DIGBY WELLS ENVIRONMENTAL

Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province

Greenhouse Gas and Climate Change Assessment

Project Number:

VMC3049

Prepared for:

Pamish Investments No. 39 (Pty) Ltd

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EXECUTIVE SUMMARY

Pamish Investments No. 39 (Pty) Ltd (Pamish) is proposing the development and operation of a new Magnetite Open Pit Mine and associated infrastructure at a site located 45 km northwest of Mokopane in Limpopo Province (hereafter referred to as the project). Please refer to Appendix A for the layout plans.

In line with the proposed Project's commitment to the IFC Performance Standards, specifically IFC Performance Standard 3: Resource Efficiency and Pollution Prevention, the Project will be required to promote the reduction of project-related greenhouse gas (GHG) emissions and to evaluate technically feasible and cost-effective options to reduce or offset GHG emissions.

The report comprises both an *ex ante* emission estimation as well as a climate response model. The estimated absolute operational phase emissions are 166 807 tonnes CO_2 equivalent (tCO_2-e) per annum. This equates to 0.04% of current South African emissions and 0.0004% of global emissions. Although this project is an insignificant contributor, climate change is a cumulative impact as a result of numerous activities.

In isolation the project emissions as they have been calculated do not have any significant long term climate change impacts. However contributions to climate change and sustainability are aspects that can only truly be assessed cumulatively. When the project becomes operational, an intensity emission target must be set and linked to a metric reasonable for the operation and performance monitored against the target.

Once the project is operational, it is recommended that emission reduction strategies for the following, be implemented:

- Vehicle Fleet, for both company and third party vehicles;
- Sewage Treatment Plant; and
- General GHG reduction and off-set strategies.

Resource consumption monitoring measures have also been recommended and should form part of the overall monitoring programme of the operation. The GHG monitoring programme is built on the ISO 14064-2 standard.

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1 Introduction

1.1 Project Background

Pamish Investments No. 39 (Pty) Ltd (Pamish) is proposing the development and operation of a new Magnetite Open Pit Mine and associated infrastructure at a site located 45 km northwest of Mokopane in Limpopo Province (hereafter referred to as the project). Please refer to Plan 1 for a regional setting and Plan 2 for a local setting.

In terms of the requirements of the Minerals and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002), (MPRDA) as amended, a Mining Right Application (MRA) must be submitted to the Department of Mineral Resources (DMR) for the project. In support of the MRA, an Environmental Impact Assessment (EIA) process must be undertaken in accordance with the new EIA Regulations (GN R. 982), December 2014 promulgated in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998). Environmental authorisation is in addition required for certain listed activities ancillary to the mining operation as contained in Listing Notices (GN R983, 984 and 985).

Within the project site, two Titanium- magnetite zones have been identified, namely the main magnetite layer and the iron and titanium-rich zone. The main magnetite layer consists of two massive Titanium-magnetite layers separated by a parting consisting of lower concentrations of Titanium-magnetite.

Open pit mining is considered the optimal mining method based on the thickness and positioning of the mineral resource. The main magnetite layer is covered by 2 m of topsoil which will be stripped to expose the outcrop. Open pit mining is proposed to be undertaken outwards from the middle of the strike length advancing north and south to an initial depth of 20 m below the surface then to 40 m and thereafter to 60 m, and 80 m. A bench height of 10 m will be used to allow for the separate loading of the two ore layers and the parting. The parting ore will either be stockpiled as a low grade ore or be sent to the waste rock dump, depending on its grade.

There are two open pits planned, which are separated by the D4380 Provincial Road, the footprint of the open pits are 129 ha and 66 ha. Please refer to Plan 3 for an infrastructure layout plan in Appendix A.

The Life of Mine (LoM) is approximately 30 years with a Run of Mine (RoM) of approximately one million tonnes per annum (tpa).

1.2 Terms of Reference

In line with the proposed Project's commitment to the IFC Performance Standards, specifically IFC Performance Standard 3: Resource Efficiency and Pollution Prevention, the Project will be required to promote the reduction of project-related greenhouse gas (GHG) emissions and to evaluate technically feasible and cost-effective options to reduce or offset GHG emissions.

The development of an *ex ante* GHG emissions estimate and reporting framework is the first step in determining potential emission reduction or offset opportunities for the project and allows for integration of such opportunities in the project design and future development. The terms of reference for the carbon footprint estimation and reporting framework includes:

- Legislative and policy framework analysis;
- Identification of GHG emission sources;
- Calculation of GHG emissions and emission intensity;
- Potential climate change assessment; and
- Reporting framework and management plan.

The aspects of the project with relevance to this study are:

- Site clearance and vegetation removal;
- Change of land-use from agriculture to mining;
- Development of two open pits by blasting and truck and shovel methods (129 ha and 69 ha footprints);
- Use of fuels (in the fleet and generators), maintenance/workshop oils, and explosives; and
- Waste generation, storage and disposal (hazardous and general);

1.3 Purpose and Scope of this Report

This report attempts to quantify the potential greenhouse gas (GHG) emissions of the Magnetite project and identify the impact that the legislation and policies (discussed below), will have on the project. The report has also been compiled taking into account the Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard as developed by the World Business Council for Sustainable Development and the World Resources Institute (WBCSD/WRI).

2 Details of the Specialist

Marcelle Radyn holds a Bachelor of Science Degree with Honours in the fields, Environmental Science and Management. Marcelle was previously employed with a consulting civil engineering company where he was responsible for integrated water and waste management plans, water use licensing, water monitoring and water balance modelling for large mining operations. He has undertaken specialist training with the GHG Management Institute based in the United States and is currently responsible for growing this department within Digby Wells. Marcelle has undertaken GHG assessments and audits for various gold mines, coal mines and power stations around South and Western Africa.

3 Legislative and Policy Framework

3.1 International Framework

Magnetite requires its Environmental and Social Impact Assessment (ESIA) to be compliant with the International Finance Corporation's (IFC) performance standards, as well as with the Equator Principles (EP) guidelines for ESIA's.

The IFC Guidelines of 2012 require an applicant to investigate and implement technically and financially feasible alternatives/options to reduce GHG emissions. The applicant for a project that emits, or is expected to emit, more than 25 000 tonnes of CO_2-e per annum must account for direct and indirect emissions and recalculate these emissions annually to monitor performance.

The current EPs, released in June 2013, require the quantification of GHG emissions and for measures to be taken to reduce these emissions where technically and financially viable. The EPs require this quantification for all projects in all locations if the anticipated emissions are in excess of 100 000 tones CO_2-e per annum.

3.2 National Framework

3.2.1 National Climate Change Response White Paper, 2011

The National Climate Change Response White Paper was released in 2011. The White Paper presents the South African Government's vision for an effective climate change response and the long-term transition to a climate-resilient and lower-carbon economy and society. The objectives are:

- Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity; and
- Make a fair contribution to the global effort to stabilise GHG concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner.

One of the key elements in the approach to achieve these objectives is the deployment of a range of economic instruments to support the system of desired emissions reduction outcomes, including the appropriate pricing of carbon and economic incentives, as well as the possible use of emissions offset or emission reduction trading mechanisms for those relevant sectors, sub-sectors, companies or entities where a carbon budget approach has been selected. This is detailed further in the Carbon Tax Discussion Paper, published in May 2013 by the National Treasury of South Africa.

3.2.2 Draft National Greenhouse Gas Emission Reporting Regulations

The Department of Environmental Affairs (DEA) has gazetted draft regulations for the mandatory reporting of greenhouse gases emissions through the National Environmental Management: Air Quality Act (NEM:AQA), Act 39 of 2004.

The Gazette, No 411 of 2015, was published on 11 May 2015 with a 60 day commenting period. The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only and are structured around the Intergovernmental Panel on Climate Change (IPCC) guidelines. Although these have not yet been accepted by parliament, the industry expects it to be imminent.

The Department of Energy has also published Draft Regulations Regarding Registration, Reporting on Energy Management and Submission of Energy Management Plans in GN 259 on 27 March 2015. These are out for public comment but will need to be incorporated into the overall management plan once the Regulations are legislated.

3.2.3 Carbon Tax Discussion Paper

The National Treasury released a Discussion Paper on the carbon tax option for reducing national GHG emissions in 2013, an update to the 2010 discussion paper.

Following extensive consultation, a preference for a fuel input tax emerged. It was agreed that emissions factors and/or procedures are available to quantify CO_2-e emissions with a relatively high level of accuracy for different processes and sectors. The DEA will approve the appropriate emissions factors and procedures, in line with international information published by the IPCC. According to the 2011 White Paper, the DEA will introduce mandatory reporting of GHG emissions for entities, companies and installations that emit in excess of 100 000 tons of GHGs annually, or consume electricity that results in more than 100 000 tons of emissions from the electricity sector.

