On the basis that no new noise sources would be introduced which could result in 'startle' response and subsequent effects on behaviour, and that the proposed increase in traffic on Obley Road would not increase noise levels significantly and remain well below the road noise criteria, it is considered unlikely that the Proposal would impact on the breeding programs of the Taronga Western Plains Zoo. The Applicant is committed to maintaining communications with zoo management and modifying operations where practicable to further minimise the potential impacts. This could include scheduling road upgrades on Obley Road in the vicinity of the zoo outside of the proposed breeding period for the relevant species.

### 4.2.8 Monitoring

The Applicant would prepare and implement a *Noise Management Plan* (NMP) and *Blast Management Plan* as previously discussed in Section 4.2.6.6. The Applicant anticipates the requirements of a noise monitoring program for the Proposal would include:

- real-time noise and blast monitoring procedures and trigger levels;
- weather station monitoring procedures and adverse weather trigger levels;
- routine and complaint-driven attended noise and blast monitoring procedures;
- review and continual improvement procedures; and
- reporting procedures, including reporting to relevant government agencies and the surrounding community.

## 4.3 AIR QUALITY

### 4.3.1 Introduction

The Director-General's Requirements (DGRs) issued by DP&I identified "***Air Quality***" as a key issue for assessment including "*a quantitative assessment of potential:*

- *construction and operational impacts, with a particular focus on dust emissions (including $PM_{2.5}$ and $PM_{10}$ emissions) and processing emissions;*
- *reasonable and feasible mitigation measures to minimise, including evidence that there are no such measures available other than those proposed; and*
- *monitoring and management measures, in particular real-time air quality monitoring."*

Additional matters for consideration in preparing the EIS were also provided in the correspondence attached to the DGRs from the NSW Environment Protection Authority (EPA) which requested that "*The goal should be to maintain existing rural air quality and protect sensitive receptors, both on and off site, from adverse impacts of dust and odour in particular and other relevant air pollutants*". The Office of Environment and Heritage requested that the EIS include "*an assessment of, and report on, the project's predicted greenhouse gas emissions ($tCO_2e$)*".

Based on the risk analysis undertaken for the Proposal (Section 3.5), the potential impacts relating to air quality and their risk rankings without the adoption of any mitigation measures are summarised as follows.

- Nuisance/amenity impacts from blasting and vehicle movements, product processing and local wind effects causing dust deposits on window sills, cars, surfaces etc. (low to medium).
- Adverse health impacts (if concentration of particulate matter less than 10µm in diameter ($PM_{10}$) are excessive) (medium to high).
- Dust generation causing decreased productivity of pastures (low).
- Increased contributions to greenhouse gases from the processing plant stacks and vents, as well as vehicle emissions (medium).
- Health related impacts (stock) due to consumption of contaminated pasture (high).
- Temporary reduction in local amenity due to odour and visible plume (medium).
- Acute health impacts associated with $NH_3$, $SO_2$ and $SO_3$ emissions (high).

The air quality and greenhouse gas impact assessment for the Proposal was undertaken by Ms Justine Firth and Mr Damon Roddis of Pacific Environment Limited (PEL). The resulting report is presented as Part 2 of the *Specialist Consultants Studies Compendium* and is referred to hereafter as "PEL (2013)". This subsection of the EIS provides a summary of the air quality and greenhouse gas impact assessment, concentrating on those matters raised in the DGRs and submissions to the DGRs provided by various government agencies. A consolidated list of the identified requirements and where each is addressed in the EIS is presented in **Appendix 3**.

## 4.3.2 Potential Sources of Air Contaminants

### 4.3.2.1 Particulate Matter and Dust Deposition

Particulate matter (PM) has the capacity to affect health and to cause nuisance effects and is categorised by its size and/or by chemical composition. The potential for harmful effects depends on both. Particulate size ranges are commonly described as follows.

- Total suspended particulates (TSP) – refers to all suspended particles in the air. In practice, the upper size range is typically 30µm to 50µm, as larger particles would usually remain in the air for only a few minutes and settle near the source.
- $PM_{10}$ – refers to all particles with equivalent aerodynamic diameters of less than 10µm, that is, all particles that behave aerodynamically in the same way as spherical particles with diameters less than 10µm and with similar unit density. $PM_{10}$ particles are a sub-component of TSP.
- $PM_{2.5}$ – refers to all particles with equivalent aerodynamic diameters of less than 2.5µm. These are often referred to as the fine particles and are a sub-component of $PM_{10}$.

In addition to health impacts, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including native vegetation and crops. Dust deposition can soil materials and property, and generally degrade aesthetic elements of the environment and are assessed for nuisance or amenity impacts.

Dust deposition includes all particle sizes however, as described for TSP, particles larger than 30µm to 50µm usually remain in the air for only a few minutes and settle near the source.

### 4.3.2.2 Oxides of Nitrogen, Sulphur Dioxide and Hydrogen Chloride

Oxides of nitrogen ($NO_x$) are produced when fossil fuels are combusted in internal combustion engines (e.g. motor vehicles, earthmoving equipment). $NO_x$ emitted by fossil fuel combustion are comprised mainly of nitric oxide (NO) and nitrogen dioxide ($NO_2$). NO is much less harmful to humans than $NO_2$ and is not generally considered an air quality parameter at the concentrations normally found in urban environments. Trace emissions of $NO_2$ are expected from various stacks within the processing plant as well as being a result of the oxidation of ammonium nitrate during blasting.

Sulphur dioxide ($SO_2$) is formed when fuel containing sulphur (mainly coal and oil) is burned. $SO_2$ is a major precursor to acid rain, which is associated with the acidification of lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility. Emissions of $SO_2$ from diesel have been progressively declining in Australia as more stringent sulphur fuel standards have been introduced, however, trace emissions are expected from some stacks within the processing plant.

The plant includes a double absorption contact process to manufacture sulphuric acid. This involves burning sulphur to produce the intermediates, $SO_2$ gas, $SO_3$ gas and finally oleum liquid, which is diluted with water to produce concentrated sulphuric acid. Trace emissions of $SO_2$ gas and $H_2SO_4$ mist are expected from the acid plant stack, particularly during start up.

Hydrochloric acid (HCl) is not readily formed in the ambient environment, with the most significant source of ambient contributions derived from anthropogenic emissions released during industrial processes. Trace emissions from the processing operations are expected.

### 4.3.2.3 Radon

As discussed in Section 2, the ore to be mined and processed contains low levels of naturally occurring uranium and thorium, which when mined can result in the release of radon gas. Radon is an inert gas and a radioactive decay product of uranium and thorium. Radon itself is not a significant source of radiation exposure, however, as a decay product of uranium has a half-life of 3.8 days and therefore is able move in air before decaying to the more hazardous shorter lived radon decay products (RnDP)[7].

[7] The Radon as a decay product of thorium has a half-life of only 1 minute and therefore it does not travel far in air before decaying. The decay subsequent decay products (Thoron Decay Products – ThDP) also have very short half-lives such that there are no long term decay products.

#### 4.3.2.4 Greenhouse Gas Emissions

Greenhouse gases would be produced as a consequence of the Proposal, the primary source of which being through the combustion of fuel by hydrocarbon-powered equipment and vehicles. Greenhouse gas emissions would also be generated through combustion of natural gas for heating purposes, on-site electricity consumption and the movement of the vehicles to and from the DZP Site. Although carbon dioxide ($CO_2$) would be the principal gas produced, greenhouse gases emitted as a result of the Project would also include carbon monoxide (CO), methane ($CH_4$), oxides of nitrogen ($NO_X$), $SO_2$, $NH_4$ and non-methane volatile organic compounds (NMVOCs). For the purposes of the air quality assessment, all greenhouse gas levels are expressed in $CO_2$ equivalent units ($CO_2$-e).

#### 4.3.2.5 Odour

An odour is perceived when chemicals in gaseous form stimulate the human olfactory system. Due to the diversity of the receptors within the nose, intensity of odour impacts can vary as reactions to odour are highly subjective. Odour is affected by climatic and seasonal conditions, with impacts increasing in intensity during calm conditions. The waste residues generated by the Proposal would have an odour and therefore assessment of impacts on surrounding landowners is required.

### 4.3.3 Existing Environment

#### 4.3.3.1 Introduction

Historical dust deposition and TSP monitoring has been conducted in the Toongi area by the Applicant between 2001 and 2002. The historical monitoring network comprised nine dust deposition gauges (DDGs) and a single High Volume Air Sampler (HVAS) fitted with a sample head for TSP. Dust deposition monitoring resumed in November 2012 as part of a baseline radiation assessment. **Figure 4.15** identifies the location of the historic and current monitoring locations.

As there is limited monitoring data available for the DZP Site, EPA monitoring stations from further afield have been referenced. It is acknowledged that these monitoring locations are geographically distant from the DZP Site, however, the data is considered to be useful in providing an indicative (although conservatively high) estimate of background air quality for rural areas in NSW.

The EPA sites selected are based on distance from the DZP Site, land use in the vicinity of the monitoring station and site representation.

The following sources have been referenced to establish baseline air quality:

- current dust deposition monitoring (see **Figure 4.15**);
- historical dust deposition monitoring (see **Figure 4.15**);
- historical TSP monitoring (see **Figure 4.15**);
- $PM_{10}$ data from Bathurst, located 140km southeast of the DZP Site;
- $PM_{10}$ data from Tamworth, located 260km northeast of the DZP Site;
- $SO_2$ data from Bargo, located 280km southeast of the DZP Site; and
- $NO_2$ data from Beresfield, located 280km southeast of the DZP Site.

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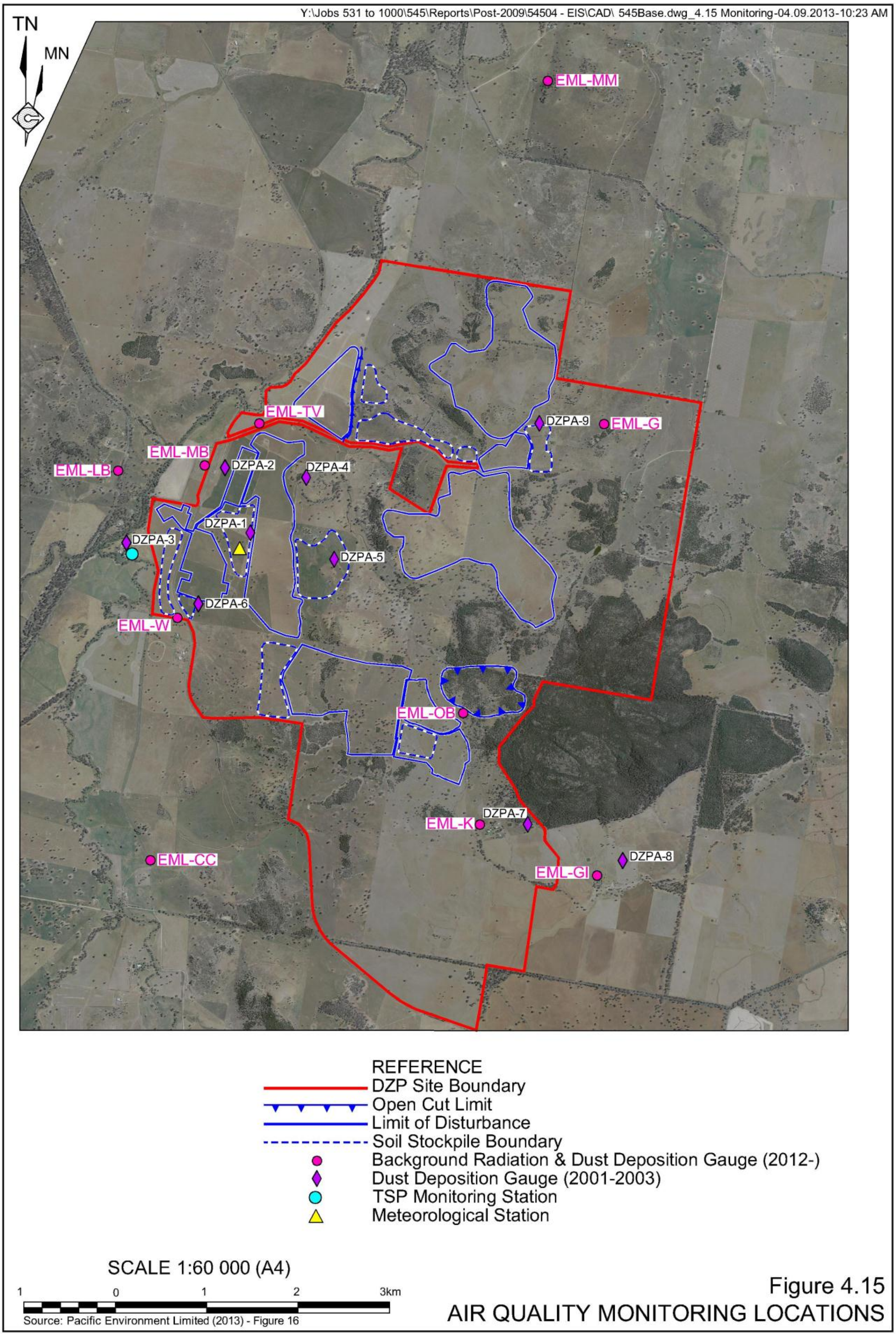



Source: Pacific Environment Limited (2013) - Figure 16

Figure 4.15
AIR QUALITY MONITORING LOCATIONS

#### 4.3.3.2 Deposited Dust

Dust deposition was monitored at nine Dust Deposition Gauges (DZPA-1 to DZPA-9) on and surrounding the DZP Site from March 2001 to February 2003 (see **Figure 4.15**). With the exception of November and December 2002, the monitored locations have reported dust deposition levels below the 4g/m$^2$/month dust fallout goal. The high dust levels recorded for November and December of 2002 is consistent with the low rainfall recorded for these months in the area. Furthermore, annual grain harvest occurs in November and December each year which coinciding with livestock grazing on crop stubble makes this a locally dusty time of year. The annual average dust deposition rate across all nine dust gauges was 1.0g/m$^2$/month for March 2001 to February 2002 and 1.2g/m$^2$/month for March 2002 to February 2003.

The current dust monitoring program commenced in September 2012 as part of a baseline radiation monitoring program and provides for the collection of dust deposition data quarterly at ten locations (prefaced as EML- on **Figure 4.15**). The quarterly data is then averaged to provide monthly and daily estimates for comparison against the NSW EPA criteria of 4 g/m$^2$/month. To date, only two months of data are available, however, this data show that the measured levels are well below the criterion. A background dust deposition level of 2g/m$^2$/month (annual average) has been adopted for this assessment.

#### 4.3.3.3 Particulate Matter

**Total Suspended Particulates**

The 24-hour TSP concentrations recorded at DZPA-3 for the period from March 2001 to April 2002 are presented in **Table 4.19.** The annual average TSP concentration of 19µg/m$^3$ for the monitored year is well below the EPA criterion of 90µg/m$^3$.

**Table 4.19**
**TSP Monitoring Results for March 2001to February 2002**

| Averaged Period | Average TSP Concentration (µg/m$^3$) |
|---|---|
| Mar-01 | 14 |
| Apr-01 | 19 |
| May-01 | 12 |
| Jun-01 | 5 |
| Jul-01 | 6 |
| Aug-01 | 4 |
| Sep-01 | 10 |
| Oct-01 | 12 |
| Nov-01 | 24 |
| Dec-01 | 41 |
| Jan-02 | 63 |
| Feb-02 | 17 |
| **Annual Average (Mar 2001- Feb 2002)** | **19** |
| Source: PEL (2013) - Table 13 | |

The more elevated concentration in November to January is illustrative of local land use during these months, namely grain harvest and livestock grazing.

### Particulate Matter less than 10 microns ($PM_{10}$)

There is no site specific $PM_{10}$ monitoring data available in the vicinity of the DZP Site. As indicated in Section 4.3.3.1, reference can be made to available monitoring data collected by the EPA in rural NSW. A time series of the 24-hour $PM_{10}$ concentrations recorded at Tamworth and Bathurst from January 2008 to February 2013 is presented in **Figure 4.16**. The annual average $PM_{10}$ for each site is shown in **Table 4.20**.

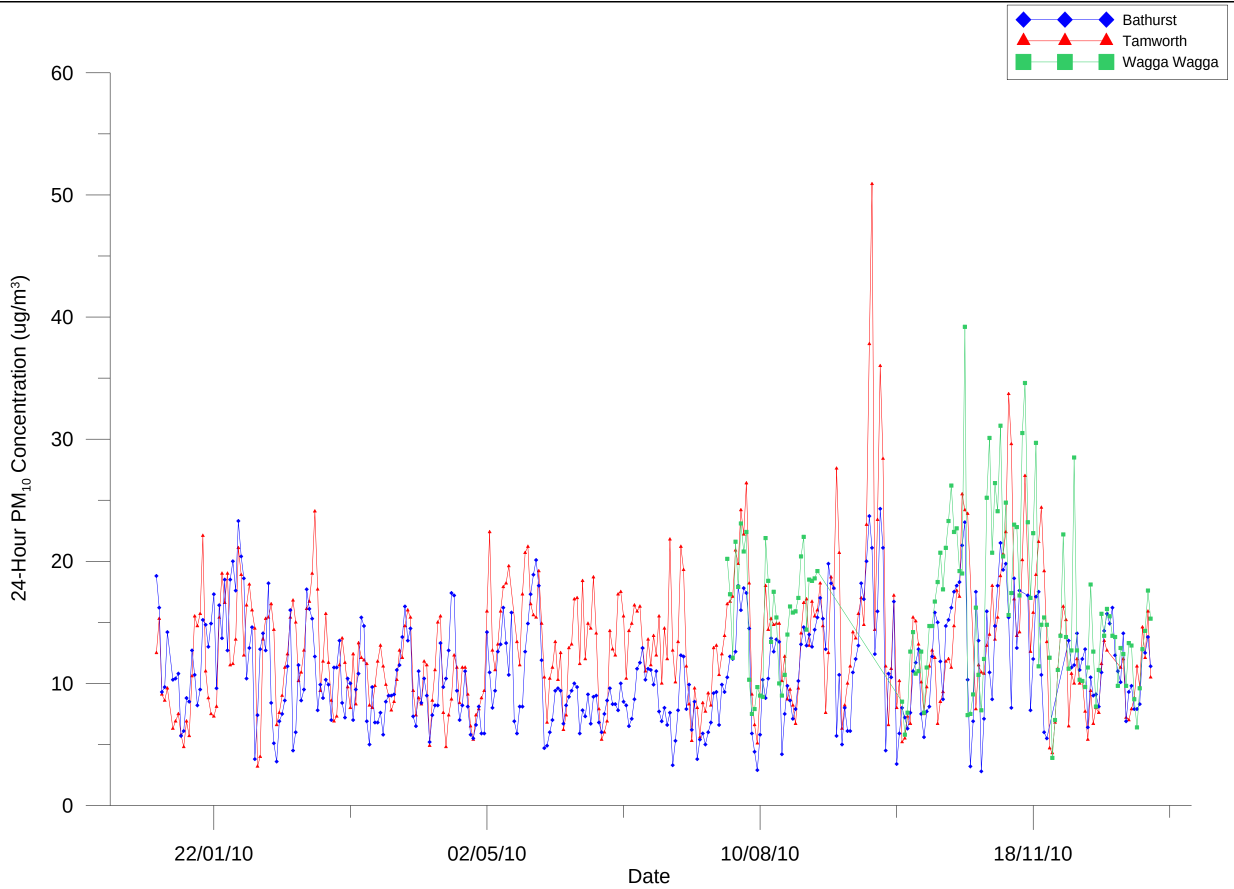



**Figure 4.16**
**OEH 24-HOUR $PM_{10}$ MONITORING DATA (µg/m³)**

Source: PEL (2013) - Figure 18

**Table 4.20**
**Annual Average $PM_{10}$ Concentration for Rural NSW**

| Year | Tamworth (µg/m³) | Bathurst (µg/m³) |
|---|---|---|
| 2008 | 16 | 14 |
| 2009 | 22 | 17 |
| 2010 | 12 | 9 |
| 2011 | 13 | 11 |
| 2012 | 16 | 13 |
| 2013[1] | 14 | 16 |
| Average | 16 | 13 |
| Note 1: Data available to 20 February 2013 | | |
| Source: PEL (2013) - Table 14 | | |

For scaling purposes, the 24-hour average $PM_{10}$ concentrations measured on the day of a significant dust storm that impacted much of the east of Australia on 23 September 2009 has been removed from the dataset. All other significant weather events have been included in the datasets.

The annual average data shows that 2009 experienced the highest annual average $PM_{10}$ concentration at both monitoring stations. This result is likely due to the prevailing drought conditions across NSW during this period. The average across both data sets is 16µg/m$^3$ and has been adopted as the annual average $PM_{10}$ background for this assessment.

### Particulate Matter less than 2.5 microns ($PM_{2.5}$)

As with $PM_{10}$, there is no site specific $PM_{2.5}$ monitoring data available in the vicinity of the DZP Site. The closest and most similar in environment to the DZP Site is the $PM_{2.5}$ concentration data measured at Wagga Wagga North.

Data from this site is considered highly conservative and would provide a site representative dataset for the Proposal due to ongoing air quality issues in the area. The annual average $PM_{2.5}$ concentration ranges between 7µg/m$^3$ and 9µg/m$^3$. The NEPM advisory reporting standard is 8µg/m$^3$. An annual average $PM_{2.5}$ concentration of 7µg/m$^3$ has been conservatively adopted for this assessment.

## 4.3.3.4 Other Air Quality Parameters

### Sulphur Dioxide

The 1-hour maximum $SO_2$ concentrations measured at the EPA's Bargo monitoring site between 2009 and 2012 are presented in **Table 4.21**. The maximum recorded 1-hour average concentration was 31µg/m$^3$, well below the EPA criterion of 570µg/m$^3$.

**Table 4.21**
**1-hour maximum $SO_2$ concentrations for Bargo**

| Year | 1-hour maximum (µg/m$^3$) |
|---|---|
| **EPA criterion** | **570** |
| 2008 | 31 |
| 2009 | 23 |
| 2010 | 29 |
| 2011 | 26 |
| 2012 | 27 |
| **Average** | **27** |
| Source: PEL (2013) - Table 15 | |

### Nitrogen Dioxide

The annual average and 1-hour maximum $NO_2$ concentrations measured at the EPA's Bargo monitoring site between 2009 and 2012 are presented in **Table 4.22**. The annual average $NO_2$ concentrations range between 10µg/m$^3$ and 12µg/m$^3$, with the average across all years being 11µg/m$^3$. The maximum recorded 1-hour average concentration was 126µg/m$^3$, well below the EPA criterion of 246µg/m$^3$. The daily varying values within this data set have been adopted for this assessment.

**Table 4.22**
**Annual Average and 1-hour maximum $NO_2$ concentrations for Bargo**

| Year | Annual average (µg/m³) | 1-hour maximum (µg/m³) |
|---|---|---|
| **EPA criterion** | **62** | **246** |
| 2008 | 12 | 83 |
| 2009 | 10 | 103 |
| 2010 | 10 | 126 |
| 2011 | 10 | 98 |
| 2012 | 10 | 94 |
| Average | 11 | 101 |
| Source: PEL (2013) - Table 16 | | |

### Hydrogen Chloride and Fluoride

There is no available monitoring data for hydrogen chloride (HCl) or hydrogen fluoride (HF) in the vicinity of the DZP Site or as part of the EPA monitoring network. In consideration of the predominantly agricultural surrounding land use and distinct lack of industry that would likely contribute to background HCl and HF baseline levels, it has been assumed that the respective air quality parameters would be present at very low levels, if not trace concentrations. In any event, the Approved Methods[8] require that only the incremental (as opposed to the cumulative) impact requires evaluation.

### 4.3.3.5 Summary of Air Quality Parameters

Based on the available monitoring data described in Sections 4.3.3.2 to 4.3.3.4, **Table 4.23** provides a summary of the background concentrations to be adopted for the assessment.

**Table 4.23**
**Adopted Background Contributions**

| Air quality parameter | Averaging period | EPA criteria | Adopted background concentration |
|---|---|---|---|
| Dust deposition | Annual | 4g/m²/month | 2g/m²/month |
| TSP annual | Annual | 90µg/m³ | 19µg/m³ |
| $PM_{10}$ | Annual | 30µg/m³ | 16µg/m³ |
| | 24 hour | 50µg/m³ | Daily varying |
| $PM_{2.5}$ | Annual | 8µg/m³ | 7µg/m³ B |
| | 24 hour | 25µg/m³ | n/a |
| $SO_2$ | Annual A | 60µg/m³ | 3µg/m³ |
| | 24 hour A | 228µg/m³ | 11µg/m³ |
| | 1 hour | 570µg/m³ | 27µg/m³ |
| | 10 minute A | 712µg/m³ | 34µg/m³ |
| $NO_2$ | Annual | 62µg/m³ | Daily varying |
| | 1 hour | 246µg/m³ | Daily varying |
| Note A: Pro-rated in accordance with the 1-hour monitoring data for $SO_2$ | | | |
| Note B: In consideration of the relatively higher $PM_{10}$ concentrations measured at Wagga Wagga and Wagga Wagga North, the annual average $PM_{2.5}$ background contribution has been assumed. | | | |
| Source: PEL (2013) - Table 17 | | | |

[8] *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (EPA, 2005)

#### 4.3.3.6 Greenhouse Gases

Existing background concentrations of carbon dioxide and methane are recognised to be negligible and typical of a rural area.

### 4.3.4 Assessment Criteria

#### 4.3.4.1 Particulate Matter and Dust Deposition

The Approved Methods (DEC, 2005) specify the air quality assessment criteria relevant for assessing impacts from air pollution. These criteria are in fact health-based (i.e. they are set at levels to protect against health effects) and are consistent with the *National Environment Protection Measure for Ambient Air Quality* (referred to as the Ambient Air-NEPM) (NEPC, 1998a, 2003). However, the EPA's criteria include averaging periods which are not included in the Ambient Air-NEPM. Conversely, the Ambient Air NEPM recognises it is realistic to accept up to five exceedances of the 24-hour $PM_{10}$ level per year.

**Table 4.24** summarises the air quality criteria for concentrations of particulate matter that are relevant to the investigations undertaken by PEL.

**Table 4.24**
**Air Quality Standards/Criteria for Particulate Matter Concentrations**

| Pollutant | Averaging Period | Standard/Goal | Agency |
|---|---|---|---|
| TSP | Annual mean | 90µg/m$^3$ | National Health and Medical Research Council. |
| $PM_{10}$ | Maximum 24-hour average | 50µg/m$^3$ | EPA impact assessment criteria;<br>Ambient Air-NEPM reporting goal, allows five exceedances per year |
| | Annual mean | 30µg/m$^3$ | EPA impact assessment criteria. |
| $PM_{2.5}$ | Annual Mean | 8µg/m$^3$ | Ambient Air-NEPM Advisory Reporting Standard. |
| | Maximum 24-hour average | 25µg/m$^3$ | |
| Note: µg/m$^3$ – micrograms per cubic metre. | | | |
| Source: PEL (2013) - modified after Tables 4 and 5 | | | |

It is noted that the Ambient Air-NEPM $PM_{2.5}$ advisory reporting standards are not impact assessment criteria. Notwithstanding, and in the absence of any other relevant standard/goal, the advisory reporting standards have been used in this report for comparison against dispersion modelling results (Section 4.3.7).

In addition to health impacts, airborne dust also has the potential to cause nuisance effects by depositing on surfaces, including vegetation. Referred to as dust deposition, this can soil materials and generally degrade aesthetic elements of the environment, and are assessed for nuisance or amenity impacts. **Table 4.25** shows the maximum acceptable increase and accumulation with other sources in dust deposition over the existing dust levels from an amenity perspective. These criteria for dust deposition levels are set to protect against nuisance impacts (EPA, 2005).

**Table 4.25**
**EPA Criteria for Dust (Insoluble Solids) Deposition**

| Pollutant | Averaging Period | Maximum Increase in Deposited Dust Level | Maximum Total Deposited Dust Level |
|---|---|---|---|
| Deposited Dust | Annual | $2g/m^2$/month | $4g/m^2$/month |
| Note: $g/m^2$/month – grams per square metre per month. | | | |
| Source: PEL (2013) - Table 6 | | | |

### 4.3.4.2 Gaseous Air Quality Parameters Assessment Criteria

**Table 4.26** summarises the air quality criteria nominated in the Approved Methods (EPA, 2005) for concentrations of gaseous air quality parameters that are relevant to this assessment, i.e. contained within diesel fume and blast assessments.

**Table 4.26**
**Air Quality Criteria for Gaseous Air Quality Parameters**

| Air quality parameter | EPA Impact assessment criteria | Averaging Period |
|---|---|---|
| Sulphur Dioxide | 712 µg/m³ (0.25 ppm) | 10-minute |
| | 570 µg/m³ (0.2 ppm) | 1-Hour |
| | 228 µg/m³ (0.08 ppm) | 24-Hour |
| | 60 µg/m³ (0.02 ppm) | Annual |
| Nitrogen Dioxide | 246 µg/m³ (0.12 ppm) | 1-Hour |
| | 62 µg/m³ (0.03 ppm) | Annual |
| Hydrogen Chloride | 0.14 mg/m³ (0.09 ppm) | 1 hour |
| Source: PEL (2013) – Table 7 (after EPA, 2005) | | |

### 4.3.4.3 Odour

The Approved Methods include ground-level concentration (GLC) criterion for complex mixtures of odorous air compounds. They have been refined by the EPA to take account of population density in the area. **Table 4.27** lists the odour glc criterion to be exceeded not more than 1% of the time, for different population densities.

**Table 4.27**
**Odour Performance Criteria for the Assessment of Odour**

| Population of affected community | GLC criterion for complex mixtures of odorous air quality parameters (OU) |
|---|---|
| ~2 | 7 |
| ~10 | 6 |
| ~30 | 5 |
| ~125 | 4 |
| ~500 | 3 |
| Urban (2000) and/or schools and hospitals | 2 |
| Source: Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW (EPA, 2005) | |

A conservative approach has been adopted in the determination of the odour impact assessment criteria by basing the criteria on the most densely populated area within the vicinity of the Proposal. There are five sensitive receptors[9] located within a 1km$^2$ area to the immediate west of the DZP Site. On the basis that each receptor would be home to two people, it is appropriate to adopt an impact assessment GLC criterion of 6 OU (see **Table 4.27**).

## 4.3.5 Assessment Methodology

### 4.3.5.1 Modelling Methodology

The overall approach to the assessment undertaken by PEL (2013) follows the Approved Methods (EPA, 2005) using the Level 2 assessment methodology. The Approved Methods specify how assessments based on the use of atmospheric dispersion models should be completed. The atmospheric dispersion modelling conducted by PEL (2013) is based on an advanced modelling system using The Air Pollution Model (TAPM) and CALMET/CALPUFF.

### 4.3.5.2 Particulate Matter Emissions

Particulate matter emissions were calculated for the following.

- Particulate matter from the surface operations from the Proposal.
- Odour emissions from the SRSF and LRSF.
- Radon emissions from ore handling activities and exposed areas.
- Other air emissions released from the processing plant ($SO_2$, $NO_2$ and HCl).

The proposed operations were analysed and estimates of dust emissions for the key dust generating activities made by PEL (2013). Emission factors developed both in Australia, and by the US EPA, were applied to estimate the amount of dust produced by each activity. The emission factors applied are considered to be the most reliable, contemporary methods for determining dust generation rates.

The proposed development sequence of the Proposal has been analysed and detailed dust emissions inventories prepared by PEL (2013) for two key operating scenarios, namely Year 5 and Year 15 of operations. These years are considered to be representative of worst-case operations, i.e. where ore and waste rock production are highest, where extraction or wind erosion areas are largest and where operations are located closest to receptors.

Estimates of TSP, $PM_{10}$ and $PM_{2.5}$ emissions for each source were developed on an hourly time step taking into account the activities that would take place at that location. Thus, for each source, for each hour, an emission rate was determined which depended upon the level of activity and the wind speed. Dust generating activities were represented by a series of volume sources situated according to the location of activities for the modelled scenarios.

