63 Wessel Road, Rivonia, 2128 PO Box 2597, Rivonia, 2128 South Africa
Tel: +27 (0) 11 803 5726 **Fax:** +27 (0) 11 803 5745 **Web:** www.gcs-sa.biz

Water Balance Update Study for the Leeuwpan Coal Mine

Report

Version - 1

28 November 2018

Exxaro Leeuwpan Coal

GCS Project Number: 18-0538

Client Reference: GCS Water Balance Update - Leeuwpan Coal

POWERING POSSIBILITY

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Author	Sbongiseni Mazibuko		28th of November 2018
Document Reviewer	Kevin Scott		28th of November 2018
Unit Manager	Alkie Marais		28th of November 2018

LIST OF ACRONYMS

DEM	Digital Elevation Model
DMS	Dense Medium Separation
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
GCS	GCS Water and Environment (Pty) Ltd
GN704	General Notice 704
HDPE	High-Density Polyethylene
MAE	Mean Annual Evaporation
mamsl	meters above mean sea level
MAP	Mean Annual Precipitation
PCD	Pollution Control Dam
PFD	Process Flow Diagram
RM2	Rational Method Alternative 2
RM3	Rational Method Alternative 3
ROM	Run of Mine
SDF	Standard Design Flood
SoW	Scope of Work
STP	Sewage Treatment Plant
WMA	Water Management Area
WR2012	South African Water Resources 2012 Study
WUL	Water Use Licence

EXECUTIVE SUMMARY

GCS (Pty) Ltd (GCS) was appointed by Exxaro Leeuwpan Coal (Exxaro) to undertake a water balance update study for the existing Leeuwpan Coal Mine (Leeuwpan), near the town of Delmas in the Mpumalanga Province of South Africa. Leeuwpan is located in quaternary catchment B20A of the Olifants Water Management Area (WMA-2). This study is required to update the water balance for the Leeuwpan mine that is required in terms of the existing Water Use Licence. The revised water balance needs to include the new Block OI pit and the three operational mine process plants.

Leeuwpan mine is situated in the Mpumalanga Highveld, which is characterised by warm wet summers and dry cold winters. Although monthly average temperatures range between 7.7ºC, and 23.6ºC, peak temperatures of about 37°C can be expected in mid-summer. Minimum daily temperatures will seldom fall below 3°C, and frost is rare for this area. Most rain falls between the summer months of November to January. Average monthly evaporation exceeds average rainfall throughout the year. Mean Annual Evaporation (MAE) (Symons Pan) of 1 677 mm, and Mean Annual Precipitation (MAP) of 667 mm are reported for the site. The surrounding topography is relatively flat high-veld grasslands with large areas of cultivated farmland. The mine is situated in the upper catchment of the Bronkhortspruit.

A site visit on the 13th of September 2018 allowed the inspection of water infrastructure on the mine and collection of information that was used to compile a Process Flow Diagram (PDF) that provides a basis for the calculation of the overall mine water balance.

The mine relies on the three (3) boreholes (Witklip, Henk's and Load Out) for raw water supply to offices and workshop areas for domestic consumption. Water from six (6) open cast pits (OD north & south, OJ, OH & OM, Weltervreden OWM, and Moabsvelden OWM) is used for mine process plant operations. Pits receive water from groundwater ingress, runoff and rainfall, and lose water to seepage and evaporation. Water used in the process plant is pumped to, and supplied from three (3) reservoirs, which are referred to as the Silver PCDs. The Witklip PCD provides added back-up storage. The Plant PCD should, in theory trap runoff from the plant and stockpile area for re-use in the plant. During the September site visit, it was noted that the silt-trap upstream of this PCD was under-sized and the PCD was largely filled with sediments.

The beneficiation process at the Leeuwpan Coal Mine is conducted with three (3) plants: Crush and Stack, Dense Medium Separator (DMS) and Frazer DMS on a 24hrs basis for 313 days per year. These plants process - on a monthly basis – 7 174 ton (Crush and Stack Plant), 5 776 ton (Fraser DMS Plant), and 7 381 ton (DMS Plant) of Run of Mine (ROM). Frazer DMS and DMS plants produce 2 298 and 2 899 ton of coal per month, respectively.

The calculated annual, monthly and daily average water balances were based on the information received from the client, mine site visit, and previous relevant studies conducted for the Leeuwpan Mine. The total volume of water used on the mine was calculated at 302 400 m^3/a, where an annual volume of 139 209 m^3 is abstracted from the Silver PCDs and 11 991 m^3/a is re-used water from the Plant PCD. Dust suppression water is supplied from the Silver PCD and accounts for 10 200 m^3/a. The inclusion of the OI Pit into the mine water balance will provide an excess of 372 796 m^3 of water per year. Current dirty water storage facilities (Silver and Witklip PCDs) cannot contain this volume of excess water.

Recommendations made as a result of this study include:

- Water flow meters should be installed to monitor inflows into and outflows from; the Plant Beneficiation, Silver PCDs, dust suppression bowser, and Phola Sewage Treatment Plant (STP). Flow volume data will provide a better understanding of water flow patterns at the mine and facilitate the calibration of more accurate water balance calculations.
- Upgrading of, and improved maintenance of, the silt trap at the Plant PCD. This will improve efficiency of the system and mitigate sedimentation in the Plant PCD.
- Raw water abstractions from boreholes should be monitored to ensure that the mine adheres to conditions of the water use licence issued for the mine. Flow volume data for the period January 2018 to August 2018 suggests that raw water on the mine has increased, which implies that the mine should apply for a new water use license that reflects current and future demands.
- Additional storage for excess water expected from the dewatering of the new OI pit needs to be planned. Water storage issues can be addressed as follows:
    - Back-filled pits that are far from the plant area should be rehabilitated in order to reduce the quantities of water flowing into the Silver PCD.
    - Use Pit OD (South and North) as a storage facility. This will allow storage of some excess water, and allow for increased evaporative water losses.
    - Pump water from the Silver PCDs into the Witklip PCD where water will evaporate or could be treated and discharged back into the environment.

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1 INTRODUCTION

GCS (Pty) Ltd (GCS) was appointed by Exxaro Leeuwpan Coal to update the water balance study for the Leeuwpan Coal Mine (Leeuwpan). The mine is located situated 8 km east of the town of Delmas, within the Victor Khanye Local Municipality in the Mpumalanga Province of South Africa. The mine site lies in headwaters of quaternary B20A of the Olifants Water Management Area (WMA-2) (Figure 1.1).

Leeuwpan Coal Mine aims to apply principles of sustainable water management and contribute towards integrated water management in the region. This involves the development of a water balance model and monitoring systems that will facilitate accurate water accounting for the mine. Leeuwpan is in the process of updating its mine water balance and incorporating open cast Block OI into the existing Water Use Licence. A recent water balance study conducted in 2017 by (Linstrom, 2017) was not in line with the Best Practice Guidelines (BPG) for Water Resource Protection in the mining sector: Guideline G2 (Salt and Water Balances) (DWAF, 2006c) and did not explicitly include all mine components. This study intends to provide a detailed water balance that adheres to this guideline.

