WATER
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# Mashala Resources
# De Wittekrans Hydrological Study

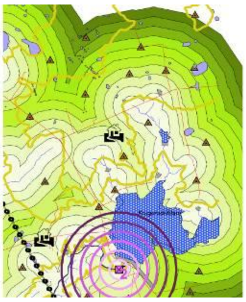
## Report

### Version - 2

### August 2010

### Client Name: Mashala Resources
### Project Number: 08-111

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#### 1.1.1.1 *DOCUMENT ISSUE STATUS*

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# 1. INTRODUCTION

GCS (Pty) Ltd was assigned to carry out a hydrological study on the surface water aspects for the Mashala Resources Project for the proposed mine.

The coal mine area is situated on portions of the following farms De Wittekrans 218IS, Tweefontein 203IS, Groblershoop 192IS and Israel 207IS, north of Ermelo in the Mpumulanga Province. The project lies next to the N11 and falls within the Olifants River basin near the Southern catchment boundary of the Klein Olifants River (tributary of the Olifants River).

The spatial information was derived using a GIS (Geographical Information System) database, Arcview 3.1 in conjunction with Google Earth. The maps used to gain knowledge of the area were 2629BA, BB, BC and BD.

The initial and basic Hydrological study report (V1) was done in July 2009. The report was included in the EIA/EMP which was submitted to the authorities and I&AP's (Interested and Affected Parties), subsequently to be reviewed by various parties. A sequence of discussion meetings was held and feedback documentation supplied.

This document acts as a follow-up Hydrological assessment for the proposed De Wittekrans Coal Mine.

The following list of the main queries is the DMR and I&AP comments on the initial Hydrological study report (V1).

## 1.2 DMR comments regarding Groundwater

a) Point 5: Provide a surface and runoff management plan

b) Point 6: Describe the impacts associated with decant into the Klein Olifants River and provide possible mitigation measures and the cost thereof.

### 1.3 Comments received from I&AP's regarding Groundwater

a) Point 28: I&AP has determined that the calculation of the rainwater and the ingress into the opencast is incorrect and must be calculated. Please verify if this is correct.

b) Point 31: The treatment of all water must be quantified and methods of treatment must be clear. An approach of zero decant = zero impact must be possible.

c) Point 47: What will the impact be on the Klein Olifants system from the mining activities?

d) Point 90: No baseline information is available on the surface water quality and the reports lacks information on the macro-variables and metal concentration that are used to assess water quality by comparing the values to the Water Quality Guidelines for the natural environment published by DWAF in 1996.

e) Point 91: No attention was given to the impact that the proposed mining activity will have on the surface water down-stream of the project.

f) Point 101: One of the major long term impacts of the opencast mining is the effect decant will have on the Klein Olifants River and on the Olifants River system as a whole. The effects on the river system as a whole and especially the cumulative effect of the opencast mine together with existing mining in the catchment area of the greater Olifants River system is not addressed in any depth. Mashala clearly indicates that "…with regard to the opencast pits, it will not be practical or cost effective to backfill these areas" (EIA p316), this while in their study on the decant the hydrological assessment report goes out of the assumption that "At decommissioning, the pits must be backfilled and re-vegetated as quickly as possible to ensure that the rate of recharge to the pits is minimized as soon as possible (p76, Hydrological Assessment Report). Considering Mashala's position, it can therefore be expected that the recharge will be considerably higher than anticipated by the hydrological report and that decant of highly contaminated water will occur. The decant points identified indicate that the opencast pits will decant in the Klein Olifants River and its tributaries. There is ample evidence that abandoned opencast mines (and quite a number of abandoned underground mines) eventually decant unless very specific management measures are taken. Large volumes of highly contaminated water can therefore be expected to decant in the Klein Olifants River after closure.

## 1.4 Scope and Objectives

This objective of this report is to updated and revised the original initial Hydrological study report (V1) and address the changes of the mine plan and comments received from DMR and I&AP's.

The surface water aspects of the mining colliery will be discussed and the focus will be on the impacts that the surface water has on the environment. The following existing surface infrastructure has relevance:

- 4 bore cut portals to access the underground sections
- Open cast working
- Coal processing plant
- Co-disposal facility
- Run-of-mine coal stockpiles
- Coal discard dumps
- Topsoil stockpiles
- Lined pollution control dams
- Access and haul road
- Storm water and water management systems
- Dewatering infrastructure
- Conveyors and roads
- Substation and power lines
- Storage facilities for fuel, water and explosives
- Portable water pipelines
- Sewer treatment facility
- Ventilation shafts
- Plant offices, change rooms, store rooms, workshop and other necessary infrastructure

## 1.5 Definitions

In this report any expression to which a meaning has been assigned, shall have the meaning so assigned, unless the context indicates otherwise-

**"activity",** means the mining operation and the use of loading and off-loading zones, transport facilities and storage yards;

**“coal”,** A solid, brittle, more or less distinctly stratified combustible carbonaceous rock, formed by partial to complete decomposition of vegetation; varies in colour from dark brown to black; not fusible without decomposition and very insoluble;

**"clean water system",** includes any dam, other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of un-contaminated 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;

"**dirty catchment**", means any area at a mine or activity which causes, has caused or is likely to cause contamination of a water resource;

"**dirty water system**", includes any dam, other form of impoundment, canal, works, pipeline, residue deposit and any other structure or facility constructed for the retention or conveyance of water containing waste;

"**facility**", in relation to an activity, includes any installation and appurtenant works for the storage, stockpiling, disposal, handling or processing of any substance;

"**residue**", includes any debris, discard, tailings, slimes, screenings, slurry, waste rock, foundry sand, beneficiation plant waste, ash and any other waste product derived from or incidental to the operation of a mine or activity and which is stockpiled, stored or accumulated for potential re-use or recycling or which is disposed of;

"**residue deposit**", includes any dump, tailings dam, slimes dam, ash dump, waste rock dump, in-pit deposit and any other heap, pile or accumulation of residue;

"**stockpile**", includes any heap, pile, slurry pond and accumulation of any substance where such substance is stored as a product or stored for use at any mine or activity;

"**water system**", includes any dam, any other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of water;

## 1.6 Legal Aspects

The principal Act considered in respect of water related issues, which is administrated by the Department of Water Affairs and Forestry (DWAF), is the National Water Act, 1998 (NWA) (Act 36 of 1998). The NWA emphasises effective management of South Africa water resources through the basic principles of the Integrated Water Resource Management. (IWRM). Attention is drawn to the strict provisions in the Water Act to control pollution of water. Pollution in terms of water refers to the alteration of the physical, chemical or biological properties of water so as to render it less fit for other uses. Capacity requirements of clean and dirty water systems must be designed in accordance with the Government Gazette, Notice 704. The requirements are summarised below as follows:

Every person in control of a mine or activity must-

- Confine any unpolluted water to a clean water system, away from any dirty area;

- collect the water arising within any dirty area, including water seeping from mining operations, outcrops or any other activity, into a dirty water system;

- design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years;

- design, construct, maintain and operate any dam or tailings dam that forms part of a dirty water system to have a minimum freeboard of 0.8 metres above full supply level, unless otherwise specified in terms of Chapter 12 of the National Water Act;

- design, construct and maintain all water systems in such a manner as to guarantee the serviceability of such conveyances for flows up to and including those arising as a result of the maximum flood with an average period of recurrence of once in 50 years

## 1.7 Site Location

The area and activities under investigation is located on the Farms Groblershoek, Wittekrans, Groblershoop and Tweefontein. This sites falls under the magisterial district of Ermelo in the Mpumalanga Province. The activities and catchment areas as are indicated on Figure 2 and the covered area is approximately 136ha. Refer to Figure 2 and in Appendix A.

## 1.8 Responsible Water Authority

The Department of Water Affairs and Forestry (Mpumalanga Region) performs water quality management and is also responsible for authorising water use from the river system and would therefore have to authorize permission for this project.

## 1.9 Catchment Analysis

### *1.9.1 <u>Regional Climate</u>*

The De Wittekrans site is at approximately 1 700m above sea level. It is located in the Highveld region of South Africa which is a warm, mild summer rainfall region. It is characterised by warm wet summers and cool dry winters. During the warm summer months of December and January the average maximum temperature is above 25˚C, while the minimum temperatures in winter have been recorded to drop below 0˚C.

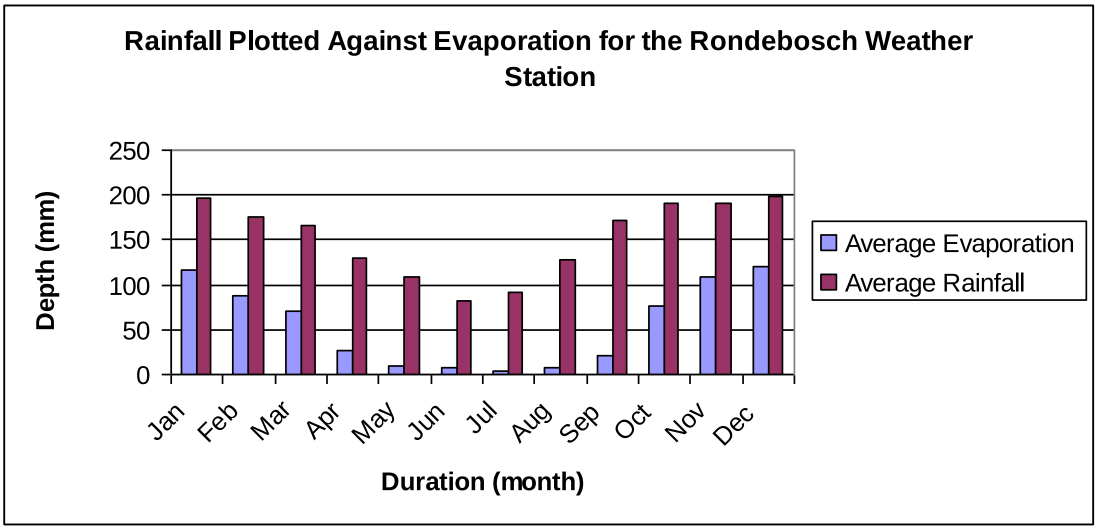
### *1.9.2 Mean Annual Precipitation (MAP)/Mean Annual Evaporation (MAE)*

In order to obtain a record containing monthly averages for rainfall and evaporation the Department of Water Affairs and Forestry was consulted. The closest reliable rainfall station to the project area with such a record is the Rondebosch Station at Middelburg Dam. It has rainfall records and evaporation data from June 1979 to June 2008. From this data the average monthly values and the average annual values were calculated. The MAP is 652.2mm while the MAE is 1814mm. Data from the Rondebosch station (refer to table 1) was used for water balance calculations and data from the Tevreden Station 479348 (refer to table 2) was used for flood calculations. The Tevreden Station is at a very similar altitude, approximately 30m difference and is 8.8km away. The MAP at this station is 693mm.

**Table 1: MAP/MAE (mm)**

| Month | Average Rainfall | Average Evaporation |
|---|---|---|
| January | 117 | 197.2 |
| February | 87.2 | 175.2 |
| March | 71.4 | 165.1 |
| April | 26.7 | 130.3 |
| May | 10 | 107.9 |
| June | 8 | 82.9 |
| July | 3.4 | 84.8 |
| August | 8.5 | 92.5 |
| September | 21.3 | 171.8 |
| October | 77.1 | 191.7 |
| November | 109.4 | 190.8 |
| December | 121 | 197.9 |
| Mean Annual | **652.2** | **1814** |

**Figure 1: MAP/MAE**




### *1.9.3 Design Rainfall*

The Design Rainfall is used for various return periods for design calculation purposes. Rainfall is the primary input needed in order to generate flow sequences. The design rainfall used was taken from the SAWB (South African Weather Bureau) station 0479348 – Tevreden. The MAP used for the calculations in the Rational Method (Table 3) was taken from this weather station as this is closer to the site than the Rondebosch Station, in paragraph 1.5.2, and would therefore give a more accurate result for the calculation purposes.

**Table 2: Design Rainfall Depths**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Station Name** | Tevreden | | | | | |
| **NUMBER** | 479348 | | | | | |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** |
| **Design Rainfall (mm)** | 51 | 68 | 80 | 92 | 108 | 121 |

### *1.9.4 Quaternary Catchments and Sub Basins*

The study area falls within the B12A DWAF quaternary catchment as indicated in Appendix A (Figure 2).

Locally the Klein Olifants, originating at the continental watershed (separating the Indian and Atlantic Ocean Catchments), draining the surface rights area of the colliery in a northern direction. The Klein Olifants is classified as a tributary of the Olifants river.

The Olifants River flows northwards through Witbank Dam (New Doringpoort Dam) and the Loskop Dam and is then forced east by the Transvaal Drakensberg, cutting through this mountain range at the Abel Erasmus Pass. It then flows east to join the Letaba River, before crossing into Mozambique and becoming the Rio dos Elefantes. It then joins the Limpopo River and the Rio Changane before the Limpopo River enters the Indian Ocean at Xai-Xai north of Maputo.

The Olifants River and some of its tributaries, notably the Klein Olifants River (originating near Hendrina, joining the Olifants River downstream of the Middelburg Dam), the Elands River, Wilge River and Bronkhorstspruit, rise along the continental watershed in the Highveld grasslands. Thirty-one large dams in the Olifants River catchment include the Witbank Dam (New Doringpoort Dam), Renosterkop Dam, Rust de Winter Dam, Blyderivierspoort Dam, Loskop Dam, Middelburg Dam, Ohrigstad Dam, Arabie Dam and the Phalaborwa Barrage in South Africa and the Massingir Dam in Mozambique.

The following statistics are applicable to the Olifants River Catchment Basin:

#### 1.9.4.1 Surface Area

54 475 km²

#### 1.9.4.2 Location:

The Olifants River passes through three provinces of South Africa (Gauteng, Mpumalanga, Limpopo Province), through the Kruger National Park, into Mozambique, where it flows into the Limpopo River. It is therefore a tributary of the Limpopo River with the confluence of the two rivers in Mozambique immediately after the Olifants River has passed through the Massingir Dam.

1.9.4.3 Average annual precipitation:

631 mm (average over the entire Olifants River Basin in South Africa only)

1.9.4.4 Supply:

Mean Annual Runoff 1 992 x $10^6$ m³

1.9.4.5 Demand:

976 million m³ in 2000 (including hydropower). Estimated demand for 2010: 1 210 million m³. The river has been known to have zero flow during short periods where it enters Kruger National Park.

1.9.4.6 Aquifer:

Groundwater is an important source of water for many small towns, villages and small- and large-scale farmers. Most of the groundwater in the Olifants River Basin exists in relatively shallow weathered or fractured aquifers. Usually both exist at different elevations, the fractured aquifers locating below the weathered aquifers. In most cases, the Olifants River plays an important role in the recharge of these aquifers, while interaction between the ground- and surface water (in both directions) is fairly commonplace in this basin.

1.9.4.7 Topography:

Altitudes on the South Africa side range between 2 300 and 300 m at the Mozambique border.

1.9.4.8 Population:

Currently (2010) about 3.5 million, some living in urban areas with modern domestic water supply and sanitation systems, but most living in rural areas or towns with rudimentary or no formal domestic water supply system and no sanitation system.

1.9.4.9 Land uses:

- Agriculture, of which commercial and small-scale irrigation is about 100 000 ha. Main crops are maize, cotton, vegetables, citrus, wheat and tobacco.
- Forestry area: 71 500 ha
- The Kruger National Park is the largest game reserve in South Africa, with about 20 000 ha (mostly in the Olifants River basin)

1.9.4.10 Infrastructure:

There are over 2 500 dams, of which 30 are classified as major dams (>2 million $m^3$).

1.9.4.11 Water users in the Olifants River Basin:

- Urban: largely from the river
- Mining and industry: largely from the river, including small amounts imported from another basin. More than half of South Africa's electricity is generated in the Upper Olifants River Basin.
- Agriculture: largely from the river. There is a strong distinction between "commercial" farmers, who have relatively larger farms, sophisticated technologies, often grow high-value crops (e.g., citrus, maize), most of which are for export, and "small-scale" farmers, most of whom are undercapitalized, with poor support services, lack skills and good market access, and are struggling.
- Recreation: boating and fishing on river and in reservoirs.

- Environment: especially the Kruger National Park but also the many dams in the watercourse.

