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# Tropicana Joint Venture

AngloGold Ashanti Australia

Independence Group NL

## Tropicana Gold Project

## Operational Area Surface Water Assessment

Report

June 2009

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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# Executive Summary


### Background

AngloGold Ashanti Australia Limited (AngloGold Ashanti) on behalf of the Tropicana Joint Venture is currently undertaking a pre-feasibility study and progressing the environmental approvals for the proposed Tropicana gold project, located 330 km northeast of Kalgoorlie.

This report presents the results of an investigation into potential impacts on the existing hydrology from proposed mine infrastructure and on flood risk for the mine pit. An evaluation of these issues is needed to inform the mine planning process, to contribute to decisions on the footprint for key mine infrastructure, particularly the waste dump and tailings storage facility, and to define any potential environmental impact.

### Characteristics of the local hydrology

The majority of the drainage catchments upstream of the mine site are characterised by sandy soils, low relief, poorly defined drainage lines and areas with strong linear sand dunes and internal drainage. Accordingly, much of the catchments are not likely to produce stormwater at the mine site itself.

However, local drainage around the mine site has potential to produce stormwater that could impact on the mine infrastructure and operations. There is a drainage line/valley through the proposed processing area and tailings storage facility which probably conveys stormwater during larger rainfall events. There is also an area upstream of the processing plant that could pond stormwater for short periods after heavy rainfall. Stormwater flows and ponding can also occur to the east along the existing access road to the airport. Climate change could also cause increased runoff than currently experienced leading potentially to considerably higher stream flows and ponding at the mine site.

### Assessment of impact of mine infrastructure

The stormwater drainage concept for the site (presented in Section 3) allows for stormwater management on-site and for diversion of external stream flow. This concept along with the application of standard engineering design procedures for the design of access roads and other infrastructure outside of the main site area will minimise impact on the local environment.

There are not likely to be significant shadowing effects (i.e. reduction in surface water flows immediately downsteam) associated with the proposed infrastructure as a reduction in local flows is small relative to flows from the remainder of the contributing catchment at that point and as impact on local stormwater does not propagate downstream to any degree.

Discharge of stormwater with elevated levels of salt, sediment or contaminants to the environment is not likely as this stormwater will either be contained on-site or treated or infiltrated locally.

### Flood risk for the mine pit

Stormwater from the external catchment does not present a flood risk to the pit provided a drainage pathway from the south to the north is constructed and that a levee/minimum earthworks level along the western edge of the mine site is maintained.

# 1. Introduction

## 1.1 Background

AngloGold Ashanti Australia Limited (AngloGold Ashanti) on behalf of the Tropicana Joint Venture is currently undertaking a pre-feasibility study and progressing the environmental approvals for the proposed Tropicana gold project, located 330 km northeast of Kalgoorlie (Figure 1).

Surface water management issues need to be considered as part of the pre-feasibility and approvals process. The main surface water issues relate to impacts on the existing hydrology from proposed mine infrastructure and to flood risk for the mine pit. An evaluation of these issues is needed to inform the mine planning process, to contribute to decisions on the footprint for key mine infrastructure, particularly the waste dump and tailings storage facility, and to define any potential environmental impact.

This report presents the results of this investigation.

## 1.2 Scope of work

The general objective of this investigation is to review the impact of proposed mine infrastructure on existing hydrology and to characterise flood risk for the pit at the Tropicana prospect.

Specific areas to be covered include:

» Initial review of background material, desktop characterisation of hydrology and comment on required further work.

» Site visit to verify on-ground conditions.

» Assessment of impacts of the proposed mine infrastructure on hydrology, flow patterns and shadowing of downstream areas.

» Assessment of flood risk for the pit, based on proposed mine infrastructure.

» Suggestions for modification to the location or characteristics of mine infrastructure to better manage potential impacts on local hydrology or pit flood risk.

» Development of a concept stormwater management plan for the mine site.

» Summary of findings of the study and recommendations on further actions or work, if required.

The deliverable is this report, outlining the review results and presenting recommendations.

## 1.3 Summary of methods

The work was undertaken as a desktop review with a 2 day site visit. The analysis was based on information provided by AngloGold Ashanti and on readily available topographic information.

### 1.3.1 Data

The following data and information were available:

» 2 m and 4 m contour data, covering most of the catchment area upstream of the mine site, supplied by AngloGold Ashanti.

» Aerial imagery, covering the area of the mine site, supplied by AngloGold Ashanti.

- Location of the pit, waste dumps, tailings dam and other mine infrastructure, supplied by AngloGold Ashanti.
- 1:250,000 scale regional topographic and geology mapping.
- Results of infiltration measurements, undertaken by AngloGold Ashanti.
- A report presenting a hydrologic assessment of Tropicana, undertaken in 2007 by URS Australia Pty Ltd (URS 2007).
- Other reports and information as referenced.

The site visit was undertaken by GHD (R. Connolly) on the 13-14th February. Areas around the mine site, including the main drainage lines/valleys and the two upstream claypans were visited.

### 1.3.2 Rainfall analysis

Rainfall event information was derived using three methods: the Australian Rainfall and Runoff method (Pilgrim 2001) for average recurrence intervals (ARI) of 1 to 100 years; CRC-FORGE (Department of Environment 2004) for 500 and 1000-year ARI events; and from partial and annual series analysis of SILO (BoM 2008) daily rainfall record generated for the site. Note that there are discrepancies between rainfall amounts derived with the different methods, indicating uncertainty in the estimates.

An estimate of maximum change in rainfall as a result of climate change was made based on predictions by CSIRO OzClim (CSIRO 2008). Design rainfall was reduced by 10 % for 1-year ARI events and increased by 30% for 1000-year ARI events and varied between these ranges for events between 1 and 1000-year ARI.

### 1.3.3 Runoff analysis

An analysis of runoff volumes and catchment storage in depressions/claypans was undertaken using catchment and storage areas digitised using the available topographic data and with estimated runoff coefficients. Values used are discussed in Section 2.4.3.

Runoff was calculated by multiplying rainfall by a runoff coefficient, which varied with event duration and ARI. Runoff coefficients were estimated based on site observations, general knowledge of runoff in the area and considering values used in URS (2007).

Note that there is uncertainty in the runoff and storage analysis predictions as knowledge of runoff characteristics of the catchment is limited. A limited sensitivity analysis of the effect of varying runoff coefficient was undertaken to help understand the potential implications of uncertainty in the model parameters.

Measurements of infiltration at sites throughout the mine area were supplied by AngloGold Ashanti and these data were used to help inform estimates of runoff characteristics. The infiltration observations were collected by AngloGold Ashanti (Massoud Massoudi) in September 2007 using double ring, falling head permeameter (Photo 1). The internal diameter of the inside, measuring, ring was 155 mm. Steady state infiltration rates were converted from the observed ml per time period to mm/h based on a simple area transformation, not accounting for any sorptivity component.

### 1.3.4 Flood risk analysis

Flood risk for the mine pit was assessed based on ground surface elevation in the major drainage pathways/valleys through the mine area, likely pit rim levels (US1000 extent) and estimated peak design stormwater flows. Peak design flows were estimated with the Rational Method (Pilgrim 2001) using Arid Zone parameter values. The US1000 pit boundary was assessed as this is likely to be the largest pit extent. Smaller pit shells have been identified by AngloGold Ashanti (US700 and US600) but these fall within the US1000 footprint and so will have a similar or smaller flood risk than with the US1000 pit.

Note that, due to limited calibration data, there is uncertainty in peak design flow predictions.

### 1.3.5 Environmental impact analysis

An evaluation of potential environmental impact was made based on the supplied mine layout and the hydrologic analysis. It was assumed that:

- Rain falling on the tailings storage facility, process plant area, waste dumps and in the pit would be captured and reused on-site.
- On closure, disturbed areas would be reshaped and rehabilitated and infrastructure removed.

### 1.3.6 Stormwater management concept

The concept stormwater management plan for the mine operational phase was developed based on the following assumptions:

- Development of a pathway for stormwater sourced from the south and west of the site to be conveyed past the mine site.
- Collection of stormwater from the waste dumps and process plant in a drainage and storage network.
- Immediate use for processing/road watering of water collected in storages.
- Storages to contain stormwater from a 100-year ARI event.
- Storages to be lined to minimise leakage if receiving potentially contaminated stormwater.
- Storages to lie under the proposed waste dump footprint, where possible, with a view to incorporating the storages into the waste dump on toward closure.
- The mine pits, waste dumps and infrastructure are developed to their maximum extent.

The criteria for closure were based on:

- Retention of the diversion pathway west of the mine site.
- Removal of general infrastructure and rehabilitation of the landform.
- Diversion of stormwater sourced from rehabilitated waste dumps and process plant areas to the old pit, where possible, or to infiltration areas with intermittent overflow to the regional drainage network.

Note that the infrastructure location and dimensions are indicative and are not suitable for construction in their current form.

**Photo 1 Ponded ring used for infiltration measurements**

Photo source: AngloGold Ashanti.

# 2. Characterisation of hydrology

## 2.1 Introduction

Local hydrology has been described in a study undertaken in 2007 by URS Pty Ltd (URS 2007). This study focused on defining the catchments that contribute flow to the area of the mine site and on quantifying flooding risk for the pit. The hydrologic characterisation given by URS (2007) is summarised here and extended as required to assess impacts of mine infrastructure on surface water movement and the environment and on pit flood risk.