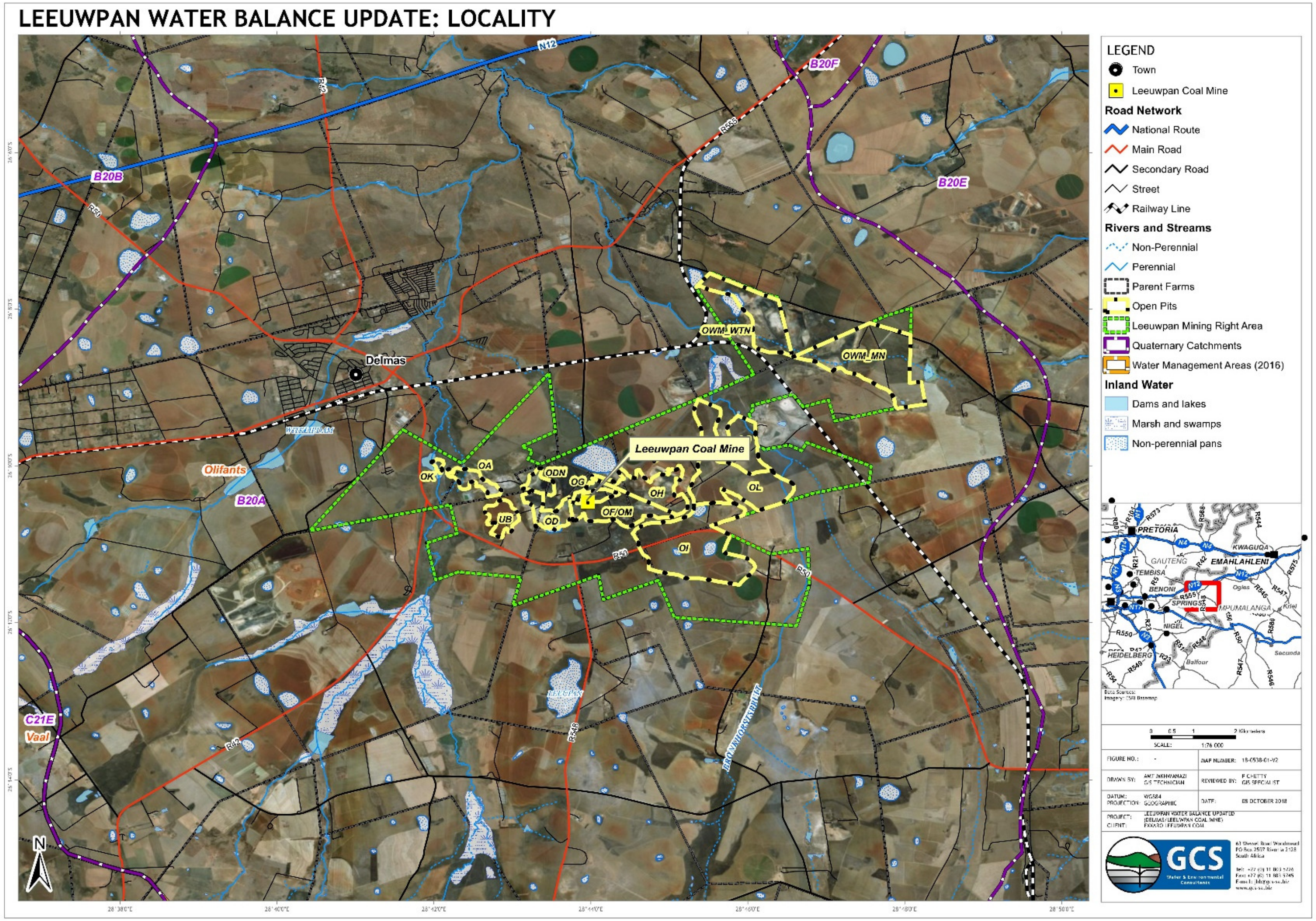


Figure 1.1: Study site locality

2 SCOPE OF WORK

The Scope of Work (SoW) was defined as follows:

1. Information Sourcing and Literature Review:
    - Acquisition and assessment of the relevant existing literature regarding Leeuwpan mine water balance;
    - Review of the legislative and policy framework relating to mine water use and water use licence (s) (WUL).
2. Site Visit:
    - A mine site visit to ground-truth the existing mine infrastructure relative to water reticulation and use;
    - Collection of relevant information that can be used to complete a mine Process Flow Diagram (PFD) and for the calculation of an overall mine water balance;
3. Baseline Climate and Hydrology:
    - Provide relevant information on climate and hydrology for the mine site area;
    - Calculation of rainfall, runoff and evaporation volumes to and from all mine pits and other water infrastructure;
4. Mine Water Balance Update:
    - Update a water Process Flow Diagram;
    - Update the average annual mine water balance; and
    - Develop annual, monthly and daily water balances.
5. Reporting:
    - Compile a report that describes findings and conclusions drawn from the study and recommends interventions to improve the water balance and mine-water management on site.

3 METHODOLOGY

3.1 Site Visit

A site visit on the 13th of September 2018 allowed the inspection of water infrastructure on the mine and collection of information that was used to compile a Process Flow Diagram (PDF) that provides a basis for the calculation of the overall mine water balance.

3.2 Information Sourcing and Literature Review

The following documents and reports were reviewed during the study:

- Previous Leeuwpan water balance studies conducted by GCS in 2016 (GCS, 2016) and Exxaro in 2017 (Linstrom, 2017);
- Hydrogeological study report conducted by (GCS, 2014);
- Previous Integrated Water and Waste Management Plan report (GCS, 2014a) and the Integrated Water Use Licence Application (GCS, 2014b);
- Raw water consumption figures from the measuring points on various mine site units;
- General Notice 704 (South Africa, 1998) of the South African National Water Act (Act No. 36 of 1998) (NWA); and
- The South African Department of Water and Sanitation (DWS) (formerly the Department of Water Affairs and Forestry – DWAF) Best Practice Guideline (BPG) G2: Water and Salt Balances (DWAF, 2006c).

3.3 General Climate and Local Hydrology

Baseline climate and hydrological information for the site was updated using data obtained from the South African Water Resources Study (WR2012) database (Bailey & Pitman, 2015) and the South African Atlas of Agrohydrology and Climatology (Schulze, 1997). This information was used to derive seasonal distribution patterns of variables that are used as inputs into the mine water balance computations.

3.4 Average Water Balance

The water balance update was conducted in accordance with the DWS Best Practice Guideline G2: Salt and Water Balances (DWAF, 2006c). An updated schematic process flow diagram, which shows all relevant water flow linkages, was generated using the existing PDF and water balance information (Linstrom, 2017) and information obtained during a site visit. The client signed off the updated PFD before water balance models were generated.

4 LEGISLATIVE REQUIREMENTS AND BEST PRACTICE GUIDELINES

4.1 The National Water Act and Water Use for Mining and Related Activities

4.1.1 The National Water Act

Water resources management in South Africa is governed by the National Water Act (NWA). The Department of Water and Sanitation (DWS) must, as custodians of water, ensure that resources are used, conserved, protected, developed, managed and controlled in a sustainable manner for the benefit of all persons and the environment.

