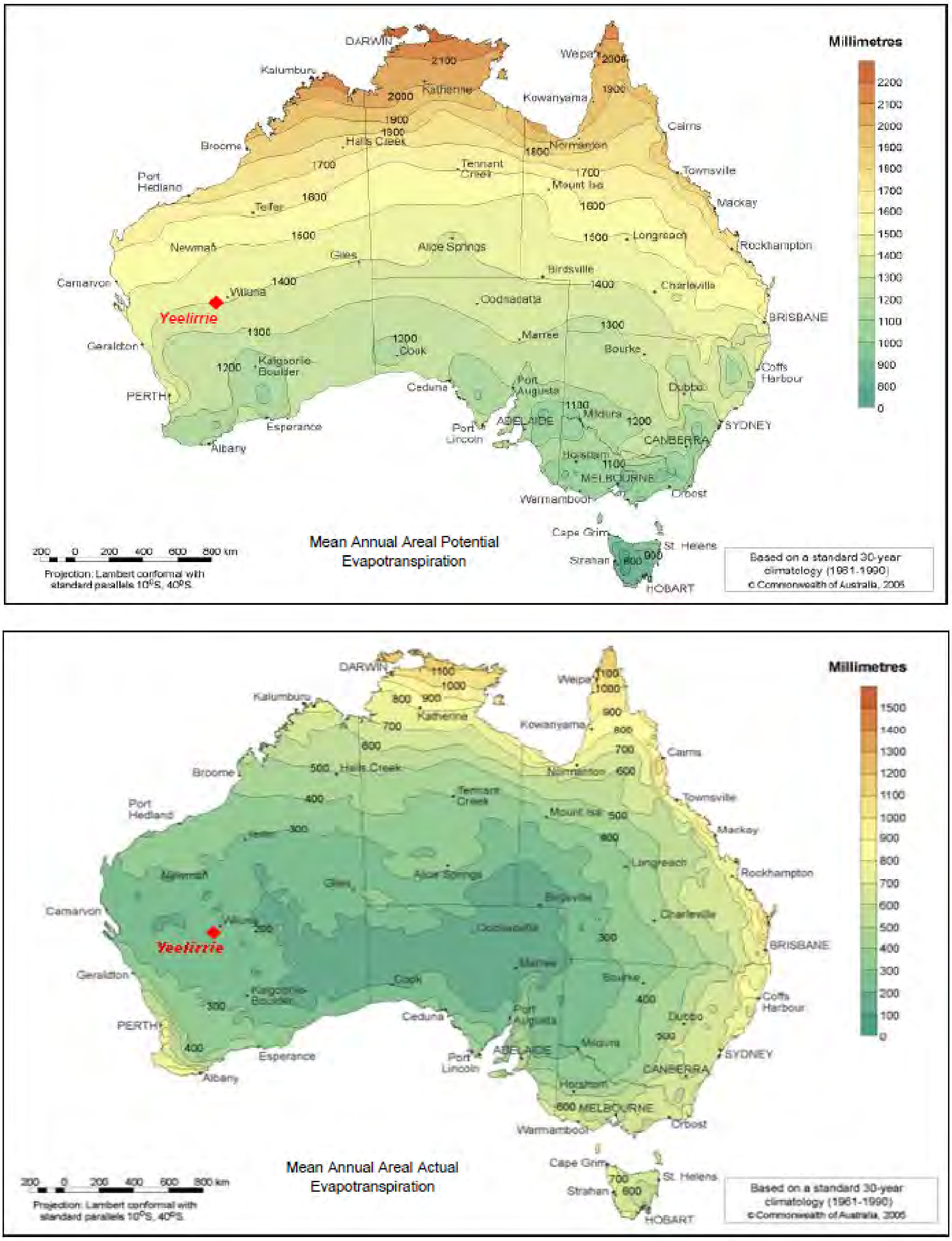


Figure 3 Regional Annual Potential and Actual Evapotranspiration (BoM, 2010)

APPENDIX A COMPARISON OF UPDATED SILO DATA DRILL DATA

URS

Memorandum

Date: 31 March 2015

To: Bas Wijers

From: Tim Wallis

Subject: Yeeriliee Water Balance - Comparison of Updated SILO Data Drill Data

1. Background

- The Yeelirrie GoldSim water balance model (WBM) was initially completed in 2011;
- Input model climate data consists of daily rainfall and evaporation (pan) data obtained from the Bureau of Meteorology (BoM) SILO Data Drill;
- The Yeeriliee WBM is currently being updated to reflect a revised mine plan and mine layout;
- Since the Data Drill for the 2011 WBM was obtained a number of significant updates to the SILO database have been implemented to improve SILO's data quality and data interpolation algorithms. In particular, the updates implemented in 2012 and 2014 have resulted in changes to the derived Data Drills.