Note that there is some variation between catchments delineated by URS (2007) and as presented in this report. Differences may have been due to varying interpretation methods or data. GHD did not have access to the URS data and interpretation to check the cause of the differences.

Infiltration measurements through the mine area have also been provided by AngloGold Ashanti. These are summarised here and used to help infer runoff potential for contributing catchments.

The mine site is located in an area with little local hydrologic and catchment data and relatively coarse topographic data. Accordingly, the analysis is limited to the extent that interpretation can be drawn from the available data.

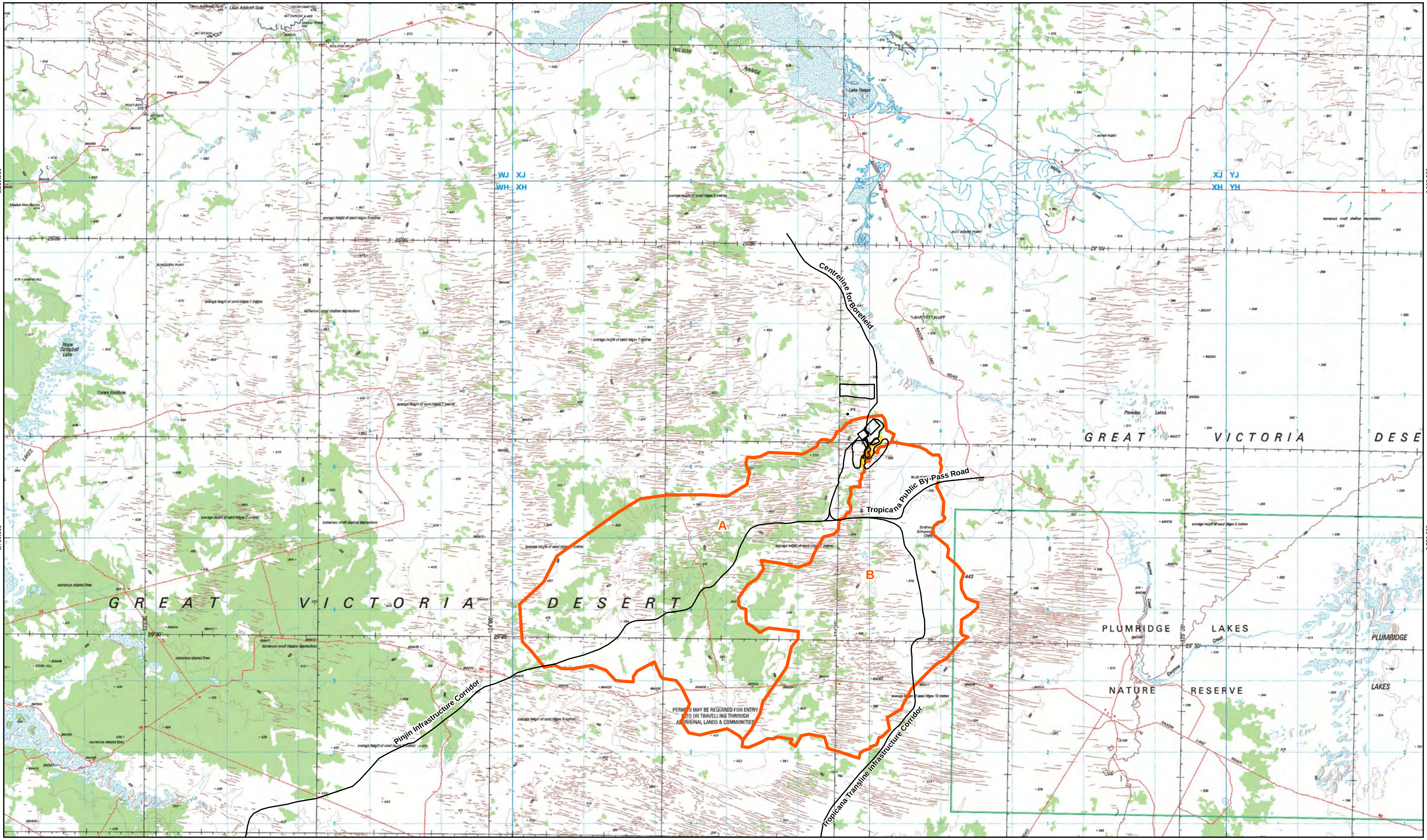
## 2.2 Regional hydrology

The mine site lies within the drainage basin for Lake Rason. Regional drainage is shown in Figure 1. A Lake Rason drainage line lies some 6 km northeast of the downstream edge of the proposed location of mine infrastructure and the main lake lies some 50 km to the north.

Lake Rason is classified as a wetland with regional significance (Australian Government 2008) and is significant for the maintenance of regional ecological processes. The main lake system occupies an area of some 140 $km^2$, fills intermittently after rainfall and is saline (Australian Government 2008). It is unlikely that Lake Rason ever fills to capacity and overtops. Water ponded in the lake is probably lost to evaporation and seepage.

Ponding in Lake Rason and its associated drainage system does not appear to affect drainage or flooding at the mine site. While the available detailed topographic data does not extend as far as this drainage line, aerial imagery does not indicate a connection between the overland flow path near the mine and the lake drainage. Ponding in the lake, as evidenced by salt deposition, does not extend as far south as the mine site.

Regional geology is shown in Figure 2. The area is mapped as mainly eolian sands with areas of colluvium.




1:500,000 at A3

0 2.5 5 10 15 20

Kilometres

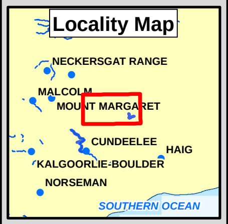
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

N

LEGEND

**Conceptual Site Layout**
**AngloGold Ashanti Australasia - 200808**

- Access Roads
- Proposed Mine Infrastructure
- US1000 Shell - AngloGold Ashanti Australia - 200707
- Catchments - GHD - 20080218

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Operational Area
Surface Water Assessment

# Regional Drainage

| | |
|---|---|
| Job Number | 6121984 |
| Revision | 1 |
| Date | June 2009 |

Figure 1

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Note that positional errors can be > 5m in some areas. Dataset names include published date where available. Background taken from 1:250,000 Topographic Mosaic, Geoscience Australia, May 2004. Created by: K Iralu

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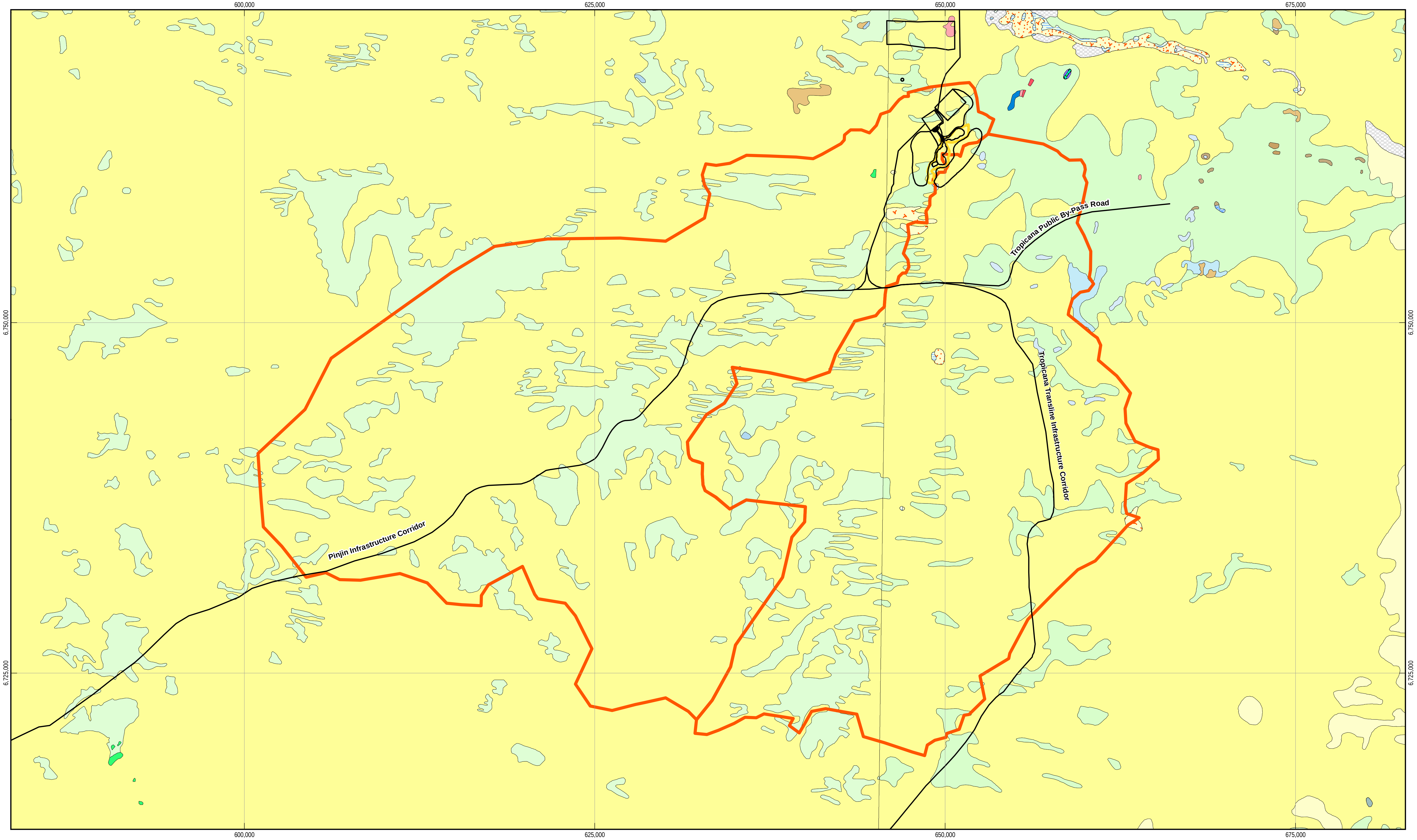


