# TSWANA LIME QUARRY

# WATER BALANCE STUDY

## August 2022

**REVISION 01**

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**SYNOPSIS**

Specialist water balance study required as part of the Water Use Licence Application.

**KEY WORDS:**

Tswana Lime Quarry, National Water Act 36 of 1998, Water Balance Study



**QUALITY VERIFICATION**

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2008 which has been independently certified by DEKRA Certification under certificate number 90906882

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# TSWANA LIME QUARRY
# WATER BALANCE STUDY

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# 1 INTRODUCTION

JG Afrika (Pty) Ltd were appointed by Lafarge Industries South Africa (Pty) Ltd to undertake a Water Balance Study for the Tswana Lime Quarry, located in the North West Province. The quarry is located on Portion 0 of Driefontein Farm No 46 near Itsoseng. This water balance study is required as part of a Water Use Licence Application (WULA) for the quarry, based on the requirements of the National Water Act (Act 36 of 1998). The objectives of this water balance study are to:

- Compile a graphic representation of the water flow reticulation for the quarry and its associated workshop, crusher and administration areas,
- Determine the volume of water required in the various activities associated with the quarry, and
- Define the water sources, changes in water storage and mechanisms, and volumes of water losses associated with the quarry.

## 1.1 Declaration of Independence

JG Afrika were appointed to conduct an independent water balance study for the Lafarge Tswana Lime Quarry. JG Afrika have undertaken this study in an objective manner, even if this results in views and findings that are not favourable to the Applicant or Client. JG Afrika have the expertise required to undertake the necessary studies and the following report presents the results in an objective manner. The main author of the report, Mr. Phillip Hull, is an Executive Associate and Senior Hydrologist at JG Afrika, has an MSc. in Hydrology, is professionally registered and has 15 years of relevant project experience.

## 2 SITE DESCRIPTION

The location of the Tswana Quarry is presented in **Figure 2-1**. As depicted in this map, the quarry is located approximately 37 km northwest from Lichtenburg town, within the Ditsobotla Local Municipality of the North West Province. A site plan of the Tswana Quarry is provided in **Figure 2-2**.

### 2.1 Tswana Quarry Operations Description

It is JG Afrika's understanding that the Tswana Quarry operations involve mining limestone rock from opencast pits using conventional drilling and blasting methods. The topsoil and overburden are removed by means of trucks and relocated to an area near the open pit. The mined limestone material is loaded onto haul trucks by excavators and transported to the primary crusher. Following the crushing process, the materials are transported to the Lafarge Cement Plant via railway.

### 2.2 Climate Description

The Tswana Quarry lies within an arid to temperate climatic region (Köppen-Geiger Climate Classification Maps, 2018). Rainfall occurs mostly during the summer and the climate category can be described as dry and hot during the summer months and cold during the winter months.

Temperature data for the project area was obtained from the South African Weather Services (SAWS) meteorological station 0472280 A, as presented in **Table 2-1**. The monthly distribution of average daily maximum temperatures shows that the maximum temperatures range from 18.9°C in June to 28.7°C in January. The region is the coldest during the month of June when the temperature drops to -0.4°C on average.

*Table 2-1 Temperature Recorded for Years 1950 – 1999 at SAWS 0472280 A*

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. Temperature (°C) | 22.2 | 21.6 | 20.0 | 16.7 | 12.8 | 9.3 | 9.4 | 12.2 | 16.7 | 19.3 | 21.0 | 21.8 |
| Min. Temperature (°C) | 15.7 | 15.1 | 13.2 | 8.7 | 3.7 | -0.4 | -0.3 | 2.5 | 7.6 | 11.4 | 13.6 | 15.1 |
| Max. Temperature (°C) | 28.7 | 28.0 | 26.8 | 24.6 | 22.0 | 18.9 | 19.2 | 21.9 | 25.7 | 27.3 | 28.4 | 28.4 |

