Q

Air Report

Appendix Q

Arafura Resources Limited

Nolans Project Environmental Impact Statement

Appendix Q: Air Report

May 2016

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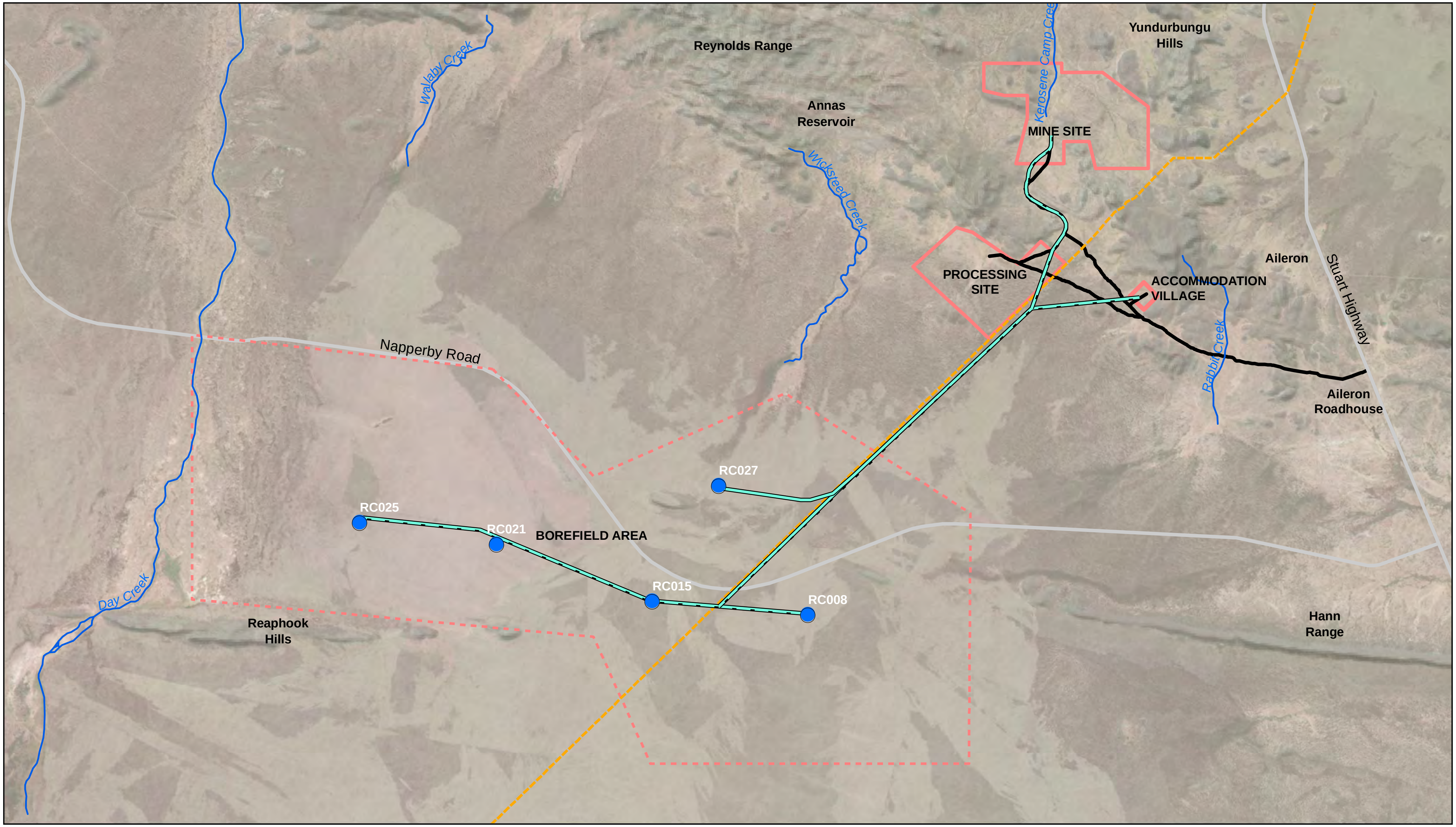
1. Introduction

1.1 Project context

Arafura plans to mine, concentrate and chemically process rare earths at the Nolans Site, then transport a rare earths intermediate product to an offshore refinery (Separation Plant) for final processing into high-value rare earth products.

The layout of the proposed mine is shown in Figure 1 and shows the three principal areas comprising the mine site, processing plant and borefield in addition to workers accommodation camp and access roads.

A large mining operation involving up to 10 Mtpa of material movement will inescapably produce dust emissions. Moreover, specific processing plant infrastructure comprising an Acid Plant and Power Plant, will also produce emissions to the atmosphere. These emissions need to be considered and modelled to quantify the impact on the environment and are considered in the technical report.



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0 2 4 6 8

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Water Bores
- Proposed Powerline
- Proposed Pipelines and Easement
- Existing Gas Pipeline and Easement
- Waterways
- Existing Roads
- Existing Access Track
- Borefield Area
- Site Boundaries

ARAFURA RESOURCES LIMITED

GHD

Arafura Resources Limited
Nolans Project

Job Number	4322301
Revision	0
Date	18 Mar 2016

General facilities arrangement

Figure 1

G:\43\22301\GIS\Maps\4322301_728_GFA.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Imagery (2008), Roads, Waterways, Placenames (2015). ESRI - Shaded Relief (2009). ARL - Water Bores, Proposed Pipelines, Borefield Area, Proposed Mine Site, Treatment Plant and Accommodation Village (2015). Created by: CW, CM

1.2 Purpose of this report

The purpose of this report is to provide a description of the air quality environment at the Nolans Rare Earths Project site. The report will consider baseline data and monitoring that define the physical, climatic and particulate matter (dust) conditions of the Nolans site. Modelling is used to provide predications on the major risks to the environment concerning air quality – principally particulate matter as both in-air concentration and dust deposition. This information is used to support an assessment of Nolans project impacts on the air quality environment which are documented in EIS Chapter 13.

The TOR for the preparation of an environmental impact assessment issued by the NT EPA for the project requested the following assessment in relation to air quality impacts:

- Inventory (name, composition and quantities) of Project generated air emissions, including from land disturbance, all processing circuits, disposal facilities, vehicles, plants and machinery
- Proposed monitoring regime and equipment
- Reporting requirements and compliance with relevant health and/or environmental standards
- Air quality target thresholds with reference to regulatory industry-standard, health-related safe-limits, or aspirational parameter levels
- Proposed emission control methods, including dust suppression strategies and monitoring of potential dust impacts.

This technical report addresses the potential air quality impacts on the environment resulting from the Nolans mine site for all stages of the project as required in the TOR for the project.

1.3 Scope and limitations

This report: has been prepared by GHD for Arafura Resources Limited and *may only be used and relied on by Arafura Resources Limited for the purpose agreed between GHD and the Arafura Resources Limited as set out in Section 1 of this report.*

GHD otherwise disclaims responsibility to any person other than Arafura Resources Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on project design assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Arafura Resources Limited and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has not been involved in the preparation of the Environmental and Public Radiation Technical Report prepared by JRHC Enterprises Pty Ltd and has had no contribution to, or review of the Environmental and Public Radiation Technical Report prepared by JRHC Enterprises Pty Ltd other than in the provision of *dispersion modelling results of tracer releases from the mining and RE Plant locations. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any other part of the Environmental and Public Radiation Technical Report prepared by JRHC Enterprises Pty Ltd.*

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

1.4 Assumptions

The initial construction phase of mining operations involves stripping of vegetation and then site development of the operational pit(s) by removing waste/overburden. The initial 'construction' phase will have less dust emissions than when the pit is being fully 'mined' and so the pit stage modelling (as scenarios) has included worst-case material movement as an operational impact.

Particulate emissions from mobile plant are insignificant compared to dust emissions from mining operations so these have not been modelled. Similarly, gaseous emissions from mobile plant are very low risk (e.g. truck exhaust compared to MW scale power generation) and have not been modelled.

The open pit will require dewatering so an unknown moisture content of the waste and ore requires an assumption to a default (worst case) moisture content consistent to National Pollutant inventory (NPI) estimates. This results in a conservative assumption on dust emissions. Moreover, once the ROM material has passed through initial primary crushing it becomes high in moisture content such that dust emissions through the rest of the process, including the processing (RE) plant and tailings storage, are negligible to non-existent.

2. Existing conditions

In order to use dispersion modelling to predict the impact from mining operations, site specific meteorological data and background air quality is required. Data used in this assessment is described in this section.

2.1 Climate

As Nolans mine is located 135 km north of Alice Springs it may be considered the same climate classification as desert (semi-arid; hot persistently dry) or the Grassland (hot persistently dry) to the north and north-west of Alice Springs. On site observations from Nolans mine site from July 2011 to June 2015 were validated against the closest Bureau of Meteorology (BoM) automatic weather station (AWS), NT Grape Farm (site 015643). Nolans mine site and BoM data were generally in agreement.

2.2 On-site observations from 2011 to 2015

2.2.1 Temperature

Temperatures follow the expected seasonal pattern of cycling between warmer temperatures in the summer (peaking in December-January) and cooler temperatures (lowest in July) in the winter. Figure 2 indicates the annual cycle and compares the site monthly averages to the longer term BoM site. The maximum average hourly temperature was 42.6° C at 4 pm on January 11 2011 while the minimum was -1.16° C at 5 am on 8 July 2014. Note that while temperatures often overnight in winter get as low as freezing point, there are few if any frosts as the desert dew point is lower and a dew does not form (to then be frozen into a frost).

The air temperatures are very similar with the on-site maximum matching closely with the BoM data and the on-site minimum being slightly higher in general.

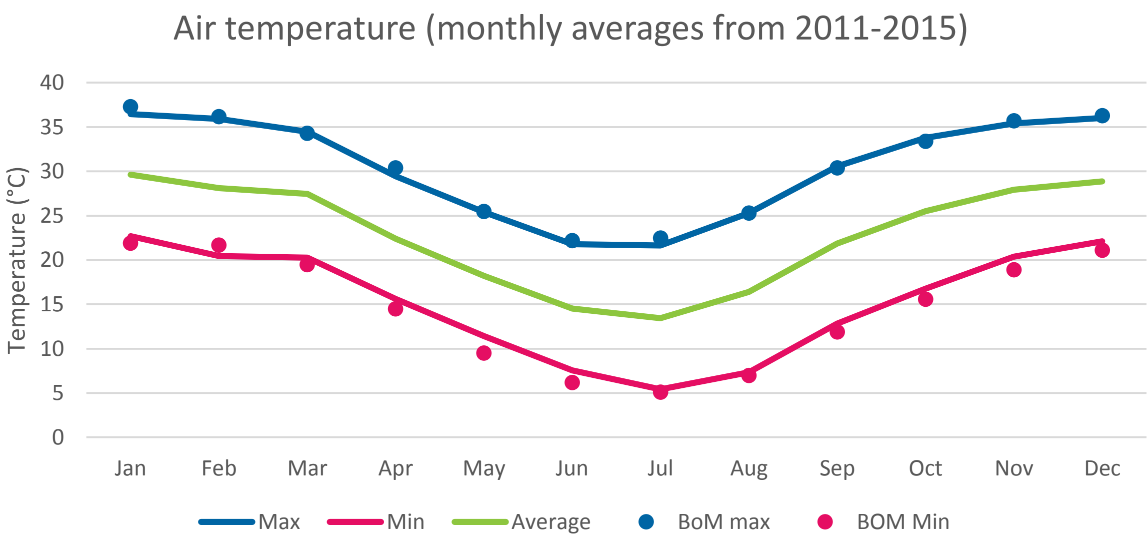


Figure 2 Air temperatures

2.2.2 Relative humidity

Figure 3 shows that relative humidity was higher in summer (likely due to greater rainfall and associated higher dew points at times) and in winter (likely due to the air temperature being lower as cooler air is not able to hold as much water). Spring had the lowest humidity. The maximum hourly average was 95.94% at 9 am on 10 April 2014 while the minimum was 4.04% at 5 pm on 27 October 2013.

This is consistent with the BoM data although the on-site humidity is generally lower than the BoM data, especially in the spring months.

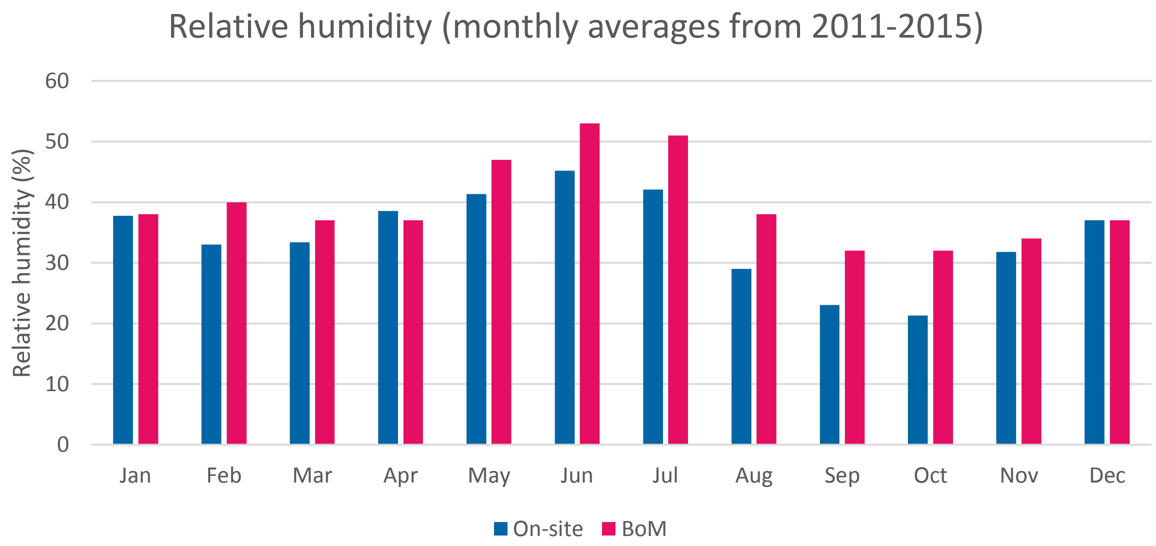


Figure 3 Relative humidity

2.2.3 Rainfall

The rainfall at the location, see Figure 4, follows a seasonal trend of a wet season in the summer to early autumn months and dry conditions for the rest of the year. The spring months appear to be especially dry, suggesting this the most vulnerable period for poor dust conditions.

The trend is consistent with the BoM data although there are discrepancies in the averages (the BoM data is a much longer trend series than recorded on site). However, these discrepancies are a result of the 2011-2015 rainfall being anomalous with the climatological rainfall averages in the area.

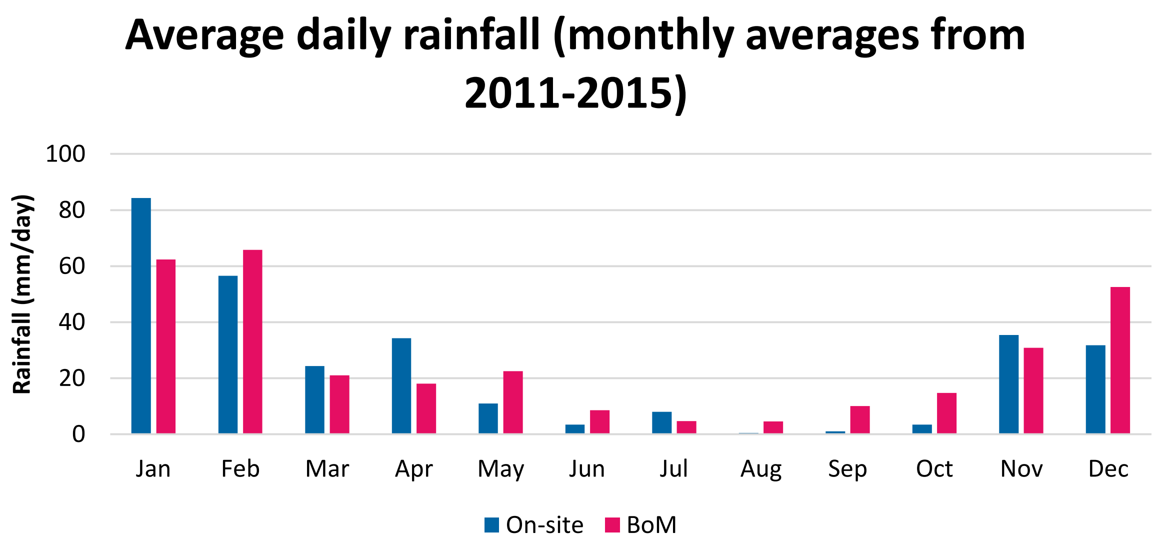


Figure 4 Rainfall

2.3 Wind dispersion

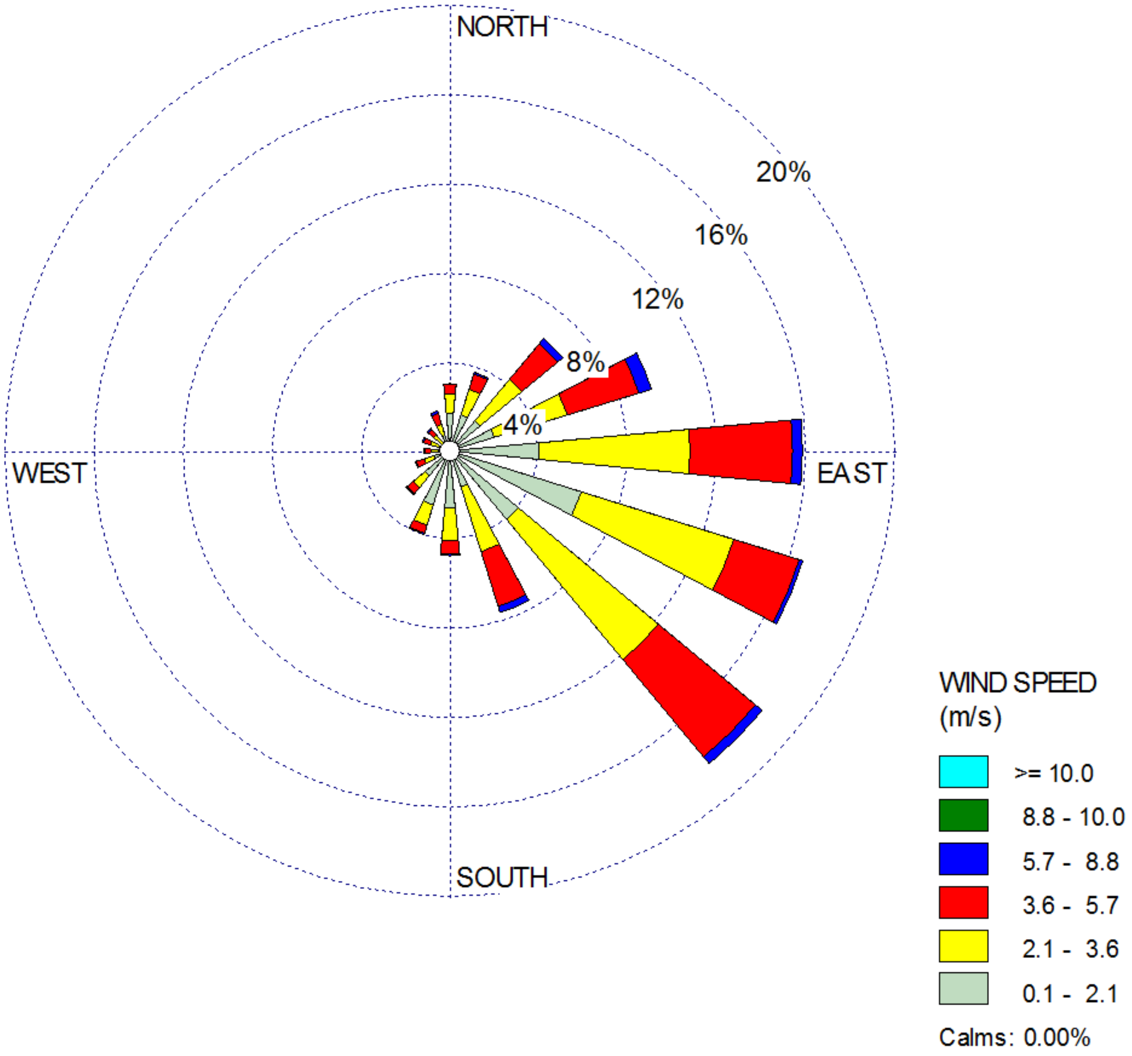


Figure 5 Annual wind rose

Figure 5 indicates that the vast majority of winds come from the south-east quadrant with an average wind speed of 2.77 m/s. There are also a small proportion of winds from north of east (compared to south of east) and very few winds coming from a westerly component. In terms of poor dust conditions, the incidence of light winds is important for poor dispersion, while the strongest winds create the most wind erosion. As seen in the wind rose, most of the light winds (0.1 – 2.1 m/s) originate from the south-east. The strongest winds have the vast majority with an easterly component. This suggests sensitive receptors west and north-west of the site will be most vulnerable.

The wind distribution remains fairly constant throughout the year, see Figure 6 for a seasonal variation, although there is a greater incidence of winds from north of east during spring and summer. The warmer months of the year see the sub-tropical ridge across Australia migrate well to the south and causing some disturbance to the prevailing south-east trade winds near the Tropic of Capricorn.

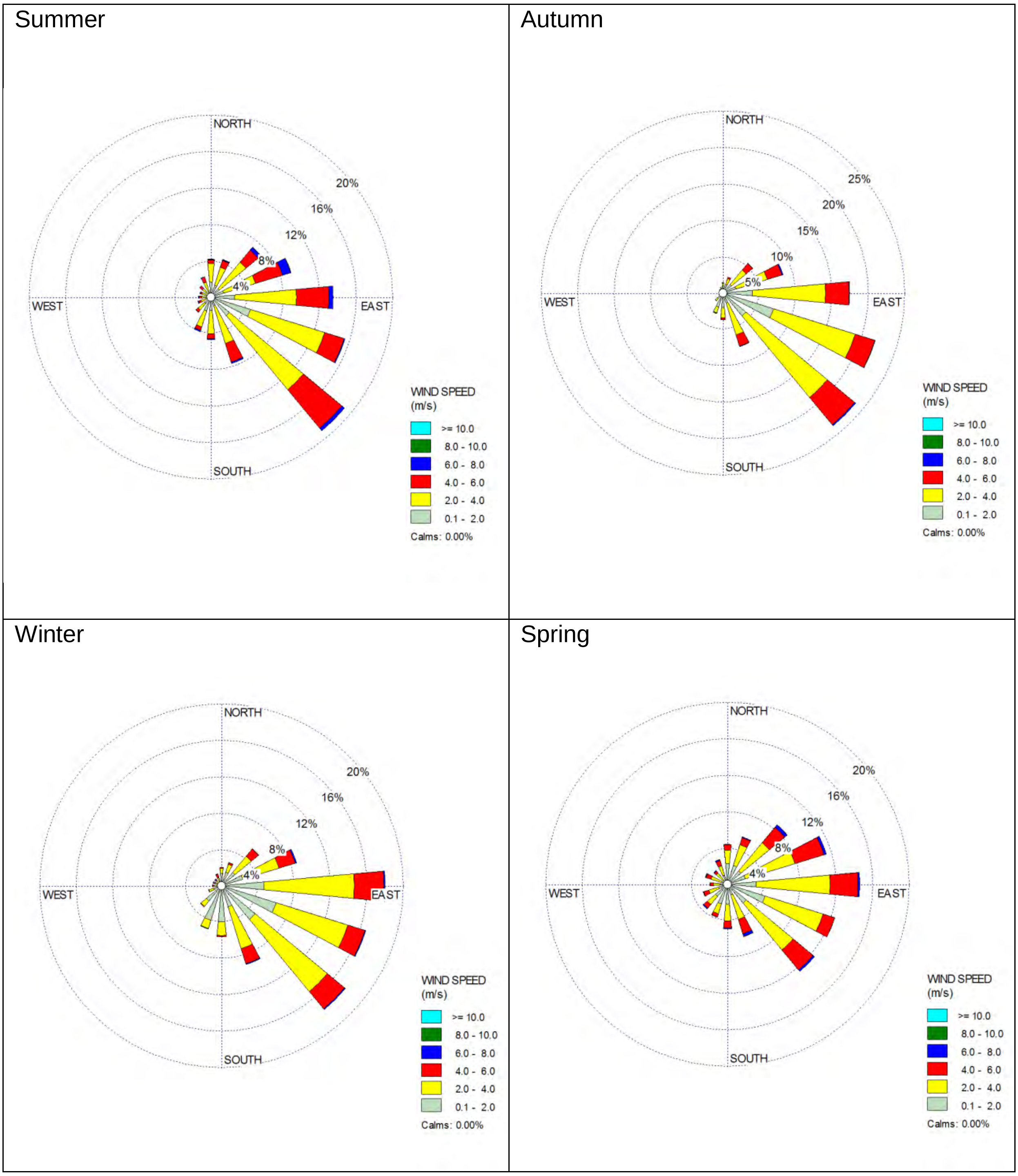


Figure 6 Seasonal wind roses

An AUSPLUME meteorological input file was compiled from the on-site meteorological data. This included information on dry bulb temperature, wind speed, wind direction, atmospheric stability, mixing height and standard deviation of the wind direction (sigma-theta). For convenience, and after passing suitable QA/QC checks on data availability, the calendar year of 2014 was used to convert 10-minute averages into hourly averages and derived dispersion variables of stability and mixing height.

Since there are no at cloud data for the site (or even nearby any BoM climatic site) or a temperature difference (2 m to 10 m) to pair with the solar radiation, it was only possible to derive an atmospheric stability derivation using the Modified Sigma Theta (MST) method from the USEPA[1]. The sigma-theta measurements pass the data checking procedure as indicated in Figure 7 of being highly variable at low wind speeds but consistently decreasing (narrowing wind direction variation) with wind speed. The highest wind speeds (> 7 m/s) indicate that the sigma-theta is in the range of 10 to 15 degrees – this is consistent with a surface roughness selection of 0.1 m to correspond to a partially vegetated, flat-rural landscape.

