# Ammaroo Ammonium Phosphate Fertiliser Project

## Referral for Significant Variation

## Appendices J - Q

Verdant Minerals Pty Ltd

9 November 2022

# Appendix J

## HydroGeoLogic Pty Ltd 2022 – Ammaroo Ammonium Phosphate Fertiliser Project Mine Bore Field – Groundwater Model Peer Review

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**4 July 2022**

**Dear Susan,**

**AMMAROO PHOSPHATE PROJECT MINE BORE FIELD - GROUNDWATER MODEL PEER REVIEW**

This brief letter report summarises the outcomes of an independent review of the groundwater modelling and impact assessment investigation relating to the water supply borefield for the Ammaroo Phosphate Project being developed by Verdant Minerals.

The Ammaroo Project site is located between Alice Springs and Tennant Creek in the central Northern Territory. The water supply borefield is south of the site and accesses the aquifers of the southwestern Georgina Basin in an area that is about 20 km to the southeast of the declared Western Davenport Water Control District (WCD).

This peer review was conducted in accordance with the principles and criteria outlined in the best practice Australian Groundwater Modelling Guidelines ('AGMG'; Barnett et al. 2012), with consideration of the recent uncertainty analysis guidance (Middlemis et al., 2018, 2019). The 2012 AGMG suggests a compliance checklist to summarise review outcomes, which is presented herein as Table 1 (see next page). The review methodology evaluated whether best practice has been applied to the modelling study, with a focus on:

- the hydrogeological understanding and conceptualisation, and implementation in the numerical model, and its fitness for the purpose of groundwater assessment;
- conformance to best practice guidelines in relation to model calibration performance, with consideration of grid, domain, boundary conditions, layering and parameterisation; non-uniqueness, sensitivity/uncertainty and prediction scenarios;
- whether the assessments made, or conclusions reached, are supported by the evidence presented, and/or whether additional information, monitoring, assessment and/or modelling may be required to inform the assessment.

Table 1 - Groundwater Model Compliance Checklist: 10-point essential summary - Ammaroo (2022)

| Question | Y/N | Comments re Ammaroo Phosphate project groundwater model (2022) |
|---|---|---|
| 1. Are the model objectives and model confidence level classification clearly stated? | Yes | Borefield water supply impact assessment context. Southwest Georgina Basin, near but not within Water Control District. Quantitative uncertainty analysis surpasses qualitative confidence level characterisation. |
| 2. Are the objectives satisfied? | Yes | Highly competent model design and advanced methods of predictive uncertainty applied to 25- and 40-year mining scenarios (100-year runs). Results presented as probability distributions of drawdown and flux change. |
| 3. Is the conceptual model consistent with objectives and confidence level? | Yes | Ensemble of 12 system-boundary conceptual models applied to uncertainty scenarios. Consistent with available information and project context. |
| 4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer? | Yes | Model report summarises available investigations and data. Competent hydrogeologists and modellers have evaluated the data, conceptual model ensembles, numerical model design and execution, sensitivity and uncertainty assessments and outcomes. |
| 5. Does the model design conform to best practice? | Yes | The model software (Modflow-6, PESTPP-IES), design and boundaries (Pilot Points, SEGLIST flux vertices), quad-tree grid (1 layer, 156-500 m cells), parameter ranges and quantitative uncertainty assessment (100 realisations x 12 conceptual models = 1200 total) form excellent best practice example of design/execution. |
| 6. Is the model calibration satisfactory? | Yes | Report correctly prefers 'conditioning' term to 'calibration'. Methodology designed around predictive uncertainty techniques applied to ensemble of conceptual models and parameter ranges. Reasonable rejection criterion applied (reject if sRMS >10%). Result was 946-run forecast ensemble, most with sRMS <6%. |
| 7. Are the calibrated parameter values and estimated fluxes plausible? | Yes | Best practice methods applied to model design and parameterisation, facilitating comprehensive predictive uncertainty analysis of fluxes and drawdowns and the key parameter uncertainties involved. |
| 8. Do the model predictions conform to best practice? | Yes | Prediction scenarios run for 25- and 40-year project life and subsequent 75- and 60-year recovery periods resp., applied with predictive uncertainty techniques, and with clear report narrative and plotting of results. |
| 9. Is the uncertainty associated with the predictions reported? | Yes | Study is commended for the quantified predictive uncertainty analysis methods. Results indicate low risk of significant drawdown at the existing users bores or material effects on flux across WCD boundaries. |
| 10. Is the model fit for purpose? | Yes | My professional opinion is that the Ammaroo 2022 modelling is a sound example of leading practice in design and execution, notably including a quantified uncertainty analysis with multiple conceptualisations, and is fit for the impact prediction purpose. |

It is my professional opinion that the hydrogeological modelling study has been undertaken consistent with best practice, notably in relation to the quantified uncertainty analysis methods applied. An ensemble of 12 system-boundary conceptual models were developed, each represented with 100 parameter realisations, giving a total of 1200 realisations that are designed to test the uncertainties affecting the drawdown and flux impact predictions. Reasonable rejection criteria were applied (reject if sRMS >10%), resulting in the 946-run forecast ensemble, most with a reasonable scaled RMS criterion of less than 6%. The 2022 Ammaroo modelling study is commended for improving on the excellent previous modelling work (Knapton 2017), and again confirms the low risk of significant drawdown at the existing user bores or material changes to the flux across the WCD boundaries.

In closing, it is also worth making some comments about 'model confidence level issues'.

**'MODEL CONFIDENCE LEVEL' AND QUANTITATIVE UNCERTAINTY ANALYSIS**

The 'model confidence level classification' set out in the Australian Groundwater Modelling Guidelines ('AGMG'; Barnett et al. 2012) is an outmoded qualitative assessment of the level of data available, especially aquifer responses to hydrological stresses, as well as the conceptualisation and calibration process and performance, and the manner in which the predictions are formulated. The AGMG also set out some basic guidance on the uncertainty analysis methods that were in the early stages of the model development at that time (a decade ago). The AGMG is being revised and this qualitative assessment is being discontinued.

It is a common misconception that the model confidence level assessment is mandatory for every model, given that the AGMG actually recommends the confidence level method for application to situations when a formal uncertainty analysis has not been conducted. The 2022 Ammaroo groundwater assessment report does not discuss the model confidence level classification, and nor does it need to, given the uncertainty assessment methodology applied.

It is also worth noting that the uncertainty guidance provided in the 2012 AGMG was augmented and updated by Middlemis et al. (2018 and 2019), including the key principle that "a model should be able to quantify its own reliability [via a well-executed uncertainty analysis], rather than relying on the AGMG confidence level scheme, which is prone to misinterpretation". This was warranted in the sense of concerns that the AGMG was being used inappropriately in some cases to justify 'indiscriminate complexification' of models, rather than the 'effective simplification' that is warranted for application to the current best practice methods of quantitative uncertainty analysis.

The 2018 guidance frames uncertainty analysis as an integral part of risk management, in that it informs and complements other aspects such as risk assessment, mitigations/treatments, communicating outcomes and prioritising efforts to reduce uncertainty. It requires a balance to be struck between model simplicity and complexity for the purpose of uncertainty evaluation, commensurate with the risk/consequence profile of the project, as has been achieved for the 2022 Ammaroo model.

The 2012 AGMG and the 2018 uncertainty guidance are both in the process of being updated. This peer reviewer is advised that the AGMG revision will involve the rejection of the 'model confidence level' scheme and its formal replacement with uncertainty analysis methodologies. The quantitative uncertainty analysis conducted for the 2022 Ammaroo modelling is consistent with existing best practice guidance and should be consistent with the new guides (expected in late 2022).

Yours sincerely, **HydroGeoLogic Pty Ltd**

Hugh

**Hugh Middlemis**

**Principal Groundwater Engineer**

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## DECLARATIONS:

The peer review was conducted by Hugh Middlemis, who has the necessary skills, experience and familiarity with NT conditions, including:

- Peer review of Ammaroo groundwater modelling in 2017.
- Independent expert reviews of groundwater assessments and/or water management plans for several NT mining projects; Jervois Base Metals Groundwater Monitoring and Management Plan (2020); Cambrian Limestone Aquifer and Roper River Model (Daly/Roper Basin model review 2020); Tindall Limestone Aquifer (2020); Chandler Salt Water Management Plan (2017); Ranger Pit 1 (2016).
- Hugh was previously Technical Director on several Aquaterra projects in the NT, notably the following, which also involved site investigations: Angela uranium (2010-11); McArthur River mine dewatering and river-aquifer interactions (2012-13); Middle Point groundwater model (1999); Elizabeth River waterway project groundwater model (NT Dept of Transport, 1999); Woodcutters mine decommissioning (1999); Groote Eylandt mine dewatering and river-aquifer interactions (1998-2002).
- Hugh lived in Katherine and Darwin for five of his middle-school years.

**We assert no conflict of interest issues in relation to this work.** Mr Middlemis has not worked on the Ammaroo project, nor for Verdant nor IGS consultants, other than in a review role.

For the record, Hugh Middlemis established Hydrogeologic Pty Ltd as an independent consultancy in 2013, with the core business of providing specialist advice on groundwater model conceptualisation, design and independent peer reviews. Hugh holds a degree in civil engineering and a masters in hydrology and hydrogeology. He has more than 40 years' experience and was principal author of the MDBA 2001 best practice groundwater modelling guidelines that formed the basis for the 2012 AGMG. More recently, Hugh was principal author of two reports on modelling uncertainty (2018 and 2019).

# Appendix K

## IGS 2022 - Groundwater Modelling Technical Memorandum

# Assessment of Groundwater Extraction from the Ammaroo Phosphate Project Mine Bore Field

Report prepared for Verdant Minerals

23 June 2022

IGS Innovative Groundwater Solutions

ACE Aquatic & Coastal Environments

# Assessment of Groundwater Extraction from the Ammaroo Phosphate Project Mine Bore Field

A report prepared for Verdant Minerals

by

Innovative Groundwater Solutions

23 June 2022

## Document control

| Version | Date Issued | Author | Reviewed by | Date Approved | Revision Required |
|---|---|---|---|---|---|
| 0.0 | 20th June 2022 | Tariq Laattoe | G. Harrington | 20th June 2022 | Moderate |
| 1.1 | 23rd June 2022 | Tariq Laattoe | G. Harrington | 23rd June 2022 | Minor |

## Distribution

| Date | Version | Issued To |
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| 20th June 2022 | 1.0 Final Draft | Verdant Minerals (S. Dippel, M.Skelton) |
| 23rd June 2022 | 1.1 Final | Verdant Minerals (S. Dippel, M.Skelton) |

### SUGGESTED CITATION

Innovative Groundwater Solutions (2022). *Assessment of groundwater extraction from the Ammaroo Phosphate Project mine bore field*. Final report prepared for Verdant Minerals. 23 June 2022.

### DISCLAIMER

This report is solely for the use of Verdant Minerals and may not contain sufficient information for purposes of other parties or for other uses. Any reliance on this report by third parties shall be at such parties' sole risk.

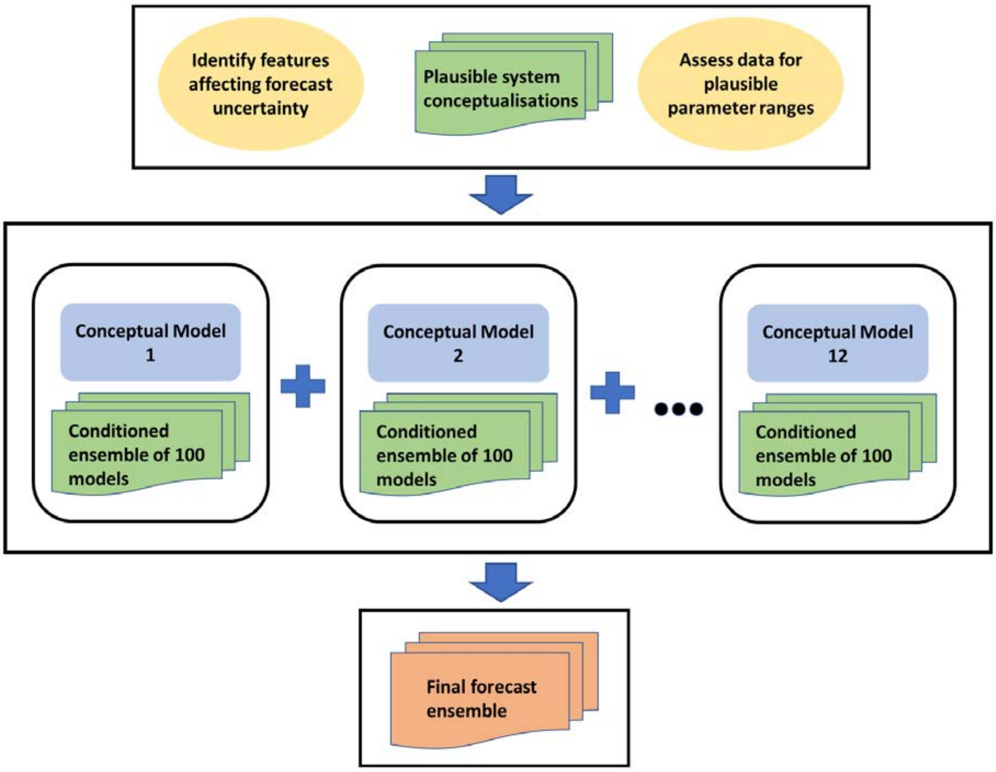
The information in this report is considered to be accurate with respect to information provided at the time of investigation. IGS has used the methodology and sources of information outlined within this report and has made no independent verification of this information beyond the agreed scope of works. IGS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that the information provided to IGS was false.

## EXECUTIVE SUMMARY

Verdant Minerals Pty Ltd, formerly Rum Jungle Resources, is proposing to develop and operate the Ammaroo Phosphate Project consisting of a phosphate mine and ancillary infrastructure, located in the Northern Territory. The project includes a bore field accessing the nearby Georgina Basin carbonate aquifer and a 12 km pipeline. As a groundwater resource, the Georgina Basin Carbonate aquifer is considered vast, with an estimated storage of between 160,000 and 320,000 Gigalitres. Verdant Minerals propose to extract 8.5 GL/yr over 25-years, which equates to between 0.07 % and 0.13 % of the estimated storage volume. This report describes the development of a groundwater model and subsequent assessment of two different extraction scenarios at the Ammaroo Phosphate Project mine borefield. The specific objectives of the study were as follows:

- Forecast groundwater drawdown impacts to existing users by simulating extraction from production bores.
- Forecast the change to flux across the boundary of the Western Davenport Water Control District that results from the simulated extraction.
- Assess the uncertainty in all forecasts.

The approach used in this investigation is outlined in the flow chart below where an ensemble of equally plausible numerical groundwater flow models is developed, conditioned to known system behavior and then used to forecast drawdown and flux.




The modelling methodology included assessment of multiple conceptual models and uncertainty in all aquifer properties plus boundary condition behavior. A total of 946 plausible models of the system were used to provide a forecast of drawdown and flux at sensitive locations, which include two third party water users and flux across the Western Davenport

Water Control District boundary. In addition, to a 25-year pumping scenario, a 40-year pumping scenario was included as a complete ensemble forecast sensitivity assessment. Results are summarised in the tables below.

Results for the 25-year extraction scenario are summarized as percentiles in the following table.

| Forecast ensemble percentile | Peak drawdown (m) at Hagen's Bore | Peak drawdown (m) at Ampilatwatja Borefield | WDWCD peak flux (ML/d) change |
|---|---|---|---|
| P10 | 1.5 | 0.4 | 0.2 |
| P50 | 2.6 | 0.9 | 0.6 |
| P90 | 4.9 | 3.0 | 4.0 |

Results for the 40-year extraction scenario are summarized as percentiles in the following table.

| Forecast ensemble percentile | Peak drawdown (m) at Hagen's Bore | Peak drawdown (m) at Ampilatwatja Borefield | WDWCD peak flux (ML/d) change |
|---|---|---|---|
| P10 | 2.0 | 0.6 | 0.2 |
| P50 | 3.8 | 1.3 | 0.8 |
| P90 | 6.8 | 4.2 | 4.4 |

For context, third party water user bores are completed to a depth of between 70 metres below ground level (mbgl) and 80 mbgl (GWS, 2017) with the water table at approximately 50 mbgl providing between 20 m and 30 m of available drawdown for pumping. The results for the 25-year scenario show that there is a very low risk for complete loss of production in third-party water user bores with the most likely (P50) drawdown being between 10% and 20% of the available drawdown at both locations. Peak flux across the WDWCD is also considered small relative to the total volume extracted from storage (23.3 ML/d) with the most likely rate of 0.8 ML/d equating to 3%.

## CONTENTS

# 1. Introduction

## 1.1. Overview

This report describes how a numerical groundwater flow model was developed and used to support planning, licensing applications and operational decisions for the Ammaroo Phosphate Project proposed mine borefield. A previous study (Knapton, 2017) was conducted for the same borefield but considered a maximum extraction rate of 4.38 GL/yr. for 25 years of operation. The present work increased this extraction rate to 8.5 GL/yr. and considered a 25-year life-of-mine (LOM) as the main model with a 40-year LOM scenario as a sensitivity run. The proposed borefield is located south of the mine in the northern margin of the South-Western Georgina Basin Carbonate Aquifer between Tennant Creek and Alice Springs in central Northern Territory.

Innovative Groundwater Solutions Pty Ltd. (IGS) was engaged by Verdant Minerals to perform a modelling investigation that included forecast uncertainty of the effects from extraction at production bores near the mine. The bores are also approximately 20 km southeast of the Western Davenport Water Control District (WDWCD) prompting assessment of extraction induced flux from the WDWCD. There was also an impetus to examine the total volume of extraction as a percentage of aquifer storage because current policy for Arid Zone aquifers (The Northern Territory Water Allocation Planning Framework) limits the total extraction over a period of at least 100 years to 80 per cent of the total aquifer storage at start of extraction. It is noteworthy that a previous assessment by Groundwater Science (GWS, 2017) under a 4.38 GL/yr. operating scenario reported the total extraction over the 25-year life of mine to be between 0.034% – 0.07% of the resource. The new proposed extraction has approximately doubled, and consequently will double the total percentage of extracted resource, remaining well below the 80% threshold. Accordingly, the goals of the investigation were to:

1. Provide drawdown predictions at locations identified as third-party water users under a 25-year LOM scenario;
2. Provide an estimate of the change in flux from the Western Davenport Water Control District (WDWCD) under a 25-year LOM scenario.
3. Assess sensitivity in (1) and (2) using a 40-year LOM scenario

The modelling specific objectives required to address these goals were as follows:

- Forecast drawdown impacts at sensitive locations by simulating extraction from production wells.
- Forecast the change to flux across the boundary of the WDWCD that results from the simulated extraction.
- Use statistical methods to support the robustness of the modelling.

Details of the approaches used to meet these objectives are covered in the body of the report with technical details relegated to Appendices where necessary.

## 1.2. Summary of existing relevant investigations

In 2012, Groundwater Science performed a review of groundwater supply prospects on behalf of Rum Jungle Resources, now Verdant Minerals, to support their Barrow Creek Phosphate Project (GWS, 2012). This study focused primarily on identifying the stratigraphic formations and geological features likely to yield sufficient groundwater for the proposed mining operation. The study produced a hydrogeological characterization of the area complete with potentiometric surfaces and associated flow directions. These were used to identify likely areas of increased transmissivity as targets for a drilling campaign.

In 2017, a groundwater study was completed by Groundwater Science to support an EIS submitted by Verdant Minerals for the Ammaroo Phosphate Project (GWS, 2017). The major emphasis of the GWS report is an impact assessment of groundwater extraction from the supply borefield during operation and post mine closure. A groundwater modelling study by CloudGMS (Knapton, 2017) was included as an Appendix to that report and is presented in more detail below. System characterization was presented with estimates of storage in the Southern Georgina Basin ranging from 160,000 to 320,000 gigalitres based on 4% drainable porosity. The estimate of 4% drainable porosity was obtained from a seven-day pumping test that also demonstrated support for bore yields over 75 L/s. Consequently, water supply for the 25-year life of mine was estimated as 0.034 to 0.07% of total storage. The report identified the Ampilatwatja Community water supply bores and Hagen’s pastoral bore as the furthest and closest sensitive receptors, respectively. Impact to groundwater dependent ecosystems (GDEs) in the form of terrestrial vegetation was considered unlikely given the depth to water table exceeds 15 m.

The CloudGMS model (Knapton, 2017) simulated a total extraction of 4.38 GL/yr. for 25 years across three production bores based on an estimated water demand for the mining operation. This value has since increased to 8.5 GL/yr over 25 years with a sensitivity to consider an extension to the mine life to 40 years prompting a new study. The CloudGMS investigation included an uncertainty analysis of drawdown impacts and flux from the WDWCD but only considered a uniform thickness model with homogenous aquifer properties, no recharge, no connection to other aquifers, and a flat water table as initial conditions. The approach focused on storage depletion and was considered appropriate for capturing the plausible worst-case scenarios for drawdown while also being adequate for providing an estimate of change to flux across the WDWCD boundary. One hundred models with randomly sampled combinations of storage and transmissivity informed by short term aquifer pumping tests comprised the forecast ensemble. Results indicated that drawdown of between 0.6 m and 2.7 m was possible at the furthest sensitive receptor, Ampilatwatja Community borefield (RN011454, RN011455) and between 1.5 m and 3.7 m at the closest sensitive receptor, Hagen’s Bore (RN010717) with the smaller value representing the 5$^{th}$ percentile (P5) and the larger value representing the 95$^{th}$ percentile (P95). The likely range of change to flux from the WDWCD was between 0.44 ML/d and 2.5 ML/d.

Most recently, Groundwater Science prepared a report for Verdant Minerals of a second seven-day pumping test and appropriate borefield design to accommodate a potential mine supply of 10 GL/yr (GWS, 2021). A constant rate test at 47 L/s was performed with results providing updates to the estimates of mean storage (3%) and mean transmissivity (4,800 $m^2$/d) of the target aquifer. Previous estimates of transmissivity were reported as a minimum of 40 $m^2$/d and a maximum of 2,600 $m^2$/d (GWS, 2017). This translated to a hydraulic conductivity range of between 0.3 m/d and 20 m/d when assuming an average saturated thickness of 150 m, which was used in the groundwater modeling study (Knapton, 2017). New estimates of transmissivity, using the same assumptions as Knapton (2017), suggest a plausible range for hydraulic conductivity of the target aquifer between 0.1 m/d and 50 m/d.

## 1.3. Approach

The approach used in this investigation is outlined in the flow chart below (Figure 1) where an ensemble of equally plausible models is developed, conditioned to known system behavior and then used to forecast drawdown and flux. The term forecast is used in preference to predictions because it is considered more appropriate when dealing with likelihoods reported as percentiles (Anderson et al., 2015); further, the term conditioned is used instead of calibrated with ensembles of models.

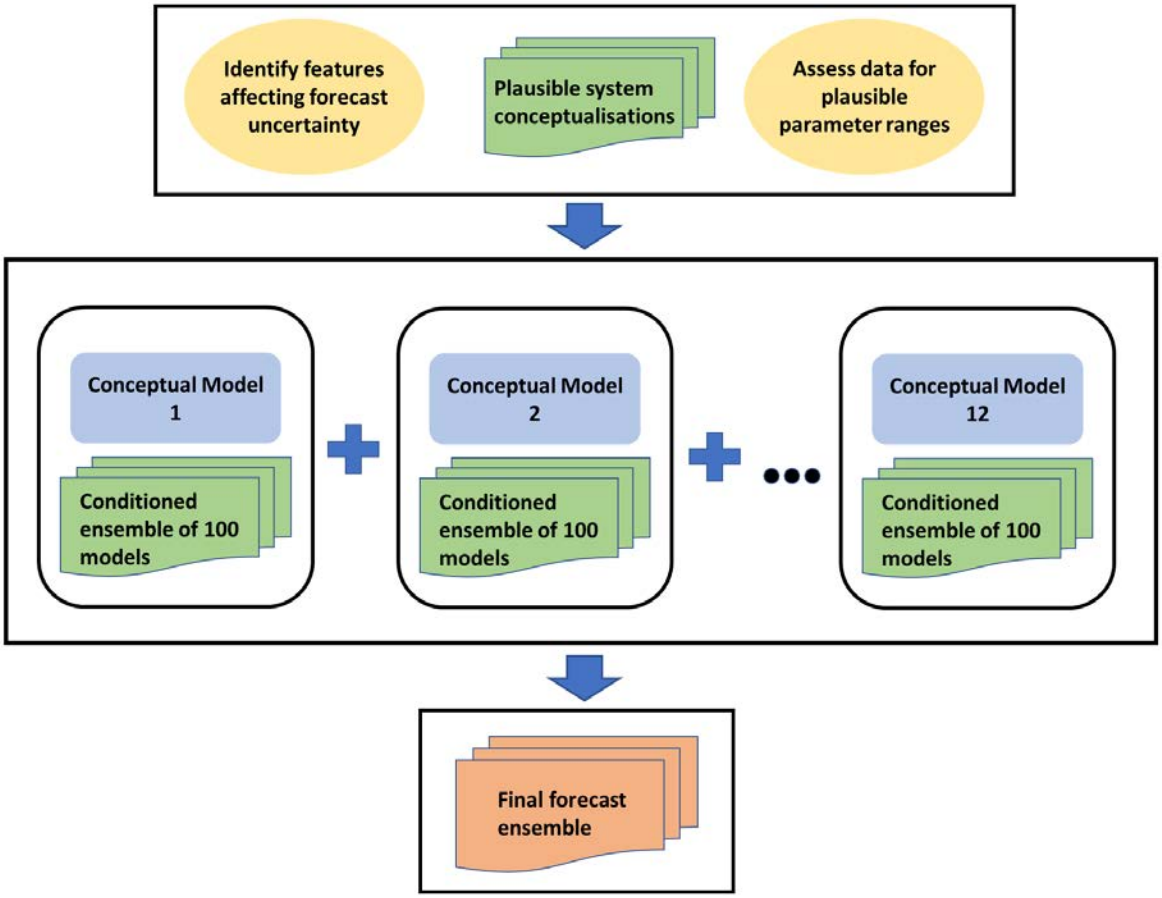



Figure 1. Flowchart outlining the overall methodology.

Features likely to have significant effect on uncertainty in forecasts were identified prior to model construction. Uncertainty in external model boundary condition behavior prompted exploration of alternative system conceptualisations based on connectivity of the simulated aquifer to adjacent systems. An ensemble of 100 models was conditioned to a steady-state (historical) hydraulic head dataset for each of 12 plausible conceptual models. The 1200 models were then filtered to accept only those with a scaled root mean squared (SRMS) error of less than 10% before being combined into the final forecast ensemble. The benefit of including alternative system conceptualisation in addition to model parameterisation provided a more robust exploration of plausible system behavior during forecast simulations.

# 2. Methodology

## 2.1. Hydrogeological setting

Only those hydrogeologic features salient to the current investigation are described herein with references provided for a more comprehensive treatise of the region. The modelled region is the Southern Georgina Basin Carbonate Aquifer where production bores are targeting the Hagen member of the Chabalowe formation. A detailed analysis of the geology, structure and resource potential of the Basin is presented in Dunster et al. (2007). Both the mine and borefield are in the Southern Georgina Basin but proximal to the northern margin where the Cambrian basin sediments thin and onlap the basement rocks of the Tennant Creek Block (Figure 2).

Aquifers in the Southern Georgina Basin include the Georgina Basin Carbonates (including Arthur Creek, Chabalowe and Arrinthrunga formations), the Dulcie Sandstone and the fractured basement. The carbonates are recognised as the most successful target for high yielding bores in the region at greater than 30 L/s while the sandstone formation is reported to provide bore yields up to 20 L/s (Figure 3). Regionally the carbonate aquifer is considered unconfined with specific yield typically in the 0.01 to 0.04 range (Jolly et al., 2004, Knapton, 2006). Saturated thickness varies from 50 m to over 1000 m (Dunster et al., 2007) with the aquifer increasing in thickness to the south-southeast (Figure 3). Recharge is generally low with long-term mean average rates around 0.2 mm/yr for the region but may reach 2.0 mm/yr where direct infiltration via fractured rock outcrops or ephemeral streams occurs (Harrington et al., 2002).

There are no groundwater discharges to surface near the study site with the water table generally between 30 m and 80 m below ground level (mbgl). Groundwater flows from the Southern Georgina Basin eastward into the broader regional Georgina Basin. Drainable porosity within the Southern Georgina Basin is estimated to be between 160,000 to 320,000 gigalitres (GWS, 2017). The carbonate aquifer is understood to be connected to the underlying fractured rock; consequently, areas of elevated terrain where fractured rock outcrops are a potential source of recharge for the Georgina Basin. This includes the Davenport Ranges to the north, and the Watt, Spring and Tomahawk Ranges to the south.

Climate in the region is considered arid with annual rainfall averaging 350 mm with a high coefficient of variation and pan evaporation of close to 4000 mm. Regionally most of the rain is associated with thunderstorms during monsoonal wet season cyclonic activity. Over drought years there is little to no rainfall recorded.

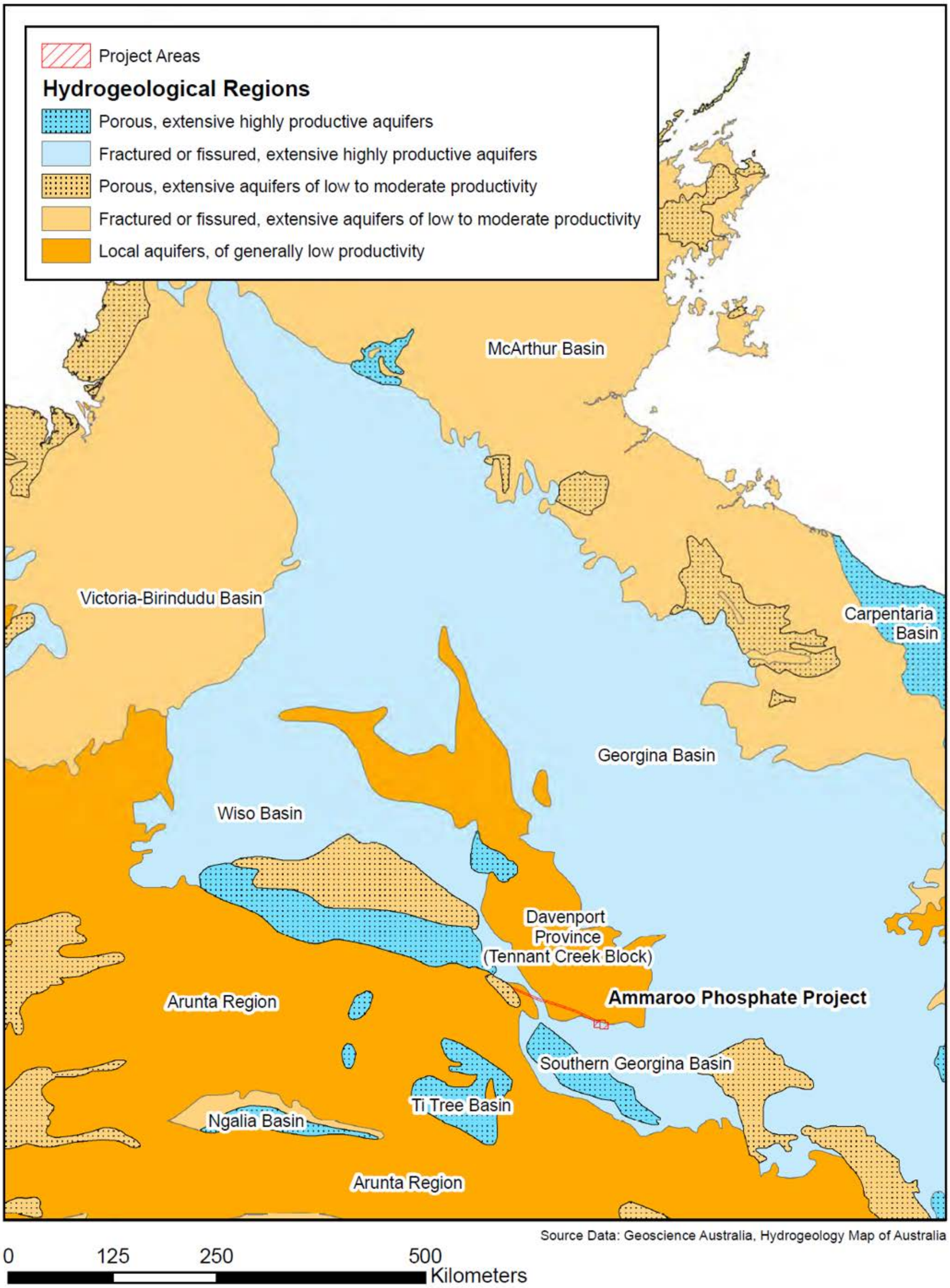



Figure 2. Location of Ammaroo Phosphate project in the Southern Georgina Basin (GWS, 2017).

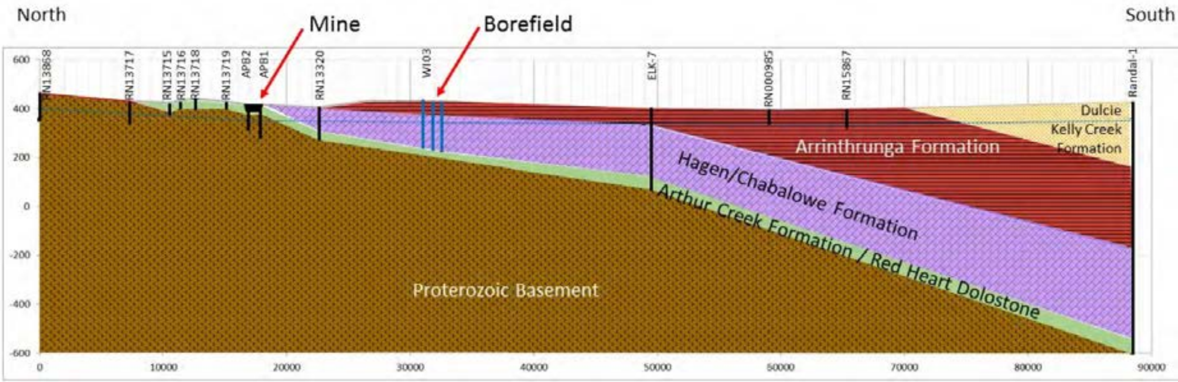



Figure 3. A North-South cross section running through the Southern Georgina Basin (GWS, 2017)

## 2.2. System Properties

System properties used in the present study were derived from the previous investigations discussed in Section 1.2 and referenced in Section 2.1. Ranges of aquifer properties used in the current groundwater modelling investigation are presented in Table 1. Heterogeneity in system properties is expected to impact uncertainty in model forecasts. The previous investigation (Knapton, 2017) precluded an assessment of system heterogeneity opting to simulate a homogenous aquifer of limited saturated thickness instead. The present investigation targeted a comprehensive uncertainty estimation of model forecasts, which required representing heterogeneity at scales that have noticeable impact on those forecasts. All system properties listed in Table 1 were considered heterogeneous with details of their implementation described in Section 3.3.1.

Table 1. System property ranges obtained from previous investigations.

| Property | unit | minimum | maximum |
|---|---|---|---|
| Hydraulic conductivity | m/d | 0.1 | 50.0 |
| Specific yield | - | 0.02 | 0.04 |
| Recharge | mm/yr | 0.2 | 2.0 |
| Connectivity (Conductance) | $m^2/d$ | 0.001 | 1000.0 |

## 2.3. Observation Data

Data used to inform model construction and ensemble conditioning included the following:

- a set of steady-state hydraulic heads located within and outside of the domain were used to develop a potentiometric surface (Figure 4),

- steady-state hydraulic heads located within the model domain were also used to create an observation dataset for ensemble conditioning (Figure 4),
- lithology logs were used to check depth to aquifer base where available,
- a DEM for the region was used to assign surface elevations to the top of the model obtained from Geoscience Australia - SRTM-derived 1 Second Digital elevation model accessed on the 24/05/2022 at: https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/72759 ,
- GIS shape files of aquifer types (Figure 4) used to define model external boundaries were obtained from Northern Territory Government Open Data Portal on the 24/05/2022 at: https://data.nt.gov.au/dataset/northern-territory-ground-water-aquifers,
- a shapefile of basement elevation contours provided by Verdant Minerals,
- a polygon shape file of the Western Davenport Water Control District provided by Verdant Minerals (Figure 4),
- coordinates as eastings and northings for the production bores provided by Verdant Minerals (Figure 4)
- coordinates as eastings and northings for Hagen’s Pastoral Bore and the Ampilatwatja Community Borefield, which are respectively, the closest and furthest sensitive receptors.

## 2.4. CONCEPTUAL MODELS

A system conceptual flow model is presented in Figure 5 along with potentiometric surface contours interpolated from the water level observations displayed in Figure 4. There is uncertainty regarding groundwater flux along most of the external boundaries due to extrapolation of the potentiometric surface into those areas where little or no hydraulic head measurements are available. For example, most of the south and south-eastern regions have no hydraulic head measurements to constrain the potentiometric surface, thereby increasing the uncertainty of boundary flux conditions in these regions of the model.

A range of fluxes may be plausible along all external boundaries (Figure 6) prompting a need to include alternative conceptual models in the uncertainty analysis. Flux boundaries were implemented as General Head Boundary (GHB) conditions. A conservative assessment of some boundary conditions as zero-flux (often referred as “no-flow boundaries”) was also necessary, given the proximity of the production bores to the northern boundary.

Alternative conceptual models were characterised by forcing zero-flux conditions along specific regions of the external boundaries. The purpose was to direct the conditioning process towards alternative combinations of aquifer properties and recharge distribution that also produced a reasonable fit with the observation dataset, thereby resulting in different drawdown propagation behaviour from the forecast ensemble. Figure 7 shows 12 conceptual models that differ by the number and location of no-flow conditions assigned along certain boundaries. Where flux boundaries are implemented, a range of flux is explored through parameterisation strategies that facilitate conditioning a range of hydraulic head and GHB conductance values.

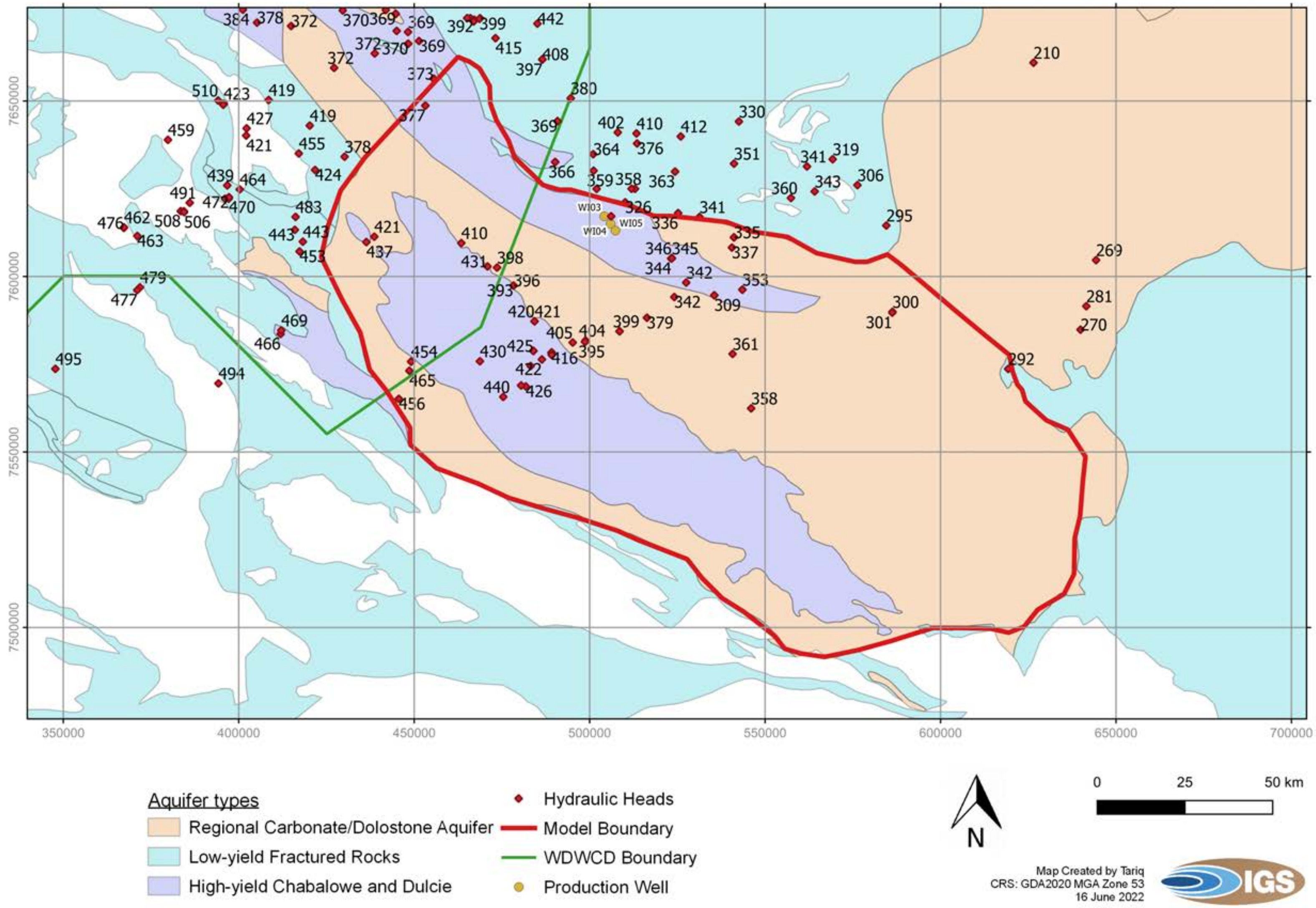



Figure 4. Map showing spatial datasets used in developing the model. Note only relevant aquifer types are included.

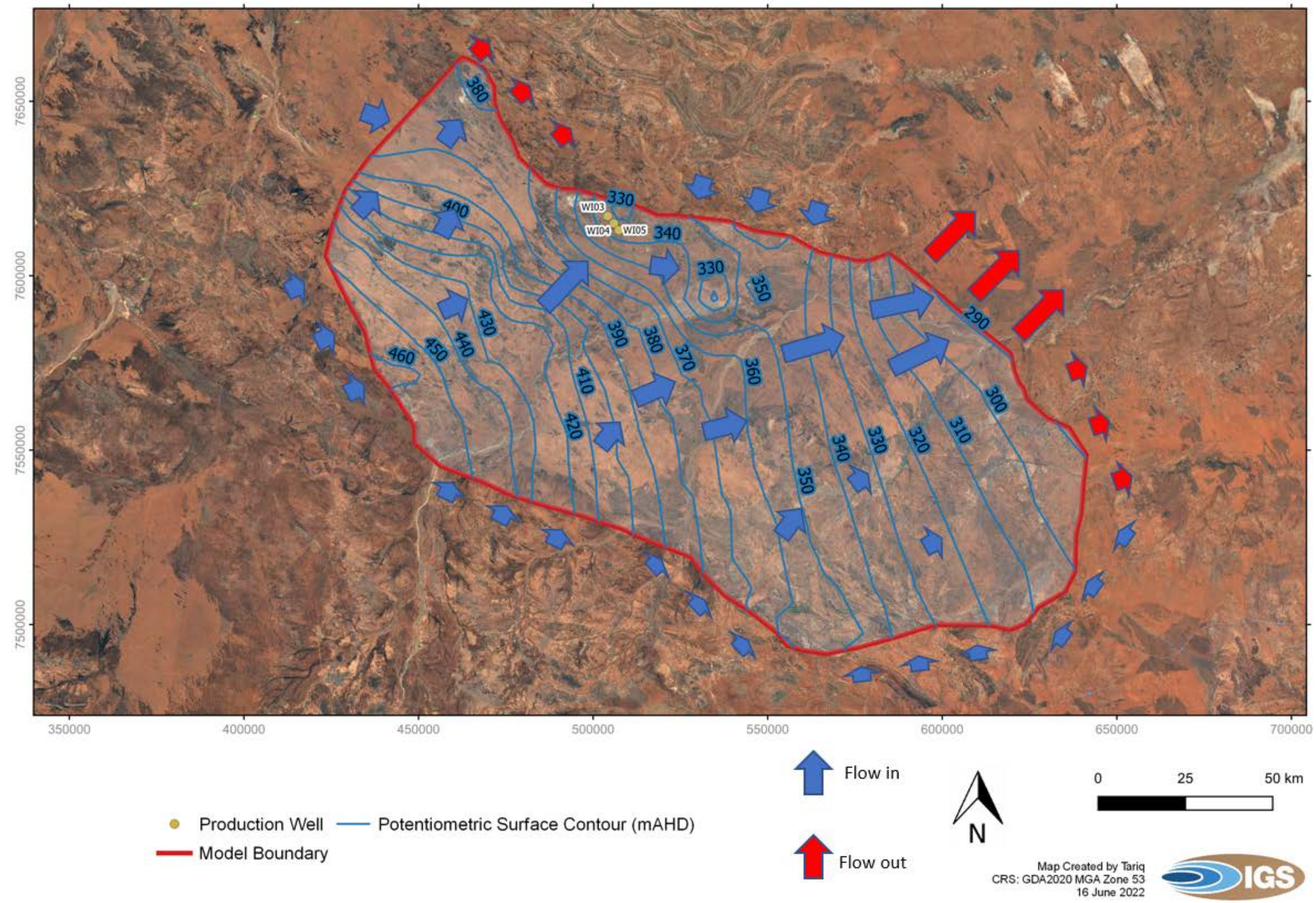



Figure 5. Potentiometric surface contours and system flow conceptualisation.

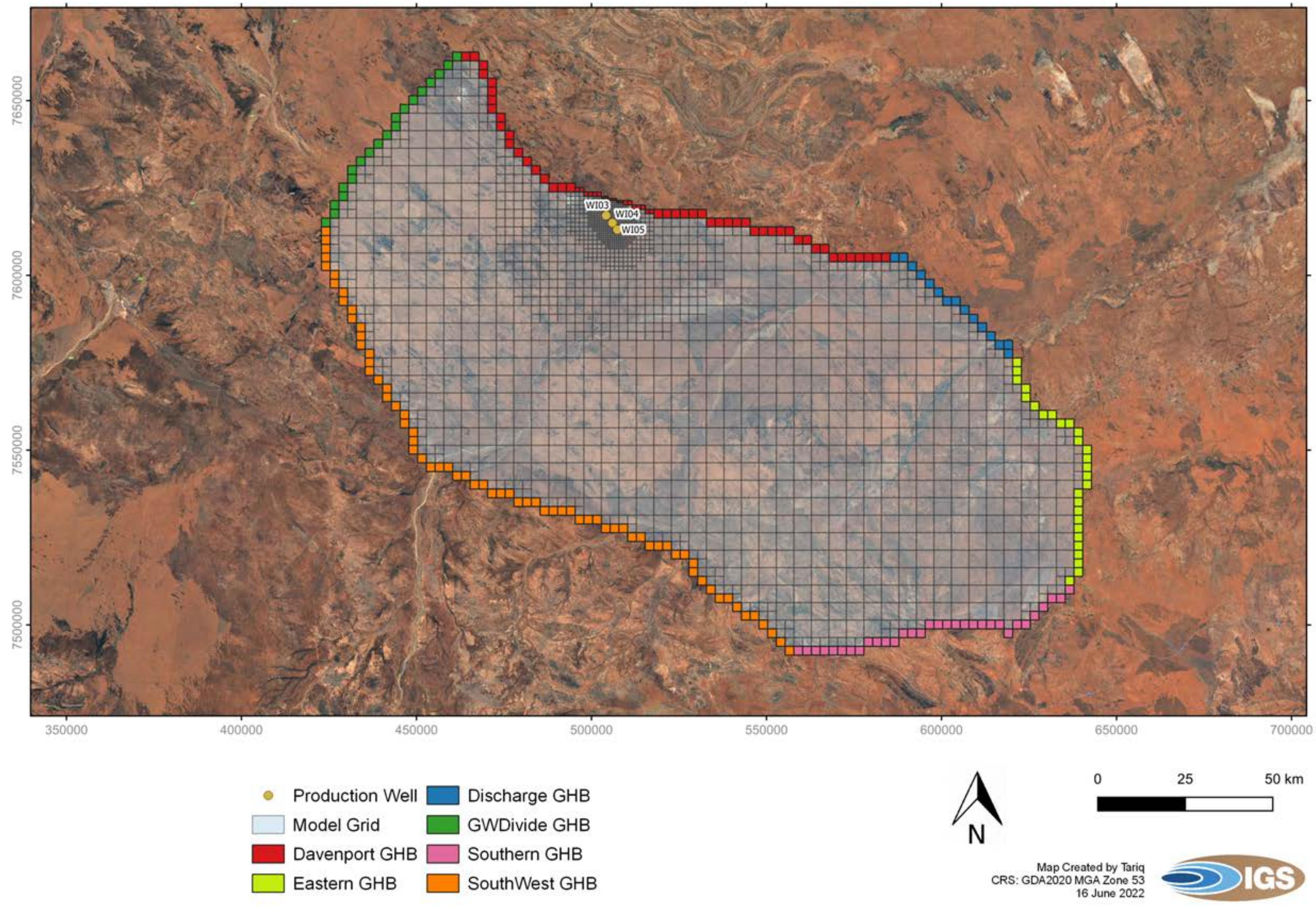



Figure 6. Model design showing grid and boundary conditions.

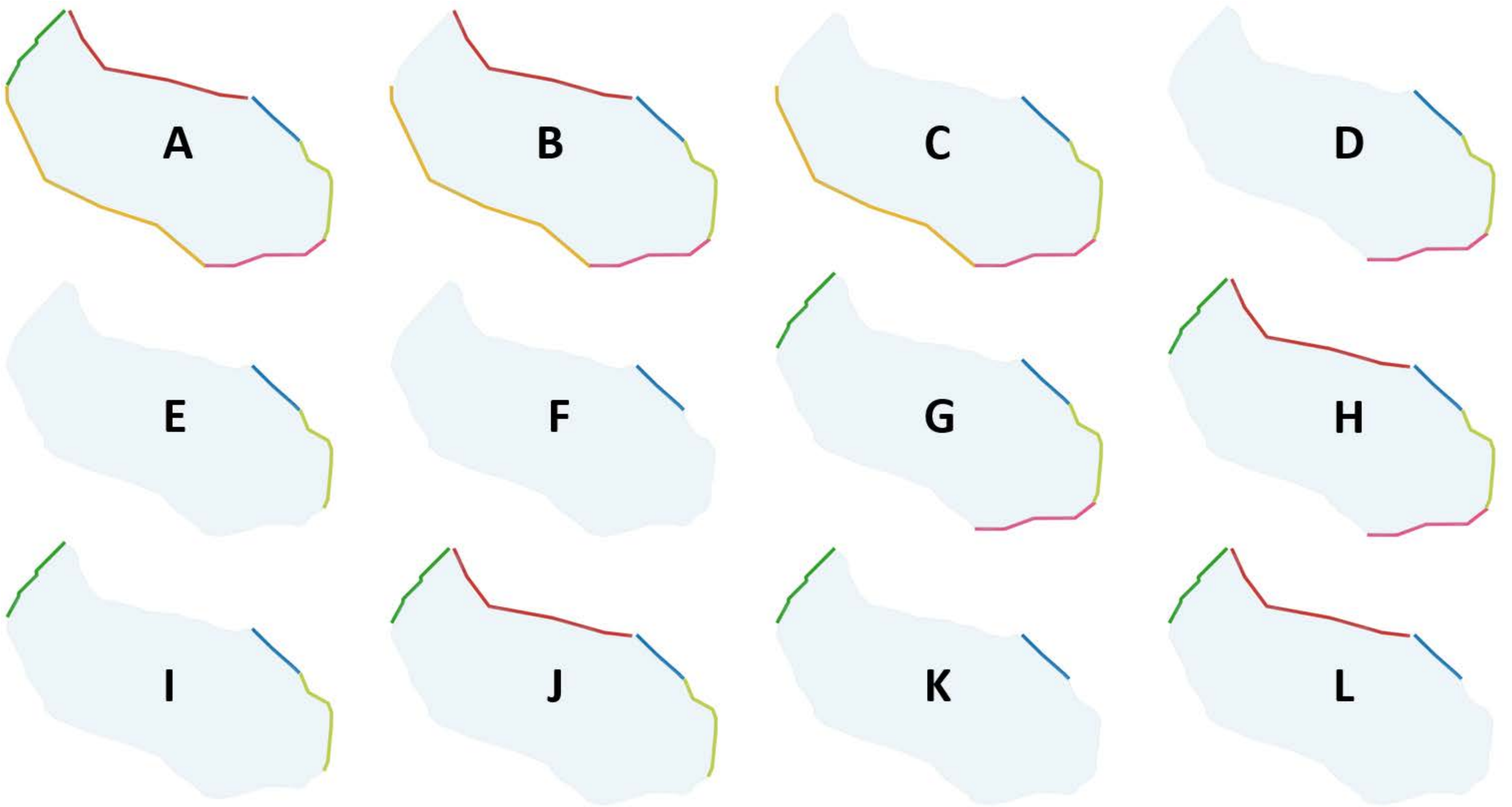



Figure 7. The 12 zero-flux boundary conceptualisations used in the ensemble development process. In each case the coloured segments were implemented as flux boundaries using GHB head and conductance parameters.

# 3. Numerical Model

## 3.1. Modelling Code

MODFLOW-6 version 6.2.2 (Langevin et al., 2017) was adopted for the current investigation using a quadtree refined grid created with Gridgen (Lien et al., 2015) - a grid generation utility. MODFLOW-6 was selected because it includes all commonly used features of previous MODFLOW versions and has new capabilities such as a full 3D hydraulic conductivity tensor, new solvers and support for adaptive time-stepping making it the default choice for the present study. The Python library, Flopy (Bakker et al., 2016) in combination with the open-source geographic information system QGIS (QGIS, 2022) were used to build the model and perform initial testing.

## 3.2. Design

Details of the model design include consideration for the ensemble conditioning methodology.

### 3.2.1. Model Grid

The model grid (Figure 6) consists of 2238 square cells with edge lengths refined to 156.25 m near production bores, 2.5 km along the external boundaries and 5.0 km in the central regions. Refinements are graded towards the extraction bores to improve accuracy where water table gradients are expected to be steep. For example, cells with edge length of 156.25 m are located within a 2.5 km radius around each production bore. Beyond that, and out to a radius of 5.0 km, model cells have 321.5 m edge lengths, followed by 625 m edges for the next 5 km until edge lengths reach 5 km. The model covers an area of approximately 15,000 km$^2$. A single model layer is used to represent the aquifer comprising both the Southern Georgina Basin Carbonates and the Dulcie Sandstone. The DEM and basement datasets were used to assign top and bottom elevations to all model cells.

### 3.2.2. External Boundaries

The carbonate aquifer hosting the production bores is known to increase in thickness to more than 420 m (GWS, 2017) towards the south and reduce in thickness towards the north. The borefield is located close to (i.e., within 3 km of) the northern contact with the metasediments of the Tennant Creek Inlier where the saturated thickness is reduced. The carbonate aquifer contact with the Tennant Creek Inlier also forms the northern external boundary of the model domain. A groundwater flow divide between the Wiso Basin and the Georgina Basin forms a hydraulic external boundary to the northwest, while the southern boundary coincides with the Arunta Complex. The south-eastern boundaries are set remotely to ensure minimal influence on the solution for both the conditioned and forecasting models.

Head controlled flux boundaries or general head boundaries (GHB) are assigned to all external model boundary cells. An interpolated potentiometric surface was used to assign the preferred values for the hydraulic head at each GHB cell and these were permitted to vary by +/- 2.5 m during conditioning. The boundaries were provided names associated with their location (Figure 6) and are also used to test different system conceptualisation by enforcing no-flow conditions as described in Section 2.3.

Cell size is variable along the northern Davenport GHB because of grid refinements near the production bores. Cell thickness is also variable being assigned as the difference between the DEM and the basement elevation (Figure 8). Both cell size and thickness affect the appropriate range for conductance values that can be assigned to the cells during conditioning. This was mitigated somewhat by dividing the estimated value for cell conductance by its thickness prior to entry in the model input file. A common upper and lower bound for conductance at all cells was then made possible.

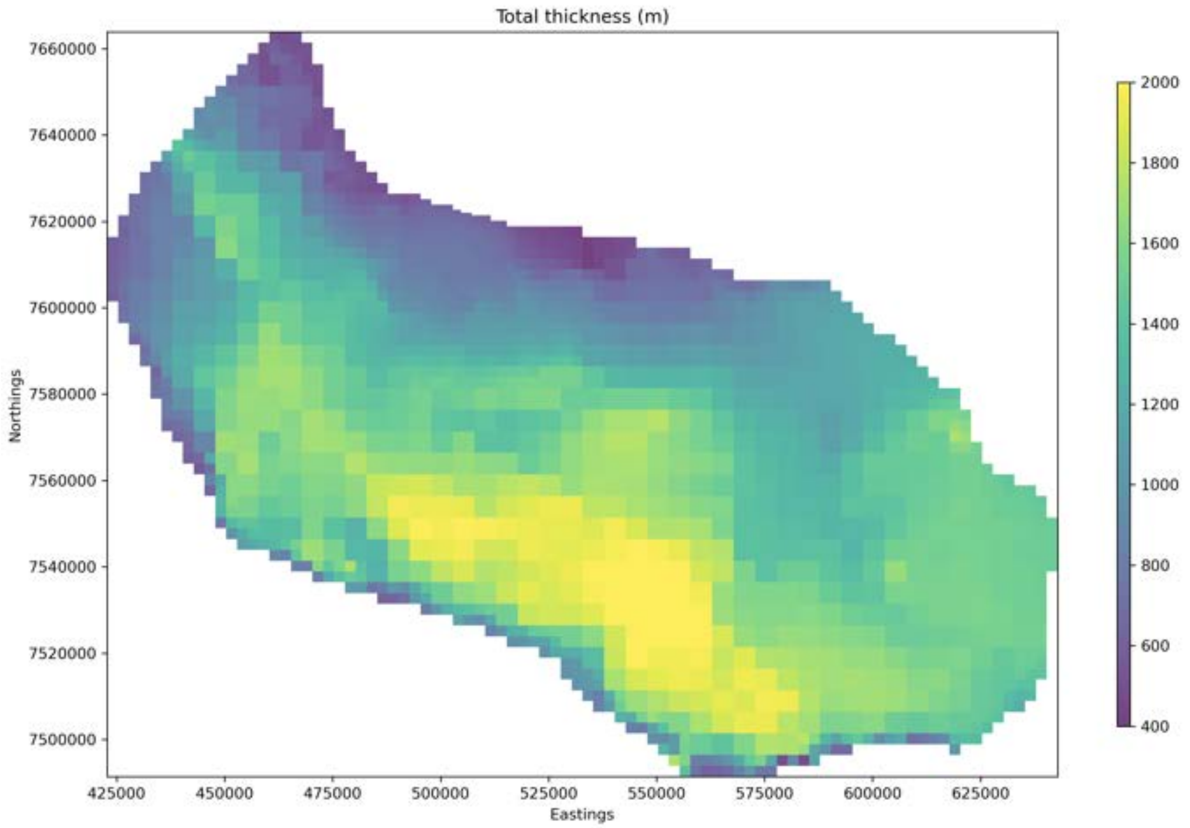



Figure 8. Model thickness obtained by subtracting the basement elevation from the DEM.

### 3.2.3. Internal boundaries

There are no known hydrogeologic features that warrant inclusion by internal boundary conditions. Ephemeral creeks are a potential source of localised episodic recharge, but flows are inconsistent. Localised recharge is nevertheless explored implicitly through pilot-point parametrisation during conditioning of the ensemble and is included in the uncertainty analysis.

### 3.2.4. Sinks

Production bores represent the only sinks in the system and are implemented via the Well Package in MODFLOW-6. Three bores are simulated with the total extraction rate of 8.5 GL/yr. spread evenly between them equating to 7.76 ML/d from each bore. Use of a single model layer negates consideration for well screen depths or intervals. It is acknowledged that the borefield may consist of a greater number of physical extraction locations but nevertheless proximal to one another. As a consequence, the overall stress on the system can be adequately captured by any number of simulated bores provided they are located in the area designated as the bore field.

#### 3.2.5. Recharge and Evapotranspiration

Recharge was simulated with the Recharge Package in MODFLOW-6 using external arrays. Spatial variability in recharge rate was accounted for through model parameterisation and explored as part of the uncertainty analysis. The plausible range of values for recharge were discussed in Section 2.1 (between 0.2 mm/yr. and 2.0 mm/yr.) and presented in Table 1.

The depth to water table across the entire model domain (i.e. well beyond a value of 10-15 m commonly used to infer potential terrestrial GDEs) precludes simulation of evapotranspiration.

#### 3.2.6. Temporal discretisation

A model featuring a single steady-state stress period was used for ensemble development then a second model with an initial steady-state stress period followed by yearly stress periods covering 100 years was used with the forecasting ensemble. Monthly time steps were used during the transient simulations.