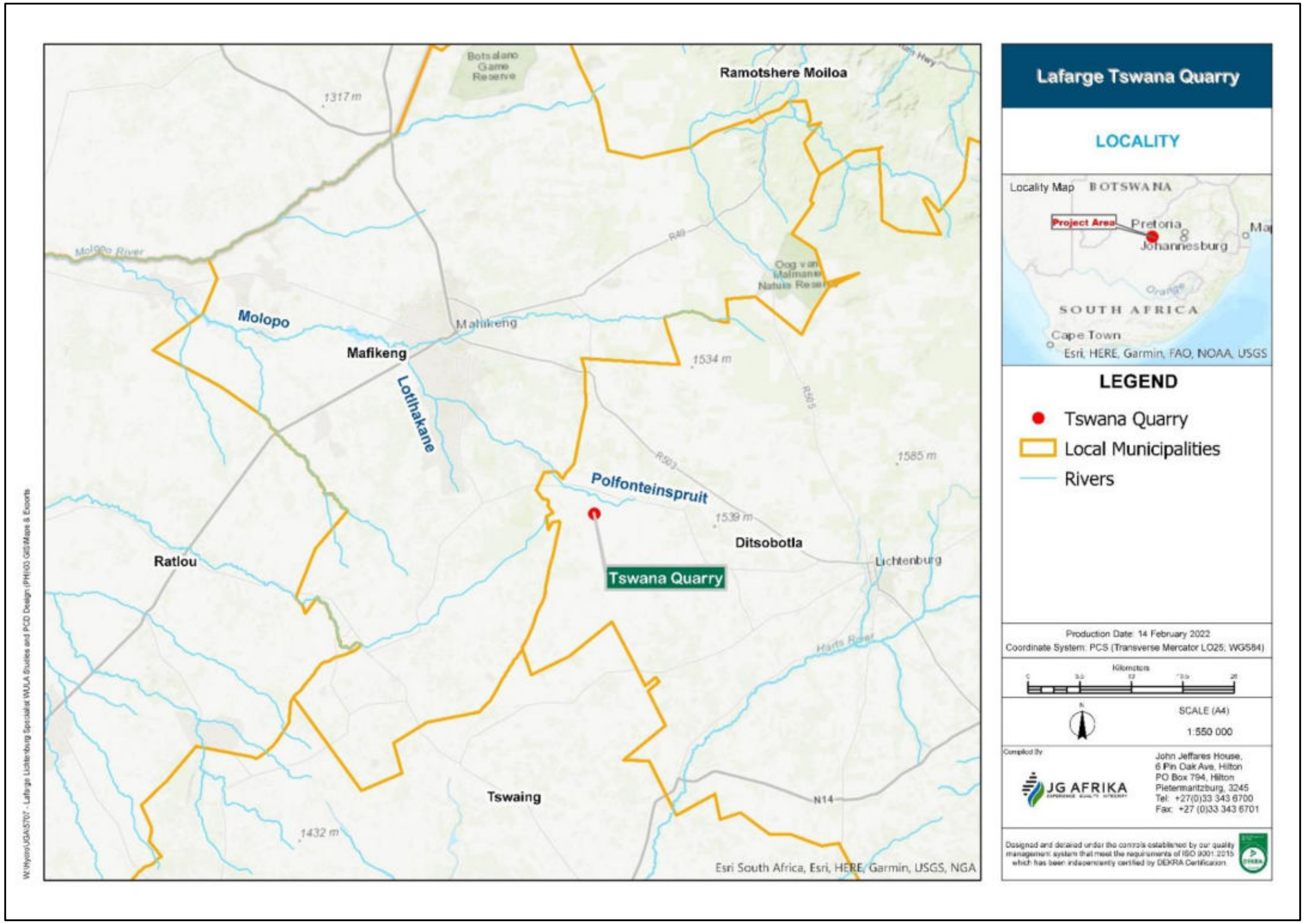


*Figure 2-1 Tswana Quarry Locality Map*

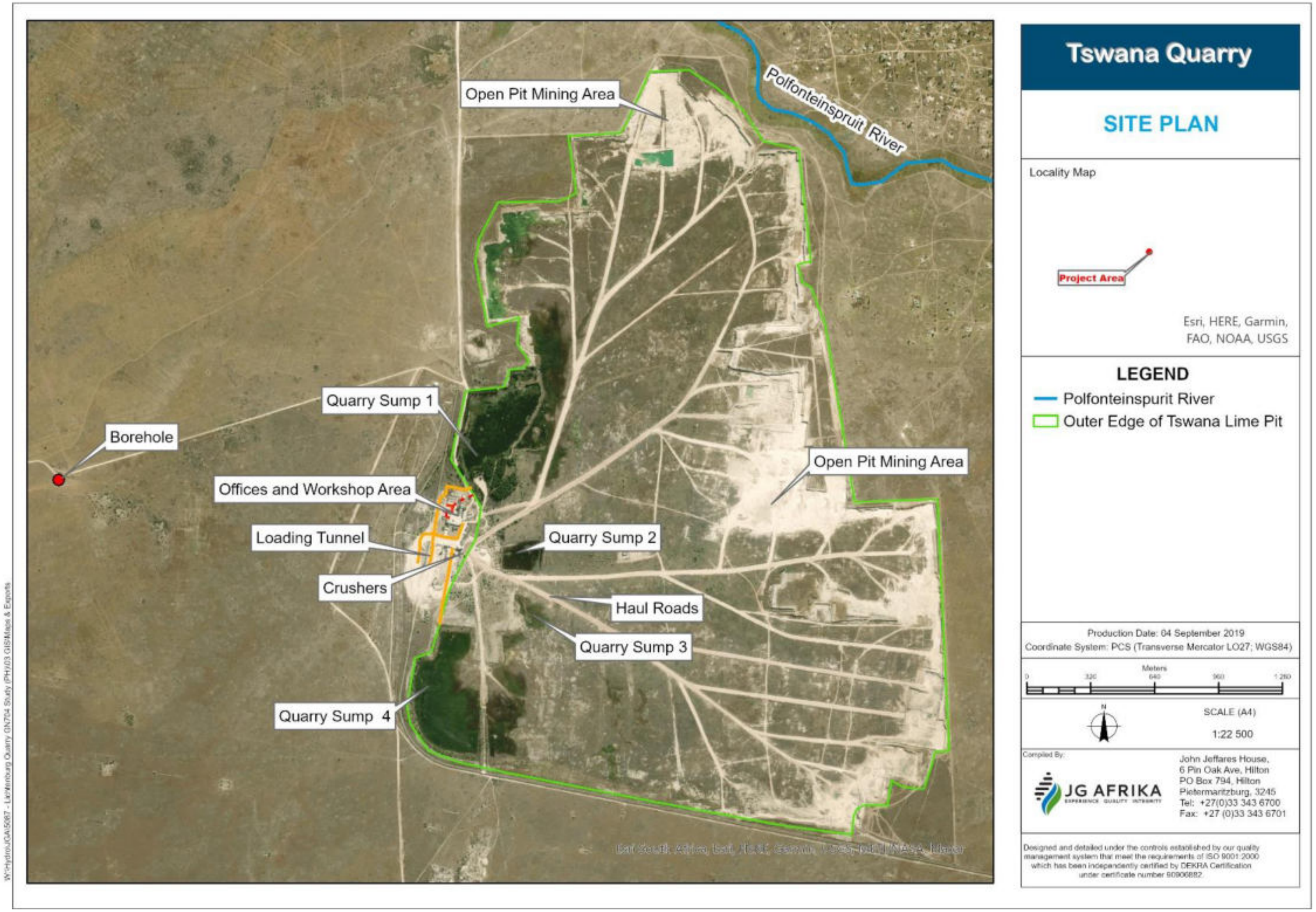


*Figure 2-2 Tswana Quarry Site Plan*

### 2.2.1 Rainfall and Evaporation

Rainfall data for the project area was obtained from the SAWS rainfall station 0471490 W. This rainfall station is located approximately 14.8 km southwest of the project site and was selected based on its record period and the reliability of the historical rainfall data. The details of this rainfall station are presented in **Table 2-2**. The mean monthly rainfall amounts over the period 1950 to 1999 are presented in **Table 2-3**. From **Table 2-3**, it is evident that most of the rainfall falls over the summer period (September to March), with a total rainfall depth over these seven months equating to 509.4 mm. It is also noted that low rainfall values are recorded over the winter months (April to August), during which a total of 91.5 mm of rainfall falls on average.

*Table 2-2 Rainfall Station Details*

| Station Number | Station Name | MAP (mm) | Years Assessed | Reliability (%) | Longitude | Latitude |
|---|---|---|---|---|---|---|
| 0471490 W | Lusthof | 601 | 1950 - 1999 | 99.7 | 25⁰ 47’ | 26⁰ 9’59" |

*Table 2-3 Average Rainfall Depths Recorded for Years 1950 – 1999 at Rainfall Station 0471490 W*

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | MAP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rainfall Depth (mm)** | 117.6 | 90.0 | 82.1 | 54.1 | 20.3 | 6.5 | 5.1 | 5.5 | 14.5 | 47.6 | 73.8 | 83.9 | 601 |

There is a high degree of variation in the annual rainfall in the data obtained from rainfall station 0471490 W. The lowest recorded annual rainfall value over the assessed period is 224.6 mm, recorded in the year 1984. **Table 2-4,** which presents the 10 wettest years over the 1950 to 2000 period, indicates the wettest recorded year over this period was 1 099.2 mm in 1967.

*Table 2-4 Ten Wettest Years Recorded for Period 1950 – 1999*

| Ranking | Year | MAP (mm) |
|---|---|---|
| 1 | 1967 | 1099.2 |
| 2 | 1975 | 943.6 |
| 3 | 1976 | 890.1 |
| 4 | 1996 | 780.5 |
| 5 | 1977 | 762.8 |
| 6 | 1956 | 724.3 |
| 7 | 1997 | 720.3 |
| 8 | 1981 | 696.7 |
| 9 | 1973 | 680.1 |
| 10 | 1978 | 673.7 |