1.9.4.12 Existing and forecasted uses and concerns:

- At present water demand exceeds supply. Current projections show that water resources will be fully utilized by 2010. Consideration of reallocation among uses may therefore be necessary.
- Water quality management will be an increasingly important issue in the future, largely because of existing mines, and pollution from closed mines.
- Provision for the environmental demands through the implementation of a 'Reserve' to maintain the ecological integrity of the resource, is expected to have a significant (negative) effect on water availability for commercial uses.
- Possible expansion of small-scale irrigation to meet equity objectives may affect water availability for other sectors. Demand management will be essential.
- Overgrazing of the upper, middle and lower middle regions is already causing high silt loads, aggravated by the highly erodible soil types found here.
- Satisfying the legitimate demands of the downstream country (Mozambique) both for water supply, and in terms of occasional flood control and also salinity control near the Indian Ocean is likely to become a serious problem in the future.

1.9.4.13 Water policy and management issues:

- Meeting human needs and environmental requirements as called for in the 1998 National Water Act
- Demand management by commercial users
- Maintaining water quality
- Satisfying downstream requirements without threatening upstream uses which generate considerable economic wealth

1.9.4.14 Institutional structure:

Currently, the National Department of Water Affairs is responsible for water resources management, including management of major infrastructure. Water Users Associations will take increasing responsibility for localized management of irrigation infrastructure and control structures, while water boards and local governments are responsible for the provision of domestic water services and the purification and discharge (back into the river) of sewage effluent.

### *1.9.5 Sub Catchment Water Systems*

The mine study area is approximately 3336 ha in size and the effective catchment area is approximately 9770 ha in size. The effective catchment area was divided into 4 sub basins according to the drainage lines as indicated in **Appendix A (Figure 3).**

- Sub-basin A –Upper Klein Olifants is approximately 4 372 ha in size. Portion 5 of the farm De Wittekrans 218 and portion 3 of the farm Israel 207 overlaps into this sub basin. The Klein Olifants River originates in this sub basin and flows in the northerly direction towards Hendrina. The longest watercourse (Klein Olifants River) in this sub basin is approximately 13,14 km.
- Sub-basin B –Tributary A is approximately 1 723 ha in size. An unnamed perennial stream flows in the northerly direction towards the farm Israel 207 and confluence with the Klein Olifants River. The length of the longest watercourse in this sub basin is 7,76 km.
- Sub-basin C –Tributary B is approximately 1 729 ha in size. An unnamed perennial stream flows in the northerly direction and confluence with the Klein Olifantspruit. This stream flows through the farm Groblershoek 191. The length of the longest watercourse in this sub basin is 7,1 km.
- Sub-basin D – Lower Olifants is approximately 10 797 ha in size. Two unnamed non-perennial stream flows on the southern side of the Klein Olifants River and one unnamed perennial stream on the northern side. This catchment is the downstream drainage point of the total mine development. The length of the longest stream is approximately 19,5 km.

### *1.9.6 River Crossings*

The Proposed Plants are separated by a Tributary for the Klein-Olifants River. This would suggest that that a river crossing may be needed either for a low level road crossing or a conveyor, depending on which plant site is chosen. However in order for this to happen foundations would need to be laid; which could disturb the soil structure and possibly cause some sediment to be lost into the river system. Therefore management measures would have to be put in place to restrict soil losses from the banks.

The implementation of this design would require a water use license because it is affected by legislation, through Section 21 of the National Water Act of 1998. where a water use is defined broadly, and includes taking and storing water, activities which reduce stream flow, waste discharges and disposals, controlled activities (activities which impact detrimentally on a water resource), altering a watercourse, removing water found underground for certain purposes, and recreation. In general a water use must be licensed unless it is listed in Schedule 1, is an existing lawful use, is permissible under a general authorisation, or if a responsible authority waives the need for a license.

More specifically the following sections apply to this particular project, which state what a water use is:

- Section 21.C: Impeding or diverting the flow of water in a watercourse.
- Section 21.I: Altering beds, banks, course or characteristics of a watercourse.

If a low level crossing is needed it will impede and divert flow during high flows. As the water rises the construction will impede and could slightly divert flow. This will alter the flow and cause turbulence. It will cause the velocity to speed up and the river banks will therefore be affected in this area. This will also therefore alter the characteristics of the river.

In order for this construction to take place, with the possible affects concerned certain stormwater management plans must be put in place:

- High flows and river flows shall be diverted around the construction as to alleviate sediment yield and erosion during the construction phase.

- Where necessary works must be constructed to attenuate the velocity of flow and protect the river banks that could potentially be damaged.
- Stormwater control works must be constructed, operated and maintained in a suitable manner.
- Increased runoff due to the construction of the conveyor, removal of vegetation or soil compaction must be managed and steps must be taken to insure that stormwater does not lead to bank instability and excessive levels of silt entering the stream.

### *1.9.7 <u>Drainage density</u>*

Drainage density is defined as the length of drainage per unit area. The term was first introduced by Horton , and is determined by dividing the total length of streams within a drainage basin by the drainage area. A high drainage density reflects a highly dissected drainage basin, with a relatively rapid hydrologic response to rainfall events, while a low drainage density means a poorly drained basin with a slow hydrologic response.

Drainage density for the tributary of the Klein Olifants is 0.439(km/km2)

## 1.10 Overview of Hydrological Principles

### *1.10.1 <u>Resource Protection</u>*

Water can be adversely affected by the construction of a plant as the area becomes contaminated by the processes that the plant undergoes. The water will be affected mainly by overland flow and therefore all water falling on the 'dirty' catchment should be managed correctly. Failure to manage impacts in an acceptable manner throughout the operation phase and post closure will result in the site operators finding it increasingly difficult to obtain community and government support for existing and future projects.

The overall Resource Protection and Waste Management policy sets out the interpretation of policy and legal principles as well as functional and organizational arrangements for resource protection in South Africa.

### *1.10.2 Storm Water Management Principles*

The management of storm water is important as it limits the affects of the plant on the environment, therefore contributing to a sustainable solution. Clean stormwater will be diverted around the dirty water catchment in a controlled manner to tie in with existing surface drainage features and flow into the tributary for the Klein-Olifants.

The principles on which the storm water management plan are based, and which are implemented in the conceptual design can be summarised as follows:

- The containment of contaminated water;
- A pollution control dam was designed and located in such a way that polluted water from site is contained.
- The monitoring of quality of water in the nearby rivers; 4 monitoring points are recommended. (Please see chapter 5 Water Quality Management for further details)
- The re-use of contained dirty water; the amount available is outlined in Chapter 4, Water Balance.
- No discharge of contaminated surface water to the environment is anticipated from this activity;

### *1.10.3 Pollution Prevention Principles*

Pollution prevention and minimisation have to be addressed first. Where complete pollution prevention is not possible, management measures have to be implemented to minimise water quality deterioration and impacts as far as possible. After pollution prevention and minimisation, water re-use and reclamation becomes the next level requiring decisions and/or actions. The main objective with water and waste management is thus the protection of the environment, specifically water resources and public health.

The most effective management tool against the pollution of water resources remains good housekeeping and ongoing maintenance. To this end, inspections and maintenance must be carried out on a regular basis.

In South Africa, Government Notice No. 704, Regulation 6 requires that the minimum freeboard for a residue disposal facility and return water dam should be at least 0.8m above full supply level. It also states that a dirty water system must be designed and operated in such a manner that it is at all times capable of handling a 1:50 year flood event on top of its normal operating level without spilling.

## 1.11 Hydrological Analysis

### *1.11.1 Flood Calculation Methods*

There are different hydrological calculation methods that can be used to calculate flows and drainage in South Africa, the most common being:

- Statistical method
- Rational method
- Alternative Rational method
- Unit Hydrograph method
- Standard Design Flood (SDF) method
- Empirical method

The methods have been developed by different institutions and therefore have different strengths and weaknesses. The different methods require different input in order to calculate the same output. The methods are described below:

- **The Statistical method**, this uses historical data to determine the flood for a given return period. This method can therefore only be used accurately where there is a good flood record available or for a nearby catchment to have a good record and similar characteristics. Where accurate records are given for a long period of time this method can be a very good option. The method can be especially good for longer return periods.
- **The Rational method**, this is based on a simplified version of the law of 'the conservation of mass'. Rainfall intensity is an important input in this

calculation. This is because uniform aerial and time distributions are assumed. The method is recommended for catchments with an area of less than $15km^2$ and only flood peaks and empirical hydrographs can be calculated. Experience is important when calculating the runoff coefficient. But modern modifications are making it less of a factor.

- **The Alternative Rational method** is an adaptation of the Rational Method. Instead of using the depth-duration-return period diagram to determine point precipitation, the Alternative method uses the modified and recalibrated Hershfield equation, proposed by Alexander for storm durations up to 6 hours, and the Department of Water Affairs' technical report TR102 for a time period of 1 to 7 days.
- **The Unit Hydrograph** method is suitable for design hydrographs and flood peaks of medium sized rural catchments ($15 – 5000km^2$). This method is based mainly on the analysis of regional historical data and is independent on personal judgment. The results are reliable although due to the averaging form of a hydrograph some natural variability can be lost; this is more evident in catchments smaller than $100km^2$.
- **The Standard Design Flood (SDF) method**, this was produced by Alexander to provide a uniform approach to flood calculations. It is based on a calibrated discharge coefficient for a recurrence interval of 2 to 100 years. Calibrated discharge parameters are based on historical data, they were determined for 29 homogenous basins across South Africa.
- **Empirical methods**, this requires a combination of personal judgment, historical data and /or the results of other methods. Empirical methods are suited for checking the magnitude of the results from other methods.

### *1.11.2 Design Flood Volume Catchment (FLoodlines)*

- The SDF method was used to calculate the flood on large catchments. The Standard Design Flood (SDF) method was developed to provide a uniform approach to flood calculations. The method is based on a calibrated discharge coefficient for a recurrence period of 2 and 100 years. Calibrated discharge parameters are based on historical data and were determined for 29 homogeneous basins in South Africa.

The hydrological information used for the calculations can be summarized as follows:

| | |
|---|---|
| Quaternary catchment | : B12A |
| Slope | : 1% |
| Effective length of river | : 33 km |

Refer to tables 3, 4 and 5 for further details.

- The Rational method was used as in accordance with the Drainage Manual 5th Edition (fully revised) compiled the South African Roads Agency Limited. This method was used for the small catchments.

The run-off that is generated within a catchment through precipitation will depend on the:

- Characteristics of the storm event
- The response characteristics of the catchment; and
- The influence of temporal storage on the run-off.

The temporal distribution of the run-off is reflected in a hydrograph. The flood peak (QP) is reached as soon as the entire catchment contributes to the flood, which is also referred to as the time of concentration (TC).

$$T_C = \left( \frac{0{,}87L^2}{1\,000\,S_{av}} \right)^{0{,}385}$$

where:

TC = time of concentration (hours)

L = hydraulic length of catchment, measured along flow path from the catchment boundary to the point where the flood needs to be determined (km)

Sav = average slope (m/m)

The average slope was calculated using (change in height) / (Distance). The measurements were acquired using the GIS system Arcview 3.1.

### *1.11.3 Hydrological Calculations*

**Table 3: Sub basin A – Upper Klein Olifants**

| SDF Method: Results | | | | | | | |
|---|---|---|---|---|---|---|---|
| Return Period (years) | Time Concent. (hours) | Point Precip. (mm) | Point Precip. (mm) **TR102** | ARF (%) | Catchment Precip. (mm) | Runoff Coefficient. (%) | Peak Flow (m^3/s) |
| 2 | 7 | 34.76 | 103 | 100 | 35 | 10 | 6 |
| 5 | 7 | 58.63 | 165 | 100 | 59 | 24 | 25 |
| 10 | 7 | 76.70 | 215 | 100 | 77 | 32 | 43 |
| 20 | 7 | 94.76 | 271 | 100 | 95 | 38 | 63 |
| 50 | 7 | 118.63 | 356 | 100 | 119 | 45 | 93 |
| 100 | 7 | 136.70 | 432 | 100 | 137 | 50 | 119 |
| 200 | 7 | 154.76 | 517 | 100 | 155 | 54 | 145 |
| 10000 | RMF | | | | | | 740 |

**Table 4: Sub basin B – Tributary A Klein Olifants**

| SDF Method: Results | | | | | | | |
|---|---|---|---|---|---|---|---|
| Return Period (years) | Time Concent. (hours) | Point Precip. (mm) | Point Precip. (mm) **TR102** | ARF (%) | Catchment Precip. (mm) | Runoff Coefficient. (%) | Peak Flow (m^3/s) |
| 2 | 4 | 31.30 | 103 | 103 | 32 | 10 | 4 |
| 5 | 4 | 52.81 | 165 | 103 | 54 | 24 | 16 |
| 10 | 4 | 69.08 | 215 | 103 | 71 | 32 | 27 |
| 20 | 4 | 85.34 | 271 | 103 | 88 | 38 | 40 |
| 50 | 4 | 106.85 | 356 | 103 | 110 | 45 | 59 |
| 100 | 4 | 123.12 | 432 | 103 | 127 | 50 | 76 |
| 200 | 4 | 139.38 | 517 | 103 | 144 | 54 | 93 |
| 10000 | RMF | | | | | | 738 |

**Table 5: Sub basin C– Tributary B Klein Olifants**

| SDF Method: Results | | | | | | | |
|---|---|---|---|---|---|---|---|
| Return Period (years) | Time Concent. (hours) | Point Precip. (mm) | Point Precip. (mm) **TR102** | ARF (%) | Catchment Precip. (mm) | Runoff Coefficient. (%) | Peak Flow (m^3/s) |
| 2 | 4 | 31.30 | 103 | 103 | 32 | 10 | 4 |
| 5 | 4 | 52.81 | 165 | 103 | 54 | 24 | 15 |
| 10 | 4 | 69.08 | 215 | 103 | 71 | 32 | 27 |
| 20 | 4 | 85.34 | 271 | 103 | 88 | 38 | 40 |
| 50 | 4 | 106.85 | 356 | 103 | 110 | 45 | 59 |
| 100 | 4 | 123.12 | 432 | 103 | 127 | 50 | 76 |
| 200 | 4 | 139.38 | 517 | 103 | 144 | 54 | 93 |
| 10000 | RMF | | | | | | 738 |

**Table 6: Sub basin D – Lower Klein Olifants**

| SDF Method: Results | | | | | | | |
|---|---|---|---|---|---|---|---|
| Return Period (years) | Time Concent. (hours) | Point Precip. (mm) | Point Precip. (mm) **TR102** | ARF (%) | Catchment Precip. (mm) | Runoff Coefficient. (%) | Peak Flow (m^3/s) |
| 2 | 11 | 37.54 | 103 | 98 | 37 | 10 | 10 |
| 5 | 11 | 63.34 | 165 | 98 | 62 | 24 | 41 |
| 10 | 11 | 82.85 | 215 | 98 | 81 | 32 | 71 |
| 20 | 11 | 102.36 | 271 | 98 | 100 | 38 | 104 |
| 50 | 11 | 128.15 | 356 | 98 | 126 | 45 | 155 |
| 100 | 11 | 147.67 | 432 | 98 | 145 | 50 | 198 |
| 200 | 11 | 167.18 | 517 | 98 | 164 | 54 | 241 |
| 10000 | RMF | | | | | | 1720 |

### *1.11.4 Peak Flow and Flood Volumes*

The following tables illustrate the parameters used to calculate the peak flow and flood volumes of a catchment or demarcated area for a given return period. The columns have been calculated whereas the other values have been obtained through research and measurement using AutoCAD, GIS Arcview 3.1 and South African Weather Bureau.

The Table below (Table 7) was used to calculate Peak Flows and flood volumes for the stream flowing between the two proposed sites. This is a tributary from the Klein-Olifants River. The data was used to determine the floodlines for the stream in order to keep the plant area out of the floodlines. Floodlines can be seen in Appendix B.

**Table 7: Summarised output**

| Sub basin | Length | Area | | Flood Volume ($m^3$) | |
|---|---|---|---|---|---|
| ID | km | ha | $km^2$ | 1:50 | 1:100 |
| A - Upper Klein Olifants | 13,14 | 4372 | 43,7 | 93 | 119 |
| B – Tributary A Klein Olifants | 7,76 | 1729 | 17,3 | 59 | 76 |
| C – Tributary B Klein Olifants | 7,1 | 1722 | 17,2 | 59 | 76 |
| D- Lower Klein Olifnts | 19,5 | 10797 | 107,9 | 155 | 198 |

# 2 FLOODLINES

The 1:50 and 1:100 year floodlines were delineated using the 1:100 and 1:50 year Peak Discharge respectively, as calculated in section 1.7.3. This was then used in the hecras model to produce the floodlines as seen in the Appendix 2.6. The purpose of delineating the 100 year floodline is to ensure compliance to legislative requirements. GN 704 states that No person in control of a mine or mining activity may locate or place any residue deposit, dam, reservoir, together with any associated structure or any other facility within the 1:100 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, borehole or well, excluding boreholes or wells drilled specifically to monitor the pollution of groundwater, or on water-logged ground, or on ground likely to become water-logged, undermined, unstable or cracked.

