Mandena Environmental Radiation Monitoring Event (November 2024)

QMM | Rio Tinto

Report

166,437 | 68011 (Rev2)

25 June 2025

We acknowledge the Traditional Custodians of Country throughout Australia and their connections to land, sea and community.

We pay respect to Elders past and present and in the spirit of reconciliation, we commit to working together for our shared future.

Caring for Country The Journey of JBS&G
Artist: Patrick Caruso, Eastern Arrernte

Executive Summary

QMM engaged JBS&G in October 2024 to undertake an initial post-study environmental radiation monitoring event at Mandena consistent with the recommendation made in the 2023 Community Radiation Study, as well as provide recommendations for ongoing environmental radiation monitoring. The scope also acknowledged feedback provided by the Andrew Lees Trust from a review undertaken by Dr Stella Swanson of the 2023 study.

The 2024 monitoring event confirmed that QMM's contribution to radiation dose within the community remains consistent with conclusions from the 2023 Community Radiation Study, which found that the mine's contribution is far smaller than the variation in natural background radiation levels and below national and international regulatory limits for radiation.

Key Findings	Key Recommendations
Ingestion - Water	
• Water samples collected outside the mine perimeter during mine process water discharge (three separate events) showed gross alpha and beta activity concentrations below WHO screening levels at all tested locations, including nearby drinking water sources and surface water near critical communities – Refer **Figure 1.** ○ Water Ministry and community representatives were present during water sampling. • Consistent with the 2023 study, radiation levels in drinking water across the surrounding environment, including the MMM River catchment, southern lakes, and community groundwater bores, remain low – refer **Figure 2** and **Figure 3**.	• Gross alpha and beta activity concentration is added to all discharge points, as well as locations within the MMM and Enandrano River on a bi-annual basis (every six months) during a discharge event. • Gross alpha and beta activity concentration is tested in both Emanaka and Andrakaraka community wells annually, to continue verifying no impact on these water sources.
External – Terrestrial Gamma	
• During review, a gap was noted in available dose rate data. Gamma surveys ceased in 2020 following a change in operations to recover rare earth concentrate (REC) as a product stream in 2017. ○ The justification is the assumption that the removal of REC has reduced the net radioactivity of post-mining spoil. Although technically correct, the collection of pre and post mining gamma levels would quantitatively support this assumption.	• Recommence pre and post mining gamma surveys, including retrospective post mining surveys for all areas mined since surveys ceased in 2020, and any area rehabilitated before 2020, but not surveyed. • To support release of former mining areas, a limited study of fruit harvested both from the trial crops and similar crops from unmined areas should be undertaken. The acquired data should be used for communication to stakeholders. If however the collected data indicates an unexpected change in the potential exposure to communities, then more detailed studies of the foodstuff may be justified.
Inhalation – Dust	
• Changes have occurred within and around the Mandena Project since 2021. These operational changes constitute a change to the assumptions established within the 2023 study. The changes have the potential to increase dust concentrations and alter radionuclide activity concentration ratios. • Regardless, since doses associated with dust inhalation were previously estimated to be below 0.1 mSv/y and average gravimetric dust concentration has decreased since, exposures from inhalation of airborne dust are still considered to be negligible.	• Previous assumptions need to be validated for current conditions. • Pre 2022 air quality data was identified as erroneously high due to instrument calibration errors, which have been subsequently corrected and independent instrument calibration validated. • Dust deposition (passive) gauges should be re-installed in key communities for the dry windy season to assess radionuclide concentrations in dust and verify whether changes to mining methods have impacted the dust inhalation pathway and exposures to communities.

Key Findings	Key Recommendations
	• Should there be any indication of higher potential doses from the inhalation pathway, then introduction of long lived alpha activity in dust using air samplers and alpha counters should be considered.

Figure 1 JBS&G and QMM Water Sample Locations

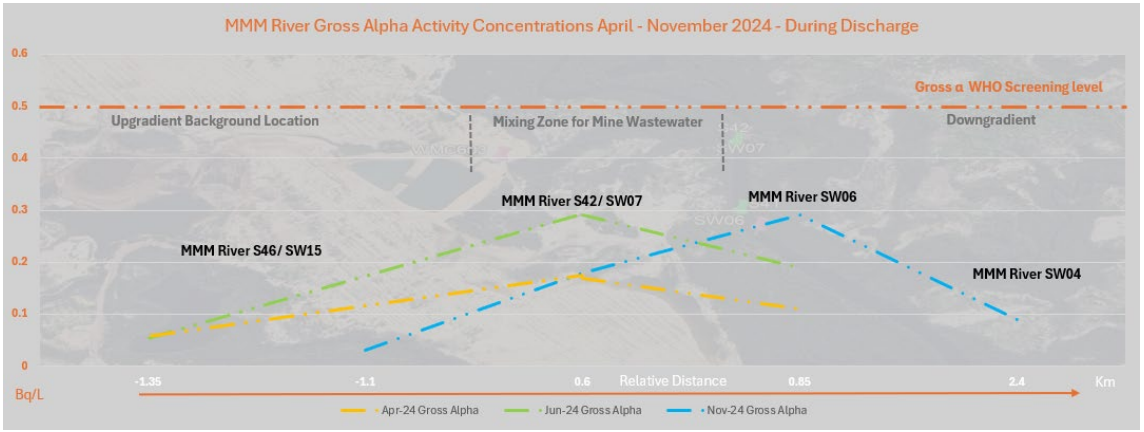

Figure 2 Measured Gross Alpha Activity Concentrations in the MMM river during discharge

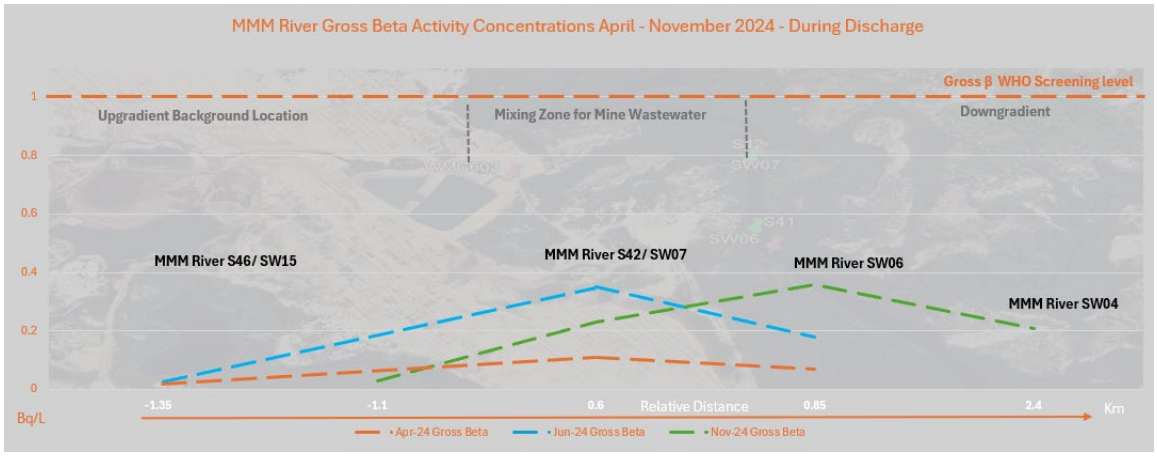

Figure 3 Measured` Gross Beta Activity Concentrations in the MMM river during discharge

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Appendices

Appendix A **Water Sampling and Results**

Appendix B **Terrestri`al Gamma Review**

Appendix C **Dust Data Review**

Abbreviations

Term	Definition
ALT	Andrew Lees Trust
ANSTO	Australia Nuclear Science and Technology Organisation
EC	Electrical Conductivity
EMP	Environmental management plan
GDWQ	Guidelines for drinking water quality
HSE	Health, safety and environment
IGW	QMM sample ID terminology
ML	Mining lease
MMM	Mandromodromotra
MSP	Mineral Separation Plant
NORM	Naturally Occurring Radioactive Material
NO_2	Nitrogen dioxide
PM	Particulate matter
PRD	Personal radiation detector
QMM	QIT Madagascar Minerals
REC	Rare earth concentrate
SOP	Standard Operating Procedure
SO_2	Sulfur dioxide
TDS	Total dissolved solids
WHO	World Health Organisation

1. Introduction

JBS&G Australia Pty Ltd (JBS&G) was engaged by QIT Madagascar Minerals (QMM) to undertake a Community Radiation Study ("the study") at the Mandena Mineral Sands Mine in Southern Madagascar (refer Figure 3). The study commenced in 2019 and was one of the largest studies of its type ever undertaken.