While rainfall is generally variable on a month-to-month and year-to-year basis, this is not the case with evaporation. Monthly evaporative demands do not vary significantly from a month in one year to the same month in the next year (i.e. evaporation in one October-month, for example, is similar to evaporation in the next October-month). Therefore, it is generally considered to be acceptable to apply 12 average monthly evaporation values over the year. The evaporation data used for the Tswana Lime Quarry was obtained from Evaporation Zone 8A (Middleton and Bailey, 2008). Catchment evapotranspiration is calculated by applying 12 monthly evapotranspiration conversion factors, as presented in **Table 2-5**. Similarly, evaporation losses from an exposed water body are calculated by applying 12 monthly lake evaporation conversion factors, as presented in **Table 2-5**. The annual potential evaporation rate for the area is 1 952 mm (WR, 2012). From **Table 2-5**, the highest evaporation rates occur during the hotter summer months of September to March.

*Table 2-5 Tswana Lime Quarry Potential Evaporation*

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Evaporation Rate (mm) | 216 | 174 | 164 | 128 | 107 | 87 | 98 | 135 | 179 | 218 | 219 | 226 | 1 952 |
| Lake Evaporation Factor | 0.84 | 0.88 | 0.88 | 0.88 | 0.87 | 0.85 | 0.83 | 0.81 | 0.81 | 0.81 | 0.82 | 0.83 | |
| Evapotranspiration Factor | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.80 | 0.80 | 0.80 | 0.80 | 1.00 | 1.00 | |

## 2.3 General Hydrology of the Site

The project site is located in the Molopo River Catchment within the Quaternary Catchment D41A of the Lower Vaal Water Management Area (WMA No. 10). Based on Department of Water and Sanitation (DWS) river coverages and 5 m contours, the Polfonteinspruit flows alongside the northern boundary of the Tswana Quarry and flows into the Lotlhakane tributary which drains into the Molopo River. The Molopo River is located approximately 42 km downstream of the project site.

# 3 WATER BALANCE STUDY

The methodology used to configure the water balance is based on the methodology outlined by the DWS, Best Practice Guidelines G2 for water and salt balances. As per the guidelines, the water balance was compiled using the following steps:

1. Define the objectives of the water balance,
2. Define the boundaries for the individual balances,
3. Identify all water circuits and develop a schematic flow diagram,
4. Develop and solve balances for the respective units,
5. Develop an output format,
6. Assess the level of detail required, and
7. State assumptions.

The following sections presents details for each of the above-mentioned steps, used in the compilation of the water balance.