[9] The assessment has conservatively considered the residences of Toongi, which are Proposal-related, as sensitive for the purpose of the odour assessment.

#### 4.3.5.3 Radon

The potential radon emissions that would be released during the operations of the Proposal have been assessed for Year 15, as PEL (2013) considers that Year 15 would result in the worst case radon emission based on the anticipated area of the LRSF that would be in use in that year.

The radon emission rates were provided by JRHC Enterprises, commissioned by the Applicant to complete a detailed radiation assessment for the Proposal (JRHC Enterprises, 2013). All radon emissions have been modelled as area sources, with the exception of emissions that would potentially be released from the processing plant. It has been assumed that all radon emissions from the processing plant would be released as a point source emission from the Ore Mill Exhaust Vent.

#### 4.3.5.4 Other Air Quality Parameters

Other air quality parameters anticipated to be released during the operation of the Proposal include $SO_2$, $NO_2$, HCl and limited concentrations of $SO_3$. For the purposes of this assessment, $SO_2$, $NO_2$ and HCl are considered the principal air quality parameters of concern and were included in the dispersion modelling completed by PEL (2013), as point source emissions from various stacks and vents at the processing plant.

#### 4.3.5.5 Odour Emissions

Based on the composition of the wastes produced as part of the ore processing operations, these would produce an odour which would be released when placed within the SRSF and LRSF.

- The liquid residues may contain ammonia.
- The solid residue would comprise a complex mixture of odorous compounds that may include $H_2S$.

Odour testing was completed for samples of each residue stream with the results presented in **Table 4.28**.

**Table 4.28**
**Odour Testing Results**

| Sample | Sample Description | Date (Time) | Odour Concentration (OU) | Specific Odour Emission Rate (OU - $m^3/m^2/s$) | Odour Character |
|---|---|---|---|---|---|
| Liquid Residue | Prepared immediately prior to sampling | 6/12/2012 (15:10) | 256 | 0.15 | Musty / Stale Water |
| Solid Residue | Prepared immediately prior to sampling | 12/02/2013 (11:28) | 128 | 0.08 | Musty / Stale Water |
| Source: PEL (2013) – Table 19 | | | | | |

Taking into account various factors influencing the odour of the residues, including the reduction in odour over time (assumed to be odourless after 7 days), odour emissions from the two waste streams were modelled by PEL (2013) as area sources with a vertical spread of 0.5m for the Year 15 scenario.

#### 4.3.5.6 Greenhouse Gas Emissions

Greenhouse Gas (GHG) emissions have been estimated based on the methods outlined in the following documents.

- The World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) Greenhouse Gas Protocol *The Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard Revised Edition* (WRI/WBCSD, 2004).
- *National Greenhouse and Energy Reporting (Measurement) Determination 2008*.
- The Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) *National Greenhouse Accounts* (NGA) *Factors 2012* (DCCEE, 2012).

The GHG Protocol establishes an international standard for accounting and reporting of GHG emissions. The GHG Protocol has been adopted by the International Standard Organisation, endorsed by GHG initiatives (such as the Carbon Disclosure Project) and is compatible with existing GHG trading schemes.

Three 'scopes' of emissions (scope 1, scope 2 and scope 3) are defined for GHG accounting and reporting purposes. This terminology has been adopted in Australian GHG reporting and measurement methods and has been employed in this assessment.

Inventories of GHG emissions can be calculated using published emission factors. Different gases have different greenhouse warming effects (referred to as global warming potentials) and emission factors take into account the global warming potentials of the gases created during combustion. The estimated emissions are referred to in terms of carbon dioxide equivalent, or $CO_2$-e, emissions by applying the relevant global warming potential. The greenhouse gas assessment has been conducted using the NGA Factors, published by the DCCEE (2012).

Proposal-related GHG sources included in the assessment are as follows.

- Fuel consumption (diesel) during mining operations – Scope 1.
- Indirect emissions associated with on-site electricity use – Scope 2.
- Indirect emissions associated with the production of transport fuels – Scope 3.
- Indirect emissions associated with the production of electricity – Scope 3.

GHG emissions for the three transport options considered (see Section 2.12.1) were calculated by PEL (2013).

### 4.3.6 Management and Mitigation Measures

#### 4.3.6.1 Introduction

The following subsections summarise management measures to be adopted by the Applicant for specific stages or features of the Proposal.

#### 4.3.6.2 Dust Management – Site Establishment Stage

Prior to the commencement of construction, the Applicant would identify triggers and prepare procedures for dealing with unfavourable meteorological conditions, such as when it is dry and windy.

Procedures for controlling dust impacts during construction would include, but not necessarily be limited to the following.

- Adopting a Level 2 watering to achieve 75% control of dust from haul roads.
- Applying gravel to disturbed areas where possible.
- Establishing rehabilitation / cover crops where possible over exposed areas.
- Modifying working practices by limiting excavation during periods of high winds.
- Limiting the extent of clearing of vegetation and topsoil to the designated footprint required for construction and appropriate staging of any clearing.
- Confining all vehicles on site to designated routes with speed limits enforced.
- Controlling and reducing trips and trip distances where possible, for example by coordinating delivery and removal of materials to avoid unnecessary trips.

#### 4.3.6.3 Dust Management - Operations

An *Air Quality Management Plan* (AQMP) would be prepared prior to the commencement of operations and would identify procedures for controlling dust impacts during operations including, but not necessarily limited to the following.

- Adopting a Level 2 watering to achieve 75% control of dust from haul roads.
- Implementing water injection during drilling of ore and overburden.
- Prevention of wind erosion on stockpiled material.

#### 4.3.6.4 Processing Plant Controls

The following mitigation measures would be adopted to minimise emissions to atmosphere from the processing plant.

- The operation of a bag house to capture particulate matter from the grinding mill.
- Emissions from the stacks and vents would be regulated by operating within the prescribed in-stack concentrations limits. This would be initially determined through the detailed design phase and verified by in-stack monitoring.
- Periodic extractive monitoring would be undertaken to demonstrate compliance with in-stack limits (every 3 months for the first year of operation and then annually, thereafter if compliance is easily achieved).
- Implement a regular and documented maintenance and inspection program for all plant items where emissions to air are deemed likely.

#### 4.3.6.5 Greenhouse Gas

The following mitigation measures are proposed to minimise greenhouse gas emissions from the Proposal.

- Maximise energy efficiency as a key consideration in the development of the mine plan. This includes electricity and process steam co-generation from the waste heat of the sulphuric acid plant.
- Implement an energy use and efficiency program.
- Undertake regular maintenance on diesel and electrically powered plant to ensure they operate efficiently.
- Develop targets for greenhouse gas emissions and energy use, and monitor and report against these.
- Dedicate a number of trucks for the excavator to minimise truck idling times.
- Ensure that haul trucks are fully loaded to maximise productivity and efficiency.
- Assess and periodically review lighting plant efficiency.

The effectiveness of these reasonable and feasible measures to reduce GHG emissions (and energy consumption) would be monitored and the Applicant would estimate its annual GHG emissions and energy consumption in accordance with its commitments under the National Greenhouse and Energy Reporting (NGER) scheme.

### 4.3.7 Assessment of Impacts

#### 4.3.7.1 Introduction

The following subsections outline the modelling results for the following air quality parameters and averaging periods prepared by PEL (2013).

- TSP – annual average.
- Deposited dust – annual average.
- $PM_{10}$ – 24-hour and annual average.
- $PM_{2.5}$ – 24-hour and annual average.
- $SO_2$ – 10 minute, 1-hour, 24-hour and annual average.
- $NO_2$ – 1-hour and annual average.
- HCl – 1-hour average.
- Odour – $99^{th}$ percentile and 1-second average.

Particulate matter (including dust deposition) was assessed for Year 5 and Year 15 with the remaining parameters assessed for Year 15 only. Results of the radon modelling have been presented in Section 4.4.8.

Contour plots of air quality parameter concentrations and particulate matter deposition levels (*Figures 24* to *35* and *38* to *44* of PEL, 2013) illustrate where different concentrations of the various air quality parameters are predicted to occur spatially. It is important to note that the contour figures are presented to provide a visual representation of the predicted impacts. To produce the contours, it is necessary to make interpolations, and as a result the contours do not always match exactly with predicted impacts at any specific location.

The actual predicted particulate concentrations/levels at nearby receptors are presented in tabular form throughout the following subsections, with those that are predicted to experience levels above the EPA's impact assessment criteria or NEPM advisory reporting goals identified in **bold**.

#### 4.3.7.2 Annual Average TSP, $PM_{10}$, $PM_{2.5}$ and Dust Deposition

**Table 4.29** presents a summary of the Year 5 and 15 predicted annual average concentrations at each of the nearby receptors, due to the operation of the Proposal cumulatively with other sources/background predictions.

Contour plots for cumulative annual average TSP, $PM_{10}$, $PM_{2.5}$ and dust deposition concentrations for Year 15 are presented in **Figure 4.17**.

**Table 4.29**
**Annual Average TSP, $PM_{10}$, $PM_{2.5}$ and Dust Deposition Concentration – Year 5 and 15**

Page 1 of 2

| Air Quality Parameter | TSP ($\mu g/m^3$) | $PM_{10}$ ($\mu g/m^3$) | $PM_{2.5}$ ($\mu g/m^3$) | Dust Deposition ($g/m^2$/month) | TSP ($\mu g/m^3$) | $PM_{10}$ ($\mu g/m^3$) | $PM_{2.5}$ ($\mu g/m^3$) | Dust Deposition ($g/m^2$/month) |
|---|---|---|---|---|---|---|---|---|
| ***Adopted Background*** | ***19*** | ***16*** | ***7*** | ***2*** | ***19*** | ***16*** | ***7*** | ***2*** |
| ***Criteria ($\mu g/m^3$)*** | ***90*** | ***30*** | ***8*** | ***4g/m²/month*** | ***90*** | ***30*** | ***8*** | ***4g/m²/month*** |
| **Receptor [E]** | **Cumulative Prediction Year 5** | | | | **Cumulative Prediction Year 15** | | | |
| R1 [A] | 21.6 | 17.1 | 7.5 | 2 | 27.4 | 18.2 | 7.7 | 2 |
| R2 [A] | 23.7 | 17.4 | 7.5 | 2 | 30.3 | 18.9 | 7.8 | 3 |
| R3 [A] | 19.5 | 16.2 | 7.1 | 2 | 20.8 | 16.6 | 7.3 | 2 |
| R4 | 19.2 | 16.1 | 7.0 | 2 | 19.6 | 16.2 | 7.1 | 2 |
| R6 | 19.3 | 16.1 | 7.1 | 2 | 19.6 | 16.2 | 7.1 | 2 |
| R7A | 19.3 | 16.2 | 7.1 | 2 | 19.8 | 16.3 | 7.1 | 2 |
| R7B [G] | 19.3 | 16.2 | 7.1 | 2 | 19.8 | 16.3 | 7.1 | 2 |
| R8A | 19.4 | 16.2 | 7.1 | 2 | 20.0 | 16.3 | 7.2 | 2 |
| R8B | 19.2 | 16.1 | 7.1 | 2 | 19.4 | 16.1 | 7.1 | 2 |
| R12 [F] | 20.7 | 16.8 | 7.4 | 2 | 23.9 | 17.4 | 7.5 | 2 |
| R18 | 19.2 | 16.1 | 7.1 | 2 | 19.6 | 16.2 | 7.1 | 2 |
| R19 | 19.7 | 16.4 | 7.3 | 2 | 21.7 | 16.9 | 7.4 | 2 |
| R20 | 20.0 | 16.6 | 7.5 | 2 | 22.9 | 17.3 | 7.7 | 2 |
| R21 | 19.3 | 16.3 | 7.3 | 2 | 19.8 | 16.4 | 7.3 | 2 |
| R22 | 20.1 | 16.6 | 7.4 | 2 | 22.2 | 17.0 | 7.5 | 2 |
| R23 | 20.0 | 16.6 | 7.4 | 2 | 21.9 | 17.0 | 7.4 | 2 |
| R24 | 19.9 | 16.6 | 7.4 | 2 | 21.6 | 16.9 | 7.5 | 2 |
| R25 | 19.9 | 16.6 | 7.4 | 2 | 21.6 | 16.9 | 7.5 | 2 |
| R26 | 19.4 | 16.4 | 7.3 | 2 | 20.2 | 16.6 | 7.4 | 2 |

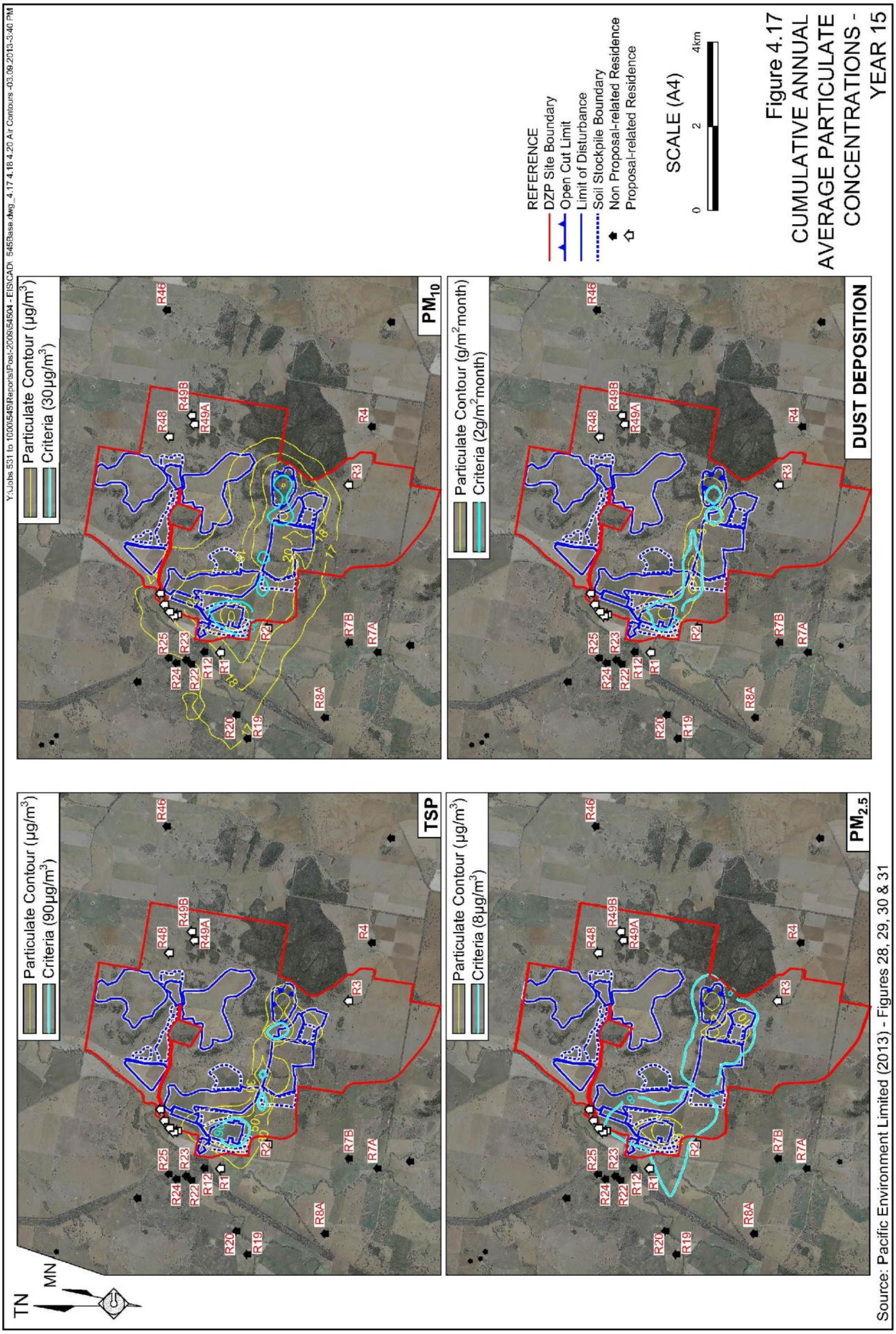
**Table 4.29 (Cont'd)**
**Annual Average TSP, $PM_{10}$, $PM_{2.5}$ and Dust Deposition Concentration – Year 5 and 15**

Page 2 of 2

| Air Quality Parameter | TSP (µg/m³) | $PM_{10}$ (µg/m³) | $PM_{2.5}$ (µg/m³) | Dust Deposition (g/m²/month) | TSP (µg/m³) | $PM_{10}$ (µg/m³) | $PM_{2.5}$ (µg/m³) | Dust Deposition (g/m²/month) |
|---|---|---|---|---|---|---|---|---|
| **Adopted Background** | **19** | **16** | **7** | **2** | **19** | **16** | **7** | **2** |
| ***Criteria (µg/m³)*** | ***90*** | ***30*** | ***8*** | ***4g/m²/month*** | ***90*** | ***30*** | ***8*** | ***4g/m²/month*** |
| **Receptor [E]** | **Cumulative Prediction Year 5** | | | | **Cumulative Prediction Year 15** | | | |
| R27 | 19.1 | 16.1 | 7.1 | 2 | 19.4 | 16.2 | 7.1 | 2 |
| R28A | 19.1 | 16.1 | 7.1 | 2 | 19.4 | 16.2 | 7.1 | 2 |
| R28B | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.2 | 7.1 | 2 |
| R30A | 19.1 | 16.1 | 7.1 | 2 | 19.4 | 16.2 | 7.1 | 2 |
| R30B | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.2 | 7.1 | 2 |
| R31A | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.2 | 7.1 | 2 |
| R31B | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.1 | 7.1 | 2 |
| R32 | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.2 | 7.1 | 2 |
| R35A | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.2 | 7.1 | 2 |
| R35B | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.1 | 7.1 | 2 |
| R38 | 19.1 | 16.1 | 7.1 | 2 | 19.3 | 16.1 | 7.1 | 2 |
| R36 | 19.1 | 16.1 | 7.1 | 2 | 19.4 | 16.2 | 7.1 | 2 |
| R40 | 19.1 | 16.1 | 7.1 | 2 | 19.4 | 16.2 | 7.1 | 2 |
| R42 | 19.1 | 16.1 | 7.0 | 2 | 19.3 | 16.1 | 7.1 | 2 |
| R43 | 19.1 | 16.1 | 7.0 | 2 | 19.4 | 16.1 | 7.1 | 2 |
| R46 | 19.2 | 16.1 | 7.0 | 2 | 19.5 | 16.2 | 7.1 | 2 |
| R48 [A] | 19.5 | 16.2 | 7.1 | 2 | 20.2 | 16.4 | 7.2 | 2 |
| R49A [A] | 19.4 | 16.2 | 7.1 | 2 | 20.3 | 16.4 | 7.2 | 2 |
| R49B [A] | 19.4 | 16.1 | 7.1 | 2 | 20.1 | 16.4 | 7.2 | 2 |
| R51 [B] | 20.5 | 16.7 | 7.4 | 2 | 23.8 | 17.5 | 7.6 | 2 |
| R54 [B] | 21.4 | 17.2 | 7.6 | 2 | 27.1 | 18.4 | 7.9 | 2 |
| R55 [C] | 21.1 | 17.1 | 7.6 | 2 | 26.2 | 18.2 | 7.8 | 2 |
| R56 [A] | 21.9 | 17.4 | 7.7 | 2 | 28.9 | 18.9 | 8.0 | 2 |
| R58 [C] | 20.7 | 16.9 | 7.5 | 2 | 24.9 | 17.8 | 7.7 | 2 |
| R61 | 19.1 | 16.0 | 7.0 | 2 | 19.2 | 16.1 | 7.0 | 2 |
| R50 [D] | 19.9 | 16.3 | 7.2 | 2 | 21.2 | 16.7 | 7.3 | 2 |

Note A: Residence owned by the Applicant
Note B: Negotiated 'Call' Option for the Residence between the Applicant and current owner (to be exercised by the Applicant)
Note C: Negotiated 'Put' Option for the Residence between the Applicant and current owner (to be exercised by the owner)
Note D: Allocated location for possible future residence (property has dwelling entitlement)
Note E: Refer to **Figure 4.6** Note F: R12 is referred to as Receptor 10 in PEL (2013)
Note G: Inferred from contour plot Source: PEL (2013) – modified after Table 24 and 25

A review of *Tables 24* and *25* of PEL (2013) indicates that the incremental contributions of the proposed operations to the local air quality are relatively low compared to the contribution of background sources. Accordingly, the modelling results for Year 5 and 15 (see **Table 4.29**) predict no exceedance of the annual average TSP, $PM_{10}$, $PM_{2.5}$ and dust deposition EPA criteria and NEPM advisory reporting standards, either for the Proposal alone (incremental prediction) (refer to PEL, 2013) or when considering the adopted background (cumulative prediction).


TSP
Particulate Contour (µg/m³)
Criteria (90µg/m³)
PM10
Particulate Contour (µg/m³)
Criteria (30µg/m³)
PM2.5
Particulate Contour (µg/m³)
Criteria (8µg/m³)
DUST DEPOSITION
Particulate Contour (g/m²month)
Criteria (2g/m²month)
REFERENCE
DZP Site Boundary
Open Cut Limit
Limit of Disturbance
Soil Stockpile Boundary
Non Proposal-related Residence
Proposal-related Residence
SCALE (A4)
0 2 4km
TN
MN
Figure 4.17
CUMULATIVE ANNUAL AVERAGE PARTICULATE CONCENTRATIONS - YEAR 15
Source: Pacific Environment Limited (2013) - Figures 28, 29, 30 & 31

Review of the contour plots for TSP, $PM_{10}$, $PM_{2.5}$ and dust deposition indicate that those areas predicted to experience the greatest particulate levels are the residences located to the west of the DZP Site, at the village of Toongi.

Incremental and cumulative particulate concentrations and deposition levels during the operation of the Proposal are thus not anticipated to result in adverse impacts at any of the receptors investigated in this assessment on an annual basis.

#### 4.3.7.3 Incremental 24-hour Average $PM_{10}$ and $PM_{2.5}$

**Table 4.30** presents the predicted maximum 24-hour $PM_{10}$ and $PM_{2.5}$ concentrations due to the Proposal alone at the receptors investigated in this assessment. **Figure 4.18** shows the corresponding contour plots for Year 15. The 24-hour $PM_{10}$ and $PM_{2.5}$ contours do not represent a single worst case day, but rather represent the potential worst case 24-hour average concentration that could be reached at any particular location across the entire modelling year.

The predicted $PM_{10}$ and $PM_{2.5}$ concentrations during Year 5 and Year 15 indicate that the incremental contribution of the Proposal would not exceed the EPA criteria (50µg/m$^3$ for $PM_{10}$) or NEPM advisory report standard (25µg/m$^3$ for $PM_{2.5}$). The incremental $PM_{10}$ and $PM_{2.5}$ concentrations are predicted to be higher in Year 15 than in Year 5 with R22 predicted to experience the highest $PM_{10}$ concentrations for both years (34µg/m$^3$ in Year 15). R46 is predicted to receive the highest $PM_{2.5}$ concentration (11µg/m$^3$ in both Year 5 and Year 15).

**Figure 4.18** indicates that those areas predicted to experience the greatest maximum 24-hour average $PM_{10}$ and $PM_{2.5}$ concentrations are the residences located to the west of the DZP Site, within the village of Toongi.

#### 4.3.7.4 Cumulative 24-hour Average $PM_{10}$

Given the daily varying nature of background 24-hour $PM_{10}$, PEL (2013) evaluated the likely cumulative maximum 24-hour $PM_{10}$ concentration at surrounding residences using a statistical approach known as a Monte Carlo Simulation. PEL (2013) focussed on the six non-Proposal related residences predicted to be most affected based on an incremental particulate matter assessment.

The Monte Carlo simulation method involves the individual 24-hour predictions for the Proposal being added to a random value from the background data set. This process is repeated many thousands of times yielding the ‘cumulative’ data set, which is then presented as a frequency distribution. The results of this analysis are presented graphically in **Figure 4.19** illustrating the statistical probability of 24-hour $PM_{10}$ concentrations being above the EPA 24-hour $PM_{10}$ criterion of 50µg/m$^3$ and the cumulative probability with the measured background.

**Table 4.30**
**Maximum 24-hour $PM_{2.5}$ and $PM_{10}$ concentrations – Year 5 and Year 15**

| Air Quality Parameter | $PM_{10}$ | $PM_{2.5}$ | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|---|
| **Criteria (µg/m$^3$)** | **50** | **25** | **50** | **25** |
| **Receptor [E]** | **Year 5** | | **Year 15** | |
| R1[a] | 13 | 5 | 33 | 8 |
| R2[a] | 17 | 7 | 34 | 10 |
| R3[a] | 3 | 3 | 18 | 5 |
| R4 | 2 | 2 | 6 | 2 |
| R6 | 2 | 2 | 4 | 2 |
| R7A | 3 | 3 | 4 | 3 |
| R7B[G] | 3 | 3 | 4 | 3 |
| R8A | 3 | 3 | 5 | 3 |
| R8B | 1 | 2 | 2 | 2 |
| R12[F] | 11 | 4 | 20 | 5 |
| R18 | 1 | 2 | 3 | 2 |
| R19 | 3 | 2 | 8 | 4 |
| R20 | 5 | 4 | 10 | 5 |
| R21 | 4 | 4 | 5 | 4 |
| R22 | 18 | 3 | 34 | 6 |
| R23 | 11 | 5 | 18 | 6 |
| R24 | 10 | 5 | 17 | 6 |
| R25 | 7 | 6 | 12 | 6 |
| R26 | 6 | 6 | 9 | 6 |
| R27 | 3 | 3 | 3 | 3 |
| R28A | 3 | 3 | 3 | 3 |
| R8B | 3 | 3 | 3 | 3 |
| R0A | 2 | 2 | 4 | 2 |
| R30B | 2 | 1 | 2 | 1 |
| R31A | 3 | 3 | 4 | 3 |
| R31B | 3 | 2 | 4 | 2 |
| R32 | 2 | 2 | 3 | 2 |
| R35A | 2 | 2 | 3 | 2 |
| R35B | 2 | 1 | 2 | 2 |
| R38 | 1 | 1 | 2 | 1 |
| R36 | 2 | 2 | 3 | 2 |
| R40 | 1 | 1 | 3 | 2 |
| R42 | 1 | 1 | 2 | 1 |
| R43 | 1 | 1 | 2 | 1 |
| R46 | 1 | 1 | 2 | 1 |
| R48[a] | 3 | 2 | 4 | 2 |
| R49A[a] | 3 | 2 | 4 | 3 |
| R49B[a] | 2 | 2 | 3 | 2 |
| R51[b] | 7 | 4 | 17 | 6 |
| R54[a] | 14 | 10 | 25 | 10 |
| R55[c] | 8 | 4 | 18 | 6 |
| R56[a] | 15 | 11 | 31 | 11 |
| R58[c] | 11 | 5 | 23 | 8 |
| R61 | 2 | 1 | 4 | 2 |
| R50[d] | 4 | 3 | 8 | 4 |

Note A: Residence owned by the Applicant
Note B: Negotiated 'Call' Option for the Residence between the Applicant and current owner (to be exercised by the Applicant)
Note C: Negotiated 'Put' Option for the Residence between the Applicant and current owner (to be exercised by the owner)
Note D: Allocated location for possible future residence (property has dwelling entitlement)
Note E: Refer to **Figure 4.6** Note F: R12 is referred to as Receptor 10 in PEL (2013)
Note G: Inferred from contour plot Source: PEL (2013) –Table 26

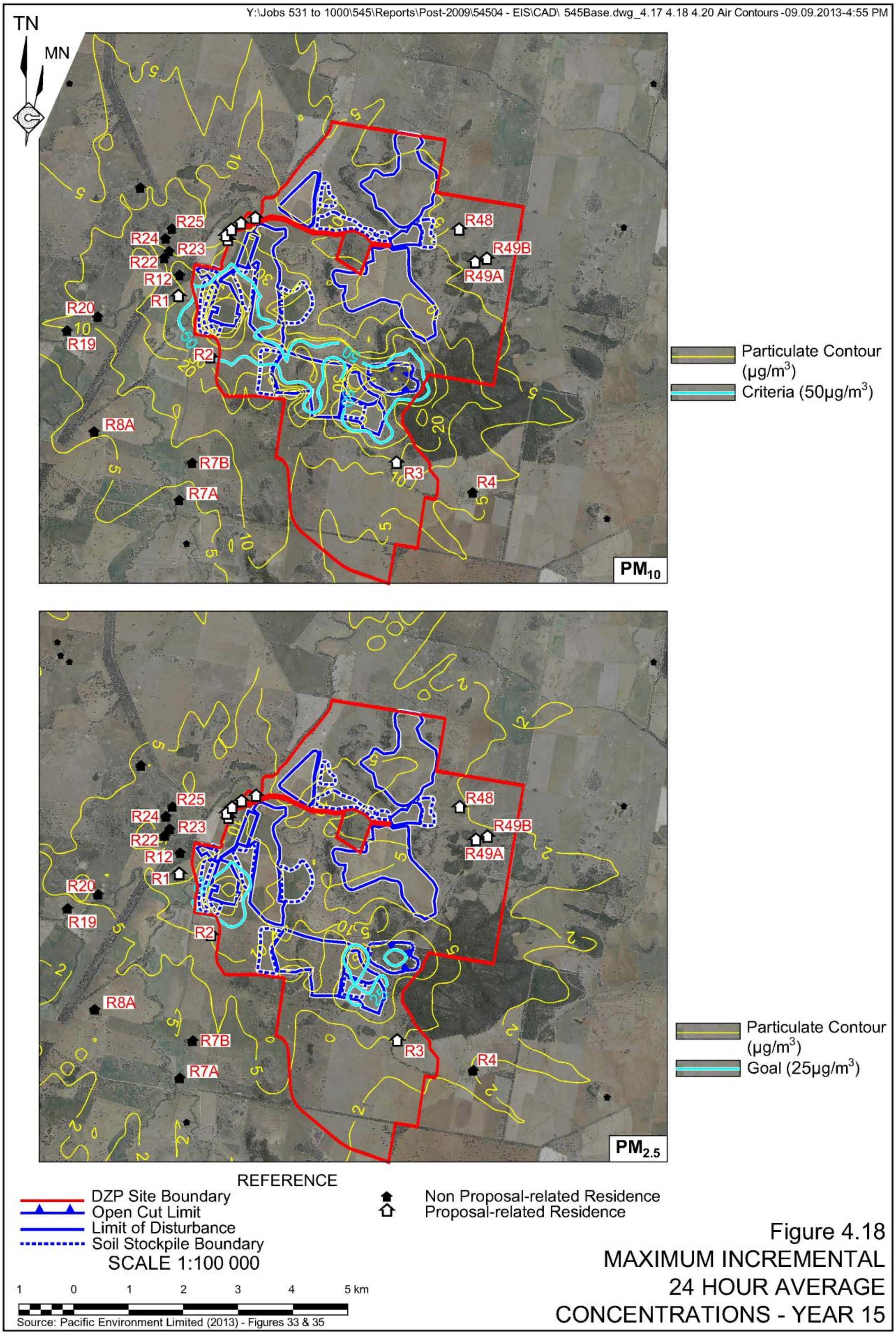
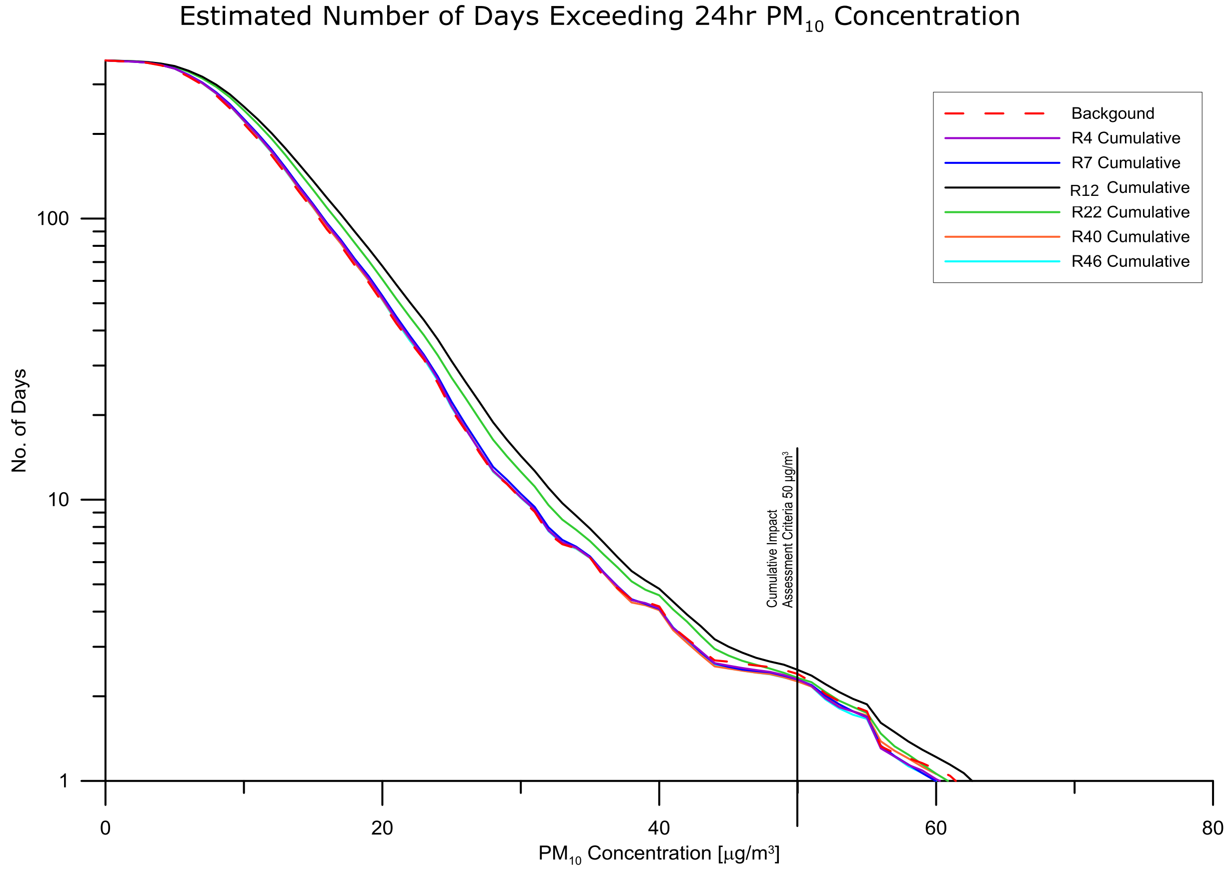



Figure 4.18
MAXIMUM INCREMENTAL 24 HOUR AVERAGE CONCENTRATIONS - YEAR 15




Note: R12 is identified as Receptor 10 in PEL (2013)

**Figure 4.19**
**CUMULATIVE 24-hr $PM_{10}$ CONCENTRATION: MONTE CARLO SIMULATION (YEAR 15)**

Source: PEL (2013) – Figure 36

**Figure 4.19** illustrates that R12 (Toongi Hall) is likely to be the most affected by $PM_{10}$ emissions of the Proposal. **Figure 4.19** also indicates that each of the assessed receptors would be subject to an exceedance of the cumulative $PM_{10}$ 24-hour criterion on 2 days. However, given the background data set already contains two exceedances of the EPA 24-hour criterion, the Proposal is not anticipated to contribute to any *additional* exceedances. On this basis, the Proposal is anticipated to satisfy the EPA criterion (PEL, 2013). Furthermore, it is noted that the line representing the background data set does not deviate from the lines representing cumulative impact to any great degree. The inference is, therefore, that the Proposal-related increment does not contribute significantly to the overall cumulative impact.