#### 3.2.7. Solver settings and model speed

The “COMPLEX” model solver settings in MODFLOW-6 were used with both the conditioning and forecast models. Convergence criteria for hydraulic heads was set at 0.001 m. Execution time for the conditioning model was between 1 and 3 seconds and between 1.0 and 1.5 minutes for the forecast model.

### 3.3. Ensemble development

#### 3.3.1. Parameterisation

The parameterisation strategy was tailored for use with the PEST (Doherty 2021a) and PESTPP (White, 2020) suite of utilities. Consequently, pilot-points were used to condition aquifer property and recharge heterogeneity, while the SEGLIST feature of PLPROC (Doherty, 2022) was used to assess plausible variation in flux at external boundaries. Pilot points were assigned as a regular grid with 10 km spacing and SEGLIST vertices were spaced 10 km apart along each boundary (Figure 9).

Ordinary Kriging was used to interpolate estimated values at pilot points to the model grid. Spatial correlation between pilot-points was managed with covariance matrices created with MKPPSTAT and PPCOV_SVA (Doherty, 2021b) utilities. The sills in the pilot-point statistical specification files were manually adjusted to the relevant variances of the parameters in the control file. The range of hydraulic head permitted at each SEGLIST vertex was the value obtained from the potentiometric surface +/- 2.5 m. The remaining parameter value ranges are presented in Table 1. An uncertainty file was then created comprising the spatial parameter covariance matrices and standard deviations for SEGLIST vertices hydraulic heads and conductances.

### 3.3.2. Conditioning

The observation dataset used for conditioning each conceptual model ensemble consists of 50 steady-state head measurements and is presented in APPENDIX A. The observation dataset precludes processing because it comprises only steady-state hydraulic heads and simulation of a single layer. Consideration was given to using gradients (spatial differencing) as observations but these were found to increase the number of conflicting observations in the prior ensemble for each conceptual model.

The iterative ensemble smoother PESTPP-IES (White, 2018) was used to condition an ensemble of 100 models for each of the 12 system-boundary conceptualisations. The number of model realisations exceeds the number of solution space dimensions. A maximum of four smoothing iterations were permitted with ensembles showing little improvement to the mean objective function after three iterations. Prior data conflicts were dropped from the observation datasets. These differed in each conceptual model's ensemble making a direct comparison of the mean objective functions between the different ensembles somewhat problematic. However, this was limited to only one or two observations in each case.

The scaled root mean squared error (SRMS) for each model realisation, in each ensemble, was then determined and only those models with an SRMS of <10% were retained and used for the forecast simulations. It is worth noting that use of SRMS as a rejection criterion in this instance may yet allow models with sub-optimal fit to the observation dataset because the scaled range is more than 100 m.

## 3.4. FORECASTING

The complete forecast ensemble was executed using the parallel model running utility PESTPP-SWP (White, 2020). Yearly drawdown observations at Hagen's Bore and the Ampilatwatja Community borefield (Figure 10) were recorded during each forecast simulation. The change in flux across the WDWCD boundary (Figure 10) was recorded using ZONEBUDGET for MODFLOW 6 (Langevin et al., 2017), which is included in the MODFOW-6 suite. Here, model cells to the north-west of the WDWCD boundary were flagged as a different zone and the combined flux, between model cells across that boundary, on the last day of each yearly stress period, was then recorded for each forecast simulation. Forecast simulations were performed for both the 25-year and 40-year borefield operation scenarios, with subsequent groundwater recovery post mine closure out to 100 years.

An assessment of forecast sensitivity to parameters was then made using the 25-year pumping scenario with PESTPP-SEN (White et al., 2020) configured for Method of Sobol (Sobol, 2001). Parameters were tied to form groups making aquifer properties homogenous and GHB properties consistent along their entire length. Each parameter was then sampled 40 times assuming a uniform distribution between their upper and lower bounds requiring a total of 1360 model runs to complete the analysis. This approach yields a comprehensive exploration of the drawdown forecast across parameter space from which parameter sensitivity is calculated.

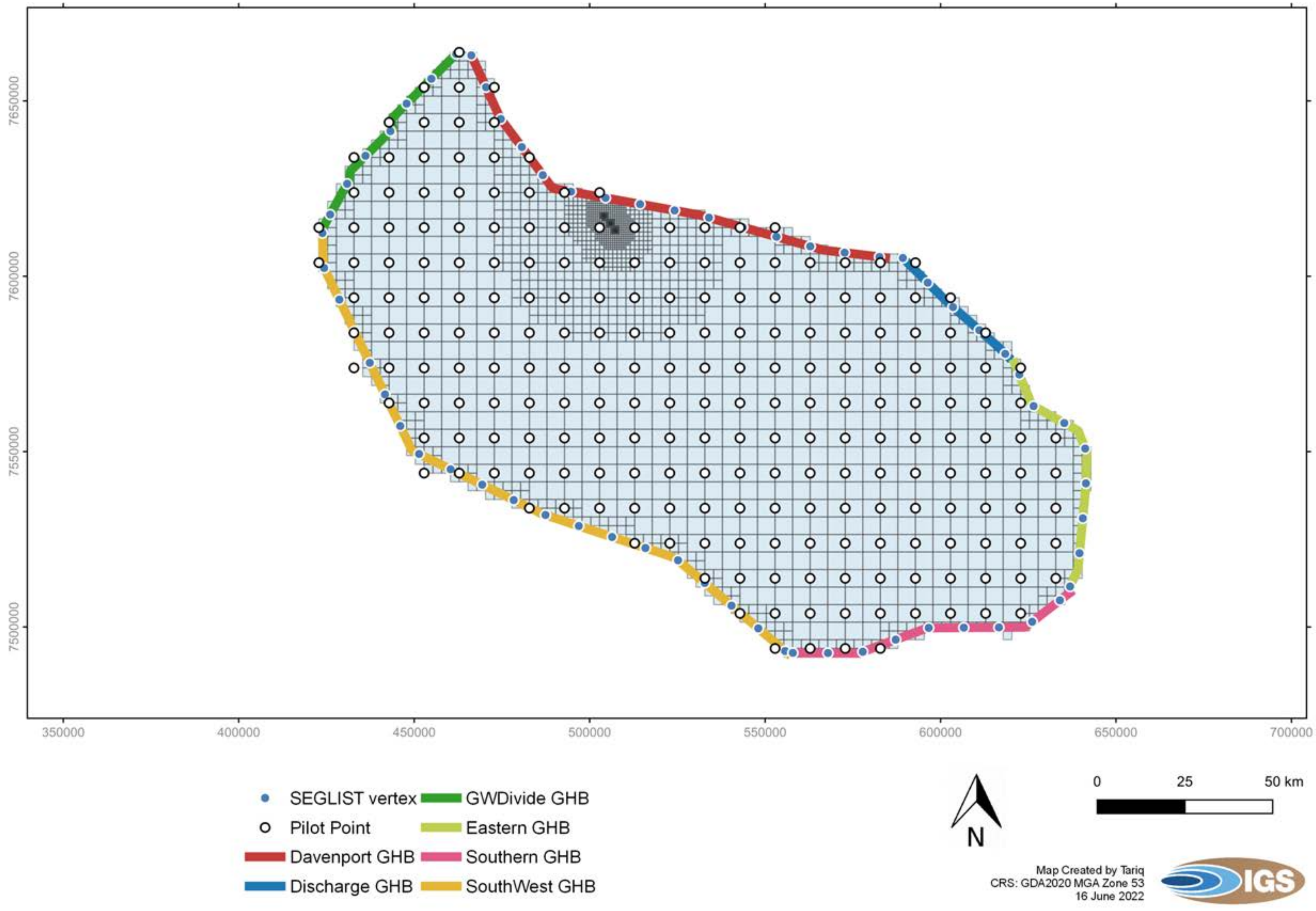



Figure 9. Pilot point and SEGLIST parameterisation.


Figure 10. Forecast ensemble monitoring locations Hagen's Bore, Ampilatwatja Community Borefield and the WDWCD boundary.

# 4. Results

### 4.1.1. Conditioning results

Box plots demonstrating the range of model-to-measurement misfit at each observation location (displayed on the x-axis) were produced for every conceptual model ensemble. For brevity, only a selection is provided here in the body of the report (Figure 11 and Figure 12) with the remainder in APPENDIX B. A histogram of the SRMS for all model realisations within each ensemble is also provided. Only histograms related to the box plots shown here in the body of the report are presented below (Figure 13 to Figure 16) with the remainder in APPENDIX C. The box in the box plots indicates the mean (centre line of box) and quartiles (upper and lower box bounds) while the whiskers show the range of values. Points beyond the whiskers are considered outliers.

The box plots provide valuable insight into the groundwater flow system behaviour by demonstrating failure to deliver an acceptable fit with the observation dataset (shown as blue dots) when different no-flow boundaries are defined. For example, conceptual model A performed slightly worse than conceptual model B (Figure 11), despite having increased flexibility in boundary conditions to facilitate reducing model-to-measurement misfit. The difference appears minor but is highlighted when a comparison of the SRMS histograms (Figure 13 and Figure 14) is made. It is also noteworthy that the set of observations are different between the two ensembles due to prior data conflict, which may be the primary factor causing the difference.

Both conceptual models E and F show poor fits with the observation data (Figure 12), which appears correlated with lack of flexibility along their external boundaries. Their SRMS histograms show that almost all models have an SRMS > 10% (Figure 15 and Figure 16). This effectively eliminates these conceptual models from the final forecast ensemble where a threshold of SRMS < 10% was used as an accept-reject criterion. The histogram of the complete forecast ensemble that only includes those models with an SRMS < 10% is also presented (Figure 17). The total number of models remaining with SRMS < 10% was 946 with a majority having an SRMS < 6%.

Two examples of the heterogeneity in aquifer hydraulic conductivity within the forecast ensemble are provided in Figure 18. A logarithm (base 10) transform of the same hydraulic conductivity field is provided on the right to better demonstrate heterogeneity across order of magnitude scale. Examples of the heterogeneity in storage and recharge in the ensemble is shown in Figure 19. Recall that storage is randomly sampled during the conditioning process and that enhanced recharge may substitute for a lack of boundary flux in those conceptual models featuring multiple zero-flux external boundary conditions.

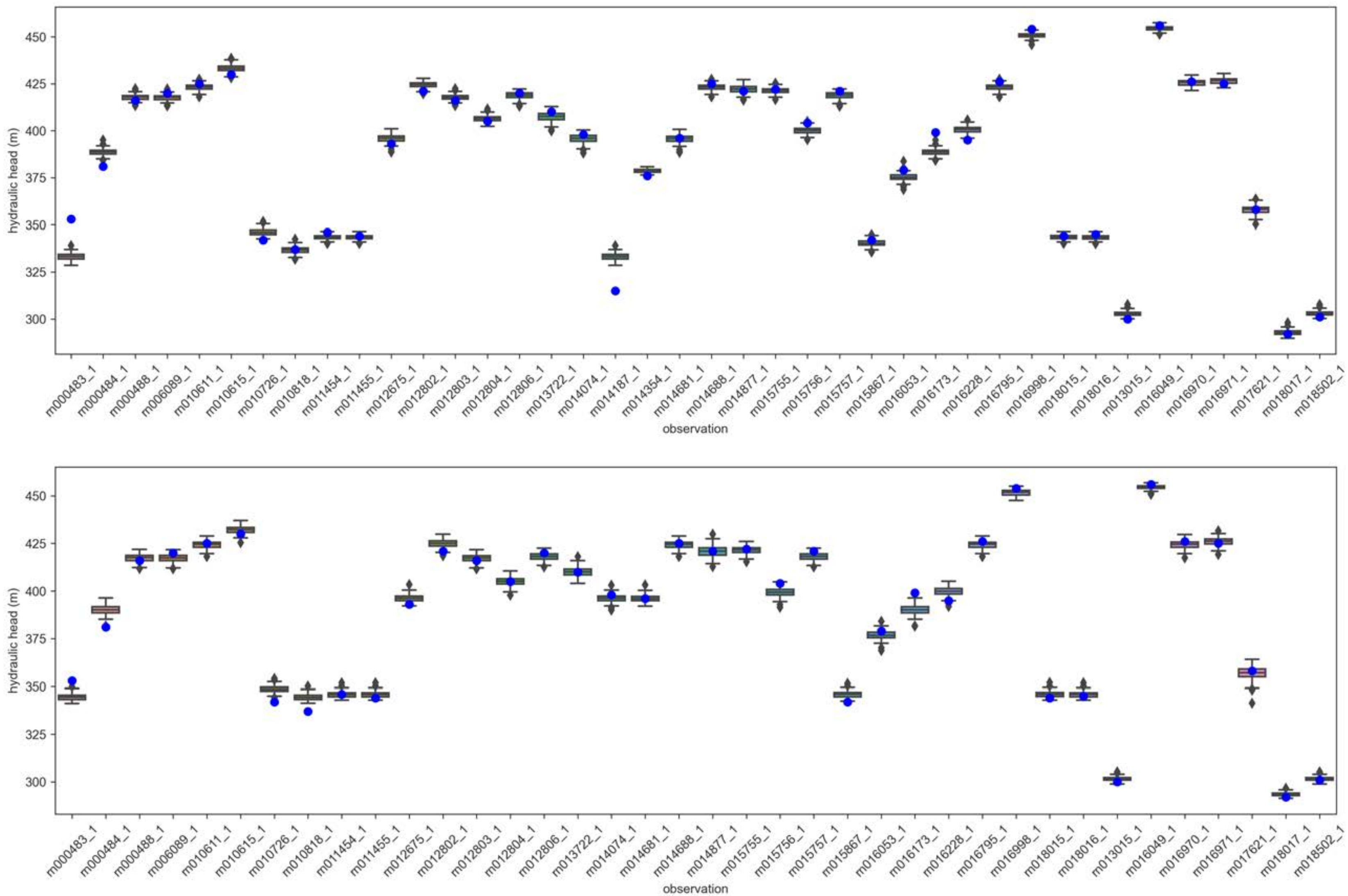



Figure 11. Box plots showing model-to-measurement misfit for conceptual model A (above) and conceptual model B (below).

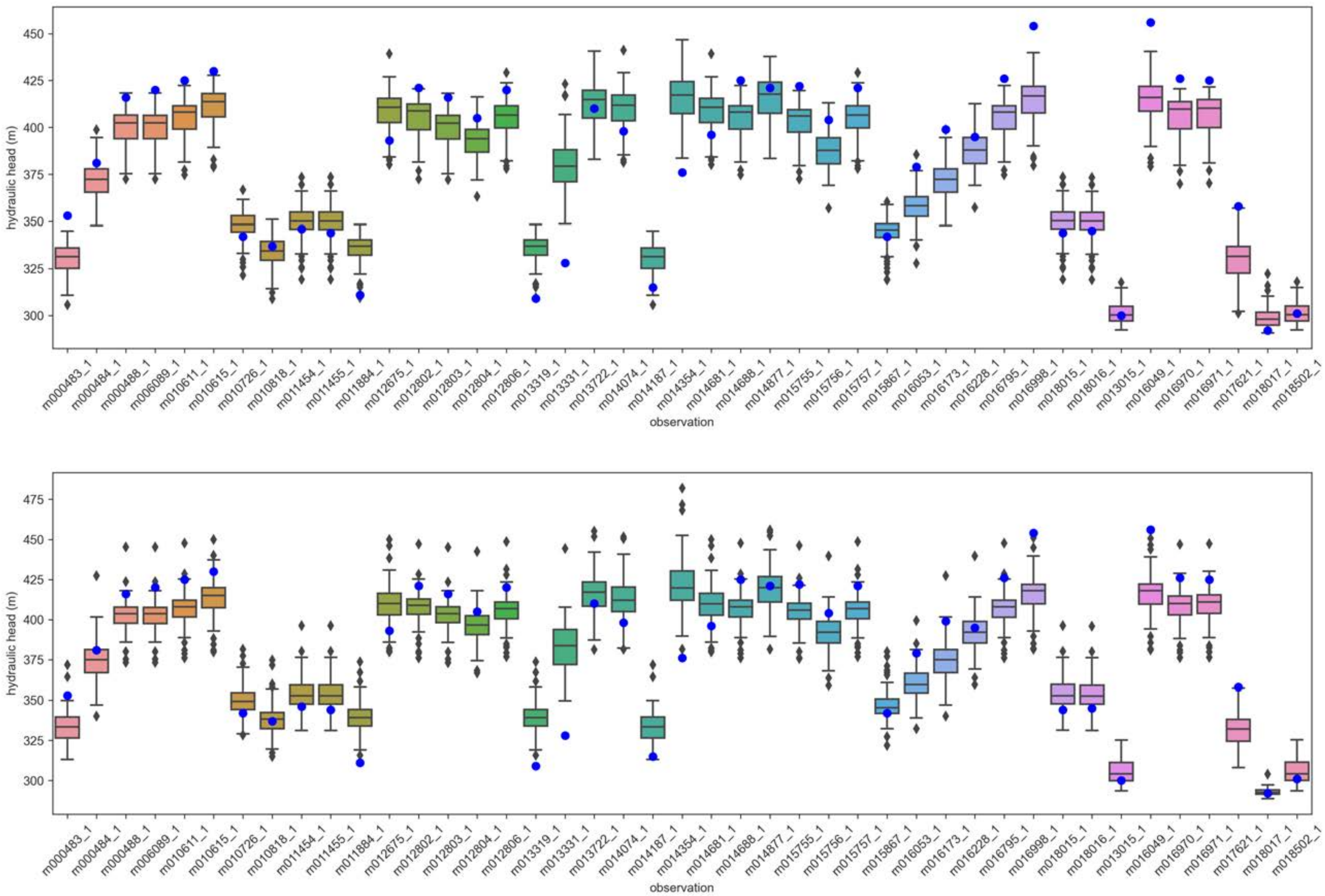



Figure 12. Box plots showing model-to-measurement misfit for conceptual model E (above) and conceptual model F (below)

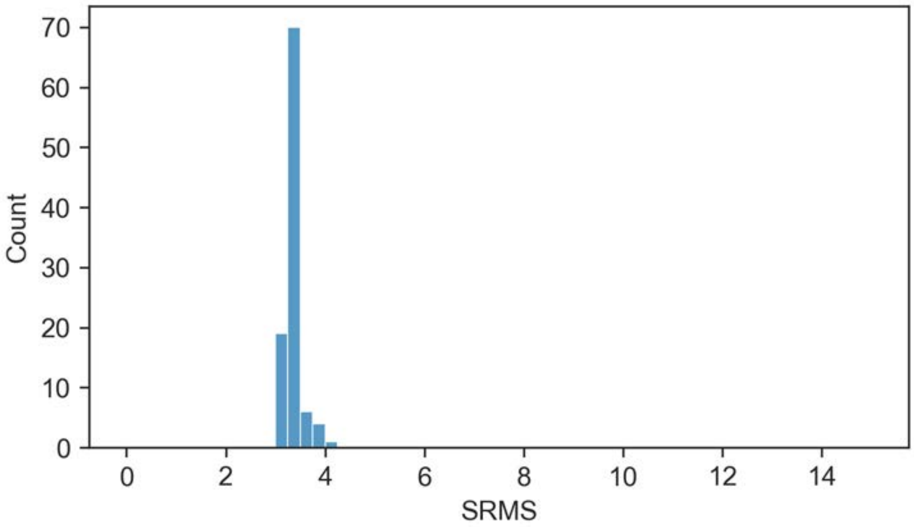



Figure 13. Conceptual model A SRMS (%) histogram.

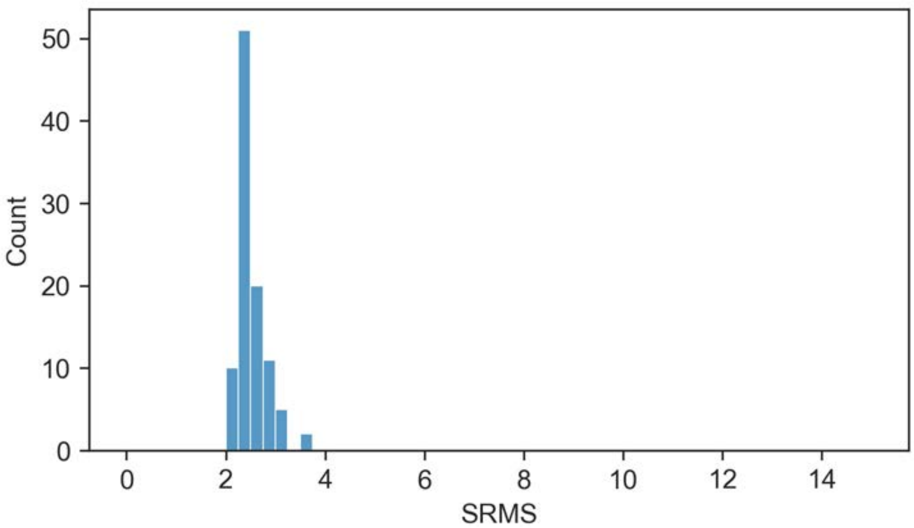



Figure 14. Conceptual model B SRMS (%) histogram.

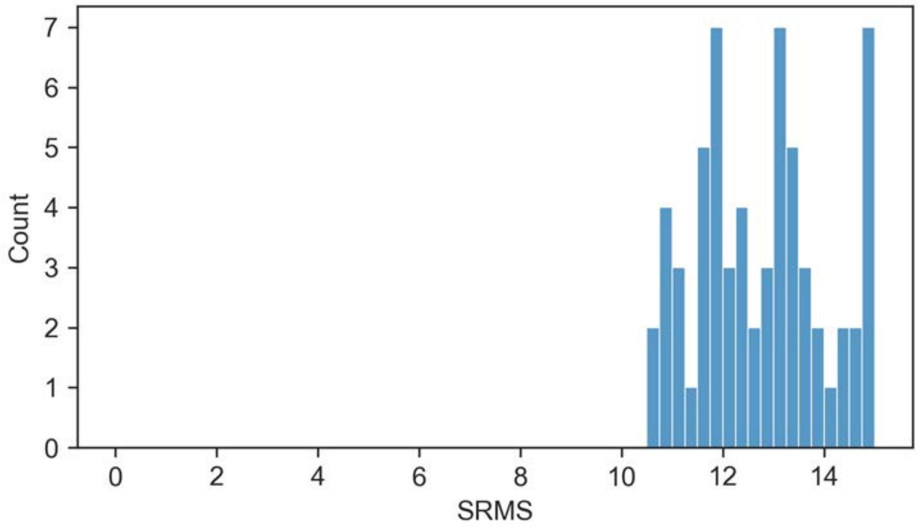



Figure 15. Conceptual model E SRMS (%) histogram.

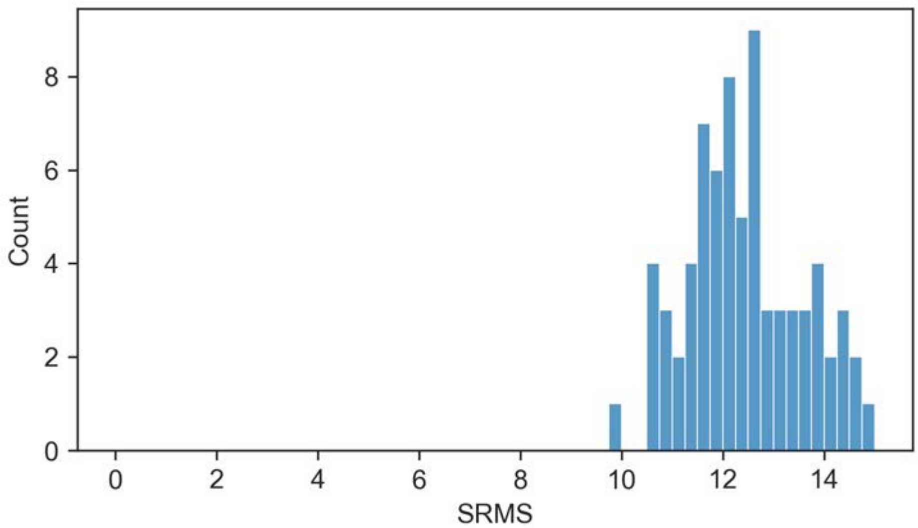



Figure 16. Conceptual model F SRMS (%) histogram.

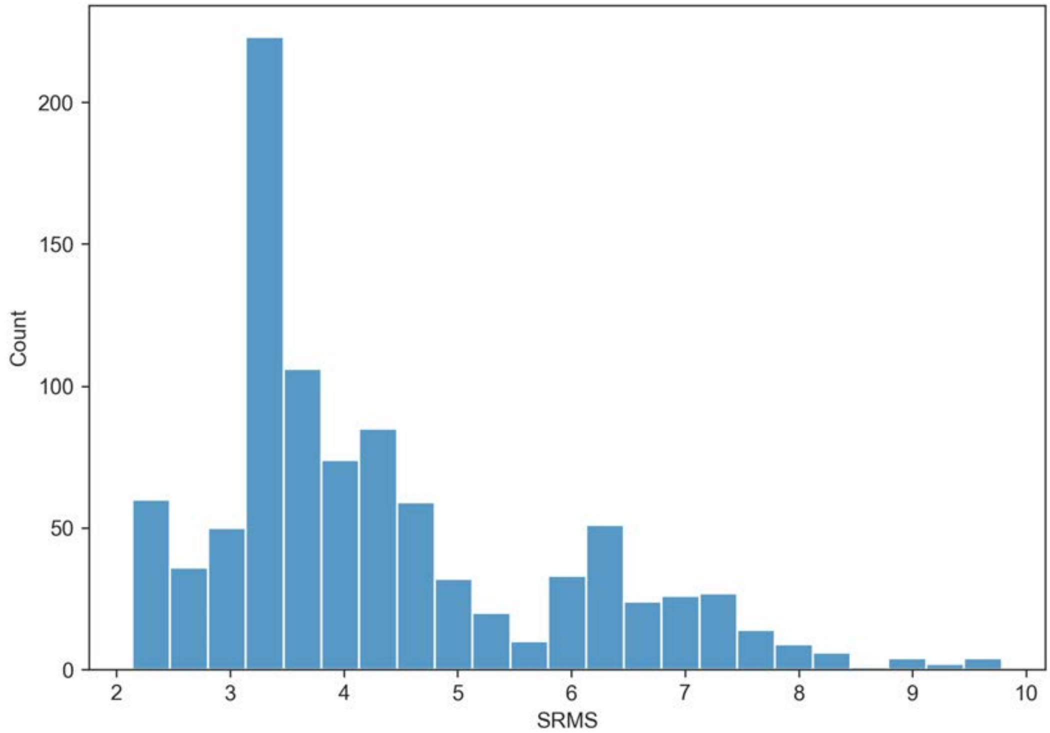



Figure 17. Forecast ensemble SRMS (%) histogram (n=946).

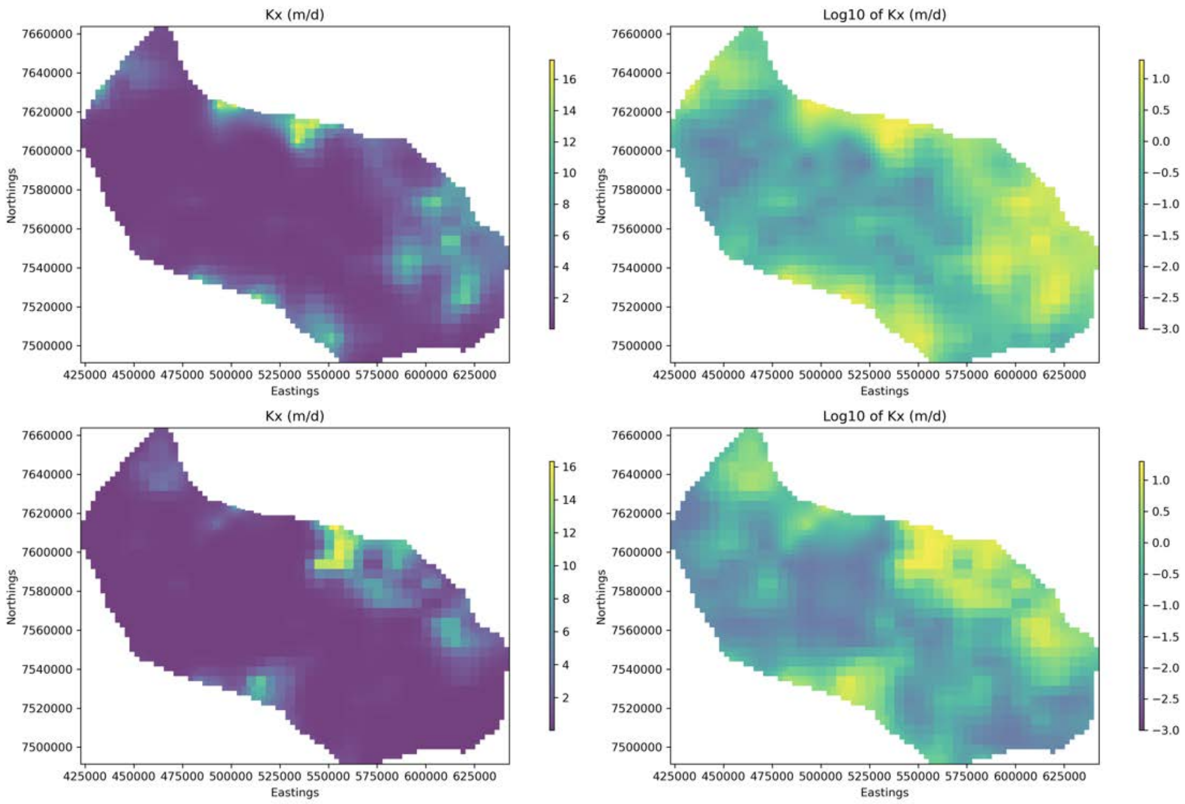



Figure 18. Two selected examples of hydraulic conductivity variability in the ensembles.

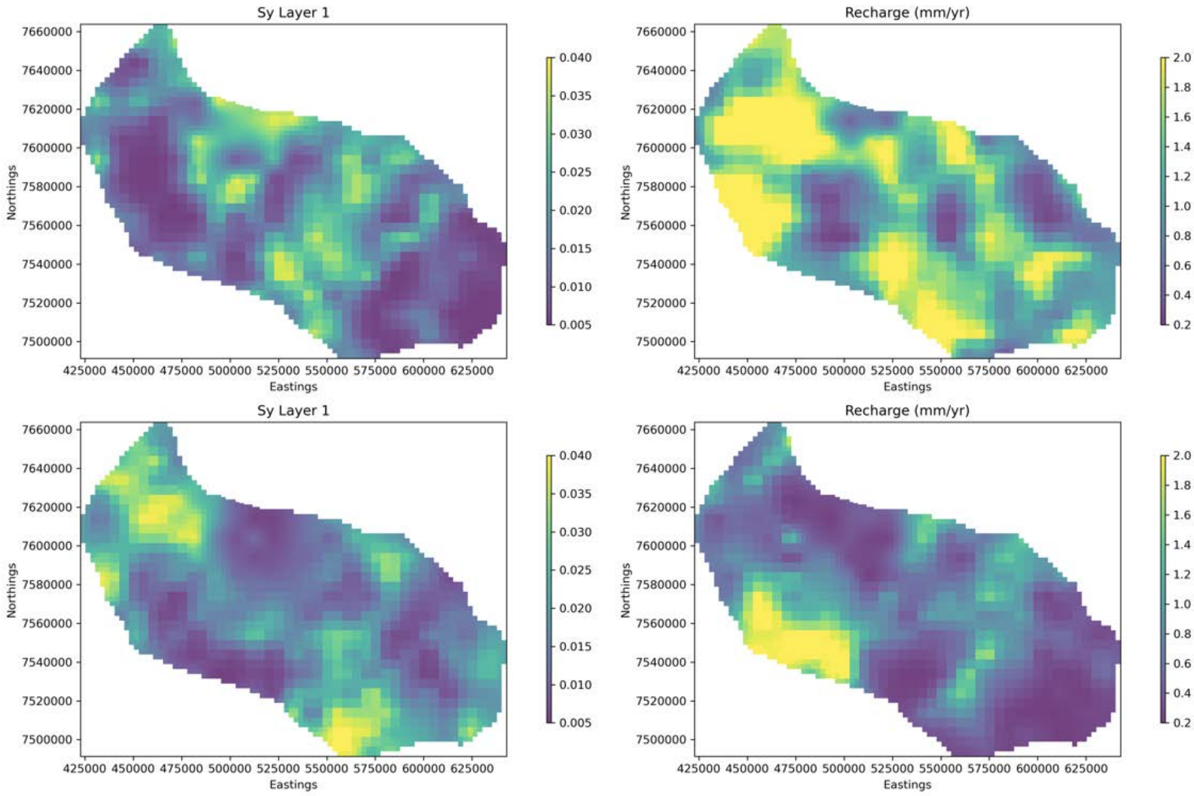



Figure 19. Two selected examples of variability in storage and recharge in the ensembles.

### 4.1.2. Forecast results for 25-year operation

Forecast results for the 25-year life of mine scenario are presented in this section and results for the 40-year life of mine scenario are presented in section 4.1.3. The simulation assumes mine operations start in the year 2022 and stop in 2047. Figure 20 shows all 946 simulated drawdown hydrographs for Hagen's Bore plotted as grey lines with the 90th, 50th and 10th percentile for peak drawdown identified by red, blue and green lines respectively. Recall that Hagen's Bore represents the closest identified sensitive receptor to the production borefield. The range of peak drawdown observed in the ensemble at Hagen's Bore is from 0.6 m to 10.5 m with peak timing occurring from year 2047 through to year 2090. Most of the model realisations with large peak drawdowns have the peak occurring earlier than those with smaller peaks. The peak drawdown for the 10th percentile (or P10) is 1.5 m occurring in 2076, for the 50th percentile (or P50) is 2.6 m occurring in year 2047, and for the 90th percentile (or P90) is 4.9 m also in the year 2047.

Drawdown at Ampilatwatja Community (Figure 21) is expected to be less than that forecast at Hagen's Bore because it is the furthest identified sensitive receptor to the production borefield. Here, the range of peak drawdown is from 0.06 m to 6.8 m with peak timing occurring from the year 2047 through to 2093. Like Hagen's Bore, the model realisations showing greater peak drawdowns tend to occur earlier than those with smaller peak drawdowns. Drawdown under the P10 realisation peaks at 0.4 m in 2056, the P50 realisation peaks at 0.9 m in 2047 and the P90 simulation peaks at 3.0 m in 2047.

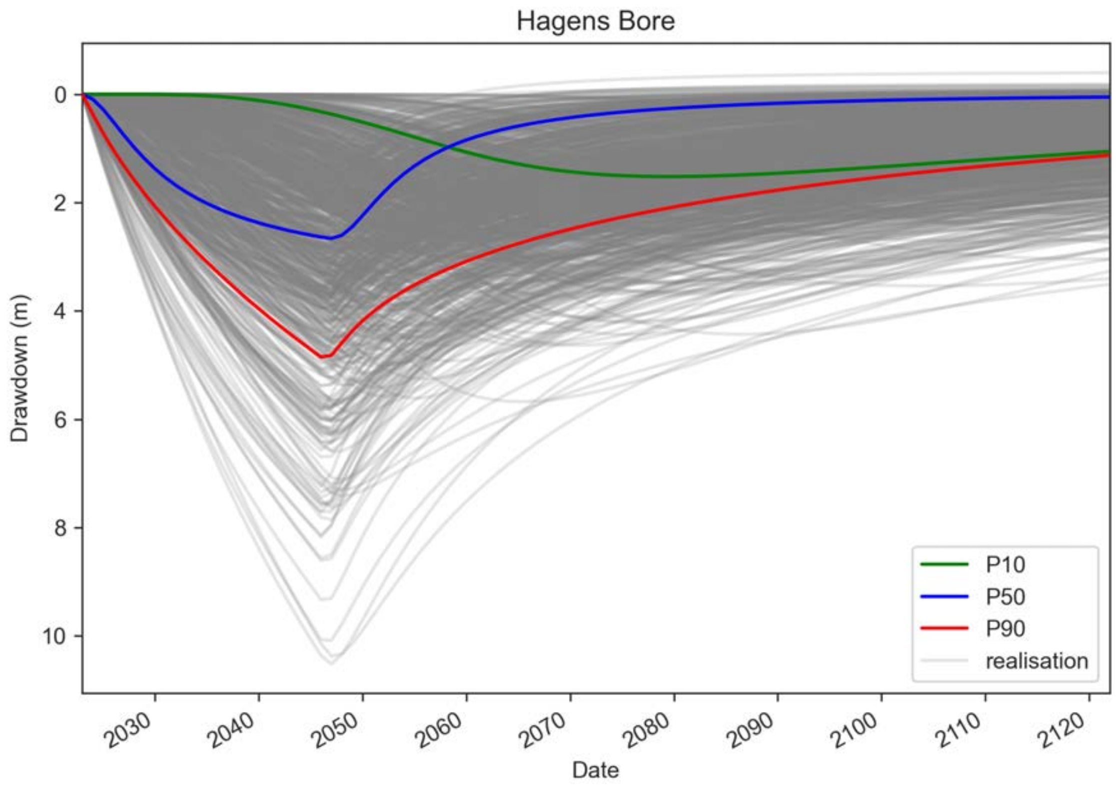



Figure 20. Simulated drawdown at Hagen's Bore with 25-year operation.

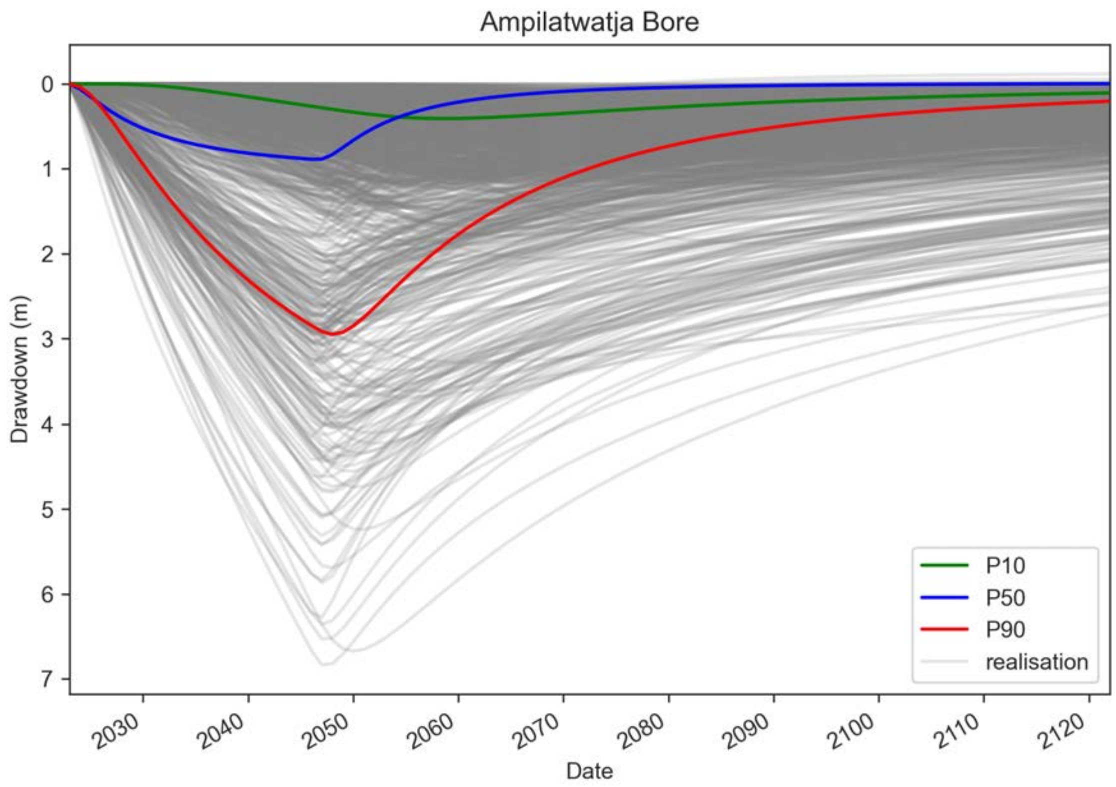



Figure 21. Simulated drawdown at Ampilatwatja Community borefield with 25-year operation.

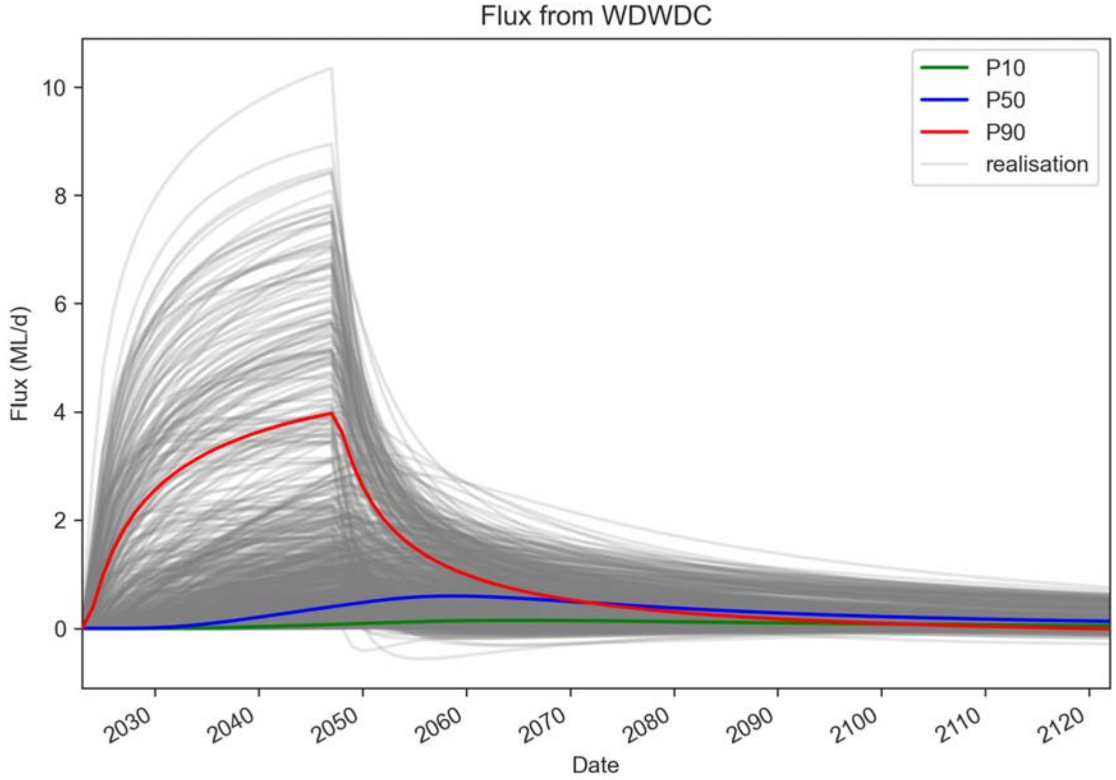



Figure 22. Change in flux from the WDWCD for the 25-year operation.

Each realisation in the forecast ensemble may produce slightly different hydraulic head gradients across the model in their starting stead-state stress period. The implication here is that the flux across the WDWCD boundary, prior to pumping, will be different in each simulation and makes a comparison of absolute flux across the WDWCD boundary problematic. The alternative is to examine change in flux across the WDWCB. The complete forecast ensemble of simulated change in flux from the WDWCD into the Southern Georgina Basin is shown in Figure 22. The peak changes range from a minimum of 0.04 ML/d to 10.3 ML/d occurring between the years 2048 and 2069. Akin to the drawdown observations, simulations showing larger changes to flux peak sooner than those with smaller changes. The P10 simulation shows a peak of 0.2 ML/d in the year 2062, the P50 shows a peak of 0.6 ML/d in the year 2057 and the P90 shows a peak of 4.0 ML/d in the year 2048. Table 2 provides a summary of the 25-year operation forecast ensemble percentiles.

Table 2. Summary table of forecast ensemble percentiles for 25-year operation.

| Forecast ensemble percentile | Peak drawdown (m) at Hagen's Bore | Peak drawdown (m) at Ampilatwatja Borefield | WDWCD peak flux (ML/d) change |
|---|---|---|---|
| P10 | 1.5 | 0.4 | 0.2 |
| P50 | 2.6 | 0.9 | 0.6 |
| P90 | 4.9 | 3.0 | 4.0 |

### 4.1.3. Forecast results for 40-year operation

Note that the total simulation time of 100 years is unchanged from the previous scenario, thereby limiting the simulation of groundwater recovery to 60 years post mine closure. Peak drawdown forecast at Hagen's Bore (Figure 23) ranges from 0.8 m to 14.6 m with peak timing occurring from year 2062 to beyond 2120. Again, most of the simulations with large peak drawdowns occur earlier than those with smaller peaks. The P10 peak is 2.0 m occurring in 2062, the P50 peak is 3.8 m in year 2063 and the P90 peak is 6.8 m also in the year 2063.

Ampilatwatja Community (Figure 24) shows a range of peak drawdown from 0.1 m to 9.8 m with peak timing occurring from the year 2062 to beyond 2120. Like Hagen's Bore, the simulations showing greater peak drawdowns tend to occur earlier than those with smaller peak drawdowns. The observed P10 simulation peaks at 0.6 m in 2120 (potentially increasing further), the P50 simulation peaks at 1.3 m in 2073 and the P90 simulation peaks at 4.2 m in 2063.

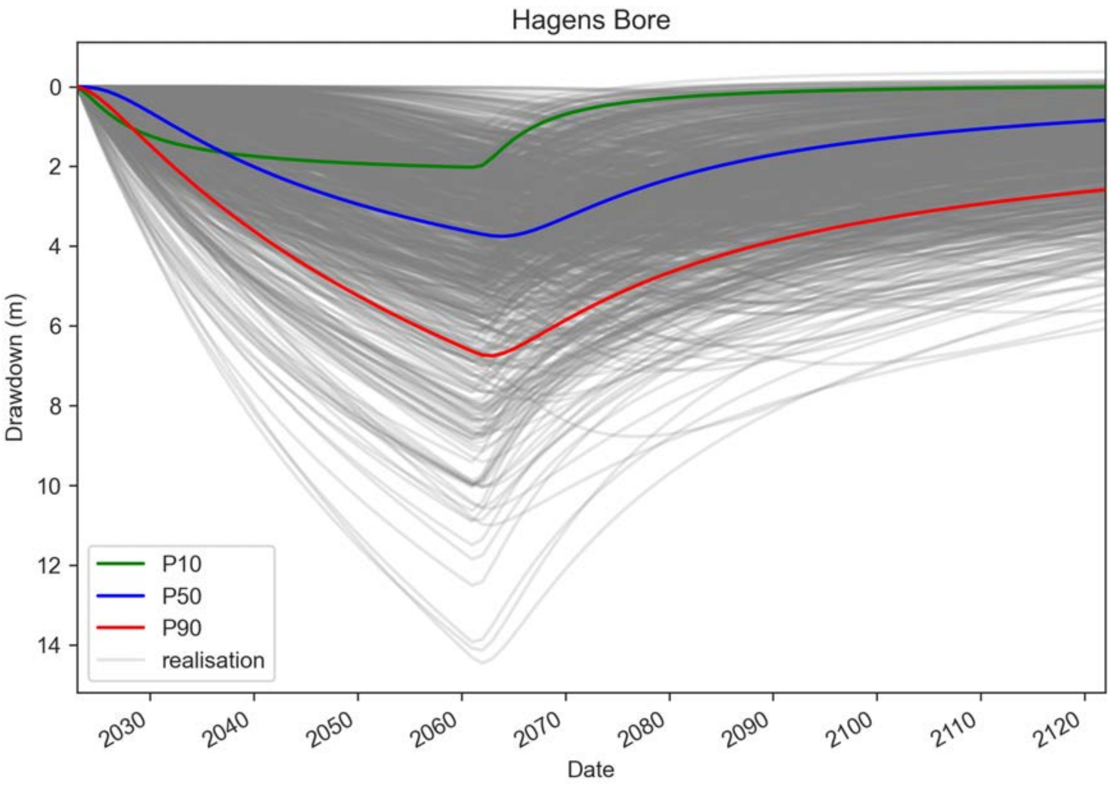



Figure 23. Simulated drawdown at Hagen's Bore with 40-year operation.

Change in flux from the WDWCD (Figure 25) shows peak changes ranging from a minimum of 0.06 ML/d to 11.0 ML/d occurring between the years 2062 and 2070. Here, the P10 simulation shows a peak of 0.2 ML/d in the year 2067, the P50 shows a peak of 0.8 ML/d also in the year 2067 and the P90 shows a peak of 4.4 ML/d in the year 2062. Table 3 provides a summary of the 40-year operation forecast ensemble percentiles and Table 4 lists the forecast range of each observation in terms of maximum and minimum peaks for both operation scenarios.

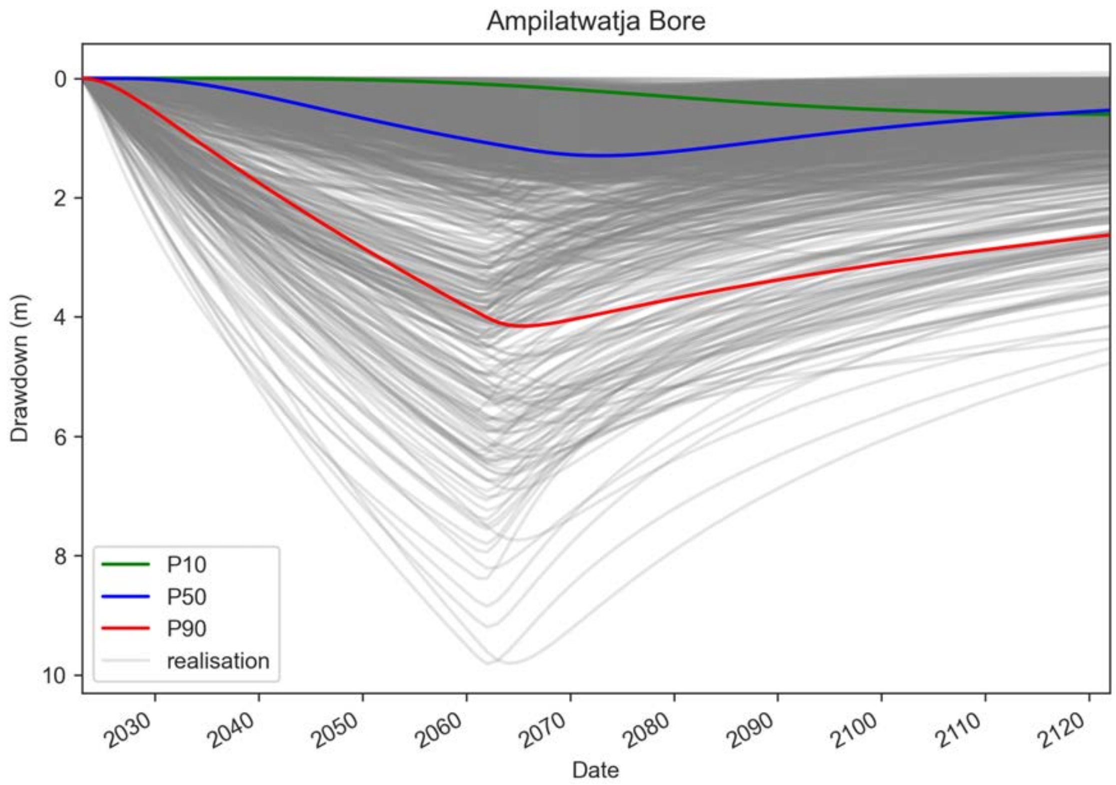



Figure 24. Simulated drawdown at Ampilatwatja Community borefield with 40-year operation.

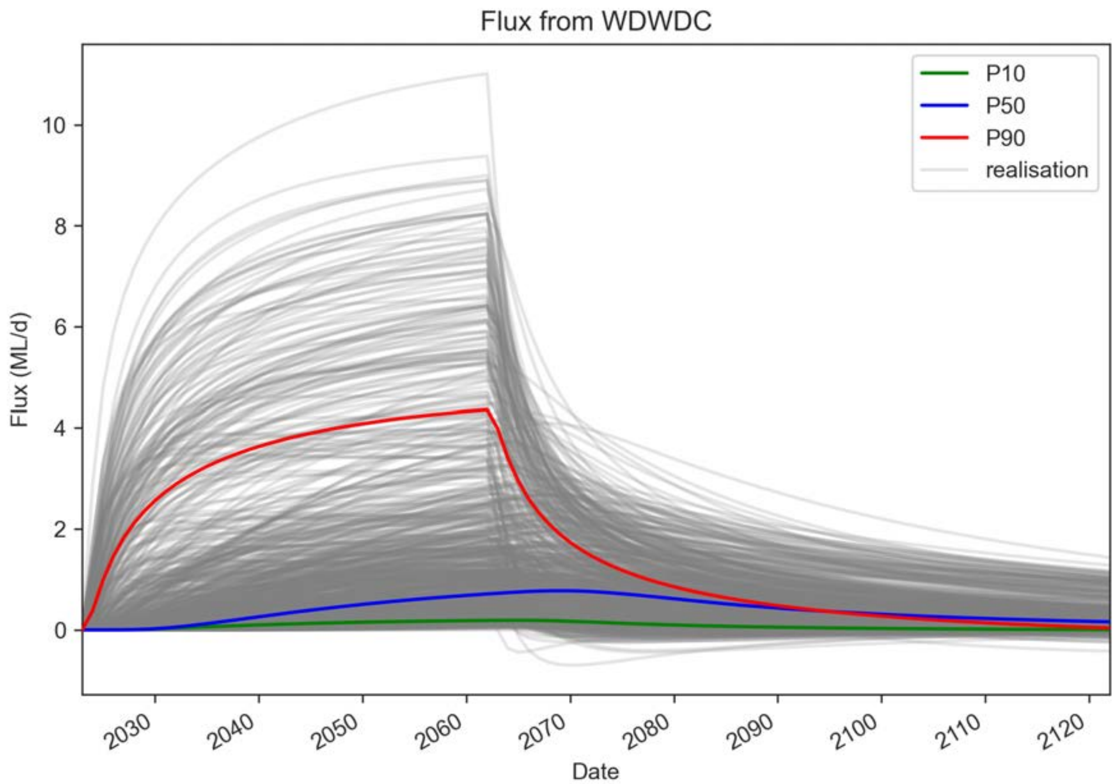



Figure 25. Change in flux from the WDWCD for the 40-year operation.

Table 3. Summary table of forecast ensemble percentiles for 40-year operation.

| Forecast ensemble percentile | Peak drawdown (m) at Hagen's Bore | Peak drawdown (m) at Ampilatwatja Borefield | WDWCD peak flux (ML/d) change |
|---|---|---|---|
| P10 | 2.0 | 0.6 | 0.2 |
| P50 | 3.8 | 1.3 | 0.8 |
| P90 | 6.8 | 4.2 | 4.4 |

Table 4. The forecast range for each observation under both operation scenarios.

| Extraction scenario (years) | Peak drawdown (m) range at Hagen's Bore | | Peak drawdown (m) range at Ampilatwatja Borefield | | WDWCD peak change in flux (ML/d) range | |
|---|---|---|---|---|---|---|
| | min | max | min | max | min | max |
| 25 | 0.6 | 10.5 | 0.06 | 6.8 | 0.04 | 10.3 |
| 40 | 0.8 | 14.6 | 0.1 | 9.8 | 0.06 | 11.0 |

#### 4.1.4. Forecast sensitivity

The Method of Sobol as it is implemented in PESTPP-SEN produces two sensitivity indices namely, first-order sensitivity and total sensitivity. First-order sensitivity reflects the parameter sensitivity to the forecast by itself while total sensitivity reflects the contributions of that parameter to the forecast in non-linear ways via its interaction with other parameters.

The parameter forecast sensitivity for drawdown are identical for the Ampilatwatja Community bore field and Hagan's Bore due to their proximity. Accordingly, forecast sensitivity metrics for both locations are presented in Figure 26 and Figure 27. Only the top seven parameters with the greatest forecast sensitivity are shown. Recall that these only reflect the sensitivity for the drawdown forecast at the end of pumping. Hydraulic conductivity, the conductance of the Davenport GHB, and recharge are prominent in both first-order and total sensitivity. The absence of specific yield in both plots may be due to the plausible range of values assigned. The South-west GHB is the longest external boundary in the model and it is therefore unsurprising that its total-sensitivity exceeds its first-order sensitivity.

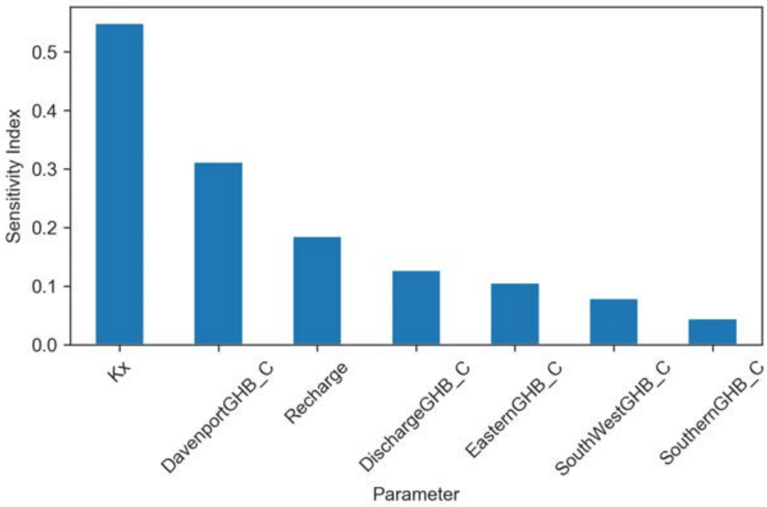



Figure 26. First-order sensitivity indices for drawdown forecast.

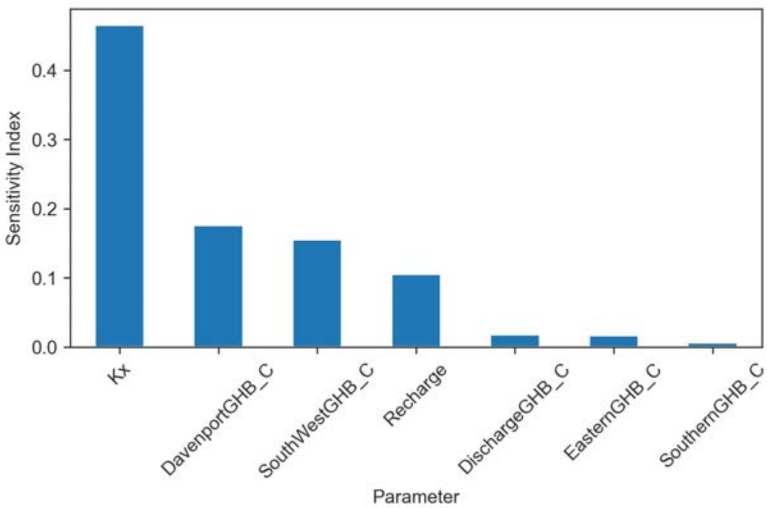



Figure 27. Total sensitivity indices for drawdown forecast.

The parameter forecast sensitivity for the WDWCD Flux at the end of pumping is displayed in Figure 28 and Figure 29. Hydraulic conductivity is overwhelmingly the most sensitive parameter with little to no influence from the other model features affecting the cross-boundary flux forecast individually. The total sensitivity plot (Figure 29) shows increased sensitivity for hydraulic conductivity in comparison to the first-order sensitivity (Figure 28). The south-west GHB and the Davenport GHB also show greater total sensitivity suggesting that the conductance assigned to those boundaries in combination with the hydraulic conductivity of the aquifer have the greatest influence on the flux from the WDWCD.

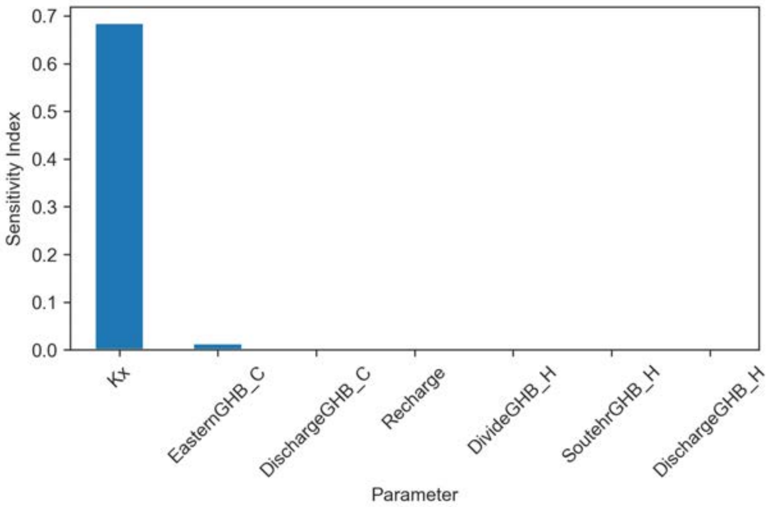



Figure 28. First-order sensitivity indices for WDWCD flux.

