Memorandum

07 October 2013

To	Brent Murdoch		
Copy to	Andrew Sawicki		
From	Nicole Conroy	Tel	(08) 8982 0109
Subject	EIS Supplementary reporting relating to Air Quality Assessment	Job no.	43/22079

1 This section of the supplementary report addresses submission #118 from NT EPA relating to air quality assessment:

No assessment is made of the need to protect the habitat of the Gouldian Finch on the site from adverse effects of dust and the hot plume from the power station. The Supplement should provide a discussion to justify this.

1.1 Assessment requirements and criteria – Application to Gouldian Finch Habitat

An assessment of air quality requires two parameters:

- an estimation of potential exposure (i.e. estimation of the concentration in the air of a particular substance, in this case dust); and
- criteria to assess the potential exposure against (i.e. levels that are deemed safe or unsafe for humans).

For human health, detailed criteria used to assess the health impact of a potential exposure exist for almost every known substance. There are also limited agricultural and eco-system exposure criteria available, however they are specific to certain substances e.g. fluoride; and none are specific to dust.

An air quality assessment was undertaken for the draft EIS using NEPM 2003 and NSW EPA DEC 2005 guidelines for ambient and deposited dust criteria. These criteria were developed to protect human health and well-being, and to minimise the nuisance effects and loss of amenity associated with deposited dust (i.e. that portion of ambient or airborne dust that falls and remains on the ground and on other horizontal surfaces).

Criteria to assess the potential exposure of terrestrial flora and fauna to air borne pollutants like dust have not been specifically derived and published. Limited dust criteria do exist for assessment of potential exposure of non-human life forms, however an exposure limit for Gouldian Finches and other native Australian bird species does not exist. Consequently, the air quality criteria used in the air quality impact assessment apply specifically to the protection of human receptors for health and amenity.

The morphology and physiology of the avian lung-air sac respiratory system is strikingly different to that of mammals' lungs (Brown *et al.* 1997)[1]; and so it is acknowledged that application of human health standards and human health criteria is not appropriate to assess air quality impacts on finches.

[1] Brown, R.E., Brain, J.D. and Wang, N., 1997. The Avian Respiratory System: A Unique Model for Studies of Respiratory Toxicosis and for Monitoring Air Quality. Environmental Health Perspectives, V.105, No.2, February 1997.

1.2 Power Station Heated Plume – Potential for Exposure of Gouldian Finch Population

It is very unlikely that birds would be exposed to a hot plume from the on-site power generation facilities. A simple calculation using Briggs plume rise equations was made to support this.

The power station will be located approximately 2 km away from the known nesting habitat of the Gouldian Finch. In the air quality impact assessment the plume was modelled with an exhaust discharge velocity of 48 m/s, a temperature of greater than 400 °C and stack diameter of 3 m.

As the exhaust plume is hot, the plume will rise near vertically to many hundreds of metres unless 'bent over' by a cross wind. To gain an indication of the plume temperature at its centreline as it passes over the Finch habitat (i.e. when strong winds are directed from the stack to the habitat), the plume rise was modelled for a neutral[2] 5 m/s wind. Under this condition, the centreline of the dispersing plume was calculated to rise from the gas turbine exhaust to a height of 462 m. At a distance 2 km away the plume was calculated to yield a dilution ratio (relative to the release at the stack) of greater than 5,000:1. Under all wind conditions it is expected that the gas turbine exhaust will be diluted by at least 1000 times (i.e. a dilution ratio of 1000 to 1). Using this minimum dilution ratio, if a bird was to fly through the exhaust plume in the Gouldian Finch habitat area, it would experience an air temperature rise of no more than 0.5 °C.

For lower wind speed conditions the plume rise will be greater given the substantial buoyancy and momentum in the plume, and so the plume is expected to rise over the Yinberrie Hills.

At higher wind speeds, the plume rise is less; however the increased wind speed further dilutes the plume centreline to dilution ratios in the order of ten thousand to one or greater. At these dilution ratios the plume centreline temperature is indistinguishable from the ambient temperature.

[2] A neutral wind refers to an atmospheric stability condition where mechanical turbulence generated from the surface roughness of the landscape determines the extent of a spread of a plume. It is categorised using a Pasquill-Gifford scale as a "D" stability class wind. A neutral wind typically occurs during high wind speed conditions greater than 5 m/s and at times of full to almost full cloud cover.