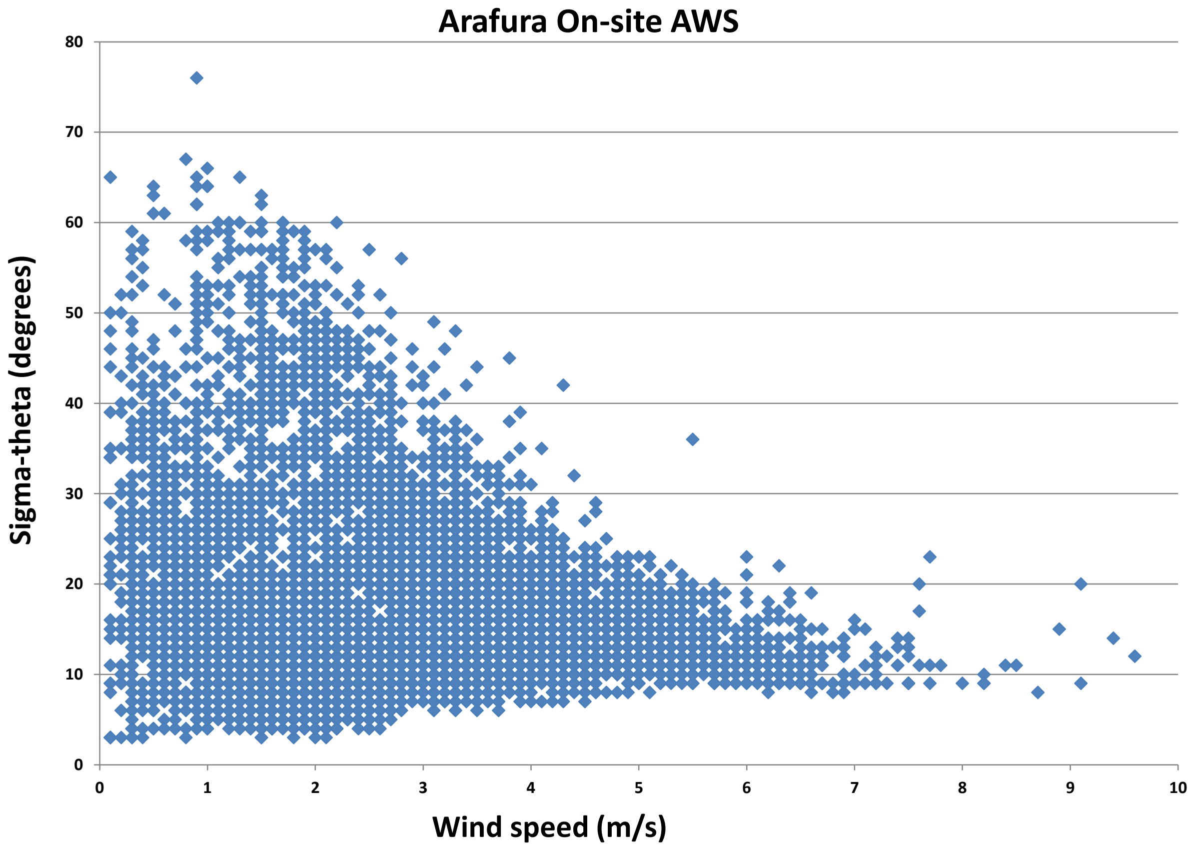


Figure 7 Standard deviation of wind direction as a function of wind speed

[1] USEPA, 2000. Meteorological Monitoring Guidance for Regulatory Modelling Applications, EPA-454/R-99-005, Research Triangle Park, NC, February 2000.

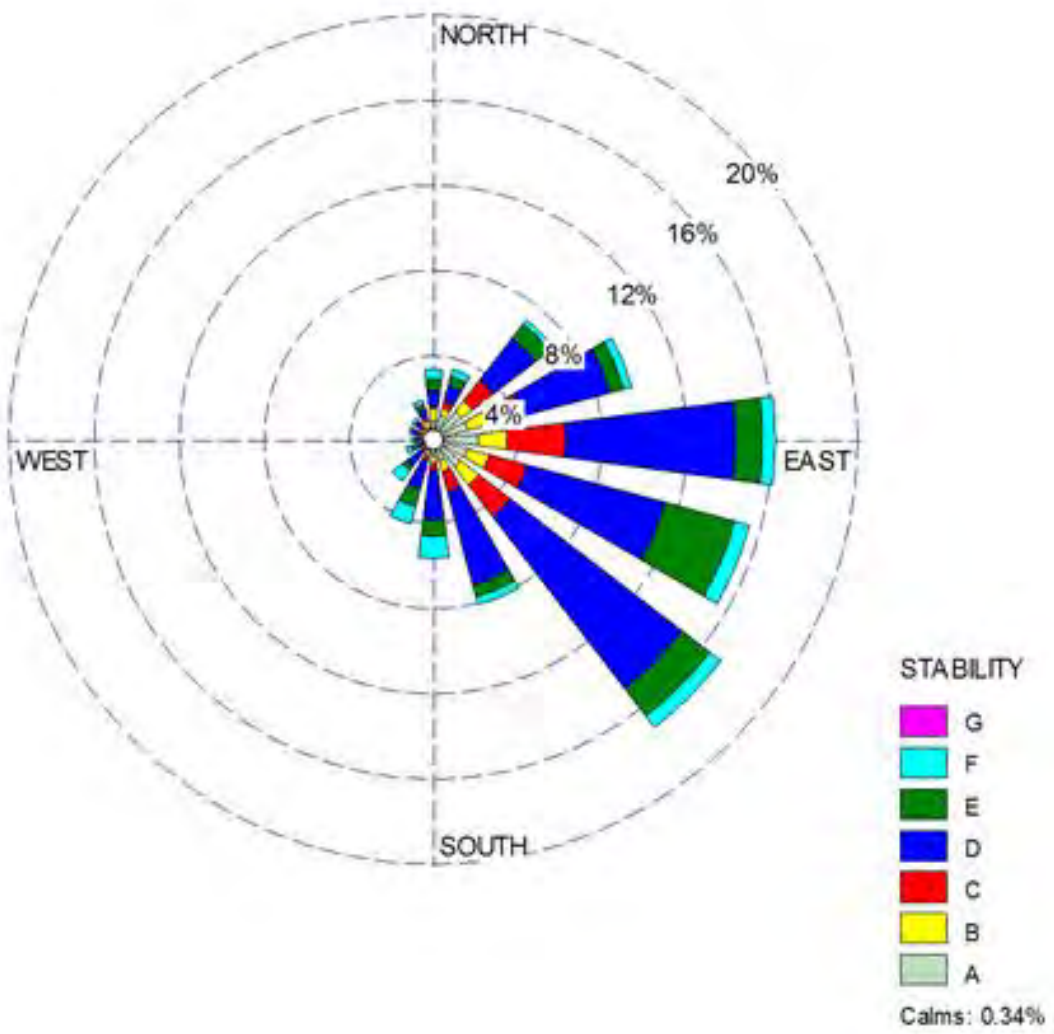


Figure 8 On-site stability rose

2.4 Ambient dust

Existing condition information is limited and thus baseline monitoring was completed to provide an indication of ambient conditions at the Project site.

The baseline monitoring data was collected on a campaign basis with more than three months of data (three events during 2010/11) for in-air concentrations and more than five years (October 2010 to July 2015) for dust deposition. Monitoring is to continue through construction and operation so as to inform future assessments of impact, based on changes to total dust and anolyte distributions across the network.

The monitoring conforms to Australian Standards within the constraints of site access, security, mains power access and ongoing plausible maintenance and servicing requirements.

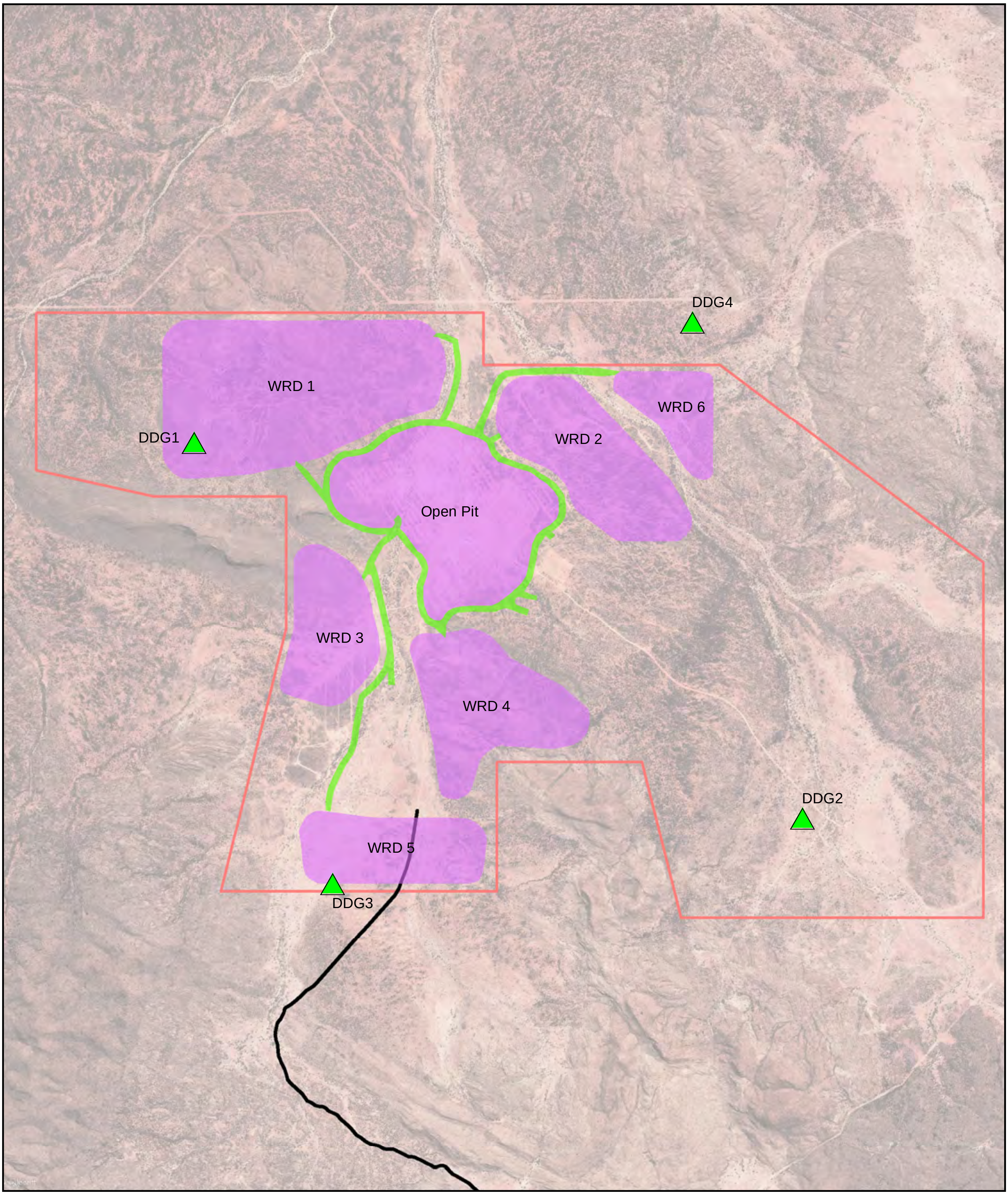
2.4.1 Method

Ambient Particulate Matter (PM) Monitoring

Inhalable dust, of 10 microns (µm) aerodynamic equivalent or less (PM_{10}), is in the area of human health impact at sensitive receivers. The ambient monitoring was focussed on the Aileron Roadhouse to the southeast of the Nolans mine site as this defines the area east of the processing site, as shown in Figure 1 and nearby where an accommodation village would be established. The instruments deployed were a continuous monitor (DustTrak) supported by a gravimetric monitor triggered every three to six days for 24-hour periods. An analysis of the latter provides information about constituent mass and radionuclides.

Deposition Monitoring

Baseline monitoring conducted involved deposited dust sampling in the area around the proposed mining site, ML26659 as shown in Figure 1. This consisted of an array of dust deposition gauges aligned around the site boundary and on the predominant upwind and downwind axis and indicated in Figure 9. Soluble, insoluble and constituent analysis for each gauge, plus further analysis as required for the radionuclide assessment were completed. Figure 10 in section 2.4.3 provides the results from the dust deposition gauge monitoring to date. These can be considered ambient/background conditions as mining operations are yet to commence. The gauges can continue once mining operations commence and they are not impacted by site operations (i.e. within pit, haul or waste rock areas).



LEGEND

- Dust Deposition Gauge
- Mine Site Boundary
- Access Road
- Dust Generation Source

1:40,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Nolans Project

Job Number	43-22301
Revision	0
Date	18 Mar 2016

Dust deposition gauge locations

Figure 9

G:\43\22301\GIS\Maps\4322301_727_DDG.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 07/03/2016). ARL - Project Areas (2015). GHD - DDG (2016). Created by: CM

2.4.2 Criteria

Assessment criteria for dust emissions resulting from the Project are summarised in Table 1. These criteria are taken from various jurisdictions around Australia (as indicated in the Table) and are considered 'industry standard' for the assessment of particulate matter impact. Note that $PM_{2.5}$ is included for completeness but environmental impact is most often associated with combustion sources. Impacts from combustion sources were identified as low risk as the power station fuel is 'clean-burning' natural gas and mobile plant is sparsely distributed and extremely low in emission quantity.

Table 1 – Assessment criteria for dusts

Pollutant	Averaging period	Return interval	Criterion
Total suspended particulates (NSW Approved Methods)	Annual	Maximum	90 µg/m3
Particulates as PM_{10} (VIC Mining PEM)	24-hours	Maximum	60 µg/m3 (for area sources)
Particulates as PM_{10} (VIC SEPP (AQM)	1-hour	99.9%ile Design GLC	80 µg/m3 (for point sources)
Particulates as $PM_{2.5}$ (NEPM)	24-hours	Maximum	25 µg/m3
Dust deposition (NSW Approved Methods)	Annual	Rolling 12-month average	2.0 g/m2/month (increment) 4.0 g/m2/month (maximum)

2.4.3 Results

Dust deposition

There are fourteen monthly events where levels of background dust deposition are above the 2.0 g/m^2/month assessment trigger as indicated in Table 2 and Figure 10. However, the average across the most continuous monitoring period indicates that all sites are below the annual assessment criterion, as summarised in Table 2. Site NDDG2, with the lowest value of <0.5 g/m^2/month, is the best indicator of the prevailing background dust for the region. Being both south and east of the proposed mining operations it best represents the dust load in the prevailing ('incoming') air to the site.

Table 2 Dust deposition results from October 2010 to July 2015

Monitor	Months where 2.0 g/m^2/month is exceeded	Months where 4.0 g/m^2/month is exceeded	12-month average
NDDG1	8	3	0.66
NDDG2	1	1	0.49
NDDG3	3	2	1.96
NDDG4	2	1	0.76

Note: Annual average calculated from all data from Nov 13 to Jul 15 due to ad-hoc gaps in the data dating back to October 2010.

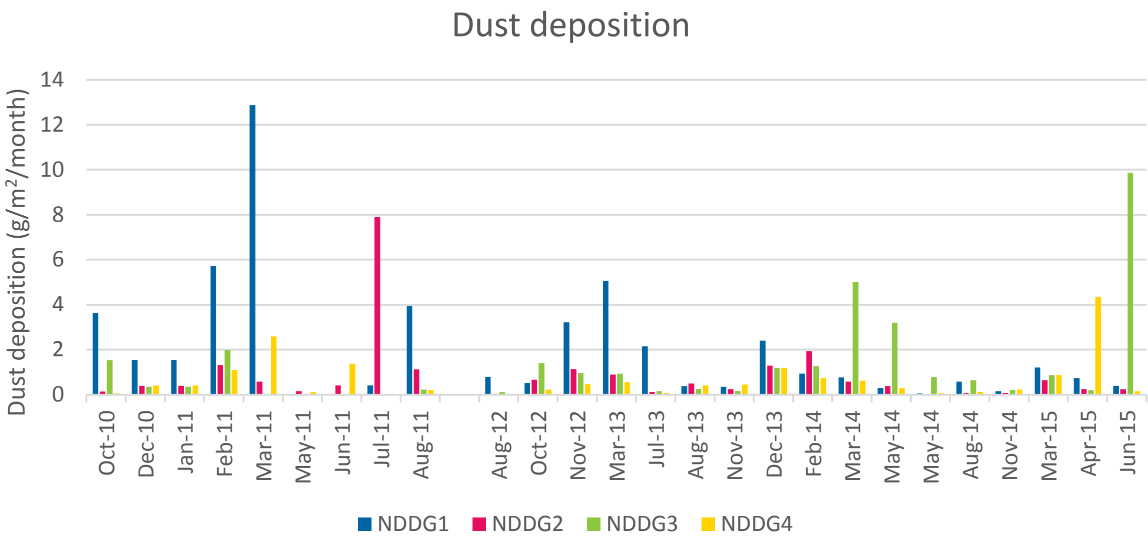


Figure 10 Dust deposition from October 2010 to July 2015

Although monthly exceedances do occur, all sites satisfy the 12-month rolling average criterion. Site NDDG3 is very close to the acceptable 'background' threshold. A regional background level of close to 0.5 g/m^2/month can be assumed as the ambient background.

PM$_{10}$ monitoring

Figure 11 provides the data for the three different periods of continuous monitoring:

- 26 September 2010 to 26 October 2010
- 28 October 2010 to 6 December 2010
- 3 February 2011 to 9 March 2011.

Daily averages of PM$_{10}$ were generally less than 20 µg/m^3 up until 12 February 2011. After this date, levels increased and appeared to stabilise between 30 and 35 µg/m^3. PM$_{10}$ levels were below the regulation criterion of 60 µg/m^3 for the full period monitored although a seasonal increase at the end of summer has been recorded.

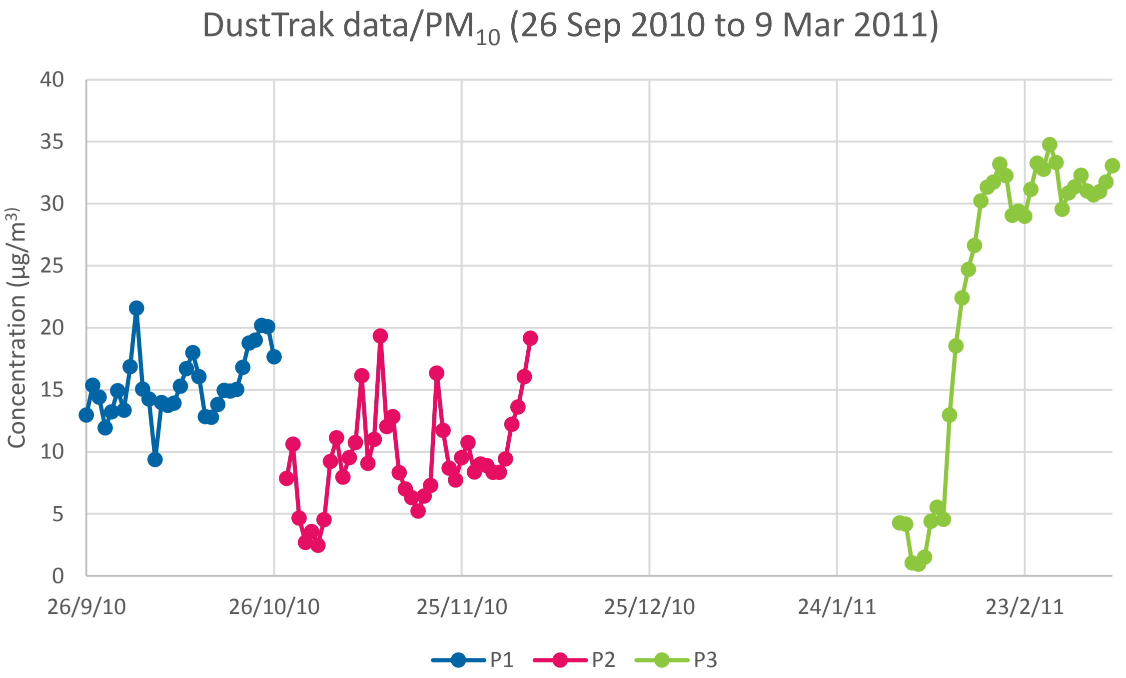


Figure 11 Daily PM_{10} concentration averages from 26 September 2010 to 9 March 2011

The earlier measurements of 10-15 µg/m^3 are more consistent with the accepted non-urban PM_{10} levels found in Australia. The seasonal increase to over 30 µg/m^3 was likely due to local sources at the Aileron Roadhouse, vehicle and heavy vehicle traffic on dry handstand surfaces, associated with drier and hotter conditions found in summer during a period when little or no rain occurs. In reality, an above average start to January 2011 (64 mm rainfall to the 11th) then dried out late into February and the start of March. This also coincided with more mine related traffic at the site office (located at the roadhouse at the time) associated with a mine drilling program.

2.5 Sensitive receptor locations

Small communities and family outstations in the surrounding area include:

- Aileron Roadhouse - important stop-over for travellers on the Stuart Highway providing various amenities.
- Alyuen (Aileron) – family outstation 130 km north of Alice Springs and 2 km west of the Stuart Highway (population about 20 - including some traditional owners).
- Alkuptija (Gillans Bore) - family outstation 3 km west of Stuart Highway and 40 km south east of Nolans mine site (population about 20).
- Burt Creek (Rice's Camp) - family outstation close to Stuart Highway and 50 km south east of Nolans mine site (population about 15).
- Injulkama (Amburla) – family outstation 40 km south of Nolans mine site and 100 km to the north west of Alice Springs (population about 10).
- Laramba is a key community due to its relative proximity to the mine site. Access to the community is by the Napperby station road, which runs west from the Stuart Highway. The community is located 83 km from the turnoff. Laramba is a large community of mostly Aboriginal people (population approximately 300) including some of the traditional owners of the mine site and it has a school, community health centre and other facilities.

- Napperby station - 3500 square kilometre cattle station 50 km to the north west which has been owned and operated by the Chisholm family since 1948. This includes a shared borefield area and Laramba community living area.
- Pine Hill (Anyumgyumba) family outstation located 35 km west of the Stuart Highway and approximately 27 km north of the Nolans mine site (population varies from 0-20). Also cattle station recently purchased by the Braitlings, who are planning organic farming.
- Pmara Jutunta (Six Mile) – major community of about 190 people 40 km to the north east of Nolans mine site and close to the Stuart Highway and Ti Tree community.
- Ti Tree community is located 170 km north of Alice Springs along the Stuart Highway. It is a large community with facilities including a school, health centre, library, police station and airstrip. Population is approximately 280 persons. Ti Tree serves as the operational centre for the Anmatjere Community Government Council (ACGC). Nturiya (Ti Tree Station) is 17 km to the west of Ti Tree and has a population of about 100.

Table 3 provides the coordinates of key locations used to identify sensitive receptor locations that could be considered for discrete point locations in the modelling. Note the significant distances involved, all double digit or more in kilometres for off-site, from a nominal point of 'Nolans Bore'.

Table 3 Sensitive receptor locations

Site	Easting (mE)	Northing (mN)	Distance (km)
Nolans Bore	319070	7501720	0
Accommodation Camp	322800	7493100	9.4
Aileron Roadhouse	330000	7494900	13
Alyuen	330600	7492000	15
Alice Springs	386000	7378600	140
Pinehill Station	299500	7523300	29
Laramba	269200	7506400	50
Napperby	268900	7509000	51
Conniston	241600	7559800	97
Annas Reservoir	309200	7500600	10

3. Emissions inventory

3.1 Process description

Arafura has completed extensive pit and orebody modelling and has a comprehensive understanding of the mineral resource. The mine development is planned in an uncomplicated manner with a conventional open-pit design. Ore and waste rock are hauled to either a ROM (Run-of-Mine) or waste stockpile area. The Concentrator processes the ROM and Long Term Stockpile (LTS) ore in a mid-sized facility with a straightforward flowsheet. A (non-emitting) slurry transfer pipeline feeds concentrate across 8 km to the RE Intermediate Plant at a rate of 52 m^3 per hour. End product and incoming supply material is hauled from the mine processing to the Stuart Highway connecting to Alice Springs.

Ancillary major plant (requiring an emission inventory) are an Acid Plant and a Power Generation (natural gas) plant. These are co-located with the RE plant at the processing site.

3.2 Dust generating sources

3.2.1 Pit and mining

The ore body has been delineated into a seven stage pit arrangement as per Figure 12. This will ensure consistent delivery of mill feed at the required plant head grade. These seven pit stages have been modelled as separate worst-case scenarios where the year with the most material being moved about the site, a ‘nominal year’, from each pit stage has been identified.

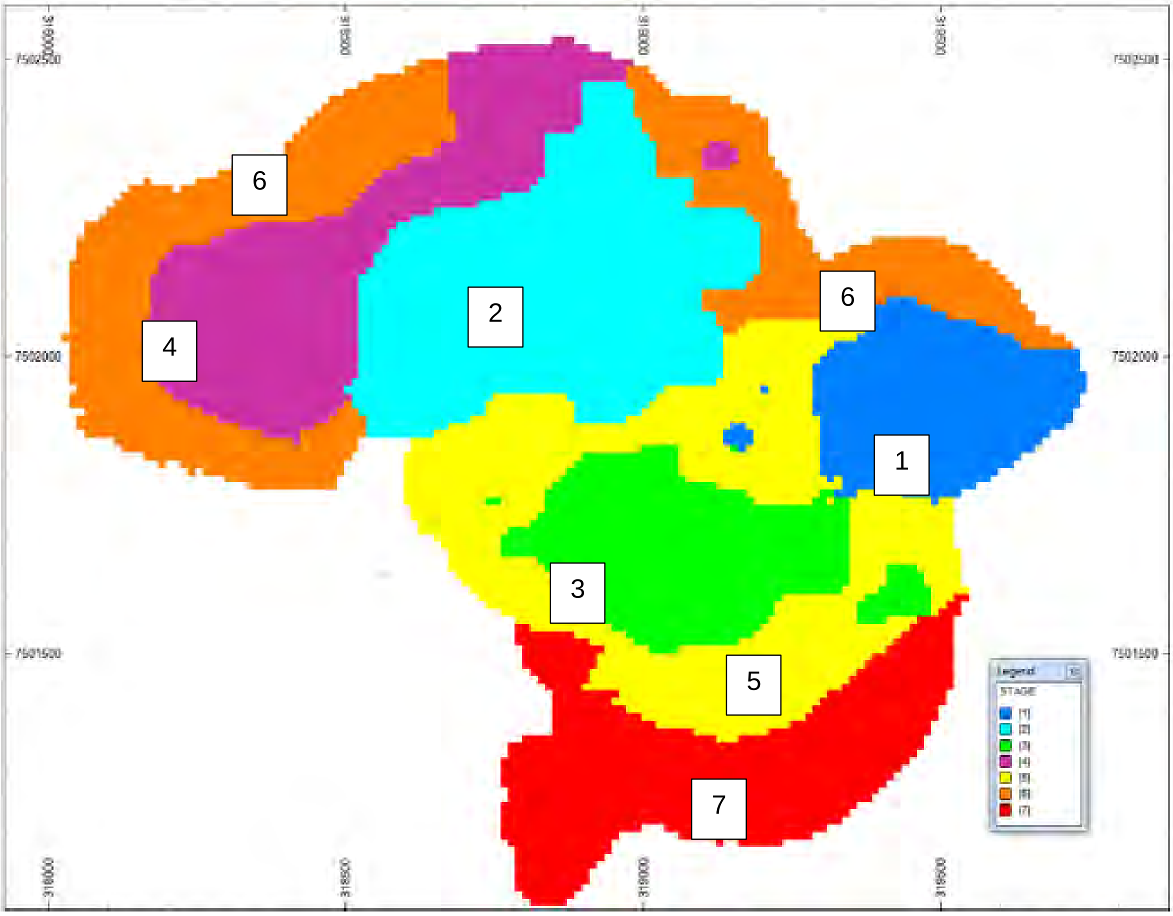


Figure 12 Pit stages

The open pit is designed to a depth of 225 metres below ground level, with a total surface area of up to 135 ha. As this depth penetrates the ground water table, it is expected that dewatering will be required from each pit to on-site turkey nest dams.