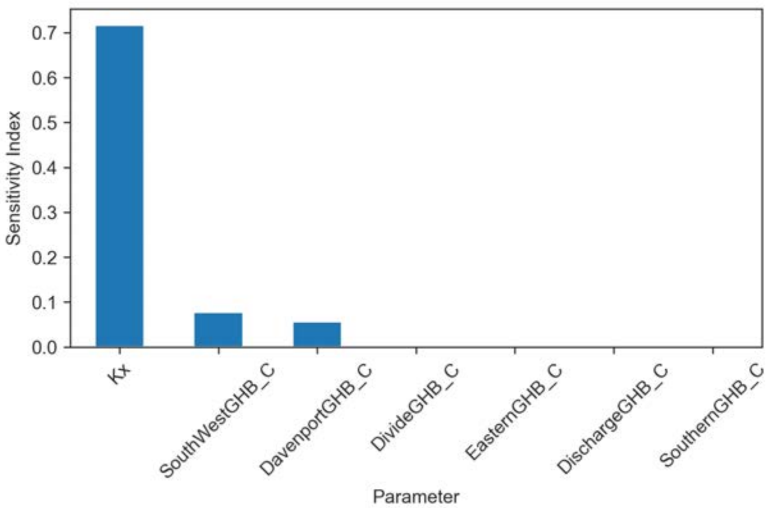



Figure 29. Total sensitivity indices for WDWCD flux.

### 4.1.5. Forecast drawdown contours for both operation scenarios

Figure 30 to Figure 35 show the spatial extent of drawdown at the end of borefield operation (i.e., 25 years or 40 years) for each of the WDWCD flux highlighted percentile simulations. That is, Figure 30, Figure 31 and Figure 32 correspond to the P10, P50 and P90 simulations in Figure 22 at the end of 25 years pumping. While, Figure 33, Figure 34 and Figure 35 correspond to the P10, P50 and P90 simulations in Figure 25 at the end of 40 years pumping. The same plots but focused on the production borefield are also provided in APPENDIX D. A 0.1 m contour is plotted as the marker for maximum drawdown extent with contours at 1.0 m and every 1.0 m thereafter to define steepness of the drawdown cone.

The plots show how the variability in aquifer property and boundary conditions affect the simulated drawdown. For the 25-year operating scenario, the sequence of P10, P50 and P90 plots show increasing drawdown extent with decreasing drawdown cone depth. If viewed in terms of the ratio between hydraulic conductivity and storage or hydraulic-diffusivity, high values of hydraulic-diffusivity (i.e., high hydraulic conductivity and low storage) results in increasing drawdown extent but reduced drawdown cone depth.

Figures showing depth to water table at the end of operation for the same simulations are provided in APPENDIX E. These are presented as colour floods instead of contours to improve clarity because of the confounding influence of variability in surface topography.

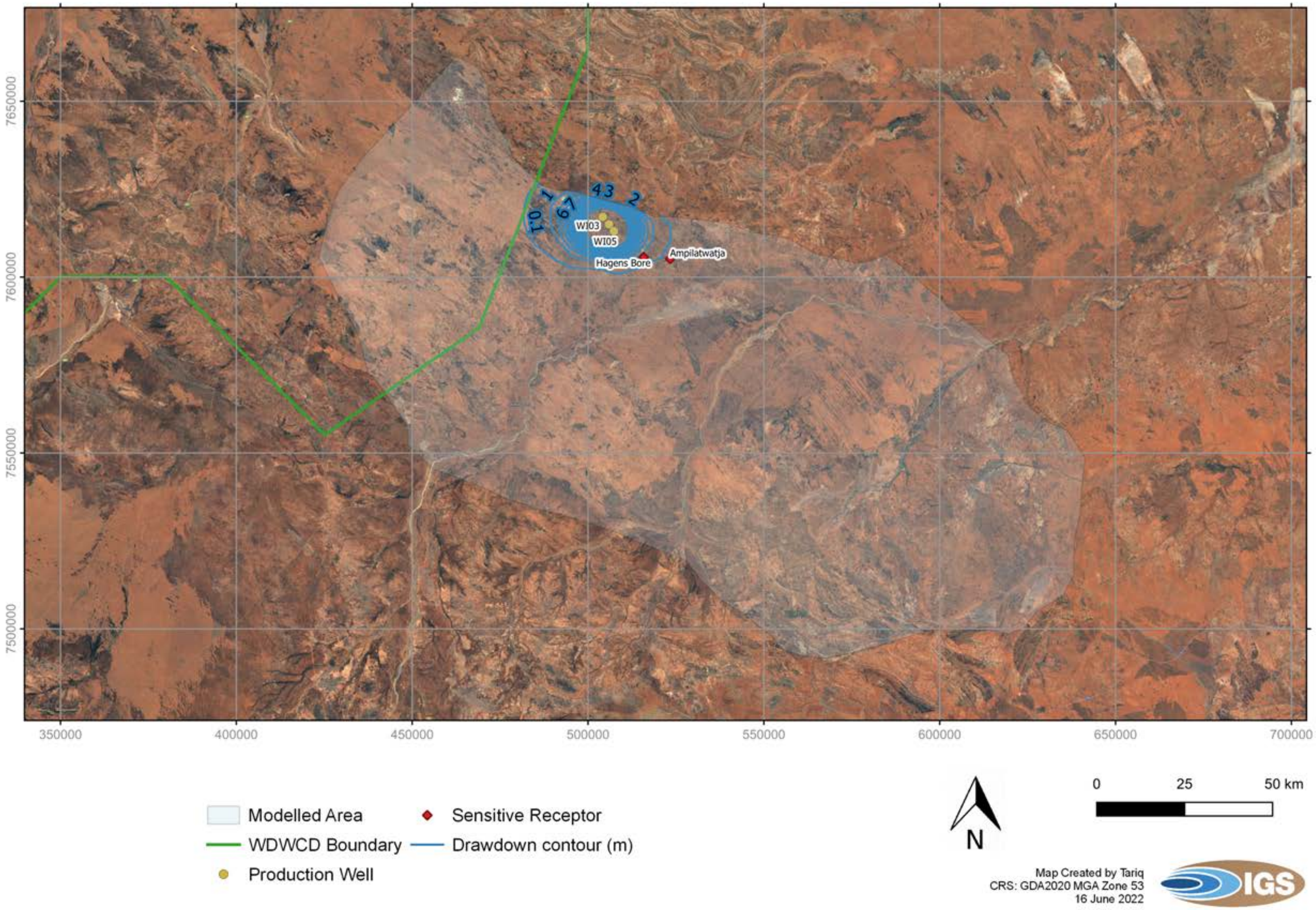



Figure 30. WDWCD flux P10 drawdown contours at the end of 25-year operation.

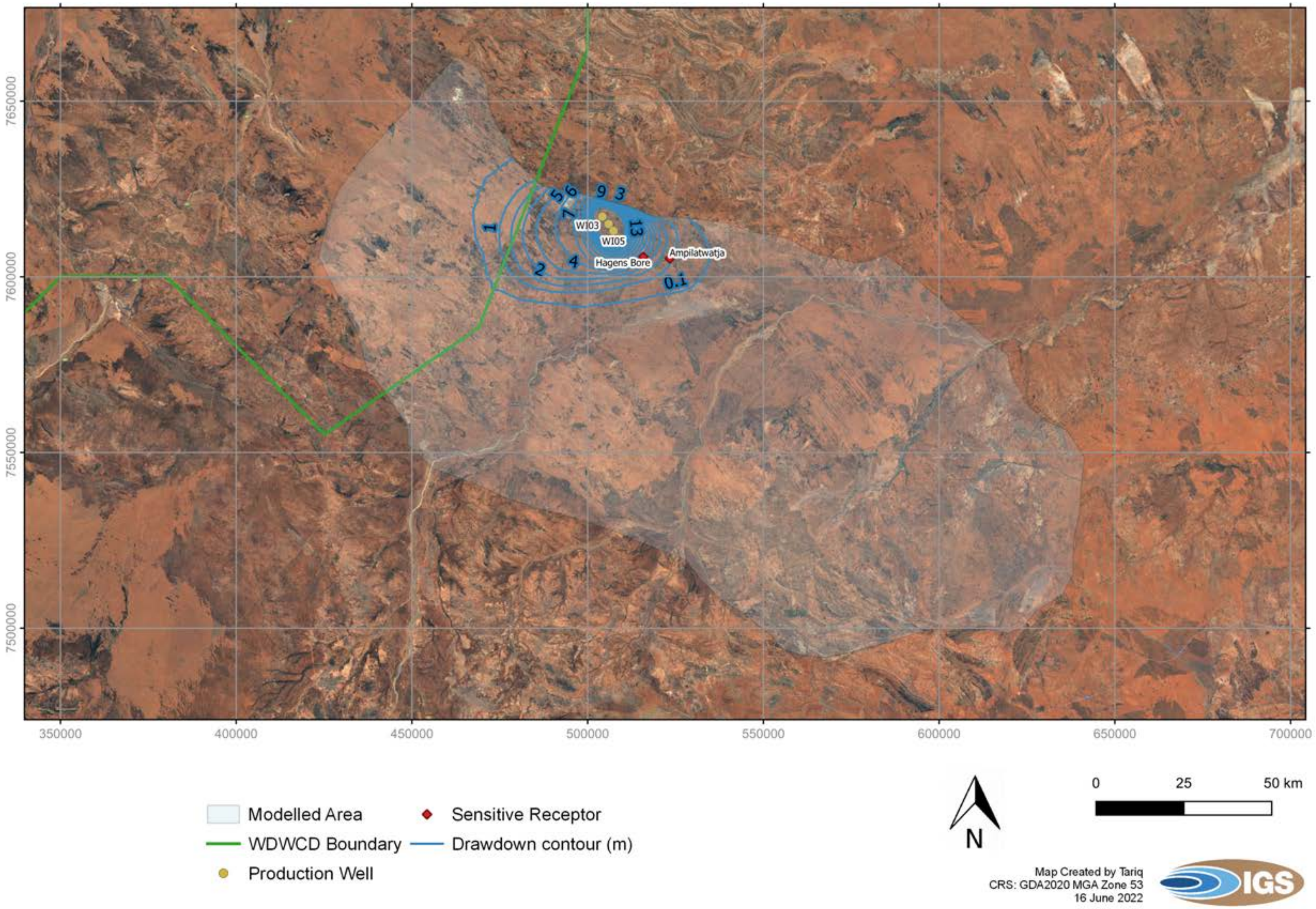



Figure 31. WDWCD flux P50 drawdown contours at the end of 25-year operation.

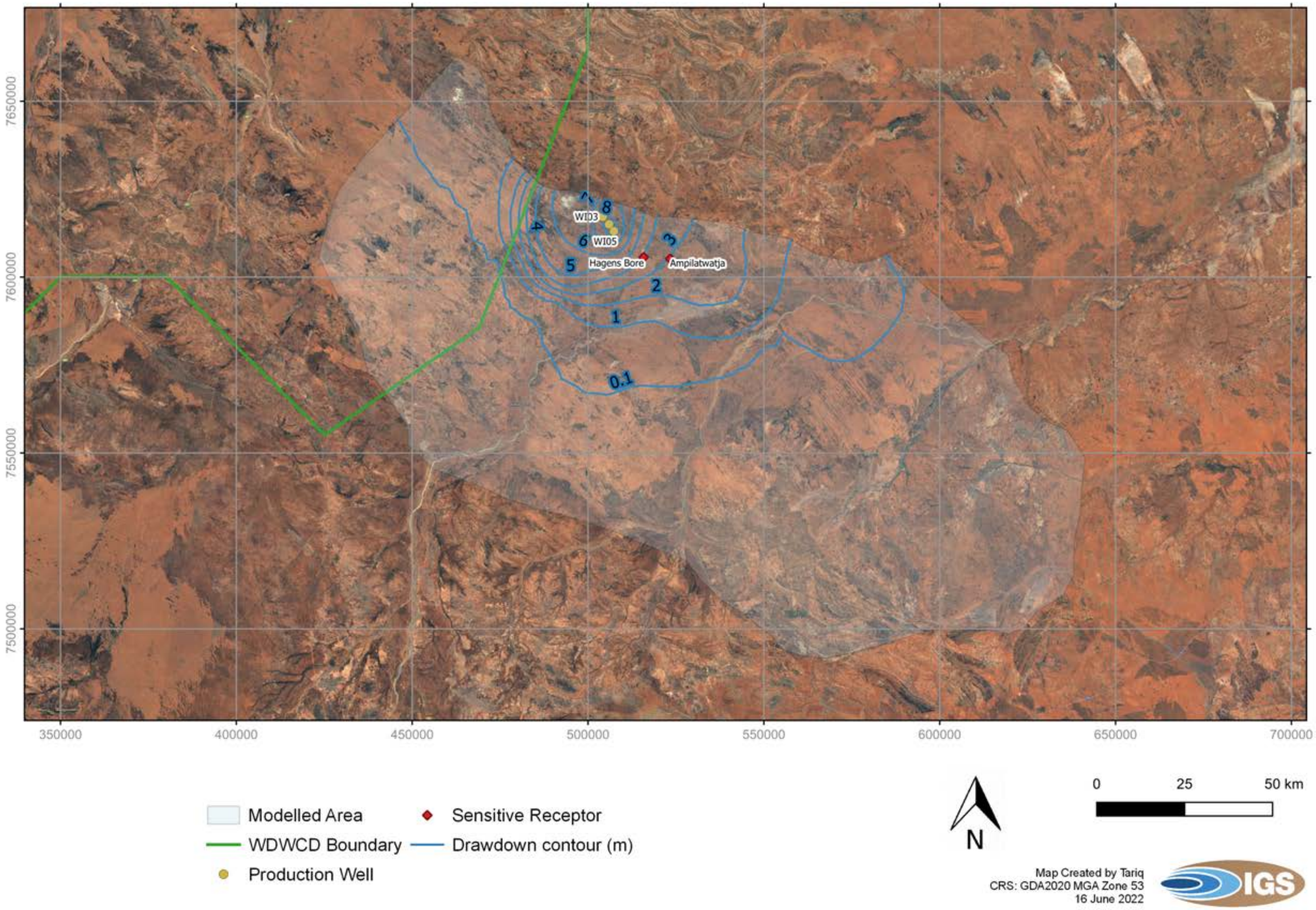



Figure 32. WDWCD flux P90 drawdown contours at the end of 25-year operation.

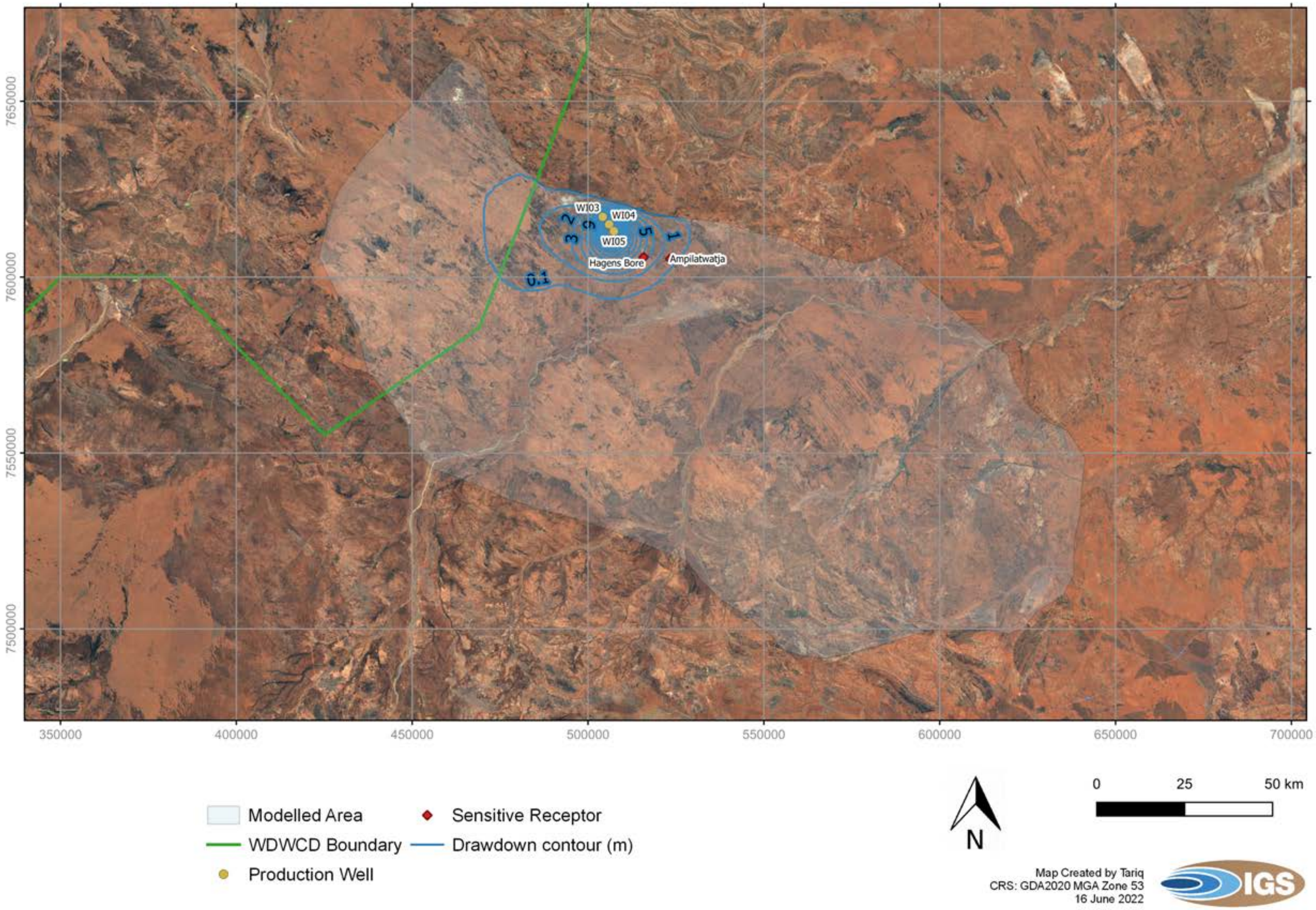



Figure 33. WDWCD flux P10 drawdown contours at the end of 40-year operation.

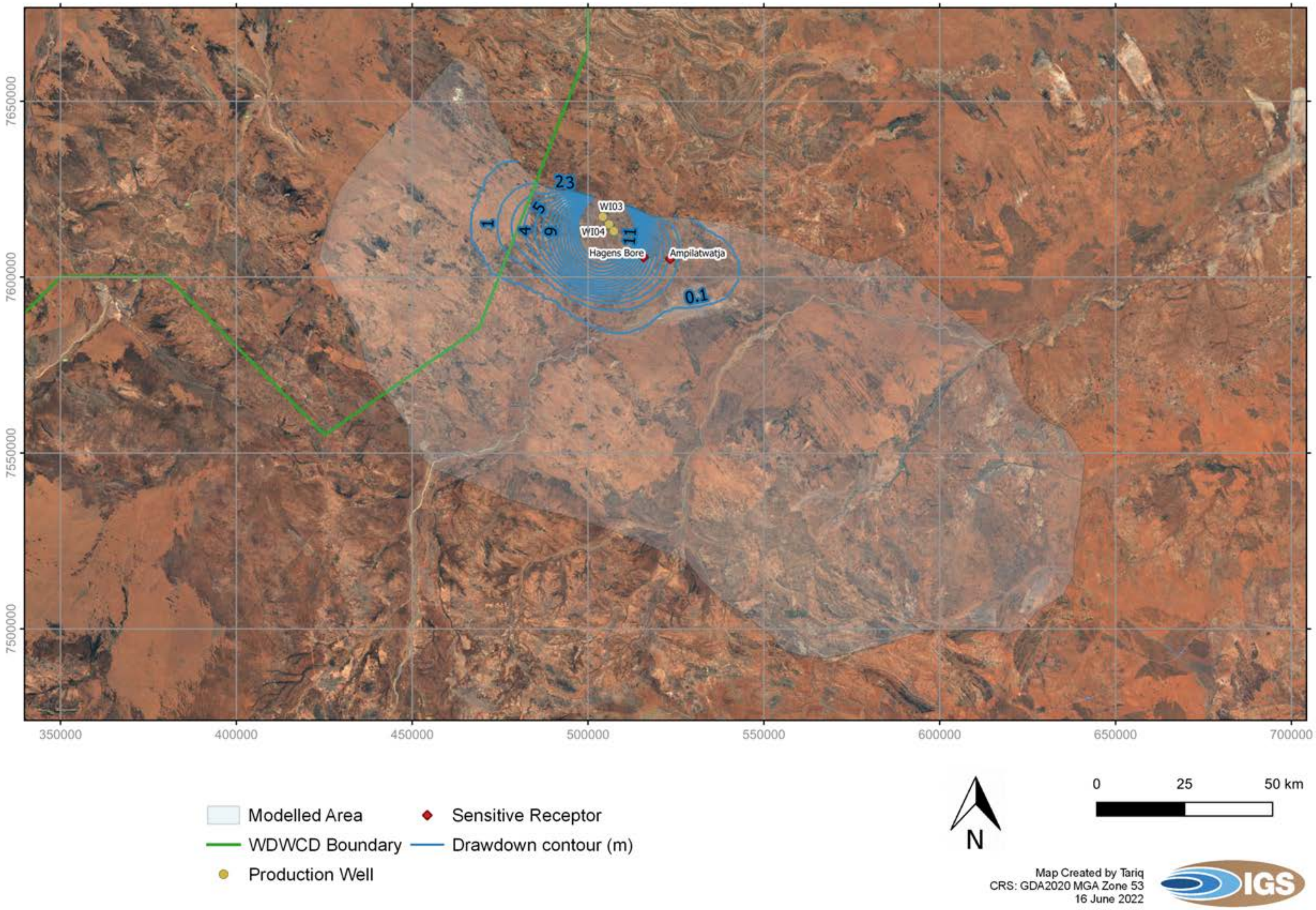



Figure 34. WDWCD flux P50 drawdown contours at the end of 40-year operation.

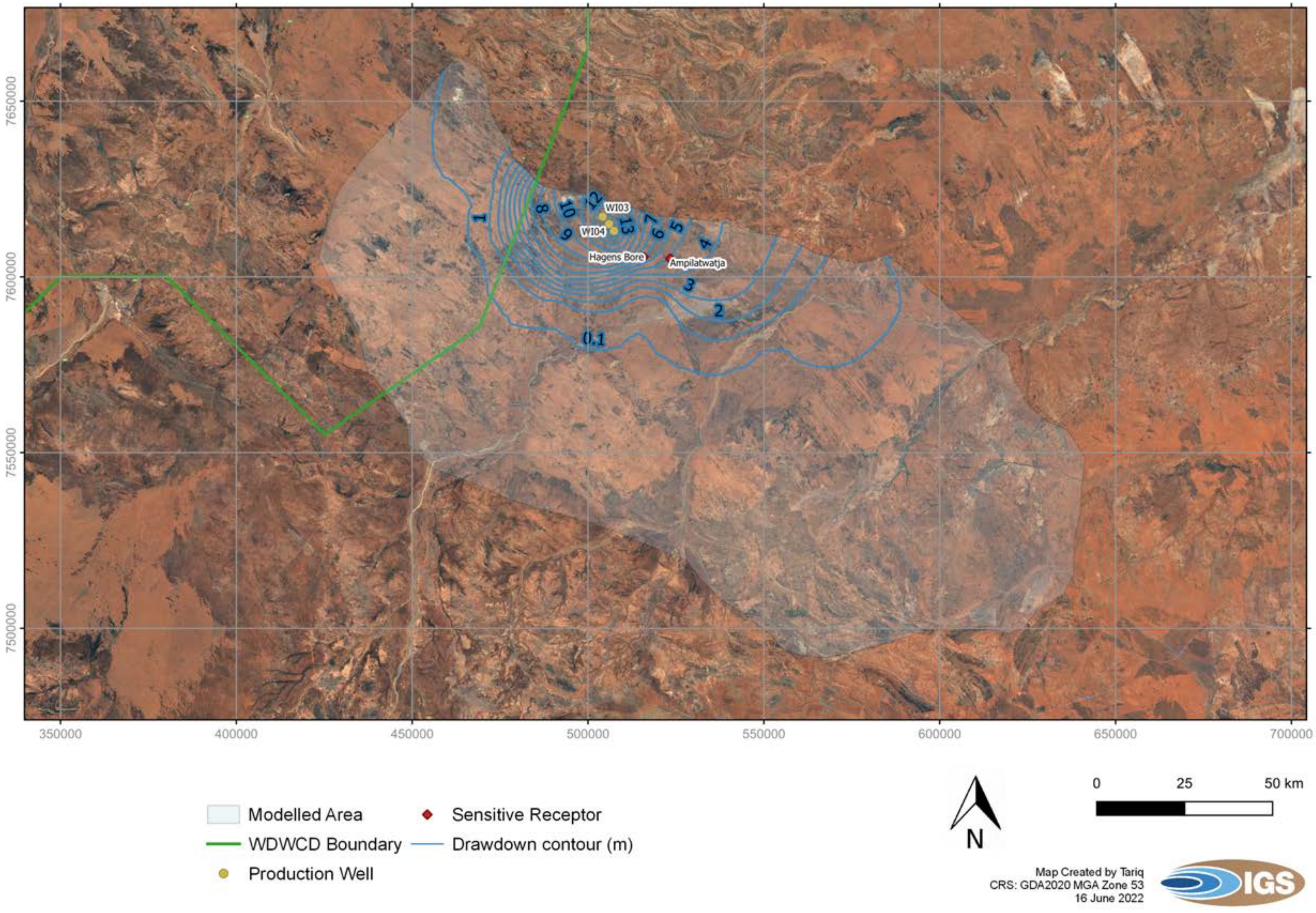



Figure 35. WDWCD flux P90 drawdown contours at the end of 40-year operation.

# 5. Discussion and Conclusions

No comparison is possible between the results of this study and the previous work of CloudGMS (Knapton, 2017) because these are very different studies with vastly different model designs, parameterisation schemes, conditioning approaches and future pumping rates being simulated. Moreover, our preferred P10 / P50 / P90 reporting metrics offer a better description of the forecast likelihood than a P5 and P95 alone as reported by Knapton (2017).

Third party water bores are completed to a depth of between 70 mbgl and 80 mbgl (GWS, 2017) with the water table at approximately 50 mbgl providing between 20 m and 30 m of available drawdown for pumping. The results for the 25-year scenario show that there is very low risk of complete loss of production in third-party water bores with the most likely (P50) drawdown being between 10% and 20% of the available drawdown at both locations. Moreover, there remains significantly more saturated aquifer (i.e., in excess of 200 m additional thickness) at depth providing ample security for any “make good” obligations. Peak flux across the WDWCD is also considered small relative to the total volume extracted from storage (23.3 ML/d) with the most likely rate of 0.8 ML/d equating to only 3% of the rate extracted from storage. This implies that the most likely extraction simulation sources 97% of its water from areas outside the WDWCD.

The sensitivity analysis highlighted hydraulic conductivity as the primary contributor to the variability in the forecasts with recharge and connectivity to the Davenport ranges GHB plus flux from the south-west GHB also contributing. The significance of flux from the Davenport Ranges is worthy of further exploration given the proximity of the production borefield to this region. Note this is only to explore the possibility of greater flux from the ranges since zero-flux boundary conditions have already been explored in the present ensemble. An increased potential for flux from the Davenport Ranges will reduce both drawdown and flux forecasts presented in this study.

The success of any uncertainty analysis depends upon capturing the real forecast within the range of plausible outcomes. For the present work this is simulated by the forecast ensemble of 946 equally plausible models. Accordingly, discussion of the relative strengths and weaknesses in the adopted methodology is warranted. Recall that the primary factors affecting drawdown propagation simulated by the model were identified as aquifer properties, recharge distribution and boundary conditions. Moreover, boundary condition behaviour was also identified as an unknown in the conceptual model of the system prompting inclusion of different system conceptualisations that either included or excluded connection to adjacent aquifers. This was considered essential given the proximity of the production borefield to the Davenport Ranges in the north, the potential for drawdown to propagate to (1) the hydraulic divide in the north-west and (2) the discharge boundary into the regional Georgina Basin.

The different conceptual models effectively eliminate a source (or sink) from the model thereby forcing alternative, but plausible, boundary condition, recharge, and aquifer property parameter combinations to be represented in the final forecast ensemble. Facilitating this was a parametrisation strategy designed with sufficient flexibility to assess heterogeneity at an appropriate scale for recharge, hydraulic conductivity, and boundary flux. Of the 12 different conceptual models featuring various zero-flux boundary combinations, two (Conceptual models E and F) were identified as highly unlikely due to their inability to provide a reasonable fit with the observation dataset. The combination of flexibility in parameterisation and assessment of alternative system conceptualisations provides confidence in the forecast ensemble to capture sufficient variability in system behavior for a robust uncertainty analysis.

The forecast ensemble produced by PESTPP-IES is dependent on both appropriate prior parameter probability distributions and the information content of the observation dataset. Issues relating to inappropriate priors are often identified by many realisations with parameters at their upper or lower bounds after conditioning. The parameter group with the greatest number of parameters at or near their bounds was hydraulic conductivity at 3%, which is minimal. Information content of the observation dataset is considered low and is reflected in the large range of potential drawdown and flux forecasts (Table 4). Note that reduced information content in the observation dataset does not affect the uncertainty assessment methodology – it only acts to increase the range in the forecast. More information will reduce the number of plausible models capable of replicating known system behaviour thereby reducing forecast uncertainty.

The accuracy in aquifer thickness and the prior probability distribution assigned to storage coefficient remain potential sources of bias in the forecasts presented herein. Storage value, or more specifically the ratio of hydraulic conductivity to storage, has a significant effect on drawdown behaviour. The plausible range for storage coefficient used in this study was derived from aquifer pumping tests performed near the production borefield and thus its representativeness for the broader aquifer within the modelled region is unknown. Because the range assigned is towards the lower end of what might be expected for an unconfined carbonate aquifer, there is potential for the broader aquifer to have higher storage, in which case the drawdown impacts would be less than those identified in this assessment. On the other hand, storage at depth in an unconfined aquifer may be lower than what has been implemented. Work by Rau et al. (2018) showed that confined conditions may prevail at depth even in the absence of a confining unit. In either case, there is no evidence to suggest that the range in storage applied in this study is inappropriate.

# 6. Limitations

This study precludes any assessment of cumulative drawdown impacts resulting from operation of landholder (i.e., pastoral) or community supply bores.

The production bore field is simulated via three bores pumping at constant rates, which may be markedly different to the actual operating strategy but nevertheless provides a reasonable approximation given the length of time over which the stress to the system is applied. Additionally, the spread of five to seven production bores proposed in the EIS remains small compared to the extent of drawdown impacts simulated.

Errors incurred through extrapolation of the potentiometric surface to obtain constraints for GHB hydraulic heads may have some impact on drawdown propagation in the south-east regions of the model. However, this is well beyond the area of interest and likely to have negligible impact to estimates of flux across the WDWCD boundary.

Climate variability in the future may have some impact on the estimated forecasts ensemble but this is expected to be minor given the already low contribution to the system from recharge.

The storage property range used in this study reflects values obtained at the production borefield where pumping tests were performed. It remains unclear if that same range is appropriate for the rest of the aquifer. Regardless, values of between 2% and 4% for unconfined storage are generally considered low for carbonate formations and therefore if inaccurate, are more likely to be conservative.

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# APPENDIX A.

Table 5. Hydraulic heads observation dataset.

| RN | Easting | Northing | RSWL (mAHD) |
|---|---|---|---|
| RN000483 | 543526 | 7596269 | 353 |
| RN000484 | 508527 | 7584419 | 381 |
| RN000488 | 489127 | 7578169 | 416 |
| RN002783 | 448627 | 7573169 | 465 |
| RN003983 | 541126 | 7611169 | 351 |
| RN006089 | 489176 | 7578423 | 420 |
| RN010611 | 483957 | 7578826 | 425 |
| RN010615 | 468727 | 7575869 | 430 |
| RN010726 | 524127 | 7594169 | 342 |
| RN010787 | 541126 | 7611169 | 335 |
| RN010818 | 540548 | 7608253 | 337 |
| RN011454 | 523358 | 7605212 | 346 |
| RN011455 | 523377 | 7605307 | 344 |
| RN011884 | 535526 | 7594669 | 311 |
| RN012675 | 478282 | 7597437 | 393 |
| RN012802 | 483191 | 7574516 | 421 |
| RN012803 | 489210 | 7577667 | 416 |
| RN012804 | 495174 | 7581200 | 405 |
| RN012806 | 484293 | 7587257 | 420 |
| RN013319 | 535526 | 7594669 | 309 |
| RN013331 | 506127 | 7617169 | 328 |
| RN013722 | 463430 | 7609557 | 410 |
| RN014073 | 470886 | 7602887 | 431 |
| RN014074 | 473619 | 7602568 | 398 |
| RN014187 | 543526 | 7596269 | 315 |

| | | | |
|---|---|---|---|
| RN014354 | 453181 | 7648704 | 376 |
| RN014681 | 478345 | 7597434 | 396 |
| RN014688 | 483957 | 7578826 | 425 |
| RN014877 | 438640 | 7611358 | 421 |
| RN014878 | 436378 | 7609837 | 437 |
| RN015755 | 486400 | 7576390 | 422 |
| RN015756 | 498837 | 7581779 | 404 |
| RN015757 | 484301 | 7587245 | 421 |
| RN015867 | 527512 | 7598294 | 342 |
| RN016053 | 516327 | 7588269 | 379 |
| RN016173 | 508527 | 7584419 | 399 |
| RN016228 | 498696 | 7581409 | 395 |
| RN016795 | 483967 | 7578825 | 426 |
| RN016998 | 449127 | 7575769 | 454 |
| RN018015 | 523250 | 7605140 | 344 |
| RN018016 | 523430 | 7605200 | 345 |
| RN006082 | 475385 | 7565718 | 440 |
| RN013015 | 586304 | 7589952 | 300 |
| RN013331 | 506127 | 7617169 | 327 |
| RN014354 | 453181 | 7648704 | 377 |
| RN016049 | 445627 | 7565169 | 456 |
| RN016052 | 540727 | 7577969 | 361 |
| RN016053 | 516327 | 7588269 | 379 |
| RN016173 | 508527 | 7584419 | 399 |
| RN016228 | 498696 | 7581409 | 396 |
| RN016795 | 483967 | 7578825 | 426 |
| RN016970 | 481797 | 7568709 | 426 |
| RN016971 | 480457 | 7568979 | 425 |
| RN016998 | 449127 | 7575769 | 455 |

| | | | |
|---|---|---|---|
| RN017621 | 546026 | 7562447 | 358 |
| RN018015 | 523250 | 7605140 | 345 |
| RN018016 | 523430 | 7605200 | 346 |
| RN018017 | 619260 | 7573689 | 292 |
| RN018502 | 586242 | 7589728 | 301 |

# APPENDIX B.

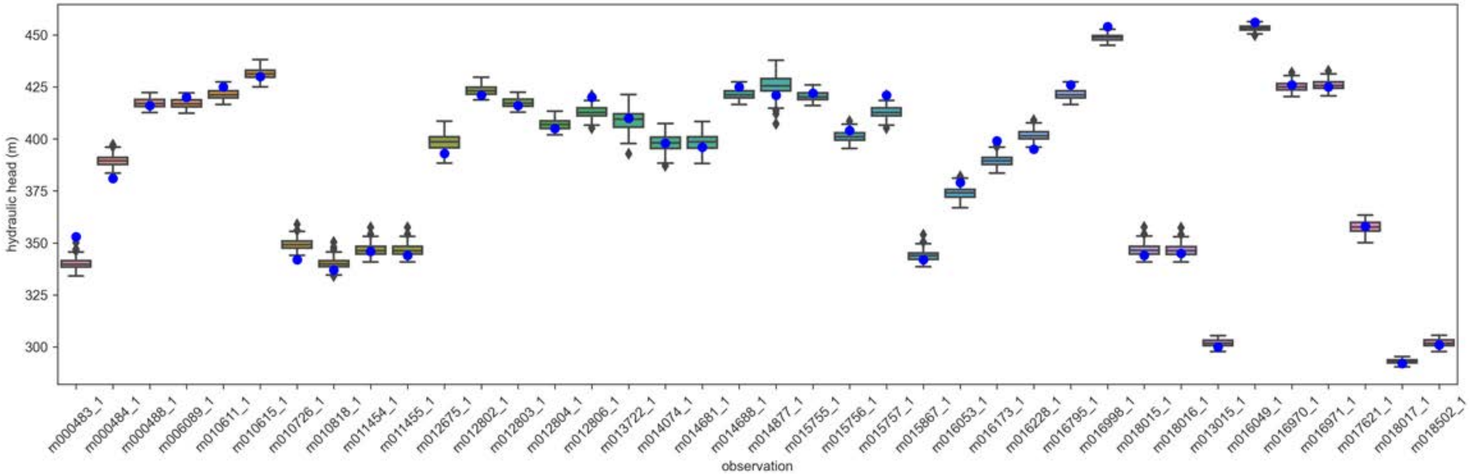


Figure 36. Box plot showing model-to-measurement misfit for conceptual model C ensemble.

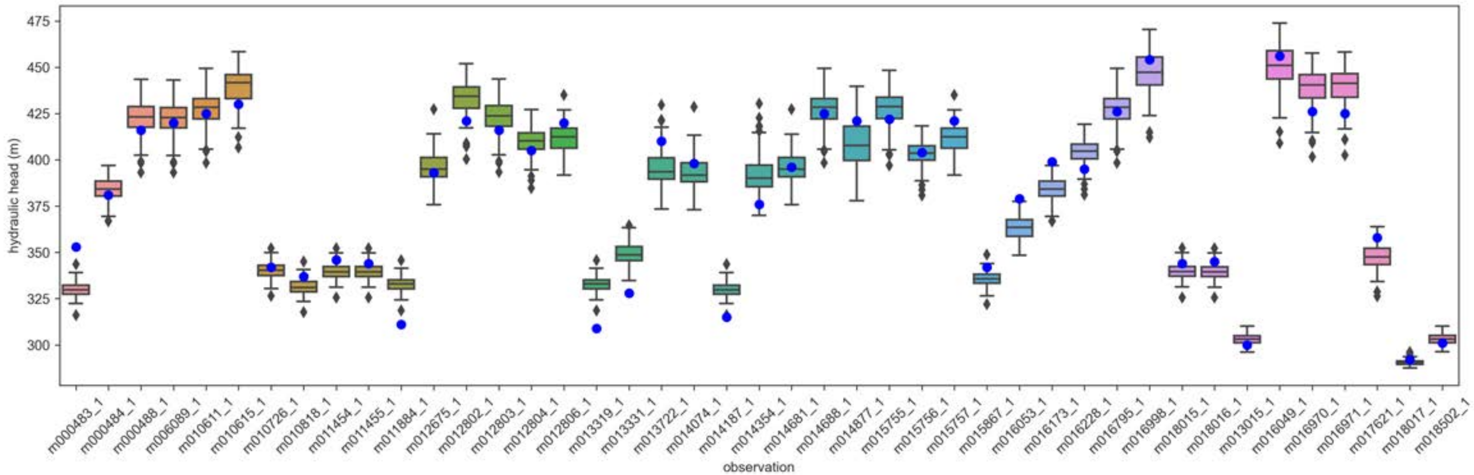


Figure 37. Box plot showing model-to-measurement misfit for conceptual model D ensemble.

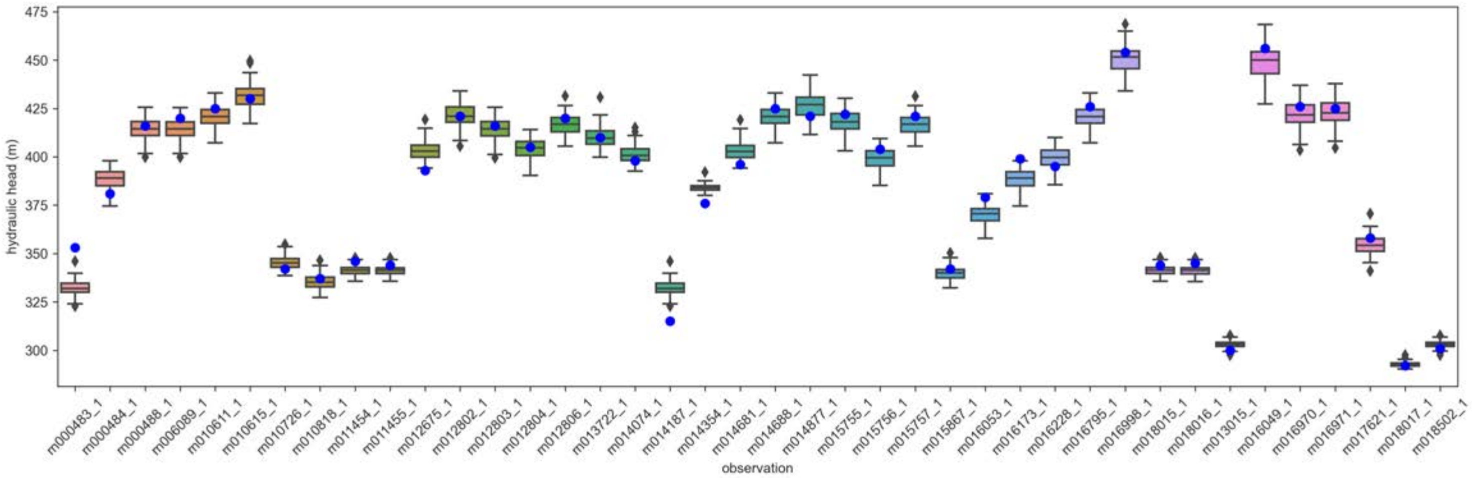


Figure 38. Box plot showing model-to-measurement misfit for conceptual model G ensemble.

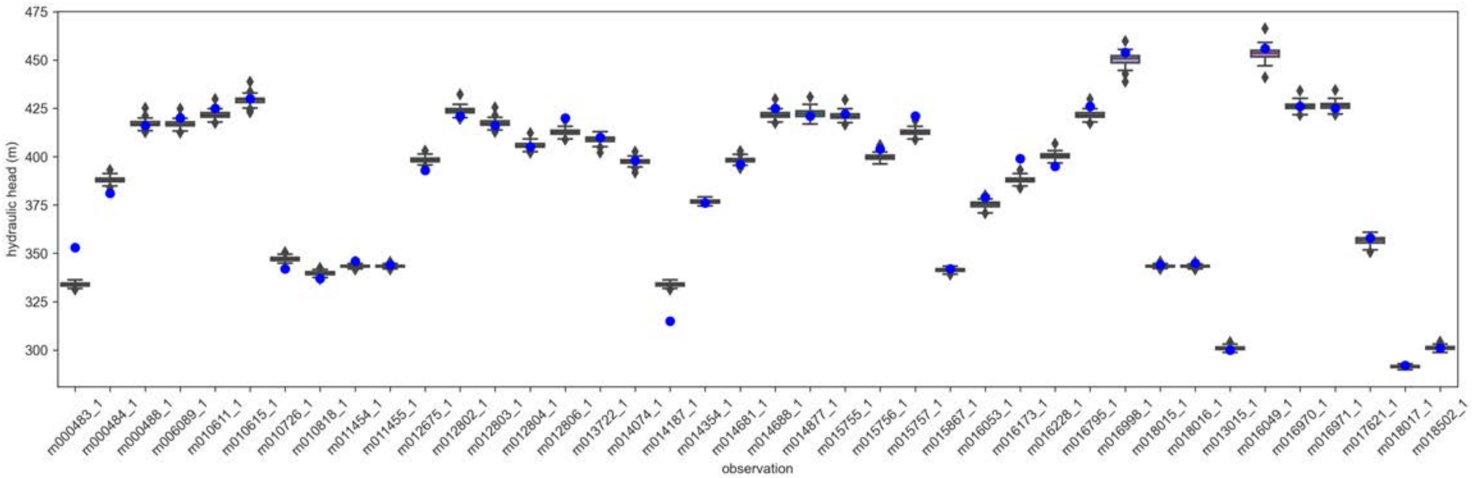


Figure 39. Box plot showing model-to-measurement misfit for conceptual model H ensemble.

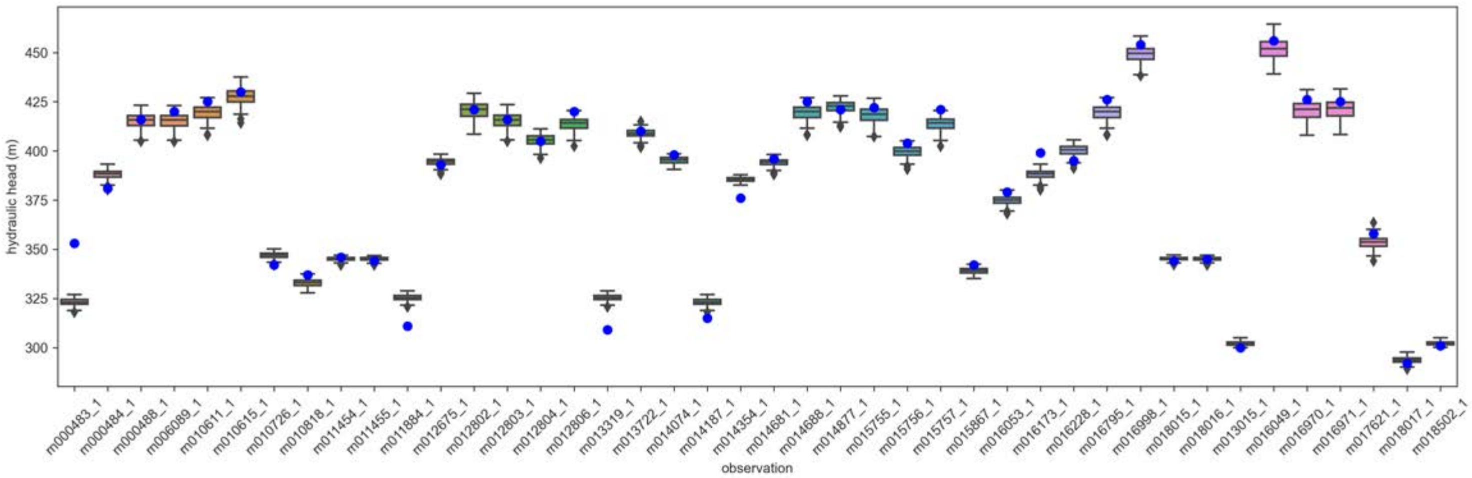


Figure 40. Box plot showing model-to-measurement misfit for conceptual model I ensemble.

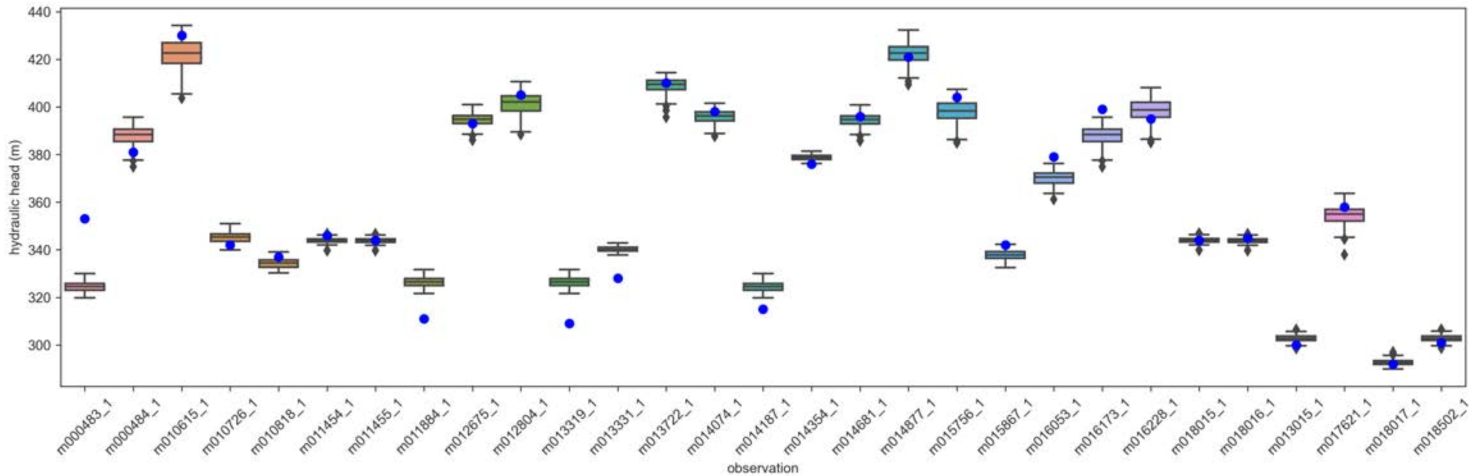


Figure 41. Box plot showing model-to-measurement misfit for conceptual model J ensemble.

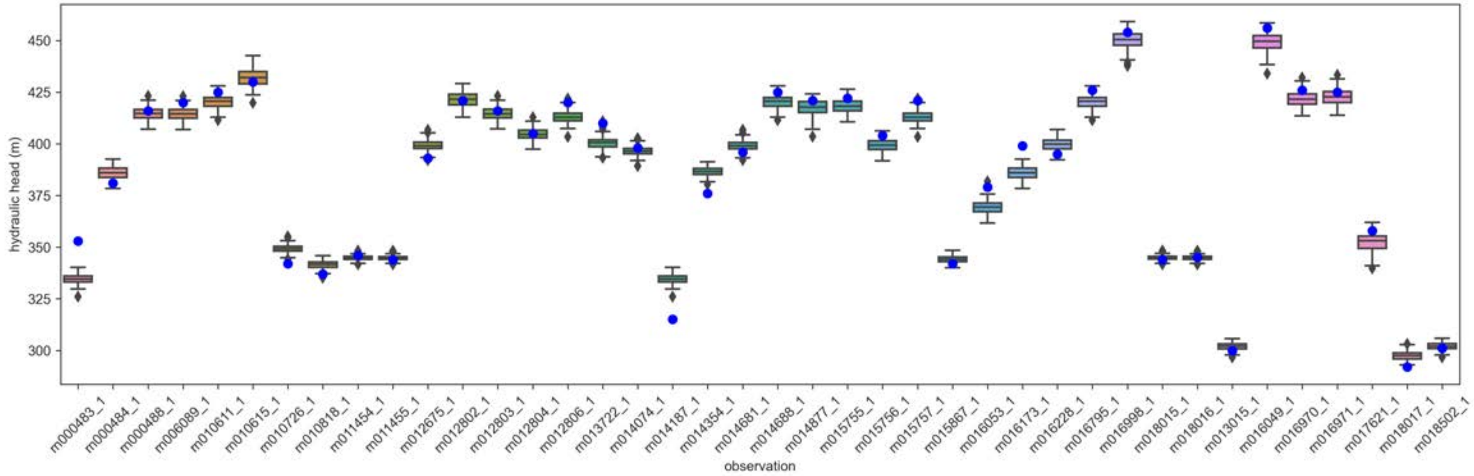


Figure 42. Box plot showing model-to-measurement misfit for conceptual model K ensemble.

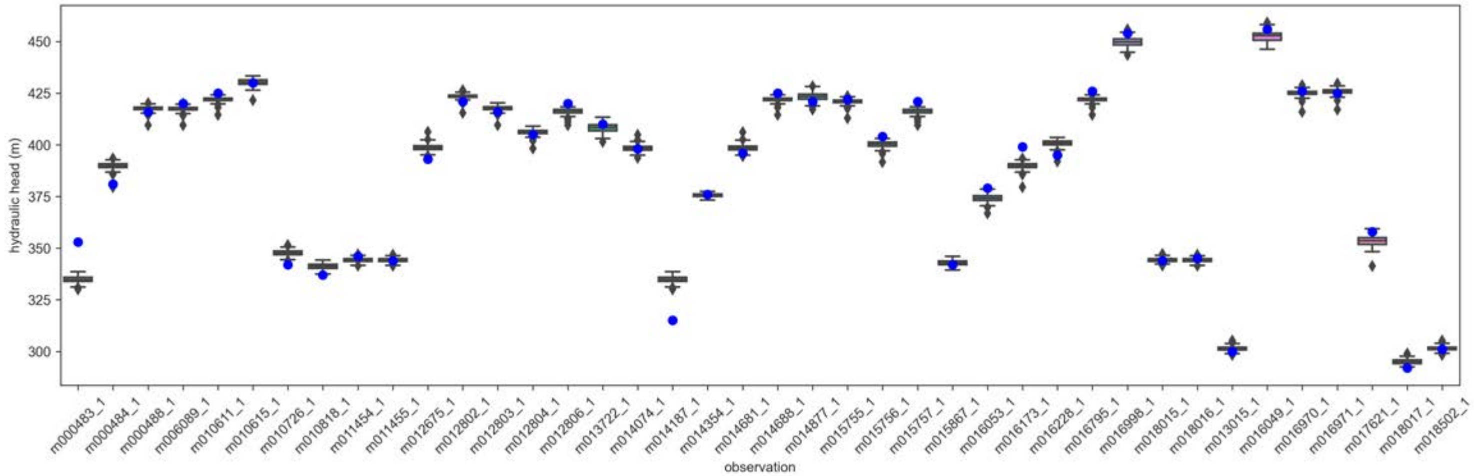


Figure 43. Box plot showing model-to-measurement misfit for conceptual model L ensemble.

# APPENDIX C.

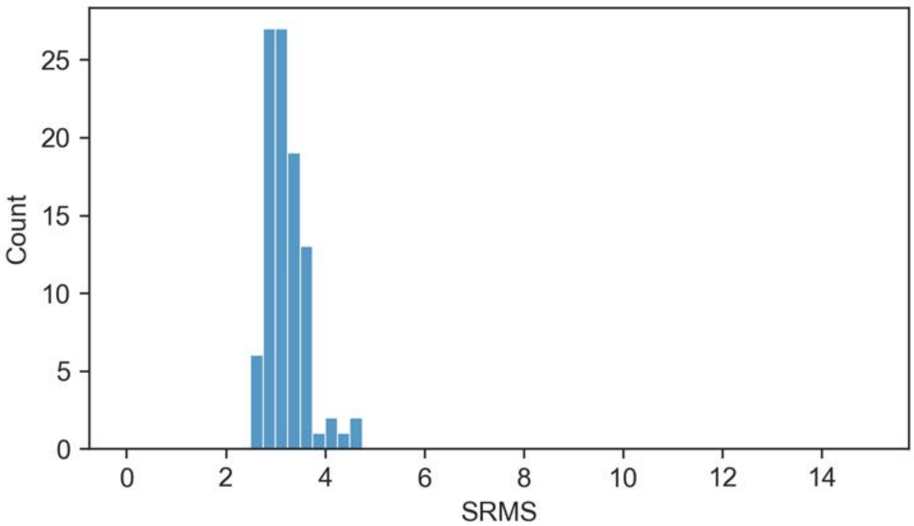


Figure 44. Conceptual model C SRMS (%) histogram.

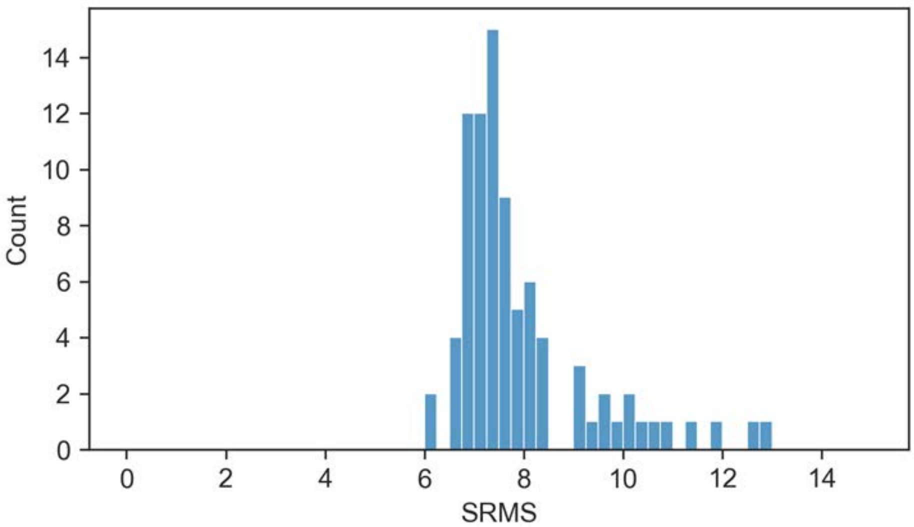


Figure 45. Conceptual model D SRMS (%) histogram.

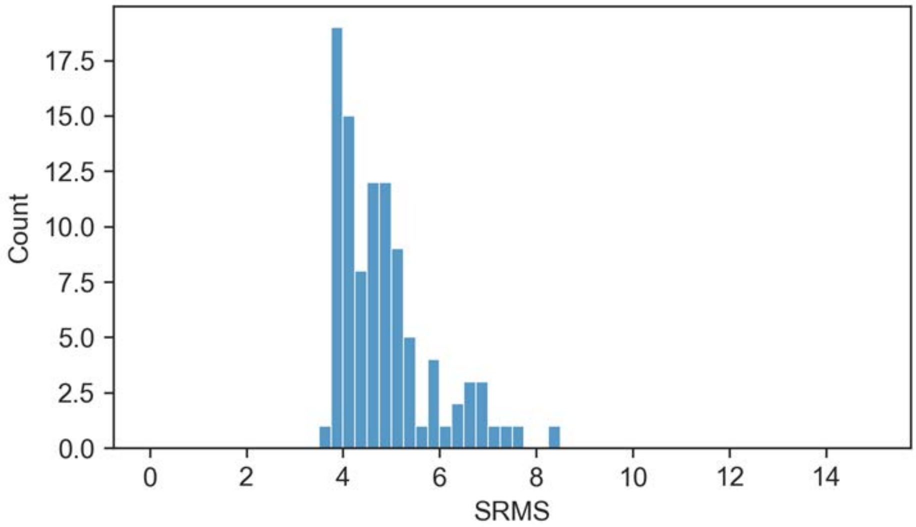


Figure 46. Conceptual model G SRMS (%) histogram.

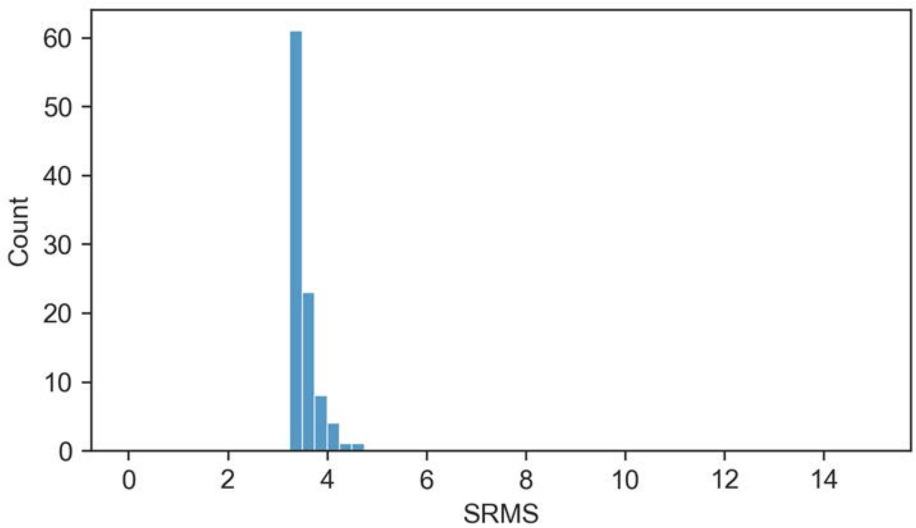


Figure 47. Conceptual model H SRMS (%) histogram.

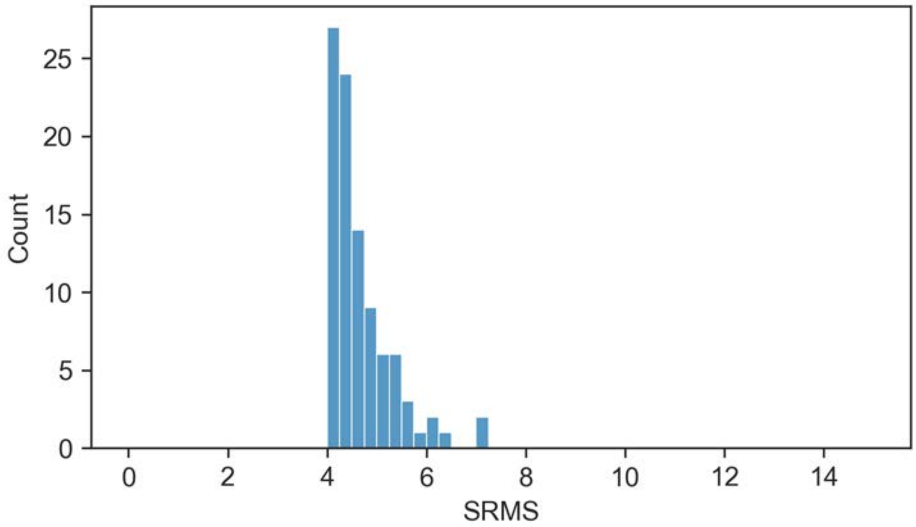


Figure 48. Conceptual model I SRMS (%) histogram.