1:250,000 at A3

0 1.25 2.5 5 7.5 10

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

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LEGEND

Access Roads

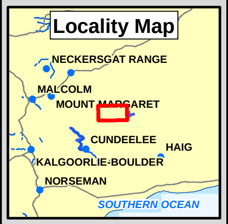
Proposed Mine Infrastructure

Catchments - GHD - 20080218

US1000 Shell
AngloGold Ashanti Australia - 200707

**1:250,000 Geology - GSWA - 1972**

Qrd, Qrf, Qro, Qrk, Qre, Qo, Ql, Qe, Qpe, Qs, Czs, Czb, Czj, Czc, Pa, Paf, Pag, Pal, P_p, P_u, P_gy, P_gl, P_m, P_b, pEg, pEc, Ad, Ar, Af

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# Regional Geology

| | |
|---|---|
| Job Number | 6121984 |
| Revision | 1 |
| Date | June 2009 |

Figure 2

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Dataset names include published date where available. Minigwal 250k Geology Sheet SH 51-7 (1972) and Plumridge 250k Geology Sheet SH 51-8 (1972) sourced from Geoscience Australia. Created by: K Iralu

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## 2.3 Weather

### 2.3.1 Climate

The climate of the area is classified as hot, persistently dry desert, according to a modified Koëppen climate classification system (BoM 2008). Average annual rainfall for the area is 173 mm (URS 2007). Rainfall can occur all year round, though average monthly rainfall tends to be slightly higher from December to June. Rainfall is highly variable.

The mine site is subject to the influence of tropical cyclones (URS 2007). Heavy rainfall can be received during summer as a result of dissipating cyclones, which occasionally trend toward the mine site from the northwest. Considerable year-to-year variation in cyclone occurrence and intensity occurs in the area (BoM 2008), meaning that rainfall and flood events are intermittent and variable in size and nature.

### 2.3.2 Rainfall events

Rainfall amounts for events of various durations and recurrence intervals are given in Table 1.

The data indicate that rainfall events tend to occur either in durations of up to one-two days or in wet periods of up to three months. Rainfall intensity in events with durations of one hour or less can exceed 100 mm/h, which is likely to produce some runoff even on very sandy soils.

Note that there are discrepancies in the rainfall amount for some events calculated using different methods; this is presumably due to limited data available for the area and to distortions caused by the methodologies.

An estimate of design rainfall associated with climate change (estimated using OzClim, CSIRO 2008) is shown in Table 1 for a 3-day duration event. The predictions indicate that smaller ARI events could show a reduction in rainfall volume while larger events could increase by as much as 30%.

### 2.3.3 Local catchments and drainage

There are two main local catchments at the mine site – an eastern catchment and a western catchment. URS (2007) termed these Catchments A and B respectively, and this terminology is maintained here. Catchments are shown on Figure 1 and local drainage and topography is shown on Figure 3.

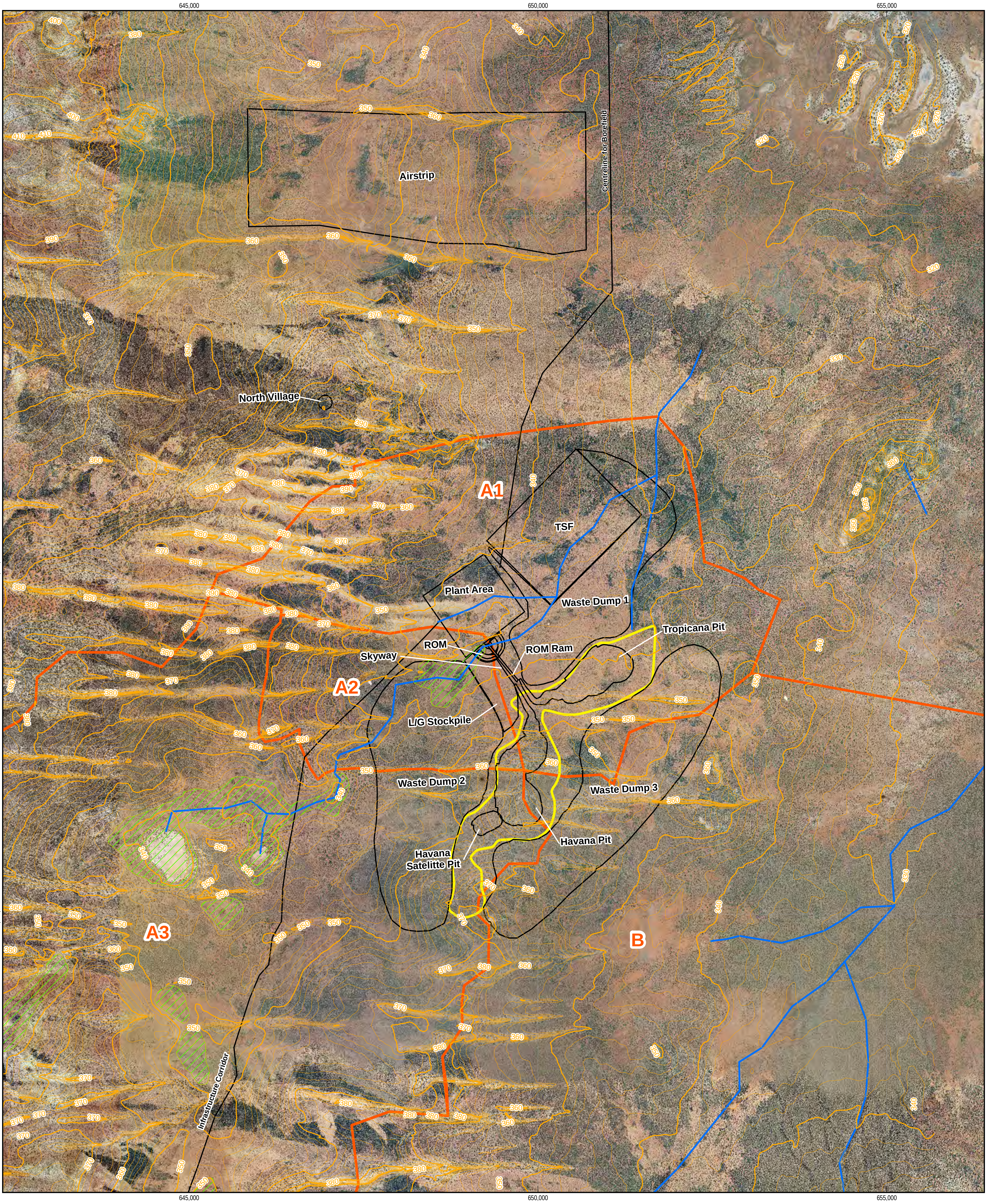
Drainage in the mine site catchments is from the southwest to the northeast, toward the southern reaches of the Lake Rason system. The catchments extend some 50 km from the mine site toward the southwest.

The mine pit and associated infrastructure are located mainly in Catchment A, on the western slopes of the north-easterly trending ridgeline and in the valley to the west. Parts of Waste Dump 3 lies in Catchment B and the access road to the existing airstrip crosses the Catchment B valley.

### Table 1 Event rainfall amounts

| Duration | Point rainfall (mm) for ARI (years) | | | | |
|---|---|---|---|---|---|
| | **1** | **10** | **100** | **500** | **1000** |
| 30 min* | 8 | 18 | 33 | | |
| 30 min*** | | | 47 | 61 | 68 |
| 1 h* | 10 | 24 | 42 | | |
| 1 h*** | | | 57 | 75 | 84 |
| 1 day* | 18 | 42 | 75 | | |
| 1 day** | 13 | 39 | 64 | | |
| 1 day*** | | | 105 | 139 | 154 |
| 2 day* | 25 | 63 | 116 | | |
| 2 day** | 21 | 52 | 79 | | |
| 2 day*** | | | 118 | 156 | 174 |
| 3 day* | 28 | 77 | 151 | | |
| 3 day** | 28 | 65 | 82 | | |
| 3 day*** | | | 124 | 164 | 183 |
| 3 day**** | 25 | 73 | 166 | 197 | 238 |
| 7 day** | 51 | 71 | 118 | | |
| 1 month** | 41 | 100 | 181 | | |
| 3 month** | 117 | 186 | 305 | | |
| 1 year** | - | 290 | 441 | | |

* Calculated using the method in Pilgrim (2001); ** calculated using partial/annual series analysis of SILO Data Drill data (BoM 2008); *** calculated using the CRC-FORGE method (DoW 2004); **** maximum, adjusted for climate change.