4.1.2 Regulations on the use of Water for Mining and Related Activities

General Notice 704 (South Africa, 1998) of the National Water Act (Act 36 of 1998) regulates the used of water for mining activities. Clean and dirty water must be separated. Dirty water must be captured and contained on the mine for either use, re-use, evaporation or purification prior to disposal. GN704 also stipulates that water used in any mine process should be recycled and re-used as far as possible.

4.2 Best Practice Guidelines

4.2.1 Water Balances

Water Use licences for most mines include conditions that include detailed and accurate water balances that meet DWS Best Practice Guidelines for Water and Salt Balances (DWAF, 2006c). Mine water balances should be dynamic to consider seasonal changes incorporate changes in, inter alia, water storage levels. Principles used in this study include:

- Dynamic water balances based on variable climate inputs and should including all inflows and outflows from any mining activity. Water balances must also reflect surface and groundwater interconnections with the water resource;
- The water balance should incorporate accurate measured volumes of water abstracted, used, or discharged at any point in the mine. Water uses include, process water intake, outflows to and return water from waste management facilities and water abstracted from mine workings;
- Water balances should incorporate accurate values determined from suitable measurement of flows or modelling of rainfall, runoff, groundwater seepage and evaporation. Where flow is not monitored, a calculated water balance should be determined through mass balance calculations;
- Measures taken to manage the flow of water should have clear objectives and should account for both current and future mining situations;

5 GENERAL CLIMATE AND LOCAL HYDROLOGY

5.1 Climate

The mine site is located in a temperate climatic zone of South Africa, which is characterised by warm summers and dry cold winters. Table 5.1 shows that the area experiences - on average - lowest temperatures in July and is warmest during January (Cleanstream, 2003). The monthly average minimum and maximum temperatures recorded in the town of Delmas are 7.7°C and 23.6°C, respectively.

Table 5.1: Average minimum and maximum temperatures at Delmas (source: (Cleanstream, 2003)

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum (°C)	14.0	13.4	11.7	8.0	3.0	-0.6	-1.6	1.2	6.2	10.1	12.4	14.0
Maximum (°C)	27.0	26.3	25.6	23.8	21.8	18.1	18.9	20.7	24.1	25.1	25.2	26.4

5.2 Rainfall and Evaporation

Most rain falls between the summer months of November to January. Average monthly evaporation exceeds average rainfall throughout the year. Mean Annual Evaporation (MAE)(Symons Pan) of 1677 mm, and Mean Annual Precipitation (MAP) of 667 mm are reported for the site (Bailey & Pitman, 2015).

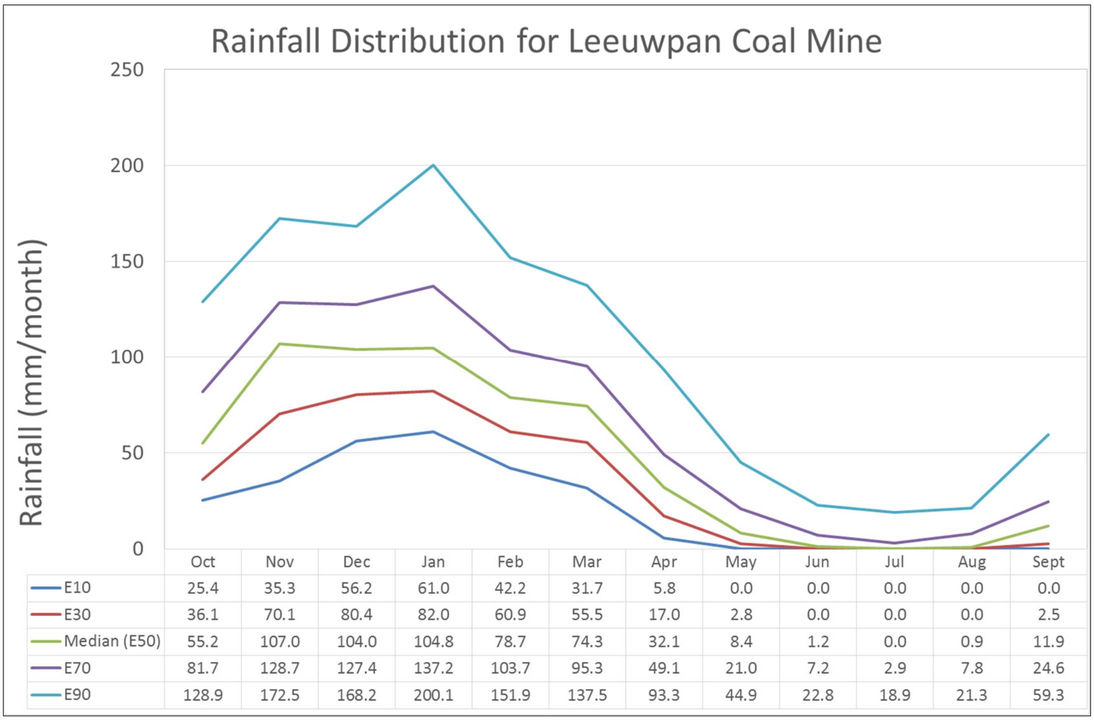


Figure 5.1: Monthly rainfall distribution for the Leeuwpan Coal mine (source: Bailey & Pitman, 2015)

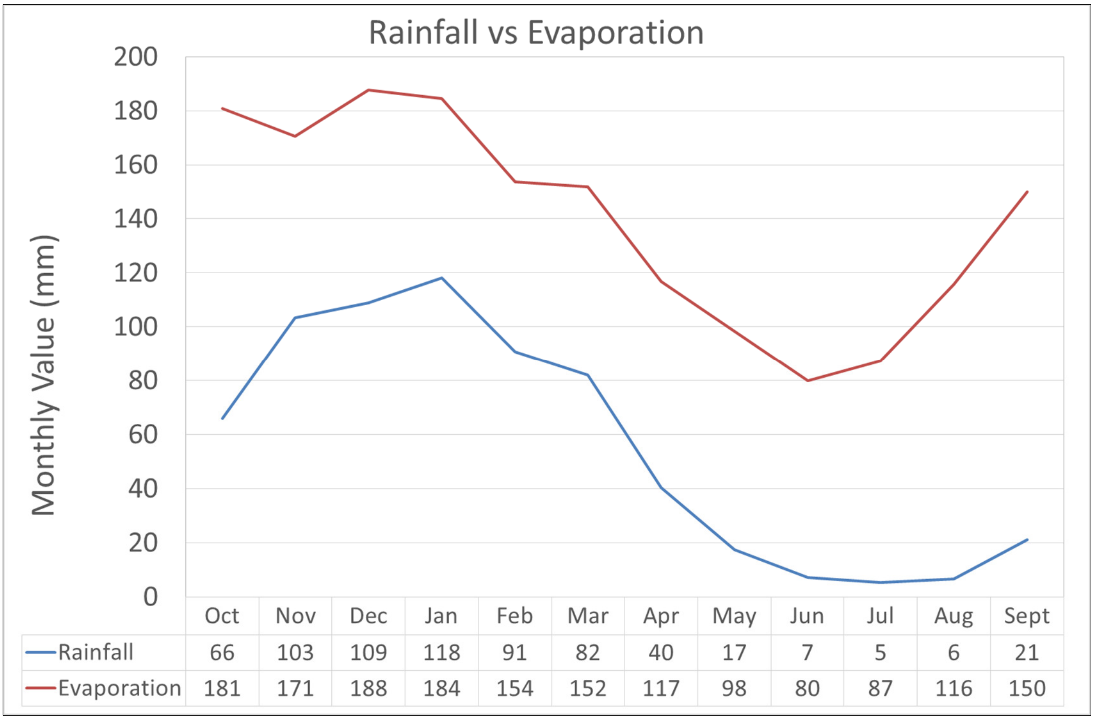


Figure 5.2: Mean monthly rainfall and evaporation for the Leeuwpan Coal mine (source: Bailey & Pitman, 2015)