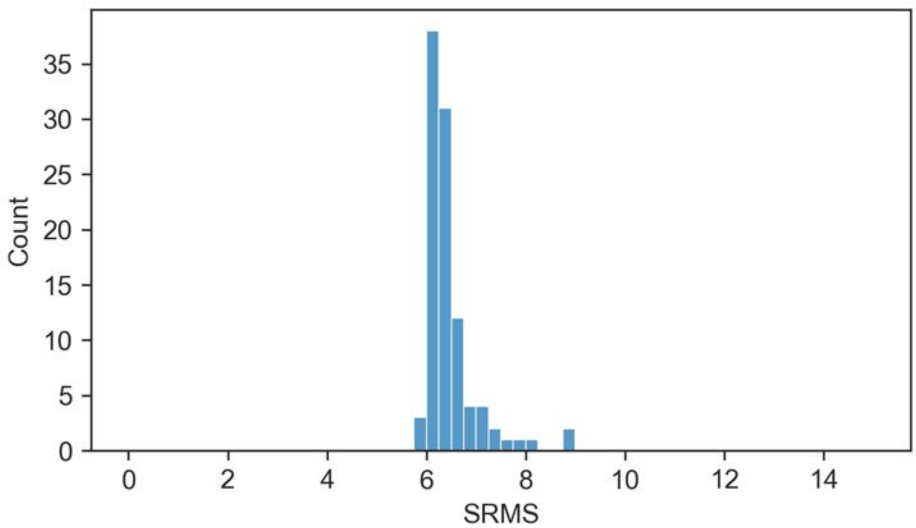


Figure 49. Conceptual model J SRMS (%) histogram.

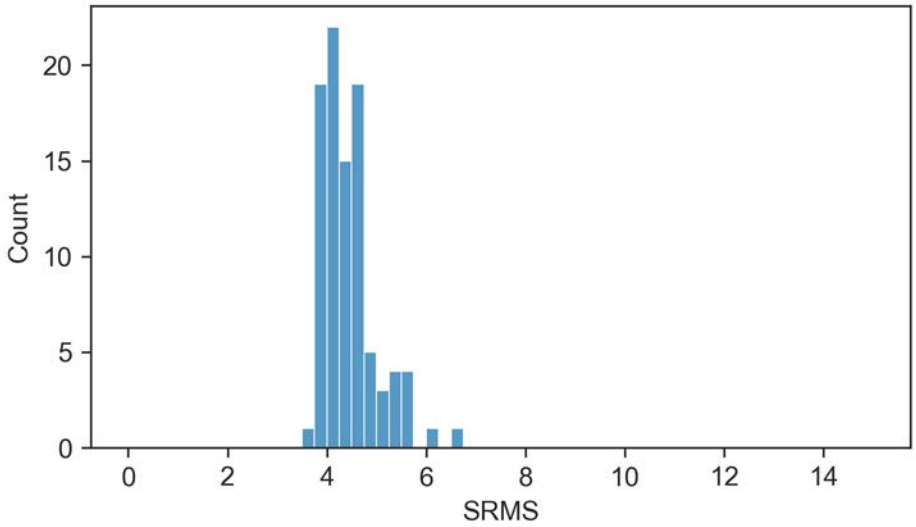


Figure 50. Conceptual model K SRMS (%) histogram.

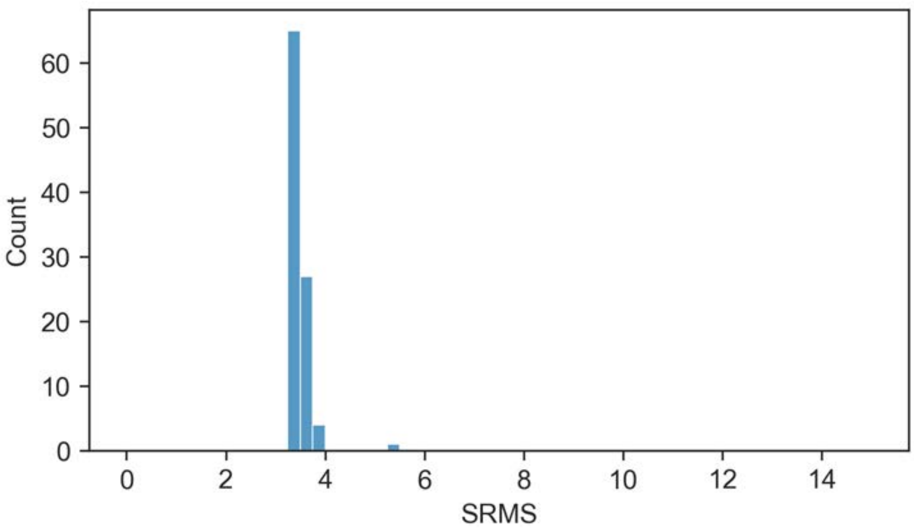


Figure 51. Conceptual model L SRMS (%) histogram.

# APPENDIX D.

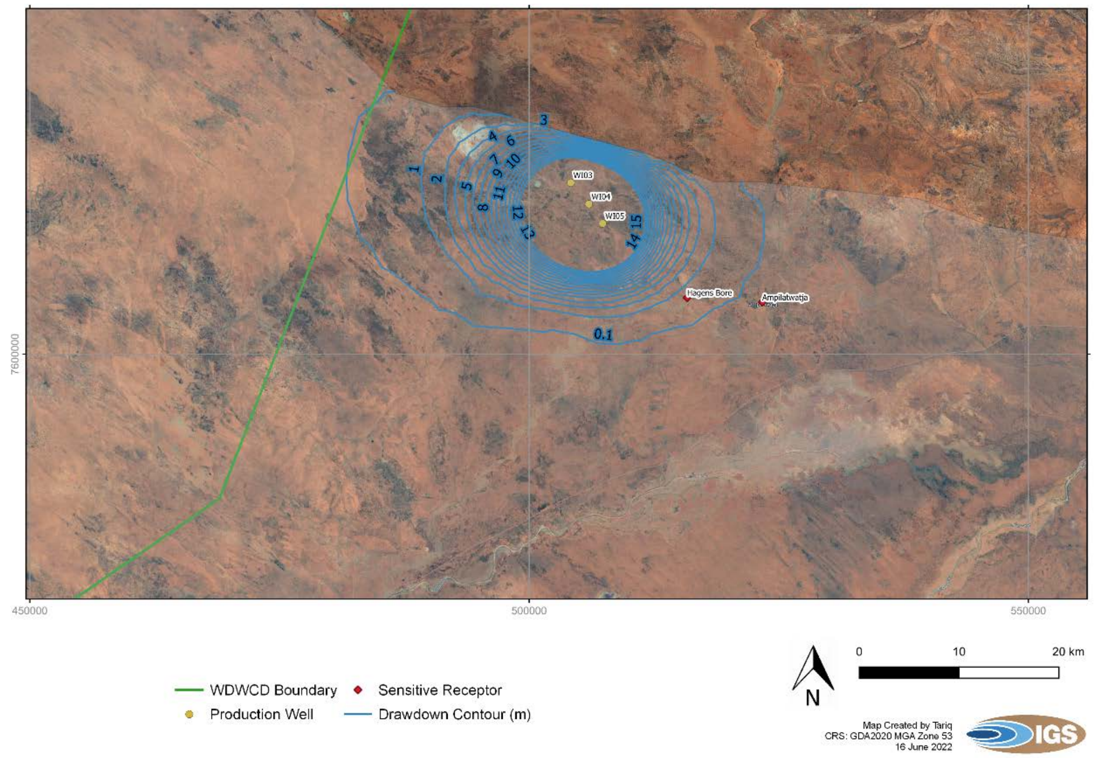


Figure 52. WDWCD flux P10 drawdown contours at the end of 25-year operation.

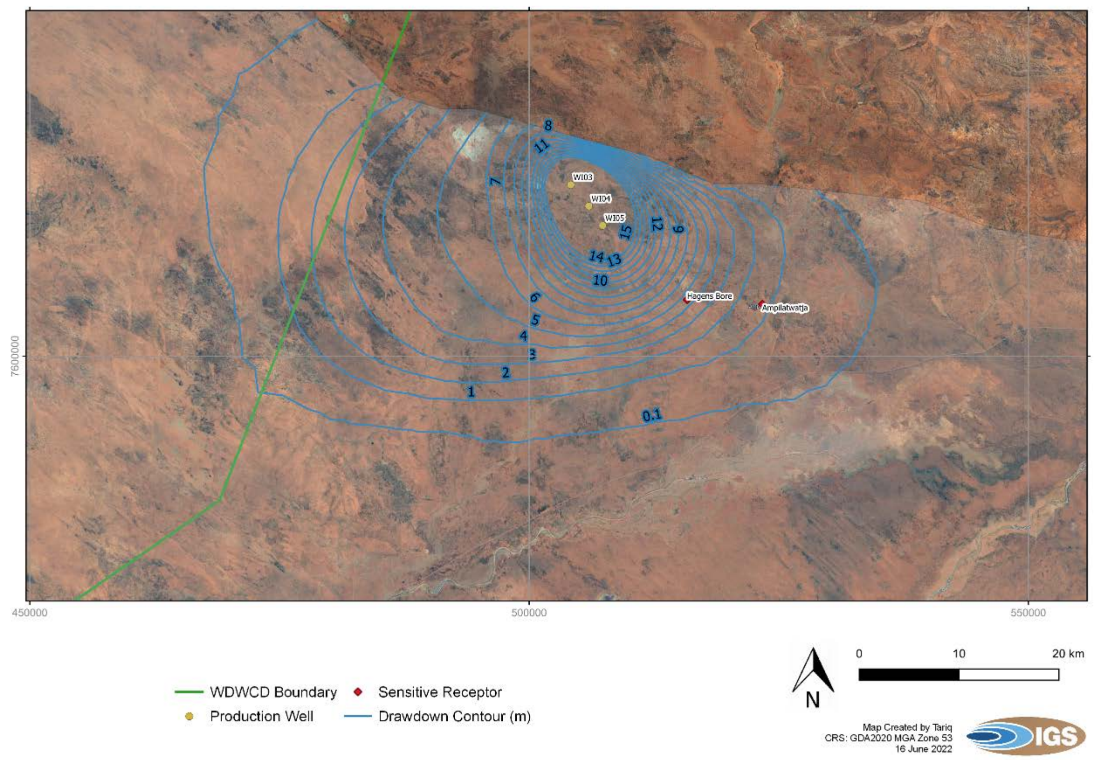


Figure 53. WDWCD flux P50 drawdown contours at the end of 25-year operation.

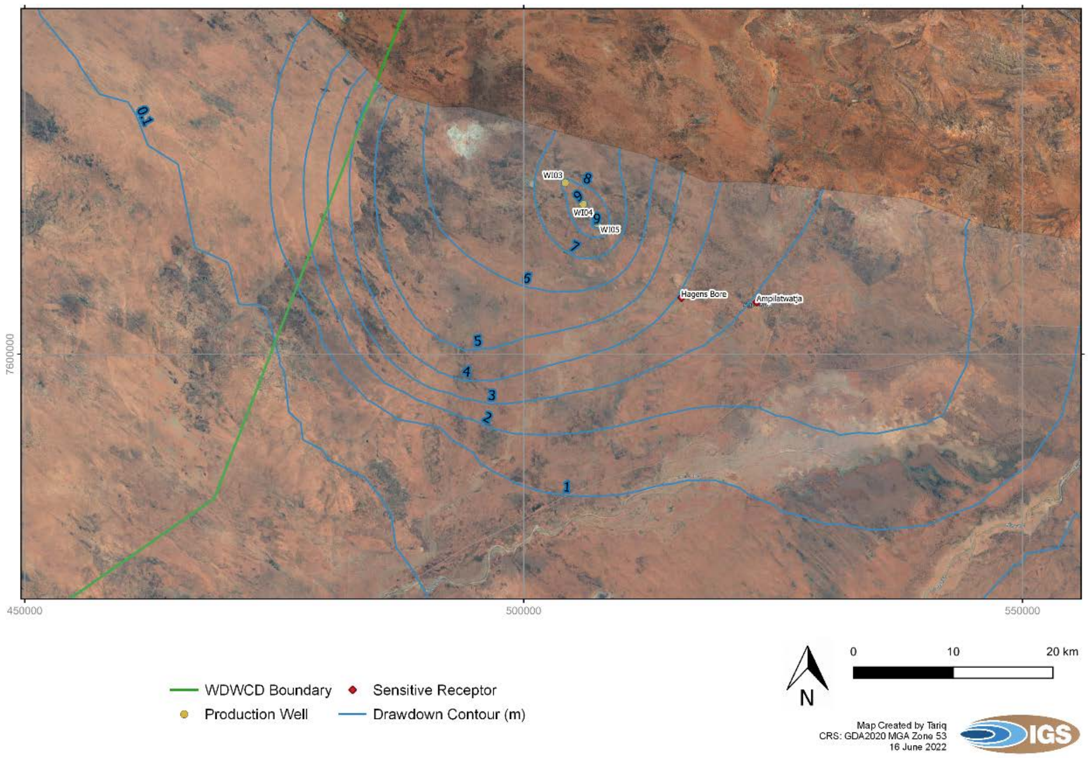


Figure 54. WDWCD flux P90 drawdown contours at the end of 25-year operation.

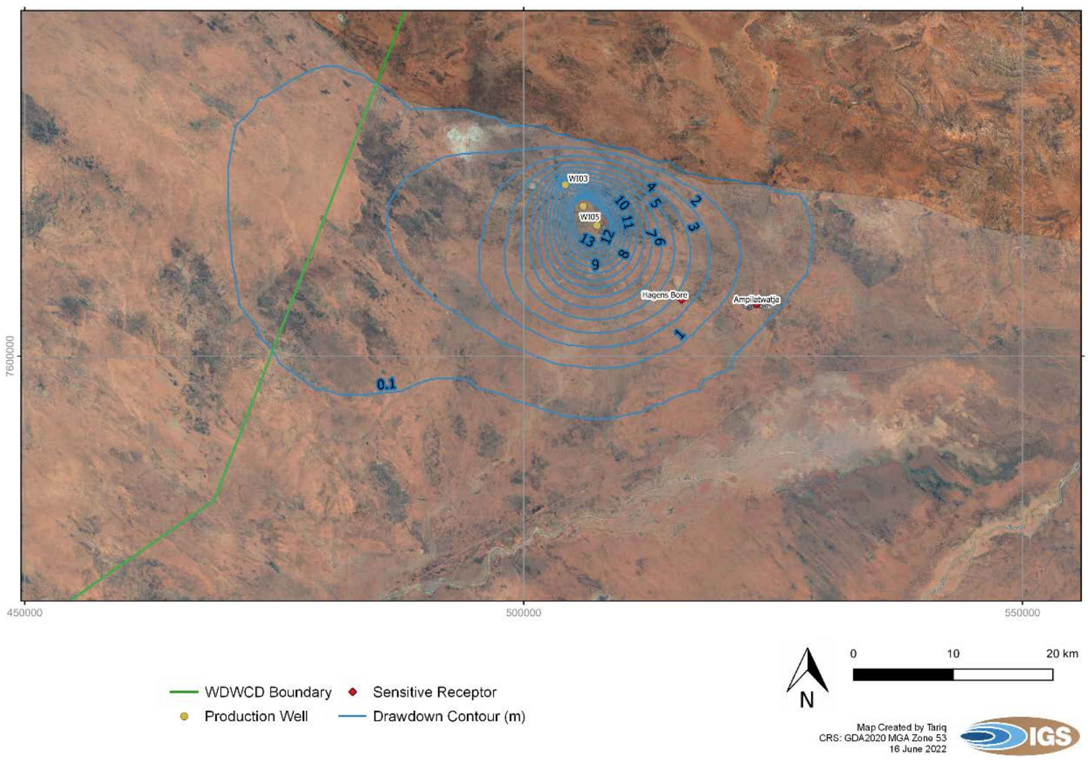


Figure 55. WDWCD flux P10 drawdown contours at the end of 40-year operation.

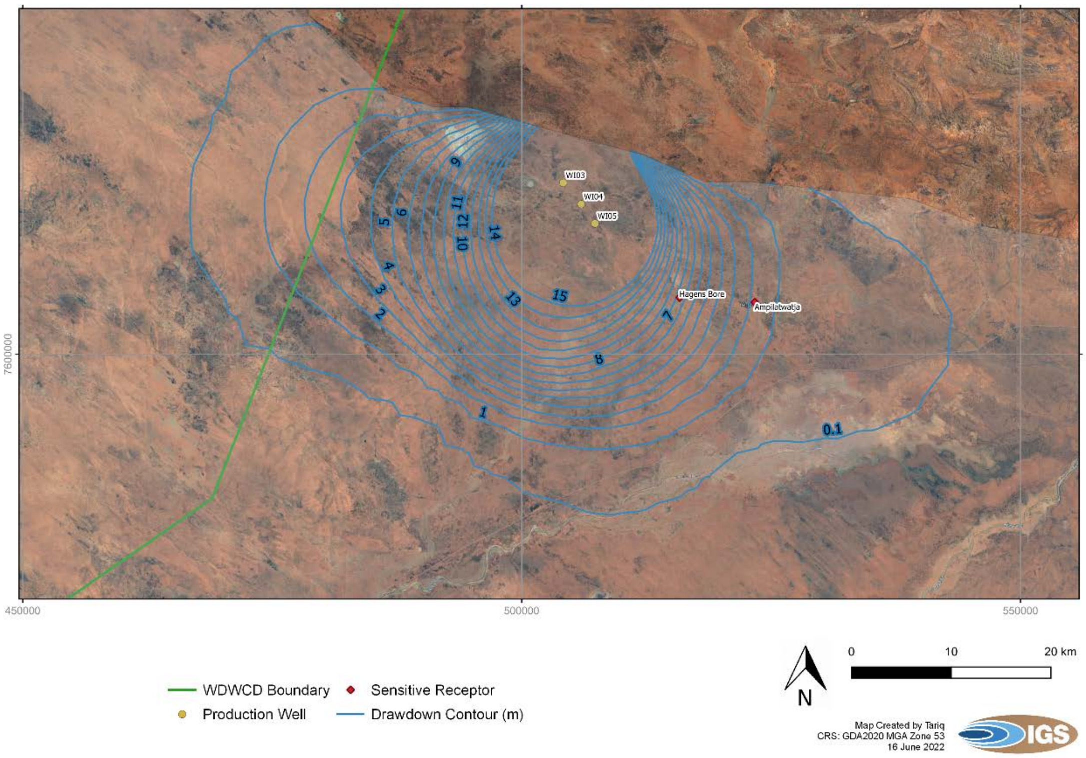


Figure 56. WDWCD flux P50 drawdown contours at the end of 40-year operation.

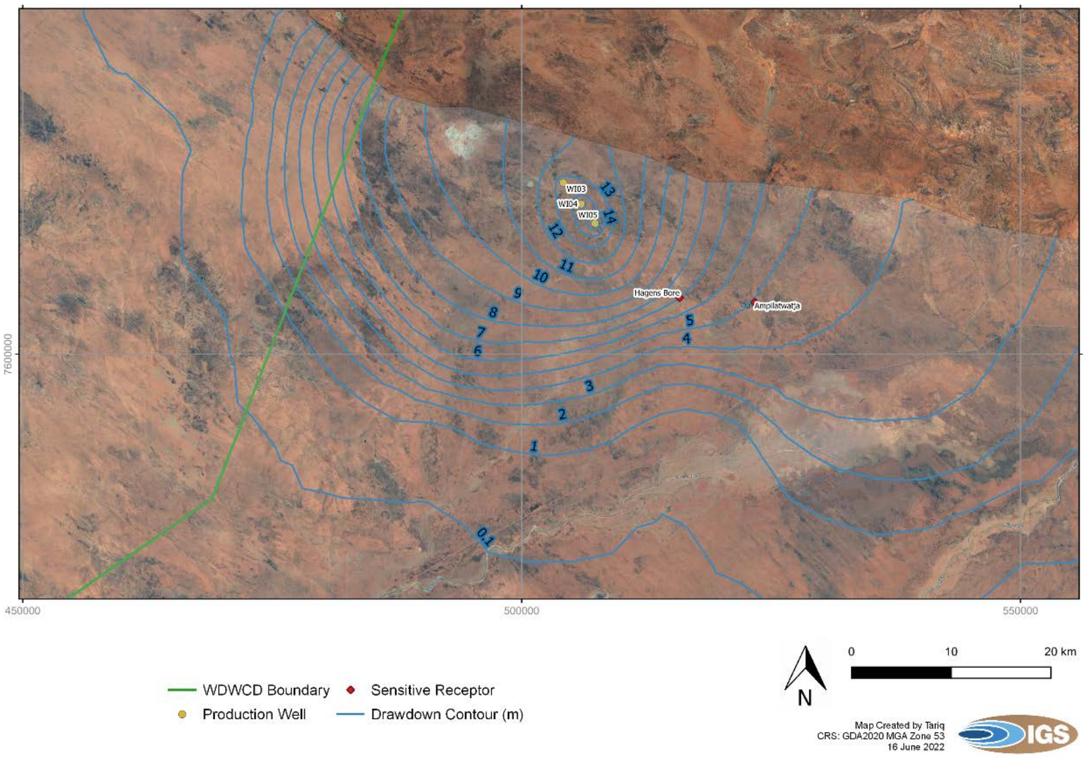


Figure 57. WDWCD flux P90 drawdown contours at the end of 40-year operation.

# APPENDIX E.

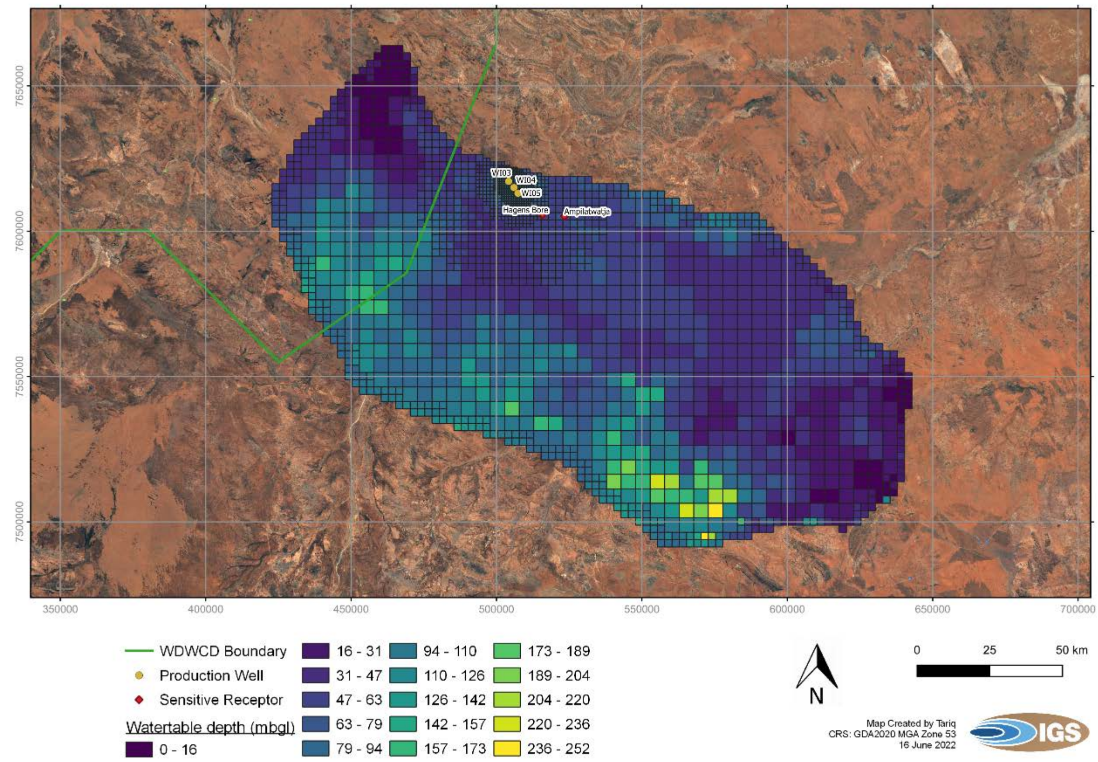


Figure 58. WDWCD flux P10 depth to water at end of 25-year operation.

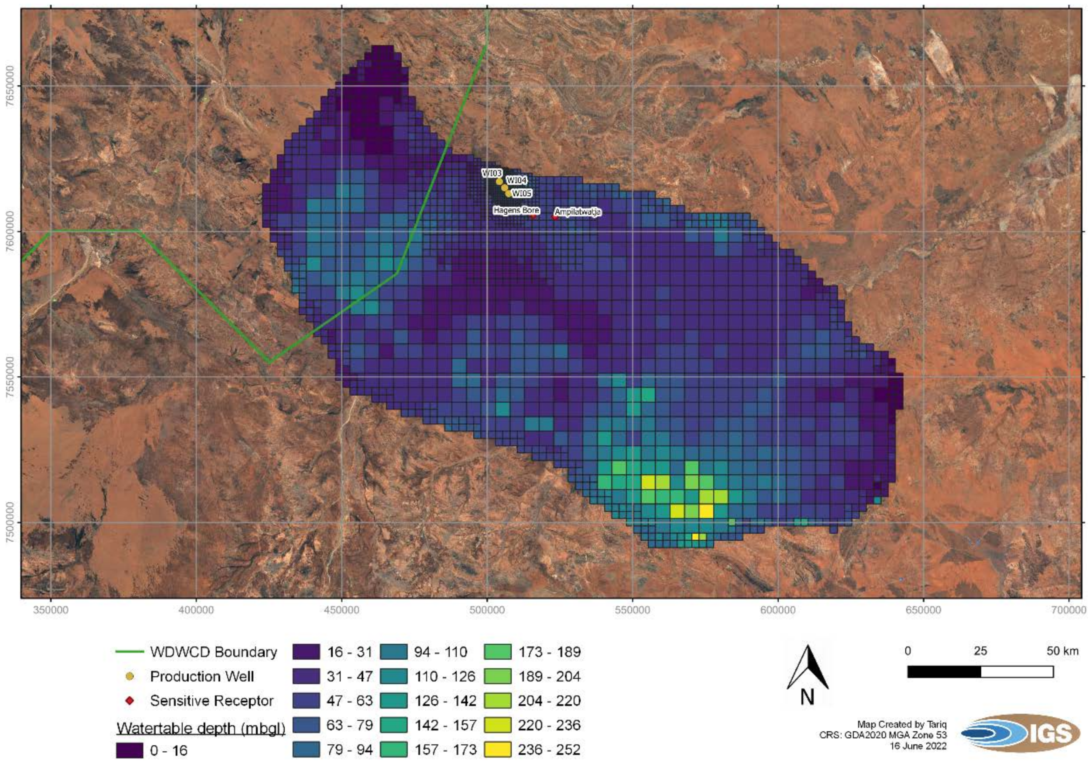


Figure 59. WDWCD flux P50 depth to water at end of 25-year operation.

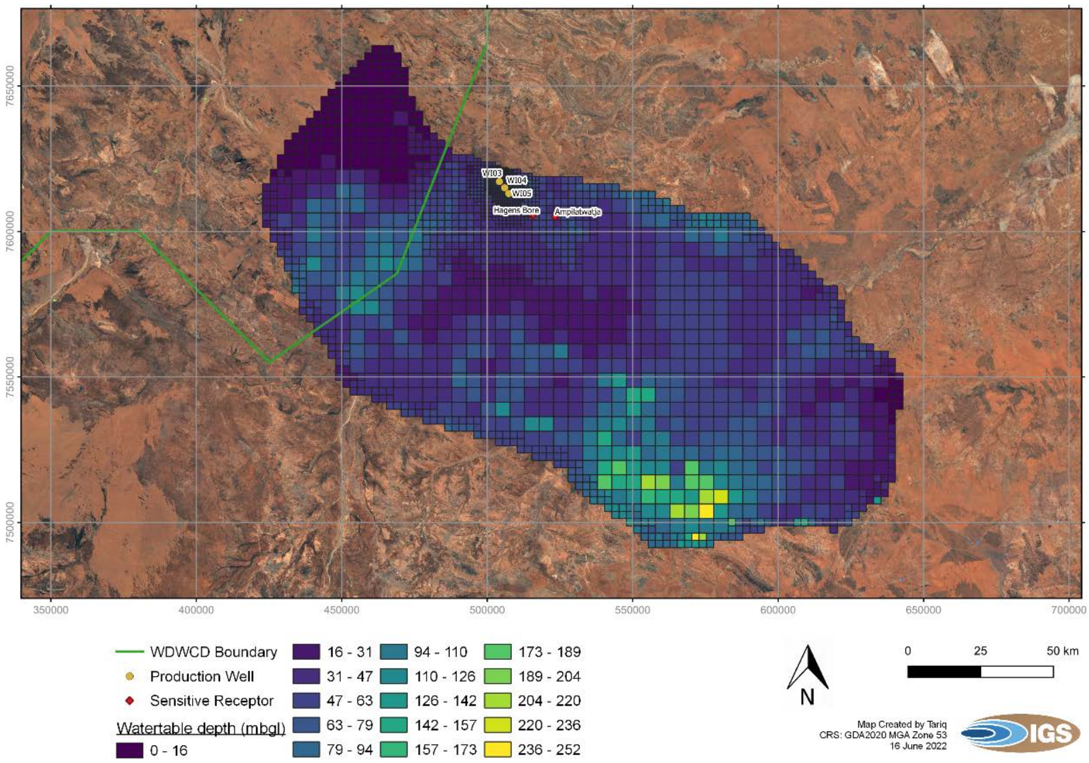


Figure 60. WDWCD flux P90 depth to water at end of 25-year operation.

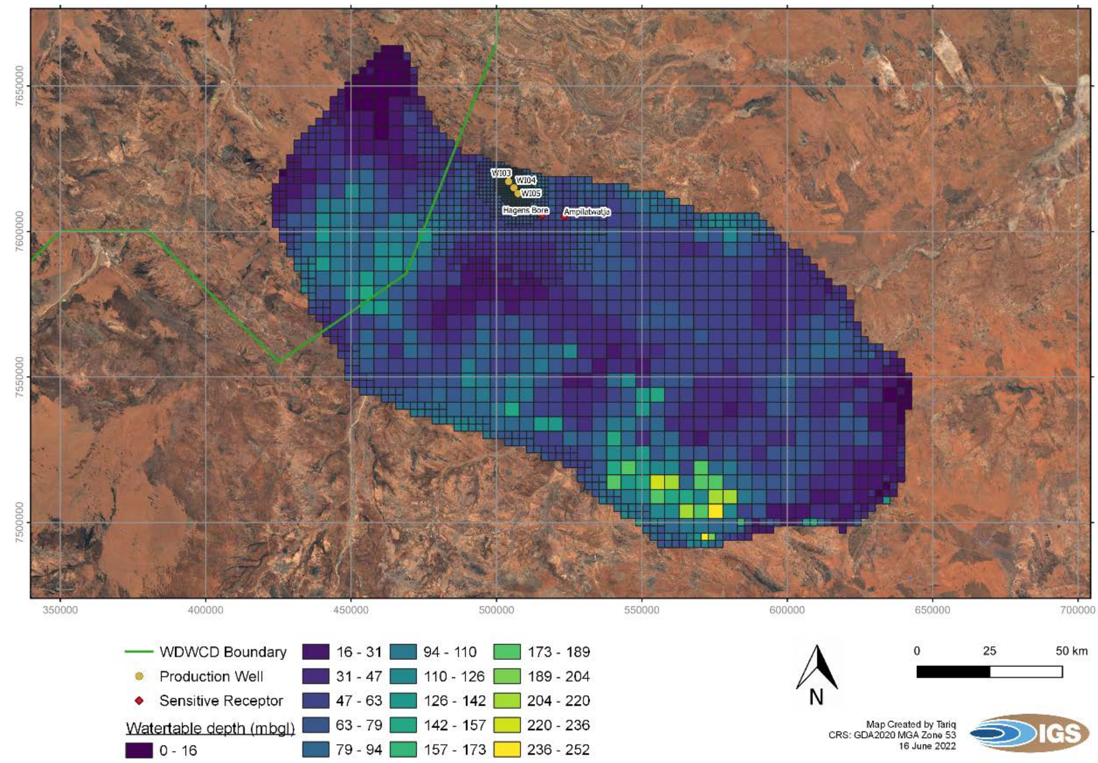


Figure 61. WDWCD flux P10 depth to water at end of 40-year operation.

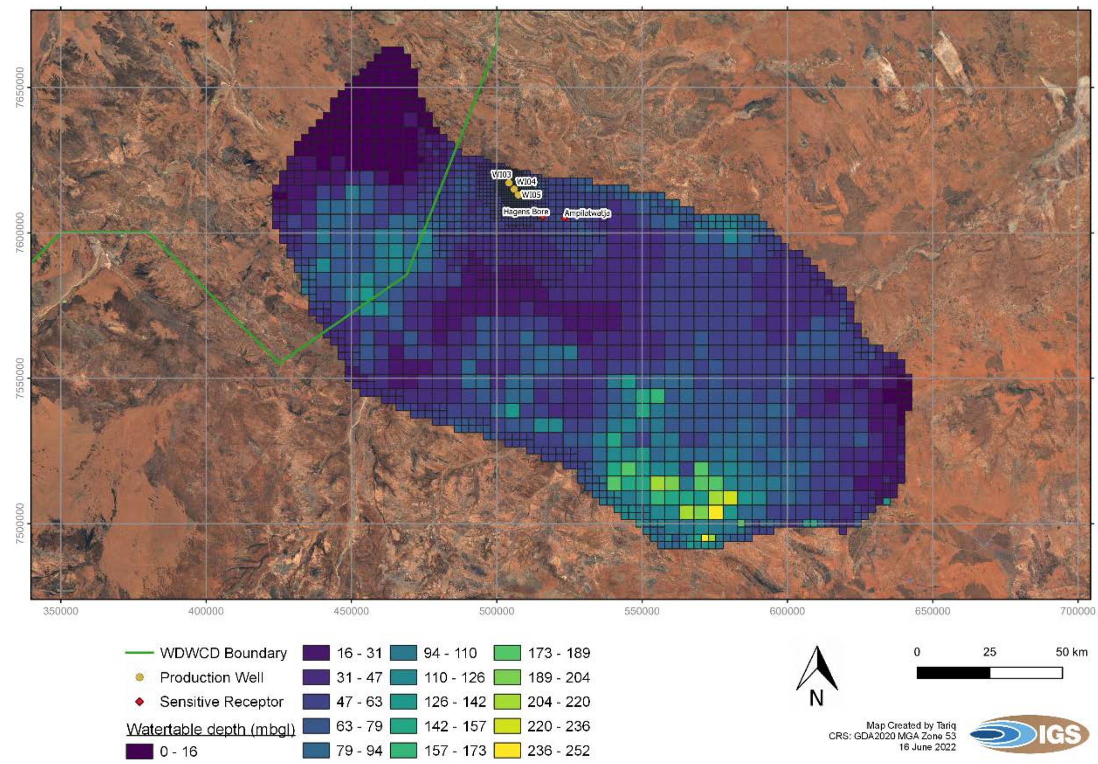


Figure 62. WDWCD flux P50 depth to water at end of 40-year operation.

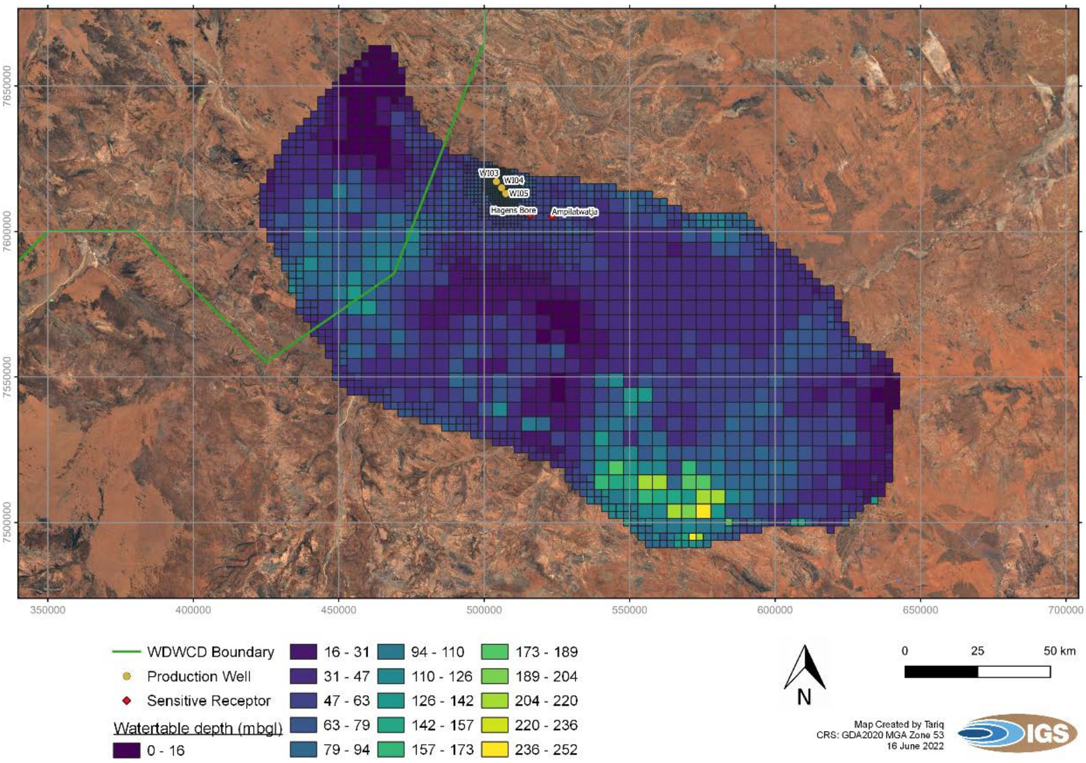


Figure 63. WDWCD flux P90 depth to water at end of 40-year operation.

# Appendix L

## Revised Social Impact Assessment

# Technical Memorandum

**October 7, 2022**

| | | | |
|---|---|---|---|
| **To** | Verdant Minerals Pty Ltd | **Email** | ctziolis@verdantminerals.com.au |
| **From** | GHD Pty Ltd | **Project No.** | 12571099 |
| **Project Name** | Ammaroo Ammonium Phosphate Fertiliser Project - Variation, Environmental Approvals and NT EPA Referral | | |
| **Subject** | Update to Social Impact Assessment (SIA) – Referral of Significant Variation | | |

# 1. Introduction

Verdant Minerals Pty Ltd (Verdant) is a Darwin-based, developer of Australian fertiliser mineral projects, including the Ammaroo Ammonium Phosphate Fertiliser Project (hereinafter abbreviated to 'Ammaroo Phosphate Project' and referred to as the 'Project'). The Project is situated in the central region of the Northern Territory, located in the western Georgina Basin approximately 220 kilometres (km) southeast of Tennant Creek, 125 km east of Barrow Creek and 270 km northeast of Alice Springs.

In 2018, the Project, was subject and approved under an Environmental Impact Assessment, and comprised the development of the Ammaroo resource, by open-cut mining, crushing, beneficiation and drying to produce a phosphate rock concentrate for transportation via rail to the Darwin Port (see Executive Summary Section of the Referral of Significant Variation). The Project planned to export the rock concentrate to international markets as the essential feed stock for the production of fertiliser products. (For the purposes of clarity, the 2018 Project will hereafter be referred to as 'the Approved Project').

To expand the economic feasibility of the Project, Verdant now plan to include the onsite production of monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers. This will entail the construction of additional onsite plant and infrastructure, including a phosphoric acid plant, sulphuric acid plant, ammonia plant, granulation plant, and amenity and service infrastructure (collectively referred to as the "Proposed Project").

As part of the Approved Project EIS, an Economic and Social Impact Assessment (ESIA 2018) was prepared, which documented the potential socio-economic impacts and opportunities of the project. To support the Proposed Project referral, a review of the ESIA was undertaken to assess any gaps and or changes to the Proposed potential socio-economic impacts to surrounding communities as a result of the updates to the project.

## 1.1 Proposal Overview

As described above, downstream activities to process phosphate rock concentrate on site to produce ammonium phosphate fertiliser would require more infrastructure, and a greater number of workforce. These activities would result in a change to the project description. An overview of the proposed updates to the project description can be found in the Executive Summary section of the Referral of Significant Variation.

The proposed project changes relevant to this SIA Addendum include:

– an increase in infrastructure required on site, including processing plant infrastructure, and an expansion to the workforce accommodation village.
– an airfield on site, (including associated infrastructure and roads) and would allow workers to be flown directly from Darwin or other locations and capital cities to site.
– an increase in groundwater extraction for use in downstream processing.
– an increase in the construction and operation workforce.
– a longer construction period would be required to build the required infrastructure.
– an increase to the economic benefits paid to Traditional Owners under the Native Title Agreement.

## 1.2 Scope and Limitations

*This technical addendum has been prepared by GHD for Verdant Minerals Pty Limited. It is not prepared as, and is not represented to be, a deliverable suitable for reliance by any person for any purpose. It is not intended for circulation or incorporation into other documents. The matters discussed in this addendum are limited to those specifically detailed in the addendum and are subject to any limitations or assumptions specially set out.*

# 2. Methodology

This SIA Addendum has utilised the methodology applied to the ESIA 2018. Social impacts were assigned a risk rating, aligned with the *AS/NZS 120 31000:2009 risk management – principles and guidelines* (Standards Australia/Standards New Zealand, 2009). Significance ratings took account of the predicted extent and duration of impacts and subjective judgement of likely community perceptions. Some risk ratings assumed an amplified significance given the project would operate in a remote area.

An overview of the risk rating assessment framework is provided in Figure 1 and Figure 2 below.

| | | Consequence Level | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Likelihood | Descriptor | Insignificant | Minor | Moderate | Major | Extreme |
| A | Almost certain | A1 | A2 | A3 | A4 | A5 |
| B | Likely | B1 | B2 | B3 | B4 | B5 |
| C | Possible | C1 | C2 | C3 | C4 | C5 |
| D | Unlikely | D1 | D2 | D3 | D4 | D5 |
| E | Rare | E1 | E2 | E3 | E4 | E5 |

***Figure 1** Risk rating assessment: categorisation of likelihood and consequence levels to assess impacts for study (ESIA, 2018)*

| | |
|---|---|
| Extreme | Intolerable – risk reduction is mandatory wherever practicable. Residual risk can be accepted only if endorse by senior management. |
| High | Intolerable or tolerable if managed to as low as reasonably practicable – Senior Management accountability |
| Medium | Intolerable or tolerable if managed to as low as reasonably practicable – management responsibility |
| Low | Tolerable – maintain systematic controls and monitor |

*Figure 2 Risk response table*

A description of the consequence and likelihood levels is provided in Table 1, as defined in the ESIA 2018.

*Table 1 Consequence and likelihood description (ESIA 2018)*

| Level | Description |
|---|---|
| **Consequence descriptors used for negative socioeconomic impacts** | |
| Insignificant | Local, small-scale, easily reversible change on social characteristics or values of the communities of interest or communities can easily adapt or cope with change. |
| Minor | Short-term recoverable changes to social characteristics and values of the communities of interest or community have substantial capacity to adapt and cope with change. |
| Moderate | Medium-term recoverable changes to social characteristics and values of the communities of interest or community have capacity to adapt and cope with change. |
| Major | Long-term recoverable changes to social characteristics and values of the communities of interest or community have limited capacity to adapt and cope with change. |
| Catastrophic | Irreversible changes to social characteristics and values of the communities of interest or community have no capacity to adapt and cope with change. |
| **Consequence descriptors for beneficial impacts** | |
| Insignificant | Local small-scale opportunities emanating from the project that the community can readily pursue and capitalise on. |
| Minor | Short-term opportunities emanating from the project. |
| Moderate | Medium-term opportunities emanating from the project. |
| Major | Long-term opportunities emanating from the project. |
| **Likelihood descriptors** | |
| Almost certain | The event is expected to occur in most circumstances; could occur at least once during a project of this nature; 91-100% chance of occurring during the project. |
| Likely | The event will probably occur in most circumstances; this event could occur up to once during a project of this nature; 51-90% chance of occurring during the project. |
| Possible | The event could occur but not expected; this event could occur up to once every 10 projects of this nature; 11-50% chance of occurring during the project. |
| Unlikely | The event could occur but is improbable; this event could occur every 10-100 projects of this nature; 1-10% chance of occurring during the project. |
| Rare | The event may occur only in exceptional circumstances; this event is not expected to occur except under exceptional circumstances (up to once every 100 projects of this nature); less than 1% chance of occurring during the project. |

Further detail regarding the methodology used in this assessment can be found in the ESIA 2018.

# 3. Overview of Existing Environment

An overview of the existing environment was provided in the ESIA 2018. This included the following areas:

– Regional areas of Tennant Creek, Barkly, and Sandover-Plenty (Statistical Area 2).
– Indigenous locations of Ampilatwatja, Utopia and Arlparra, Imangara (Murray Downs), and Ali Curung (Indigenous locations – ILOCs).
– Surrounding pastoral stations (including Ammaroo Station, Neutral Junction, Murray Downs, and Epenarra).

The ESIA 2018 was prepared using ABS Census data from 2011 and 2016. This SIA Addendum has updated ABS Census data from 2011, with 2016 and where available, 2021 census data, to understand the current social baseline conditions. This data is shown in Table 2, and a summary of the key changes in the social context at each location is provided in Table 3.

*Table 2 Population profile – Regional area (ABS Census 2011, 2016, 2021)*

| Area | TENNANT CREEK (SA2) | | | BARKLY (SA2) | | | SANDOVER- PLENTY (SA2) | | | Ampilatwatja (ILOC) | | | Utopia/Arlparra (ILOC) | | | Imangara (Murray Downs) (ILOC) | | | Ali Curung (ILOC) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Indicator:** | 2011 | 2016 | 2021 | 2011 | 2016 | 2021 | 2011 | 2011 | 2011 | 2011 | 2016 | 2021 | 2011 | 2016 | 2021 | 2011 | 2016 | 2021 | 2011 | 2016 | 2021 |
| **Population and demography** | | | | | | | | | | | | | | | | | | | | | |
| Population | 3,061 | 2,991 | 3,080 | 2,660 | 2,539 | 2,203 | 3,727 | 4,034 | 3,912 | 371 | 462 | 425 | 483 | 401 | 372 | 90 | 54 | 60 | 486 | 444 | 347 |
| Male | 49.8% | 52.60% | 50.90% | 51% | 51.90% | 51.20% | 56% | 54.90% | 55.90% | 51.8% | 48.70% | 48.90% | 47% | 46,2% | 43.20% | 47% | 50.00% | 44.60% | 46% | 49.90% | 49.30% |
| Female | 50.2% | 47.40% | 49.10% | 49% | 48.10% | 48.80% | 44% | 45.10% | 44.10% | 48.5% | 51.30% | 51.10% | 53% | 53.80% | 56.80% | 53% | 50.00% | 55.40% | 54% | 50.00% | 50.70% |
| Aboriginal and Torres Strait Islander | 52% | 51.30% | 55.40% | 78.60% | 77.50% | 72.40% | 87.90% | 84.50% | 84.70% | N/A | N/A | 90.00% | N/A | N/A | 83.80% | N/A | N/A | N/A | N/A | N/A | 88.10% |
| Median age | 32 | 33 | 33 | 25 | 26 | 26 | 28 | 28 | 30 | 21 | 20.00 | 23 | 24 | 23.00 | 25 | 20 | 27 | 18 | 21 | 23 | 21 |
| **Linguistic and cultural diversity** | | | | | | | | | | | | | | | | | | | | | |
| Language other than English spoken at home | 39.70% | 46% | 47.10% | 62.50% | 62.20% | 60.30% | 83% | 85% | 80.90% | 98.40% | 97% | 96.50% | 95.40% | 96.00% | 96.50% | N/A | N/A | N/A | 73% | 78% | 83.00% |
| Top spoken language | Warumungu | Warumungu | Warumungu | Alyawarr | Alyawarr | Alyawarr | Alyawarr | Alyawarr | Alyawarr | Alywarr | Alyawarr | Alyawarr | Alyawarr | Alyawarr | Alyawarr | N/A | N/A | N/A | Warlpiri | Warlpiri | Warlpiri |
| Overseas born | 20.20% | 25.60% | 24.30% | 6.10% | 7.60% | 8.20% | 3% | 7.30% | 7.30% | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Employment** | | | | | | | | | | | | | | | | | | | | | |
| Unemployment rate | 7.10% | 7.10% | N/A | 11.50% | 24.30% | N/A | 19% | 42.60% | N/A | 43.90% | 88.90% | N/A | 26.80% | 72.40% | N/A | N/A | N/A | N/A | 19% | 37.90% | N/A |
| Top industry of employment | Local government | State government | N/A | Sheep, Beef cattle and grain farming | Beef cattle farming | N/A | Local government | Local government | N/A | N/A | Local government | N/A | N/A | Local government | N/A | N/A | N/A | N/A | N/A | Creative Artists, Musicians, Writers, and Performers | N/A |
| Median weekly income (personal) | $632 | 650 | 671 | 278 | 349 | 416 | 246 | 265 | 356 | $161 | 225 | 396 | 168 | 230 | 373 | N/A | N/A | N/A | 244 | 237 | 368 |
| **Education** | | | | | | | | | | | | | | | | | | | | | |
| Highest level of educational attainment | | Year 9 or below | N/A | | Year 9 or below | N/A | | Year 9 or below | N/A | N/A | Year 10 | N/A | N/A | Year 9 or below | N/A | N/A | N/A | N/A | N/A | Year 9 or below | N/A |
| **Dwelling** | | | | | | | | | | | | | | | | | | | | | |
| Dwelling count | 1,259 | 1,444 | 1,395 | 922 | 1,129 | 1,158 | 978 | 1,132 | 1,290 | 47 | 54 | 50 | 74 | 68 | 66 | 15 | 12 | 14 | 70 | 70 | 61 |
| Occupancy | 79.70% | 70.30% | 83.20% | 77.20% | 64.90% | 64.70% | 73.30% | 77.30% | 74.10% | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Rented | 57% | 63.7 | 59.1 | 80.70% | 79.50% | 56.60% | 77.30% | 75.70% | 62.40% | 94% | 73.80% | 82% | 93.40% | 63.50% | 68.20% | N/A | N/A | N/A | 100.00% | 95.50% | 90.20% |
| People per household | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 5.8 | 6.3 | 6.1 | 5.6 | 5.1 | 5.1 | 5.4 | 4.1 | 4.1 | 5.8 | 5 | 5.2 |
| **Socio-economic disadvantage** | | | | | | | | | | | | | | | | | | | | | |
| SEIFA (IRSAD) | 1 | 1 | N/A | 1 | 1 | N/A | 1 | 1 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

*Table 3 Summary of change in population – 2011, 2016, and 2021*

| Area | Summary of changes |
|---|---|
| Tennant Creek (SA2) | Since ESIA 2017, Tennant Creek has changed through:<br>– An increase in Aboriginal and Torres Strait Islander population from 52% in 2011, to 55.4% in 2021.<br>– An increase in the proportion of people speaking a language other than English at home, from 39.7% in 2011, to 46% in 2016.<br>– An increase in the proportion of the population who were born overseas, from 20.2% in 2011 to 25.6% in 2016.<br>– A stable unemployment rate, which was stable between 2011 and 2016 (both 7.1%)<br>– The largest industry of employment was local government in 2011, which became state government in 2016.<br>– A greater rate of dwelling occupancy in 2021 (83.2%) compared to 2016 (70.3%). |
| Barkly (SA2) | Since ESIA 2017, the change in Barkly population can be characterised by:<br>– A decrease in population between 2016 (2,539 people) and 2021 (2,203 people)<br>– A decrease in the proportion of the population who identify as Aboriginal or Torres Strait Islander between 2016 (77.5%) and 2021 (72.4%).<br>– An increase in the unemployment rate, from 11.5% in 2011 to 24.3% in 2016.<br>– A reduction in housing occupancy, with 77.2% of dwellings occupied in 2011, compared to 64.7% in 2021. |
| Sandover-Plenty (SA2) | The change in the Sandover-Plenty population can be characterised by:<br>– An increase in the median age from 28 years old in 2016 to 30 years old in 2021.<br>– A decrease in the proportion of population who speak a language other than English at home, from 85% in 2016 to 80.9% in 2021.<br>– An increase in unemployment, from 19% in 2011 to 42.6% in 2016. |
| Ampilatwatja (ILOC) | The population in Ampilatwatja and surrounding outstations has changed through:<br>– A fluctuating population, which was 371 people in 2011, 462 people in 2016 and 425 in 2021<br>– An increase in the median age, from 20 years old in 2016 to 23 years old in 2021.<br>– An increase in unemployment, from 43.9% in 2011 to 88.9% in 2016.<br>– A fluctuation in the number of people per household, which increased from 5.8 people per house in 2011, to 6.3 in 2016. This decreased again to 6.1 in 2021, which aligns with the fluctuation in population.<br>– An increase in the proportion of households who are renting, from 73.8% in 2016 to 82% in 2021. |
| Utopia and Arlparra (ILOC) | The population of Utopia and Arlparra can be characterised by:<br>– A decrease in population, from 483 people in 201 to 372 people in 2021.<br>– An increase in the unemployment rate, which was 26.8% in 2011 and was 72.4% in 2016. |
| Imangara (ILOC) | The population of Imangara decreased from 90 people in 2011 to 60 people in 2021. No other change was able to be identified due to the small size of the datasets. |
| Ali Curung (ILOC) | The population of Ali Curung can be characterised by:<br>– A decrease in total population from 486 people in 2011 to 347 people in 2021.<br>– An increase in the proportion of the population who spoke a language other than English at home, from 73% in 2011 to 83% in 2021.<br>– An increase in unemployment, from 19% in 2011 to 37.9% in 2016.<br>– A decrease in the average number of people per household, from 5.8 in 2011, to 5 in 2016, and 5.2 in 2021. |

Other demographic indicators were consistent between ABS Census data in 2011, 2016, and 2021.

The 2016 Socio-economic Indicators for Areas (SEIFA) Index of Relative Socio-Economic Advantage and Disadvantage (IRSAD) ranked Tennant Creek, Barkly, and Sandover-Plenty with a decile of one, which indicates a high level of economic disadvantage. A high level of socio-economic disadvantage indicates that residents have a number of vulnerabilities and may be more sensitive to changes in their environment.

There were no significant changes to the surrounding pastoral stations between 2011 and 2021. However, it should be noted that events such as flooding, drought, and COVID-19 may have impacted the operation of some stations.

# 4. Consultation

An overview of the consultation process undertaken to inform relevant stakeholders about the Referral of Significant Variation is provided in section 9 of the Referral. Consultations were conducted in June 2022 in Ampilatwatja, Tennant Creek and Alice Springs, and involved engagement with:

- Department of Chief Minister and Cabinet.
- NT Chamber of Commerce.
- Barkly Regional Council.
- Central Land Council.
- Arid Lands Environment Centre.
- Saltbush Social Enterprise.
- Nearby pastoral stations.
- Services and community residents in Ampilatwatja.

Key outcomes of the consultation that are relevant to this SIA Addendum are found in Table 4.

*Table 4 Consultation outcomes relevant to SIA Addendum*

| Theme | Summary of feedback |
|---|---|
| Overall project sentiment | – Stakeholders engaged in Ampilatwatja, and Tennant Creek were overall positive about the project, supportive of it proceeding, and did not report concern regarding the Proposed project description.<br>– Support for the project due to the employment opportunities from the local community in Ampilatwatja, and the positive impact of access to benefit payments for the community. |
| Current challenges and opportunities | – It was identified that key challenges for the region was attracting and retaining skilled workforce, particularly in Tennant Creek and Alice Springs.<br>– There are a number of concurrent and proposed major projects in the Barkly region, which may put further pressure on skilled workforce and businesses in the area.<br>– There is potential for major projects in the area to provide procurement opportunities for local businesses and contractors.<br>– There are limitations to current housing and infrastructure in Ampilatwatja and Tennant Creek to house population growth. |
| Concerns | Some stakeholders raised the following concerns regarding the project:<br>– Concern was raised regarding potential for the project to draw workforce from local businesses (particularly in Tennant Creek and Alice Springs).<br>– The use of groundwater, with some stakeholders noting community were more concerned about impacts of groundwater extraction compared to 2018.<br>– Potential for road traffic accidents or degradation of road conditions, due to construction and operation traffic. It was noted that the sensitivity to road incidents has increased, particularly for Ampilatwatja and Ammaroo Station, since 2018. |

These outcomes have been incorporated, where relevant, into the assessment of socio-economic impacts in section 5.

# 5. Assessment of Potential Socio-Economic Impacts

This section provides an overview of the socioeconomic impacts identified in the ESIA 2018, and the change to these social impacts as a result of the Proposed Project. The same risk rating and assessment has been applied as in the ESIA 2018 (see section 2). It should be noted that the ESIA 2018 risk rating is the residual risk, after mitigation and management measures had been applied.