It is proposed that the tax rate be implemented as of January 2016, on a sliding scale in five year increments until it reaches full implementation in 2025. The carbon tax will apply to all direct, stationary sources of emissions, including process emissions. To manage the transition to a low-carbon economy, a transition period will provide for temporary thresholds below which an exemption from the carbon tax will be granted. In addition, an offset mechanism similar to the Clean Development Mechanism (CDM) administered locally and in a more streamlined way, will be considered. The system will be implemented with a tax-free threshold of 60%, which means tax will only be levied below for 40% of an organisation's emissions. This is subject to industry standards that could alter this threshold.

The government is proposing a carbon tax of R120 per tCO_2-e above the tax-free threshold, to be introduced. It is further proposed that the tax rate of R120 per tCO_2-e be increased at a rate of 10 per cent per annum until the end of 2019, in order to provide a clear long-term price signal. This annual rate of increase will be reviewed during 2019, with the intention to announce a revised annual rate of increase in the 2020 Budget.

It should be noted that this tax will have an estimated R0.04 to R 0.05 per kilowatt impact on the cost of electricity as Eskom will pass these costs on to the end user. This taken into consideration will be a further incentive to continuously investigate and implement alternative energy technologies.

4 Aims and Objectives

The specific objectives of the *ex-ante* estimated GHG emissions footprint and reporting framework are to:

- Describe the proposed project in terms of the main parameters that contribute to its GHG footprint;
- Define a methodology for estimating the GHG emissions of the proposed project;
- Present the results of the calculation of potential GHG emissions from the proposed project in a report;
- Define a reporting framework for the management and monitoring of the project's GHG emissions;
- Assess the potential risks of climate change on the project and the project's potential contribution thereto; and
- Recommend feasible climate change mitigation strategies for the proposed project.

5 Methodology

The report comprises both an *ex ante* emission estimation as well as a climate response model.

5.1 Greenhouse Gas Emission Estimation

The development of an *ex ante* estimated GHG emissions footprint and reporting framework at project level is the first step in determining potential emission reduction or offset opportunities for the project and allows for integration of such opportunities in the project design.

The estimated GHG footprint for the project will be developed in accordance with the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) "GHG Protocol: Corporate Accounting and Reporting Standard" (2004) and ISO14064-2. Even though the standard is intended to provide guidance on accounting for and reporting on GHG emissions at the organisational level, the standard can be applied to individual projects.

The GHG emissions will be calculated based on consumption of materials that contribute to climate change. The carbon footprint will take cognisance of Scope 1, 2 and 3 emissions, where practical. Scope 3 emissions are included for completeness.

Definitions for the various scopes are given below (WBCSD/WRI, 2004) and illustrated in Figure 1:

- Scope 1 - Direct GHG emissions: Carbon emissions occurring from sources that are owned or controlled by the company (e.g., emissions from combustion in owned or controlled boilers, furnaces and vehicles, process and fugitive emissions).
- Scope 2 - Indirect electricity GHG emissions: Carbon emissions from the generation of purchased electricity, heat or steam consumed by the company.
- Scope 3 - Other indirect GHG emissions: Carbon emissions which are a consequence of a company's activities, but occur from sources not owned or controlled by the company (e.g., the extraction and production of purchased materials; and employee travel to and from work).

The materials that are considered include, but are not limited to, diesel, petrol, lubricants and oil for fleet maintenance, air conditioning gas, and process emissions. Consumption of these materials contributes to global GHG emission levels in various ways. Consumption estimates will be used to calculate the predicted GHG emissions once the project is operational. Electricity consumption is also included to calculate the scope 2 emissions.

Once the potential GHG emissions are estimated, the potential risk to climate change will be assessed. This will include the consideration of the effect that climate change will have on the proposed project.

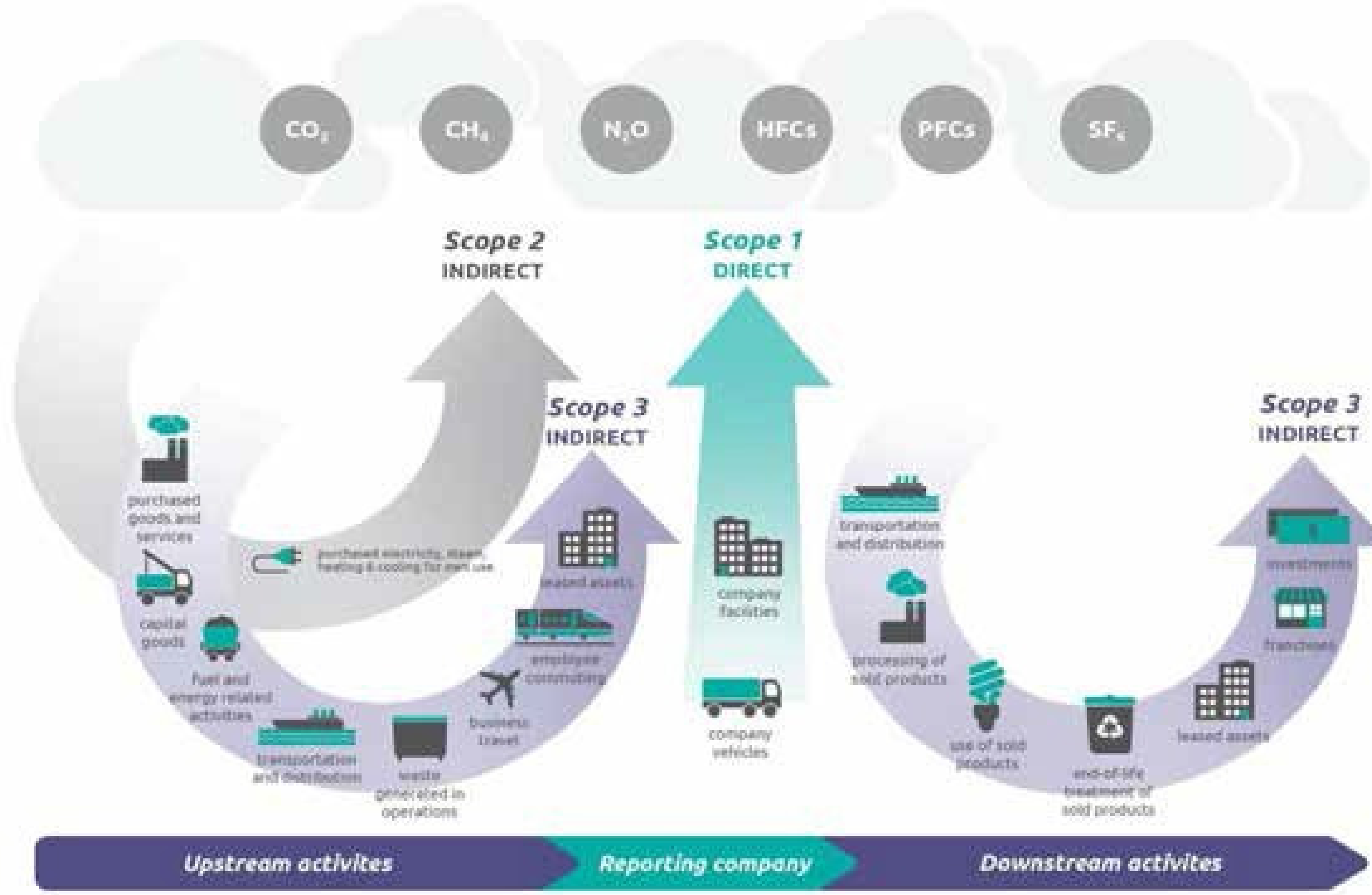

Figure 1: Illustration of the different GHG Scopes (WBCSD/WRI, 2011)

5.1.1 Reporting Year

The GHG estimate is prepared for the operational phase emissions, per annum. It is anticipated that operations will commence in 2019.

5.1.2 Assessment Boundary

The IFC performance standards state "…*Clients with projects producing significant GHG emissions are required to evaluate (i) Scope 1 Emissions: direct emissions from the facilities that they own or control within the physical project boundary and, if feasible and relevant, (ii) Scope 2 Emissions: indirect emissions associated with the project's use of energy but occurring outside the project boundary (e.g., GHG emissions from purchased electricity, heat or cooling)"* (IFC Guidance Note 3: Annex A, 2012).

The IFC Performance Standards do not require the estimation of Scope 3 emissions *ex ante*. The GHG Protocol also only requires reporting of Scope 1 and Scope 2 emissions. Given the nature of the Project, Scope 1 and 2 emissions will be the most significant and reliable to calculate, and will provide the best opportunity for mitigation. Accordingly, these categories will be the primary focus of the GHG inventory although Scope 3 emissions are included for completeness.