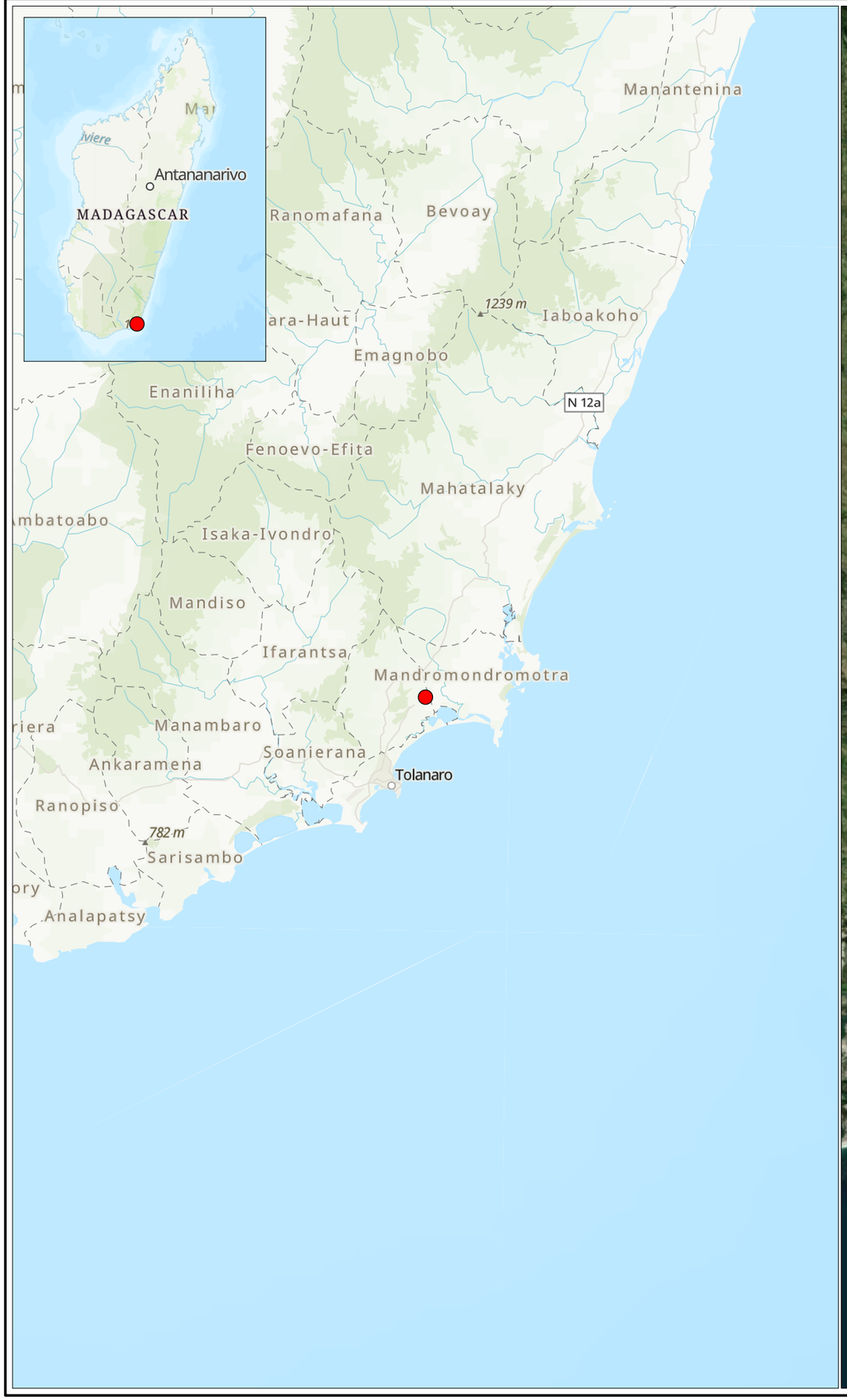
JBS&G designed a robust quality assured detailed environmental impact investigation based on a source, pathway, receptor model, targeting sampling of multiple media including soil, direct gamma, radon/thoron, surface water, groundwater, dust, fruit, vegetables, and biota (fish and prawns). The study was initially designed with four quarterly sampling events over 12 months, however due to Covid-19 and global logistical issues, the study extended to five sampling events over four years. The study assessed 26 potential exposure pathways including Direct Gamma (4), Inhalation (2) and Ingestion (20).

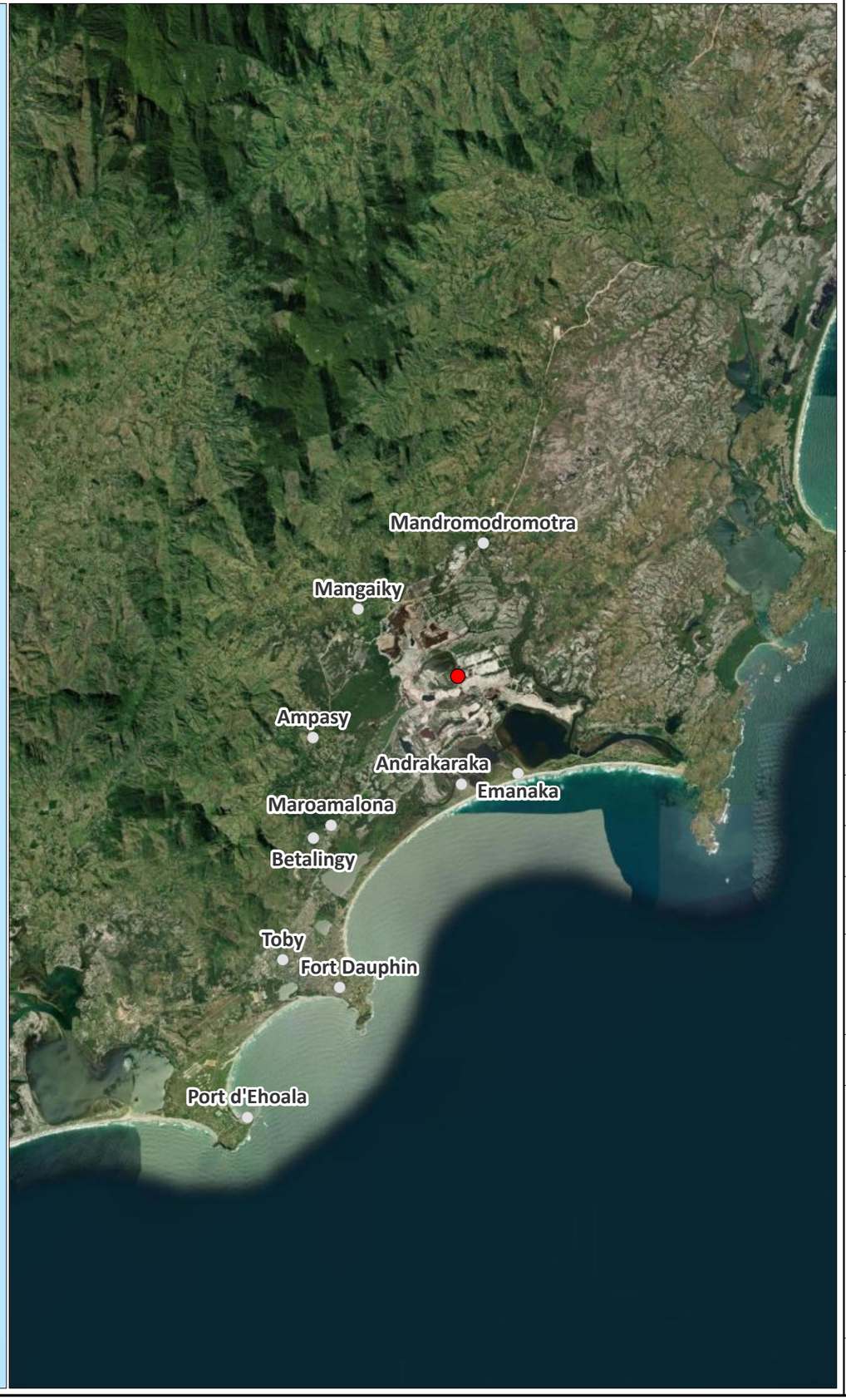
The final study report[1], delivered in 2023, concluded that the contribution to a community member radiation dose from the mining operation did not exceed 1 mSv per year above natural background[2] through all the exposure pathways assessed. The study recommended that future monitoring should focus only on specific pathways necessary to demonstrate levels remain low. The study also recommended that for those pathways identified on which mining may have an ongoing influence, discussions should occur with key stakeholders and regulators to determine the best approach towards a monitoring program. This could include ongoing gamma monitoring of revegetated mined areas, as well as the potential for impact from mine water discharges, water treatment plant residues and local dust levels as the mine continues to expand closer to local communities.

QMM engaged JBS&G in October 2024 to visit the Mandena site and surrounds to undertake an initial post-study environmental radiation monitoring event and to provide recommendations for an ongoing environmental radiation monitoring program which could be incorporated into the broader mine environmental monitoring program. This site inspection was completed in November 2024.

Representatives from the Water Ministry, as well as community representatives from both Emanaka and Andrakaraka were present for all water sampling undertaken as part of the post study monitoring event.

[1] JBS&G 2023 Mandena Community Radiation Study, Reference 57082/153,352 18 August 2023.
[2] The international annual limit for radiation exposure to a member of the public is 1 mSv per year.





Legend

- Site Location
- Communities

JBS&G

Job No: 68001

Client: Rio Tinto

Version: FINAL	Date: 28/05/2025
Drawn By: RT	Checked By: DO

Scale: 1:150,000

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km

Coord. Sys. WGS 1984 UTM Zone 38S

QMM Mandena Mineral Sands Mine, Madagascar

SITE LOCATION

FIGURE 1

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Reference: ESRI Topographic & Imagery Basemap - Accessed Imagery: 23/07/21

2. Background and Scope

The objective of the post study monitoring event was to undertake a round of monitoring consistent with the recommendation made in the JBS&G study for ongoing monitoring. One of the primary tasks was to investigate the surface water pathways and specifically the potential for the discharge of mine process water to mobilise and transport radionuclides into the receiving surface water with the potential to impact identified community receptors.

Other objectives of the monitoring event were to examine and monitor the other important environmental sources and pathways by undertaking surveys and observational visits across the mine to examine if the assumptions and observations included in the JBS&G study remain representative of the operational site and surrounding conditions for the potential for exposure to community groups, including Emanaka and Andrakaraka. This included both external and inhalation pathways via terrestrial gamma and dust.

JBS&G acknowledge the feedback provided by the Andrew Lees Trust (ALT) from a review undertaken by Dr Stella Swanson of the JBS&G study report[3] and the recommendations therein. The initial post study site visit scope was designed as a starting point for the establishment of a longer term robust environmental monitoring dataset. It is acknowledged that the environmental radiation dataset gathered for the Mandena mine and surrounding environment will continue to be improved with increased levels of confidence gained over time, and additional interpretation of trends once sufficient data has been established.

The scope of work undertaken during this sampling event included:

- Surface water and groundwater sampling at key locations previously identified;
- Laboratory analysis of water samples at Australia Nuclear Science and Technology Organisation (ANSTO) in Sydney;
- Site operational review, interviews and observations;
- Direct Gamma surveys; and
- Dust data review and analysis.

The key environmental radiation sources, pathways and receptors investigated during the first post study monitoring event, including the objective, methods and analysis are summarised in **Table 1**. The 2023 JBS&G study identified the water pathway as potentially the most significant pathway (for mine related exposure), in terms of both direct and indirect ingestion, and as such was the focus of the 2024 monitoring. Separate appendices have been prepared which detail each of the pathways. Each of the pathway reports including tasks undertaken, results and recommendations have been summarised below.

[3] Swanson Environmental Strategies 2024, Review of the JBS&G 2023 Report: Mandena Community Radiation Study, Submitted to the Andrew Lees Trust 18 March 2024.