*Table 5 Assessment of socio-economic impacts*

| Impact category | Summary of impact identified in original SIA (Approved Project) | Stakeholders affected | Project phase | Risk rating (initial) | Updated social impact (Proposed Project) | Updated risk rating | Recommended mitigation measures | Residual risk rating |
|---|---|---|---|---|---|---|---|---|
| **People and communities** | | | | | | | | |
| Community cohesion | Improved community vitality in towns such as Tennant Creek due to increased population and spending. | Tennant Creek | Operation | Positive Low | No change to this impact is expected as a result of the Proposed Project. | Positive Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – People and Communities). | Positive Low |
| Community cohesion | Reduced community cohesion and resilience due to changed demographic composition | Ampilatwatja | Operation | Negative Low | The Proposed project would require a larger workforce during both construction and operation. This could attract some people to move to Ampilatwatja, which may further reduce community cohesion for residents. However, given a large proportion of the workforce is expected to be FIFO, any additional change to community cohesion is expected to be minimal. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – People and Communities). | Negative Low |
| Community cohesion | Reduced community cohesion and resilience due to tensions over who receives project benefits | Ampilatwatja | Operation | Negative Medium | The Proposed project would increase the benefit payments made to Traditional Owners under the Native Title Agreement. This increase in the value of payments may contribute to tensions between community/family groups over who receives the benefits and who would miss out, further reducing community cohesion. Consultation for the SIA conducted in 2022 indicated that the community was concerned about the Native Title Agreement, how it would be governed and who would be receiving payments. | Negative Medium | In addition to mitigation measures recommended in ESIA 2018 (see Table 6 – People and Communities), Verdant Minerals will continue to work with the Traditional Owners and Central Land Council to finalise the Native Title Agreement and governing structure and identify the opportunities for community benefits, such as creation of a community benefit fund. | Negative Medium |
| Community cohesion | Reduced community cohesion and resilience due to any increase in crime and antisocial behaviour. | Ampilatwatja | Construction and operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – People and Communities). | Negative Low |
| Community cohesion/Social networks | Local people working on rosters with the project and away from home, reducing community and emergency volunteers and participation in sporting activities. | Tennant Creek and Ampilatwatja | Construction and operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – People and Communities). | Negative Low |
| **Economies** | | | | | | | | |
| Business | Increased pastoral productivity because of project infrastructure, such as new bores opening up more grazing land, road and rail transport improving access to markets. | Nearby pastoral stations | Operation | Positive Low | No change to this impact is expected as a result of the Proposed project. | Positive Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy). | Positive Low |
| Business | Contracts awarded to local businesses meet local content expectations, deliver economic benefits and capacity building, particularly for small businesses and Aboriginal-owned enterprises. | Businesses in Tennant Creek and Alice Springs | Construction and operation | Positive Medium | The proposed project would require a larger number and variety of goods and services to sustain the production of fertiliser on site. This would increase opportunities for local businesses, and provide economic benefit to these businesses, in the short-and long-term during construction and operation. Consultation for the SIA indicated local businesses in Alice Springs and Tennant Creek would have interest and capacity to work with the project, however, would require preparation to be able to service large contracts. | Positive Medium | In addition to mitigation measures identified in the ESIA 2018, (see Table 6 – Economy) a Local Industry Participation Plan is developed as part of the approved project to reflect the increase in potential opportunities for local businesses, including avenues for training and upskilling support provided to the businesses. | Positive High |
| Economy | Payments to contractors and workers stimulates the regional economy and GSP. | Barkly Region, Alice Springs, and Darwin | Construction and operation | Positive Medium | Due to the increased scale of the proposed project, the workforce requirements for the proposed project would increase from 300 to 1,600 jobs during construction, and 165 to 400 jobs during operation. A larger number of | Positive High | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy) | Positive High |

| Impact category | Summary of impact identified in original SIA (Approved Project) | Stakeholders affected | Project phase | Risk rating (initial) | Updated social impact (Proposed Project) | Updated risk rating | Recommended mitigation measures | Residual risk rating |
|---|---|---|---|---|---|---|---|---|
| | | | | | contractors would also be required to supply goods and services (see above). This is likely to increase the economic benefit for the Barkly Region, Alice Springs, and Darwin. | | | |
| Economy | Mobilisation of construction and operations workforce potentially leading to relocation of families to the region, e.g., Alice Springs and Tennant Creek, promoting regional growth and increasing economic activity in the region. | Alice Springs and Tennant Creek | Construction and operation | Positive Low | No change to this impact is expected as a result of the Proposed project. | Positive Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy). | Positive Low |
| Business | Reduced pastoral productivity because of impacts of weeds, erosion and disruptions to operations and mustering from dust, noise, and increased project traffic on properties. | Nearby pastoral stations | Construction and operation | Negative Moderate | No change to this impact is expected as a result of the Proposed project. | Negative Moderate | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy). | Negative Moderate |
| Business | Reduced pastoral productivity because of impacts on groundwater. | Nearby pastoral stations | Operation | Negative Low | The Proposed Project would require more groundwater to support downstream processing activities. This would lead to more groundwater extraction and a larger drawdown area. Although this would involve more water being used from groundwater bores shared by nearby pastoralists, consultation for the SIA in 2022 indicated they were not concerned about the increase in groundwater use. Groundwater Modelling prepared by Innovative Groundwater Solutions (2022) showed that the increase in water use required for the Proposed project would not lead to significant changes to the drawdown predicted for the Approved Project. | Negative Low | In addition to the mitigation measures identified in the ESIA 2018 (see Table 6 – Economy) Verdant Minerals will work with pastoralists to monitor groundwater and any potential impacts to pastoral productivity (in alignment with recommended mitigation measures made by Innovative Groundwater Solutions (2022)).<br>Consultation for the SIA indicated that there was opportunity for more engagement with pastoralists. Therefore, a Community and Stakeholder Engagement Plan is recommended for the project, to manage ongoing communication with key stakeholders, like pastoral stations. | Negative Low |
| Business | Loss of experienced staff from other employers to the project and difficulty backfilling positions. | Businesses in Darwin, Tennant Creek, and Alice Springs | Construction and operation | Negative Low | The Proposed project would require a large workforce during both construction and operation. This would increase the likelihood for workforce draw of skilled workers in Tennant Creek, Alice Springs, and Darwin as they may be attracted to work for the project due to higher wages or for a different work experience. Consultation for the SIA in 2022 indicated there were challenges with attracting and retaining staff at businesses, particularly in the Barkly Region where there are a number of major projects operating concurrently. Businesses are therefore likely to be sensitive to workforce draw and may struggle to backfill positions. This could affect the ability for the business to operate at normal capacity. | Negative High | Given the increased sensitivity of local businesses to workforce draw, in addition to the mitigation measures identified in the ESIA 2018 (see Table 6 – Economy), more consultation with regional stakeholders and potential proponents in the region is recommended. Collaboration with key government agencies and stakeholders will be required to manage the attraction and retention of skilled workforce to backfill any positions created. | Negative Medium |
| Economy | Inflationary pressures through scarcity of goods, pressure on housing affordability and availability. | Barkly Region | Operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | N/A | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy) | Negative Low |
| Business | Frustration and dashed expectations if local targets are not met due to lack of capacity or skills. | Businesses in Tennant Creek and Alice Springs | Construction and operation | Negative Medium | The requirements for goods and services would increase as a result of the increase in of the proposed project (see above). Although this would potentially provide more opportunity for local businesses, it would also increase the expectations in community for local procurement. This may increase the likelihood of frustration from community if expectations for local procurement are not met due to lack of capacity or skills required. | Negative High | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy).<br>A Local Industry Participation Plan will provide a framework for economic opportunities to local businesses. | Negative Medium |
| Business | Short-term construction period creates 'boom bust', with risk of over-capitalisation by small companies to win work. | Businesses in Tennant Creek and Alice Springs | Construction | Negative Low | The construction period would increase from two years in the Approved project, to at least three years for the Proposed project due to the scale of infrastructure required. This would provide opportunities as businesses would have a longer period to procure and deliver work. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy). | Negative Low |
| Industry | Displacement of tourism by FIFO workers taking up short-term accommodation in transit | Barkly Region | Construction and operation | Negative Low | The workforce required for the proposed project would increase from 300 to 1,600 jobs during construction, and from 165 to 400 jobs during operation. The proposed | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy). | Negative Low |

| Impact category | Summary of impact identified in original SIA (Approved Project) | Stakeholders affected | Project phase | Risk rating (initial) | Updated social impact (Proposed Project) | Updated risk rating | Recommended mitigation measures | Residual risk rating |
|---|---|---|---|---|---|---|---|---|
| | towns (such as Tennant Creek) or taking up seats on planes. | | | | project also includes an airfield, to enable direct transport of workers to site from transit towns. This would increase the amount of FIFO workers travelling to and from transit towns. Consultation for the SIA indicated that there is a current shortage in available short term and temporary accommodation in Darwin. The presence of FIFO workers may decrease the availability of short-term accommodation available for tourists, particularly during peak times. | | | |
| Economy | N/A | | Operation | | The project would benefit Traditional Owners and remote communities through the creation of significant employment opportunities together with the Native Title Agreement and the associated increase in income. | Positive High | In addition to mitigation measures identified in the ESIA 2018, (see Table 6 – Economy) Verdant Minerals will work with Traditional Owners via the Central Land Council to finalise the Native Title Agreement, and to maximise economic benefits of the project for local Traditional Owner families. Verdant Minerals will continue to work with the CLC to provide support to Traditional Owners for governance arrangements of benefit payments. | Positive High |
| Business | N/A | | Construction and operation | | The proposed rail spur would transect pastoral land, currently utilised for cattle grazing by a neighbouring pastoral station. This would require the pastoralists to alter the grazing patterns of their cattle. During consultation, the pastoral station indicated they would still be able to use the area, provided water sources were made available for the cattle on each side of the rail spur. There is therefore limited risk of severance or interruption to pastoral activities as a result of the rail spur.<br>The operation of the rail line would increase the likelihood of cattle strikes for neighbouring pastoralists. This may be an economic loss for the pastoral station. | Negative Low | To mitigate potential identified issues to cattle grazing activities, Verdant Minerals will ensure water is suppled on both sides of the rail spur in any areas where ease of access is limited.<br>In addition to mitigation measures identified in the ESIA 2018 (see Table 6 – Economy), Verdant Minerals will engage local pastoral stations to manage any additional impacts to pastoral activities that may arise during operation of the project, including management of the rail line. | Negative Low |
| Business | N/A | | Construction and operation | | The FIFO workforce requirements would increase as a result of the Proposed Project (see above). Some business in Darwin and Alice Springs may experience an increase in patronage and expenditure as FIFIO workers transit from site to their source communities. This would provide an increase in revenue for some businesses, particularly those in the retail and hospitality industry. | Positive Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Economy) | Positive Low |
| **Employment and education** | | | | | | | | |
| Employment | Mobilisation of workforce leads to jobs (including apprenticeships) for local people throughout the supply chain, including traditional owners, such as civil work, trades, administration, rehabilitation, and longer-term operational jobs. | Skilled workers in Darwin, Alice Springs, and Tennant Creek | Construction and operation | Positive Medium | The Proposed Project would result in an increase in direct and indirect employment opportunities for skilled workers, in both construction (increasing from 300 to 1,600 workers) and operation (increasing from 165 to 400 workers). This would benefit skilled workers in Darwin and Alice Springs. Residents in Ampilatwatja may also benefit from the increase in local employment opportunities, provided they have the necessary skills or training. However, most residents are not expected to have the required skills, so the benefit to Ampilatwatja residents is likely to be the same as assessed in ESIA 2018. | Positive Medium | In addition to mitigation measures identified in the ESIA 2018 (see Table 6 – Employment and education), Verdant Minerals will prepare a local Indigenous Employment Participation Plan to reduce barriers to employment, provide adequate training and job-readiness, and maximise employment opportunities for Ampilatwatja residents. | Positive High |
| Employment | Jobs for local Aboriginal people draw on traditional knowledge and provide opportunities for jobs and business ventures in progressive rehabilitation and land management, e.g., through expanded or new ranger groups, collecting and growing seedlings for nurseries. | Nearby Aboriginal communities | Operation | Positive High | No change to this impact is expected as a result of the Proposed Project. | Positive High | In addition to mitigation measures identified in the ESIA 2018 (see Table 6 – Employment and education), Verdant Minerals will prepare a local Indigenous Employment Participation Plan to support long term employment opportunities for rehabilitation and land management. | Positive High |

| Impact category | Summary of impact identified in original SIA (Approved Project) | Stakeholders affected | Project phase | Risk rating (initial) | Updated social impact (Proposed Project) | Updated risk rating | Recommended mitigation measures | Residual risk rating |
|---|---|---|---|---|---|---|---|---|
| Employment | Unmet expectations of local employment, due to a lack of work-readiness, structural (e.g., transport) or cultural issues. | Nearby Aboriginal communities and Barkly region | Construction and operation | Negative Medium | The proposed increase in workforce requirements (see above) could increase the expectations for local employment for some residents, particularly in Ampilatwatja. This could lead to frustration in community should their expectations not be met. | Negative Medium | Greater investment in mitigation measures identified in the ESIA 2018 (see Table 6 – Employment end education) would manage this impact. In addition to these mitigation measures, Verdant Minerals will prepare a Local Indigenous Employment Participation Plan to maximise employment opportunities for Ampilatwatja residents.<br>The Local Indigenous Employment Participation Plan will include a training plan, to identify gaps in required skills and provide opportunities for apprenticeships where appropriate. | Negative Low |
| **Infrastructure and social services** | | | | | | | | |
| Access to infrastructure and services | Project activities includes residual infrastructure that benefits the community, e.g., telecommunications, or spending on shared infrastructure such as roads. | Nearby Aboriginal communities and pastoral stations | Operation | Positive Medium | In addition to the infrastructure identified in the approved project, the Proposed project would include an airfield on site. The airfield would not be accessible for use by residents and the community for transport, however it could be made available for emergency evacuation by Northern Territory Emergency Services and Fire and Rescue Services. This would benefit communities in the area surrounding the project site in the case of an emergency whilst the project is operational. | Positive Medium | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Infrastructure and social services). | Positive Medium |
| Social infrastructure | Distribution of benefits increases investment in community infrastructure in nearby communities, such as sporting facilities. | Nearby Aboriginal communities and pastoral stations | Operation | Positive Low | The project would result in an increase in incomes through employment and the benefits paid to Traditional Owners through the Native Title Agreement. This may increase the opportunity for investment in social infrastructure, which would benefit the wider Ampilatwatja community. | Positive Medium | In addition to mitigation measures identified in the ESIA 2018 (see Table 6 – Infrastructure and social services), Verdant Minerals will continue to work with Traditional Owners and the Central Land Council to finalise the Native Title Agreement, to ensure benefits can be spent on upgrades to community infrastructure that would improve the Ampilatwatja community.<br>Verdant Minerals will also consider investment in a community benefit fund. | Positive Medium |
| Increased demand in social infrastructure | Workforce puts pressure on social infrastructure through increased demand, such as transport, and health, creating budgetary pressures for service providers (Government and Council). | Barkly region | Construction and operation | Negative Low | Increase in project construction and operation workforce numbers is unlikely to increase demand for social infrastructure services in nearby communities, like Tennant Creek, because most services will be provided at project workforce accommodation. In case of emergency, medical facilities will be accessed at Alice Springs or Darwin via air ambulance. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Infrastructure and social services). | Negative Low |
| Increased demand in social infrastructure | Pressure on policing and emergency services through increased crime, alcohol abuse, road trauma, chemical spills, or bushfires. | Nearby Aboriginal communities and pastoral stations | Construction and operation | Negative Medium | Increase in the construction and operation workforce on site may increase chances of occurrence of antisocial behaviour or safety incident. This may increase demand for emergency services in the local area to respond to such incidences. The site would be staffed with additional emergency services personnel and equipment, to respond to safety incidents on site. However, emergency service providers in the area, particularly police, may notice an increase in demand. | Negative Medium | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Infrastructure and social services and People and communities). | Negative Medium |
| Increased demand in social infrastructure | Pressures on already overcrowded public housing if people return to live with families or are displaced from private rental properties in Tennant Creek due to higher rents. | Tennant Creek | Operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Infrastructure and social services). | Negative Low |
| Increased demand in infrastructure | Pressure on road and transport infrastructure | Nearby Aboriginal communities and pastoral stations | Construction and operation | Negative Medium | As identified in the *Traffic Impact Assessment Addendum,* the Proposed project would involve a decrease in daily light vehicle movements (from 34 to 20 movements), and an increase in heavy vehicle movements (from 57 to 123 movements). This would lead to an increase in heavy vehicle traffic on local roads. The presence of increased heavy vehicles on the roads may cause increased wear and tear of the road, which | Negative Medium | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Infrastructure and social services). | Negative Low |

| Impact category | Summary of impact identified in original SIA (Approved Project) | Stakeholders affected | Project phase | Risk rating (initial) | Updated social impact (Proposed Project) | Updated risk rating | Recommended mitigation measures | Residual risk rating |
|---|---|---|---|---|---|---|---|---|
| | | | | | may in turn cause inconvenience and safety concerns for other road users. | | | |
| **Health, wellbeing, and safety** | | | | | | | | |
| Health | Improved health outcomes through higher incomes and access to health promotion programs, drug, and alcohol testing. | Nearby Aboriginal communities and Tennant Creek | Construction and operation | Positive N/A | No change to this impact is expected as a result of the Proposed project. | Positive N/A | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Health, wellbeing, and safety). | Positive N/A |
| Safety | Road safety risks from interaction between industrial and local traffic on locals' roads, including increased risk to other road users, including pedestrians and cattle on the road. | Nearby Aboriginal communities and pastoral stations | Construction and operation | Negative High | As identified in the *Traffic Impact Assessment Addendum,* there Proposed project would involve a decrease in daily light vehicle movements (from 34 to 20 movements), and an increase in heavy vehicle movements (from 57 to 123 movements) during construction and operation. This could decrease perception of road safety for other road users. This was raised as a concern during consultation for the SIA. | Negative Medium. | In addition to the mitigation measures identified in the ESIA 2018 (see Table 6 – Health, wellbeing, and safety), ongoing engagement between Verdant Minerals and government stakeholders regarding upgrades to the local road network. The Project will also have traffic management protocols. This could include traffic safety awareness campaigns and notifying other road users of oversized vehicles approaching or changes to traffic conditions. | Negative Low |
| Safety | Road safety risks from interaction between industrial and local traffic on locals' roads, safety risk to workers driving after shifts | DIDO workers | Construction and operation | Negative Low | The proposed project will include an airfield on site and will accommodate all workforce on site, which would reduce the need for light vehicle movements between site and the nearest airstrip. This would decrease the number of daily light vehicle movements during construction and operation (from 34 to 20 movements) and reduce the requirement for workers driving off-site after shifts. This would decrease the road safety risk for workers and other road users. | Negative Low | - | Negative Low |
| Safety | Binge drinking or alcohol abuse by local and FIFO workers leads to increased crime, anti-social behaviour. | Nearby Aboriginal communities and pastoral stations | Construction and operation | Negative Low | Increase in construction and operation workforce on site may increase the chance of antisocial behaviour. This may decrease feelings of safety for some workers, nearby pastoralists, and Aboriginal communities. However, interactions between local residents and the workforce would be limited. Therefore, any impacts to feelings of safety are expected to be minimal and will be managed through communication with Verdant and the community. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Health, wellbeing and safety and People and communities). | Negative Low |
| Safety | Thefts and vandalism of project equipment | Nearby Aboriginal communities and pastoral stations | Construction and operation | Negative Medium | No change to this impact is expected as a result of the Proposed project. | Negative Medium | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Health, wellbeing and safety and People and communities). | Negative Medium |
| Safety | Use of project access and haul roads for illicit activities such as grog-running | Nearby Aboriginal communities and pastoral stations | Construction and operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Health, wellbeing, and safety. | Negative Medium |
| Wellbeing | Mental health issues for workers spending long periods away from home and family. | FIFO workers | Construction and operation | Negative Medium | Increase in FIFO construction and operation workforce on site may increase the chances of mental health issues for some workers. However, a larger number of workers living on site at the accommodation would enable greater opportunity for social interactions and promote organized recreational activities, such as sport. This could contribute positively to the experience of some FIFO workers whilst on site and away from their families. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Health, wellbeing, and safety). | Negative Low |
| Wellbeing | Fears or negative perceptions on community amenity and wellbeing from dust, industrial activity, visual amenity, light pollution, noise from the project, changed sense of place or fears of contaminated ground water. | Nearby Aboriginal communities and pastoral stations | Construction and operation | Negative Low | The Proposed project would result in a greater amount of infrastructure on site. Views of project infrastructure would alter the landscape and could affect overall amenity and character of the area.<br>The proposed project would also include the operation of an airfield. The *Noise Impact Assessment* (2022) found that this would not lead to a noticeable increase in noise levels for local residents. However, consultation for the SIA in 2022 indicated some residents were concerned | Negative Low | In addition to the mitigation measures identified in the ESIA 2018 (see Table 6 – Health, wellbeing, and safety), develop a Community and Stakeholder Engagement Plan that includes updates to the Ampilatwatja community and surrounding pastoral stations regarding potential amenity changes.<br>Establish an ongoing dialogue and avenue to capture potential issues and concerns with the operation of the | Negative Low |

| Impact category | Summary of impact identified in original SIA (Approved Project) | Stakeholders affected | Project phase | Risk rating (initial) | Updated social impact (Proposed Project) | Updated risk rating | Recommended mitigation measures | Residual risk rating |
|---|---|---|---|---|---|---|---|---|
| | | | | | about potential noise generated from airplanes. Therefore, there may be a perception of increase in noise level and potential disturbance to local lifestyle.<br>Actual or perceived impacts to visual amenity and noise may lead to frustration for some individuals, particularly Traditional Owners who may be more sensitive to amenity changes. However, given the distance between the project and the nearest community (about 25 kilometres), most residents are not expected to be impacted, or are expected to adapt to these changes over time. | | airfield on surrounding stakeholders in the long-term and undertake noise monitoring if required. | |
| **Culture and heritage** | | | | | | | | |
| Culture | Community investment from the project contributes to cultural activities such as cross-cultural education of workers, arts, music, local festivals, and sports events. | Nearby Aboriginal communities | Operation | Positive N/A | No change to this impact is expected as a result of the Proposed project. | Positive N/A | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Culture and heritage). | Positive |
| Heritage | Any loss of cultural heritage, such as damage to sacred sites, impacting on cultural and spiritual connections. | Nearby Aboriginal communities | Construction and operation | Negative Medium | No change to this impact is expected as a result of the Proposed project. | Negative Medium | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Culture and heritage). | Negative Medium |
| Culture | Reduced traditional activities such as hunting, camping, foraging, bush medicines or art as a result of biodiversity loss or reduced access to land | Nearby Aboriginal communities | Construction and operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Culture and heritage) | Negative Low |
| **Environment** | | | | | | | | |
| Water | Project evokes negative perceptions towards the use of water by mining in an arid area that may have other beneficial users, including concerns about cultural and aesthetic values of water. | Barkly and Sandover region | Construction and operation | Negative Low | The Groundwater Modelling conducted by Innovative Groundwater Solutions (2022) indicated that although more groundwater would be required to operate the Proposed project, there would be no significant change to the drawdown by the approved project However, consultation for the SIA indicated that some people are concerned about the increase in groundwater use. This may increase the negative perceptions and concerns from stakeholders in the local and regional area. | Negative High | In addition to mitigation measures identified in the ESIA 2018 (see Table 6 – Environment), Verdant Minerals will prepare a Community and Stakeholder Engagement Plan that includes key messaging and engagement with regional stakeholders on the increase in groundwater use, and ongoing reporting on groundwater monitoring results. | Negative Medium |
| Community values | Loss of natural environment that is perceived to reduce place attachment, recreational activities, and natural values. | Barkly and Sandover region | Construction and operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | Impact would be managed through measures recommended in ESIA 2018 (see Table 6 – Environment). | Negative Low |
| **Human Rights** | | | | | | | | |
| | Human rights breaches (including inadvertent) through racism in the workforce, inequitable work practices (such as disadvantaging women), breaches of labour laws (e.g., internships and work experience), including with contractors. | Workforce | Construction and operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | The project will be subject to compliance with Northern Territory and Commonwealth labour law and Native Title Act and measures recommended in ESIA 2018 (see Table 6 – Human Rights). | Negative Low |
| | Native Title Holders not being given the chance to provide free, prior, and informed consent due to lack of time to consider the implications of a project or through inadequate communication. | Traditional Owners | Construction and operation | Negative Low | No change to this impact is expected as a result of the Proposed project. | Negative Low | The project will be subject to compliance with Northern Territory and Commonwealth labour law and Native Title Act and measures recommended in ESIA 2018 (see Table 6 – Human Rights). | Negative Low |

# 6. Recommended Mitigation Measures

The social impacts and opportunities identified and assessed in this report would be managed and mitigated through a range of measures recommended in this report, and by other relevant mitigation measures recommended as part of the Approved Project, and other Referral specialist studies.

Mitigation measures were recommended in the ESIA 2018 and have been summarised in Table 6 below. Additional mitigation measures recommended as a result of the Proposed Project have also been provided below.

*Table 6 Recommended mitigation measures*

| Impact category | Mitigation measures recommended in ESIA 2018 (Approved Project) | Additional mitigation measures recommended for the Proposed Project |
|---|---|---|
| People and communities | – Limiting interaction between FIFO workers and local and regional communities.<br>– A strict Code of Behaviour for all workers.<br>– Strict controls over the consumption of alcohol and any associated misbehaviour in the workers' village.<br>– Limiting cash payments and working with the Central Land Council (CLC) to distribute royalty money in the form of community development, social infrastructure, and education.<br>– Good communication to manage expectations about jobs and 'money' matters. | – Continue to work with the Traditional Owners and Central Land Council to finalise the Native Title Agreement and governing structure.<br>– Identify the opportunities for community benefits, such as creation of a community benefit fund. |
| Economy | – Work closely with the ICN, Chamber of Commerce and Governments to package tenders in a way that suits local businesses (where this is commercially reasonable), communicate opportunities and manage expectations.<br>– Verdant will prepare a Local Industry Participation Plan as part of its obligations under the Project Development Agreement with the NT Government (as a result of being awarded major project status).<br>– In assessing tenders, Verdant will clearly communicate the timing and scale of contracts to minimise the risk of businesses over-capitalising in equipment.<br>– Verdant will contribute to regional training programs that enhance the skills of potential staff, but which may also help other employers backfill positions of staff moving to work at the mine.<br>– Verdant will work closely with pastoralists to share water monitoring data and discuss where production bores might be located to the mutual benefit of both Verdant and pastoralists.<br>– Verdant will liaise with other short-term projects, such as Jemena's Northern Gas Pipeline, to sequence works where possible.<br>– Verdant will work closely with Government, Barkly Council, pastoralists, and communities to maximise any common user infrastructure that will have broader social and economic benefits for the region, such as roads and improved telecommunications. | – Update the Local Industry Participation Plan to reflect increase in potential opportunities for local businesses, including avenues for training and upskilling support provided to the businesses.<br>– Prepare a Community and Stakeholder Engagement Plan to manage ongoing communication with key stakeholders (including pastoralists, NT Chamber of Commerce, local businesses, and government agencies), particularly regarding project updates, groundwater monitoring, and amenity impacts.<br>– Verdant Minerals will work with pastoralists to monitor groundwater and any potential impacts to pastoral productivity (in alignment with recommended mitigation measures made by Innovative Groundwater Solutions (2022)).<br>– Ongoing collaboration with Traditional Owners and the Central Land Council to finalise the Native Title Agreement, and to maximise economic benefits of the project for local Traditional Owner families.<br>– Continue to work with the CLC to provide support to Traditional Owners for governance arrangements of benefit payments.<br>– Verdant Minerals will provide a water supply on both sides of the rail spur in any areas where ease of access is limited. |
| Employment and education | – Develop a workforce development plan, including support mechanisms. | – Verdant minerals will prepare a Local Indigenous Employment Participation Plan to reduce barriers to |

| Impact category | Mitigation measures recommended in ESIA 2018 (Approved Project) | Additional mitigation measures recommended for the Proposed Project |
|---|---|---|
| | – Establish a training committee once the timing of construction is known in order to harness all available support for jobs and training, including liaison with the Department of Education.<br>– Encourage providers to deliver driving courses to help local people get jobs driving buses or heavy equipment.<br>– Use a labour hire system.<br>– Use communication and tactics such as site visits and career days to make people aware of the range of potential jobs available.<br>– Develop a code of conduct, cultural inductions and mentoring to provide a safe and welcoming workplace for Aboriginal men and women. | employment and maximise employment opportunities for Ampilatwatja residents. This Plan will include a training plan as required.<br>– Develop partnerships with employment services and social enterprise services in Tennant Creek to maximise opportunities for long term employment for local people, particularly residents of Ampilatwatja (e.g., Saltbush). |
| Infrastructure and social services | – Work with the community to identify ways they can benefit from common user or shared infrastructure.<br>– Work with the Northern Territory Government to seek funding for upgraded local roads and regular maintenance.<br>– Traffic management plan to enhance safe driver behaviour by project transport.<br>– Verdant to have on-site medical staff to reduce pressure on local health clinics.<br>– Verdant will liaise with the Department of Housing and Community Development to forecast any predicted increase in the population of Ampilatwatja as a result of the project to allow forward planning for increased public housing demand.<br>– Encourage local workers to live at the accommodation village while on shift, particularly single workers.<br>– Verdant to have trained emergency response teams on site.<br>– Verdant to install appropriate firebreaks and safety precautions. | – Continue to work with the Traditional Owners and Central Land Council to finalise the Native Title Agreement and governing structure.<br>– Identify the opportunities for community benefits, such as creation of a community benefit fund. |
| Health, wellbeing, and safety | – Strict policies covering worker behaviour.<br>– Human resource policies that focus on worker welfare.<br>– Drug and alcohol policies at the worksite.<br>– Health promotion programs at the worksite.<br>– Good mentoring and support.<br>– Good communication with the community.<br>– Management plans to control amenity issues. | – The Project would have strict traffic management protocols to ensure the safety of all road users. This could include traffic safety awareness campaigns and notifying other road users of oversized vehicles approaching.<br>– The Proposed project will discourage DiDO workforce unless meeting strict protocols and such journeys are unavoidable.<br>– Develop a Community and Stakeholder Engagement Plan that includes updates to the Ampilatwatja community and surrounding pastoral stations regarding potential amenity changes. |

| Impact category | Mitigation measures recommended in ESIA 2018 (Approved Project) | Additional mitigation measures recommended for the Proposed Project |
|---|---|---|
| | | – Establish an ongoing dialogue and avenue to capture potential issues and concerns with the operation of the airfield on surrounding stakeholders in the long-term. |
| Culture and heritage | – obtaining all appropriate sacred site certificates and respected restricted work areas.<br>– cross-cultural training and inductions.<br>– policies covering worker behaviour.<br>– involving Traditional Owners in all surveys and seeking advice before any potentially disturbing activities.<br>– maintaining access for traditional activities, such as hunting.<br>– appropriate environmental management policies and practice. | – No additional mitigation measures are required for the Proposed project. |
| Environment | – good communication on all water and ecological issues<br>– involving the community in monitoring and rehabilitation activities. | – Verdant Minerals will prepare a Community and Stakeholder Engagement Plan that includes key messaging and engagement with regional stakeholders on the increase in groundwater use, and ongoing reporting on groundwater monitoring results. |
| Human Rights | – Central Land Council identifying native title holders with a right to negotiate and managing negotiations on their behalf.<br>– Cross-cultural training for all workers, including management.<br>– Consideration of potential human rights issues in human resource planning and practice.<br>– Codes of Behaviour that address any issues that could lead to breaches.<br>– Appropriate grievance procedures and remedies for workers to raise any concerns.<br>– Good communication to Traditional Owners about all aspects of the project timing, scale, likely disruption, and implications. | – No additional mitigation measures are required for the Proposed project |

# Appendix M

## Revised Traffic Impact Assessment Addendum

# Technical Memorandum

**09 August 2022**

| | | | |
|---|---|---|---|
| **To** | Mark Skelton | **Email** | MSkelton@verdantminerals.com.au |
| **From** | Madeleine Fletcher-Kennedy | **Project No.** | 12571099 |
| **Project Name** | Ammaroo Ammonium Phosphate Fertiliser Project - Variation, Environmental Approvals and NT EPA Referral | | |
| **Subject** | Update to Traffic Impact Assessment – Referral of Significant Variation | | |

## 1. Introduction

Verdant Minerals Pty Ltd (Verdant) is a Darwin-based, developer of Australian fertiliser mineral projects, including the Ammaroo Ammonium Phosphate Fertiliser Project (hereinafter abbreviated to 'Ammaroo Phosphate Project' and referred to as the 'Project'). The Project is situated in the central region of the Northern Territory, located in the western Georgina Basin approximately 220 kilometres (km) southeast of Tennant Creek, 125 km east of Barrow Creek and 270 km northeast of Alice Springs.

In 2018, the Project was subject to and approved under an Environmental Impact Assessment, and comprised the development of the Ammaroo resource, by open-cut mining, crushing, beneficiation and drying to produce a phosphate rock concentrate for transportation via rail to the Darwin Port. The Project planned to export the rock concentrate to international markets as the essential feed stock for the production of fertiliser products. (For the purposes of clarity, the 2018 Project will hereafter be referred to as 'the Approved Project').

To expand the economic feasibility of the Project, Verdant now plan to include the onsite production of monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers. This will entail the construction of additional onsite plant and infrastructure, including a phosphoric acid plant, sulphuric acid plant, ammonia plant, granulation plant, and amenity and service infrastructure (collectively referred to as the "Proposed Project").

### 1.1 Purpose of this Memorandum

GHD previously prepared an Environmental Impact Statement (Approved EIS) for the Ammaroo Phosphate Project (the Approved Project) on Ammaroo Station, Northern Territory. As part of Approved EIS, a Traffic Impact Assessment (TIA 2017) report was prepared which documented the potential traffic and transport impacts of the project.

Subsequently, the project scope has been expanded, with additional demand and extended program both anticipated compared with the original assessment.

Accordingly, this memo has been prepared as an addendum to the TIA 2017 to provide an updated assessment of the construction traffic impacts on the surrounding road network, as a result of the Proposed Project.

## 1.2 Scope and limitations

This technical memorandum has been prepared by GHD for Verdant Minerals Pty Ltd (Verdant). GHD has prepared this memorandum on the basis of information provided by Verdant Minerals Pty Ltd and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

## 1.3 Assumptions

The following assumptions have been used in the preparation of this memorandum:

- The construction workforce will peak at 1600 workers.
- 90% of workers will fly to the Airfield, with the remaining 10% driving to the accommodation village by private vehicle or separate bus service.
- Workers will typically work three weeks on, one week off.
- All workers will be bused from the accommodation to the job site for each shift.
- Buses will have various capacities up to a maximum of 50 passengers.
- Material and equipment deliveries to the site will generally only occur on standard business days.

# 2. Operational details

To complete the construction of the Proposed Project, a construction worker accommodation village will be established adjacent to the construction site. It is understood there will be an average of 800 workers for the first 3 years and will peak at between 1,300-1,600 workers for approximately 12-18 months.

During the peak construction period, the hours of construction would be between 6:00AM and 6:00PM, with workers working 12-hour shifts with rotating shift patterns based on a 21-day roster. Occasional night work maybe also be required.

Due to the remote locality of the project site, a permanent Accommodation Village will be constructed to accommodate workers for the operating life of the project. The operational village will be used during the peak construction period to meet the overall demand for construction workforce accommodation.

The majority of the construction workforce will be engaged on a fly-in fly-out (FIFO) basis and would be sourced from population centres such as Alice Springs, Adelaide, Darwin, Mt Isa, or other capital cities.

# 3. Traffic assessment

## 3.1 Existing traffic volumes

The existing 2015 traffic volumes along each of the key access roads are outlined within Section 2.1.2 of TIA 2017, with Section 4.3.1 providing a summary of expected traffic volume growth rates. Based on these assessments, the forecast traffic volumes have been updated to 2022 volumes and are provided in Table 1. It is noted that the volumes along Murray Downs Road and Kinjurra Road have been conservatively estimated based on counts along adjoining roads.

*Table 1 AADT traffic volumes*

| Location | Annualised AADT growth rate | Two-way traffic volumes (vpd) (2015) | Two-way traffic volumes (vpd) (2022) |
|---|---|---|---|
| Stuart Highway (north of Murray Downs Road) | 1.53% | 353 | 393 |
| Stuart Highway (south of Sandover Highway) | 3.59% | 634 | 812 |
| Sandover Highway (south of Murray Downs Road) | 2.36% | 37 | 44 |
| Murray Downs Road | 2.0%* | 40* | 46* |
| Kinjurra Road | 2.0%* | 60* | 69* |

**Estimated figure*

It is assumed that all traffic movements are split evenly between inbound and outbound movements.

## 3.2 Construction traffic

### 3.2.1 Light vehicle movements

The light vehicle movements generated during construction will typically comprise of trips generated by:

– Workers being transported between the accommodation village and the airfield.

– Workers driving to the accommodation village by private vehicle.

– Workers being bused between the accommodation village and the job site.

For purposes of this assessment, it will be assumed that the construction workforce is comprised of 1,600 workers, in accordance with the projected construction peak. Furthermore, it will be assumed that 90% of the construction personnel fly in, while the remaining 10% will drive by private vehicle or other arranged transport.

Application of this split to the peak workforce of 1,600 workers equates to 1,440 workers travelling by plane and 160 travelling by car.

**To/from the Accommodation Village by plane**

Based on a typical FIFO roster whereby workers have three weeks on followed by one week off, with flights running at least twice per week, nominally 250 workers fly in and out on each flight day.

Buses travelling between the Airfield and the accommodation will be able to accommodate up to 50 workers each. As such, on flight days there will be between 5 and 9 bus trips per flight, with buses carrying passengers in each direction, equivalent to 18 movements in both directions.

It is assumed that 10% of bus movements will occur during the peak hour, equivalent to 2 movements in each of the peak hours.

**To/from the Accommodation Village by car**

With 160 workers travelling to/from the site by private vehicle, based on the same 2- and 4-week turnovers, it will be assumed that approximately 53 workers arrive and depart the accommodation village each week.

Spread across the week, the workers travelling by private vehicle are expected to generate an additional 8 car trips to/from the accommodation village each day. It will be conservatively assumed that 50% of these movements will occur during peak hours.

**To/from the job site**

Each day the workforce will be bused between the accommodation village and the job site. Based on the use of 30- & 50-seater buses, everyday there will be between 27 trips (800 workers) and 54 trips (1600 workers) generated in each of the morning and evening peak hours. This equates to a total of 54-108 daily trips in both directions.

It is noted that trips between the accommodation village and the job site were not considered in the TIA 2017 (Approved Project) as they do not utilise the public road network. However, for information purposes these trips have been included in this update.

**Total light vehicle movements**

A comparison of the traffic generation projections from the TIA 2017 (Approved Project) and the updated Proposed Project, is included in Table 2 below.

*Table 2 Light vehicle traffic generation*

| Trip type | AM Peak | | PM Peak | | Daily | |
|---|---|---|---|---|---|---|
| | Approved | Proposed | Approved | Proposed | Approved | Proposed |
| Airport shuttle bus | 2 | 2 | 2 | 2 | 14 | 18 |
| Other LVs | 5 | 4 | 5 | 4 | 20 | 8 |
| Work shuttle bus | - | 54 | - | 54 | - | 108 |
| Total | 7 | 60 | 7 | 60 | 34 | 134 |

### 3.2.2 Heavy vehicle movements

Heavy vehicle movements across the construction period will comprise:

– Material and equipment deliveries to the job site.
– Internal truck movements between the works areas and the borrow pits.

The heavy vehicle trip generation is outlined below.

**Deliveries**

Over the 3-year construction period there is projected to be approximately 5,750 truck movements transporting equipment and materials to the site, equivalent to 11,500 movements in both directions. It is expected, the majority of equipment and materials will be sourced from the north (Darwin), with the remainder sourced from the south (Adelaide).

Noting deliveries are generally expected to occur on weekdays only, based on a five-day week with exceptions for public holidays, over the year there is expected to be approximately 8 deliveries per day. being an equivalent to 16 heavy vehicle movements in both directions.

As a safety precaution, heavy vehicles will only be permitted to drive on sealed roads at night-time, with all trips on unsealed roads to be completed during daylight hours. Between Tenant Creek and the site, trucks will run through during daylight hours. To ensure traffic impacts are minimised, truck departures and arrivals will need to be staged. Due to the daylight requirements, it is expected that trucks will depart at any time from first light up until approximately 2:00PM.

With traffic departures to be dispersed over as little as 7 hours, it will be assumed that 15% of trips occur during the peak hours, noting all truck movements will be outbound in the morning peak, and inbound in the evening peak.

Based on the above, there may be up to 3 truck movements observed in any peak hour.

**Internal trips**

Within the site, approximately 122,150 truck movements are expected, primarily to and from the borrow pits. As these will be internal on-site movements, these trips are not typically expected to utilise the public road network.

**Total heavy vehicle movements**

A comparison table of the heavy vehicle traffic generation projections from the TIA 2017 (Approved Project) and the Proposed Project is provided in Table 3 below.

*Table 3 Heavy vehicle traffic generation*

| Trip type | AM Peak | | PM Peak | | Daily | |
|---|---|---|---|---|---|---|
| | Approved | Proposed | Approved | Proposed | Approved | Proposed |
| To/from external road network | 2 | 3 | 2 | 3 | 6 | 16 |
| Internal road network only | 5 | 11 | 5 | 11 | 51 | 112 |
| Total | 7 | 14 | 7 | 14 | 57 | 128 |

## 3.3 Traffic impact

As outlined within the preceding sections, due to the change of scope for the Proposed Project, the level of traffic generated to and from the site is expected to be greater than initially projected within the TIA 2017. Nevertheless, due to the expanded program, increased from 12 months to three years, the change to daily traffic volumes is low in road capacity terms noting the local road network will easily accommodate the forecast additional traffic volumes.

Of note, the heavy vehicle trips will increase by +10 trips per day to the external road network and by +61 trips per day to the internal road network. While again these additional volumes can be supported by the road network, the impacts will need to be managed. Mitigation measures for these additional volumes have been outlined within the following section.

## 3.4 Mitigation

With due consideration of the traffic impacts that may be generated by the proposed development, particularly by the volume of heavy vehicles, the following mitigation measures have been proposed.

*Table 4 Impacts and mitigation measures*

| Impact | Mitigation measure | Timing |
|---|---|---|
| B-double / B-triple vehicles on the public road network | **Assistance crews**<br>Traffic management crews may be required to drive ahead of oversized vehicles during deliveries. The assistance crews will assist by providing warning of large vehicles ahead and holding traffic where required. | During construction |
| Increased truck volumes | **Traffic controllers**<br>Traffic controllers will be present as required to hold up any traffic where large heavy vehicles are required to occupy more than one traffic lane, drive over the road centre line or turn across oncoming traffic. | During construction |
| | **Internal access roads**<br>Internal roads will be constructed and marked early on, to prevent construction vehicles driving across pedestrian areas. | During construction |
| | **Truck warning signage**<br>To increase awareness of the increased truck volumes and the presence of heavy vehicles, truck warning signage should be installed along the unsealed roads which make up the main delivery routes. | During construction |

| Impact | Mitigation measure | Timing |
|---|---|---|
| Loading areas | All loading and unloading of materials will be limited to specific loading areas within the site. No loading or unloading is to occur on public roads. | During construction |
| Damage to road infrastructure and pavement | **Road rehabilitation**<br>Any roads damaged by the construction of the Proposed Project will be repaired to an acceptable standard, with all costs borne by Verdant Minerals. | During construction |
| Mud and debris tracking onto roads | **Vehicle wash down areas**<br>Wash down areas will be provided within the site near the construction compound base to allow workers to clean construction vehicles on site. | During construction |
| | **Dust suppression**<br>The dust impact along the roads will need to be monitored. If required, roads should be sprayed with water (potentially with a wetting or binding agent) to minimise dust in the air. | During construction |
| Bus and construction vehicle parking | All parking will occur within the site boundaries, in dedicated parking areas. All staff and drivers will be instructed not to park on public roads. | During construction |

# 4. Conclusions

Based on comparison of the traffic generated by the Approved Project in the TIA 2017 and the updated traffic projections, the net change in vehicle trips is not expected to have any undue impact on the road network, following due implementation of mitigation measures outlined within this memorandum.

With consideration of the foregoing and the expanded construction program, the updated Proposed Project is considered acceptable from a traffic engineering perspective.

Regards

**Madeleine Fletcher-Kennedy**
Traffic Engineer

# Appendix N

## Air Quality Impact Assessment

# Ammaroo Ammonium Phosphate Fertiliser Project

## Air Quality Impact Assessment

Verdant Minerals Pty Ltd

19 September 2022

→ **The Power of Commitment**

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| | |
|---|---|
| **Client name** | Verdant Minerals Pty Ltd |
| **Project name** | Ammaroo Ammonium Phosphate Fertiliser Project - Variation, Environmental Approvals and NT EPA Referral |
| **Document title** | Ammaroo Ammonium Phosphate Fertiliser Project \| Air Quality Impact Assessment |
| **Revision version** | Rev 2 |
| **Project number** | 12571099 |

**Document status**

| Status Code | Revision | Author | Reviewer | | Approved for issue | | |
|---|---|---|---|---|---|---|---|
| | | | Name | Signature | Name | Signature | Date |
| S4 | A | S.Materia | D.Craggs | | N Fries | | 14/04/22 |
| S4 | 0 | S.Materia | D.Craggs | | N Fries | | 10/05/22 |
| S4 | 1 | S.Materia | D.Craggs | | N Fries | | 09/09/22 |
| S4 | 2 | S.Materia | D.Craggs | | N Fries | | 19/09/22 |
| | | | | | | | |

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# Appendices

# 1. Introduction

## 1.1 Overview

Verdant Minerals Pty Ltd (Verdant) is a Darwin-based, developer of Australian fertiliser mineral projects, including the Ammaroo phosphate project.

The Ammaroo Ammonium Phosphate Fertiliser Project (hereinafter abbreviated to ‘Ammaroo Phosphate Project’ and referred to as the ‘Project’) is situated in the central region of the Northern Territory, located in the western Georgina Basin approximately 220 kilometres (km) southeast of Tennant Creek, 125 km east of Barrow Creek and 270 km northeast of Alice Springs.

In 2018, the Project was subject to and approved under an Environmental Impact Assessment, and comprised the development of the Ammaroo resource, by open-cut mining, crushing, beneficiation and drying to produce a phosphate rock concentrate for transportation via rail to the Darwin Port. The project planned to export the rock concentrate to international markets as the essential feed stock for the production of fertiliser products. (For the purposes of clarity this will hereafter be referred to as the “Approved Project”).

In 2014, the then Federal Minister for the Environment determined the Project to be a ‘controlled action’ and assessed the Approved Project under the *Environment Protection Biodiversity Conservation (EPBC) Act 1999*. EBPC approval was granted in January 2018 (EBPC 2014/7260). Having regard to the Environmental Impact Statement (EIS) and Supplementary Report (hereafter referred to as ‘Approved EIS’), the Northern Territory Environment Protection Authority (NT EPA) assessed the Approved Project for its potential impacts and released Assessment Report 87 to be considered in decisions made by the Northern Territory Government. In 2018, the Project was approved under the Environment Assessment Act 1982.

To expand the economic feasibility of the Project, Verdant now plan to include the onsite production of monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers. This will entail the construction of additional onsite plant and infrastructure, including a phosphoric acid plant, sulphuric acid plant, ammonia plant, granulation plant, and amenity and service infrastructure (collectively referred to as the “Proposed Project”).

This report should be read in conjunction with GHD 2017, VRM - Ammaroo Phosphate – EIS Air Quality Assessment (GHD 2017). It is noted that the previous Air Quality assessment was submitted as part of the Approved Project EIS, which was subject to review by the regulator and was ultimately approved in 2018.

## 1.2 Purpose of this report

The purpose of this report is to assess the air quality impacts from the additional onsite plant and infrastructure associated with the Proposed Project in order to address the Terms of Reference for the project.

## 1.3 Scope

The scope of works for the air quality impact assessment includes:

- A review of the approved EIS and identification of any changes to the project.
- Update the quality objectives and criteria to consider the most recent and relevant values, specifically those outlined in the 2021 National Environment Protection Measure (Ambient Air Quality) (NEPM AAQ).
- Review and update the description of the existing environment where relevant, including any updated sensitive receptors (including the mine accommodation village).
- Development of an updated emissions inventory to include:
  - Updated parameters for sources already included within the emissions inventory

- Addition of sources not previously included within the emissions inventory (including the additional onsite plant associated with the production of MAP and DAP fertiliser)

– Update the air dispersion model based on the updated emissions inventory and changes to site layout.

– Compare results of dispersion modelling to the relevant objectives / criteria.

– Provide mitigation measures where appropriate.

## 1.4 Limitations

*This report: has been prepared by GHD for Verdant Minerals Pty Ltd and may only be used and relied on by Verdant Minerals Pty Ltd for the purpose agreed between GHD and Verdant Minerals Pty Ltd as set out in section 1.2 of this report.*

*GHD otherwise disclaims responsibility to any person other than Verdant Minerals Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

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

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

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

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

## 1.5 Assumptions

This section outlines the key assumptions made throughout the air quality impact assessment:

– Any assumptions outlined in GHD 2017 are applicable to this assessment unless stated otherwise.

– Emissions estimation and subsequent dispersion modelling is not considered for activities involved with the construction phase of the project.

– Emission rates, emission standards and reference facility emission values provided by VRM are representative of the project.

– Where available, the locations of emission sources are taken from the latest site layout drawings.

– Where no plant drawings are available to indicate the location of sources, locations are selected that allow for a conservative estimate of ground level concentrations (GLC) at the nearest sensitive receptor.

– Chemical transformation of gaseous emissions is not considered in the dispersion model. For example, it is assumed that where emission rates are defined as $NO_x$ that the entirety of the emissions are $NO_2$.

– Air quality impacts have been estimated for emission sources within the mining lease boundary that are directly related to mining operations. Particulate or gaseous emissions are not considered that arise from the transport of product off-site or the delivery of equipment to the site.

# 2. Site description

## 2.1 Existing environment

Risks posed by air pollution are related to the context of the existing environment. The same emission source may pose different health risks depending on whether it is in a remote location or in a residential setting. Therefore, it is important when assessing air pollution risks to have a sound understanding of the environment surrounding the emission sources. Of particular importance are nearby sensitive land uses, local meteorology and topography, and background air quality.

A description of the existing environment is provided in Section 3 of GHD 2017, and a summary of this section and the key changes are summarised in the below sections.

### 2.1.1 Sensitive receptors

The sensitive receptors considered in this assessment and their distances to the project site are summarised in Table 2.1 and shown in Figure 2.1.

Note that the location of the mine's accommodation village has changed from the 2017 EIS assessment. The accommodation village was originally located to the north-east of the project site and has been repositioned further east of the site.

*Table 2.1 Assessed nearby sensitive receivers external to the project site*

| Sensitive receptor | Approximate distance to the mining lease | Easting, Northing<br>GDA 2020 / MGA Zone 53 |
|---|---|---|
| Ampilatwatja | 12 kms south | 523132.00 m E, 7605574.00 m S |
| Imperrenth | 29 kms north-west | 495367.00 m E, 7655026.00 m S |
| Ngkwarlerlanem | 37 kms south-west | 478416.00 m E, 7597321.00 m S |
| Imangara | 41 kms north-west | 466869.00 m E, 7672211.00 m S |
| Accommodation village | 3.6 kms east-northeast | 519987.00 m E, 7625932.00 m S |

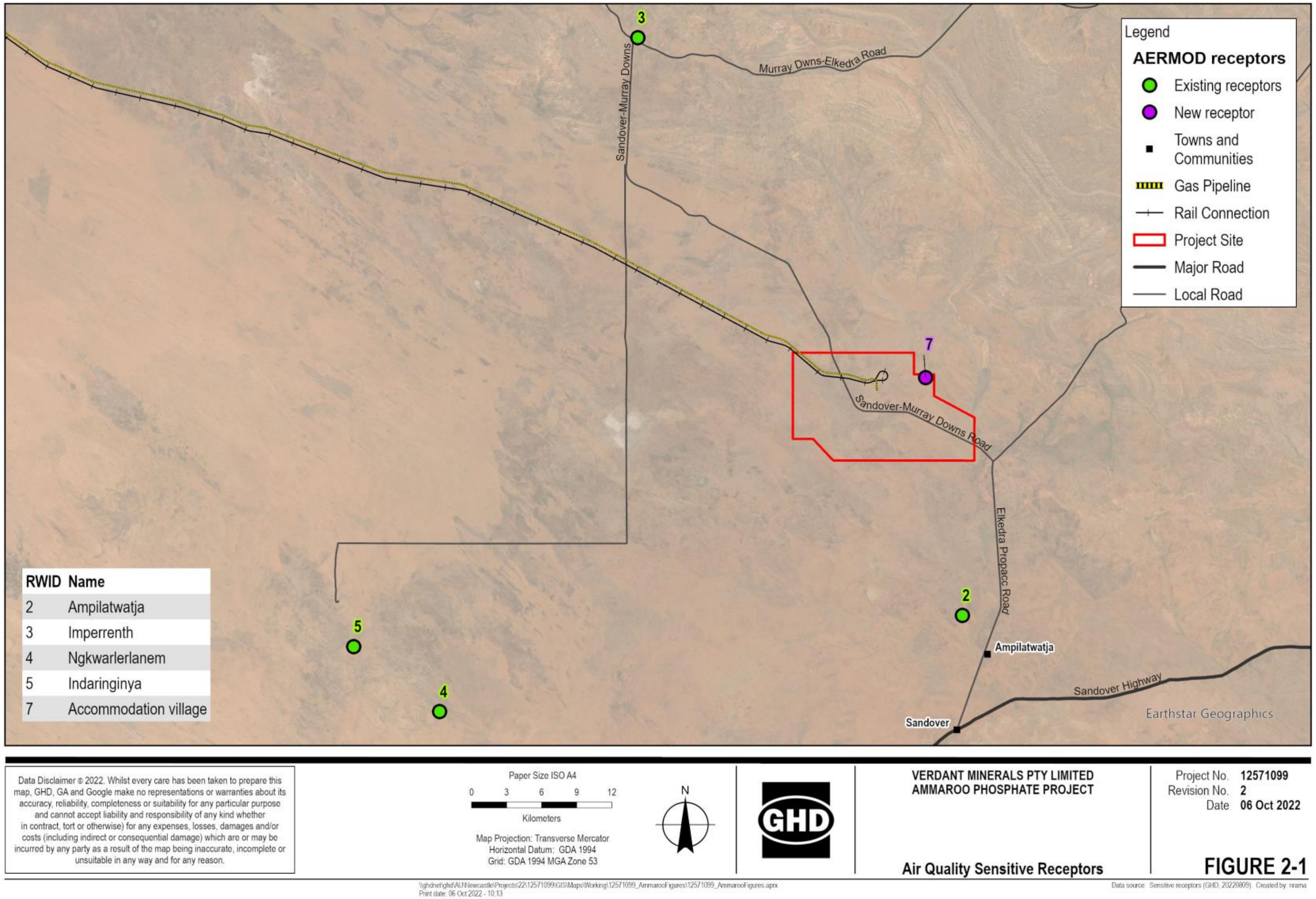


*Figure 2.1* *Air quality sensitive receptors*

## 2.1.2 Meteorology

The annual wind rose and stability class distribution shown in Figure 2.2 and Figure 2.3 have been taken from GHD 2017.

The modelled meteorological year is the 12-month period of December 2014 – November 2015. The 12-month period was selected as representative of long-term meteorological patterns, based on a review of rainfall data from the nearby Ali Currung BOM station. Data for a 22-year period were assessed to select a 12-month period, with consideration of monthly rainfalls as well as presence of La Nina/El Nino.

The wind rose indicates that south-easterly winds occur with the greatest occurrence. Therefore, sensitive receptors located to the northwest of the project site would be more frequently downwind of the project site, resulting in an increased likelihood of air pollutants travelling in that direction

The stability class distribution indicates that conditions are generally neutral with D-class occurring 34.5 percent of the time. During the night, conditions are considered stable with E- and F-class occurring 33.7 percent of the time. Due to the limited vertical mixing occurring during these hours (due to reduced solar radiation) these conditions are conducive to higher concentrations (i.e., less dilution) of air pollutants.

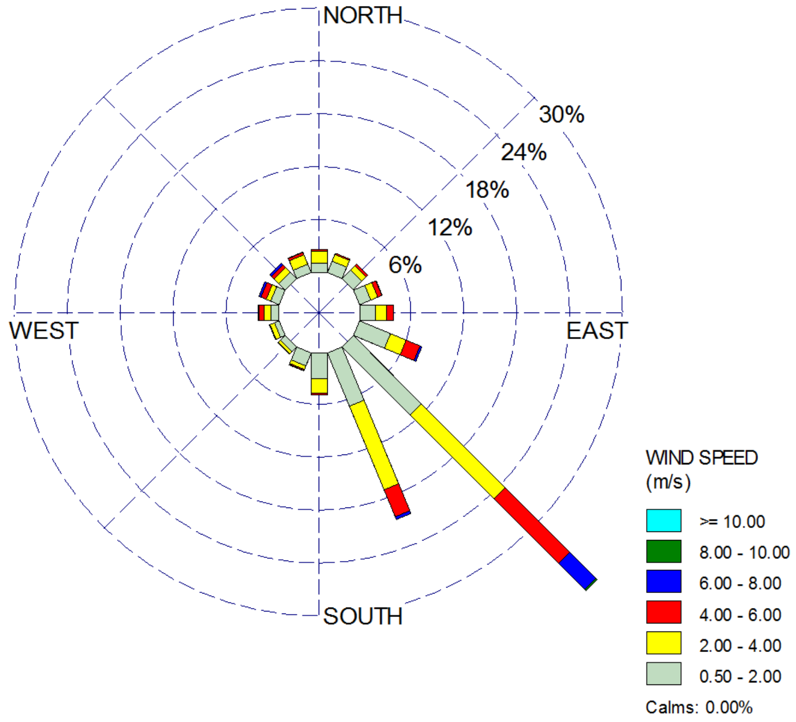


***Figure 2.2 Annual wind rose***

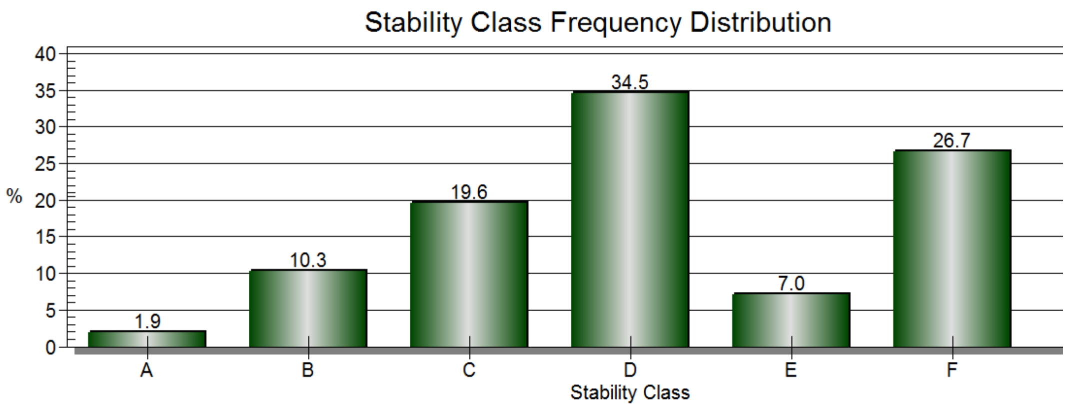


***Figure 2.3 Annual stability distribution***

### 2.1.3 Background air quality

An assessment of the total impact, which includes the Proposed Project impact in addition to background air pollutant concentrations has been undertaken. The air pollutants associated with the Proposed Project are detailed in Section 4 and summarised in Table 2.2 below.

Due to the remote location, background sources of gaseous products of combustion (such as oxides of nitrogen ($NO_x$), carbon monoxide (CO), sulphur dioxide ($SO_2$) etc.) and background sources of Ammonia ($NH_3$) and Fluorides (F) are considered to be negligible to non-existent.

In order to determine background air quality in relation to dust (particulate matter), GHD 2017 used the baseline monitoring data collected at the Nolans project (135 km northwest of Alice Springs). A 24-hour average $PM_{10}$ background value of 20 µg/m³ was deemed representative of the project area. This value has been adopted for this assessment.

***Table 2.2 Anticipated air pollutants from project areas***

| Area | $PM_{10}$ | $NO_2$ | $SO_2$ | F | $H_2SO_4$ | $NH_3$ |
|---|---|---|---|---|---|---|
| Mining Area | X | | | | | |
| Dry and wet beneficiation areas | x | | | | | |
| Phosphoric Acid Plant | X | | | X | | |
| Sulphuric Acid Plant | | | X | | X | |
| Ammonia Plant | | X | X | | | |
| Granulation Plant | X | X | X | X | | X |
| Power Plant | X | X | X | | | |
| Gypsum | X | | | | | |

# 3. Assessment criteria

Air emissions in Australia are regulated at a State and Territory-based level, with regulators in each State and Territory being required to give legislative effect to the requirements of National Environment Protection Measures (NEPMs) made by the National Environment Protection Council.

Air quality in the Northern Territory is managed using the National Environment Protection Measure (Ambient Air Quality) (NEPM AAQ), which was developed under the National Environment Protection Council Act 1994. The NEPM AAQ outlines specific air quality objectives for carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, lead, particles as $PM_{10}$ and particles as $PM_{2.5}$, which the project would be required to comply with during the construction and operation.

## 3.1 Construction

The Northern Territory Environment Protection Authority (NT EPA) published a guideline in November 2015 entitled *Guidelines to Prevent Pollution From Building Sites*. The guideline presents the sources of dust from construction sites, and mitigation measures to reduce dust emissions. GHD recommend that the relevant dust mitigation measures outlined in this document are adopted.

The specific air quality objectives outlined in the NEPM AAQ, supplemented with criteria taken from various jurisdictions around Australia, as required, should be adhered to (discussed in Section 3.3).

## 3.2 Operation

The Northern Territory does not have guidelines or policy specific to managing air quality from industry. Instead, the air quality objectives outlined in the NEPM AAQ, supplemented with criteria taken from various jurisdictions around Australia, as required, should be adhered to (discussed in Section 3.3).

## 3.3 Summary of criteria

The assessment specific air quality objectives have been developed in accordance with the NEPM AAQ. Where a pollutant was not listed in the NEPM AAQ, supplementary criteria were sourced from Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (‘Approved Methods’) and EPA Victoria Publication 1961, Guideline for Assessing and Minimising Air Pollution (utilising the more stringent value from the two documents where relevant).

A summary of the objectives / criteria relevant to this assessment are provided in Table 3.1. When determining the relevant criteria, the results of GHD 2017 were considered and the following exclusions were considered appropriate:

– The results of GHD 2017 found that the ground level concentrations (GLCs) for a number of pollutants were predicted to comply with their relevant criterion by a large margin. These pollutants, namely, total suspended particles (TSP), $PM_{2.5}$, dust deposition, and carbon monoxide (CO) can safely be assumed to comply with their relevant criteria and therefore have not been considered in this assessment.

*Table 3.1 Assessment objectives and criteria*

| Pollutant name | Pollutant ID | Averaging period | Return interval | Objective / Criteria (µg/m³) | Source |
|---|---|---|---|---|---|
| Particulate matter with aerodynamic diameter less than 10 microns | $PM_{10}$ | 24-hour | Maximum | 50 | NEPM AAQ |
| | | Annual | Average | 25 | NEPM AAQ |
| Nitrogen Dioxide | $NO_2$ | 1-hour | Maximum | 164 | NEPM AAQ |
| | | Annual | Average | 32 | NEPM AAQ |
| Sulphur Dioxide | $SO_2$ | 1-hour | Maximum | 286 | NEPM AAQ |
| | | 24-hour | Maximum | 57 | NEPM AAQ |
| Fluoride | F | 1-hour | 99.9th percentile | 60 | EPA Victoria Publication 1961 |
| | | 24-hour | Maximum | 1.5 | Approved Methods* |
| | | 7 days | Maximum | 0.8 | |
| | | 30 days | Maximum | 0.4 | |
| | | 90 days | Maximum | 0.25 | |
| Sulfuric Acid | $H_2SO_4$ | 1-hour | 99.9th percentile | 18 | Approved Methods |
| Ammonia | $NH_3$ | 1 hour | 99.9th percentile | 330 | Approved Methods |
| Note: Approved Methods criteria for fluoride are those relevant to the protection of specialised land uses, which includes all areas with vegetation sensitive to fluoride. | | | | | |

# 4. Emissions inventory

## 4.1 Summary of GHD 2017

In 2017, GHD conducted an assessment of the air emissions associated with the proposed operations of the Approved Project.

The model scenario selected represented the worst-case scenario for air quality impacts at the nearest sensitive receptor, the mine camp (hereinafter referred to as 'accommodation village'). This scenario occurred during pit operations during years 11-15, where the active pit is both proximate to the accommodation village and aligned with processing plant emission sources. As a consequence, activity data and source locations presented in GHD 2017 reflect the likely conditions during years 11-15.

