Operational Mine Water Balance for the proposed Doornhoek Fluorspar Mine, North West Province

An EOH Company

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Prepared for: **SA Fluorite (Pty) Ltd**

Prepared by: **Exigo**

Email info@exigo3.com
Tel +27 012 751 2160
Fax +27 086 607 2406
The Village Office Park (Block E), 309 Glenwood Road, Faerie Glen, Pretoria, 0043
Postnet Suite 74, Private Bag X07, Arcadia, 0007

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www.exigo3.com

Operational Mine Water Balance for the Doornhoek Fluorspar Mine, North West Province

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Conducted on behalf of:
SA Fluorite (Pty) Ltd

Compiled by:
JC Vivier (PhD Environmental Management; Pr.Sci.Nat)

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Name	Institution
Mr A Saad	SA Fluorite (Pty) Limited & Southern Palace 398 (Pty) Limited

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1 INTRODUCTION

The NWA introduced the concept of Integrated Water Resource Management (IWRM), comprising all aspects of the water resource, including water quality, water quantity and the aquatic ecosystem quality (quality of the aquatic biota and in-stream and riparian habitat). The IWRM approach provides for both resource directed and source directed measures. Resource directed measures aim to protect and manage the receiving environment. On the other hand, source directed measures aim to control the impacts at source through the identification and implementation of pollution prevention, water reuse and water treatment mechanisms.

The integration of resource and source directed measures forms the basis of the hierarchy of decision-taking aimed at protecting the resource from waste impacts. The DWS has developed a series of Best Practice Guidelines (BPGs) for mines in line with International Principles and Approaches towards sustainability. Accurate water balances are considered to be one of the most important and fundamental water management tools available to the mines. According to the BPG's, the purpose of water and salt balances includes:

- Providing the necessary information that will assist in defining and driving water management strategies;
- Auditing and assessment of the water reticulation system, with the main focus on water usage and pollution sources. This includes identifying and quantifying points of high water consumption or wastage, as well as pollution sources. Seepage and leakage points can also be identified and quantified when the balances are used as an auditing and assessment tool;
- Assisting with the design of storage requirements and minimising the risk of spillage;
- Assisting with the water management decision-making process by simulating and evaluating various water management strategies before implementation.

SA Fluorite (Pty) Limited & Southern Palace 398 (Pty) Limited intends to develop a fluorspar operation at the Doornhoek Fluorspar Project in the Zeerust District of the North West Province. The project falls under the jurisdiction of the Ditsobotla and Ramotshere Moiloa Local Municipalities located within the Ngaka Modiri Molema District Municipality (Figure 1). The project area is located between Zeerust, Mahikeng and Lichtenburg and borders the eastern section of Mahikeng Local Municipality. The project site is located approximately 220 km west of Johannesburg and 18 km south of the town of Zeerust. The proposed site is adjacent to the Witkop open pit fluorspar mine. Figure 1 indicates the location of the project site.

2 THE PROJECT

The proposed Doornhoek fluorspar mine will predominantly mine fluorspar along with the associated minerals. Lead, Zinc and copper are often associated with fluorspar deposits and vanadium is known to occur in the area. These minerals may be extracted simultaneously with the fluorspar or may be extracted later. Open pit mining would be carried out using a typical drill and blast operation, loading of ore and overburden by excavators and hauling by dump trucks. The stripping ratio for the 1.5 Million tons per annum (Mtpa) open pit scenario averages 3.8 waste to ore (w:o) ratio over the life of mine (LOM). Overburden would be hauled to a designated overburden dump during the early years of the LOM.

Due to the large area applied for and the extent of the orebody, it is estimated that the project will take at least five years of pre-development prior to any mining activities commencing. Therefore a five (5) to six (6) year pre-production period is anticipated, including the plant construction which will take 2-3 years.

For the purpose of water supply assessment an operational scenario was assumed at full production of 562 500 t/month.

Proposed mine infrastructure will consist of the following (Figure 2)

- Ore Handling and Storage facilities
- Overburden and topsoil dumps
- General Buildings
- Potable, Storm water Dams and Service Water Dams
- Processing Plant
- Emergency and Power facilities (substations)
- Fuel Storage
- Site Access Road and Haul Roads
- Tailings Storage Facility (TSF)
- Water and sewage reticulation
- Sewage Treatment Plant
- Water Treatment Plant