Table 1 Key Environmental Pathways and Receptors for the post study monitoring event

Pathway	Media	Activity/Item	Objective/method/analysis	Appendix
Ingestion	Process Water	Analysis of process water discharge samples from 2024 (wet season). These samples were collected as water quality samples during the process water discharge (April to July 2024).	Targeted samples selected from the discharge point (WMC-603), discharge samples will be analysed for gross alpha and beta activity for comparison against World Health Organisation (WHO) screening values. Note: sample volumes are limited (~3L), which can constrain the limit of detection possible.	Appendix A
	Surface Water	First bi-annual surface water sampling event (dry season).	Targeted surface water sample locations adjacent to the current and historical discharge channels, together with upgradient and down gradient locations on the Mandramondramotra River (MMM River) and the adjacent communities of Andrakaraka and Emanaka.	
	Groundwater	First bi-annual groundwater sampling event (dry season).	Targeted groundwater sample locations from the southern area of the mine and existing groundwater wells within the communities of Andrakaraka and Emanaka. Analysis for gross alpha and beta activity.	
External	Terrestrial gamma	Radiation Survey Meters.	Provision of three radiation survey meters with sufficient sensitivity to undertake ongoing pre and post mining gamma surveys at low environmental radiation levels.	Appendix B
		Review of current gamma surveys.	Review of QMM gamma survey practices and procedures to provide recommendations including revision of grid densities and / or survey procedures as required.	
Inhalation	Dust	Review of environmental dust monitoring data.	Qualitative review and comparison with radiation study radionuclide concentrations and ratios for dust.	Appendix C

3. Ingestion – Water

3.1 Scope and Purpose

The 2024 post-study monitoring event aimed to continue monitoring as recommended in the 2023 JBS&G study and improve understanding of water pathways and potential mine-related ingestion exposures. A key focus was assessing whether mine process water discharges could mobilise radionuclides into surface water, potentially affecting community receptors. JBS&G also conducted surveys and site observations to verify previous assumptions about environmental pathways. The 2023 JBS&G study identified water as the most significant pathway for exposure, making it the primary focus of the 2024 monitoring.

3.2 Methodology and Data Collection

The 2023 JBS&G study identified representative surface water and groundwater sampling locations to investigate ingestion pathways and potential receptors, based on a 2019 site visit. Many locations overlapped with existing QMM HSE water quality sample locations. The 2024 post-study monitoring event included the collection of process water samples from the discharge location WMC-603, whilst a reduced set of targeted locations to assess environmental radiation. Seven surface water sites were chosen, including five in the MMM River and two near community villages of Emanaka and Andrakaraka. Mine process water was sampled during three discharge events, including one sampled by the JBS&G team in November 2024.

In addition, four groundwater bores were targeted for sampling, including two newly installed monitoring piezometers located adjacent to the southern wetlands, one in the southwest and one in the southeast portion of the Mandena Mine and two newly installed bores from the communities at Andrakaraka and Emanaka.

In field parameters were recorded at all sites using a calibrated field water quality meter. With the exception of the mine piezometer samples, all water samples were unfiltered to reflect community drinking water conditions and were analysed at the ANSTO laboratory in Australia.

Sample locations are shown in **Figure 2** below.

Legend

- JBSG Sampling Location
- QMM Sampling Location
- Communities

JBS&G

Job No: 68001

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Drawn By: RT	Checked By: DO

Scale: 1:40,000

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km

Coord. Sys. WGS 1984 UTM Zone 38S

QMM Mandena Mineral Sands Mine, Madagascar

GROUNDWATER AND SURFACE WATER SAMPLING LOCATIONS, 2024

FIGURE 2

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Madagascar does not have specific radiological safety standards for drinking water. Resultantly, the 2024 post-study sampling event adopted the WHO Guidelines for Drinking Water Quality (GDWQ) to assess radionuclides. The GDWQ provides screening levels of 0.5 Bq/L for gross alpha activity and 1 Bq/L for gross beta activity, corresponding to an annual dose of 0.1 mSv/y. Exceeding these levels does not indicate significant risk but signals the need for further assessment, including water use studies or radionuclide-specific analysis, to better evaluate potential impacts and guide appropriate mitigation measures.

3.3 Results and Key Outcomes

The 2023 JBS&G study conducted a full radionuclide analysis, which confirmed that all samples had very low concentrations, at least one order of magnitude below WHO guidance levels, resulting in very low annual doses. Given these findings, the 2024 monitoring event adopted gross alpha and beta activity screening as a cost-effective and efficient approach. This method allows for quicker reporting and broader laboratory options while still enabling further analysis if screening levels are exceeded.

Surface water samples collected in April, June, and November 2024 during mine process water discharge, downgradient of the mine discharge location (WMC-603), showed gross alpha and beta activity concentrations below WHO screening levels at all tested locations, including nearby drinking water sources and surface water near critical[4] communities. As per WHO guidelines, no further radionuclide analysis is needed.

All samples from within the MMM River reported gross alpha and gross beta activity concentrations below the WHO screening level, including samples from locations both upstream and downstream of the point of where the process water enters the MMM River. A graphical representation of results from samples within the MMM river are presented in **Figure 6** and **Figure 7**.

Results for community wells in Andrakaraka and Emanaka were low and returned results below relevant WHO screening levels.

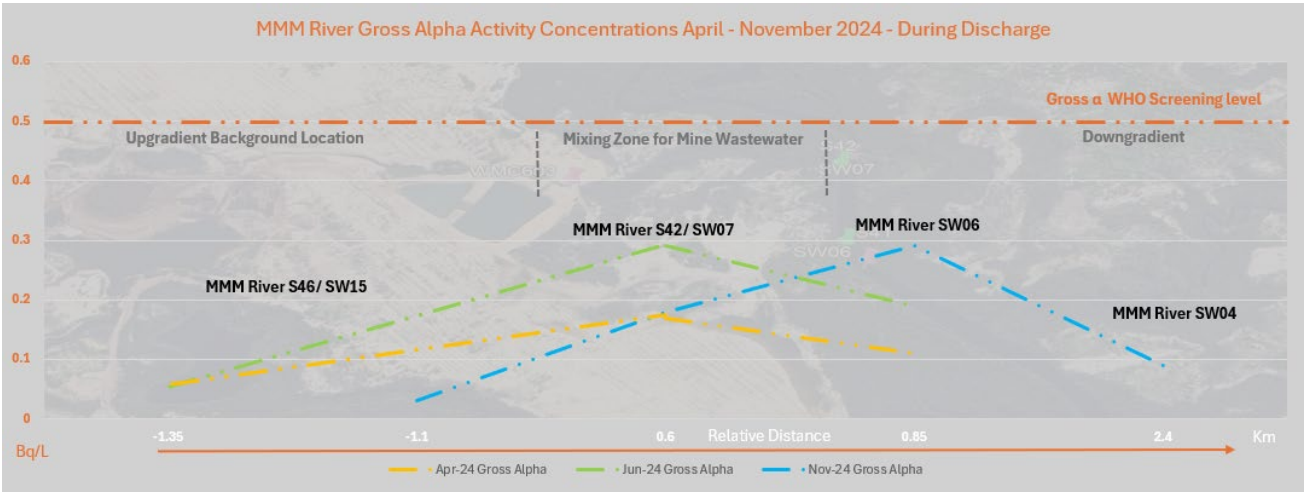

Figure 3 Measured Gross Alpha Activity Concentrations in the MMM river during discharge

Consistent with the 2023 JBS&G study, radiation levels in drinking water across the surrounding environment, including the MMM River catchment, southern lakes, and community groundwater bores, remains low and below the WHO screening levels.

[4] Critical communities are defined from a radiological assessment perspective as those groups that by their location or lifestyle are most at risk of being exposed to radiological dose from any particular pathway (IAEA General Safety Requirements Part 3).

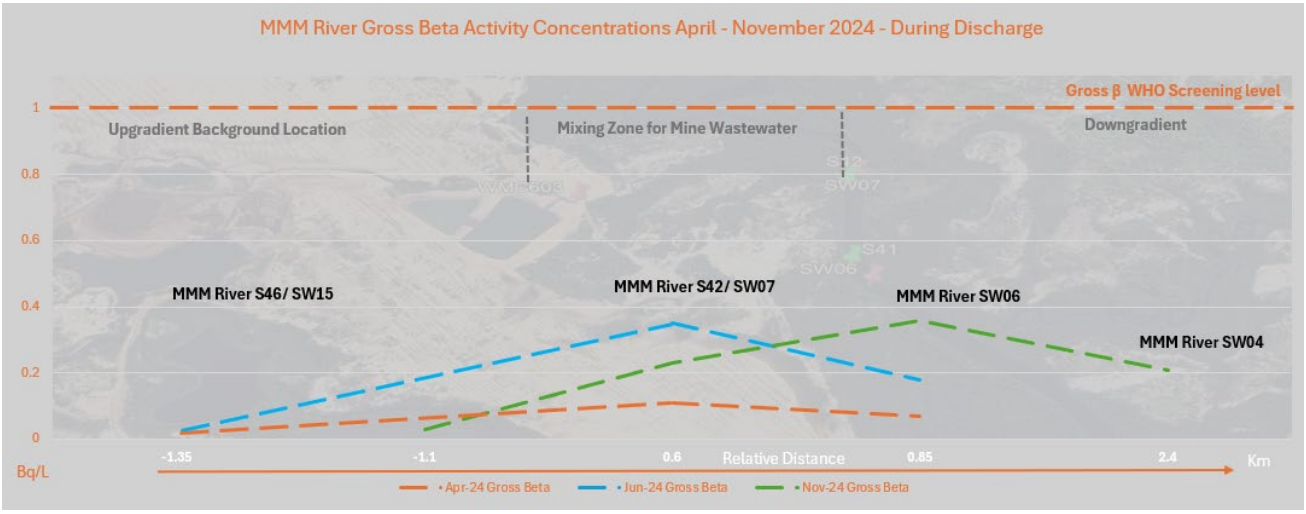

Figure 4 Measured Gross Beta Activity Concentrations in the MMM river during discharge

3.4 Recommendations

To acquire information that will improve the understanding of the potential operational impact to the ingestion pathway via drinking water, the following recommendations are offered to QMM:

- Gross alpha and beta activity analysis in water should be carried out twice a year. Samples should be collected during process water discharge into the MMM River.
- Water monitoring should be extended to any new water system affected or to be affected by mining operations. The river west of Mandena (Enandrano River) should therefore be integrated as appropriate into the water monitoring program, as QMM's activities progress towards the west.
- A complete set of surface water samples should be collected biannually during discharge of process water comprising of one sample at the discharge point (WMC-603), an upgradient sample (SW-15), three downgradient samples within the MMM river (SW07, SW06 and SW04) and one surface water sample adjacent to Andrakaraka (SW11) and Emanaka (SW12).
- The discharge and MMM river samples should be analysed for gross alpha and gross beta activity and results compared to the WHO screening levels. If there is an exceedance of the screening levels within the MMM river samples and that exceedance is not delineated by a downgradient sample location result, this will trigger analysis of the surface water samples collected adjacent to Andrakaraka (SW11) and Emanaka (SW12).
- Any exceedance of screening levels in the Andrakaraka and Emanaka surface water samples would trigger more detailed assessment and potentially additional radionuclide analysis, in accordance with the GDWQ such as alpha spectrometry.
- Any exceedances from samples within the MMM river would also trigger a review of the discharge of process water to identify the reason for the elevated concentrations.
- Gross alpha and beta activity analysis in water should be carried out for the groundwater wells at Andrakaraka and Emanaka with results compared against the WHO guidelines, with any exceedance triggering more detailed analysis, in accordance with the GDWQ such as alpha spectrometry.
- It is recommended that additional volumes of water (1L) are provided to the laboratory for the surface water samples until it is confirmed that gross alpha and beta activity in water at potential exposure sites are consistently below WHO screening levels. This contingency volume can be used for alpha spectrometry analysis, if required.

4. External – Terrestrial Gamma

4.1 Scope and Purpose

One of the objectives of the post-study monitoring event was to examine and monitor the other important environmental sources and pathways by undertaking surveys and observational visits across the mine to examine if the assumptions and observations included in the JBS&G study remain representative of the operational site and surrounding conditions for the potential for exposure to critical[5] community groups.

4.2 Methodology

The JBS&G team undertook a review of the equipment being utilised by the QMM HSE team. An outcome of the review found that there are more suitable models available for environmental surveys. Subsequently, two Thermo Scientific RadEye PRD4 monitors and one Radiacode 103 were provided to QMM, with electronic copies of standard operating procedures (SOPs) and product manuals. Whilst onsite, JBS&G engaged with site-based teams to understand the activities and sequencing for area clearance prior to mining, and closure and release of areas following mining.

4.3 Results and Key Outcomes

During review of QMM gamma survey information, a gap was noted in available data. Gamma surveys were ceased within the Mining Lease in 2020 following a change in operations to recover rare earth concentrate (REC) as a product stream in 2017. The justification is the assumption that the removal of REC has reduced the net radioactivity of post-mining spoil. Although technically correct, the collection of pre and post mining gamma levels would quantitatively support this assumption.

JBS&G have identified an opportunity to recommence gamma surveys pre and post mining to ensure that areas are characterised and natural radiation levels in all new mining areas (prior to excavation of heavy mineral sands) is well understood. This would enable the operation to establish pre-existing conditions and provide a local benchmark for remediation. By repeating measurement at the same locations after rehabilitation (following backfill and final landform), remediation can be validated or alternatively, localised areas requiring further remediation can be identified early.

During November 2024, JBS&G also undertook a range of surveys across the region (informally) and within the Mining Lease in an unmined area (pre mining survey) and in rehabilitated areas (post mining survey).

Results of the surveys are summarised in **Table 2.**

Table 2 Summary of gamma dose rates for each area surveyed in November 2024

Area	Description	Data points	Dose rate at 1 m (uSv/h)				
			average	median	min	max	St Dev
Anosy region	Regional survey using 4 x Radiacode 103 devices	48,247	0.24	0.16	0.003	13	0.46
Mandena	An area rehabilitated in 2014 and an area rehabilitated in 2023 (post mining), both within the ML.	1,197	0.09	0.05	0.03	0.51	0.08
North Snake	Area rehabilitated in North Snake currently being used in a rehabilitation trial (fruit	430	0.20	0.20	0.04	0.50	0.08

[5] Critical communities are defined from a radiological assessment perspective as those groups that by their location or lifestyle are most at risk of being exposed to radiological dose from any particular pathway (IAEA General Safety Requirements Part 3).

Area	Description	Data points	Dose rate at 1 m (uSv/h)				
			average	median	min	max	St Dev
	production of pineapples and mango trees)						
2025 mine plan	Unmined area survey (pre mining) within the ML	999	0.04	0.04	0.03	0.10	0.01

The rehabilitation trial orchard of fruit trees (pineapple and mango) in North Snake presents an opportunity for QMM to develop criteria for release, and compare key markers food produced in former mining areas with crops from unmined areas in the same province.

Acquisition of pre-mining dose rate measurements (by undertaking pre-mining gamma surveys) enables comparison, and is able to support early identification of small areas that may require further remediation.

4.4 Recommendations

JBS&G recommend that the QMM HSE team:

- Recommence pre and post mining gamma surveys, including retrospective post mining surveys for all areas mined since surveys ceased in 2020, and any area rehabilitated before 2020, but not surveyed.
- To support release of former mining or operational areas, a limited study of fruit harvested both from the trial food crops in North Snake and similar crops from unmined areas should be undertaken. The acquired data should be used for communication to stakeholders. If however the collected data indicates any potential for a significant change in the potential exposure to communities, such as some fruit having atypical bioaccumulation of a specific radionuclide, then more detailed studies of the foodstuff may be justified.

5. Inhalation – Dust

5.1 Scope and Purpose

The 2024 post-study monitoring event aimed to validate assumptions from the 2023 JBS&G study by assessing environmental pathways through surveys and observational visits across the mine. It included a qualitative review of dust monitoring data, comparing recent dust concentrations to past levels to evaluate potential impacts on nearby communities. The review also examined monitoring locations relative to current mining operations and considered the mine's short- and long-term plans to assess potential future changes to the mining footprint.

5.2 Results and Key Outcomes

Changes have occurred within and around the Mandena Project since 2021. These operational changes constitute a change to the dust source-pathway-receptor assumptions established within the 2023 JBS&G study.

The changes, listed below, have the potential to increase dust concentrations in air and alter radionuclide concentration ratios in the dust in comparison to those established by the initial study:

- Dry mining has become part of the QMM extraction processes (this was not considered by the 2023 JBS&G study);
- Extraction areas have moved to the western and north-western ore body boundaries, close to the communities of Mangaiky and Ampasy, and extraction in these areas uses dry mining methods;

- Truck haulage has increased over the last 3 years (from four to 16 haul trucks) as a consequence of the increase to dry mining;
- With the exception of watering haulage roads, there are limited controls applied for dust suppression;
- The expansion of the mine footprint has increased the site boundary, and public access to rehabilitated areas and active mining fronts is not fully restricted; and
- A major road is under construction in the area, however this is not an activity associated with QMM or the mining operation.
    - The section linking Ampasy to Mandromondromotra (MMM) is largely completed. The construction of the road and the subsequent traffic (trucks and cars commonly travelling at speed greater than 60 km/h) introduces new sources of dust that were not present prior to 2024.

Air quality data for 2022, 2023 and 2024 was provided to JBS&G by the QMM Mandena environmental team. This data was compared to the 2020 – 2021 data provided by QMM for the 2023 JBS&G study.

Three stations have been operating on a regular basis between 2022 and 2024, Mangaiky and Ampasy (to the west of the mining area) and MMM (upwind location to the north-east if the mining area).

Analysis of the data provided for the 2022 to 2024 period shows that:

- Despite using the same model equipment, measurements are generally about one order of magnitude lower than data provided for the period 2020 - 2021. The original JBS&G report used the 2021 dust concentration data provided by the QMM operation which was subsequently established to be erroneously high due to calibration issues with the dust monitoring instruments. Notwithstanding, using the overestimated 2021 dust concentration data in the original JBS&G report, the dust pathway was confirmed as a minor contributor to community dose. Subsequent dust monitoring data provided by QMM from 2022, 2023, and 2024 with independent calibration certification provided for the dust monitoring equipment, confirmed that the actual dust concentrations are substantially lower and confirmed that the inhalation pathway is a very minor contributor to public dose.
- Averages and maxima do not show a substantial difference between downwind stations (Mangaiky and Ampasy) and the upwind station (MMM).
- Monitoring at Andrakaraka and Toby Nenilava appears to have ceased at the end of 2023 and the start of 2024 respectively, following relocation of mining activities away from the southern communities; and
- Additional stations have been added to the 2024 schedule to capture new mining areas (Vatovy, North Snake, Turtle, Mandena and the Port of Ehola)[6]. Only three stations from Vatovy (Mamirano, Soanareny and Soarano) had been operational at the time of the review in November 2024.

Since doses associated with dust inhalation were estimated to be below 0.1 mSv/y during the 2020 - 2021 period and average gravimetric dust concentration in the air has significantly decreased since, exposures from inhalation of airborne dust are still considered to be negligible. Importantly, ongoing dust monitoring is required to validate this position and any potential change or increase in the inhalation pathway (due to the changes in mining practices and or locations) requires assessment as described within the recommendations below.

5.3 Recommendations

JBS&G recommend the following:

[6] Noting JBS&G have not been provided with coordinates for these new monitoring locations.

- Pre 2022 air quality data should be re-evaluated to investigate reasons for the order of magnitude change reduction between older results and the values measured between 2022 and 2024.
- Previous assumptions need to be validated for current conditions.
- Dust deposition (passive) gauges should be re-installed in key communities (Mangaiky, Ampasy and MMM) for the dry windy season to assess radionuclide concentrations in dust and investigate whether changes to mining methods may have impacted the dust inhalation pathway and exposures to critical[7] groups (communities).
- Should there be any indication of higher potential doses from the inhalation pathway then introduction of long lived alpha activity in dust using air sampler pumps and alpha counters should be considered. Locations where this methodology could be applied include:
    - at the boundary of active mining areas;
    - within freshly rehabilitated areas trialled for crops; and
    - within active areas potentially accessed by communities.