The modelled sources in GHD 2017 included:

– Mining operations including the excavation of overburden and ore.
– Material transport including haul routes between the pit and run of mine (ROM) stockpile.
– Materials processing including crushing and screening.
– Wind erosion from exposed dirt sources including the active pit, the previous pit, rehabilitation pits and the ROM stockpiles.
– A power plant comprising of multiple high efficiency gas engines (~2.5 MW each)

Air emission rates were estimated using the National Pollutant Inventory (NPI) Emissions Estimation Technique (EET) Manuals as follows:

– Mining, material transport and processing, and wind erosion:
  - NPI EET Manual for Mining, Version 3.1 (Australian Government, 2012).
  - NPI EET Manual for Mining and Processing of Non-Metallic Minerals, Version 2 (Australian Government, 2014).
– Power plant:
  - NPI EET Manual for Combustion Engines, Version 3.0 (Australian Government, 2008).
  - NPI EET Manual for Combustion in Boilers, Version 3.6 (Australian Government, 2011).

## 4.2 Changes to GHD 2017

A number of sources modelled in GHD 2017 were required to be relocated based on the latest site plan layout provided by Verdant. This mainly included sources associated with the processing plant and material transport sources. The power plant's sources and the rotary drier source were removed from the model and replaced with a more representative source where appropriate, discussed in Section 4.3.

A summary of the changes made to sources modelled as part GHD 2017 is provided in Table 4.1

*Table 4.1 Changes to sources outlined in GHD 2017*

| Emission source ID | Description | Change in new mode (Proposed Project) |
|---|---|---|
| M6 | Dumping ore on ROM stockpile | Source moved to new ROM stockpile location |
| M7 | Front-end-loaders on ore on ROM stockpile | Source moved to new ROM stockpile location |
| H1-H4 | Hauling ore to ROM stockpile | Location and distance of haul route updated in line with latest site plan |
| H5-H10 | Haul trucks returning to pit | Location and distance of haul route updated in line with latest site plan |
| P1 and P4 | Screen | Sources moved to dry and wet beneficiation areas, respectively |

| Emission source ID | Description | Change in new mode (Proposed Project) |
|---|---|---|
| P3, P6, P8 | Conveyor | Sources moved to between the dry and wet beneficiation areas |
| P2 | Primary crusher | Source moved to dry beneficiation area |
| P5 | Secondary crusher | Source moved to wet beneficiation area |
| P7 | Loading stockpiles | Source moved to dry beneficiation area |
| P9 | Rotary drier | Source deleted and replaced with R_G1 (refer to Section 4.3) |
| P10 | Train load-out | Source moved to between the dry and wet beneficiation areas |
| S1 | ROM stockpile | Source moved to new ROM stockpile location |
| S2 | Beneficiation stockpile | Source moved to wet beneficiation area |
| S3 | Topsoil stockpile | Source re-shaped (same area) and moved slightly west |
| C1 and C2 | 2.5 MW Diesel generators | Source deleted |
| C3-C10 | 2.5 MW Natural gas generators | Source deleted and replaced with P_PO1 – P_PO8 (refer to Section 4.3) |
| C11 | Natural gas fired rotary drier | Source deleted |

# 4.3 Additional sources

## 4.3.1 Overview

As outlined above, since the preparation of GHD 2017, Verdant now plan to include the onsite production of monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertiliser product and storage fertilisers. This will entail the construction of additional onsite plant and infrastructure, which is required to be assessed as part of this assessment. The air emissions associated with this additional process will largely be from stack (point) sources occurring from the following plants:

- Phosphoric Acid Plant.
- Sulphuric Acid Plant.
- Ammonia Plant.
- Granulation Plant.

Detailed description of these sources can be found in Section 5 of the main EIS Referral Document.

Further, the configuration of the Power Plant has changed since GHD 2017 and is therefore required to be updated. The Power Plant will likely consist of an 8+1 configuration of gas engine generators at 75% loading, with an electrical energy output of 2.23 MW per generator. Eight gas engine generators were modelled in this assessment as individual stack (point) sources.

Finally, dust emissions from an additional wind erosion (area) source, namely the Gypsum Dry Stack associated with the Phosphoric Acid Plant was also required to be included.

An overview of the additional sources associated with the above activities is provided in Table 4.2

*Table 4.2 Additional air emission sources as part of Proposed Project*

| Area | Source ID | Source description | $PM_{10}$ | $NO_2$ | $SO_2$ | F | $H_2SO_4$ | $NH_3$ |
|---|---|---|---|---|---|---|---|---|
| Phosphoric Acid Plant | PR_PH1 | Reaction and Filtration Stack | X | | | X | | |
| | PR_PH2 | Reaction and Filtration Stack | X | | | X | | |
| Sulphuric Acid Plant | PR_S1 | Conversion | | | X | | X | |
| Ammonia Plant | PR_A1 | Flue Gas Reformer Stack | | X | X | | | |
| Granulation Plant | PR_G1 | Granulation Plant Scrubber Stack | X | X | X | X | | X |
| Power Plant | P_PO1 – P_PO8 | Power Plant Generator 1 to 8 | X | X | X | | | |
| Gypsum | G1 | Gypsum stack (stockpile) | X | | | | | |

## 4.3.2 Source parameters

The stack parameters used in this assessment were provided by Verdant and are outlined in Table 4.3. The stack parameters for each source were taken from comparable reference facilities, including the Licensor reference plant.

*Table 4.3 Discharge parameters*

| Source ID | Source description | Height (m) | Diameter (m) | Temperature (ºC) | Velocity (m/s) |
|---|---|---|---|---|---|
| PR_PH1 and PR_PH2 | Reaction and Filtration Stacks | 65 | 1.4 | 35 | 9.5 |
| PR_S1 | Conversion | 80 | 3.1 | 82 | 14.1 |
| PR_A1 | Flue Gas Reformer Stack | 36 | 3.6 | 162 | 4.9 |
| PR_G1 | Granulation Plant Scrubber Stack | 63 | 4.2 | 107 | 16.0 |
| P_PO1 – P_PO8 | Power Plant Generator 1 to 8 | 4 | 0.6 | 455 | 36.4 |

## 4.3.3 Emission estimation

Various emission estimation techniques were used to develop the emission rates for the sources not previously included in the GHD 2017 emissions inventory. These methods included:

- Use of an emission concentration standard taken from one (or more) of the following sources:
  - European Commission, Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals - Ammonia, Acids and Fertilisers (BAT Europe).
  - International Finance Corporation Work Bank Group, Environmental, Health and Safety Guidelines for Phosphate Fertilizer Manufacturing (Work Bank).
  - Supplied by the Licensor.
- National Pollutant Inventory (NPI) Emissions Estimation Technique (EET) Manuals:
  - NPI EET Combustion in Boilers, Version 3.6 (Australian Government, 2011).
  - NPI EET Combustion Engines, Version 3.0 (Australian Government, 2008).
  - NPI EET Manual for Mining, Version 3.1 (Australian Government, 2012).
- Data from a reference facility (namely a Haldor Topsoe reference plant).

An overview of the emission rates that were calculated for this assessment are provided in Table 4.4.

*Table 4.4 Emission estimation for additional sources*

| Source ID | Source description | Pollutant | Emission estimation method | Emission standard (mg/Nm³) | NPI EET emission factor | Emission rate (g/s) | Source |
|---|---|---|---|---|---|---|---|
| PR_PH1 | Reaction and Filtration Stack | HF (as F) | Emission standard x flow rate | 5 | N/A | **0.065** | – Supplied by the Licensor<br>– BAT Europe<br>– World Bank |
| | | $PM_{10}$ | Emission standard x flow rate | 50 | N/A | **0.65** | – BAT Europe and confirmed by Licensor |
| PR_PH2 | Reaction and Filtration Stack | F | Emission standard x flow rate | 5 | N/A | **0.065** | – Supplied by the Licensor<br>– BAT Europe<br>– World Bank |
| | | $PM_{10}$ | Emission standard x flow rate | 50 | N/A | **0.65** | – BAT Europe and confirmed by Licensor |
| PR_S1 | Conversion | $SO_2$ | Emission standard x flow rate | N/A | N/A | **104.17** | – BAT Europe |
| | | $H_2SO_4 + SO_3$ (as $H_2SO_4$) | Emission standard x flow rate | 60 | N/A | **4.92** | – BAT Europe |
| PR_A1 | Flue Gas Reformer Stack | $NO_2$ | Reference facility | N/A | N/A | **7.9** | – Haldor Topsoe reference plant<br>– 200 tonnes per annum<br>– 80% capability factor |
| | | $SO_2$ | Reference facility | N/A | N/A | **0.08** | – Haldor Topsoe reference plant<br>– 2 tonnes per annum<br>– 80% capability factor |
| PR_G1 | Granulation Plant Scrubber Stack | $NO_2$ | NPI EET | N/A | 0.0828 kg/GJ | **0.74** | – NPI EET Combustion in Boilers<br>– Gas consumption: 32.11 GJ/h |
| | | $SO_2$ | NPI EET | N/A | 0.00054 kg/GJ | **0.005** | – NPI EET Combustion in Boilers |

| Source ID | Source description | Pollutant | Emission estimation method | Emission standard (mg/Nm³) | NPI EET emission factor | Emission rate (g/s) | Source |
|---|---|---|---|---|---|---|---|
| | | | | | | | – Gas consumption: 32.11 GJ/h |
| | | $NH_3$ | Emission standard x flow rate | 30 | N/A | **5.4** | – Licensor document |
| | | F | Emission standard x flow rate | 5 | N/A | **0.90** | – World Bank |
| | | $PM_{10}$ | Emission standard x flow rate | 30 | N/A | **5.4** | – Licensor document |
| P_PO1 – P_PO8 | Power Plant Generator 1 to 8 (modelled as 8 separate sources) | $NO_2$ | NPI EET | N/A | 0.0005 kg/kWh | **0.310** | – NPI EET Combustion Engines<br>– Electrical energy output of 2.23 MW per generator |
| | | $SO_2$ | NPI EET | N/A | 0.00000079 kg/kWh | **0.00049** | – NPI EET Combustion Engines<br>– Electrical energy output of 2.23 MW per generator |
| | | $PM_{10}$ | NPI EET | N/A | 0.0000029 kg/kWh | **0.0018** | – NPI EET Combustion Engines<br>– Electrical energy output of 2.23 MW per generator |
| G1 | Gypsum stack (stockpile) | $PM_{10}$ | NPI EET | N/A | 0.20 kg/ha/hour | **1.4** | – NPI EET Manual for Mining<br>– Area: 25 ha |

## 4.4 Emission source summary

A summary of the modelled emission rates for each source included in this assessment is provided in Table 4.5 for $PM_{10}$, and Table 4.6 for all remaining pollutants. All emissions are 'as modelled', and as such include all control measures and pit retention factors. Therefore, the emissions inventory is a summary of the emissions which will impact on the predicted GLCs.

A breakdown of the $PM_{10}$ emissions by project area is provided in Figure 4.1. From Figure 4.1, it can be seen that the areas with the highest $PM_{10}$ emissions are the mine area, dry beneficiation, and wet beneficiation. It is noted that the sources in these areas were modelled as part of GHD 2017, and their emission rates have remained largely unchanged. When this is compared to the $PM_{10}$ emissions from the additional sources (discussed in Section 4.3), it can be seen that these additional sources contribute a relatively small amount.

A total of 43 individual sources were input to the AERMOD dispersion model to represent the emissions from the project. The location of all modelled sources is shown in Figure 4.2. To define the location of air emission sources within each source area (i.e., mine area), the minimum distance between each source (within the source area) and the accommodation village (most critical sensitive receptor) was adopted, as appropriate.

*Table 4.5 Summary of $PM_{10}$ emissions*

| Area | Source ID | Description | $PM_{10}$ emission rate (g/s) |
|---|---|---|---|
| Mine area | M1 | Excavators or front-end-loaders on overburden in pit | 6.7 |
| | M2 | Loading overburden to trucks in pit | 5 |
| | M3 | Dumping overburden in pit | 2.4 |
| | M4 | Excavators or front-end-loaders on ore in pit | 2.6 |
| | M5 | Loading ore to trucks in pit | 1.9 |
| | M8 | Dozer in pit | 1.1 |
| | M9 | Grader in pit | 0.26 |
| | M10 | Grader in pit | 0.26 |
| | M11 | Grader in pit | 0.26 |
| | S3 | Topsoil stockpile | 1.5 |
| | O1 | Active pit | 0.53 |
| | O2 | Previous pit | 0.56 |
| | O3 | Rehab pit 1 | 0.39 |
| | O4 | Rehab pit 2 | 0.22 |
| | O5 | Rehab pit 3 | 0.056 |
| Between mine area and dry beneficiation area | H | Hauling ore to ROM stockpile and returning to pit | 1.6 |
| Dry beneficiation area | M6 | Dumping ore on ROM stockpile | 1 |
| | M7 | Front-end-loaders on ore on ROM stockpile | 2.7 |
| | P1 | Screen | 4.9 |
| | P2 | Primary crusher | 1.6 |
| | P7 | Loading stockpiles | 0.14 |
| Between dry and wet beneficiation areas | P8 | Conveyor | 0.012 |
| | P3 | Conveyor | 0.012 |
| | P6 | Conveyor | 0.012 |
| | P10 | Train load-out | 0.008 |

| Area | Source ID | Description | $PM_{10}$ emission rate (g/s) |
|---|---|---|---|
| Wet beneficiation area | P4 | Screen | 4.9 |
| | P5 | Secondary crusher | 4.9 |
| | S1 | ROM stockpile | 0.13 |
| | S2 | Beneficiation stockpile | 0.028 |
| Gypsum | G1 | Gypsum stack (stockpile) | 1.4 |
| Phosphoric Acid Plant | PR_PH1 | Reaction and Filtration Stack | 0.65 |
| | PR_PH2 | Reaction and Filtration Stack | 0.65 |
| Sulphuric Acid Plant | PR_S1 | Conversion | - |
| Ammonia Plant | PR_A1 | Flue Gas Reformer Stack | - |
| Granulation Plant | PR_G1 | Granulation Plant Scrubber Stack | 5.41 |
| Power Plant | P_PO1 | Power Plant Generator 1 | 0.0018 |
| | P_PO2 | Power Plant Generator 2 | 0.0018 |
| | P_PO3 | Power Plant Generator 3 | 0.0018 |
| | P_PO4 | Power Plant Generator 4 | 0.0018 |
| | P_PO5 | Power Plant Generator 5 | 0.0018 |
| | P_PO6 | Power Plant Generator 6 | 0.0018 |
| | P_PO7 | Power Plant Generator 7 | 0.0018 |
| | P_PO8 | Power Plant Generator 8 | 0.0018 |
| **TOTAL** | | | **53.8** |

*Table 4.6 Summary of plant emissions (excluding $PM_{10}$)*

| Area | Source ID | Description | Emission rate (g/s) | | | | |
|---|---|---|---|---|---|---|---|
| | | | $NO_2$ | $SO_2$ | F | $H_2SO_4$ | $NH_3$ |
| Phosphoric Acid Plant | PR_PH1 | Reaction and Filtration Stack | | | 0.065 | | |
| | PR_PH2 | Reaction and Filtration Stack | | | 0.065 | | |
| Sulphuric Acid Plant | PR_S1 | Conversion | | 104.17 | | 4.9 | |
| Ammonia Plant | PR_A1 | Flue Gas Reformer Stack | 7.9 | 0.08 | | | |
| Granulation Plant | PR_G1 | Granulation Plant Scrubber Stack | 0.74 | 0.005 | 0.90 | | 5.4 |
| Power Plant | P_PO1 | Power Plant Generator 1 | 0.310 | 0.00049 | | | |
| | P_PO2 | Power Plant Generator 2 | 0.310 | 0.00049 | | | |
| | P_PO3 | Power Plant Generator 3 | 0.310 | 0.00049 | | | |
| | P_PO4 | Power Plant Generator 4 | 0.310 | 0.00049 | | | |
| | P_PO5 | Power Plant Generator 5 | 0.310 | 0.00049 | | | |
| | P_PO6 | Power Plant Generator 6 | 0.310 | 0.00049 | | | |
| | P_PO7 | Power Plant Generator 7 | 0.310 | 0.00049 | | | |
| | P_PO8 | Power Plant Generator 8 | 0.310 | 0.00049 | | | |
| **TOTAL** | | | **11.1** | **104.3** | **1.0** | **4.9** | **5.4** |

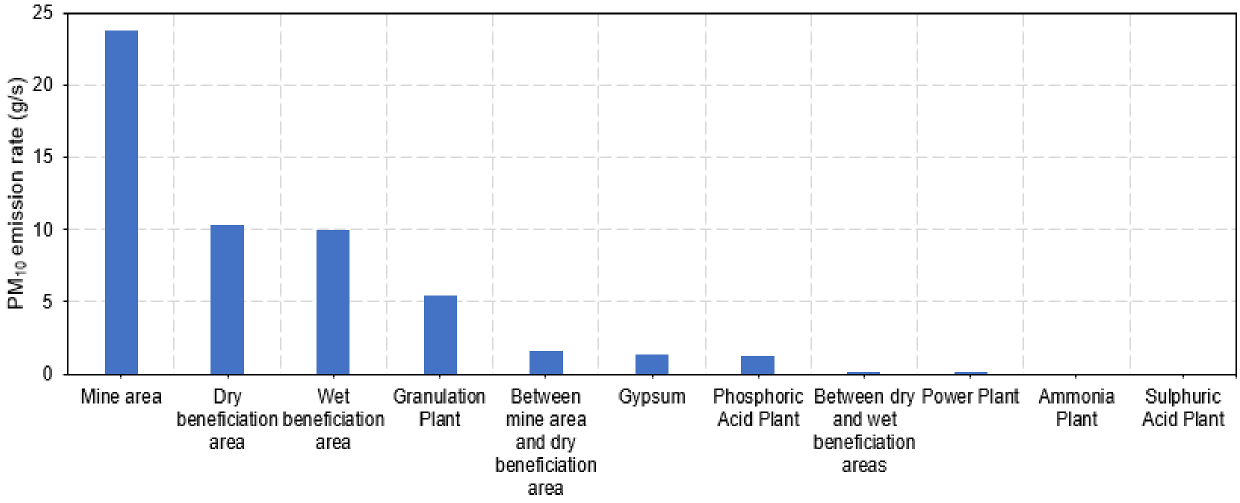


***Figure 4.1*** ***$PM_{10}$ emission rates by project area***

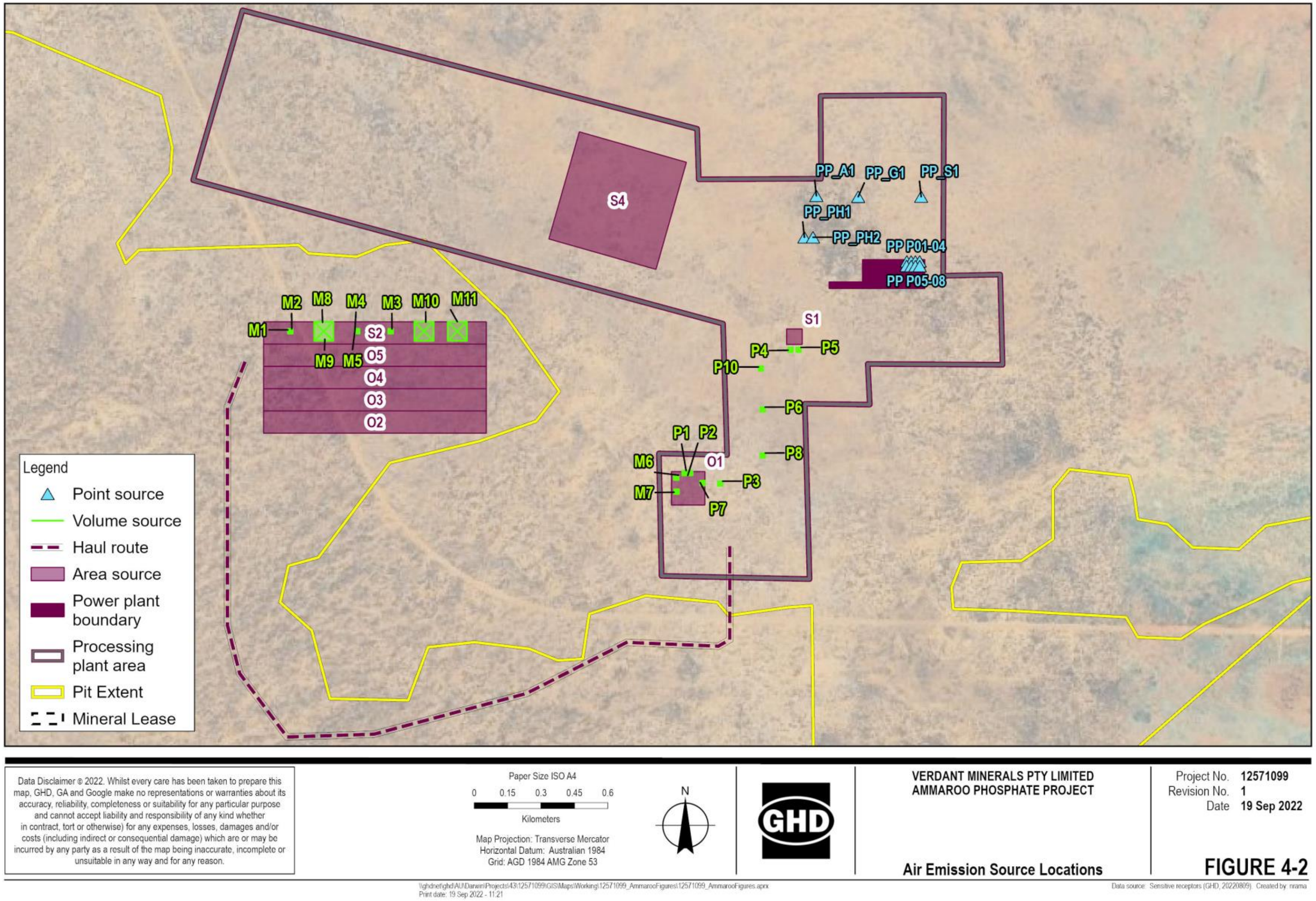


*Figure 4.2 Air emission source locations*

# 5. Separation distance assessment

## 5.1 Purpose

A separation distance is a planning instrument used to provide separation of sensitive land uses (i.e., residential, schools, hospitals) from premises with the potential for off-site emissions that can cause disamenity. Under routine operations, any adverse impact is to be confined on-site so that an external buffer should not be required.

The purpose of the separation distance guidelines is to provide recommended minimum separation distances between industrial land uses with the potential for off-site emissions and sensitive land uses. Accordingly, the relevant uses for a buffer assessment involve the following:

– Provide clear direction on which land uses require separation.
– Inform and support strategic land use planning decisions.
– Prevent new sensitive land uses from impacting on existing industrial uses.
– Prevent new or expanded industrial land uses from impacting on existing sensitive land uses.
– Identify compatible land uses that can be established within a separation distance area.

## 5.2 NT EPA Recommended Land Use Separation Distances

The NT EPA Recommended Land Use Separation Distances Guideline (NT EPA, 2017) should be considered when preparing a planning proposal or amendments to existing development plans. The guideline defines a separation distance as the recommended distance to separate a source of emissions (offensive odour, noise, smoke, dust, or fumes) from sensitive land uses in order to avoid adverse impacts to human health and amenity. A sensitive land use is described as land use where people live or regularly spend time, and which require a particular focus on protecting the health and well-being of humans and amenity values from the emissions of an activity. Sensitive land uses may include, but are not limited to, residential premises, accommodation facilities such as hotels and nursing homes, hospitals, childcare centres, schools, and some outdoor recreation facilities.

Importantly, separation distances are not intended to replace effective source control technology and practices and are to be used in conjunction with best or leading practice environmental management.

Table 5.1 outlines the separation distances applicable to the Proposed Project. GHD has applied Method 2 to the application of separation distances, namely, the separation distance is measured from the activity boundary of a potentially impacting activity to the property boundary of the nearest sensitive land use.

*Table 5.1 Separation distances applicable to the Proposed Project*

| Activity type | Activity description | Scale | Separation distance (m) | Drawn from |
|---|---|---|---|---|
| Fertiliser production | Production of inorganic fertilisers. | ≥ 2,000 tonnes per year | 1,000 | Processing plant boundary |
| Mineral sands mining or processing | Premises on which mineral sands ore is mined, screened, separated, or otherwise processed. | ≥ 5,000 tonnes per year | 2,000 | Mining and processing plant boundaries |
| Processing or beneficiation of metallic or non-metallic ore | Premises on which:<br>• Metallic or non-metallic ore is crushed, ground, milled or otherwise processed | ≥ 50,000 tonnes per year | 2,000 | Processing plant boundary |

| Activity type | Activity description | Scale | Separation distance (m) | Drawn from |
|---|---|---|---|---|
| | • Tailings from metallic or non-metallic ore are reprocessed<br>• Tailings or residue from metallic or non-metallic ore are discharged into a containment cell or dam | | | |
| Electric power generation | Electrical power generation using natural gas as fuel. | ≥ 20 megawatts (MW) in aggregate | 1,000 | Power plant boundary |

## 5.3 Result

The separation distances as summarised in Table 5.1 and are presented in Figure 5.1. It can be seen from Figure 5.1 that none of the relevant separation distances identified extend to the nearest sensitive receptor location, being the workforce's accommodation village.

The result of the separation distance assessment suggests that there is a low risk of residual emissions leading to off-site air quality impacts, including odour, smoke, dust, or fumes.

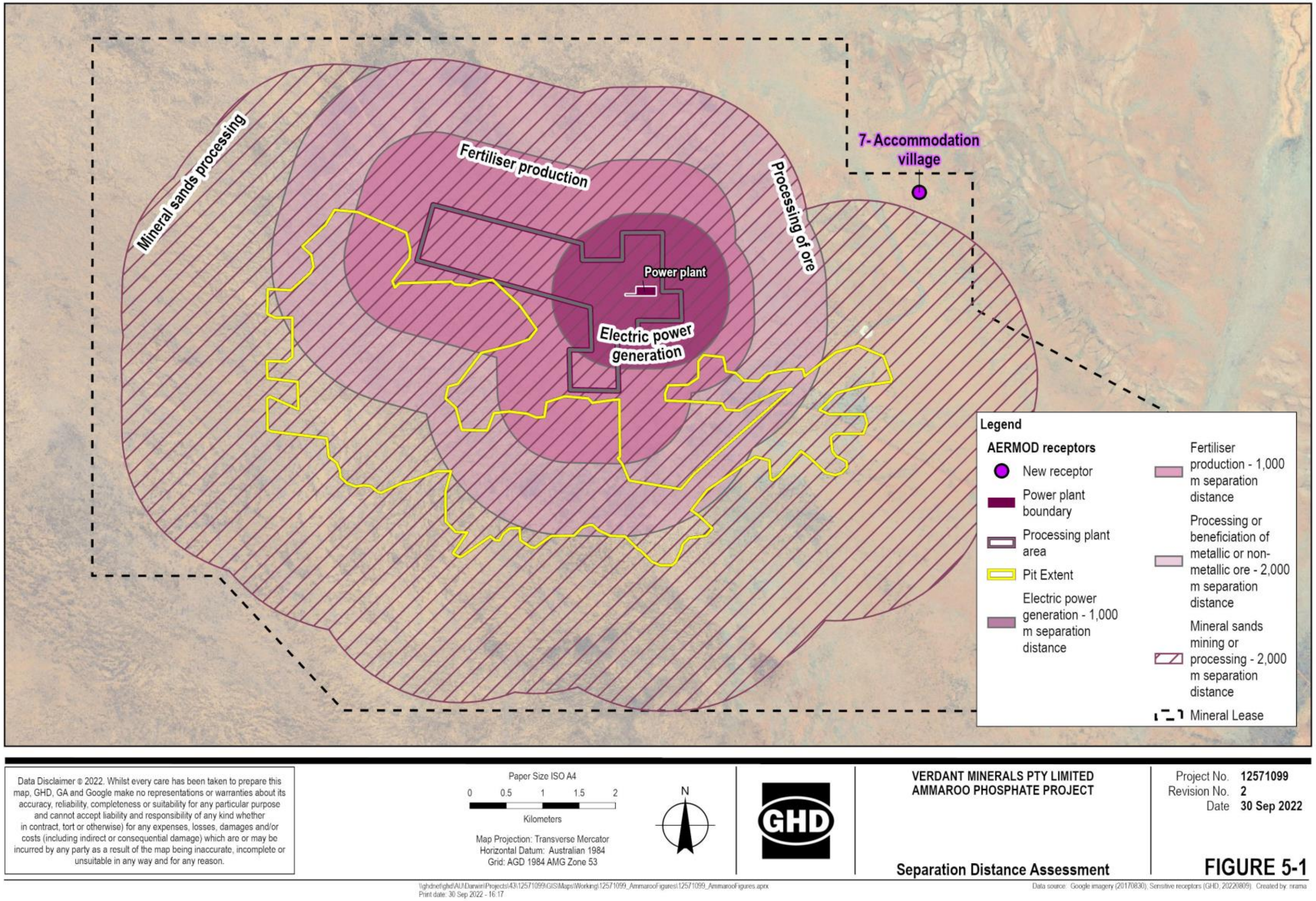


*Figure 5.1 Separation distance assessment*

# 6. Impact assessment

## 6.1 Overview

The air quality impact assessment was completed using the AERMOD dispersion model, consistent with GHD 2017. No changes were made to the model configuration, with the only changes to the model being:

- An additional receptor being the “accommodation village” which was added to represent the ‘changed’ location of the mine accommodation camp.
- Changes to some source locations and deletion of certain sources as required (discussed in Section 4.2).
- Additional sources to represent air quality emissions associated with the production of MAP and DAP fertiliser product and storage fertilisers (discussed in Section 4.3).

## 6.2 Results

The dispersion modelling results are presented in Section 6.2.1 for the discrete receptor locations and in Section 6.2.2 as gridded receptor contour plots.

### 6.2.1 Discrete receptors

Table 6.1 presents the dispersion modelling predicted ground level concentrations (GLCs) at the discrete receptor locations identified in Section 2.1.1. Results for fluoride are presented as the maximum GLC to account for potential impacts on vegetation anywhere off-site, not only at the receptor locations. The results in Table 6.1 include background pollutant concentrations where relevant (namely a background value of 20 µg/m³ added to the $PM_{10}$ predicted GLCs).

From Table 6.1, the results of the impact assessment show that compliance is predicted for all pollutants outlined in Table 3.1. The following is observed:

- Compliance with the objectives for $PM_{10}$ is achieved at all sensitive receptors, with the highest predicted GLC being 80% of the 24-hour average objective, and 85% of the annual average objective, at the proposed location of the accommodation village.
  - It is noted that $PM_{10}$ emissions were estimated for a worst-case scenario in which the mining operations occur close to the mine accommodation village, and where the majority of emission sources are to some degree aligned with this receptor.
- Compliance with the objectives for $NO_2$ is achieved at all sensitive receptors, with the highest predicted GLC being 6% of the 1-hour average objective, at the accommodation village.
- Compliance with the objectives for $SO_2$ is achieved at all sensitive receptors, with the highest predicted GLC being 9% of the criterion at the accommodation village.
- Compliance with the criteria for F is achieved at all locations on the grid, with the highest predicted GLC being 50% of the 30-day average criterion. It is noted that the adopted criterion is for the protection of sensitive vegetation only.
- Compliance with the criterion for $H_2SO_4$ is achieved at all sensitive receptors, with the highest predicted GLC being 4% of the criterion, at the accommodation village.
- Compliance with the criterion for $NH_3$ is achieved at all sensitive receptors, with the highest predicted GLC being 0.2% of the criterion, at the accommodation village.

*Table 6.1 Results of impact assessment – including background*

| Pollutant | Averaging period | Return interval | Back-ground ($\mu g/m^3$) | Predicted GLC ($\mu g/m^3$) including background | | | | | | Objective / Criteria ($\mu g/m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Accommodation village | Ampilatwatja | Imperrenth | Ngkwarl-erlanem | Imangara | Maximum on grid | |
| $PM_{10}$ | 24-hour | Maximum | 20 | 40 | 24 | 25 | 24 | 21 | NA | 50 |
| | Annual | Average | | 21 | 20 | 21 | 20 | 20 | | 25 |
| $NO_2$ | 1-hour | Maximum | 0 | 10 | 4.6 | 4.1 | 3.4 | 2.7 | | 164 |
| | Annual | Average | 0 | 0.063 | 0.037 | 0.16 | 0.011 | 0.011 | | 31 |
| $SO_2$ | 1-hour | Maximum | 0 | 27 | 15 | 15 | 12 | 10 | | 286 |
| | 24-hour | Maximum | 0 | 2.6 | 3.0 | 3.9 | 1.7 | 1.2 | | 57 |
| F* | 1-hour | 99.9th percentile | NA | | | | | | 1.3 | 60 |
| | 24-hour | Maximum | | | | | | | 0.4 | 1.5 |
| | 30-day | Maximum | | | | | | | 0.2 | 0.4 |
| $H_2SO_4$ | 1-hour | 99.9th percentile | 0 | 0.78 | 0.64 | 0.57 | 0.34 | 0.36 | NA | 18 |
| $NH_3$ | 1 hour | 99.9th percentile | 0 | 0.57 | 0.53 | 0.52 | 0.31 | 0.33 | | 330 |

Note: Assessment is made against 1-hour, 24-hour and 30-day averaging periods for fluoride impacts only as there are no options for 7-day, and 90-day averaging periods for gridded receptors (max on grid) in the Lakes AERMOD model.

### 6.2.2 Contour plots

A contour plot for showing the predicted cumulative 24-hour average $PM_{10}$ GLCs (the most critical pollutant) is provided in Figure 6.1 below. The contour plots show the spatial variability of the air quality impact surrounding the mine site and processing plant. As expected, due to the predicted wind direction, impacts are greatest to the northwest of the emission sources. A similar pattern of dispersion would be seen for the other air pollutants.

From Figure 6.1, it can be seen that the new location of the accommodation village is located outside the 50 $\mu g/m^3$ objective contour. This shows that $PM_{10}$ compliance at the new mine accommodation village is achieved.

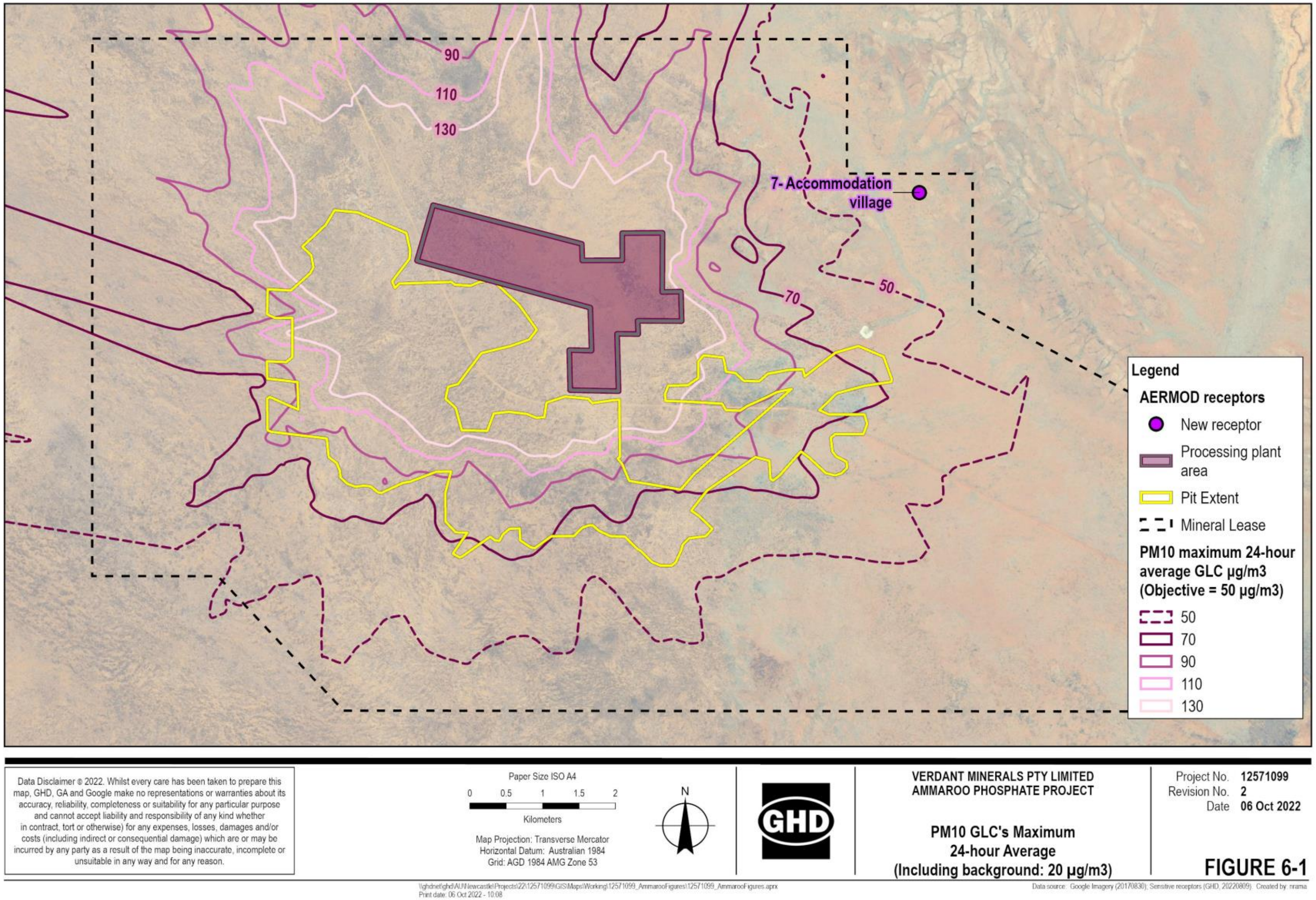


*Figure 6.1* ***$PM_{10}$ GLC's Maximum 24-hour Average (Including background: 20 µg/m³)***

# 7. Management and mitigation measures

## 7.1 Management of particulate impacts

The results of the impact assessment show that compliance is predicted for all pollutants. The $PM_{10}$ GLC's were predicted to be up to 85% of the air quality objectives at the accommodation village, which indicates that $PM_{10}$ is the critical pollutant. The remaining pollutants were predicted to not be more than 50% of their relevant objective or criterion.

When a breakdown of the source emission rates is analysed, it can be seen that the majority of the $PM_{10}$ emissions are from the mining and beneficiation operations with a relatively small contribution from the additional sources associated with the production of MAP and DAP fertiliser product and storage of fertilisers.

As such, the following recommendations, as outlined in GHD 2017, are considered appropriate:

– Adhere to the dust control measures described in Section 4.5.2 of GHD 2017.
– A monitoring site is established at the new accommodation village to audit the dust management plan. This would include $PM_{10}$ in-air concentration and a dust deposition gauge (as part of a wider gauge network). If dust levels are found to approach the objective level, to further mitigate the risk of $PM_{10}$ exceedances at the mine accommodation village, meteorology specific control measures should be considered. Where a meteorological forecast indicates that winds will be blowing towards the new mine accommodation village or a reactive monitor reaches a predefined trigger level, measures such as reducing site activity or significantly increasing the intensity of dust controls (such as water sprays or chemical dust suppressants on major haul road links) should be carried out.
– An air quality management plan should be developed outlining:
  - Air quality management practices
  - Emission control measures
  - Air quality monitoring strategies
  - Reactive dust monitoring program, if required.

## 7.2 Further assessment during detailed design

The air emission rates, and source locations used for the new MAP/DAP plant were based on early-stage design information, and included:

– Some emission guarantees provided by Licensors.
– Emission estimates based on best available techniques.
– Source locations based on current plant layout maps.

As the design of the plant progresses, and as more detailed information emerges, the emissions and source locations used in the modelling exercise may be subject to change. However, given the margin of compliance with key pollutants from the MAP/DAP plant, it is expected that only major changes to the design would lead to changed impacts which would exceed the criteria levels.

It is recommended that an updated air quality assessment is completed during detailed design, to verify the progressed design's compliance with the relevant air quality objectives. The updated air quality assessment would:

– Consider updated modelling of point source emissions (fertiliser plant, power plant) based on updated vendor guarantees, source locations, and building layouts.
– Conduct dispersion modelling of additional mining stage scenarios, to reflect to most up to date mine planning capturing a range of pit locations and mining intensities.
– Inform the development of air quality management and monitoring plans.

In addition to completing an updated air quality modelling assessment, the following air quality plans should be developed:

1. Air quality management plan – comprehensive document summarising all operational measures and procedures relating to the management of air emissions. The plan would include all control measures and ongoing management activities which would mitigate risk of air quality impacts. The plan would outline responsibilities, including for execution of any required air quality monitoring and reporting.
2. Air quality monitoring plan – summary document, outlining methodology and reporting requirements for all relevant air quality monitoring activities. Details would be outlined for the following monitoring types, as appropriate; emissions sampling (routine or continuous emissions monitoring system (CEMS)), compliance ambient air quality monitoring, reactive monitoring, visual monitoring, and meteorological monitoring.

# 8. Conclusion

Verdant propose to further develop the 2018 Approved Project to include the onsite production of MAP and DAP fertiliser. This will entail the construction of additional onsite plant and infrastructure, resulting in a change to the air quality impacts previously assessed in GHD 2017. Therefore, an assessment of the air quality impacts associated with the new and formerly modelled air quality sources was required to be undertaken.

The emissions inventory prepared as part of GHD 2017 was updated to include:

– Updated parameters for sources already included within the emissions inventory
– Addition of sources not previously included within the emissions inventory (including the additional onsite plant associated with the production of MAP and DAP fertiliser)

The results of the impact assessment show that compliance is predicted for all pollutants. The $PM_{10}$ GLC's were predicted to be up to 85% of the air quality objectives at the accommodation village, which indicates that $PM_{10}$ is the critical pollutant. The remaining pollutants were predicted to not be more than 50% of their relevant objective or criterion. The predicted fluoride (F) impacts are estimated to be 50% of the 30-day average objective at the maximum location on the grid.

When a breakdown of the source emission rates is analysed, it can be seen that the majority of $PM_{10}$ emissions are from the mining and beneficiation operations with a relatively small contribution from the sources associated with the production of MAP and DAP fertiliser product and storage fertilisers.

Therefore, a number of dust mitigation measures (as previously recommended in GHD 2017) have been recommended and should be implemented, where feasible and reasonable, to minimise potential dust impacts from the project site.

It is recommended that an updated air quality assessment is completed during detailed design, to verify the progressed design's compliance with the relevant air quality objectives.

Further, it is recommended that air quality management and air quality monitoring plans are developed prior to operations commencing.

## 8.1 Peer Review of Updated Air Quality Impact Assessment Study

At the request of the NT EPA, Verdant also commissioned an independent Peer Review of the GHD Updated Air Quality Impact Assessment Report. This Peer Review by Etkimo stated "Based on the provided updated air quality assessment report, Ektimo are satisfied that our review points have been addressed at this time".

The full Peer Review Letter Report (Reference: R013261-2) is enclosed in this document.

# 9. References

Australian Government. (2008). National Pollutant Inventory Emission Estimation Technique Manual for Combustion Engines Version 3.0. Canberra: Commonwealth of Australia.

Australian Government. (2011). National Pollutant Inventory Emission Estimation Technique Manual for Combustion in Boilers Version 3.6. Canberra: Commonwealth of Australia.

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Australian Government. (2014). National Pollutant Inventory Emission Estimation Technique Manual for Mining and Processing of Non-Metallic Minerals Version 2.1. Canberra: Commonwealth of Australia.

Department of the Environment. (2022). National Environment Protection (Ambient Air Quality) Measure. Commonwealth of Australia.

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GHD. (2017), VRM - Ammaroo Phosphate – EIS Air Quality Assessment. Darwin: GHD.

NSW EPA (2017), Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales

NT EPA (2017), Guideline: Recommended Land Use Separation Distances Version 1.0

# Appendices

# Appendix A

## Etkimo Peer Review of Updated Air Quality Impact Assessment

Ektimo

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27 September 2022

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**Attention: Mark Skelton**

## Ammaroo Phosphate Project Air Quality Assessment Independent Review
## GHD updated air quality assessment

Ektimo reviewed the GHD air quality assessments of 2022 and 2017 for the Ammaroo Phosphate Project as per our document R013261 issued 8th August 2022.

Ektimo subsequently received, via Verdant Minerals, GHD's response and proposed action in an email from Mark Skelton dated 17th August 2022. Ektimo reviewed and subsequently responded as per our document R013261-1 issued 19th August 2022, with an online meeting on 30th August 2022 to review outstanding items.

Ektimo subsequently received, via Verdant Minerals, GHD's updated air quality assessment (Revision 2) dated 19th September 2022. With respect to this document, Ektimo note the following:

- This air quality assessment is a part of a suite of documents, with a detailed description of the proposed project provided separately in Section 5 of the EES referral.
- Section 7.2 details the requirement for a further air quality assessment with additional emission scenarios around detailed design data as this becomes available to inform the development of an air quality management plan and an air quality monitoring plan that, when adopted, would mitigate the risk of the site activities causing air quality impacts. Ektimo assume that Verdant Minerals' generic obligations with respect to the requirements of the General Environmental Duty, legislated following the original 2017 GHD air quality assessment within the NT Environment Protection Act 2019 and not mentioned in this Revision 2 document, are detailed in other documents supporting the broader EES Referral.
- Some required minor text edits within the Revision 2 document are noted for GHD's action in the email within which this letter was transmitted to Verdant.

Based on the provided updated air quality assessment report, Ektimo are satisfied that our review points have been addressed at this time.

**Yours faithfully**

**Ektimo**

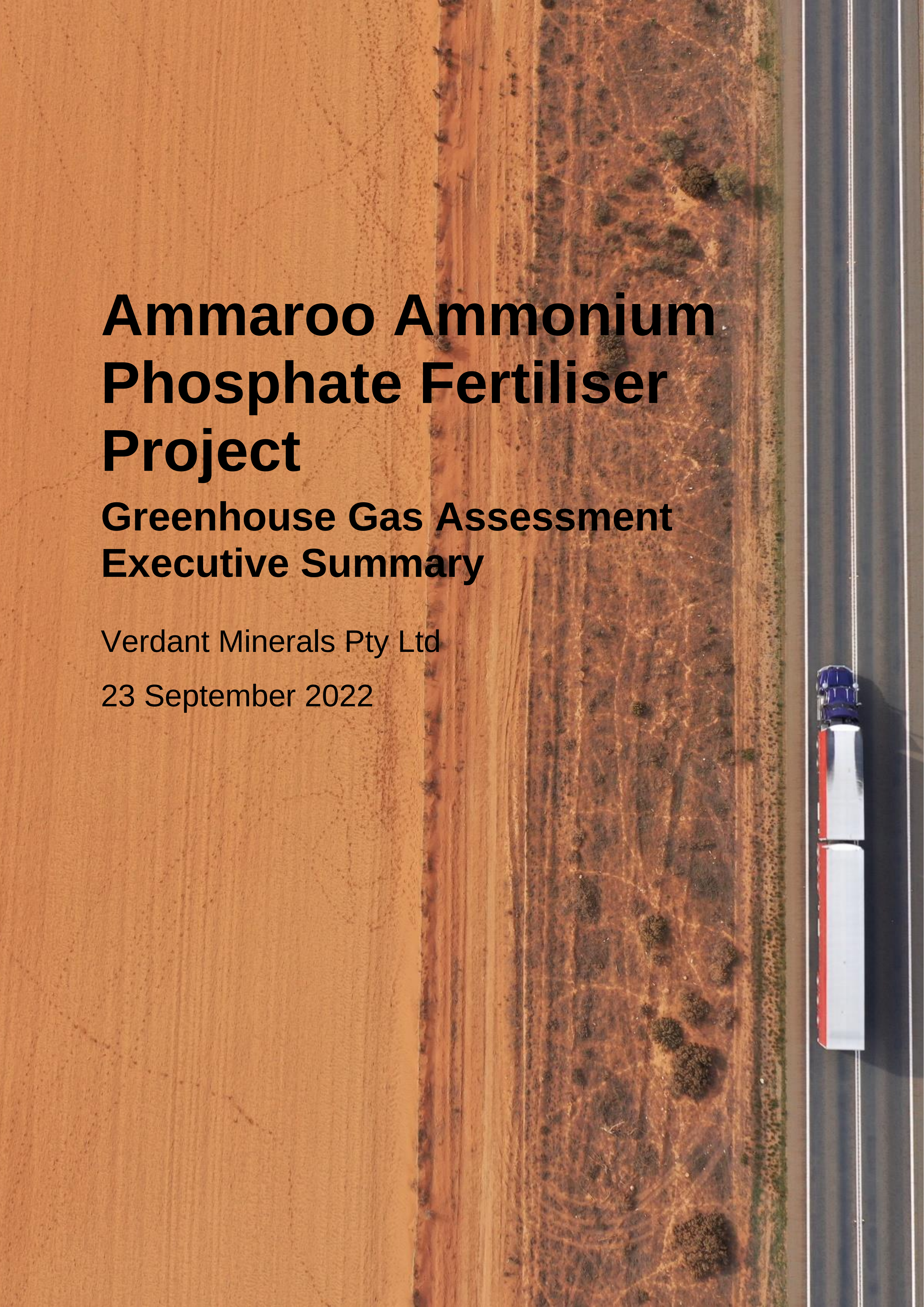
**Andrew Lewis**
**Air Quality Environmental Consultant**

ghd.com

→ The Power of Commitment

# Appendix O

## Greenhouse Gas Executive Summary



# Ammaroo Ammonium Phosphate Fertiliser Project

## Greenhouse Gas Assessment Executive Summary

Verdant Minerals Pty Ltd

23 September 2022

| Project name | Ammaroo Ammonium Phosphate Fertiliser Project - Variation, Environmental Approvals and NT EPA Referral | | | | | |
|---|---|---|---|---|---|---|
| Document title | Ammaroo Ammonium Phosphate Fertiliser Project \| Greenhouse Gas Assessment Executive Summary | | | | | |
| Project number | 12571099 | | | | | |
| File name | 12571099-REP-0_Ammaroo Ammonium Phosphate Fertiliser Project Referral - Appendix O.docx | | | | | |

| Status Code | Revision | Author | Reviewer | | Approved for issue | | |
|---|---|---|---|---|---|---|---|
| | | | Name | Signature | Name | Signature | Date |
| S4 | | I Deng | S Trahair | | D Blyth | | 09/09/2022 |
| S4 | | I Deng | S Trahair | | D Blyth | | 23/09/2022 |
| S4 | | I Deng | S Trahair | | D Blyth | | 07/10/2022 |

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# Abbreviations

| Abbreviation | Description |
|---|---|
| | Air separation unit |
| C&D | Construction and demolition |
| CCUS | Carbon capture utilisation and storage |
| $CO_2$ | Carbon dioxide |
| $CO_2$-e | Carbon dioxide equivalent |
| EF | Emissions factor |
| EIA | Environmental impact assessment |
| EIS | Environmental impact statement |
| EPA | Environment protection authority |
| EPBC | Environment Protection and Biodiversity Conversation Act 1999 |
| EV | Electric vehicles |
| FIFO/DIDO | Fly-in fly-out/drive-in drive-out |
| GGAP | Greenhouse gas abatement plan |
| GHG | Greenhouse gas |
| GJ | Gigajoules |
| $H_2$ | hydrogen |
| ha | Hectares |
| HPS | High pressure superheated steam |
| kL | Kilolitre |
| km | Kilometre |
| LGCs | Large generation certificates |
| LNG/LPG | Liquified natural gas/liquified petroleum gas |
| $m^3$ | Metre cubed |
| MAP/DAP | Monoammonium phosphate/diammonium phosphate |
| ML | Megalitre |
| MSW | Municipal solid waste |
| MWh | Megawatt hour |
| NG | Natural gas |
| NGER | National Greenhouse Gas and Emissions Reporting |
| $NH_3$ | Ammonia |
| NT | Northern Territory |
| $P_2O_5$ | Phosphorus pentoxide |
| PV | Photovoltaic |
| $SF_6$ | Sulphur hexafluoride |
| SMR | Steam methane reformer |
| The Proposed Project | Ammaroo Phosphate and Ammonia Project |
| The Approved Project | Ammaroo Phosphate Mine Project |
| Verdant | Verdant Minerals Limited |

# 1. Introduction

Verdant Minerals Pty Ltd (Verdant) is a Darwin-based, developer of Australian fertiliser mineral projects, including the Ammaroo Ammonium Phosphate Fertiliser Project (hereinafter abbreviated to 'Ammaroo Phosphate Project' and referred to as the 'Project'). The Project is situated in the central region of the Northern Territory, located in the western Georgina Basin approximately 220 kilometres (km) southeast of Tennant Creek, 125 km east of Barrow Creek and 270 km northeast of Alice Springs.

In 2018, the Project, was subject to and approved under an Environmental Impact Assessment, and comprised the development of the Ammaroo resource, by open-cut mining, crushing, beneficiation and drying to produce a phosphate rock concentrate for transportation via rail to the Darwin Port. The Project planned to export the rock concentrate to international markets as the essential feed stock for the production of fertiliser products. (For the purposes of clarity, the 2018 Project will hereafter be referred to as 'the Approved Project').

Verdant has proposed further development to the approved Ammaroo Phosphate Project. To expand the economic feasibility of the original project, Verdant now propose the onsite production of monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers (the Proposed Project). This will entail the construction of additional onsite plant, infrastructure, and operations.

The Northern Territory Government's Large Emitters Policy (Large Emitters Policy) commenced on 1 September 2021. This policy requires that new projects and expansion of existing projects, considered to be 'large emitters' are required to obtain an environmental authorisation under Territory legislation and are required to meet the obligations of the Policy. The thresholds for a project to be considered a 'Large Emitter' are *'The industrial project threshold is 100,000 tonnes carbon dioxide equivalent (t$CO_2$-e) (scope 1) in any financial year over the life cycle of a project'.*

The emissions from the Proposed Project trigger the Large Emitters Policy and hence a greenhouse gas emissions (GHG) assessment of the emissions is required.

The greenhouse gas assessment is prepared in compliance with the *National Greenhouse Gas and Energy Reporting Act 2007* (NGER Act), NT government guidelines for large emitters and other relevant standards.

## 1.1 Purpose of this Executive Summary

GHD prepared a Greenhouse Gas (GHG) Assessment Executive Summary Report for the Proposed Project as part of this EIS Referral. This GHG Executive Summary report provides an overview of the construction and operational emissions associated with the Proposed Project and supports the basis for developing a pathway to net zero by 2050. A greenhouse gas abatement plan (GGAP) for the Proposed Project will be developed in consultation with the NT EPA as part of this EIS Referral process.

Key emission sources, GHG inventory, and potential initial abatement strategies are discussed in the report.

## 1.2 Scope, Limitations, Assumptions, and Exclusions

Scope 1 and scope 2 construction emissions, and scope 1, scope 2 and scope 3 annual operation emissions for the Proposed Project have been determined, as required by NT EIA guidelines. Discussion and outline of efficient design mechanisms and abatement strategies are also included. A complete list of assumptions will be provided in the full GHG report and GGAP which will be prepared in parallel to the EIS Referral process.

Boundary of this assessment:

– Proposed Project's construction, and life of mine operation emissions are considered in this GHG assessment. The facility is expected to produce up to 1Mtpa of monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers.
– Previously Approved Project facilities operational emissions and diesel for earthworks and construction of the plant, vegetation clearance footprint of the airfield, and bore fields.

– Scope 3 emissions associated with operations, such as the transport of materials, embodied emissions and the emissions associated with the use of the fertiliser are assessed.
– Discussion of abatement strategies outcomes and design considerations.

### 1.2.1 Inclusions and Exclusions

*Table 1 Scope of inclusions, exclusions, and assumptions*

| Phase | Scope | Description |
|---|---|---|
| | | Inclusions |
| **Construction** | 1 | - Diesel used in plant and equipment from construction and used at the workers accommodation.<br>- Water supply pumping, wastewater treatment.<br>- Disposal of waste at on-site landfill.<br>Emissions associated with the construction of facilities already approved, in line with the approach used for the Proposed Project. These include diesel use and vegetation removal for construction of:<br>- The mine site, processing plant and tailings storage facility.<br>- 105km of rail and 137km gas pipeline.<br>- Bore field and 17km water pipeline.<br>- Roads, administration building, and accommodation village.<br>- Airfield.<br>- Fertiliser plant (MAP/DAP granulation plant, Sulphuric acid plant, Phosphoric acid plant, Ammonia plant).<br>- Realignment of approximately 12km of Murray Downs Road. |
| | 2 | Nil – all electricity to be generated on site using diesel generators. |
| **Operation** | 1 | - Diesel used in plant and equipment during mining.<br>- Natural gas in power gas engines and for process heaters (aux boilers and driers).<br>- Carbon dioxide process emissions generated during ammonia production.<br>- Disposal of waste at on-site landfill. |
| | 2 | - Grid electricity consumption at the Darwin Port site only (all electricity to be generated on Ammaroo site using the on-site power plant or renewables). |
| | 3 | - Transport of raw materials and equipment to the site.<br>- Transport of products from the site.<br>- Worker commuting, including private transport to/from the site and fly in, fly out/drive in, drive out (FIFO/DIDO).<br>- Embodied emissions from major raw materials and fuels (sulphur, diesel, natural gas, major chemicals, etc.).<br>- Scope 3 emissions associated with fuel and electricity.<br>- Scope 3 emissions associated with fertiliser use. |
| | | Exclusions |
| **All** | - | Emissions associated with combustion of fuels used in minor quantities such as LPG, gasoline, solvents, oils, and greases during construction.<br>Emissions associated with the leakage of hydrofluorocarbons or sulphur hexafluoride as these are likely to be negligible. |
| **Construction** | 3 | Scope 3 emissions including transport of plant equipment, worker commuting, and embodied emissions in materials such as concrete. |
| **Operations** | 3 | Scope 3 emissions from transport of raw materials, equipment and product to/from Australia and distribution of the fertiliser within Australia.<br>Scope 3 embodied emissions of some propriety chemicals where emission factors were not available. |

### 1.2.2 Assumptions and Limitations

The following limitations apply to the preparation of this assessment:

– This emissions inventory and estimations have been prepared based on the information available at the time, including documents provided by Verdant and other studies conducted as part of the EIS. These numbers are subject to changes from design, new information, and equipment revisions.
– Wherever possible, project design information was used to calculate greenhouse gas emissions, however given the limited availability of information, a number of assumptions have been made. Assumptions have been informed by industry experience and related projects where possible.
– As the project progresses through planning, detailed design, construction and operational phases, this inventory is to be updated with more relevant information.
– Unless otherwise specified, scope 1 and 2 emission factors used were as per the NGER (Measurement) Determination. Other emissions factors, for scope 3 materials, were derived from SimaPro. The assessment was based on emission factors (EF) available at the time of the assessment and future changes in emission factors or global warming potential were not considered.

*This report: has been prepared by GHD for Verdant Minerals Pty Ltd and may only be used and relied on by Verdant Minerals Pty Ltd for the purpose agreed between GHD and Verdant Minerals Pty Ltd as set out in section 1.2 of this report.*

*GHD otherwise disclaims responsibility to any person other than Verdant Minerals Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

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

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

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

# 2. Emission Sources and Discussion

A greenhouse gas inventory was prepared for the construction and operation emissions for the life of the Project. The results of the inventory are shown in Table 2. All values are estimates, based on the best available information at the time and are subject to change as per final design, new information and equipment revisions.

*Table 2 Estimated total emissions for Ammaroo Phosphate Project for construction and operational emissions*

| Project Phase | Scope 1 Emissions | Scope 2 Emissions | Scope 3 Emissions | Total Emissions |
|---|---|---|---|---|
| | (t $CO_2$-e) | (t $CO_2$-e) | (t $CO_2$-e) | (t $CO_2$-e) |
| Construction | 384,450 | - | - | 384,450 |
| Operation (average per annum) | 491,500 | 300 | 977,300 | 1,469,200 |
| Operation (life of project) | 12,335,000 | 7,100 | 24,439,800 | 36,782,100 |

## 2.1 Construction

Construction emissions are shown in Table 3 below and the majority is expected to be lost carbon sinks from vegetation removal. Diesel usage for earthworks is the secondary major emission source. Table 3 shows the breakdown of emissions and total percent of scope 1 emissions. The Proposed Project construction site will be remote from grid power; hence scope 2 emissions are not expected. Scope 3 emissions are not included in the construction inventory.

The majority of construction emissions are due to vegetation removal, accounting for 255,100 t $CO_2$-e (approximately 66%) of scope 1 total construction emissions. Diesel used for earthworks are estimated to produce 41,000 t $CO_2$-e (11% of total construction emissions).

Annualised construction emissions are approximately 128,100 t $CO_2$-e per annum. Compared to Australia's and the NT's annual emissions, construction emissions would amount to 0.026% and 0.62%, respectively.