## 3.1 Methodology

**Step 1: Define the objectives of the balances**

The objective of this study is to prepare a water balance to simulate:

- Water pumped from the water supply borehole, located to the west of the quarry, to two Jojo Tanks, which are used to provide water to the ablutions, kitchen area, change-house, workshop and for dust suppression at the crusher area.
- The volume of water used at the workshop area for ad-hoc cleaning.
- The volume of water used for dust suppression at the crushers.
- The volume of water reporting to the two sumps located in the open pit (differentiation has been made between Quarry Sump 1 and Quarry Sump 2, as depicted in **Figure 2-2**).
- The volume of water that is associated with rainfall, runoff and evaporation within the open pit.
- The volume of water used at the Heavy-Duty Vehicle (HDV) wash bay.

**Step 2: Define the boundaries for the individual balances**

This water balance is limited to the reticulation associated with the Tswana Lime Quarry. This includes water abstracted from the supply borehole, water used for dust suppression, domestic water requirements and the environmental water balance (rainfall, runoff, evaporation and seepage) associated with the open pit and two main sumps located within the open pit.

**Step 3: Identify all water circuits and develop a schematic flow diagram**

There is an inherent difficulty in representing a complicated dynamic water reticulation system and hydrological cycle in a simplified water balance model. In order to achieve the objectives of this study, the circuits through which water flows at the Tswana Lime Quarry have been simplified into seven circulation areas, as presented in **Figure 3-1**. This schematic is based on information provided by the Client and notes taken during the site visit in January 2022. As per the information provided, the following water reticulations have been included in the water balance schematic:

- **Borehole**. The main source of water to the quarry is pumped from a borehole, located to the east of the quarry, as depicted in **Figure 2-2**. Water is pumped from the borehole to the Jojo Tanks located near the workshop and administrative buildings. As presented in **Figure 3-1**, a significant amount of water is lost to the environment. This is as a result of leaks along the pipeline between the borehole and the Jojo Tank. Based on discussions with Lafarge, it is noted that community members have been known to puncture the pipeline, which causes a leak and allows them to access water for their livestock.
- **Jojo Tank**. As presented in **Figure 3-1**, water is circulated from the Jojo Tank to the administration buildings, change-house and kitchen and to housing units (currently not used) located on site. In addition to the domestic water uses, water from the Jojo Tanks is also used for dust suppression at the crushing plant.
- **Workshop**. Water used at the workshop area is limited to water used for washdowns and for domestic purposes, and is sourced from the Jojo Tanks, as mentioned above.
- **Crushing Plant**. Associated with the crushing process is a high risk of producing dust. Therefore, a total of eight sprayers are located at the crushing plant to reduce the amount of dust produced. The volume of water used at each of these sprayers has been estimated (as presented later in **Table 3-1**) for the purposes of this water balance.
- **Open Pit**. The open pit covers an extensive area to the east, northeast and southeast of the administration and workshop areas. It is not a deep excavation, and is estimated to be less than 10 m deep at its deepest point.
- **Quarry Sumps**. Located within the open pit are several sumps, located along the western edge of the pit. These sumps capture stormwater runoff from within the pit and stormwater from

the workshop and administration building areas and the crusher area. Water from Quarry Sumps is used at the HDV washbay and is also used for dust suppression on the roadways within the pit. Due to the interconnection between the sumps, and the fact that they are all located within the open pit, for the purposes of this water balance they have been considered as a single entity.

- **Wash Bay**. The wash bay is located within the open pit, on the southern banks of the Quarry Sump 1 (as depicted in **Figure 2-2**). During washing, water is pumped directly from the sump to a high-pressure spray gun. Water from the wash bay then runs off directly back into the sump area. During the site assessment no signs of hydrocarbon contamination were noted in the vicinity of the sump and surrounding vegetation.

**Step 4 and 5: Develop and solve balances for the respective units, and develop an output format**

**Figure 3-1** to **Figure 3-3** presents the resulting water balance for the Tswana Lime Quarry for annual average, annual average daily, dry season average daily (represented by average water use in the July months) and wet season average daily (represented by average water use in the February months) water balances. Water inputs into the various infrastructure are generally presented on the left of the diagram and outflows are presented on the right of the diagram. Values provided in **Figure 3-1** are in cubic meters per annum ($m^3$/annum) and **Figures 3-2** to **3-4** are in cubic meters per day ($m^3$/day).