6. Proposed Monitoring

JBS&G have proposed ongoing radiation monitoring across water, gamma and dust, which targets ingestion, external and inhalation pathways. The proposed monitoring has been drafted in a way to replicate monitoring tables included in the site's current EMP and is included in Table 3.

[7] Critical communities are defined from a radiological assessment perspective as those groups that by their location or lifestyle are most at risk of being exposed to radiological dose from any particular pathway (IAEA General Safety Requirements Part 3).

Table 3 Proposed EMP monitoring requirements

Relevant Reference for amendment/addition	Description of potential impact	Indicator	Monitoring location	Parameter	Frequency
Discharge water / Surface water					
	Changes in the radiological quality of surface waters systems following the release of water.	Surface water quality	Discharge point WMC-603 and any other new discharge points reporting to surface water systems on MMM River or Enandrano River)	Gross alpha and beta activity	Bi-annually (every 6 months during a discharge event)
Surface water					
	Changes in the radiological quality of surface waters systems following the release of water.	Surface water quality	Surface water sampling 1 x upstream of each discharge point 3 x downstream of each discharge point 1 x Adjacent Andrakaraka and Emanaka	EC TDS pH Gross alpha and beta activity within the MMM river initially, extending to analysis of the Andrakaraka and Emanaka samples if exceedances identified within the MMM river samples. Discretionary analysis for individual radionuclides(alpha spectrometry) if appropriate.	Bi-annually (every 6 months during a discharge event) Must be within 48 hours of discharge sample being collected.
Groundwater					
	Modification of groundwater quality due to water infiltration from dredging basin (pH, turbidity, suspended solids, etc.);	Groundwater quality	Community wells within Emanaka and Andrakaraka	Gross alpha and beta activity	Annually

Relevant Reference for amendment/addition	Description of potential impact	Indicator	Monitoring location	Parameter	Frequency
Radiation / Terrestrial Gamma					
1	Enhancement of external radiation levels above clearance criteria post rehabilitation associated with high levels of NORM at the surface	Dose rate measurements using calibrated meters (Thermo Scientific RadEye PRD4 and Radiocode 103)	All areas before mining (ideally shortly after vegetation clearance) and directly after rehabilitation (final landform).	Dose rate at 1 m above natural ground level, recorded in uSv/h (corrected using calibration factors) The appropriate survey spacing is 50 m for point measurements. However, if any measurements exceed the release threshold, then additional infill measurements should be taken on a tighter grid to enable a suitable coverage of any anomaly.	Systematic surveys for all areas before mining (ideally shortly after vegetation clearance) and directly after rehabilitation (final landform).
2	Community concern	Community sentiment around the safety of eating fruit	Each new post mining area.	Radionuclide concentrations in fruit produced on post mining areas. Limited sampling three (3) per fruit type, to obtain sufficient data to enable ongoing communication of the safe nature of this fruit / absence of risk.	Samples to be analysed from the first crop of each new post mining area. Repeat the analysis as needed i.e. guided by feedback from the community engagement team on broader community sentiment around the safety of consuming fruit.
Air Quality					
ISA01	**Mining sector:** Changes in ambient air quality (Air pollutants: (PM1, PM2.5, PM10, NO_2 and SO_2) NAP and at the level of villages or hamlets (villages of	Rate of particles in the air	Villages of Soanareny, Soarano, Ankofa, Mangaiky, Mamirano, Enandrano, Emahasoa,	PM1, PM2.5 and PM10 Number of air quality complaints NO_2 and SO_2	Quarterly

Relevant Reference for amendment/addition	Description of potential impact	Indicator	Monitoring location	Parameter	Frequency
	Soanareny, Soarano, Ankofa, Mangaiky, Mamirano, Enandrano, Emahasoa, Ampasy and Maroamalona) located on the outskirts of the MSP plant area due to mining activities		Ampasy and Maroamalona)		
ISA02	Changes in ambient air quality (Air pollutants: (P PM1, PM2.5, PM10, NO_2 and SO_2) NAP and at the level of villages or hamlets located on the periphery of the MSP plant area due to stationary sources	Rates of metals and particles at the stack outlet	MSP	PM 10 (Metals, etc.) PM1, PM2.5 and PM10 incl. metals) SO_2, NO_2 CO, CO2	Once every 5 years
N/A	Changes in mining techniques and mining scale, external factors, focusing on Mangaiky, Ampasy and MMM, located in close vicinity of the dry mining areas	Radionuclide ratios in dust	Mangaiky, Ampasy and MMM, located in close vicinity of the dry mining areas	Radionuclide activity concentration	Once in the dry months (6 months deployment)

7. Limitations

This report has been prepared for use by the client who has commissioned the works in accordance with the project brief only, and has been based in part on information obtained from the client and other parties.

The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose.

JBS&G accepts no liability for use or interpretation by any person or body other than the client who commissioned the works. This report should not be reproduced without prior approval by the client, or amended in any way without prior approval by JBS&G, and should not be relied upon by other parties, who should make their own enquires.

Sampling and chemical analysis of environmental media is based on appropriate available guidance documents made and approved by the relevant regulatory authorities. Conclusions arising from the review and assessment of environmental data are based on the sampling and analysis considered appropriate based on the regulatory requirements.

Limited sampling and laboratory analyses were undertaken as part of the investigations undertaken, as described herein. Conditions between sampling locations and media may vary, and this should be considered when extrapolating between sampling points. Chemical analytes are based on the information detailed in the site history. Further chemicals or categories of chemicals may exist at the site, which were not identified in the site history and which may not be expected at the site.

The conclusions and recommendations reached in this report are based on the information obtained at the time of the investigations.

This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown information pertaining to the site, JBS&G reserves the right to review the report in the context of the additional information.

Appendix A Water Sampling and Results

Appendix A | Event Monitoring Report - Water

Rio Tinto | QMM

Report

JBS&G 68011 | 166,088

15 April 2025

We acknowledge the Traditional Custodians of Country throughout Australia and their connections to land, sea and community.

We pay respect to Elders past and present and in the spirit of reconciliation, we commit to working together for our shared future.

Caring for Country The Journey of JBS&G
Artist: Patrick Caruso, Eastern Arrernte

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Abbreviations

Term	Definition
ACW	Andrakaraka Community Well (bore)
ANSTO	Australian Nuclear Science and Technology Organisation
DO	Dissolved oxygen
ECW	Emanaka Community Well (bore)
GDWQ	Guidelines for Drinking Water Quality (WHO)
IDC	Individual Dose Criterion
JBS&G	JBS&G Australia Pty Ltd
MMM	Mandramondramotra
MMM River	Mandramondramotra River
NORM	Naturally Occurring Radioactive Materials
QMM	QIT Madagascar Minerals
REC	Rare Earth Concentrate
SOP	Standard Operating Procedure
TDS	Total Dissolved Solids
The study	JBS&G Community Radiation Study (2023)
WHO	World Health Organisation
WTP	Water Treatment Plant

1. Introduction

JBS&G Australia Pty Ltd (JBS&G) was engaged by QIT Madagascar Minerals (QMM) to undertake a Community Radiation Study ("the study") at the Mandena Mineral Sands Mine in Southern Madagascar (refer Figure 1-1). The study commenced in 2019 and was one of the largest studies of its type ever undertaken.

JBS&G designed a robust quality assured detailed environmental impact investigation based on a source, pathway, receptor model, targeting sampling of multiple media including soil, direct gamma, radon/thoron, surface water, groundwater, dust, fruit, vegetables, and biota (fish and prawns). The study was initially designed with four quarterly sampling events over 12 months, however due to Covid-19 and global logistical issues, the study extended to five sampling events over four years. The study assessed 26 potential exposure pathways including Direct Gamma (4), Inhalation (2) and Ingestion (20).

The final study report[1], delivered in 2023, concluded that the contribution to a community member radiation dose from the mining operation did not exceed 1 mSv per year above natural background through all the exposure pathways assessed. The study recommended that future monitoring should focus only on specific pathways necessary to demonstrate levels remain low. The study also recommended that for those pathways identified on which mining may have an ongoing influence, discussions should occur with key stakeholders and regulators to determine the best approach towards a monitoring program. This could include ongoing gamma monitoring of revegetated mined areas, as well as the potential for impact from mine water discharges, water treatment plant residues and local dust levels as the mine continues to expand closer to local communities.

