PROPOSED WEST WITS MINING PROJECT: SURFACE WATER STUDY

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Project Manager	Kevin Bursey
Project Manager e-mail	kbursey@slrconsulting.com
Author	Chenai Makamure and Kevin Bursey
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EXECUTIVE SUMMARY

Introduction

SLR Consulting (South Africa) (Pty) Ltd (SLR) was appointed by West Wits MLI (Pty) Ltd (West Wits) to undertake a Technical Specialist Surface Water Study as part of the Environmental Impact Assessment (EIA) process for an application for a Mining Right for the proposed West Wits MLI (Proprietary) Limited (West Wits) mining operation in City of Johannesburg Metropolitan Municipality, Gauteng Province.

The proposed West Wits mining operation would be located south of Roodepoort and to the north of Soweto in the City of Johannesburg Metropolitan Municipality, Gauteng.

In broad terms the proposed project would involve the development of five open pit mining areas (referred to as the Mona Lisa Bird Reef Pit, Roodepoort Main Reef Pit, Rugby Club Main Reef Pit, 11 Shaft Main Reef Pit and Kimberley Reef East Pit in Figure 2-4) and refurbishment of two existing infrastructure complexes (referred to as the Bird Reef Central Infrastructure Complex and Kimberley Reef East Infrastructure Complex in Figure 2-4) to access the existing underground mine workings. The proposed project will also include the establishment of run of mine (ROM) ore stockpiles, topsoil stockpiles and temporary waste rock dumps as well as supporting infrastructure including material storage and handling facilities, general and hazardous waste management facilities, sewage management facilities, water management infrastructure, communication and lighting facilities, centralised and satellite offices, workshops, wash bays, stores, change houses, lamp rooms, vent fans and security facilities. No mineral processing will take place on site besides crushing that will take place on site at the run-of-mine ore stockpiles and crusher areas at each of the five open pit mining areas and the infrastructure complexes, where ore will be crushed prior to transportation off-site for concentrating of minerals at an existing mineral processing plant.

Baseline Hydrology

The average rainfall and evaporation for the project area is based on the nearest Department of Water and Sanitation (DWS) managed rainfall gauging station. This station is called Zuurbekom (DWS Reference: C2E007). The monthly average rainfall for the site is based on the available records from the rainfall gauge as recorded from 1958 to 2018. These parameters are important to inform the stormwater management plan and site wide water balance.

The mean annual precipitation (MAP) at the monitoring station is defined as 683 mm. There is a significant variation in annual rainfall where, 30 % of the years' in the rainfall record experienced less than 584 mm and 30 % of the years' experienced more than 733 mm of annual rainfall, whilst the driest year experienced only 317 mm of rainfall and the wettest year experienced 1 043 mm of rainfall.

Baseline Water Quality

A hydrocensus was undertaken by NOA Agencies (Pty) Ltd to collect groundwater and surface water samples to determine baseline water quality. Four streams were sampled during the hydrocensus and water quality results were compared to the In-stream water quality guidelines (WQG) for the Klip River catchment as set out by the Klip River Forum. The water quality sampled was also compared to the South African National Standards (SANS) 241 and DWS drinking water guidelines as summarised in Appendix A. All four samples indicate water that is not suitable for human consumption.

The Klip River Forum is constituted in terms of the National Water Act, 1998 (Act 36 of 1998) and is a non-profit organisation consisting of stakeholders actively participating in sustainable water resource management of the Klip River Catchment and its associated tributaries.

WITStream 2 showed elevated levels of *E.coli* while all other elements were within drinking water standards. This sampling point is in the headwaters of the Klip River and has not yet had any polluted flows from mining areas contributing to the water channel.

All other samples showed concentrations of sulphate, manganese, nickel and uranium exceeding the chronic / acute health limits as set by the drinking water standards, while WITStream 3 also showed high concentrations of lead. The pH of these three samples ranged between 3.3 and 4.5 indicating the presence of Acid Mine Drainage (AMD) from existing facilities.

Conceptual Stormwater Management Plan

Informed by the baseline hydrology of the site and surroundings (presented in Section 2), a review of the proposed surface infrastructure has been undertaken, and a series of design principles for stormwater management have been developed to ensure compliance with the requirements of Government Notice (GN) Regulation 704.

In order to meet the design principles detailed above, conceptual design details for the proposed stormwater management measures are recommended for each of the proposed opencast mine pits and infrastructure complexes, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each management measure proposed.

The channels were sized to accommodate the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing is uniform along the entire length. Some cut and fill may be required along the length of the channels to achieve the required gradient to ensure that water flows freely within these channels. The clean water will be kept out of the dirty water channels by construction of a linear bund upstream of the channel with material excavated from the channel.

The freeboard requirements for channels are as follows (already catered for in the channel sizing):

- The peripheral stormwater diversion and dirty water collection channels or drains will have either a 0.3 m or 0.6 m freeboard. If the flow is less than 10 m^3/s, then 0.3 m of freeboard is included and if the flow is greater than 10 m^3/s, then 0.6 m of freeboard is included.
- The worst case rainfall event for each catchment was taken from the Storm Depth Duration Frequency (DDF) estimates.
- Following confirmation of the design flows for each diversion channel, the channels have been sized using the Manning’s Equation to ensure that the flow capacity of the channel is sufficient to contain and convey the 1:50 year rainfall event.

Site wide Water Balance

A daily average site wide water balance model was developed for the proposed West Wits Mining project to establish the:

- Storage sizes for the proposed dirty water dams/sumps (complex pollution control dams (PCDs)).
- The average wet, dry season and monthly water balances across the proposed mine.

The model focused predominantly on the interaction between rainfall, evaporation, groundwater ingress, mine water demands and make-up water with the aim of developing a water balance control philosophy for the management of water on the mine.

The water balance, dams and the associated operational infrastructure are to be designed in compliance with the National Water Act (Act No. 36 of 1998), GN704 and DWS Best Practice Guideline (BPG) which recommends following:

- The size of the berms must be able to convey the 50 year flood peak without overtopping while the PCD must only spill on average once in 50 years.
- Furthermore, Regulation 6 of GN 704 requires that the capacity requirements of dirty water systems be designed "so that it is not likely to spill into any clean water system more than once in 50 years".

A water balance approach has been adopted which takes into account daily runoff, evaporation and water re-use. The reuse of water is an important component of the PCD dam sizing and is related to the potential pump out rate from the water dams.

Floodline Determination

Sub-catchments were delineated for modelling purposes for the Eastern and Western streams that would be influenced by the proposed West Wits Project.

The topographical data forms the foundation for the HEC-RAS model and is used to extract elevation data for the river profiles together with the river cross-sections. The topographical data is also used to determine placement positions for the cross-sections along the river profile, so that the watercourse can be accurately modelled.

The proposed mine infrastructure does not traverse any of the modelled streams which means that the proposed mine will not impact on the surface watercourses.

Impact Assessment

Informed by the mine plan layout, baseline hydrology, design specifications for the stormwater management system, the floodlines, and the water balance results, the potential impacts of the proposed activities on surface water receptors are presented in this section along with a summary of mitigation measures.

Impacts are assessed cumulatively where the currently impacted environment is considered as a baseline to the proposed project.

The impacts of the proposed activities and the infrastructure have been identified and then assessed based on the impact's magnitude, duration, probability, extent, severity and consequences and the receptor's sensitivity. This analysis then culminates in the determination of the impact significance which indicates the most important impacts and those that require management. The local surface water resources are considered to be of low sensitivity

Recommendations

It is recommended that the hydraulic gradients and channel sizes are confirmed during the detailed design of the stormwater channels. The requirement for, and design of, in-channel velocity control measures should be confirmed during the detailed design of the channels. The specification for lining of the channels and the PCDs should also be confirmed during the detailed design of these features.

- Stormwater management:
  - Separation of clean and dirty water through the development of stormwater structures as detailed in Section 4 of this report. It must be ensured that diverted runoff from disturbed area is collected in dirty areas and clean water freely discharges to the surrounding clean catchment.

  - As discussed in section 4 above, it is proposed that stormwater from dirty catchments is contained and reused for dust suppression. Alternatively it must be treated and discharged (section 5), effectively reducing the catchment area draining to the local watercourses.
  - Management of silt as detailed in Section 5 by ensuring that the disturbance of soil is minimised, sediment source and erosion control, phasing of earthworks activities, diversion of upslope runoff from entering the earthworks areas and downstream treatment of any collected sediment runoff i.e. use of silt traps.
- Water Balance: the site's water circuit has been defined and collection and water management strategy defined with the reuse of dirty water prioritised. In order to reduce the impacts from the project on the surface water resources, mine water should be treated and discharge of excess mine water should be planned.
- Floodlines – It is recommended that the infrastructure be located outside of the 1:100 year Return Period floodline and follow the requirements laid out in GN 704.

In addition to the measures presented and discussed throughout this report, the following management measures should be implemented:

- Good housekeeping practices must be implemented and maintained by clean-up of accidental spillages, as well as ensuring all dislodged material like run-of-mine stockpile are kept within the confined storage footprints. In addition clean-up material and materials safety data sheets for chemical and hazardous substances should be kept on site for immediate clean-up of accidental spillages of pollutants;
- Regularly schedule inspection and maintenance of water management facilities, to include inspection of drainage structures for any in channel erosion or cracks; de-silting of silt traps/sumps and PCDs; and any pumps and pipelines should be maintained according to manufacturer's specifications;
- Vehicles and plant equipment servicing must be undertaken within suitably equipped facilities, either within workshops, or within bunded areas, from which any stormwater is conveyed to a pollution control dam, after passing through an oil and silt interceptor;
- Pollutant storage – any substances which may potentially pollute surface water must be stored within a suitably sized bunded area and where practicable covered by a roof to prevent contact with rainfall and/or runoff;
- Water conservation and water demand management (WC/WDM) measures should be implemented to ensure that as much water as is possible, is collected and reused; and
- From operations onwards, grading of disturbed area and application of the final layers of growth medium, must be contoured as far as can be achieved in a safe and practical manner; and vegetation of disturbed areas including seeding should be performed immediately following application of the growth medium to avoid erosion.

All measures implemented for the mitigation of impacts, should be regularly reviewed as best practice and as compliance with various licences issued on site by authorities. The purpose of the mitigation measures is to ensure that the pre-mining / current water resource status is not deteriorated by the mining activities.

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ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
AMD	Acid Mine Drainage
DDF	Depth Duration-Frequency
DWS	Department of Water and Sanitation
GIS	Geographic Information System
m amsl	Metres above mean sea level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
Mcm	Million cubic metres
NFEPA	National Freshwater Ecosystem Priority Areas
SANS	South African National Standards
WMA	Water Management Area
WQG	Water Quality Guideline

1. INTRODUCTION

1.1 BACKGROUND

SLR Consulting (South Africa) (Pty) Ltd (SLR) was appointed by West Wits MLI (Pty) Ltd (West Wits) to undertake a Technical Specialist Surface Water Study as part of the Environmental Impact Assessment (EIA) process for an application for a Mining Right for the proposed West Wits MLI (Proprietary) Limited (West Wits) mining operation in City of Johannesburg Metropolitan Municipality, Gauteng Province.

This surface water study was undertaken by a suitably qualified and experienced Hydrologist registered with the South Africa Council for Natural Scientific Professions (SACNASP) as a Professional Natural Scientist (Pr.Sci.Nat.) in the field of Water Resources Science. A CV of the author is included Appendix A.

1.2 PROJECT DESCRIPTION

The proposed West Wits mining operation would be located south of Roodepoort and to the north of Soweto in the City of Johannesburg Metropolitan Municipality, Gauteng.

In broad terms the proposed project would involve the development of five open pit mining areas (referred to as the Mona Lisa Bird Reef Pit, Roodepoort Main Reef Pit, Rugby Club Main Reef Pit, 11 Shaft Main Reef Pit and Kimberley Reef East Pit) and refurbishment of two existing infrastructure complexes (referred to as the Bird Reef Central Infrastructure Complex and Kimberley Reef East Infrastructure Complex) which will be used for servicing and providing access to the underground mine operations.

The proposed project would also include the establishment of run of mine (ROM) ore stockpiles, topsoil stockpiles and waste rock dumps as well as supporting infrastructure including material storage and handling facilities (for fuel, lubricants, general and hazardous substances), general and hazardous waste management facilities, sewage management facilities, water management infrastructure, communication and lighting facilities, centralised and satellite offices, workshops, wash bays, stores, change houses, lamp rooms, vent fans and security facilities. No mineral processing will take place on site besides primary mineral processing/ crushing that will take place on site at the run-of-mine ore stockpiles and crusher areas at each of the five open pit mining areas and the infrastructure complexes, where ore will be crushed prior to transportation off-site for concentrating of minerals at an existing plant. All run-of mine material will be transported to an existing processing plant off-site. The expected life of mine is five (5) years for the open pit operations (inclusive of rehabilitation) and 20 years for underground mining workings (20 years for the Kimberley Reef East, and 10 years for the Bird Reef Central underground workings).

1.3 ENVIRONMENTAL LEGISLATION

National Water Act (Act No. 36 of 1998), Government Notice 704 (Government Gazette 20119 of June 1999) (hereafter referred to as GN 704), was established to provide regulations for the use of water for mining and related activities aimed at the protection of water resources. Regulations 4, 5, 6, 7 and 10 of the GN 704 are applicable in this study and are summarised below:

- Regulation 4 - defines the restrictions for the locality of mine workings and infrastructure. Any residue deposit, dam, reservoir together with any associated structure or any other facility should be situated outside the 1:100 year flood-line. Any underground or opencast mining, prospecting or any other operation or activity should be situated or be undertaken outside of the 1:50 year flood-line. Where the flood-line is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for infrastructure and activities;

- Regulation 5 - restricts the use of any residue or substance which causes or is likely to cause pollution of a water resource. This residue may not be used in the construction of any dams, impoundments or embankments or any other infrastructure which may cause pollution of a water resource;
- Regulation 6 - describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated to ensure conveyance of the flow equivalent to a 1:50 year recurrence flood event. Clean and dirty water systems should not spill into each other more frequently than once in 50 years. Any dirty water dams should have a minimum freeboard of 0.8 m above full supply level.
- Regulation 7 - describes the measures which must be taken to protect water resources. All dirty water or substances which may cause pollution should be prevented from entering a water resource (by spillage, seepage, erosion etc.) and it must be ensured that any water used in any process is recycled as far as is practicable.

In addition to the GN 704 regulations, the Department of Water and Sanitation (DWS) Best Practice Guidelines (BPG) for the mining industry have also been accounted for in this analysis as follows:

- BPG G1: Stormwater Management;
- BPG A4: Pollution Control Dams; and
- BPG G3: Water Monitoring Systems.

1.4 SCOPE OF WORK AND REPORT STRUCTURE

The scope of work for this study included the following:

- Baseline Hydrology – Section 2 presents a review and analysis of various sources of rainfall and evaporation data. The section also presents the characterisation of the baseline hydrology of the site and surroundings including topography, watercourse network and catchment delineation, and site observation of hydrology setting.
- Water quality - Section 3 presents a review of the wet and dry season water quality data provided to SLR to classify the baseline water quality.
- Conceptual Stormwater Management - Section 4 presents the recommended stormwater management measures including a review of the layout, peak flow estimation (Rational method only), hydraulic sizing of the drainage infrastructure (berms and channels), and the location and indicative capacity of Pollution Control Dams (PCD) and silt traps.
- Basic Site Wide Water Balance– Section 5 presents the mine steady state water balance for wet and dry seasons and the annual averages for 3 scenarios (e.g. start-up, mid-life of mine, end-life of mine) to inform estimates on re-use rates, makeup water and discharge requirements.
- Impact Assessment – Section 6 presents a qualitative assessment of the significance of the impact of the project on the baseline surface water environment, a range of mitigation measures to minimise said impacts, and recommendations on monitoring; and
- Conclusions – Section 7 presents a summary of the main conclusions and recommendations of this report.
- References – Section 8 presents a list of the reference documents used for preparation of this report.

The report structure complies with the requirements of Appendix 6 of the EIA Regulations as per the table provided in Appendix C of this report.

2. BASELINE HYDROLOGY

2.1 INTRODUCTION

In order to inform the stormwater management plan and site wide water balance, an understanding of the regional hydrology is required. This section presents a review of various information sources and defines the climatic and hydrological conditions that were found to be applicable in assessing this site and its surroundings.

2.2 CLIMATE

2.2.1 Rainfall

The average rainfall for the project area is based on the nearest Department of Water and Sanitation (DWS) managed rainfall gauging station. This station is called Zuurbekom (DWS Reference: C2E007) situated at Waterworks train station, 7.5 km south-west of the project area. The monthly average rainfall for the site is based on the available records, from the rainfall gauge as recorded from 1958 to 2018, and is presented in Table 2-1.

TABLE 2-1: MONTHLY AVERAGE RAINFALL – ZUURBEKOM C2E007

Month	Rainfall (mm)
January	126.9
February	88.5
March	78.8
April	50.3
May	16.1
June	7.1
July	3.0
August	6.9
September	22.1
October	70.6
November	100.1
December	112.9
Total	683.3

The percentile distribution of the total annual rainfall (assumed water year starts on 1 August) for the recorded period is therefore as presented in Figure 2-1.

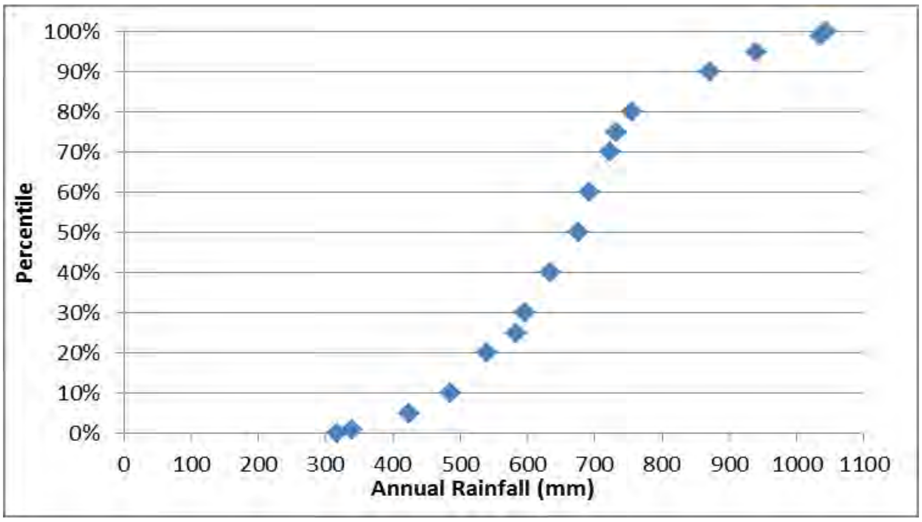


FIGURE 2-1: PERCENTILE DISTRIBUTION OF ANNUAL RAINFALL TOTALS 1958-2018 (ZUURBEKOM)

The mean annual precipitation (MAP) at the monitoring station is defined as 683mm (see Table 2-1). Figure 2-1 shows that there is a significant variation in annual rainfall where, 30% of the years' in the rainfall record experienced less than 584 mm and 30% of the years' experienced more than 733 mm of annual rainfall. Whilst the driest year experienced only 317 mm of rainfall and the wettest year experienced 1 043 mm of rainfall.

A review of daily rainfall records from the DWS rainfall gauge at Zuurbekom provides information on the wettest multi-day periods recorded within the region. The Zuurbekom rainfall station has a daily rainfall record from 1959 through until 2017 (59 years).

A review of the daily rainfall records from the Zuurbekom rainfall gauge illustrates a maximum 1-day (24 hours) rainfall of 105 mm between 1959 and 2017.The five highest rainfall events from the full record available are presented in Table 2-2.

TABLE 2-2: FIVE HIGHEST RAINFALL EVENTS (MM) RECORDED IN 1 DAY (ZUURBEKOM)

Date	Rainfall (mm)
1987/09/27	105.0
2010/12/15	99.0
1993/10/05	96.5
1997/03/05	91.5
1993/10/06	88.0

A summary of the wettest multi-day periods as recorded at Zuurbekom are presented in Table 2-3. This table shows the maximum rain fall at the station over numbers of consecutive days ranging from 1 to 180 days. As can be seen, the maximum rainfall over a 30-day period was 367.0 mm which is almost 54% of the MAP. The maximum rainfall over a 2 and a 4 month period was 80% and 112% of the MAP. The maximum rainfall over any period of 180- consecutive days was 942.9 mm which is over 138% of the MAP. It is concluded that whilst MAP in this area is fairly low there have been significant rainfall periods and events in this area.

TABLE 2-3: WETTEST PERIODS RECORDED ON CONSECUTIVE DAYS (ZUURBEKOM)

Days	Rainfall (mm)
1	105.0
2	184.5
3	189.5
4	201.5
5	206.5
6	208.0
7	251.5
15	266.3
30	367.8
60	553.3
120	767.8
180	942.9

2.2.2 Evaporation

Average monthly evaporation for the project site is based on the Zuubekom (C2E007) Symon's Pan Evaporation station as sourced from DWS. Pan evaporation records are available from 1959 to 2017. A pan coefficient can then be used to convert the recorded S-pan evaporation to open water evaporation which is applicable for a conventional dam or pond (see Table 2-4.

TABLE 2-4: MONTHLY AVERAGE EVAPORATION - ZUURBEKOM C2E007

Month	S-Pan Evaporation (mm)	Pan Coefficient*	Open Water Evaporation (mm)
January	166.9	0.84	140.2
February	137.5	0.88	121.0
March	128.4	0.88	113.0
April	101.1	0.88	89.0
May	85.6	0.87	74.5
June	68.2	0.85	58.0
July	76.4	0.83	63.4
August	106.4	0.81	86.2
September	143.9	0.81	116.6
October	162.5	0.81	131.6
November	161.4	0.82	132.3
December	170.1	0.83	141.2
Total	**1523**	**N/A**	**1266.9**

**Surface Water Resources of South Africa 1990 - Volume 1 Appendices. Water Research Commission (WRC) Report 298/1.1/94*

2.2.3 Storm Depth-Duration-Frequency (DDF)

Design storm estimates for various return periods and storm durations were sourced from the Design Rainfall Estimation Software for South Africa, developed by the University of Natal in 2002 as part of a Water Research Commission (WRC) project K5/1060 (Smithers and Schulze, 2002). The software was used to extract the storm depth-duration-frequency (DDF) data from the six closest rainfall stations, as presented in Table 2-5.

TABLE 2-5: SUMMARY OF WEATHER STATIONS USED FOR GENERATING STORM DDF FOR THE PROJECT SITE

Station Name	SAWS Number	Distance (km)	Record Length (years)	Mean Annual Precipitation (mm)	Altitude (mamsl)
ZUURBEKOM	0475528	7.3	90	670	1588
KLIPSPRUIT (PUR)	0475736	9.2	55	680	1640
DURBAN ROODEPOORT DEEP	0475611	9.7	95	759	1740
LUIPAARDSVLEI	0475404	10.9	50	651	1603
MARAISBURG (GM)	0475761	11.5	78	758	1697
ROODEPOORT (MUN)	0475669	12.1	94	737	1780

Differences in the MAP for the Zuurbekom station (Table 2-1) and the Daily Rainfall Extraction Utility program (Table 2-5) should be noted. This is due to the variation in the lengths of the records available and the geographic distances between the various stations. The differences in the MAP were assessed to be insignificant to the design of the water management measures presented in this report.

The adopted storm rainfall depth which will be used in the peak flow calculations is based on the gridded rainfall depths for the above six stations. A summary of the rainfall depths for the 5 minute duration storm up to the 7 day duration storm for various recurrence intervals are shown below in Table 2-6.

TABLE 2-6: STORM DEPTH-DURATION-FREQUENCY (DDF) RAINFALL FOR THE PROJECT SITE

Duration	Rainfall Depth (mm)						
	1:2 years	1:5 years	1:10 years	1:20 years	1:50 years	1:100 years	1:200 years
5 minutes	8.8	12.1	14.7	17.4	21.3	24.6	28.2
10 minutes	12.7	17.5	21.1	25.0	30.7	35.4	40.6
15 minutes	15.7	21.6	26.2	31.0	38.0	43.8	50.3
30 minutes	20.1	27.7	33.5	39.7	48.7	56.2	64.5
45 minutes	23.2	32.1	38.8	45.9	56.3	65.0	74.6
1 hour	25.7	35.5	43.0	50.9	62.4	72.0	82.7
1.5 hours	29.8	41.1	49.7	58.8	72.1	83.3	95.6
2 hours	33.0	45.6	55.1	65.2	80.0	92.3	106.0
4 hours	39.6	54.6	66.0	78.1	95.8	110.7	127.0
6 hours	44.0	60.7	73.4	86.9	106.5	123.0	141.2
8 hours	47.4	65.4	79.1	93.7	114.8	132.6	152.2
10 hours	50.2	69.4	83.9	99.3	121.7	140.6	161.3

Duration	Rainfall Depth (mm)						
12 hours	52.7	72.7	88.0	104.1	127.7	147.4	169.2
16 hours	56.8	78.4	94.8	112.2	137.6	158.9	182.4
20 hours	60.2	83.1	100.5	119.0	145.9	168.5	193.3
24 hours	63.2	87.2	105.4	124.8	153.0	176.7	202.7
1 day	54.7	75.5	91.3	108.1	132.5	153.1	175.6
2 days	67.4	93.0	112.5	133.1	163.3	188.5	216.3
3 days	76.1	105.1	127.1	150.4	184.4	213.0	244.4
4 days	82.9	114.5	138.4	163.8	200.9	231.9	266.2
5 days	88.6	122.3	147.9	175.0	214.6	247.8	284.4
6 days	93.5	129.1	156.1	184.7	226.5	261.6	300.2
7 days	97.9	135.1	163.4	193.4	237.1	273.8	314.2

2.3 HYDROLOGICAL SETTING

2.3.1 Introduction

South Africa is divided into nine water management areas (National Water Resource Strategy 2, 2013), each managed by its own water board. Each of the water management areas (WMA) is made up of several quaternary catchments which relate to the drainage regions of South Africa.

The Water Resources of South Africa Manual WR2012 (WRC, 2012) shows that the project area falls within the Upper Vaal WMA 5, and all runoff from the project area ultimately drains westward into the Orange River.

2.3.2 Regional Hydrology

The regional hydrological setting of the project site is indicated in Figure 2-2.

The WR2012 study, presents hydrological parameters for each quaternary catchment, and shows that the project area falls entirely within the quaternary catchment C22A, which has a catchment area of 548 km^2 and a mean annual runoff of 28.06 million cubic meters (mcm) draining into the Klip River before the confluence with the Rietspruit River.

2.3.3 Topography

Various sources of topographical data for the project area and surroundings were reviewed including:

- Site Topographic Data – topographical data provided by the applicant including 0.5 m contours.
- ASTER GDEM – the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model which features an elevation level provided on a 30 m grid.
- 20 m contours from the 1:50 000 topographical maps of South Africa.

The Project Area is located between 1 600 m and 1 780 m amsl and in general the area slopes to the south-west.

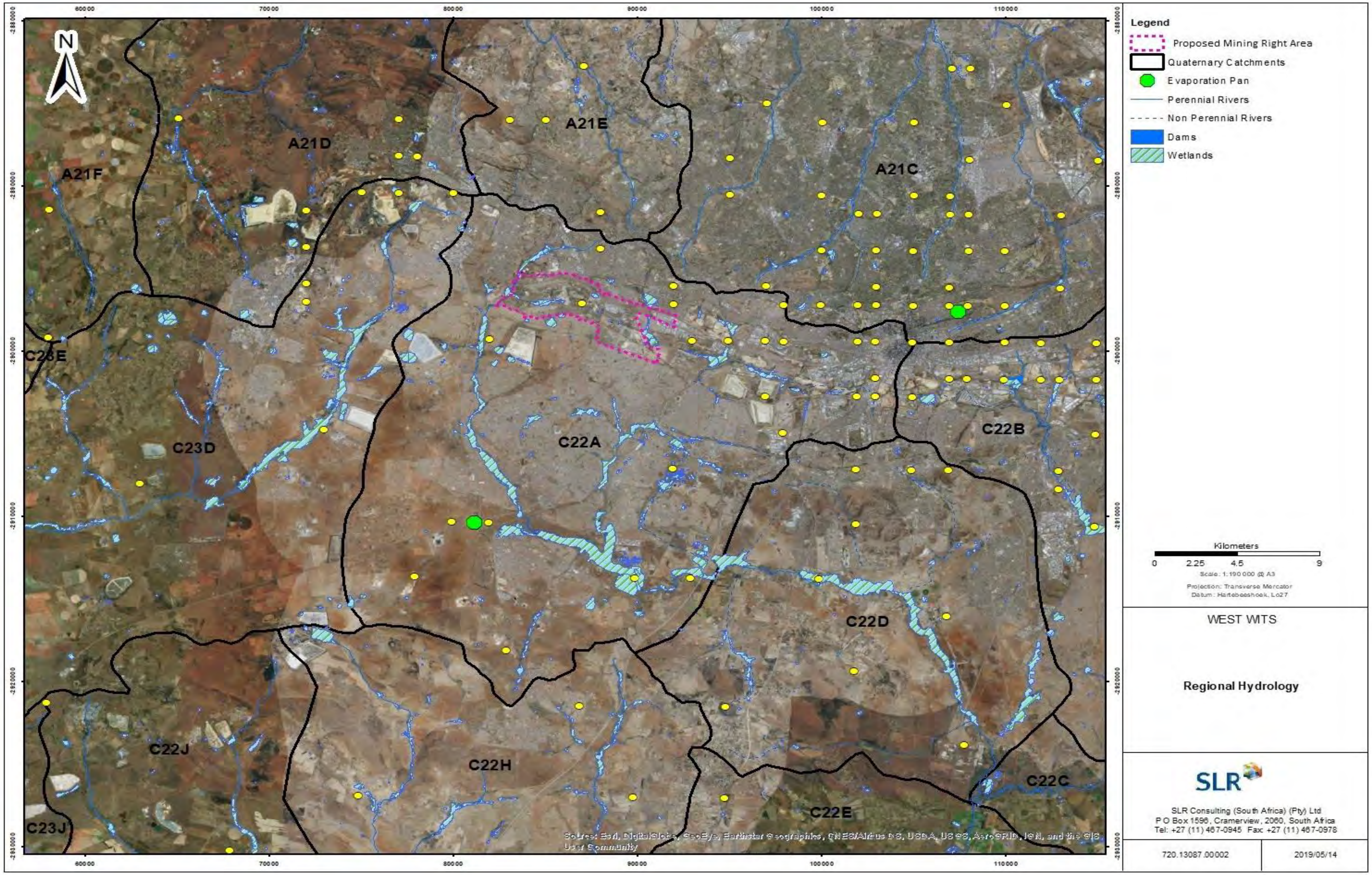


FIGURE 2-2: REGIONAL HYDROLOGY OF THE PROPOSED WEST WITS PROJECT SITE

FIGURE 2-3: LOCAL HYDROLOGY OF THE PROPOSED WEST WITS PROJECT SITE

2.3.4 Watercourse Network and Drainage Lines

The Klip River is a perennial watercourse (WRC, 2012) which originates approximately 4 km north of the proposed mining right application area (Figure 2-5). The river flows south along the western boundary of the proposed mining right application area. There are several other additional drainage lines in the proposed project area which are all tributaries of the Klip River (Figure 2-3).

The west stream originating on the slopes of old slimes dams and was found to be overgrown with reeds (Figure 2-6) during a site visit on 19 April 2018. The east stream flows south of the Mona Lisa pit and north of the Kimberley West pit (Figure 2-4). Both of these pits are situated on the slopes and any drainage from these areas will flow into the river channel. Eroded material from the old slimes dams flows into the drainage channel, and is likely to impact upon the water quality of the receiving watercourse (Figure 2-7 and Figure 2-8).

Figure 2-4 below indicates the positions where photos were taken.

