COZA IRON ORE PROJECT

DESKTOP HYDROLOGY ASSESSMENT

REPORT

May 2013

QUALITY VERIFICATION

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

Verification	Capacity	Name	Signature	Date
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1 INTRODUCTION

Jeffares & Green (Pty) Ltd have been appointed by Synergistics (Pty) Ltd to undertake a series of hydrological studies for the proposed COZA Iron Ore project located on Farm Driehoekspan 435 (Remaining Extent) and Doornpan 445 (Portion 1) in the Tsantsabane Local Municipality in the Northern Cape Province. The hydrological studies are to be undertaken to satisfy the requirements of the Minerals and Petroleum Resources Development Act (No 28 of 2002), the Environmental Management Act (No 107 of 1998) and the National Water Act (No 36 of 1998). This component of the greater hydrological study is a baseline hydrological characterisation of the proposed COZA Iron Ore project area. The objective of the baseline characterisation is to:

- describe the hydrology of the area by defining the general climatic conditions;
- describe landuse and topographical conditions;
- identify wetlands and pans within the study area;
- determine the design rainfall to be used in flood calculations;
- identify and delineate stream and river channels and their associated catchment areas; and
- determine the Mean Annual Runoff (MAR) for the project area and contributing catchments.

This baseline characterisation study is to form part of the environmental impact assessment scoping report.

2 SITE DESCRIPTION

The COZA Iron Ore project is located approximately 10 km north of the town Postmasburg within the Northern Cape Province, as depicted in **Figure 2-1**. It is approximately 180 km east from Upington, and 180 km west of Kimberly. Other small towns in close proximity to the study site are Kathu, Sesheng and Dingleton.

As per the terms of reference, the COZA Iron Ore project will involve mining from two opencast pits on portions of the farms Doornpan (approximately 25 ha of disturbed area) and Driehoekspan (approximately 80 ha of disturbed area). The topsoil and overburden is to be removed by means of truck and shovel and relocated to an area in close proximity to the open pits. No processing, other than blending of material (to be done at the run-of-mine stockpile) will take place at the proposed sites.

2.1 Climatic Conditions

The COZA Iron Ore project area falls within the steppe climate zone, as per the Kőppen BS classification. This climate category can be described as semi-arid, and is able to support short scrubby vegetation, predominantly including shrubs and grasslands.

Temperature data for the area of the project site was obtained from the South African Weather Service (SAWS) station 0321141 W. This station is located approximately 20 km south of the project area, as depicted in **Figure 2-1**. The average monthly maximum and minimum temperatures for the project site, calculated from the weather station 0321141 W from weather data spanning the period 1950 to 2000, are presented in **Table 2-1**. The maximum temperature recorded at this weather station is 46.5 ºC and the minimum is -8.4 ºC.

Table 2-1 Monthly Average Maximum and Minimum Temperatures Recorded For Years 1950 – 2000 at Station 0321141 W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum Temperature (ºC)	16.2	15.1	13.8	10.3	6.0	2.1	1.9	4.4	6.9	10.0	13.4	15.6
Maximum Temperature (ºC)	32.0	29.3	28.6	25.0	22.3	17.1	18.0	20.7	24.4	27.0	29.7	31.2

Rainfall data for the area of the COZA Iron Ore project site was obtained from the SAWS rainfall station 0320828 W. This rainfall station is located approximately 14 km southwest of the project site, and was selected based on the record period and the reliability of the historical data. The details of this rainfall station are presented in **Table 2-2**. The mean

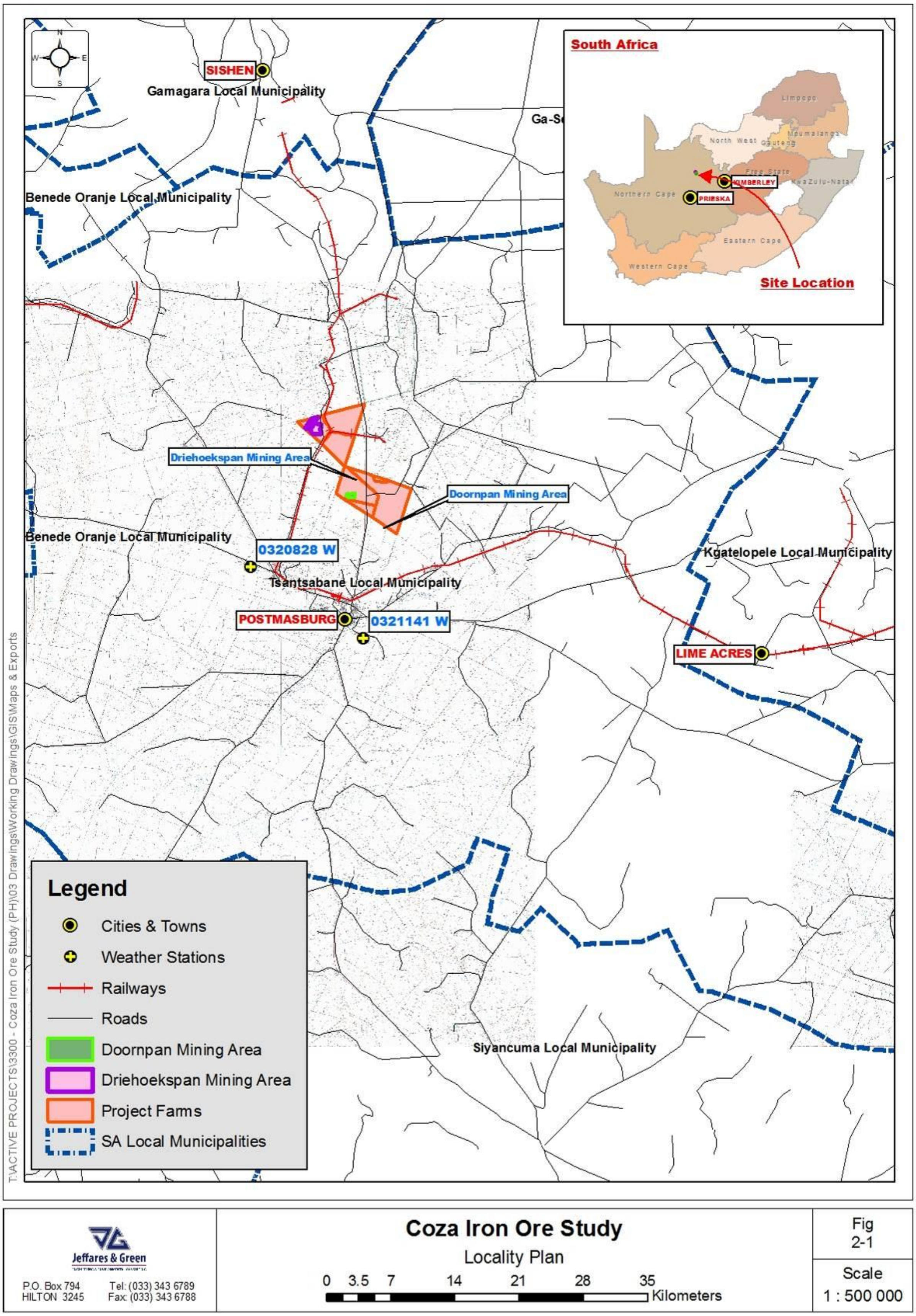

Figure 2-1 Locality Plan of the Proposed COZA Iron Ore Project

monthly rainfall amounts over the period 1950 to 2000 are presented in **Table 2-3**. From **Table 2-3** it is evident that most of the rainfall falls over the summer period (November to April). Rainfall over this period is predominately convectional. It is also noted that small amounts of rainfall are recorded over the winter months (May to October). Rainfall falling over this period is predominantly frontal.

Table 3-2 Rainfall Station Details

Station Number	Station Name	MAP (mm)	Years Assessed	Reliability (%)	Longitude	Latitude
0320828 W	Aucampsrus	318	1950 - 2000	99.2	22º 58'	28º 17'

Table 3-3 Monthly Average Rainfall Depths Recorded For Years 1950 – 2000 at Rainfall Station 0320828 W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAP
Rainfall Depth (mm)	48	60	62	34	13	5	2	6	7	19	24	38	318

While rainfall is generally variable on a month-to-month basis, this is not the case with evaporation data. The latter is known to not vary significantly from one year to next (i.e. evaporation in one October-month, for example, is similar to evaporation in the next October-month). Therefore, it is generally considered to be acceptable to apply 12 average monthly evaporation values over the year. The evaporation data used in this study for the COZA Iron Ore Project was obtained from evaporation zone **7A** (Middleton and Bailey, 2008). Catchment evapo-transpiration is calculated by applying 12 monthly evapotranspiration conversion factors, as presented in **Table 2-4**. Similarly, evaporation losses from an exposed water body are calculated by applying 12 monthly lake evaporation conversion factors, as presented in **Table 2-4**. The annual potential evaporation rate for the COZA Iron Ore study area is 2 450 mm. From **Table 2-4**, the highest evaporation rates occur during the hotter summer months of October to March.

Table 2-4 COZA Iron Ore Potential Evaporation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Evaporation Rate (mm)	333	256	221	154	111	85	98	133	184	247	292	336	2450
Lake Evaporation Factor	0.84	0.88	0.88	0.87	0.85	0.83	0.81	0.81	0.81	0.81	0.82	0.83	
Evapotranspiration Factor	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.80	0.80	0.80	1.00	1.00	

2.2 Topography

The topography of the area surrounding the project area is characteristically flat to undulating, as depicted in **Figure 2-2**. The site has an average elevation of approximately 1 385 m above mean sea level (AMSL). The project area is flanked to the east by the Klipfontein range of hills, which run in a north to south orientation.

2.3 Landuse, Landcover and Soils

The dominant landuse in the area surrounding the COZA Iron Ore project is livestock farming. Due to the arid nature of the climate, intensive commercial agriculture is not possible. Mining activities and the infrastructure associated with mining activities (opencast pits, overburden rockdumps etc.) are also prevalent in the area, due to the presence of Iron Ore.

The project area falls within the Eastern Kalahari Bushveld Bioregion of the Savanna Biome. The vegetation types found in the area include Kathu Bushveld, Kuruman Thornveld and Southern Kalahari Salt Pans (Mucina & Rutherford, 2006).

The soils in the region are generally shallow, normally not exceeding more than 300 mm in depth. The predominant soil types are those of Glenrosa and Mispah. The Glenrosa type soil is characterised by an Orthic A horizon over a Lithocutanic B horizon, whereas the Mispah type soil is characterised by an Orthic A horizon over bedrock.

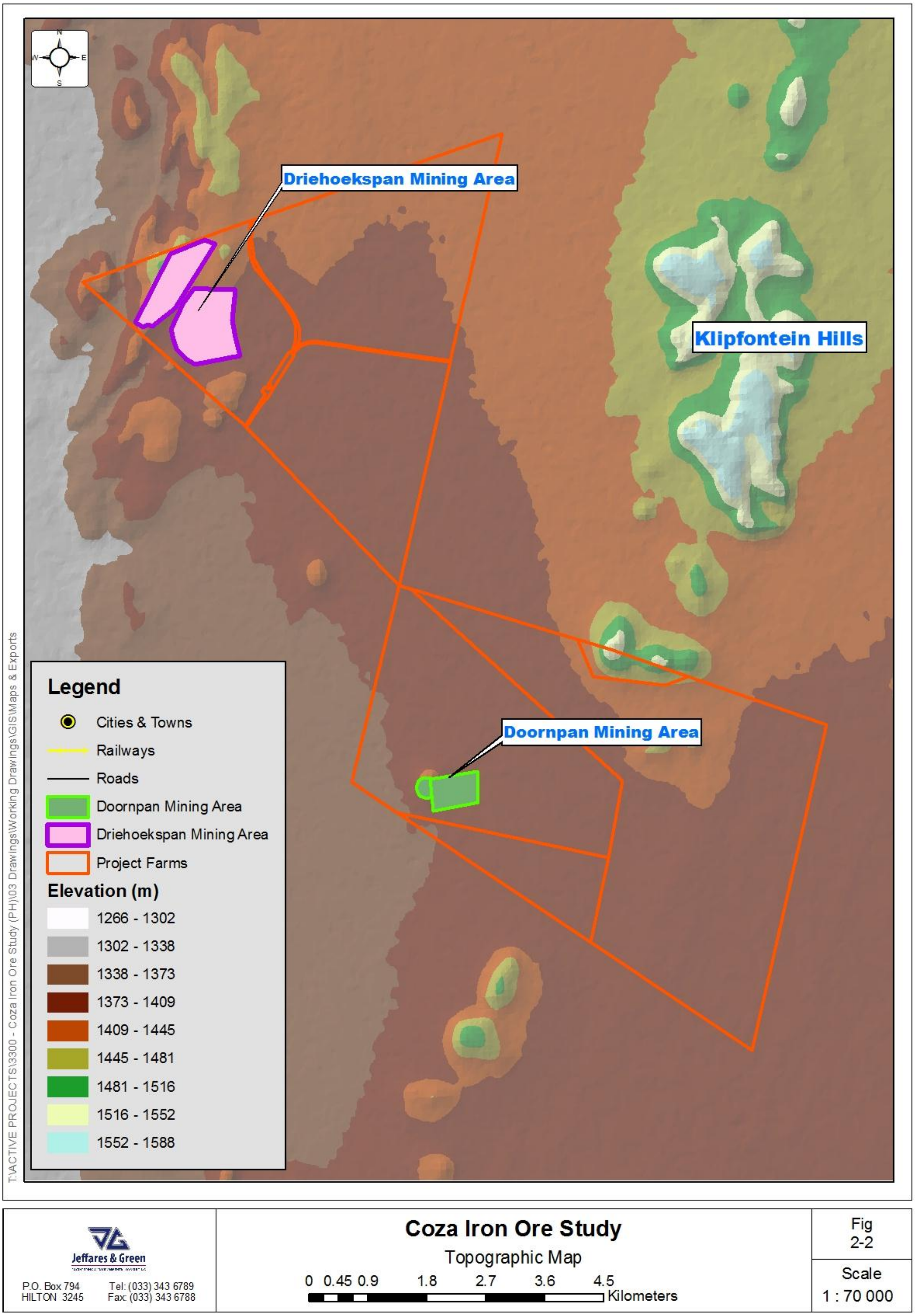

Figure 2-2 General Topography

3 HYDROLOGY

The project site is located within upper reaches of quaternary catchment D73A, which in turn forms part of the greater Orange River catchment area. The Orange River is located approximately 120 km southwest of the project site. According to the Water Resources of South Africa 2005 study (WR2005), quaternary catchment D73A is classed as endorheic. Endorheic can be described as a catchment area with no outlet. Rainfall falling on the catchment does not exit the catchment as surface flow, but may only leave as evaporation and seepage. Details of the quaternary catchment D73A including its associated Mean Annual Runoff (MAR) and runoff depth are provided in **Table 3-1**. The MAR equal to 0 is because of the endorheic nature of the catchment, although the MAR depth is 14.7 mm.