5.3 Local Runoff

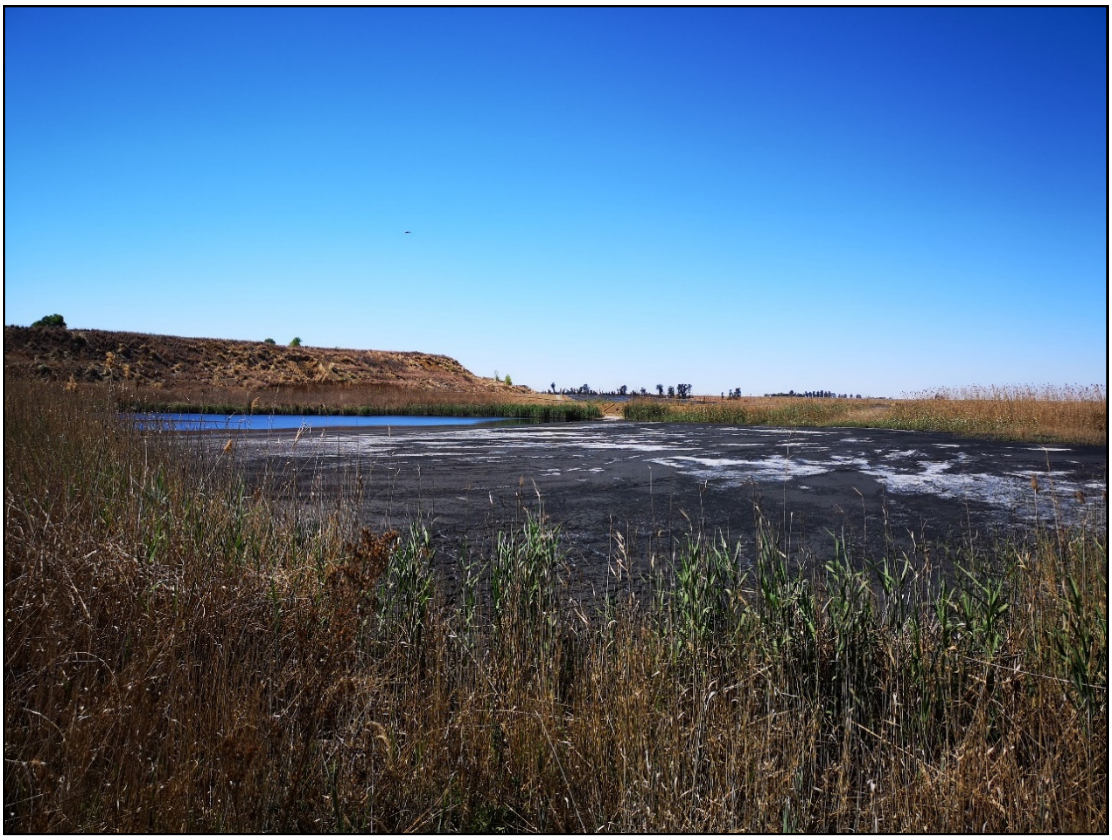
Leeuwpan Coal Mine is located in the upper catchment of the Bronkhorstspruit (Quaternary Catchment B20A) which flows in a north-easterly direction. The area has flat to gentle topography with wide valley bottoms near the mine. While some seepage from back-filled mine pits is expected, most mine runoff is contained in residual pit lakes and PCD's. Ponded water is lost through evaporation.

6 SITE VISIT

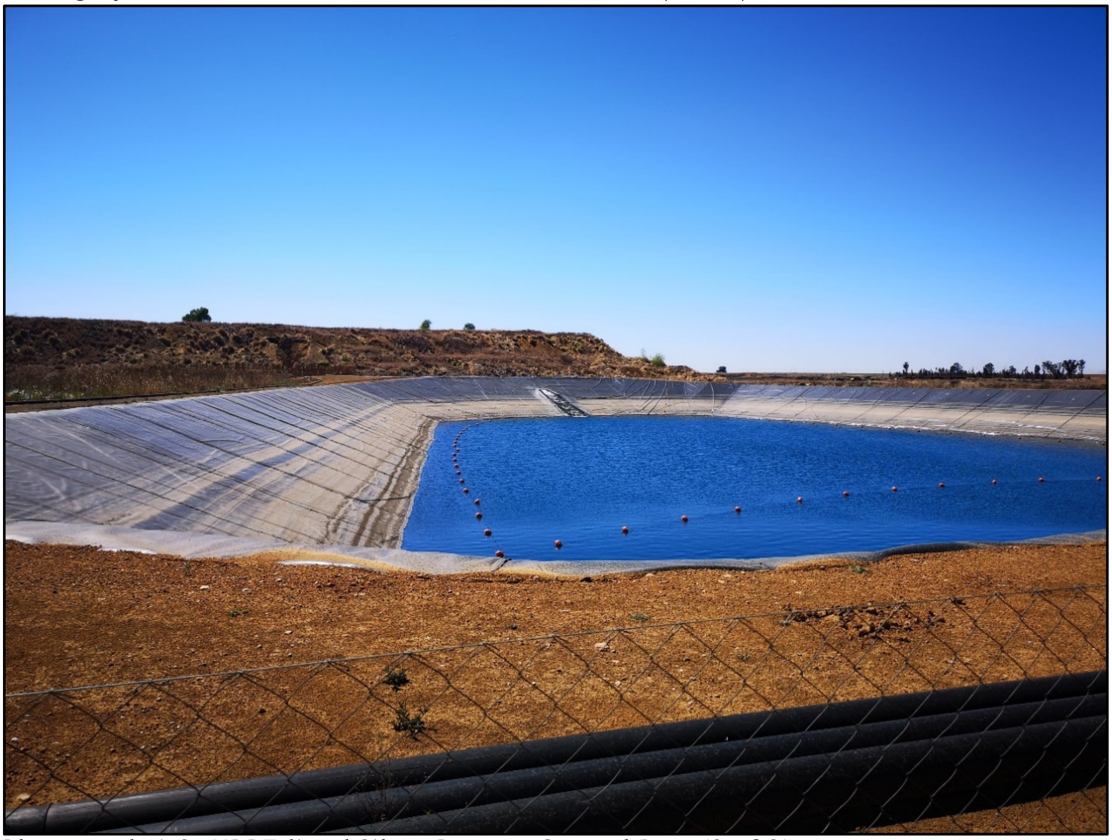
A site visit was conducted on the 13th of September 2018 to inspect mine infrastructure and facilities, develop an understanding of water balance processes and collect information. Information collected during this visit informed the development of a water Process Flow Diagram (PFD), on which detailed water balance calculations were based.