Mining consists of some/limited blasting of waste rock and ore and use of dozers (49 t CAT D9T), graders (CAT 16M) and excavators (108 t Hitachi EXI 200). It is likely that ammonium nitrate fuel oil (ANFO) will be used in the waste rock because it is hard and relatively dry, while emulsion will be used in the ore as it is porous and a wetter material. Mining will be conventional using excavators, dump trucks and dozers with limited augmentation from blasting.

The ore and waste rock are loaded in the pit by excavators (108 t Hitachi EXI 200) into haul trucks (90 t CAT 777F). The mining will progress through the seven stages and peak years have been identified for each stage (corresponding to nominal year of mine operation). Table 4 provides key indicators used to identify material transfer to be used in developing the emission inventory across seven worst-case scenarios.

Table 4 Pit staging (Mtpa)

Stage	Nominal year	Ore Material Types[1]		Ore from Pit[1]			To Waste Dump[2]	To Concentrator	
		0, 1, 2, 3	4, 5, 6	ROM[5]	LTS[6]	Reject[6]		ROM[5]	LTS[6]
1	1	0.36	0.083	0	0.4	0.05	4.4	0	0
2	8	1.8	0.25	0.7	1.26	0.1	2.8	0.71	0
3	10	0.22	0.48	0.36	0.29	0.1	2.3	0.36	0.74
4	11	0.65	0.77	0.73	0.39	0.3	8.6	0.73	0.37
5	20	0.71	1.14	1.0	0.4	0.4	8.1	1.01	0.09
6	31-35	0.53	1.29	0.6	0.3	0.1	8.9	0.62	0.39
7	38	0.24	0.31	0.2	0.3	0.003	9.4	0.25	0.65

Notes:

1. 'Ore material types' add to approximate 'ore from pit' total
2. 'Ore' plus 'waste' is mining rate – initially 5 Mtpa but then 10 Mtpa (year 11 and thereafter)
3. Approximately five haul trucks will be assigned to waste rock movement while 4 trucks will be used for the ore material – this ratio will change depending on operational requirements.
4. The ore is saturated below a depth of 12 m but will dry out naturally. The stockpiles will be located adjacent to the northern side of the ROM and will be within tramming distance of the front End Loaders (FEL) and can be watered if required to reduce dust emission
5. From the ROM, a FEL will be used to tram material to the crusher
6. The LTS and Reject pads will be hardstand constructed from benign waste rock.
7. Tailings from the Reject pad will be relocated to a tailing dam east of the concentrator in the form of a liquid-solid. Some recovery of supernatant water is expected.

As the ore body is generally within the aquifer, which will be dewatered ahead of mining, it is envisaged that the ore will have high moisture content and dust generation when mining will be lower than mining waste. However, to minimise dust generation when mining ore, wetting of the ore during excavation with water cannon mounted on the water trucks will be carried out where necessary. This type of 'fogging spray' control system for transfer points can achieve a control efficiency of 80% (Liu, 1994).

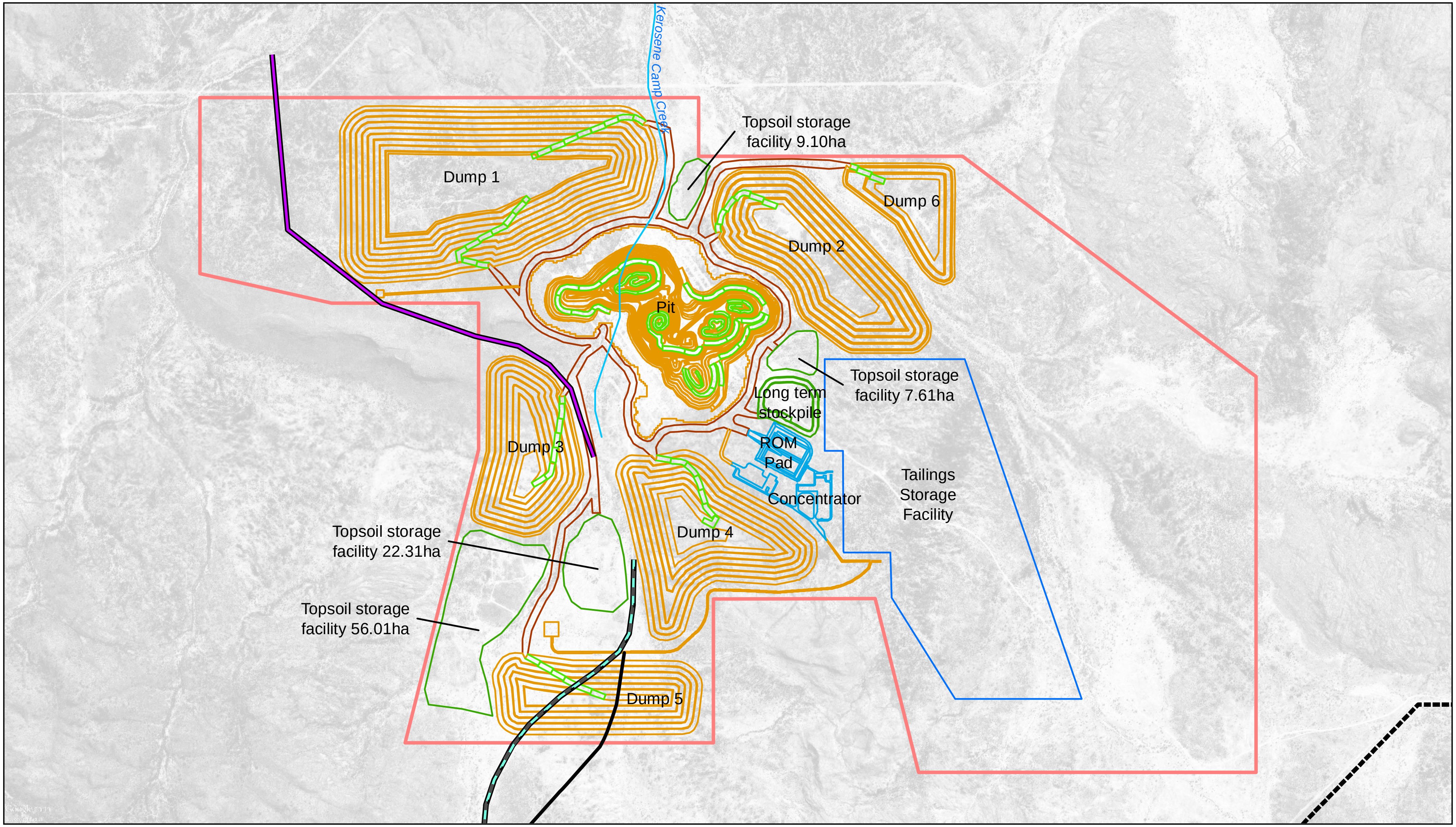
3.2.2 Hauling

Overburden and waste material will be deposited in purpose constructed Waste Rock Dumps with a stand-off distance from the pit of 50 m.

The CAT 777F haul trucks are used to transport material out of pit to either:

- The concentrator ROM or Long Term Stockpile (LTS) – fixed location
- One of six waste dumps (variable locations).

The general arrangement of the central mining and haul road network is provided in Figure 13. All dual access ramps have been designed at 30 m width to allow safe two-way access for mine trucks up to 150 t class. One way ramps have been designed with 16 m width with the exception of access to pit bottom where the single ramp width is 30 m.



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0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

LEGEND

- Powerline
- Potable Water Pipeline
- Diversion Channel
- Water Supply Pipeline
- Waterways
- Access Road
- Existing Gas Pipeline
- Proposed Mine Site Boundary

Arafura Resources Limited
Nolans Project

Job Number	4322301
Revision	0
Date	18 Mar 2016

Waste rock dump layout

Figure 13

G:\43\22301\GIS\Maps\4322301_729_WasteDumpLayout.mxd

Level 5 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: Google Earth Pro - Imagery (Date extracted: 29/04/2015). ARL - Proposed Pipelines, Proposed Mine Site, Proposed Diversion Channel Options, Tailings Storage Facility (2015). Created by: CM

Dust suppression for haul roads and operating areas (in pit as well as waste dumps and ROM pad) is required at Nolans to limit dust inhalation by pit personnel (radiation requirements) and provide safe visual operating conditions. To minimise water usage and subsequent bore field capital and operating costs, a chemical binding agent, such as Dustbloc or other similar products, will be used in operations. Typically, Dustbloc is added to water at a ratio of 1:40 initially (Dustbloc:Water). Level 2 watering (>2 litres/m^2/hr) can achieve 75% dust suppression while salt encrusted and sealed roads achieve close to a 100% reduction (NPI, 2012). The chemical treatment mixed with water as proposed here is more likely to achieve reduction equivalent to "Wetting agent – other than water" of close to 80% (Liu, 1997).

The (sealed) access road from the Stuart Highway will cross the headwaters of numerous ephemeral creeks that eventually drain southwards into the Lake Lewis catchment. Detailed logistics modelling indicates that the Project will have annual movements of approximately 193,000 tonnes of in-bound raw materials to the Nolans Site, and these will predominantly be in the form of standard intermodal cargo. The heavy vehicle movements associated with this will be on the Stuart Highway and a sealed access road and therefore producing minimal dust.

3.2.3 Stockpiles and concentrate plant

Ore will be processed through a plant producing a concentrate and a tailing product:

- Concentrator plant for comminution (to break into smaller parts)
- Beneficiation circuits (to improve physical or chemical properties of ore
- Heavy and light vehicle workshop and administration offices, and facilities comprising wash down area, tyre change facility, lube storage facility etc.

Mining operations will deliver broken ore to a ROM pad (from which a front end loader will feed the crushing circuit) as well as to the LTS. Plant feed (MT123 and MT456) is mined from the open pit mine and stockpiled on the ROM pad adjacent to the primary crusher. The ROM plant feed is rehandled once and is processed soon after being mined. Lower grade material mined during the early years of the Project is stockpiled off the ROM pad and is rehandled twice – once from the Long Term Stockpile to the ROM, and again from the ROM to primary crusher.

A single stage crushing and concentration plant using a combination of heavy media separation and froth flotation will produce a concentrate. The Concentrator is a mid-sized facility that features conventional comminution and processing technology buildings. Ventilation stacks are not required at the concentrator and the beneficiation circuit after crushing, the material will be wet.

The comminution includes a conventional crushing circuit fed by a front end loader and subsequently conveyed to a single ball mill for grinding. To help mitigate dust impacts prior to crushing, there will be a roof over the float cells, sheltering on the windward side and a dust suppression system over the jaw crusher.

In the beneficiation circuit, ground material is fed to a magnetic separation circuit to produce a magnetic concentrate. This concentrate is reground and upgraded further using flotation to produce a higher grade RE concentrate. The magnetic tails are also processed through a flotation circuit to produce a higher grade phosphate concentrate. The RE and phosphate concentrates are then combined as the feed material and the concentrate is pumped to an intermediate processing site located immediately to the south of the mine lease area (see section 3.2.5).

Tailings are transferred to a Tailings Storage Facility. The tailing will be wet and so dust emission from these will be insignificant except if they dry out around their edges.

Thorium and uranium will be present in material that is input to the beneficiation plant and in material that is both stockpiled and/or disposed to waste dumps. Waste that contains uranium and thorium with an activity concentration of >1 Bq/g will be placed within selected areas of waste dumps and will be encapsulated with benign waste rock.

Radiation will be emitted and these were modelled (to assist the Radiation Technical Report at Appendix P) as area sources from stockpile areas (waste rock and tails), processing and beneficiation plants as well as from the open pit, (a tracer methodology was used where Bq/s emissions replaced the usual g/s of air dispersion modelling). Radiation levels associated with the waste rock are expected to be low and there will be appropriate radiation management protocols in place to ensure worker and public safety (see Appendix P).

Upon closure, stockpiles, waste dumps and residue storage facilities that contain radioactive material will be capped with benign waste rock to a thickness of 2 m to ensure underlying waste and tailings will not be exposed or eroded in the long term.

3.2.4 Wind erosion

A topsoil storage with a footprint of 95 ha and height of 3 m will be present. It will be used and refilled progressively as dumps are built and closed. Waste soil that is removed from dumps will be added into the stockpile for reuse.

The flotation tailings storage facility (FTSF) is an area of about 100 ha with an embankment height of 25.1 m. A LOM tailings storage envelope of 245 ha has been planned to allow for extensions to the tailings dam area if mine life extends beyond 45 years. These contain the beneficiation tailings and are in the TSF east of the concentrator. As they are wet there will be little to no dust emissions.

3.2.5 Rare earth (RE) plant

The RE intermediate extraction plant at the processing site will require construction of the following infrastructure to produce rare earth concentrate:

- Extraction processing units
- Process residue storage facilities (RSFs) to store all residues products including all wet and fine material. They will consist of one cell with an embankment up to 24 m totalling a combined potential footprint area of 160 ha
- Construction of evaporation ponds consisting of six cells each of 10 ha and an embankment height of 2.5 m.

The RE Intermediate plant will produce five waste streams and an intermediate rare earth product. Each waste stream will be confined to and stored within one storage facility on site located to the north-west of the intermediate plant which is 8 km south of the mine:

- water leach residue
- neutralisation residue
- phosphate residue
- excess process liquor.

The tailings will be wet with the radiation described in Appendix P.

3.3 Gaseous generating source(s)

The RE Intermediate Plant has several ancillary plants associated with it, such as a sulphuric acid plant, steam and power generation, and water treatment, as well as other infrastructure and services. Whilst the power plant fuel is 'clean' natural gas, which has very little sulphur content, the acid plant tail gas will have some Sulphur Dioxide (SO_2) as an emission. Key gaseous constituents from these major emitting point source need to be modelled to check on compliance to ground level impact. Table 5 provides assessment criteria for these gaseous constituents remarking that if plant achieve these compliance limits then other gaseous constituent pollutants will also be within limits.

Table 5 Assessment criteria for gaseous emissions

Pollutant	Averaging period	Return interval (design GLC)	Criterion
Carbon Monoxide – CO (VIC SEPP (AQM))	1-hour	99.9%ile	29,000 µg/m^3
Nitrogen Dioxide – NO_2 (VIC SEPP (AQM))	1-hour	99.9%ile	190 µg/m^3
Nitrogen Dioxide – NO_2 (NSW Approved Methods)	Annual	Maximum	62 µg/m^3
Sulphur Dioxide – SO_2 (VIC SEPP (AQM))	1-hour	99.9%ile	450 µg/m^3

3.3.1 Rare earth (RE) plant

The RE Intermediate Plant comprises the following major processing facilities:

- Sulphuric Acid Pre-Leach (SAPL)
- Sulphation and water leach
- Double Sulphate Precipitation (DSP) and purification
- RE chloride intermediate and cerium carbonate production.

The plant will not be fully enclosed so there will be no need for ventilation stacks to be present. All emissions will have purpose-built scrubbers to deal with their respective type of emission.

3.3.2 Sulphuric acid plant

Once operational the RE Intermediate Plant demand for sulphuric acid will be serviced by an on-site sulphur burning acid plant. Inbound sulphur will be procured on the international sulphur market and it is proposed that bulk shipments will be containerised in Darwin for ease of transport by rail and road to Nolans site via Alice Springs.

It is assumed that the sulphuric acid plant will have a 3/1 Arrangement – i.e. 3 catalyst beds before intermediate absorber followed by 1 catalyst bed. This is a standard arrangement for a modern contact sulphuric acid plant for obtaining SO_2 emissions of 4 lb/ST (2 kg/MT) or 99.7% conversion.

Given the sulfur feed rate is known (11.7 tonnes/hr) the emissions of Sulpfur dioxide can be calculated.

3.3.3 Power station

The power demand for the Nolans Site is estimated to be 18.5 MW. There is no local grid supply opportunity in the Nolans region and therefore power demand will be serviced by cogeneration from a sulphuric acid plant and gas fired on-site generation.

The sulphuric acid plant will generate power via a steam turbine from the steam arising from burning sulphur and will deliver a net power output of approximately 6 MW over and above its internal consumption requirements.

The normal operating natural gas fired generation requirement of approximately 12.5 MW is planned to be supplied by a group of combined cycle gas turbine based generators. A high pressure (natural) gas pipeline from the Amadeus Basin to Darwin passes through the Nolans Site. The power plant will be located at the RE Intermediate Plant site adjacent to the sulphuric acid plant.

The primary pollutants of concern from a gas fired plant are nitrogen oxides and carbon monoxide (Department of Sustainability, Enviornment, Water, Population and Communities, 2012). Emissions of particulate matter, sulphur dioxide and other substances were not considered due to a low emissions values and subsequent impacts being insignificant fractions of the respective pollutant criterion.

Specifications for the gas fired generation were obtained from a reciprocating engine for natural gas and based on previous assessments conducted by GHD for natural gas fired power stations (not involving gas turbines).

3.4 Model inputs – mine operations

3.4.1 Emission Sources

Air emissions during the operation of the mine have been estimated for the following activities for the seven stages (at 'nominal years') of the operation of the mine:

- Blasting
- Removal of topsoil (overburden) in pits
- Removal of overburden by truck-shovels
- Removal of overburden by bulldozer
- Excavators mining ore and loading haul trucks
- Loading of haul trucks with overburden
- Transportation of ore by haul truck to Run-Of-Mine (ROM) pad
- Transportation of overburden by haul truck to nearest waste dump
- Dumping of waste material at nearest out of pit waste dumps
- Ore handling (loading, unloading etc.) at the ROM pad
- Primary crushing of ore
- Ore conveying
- Wind erosion from active ore stockpiles
- Wind erosion from exposed waste dumps
- Wind erosion from active pits
- Grading of haul roads, waste dumps and OCM pits

- Hauling on unpaved roads.

3.4.2 Hazardous Air Pollutants

The pollutants of interest in this assessment of mining operations are:

- Total Suspended Particles (TSP)
- Particulate matter less than 10 µm in equivalent aerodynamic diameter (EAD) (PM_{10}).

In addition to predicting ambient levels of particulate matter, dust deposition was also assessed.

Dust Generation

The general equation used to estimate TSP and PM_{10} emissions from mining activities is described mathematically as:

$$E_i = A \times EF_i \times \left(\frac{100 - CE}{100}\right)$$

Where:

E_i = Emission rate of pollutant *i* (kg per activity)

A = Activity data (units dependent on emission factors)

EF_i = Uncontrolled emissions factor for pollutant *i* (kg per activity)

CE = Control efficiency (%)

Where possible, the activity data and control efficiencies used in the modelling to estimate emissions from the sources described in Section 3.4.1 were based on the mine plan and other detailed information provided by Arafura Resources. Where required, emission factors used to estimate emissions of TSP and PM_{10} have been sourced from the publically available National Pollutant Inventory (NPI) Emissions Estimation Technique Manual for Mining, Version 3.1 (NPI, 2012).

Activity data is usually dependent on the amount of material moved as kilograms of TSP or PM_{10} per tonne of material or on the total distance of a vehicle travelled (Vehicle Kilometres Travelled, VKT). Therefore, a reduction in the total gross amount of material processed, or in the total number of kilometres travelled by vehicles, will reduce emissions. Dust emissions, as per NPI (2012), are independent of vehicle speeds except for dust emissions from small vehicle movements, i.e. 4WD's, utility vehicles and graders.

The moisture content for overburden used in this modelling is described as follows:

- Overburden: 2 per cent (PAE-Holmes, 2011, p.A-7)

The silt content for the modelling was based on a widely accepted default average silt content for the entire mine site of 6.0 per cent.

A description of the sources of the emissions is provided in the following sections. A summary of the emission factors used for the modelling is provided in Table 6.

Wind erosion was based on the AP-42 emissions estimation equation provided in the NPI Mining Manual (NPI, 2012, pp.59-60, equation 22). This equation relates the annual average wind erosion rate to the silt content (6 per cent), the number of days per year when the rainfall is greater than 0.25 mm and the percentage of the time when the wind speed is greater than 5.4 m/s at the mean height of a stockpile.

The local meteorological data for Nolans indicates that the mean number of rain days is 44. The wind speed is greater than 5.4 m/s for 6.28 per cent of the time.

The equation used for wind erosion was as follows:

$$EF_{TSP\ (kg/ha/yr)} = 1.9 \times \left(\frac{s_{(\%)}}{1.5}\right) \times 365 \times \left(\frac{365 - p}{235}\right) \times \left(\frac{f_{(\%)}}{15}\right)$$

:

Where:

$S(\%)$ = silt content (% by weight) = 6 %

P = the number of days per year when rainfall is greater than 0.25 mm = 44; and

$f\ (\%)$ = percentage of time that wind speed is greater than 5.4 m/s at the mean height of the stockpile = 6.28 %.

In effect, the annualised emissions as determined by AP-42 and NPI (2012) for wind erosion are distributed throughout the year based on a wind dependent relationship. The uncontrolled wind erosion EF's are provided in Table 6.

Table 6 Summary of uncontrolled emissions factors

Activity	Required Information	Pollutant	Emission Factor	Units	Derivation
Graders	Operational hours	TSP PM10	0.299 0.122	kg/VKT	Calculated from operational hours and default speed
Excavators/shovels on overburden	Tonnes of overburden moved	TSP PM10	0.0016 0.00076	kg/tonne	Calculated from moisture content and mean wind speed
Loading ore to trucks by shovel	Tonnes of ore moved	TSP PM10	0.0016 0.00076	kg/tonne	Calculated from moisture content and mean wind speed
Bulldozers on overburden	Operational hours	TSP PM10	9.066 1.893	kg/h/veh	Calculated from moisture and silt content
Unpaved haul roads	Total kilometres travelled	TSP PM10	19.703 5.589	kg/VKT	Calculated from default silt content and average vehicle weight
Blasting	Number of blasts	TSP PM10	36.1 18.7	kg/blast	Calculated from blast area
Trucks dumping overburden	Tonnes of overburden moved	TSP PM10	0.012 0.0043	kg/tonne	Default
Trucks loading ROM ore stockpiles	Tonnes of ore moved	TSP PM10	0.0016 00.00076	kg/tonne	Calculated from moisture content and mean wind speed
Unloading ROM coal stockpiles	Tonnes of ore moved	TSP PM10	0.0016 00.00076	kg/tonne	Calculated from moisture content and mean wind speed
Primary crushing	Tonnes of ore processed	TSP PM10	0.20 0.02	kg/tonne	Default for high moisture
Ore conveyors	Tonnes of ore moved	TSP PM10	0.0016 00.00076	kg/tonne	Calculated from moisture content and mean wind speed
Wind erosion	Disturbed area	TSP PM10	0.18 0.09	kg/ha/hr	Wind speed dependent

3.4.3 Mine operations

The following activities were identified as occurring inside of the operational/working ore pits:

- Bulldozers on overburden/waste rock
- Loading overburden/waste rock onto trucks
- Loading ore onto trucks
- Blasting
- Graders

The dust emissions from the mining operations were based on the information provided in the mine plan (refer Chapter 3 in the EIS). This specified the amount of material (overburden/waste rock and ore) that was estimated to be moved and the number and type of operational equipment for each 'nominal year' for the Mine in the seven operational scenarios.

Bulldozer operations were based on the estimated number of operational hours and the number of operating vehicles in the mine plan. As both silt and moisture content were known, the most accurate method to estimate dust emissions was by the use of the equations as opposed to the default values.

Loading overburden into haul trucks was assumed to be undertaken by front end and shovel loaders. The NPI Mining equations (NPI, 2012, equations 10 and 11) were applied as information regarding the average moisture content and the average wind speed were known. The amount of overburden moved was provided in the Mine plan. This method was considered conservative as wind speeds inside the pit are likely to be lower than those outside of it, for which the average wind speed was determined. Furthermore, a two per cent assumed moisture content for the overburden is unlikely to be representative of moisture levels at depths beyond 30 cm, which can be rapidly removed using modern earth moving equipment, and the pits being below the water table and requiring de-watering.

Blasting is not the primary mining method, but will be used on a required basis. As such, a detailed blasting schedule was not available. It was assumed for the purposes of estimating air emissions that blasting was to occur once every week, with an average blast area of 3,000 m^2. The current NPI emission estimation technique (NPI, 2012, equation 19, p.53) does not require information regarding blast hole depth or moisture content as older NPI Mining versions did to estimate emissions.

Dust emissions from grader operations were estimated from the number of operational hours of all graders and an average grader speed of 5 km/h, which was used to estimate annual VKT. The total material moved in the pit was assumed to be evenly distributed across all of the active pit area for each scenario.

Run-of-mine pad

The following activities were identified as occurring at the ROM pads:

- Loading ROM stockpiles
- Unloading ROM stockpiles
- Loading primary crusher
- Primary crushing.

Wind erosion from stockpiles was considered as a separate item.

The Mine plan specifies that there will be one ROM pad in operation for the duration of mining operations. The ore would be delivered to the ROM where it would be put through the crusher and loaded onto a conveyor. The NPI Mining equations (NPI, 2012, equations 10 and 11) were applied as information regarding the average moisture content and the average wind speed were known.

Default NPI (2012, Table 3) emission factors for each process was assumed. The ore is considered as “low moisture” content (NPI 2012, p.62) as the ore can ‘dry out’ after removal from the pit and during residence time on the ROM stockpile. Screening processes for the ore does occur at the ROM, however, as per NPI (NPI 2012, p.62) “…*emissions from a primary crushing activity include emissions from the screens, the crusher, the surge bin, the apron feeder, and conveyor belt transfer points that are integral to the crusher*.”

Haul roads

Dust emissions from haul roads were assumed to be 100 per cent generated from the movement of large haul vehicles. Wind erosion emissions from the haul roads were not modelled as it was assumed that the haul roads would be within the confines of either a pit or a waste dump. Therefore, haul road wind erosion emissions were not double accounted. Likewise, the dust emissions from the haul truck movement were assumed to originate from either a pit, haul road or a waste dump source.

Emissions were assumed to be evenly distributed across all of the active pit and associated waste dump with specific haul road paths identified.