2 This section of the supplementary report addresses submission #119 from NT EPA relating to dust emissions:

The estimate of dust emissions is considered to involve a number of optimistic assumptions:

- *wind erosion occurs only in Dry season;*
- *no dust generation after hydrocyclone feed sump;*
- *70 % reduction in dust from crushing screening, conveyors (method of control not specified);*
- *moisture reduces dust emission from haul roads, and maximum dust controls used on haul roads - reduces dust emissions by further 90 %;*
- *no dust from light vehicle travel;*
- *no dust from sealed roads (i.e., secondary dust ignored);*
- *no dust from tailings storage.*

No sensitivity analysis for dust emissions was evident in the report, so the importance of various dust controls is not established in the assessment. This needs to be discussed further in the Supplement.

2.1 Dust Controls on Crushers and Screens

Dust controls are specified for each process in Chapter 16 of the draft EIS (Table 16-5) based on the National Pollutant Inventory (NPI) Emissions Estimation Manual for Mining. The NPI provides detailed pollutant emissions data for numerous processes and industries. These data and emission factors are based on reported data from Australia and overseas. Numerous studies have been undertaken over the last 30+ years to compile the estimates of emissions and control technique efficiency. In Australia, the application of NPI emission estimation and control factor efficiencies is considered standard practice for the assessment of air quality impacts and they are recognised as being appropriate and conservatively accurate.

The applied emission factors[3] for screens and crushers are considered to have been very conservative (i.e. they overestimate the likely emissions), and are likely to be smaller in reality.

A control factor of 75% was applied to the primary crushing, secondary crushing and screening operations. A 70% control was applied to conveyor transfer operations. These factors account for enclosure of these operations. The generous application of water to all crushing and ore transfer operations would result in an improved dust control factor of at least a further 50%, however a worst case condition was assumed where water sprays were not applied.

Emissions from screens and crushers accounted for approximately 414 tonnes per year of PM_{10}, or 16.1% of total annual emissions.

Application of maximum possible controls with full enclosure, water sprays and particulate scrubbing may increase the control factor to 99%, which would result in annual emissions being reduced to 16.6 tonne per year of PM_{10}. This would result in a nominal reduction of all ground level concentrations (GLCs) and deposited dust rates by 15%, based on pro-rata scaling. This could reduce the predicted maximum 24 hour averaged GLC at the Werenbun Community from 70.5 µg/m³ to 63 µg/m³. A potential 15% reduction in dust emissions and GLCs is considered significant.

[3] An emission factor is used to determine the amount of dust generated, in kg per unit time, from a specific process, based on another variable such as the amount of earth unloaded or ore processed in tonnes per unit time.

2.2 Dust Controls on Haul Road

NPI Mining (2012) applies a maximum dust suppression control factor of 75% for haul roads when Level 2 watering is implemented. Level 2 watering requires greater than 2 litres per square meter per hour of water to be applied to all roads subject to heavy vehicle traffic.

A dust emission control factor of 90% was applied to the predicted haul road generated dust, based on the work of Kinsey and Cowherd (Buonicore and Davis 1992)[4] who showed that dust emissions from unpaved roads can be reduced by greater than 90% by using chemical stabilisation. Predicted PM_{10} dust emissions from haul roads with 90% controls applied was 1278 tonnes per year. This corresponds to approximately 50% of total annual emissions from the mine. The application of a chemical dust suppression agent is discussed in more detail in the Appendix T of the draft EIS.

Application of level 2 watering only without the application of chemical suppressants would result in PM_{10} dust emissions on haul roads increasing by 1917 tonnes per year. Therefore, in the event that chemical suppressants were not applied, it is estimated that total site PM_{10} emissions would increase by approximately 75% from that modelled; and a corresponding increase in predicted dust GLCs would result. This could increase the predicted maximum 24 hour averaged GLC at the Werenbun Community from 70.5 µg/m³ to 108 µg/m³. This sensitivity analysis indicates that predicted dust levels are highly sensitive to the applied haul road dust suppression control method.

Dust from haul roads (mechanically generated) is considered to be the single most important dust emission source to be targeted with controls. The dust management plan will focus on the minimisation of this dust source. Further, haul road dust emissions are directly proportional to the amount of earth transferred. For a given sized haul vehicle, more earth movement equals more vehicle kilometres travelled (VKT), which equals more dust.