Photograph 6.1 to 6.3 show the three dams which comprise Silver Process Control Dams (Silver PCDs) that store dirty water for mine operation. Currently dam 1 and 2 (Photograph 6.1 and Photograph 6.2) are filled with silt and only dam 3 has been upgraded with High-Density Polyethylene (HDPE) lining. The intention is that the reservoirs and 'Dam 3' will be used to control the flow of 'dirty water' and that the unlined dams will be rehabilitated.

Photograph 6.1: Unlined Silver Process Control Dam (1 of 3)



Photograph 6.2: Unlined Silver Process Control Dam (2 of 3)



Photograph 6.3: HDPE-lined Silver Process Control Dam (3 of 3)

The Witklip PCD (Photograph 6.4) is used a storage facility to supplement plant process water when the supply is exceeded by the demand. With the decommissioning of the Witklip pit, this PCD currently only receives water from rainfall and the Witklip borehole, but provides back-up storage for the Silver PCDs (Leeuwpan personnel, 2018).

Photograph 6.4: Witklip Dam

Photograph 6.5 shows Pit OD (South) which forms part of a number of open pits used to supply process water for the Leeuwpan mine. All the pits receive water from rainfall and groundwater ingress and losses are through evaporation. Pit OD has relatively large storage capacity could allow for storage and evaporation of surplus dirty water.

Pit OI (see Photograph 6.6) is a new pit that is being developed. Dewatering of this pit is likely to lead to significant excesses of dirty water if current water management practices are followed. After the completion of the cut, the open surface area for the OI pit will 3 010 000 m^2 and is assumed that any pit lake will be limited to only 5% of this surface area.

Photograph 6.5: Pit OD South

Photograph 6.6: New Pit OI

Large quantities of silt are contained in dirty water discharged from the plant area to a silt trap (Photograph 6.8). Although maintenance of a silt trap does take place, the volume of sediments in the Plant PCD (Photograph 6.8) suggests that the efficiency of the silt trap is low. This negates the effective storage capacity of the PCD and affects mine water balances.

Photograph 6.7: Silt trap

Photograph 6.8: Plant PCD

7 MINE WATER BALANCE

7.1 Process Flow Diagram and Linkages

The insights into how all water flow processes within the Leeuwpan mine are linked are presented with a Process Flow Diagram (PFD) which was confirmed by the client. The mine operational philosophy (obtained from the previous reports), site visit and the information obtained from the mine personnel were used to draft a PFD and to formulate the assumptions used in the calculation of the mine water balances. All this information is summarised as follows:

- All infrastructure footprint and catchment areas used in the water balance calculations are based on the provided infrastructure layout plan.
- One hundred (100) litres per person per day of potable water will be used by 1 094 permanent employees at the mine site (Leeuwpan personnel, 2018). It was assumed that of the 100 L supplied, 10% will be consumed and the remaining 90% is retuned into the system through the Phola sewer treatment facility.
- Raw water is abstracted from the Witklip, Henk's and Load Out boreholes and pumped into the Silver and Workshop Tanks with a capacity of 80 m^3.and 60 m^3, respectively as well as to the plant area. The three boreholes are licenced to abstract 68 200 m^3/a (Leeuwpan personnel, 2018).
- Silver Tanks supply raw water for domestic consumption and for gardening service in the office area whereas the workshop areas domestic is supplied by Workshop Tanks. An annual total of 40 000 m^3 of water is allocated for domestic water use in the workshop and office areas (Linstrom, 2017). Based on the number of permanent employees of the mine, the annual total volume of 34 242 m^3 is required for domestic use. An estimated volume of 3 424 m^3/a of water is consumed and 30 818 m^3/a returns to the system through Phola Sewage Treatment Plant (STP).
- Sewage effluent from the mine site is stored in ten (10) Conservancy Tanks (80 m^3) at the Phola STP near the workshop area where it is collected and transported out of mine site by a honey sucker.
- Rain falling onto the Wash bay low Lying dirty area (79 187 m^2) infiltrates and some runoff into the low-topography zones where it percolated into the ground. The clean Low Lying Area 2 (295 779 m^2) also experiences a similar hydrological phenomenon. Water losses in these areas are through evaporation from the ponded surfaces.

- There are currently five (5) dewatering open pit areas (OD north & south, OJ, OH & OM, Weltervreden OWM and Moabsvelden OWM) which are used as a source of water for mine processes through the Silver PCDs. These pits receive water from rainfall, groundwater ingress and surface runoff from the pits wall sloping into the pit. Groundwater ingress quantities to all pits were obtained from groundwater simulation results given in a hydrogeological report (GCS, 2014). Water losses are through evaporation from the open surface water and pit slopes.
- No measurements of rainfall and evaporation data are available for the qualification of inflow and outflows into the system. Therefore, it was assumed that between 15% and 25% of rain falling in the backfilled pits contributes to the pit sumps as runoff and is available for pumping. The backfilled voids and high porosity of the soils allows for large storage capacity of water which is assumed to percolate to the base of the local point of the pit.
- Rainfall, surface runoff, evaporation, and groundwater ingress estimated data for the open pits and other dirty water areas used in the calculation of the water balances are summarised in Table 7.1.
- Water from all pits is pumped into the Silver PCD's with the exception of the Witklip pit which is pumped into the Witklip PCD. However, the Witklip PCD is also connected to the Silver PCD's where it is used to supply when there is an increased demand and is also used to store water when there is surplus from the Silver PCD's (Leeuwpan personnel, 2018). The calculation of the water balances assumed that the two unlined dams (section 6) will be lined and there will be no groundwater seepage.
- The three (3) Silver PCD's are at the centre of mine process water. These PCDs store and supply water to the plant area for processing and for dust suppression which accounts for 10 200 m^3/year (Linstrom, 2017).
- The Leeuwpan mine has three plants: Crush and Stack, Dense Medium Separator (DMS), and Fraser DMS which were all assumed to be operation 24 hours per day for 313 days/year (GCS, 2014a). The average monthly and annual quantities of Run of Mine and Product processed by the three plants are summarised in Table 7.2. Estimation and the calculation of volumes of water balance components for the mine were based on the information obtained from the client. Based on the information provided, the following assumptions were made:
    - The Crush and Stack Plant use dry operation and does not use water.
    - Only the DMS and Fraser DMS plants use water.
    - ROM moisture was estimated at 4% whereas product moisture and other losses were at 8% and 4%, respectively (Linstrom, 2017).

- The average annual ROM and product sold from the mine are 151 200 m^3/tonn and 3 780 000 m^3/tonn. Total losses (product and plant loses) are estimated to be 4% (151 200 m^3/tonn) of the product sold (Linstrom, 2017).