LEGEND

Contours (2m) - AngloGold Ashanti Australasia - 2008

Drainage Lines - GHD - 20040201

**Conceptual Site Layout - AngloGold Ashanti Australasia - 200808**

Access Roads

Proposed Mine Infrastructure

Storage (Natural) - GHD - 20080827

US1000 Shell
- AngloGold Ashanti Australia - 200707

Catchments - GHD - 20080218

1:50,000 (at A3)

0 0.25 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

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Locality Map

Tropicana Gold Project
Operational Area
Surface Water Assessment

Local Drainage

| | |
|---|---|
| Job Number | 6121984 |
| Revision | 1 |
| Date | June 2009 |

Figure 3

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## 2.4 Runoff characteristics

### 2.4.1 Soils and landscape

Catchments A and B are characterised by low relief, poorly defined drainage lines and areas with strong linear sand dunes and internal drainage.

URS (2007) estimated that only about 26% of Catchment A, that nearest the mine site, drains to the catchment outlet. Infiltration rates in the upper part of the catchment are high, so runoff is low, and what runoff does occur is trapped by sand dunes and in local depressions. The lower part of the catchment appears to drain, but still contains local depressions which retain stormwater and there are no well-defined watercourses. The lower parts of Catchment A contain colluvium soils, which are likely to produce more runoff than sandy areas.

Catchment B has similar characteristics to Catchment A, with sand dunes in the upper catchment, internally drained areas and poorly defined, low-gradient drainage lines. URS (2007) estimated that about 30% of the catchment would produce runoff at the catchment outlet (i.e. east of the mine site).

A site visit by GHD staff (R Connolly) in February 2008 confirmed that there are few defined stream channels or watercourses in the area of the mine site. Photo 2 shows a typical sand dune near the mine site (just south of Salty Dog) and Photos 3, 4 and 8 show drainage lines/valleys throughout the site. The lack of defined channels indicates that runoff rates are low and any stormwater probably flows as shallow, slow-moving sheet flow. Stormwater probably infiltrates soon after the rainfall event.

Site staff observed stormwater ponding during and after a rainfall event which occurred in mid December 2007. A total of 56 mm of rain fell over 5 days. This corresponds to an ARI of about 2 years (see Table 1). Ponding was observed in a low-lying area near the airport during and after the event. The ponded water then dissipated over subsequent days.

There is also little evidence of salt accumulation normally associated with regular sustained ponding in depressions and claypans in the region, indicating that these areas infrequently store stormwater. Photos 5, 6 and 7 show areas with potential storage and claypans near the mine site.

Colluvium areas show signs of surface crusting and hard setting, indicating potential for runoff during higher intensity rainfall events. Photo 9 shows crusting/hard-setting in the drainage line downstream of the mine site.

**Photo 2 Sand dune (Salty Dog)**

**Photo 3 Drainage line/valley downstream (north) of the mine site**

**Photo 4 Drainage line/valley at the proposed process plant location**

**Photo 5 Storage area upstream (south) of the proposed process plant location**

**Photo 6 Small claypan upstream of the proposed process plant location**

**Photo 7 Large claypan upstream of the proposed process plant location**

**Photo 8 Drainage line/valley in Catchment B**

**Photo 9 Crusting/hardsetting, lower Catchment A**

### 2.4.2 Infiltration observations

A summary of infiltration test observations, as made by AngloGold Ashanti, is given in Table 2. Site locations are plotted in Figure 4.

The test results indicate considerable variation in infiltration rates. Sandy soils have high infiltration, as expected. Infiltration rate tends to fall with increasing proportion of clay material. The claypan tested (Site IT007) had relatively low infiltration rates and possibly exhibited non-wetting tendencies.

**Table 2 Infiltration test observations**

| Site | Steady infiltration rate (mm/h) | Soils | Observation |
|---|---|---|---|
| IT003 | 343 | Sandy with some fine clay material. | Reasonably flat area with large trees. Situated close to the access road. |
| IT004 | 241 | Sandy with fine clay material. A hard crest has formed on the top layer above the softer material. | A gentle drop with surrounding trees and vegetation. |
| IT005 | 158 | Sandy with a much higher clay content and fine material and the surface crest is harder. | |
| IT006 | 537 | Very sandy with much less fine material. | Positioned between the dunes which are up to 20 m to 30 m high. |
| IT007 | 39 | Claypan and a major water collection area. | After the test was completed and the ring was removed, the material under the ring (100 mm depth) was dry soil. Water penetration is minimal. |
| IT008 | 231 | Very close to the dunes and the soil is sandy. | Approximately 100 m to 150 m distance to a major dune. |
| IT009 | 162 | Sandy with a reasonably high content of fine clay for Tropicana. | Positioned close to mine access road in the flat area with smaller vegetation and trees. |

Data source: AngloGold Ashanti.

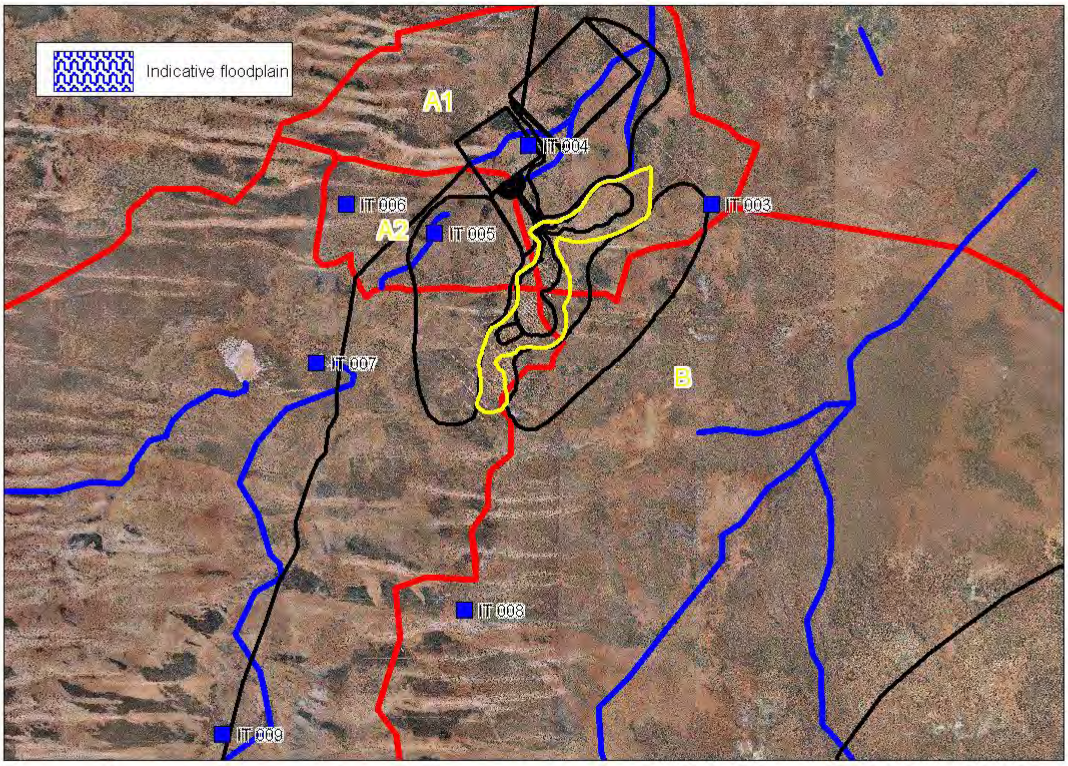



**Figure 4 Infiltration test locations**

### 2.4.3 Runoff and lake storage

Runoff predictions describing the estimated catchment response to rainfall and an evaluation of the runoff needed to produce overtopping of the storage areas just upstream of the mine site (storage 21, in sub-catchment A3 and storage 27 in sub-catchment A2) is given in Table 2. Catchment B was not simulated in detail as most of the mine infrastructure lies in Catchment A. Two estimates of runoff parameters are made – a best estimate, and that required for key storages to overtop.

Based on the URS (2007) conclusions and on study of topographic information, the upper parts of Catchments A (sub-catchment A4) and B (sub-catchment B2) were assumed to not generally contribute stormwater to the lower parts of the catchment. Any runoff in the upper catchments could be trapped in the distributed network of sand dunes and associated internally drained areas. There is uncertainty in this assumption, though, and this needs to be borne in mind in the design of mine infrastructure and in risk planning.

For the most likely catchment parameters and assuming current rainfall conditions, storage in sub-catchments A2 and A3 appeared to be large enough to contain stormwater from events up to a 1000-year ARI of any duration, assuming the storages were dry prior to the start of rainfall and with the best-estimate runoff parameters. If runoff in large events is higher than expected, these storages are likely to have sufficient capacity to contain stormwater from at least a 100-year ARI event but events larger than that could cause overtopping.

In the event of climate change of the magnitude discussed in Section 2.3, runoff volumes could increase to the point that short-duration 100-year ARI events could cause overtopping of storages in sub-catchments A2 and A3.

There is no significant storage in sub-catchments A1 or B1, so these areas could produce stormwater flows during larger events.

Accordingly, mine planning should allow for drainage from the sub-catchment immediately around the mine site (sub-catchment A1), but also allow for the risk that stormwater could exceed the capacity of upstream catchments and contribute to flows through the mine area.