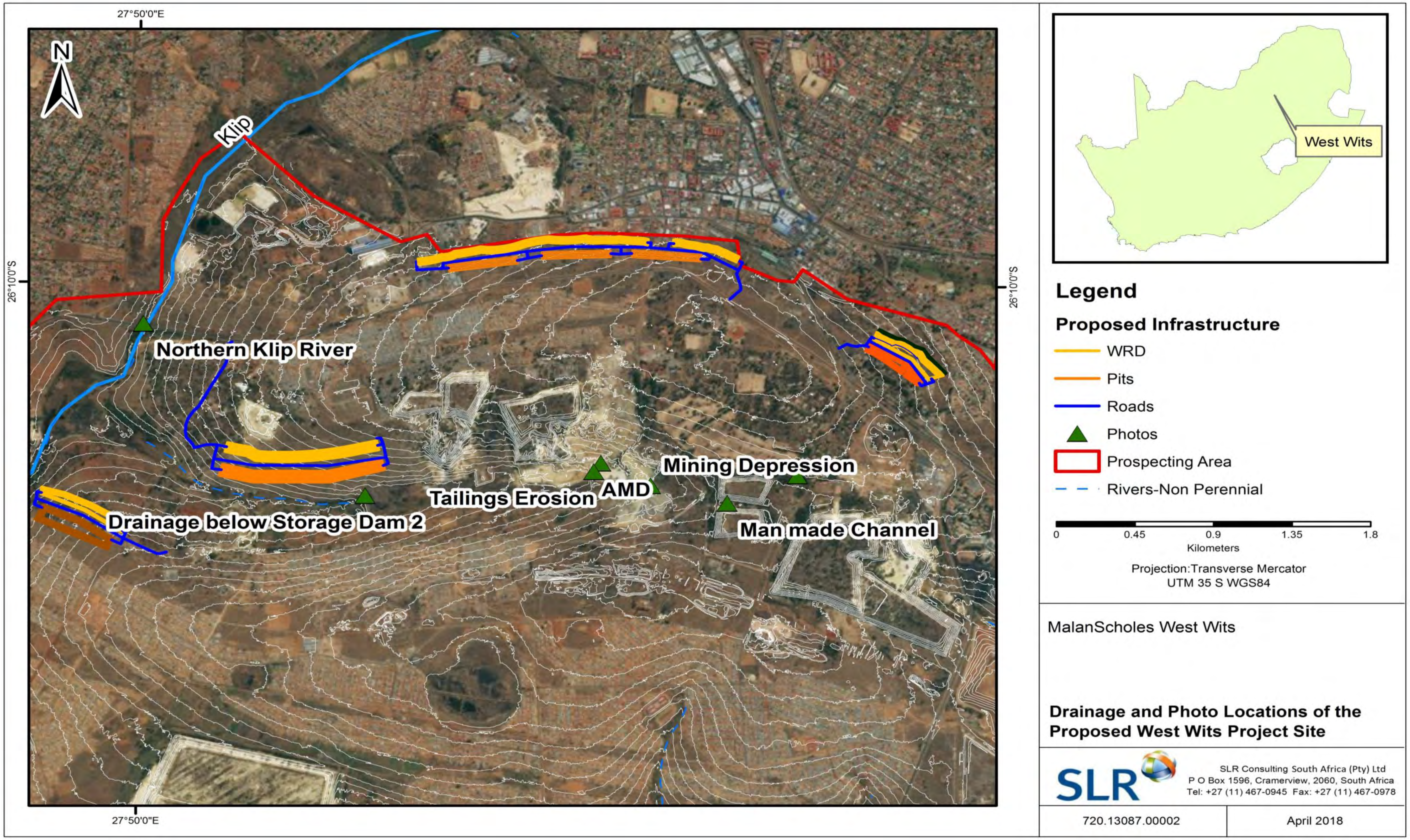


FIGURE 2-4: SITE LAYOUT

FIGURE 2-5: HEADWATERS OF THE NORTHERN KLIP RIVER LOOKING UPSTREAM

FIGURE 2-6: DRAINAGE DOWNSTREAM OF STORAGE DAM IN DRAINAGE D1, OVERGROWN BY REEDS

FIGURE 2-7: ERODED SLIMES MATERIAL FLOWING INTO THE NATURAL DRAINAGE CHANNEL (PHOTO: SLIMES EROSION)

FIGURE 2-8: DISCOLOURATION OF STREAM WATER (PHOTO: AMD)

The D1 drainage channel is restricted and flows between two man made dams before the confluence with the Klip River in the west. The channel is highly disturbed and does not follow a natural channel path but rather flows through abandoned mine workings. The channel is non-perennial and flows are not expected during winter months.

D2 originates on the slopes and consists of seepage water from the slimes dam located upstream of the drainage tributary. D2 flows in a south westerly direction and will transport surface water into the Klip River at the most south western edge of the proposed mining right boundary.

D3 and D4 form their own local catchment and originate in the centre of the proposed mining site, with very limited flow they drain south east through a rural area.

D5 drains through a valley and passes over old slime dam deposits that are currently being reworked and moved. D5 then discharges into the Fleurhof Dam at the east end of the prospecting boundary. Drainage line D5 is considered non-perennial and did not flow during the site visit.

D6 drains through the Florida Lake (currently overflowing, see Figure 2-9) to the north of the proposed mining right boundary and flows southwards carrying any surface water downstream into the Fleurhof Dam (Figure 2-1. The Fleurhof Dam was not overflowing, therefore no water was released downstream of the dam and surface water from the Fleurhof Dam will collect in the dam until the full capacity is reached before being discharged downstream.

Drainage lines D3 – D6 form part of the tributaries flowing into the Klip River that then drains south-east through quaternary catchment C22D until it joins with the Rietspruit River in quaternary catchment C22C. The mouth of the Klip River is at Vereeniging where it flows into the Vaal River which is a tributary of the Orange River.

FIGURE 2-9: OVERFLOW OF FLORIDA LAKE

Three local catchments were delineated from drainage lines and surface topography labelled 1 – 3 in Figure 2-3. The contributing catchment of the Klip River (Catchment 1) is the largest with an area of 84.4 km^2 while catchment 2 has the smallest area of 6.7 km^2. Catchment 3 is in the north eastern end of the site boundary and has an area of 29.1 km^2.

The majority of the watercourse and the drainage lines within the site boundary are heavily modified. Several drainage lines including D1, D2, D5 and D6 are diverted from their natural courses or are impounded by dams. There are numerous slimes dams in close proximity to the surface water features and seepage from the slime dams flows into the drainage lines and the watercourse in several locations.

2.3.5 Wetlands

Based on the National Freshwater Ecosystem Priority Areas (NFEPA) wetland GIS metadata (SANBI, 2011) presented in Figure 2-3, several wetlands and pans are identified within the project area, which typically suggests low permeability ground conditions preventing infiltration into the underlying groundwater and / or elevated groundwater levels. The upper reaches of the Klip River are comprised of some wetland areas which have a low gradient and slope towards the south. Very low flow velocities will be expected in these areas.

The project area also contains some natural depressions/pans and seepage wetlands/channelled valley bottom wetlands where groundwater naturally comes to the surface along drainage lines.

2.3.6 Flows

Four river flow gauging stations (DWS) were identified within a reasonable distance from the project area; details are given in Table 2-7 below. No flow information is available for the closest gauging stations (C2H020 and C2H041).

TABLE 2-7: RIVER FLOW GAUGING STATIONS IN THE KLIP RIVER (DWS)

Station Number	Station Name	Latitude	Longitude	Catchment Area (km2)	Available data (Years)	Location Relevant to site
C2H020	Witpoortjie	-26.1838	27.81827	46	N/A	On western site boundary
C2H021	Witkop	-26.4541	28.0855	1726	44	50 km Downstream after confluence with Rietspruit River
C2H041	Doornkop	-26.2586	27.81219	112	N/A	5 km Downstream
C2H137	Zwartkopjes	-26.3803	28.0708	724	6	40 km Downstream

(Catchment area for C2H137 could not be sourced and therefore the area was estimated from topographic data)

The time series flow data records were analyzed to understand the average, high and low flows for each month, as presented in Table 2-8, Figure 2-10 and Figure 2-11. Low flows are expressed as Q_{90} which is the flow which is exceeded 90% of the time during a given month, and high flows are expressed as Q_{10} which is the flow which is exceeded only 10% of the time during a given month.

TABLE 2-8: AVERAGE, LOW AND HIGH MONTHLY FLOWS (MILLION M^3/MONTH)

	C2H137 (2011-2018)			C2H021 (1952-1996)		
Month	Low Flow	Ave. Flow	High Flow	Low Flow	Ave. Flow	High Flow
October	19.76	24.70	25.92	1.85	13.50	27.10
November	18.00	23.90	31.15	5.32	19.30	28.80
December	22.25	35.20	38.70	8.12	22.20	40.00
January	9.586	19.35	29.87	6.31	20.40	38.70
February	27.78	39.30	40.82	7.16	16.90	40.22

	C2H137 (2011-2018)			C2H021 (1952-1996)		
March	9.662	23.30	41.90	4.80	19.25	46.01
April	22.66	25.90	30.32	4.90	17.20	29.72
May	21.12	22.80	25.02	3.06	12.10	25.96
June	21.11	22.35	23.24	2.77	13.30	22.40
July	21.92	22.25	24.54	3.47	14.05	23.14
August	20.96	21.25	25.04	2.22	11.20	26.10
September	13.88	21.30	28.12	1.63	10.40	23.90

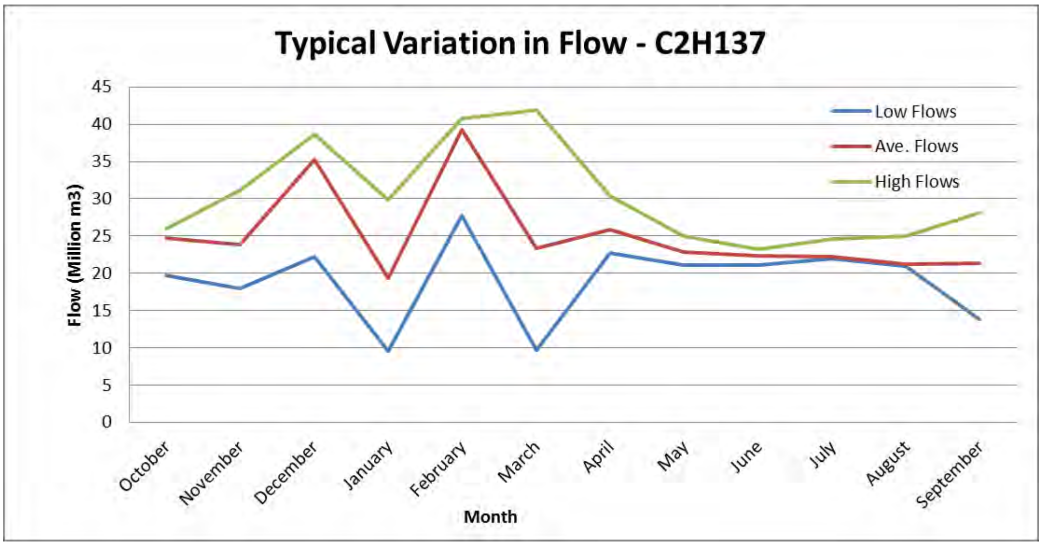


FIGURE 2-10: AVERAGE, LOW AND HIGH FLOWS AT STATION C2H137

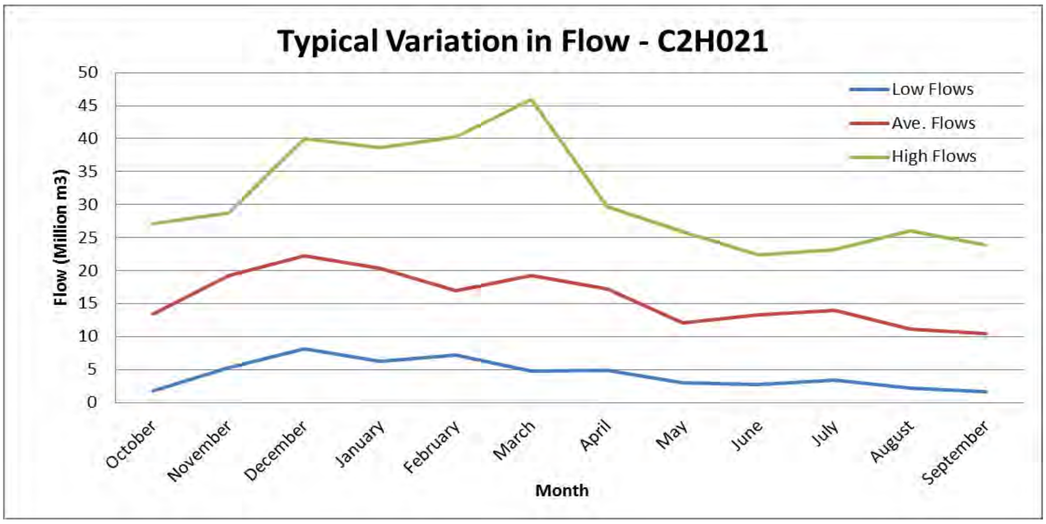


FIGURE 2-11: AVERAGE, LOW AND HIGH FLOWS AT STATION C2H021

Due to incomplete flow data for station C2H137 it was not used in further analyses. Monthly average flow per km^2 was calculated for C2H021 as shown in Table 2-9. The calculated flow/km^2 was used to estimate the average monthly flows for the three main runoff zones delineated from the topographic data collected and are as shown in Figure 2-3 and Table 2-9.

This is assumed that there is a direct correlation between average flow and catchment size.

TABLE 2-9: MONTHLY AVERAGE FLOW FOR STATION C2H021 AND ESTIMATED FLOWS FOR CATCHMENT 1 - 3

	C2H021		Catchment 1	Catchment 2	Catchment 3
Catchment Size (km^2)	1726	1	84.4	6.7	29.1
Month	Average monthly flows (million m^3)	Average monthly flows (million m^3/km^2)	Average monthly flows (million m^3)	Average monthly flows (million m^3)	Average monthly flows (million m^3)
October	13.50	0.008	0.660	0.052	0.228
November	19.30	0.011	0.944	0.075	0.325
December	22.20	0.013	1.086	0.086	0.374
January	20.40	0.012	0.998	0.079	0.344
February	16.90	0.010	0.826	0.066	0.285
March	19.25	0.011	0.941	0.075	0.325
April	17.20	0.010	0.841	0.067	0.290
May	12.10	0.007	0.592	0.047	0.204
June	13.30	0.008	0.650	0.052	0.224
July	14.05	0.008	0.687	0.055	0.237
August	11.20	0.006	0.548	0.043	0.189
September	10.40	0.006	0.509	0.040	0.175

2.3.7 Vegetation

The WR2012 shows the natural vegetation of the project area to be false grassveld types. According to the Vegetation Map of South Africa (SANBI, 2006) the natural vegetation type of the quaternary catchment C22A consists mainly of Soweto Highveld grassland and smaller sections of Tsakane Clay grassland. The catchment also contains a small area with Eastern Temperate Freshwater Wetlands.

During the site walkover it was observed that natural vegetation had been heavily impacted by activities on the site and large areas of the site have very poor vegetation coverage. This has resulted in increased erosion of soils and relatively high of runoff from sloping areas.

2.3.8 Soils and Geology

WR2005 shows the project area to be situated in an area of “Porous unconsolidated sedimentary strata”, with soils described as “moderate to deep, sandy loam”. The infiltration in the area is moderate to low and therefore is likely to generate moderate to high runoff events.

The project area is underlain by the Central Rand Group consisting of the Turffontein and Malmani Subgroup in the north and central areas. The south of the project area is underlain by the Klipriviersberg Group consisting of the Ventersdorp Subgroup. The main geology consists of conglomerate, quartzite, tuff and andesite with a natural low permeability.

During the site walkover it was observed that natural soils are heavily impacted by activities on the site and large areas of the site are covered with slimes dams, waste rock material, and due to earthworks activities soils are loose and poorly consolidated and easily erodible in many areas.

3. BASELINE WATER QUALITY

A hydrocensus was undertaken by NOA Agencies (Pty) Ltd in March 2018 to collect groundwater and surface water samples. Four streams were sampled during the hydrocensus (Table 3-1 and Figure 3-1) and water quality results are compared to the In-stream water quality guidelines (WQG) for the Klip River catchment as set out by the Klip River Forum, and are summarised in Table 3-2.

TABLE 3-1: SURFACE WATER SAMPLING IN THE PROSPECTING AREA (NOA AGENCIES, 2018)

Sample ID	Latitude (°)	Longitude (°)	Comments
WITStream 1	-26.17845	27.83636	Drainage D1, stream south of Mona Lisa, flowing Westwards
WITStream 2	-26,16916	27.8336	Headwaters of the Klip River at the culvert of road R41, flowing southwards
WITStream 3	-26,19532	27.90214	Drainage D5, at the culvert south east of 11 Shaft, stream flowing East into Fleurhof dam
WITStream 4	-26,19361	27.8976	Upstream of WITStream 3 in the same drainage, before tailing workings

The Klip River Forum is constituted in terms of the National Water Act, 1998 (Act 36 of 1998) and is a non-profit organisation consisting of stakeholders actively participating in sustainable water resource management of the Klip River Catchment and its associated tributaries.

The water quality sampled was also compared to the South African National Standards (SANS) 241 and DWS drinking water guidelines as summarised in Appendix A. All four samples indicate water that is not suitable for human consumption.

WITStream 2 showed elevated levels of E.coli while all other elements were within drinking water standards. This sampling point is in the headwaters of the Klip River and has not yet had any polluted flows from mining areas contributing to the water channel.

All other samples showed concentrations of sulphate, manganese, nickel and uranium exceeding the chronic / acute health limits, while WITStream 3 also showed high concentrations of lead. The pH of these three samples ranged between 3.3 and 4.5 indicating the presence of Acid Mine Drainage (AMD) from existing facilities.

Other elements that were also present in elevated levels are aluminium, calcium, iron, magnesium, potassium and ammonia.

Streams that drain the project area appear to be contaminated by historical and possibly current mining and industrial activities and the water must not be used unless treated. A possible source of the poor water quality is the old slimes dams in this area (Noa Agancies, 2018).

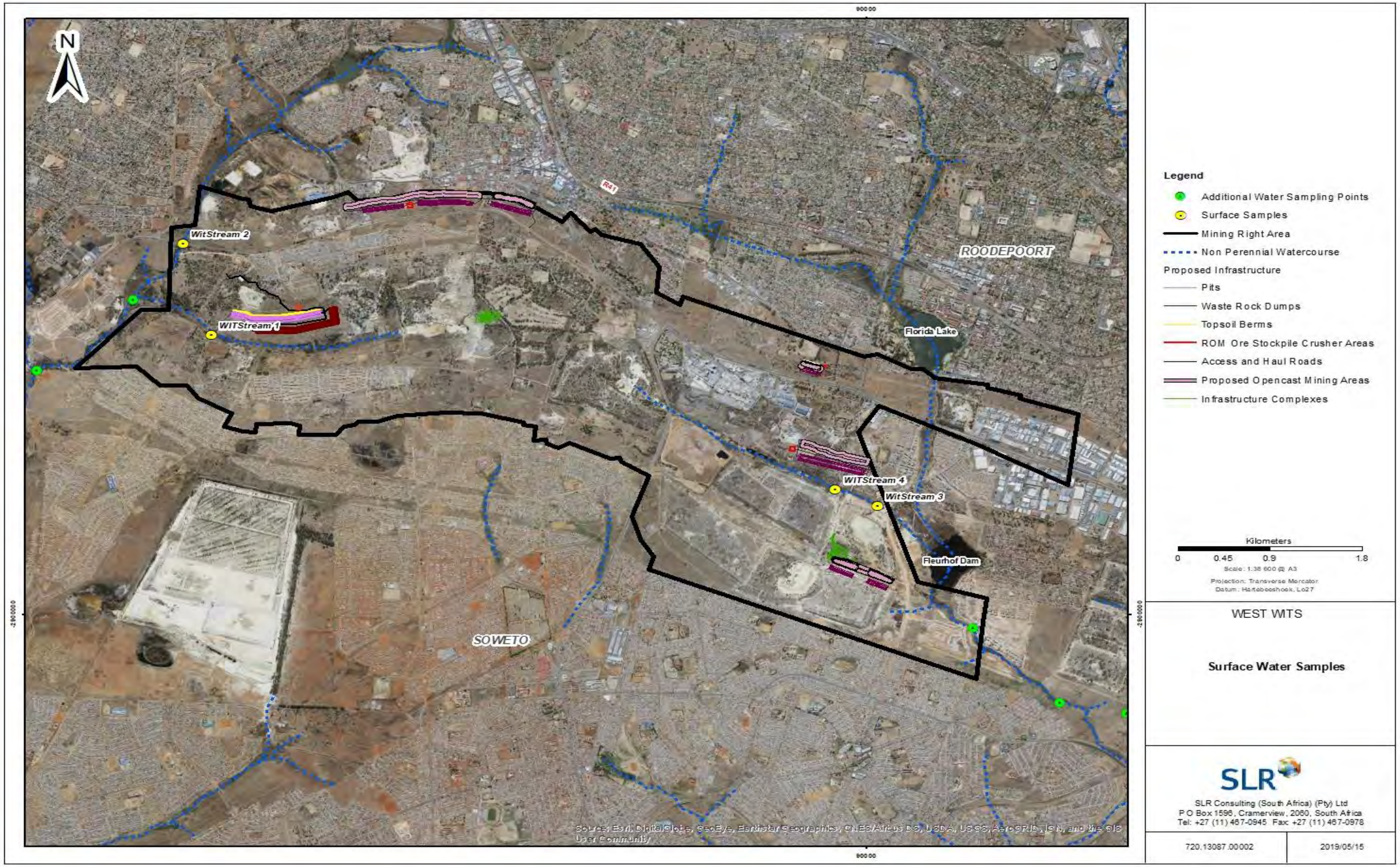


FIGURE 3-1: SURFACE WATER SAMPLE LOCATIONS

TABLE 3-2: SURFACE WATER HYDRO-CHEMICAL RESULTS COMPARED TO KLIP RIVER WQG (NOA AGENCIES, 2018)

Determinant	Unit	*Ideal Catchment Background*	Acceptable Management Target	**Tolerable Interim Target**	Unacceptable	WIT Stream 1	WIT Stream 2	WIT Stream 3	WIT Stream 4
pH at 25°C	pH units	*6 - 9*			<6; >9	4.5	*7.0*	3.4	3.3
Electrical Conductivity at 25°C	mS/m	*<80*	80 - 100	**100 - 150**	>150	**103**	*32*	306	293
Aluminium	mg/l		<0,3	**0,3 - 0,5**	>0,5	5.00	*<0.02*	11.4	14.0
Ammonia	mg/l	*<0,5*	0,5 - 1,5	**1,5 - 4,0**	>4,0	7.88	*<0.11*	48	15.3
Chloride	mg/l	*<50*	50 - 75	**75 - 100**	>100	*26*	*19.8*	227	249
Fluoride	mg/l	*<0,19*	0,19 - 0,7	**0,7 - 1,0**	>1,0	*<0.03*	*0.10*	*<0.03*	*<0.03*
Iron	mg/l	*<0,5*	0,5 - 1,0	**1,0 - 1,5**	>1,5	*<0.02*	*<0.02*	**1.46**	1.88
Magnesium	mg/l	*<8,0*	8 - 30	**30 - 70**	>70	29	11.0	84	85
Manganese	mg/l	*<1,0*	1 - 2	**2 - 4**	>4,0	4.78	*0.10*	18.1	29
Nitrate	mg/l	*<2,0*	2 - 4	**4 - 7**	>7,0	*0.06*	*1.30*	31.5	2.20
Sodium	mg/l	*<50*	50 - 80	**80 - 100**	>100	*34*	*21*	175	186
Sulphate	mg/l	*<200*	200 - 350	**350 - 500**	>500	597	*83*	1392	1322

4. CONCEPTUAL STORMWATER MANAGEMENT PLAN

4.1 INTRODUCTION

Mining operations have the potential to impact upon the baseline water quality of an area in the following ways:

- Bulk earthworks during construction will strip vegetation and expose top soils and subsoils to erosion by stormwater thereby increasing levels of suspended solids within local watercourses and water features;
- Stockpiles or waste material dumps will expose various chemical elements to stormwater, mobilising elements into local watercourses and water features;
- Storage and usage of process specific chemicals and vehicular related pollutants which, if not properly managed, may be washed out by stormwater into local watercourses and water features; and
- Discharge of polluted or improperly treated stormwater, process water and sewage water into local watercourses or water features.

Any impact upon the baseline water quality caused by primary mineral processing operations may impact upon the local aquatic ecosystems, and/or local human populations who use the water for drinking, washing, irrigating or livestock watering.

In addition to the above, if not managed correctly, stormwater may pose a risk of flooding to developments downstream.

The aim of this conceptual stormwater management plan is to mitigate the above impacts by fulfilling the requirements of the National Water Act (Act 36 of 1998) and more particularly GN 704 (as discussed in Section 1).

The following definitions from GN 704 are appropriate to the classification of catchments and design of stormwater management measures at the proposed West Wits project:

- **Clean water system:** includes any dam, other forms of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted (clean) water;
- **Dam:** includes any settling dam, slurry dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste (i.e. dirty water);
- **Dirty area:** means any area at a mine or ***activity*** which causes, has caused or is likely to cause pollution of a water resource;
- **Dirty water system:** This includes any dirty water diversion bunds, channels, pipelines, dirty water dams or other forms of impoundment, and any other structure or facility constructed for the retention or conveyance of water containing waste (i.e. dirty water); and
- **Activity:** means any mining related process on the mine including the operation of washing plants, mineral processing facilities, mineral refineries and extraction plants; the operation and the use of mineral loading and off-loading zones, transport facilities and mineral storage yards, whether situated at the mine or not; in which any substance is stockpiled, stored, accumulated, dumped, disposed of or transported.

The following terms were used to describe the elements of the PCSWWM Software used for the development of the stormwater management plan.

TABLE 4-1: DESCRIPTION OF THE SWMP TERMS

SWMP Element	Description
Catchment	That area determined by topographic features within which falling rain will contribute to runoff to a particular point under consideration.
Conduit	Any artificial or natural duct, either open or closed, intended for the conveyance of fluids.
Weir	An overflow structure across a channel which may be used for controlling upstream surface level, or for measuring discharge, or for both; usually used in combination with a reference to the shape of the notch or the form of the crest. See following terms modifying
channel	A perceptible natural or artificial waterway which periodically or continuously contains moving water or which forms a connecting link between two bodies of water. It has a definite bed and banks which confine the water.
Outfall or outlet	The point, location or structure where waste water or drainage discharges from a stream, river, lake, tidal basin or drainage area; or pipe, channel, sewer, drain, or other conduit.

4.2 DESIGN PRINCIPLES FOR STORMWATER MANAGEMENT PLAN

Informed by the baseline hydrology of the site and surroundings (presented in Section 2), a review of the proposed surface infrastructure has been undertaken, and a series of design principles for stormwater management have been developed to ensure compliance with the requirements of GN 704.

The proposed conceptual stormwater management plan (SWMP) is presented on Figure 4-1 to Figure 4-7, the key features include:

- Clean stormwater from the catchments on the north of each facility will be diverted around the dirty water catchments by a perimeter berm as discussed further for each infrastructure and mining complex in Section 4.4;
- Clean stormwater will be diverted around dirty catchments and allowed to flow towards the river;
- Dirty stormwater from the primary mineral processing sites (run of mine (ROM) stockpile and crusher area for each mining area) will be conveyed to a suitably sized Pollution control Dam (PCD and re-used for dust suppression subject to water quality;
- At the open cast mining pits, the stormwater is collected in a sump mixing with groundwater ingress into the pit and will be dewatered / pumped to a PCD and then through a water treatment plant before reuse or discharge; and
- Dirty stormwater from the waste rock dumps in cases where they are not located within the pit footprint will be collected in PCDs located at each of the open pit mining areas and infrastructure complexes. In order to maintain the capacities of the PCD’s, silt traps need to be built along the channel systems entering the PCDs. These silt traps must be double compartment silt traps so that they can be cleaned out while continuing to allow the stormwater to flow through the other compartment.

In addition to the PCDs, a series of water treatment plants are proposed, which will treat water pumped out of the shafts and pits prior to commencement of mining and during mining and reused with the stormwater, as discussed further in Section 5. This is to allow sufficient abstraction from the PCDs to effectively manage the size and cost of these structures.

In order to meet the design principles detailed above, conceptual design details for the proposed stormwater management measures are presented below for each of the proposed opencast mine pits and infrastructure complexes, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each management measure proposed.