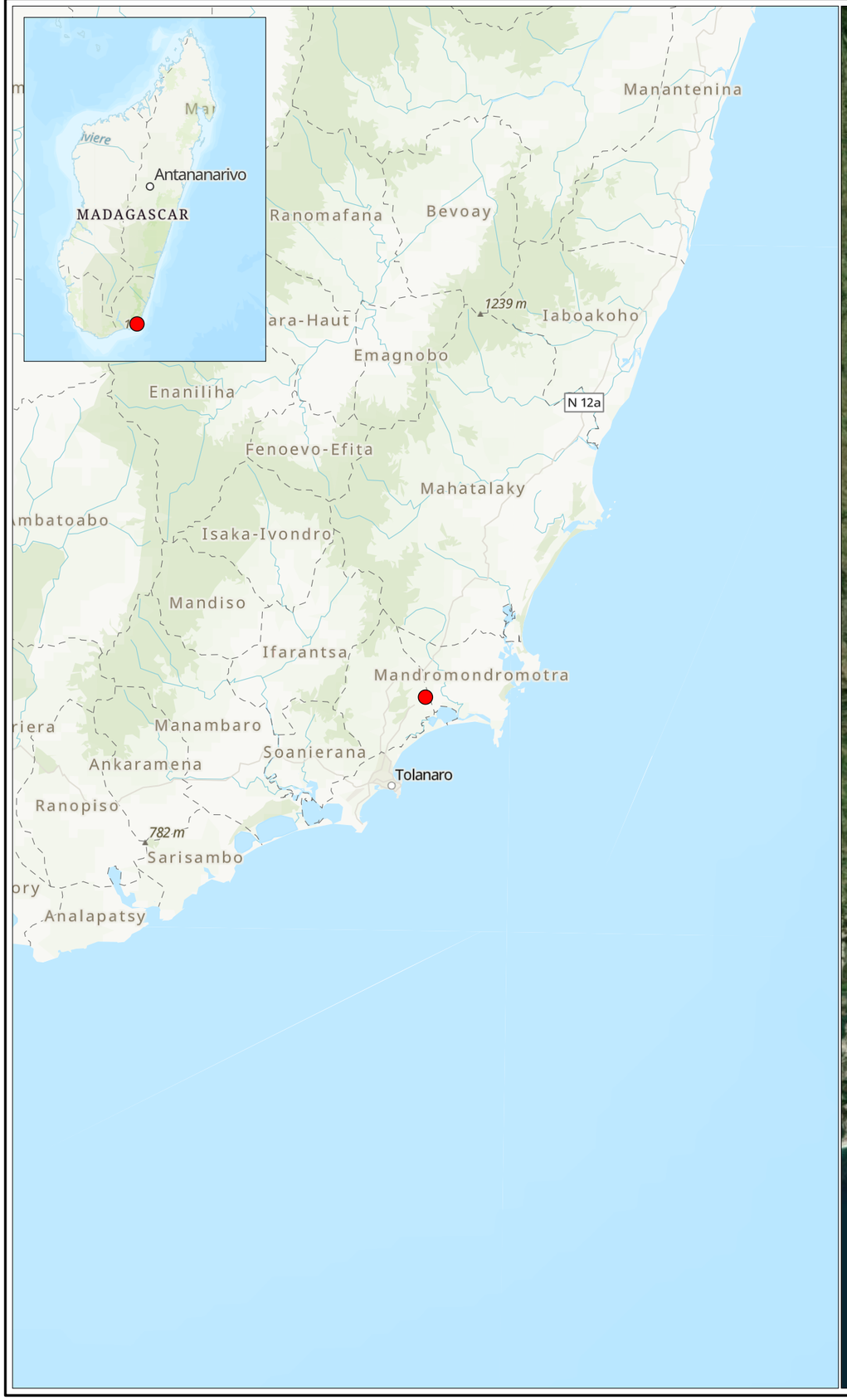
QMM engaged JBS&G in October 2024 to visit the Mandena site and surrounds to undertake an initial post-study environmental radiation monitoring event and to provide recommendations for an ongoing environmental radiation monitoring program which could be incorporated into the broader mine environmental monitoring program. The monitoring event was completed in November 2024.

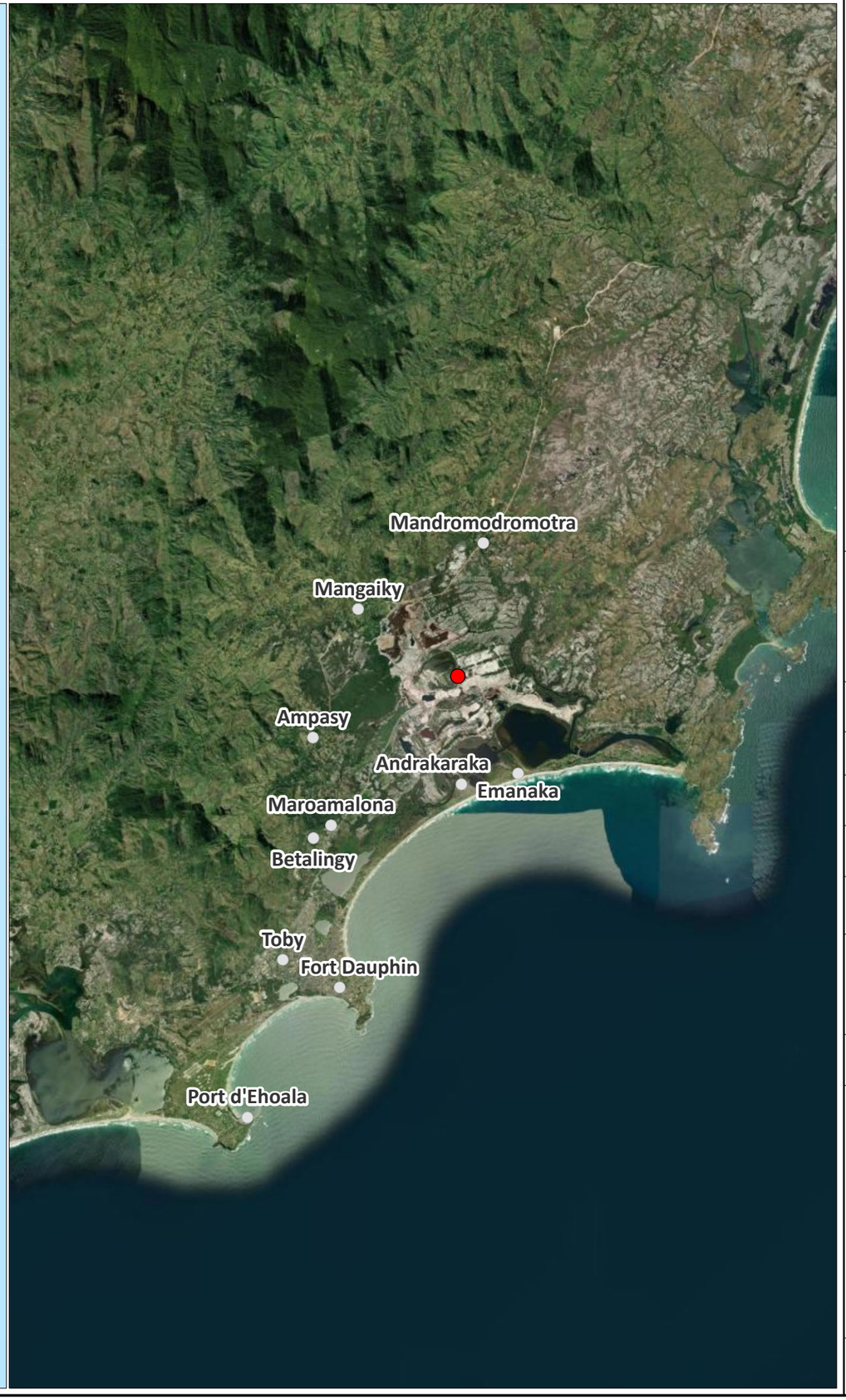
Representatives from the Water Ministry, as well as community representatives from both Emanaka and Andrakaraka, were present for all water sampling undertaken as part of the post-study monitoring event.

The 2023 JBS&G study identified the water pathway as potentially the most significant pathway (for mine related exposure), in terms of both direct and indirect ingestion, and as such was the focus of the 2024 monitoring. Other pathways of focus included both external and inhalation pathways via terrestrial gamma and dust. Separate appendices have been prepared which detail each of the pathways.

This Appendix covers the Ingestion Pathway, focusing on water.

[1] JBS&G 2023 Mandena Community Radiation Study, Reference 57082/153,352 18 August 2023.





Legend

- Site Location
- Communities

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QMM Mandena Mineral Sands Mine, Madagascar

SITE LOCATION

FIGURE 1

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Reference: ESRI Topographic & Imagery Basemap - Accessed Imagery: 23/07/21

2. Background and Scope

JBS&G acknowledge the feedback provided by the Andrew Lees Trust (ALT) from a review undertaken by Dr Stella Swanson of the JBS&G study report[2] and the recommendations therein. The initial post study site visit scope was designed as a starting point for the establishment of a longer term robust environmental monitoring dataset. It is acknowledged that the environmental radiation dataset gathered for the Mandena mine and surrounding environment will be improved with increased levels of confidence gained over time, and additional interpretation of trends once sufficient data has been established.

The objective of the post study monitoring event was to undertake a round of monitoring consistent with the recommendation made in the JBS&G study for ongoing monitoring.

The study identified opportunities to improve knowledge relating to water, and the potential for mine impact on ingestion exposures.

One of the primary tasks of the 2024 monitoring event was to investigate surface water pathways, and specifically the potential for the discharge of mine process water to mobilise and transport radionuclides into the receiving surface water with the potential to impact identified community receptors.

During the monitoring event, JBS&G took the opportunity to examine and monitor other environmental sources and pathways by undertaking surveys and observational visits across the mine, to examine whether assumptions and observations included in the study remain representative of the operational site and surrounding conditions and relevant for potential exposure to critical community groups.

The 2023 JBS&G study identified the water pathway as potentially the most significant pathway, in terms of both direct and indirect ingestion, and as such was the focus of the 2024 monitoring. This report focuses on the ingestion pathway (water as media), and key environmental radiation pathways and media investigated during the first post study monitoring event are summarised in Table 2-1, including the activities undertaken, and objective, methods and analysis.

Table 2-1 Key Environmental Pathways and Receptors for the post-Study Monitoring Event, 2024

Pathway	Media	Activity/Item	Objective/method/analysis
Ingestion	Process Water	Analysis of process water discharge samples from 2024 (wet season). These samples were collected as water quality samples during the process water discharge (April to July 2024).	Targeted samples selected from the discharge point (WMC-603), sample volumes are limited which will constrain the limit of detection possible, discharge samples will be analysed for gross alpha and beta activity for comparison against World Health Organisation (WHO) screening values.
	Surface Water	First bi-annual surface water sampling event (dry season).	Targeted surface water sample locations adjacent to the current and historical discharge channels, together with upgradient and down gradient locations on the Mandramondramotra River (MMM River) and adjacent the communities of Andrakaraka and Emanaka.

[2] Swanson Environmental Strategies 2024, Review of the JBS&G 2023 Report: Mandena Community Radiation Study, Submitted to the Andrew Lees Trust 18 March 2024.

Pathway	Media	Activity/Item	Objective/method/analysis
	Groundwater	First bi-annual groundwater sampling event (dry season).	Targeted groundwater sample locations from the southern area of the mine and existing groundwater wells within the communities of Andrakaraka and Emanaka. Analysis for gross alpha and beta activity.

3. Methodology – Surface Water and Groundwater

Appropriate representative surface water and groundwater sample locations were identified to investigate the source, pathway and potential receptors for both surface water and groundwater during the JBS&G study, following the initial site visit by the JBS&G study team in 2019. Many of the sample locations are co-located with the established mine water quality water sample locations.

The scope of the post-study monitoring event selected a reduced number of targeted sample points suitable to assess environmental radiation conditions and achieve the monitoring event objectives.

Seven surface water locations were selected for targeted analysis, five of which are within the Mandramondramotra River (MMM River), representing up gradient and down gradient sample points to the process water discharge point WMC-603. Two surface water points were selected proximate to the community villages of Andrakaraka and Emanaka.

