

# Appendix 3

## **Response to Submissions – Dubbo Zirconia Project (EMGA Mitchell McLennan, 19 December 2013)**

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19 December 2013

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Re: Response to submissions - Dubbo Zirconia Project

Dear Alex,

## 1 Introduction

EMGA Mitchell McLennan Pty Limited (EMM) has been engaged by RW Corkery & Co Pty Ltd to address the submissions on noise for the recent assessment of the proposed Dubbo Zirconia Project (DZP). The focus is on road traffic noise and potential impacts on sensitive areas of the Taronga Western Plains Zoo (TWPZ) situated off Obley Road and a private residence at the intersection of Obley Road and Toongi Road, Dubbo NSW.

## 2 Submissions

This letter has been prepared in response to two submissions, one received from the TWPZ on 15 November 2013 and the other from Mr K. Riley on 14 November 2013.

In their correspondence of 15 November 2013, TWPZ raised concerns regarding maximum traffic noise levels on sensitive areas of the zoo during night time periods, in particular DZP heavy vehicles using Obley Road between the Newell Highway and Camp Road. Sensitive areas include the rhinoceros breeding facility and the African Wild Dogs exhibit, located adjacent to Obley Road, and the Zoofari Lodge, located approximately 1.85 km from Obley Road.

The submission of 14 November 2013 from Mr K. Riley relates to traffic noise impacts during construction and operation of the DZP. The concern related to potential noise impacts associated with trucks stopping, turning and accelerating at the intersection of Toongi and Obley Roads.

### 3 Methodology

Three transportation options are proposed for the DZP. The worst case scenario, as outlined in the Noise and Vibration Impact Assessment (EMM 2013), with the most potential to impact on the rhinoceros breeding pens is the rail to Dubbo / Road to Toongi transport option. This option has potential to generate the most truck movements on Obley Road.

In order to determine the potential maximum road noise impacts associated with this scenario, operator-attended monitoring was completed on 29 November 2013 at two locations, adjacent to the rhinoceros pens and the Zoofari Lodge (refer to Figure 1). It is noted that the rhinoceros pens are located closer to Obley Road than the African Wild Dog exhibit, and hence results presented for the rhinoceros pens are conservatively representative of noise at the African Wild Dog facility.

The purpose of monitoring was to determine the maximum noise level ( $L_{max}$ ) associated with road truck passbys during the day and night periods at these two locations. The information has been used to conduct predictive modelling of road traffic noise. The results of the model have been used to guide noise management and mitigation measures where required.

### 4 Monitoring results

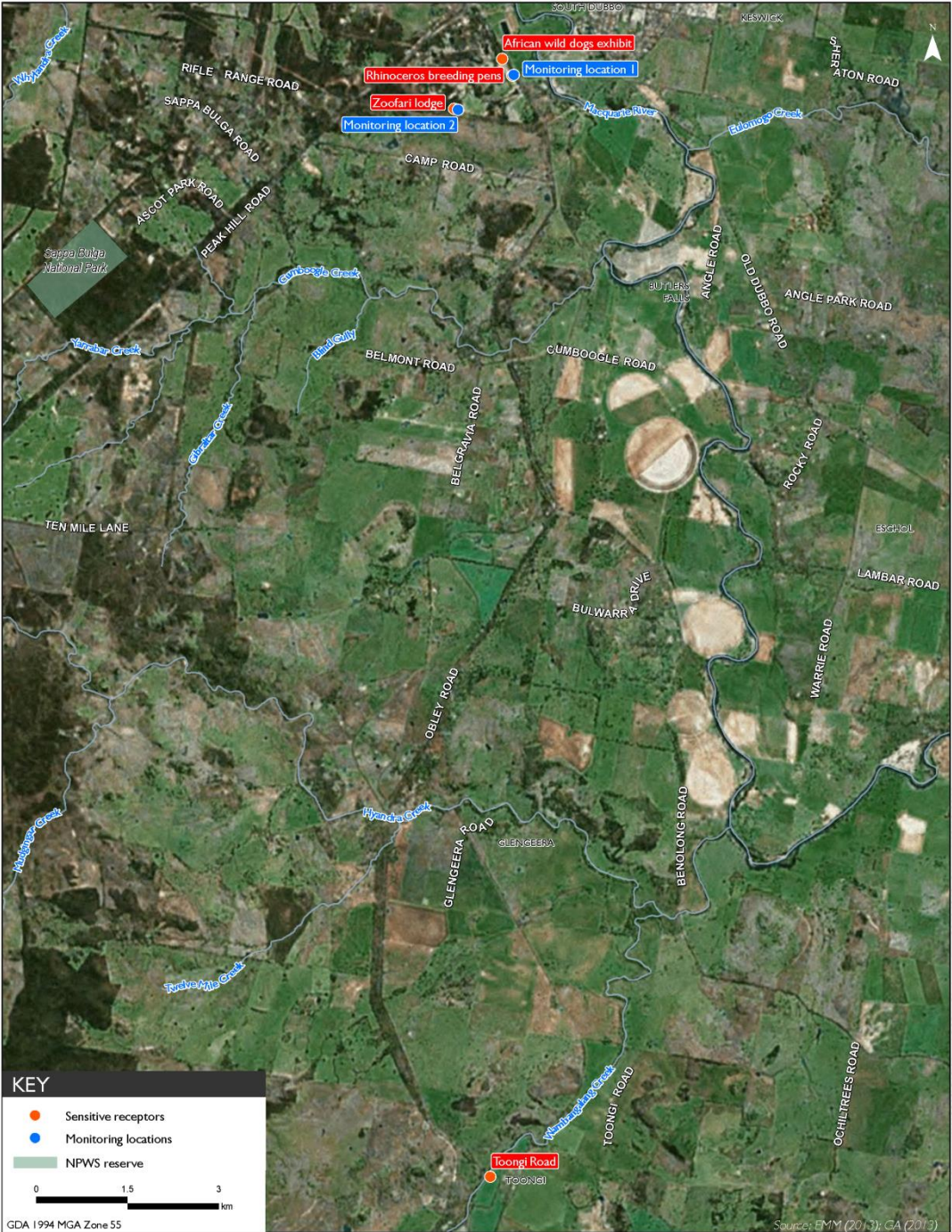
EMM conducted one hour attended background noise surveys during the day and night time periods on 29 November 2013. Monitoring was completed in accordance with the RTA Environmental Noise Management Manual *Practice Note III – Protocol for assessing maximum noise levels* (RTA 2001).

Instrumentation used for monitoring was a Svantek 979 sound analyser, which is a Type 1 sound meter in accordance with Australian Standards. The meter was field calibrated before and after each measurement. The instrument was within its NATA laboratory calibration period during the time of these readings and certificates can be made available on request.

Measurements were completed on the access road adjacent to the rhinoceros breeding pens and Zoofari lodge. The weather conditions at the time of monitoring included clear skies, no rain and light winds.

Observations included a relatively low flow of traffic, with little heavy vehicle activity. Ambient noise levels during the day were dominated by road traffic and rural noise sources, and during the night time period, ambient noise levels decreased significantly, particularly at the Zoofari Lodge, where background or  $L_{90}$  noise levels were recorded below 30 dB(A). At the Zoofari Lodge during the day period, road traffic noise from Obley Road was inaudible because of the distance from the road, and during the night time period, the noise contribution from heavy vehicles on Obley Road was insignificant compared to that of the Newell Highway.

A summary of the results of the attended noise monitoring are provided in Table 1. All traffic observations at the rhinoceros breeding pens (R1) refer to traffic on Obley Road. Measurements and observations from the Zoofari Lodge (R2) involved distinguishing sources from Obley Road and the Newell Highway to the north of the TWPZ.



Sensitive receptors and monitoring locations  
 DZP Lmax road noise assessment  
 Figure 1

**Table 1** Summary of operator attended 1-hour monitoring results – 29 November 2013

Receptor	Time (hrs)	Noise descriptor dB(A)		Noise monitoring observations	Traffic count and observations
		L <sub>eq</sub> (1-hr)	L <sub>90</sub> (1-hr)		
Day period (7 am to 10 pm)					
R1. Rhinoceros breeding pens	17:03	50	39	Rural noises 38-39 dB(A) Car passbys 62-69 dB(A) B-double L <sub>max</sub> : 66-73 dB(A) <sup>1</sup>	Light vehicles: 128 movements Heavy vehicles: 2 movements
2. Zoofari Lodge	18:18	41	34	Traffic not audible. Wind constant 42-43 dB(A) Rural / animal noise: 41-49 dB(A).	Road noise inaudible.
Night period (10 pm to 7 am)					
R1. Rhinoceros breeding pens	22:02	46	35	Rural noise: 36-38 dB(A) Car passbys: 55 dB(A)	Light vehicles: 10 movements Heavy vehicles: 0 movements
R2. Zoofari Lodge	23:14	34	30	Distant traffic (Newell Highway): 30 dB(A). Distant traffic (Obley Road): <30 dB(A).	Light vehicles – Obley Road: 3 movements Light vehicles – Newell Highway: 18 movements Heavy vehicles (Newell Highway): 4 movements No heavy vehicle movements audible from Obley Road.

Notes: 1.Noise source predominantly from trailer banging as the truck passed over an uneven section of road.

Noise measurements and observations indicate that current road traffic noise is not expected to be a contributing factor to the noise environment at the Zoofari Lodge during the day period. At night, the ambient noise environment is relatively low and typical of rural settings. The Lodge is located 1.2 km from Obley Road and road noise was only just audible, with traffic noise discernable from the Newell Highway.

The maximum noise level associated with heavy vehicle movements were quantified during the day period at receptor R1 as 73 dB(A), associated with the B-double trailer rattling as the truck passed over an uneven section of Obley Road.



## 5 Assessment

### 5.1 Assessment locations

Table 2 presents the locations identified for this assessment and respective distances to Obley Road.

**Table 2 Sensitive receptors and distance to Obley Road**

Receptor	Distance to Obley Road (m)
R1. Rhinoceros breeding pens	65
R2. Zoofari Lodge <sup>1</sup>	1200
R3. Toongi residence	160

Note: 1. Receptor located 1100 m from Newell Highway.

### 5.2 Traffic noise

Guidance on maximum noise levels and sleep disturbance is listed in the Road Noise Policy (RNP) (Environment Protection Agency (EPA) 2011). This guidance states that:

- maximum internal noise levels below 50 to 55 dB(A) are unlikely to wake sleeping occupants; and
- one or two noise events per night, with maximum internal noise levels of 65-70 dB(A), are not likely to affect the health and well being of occupant's significantly.

It is commonly accepted by acoustic practitioners and regulatory bodies that a partially open window would reduce external noise levels by 10 dB(A). Therefore, external noise levels in the order of 60-65 dB(A) calculated at the facade of a residence are unlikely to cause sleep disturbance affects at worst case (ie with windows open).

#### 5.2.1 Road traffic noise assessment

##### i Assessed road traffic movements

During construction, it is estimated that construction traffic generation would be in the order of 9 vehicles (or 18 movements per day) over a period of 70 weeks; this value was considered a worst case scenario.

During operations, the traffic generation for the worst case Dubbo / Road to Toongi transport option are 158 daily truck movements. In addition to heavy vehicle movements, DZP will generate 220 light vehicle movements per day. This would result in the generation of approximately 378 vehicles per day.

##### ii Road traffic noise calculations

The Calculation of Road Traffic Noise (CoRTN) (UK Department of Transport) method was used to predict the  $L_{eq}$  noise levels at the residential receptor at Toongi Road (R3) for additional traffic travelling along Obley Road. The overall volumes of heavy and light vehicle movements have been incorporated into the CoRTN calculations to predict noise emissions for the day and night assessment periods. The results are presented in Table 3.

The road traffic noise assessment has been conducted in accordance with the RNP (EPA 2011). The freeway/arterial/sub-arterial criteria have been adopted for Obley Road. Additionally, the RNP states where existing road traffic noise criteria are already exceeded, any additional increase in total traffic noise level should be limited to 2 dB, which is generally accepted as a person's threshold of perceptibility to a change in noise level. For freeways, arterial, sub-arterial and transit ways, the relative increase criteria defined by the RNP states that total traffic noise level increases must not exceed existing daytime  $L_{eq(15-hr)}$  or existing night time  $L_{eq(9-hr)}$  traffic levels by more than 12dB(A). This excludes local roads.

**Table 3** Obley Road truck noise assessment to Toongi Road residence (R3),  $L_{eq(1-hr)}$ , dB(A)

Period	Assessment criteria	Existing Obley Road traffic noise	Calculated DZP project traffic noise	Total traffic noise (current and project)
Day	60 (external)	48	53	54
Night	55 (external)	45	50	51

Notes: 1. Criteria for freeway/arterial/sub-arterial roads.

Road noise levels at receptor R3 satisfy the RNP road traffic noise and relative increase criteria during day and night time periods.

#### 5.2.2 Maximum road truck noise levels

Maximum noise levels from DZP heavy vehicle movements would be generally associated with trailers banging during passbys following delivery of products or reagents to the DZP. This would occur when trucks slow to a stop and accelerate away from the intersection at Toongi Road/Obley Road and decelerate along Obley Road (adjacent to the TWPZ) approaching the intersection of Obley Road and the Newell Highway.

The maximum noise level associated with heavy vehicle movements was quantified through attended measurements at receptor R1 as 73 dB(A). It is not anticipated that  $L_{max}$  noise levels will change as a result of the proposed DZP, therefore this level has been adopted for predictive modelling in this assessment. The occurrence of these events depends on the frequency of night time passbys, driver behaviour and vehicle maintenance.

Based on the distances to the nearest receptors (TWPZ and Toongi residence), the anticipated  $L_{max}$  levels are presented in Table 4. In the absence of noise criteria for livestock or other animals, we have listed the RNP criteria alongside the rhinoceros breeding pen receptor.

**Table 4** Predicted  $L_{max}$  noise levels from truck activity

Nearest receptor	Distance from road to receptor (m)	RNP internal $L_{max}$ criterion for persons, dB(A)	Predicted $L_{max}$ , dB(A)
Rhinoceros pens (TWPZ) (R1)	65	n/a	70 (external)
Zoofari (TWPZ) (R2)	1200	55 <sup>2</sup>	<55 <sup>1</sup>
Residence at Toongi (R3)	160	55	55 <sup>1</sup>

Notes: 1. Internal noise level.