The dust generated from the movement of light vehicles was not modelled as:

- It was considered negligible in comparison to the heavy vehicle emissions
- For safety, it is unlikely that frequently traversed light vehicle roads would be combined with haul truck routes.

Haul trucks were assumed to have an empty weight of 75 tonnes, and a payload capacity of 165 tonnes (full load weight of 240 tonnes). NPI (2012) emission factors for mining, unlike previous NPI Mining Manual versions, separates heavy and light vehicle wheel generated dust into separate categories. The default values specified in the NPI (2012) were deemed inappropriate for use as they are based on an assumption that the average vehicle weight (mass) is 48 tonnes. As the average haul truck mass for the Project (Mine) is predicted to be over 150 tonnes, the application of the default values represents a gross under-estimate of dust emissions.

The vehicle kilometres travelled (VKT) of the haul trucks was estimated using information for the truck capacity, the amount of overburden/waste rock and ore removed from the pits and the designated haul road distances between the confines of the pit and the ROM pad or waste dump. It was assumed that the ore and overburden/waste rock removal was evenly distributed to all of the active pit and associated waste dump.

Ore transfer points

The following activities were identified as occurring at ore transfer points:

- Conveyor transfers

The NPI Mining equations (NPI, 2012, equations for miscellaneous transfer points) were applied as information regarding the average moisture content and the average wind speed were known.

Waste dumps

The following activities were identified as occurring at the out-of-pit waste dumps:

- Dumping of waste rock

Default NPI (2012) factors were assumed.

Wind erosion from the exposed areas of the waste dumps was considered as a separate emission source.

Dust emissions from grader operations were modelled at the waste dumps; however, they were calculated for mining operations and assumed to be equally distributed between the pit and the waste dump.

3.5 Modelled scenarios

3.5.1 Overview

Seven scenarios were modelled to represent the dust emissions from Mine operations during its projected lifespan. A summary of these 'nominal year' stages is provided in Table 7.

Table 7 Summary of Modelled Mine Operational Stages Uncontrolled Wind Erosion Emissions Factors

Stage	Representative Year	ROM Capacity (M-tonnes)	Long term stockpile (LTS) Capacity (M-tonnes)	Reject (M-tonnes)	Mining Rate (M-tonnes)	Waste Dump (M-tonnes)	Uncontrolled PM10 Production Emissions (tonne/y)
1	1	0	0.4	0.05	4.8	4.37	1511
2	8	0.7	1.26	0.1	4.9	2.8	1629
3	10	0.36	0.29	0.1	1.9	2.3	1523
4	11	0.73	0.39	0.3	10	8.6	1759
5	20	1.0	0.4	0.4	10	8.1	1310
6	31-35	0.6	0.3	0.1	10	8.9	2026
7	38	0.2	0.3	0.003	10	9.4	1073

Uncontrolled dust sources

A breakdown of the estimated PM_{10} dust emissions for the stages was assessed, which found that the greatest single source of dust emissions is from haul trucks. The haul trucks are estimated to account for up to 62 per cent of production related PM_{10} emissions (maximum occurring in stage 1).

Dust emissions from haul trucks can be minimised using various control techniques (discussed in subsequent sections), however, emissions from dumping waste rock have no controls. Only unquantifiable operational controls can be applied to waste rock dumping. These operational controls include gentle dumping of overburden on the waste rock dumps.

Uncontrolled wind erosion

Uncontrolled PM_{10} dust emissions from exposed areas due to wind erosion was found to account for approximately 10 per cent of the total dust emissions from the mine, during all stages of its life. As wind erosion has the potential to be the second largest individual dust source, implementing appropriate and effective control measures is important.

Passive controls for pit retention can be applied, which equates to a 5 per cent reduction for PM_{10} generated sources inside of any pit, as per NPI (NPI 2012) emission estimation guidelines.

3.5.2 Particle size distribution

In order to model dust deposition, which is based on emission rates of TSP, the particle size distribution must be specified. The model algorithms then simulate the fall velocities, with the coarser particles settling out from the dust plume at shorter distances and under higher wind speeds than the finer fractions. There are nominally three sources of dust from the site. These sources are from unprocessed/stockpiled ore, process ores and wind erosion from exposed surface areas.

To give a representative pattern of dust deposition from the site, three particle size distributions for TSP were applied, as shown in Table 8. These distributions are based on US EPA references, as shown in Table 8.

TSP was only modelled up to a size of 50 µm. This is based on two factors, 1) large particles fall out close to the source and are therefore unlikely to cause an impact beyond the mine site boundary; and 2) TSP is defined under Queensland air quality regulations for the purpose of assessing air quality as having a mean EAD of *not more than 50 microns* (Air EPP 2008, p.11).

Table 8 Particle size distributions of modelled TSP

Range (µm)	Mean Size (µm)	Unprocessed Ore (a) Mass Fraction	Processed Ore (b) Mass Fraction	Wind Erosion (c) Mass Fraction
0 to 2.5	1.25	0.15	0.16	0.08
2.5 to 6.0	4.25	0.19	0.21	0.27*
6.0 to 10	8.0	0.17	0.25	0.16*
10 to 50	30	0.49	0.38	0.50
Total		1.00	1.00	1.00

US EPA Document EPA-450/4-86-013 July 1986, Table 3-2, p.22.
US EPA Document EPA-450/4-86-013 July 1986, p.A-7.
US EPA AP-42 Industrial Wind Erosion, Chapter 13.2.5, Equation 2.
* Distribution derived from unprocessed ore distribution.

3.6 Dust control

3.6.1 Overview

Control techniques have been assumed and modelled for each of the sources identified at each stage of the mine operations. Some processes have no controls, while other dust sources can be reduced through the application of various measures including full enclosures if required.

3.6.2 Control techniques

A summary of the controls applied for the air emissions modelling are provided in Table 9.

Of the identified control measures, these have been applied and used to calculate emissions before and after application. A maximum 74 per cent reduction in emissions from production activities was found to be achievable with the application of the control measures as summarised in Table 10. The control measure is further discussed in this section.

Table 9 Summary of applied controls (including pit retention)

Activity	Applied Controls	Percentage Reduction (%)
Graders	Moist soil	50
Excavators/shovels on overburden	None	0
Loading ore to trucks by shovel	None	0
Bulldozers on overburden	None	0
Unpaved haul roads	75% for level 2 watering (> 2 litres/m2/h)	75
Blasting	None	0
Trucks dumping overburden	None	0
Loading primary crusher	Water Sprays	50
Wind erosion from stockpiles	Water sprays	50
Wind erosion (Active areas)	None	0
Pit Retention	-	50 % for TSP, 5 % for PM10

Table 10 Summary of PM_{10} dust emissions with maximum controls applied

Stage	Uncontrolled Production Emissions (tonne/y)	Controlled Production Emissions (tonne/y)	Percentage Reduction (%)
1	1511	420	72
2	1629	469	71
3	1524	422	72
4	1760	515	71
5	1310	409	69
6	2027	530	74
7	1073	340	68

Pit retention factors

Pit retention control factors have been included. This type of control is considered a passive control, in that it acts due to the surrounding environment and does not have to be actively applied.

NPI (2012) default pit retention factors are applied to all pit emissions based on the following reduction factors:

- TSP – 50 per cent pit reduction
- PM_{10} – 5 per cent pit reduction.

Pit retention factors were applied to all dust sources, including wind erosion, from within any operational pit. This includes 50 per cent of the TSP emissions from the following sources:

- Haul roads
- Bulldozers on overburden
- Graders.

Haul roads

As haul roads have been identified as being responsible for approximately 60 per cent of dust emissions due to active production, special attention has been applied to controlling these emissions. Level 2 watering, as described in NPI (2011) as greater than 2 litre/m^2/h was applied to reduce dust levels for the maximum emissions phase of the Mine. Additionally, the Client has identified the use of a road binding material which is able to achieve an 80% reduction.

Wind erosion

No controls have been applied to wind erosion from active pits and the large areas of the waste dumps.

3.7 Best practice dust control

The following best practice dust control measures should be employed, where practical:

- Disturb only the minimum area necessary for mining
- Reshape topsoil and rehabilitate completed waste rock dumps as soon as practicable
- Revegetate long term stockpiles not regularly used
- Clearly define edges of haul roads and designated paths on waste rock dumps
- Revegetate dis-used haul roads
- Minimise hauling distance
- Set appropriate vehicle speed limits
- Limit the number of minor roads
- Assess meteorological conditions prior to any blasting and delay (if possible) during periods of higher wind speeds.

3.8 Summary of emissions

A summary of the modelled emission rates for each of the source types is provided in Table 11 for Stage 1 only while all of the remaining scenario stages are in Appendix A. All emissions are ‘as modelled’, and as such include all control measures and pit retention factors, e.g. TSP emissions from pit sources have been halved as 50 per cent of emissions do not escape the pit. Therefore, the emissions inventory is a summary of the emissions which will impact on the predicted GLCs and dust deposition.

Modelled emissions rates from area sources – pits and waste dumps – were evenly distributed around the modelled active source for each scenario.

A total of 24 individual sources were used in the Ausplume modelling to represent the emissions from the mine.

Table 11 Modelled emissions rates with full controls applied (including pit retention) for stage 1

Location	Activity	Activity Data	Units	Total TSP Emissions (kg/y)	Total PM_{10} Emissions (kg/y)
TOTALS					
Open Cut Mine	Excavators/shovels on overburden (extracting)	4,850,000	tonne/y	7748	3664
	Loading into truck	4,850,000	tonne/y	7748	3664
	Blasting	52	blasts/y	1880	974
	Bulldozers on overburden	26,280	veh.h	226,342	47,273
	Graders	5,840	VKT	3	1
ROM Pads	Trucks loading ROM ore stockpiles	450,000	tonne/y	719	340
Haul Roads	Unpaved haul roads		VKT	436,173	186,140
	In-pit:	61,538		220,001	62,409
	Out-of-pit:	55,827			
ROM	Primary crushing	450,000	tonne/y	45,000	4,500
Transfer Points	ore conveyor	450,000	tonne/y	719	340
Waste Dump	Trucks dumping overburden -ROM	450,000	tonne/y	5,400	1,917
	Trucks dumping overburden - Dumps	4,400,000	tonne/y	52,800	18,744
Wind Erosion	All Sources	226	ha	180,246	90,123
TOTAL				1,184,779	420,090

3.9 Model inputs - processing (RE) operations

3.9.1 Sulphuric acid plant

Emissions of SO_2 can be estimated using two methods which are described below.

Method 1

Using the sulphur feed rate of 11.7 t/hr and multiplying by the molar mass ratio of sulfur dioxide and sulfur (64/32=2) then multiplying by the efficiency of the catalytic absorber (99.7%) gives an SO_2 emission rate of 19.5 g/s.

Method 2

A sulphur feed rate of 11.7 t/hr equates to 19.8 m^3/hr of acid being produced at 1.82 t/m^3. This results in 36 tonnes/hr of acid being produced.

As specified by US government regulation in 40 CFR 60 Subpart H 60.82, best practice for a single contact acid plant is an emission rate of 2 kg/metric tonne of sulphur dioxide is allowed as tail emissions. This requires 72 kg/hr (20 g/s) of sulphur dioxide being emitted as a maximum for this sized acid plant.

GHD has modelled 20 g/s as the SO_2 emission rate for the sulphuric acid plant.

The following specifications were used in the model:

- Exhaust temperature of 82^o Celsius
- Exhaust gas flow of 15 m/s.

In addition to this, the dimensions of the stack have been assumed to be:

- 1.36 metres internal diameter (so as achieve the above flow rate)
- 20 metres height.

A sensitivity analysis was performed for the acid plant stack so as to identify the optimum lowest stack height that achieves the regulated GLC criterion.

3.9.2 Power generation

Three gas turbines of 5 MW capacity each were assumed as a conservative estimate for this assessment to represent the 12.5 MW loading required for the plant. The estimated emissions are listed in Table 12 below.

Table 12 Estimated emissions for natural gas fired plant

	NPI emission estimate	Scaled factor (per generator)
NO_2	1.4E+05 uncontrolled kg/PJ	0.38 (NO_2:NOx ratio of 30%)
CO	3.5E+04 uncontrolled kg/PJ	2.66

The following specifications were used in the model:

- Exhaust temperature of 400 ^{o} Celsius
- Exhaust gas flow of 31 m/s.

In addition to this, the dimensions of the stack have been assumed to be:

- 0.6 metres internal diameter (to achieve the above flow rate)
- 12.5 metres height.

Combining the three flues into a single ‘stack’ is common as this generates additional plume rise. However, the model has assumed three standalone gas engines with individual stacks but all emitting from the one point). Either configuration will achieve the GLC’s as modelled.

4. Impact modelling

To assess the impact of the mine operations on the environment, the emissions from section 3 were used as input for the seven discrete ‘nominal year’ mine scenarios and RE Plant stack sources. The AUSPLUME dispersion model used these inputs with utilisation of the meteorology, from section 2.3, as a fixed year.

Gridded receptor locations were utilised around each of the respective sources to define the spatial impact pattern and to identify the worst-case maximum impact at ground level (either as ground levels concentrations, GLC’s, or dust deposition).

4.1 Mine

4.1.1 PM_{10}

Appendix B provides the daily PM_{10} impact contours for each modelled scenario as the 99.9 percentile (Figures B1 to B7). These can be directly compared to the 60 µg/m^3 assessment criterion of Table 1.

All pit stage scenarios modelled show an impacted area beyond the mine boundary to the north that extends for 2-4 kilometres; but this is across near-mine areas that are devoid of human-related sensitive receptor locations. All other criterion isolines in other directions are generally contained within the mine boundary. Sensitive receptor locations such as the Accommodation Village, Aileron/ Alyuen and (potentially) Annas Reservoir are well outside the assessment criterion contour. The modelling therefore indicates that human health impacts from mining dust is within acceptable levels.

4.1.2 Total suspended dust

Appendix B provides the annual average TSP impact contours (Figures B8 to B14) for each modelled scenario (average for all 8760 hours of 2014). These can be directly compared to the 90 µg/m^3 assessment criterion of Table 1.

All pit stage scenarios modelled generally show an impacted area contained within the mine boundary and also well within the PM_{10} daily impact. Stages 2 and 4 have marginal extensions of the assessment criterion beyond the northern boundary of the mine operations. This is due to the use of waste dump 1 being adjacent to the mine boundary and the prevailing south-east quadrant winds for the year. No sensitive receptor location will be adversely impacted.

4.1.3 Dust deposition

Annualised dust deposition impact contours for each modelled scenario are provided in Appendix B (Figures B15 to B21). These can be directly compared to the 2 g/m^2/month incremental assessment criterion of Table 1. All pit stage scenarios modelled, except stages 5 and 7, show an impacted area just beyond the mine boundary to the north that, however, does not extend as far as the daily PM_{10} impact. Once again, all of these are across near-mine areas that are devoid of sensitive receptors. All other criterion isolines in other directions are generally contained within the mine boundary with the notable exception of on the western boundary when waste rock dump 3 is in use (‘nominal year’ stages of 5 and 6).

4.2 Acid plant

The Acid Plant has been assessed for SO_2 emissions and GLC’s only – as this is the major component in the tail gas exiting the stack. Appendix B provides the SO_2 1-hour maximum, as the 99.9 percentile, GLC contours (Figure B22) and the annual average impact contours (Figure

B23). The 1-hour impacts are in the near-field of 2-4 kilometres to the south-west and south while the annual average reflects the prevailing annual wind pattern with maximum impacts to the north-west. The stack height was optimised so that the 1-hour criterion of 450 µg/m^3 was not exceeded. At the nearest sensitive receptor location of the Accommodation Village the assessed impacts are well within the assessment criteria.

4.3 Power plant

The Power Plant has been assessed for CO and NO_2 as a gas fired power plant burns 'cleaner' than for other (solid/liquid) fuels such as coal or diesel. It is universally found that the NO_2 constraint is the pollutant closest to any assessment criterion when the fuel type is natural gas. Appendix B provides the CO and NO_2 1-hour maximums, as the 99.9 percentile, GLC contours (Figures B24 and Figure B25, respectively) and the annual average NO_2 impact contours (Figures B26). As expected, the same pattern as for SO_2 of hourly impacts to the south-west and west with annual impacts to the north-west ensues. In this instance, all of the criteria are at least an order of magnitude below the respective criteria. There is no need to optimise the stack height as a standard 12.5 m high stack is able to achieve the air quality regulated levels. Note that the impact of the Power Plant exhaust gases is very low at the Accommodation Village.

5. Discussion

5.1 Summary of impact

Key risk pathways associated with air quality have been identified in the risk register for the project (Appendix F). These are discussed below, noting that the key impacts associated with mining dust moving and depositing away from sources, and the gaseous emissions from significant plant (acid and Power) are the highest ranked risks. The lower ranked risk pathways were not quantitatively modelled.

- Vegetation clearing and site establishment mobilising dust
- Haulage and transport of material within the Project area, along haul roads within the mine site, and along access tracks; and general site movements over unsealed surfaces resulting in generation and dispersion of particulate or dust (TSP)
- Wind erosion mobilising dust from exposed surfaces, such as from pits, waste dumps, tailings and residue storage facilities, laydown areas, stockpiles, roads and sites of vegetation clearing
- Drilling, blasting, excavation and materials handling at the Mine Site during operations results in dispersion of particulates and dust from the Mine Site
- Operation of concentrator (comminution and beneficiation circuits) at the Mine Site, resulting in dispersion of particulate, gas or dust.
- Operation of RE processing units, sulfuric acid plant and gas fired generators at the Processing Site results in dispersion of emissions
- Vehicle emissions and heavy equipment emissions results in impacts to air quality.

The operation of RE processing units (acid Plant and Power Plant) that produce significant amounts of gaseous pollutants have been shown to be well within compliance limits.

As expected, and identified in the risk register, the downwind dispersion of dust has the greatest impact when considering the assessment criteria. As usual for large scale open–pit mining, it is the dust-in-air concentrations rather than the amenity impact of dust deposition that are above nominal compliance limits for greater distances. However, due to the lack of sensitive human receptor locations within the impact zones the environmental impact can be considered to be acceptable.

As dust has the greatest potential risk pathway to the air quality values surrounding the mining operations, an audit check on the modelled assessment is recommended. A dust monitoring regime is discussed in the next section.

Best practice dust control measure have been provided in section 3.7 together with commitments already made by Arafura Resources.

5.2 Dust monitoring

As a dust management tool during the operational phases of the Mine, ambient air quality and dust deposition monitors can be installed to quantify the actual dust impacts near the Mine from the Mine operations.

A system of monitors can be installed in which up-wind dust deposition gauges measure background dust levels, while down-wind gauges are able to quantify the impact from mine operations. Such a system will require at least two gauges (preferably more) with an on-site meteorological monitoring station to determine local wind conditions at the time of any high dust event. When considering the locations of air monitoring equipment, sensitive receptors and distance to mining activities should be taken into consideration. For the nearest sensitive receptor location, albeit in a predominately upwind location at the Accommodation Village, a real-time dust-in-air monitor is recommended for the first five years of mine operation.

A properly equipped and resourced dust monitoring network, combined with more accurate mine operations data would provide an opportunity to evaluate emissions estimates and dispersion model predictions.

5.3 Conclusion

It has been demonstrated that air quality impacts are mostly low-risk for the proposed operations. However, for the highest risks associated with down-wind dust there are audit measure available to confirm that mining operations have minimal and acceptable impacts on the environment.

Appendices

Appendix A - Modelled Emissions Rates

Table 1 Modelled Emissions Rates with Full Controls Applied (Including Pit Retention) for Stage 2

Location	Activity	Activity Data	Units	Total TSP Emissions (kg/y)	Total PM_{10} Emissions (kg/y)
TOTALS					
Open Cut Mine	Excavators/shovels on overburden (extracting)	4,850,000	tonne/y	7764	3672
	Loading into truck	4,850,000	tonne/y	7764	3672
	Blasting	52	blasts/y	1880	974
	Bulldozers on overburden	26,280	veh.h	226,342	47,273
	Graders	5,840	VKT	3	1
ROM Pads	Trucks loading ROM ore stockpiles	450,000	tonne/y	3291	1556
Haul Roads	Unpaved haul roads In-pit: Out-of-pit:	61,538 55,827	VKT	602,246 318,294	170,842 90,292
ROM	Primary crushing	450,000	tonne/y	206,000	20,600
Transfer Points	ore conveyor	450,000	tonne/y	3291	1556
Waste Dump	Trucks dumping overburden -ROM	450,000	tonne/y	24,720	24,720
	Trucks dumping overburden - Dumps	4,400,000	tonne/y	33,600	11,928
Wind Erosion	All Sources	226	ha	184,323	92,162
TOTAL				1,619,516	469,249

Table 2 Modelled Emissions Rates with Full Controls Applied (Including Pit Retention) for Stage 3

Location	Activity	Activity Data	Units	Total TSP Emissions (kg/y)	Total PM_{10} Emissions (kg/y)
TOTALS					
Open Cut Mine	Excavators/shovels on overburden (extracting)	4,850,000	tonne/y	4872	2304
	Loading into truck	4,850,000	tonne/y	4872	2304
	Blasting	52	blasts/y	1880	974
	Bulldozers on overburden	26,280	veh.h	226,342	47,273
	Graders	5,840	VKT	3	1
ROM Pads	Trucks loading ROM ore stockpiles	450,000	tonne/y	1198	567
Haul Roads	Unpaved haul roads In-pit: Out-of-pit:	61,538 55,827	VKT	634,385 247,902	179,960 70,324
ROM	Primary crushing	450,000	tonne/y	75,000	7500
Transfer Points	ore conveyor	450,000	tonne/y	1198	567
Waste Dump	Trucks dumping overburden -ROM	450,000	tonne/y	9000	9000
	Trucks dumping overburden - Dumps	4,400,000	tonne/y	27,600	9798
Wind Erosion	All Sources	226	ha	182,138	91,069
TOTAL				1,416,391	421,641

Table 3 Modelled Emissions Rates with Full Controls Applied (Including Pit Retention) for Stage 4

Location	Activity	Activity Data	Units	Total TSP Emissions (kg/y)	Total PM_{10} Emissions (kg/y)
TOTALS					
Open Cut Mine	Excavators/shovels on overburden (extracting)	4,850,000	tonne/y	15,815	7480
	Loading into truck	4,850,000	tonne/y	15,815	7480
	Blasting	52	blasts/y	1880	974
	Bulldozers on overburden	26,280	veh.h	226,342	47,273
	Graders	5,840	VKT	3	1
ROM Pads	Trucks loading ROM ore stockpiles	450,000	tonne/y	2268	1073
Haul Roads	Unpaved haul roads In-pit: Out-of-pit:	61,538 55,827	VKT	616,471 377,679	174,878 107,138
ROM	Primary crushing	450,000	tonne/y	142,000	14,200
Transfer Points	ore conveyor	450,000	tonne/y	2268	1073
Waste Dump	Trucks dumping overburden -ROM	450,000	tonne/y	17,040	17,040
	Trucks dumping overburden - Dumps	4,400,000	tonne/y	103,200	36,636
Wind Erosion	All Sources	226	ha	199,989	99,994
TOTAL				1,720,769	515,240

Table 4 Modelled Emissions Rates with Full Controls Applied (Including Pit Retention) for Stage 5

Location	Activity	Activity Data	Units	Total TSP Emissions (kg/y)	Total PM_{10} Emissions (kg/y)
TOTALS					
Open Cut Mine	Excavators/shovels on overburden (extracting)	4,850,000	tonne/y	15,819	7482
	Loading into truck	4,850,000	tonne/y	15,819	7482
	Blasting	52	blasts/y	1880	974
	Bulldozers on overburden	26,280	veh.h	226,342	47,273
	Graders	5,840	VKT	3	1
ROM Pads	Trucks loading ROM ore stockpiles	450,000	tonne/y	2875	1360
Haul Roads	Unpaved haul roads In-pit: Out-of-pit:	61,538 55,827	VKT	531,993 186,914	150,913 53,023
ROM	Primary crushing	450,000	tonne/y	180,000	18,000
Transfer Points	ore conveyor	450,000	tonne/y	2875	1360
Waste Dump	Trucks dumping overburden -ROM	450,000	tonne/y	21,600	21,600
	Trucks dumping overburden - Dumps	4,400,000	tonne/y	97,200	34,506
Wind Erosion	All Sources	226	ha	130,134	65,067
TOTAL				1,413,456	409,042

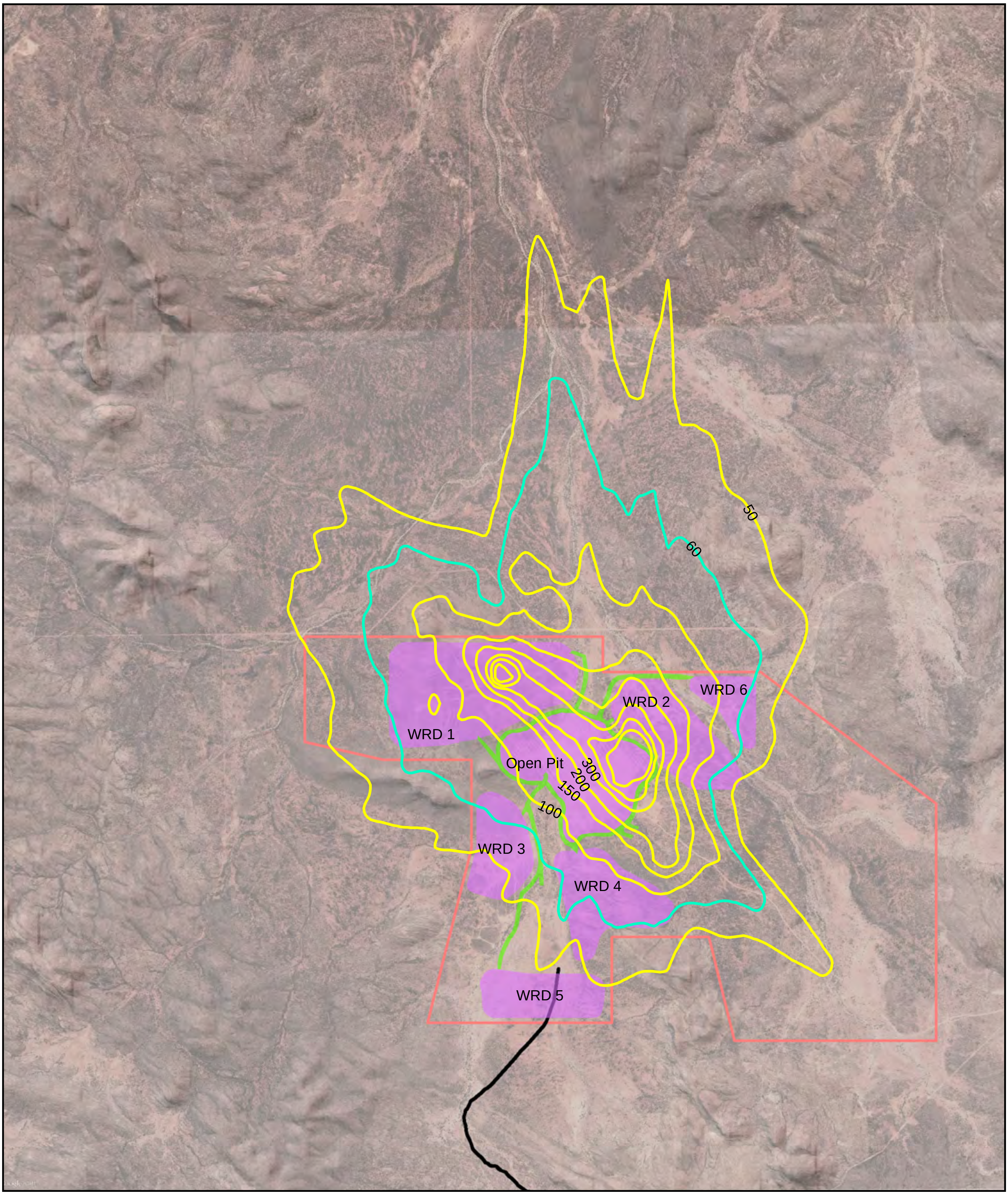
Table 5 Modelled Emissions Rates with Full Controls Applied (Including Pit Retention) for Stage 6