2.3 Sealed Roads

No dust was modelled as being generated from sealed roads. The NPI Mining (2012) controls specify a 100% control factor for sealed or salt-encrusted roads. In order to be consistent with the emissions inventory calculation methodology, modelling did not incorporate dust from sealed roads.

In reality there will be some re-entrained dust[5] from sealed roads, however emission factors for this are not reliable. This is confirmed by the World Road Association (PIARC 2012)[6] default dust emission factor of 0.000028 kg/VKT (28 mg/VKT) for light vehicles and 0.000104 kg/VKT (104 mg/VKT) for heavy vehicles (10 tonnes gross). These PIARC (2012) values are not based on sealed roads near and inside a mine site, but nevertheless, they are orders of magnitude less than the NPI default emission factors for unsealed haul roads of 1.25 kg/VKT (1,250,000 mg/VKT).

Therefore, as the dust emissions from sealed roads have been shown to have a potentially negligible contribution, inclusion of them in the air quality assessment was not warranted. Regular washing/sweeping of sealed roads will be part of a site wide dust management plan to minimise dust emissions from this potential source.

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[4] Buonicore A.J. & Davis W.T. (eds), 1992, Fugitive Dust in Air Pollution Engineering Manual, Van Nostrand Reinhold, New York, U.S. Geological Survey, pp.133-146.

[5] Re-entrained dust is dust that has been generated elsewhere and has settled onto a sealed road surface. As a fast moving vehicle travels along the sealed road it lifts the dust particle into the air in its wake, thereby entraining it so that the wind can transport it further afield.

[6] PIARC 2012. Road Tunnels: Vehicle Emissions and Air Demand for Ventilation. PIARC Technical Committee C4 Road Tunnels Operation, World Road Association. Report No.: 2012R05EN.

2.4 Light Vehicle Travel

Dust emissions from light vehicle travel at the proposed mine site was not modelled given:

- it is considered to be a minor source compared to dust emissions from heavy haul vehicles; and
- the majority of light vehicles were assumed not to travel on dedicated haul roads.

Speed limit restrictions – likely 25 km/h – will keep dust to a minimum. The NPI Mining (2012) default heavy vehicle PM_{10} emission factor is 1.25 kg/VKT. The default light vehicle emission factor is 0.33 kg/VKT. It is expected that there will be at least 100 times more haul vehicle kilometres travelled on unsealed roads than light vehicles. Coupled with a speed limit of 25 km/h, this effectively reduces the PM_{10} light vehicle default emission factor (for comparison only) to 0.0023 kg/VKT, at least 500 times smaller than the emissions factor for a heavy vehicle.

Furthermore, the average mass of the heavy vehicles proposed to be used in the project is approximately 300 tonnes, while the default value of 1.25 kg/VKT is based on a 45 tonne vehicle. This results in an increase in the emission factor for heavy vehicles from 1.25 kg/VKT to a comparative value of greater than 8 kg/VKT. Therefore, light vehicle emissions were loosely calculated to be three orders of magnitude smaller than heavy vehicle emissions (viz. 0.0023 vs 8), and their omission results in an approximate error in the total emission inventory of less than 0.05%.

2.5 Wind Erosion

All mechanically generated dust, including dust from haul vehicles on haul roads, was assumed to occur during **both** the wet and dry season. In contrast, wind erosion from exposed and disturbed soil was modelled as occurring **only** during the dry season. This is based on the assumption that in the wet season there is (i) enough rainfall to suppress passive wind erosion, and (ii) high relative humidity - sufficient to slow the rate of evaporation so that surface moisture levels remain high. For the modelled 12 month period, the wet season was modelled as occurring between 1 December 2007 and 31 March 2008 inclusive, 122 days or one third of the year.

The decision to remove wind erosion from wet season modelling was based on the following factors.

- as shown in the BoM statistics below in Figure 1 for Tindal RAAF base, the average monthly rainfall during the wet season months of December to March is at least 170 mm, or 6 mm per day. This corresponds to 6 litres of water per day per square meter being applied to all exposed surfaces. Coupled with high relative humidity, exposed surfaces are unlikely to dry to an extent where wind erosion would easily occur; and
- NPI Mining (2012) emission factors and controls have been derived based on temperate climatic conditions, both here and in the United States. Documentation of modelling of emissions and control of dust sources specific to tropical climates is not available. How wet/dry season conditions are modelled is subject to the judgement of the modeller and the specifics of the process and project.