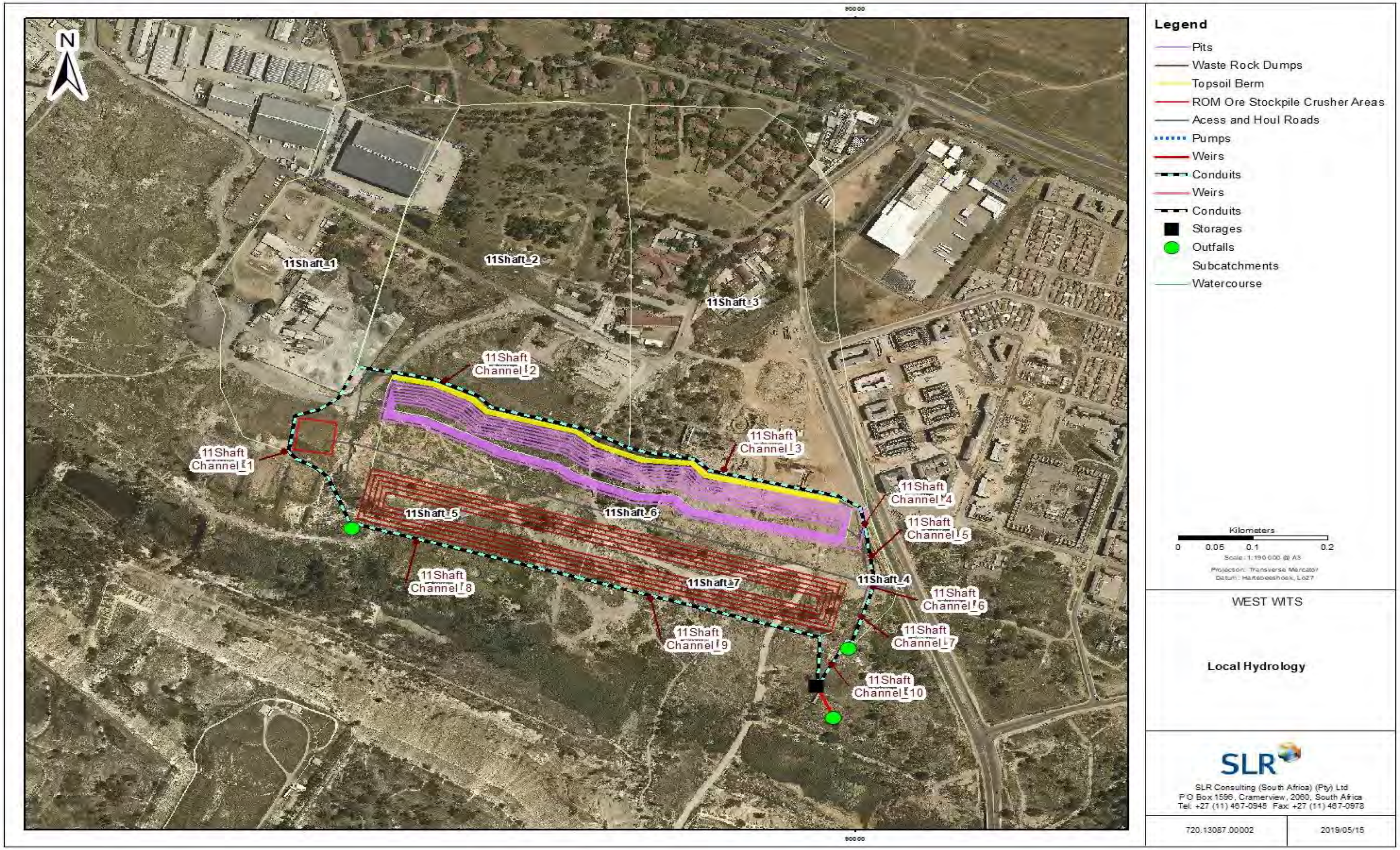


FIGURE 4-1: STORMWATER MANAGEMENT PLAN (SWMP) FOR THE 11 SHAFT MAIN REEF PIT

FIGURE 4-2: SWMP FOR THE KIMBERLEY REEF EAST PIT

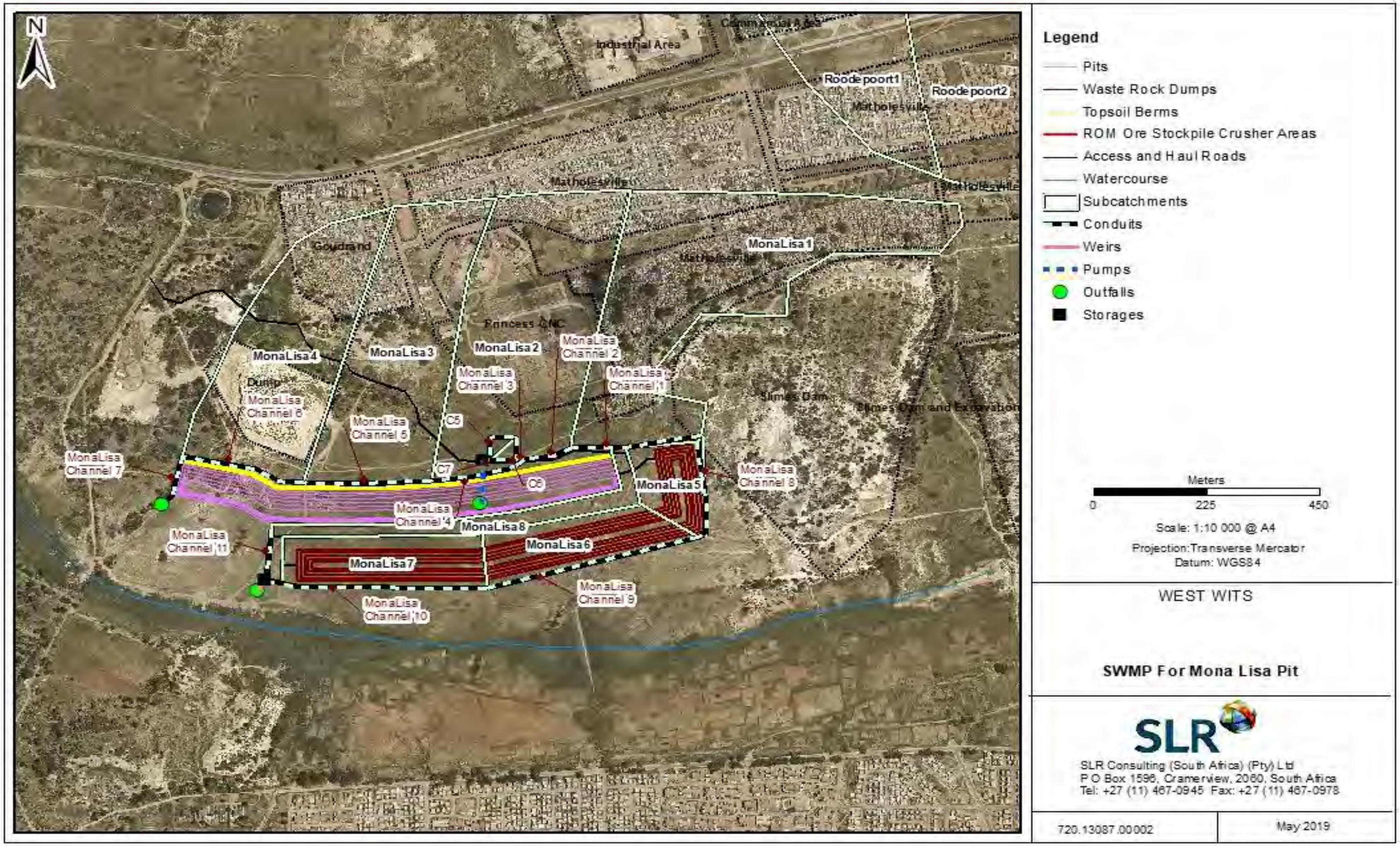


FIGURE 4-3: SWMP FOR THE MONA LISA BIRD REEF PIT

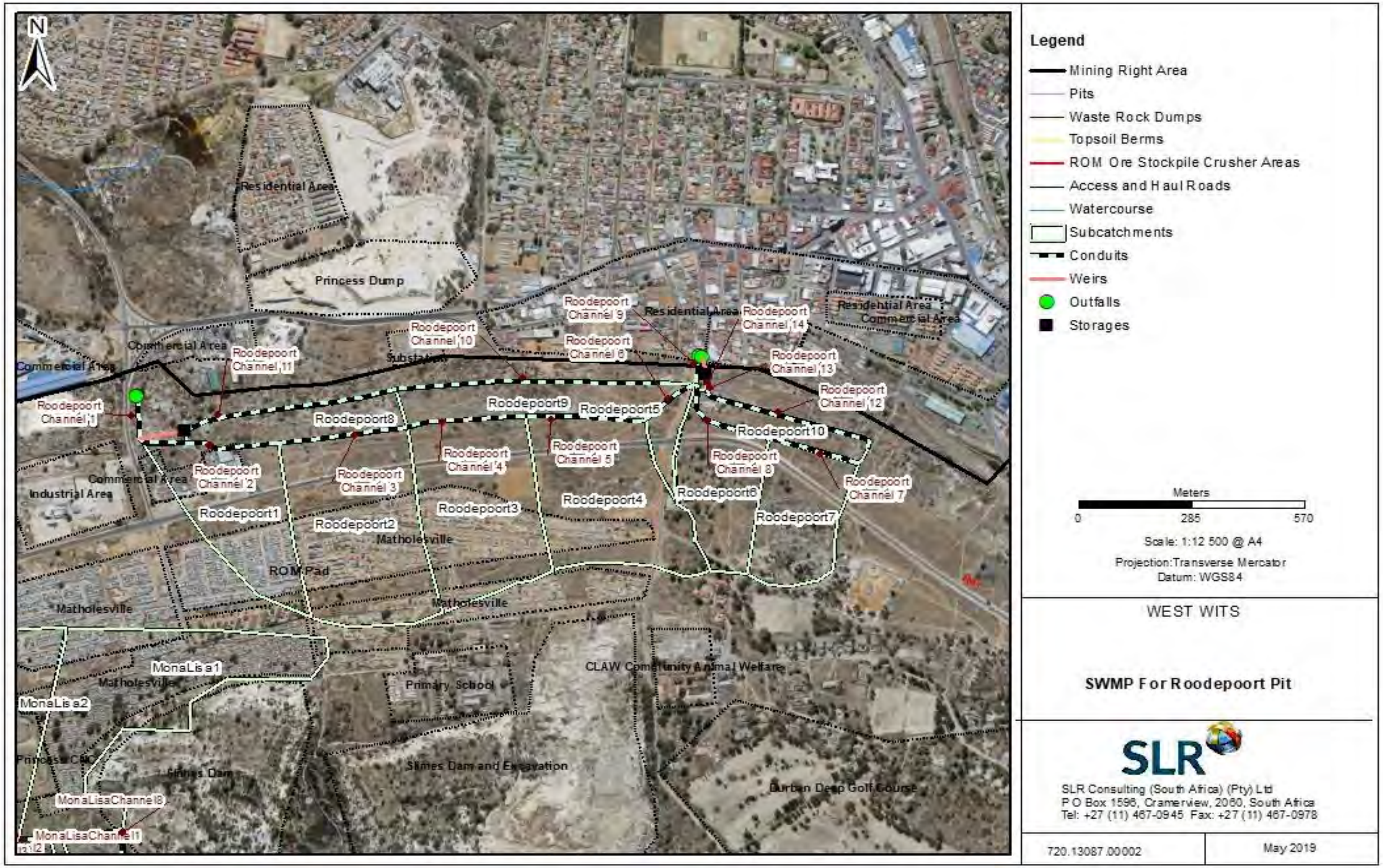


FIGURE 4-4: SWMP FOR THE ROODEPOORT MAIN REEF PIT

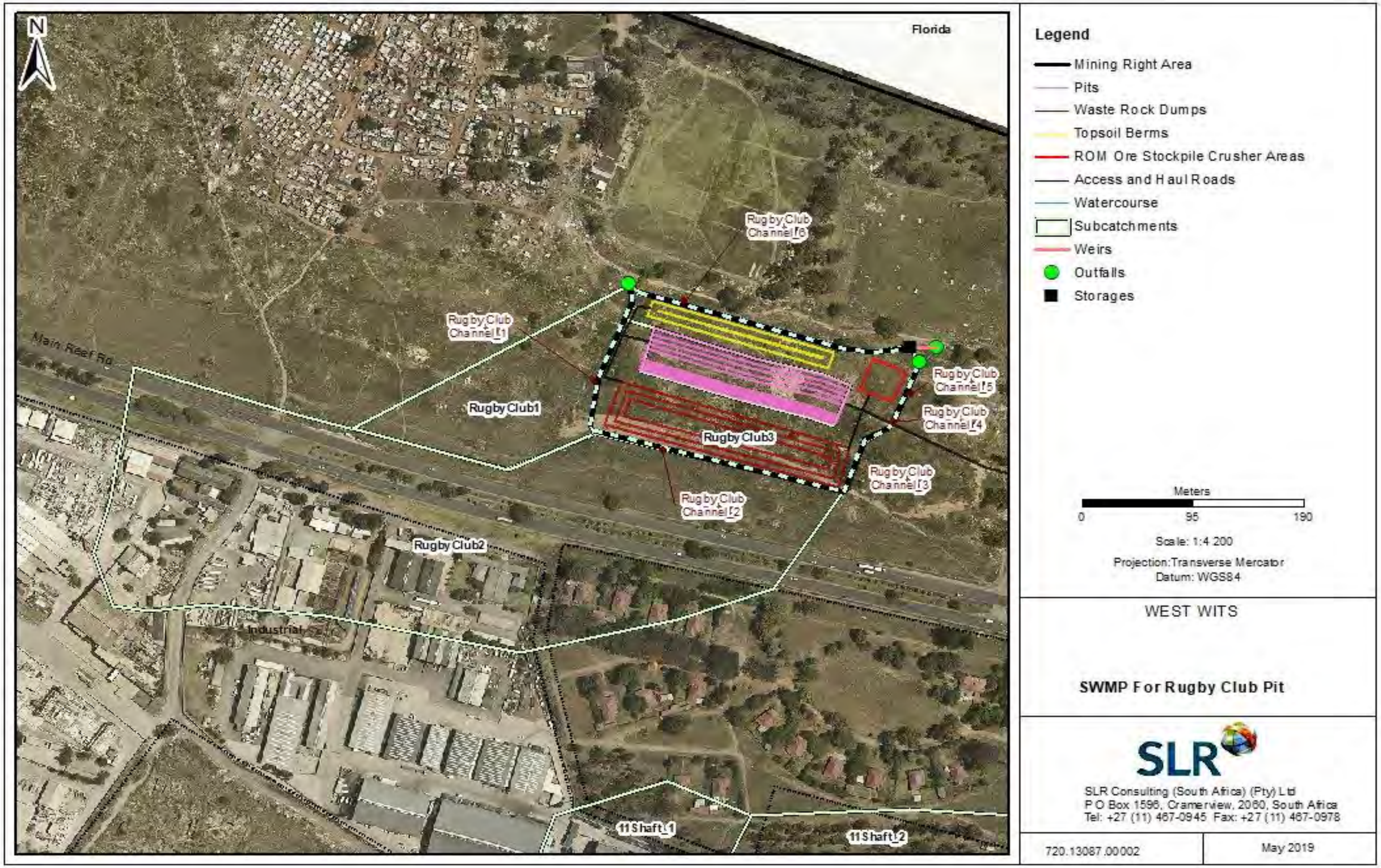


FIGURE 4-5: SWMP FOR THE RUGBY CLUB MAIN REEF PIT

FIGURE 4-6: SWMP FOR THE BIRD REEF CENTRAL INFRASTRUCTURE COMPLEX

FIGURE 4-7: SWMP FOR THE KIMBERLEY REEF EAST INFRASTRUCTURE COMPLEX

4.3 POLLUTION CONTROL DAMS

4.3.1 Introduction

The proposed PCDs in the underground mining infrastructure complexes should be located downslope of the shaft areas, which ensures gravity drainage of runoff from all dirty water catchments identified. The PCDs will be lined to prevent seepage of dirty water, which otherwise might pollute local surface and ground water resources. The PCDs will feature an engineered spillway to convey design exceedance events through the PCDs to the environment without causing erosion of the dam walls, which would otherwise compromise the structural integrity of the PCDs.

The following stormwater PCDs are recommended to contain runoff from dirty catchment areas:

- Mona Lisa Bird Reef Pit
- Roodepoort Main Reef Pit
- Rugby Club Main Reef Pit
- 11 Shaft Main Reef Pit
- Kimberley Reef East Pit
- Bird Reef Central Infrastructure Complex and shaft - which collects runoff from the Processing Plant area
- Kimberley Reef East Infrastructure Complex and shaft - which collects runoff from the Processing Plant area

4.3.2 Hydraulic Design Standards

GN 704 requires that dirty water containment facilities are designed, constructed, maintained and operated so that they are not likely to spill into a clean water environment more frequently than once in 50 years. A critical component in sizing the containment pond is the rate at which water is pumped from the pond for re-use at the site, which forms part of the site wide water balance. GN 704 also requires that as a minimum, the 1:50 year storm design volume and a 0.8 m freeboard allowance should always be available.

The PCDs are discussed further in the Water Balance section of the report (Section 5).

4.4 DRAINAGE CHANNELS

4.4.1 Introduction

The clean and dirty stormwater catchments and route of drainage channels are presented in Figure 4-1 to 4-7.

4.4.2 Hydraulic Design Standards

As discussed in Section 1.3, GN 704 requires the following:

- **Capacity:** dirty water systems are to be designed, constructed, maintained and operated so that they are not likely to spill into a clean water system or the environment more frequently than once in 50 years.
- **Conveyance:** all water systems are to be designed, constructed, maintained and operated so that they convey a 1:50 year flood event.
- **Freeboard:** as a minimum, any dirty water dams are to be designed, constructed, maintained and operated to have 0.8 m freeboard above full supply level.
- **Collect and Re-Use:** ensure that dirty water is collected and re-used as far as practicable.
- **Diversion:** minimise flow of any surface water or floodwater into operational areas.

Based on the infrastructure layouts, clean and dirty water catchment areas were delineated based on the expected quality of stormwater generated from the different catchments as presented in Figure 4-1 to Figure 4-7 , where:

- Clean water catchment areas include the administration buildings, security buildings, parking areas and the areas upstream of infrastructure; and
- Dirty water catchment areas include the proposed infrastructure footprint including the ROM pads, pits, Waste Rock Dumps (WRDs), topsoil stockpiles, loading areas and the proposed mine roads.

The proposed conceptual stormwater management layout plan is presented on Figure 4-1 to Figure 4-7. The key features include:

- Clean stormwater will be prevented from entering dirty water catchments by creating perimeter berms around the infrastructure footprint (channels and berms);
- Stormwater generated from the offices and parking areas will be considered clean and managed by clean water diversion berms or unlined clean water channels, and diverted around dirty areas;
- Dirty water generating areas within the infrastructure layout areas and plants will generate runoff into the dirty water collection channels;
- Dirty stormwater will be collected by concrete lined open channels and circular culverts and conveyed to the pollution control dam (PCD). Open channels are preferred for ease of maintenance and they minimise how deep the stormwater infrastructure needs to be excavated below ground level to accommodate design capacity, whilst maintaining suitable drainage gradients;
- Some stormwater manipulations are also required in places in the form of berms (speed bumps) and small concrete walls to direct the flow of the stormwater in the desired direction;
- Collected stormwater in the channels should pass through silt traps before being conveyed into the PCD. The sediment in the stormwater (likely to include ore) can then be recovered from the silt traps;
- Ground levels may need to be raised in certain areas, to achieve drainage gradients and remove low spots although this will need to be confirmed through more detailed design work; and
- The PCDs will need to be a lined facility and equipped with a return water system.

In order to meet the design principles detailed above, conceptual design details for the proposed stormwater management measures are presented below, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each measure proposed.

4.4.3 Design Methodology

Peak flows for the conveyance infrastructure were estimated using the Soil Conservations Services (SCS) Method applied within the PCSWMM stormwater design software package. A curve number (CN) is used for each catchment to characterize the runoff properties for a particular soil and ground cover. The CN value is a primary input parameter for the SCS runoff equation, as used by the PCSWMM software. A high CN value (such as 98 for pavement) causes most of the rainfall to appear as runoff, with minimal losses. Lower values (such as 58 for certain wooded areas) correspond to an increased ability of the soil to retain rainfall, and will produce much less runoff and increased infiltration. A Type III storm profile was applied to the 1:50 year 24 hour rainfall depth (153 mm) to estimate peak flows from each catchment.

The channels were sized to take the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing will be uniform along the entire length. Some cut and fill may be required along the length of the channels to achieve the required gradient to ensure that water flows freely within these channels. The clean water will be kept out of the dirty water channels by construction of a linear bund upstream of the channel (see Figure 4-8) with material excavated from the channel.

The freeboard requirements are as follows (already catered for in the sizing):

- The peripheral stormwater diversion and dirty water collection channels or drains will have either a 0.3 m or 0.6 m freeboard. If the flow is less than 10 m^3/s, then 0.3 m of freeboard is included and if the flow is greater than 10 m^3/s, then 0.6 m of freeboard is included.

The worst case rainfall event for each catchment (i.e. duration = time of concentration) was taken from the Storm DDF estimates presented in Table 2-6: STORM DEPTH-DURATION-FREQUENCY (DDF) RAINFALL FOR the PROJECT SITETable 2-6.

Following confirmation of the design flows for each diversion channel, the channels have been sized using the Manning's Equation to ensure that the flow capacity of the channel is sufficient to convey the 1:50 year rainfall event.

The Manning's equation is:

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

Where:

A = Area of Channel

R = Hydraulic Radius (area / wetted perimeter);

S = Longitudinal Slope of Channel; and

n = Manning's Roughness Coefficient

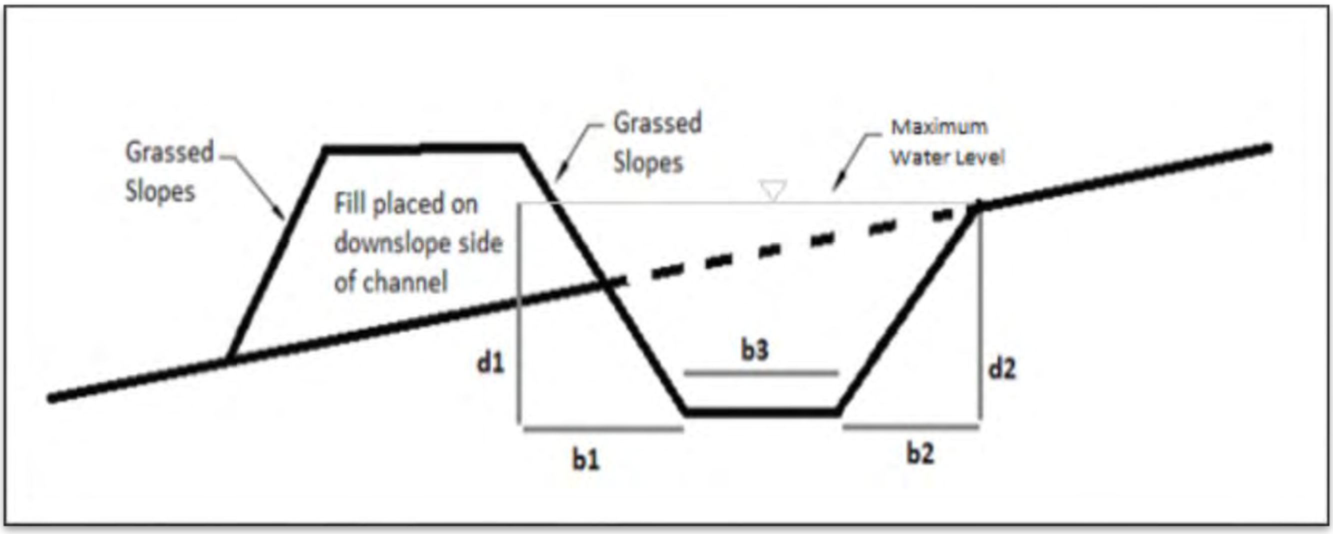


FIGURE 4-8: SCHEMATIC OF A CROSS-SECTIONAL VIEW OF THE CHANNEL DESIGN

4.4.4 Sub-Catchments

The sub-catchments contributing flow into the clean water diversion channels and the dirty water collection channels have been modelled within the PCSWMM software. The salient details of the sub-catchment characteristics are given in Table 4-2 below. The Mannings 'n' coefficient for the pervious areas and the impervious are 0.13 and 0.015 respectively. The impervious area for each sub-catchment has been changed to represent the different flow responses within the different sub-catchments.

TABLE 4-2: SUB-CATCHMENT CHARACTERISTICS USED IN THE PCSWMM MODEL

Name	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Impervious Area (%)	Curve Number	Runoff Volume (m^3)	Peak Runoff (m^3/s)	Runoff Coefficient
11Shaft_1	9.45	210	449.9	2.9	20	78	10470	2.9	0.72
11Shaft_2	14.68	300	489.4	2.9	20	78	16250	4.4	0.72
11Shaft_3	15.91	290	548.5	3.3	20	78	17580	4.7	0.72
11Shaft_4	0.44	20	222.0	3.2	5	78	460	0.1	0.68
11Shaft_5	4.52	280	161.3	2.0	5	78	4700	1.4	0.68
11Shaft_6	6.04	600	100.6	2.0	5	78	6320	2.3	0.68
11Shaft_7	3.10	350	88.5	2.0	5	78	3250	1.2	0.69
Kimberley1	2.89	100	289.2	2.3	5	78	2990	0.7	0.68
Kimberley2	8.71	270	322.5	1.9	5	78	8960	1.9	0.67
Kimberley3	10.58	400	264.6	1.1	5	78	10870	2.2	0.67
Kimberley4	4.47	340	131.5	2.0	5	78	4670	1.5	0.68
Kimberley5	1.35	325	41.6	2.0	5	78	1430	0.7	0.69
Kimberley6	2.85	325	87.8	2.0	5	78	2990	1.1	0.69
MonaLisa1	19.20	250	768.0	2.9	60	78	25240	9.5	0.86
MonaLisa10	0.12	50	24.9	2.0	5	78	130	0.1	0.69
MonaLisa2	16.74	270	619.9	2.9	60	78	22040	8.8	0.86
MonaLisa3	13.55	200	677.7	2.5	35	78	16010	5.0	0.77
MonaLisa4	12.79	230	555.9	3.6	20	78	14140	3.8	0.72
MonaLisa5	2.41	130	185.4	2.0	5	78	2510	0.7	0.68
MonaLisa6	4.11	110	374.0	2.0	5	78	4220	0.8	0.67
MonaLisa7	4.61	110	418.8	2.0	5	78	4710	0.9	0.67
MonaLisa8	2.94	35	841.0	3.1	5	78	2960	0.4	0.66

Name	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Impervious Area (%)	Curve Number	Runoff Volume (m^3)	Peak Runoff (m^3/s)	Runoff Coefficient
MonaLisa9	0.13	50	26.4	2.0	5	78	140	0.1	0.69
Roodepoort1	10.12	200	505.9	4.0	40	78	12300	4.7	0.80
Roodepoort10	2.96	450	65.8	2.0	5	78	3110	1.3	0.69
Roodepoort2	16.68	325	513.2	3.4	30	78	19370	6.4	0.76
Roodepoort3	14.17	310	457.1	2.9	25	78	16080	4.9	0.74
Roodepoort4	13.82	325	425.1	3.3	20	78	15340	4.5	0.73
Roodepoort5	1.63	80	204.2	3.5	5	78	1700	0.5	0.68
Roodepoort6	7.42	200	370.8	2.7	10	78	7840	1.8	0.69
Roodepoort7	7.76	210	369.6	1.0	10	78	8110	1.5	0.68
Roodepoort8	4.69	550	85.4	2.0	5	78	4920	1.9	0.69
Roodepoort9	6.66	670	99.3	2.0	5	78	6970	2.5	0.68
RugbyClub1	1.74	100	174.5	4.6	25	78	2000	0.9	0.75
RugbyClub2	10.18	170	598.6	2.7	25	78	11490	3.2	0.74
RugbyClub3	2.50	255	97.9	2.0	10	78	2680	1.0	0.70
BirdReefInfrastructure1	12.32	235	524.4	5.0	15	84	14600	3.9	0.77
BirdReefInfrastructure2	16.82	240	700.8	3.8	15	84	19770	4.5	0.77
BirdReefInfrastructure3	1.27	100	127.0	5.5	5	92	1690	0.7	0.87
BirdReefInfrastructure4	1.39	100	138.9	3.3	5	92	1840	0.7	0.87
KimberleyEastInfrastructure1	37.81	740	510.9	3.9	5	78	38810	7.8	0.67
KimberleyEastInfrastructure2	10.57	300	352.3	3.0	5	78	10900	2.5	0.67
KimberleyEastInfrastructure3	4.27	260	164.2	6.7	5	92	5670	2.3	0.87
KimberleyEastInfrastructure4	0.30	40	76.2	3.5	5	92	410	0.2	0.87

4.5 CONVEYANCE INFRASTRUCTURE DESIGN

The dirty stormwater catchments and the location of the drainage channels are presented in Figure 4-1 to Figure 4-7. The estimated design flows and recommended conveyance infrastructure (culverts, kerbing and channels) are presented below in Table 4-2.

4.5.1 Recommended Conveyance Infrastructure Sizes

Figures 4-1 to Figure 4-7 presents the location of the proposed stormwater conveyance infrastructure as well as the sub-catchments which flow into them. The peak flow estimates for each of the stormwater channels, as well as the preliminary channel sizes recommended to accommodate the design flows are presented in Table 4-3. The dirty water channels will be concrete lined to prevent any seepage of dirty water to the underlying groundwater environment. The clean water channels do not automatically require lining, however in this case the velocities in the channels are high so it is recommended that the channels are concrete lined to prevent erosion and scour. Circular culverts are recommended for conveying flows beneath major road crossings.

During the construction of the conveyance infrastructure, the location of existing services must be considered, and the drainage channels worked around these where necessary.

TABLE 4-3: STORMWATER CHANNEL SIZING

Name	Length (m)	Cross-Section	Depth (m)	Bottom Width (m)	Side Slopes (H:V)	Barrels	Slope (m/m)	Maximum Flow (m^3/s)	Maximum Velocity (m/s)	Depth of Water in Drain (m)
11ShaftChannel_1	323.9	TRAPEZOIDAL	0.70	1.0	2	1	0.0712	2.9	6.5	0.29
11ShaftChannel_10	83.6	TRAPEZOIDAL	0.90	1.0	2	1	0.0599	2.3	1.8	0.59
11ShaftChannel_2	384.6	TRAPEZOIDAL	0.90	1.0	2	1	0.0182	4.3	3.2	0.61
11ShaftChannel_3	330.4	TRAPEZOIDAL	1.00	1.5	2	1	0.0106	8.9	4.7	0.67
11ShaftChannel_4	40.7	CIRCULAR	0.90	0.0	0	3	0.0492	9.0	6.0	0.67
11ShaftChannel_5	78.5	TRAPEZOIDAL	1.00	1.0	2	1	0.0191	9.0	6.8	0.60
11ShaftChannel_6	10.3	CIRCULAR	0.90	0.0		3	0.0972	9.0	7.6	0.54
11ShaftChannel_7	99.4	TRAPEZOIDAL	0.90	1.0	2	1	0.0403	9.0	7.1	0.59
11ShaftChannel_8	307.6	TRAPEZOIDAL	0.80	1.0	2	1	0.0049	1.4	2.1	0.38
11ShaftChannel_9	414.7	TRAPEZOIDAL	1.00	2.2	2	1	0.0060	2.5	1.0	0.68
KimberleyEastChannel1	20.7	TRAPEZOIDAL	0.60	0.5	2	1	0.0483	0.7	4.0	0.20
KimberleyEastChannel2	162.3	TRAPEZOIDAL	0.60	0.5	2	1	0.0463	0.7	3.9	0.20
KimberleyEastChannel3	292.9	TRAPEZOIDAL	0.70	1.0	2	1	0.0325	1.9	3.5	0.33
KimberleyEastChannel4	300.7	TRAPEZOIDAL	0.90	1.0	2	1	0.0500	4.1	5.8	0.40
KimberleyEastChannel5	163.1	TRAPEZOIDAL	0.90	1.0	2	1	0.0338	4.1	4.2	0.50
KimberleyEastChannel6	17.6	CIRCULAR	0.75	0.0		2	0.0426	4.1	6.2	0.53
KimberleyEastChannel7	35.9	TRAPEZOIDAL	0.90	1.0	2	1	0.0209	4.1	4.5	0.47
KimberleyEastChannel8	334.6	TRAPEZOIDAL	0.60	1.0	2	1	0.0269	1.5	3.8	0.26
KimberleyEastChannel9	325.2	TRAPEZOIDAL	0.90	1.0	2	1	0.0523	2.1	1.7	0.59
MonaLisaChannel1	261.2	TRAPEZOIDAL	1.00	1.5	2	1	0.0172	9.5	5.6	0.62
MonaLisaChannel10	442.5	TRAPEZOIDAL	1.00	1.0	2	1	0.0317	2.4	1.6	0.66

Name	Length (m)	Cross-Section	Depth (m)	Bottom Width (m)	Side Slopes (H:V)	Barrels	Slope (m/m)	Maximum Flow (m^3/s)	Maximum Velocity (m/s)	Depth of Water in Drain (m)
MonaLisaChannel11	111.7	TRAPEZOIDAL	0.80	1.0	2	1	0.1172	0.4	0.5	0.44
MonaLisaChannel12	98.4	TRAPEZOIDAL	0.30	0.3	1	1	0.0356	0.1	2.9	0.07
MonaLisaChannel13	102.4	TRAPEZOIDAL	0.30	0.3	1	1	0.0273	0.1	1.9	0.09
MonaLisaChannel14	13.4	TRAPEZOIDAL	1.00	1.0	1	1	0.1906	0.1	3.5	0.10
MonaLisaChannel2	98.8	TRAPEZOIDAL	1.30	3.0	2	1	0.0354	18.1	6.7	0.64
MonaLisaChannel3	18.9	CIRCULAR	1.05	0.0		4	0.0529	18.1	7.6	0.68
MonaLisaChannel4	175.7	TRAPEZOIDAL	1.40	2.0	2	1	0.0370	18.1	7.7	0.69
MonaLisaChannel5	254.8	TRAPEZOIDAL	1.60	2.5	2	1	0.0334	22.8	7.6	0.75
MonaLisaChannel6	254.5	TRAPEZOIDAL	1.40	2.5	2	1	0.0334	26.6	9.0	0.74
MonaLisaChannel7	118.4	TRAPEZOIDAL	1.30	2.0	2	1	0.0677	26.6	11.2	0.70
MonaLisaChannel8	218.3	TRAPEZOIDAL	0.60	0.6	2	1	0.0712	0.7	3.5	0.20
MonaLisaChannel9	438.2	TRAPEZOIDAL	0.60	1.0	2	1	0.0365	1.5	3.6	0.28
RoodepoortChannel1	111.8	TRAPEZOIDAL	1.20	3.0	2	1	0.0448	19.6	8.5	0.56
RoodepoortChannel10	650.4	TRAPEZOIDAL	0.60	0.8	2	1	0.0200	2.5	4.1	0.39
RoodepoortChannel11	546.0	TRAPEZOIDAL	1.00	1.8	2	1	0.0202	4.3	1.9	0.69
RoodepoortChannel12	448.0	TRAPEZOIDAL	0.70	1.0	1	1	0.0089	1.3	2.5	0.39
RoodepoortChannel13	21.1	CIRCULAR	0.60	0.0		1	0.0953	1.2	9.0	0.29
RoodepoortChannel14	31.0	TRAPEZOIDAL	0.90	1.0	1	1	0.0971	1.2	1.5	0.54
RoodepoortChannel2	363.5	TRAPEZOIDAL	1.30	3.0	2	1	0.0289	19.6	7.7	0.60
RoodepoortChannel3	327.9	TRAPEZOIDAL	1.30	3.0	2	1	0.0183	15.2	5.6	0.64
RoodepoortChannel4	301.8	TRAPEZOIDAL	1.00	1.5	2	1	0.0133	9.2	5.0	0.66
RoodepoortChannel5	293.7	TRAPEZOIDAL	0.90	1.0	2	1	0.0187	4.4	3.4	0.59
RoodepoortChannel6	400.0	TRAPEZOIDAL	0.70	1.0	2	1	0.0025	0.5	0.9	0.34

Name	Length (m)	Cross-Section	Depth (m)	Bottom Width (m)	Side Slopes (H:V)	Barrels	Slope (m/m)	Maximum Flow (m^3/s)	Maximum Velocity (m/s)	Depth of Water in Drain (m)
RoodepoortChannel7	231.6	TRAPEZOIDAL	0.80	1.0	2	1	0.0086	1.5	2.2	0.38
RoodepoortChannel8	277.3	TRAPEZOIDAL	0.80	1.0	2	1	0.0216	3.3	4.5	0.41
RoodepoortChannel9	73.9	TRAPEZOIDAL	0.80	1.0	2	1	0.0338	3.8	5.3	0.40
RugbyClubChannel_1	135.9	TRAPEZOIDAL	0.60	0.6	2	1	0.0295	0.9	3.5	0.23
RugbyClubChannel_2	220.8	TRAPEZOIDAL	0.80	1.0	2	1	0.0204	3.2	4.3	0.41
RugbyClubChannel_3	73.4	TRAPEZOIDAL	0.90	1.0	2	1	0.0409	4.2	4.0	0.59
RugbyClubChannel_4	11.0	CIRCULAR	0.68	0.0		2	0.0457	4.1	6.5	0.56
RugbyClubChannel_5	56.5	TRAPEZOIDAL	0.80	1.0	2	1	0.0266	4.1	5.0	0.44
RugbyClubChannel_6	240.7	TRAPEZOIDAL	0.90	1.0	2	1	0.0291	1.0	1.1	0.55
BirdReefInfrastructureChannel1	152.6	TRAPEZOIDAL	0.80	1.0	2	1	0.0262	3.9	5.9	0.38
BirdReefInfrastructureChannel2	151.0	TRAPEZOIDAL	0.70	1.0	2	1	0.1066	3.9	8.1	0.30
BirdReefInfrastructureChannel3	181.1	TRAPEZOIDAL	0.80	1.0	2	1	0.0387	4.5	5.8	0.42
BirdReefInfrastructureChannel4	131.4	TRAPEZOIDAL	0.60	0.6	2	1	0.0228	0.7	3.4	0.21
BirdReefInfrastructureChannel5	118.6	TRAPEZOIDAL	0.90	1.0	2	1	0.0931	1.4	1.2	0.54
KEInfrastructureChannel1	332.9	TRAPEZOIDAL	1.00	1.0	2	1	0.0542	7.8	7.7	0.51
KEInfrastructureChannel2	409.5	TRAPEZOIDAL	0.70	1.0	2	1	0.0367	2.5	4.9	0.32
KEInfrastructureChannel3	167.2	TRAPEZOIDAL	0.80	1.0	2	1	0.0629	2.3	3.1	0.42
KEInfrastructureChannel4	19.1	CIRCULAR	0.75	0.0		1	0.0524	2.2	6.5	0.56
KEInfrastructureChannel5	252.3	TRAPEZOIDAL	0.60	1.0	2	1	0.0060	2.1	1.7	0.59
KEInfrastructureChannel6	57.6	TRAPEZOIDAL	0.70	1.0	2	1	0.0435	0.2	0.3	0.39

4.6 LIMITATIONS AND FURTHER WORK

A critical component in sizing of the PCDs in accordance with GN 704 is the rate at which water will be pumped from the pond for re-use at the plant. As part of the detailed design, which will be undertaken in support of the Water Use License Application (WULA), the PCD volume and pump-out rate will be checked using a daily time-step water balance model. It is recommended that the capacity of the PCDs is again reviewed during detailed design of the stormwater measures to ensure compliance with GN 704 and BPG A4 (DWAF, 2007), considering the predicted inflows and outflows for the site wide water balance.