Figure 1 Project Locality Map

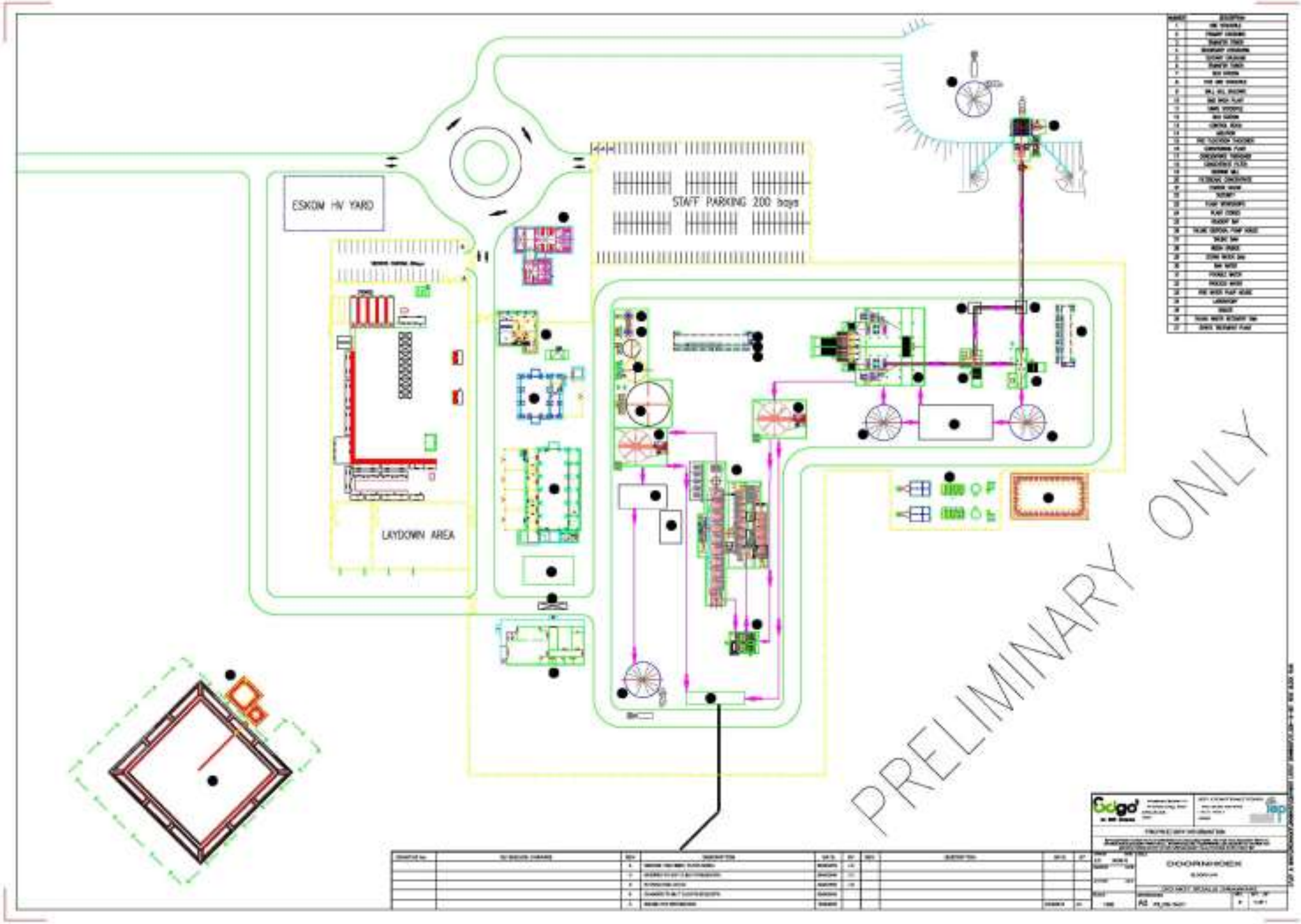

Figure 2 Plant Layout Block Plan

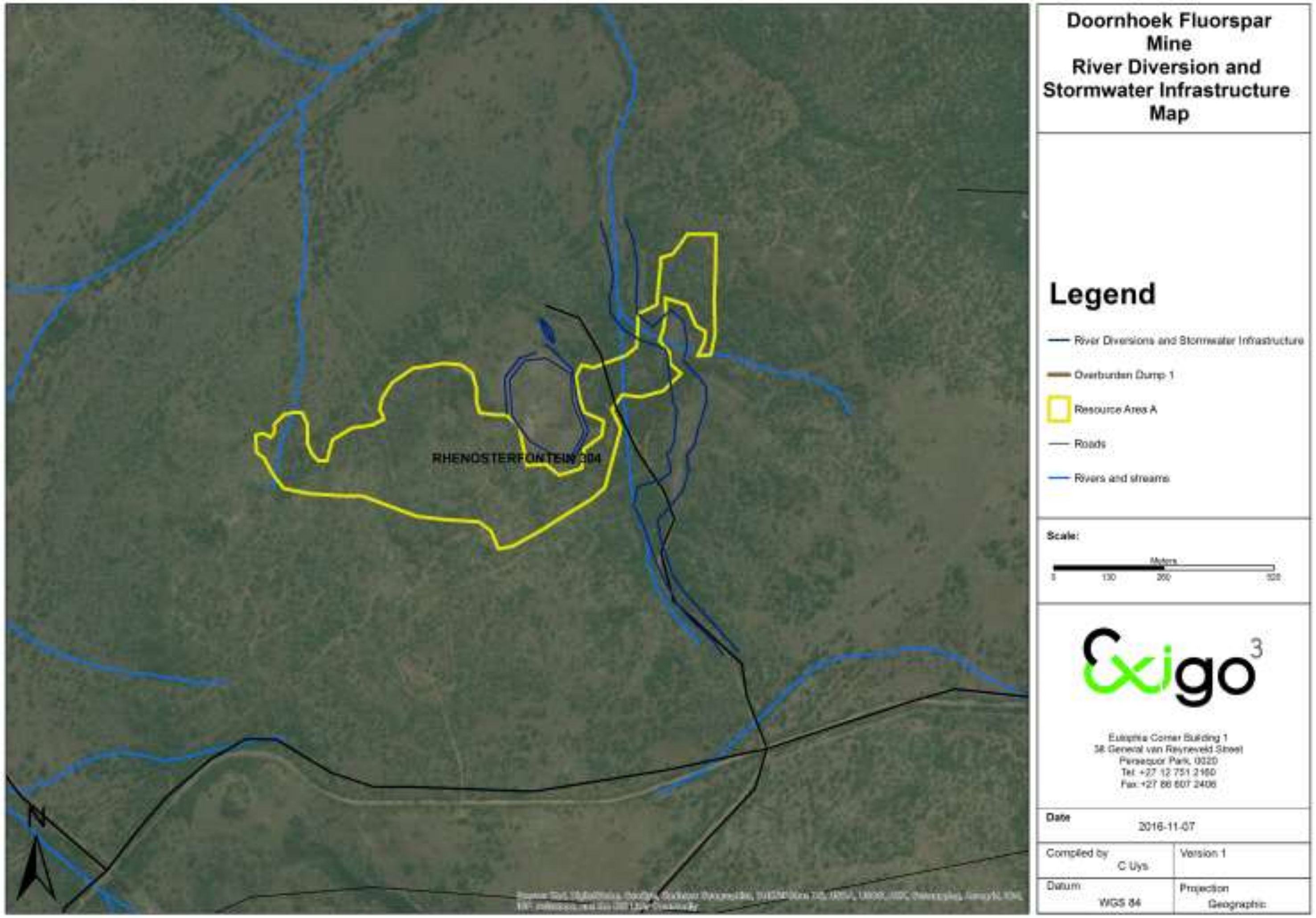

Figure 3 **Site Layout Plan and Storm water Infrastructure Resource Area A**

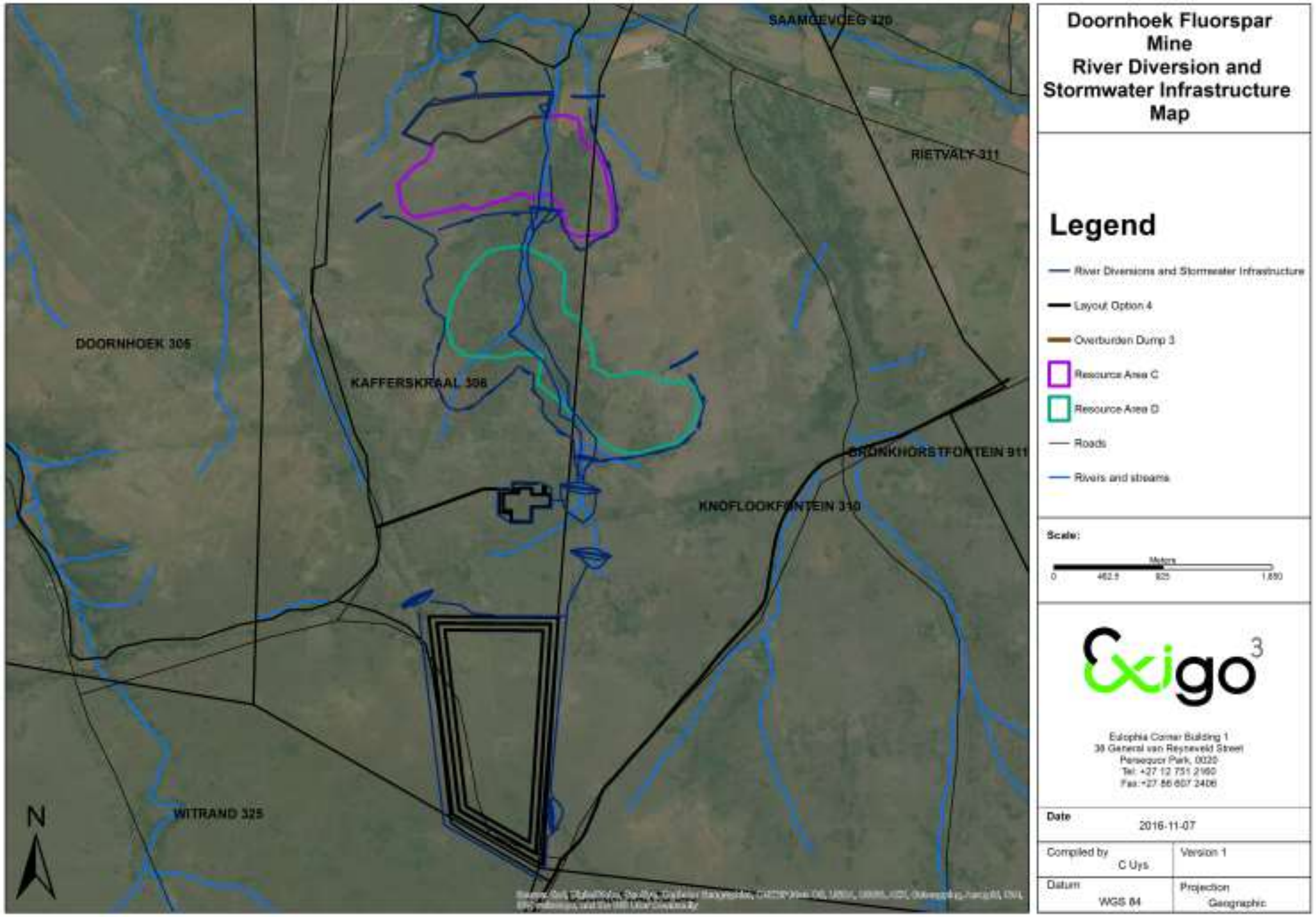

Figure 4 Site Layout Plan and Storm water Infrastructure Resource Area C and D

3 ASSUMPTIONS AND LIMITATIONS

The water balance is conceptual and is subject to further feasibility studies and supporting engineering designs. The list of assumptions is detailed in **Table 4**.

4 WATER USES AUTHORISED

An Integrated Water Use License Application (IWULA) for the mining development will be submitted to the Department of Water and Sanitation (DWS) during the EIA Phase of the project.

5 DEVELOPMENT OF THE WATER BALANCE

5.1 Objective of the balances

The objective of this water balance is to:

- Assess make-up water requirements during the operational phase of the project taking into account drought and flood scenarios;

5.2 Boundaries of the balance

The boundaries of the balances include the following aspects:

- Water Supply from an external source