## Table 3 Predicted ponding

| Scenario | Cmnt. area | Rain area | Evap. area | Store cap. | Rainfall duration | Rain* | Rain* | Runoff coef. | Runoff | Runoff | Evap. | Evap. | Net ponding | Overflow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ($km^2$) | ($km^2$) | ($km^2$) | (ML) | (days) | (mm) | (ML) | (%) | (mm) | (ML) | (mm) | (ML) | (ML) | (ML) |
| *Storage 21, sub-catchment A3:* | | | | | | | | | | | | | | |
| Average annual | 187.3 | 5.2 | 5.2 | 10,091 | 365 | 173 | 907 | 2 | 3.5 | 648 | 2,378 | 12,476 | 0 | 0 |
| 1-year, ARI 72 h | 187.3 | 5.2 | 5.2 | 10,091 | 3 | 24 | 127 | 2 | 0.5 | 90 | 19 | 102 | 115 | 0 |
| 100-year ARI 72 h | 187.3 | 5.2 | 5.2 | 10,091 | 3 | 130 | 682 | 5 | 6.5 | 1,218 | 19 | 102 | 1,798 | 0 |
| 100-year ARI 72 h, runoff rate required to overtop storage | 187.3 | 5.2 | 5.2 | 10,091 | 3 | 130 | 682 | 40 | 52.0 | 9,742 | 19 | 102 | 10,322 | 232 |
| 500-year ARI 72 h | 187.3 | 5.2 | 5.2 | 10,091 | 3 | 164 | 861 | 7 | 11.5 | 2,152 | 19 | 102 | 2,910 | 0 |
| 1000-year ARI 72 h | 187.3 | 5.2 | 5.2 | 10,091 | 3 | 183 | 959 | 10 | 18.3 | 3,426 | 19 | 102 | 4,283 | 0 |
| 1000 year 72 h, climate change | 187.30 | 5.25 | 5.25 | 10,091 | 3 | 238 | 1,247 | 10 | 23.8 | 4,453 | 19 | 102 | 5,599 | 0 |
| 100-year ARI 0.5 h | 187.3 | 5.2 | 5.2 | 10,091 | 0.02 | 20 | 106 | 54 | 10.8 | 2,030 | 0 | 1 | 2,135 | 0 |
| 100-year ARI 0.5 h, runoff rate required to overtop storage | 187.3 | 5.2 | 5.2 | 10,091 | 0.02 | 20 | 106 | 100 | 20.2 | 3,774 | 0 | 1 | 3,879 | 0 |
| 500-year ARI 0.5 h | 187.3 | 5.2 | 5.2 | 10,091 | 0.02 | 61 | 321 | 70 | 42.9 | 8,035 | 0 | 1 | 8,355 | 0 |
| 1000-year ARI 0.5 h | 187.3 | 5.2 | 5.2 | 10,091 | 0.02 | 68 | 356 | 75 | 50.9 | 9,527 | 0 | 1 | 9,882 | 0 |
| 1000 year 0.5 h climate change | 187.30 | 5.25 | 5.25 | 10,091 | 0.02 | 88 | 462 | 75 | 66.1 | 12,386 | 0 | 1 | 12,847 | 2,757 |
| 100-year ARI 12 h | 187.3 | 5.2 | 5.2 | 10,091 | 0.50 | 73 | 382 | 5 | 3.7 | 697 | 3 | 17 | 1,062 | 0 |
| 100-year ARI 12 h, 100-year ARI 72 h, runoff rate required to overtop storage | 187.3 | 5.2 | 5.2 | 10,091 | 0.50 | 73 | 382 | 72 | 52.5 | 9,833 | 3 | 17 | 10,198 | 108 |
| 100-year ARI 3 month | 187.3 | 5.2 | 5.2 | 10,091 | 90 | 305 | 1,600 | 2 | 6.1 | 1,143 | 583 | 3,059 | 0 | 0 |
| *Storage 27, sub-catchment A2:* | | | | | | | | | | | | | | |
| Average annual | 6.8 | 0.4 | 0.4 | 443 | 365 | 173 | 77 | 2 | 3.5 | 23 | 2,378 | 1,052 | 0 | 0 |
| 1-year ARI 72 h | 6.8 | 0.4 | 0.4 | 443 | 3 | 28 | 12 | 2 | 0.6 | 4 | 19 | 9 | 8 | 0 |
| 100-year ARI 72 h | 6.8 | 0.4 | 0.4 | 443 | 3 | 151 | 67 | 5 | 7.6 | 51 | 19 | 9 | 110 | 0 |
| 100-year ARI 72 h, runoff rate required to overtop storage | 6.8 | 0.4 | 0.4 | 443 | 3 | 151 | 67 | 38 | 57.5 | 389 | 19 | 9 | 448 | 5 |

| Scenario | Cmnt. area | Rain area | Evap. area | Store cap. | Rainfall duration | Rain* | Rain* | Runoff coef. | Runoff | Runoff | Evap. | Evap. | Net ponding | Overflow |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 500-year ARI 72 h | 6.8 | 0.4 | 0.4 | 443 | 3.00 | 164 | 73 | 7 | 11.5 | 78 | 19 | 9 | 142 | 0 |
| 1000-year ARI 72 h | 6.8 | 0.4 | 0.4 | 443 | 3.00 | 183 | 81 | 10 | 18.3 | 124 | 19 | 9 | 196 | 0 |
| 1000 year 72 h climate change | 6.78 | 0.44 | 0.44 | 443 | 3 | 238 | 105 | 10 | 23.8 | 161 | 19 | 9 | 258 | 0 |
| 100-year ARI 0.5 h | 6.8 | 0.4 | 0.4 | 443 | 0 | 33 | 14 | 54 | 17.5 | 118 | 0 | 0 | 133 | 0 |
| 100-year ARI 0.5 h, runoff rate required to overtop storage | 6.8 | 0.4 | 0.4 | 443 | 0 | 33 | 14 | 100 | 32.5 | 220 | 0 | 0 | 235 | 0 |
| 500-year ARI, 0.5 h | 6.8 | 0.4 | 0.4 | 443 | 3.00 | 61 | 27 | 70 | 42.9 | 291 | 19 | 9 | 309 | 0 |
| 1000-year ARI 0.5 h | 6.8 | 0.4 | 0.4 | 443 | 3.00 | 68 | 30 | 75 | 50.9 | 345 | 19 | 9 | 366 | 0 |
| 1000 year, 0.5 h climate change | 6.78 | 0.44 | 0.44 | 443 | 3 | 88 | 39 | 75 | 66.1 | 448 | 19 | 9 | 478 | 35 |
| 100-year ARI 12 h | 6.8 | 0.4 | 0.4 | 443 | 1 | 93 | 41 | 5 | 4.8 | 32 | 3 | 1 | 72 | 0 |
| 100-year ARI 12 h, runoff rate required to overtop storage | 6.8 | 0.4 | 0.4 | 443 | 1 | 93 | 41 | 64 | 59.8 | 405 | 3 | 1 | 445 | 2 |
| 100-year ARI 3 month | 6.8 | 0.4 | 0.4 | 443 | 90 | 305 | 135 | 2 | 6.1 | 41 | 583 | 258 | 0 | 0 |

* Rainfall reduced for areal extent.

### 2.4.4 Design peak flows

A summary of predicted design peak flows for the mine-site catchment, pre mine development, is given in Table 4. Predictions for the lower part of the catchment (sub-catchments A1 and B1), for which the storage capacity analysis indicated would contribute flow, are given. Predictions for the total catchment are also given, to illustrate a possible flow in the event of the catchment storages upstream overtopping. Predictions are for the sub-catchment outlet. Flows further up within the sub-catchment (e.g. through the mine site in sub-catchment A1) will be proportionally smaller.

Note that these predictions are based on few data and accordingly have a degree of uncertainty.

With the upper catchment included, the 100-year average recurrence interval (ARI) flow for Catchment A is predicted to be 135 $m^3/s$. Without the upper section, the 100-year ARI flow reduces to 50 $m^3/s$, or to about 40% of the design peak flow for the total catchment. The sub-catchment A1 flow will reduce the peak flow to 28 $m^3/s$ after capture of stormwater on infrastructure effectively reduces the catchment size.

A potential 100-year ARI flow of 28 $m^3/s$ at the outlet of the undeveloped sub-catchment A1 is substantial, and allowance for a drainage pathway through the mine are should be made to allow for this flow to pass the mine area, both during mining and after closure.

A 100-year ARI event would likely produce slow-moving flooding in the drainage line/valley through the mine area of between 75 and 200 m wide at up to 1 m deep. As there are few defined streamlines in the area and land grades are low, this would most likely occur as slow moving, relatively shallow floodwater, occurring over a period of up to several days. An estimate of the floodplain extent in the vicinity of the mine site is shown in Figure 5.

It appears unlikely that the upper catchment will contribute stormwater to the lower catchment, but for planning purposes and given the uncertainty in our understanding of catchment characteristics and potential for climate change, it is appropriate to consider both cases.

**Table 4 Predicted design peak flows**

| Catchment | Area | Design peak flow for ARI (years), ($m^3/s$) | | |
|---|---|---|---|---|
| | ($km^2$) | 1 | 10 | 100 |
| A – total, undeveloped | 1,048 | 2 | 38 | 135 |
| A1- catchment containing the mine site, undeveloped | 23 | 1 | 15 | 50 |
| A1- catchment containing the mine site less internal drainage on process plant, waste dumps and tailings storage facility | 13 | 1 | 8 | 28 |
| B – total, undeveloped | 809 | 3 | 48 | 167 |
| B1- lower catchment only, undeveloped | 132 | 1 | 23 | 77 |
| B1- lower catchment only, less internal drainage on pit and Waste Dump 3 | 128 | 1 | 22 | 75 |

* Average recurrence interval; calculated using the Rational Method, Arid Zone Parameter values (Pilgrim 2001); assumes current rainfall conditions; catchments are shown in Figure 3.