Wind erosion during the wet season months could increase annual PM_{10} emissions from 326 tonnes to 488 tonnes, or just over 6% of the site total (2556 tpy) per year. This error is not considered significant given that the wind erosion was based on the conservative NPI Mining (2012) default value of 0.2 kg/ha/h for PM_{10}.

The maximum predicted GLC, and therefore deposition, of PM_{10} dust to the northwest of the mine (i.e. the Yinberrie Hills SOCS) would not be significantly affected by inclusion of wet season wind erosion. South east trade winds dominate during the dry season, which results in the maximum GLC impact of dust to the north west of the mine (towards the Yinberrie Hills SOCS). The addition of the wet season months, with the inclusion of the more northwest monsoon wind does not result in significant Yinberrie Hill impacts; however, the predicted result at the Werenbun Community could be up to 6% higher.

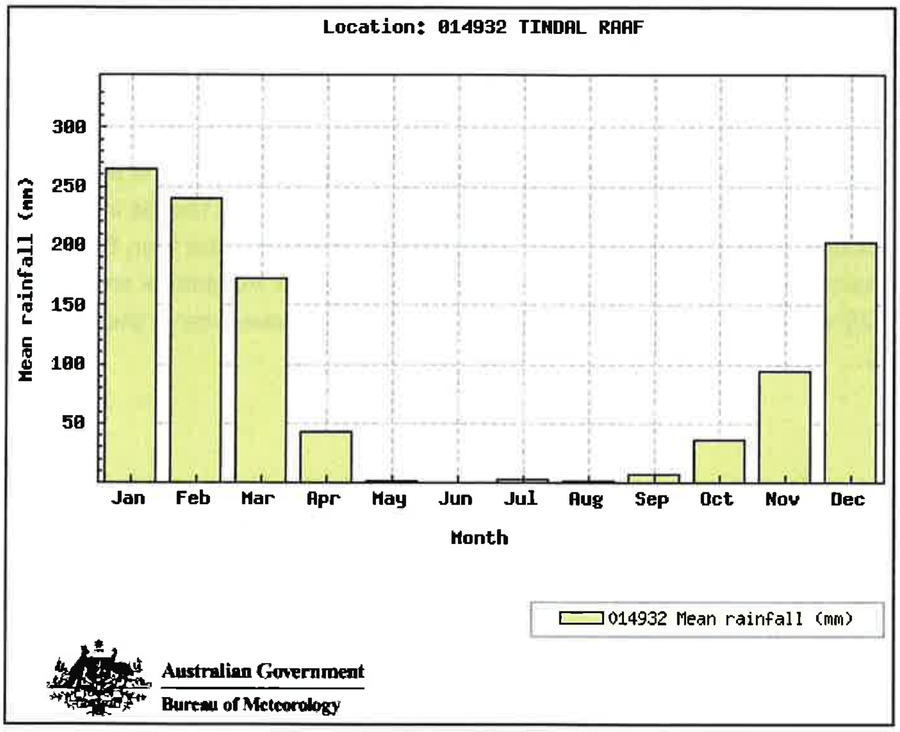

Figure 1 Mean Rainfall Data for Tindal RAAF 1969 to 2013

2.6 Tailings Storage Emissions

No dust emissions were modelled from the tailing storage facility (TSF) during the wet season since it is likely that the contents will be constantly wet from the TSF acting as a dam for monsoonal rain.

During the dry season the surface of the TSF will likely become dry, especially at the edges or furthest reaches away from the tailings inlet, and as the tailings surface dries, it is likely to develop a crust. This crust, if left undisturbed by mechanical processes, such as motor vehicle or pedestrian traffic, is likely to generate very little dust, and any dust it does generate would likely only be the equivalent of background levels, which have been taken into account in the modelling.

In the event that dust emissions did come from the TSF surface, it is likely that the annual amount would be in the order of 150 tonnes per year of PM_{10}. This amount of PM_{10} dust is equivalent to the already modelled annual wind erosion from the open cut Batman Pit. A potential extra 150 tonnes per year from a dry TSF equates to an annual increase of 6% in PM_{10} emissions.