The floodlines can be observed as well as all the data and explanations on how floodlines are calculated in Appendix 9.2 Floodline Discussion. The study area falls out of the 1:100 year flood zone. In accordance with GN 704 the distance of 100m buffer was considered as this was further than the floodlines. This was shown to also be out of the proposed site area and therefore there is no restriction on the plant area, as it is falls out of the restricted area.

# 3 POLLUTION CONTROL DAMS

## 3.1 Design Flood Volumes

The mine operations will consist of a plant area, open cast mining and underground works.

The total plant infrastructure area is about 245 ha and is located on the watershed between Sub basin B and C. The mine had to allow for two pollution control dams. The calculation is based on the rational method. See Appendix B for the calculation Sheets.

Microsoft excel spreadsheets were also used to calculate flood volumes. For this project the Rational Method was selected as it seemed to give the best indication of flow when compared to spreadsheet calculations.

### *3.1.1 Runoff Coefficients - Plant*

**Table 8: Runoff Coefficient Factors**

| C=Cs+Cp+Cv | 0.55 | | | | |
|---|---|---|---|---|---|
| Rural | | | | | |
| Surface Slopes | | Permeability | | Vegetation | |
| Vlei's & pan's (<3%) | 0 | Very permeable | 0 | Dense Bush | 0 |
| Flat areas (3 to 10%) | 65 | Permeable | 60 | Cultivated land | 00 |
| Hilly areas (10 to 30%) | 30 | Semi-permeable | 40 | Grass land | 85 |
| Steep areas (>30%) | 0 | Impermeable | 0 | Bare surface | 5 |
| **Total %** | 100 | **Total %** | 100 | **Total %** | 100 |

| COMPONENT | CATERORY | MAP(mm) <600 | MAP(mm) 600-900 | MAP(mm) >900 |
|---|---|---|---|---|
| **SURFACE SLOPE IN %** | <3 | 0.01 | 0.03 | 0.03 |
| **Cs** | 3 TO 10 | 0.06 | 0.08 | 0.11 |
| | 10 TO 30 | 0.12 | 0.16 | 0.20 |
| | >30 | 0.22 | 0.26 | 0.30 |
| **PERMEABILITY OF** | Very permeable | 0.03 | 0.04 | 0.05 |
| **THE SOIL** | Permeable | 0.06 | 0.08 | 0.10 |
| **Cp** | Semi-permeable | 0.12 | 0.16 | 0.20 |
| | Impermeable | 0.21 | 0.26 | 0.30 |
| | Dense Bush | 0.03 | 0.04 | 0.05 |
| **VEGETATION** | Cultivated land | 0.07 | 0.11 | 0.15 |
| **Cv** | Grass land | 0.17 | 0.21 | 0.25 |
| | Bare surface | 0.26 | 0.28 | 0.30 |

| MAP (mm) | 693 |
|---|---|
| Vlei's & pan's (<3%) | 0.00 |
| Flat areas (3 to 10%) | 0.05 |
| Hilly areas (10 to 30%) | 0.05 |
| Steep areas (>30%) | 0.00 |
| **Cs** | **0.10** |
| Very permeable | 0.00 |
| Permeable | 0.05 |
| Semi-permeable | 0.06 |
| Impermeable | 0.00 |
| **Cp** | **0.11** |
| Dense Bush | 0.00 |
| Cultivated land | 0.04 |
| Grass land | 0.20 |
| Bare surface | 0.01 |
| **Cv** | **0.25** |

### 3.1.2 Runoff Coefficients - Opencast Areas

**Table 9: Runoff Coefficient Factors**

| C=Cs+Cp+Cv | 0.35 | | | | |
|---|---|---|---|---|---|
| **Rural** | | | | | |
| **Surface Slopes** | | **Permeability** | | **Vegetation** | |
| Vlei's & pan's (<3%) | 0 | Very permeable | 0 | Dense Bush | 0 |
| Flat areas (3 to 10%) | 70 | Permeable | 60 | Cultivated land | 55 |
| Hilly areas (10 to 30%) | 30 | Semi-permeable | 40 | Grass land | 40 |
| Steep areas (>30%) | 0 | Impermeable | 0 | Bare surface | 5 |
| **Total %** | **100** | **Total %** | **100** | **Total %** | **100** |

| COMPONENT | CATERORY | MAP(mm) | | |
|---|---|---|---|---|
| | | <600 | 600-900 | >900 |
| SURFACE SLOPE IN % Cs | <3 | 0.01 | 0.03 | 0.03 |
| | 3 TO 10 | 0.06 | 0.08 | 0.11 |
| | 10 TO 30 | 0.12 | 0.16 | 0.20 |
| | >30 | 0.22 | 0.26 | 0.30 |
| PERMEABILITY OF THE SOIL Cp | Very permeable | 0.03 | 0.04 | 0.05 |
| | Permeable | 0.06 | 0.08 | 0.10 |
| | Semi-permeable | 0.12 | 0.16 | 0.20 |
| | Impermeable | 0.21 | 0.26 | 0.30 |
| VEGETATION Cv | Dense Bush | 0.03 | 0.04 | 0.05 |
| | Cultivated land | 0.07 | 0.11 | 0.15 |
| | Grass land | 0.17 | 0.21 | 0.25 |
| | Bare surface | 0.26 | 0.28 | 0.30 |

| MAP (mm) | 693 |
|---|---|
| Vlei's & pan's (<3%) | 0.00 |
| Flat areas (3 to 10%) | 0.06 |
| Hilly areas (10 to 30%) | 0.04 |
| Steep areas (>30%) | 0.00 |
| **Cs** | **0.10** |
| Very permeable | 0.00 |
| Permeable | 0.05 |
| Semi-permeable | 0.06 |
| Impermeable | 0.00 |
| **Cp** | **0.11** |
| Dense Bush | 0.00 |
| Cultivated land | 0.06 |
| Grass land | 0.07 |
| Bare surface | 0.01 |
| **Cv** | **0.14** |

**Table 10: Plant calculation Summary Sheet**

| Plant | Area | C Factor | Time (Tc) | Intensity (I 50) | Q 50 | Volume Storage |
|---|---|---|---|---|---|---|
| ID | Ha | Constant | min | mm/H | M3/s | 1:50 |
| Plant A | 53,2 | 0,533 | 54 | 91,4 | 6,8 | 10870 |
| Plant B | 191,9 | 0,533 | 55 | 88 | 10,4 | 39610 |

There are 6 open cast sites in total. The total area of the all 6 sites amount to 111 ha. This is constitute about 3 % of the total mine area of 6663 ha. The rest of the area consist of open or buffer areas, underground works and the plant area. See Appendix B for the calculation sheets.

**Table 11: Open Cast Runoff calculation Summary Sheet**

| Plant | Area | C Factor | Time (Tc) | Intensity (I 50) | Q 50 |
|---|---|---|---|---|---|
| ID | Ha | Constant | min | mm/H | M3/s |
| Open Cast 1 | 7,4 | 0,35 | 28 | 135 | 0,5 |
| Open Cast 2 | 26,9 | 0,35 | 39 | 111 | 3,1 |
| Open Cast 3 | 28 | 0,35 | 34 | 120 | 0,92 |
| Open Cast 4 | 3,6 | 0,35 | 21 | 141 | 5,1 |
| Open Cast 5 | 7 | 0,35 | 28 | 135 | 0,9 |
| Open Cast 6 | 63,1 | 0,35 | 56 | 87 | 2,77 |

Dirty water capacities are used to determine the sizes of pollution control dams in accordance to the General Notice No. 704 (GN704). A layout map of infrastructure must be provided for the sizing of pollution control dams.

The above table illustrates the flood volumes for the reaches of Plant A and B. This is calculated from the Peak discharge values given in Table 3, above. It is calculated using the theory of a hydrograph where the hydrograph is a triangle. Flood Volume is the area of that triangle. Area of a triangle is equal to half the base multiplied by the height. Peak Discharge is the height and Time of concentration is one third of the base, therefore it can be calculated through that theory. The pollution control dams must be designed to hold the 1:50 year flood volume as in accordance with GN 704.

### 3.2 Sizing of PC Dams

The dams are conceptually designed around the 1:50 year flood volume as in accordance with GN 704. There is also a freeboard added to act as a safety barrier, in case there are a few extreme events in a short amount of time, to give some extra leeway. The dams are designed as a square for ease of conceptualization and are designed with walls of less than 5m to comply with the National Water Act 1998 and not need to apply for the construction. The conceptual designs follow in the tables below for Plant Sites A and B.

**Table 12: Conceptual Design for Site A PC Dam**

| SITE A | Top length (m) | Top Width (m) | Bottom length (m) | Bottom Width (m) | Depth (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|
| Design capacity | 70.000 | 45.000 | 64.000 | 37.800 | 4.000 | **11600** |
| Design capacity & Freeboard volume | 71.600 | 46.600 | 64.000 | 37.800 | 4.800 | **13900** |

**Table 13: Conceptual Design for Site B PC Dam**

| SITE B | Top length (m) | Top Width (m) | Bottom length (m) | Bottom Width (m) | Depth (m) | Volume ($m^3$) |
|---|---|---|---|---|---|---|
| Design capacity | 125.000 | 85.000 | 119.000 | 77.800 | 4.000 | **40700** |
| Design capacity & Freeboard volume | 126.600 | 86.600 | 119.000 | 77.800 | 4.800 | **48800** |

The design capacity of the dam is determined by adding the following volumes:

- Maximum operating capacity
- 1:50 year flood volume
- Freeboard volume.

The proposed PC dams as indicated in tables 12 and 13 do not include the maximum operating capacity. Therefore, it must be noted that the PC Dams must be operated as empty as possible to ensure that the flood volume as required by GN 704 is contained and the freeboard volume is reserved. For this reason the water balance is done below which illustrates the accumulative balance on average per month. This gives an indication of the water that should be abstracted from the PC dam in order to run it at the required level. If there will not be I high enough abstraction from the PC dam by the plant then the volume of maximum operating capacity must be added to the size of the PC dam.

### 3.3 Positioning of PC Dams

The dams for Plant A and Plant B are to be positioned at the lowest point of each plant, to ensure gravitational flow from the dirty water catchment to the dam. This will reduce pumping costs.
The proposed locations are indicated on appendix A. Please refer to the coordinates below:

| | |
|---|---|
| PC Dam A: | S 26 15 30 |
| | E 29 46 29 |
| PC Dam B: | S 26 15 56 |
| | E 29 46 51 |

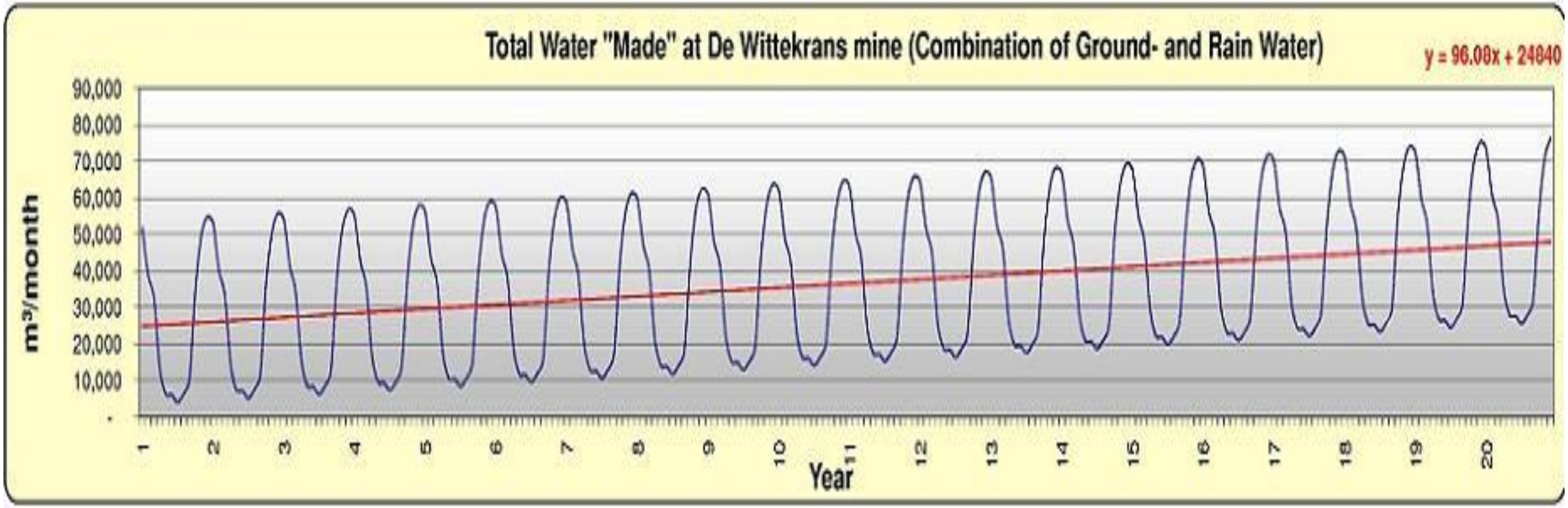
## 4 WATER BALANCE

The water balance was calculated only taking natural rainfall and evaporation into account, with abstractions as set out in the WRC Water Balance report. The water inflow is based in average calculation to accommodate for all the activities.
The underground inflow rates are calculated in the Hydro geological report. An average inflow rate of 15 $m^3$/month was used to simulate the water balance.
The opencast mine will contribute up to 45% of the rainfall initially. After rehabilitation the re-charge to the ground water will be less than 3%.
The mine indicates that no water will be abstracted from the surface or boreholes that will be used for mine activities. All the water usage will be from the underground workings and recycled water from the dirty water system.
As soon as the surface infrastructure is finalised and the operating capacities/requirements are finalised, a comprehensive water balance indicating all water uses and water units shall be produced. The comprehensive water balance was not part of this study.

The tables below indicate the available water over an accumulative monthly basis. The purpose of the water balance is to indicate how much water can be retained from site for re-use in other processes that may not be impacted by contaminated water. Only the first 3 years are tabled.