Table 3-1 Quaternary Catchment Details

Quaternary Catchment	Catchment Area (km^2)	Evaporation Zone	Rain Zone	Water Management Area	MAR (MCM)	MAR Depth (mm)	MAP (mm)
D73A	3 236	7A	D7C	10	0	14.7	323

The drainage in the immediate area surrounding the proposed COZA Iron Ore Project is such that all the surface water drainage lines lead to a wetland or pan area. These wetlands and pans generally do not present an outlet channel, and so the characteristics of the greater quaternary catchment area are also evident around the proposed mining areas.

Drainage lines, wetlands and pans located within the project area need to be managed such that all mining activities are compliant with relevant legislation. It is therefore important to highlight sections of the legislation that may be relevant to the COZA Iron Ore project.

3.1 Relevant Legislation

The *National Water Act, 1998 Act No. 36 of 1998* (NWA) was created in order to ensure the protection and sustainable use of water resources (including wetlands) in South Africa. The NWA recognises that the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users. Bearing these principles in mind, there are a number of stipulations within the NWA that are relevant to the potential impacts on surface water resources that may be associated with the COZA Iron Ore project. These stipulations are explored below and are discussed in the context of the proposed development.

Firstly, it is important to discuss the type of water resources (surface) protected under the NWA. Under the NWA, a ‘water resource’ includes a watercourse, surface water, estuary, or aquifer. Specifically, a watercourse is defined as (*inter alia*):

- a river or spring;
- a natural channel in which water flows regularly or intermittently; or
- a wetland, pan, lake or dam into which, or from which, water flows.

In this context, it is important to note that reference to a watercourse includes, where relevant, its bed and banks. Furthermore, it is important to note that water resources, including wetlands, are protected under the NWA. ‘Protection’ of a water resource, as defined in the NWA entails the:

- Maintenance of the quality and the quantity of the water resource to the extent that the water use may be used in a sustainable way;
- prevention of degradation of the water resource; and
- rehabilitation of the water resource.

In the context that the proposed mining project and the identification of potential impacts it may have on the surface water resources, the definition of pollution and pollution prevention contained within the NWA is relevant. ‘Pollution’, as described by the NWA, is the direct or indirect alteration of the physical, chemical or biological properties of a water resource, so as to make it (*inter alia*):

- less fit for any beneficial purpose for which it may reasonably be expected to be used; or
- harmful, or potentially harmful, to the welfare or human beings, to any aquatic or nonaquatic organisms, or to the resource quality.

The inclusion of physical properties of a water resource within the definition of pollution entails that any physical alterations to a water body, for example the excavation of a wetland or changes to the morphology of a water body, can be considered to be pollution. Activities that cause alteration of the biological properties of a watercourse, i.e. the fauna and flora contained within that watercourse, are also considered pollution.

In terms of section 19 of the NWA, owners/managers/people occupying land on which any activity or process undertaken which causes, or is likely to cause, pollution of a water resource must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring. These measures may include measures to (*inter alia*):

- cease, modify, or control any act or process causing the pollution;
- comply with any prescribed waste standard or management practice;
- contain or prevent the movement of pollutants;
- remedy the effects of the pollution; and
- remedy the effects of any disturbance to the bed and banks of a watercourse.

The *National Environmental Management Act 107 of 1998* (NEMA) was created essentially to establish:

- principles for decision-making on matters affecting the environment;
- institutions that will promote co-operative governance; and
- procedures for co-ordinating environmental functions exercised by organs of the state to provide for the prohibition, restriction or control of activities which are likely to have a detrimental effect on the environment.

It is stipulated in NEMA, *inter alia*, that everyone has the right to an environment that is not harmful to his or her health or well-being. Moreover, everyone has the right to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

Accordingly, several of the principles of NEMA, applicable to wetlands and pans, stipulate that:

- Development must be socially, environmentally and economically sustainable;
- sustainable development requires the consideration of all relevant factors including the following:
  - That the disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be altogether avoided, are minimised and remedied.
  - That pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied.
  - That negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimised and remedied.
- the costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution,

environmental damage or adverse health effects must be paid for by those responsible for harming the environment; and

- sensitive, vulnerable, highly dynamic or stressed ecosystems, such as coastal shores, estuaries, wetlands, and similar systems require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure.

3.2 Identification of Surface Water Features

Using the definition of a surface water resource under the NWA, this study will encompass a river or spring, a natural channel in which water flows regularly or intermittently, a wetland, pan, lake or dam into which, or from which, water flows.

For wetlands specifically, the lawfully accepted definition of a wetland in South Africa is that within the NWA. Accordingly, the NWA defines a wetland as, "land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil".

Moreover, wetlands are accepted as a piece of land on which the period of saturation of water is sufficient to allow for the development of hydric soils, which in normal circumstances would support hydrophytic vegetation (i.e. vegetation adapted to grow in saturated and anaerobic conditions).

Wetlands may either be palustrine (marsh-like) or lacustrine (lake-like) in nature. Palustrine and lacustrine wetlands can be divided up into different hydrogeomorphic forms, based on their position within the landscape, hydrological connectivity and water input. Kotze *et al*. (2005) have described a number of different wetland hydrogeomorphic forms:

- Hillslope Seepage feeding a stream.
- Hillslope Seepage not feeding a stream.
- Channelled Valley Bottom.
- Un-channelled Valley Bottom.
- Pan/Depression.
- Floodplain.

3.2.1 Wetland/Pan Identification

Wetlands and Pans are a very important component of the natural environment. Wetlands and pans are typically characterised by high levels of biodiversity and are critical for the sustaining of human livelihoods through the provision of water for drinking and other human uses. These are sensitive features of the natural environment, and pollution or degradation of surface water can result in a loss of biodiversity, as well as an adverse impact on the human users that depend on the resource to sustain their livelihoods. As such, wetlands and pans are specifically protected under the NWA and generally under the NEMA, as presented in **Section 3.1**.

Hydric soils, which are soils that are found within wetlands and pans, are defined by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) as being, "soils that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part". These anaerobic conditions would typically support the growth of hydromorphic vegetation (vegetation adapted to grow in soils that are saturated and starved of oxygen) and are typified by the presence of redoximorphic features. The presence of hydric (wetland or pan) soils on the site of a proposed development may be significant, as the alteration or destruction of these areas, or development within a certain radius of these areas would require authorisation in terms of the NWA and in terms of the NEMA.

The identification of wetlands in the area of the COZA Iron Ore project have been undertaken using Geographic Information System (GIS) software developed by ESRI. The collection of data source information encompasses the National Freshwater Priority Areas (NFEPA, 2011) database and the Environmental Potential Atlas (ENPAT, 2000 & 2002). The use of Google Earth™ imagery has also been used to supplement these data sources. Colour (Google Earth™) satellite imagery depicting specifically soil colour has been used as a means of delineating wetland boundaries. For example, wetland soil colours are often ‘greyer’ in hue, reflecting the gleyed soils that typically occur within wetlands. These can be differentiated from the orange/brown/yellow more oxidised non-wetland soils that exist outside of the wetland.

Utilising the above-mentioned sources, wetlands and pans were identified in the area surrounding the COZA Iron Ore project, specifically the Doornpan and Driehoekspan mining areas. As presented in **Figure 3-1**, based on the NFEPA wetland database, a wetland area is suggested to occur within the Driehoekspan mine area. In order to confirm the location of the proposed wetland, a site visit to the specific location of the proposed wetland was undertaken. Based on the site assessment, no hydromorphic plants, signs of surface wetness and topographical characteristics suggesting the location of a wetland or pan were identified. Based on this, it was confirmed that there are no wetlands or pans occurring within the Driehoekspan Mining area, as suggested by the NFEPA database.

As depicted in **Figure 3-2** there are no wetland or pans falling within the Doornpan opencast mining or mining infrastructure areas. A wetland or pan has been delineated using Google Earth imagery to the west of the proposed Doornpan mining area. This wetland or pan is of little concern as it falls outside of the mining area.

3.2.2 Drainage Line and Catchment Area Delineation

Drainage lines and the catchment areas contributing to overland and defined flow of the Driehoekspan and Doornpan mining areas have been delineated, as depicted in **Figure 3-1** and **Figure 3-2**, respectively. Drainage lines and catchment areas have been delineated based on a combination of 20 m interval contour lines extracted from 1:50 000 topographic maps, and freely available Space Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data. STRM DEM data is available at several resolutions, however, the highest resolution available and that used in this study is 90 m (a resolution of 90 m refers to an average elevation per 90 m by 90 m block over the study area). The accuracy of delineated drainage lines are dependent on the accuracy and level of detail provided from the above mentioned sources of contour data. It is therefore likely, as more detailed contour information becomes available, more drainage lines will become evident in and around the project area.

Based on the available contour information, it was found that drainage lines traverse the proposed Driehoekspan mining area. These drainage lines are not associated with large catchment areas, as depicted in **Figure 3-1**. No drainage lines were evident for the area surrounding the proposed Doornpan mining area. It is, however, likely that overland flow will contribute to the Doornpan mining area, as depicted in **Figure 3-2**. The lack of defined drainage channels in this area may change as more detailed contour information becomes available, as previously mentioned. The catchment area contributing to the Driehoekspan mining area is 1.28 km^2, and that contributing to the Doornpan mining area is 1.38 km^2.