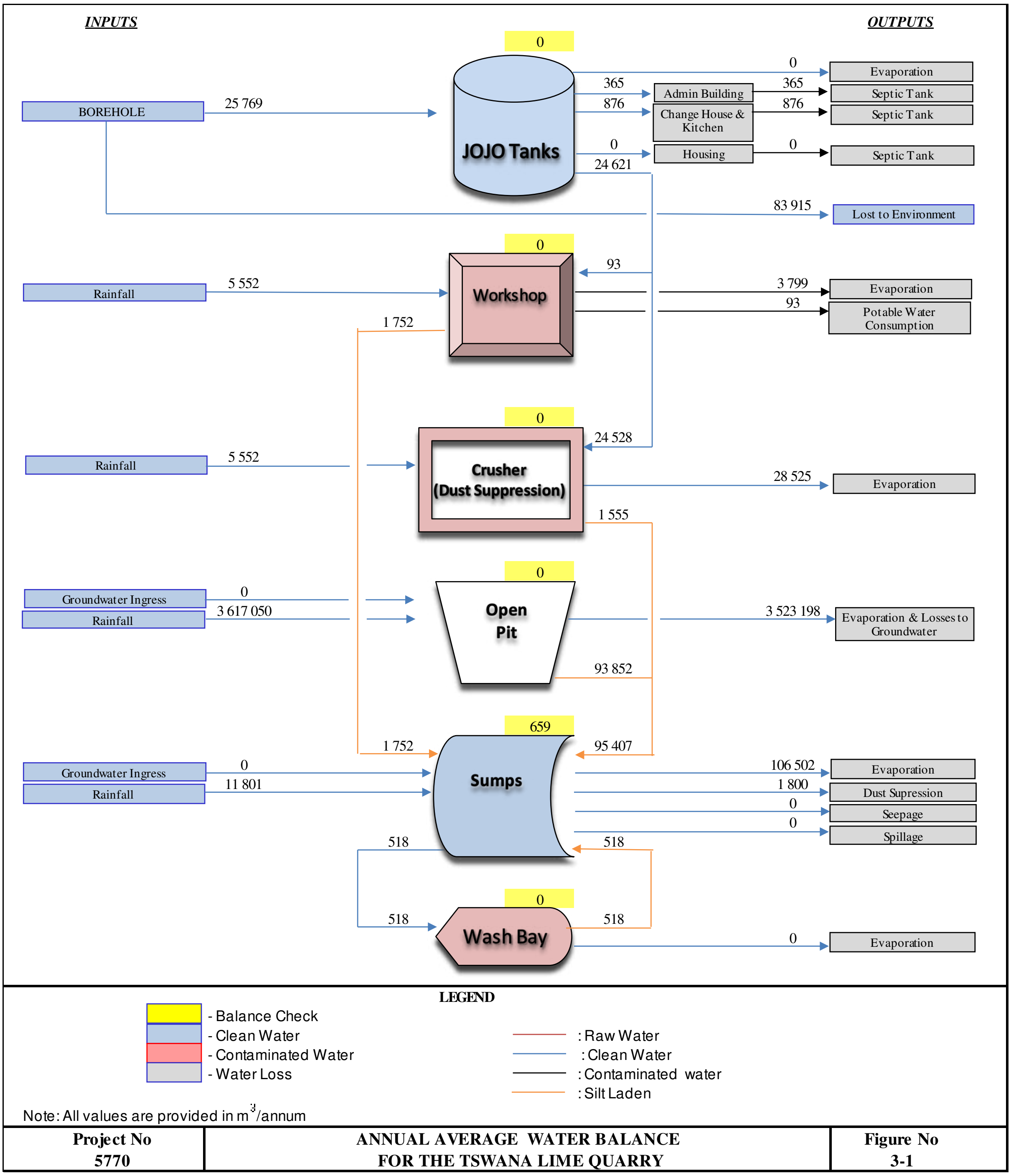


*Figure 3-1 Tswana Lime Quarry Average Annual Water Balance*

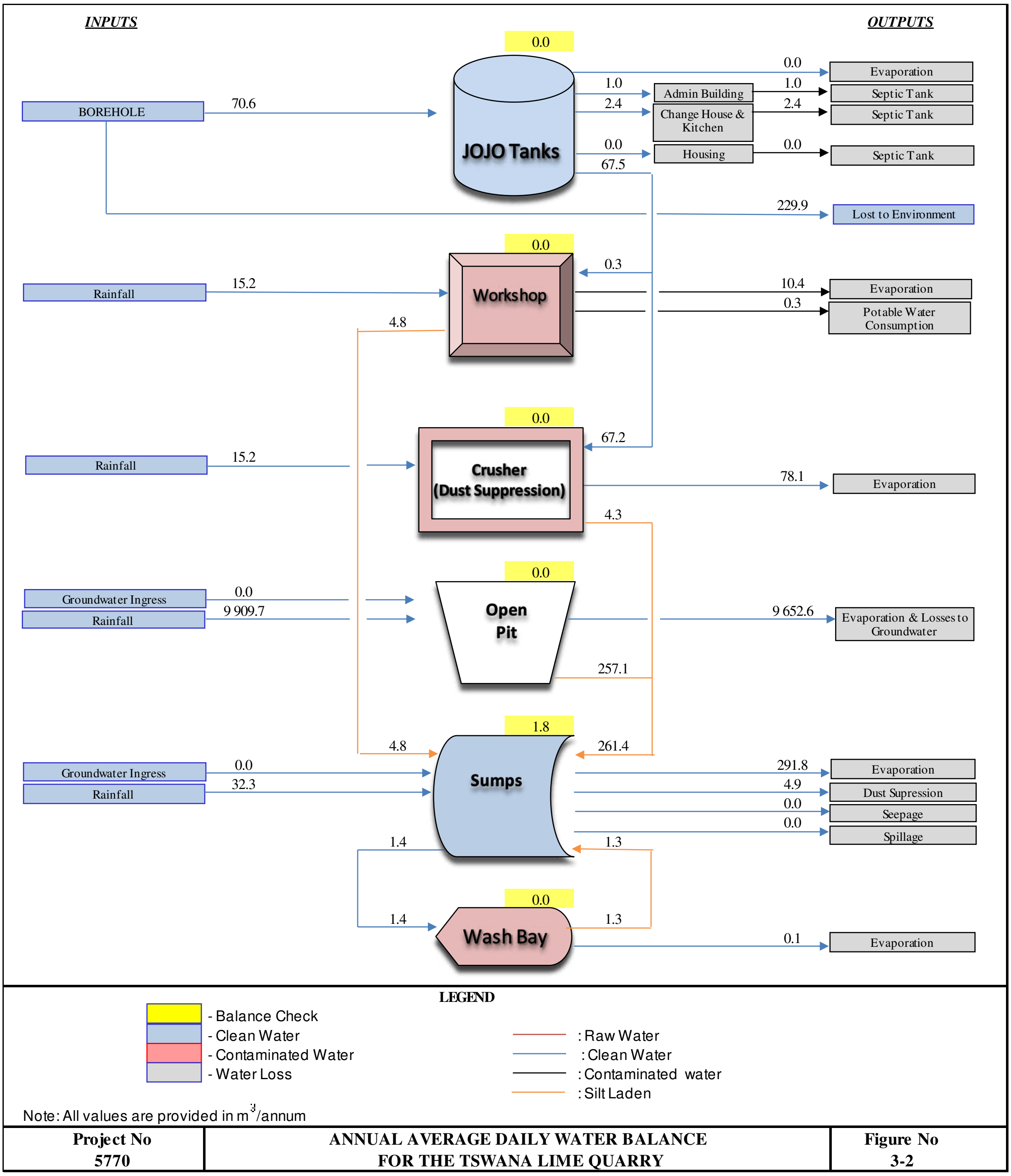


*Figure 3-2 Tswana Lime Quarry Average Annual Daily Water Balance*

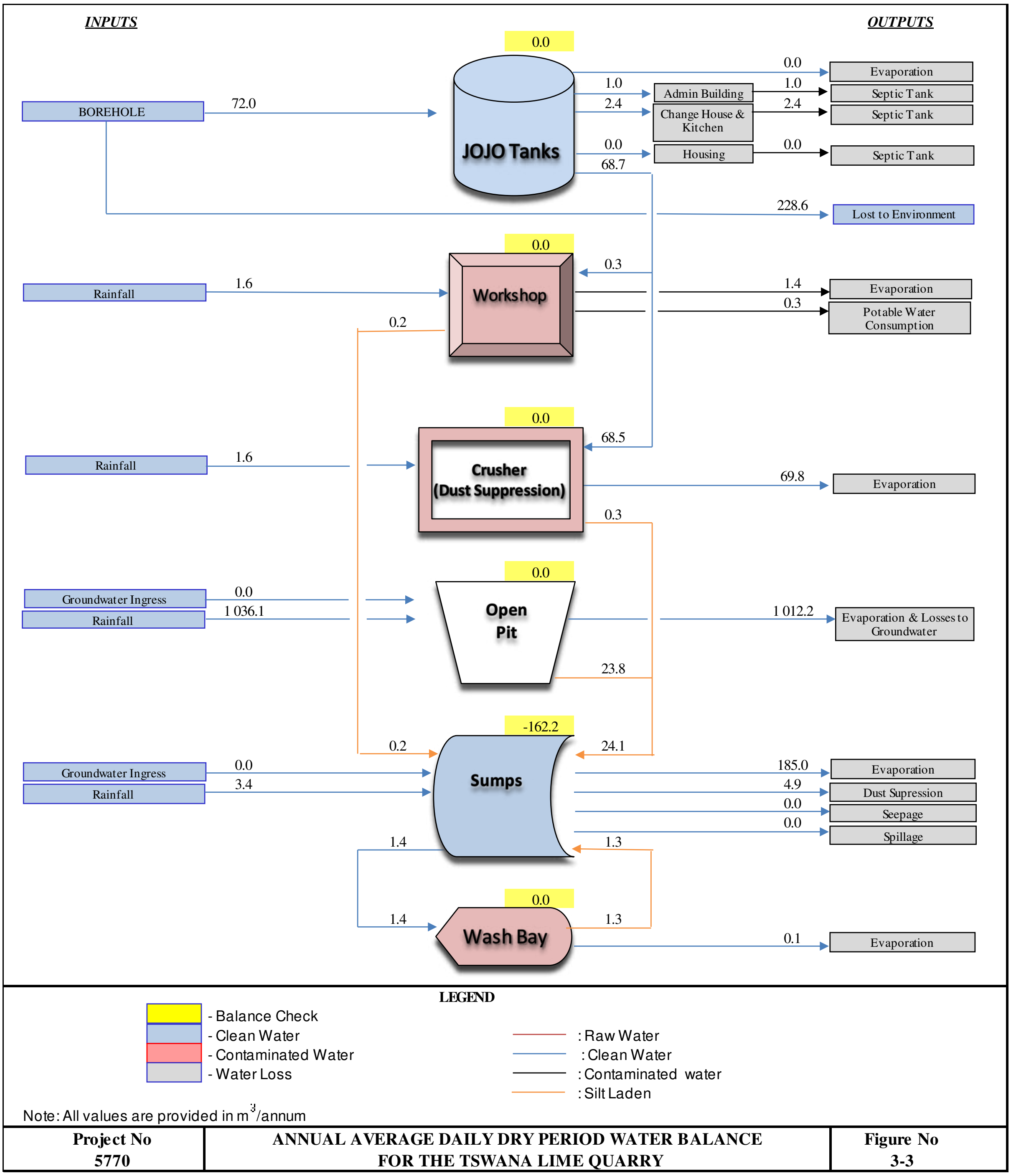


*Figure 3-3 Tswana Lime Quarry Average Daily Dry Period (July) Water Balance*

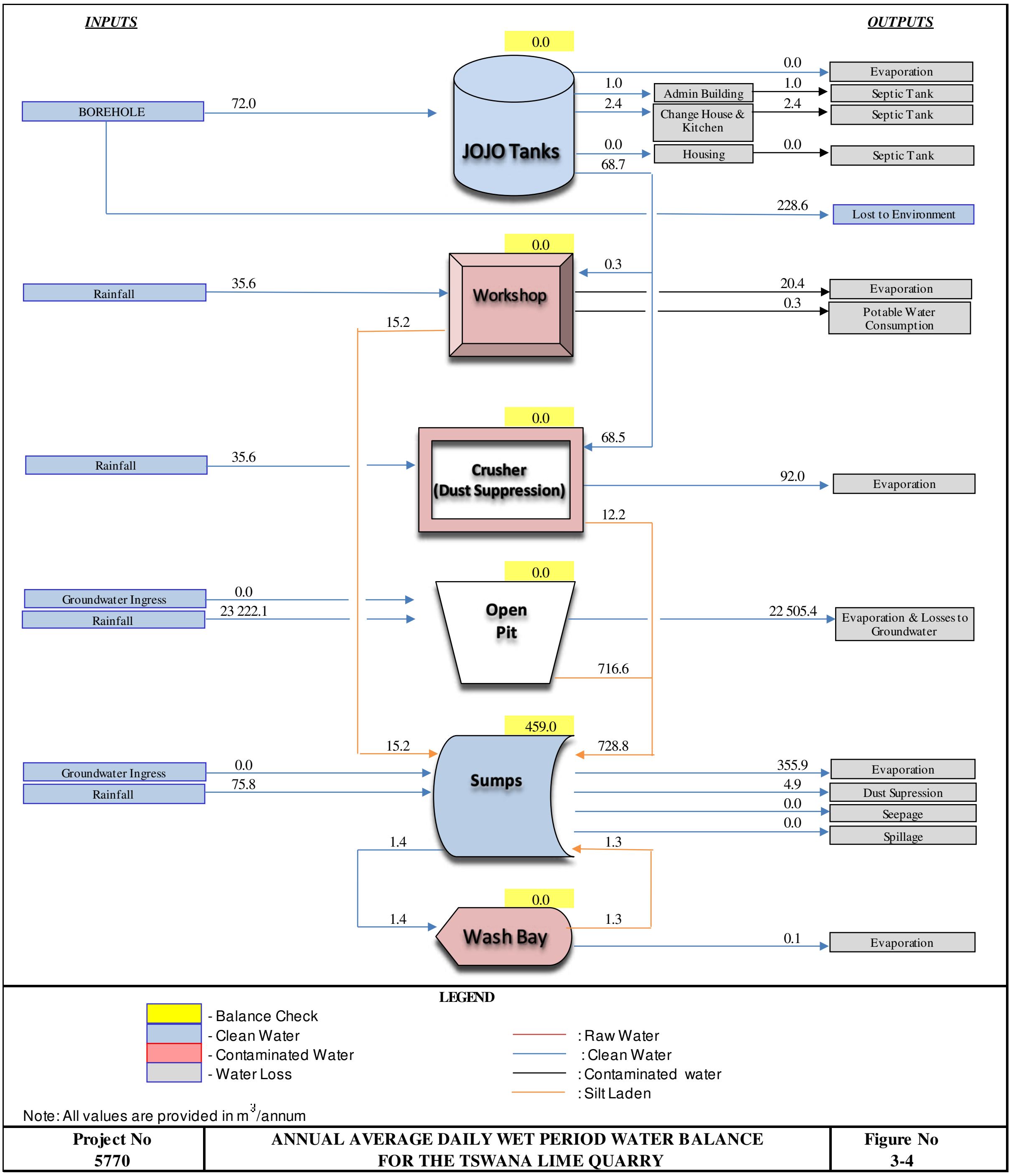


*Figure 3-4 Tswana Lime Quarry Average Daily Wet Period (January) Water Balance*

**Step 6: Assess the level of detail required**

The level of detail provided in the water balance is average annual and average daily flow values in cubic meters, which in turn are scaled based on average monthly water use values. The water balance has been simulated over the period of 50 years (1950 to 2000). This is done so that the variability of climate, which affects the water balance results, is accounted for. This level of detail is sufficient for this study (for the purposes of a WULA). In addition to the water balances based