- Open pit mining operations and associated dewatering
- On-site Storm water Management
- Plant Complex with Tailings Storage Facility and Return System

6 DESCRIPTION OF THE WATER CIRCUIT AND DEVELOPMENT OF A SCHEMATIC FLOW DIAGRAM

The water balance for the Doornhoek Operations is developed in accordance with the DWA, 2006 Best Practice Guideline G2: Water and Salt Balances (DWAF, 2006a). A static xls based model was developed for the operation assuming the following water sources and sinks identified from the site layout plan and project description (Table 1):

Table 1 Sources and Sinks

Sources	Sinks
• Rain • Fissure water • Storm water Run-off (dirty water cycle) • Treated Sewage water	• Mining losses (drilling, evaporation, water in ore) • Evaporation • Seepage TSF and Storm Water Dams • Potable water consumption (Mining, Change Houses, Workshops and Offices) • Fire Water • Dust Suppression

6.1 Climatic Data

The study area falls within a summer rainfall region, with over 96% of the annual rainfall occurring during the October to April period. Mean monthly rainfall records, as recorded at the station no. 0509283 for 2013, are summarised in Table 3 and Figure 5. The Average mean annual precipitation in the area is 575 mm/a with a minimum of 291 mm/a and maximum of 1040 mm/a.

Evaporation data was available for the period 1987 to 2015. Average monthly evaporation data for the period is presented in the table below:

Table 2 Average Monthly Evaporation Data (1987 – 2015 A3E003)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	205	186	174	138	122	105	119	162	214	247	236	223

Table 3: Rainfall Statistics (station no. 0509283, 1928 - 2012).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
Average	97.6	88.6	80.8	44.5	15.7	8.4	2.8	5.0	14.6	48.2	69.7	99.1	574.9
Maximum	301.2	277.0	234.9	206.5	90.3	140.9	72.9	62.2	88.5	193.0	214.8	249.6	1040.4
Minimum	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	291.0
Lower 5th	28.8	25.7	13.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	10.5	17.8	327.3
Upper 95th	207.7	220.1	175.6	129.4	57.3	35.7	15.4	30.9	71.7	119.2	162.5	194.0	816.4
Lower 2nd	19.7	14.1	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	14.3	295.1
Upper 98th	230.9	253.4	196.4	136.6	66.6	47.7	26.0	36.6	82.6	137.5	174.5	231.8	1016.1