2. Residential criterion has conservatively been applied due in absence of a more appropriate criterion.



The modelled noise levels identify that the rhinoceros pens would experience  $L_{max}$  noise levels of up to 70 dB(A) in external areas most exposed to road traffic. These maximum noise levels are expected to be consistent with existing noise exposure, albeit with more events predicted as a consequence of the proposal.

The modelled internal  $L_{max}$  noise level of 55 dB(A) at the Toongi residence R3 satisfies the criterion. Calculations have incorporated a correction for partially opened windows of 10 dB(A).

Noise levels at the Zoofari Lodge (R2) are expected to be at or below the  $L_{max}$  criteria. Notwithstanding, other noise management measures are provided in this report for consideration.

### 5.3 Recommendations and mitigation measures

Several noise management and mitigation options are provided below, and all would be effective in reducing noise levels at receivers adjacent to Obley Road.

#### 5.3.1 Noise barrier adjacent to rhinoceros breeding pens

A vegetated noise barrier installed along the boundary of the rhinoceros breeding pens would mitigate noise received during the night time period. The implementation of this barrier in conjunction with further measures described in the following sections would see significant road traffic noise level reductions.

Resultant maximum noise levels at the rhinoceros pens (R1) have been calculated following the installation of noise barriers of various heights along the road-side boundary of the pens. The results are presented in Table 5.

**Table 5 Predicted  $L_{max}$  noise levels from truck activity at rhinoceros breeding pens, dB(A)**

Barrier height (m)	Predicted $L_{max}$ noise levels
0	70
1	66
2	64
3	59

The results indicate that the implementation of a barrier would significantly reduce resultant noise levels at the rhinoceros breeding pens.

#### 5.3.2 Road surface upgrade

Observations made during the attended monitoring survey noted that the maximum road noise levels were largely attributable to truck trailer banging while passing over an uneven section of road. Adequate maintenance of the road would reduce trailer banging incidents which generate  $L_{max}$  noise levels.

Relevant sections of road that may generate elevated noise emissions may be upgraded to an exposed aggregate or asphalt / open graded asphalt road type. These road types are beneficial in reducing average  $L_{eq}$  noise levels associated with truck tyre noise. The road surface corrections for surface types

are presented in Figure 1, sourced from the RTA Environmental Noise Management Manual (RTA 2001), and apply for threshold speeds and higher.

Table 3.1

Road surface noise corrections, relative to dense graded asphaltic concrete			
Surface type (regularly trafficked)	Noise level variation, dB(A)		
	Traffic noise	Individual vehicles pass-by noise	
		Cars	Trucks
14 mm chip seal	+ 4.0	+ 4.0	+ 4.0
Portland cement concrete: tyned and dragged	0 to + 3.0	+ 1.0 to + 3.5	- 1.0 to + 1.0
Cold overlay	+ 2.0	+ 2.0	+ 2.0
Portland cement concrete: exposed aggregate	- 0.5 to - 3.0	- 0.1	- 6.7
Stone mastic asphalt	- 2.0 to - 3.5	- 2.2	- 4.3
Open graded asphaltic concrete	0 to - 4.5	- 0.2 to - 4.2	- 4.9

The road surface correction applied depends on the road surface's porosity, macrotexture, depth and wavelength, the percentage of heavy vehicles and vehicle speeds.

Figure 1 Road surface noise corrections

Source: RTA Environmental Noise Management Manual (RTA 2001).

### 5.3.3 Speed limit reduction

The RTA Environmental Noise Management Manual (RTA 2001) states that halving the average speed on high-speed roads would result in a noise reduction of up to 5-6 dB(A) in traffic noise. An option to decrease noise emissions further would be to reduce the speed limit between Camp Road and the Obley Road / Newell Highway intersection (adjacent to the rhinoceros pens) to 80 km/h. The lower speed limit would result in a further 4 dB reduction on predicted levels.

### 5.3.4 Vehicle selection

The proponent has committed to ensuring that trucks are selected to minimise impacts. Road trucks should be roadworthy and designed in accordance with relevant standards and guidelines, and maintained in good work condition.

### 5.3.5 Building construction

Installation of an air conditioning system at the Toongi residence (receptor R3) would be effective in facilitating further noise reductions for the interior of the residence. This would allow windows to be kept closed if desired and resultant noise levels would be in the order of 45 dB(A) internally.

## 6 Summary

The road noise contribution from the DZP is predicted to satisfy the EPA's RNP and maximum ( $L_{max}$ ) noise events will remain consistent with current noise levels experienced at receptors along Obley Road. The  $L_{max}$  noise levels satisfy relevant criteria at the Zoofari Lodge (R2) and Toongi residence (R3).

To reduce road traffic noise the DZP could introduce management measures to minimise the potential for adverse impacts at the rhinoceros breeding pens. These measures include a combination of options such as a noise barrier adjacent to the rhinoceros breeding pens, the improvement of road surfaces and/or reduction of speed limits. Furthermore, all vehicles used at the DZP site will comply with relevant Australian guidelines and be maintained in good working condition. Additionally, the DZP will apply a driver policy to require drivers to behave in a conservative manner and avoid using the vehicle's horns and air brakes when passing this area.

The installation of an air conditioning system at the Toongi residence (R3) would allow windows to be kept closed and result in further reduction of internal noise levels.

We trust this letter addresses your requirements, if you have any questions please contact our office.

Yours sincerely



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# Appendix 4

## Transport Hazard Assessment (Sherpa Consulting Pty Ltd, 20 December 2013)

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## DUBBO ZIRCONIA PROJECT

### TRANSPORT HAZARD ANALYSIS

## AUSTRALIAN ZIRCONIA LTD

PREPARED FOR: **R.W. Corkery & Co Pty Limited**  
on behalf of Australia Zirconia Limited

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## **ABBREVIATIONS**

ADG	Australian Dangerous Goods
AZL	Australian Zirconia Ltd
DG	Dangerous Goods
DGR	Director-Generals Requirement
DoP	NSW Department of Planning
DZP	Dubbo Zirconia Project
EIS	Environmental Impact Statement
HIPAP	Hazardous Industry Planning Advisory Paper
MSDS	Material Safety Datasheet
NSW	New South Wales
PG	Packing Group
PHA	Preliminary Hazard Analysis
REE	Rare Earth Elements
RWC	RW Corkery
SEPP	State Environmental Planning Policy

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## 1. INTRODUCTION

### 1.1. Project Description

Australian Zirconia Ltd (AZL), a wholly owned subsidiary of Alkane Resources Limited, has submitted a development application to develop and operate the Dubbo Zirconia Project (DZP). The mining and mineral processing operation plant for rare metals (Zirconium and Niobium) and Rare Earth Elements (REEs) is located near Toongi, approximately 25 km south of Dubbo. The Proposal incorporates complex industrial processing components involving dangerous goods e.g. anhydrous ammonia, hydrochloric acid and caustic soda, to separate the rare metals and earth elements from the ore.

### 1.2. EIS Background

The application included an Environmental Impact Statement (EIS, Ref 1) prepared by R.W. Corkery (RWC) which was exhibited publically over November 2013.

As part of the EIS preparation, RWC retained Sherpa Consulting Pty Ltd (Sherpa) to assist in completing the hazard analysis associated with the project. As part of the hazard analysis process, the proposed development was reviewed against the State Environmental Planning Policy 33 – Hazardous and Offensive Development (SEPP 33) to determine whether it would be considered by SEPP 33 to be 'potentially hazardous industry'. The Proposal was found to be 'potentially hazardous' and a Preliminary Hazard Analysis (PHA) was therefore prepared and included in the EIS.

The SEPP 33 transport screening thresholds were also found to be exceeded by the proposed numbers of hazardous material movements due to the number of ammonia truck movements, hence a transport route selection study in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) 11 – Route Selection (Ref. 2) is required under SEPP 33. Due to uncertainties around the supply arrangements for the chemicals, this was not included in the EIS but was to be prepared once there was more certainty around supply arrangements.

### 1.3. Requirement for Study

Two submissions to the EIS that related specifically to transport of hazardous materials were received as follows.

1. *Dubbo Council, Letter to DoP, 15 November 2013*

- (o) Page 4-305. Consultation with the Local Emergency Management Committee (LEMC) in relation to Traffic Incident/Potential Incident(s) etc will need to be undertaken as part of the required 'Transport Route Selection Study' and should be identified as such.

The 'Transport Hazard' (Transport Route Selection Study) should be addressed as part of this EIS.

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2. Taronga Western Plains Zoo, Letter to DoP, 15 November 2013

**Hazardous Material Risks**

The EIS identifies a range of hazardous materials that are likely to be transported by truck along Obley Road adjacent to the zoo. A traffic incident involving a spill from one of these vehicles could potentially have serious consequences for the welfare of zoo patrons, staff and animals.

While it is appreciated that a spill is unlikely, there is relatively little detail provided in the EIS to determine this likelihood and any associated consequences. Section 4.14.4.1 of the EIS refers to a Sherpa (2013) report as identifying that transport risk screening thresholds are exceeded due to the movement of hazardous materials, and that a transport route selection study is required. The Sherpa (2013) report

..... and also requested the proponent to:

- Provide more detail on the likelihood and potential consequences of an incident involving a loss of containment in the vicinity of the zoo, of hazardous materials being transported to and from the proposed facility.
- Identify likely emergency response procedures in the event of an incident in the vicinity of TWPZ.

**1.4. Potential Transport Options**

As discussed in Section 2 of the EIS, there are three options for the bulk supply of materials to the DZP Site:

- A - Rail to Toongi from Newcastle. Approximately 3 trains per week and road for materials not suitable for rail.
- B - Rail to Dubbo (Fletcher International Exports Rail Terminal), Transfer materials at Dubbo to storage and then road transport to Toongi. (Note that the route between Fletchers Rail Yard and the Newell Highway via Yarrandale and Bothenba Roads is already used for heavy vehicles and hazardous material transport).
- C - Road to Toongi. Truck all materials to Toongi by road via main highways from supplier, then onto Obley Road from the Newell Highway in Dubbo and onto Toongi Road to DZP. (Small amounts of containerised materials may still be transported by rail as per Option B).

As the rail infrastructure needs reopening / substantial upgrade, and there is no certainty around supply agreements of reagents from Newcastle, in the initial few years

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of the DZP operation, Option C will occur. (Although rail transport options will continue to be investigated and transition to rail options may occur over the project life).

#### 1.5. Scope and Objectives

RWC has requested that Sherpa prepare a transport hazard analysis to address the EIS submissions received in relation to road transport of hazardous material transport.

The objectives of the study are to:

- review any updates to predicted hazardous material transport volumes and update the SEPP 33 transport screening assessment to determine which reagents require consideration
- summarise the hazards and the potential hazardous incidents during transport (i.e. causes of loss of containment and possible impact area) and the safeguards associated with preventing incidents during transport
- identify whether there are any factors that are likely to preclude Option C as a hazardous material transport route taking into account the following factors from HIPAP11:
  - mandatory factors (ie statutory requirements)
  - subjective factors (including sensitive populations, special land uses and emergency response capability)
  - road and traffic factors
  - potential environmental and land use risk
- provide recommendations as required.

#### 1.6. HIPAP 11

The HIPAP 11 study process generally includes:

- Examination of the road hierarchy and identification of routes for heavy vehicle transportation. Note that this has been undertaken as part of the EIS in the Traffic Impact Assessment (Section 4 of the EIS (RWC, 2013) and Part 11 of the Specialist Consultant Studies Compendium) which identifies the required upgrades to roads for the expected increased volumes of heavy vehicles.
- elimination of those routes where there are legal or physical constraints, special/sensitive land uses or where there is inadequate emergency access
- rating the potential routes on the basis of environment and land use risk factors, traffic factors and economic factors;
- a comparison of each of the route alternatives on the basis of their rating against each of the factors.

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The ultimate decision is a balanced judgment considering each of the factors, since it is not possible to integrate them into a single indicator of acceptability because of their diversity. The guidelines have been developed to help in land use safety planning. They are not intended to be used as a basis for preventing vehicles carrying hazardous materials from travelling on roads classified under the Roads Act 1993. Similarly, they should not be used as an argument for upgrading any roads classified under the Roads Act. (These matters fall within the jurisdiction of the relevant NSW Government agencies).

It should be noted that the guidelines relate to road transportation only. Transport decisions should also consider the merits of alternative modes such as rail, sea or pipeline. The guidelines presuppose that such an evaluation has been done and that road has been identified as the preferred mode.

#### 1.7. Methodology

As the chemical suppliers have not been identified, it is not possible to review an overall route. However it is assumed that all reagents would be sourced from main centres such as Sydney and Newcastle and transported on existing heavy vehicle approved roads to Dubbo

Therefore the approach taken is to:

1. Identify the potential incident scenarios in the form of a hazard identification word diagram
2. Qualitatively review the factors identified in HIPAP11 for two segments of the Option C road transport route:
  - a. Generic main road from a main centre to Dubbo (e.g. Mitchell / Newell / Golden Highways)
  - b. From Newell Highway turnoff onto Obley Road and then onto Toongi Road to the DZP Site.
3. Develop recommendations for any additional assessment.

#### 1.8. Limitations

Consideration of alternative road routes from Dubbo to DZP is not included. As part of developing the EIS traffic impact assessment, alternative road routes were reviewed and the Obley Road / Toongi Road route is preferred as it is the most direct and has the highest existing road quality.

It is noted that Option B road component from Fletcher International Exports Rail Terminal is not assessed as this route is an existing hazardous material transport route, relatively small volumes will be via this route, and the majority of the route is the same as Option C.

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This report provides a high level assessment only. As part of the licensing requirements for transport of Dangerous Goods (DG) under the Australian Dangerous Goods Code (ADGC), a transporter must prepare a detailed route specific transport risk assessment. This will be undertaken by the transporter for each reagent once supplier agreements are in place.

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## 2. TRANSPORT DETAILS

### 2.1. Quantities

Reagent transport quantities anticipated for the project are given in APPENDIX A.

The maximum truck reagent loads (all materials) are estimated at 67 per day (laden) with gives 134 per day total movements (taking into account return empty trip). This corresponds to maximum heavy vehicle movements of 138 to 158 per day in the EIS depending in the transport option (Table 2.8).

Table 2.1 summarises the updated SEPP 33 screening assessment. Both ammonia and Class 8 (corrosive) materials exceed the SEPP 33 transport screening thresholds hence need to be considered in the transport hazard analysis.