It is also recommended that the hydraulic gradients and channel sizes are confirmed during the detailed design of the channels. The requirement for, and design of, in-channel velocity control measures should be confirmed during the detailed design of the channels.

The specification for lining of the channels and the PCDs should also be confirmed during the detailed design of these features.

5. SITE WIDE WATER BALANCE

5.1 INTRODUCTION

A daily average site wide water balance model was developed for the proposed West Wits Mining project to establish the:

- Storage sizes for the proposed dirty water dams/sumps (complex PCDs.).
- The average wet, dry season and monthly water balances across the complex

The model will focus predominantly on the interaction between rainfall, evaporation, groundwater ingress, mine water demands and make up water with the aim of developing a water balance control philosophy for the management of water on the mine.

5.2 DESIGN STANDARDS

As discussed in Section 1.3, the water balance, dams and the associated operational infrastructure are to be designed in compliance with the National Water Act (Act No. 36 of 1998), GN704 and DWS BPG which recommends following:

- The BPG (A4) requires that the determination of the size of the PCD is determined such that it will only spill once in 50 years and requires the application of a continuous model at a daily time step.
- Furthermore, Regulation 6 of GN 704 requires that the capacity requirements of dirty water systems be designed “so that it is not likely to spill into any clean water system more than once in 50 years”.

A water balance approach has been adopted which takes into account daily runoff, evaporation and water re-use. The reuse of water is an important component of the PCD dam sizing and is related to the potential pump out rate from the processing plants water dam.

5.3 METHODOLOGY

A dynamic water balance has been developed for the stormwater catchments and is run on a daily time step using 59 years of rainfall data obtained from Zuurbekom rain gauge station as presented in Section 2. The daily rainfall data record is from 1959 through until 2018. The model demonstrates how flows and stored water vary in response to wet and dry periods in order to understand the dam capacity requirements. The model is run using the GoldSim simulation software.

Hydrological and hydraulic input parameters that will be used for the development of the site wide water balance are detailed below.

5.4 WATER BALANCE CONTROL PHILOSOPHY

Based on the safety of mine personnel, protection of the environment and the anticipated future cost of water the following overall water balance priorities were set in order of precedence:

- **Water balance priority 1 - Surface water runoff management:** Any unpolluted water (clean water) must be separated or diverted, away from any polluted water (dirty water) area. The accumulation of water into the open pit must be limited to minimise the impact on mining activities and mine personnel within the open pit.
- **Water balance priority 2 – Containment of dirty water to meet Regulation 704**
  - Each **Dirty water dam** must be maintained and operated so that it is:
    - not likely to spill into any clean water system more than once in 50 years; and
    - at all times capable of handling the 1:50 year flood-event on top of its mean operating level without spilling.
- **Water management priority 3 - Process make up water:** Make up water must be kept to a minimum by optimising the re-use of existing dirty water sources, and limiting the use of more costly clean water sources.

Incorporating the above priorities, water allocation for process water usage at the proposed West Wits Mine will be allocated in the following order of precedence:

- Return water from the proposed Plant PCD
- Make up water from the process make up water source

5.5 INPUT PARAMETERS

5.5.1 Daily rainfall data (for water balance purposes)

A daily time series rainfall was used to estimate the stormwater volumes inflows into the pit sumps, dirty water dams/ PCD. Daily rainfall data was extracted for Zuurbekom rainfall station number C2E007 from 1959/02/01 to 2019/01/31 and is shown in FIGURE 5-1 below. More detail of the station is presented in Section 2.

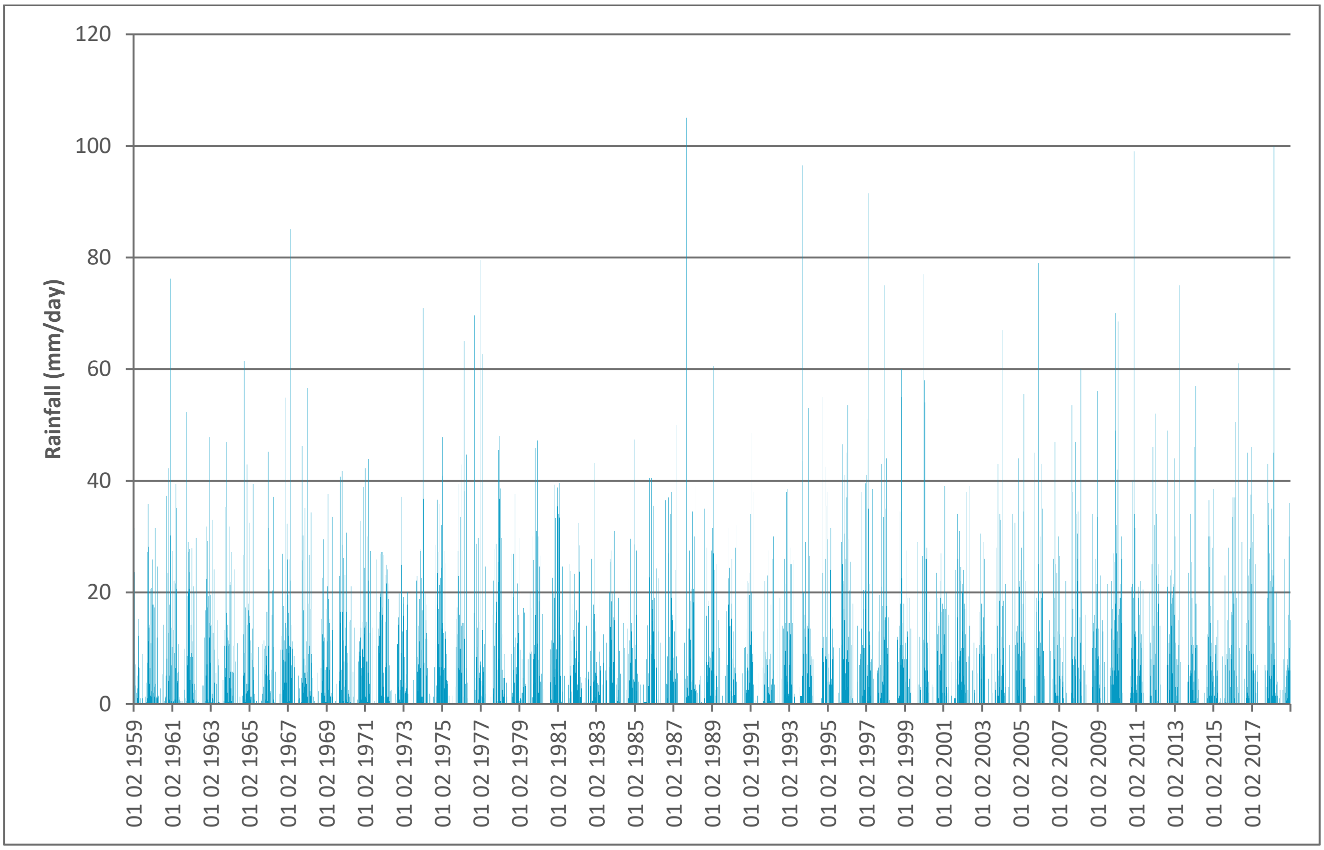


FIGURE 5-1: DAILY RAINFALL DEPTHS FOR ZUURBEKOM 0475528 W - FROM 1959/02/01 TO 2019/01/31

5.5.2 Evaporation data

Evaporation losses from the pit sump and dirty water data are estimated on a daily basis by multiplying the pro-rata'd average open water evaporation rate by the surface area of the dam. The lake evaporation figures as presented in Section 2 was calculated from the Zuubekom (C2E007) Symon's Pan data. Also presented within Section 2 is the average monthly lake evaporation figures which were then converted to daily figures.

Pool evaporation percentage (as percentage of evaporation of fully exposed pool) was estimated to be 100% for all surface water dams as presented in Table 2-6.

TABLE 5-1: POOL EVAPORATION PERCENTAGE

Parameter	All dam pools	Source/Notes
Pool evaporation percentage (as percentage of evaporation of fully exposed pool)	100%	SLR assumed value based on the assumption that no aqua guard (or cover) will be installed above any of the pool surfaces.

5.5.3 Seepage Parameters

Based on Darcy's law, the estimated daily seepage outputs were calculated by multiplying seepage area by the estimated coefficient of permeability. The coefficient of permeability for the different water containment facilities are listed below in Table 5-2 based on geotechnical consideration.

TABLE 5-2: SEEPAGE AND UDNERDRAINAGE PARAMETERS FOR WATER CONTAINMENT FACILITIES

Parameter	Open Pit Sump	Waste Rock Dump and Rom Stockpile	All other dams
Seepage rate	1e-7 m/s (from the sump pool area to the underground)	0 m/s (through waste rock dump to groundwater or underdrainage)	0 m/s (assuming lined dams)
Underdrainage		No underdrainage infrastructure is envisaged at this stage	

5.5.4 Groundwater inflows into mining areas

Groundwater inflow into the open pits and underground mining areas are modelled as steady state inflows and are assumed to be suitable for all non-potable water uses. Modelled[1] groundwater inflows into the mining areas are presented in TABLE 5-3.

TABLE 5-3: DATA FOR GROUND WATER INFLOW INTO OPEN PITS AND UNDERGROUND MINING AREAS

Complex	Infrastructure	Groundwater (m^3/day)	
		Lower	Upper
Kimberley Reef East	Open Pit	225	466
11 Shaft	Open Pit	600	1215
Rugby Club	Open Pit		50
Mona Lisa	Open Pit	1350	2700
Roodepoort	Open Pit	370	730
Bird reef central	Underground	490	2098
Kimberley east	Underground	860	3594
Bird reef central	Underground		882
Kimberley east	Underground		1892

[1] NOA Agencies (Pty) Ltd, 2019. West Wits MRA Hydrogeological Specialist Investigation (March 2019)

NOA agencies, indicated that there is a wide range of uncertainty due to additional studies and data requirements, and that both upper and lower inflows are an indication of volumes that can be possibly intercepted for the open pit and the underground mining areas.

As a conservative approach, the upper groundwater make was assumed and this assumption should be revised when more up to date monitoring data is available. This results in a more conservative pump out rates from the PCDs in order to have small dams.

5.5.5 Stormwater

Stormflow volume is defined as the runoff response to a specific rainfall event, and consists of both surface runoff and subsurface flow, but excludes base flow (delayed subsurface response). Daily stormflow volumes will be calculated by multiplying daily stormflow depths by the contributing catchment areas.

Each of the open pit mining complexes is characterised by a Run of Mine (ROM) pad, Dump, Pit and associated topsoil stockpile. For the purposes of this model the pit and the topsoil have been treated as a single unit. Where two different units like these have been combined as one catchment, the CN is determined through area weighting.

The stormwater management plan adheres to the regulations of the GN 704 all of which is routed to the complex PCDs. Design storm volumes for the key dirty water facilities, as calculated from the above data (TABLE 5-4) and 1 in 50 year 24 hour storm rainfall data of 153mm are included below for design purposes of the final PCD. These design storm volumes will be evaluated against water balance modelled volumes for sizing of the dirty water facilities as part of the water balance modelling to meet Regulation 704.

TABLE 5-4: SCS CURVE NUMBERS (CNII)

Complex	Infrastructure	Footprint (m^2)	Footprint (ha)	Area Weighting	CN	SCS Storm Volume m^3
Kimberley East	ROM	2 500	0.250		82	267
	Dump	22 815	2.282		84	2548
	Pit and	20 623	2.062	0.773	94	2815
	Topsoil			0.227		
Mona Lisa	Rom	67 391	6.739		84	7527
	Dump	2 500	0.250		82	267
	Pit and	67 022	6.702	0.935	97	9669
	Topsoil			0.065		
Roodepoort	ROM	2 500	0.250		82	267
	Dump	46 075	4.608		84	5146
	Pit and	56 539	5.654	0.882	96	8012
	Topsoil			0.118		
Roodepoort	Dump	20 000	2.000		84	2234
	Pit and	16 256	1.626	0.885	96	2306
	Topsoil			0.115		
11Shaft	ROM	2 500	0.250		82	267
	Dump	51 873	5.187		84	5794
	Pit and	43 891	4.389	0.927	97	6315
	Topsoil			0.073		
Rugby club	ROM	900	0.090		82	96
	Dump	8 177	0.818		84	913
	Pit and	9 323	0.932	0.739	93	1258
	Topsoil			0.261		
Kimberley East Infrastructure	Shaft Infrastructure	45 740	4.574		92	6016
Circular Shaft Infrastructure	Shaft Infrastructure	26 593	2.659		92	3498

5.5.6 Water Consumption

The additional key variables and assumptions for the dynamic water balance model related to water consumption are the following:

- The dams are modelled, assuming vertical sides for simplicity;
- The return water system pumps water out of the dam for re-use at the plant whenever water is available. The total volume pumped for reuse from the OPCD has been selected such that a small dam

of less than 45 000 m^3 can be installed and the pump out rate is just high enough to prevent spillage at low water usage.

- Where considered appropriate, controlled discharge of excess water to the environment can be achieved through treatment of excess process water (as fed from the Process Water Tank) to a recommended discharge water quality standard. The process water treatment of excess process water (as fed from the Process Water Tank) will be implemented.
- The pump out rate was further determined considering that the life of each mine pit is short and assuming that there would be insufficient space available to introduce large PCDs.
- The area that the dust suppression systems was assumed to need to service was taken as 30% of the proposed footprint. It is assumed that dust suppression would be required to use underground dewatering and used at the following locations underground and on surface:
  - Crushing areas at crushers or breakers inside the pit
  - Roads and all stockpiles
- Sewage treatment will be undertaken and the release of treated sewage effluent to the environment will take place at accepted discharge water quality standards. Water in sewage is generally assumed to be 80 % of the potable water demand.

For the purpose of this study the pump out rate is not provided and is rather modelled as a variable in order to determine the optimum sized PCD dams. Process water treatment requirements will be calculated by Goldsim based on the following key scenarios (as outlined within Table 5-6). The additional input parameters are summarised in Table 5-5.

TABLE 5-5: SUMMARY OF WATER BALANCE INPUTS

Parameter	Value	Source/Notes
Dry ore throughput from Underground	15 000 tpm	SLR, 2018 – Scoping Report
Dry ore throughput from Open pit	15 000 tpm	SLR, 2018 – Scoping Report
Dust Suppression	40% of footprint at an application rate of 4mm of water per day	SLR Assumed
Potable water	Open cast mining areas = 50 employees Undergoing mining at peak production = 500 employees Assumed minimum water requirement of 90 l/person/day	SLR, 2018 – Scoping Report

5.6 RESULTS

The daily time step derived PCD sizing and the average water balances are presented in this section as informed by the 59 year long daily rainfall records.

5.6.1 PCD Sizing

The sizing of the PCDs was undertaken for each infrastructure complex based on a proposed return water rate. The water balance did not provide for optimisation of the pump out rate or PCD Sizing, therefore the PCD sizing has been based on assumed pump out rates that are just high enough to prevent spillage at low water usage and reduce the PCD sizing to a smaller size. For example, in the sizing of the Mona Lisa Open pit PCD a pump out rate of 120 m^3/hr would result in several spills, whist a pump out rate of 125 m^3/hr would not result in any spills and thereafter model becomes less sensitive to any values greater. The proposed PCD sizing is presented in Table 5-6 below

TABLE 5-6: SUMMARY OF WATER BALANCE DERIVED PCD SIZING AND PROPOSED PUMP OUT RATES

Area	1:50 24hr Storm Volume (SCS) m^3	Dam Pool Area (m^2)	Pump out rate for use m^3/hr	Modelled max Volume (m^3)	Daily Modelled Dam Sized (m^3)	GW Ingress (m3/day)	Recommended Treatment plant size (m^3/day)
Rugby Club Open Pit Mining Area	2 267	2 500	5	4 076	5 000	50	1 000
11 Shaft Open Pit Mining Area	12 376	10 000	60	26 634	30 000	1 215	1 500
Mona Lisa Open Pit Mining Area	17 464	15 000	125	43 280	45 000	2 700	3 000
Kimberley East Open Pit Mining Area	5 631	2 500	30	9 235	10 000	466	1 000
Roodepoort Open Pit Mining Area (PCD1)	13 426	8 000	35	23 021	25 000	487	1 000
Roodepoort Open Pit Mining Area (PCD2)	4 540	2 500	15	7 804	10 000	243	1 000
Kimberley Reef East Infrastructure Complex (u/g)	6 016	8 500	155	15 750	20 000	3 594	4 000
Bird Reef Central Infrastructure Complex (u/g)	3 498	2 500	100	4 576	6 000	2 098	1 500

5.6.2 Average Water Balance Summaries

The water balances for each complex indicates that there will be discharges required from the process water treatment facility. This can be attributed to a lack of other opportunities to use excess water at the open pit mining areas and infrastructure complexes except for dust suppression.

The modelled results are summarised into monthly average wet and dry season water balances as well as the average monthly water balances. The wet and dry seasons are represented by the averages seen in January and July respectively, for the 59 year modelling period.

5.6.3 Rugby Club Open Pit Mining Area

The monthly average, monthly dry and wet season are presented in Figure 5-2 through to Figure 5-4 below.

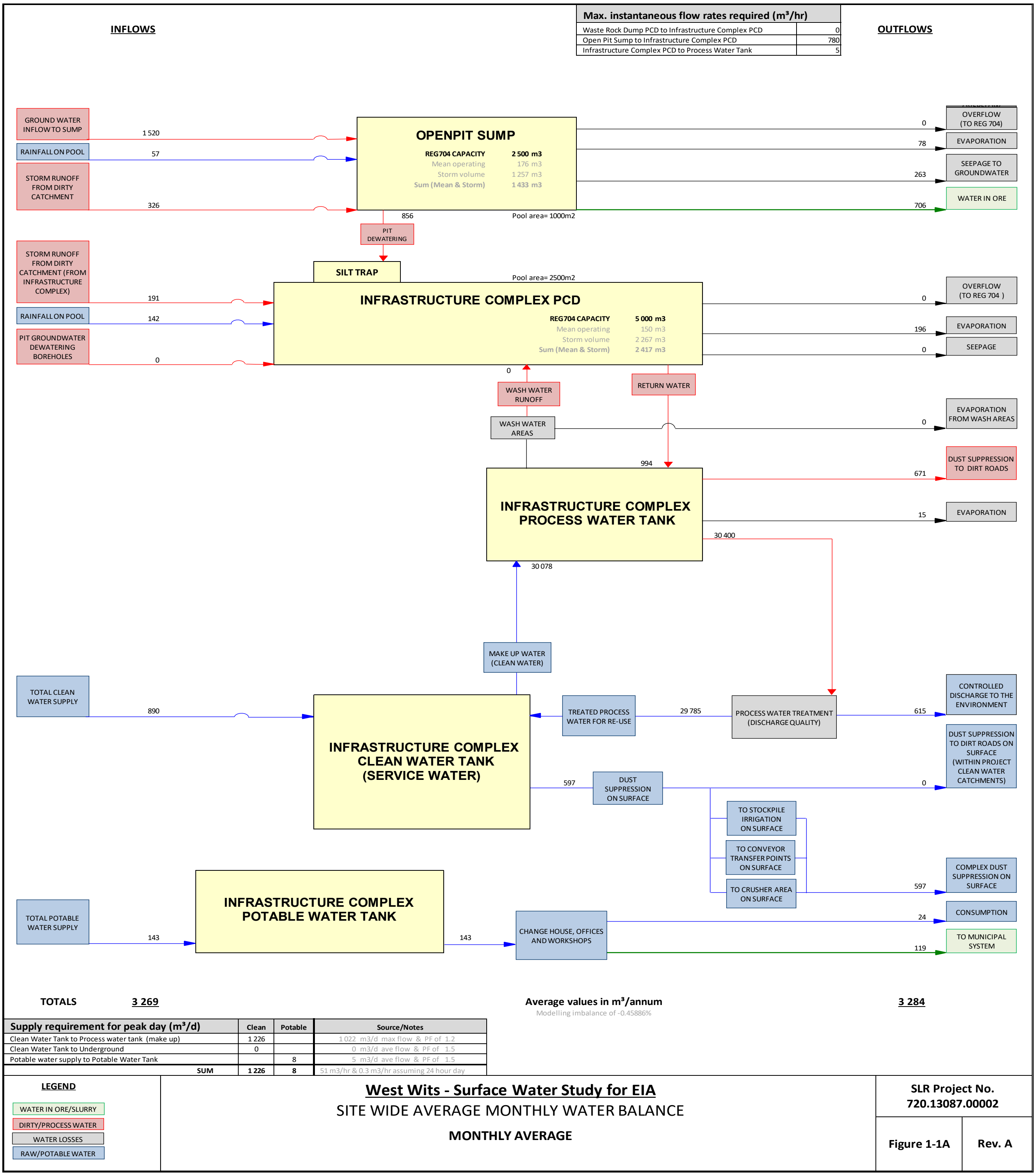
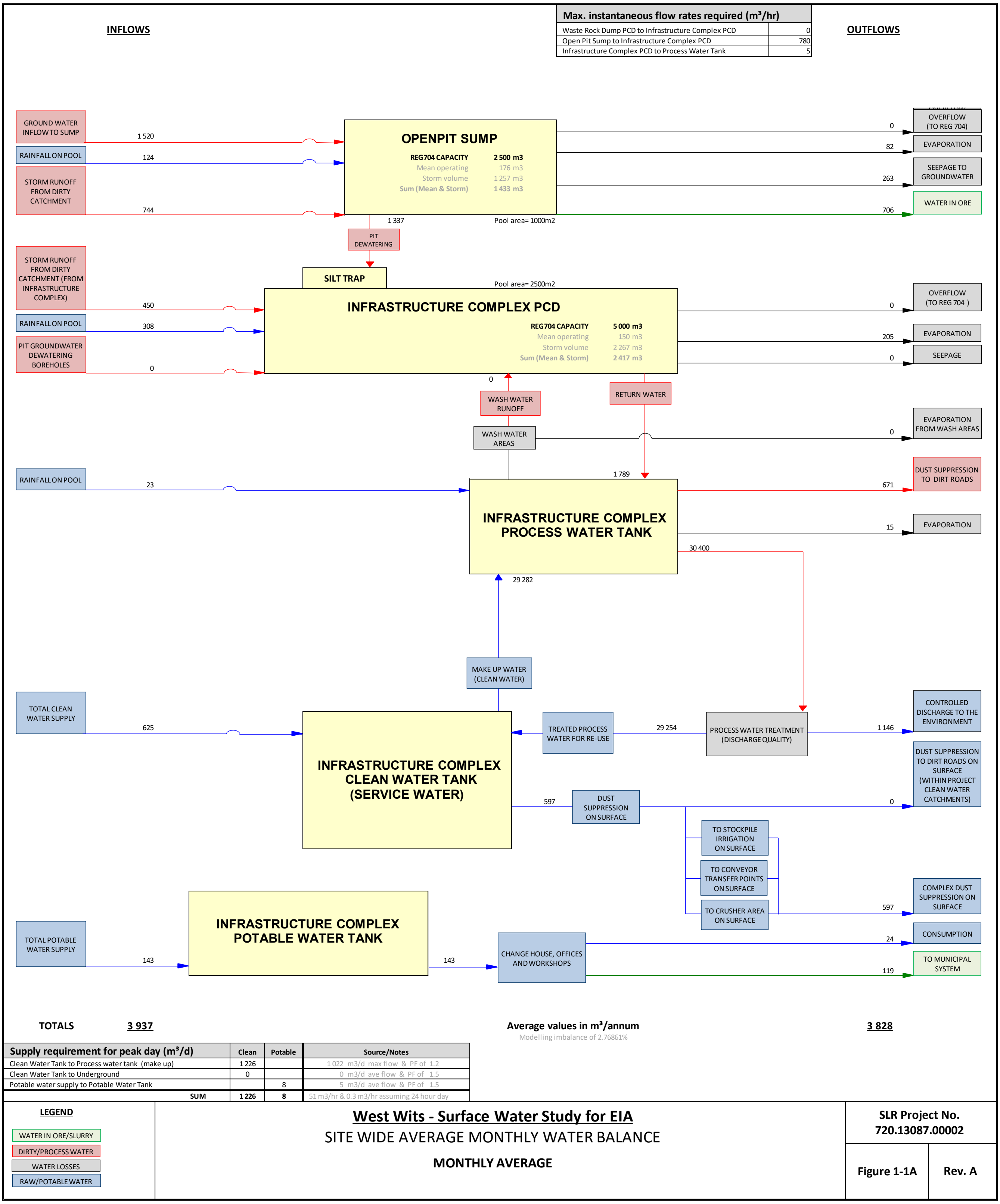


FIGURE 5-2: MONTHLY AVERAGE WATER BALANCE FOR THE RUGBY CLUB OPEN PIT MINING AREA



Max. instantaneous flow rates required (m³/hr)	
Waste Rock Dump PCD to Infrastructure Complex PCD	0
Open Pit Sump to Infrastructure Complex PCD	780
Infrastructure Complex PCD to Process Water Tank	5

Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	1 226		1 022 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		8	5 m3/d ave flow & PF of 1.5
SUM	1 226	8	51 m3/hr & 0.3 m3/hr assuming 24 hour day

FIGURE 5-3: MONTHLY WET SEASON WATER BALANCE FOR THE RUGBY CLUB OPEN PIT MINING AREA

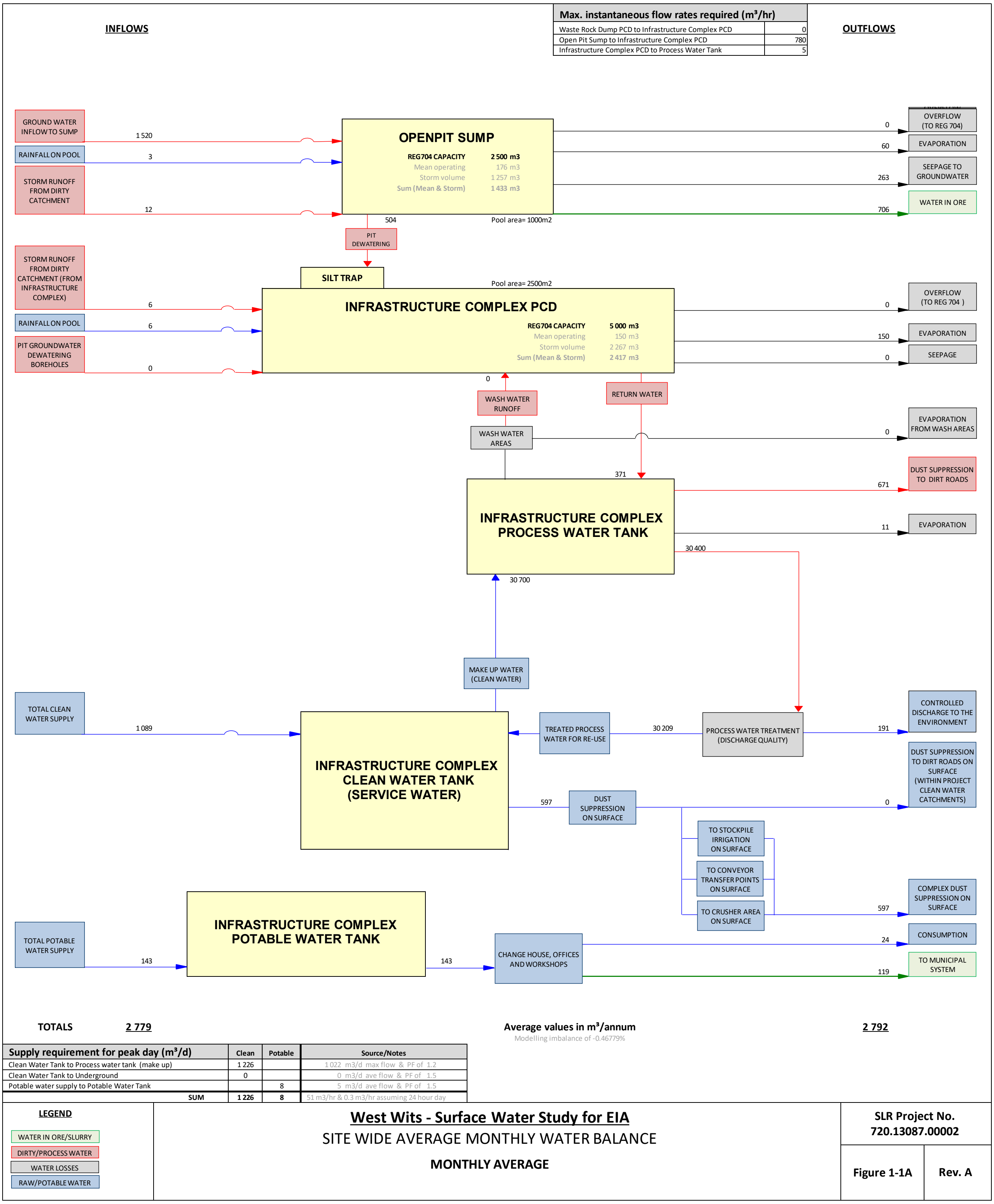


FIGURE 5-4: MONTHLY DRY SEASON WATER BALANCE FOR THE RUGBY CLUB OPEN PIT MINING AREA

5.6.4 11 Shaft Open Pit Mining Area

The monthly average, monthly dry and wet season are presented in Figure 5-5 through to Figure 5-7 below.