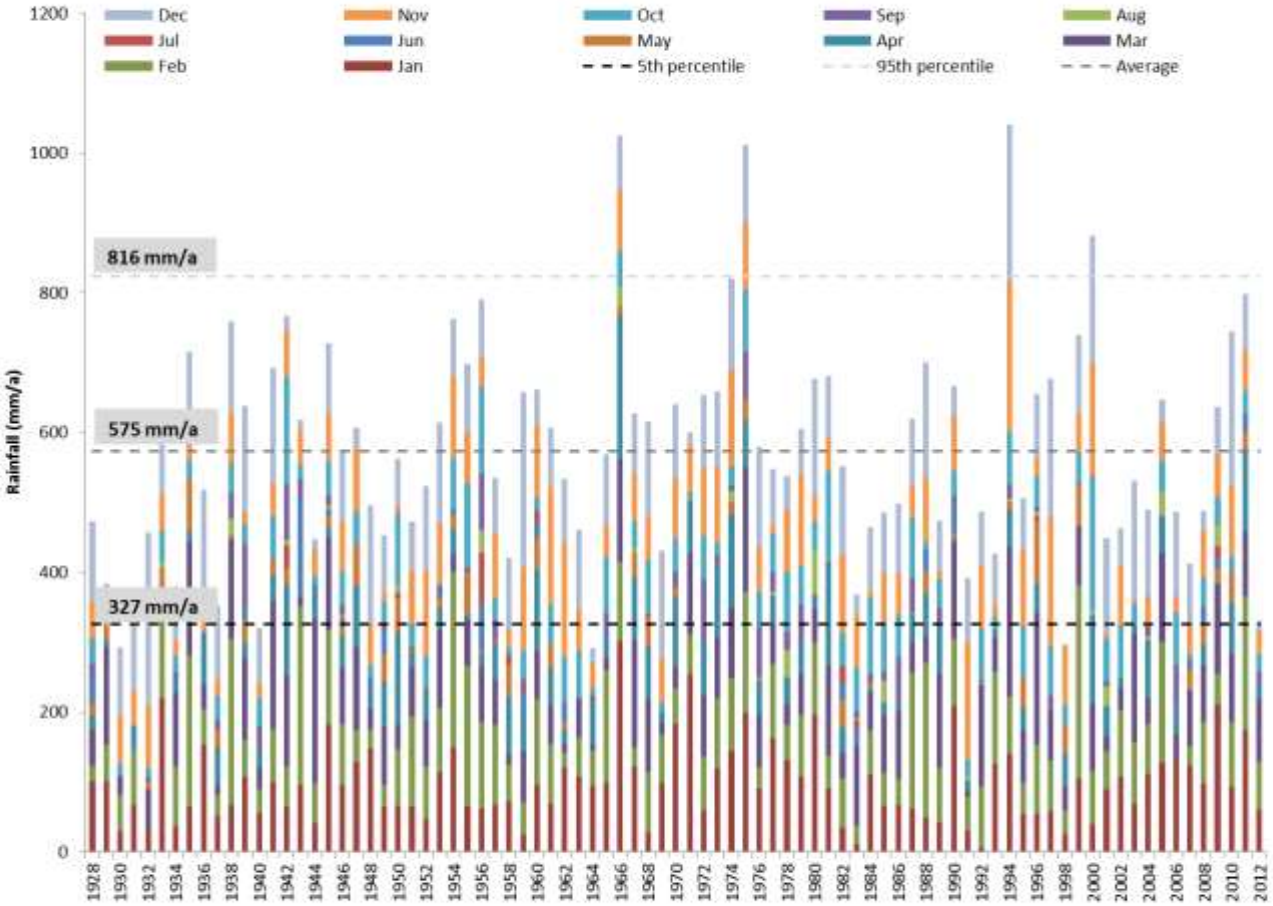

Figure 5: Rainfall graph (station no. 0509283, 1928 - 2012)

6.2 Water Supply

The following water supply options were identified (refer to Section 8.4.1 of the Environmental Impact Assessment and Environmental Management Programme Report (EIA&EMPR):

- Municipal supply – Witkop Mine infrastructure (transfer of Witkop water allocation).
- Grey water discharge from Zeerust sewage treatment plant. Water transferred via Witkop infrastructure or via a new pipeline.
- Expansion and additional development of current groundwater supply for municipal use and utilization of Witkop infrastructure.
- Development of a standalone wellfield, targeting dolomitic formations south and southeast of the project area.
- Transfer of existing irrigation water allocations from the Zeerust dam, use of groundwater from existing boreholes no longer in use by landowners.

Groundwater supply was identified as the preferred option for further development.

6.3 Water Balance

6.3.1 Assumptions and Input Parameters

Assumptions, input parameters and associated references are detailed in the table below (Table 4).

Table 4 Input parameters and Assumptions

	Description	Amount	Comment
Plant	Mine production (t/annum) (ROM) (avg)	6,750,000	Ramp Up Figures Provided by ENRC
	Mine production (t/month) (ROM) (avg)	562500	Calculated
	Plant feed (% of total mined ore only)	22%	Client
	Product (% of plant feed)	16.0%	20 000t/m acid grade filter cake, EMPR, 2016
	Moisture in product (%)	8.0%	EMPR, 2016
	Mining water use (m^3/ton)	0.01	Assumption
	Plant feed (Tailings) post crush dry density (1)	1.8	Client
	Tailings slurry density (1)	1.2	Client
	Balance factor (%)	10%	
	Plant beneficiation process water use ($m^{3/t)}$	0.01	Assumption
	TSF Deposition Rate (% of Plant Feed)	84%	PEA Report, Applied conversion rate
Construction	No People (during construction)	222	EMPR, 2016
	Water used (l/person/day)	120	

	Description	Amount	Comment
Operational People	No People	220	ENRC, SLP
	Water used (M3)	120	
Mining area	Waste as a % of RoM	78%	
	Waste rock moisture content (%)	4%	Assumption
	Ore moisture content (%)	8%	Assumption
	Water Returned from rainwater on Open pits (%)	30%	
	Fissure Water (m3/month)	60000	Modeled (Exigo, 2016) Sustainable year 13
Tailings Storage Facility	Water returned from tailings dam (%)	40%	
	Seepage to aquifer (%)	15%	Modelled: 700m3/day
	Evaporation pond (%)	35%	
	Interstitial lock-up (%)	10%	
	Total tailings losses (%)	60%	
		100%	
Waste rock dump	Infiltration & seepage to groundwater (% of rain)	0%	
Sewage works	Sewage water to plant	Yes	**Options**
	Sewage water in out ratio (%)	90%	Assumption
	Sewage Outflow to Sewage Works	No	

6.3.2 Clean Water Circuit

Water from the External Water Source will be pumped to a Raw Water Reservoir from where it will be distributed to the Treatment Plant and Process Water Reservoir. From the water treatment plant potable water will be distributed to the change houses, offices, workshops and mine workings.