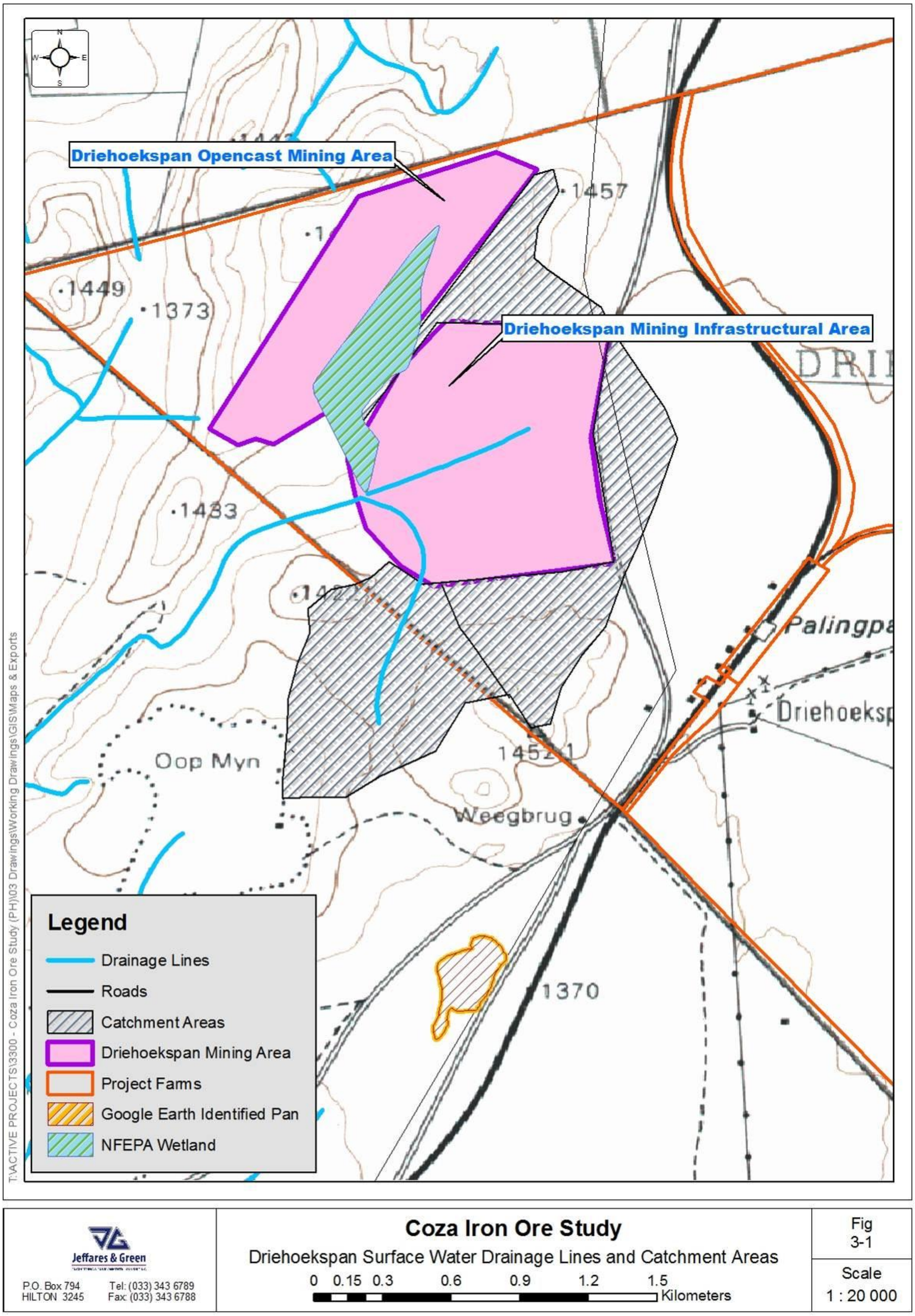

Figure 3-1 Driehoekspan Drainage Lines and Catchment Areas

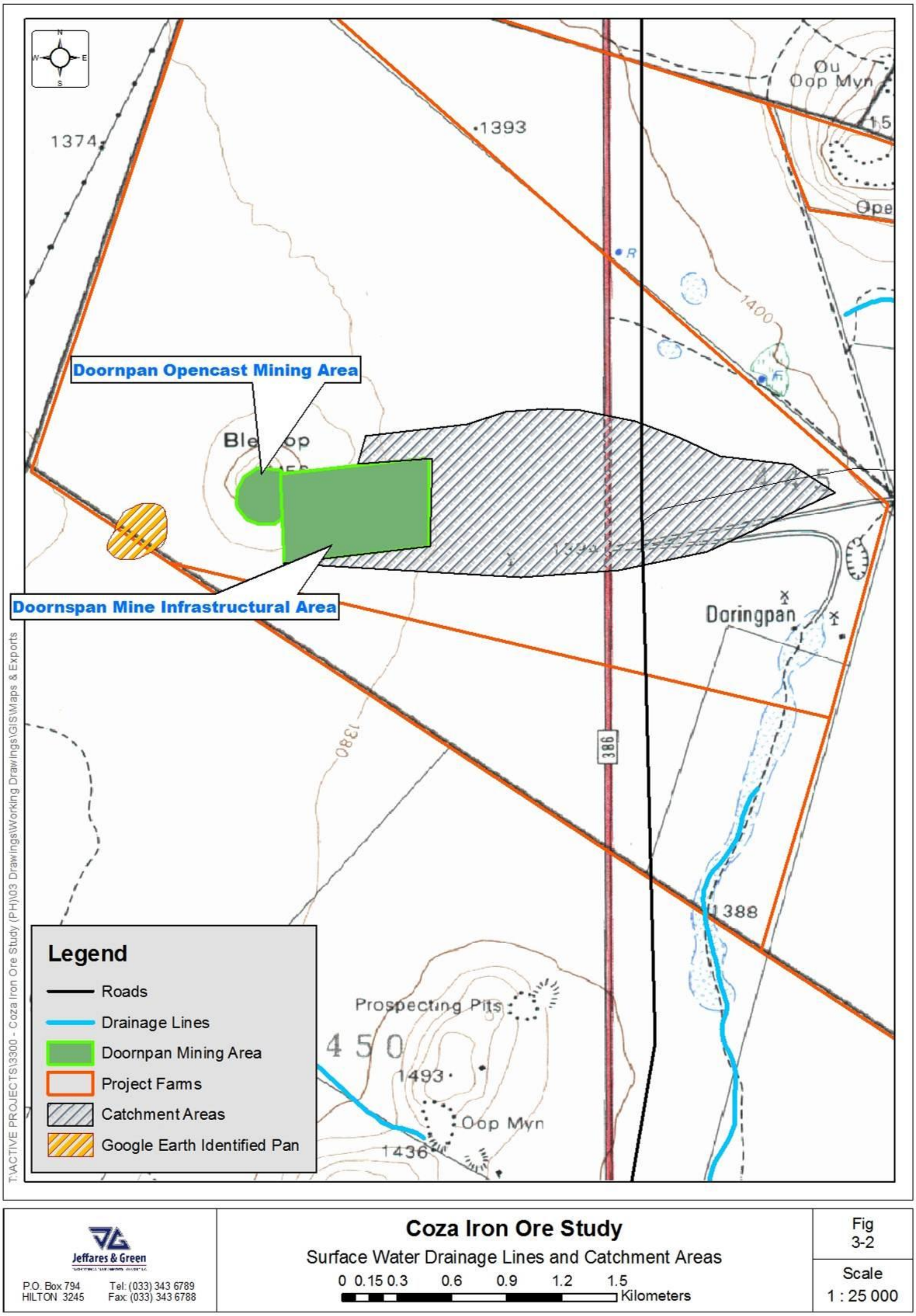

Figure 3-2 Doornpan Drainage Lines and Catchment Areas

3.3 Stormwater Management

The Department of Water Affairs (DWA) Best Practice Guidelines A1 (2006), which were developed specifically for stormwater management in small-scale mining, will be used to make recommendations for the development the Stormwater Management Plan (SWMP). From these guidelines, there are four primary principles that need to be considered and applied when formulating a SWMP, these include:

1. Clean water must be kept clean and be routed to a natural watercourse by a system separate from the dirty water system, while preventing or minimising the risk of spillage of clean water into dirty water systems.
2. Dirty water must be collected and contained in a system separate from the clean water system and the risk of spillage or seepage into clean water systems must be minimised.
3. The SWMP must be sustainable over the life cycle of the mine and over different hydrological cycles and it must incorporate principles of risk management.
4. The statutory requirements of various regulatory agencies and the interests of stakeholders must be considered and incorporated.

In order for the SWMP to be compliant with statutory requirements, the sizing of the stormwater management infrastructure must be done using the 1:50 year return period storm event. Rainfall data at a daily time-step is essential for determining design flood events. For this purpose, daily rainfall data was extracted from the six closest rainfall stations for which design rainfall is available using the Design Rainfall Utility developed by Smithers and Schulze (2000). Details of the six closest rainfall stations to the COZA Iron Ore project area are presented in **Table 3-2**. The design rainfall depths presented in **Table 3-3** were based on the data from the rainfall stations listed in **Table 3-2**.

Table 3-2 Rain Gauge Characteristics Used to Determine the Design Rainfall

Station Name	SAWS Number	Distance from Site (km)	Record Used (years)	Mean Annual Precipitation (mm)	Altitude (m)
Mangannore	0321159 W	7.2	34	377	1 438
Lohatla	0321032 W	12.6	36	368	1 365
Aucampsrus	0320828 W	14.0	57	317	1 289
Postmasburg (Pol)	0321110 W	18.4	75	323	1 325
Mooidraai	0321116 W	29.3	30	322	1 310
Tierkop	0321441 W	30.5	59	361	1 419

Table 3-3 Design Rainfall of the Proposed Mining Area

Duration	Return Period (Years) Design Rainfall Depth (mm)						
	1:2	1:5	1:10	1:20	1:50	1:100	1:200
5 min	7.7	10.9	13.1	15.4	18.5	20.9	23.5
10 min	11.4	16.1	19.5	22.8	27.4	31.1	34.8
15 min	14.4	20.4	24.6	28.8	34.6	39.2	43.9
30 min	18.7	26.4	31.9	37.4	44.9	50.8	57.0
45 min	21.7	30.8	37.1	43.5	52.2	59.2	66.4
1 hour	24.2	34.3	41.3	48.5	58.2	65.9	74.0
1.5 hour	28.2	39.9	48.1	56.5	67.8	76.8	86.1
2 hour	31.4	44.5	53.6	62.9	75.5	85.5	96.0
4 hour	36.3	51.4	62.0	72.7	87.3	98.8	110.9
6 hour	39.5	55.9	67.5	79.1	95.0	107.6	120.7
8 hour	41.9	59.4	71.6	84.0	100.8	114.2	128.1
10 hour	43.9	62.2	75.0	88.0	105.7	119.7	134.2
12 hour	45.6	64.6	77.9	91.4	109.7	124.3	139.4
16 hour	48.5	68.6	82.8	97.0	116.5	132.0	148.1
20 hour	50.8	71.9	86.7	101.7	122.1	138.3	155.1
24 hour	52.7	74.6	90.1	105.6	126.8	143.6	161.1
1 day	42.5	60.1	72.5	85.0	102.1	115.6	129.7
2 day	51.3	72.6	87.6	102.7	123.3	139.7	156.7
3 day	57.3	81.1	97.8	114.7	137.7	156.0	175.0
4 day	61.2	86.6	104.6	122.6	147.2	166.7	187.0
5 day	64.5	91.2	110.1	129.1	155.0	175.5	196.9
6 day	67.2	95.2	114.8	134.6	161.7	183.1	205.4
7 day	69.7	98.6	119.0	139.5	167.5	189.7	212.9

The peak discharge for a particular site can be calculated using various methodologies, however, the approach adopted in this study is the Rational Method. The Rational Method is one of the best-known and widely used methods for determining the peak floods of small to medium catchments (100 km^2 or less). The peak flow equation is based on a runoff coefficient (C), average rainfall intensity (I) and the effective area of the catchment (A).

The Rational formula is defined as:

$$Q = 0.278(CIA)$$ **Equation 1**

Where:

Q = peak flow (m^3/s)

C = run-off coefficient (dimensionless)

I = average rainfall intensity over catchment (mm/hour)

A = effective area of catchment (km^2)

The Rational formula has the following assumptions:

- The rainfall has a uniform spatial distribution across the total contributing catchment;
- the rainfall has a uniform time distribution for at least a duration equal to the time of concentration;
- the peak discharge occurs when the total catchment contributes to the flow occurring at the end of the critical storm duration, or the time of concentration;
- C remains constant for the storm duration, or the time of concentration; and
- the return period of the peak flow, T, is the same as that of the corresponding rainfall intensity.

3.4 Water Quality and Water Use

Surface water quality in the project area is not likely to be an issue. This assumption has been made based on the lack of surface water as a result of the arid nature of the project site, as well as the small size of the catchment areas contributing to the proposed mining areas, as depicted in **Figure 3-1** and **Figure 3-2**. A baseline surface water quality assessment will, however, be undertaken during the planned site visit. This will be done by taking surface water samples if and where surface water is located. If stormwater runoff from the proposed mining area is managed correctly, i.e. as per the DWA Best Practice Guidelines A1 (2006) presented in **Section 3.3**, water quality downstream of the proposed COZA Iron Ore project are not likely to be negatively affected.

There are a number of registered water users in the vicinity of the COZA Iron Ore project area. These registered water users are presented in **Table 3-4** and depicted in **Figure 3-3**. The total volume of licenced water use is approximately 2.7 Million Cubic Meters (MCM). The source of all licenced water use abstractions is from boreholes.

Table 3-4 Registered Water Users

Registration Number	Registered Use (m^3/annum)	Latitude	Longitude	Start Use Date	Registered Water Use Number	Source
25022350	23 400	-28.1575	23.1025	01-01-1980	25022350/1	BOREHOLE
25051648	2 600 000	-28.1503	22.9989	06-01-2008	25051648/1	BOREHOLE
25051648	7 300	-28.1503	22.9989	05-01-2008	25051648/1	BOREHOLE
25058874	7 300	-28.1914	23.1080	03-01-2012	25058874/1	BOREHOLE