Dust emissions from the surface of TSF2 were not modelled because the facility will be under construction during the year selected for modelling, however emissions from the construction of the TSF2 during year 3 were included in the model.

2.7 Emissions after Hydrocyclone Feed Sump

No emissions were modelled as occurring after the hydrocyclone feed sump because the process flow chart upon which the modelling was based (Figure 2) differed from that which was included in the final EIS report submitted to the NT EPA (Figure 3).

At the time of assessment there were no dust emitting processes evident within the process flow chart. That has changed, with the new process flow chart containing four screens and additional material transfer points.

Based on the modelled emissions for the fine screening process, which were estimated to be 12 tonnes per year with a 99% control factor for process enclosure, the total additional PM_{10} emissions for an additional four screening processes are estimated to be no more than 40 tonnes per year. These additional four screens would contribute to a total site emission increase of 1.5%.

Without controls such as enclosure, screening of fine material is known to be a high source of dust emissions. The stated controls in the draft EIS in Chapter 16, Table 16-5 for screening was a 75% reduction due to scrubbing. This control method was applied to the coarse screening following the primary and secondary crushers.

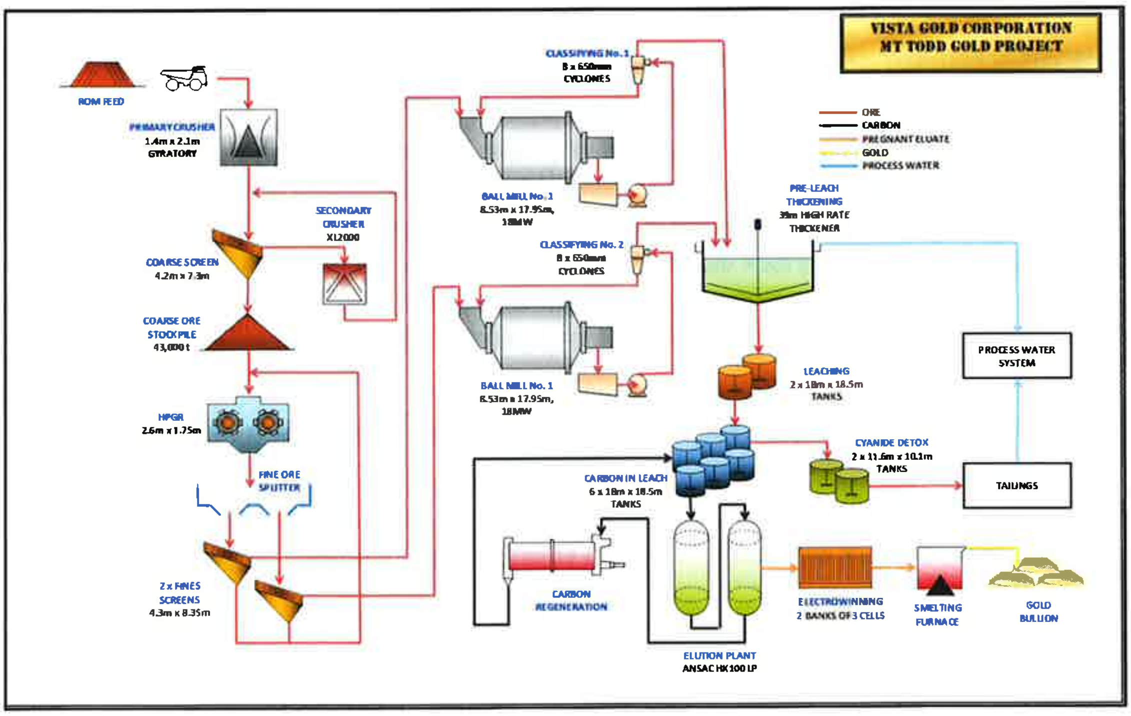

Figure 2 Process Flow Chart supplied and used for Air Quality Assessment

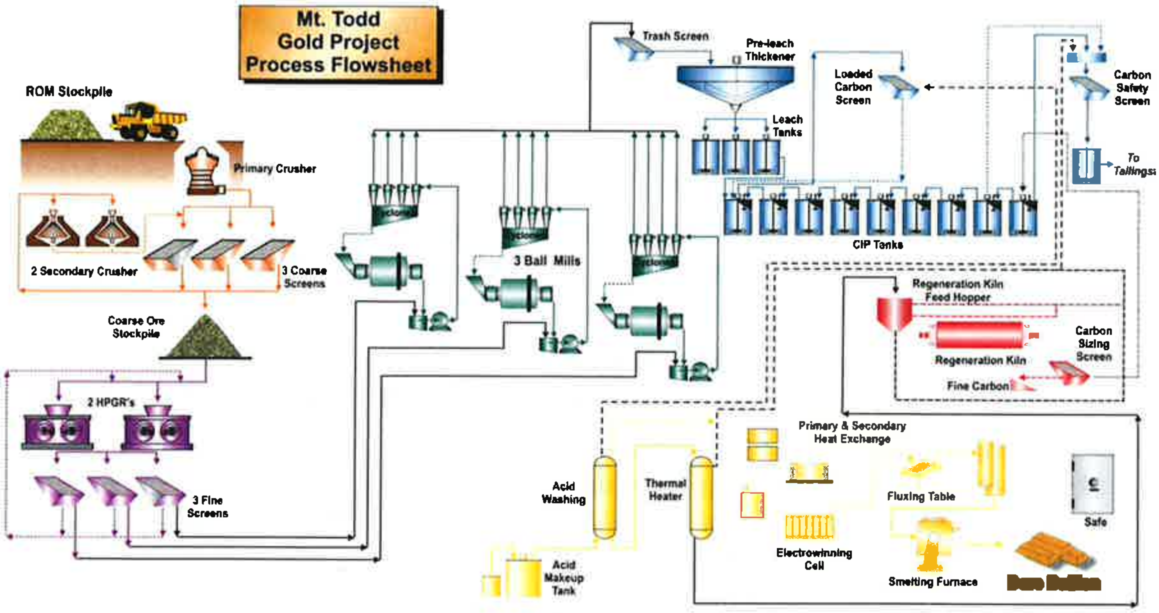

Figure 3 Process Flow Chart supplied by Vista after Air Quality Assessment

2.8 Sensitivity Analysis on Adopted Dust Emission factors

No sensitivity analysis was undertaken for the purposed of the draft EIS (Chapter 16 and Appendix T) as this is beyond the scope of a normal air quality assessment.

Sensitivity analysis is normally carried out only within the context of analysis of controls. Controls should be concentrated on the largest emission source, this being wheel generated dust from haul vehicles.