This memorandum presents the findings of a comparison between the previous and updated SILO Data Drills to provide additional context to any results generated by the updated WBM.

1.1 SILO Data Drill Assumptions

Table 1 SILO Data Drill Assumptions

Assumption	Previous SILO Data Drill	Updated SILO Data Drill
Location	Lat, Long (dd): -27.20 119.90 (27 12'S 119 54'E)	
Estimated elevation	N/A	548m
Extraction date	27/02/2010	26/03/2015
Data used for comparison	1/1/1900 to 31/12/2009[1]	
Variables analysed	Daily rainfall and pan evaporation	

[1] Represents the 'unwrapped' date range of the input climate data to the 2011 WBM

2. Data Drill Comparison

- Comparison of the old and new Data Drills were made at both an annual (rainfall only) and monthly scale (rainfall and evaporation);
- Evaporation data was compared for the non-synthetic (1970 onwards) data only as prior to this both Data Drills have identical data;
- Annual rainfall totals from both datasets were compared at a range of AEPs;
- Average monthly totals were also compared but for median values only; and
- Differences in the data sets have been presented as relative and absolute values.

2.1 SILO Data Drill Comparison – Rainfall

Observations:

From Figure 1 and

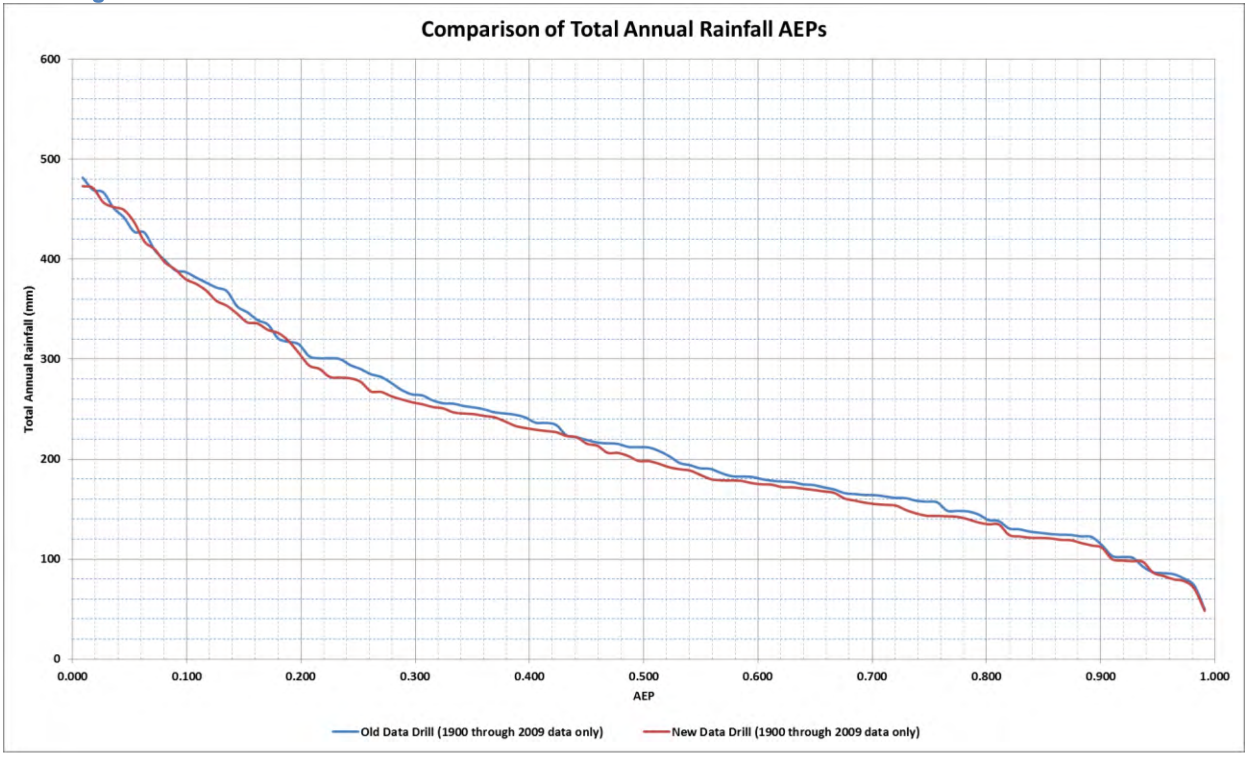


Figure 1 Total Annual Rainfall AEPs (1900-2009 Data)

Table 2 it can be seen that:

- Total annual rainfall totals are generally lower with the new Data Drill except for AEPs greater than 0.9 where the differences are negligible;
- Median annual rainfall for the new Data Drill is approximately 198mm compared to 212mm for the old data - a reduction of 6.5 when compared to the old Data Drill;

- Observed differences in total annual rainfall are generally greatest for AEPs between 0.2 and 0.8;

From Figure **2** and Table 3 it can be seen that:

- Median monthly rainfall shows a notable dry season from August through November and a wetter season extending from December through July;

- Differences in median monthly rainfall for the old and new Data Drills range from -9.8% (-1.6mm) in February to 0.0% (0mm) in June and October;

Comments and potential impact on WBM:

Assuming the old and new Data Drills were input to the same WBM, predicted water inflows resulting from either direct rainfall (over storage water surfaces) or runoff using the new Data Drill are:

- Likely to be lower (approximately 5-6%) for the majority of years (AEPs 0.8 to 0.2) due to a reduction in total annual rainfall;

- Likely to be relatively unchanged for extreme wet years (AEP 0.05 or less) due to an insignificant change in total annual rainfall;

- Likely to be lower (approximately (2-4%) for extreme dry years (AEP 0.95 or more) due to a reduction in total annual rainfall; and

- Relative reduction to wet season monthly inflows is likely to be greater than to dry season monthly inflows;