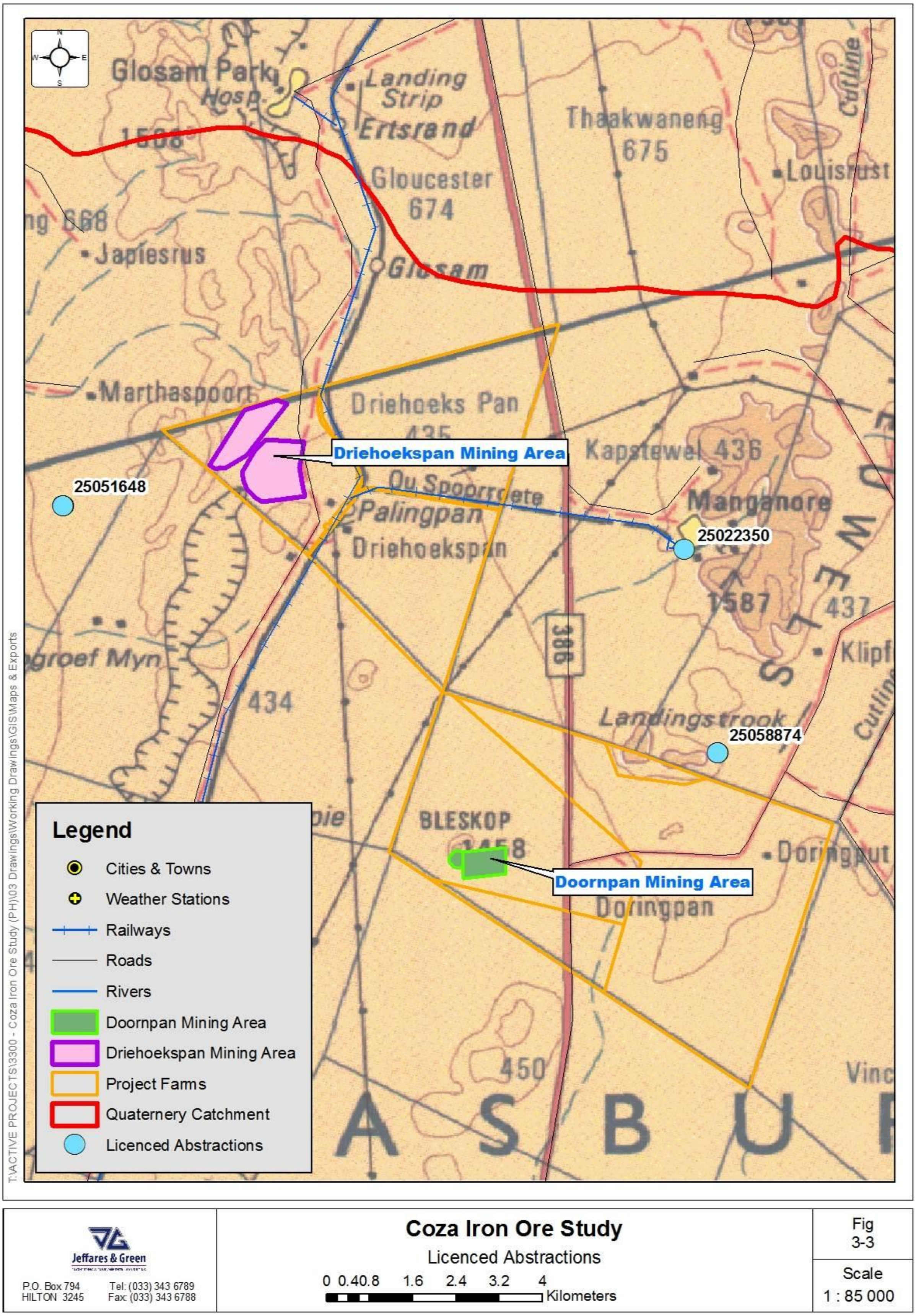

Figure 3-3 Registered Water Abstractions

4 CONCLUSIONS

A surface water resource delineation and hydrological characterisation assessment for the COZA Iron Ore project, located on the farms Driehoekspan 435 (Remaining Extent) and Doornpan 445 (Portion 1), in the Tsantsabane Local Municipality of the Northern Cape Province, was undertaken. It was found that the proposed Driehoekspan mining area intersected with a number of drainage lines and a wetland area, as defined by the NFEPA database. The location of this wetland area will need to be confirmed during the planned site visit to the proposed mining sites. It was found that the Doornpan mining area did not intersect with any drainage lines or wetland areas, this will also need to be confirmed during the site visit. When more detailed survey information becomes available, a more comprehensive analysis of drainage lines intersecting with the proposed mining area can be undertaken. The more detailed data may lead to the identification of additional drainage lines within the project area.

The proposed mining area is located within the quaternary catchment D73A, which is classed as endorheic. Endorheic can be described as a catchment area with no outlet, thus the rainfall that lands on the catchment only leaves through evaporative or seep processes.

Surface water quality in the project area is not likely to be an issue, due to the arid nature of the project site and the small size of the catchments contributing to the proposed mining areas. A total of four licenced water abstractions were identified in the vicinity of the project area. The total volume of licenced water use is 2.7 MCM. The source of all licenced water use abstractions is from boreholes.

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COZA IRON ORE PROJECT

DRIEHOEKSPAN MINE WATER BALANCE ASSESSMENT REPORT

October 2015

REVISION 00

Carried out by:

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DRIEHOEKSPAN MINE WATER BALANCE ASSESSMENT REPORT

VERIFICATION PAGE				Form 4.3.1 Rev 01
REPORT NO. 01		DATE : October 2015		STATUS: **Draft**
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QUALITY VERIFICATION This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2008 which has been independently certified by DEKRA Certification under certificate number 90906882				
Verification	Capacity	Name	Signature	Date
By Author	Senior Hydrologist	Phillip Hull		26/10/2015
Checked by	Associate / Senior Hydrologist	Ryan Gray		26/10/2015
Authorised by	Director	Simon Johnson		29/10/2015

DRIEHOEKSPAN MINE WATER BALANCE ASSESSMENT REPORT

TABLE OF CONTENTS

1 INTRODUCTION

Jeffares & Green (Pty) Ltd (J&G) have been appointed by Synergistics (Pty) Ltd to undertake a series of hydrological studies for the proposed COZA Iron Ore project located on Farm Driehoekspan 435 (Remaining Extent), Doornpan 445 (Portion 1) and Jenkins 562 in the Tsantsabane Local Municipality in the Northern Cape Province. The hydrological studies are to be undertaken to satisfy the requirements of the Minerals and Petroleum Resources Development Act (No 28 of 2002), the Environmental Management Act (No 107 of 1998) and the National Water Act (No 36 of 1998). This component of the greater hydrological study is a water balance study for the proposed Driehoekspan mining concession area.

1.1 Declaration of Independence

J&G have been appointed to conduct an independent water balance study for the proposed Driehoekspan Mine. J&G have therefore undertaken this study in an objective manner, even if this results in views and findings that are not favourable to the applicant or client. J&G have the expertise required to undertake this study and the resultant report presents the results in an objective manner.

2 SITE DESCRIPTION

The proposed Driehoekspan mine is located approximately 20 km north of the town Postmasburg within the Northern Cape Province, as depicted in **Figure 2-1**. It is approximately 180 km east from Upington and 180 km west of Kimberly. Other small towns in close proximity to the study site are Kathu, Sesheng and Dingleton. A site plan presenting the location of the proposed Driehoekspan Mine in relation to the Doornpan and Jenkins mining areas, as well as the main towns in the vicinity of the proposed mining sites is provided in **Figure 2-2**.

As per the terms of reference, the Driehoekspan Mine Project will involve mining an opencast pit on a portion of the farm Driehoekspan. The topsoil and overburden is to be removed by means of truck and shovel and relocated to an area in close proximity to the open pits. No processing, other than blending of material (to be done at the run-of-mine stockpile) will take place at the proposed site.

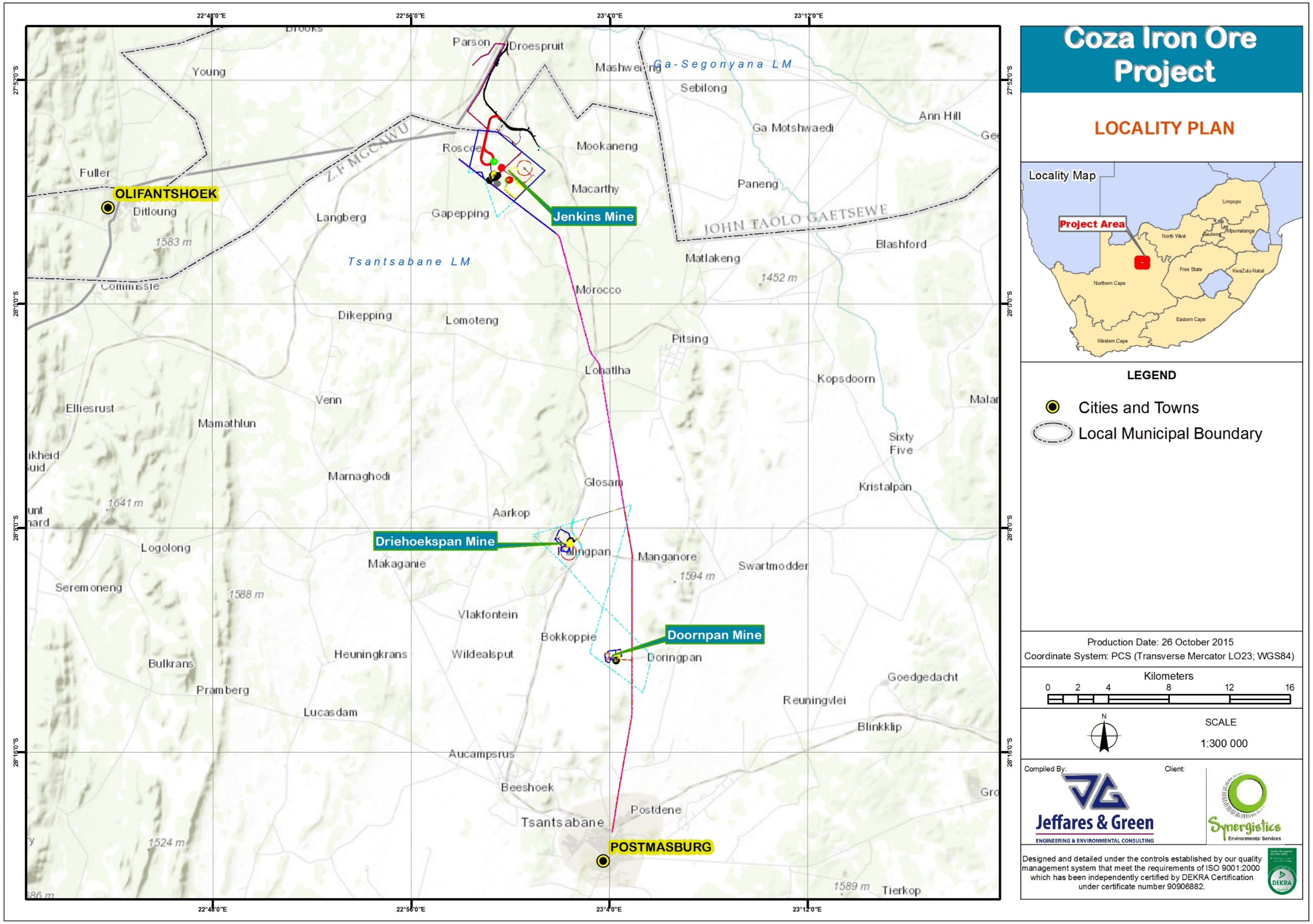

Figure 2-1 Driehoekspan Mine Locality Map

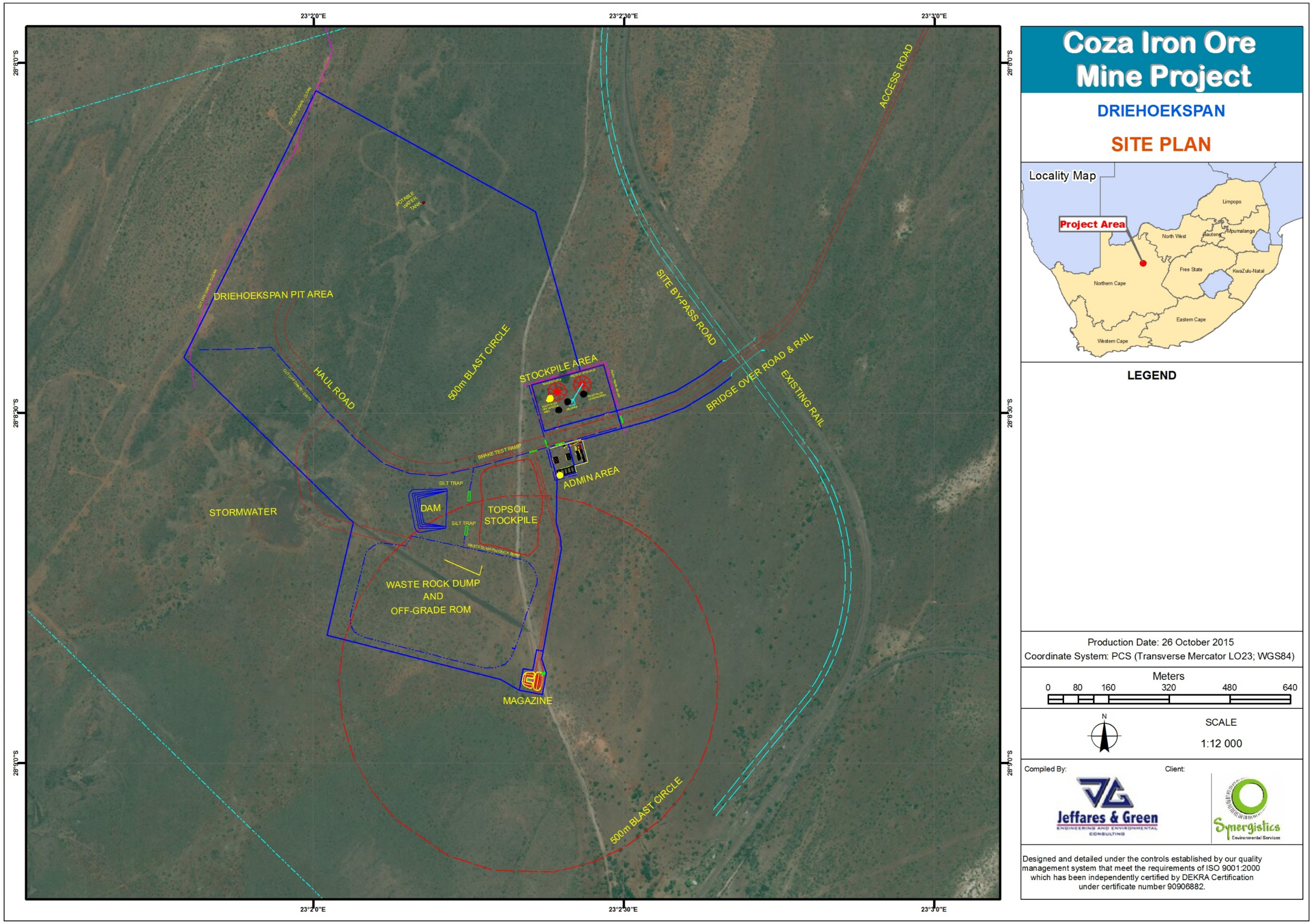

Figure 2-2 Driehoekspan Mine Site Plan

J&G conducted a site assessment on the 23rd of June 2015. The objective of this site visit was to assess topographical, soil and land cover characteristics of the project area. These site characteristics form the basis for understanding the hydrology of the project area. **Photographs 1** and **2**, taken during the site visit, present the general topography and vegetation cover at the proposed Driehoekspan Mine.