on average annual water usages (**Figure 3-1**), average annual daily water balance figures, average dry season daily (July months) and average wet season daily (January months) water balance scenarios are presented in **Figure 3-2** to **3-4**, respectively.

**Step 7: Assumptions**

It was necessary to apply a series of assumptions in the compilation of the water balance and these have been presented in **Table 3-1**.

*Table 3-1 Assumptions Made for the Water Balance*

| Section | Variable | Value | Comment |
|---|---|---|---|
| **Climate** | MAP (mm) | 601 | Obtained from the rainfall station (0471490 W) for the years 1950-2000, as presented in **Section 2.3.1** |
| | MAE (mm) | 1 952 | Obtained from the WR2012 Study for quaternary catchment D41A. evaporation zone **8A**, as outlined in **Section 2.3.1** |
| **Administration Building** | Potable Water Usage ($m^3$/day) | 1.00 | Based on 40 staff using an average of 25 litres/person/day (Estimated) |
| **Change House and Kitchen** | Potable Water Usage ($m^3$/day) | 2.40 | Based on 30 staff using an average of 80 litres/person/day (Estimated) |
| **Housing** | Potable Water Usage ($m^3$/day) | 0.00 | It is our understanding that the housing is not currently being used |
| **Workshop** | Potable Water Usage ($m^3$/day) | 0.25 | Based on 10 staff using an average of 30 litres/person/day (Estimated based on information provided by Lafarge) |
| **Crushing Plant** | Dust Suppression ($m^3$/day) | 67.2 | Based on 8 sprayers, working for 14 hours a day and each sprayer applying 0.6 $m^3$ of water per hour |
| **Quarry Sump 1** | Area of Sump at Full Supply Capacity ($m^2$) | 252 137 | Based on aerial imagery of the sump |
| | Maximum Volume of the sump ($m^3$) | 504 274 | Estimated based on the assumption that the sump is an average of 2 m deep across the surface area |
| | Catchment Area ($km^2$) | 0.145 | Based on aerial imagery and contour information |
| | Runoff Factor from pervious surfaces | 0.05 | Estimated. |