5.1.3 Emission Factors

5.1.3.1 Sewage Treatment Plant

The emissions as a result of sewage produced on site during the operational phase were calculated according to the following formula:

$$\square\square\square = [((\square\ \square\ \square\square\square)\ \square\ (1 - \square\square\square)\ \square\ \square a\ \ \square\ \square\square\square)) + (\square\ \square\ \square\square\square\ \square\ \square\square\square\ \square\ \ \square\square\square\square)) - \square]\ \square\ 21$$

Where:

P =	The population served and measured in 1000 persons and sourced from waste treatment records
DCw =	The quantity in kilograms of Biochemical Oxygen Demand (BOD) per capita per year of wastewater. In the event that no waste analysis data is available, a default value of 22.5 kg per person per year can be used
Fsl =	Default fraction of BOD removed as sludge. Should be readily available from internal records of wastewater treatment plants (default value of 0.29)
EFw =	Default methane emission factor for wastewater with value of 0.65 kg CH4/kg BOD
EFsl =	Default methane emission factor for sludge with value of 0.65 kg CH4/kg BOD (sludge)
Fan =	Fraction of BOD anaerobically treated. This value varies according to wastewater treatment type. IPCC defaults are:

- Managed aerobic treatment – 0
- Unmanaged aerobic treatment – 0.3
- Anaerobic digester/reactor – 0.8
- Shallow anaerobic lagoon (<2 metres) – 0.2
- Deep anaerobic lagoon (>2 metres) – 0.8

R = Recovered methane from wastewater in an inventory year, measured/expressed in tonnes

This is the formula prescribed by the Department of Climate Change and Energy Efficiency of the Australian Government (AG, 2010).

5.1.3.2 Fuel for the Fleet and Generators

The emission factors for the diesel consumption of the fleet were obtained from the UK's Department of Environment, Food and Rural Affairs, 2014 (DEFRA, 2014).

When grid electricity is not available onsite generation will be through the use of generators. The same emissions factors have been applied for this.

5.1.3.3 Grid Electricity

Grid electricity will be consumed from an installed capacity of 15 MVA operating for 16 hours per day for 250 days at a 0.8 power factor. The emission factor was obtained from Eskom's integrated report (2014).

5.1.3.4 Well to Tank Emissions

Well to tank (WTT) emissions are scope 3 emissions associated with obtaining a fuel or material. The WTT emissions are included for Diesel consumption and electricity generation. The emission factors were obtained from DEFRA (2014).

5.1.3.5 Land Use Change

The project requires that a certain amount of land be cleared for construction activities. As the biomass is cleared it becomes a carbon source and contributes to the project's emissions. The emissions are based on the gross primary productivity of the vegetation type in the project area and the carbon stock of the soil type found on site. The total carbon stock is determined by:

$$\square\square\square = (\Sigma\square\square\square + \Sigma\square\square\square) + \square\square\square$$

Where:

$\Sigma\square\square\square$ = The sum of all soil organic carbon

$\Sigma\square\square\square$ = Sum of the biomass carbon stocks

$\square\square\square$ = Gross primary productivity of the biomass found on site

5.1.4 Global Warming Potentials

The purpose of the Global Warming Potentials (GWP) is to convert the various GHG emissions into comparable CO_2 equivalents (CO_2-e). This allows for easier comparison between different GHG sources. The GWP used for the calculation of GHG emissions for the proposed project are based on the IPCC's fifth assessment report (2013), and listed in Table 5-1. Global emission potentials for all GHGs are included in Table 5-1.

Table 5-1: Global Warming Potentials[1]

Greenhouse gas	Global Warming Potential
CO_2	1
CH_4 (fossil CH_4)	28 (30)
N_2O	265
Sulfur hexafluoride	23 500

5.2 Climate Response Model

The model used to determine the potential climate change impacts of the project is a simple energy balance model. The inputs are anthropogenic emissions, changes in atmospheric and surface water concentration of the relevant GHGs and the associated changes in radiative forcing. Once the potential radiative forcing change is understood, the project's potential effect on climate can be evaluated. It can be summarised in these steps:

- Determine potential GHG emissions;
- Calculate atmospheric concentration changes due to emissions;
- Calculate radiative forcing based on atmospheric concentrations; and
- Evaluate impact on climate.

This is a simple model as it parameterizes key processes that are dealt with by the far more advanced and complex atmosphere ocean general circulation models (AOGCMs), which are not appropriate for applications such as environmental assessment. The model is largely based on the work done by Joos et al. (1996). The baseline concentrations for CO_2 are set at 278.305 ppm. The model is written in Python by Jared Lewis of Bodeker Scientific.

5.2.1 Atmospheric Concentration

It is not sufficient to simply assume that 100% of the estimated emissions will contribute to the atmospheric concentration of the particular GHG. This will result in gross over estimation of climate effects as sinks are not taken into consideration.

Many compounds contribute to radiative forcing when their atmospheric concentration is changed. This report focuses on well-mixed GHGs, which are defined as GHGs that are sufficiently mixed throughout the troposphere so that concentration measurements from a few remote surface sites can characterize the climate-relevant atmospheric burden (IPCC, 2013). These gases may still have local variation near sources and sinks and even small hemispheric gradients but in general there will not be a significant difference between measurements. Global forcing per unit emission and emission metrics for these gases thus

[1] GWP values do not account for climate carbon feedback loops

do not depend on the geographic location of the emission, and forcing calculations can assume even horizontal distributions. These gases, or a subset of them, have sometimes been referred to as ‘long-lived greenhouse gases’ as they are well mixed because their atmospheric lifetimes are much greater than the time scale of a few years for atmospheric mixing, but the physical property that causes the aforementioned common characteristics is more directly associated with their mixing within the atmosphere. Well-mixed GHGs include CO_2, N_2O, CH_4, SF_6, and many halogenated species.

5.2.1.1 Emissions to Concentration

A simplified version of the Bern Carbon Cycle model is used to convert CO_2 emissions to atmospheric CO_2 concentrations. The method is described in greater detail in Joos *et al*. (1996) and Harman *et al.* (2011). The first year assumes the partial pressure of CO_2 in the surface layer of the ocean is in equilibrium with atmospheric CO_2 concentrations, and the net flux of CO_2 between the atmosphere and biosphere is zero. The CO_2 adding by the project is calculated by taking the CO_2 emissions in PgC and dividing by 2.123, to convert to ppm of CO_2. This increase in atmospheric CO2 removes the equilibrium between the atmosphere and the ocean.

5.2.1.2 Ocean Carbon Cycle

The elevated atmospheric CO_2 concentration drives a flux of CO_2 between the atmosphere and the ocean. The magnitude of the flux is calculated using:

Equation 1: Atmosphere-Ocean Carbon Cycle Flux

$$f_a = k_g(\delta pCO_{2,a} - \delta pCO_{2,s})$$

Where:

- f_a is the air-sea flux of CO_2;
- k_g is the air-sea flux gas exchange coefficient;
- $\delta pCO_{2,a}$ is the change in partial pressure in the atmosphere; and
- $\delta pCO_{2,s}$ is the change in partial pressure to the sea water.

The model uses response functions, calibrated against more complex models, to represent the various process in the ocean mixed layer.

5.2.1.3 Terrestrial Carbon Cycle

As with the ocean carbon cycle, the terrestrial carbon cycle is as a result of many complex processes, which are simplified here in a two box model (Joos *et al*., 1996; Harman *et al., 2011).* In essence it is dependent on the flux to the biosphere, the net primary productivity and the flux from the biosphere due to heterotrophic respiration (Harman *et al.,* 2011).

The two boxes are described by:

Equation 2: Atmosphere-Terrestrial Carbon Cycle Flux

$$f_{npp} = \left(\frac{60\,GtC}{yr} \times \beta \times \ln\left(\frac{CO_{2,ppm}}{278\,ppm}\right)\right) - \delta f_{decay}$$

Where:

- $\left(\frac{60\,GtC}{yr} \times \beta \times \ln\left(\frac{CO_{2,ppm}}{278\,ppm}\right)\right)$ is the change in nett primary productivity;
- β is the fertilization factor set at 0.287;
- δf_{decay} is the change in decay due to an increase in primary productivity.

5.2.2 Radiative Forcing

The IPCC AR4 report, defines radiative forcing as:

"*Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.*"

The radiative forcing of a gas depends on the extent to which the gas can absorb radiation and its atmospheric life. In this report radiative forcing values are relative to preindustrial conditions, defined as 280 ppm CO_2 in the year 1750 a.c.e, and are expressed in Watts per square meter (W/m^2). The total radiative forcing effect of the project's GHG emissions are determined using the IPCC's (IPCC 2001) recommended expressions to convert greenhouse gas changes, relative to 1750, to instantaneous radiative forcing (hence not allowing for stratospheric adjustment).

The model expresses the net radiative flux in the troposphere as (IPCC):

$$\Delta F = f(C_0, C)$$

where ΔF is the change in net radiative flux corresponding to the volumetric concentration change of the particular GHG, from C_0 (preindustrial condition) to C[2]. To calculate ΔF the net radiative flux for each GHG must be calculated.

[2] C takes the project's emissions into account by using the latest measured GHG atmospheric concentrations and adding the estimated project contributions.