TABLE 2.1: DG VEHICLE TRANSPORT SUMMARY

Reagent	Traffic generation		Annual Delivery (ton)	DG Class	Comments	SEPP33 Threshold Vehicle Movements		Threshold Exceeded ?
	Annually	Peak Weekly				Annually	Peak Weekly	
All Class 8: - Hydrochloric Acid - 50% caustic	3795	79	91087	Class 8 PG II	Sulfuric acid will be manufactured on site so no truck movements	500	30	YES
Anhydrous ammonia	326	7	9767	Class 2.3		100	6	YES

### 2.2. Routes

The proposed transport route is shown in Figure 1 and potentially sensitive locations are shown in Figure 2 (these figures are extracts from EIS).

Section 4 of the EIS and Part 11 of the Specialist Consultant Studies Compendium include detailed analysis of the adequacy of the roads for the proposed volumes of heavy vehicle and recommends various road safety upgrades including:

- 1) Upgrade of Obley Road between Toongi Road and the Newell Highway to B-double standard
  - a. Road will be improved/upgraded for a 20-year life road
  - b. Entire length of road will be 10 m sealed road over an 12m gravel formation (two 3.5m lanes plus sealed shoulder of 1.5m on both sides)
  - c. Straightening of some sections of the road to improve road safety
- 2) Upgrade of Obley Road/Toongi Road Intersection.  
Turning lanes will be extended north of Toongi road
- 3) Building a bridge over Wambangalang Creek to a 1-in-20 year flood height
- 4) Improvement of creek crossings at Hyandra and Twelve Mile Creeks

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- 5) Upgrade of the Obley Road / Taronga Western Plains Zoo Main Visitor Entrance intersection to improve traffic conditions and general safety
- a. Upgrading the section of Obley Road between Newell Highway and Zoofari Lodge entrance using an asphaltic concrete seal ('hot seal')
  - b. Lengthening the right turning bay at the main visitor entrance to the zoo
  - c. Further measures such as street lighting opposite entrance to be considered in consultation with the Zoo & Council

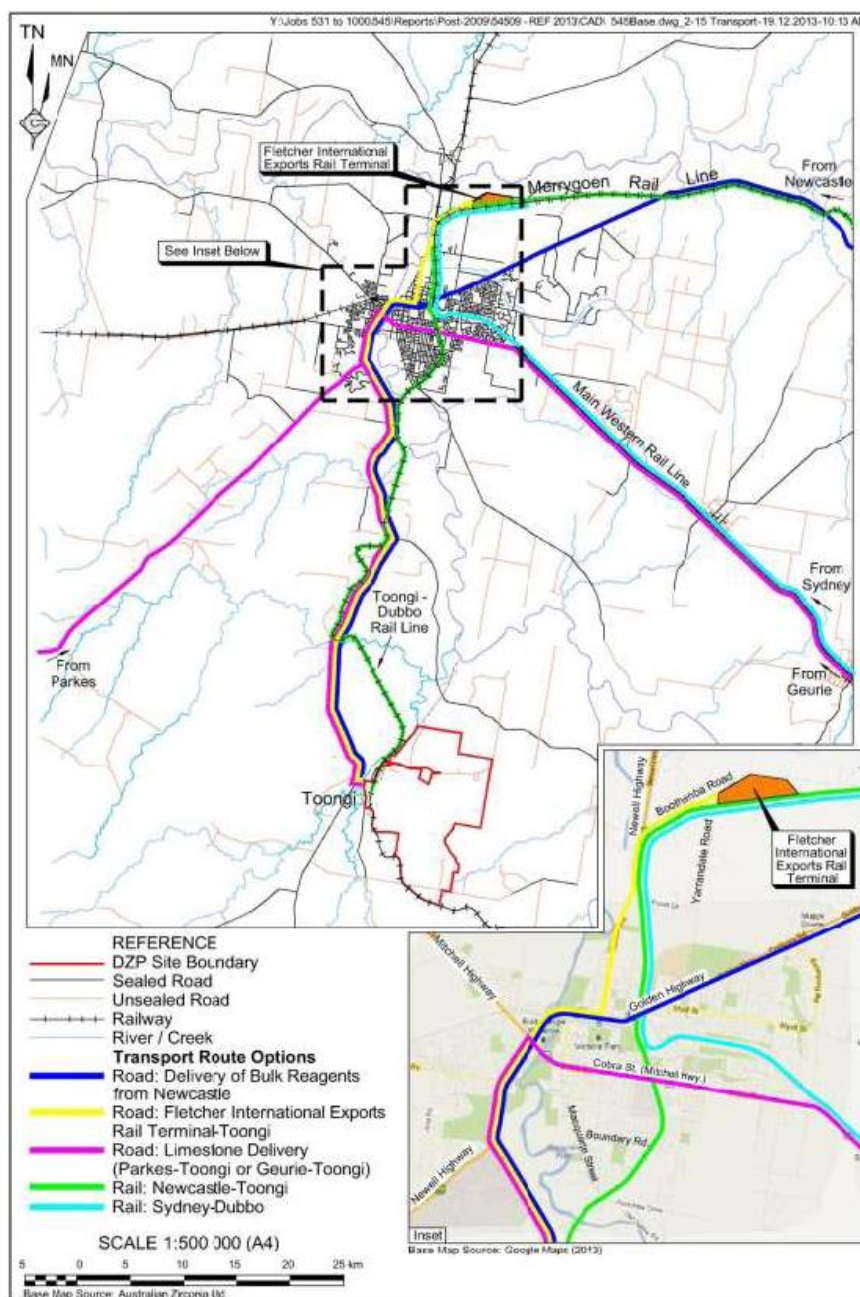
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FIGURE 1: TRANSPORT ROUTE (REF FIG 2.15 EIS)



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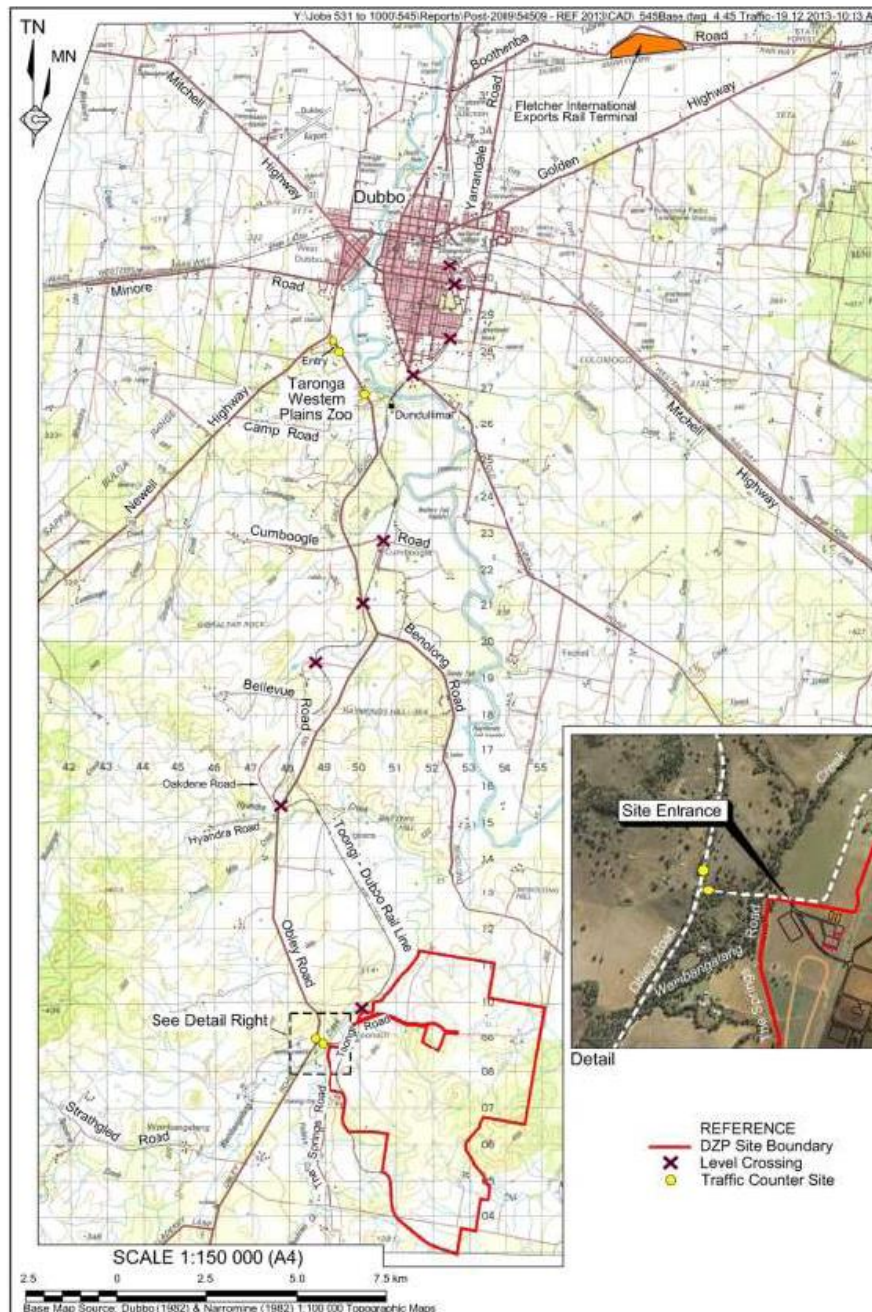
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FIGURE 2: LOCATIONS OF INTEREST ALONG OBLEY ROAD ROUTE (REF FIG 4.45 EIS)



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### 3. HAZARD IDENTIFICATION

#### 3.1. Overview

Anhydrous ammonia, caustic solution and hydrochloric acid are classified as Dangerous Goods and an assessment of the potential hazards associated with the transport of these products has been undertaken to ensure that appropriate safeguards are in place.

#### 3.2. Properties of Anhydrous Ammonia

Ammonia is a toxic gas transported at ambient temperature under pressure in liquefied form. It is a powerful irritant to eyes and mucous membranes of the respiratory tract. Inhalation of high concentrations of the vapour (several thousand ppm) may cause pulmonary oedema, which may be fatal. At low concentrations, ammonia vapour irritates the eyes, nose and throat. Ammonia can be detected in the atmosphere by smell at concentrations as low as 5 ppm. The toxic effects of ammonia on people are summarised in Table 3.1.

Spills of ammonia may result in irritating effects for many hundreds of metres and concentrations resulting in serious injury closer to the release.

**TABLE 3.1: TOXIC EFFECTS OF ANHYDROUS AMMONIA**

Ammonia Concentration (ppm)	Resulting Conditions on Humans
5 – 25	Minor irritation of the eye and respiratory tract, odour threshold by most persons.
25	National exposure standard (ES-TWA).
100	No adverse effect for average worker. Deliberate exposure for long periods not permitted.
400	Immediate nose and throat irritation. No serious effects after 30 minutes to 1 hour.
700	Immediate eye irritation. No serious effect after 30 minutes to 1 hour.
1,700	Convulsive coughing. Severe eye, nose and throat irritation. Could be fatal after 30 minutes.
2,000 – 5,000	Convulsive coughing. Severe eye, nose and throat irritation. Could be fatal after 15 minutes.
5,000	Lowest concentration known to be lethal to humans exposed for 5 minutes via inhalation.
5,000 – 10,000	Respiratory spasm. Rapid Asphyxia.

Ammonia is also flammable, however it has a narrow flammability range (16 vol% to 25 vol%) and requires a strong ignition source (compared to hydrocarbons). The flammable effects of ammonia are secondary to any toxic effects and are not specifically considered in this assessment.

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### 3.3. Properties of Class 8 Corrosives

Hydrochloric acid is a colourless, corrosive liquid and evolves hydrogen chloride (HCl) fumes (eg from tank vents, spills, etc). HCl is an irritant gas that attacks the respiratory system. Spills of hydrochloric acid would have relatively limited local irritant effects and may cause damage to aquatic life due to low pH if spills reach waterways.

Sodium hydroxide is a colourless salt, which is soluble in water. It will be transported as 50% solution. It is corrosive and skin contact with the solution may result in severe pains and skin burns. Eye contact may result in serious permanent eye damage. Spills of caustic would have relatively limited local irritant effects and may cause damage to aquatic life due to high pH if spills reach waterways.

### 3.4. Hazardous Incidents

The event of most concern during transport of ammonia is a leak from the tanker. Potential causes of such leaks include:

- Spontaneous failures due to mechanical faults, corrosion, etc.
- Impact events such as a vehicle accident.

Incidents are summarised, together with causes, consequences and safeguards in the hazard identification word diagram in Table 3.2.

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**TABLE 3.2: HAZID WORD DIAGRAM**

Transport Activity	Initiating Events	Hazard Type	Consequences	Prevention/ Protection Measures
Road tanker transport Class 8 - Hydrochloric acid (33 wt%) - Caustic solution (50%)	Tanker valve leakage / failure Impact leading to loss of containment - Loss of control of vehicle and impact on roadside obstacle - Collision with another vehicle	Corrosive Irritant Fumes	Spill and pool of HCl Evolution of irritant fumes (in immediate area of spill)  Pollution of waterways due to low pH acid or high PH caustic (but no persistent pollutant effect)	Tanker/vehicle design standards as per ADG (AS2809). Thin walled tanker, puncture may occur in a vehicle accident. Excess flow valves on tanker Driver training and ADGC licensing Route specific risk assessment as part of transporter compliance with ADGC. Driver emergency response procedures
Road tanker transport Anhydrous ammonia	Tanker valve leakage / failure Impact leading to loss of containment - Loss of control of vehicle and impact on roadside obstacle - Collision with another vehicle	Toxic gas	Evolution of toxic fumes (effect area many hundreds of metres)	Tanker/vehicle design standards as per ADG (AS2809). Ammonia tankers have thick walls as they are pressure vessel – difficult to puncture, very unlikely unless a high energy impact (such a train impact or tanker rollover). Excess flow valves on tanker Driver training and ADGC licensing Route specific risk assessment as part of transporter compliance with ADGC. Driver emergency response procedures

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#### 4. ROUTE SELECTION FACTORS

##### 4.1. Overview

As described in HIPAP 11, factors that influence routing decisions may be grouped into the following interrelated categories:

- Mandatory factors, including statutory requirements and legal and physical constraints.
- Subjective factors that reflect community priorities and values which may not be easily quantified. Such factors include sensitive populations, special land uses and emergency response capability.
- Road and traffic factors including the identification of the most suitable routes.
- Environmental and land use risk, including the identification of hazards and the quantification of risk. These are location dependent.
- Operational factors including economics and operator's requirements.