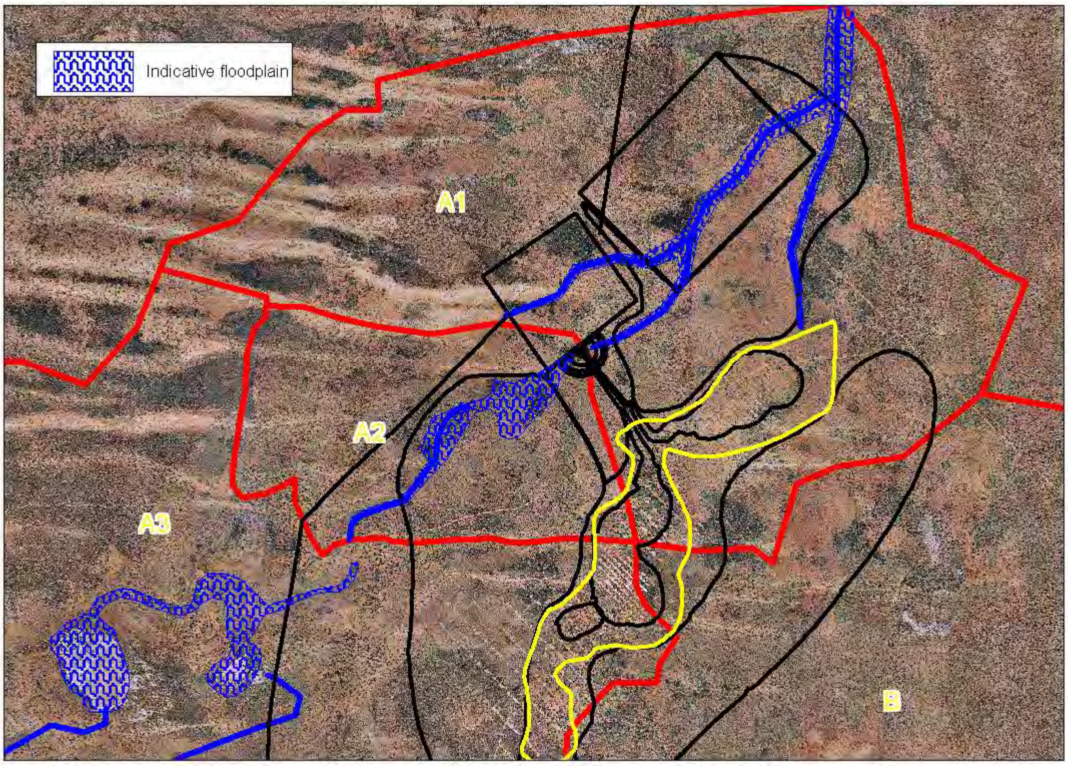



Figure 5 Indicative extent of the existing floodplain at the mine site

## 2.5 Conclusions

The majority of the drainage catchments upstream of the mine site and associated infrastructure are characterised by low relief, poorly defined drainage lines and areas with strong linear sand dunes and internal drainage. Accordingly, much of the catchments are not likely to produce stormwater at the mine site itself.

However, local drainage around the mine site has potential to produce stormwater that could impact on the mine infrastructure and operations. There is a drainage line/valley through the lower parts of the mine site (lower parts of catchment A, sub-catchment A1), from the processing area, which will probably convey stormwater during larger rainfall events. This stormwater will probably be sourced from a 23 km$^2$ catchment around the mine site area. There is an area upstream of the processing plant that could pond stormwater, sourced from a 7 km$^2$ local catchment (sub-catchment A2), for short periods after heavy rainfall.

The much larger (1,025 km$^2$) upstream section of Catchment A is likely to be largely internally drained and should not contribute stormwater flows to the drainage line/valley through the mine area. However, there is uncertainty in the predicted runoff volumes, so mine planning should consider the possibility that this large catchment does contribute stormwater to the mine area. Climate change could also cause increased runoff than currently experienced leading potentially to considerably higher stream flows and ponding at the mine site.

The catchment to the east (Catchment B) has similar characteristics to Catchment A and will likely produce stormwater flows at it’s outlet from a relatively small lower sub-catchment.

# 3. Surface water management concept

## 3.1 Introduction

A conceptual stormwater drainage and collection system is presented in this section.

The concept is based on the assumptions that all stormwater from waste dumps and the processing plant area during the mine operational phase would be drained under gravity to storage ponds and reused for processing or road watering and that the mine is developed to its maximum extent. It is possible that the mine may not be developed to its full extent and that other characteristics of the drainage system could change, so this concept may need to be refined as the mine plan develops.

Note that the concept is indicative and not suitable for construction in its current form.

## 3.2 Stormwater management concept - operation

The stormwater management concept is illustrated in Figure 6 and 7. The concept has three main components: diversion of stormwater from above the site, location of storages, and location of a gravity drainage network. There is also potential for discharging small quantities of good quality storm water off-site, ultimately to infiltrate.

### 3.2.1 Diversion

Stormwater sourced from outside the mine site, to the west and south, will be diverted around the west of the mine, rejoining the natural valley to the north. This would be a channel cut through sand dunes and part of the valley hillslope to maintain a maximum invert levels interspersed with several low-lying areas. A long-section along the diversion channel, from south to north, is shown in Figure 8. The low-lying areas could be filled with cut from the channel alignment, as indicated on Figure 7, which would minimise ponding. Alternatively, these areas could be left to accumulate stormwater in smaller events and overflow along the diversion alignment in larger events. The ponding areas could also help to attenuate peak discharge rates, thus making the cuts smaller.

The diversion channel would be constructed as a permanent structure.

A flood protection levee is indicated along the western extent of the mine infrastructure to contain ponds and prevent floodwater ingress into the mine area. In practice, this levee could be integrated into the mine infrastructure, including Waste Dump 2 and the plant area.

Note that it is important that a diversion flow path is allowed around the mine, as discussed in Section 2. This diversion allows drainage of stormwater from the upstream catchment, reducing flood risk for the mine.

### 3.2.2 Storages

Four potential storage sites have been identified. Storage 1 contains stormwater sourced from Waste Dump 1. This is located just north of the tailings storage facility to take advantage of the natural land slope for gravity drainage. Due to limited space within the waste dump footprint in this area, a supplemental storage, Storage 4, is located just north of the Tropicana Pit. This storage contains stormwater from the area east of the pits and from the northern half of Waste Dump 3.

Storage 2 contains stormwater sourced mainly from Waste Dump 2, the southern part of Waste Dump 3, and areas to the west and south of the pits.

Storage 5 is located in a low spot between the plant area and the tailings storage facility and could be used to contain water from the processing area and part of Waste Dump 1. Alternatively this area could be filled with waste and stormwater directed to Storage 2.

### 3.2.3 Drainage network

A gravity drainage network collecting stormwater from the site and transferring it to the storages is shown on Figures 6 and 7. Note that for gravity drainage this will involve deep cuts (up to 12 m), as noted on Figure 7, and will require filling of an area on the western edge of Waste Dump 2. An alternative to these cuts and filling, if stormwater is of good quality, is to drain toward low points and then contain and infiltrate stormwater.

The drainage network generally follows the grade of the ground surface, so the waste dumps and associated drainage structures should be constructed starting from their upslope extent.

### 3.2.4 Stormwater discharge

In areas where it is impractical to drain to the on-site storages and where stormwater is expected to be of good quality, it may be appropriate to discharge to local infiltration areas or to the wider environment. As there is little flow connectivity in the area, particularly in smaller events, discharge is likely to infiltrate close to the release point.