This can be expressed, for CO_2, CH_4 and N_2O respectively, as:

Equation 3: Radiative Forcing of GHGs

$$\Delta F(CO_2) = \alpha \ln\left(\frac{C}{C_0}\right)$$

$$\Delta F(CH_4) = \beta(\sqrt{M} - \sqrt{M_0}) - [f(M, N_0) - f(M_0, N_0)]$$

$$\Delta F(N_2O) = \varepsilon(\sqrt{N} - \sqrt{N_0}) - [f(M_0, N) - f(M_0, N_0)]$$

Where

$$f(M, N) = 0.47 \ln[1 + 2.01 \times 10^{-5}(MN)^{0.75} + 5.31 \times 10^{-15} M(MN)^{1.52}]$$

- C_0, M_0, N_0, are the unperturbed 1750 values;
- C is CO_2 in ppm, M is CH_4 in ppb, N is N_2O in ppb;
- C_0 = 278 ppm, M_0 = 722 ppb, N_0= 270 ppb; and
- α = 5.35, β = 0.036, ε = 0.12, represent the radiative efficiency of the gases.

5.2.3 Temperature Change

Once the change in radiative forcing is understood, it can be related to a potential change in temperature through the use of a double impulse response function of the following form:

Equation 4: Temperature Response to Changes in Radiative Forcing

$$\Delta T(t) = \frac{\delta T_{2x}}{Q_{2x}} \int_{t_0}^{t} Q(t') \left[\sum_{s=1}^{2} c_s \left(\frac{1}{\tau_s}\right) \exp^{-\frac{t-t'}{\tau_s}}\right] dt'$$

Where:

- Coefficients c_s and τ_s are obtained from a fit to the Hadley Centre Climate Model (HadCM3);
- The model compensates for other gases with $\frac{\delta T_2}{Q_{2x}}$ set to 1.1.

5.2.4 Sea level Rise

A similar approach (double impulse response function), is used to calculate the potential change in sea level rise. Due to the high levels of uncertainty in estimating sea level changes, this estimate is purely as a result of thermal expansion. It does not account for melting glaciers or ice sheets.

6 Assumptions and Limitations

6.1 Greenhouse Gas Emission Estimation

The following is relevant to the assessment boundary that was established:

- Diesel generators will not be used for more than 1.5% of the operational days per year, which equates to approximately 10% of the vehicle diesel consumption. As per the design engineers, 90% of all diesel will be consumed by the fleet;
- Local information on diesel emission factors was not available therefore DEFRA was used. This may result in understating the emissions;
- The power factor is assumed to be 0.8 allowing for 12 MW/15MVA installed power;
- The report does not account for emissions associated with magnetite downstream;
- Sewage treatment will use a managed aerobic process;
- For the land use change emissions the total pit area will be cleared within five years, the infrastructure will be constructed within a year and the stockpiles and tailings facilities will develop over the LoM;

6.2 Climate Response Model

The following are relevant to the model:

- Changes in radiative forcing for those GHGs where no emission factor is available, the model uses CO_2-e;
- The model assumes a start date of 2016 and a life of mine of 20 years.
- The IPCC's recommended expressions to convert greenhouse gas changes are empirical expressions derived from atmospheric radiative transfer models and generally have an uncertainty of about 10%. The uncertainties in the global average abundances of the long-lived GHGs are much smaller (<1%);
- The expressions must be considered as global mean forcings as they include the radiative effects of global mean cloud cover;
- Indirect climate effects due to atmospheric chemistry is not accounted for;
- For the first year of modelling there is a zero net exchange between atmospheric CO_2, the ocean and biosphere; and
- The model does not include emissions from any sources other than this project.

6.3 Atmospheric Concentrations

The atmospheric concentrations used are given in Table 6-1.

Table 6-1: Atmospheric concentrations and GWP for well-mixed GHGs[3]

Gas	[4]Pre-1750 tropospheric concentration1	Recent tropospheric concentration	GWP(100-yr time horizon)	Atmospheric lifetime (yrs)
Concentrations in parts per million (ppm)				
Carbon dioxide (CO_2)	278.305	395.4	1	~100-300
Concentrations in parts per billion (ppb)				
Methane (CH_4)	722	1762	28 (30)	12
Nitrous oxide (N_2O)	270	324	265	121
Concentrations in parts per trillion (ppt)				
Sulfur hexafluoride (SF_6)	zero	7.39	23 500	3 200

7 Results and Discussion

7.1 Estimated Greenhouse Gas Emissions

The estimated absolute operational phase emissions are 166 807 tCO_2-e per annum. A breakdown of emissions according to their sources is presented in Table 7-1**.**

Table 7-1: Estimate GHG emissions for the Magnetite project

SUMMARY	**EMISSIONS**
Scope 1 - activities	**tCO_2-e**
Diesel consumption (vehicles)	30 803
Diesel consumption (generators)	3 548
Emissions from sewage treatment	2
ANFO consumption	223
Land clearing	17 120
Sub-total (scope 1)	**51 695**

[3] Data from the U.S Department of Energy, DOI: 10.3334/CDIAC/atg.032

[4] Used to run the model

SUMMARY	EMISSIONS
Scope 2 - activities	
Eskom power consumption	49 440
Sub-total (scope 1 + 2)	**101 135**
Scope 3 - activities	
Eskom transmission and distribution losses	4 436
Electricity fuel WTT	7 337
Upstream emissions (well to tank)	2 205
Sub-total (scope 3)	**13 978**
Grand total (tCO_2-e)	**166 807**

7.2 Carbon Tax

The carbon tax design has specific implications for specific sectors, and also has various mechanisms that will allow for the adjustment of the basic tax-free threshold. The below is a discussion on its implications for the mining sector.

The proposed benchmark for the CO_2 emissions intensity of mines during the first phase (2016-2020) has not yet been set, but it will be based on the most energy efficient member of the Sector, when it is published. The current estimation gives the emission intensity as 0.08 tCO^2/t run of mine. This is below the proposed benchmarks for the Steel and Iron Sectors. It must be noted that this is still a high level estimation due to the limited information available at the time of compiling the report.

To the extent that the carbon tax will cover gross emissions as opposed to net emissions, a rebate will apply in the case of offset programmes for which an upper limit of 10% has been set.

7.3 Climate Response Model

Subsequent to sequestration the estimated change in atmospheric concentration of CO_2, CH_4 and N_2O is given in Figure 2 to Figure 4, with the associated change in temperature and sea level given in Figure 5 and Figure 6, respectively.

The results indicate that the change in atmospheric CO2 as a result of the project's emissions, will peak at approximately 27.8 x 10^{-6} parts per million (ppm). The CH4 and N2O peak atmospheric concentrations will be approximately 8 x 10^{-6} and 270 x 10^{-6} parts per billion (ppb), respectively. This increase in GHG emissions will have a resultant effect on temperature due to the increase in radiative forcing potential of the atmosphere. However, in isolation the project's effects on temperature change and sea level change is negligible.