##### 4.2. HIPAP 11 Considerations

HIPAP 11 provides a list of relevant issues for consideration in routing decisions. These issues are summarised in Table 4.1 for the generic route from main centres and also the route from Dubbo via Obley and Toongi Roads to the DZP.



TABLE 4.1: ROUTE SELECTION FACTORS AND CONSIDERATIONS

Factors	Considerations	Generic Routes from Main Centres to Dubbo (eg via Newell / Mitchell / Golden Highways)	Option C – Dubbo to DZP via Obley Rd / Toongi Rd	Recommendations
Mandatory	Physical considerations	The route is currently used for DG transport and has been confirmed to be B-double capable. The roads on the identified route are therefore considered to be structurally adequate for the proposed reagent transport.	The roads on the route have been considered in detail in the EIS. Subject to the road safety improvements and upgrades recommended, it is considered that there are no physical factors (eg weight limitations on bridges or height restrictions on underpasses) that preclude the use of the identified route for transport of hazardous materials to the DZP.	Nothing specific beyond EIS Traffic assessment recommendations re: road safety
	Legislation, codes and standards	Transport of Dangerous Goods such as ammonia is regulated under the ADG7 (Australian Dangerous Goods Code, version 7) managed by WorkCover NSW. In the regulations require that: <ul style="list-style-type: none"> <li>- A road vehicle transporting dangerous goods should wherever practicable avoid heavily populated or environmentally sensitive areas, congested crossings, tunnels, narrow streets, alleys, or sites where there is, or may be, a concentration of people</li> <li>- Routes should be pre-planned wherever possible</li> <li>- Routes should be selected to minimise the risk of personal injury, of harm to the environment or property during the journey</li> <li>- A risk assessment in accordance with AS4360 (now superseded by AS31000) Risk Management be prepared. (This is undertaken on a route specific basis by the transport company).</li> <li>- Both drivers and vehicles are Dangerous Goods licensed</li> <li>- Vehicles carrying Dangerous Goods adhere to design standards (AS2809 series Road Tank Vehicles for Dangerous Goods).</li> </ul>		Nothing specific

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Factors	Considerations	Generic Routes from Main Centres to Dubbo (eg via Newell / Mitchell / Golden Highways)	Option C – Dubbo to DZP via Obley Rd / Toongi Rd	Recommendations
Subjective	Sensitive land uses	Not assessed. Routes not known, however as they are likely to be by Highways and approved B-double routes, no specific issues anticipated	Dubbo Western Plains Zoo	Ensure the identification of specific sensitive locations is included in transporter risk assessment once route through Dubbo determined.
	Sensitive ecosystems and natural landscapes		Creek crossings including - Hyandra Ck - Cumboohgle Ck - Twelve Mile Creek	Ensure the identification of specific environmentally sensitive locations is included in transporter risk assessment.
	Emergency and evacuation planning and infrastructure		Local fire Brigade District Emergency Management Committee (DEMC)	Ensure that consultation regarding emergency response in vicinity of sensitive location occurs between operator, transporter and DEMC and also include Taronga Western Plains Zoo (TWPZ). Emergency response for TWPZ specific to an ammonia leak to be defined. This should include identification of a safe emergency assembly area (based on wind direction).
Road and traffic	Road structure	Not assessed. Routes not known, however as they are likely to be by Highways and approved B-double routes, no specific issues anticipated	The roads on the route have been considered in detail in the EIS. This is the best available route as it is the minimum distance and roads required the least upgrade.	Nothing specific beyond EIS Traffic assessment recommendations re: road safety
	Volume & composition			
	Travel time			
	Level of service			
	Traffic signals			
	Alternative routes			

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Factors	Considerations	Generic Routes from Main Centres to Dubbo (eg via Newell / Mitchell / Golden Highways)	Option C – Dubbo to DZP via Obley Rd / Toongi Rd	Recommendations
Environmental and land use risk	Adjacent land use	Not assessed. Routes not known, however as they are likely to be by Highways and approved B-double routes, no specific issues anticipated	As per previous section	Nothing specific
	Population levels	As above	Does not pass through high density or residential areas	Nothing specific
	Sensitivity of ecosystems	As above	As identified above	Nothing specific
	Accident and incident rates potential	As above	Considered in EIS. No history of heavy vehicle accidents. Accident rates were found to be not dependent on road design factors – driver and related factors such as alcohol.	NOTE: If rail option goes ahead level crossing introduces a new hazard for remaining DG road transport. A train accident is a high energy event and has much greater potential to result in a failure of integrity of the load than a vehicle accident.
	Hazards	As per HAZID word Diagram		Nothing specific
	Risk level	As above	Judged to be low subject to road safety upgrades	Nothing specific
	Drainage system	As above		Nothing specific
	Emergency access	As above	As above	Nothing specific
	Driver Training	All drivers who carry Dangerous Goods are required to be licensed by state regulatory agencies In NSW the EPA is the responsible agency. To obtain a licence, drivers must complete an accredited training course, complete a medical and meet the driving history requirements.		Nothing specific
	Vehicle Safety design and maintenance	As per AS2809 series		Nothing specific

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Factors	Considerations	Generic Routes from Main Centres to Dubbo (eg via Newell / Mitchell / Golden Highways)	Option C – Dubbo to DZP via Obley Rd / Toongi Rd	Recommendations
Operational	Distance		Shortest route selected	Nothing specific
	Travel time		Shortest route selected	
	Operating costs		Shortest route selected with least road upgrading required	

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#### 4.3. Transporter Route Risk Analysis

Route risk analysis is undertaken by the transport contractor in accordance with the following documents;

- AS/NZS 4360:2004 Risk Management Standard (now superseded by AS31000)
- Australian Code for the Transport of Dangerous Goods by Road and Rail

Issues considered in the transport route risk analysis include the physical conditions experienced along the route, the impact of changing conditions and other factors such as speed and fatigue (Table 4.2).

The outcome of the transport risk analysis is incorporated into the driver training for the route being travelled.

TABLE 4.2: ROUTE RISK ANALYSIS

Physical Conditions	Changing Conditions	Other Issues
Restricted View – especially at intersections and 'blind corners'	Oncoming traffic – known passing areas	Speed – yours and other traffic on the road
Roundabouts – size, location, condition, alternative route to avoid these	Other heavy vehicle movement	Fatigue Management
Pedestrian Crossings and islands	School and public bus route	First time travel on the route
Intersections and concealed roadways	Congestion	Emergency Response Procedure in place
Bridges – esp. if small or one way	Road works – scheduled and unscheduled	Safety Management Plan in place
Roadway shoulders / known pull over areas	Detours – scheduled and unscheduled	Media reports – cultural events, sporting events, protest action, political activity
Concealed crest, sharp curves, poor camber	Weather – rain, high wind areas	Maintain communication with base
Over / Underpass clearance	Known flood areas	
Rail crossings	Livestock / farm areas	
Floodways, culverts, water courses	Bush fires – usually seasonal	
Overtaking lanes	Transport Vehicle fire	
Designated rest areas and Road house locations		
Recreational areas and Industrial areas		
Locations of Protected Works A & B type areas		

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#### 4.4. Emergency Plans

All drivers undergo emergency response training for incidents such as vehicle accidents or vehicle fires. The training includes:

- Mitigation measures in the event of a vehicle fire, such as battery isolation and extinguishing of fires;
- Measures to ensure the safety of the public, including, in the event of a large fire or leak the implementation of an exclusion zone around the vehicle.
- Activation of the transporter Emergency Response Systems to assist in the management of the incident. The general public are also able to activate the Emergency Response System, with the contact details for the co-ordinating group detailed on the vehicle Dangerous Goods placarding.

Each vehicle carries an Emergency Procedure Guide which summarises the actions to be undertaken in the event of a vehicle fire or leak and also a guide for each type of product being carried (i.e. ammonia).

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## 5. CONCLUSIONS AND RECOMMENDATIONS

Overall there were no factors identified that would preclude the use of the proposed route.

The following recommendations are made. These should be addressed once transporters have been selected.

1. Ensure the transporter risk assessment includes the identification of specific sensitive locations once route through Dubbo determined.
2. Ensure the identification of specific environmentally sensitive locations is included in transporter risk assessment.
3. Ensure that consultation regarding emergency response in vicinity of sensitive location occurs between operator, transporter and DEMC and also include TWPZ.
4. Emergency response requirements for Dubbo Zoo specific to an ammonia leak to be defined. This should include identification of a safe emergency assembly area (based on prevailing wind direction).

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## APPENDIX A. REAGENT TRANSPORT QUANTITIES

Updated reagent quantities as supplied by RWC, ref *Road Rail Reagent Summary\_DRAFT\_Ver6\_9-Feb 8\_2013.XLS*

Reagents	Dangerous Goods Classification	Port of entry/ Origin	Annual tonnage (November 13 - 2012)	Package/Bulk	Truck Numbers (annual)	Trucks per week	Trucks per day (6 day week)	Tonnes pay load per truck	Include in SEPP33?
Sulphuric Acid 98%	Cl 8 UN1830 PGI	Manuf on site Toongi	317,169		Static Storage				Y
Limestone		Geurie Parkies	194,039	Bulk	4,513	94	16	43	n
Salt		Salt Lake Vic	90,740	Bulk	2110	44	7	43	n
Hydrochloric Acid	Cl 8 UN1789 PGI	Newcastle	42,403	IMO1	1767	37	6	24	Y
Caustic Soda 50% Soln	Cl 8 UN1824 PGI	Newcastle	48,684	Bulk 50% solution IMO1	2,029	42	7	24	Y
Soda Ash		Newcastle	44,064	Bulk	1,836	38	6	24	n
Sulphur Prill	Non Haz. once in Aus - IMDG Classification Cl 4.1 UN1350	Newcastle	103,650	Bulk	4,319	90	15	24	n
Quick Lime		Charbon	31,281	Bulk	762	16	3	40	n
Anhydrous Ammonia	Cl 2.3 SR8 UN1005	Newcastle (Kooragang Island)	9,767	Bulk	326	7	1	30	Y
Distillate		Ex Syd	1,424	B Double Tanker	45	1	0.0	32	n
Alamine (336)		Newcastle	112	Drums in containers	7	0.1	0.0	16	n
Shellisol D60/Exxsol D60		Shell - Geelong refinery ASCC - ex Melbourne	615	Isotainers	25	1	0.1	25	n
Sodium Sulphate Anhydrous		Sydney	29,485	Pneu Tank SG 2.67	983	20	3	30	n
Shellisol 2046/Escaid 110		Sydney	1,377	Bulk bags	69	1	0	20	n
Sodium sulfide (Na2S)	Cl 8 UN1849 PGI	Sydney	2,817	Drums on pallets in container	252	5	1	11.2	n
Aluminum Powder		Sydney	1,700		85	2	0.3	20	n
Hematite		Sydney	1,000	Bulk 333 40' containers	71	1	0.2	14	n
Dicalite Filter Aid (Al filter)		Sydney	500	816 kg boxes, 16 boxes per FCL	34	1	0.1	15	n
Tributyl Phosphate		Shell - Pernis Refinery (Netherlands) ASCC - ex Sydney	112	Isotainers	4	0.1	0.0	25	n
Coagulant Floquat 4440		Syd	328	IBC in FCL (6m)	16	0.3	0.0	20	n
Alamine 336		Syd	112	IBC in FCL	6	0.1	0.0	18	n
Total sum of columns			601,628			401	66.7		

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## APPENDIX B. REFERENCES

- 1 RWC Australian Zirconia Ltd Environmental Impact Statement, Dubbo Zirconia Project Report No. 545/04, September 2013
- 2 NSW Department of Planning, Hazardous Industry Planning Advisory Paper No. 11 – Route Selection, January 2011.

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# Appendix 5

## **Post Submission Works for Dubbo Zirconia Project (Pacific Environment Limited, 19 December 2013)**

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19 December 2013

Mr Alex Irwin  
RW Corkery & Co Pty Limited  
62 Hill Street  
Orange NSW 2800

**RE: Post submission works for Dubbo Zirconia Project**

The Dubbo Zirconia Project (DZP) air quality impact assessment (AQIA) (Pacific Environment, 2013) predicted ground level concentrations for a number of air pollutants, including sulfur dioxide (SO<sub>2</sub>). One Applicant-owned residence (Residence 1) located to the immediate southwest of the Processing Plant was predicted to experience SO<sub>2</sub> concentrations above NSW EPA criteria for the 10-minute and 1-hour averaging periods.

The modelling results presented in the AQIA did not include any additional pollution control / emissions abatement for SO<sub>2</sub> released from the acid plant component of the processing plant.

In view of the above, the NSW EPA requested that DZP:

- Quantify the frequency of exceedance of 10 minute and 1 hour SO<sub>2</sub> criteria at the nominated residence.
- Calculate a maximum (approximate) stack emission concentration for SO<sub>2</sub> to predict compliance with all criteria.

Table 1 shows the results of the time series data analysis for the SO<sub>2</sub> predictions.

**Table 1: Time series analysis for the 10 minute and 1 hour average SO<sub>2</sub> concentrations (µg/m<sup>3</sup>)**

Residence 1	1 hour	1 hour	10 minute	10 minute
Criterion	Incremental	Cumulative	Incremental	Cumulative
	570	570	712	712
Maximum	679	706	971	1005
# exceedances	1	1	1	1
2nd highest	210	237	302	336
# exceedances	0	0	0	0

As shown in Table 1, the predicted exceedance at this location occurs only during a single hour for both the 1 hour and 10 minute averaging periods. The second highest predicted concentrations are well below the relevant criteria, even when considered cumulatively (i.e. incorporating background / other potential sources).

The cumulative frequency plots for the incremental and cumulative results for the 1 hour and 10 minute averaging periods at Residence 1 are shown in Figure 1.