Location	Activity	Activity Data	Units	Total TSP Emissions (kg/y)	Total PM_{10} Emissions (kg/y)
TOTALS					
Open Cut Mine	Excavators/shovels on overburden (extracting)	4,850,000	tonne/y	15,815	7480
	Loading into truck	4,850,000	tonne/y	15,815	7480
	Blasting	52	blasts/y	1880	974
	Bulldozers on overburden	26,280	veh.h	226,342	47,273
	Graders	5,840	VKT	3	1
ROM Pads	Trucks loading ROM ore stockpiles	450,000	tonne/y	1597	756
Haul Roads	Unpaved haul roads In-pit: Out-of-pit:	61,538 55,827	VKT	876,565 392,125	248,660 111,236
ROM	Primary crushing	450,000	tonne/y	100,000	10,000
Transfer Points	ore conveyor	450,000	tonne/y	1597	756
Waste Dump	Trucks dumping overburden -ROM	450,000	tonne/y	12,000	12,000
	Trucks dumping overburden - Dumps	4,400,000	tonne/y	106,800	37,914
Wind Erosion	All Sources	226	ha	89,987	44,994
TOTAL				1,840,526	529,523

Table 6 Modelled Emissions Rates with Full Controls Applied (Including Pit Retention) for Stage 7

Location	Activity	Activity Data	Units	Total TSP Emissions (kg/y)	Total PM_{10} Emissions (kg/y)
TOTALS					
Open Cut Mine	Excavators/shovels on overburden (extracting)	4,850,000	tonne/y	15,819	7482
	Loading into truck	4,850,000	tonne/y	15,819	7482
	Blasting	52	blasts/y	1880	974
	Bulldozers on overburden	26,280	veh.h	226,342	47,273
	Graders	5,840	VKT	3	1
ROM Pads	Trucks loading ROM ore stockpiles	450,000	tonne/y	804	380
Haul Roads	Unpaved haul roads In-pit: Out-of-pit:	61,538 55,827	VKT	419,091 168,166	118,886 47,704
ROM	Primary crushing	450,000	tonne/y	50,300	5030
Transfer Points	ore conveyor	450,000	tonne/y	804	380
Waste Dump	Trucks dumping overburden -ROM	450,000	tonne/y	6036	6036
	Trucks dumping overburden - Dumps	4,400,000	tonne/y	112,800	40,044
Wind Erosion	All Sources	226	ha	117,449	58,724
TOTAL				1,135,312	340,398

Appendix B - Impact Contour Plots



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 60 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:60,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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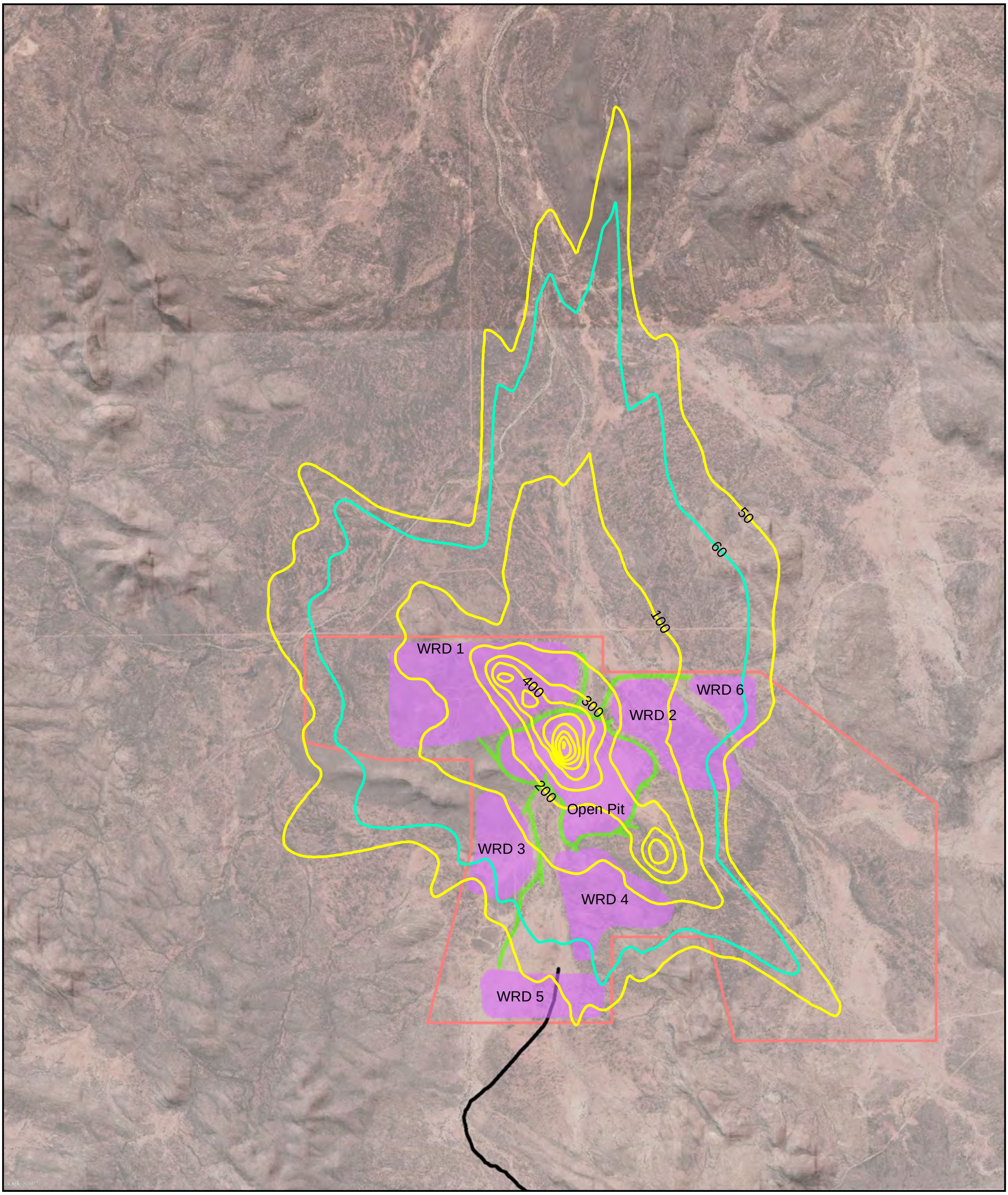
Stage 1 PM10 Concentration (ug/m^3) 24 Hour Average

Figure B1

G:\43\22301\GIS\Maps\4322301_701_Stage1_PM10_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg³
- Criterion 60 ug/mg³
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:60,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Date	22 Mar 2016

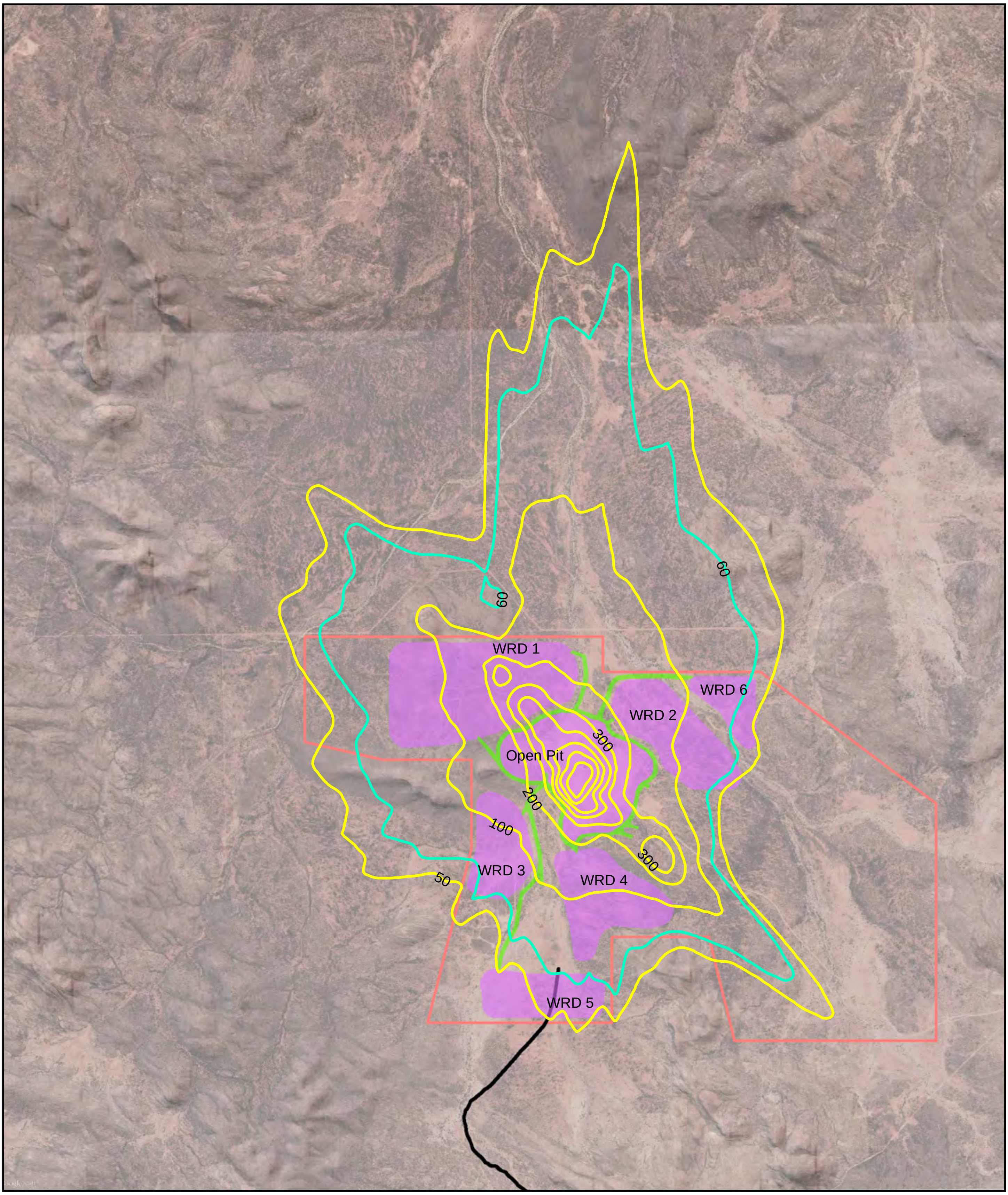
Stage 2 PM10 Concentration (ug/m³)
24 Hour Average

Figure B2

G:\43\22301\GIS\Maps\4322301_702_Stage2_PM10_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 60 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:60,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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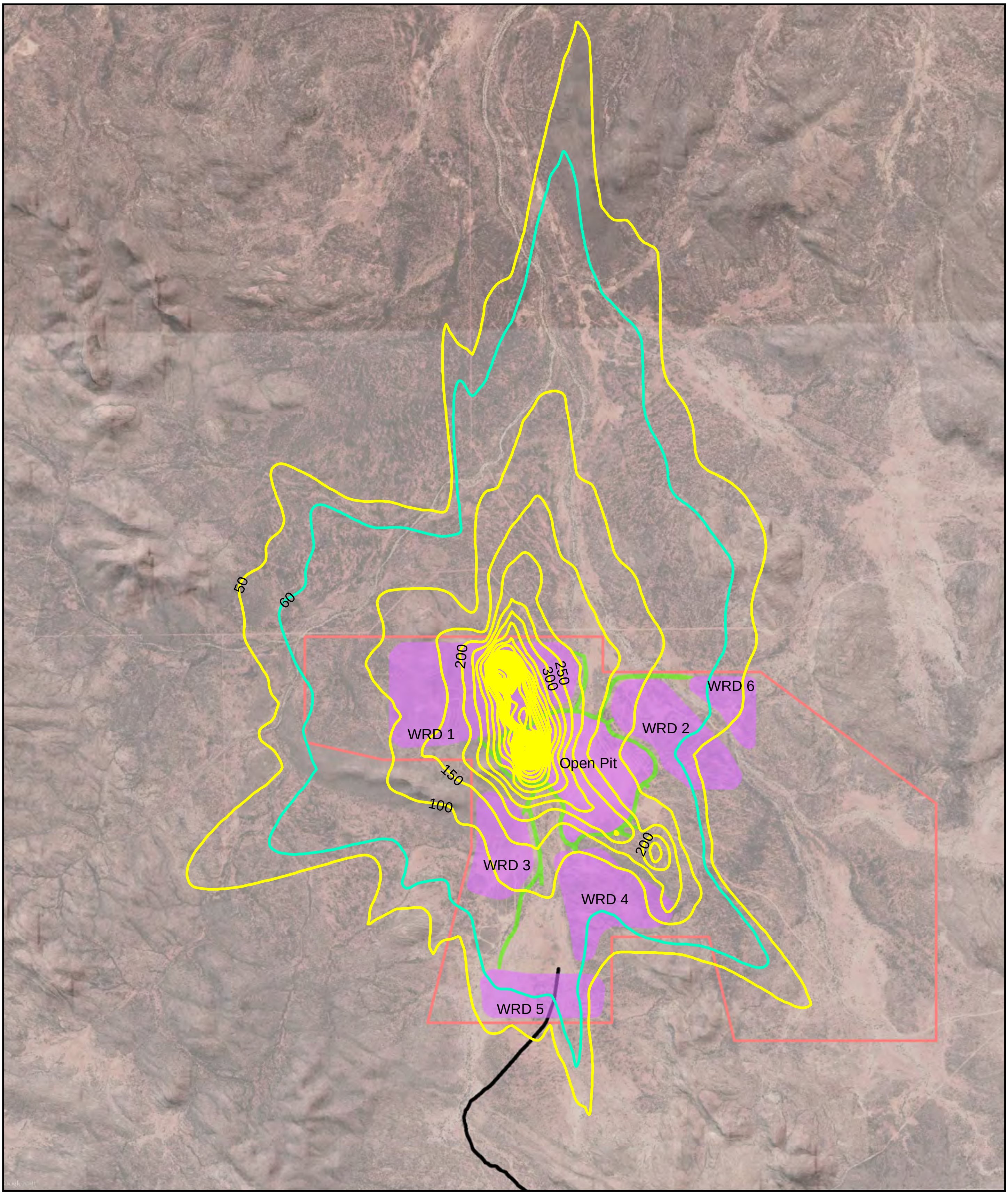
Stage 3 PM10 Concentration (ug/m^3)
24 Hour Average

Figure B3

G:\43\22301\GIS\Maps\4322301_703_Stage3_PM10_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 60 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:60,000 @ A4
0 0.5 1 1.5 2
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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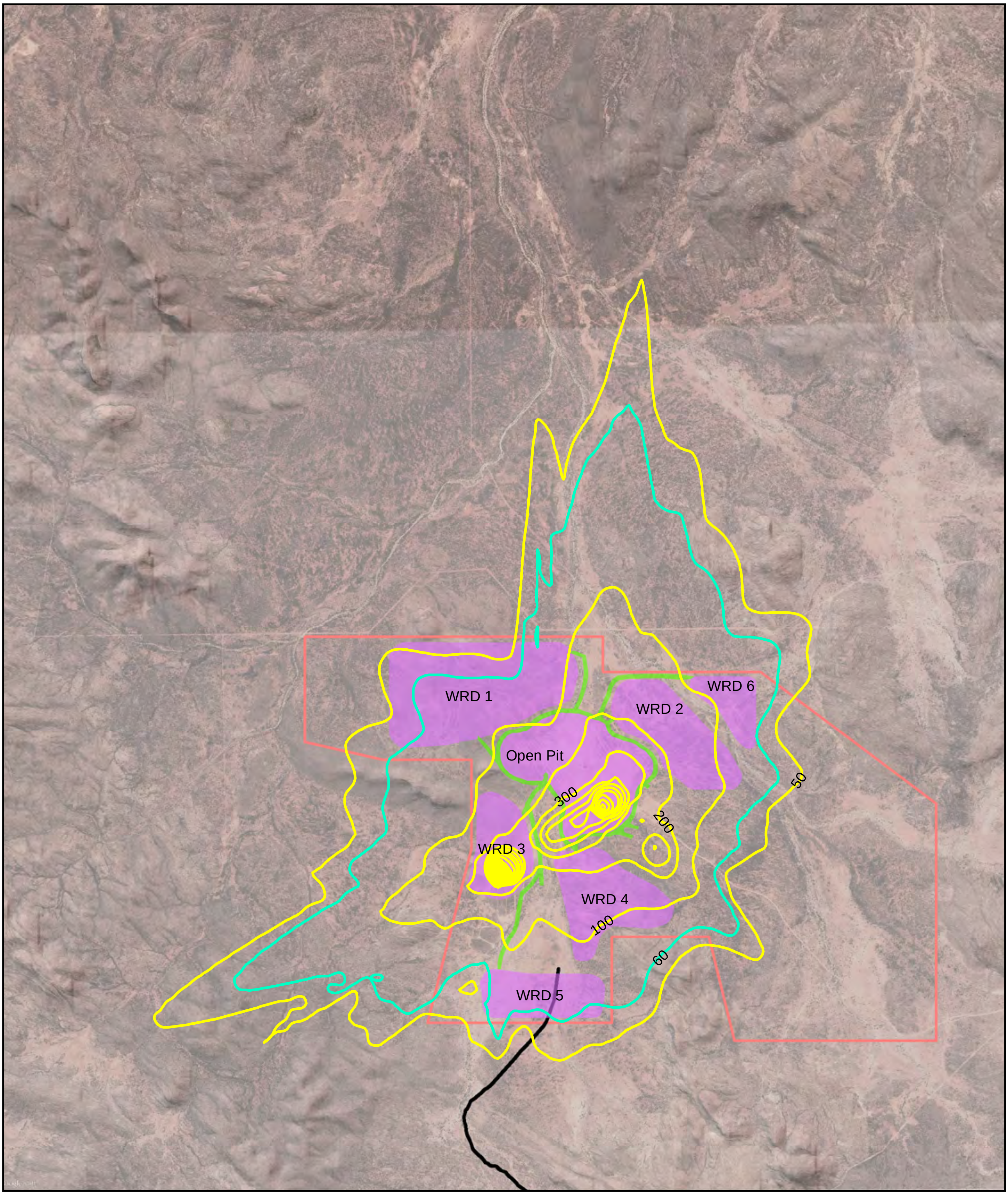
Stage 4 PM10 Concentration (ug/m^3)
24 Hour Average

Figure B4

G:\43\22301\GIS\Maps\4322301_704_Stage4_PM10_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 60 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:60,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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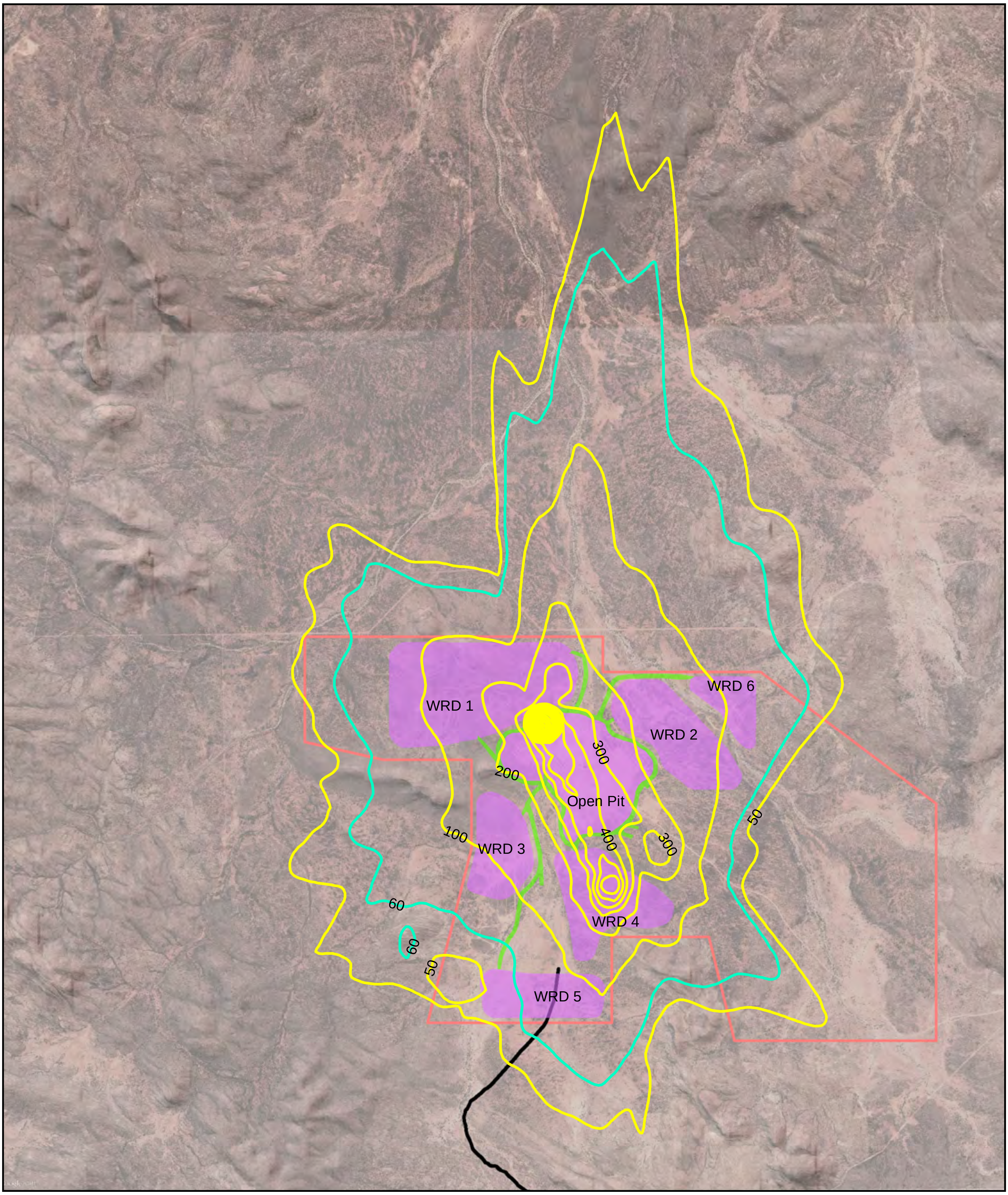
Stage 5 PM10 Concentration (ug/m^3) 24 Hour Average

Figure B5

G:\43\22301\GIS\Maps\4322301_705_Stage5_PM10_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

Access Road	Haul Roads
Concentration ug/mg^3	Dust Generation Source
Criterion 60 ug/mg^3	Mine Site Boundary

1:60,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Date	22 Mar 2016

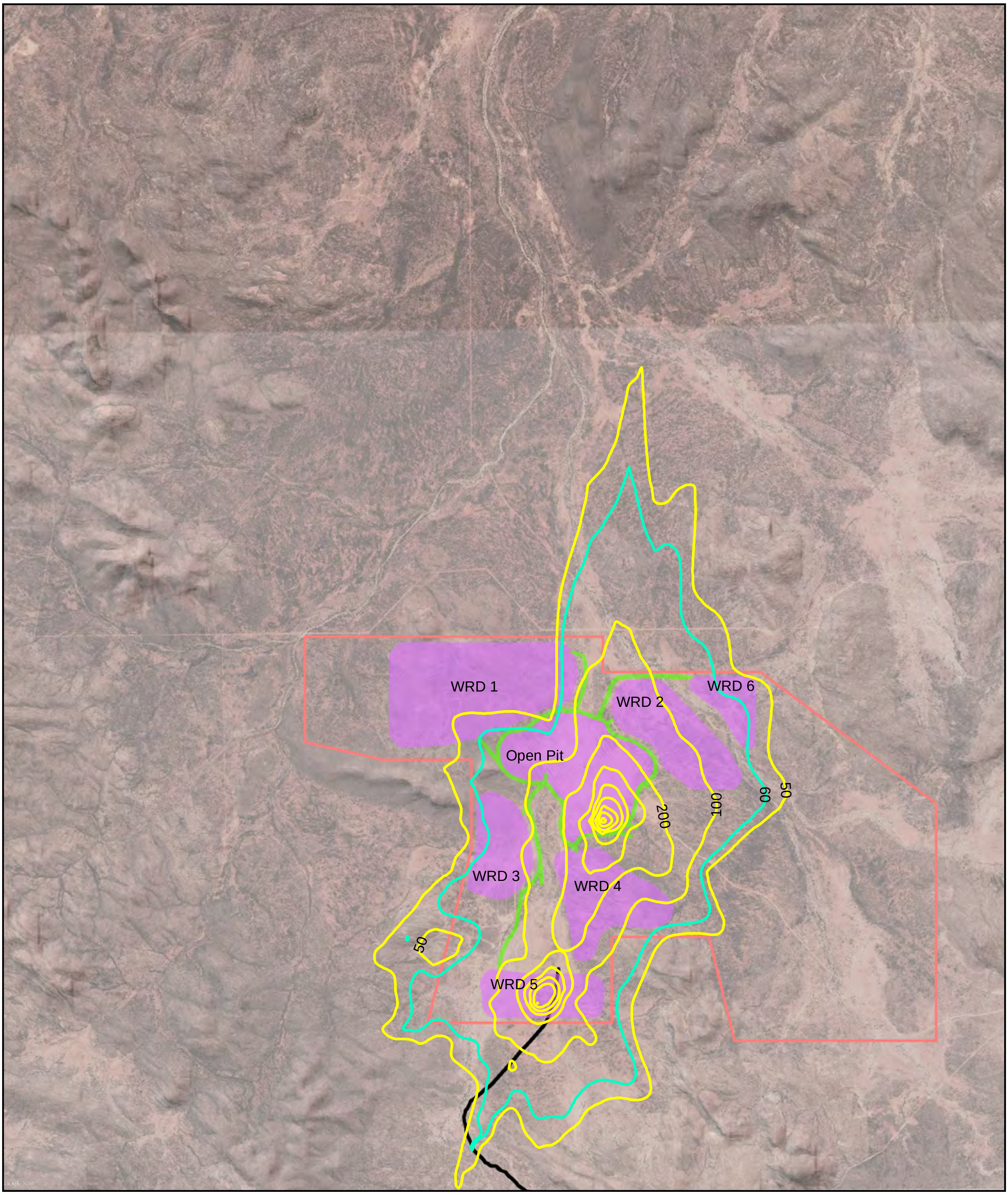
Stage 6 PM10 Concentration (ug/m^3)
24 Hour Average