*Table 3 Estimated construction emissions and breakdown for the Project*

| Construction - Emission source | Value | | Scope 1 emissions | Total emissions | Emissions proportion of total |
|---|---|---|---|---|---|
| | Quantity | Units | (t $CO_2$-e) | (t $CO_2$-e) | % |
| Diesel use - Main construction areas | | | | | |
| Diesel - Construction Earthworks | 15,200 | kL | 41,100 | 41,100 | 10.7% |
| Diesel - Darwin Port | 200 | kL | 400 | 400 | 0.1% |
| Diesel use - ancillary infrastructure | | | | | |
| Diesel - Airstrip | 800 | kL | 2,100 | 2,100 | 0.5% |
| Diesel - Bore Drilling | 20 | kL | 50 | 50 | 0.0% |
| Diesel - Gas & Water Pipelines | 2,400 | kL | 6,400 | 6,400 | 1.7% |
| Diesel - Rail | 22,600 | kL | 61,200 | 61,200 | 15.9% |
| Diesel - Realignment of Murray Downs Road | 200 | kL | 500 | 500 | 0.1% |
| Other emissions | | | | | |
| Diesel - Water Pumping | 100 | kL | 200 | 200 | 0.1% |
| Diesel - Accommodation Camp | 4,700 | kL | 12,800 | 12,800 | 3.3% |
| Vegetation Removal - Lost Carbon Sink | 2,300 | ha | 255,100 | 255,100 | 66.4% |

| | | | | | |
|---|---|---|---|---|---|
| Diesel - Vegetation Removal | 900 | kL | 2,500 | 2,500 | 0.7% |
| Waste - MSW and C&D | 1,800 | t | 2,100 | 2,100 | 0.5% |
| **Total construction emissions over 3 years** | | | **384,450** | **384,450** | **100%** |
| **Annualised construction emissions (nominal)** | | | **128,100** | **128,100** | **100%** |

## 2.2 Operations

Operational (annual) emissions consist of scope 1 emissions from the ammonia plant (69% of scope 1 operations emissions) and natural gas used in power generation, intermittent steam generation and for process drying as well as other minor sources of emissions include plant and equipment used during mining and scope 3 emissions from fertiliser use.

Estimated scope 2 emissions are negligible. The Darwin Port site will be the only site connected to grid electricity and is estimated to emit 300 t $CO_2$-e (0.02% of operations emissions) scope 2 emissions per year.

Scope 3 emissions sources include: the transport of raw material and equipment, worker commuting, embodied emissions from major raw materials and emissions associated with fuel/electricity and downstream fertiliser use. Table 4 is a summary of major and minor operation emission sources and emissions proportion.

*Table 4 Estimated operation (annual) emissions and breakdown*

| Emission source | Values | | Scope 1 emissions | Scope 2 emissions | Scope 3 emissions | Total emissions | Proportion of scope 1 emissions | Proportion of total emissions |
|---|---|---|---|---|---|---|---|---|
| | Quantity | Units/a | (t $CO_2$-e) | (t $CO_2$-e) | (t $CO_2$-e) | (t $CO_2$-e) | % | % |
| MAP/DAP granulation plant | 1,000,000 | t Fertiliser | 21,300 | 0 | 3,200 | 24,500 | 4.3% | 1.7% |
| Sulphuric acid plant | 3,451,700 | m3 | 7,000 | 0 | 1,400 | 8,400 | 1.4% | 0.6% |
| Phosphoric acid plant | 500,000 | t P2O5 | 4,300 | 0 | 0 | 4,300 | 0.9% | 0.3% |
| Ammonia plant | 200,000 | t NH3 | 340,000 | 0 | 73,100 | 413,100 | 69.2% | 28.1% |
| Power plant | 190,100 | MWh | 96,000 | 0 | 19,900 | 115,900 | 19.5% | 7.9% |
| MAP fertiliser | 500,000 | t | 0 | 0 | 279,800 | 279,800 | 0.0% | 19.0% |
| DAP fertiliser | 500,000 | t | 0 | 0 | 503,700 | 503,700 | 0.0% | 34.3% |
| **Summary of major operation (annual) emissions sources** | | | | | | | 95.3% | 91.9% |
| Diesel mining | 4,400 | kL | 11,900 | - | 600 | 12,500 | 2.4% | 0.9% |
| Diesel (light vehicles, generator, Darwin Port, vegetation clearance) | 800 | kL | 2,500 | - | 100 | 2,600 | 0.5% | 0.2% |
| Vegetation removal (mining) | 1,500 | ha | 6,600 | - | - | 6,600 | 1.3% | 0.5% |
| NG pipeline fugitives | 100 | km | 1,600 | - | - | 1,600 | 0.3% | 0.1% |
| Waste disposal | 200 | t | 300 | - | - | 300 | 0.1% | 0.02% |
| Electricity Darwin Port | 500 | MWh | - | 300 | 20 | 300 | - | 0.02% |
| Worker commuting | 19,302,800 | passenger/km | - | - | 2,700 | 2,700 | - | 0.2% |
| Rail freight | 2,235,100 | kt/km | - | - | 62,200 | 62,200 | - | 4.4% |
| Embodied emissions main materials | 76,100 | t | - | - | 30,600 | 30,600 | - | 2.1% |
| **Summary of minor operation (annual) emissions sources** | | | | | | | 4.6% | 8.34% |

Table 5 is a collation of NT and Australia's annual emissions published by the National Gas Inventories 2020 which will serve as a comparison for the Proposed Project's scope 1 and 2 operation emissions, total annual operations emissions are also included in this table. Emissions calculated in the NGA do not include scope 3 emissions.

*Table 5 Annual emissions of NT, Australia, and Ammaroo's projected operational emissions*

| Annual emissions | Value | |
|---|---|---|
| | Q | Units |
| NT (annual emissions) | 17,300,000 | t $CO_2$-e |
| Australia (annual emissions) | 497,700,000 | t $CO_2$-e |
| Scope 1 + scope 2 (annual operations) | 491,800 | t $CO_2$-e |

*Source: National Gas Accounts (NGA) 2020*

Table 6 compares NT and Australia's emissions with Ammaroo's annual operating emissions. The quantity of emissions estimated to occur during operations are estimated to be approximately 491,500t $CO_2$-e scope 1 and 300 t $CO_2$-e scope 2 per annum. Total scope 1 and scope 2 operational emissions of the proposed Project per annum is estimated at 491,800 t $CO_2$-e emissions, 2.84% of NT's total annual emissions and 0.1% of Australia's total annual emissions.

*Table 6 Proportion of NT, Australia's emissions compared to Ammaroo's annual operational emissions*

| Emission source (operations) | Proportion (%) |
|---|---|
| Scope 1 + scope 2 (annual operations) compared with NT | 2.84% |
| Scope 1 + scope 2 (annual operations) compared with Australia | 0.1% |

# 3. Abatement strategy

Addressing the NT Large Emitters policy, strategies will be required to align the emissions from the Proposed Project with the NT's goal of net zero by 2050. Currently, several abatement strategies are under consideration. The abatement strategy will have to consider the impact on technical and operational reliability and safety of the operation and also be economically viable for the Proposed Project.

The following measures have so far been evaluated and considered to offer potential pathways to reduce GHG generation and energy use during operations and construction, where technically and commercially viable:

- Embed energy efficient plant design: designing processes that recycle heat and steam and selecting equipment with high energy efficiency. Preference for electric equipment (motors and heaters verses steam or gas) that enable supplementation with renewable energy.
- Continuous process design to improve capital, energy, and process efficiency.
- Progressively deploying levels of solar photovoltaic (PV), wind turbines and battery storage to substitute gas used in power generation.
- Converting or replacing the mining fleet and other site vehicles to electric vehicles (EV) as commercially viable technology becomes available.
- Progressively expanding investment in renewable energy (solar PV, wind, battery storage) and electrolysis and hydrogen storage to substitute natural gas as feed to the ammonia plant up to 5% intermittently and then up to 10% continuously of $H_2$ feed to the plant.
- Increasing investment in renewables, $H_2$ electrolysis, $H_2$ storage beyond 10% and installing an air separation unit (ASU), to reduce natural gas feed to the steam methane reformer (SMR) and combine with 50% green hydrogen ($H_2$) as feed to ammonia ($NH_3$) plant.
- Further extensive investment in renewables (including potentially solar thermal), $H_2$ electrolysis, $H_2$ storage to replace natural gas feed as the primary feed to the Ammonia plant. i.e., 100% green $H_2$.

Alternatively, external 3rd party renewables in the form of green energy or green $H_2$ may be available should other investments in extensive renewable projects be developed. At the time of this referral, there are no such projects planned in the vicinity of the Proposed Project.

## 3.1 Efficient Design

The site has been designed to integrate as many of the energy systems as possible, thereby maximising heat recovery and efficiency across the site. This approach has enabled a significant reduction in baseline GHG emissions compared with sites without such an approach and will be continuously improved should new and more efficient processes/technologies become available. Examples of efficient design include:

- Waste heat recovery (in the form of high pressure super-heated steam (HPS)) from sulphuric acid and ammonia plants will be used to produce up to 54 MW of electrical power, with additional intermittent power generation of up to 24 MW obtained from gas engine generators.
- Design of the beneficiation plant utilising dry ore sorting technology to reduce waste being rock being fed to the wet beneficiation plant thereby reducing the capacity of the wet beneficiation plant, with comparably lower power consumption, compared to conventional design.
- The phosphoric acid plant may utilise continuous ion exchange technology (CIX) offering energy savings of up to 10% compared with conventional processes to remove impurities in the final weak acid streams.
- Extensive application of waste heat exchangers where possible to extract available process heat.
- Use of fin fan cooling and condensers, to reduce water losses and hence water handling power needs.
- Electrification of the major compressors within the ammonia plant to enable a central HPS power plant for the site and greater flexibility for the integration of renewable energy options in the ammonia plant.

## 3.2 Renewable Energy to Net Zero

The opportunities to progressively utilise renewable energy as a commercially and technically viable option to reduce the GHG emissions from the Proposed Project are currently under investigation by Verdant. This includes the phased installation of solar PV, wind turbines, and thermal solar energy generation schemes to meet the various operating conditions of the Project, together with a hydrogen electrolysis strategy.

Based on current technology developments, it is also likely that extensive energy storage in the form of industrial scale batteries and H2 storage, will be required to develop a safe and reliable pathway to achieving net zero operations. Based on current technology, this pathway will be at significant additional capital cost to the Project.

The Proposed Project is considering a combination of solar PV, wind generation and battery storage to be an initial stage to offset a proportion of the emissions from the gas engine generation. The pace of this investment will be determined in consultation with the NT EPA recognising the commercial impact of such investment and the desire to reach reduction targets, within certain timelines. From 2035, it is expected that greater than 80% of the emissions from the gas engines will be abated using renewables and a quantity of green hydrogen will be available either as fuel for the gas engines or feed to the ammonia plant.

## 3.3 Pathway to Green Ammonia (Net Zero) ASU and Other Investment

The substitution of natural gas feed into the SMR of the ammonia plant and the subsequent replacement of natural gas produced hydrogen with green hydrogen will be technically complex and capital intensive. Process limitations in the operation of the SMR and the feed requirements of the ammonia synthesis plant will initially limit the extent of direct green hydrogen substitution to approximately 10% of the total hydrogen made. After this point, additional nitrogen will be needed to be fed to the ammonia synthesis plant from a new air separation unit (ASU). The SMR will also become unstable at lower levels of natural gas feed and will require modification or total replacement to facilitate the substitution of natural gas feed with green hydrogen.

It follows that significant investment in renewables, hydrogen electrolysis and hydrogen storage will be required to substitute beyond 10% hydrogen in the feed, in addition to the investment in an ASU and other major modifications to the ammonia plant to adjust for operations without the inherent process steam which will no longer be generated in the SMR.

The total replacement of emissions from the ammonia plant through feeding 100% green ammonia using existing technology, including solar thermal applications, will require very significant capital investment.

Verdant will be working with technology providers to find more economically viable pathways to net zero ammonia production.

## 3.4 Conversion of Fleet to EV

It is unlikely electric vehicle (EV) fleets will be commercially available for the start-up of the Proposed Project. Verdant will propose to utilise conventional equipment whilst building knowledge of the mining process and then transition to an autonomous EV fleet when starting the first new pit once commercial application of the new technology is viable.  Through such a planned transition to an autonomous EV fleet, Scope 1 emissions from mining equipment and heavy vehicle diesel will be abated. All site vehicles are planned to be converted to EV by 2050 to align with NT net zero goals.

## 3.5 Carbon Capture Utilisation and Storage (CCUS)

CCUS is not considered to be a viable abatement option at this stage due to the distance of the site from potential sequestration sites. CCUS may become a viable abatement option in the future if a cost-effective compression, pipeline transport and sequestration site become available and is a viable alternative to other options.

# 4. Conclusion

The quantity of emissions for the Proposed Project are estimated to be approximately 384,450 t $CO_2$-e during construction, comprising scope 1 emissions only, for the entire construction period. The majority of construction emissions are due to vegetation removal, accounting for 255,100 t $CO_2$-e (approximately 66%) of scope 1 construction emissions. Annualised construction emissions are 0.62% of NT total annual emissions and 0.026% of Australia's total annual emissions.

The quantity of emissions estimated to occur during operations are estimated to be approximately 1,469,100 t $CO_2$-e per annum, comprising 491,500 t $CO_2$-e scope 1, 300 t $CO_2$-e scope 2, and 977,320 t $CO_2$-e scope 3 emissions per annum. Total scope 1 and scope 2 operational emissions of the Proposed Project per annum is estimated at 491,800 t $CO_2$-e emissions, 2.84% of NT's total annual emissions and 0.1% of Australia's total annual emissions. The majority of operational emissions are due to the ammonia plant, estimated to produce 340,000 t $CO_2$-e scope 1 emissions at peak capacity.

Abatement strategies will be considered and explored for all phases of the project to determine areas where savings can be made while maintaining a high level of stability and efficiency.

Several opportunities have been identified to align the project with NT government's goal of net zero by 2050. Efficient and mindful design and renewable energy supplementation using solar photovoltaics (PV) and green ammonia, are currently under exploration by Verdant. The PV and battery plan is expected to replace the NG engine within the first ten years of daytime operation.

This emissions inventory and GHG management plan is based on information available at the time of this EIS and is to be updated as the project progresses through the planning, detailed design, construction, and operational phases, as more information becomes available.

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# Appendix P

## Noise Impact Assessment

# Ammaroo Ammonium Phosphate Fertiliser Project

## Noise Impact Assessment

Verdant Minerals Pty Ltd

23 September 2022

→ **The Power of Commitment**

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| | |
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| **Project name** | Ammaroo Ammonium Phosphate Fertiliser Project - Variation, Environmental Approvals and NT EPA Referral |
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| | | | | | | | |



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# Appendices

# 1. Introduction

## 1.1 Overview

Verdant Minerals Pty Ltd (Verdant) is a Darwin-based, developer of Australian fertiliser mineral projects, including the Ammaroo Ammonium Phosphate Fertiliser Project (hereinafter abbreviated to 'Ammaroo Phosphate Project' and referred to as the 'Project'). The Project is situated in the central region of the Northern Territory, located in the western Georgina Basin approximately 220 kilometres (km) southeast of Tennant Creek, 125 km east of Barrow Creek and 270 km northeast of Alice Springs.

In 2018, the Project was subject to and approved under an Environmental Impact Assessment, and comprised the development of the Ammaroo resource, by open-cut mining, crushing, beneficiation and drying to produce a phosphate rock concentrate for transportation via rail to the Darwin Port. The project planned to export the rock concentrate to international markets as the essential feed stock for the production of fertiliser products. (For the purposes of clarity this will hereafter be referred to as the "Approved Project").

In 2014, the then Federal Minister for the Environment determined the Project to be a 'controlled action' and assessed the Approved Project under the *Environment Protection Biodiversity Conservation (EPBC) Act 1999*. EBPC approval was granted in January 2018 (EBPC 2014/7260). Having regard to the Environmental Impact Statement (EIS) and Supplementary Report (hereafter referred to as 'Approved EIS'), the Northern Territory Environment Protection Authority (NT EPA) assessed the Approved Project for its potential impacts and released Assessment Report 87 to be considered in decisions made by the Northern Territory Government. In 2018, the Project was approved under the Environment Assessment Act 1982.

To expand the economic feasibility of the Project, Verdant now plan to include the onsite production of monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers. This will entail the construction of additional onsite plant and infrastructure, including a phosphoric acid plant, sulphuric acid plant, ammonia plant, granulation plant, and amenity and service infrastructure (collectively referred to as the "Proposed Project") resulting in a change to the assessed noise and vibration impacts.

This report should be read in conjunction with GHD 2017, VRM - Ammaroo Phosphate – EIS Noise and Vibration Impact Assessment (GHD 2017). It is noted that the previous Noise Impact Assessment was submitted as part of the Approved Project EIS, which was subject to review by the regulator and was ultimately approved in 2018.

## 1.2 Purpose of this Report

The purpose of this report is to assess the construction and operational noise and vibration impacts from the additional onsite plant and infrastructure associated with the Proposed Project in order to address the Terms of Reference for the project.

## 1.3 Scope

The scope of works for the noise and vibration impact assessment includes:

– A review of the approved EIS and identification of any changes to the project
– Update of the assessment criteria in accordance with the *Northern Territory Noise Management Framework Guideline* (NT EPA, 2018).
– Assessment of the construction and operational noise levels associated with the changes from the Approved Project and identification of potential impacts.
– Provision of noise mitigation measures to minimise potential impacts where exceedances are identified.
– Preparation of an addendum report to supplement the existing report detailing the outcomes of this assessment.

## 1.4 Limitations

*This report: has been prepared by GHD for Verdant Minerals Pty Ltd and may only be used and relied on by Verdant Minerals Pty Ltd for the purpose agreed between GHD and Verdant Minerals Pty Ltd as set out in section 1.2 of this report.*

*GHD otherwise disclaims responsibility to any person other than Verdant Minerals Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

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

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

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

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

## 1.5 Assumptions

This section outlines the key assumptions made throughout the noise impact assessment:

– Any assumptions outlined in GHD 2017 are applicable to this assessment unless stated otherwise.

– Specific equipment selections have not been finalised. Representative equipment source noise level data have been used and are based on the likely operational plant and equipment that will be installed. Source noise level data has been obtained from projects of a similar nature to this Project.

# 2. Site Description

## 2.1 Existing Environment

A description of the existing environment is provided in the EIS noise and vibration impact assessment (GHD, 2017). The EIS assessment adopted a background noise level of 42 dBA based on measurements that are considered typical of a rural environment.

Since the submission of the EIS, the EPA have published the Northern Territory Noise Management Framework Guideline (NMFG) (NT EPA, 2018) which outlined minimum assumed rating background levels (RBLs) for the day, evening, and night. The minimum assumed RBLs are provided in Table 2.1 and have been adopted for this assessment and would provide a conservative assessment when compared to the EIS assessment.

*Table 2.1 Minimum assumed RBLs*

| Time of day | Minimum assumed RBL, dBA |
|---|---|
| Day | 35 |
| Evening | 30 |
| Night | 30 |

## 2.2 Sensitive Receptors

The sensitive receptors considered in this system and their distances to the Project site are summarised in Table 2.2 and shown in Figure 2.1.

Note that the location of the mine's accommodation village has changed from the 2017 EIS assessment. The accommodation village was originally located to the north-east of the project site and has been repositioned further east of the site. The distance to the mine camp (i.e., accommodation village) remains relatively unchanged.

*Table 2.2 Assessed nearby sensitive receivers external to the Project site*

| Sensitive receiver | Approximate distance to the mining lease | Easting, Northing GDA 2020 / MGA Zone 53 |
|---|---|---|
| Mine camp (i.e., Accommodation village) | 3.6 kms east-northeast | 519987.00 m E, 7625932.00 m S |
| Ampilatwatja | 12 kms south | 523132.00 m E, 7605574.00 m S |
| Imperrenth | 29 kms north-west | 495367.00 m E, 7655026.00 m S |
| Imangara | 61 kms north-west | 466869.00 m E, 7672211.00 m S |
| Ali-Curung | 86 kms north-west | 438463.00 m E, 7677101.00 m S |
| Ngkwarlerlanem | 37 kms south-west | 478416.00 m E, 7597321.00 m S |
| Indaringinya | 41 kms south-west | 471067.00 m E, 7602904.00 m S |
| Illeuwurru | 72 kms south-west | 437306.00 m E, 7610422.00 m S |
| Tara | 112 kms east | 396121.00 m E, 7621483.00 m S |
| Annerre | 114 kms east | 396355.00 m E, 7648574.00 m S |

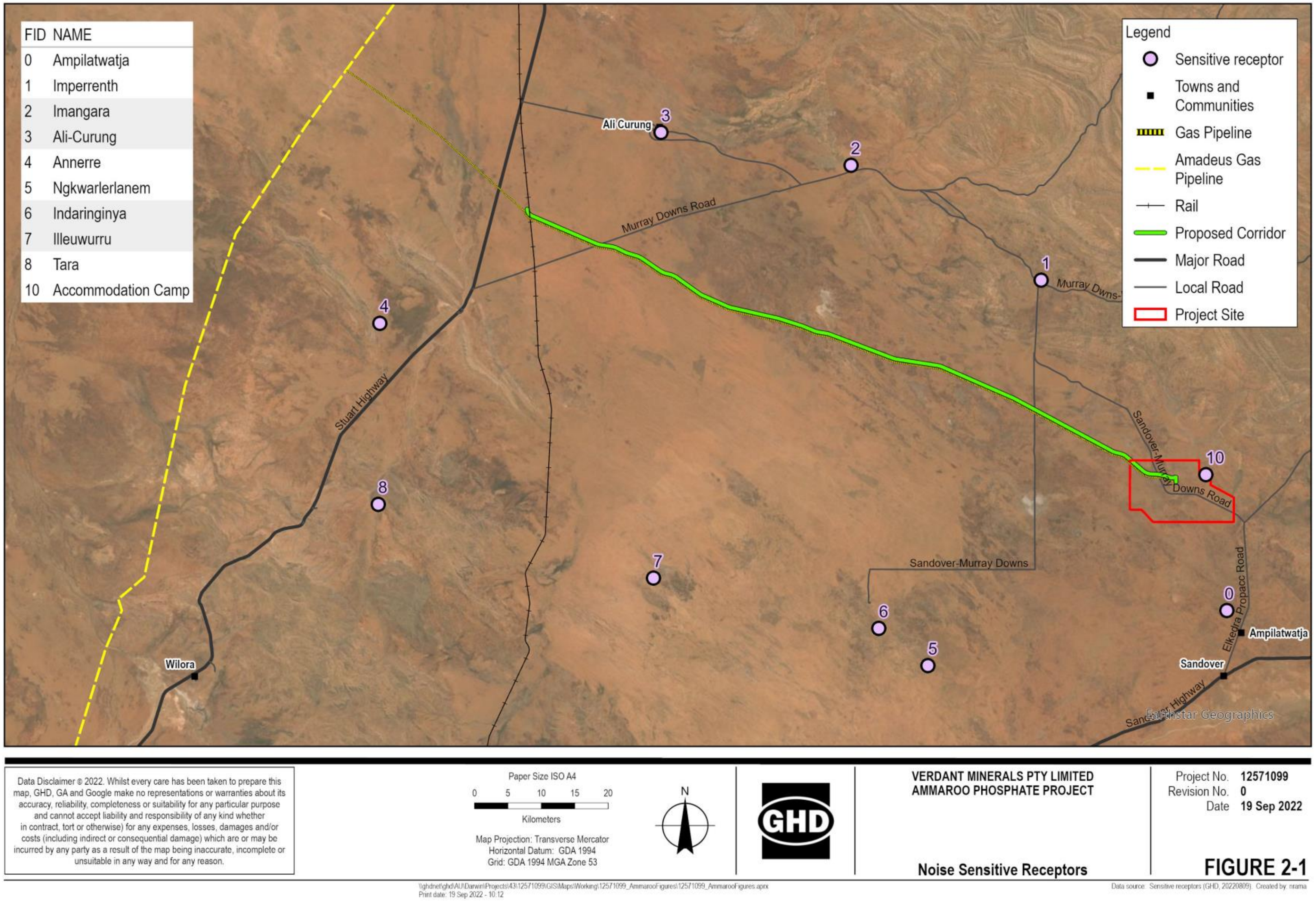


*Figure 2.1* *Noise sensitive receptors*

## 2.3 Meteorology

The annual wind rose and stability class distribution shown in Figure 2.2 and Figure 2.3 have been taken from the EIS assessment report.

The wind rose indicates that south-easterly winds occur with the greatest occurrence. Therefore, sensitive receptors located to the north-west of the project site would likely be in locations where there would be noise enhancing meteorological conditions.

The stability class distribution indicates that conditions are generally neutral with D-class occurring 34.5 percent of the time. During the night, conditions are considered stable with E- and F-class occurring 33.7 percent of the time. These conditions would be conducive to noise enhancing meteorological conditions.

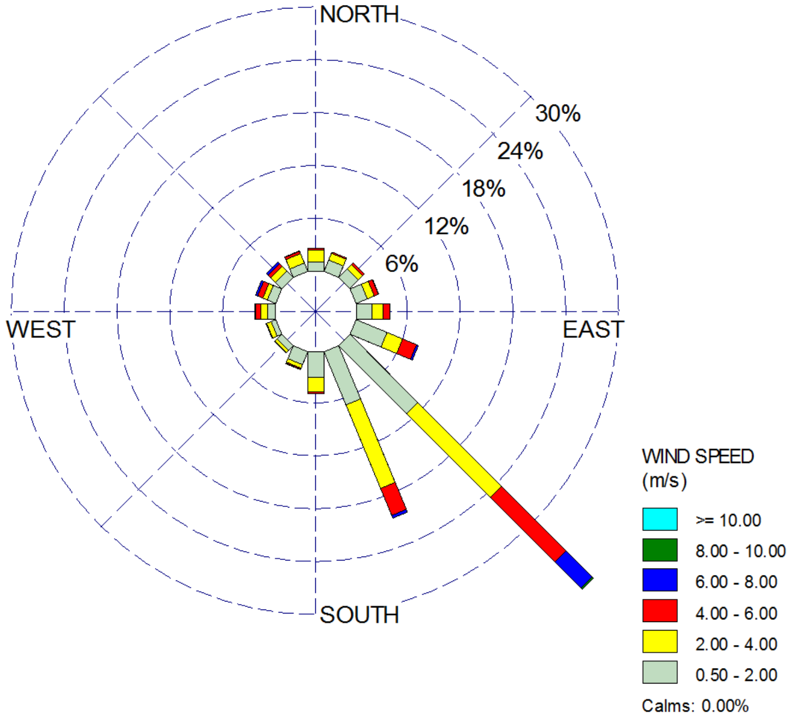


*Figure 2.2 Annual wind rose*

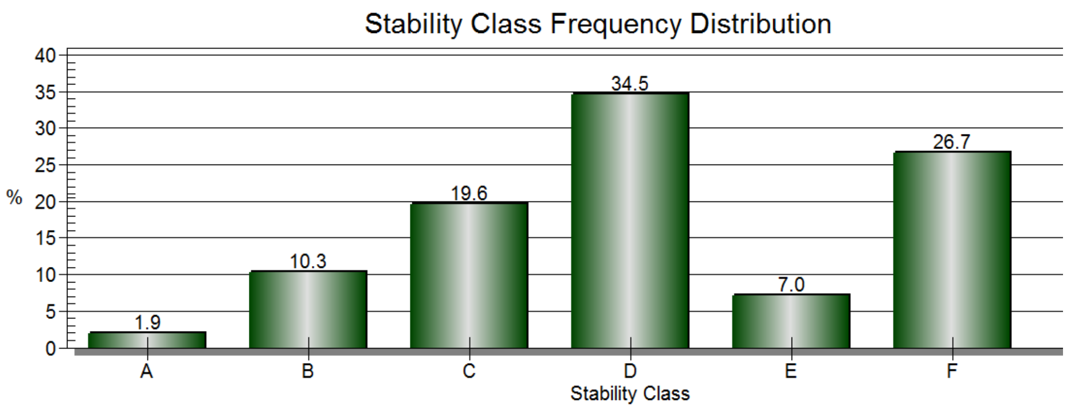


*Figure 2.3 Annual stability distribution*

# 3. Assessment Criteria

## 3.1 Construction Noise Criteria

### 3.1.1 Proposed Construction Hours

Construction noise management levels for the project are based on the Northern Territory Noise Management Framework Guideline (NMFG) (NT EPA, 2018). Recommended standard hours of work are as follows:

– Monday to Saturday: 7 am to 7 pm.
– Sundays or public holidays: 9 am to 6 pm.

Construction activities undertaken outside the recommended standard hours of work would incur a regulatory response in accordance with section 2.2.4 of the NMFG. However, the guideline does acknowledge five categories of work that may be undertaken outside the recommended standard hours:

1. The delivery of oversized plant or structures.
2. Emergency work to avoid the loss of life, damage to property or to prevent environmental harm.
3. Maintenance and repair of public infrastructure.
4. Public infrastructure works that shorten the length of the project and are supported by the affected community.
5. Works where a proponent demonstrates and justifies a need to operate outside the recommended standard hours.

### 3.1.2 Assigned Construction Noise Levels

Assigned construction noise levels (ACNL) for residential premises and other sensitive land uses are provided in the NT NMFG. The method to determine the ACNL for residentials receivers is outlined in Table 3.1.

*Table 3.1 Assigned construction noise levels for residential receivers*

| Time of day | Noise management level, $L_{Aeq(15min)}$ | Application notes |
|---|---|---|
| Recommended standard hours | Noise affected:<br>RBL + 10 dBA | The noise affected level represents the point above which there may be some community reaction to noise.<br>- where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level<br>- the proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details. |
| Outside recommended standard hours | Noise affected:<br>RBL + 5 dBA | A strong justification would typically be required for works outside the recommended standard hours.<br>The proponent should apply all feasible and reasonable work practices to meet the noise affected level.<br>Where all feasible and reasonable measures have been applied and noise is more than 5 dBA above the noise affected level, the proponent should consult with the community. |

The adopted assigned construction noise levels for this project are as follows:

– Recommended standard hours: 45 dBA.
– Outside recommended standard hours: 35 dBA.

## 3.2 Operational Noise Criteria

The Northern Territory Noise Management Framework Guideline (NMFG) (NT EPA, 2018) provides guidance on the assessment of noise emissions from commercial and industrial sites. The NMFG introduces a project specific assigned noise level (PSANL) which is a recommended mandatory limit that if exceeded will require noise management measures to be implemented.

The PSANL is the lower value of the following two components.

– **Project intrusiveness noise level**: this aims to protect against significant changes in noise levels. These are only applied to residential receptors.
– **Project amenity noise level:** this aims to protect against cumulative noise impacts from industry and maintain amenity for sensitive land uses.

### 3.2.1 Project Intrusiveness Noise Level

The intrusiveness noise level aims to protect against significant changes in noise levels. Typically, this will be the project noise trigger level in areas with low existing background noise levels. The intrusiveness noise level is determined by a 5 dBA addition to the measured rating background level (RBL).

The NMFG acknowledges that in some rural situations the RBL may be the same for the day, evening, and night. In these cases, it is recognised that impacts during the day would not be the same as those during the evening or night. The minimum project intrusiveness noise levels in the NMFG are provided in Table 3.2 and are based on the minimum assumed RBLs outlined in section 2.1.

***Table 3.2 Minimum assumed RBLs and project intrusiveness noise levels***

| Time of day | Minimum assumed RBL, dBA | Minimum project intrusiveness noise level, dBA |
|---|---|---|
| Day | 35 | 40 |
| Evening | 30 | 35 |
| Night | 30 | 35 |

### 3.2.2 Project Amenity Noise Level

The recommended maximum assigned amenity noise levels are the noise level objectives for all industrial noise at a sensitive receptor and are determined based on the overall acoustic characteristics of the receiver area, the receiver type, and the existing level of industrial noise.

The project specific amenity noise level represents the noise level objective for noise from a single development. It aims to limit the cumulative noise impacts from other industries and developments on all receiver types. The project amenity noise level is determined by a 5 dBA subtraction from the recommended amenity noise level for receivers that are not impacted by more than four individual industrial noise sources.

The project amenity noise level may be modified in the following cases:

– developments within high traffic noise levels.
– developments located near or inside an existing or proposed industrial cluster.
– where the project specific amenity noise level is at least 10 dBA lower than the existing industrial noise level.
– where there are no other existing or proposed industries within the development area.

The NMFG recommended amenity criteria for the identified receiver types surrounding the Project site are provided in Table 3.3.

*Table 3.3 Noise policy for industry amenity noise levels*

| Receiver type | Time of day | Recommended maximum amenity $L_{Aeq(period)}$ noise level, dBA |
|---|---|---|
| Residential – rural | Day | 50 |
| | Evening | 45 |
| | Night | 40 |

### 3.2.3 Project Specific Assigned Noise Level

The project specific assigned noise levels that are used to assess potential operational noise impacts are provided in Table 3.4.

*Table 3.4 Project noise trigger levels, dBA*

| Receiver | Time period | Project intrusiveness noise level, $L_{Aeq(15\ min)}$[1,2] | Project specific amenity noise level, $L_{Aeq(15\ min)}$[1,2] | Project specific assigned noise trigger level, dBA |
|---|---|---|---|---|
| Residential - rural | Day | 40 | 48 | **40** $L_{Aeq(15\ min)}$ |
| | Evening | 35 | 43 | 35 $L_{Aeq(15\ min)}$ |
| | Night | 35 | 38 | 35 $L_{Aeq(15\ min)}$ |

Note 1: The project specific amenity noise levels have been calculated by subtracting 5 dBA from the recommended maximum amenity noise levels as the identified receptors are not impacted by more than four individual industrial noise sources.

Note 2: The NMFG recommends applies a 3 dBA addition to the $L_{Aeq(period)}$ noise level to convert the amenity noise level to a $L_{Aeq(15\ min)}$

Note 3: The NMFG recommends that evening intrusiveness levels should be no greater than the day-time intrusiveness level. Therefore, the day-time background noise level has been used to calculate the project intrusiveness noise level for the evening period.

## 3.3 Low Frequency, Tonal and Impulsive Noise

The NMFG requires that modifying factor adjustments are added to the measured or predicted noise levels if the noise sources contain tonal, low frequency or noise characteristics. These noise characteristics can cause greater annoyance to the community than other noise at the same noise level. The modifying factor adjustments are summarised in Table 3.5 and are assessed at the receiver.

Low frequency noise is assessed through a comparison between the measured or predicted C and A weighted levels at each receiver. The A-weighting curve is used to approximate the sensitivity of the human ear at low levels. The C-weighting curve is designed to be more responsive to low-frequency noise.

*Table 3.5 Modifying factor adjustments*

| Factor | Assessment/ measurement | When to apply | Correction[1,2] |
|---|---|---|---|
| Tonal noise | One-third octave or narrow band analysis | Level of one-third octave band exceeds the level of the adjacent bands on both sides by:<br>5 dB or more if the centre frequency of the band containing the tone is in the range 500 – 10,000 Hz<br>8 dB or more if the centre frequency of the band containing the tone is in the range 160 – 400 Hz<br>15 dB or more if the centre frequency of the band containing the tone is in the range 25 – 125 Hz | 5 dBA[2] |
| Low frequency noise | Measurement of C-weighted and A-weighted level | Measure/assess C and A weighted levels over same time period. Correction to be applied if the difference between the two levels is 15 dB or more and:<br>where any of the one-third octave noise threshold level are exceeded by up to and including 5 dB and cannot be mitigated, a 2-dBA positive adjustment to measured/predicted A-weighted levels applies for the evening/night period<br>where any of the one-third octave noise threshold levels are exceeded by more than 5 dB and cannot be mitigated, a 5-dBA positive adjustment to measured/predicted A-weighted levels applies for the evening/night period and a 2-dBA positive adjustment applies for the daytime period. | 5 dBA[2] |
| Impulsive noise | A-weighted fast response and impulse response | If the difference in A-weighted maximum noise levels between fast response and impulse response is greater than 2 dB. | Apply the difference in measured noise levels as the correction up to a maximum of 5 dBA |
| Intermittent noise | Subjectively assessed | The source noise heard at the receiver varies by more than 5 dBA and the intermittent nature of the noise is clearly audible.<br>This adjustment is applied to the night-time period only. | 5 dBA |
| Duration[3] | If the duration of the noise event in any 24-hour period is as follows:<br>- 1.0 to 2.5 hours then increase the noise criteria by 2 dBA day and 0 dBA night<br>- 15 minutes to 1 hour then increase the noise criteria by 5 dBA day and 0 dBA night<br>- 6 minutes to 15 minutes then increase the noise criteria by 7 dBA day and 2 dBA night<br>- 1.5 minutes to 6 minutes then increase the noise criteria by 15 dBA day and 5 dBA night<br>- less than 1.5 minutes then increase the noise criteria by 20 dBA day and 10 dBA night. | | |

Note 1: Where two or more modifying factors are present the maximum correction is limited to 10 dBA.

Note 2: Where a source emits a tonal and low-frequency noise, only one 5 dB correction should be applied if the tone is in the low frequency range.

Note 3: Duration correction is a negative correction which increases the noise criteria

# 4. Construction Impact Assessment

## 4.1 Overview

A construction noise and vibration impact assessment was undertaken as part of the EIS Referral. This assessment included an evaluation of the following noise sources:

– Airborne construction noise.
– Construction vibration.
– Blasting overpressure and ground vibration.

No changes to the construction vibration and blasting assessments are proposed as part of this Proposed Project and have not been considered in this addendum report. The updates considered in this addendum report are due to the changes in the accommodation village location and includes an update to the recommended management measures based on the NMFG.

## 4.2 Methodology

In the absence of detailed project information, the Project is assumed to use standard construction equipment, general trade equipment and specialised equipment as required for the construction of the processing plant infrastructures.

Propagation calculations take into account sound intensity losses due to hemispherical spreading, with additional minor losses such as atmospheric absorption, directivity and ground absorption ignored in the calculations.

## 4.3 Construction Equipment

Plant and equipment anticipated for construction are provided in Table 4.1. Typical equipment sound power are based off AS2436-2010 *Guide to noise and vibration control on construction, demolition, and maintenance sites* (Australian Standards, 2010).

Note that final equipment types and numbers may not be known until shortly before commencement of construction, however given the noise predictions are based on worst-case scenario based on equipment operating at maximum power for the entire period, the received noise levels are not expected to change significantly.

Other equipment may be used; however, it is anticipated that they would produce similar net noise emissions when used concurrently with the equipment listed. The activity sound power levels are based on the loudest two items of equipment operating simultaneously. The operation for each equipment has been corrected based on the expected operation during a worst-case 15-minute period.

***Table 4.1 Construction plant sound power levels, dBA***

| Equipment | Sound power level, dBA |
|---|---|
| Scraper | 116 |
| Crane | 105 |
| Backhoe | 104 |
| Compressor | 101 |
| Concrete pump | 108 |
| Dump truck | 117 |
| Water truck | 107 |
| Compactor | 113 |
| Concrete batch plant | 113 |

| Equipment | Sound power level, dBA |
|---|---|
| Dozer | 114 |
| Grader | 110 |
| Loader | 113 |
| Excavator | 107 |

## 4.4 Predicted Construction Noise Levels

Received noise produced by anticipated activities during the construction phase is shown in Table 4.2 for a variety of distances, with no noise barriers or acoustic shielding in place and with each plant item operating at full power. The sound pressure levels shown are maximum levels produced when machinery is operated under full load.

*Table 4.2 Predicted construction plant item noise levels, dB(A)*

| Plant item | Distance of source to receiver (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 50 | 250 | 500 | 750 | 1000 | 2000 | 3000 | 8000 |
| Scraper | 74 | 60 | 54 | 51 | 48 | 42 | 38 | 30 |
| Crane | 63 | 49 | 43 | 40 | 37 | 31 | 27 | 19 |
| Backhoe | 62 | 48 | 42 | 39 | 36 | 30 | 26 | 18 |
| Compressor | 59 | 45 | 39 | 36 | 33 | 27 | 23 | 15 |
| Concrete pump | 66 | 52 | 46 | 43 | 40 | 34 | 30 | 22 |
| Dump truck | 75 | 61 | 55 | 52 | 49 | 43 | 39 | 31 |
| Water truck | 65 | 51 | 45 | 42 | 39 | 33 | 29 | 21 |
| Compactor | 71 | 57 | 51 | 48 | 45 | 39 | 35 | 27 |
| Concrete batch plant | 71 | 57 | 51 | 48 | 45 | 39 | 35 | 27 |
| Dozer | 72 | 58 | 52 | 49 | 46 | 40 | 36 | 28 |
| Grader | 68 | 54 | 48 | 45 | 42 | 36 | 32 | 24 |
| Loader | 71 | 57 | 51 | 48 | 45 | 39 | 35 | 27 |
| Excavator | 65 | 51 | 45 | 42 | 39 | 33 | 29 | 21 |

## 4.5 Predicted Construction Noise Impacts

The nearest sensitive receptor is the accommodation village location 3.6 km east northeast of the Project site. The noise level contribution from each construction plant item would be below the assigned construction noise level of 45 dBA during standard hours of work.

Outside the standard hours of work operation of scrapers, dump trucks and dozers have the potential to generate noise emissions above the assigned construction noise level of 35 dBA. Any works undertaken outside the standard hours of work would require justification.

## 4.6 Management and Mitigation Measures

The NMFG states that a Noise Management Plan (NMP) would ordinarily be required for all construction projects. The NMP would detail the allowable hours for construction, details on construction noise and vibration management measures in addition to complaints handling procedures.

The NMP would be submitted to the NT EPA and must contain:

1. Details of the person / entity proposing to make the noise.
2. A site plan including neighbouring land-use details.

3. Details of noise emission which cannot comply with the NMFG, including anticipated noise levels ($L_{Aeq}$, $L_{Amax}$), duration(s) and timing
4. Reasons/justification for the carrying out of noise emissions which cannot comply with the NMFG
5. Details demonstrating how noise emissions will be managed to minimise impacts on any noise sensitive receptors, including reference to any relevant standards such as AS2436
6. Demonstrated that all affected, or potentially affected noise sensitive receptors have been:
   a. Consulted regarding the proposed noise emissions at least two weeks prior to the noise event occurring
   b. Provided with a description of the expected noise emission, including time and date of noise emission
   c. Provided the opportunity to provide feedback
7. Demonstration on how feedback from affected, or potentially affected noise sensitive receptors has been considered and incorporated into proposed noise emissions management and the Noise Management Plan
8. A noise monitoring programme that details:
   a. Monitoring frequency
   b. Monitoring locations
   c. Actions that will be undertaken should monitored noise emission levels exceed anticipated noise levels
9. A consultation programme that includes procedures for communicating changes in planned events to all affected, or potentially affected noise sensitive receptors
10. A complaint response process, which includes a requirement to keep a complaints register where the following details will be recorded:
    a. Contact details of all complainants.
    b. The time and date the complaint is received.
    c. A description of the complaint.
    d. A description of the activities occurring which gave rise to the complaint.
    e. Any action taken as a result of the complaint.
11. The name of a person who will be responsible for implementing the Noise Management Plan.
12. The name and phone number of the person to whom a complaint may be made about noise emissions associated with the Noise Management Plan.

General noise and vibration management measures that should be implemented as part of this Proposed Project are outlined in Table 4.3.

*Table 4.3 Construction noise and vibration management measures*

| **Construction noise and vibration management measures** |
|---|
| **Community notification practices** |
| Potentially noise affected neighbours contacted at the earliest possible time before any site work begins. As a minimum it is expected that all potentially affected sensitive noise receptors be given 48 hours' notice prior to the commencement of construction activities |
| Potentially noise affected neighbours informed about the nature of the construction stages and the duration of noisier activities – for example, excavation and rock-breaking |
| Providing contact details on a site board at the front of the site, and maintain a complaints register suited to the scale of works |
| Providing copies of noise management plans, if available, to potentially noise affected neighbours. |
| **Operational practices** |
| Where practical, undertake the noisiest works during the recommended standard hours |
| Turn off plant that is not being used |
| Examine and implement where feasible and reasonable, the use of silenced equipment and noise shielding around stationary plant (such as generators), subject to manufacturers' design requirements |
| Ensure plant is regularly maintained, and repair or replace equipment that becomes noisy |

| Construction noise and vibration management measures |
| --- |
| Arrange the work site to minimise the use of movement alarms on vehicles and mobile plant |
| **Involvement of workers in minimising noise** |
| Avoid dropping materials from a height |
| Talk to workers about noise from the works at the identified land uses and how it can be reduced, and |
| Use radios and stereos indoors rather than outdoors. |
| **Handling complaints** |
| Keep staff who receive telephone complaints informed regarding current and upcoming works and the relevant contacts for these works |
| Handle complaints in a prompt and responsive manner |
| Where there are complaints about noise from an identified work activity, review and implement, where feasible and reasonable, actions additional to those described above to minimise noise output, and |
| Providing all complaints to the NT EPA Pollution Hotline within 24 hours upon receiving a complaint. |

# 5. Operational Impact Assessment

## 5.1 Overview

An operational noise and vibration impact assessment was undertaken as part of the EIS assessment. This assessment included an assessment of the following noise sources:

- Mining operations.
- Road traffic noise on the public road network.
- Rail traffic noise including an assessment on sleep disturbance impacts.
- Rail vibration.

No significant changes to the road and rail traffic are anticipated as part of this Proposed Project and therefore have not been considered in this addendum report. This report assesses the potential noise impacts due to the additional onsite plant and infrastructure associated with the production of MAP fertiliser and diammonium phosphate.

## 5.2 Modelling Methodology

Noise modelling was undertaken using SoundPlan Version 8.2 noise modelling software to predict the effects of airborne operational noise from the Project mine.

SoundPlan is a computer program for the calculation, assessment, and prognosis of noise propagation. SoundPlan calculates environmental noise propagation from noise sources within the Project mine boundary in accordance with ISO 9613-2, "*Acoustics – Attenuation of sound during propagation outdoors"* (ISO, 1996). Propagation calculations take into account sound intensity losses due to hemispherical spreading, atmospheric absorption, and ground absorption.

The ISO 9613-2 algorithm also takes into account the presence of a well-developed moderate ground-based temperature inversion, such as that which commonly occurs on clear, calm nights or during 'downwind' conditions, which are favourable to sound propagation. As a result, predicted received noise levels are expected to represent a worst-case scenario.

The noise model from the EIS assessment has been modified to include additional plant and equipment associated with this Project.

## 5.3 Modelling Parameters

The following noise modelling inputs and assumptions were made to establish site specific conditions:

- Surrounding land was modelled assuming a mixture of hard and soft ground with a ground absorption coefficient of 0.75. This ground absorption coefficient is considered conservative as the land surrounding the site is composed primarily of soft ground.
- Terrain topography with a five-metre resolution of the study area was used to generate the site used to predict noise levels.
- Sensitive receptors were modelled at a height of 1.5 m above ground level.
- Atmospheric propagation conditions were modelled with noise enhancing wind conditions for noise propagation (downwind conditions). This provides a conservative approach that assumes source-to receiver winds at all assessed receivers.

## 5.4 Modelling Assumptions

The following modelling conditions and assumptions have been made regarding the operational noise assessment:

- For the worst-case scenario, the plant is assumed to run continuously over the 15-minute day, evening, and night-time assessment period.
- Details of the exact locations of each equipment are unknown at this stage. Sources have been modelled separately for each plant area based on the plant and equipment's estimated height above ground.
- Plant areas would be operational simultaneously and the total noise from all plant areas has been considered
- The number of equipment associated with mining operations has been updated from the EIS assessment based on the latest available information.
- Each haul truck and water cart would generate one movement during the worst-case 15-minute period
- The haul trucks and water carts would travel along the haul routes at 20 km/h.
- Heavy vehicle traffic generation along the public road network would increase from two to three vehicles (based on the updated Traffic Impact Assessment) during peak periods when compared to the EIS assessment. This increase is considered insignificant and would not cause road traffic noise impacts. Therefore, operational road traffic noise has not been considered in this assessment.
- There would be up to 3.5 rail movements per week resulting in less than one movement per day on average. The EIS assessment modelled two trains during the day (15 hour) period and night (9 hour) period. Noise from rail movements have not been considered as the EIS assessment is considered conservative.

The model is considered conservative as it does not include the acoustic shielding effects from the operational plant structures and equipment and assumes propagation into the free-field.

## 5.5 Modelled Equipment

Modelled sound power levels for mobile and fixed sources for the project sites are summarised in Appendix B. The plant and equipment listed in the table are expected to be the major noise sources from the Project, and that the associated sound power levels are maximum predicted levels produced when machinery is operating under full load.

The plant areas considered as part of this operational noise assessment are:

- Mining area (as per the EIS report).
- Dry Beneficiation Plant.
- Wet Beneficiation Plant.
- Phosphoric Acid Plant.
- Gypsum Handling.
- Granulation Plant.
- Rail – associated with loading and unloading operations.
- Sulphuric Acid Plant.
- Water Treatment Plant.
- Power station.
- Auxiliary equipment and utilities.
- Ammonia Plant.

The locations of the modelled plant areas are shown in Figure 5.1.

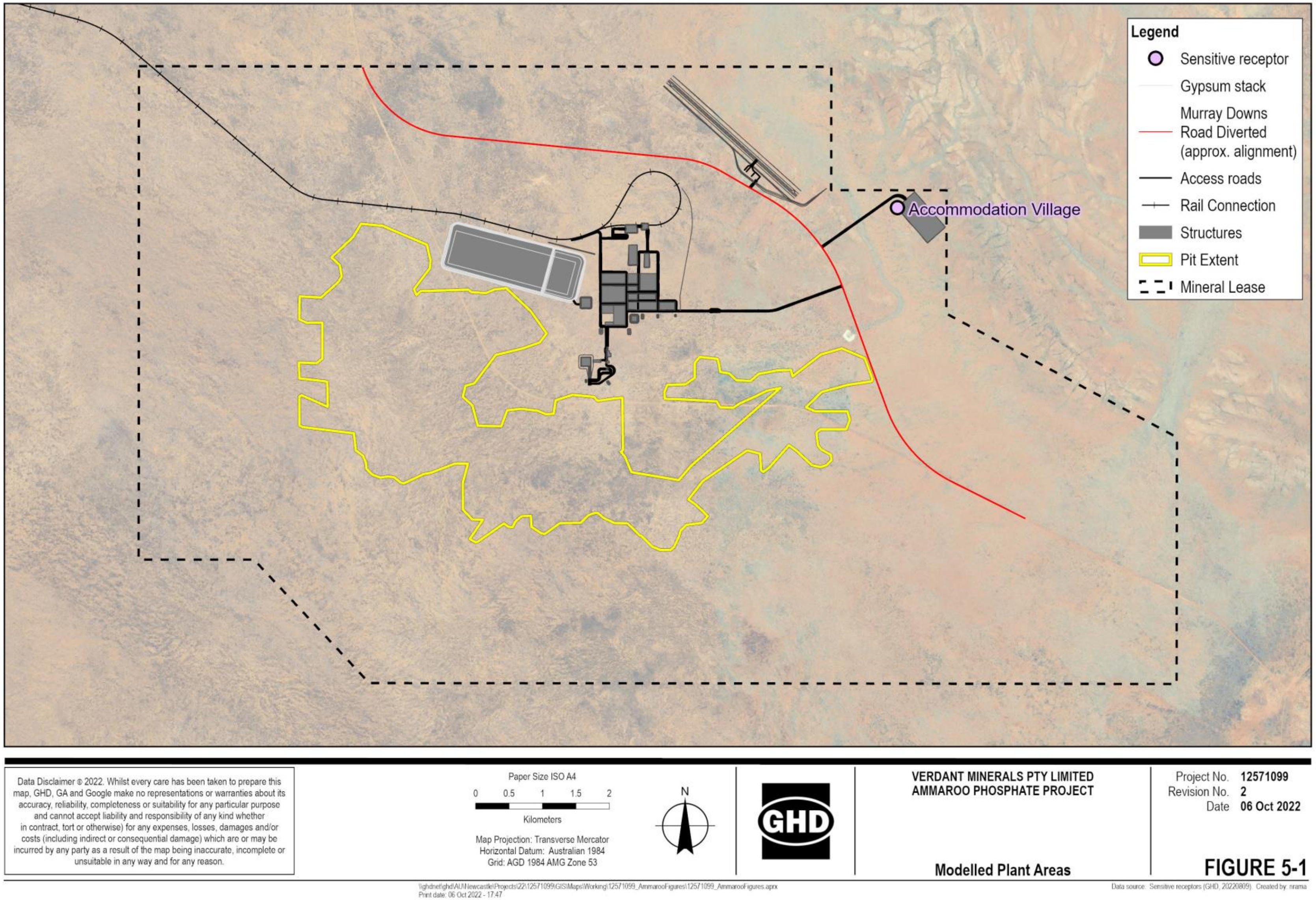


*Figure 5.1* *Modelled plant areas*

## 5.6 Predicted Operational Noise Impacts

The predicted operational noise levels from the Project are outlined in Table 5.1 including the contributions from each plant area. Operational noise contours are shown in Figure 5.2.

Potential operational noise impacts occur when the operational noise levels exceed the project specific assigned noise levels outlined in section 3.2. The night-time project specific assigned noise level of 35 dBA has been adopted as operations during the day, evening and night-time periods are constant and the potential noise impacts would be highest during the night-time period.

No exceedances of the project specific assigned noise levels are predicted. The highest noise levels are anticipated at the accommodation village located 3.6 km east northeast of the project site. Noise at the accommodation village is expected to be dominated from the following plant areas:

- Ammonia plant due to steam drum operations.
- Mining operations primarily due to haul truck and grader movements.
- Sulphuric acid plant due to the steam vents.

The model is considered conservative due to the following factors:

- It does not include shielding from the operational plant and equipment and assumes propagation into the free-field.
- The propagation algorithm used takes into account noise enhancing wind conditions with source to receiver winds. Occurrences of source to receiver winds (south-westerly winds) for the accommodation village are negligible based on the wind rose shown in Figure 2.2.
- Mining operations have been modelled based on the existing terrain and do not account for shielding which would result from equipment operating within an open-cut mine.
- Mining operations are modelled in the pit located closest to the nearest sensitive receptor. This mining pit would not be operational within the first 10 years of operations. Advancement in mining technology, such as the use of electric motors, has the potential to provide additional noise benefits once this pit is operational.

The results indicate that there is the potential for low frequency noise as C-weighted noise levels are at least 15 dB above the A-weighted noise levels. The spectral contributions at the accommodation village were analysed to determine whether the octave band thresholds were exceeded. The spectral contributions within each octave band are below the thresholds therefore no adjustments to the predicted A-weighted noise levels are required.

*Table 5.1 Predicted operational noise levels*

| Name | Plant area contribution, dBA | | | | | | | | | | | | Total, dBA | Total, dBC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ammonia Plant | Auxiliary | Dry Beneficiation | Granulation Plant | Gypsum | Mining | Phosphoric Acid | Power Station | Rail | Sulphuric Acid | Wet Beneficiation | WTP | | |
| Accommodation village | 29 | < 10 | 14 | 11 | < 10 | 30 | 19 | 16 | < 10 | 16 | 15 | < 10 | 33 | 61 |
| Ali-Curung | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Ampilatwatja | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | 10 | 40 |
| Annerre | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Illeuwurru | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Imangara | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Imperrenth | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Indaringinya | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Ngkwarlerlanem | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Tara | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |

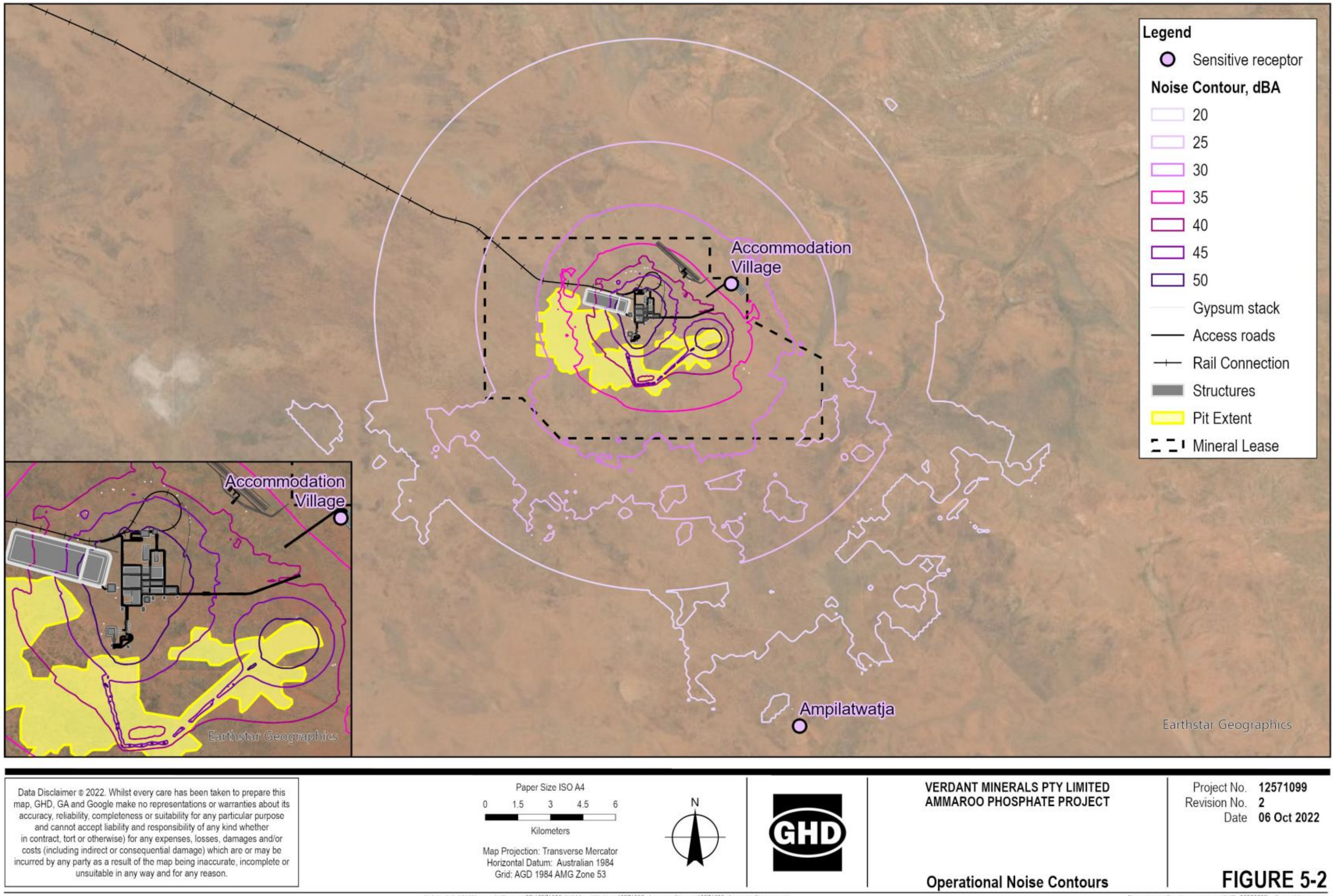


*Figure 5.2 Operational noise contours*

## 5.7 Management and Mitigation Measures

The following noise management measures should be implemented during operations to minimise noise emissions during operations:

- Where appropriate, selection of quiet equipment/system early in the design phase should be considered to minimise noise emissions. This would assist in minimising the off-site impact and help in preserving the hearing quality and reducing the potential health and safety impacts for on-site employees.
- Equipment shall be selected to have operating sound power levels compliant with the noise levels outlined in Appendix B. Additional modelling shall be undertaken where the noise levels of the selected equipment are above these levels in order to confirm noise impacts.
- All mobile equipment should be selected to minimise noise emissions and maintained in good repair. Machines found to produce excessive noise compared to normal industry expectations should be removed from the site or stood down until repairs or modifications can be made.
- Haul truck movements on exposed haul routes or open ridgelines of the open cut mine should be prevented during the evening and night.
- Where feasible, haul truck movements should be along routes with a low gradient.
- Conveyors should be selected with low noise output.
- Where reasonable, equipment should be selected to use quieter engines (e.g., electric instead of internal combustion).
- Broadband reversing alarms (audible movement alarms) should be used for all site equipment, subject to meeting occupational health and safety requirements.
- Where practical, machines should be operated at low speed or power and switched off when not being used rather than left idling for prolonged periods.
- Minimising reversing with beepers.
- Avoid metal to metal contact on material.
- All engine covers should be kept closed while equipment is operating.

# 6. Conclusion

Verdant propose to further develop the approved Ammaroo Phosphate Project to include the onsite production of MAP and DAP fertiliser. This will entail the construction of additional onsite plant and infrastructure, resulting in a change to the acoustic environment previously assessed in GHD 2017. A noise and vibration assessment was undertaken as part of the Approved Project and included an assessment of:

– Construction noise and vibration.
– Construction blasting.
– Operational noise from mining operations.
– Operational road and rail traffic noise and vibration.

Impacts from the following items have not been considered in the Proposed Project’s noise impact assessment as there have been no significant changes from the approved assessment or the approved assessment was considered conservative.

– Construction vibration and blasting.
– Operational road and rail traffic noise and vibration.

This assessment was undertaken to identify potential construction and operational noise impacts from the additional onsite plant and infrastructure. The accommodation village has been relocated as part of this assessment and is located 3.6 km east-northeast of the onsite plant.

Construction noise impacts are not anticipated as noise levels are below the assigned construction noise levels at all sensitive receptors.

Operational noise impacts from mining and processing activities have been considered in this assessment. No operational noise impacts are anticipated as the predicted noise levels are below the project specific assigned noise levels at all sensitive receptors.