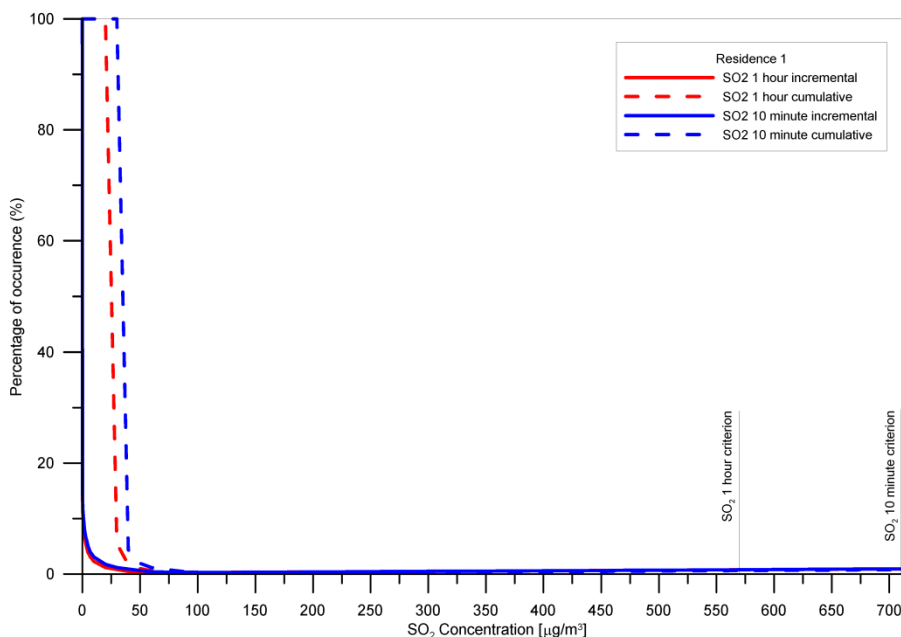


Figure 1: Cumulative frequency plot for 10 minute and 1 hour average SO<sub>2</sub> concentrations at Residence 1

Similar to Figure 36 in the AQIA, the cumulative frequency plots indicate the percentage of time that the SO<sub>2</sub> concentrations were experienced at Residence 1. In summary the plot indicates:

- 87% of the time the incremental 1 hour average SO<sub>2</sub> concentrations are below 0.2 µg/m<sup>3</sup>
- 95% of the time the cumulative 1 hour average SO<sub>2</sub> concentrations are below 30 µg/m<sup>3</sup>
- 86% of the time the incremental 10 minute average SO<sub>2</sub> concentrations are below 0.2 µg/m<sup>3</sup>
- 96% of the time the cumulative 10 minute average SO<sub>2</sub> concentrations are below 40 µg/m<sup>3</sup>.

The meteorology that occurred at the time of the single predicted exceedance event is summarised in the **Table 2**.

Table 2: Summary of model meteorological data during hour of predicted exceedance

YEAR	MONTH	DAY	HOUR	SEC	WS (m)	WD (deg)	T (K)	Pasquill-Gifford Stability Class	Mix. Hgt (m)
2008	11	28	22	3600	3.1	64	292	D	160

It is worth noting that the highest prediction at Residence 10 also occurred during the same hour, with results for the 1 hour maximum approximately 63% (i.e. - 426 µg/m<sup>3</sup> for incremental), of those predicted for Residence 1. Both residences are located in a small valley, with Residence 1 located slightly lower in elevation than Residence 10. In view of the meteorology during the hour of exceedance, the prevailing wind direction was from the northeast and is likely to have been located in a more concentrated section of the SO<sub>2</sub> plume.



**Table 3** provides a summary of the stack parameters used for the air dispersion modelling, mass emission rates and corresponding in-stack concentrations. Highlighted is the in-stack concentration required to meet compliance with the NSW ambient air quality impact assessment criteria for all residences.

**Table 3: Stack Exit Parameters to Satisfy Ambient Air Quality Goals**

Name	Exit temperature (K)	Stack height (m)	Stack diameter (m)	Flow rate (Nm <sup>3</sup> /h)	Exit velocity (m/s)	SO <sub>2</sub> (mg/m <sup>3</sup> )	SO <sub>2</sub> (ppm)	SO <sub>2</sub> (g/s)
Fe Precipitation vent 1	323	20	0.6	2500	2.5	-	-	-
Fe Precipitation vent 2	323	20	0.6	2500	2.5	-	-	-
Sulphuric Acid Plant stack	353	90	1.5	80000	12.6	544	190	12.09
Roaster heater exhaust vent - Roaster 1	548	30	1.0	10000	3.5	-	-	-
Roaster heater exhaust vent - Roaster 2	548	30	1.0	10000	3.5	-	-	-
Gas Boiler stack	423	30	1.2	50000	12.3	-	-	-
Roaster Scrubber Stack	323	30	0.6	10000	9.8	140	49	0.39
Ore Mill exhaust vent	383	20	1.2	50000	12.3	-	-	-
Ore Preheater exhaust vents Roaster 1	473	20	1.0	25000	8.8	-	-	-
Ore Preheater exhaust vents Roaster 2	473	20	1.0	25000	8.8	-	-	-
Ammonia scrubber vent	303	20	0.3	1000	3.9	-	-	-
Zr Dryer vent	383	20	1.0	20000	7.1	-	-	-
Nb Dryer vent	383	20	0.6	10000	9.8	-	-	-
Ferro-niobium Process stack	323	30	0.6	10000	9.8	50	17	0.14

The modelling results indicate that the in-stack concentration of SO<sub>2</sub> would need to be limited to 544 mg/m<sup>3</sup> (190 ppm). This is approximately 70% of the in-stack concentration adopted for the purposes of the AQIA (800 mg/m<sup>3</sup>; 280 ppm).

Additional pollution abatement is proposed for the acid plant, in the form of a Caesium catalyst and/or scrubber system. Such proposed pollution abatement would be capable of achieving maximum in-stack SO<sub>2</sub> concentrations below those detailed in **Table 3**. By adopting such technologies, compliance with the 10-minute and 1 hour average ground level air quality criteria would be achieved at all off-site receptors.

The results table relating to modelling using the stack exit parameters in **Table 3** is provided in **Table 4**, for all residences. Highlighted are the model predictions for all SO<sub>2</sub> averaging periods predicted for Residence 1. All results show compliance with the NSW air quality impact assessment criteria.

Table 4: Revised Dispersion Modelling Results to Satisfy Ambient SO<sub>2</sub> Criteria at all Residences

Residence ID	Incremental prediction				Cumulative prediction			
Averaging period	10 minute	1 hour	24 hour	Annual	10 minute	1 hour	24 hour	Annual
EPA Criterion	712	570	220	60	712	570	220	60
Adopted background	-	-	-	-	34	27	11	3
1 <sup>a</sup>	675	472	20	1	709	499	31	4
2	186	130	8	1	220	157	19	4
3	96	67	6	0	130	94	17	3
4	68	48	4	0	102	75	15	3
6	46	32	4	0	80	59	15	3
7	40	28	4	0	74	55	15	3
8A	39	27	4	0	73	54	15	3
8B	25	18	3	0	59	45	14	3
10	424	296	12	1	458	323	23	4
18	40	28	4	0	74	55	15	3
19	40	28	5	1	74	55	16	4
20	76	53	8	1	110	80	19	4
21	39	27	8	1	73	54	19	4
22	85	59	6	1	119	86	17	4
23	124	87	6	1	158	114	17	4
24	200	140	6	1	234	167	17	4
25	176	123	9	1	210	150	20	4
26	216	151	11	0	250	178	22	3
27	48	33	4	0	82	60	15	3
28A	39	27	3	0	73	54	14	3
28B	44	30	3	0	78	57	14	3
30A	52	36	3	0	86	63	14	3
30B	41	29	2	0	75	56	13	3
31A	28	19	3	0	62	46	14	3
31B	42	29	3	0	76	56	14	3
32	45	32	3	0	79	59	14	3
35A	90	63	3	0	124	90	14	3
35B	65	46	4	0	99	73	15	3
38	40	28	2	0	74	55	13	3
36	54	38	2	0	88	65	13	3
40	50	35	3	0	84	62	14	3
42	23	16	3	0	57	43	14	3
43	55	39	2	0	89	66	13	3
46	23	16	3	0	57	43	14	3
48 <sup>a</sup>	63	44	5	0	97	71	16	3
49A <sup>a</sup>	37	26	4	0	71	53	15	3
49B <sup>a</sup>	32	22	4	0	66	49	15	3
51 <sup>b</sup>	148	103	6	1	182	130	17	4
54 <sup>c</sup>	178	125	8	1	212	152	19	4
55 <sup>c</sup>	174	122	7	1	208	149	18	4
56 <sup>a</sup>	212	148	8	1	246	175	19	4
58 <sup>c</sup>	400	280	13	1	434	307	24	4
61	19	14	2	0	53	41	13	3
50 <sup>d</sup>	56	39	6	0	90	66	17	3

<sup>a</sup> Mine owned residence; <sup>b</sup> Agreed contract (call option); <sup>c</sup> Agreed contract (put option); <sup>d</sup> Potential future residence.

Yours sincerely,



Justine Firth  
Senior Scientist – Air Quality  
Pacific Environment Limited

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# **Appendix 6**

## **Material Safety Data Sheets**

(Total No. of pages including blank pages = 16)

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Chemwatch: 25364

Page 1 of 7  
Version No: 5.1.1.1

## zirconium dioxide



### ZIRCONIUM DIOXIDE

Merck

Chemwatch: 25364  
Version No: 5.1.1.1  
Material Safety Data Sheet

Print Date: 22/11/2013  
Issue Date: 01/01/2013  
S.Local.ZAF.EN.RISK

## SECTION 1 Identification of the substance / mixture and of the company / undertaking

### Product Identifier

Product name:	ZIRCONIUM DIOXIDE
Chemical Name:	zirconium dioxide
Synonyms:	O2-Zr(IV), Patinal tablets, Zr(IV)O2, ZrO2, zirconia, zirconic anhydride, zirconium (IV) oxide anhydrous, zirconium dioxide calcined, zirconium oxide
Proper shipping name:	Not Applicable
Chemical formula:	O2Zr
Other means of identification:	Not Available
CAS number:	1314-23-4

### Relevant identified uses of the substance or mixture and uses advised against

Relevant identified uses: In pigments, abrasives, glass, refractory crucibles, furnace linings, enamels, incandescent lighting, therapeutic (skin) treatments.

### Details of the supplier of the safety data sheet

Registered company name:	Merck	Sigma-Aldrich
Address:	207 Colchester Road Kilsyth 3137 VIC Australia	12 Anella Avenue Castle Hill 2154 NSW Australia
Telephone:	+61 3 9728 7600	+61 2 9841 0555
Fax:	+61 3 9728 1351	+61 2 9841 0500
Website:	http://203.221.251.46/msds/msds.aspx	www.sigma-aldrich.com
Email:	admin@merck.com.au	ausmail@sial.com

### Emergency telephone number

Association / Organisation:	Not Available	Not Available
Emergency telephone numbers:	Not Available	1800 448 456
Other emergency telephone numbers:	Not Available	1800 448 456

## SECTION 2 Hazards identification

### Classification of the substance or mixture

#### ChemWatch Hazard Ratings

	MinMax	
Flammability	0	0 = Minimum
Toxicity	2	1 = Low
Body Contact	2	2 = Moderate
Reactivity	0	3 = High
Chronic	2	4 = Extreme

### Risk Phrases <sup>[1]</sup>

R36/37/38	Irritating to eyes, respiratory system and skin.
R22?	Ingestion may produce health damage*.
R33?	Cumulative effects may result following exposure*.

\*LIMITED EVIDENCE

Legend: 1. Classified by Chemwatch; 2. Classification drawn from EC Directive 67/548/EEC - Annex I; 3. Classification drawn from EC Directive 1272/2008 - Annex VI

### GHS Classification<sup>[1]</sup>:

STOT - SE (Resp. Irr.) Category 3, STOT-SE Category 3, Eye Irrit. 2, Skin Corrosion/Irritation Category 2, Acute Toxicity (Oral) Category 5\*

\*LIMITED EVIDENCE

Legend: 1. Classified by Chemwatch; 2. Classification drawn from EC Directive 67/548/EEC - Annex I; 3. Classification drawn from EC Directive 1272/2008 - Annex VI

### Label elements

#### GHS label elements



Chemwatch: 25364

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## zirconium dioxide

Signal word:	WARNING
<b>Hazard statement(s):</b>	
H303	May be harmful if swallowed*
H315	Causes skin irritation
H319	Causes serious eye irritation
H335	May cause respiratory irritation
H335+H336	May cause respiratory irritation or drowsiness or dizziness.
*LIMITED EVIDENCE	
<b>Precautionary statement(s): Prevention</b>	
P261	Avoid breathing dust/fume/gas/mist/vapours/spray.
P264	Wash all exposed external body areas thoroughly after handling.
P271	Use only outdoors or in a well-ventilated area.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
<b>Precautionary statement(s): Response</b>	
P302+P352	IF ON SKIN: Wash with plenty of water and soap
P304+P340	IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P312	Call a POISON CENTER/doctor/physician/first aider/if you feel unwell.
P321	Specific treatment (see advice on this label).
P332+P313	If skin irritation occurs: Get medical advice/attention.
P337+P313	If eye irritation persists: Get medical advice/attention.
P362+P364	Take off contaminated clothing and wash it before reuse.
<b>Precautionary statement(s): Storage</b>	
P403+P233	Store in a well-ventilated place. Keep container tightly closed.
P405	Store locked up.
<b>Precautionary statement(s): Disposal</b>	
P501	Dispose of contents/container to authorised chemical landfill or if organic to high temperature incineration
<b>Label elements</b>	



Relevant risk statements are found in section 2

Indication(s) of danger:	Xi
<b>Safety advice:</b>	
S24	Avoid contact with skin.
S25	Avoid contact with eyes.
S26	In case of contact with eyes, rinse with plenty of water and contact Doctor or Poisons Information Centre.
S37	Wear suitable gloves.
S39	Wear eye/face protection.
S40	To clean the floor and all objects contaminated by this material, use water and detergent.
S46	If swallowed, seek medical advice immediately and show this container or label.
S56	Dispose of this material and its container at hazardous or special waste collection point.
S64	If swallowed, rinse mouth with water (only if the person is conscious).
<b>Other hazards</b>	
Not Available	

## SECTION 3 Composition / information on ingredients

Substances		
CAS No	%[weight]	Name
1314-23-4	99	<a href="#">zirconium dioxide</a>
Mixtures		

See section above for composition of Substances

## SECTION 4 First aid measures

Description of first aid measures
<b>Eye Contact:</b>

If this product comes in contact with the eyes:

- Wash out immediately with fresh running water.
- Ensure complete irrigation of the eye by keeping eyelids apart and away from eye and moving the eyelids by occasionally lifting the upper and lower lids.
- Seek medical attention without delay; if pain persists or recurs seek medical attention.
- Removal of contact lenses after an eye injury should only be undertaken by skilled personnel.