**Table 14: Water inflow Balance for the mine**

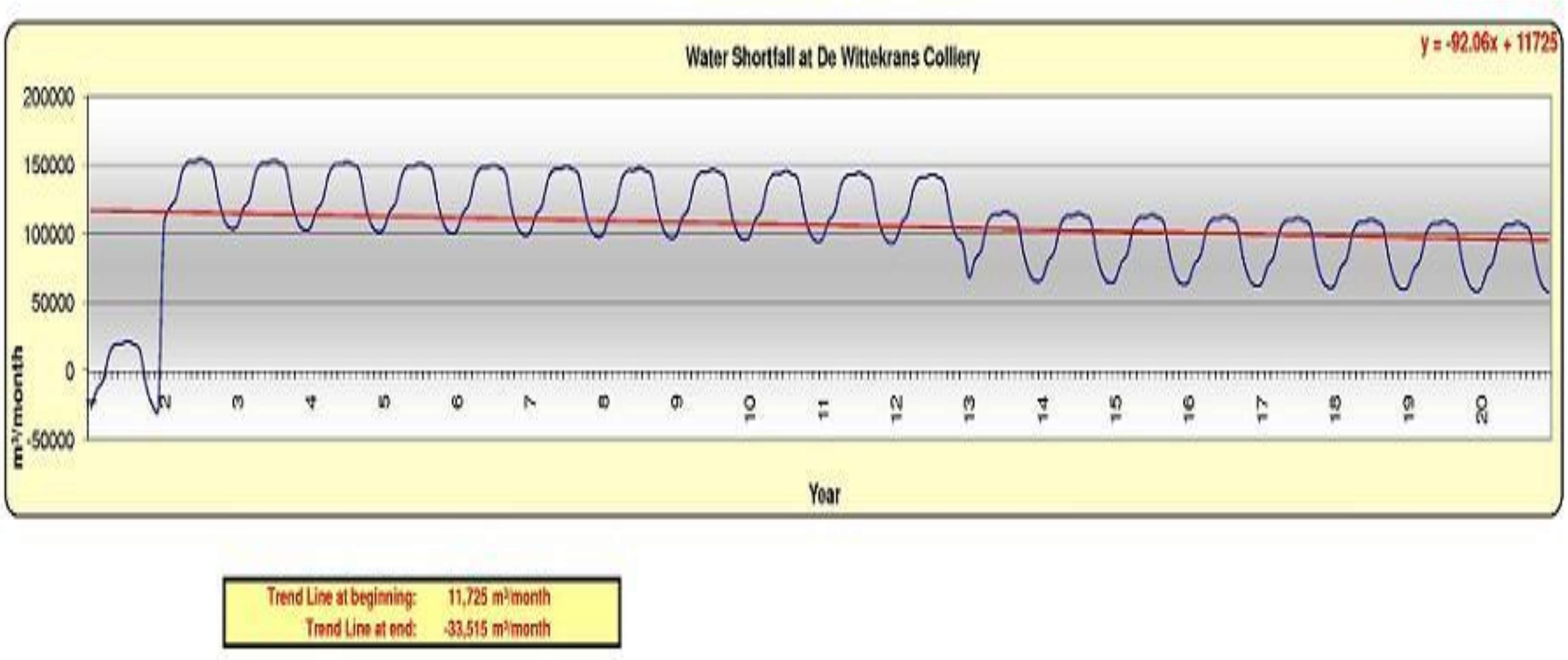
| Year | Month | Underground inflow (m³/day) | | | | Rainfall onto Surface Infrastructure (m³/month) | | | | | | | Evaporation off Dam Surfaces (m³/month) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Boxcut | Decline | Underground area Ha/month | Total Underground Inflow (m³/month) | Discard Dump and Plant A (45% of rainfall) (Ha) | Discard Dump B Plant B (45% Of Rainfall) (Ha) | Plant, stockpile and loading area (55% of Rainfall) (Ha) | Alternative Discard Dump (45% of Rainfall) (not included) (Ha) | Pollution Control Dams A (80% of Rainfall) (Ha) | Pollution Control Dam B (80% of Rainfall) (Ha) | Mine Water Dams (100% of Rainfall) (Ha) | Pollution Control Dam A (1 Ha) | Pollution Control Dam B (0.8 Ha) | Mine Water Dams (Ha) | Total Monthly Inflow (Ground- & Surface Water) (m³/month) |
| | | | | 6.50 | 15.00 | 15.00 | 35.00 | 40.00 | | 0.80 | 1.00 | 0.55 | 0.80 | 1.00 | 0.55 | |
| | | | | | | 0.45 | 0.45 | 0.55 | | | | | | | | |
| 1 | Jan | 6 | 105 | 6 | 1,759 | 7,898 | 18,428 | 25,740 | | 8,834 | 19,598 | 26,384 | 1,578 | 1,972 | 1,085 | 51,940 |
| | Feb | 6 | 105 | 13 | 1,857 | 5,886 | 13,734 | 19,184 | | 6,822 | 14,904 | 19,664 | 1,402 | 1,752 | 964 | 39,129 |
| | Mar | 6 | 105 | 19 | 1,954 | 4,820 | 11,246 | 15,708 | | 5,756 | 12,416 | 16,101 | 1,321 | 1,651 | 908 | 32,346 |
| | Apr | 6 | 105 | 26 | 2,052 | 1,802 | 4,205 | 5,874 | | 2,738 | 5,375 | 6,021 | 1,042 | 1,303 | 717 | 13,124 |
| | May | 6 | 105 | 32 | 2,149 | 675 | 1,575 | 2,200 | | 1,611 | 2,745 | 2,255 | 863 | 1,079 | 593 | 6,225 |
| | Jun | 6 | 105 | 39 | 2,247 | 540 | 1,260 | 1,760 | | 1,476 | 2,430 | 1,804 | 663 | 829 | 456 | 6,019 |
| | Jul | 6 | 105 | 45 | 2,344 | 230 | 536 | 748 | | 1,166 | 1,706 | 767 | 678 | 848 | 466 | 3,989 |
| | Aug | 6 | 105 | 52 | 2,442 | 574 | 1,339 | 1,870 | | 1,510 | 2,509 | 1,917 | 740 | 925 | 509 | 6,203 |
| | Sep | 6 | 105 | 58 | 2,539 | 1,438 | 3,355 | 4,686 | | 2,374 | 4,525 | 4,803 | 1,374 | 1,718 | 945 | 10,203 |
| | Oct | 6 | 105 | 65 | 2,636 | 5,204 | 12,143 | 16,962 | | 6,140 | 13,313 | 17,386 | 1,534 | 1,917 | 1,054 | 34,971 |
| | Nov | 6 | 105 | 71 | 2,734 | 7,385 | 17,231 | 24,068 | | 8,321 | 18,401 | 24,670 | 1,526 | 1,908 | 1,049 | 49,641 |
| | Dec | 6 | 105 | 78 | 2,831 | 8,168 | 19,058 | 26,620 | | 9,104 | 20,228 | 27,286 | 1,583 | 1,979 | 1,088 | 54,797 |
| 2 | Jan | 5 | 100 | 84 | 2,848 | 7,898 | 18,428 | 25,740 | | 8,834 | 19,598 | 26,384 | 1,578 | 1,972 | 1,085 | 53,028 |
| | Feb | 5 | 100 | 91 | 2,945 | 5,886 | 13,734 | 19,184 | | 6,822 | 14,904 | 19,664 | 1,402 | 1,752 | 964 | 40,218 |
| | Mar | 5 | 100 | 97 | 3,043 | 4,820 | 11,246 | 15,708 | | 5,756 | 12,416 | 16,101 | 1,321 | 1,651 | 908 | 33,435 |
| | Apr | 5 | 100 | 104 | 3,140 | 1,802 | 4,205 | 5,874 | | 2,738 | 5,375 | 6,021 | 1,042 | 1,303 | 717 | 14,212 |
| | May | 5 | 100 | 110 | 3,238 | 675 | 1,575 | 2,200 | | 1,611 | 2,745 | 2,255 | 863 | 1,079 | 593 | 7,313 |
| | Jun | 5 | 100 | 117 | 3,335 | 540 | 1,260 | 1,760 | | 1,476 | 2,430 | 1,804 | 663 | 829 | 456 | 7,097 |
| | Jul | 5 | 100 | 123 | 3,432 | 230 | 536 | 748 | | 1,166 | 1,706 | 767 | 678 | 848 | 466 | 5,077 |
| | Aug | 5 | 100 | 130 | 3,530 | 574 | 1,339 | 1,870 | 15 | 1,510 | 2,509 | 1,931 | 740 | 925 | 509 | 7,306 |
| | Sep | 5 | 100 | 136 | 3,627 | 1,438 | 3,355 | 4,686 | | 2,374 | 4,525 | 4,803 | 1,374 | 1,718 | 945 | 11,292 |
| | Oct | 5 | 100 | 143 | 3,725 | 5,204 | 12,143 | 16,962 | | 6,140 | 13,313 | 17,386 | 1,534 | 1,917 | 1,054 | 36,059 |
| | Nov | 5 | 100 | 149 | 3,822 | 7,385 | 17,231 | 24,068 | | 8,321 | 18,401 | 24,670 | 1,526 | 1,908 | 1,049 | 50,729 |
| | Dec | 5 | 100 | 156 | 3,920 | 8,168 | 19,058 | 26,620 | | 9,104 | 20,228 | 27,286 | 1,583 | 1,979 | 1,088 | 55,886 |
| 3 | Jan | 5 | 95 | 162 | 3,939 | 7,898 | 18,428 | 25,740 | | 8,834 | 19,598 | 26,384 | 1,578 | 1,972 | 1,085 | 54,119 |
| | Feb | 5 | 95 | 169 | 4,037 | 5,886 | 13,734 | 19,184 | | 6,822 | 14,904 | 19,664 | 1,402 | 1,752 | 964 | 41,309 |
| | Mar | 5 | 95 | 175 | 4,134 | 4,820 | 11,246 | 15,708 | | 5,756 | 12,416 | 16,101 | 1,321 | 1,651 | 908 | 34,526 |
| | Apr | 5 | 95 | 182 | 4,231 | 1,802 | 4,205 | 5,874 | | 2,738 | 5,375 | 6,021 | 1,042 | 1,303 | 717 | 15,384 |
| | May | 5 | 95 | 188 | 4,329 | 675 | 1,575 | 2,200 | | 1,611 | 2,745 | 2,255 | 863 | 1,079 | 593 | 8,404 |
| | Jun | 5 | 95 | 195 | 4,426 | 540 | 1,260 | 1,760 | | 1,476 | 2,430 | 1,804 | 663 | 829 | 456 | 8,188 |
| | Jul | 5 | 95 | 201 | 4,524 | 230 | 536 | 748 | | 1,166 | 1,706 | 767 | 678 | 848 | 466 | 6,169 |
| | Aug | 5 | 95 | 208 | 4,621 | 574 | 1,339 | 1,870 | | 1,510 | 2,509 | 1,917 | 740 | 925 | 509 | 8,383 |
| | Sep | 5 | 95 | 214 | 4,719 | 1,438 | 3,355 | 4,686 | | 2,374 | 4,525 | 4,803 | 1,374 | 1,718 | 945 | 12,383 |
| | Oct | 5 | 95 | 221 | 4,816 | 5,204 | 12,143 | 16,962 | | 6,140 | 13,313 | 17,386 | 1,534 | 1,917 | 1,054 | 37,151 |
| | Nov | 5 | 95 | 227 | 4,914 | 7,385 | 17,231 | 24,068 | | 8,321 | 18,401 | 24,670 | 1,526 | 1,908 | 1,049 | 51,820 |
| | Dec | 5 | 95 | 234 | 5,011 | 8,168 | 19,058 | 26,620 | | 9,104 | 20,228 | 27,286 | 1,583 | 1,979 | 1,088 | 56,977 |
| 4 | Jan | 5 | 90 | 240 | 5,030 | 7,898 | 18,428 | 25,740 | | 8,834 | 19,598 | 26,384 | 1,578 | 1,972 | 1,085 | 55,211 |
| | Feb | 5 | 90 | 247 | 5,128 | 5,886 | 13,734 | 19,184 | | 6,822 | 14,904 | 19,664 | 1,402 | 1,752 | 964 | 42,400 |
| | Mar | 5 | 90 | 253 | 5,225 | 4,820 | 11,246 | 15,708 | | 5,756 | 12,416 | 16,101 | 1,321 | 1,651 | 908 | 35,617 |
| | Apr | 5 | 90 | 260 | 5,323 | 1,802 | 4,205 | 5,874 | | 2,738 | 5,375 | 6,021 | 1,042 | 1,303 | 717 | 16,395 |
| | May | 5 | 90 | 266 | 5,420 | 675 | 1,575 | 2,200 | | 1,611 | 2,745 | 2,255 | 863 | 1,079 | 593 | 9,496 |
| | Jun | 5 | 90 | 273 | 5,518 | 540 | 1,260 | 1,760 | | 1,476 | 2,430 | 1,804 | 663 | 829 | 456 | 9,280 |
| | Jul | 5 | 90 | 279 | 5,615 | 230 | 536 | 748 | | 1,166 | 1,706 | 767 | 678 | 848 | 466 | 7,260 |
| | Aug | 5 | 90 | 286 | 5,712 | 574 | 1,339 | 1,870 | | 1,510 | 2,509 | 1,917 | 740 | 925 | 509 | 9,474 |
| | Sep | 5 | 90 | 292 | 5,810 | 1,438 | 3,355 | 4,686 | | 2,374 | 4,525 | 4,803 | 1,374 | 1,718 | 945 | 13,474 |
| | Oct | 5 | 90 | 299 | 5,907 | 5,204 | 12,143 | 16,962 | | 6,140 | 13,313 | 17,386 | 1,534 | 1,917 | 1,054 | 38,242 |
| | Nov | 5 | 90 | 305 | 6,005 | 7,385 | 17,231 | 24,068 | | 8,321 | 18,401 | 24,670 | 1,526 | 1,908 | 1,049 | 52,912 |
| | Dec | 5 | 90 | 312 | 6,102 | 8,168 | 19,058 | 26,620 | | 9,104 | 20,228 | 27,286 | 1,583 | 1,979 | 1,088 | 58,068 |
| 5 | Jan | 5 | 85 | 318 | 6,125 | 7,898 | 18,428 | 25,740 | | 8,834 | 19,598 | 26,384 | 1,578 | 1,972 | 1,085 | 56,305 |
| | Feb | 5 | 85 | 325 | 6,222 | 5,886 | 13,734 | 19,184 | | 6,822 | 14,904 | 19,664 | 1,402 | 1,752 | 964 | 43,495 |
| | Mar | 5 | 85 | 331 | 6,320 | 4,820 | 11,246 | 15,708 | | 5,756 | 12,416 | 16,101 | 1,321 | 1,651 | 908 | 36,712 |
| | Apr | 5 | 85 | 338 | 6,417 | 1,802 | 4,205 | 5,874 | | 2,738 | 5,375 | 6,021 | 1,042 | 1,303 | 717 | 17,489 |
| | May | 5 | 85 | 344 | 6,515 | 675 | 1,575 | 2,200 | | 1,611 | 2,745 | 2,255 | 863 | 1,079 | 593 | 10,590 |
| | Jun | 5 | 85 | 351 | 6,612 | 540 | 1,260 | 1,760 | | 1,476 | 2,430 | 1,804 | 663 | 829 | 456 | 10,374 |
| | Jul | 5 | 85 | 357 | 6,709 | 230 | 536 | 748 | | 1,166 | 1,706 | 767 | 678 | 848 | 466 | 8,354 |
| | Aug | 5 | 85 | 364 | 6,807 | 574 | 1,339 | 1,870 | | 1,510 | 2,509 | 1,917 | 740 | 925 | 509 | 10,569 |
| | Sep | 5 | 85 | 370 | 6,904 | 1,438 | 3,355 | 4,686 | | 2,374 | 4,525 | 4,803 | 1,374 | 1,718 | 945 | 14,569 |
| | Oct | 5 | 85 | 377 | 7,002 | 5,204 | 12,143 | 16,962 | | 6,140 | 13,313 | 17,386 | 1,534 | 1,917 | 1,054 | 39,336 |
| | Nov | 5 | 85 | 383 | 7,099 | 7,385 | 17,231 | 24,068 | | 8,321 | 18,401 | 24,670 | 1,526 | 1,908 | 1,049 | 54,006 |
| | Dec | 5 | 85 | 390 | 7,197 | 8,168 | 19,058 | 26,620 | | 9,104 | 20,228 | 27,286 | 1,583 | 1,979 | 1,088 | 59,163 |




**Graph:** The seasonal fluctuation of the water entering the De Wittekrans Colliery from rainfall and groundwater sources is clearly evident in the graph. The seasonality is attributable to the rainfall on surface infrastructure, while the groundwater influx is more-or-less constant and is represented by the area below the bottom (minimum) curves of the graph. The model from which this graph was developed is attached as ***Appendix*** . This graph does not show the water surplus reduction, resulting from water usage at the mine.