### 3.2.5 Access roads and other infrastructure

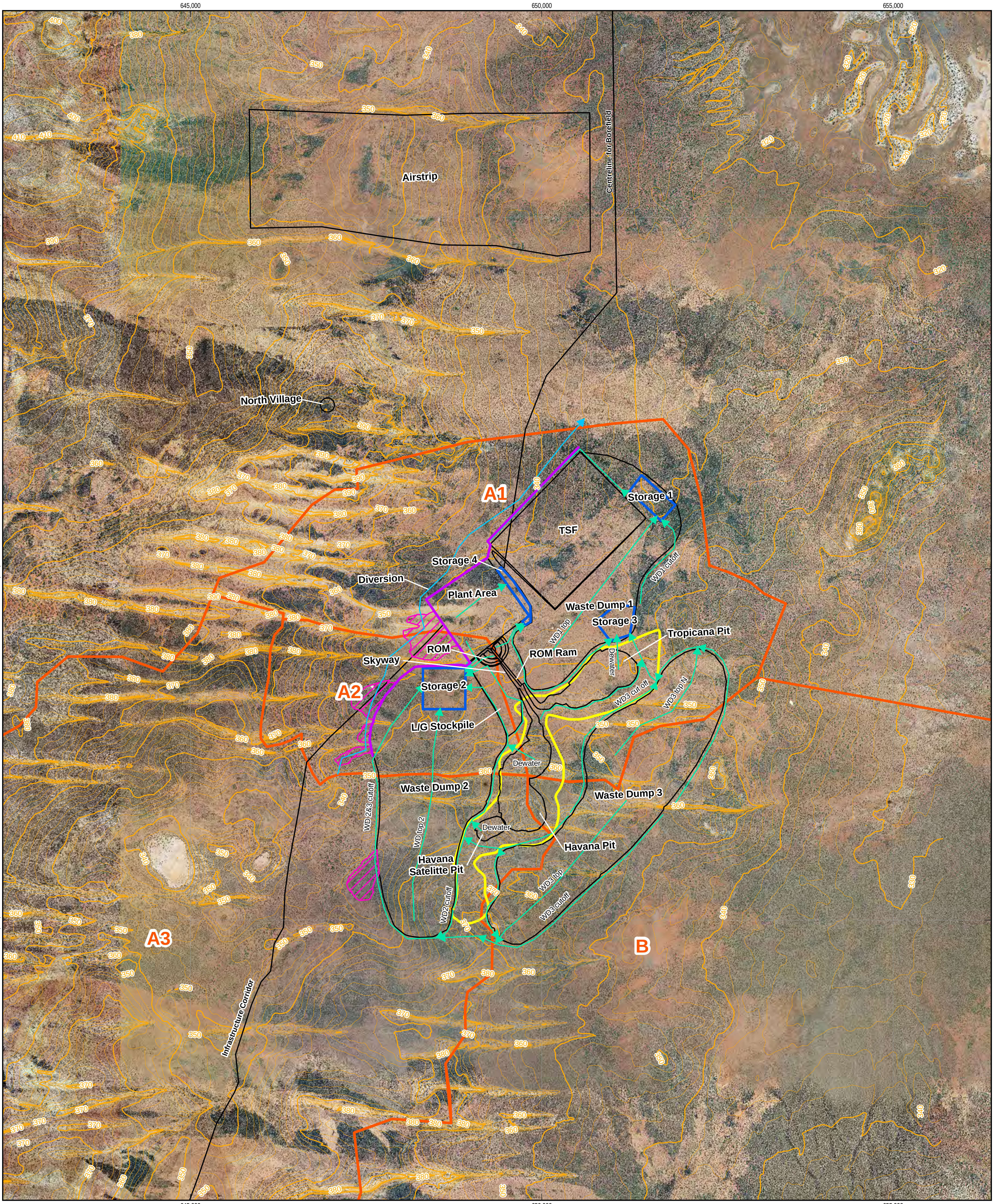
In areas where stormwater will not be retained on-site, such as access roads outside of the immediate mine area, normal engineering design principles will be used to manage stormwater drainage outfalls, flow concentration at road crossings, etc. This will include maintaining existing flow paths, stabilising outfalls to protect against erosion, ensuring stormwater from the areas has appropriate water quality, minimising ponding against embankments, roads, etc.

## 3.3 Stormwater management – closure

On closure, buildings, roads, plant, storages, etc will be removed and the landform rehabilitated and revegetated. Where possible, stormwater from the waste dumps will be drained under gravity to the pit. In areas where this is not possible, stormwater will be directed to semi-contained areas and infiltrated. In large events, good quality stormwater could be released to the environment after appropriate treatment (e.g. settling of sediment).

The diversion channel to the west of the site will be retained.

This concept can be developed further once a final mine layout is known.




LEGEND

Contours (2m) - AngloGold Ashanti Australasia - 2008

**Conceptual Site Layout - AngloGold Ashanti Australasia - 200808**

Access Roads

Proposed Mine Infrastructure

Low Lying Areas - GHD- 200808

US1000 Shell - AngloGold Ashanti Australia - 200707

Ponds - GHD - 20080821

Catchments - GHD - 20080218

Drainage Op - GHD - 20080821

Drainage Close - GHD - 20080821

Levee Close - GHD - 20080821

1:50,000 (at A3)

0 0.25 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

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GHD

INDEPENDENCE GROUP NL

ANGLOGOLD ASHANTI AUSTRALIA

Locality Map

MOUNT EAST
PINJIN
KALGOORLIE-BOULDER
KAMBALDA
WIDGIEMOOLTHA
ZANTHUS
SEEMORE DOWNS
RAWLINNA
MOUNT PLEASANT

Tropicana Gold Project
Operational Area
Surface Water Assessment

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| Job Number | 6121984 |
| Revision | 1 |
| Date | June 2009 |

# Surface Water Management Concept - Detail

Figure 6

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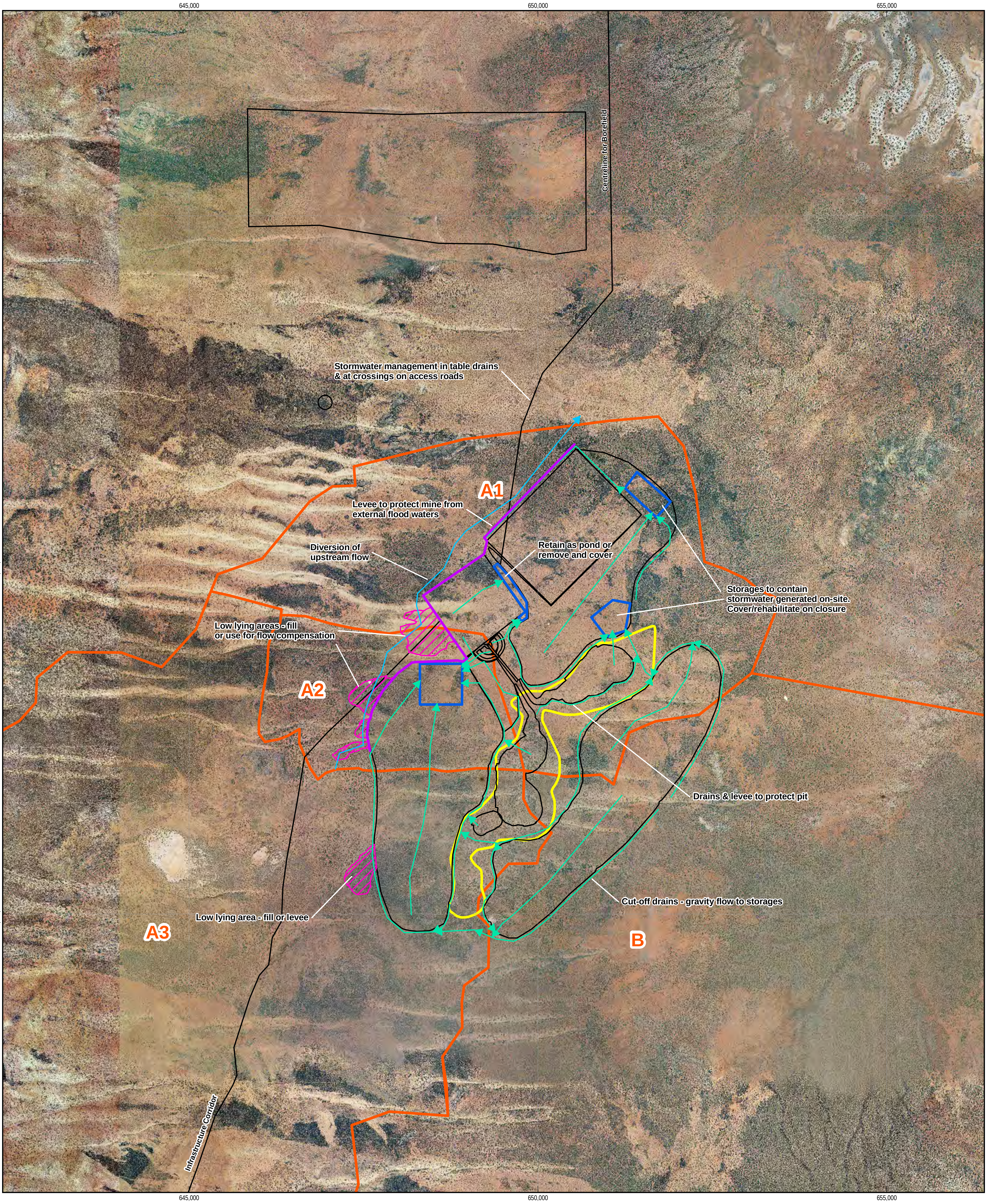


LEGEND

**Conceptual Site Layout - AngloGold Ashanti Australasia - 200808**

Access Roads
Proposed Mine Infrastructure

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Ponds - GHD - 20080821
Catchments - GHD - 20080218
Drainage Op - GHD - 20080821
Drainage Close - GHD - 20080821
Levee Close - GHD - 20080821

1:50,000 (at A3)

0 0.25 0.5 1 1.5 2 2.5

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 51

N

Locality Map

Tropicana Gold Project
Operational Area
Surface Water Assessment

| | |
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| Job Number | 6121984 |
| Revision | 1 |
| Date | June 2009 |

# Surface Water Management Concept - Annotation

Figure 7

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Dataset names include published date where available. Imagery sourced from AngloGold Australia Limited Dec 2007. Created by: W Davis, N Tan

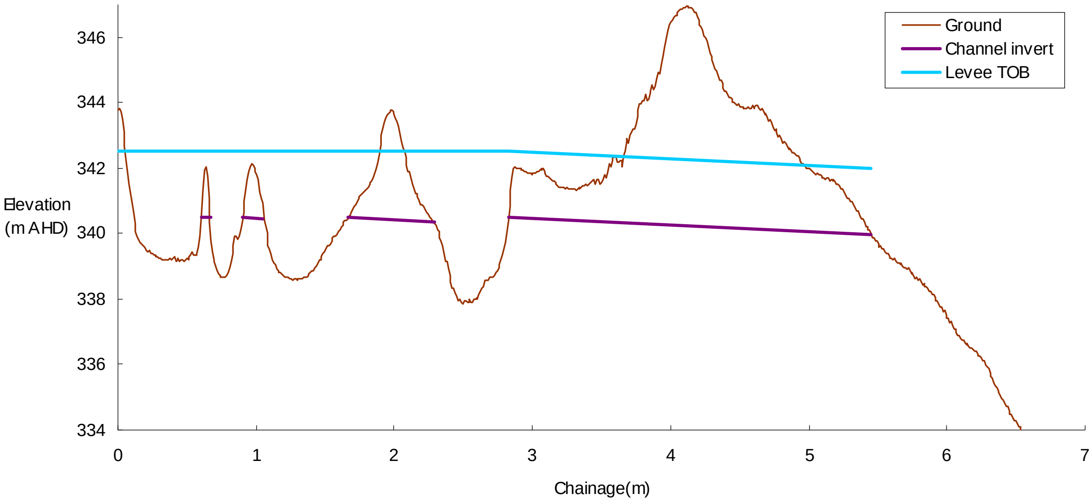


**Figure 8 Long-section along the diversion channel, south to north**

## 3.4 Recommendations

The drainage concept presented in the section should be revised as the location and footprint of mine infrastructure changes. Additional modelling may be required to further quantify stream flows from the upstream catchment, including in very large events, and to contribute to the design of the diversion channel and on-site drainage. More detailed design is required before construction.