Photograph 1 and 2 **Depiction of the General Topography and Vegetation at the Proposed Driehoekspan Mine**

2.1 Climatic Conditions

The COZA Iron Ore project area falls within the steppe climate zone, as per the Kőppen BS classification. This climate category can be described as semi-arid and is able to support short scrubby vegetation, predominantly, including shrubs and grasslands, as depicted in **Photographs 1** and **2**.

Temperature data for the project area was obtained from the South African Weather Service (SAWS) station 0321141 W. This station is located approximately 25 km south of the Driehoekspan Mine project area, as depicted in **Figure 2-3**. The average monthly maximum and minimum temperatures for the project area, calculated using weather data spanning the period 1950 to 2000, are presented in **Table 2-1**. The maximum temperature recorded at this weather station is 46.5 ºC and the minimum is -8.4 ºC.

Table 2-1 Monthly Average Maximum and Minimum Temperatures Recorded For Years 1950 – 2000 at Station 0321141 W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum Temperature (ºC)	16.2	15.1	13.8	10.3	6.0	2.1	1.9	4.4	6.9	10.0	13.4	15.6
Maximum Temperature (ºC)	32.0	29.3	28.6	25.0	22.3	17.1	18.0	20.7	24.4	27.0	29.7	31.2

Rainfall data for the project area was obtained from the SAWS rainfall station 0320828 W. This rainfall station is located approximately 30 km south of the project site and was selected based on the record period and the reliability of the historical data. The details of this rainfall station are presented in **Table 2-2**. The mean monthly rainfall amounts over the period 1950 to 2000 are presented in **Table 2-3**. From **Table 2-3**, it is evident that most of the rainfall falls over the summer period (November to April). Rainfall over this period is predominately convectional. It is also noted that low rainfall values are recorded over the winter months (May to October). Rainfall falling over this period is predominantly frontal.

Table 2-2 Rainfall Station Details

Station Number	Station Name	MAP (mm)	Years Assessed	Reliability (%)	Longitude	Latitude
0320828 W	Aucampsrus	318	1950 - 2000	99.2	22º 58'	28º 17'

Table 2-3 Average Monthly Rainfall Depths Recorded For Years 1950 – 2000 at Rainfall Station 0320828 W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAP
Rainfall Depth (mm)	48	60	62	34	13	5	2	6	7	19	24	38	318

While rainfall is generally variable on a month-to-month basis, this is not the case with evaporation. Evaporative demands do not vary significantly from one year to next (i.e. evaporation in one October-month, for example, is similar to evaporation in the next October-month). Therefore, it is generally considered to be acceptable to apply 12 average monthly evaporation values over the year. The evaporation data used for the Coza Iron Ore Project was obtained from evaporation zone **7A** (Middleton and Bailey, 2008). Catchment evapotranspiration is calculated by applying 12 monthly evapotranspiration conversion factors, as presented in **Table 2-4**. Similarly, evaporation losses from an exposed water body are calculated by applying 12 monthly lake evaporation conversion factors, as presented in **Table 2-4**. The annual potential evaporation rate for the COZA Iron Ore study area is 2 450 mm. From **Table 2-4**, the highest evaporation rates occur during the hotter summer months of October to March.

Table 2-4 COZA Iron Ore Potential Evaporation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Evaporation Rate (mm)	333	256	221	154	111	85	98	133	184	247	292	336	2 450
Lake Evaporation Factor	0.84	0.88	0.88	0.87	0.85	0.83	0.81	0.81	0.81	0.81	0.82	0.83	
Evapotranspiration Factor	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.80	0.80	0.80	1.00	1.00	

3 WATER BALANCE

The monthly water balance for the Driehoekspan mining area was compiled based on the methodology outlined by the Department of Water Affairs (DWA) best practice guidelines G2 for water and salt balances. As per the guidelines, the water balance was compiled using the following steps and methodology:

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

3.1 Methodology

Step 1: Define the objectives of the balances

The objectives of the study are to prepare a water balance to simulate:

- Average monthly water requirements for:
    - o Dust suppression,
    - o Drilling rigs,
    - o Working faces and shovel,
    - o Wash bay requirements, and
    - o Potable water consumption.

- The storage of water in the pollution control dam; and
- The movement of water between the different sections of the mine.

Step 2: Define the boundaries for the individual balances

The following individual balances have been identified and solved for the proposed Driehoekspan mining area:

- Driehoekspan Pit,
- Process Water Reservoir,
- Washbay,
- Pollution Control Dam,
- Potable Water Reservoir,
- Offices, Changehouse and Workshop, and
- Waste Water Treatment Works.

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

The third step in creating the Driehoekspan Water Balance was to develop a schematic of the flow diagrams for the mining area. The schematic depicting the future mine situation is shown in **Figure 3-1**. As depicted it is envisaged that fissure water and rainfall falling into the pit will be pumped to the process water reservoir (to augment supply if excess water exists). In addition to this, the main water supply to the mine will be borehole water pumped to the Process Water Dam. It is assumed that water from the process water reservoir will supply water required for dust suppression, working faces, drill rigs and water required at the washbay. It is proposed that water from the washbay is directed to the pollution control dam from which excess water should be used for dust suppression. This will ensure the optimum use of water. It is also proposed that treated waste water from the treatment works is directed to the pollution control dam to allow this water to be used for dust suppression.

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

The **Figure 3-1** shows the resulting water balance for the mine. Inputs into the various infrastructure are given on the left of the diagram and outflows are given on the right of the diagram. All figures given in the balance are given as cubic meters per day (m^3/day). It is expected that during year five and six, fissure water will decant into the open pit.

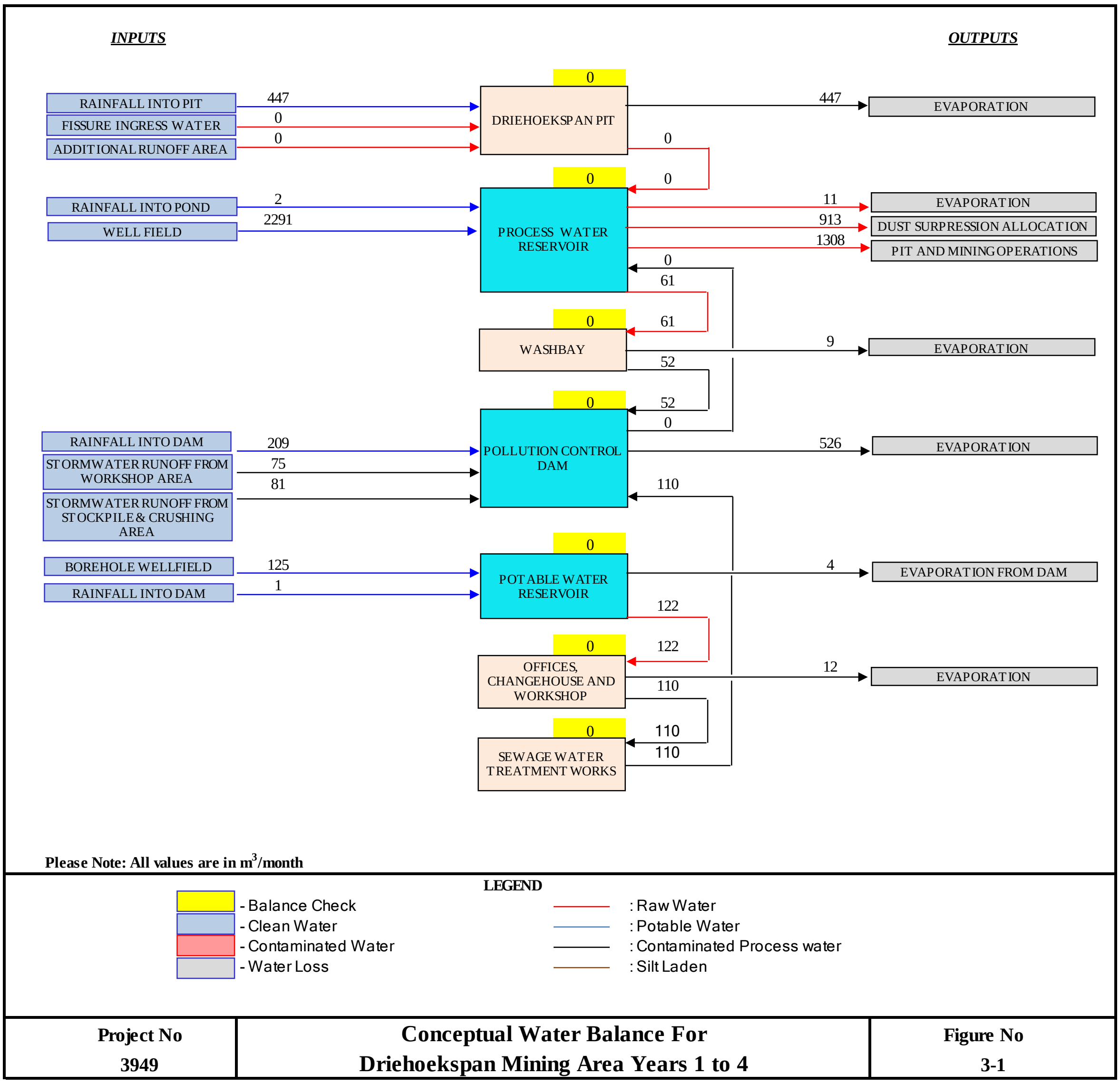

Figure 3-1 Driehoekspan Year 1 to Year 4 Conceptual Water Balance

Step 6: Assess the level of detail required

The level of detail provided in the water balance is based on average monthly values in cubic meters. This level of detail is sufficient for this study, as the input variables used to calculate the water balance have been given on a month-by-month basis. Thee different water balances have been provided in this report. The first, presented in **Figure 3-1**, is representative of the mine during the first four years of the mine. The second, presented in **Figure 3-2**, is representative of the mine during year five where it is expected that maximum groundwater ingress to the open pit equal to 15 m^3/day will occur. **Figure 3-3** presents the mine water balance during year six, where it is expected that the daily fissure water ingress to the open pit will be 20 m^3/day.