### 4.3.7.5 $SO_2$ Emissions

The dispersion modelling results for the predicted incremental and cumulative impacts for $SO_2$ are presented in **Table 4.31** for the maximum 10 minute average, maximum 1-hour average, maximum 24-hour average and annual average averaging periods, respectively.

**Table 4.31**
**Predicted Incremental and Cumulative $SO_2$ Emissions**

| Averaging period | 10 minute | 1-hour | 24-hour | Annual | 10 minute | 1-hour | 24-hour | Annual |
|---|---|---|---|---|---|---|---|---|
| ***Adopted background*** | - | - | - | - | *34* | *27* | *11* | *3* |
| ***Criteria (μg/m³)*** | *712* | *570* | *228* | *60* | - | *246* | - | *62* |
| **Receptor [E]** | **Incremental Prediction** | | | | **Cumulative Prediction** | | | |
| R1[a] | **971** | **679** | 29 | 1 | **1,005** | **706** | 40 | 3.9 |
| R2 [a] | 274 | 192 | 11 | 1 | 308 | 219 | 22 | 3.9 |
| R3 [a] | 141 | 98 | 9 | 0 | 175 | 125 | 20 | 3.3 |
| R4 | 100 | 70 | 7 | 0 | 134 | 97 | 18 | 3.2 |
| R6 | 67 | 46 | 6 | 0 | 101 | 73 | 17 | 3.2 |
| R7A | 58 | 41 | 5 | 0 | 92 | 68 | 16 | 3.2 |
| R7B [G] | 60 | 42 | 5 | 0 | 95 | 70 | 16 | 3.2 |
| R8A | 56 | 39 | 6 | 0 | 90 | 66 | 17 | 3.3 |
| R8B | 37 | 26 | 4 | 0 | 71 | 53 | 15 | 3.2 |
| R12 [F] | 610 | 426 | 18 | 1 | 644 | 453 | 29 | 3.7 |
| R18 | 59 | 41 | 5 | 0 | 93 | 68 | 16 | 3.3 |
| R19 | 57 | 40 | 7 | 1 | 91 | 67 | 18 | 3.7 |
| R20 | 110 | 77 | 11 | 1 | 144 | 104 | 22 | 4.0 |
| R21 | 56 | 39 | 12 | 1 | 90 | 66 | 23 | 3.7 |
| R22 | 124 | 87 | 9 | 1 | 158 | 114 | 20 | 3.8 |
| R23 | 182 | 127 | 8 | 1 | 216 | 154 | 19 | 3.8 |
| R24 | 285 | 199 | 9 | 1 | 319 | 226 | 20 | 3.8 |
| R25 | 255 | 178 | 13 | 1 | 289 | 205 | 24 | 3.7 |
| R26 | 316 | 221 | 16 | 1 | 350 | 248 | 27 | 3.5 |
| R27 | 70 | 49 | 5 | 0 | 104 | 76 | 16 | 3.2 |
| R28A | 56 | 39 | 5 | 0 | 90 | 66 | 16 | 3.2 |
| R28B | 64 | 45 | 5 | 0 | 98 | 72 | 16 | 3.2 |
| R30A | 75 | 53 | 4 | 0 | 109 | 80 | 15 | 3.2 |
| R30B | 59 | 41 | 3 | 0 | 93 | 68 | 14 | 3.2 |
| R31A | 40 | 28 | 4 | 0 | 74 | 55 | 15 | 3.2 |
| R31B | 62 | 43 | 4 | 0 | 96 | 70 | 15 | 3.2 |
| R32 | 66 | 46 | 4 | 0 | 100 | 73 | 15 | 3.2 |
| R35A | 132 | 92 | 5 | 0 | 166 | 119 | 16 | 3.3 |
| R35B | 94 | 66 | 6 | 0 | 128 | 93 | 17 | 3.3 |
| R38 | 58 | 41 | 3 | 0 | 92 | 68 | 14 | 3.2 |
| R36 | 79 | 55 | 3 | 0 | 113 | 82 | 14 | 3.3 |
| R40 | 72 | 50 | 5 | 0 | 106 | 77 | 16 | 3.3 |
| R42 | 34 | 24 | 4 | 0 | 68 | 51 | 15 | 3.2 |
| R43 | 80 | 56 | 3 | 0 | 114 | 83 | 14 | 3.2 |
| R46 | 33 | 23 | 4 | 0 | 67 | 50 | 15 | 3.2 |
| R48 [a] | 91 | 63 | 7 | 0 | 125 | 90 | 18 | 3.3 |
| R49A [a] | 53 | 37 | 6 | 0 | 87 | 64 | 17 | 3.3 |
| R49B [a] | 45 | 32 | 6 | 0 | 79 | 59 | 17 | 3.3 |
| R51 [b] | 214 | 149 | 8 | 1 | 248 | 176 | 19 | 3.9 |
| R54 [a] | 261 | 182 | 12 | 1 | 295 | 209 | 23 | 4.0 |
| R55 [c] | 249 | 174 | 10 | 1 | 283 | 201 | 21 | 4.1 |
| R56 [a] | 303 | 212 | 11 | 1 | 337 | 239 | 22 | 4.1 |
| R58 [c] | 582 | 407 | 18 | 1 | 616 | 434 | 29 | 4.1 |
| R61 | 27 | 19 | 2 | 0 | 61 | 46 | 13 | 3.1 |
| R50 [d] | 83 | 58 | 8 | 1 | 117 | 85 | 19 | 3.5 |

Note A: Residence owned by the Applicant
Note B: Negotiated 'Call' Option for the Residence between the Applicant and current owner (to be exercised by the Applicant)
Note C: Negotiated 'Put' Option for the Residence between the Applicant and current owner (to be exercised by the owner)
Note D: Allocated location for possible future residence (property has dwelling entitlement)
Note E: Refer to **Figure 4.6** Note F: R12 is referred to as Receptor 10 in PEL (2013)
Note G: Inferred from contour plot Source: PEL (2013) –Table 27

Contour plots for the maximum 10 minute, 1-hour and 24-hour and annual average cumulative $SO_2$ impacts for Year 15 are presented in **Figure 4.20** (after *Figures 38* to *41* of PEL, 2013).

Exceedances of the 10 minute and 1-hour criteria are predicted at R1, which is under contract for purchase by the Applicant and is therefore considered Proposal-related. This notwithstanding, any future plans for occupation of this residence must consider the predicted health and amenity impacts associated with the predicted $SO_2$ emissions that could be received.

Exceedances are not predicted to occur at any other residence. R12 (Toongi Hall), located to the west of the DZP Site, is predicted to be the most greatly impacted Non-Proposal related residence for all of the $SO_2$ averaging periods for both the incremental and cumulative results.

As would be expected, the contour plots of **Figure 4.20** indicate that for the shorter term averaging periods (i.e. 10 minute, 1-hour and 24-hour) the most greatly impacted areas are located closest to the processing plant. Furthermore, there are some areas close to the processing plant and beyond the DZP Site boundary that are predicted to exceed the 10 minute EPA averaging period. For the annual averaging period, the areas predicted to experience the greatest $SO_2$ concentrations are predicted to be to the west of the DZP Site boundary, e.g. R12.

#### 4.3.7.6 $NO_2$ Emissions

**Table 4.32** presents the maximum 1-hour average and annual average dispersion modelling results for $NO_2$. PEL (2013) applied the Ozone Limiting Method (OLM) to predict $NO_2$ concentrations. The OLM assumes that all the available ozone ($O_3$) in the atmosphere would react with the NO (which generally makes up 90% of source $NO_x$ emissions) in the plume until either all the $O_3$ or all the NO is used up. This approach provides an added level of conservatism to the estimated the $NO_x$ to $NO_2$ conversion.

**Table 4.32**
**Predicted $NO_2$ Emissions**

Page 1 of 2

| Receptor [E] | Cumulative Concentration (µg/m$^3$) | |
|---|---|---|
| | **1-hour** | **Annual** |
| **Criterion** | **246** | **62** |
| R1 [a] | 208 | 50 |
| R2 [a] | 179 | 47 |
| R3 [a] | 107 | 33 |
| R4 | 96 | 32 |
| R6 | 139 | 34 |
| R7A | 151 | 35 |
| R7B [G] | 160 | 36 |
| R8A | 190 | 37 |
| R8B | 146 | 34 |
| R12 [F] | 162 | 48 |
| R18 | 179 | 36 |
| R19 | 173 | 46 |
| R20 | 188 | 48 |
| R21 | 164 | 45 |
| R22 | 200 | 48 |
| R23 | 148 | 46 |

**Table 4.32 (Cont'd)**
**Predicted $NO_2$ Emissions**

Page 2 of 2

| Receptor [E] | Cumulative Concentration (µg/m$^3$) | |
|---|---|---|
| | **1-hour** | **Annual** |
| **Criterion** | **246** | **62** |
| R24 | 205 | 47 |
| R25 | 200 | 48 |
| R26 | 161 | 46 |
| R27 | 132 | 37 |
| R28A | 153 | 37 |
| R28B | 138 | 37 |
| R30A | 123 | 37 |
| R30B | 114 | 36 |
| R31A | 110 | 36 |
| R31B | 111 | 35 |
| R32 | 129 | 36 |
| R35A | 97 | 36 |
| R35B | 92 | 36 |
| R38 | 102 | 34 |
| R36 | 103 | 35 |
| R40 | 111 | 34 |
| R42 | 91 | 33 |
| R43 | 110 | 32 |
| R46 | 111 | 32 |
| R48 [a] | 123 | 35 |
| R49A [a] | 152 | 34 |
| R49B [a] | 149 | 34 |
| R51 [b] | 157 | 49 |
| R54 [a] | 201 | 55 |
| R55 [c] | 197 | 55 |
| R56 [a] | 198 | 57 |
| R58 [c] | 218 | 51 |
| R61 | 100 | 31 |
| R50 [d] | 141 | 40 |

Note A: Residence owned by the Applicant
Note B: Negotiated 'Call' Option for the Residence between the Applicant and current owner (to be exercised by the Applicant)
Note C: Negotiated 'Put' Option for the Residence between the Applicant and current owner (to be exercised by the owner)
Note D: Allocated location for possible future residence (property has dwelling entitlement)
Note E: Refer to Figure 4.6
Note F: R12 is referred to as Receptor 10 in PEL (2013)
Note G: Inferred from contour plot

Source: PEL (2013) – Table 28

Residence 25 is predicted to be the most impacted private residence for the maximum 1-hour average $NO_2$, predicted to experience up to 200µg/m$^3$, which is below the EPA criterion of 246µg/m$^3$. Residence 22 is predicted to experience the highest annual average $NO_2$ concentration with results indicating an annual average concentration of 48µg/m$^3$, which is also below the EPA criteria of 62µg/m$^3$.

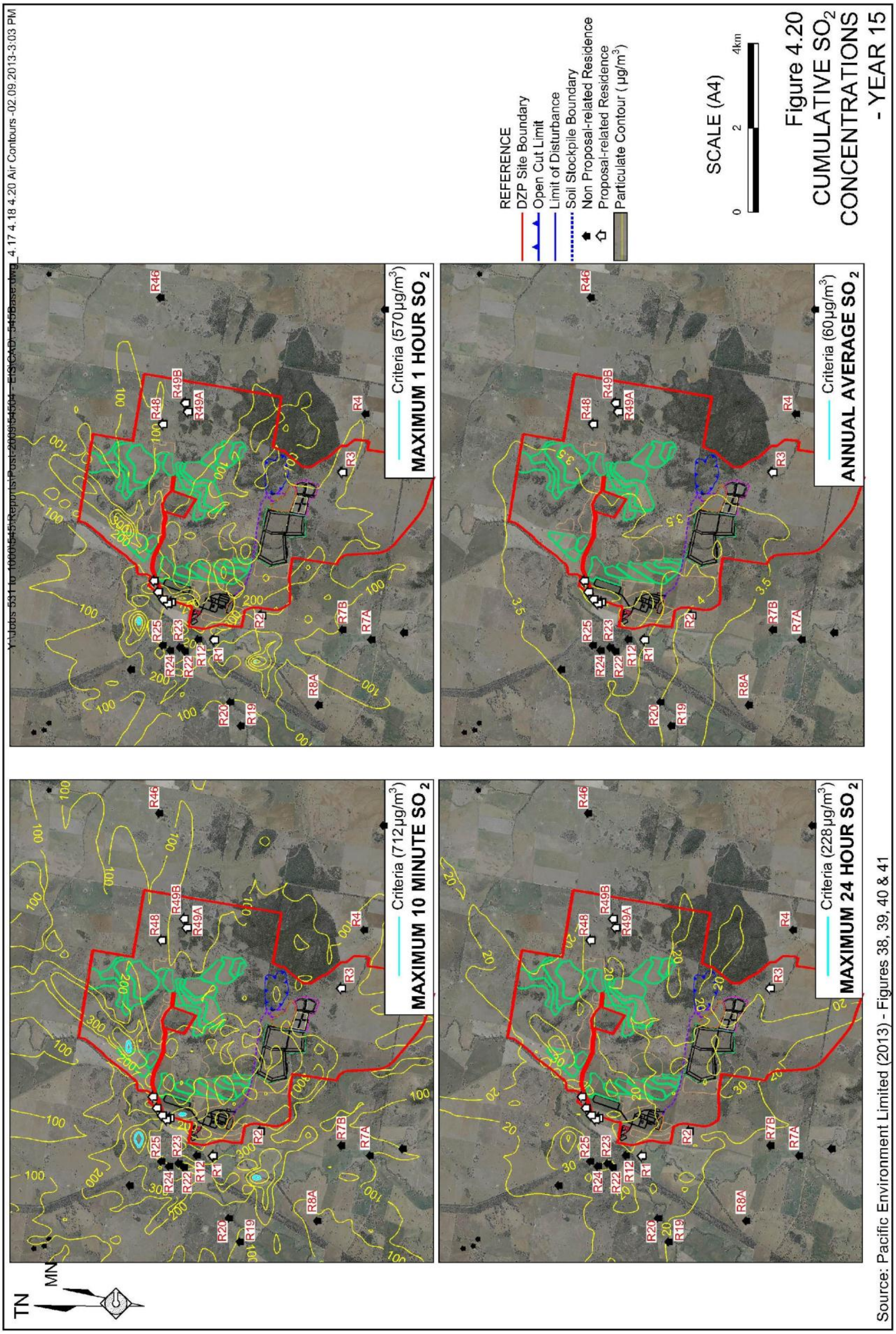



Figure 4.20
CUMULATIVE $SO_2$ CONCENTRATIONS - YEAR 15

The predicted concentrations do not exceed the EPA criteria of 246µg/m$^3$ and 62µg/m$^3$ respectively.

#### 4.3.7.7 HCl Emissions

The dispersion modelling results of PEL (2013) indicate that HCl emissions would not result in an exceedance of the EPA criterion of 0.14mg/m$^3$ (140µg/m$^3$) at any receptor (refer to *Table 29* of PEL, 2013).

#### 4.3.7.8 Radon

Excluding Proposal-related, i.e. those which hold an agreement for purchase, PEL (2013) predicts a maximum annual average radon concentration of 0.09Bq/m$^3$ at Receptors R18, R19 and R25. *Table 30* and *Figure 43* of PEL (2013) (Part 2 of the Specialist Consultant Studies Compendium) provide the predicted concentration at each receptor surrounding the DZP Site.

The predicted concentration of radon predicted by PEL (2013) has been used to assess potential impacts against radiation criteria by JRHC (2013) (refer to Sections 4.4.8.2 and 4.4.8.3)

#### 4.3.7.9 Odour

The dispersion modelling results for the 1 second (nose response) average 99$^{th}$ percentile odour predictions of PEL (2013) are presented in **Table 4.33**.

The highest 1-second 99$^{th}$ percentile odour concentration (0.5 OU at R24 and R25) is well below the adopted odour criterion of 6 OU and also below the most stringent EPA odour criterion of 2 OU, typically applied to urban areas, schools and hospitals.

**Table 4.33**
**Predicted Odour Impact**

Page 1 of 2

| Receptor [E] | 99$^{th}$ Percentile Prediction Odour Concentration (OU) | Receptor [E] | 99$^{th}$ Percentile Prediction Odour Concentration (OU) |
|---|---|---|---|
| ***NSW EPA criterion*** | ***6*** | ***NSW EPA criterion*** | ***6*** |
| 1 [a] | 0.4 | 30B | 0.2 |
| 2 [a] | 0.9 | 31A | 0.2 |
| 3 [a] | 0.3 | 31B | 0.2 |
| 4 | 0.1 | 32 | 0.2 |
| 6 | 0.2 | 35A | 0.2 |
| 7A | 0.2 | 35B | 0.2 |
| 7B [G] | 0.2 | 38 | 0.1 |
| 8A | 0.2 | 36 | 0.2 |
| 8B | 0.1 | 40 | 0.2 |
| 12 [F] | 0.4 | 42 | 0.1 |
| 18 | 0.4 | 43 | 0.1 |
| 19 | 0.4 | 46 | 0.1 |
| 20 | 0.2 | 48 [a] | 0.3 |
| 21 | 0.1 | 49A [a] | 0.5 |
| 22 | 0.4 | 49B [a] | 0.4 |
| 23 | 0.4 | 51 [b] | 1.0 |

**Table 4.33 (cont'd)**
**Predicted Odour Impact**

Page 2 of 2

| Receptor [E] | 99th Percentile Prediction Odour Concentration (OU) | Receptor [E] | 99th Percentile Prediction Odour Concentration (OU) |
|---|---|---|---|
| ***NSW EPA criterion*** | ***6*** | ***NSW EPA criterion*** | ***6*** |
| 24 | 0.5 | 54 [a] | 0.6 |
| 25 | 0.5 | 55 [c] | 0.7 |
| 26 | 0.4 | 56 [a] | 0.6 |
| 27 | 0.2 | 58 [c] | 0.8 |
| 28A | 0.2 | 61 | 0.1 |
| 28B | 0.2 | 50 [d] | 1.2 |
| 30A | 0.2 | | |

Note A: Residence owned by the Applicant
Note B: Negotiated 'Call' Option for the Residence between the Applicant and current owner (to be exercised by the Applicant)
Note C: Negotiated 'Put' Option for the Residence between the Applicant and current owner (to be exercised by the owner)
Note D: Allocated location for possible future residence (property has dwelling entitlement)
Note E: Refer to **Figure 4.6** Note F: R12 is referred to as Receptor 10 in PEL (2013)
Note G: Inferred from contour plot Source: PEL(2013) – Table 31

### 4.3.7.10 Greenhouse Gas Emissions

A summary of the total GHG emissions associated with the Proposal (for transport Option C) are presented in **Table 4.34**.

**Table 4.34**
**Summary of GHG Emissions (t $CO_2$-e)**

| | Scope 1 Emissions (t CO2-e) | Scope 2 Emissions (t CO2-e) | Scope 3 Emissions (t CO2-e) | Total (Scope 1 and Scope 2 | Total (All scopes) |
|---|---|---|---|---|---|
| **Average Operational Year** | | | | | |
| Option A | 140 040 | 120 560 | 1 107 | 260 600 | 262 101 |
| Option B | 140 040 | 120 560 | 1 126 | 260 600 | 261 727 |
| Option C | 140 040 | 120 560 | 1 501 | 260 600 | 261 707 |
| **Life of mine** | | | | | |
| Option A | 2 800 807 | 2 411 200 | 1 277 650 | 5 212 007 | 6 497 532 |
| Option B | 2 800 807 | 2 411 200 | 1 278 032 | 5 212 007 | 6 490 040 |
| Option C | 2 800 807 | 2 411 200 | 1 285 525 | 5 212 007 | 6 489 657 |

Source: Modified after PEL (2013) – Table 32

The Proposal's contribution to projected climate change, and the associated impacts, would be in proportion with its contribution to global GHG emissions. Average annual Scope 1 and Scope 2 emissions from the Proposal (0.26 million tonnes [Mt] $CO_2$-e) would represent approximately 0.04% of Australia's commitment for annual emissions under the Kyoto Protocol (591.5Mt $CO_2$-e/annum) and a very small portion of global greenhouse emissions, given that Australia contributed approximately 1.5% of global GHG emissions in 2005 (Commonwealth of Australia, 2011).

It is expected that the Proposal would exceed the facility threshold of 25 000t $CO_2$-e per annum for participation in the carbon pricing mechanisms, and as such Scope 1 and Scope 2 GHG emissions from the Proposal would be subject to the carbon pricing mechanism. As such, it is anticipated that the Applicant would directly contribute to the revenue generated by the carbon pricing mechanism.

### 4.3.8 Monitoring

The above assessment indicates that the concentrations of all potential contaminant levels associated with the Proposal are likely to be acceptable. However, in order to demonstrate compliance with the Proposal air quality goals (refer Section 4.3.4), the Applicant would undertake an air quality monitoring program to demonstrate compliance with the nominated air quality goals. This would include monitoring of deposited dust levels, TSP and $PM_{10}$ at surrounding residences and/or locations surrounding the processing plant, subject to landowner agreement. Monitoring of $SO_2$, $NO_2$ and HCl at residential receptors is not considered necessary due to the very minor incremental contributions to background predicted.

Periodic extractive monitoring for $SO_2$, $NO_2$, HCl and $PM_{10}$ would be undertaken to demonstrate compliance with in-stack limits. Initially this would be completed every 3 months (for the first year of operation) and then annually, if compliance is easily achieved.

The locations, frequency and implementation of the proposed monitoring program would be prepared in consultation with the DP&I and EPA following approval of the Proposal. In addition, the Applicant would monitor its diesel and electricity usage and report on greenhouse gas emissions as required under relevant State and Commonwealth regulations.

## 4.4 RADIATION

### 4.4.1 Introduction

Radiation was not mentioned within the Director-General's Requirements issued by the DP&I as an issue for assessment, however, the Applicant recognises that the ore body contains elevated concentrations of naturally occurring uranium and thorium which may result in radioactivity levels greater than average during operations. Therefore the Applicant has considered radiological impacts in the risk analysis undertaken for the Proposal (Section 3.5), the potential impacts relating to radiation and their risk rankings (in parenthesis) without the adoption of any mitigation measures are as follows.

- Adverse health outcomes for workforce from low level radiation emitted by ore (low).
- Adverse health outcomes for surrounding landowners / residents during the period of mine operation (low).
- Long-term adverse health outcomes for surrounding landowners / residents following the completion of the Proposal (low).
- Degradation of local vegetation and/or reduced survival rates of local fauna during the life of the Proposal (low).

- Long-term degradation of local vegetation and/or reduced survival rates of local fauna following the completion of the Proposal (low).
- Adverse health outcomes for those exposed to the equipment or scrap (low).
- Adverse health outcomes for the customer or end user (low).

The Applicant commissioned JRHC Enterprises Pty Ltd to undertake a radiation assessment to define the risks associated with radiation. The radiation assessment (JRHC, 2013) utilises the air quality modelling undertaken by Pacific Environment Limited (PEL, 2013). JRHC (2013) is provided in full as Part 3 of the *Specialist Consultant Studies Compendium*. This subsection of the EIS provides a summary of the radiation assessment, concentrating on those matters considered to be of greatest potential impact based on the risk analysis.

### 4.4.2 Background to Radiation

All matter is made of atoms which themselves are made up of protons and neutrons in a nucleus, and electrons orbiting around the nucleus. Some atoms are unstable and breakdown, giving off energy in the form of radiation. These are known as radioactive atoms or radionuclides.

Different radionuclides emit radiation at different rates. The breakdown (or decay) of radionuclides reduces the number of protons and neutrons remaining, so that the amount of radiation emitted continually reduces. The time taken for one half of the radionuclides to decay away is known as the ‘half-life’. Each radionuclide has its own half-life which can range from fractions of a second to billions of years.

When a radionuclide decays, the new atom formed may itself be radioactive, which in turn decays to another radionuclide, and this can continue until a stable element is reached. When this occurs, the chain of radioactive decays is called the ‘decay series’ or ‘decay chain’.

Radionuclides are ubiquitous and naturally occurring, existing everywhere in the environment, in food, air, water, soils and rocks. For example, uranium is a naturally occurring heavy metal and is widespread in earth’s crust, with an average concentration of about three parts per million (ppm). Since radionuclides exist naturally in all materials, it is usual to only define a material as “radioactive” when the concentration of a radionuclide in the material exceeds a certain level.

There are three types of radiation emitted by naturally occurring radionuclides.

- **Alpha radiation** consists of alpha particles (two neutrons and two protons) and has a very short range in air (a few centimetres), depositing their energy quickly. They are unable to penetrate the epidermis (outer layer of skin), but can be hazardous when inhaled or ingested.
- **Beta radiation** consists of high-energy electrons. They have moderate penetration, typically about one metre in air and a few millimetres in water or tissue.
- **Gamma radiation** is not a particle but an electromagnetic wave similar to light and X-rays but of much higher energy. Gamma rays are generally able to penetrate up to several centimetres of metal or 10cm of concrete, and usually pass right through the human body.

Exposure to radiation can only occur when there is an exposure pathway between the radioactive material and the exposed biota. This can occur in two ways:

- through the external exposure pathway: where the source of radioactivity is outside the body; and
- through the internal exposure pathway: where the source of radioactivity is inside the body, for example in inhaled air.

When describing radiation, there are two important concepts, namely: the amount of radioactivity in a material; and the resultant exposure from the radioactivity (this is also referred to as a "dose").

The amount of radioactivity is described by its 'activity' and is measured in the unit of becquerel (Bq), which is the amount of radioactive material that produces one radioactive decay per second. The activity concentration is the amount of radioactivity in a unit mass (or volume) of material and is usually measured in becquerels per gram (Bq/g) or per litre (Bq/L).

Dose refers to the amount of radiation received at a point or to a person. Dose is also a relative measure of the effect (or 'detriment') of radiation on the human body and is measured in the units of Sieverts (Sv) and takes into account the different types of radiation and different exposure situations. The sievert is quite a large unit of measure, and doses are usually expressed in millisieverts (mSv), being thousandths of a sievert, or microsieverts (µSv), being one millionth of a sievert.

Due to radiation being very common in nature, everyone is exposed to natural radiation throughout their life. This radiation comes from the rocks and soil of the earth, the air we breathe, water and food we consume, and from cosmic radiation from space. Natural background can vary considerably in different places in the world. While the world average level of radiation is 2.4mSv/y, the typical range is quoted as 1 to 10mSv/y (UNSCEAR, 2000).

In addition to natural background exposure, some people around the world are regularly exposed to radiation in their work, and from leisure activities (such as flying) and in medical procedures. **Table 4.35** shows the average annual doses for a range of different activities.

**Table 4.35**
**Radiation Exposures (in Addition to Natural Background Levels)**

| Source/Practice | Average Annual Effective Dose (mSv) |
|---|---|
| Working in the nuclear fuel cycle | 1.8 |
| Industrial uses of radiation | 0.5 |
| Medical uses of radiation (doctors/nurses) | 0.3 |
| Average public exposure to medical radiation | 1.2 |
| Air crew (from cosmic radiation) | 3.0 |
| Mining (other than coal) | 2.7 |
| Coal mining | 0.7 |
| Source: UNSCEAR (2000) | |

## 4.4.3 Existing Environment

### 4.4.3.1 Background Radiation Monitoring

Background radiation monitoring was undertaken in 2001-2002, in the general area of the DZP Site. This included a regional gamma survey, radionuclides in dust in air and radionuclides in water. Results of this work are summarised in the following subsections.

### 4.4.3.2 Gamma Radiation

Background gamma radiation levels vary widely across Australia, with levels typically considered to be between 0.02 and 0.1µSv/h (Mudd, 2002). The levels of gamma radiation primarily depend on the levels of natural radionuclides in soil, including radionuclides from the $U^{238}$, $Th^{232}$ and $K^{40}$ decay chains.

In 2002, the Applicant undertook a gamma survey across the DZP Site and in the broader Dubbo region (Hewson, 2002) the results of which are presented in **Table 4.36**.