Mine planning should consider the risk that stormwater flows and ponding in the mine area could be significantly different (either higher or lower) to the predictions given in this report.

# 4. Assessment of impact of mine infrastructure

## 4.1 Introduction

This section presents an assessment of the potential impact of mine infrastructure on surface water flow paths at and downstream of the mine site.

This analysis is based on the current mine layout plan as supplied by AngloGold Ashanti. If this plan is modified, then the analysis of impact should be updated accordingly.

## 4.2 Description of the infrastructure

Most of the main infrastructure is located on the eastern slopes and across the valley floor of Catchment A. Only part of Waste Dump 3 and the access road to the existing airport lie in or downstream of Catchment B. Mine infrastructure and local hydrologic features are shown in Figure 3.

The mine pit and associated infrastructure are located mainly in Catchment A, on the western slopes of the northeasterly trending ridgeline and in the valley to the west. The pit and part of Waste Dump 3 lie on or near the ridge line. Waste Dump 1, the western extent of Waste Dump 2, the processing area and parts of the tailings storage facility lie on or across the drainage line.

The eastern parts of Waste Dump 3 lie in Catchment B.

The village (houses the workforce during the mine operational phase) lies on higher ground to the northeast of the mine. The temporary camp (for the exploration/construction workforce) lies to the east of the pit.

The proposed airstrip is some 4 km north of the mine site. The access road will probably follow the borefield pipeline and traverses a gently sloping plain.

A stormwater drainage concept for the mine site is discussed in Section 3. During operation of the mine, this concept broadly involves diverting stormwater from the upstream catchment around the mine and containing and reusing stormwater generated on-site. At closure stormwater from the site would be contained in the pit or in local infiltration areas, with some good quality water released in larger events.

Dewater from the pits will be pumped to storages on-site and reused.

## 4.3 Potential impacts and management

Potential impacts of the mine on surface water hydrology of the area can be categorised into:

- Downstream shadowing effects due to capture of stormwater on-site.
- Increased stormwater generation and modification to flow paths associated with disturbed, compacted or built areas.
- Modification of the existing drainage valley that runs through the site and diversion of stormwater flows from upslope around the west of the mine site.
- Discharge of stormwater from the site with elevated levels of sediment, salt or contaminants.

### 4.3.1 Downstream shadowing

Capture of stormwater generated in the main mine area (the pit, waste dumps, process plant area and tailings storage facility) will lead to a reduction in stormwater flows in any remnant drainage channels in the mine area. As stormwater does not appear to flow any distance, instead reinfiltrating close to source, this reduction in catchment area is not likely to adversely impact on the environment downstream. An evaluation of changes to predicted peak design flows is given in Table 4.

The pit and waste dumps are unlikely to have any significant shadowing effects, i.e. reduction in surface water flows immediately downsteam, as they are located on top of and across the divide between Catchments A and B.

Effects of stormwater capture after mine closure will vary depending on how stormwater from the old infrastructure areas is handled, but is unlikely to result in a greater impact than during the operational phase of the mine.

### 4.3.2 Increased stormwater generation and flow path modification

Most runoff from the mine site will be contained and reused on-site, so will not interact with the wider environment. There may be some increased runoff associated with infrastructure that is not contained on-site, such as from access road surfaces, but the area of these surfaces is small compared with the wider catchment so this will have negligible impact.

Normal engineering design principles will be used to manage stormwater drainage outfalls, flow concentration at road crossings, etc. This will include maintaining existing flow paths, stabilising outfalls to protect against erosion, ensuring stormwater from the areas has appropriate water quality, minimising ponding against embankments, roads, etc. These structures will be removed or reshaped and rehabilitated on closure of the mine.

Accordingly, impacts on the environment are expected to be minimal.

### 4.3.3 Modification of the drainage valley

The existing drainage valley in the mine area will ultimately be covered by mine infrastructure and blocked. Stream flows in this area will be diverted around the western edge of the mine site. The diversion will be installed early in the project and will be permanent. The diversion could increase ponding in some existing low-lying areas.

Normal engineering design principles will be used to ensure that the diversion channel has adequate capacity is erosionally stable, and is revegetated, and reproduces drainage characteristics of the area.

The diversion may modify local ponding characteristics compared with the existing drainage channel. However, there is little connected stream flow in the area and ponding is a natural feature, so the diversion is not likely to impact on the local hydrology.

### 4.3.4 Discharge of contaminated stormwater

Areas of the mine site have the potential to generate stormwater with differing levels and types of pollutants. Disturbed areas, particularly where soils have higher clay contents, could generate stormwater with elevated turbidity. Parts of the processing plant and workshop areas could contain oils and other sources of contamination. Waste dumps could have areas with acid-forming materials. Areas watered with saline water, such as roads, may accumulate salt which could be washed off in subsequent rainfall events.

During mine operation, stormwater from all potentially contaminated areas within the main mine site will be contained in storages on-site and reused. Accordingly, stormwater sourced from the site poses little risk to the environment.

Dewater from the pits will be contained in the on-site storages and will not be discharged to the environment.

Access roads, parking areas, etc, that are watered with saline water could accumulate salt and generate elevated salt levels in stormwater sourced from the watered surface. This stormwater would normally infiltrate in table drains close to the watered area and will be rehabilitated when no longer needed. Should impacts from salt wash-off become noticeable in some areas these can be managed with containment in sumps.

Roads and other bare disturbed areas can also generate stormwater with elevated turbidity and/or cause flow concentrations and scour. This issue can be managed with appropriate design of flow concentration structures (see Section 4.3.2) and using normal engineering design to trap any sediment close to the road (e.g. in table drains) where the area can be rehabilitated.

After closure, most stormwater from the site will either be captured in the pit or infiltrated. Only clean stormwater in larger events could be released from some areas to the environment. Accordingly, after closure there is likely to be little risk to the environment from the release of contaminated stormwater.

## 4.4 Conclusions

While the mine site will cover an existing drainage valley, with the use of a diversion and appropriate on-site stormwater management, there is likely to be little impact on the surface water hydrology of the surrounding landscape.

There are not likely to be significant shadowing effects (i.e. reduction in surface water flows immediately downstream) associated with the proposed infrastructure because the reduction in local flows is small relative to flows from the remainder of the contributing catchment at that point and as impacts on local stormwater does not propagate downstream to any degree.

Discharge of stormwater with elevated levels of salt, sediment or contaminants to the environment is not likely as this stormwater will either be contained on-site or treated or infiltrated locally.

# 5. Flood risk for the mine pit

## 5.1 Introduction

This section presents an assessment of flood risk for the mine pit. The US1000 pit boundary was assessed as this is likely to be the largest pit extent, extend further downhill and thus be at greatest risk from flood ingress. Smaller pit areas have been delineated by AngloGold Ashanti (US700 and US600) and these could be mined as several pits. The assessment given here, for the US1000 footprint, should be equally applicable to the other footprints, provided they remain within the US1000 footprint.

An assessment in URS (2007), which included detailed HEC-RAS modelling, concluded that there was no flood risk for the pit. Predicted flows in the main channel line near the pit reached depths of only 0.2 m.

## 5.2 Flood risk

Ground level at the rim of the pit tends to increase from a low of 338 m AHD in the north up to 350 m AHD in the south. Ground levels in the Catchment A valley through the mine site vary from 334 m AHD in the north to 338 m AHD in the south. As the pit is effectively located on a low ridge line, the land slope around the pit is generally away from the pit edge.

The drainage concept (see Section 3) will ensure that external stream flow can bypass the mine site without presenting a flood risk to the pit or other mine infrastructure. Flow rates from disturbed areas of the mine site are likely to be elevated relative to the existing conditions, but these should be readily accommodated with the drainage concept.

The pit will collect rain falling directly into the pit and runoff from access roads, etc. This is not likely to form a safety risk as pit access can be limited during periods of heavy rainfall and sumps and dewatering systems can be used to manage water levels in the pit.

The Catchment B drainage line is further away from the pit than the Catchment A drainage line and the ground surface is lower. Ground level in the main valley varies from 328 m AHD in the north to 332 m AHD in the south. Flow depths are likely to be similar to in Catchment A (i.e. less than 1 m). Accordingly, stormwater flows in Catchment B do not present a flood risk for the pit.

## 5.3 Conclusions

Stormwater does not present a flood risk to the pit provided a drainage pathway from the south to the north is constructed and that a levee/minimum earthworks level along the western edge of the mine site is maintained.

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