The average volume potable water required for consumption within the Offices, Workshops, Mining and Change House was calculated to be on average 810 m^3/month.

The clean water circuit will be supplemented with water from boreholes, which is currently the preferred water supply option.

6.4 Mining Operations and Dewatering

Service water will be pumped from the raw water reservoir to the opencast workings and recycled via settling dams and Mining Reservoir 1. From Mining Reservoir 1, water will report to the Process Water Dam from where it will be used within the plant water circuit. Make-up water is required and will be obtained from (**Figure 7**):

- Fissure water inflow
- External Water Source (Wellfields)
- Storm water Run-off

- Rainfall on the open pit areas

At an average mining rate of 562 500 tonnes/month the water requirement for dust suppression, blasting and drilling was calculated to be 5625 m^3/month. Losses were also attributed to the following:

- Evaporation and moisture out via overburden and waste rock: 17550 m^3/month
- Moisture out to product: 9900 m^3/month
- Losses through the settlers: 3380 m^3/month
- Excess water to the process water reservoir for top-up in the plant: 63329 m^3/month

Sources were made up of the following aspects:

- Rainfall on the open pit areas: 16769 m^3/month
- Fissure water: 60 000 m^3/month

The graph below illustrates the simulated inflows during steady state production. The average sustainable fissure contribution to Make-up water was simulated at 60 000m^3/month (6)

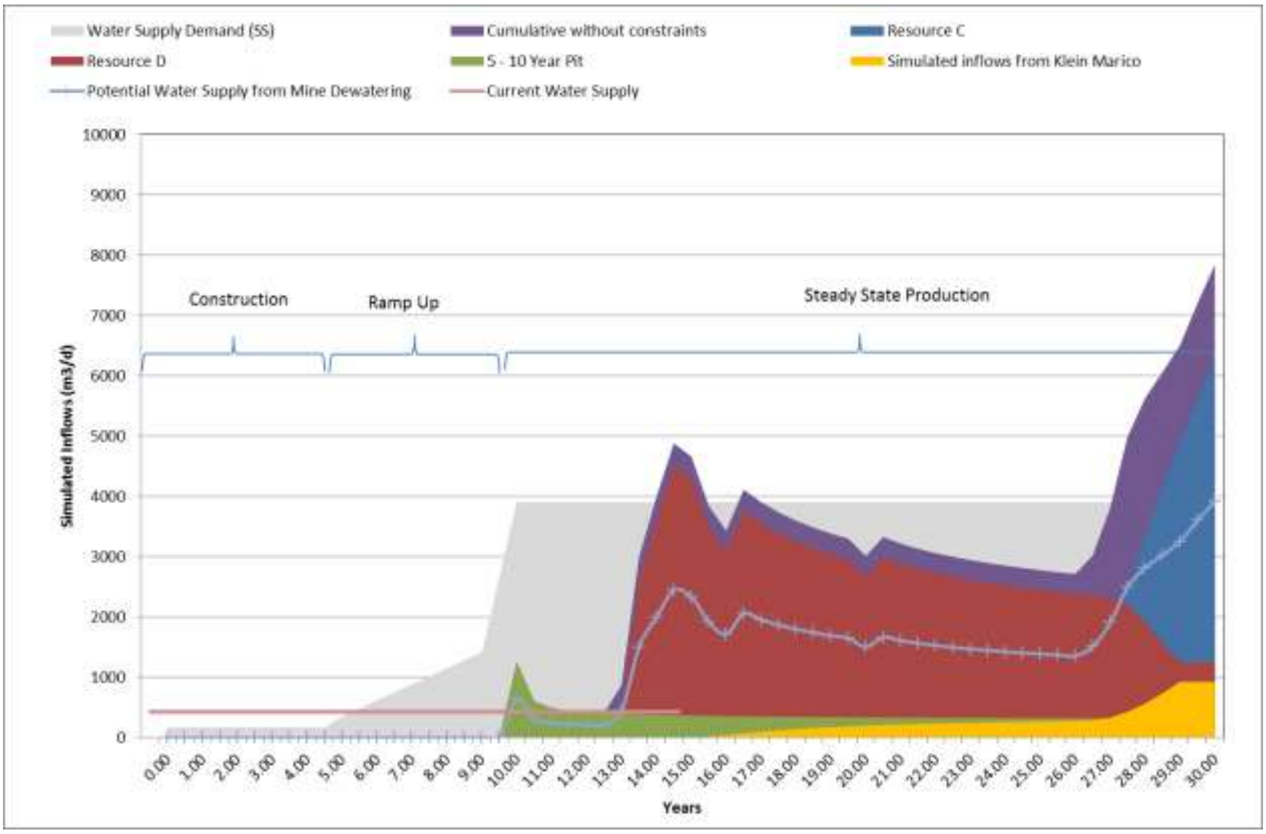

Figure 6 Simulated volumes associated with mine dewatering

6.5 Plant Water Circuit

The plant receives make-up water from the Wellfields, and fissure water from the Open pit mining operations (Figure 6). The plant water flow components are discussed in this section.