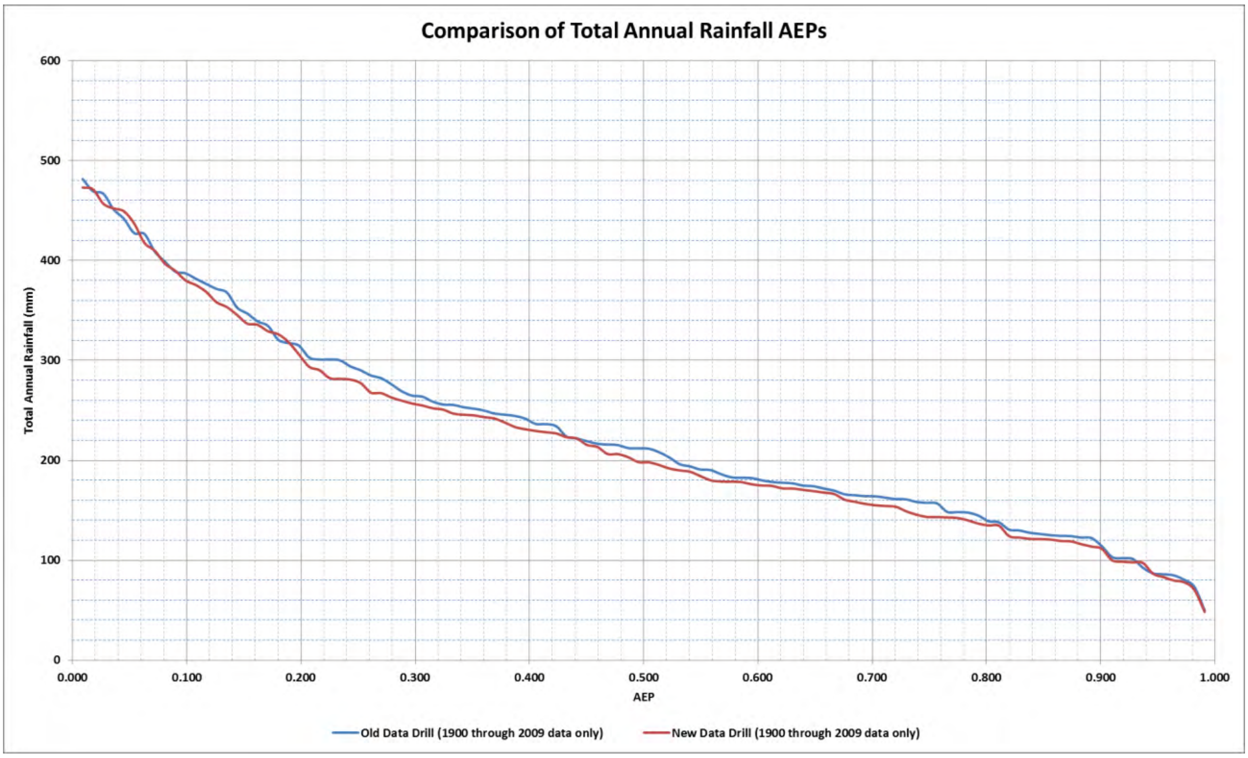


Figure 1 Total Annual Rainfall AEPs (1900-2009 Data)

Table 2 Comparison of Total Annual Rainfall (1900-2009 Data)

Percentile	AEP	AEP (1:__)	Description	Old Data (mm)	New Data (mm)	Difference	
						Relative	Absolute (mm)
0.000	0.991	1.0	Minimum	49.7	48.3	-2.8%	-1.4
0.010	0.990	1.0	1:100 Dry year	73.9	70.9	-4.0%	-3.0
0.020	0.98	1.0	1:50 Dry year	81.3	78.3	-3.7%	-3.0
0.050	0.950	1.1	1:20 Dry Year	89.4	91.3	2.1%	1.9
0.100	0.900	1.1	1:10 Dry year	121.4	113.5	-6.5%	-7.9
0.500	0.500	2.0	Median year	211.8	198.1	-6.5%	-13.7
0.900	0.100	10.0	1:10 Wet year	382.2	375.9	-1.6%	-6.3
0.950	0.050	20.0	1:20 Wet year	427.0	428.2	0.3%	1.2
0.980	0.020	50.0	1:50 Wet year	464.0	456.0	-1.7%	-8.0
0.990	0.010	100.0	1:100 Wet year	469.1	469.8	0.2%	0.7
1.000	0.009	111.0	Maximum	481.5	473.0	-1.8%	-8.5