Figure B6

G:\43\22301\GIS\Maps\4322301_706_Stage6_PM10_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

Access Road	Haul Roads
Concentration ug/mg^3	Dust Generation Source
Criterion 60 ug/mg^3	Mine Site Boundary

1:60,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Nolans Project

Job Number	43-22301
Revision	0
Date	22 Mar 2016

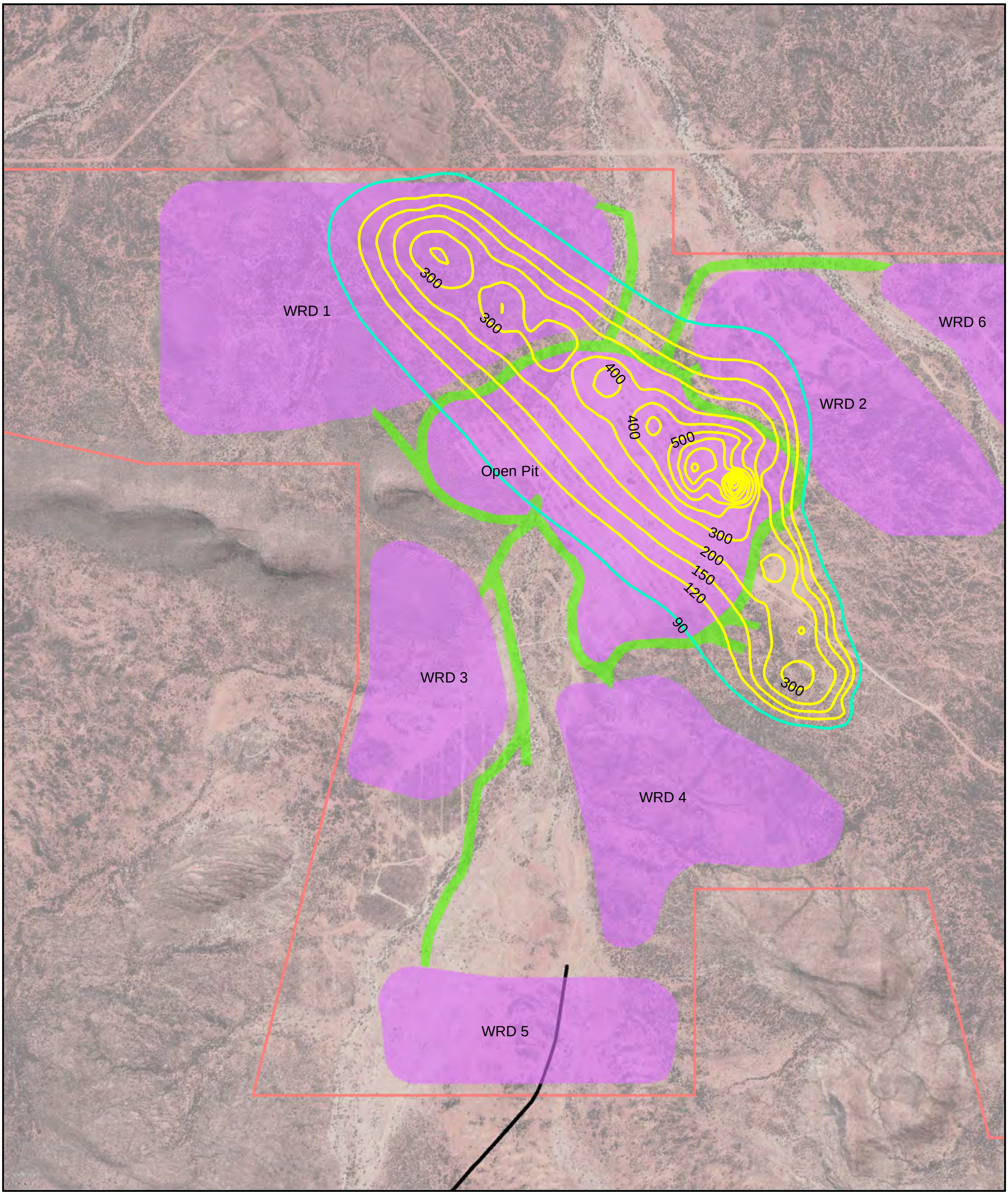
Stage 7 PM10 Concentration (ug/m^3)
24 Hour Average

Figure B7

G:\43\22301\GIS\Maps\4322301_707_Stage7_PM10_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 05/11/2015). ARL - Project Areas (2015). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 90 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:25,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

Arafura Resources Limited
Nolans Project

Job Number	43-22301
Revision	0
Date	22 Mar 2016

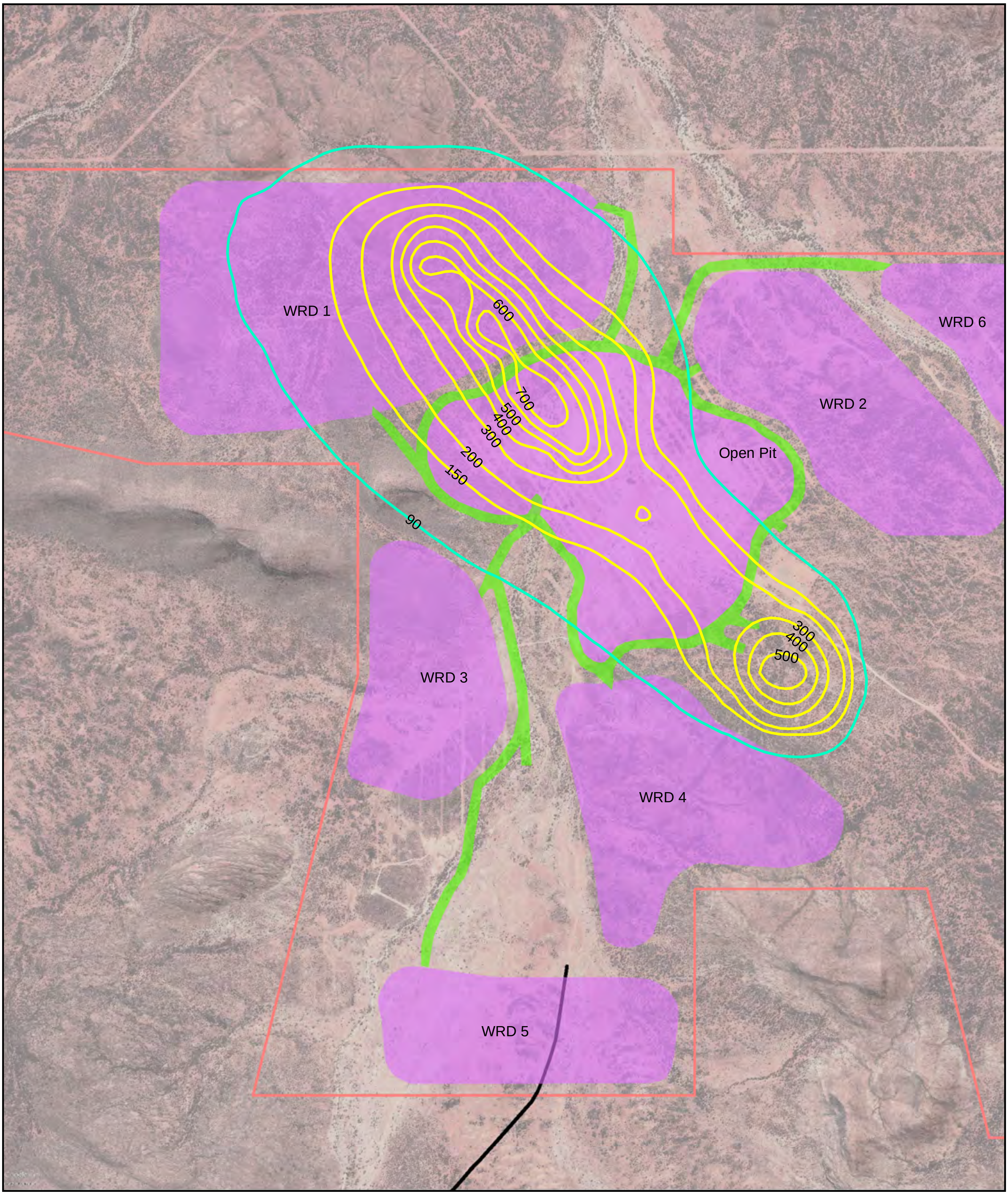
Stage 1 TSP Concentration (ug/m^3) Annual Average

Figure B8

G:\43\22301\GIS\Maps\4322301_708_Stage1_TSP_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg3
- Criterion 90 ug/mg3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:25,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number	43-22301
Revision	0
Date	22 Mar 2016

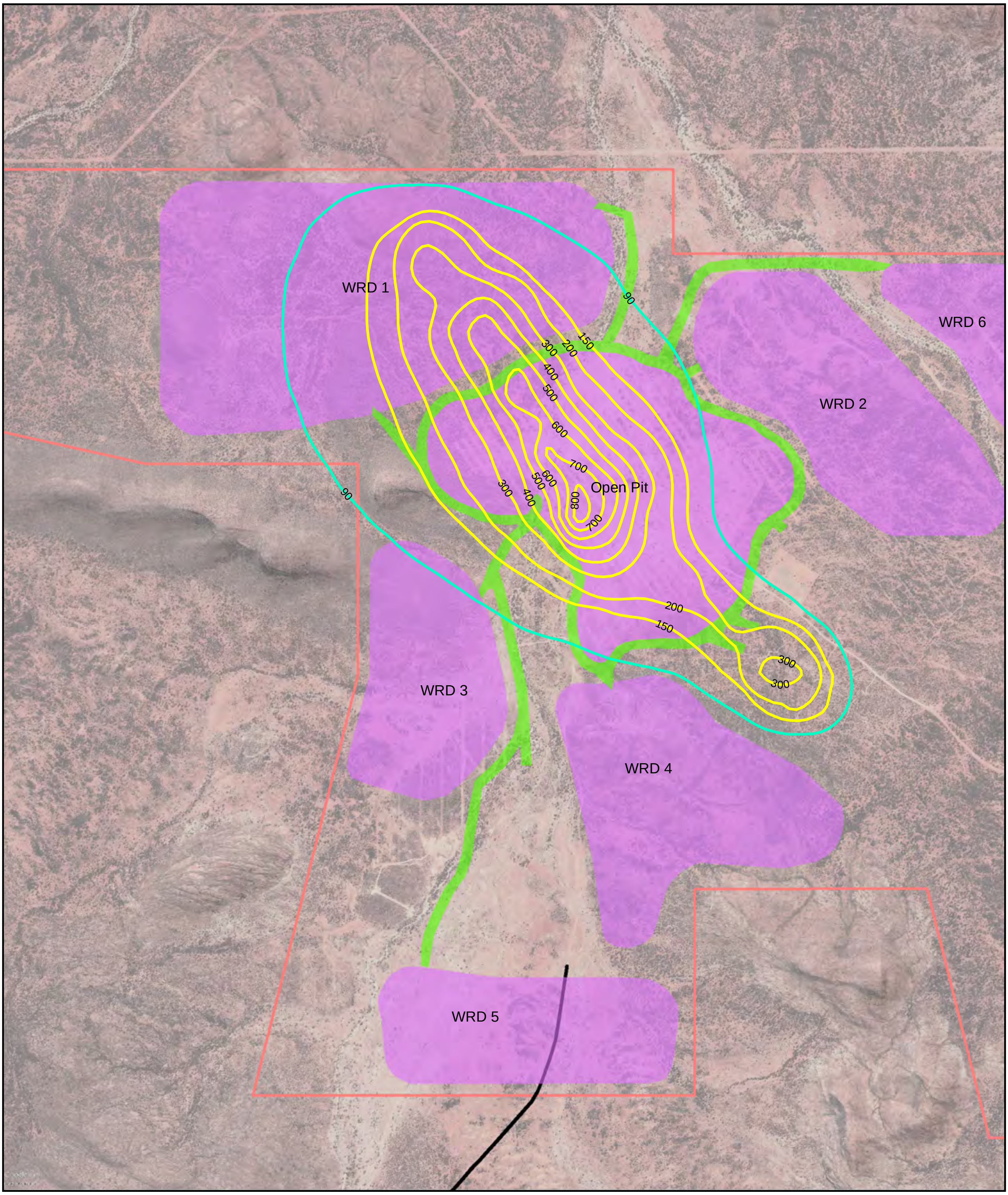
Stage 2 TSP Concentration (ug/m3) Annual Average

Figure B9

G:\43\22301\GIS\Maps\4322301_709_Stage2_TSP_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 90 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:25,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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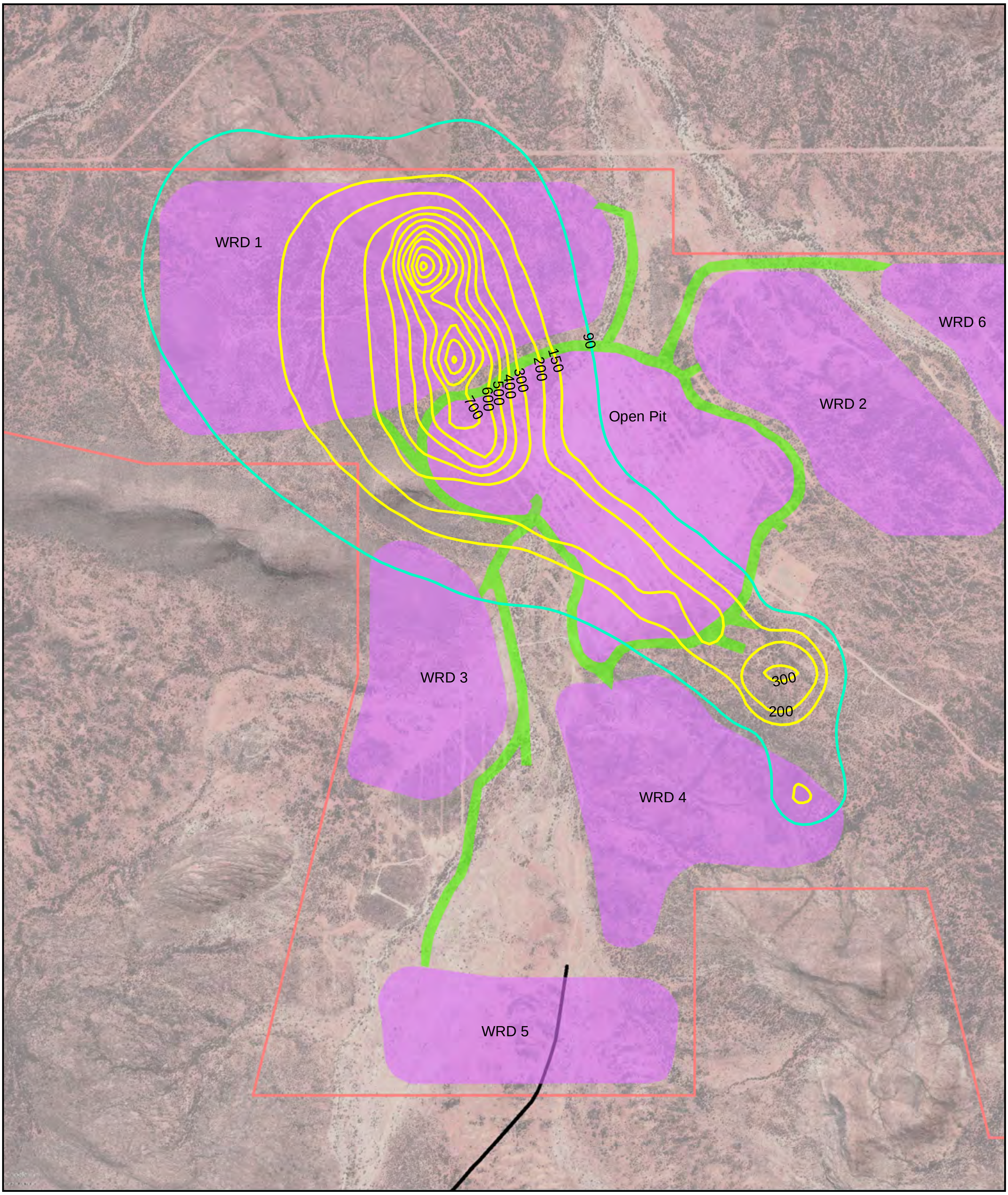
Date	22 Mar 2016

Stage 3 TSP Concentration (ug/m^3) Annual Average

Figure B10

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 90 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:25,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number 43-22301
Revision 0
Date 22 Mar 2016

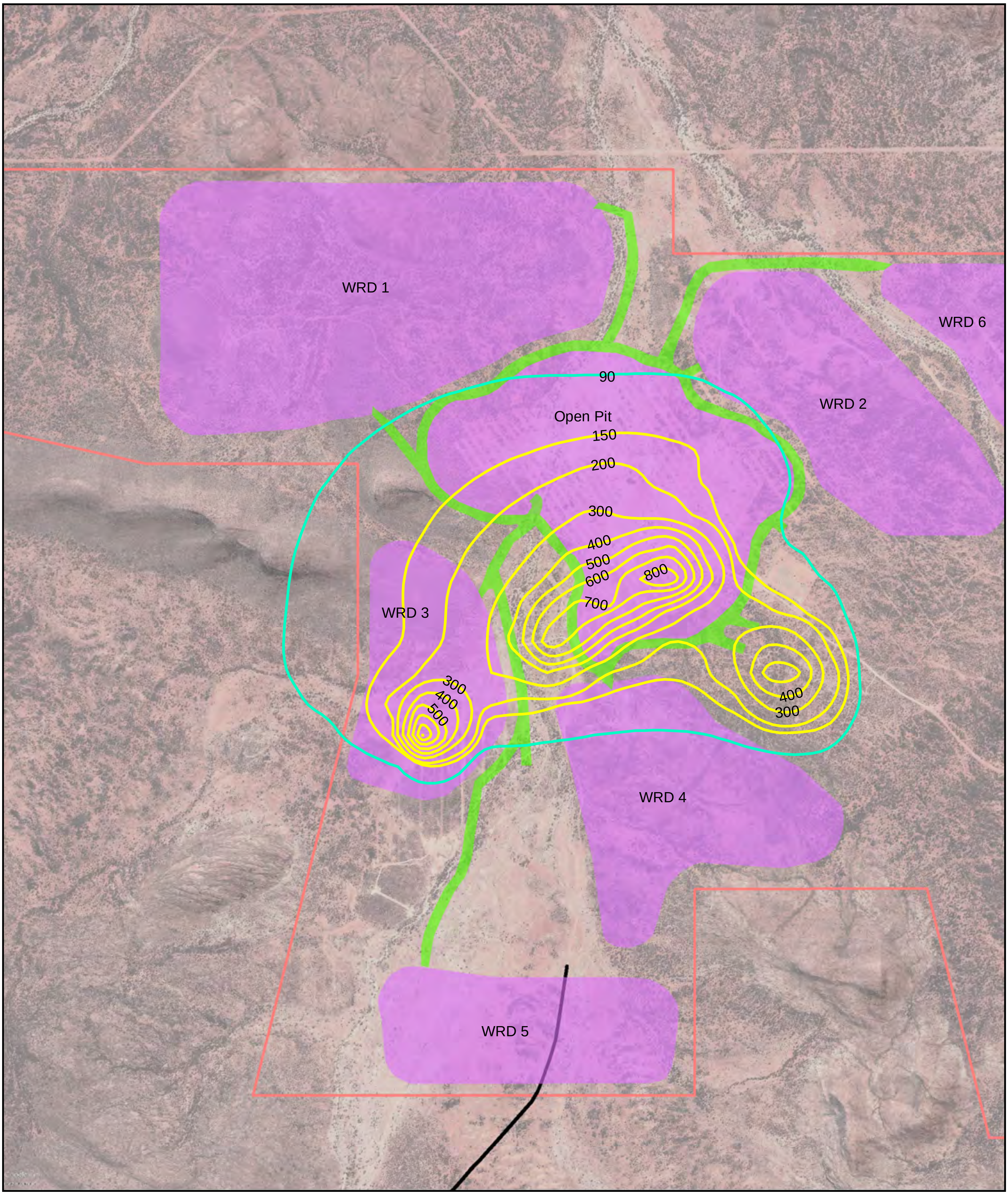
Stage 4 TSP Concentration (ug/m^3)
Annual Average

Figure B11

G:\43\22301\GIS\Maps\4322301_711_Stage4_TSP_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 90 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:25,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number	43-22301
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Date	22 Mar 2016

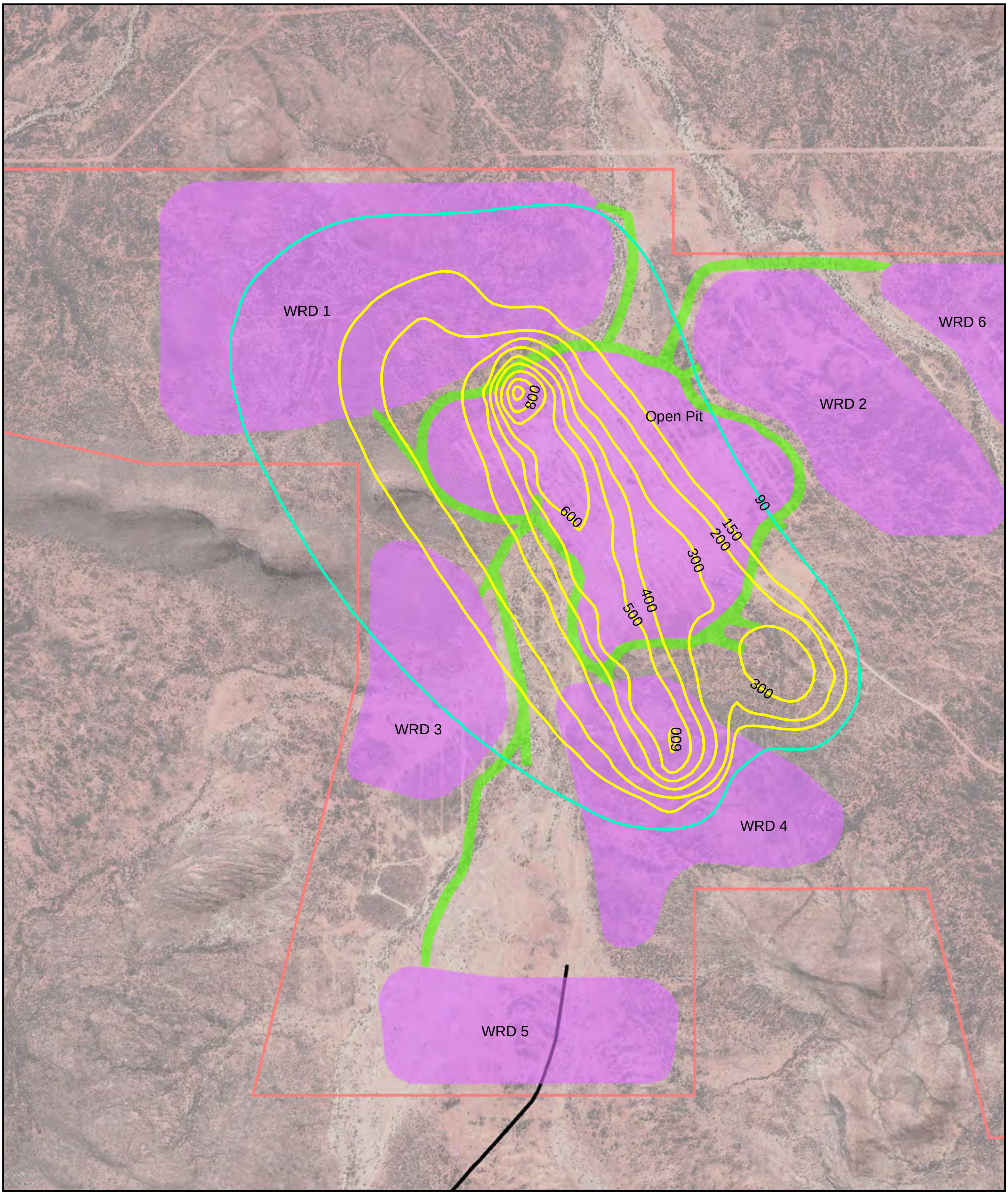
Stage 5 TSP Concentration (ug/m3) Annual Average

Figure B12

G:\43\22301\GIS\Maps\4322301_712_Stage5_TSP_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/mg^3
- Criterion 90 ug/mg^3
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:25,000 @ A4
0 250 500 750 1,000
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number	43-22301
Revision	0
Date	22 Mar 2016