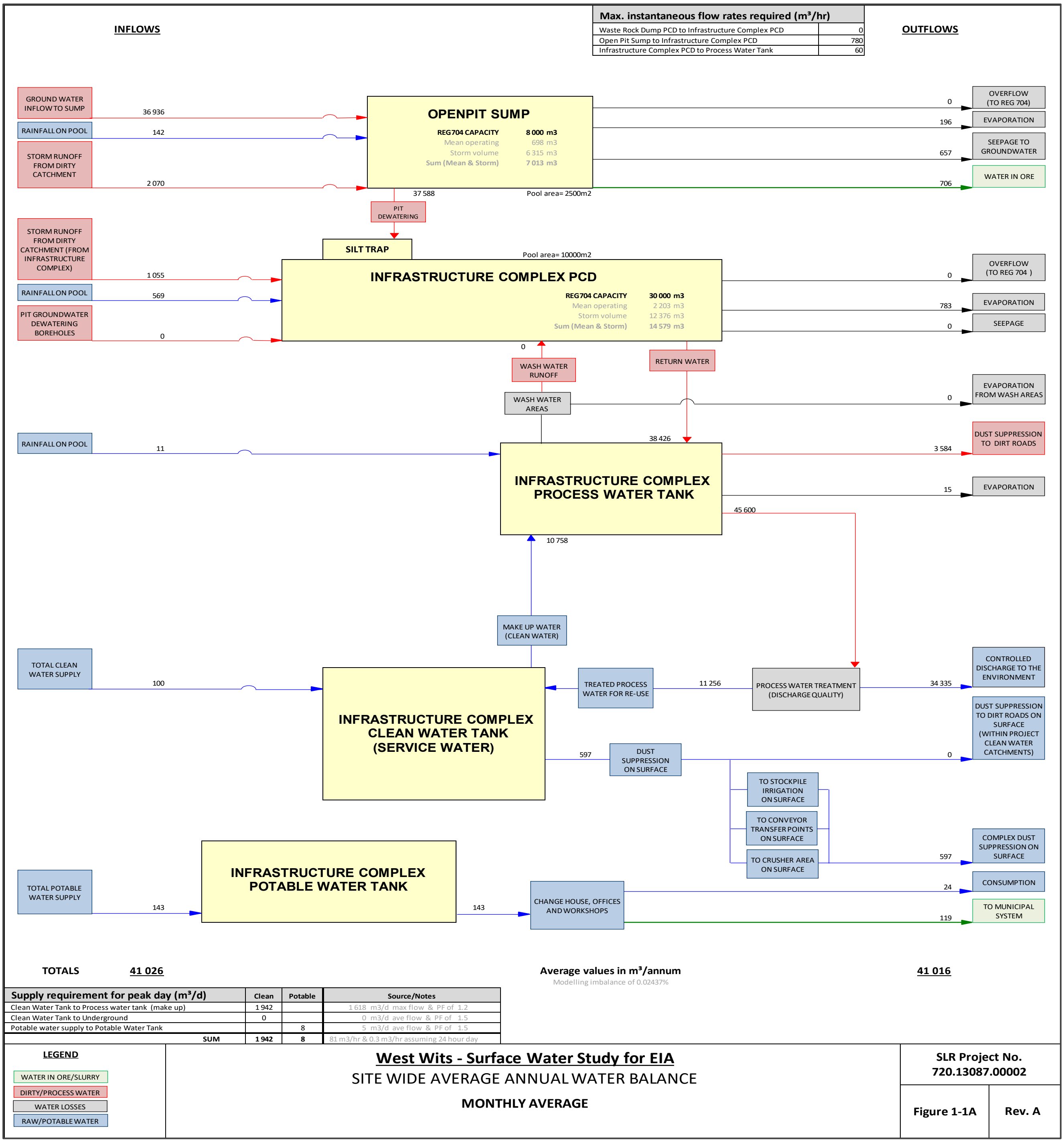


FIGURE 5-5: MONTHLY AVERAGE WATER BALANCE FOR THE 11 SHAFT OPEN PIT MINING AREA

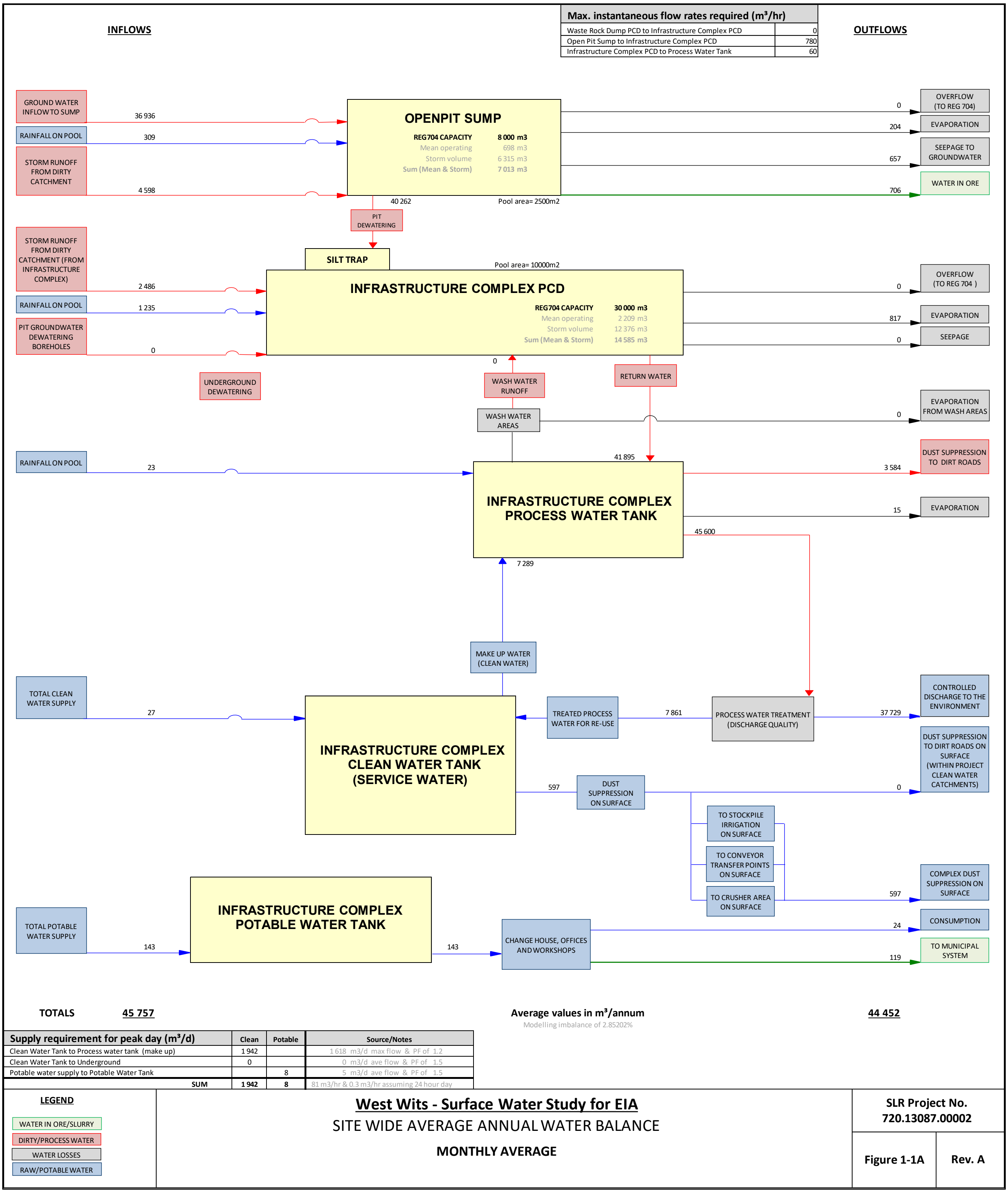
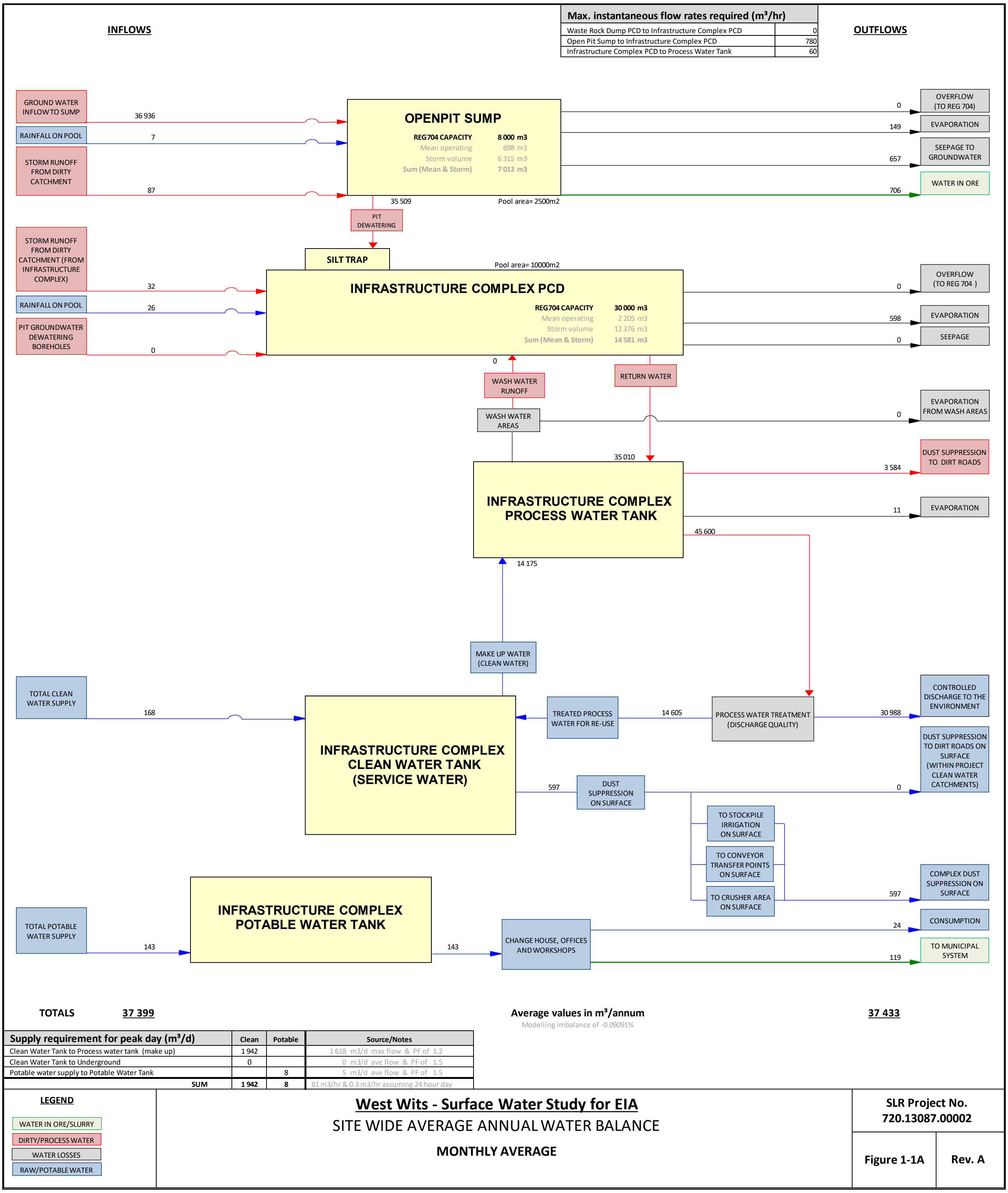


FIGURE 5-6: MONTHLY WET SEASON WATER BALANCE FOR THE 11 SHAFT OPEN PIT MINING AREA



Max. instantaneous flow rates required (m³/hr)	
Waste Rock Dump PCD to Infrastructure Complex PCD	0
Open Pit Sump to Infrastructure Complex PCD	780
Infrastructure Complex PCD to Process Water Tank	60

Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	1 942		1 618 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		8	5 m3/d ave flow & PF of 1.5
SUM	1 942	8	81 m3/hr & 0.3 m3/hr assuming 24 hour day

FIGURE 5-7: MONTHLY DRY SEASON WATER BALANCE FOR THE 11 SHAFT OPEN PIT MINING ARAE

5.6.5 Mona Lisa Open Pit Mining Area

The monthly average, monthly dry and wet season are presented in Figure 5-8 through to Figure 5-10 below.

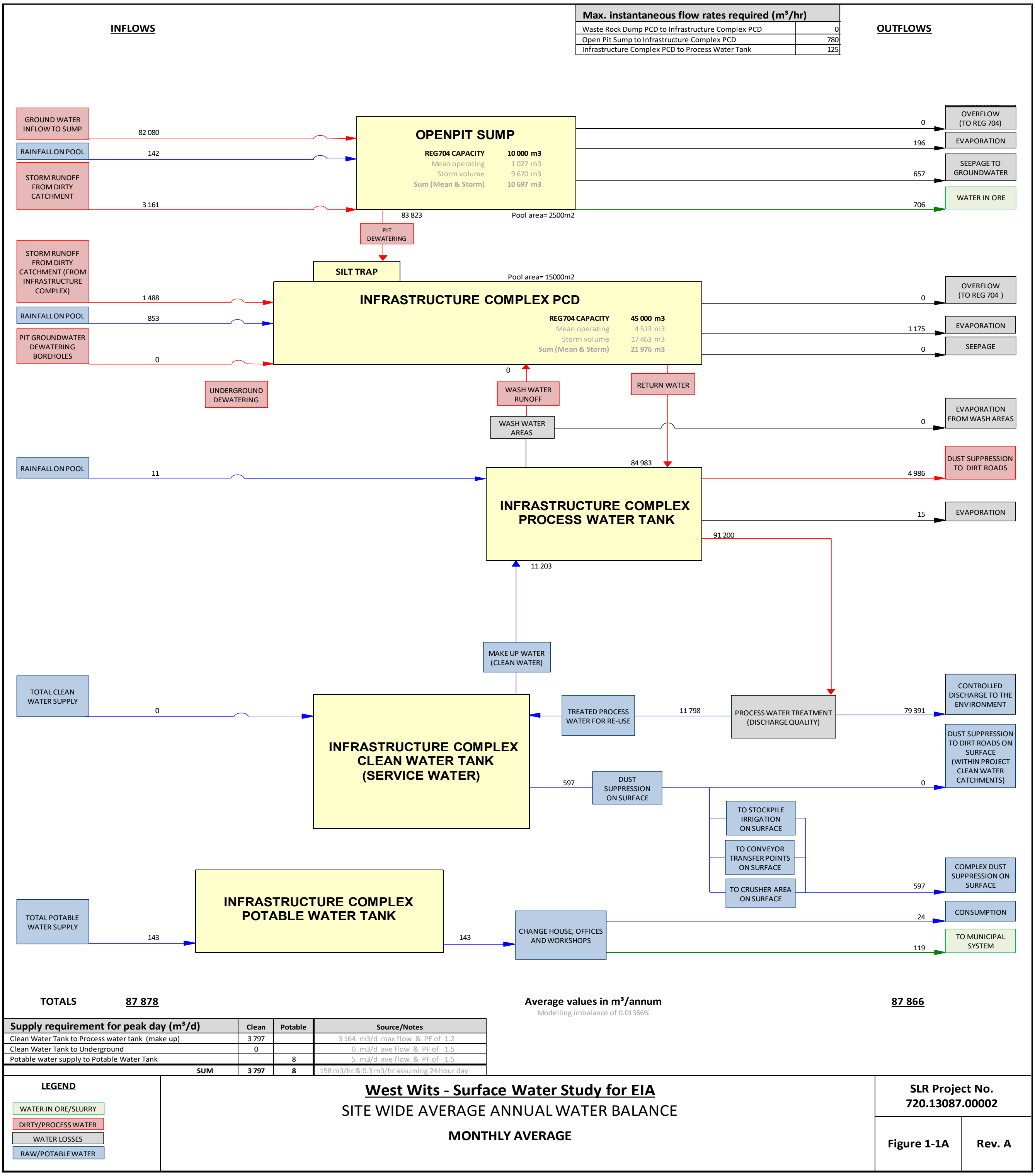


FIGURE 5-8: MONTHLY AVERAGE WATER BALANCE FOR THE MONA LISA OPEN PIT MINING AREA

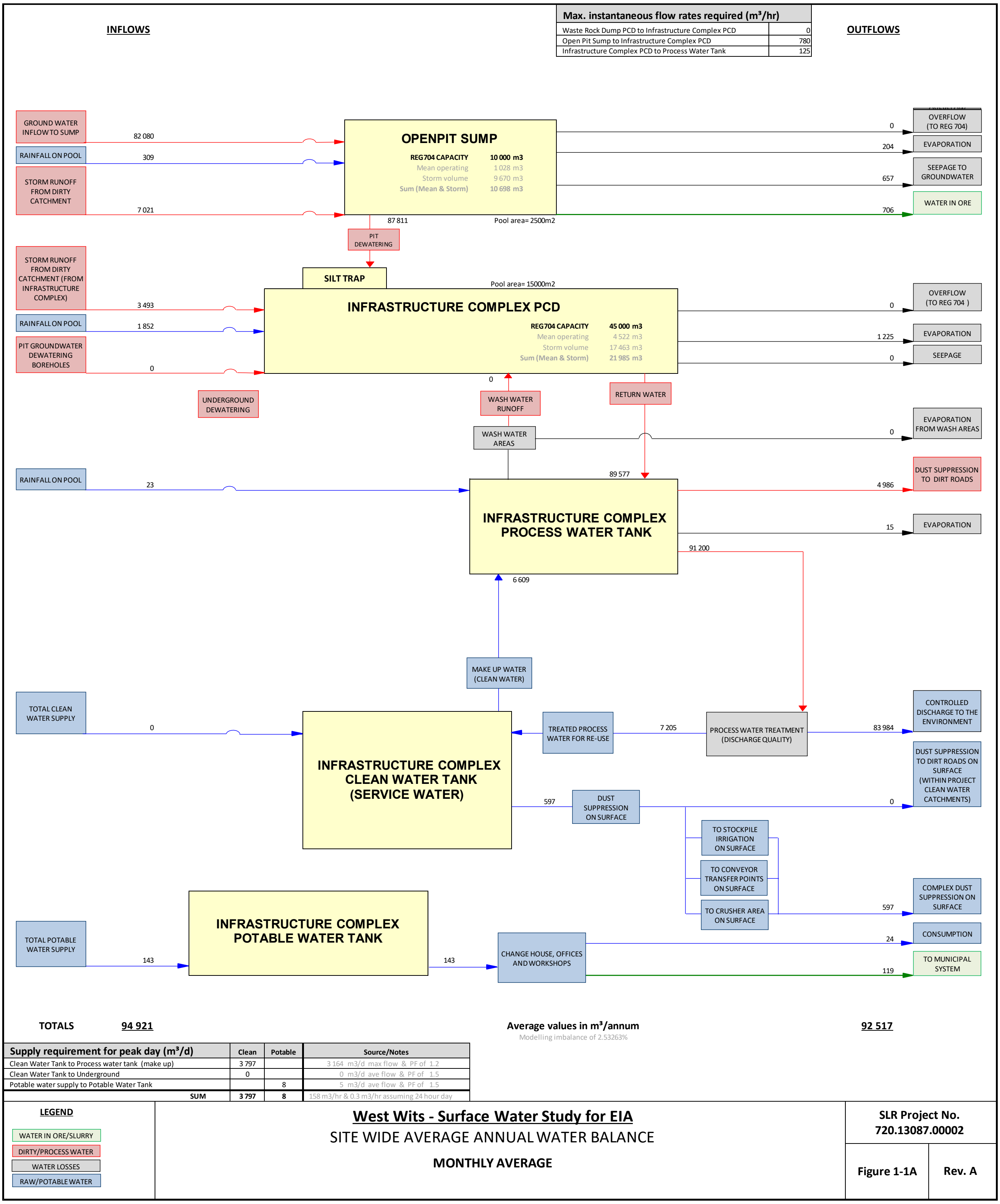
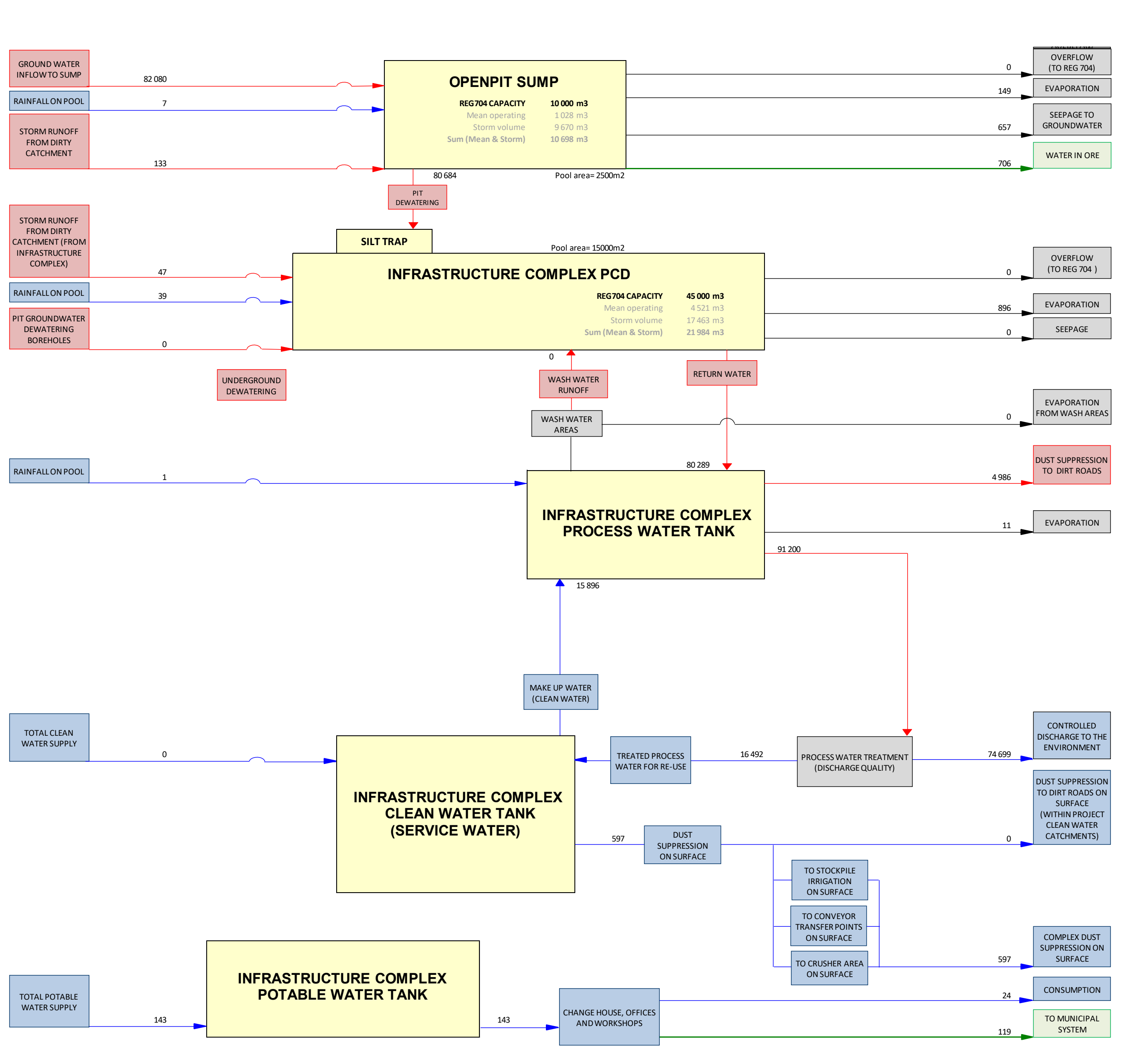


FIGURE 5-9: MONTHLY WET SEASON WATER BALANCE FOR THEMONA LISA OPEN PIT MINING AREA

Max. instantaneous flow rates required (m³/hr)	
Waste Rock Dump PCD to Infrastructure Complex PCD	0
Open Pit Sump to Infrastructure Complex PCD	780
Infrastructure Complex PCD to Process Water Tank	125



TOTALS **82 450**

Average values in m³/annum

Modelling imbalance of -0.47787%

82 844

Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	3 797		3 164 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		8	5 m3/d ave flow & PF of 1.5
SUM	3 797	8	158 m3/hr & 0.3 m3/hr assuming 24 hour day

LEGEND

- WATER IN ORE/SLURRY
- DIRTY/PROCESS WATER
- WATER LOSSES
- RAW/POTABLE WATER

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FIGURE 5-10: MONTHLY DRY SEASON WATER BALANCE FOR THEMONA LISA OPEN PIT MINING AREA

5.6.6 Kimberley Reef East Open PitMining Area

The monthly average, monthly dry and wet season are presented in Figure 5-11 through to Figure 5-13 below.

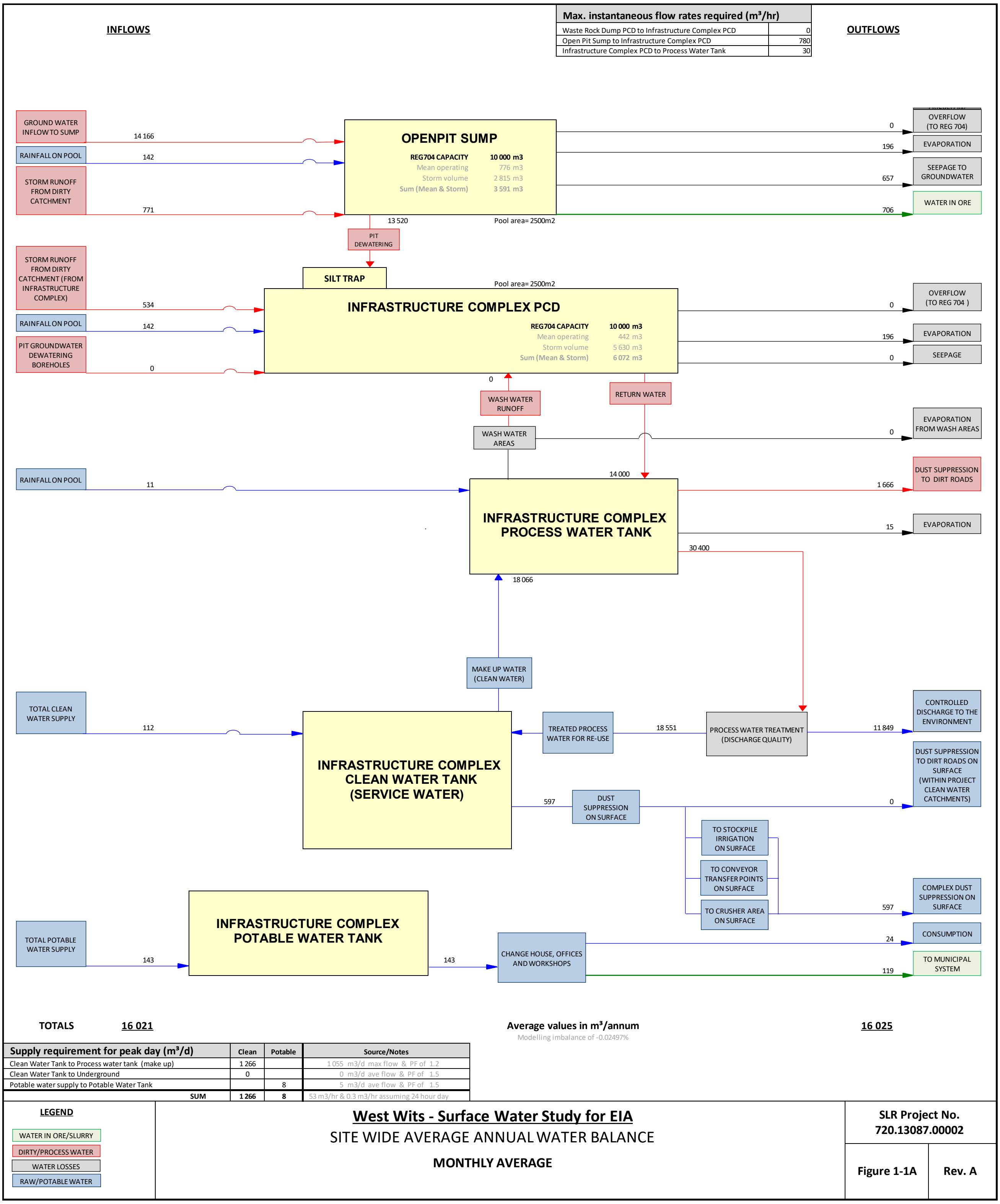


FIGURE 5-11: MONTHLY AVERAGE WATER BALANCE FOR THE KIMBERLEY REEF EAST OPEN PIT MINING AREA

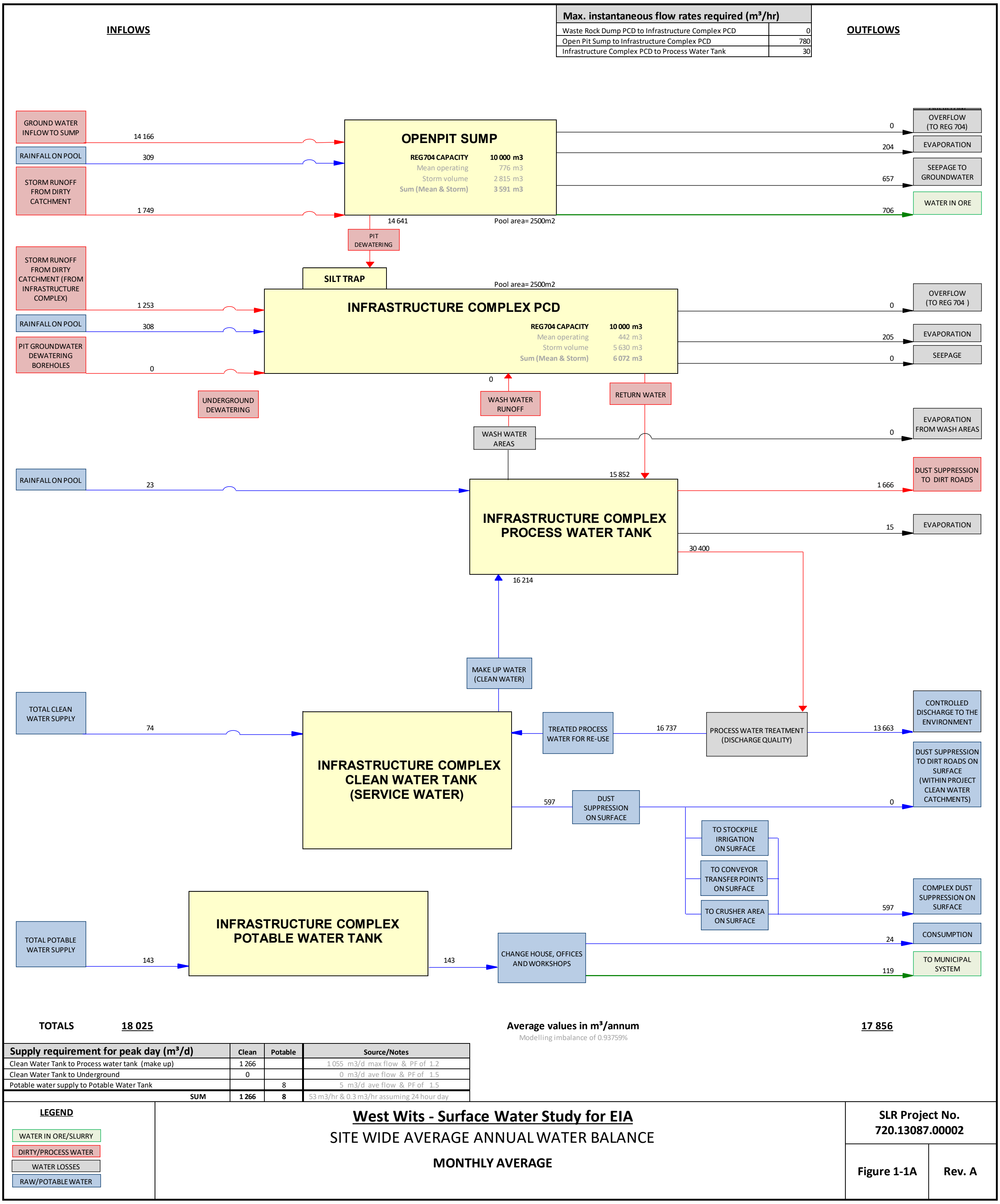
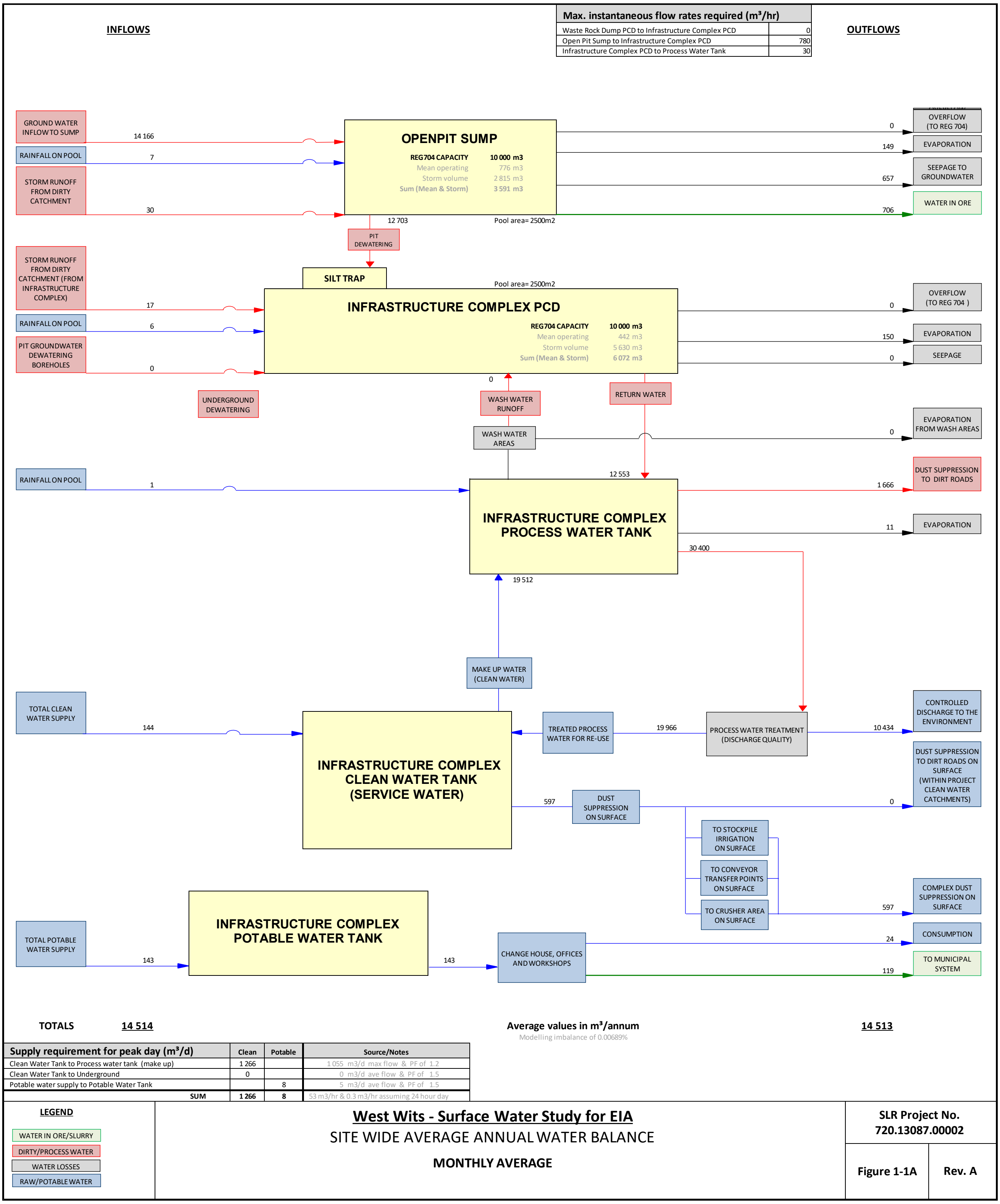