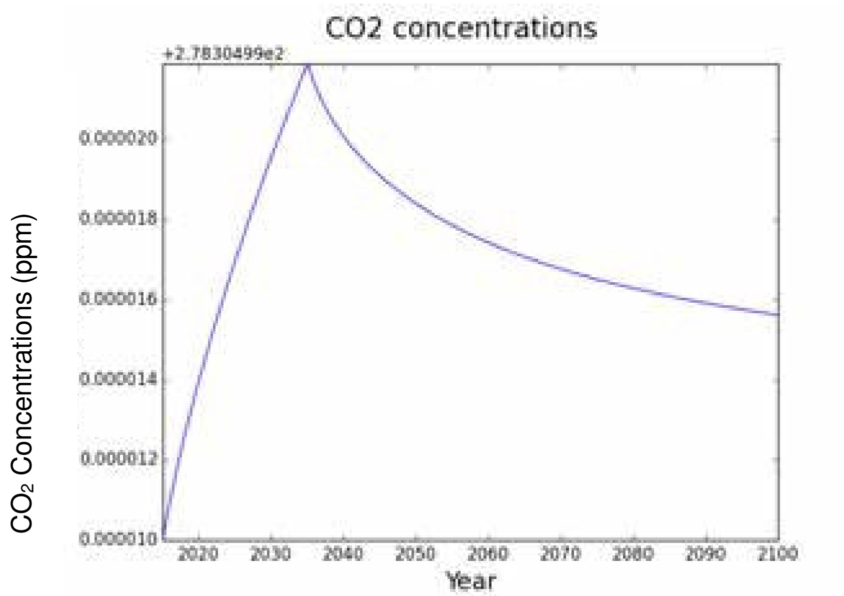

Figure 2: Change in CO_2 Concentrations Over Time

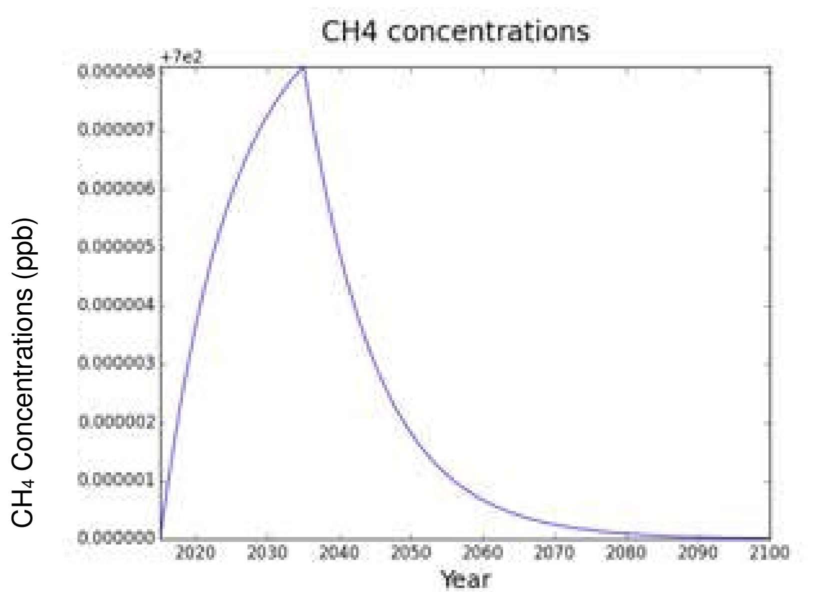

Figure 3: Change in CH_4 Concentrations Over Time

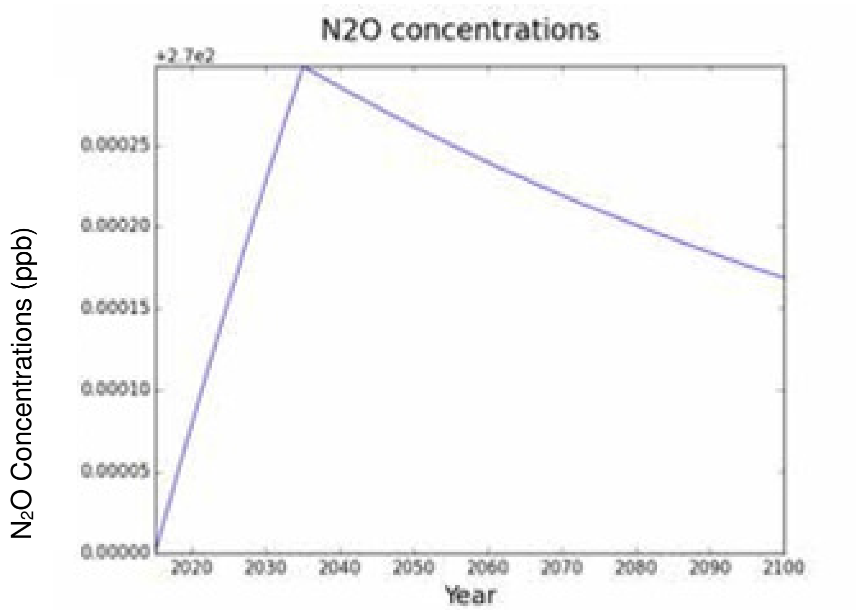

Figure 4: Change in N_2O Concentrations Over Time

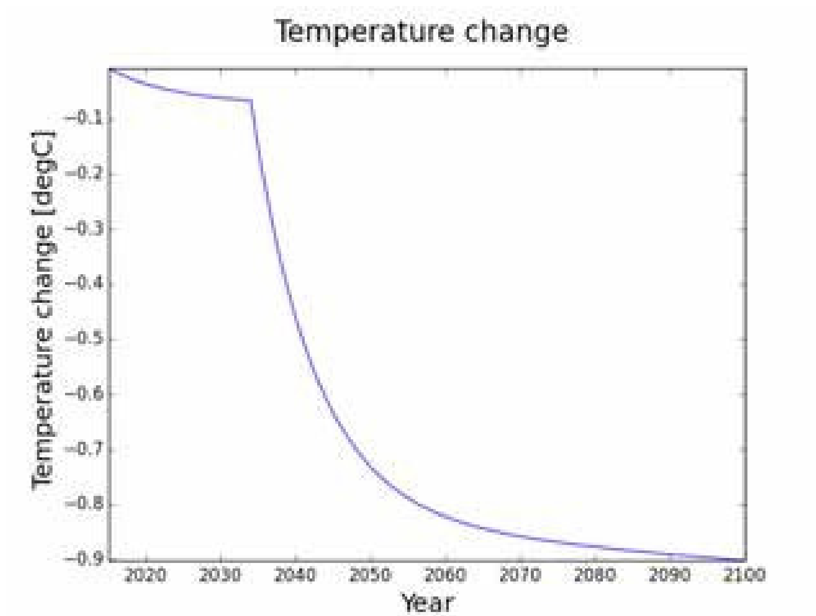

Figure 5: Potential Temperature Change as a result of the Project's Emissions

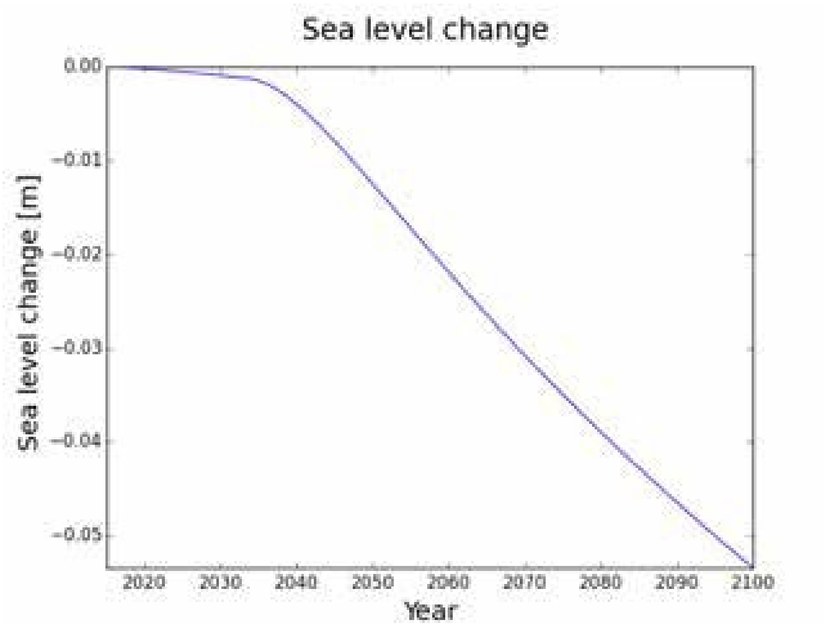

Figure 6: Potential Sea Level Change as a Result of the Project's Impact on Temperature

7.4 Cumulative Assessment

For comparative purposes the GHG emissions of the project are compared with national and global GHG emissions in Table 7-2.

Table 7-2: Project Related GHG Emissions in Comparison with Global Emissions

Emissions Source	Absolute Emissions (k tonnes CO2-e)	Percentage of South African emissions	Percentage of Global emissions
Magnetite project estimated emissions	166.81	0.04%	0.0004%
South Africa (Industrial)	20 090.00	4.40%	0.0459%
South Africa (Total)	456 850.00	100.00%	1.0426%
Global emissions	43 816 700.00	-	100.00%

*Obtain from CAIT, retrieved 2016-06-11

Locally and globally the projects predicted impact is negligible.

8 Emission Reduction Strategies

8.1 Vehicle Fleet

Once the project is operational, the emissions from the vehicle fleet can be reduced by putting the following practices into place:

- Enforce speed limits to avoid excessive fuel consumption;
- Shorten travelling distances;
- Investigate the feasibility of using biodiesel in LDVs and possibly in HDVs as well (many of the Caterpillar vehicles already have the ability to use biodiesel);
- Investigate the feasibility of using hybrid vehicles where heavy duty vehicles are not required;
- Create a central parking hub for all LDVs and staff personal vehicles to reduce unnecessary vehicle use over short distances. This will also minimise the inefficient stop-go driving encountered in areas with high vehicle and foot-traffic;
- Define the purpose of the vehicle and purchase accordingly (i.e. do not purchase a four wheel drive when a two wheel drive will suffice);
- When purchasing vehicles, select the most fuel efficient vehicles for the intended purposes;
- Regular maintenance of vehicles (oil changes and correct tyre pressure), can improve fuel efficiency; and
- Educate drivers on how driving at high engine revolution and idling increases emissions and how behavioural changes can reduce these.

8.2 Sewage Treatment Plant

The GHG emission calculations assume that there is no methane captured and reused from the sewage treatment plant. Available technology is able to capture between 30 and 60% of methane emitted from a sewage treatment plant (Shimizu, 2006). Should the project employ such technology they may realise a 534 to 1068 kg CO_2-e reduction per annum. If this methane is used for electricity production, a further reduction will be realised.