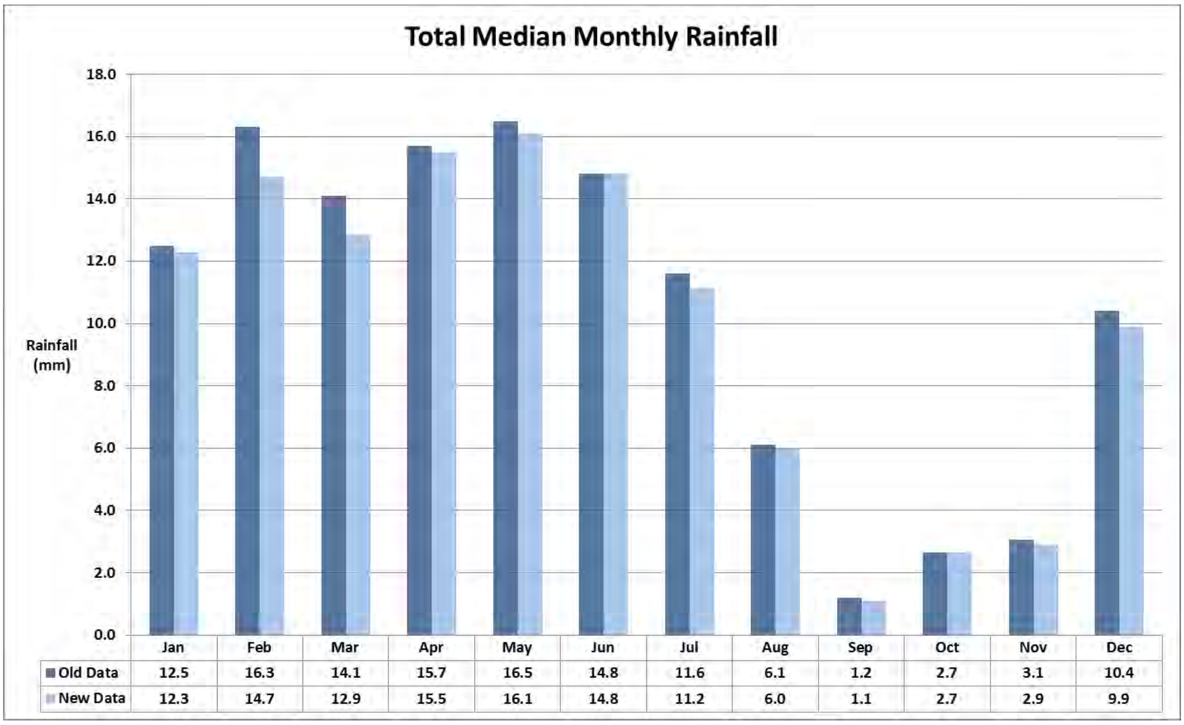


Figure 2 Median Total Monthly Rainfall (1900-2009 Data)

Table 3 Comparison of Median Total Monthly Rainfall (1900-2009 Data)

Month	Old Data (mm)	New Data (mm)	Difference	
			Relative	Absolute (mm)
Jan	12.5	12.3	-1.6%	-0.2
Feb	16.3	14.7	-9.8%	-1.6
Mar	14.1	12.9	-8.9%	-1.3
Apr	15.7	15.5	-1.3%	-0.2
May	16.5	16.1	-2.4%	-0.4
Jun	14.8	14.8	0.0%	0.0
Jul	11.6	11.2	-3.9%	-0.5
Aug	6.1	6.0	-1.6%	-0.1
Sep	1.2	1.1	-8.3%	-0.1
Oct	2.7	2.7	0.0%	0.0
Nov	3.1	2.9	-4.9%	-0.1
Dec	10.4	9.9	-4.8%	-0.5

2.2 SILO Data Drill Comparison – Evaporation

Observations:

From Figure 3 and Table 4 it can be seen that:

- Median monthly evaporation shows a distinct season distribution with levels highest during the summer months of November through February and lowest in the winter (May through august);
- Pan evaporation is significantly in excess of rainfall (compare with Figure 2);
- For all months median monthly pan evaporation is lower for the new Data Drill when compared to the old; and
- Relative differences range from -1.1% (April) to -7.7% (May and December);

Comments and potential impact on WBM:

Assuming the old and new Data Drills were input to the same WBM:

- The use of the Australian Water Balance Model (AWBM) as the rainfall-runoff model for the WBM requires evaporation data as an input. Rainfall excess (runoff) results if the model's conceptual surface storages are exceeded after a daily balance is conducted (i.e. if the previous depth + rainfall less evaporation is > than the stores capacity). Use of a lower evaporation rate may therefore slightly increase estimated runoff volumes;
- Evaporation data is also used to estimate daily losses from water storages. Use of a reduced evaporation rate may potentially result in lower evaporative losses; and

- The potential impact of the new evaopration data is somewhat reduced however due to the fact that differences only exist in the non-synthetic data (1970 onwards).

3. Conclusions

The revised SILO Data Drill for the Yeeriliee water balance shows reduced rainfall and evaporation (non-synthetic data only) values. The likely impact of reduced rainfall is to reduce inflows to the model (via runoff and direct rainfall). However the likely impact of a reduced evaporation rate is a potentially increased runoff rate and higher water storage evaporation rates. Without an assessment of both datasets using the GoldSim WBM it is difficult to predict the final impact of the revised Data Drill however the results contained in this memo will help to provide some background context to the updated WBM results.