FIGURE 5-12: MONTHLY WET SEASON WATER BALANCE FOR THE KIMBERLEY REEF EAST OPEN PIT MINING



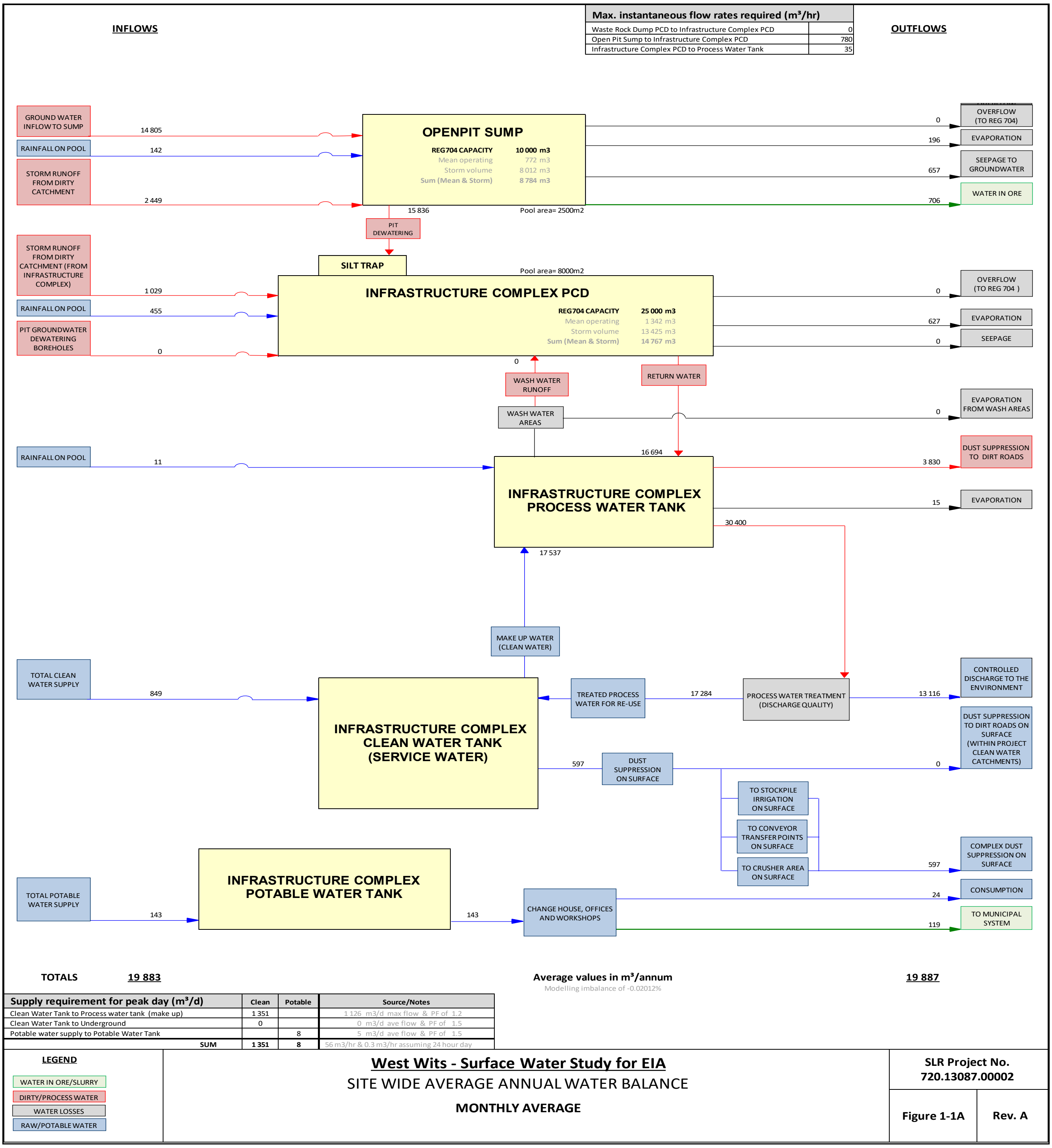
Max. instantaneous flow rates required (m³/hr)	
Waste Rock Dump PCD to Infrastructure Complex PCD	0
Open Pit Sump to Infrastructure Complex PCD	780
Infrastructure Complex PCD to Process Water Tank	30

Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	1 266		1 055 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		8	5 m3/d ave flow & PF of 1.5
SUM	1 266	8	53 m3/hr & 0.3 m3/hr assuming 24 hour day

FIGURE 5-13: MONTHLY DRY SEASON WATER BALANCE FOR THE KIMBERLEY REEF EAST OPEN PIT MINING

5.6.7 Roodepoort Open Pit Mining Area

The monthly average, monthly dry and wet season are presented in Figure 5-14 through to Figure 5-19 below for Roodepoort Pit PCD1 and PCD2.



Max. instantaneous flow rates required (m³/hr)	
Waste Rock Dump PCD to Infrastructure Complex PCD	0
Open Pit Sump to Infrastructure Complex PCD	780
Infrastructure Complex PCD to Process Water Tank	35

Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	1 351		1 126 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		8	5 m3/d ave flow & PF of 1.5
SUM	1 351	8	56 m3/hr & 0.3 m3/hr assuming 24 hour day

FIGURE 5-14: MONTHLY AVERAGE WATER BALANCE FOR THE ROODEPOORT OPEN PIT MINING AREA (PCD1)

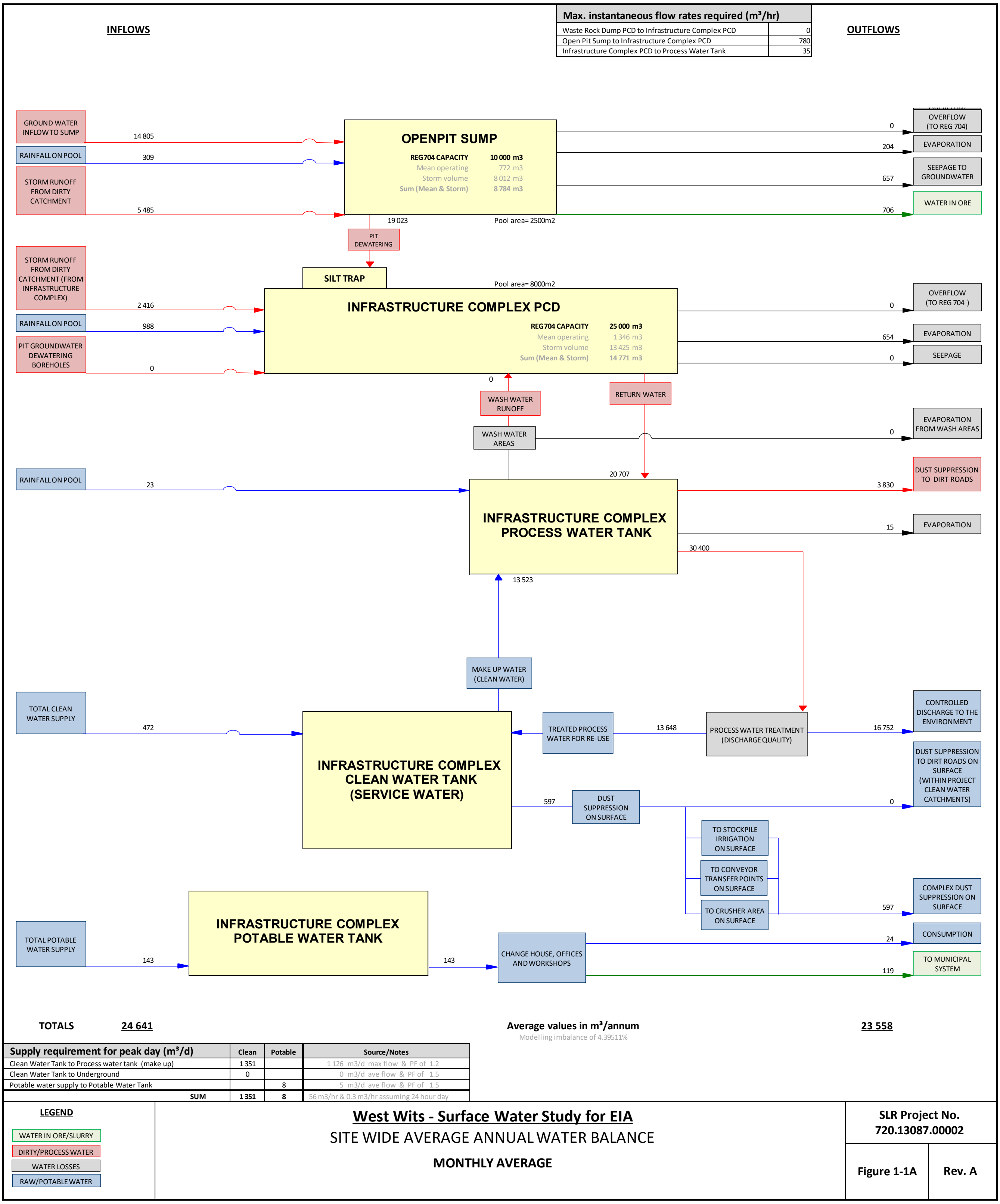
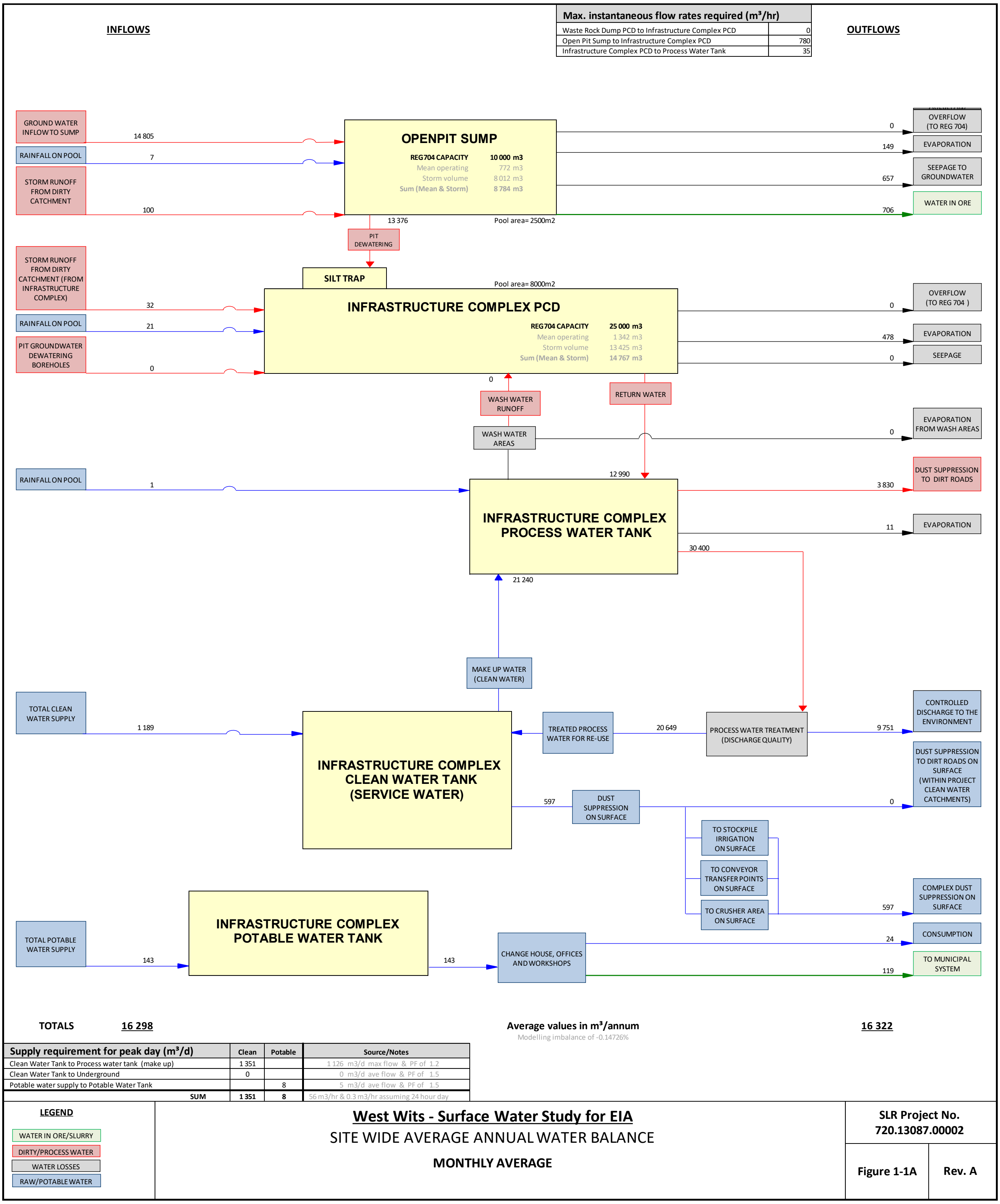


FIGURE 5-15: MONTHLY WET SEASON WATER BALANCE FOR THE ROODEPOORT OPEN PIT MINING (PCD1)



Max. instantaneous flow rates required (m³/hr)	
Waste Rock Dump PCD to Infrastructure Complex PCD	0
Open Pit Sump to Infrastructure Complex PCD	780
Infrastructure Complex PCD to Process Water Tank	35

Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	1 351		1 126 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		8	5 m3/d ave flow & PF of 1.5
SUM	1 351	8	56 m3/hr & 0.3 m3/hr assuming 24 hour day

FIGURE 5-16: MONTHLY DRY SEASON WATER BALANCE FOR THE ROODEPOORT OPEN PIT MINING (PCD1)

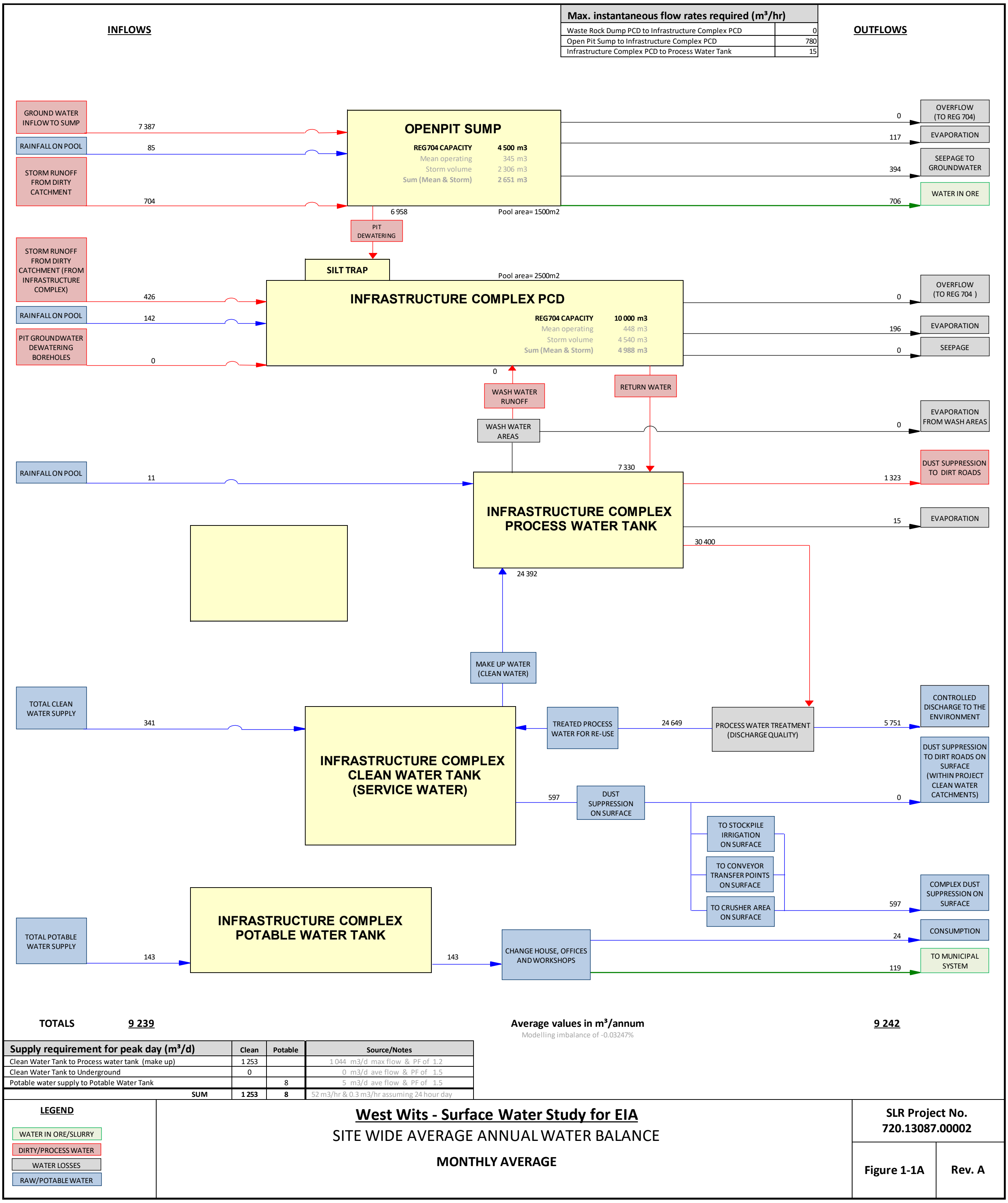


FIGURE 5-17: MONTHLY AVERAGE WATER BALANCE FOR THE ROODEPOORT OPEN PIT MINING AREA (PCD2)

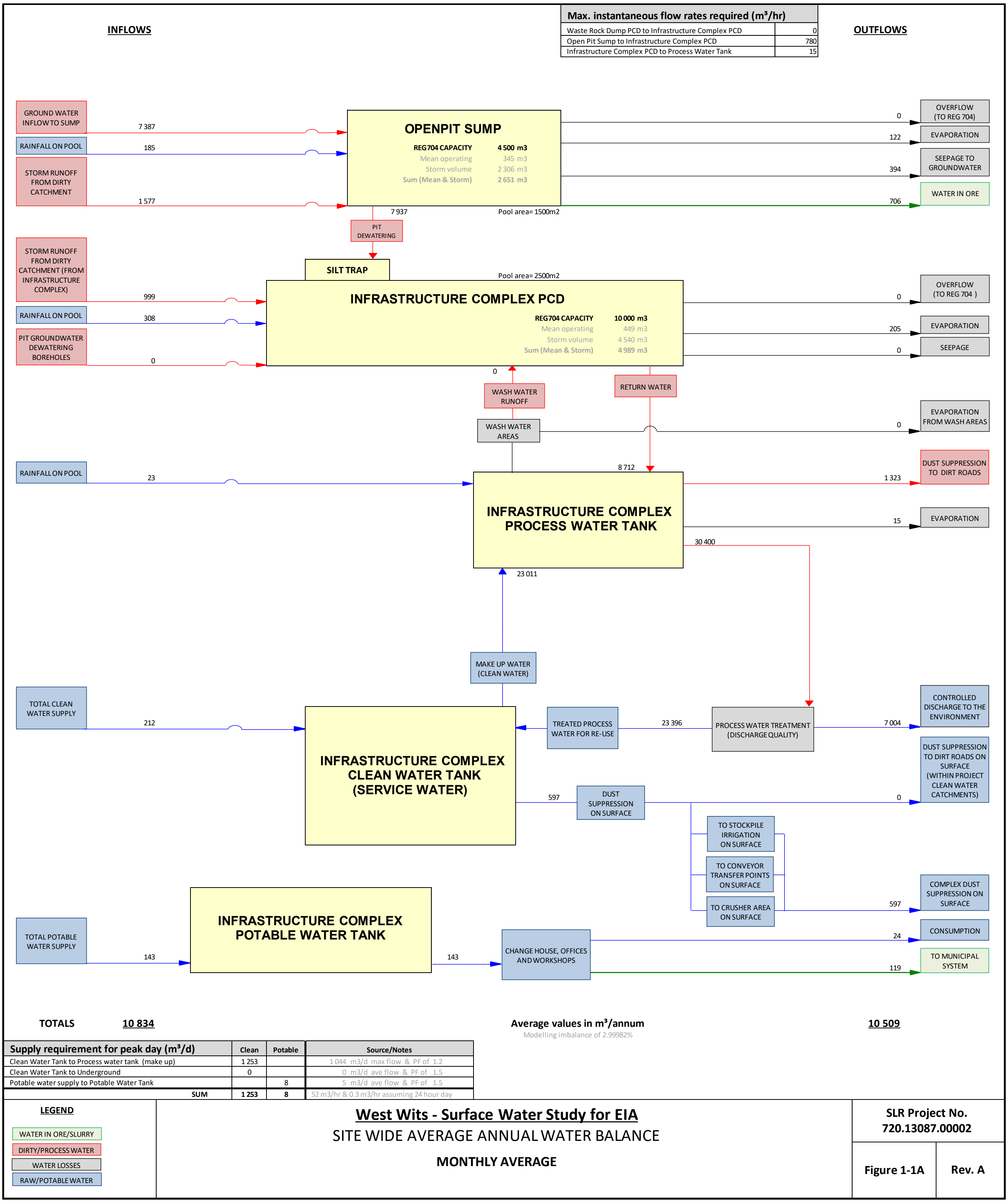


FIGURE 5-18: MONTHLY WET SEASON WATER BALANCE FOR THE ROODEPOORT OPEN PIT MINING (PCD2)

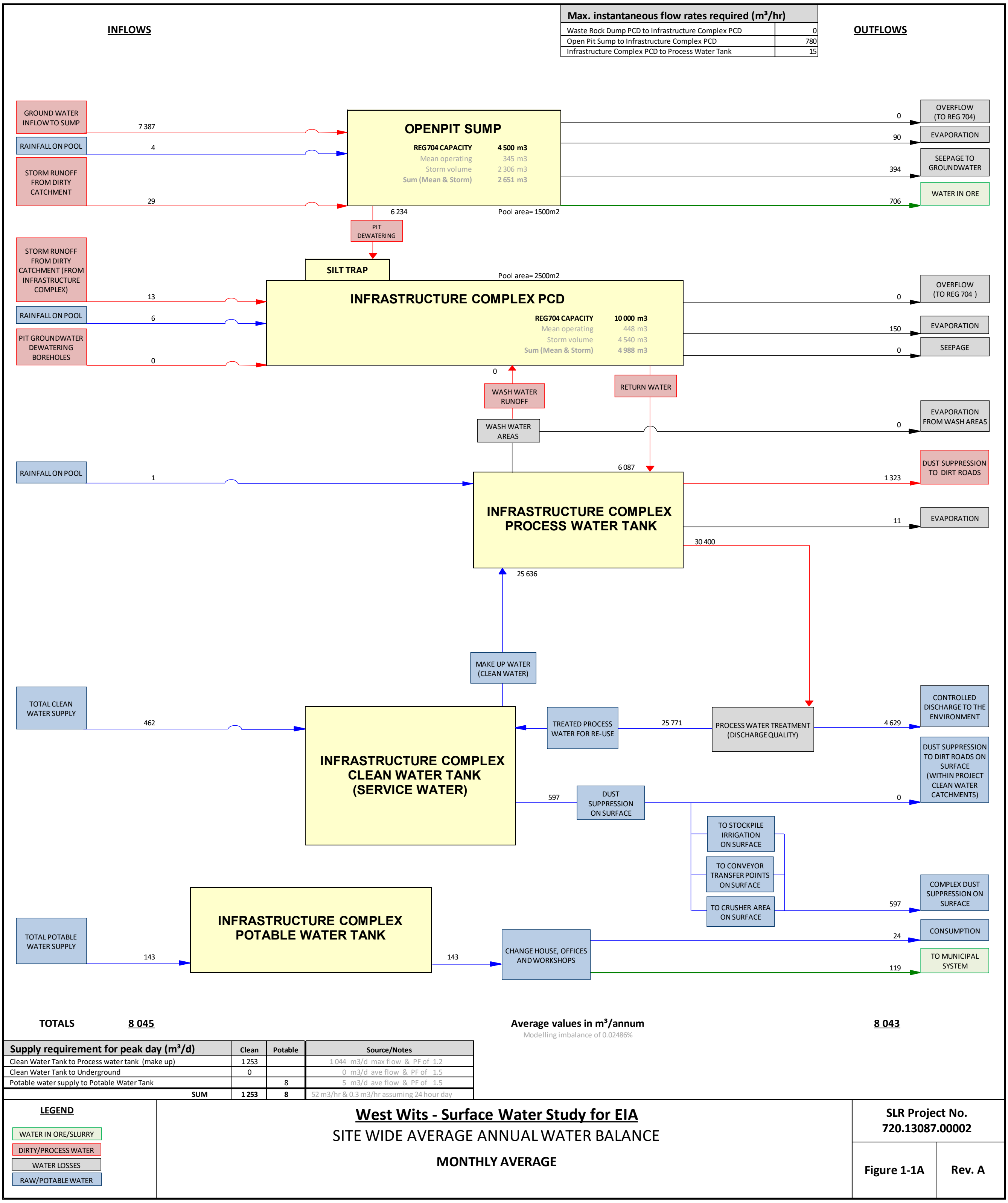


FIGURE 5-19: MONTHLY DRY SEASON WATER BALANCE FOR THE ROODEPOORT OPEN PIT MINING (PCD2)

5.6.8 Kimberley Reef East Infrastructure Complex and Underground Mining Area

The monthly average, monthly dry and wet season are presented in Figure 5-20 through to Figure 5-22 below.