Process Water Reservoir

The Process Water Dam (PWD) receives make up water from the Raw Water Reservoir and the Mining Reservoir 1. . The Concentrator Plant does not require water of a particular quality and uses water that is recycled from various sources, (i) the Tailings Thickener, (ii) the Tailings Storm water Dams, (iii) the Return Water Dam (iv) Sewerage Treatment Works and (v) Excess Fissure Water from the Opencast Workings.

Contact water from the plant area flows to the Plant Storm water Dam. The purpose of the Plant SWD is to prevent contaminated run-off from the plant area from flowing into the environment. Water from this reservoir is pumped to the Process Water Dam when capacity has been reached to limit the risk of the Plant Storm Water Reservoir from overflowing during storm events.

Provision has been made in the water balance for the beneficiation processes within the plant (1235 m^3/month) and water losses through the product stockpiles (1584 m^3/month).

6.6 Tailings Disposal Facility and Return Water Circuit

Thickened tailings from the Tailings Thickener is pumped to the Tailings Disposal Facility (surface area 150 ha) where excess water is recovered via a penstock and under drains and stored in the Return Water Dam (RWD) from where it is recycled back to the Concentrator Plant. The RWD will be a lined facility. When the Concentrator Plant cannot receive any more water, the RWD will overflow into the Tailings Disposal Facility Storm Water Dam/s with a total capacity of 79 010 m^3.

The Tailings Disposal Facility Storm Water Dam (TDFSWD) system has a surface area of 48148 m^2. The dams' relative position to the TSF is detailed in **Error! Reference source not found.**.

To keep the TDFSWD as empty as possible at all times, water will be pumped back via a sump to the RWD when the RWD is not full. This reservoir will be designed to comply with the requirements of Regulation GN704 and is the last resort for any excess water on the mine.

The following sinks were identified within the Tailings and Return Water Circuit:

- Seepage to the aquifer: 23388 m^3/month
- Evaporation Losses from the surface area of the TSF and the Return water Dam: 71174 m^3/month
- Interstitial Lock Up within the TSF Facility: 15592 m^3/month

Water returned from the circuit for re-use in the plant is on average 60087 m^3/month and the contribution from rainwater on the TSF is 21560 m^3/month.

The flows and return flows are presented in Figure 8.