General construction and operational noise management measures have been recommended and should be implemented, where feasible and reasonable, to minimise potential noise impacts from the project site.

# 7. References

Australian Standards. (2010). *Guide to noise and vibration control on construction, demolition and maintenance sites.*

GHD. (2017). *Ammaroo Phosphate - EIS - Tech report - Noise and Vibration Impact Assessment.*

ISO. (1996). *ISO 9613.2 Acoustics - Attenuation of sound during propagation outdoors. Part 2: General method of calculation.* ISO.

NT EPA. (2018). *Northern Territory Noise Management Framework Guideline.*

NTG. (November 2014). *NT Roads Policies: Road Traffic Noise on NT Government Controlled Roads. v1.0.* Northern Territory Government - Department of Planning and Infrastructure.

# Appendices

# Appendix A

## Glossary

| Item | Description |
| --- | --- |
| ACNL | Assigned Construction Noise Level |
| dB | Decibel is the logarithmic unit used for expressing the sound pressure level (SPL) or power level (SWL) in acoustics. |
| dBA | Frequency weighting filter used to measure 'A-weighted' sound pressure levels, which conforms approximately to the human ear response, as our hearing is less sensitive at very low and very high frequencies. |
| EIS | Environmental Impact Statement |
| $L_{Aeq(period)}$ | Equivalent sound pressure level: the steady sound level that, over a specified period of time, would produce the same energy equivalence as the fluctuating sound level actually occurring. |
| $L_{Aeq(15\ hour)}$ | The LAeq noise level for the period 7 am to 10 pm. |
| $L_{Aeq(9\ hour)}$ | The LAeq noise level for the period 10 pm to 7 am. |
| $L_{Aeq(1\ hour)}$ | The highest hourly LAeq noise level during the day and night periods. |
| NT EPA | Northern Territory Environmental Protection Agency |
| NMFG | Northern Territory Noise Management Framework Guideline (NT EPA, 2018) |
| NMP | Noise Management Plan |
| PSANL | Project Specific Assigned Noise Level |
| RBL | Rating Background Level |
| Sensitive receptor | A noise sensitive receptor included the following: residences, schools, childcare centres, places of worship, and health care institutions. |

# Appendix B

## Operational equipment noise levels

| Plant item | Number | Source height | Octave centre frequency (Hz), dBA | | | | | | | | | Total SWL, dBA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| **Mining** | | | | | | | | | | | | |
| Excavator CAT5015B | 2 | 2.5 | - | 83 | 100 | 102 | 105 | 104 | 101 | 92 | 84 | 110 |
| Haul truck CAT777 | 10 | 3 | - | 94 | 104 | 112 | 111 | 110 | 112 | 107 | 106 | 118 |
| Dozer CATD9T | 3 | 2.5 | - | 86 | 95 | 99 | 107 | 103 | 102 | 100 | 92 | 110 |
| Grader CAT14M | 1 | 3 | - | 78 | 94 | 100 | 106 | 110 | 106 | 103 | 98 | 114 |
| Water cart | 1 | 3 | - | 86 | 89 | 89 | 93 | 99 | 98 | 93 | 85 | 103 |
| **Dry Beneficiation Plant** | | | | | | | | | | | | |
| Ore sorter | 6 | 2 | 69 | 86 | 87 | 93 | 101 | 103 | 106 | 109 | 90 | 112 |
| Air compressor | 1 | 2 | 51 | 64 | 74 | 86 | 95 | 102 | 102 | 97 | 94 | 106 |
| Conveyors, dB/m | 20 | 2 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| **Wet Beneficiation Plant** | | | | | | | | | | | | |
| Rod mills | 2 | 0.5 | 60 | 78 | 91 | 95 | 103 | 110 | 111 | 107 | 97 | 115 |
| Agitators | 13 | 2 | 57 | 70 | 81 | 89 | 94 | 95 | 93 | 87 | 79 | 100 |
| Pumps | 29 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| **Phosphoric Acid Plant** | | | | | | | | | | | | |
| Rock slurry conveyor, dB/m | 2 | 10 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Attack + Digestion tank agitators | 18 | 10 | 45 | 58 | 69 | 77 | 83 | 86 | 84 | 79 | 73 | 90 |
| Flash cooler circulation pumps | 2 | 6 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Fash Cooler vacuum pumps | 2 | 8 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Filter feed pump | 2 | 1.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Gas scrubber fans | 2 | 6.5 | 58 | 67 | 80 | 88 | 93 | 93 | 91 | 86 | 83 | 98 |
| Gas scrubber pumps | 4 | 1 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Rotating titling pan filters | 2 | 6.5 | 58 | 67 | 80 | 88 | 93 | 93 | 91 | 86 | 83 | 98 |
| Vacuum pumps | 2 | 6.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Filter drying fan | 4 | 6.5 | 58 | 67 | 80 | 88 | 93 | 93 | 91 | 86 | 83 | 98 |

| Plant item | Number | Source height | Octave centre frequency (Hz), dBA | | | | | | | | | Total SWL, dBA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| Pumps | 11 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Conveyors, dB/m | 3 | 5 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Axial flow pumps | 5 | 2 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Transfer pumps | 5 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Vacuum pumps | 5 | 2 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Steam LP supply | 5 | 1 | 57 | 71 | 82 | 90 | 95 | 98 | 99 | 96 | 89 | 104 |
| Condensate pump | 5 | 0.5 | 45 | 58 | 69 | 77 | 83 | 86 | 84 | 79 | 73 | 90 |
| Storage tanks agitators | 7 | 5 | 45 | 58 | 69 | 77 | 83 | 86 | 84 | 79 | 73 | 90 |
| Storage tank pumps | 11 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Fluorine scrubber seal tank agitator | 10 | 0.5 | 57 | 70 | 81 | 89 | 94 | 95 | 93 | 87 | 79 | 100 |
| Fluorine scrubber recirculation pumps | 10 | 1 | 45 | 58 | 69 | 77 | 83 | 86 | 84 | 79 | 73 | 90 |
| Storage tank pumps | 3 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Agitators | 1 | 1 | 53 | 66 | 77 | 84 | 90 | 91 | 89 | 83 | 74 | 95 |
| Cold well pumps | 6 | 1 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Hot well pumps | 6 | 1 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Cooling fans | 13 | 3 | 45 | 56 | 75 | 85 | 86 | 83 | 81 | 84 | 65 | 91 |
| **Gypsum Handling** | | | | | | | | | | | | |
| Overland conveyor, dB/m | 1 | 1 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Distribution conveyors, dB/m | 10 | 10 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Dozer CATD9T | 1 | 2.5 | - | 86 | 95 | 99 | 107 | 103 | 102 | 100 | 92 | 110 |
| Front-end loader | 1 | 2.5 | 65 | 90 | 92 | 95 | 101 | 100 | 100 | 93 | 85 | 106 |
| **Granulation Plant** | | | | | | | | | | | | |
| Agitators | 1 | 5 | 57 | 70 | 81 | 89 | 94 | 95 | 93 | 87 | 79 | 100 |
| Pumps | 1 | 1 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Rotating drum | 1 | 10 | 62 | 80 | 93 | 97 | 105 | 112 | 113 | 109 | 99 | 117 |

| Plant item | Number | Source height | Octave centre frequency (Hz), dBA | | | | | | | | | Total SWL, dBA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| Gas fired rotating drum | 1 | 10 | 62 | 80 | 93 | 97 | 105 | 112 | 113 | 109 | 99 | 117 |
| Combustion chamber air blowers | 2 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Fans | 1 | 3 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Pumps | 6 | 2 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Primary elevator + Screen | 1 | 10 | 72 | 80 | 92 | 100 | 109 | 108 | 99 | 94 | 93 | 112 |
| Secondary elevator + Screen | 1 | 0.5 | 31 | 60 | 80 | 86 | 98 | 101 | 104 | 103 | 96 | 108 |
| Product screen elevator + Screen | 1 | 0.5 | 31 | 60 | 80 | 86 | 98 | 101 | 104 | 103 | 96 | 108 |
| Polishing elevator + screen | 1 | 0.5 | 31 | 60 | 80 | 86 | 98 | 101 | 104 | 103 | 96 | 108 |
| Coating drum | 1 | 0.5 | 97 | 100 | 101 | 97 | 101 | 103 | 106 | 98 | 91 | 111 |
| Oversize pulveriser | 1 | 5 | 68 | 85 | 97 | 103 | 113 | 115 | 112 | 104 | 97 | 119 |
| Polishing to Secondary Conveyors, dB/m | 1 | 10 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Dryer to Primary elevator Conveyors, dB/m | 1 | 0.5 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Conveyors, dB/m | 1 | 10 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Front-end loader / reclaimer | 1 | 2.5 | 65 | 90 | 92 | 95 | 101 | 100 | 100 | 93 | 85 | 106 |
| Load bin | 1 | 0.5 | 67 | 70 | 82 | 89 | 95 | 93 | 90 | 87 | 81 | 99 |
| **Rail** | | | | | | | | | | | | |
| Train rail off-loading | 1 | 2 | 71 | 74 | 86 | 93 | 99 | 97 | 94 | 91 | 85 | 103 |
| **Sulphuric Acid Plant** | | | | | | | | | | | | |
| Conveyors, dB/m | 1 | 10 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Front-end loader / reclaimer | 1 | 2.5 | 65 | 90 | 92 | 95 | 101 | 100 | 100 | 93 | 85 | 106 |
| Conveyors, dB/m | 1 | 10 | 36 | 49 | 58 | 66 | 74 | 76 | 72 | 65 | 54 | 80 |
| Agitators | 1 | 5 | 53 | 66 | 77 | 84 | 90 | 91 | 89 | 83 | 74 | 95 |
| Filters | 3 | 4 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Pumps | 1 | 5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |

| Plant item | Number | Source height | Octave centre frequency (Hz), dBA | | | | | | | | | Total SWL, dBA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| Waste heat boiler | 1 | 5 | 57 | 71 | 82 | 90 | 95 | 98 | 99 | 96 | 89 | 104 |
| Sulphur Furnace | 1 | 2 | 61 | 74 | 85 | 93 | 98 | 100 | 98 | 93 | 86 | 104 |
| Economiser | 2 | 5 | 52 | 66 | 74 | 83 | 85 | 83 | 83 | 79 | 65 | 90 |
| Converter | 1 | 8 | 52 | 66 | 74 | 83 | 85 | 83 | 83 | 79 | 65 | 90 |
| Heat exchanger | 1 | 5 | 52 | 66 | 74 | 83 | 85 | 83 | 83 | 79 | 65 | 90 |
| Drying and Final Acid towers including Circulation pumps and Pump tank | 1 | 8 | 55 | 68 | 79 | 87 | 92 | 94 | 92 | 87 | 80 | 98 |
| Heat recovery system and Intermediate Absorption Acid Tower | 1 | 8 | 56 | 69 | 80 | 88 | 93 | 95 | 93 | 88 | 81 | 99 |
| Heat Recovery Boiler | 1 | 4 | 55 | 68 | 79 | 87 | 92 | 94 | 92 | 87 | 80 | 98 |
| Pumps for heat recovery system | 1 | 5 | 56 | 69 | 80 | 88 | 94 | 95 | 93 | 88 | 81 | 100 |
| Pumps for water circulation in Cooling Towers | 1 | 6 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Fans | 1 | 3 | 58 | 67 | 80 | 88 | 93 | 93 | 91 | 86 | 83 | 98 |
| Fin Fan Coolers | 1 | 4 | 61 | 74 | 85 | 93 | 98 | 100 | 98 | 93 | 86 | 104 |
| Boiler feed water pumps | 1 | 4 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| De-aerator | 1 | 5 | 57 | 71 | 82 | 90 | 95 | 98 | 99 | 96 | 89 | 104 |
| Steam vent | 3 | 50 | 71 | 87 | 97 | 111 | 110 | 109 | 105 | 100 | 88 | 115 |
| **WTP** | | | | | | | | | | | | |
| Chemical dosing pump | 1 | 5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Agitators | 1 | 5 | 53 | 66 | 77 | 84 | 90 | 91 | 89 | 83 | 74 | 95 |
| **Power Station** | | | | | | | | | | | | |
| Steam Turbine Generators | 3 | 3 | 59 | 71 | 87 | 96 | 97 | 100 | 95 | 90 | 83 | 104 |
| Air cooled condensors | 3 | 5 | 59 | 71 | 87 | 96 | 97 | 100 | 95 | 90 | 83 | 104 |
| Gas engine generators | 8 | 2 | 49 | 61 | 77 | 86 | 87 | 90 | 85 | 80 | 73 | 94 |
| **Auxiliary equipment and utilities** | | | | | | | | | | | | |

| Plant item | Number | Source height | Octave centre frequency (Hz), dBA | | | | | | | | | Total SWL, dBA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 31.5 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 | |
| Steam vents | 4 | 6 | 61 | 77 | 87 | 101 | 100 | 99 | 95 | 90 | 78 | 105 |
| Air compressor | 1 | 4 | 56 | 70 | 82 | 94 | 102 | 102 | 98 | 95 | 90 | 106 |
| **Ammonia Plant** | | | | | | | | | | | | |
| Hydrogenator / sulphur absorber | 1 | 10 | 70 | 98 | 99 | 95 | 99 | 101 | 104 | 96 | 89 | 109 |
| Primary reformer | 1 | 10 | 70 | 98 | 99 | 95 | 99 | 101 | 104 | 96 | 89 | 109 |
| Secondary reformer | 1 | 10 | 70 | 98 | 99 | 95 | 99 | 101 | 104 | 96 | 89 | 109 |
| Waste heat boiler | 1 | 10 | 60 | 70 | 84 | 87 | 94 | 97 | 97 | 95 | 87 | 102 |
| Flue gas blower | 1 | 10 | 56 | 70 | 82 | 94 | 102 | 102 | 98 | 95 | 90 | 106 |
| Super heater | 1 | 10 | 70 | 98 | 99 | 95 | 99 | 101 | 104 | 96 | 89 | 109 |
| BFW pre-heater | 1 | 10 | 70 | 98 | 99 | 95 | 99 | 101 | 104 | 96 | 89 | 109 |
| Steam drum | 1 | 10 | 75 | 109 | 109 | 105 | 109 | 112 | 114 | 106 | 99 | 119 |
| Pumps | 26 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Air Compressor | 1 | 10 | 46 | 60 | 72 | 84 | 92 | 92 | 88 | 85 | 80 | 96 |
| Syn gas compressor | 1 | 0.5 | 46 | 60 | 72 | 84 | 92 | 92 | 88 | 85 | 80 | 96 |
| Ammonia storage | 1 | 10 | 45 | 59 | 71 | 83 | 91 | 91 | 87 | 84 | 79 | 95 |
| Ammonia storage pumps | 1 | 0.5 | 53 | 64 | 83 | 93 | 94 | 91 | 89 | 92 | 73 | 99 |
| Compressor | 1 | 10 | 52 | 66 | 74 | 83 | 85 | 83 | 83 | 79 | 65 | 90 |

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→ The Power of Commitment

# Appendix Q

## Economic Impact Assessment

September 2022

# Economic impact assessment of proposed Ammaroo Phosphate Project

## Final Report

ACIL ALLEN

# Report summary and key findings

# Report summary

Verdant Minerals Proprietary Limited (Verdant) is proposing to develop the Ammaroo Phosphate Project (Ammaroo Project). With a resource of over a 1 Billion tonnes of Phosphate ($P_2O_5$), it is the **largest JORC compliant phosphate resource in Australia** and one of the largest undeveloped phosphate resources in the world.

Verdant have commissioned ACIL Allen Consulting (ACIL Allen) to assess the economic impacts that the Project will have on the local and national economies. This report sets out the findings of this assessment. The assessment results are presented in the form of the direct and indirect economic impacts on the economies of the local **Barkly region (Barkly), the Northern Territory** and Australia over the Project life.

To understand the results, it is useful to consider what is meant by direct and indirect impacts. In the case of employment, the direct jobs created by the project are easy to identify and quantify. For the Ammaroo project direct employment impacts are **2,832 full time equivalent jobs** over three years of construction (with an average of 829 Australian jobs a year) and an average of **556 workers in each year of operation**.

Additional benefit to the economy, however, is obtained through the indirect jobs resulting from the construction and operation of the Project. These indirect jobs result from the purchases made by Verdant during construction with commensurate increase in activity and income for Australian businesses. As a result, these businesses increase their production and their inputs into production, particularly in relation to labour. In other words, these **local businesses purchase more goods, services and labour to operate their businesses**. This effect continues down the supply chain creating jobs at each stage.

## Impact Results Key Findings

### Jobs

Barkly: 322 FTE p.a.
NT: 614 FTE p.a.
Australia: 269 FTE p.a.

During operations, Ammaroo could increase the NT population by around 1,300 persons (assuming some workers bring families).

### Gross Product

Barkly: $8.8bn ($309m p.a.)
NT: $11.4bn ($398m p.a.)
Australia: $11.0bn ($388m p.a.)

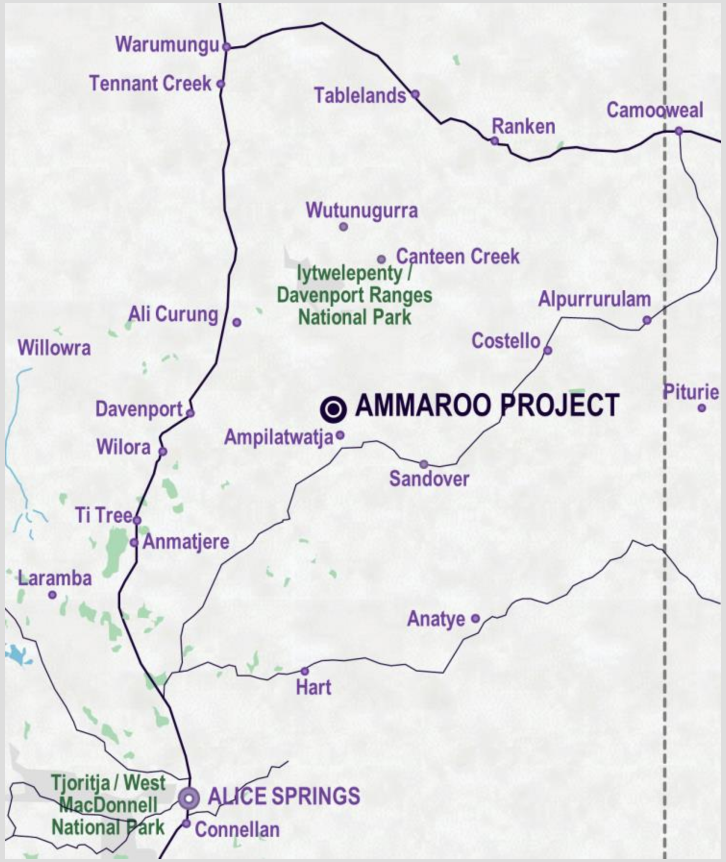
Much of the economic value from the Project is generated in the Barkly region and the Northern Territory.

### Income

Barkly: $2.2bn ($75m p.a.)
NT: $5.9bn ($201m p.a.)
Australia: $12.0bn ($419m p.a.)

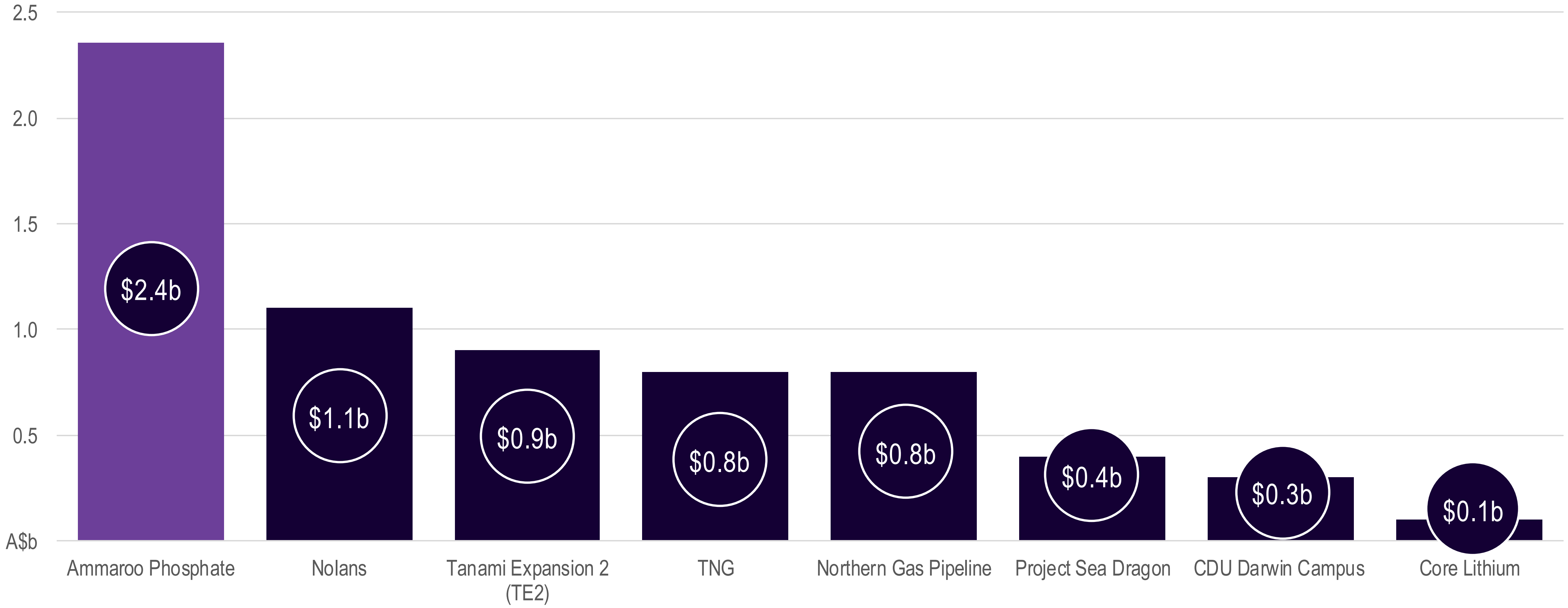
The Ammaroo Project delivers an average real income boost of $800 a year per resident of the Barkly region.

## Location of Ammaroo Project



# Ammaroo's capital expenditure in context

**Figure 1: Major active and historic public and private sector investment projects, by capital expenditure, $billion**




Source: ACIL Allen from various sources.

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# Report overview and Methodology

# Report Overview

### Verdant Minerals and the Ammaroo Project

Verdant is fertiliser minerals project developer, focussed on the Northern Territory of Australia. Verdant was founded in 2007, and after being listed on the Australian Stock Exchange was acquired by two shareholders in 2019 and taken private. The two shareholders CD Capital Natural Resources Fund III and Washington H Soul Pattinson are committed to the Development of the Ammaroo Project.

The Ammaroo Ammonium Phosphate Project (Ammaroo, Project) has a resource of over 1 Billion tonnes of Phosphate ($P_2O_5$) which is the **largest JORC compliant phosphate resource in Australia** and one of the largest undeveloped phosphate resources in the world.

The Ammaroo Project is located in the Barkly region in the Northern Territory, **approximately 270km northeast of Alice Springs**, 220km southeast of Tennant Creek, and 95km from the Adelaide to Darwin Railway.

The Project will produce in the order of 2 million tonnes per annum (Mtpa) of phosphate rock concentrate, with further downstream processing into **500,000 tonnes per annum (tpa) of phosphoric acid** (100% $P_2O_5$) and production of **200,000 tpa of ammonia**, for conversion to approximately **1 Mtpa of ammonium phosphate fertilisers**, such as Di-Ammonium Phosphate (DAP) and Mono-Ammonium Phosphate (MAP).

Production of DAP and MAP will occur in Australia with additional investment in Ammonia and granulation capacity. This would allow Verdant to supply domestic and international markets with finished fertilisers.

Mining will be undertaken via conventional open pit mine and ore handling systems. The mined ore will be crushed and beneficiated into a phosphate rock concentrate. The concentrate is then fed into a Phosphoric Acid Plant and reacted with Sulphuric acid. The sulphuric acid is manufactured on site from imported elemental sulphur. A by-product of sulphuric acid manufacturing is waste heat. The Project will use this waste heat to generate electricity and steam, which will negate the need for hydrocarbon power generation to be the main source of power for the site.

### About this report

In August 2022, Verdant commissioned ACIL Allen to undertake an independent economic impact assessment of the Ammaroo Project using the latest proposed mine and development plan. The commissioning of this report follows Verdant's decision to pursue further downstream processing of Phosphate concentrate to DAP and MAP. ACIL Allen has prepared this assessment based on detailed project financial information obtained from Verdant on a confidential basis.

An overview of ACIL Allen's methodology and key assumptions used for this assessment is presented on the next page. This report provides an overview of the significant economic benefits that could be realised from the development of the Ammaroo Project in terms of its contribution to the Barkly, Northern Territory and national economies in the following ways:

- Output (Gross Regional Product, Gross State Product and Gross Domestic Product at a regional, State and national level)
- Income (the additional local wages and salaries and profits created by the project)
- Employment (full time equivalent job years, on both a direct an indirect basis)
- Taxation (by heads of taxation, including local government where this is available / applicable)

Outside of the economic benefits, it is expected that the proposed development of Ammaroo will be strongly aligned with a number of core economic and social development policies of the NT Government with a range of **Benefits to the Territory**:

1. **$40Bn Economy by 2030** – Development of the Ammaroo Project will increase annual GTP by $427m, and make a material contribution to the Northern Territory achieving an economy of $40Bn by 2030
2. **Economic diversification** – once developed, Ammaroo will be the first major downstream fertiliser project in the Northern Territory, and is complimentary to the development of the Agri-business, mining and manufacturing sectors which are targeted industries of the NT's economic development framework.
3. **Regional Development** – Ammaroo will provide a significant economic boost to Central Australia, which has suffered from minimal investment and has traditionally relied on tourism to drive economic opportunities for its residents.
4. **Population Growth** – The Project will provide high quality, long term sustainable Jobs, which will increase the Northern Territory population by attracting high skilled workers and their families.

# Ammaroo – Key Results

The **Ammaroo Project will create long term, sustainable job opportunities for local people**, which will result in a more diversified jobs market in the currently narrow job market in the region, particularly for Indigenous people who currently experience a high level of unemployment. During operations, the majority of the employees are estimated to be from the Northern Territory, with 102 employees coming from the Barkly, Alice Springs and Tennent Creek region. It's expected that 192 employees will travel from interstate to work at the Ammaroo Project.

During construction, the Ammaroo Project will require a total workforce of 2,832 employee years, with an average of 829 full time equivalent Australian workers each year of construction. During steady state operation, it is estimated that **the Project will continue to directly employ 556 full time equivalent workers in each year**, including 78 FTE's based in Darwin and a contractor maintenance and sustaining capital workforce of 150 FTE's.

The **capital expenditure includes investment** in capital for direct use within the mining operations, but also **infrastructure, which may provide benefits to local industry** and/or community either during or after mining operations.

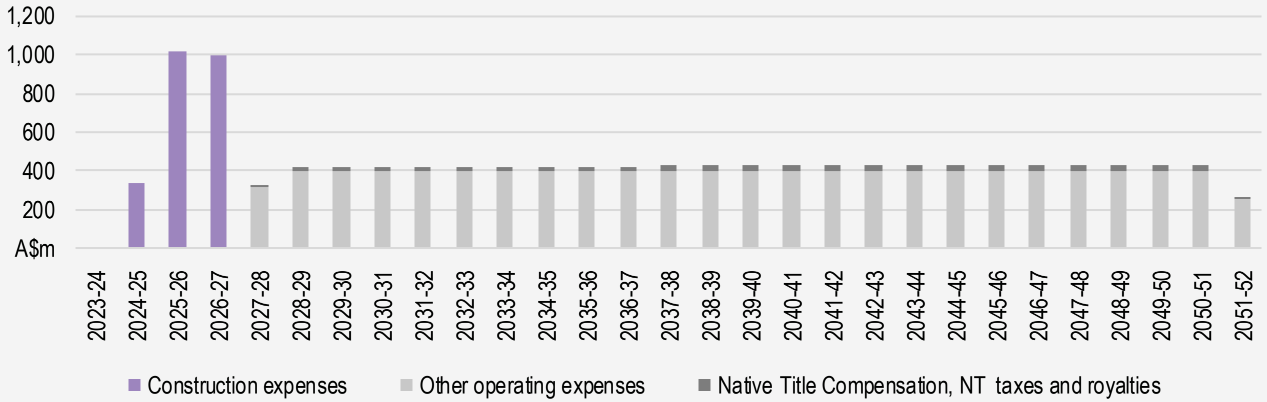
The construction expenditure of the Ammaroo Project is estimated to have an Australian content of 76 per cent. Of the total spending in Australia an estimated $932 million will be spent in the Northern Territory, including $311 million in the local Barkly region.

The Project will begin operating in 2027-28. Over the following 25 years there will be over $10.3 billion of operational spending, or an average of $413 million a year. This excludes rehabilitation spending, royalties, payroll taxes or Native Title compensation payments.

**Nearly $5.8 billion, or 46 per cent, of the total operations expenditure will be spent on goods and services purchased from the Northern Territory**, or an average of around $231 million a year. Similarly, it is expected that 16 per cent of all operational expenditure will be spent in the local Barkly region. This is equivalent to a total of $2.0 billion over 25 years or $82 million a year.

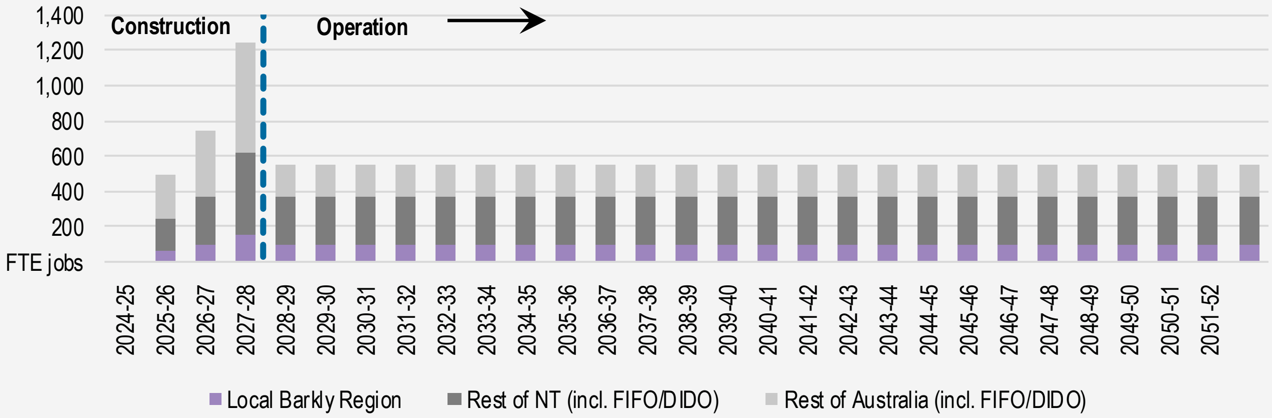
**During the operations phase, a further $508 million is expected to be spent on Northern Territory payroll taxes and royalties and Native Title compensation.**

**Figure 2: Ammaroo project construction and operation costs ($ million)**




*Source: ACIL Allen from Verdant data*

**Figure 3: Direct jobs – Ammaroo Project construction and operation (number of FTE jobs a year)**




*Source: ACIL Allen from Verdant data*

# Methodology and Assumptions

## Methodology

Verdant Minerals Proprietary Limited commissioned ACIL Allen to conduct an assessment of their proposed Ammaroo Project (one of the largest undeveloped phosphate resources in the world). ACIL Allen's analysis estimates the economic impacts that the development of the deposit will provide to the local and national economies.

Economic impact modelling was undertaken using computable general equilibrium (CGE) modelling. For this analysis, ACIL Allen's CGE model, *Tasman Global*, was used to estimate the regional, Territory, and national economic impacts of the construction and operation activities associated with the Ammaroo Project.

In applications of the *Tasman Global* model, a Reference Case simulation forms a 'business-as-usual' basis with which to compare the results of various simulations. The Reference Case provides projections of growth in the absence of the Ammaroo project in terms of Gross Product, population, labour supply, industry output and so on and provides projections of endogenous variables such as productivity changes and consumer tastes. The Policy Case assumes all productivity improvements, tax rates and consumer preferences change as per the Reference Case projections but also includes the impacts of the proposed Ammaroo Project. The two scenarios give two projections of the economy and the net impact of the Ammaroo Project is then calculated as deviations from the Reference Case as illustrated in Figure 4. *Further details of the Tasman Global model can be found in Appendix A.*

ACIL Allen estimates the economic impact of Ammaroo using the following indicators:

- **Real output** (Gross Domestic Product (GDP), Gross State Product (GSP) and Gross Regional Product (GRP)): Real output represents the total dollar value of all finalised goods and services produced over a specific time period and is considered as a measure of the size of the economy.
- **Real income:** (Gross Real Income): Real income measures the income available for final consumption and saving after adjusting for inflation. An increase in real income means that there has been a rise in the capacity for consumption as well as a rise in the ability to accumulate wealth in the form of financial and other assets. The change in real income from a development is a measure of the change in the economic welfare of residents within an economy. For this reason, real income is ACIL Allen's preferred measure of economic impact.
- **Employment:** Labour market impacts are typically produced on an annual FTE basis.
- **Real taxation:** Taxation results are completed by major heads of taxation. This typically includes royalties, payroll tax and GST at a State level, and company tax (both directly paid by the project and by others as a result of changes in economic activity), personal income tax, and other Commonwealth taxes like excise.

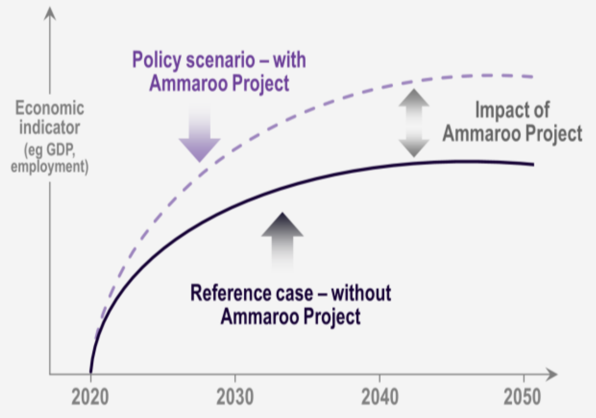
The results for each indicator are presented in terms of the direct impacts (for example, the workforce directly employed by the Project, or the direct taxation payments made) and the indirect impacts (this will be the primary output of the economic modelling, highlighting the flow on impacts of Ammaroo's operations across the economy and industry).These results will be presented at a national, state and regional level.

## Assumptions

Construction of the project is expected to take three years beginning in FY2024. Production is expected to commence in FY2028 and last for 25 years. However, the first **25 years of mining would utilize approximately 10 per cent of the known resource**. Hence, the operation of the Ammaroo Project could continue many more decades beyond 2050.

The Ammaroo Project is estimated to require around $2,355 million of capital expenditure (including labour costs) over the period from FY2024 to FY2027 for studies, and initial construction of the Project.

**Figure 4: Illustrative scenario analysis using *Tasman Global***



## Micro-industry approach

To accurately assess the economic impacts or economic contribution of a major project such as the Ammaroo Project, it is necessary to represent the Project in the model's database. An accurate representation can be achieved by establishing the proposed project as a new 'micro-industry' in the database.

The micro-industry approach is so called because it involves the creation of one or more new, initially very small, industries in the *Tasman Global* database. The specifications of each of the micro-industry's costs and sales structures are directly derived from the financial data for the Ammaroo Project to be analysed. At the outset, the new industry is necessarily very small so that its existence in the *Tasman Global* database does not affect the database balance or the "business-as-usual" Base Case outcomes.

Besides having a separate cost structure for the Ammaroo Project, a further challenge is to faithfully represent the time profile of the individual cost items. This is particularly important for the investment phase where there are typically large changes in demands for machinery, labour and imported components year on year. This challenge is met in *Tasman Global* by incorporating detailed year on year input changes by source.

Using the micro-industry approach for project evaluations is the most accurate way to capture the detailed economic linkages between the Ammaroo Project and the other industries in the economy. This approach has been developed by ACIL Allen because each project is unique relative to the more aggregated industries in the *Tasman Global* database.

Consequently, in addition to the standard industries represented in *Tasman Global*, the database also identifies the construction and operation phases of the Ammaroo Project as separate micro-industries with their own input cost structure, sales, employment, tax revenues and greenhouse gas emissions based on detailed information generated as part of the analysis.

Another important aspect in the CGE modelling approach used for this analysis is to have separate identification of the capital stock created as part of the Ammaroo Project's investment phase and isolating it until the capital is available for use, thereby preventing the economy gaining false benefits from, say, half a bridge.

## Direct versus indirect effects

To understand the results of the analysis, it is important to consider both direct and indirect impacts. In the case of employment, the direct jobs created by the project are easier to identify and quantify. Additional benefit to the economy, however, is obtained through the indirect jobs resulting from the construction and operation of the Project.

These indirect jobs result from the purchases from Australian businesses made by Verdant during construction and operation. As a result, these businesses increase their production and their inputs into production, particularly in relation to labour. In other words, these local businesses purchase more goods, services and labour to operate their businesses. This effect continues down the supply chain creating jobs at each stage.

A final stimulus occurs as a result of the profits and taxes generated from the project. It is assumed that the increased profits and Federal Government tax revenues paid by Verdant during the construction and operation of the Ammaroo Project are distributed throughout Australia proportionate to population.

The same direct and indirect impacts are realised for the contribution the project makes to Gross Product, and income.

## Macro-industry impacts

One of the most commonly quoted macroeconomic variables at a national level is real GDP, which is a measure of the aggregate output generated by an economy over a given period of time (typically a year). GDP may be calculated in different ways:

— On the expenditure side by adding together total private and government consumption, investment and net trade.

— On the income side as the sum of returns to the primary factors of production (labour, capital and natural resources) employed in the national economy plus indirect tax revenue.

The regional level equivalent to GDP is GRP – at the state or territory level it is called GSP or GTP, respectively. To reduce the potential confusion with the various acronyms, the term Gross Product has been used in the discussion of the results presented in this report.

These measures of the real Gross Product of an economy should be distinguished from measures of the economy's real income, which provide a better indication of the economic welfare of the residents of a region. It is possible for real Gross Product to increase while at the same time real income (economic welfare) declines. In such circumstances, people and households would be worse off despite economic growth.

In *Tasman Global*, the relevant measure of real income at the national level is real gross national disposable income, or RGNDI, as reported by the Australian Bureau of Statistics (ABS).

The change in a region's real income as a result of a new project is the change in real Gross Product plus the change in net external income transfers plus the change in the region's terms of trade (which measure the change in the purchasing power of the region's exports relative to its imports). Changes in the terms of trade can have a substantial impact on residents' welfare independently of changes in real economic output.

In global CGE models such as *Tasman Global*, the change in real income is equivalent to the change in consumer welfare using the equivalent variation measure of welfare change resulting from exogenous shocks. Hence, it is valid to say that the projected change in real income (from *Tasman Global*) is also the projected change in consumer welfare.

## Discounted future costs and benefits

To compare future costs with future benefits, the future cash flows need to be discounted and brought into present value terms. The need to discount future cash flows can be viewed from two main perspectives, both of which focus on the opportunity cost of the cash flows implied by the timing of payments.

The first perspective is the general observation that individuals prefer a dollar today to a dollar in the future. This is most obvious in the fact that banks need to pay interest on deposits to entice individuals to forgo current spending. This general preference for current consumption is reflected by the 'rate of time preference' and relates to all economic benefits (and costs), not just those that are financial in nature. Since individuals are not indifferent between cash flows from different periods, those flows cannot be directly compared. For monetised flows to be directly comparable in a benefit-cost analysis, those costs or benefits incurred in the future need to be discounted back to current dollar terms. This reflects society's preferences, which place greater weight on consumption occurring closer to the present.

The second perspective is that flows of costs and benefits resulting from the Ammaroo Project also have an opportunity cost for investment. The construction and operation of the Ammaroo Project will impose costs on investors, and those costs will need to be funded in some way. This funding requirement imposes costs on the affected party, either through the interest paid for borrowing the money, or the returns forgone when equity funds are not available to be used for other purposes.

The Ammaroo Project would therefore only be beneficial if it provides a return in excess of the cost to society of deferring consumption, or of the return that could have been earned on the best alternative use of the funds. By applying a discount rate to future cash flows, the required rate of return is explicitly taken into account in the net present value calculation.

Both perspectives demonstrate that the need to discount future cash flows can be viewed in terms of the opportunity cost of the cash flows, whether this is the cost of delaying consumption or the alternative investment opportunities forgone. Since most of the costs and benefits of the mine are spread out over time, and their value depends on when they are received, discounting is important to summarising the total net benefit of the Ammaroo Project.

Typically, each option is conducted with one discount rate applied to all benefits and all costs over the entire time frame of interest. In 1970, Kenneth Arrow and Robert Lind explained that this may be inappropriate, because different discount rates should be used depending on the nature of the benefits and costs, including risk and uncertainty, and depending on who is affected. For example, if all costs and benefits are spread across the whole community it could be appropriate to use a risk-free rate. However, if sizeable benefits and costs accrue directly to particular individuals or groups, they also bear the cost of bearing risk and uncertainty, which may be significant. Then, the discount rate should be consistent with the preferences and attitudes of the relevant parties. Therefore, different streams of benefits and costs should be discounted differently, according to whether they accrue publicly or privately. Application of the insights of Arrow and Lind to an assessment of the Ammaroo Project would suggest using a risk-free discount rate for public benefits in the form of employment and provision of infrastructure effects, but a risk-inclusive discount rate for private benefits to investors in the Project. The real options literature has also made a strong case for use of multiple discount rates for different streams of costs and benefits, with different risk and uncertainty attributes.

While quantitative methods for estimating the opportunity cost of capital employed in public projects exist (such as the capital asset pricing model), they are dependent on a range of regularly changing variables (such as the statutory tax rates, equity risk premiums, gearing levels and the risk-free rate). Because of the uncertainty and complexity involved in choosing the ‘correct’ discount rate for each cash flow stream, and the potential impact that alternative discount rates can have on the net benefit, it is often recommended that different rates should be used in the analysis to demonstrate the sensitivity of results to the discount rate assumption. For example, the Australian Office of Best Practice Regulation recommends the use of three discount rates. For this analysis, ACIL Allen has presented the net benefits of the Ammaroo Project using annual real discounts rates of 3, 7 and 10 per cent, with the lower and upper levels, respectively, reflecting a social rate of time preference and an indicative investor’s internal cost of capital, while the 7 per cent rate effectively represents a hybrid of the social and commercial discount rates.

# Modelling results

# Change in Real Gross Product[1]

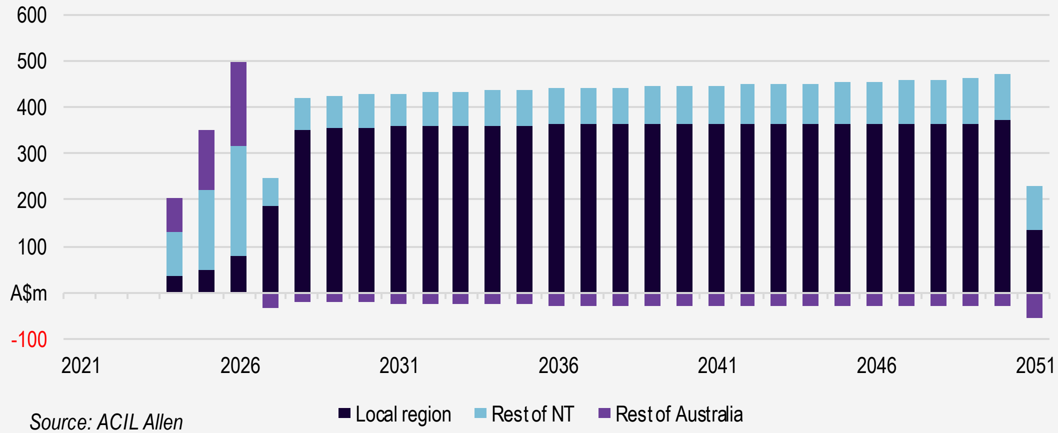
The expenditure in the construction and operation phases of the Ammaroo Project will stimulate the economies of the local Barkly region, the Northern Territory, and Australia more broadly. The resulting increase in the value of production as a result of the project is referred to as contribution to Gross Product. Gross Domestic Product (GDP) is the final value of the economic output generated by an economy over a period of time (typically a year). It is also a representation of the value added by economic activity, which includes the wages and gross operating surplus of the Ammaroo Project.

ACIL Allen estimates that over the full 28-year life of the Ammaroo Project (three years of construction and 25 years of operation), the Project will increase Australian real GDP by $11.0 billion, or an average of $388 million a year. In the Northern Territory, Gross Territory Product (GTP) is estimated to rise by $11.4 billion (or $398 million a year), with $8.8 billion generated in the local Barkly region ($309 million a year). Of this:

- $1,051 million of Australia's additional real GDP is generated during the construction period, with $671 million of additional Northern Territory real GTP and $161 million of additional Gross Regional Product (GRP) generated in the local Barkly region during the construction period.
- $10.0 billion (or an average of $400 million a year) of Australia's additional real GDP is generated during the operations phase. Most of the contribution to the increase in Gross Product during the operations phase will be driven by growth in the local Barkly region, with almost $8.6 billion added to its GRP, equal to an average of $345 million a year for each year of operation.

The assumed high levels of local content in the Project means that much of the economic value from the Project remains in Australia and particularly in the Northern Territory.

**Figure 5: Change in real gross product – Ammaroo Project ($ million, 2022 terms)**




*Source: ACIL Allen*

**Table 1: Projected Change in real Gross Product as a result of the Ammaroo Project – total project (in real 2021 terms)**

| | Total (2023–2050) | Average (2023–2050) | NPV 3% real | NPV 7% real | NPV 10% real |
|---|---|---|---|---|---|
| | 2022 $Am | 2022 $Am | 2022 $Am | 2022 $Am | 2022 $Am |
| Local Barkly region (real GRP) | 8,785 | 309 | 5,317 | 2,964 | 2,021 |
| Northern Territory (real GTP) | 11,362 | 398 | 6,976 | 3,994 | 2,791 |
| Australia (real GDP) | 11,038 | 388 | 6,899 | 4,057 | 2,896 |

*Notes: NPV = net present value using real discount rate. All years are financial years ending June 30. The local Barkly region comprises the Barkly SA3 plus the Alice Springs SA3.*
*Source: ACIL Allen*

[1] Real Output is the broadest measure of economic activity. It represents the total dollar value of finalised goods and services produced over a specific time period and is considered as a measure of the size of an economy. At a national level, it is referred to as Gross Domestic Product (GDP); at the Territory level, Gross Territory Product (GTP); and, at a regional level, Gross Regional Product (GRP).

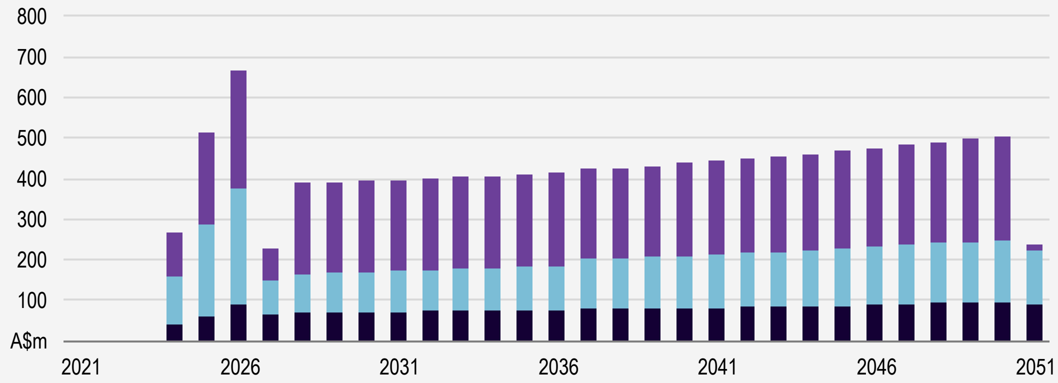
# Change in Real Income[2]

Real income is a measure of the ability to purchase goods and services, adjusted for inflation. A rise in real income indicates a rise in the capacity for current consumption, but also an increased ability to accumulate wealth in the form of financial and other assets. The change in real income from a development is a measure of the change in the economic welfare of residents.

The construction and operation of the Ammaroo Project will directly and indirectly boost incomes in the local Barkly economy, largely through the direct wages and salaries to workers providing labour services to the Project. There will also be indirect impacts on incomes in the wider economy including from the supply chain that supports the Project and some benefit from locally retained profits. At the broader state and national levels, there are the same income sources as the local Barkly region, but also relatively more significant benefits from the redistribution of wealth from the profits of the project and from state and national taxes.

ACIL Allen estimates that over the full 28-year life of the Ammaroo Project (three years of construction and 25 years of operation), the Project will generate $12.0 billion towards the incomes of the residents of Australia or an average of $419 million a year. In the Northern Territory, incomes are estimated to rise by $5.9 billion or $201 million a year, while in the local Barkly region, incomes will rise by $2.2 billion over the life of the project or an average of $75 million a year.

**Figure 6: Change in real incomes: Ammaroo Project ($ million, 2020 terms)[6]**




*Source: ACIL Allen*

**Table 2: Projected Change in real income as a result of the Ammaroo Project – total project (in real 2021 terms)**

| | Total (2023–2050) | Average (2023–2050) | NPV 3% real | NPV 7% real | NPV 10% real |
|---|---|---|---|---|---|
| | 2022 $Am | 2022 $Am | 2022 $Am | 2022 $Am | 2022 $Am |
| Local Barkly region | 2,190 | 75 | 1,343 | 776 | 549 |
| Northern Territory | 5,861 | 201 | 3,663 | 2,181 | 1,582 |
| Australia | 11,968 | 419 | 7,492 | 4,442 | 3,202 |

*Notes: NPV = net present value using real discount rate. All years are financial years ending June 30. The local Barkly region comprises the Barkly SA3 plus the Alice Springs SA3.*
*Source: ACIL Allen*

[2] Real income is a measure of the welfare of residents in an economy through their ability to purchase goods and services and to accumulate wealth. In CGE models such as Tasman Global, he change in real income is a measure of the change in economic welfare.

# Change in Employment[3]

The Ammaroo Project will result in job creation in the form of direct and indirect employment. The direct employment refers to those jobs required to construct and operate the project. There will also be indirect jobs that are created by the additional spending in the economy on goods and services, including wages, to construct and operate the project. This includes the spending of the increase in net income as a result of the Project. It also includes the contractor workforce.

The Project will result in net migration of people from other parts of Australia to live in the local Barkly region and in the Northern Territory more generally.

While the movement of workers to the Northern Territory during the construction workforce will be larger, it will only occur over the three years of construction. The flow of workers to the Northern Territory during the operation phase will be more stable and of a longer term nature. Importantly, job creation as a result of the development of the Ammaroo Project represents long term structural diversification of the jobs market in the local Barkly region and in the Northern Territory more generally.

The movement of workers to the Northern Territory increases the population in the region. If all the direct Verdant workers (including the contractors) represent workers moving to the Northern Territory from elsewhere in Australia, the long term population increase during the operation phase could be as much as 650 households or around 1,300 people assuming that some workers move with their families.

Over the full 28-year life of the Ammaroo Project (three years of construction and 25 years of operation), a total of 7,537 full time equivalent job years will be created in Australia including the jobs directly employed on the Project in construction and operation as well as the contractor workforce and other flow on job creation. This includes 322 full time equivalent (FTE) jobs a year in the local Barkly region, and 614 FTE jobs a year in the Northern Territory more bradly. The net impact in Australia is equivalent to an average of 269 FTE jobs in each of the 28 years of the Project.

[3] Real employment is measured in job years. A job year is employment of one full-time equivalent (FTE) person for one year.

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**Figure 7: Projected change in total employment in each region as a result of the Ammaroo Project, relative to the reference case (full-time equivalent jobs)**

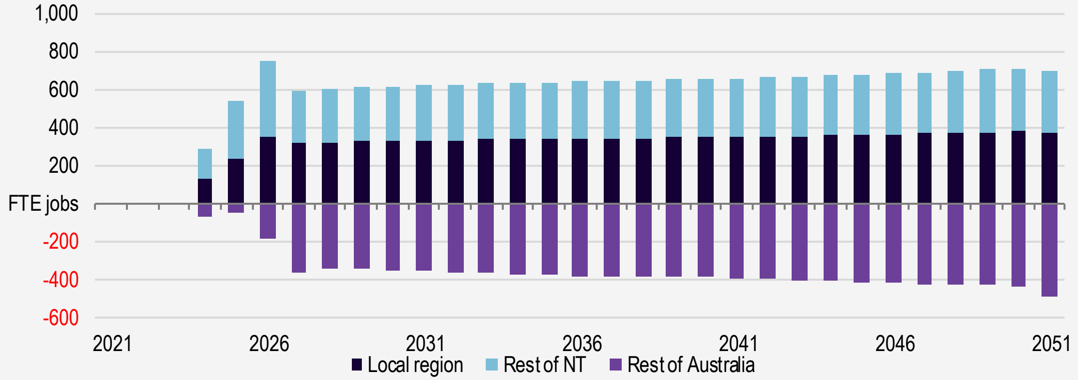


**Figure 8: Net job creation – Ammaroo Project: construction and operation (number of jobs)**

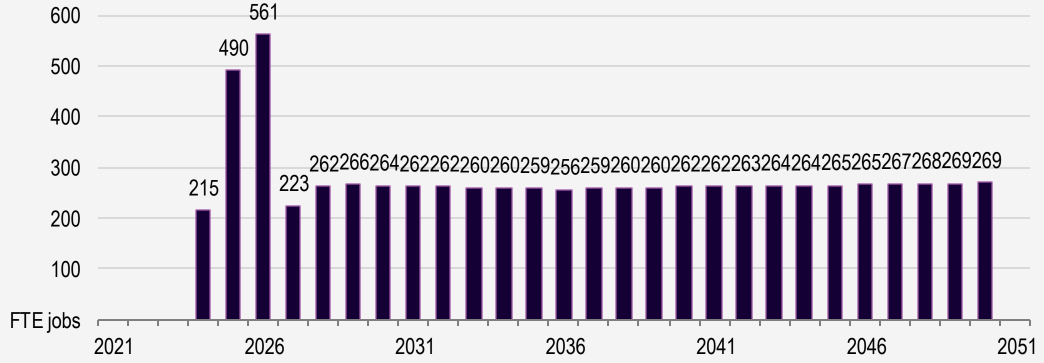


**Table 3: Job creation: Ammaroo Project: total (number of FTE job years)**

| | Average annual contribution to job creation (FTE job years) | Total number of jobs over life of project (FTE job-ears) |
|---|---|---|
| Local Barkly region | 322 | 9,012 |
| Northern Territory | 614 | 17,196 |
| Australia | 269 | 7,537 |

*Note: Employment by place of residence*
*Source: ACIL Allen*

# Sensitivity Analysis

ACIL Allen conducted sensitivity analysis to estimate how the estimated impacts varied under two different labour market environments, namely:

1. Fully constrained labour market where no additional jobs in Australia are allowed relative to the Reference Case (but people are allowed to move between regions)
2. Unconstrained labour market, where the supply of labour (at the Reference Case wage rates) is fully responsive to demand.

The results highlight the sensitivity of the projected impacts to the flexibility of the Australian labour market in response to the jobs stimulated by the Ammaroo Project.

As can be seen, the Lower bound impacts are much closer to the results using the Standard Tasman Global labour market assumptions than the Upper bound, indicating that there is potentially more economic and employment upside associated with the projected impacts. For example, for the Northern Territory as a whole, the change in:

— real GTP is 2.2 per cent lower under the Fully constrained labour market, but 15.2 per cent higher under the Unconstrained labour market

— real income is 4.2 per cent lower under the Fully constrained labour market, but 29.3 per cent higher under the Unconstrained labour market

— employment is 7.0 per lower under the Fully constrained labour market, but 51.8 per cent higher under the Unconstrained labour market

— this provides a range of an average annual increase of 571–932 FTE jobs created in the Northern Territory as a result of the Ammaroo Project (with an estimated average annual increase of 614 FTE jobs under the Standard Tasman Global labour market).

A key constraint to achieving the projected impacts under the Unconstrained labour market for the local Barkly region and the Northern Territory more broadly, will be the ability for the Ammaroo Project to successfully train up unemployed or underemployed locals or to attract the workers and their families from interstate and/or overseas.

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**Table 4: Labour market sensitivity analysis – macroeconomic impacts)**

| | Real economic output | | | Real income | | |
|---|---|---|---|---|---|---|
| | Fully constrained (Lower bound) | Standard Tasman Global labour market (Policy case) | Unconstrained (Upper bound) | Fully constrained (Lower bound) | Standard Tasman Global labour market (Policy case) | Unconstrained (Upper bound) |
| | 2022 A$m | 2022 A$m | 2022 A$m | 2022 A$m | 2022 A$m | 2022 A$m |
| Local Barkly region | 8,687 | 8,785 | 9,488 | 2,089 | 2,190 | 2,909 |
| Northern Territory | 11,109 | 11,362 | 13,086 | 5,614 | 5,861 | 7,581 |
| Australia | 9,588 | 11,038 | 18,842 | 10,776 | 11,968 | 19,641 |
| | Percentage change relative to the Standard Tasman Global labour market | | | | | |
| | % | % | % | % | % | % |
| Local Barkly region | -1.1 | 0 | 8.0 | -4.6 | 0 | 32.8 |
| Northern Territory | -2.2 | 0 | 15.2 | -4.2 | 0 | 29.3 |
| Australia | -13.1 | 0 | 70.7 | -10.0 | 0 | 64.1 |

*Source: ACIL Allen*

**Table 5: Labour market sensitivity analysis – employment impacts**

| | Fully constrained (Lower bound) | Standard Tasman Global labour market (Policy case) | Unconstrained (Upper bound) |
|---|---|---|---|
| | Employee years | Employee years | Employee years |
| Local Barkly region | 8,551 | 9,012 | 12,452 |
| Northern Territory | 15,985 | 17,196 | 26,109 |
| Australia | 0 | 7,537 | 62,817 |
| | Percentage change relative to the Standard Tasman Global labour market | | |
| | % | % | % |
| Local Barkly region | -5.1 | 0 | 38.2 |
| Northern Territory | -7.0 | 0 | 51.8 |
| Australia | -100.0 | 0 | 733.4 |

*Source: ACIL Allen*

# Appendix A

# Overview of *Tasman Global*

*Tasman Global* is a dynamic, global computable general equilibrium (CGE) model that has been developed by ACIL Allen for the purpose of undertaking economic impact analysis at the regional, state, national and global level.

A CGE model captures the interlinkages between the markets of all commodities and factors, taking into account resource constraints, to find a simultaneous equilibrium in all markets. A global CGE model extends this interdependence of the markets across world regions and finds simultaneous equilibrium globally. A dynamic model adds onto this the interconnection of equilibrium economies across time periods. For example, investments made today are going to determine the capital stocks of tomorrow and hence future equilibrium outcomes depend on today's equilibrium outcome, and so on.

A dynamic global CGE model, such as *Tasman Global*, has the capability of addressing total, sectoral, spatial and temporal efficiency of resource allocation as it connects markets globally and over time. Being a recursively dynamic model, however, its ability to address temporal issues is limited. In particular, *Tasman Global* cannot typically address issues requiring partial or perfect foresight. However, as documented in Jakeman et al (2001), it is possible to introduce partial or perfect foresight in certain markets using algorithmic approaches. Notwithstanding this, the model does have the capability to project the economic impacts over time of given changes in policies, tastes and technologies in any region of the world economy on all sectors and agents of all regions of the world economy.

*Tasman Global* was developed from the 2001 version of the Global Trade and Environment Model (GTEM) developed by ABARE (Pant 2001) and has been evolving ever since. In turn, GTEM was developed out of the MEGABARE model (ABARE 1996), which contained significant advancements over the GTAP model of that time (Hertel 1997).

*Tasman Global* is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before an economic disturbance and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues for which both the timing of and the adjustment path that economies follow are relevant in the analysis.

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database is derived from the Global Trade Analysis Project (GTAP) database (Aguiar et al. 2019). This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities. It is the most detailed database of its type in the world.

*Tasman Global* builds on the GTAP database by adding the following important features:

— a detailed population and labour market database

— detailed technology representation within key industries (such as electricity generation and iron and steel production)

— disaggregation of a range of major commodities including iron ore, bauxite, alumina, primary aluminium, brown coal, black coal and LNG

— the ability to repatriate labour and capital income

— explicit representation of the states and territories of Australia

— the capacity to represent multiple regions within states and territories of Australia explicitly.

Nominally, version 10.1 of the *Tasman Global* database divides the world economy into 153 regions (145 international regions plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Allen regularly models Australian or international projects or policies at the regional level including at the or at the state/territory/provincial level for various countries.

The *Tasman Global* database also contains a wealth of sectoral detail currently identifying up to 76 industries. The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands.

Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input.

*Tasman Global* also has a detailed representation of the Australian labour market, recognising 97 different occupations within Australia, and producing results in terms of impacts on labour supply, participation rates and unemployment rates.

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