At the time of assessment, he only other single source to exceed 10% of the total inventory was unloading waste rock to the waste rock dump (11%), and this source can only be controlled with the use of water sprays – thus providing up to 70% reduction. This control method is unlikely to be applied at the mine due to the ever changing unloading area at the waste rock dump and the control on this source was therefore not modelled. It may be possible for a water cart with water cannon to be stationed near the active waste rock unloading area. This would provide a 70% reduction to 11% of the total emissions. In other words, a 7% total site wide emissions reduction.

Placing expensive and complicated dust control systems on processes that generate proportionally small amounts of dust is not considered to be reasonably practicable.

The dust emissions are most sensitive to the amount of earth moved and ore processed. The larger the production rate, the larger the dust emissions. The dust emissions, and therefore the predicted dust GLCs, are directly scalable from the production rate.

3 This section of the supplementary report addresses comments #120 from the NT EPA relating to Ausplume Model predictions:

The Ausplume model is considered a satisfactory method for predicting ground level concentrations of the various contaminants. It is noted that the model setup used a low surface roughness (conservative) and flat terrain. The latter is generally satisfactory, but will not predict plume impingement, if any, with the hill adjacent to Batman Pit, which contains Gouldian Finch habitat. The implications of this to the model predictions should be discussed

3.1 Terrain Modelling

The modelling of terrain features using AUSPLUME makes no difference to the predicted ground level concentrations (GLCs) or predicted deposition rates from low level release sources modelled as volume and/or area sources within the AUSPLUME model. The terrain is not modelled for these sources as it is not required. AUSPLUME does not account for terrain features using these low level release source types.

A more advanced model such as the US EPA approved model CALPUFF is required to be used for terrain influence on low level releases to be full assessed. From experience, this will result in little difference to the predicted impact during moderate to high winds, greater than 1 m/s, as the hills are not large enough to significantly alter the local wind directions at these wind speeds.