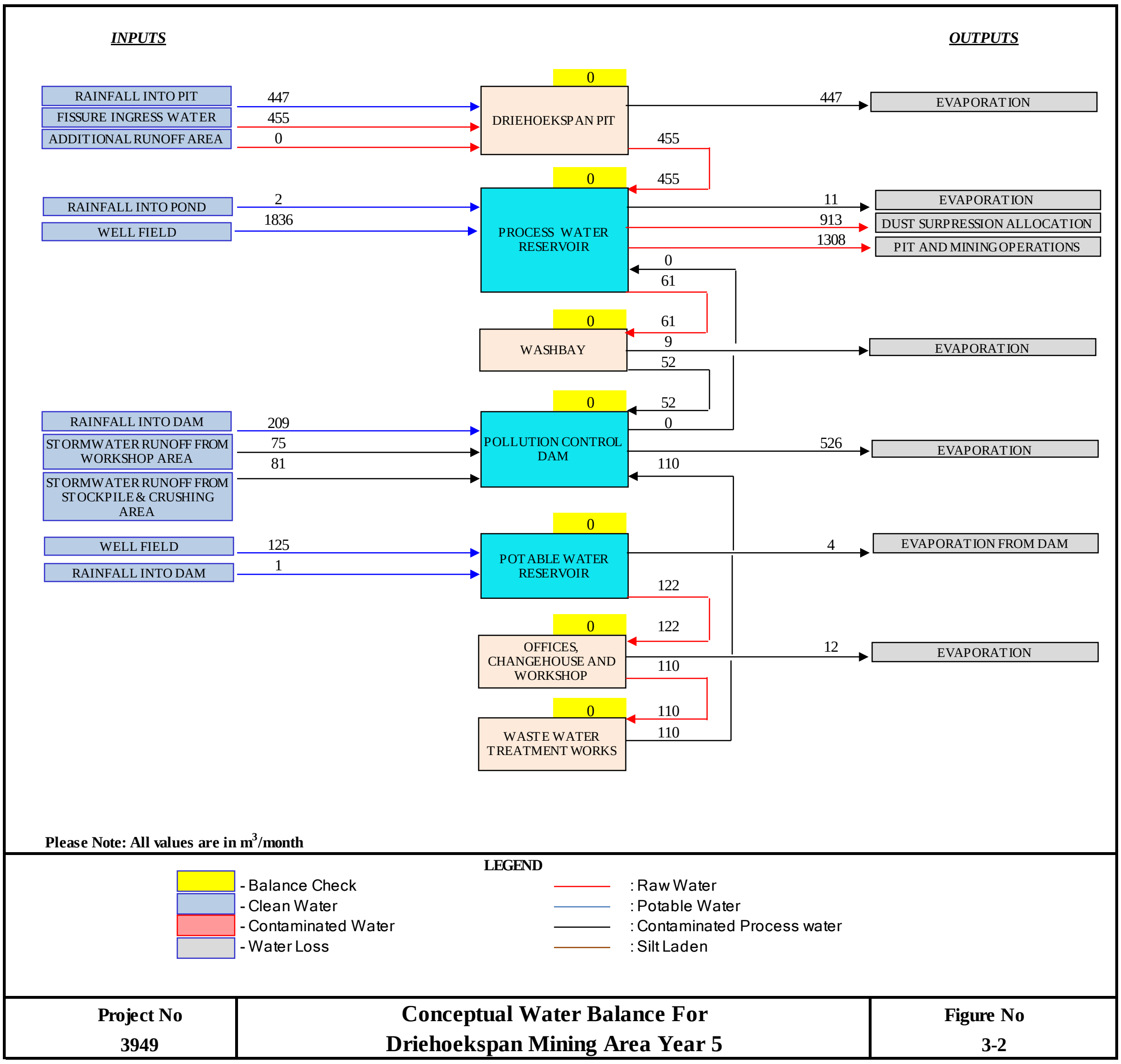

Figure 3-2 Driehoekspan Year 5 Conceptual Water Balance

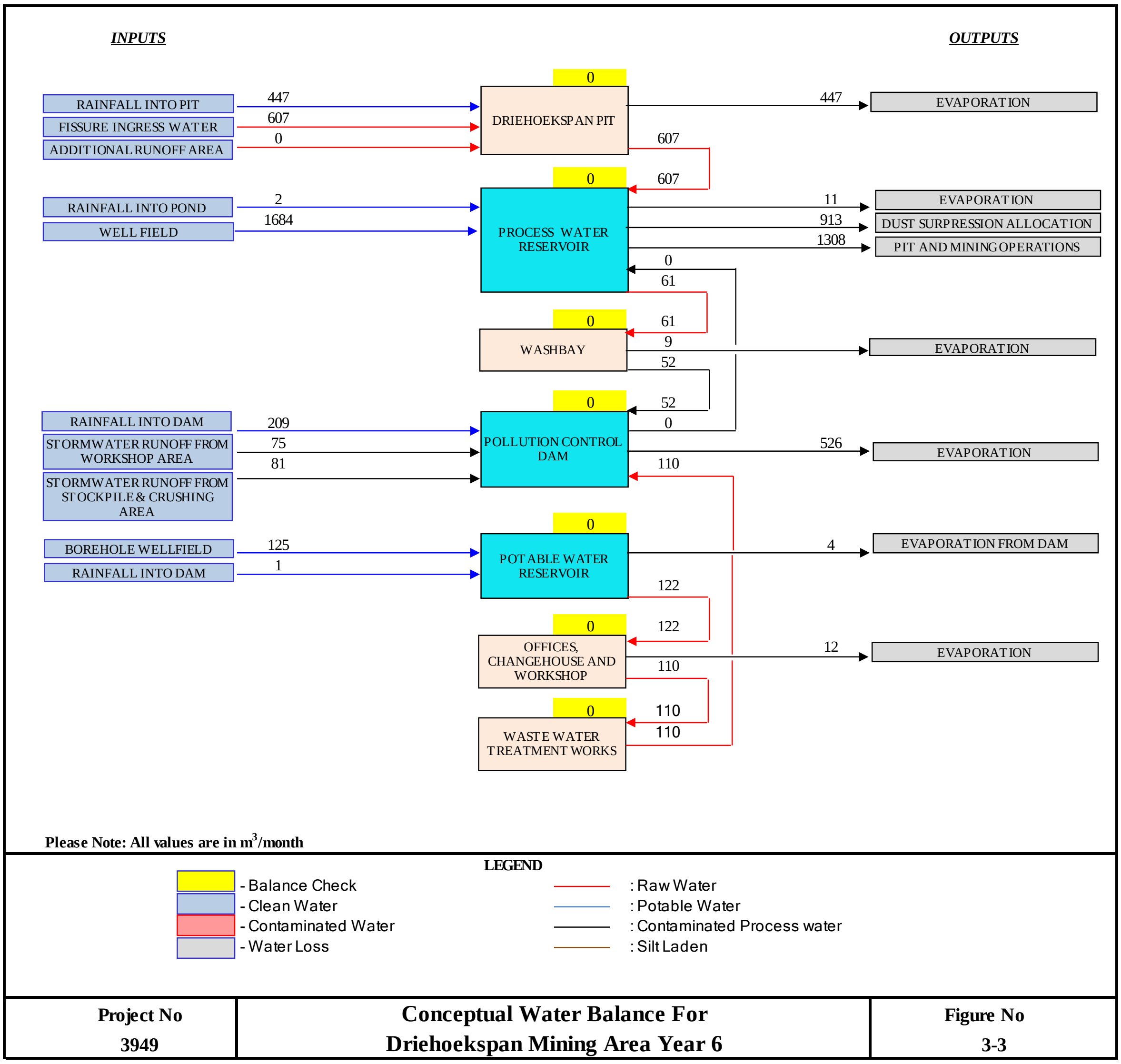

Figure 3-3 Driehoekspan Year 6 Conceptual Water Balance

Step 7: Assumptions

Due to the fact that the mine does not yet exist, it was necessary to make a number of educated assumptions for the water balance. **Table 3-1** describes the assumptions made in developing the water balance.

Table 3-1 Assumptions Made for the Water Balance

Variable	Value	Comment
Climate		
Mean Annual Rainfall (mm)	322	Obtained from WR2012 for Quaternary Catchment D73A.
Mean Annual Evaporation (mm)	2 450	Obtained from WR2012 for Evaporation Zone 7A.
Mine Layout		
Pollution Control Dam Area (m^2)	7 800	Measured on the layout plan.
Process Water Dam Area (m^2)	64	Information Provided (Diameter of 20 m).
Potable Water Dam Area (m^2)	24	Information Provided (Diameter of 8 m).
Driehoekspan Pit Area (m^2)	200 000	Measured from layout plan provided.
Crushing, Screening & Stockpile Area (m^2)	150 000	Measured from layout plan provided.
Workshop Area (m^2)	15 000	Measured from layout plan provided.
Pollution Control Dam Volume (m^3)	10 000	Provided by the Client.
Driehoekspan pit surrounding catchment area	-	Assumed diversion berms will be placed around the open pit.
Water Requirements		
Dust Suppression (m^3/month)	915	Provided by the Client (30 m^3/day).
Wash Bay (m^3/month)	61	Assumed individual area uses, however, the figure of 45 m^3/day or 1 371.8 m^3/month for process water demands (i.e. water used at the washbay, working faces and drill rigs) was provided by the client.
Working Faces/shovel (m^3/month)	1 155.8	
Drill Rigs (m^3/month)	155	
Potable Water (m^3/month)	125	As provided by the client. 80 staff and 50 ℓ per person per day (including that lost to evaporation from the Potable Water Reservoir).
Groundwater Ingress – Driehoekspan Pit		
Ground Water Ingress Year 1 (m^3/day)	0	Provided by the client.
Ground Water Ingress Year 2 (m^3/day)	0	
Ground Water Ingress Year 3 (m^3/day)	0	
Ground Water Ingress Year 4 (m^3/day)	0	
Ground Water Ingress Year 5 (m^3/day)	15	
Ground Water Ingress Year 6 (m^3/day)	20	

4 CONCLUSION AND RECOMMENDATIONS

A water balance for the proposed Driehoekspan mining area was undertaken using a number of assumptions, based largely on information supplied by the client. The water balance provides average monthly water requirements in cubic meters for the various sections of the mine. These water requirements are summarised as follows:

- Based on information supplied, process water requirements for the mine are approximately 2 282 m^3/month. This is based on a daily water requirement of 45 m^3/day for the mining operations (open faces and drill rigs for example) and approximately 30 m^3/day used for dust suppression.
- Potable water requirements were based on a staff compliment of 80 people each using approximately 50 litres of water a day. This equates to a potable water demand of approximately 4 m^3/day or 125 m^3/month.
- During years 1 to 4, the water demand from the wellfields will be 2 291 m^3/month for process water and 125 m^3/month for potable water. This equates to a daily water demand of approximately 79 m^3/day. During year 5 this demand decreases to approximately 65 m^3/day and during year 6 it decreases further to approximately 60 m^3/day. These decreases in process water demand are due to groundwater ingress to the open pit being pumped to the process water dam and therefore supplementing process water demands.

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COZA IRON ORE MINE PROJECT

1:50 AND 1:100 YEAR FLOODLINE REPORT

November 2015

QUALITY VERIFICATION

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

Verification	Capacity	Name	Signature	Date
By Author	Hydrologist	Phillip Hull		13/12/2013
Checked by	Hydrologist	Ryan Gray		13/12/2013
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ENGINEERING & ENVIRONMENTAL CONSULTING

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1 INTRODUCTION

Jeffares & Green (Pty) Ltd were appointed by Synergistics (Pty) Ltd to undertake a series of hydrological studies for the proposed COZA Iron Ore project located on Farm Driehoekspan No. 435 (Remaining Extent) and Doornpan No. 445 (Portion 1) in the Tsantsabane Local Municipality in the Northern Cape Province. The hydrological studies are to be undertaken to satisfy the requirements of the Minerals and Petroleum Resources Development Act (No 28 of 2002), the Environmental Management Act (No 107 of 1998) and the National Water Act (No 36 of 1998). This component of the greater hydrological study is a flood study of both the Driehoekspan and Doornpan mining concession areas. The flood study was undertaken by delineating the 1:50 and 1:100 year floodlines.

In order to determine accurate floodline delineations, detailed survey data of the study area is required. In this study, detailed survey data in the form of a Lidar Survey covering the two proposed mining sites was provided.

1.1 Declaration of Independence

J&G have been appointed to conduct an independent floodline study for the proposed Driehoekspan and Doornpan Mine Areas. J&G have therefore undertaken this study in an objective manner, even if this results in views and findings that are not favourable to the applicant or client. J&G have the expertise required to undertake this study and the resultant report presents the results in an objective manner.

2 SITE DESCRIPTION

The COZA Iron Ore project is located approximately 10 km north of the town Postmasburg within the Northern Cape Province, as depicted in **Figure 2-1**. It is approximately 180 km east from Upington, and 180 km west of Kimberley. Other small towns in close proximity to the study site are Kathu, Sesheng and Dingleton.

As per the terms of reference, the COZA Iron Ore project will involve mining from two opencast pits on portions of the farms Doornpan (approximately 25 ha of disturbed area) and Driehoekspan (approximately 80 ha of disturbed area). The topsoil and overburden is to be removed by means of truck and shovel and relocated to an area in close proximity to the open pits. No processing, other than blending of material (to be done at the run-of-mine stockpile) will take place at the proposed sites.

The project area falls within the steppe climate zone, as per the Kőppen BS classification. This climate category can be described as semi-arid, and is able to support short scrubby vegetation, predominantly including shrubs and grasslands. The general topography of the area surrounding the mining sites is characteristically flat to undulating, as depicted in **Figure 2-2**.

The soils in the region are generally shallow, normally not exceeding more than 300 mm in depth. The predominant soil types are those of Glenrosa and Mispah. The Glenrosa type soil is characterised by an Orthic A horizon over a Lithocutanic B horizon, whereas the Mispah type soil is characterised by an Orthic A horizon over bedrock.