**Table 4.36**
**Background Gamma Monitoring**

| Location | Gamma Levels (µSv/h) |
|---|---|
| Above mineralisation | 1.0 – 3.5 (average 2.5) |
| Proposed Processing Plant Area | 0.1 |
| Proposed Waste Rock Emplacement | 0.1 – 1.0 |
| Western Plains Zoo Area | 0.2 – 0.4 |
| Macquarie River Bank | 0.2 – 0.4 |
| Source: Modified after Mason (2001) - Table 4 | |

### 4.4.3.3 Radionuclide Levels in Airborne Dust

Radioactive materials which occur naturally in soils and rocks can become airborne and form dusts. During 2001-2002, dust sampling was undertaken using a high volume sampler located at Wychitella (Radiation-Wise, 2002). The sampling involved drawing a high volume of air through a filter paper to collect particulate matter which was then analysed for its radionuclide content and the total amount of dust. The radionuclide was measured in Becquerel (bq) which is a standard international unit of measurement of radioactive activity and defined as one radioactive disintegration per second. Sampling involved taking one 24-hour sample per month for 12 months. A summary of the results can be seen in **Table 4.37**.

**Table 4.37**
**High Volume Dust Sampling Results**

| Month | Total Dust Mass Concentration (µg/m$^3$) | Total Alpha Concentration (µbq/m$^3$) |
|---|---|---|
| Average | 19 | 263 |
| Maximum | 56 | 728 |
| Minimum | 3.8 | 68 |
| Source: Radiation-Wise (2002) | | |

Conversion of the results in bq to the equivalent exposure in Sv was undertaken as part of the impact assessment of JRHC (2013).

#### 4.4.3.4 Radionuclide Concentrations in Water

Monitoring for uranium and thorium in surface water and groundwater was conducted in 2002 and a summary of the results are presented in **Table 4.38** (Golder, 2002). The Australian Government published guidelines for drinking water quality (NHMRC, 2011) and the levels (where available) have been included in **Table 4.38** for comparison purposes.

The low radionuclide content of the groundwater is an indication that uranium and thorium are not readily mobilised from the deposit.

**Table 4.38**
**Radionuclides in Surface Water and Groundwater**

| Location | Concentration (µg/L) | | Concentration (Bq/L) | |
|---|---|---|---|---|
| | Uranium | Thorium | $Ra^{226}$ | $Ra^{228}$ |
| Surface Water - Upstream of deposit[1] | <1 | <1 | | |
| Surface Water - Downstream of deposit[1] | 13 | <1 | | |
| Groundwater[1] | <1 - 81 | <1 - 79 | <0.2 | <0.2 |
| Australian Drinking Water Guidelines 6[2] | 17 | N/A | >0.5Bq/L gross α/β triggers further investigation | |
| Source 1: Golder (2002)<br>Source 2: NHMRC (2011) | | | | |

The mineralised material to be recovered from the open cut contains between 80-160 ppm uranium and between 250-500 ppm thorium, and contains radionuclides from the $U^{238}$, $U^{235}$ and $Th^{232}$ decay chains. For reference, the world average for soils is 3ppm for uranium and 6ppm for thorium (UNSCEAR, 2000).

The concentration of uranium and thorium in the mineralised material is not excessive, however, it is at the level at which it is just defined as radioactive. These levels of uranium and thorium necessitate the consideration of radiological impacts on workers, the public and on the environment.

### 4.4.4 Potential Impacts

The acute health effects of radiation exposure (both internal and external) are well known. At high doses (above 1 000mSv) significant numbers of cells may be killed, leading to the breakdown of the organ or tissue, and possibly resulting in death.

At moderate doses, chronic health effects may arise from cells that are damaged by the radiation but not killed. This may be the initiating event for development of a cancer with several studies finding an increased risk of cancer among people exposed to moderate doses of radiation. The studies show that the risk increases as the radiation dose increases.

In general, none of the studies has been able to measure increases in cancer risk from exposures to low doses of radiation (below about 50mSv), however, it is conservatively assumed that there is an increased risk.

The premier international body for radiation protection is the International Commission on Radiological Protection (ICRP). Using studies and their results as the basis of the setting of radiation standards for exposure of workers and the general public, the effective annual dose limits recommended by the ICRP are 20mSv for a designated radiation worker and 1mSv for a member of the public.

The limits recommended by the ICRP have generally been adopted around the world. Dose limits form only one part of the ICRP radiation protection system, with justification of the practice and minimisation of doses being the other two elements.

The radiological protection of the non-human living environment (being plants and animals) has, up until recently, been thought to be assured by ensuring that humans have been protected. In recent times, this approach has been changed and it is now appropriate for a radiological assessment of non-human biota (NHB) to be conducted. International standards exist to conduct this assessment.

### 4.4.5 Assessment Criteria

Radiation and its effects have been studied for almost 100 years and there is International consensus on its effect and controls. It is generally accepted that control of radiation is best achieved by following the recommendations of the ICRP.

In Publication 26 (ICRP, 1977), the ICRP recommends a "system of dose limitation" which has become the internationally accepted foundation for radiation protection and is universally adopted as the basis of legislative systems for the control of radiation and as the basis for standards. It is made up of three key elements as follows.

- "Justification": this means that a practice involving exposure to radiation should only be adopted if the benefits of the practice outweigh the risks associated with the radiation exposure.
- "Optimisation": this means that radiation doses received should be "As Low As Reasonably Achievable", taking into account economic and social factors. This is also known as the ALARA principle.
- "Limitation": this means that individuals should not receive radiation doses greater than the prescribed dose limits.

While the ALARA principle is recognised as the foundation for radiation protection, radiation dose limits have been established to provide an absolute level of protection and are;

- an annual limit to a worker of 20mSv , and
- an annual limit to a member of the public of 1mSv.

These limits have been adopted throughout Australia and would apply to the Proposal.

## 4.4.6 Assessment Methodology

### 4.4.6.1 Overview

The assessment of radiological impact follows the recognised methods outlined by the ICRP Publication 103 (ICRP, 2007) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) publication *Recommendations for Limiting Exposure to Ionizing Radiation (1995)* (ARPANSA, 2002). This involves estimating the potential exposure doses from each of the exposure pathways and applying standard "dose conversion factors" which take into account the characteristics of the exposure. The doses from each of the exposure pathways are then added together to give an indication of the potential overall doses that workers or a member of the public may receive.

Details of the methods are provided in full in Part 3 of the *Specialist Consultant Studies Compendium* (JRHC, 2013). The following sections provide a summary of these methods.

### 4.4.6.2 Occupational Doses

When assessing occupational doses, the three main exposures are considered to be gamma radiation, inhalation of the decay products of radon and inhalation of radionuclides in airborne dust.

- Gamma Radiation. Gamma doses are estimated by considering the exposure geometry and the radionuclide content of the source materials.
- Inhalation of the decay products of radon. Radon decay product exposure is mainly a concern for personnel to be employed by the Proposal, so the exposures are determined by calculating the emanation of radon from the mineralised material into the open cut workings and calculating the residence time of the air (or how long it takes for air to change in the open cut).
- Inhalation of radionuclides in airborne dust. It is important to understand the radionuclides that exist in the dust because they interact differently when taken into the body. For the open cut, the radionuclides are assumed to be in secular equilibrium (where the quantity of radionuclides remains constant because the production rate is equal to the decay rate). For the processing plant, sampling and analysis was undertaken by ANTSO (ANSTO 2012a) to determine the radionuclide content of different materials and these results were used as the basis for estimating what may be inhaled by a worker. A conservative estimate of exposure conditions (that is, the amount of dust in air and the time a worker may be exposed) were made and used as the basis of the dust dose assessment.

### 4.4.6.3 Public and Environmental Radiological Impacts

For persons located outside the boundary of the DZP Site, the main exposure pathway is through airborne dispersion of dust containing radionuclides and radon.

As discussed in Section 4.3, Pacific Environment Limited (PEL) was commissioned to undertake air quality modelling to quantify the amount of dust and radon gas at various distances from the operating areas. This modelling was based on estimated emissions and provided "impact contour plots" outputs (PEL, 2013), which were used as the basis for the public and environmental radiological assessment. Details on the methodology and assumptions are provided in PEL (2013) and its application in JRHC (2013).

Impacts from radioactive air emissions were determined for:

- radioactive particulate emissions (leading to increased radionuclide concentrations in air and radionuclide deposition to soils); and
- radon emissions (leading to potential increases in radon decay product (RnDP) concentrations).

The air quality modelling provided estimates of the deposition of dusts and radionuclides into the environment, which provided the base data for conducting a non-human biota impact assessment.

### 4.4.7 Management and Mitigation Measures

The Applicant intends to manage and control radiation through good design and appropriate ongoing operational management systems. This is consistent with best practice as proposed by the recommendations and guidelines of the ICRP. The guidance provided in the ARPANSA publication *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (ARPANSA, 2005), would also be used to guide the management controls.

General site controls would include the following.

- Establishment of radiation design criteria, including:
  - design of the residue storage facilities as zero-discharge facilities with a geo-membrane lining and leak detection system;
  - ensuring that all heavy mining equipment is air conditioned to minimise impacts of dust to workers;
  - minimising dust using standard dust suppression techniques (wetting of materials before handling, wetting of roadways, provision of dust collection and extraction systems);
  - construction of a separate wash-down pad for vehicles that have come from any operating areas;
  - bunding to collect and contain spillages from tanks containing process slurries;
  - burial of, or bunding of the residue pipeline within defined corridor(s) to control spillage from residue pipeline failures;
  - providing sufficient access and egress for mobile equipment to allow clean-up where there is the possibility for large spillages;
  - leach and precipitation of radionuclides from ore prior to production of final compounds for despatch and disposal as solid or liquid residue;

- installation of a venturi scrubber and wet electrostatic precipitator (ESP) as part of the FeNb processing circuit to capture and remove volatilised Polonium 210 and Lead 210 prior to ventilation from the circuit; and
- slurrying and mixture of residues from the FeNb processing circuit scrubber and ESP with the solid residues to be disposed of in the SRSF.

- Classification of work areas and workers.
  - The Applicant has defined the whole of the Proposal within the fence-line as a "supervised area" (as defined in ARPANSA, 2005). Within this broader area, the open cut would be defined as a "controlled area" as would the milling and crushing areas, and the light rare earths processing area.
  - The Applicant has defined the FeNb processing circuit as a controlled area based on the capture and removal volatilised Polonium 210 and Lead 210 prior to ventilation from the circuit.
  - Employees working in the controlled areas would be defined as designated radiation workers. Other workers would be defined as "non-designated" radiation workers.
- Site Access Control
  - All visitors entering and departing the DZP Site would be required to report to the gatehouse or other nominated locations for registration including time of arrival and departure, and an induction, if required.
  - Vehicle access would be through the main boom gate, and exit from site would require all vehicles having trafficked the controlled area to pass through the wheel wash. Water from the wheel wash and wash-down areas would be collected and settled to remove solids, then treated for re-use at the on-site water treatment plant.
- Change Room Facilities
  - Workers in the "controlled area" ("designated workers") would be required to change into work clothes at the commencement of their shift and then shower and change into "street clothes" at the end of their shift. This would be a general health and hygiene requirement (not just a radiation requirement) that would be implemented once the Proposal commences and would continue throughout the life of the Proposal.
  - Dirty clothes would be laundered on-site, with waste water sent to an on-site water treatment plant.
- Establishment of site-wide administrative controls including;
  - pre-employment and routine medical checks for workers;
  - inductions and regular training of all employees and contractors;
  - development of safe work procedures, which includes radiation safety aspects;
  - procedures to segregate, isolate and clean up contamination or contaminated equipment;

  - procedures for equipment or materials leaving the controlled area;
  - mandatory use of personal hygiene facilities (wash facilities) at entrances to lunch rooms and offices;
  - employment of suitably qualified and experienced radiation safety professionals to assist during the final design, construction and the operational phases of the Proposal; and
  - use of a computer-based data management system to store and manage all information relating to radiation management and monitoring.
- Systems for managing potentially radioactive wastes.
  - Material such as contaminated equipment and wastes from operational areas, including discarded conveyor belts, rubber lining material, pipes, filter media and used protective equipment would be cleaned on-site and disposed in accordance with approved regulatory controls (see Section 2.11.2).
  - Spill management procedures (in the event a LRSF pipeline did leak/rupture).

## 4.4.8 Assessment of Impacts

### 4.4.8.1 Introduction

JRHC (2013) provides a detailed description of the potential radiological impacts of the Proposal, specifically in relation to occupational doses, public doses and radiological impacts to the environment. A summary of the impacts is provided as follows.

### 4.4.8.2 Occupational Doses

Potential doses have been calculated for mine workers and processing plant workers and have been based on determining the doses from the following exposure pathways;

- Gamma irradiation,
- inhalation of radioactive dust; and
- for miners, inhalation of radon decay products (RnDP) and thoron decay products (ThDP).

For the processing plant, initial dose estimates were made by ANSTO (2012a and 2012b) and these have been refined where appropriate.

A summary of the estimated doses for miners is provided in **Table 4.39**. A summary of the estimated doses for processing plant workers is provided in **Table 4.40**.

**Table 4.39**
**Occupational Dose Estimates**

| Work Group | Average Annual Dose (mSv/y) | | | | | Dose Limit (mSv/y) |
|---|---|---|---|---|---|---|
| | Gamma | RnDP | ThDP | Dust | Total | |
| Miners | 2.0 | 0.018 | 0.008 | 0.30 | 2.3 | 20 |
| Source: JRHC (2013) – Table 8 | | | | | | |

**Table 4.40**
**Processing Plant Work Area Doses**

| Processing Plant Work Area | Doses (mSv/y) | | | Dose Limit (mSv/y) |
|---|---|---|---|---|
| | Gamma | Dust Inhalation | Total | |
| Ore Milling/Handling /Roasting | 2.0 | 0.4 | 2.4 | 20 |
| Light Rare Earth processing | 0.5 | 8.5 | 9.0 | |
| Heavy Rare Earth processing | 0.7 | 2.6 | 3.3 | |
| Niobium Processing | 0.8 | 1.2 | 2.0 | |
| Source: JRHC (2013) – Table 9 | | | | |

Initial indications from ANSTO (2012a) and ANSTO (2012b) are that light rare earth plant workers may receive up to 9mSv/y, however, it is not expected that doses would reach those levels due to operational controls. Similarly, controls within the FeNb processing circuit would effectively eliminate the potential dust inhalation dose. While the dose is well below the dose limit standard of 20mSv/y, dust controls would be implemented within the Processing Plant Area generally to minimise dose in accordance with the ALARA principle.

It should be noted that the occupational dose estimates are considered to be conservative and monitoring during operations would be conducted to provide more accurate assessments.

#### 4.4.8.3 Public Dose Assessment

Public doses would arise when emissions from inside the DZP Site impact on areas outside the DZP Site.

Of the main exposure pathways, gamma radiation is not considered to be significant because sources of gamma radiation are well within the DZP Site and inaccessible. Therefore, gamma radiation levels from the Proposal beyond the boundary of the proposed plant would be negligible.

For the public, the only potential exposure pathways are via the airborne pathways being:

- inhalation of radioactive dust; and
- inhalation of radon and decay products (RnDP) and thoron and decay products (ThDP) (refer to JHRC, 2013 for further detail).

For this assessment, potential doses for occupants of the four residences located to the immediate west of Obley Road (R22 to R25 – see **Figure 4.6**) have been conducted as these are the closest potentially exposed non-Proposal related receptors. Other non-Proposal related receptors are located further from the emission sources and would receive less exposure.

To estimate doses to the occupants of the four residences (R22 to R25), standard methods are used (see JRHC, 2013) which are based on the results of the air quality modelling. A summary of the estimated doses for R22 to R25 is provided in **Table 4.41**.

**Table 4.41**
**Predicted Public Dose**

| Residences | Dose From Pathway (mSv/y) | | | | Public Dose Limit (mSv/y) |
|---|---|---|---|---|---|
| | Inhalation of RnDP ($Rn^{222}$) | Inhalation of Dust | Gamma Radiation | Total Dose | |
| R22 to R25 | 0.0075 | 0.020 | 0 | 0.028 | 1 |
| Source: JRHC (2013) – Table 10 | | | | | |

It is noted that receptors within Toongi are located closer to the Processing Plant Area and therefore could receive greater exposure. These receptors are, however, Proposal-related and have not been included in the assessment for this reason.

#### 4.4.8.4 Non-Human Biota Exposure

In ICRP publication 103 (ICRP, 2007), a system for the radiological protection of non-human biota was outlined, which included a method for assessing radiological impact to reference species. A software tool, called ERICA (Environmental Risk from Ionising Contaminants Assessment) developed under the European Commission, was used to determine a relative radiological risk factor to a species as a "dose rate" based on site specific data.

An assessment was conducted using the dust deposition outputs of the air quality modelling and showed that impacts to non-human biota outside the DZP Site would be negligible (JRHC, 2013 – *Appendix D*).

#### 4.4.8.5 Public Dose Following Closure

The Applicant has developed closure and rehabilitation plans for the proposed activities. From a radiological perspective, the overall approach is to ensure that the radiation levels at the DZP Site are returned to levels consistent with those which existed prior to the Proposal. With the implementation of the closure and rehabilitation plans, there are, therefore, no reasonable pathways for public exposure, and doses are expected to be negligible and much less than the member of public dose limit of 1mSv/y (above natural background).

#### 4.4.8.6 Summary

The radiation assessment of the Proposal shows that the impacts would be manageable and well below the recognised limits. A summary of the radiological impacts of the Proposal is presented in **Table 4.42**.

**Table 4.42**
**Summary of Radiation Impacts for the Proposal**

| Dose Groups | Expected Dose/Impact (mSv/y) | Dose Limit/Standard (mSv/y) |
|---|---|---|
| Workers | 2 to 9mSv/y* | 20mSv/y |
| Member of Public | <0.1mSv/y | 1mSv/y |
| Non-Human Biota | No impact | - |
| Note * depending on the work area | | |

### 4.4.9 Monitoring

As part of the ongoing management of radiation, an occupational and environmental monitoring program would be developed and implemented. An outline of the proposed occupational radiation monitoring is shown in **Table 4.43**.

**Table 4.43**
**Dose Assessment Monitoring Program (Indicative Only)**

| Radiation Exposure Pathway & Monitoring Method | Open Cut | Processing Plant | Administration Area |
|---|---|---|---|
| Gamma radiation – Personal TLD badges | Quarterly TLD badges | Quarterly TLD badges on selected workers | NR |
| Gamma radiation – Survey with hand held monitor | Monthly area survey | Monthly area survey | Monthly area survey |
| Airborne dust – Sampling pumps with radiometric and gravimetric analysis of filters | Weekly personal dust sampling for; truck driver, loader operator, maintenance personnel, & miner | Fortnightly personal samples in selected work areas<br>Weekly sampling in the Light Rare Earth Recovery and Refining circuit and FeNb processing circuit | Monthly area samples |
| Radon Decay Products – Rolle or Borak method | Monthly "grab" sampling in open cut. | NR | NR |
| Thoron Decay Products – Cote method | Monthly "grab" sampling in open cut. | NR | NR |
| Surface Contamination | Monthly survey | Monthly survey | Monthly survey |
| NR = Not Required | | | Source: Modified after JRHC (2013) – Table 11 |

The Applicant has recently installed a network of environmental radiation monitors. **Figure 4.15** (in Section 4.3) identifies the locations of these Environmental Radiation Monitoring Locations (ERMLs) and **Table 4.44** details the ongoing monitoring that would be undertaken at these sites.

The occupational and environmental monitoring program would be reviewed after three years.

**Table 4.44**
**Environmental Radiation Monitoring Program**

| Parameter | Monitoring | Location |
|---|---|---|
| Gamma radiation | Quarterly environmental TLD badges | ERML |
| | Handheld environmental gamma monitor | Annual survey at perimeter of operational area |
| Airborne dust | Passive dust sampling, with samples composited for one year then radiometric analysis | ERML |
| Radon Concentrations | Quarterly passive monitoring | ERML |
| Thoron Concentrations | Quarterly passive monitoring | ERML |
| Radionuclides in Soils | Sampled every 5 years | ERML |
| Radionuclides in Groundwater | Water sampled annually at monitoring bore locations | Refer to Section 4.6.6.3 |
| Source: Modified after JRHC (2013) – Table 12 | | |

# 4.5 SURFACE WATER

## 4.5.1 Introduction

The Director-General's Requirements identified "***Water Resources*** *as a key issue for assessment – including*:

- *a detailed assessment of potential impacts on the quality and quantity of existing surface and groundwater resources, including:*
  - *impacts on affected licensed water users and basic landholder rights; and*
  - *impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows.*
- *a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures;*
- *an assessment of proposed water discharge quantities and quality/ies against receiving water quality and flow objectives;*
- *an assessment of proposed modifications to surface water management, including modelling the redistribution of waters and an assessment of the impact on neighbouring properties and the associated watercourse and floodplain;*
- *identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000;*
- *demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP);*
- *a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo;*
- *a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts*."

Additional matters for consideration in preparing the EIS were also provided in the correspondence attached to the DGRs from the NSW Office of Water (NOW) which amongst others request that the EIS provide "*an assessment of any proposed modification to surface water management including modelling of redistribution of waters and an assessment of impact on neighbouring properties and the associated watercourse and floodplain*"; "*preparation of a surface water management plan …. to integrate the proposed water balance and management for the site and to identify adequate mitigating and monitoring requirements for both water quality and water volume*"; and "*identification of site water demands, water sources (surface and groundwater), water disposal methods and water storage structures in the form of a water balance*".

The NSW EPA and Central West Catchment Management Authority also provided detailed requirements for the assessment of surface water affected by the Proposal.

Based on the risk analysis undertaken for the Proposal (Section 3.5), the potential impacts relating to surface water and their risk rankings (in parenthesis) without the adoption of any mitigation measures are as follows.

- Reduced flows to Wambangalang Creek and other tributaries of the Macquarie River (medium).
- Reduced availability of water to downstream users (medium).
- Pollution of local and downstream waterways resulting in detrimental effects to flora and fauna (low).
- Contamination of local surface water (medium).
- Contamination of drinking water supply (medium).
- Increased erosion potential resultant from changed alignment of flow (low).
- Increased erosion potential within Wambangalang and Paddys Creek catchments (low).
- Detrimental impacts on surrounding properties as a result of changes to flooding regime (low).
- Increased sediment load in drains and/or waterways (medium).
- Increased siltation in drains and/or waterways (medium).

The surface water assessment for the Proposal was undertaken by Mr Mark Passfield of Strategic Environmental and Engineering Consulting (SEEC) Pty Ltd. The resulting report is presented as Part 4 of the *Specialist Consultants Studies Compendium* and is referred to hereafter as “SEEC (2013)”. This subsection of the EIS provides a summary of the surface water assessment, concentrating on those matters raised in the DGRs and submissions to the DGRs provided by various government agencies. A consolidated list of the identified requirements and where each is addressed in the EIS is presented in **Appendix 3**.

## 4.5.2 Existing Environment

### 4.5.2.1 Introduction

An overview of the surface water environment within and surrounding the DZP Site is presented in Section 4.1.2. This subsection builds on that description and provides a description of the surrounding hydrological environment, water quality and surrounding water users.

#### 4.5.2.2 Existing Flooding Regime

**DZP Site**

SEEC (2013) undertook a flood assessment for a 1 in 100 year Annual Recurrence Interval (ARI) rainfall event for Wambangalang and Paddys Creeks and Watercourses B, C and E. This assessment was undertaken using the HEC-RAS (Hydrologic Engineering Centres River Analysis System) flood modelling software. Peak flows were determined in accordance with the Rational Method as outlined in the document *Australian Rainfall and Runoff; A Guide to Flood Estimation* published by the Institute of Engineers Australia.

The results of the assessment are presented in **Figure 4.21**. In summary, the extent of flooding in the upper reaches of Watercourses B, C and E is expected to be limited because of the limited catchment and relatively more steeply sloped land. By contrast, a 1 in 100 year ARI event is likely to result in inundation of the land surrounding the lower reaches of those creeks, as well as Wambangalang and Paddys Creeks to a distance of up to approximately 300m from the centre line of the creek. In particular, **Figure 4.21** indicates that, in the absence of management and mitigation measures, sections of the Processing Plant Area may be inundated. Section 4.5.5.7 provides further assessment of the anticipated impacts associated with a 1 in 100 year ARI event, taking into account the management and mitigation measures identified in Section 4.5.4.

**Toongi and Obley Roads**

The Proposal would require an upgrade to Toongi and Obley Roads, including upgrading of several creek crossings. SEEC (2013) undertook an assessment of the following crossings to determine the existing flood levels using the methodology described previously.

- Toongi Road at Wambangalang Creek - this crossing currently comprises a low level concrete causeway (with six 1 050mm reinforced concrete low flow pipes) that is below the modelled 1 in 100 year ARI flood height of approximately 282.6m AHD.
- Obley Road at Cumboogle Creek – this crossing currently comprises a concrete bridge structure elevated above the local flood plain.
- Obley Road at Hyandra Creek - this crossing currently comprises a 12m span steel bridge, with the deck of the bridge below the 1 in 5 ARI flood event. The modelled elevation of the 1 in 100 year ARI flood height at this crossing is 285.2m AHD.
- Obley Road at Twelve Mile Creek - this crossing currently comprises a causeway with a single 450mm reinforced concrete pipe low flow causeway. The elevation of the causeway and the road for several hundred metres in each direction is below the 1 in 5 ARI flood event. The modelled elevation of the 1 in 100 year ARI flood height at this crossing is 285.81m AHD.

On the basis of these flood levels, Constructive Solutions (2013) prepared conceptual alignment and bridge deck designs for the Wambangalang Creek, Hyandra Creek and Twelve Mile Creek crossings (see *Appendix D(ii)* of Constructive Solutions, 2013). As noted in Sections 2.2.5.2 and 2.2.5.3, the Applicant proposes to upgrade these crossings to allow for passage of flood waters up to the 1 in 20 ARI flood event.

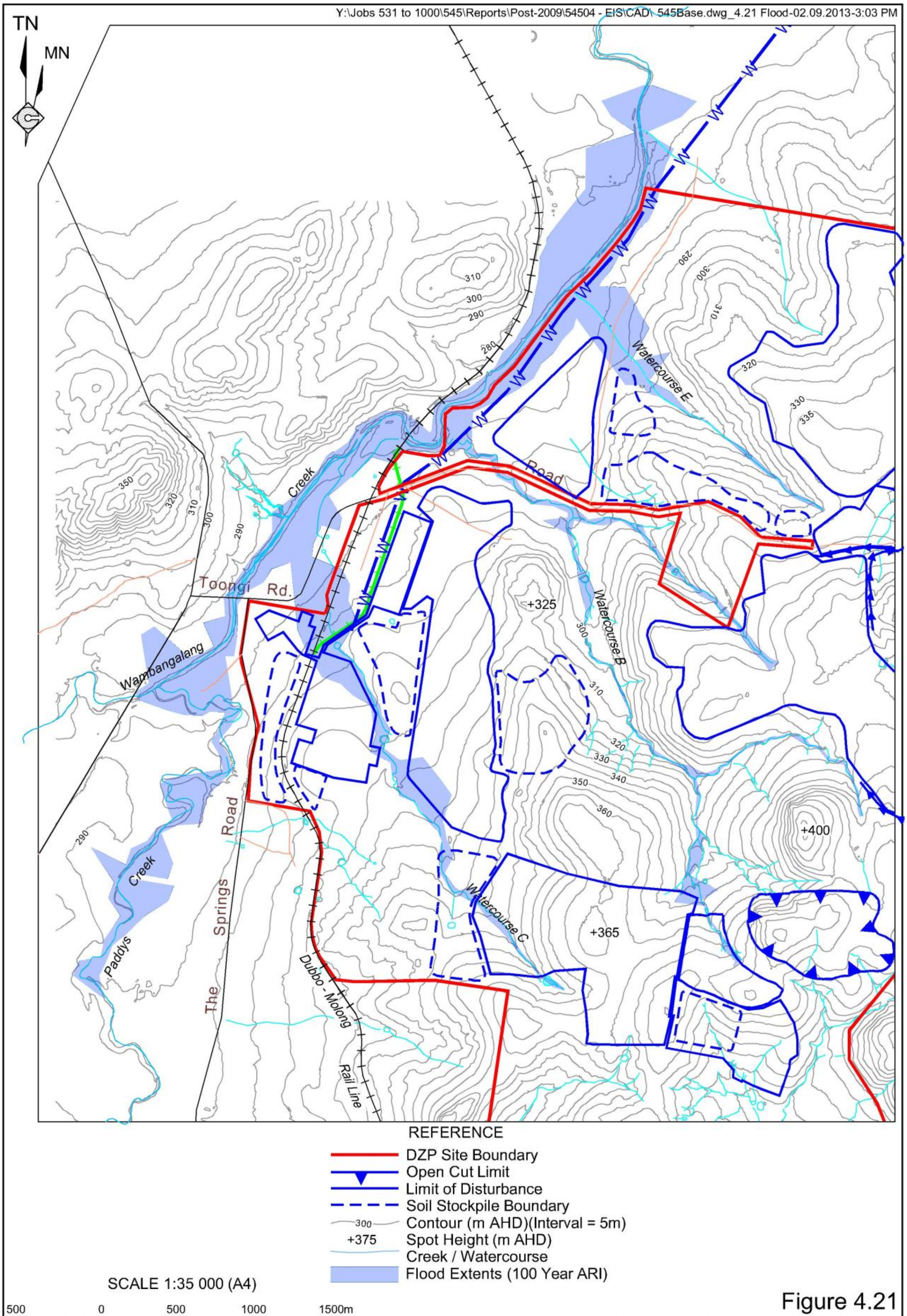



Figure 4.21
EXISTING FLOOD REGIME

#### 4.5.2.3 Surface Water Quality

Two surface water sampling programs have been undertaken by the Applicant within and surrounding the DZP Site. Details of the results of the sampling programs are presented in *Tables 1* and *2* of SEEC (2013). In summary, surface water quality within and surrounding the DZP Site may be described as follows.

- Salinity – the upper reaches of Cockabroo Creek (north Tributary) and Watercourse A recorded electrical conductivities between 95µS/cm and 330µS/cm. By contrast the lower section of Watercourses B and C and Wambangalang Creek recorded electrical conductivities between 1 830µS/cm and 3 800µS/cm. SEEC (2013) notes that the Toongi Catchment is recorded as being prone to significant salinity. Surface water salinities between 2 000 to 3 000µS/cm have been commonly recorded in this catchment, with some results of more than 6 000µS/cm.
- pH – results were recorded between 6.82 and 8.66, with more samples returning slightly alkaline results.
- Turbidity – varied between 2.6NTU and 100NTU.
- Nitrogen and phosphorous – were both elevated above ANZECC (2000) criteria.

Smithson (2001) identifies that the areas at greatest risk for dryland salinity are those where the groundwater table is within 5m of the natural ground surface. Based on mapping prepared by Smithson (2001 – *Figures 6* and *13*) there are no recorded areas of dryland salinity sites within the DZP Site. Less than 5% of the DZP Site is expected to have water tables within 5m of the natural ground surface. It is noted that *Appendix H* of EES (2013) (Part 5 of the *Specialist Consultant Studies Compendium*) provides a detailed summary of Smithson (2001) including the noted maps.

#### 4.5.2.4 Surrounding Water Users and Availability

Surface water licences within the Wambangalang Whyandra Creek Water Source are described in the *Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources*. In summary, the report identifies five existing licences within the boundaries of the water source, with a total entitlement of 165ML/year, of which 85% is used for irrigation and 15% for domestic or stock use. None of the five licences are located on either Paddys Creek or Wambangalang Creek. The Water Sharing Plan advocates no further licences are issued in this catchment and water may only be harvested when pools are at full capacity.

The DZP Site is within the Macquarie River Catchment upstream of Dubbo. The Macquarie River includes numerous water users, including the City of Dubbo which draws 85% of its town water supply from the river.

### 4.5.3 Potential Surface Water Impacts

The development and operation of the Proposal could have a range of potential surface water-related impacts. The principal potential impacts and the risks associated with each are identified in Section 3.5 and are described in more detail below. Each of the potential impacts outlined below has been assessed in detail by SEEC (2013) in conjunction with the Applicant to ensure appropriate design and operational safeguards are in place to avoid or minimise potential adverse environmental impacts (see Section 4.5.5).