8.3 General GHG Reduction and Off-Set Strategies

GHG reduction strategies relate to the implementation of engineering solutions to reduce the GHG footprint of a project. The IFC EHS guidelines recommend that the following be considered in the reduction and control of GHG emissions:

- Enhancement of energy efficiency;
- Protection and enhancement of carbon sinks and reservoirs (e.g. forests). This includes promoting reforestation and actively engaging in ‘planting initiatives’ to

counter balance the land clearing activities that will result in a loss of carbon sequestration;

- Promotion, development and increased use of renewable forms of energy;
- Investments in research and development of carbon capture and storage (CCS) technologies; and
- Limitation and/or reduction of methane emissions through recovery and use in waste management.

9 Monitoring and Management

The purpose of monitoring of GHG emissions and reporting on GHG emissions performance is the key to the successful identification of physical, regulatory and financial risks and opportunities relating to climate change.

This section presents a proposed GHG reporting framework and management plan, based on the *ex-ante* quantification of GHG emissions from the proposed project. The monitoring programme is built on the ISO 14064-2 standard.

In order for the project’s annual GHG emission quantification to be accurate, the parameters indicated in Table 9-2 must be monitored. The following information must be captured for each of the indicators:

- Origin of the data;
- Monitoring methodologies i.e. estimation, modelling, measurement or calculation; and
- Monitoring times and periods, considering the needs of intended users.

Once the Draft Regulations Regarding Registration, Reporting on Energy Management and Submission of Energy Management Plans are legislated, it needs to be incorporated into the monitoring and management plan.

Table 9-1: GHG Emission Reduction Action Plan

No	Activity	Action Required	Responsible Person	Project Phase
1	Mobile combustion (vehicle fleet)	Investigate different layouts as per the recommendations	Infrastructure engineering and layout team as well as the procurement department (when purchasing vehicles)	Design
2	Waste: Sewage treatment plant	Investigate possibility of capturing all methane and using it to generate electricity.	Design engineering team	Design
3	Energy and GHG management plan	Develop an energy and GHG emissions monitoring and management plan. The plan must include an annual review of the emission sources and the potential for mitigating GHG emissions through the use of alternative energy. The plan must include a review of the strategies already implemented and their efficacy. The plan must be developed in compliance with ISO 14064-3 and South African legislation.	Environmental control officer.	Operational

Table 9-2: GHG Emissions Monitoring Plan

Indicator (units)	Monitoring Method	Frequency	Responsible Person
Fuel Consumption (litres/month)	Diesel consumption volumes must be captured. This includes: Diesel and petrol issued by the stores; External diesel and petrol purchases (per department), and reimbursed. It must be clearly distinguished between consumption of company vehicles and those of third parties or contractors.	Monthly	Logistic & Logistic and Line Managers with assistance from the Environmental Manager
Lubricating Oil and Grease (litres/month)	Consumption of lubricating oil and grease should be recorded. This is done by keeping track of the quantity of oil issued by the stores.	Monthly	Logistic Manager and Line Managers with assistance from the Environmental Manager
Incinerated hydrocarbon contaminated waste (kg/month)	Weigh and record quantity of all hydrocarbon contaminated waste (in kgs) that is incinerated	Monthly	Line Managers with the assistance of the Environmental Manager
Incinerated biomass (kg/month)	The weight of all incinerated biomass must be recorded. This will generally be wooden boxes used for packaging.	Monthly	Line Managers with the assistance of the Environmental Manager
Gas Consumption (kg/month or m^3/month, as appropriate)	Consumption of other gases with GHG potential must also be recorded. These are predominantly butane and acetylene, where applicable.	Monthly	Line Managers with the assistance of the Environmental Manager
Air Conditioning Gas (m^3/month)	The volume and types of air conditioning gas that is consumed must be recorded.	Monthly	Maintenance Manager with the assistance of the Environmental Manager

Indicator (units)	Monitoring Method	Frequency	Responsible Person
Sewage Production (m^3/month)	A flow meter must be installed on the sewage line to monitor the volume of sewage produced. If a flow meter is not possible, accurate records of the number of staff on site must be held.	Monthly	Maintenance and HR Manager with the assistance of the Environmental Manager
	Measurements of the Chemical Oxygen Demand must be taken. This is used to more accurately quantify the GHG emissions from the sewage treatment plant.	Weekly	Environmental Manager
Waste streams (kg/month)	The weight of all the recyclable waste must be recorded in kilograms, per category. These are: Used hydrocarbons; Plastic; and Scrap metal (including food tins).	Monthly	Store and workshop Managers, where applicable, with assistance of the Environmental Manager
	The weight of all organic waste must be recorded, along with the method of disposal (covered or open landfill, composted or recycled) The weight must be recorded for the following: Food waste; Paper and cardboard; and Wood and Vegetation.	Monthly	Store and workshop Managers, where applicable, with assistance of the Environmental Manager
	The weight of all medical waste incinerated must be recorded.	Monthly	Health Manager with the assistance of the Environmental manager
	The weight of all mixed waste that is sent to be landfilled must be recorded.	Monthly	Line management with assistance of the Environmental Manager

Indicator (units)	Monitoring Method	Frequency	Responsible Person
Commercial Flights (km/trip)	The number of passengers, their flight routes and distances and the flight class (i.e. economy or business), must be recorded.	Monthly	HR Manager with the assistance of the Environmental Manager

These are the major Scope 1 GHG contributors for a new operation and are a good starting point for monitoring and quantifying annual GHG emissions. More refined measures for monitoring total emissions (including all Scope 3) can be implemented once these basics are implemented with success.

10 Comments and Response

Will the mine affect the climate?	Mack Marakalala	Good Hope	30 March 2015	Village Meeting	The mine will produce Greenhouse Gas (GHG) emissions. A GHG study was undertaken and indicated that the estimated absolute operational phase emissions are 166 807 tonnes CO2 equivalent (tCO2-e) per annum. This equates to 0.04% of current South African emissions and 0.0004% of global emissions. In isolation the project emissions as they have been calculated do not have any significant long term climate change impacts.
How will the mine impact on climate change?	Isaac Mila	Undisclosed	28 March 2015	Public Meeting	The mine will produce Greenhouse Gas (GHG) emissions. A GHG study was undertaken and indicated that the estimated absolute operational phase emissions are 166 807 tonnes CO2 equivalent (tCO2-e) per annum. This equates to 0.04% of current South African emissions and 0.0004% of global emissions. In isolation the project emissions as they have been calculated do not have any significant long term climate change impacts.

11 Conclusion and Recommendations

In isolation the project emissions as they have been calculated are not significant impacts to long term climate change. However contributions to climate change can only be assessed cumulatively. Once the project is operational, an intensity emission target must be set to monitor efficiency.

The total emissions that have been estimated in this report represent the majority of the emissions, but it is very likely that the emissions assessment accuracy will increase once accurate operational phase data is available, and the emissions boundary is expanded. This gap needs to be addressed once the mine becomes operational by implementing the recommendations made below:

- Recalculate the emissions once definitive feasibility information is available;
- Investigate the alternatives discussed to reduce the project's GHG footprint;
- Hydrocarbon contaminated waste has not been included in the baseline GHG emission calculations. The volume of this waste will be included in operational monitoring procedures and GHG emissions calculated annually based on measured results;
- Medical waste has not been included in the baseline GHG emission calculations as it cannot be estimated with confidence. The volume of this waste will be included in operational monitoring procedures and GHG emissions calculated annually based on measured results;
- It is recommended that the quantity of all waste streams disposed of, be recorded and used in the annual GHG emissions footprint;
- All recyclable waste will be separated at source and managed separately for recycling. This includes scrap metal, plastic and used oil; and
- The monitoring plan must be implemented to allow accurate calculation of the GHG emissions once the operations commence.