Modelling of terrain features in AUSPLUME is only of benefit for the assessment of stack sources.

The effective plume height, as described in section 1.2, is in the order of hundreds of metres. The Yinberrie Hills are considerably lower at less than 100 m; therefore, as shown in Figure 4, adjustments to the plume height due to terrain only occur after the plume has reached its apex. Furthermore, the default model option in AUSPLUME is the Egan Half Height Approach, described below.

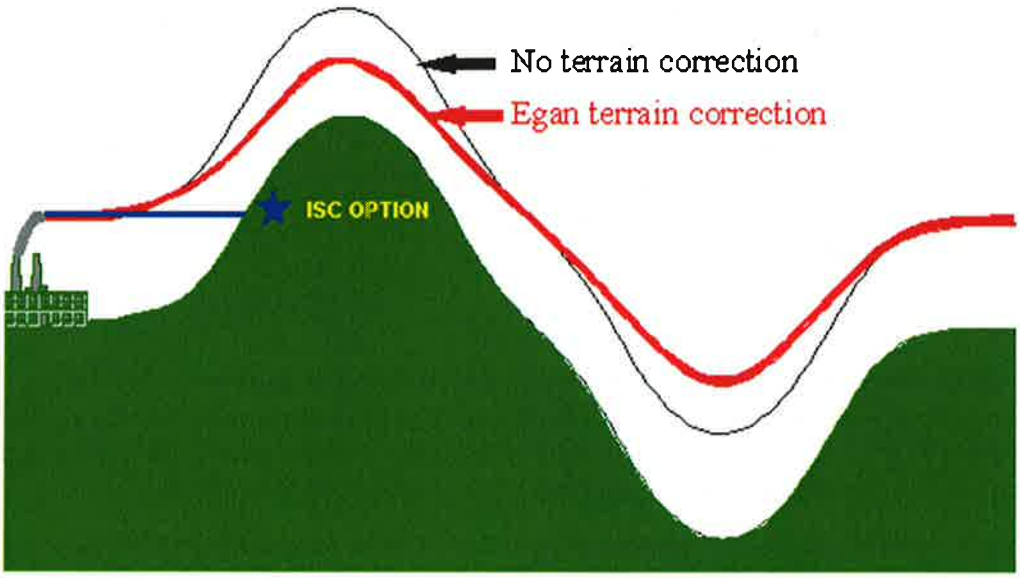

Figure 4 AUSPLUME terrain modelling (AUSPLUME Version 6 Help)

3.2 Egan Half Height Approach

In neutral or unstable conditions, a plume will tend to be uplifted by broad terrain features. Under stable conditions, this lifting will generally be less and the plume will pass closer to the face of the hill and may even impact on the surface. On the other hand, plumes passing into a valley will tend to move further from the ground. In both situations, the variation in plume centre line height above the local terrain becomes more apparent as the atmospheric stability increases.

This modified Egan method specifies changes in the plume centre line in proportion to the changes in the elevation of the underlying terrain. These changes are also a function of the atmospheric stability and allow a closer approach to the terrain surface under stable conditions. This is the preferred terrain correction option. (AUSPLUME Version 6 Help)

In general, plume strikes are most likely to occur during stable, light wind conditions where wind speeds are less than 1 m/s. For the terrain surrounding the Mt Todd site, the wind speed has to be higher than 5 m/s otherwise plume rise from the initial buoyancy will carry the exhaust above the hills. Furthermore, at 5 m/s the atmospheric stability class will be neutral, which will result in greater dispersion and dilution of the power station plumes than is obtained in a stable atmosphere. These combining factors indicate that the risk of a plume strike occurring in the Yinberrie hills is small, and that the modelling of terrain would have made only minor differences in the predicted maximum GLCs from the power station exhaust plume.

4 This section of the supplementary report addresses comments #122 from the NT EPA relating to dust deposition rates.

Predicted dust deposition rates are very high in the area to the north-west of Batman Pit. The predicted peak deposition rate of 30 g/m²/month is 15 times the acceptable level of 2 g/m²/month. While this would not be of significance in a mine site, or even in a remote rural area close to the mine, there is a concern that the peak dust deposition seems to occur in the habitat for the Gouldian Finch. This conflict requires further consideration in the Supplement.