Table 7.1: Rainfall, runoff, evaporation and groundwater ingress for the Leeuwpan Mine

Component	Area (m^2)	Rainfall (m^3/a)	Runoff (m^3/a)	Evaporation (m^3/a)	Groundwater Ingress (m^3/a)
Silver PCD's	43 000	28 724	-	26 161	HDPE lined
Witklip PCD	26 000	17 368	-	64 900	HDPE lined
Plant PCD	30 000	20 040	37 230	45 279	HDPE lined
Pit OD (North & South)	297 500	198 730	79 492	14 230	65 700
Pit OH & OM	114 788	76 678	26 837	114 557	29 200
Pit OI	3 010 000	2 010 680	603 204	13 416	219 000
Pit OJ	105 000	70 140	17 535	152 667	16 500
Weltervreden OWM Pit	900 000	601 200	240 480	311 551	65 700
Moabsvelden OWM Pit	117 667	78 602	31 441	132 797	65 700

Table 7.2: Leeuwpan Coal Mine average monthly and annual coal production (source: (Leeuwpan personnel, 2018)

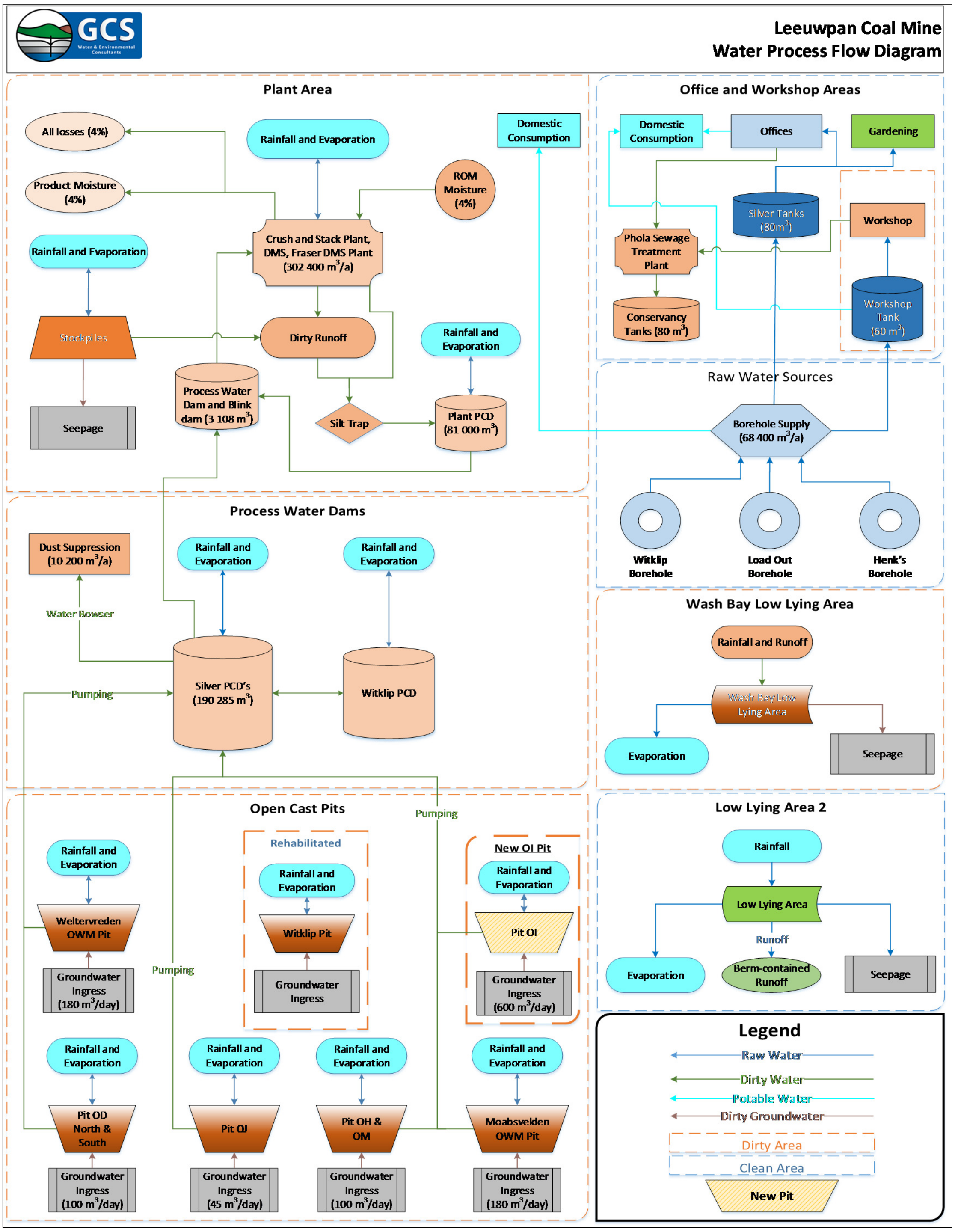
Plant	ROM		Product	
	(tonn/month)	(tonn/annum)	(tonn/month)	(tonn/annum)
DMS	7 381	2 310 253	2 899	907 387
Frazer DMS	5 776	1 807 888	2 298	719 274
Crush and Stack Plant	7 174	2 245 462	7 174	2 245 462

The client (Leeuwpan personnel, 2018) provided the measured volumes of raw water abstracted from the boreholes for the period January 2018 to August 2018 (Table 7.3). It is evident from the table that the mine is complying with their water use licence in terms of water abstraction. During the compilation of this report, the total volume of water abstracted from the boreholes for year 2018 accounts for 128 062 m^3, which is in excess of 63 862 m^3 of the licensed volume. The provision of these data was aimed at optimising the calculation of the mine components that use raw water. These data were, therefore, not used in the overall water balance calculations.

Table 7.3: Measured water volumes abstracted from Leeuwpan Coal Mine (all in m^3)

Boreholes	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Total
Witklip	13 035	17 553	16 308	17 898	9 693	16 877	17 525	18 777	127 666
Henks	28	34	34	26	33	16	23	24	218
Load Out	20	23	20	17	18	18	62	0	178
Total	**13 083**	**17 610**	**16 362**	**17 941**	**9 744**	**16 911**	**17 610**	**18 801**	**128 062**

Figure 7.1: Water Process Flow Diagram



7.2 Water Balances

Three water balances were calculated for the Leeuwpan Coal mine and are used to provide a general insight into the overall total water demands and uses. These include an annual average water balance (Table 7.4), an average monthly balance (Table 7.5) and an average daily water balance (Table 7.6).

All water balance calculations were based on the optimised volumes obtained from the mine personnel as well as the estimated calculations using hydrological principles. The inclusion of the OI block into the water balance calculations resulted in 372 796 m^3/a of excess water. This necessitates the requirement to provide an additional storage of dirty water within the plant site. The following recommendations are made in this regard:

- Pumping dirty water from the Silver PCD's to the Witklip PCD and allow it to evaporate.
- Due to the limitation of storage capacity of the Witklip PCD, complete the rehabilitation of the OWM Moabsvelden Pit, OWM Weltervreden Pit, Pit OJ and Pit OH & OM to reduce the quantities of water that have to be abstracted into the Silver PCDs.
- Pit OD (South and North) can be used as an additional storage facility because of large volume. This increase dirty water losses through evaporation.