| Section | Variable | Value | Comment |
|---|---|---|---|
| | Runoff Factor from outside of the open pit (i.e. the workshop and admin building areas) | 0.60 | Estimated |
| | Water used for haul road dust suppression ($m^3$/day) | 0.46 | Estimated based on a tanker with a capacity of 5000 litres applying two loads of water along the haul roads for 15 days of the month |
| **Quarry Sump 2** | Area of Sump at Full Supply Capacity ($m^2$) | 25 385 | Based on aerial imagery of the sump |
| | Maximum Volume of the sump ($m^3$) | 50 770 | Estimated based on the assumption that the sump is an average of 2 m deep across the surface area |
| | Catchment Area ($km^2$) Other than that from within the open pit | 0.053 | Based on aerial imagery and contour information |
| | Runoff Factor from external catchment area | 0.05 | Estimated. |
| | Runoff Factor from hardened surfaces (i.e. the crushing plant area) | 0.60 | Estimated |
| **Quarry Sump 3** | Area of Sump at Full Supply Capacity ($m^2$) | 16 609 | Based on aerial imagery of the sump |
| | Maximum Volume of the sump ($m^3$) | 33 218 | Estimated based on the assumption that the sump is an average of 2 m deep across the surface area |
| | Catchment Area ($km^2$) Other than that from within the open pit | 0.08 | Based on aerial imagery and contour information |
| | Runoff Factor from external catchment area | 0.05 | Estimated. |
| | Runoff Factor from hardened surfaces (i.e. the crushing plant area) | 0.60 | Estimated |
| **Quarry Sump 4** | Area of Sump at Full Supply Capacity ($m^2$) | 204 854 | Based on aerial imagery of the sump |
| | Maximum Volume of the sump ($m^3$) | 409 708 | Estimated based on the assumption that the sump is an average of 2 m deep across the surface area |
| | Catchment Area ($km^2$) Other than that from within the open pit | 0.254 | Based on aerial imagery and contour information |
| | Runoff Factor from external catchment area | 0.05 | Estimated. |
| | Runoff Factor from hardened surfaces (i.e. the crushing plant area) | 0.60 | Estimated |
| **Open Pit** | Area of pit ($km^2$) | 6.13 | Estimated based on aerial imagery and contour information (this does not include the area of the sumps located within the open pit) |
| | Runoff factor from within the open pit | 0.02 | This runoff factor is low due to the numerous cavities located within the pit that would result in limited runoff reaching the two Quarry Sumps. |

# 4 WATER BALANCE RESULTS AND CONCLUSIONS

The water balance for the Tswana Lime Quarry was based on a number of assumptions (based on experience with similar projects), information supplied by management of the quarry and notes taken during a site visit in January 2022. The accuracy of the resulting water balance is therefore related to the accuracy of the assumptions/estimations made in the compilation of the water balance. The water balance compiled as part of this project provides average daily water movement in cubic meters for annual average, dry period average (based on the months of July) and wet period (based on the months of February). The water balance results are summarised as follows:

- Drinking water has been excluded from the water balance study as this is brought onto site from an external source and is used strictly for drinking purposes.
- Domestic water (used for the ablutions, cleaning purposes etc.) has been allowed for in the water balance. The total domestic water use is estimated at 3.65 $m^3$/day (or 1332 $m^3$/year). This water sourced from an onsite borehole, from which water is pumped to two Jojo Tanks and then distributed to the various areas of use.
- In addition to the domestic water use from the Jojo Tanks, water used for dust suppression is by far the biggest water user at the quarry. The water used for dust suppression purposes at the crushing plant equates to 67.2 $m^3$/day (or approximately 25 000 $m^3$/year).
- Flow meter records of water pumped from the borehole indicated significantly more water being pumped than what is estimated to be used at the quarry. Upon investigation of this, it was noted that community members often puncture the water supply pipeline so that they are able to provide drinking water to their livestock. This loss of water is estimated to be approximately 230 $m^3$/day (84 000 $m^3$/year), and has been captured in the water balance accordingly.
- Two main sumps were identified within the open pit. These were called Quarry Sump 1 and Quarry Sump 2. Quarry Sump 1, located to the northeast of the workshop area, is used for washing of vehicles (on the bank of sump) and for dust suppression along the haul roads (estimated to be 4.6 $m^3$/day or 1682 $m^3$/month). For the purposes of the water balance study, due to the fact that all of the sumps are located within the open pit and are connected, the quarry sumps were treated as a single entity.

Based on the water balance study, the following recommendations are provided:

- Flow meters should be installed on the pipeline used to supply water for dust suppression at the crushing plant. This will allow for more confidence to be gained in the water balance and the results associated with the water balance.
- Confirmation on the volume of water lost between the borehole and the Jojo Tanks should be investigated further. Based on the water balance results, the volume of water lost to the environment along this pipeline is significant. Interventions to try to reduce the volume of water lost would then also need to be investigated, so that these losses can be mitigated against.

## 5 REFERENCES


Department of Water Affairs and Forestry. 2006. Best Practice Guideline G2 Water and Salts Balances.

K¨oppen, W., and Geiger. G., (2018). Das geographisca System der Klimate, in: Handbuchder Klimatologie, edited by: K¨oppen, W. and Geiger, G., 1. C.Gebr, Borntraeger, 1–44, 1936

Middleton, B.J. and Bailey, A.K. (2012) Water Resources of South Africa, 2012 Study. Water Research Commission, Pretoria, Report TT382/08.

National Water Act 36 of 1998. To provide for fundamental reform of the law relating to water resources; to repeal certain laws; and to provide form matters connected therewith.

Smithers, J.C. and Schulze, R.E. 2003. Design Rainfall and Flood Estimation in South Africa. Water Research Commission, Pretoria, RSA, WRC Report 1060/1/03. pp 156 plus CD-Rom