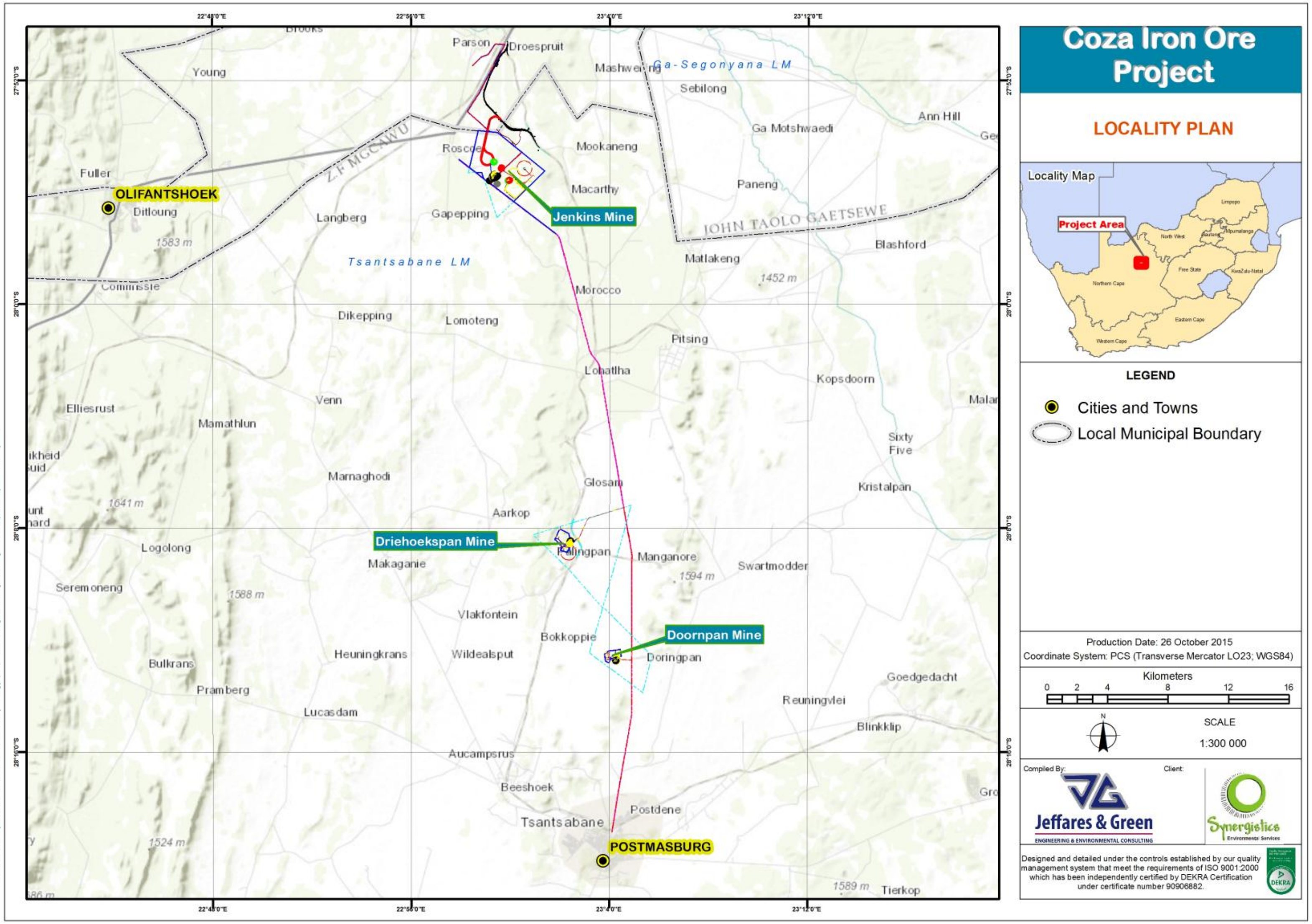

Figure 2-1 Locality Plan of the Proposed COZA Iron Ore Project

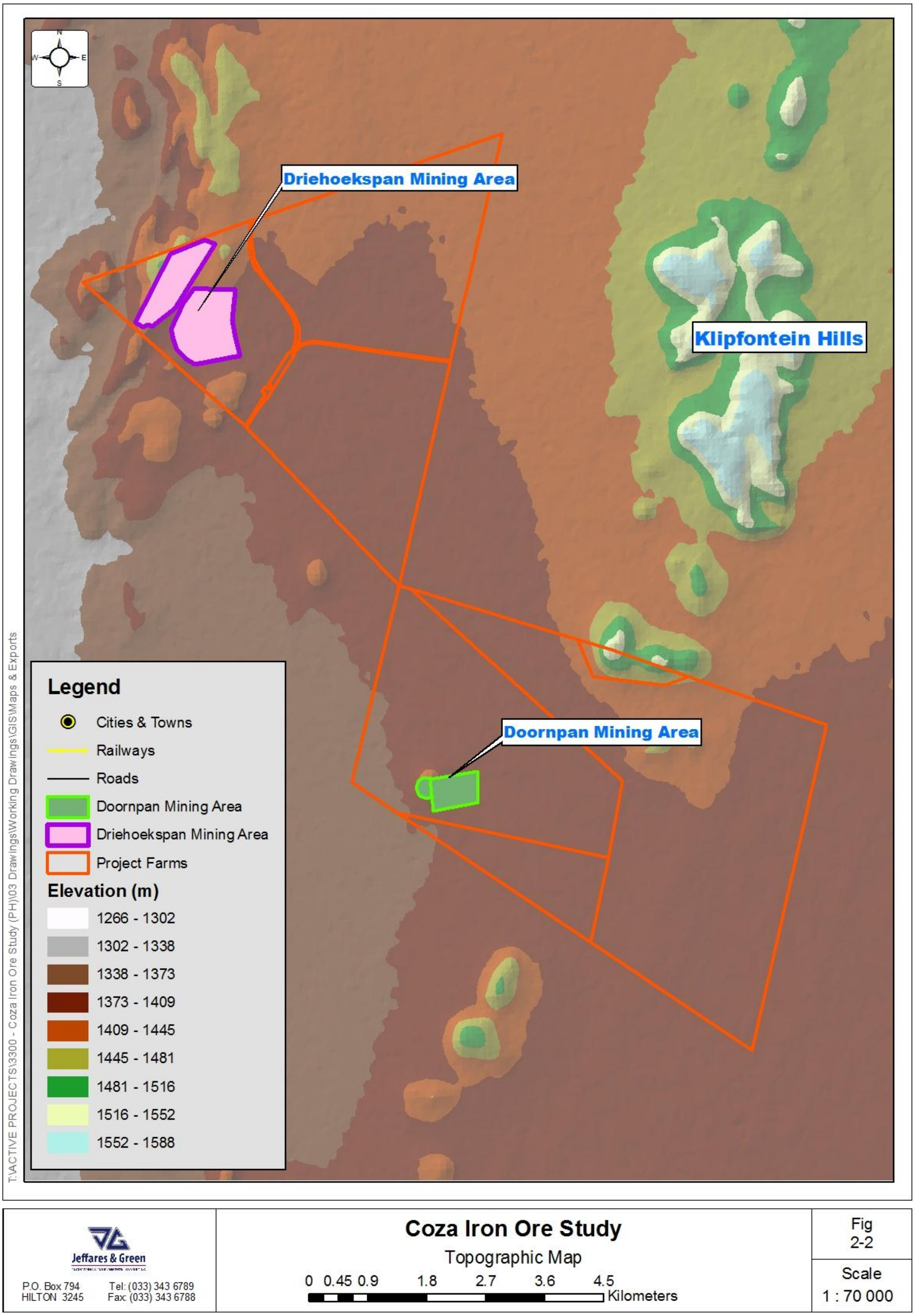

Figure 2-2 General Topography

3 METHODOLOGY

3.1 Design Rainfall

Design rainfall is required as an input into deterministic methods of calculating peak discharge values associated with various recurrence interval storm events (floods). For this purpose, the Design Rainfall Utility developed by Smithers and Schulze (2000), which utilises a regionalised L-moment Algorithm and scale invariance to estimate design rainfall at any 1’ × 1’ grid interval in South Africa, was used to determine design rainfall for the two proposed mining sites. The design rainfall depths used in peak discharge calculations are presented in **Table 3-1** and **Table 3-2** for the Driehoekspan and Doornpan mining areas respectively.

Table 3-1 Design Rainfall of the Driehoekspan Mining Site

Duration	Return Period (Years) Design Rainfall Depth (mm)						
	1 : 2	1 : 5	1 : 10	1 : 20	1 : 50	1 : 100	1 : 200
5 min	7.7	10.9	13.2	15.4	18.5	21.0	23.5
10 min	11.5	16.2	19.6	22.9	27.5	31.2	35.0
15 min	14.4	20.4	24.7	28.9	34.7	39.3	44.1
30 min	18.8	26.6	32.1	37.6	45.1	51.1	57.4
45 min	21.9	31.0	37.4	43.8	52.6	59.6	66.9
1 hour	24.4	34.5	41.7	48.9	58.7	66.5	74.6
1.5 hour	28.5	40.3	48.6	57.0	68.4	77.5	87.0
2 hour	31.7	44.9	54.2	63.6	76.3	86.4	97.0
4 hour	36.7	51.9	62.6	73.4	88.2	99.9	112.1
6 hour	39.9	56.5	68.2	79.9	96.0	108.7	121.9
8 hour	42.4	60.0	72.4	84.9	101.9	115.4	129.5
10 hour	44.4	62.8	75.8	88.9	106.8	120.9	135.6
12 hour	46.1	65.3	78.8	92.4	110.9	125.6	140.9
16 hour	49.0	69.3	83.6	98.1	117.8	133.4	149.6
20 hour	51.3	72.6	87.6	102.7	123.4	139.7	156.7
24 hour	53.3	75.4	91.0	106.7	128.1	145.1	162.8
1 day	42.9	60.7	73.3	85.9	103.2	116.8	131.1
2 day	51.9	73.4	88.6	103.8	124.7	141.2	158.4
3 day	57.9	82.0	98.9	116.0	139.3	157.8	177.0
4 day	62.0	87.7	105.8	124.0	148.9	168.7	189.3
5 day	65.3	92.3	111.4	130.6	156.9	177.7	199.3
6 day	68.1	96.3	116.2	136.3	163.7	185.4	208.0
7 day	70.6	99.9	120.5	141.3	169.6	192.1	215.5

Table 3-2 Design Rainfall of the Doornpan Mining Site

Duration	Return Period (Years) Design Rainfall Depth (mm)						
	1 : 2	1 : 5	1 : 10	1 : 20	1 : 50	1 : 100	1 : 200
5 min	7.7	10.8	13.1	15.4	18.4	20.9	23.4
10 min	11.4	16.1	19.5	22.8	27.4	31.0	34.8
15 min	14.4	20.3	24.5	28.8	34.5	39.1	43.9
30 min	18.6	26.3	31.8	37.3	44.8	50.7	56.9
45 min	21.7	30.7	37.0	43.4	52.1	59.0	66.2
1 hour	24.1	34.2	41.2	48.3	58.0	65.7	73.7
1.5 hour	28.1	39.8	48.0	56.3	67.6	76.5	85.8
2 hour	31.3	44.3	53.4	62.7	75.2	85.2	95.6
4 hour	36.2	51.2	61.7	72.4	86.9	98.5	110.5
6 hour	39.4	55.7	67.2	78.8	94.6	107.2	120.2
8 hour	41.8	59.1	71.4	83.7	100.5	113.8	127.7
10 hour	43.8	62.0	74.8	87.7	105.3	119.2	133.7
12 hour	45.5	64.4	77.7	91.0	109.3	123.8	138.9
16 hour	48.3	68.3	82.5	96.7	116.1	131.5	147.5
20 hour	50.6	71.6	86.4	101.3	121.6	137.7	154.5
24 hour	52.5	74.4	89.7	105.2	126.3	143.1	160.5
1 day	42.3	59.9	72.2	84.7	101.7	115.2	129.2
2 day	51.1	72.3	87.2	102.3	122.8	139.1	156.1
3 day	57.1	80.7	97.4	114.2	137.2	155.4	174.3
4 day	61.0	86.3	104.1	122.1	146.6	166.0	186.2
5 day	64.2	90.8	109.6	128.5	154.3	174.8	196.1
6 day	66.9	94.7	114.3	134.0	160.9	182.3	204.5
7 day	69.4	98.2	118.4	138.9	166.8	188.9	211.9

3.2 Design Flood Hydrology

The method adopted for the peak discharge calculations was the Rational Method. The Rational Method is one of the best-known and widely used methods for determining the peak floods of small to medium catchments (100 km^2 or less). The peak flow equation is based on a runoff coefficient (C), average rainfall intensity (I) and the effective area of the catchment (A).

The Rational formula is defined as:

$Q = 0.278(CIA)$ **Equation 1**

Where:

Q = peak flow (m^3/s)

C = run-off coefficient (dimensionless)

I	=	average rainfall intensity over catchment (mm/hour)
A	=	effective area of catchment (km²)

The Rational formula has the following assumptions:

- The rainfall has a uniform spatial distribution across the total contributing catchment;
- The rainfall has a uniform time distribution for at least a duration equal to the time of concentration;
- The peak discharge occurs when the total catchment contributes to the flow occurring at the end of the critical storm duration, or time of concentration;
- C remains constant for the storm duration, or the time of concentration; and
- The return period of the peak flow, T, is the same as that of the corresponding rainfall intensity.

Catchment C Factors, required as input in to the Rational Method, are determined by accounting for a combination of catchment landcover types (C_v), soils (C_p) and slope (C_s). The land use of the Driehoekspan and Doornpan contributing catchment areas were classed into three sections, namely thin bush (50 %), grassland (45%) and open ground (5%). The soils of the contributing catchment were classed between impermeable and semi-permiable (soil class C/D). The surface slope for each catchment was estimated from a digital terrain model (DTM) created from 1 m contour data. Four classes of surface slope (< 3, 3 - 10, 10 - 30 and 30 - 100 %) were identified from the DTM, which were used in the determination of their respective areas and enabled the calculation of the slope component of the C-factor.

The slope of each river channel, which is used to calculate the time of concentration, was calculated using the ArcMAP 9.3 software, based on the 1 m contour information provided by the client.

3.3 Hydraulic Modelling

The HEC-RAS model was used to undertake the 1-dimensional hydraulic modelling using spatial data at 1 m contour intervals, as provided by the client. To further increase the accuracy of the simulations, the contour data was input into ArcMAP and used to create a DTM (**Figure 4-1** and **Figure 4-2**). This allows for the cross-section elevations and other topology to be extracted from the DTM utilising HEC-GeoRAS (an ArcMAP 9.3 extension that links directly with the hydraulic model). This data was subsequently exported into the HEC-RAS model for hydraulic modelling of the previously calculated peak discharge values.

The roughness of the channel and floodplain surfaces needs to be accounted for within the hydraulic model. In this case, Manning's n values (Chow, 1959) were used to describe the surface roughness within HEC-RAS. **Table 3-3** presents the general Manning's n values for the river/stream reaches modelled.

Table 3-3 Manning's n Values used in the Hydraulic Modelling (Chow, 1959)

Location	Manning's n	Description
Channel	0.04	Clean and Winding with Stones and Vegetation
Floodplain	0.05	Scattered Brush

4 RESULTS

The following section presents the results of the flood study undertaken for the proposed Driehoekspan and Doornpan Mining areas. A DTM was developed for each of the proposed mining sites in order to delineate catchment areas and drainage lines, as presented in **Figure 4-1** and **Figure 4-2** for the Driehoekspan and Doornpan mining areas respectively. There are no defined drainage lines in the vicinity of the proposed Doornpan mining area and so, as a result, a floodline study is not required for this mining precinct. This is shown in **Figure 4-1**.

4.1 Peak Discharge Calculations and Floodline Delineation

The catchment specific variables used in the Rational Method to calculate peak discharge values are presented in **Table 4-1** and **Table 4-2**, with the resultant peak discharge values also presented in **Table 4-2**. The C-Factors presented in **Table 4-2** are relatively low (considering the soil, vegetation and slopes of the catchment areas being conducive for a high C-Factor) largely due to the inherently low rainfall of the area in which the project falls.

The 1:50 and 1:100 year floodlines, based on the peak discharge values presented in **Table 4-2**, are provided in **Figure 4-3**.