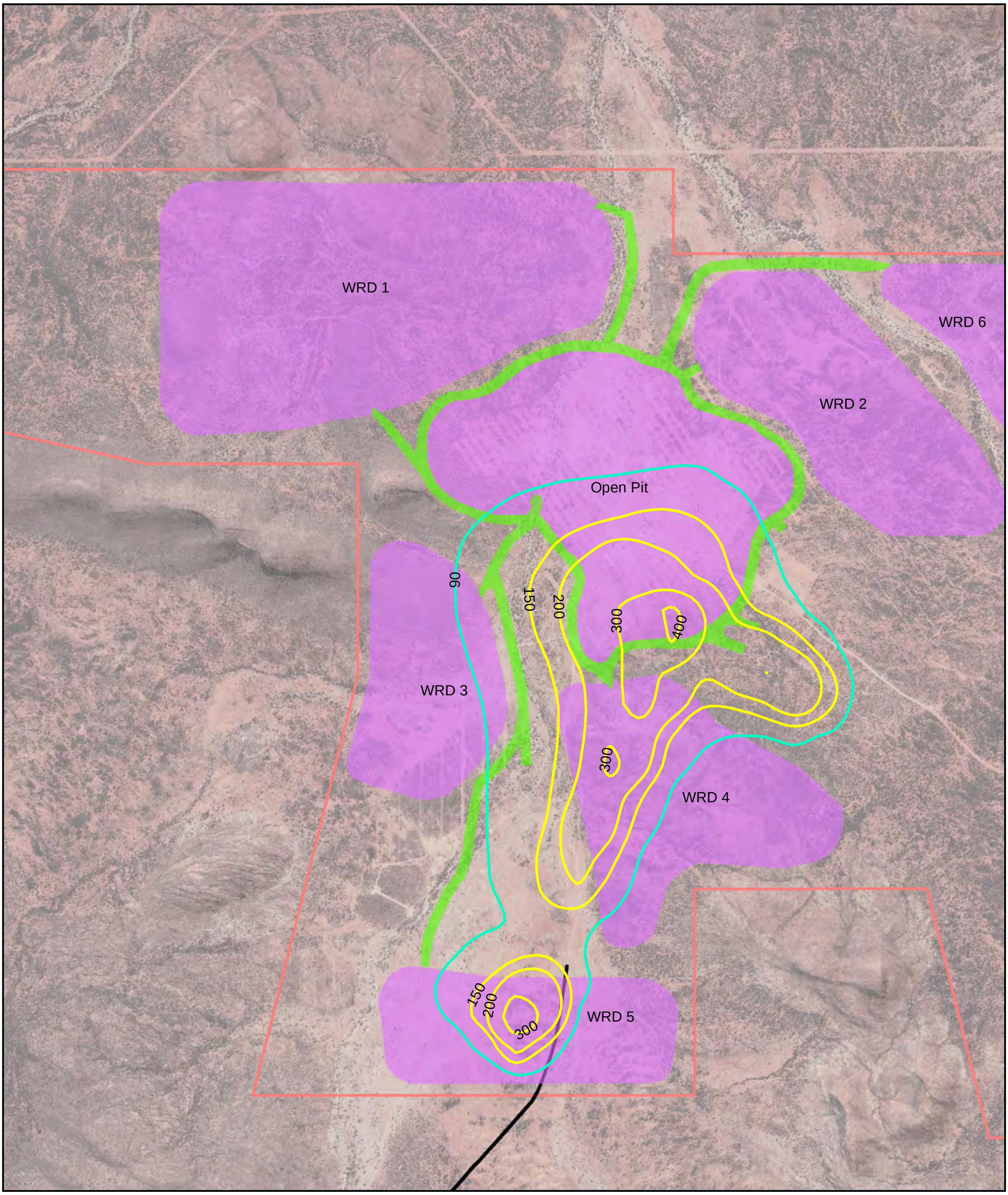
Stage 6 TSP Concentration (ug/m3) Annual Average

Figure B13

G:\43\22301\GIS\Maps\4322301_713_Stage6_TSP_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

Access Road	Haul Roads
Concentration ug/mg^3	Dust Generation Source
Criterion 90 ug/mg^3	Mine Site Boundary

1:25,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Revision 0
Date 22 Mar 2016

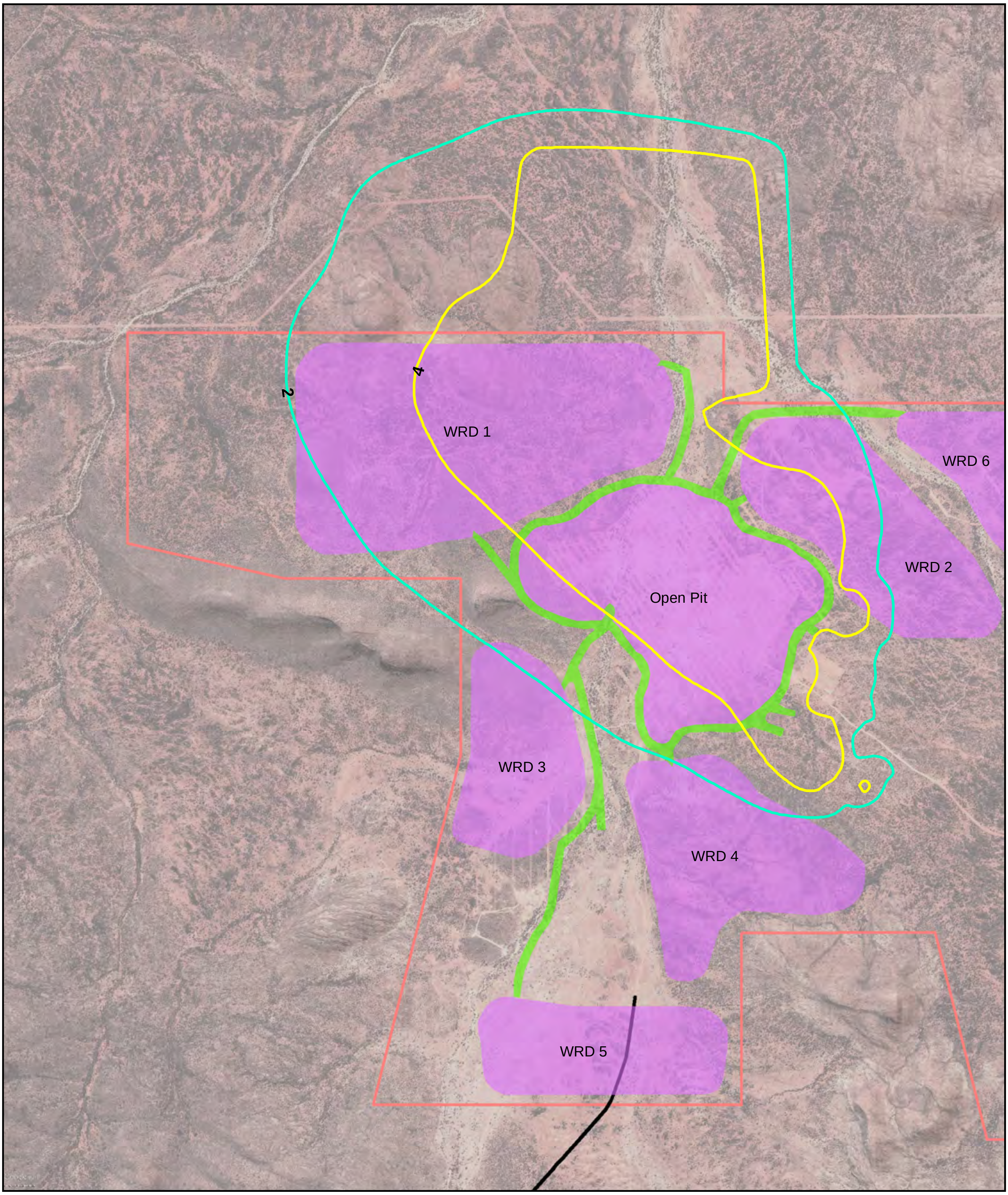
Stage 7 TSP Concentration (ug/m^3) Annual Average

Figure B14

G:\43\22301\GIS\Maps\4322301_714_Stage7_TSP_Conc.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration g/m^2/month
- Criterion 2 g/m^2/month
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:30,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number	43-22301
Revision	0
Date	22 Mar 2016

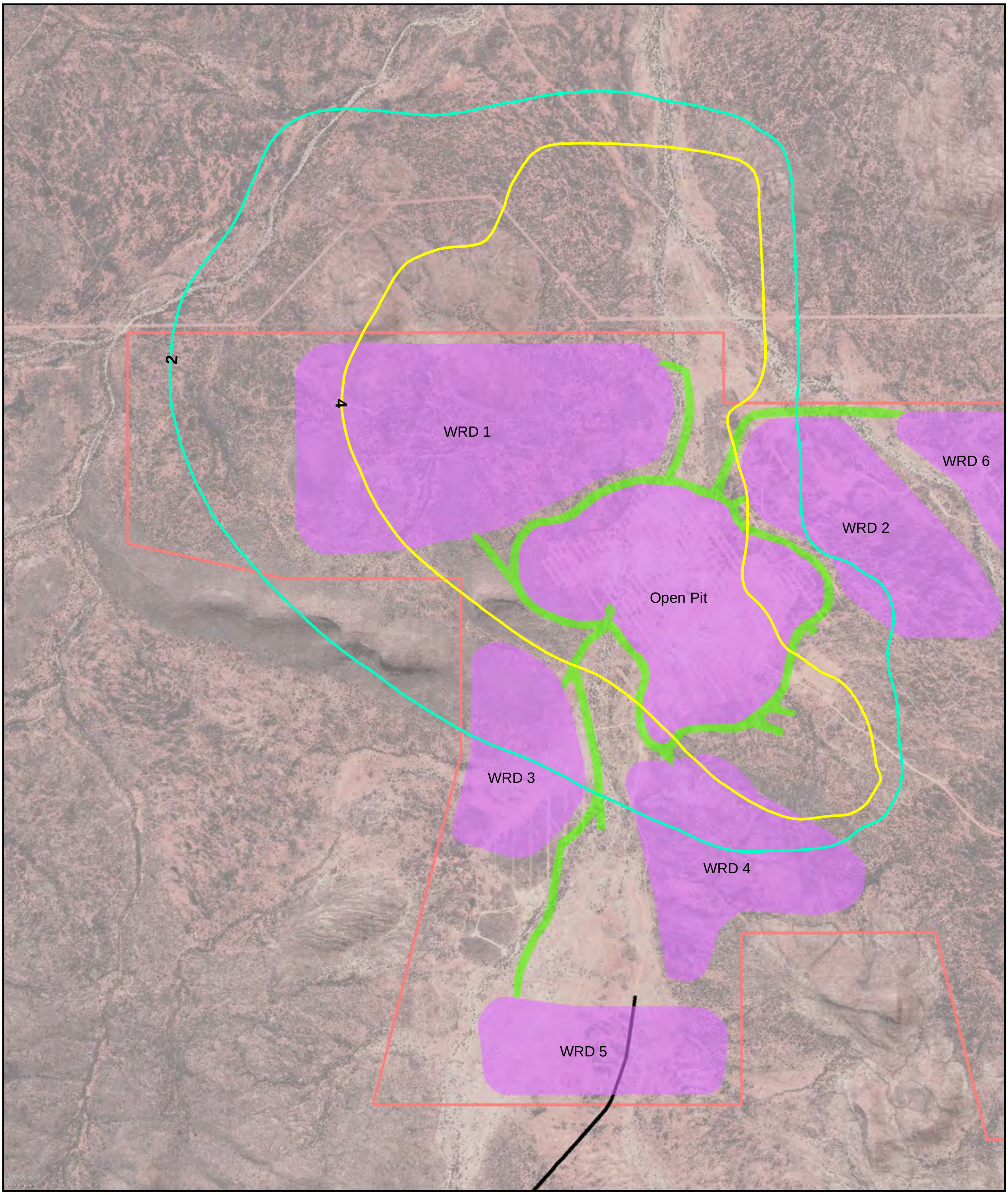
Stage 1 Dust Deposition (g/m2/month) Rolling Annual Average

Figure B15

G:\43\22301\GIS\Maps\4322301_715_Stage1_TSP_DustDepo.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

Access Road	Haul Roads
Concentration g/m²/month	Dust Generation Source
Criterion 2 g/m²/month	Mine Site Boundary

1:30,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number 43-22301
Revision 0
Date 22 Mar 2016

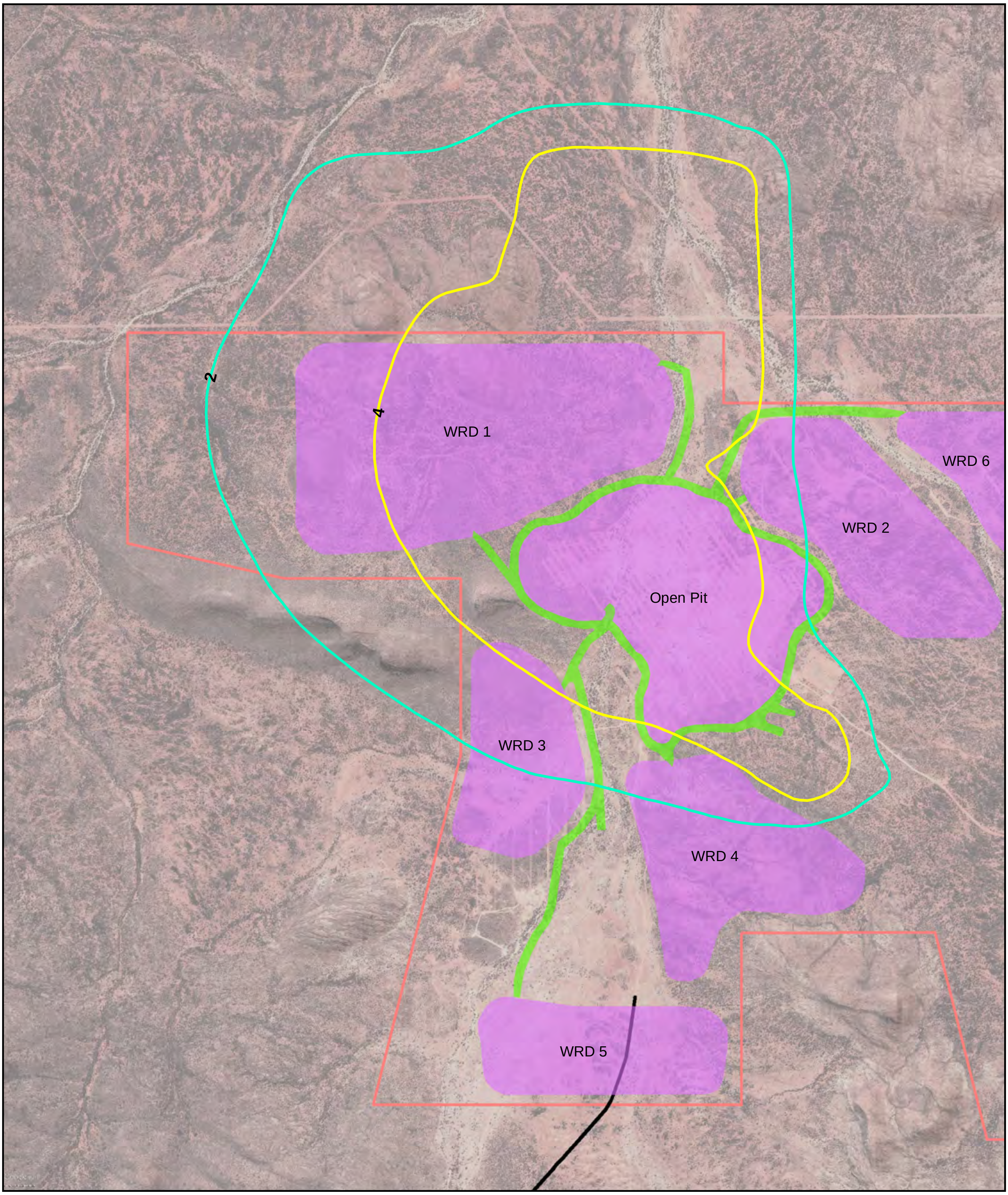
Stage 2 Dust Deposition (g/m2/month) Rolling Annual Average

Figure B16

G:\43\22301\GIS\Maps\4322301_716_Stage2_TSP_DustDepo.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

Access Road

Concentration g/m^2/month

Criterion 2 g/m^2/month

Haul Roads

Dust Generation Source

Mine Site Boundary

1:30,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Job Number	43-22301
Revision	0
Date	22 Mar 2016

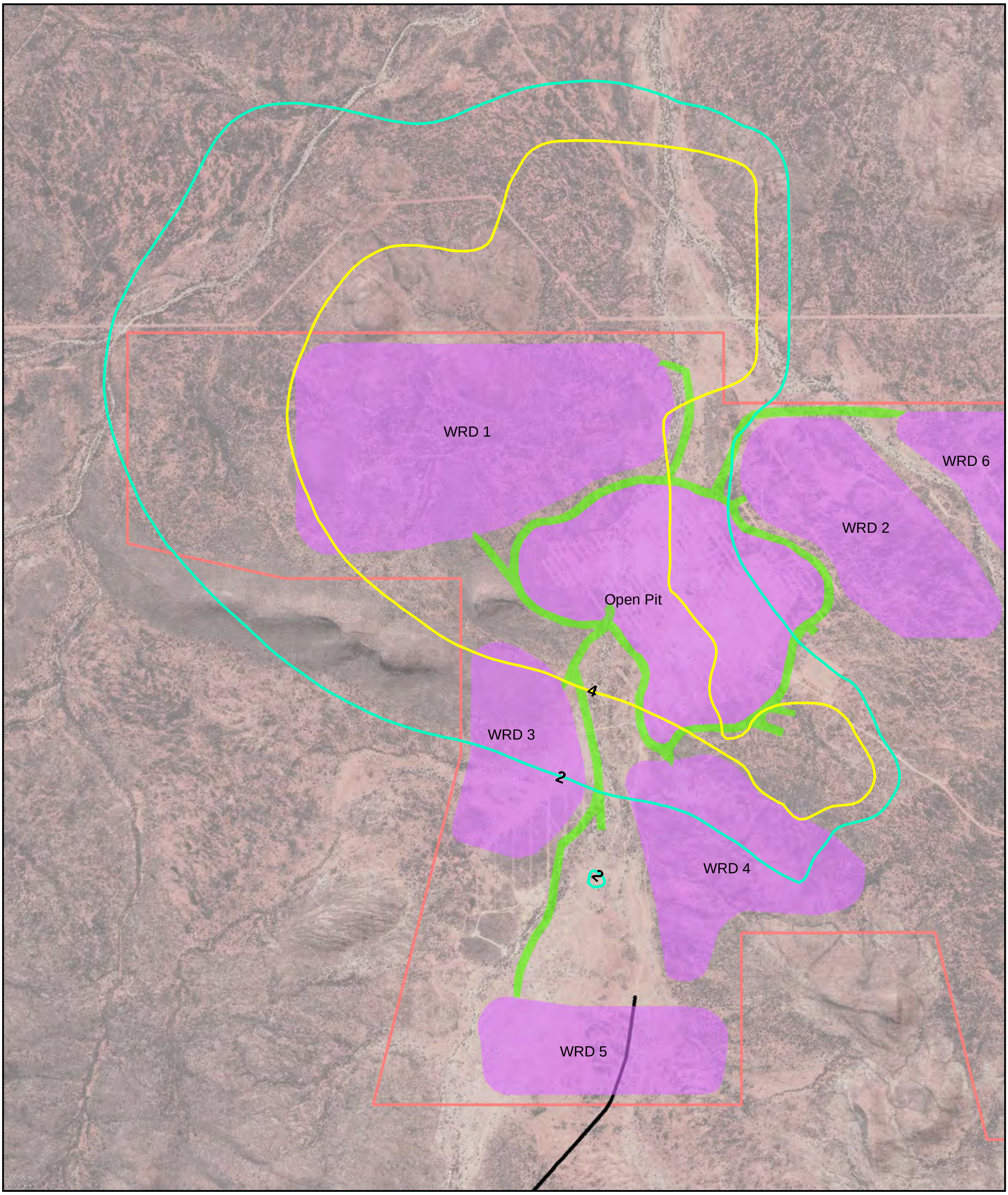
Stage 3 Dust Deposition (g/m^2/month) Rolling Annual Average

Figure B17

G:\43\22301\GIS\Maps\4322301_717_Stage3_TSP_DustDepo.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

Access Road

Concentration g/m²/month

Criterion 2 g/m²/month

Haul Roads

Dust Generation Source

Mine Site Boundary

1:30,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Job Number	43-22301
Revision	0
Date	22 Mar 2016

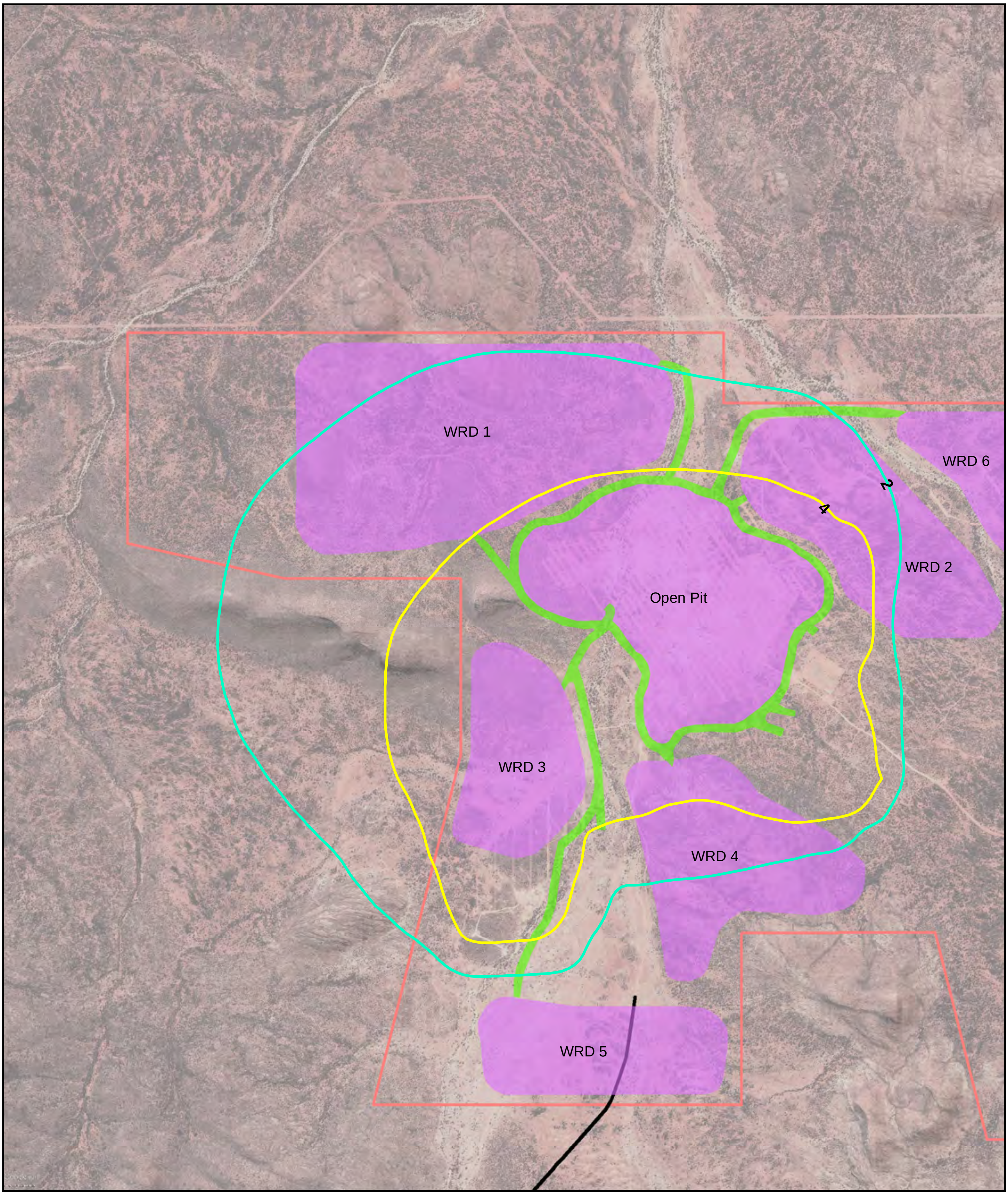
Stage 4 Dust Deposition (g/m2/month)
Rolling Annual Average

Figure B18

G:\43\22301\GIS\Maps\4322301_718_Stage4_TSP_DustDepo.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration g/m²/month
- Criterion 2 g/m²/month
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:30,000 @ A4

0 250 500 750 1,000

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number 43-22301
Revision 0
Date 22 Mar 2016

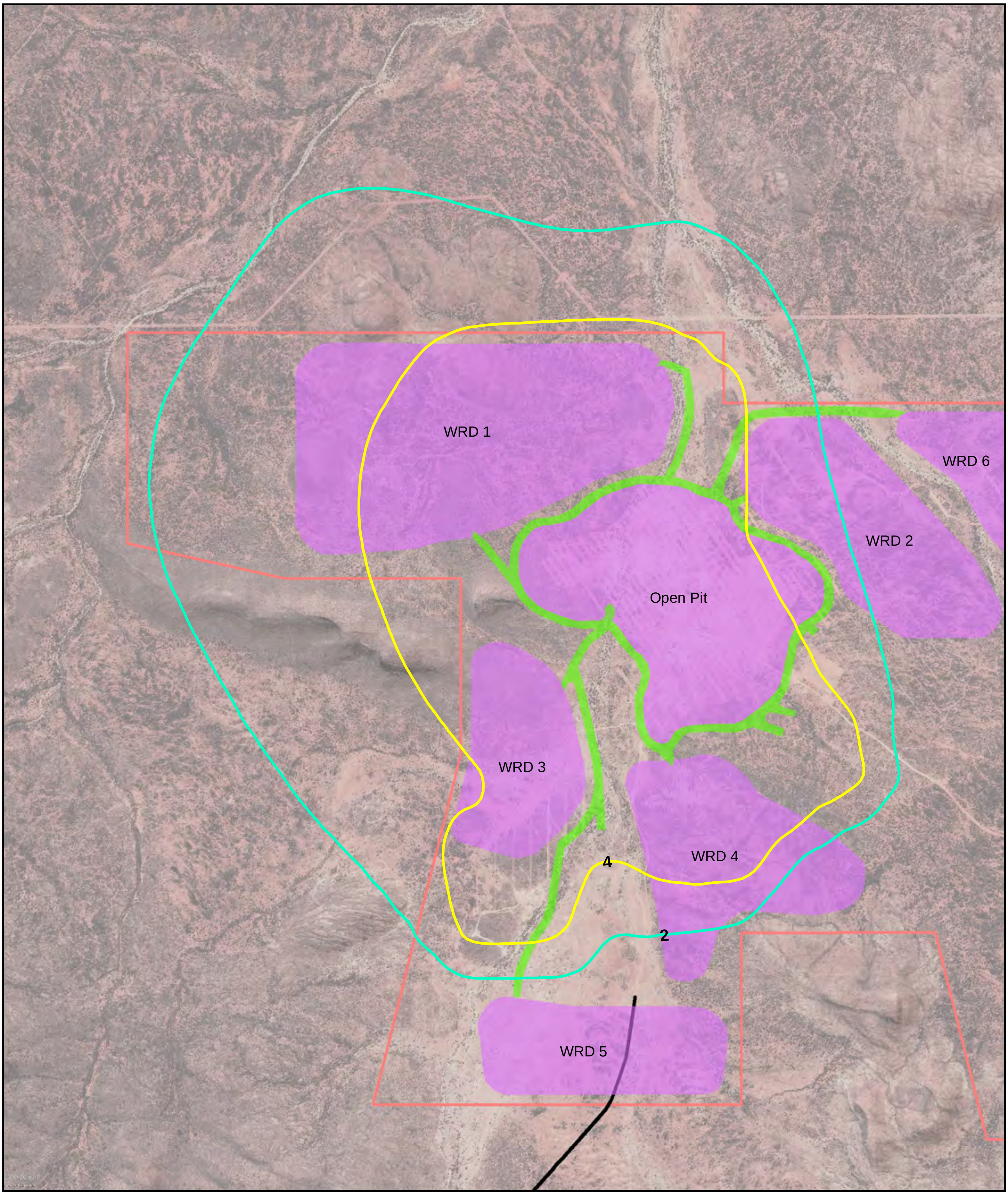
Stage 5 Dust Deposition (g/m2/month) Rolling Annual Average