**Table 15: Water usage of the Mine**

| Year | Month | Total Monthly Inflow (Ground- & Surface Water) (m³/month) | Total Water Requirements by Mine (m³/month) | Monthly shortfall (m³/month) |
|---|---|---|---|---|
| 1 | Jan | 51,940 | 25,807 | -26133 |
| | Feb | 39,129 | 25,807 | -13322 |
| | Mar | 32,346 | 25,807 | -6539 |
| | Apr | 13,124 | 25,807 | 12683 |
| | May | 6,225 | 25,807 | 19582 |
| | Jun | 6,009 | 25,807 | 19798 |
| | Jul | 3,989 | 25,807 | 21818 |
| | Aug | 6,203 | 25,807 | 19604 |
| | Sep | 10,203 | 25,807 | 15604 |
| | Oct | 34,971 | 25,807 | -9164 |
| | Nov | 49,641 | 25,807 | -23834 |
| | Dec | 54,797 | 25,807 | -28990 |
| 2 | Jan | 53,028 | 159,588 | 106560 |
| | Feb | 40,218 | 159,588 | 119371 |
| | Mar | 33,435 | 159,588 | 126154 |
| | Apr | 14,212 | 159,588 | 145376 |
| | May | 7,313 | 159,588 | 152275 |
| | Jun | 7,097 | 159,588 | 152492 |
| | Jul | 5,077 | 159,588 | 154511 |
| | Aug | 7,306 | 159,588 | 152282 |
| | Sep | 11,292 | 159,588 | 148297 |
| | Oct | 36,059 | 159,588 | 123529 |
| | Nov | 50,729 | 159,588 | 108859 |
| | Dec | 55,886 | 159,588 | 103703 |
| 3 | Jan | 54,119 | 159,588 | 105469 |
| | Feb | 41,309 | 159,588 | 118279 |
| | Mar | 34,526 | 159,588 | 125063 |
| | Apr | 15,304 | 159,588 | 144285 |
| | May | 8,404 | 159,588 | 151184 |
| | Jun | 8,188 | 159,588 | 151400 |
| | Jul | 6,169 | 159,588 | 153420 |
| | Aug | 8,383 | 159,588 | 151206 |
| | Sep | 12,383 | 159,588 | 147205 |
| | Oct | 37,151 | 159,588 | 122438 |
| | Nov | 51,820 | 159,588 | 107768 |
| | Dec | 56,977 | 159,588 | 102612 |
| 4 | Jan | 55,211 | 159,588 | 104378 |
| | Feb | 42,400 | 159,588 | 117188 |
| | Mar | 35,617 | 159,588 | 123971 |
| | Apr | 16,395 | 159,588 | 143193 |
| | May | 9,496 | 159,588 | 150093 |
| | Jun | 9,280 | 159,588 | 150309 |
| | Jul | 7,260 | 159,588 | 152328 |
| | Aug | 9,474 | 159,588 | 150114 |
| | Sep | 13,474 | 159,588 | 146114 |
| | Oct | 38,242 | 159,588 | 121346 |
| | Nov | 52,912 | 159,588 | 106677 |
| | Dec | 58,068 | 159,588 | 101520 |
| 5 | Jan | 56,305 | 159,588 | 103283 |
| | Feb | 43,495 | 159,588 | 116094 |
| | Mar | 36,712 | 159,588 | 122877 |
| | Apr | 17,489 | 159,588 | 142099 |
| | May | 10,590 | 159,588 | 148998 |
| | Jun | 10,374 | 159,588 | 149215 |
| | Jul | 8,354 | 159,588 | 151234 |
| | Aug | 10,568 | 159,588 | 149020 |
| | Sep | 14,569 | 159,588 | 145020 |
| | Oct | 39,336 | 159,588 | 120252 |
| | Nov | 54,006 | 159,588 | 105582 |
| | Dec | 59,163 | 159,588 | 100426 |




**Graph:** The adjusted water requirements of the colliery if the groundwater and surface water collected by bunded surface infrastructure (plant area, Loading area, Mine water dams and discard dump/pollution control dams) is recycled back to the plant. The progressive decrease of the water shortfall at the colliery over the LOM is attributed to the progressive increase in inflow of groundwater into the mine workings over the same period.

# 5 WATER QUALITY MANAGEMENT

## 5.1 Frequency of Monitoring and Reporting to DWAE

The monitoring points are to be monitored on a regular basis, quarterly; for example every 3 months. At this stage a report should be compiled with the results and findings and should be sent to DWAF for them to gain an understanding of the overall quality of the water in this catchment. The points should further be monitored, on top of the quarterly report, if there is any concern of spillage where possible contamination could take place.

## 5.2 Variables to be Monitored

The following variables should also be monitored:

- pH: Minimum, Maximum and Mean
- EC: Minimum, Maximum and Mean
- $SO_4$: Minimum, Maximum and Mean
- N: Minimum, Maximum and Mean

## 5.3 Proposed Monitoring Points

Monitoring points have been proposed to assure that impacts to the river systems are limited. These monitoring points must be monitored regularly at regular intervals as well as if any spillage of some sort occurs or if there is any reason as to why pollutants may have affected the river system. The positions can be seen on the map provided in Appendix A and the co-ordinates are as follows:

- Tributary upstream of Plants: 26° 16' 43.223"S
  29° 46' 52.741"E
- Tributary downstream of plants: 26° 15' 29.177"S
  29° 46' 56.336"E
- Klein-Olifants above convergence: 26° 14' 27.084"S
  29° 46' 56.595"E
- Klein-Olifants below convergence: 26° 14' 24.526"S
  29° 46' 50.736"E

# 6 RISK ASSESSMENT

## 6.1 Risk Assessment Factors

The **aspect** is a description of what causes the effect, what will be affected and how it will be affected.

The **extent** is a description wherein it is indicated whether the impact will be local (limited to the immediate area or site of development), regional, national or international. A score of between 1 and 5 is assigned as appropriate (with a score of 1 being low and a score of 5 being high).

The **duration** is a description wherein it is indicated whether:

- the lifetime of the impact will be of a very short duration (0–1 years) – assigned a score of 1
- the lifetime of the impact will be of a short duration (2-5 years) - assigned a score of 2
- medium-term (5–15 years) – assigned a score of 3
- long term (> 15 years) - assigned a score of 4
- Permanent - assigned a score of 5.

The **intensity** is quantified on a scale from 0-4, where a score is assigned:

- 0 is small and will have no effect on the environment;
- 1 is low and will cause a slight impact on processes;
- 2 is moderate and will result in natural, cultural and social functions continuing but in a modified way;
- 3 is high (natural, cultural and social functions are altered to the extent that they temporarily cease); and
- 4 is very high natural, cultural and social functions permanently cease.

The **probability** of occurrence describes the likelihood of the impact actually occurring. Probability is estimated on a scale of 1-5, and a score assigned:

- where 1 is very improbable (probably will not happen);
- Assigned a score of 2 is improbable (some possibility, but low likelihood);

- Assigned a score of 3 is probable (distinct possibility);
- Assigned a score of 4 is highly probable (most likely); and
- Assigned a score of 5 is definite (impact will occur regardless of any prevention measures).

The **significance** is determined through a synthesis of the characteristics described above (refer formula below) and can be assessed as low, low-moderate, moderate, moderate-high or high. The significance is determined by combining the criteria in the following formula:

S = E+D+M+P; where:

S = Significance weighting

E = Extent

D = Duration

M = Magnitude

P = Probability

The significance weightings for each potential impact are as follows:

- 2 - 4 points: Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
- 5 – 7 points: Low – Moderate (i.e. where impacts may have slight influence on decision making, unless affectively mitigated),
- 8 - 10 points: Moderate (i.e. where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- 11 – 13 points Moderate – High (i.e. where the impact should have an influence on the decision process to develop, however implementation of mitigation measures will soften the decision.
- 14 – 16 points: High (i.e. where the impact must have an influence on the decision process to develop in the area),
- 17 – 19 points Very High (i.e. where the impact is detrimental and the decision should be made not to continue with development.

# 7 RISK ASSESSMENT AND MITIGATION TABLES

**Table 16: Risk Rating Construction Phase**

| Aspect | Activity description and potential impacts on the environment | Probability | Extent | Duration | Intensity | Significance | Management Measurements | Action Plan |
|---|---|---|---|---|---|---|---|---|
| Sediment/Transport Erosion | Construction will lead to the removal of vegetation, leaving bare soil surfaces. When it rains it will lead towards sediment being picked up and carried off, leaving eroded surfaces | 3 | 2 | 1 | 3 | 9 - Moderate | Vegetative berms will be constructed in order to trap any sediment during the construction phase | This will be monitored and soil will be collected at the berms and put back from where it was lost |
| | With management measures | 2 | 1 | 1 | 1 | 5 - Low to Moderate | | |
| Deterioration of River Banks | Constructing conveyors and roads across rivers could result in the loosening of ground and therefore the deterioration of the river banks. | 2 | 1 | 1 | 3 | 7 - Low to Moderate | Caution must be taken when constructing near to river banks, vegetation must not be removed from the banks | Contractors must keep a certain distance from the bank trying to avoid loosening any material |
| | With management measures | 0 | 1 | 1 | 1 | 3 - Low | | |
| Stream Flow Reduction | Where dams are being built water could get trapped in the early stages, affecting the runoff that generates streamflow | 2 | 3 | 1 | 2 | 8 - Moderate | Measures must be taken in order to eliminate clean water daming where it is not necessary | When construction takes place contractors must be carefull not to alter the landscape where it is not necessary |
| | With management measures | 1 | 3 | 1 | 1 | 6 - Low to Moderate | | |
| Removal of Vegetation | During construction vegetation will be removed | 3 | 2 | 1 | 4 | 10 - Moderate | Vegetation will be removed during the construction process, it is essential that it be replaced after construction has finished | All bare surfaces must be planted with indigenous vegetation, if possible the vegetation removed should be used |
| | With management measures | 3 | 1 | 1 | 2 | 7 - Low to Moderate | | |
| Deterioration of Water Quality | In the constuction phase some fuels may be spilt as well as sedement lost which will both affect the water quality | 3 | 2 | 1 | 3 | 9 - Moderate | All fuels and waste used should be placed and stored in a controlled manner | All grease, lubricants, paints, flammable liquids, garbage, abandoned machinery and other combustible materials will be included |
| | With management measures | 1 | 2 | 1 | 2 | 6 - Low to Moderate | | |

**Table 17: Risk Rating Operation Phase**

| Aspect | Activity description and potential impacts on the environment | Probability | Extent | Duration | Intensity | Significance | Management Measurements | Action Plan |
|---|---|---|---|---|---|---|---|---|
| Sediment/Transport Erosion | If vegetation is not replaced after construction phase, leaving bare soil surfaces. When it rains it will lead towards sediment being picked up and carried off, leaving eroded surfaces | 3 | 2 | 3 | 3 | 11 - Moderate to High | Vegetative berms will be constructed in order to trap any sediment during the construction phase | This will be monitored and soil will be collected at the berms and put back from where it was lost |
| | With management measures | 1 | 1 | 3 | 1 | 6 - Low to Moderate | | |
| Deterioration of River Banks | Maintenance of conveyors and the use of roads could result in damaging river banks | 2 | 2 | 3 | 3 | 10 - Moderate | During operation the banks should keep free of any activity, unless essential, whereby extreme caution must be taken | Contractors must keep a certain distance from the bank trying to avoid loosening any material |
| | With management measures | 0 | 1 | 3 | 0 | 4 - Low | | |
| Stream Flow Reduction | Where the dams are built there will be amount of water trapped, reducing stream flow reduction. The | 3 | 3 | 3 | 3 | 12 - Moderate to High | The PC Dam facility will reduce stream flow by catching dirty water, however clean water must be channeled around the dams to limit the losses | This can be done by constructing channels and berms around the area, catching clean water and channeling it into the natural system |
| | With management measures | 2 | 2 | 3 | 1 | 8 - Moderate | | |
| Removal of Vegetation | Some vegetation may further be removed after construction phase | 3 | 2 | 3 | 3 | 11 - Moderate to High | Vegetation must be replaced after the construction phase | |
| | With management measures | 0 | 1 | 3 | 0 | 4 - Low | | |
| Deterioration of Water Quality (Acid Mine drainage) | Pollutants from the discard and mine activities could spill into the system and be washed into the river reducing its quality | 3 | 4 | 3 | 4 | 14 - Moderate to High | Without mitigation contaminated run-off water from the discard dump and washing plant/stockpile/loading areas, etc. will be released into the surface streams. released into the system | With mitigation all surplus water will be re-used on-site as mine service water. Also, prevention of contamination will be implemented and clean and dirty water streams will be separated. |
| | With management measures | 2 | 3 | 2 | 2 | 9 - Moderate | | |

**Table 18: Risk Rating Closure Phase**

| Aspect | Activity description and potential impacts on the environment | Probability | Extent | Duration | Intensity | Significance | Management Measurements | Action Plan |
|---|---|---|---|---|---|---|---|---|
| Sediment/Transport Erosion | Closure will result in heavy construction again leaving bare surfaces which could result in sediment transportation | 3 | 2 | 3 | 3 | 11 - Moderate to High | Vegetative berms will be constructed in order to trap any sediment during the closure phase | This will be monitored and soil will be collected at the berms and put back from where it was lost |
| | With management measures | 0 | 1 | 1 | 1 | 3 - Low | | |
| Deterioration of River Banks | Removal of the conveyors would potentially leave banks damaged | 2 | 1 | 2 | 3 | 8 - Moderate | The river banks must be rehabilitated properly after closure | contractors must keep a certain distance from the bank trying to avoid loosening any material |
| | With management measures | 0 | 1 | 1 | 1 | 3 - Low | | |
| Stream Flow Reduction | If slopes and surfaces were not returned back to their original state some damming could take place decreasing stream flow | 2 | 2 | 2 | 2 | 8 - Moderate | The surface and slopes of the land must be rehabilitated back to pristine conditions | By taking huge detail of the area before construction and returning it as best one can to look as though it was natural |
| | With management measures | 0 | 1 | 1 | 0 | 2 - Low | | |
| Removal of Vegetation | Vegetated banks will be torn down when the dam is removed | 3 | 2 | 2 | 3 | 10 - Moderate | All vegetative matter must be returned to natural conditions | Indigenous vegetation must be replaced where bare surfaces exist |
| | With management measures | 1 | 1 | 1 | 0 | 3 - Low | | |
| Deterioration of Water Quality | If polluted areas are not rehabilitated properly then water quality could be affected | 2 | 2 | 2 | 3 | 9 - Moderate | All toxic waste and mine matter must be removed and contained | Rehabilitation of the land must leave it in pristine conditions removing all waste and by products |
| | With management measures | 1 | 2 | 1 | 1 | 5 - Low to Moderate | | |

Tables 16 to 18 illustrate the risk associated with the construction of the mine infrastructure. This risk had been averaged could change when the mine finalise the mine plans and various activities decided on each plant site. For example if there were less crossings on the tributary for the Klein-Olifants with roads and conveyors it would make a major benefit for the risk associated with the laws of GN 704. Therefore lessoning the amount of required river crossings by both road and conveyor would be highly beneficial to the project from a water perspective.

The Tables above also illustrate to us the importance of mitigation measures and how these must be followed strictly in order to reduce risk and damage to the environment.

# 8 DISCUSSION AND CONCLUSION

The purpose of this study was to assess the impacts of the construction of the proposed Surface Infrastructure on the surface water in the outlined mine area.

The mine indicates to utilise 2 plant facilities. With Plant Part A on the Eastern Side of the tributary flowing into the Klein-Olifants River and Plant Part B on the Western side. This can be seen in the map provided in Appendix A.

There were major sections which were analyzed in this study; Floodlines, PC Dams, Water Balance and Risk Assessment.

The floodlines generated showed that both sites would be out of the 1:100 year flood zone, applying to the regulation, stipulated in GN 704. Floodlines were also beyond the 100m buffer from the centre of the river, also stipulated by GN 704. Therefore there was no major concern as far as the placements of either plant were concerned.

The PC Dams were sized according to the water that would be generated from the Plant area. This was done using the 1:50 year flood volume from this area; which is the minimum size of a PC Dam stipulated by GN 704. The difference found here was that Plant B would in fact need a bigger dam than Plant A, as more water would be generated from Plant B. However this amount does not hold a huge significance and would depend on how much water the plant would use in operation. It may actually be more worthwhile to have the bigger dam for this reason.

The water balance was done showing that if water were not to be abstracted from the PC Dam the dam for the Plant overflow. As regulated by GN 704, the PC dams must be kept as empty as possible. Therefore, the amount of water indicated as a surplus in the water balance, must be re-used. Therefore without abstraction the size of the dam would have to be designed much bigger to be able to contain the dirty water. This again would depend how much water the plant would require as to which position would be more favourable.

The hall roads major risk assessment is only the river crossings, either by road or by conveyor. The other us dust and will be manage with dust suppression methods and speed control measurements. The river crossing will need a Water Use License to be applied, for this reason the fewer crossings the better. The client must determine which plant would use less crossings and this would be the preferred site from a surface water point of view, as well as a time constraint. To traverse the river either by road or rail will also be a costly exercise therefore the less crossings the better.

The Open Cast mining risk is very low because little impact will be on the surface runoff. The total Area of the open Cast mining is about 136 Ha of the catchment area of 10 800 Ha. This is about 1 % of the area. The variation in the rainfall patterns of more than this percentage. After the rehabilitation the surface runoff will be reinstated.

The mine needs to adhere to all the necessary legislation of the IWMA. When this is implemented a very low risk will be enforced onto the environment.