Table 4-1 Catchment Characteristics Used in Determining Peak Discharge Values for (cf. Figure 4-2)

River Number	Area (km^2)	Length of Longest Water Course (m)	Average Channel Slope (m/m)	Time of Concentration (hours)
Catchment 1	0.70	1 719	0.030	0.39
Catchment 2	0.83	1 880	0.020	0.48
Catchment 3	0.56	1 238	0.036	0.28
Main Catchment	2.57	2 105	0.027	0.47

Table 4-2 Design Flood Results of the Various Catchments within the Driehoekspan Mining Area

River Name	Area (km^2)	Catchment C-Factor		Design Rainfall (mm)		Peak Discharge (m^3/s)	
		1:50	1:100	1:50	1:100	1:50	1:100
Catchment 1	0.70	0.346	0.350	103.6	117.3	6.98	8.32
Catchment 2	0.83	0.346	0.350	91.3	103.3	7.18	8.56
Catchment 3	0.56	0.346	0.350	127.1	143.9	6.73	8.03
Main Catchment	2.57	0.346	0.350	127.1	143.9	22.90	27.27

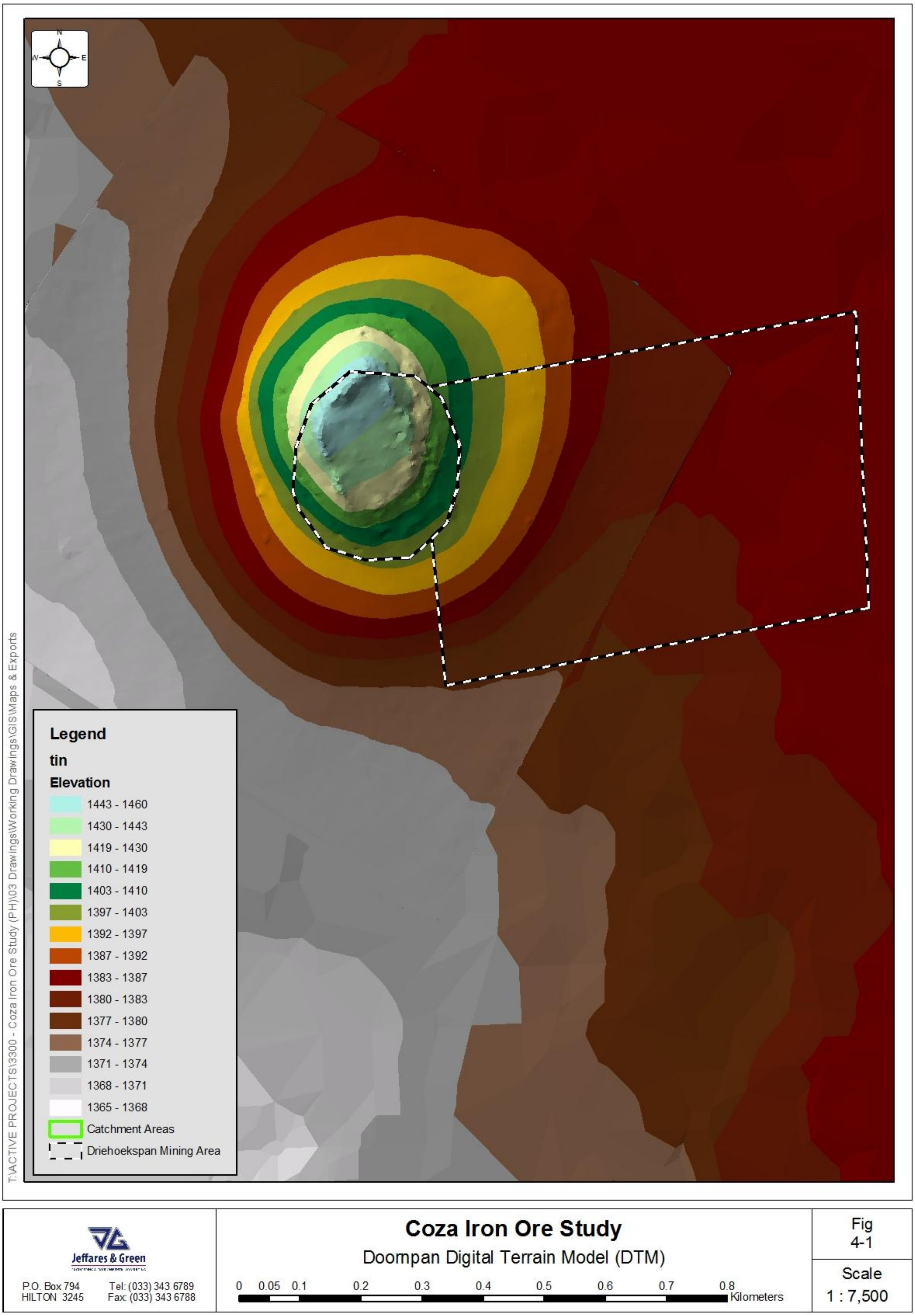

Figure 4-1 Doornpan DTM used for the Delineation of Drainage Lines and Catchment Areas

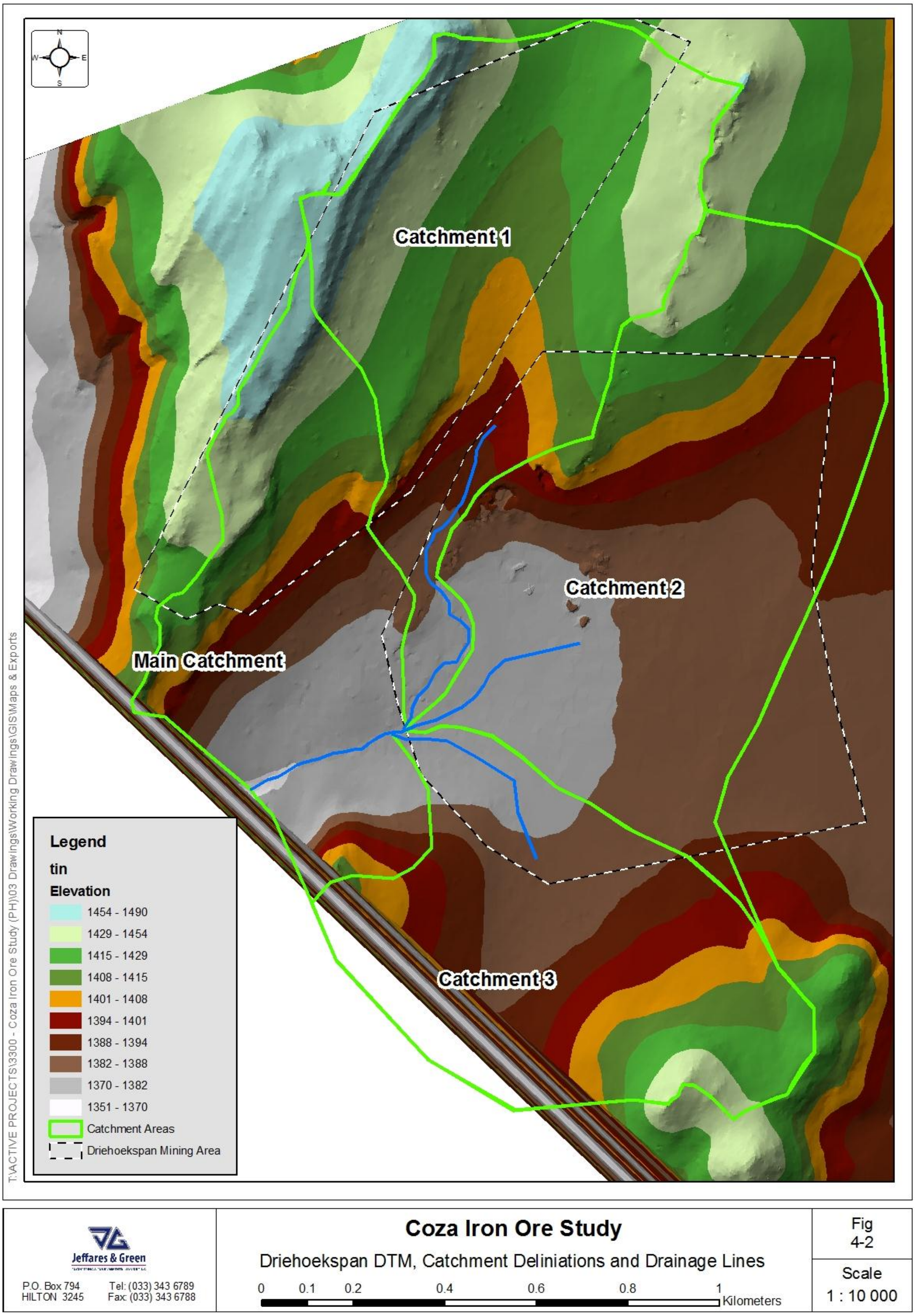

Figure 4-2 Driehoekspan DTM used for the Delineation of Drainage Lines and Catchment Areas

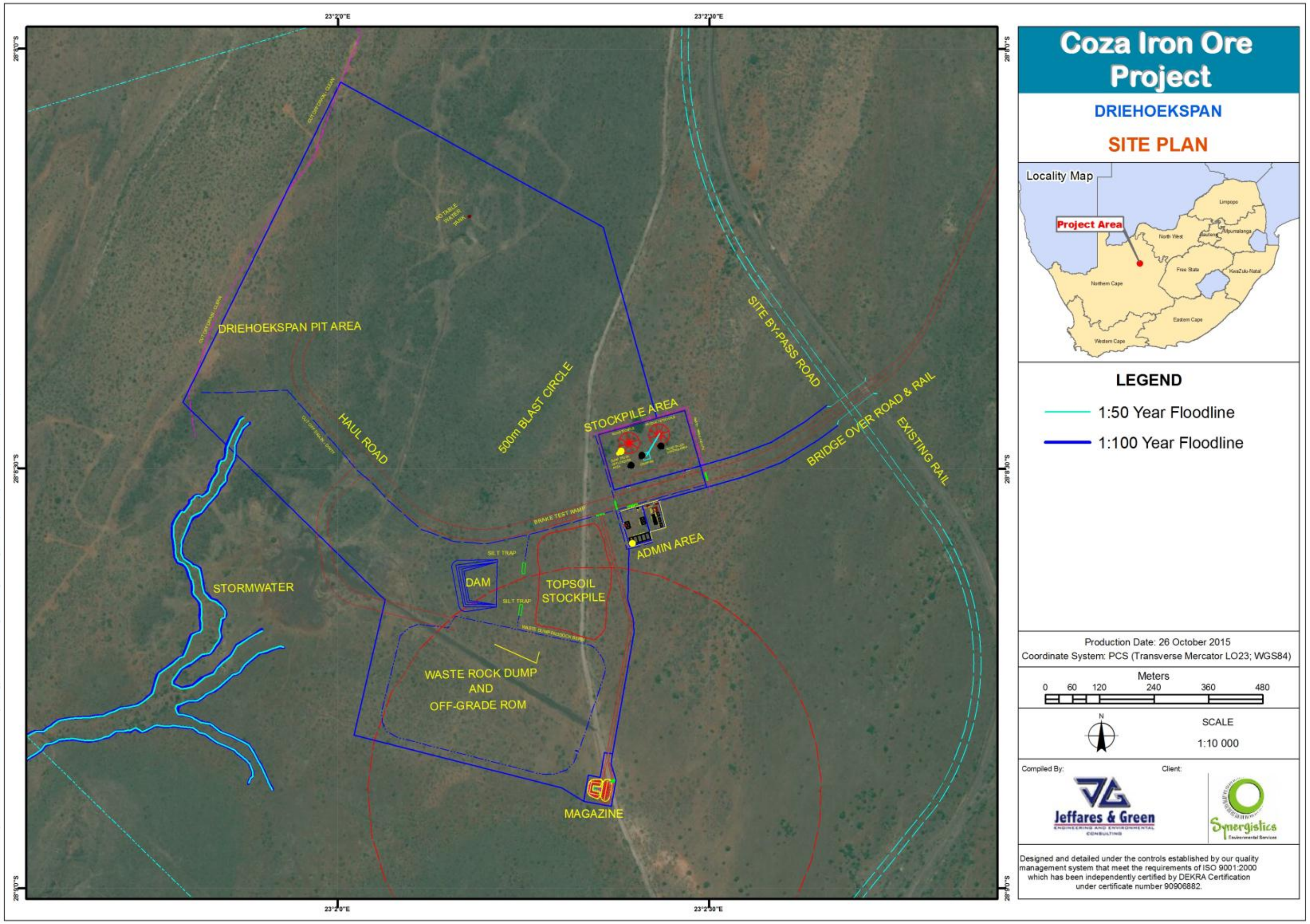

Figure 4-3 1:50 and 1:100 Floodlines for the Driehoekspan Study Area

5 CONCLUSIONS AND RECOMMENDATIONS

It was found that there are no defined drainage lines in the area of the proposed Doornpan mining area. As a result of this, there is no requirement for a floodline delineation in this mining precinct.

Based on survey information provided and the site visit undertaken, It was found that there are three drainage lines falling within the proposed Driehoekspan mining precinct that required floodline delineations. The 1:50 and 1:100 year return period floodlines were delineated along each of the three identified drainage lines. Based on the results of the floodlines study, it was found that all mining infrastructure is located outside of the delineated 1:50 and 1:100 year floodlines. It should, however, be noted that due to the flat nature of the area in which mining infrastructure is to be located, undefined sheet flow is likely during significant storm events. This is unlikely to pose any risk to mine infrastructure due to the low velocities associated with the sheet flow, however, it is recommended that bunding around mine infrastructure (rock dumps, soil stockpiles, workshops etc.) are implemented as part of the stormwater management plan to be compiled for the mine.

6 REFERENCES

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