Figure B19

G:\43\22301\GIS\Maps\4322301_719_Stage5_TSP_DustDepo.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

Access Road
Concentration g/m^2/month
Criterion 2 g/m^2/month
Haul Roads
Dust Generation Source
Mine Site Boundary

1:30,000 @ A4
0 250 500 750 1,000
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

N

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Job Number	43-22301
Revision	0
Date	22 Mar 2016

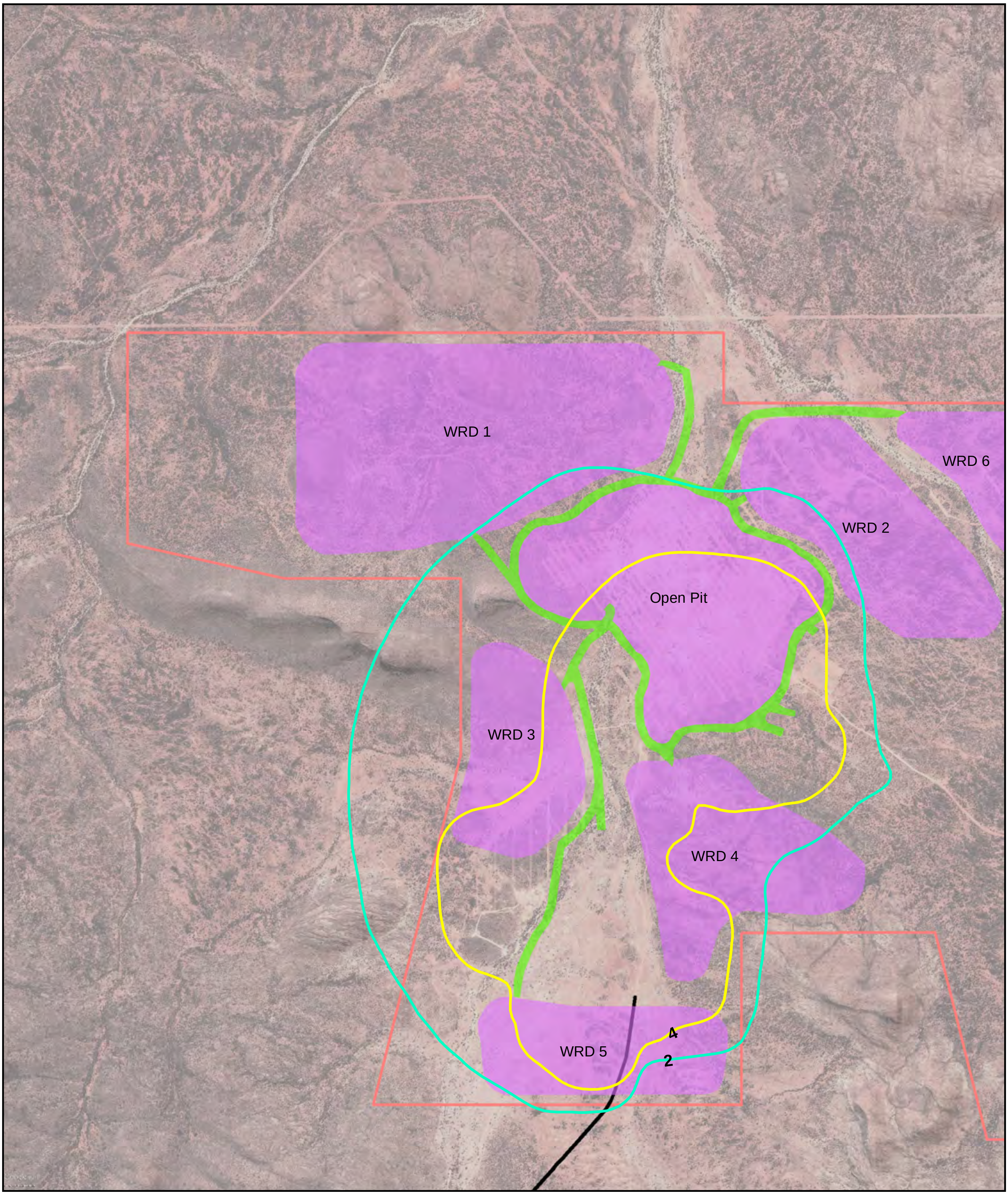
Stage 6 Dust Deposition (g/m2/month) Rolling Annual Average

Figure B20

G:\43\22301\GIS\Maps\4322301_720_Stage6_TSP_DustDepo.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration g/m^2/month
- Criterion 2 g/m^2/month
- Haul Roads
- Dust Generation Source
- Mine Site Boundary

1:30,000 @ A4
0 250 500 750 1,000
Metres
Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number	43-22301
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Date	22 Mar 2016

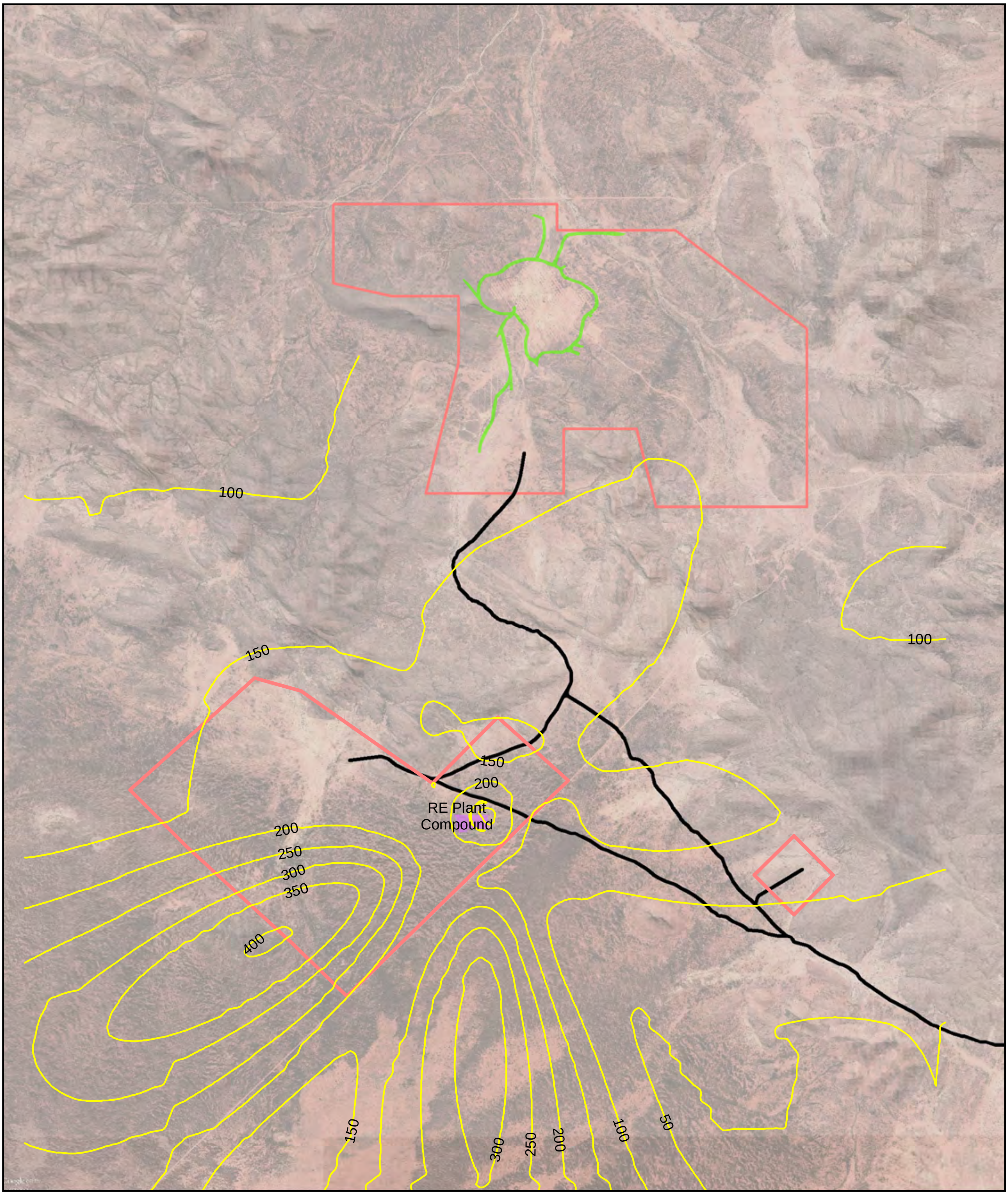
Stage 7 Dust Deposition (g/m2/month) Rolling Annual Average

Figure B21

G:\43\22301\GIS\Maps\4322301_721_Stage7_TSP_DustDepo.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/m3
- Criterion 450 ug/m3
- Haul Roads
- Plant Generation Source
- Project Areas

1:80,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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Job Number	43-22301
Revision	0
Date	30 Mar 2016

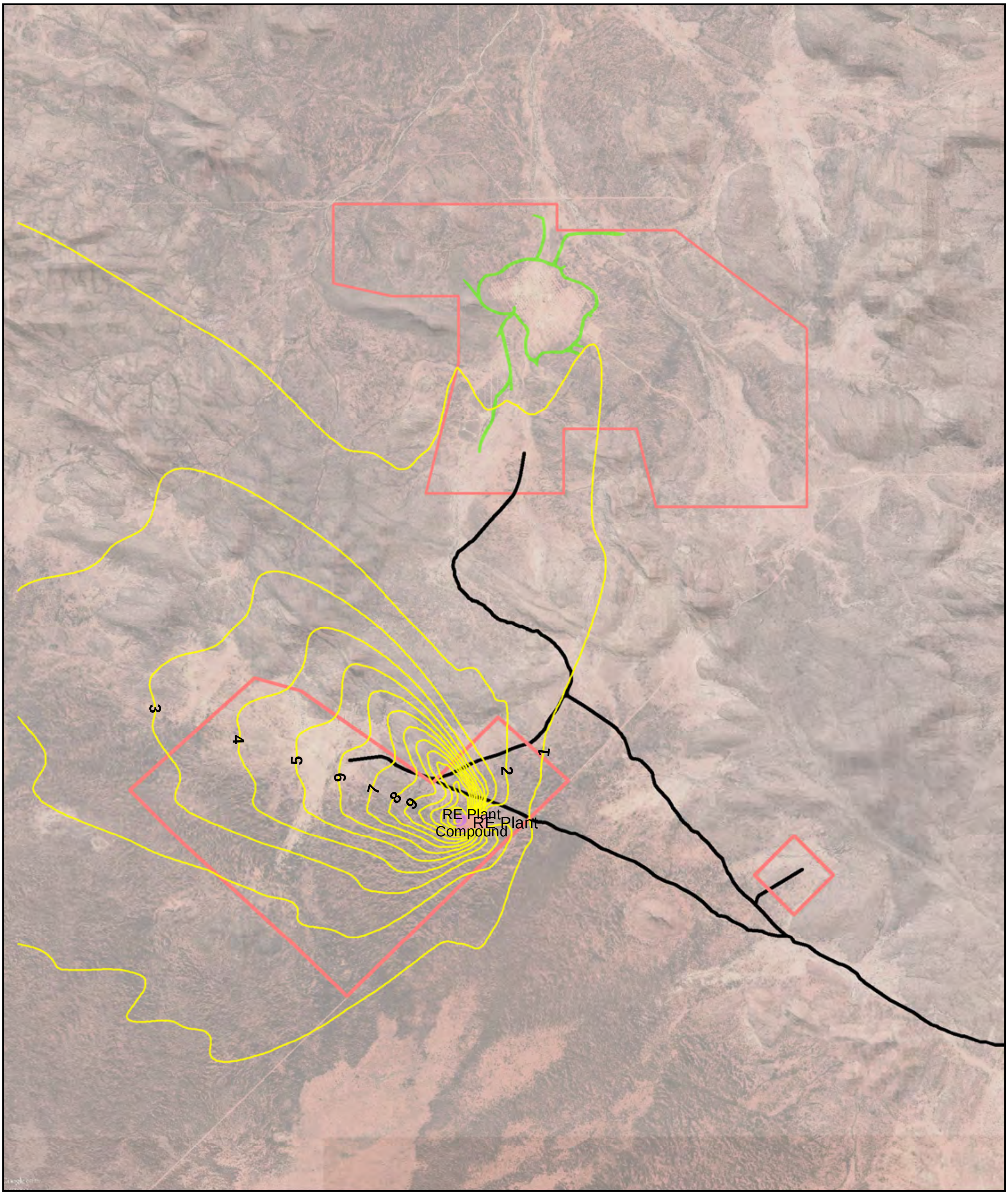
SO2 Concentration (ug/m3)
1 Hour Average

Figure B22

G:\43\22301\GIS\Maps\4322301_725_SO2_Criterion1HrAvg.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

Access Road

Haul Roads

Concentration ug/m^3

Plant Generation Source

Criterion 60 ug/m^3

Project Areas

1:80,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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SO2 Concentration (ug/m3)
Annual Average

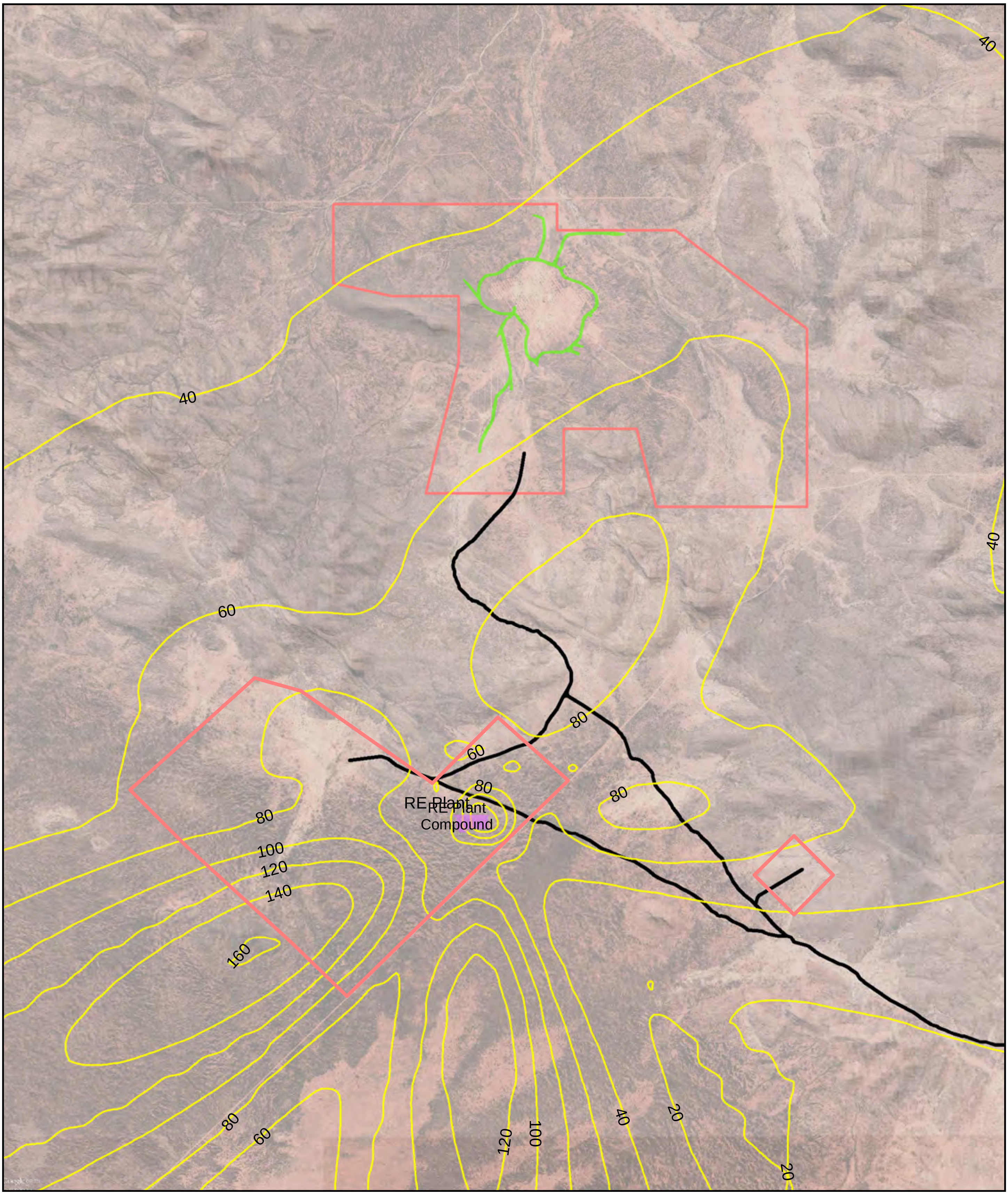
Job Number	43-22301
Revision	0
Date	30 Mar 2016

Figure B23

G:\43\22301\GIS\Maps\4322301_726_SO2_CriterionAnnualAvg.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/m^3
- Criterion 29,000 ug/m^3
- Haul Roads
- Plant Generation Source
- Project Areas

1:80,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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CO Concentration (ug/m3)
1 Hour Average

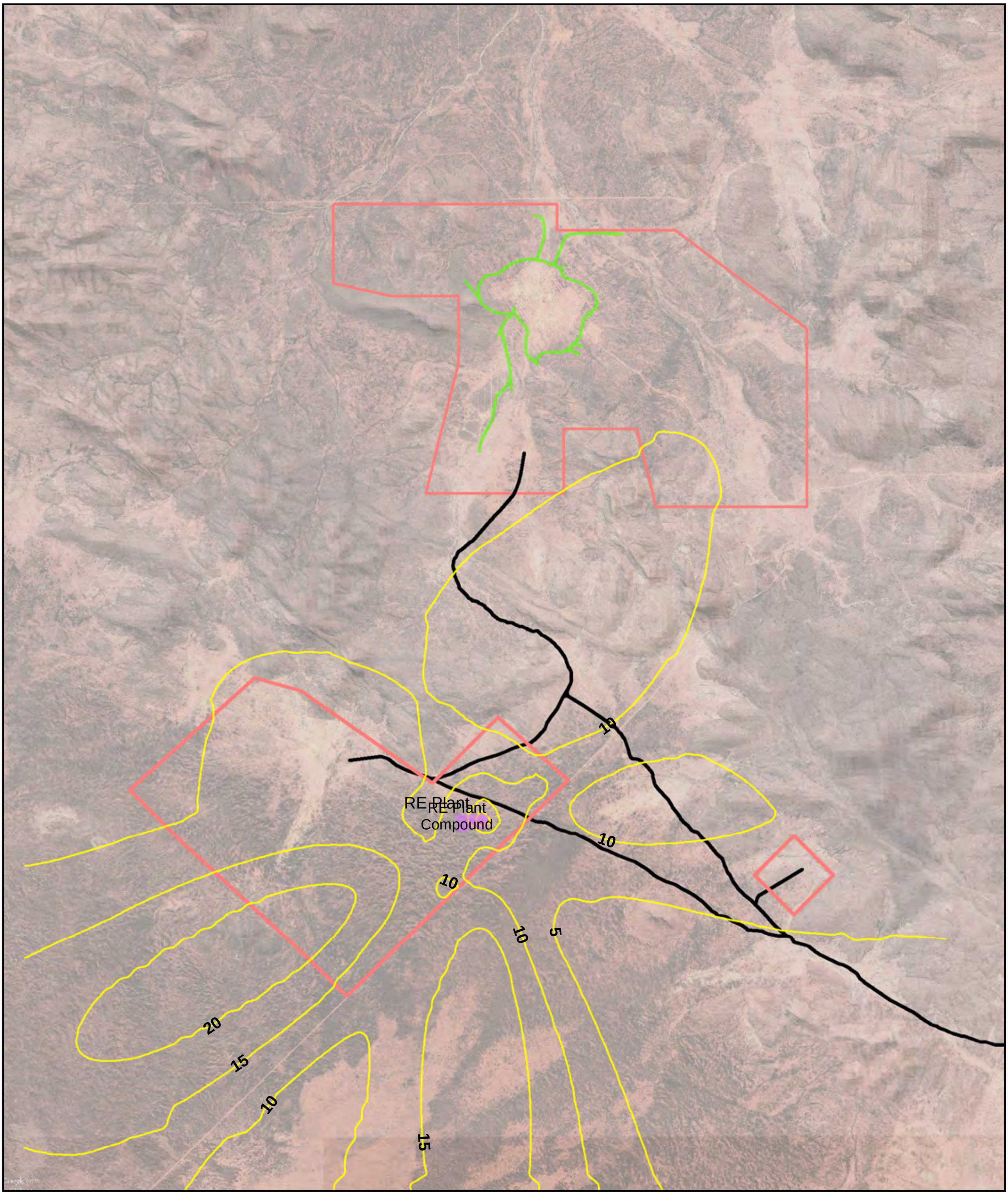
Job Number	43-22301
Revision	0
Date	30 Mar 2016

Figure B24

G:\43\22301\GIS\Maps\4322301_722_CO_Criterion1hrAvg.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/m^3
- Criterion 190 ug/m^3
- Haul Roads
- Plant Generation Source
- Project Areas

1:80,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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NO2 Concentration (ug/m^3)
1 Hour Average

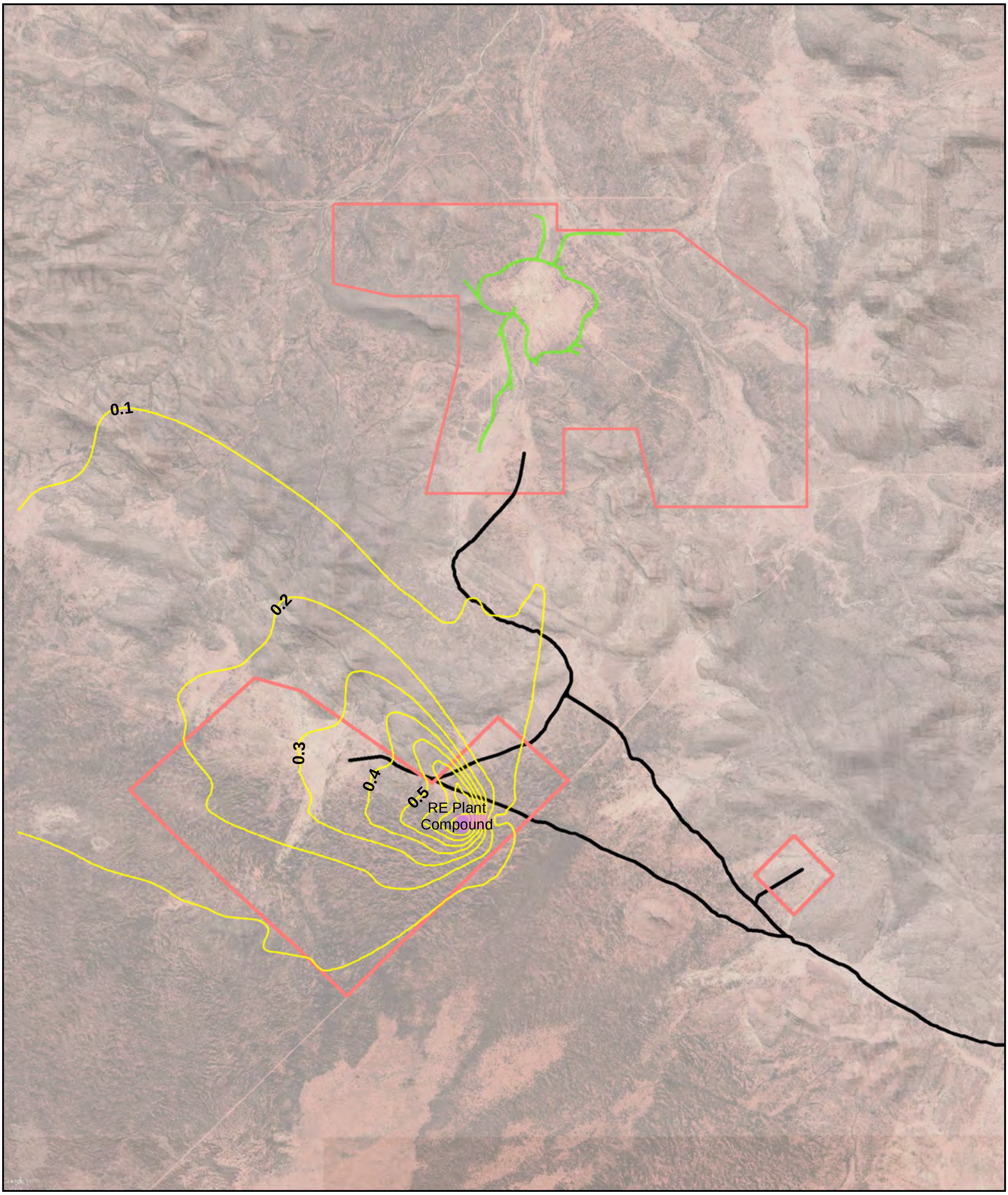
Job Number	43-22301
Revision	0
Date	30 Mar 2016

Figure B25

G:\43\22301\GIS\Maps\4322301_723_NO2_Criterion1hrAvg.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia **T** 61 8 8982 0100 **F** 61 8 8981 1075 **E** drwmail@ghd.com **W** www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM



LEGEND

- Access Road
- Concentration ug/m^3
- Criterion 62 ug/m^3
- Haul Roads
- Plant Generation Source
- Project Areas

1:80,000 @ A4

0 0.5 1 1.5 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 53

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NO2 Concentration (ug/m3)
Annual Average

Job Number	43-22301
Revision	0
Date	30 Mar 2016

Figure B26

G:\43\22301\GIS\Maps\4322301_724_NO2_CriterionAnnualAvg.mxd

Level 5, 66 Smith Street Darwin NT 0800 Australia T 61 8 8982 0100 F 61 8 8981 1075 E drwmail@ghd.com W www.ghd.com

Data source: GA - Roads, Waterways, Placenames, Placenames, Lakes (2015). ESRI - Shaded Relief (2009). Google Earth Pro - Imagery (Date extracted: 15/02/2016). ARL - Project Areas (2015). GHD - AQ Modelling (2016). Created by: CM

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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