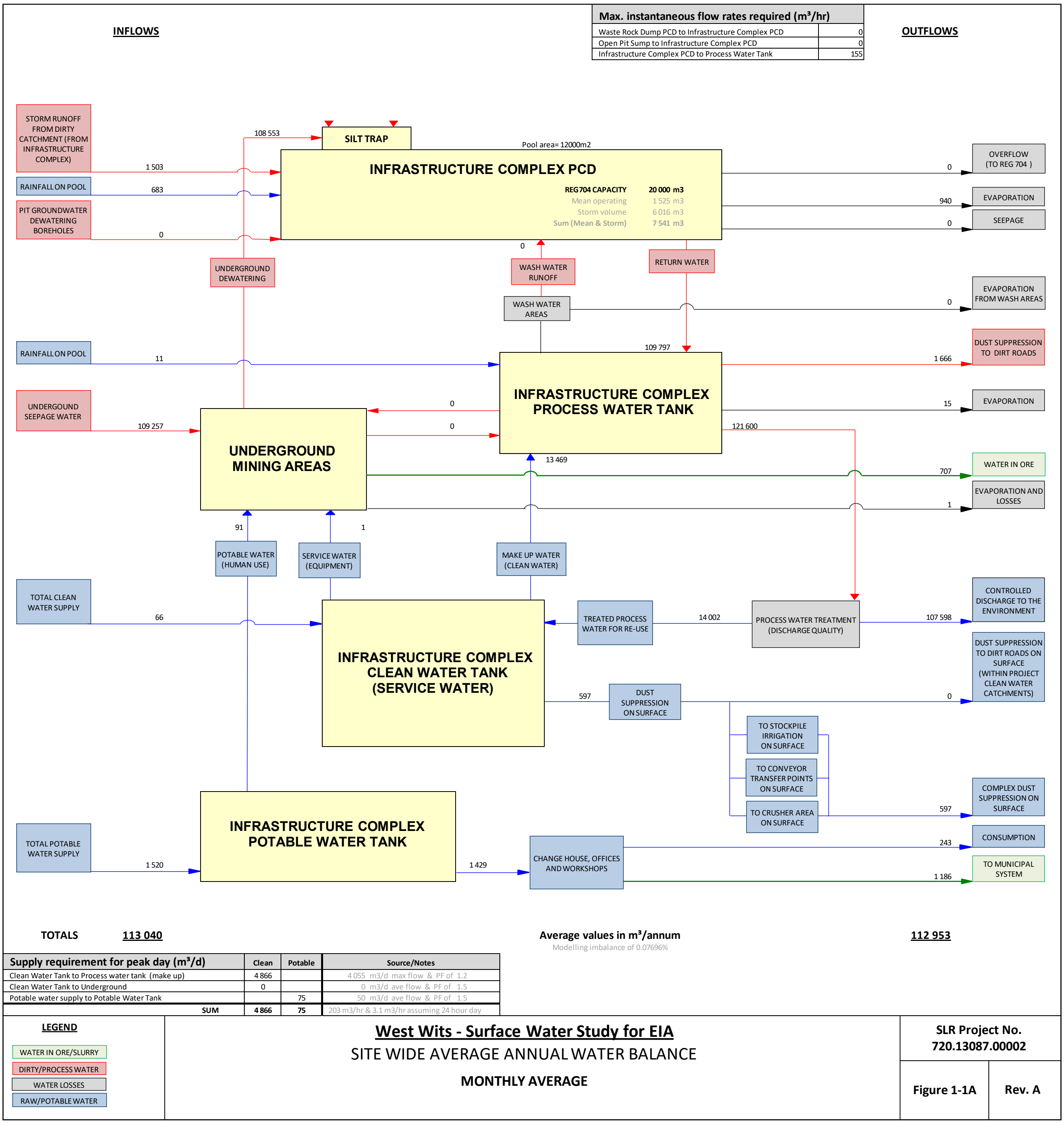


FIGURE 5-20: MONTHLY AVERAGE WATER BALANCE FOR THE KIMBERLEY REEF EAST INFRASTRUCTURE COMPLEX AND UNDERGROUND MINING AREA

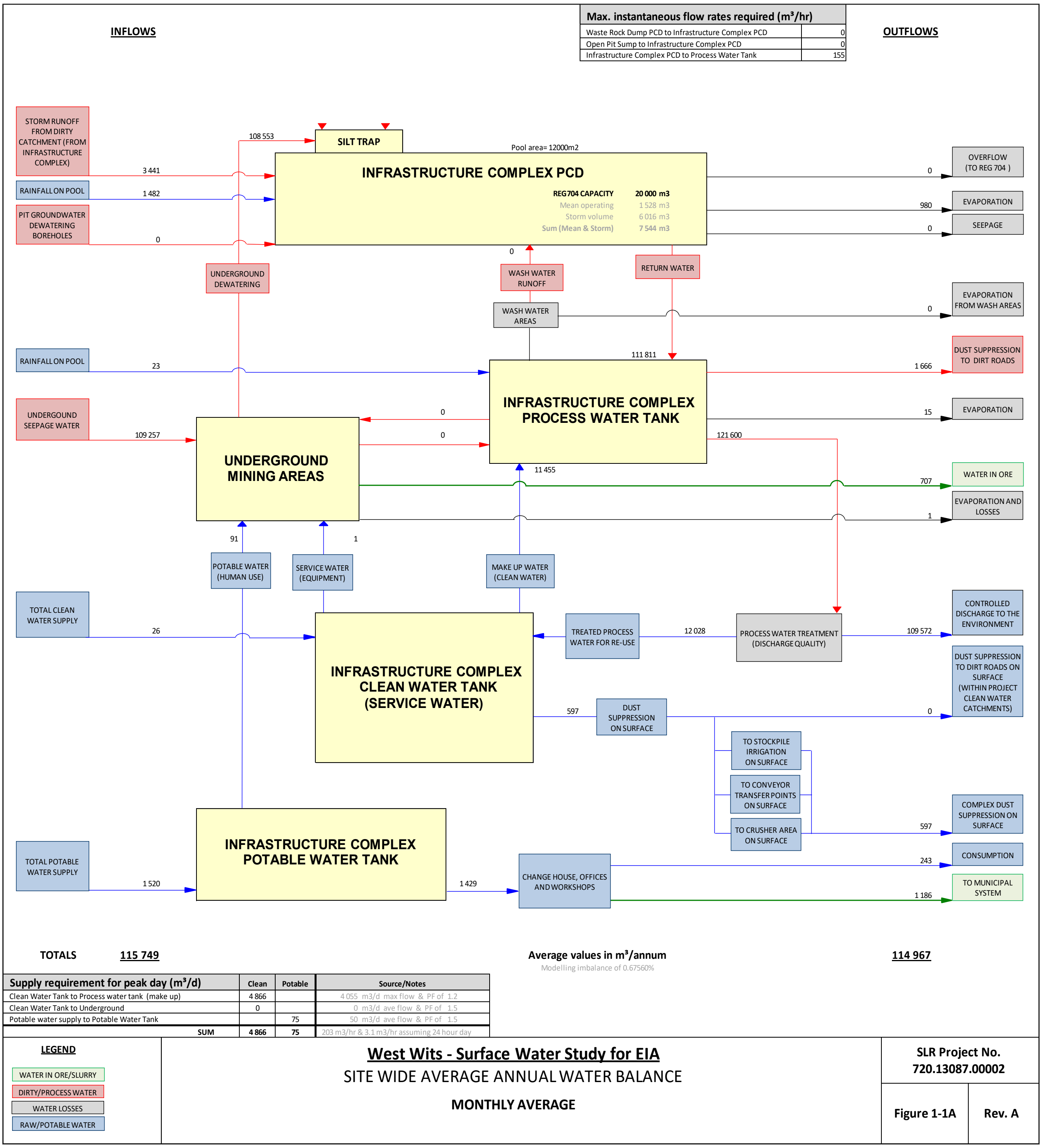


FIGURE 5-21: MONTHLY WET SEASON WATER BALANCE FOR THE KIMBERLEY REEF EAST INFRASTRUCTURE COMPLEX AND UNDERGROUND MINING AREA

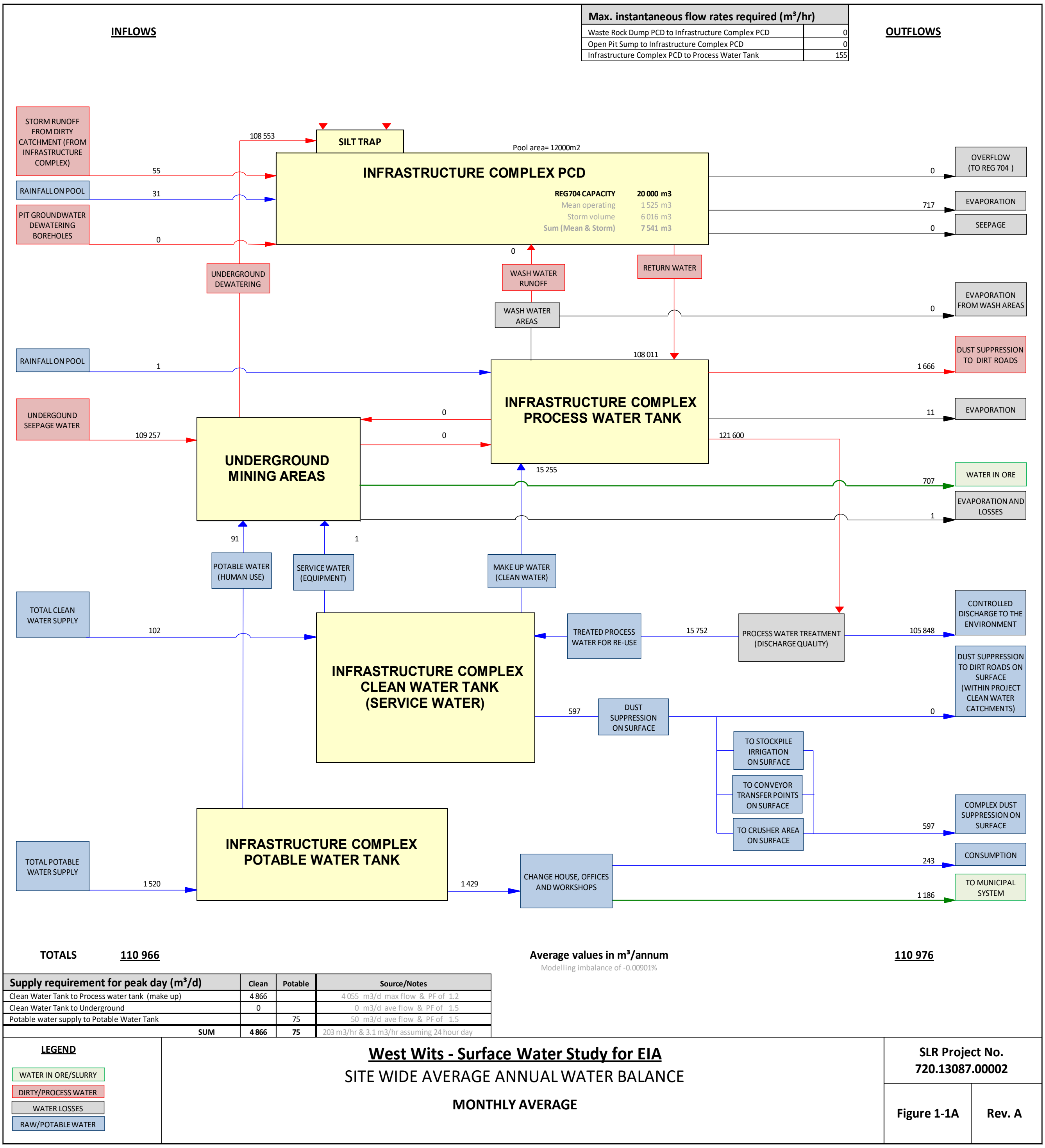
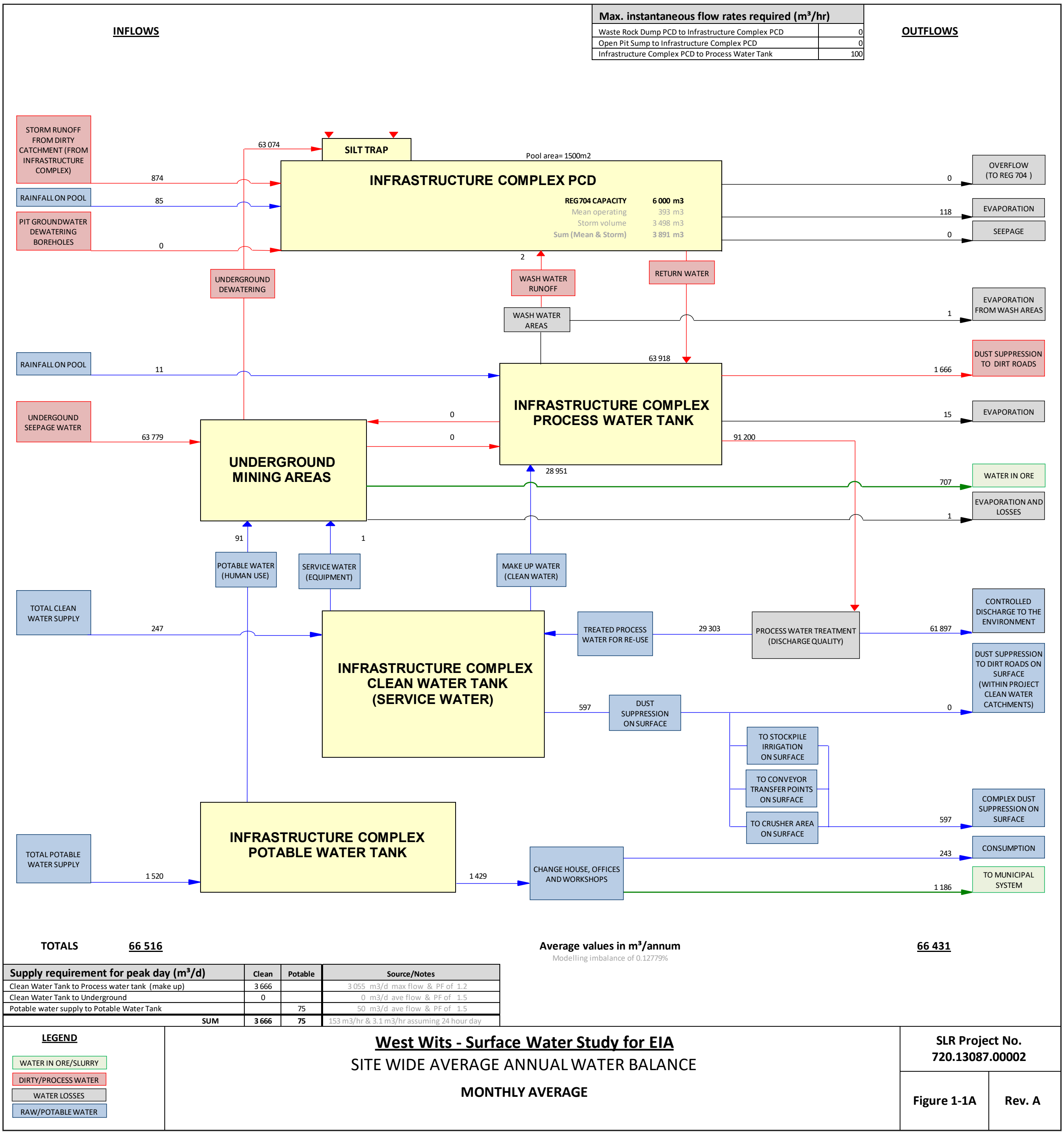


FIGURE 5-22: MONTHLY DRY SEASON WATER BALANCE FOR THE KIMBERLEY REEF EAST INFRASTRUCTURE COMPLEX AND UNDERGROUND MINING AREA

5.6.9 Bird Reef Central Infrastructure Complex and Underground Mining Area

The monthly average, monthly dry and wet season are presented in Figure 5-23 through to Figure 5-25 below.



Max. instantaneous flow rates required (m³/hr)	
Waste Rock Dump PCD to Infrastructure Complex PCD	0
Open Pit Sump to Infrastructure Complex PCD	0
Infrastructure Complex PCD to Process Water Tank	100

Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	3 666		3 055 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		75	50 m3/d ave flow & PF of 1.5
SUM	3 666	75	153 m3/hr & 3.1 m3/hr assuming 24 hour day

FIGURE 5-23: MONTHLY AVERAGE WATER BALANCE FOR THE BIRD REEF CENTRAL INFRASTRUCTURE COMPLEX AND UNDERGROUND MINING AREA

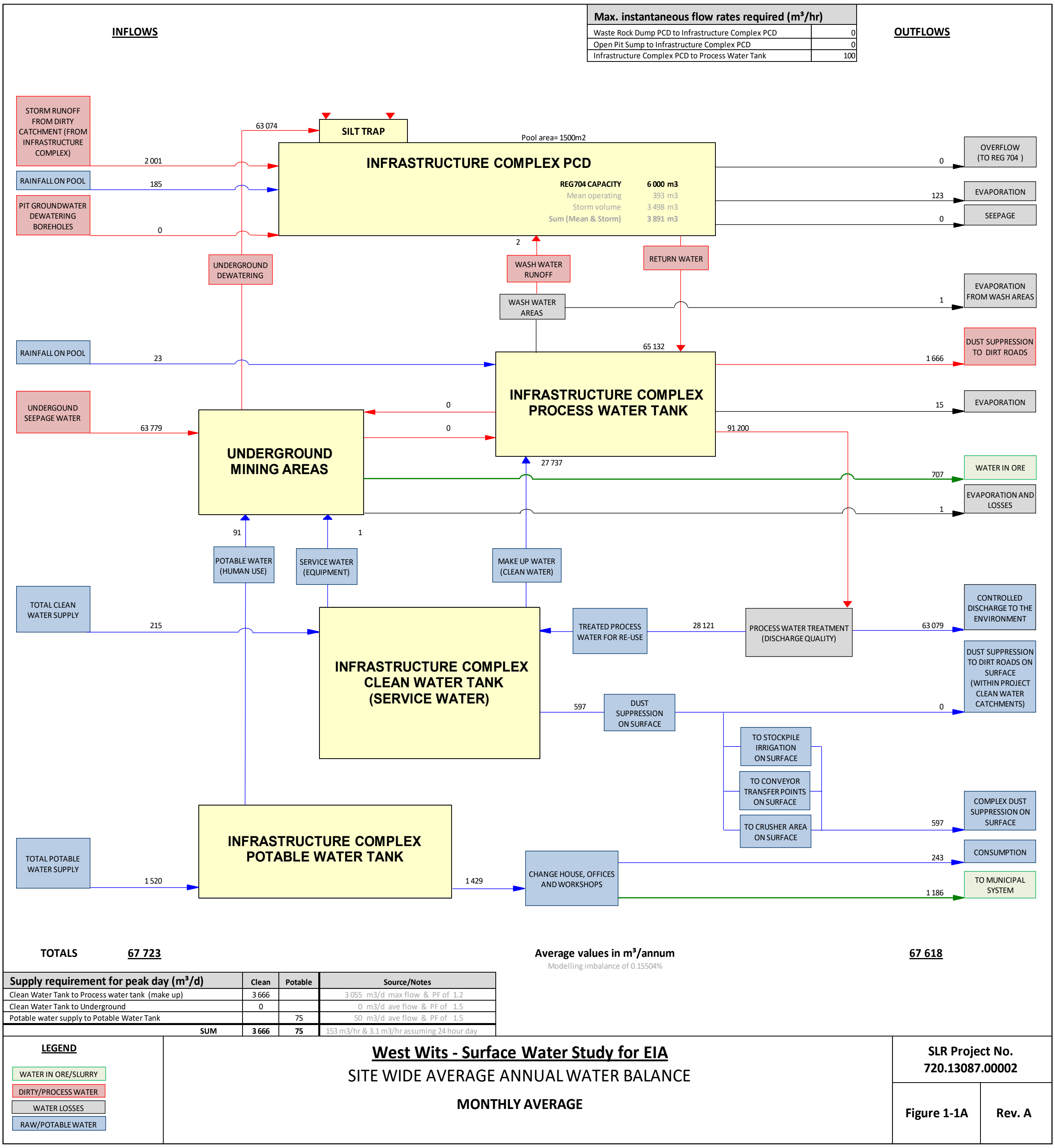
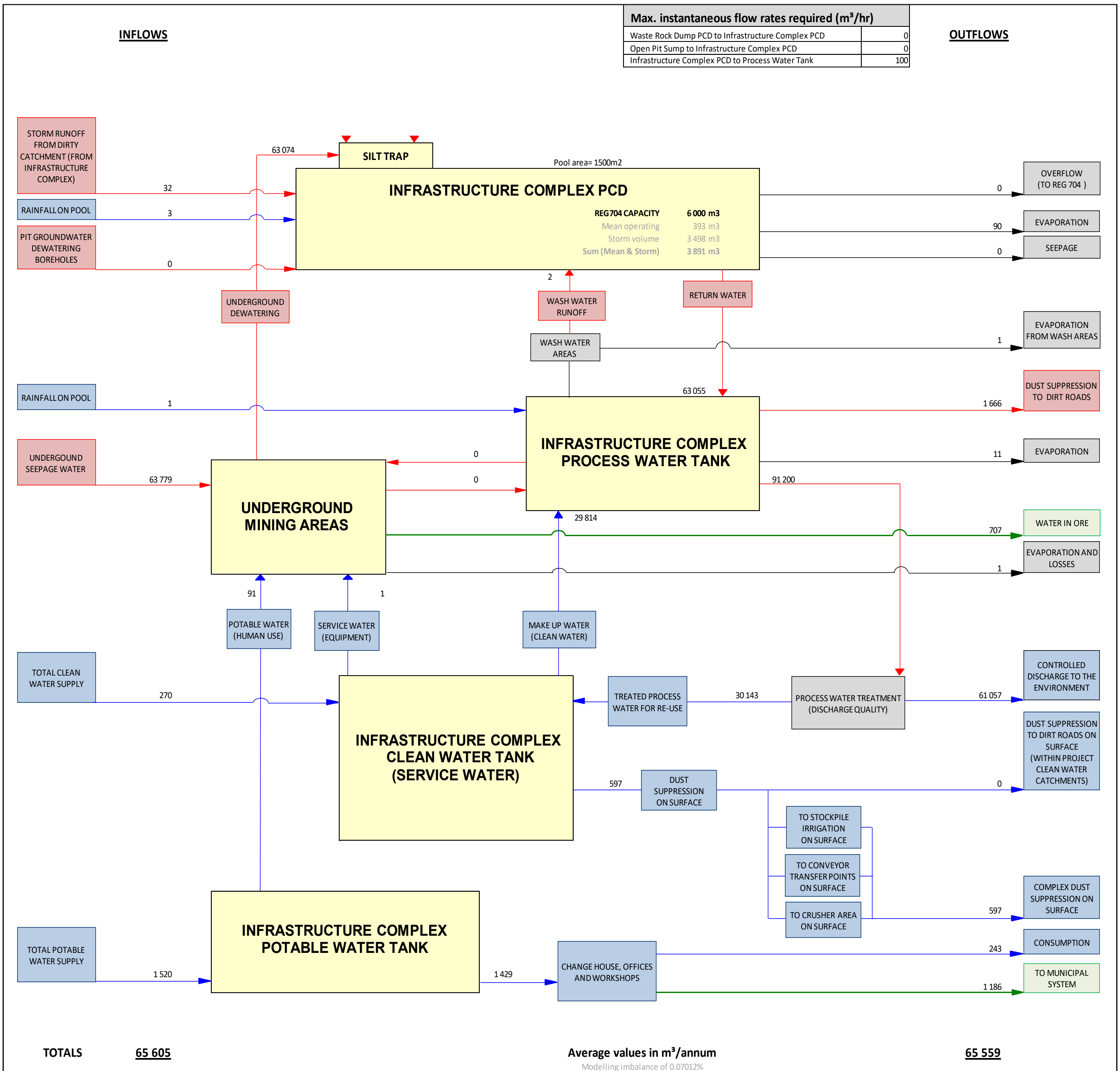


FIGURE 5-24: MONTHLY WET SEASON WATER BALANCE FOR THE BIRD REEF CENTRAL INFRASTRUCTURE COMPLEX AND UNDERGROUND MINING



Supply requirement for peak day (m³/d)	Clean	Potable	Source/Notes
Clean Water Tank to Process water tank (make up)	3 666		3 055 m3/d max flow & PF of 1.2
Clean Water Tank to Underground	0		0 m3/d ave flow & PF of 1.5
Potable water supply to Potable Water Tank		75	50 m3/d ave flow & PF of 1.5
SUM	3 666	75	153 m3/hr & 3.1 m3/hr assuming 24 hour day

LEGEND
WATER IN ORE/SLURRY
DIRTY/PROCESS WATER
WATER LOSSES
RAW/POTABLE WATER

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MONTHLY AVERAGE

SLR Project No. 720.13087.00002
Figure 1-1A
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FIGURE 5-25: MONTHLY DRY SEASON WATER BALANCE FOR THE BIRD REEF CENTRAL INFRASTRUCTURE COMPLEX AND UNDERGROUND MINING AREA

6. FLOODLINE DETERMINATION

6.1 METHODOLOGY

6.1.1 Information Sourcing and Literature Review

A review of various information sources was undertaken to define the baseline climatic and hydrological conditions of the site and surroundings. Hydro-meteorological analysis was carried out using the data obtained from the following sources:

- Water Resources (WRC, 2012) database;
- The Daily Rainfall Extraction Utility programme;
- Design rainfall software (Smithers and Schulze, 2002); and a
- Report by CWT Consulting entitled: Determination of the 1:100 Year Flood Lines in Two Stream: West Wits Mining Boundaries, Report No. CWT 242018 (July, 2018).

The South African Atlas of Climatology and Agro-hydrology (WRC, 2008) was used to classify general land cover.

6.1.2 Site Visit

The site visit was undertaken by Kevin Bursey (SLR Consulting) on the 6th February 2019. The culvert, hydraulic information and the catchment conditions were documented in the form of photos and field notes.

6.1.3 Topographical Data

The topographical data forms the foundation for the HEC-RAS model and is used to extract elevation data for the river profile together with the river cross-sections. The topographical data is also used to determine placement positions for the cross-sections along the river profile, so that the watercourse can be accurately modelled.

Site topographical information was provided by the client in the form of a contour survey. The contour plan covered the entire site and the contour interval was 0.5 m.

6.1.4 Design Flood Peaks

The watercourse network and relevant catchments have been delineated in the report by CWT (July, 2019). The report detailed the following methods for determining the flood peaks:

- Rational Method (RM), as implemented by the Department of Water Affairs;
- Rational method using an alternative implementation.
- Standard Design Flood (SDF) method as developed at Pretoria University.
- The Unit Hydrograph method.
- The Herbst Algorithm as developed at the Department of Water & Sanitation.

- The Hydrologic Responsive Unit (HRU) Algorithm as developed at the University of Witwatersrand.
- The Stephenson & Ten Noordt Algorithms as developed at the University of Witwatersrand.

Due to the size of the catchment the results obtained from only the first four methods mentioned above are deemed to be applicable for this study (CWT, July 2018).

6.2 FLOODLINES HYDRAULIC MODELLING

Floodlines for the Eastern and Western Stream watercourses were analysed for the 1 in 100-year recurrence interval storm events.

The main rivers and streams included in the analysis were those agreed-upon in the proposal phase of this study, augmented by further rivers and streams identified in the Department of Water and Sanitation (DWS) database (DWS, 2016).

6.3 CHOICE OF SOFTWARE

HEC-RAS 5.0.3 was used for the purpose of modelling the flood elevation profile for the 1:100 year flood event. HEC-RAS is a hydraulic programme designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

In this study the following software were used:

- Arc GIS 10.5 for Geographic Information Systems (GIS) work and mapping (ESRI, 2012);
- HEC-GeoRAS programme (US Army Corps of Engineers, 1995); and
- HEC-RAS hydraulic model (US Army Corps of Engineers, 1995).

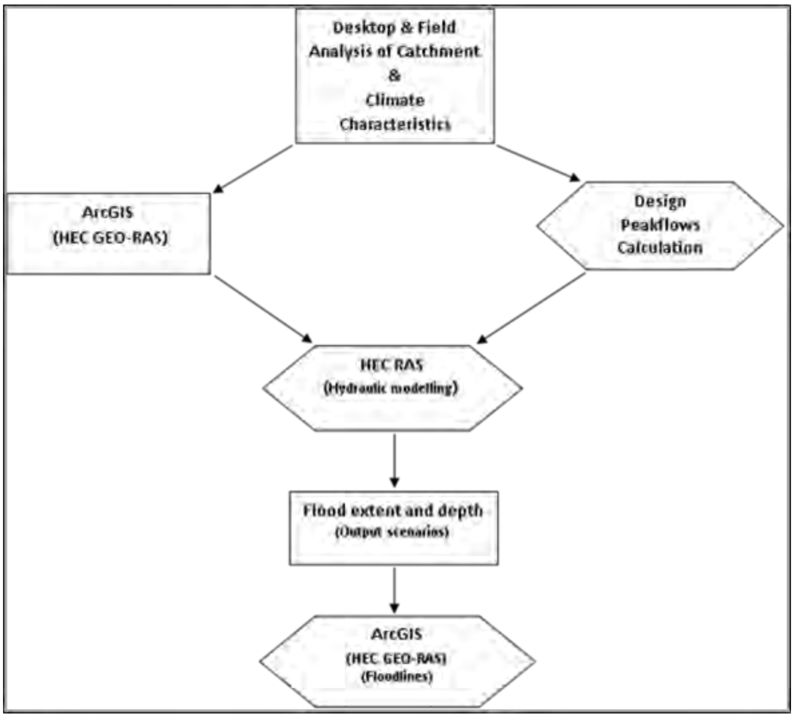


FIGURE 6-1: SUMMARY OF FLOODLINE METHODOLOGY

6.4 FLOOD HYDROLOGY

6.4.1 Catchment delineation

Sub-catchments were delineated for modelling purposes for the two streams that would be influenced by the proposed West Wits Project. Sub-catchment characteristics are as shown in Table 6-1. An image of the sub-catchments can be found in Appendix A, in the report by CWT Consulting entitled: Determination of the 1:100 Year Flood Lines in Two Stream: West Wits Mining Boundaries, Report No. CWT 242018 (July, 2018). The sub-catchment characteristics are shown in Table 6-1 below.

TABLE 6-1: SUB-CATCHMENT CHARACTERISTICS (CWT, JULY 2019)

Parameter	Western Stream	Eastern Stream
Area (km^2)	6.0	4.7
Length of longest watercourse (km)	3.34	2.83
Equal area height difference (m)	57.2	42.3
10 – 85 slope height difference (m)	48.0	44.0
Distance to catchment centroid (km)	2.20	1.91
Time of concentration (hours)	0.77	0.66

6.4.2 Flood peak estimates and boundary conditions

Design peak flows for the 1:100-year recurrence interval storm event were computed for the watercourses in the study site using the RM, ARM, SDF and UH methodologies. This was undertaken in order to compare the results obtained by these methods. The comparison of the different flood peaks, using different methodologies, can be seen in Table 6-2 below (CWT, July 2018).

TABLE 6-2: RESULTS OF THE DETERMINISTIC FLOOD PEAK CALCULATIONS (CWT, JULY 2018)

Method	Western Stream 1:100 Year RP (m^3/s)	Eastern Stream 1:100 Year RP (m^3/s)
Rational Method as implemented by the Department of Water Affairs	138	120
Rational Method using Alternative Algorithms	146	128
Standard Design Flood Method (SDF) developed at the University of Pretoria	110	96
The Unit Hydrograph Method	83	63

The peak flows for each of the watercourses sub-catchments estimated within the site boundary were assessed for use in the HEC-RAS Model. It was decided to adopt the flood peaks shown in Table 6-3 for sub-catchments (CWT, July 2018) because they are average peak flows for all the methods used.

TABLE 6-3: RECOMMENDED FLOOD PEAK TO BE USED IN THE FLOODLINE DETERMINATION (CWT, JULY 2018)

Flood Peaks	Western Stream 1:100 Year RP (m^3/s)	Eastern Stream 1:100 Year RP (m^3/s)
Recommended flood peaks to be used in the floodline determination	119	102

6.5 HYDRAULIC FLOOD MODELLING

6.5.1 Hydraulic structures

The notable hydraulic structures which were input into the model were:

- Dam 1 (Western Stream) - Old dam that is completely overrun with reeds. The dam is silted up and was empty on the day of the site visit. The wall on the upstream side is only about 0.75 m deep. The wall on the downstream side is about 10 m high. There is a rudimentary spillway on the right hand side of the dam that is 1.2 m high and 20 m wide. This is shown in Figure 6-2;
- Culvert 1 (Eastern Stream) - Culvert and road crossing at the topmost section of the river reach. The culvert is a single circular one measuring 1.2 m in diameter and was a third blocked. The road deck was 0.7 m above the top of the pipe. This is shown in Figure 6-3;
- Culvert 2 (Eastern Stream) - Culvert and road crossing near the top section of the river reach. The culvert is a double box shaped portal, measuring 1.5 m in width and depth. The left hand portal was two-thirds blocked. The road deck was 0.7 m above the top of the pipe. This is shown in Figure 6-4;
- Culvert 3 (Eastern Stream) - Culvert and road crossing. The culvert is a single circular one measuring 1.5 m in diameter. The road deck was 0.4 m above the top of the pipe. This is shown in Figure 6-5;
- Culvert 4 (Eastern Stream) - Bridge and road crossing near the bottom section of the river reach. The bridge has 3 plinths and therefore four portals, measuring 20 m in width and 3.5 m in depth. The right hand portal is a third blocked. The road deck is 1.4 m thick. This is shown in Figure 6-6;

FIGURE 6-2: WESTERN STREAM - OLD DAM

FIGURE 6-3: EASTERN STREAM - CULVERT 1

FIGURE 6-4: EASTERN STREAM - CULVERT 2

FIGURE 6-5: EASTERN STREAM - CULVERT 3

FIGURE 6-6: EASTERN STREAM - CULVERT 4

6.6 ROUGHNESS COEFFICIENTS

The Manning's roughness factor n is used to describe the flow resistant characteristics of a specific surface. Based on the site visit undertaken, it was observed that the water channel could be described as: irregular sections with pools, fairly regular section, unmaintained, vegetal and some weedy channels and an n value of 0.05 was assigned to the channel and 0.045 was assigned to the banks (floodplains).

6.7 ASSUMPTIONS IN THE HYDRAULIC MODEL

In-line with the development of the floodlines the following assumptions were made:

- The topographic data provided was of a sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail;

- There would be no significant attenuation or storage of floodwater within the farm dams in the vicinity of the project;
- Hydraulic structures such as culverts at the site boundary were modelled as part of this study;
- The Manning's 'n' values used is considered suitable for use in all the modelled storm events (1:100 year event) modelled, as well as in representing both the channel and floodplain;
- No abstractions from the river section or discharges into the river section were taken into account during the modelling;
- Levees have been added to confine the modelling to the channels;
- Steady state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate; and
- A mixed flow regime which is tailored to both subcritical and supercritical flows was selected for running of the steady state model.

6.8 FLOODLINE DELINEATION FOR THE CURRENT SCENARIO

Floodlines for the 1:100-year recurrence intervals were determined for the current river network passing through the project site the 100m buffer of the watercourses and presented in Figure 6-7 and Figure 6-8.