- Reduced flows to Wambangalang Creek and other tributaries of the Macquarie River and reduced availability of water to downstream users through a temporary or permanent reduction in catchment area or changes to the existing flow regime.
- Stress and possible reduction in viability of native flora or fauna or degradation of aquatic habitats as a result of reduced flows or changes to the existing flow regime or water quality.
- Contamination of soil resources and indirect impacts on future land use as a result of changes in water quality.
- Health-related impacts for people or stock due to consumption of contaminated water.
- Increased erosion or sedimentation potential from changes to the existing flow regime.
- Occurrence of dryland salinity on the DZP Site lands.

## 4.5.4 Management and Mitigation Measures

### 4.5.4.1 Introduction

The management of surface water to avoid or minimise the adverse impacts throughout the development and operation of the Proposal requires a coordinated and systematic approach that collectively addresses all potential surface water impacts. This subsection outlines how the Applicant would manage the quantity and quality of surface water encountered within each section of the DZP Site from the early stages of site establishment and construction through to completion of the final rehabilitation program.

Surface water would be managed on site according to quality, namely:

- clean water, namely runoff (typically upslope) that is not affected by any disturbed areas or Proposal-related activity(ies);
- dirty or sediment-laden water, namely runoff containing only sediment and originating from disturbed or bare areas within the DZP Site; or
- contaminated water, namely water with the potential to contain chemicals or salt.

This subsection concludes with an overview of the site water balance which outlines how the Applicant would prioritise the use of water within the DZP Site and ensure sufficient water is available for processing operation and dust suppression.

The management of surface water within the Site would be a continually evolving component of the overall management of the operation and be assessed against the *Water Management Plan* that is to be updated throughout the life of the Proposal.

### 4.5.4.2 Surface Water Management Plan

#### 4.5.4.2.1 Introduction

**Figure 4.22** presents the proposed indicative surface water controls for the DZP Site with **Figures 4.23** and **4.24** providing a more detailed illustration of the proposed indicative surface water controls around the processing plant and DZP Site Administration Area, and open cut, WRE and SECs respectively. The following presents a brief description of the management of surface water within each of the component areas of the DZP Site. Section 4.5.4.4 presents the indicative water balance for the Proposal, based in part on the following.

#### 4.5.4.2.2 Overview of the Proposed Surface Water Management

The soils of the DZP Site are moderately erodible and generally either fine grained or significantly dispersive (SSM, 2013). Areas of bare soil would be potential sources of erosion and subsequent sedimentation unless they are managed correctly.

Erosion and sediment control for the DZP Site would be formalised in one or more *Erosion and Sediment Control Plans* (ESCP) for the DZP Site (and other component areas of disturbance) in accordance with the requirements of Landcom (2004), DECC (2008a) and DECC (2008d). The ESCP for specific components of the DZP would be prepared prior to the commencement of ground disturbing activities and would be updated progressively as the extent of earthworks increases or changes.

In summary, sediment loss would be controlled by a series of best management practices (BMPs) which would include:

- diverting surface water runoff away from active works areas;
- minimising areas of disturbed ground by:
  - only disturbing land when works are required;
  - delineating no-go areas; i.e. controlling access to only those areas that would be worked; and
  - effectively and promptly stabilising ground that has reached its final design form or land that would not be re-worked within 20 days;
- implementing ancillary or secondary measures such as:
  - reducing slope lengths on disturbed surfaces to control soil loss;
  - using sediment fence or similar sediment traps where necessary; and
  - using a series of “wet-type” sediment basins and actively managing them to the requirements of Landcom (2004) and DECC (2008d).
- Inspect all surface water control structures at least quarterly and following any rainfall event of more than 10mm in 24-hours to ensure their adequacy, and identify where remedial action is required.
- Ensure that all potentially salt or chemical-laden water is retained within the DZP Site and is used for processing operations or is pumped to the Liquid Residue Storage Facility.

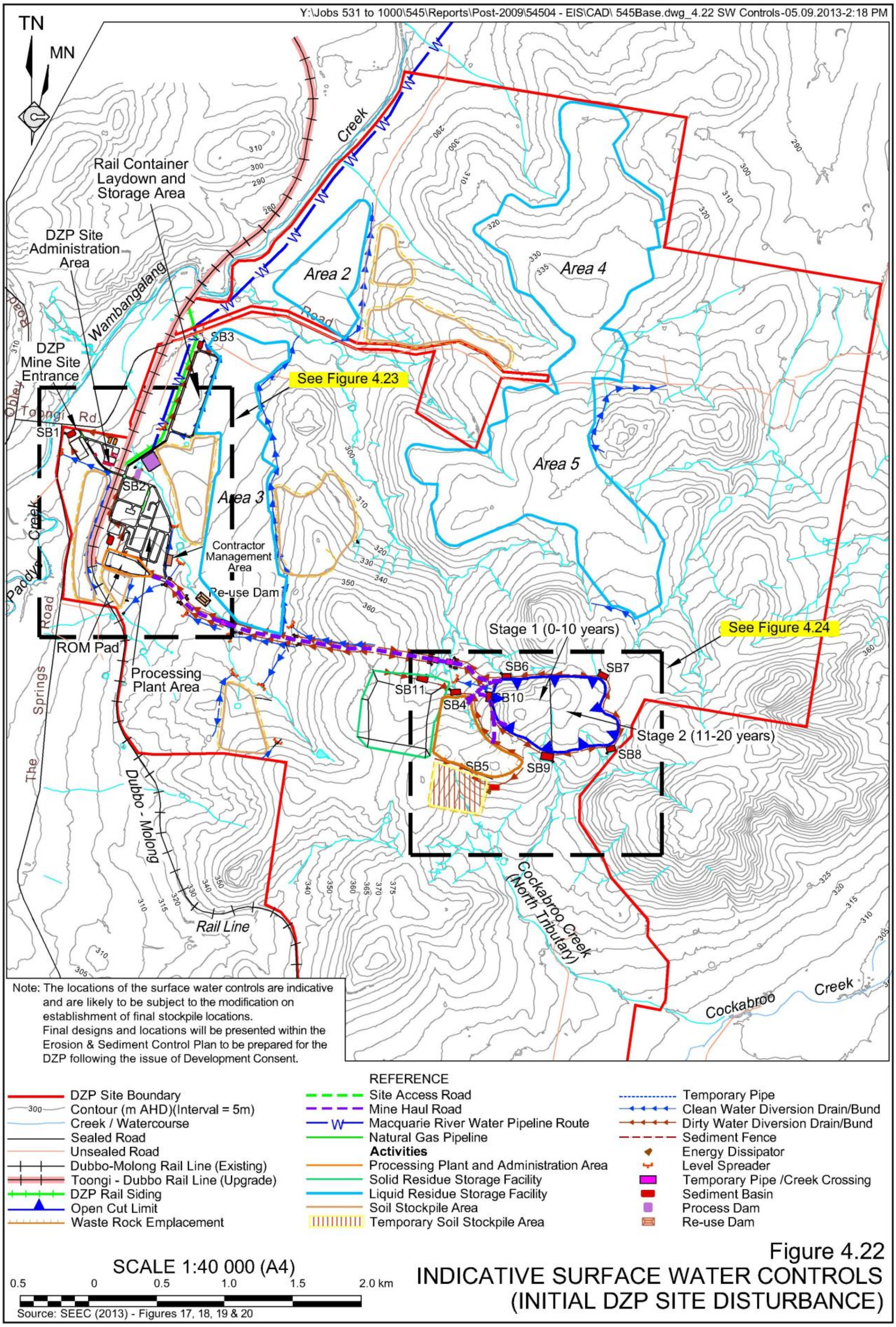



Figure 4.22
INDICATIVE SURFACE WATER CONTROLS
(INITIAL DZP SITE DISTURBANCE)

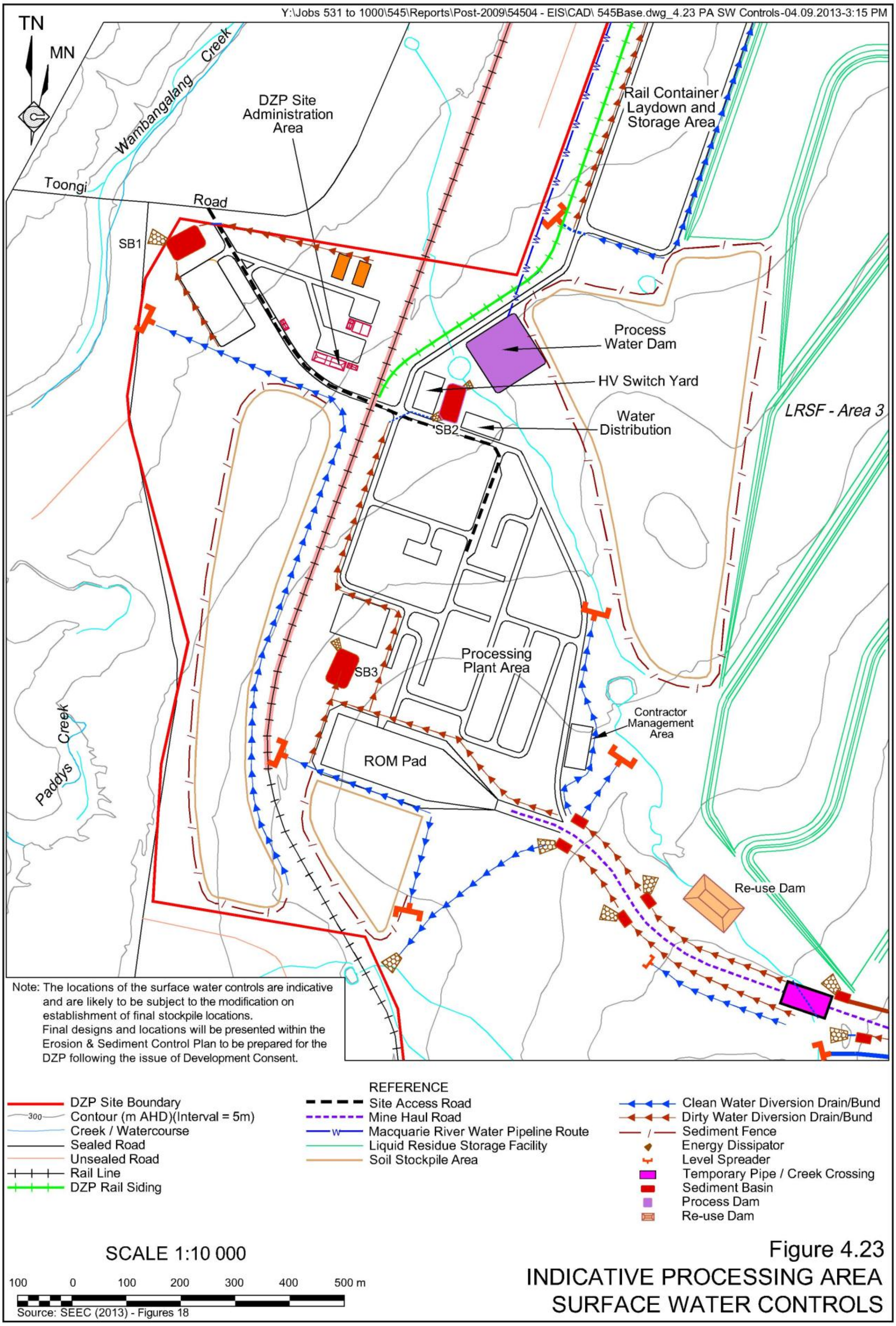



Figure 4.23
INDICATIVE PROCESSING AREA SURFACE WATER CONTROLS

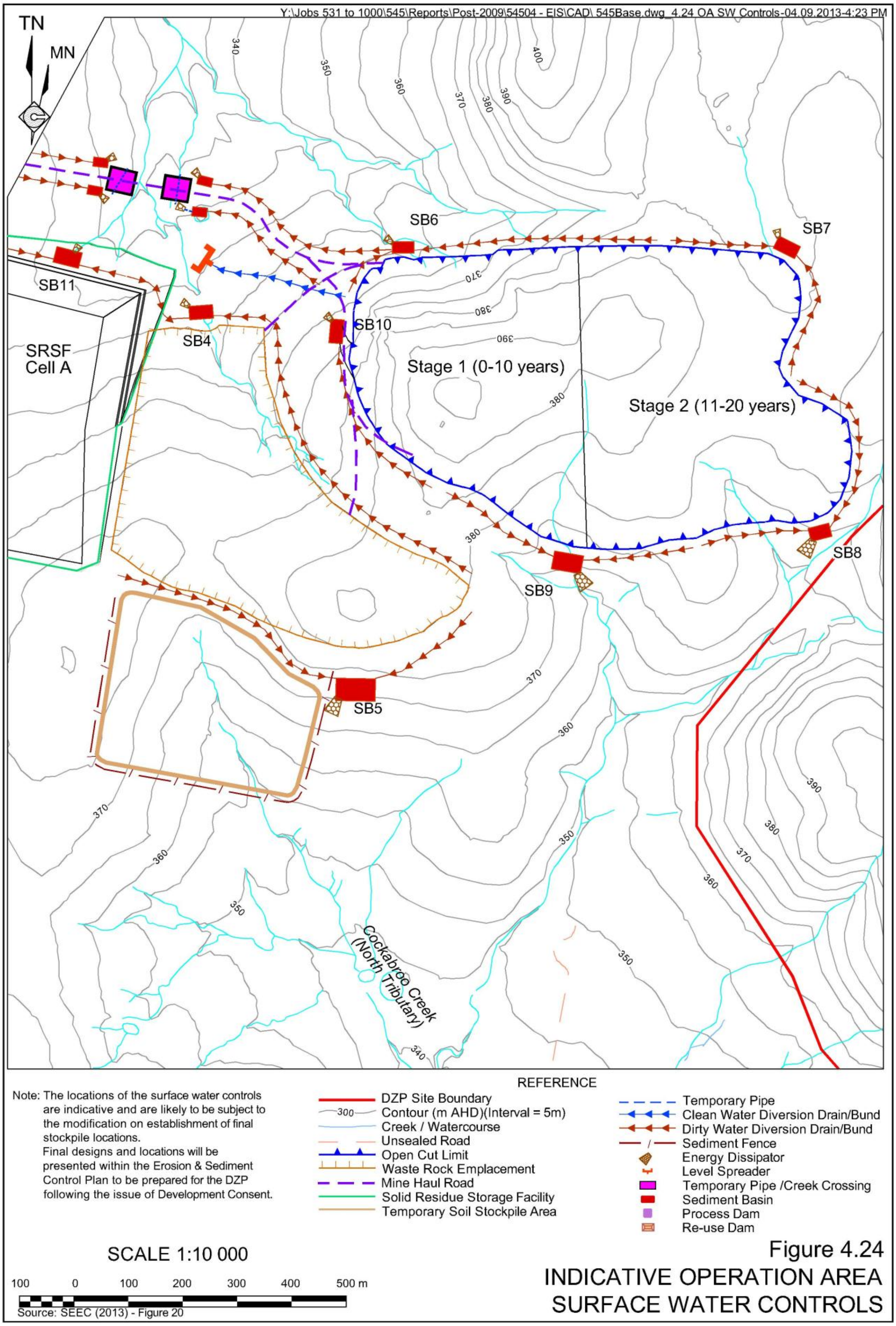



Figure 4.24
INDICATIVE OPERATION AREA SURFACE WATER CONTROLS

- Ensure that all potentially sediment-laden water is directed to appropriately designed sediment basins and is either used for processing operations or dust suppression or, following testing to verify the quality of the water is acceptable, is discharged to natural drainage.
- Ensure that all surface water flows from undisturbed sections of the DZP Site are diverted around disturbed sections and permitted to flow to natural drainage.
- Ensure that all roads within the DZP Site are constructed in accordance with DECC (2008b).
- Ensure that the capacity of existing and proposed water storages to be constructed under the Applicant's harvestable rights does not exceed 182ML.
- Ensure that all areas where reagents or processing-related chemicals or by-products are sealed, bunded and, where appropriate, covered, with a suitable sump for the collection and removal of incident rainfall.
- Ensure that all areas of proposed disturbance, with the exception of the proposed open cut, are progressively rehabilitated and that surface water control structures are removed once the rehabilitated areas have achieved a 70% cover.

Specific areas of the DZP Site, namely the ROM Pad and WRE, would generate runoff potentially containing sediment with trace concentrations of uranium and thorium. Runoff from these areas of the DZP Site would be captured and discharged to the LRSF, i.e. not discharged to natural drainage. The Processing Plant and DZP Site Administration Area would be exposed to reagents which if spilled would be contaminating to the environment. Consequently, these areas have been designed for nil discharge.

The surface water management structures that would be constructed within the DZP Site would include the following.

- Clean water diversions to divert surface water run off from undisturbed sections of the DZP Site around areas of proposed disturbance.
- Dirty water diversions to divert sediment-laden water to sediment basins for settling prior to discharge to natural drainage or use for processing operations.
- Diversion of dirty water runoff from mineralised ore (ROM Pad) and waste rock (WRE) and collection within storage basins. As these basins fill, the water would be pumped to the LRSF to ensure no discharge from the DZP Site.
- Sealed and bunded areas for the retention of potentially contaminated runoff within the Processing Plant and DZP Site Administration Area. Runoff from areas not exposed to potentially contaminating reagents would be diverted to sediment basins for settling prior to discharge to natural drainage or use for processing operations.
- Twelve principal sediment and storage basins for the collection of sediment-laden or potentially contaminated water for transfer to the Water Re-use Dam, Process Water Pond or, following settling of suspended sediment, discharge to natural drainage via a stabilised spillway. A range of smaller sediment basins/stormwater retention structures would be constructed as required adjacent to the haul road and down-slope of the LRSF, SRSF and Salt Encapsulation Cells as constructed.

- A Water Re-use Dam for collection and storage of sediment-laden water for use for dust suppression, processing operations or discharge to natural drainage.
- A Process Water Pond for the storage of water from the water pipeline and other water sourced from onsite for use within the processing plant.

**Table 4.45** presents the design volumes for each of the proposed sediment and storage basins. These volumes have been estimated based on the following.

- Design rainfall depth equal to the 90$^{th}$ percentile 5-day depth of 35.6mm (for sediment basins collecting runoff from all areas of disturbance not exposed to ore or waste rock: SB1 – SB3, SB6 – SB11).
- Design rainfall depth = Double the 1 in 100 ARI time of concentration ($t_c$) event (for sediment basins collecting runoff from ore stockpiles [ROM Pad] or waste rock [WRE]: SB4, SB5 & SB12).
- A rainfall erosivity factor (R-Factor) of 1 350.
- A soil erodibility factor (K-Factor) of 0.04.

**Table 4.45**
**Proposed Sediment Basin Volumes**

| Sediment / Storage Basin | Catchment | Water Volume ($m^3$) | Sediment Volume ($m^3$) | Total Proposed Volume ($m^3$) |
|---|---|---|---|---|
| SB1 | DZP Site Administration Area | 1 900 | 100 | 2 000 |
| SB2 | Rail Container Laydown and Storage Area | 4 850 | 150 | 5 000 |
| SB3 | Processing Plant Area | 2 500 | 100 | 2 600 |
| SB4 | Waste Rock Emplacement | 10 000 | 100 | 10 100 |
| SB5 | Waste Rock Emplacement | 5 000 | 50 | 5 050 |
| SB6 | Open Cut | 2 600 | 500 | 3 100 |
| SB7 | Open Cut | 1 350 | 150 | 1 500 |
| SB8 | Open Cut | 2 900 | 300 | 3 200 |
| SB9 | Open Cut | 2 500 | 600 | 3 100 |
| SB10 | Open Cut | 1 100 | 300 | 1 400 |
| SB11 | Solid Residue Storage Facility | 5 100 | 500 | 5 600 |
| SB12 | ROM Pad | 6 000 | 100 | 6 100 |
| Source: SEEC (2013) – Table 4 | | | | |

A conceptual arrangement of the various diversion drains, dirty water collection drains and Sediment Basins on the DZP Site, for initial operations on the DZP Site[1], are shown in **Figures 4.22** to **4.24**. It is noted that the exact location and orientation of sediment basins would be defined in the ESCPs for the DZP following receipt of development consent and prior to commencement of construction.

[1] **Figures 4.22** to **4.24** consider disturbance associated with the DZP Processing and Site Administration Area, open cut, WRE, Cell A of the SRSF, Mine Haul Road and various soil stockpiles. Erosion and sediment control for the LRSF, additional cells of the SRSF, Salt Encapsulation Cells and other disturbance not illustrated would be included in a *Progressive Erosion and Sediment Control Plan* for the DZP Site.

Sediment Basins would also be required to accompany the construction of the various stages of the Liquid Residue Storage Facility, Cells B and C of the Solid Residue Storage Facility and Salt Encapsulation Cells. These basins would be designed in accordance with the above guidelines and would be described in progressive updates or new ESCPs before construction begins.

The following subsections consider the critical features of surface water management for the various components of the DZP Site.

#### 4.5.4.2.3 DZP Site Administration Area

The DZP Site Administration Area would generate potentially sediment-laden water only. This area would be drained to SB1 (see **Figure 4.23**). Discharge of excess stormwater would be directed (ultimately) to Wambangalang Creek via engineered outlets.

#### 4.5.4.2.4 Rail Container Laydown and Storage Area

The Rail Container Laydown and Storage Area would be concrete sealed and bunded and would include temporary storage areas for loaded and unloaded containers of reagents and other consumables. Each storage area would be individually bunded which would contain any spill should it occur. Surfaces between bunded areas and roofs would generate ‘uncontaminated’ stormwater runoff (sediment-laden only) and would drain to SB3 (see **Figure 4.23**). Should a spill of reagents occur outside the bunded bays, the outlet to SB3 would be closed and any accumulated water collected and transferred to the Liquid Residue Storage Facility. Discharge of excess stormwater would be directed (ultimately) to Wambangalang Creek via engineered outlets.

#### 4.5.4.2.5 Processing Plant Area

This area would include a mixture of sealed and bunded areas, including the processing plant itself and all reagent and chemical storage areas (see **Figure 4.23**). In addition, a range of unsealed areas, including road ways and hardstand areas would be constructed.

Processing areas and storage areas for reagents would be bunded and sealed. All bunded areas would have a sump from which potentially-contaminated runoff would be drawn and either returned to the relevant component of the processing operation or neutralised (as required) and pumped to the LRSF for disposal distributed to either the Process Water Dam or the Liquid Residue Storage Facility. Bunded areas that are open to the weather would have sufficient volume to trap 110% of the volume of the largest storage tank plus a volume of 0.2 x area ($m^3$) to allow for 200mm of incident rainfall. At no time would water sourced from these bunded areas be released to the environment. Spill containment kits would also be kept on site. Should a spill of reagents occur outside the bunded areas, the outlet to SB2 would be closed and any accumulated water collected and transferred to the Liquid Residue Storage Facility.

Surfaces between bunded areas and roofs would generate ‘uncontaminated’ stormwater runoff (sediment-laden only) and would drain to SB2, which would initially serve as the sediment basin during establishment of the Processing Plant Area. Discharge of excess stormwater would be directed (ultimately) to Wambangalang Creek via engineered outlets.

To the north of the Processing Plant Area is the Process Water Pond accepting and storing water sourced from the Macquarie River, groundwater sources and on-site surface water harvest (see Section 2.8.2). This pond would be constructed as a turkey's nest structure, i.e. isolated from surface flows, HDPE lined and would not accept any contaminated run-off from the Processing Plant Area, ROM Pad or WRE.

#### 4.5.4.2.6 ROM Pad

SEEC (2013) identifies that the ore material is unlikely to leach metals or contaminants. However, detectable levels of some rare earth elements and radionuclides would be entrained in any sediment suspended within runoff. As a result, runoff from this area would be treated as contaminated and would be drained to a dedicated storage basin (SB12) designed to exceed the 100year $t_c$ storm volume (3ML) by a factor of two (see **Figure 4.23**).

To prevent a large accumulation of such material, which could be subject to re-mobilisation, sediment would periodically (every three months) be removed and placed in the SRSF.

In addition a diesel pump(s) capable of 30kL/hour would be installed to pump water to one of the active LRSF cells. Trapped water in SB12 would be pumped as soon as practicable after in-flow commences and combined with the design storage capacity would ensure there could be no overflow in any 100 year storm event.

#### 4.5.4.2.7 Haul Road

The haul road would be constructed to the standards identified in DECC (2008a) and would drain to a series of sediment basins (designed in accordance with DECC, 2008d). Markers would be placed in each basin to identify the minimum required water storage volume and the maximum permissible sediment storage volumes. When the maximum sediment storage is reached, the sediment would be removed and placed on the WRE. Within 5-days of the conclusion of a rainfall event resulting in accumulation of water over the minimum water storage marker, the water would be pumped or siphoned to the Re-use Dam, used directly for dust suppression or, following settling of the suspended sediment, discharged to natural drainage.

#### 4.5.4.2.8 Open Cut

The open cut would initially be free draining and could produce potentially sediment-laden water. A range of dirty water diversion drains and temporary sediment basins would be constructed around the perimeter or within the footprint of the open cut (SB7 to SB11 illustrated on **Figure 4.24**) and water would be pumped to the Re-use Dam, Process Water Pond, used directly for dust suppression or, following settling of the suspended sediment, be discharged to natural drainage.

Following development of the open cut to the point where it is no longer free draining and becomes internally draining, the sediment basins would be decommissioned.

#### 4.5.4.2.9 Waste Rock Emplacement

Runoff from the WRE would contain sediments with detectable concentration of metals, rare earths and radionuclides which would drain to two storage basins (SB4 and SB5) (see **Figure 4.24**). The storage capacity of the storage basins have been designed to exceed the 100year $t_c$ storm volume (5ML and 2.5ML respectively) by a factor of two[2].

To prevent a large accumulation of such material, which could be subject to re-mobilisation, sediment would periodically (every three months) be removed and placed in the SRSF.

Pumps capable of transferring at least 100kL/hour (SB4) and 45kL/hour (SB5) would be installed to pump trapped water to one of the active LRSF cells. Trapped water in SB4 and SB5 would be pumped as soon as practicable after in-flow commences and combined with the design storage volume would ensure there could be no overflow in any 100 year storm event.

#### 4.5.4.2.10 Solid Residue Storage Facility

During the construction of the SRSF, runoff would be diverted to one or more sediment basins constructed in accordance with Landcom (2004) and DECC (2008d). As the embankments for each cell of the SRSF are completed and revegetated, these sediment basins would be decommissioned.

As noted in Section 2.9.2.5, a clean water diversion drain would be constructed to the south of Cell C to divert runoff from the catchment of Watercourse C from accumulating against the southern embankment.

Once constructed, the SRSF would be double lined with HDPE or equivalent and would be internally draining (refer to *Section 3.7* of **Appendix 6**). Incident rainfall on the SRSF would drain to a central collection point and then pumped to the LRSF for storage and evaporation.

It is unlikely that a phreatic surface would be developed within the SRSF even following heavy rainfall as the upper working surface of the residue would be compacted and have a very low permeability. In the unlikely event that a phreatic surface is developed within the SRSF, this would migrate under pressure to the slotted concrete tower section of the internal drainage system (refer to *Section 3.7* of **Appendix 6**) before draining to a central collection point before being pumped to the LRSF.

#### 4.5.4.2.11 Liquid Residue Storage Facility

During the construction of the LRSF, rainfall would be diverted around the exposed surfaces through the construction of diversion banks (in accordance with Landcom, 2004 and DECC, 2008d). Incident rainfall on the exposed surfaces during construction would be diverted to one or more sediment basins constructed in accordance with Landcom (2004) and DECC (2008d). As the embankments for each cell of the LRSF are completed and revegetated, these sediment basins would be decommissioned.

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[2] And assuming 50% of the WRE is disturbed/impervious.

The LRSF would be constructed to accept, store and evaporate up to 2.5GL per year of saline water from the processing plant. Section 2.9.3 provides a detailed description of the design, construction and management of those facilities. In summary, each of the facilities would comprise a number of salt crystallisation cells which would be shaped to form a generally flat area. Each cell would be lined with a 1.5mm HDPE welded liner and would have an operating depth of 5m, with a minimum 1m freeboard.

During the operational life of each cell, water levels would be managed to ensure that the maximum rate of evaporation is achieved. The applicant anticipates that approximately 900t of salt per day would be transferred to the LRSF. As this material crystallises, cells would be progressively emptied and the accumulated salt removed, taking care not to damage the underlying liner.

The LRSF would be isolated from surface water flows and the only water that would accumulate in the cells would be incident rainfall and liquid residue pumped from the processing plant. Similarly, the facilities would not discharge to natural drainage. As a result, the only losses from the LRSF would be via evaporation.

SEEC (2013) undertook an assessment of the operational water balance for the LRSF using the software *Model for Urban Stormwater Improvement Conceptualisation* (MUSIC) developed by eWater. Three rainfall scenarios were assumed, based on daily rainfall records from the Bureau of Meteorology-operated Mentone weather station (Station Number 065030).

- Scenario 1 (1900 to 1921): representing a reasonable consistent rainfall pattern over the life of the Proposal. Mean annual rainfall over the modelled period was 579mm.
- Scenario 2 (1970 to 1991): representing a period starting off wet and then becoming dry. Mean annual rainfall over the modelled period was 579mm.
- Scenario 3 (1949 to 1970): representing a "worst case" model with mean annual rainfall over the modelled period of 731mm.

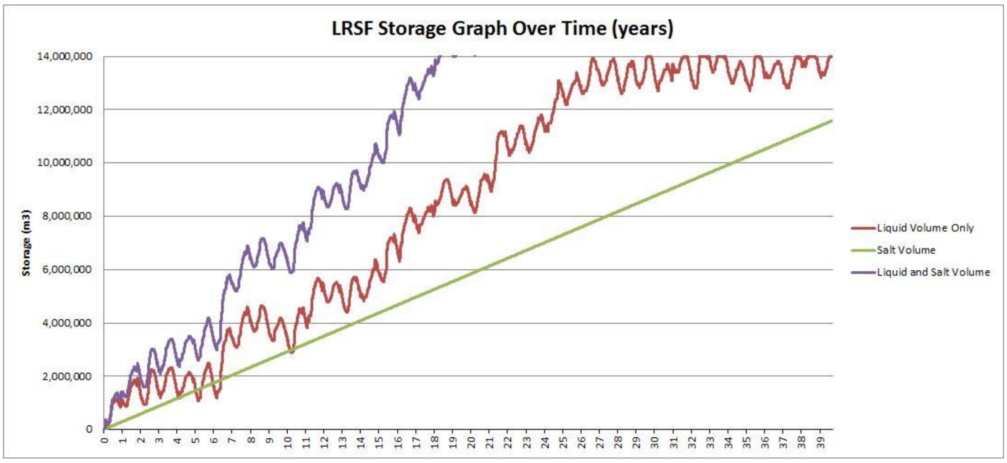
Monthly evaporation was based on an assumed evaporation rate equal to 72% of the measured pan evaporation rate at the Bureau of Meteorology-operated Wellington Agricultural Research Centre weather station (Station Number 065035).

**Figure 4.25** and **Table 4.46** present the results of the modelling. In summary, taking into account the fact that salt would be harvested as it accumulates, the LRSF would have sufficient capacity to store and evaporate liquid residue for a period of 29 years (Scenarios 1 and 2) and 16 years (Scenario 3).