In order to improve the accuracy of the mine water balances, it is recommended that additional flow meter and records of water flow volumes be conducted at:

- Flow meter at the outlet of the Silver PCDs to the plant beneficiation;
- Flow meter at the outlet of the Plant PCD to the plant beneficiation to account for water re-use volumes;
- Water abstractions from all dewatering pits should also be measured at the inlet of the Silver PCDs;
- Keep records of daily water volumes used for dust suppression and raw water usage from the boreholes.

Table 7.4: Average annual water balance

Annual Average Water Balance for Leeuwpan Coal Mine					
Facility Name	**Water In**		**Water Out**		**Balance**
Leeuwpan Coal Mine	**Water Circuit/stream**	**Quantity (m^3/year)**	**Water Circuit/stream**	**Quantity (m^3/year)**	
Raw Water	From: Witklip Borehole	30 864	To: Workshop	20 600	
	From: Henk's Borehole	36 336	To: Offices	20 400	
	From: Load Out Borehole	1 200	To: Plant offices	21 600	
			To: Gardening	5 800	
	Total	**68 400**		**68 400**	-
Domestic Consumption	From: Workshop	20 600	To: Phola STP	37 576	
	From: Offices	20 400	To: Domestic Consumption	3 424	
	Total	**41 000**		**41 000**	-
Phola Sewage Treatment Plant	From: Phola STP	37 576	To: Honey Sucker	37 576	
	Total	**37 576**		**37 576**	-
Plant Beneficiation (Crush and Stack, DMS, Frazer DMS)	From: Silver PCD's	139 209	To: Losses (other)	151 200	
	From: Plant PCD	11 991	To: Product Moisture	151 200	
	From: ROM Mositure	151 200			
	Total	**302 400**		**302 400**	-
Silver PCD's	From: Pit OD	39 665	To: Evaporation	64 900	
	From: Pit OH & OM	42 024	To: Plant Beneficiation	139 209	
	From: Pit OI	334 452	To: Dust Supression	10 200	
	From: Pit OJ	59 414	To: Witklip PCD	17 208	
	From: Weltevrededn OWM Pit	100 035	To: Excess	372 796	
	From: Rainfall	28 724			
	Total	**604 313**		**604 313**	-
Witklip PCD	From: Rainfall	17 368	To: Evaporation	26 161	
	From: Silver PCD's	17 208	To: Silver PCD's	8 415	
	Total	**34 576**		**34 576**	-
Plant PCD	From: Dirty Runoff Water	37 230	To: Evaporation	45 279	
	From: Rainfall	20 040	To: Plant Beneficiation	11 991	
	Total	**57 270**		**57 270**	-
Pit OJ	From: Groundwater Seepage	16 500	To: Evaporation	14 230	
	From: Rainfall	70 140	To: Storage/Losses	59 414	
			To: Silver PCD's	12 996	
	Total	**86 640**		**86 640**	-
Weltervreden OWM Pit	From: Groundwater Seepage	65 700	To: Evaporation	114 557	
	From: Rainfall	601 200	To: Storage/Losses	452 308	
			To: Silver PCD's	100 035	
	Total	**666 900**		**666 900**	-
Pit OD North and South	From: Groundwater Seepage	65 700	To: Evaporation	195 722	
			To: Silver PCD's	39 665	
	From: Rainfall	198 730	To: Storage/Losses	29 044	
	Total	**264 430**		**264 430**	-
Moabsvelden OWM Pit	From: Groundwater Seepage	65 700	To: Evaporation	13 416	
			To: Storage/Losses	102 025	
	From: Rainfall	78 602	To: Silver PCD's	28 860	
	Total	**144 302**		**144 302**	-
Pit OH & OM	From: Groundwater Seepage	29 200	To: Evaporation	63 855	
	From: Rainfall	76 678	To: Silver PCD's	42 024	
	Total	**105 878**		**105 878**	-
Pit OI	From: Groundwater Seepage	219 000	To: Evaporation	201 911	
			To: Storage/Losses	1 693 317	
	From: Rainfall	2 010 680	To: Silver PCD's	334 452	
	Total	**2 229 680**		**2 229 680**	-
Total Water Balance		**4 499 063**		**4 499 063**	-

Table 7.5: Average monthly balance

Monthly Average Water Balance for Leeuwpan Coal Mine					
Facility Name	**Water In**		**Water Out**		**Balance**
Leeuwpan Coal Mine	**Water Circuit/stream**	**Quantity (m^3/month)**	**Water Circuit/stream**	**Quantity (m^3/month)**	
Raw Water	From: Witklip Borehole	2 572	To: Workshop	1 717	
	From: Henk's Borehole	3 028	To: Offices	1 700	
	From: Load Out Borehole	100	To: Plant offices	1 800	
			To: Gardening	483	
	Total	**5 700**		**5 700**	-
Domestic Consumption	From: Workshop	1 717	To: Phola STP	3 131	
	From: Offices	1 700	To: Domestic Consumption	285	
	Total	**3 417**		**3 417**	-
Phola Sewage Treatment Plant	From: Phola STP	3 131	To: Honey Sucker	3 131	
	Total	**3 131**		**3 131**	-
Plant Beneficiation (Crush and Stack, DMS, Frazer DMS)	From: Silver PCD's	11 601	To: Losses (other)	12 600	
	From: Plant PCD	999	To: Product Moisture	12 600	
	From: ROM Mositure	12 600			
	Total	**25 200**		**25 200**	-
Silver PCD's	From: Pit OD	3 305	To: Evaporation	5 408	
	From: Pit OH & OM	3 502	To: Plant Beneficiation	11 601	
	From: Pit OI	27 871	To: Dust Supression	850	
	From: Pit OJ	4 951	To: Witklip PCD	1 434	
	From: Weltevrededn OWM Pit	8 336	To: Excess	31 066	
	From: Rainfall	2 394			
	Total	**50 359**		**50 359**	-
Witklip PCD	From: Rainfall	1 447	To: Evaporation	2 180	
	From: Silver PCD's	1 434	To: Silver PCD's	701	
	Total	**2 881**		**2 881**	-
Plant PCD	From: Dirty Runoff Water	3 103	To: Evaporation	3 773	
	From: Rainfall	1 670	To: Plant Beneficiation	999	
	Total	**4 773**		**4 773**	-
Pit OJ	From: Groundwater Seepage	1 375	To: Evaporation	1 186	
	From: Rainfall	5 845	To: Storage/Losses	4 951	
			To: Silver PCD's	1 083	
	Total	**7 220**		**7 220**	-
Weltervreden OWM Pit	From: Groundwater Seepage	5 475	To: Evaporation	9 546	
	From: Rainfall	50 100	To: Storage/Losses	37 692	
			To: Silver PCD's	8 336	
	Total	**55 575**		**55 575**	-
Pit OD North and South	From: Groundwater Seepage	5 475	To: Evaporation	16 310	
			To: Silver PCD's	3 305	
	From: Rainfall	16 561	To: Storage/Losses	2 420	
	Total	**22 036**		**22 036**	-
Moabsvelden OWM Pit	From: Groundwater Seepage	5 475	To: Evaporation	1 118	
			To: Storage/Losses	8 502	
	From: Rainfall	6 550	To: Silver PCD's	2 405	
	Total	**12 025**		**12 025**	-
Pit OH & OM	From: Groundwater Seepage	2 433	To: Evaporation	5 321	
	From: Rainfall	6 390	To: Silver PCD's	3 502	
	Total	**8 823**		**8 823**	-
Pit OI	From: Groundwater Seepage	18 250	To: Evaporation	16 826	
			To: Storage/Losses	141 110	
	From: Rainfall	167 557	To: Silver PCD's	27 871	
	Total	**185 807**		**185 807**	-
Total Water Balance		**374 922**		**374 922**	-