Mine process water was sampled during three discharge events in 2024, including one sampling event undertaken by JBS&G during the November 2024 post-study sampling event.

With the exception of the mine piezometer samples, all samples were collected without filtration to replicate the conditions of drinking water collection by the communities.

Groundwater and surface water samples collected during the 2024 monitoring event were submitted to the ANSTO laboratory in Lucas Heights Australia.

The details of the targeted sample locations are summarised in Table 3-1 and Table 3-2 and shown in Figure 3-1.

Table 3-1 Targeted Surface Water Sample Locations, 2024

Sample Location ID	Location	Easting	Northing
SW-15	Upstream sample location to WMC-603 in MMM River	706298	7240230
S46	Upstream sample location to WMC-603 in MMM River	706208	7240485
SW-08	Upstream sample location to WMC-603 in MMM River	706006	7239263
SW-07	Downstream sample location from WMC-603 in MMM River	706507	7239196
S42	Downstream sample location from WMC-603 in MMM River	706503	7239169
SW-06	Downstream sample location from WMC-603 in MMM River	706634	7238899
S41	Downstream sample location from WMC-603 in MMM River	706579	7238944
SW-04	Sample location within lower MMM River	707648	723627
SW-11	Surface water sample location proximal to Andrakaraka	704301	7236076
SW-12	Surface water sample location proximal to Emanaka	706242	7236395

Surface water sampling locations with a designation beginning ‘SW’ are from the JBS&G November 2024 monitoring round, while others are linked to QMM sampling programs and relate to discharge event sampling

undertaken in mid-2024. Note that some locations are located close to each other, but are given separate identifications due to minor differences between coordinate sets.

Four groundwater bores were targeted for sampling:

- Two newly installed monitoring piezometers located adjacent to the southern wetlands, one in the southwest and one in the southeast portion of the Mandena Mine.
- Two newly installed bores from the communities at Andrakaraka and Emanaka (noting that both community bores were installed as part of an onsite water quality treatment system using filtration beds and ultraviolet radiation powered by solar electricity).

Table 3-2 Targeted 2024 Groundwater Sample Locations

ID	Location	Easting	Northing	Approximate depth (m)	SWL (m BGL)	Bore construction
GWBH10	Mining Lease boundary	703539.8	7236818.8	15	0.9	76 mm Piezometer
GWBH15	Mining Lease boundary	705157.4	7236818.8	15	2.3	76 mm Piezometer
ACW	Community well in Andrakaraka *Replacement for GW-08	704380.2	7236055.8	9	2.2	100 mm PVC cased bore
ECW	Community well in Emanaka *Replacement for GW-01	705878.5	7236315.6	12	2.5	100 mm PVC cased bore

Legend

- JBSG Sampling Location
- QMM Sampling Location
- Communities

JBS&G

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Scale: 1:40,000

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QMM Mandena Mineral Sands Mine, Madagascar

GROUNDWATER AND SURFACE WATER SAMPLING LOCATIONS, 2024

FIGURE 2

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Reference: ESRI Imagery Basemap - Accessed Imagery: 23/07/21

3.1 Mine Process Water and Surface Water

A network of interconnected decantation ponds is used to progressively improve water quality of the process water from the minerals separation plant by reducing turbidity prior to the water entering the water treatment plant. This water is then treated at an onsite Water Treatment Plant (WTP) to manage water quality in accordance with QMM's discharge permit. The water is finally released at the discharge location WMC-603 (refer Figure 3-2).

A data gap was identified during the JBS&G study, related to the periodic discharge of process water from the Mandena mine into the MMM river. Samples of surface water were collected during three distinct active discharge events at the point of discharge and within the MMM river:

- Two sampling rounds were completed by the QMM Environment team in April and June 2024; and
- One round was completed by JBS&G in November 2024, as part of the post study sampling event.

The location of the WMC-603 discharge point in summarised in Table 3-3. The location during sampling is shown in Figure 3-2.

Table 3-3 WMC-603 sampling location

Sample ID	Location	Easting	Northing
WMC-603	Approved treated mine process water discharge location within the Mining Lease	706010	7238950

3.1.1 QMM Environment Team Water Quality Samples April and June 2024

Water samples had been collected by the QMM environment team in accordance with QMM's sampling procedures during active discharge of process water during 2024. Those samples were sent to Australia for water quality sampling at the Eurofins Environmental Testing laboratory in Melbourne. JBS&G identified an opportunity to analyse residual sample volumes for gross alpha and gross beta activity.

JBS&G selected targeted monitoring locations from April and June 2024 water quality sampling rounds for additional assessment and requested transfer of remnant water samples to the ANSTO laboratory for further analysis. The monitoring locations selected for gross alpha and beta activity analysis were:

- The discharge point WMC-603, QMM's current approved release point for process water, upstream of a circa 500 m long densely vegetated channel connecting to the MMM river;
- Upstream of the discharge point within the MMM River (S46); and
- Down gradient of the discharge point within the MMM River (S42 and S41).

3.1.2 JBS&G Process Water Sampling November 2024

Representative process water samples were collected by JBS&G from the discharge location WMC-603 on 19 November 2024 using a swing arm pole with collection container (Figure 3-2). The collection container was triple rinsed with flowing water at the sample location site. Sampled water was transferred into new sterile 1L plastic sample bottles and placed in a cooler box immediately following collection.

A representative of the Water Ministry was present for this sample collection event.

Figure 3-2 Location of WMC-603 with onsite water flow pathways

3.1.3 Water discharge volumes

The volume of process water released from the WMC-603 discharge location is recorded by QMM (both treated and emergency release volumes).

The daily discharge volume of process water for the QMM sampling undertaken on 30 April 2024 was 31,355 m^3, noting the onsite QMM weather station recorded 135 mm of rainfall in April 2024.

The daily discharge volume of process water for the QMM sampling undertaken on 18 June 2024 was 35,734 m^3, noting the onsite QMM weather station recorded 284 mm of rainfall in June 2024.

The WTP was operating from 14 November 2024 until 2pm, 18 November 2024 at various flow rates as the site commissioned a new module (increasing the total volume the site can treat), and again from 19 to 20 November 2024. Flow rates generally ranged from 400 m^3/hour to 1,100 m^3/hour over these time periods. The flow rate decreased over 18 – 20 November 2024 prior to sampling owing to the low water level and availability of water for discharge. 3,074 m^3 of process water was released on the day of surface water sampling in the MMM River (20 November 2024), noting the onsite QMM weather station recorded 71 mm of rainfall in November 2024.

3.2 Surface Water Sample Methodology

The surface water sampling locations SW15, SW08, SW07, SW06, SW04 and SW11 were accessed via boat. SW12 was obtained directly from the shoreline of Lake Ambavarano. Refer Attachment C.

Samples collected via boat were recovered using a swing arm pole with collection container (refer Figure 3-3). The collection container was triple rinsed with river water at the sample location site each time a new sample was collected, samples were placed into new 1 L plastic sterilised laboratory bottles.

Sample SW12 was collected directly into new 1L plastic sterilised laboratory bottles, after triple rinsing (Figure 3-4).

All water samples were placed in a cooler box immediately following collection.

Representatives from the Water Ministry, as well as community representatives from both Emanaka and Andrakaraka were present for all offsite water sampling undertaken by JBS&G.

Figure 3-3 Surface water collection from the boat (swing arm and collection container)

Figure 3-4 Surface water collection from the lake shore (directly in sterile bottle)

3.3 Groundwater Sample Methodology

Groundwater samples were collected from the four groundwater wells (as listed in Table 3-2).

- Two minesite piezometers (GWBH10 and GWBH15); and
- Two bores feeding water treatment plants in the communities of Andrakaraka and Emanaka.

3.3.1 Minesite Piezometers

A series of piezometers were installed across the Mandena Mining Lease in 2024. Two piezometers (GWBH10 and GWBH15) located along the southern boundary of the site, adjacent to the southern wetlands and decantation ponds, were selected for sampling as part of the November 2024 sampling event (Figure 3-5). Refer Attachment C.

Legend

- JBSG Sampling Location
- Communities

JBS&G

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km

Coord. Sys. WGS 1984 UTM Zone 38S

QMM Mandena Mineral Sands Mine, Madagascar

LOCATION OF MINE PIEZOMETERS

FIGURE 3

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Reference: ESRI Imagery Basemap - Accessed Imagery: 23/07/21

Samples were collected using a Solinst 415 12v submersible pump and new dedicated tubing (Figure 3-6. Each piezometer was purged displacing approximately three well volumes and measurement verified stability of water quality parameters prior to collection of a water sample into a new sterilised 1 L plastic bottle.

The water samples were placed in a cooler box and sealed by the Water Ministry representative prior to dispatch.

Figure 3-6 Set up of the submersible pump at GWBH10

3.3.2 Community Groundwater Bores

Samples from recently installed community bores at Emanaka and Andrakaraka were collected from the extraction well locations (Figure 3-7).

Legend

- JBSG Sampling Location
- Communities

JBS&G

Job No: 68001

Client: Rio Tinto

Version: FINAL	Date: 28/05/2025
Drawn By: RT	Checked By: DO

Scale: 1:40,000

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km

Coord. Sys. WGS 1984 UTM Zone 38S

QMM Mandena Mineral Sands Mine, Madagascar

GROUNDWATER BORES OF ANDRAKARAKA (ACW, FORMERLY GW08) AND EMANAKA (ECW, FORMERLY GW01)

FIGURE 4

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Reference: ESRI Imagery Basemap - Accessed Imagery: 23/07/21

Both bores are solar operated and are pumped into purpose build sediment deposition channel infrastructure (refer Figure 3-8 and Figure 3-9) before being filtered, treated with ultraviolet and then pumped to a concrete reservoir and piped to various community standpipe taps.

Emanaka *Andrakaraka*

Figure 3-8 Community Bores in Andrakaraka and Emanaka

The bore at Emanaka (ECW) is operational most days from sunrise. The JBS&G team visited the ECW at approximately 09:30am on 21 November 2024. As the bore had not been operating since the previous day, the bore was run for 15 minutes, with field parameters taken regularly by the QMM team. Once parameters had stabilised, a 3L sample (3 x 1 L bottles) was taken. The sample was able to be taken directly from the pump discharge location upstream from the deposition channel infrastructure – refer Figure 3-9.