The maximum predicted dust deposition rates are approximately 30 g/m²/month (annual averaged). These occur adjacent to the northwest side of the Batman Pit however the disposition rate decreases with distance from the modelled sources as shown in the draft EIS Figure 16-4. At the location of the nearest identified nesting box the predicted deposited dust is 25 g/m²/month (annual averaged).

The applied incremental criterion for deposited dust was 2 g/m²/month (annual average). This is based on the NSW Approved Methods guidelines (DEC, 2005, p.28). The source of this value has been traced back to a NSW State Pollution Control Commission (SPCC) 1983 report *Air Pollution from Coal Mining and Related Developments*. It states the following:

> *In the absence of any firm criteria, the SPCC believes it is reasonable to adopt interim criteria for assessing the amenity impact of dust fallout in the coal-mining areas of New South Wales, and has therefore adopted a 4 g/m² per month (annual average) as a level "inconsistent" with the current amenity of these areas – i.e. a level at which, in general, a loss of amenity will first be perceived – and 10 g/m²/month (annual average) as an "unacceptable" level. (SPCC, 1983, p.15)*

The deposited dust assessment criteria are purely based on "amenity" issues with regards to coal dust. The applied deposited dust criterion is not appropriate for the assessment of environmental impact on anything other than human residential amenity, which had to be assessed at community locations (Werenbun) to the southeast of the mine.

Doley and Rossato (2010) examined the impact of overburden dust on vegetation and in particular cotton crops. It was found that dust deposition rates of 0.5 g/m²/day (≈ 15 g/m²/month) may reduce cotton crop photosynthesis by up to 11% and cotton yield by up to 3%. For dust deposition rates of up to 30 g/m²/month, cotton crop photosynthesis and cotton yield were reduced by 22% and 9% respectively. The cotton crops did not die as a result of the deposited dust.

Annual monsoon rains are expected to clean any residual deposited dust from surrounding vegetation.

5 This section of the supplementary report addresses comments #111 from the NT EPA relating to flora and vegetation.

The composition of dust and its potential effects on vegetation has not been discussed. The potential for particulate Sulphidic material and other contaminants to become airborne and have impacts (on vegetation within the Yinberrie Hills) should be discussed.

Haul roads, ROM pads, Tailing Storage Facilities and embankments will all be constructed from NAF material. Sulphidic waste material from the pit, once identified, will be selectively handled and encapsulated in the WRD. These practices will minimise sulphidic dust particle transport from the site.

The literature on the effects of dust pollution on plant communities has largely focused on the impact of cement dust and/or limestone quarry dust on crops, and to a lesser extent on natural communities, in the northern hemisphere[7].

Different types of dust appear to affect vegetation communities in different ways, and the relative sensitivity of different plant species is not well understood; so it is not possible to extrapolate findings from a study of limestone or coal dust in the northern hemisphere to the impacts of sulphidic dust on tropical savanna vegetation.

Particulate matter that results from mining activities can have a number of impacts on surrounding vegetation communities, either through physical or chemical damage to the plants themselves, or through changes in soil chemistry that impact nutrient availability. A study of iron ore mining on Brazilian coastal vegetation found that particulate iron did affect soils, and thus potentially nutrient availability; but iron levels in the soils did not exceed typical values [8].

The predominant effect on plant species from dust appears to be a reduction in photosynthetic capacity. What is not well understood is whether the physical effects of dust on plants is permanent or whether plant species have the capacity to recover following leaf drop and/or rainfall (Turner 2012)[9]. It is likely that the capacity of vegetation communities to withstand the effects of increased dust loading is affected by the level of secondary and/or seasonal stressors such as drought, flood, fire and insect predation.

For the purposes of this assessment, there is little information available relating to a threshold level of dust loading on plants, or the effects of sulphidic dust on plant physiology, that could form the basis of a discussion on the effects of sulphidic dust on vegetation within the Yinberrie Hills.

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[7] Farmer, A.M. 1993, The Effects of Dust on Vegetation – A review, in Environmental Pollution Vol 79, 1993, pp. 63-75.

[8] Kuki K.N., Oliva M.A. & Pereira E.G. 2008, in Environmental Management Vol. 42, 2008, pp. 111-121.

[9] Turner G. 2012, The potential impacts of dust loading on vegetation surrounding mine sites, Mining IQ Editorial, 1st October 2012.