The mine also have Besides the above recommendations there would be no major reason why or why not this project could not continue into the next phase as if all mitigation measures are carried out correctly there should be no major damage to the local surface water systems.

# 9 REFERENCES

http://www.dwaf.gov.za/hydrology Department of Water Affairs and Forestry

South African National Roads Agency Ltd, 2006. Drainage Manual. 5th Edition, Fully Revised

Utility Programs for Drainage, Version 1.0.2. Sinotech CC.

# 10 APPENDIX

## 10.1 Appendix A Project drawings

**DE WITTEKRANS PROPOSED MINING AREA**

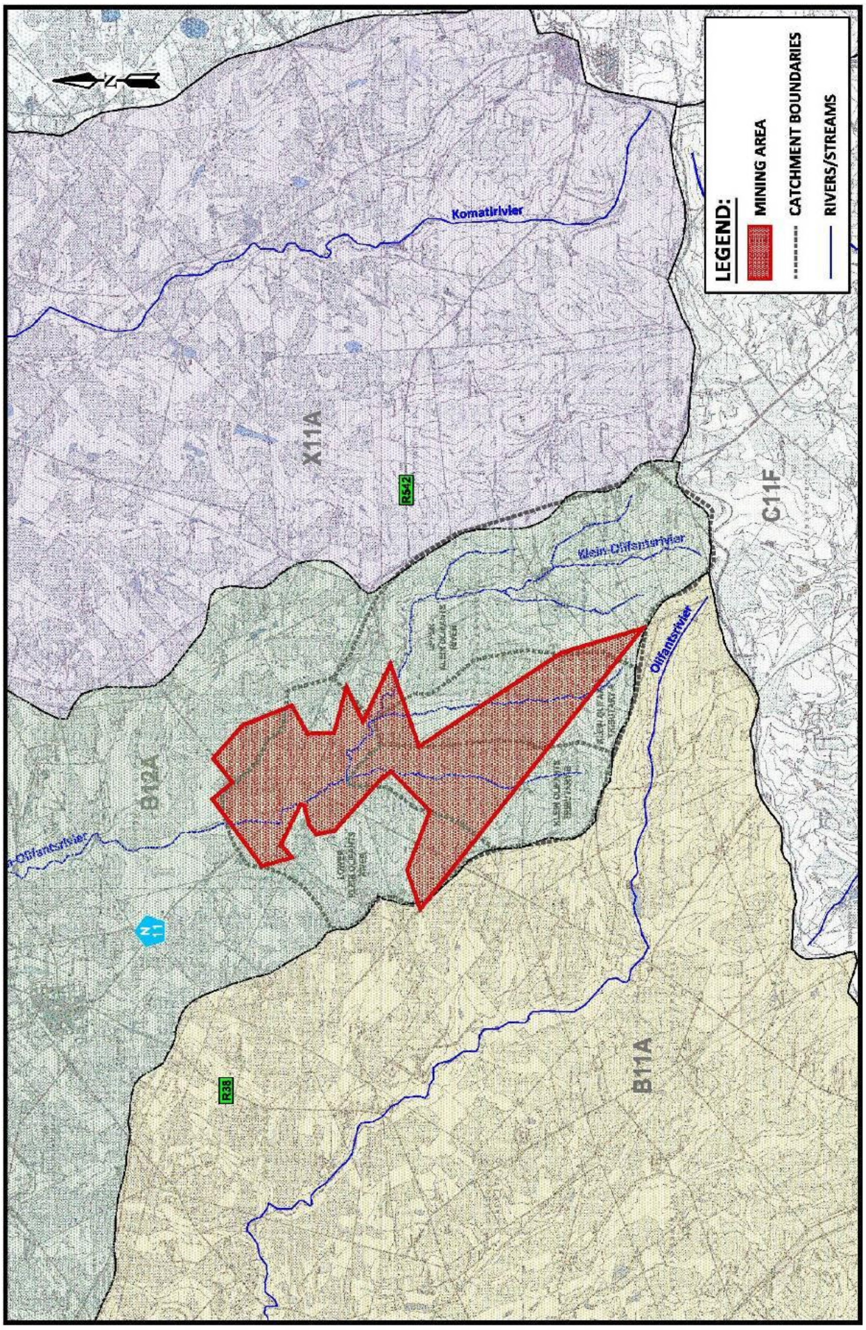



**Figure 1 - Surface Water Catchment and Streams**

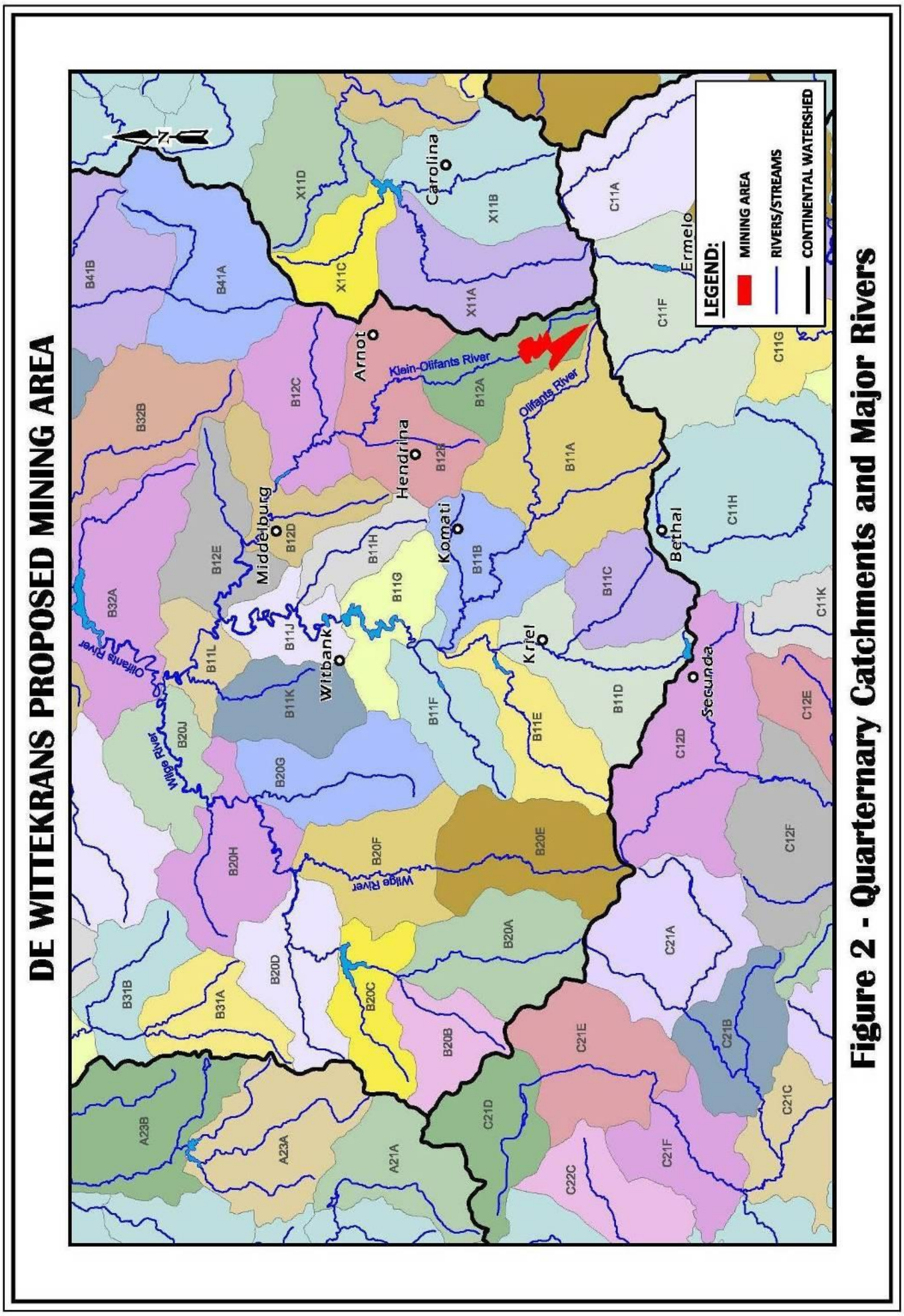
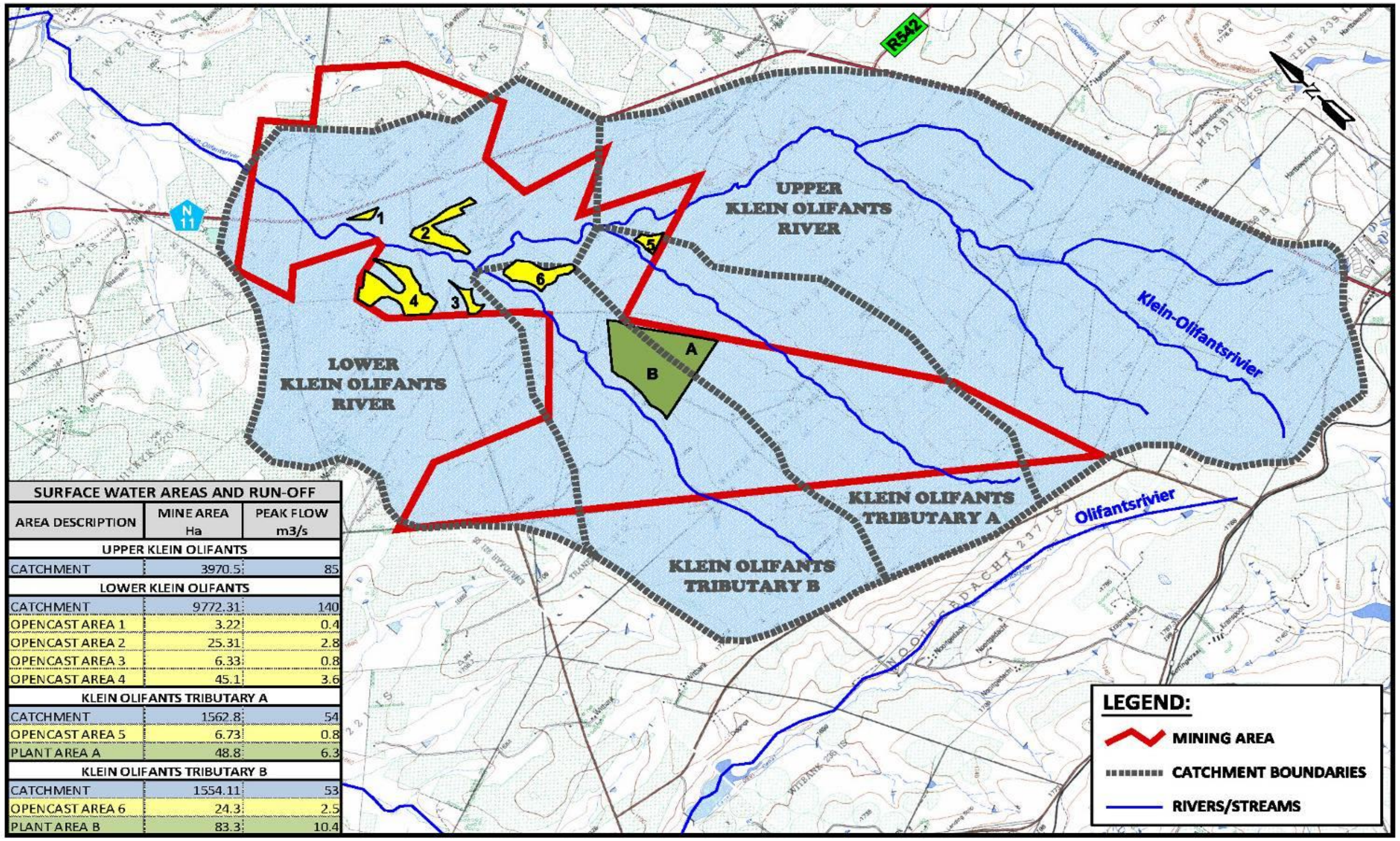



Figure 2 - Quarternary Catchments and Major Rivers

## DE WITTEKRANS PROPOSED MINING AREA




| SURFACE WATER AREAS AND RUN-OFF | | |
|---|---|---|
| AREA DESCRIPTION | MINE AREA Ha | PEAK FLOW m3/s |
| UPPER KLEIN OLIFANTS | | |
| CATCHMENT | 3970.5 | 85 |
| LOWER KLEIN OLIFANTS | | |
| CATCHMENT | 9772.31 | 140 |
| OPENCAST AREA 1 | 3.22 | 0.4 |
| OPENCAST AREA 2 | 25.31 | 2.8 |
| OPENCAST AREA 3 | 6.33 | 0.8 |
| OPENCAST AREA 4 | 45.1 | 3.6 |
| KLEIN OLIFANTS TRIBUTARY A | | |
| CATCHMENT | 1562.8 | 54 |
| OPENCAST AREA 5 | 6.73 | 0.8 |
| PLANT AREA A | 48.8 | 6.3 |
| KLEIN OLIFANTS TRIBUTARY B | | |
| CATCHMENT | 1554.11 | 53 |
| OPENCAST AREA 6 | 24.3 | 2.5 |
| PLANT AREA B | 83.3 | 10.4 |

**Figure 3 - Surface Water: Mine Catchment Areas**

## 10.2 Appendix B: floodlines

### ***10.2.1 Introduction to floodlines***

GCS was appointed to conduct a flood line delineation study for Mashala Resources (Pty) Ltd at the De- Witterkrans section. The objective of the flood line delineation is to clearly indicate whether Alternative 4 or Alternative 1 (As per Appendix A) is more suitable for the Plant activity Area. This report indicates the 1:50 and 1:100 year flood lines of the Tributary of Klein Olifants River.

A site visit was conducted on the 20 May 2009 where topography, visual inspection of soil type in the area and any obstruction along the tributary of the Klein Olifants River were observed, no actual data was collected in the field and all the flood line modelling have been based on critical flow. The flow rates and volumes have been determined from the Hydrological Report (Please refer to hydrological report).

The survey data used to delineate the flood lines were 5 meter contours, map 2630bd.tiff, 1:50 000 (1993). Survey data received from client did not include the river between the two sites.

As per cross-section data, Chainage 38 is upstream and Chainage 1 is downstream of tributary (See Appendix 2.3.1 and 2.3.4, respectively). The flow for 1:50 and 1:100 year flood lines are constant throughout the stream due to there being only one river reach.

### ***10.2.2 Discussion***

The flood lines were delineated for the Tributary of the Klein Olifants River of which a length of

Approximately 3700 meters was studied. This tributary passed through the Plant site Alternative 1 and 4. Since only one reach was studied the flow along that stream was constant for the 1:50 and 1:100 year flood line. The values are 93 and 119 $m^3/s$, respectively.

#### 10.2.2.1 Software

The software used to complete this study is as follows:

HEC RAS 3.1.2- For modelling the flood lines and final output data;

Global Mapper Pro- Generating the cross sections;

AutoCAD 2006- For plotting the points and the final layout;
Google Earth Imaging- Background image of the site

#### 10.2.2.2 Long Section

As per Appendix 2.2.1, between chainage 7 and 25 the topography is less steep than the surrounding areas and by referring to the long section it clearly indicates that the flow is constant for the entire reach. The Hence, potential of sediment transfer between those chainages are at its minimal along the right bank of the river. Then at chainage 31 there would be a higher erosion area, due to the high velocity (2.04 $m^3/s$) that the sediments are passing this stream point.
Overall, the area along the tributary is fairly steep (average slope: 0.005m/m) and flowing at a constant velocity, allowing the stream to be exposed to minimal erosion.

#### 10.2.2.3 Cross Section

500meter wide cross sections were generated along the tributary at 200 meter intervals. Cross- section 38 is at the most upstream point, at an elevation of approximately 1660 m above mean sea level. As per Appendices 2.3.1, 2.3.2 and 2.3.3, it indicates that there is a narrow flow area, which results in a high velocity, allowing sediment transfer and potentially high erosion area.

#### 10.2.2.4 Surface water Modelling

Flood lines were simulated using the Hec-Ras Computer programme.This program comprise of a separate hydrological analysis component, data storage and reporting system. One of the steps required, is to draw in the river system schematics, by entering cross-section data.

Usually GCS request the client to submit 2m contour data for infinite accuracy, arising a more accurate X-Y-Z perspective plot for modeling. 5m contours were used to run the model.

The output variables can be defined as follows:

Crit W.S. : Critical Water Surface Elevation.
E.G. Elev : Energy Grade line for calculated WS elevation
Flow Area : Total Area of cross section active flow.
Froude # Chnl : Froude Number for the main channel.