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## zirconium dioxide

### Skin Contact:

If skin contact occurs:

- Immediately remove all contaminated clothing, including footwear.
- Flush skin and hair with running water (and soap if available).
- Seek medical attention in event of irritation.

### Inhalation:

- If fumes or combustion products are inhaled remove from contaminated area.
- Lay patient down. Keep warm and rested.
- Prostheses such as false teeth, which may block airway, should be removed, where possible, prior to initiating first aid procedures.
- Apply artificial respiration if not breathing, preferably with a demand valve resuscitator, bag-valve mask device, or pocket mask as trained. Perform CPR if necessary.
- Transport to hospital, or doctor, without delay.

### Ingestion:

- **If swallowed do NOT induce vomiting.**
- If vomiting occurs, lean patient forward or place on left side (head-down position, if possible) to maintain open airway and prevent aspiration.
- Observe the patient carefully.
- Never give liquid to a person showing signs of being sleepy or with reduced awareness; i.e. becoming unconscious.
- Give water to rinse out mouth, then provide liquid slowly and as much as casualty can comfortably drink.
- Seek medical advice.

### Indication of any immediate medical attention and special treatment needed

Treat symptomatically.

## SECTION 5 Firefighting measures

### Extinguishing media

- There is no restriction on the type of extinguisher which may be used.
- Use extinguishing media suitable for surrounding area.

### Special hazards arising from the substrate or mixture

#### Fire Incompatibility:

None known.

### Advice for firefighters

#### Fire Fighting:

- Alert Fire Brigade and tell them location and nature of hazard.
- Wear breathing apparatus plus protective gloves in the event of a fire.
- Prevent, by any means available, spillage from entering drains or water courses.
- Use fire fighting procedures suitable for surrounding area.

#### Fire/Explosion Hazard:

- Non combustible.
- Not considered a significant fire risk, however containers may burn.

& Decomposition may produce toxic fumes of:

## SECTION 6 Accidental release measures

### Personal precautions, protective equipment and emergency procedures

#### Minor Spills:

- Remove all ignition sources.
- Clean up all spills immediately.
- Avoid contact with skin and eyes.
- Control personal contact with the substance, by using protective equipment.

#### Major Spills:

Moderate hazard.

- **CAUTION:** Advise personnel in area.

Personal Protective Equipment advice is contained in Section 8 of the MSDS.

## SECTION 7 Handling and storage

### Precautions for safe handling

#### Safe handling

- Avoid all personal contact, including inhalation.
- Wear protective clothing when risk of exposure occurs.
- Use in a well-ventilated area.
- Prevent concentration in hollows and sumps.

#### Other information

- Store in original containers.
- Keep containers securely sealed.
- Store in a cool, dry, well-ventilated area.
- Store away from incompatible materials and foodstuff containers.

### Conditions for safe storage, including any incompatibilities

#### Suitable container:

- Polyethylene or polypropylene container.
- Check all containers are clearly labelled and free from leaks.

Chemwatch: 25364

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Version No: 5.1.1.1

## zirconium dioxide

### Storage incompatibility:

- WARNING: Avoid or control reaction with peroxides. All *transition metal* peroxides should be considered as potentially explosive.



X: Must not be stored together

O: May be stored together with specific precautions

+: May be stored together

### Package Material Incompatibilities:

## SECTION 8 Exposure controls / personal protection

### Control parameters

#### Occupational Exposure Limits (OEL)

##### INGREDIENT DATA

Source	Ingredient	Material name	TWA	STEL	Peak	Notes
South Africa Hazardous Chemical Substances - Recommended Limits	zirconium dioxide	Zirconium and compounds - as Zr	5 (mgm3)	10 (mgm3)	Not Available	Not Available
South Africa Occupational Exposure Limits for Airborne Pollutants	zirconium dioxide	Zirconium compounds [as Zr]	5 (mgm3)	10 (mgm3)	Not Available	Not Available

#### Emergency Limits

Ingredient	TEEL-0	TEEL-1	TEEL-2	TEEL-3
zirconium dioxide	6.75(ppm)	13.5(ppm)	13.5(ppm)	33.8(ppm)

Ingredient	Original IDLH	Revised IDLH
zirconium dioxide	500(mgm3)	25(mgm3)

### Exposure controls

#### Appropriate engineering controls

Engineering controls are used to remove a hazard or place a barrier between the worker and the hazard. Well-designed engineering controls can be highly effective in protecting workers and will typically be independent of worker interactions to provide this high level of protection.

The basic types of engineering controls are:

Process controls which involve changing the way a job activity or process is done to reduce the risk.

#### Personal protection



#### Eye and face protection:

- Safety glasses with side shields.
- Chemical goggles.
- Contact lenses may pose a special hazard; soft contact lenses may absorb and concentrate irritants. A written policy document, describing the wearing of lens or restrictions on use, should be created for each workplace or task.

#### Skin protection:

See Hand protection below

#### Hand protection:

The selection of suitable gloves does not only depend on the material, but also on further marks of quality which vary from manufacturer to manufacturer. Where the chemical is a preparation of several substances, the resistance of the glove material can not be calculated in advance and has therefore to be checked prior to the application.

The exact break through time for substances has to be obtained from the manufacturer of the protective gloves and has to be observed when making a final choice.

#### Body protection:

See Other protection below

#### Other protection:

- Overalls.
- P.V.C. apron.
- Barrier cream.

#### Thermal hazards:

#### Recommended material(s):

##### GLOVE SELECTION INDEX

Glove selection is based on a modified presentation of the:

"Forsberg Clothing Performance Index".

The effect(s) of the following substance(s) are taken into account in the ZIRCONIUM DIOXIDE

Not Available

Material	CPI
----------	-----

\* CPI - Chemwatch Performance Index

#### Respiratory protection:

Required Minimum Protection Factor	Half-Face Respirator	Full-Face Respirator	Powered Air Respirator
up to 10 x ES	P1 Air-line*	-	PAPR-P1
up to 50 x ES	Air-line**	P2	PAPR-P2
up to 100 x ES	-	P3	-
		Air-line*	-
100+ x ES	-	Air-line**	PAPR-P3

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## zirconium dioxide

A: Best Selection  
B: Satisfactory; may degrade after 4 hours continuous immersion  
C: Poor to Dangerous Choice for other than short term immersion

\* - Negative pressure demand \*\* - Continuous flow

A/(All classes) = Organic vapours, B AUS or B1 = Acid gasses, B2 = Acid gas or hydrogen cyanide(HCN), B3 = Acid gas or hydrogen cyanide(HCN), E = Sulfur dioxide(SO<sub>2</sub>), G = Agricultural chemicals, K = Ammonia(NH<sub>3</sub>), Hg = Mercury, NO = Oxides of nitrogen, MB = Methyl bromide, AX = Low boiling point organic compounds(below 65 degC)

### SECTION 9 Physical and chemical properties

#### Information on basic physical and chemical properties

##### Appearance

Heavy, white amorphous powder or crystals, practically insoluble in water. No odour or taste. Slightly soluble in mineral acids.

Physical state	Divided Solid	Relative density (Water = 1)	5.85
Odour	Not Available	Partition coefficient n-octanol / water	Not Available
Odour threshold	Not Available	Auto-ignition temperature (°C)	Not applicable
pH (as supplied)	Not applicable	Decomposition temperature	Not available.
Melting point / freezing point (°C)	2680	Viscosity (cSt)	Not Applicable
Initial boiling point and boiling range (°C)	<ul style="list-style-type: none"> <li>Non combustible.</li> <li>Not considered a significant fire risk, however containers may burn.</li> </ul>	Molecular weight (g/mol)	123.22
		Taste	Not Available
Flash point (°C)	Not Available	Explosive properties	Not Available
Evaporation rate	Not applicable	Oxidising properties	Not Available
Flammability	Not Available	Surface Tension (dyn/cm or mN/m)	Not Available
Upper Explosive Limit (%)	Not applicable	Volatile Component (%vol)	Negligible
Lower Explosive Limit (%)	Not applicable	Gas group	Not Available
Vapour pressure (kPa)	Negligible	pH as a solution(1%)	Not applicable.
Solubility in water (g/L)	Immiscible		
Vapour density (Air = 1)	Not applicable.		

### SECTION 10 Stability and reactivity

#### Reactivity:

See section 7

#### Chemical stability:

- Presence of incompatible materials.
- Product is considered stable.
- Hazardous polymerisation will not occur.

#### Possibility of hazardous reactions:

See section 7

#### Conditions to avoid:

See section 7

#### Incompatible materials:

See section 7

#### Hazardous decomposition products:

See section 5

### SECTION 11 Toxicological information

#### Information on toxicological effects

##### Inhaled:

Evidence shows, or practical experience predicts, that the material produces irritation of the respiratory system, in a substantial number of individuals, following inhalation. In contrast to most organs, the lung is able to respond to a chemical insult by first removing or neutralising the irritant and then repairing the damage. The repair process, which initially evolved to protect mammalian lungs from foreign matter and antigens, may however, produce further lung damage resulting in the impairment of gas exchange, the primary function of the lungs. Respiratory tract irritation often results in an inflammatory response involving the recruitment and activation of many cell types, mainly derived from the vascular system.

##### Ingestion:

Accidental ingestion of the material may be damaging to the health of the individual. The acute oral toxicities of inorganic zirconium salts is low due to their poor gastrointestinal absorption. Intraperitoneal or intravenous injection produces toxic effects approximately 20 times greater than by ingestion. Acutely poisoned animals show progressive depression until death.

##### Skin Contact:

Evidence exists, or practical experience predicts, that the material either produces inflammation of the skin in a substantial number of individuals following direct contact, and/or produces significant inflammation when applied to the healthy intact skin of animals, for up to four hours, such inflammation being present twenty-four hours or more after the end of the exposure period. Skin irritation may also be present after prolonged or repeated exposure; this may result in a form of contact dermatitis (nonallergic). The dermatitis is often characterised by skin redness (erythema) and swelling (oedema) which may progress to blistering (vesiculation), scaling and thickening of the epidermis. At the microscopic level there may be intercellular oedema of the spongy layer of the skin (spongiosis) and intracellular oedema of the epidermis.

##### Eye:

Evidence exists, or practical experience predicts, that the material may cause eye irritation in a substantial number of individuals and/or may produce significant ocular lesions which are present twenty-four hours or more after instillation into the eye(s) of experimental animals. Repeated or prolonged eye contact may cause inflammation characterised by temporary redness (similar to windburn) of the conjunctiva (conjunctivitis); temporary impairment of vision and/or other transient eye damage/ulceration may occur.

##### Chronic:



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## zirconium dioxide

Long-term exposure to respiratory irritants may result in disease of the airways involving difficult breathing and related systemic problems. Limited evidence suggests that repeated or long-term occupational exposure may produce cumulative health effects involving organs or biochemical systems. Long term exposure to high dust concentrations may cause changes in lung function (i.e. pneumoconiosis) caused by particles less than 0.5 micron penetrating and remaining in the lung. A prime symptom is breathlessness.

TOXICITY	IRRITATION
<b>zirconium dioxide</b>	
Not Available	Not Available

\* Value obtained from manufacturer's MSDS  
unless otherwise specified data extracted from RTECS - Register of Toxic Effects of Chemical Substances

### ZIRCONIUM DIOXIDE

Asthma-like symptoms may continue for months or even years after exposure to the material ceases. This may be due to a non-allergenic condition known as reactive airways dysfunction syndrome (RADS) which can occur following exposure to high levels of highly irritating compound. Key criteria for the diagnosis of RADS include the absence of preceding respiratory disease, in a non-atopic individual, with abrupt onset of persistent asthma-like symptoms within minutes to hours of a documented exposure to the irritant. A reversible airflow pattern, on spirometry, with the presence of moderate to severe bronchial hyperactivity on methacholine challenge testing and the lack of minimal lymphocytic inflammation, without eosinophilia, have also been included in the criteria for diagnosis of RADS.

<b>Acute Toxicity:</b>	Not Applicable	<b>Carcinogenicity:</b>	Not Applicable
<b>Skin Irritation/Corrosion:</b>	Skin Corrosion/Irritation Category 2	<b>Reproductive:</b>	Not Applicable
<b>Serious Eye Damage/Irritation:</b>	Eye Irrit. 2	<b>STOT - Single Exposure:</b>	STOT - SE (Resp. Irr.) Category 3
<b>Respiratory or Skin sensitisation:</b>	Not Applicable	<b>STOT - Repeated Exposure:</b>	Not Applicable
<b>Mutagenicity:</b>	Not Applicable	<b>Aspiration Hazard:</b>	Not Applicable

### CMR STATUS

## SECTION 12 Ecological information

### Toxicity

Metal-containing inorganic substances generally have negligible vapour pressure and are not expected to partition to air. Once released to surface waters and moist soils their fate depends on solubility and dissociation in water. Environmental processes (such as oxidation and the presence of acids or bases) may transform insoluble metals to more soluble ionic forms. Microbiological processes may also transform insoluble metals to more soluble forms.

### Persistence and degradability

<b>Ingredient</b>	<b>Persistence: Water/Soil</b>	<b>Persistence: Air</b>
Not Available	Not Available	Not Available

### Bioaccumulative potential

<b>Ingredient</b>	<b>Bioaccumulation</b>
Not Available	Not Available

### Mobility in soil

<b>Ingredient</b>	<b>Mobility</b>
Not Available	Not Available

## SECTION 13 Disposal considerations

### Waste treatment methods

#### Product / Packaging disposal:

Legislation addressing waste disposal requirements may differ by country, state and/or territory. Each user must refer to laws operating in their area. In some areas, certain wastes must be tracked. A Hierarchy of Controls seems to be common - the user should investigate:

## SECTION 14 Transport information

### Labels Required:

Marine Pollutant: NO

Land transport (UN): NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS

Air transport (ICAO-IATA / DGR): NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS

Sea transport (IMDG-Code / GGVSee): NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS

## SECTION 15 Regulatory information

### Safety, health and environmental regulations / legislation specific for the substance or mixture

zirconium dioxide(1314-23-4) is found on the following regulatory lists

"Fisher Transport Information", "Sigma-Aldrich Transport Information", "OECD List of High Production Volume (HPV) Chemicals", "United Nations Consolidated List of Products Whose Consumption and/or Sale Have Been Banned, Withdrawn, Severely Restricted or Not Approved by Governments", "South Africa Hazardous Chemical Substances - Recommended Limits", "South Africa Occupational Exposure Limits for Airborne Pollutants"

## SECTION 16 Other information

### Other information

Classification of the preparation and its individual components has drawn on official and authoritative sources as well as independent review by the Chemwatch Classification committee using available literature references.