FIGURE 6-7: FLOODLINES AND 100M BUFFER FOR THE WESTERN STREAM

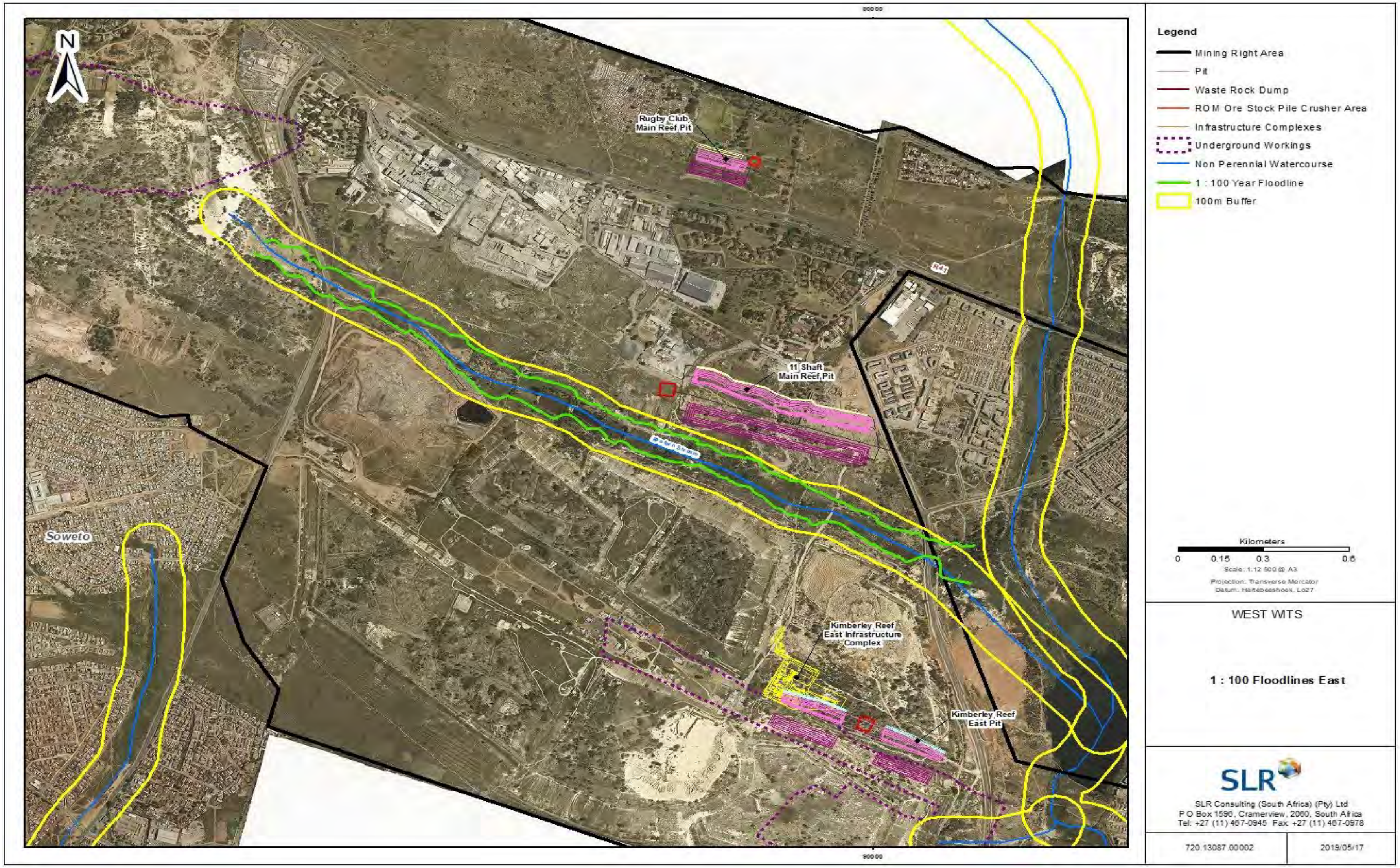


FIGURE 6-8: FLOODLINES AND 100M BUFFER FOR THE EASTERN STREAM

7. IMPACT ASSESSMENT, MITIGATION AND MONITORING

Informed by the mine plan layout, baseline hydrology, design specifications for the stormwater management measures, the floodlines, and the water balance results, the potential impacts of the proposed activities on surface water receptors as well as the sensitivity of the surface water resources are presented in this section along with a summary of mitigation measures.

Impacts are assessed cumulatively where possible as related to the currently impacted environment. However, the impacts of the various (surrounding/neighbouring) activities in the wider region have not been cumulatively assessed in this report.

7.1 METHODOLOGY AND APPROACH

The technical work undertaken in the baseline assessment was used to inform the surface water impacts assessments. The specific report structure and methodologies for each section have been summarised below:

- Climate – Section 2 presents a review of local rainfall including storm rainfall intensities and evaporation data, which are used to inform water management at the site.
- Baseline Hydrology - Section 2 presents a description of the baseline hydrology of the site and surroundings including: topography, vegetation coverage, hydrological soil types, hydrogeology, watercourse network, catchment delineations, and sensitive surface water receptors. Information was obtained from various sources of baseline information and informed by a site visit undertaken by an SLR Hydrologist during February 2019.
- Water Quality – Section 3 presents wet and dry season water quality sampling results and assessments benchmarked against the local and international water quality standards and guidelines.
- Stormwater Management – Section 4 presents recommendations on stormwater management measures to be implemented at the operational site including catchment classification (clean or dirty) and delineation, location and preliminary capacity estimation for return water dams and/or pollution control dams, peak flow estimation and hydraulic sizing of channels.
- Site Wide Water Balance– Section 5 presents the mine steady state water balance for wet and dry season and annual averages for 3 scenarios (e.g. startup, mid-life of mine, end-life of mine) and a dynamic daily time-step water balance model to understand the impacts of climatic extremes and estimate capacity requirements for PCDs.
- Floodlines – Section 6 presents the results of the floodline analysis and indicates where infrastructure can be located to ensure that it is sited outside of the 1:100 year Return Period floodline and follow the principles laid out in GN 704.
- Impact Assessment and Mitigation – Section 7 presents a description of identified potential impacts upon the baseline environment and a summary of the mitigation measures (developed as part of PFS scope), assessing residual impacts and developing a monitoring programme.

The proposed method for the assessment of environmental issues is set out in the Table 7-1 below. Part A provides a list of criteria that can be selected in order to rank the severity, duration and spatial scale of an impact. The consequence of the impact is determined by combining the selected criteria ratings allocated for severity, spatial scale and duration in part B. The significance of the impact is determined in Part C whereby the consequence determined in part B is combined with the probability of the impact occurring. The interpretation of the impact significance is given in Part D.

TABLE 7-1: CRITERIA FOR ASSESSING IMPACTS

PART A: DEFINITION AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of severity, spatial extent and duration**
Criteria for ranking of the SEVERITY of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE					
SEVERITY = L					
DURATION	Long term	**H**			
	Medium term	**M**	**Low**	**Low**	
	Short term	**L**	**Low**	**Low**	
SEVERITY = M					
DURATION	Long term	**H**		**High**	**High**
	Medium term	**M**			**High**
	Short term	**L**	**Low**		
SEVERITY = H					
DURATION	Long term	**H**	**High**		
	Medium term	**M**	**Medium**		
	Short term	**L**	**Medium**		**High**
			L	**M**	**H**
			Localised Within site boundary	Fairly widespread Beyond site boundary	Widespread Far beyond site boundary

			Site	Local	Regional/ national
			SPATIAL SCALE		
PART C: DETERMINING SIGNIFICANCE					
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**H**			
	Possible/ frequent	**M**			**High**
	Unlikely/ seldom	**L**	**Low**	**Low**	
			L	**M**	**H**
			CONSEQUENCE		
PART D: INTERPRETATION OF SIGNIFICANCE					

Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

***H = high, M= medium and L= low and + denotes a positive impact.**

7.2 SENSITIVITY OF WATER RESOURCES

The local surface water resources are considered to be of low sensitivity, the rationale for this sensitivity ranking is as follows:

- The project site is located in the upland areas of the C22A Quaternary Catchment which is a highly impacted catchment. The Quaternary is about 85% urban.
- Locally, surface water quality is highly impacted as shown in the baseline / pre-mining water quality where the existing water quality is not fit for human consumption.
- The rivers and dams in the project area are already impacted by illegal miners scouring and digging the river beds in an effort to find gold. Therefore the rivers and dams have been assessed as highly impacted already.

7.3 IMPACTS ASSESSMENT

The impacts of the proposed activities and the infrastructure have been identified and then assessed based on the impact's magnitude and the receptor's sensitivity. This analysis then culminates in the determination of the impact significance which indicates the most important impacts and those that require management.

7.3.1 Impact Description

Identification of the impact of the major activities on the surface water resources have been carried out for the three main stages of the project namely the construction, operation and closure phases as presented in Table 7-2.

TABLE 7-2: SUMMARY OF PROJECT ACTIVITIES, INTERACTION AND POTENTIAL IMPACTS TO SURFACE WATER RESOURCES

Project Activities	Interaction	Impact description
Construction		
Initial earthworks associated with site clearing, stripping and stockpiling of soil resources, preparations and construction of new surface infrastructure.	Water quality	Deterioration of water quality as a result of the following • Clearing the surface and site preparations, for the mine infrastructure will result in exposure of soil surfaces to erosion factors. When a large area of vegetation is cleared and topsoil disturbed, exposing a large area of loose material, susceptible to erosion. During rainfall events, runoff from the exposed site will transport the eroded soil material in to the nearby water resources. • Uncontrolled spills of contaminants such as fuel and oils, and subsequent washing away of these into the surface water resources.
	Water quantity	• A reduction of runoff water quantity to the surface water resources system. When the initial stormwater management measures are constructed on site, the catchment area for runoff is reduced by 0.15%. • Although the region is generally semi-arid and significant rainfall events do occur, impact on surface water resources as a result of water extraction during construction is anticipated. The water balance is water positive and abstraction from the PCDs for dust suppression will need to be augmented with abstraction with the intention to treat to the point where water is released back into the environment.
Operation		
Open pit mining, stockpiling, processing and operation of surface infrastructure (diversion channels, pollution control	Water quality	Deterioration of water quality as a result of the following: • Contaminated stormwater runoff from operational areas containing potential pollutants such as oils, solvents, paints, fuels and waste materials and discharge of dirty water into the catchment when extreme events do occur. Some of the structures may have the potential for seepage such as the waste

Project Activities	Interaction	Impact description
dams, stockpiles, workshops & offices, crushing and screening plant).		rock dump, RoM pad, PCD dams and plant infrastructure areas. • The project could cause pollution of water resources through sediment transport and other chemical parameters from runoff from the pit waste and plant areas. • Discharge of excess water from the PCDs would also present risks to water quality
	Water quantity	• Informed by the water balance, there may be need for discharge of excess water to the environment after processing reuse (NB: storage was not considered in the water balance). The excess water discharge could result in alteration of flow regime of the streams. However these impacts may be moderate, considering some reduction in flow from dirty stormwater sub-catchments and implementation of mitigation measures (storage and flow control measures).
Closure		
Cessation of the mining and the removal and demolition of surface infrastructure and rehabilitation.	Water quality	• Removal and handling of hazardous waste offsite and waste storage facilities, damage to waste handling facilities resulting in water quality deterioration
Removal of surface infrastructure and rehabilitation.	Water quantity	• With adequate rehabilitation and closure some of the catchment is returned to a self-sustaining system. Return of natural drainage patterns as a result of freely draining topography

7.3.2 Impacts Rating

Based on a review of the project description and listed activities in the previous section, a total of about 100 ha (1 km^2) is proposed for mining and supporting infrastructure. These areas add up to 0.15% of the Quaternary Catchment C22A thereby implying a small disturbed area of impacts.

The proposed mining project design includes various mitigation measures. Theoretically without these measures the impacts on the environment would be much higher, although the mine would almost certainly not be allowed to proceed without compliance with current best practice and relevant industry guidelines presented in this and other reports.

Using the impact methodology in Section 7.1, the this section assesses the impacts of the potential unmitigated impacts (unrealistic worst-case scenario), and residual impacts of the project after considering the design mitigation measures proposed within this report using the qualitative assessment presented in Table 7-3.

TABLE 7-3: QUALITATIVE IMPACT ASSESSMENT

Issue	Description	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
A. Construction							
Impact on Baseline Surface Water Quality – Unmitigated	Without considering stormwater and sediment management, the project could cause contamination of water resources through sediment transport and hydrocarbon spillages from runoff during initial earthworks into the catchment.	Without mitigation, the project could have a high severity impact on the quality of surface water resources which are already high in turbidity (H)	Impacts will last medium term for the duration of project. (M)	Water quality impacts could be fairly widespread beyond the site boundary but would lessen with distance downstream, due to dilution and filtering within the river systems (M)	Medium	Without mitigation there is a possibility of exposure to the impact on the quality of surface water resources. (M)	Medium
Impact on Baseline Surface Water Quality - Mitigated	A stormwater management plan including sediment management is developed in accordance with GN 704 to ensure that dirty water is conveyed to containment facilities and does not discharge or spill into clean water more frequently than once in 50 years. The South African Best Practice Guidelines good practices are also considered.	Considering the mitigation measures discussed within this report, the mine will have a low severity impact on the quality of surface water resources. (L)	Impacts will last medium term for the duration of project. (M)	Any impacts would be localised within the holding facilities. (L)	Low	Probability of impacts is unlikely as mitigation measures are designed for extreme events. (L)	Low

Issue	Description	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
Impact on catchment runoff - Unmitigated	Without considering any mitigation measures or water management measures, the collection of stormwater and physical alteration of drainage lines may reduce catchment area for runoff to the streams by approximately 0.15%	The project area is minor compared to the C22A Quaternary Catchment; therefore the severity of reduction in runoff flows is low. (L)	Impacts could last the project life (M)	Impacts could affect only the local smaller catchments (L)	Low	Reduction in catchment runoff flows is likely, especially in the rainy season (L)	Low
Impact on catchment runoff - Mitigated	The proposed stormwater management measures remain in place throughout the project as such; collection of stormwater will continue with the project and may still reduce baseline flows into the water resources system	The project area is small compared to the C22A Quaternary Catchment; therefore the severity of reduction in runoff flows is low. (L)	Impacts could last the project life (M)	Impacts could affect only the local smaller catchments to a small extent (L)	Low	Reduction in catchment runoff flows is likely, especially in the rainy season (L)	Low

Issue	Description	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
B. Operation							
Impact on Baseline Surface Water Quality – Unmitigated	Without considering stormwater management measures the project could cause pollution of water resources through discharge of water, potential spillage, leaching and seepage of chemical contaminants, as well as sediments into the water resources.	Without mitigation, the project could have a high severity impact on the quality of surface water resources as can be seen from the baseline surface water quality. (H)	Impacts could last the project life and even beyond closure (H)	Water quality impacts could extend region wide but would lessen with distance downstream, due to dilution and filtering within the streams (M)	Medium	Without mitigation there could be a high likelihood of impacting the quality of surface water resources. (H)	High
Impact on Baseline Surface Water Quality – Mitigated	A stormwater management plan has been developed to ensure that dirty water is conveyed to containment facilities and does not discharge or spill into clean water more frequently than once in 50 years. This ensured that stockpiles seepage and any contaminated plant runoff is collected and managed as dirty water.	Considering the mitigation measures presented within this report, the mine will have a moderate severity impact on the quality of surface water resources. (M)	Impacts will last medium term for the duration of project. (M)	Any impacts would be localised within the holding facilities and will also be downstream of discharge points if discharge water quality is not controlled (M)	Medium	Probability of impacts is most likely in successive extreme events as mitigation measures are designed for extreme events and continuous management of sediments. (M)	Medium.

Issue	Description	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
Impact on surface water flow regimes - Unmitigated*	Without considering storage of water and flow discharge and erosion control measures, and considering the average water balance for the various complexes are water positive, requiring discharge of water from the PCDs and pits; could impact (increasing the flows into) the water resources and thereby altering their flow regime.	The water balance requires for pumping from the pits into the PCDs. The PCDs require that water is abstracted from them for dust suppression and treatment. The treatment will be through water treatment plants. The magnitude can be High for some streams. (H)	Impacts will be reversible over time but lasting the life of project (M)	Impacts will be experienced locally on the water resources (M).	Medium	With the current modelled scenario, discharge will be required and, impact on baseline flows in local watercourses, will be expected. (H)	Medium
Impact on surface water flow regimes - Mitigated*	It is anticipated that discharge volumes will increase (see the water balance section). Storage, discharge velocity control and erosion controls will be implemented at discharge points and water reused as much as is possible, thereby managing discharge volumes	The water balance requires for discharge. The magnitude can remain moderate to low if erosion protection measures are in place and the discharge is controlled. (M)	Impacts will be reversible over time but lasting the life of project (M)	Impacts will be experienced locally on the water resources (M).	Medium	With discharge, impacts may still be anticipated, however they will be at a controlled rate, and some storage considered within the PCD for a minimum number of days. (M)	Medium

Issue	Description	Severity	Duration	Spatial Scale	Consequence	Probability	Significance
C. Closure							
Impacts on surface water quality – Unmitigated	Without considering the waste handling procedures, the cessation of the mining and the removal and demolition of surface infrastructure and rehabilitation could result in potential accidental spillages and damage to waste handling facilities resulting in water quality deterioration.	Without mitigation, the project could have a severe impact on the quality of surface water resources (H)	The impacts of the mine will be for a short term (L)	Impacts will be experienced locally on the water resources (M).	Medium	Without mitigation there could be a possible chance of impacting the quality of surface water resources (M)	Medium
Impacts on surface water quality - Mitigated	Mitigation measures recommended for the management of accidental spills and the use of accredited removals if implemented will reduce and manage the impacts.	Considering the mitigation measures presented within this report, the mine will have a low severity of the impact on the quality of surface water resources. (L)	Impacts will be short term and be reversible over time (L)	Any impacts will be localised within the holding facilities. (L)	Low	Probability of impacts is unlikely as mitigation measures are designed for extreme events. (L)	Low.

7.4 MITIGATION MEASURES

A summary of the measures developed to ensure compliance to legislative and design standards are presented below with additional mitigation measures that are also recommended to further reduce residual impacts on the surface water quality and quantity.

Designed mitigation measures:

- Stormwater management:
    - Separation of clean and dirty water through the development of stormwater structures as detailed in Section 4 of this report. It must be ensured that diverted runoff from disturbed area is collected in dirty areas and clean water freely discharges to the surrounding clean catchment.
    - As discussed in section 4 above, it is proposed that stormwater from dirty catchments is contained and reused at the processing plant and as dust suppression. Alternatively it must be treated and discharged (section 5), effectively reducing the catchment area draining to the local watercourses.
    - Management of silt as detailed in Section 5 by ensuring that the disturbance of topsoils is minimised, sediment source and erosion control, phasing of earthworks activities, diversion of upslope runoff from entering the earthworks areas and downstream treatment of any collected sediment runoff i.e. use of silt traps;
- Water Balance: the project's water circuit has been defined and collection and water management strategy defined with the reuse of dirty water prioritised, thereby reducing the impacts from the project on the surface water resources through planning for discharge of excess mine water.

In addition to the measures presented and discussed throughout this report, the following management measures should be implemented:

- Infrastructure design: the design of all onsite access roads, plant areas, stockpiles, pump station etc. must include stormwater management and erosion control during both the construction and operational phases;
- Good housekeeping practices must be implemented and maintained by clean-up of accidental spillages, as well as ensuring all dislodged material like run-of-mine stockpile are kept within the confined storage footprints. In addition clean-up material and materials safety data sheets for chemical and hazardous substances should be kept on site for immediate clean-up of accidental spillages of pollutants;
- Regularly schedule inspection and maintenance of water management facilities, to include inspection of drainage structures and liners for any in channel erosion or cracks; de-silting of silt traps/sumps and PCDs; and any pumps and pipelines should be maintained according to manufacturer's specifications;
- Vehicles and plant equipment servicing must be undertaken within suitably equipped facilities, either within workshops, or within bunded areas, from which any stormwater is conveyed to a pollution control dam, after passing through an oil and silt interceptor;
- Pollutant storage – any substances which may potentially pollute surface water must be stored within a suitably sized bunded area and where practicable covered by a roof to prevent contact with rainfall and/or runoff;
- Water conservation and water demand management (WC/WDM) measures to ensure that as much water as is possible, is collected and reused; and

- From operations onwards, grading of disturbed area and application of the final layers of growth medium, must be contoured as far as can be achieved in a safe and practical manner; and vegetation of disturbed areas including seeding should be performed immediately following application of the growth medium to avoid erosion.

All measures implemented for the mitigation of impacts, should be regularly reviewed as best practice and as compliance with various licences issued on site by authorities. The purpose of the mitigation measures is to ensure that the pre-mining / current water resource status is not deteriorated by the mining activities.

7.5 MONITORING

A monitoring programme is an essential tool to identify any risks of potential impacts as they arise and to assist in impact management plans by assessing if mitigation measures are operating effectively. Monitoring should be implemented throughout the life of the mine.

7.5.1 Monitoring

Recommendations on surface water monitoring are presented in Table 7-4.

TABLE 7-4 : SURFACE WATER MONITORING PROGRAMME

Monitoring Element	Description	Frequency
Water quality	• Ensure that monitoring continues to be implemented to cover all streams affected by mining activity areas. A monitoring programme should be developed and this should cover upstream and downstream receptors. • Additional sampling sites downstream of each operation are recommended to ensure that all the discharge points are covered. • Water quality at upstream and downstream discharge and storage points assist with the salt balance by monitoring the TDS and SO_4. • Analytical suites for recommended water quality analysis are shown in Appendix A to cover the dry and wet season in order to establish the baseline water quality status, then after, the list can be reduced to parameters of concern in Table 7-6.	Monthly Monitoring needs to carry on after the project has ceased and the results reach a steady state to detect residual impacts.
Flow Volumes	Flow monitoring should be carried out in channels and pipelines and at abstraction and discharge facilities on site including pit dewatering.	On a monthly basis to update and calibrate the water balance for the mine.
Water Levels	Monitoring water levels in dams and channels to ensure the freeboard is maintained.	Monthly through the dry season and weekly through the wet season or after storm events.

Monitoring Element	Description	Frequency
Water management structures and facilities	Inspection of channels, silt traps, culverts, pipeline, dam walls and dams for signs of erosion, cracking, silting and blockages of inflows, to ensure the performance of the stormwater remains acceptable.	Weekly to monthly during wet season and after storm events or as per site management schedule. Monthly in dry season.
Meteorological data	Measure rainfall for water balance updates where possible.	Daily.

Additional sampling sites downstream of each operation are recommended to ensure that all the discharge points are covered. These points are provided in Table 7-5 and Figure 3-1.

TABLE 7-5 ADDITIONAL SURFACE WATER MONITORING POINTS

Sample ID	Latitude (°)	Longitude (°)
SW1	-26.171362	27.824326
SW2	-26.1808484	27.819681
SW3	-26.205962	27.910516
SW4	-26.214071	27.919792
SW5	26.215009	2792576

The monitoring plan should be reviewed periodically to ensure appropriateness of sites and sampling frequency during operation.

TABLE 7-6 : SURFACE WATER QUALITY PARAMETERS OF CONCERN

Determinant	
pH	Nitrate as N
Electrical conductivity	Ammonia
Total dissolved solids	Potassium
Total suspended solids	Nickel
Aluminium	Manganese
Calcium	Magnesium
Fluoride as F	Iron
Total alkalinity as CaCO3	Copper
Chloride as Cl	Lead
Sulphate as SO4	Sodium
Uranium	*E.coli*

7.5.2 Reporting

Reporting on the above monitoring should be as follows:

- Internal Reporting – Monthly for
  - Flow Volumes
  - Water Levels
  - Drainage Inspections
  - Pollutant Inspections
- External Reporting – Annual:
  - Abstraction Volumes
  - Discharge Volumes
  - Water Quality
  - Spillages / Emissions

Accidental spillages and overflows should be reported as and when they occur to the relevant authorities.

8. CONCLUSIONS AND RECOMMENDATIONS

This surface water study was undertaken by a suitably qualified, experienced and independent Hydrologist to comply with the NEMA regulations requirements. A summary of the NEMA regulations requirements for technical specialist studies and cross references to the relevant supporting information is presented in Appendix A.

A stormwater management plan has been developed to ensure compliance with the requirements of GN 704. The clean water channels do not automatically require lining, however in this case the velocities in the channels are high so it is recommended that the channels are concrete lined to prevent erosion and scour. Circular culverts are recommended for conveying flows beneath major road crossings. During the construction of the conveyance infrastructure, the location of existing services must be considered, and the drainage channels worked around these where necessary.

A site wide water balance has been developed, to estimate the return water, make up water and /or discharge requirements with the proposed infrastructure for start-up, operations and end of life of mine. The project’s water circuit has been defined and collection and water management strategy defined where the reuse of dirty water will be prioritised, thereby ideally reducing the impacts from the project on the surface water resources through planning for discharge of excess mine water and storing for use in low water supply periods.

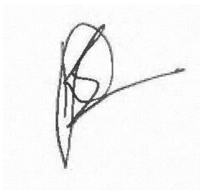
Floodlines for the 1:100-year recurrence intervals were determined for the current river network passing through the project site. The local surface water resources are considered to be of low sensitivity

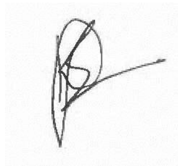
Informed by the mine plan layout, baseline hydrology, design specifications for the stormwater management measures, the floodlines, and the water balance results, the potential impacts of the proposed activities on surface water receptors as well as the sensitivity of the surface water resources are presented in this section along with a summary of mitigation measures.

A monitoring programme is an essential tool to identify any risks of potential impacts as they arise and to assist in impact management plans by assessing if mitigation measures are operating effectively. Monitoring should be implemented throughout the life of the mine.

The outcomes of the baseline assessments, floodlines modelling and stormwater management should be implemented in the design of the mine. Subject to implementing the mitigation measures and recommendations proposed herewith, it is concluded that the activities should be authorised.

All measures implemented for the mitigation of impacts, should be regularly reviewed as best practice and as compliance with various licences issued on site by authorities. The project can continue, if all mitigation and monitoring measures are to be implemented.





Chenai Makamure and Kevin Bursey

(Report Author)

Kevin Bursey

(Project Manager)

Kevin Bursey

(Project Reviewer)

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APPENDIX A: SURFACE WATER HYDRO-CHEMICAL RESULTS COMPARED TO SANS 241 AND DWS STANDARDS (NOA AGENCIES)

Determinant	Unit	SANS 241 Standards Limits		DWS Drinking Standards	WITStream 1	WITStream 2	WITStream 3	WITStream 4
pH at 25°C	pH units	**≥5 - ≤9.7**			**4.5**	7.0	**3.4**	**3.3**
Electrical Conductivity at 25°C	mS/m	**Aesthetic ≤170**			103	32	**306**	**293**
Chloride	mg/l	**Aesthetic ≤300**			26	19.8	227	249
Sulphate	mg/l	**Aesthetic ≤250**	Acute health ≤500		597	83	1392	1322
Fluoride	mg/l		Chronic health ≤1.5		<0.03	0.10	<0.03	<0.03
Orthophosphate	mg/l				0.84	<0.04	0.77	<0.04
SANS	mg/l				<0.11	<0.11	<0.11	<0.11
Saline Ammonia	mg/l				7.88	<0.11	48	15.3
Cyanide (Total)	mg/l		Acute health ≤200		<10	<10	<10	<10
Dissolved Aluminium	mg/l	**Operational ≤0.3**			**5.00**	<0.02	**11.4**	**14.0**
Dissolved Antimony	mg/l		Chronic health ≤0.02		<0.009	0.01	<0.009	0.02
Dissolved Arsenic	mg/l		Chronic health ≤0.01		<0.04	<0.04	<0.04	<0.04
Dissolved Barium	mg/l		Chronic health ≤0.7		0.03	0.02	<0.02	<0.02
Dissolved Beryllium	mg/l				<0.02	<0.02	<0.02	<0.02
Dissolved Boron	mg/l		Chronic health ≤2.4		0.11	0.07	0.34	0.31
Dissolved Cadmium	mg/l		Chronic health ≤0.003		<0.02	<0.02	<0.02	<0.02
Dissolved Calcium	mg/l			No health. Scaling intensifies from 32mg/L	147	34	365	345
Dissolved Chromium	mg/l		Chronic health ≤0.05		<0.02	<0.02	<0.02	<0.02
Dissolved Cobalt	mg/l				0.63	<0.02	0.91	0.92
Dissolved Copper	mg/l		Chronic health ≤2		0.06	<0.02	0.17	0.13
Dissolved Iron	mg/l	**Aesthetic ≤0,3**	Chronic health ≤2		<0.02	<0.02	**1.46**	**1.88**
Dissolved Lead	mg/l		Chronic health ≤0.01		<0.03	<0.03	0.04	0.06
Dissolved Lithium	mg/l				<0.02	<0.02	<0.02	<0.02

Determinant	Unit	SANS 241 Standards Limits		DWS Drinking Standards	WITStream 1	WITStream 2	WITStream 3	WITStream 4
Dissolved Magnesium	mg/l			Diarrhoea and scaling issues from 70mg/L	29	11.0	84	85
Dissolved Manganese	mg/l	**Aesthetic ≤0,1**	Chronic health ≤0.4		4.78	0.10	18.1	29
Dissolved Mercury	mg/l		Chronic health ≤0.006		<0.002	<0.002	<0.002	<0.002
Dissolved Nickel	mg/l		Chronic health ≤0.07		1.72	<0.02	1.35	1.28
Dissolved Selenium	mg/l		Chronic health ≤0.04		<0.07	<0.07	<0.07	<0.07
Dissolved Silver	mg/l				<0.01	<0.01	<0.01	<0.01
Dissolved Strontium	mg/l				0.19	0.11	0.79	0.72
Dissolved Thallium	mg/l				<0.02	<0.02	0.02	0.03
Dissolved Tin	mg/l				<0.02	<0.02	<0.02	<0.02
Dissolved Titanium	mg/l				<0.03	<0.03	<0.03	<0.03
Dissolved Vanadium	mg/l			Not suitable over 1.0	<0.02	<0.02	<0.02	<0.02
Dissolved Zinc	mg/l	**Aesthetic ≤5**			0.86	0.19	2.32	2.08
Dissolved Zirconium	mg/l				<0.02	<0.02	<0.02	<0.02
Potassium	mg/l			No aesthetic or health effects below 50mg/L	7.23	5.47	90	98
Sodium	mg/l	**Aesthetic ≤200**			34	21	175	186
Dissolved Molybdenum	mg/l				<0.11	<0.11	<0.11	<0.11
Dissolved Uranium	mg/l		Chronic health ≤0.03		0.17	0.03	0.13	0.05
E.coli	mg/l		Acute health - Not detected		0	50	0	0
Total Dissolved Solids at 180°C	mg/l	**Aesthetic ≤1200**			684	217	**2041**	**1954**
Nitrate	mg/l		Acute health ≤11		0.06	1.30	31.5	2.20
Ammonia	mg/l	**Aesthetic ≤1.5**			**7.88**	<0.11	**48**	**15.3**

APPENDIX B: REPORT BY CWT CONSULTING ENTITLED: DETERMINATION OF THE 1:100 YEAR FLOOD LINES IN TWO STREAM: WEST WITS MINING BOUNDARIES, REPORT NO. CWT 242018 (JULY, 2018)

APPENDIX C: SUMMARY OF NEMA REGULATION (2017) APPENDIX 6

NEMA Regs (2014) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Section 1 and Appendix A
The expertise of that person to compile a specialist report including a curriculum vitae	Appendix A
A declaration that the person is independent in a form as may be specified by the competent authority	Appendix C
An indication of the scope of, and the purpose for which, the report was prepared	Section 1.4
An indication of the quality and age of baseline data used for the specialist report	Section 2.2
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 3 and Section 6
The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 2
A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Numerous methodologies discussed throughout the report
Details of an assessment of the specific identified sensitivity of the site related to the proposed activity (or activities) and its associated structures and infrastructure inclusive of a site plan considering alternatives	Baseline hydrological conditions are discussed in Section 2
An identification of any areas to be avoided, including buffers	Flood-lines and buffers are discussed in Section 6
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Figure 4-2
A description of any assumptions made and any uncertainties or gaps in knowledge;	Limitations and further work are discussed in Sections 4.6 and 5.6.
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Alternatives are discussed within Kruidfontein EMPr.
Any mitigation measures for inclusion in the EMPr	Section 4, Section 5, Section 6 and Section 7
Any conditions for inclusion in the environmental authorisation	N/A
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 7.5
A reasoned opinion as to whether the proposed activity or portions thereof	Section 7

should be authorised and	
Regarding the acceptability of the proposed activity	Section 7
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Various recommendations are made throughout the report, most notably Sections 4, 5 and 6.
A description of any consultation process that was undertaken during the course of carrying out the study	N/A
A summary and copies if any comments that were received during any consultation process	N/A
Any other information requested by the competent authority.	N/A

AFRICAN OFFICES

South Africa

CAPE TOWN
T: +27 21 461 1118

FOURWAYS
T: +27 11 467 0945

SOMERSET WEST
T: +27 21 851 3348

Namibia

WINDHOEK
T: + 264 61 231 287

SWAKOPMUND
T: + 264 64 402 317