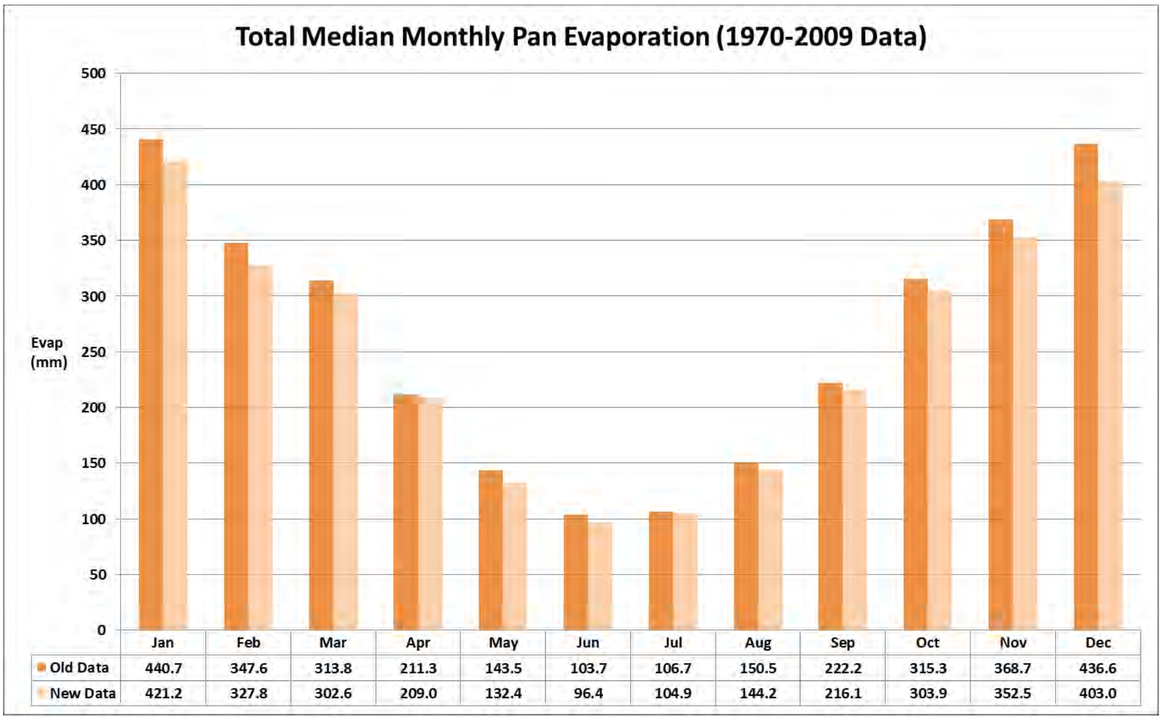


Figure 3 Median Total Monthly Pan Evaporation (1970-2009 Data)

Table 4 Comparison of Median Total Monthly Pan Evaporation (1970-2009 Data)

Month	Old Data (mm)	New Data (mm)	Difference	
			Relative	Absolute (mm)
Jan	440.7	421.2	-4.4%	-19.5
Feb	347.6	327.8	-5.7%	-19.8
Mar	313.8	302.6	-3.6%	-11.2

Apr	211.3	209.0	-1.1%	-2.3
May	143.5	132.4	-7.7%	-11.1
Jun	103.7	96.4	-7.0%	-7.3
Jul	106.7	104.9	-1.7%	-1.8
Aug	150.5	144.2	-4.2%	-6.3
Sep	222.2	216.1	-2.7%	-6.1
Oct	315.3	303.9	-3.6%	-11.4
Nov	368.7	352.5	-4.4%	-16.2
Dec	436.6	403.0	-7.7%	-33.6

APPENDIX B LIFE OF MINE WATER BALANCE MODEL ACCOUNTING

Raw Water Pond	Site Wide throughout LoM
Unit	**ML**
Inflows	
Direct Rainfall	6961.3
Local Runoff	8254.6
Brackish Wellfields	16913.3
Saline Wellfields	16450.3
Pit floor Dewatering	18609.5
Water contained in Ore	6834.0
Water contained in Reagents	1708.5
Net Gain in Process Plant due to Reactions	394.3
Total Inflows	**76125.8**
Outflows	
Evaporation	40181.1
Entrained Water in Settled Tailings	16162.2
Groundwater Reinjection (RWP2)	2630.7
Overflows	1107.4
Dust Suppression	13006.7
Vehicle Washdown	270.3
Constructions	1391.0
Personnel/Camp	995.3
Total Outflows	**75744.8**
Initial Volume	17.5
Storage Volume	404.2
Balance Check	**-5.7**
Percent Error	**0.008%**

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