A list of reference resources used to assist the committee may be found at:



### **zirconium dioxide**

[www.chemwatch.net/references](http://www.chemwatch.net/references)

The (M)SDS is a Hazard Communication tool and should be used to assist in the Risk Assessment. Many factors determine whether the reported Hazards are Risks in the workplace or other settings. Risks may be determined by reference to Exposures Scenarios. Scale of use, frequency of use and current or available engineering controls must be considered.

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ZIRCONIUM HYDROXIDE

Tennant Trading

Chemwatch: 56750  
Version No: 5.1.1.1  
Material Safety Data Sheet

Print Date: 22/11/2013  
Issue Date: 01/01/2013  
S.Local.ZAF.EN.RISK

**SECTION 1 Identification of the substance / mixture and of the company / undertaking**

**Product Identifier**

Product name:	ZIRCONIUM HYDROXIDE
Chemical Name:	zirconium hydroxide
Synonyms:	O4-H4-Zr, Zr(OH)4, zirconium hydroxide, zirconium tetrahydroxide, zirconium(IV) hydroxide
Proper shipping name:	Not Applicable
Chemical formula:	H4-O4-Zr
Other means of identification:	Not Available
CAS number:	14475-63-9

**Relevant identified uses of the substance or mixture and uses advised against**

Relevant identified uses:	Source of zirconium dioxide, zirconium sulfate, glass colourants.
---------------------------	---

**Details of the supplier of the safety data sheet**

Registered company name:	Tennant Trading
Address:	Level 2, 40 Yeo Street Neutral Bay 2089 NSW Australia
Telephone:	+61 2 9908 9100
Fax:	+61 2 9908 9111
Website:	Not Available
Email:	Not Available

**Emergency telephone number**

Association / Organisation:	Not Available
Emergency telephone numbers:	+61 3 9573 3112
Other emergency telephone numbers:	+61 3 9573 3112

**SECTION 2 Hazards identification**

**Classification of the substance or mixture**

**ChemWatch Hazard Ratings**

	0	1	2	3	4
Flammability	0	1	2	3	4
Toxicity	0	1	2	3	4
Body Contact	0	1	2	3	4
Reactivity	0	1	2	3	4
Chronic	0	1	2	3	4

**Risk Phrases [1]**

R36/37/38	Irritating to eyes, respiratory system and skin.
R337	Cumulative effects may result following exposure*.
R227	Ingestion may produce health damage*.

\*LIMITED EVIDENCE

**Legend:** 1. Classified by Chemwatch; 2. Classification drawn from EC Directive 67/548/EEC - Annex I; 3. Classification drawn from EC Directive 1272/2008 - Annex VI

**GHS Classification [1]:**

STOT - SE (Resp. Irr.) Category 3, STOT-SE Category 3, Eye Irrit. 2, Skin Corrosion/Irritation Category 2, Acute Toxicity (Oral) Category 5\*

\*LIMITED EVIDENCE

**Legend:** 1. Classified by Chemwatch; 2. Classification drawn from EC Directive 67/548/EEC - Annex I; 3. Classification drawn from EC Directive 1272/2008 - Annex VI

**Label elements**

**GHS label elements**



Signal word:	WARNING
--------------	---------

**Hazard statement(s):**

H303	May be harmful if swallowed*
H315	Causes skin irritation
H319	Causes serious eye irritation
H335	May cause respiratory irritation
H335+H336	May cause respiratory irritation or drowsiness or dizziness.



\*LIMITED EVIDENCE

Precautionary statement(s): Prevention	
P261	Avoid breathing dust/fume/gas/mist/vapours/spray.
P264	Wash all exposed external body areas thoroughly after handling.
P271	Use only outdoors or in a well-ventilated area.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
Precautionary statement(s): Response	
P302+P352	IF ON SKIN: Wash with plenty of water and soap.
P304+P340	IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P312	Call a POISON CENTER/doctor/physician/first aider/if you feel unwell.
P321	Specific treatment (see advice on this label).
P332+P313	If skin irritation occurs: Get medical advice/attention.
P337+P313	If eye irritation persists: Get medical advice/attention.
P362+P364	Take off contaminated clothing and wash it before reuse.
Precautionary statement(s): Storage	
P403+P233	Store in a well-ventilated place. Keep container tightly closed.
P405	Store locked up.
Precautionary statement(s): Disposal	
P501	Dispose of contents/container to authorised chemical landfill or if organic to high temperature incineration.
Label elements	



Relevant risk statements are found in section 2

Indication(s) of danger:	
	Xi
Safety advice:	
S24	Avoid contact with skin.
S25	Avoid contact with eyes.
S26	In case of contact with eyes, rinse with plenty of water and contact Doctor or Poisons Information Centre.
S37	Wear suitable gloves.
S39	Wear eye/face protection.
S40	To clean the floor and all objects contaminated by this material, use water and detergent.
S46	If swallowed, seek medical advice immediately and show this container or label.
S56	Dispose of this material and its container at hazardous or special waste collection point.
S64	If swallowed, rinse mouth with water (only if the person is conscious).
Other hazards	
Not Available	

### SECTION 3 Composition / information on ingredients

Substances		
CAS No	%[weight]	Name
14475-63-9	99	<a href="#">zirconium hydroxide</a>
Mixtures		

See section above for composition of Substances

### SECTION 4 First aid measures

Description of first aid measures	
Eye Contact:	
If this product comes in contact with the eyes:	
<ul style="list-style-type: none"> <li>Wash out immediately with fresh running water.</li> <li>Ensure complete irrigation of the eye by keeping eyelids apart and away from eye and moving the eyelids by occasionally lifting the upper and lower lids.</li> <li>Seek medical attention without delay, if pain persists or recurs seek medical attention.</li> <li>Removal of contact lenses after an eye injury should only be undertaken by skilled personnel.</li> </ul>	
Skin Contact:	
If skin contact occurs:	
<ul style="list-style-type: none"> <li>Immediately remove all contaminated clothing, including footwear.</li> <li>Flush skin and hair with running water (and soap if available).</li> <li>Seek medical attention in event of irritation.</li> </ul>	
Inhalation:	
<ul style="list-style-type: none"> <li>If fumes or combustion products are inhaled remove from contaminated area.</li> <li>Lay patient down. Keep warm and rested.</li> <li>Prostheses such as false teeth, which may block airway, should be removed, where possible, prior to initiating first aid procedures.</li> <li>Apply artificial respiration if not breathing, preferably with a demand valve resuscitator, bag-valve mask device, or pocket mask as trained. Perform CPR if necessary.</li> <li>Transport to hospital, or doctor, without delay.</li> </ul>	
Ingestion:	
<ul style="list-style-type: none"> <li>If swallowed <b>DO NOT</b> induce vomiting.</li> <li>If vomiting occurs, lean patient forward or place on left side (head-down position, if possible) to maintain open airway and prevent aspiration.</li> <li>Observe the patient carefully.</li> <li>Never give liquid to a person showing signs of being sleepy or with reduced awareness; i.e. becoming unconscious.</li> <li>Give water to rinse out mouth, then provide liquid slowly and as much as casualty can comfortably drink.</li> </ul>	

- Seek medical advice.

Indication of any immediate medical attention and special treatment needed

Treat symptomatically.

## SECTION 5 Firefighting measures

Extinguishing media

- There is no restriction on the type of extinguisher which may be used.
- Use extinguishing media as suitable for surrounding area.

Special hazards arising from the substrate or mixture

Fire incompatibility:

None known.

Advice for firefighters

Fire Fighting:

- Alert Fire Brigade and tell them location and nature of hazard.
- Wear breathing apparatus plus protective gloves if fire is extensive.
- Prevent, by any means available, spillage from entering drains or water courses.
- Use fire fighting procedures as suitable for surrounding area.

Fire/Explosion Hazard:

Decomposition may produce toxic fumes of, metal oxides.

## SECTION 6 Accidental release measures

Personal precautions, protective equipment and emergency procedures

Minor Spill:

- Remove all ignition sources.
- Clean up all spill immediately.
- Avoid contact with skin and eyes.
- Control personal contact with the substance, by using protective equipment.

Major Spill:

Major hazard.

- **CAUTION:** Advise personnel in area.

Personal Protective Equipment to be contained in Section 8 of the MSDS.

## SECTION 7 Handling and storage

Precautions for safe handling

Safe handling

- Avoid all personal contact, including inhalation.
- Wear protective clothing when risk of exposure occurs.
- Use in a well ventilated area.
- Prevent concentration in low level and traps.

Other information

- Store in original containers.
- Keep containers securely sealed.
- Store in a cool, dry area protected from environmental extremes.
- Store away from incompatible materials and foods in containers.

Conditions for safe storage, including any incompatibilities

Suitable container:

- Polyethylene or polypropylene container.
- Check all containers are clearly labelled and free from leaks.

Storage incompatibility:

- **WARNING:** Avoid or control reaction with peroxides. All transition metal peroxides should be considered as potentially explosive.



+: Must not be stored together

O: May be stored together with specific precautions

+: May be stored together

Package Material incompatibilities:

## SECTION 8 Exposure controls / personal protection

Control parameters

Occupational Exposure Limits (OEL)

INGREDIENT DATA

Source	Ingredient	Material name	TWA	STEL	Risk	Note
South Africa Hazardous Chemical Substances - Recommended Limits	Zirconium hydroxide	Zirconium and compounds - as Zr	5 (mg/m <sup>3</sup> )	10 (mg/m <sup>3</sup> )	Not Available	Not Available
South Africa Occupational Exposure Limits for Airborne Pollutants	Zirconium hydroxide	Zirconium compounds [as Zr]	5 (mg/m <sup>3</sup> )	10 (mg/m <sup>3</sup> )	Not Available	Not Available



Emergency Limits				
Ingredient	TEEL-0	TEEL-1	TEEL-2	TEEL-3
zirconium hydroxide	8.73(ppm)	17.5(ppm)	17.5(ppm)	43.6(ppm)
Ingredient	Original IDLH		Revised IDLH	
zirconium hydroxide	500(mgm3)		25(mgm3)	

#### Exposure controls

##### Appropriate engineering controls

Engineering controls are used to remove a hazard or place a barrier between the worker and the hazard. Well-designed engineering controls can be highly effective in protecting workers and will typically be independent of worker interactions to provide this high level of protection.

The basic types of engineering controls are:

Process controls which involve changing the way a job activity or process is done to reduce the risk.

##### Personal protection



##### Eye and face protection:

- Safety glasses with side shields.
- Chemical goggles.
- Contact lenses may pose a special hazard; soft contact lenses may absorb and concentrate irritants. A written policy document, describing the wearing of lens or restrictions on use, should be created for each workplace or task.

##### Skin protection:

See Hand protection below

##### Hand protection:

The selection of suitable gloves does not only depend on the material, but also on further marks of quality which vary from manufacturer to manufacturer. Where the chemical is a preparation of several substances, the resistance of the glove material can not be calculated in advance and has therefore to be checked prior to the application. The exact break through time for substances has to be obtained from the manufacturer of the protective gloves and has to be observed when making a final choice.

##### Body protection:

See Other protection below

##### Other protection:

- Overalls.
- P.V.C. apron.
- Barrier cream.

##### Thermal hazards:

##### Recommended material(s):

##### GLOVE SELECTION INDEX

Glove selection is based on a modified presentation of the:

"Forsberg Clothing Performance Index".

The effect(s) of the following substance(s) are taken into account in the ZIRCONIUM HYDROXIDE

Not Available

Material	CPI
----------	-----

\* CPI - Chemwatch Performance Index

A: Best Selection

B: Satisfactory; may degrade after 4 hours continuous immersion

C: Poor to Dangerous Choice for other than short term immersion

##### Respiratory protection:

Required Minimum Protection Factor	Half-Face Respirator	Full-Face Respirator	Powered Air Respirator
up to 10 x ES	P1 Air-line*	-	PAPR-P1
up to 50 x ES	Air-line**	P2	PAPR-P2
up to 100 x ES	-	P3	-
		Air-line*	-
100+ x ES	-	Air-line**	PAPR-P3

\* - Negative pressure demand \*\* - Continuous flow

A(All classes) = Organic vapours, B AUS or B1 = Acid gasses, B2 = Acid gas or hydrogen cyanide(HCN), B3 = Acid gas or hydrogen cyanide(HCN), E = Sulfur dioxide(SO2), G = Agricultural chemicals, K = Ammonia(NH3), Hg = Mercury, NO = Oxides of nitrogen, MB = Methyl bromide, AX = Low boiling point organic compounds(below 65 degC)

## SECTION 9 Physical and chemical properties

### Information on basic physical and chemical properties

#### Appearance

White, bulky amorphous powder; does not mix with water. Soluble in dilute mineral acids. Decomposes to zirconium dioxide at 550 deg C.

Physical state	Divided Solid	Relative density (Water = 1)	3.25
Odour	Not Available	Partition coefficient n-octanol / water	Not Available
Odour threshold	Not Available	Auto-ignition temperature (°C)	Not applicable
pH (as supplied)	Not applicable	Decomposition temperature	550
Melting point / freezing point (°C)	Not Available	Viscosity (cSt)	Not Applicable
Initial boiling point and boiling range (°C)	Not Available	Molecular weight (g/mol)	159.22
Flash point (°C)	Not Available	Taste	Not Available
Evaporation rate	Not applicable	Explosive properties	Not Available
Flammability	Not Available	Oxidising properties	Not Available
Upper Explosive Limit (%)	Not applicable	Surface Tension (dyn/cm or mN/m)	Not Available
Lower Explosive Limit (%)	Not applicable	Volatile Component (%vol)	Negligible
Vapour pressure (kPa)	Negligible	Gas group	Not Available
Solubility in water (g/L)	Immiscible	pH as a solution(1%)	Not applicable.
Vapour density (Air = 1)	Not applicable.		

## SECTION 10 Stability and reactivity

#### Reactivity:

See section 7

#### Chemical stability:

- Presence of incompatible materials.
- Product is considered stable.
- Hazardous polymerisation will not occur.