Min Ch El : Minimum main channel elevation.

Q total : Total flow in cross section

Top W Chnl : Top Width of the main channel.

Vel Chnl : Average Velocity of flow in main channel.

WS elev : Calculated water surface from energy equation

**Table 2.1 : HecRas output table**

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | Vel Chnl | Flow Area | Top Width | Froude Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (m3/s) | (m) | (m) | (m) | **(m)** | (m/s) | (m2) | (m) | |
| | | | | | | | | | | | |
| 1 | 38 | 01:50 | 93 | 1699.06 | 1699.64 | 1699.36 | **1699.65** | 0.39 | 130.4 | 384.27 | 0.21 |
| 1 | 38 | 0.1111 | 119 | 1699.06 | 1699.71 | 1699.4 | **1699.72** | 0.43 | 155.81 | 399.98 | 0.22 |
| | | | | | | | | | | | |
| 1 | 37 | 01:50 | 93 | 1698.78 | 1699.25 | 1699.08 | **1699.26** | 0.47 | 106.7 | 390.91 | 0.29 |
| 1 | 37 | 0.1111 | 119 | 1698.78 | 1699.3 | 1699.11 | **1699.32** | 0.53 | 127.68 | 403.28 | 0.3 |
| | | | | | | | | | | | |
| 1 | 36 | 01:50 | 93 | 1698 | 1698.47 | 1698.31 | **1698.49** | 0.62 | 80.44 | 319.53 | 0.4 |
| 1 | 36 | 0.1111 | 119 | 1698 | 1698.53 | 1698.35 | **1698.55** | 0.68 | 99.06 | 336.79 | 0.4 |
| | | | | | | | | | | | |
| 1 | 35 | 01:50 | 93 | 1696.96 | 1697.46 | 1697.27 | **1697.48** | 0.65 | 77.72 | 257.94 | 0.38 |
| 1 | 35 | 0.1111 | 119 | 1696.96 | 1697.53 | 1697.31 | **1697.55** | 0.69 | 96.77 | 291.76 | 0.38 |
| | | | | | | | | | | | |
| 1 | 34 | 01:50 | 93 | 1695 | 1695.33 | 1695.33 | **1695.44** | 1.46 | 34.33 | 158.14 | 1 |
| 1 | 34 | 0.1111 | 119 | 1695 | 1695.38 | 1695.38 | **1695.51** | 1.58 | 42.6 | 172.04 | 1.01 |
| | | | | | | | | | | | |
| 1 | 33 | 01:50 | 93 | 1686.74 | 1687.64 | 1687.35 | **1687.7** | 1.07 | 47.16 | 82.44 | 0.45 |
| 1 | 33 | 0.1111 | 119 | 1686.74 | 1687.76 | 1687.44 | **1687.83** | 1.16 | 57.64 | 89.26 | 0.46 |
| | | | | | | | | | | | |
| 1 | 32 | 01:50 | 93 | 1685.39 | 1685.96 | | **1686.05** | 1.33 | 37.77 | 97.69 | 0.68 |
| 1 | 32 | 0.1111 | 119 | 1685.39 | 1686.04 | | **1686.15** | 1.46 | 45.84 | 104.62 | 0.71 |
| | | | | | | | | | | | |
| 1 | 31 | 01:50 | 93 | 1681.23 | 1681.79 | 1681.79 | **1681.98** | 1.9 | 26.45 | 73.23 | 1.01 |
| 1 | 31 | 0.1111 | 119 | 1681.23 | 1681.88 | 1681.88 | **1682.09** | 2.04 | 32.89 | 79.15 | 1.01 |
| | | | | | | | | | | | |
| 1 | 30 | 01:50 | 93 | 1678.85 | 1680.14 | 1679.43 | **1680.16** | 0.54 | 92.41 | 111.78 | 0.19 |
| 1 | 30 | 0.1111 | 119 | 1678.85 | 1680.29 | 1679.52 | **1680.3** | 0.62 | 108.91 | 118.02 | 0.2 |
| | | | | | | | | | | | |
| 1 | 29 | 01:50 | 93 | 1679.01 | 1679.79 | | **1679.83** | 0.9 | 56.15 | 105.7 | 0.39 |
| 1 | 29 | 0.1111 | 119 | 1679.01 | 1679.91 | | **1679.96** | 0.96 | 69.74 | 114.58 | 0.39 |
| | | | | | | | | | | | |
| 1 | 28 | 01:50 | 93 | 1678.17 | 1679.1 | | **1679.13** | 0.81 | 61.97 | 103.66 | 0.33 |
| 1 | 28 | 0.1111 | 119 | 1678.17 | 1679.21 | | **1679.26** | 0.9 | 74.8 | 111.29 | 0.35 |
| | | | | | | | | | | | |
| 1 | 27 | 01:50 | 93 | 1677.44 | 1678.19 | | **1678.25** | 1.09 | 46.3 | 97.71 | 0.5 |
| 1 | 27 | 0.1111 | 119 | 1677.44 | 1678.3 | | **1678.37** | 1.17 | 57.37 | 104.9 | 0.5 |
| | | | | | | | | | | | |
| 1 | 26 | 01:50 | 93 | 1676.62 | 1677.61 | | **1677.63** | 0.64 | 78.27 | 121.57 | 0.26 |
| 1 | 26 | 0.1111 | 119 | 1676.62 | 1677.78 | | **1677.8** | 0.67 | 99.93 | 132.42 | 0.25 |
| | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25 | 01:50 | 93 | 1675.83 | 1677.56 | | **1677.56** | 0.27 | 186.11 | 163.82 | 0.08 |
| 1 | 25 | 0.1111 | 119 | 1675.83 | 1677.72 | | **1677.72** | 0.31 | 213.48 | 171.56 | 0.09 |
| | | | | | | | | | | | |
| 1 | 24 | 01:50 | 93 | 1675.13 | 1677.55 | | **1677.55** | 0.17 | 298.19 | 187.07 | 0.04 |
| 1 | 24 | 0.1111 | 119 | 1675.13 | 1677.71 | | **1677.71** | 0.2 | 328.61 | 193.2 | 0.05 |
| | | | | | | | | | | | |
| 1 | 23 | 01:50 | 93 | 1675.84 | 1677.53 | | **1677.53** | 0.26 | 190.04 | 170.94 | 0.08 |
| 1 | 23 | 0.1111 | 119 | 1675.84 | 1677.69 | | **1677.69** | 0.31 | 217.28 | 179 | 0.09 |
| | | | | | | | | | | | |
| 1 | 22 | 01:50 | 93 | 1676.29 | 1677.48 | | **1677.49** | 0.39 | 129.76 | 166.63 | 0.14 |
| 1 | 22 | 0.1111 | 119 | 1676.29 | 1677.63 | | **1677.64** | 0.43 | 155.15 | 176.87 | 0.15 |
| | | | | | | | | | | | |
| 1 | 21 | 01:50 | 93 | 1676.22 | 1677.41 | | **1677.41** | 0.31 | 159.91 | 202.3 | 0.11 |
| 1 | 21 | 0.1111 | 119 | 1676.22 | 1677.55 | | **1677.56** | 0.35 | 189.49 | 213.86 | 0.12 |
| | | | | | | | | | | | |
| 1 | 20 | 01:50 | 93 | 1675.96 | 1677.38 | | **1677.38** | 0.21 | 236.27 | 240.27 | 0.07 |
| 1 | 20 | 0.1111 | 119 | 1675.96 | 1677.51 | | **1677.52** | 0.25 | 269.92 | 250.17 | 0.08 |
| | | | | | | | | | | | |
| 1 | 19 | 01:50 | 93 | 1675.74 | 1677.36 | | **1677.36** | 0.19 | 266.92 | 246.74 | 0.06 |
| 1 | 19 | 0.1111 | 119 | 1675.74 | 1677.49 | | **1677.49** | 0.22 | 300.4 | 256.37 | 0.07 |
| | | | | | | | | | | | |
| 1 | 18 | 01:50 | 93 | 1675.71 | 1677.35 | | **1677.35** | 0.18 | 282.25 | 255.29 | 0.05 |
| 1 | 18 | 0.1111 | 119 | 1675.71 | 1677.48 | | **1677.48** | 0.21 | 315.91 | 264.36 | 0.06 |
| | | | | | | | | | | | |
| 1 | 17 | 01:50 | 93 | 1675.98 | 1677.33 | | **1677.33** | 0.21 | 238.58 | 253.2 | 0.07 |
| 1 | 17 | 0.1111 | 119 | 1675.98 | 1677.45 | | **1677.46** | 0.25 | 270.91 | 263.46 | 0.08 |
| | | | | | | | | | | | |
| 1 | 16 | 01:50 | 93 | 1675.9 | 1677.31 | | **1677.31** | 0.19 | 262.39 | 265.79 | 0.06 |
| 1 | 16 | 0.1111 | 119 | 1675.9 | 1677.43 | | **1677.43** | 0.23 | 294.99 | 274.98 | 0.07 |
| | | | | | | | | | | | |
| 1 | 15 | 01:50 | 93 | 1675.61 | 1677.3 | | **1677.3** | 0.15 | 339.05 | 291.21 | 0.04 |
| 1 | 15 | 0.1111 | 119 | 1675.61 | 1677.42 | | **1677.42** | 0.18 | 373.7 | 299.69 | 0.05 |
| | | | | | | | | | | | |
| 1 | 14 | 01:50 | 93 | 1675.54 | 1677.29 | | **1677.29** | 0.13 | 378.03 | 311.57 | 0.04 |
| 1 | 14 | 0.1111 | 119 | 1675.54 | 1677.41 | | **1677.41** | 0.16 | 414.26 | 319.15 | 0.05 |
| | | | | | | | | | | | |
| 1 | 13 | 01:50 | 93 | 1675.62 | 1677.29 | | **1677.29** | 0.14 | 354.49 | 307.5 | 0.04 |
| 1 | 13 | 0.1111 | 119 | 1675.62 | 1677.4 | | **1677.4** | 0.17 | 389.49 | 315.38 | 0.05 |
| | | | | | | | | | | | |
| 1 | 12 | 01:50 | 93 | 1675.71 | 1677.28 | | **1677.28** | 0.14 | 346.69 | 313.48 | 0.04 |
| 1 | 12 | 0.1111 | 119 | 1675.71 | 1677.39 | | **1677.39** | 0.18 | 381.59 | 322.79 | 0.05 |
| | | | | | | | | | | | |
| 1 | 11 | 01:50 | 93 | 1675.81 | 1677.27 | | **1677.27** | 0.16 | 310.24 | 301.52 | 0.05 |
| 1 | 11 | 0.1111 | 119 | 1675.81 | 1677.37 | | **1677.38** | 0.2 | 342.77 | 309.73 | 0.06 |
| | | | | | | | | | | | |
| 1 | 10 | 01:50 | 93 | 1676.11 | 1677.25 | | **1677.25** | 0.19 | 264.33 | 319.32 | 0.07 |
| 1 | 10 | 0.1111 | 119 | 1676.11 | 1677.35 | | **1677.36** | 0.23 | 297.36 | 329.56 | 0.08 |
| | | | | | | | | | | | |
| 1 | 9 | 01:50 | 93 | 1676.06 | 1677.22 | | **1677.22** | 0.27 | 183.35 | 279.8 | 0.11 |
| 1 | 9 | 0.1111 | 119 | 1676.06 | 1677.31 | | **1677.32** | 0.32 | 210.14 | 295.31 | 0.12 |
| | | | | | | | | | | | |
| 1 | 8 | 01:50 | 93 | 1676.43 | 1677.14 | | **1677.15** | 0.29 | 175.25 | 370.38 | 0.13 |
| 1 | 8 | 0.1111 | 119 | 1676.43 | 1677.22 | | **1677.23** | 0.33 | 205.88 | 383.01 | 0.14 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| 1 | 7 | 01:50 | 93 | 1676.52 | 1676.88 | 1676.75 | **1676.9** | 0.68 | 74.03 | 291.69 | 0.43 |
| 1 | 7 | 0.1111 | 119 | 1676.52 | 1676.94 | 1676.79 | **1676.96** | 0.73 | 92.34 | 309.97 | 0.43 |
| | | | | | | | | | | | |
| 1 | 6 | 01:50 | 93 | 1675.2 | 1675.76 | 1675.55 | **1675.79** | 0.76 | 66.03 | 177.26 | 0.4 |
| 1 | 6 | 0.1111 | 119 | 1675.2 | 1675.83 | 1675.6 | **1675.87** | 0.84 | 79.69 | 188.84 | 0.41 |
| | | | | | | | | | | | |
| 1 | 5 | 01:50 | 93 | 1673.52 | 1673.8 | 1673.78 | **1673.87** | 1.17 | 42.91 | 216.33 | 0.84 |
| 1 | 5 | 0.1111 | 119 | 1673.52 | 1673.85 | 1673.82 | **1673.93** | 1.28 | 52.59 | 226.2 | 0.84 |
| | | | | | | | | | | | |
| 1 | 4 | 01:50 | 93 | 1669.66 | 1670.13 | | **1670.19** | 1.09 | 45.94 | 153.47 | 0.64 |
| 1 | 4 | 0.1111 | 119 | 1669.66 | 1670.19 | | **1670.27** | 1.2 | 55.9 | 164.92 | 0.66 |
| | | | | | | | | | | | |
| 1 | 3 | 01:50 | 93 | 1665.56 | 1665.96 | 1665.96 | **1666.1** | 1.61 | 31.14 | 118.18 | 1 |
| 1 | 3 | 0.1111 | 109 | 1665.56 | 1666.02 | 1666.02 | **1666.18** | 1.74 | 38.51 | 126.77 | 1.01 |
| | | | | | | | | | | | |
| 1 | 2 | 01:50 | 93 | 1662.14 | 1662.7 | 1662.51 | **1662.74** | 0.81 | 62.2 | 168.09 | 0.42 |
| 1 | 2 | 0.1111 | 119 | 1662.14 | 1662.78 | 1662.56 | **1662.82** | 0.9 | 74.98 | 179.56 | 0.44 |
| | | | | | | | | | | | |
| 1 | 1 | 01:50 | 93 | 1659.99 | 1660.28 | 1660.28 | **1660.39** | 1.42 | 35.36 | 178.3 | 1.02 |
| 1 | 1 | 0.1111 | 119 | 1659.99 | 1660.33 | 1660.33 | **1660.45** | 1.51 | 44.55 | 193.37 | 1 |

### *10.2.3 <u>Flood line conclusions</u>*

The average froude number is 0.8 with the tributary having a maximum velocity of 2.04m/s. The minimum main channel elevation is based on the survey provided. Where the EG elevation is based on water surface and the energy passing through the tributary. The average slope is 0.005m/m which is fairly steep in certain areas.

The output tables indicates that Plant Site 1 is located out of the 1:100 year flood zones and therefore complies with the requirements of GN704 regarding restrictions on locality of dams.