Table 7.6: Average daily water balance

Daily Average Water Balance for Leeuwpan Coal Mine					
Facility Name	**Water In**		**Water Out**		**Balance**
Leeuwpan Coal Mine	**Water Circuit/stream**	**Quantity (m^3/day)**	**Water Circuit/stream**	**Quantity (m^3/day)**	
Raw Water	From: Witklip Borehole	85	To: Workshop	56	
	From: Henk's Borehole	100	To: Offices	56	
	From: Load Out Borehole	3	To: Plant offices	59	
			To: Gardening	16	
	Total	**187**		**187**	-
Domestic Consumption	From: Workshop	56	To: Phola STP	103	
	From: Offices	56	To: Domestic Consumption	9	
	Total	**112**		**112**	-
Phola Sewage Treatment Plant	From: Phola STP	103	To: Honey Sucker	103	
	Total	**103**		**103**	-
Plant Beneficiation (Crush and Stack, DMS, Frazer DMS)	From: Silver PCD's	381	To: Losses (other)	414	
	From: Plant PCD	33	To: Product Moisture	414	
	From: ROM Mositure	414			
	Total	**828**		**828**	-
Silver PCD's	From: Pit OD	109	To: Evaporation	178	
	From: Pit OH & OM	115	To: Plant Beneficiation	381	
	From: Pit OI	916	To: Dust Supression	28	
	From: Pit OJ	163	To: Witklip PCD	47	
	From: Weltevrededn OWM Pit	274	To: Excess	1 021	
	From: Rainfall	79			
	Total	**1 656**		**1 656**	-
Witklip PCD	From: Rainfall	48	To: Evaporation	72	
	From: Silver PCD's	47	To: Silver PCD's	23	
	Total	**95**		**95**	-
Plant PCD	From: Dirty Runoff Water	102	To: Evaporation	124	
	From: Rainfall	55	To: Plant Beneficiation	33	
	Total	**157**		**157**	-
Pit OJ	From: Groundwater Seepage	45	To: Evaporation	39	
	From: Rainfall	192	To: Storage/Losses	163	
			To: Silver PCD's	36	
	Total	**237**		**237**	-
Weltervreden OWM Pit	From: Groundwater Seepage	180	To: Evaporation	314	
	From: Rainfall	1 647	To: Storage/Losses	1 239	
			To: Silver PCD's	274	
	Total	**1 827**		**1 827**	-
Pit OD North and South	From: Groundwater Seepage	180	To: Evaporation	536	
			To: Silver PCD's	109	
	From: Rainfall	544	To: Storage/Losses	80	
	Total	**724**		**724**	-
Moabsvelden OWM Pit	From: Groundwater Seepage	180	To: Evaporation	37	
			To: Storage/Losses	280	
	From: Rainfall	215	To: Silver PCD's	79	
	Total	**395**		**395**	-
Pit OH & OM	From: Groundwater Seepage	80	To: Evaporation	175	
	From: Rainfall	210	To: Silver PCD's	115	
	Total	**290**		**290**	-
Pit OI	From: Groundwater Seepage	600	To: Evaporation	553	
			To: Storage/Losses	4 639	
	From: Rainfall	5 509	To: Silver PCD's	916	
	Total	**6 109**		**6 109**	-
Total Water Balance		**12 326**		**12 326**	-

8 CONCLUSIONS

The main conclusions derived from this study based on the water balances computation are presented below:

- The greater Leeuwpan Coal mine is located in a temperate climatic zone of South Africa which is characterised by wet hot summers and dry cold winters. A Mean Annual Precipitation (MAP) and Mean Annual Evaporation (MAE) of 667 mm and 1 677 mm, respectively, is experienced by the area.
- Raw water for domestic consumption is abstracted from three (3) boreholes which have a licenced annual allocation of 68 000 m^3 and is stored in the Silver tanks (Mine offices) and Workshop tanks. The recorded abstraction volumes for the period January 2018 to August 2018 show that the mine does not comply with raw water use licences as the volumes exceeded the licenced volume. Due to the lack of flow records at the end users, not conclusive explanations were provided as to where could these quantities of water are used.
- Sewage effluent is stored and collected by a honey sump from Phola Sewage treatment Plant, however, there are no measurements of the actual quantities of water taken out of the site for treatment.
- Due to the lack of water flow volume data in most components of the mine, water balance calculations were based on assumptions drawn from the information received and using the principles of hydrological system.
- A total of six (6) dewatering open pits (including OI Pit) are the source of mine plant process water. Water from these pits is pumped into the Silver PCD's where it is used for plant beneficiation (302 400 m^3/a) and dust suppression (10 200 m^3/a).
- The total volume of water required for the Plant Beneficiation process was calculated at 139 209 m^3/a from the Silver PCDs and 11 991 m^3/a re-used water from the Plant PCD.
- It was calculated that when the OI pit is dewatering, the mine site will have an excess of 372 796 m^3/a of mine water, based on the assumption that the process plant demand will remain similar to the current status. Additional mine water storage that can allow water to evaporate or be treated and discharged into the surrounding environment is required.

9 RECOMMENDATIONS

Recommendations made as a result of this study include:

- Water flow meters should be installed to monitor inflows into and outflows from; the Plant Beneficiation, Silver PCDs, dust suppression bowser, and Phola Sewage Treatment Plant (STP). Flow volume data will provide a better understanding of water flow patterns at the mine and facilitate the calibration of more accurate water balance calculations.
- Upgrading of, and improved maintenance of, the silt trap at the Plant PCD. This will improve efficiency of the system and mitigate sedimentation in the Plant PCD.
- Raw water abstractions from boreholes should be monitored to ensure that the mine adheres to conditions of the water use licence issued for the mine. Flow volume data for the period January 2018 to August 2018 suggests that raw water on the mine has increased, which implies that the mine should apply for a new water use license that reflects current and future demands.
- Additional storage for excess water expected from the dewatering of the new OI pit needs to be planned. Water storage issues can be addressed as follows:
    - Back-filled pits that are far from the plant area should be rehabilitated in order to reduce the quantities of water flowing into the Silver PCD.
    - Use Pit OD (South and North) as a storage facility. This will allow storage of some excess water, and allow for increased evaporative water losses.
    - Pump water from the Silver PCDs into the Witklip PCD where water will evaporate or could be treated and discharged back into the environment.

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