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Appendix A: Plans

Plan 1: Regional Setting

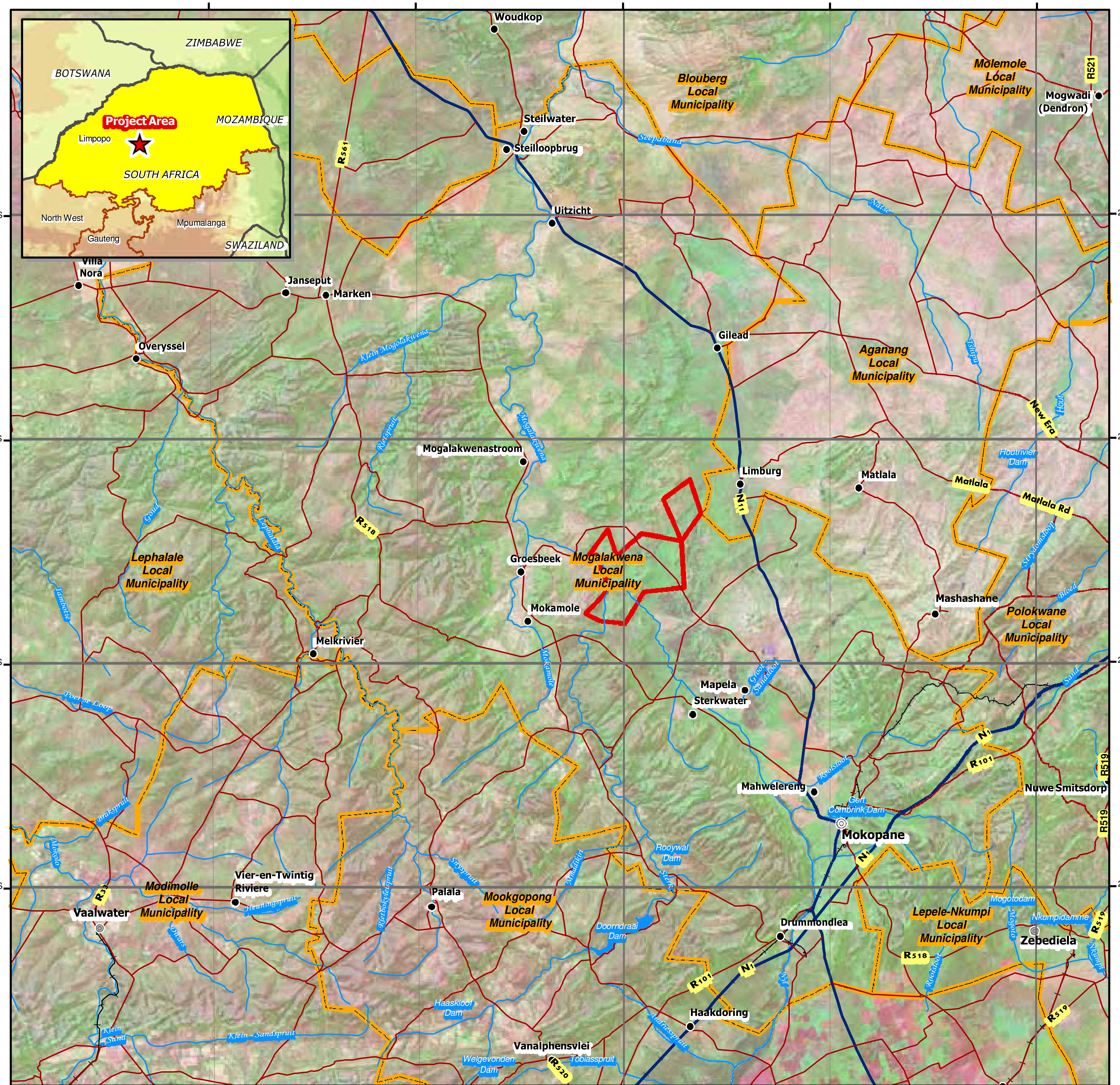
Plan 2: Local Setting

Plan 3: Infrastructure Layout

Plan 1

Pamish Investments Magnetite Mine EIA

Regional Setting



Legend

- Project Area
- Secondary Town
- Other Town
- Settlement
- Main Road
- National Road
- Railway Line
- River
- Dam
- Local Municipal Boundary

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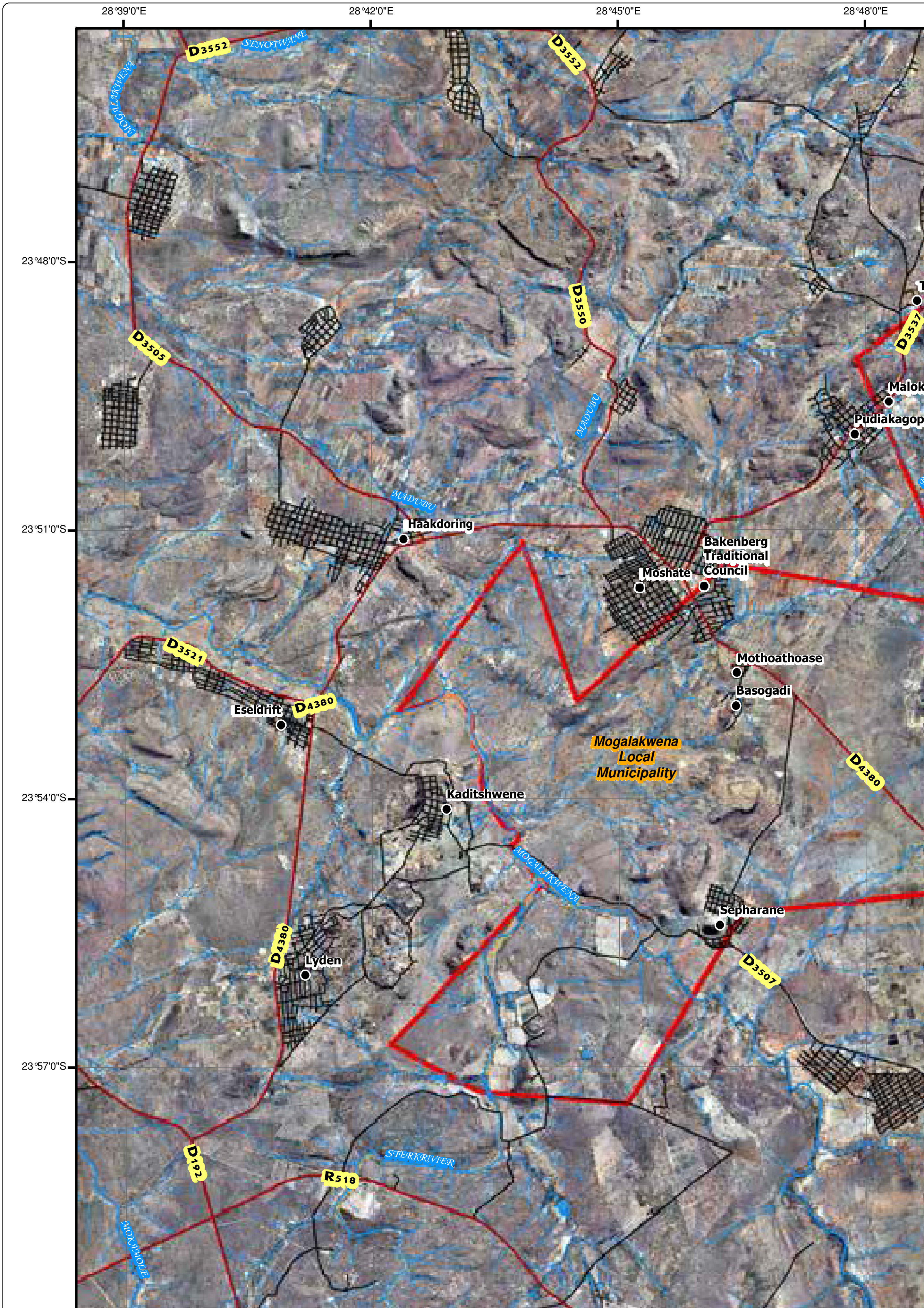
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Haakdoring
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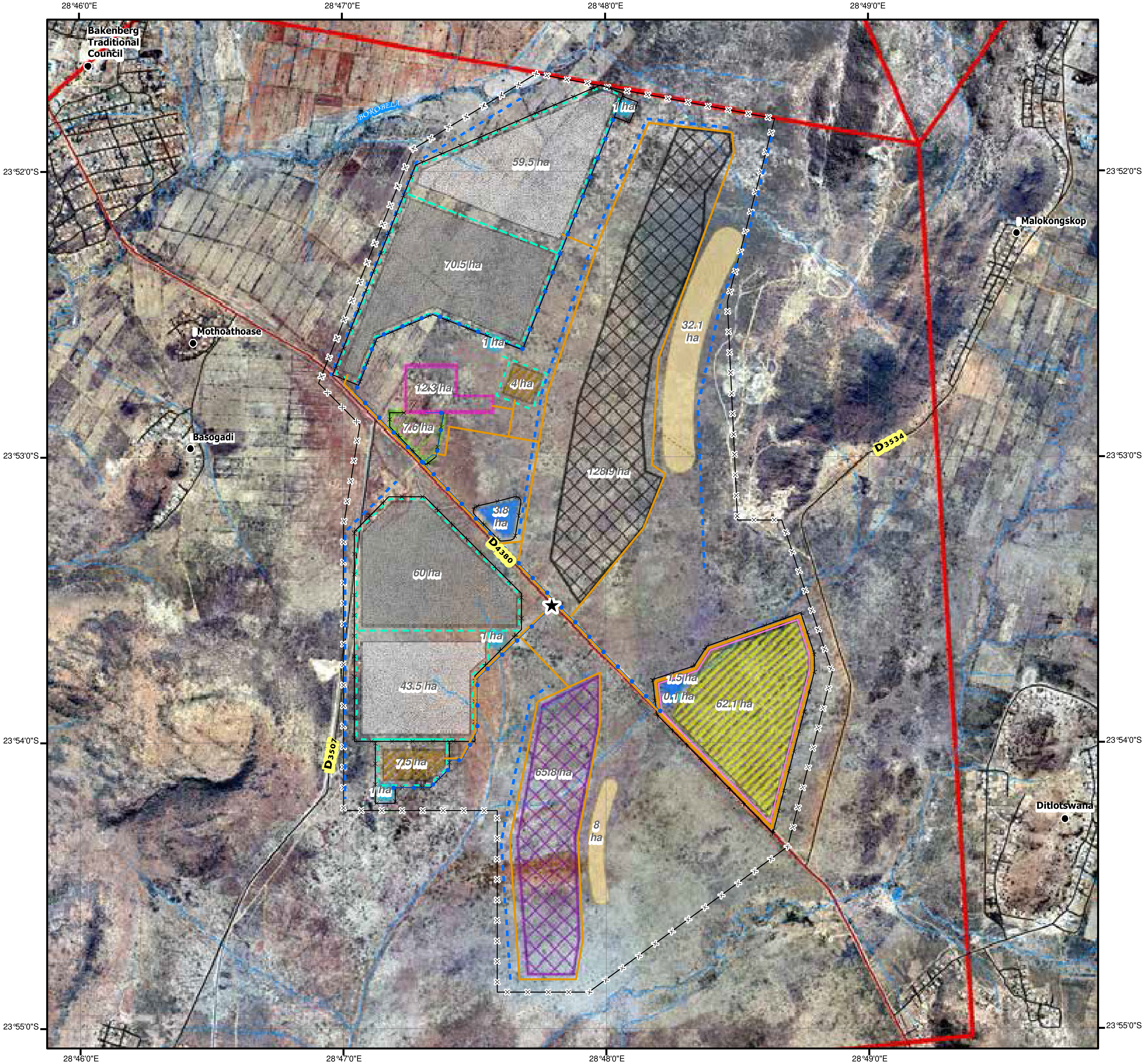