**NOTE: FOR FLOOD LINE LAYOUTS INDICATING 1:50 AND 1:100 YEAR FLOOD LINES REFER TO APPENDIX 3.2.**

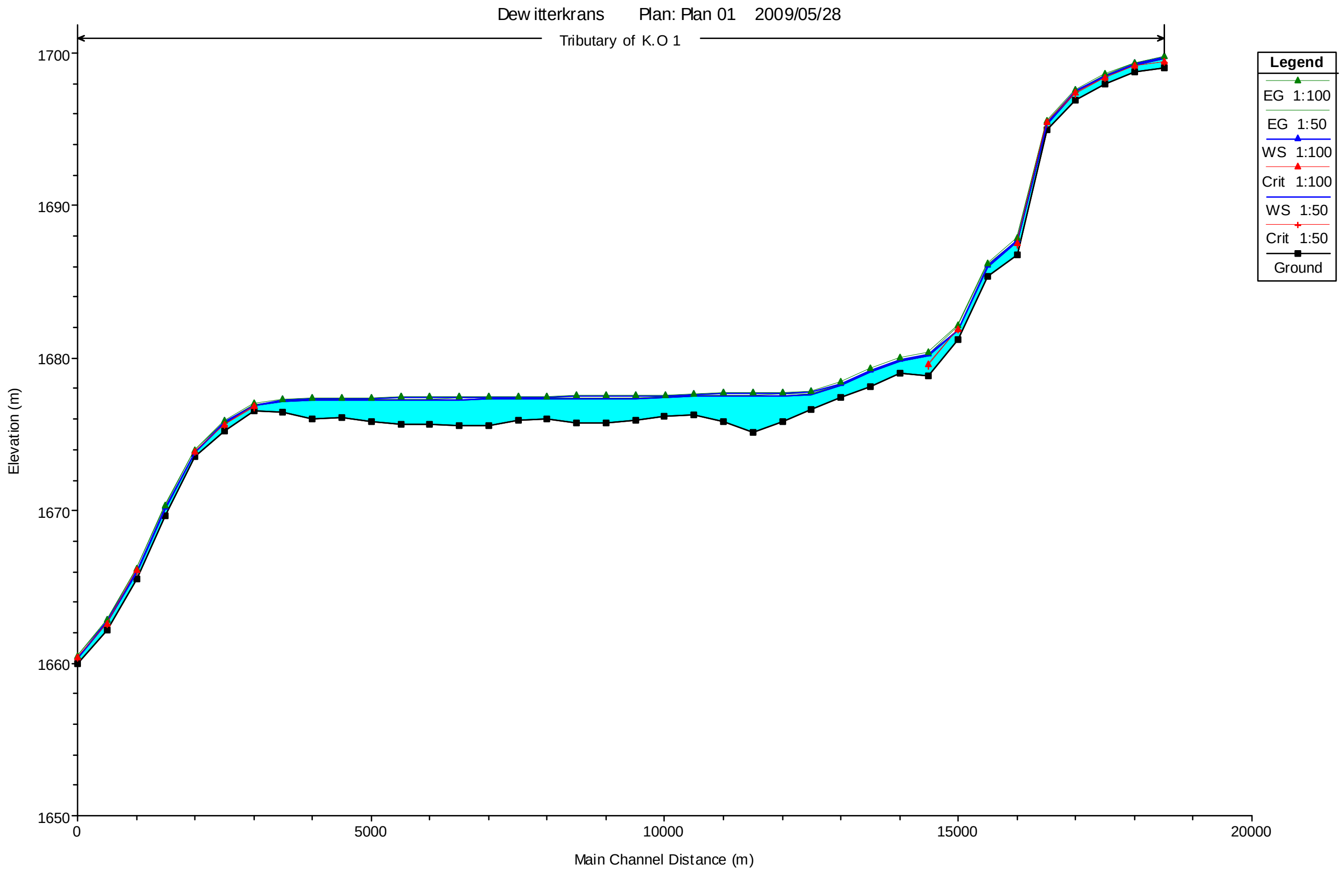
### *10.2.4 <u>Schedule of Reference</u>*


- Midgley, D.C., Pitman W.V., Middleton, B.J. 1994. Surface Water Resources of South Africa 1990. WRC Report No 298/1.1/94, Volume 1 and Appendices;
- Smithers, J.C. and Shulze, R.E., 2000b. Design rainfall and flood estimation in South Africa. WRC Report No 1060/1/03;

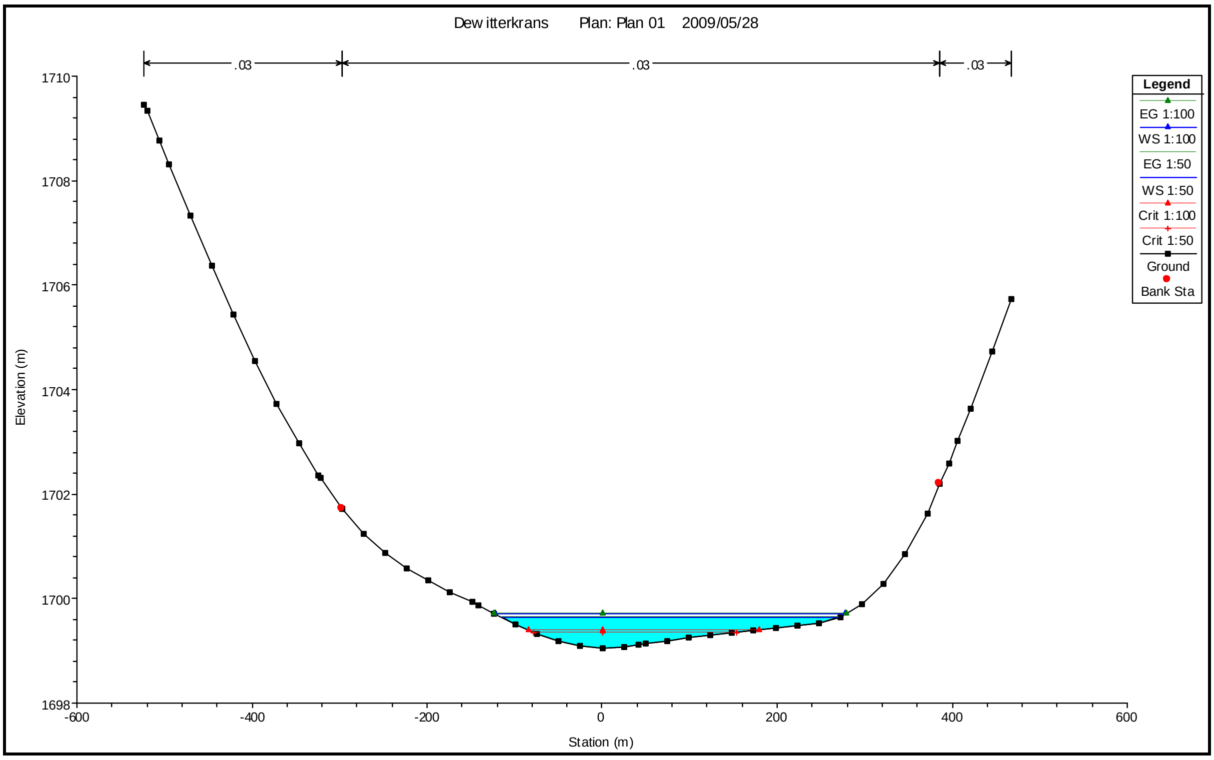
- Lynch, S.D. 1994. Raster (grid) Rainfall database of annual, monthly and daily rainfall for Southern Africa .WRC Report 1156/1/04, and

- Van Dijk, M. 2005. University of Pretoria, UP Flood, Flood Analyses Programs. April 2005. Users Manual Version 4.0.2

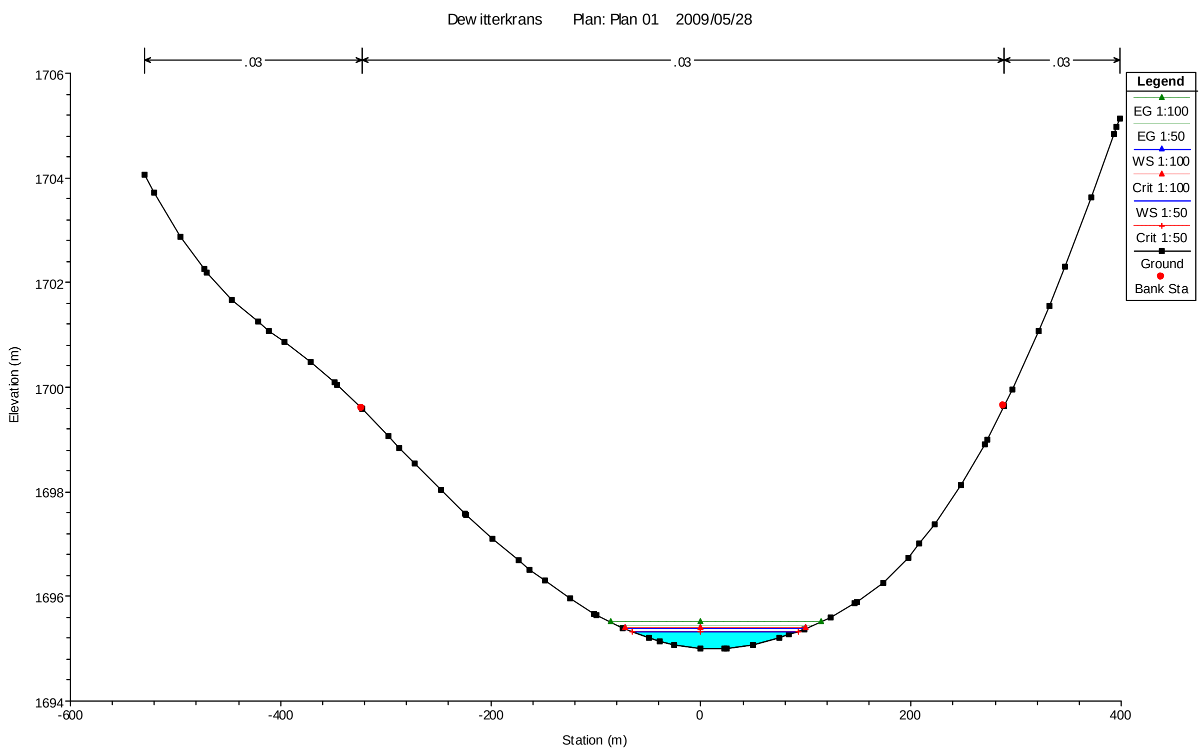
# Appendix 2.1: Long section



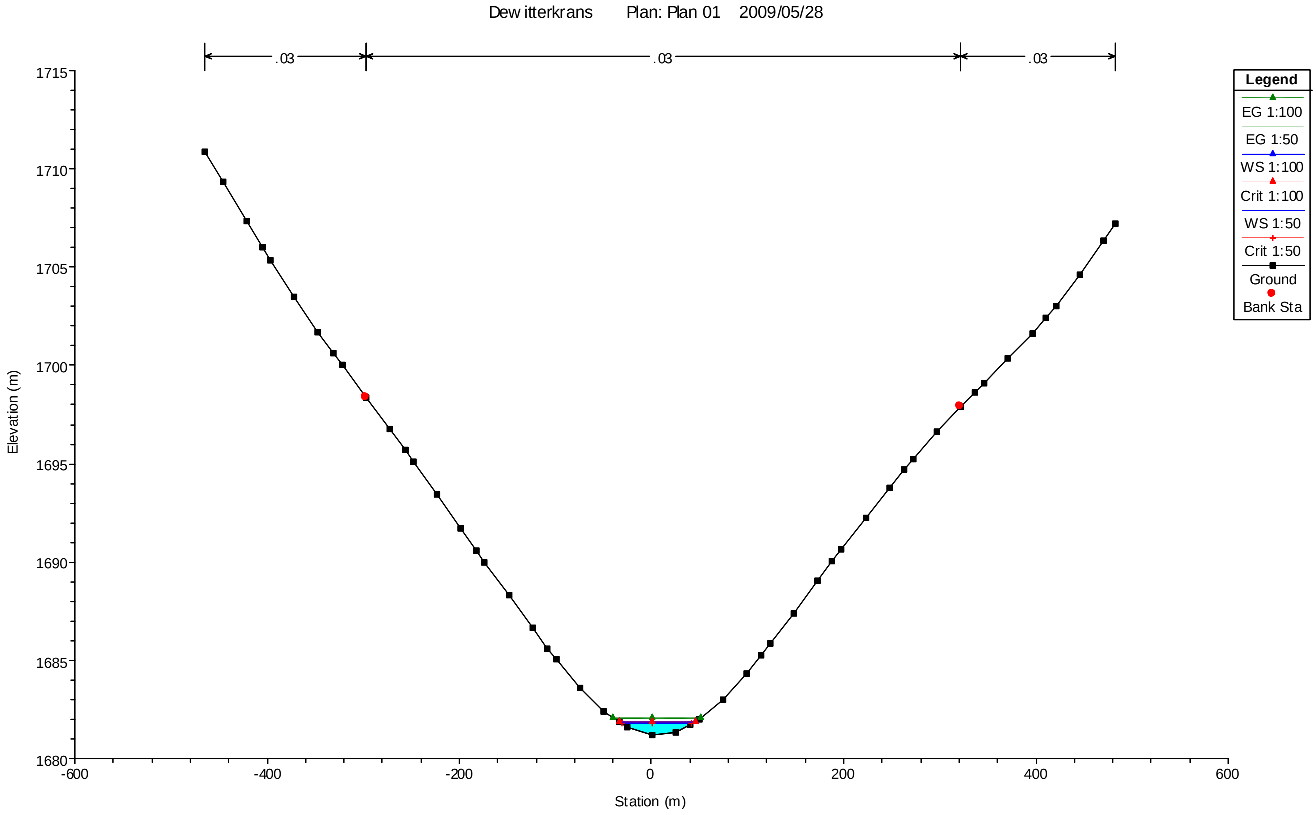
## Appendix 2.2: Cross section 38



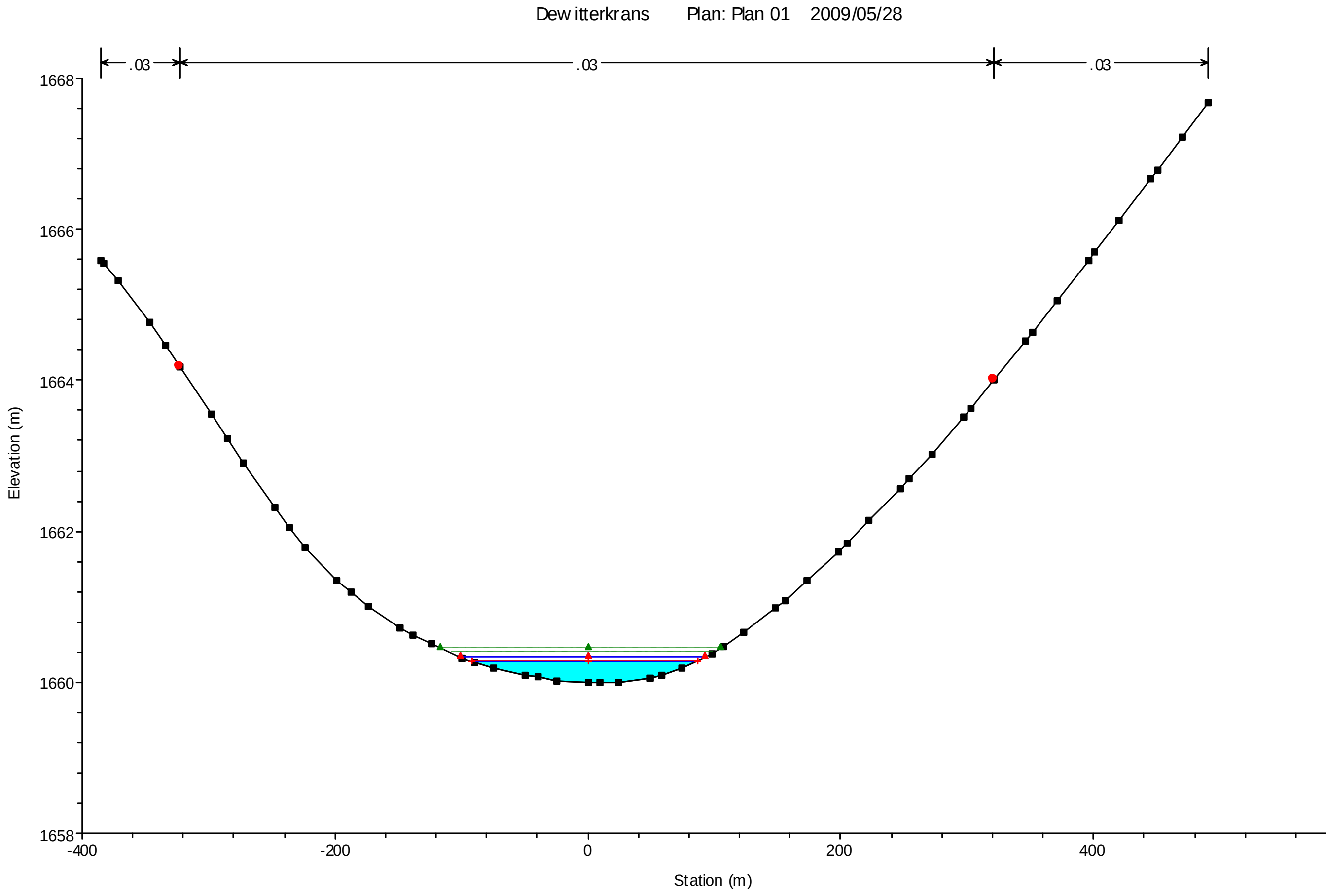

## Appendix 2.3: Cross section 34



# Appendix 2.4: Cross section 31



# Appendix 2.5: Cross section 1



# APPENDIX 2.6: FLOODLINE LAYOUT