**Possibility of hazardous reactions:**

See section 7

**Conditions to avoid:**

See section 7

**Incompatible materials:**

See section 7

**Hazardous decomposition products:**

See section 5

## SECTION 11 Toxicological information

### Information on toxicological effects

**Inhaled:**

Evidence shows, or practical experience predicts, that the material produces irritation of the respiratory system, in a substantial number of individuals, following inhalation. In contrast to most organs, the lung is able to respond to a chemical insult by first removing or neutralising the irritant and then repairing the damage. The repair process, which initially evolved to protect mammalian lungs from foreign matter and antigens, may however, produce further lung damage resulting in the impairment of gas exchange, the primary function of the lungs. Respiratory tract irritation often results in an inflammatory response involving the recruitment and activation of many cell types, mainly derived from the vascular system.

**Ingestion:**

Accidental ingestion of the material may be damaging to the health of the individual.

The acute oral toxicities of inorganic zirconium salts is low due to their poor gastrointestinal absorption. Intraperitoneal or intravenous injection produces toxic effects approximately 20 times greater than by ingestion. Acutely poisoned animals show progressive depression until death.

**Skin Contact:**

Evidence exists, or practical experience predicts, that the material either produces inflammation of the skin in a substantial number of individuals following direct contact, and/or produces significant inflammation when applied to the healthy intact skin of animals, for up to four hours, such inflammation being present twenty-four hours or more after the end of the exposure period. Skin irritation may also be present after prolonged or repeated exposure; this may result in a form of contact dermatitis (nonallergic). The dermatitis is often characterised by skin redness (erythema) and swelling (oedema) which may progress to blistering (vesiculation), scaling and thickening of the epidermis. At the microscopic level there may be intercellular oedema of the spongy layer of the skin (spongiosis) and intracellular oedema of the epidermis.

**Eye:**

Evidence exists, or practical experience predicts, that the material may cause eye irritation in a substantial number of individuals and/or may produce significant ocular lesions which are present twenty-four hours or more after instillation into the eye(s) of experimental animals.

Repeated or prolonged eye contact may cause inflammation characterised by temporary redness (similar to windburn) of the conjunctiva (conjunctivitis); temporary impairment of vision and/or other transient eye damage/ulceration may occur.

**Chronic:**

Long-term exposure to respiratory irritants may result in disease of the airways involving difficult breathing and related systemic problems.

Limited evidence suggests that repeated or long-term occupational exposure may produce cumulative health effects involving organs or biochemical systems.

Long term exposure to high dust concentrations may cause changes in lung function (i.e. pneumoconiosis) caused by particles less than 0.5 micron penetrating and remaining in the lung. A prime symptom is breathlessness.

TOXICITY	IRRITATION
<b>zirconium hydroxide</b>	
Not Available	Not Available

\* Value obtained from manufacturer's msds

unless otherwise specified data extracted from RTECS - Register of Toxic Effects of Chemical Substances

### ZIRCONIUM HYDROXIDE

Asthma-like symptoms may continue for months or even years after exposure to the material ceases. This may be due to a non-allergenic condition known as reactive airways dysfunction syndrome (RADS) which can occur following exposure to high levels of highly irritating compound. Key criteria for the diagnosis of RADS include the absence of preceding respiratory disease, in a non-atopic individual, with abrupt onset of persistent asthma-like symptoms within minutes to hours of a documented exposure to the irritant. A reversible airflow pattern, on spirometry, with the presence of moderate to severe bronchial hyperactivity on methacholine challenge testing and the lack of minimal lymphocytic inflammation, without eosinophilia, have also been included in the criteria for diagnosis of RADS.

<b>Acute Toxicity:</b>	Not Applicable	<b>Carcinogenicity:</b>	Not Applicable
<b>Skin Irritation/Corrosion:</b>	Skin Corrosion/Irritation Category 2	<b>Reproductivity:</b>	Not Applicable
<b>Serious Eye Damage/Irritation:</b>	Eye Irrit. 2	<b>STOT - Single Exposure:</b>	STOT - SE (Resp. Irr.) Category 3
<b>Respiratory or Skin sensitisation:</b>	Not Applicable	<b>STOT - Repeated Exposure:</b>	Not Applicable
<b>Mutagenicity:</b>	Not Applicable	<b>Aspiration Hazard:</b>	Not Applicable

### CMR STATUS

## SECTION 12 Ecological information

### Toxicity

Metal-containing inorganic substances generally have negligible vapour pressure and are not expected to partition to air. Once released to surface waters and moist soils their fate depends on solubility and dissociation in water. Environmental processes (such as oxidation and the presence of acids or bases) may transform insoluble metals to more soluble ionic forms. Microbiological processes may also transform insoluble metals to more soluble forms.

### Persistence and degradability

<b>Ingredient</b>	<b>Persistence: Water/Soil</b>	<b>Persistence: Air</b>
Not Available	Not Available	Not Available

### Bioaccumulative potential

<b>Ingredient</b>	<b>Bioaccumulation</b>
Not Available	Not Available

### Mobility in soil

<b>Ingredient</b>	<b>Mobility</b>
Not Available	Not Available

## SECTION 13 Disposal considerations

Waste treatment methods

Product / Packaging disposal:

Legislation addressing waste disposal requirements may differ by country, state and/ or territory. Each user must refer to laws operating in their area. In some areas, certain wastes must be tracked. A Hierarchy of Controls seems to be common - the user should investigate:

SECTION 14 Transport information

Labels Required:

Marine Pollutant: NO

Land transport (UN): NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS

Air transport (ICAO-IATA / DGR): NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS

Sea transport (IMDG-Code / GGVSee): NOT REGULATED FOR TRANSPORT OF DANGEROUS GOODS

SECTION 15 Regulatory information

Safety, health and environmental regulations / legislation specific for the substance or mixture

zirconium hydroxide(14475-63-9) is found on the following regulatory lists

"OECD List of High Production Volume (HPV) Chemicals", "United Nations Consolidated List of Products Whose Consumption and/or Sale Have Been Banned, Withdrawn, Severely Restricted or Not Approved by Governments", "South Africa Hazardous Chemical Substances - Recommended Limits", "South Africa Occupational Exposure Limits for Airborne Pollutants"

SECTION 16 Other information

Other information

Classification of the preparation and its individual components has drawn on official and authoritative sources as well as independent review by the Chemwatch Classification committee using available literature references.

A list of reference resources used to assist the committee may be found at:

[www.chemwatch.net/references](http://www.chemwatch.net/references)

The (M)SDS is a Hazard Communication tool and should be used to assist in the Risk Assessment. Many factors determine whether the reported Hazards are Risks in the workplace or other settings. Risks may be determined by reference to Exposures Scenarios. Scale of use, frequency of use and current or available engineering controls must be considered.

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# Appendix 7

## **Letter Report from NSW Department of Trade and Investment, Regional Infrastructure and Services – Division of Resources re: Plant Fossil Site at Grandale, DZP (20 November 2013)**

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20 November 2013

Alex Irwin  
Senior Environmental Consultant  
RW Corkery & Co Pty Limited  
62 Hill St  
Orange NSW 2800

Our Reference: OUT13/34597

EMAILED

Dear Alex

**Re: Plant fossil site at Grandale, Dubbo Zirconia project**

Thank you for the opportunity to provide advice on this matter.

Plant fossil-bearing strata occur on the flanks of a small hill (locally referred to as Fossil Hill) (Figure 1, attached) which is capped by a thin layer of basalt. The Middle Triassic plant fossils constitute the Benelong Flora (Holmes 1982) and have been described in the scientific literature (e.g. Holmes 1982; White 1986). Dr Ian Percival (Principal Research Scientist (palaeontology) Geological Survey of New South Wales) has noted that the fossils include representatives of several species which are found nowhere else. Hence, the site is scientifically significant.

It is understood that the current plan of development for the proposed Dubbo Zirconia project requires the construction of terraced tailings dams, one of which is proposed to overlap with Fossil Hill. It has therefore been necessary to ascertain how the fossil site should best be managed in order to minimise adverse impact on both the mine development and an important scientific resource.

A field inspection of the site was undertaken by Dr Lawrence Sherwin (contract palaeontologist) and myself on the 6 November 2013. A brief report by Dr Sherwin is attached. He considers that the proposed mine development will not adversely impact upon what is already a disturbed site. However, in accordance with Dr Sherwin's advice, the Mineral Resources Branch (MRB) of NSW Trade & Investment recommends that any excavation work which is carried out at the site should be inspected by a qualified person for any further geological and palaeontological information and if possible at least one exposure be retained for future reference.

NSW Department of Trade and Investment, Regional Infrastructure and Services  
RESOURCES & ENERGY DIVISION  
PO Box 344 Hunter Region Mail Centre NSW 2310  
Tel: 02 4931 6666 Fax: 02 4931 6726  
ABN 51 734 124 190  
[www.dtrir.nsw.gov.au](http://www.dtrir.nsw.gov.au)



Should you require further information regarding this matter please contact the MRB Land Use team at [landuse.minerals@industry.nsw.gov.au](mailto:landuse.minerals@industry.nsw.gov.au).

Yours sincerely

Gary Burton  
Senior Geologist Land Use



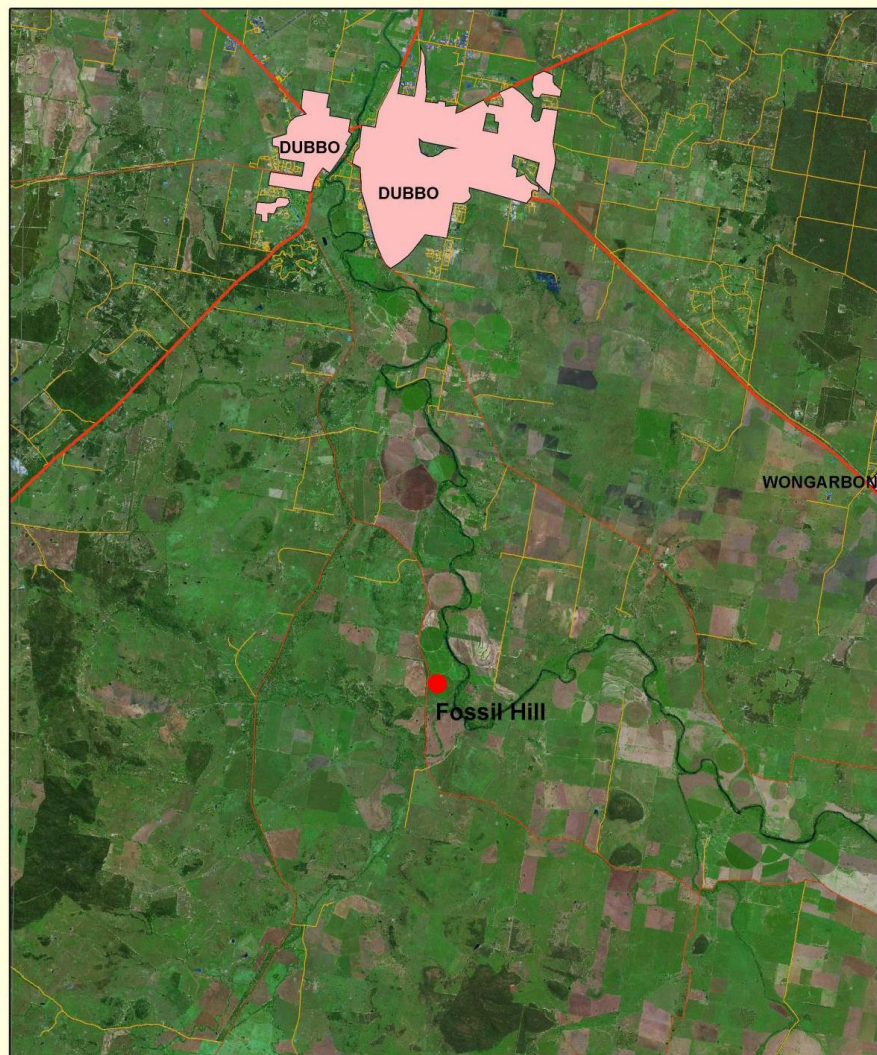


Figure 1. Location of Fossil Hill

#### Benolong fossil site

Triassic plant fossils at 'Grandale' property, better known as the Benolong flora, have been described in significant papers by Dun (1909) and Holmes (1982). The locality is also known as the 'Ugothery' site, that being the original property prior to a subdivision. Many photos of the best preserved specimens, which are outstanding examples of Triassic flora, were photographed for the volume 'The Greening of Gondwana' (White 1986). The fossiliferous beds are within the Napperby Formation (Pogson et al in Meakin & Morgan 1999). The site was visited on 6-11-2013 in company with reps from Alkane Mining and R.W. Corkery & Assocs to assess potential conflicts with the siting of evaporation ponds to be built as part of the proposed Toongi Mine. The attached photographs were taken the same day.



Figure 1.

The fossiliferous beds are in a pale grey silty claystone overlain by Tertiary basalt of probable Miocene age (Wellman & McDougall 1974) and form a low, largely cleared hill (Fig 1), also known locally as 'Fossil Hill'. Most of the recorded fossils are believed to have been collected from the northern slope (Fig 2) of this hill but the bedding of the sediments was much disrupted by rock ripping said to have taken place in 1974. Fossiliferous slabs were bulldozed into several piles (Fig 3) on the upper slope and have been much disturbed by fossil collectors in following years. Actual outcrop (Fig 4), as distinct from float, is poorly exposed.

Given the already disturbed nature of this site it is unlikely that a series of terraced evaporation ponds on this slope would cause any more damage to this significant fossil site. The construction of these ponds will very likely require a series of benches cut into the northern slope which will provide excellent exposures of the local stratigraphy. If possible, the best of these should be retained in perpetuity for their geological importance and future reference. Ideally, excavation of the site should receive periodic inspection in case any significant palaeontological discoveries are made, eg., fossil vertebrates of the kind found in the Talbragar Fish Beds,





Figure 2. View to north from 'Fossil Hill'.



Figure 3 Rock pile of fossiliferous sediments and basalt boulders.



Figure 4. Probable outcrop.

#### References

- DUN W.S. 1909. Notes on fossil plants from lower Mesozoic strata, Benolong, Dubbo district. *Records of the Geological Survey of New South Wales*, **8**, 311–317.
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- WELLMAN P.A. & MCDOUGALL I. 1974. Potassium–argon ages on the Cainozoic volcanic rocks of New South Wales. *Journal of the Geological Society of Australia*, **21**, 247–272.
- WHITE M.E. 1986. *The Greening of Gondwana*. Reed Books, Frenchs Forest NSW, 256 pp.