Plan 3

Pamish Investments Magnetite Mine EIA

Infrastructure Layout

Legend

- Project Area
- Settlement
- Main Road
- Minor Road
- Track
- Non-Perennial Stream
- Dam Wall
- Dam / Lake

Infrastructure

- Access Point
- Dirty Water Trench (17128 m)
- Fence (18103 m)
- Perimeter Fence (16478 m)
- Pipeline (8100 m)
- Site Road (25504 m)
- Solution Trench (3557 m)
- Storm Water Trench (12732 m)
- Contractor's Camp (7.6 ha)
- Low Grade Stockpile (130.5 ha)
- Lower Grade Stockpile (103 ha)
- PCD (4 ha)
- Pit 1 (128.9 ha)
- Pit 2 (65.8 ha)
- Plant Area (12.3 ha)
- Return Water Dam (0.1 ha)
- Stormwater Dam (5.3 ha)
- Tailings Dam (62.1 ha)
- Topsoil Stockpile (40.1 ha)
- Waste Rock Dump (11.5 ha)

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Appendix B: Global Warming Potentials

Global Warming Potentials

The following table includes the direct (except for CH_4) 100-year time horizon global warming potentials (GWP) relative to CO_2. This table is adapted from table 2.14 of the IPCC Fourth Assessment Report, 2007. The 4th assessment report values are the most recent (2007), but the second assessment report values (1995) are also listed. For more information, please see the IPCC website (www.ipcc.ch).

[Table] Direct (except for CH_4) global warming potentials (GWP) relative to CO_2 (adapted from table 2.14, IPCC Fourth Assessment Report, 2007)

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon	
		Second assessment report (SAR)	4th assessment report (AR4)
Carbon dioxide	CO_2	1	1
Methane	CH_4	21	25
Nitrous oxide	N_2O	310	298
Substances controlled by the Montreal Protocol			
CFC-11	CCl_3F	3,800	4,750
CFC-12	CCl_2F_2	8,100	10,900
CFC-13	$CClF_3$		14,400
CFC-113	CCl_2FCClF_2	4,800	6,130
CFC-114	$CClF_2CClF_2$		10,000
CFC-115	$CClF_2CF_3$		7,370
Halon-1301	$CBrF_3$	5,400	7,140
Halon-1211	$CBrClF_2$		1,890
Halon-2402	$CBrF_2CBrF_2$		1,640
Carbon tetrachloride	CCl_4	1,400	1,400
Methyl bromide	CH_3Br		5
Methyl chloroform	CH_3CCl_3	100	146

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon	
		Second assessment report (SAR)	4th assessment report (AR4)
HFCF-21	$CHCl_2F$		151
HCFC-22	$CHCLF_2$	1,500	1,810
HCFC-123	$CHCl_2CF_3$	90	77
HCFC-124	$CHClFCF_3$	470	609
HCFC-141b	CH_3CCl_2F	600	725
HCFC-142b	CH_3CClF_2	1,800	2,310
HCFC-225ca	$CHCl_2CF_2CF_3$		122
HCFC-225cb	$CHClFCF_2CClF_2$		595
Hydrofluorocarbons			
HFC-23	CHF_3	11,700	14,800
HFC-32	CH_2F_2	650	675
HFC-41	CH_3F_2	150	92
HFC-125	CHF_2CF_3	2,800	3,500
HFC-134	CHF_2CHF_2	1000	1,100
HFC-134a	CH_2FCF_3	1,300	1,430
HFC-143	CH_2FCHF_2	300	353
HFC-143a	CH_3CF_3	3,800	4,470
HFC-152	CH_2FCH_2F		53
HFC-152a	CH_3CHF_2	140	124
HFC-161	CH_3CH_2F		12
HFC-227ea	CF_3CHFCF_3	2,900	3,220
HFC-236cb	$CH_2FCF_2CF_3$		1,340
HFC-236ea	CHF_2CHFCF_3		1,370
HFC-236fa	$CF_3CH_2CF_3$	6,300	9,810
HFC-245ca	$CH_2FCF_2CHF_2$	560	693

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon	
		Second assessment report (SAR)	4th assessment report (AR4)
HFC-254fa	$CHF_2CH_2CF_3$		1,030
HFC-365mfc	$CH_3CF_2CH_2CF_3$		794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1,300	1,640
Perfluorinated compounds			
Sulfur hexafluoride	SF_6	23,900	22,800
Nitrogen trifluoride	NF_3		17,200
PFC-14	CF_4	6,500	7,390
PFC-116	C_2F_6	9,200	12,200
PFC-218	C_3F_8	7,000	8,830
PFC-318	$c\text{-}C_4F_8$	8,700	10,300
PFC-3-1-10	C_4F_{10}	7,000	8,860
PFC-4-1-12	C_5F_{12}	7,500	9,160
PFC-5-1-14	C_6F_{14}	7,400	9,300
PCF-9-1-18	$C_{10}F_{18}$		>7,500
Trifluoromethyl sulfur pentafluoride	SF_5CF_3		17,700
Perfluorocyclopropane	$c\text{-}C_3F_6$		>17,340
Fluorinated ethers			
HFE-125	CHF_2OCF_3		14,900
HFE-134	CHF_2OCHF_2		6,320
HFE-143a	CH_3OCF_3		756
HCFE-235da2	$CHF_2OCHClCF_3$		350
HFE-245cb2	$CH_3OCF_2CF_3$		708
HFE-245fa2	$CHF_2OCH_2CF_3$		659
HFE-254cb2	$CH_3OCF_2CHF_2$		359

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon	
		Second assessment report (SAR)	4th assessment report (AR4)
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	575	
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	580	
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	110	
HFE-449sl (HFE-7100)	$C_4F_9OCH_3$	297	
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	59	
HFE-43-10pccc124 (H-Galden 1040x)	$CHF_2OCF_2OC_2F_4OCHF_2$	1,870	
HFE-236ca12 (HG-10)	$CHF_2OCF_2OCHF_2$	2,800	
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	1,500	
HFE-227ea	$CF_3CHFOCF_3$	1,540	
HFE-236ea2	$CHF_2OCHFCF_3$	989	
HFE-236fa	$CF_3CH_2OCF_3$	487	
HFE-245fa1	$CHF_2CH_2OCF_3$	286	
HFE 263fb2	$CF_3CH_2OCH_3$	11	
HFE-329mcc2	$CHF_2CF_2OCF_2CF_3$	919	
HFE-338mcf2	$CF_3CH_2OCF_2CF_3$	552	
HFE-347mcf2	$CHF_2CH_2OCF_2CF_3$	374	
HFE-356mec3	$CH_3OCF_2CHFCF_3$	101	
HFE-356pcf2	$CHF_2CH_2OCF_2CHF_2$	265	
HFE-356pcf3	$CHF_2OCH_2CF_2CHF_2$	502	
HFE 365mcf3	$CF_3CF_2CH_2OCH_3$	11	
HFE-374pc2	$CHF_2CF_2OCH_2CH_3$	557	
Perfluoropolyethers			
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	10,300	

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon	
		Second assessment report (SAR)	4th assessment report (AR4)
Hydrocarbons and other compounds-direct effects			
Dimethylether	CH_3OCH_3		1
Chloroform	$CHCl_3$	4	31
Methylene chloride	CH_2Cl_2	9	8.7
Methyl choloride	CH_3Cl		13
Halon-1201	$CHBrF_2$		404
Trifluoroiodomethane	CF_3I	<1	0.4