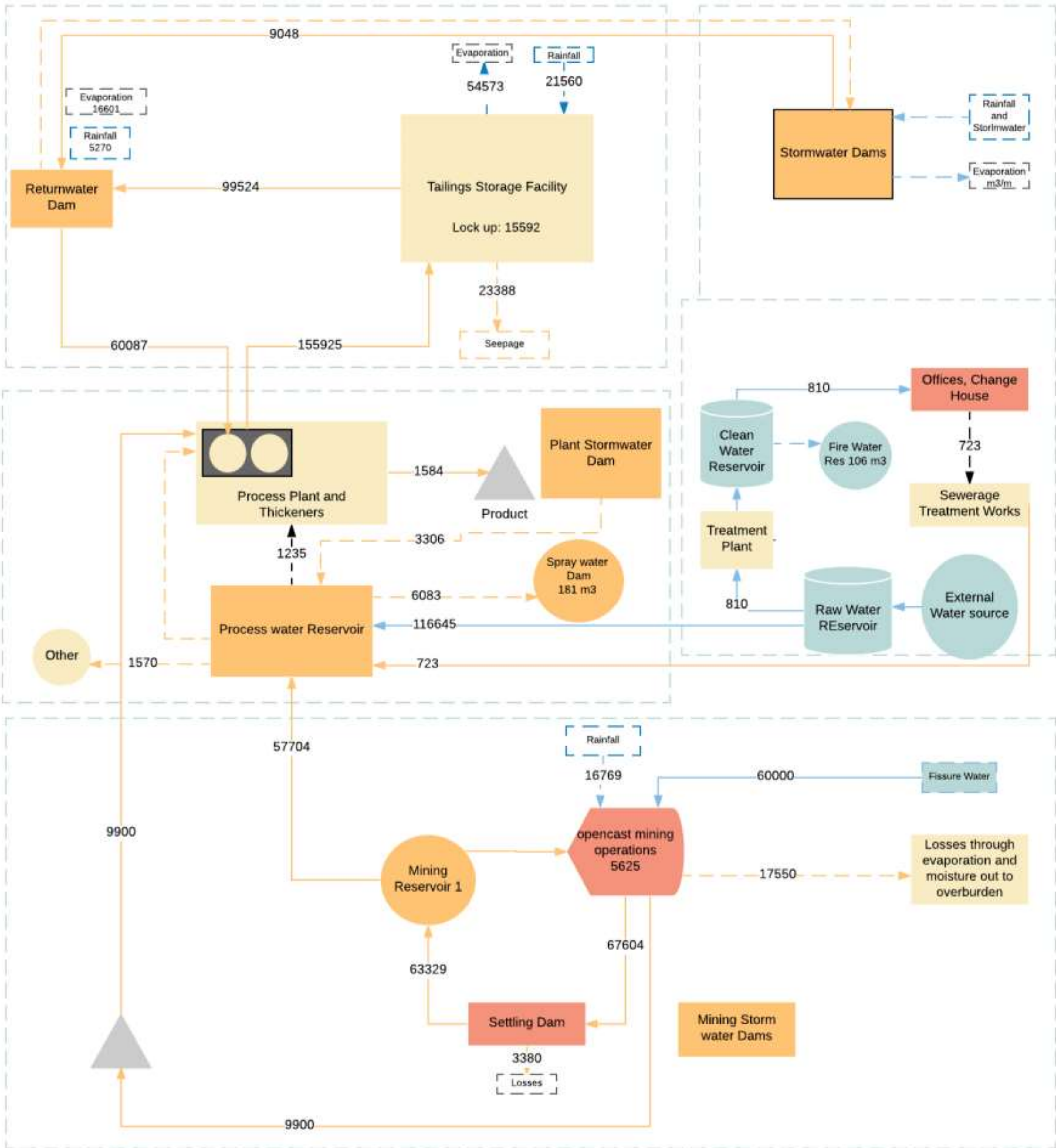

Figure 7 Water reticulation and average monthly flow rates

6.7 Storm water Management

Different layout options regarding the mining plant, offices, parking and ore dump sites were investigated. All storm water and other effluent originating from these areas were treated as dirty water. The dirty water will have to be intercepted and prevented from flowing into the clean water systems after a rain storm. The preferred option is presented in Figure 4**Error! Reference source not found.**. Apart from the canals four dams are also needed. The dam wall heights will vary from 2,5m to 4,5m. The total combined storage capacity will be 149 010 m3. A storm water dam of 1700 m^3 will be constructed at the overburden dump at Resource A and another stormwater dam of 19 000 m^3 will be constructed at the overburden dump at Resource C.

The net water contribution from the storm water management reservoirs are:

- 9048 m^3/month from the tailings storage storm water dams
- 3306 m^3/month from the plant storm water dam (during rain events)

6.8 Results and Discussion

The average monthly flows are presented in Figure 7. Selected Sources at Sinks at average flow rates are presented in Figure 8 and Figure 9. Results are summarised below:

- The average calculated make-up water from the external water source (wellfields) at full production is 116 654 m^3/month (3830 m^3/day). The average tonnes of ore processed at full production 123 750 tonnes per month. The average water use per tonne of ore processed was calculated at 0.94 m^3/tonnes of ore which is within the expected range of between 0.7 m^3/t to 1.2m^3/t for similar mining developments.
- The average percentage calculated for water returned from the TSF was 40 % with 60 % losses as a result of interstitial lock-up, seepage and evaporation. The seepage component of 23 388 m^3/mon must be recaptured and pumped back to the system.
- Fissure water available for make-up water in the concentrator plant is on average 60 000 m^3/month
- A 1:50 year drought and 1:50 flood were also simulated. Make-up water requirements vary between 161,283 m^3/month (drought) and 871 m3/month (excessive wet year). Provision needs to be made in the storm water management plan to accommodate extra volumes of storm water during flood scenario's. Since the Water Balance is at pre-feasibility level, a safety factor of 20% was applied to accommodate drought periods where storm water and fissure water may not be adequate to supplement the demand. This equates to a monthly make-up volume of 137 880 m^3/month that would need to be secured from external sources.
- Provision needs to be made for construction and ramp-up requirements prior dewatering.

6.9 Conclusion

This water balance has focussed on assessing make-up water requirements during the operational phase of the project taking into account drought and flood scenarios; with recommendations on the optimisation of water uses and scheduling. The simulated drought flood conditions result in the make-up water requirements varying. Groundwater is proposed as the preferred water supply option (Refer to Section 8.4.1 of the Environmental Impact Assessment and Environmental Management Programme Report (EIA&EMPR)). The opportunity exists for optimization of the average water use per tonne of ore processed as well as increasing the returns from the TSF.

The net fissure water that is available for make-up water in the concentrator plant will be further refined following the recommendations made in the hydrogeological assessment. Including, amongst other that the characteristics/integrity of the dyke structures be further evaluated by means of conducting geophysics surveys, drill and test sets of boreholes to evaluate the hydraulic connectivity of compartments, the material properties of the dykes and obtain the necessary spatial head distribution for model calibration.

The findings from this report will be included in support of the Integrated Water Use License Application (IWULA) for the mining development to be submitted to the Department of Water and Sanitation (DWS). In line with the relevant BPG’s, this water balance provides the necessary information that will assist in defining and driving water management strategies going forward, and in future will assist with the auditing and assessment of the water reticulation system, including the identifying and quantifying points of high water consumption or wastage, as well as pollution sources. It is recommended to be utilized with the water management decision-making process before the implementation thereof.

Figure 8 **Water Sources (m3/month p50)**

Figure 9 Sinks (m3/month/ P50)

7 REFERENCES

Department of Water Affairs and Forestry, 2006. Best Practice Guideline G2: Water and Salt Balances.

Meyer, SM, JFW Mostert and Vivier, JJP. 2016. Doornhoek Fluorspar Mine: Hydrogeological Specialist Investigation. ES16/068