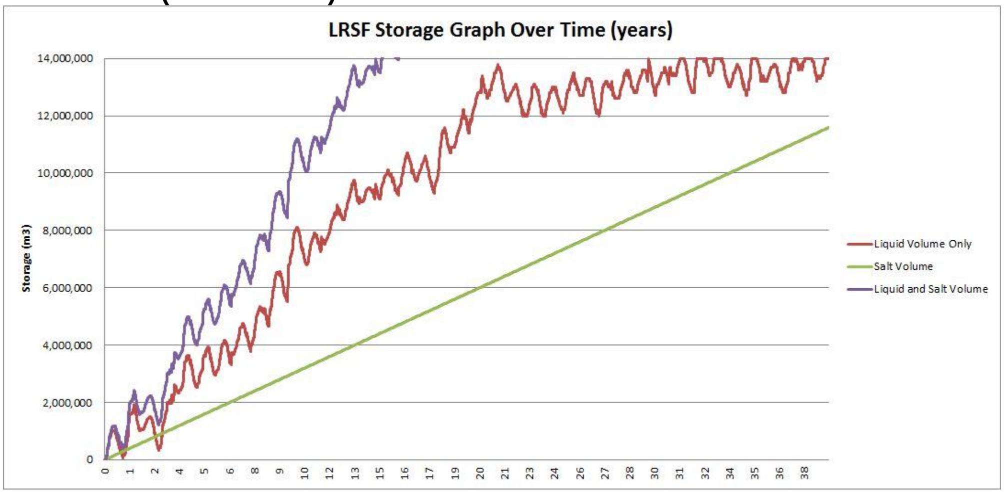
**Table 4.46**
**Anticipated Time to Achieve Maximum Capacity**

| Model Number | Predicted Time to Maximum Capacity (Water Only)[1] | Predicted Time to Maximum Capacity (Water and Salt) |
|---|---|---|
| 1 | 29 years | 18 years |
| 2 | 29 years | 15 years |
| 3 | 16 years | 13 years |
| Note 1: Assumes accumulated salt is removed periodically | | |
| Source: SEEC (2013) – Table 6 | | |

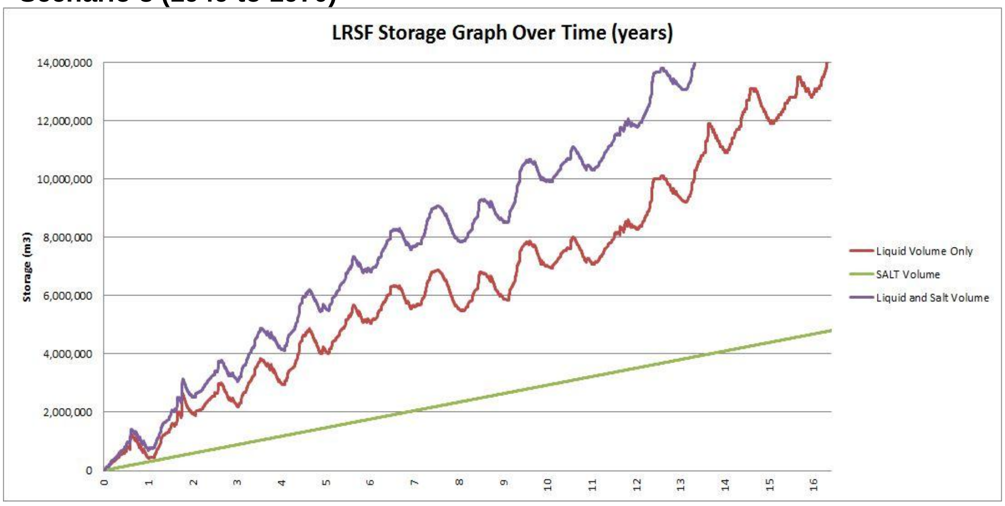
**Scenario 1 (1900 to 1921)**




**Scenario 2 (1970 to 1991)**




**Scenario 3 (1949 to 1970)**




Source: SEEC (2013) – Figures 23, 24 and 25

**Figure 4.25**
**LIQUID RESIDUE STORAGE FACILITY PERFORMANCE**

The Applicant would ensure that water and salt levels within the cells are monitored regularly and in the event that above average rainfall over an extended period results in accumulation of water within the LRSF at a rate that would result in the capacity being reached prior to the completion of the proposed processing operations, the Applicant would implement measures to either maximise the rate of evaporation through the use of sprinklers or foggers, maximise the storage volume through removal of accumulated salt or restriction of the rate of water transfer from the processing plant through a reduction in the rate of processing or similar means.

#### 4.5.4.3 Harvestable Rights

Section 53 of the *Water Management Act 2000* permits landholders to harvest and use a portion of the total runoff from their land without requiring a licence, provided that:

- the total capacity of the harvestable rights water storages is less than the capacity permitted under the right; and
- that all storages are constructed either off-line or on first or second order, non-spring fed streams.

Water captured within harvestable rights dams may be used for any purpose, including mining-related purposes.

The Applicant would, following granting of development consent, own approximately 3 450ha within and surrounding the DZP Site. However, the Proposal would result in disturbance and isolation from the various surface water catchments of approximately 640ha. As a result, for the purposes of estimating the harvestable rights capacity, a landholding of 2 810ha has been assumed. Taking into account the relevant harvestable rights multiplier for the DZP Site of 0.065ML/ha, the harvestable right capacity for the land to be held by the Applicant would be approximately 182ML.

SEEC (2013) notes that there are approximately 64 existing farm dams on the DZP Site and surrounding properties which are or would be owned by the Applicant on issue of development consent with a total estimated volume of approximately 82ML. As a result, a further 100ML of storages could be built without exceeding the Applicant's harvestable right.

The Applicant proposes to use, where practicable, water collected within sediment basins for Proposal-related purposes, including dust suppression and processing operations. As a result, these basins are required to be included under the Applicant's harvestable right. SEEC (2013) estimates that SB1 to SB12 would have a combined capacity of approximately 34ML. As a result, the Re-use Dam would have a capacity of approximately 66ML.

Given that the capacity of the existing and proposed structures is within the harvestable right capacity, and that all proposed dams or sediment basins would be located off line or on first or second order streams, the Applicant contends that the proposed storages are compliant with the requirements of Section 53 of the *Water Management Act 2000*.

The Process Water Pond and other process-related water storages within the DZP Site would store potentially salt or chemical-laden water and would therefore not be included under the Applicant's harvestable right.

SEEC (2013) estimates that, assuming all water collected within sediment basins is transferred to the Re-use Dam, an average of 0.3ML per day or 109ML per year (approximately 0.4% of total annual demand), could be incorporated into the overall water supply strategy for dust suppression or processing operations.

#### 4.5.4.4 Site Water Balance

Section 2.8 provides an overview of water requirements and sources for the Proposal. In summary, the Applicant anticipates that up to 4.05GL of make-up water per year for processing operations may be required. In addition, the Applicant estimates that an additional approximately 39.6ML of water would be required for dust suppression purposes.

The required water would be sourced from the following sources.

- Macquarie River (high security licences).
- Macquarie River (general security licences)
- Groundwater (Macquarie River alluvial aquifer).
- Groundwater (fractured rock aquifer).
- On-site surface water harvesting.

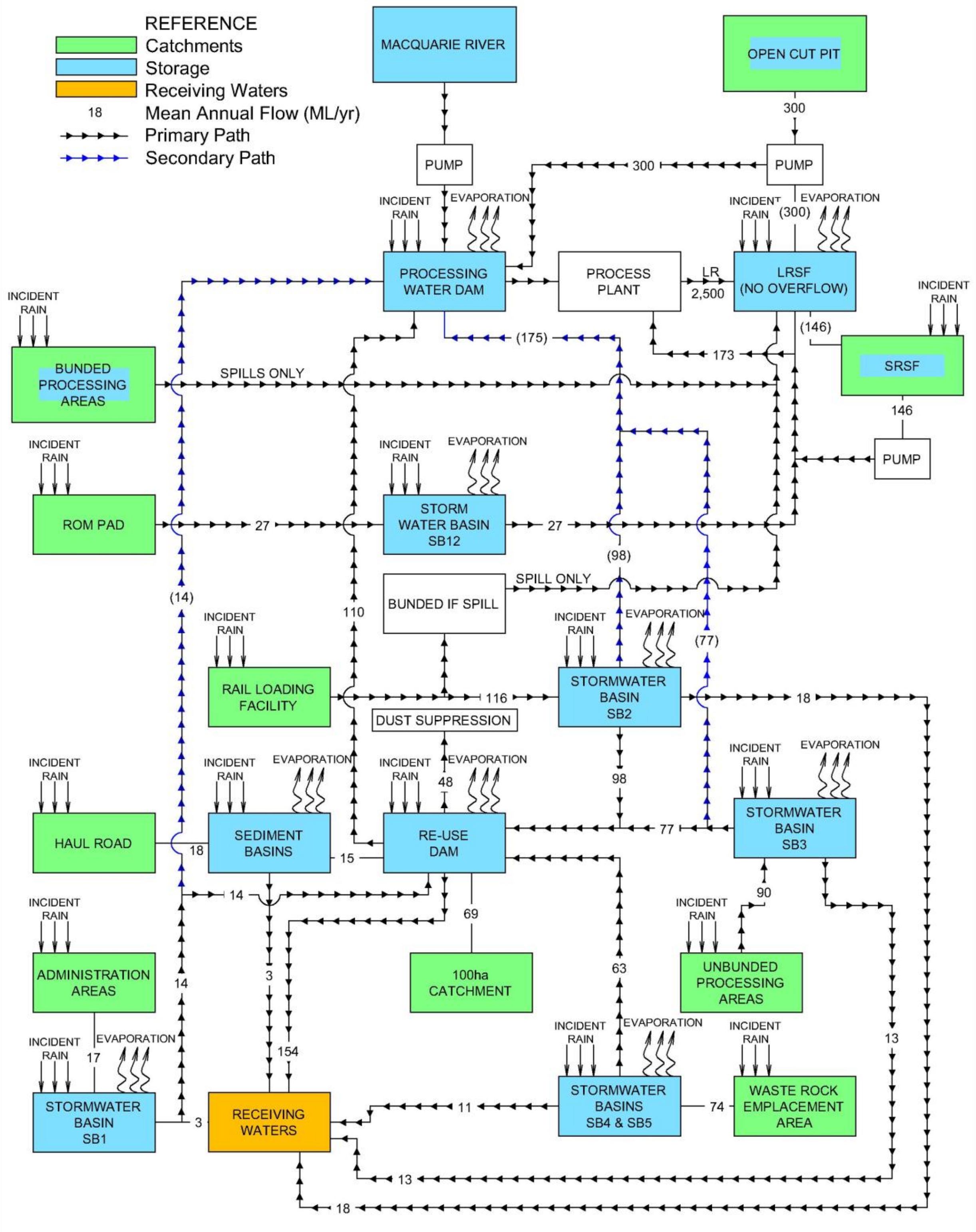
**Figure 4.26** presents an overview of surface water flows within the DZP Site. In summary:

- all potentially contaminated water would either be re-used in the immediate process, or neutralised and then disposed of to the LRSF; or
- all potentially sediment-laden water would be directed to sediment basins where it would be either transferred to the Re-use Dam for use for dust suppression or processing operations, used directly for dust suppression or discharged following confirmation that the water quality is acceptable.

#### 4.5.4.5 Decommissioning and Final Landform Water Management

As indicated in Section 2.17, progressive rehabilitation would occur throughout the life of the Proposal. However, as a result of the nature of the proposed mining operations, the majority of rehabilitation would be undertaken following the completion of mining and processing operations.

Section 2.17.4 provides an overview of the final landform. In summary, all infrastructure not required for future land use would be removed and the majority of the DZP Site would be returned to the original landform, with the exception of the open cut, SRSF and Salt Encapsulation Cells. The SRSF would initially be reshaped, covered and rehabilitated. The LRSF would be permitted to dry out and the accumulated salt, together with the liner, would be placed within the Salt Encapsulation Cells. The footprint of the LRSF would be progressively reshaped and rehabilitated as individual cells are decommissioned. Finally, the Salt Encapsulation Cells would be reshaped and rehabilitated. The Applicant anticipates that rehabilitation operations would require approximately 2 to 5 years to complete to a standard where the mining lease may be relinquished following the completion of mining and processing operations.




Source: SEEC (2013) - Figure 27

Figure 4.26
DZP SITE WATER BALANCE

#### 4.5.4.6 Additional Management Measures

The following presents an overview of the additional management and mitigation measures that the Applicant would implement to minimise the potential for adverse surface water-related risks associated with the Proposal.

- Inspect all surface water control structures at least quarterly and following any rainfall event of more than 10mm in 24-hours to ensure their adequacy, and identify where remedial action is required.
- Ensure that all potentially salt or chemical-laden water is retained within the DZP Site and is used for processing operations or is pumped to the LRSF.
- Ensure that all potentially sediment-laden water is directed to appropriately designed sediment basins and is either used for processing operations or dust suppression or, following testing to verify the quality of the water is acceptable, is discharged to natural drainage.
- Ensure that all surface water flows from undisturbed sections of the DZP Site are diverted around disturbed sections and permitted to flow to natural drainage.
- Ensure that all roads within the DZP Site are constructed in accordance with DECC (2008b).
- Ensure that the capacity of existing and proposed water storages to be constructed under the Applicant's harvestable rights does not exceed 182ML.
- Ensure that all areas where reagents or processing-related chemicals or by-products are sealed, bunded and, where appropriate, covered, with a suitable sump for the collection and removal of incident rainfall.
- Ensure that all areas of proposed disturbance, with the exception of the proposed open cut, are progressively rehabilitated and that surface water control structures are removed once the rehabilitated areas have achieved a 70% cover.

### 4.5.5 Assessment of Impacts

#### 4.5.5.1 Introduction

The proposed management and mitigation measures were taken into account by SEEC (2013) when assessing residual surface water impacts within and surrounding the DZP Site. An assessment of the residual impacts is outlined in the following subsections.

#### 4.5.5.2 Surface Water Flow Volumes

**During the Life of the Proposal**

SEEC (2013) estimates that the runoff coefficient for the DZP Site is approximately 11%. Assuming an annual average rainfall of 643.7mm (Section 4.1.3.3) and an area for the DZP Site of approximately 2 864ha, SEEC (2013) estimates that the average annual runoff from the area is approximately 2 027ML.

The Applicant anticipates that approximately 640ha would be removed from natural catchments throughout the life of the Proposal. This would represent those areas where surface water may be potentially contaminated and where that water would not be permitted to flow to natural drainage. Based on this reduction in catchment area, SEEC (2013) states that 453ML per year of surface water flows would be lost to surrounding catchments. Overall, this represents a loss of approximately 22% compared to existing DZP Site flows.

Based on the areas of each catchment within the DZP Site and the assumptions identified previously, **Table 4.47** presents the anticipated losses on a catchment-by-catchment basis throughout the life of the Proposal.

**Table 4.47**
**Reduction in Annual Surface Water Flows – During the Life of the Proposal**

| Catchment | Area | Estimated Existing Flow | Estimated Temporary Reduction in Flow | Loss |
|---|---|---|---|---|
| Wambangalang and Paddys Creek Catchments | 36 8800ha[1] | 26 100ML/year | 338ML/year | 1.3% |
| Cockabroo Creek catchment | 590ha[2] | 420ML/year | 20ML/year | 5% |
| Macquarie River (undefined) Catchment | 660ha[2] | 467ML/year | 95ML/year | 20% |
| Note 1: Area upstream of DZP Site entrance | | | | Note 2: Area within DZP Site |
| Source: SEEC (2013) – After Section 4.1.1 | | | | |

The Applicant contends that the proposed reduction in surface water flows during the life of the Proposal would not be significant on the basis of the following.

- The small reductions in the Wambangalang Creek and Cockabroo Catchments would be difficult to detect and probably masked by any base flow.
- There are no existing water licences downstream of the DZP Site and so there would be no predicted impacts to licensed users.
- While there may be recreational users of Wambangalang Creek, it is unlikely they would be accessing the creek when rainfall is sufficiently high to cause runoff and therefore, it is unlikely they would be affected.

### Following the Completion of the Proposal

Following completion of the proposed activities, the DZP Site would be reshaped, covered with soil and revegetated. Following completion of rehabilitation operations, the majority of surface water retention structures would be removed, with the exception of the open cut void which would remain and would continue to collect incident rainfall. Surface water flows would continue to be diverted away from the void. The area of the proposed open cut would be approximately 36ha. SEEC (2013) notes that this would result in a minimal impact on surface water flows within surrounding watercourses.

#### 4.5.5.3 Surface Water Flow Rate

SEEC (2013) notes that while the Proposal would not result in significant reduction in surface water flows, the increase in the area of impervious surfaces has the potential to increase the rate at which stormwater would flow to natural drainage. SEEC (2013) notes that this risk would be managed through the construction of sediment and stormwater detention basins (see Section 4.5.4) and that, as a result, the Proposal would not result in significant increases in the rate of stormwater runoff.

#### 4.5.5.4 Water Quality

A range of potential surface water contaminants would be used, stored or generated within the DZP Site.

Section 2.7 and **Figure 2.10** provide details on the management of reagents within the Processing Plant and DZP Site Administration Area, which effectively involve the containerised delivery to the DZP Site and storage and use on bunded concrete pads. Any water collected within the bunded areas would be collected and re-used in the process where possible, or neutralised and disposed of in the LRSF. Furthermore, should spillage occur within areas draining to the sediment basins of the Processing Area and Rail Laydown and Container Storage Area, the outlets to the sediment basins would be closed to prevent discharge. On this basis, storage and use of potential contaminants to water within the Processing Plant and DZP Site Administration Area is considered unlikely to result in any adverse impact to water quality within the Wambangalang Creek catchment.

SB4, SB5 and SB12 would collect and store potentially contaminated water as a result of runoff from mineralised ore and waste rock stockpiles. This would. To facilitate this, a sediment forebay would be designed into the dam’s structure.

Assuming correct construction practices are adopted (including designing the spillway to handle the probable maximum flow) the risk of dam failure is considered very low. However, under exceptionally high rainfall (greater than any 100 year storm event) the dam could conceivably overtop.

In the unlikely event SB12 overtops, the flow to Wambangalang Creek would be diluted there by flows exceeding $479m^3$/sec (the 100 year peak storm flow). By comparison, the peak flow in any 100 year storm from SB12 would be approximately $1.64m^3$/s (0.3%).

Similarly, should SB4 or SB5 overtop, the flows to Wambangalang Creek and Cockabroo Creek would be diluted by the storm flows within these catchments. In the case of SB4, the flow from this basin under 1 in 100 ARI conditions ($3.6m^3$/s) represents only 0.75% of the equivalent condition flow within Wambangalang Creek.

Further reducing the impact of any overflow from SB4, SB5 and SB12, flows within the local catchments would continue to flow at a high volume after the pulse of water from the basins have completed (having a further dilution effect). Under such circumstances the dilution effect would ensure there would be no identifiable increase in isotope concentrations in the stream’s sediment (which would have been significantly altered by the high flows anyway).

In light of those measures, SEEC (2013) states that the Proposal would not result in significant adverse surface water quality impacts.

#### 4.5.5.5 Sediment and Erosion Control

Section 4.5.4.2 presents an overview of the sediment and erosion control measures that would be implemented. In light of the proposed controls, and the fact that they would be consistent with Landcom (2004) and DECC (2008a and 2008b), SEEC (2013) states that sediment and erosion-related impacts associated with the Proposal would not be significant.

#### 4.5.5.6 Downstream Water Users

As identified in the preceding subsections, the Proposal is not expected to result in significant adverse impacts associated with altered surface water flow volumes or rates or surface water quality associated with contamination by chemicals or sediment. As a result, the Applicant contends that the Proposal would similarly not result in adverse impacts to downstream water users.

The Applicant also notes that of the five surface water licences within the *Wambangalang Hyandra Creek Water Source* of the *Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources*, none are located on Paddys or Wambangalang Creeks and therefore would not be impacted by the minor reduction in total runoff predicted for these catchments.

Furthermore, the Applicant notes that the area of the DZP Site is insignificant compared with the catchment of the Macquarie River upstream of Dubbo. As a result, the Applicant contends that the Proposal would not have an adverse impact on water users within the Macquarie River Catchment, including the residents of Dubbo.

#### 4.5.5.7 Flooding

**Figure 4.21** presents the existing 1 in 100 year ARI flood extents. That modelling indicates that a section of the Processing Plant Area would be subject to inundation from Watercourse C in the event of an extreme rainfall event. As a result, those sections of the footprint of the Processing Plant Area closest to Watercourse C would be raised above the 1 in 100 year ARI flood level.

SEEC (2013) undertook an assessment of the impact of the proposed works. In summary, the footprint of the Processing Plant Area was assumed to be raised to approximately 295.9m AHD, an increase of between 1.0m and 1.5m. The construction of embankments within the flood zone of Watercourse C, to remain at least 20m from the top of the bank of Watercourse C, would result in a slight increase in flow. SEEC (2013) calculate that flows are predicted to increase by about 0.4 to 0.5 m/sec but would remain under 1.6m/s, which is below the accepted velocity for stability in naturally vegetated channels (Landcom, 2004). Flooding within Watercourse C would encroach slightly on the bottom embankment of LRSF – Area 3 (refer to *Figure 23* of SEEC, 2013). As recommended by SEEC (2013), this section of the embankment would be protected from erosion by placement of rock-pitching (150-300mm) over a geotextile fabric.

#### 4.5.5.8 Waste Water Management

Waste water within the DZP Site would be treated using an aerated waste water treatment system. This water would be disposed of in accordance with Australian Standard *AS/NZS 1547:2012 - On-site domestic waste water management* or the requirements of Dubbo City Council. Indicatively, this water would be used to irrigate an area of vegetation a minimum of 100m from Paddys or Wambangalang Creek and 40m away from any other watercourse. Finally, the Applicant anticipates that a Section 68 application under the *Local Government Act 1993* and regular inspections by a qualified waste water contractor would be required.

In light of the above, the Applicant anticipates that there would be no adverse waste water-related impacts associated with the Proposal.

### 4.5.6 Monitoring and Contingency Management

#### 4.5.6.1 Surface Water Quality Monitoring

The Applicant would prepare a detailed *Water Management Plan* incorporating the proposed surface water quality monitoring program. In summary, that program would include monitoring at the following locations for the following purposes (**Figure 4.27**).

- SW1 to SW8 – monitoring of water quality in surrounding creeks and watercourses.
- SW9 – monitoring of water quality within the Re-use Dam.
- SW10 – monitoring of water quality within SB3 to determine if there are any contamination issues associated with the Processing Plant Area.
- SW11 – monitoring of water quality within SB2 to determine if there are any contamination issues associated with the Rail Container Laydown and Storage Area.
- SW12 to SW14 - monitoring of water quality down slope of the LRSF to determine if there are any leakage issues associated with those facilities.

**Table 4.48** presents the frequency of monitoring for each of the above monitoring locations.

**Table 4.48**
**Surface Water Quality Monitoring Frequency**

| Monitoring Location | Description | Monitoring Frequency |
|---|---|---|
| SW1 to SW8 | Surrounding ephemeral creeks | Monthly or after rain, potentially with a rising flow sampler[1] |
| SW9 | Re-use Dam | Monthly following input from other basins |
| SW10 and SW11 | Processing Plant Area | Following rainfall (>10mm in 24 hours) |
| SW14 to SW16 | Downslope of the Liquid Residue Storage Facilities | Monthly or when flow observed |
| Note 1: A rising flow sampler is a piece of equipment installed in a creek that collects an water sample automatically as the creek begins to flow. | | |
| Source: SEEC (2013) – After Table 9 | | |

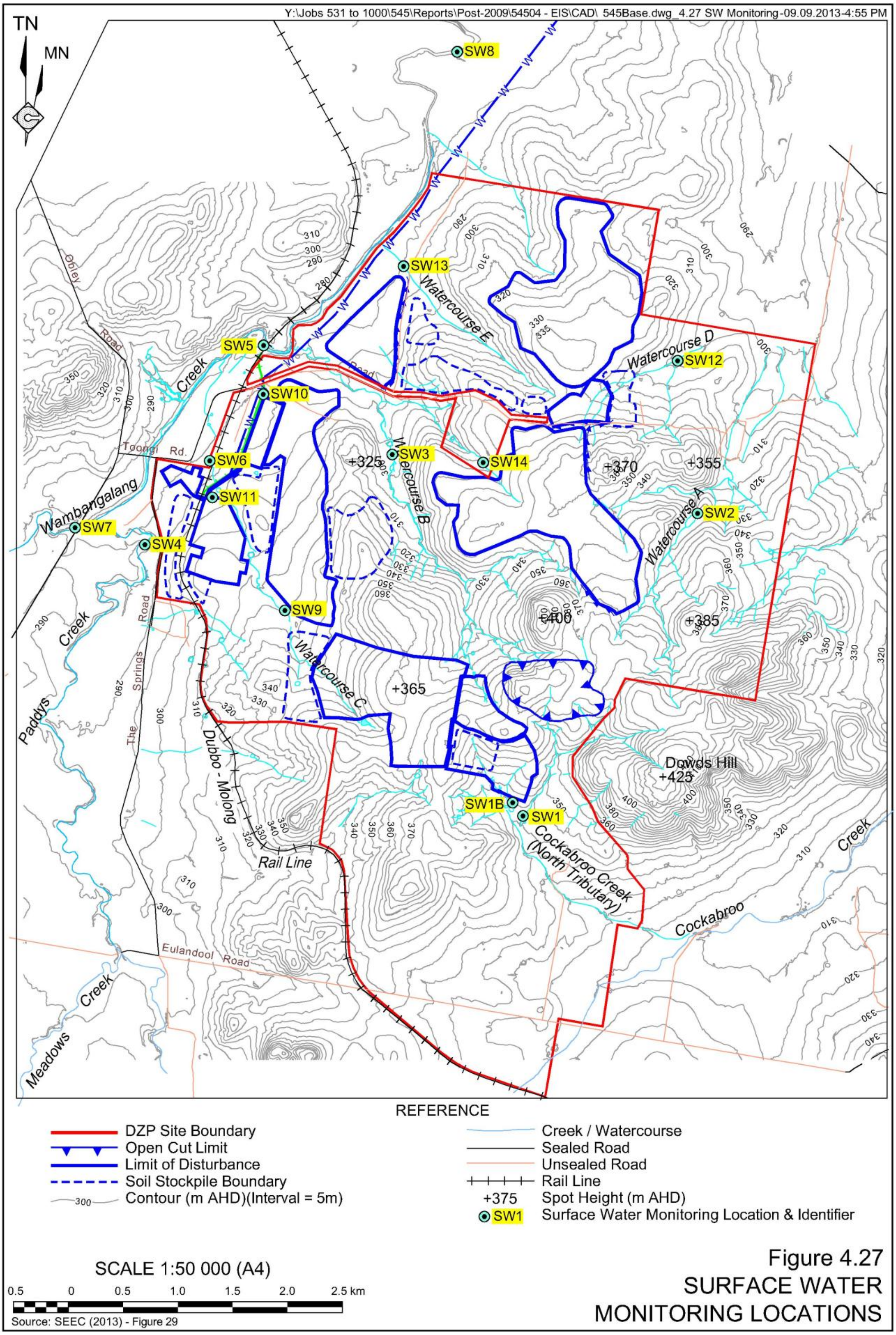



Figure 4.27
SURFACE WATER
MONITORING LOCATIONS

#### 4.5.6.2 Contingency Management

**Table 4.49** presents the trigger values that would be implemented throughout the life of the Proposal.

**Table 4.49**
**Surface Water Trigger Values**

| Physical and Chemical Stressors | Trigger Value |
|---|---|
| **SW1 to SW8 – Surrounding Watercourses** | |
| pH | <6.5 or >8.0 |
| Electrical conductivity | >3 000µS/cm |
| Total Phosphorus | >20µg/L |
| Total Nitrogen | >250µg/L |
| Dissolved Oxygen | <90% or >110% |
| Turbidity | 2-25 NTU |
| Aluminium | 55µg/L |
| Arsenic (as Arsenic III) | 24µg/L |
| Zinc | 8µg/L |
| Copper | 1.4µg/L |
| Lead | 3.4µg/L |
| Silver | 0.05µg/L |
| Nickel | 11µg/L |
| Boron | 370µg/L |
| Manganese | 1 900µg/L |
| Cadmium | 0.2µg/L |
| Radioactivity Gross Alpha | Any detectable |
| Radioactivity Gross Beta | Any detectable |
| **SW9, SW12 and SW13 – Re-use Dam and Waste Rock Emplacement** | |
| pH | >6.5 and <8.0 |
| Salinity (EC) | <3 000µS/cm |
| TSS | <50mg/L[1] |
| Visible Oils | Any detectable[1] |
| **SW10 and SW11 – Processing Plant and Rail Container Laydown and Storage Areas** | |
| Applicable Solvents | Any detectable |
| Salinity (EC) | Total <3 000µS/cm |
| Salinity species[2] | - |
| pH | >6.5 and <8.0 |
| **SW14 to SW16 – Downslope of the LRSF** | |
| Salinity (EC) | Total <3 000µS/cm |
| Salinity species[2] | - |
| Note 1: Applicable prior to discharge<br>Note 2: Salinity species = sodium, calcium, magnesium, chloride, sulfate and carbonate | |
| Source: SEEC (2013) – After Tables 9 to 12 | |

In the event that any of the identified trigger values are exceeded, the Applicant would implement a detailed response plan that would be incorporated within the *Water Management Plan*. In summary, however, potential responses may include:

- implementation of further testing;
- retention of water in sediment basins on site; and
- further investigations to determine the nature and cause of the exceedance and, if Proposal-related, remedial actions to rectify the issue and prevent recurrence.

# 4.6 GROUNDWATER

## 4.6.1 Introduction

The Director-General's Requirements identified ***Water Resources*** *as a key issue for assessment – including*:

- *a detailed assessment of potential impacts on the quality and quantity of existing surface and groundwater resources, including:*
  - *impacts on affected licensed water users and basic landholder rights; …*
- *identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000;*
- *a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts."*

Additional matters for consideration in preparing the EIS were also provided in the correspondence attached to the DGRs from the NSW Office of Water (NOW) which requested that the EIS include, amongst other requirements: *Details of the predicted highest groundwater table at the development site*; *Details of any works likely to intercept, connect with or result in pollutants infiltrating into the groundwater sources*; *A description of the flow directions and rates and the physical and chemical characteristics of the groundwater source*; *Details of how the proposed development will not potentially diminish the current quality of groundwater, both in the short and long term*; and *An assessment of the potential for saline intrusion of the groundwater and measures to prevent such intrusion into the groundwater aquifer.*

The EPA, DTIRIS-DRE and Central West CMA also provided detailed requirements for the assessment of surface water affected by the Proposal.

Based on the risk analysis undertaken for the Proposal (Section 3.5), the potential impacts relating to groundwater and their risk rankings (in parenthesis) without the adoption of any mitigation measures are as follows.

- Reduction in groundwater quality (medium to high).
- Reduction in the beneficial uses of the water and therefore availability to existing groundwater users (medium to high).
- Contamination of Dubbo City water supply (medium).

- Health-related impacts (people) due to consumption of contaminated water (medium).
- Health-related impacts (stock) due to consumption of contaminated water (medium to high).
- Degradation of groundwater dependent ecosystems (low).
- Reduction in the volume of water contained within the affected groundwater aquifer (low).
- Reduced yields of local groundwater bores (medium).
- Reduced surface flows to Wambangalang and other creek catchments of the Macquarie River (low).
- Degradation of riparian or aquatic vegetation / ecosystems (low).

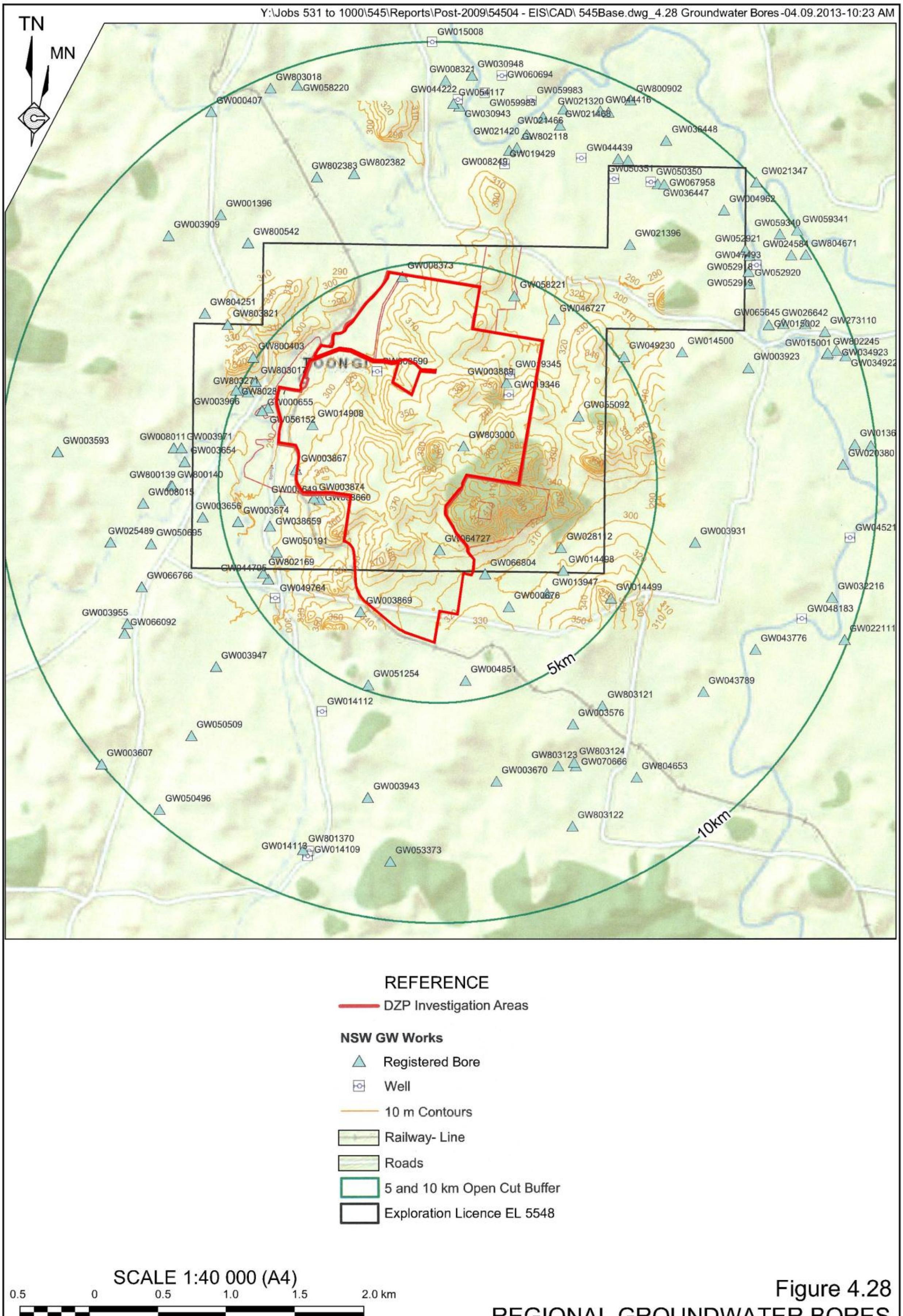
The groundwater assessment for the Proposal was undertaken by Messrs Mark Stuckey, Alan Wade and Stuart Brisbane of Environmental Earth Sciences Pty Ltd (EES). The resulting report is presented as Part 5 of the *Specialist Consultants Studies Compendium* and is referred to hereafter as "EES (2013)". This subsection of the EIS provides a summary of the groundwater assessment, concentrating on those matters raised in the DGRs and submissions to the DGRs provided by various government agencies. A consolidated list of the identified requirements and where each is addressed in the EIS is presented in **Appendix 3**. It is noted that surface water-related matters are addressed in Section 4.5 and aquatic ecology in Section 4.8.

## 4.6.2 Existing Environment

### 4.6.2.1 Local Hydrogeological Setting

Considerable data has been assembled on the occurrence of groundwater below the DZP Site and immediate surrounds through a detailed groundwater investigations undertaken by Golder Associates Pty Ltd in 2001 and 2002 (Golder, 2002), and an investigation undertaken by Ann Smithson, of the Department of Land and Water Conservation in 2001 entitled *Hydrogeological Investigation of Dryland Salinity in the Toongi Catchment, Central West Region, NSW* (Smithson, 2001). These investigations have been supplemented by groundwater monitoring and testing completed by EES in 2012 and 2013 on bores on, and immediately surrounding the DZP Site (refer to EES, 2013 – *Section 4.2*), and a review of registered groundwater bore network database maintained by NOW.

**Figure 4.28** displays the locations of the groundwater bores within both a 10km radius and a 5km radius of the open cut. As part of the Golder (2002) investigations, 23 groundwater monitoring bores were installed on and surrounding the DZP Site (DWB001 to DWB023). Of these, 21 have been monitored and/or tested in 2001/2002 and/or 2012/2013. In addition, monitoring and/or testing has been undertaken in two of the registered groundwater bores (GW008373 and GW058221) and three unregistered wells (two on the "Cockleshell Corner" property and one within Toongi). The network of groundwater monitoring bores within and surrounding the DZP Site is presented on **Figure 4.29**.




Source: EES (2013) - Figure 7

Figure 4.28
REGIONAL GROUNDWATER BORES

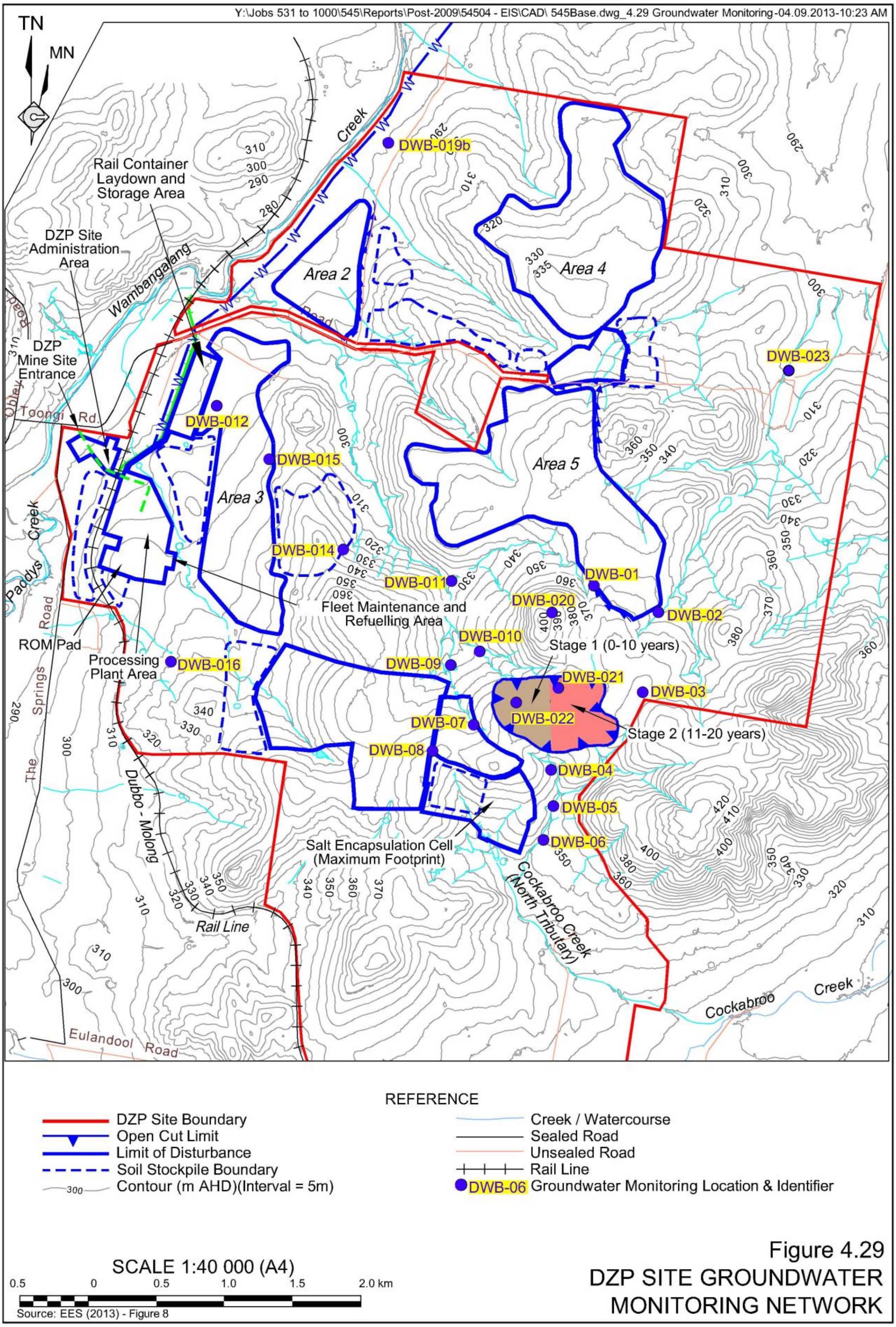



Figure 4.29
DZP SITE GROUNDWATER MONITORING NETWORK

*Section 4* and *Appendix G* of EES (2013) describe the bore installation, monitoring, sampling and testing undertaken on the 26 bore monitoring network presented in **Figure 4.29**.

#### 4.6.2.2 DZP Conceptual Site Model

Based on the information obtained from this monitoring described above, evaluation of the information provided by Smithson (2001) and Golder (2002), the registered groundwater bore database, anecdotal evidence provided by local landholders, interpretation of geological maps supplied by the Applicant and review of other relevant specialist assessments (SSM, 2013, SEEC, 2013) a Conceptual Site Model (CSM) was generated by EES (2013) for the catchments of the DZP Site. A CSM is a two- to three-dimensional interpretation of the soil, geology and hydrogeology relationships within a catchment which identifies groundwater flow paths and environmental receptors. Through description of the hydrogeological environment by way of a CSM, areas of the DZP Site at greatest risk of impact or constraint are identified allowing for the design and implementation of appropriate management measures.

Section 5 of EES (2013) provides a detailed description of the CSM development. Critical features of the CSM as relevant to the assessment of the Proposal are provided as follows.

**Groundwater Aquifers**

Two connected groundwater systems occur in the Toongi catchment, namely, a consolidated fractured rock system and an unconsolidated sedimentary system consisting mostly of alluvium (with minor colluviums and aeolian deposits). The alluvium overlies the fractured rock system, mostly filling past valleys and watercourses beneath current day ephemeral creek lines (Smithson, 2001).

- Fractured Rock System

  EES (2013) reports the fractured rock groundwater system as unconfined near the top of the aquifer (water-table surface) but confined at depth, resulting in variations in flow paths (local, intermediate or regional flow systems). These systems have been interpreted to be relatively saline due to longer time periods for geochemical interaction with the aquifer matrix (Smithson, 2001). Groundwater flow is controlled by fractures with preferential flow through formations with a relatively high density of open interconnected fractures. Recharge mechanisms to the fractured rock system have been identified where trachyte intrusions outcrop at the top of the catchment. Some local recharge is expected (and observed) along the alluvial valleys, either as direct rainfall recharge or recharge from the creeks during periods of flow.

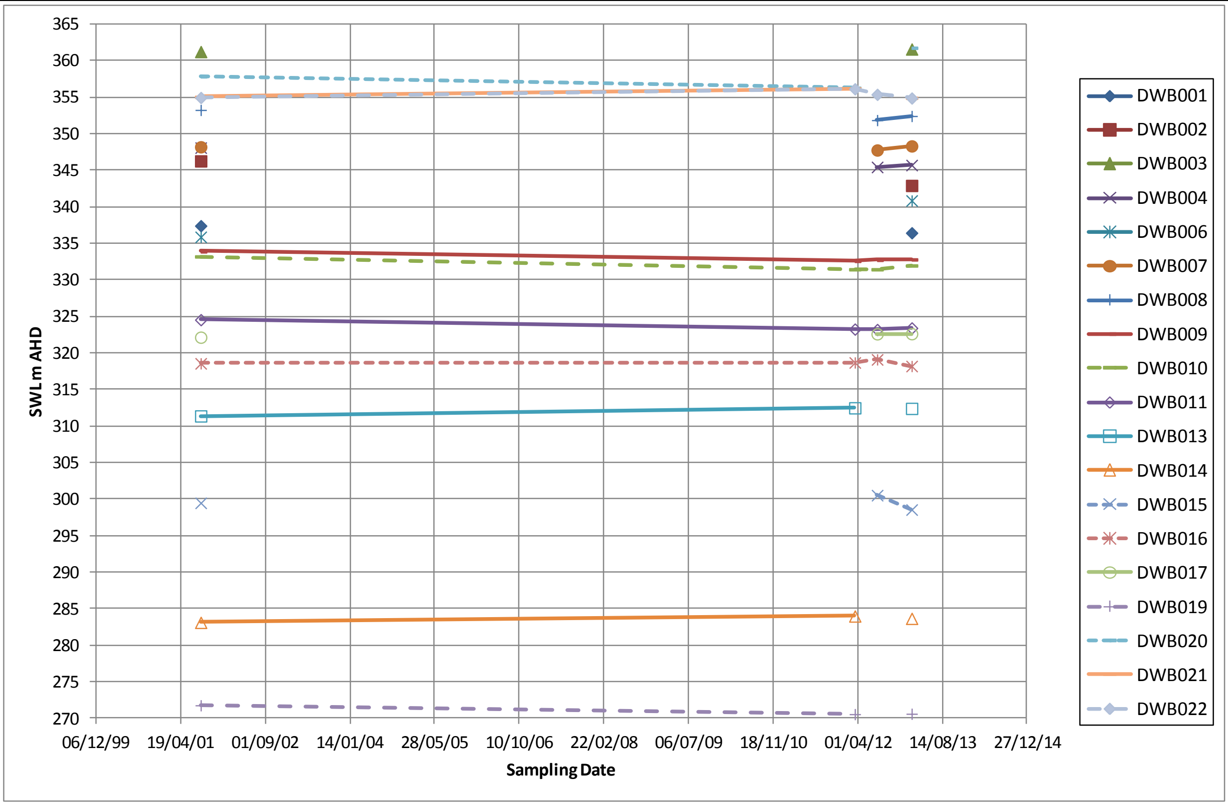
- Alluvium System

  The alluvium system is associated with the filling of valleys and watercourses and displays thicknesses ranging from 3.5m below ground level to 43.5m below ground level with depth below surface typically between 16m to 20m. The alluvium system, being unconsolidated and relatively shallow and fresh, generally corresponds rapidly to recharge via rainfall. As such, groundwater flows from the topographic high points of the Jurassic trachyte intrusions of the DZP Site and Dowds Hill to the southeast towards the local creek systems of Wambangalang and Paddys to the west, Cockabroo to the south and the Macquarie River tributaries to the north.

### Groundwater Levels and Gradient

A review of the groundwater monitoring programs described in Golder (2002) and EES (2013) illustrates some minor variation in standing water level (SWL) likely to correspond with rainfall (recharge conditions) (see **Figure 4.30**). Notably, monitoring in 2001 followed a period of average rainfall whereas monitoring in 2012/2013 followed a period of above average rainfall following an extended drought period (2001 – 2009). On the basis of the preceding rainfall conditions, it is considered that the groundwater levels recorded reflect SWLs at their more elevated levels.

**Figure 4.31** displays the indicative existing groundwater level contours (for 2013) based on interpolation of the SWLs and consideration of such factors as topography and geology.




Source: EES (2013) – Chart 1

**Figure 4.30**
**MEASURED MONITORING BORE STANDING WATER LEVELS**

From the review of the groundwater levels and monitoring bore locations, it has been determined that the groundwater contours and hence gradients are effectively a reflection of the overlying topography. Depths to groundwater are greatest in areas of groundwater recharge (trachyte intrusives, e.g. in the vicinity of the proposed open cut) and shallowest in areas of groundwater discharge. Groundwater flows radially from the high ground area of the proposed open cut to the surrounding valleys. EES (2013) interpret the groundwater flow system as continuing into the alluvium in the valleys around the edges of the bedrock, and within the colluvium and alluvium infilling gullies in the higher ground areas.

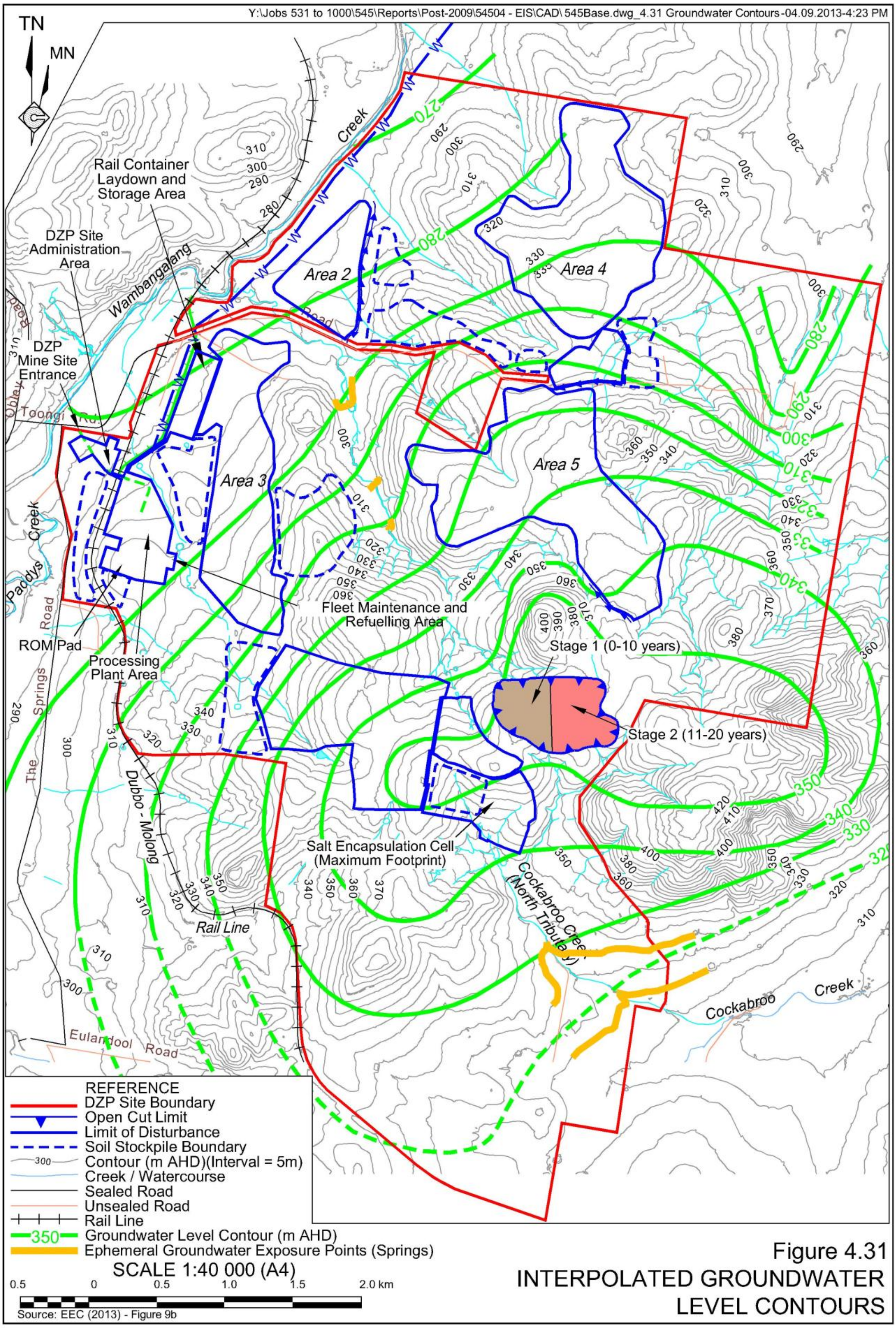



Figure 4.31
INTERPOLATED GROUNDWATER LEVEL CONTOURS

### Groundwater – Surface Water Interaction

While no detailed mapping of springs has been undertaken, and EES (2013) observed no large-scale groundwater discharge features, a review of the interpreted groundwater contours indicates that the water table would, when elevated, be exposed in gullies, generally at the slope-break point (see **Figure 4.31**). The occurrence of these springs on the North Tributary of Cockabroo Creek and Watercourse B are a feature of these properties and have been observed flowing in the locations indicated on **Figure 4.31**.

However, while groundwater discharge occurs ephemerally, the seepage rate is considered to be relatively low as the water passes through the colluvium in the base of the gullies and does not result in continuous surface expression.

The major creeks limit the extent of the groundwater flow from the DZP Site. The groundwater flow system radiating from the DZP Site is bounded to the west at Wambangalang Creek/Paddys Creek. Its extent is also limited to the south and north respectively by Cockabroo Creek and unnamed tributaries of the Macquarie River that drains the northeastern portion of the DZP Site. Conceptual cross sections representing hydrogeological processes across the site have been provided in *Figures 10a* and *10b* of EES (2013).

### Groundwater Quality

Groundwater has been collected and analysed for the following analytes.

- pH, electrical conductivity (EC), dissolved oxygen (DO) and Total Dissolved Solids (TDS).
- Major Ions (Na, Ca, Mg, K, $NH_4$, Cl, $SO_4$ and F).
- Nutrients ($HCO_3$, $NO_3$, $PO_4$).
- Trace Elements (Sb, As, Ba, B, Cu, Cd, Cr, Fe, Mn, Mo, Ni, Pb, U, Zn).

The results of the analysis resulted in the groundwater being described as of generally good quality water with neutral pH ranges, low concentrations of most dissolved metals and being defined overall as fresh to slightly brackish but identified as not suitable for human consumption (drinking water).

It should be noted that minor changes of groundwater quality do occur (particularly TDS) across the DZP Site. Generally the salinity (EC) of the groundwater increases within the fractured rock aquifer the further from the recharge zone. A reduction in salinity is then observed within the alluvium aquifer, presumably in response to direct recharge of fresh water into this aquifer. This concept is further supported by ionic ratios and Na-Cl ratios with additional, in-depth analysis provided in EES (2103).

### Groundwater Availability and Use

Eleven registered bores exist within the DZP Site (see **Figure 4.28** and **Table 4.50**) with groundwater yields generally low (<1L/sec). The identified water-bearing zones were found to be within unconsolidated alluvium and colluvial sediments in the lower to mid catchments and likely fracturing of basement rocks in the upper catchment areas. There are also several unregistered bores within the village of Toongi that intercept shallow groundwater within the alluvium system and are used for a mixture of stock and domestic purposes but there are no known large scale groundwater users within a 10km radius of the DZP Site.

As the groundwater quality is not suitable for human consumption, groundwater within the DZP Site is used primarily to support stock watering.

Additional, minor groundwater users include:

- the freshwater ecosystems within the local ephemeral creeks;
- recreational and aesthetic uses; and
- possible irrigation on alluvium adjacent to creek systems.

**Table 4.50**
**Registered Groundwater Bores within the DZP Site**

| Bore ID | Use | Depth (m) | Water Bearing Zone(s) (m) | | | Yield (L/sec) | Geology |
|---|---|---|---|---|---|---|---|
| | | | From depth | To depth | Thickness | | |
| GW000655 | NK | 45.10 | 32.30 | 35.30 | 3.00 | 0.30 | Unconsolidated |
| GW003590 | NK | 37.50 | 34.40 | 34.40 | 0.00 | 0.46 | Not Recorded |
| GW003867 | Domestic stock | 50.30 | 28.30 | 28.30 | 0.00 | 0.76 | Not Recorded |
| GW003889 | Stock | 79.20 | 1.80 | 10.00 | 8.20 | 0.08 | Not Recorded |
| | | | 51.50 | 51.50 | 0.00 | - | - |
| GW014908 | Stock | 28.00 | 19.50 | 20.10 | 0.60 | 0.06 | Not Recorded |
| | | | 22.60 | 23.80 | 1.20 | 0.30 | Not Recorded |
| | | | 24.10 | 26.20 | 2.10 | 0.61 | Consolidated |
| GW019345 | NK | 7.80 | - | - | - | - | - |
| GW019346 | NK | 27.70 | - | - | - | - | - |
| GW056152 | Domestic stock | 27.40 | - | - | - | - | - |
| GW064727 | Domestic stock | 51.00 | 30.00 | 34.00 | 4.00 | 0.32 | Consolidated |
| | | | 50.00 | 51.00 | 1.00 | 4.73 | Consolidated |
| GW803000 | Domestic stock | 72.00 | 30 | 36 | 6.00 | 6.00 | - |

Note 1: Source: Groundwater Works Summary from Department of Natural Resources, NSW (March, 2012)
Note 2: SWL – Static Water Level; NK – Not Known
Source: EES (2013) – Table 5

It should be noted, however, that groundwater within the vicinity of the DZP Site is noted as of marginal quality for irrigational use and as such, no current irrigation activities are undertaken.

In summary, groundwater within the DZP Site is unsuitable for human consumption but is used on a small scale for irrigation and domestic purposes primarily centred around the village of Toongi. The low yields and moderate quality water, as well as a lack of major groundwater users, results in groundwater being a little importance within the DZP Site with the exception of groundwater discharges providing water to the local ephemeral creek systems.

### 4.6.3 Assessment Methodology

Potential impacts to groundwater beneficial users, as a result of the proposed mining operations, have been assessed in the context of the local hydrogeological setting, i.e. the CSM (see Section 4.6.2.3) and the relevant legislation and guidelines.

The nature of the groundwater flow system, i.e. a local flow system discharging to the local creeks, means that all potential impacts of the Proposal are considered to be locally constrained. The area of potential impacts is constrained to the west by Wambangalang and Paddys Creeks and to the south by a tributary of Cockabroo Creek in the vicinity of bore DWB016 (see **Figure 4.29**).

All of the potential sources of impacts are currently planned to be located within the groundwater flow systems flowing to Wambangalang/ Paddys Creek and to Cockabroo Creek, with the exception of some of the LRSF which overlap the catchment divide between Wambangalang Creek and a tributary of the Macquarie River.

On the basis that the open cut would be developed so as to remain above the regional water table, and as such, dewatering and associated drawdown would not take place, groundwater flow or transport modelling was not undertaken. Rather, the assessment of impacts is based on the CSM and knowledge and experience of EES of flow systems in similar environments and for similar projects. The assessment of EES (2013) considers:

- the potential impacts on groundwater associated with the Proposal (refer to Section 4.6.4);
- the proposed operational safeguards, controls and management measures proposed by the Applicant to avoid, minimise or mitigate these impacts (refer to Section 4.6.4); and
- the risk associated with each potential impact based on likelihood and consequence along with nature of higher risk impacts (refer to Section 4.6.5).

### 4.6.4 Potential Impacts on Groundwater and Proposed Management and Mitigation Measures

#### 4.6.4.1 Introduction

The following subsections provide a summary of the description of potential impacts presented in *Section 6* of EES (2013), along with the proposed impact avoidance, minimisation and mitigation.

#### 4.6.4.2 Potential Physical Impacts During Operations and Post Closure

##### 4.6.4.2.1 Introduction

Given the open cut would be developed above the groundwater table, no dewatering would be required and there would be no drawdown of groundwater levels associated with the Proposal. Physical impacts on local groundwater conditions would be associated with changes to recharge rates and flows resultant from the construction of various features of the DZP Site, each of which is considered as follows.

#### 4.6.4.2.2 Open Cut

**Potential Impacts**

During mining operations, standing water collected within the open cut would be removed and therefore there would be no major change to recharge rates. Under post closure conditions, enhanced recharge could be expected to be more significant resulting in an increase in groundwater levels in the vicinity of the open cut. This impact is not predicted to extend to the alluvial sediments surrounding the high ground.

EES (2013) notes that the net increase in the recharge rate would be expected to be balanced by a net increase in the discharge rate to the local gullies and possibly in new 'springs' which did not exist prior to the Proposal.

Any impacts are not considered of significant consequence and hence no mitigation measures other than ongoing SWL monitoring would be undertaken.

#### 4.6.4.2.3 Waste Rock Emplacement

**Potential Impacts**

As the WRE would not be lined, the rate of recharge over the impact area (approximately 20ha) is likely to increase both during the Proposal and on closure. However, given the impact area represents less than 1% of the total DZP Site, the effect on groundwater is expected to be minor.

#### 4.6.4.2.4 Solid Residue Storage Facility

**Potential Impacts**

The construction of the SRSF would reduce the rate of recharge over the footprint of the SRSF area (approximately 103ha) both during operations and post closure. Representing less than 5% of the total DZP Site, the effect on the total groundwater flux through the local groundwater flow systems within the Wambangalang Creek catchment and the Cockabroo Creek Catchment is expected to be minor. A moderate reduction in the level of the water table (in the order of 1m to 3m) beneath and in the vicinity of the SRSF cells is expected (EES, 2013).

**Impact Mitigation**

Groundwater monitoring bores would be installed around the SRSF, primarily to monitor for changes in water chemistry which could indicate a leak, however, would also confirm changes to SWL occur as predicted.

It is noted that given the potential increase in recharge resultant from the retention of the open cut void in the final landform, this reduction in recharge would act to minimise any impacts associated with this increase in recharge via the open cut post closure (refer to Section 4.6.4.2.2).

#### 4.6.4.2.5 Salt Encapsulation Cells

**Potential Impacts**

As for the SRSF, the effect of the SECs would be to reduce the rate of recharge over the area of impact (approximately 35ha). This represents less than 2% of the total DZP Site, therefore the effect is expected to be minor. EES (2013) predicts a moderate reduction in groundwater level beneath and in the vicinity of the SECs due to the reduction in the recharge rate in this area both during the Proposal and post closure.

**Impact Mitigation**

Groundwater monitoring bores would be installed around the SECs, primarily to monitor for changes in water chemistry which could indicate a leak, however, would also confirm changes to SWL occur as predicted.

#### 4.6.4.2.6 Liquid Residue Storage Facility

**Potential Impacts**

With liquid residue to be placed on an impermeable liner, the net effect would be to reduce the rate of recharge over the footprint of the LRSF (approximately 425ha) during operations. EES (2013) reports that the area of impact would result in a reduction in recharge of approximately 17% across the affected catchments within the DZP Site and it would be expected that there would be a moderate reduction in the water table beneath and in the vicinity of the LRSF. This reduction in recharge would be limited to the life of the Proposal as the LRSF is to be returned to agricultural use (following rehabilitation – see Section 2.17.6.6) on closure when the recharge rate is expected to return to close to the baseline rate and the SWL to pre-disturbance elevation.

It is possible that a breach or breaches of the LRSF liner could occur which would result in the infiltration of liquid from the LRSF to the underlying groundwater. Should such a breach / leak occur, the downward hydraulic gradient caused by the liquid level in the pond above the breach would initially infiltrate downwards, and subsequently laterally. The rate of migration of the liquid would be controlled by the hydraulic conductivity (k) of the underlying materials. Should leakage occur, EES (2013) notes that it is likely that the water table would rise beneath the cell until the ground became fully saturated.

EES (2013) considers the potential rate of discharge (Q) of the saline liquid from the areas of the LRSF area located over clay alluvium and fractured bedrock based on the following calculation.

$$Q = T \times i \times L$$

Where:

$Q$ = rate of leakage ($m^3$/day)

$T$ = Lateral transmissivity ($m^2$/day)

$i$ = Maximum horizontal hydraulic gradient (m/m)

$L$ = length of leak (m)

In reality, the likely size of any breach (leak) of the liner would be small and would limit the rate of discharge. Furthermore, the lateral transmissivity and hydraulic gradient of the low permeability clays below the LRSF would also be low further limiting the rate at which any small leak discharges and affects local groundwater.

In a worst case scenario, a breach of the liner would result in a rise in the water table and discharge as base flows within the local catchment or at surface adjacent to the outer LRSF embankment. *Figure 13* of EES (2013) presents the possible worst-case scenario in the event of a breach of the liner.

### Impact Mitigation

Modern liners and installation techniques are such that the potential for these to be breached is almost certainly likely to be as a result of one of three factors.

1. Incorrect installation of the HDPE liner.
2. Installation over ground containing rocks or other objects capable of piercing the HDPE liner.
3. Operation of equipment directly on the liner.

Effectively, all three mechanisms for liner breach reflect poor operation or human error. The Applicant has committed to the following measures to avoid the potential for this occurrence.

- Adoption and implementation of a Cell and Liner Construction Protocol.
  - Certification of all lining material would be obtained from the manufacturer prior to delivery to the DZP Site.
  - The number of all individual batches of the lining material would be registered and the date and location of the use of each roll recorded by the contractor.
  - The foundations of each salt crystallisation cell would be constructed to the extents and grades shown on the final drawings.
  - The finished surface would be free of all roots, rocks and other matter which could impact on the liner. The area in each cell would be lightly tined, moisture conditioned and compacted prior to the placement of the lining.
  - Should there be a delay of more than 48 hours between the completion of the cell foundations and the application of the liner, the area would be proof rolled again prior to rolling out the lining.
  - A final inspection of each cell prior to liner rolling out would be performed by the supervising engineer. If the cell foundations are deemed unsuitable, for instance if surface rocks and sticks remain, a layer of compacted sand with a minimum depth of 150mm would be placed over the cell floor prior to constructing the liner.

- Adoption and implementation of a *Liner Integrity Testing Protocol*.
  - The HDPE lining of the LRSF cells would be completed by an experienced contractor who has a proven track record in the installation of large areas of lining.
  - All lining material and construction methods and testing would conform to the relevant Australian Codes and the contractor would be required to use the most up to date equipment. All equipment would require certification prior to the start of the project and at regular intervals (in accordance with the manufacturer's recommendation and the relevant Australian Codes) during the work.
  - The welding of the liner would be tested both by the contractor and by an independent testing organisation hired by the Applicant.
  - Small sections of the liner would be regularly removed for off-site laboratory testing in accordance with the relevant code. Should any test results return negative results, the work carried out between tests would be fully reviewed.
- The water balance within the salt crystallisation cells would be monitored.
  - Prior to the installation of the liner in each cell, the area would be surveyed and a depth/volume curve prepared. This would allow the volume of liquid residue in each cell to be determined by measuring the level of the liquid in each cell.
  - The volume of water delivered to each cell would be accurately monitored by reading the flow meters on each delivery pipe. Evaporation losses from the cells would be compared with that from several Class A Australian Standard Evaporation pans located adjacent to each group of cells. Rain gauges would also be positioned adjacent to each group of cells.
  - Data from the evaporation pans, rain gauges and flow meters would be fed back into the LRSF Water Balance Model from the early stages of the operation to enable a Pan Factor to be determined relating Class A pan evaporation to actual cell water loss.
  - On establishment of an evaporation rate for the liquid residue, continuous monitoring of liquid residue level, flow in, and evaporation loss out would enable any major water loss due to a liner failure to be identified and magnitude potentially quantified.
  - Identification of a liner leak would lead to the implementation of a *Leak Detection Response Strategy*.
- Water levels and quality would be monitored beyond the downstream toe of all external embankments.
  - Paired bores, one immediately downstream of the outer embankment and another up to 50m down gradient, would be installed and compared for signs of changing water quality or SWL which could be indicative of a liner breach.

  - Identification of a liner leak would lead to the implementation of a *Leak Detection Response Strategy*.

- Design and implement a *Leak Detection Response Strategy*.
  - If changes in groundwater quality and/or level are identified, or if the LRSF Water Balance Model indicates anomalies suggesting loss of liquid residue by leakage, an investigation by a qualified hydrogeologist would be triggered.
  - Initial response would likely be the excavation of a series of test pits parallel to the downstream toe of the outer embankment of the cell from where the leak is suspected as having occurred.
  - Should collection of water in these pits suggest that there may be seepage coming from up gradient, a continuous trench would likely be excavated to a depth of 3m or to the water table (if less than 3m below surface). The trench would be backfilled with drainage material and a sump and pump installed to remove the accumulated water. Pumping would continue until be quality of the recovered water is the same as the back ground quality of the groundwater.
  - If seepage continues, indicated by the water quality not returning to that of the background, i.e. the paired bore, the liquid within the cell(s) would be transferred by pumping to an adjacent cell(s). If the removal of the water produces a noticeable change in water level in the monitoring bore(s) and/or trench, further investigations into the integrity of the liner would be undertaken, which could include:
    - total removal of liquid from the cell;
    - removal of any accumulated salts from the base of the cell;
    - inspection of the joins in the liner following cleaning by high pressure water;
    - testing of the joins to determine the area of failure;
    - cleaning of the liner and inspection; and/or
    - removal of the liner and inspection of the cell foundation.
  - If following identification of the leak, the liner is to be repaired, this would be subject to the same inspection standards as noted for the *Liner Integrity Testing Protocol*.
  - All contaminated material down to the water table (up to a maximum depth of 3m) would be removed and replaced with uncontaminated material prior to re-lining or installation of a new liner.
  - If the decision is made to abandon the cell (for a period or permanently), the cell would continue to be monitored but allowed to remain dry.

- Harvesting of precipitated salts would be undertaken in accordance with a *Salt Harvesting Protocol*.
  - Harvesting of precipitated salts would only occur on accumulation of greater than 1.5m of salt (determined by survey comparison to the original cell survey referenced in the *Cell and Liner Construction Protocol*).
  - Salt would only be harvested down to 1m of the surveyed level of the underlying liner in each cell.
  - The salt removal process would be surveyed by earthmoving equipment utilising GPS equipment for vertical accuracy to ensure the 1m buffer is maintained.
  - Should any part of the liner be compromised, in that instance the entire liner for the cell would be replaced and its integrity independently verified (in accordance with the *Liner Integrity Testing Protocol*) prior to recommissioning of the cell.
- The liner would be continuous (by welding) over the internal embankments.
  - This would ensure that lapping water caused by wind / wave action across the cells does not result in saline liquid leaking under the liner at the top of each embankment.

#### 4.6.4.3 Potential Chemical Impacts during Operations and Post Closure

##### 4.6.4.3.1 Introduction

The potential chemical impacts on groundwater are tied closely to the physical impacts, i.e. in assessing the potential chemical impacts, it is assumed that the relevant changes to recharge nominated in Sections 4.6.4.2 occur.

##### 4.6.4.3.2 Open Cut

**Potential Impacts**

The various metals and other contaminants contained within the ore are not soluble in water and so would not leach into the groundwater. The solubility of most heavy metals is controlled by acidity. Notably, the ore contains only negligible sulphur concentration (<0.01%) which could be oxidised and lead to acidification of any accumulated water.

##### 4.6.4.3.3 Waste Rock Emplacement

**Potential Impacts**

Due to the benign nature of the waste rock, there is not considered to be any opportunity for chemically impacted or acidic liquid to migrate into groundwater. Therefore potential chemical impacts to groundwater are predicted to be negligible, as is the potential for any impact to beneficial users and receptors

#### 4.6.4.3.4 Solid Residue Storage Facility

**Potential Impacts**

Based on the design of the SRSF, double liner and leak detection system, there would be no opportunity for liquid to migrate into the groundwater from the SRSF. Therefore, chemical impacts to groundwater as a result of the SRSF are predicted to be negligible. It therefore follows that there is no perceived potential for the SRSF cells to impact any beneficial users of groundwater.

#### 4.6.4.3.5 Salt Encapsulation Cells

**Potential Impacts**

As long as the liner remains intact, there would be no opportunity for liquid to migrate into the groundwater. Therefore, chemical impacts to groundwater as a result of the SECs are predicted to be negligible. However, the validity of this conclusion depends on continuous monitoring of the leak detection system for a period of decades following mine closure.

**Impact Mitigation**

The leak detection system would remain operational following the completion of the SECs until such time as leakage is deemed not likely.

#### 4.6.4.3.6 Liquid Residue Storage Facility

**Potential Impacts**

On the basis of the liner remaining intact, there would be no chemical impacts on groundwater associated with the LRSF.

Should a leak occur, however, highly saline liquid (>62 500mg/L) could enter the groundwater below the LRSF potentially leading to the following impacts.

- **Groundwater Salinity**

  The salinity impact would migrate at the average linear velocity of the groundwater flow and would ultimately extend as far as the point where the groundwater discharges to surface water. As such, if a leak was to continue, the salinity of the groundwater below and downstream of the LRSF could increase which would significantly compromise beneficial uses associated with ecosystems, stock watering, recreational (including direct contact and aesthetic) use, irrigation and drinking.

- **Land Salinisation**

  If a leak was to occur and remain undetected and uncontrolled, the salinity of the soil adjacent to the outer embankment (where the groundwater level would intercept or rise to within 2m of the ground surface) would become saline, i.e. dryland salinity.

### Impact Mitigation

The mitigation measures discussed in Section 4.6.4.2.6 apply equally to avoiding, minimising and mitigating chemical impacts associated with the LRSF.

## 4.6.4.4 Potential Impacts on Groundwater Availability

Groundwater users more than approximately 100m to the west of Wambangalang Creek are unlikely to be affected by the DZP Site as they are outside the local flow system.

The most sensitive users appear to be those within the Wambangalang Catchment including the unregistered bore usage in the village of Toongi and the cluster of bores around Cockleshell Corner (see **Figure 4.28**). EES (2013) reports that due to the localised nature of impacts on recharge around such structures as the SRSF, LRSF and SECs, there is unlikely to be any significant drawdown at these bores.

Salinization of the groundwater could potentially affect the ability of bore holders to use this water, however, this would only occur should the liner of the LRSF be breached (which is not considered likely given the proposed management measures to be implemented – see Section 4.6.4.2.6)

## 4.6.4.5 Potential Impacts on Groundwater Dependent Ecosystems

### Potential Impacts

EES (2013) notes that based on groundwater dependent ecosystem (GDE) mapping prepared by BOM (2012) only, Paddys Creek to the west is listed as having a "high potential for groundwater interaction". Groundwater interaction refers to a surface water system that is "reliant on surface expression of groundwater". Potential physical and chemical impacts associated with the Proposal would not impact on base flows to Paddys Creek and therefore the Proposal would not impact on any GDEs.

Wambangalang Creek to the north of Obley Road and Cockabroo Creek to the north of Eulandool Road are both listed as having a "moderate potential for groundwater interaction". As for Paddys Creek, the potential physical and chemical impacts associated with the Proposal on the Cockabroo Creek catchment would be limited to the immediate vicinity of the open cut, WRE and SRSF and therefore not impact on any GDEs.

In the event of leakage from the LRSF, there is a small possibility that saline water could impact on any GDEs contained within Wambangalang Creek between the DZP Site and Macquarie River.

### Impact Mitigation

The proposed impact avoidance, minimisation and mitigation measures proposed in Section 4.6.4.2.6 would reduce the potential to almost nil.

#### 4.6.4.6 Potential Impacts on Dryland Salinity

**Potential Impacts**

Dryland salinity was initially identified as a high salinity hazard rating within the Toongi catchment but additional studies (Smithson, 2001) identified no moderately or highly saline areas within the DZP Site or immediate surrounds (EES, 2013). Areas considered at greatest risk of dryland salinity by Smithson (2001) are those where the groundwater table is less than 5m below natural ground surface. Such areas occur in the vicinity of Wambangalang Creek and the village of Toongi which are associated with alluvial flats with the areas of disturbance for the Proposal located away from these areas of elevated groundwater table (see **Figure 4.31**). EES (2013 – *Appendix J*) also notes "*There was no indication that groundwater or salt has encroached the surface at these locations (groundwater discharge springs or where groundwater levels intercepted the ground) surface … and there was also no indication of salinity or groundwater discharge on the alluvial flats where cropping and lucerne pastures were prominent.*"

The following contributors to dryland salinity in the vicinity of the DZP Site are identified Smithson (2001). The following provides an assessment of the anticipated impacts associated with each.

- Changes in slope angles.

  The Proposal would require modifications to the existing landforms, in particular, for the LRSF. Each cell of the LRSF would be excavated approximately 3m into weathered material and would not intersect the bedrock. As groundwater in the vicinity of the four distinct areas of the LRSF is greater than 5m below surface (refer to Section 4.6.2), there would be no intersection or obstruction to sub-surface flows. As a result, in the absence of any leakage from the LRSF, there would be no change to hydrological processes that would lead to dryland salinity.

- Removal of native vegetation.

  The native vegetation to be removed throughout the life of the Proposal would be predominantly derived grasslands or grassy woodlands where deep rooted trees occur as isolated paddock trees or in clumps over elevated hill tops of the DZP Site. This vegetation is principally located in elevated areas of the DZP Site on lands that are identified as having a low salinity risk.

- Leaky agricultural land uses.

  This risk factor related to land uses that may result in excess groundwater re-charge. The principal water storages within the DZP Site would be either lined (for example the LRSF) or would be maintained with limited water in storage (for example, the sediment basins or the Re-use Dam). As a result, there would be limited potential for discharge to groundwater from these structures. However, the open cut would collect incident rainfall. Throughout the life of the Proposal, entrained water would be removed from the open cut and the Proposal would not result in increased groundwater recharge.

Under post closure conditions, enhanced recharge is expected to be more significant and moderate increases in groundwater levels of several metres can be expected in the vicinity of the open cut (refer to Section 4.6.4.2). This could have the effect of locally increasing the hydraulic gradient away from the open cut which is likely to cause some groundwater discharge in incised gullies and creeks draining the high ground. These discharges are not expected to be saline, given the relatively short residence time between recharge and discharge, and so would not lead to increased salt load within the catchment. Furthermore, EES (2013) reports that changes in groundwater flux associated with any increased recharge would not extend to the alluvium aquifer and therefore not increase the dryland salinity.

On the basis of the above, in the absence of leakage from the LRSF (discussed in Sections 4.6.4.3.6), the construction and operation of the various features of the Proposal would not result in an increase in the groundwater table over the life of the Proposal and therefore not increase the dryland salinity risk during operations.

#### Impact Mitigation

The impact mitigation described with respect to avoiding, minimising and mitigating physical and chemical impacts associated with a breach or leaking LRSF apply to the management of dryland salinity. That is, by preventing or mitigating such occurrences, the salinization of the groundwater and surface soils would also be prevented.

In addition to these controls associated with the LRSF, the Applicant has committed to the implementation of a Biodiversity Offset Area which would result in the establishment of deep rooted vegetation between LRSF Areas 2 and 3. This vegetation would assist in maintaining the groundwater table in these areas.

The Applicant would also undertake additional plantings as required to positively influence local riparian corridors and respond to rising groundwater tables (not associated with a potential leak from the LRSF).

## 4.6.5 Assessment of Impacts

### 4.6.5.1 Risk-based Assessment of Impacts

As noted in Section 4.6.3, the assessment of EES (2013) has taken a risk-based approach to assessment. **Table 4.51** (modified after *Table 10* of EES, 2013) presents a summary of the potential groundwater impacts discussed in Section 4.6.4. EES (2013) considers each potential impact in terms of their likelihood and consequence, with a score attributed to both likelihood and consequence on a scale from 1 to 5 in each case. The overall risk was then identified based on the sum of the likelihood and consequence scores. A high score represents low risk and low score represents higher risk.

### 4.6.5.2 Low or Moderate Risk Sources

*Sections 6.3* and *6.4* of EES (2013) review each of the potential impacts associated with the Proposal in detail. In most cases, the low likelihood or limited consequence associated with each potential impact is such that even using the conservative risk assessment of EES (2013), the risk level is low or moderate. On the basis of the proposed operational safeguards, management measures, monitoring practices and contingency management to be implemented, these levels of risk are assessed as reasonable and equivalent to those of other mining operations.

### 4.6.5.3 High Risk Sources

EES (2013) scored two potential impacts as high risk. These are considered in more detail as follows.

#### Chemical Impact to Groundwater Resulting from a Leakage of the LRSF Liner

On the basis that a breach of the LRSF liner is 'possible' resulting in a 'major' consequence, EES (2013) allocate a risk score of 5 (high). It is important to recognise, however, that having reviewed the safeguards, monitoring and contingency measures proposed by the Applicant (see Section 4.6.4.2.6), EES (2013) refer to the potential impacts as limited in extent and temporary in nature.

**Table 4.51**
**Risk Associated with Potential Impacts**

Page 1 of 3

| Proposal Component | Aspect of Proposal Component | Potential Impacts to Groundwater | Likelihood of Impact | Consequence of Impact | Overall Level of Risk | Comments |
|---|---|---|---|---|---|---|
| LRSF | Leakage due to Breached Liner | Physical Impact to Groundwater | Possible (3) | Minor (4) | **Moderate (7)** | ALARP (localised risk). Refer to Section 4.6.5.3 for assessment |
| | | Chemical Impact to Groundwater | Possible (3) | Major (2) | **High (5)** | |
| | | Ensuing Physical Impact to Ecosystems or Groundwater Users | Unlikely (4) | Minor (4) | **Low (8)** | |
| | | Ensuing Chemical Impact to Ecosystems or Groundwater Users | Unlikely (4) | Major (2) | **Moderate (6)** | |
| | | Ensuing Land Salinisation | Unlikely (4) | Major (2) | **Moderate (6)** | |
| | Negligible recharge due to Liner | Physical Impact to Groundwater | Likely (2) | Minor (4) | **Moderate (6)** | Planned outcome |
| | | Chemical Impact to Groundwater | Very unlikely (5) | Minor (4) | **Low (9)** | |
| | | Ensuing Physical Impact to Ecosystems or Groundwater Users | Possible (3) | Minor (4) | **Moderate (7)** | |
| | | Ensuing Chemical Impact to Ecosystems or Groundwater Users | Very unlikely (5) | Minor (4) | **Low (9)** | |

ALARP = As Low As Reasonably Possible

**Table 4.51 (Cont'd)**
**Risk Associated with Potential Impacts**

Page 2 of 3

| Proposal Component | Aspect of Proposal Component | Potential Impacts to Groundwater | Likelihood of Impact[1] | Consequence of Impact[2] | Overall Level of Risk[3] | Comments |
|---|---|---|---|---|---|---|
| SRSF or SEC | Leakage due to Breached Liner | Physical Impact to Groundwater | Very unlikely (5) | Minor (4) | **Low (9)** | ALARP (refer to EES, 2013) |
| | | Chemical Impact to Groundwater | Very unlikely (5) | Major (2) | **Moderate (7)** | |
| | | Ensuing Physical Impact to Ecosystems or Groundwater Users | Very unlikely (5) | Minor (4) | **Low (9)** | |
| | | Ensuing Chemical Impact to Ecosystems or Groundwater Users | Very unlikely (5) | Critical (1) | **Moderate (6)** | |
| | | Ensuing Land Salinisation | Very unlikely (5) | Major (2) | **Moderate (7)** | |
| | Negligible recharge due to Liner | Physical or Chemical Impact to Groundwater | Likely (2) | Minor (4) | **Moderate (6)** | Planned outcome |
| | | Ensuing Physical or Chemical Impact to Ecosystems or Groundwater Users | Possible (3) | Minor (4) | **Moderate (7)** | |
| Open Cut | Enhanced Recharge due to no runoff | Physical Impact to Groundwater | Likely (2) | Moderate (3) | **High (5)** | ALARP (localised post closure impact). Refer to Section 4.6.5.3 for assessment |
| | | Chemical Impact to Groundwater | Unlikely (4) | Minor (4) | **Low (8)** | |
| | | Ensuing Physical Impact to Ecosystems or Groundwater Users | Unlikely (4) | Minor (4) | **Low (8)** | |
| | | Ensuing Chemical Impact to Ecosystems or Groundwater Users | Unlikely (4) | Moderate (3) | **Moderate (7)** | |
| WRE | Enhanced Recharge | Physical Impact to Groundwater | Likely (2) | Minor (4) | **Moderate (6)** | ALARP (refer to EES, 2013) |
| | | Chemical Impact to Groundwater | Unlikely (4) | Major (2) | **Moderate (6)** | |
| | | Ensuing Physical Impact to Ecosystems or Groundwater Users | Unlikely (4) | Minor (4) | **Low (8)** | |
| | | Ensuing Chemical Impact to Ecosystems or Groundwater Users | Unlikely (4) | Major (2) | **Moderate (6)** | |
| ALARP = As Low As Reasonably Possible | | | | | | |

**Table 4.51 (Cont'd)**
**Risk Associated with Potential Impacts**



| Proposal Component | Aspect of Proposal Component | Potential Impacts to Groundwater | Likelihood of Impact[1] | Consequence of Impact[2] | Overall Level of Risk[3] | Comments |
|---|---|---|---|---|---|---|
| Processing Plant Area | Leakage due to Cracks/ Breaches in Paved Area | Physical Impact to Groundwater | Very unlikely (5) | Minor (4) | **Low (9)** | ALARP (refer to EES, 2013) |
| | | Chemical Impact to Groundwater | Very unlikely (5) | Critical (1) | **Moderate (6)** | |
| | | Ensuing Physical Impact to Ecosystems or Groundwater Users | Very unlikely (5) | Minor (4) | **Low (9)** | |
| | | Ensuing Chemical Impact to Ecosystems or Groundwater Users | Very unlikely (5) | Critical (1) | **Moderate (6)** | |
| | | Ensuing Land Salinisation | Very unlikely (5) | Major (2) | **Moderate (7)** | |
| | Negligible recharge due to Pavement | Physical or Chemical Impact to Groundwater | Likely (2) | Minor (4) | **Moderate (6)** | Planned outcome |
| | | Ensuing Physical or Chemical Impact to Ecosystems or Groundwater Users | Possible (3) | Minor (4) | **Moderate (7)** | |

ALARP = As Low As Reasonably Possible

Note 1. Likelihood scale has five categories with scores from 5 to 1, i.e. Very Unlikely (5), Unlikely (4), Possible (3), Likely (2), Very Likely (1)

Note 2. Consequence scale has five categories with scores from 5 to 1, i.e. Negligible (5), Minor (4), Moderate (3), Major (2), Critical (1)

Note 3. Overall risk value = Consequence value + Likelihood value; consequence and likelihood are considered separately

Source: Modified after EES (2013) – Table 10

Based on the limited extent and temporary nature of any leak from the LRSF, it is suggested that EES (2013) has been overly conservative in their assessment of risk. Even if, despite the detailed and comprehensive quality control and management protocols, the likelihood of a breach is classified as 'possible' (a classification of 'unlikely' is considered more reasonable based on the proposed controls and management), the limited and temporary nature of the impact is such that classifying as a 'major' consequence is overstating the risk. If a 'moderate' consequence is assigned, the risk would be reduced to a 'Moderate' level (score of 7). The following quotes directly from EES (2013) (*Section 6.4.3*) and supports this assessment.

> *However, in the event of a breached liner, it can be expected that the leak would be detected by groundwater monitoring and repaired ... such that the leak would be temporary and its consequent effects would be minimised. Although it would be unlikely that a significant proportion of any brine that leaks into the groundwater could be effectively removed, it can be expected that the total volume of leakage would be small in comparison to the total volume of groundwater beneath and down-gradient from the LRSF.*
>
> *Consider the example …… in which a leakage flux of 10m$^3$/day is taking place from a LRSF over alluvium. For a leak of this order of magnitude, it can be expected that there would be a relatively rapid increase in groundwater levels in the monitoring bores such that the leak would be identified and the leaking liner would be repaired within a period of weeks to months. Therefore, the total volume of brine seeping into the groundwater would be expected to be less than 2,000m$^3$ (based 10m$^3$/day for 200 days).*

> *For comparison, a volume of saturated alluvium which is 50m in width perpendicular to groundwater flow direction x 100m in length parallel to the flow direction x 30m thick beneath a LRSF can be expected to contain a volume of greater than 50,000$m^3$ of water (based on a porosity of greater than 0.3).*

Furthermore, EES (2013) notes that while the liquid residue in the LRSF would contain low levels of metals such as Al, Mn, U and Zr, and a significant portion (11.8%) as sulphur (S) species (DECA, 2013), the risk of acidification of the residue (from oxidation of S to form $H_2SO_4$) and subsequent release metals into solution is low. This is because all of the sulphur species would be in oxidised forms (such as $SO_4$) which would be neutralised by carbonates (lime and limestone) to precipitates such as gypsum ($CaSO_4$).

EES (2013) also considers the possibility for leakage from the LRSF to impact on down-gradient receptors such as Wambangalang Creek and associated groundwater dependent ecosystems or groundwater users to be unlikely as while groundwater flow could transport a plume of brine, dispersion through in-situ groundwater and the limited duration of the source would together have the effect of significantly reducing the concentration with distance from the LRSF.

It is therefore assessed, that while the potential for a leak of the LRSF liner cannot be discounted, the Applicant would implement and enforce controls and measures to reduce this possibility to *As Low As Reasonably Possible* (ALARP) given the proposed design of the LRSF. The subsequent impact on the aquifer would be minimised, such that in the event of a leak any impacts on groundwater quality would be prevented from extending beyond the DZP Site through the implementation of the proposed monitoring system and *Leak Detection Response Strategy*.

#### 4.6.5.4 Altered Groundwater Flows due to Enhanced Recharge via the Open Cut

The risk of an increase in groundwater flux due to enhanced recharge associated with the open cut is interpreted to be 'high' by EES (2013), based on the assumption that an increased recharge through the open cut is 'likely' and that this would have a 'major' consequence. It is considered that EES (2013) overstates the likelihood of increased recharge through the floor of the open cut given:

- local evaporation rates significantly exceed rainfall rates (1 799mm vs 677mm) suggesting that under most rainfall conditions, there would be little standing water accumulated in the open cut to recharge the aquifer; and
- other features of the DZP Site within the same recharge catchments are assessed as reducing recharge.

Notably, EES (2013) reports that there would be a low risk of impact upon groundwater quality (see **Table 4.51**) given insolubility of trace metals and lack of any acid generating material (see Section 2.5.2.2).

The above notwithstanding, EES (2013) notes the following (*Section 6.6*) with respect to the potential impact.

> *Although this is scored as a high risk by this methodology, an interpreted "high risk" of enhanced groundwater flow is more a function of the itemised risk methodology than a true issue of concern. The most likely effect would be enhanced groundwater discharge/spring flow in the highland gullies, which could be considered to be a positive impact.*

Considering the above statement of EES (2013), even in the event of increased recharge, any resultant impact is not considered to have any significant adverse environmental consequences.

#### 4.6.5.5 Land Salinization

At any location where the water table is raised to within 2m of the ground surface there is the potential for land salinization to take place. EES (2013) do not predict this to occur either during or following mining operations based on the following.

- Assuming the liners of the LRSF are effective at preventing leakage, the elevation of the water table is not predicted to increase (it may in fact decrease as a result of reduced recharge) as a result of the Proposal.
- In the unlikely event of a breached liner, it can be expected that the leak would be detected and repaired within a period of a few weeks to months such that the leak would be temporary and its effect on groundwater quality would be localised. This also means that any increase in the water table as a result of a liner leak would be localised and temporary.
- Should a rise in the water table rise to within 3m of the ground surface near the toe of the lower embankment of a LRSF be detected by monitoring, trenching or an equivalent contingency measure would be implemented to intercept seepage and/or maintain the water table at more than 2m below ground level.
- On decommissioning, all salt would be removed from the LRSF and the ground surface returned to (approximately) its original level.

#### 4.6.5.6 Conclusion

As for any site where potentially polluting materials are to be managed, or the landform is to be modified, the risk of altered flows or pollution of groundwater cannot be eliminated. An assessment of the relative risks associated with activities on the DZP Site (**Table 4.51**) has confirmed that there would remain some risk of impacts to groundwater as a consequence of the Proposal. However, on the basis of the proposed safeguards, operational controls, mitigation and management measure, monitoring programs and commitment to implementation of a contingency *Leak Detection Response Strategy*, both the likelihood and consequence of impact have been reduced to "As Low As Reasonably Possible". On this basis, and the fact that as noted by EES (2013) any impact would be limited in extent and temporary in nature, it is assessed that any residual impacts are acceptable and would be minimised and mitigated, if observed.

## 4.6.6 Groundwater Management Plan

### 4.6.6.1 Aims

As indicated by the results of the risk analysis summarised in **Table 4.51** and discussion of Section 4.6.5, it is not possible to eliminate the risk of impact completely. The Applicant acknowledges that the preparation, implementation and continual review of a *Groundwater Management Plan* would be required to ensure the risks of impact are maintained as low as possible and impacts are identified and mitigated as quickly and effectively as possible should they occur.

### 4.6.6.2 Groundwater Management

The *Groundwater Management Plan* would formalise the impact avoidance, minimisation and mitigation measures nominated in Section 4.6.4, as well as any other measures required by the development consent or government agencies. The *Groundwater Management Plan* would be auditable and include criteria and key performance indicators for assessment of performance, and trigger levels for the implementation of the various mitigatory measures. The *Groundwater Management Plan* would be a 'live' document and require annual review and update at least every three years.

It is anticipated the *Groundwater Management Plan* would be prepared in consultation with the DP&I, NOW, EPA and Dubbo City Council.

### 4.6.6.3 Groundwater Monitoring Program

A key component of the *Groundwater Management Plan* would be the development and implementation of a groundwater monitoring program.

The monitoring program would consist of two separate components.

1. Shallow piezometers to be installed around the SRSF, LRSF and SECs which would monitor changes in water level and quality surrounding these structures as way of identifying leaks.
2. The existing groundwater bore network on and surrounding the DZP Site to monitor for any changes to local conditions as a result of the Proposal.

#### Shallow Piezometer Monitoring

Constructed to a depth of between 3m and 5m, these shallow piezometers would be constructed at intervals of between 150m and 300m around the SRSF, LRSF and SECs. An indication of the location of these bores surrounding LRSF Area 3 is provided by **Figure 2.13**, however, it is noted that the exact locations would be determined following approval of the Proposal and final engineering design of the LRSF.

As noted in Section 4.6.4.2.6, the piezometers installed around the LRSF would be paired to allow for localised changes in water level or quality to be identified.

It is proposed that each piezometer would be monitored at least monthly and tested for SWL, pH, EC and temperature with a field testing unit. Samples would be taken on a less frequent basis and sent to a NATA registered laboratory for analysis of parameters including but not necessarily limited to:

- pH, TDS, cations (Na, Ca, Mg, K) and anions (Cl, $SO_4$, $HCO_3$, $PO_4$, F);
- dissolved metals / metalloids including aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), boron (B), bromide (Br), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), strontium (Sr), uranium (U), vanadium (V) and zinc (Zn).

**Groundwater Bore Network**

EES (2013) confirms that the locations of the existing bores within the DZP Site would be appropriate for ongoing monitoring, however, bores DWB001 to DWB011 would be replaced (due to a lack of seal installed in the original bores) to prevent possible pathways for contamination to enter the groundwater from the ground surface. In addition to the replacement of bores DWB001 to DWB011, it is proposed to install several new bores. These bores, summarised as follows, would be monitored on a quarterly basis.

- Background bores: DWB002, DWB003, DWB004 and DWB006.
- Open cut bores: GWB021 and DWB022 (until mining commences).
- Down-gradient of the open cut and up-gradient of the LRSF: DWB007, DWB010, DWB011 and DWB020.
- Lower catchment bores: bores DWB015, DWB016, DWB019 and DWB023.
- Additional bores to be placed down-gradient of the LRSF, SRSF and SECs:
  - in the vicinity of bore GW008373;
  - south of DWB019 between the LRSF and Wambangalang Creek;
  - north of DWB012 between the LRSF and Wambangalang Creek;
  - north of DWB015 between the LRSF and the processing plant;
  - between the processing plant and the confluence of Wambangalang and Paddys Creeks; and
  - south of each of the SRSF and the Salt Encapsulation Cells.

In total, 21 bores are proposed for assessing groundwater levels and quality within the DZP Site prior to mining operations, and 19 bores are proposed as part of mining operations monitoring. Each bore would be sampled quarterly and sent to a NAT accredited laboratory for analysis of:

- pH, TDS, cations (Na, Ca, Mg, K), anions (Cl, $SO_4$, $HCO_3$, $PO_4$, F) and nutrients ($NH_3$, $NO_3$ and $NO_2$);