Emanaka *Andrakaraka*

Figure 3-9 Sediment deposition channel infrastructure at Emanaka and Andrakaraka

The bore at Andrakaraka (ACW) operates most days from sunrise. The JBS&G team visited the ACW at approximately at 11:05 on 21 November 2024. The bore had been operating since approximately 06:00. Parameters were monitored and were found to be stable. A 3L sample (3 x 1L bottles) was obtained from within the sediment deposition channel infrastructure, as close to the discharge point as possible, due to the discharge pipe being below the water level – refer Figure 3-10.

The water samples were placed in a cooler box and water samples sealed by the Water Ministry representative prior to dispatch.

Emanaka

Andrakaraka

Figure 3-10 Discharge pipe at Emanaka and Andrakaraka

3.4 Laboratory Analysis

The water samples collected by QMM in mid-2024 and by JBS&G in November 2024 (as described in sections 3.1 to 3.3) are listed in Table 3-4**.** All samples were sent to the Australian Nuclear Science and Technology Organisation (ANSTO) for analysis. Larger volumes of water were collected in this sampling event to allow for an initial gross alpha and gross beta screening and accommodate potential subsequent alpha spectrometry analysis (if the results had indicated gross alpha or gross beta levels above screening values in drinking water).

A duplicate sample was taken at SW-07. Three 1 L sample containers were collected and labelled as SW-00 and sent to ANSTO for analysis.

Table 3-4 Samples sent to ANSTO for analysis

Sample ID	Date sampled	Volume	Test work requested
S41	30/04/2024	1 x ~0.5L container	Gross α / β
S42	30/04/2024	1 x ~0.5L container	Gross α / β
S46	30/04/2024	1 x ~0.5L container	Gross α / β
WMC603	30/04/2024	1 x ~0.5L container	Gross α / β
S41	18/06/2024	1 x ~0.5L container	Gross α / β
S42	18/06/2024	1 x ~0.5L container	Gross α / β
S46	18/06/2024	1 x ~0.5L container	Gross α / β
WMC603	18/06/2024	1 x ~0.5L container	Gross α / β
WMC603	19/11/2024	3 x 1L container	Gross α / β
SW-04	20/11/2024	3 x 1L container	Gross α / β
SW-06	20/11/2024	3 x 1L container	Gross α / β
SW-07	20/11/2024	3 x 1L container	Gross α / β

Sample ID	Date sampled	Volume	Test work requested
SW-00 (SW-07 duplicate)	20/11/2024	3 x 1L container	Gross α / β
SW-08	20/11/2024	3 x 1L container	Gross α / β
SW-15	20/11/2024	2 x 1L container	Gross α / β
SW-11	21/11/2024	3 x 1L container	Gross α / β
SW-12	21/11/2024	3 x 1L container	Gross α / β
ACW	21/11/2024	3 x 1L container	Gross α / β
ECW	21/11/2024	3 x 1L container	Gross α / β
GWBH10	25/11/2024	2 x 1L container	Gross α / β
GWBH15	25/11/2024	2 x 1L container	Gross α / β

3.5 QA/QC Procedures

An objective of the sampling program was to collect data that are sufficiently reliable and robust to enable comparison to internationally recognised drinking water quality guideline values. As such, a range of QA/QC procedures were implemented throughout the sampling program, including the following:

- Use of a calibrated water quality meter for field measurement of physicochemical parameters;
- Collection and analysis of blind-coded field duplicate samples for intra-laboratory data precision assessment;
- Use of a dedicated pair of disposable nitrile gloves during sampling at each location, and the use of dedicated laboratory supplied sample containers to minimise the potential for cross-contamination between sampling locations; and
- Use of appropriate chain of custody documentation to accompany samples submitted for laboratory analysis.
- The ANSTO laboratory method of analysis is based on ISO standards 9696:2017 Water Quality Gross alpha activity and 9697:2018 Gross beta activity.
- ANSTO - determined activities were referenced against americium-241 standards for alpha activity and potassium-40 standards for beta activity. Detector background counts were taken between sample counting; and
- The ANSTO Environmental Monitoring Laboratory is benchmarked against international standards and regularly participates in relevant national and international proficiency exercises.

4. Results

4.1 Physicochemical Field Parameters and Observations

A summary of the field measured physicochemical field parameters is provided below in Table 4-1.

The results generally indicate fresh water from a salinity perspective, as evidenced by the field EC and calculated total dissolved solids (TDS) results. The World Health Organisation (WHO) (2017) GDWQ identifies that a "*TDS level of less than about 600 mg/L is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/L*". All calculated results for TDS were less than 600 mg/L, indicating good palatability of the water with respect to salinity.

A range of pH results were reported within the MMM River ranging from acidic to neutral (and near neutral) values. On review of the field pH results with respect to grouped locations, a trend of lower pH results has been observed in the samples collected from locations adjacent to, and downstream of, the mine surface water discharge points. A summary of pH observations with respect to the sampling locations is provided below:

- From the MMM River upstream of the mine surface water discharge point, pH 6.1;
- At the process water discharge point WMC-603, pH 7.3;
- From the MMM river where the channel from the discharge point joins the river, pH 5.3;
- From the MMM River downstream of the discharge points, pH 4.6;
- At the most southern point in the MMM River prior to Lake Ambavarano, pH 6.5; and
- From the sampling point on the other side of Lake Ambavarano (south-western side), pH 7.9.

The dissolved oxygen (DO) and redox results were typical of a moderately oxygenated environment, with oxidative conditions present at the time of sampling. The water temperatures during sampling were relatively consistent across locations and were typically in the range of 25°C to 30°C.

Table 4-1 Summary of measured Water Physiochemical Parameters

Date	DO ppm	EC (µS/cm)	TDS (mg/L)	pH	Temp (oC)	Comments
MMM River – Upstream of Mine Discharge Points	6.1	62	37	6.1	28.5	Results indicate slightly acidic to neutral conditions, fresh salinity, moderate dissolved oxygen content, and oxidising conditions exist
MMM River – Adjacent Mine Discharge Points	6.17	179	107	5.8	28.8	Results indicate generally acidic conditions, fresh salinity, moderate dissolved oxygen content, and oxidising conditions exist
MMM River – Downstream of Mine Discharge Points	6.7	234	138	5.4	29.4	Results indicate generally acidic conditions, fresh salinity, moderate dissolved oxygen content, and oxidising conditions exist
Lake Ambavarano	6.08	1564*	940*	7.9	28.3	Results indicate neutral pH conditions, fresh salinity, moderate dissolved oxygen content, and oxidising conditions exist
Meander River	7.6	249	159	7.3	28.8	Results indicate neutral pH conditions, fresh salinity, moderate dissolved oxygen content, and oxidising conditions exist
Village Bores	7.6-8.3	267-638	159-401	7.3-7.4	25.9-28.8	Results indicate neutral pH conditions, fresh salinity, high dissolved oxygen content, and oxidising conditions exist

*The conductivity reading taken at the shores of Lake Ambavarano at Emanaka is considered potentially erroneous, it is an order of magnitude higher than any previous reading taken during the JBS&G study.

4.2 Radiometric Parameters

Water sampling and analysis for gross alpha and gross beta activity levels was an objective of the November 2024 monitoring event, addressing a need for ongoing monitoring of the water ingestion pathway to support initial data collected by the JBS&G study and improve knowledge relating to mine water discharge events.

4.2.1 Adopted Water Quality Screening Levels

There are no Malagasy, or region-specific standards utilised by the regulatory authorities in Madagascar to ensure radiological safety associated with drinking water. In a conservative approach, the WHO Guidelines for Drinking Water Quality (GDWQ Fourth Edition) have been adopted for the assessment of radionuclides in water for the first post study sampling event.

The GDWQ provides screening levels for an initial assessment of health risks from radionuclides in drinking-water. The screening levels are total activity concentrations that can be measured as part of drinking-water monitoring. They have been developed based on data and are set such that results below the screening levels are unlikely to result in doses above an individual dose criterion (IDC). The GDWQ screening levels are 0.5 Bq/L for gross alpha activity and 1 Bq/L for gross beta activity. Those levels approximately correspond to an IDC of 0.1 mSv/y (based on a standard assumption for the amount of water consumed by an individual). This represents a low dose and does not distinguish between background contributions and any operational increment.

If either of the screening levels is exceeded, it does not imply that there is a significant risk but rather flags the need for further study to determine more accurately the potential impact of the utilisation of the water. This can range from more detailed assessment of the water use by communities through to additional analysis of individual radionuclide activity concentrations. This further study can then determine more accurately the radiological impact and guide appropriate responses to reduce impacts if required.

The GDWQ provides some direction for this additional assessment, including ‘guidance levels’ that are provided for individual radionuclides.

During the initial JBS&G study (2023), full radionuclide analysis was undertaken to provide comprehensive information for radionuclide activity in water sources and allow calculation of ingestion dose.

Results showed that individual concentrations of radionuclides in all samples were very low. They remained at least one order of magnitude below relevant WHO guidance levels and were associated with very low annual doses (refer Appendix A4 of 2023 JBS&G study). As a result, gross alpha and beta activity screening levels are adequate for the 2024 monitoring event.

This is a pragmatic approach to support ongoing monitoring, with quicker reporting timeframes, a wider laboratory selection and reduced sample preparation and analytical cost.

The sampling program for the 2024 monitoring event allowed for collection of sufficient sample volume, so that additional analysis could be undertaken in the event that any screening value was exceeded.

4.2.2 Wastewater Discharge Event Surface Water Sampling Results

Samples collected during discharge of treated process water in April, June and November 2024 were analysed by ANSTO for gross alpha and gross beta activity concentration. Results are summarised in Table 4-2, with comparison to screening levels.

All samples from within the MMM River reported gross alpha and gross beta activity concentrations below the WHO screening level, including samples from locations both upstream and downstream of the point of where the process water enters the MMM River.

Upstream activity concentrations for gross alpha ranged between <0.03 Bq/L (below the limit of reporting) and 0.05 Bq/L and gross beta values ranged <0.03 Bq/L (below the limit of reporting) and 0.03 Bq/L (measured at the limit of reporting).

Concentrations at the first downstream location for gross alpha ranged between <0.17 Bq/L (below the limit of reporting) and 0.29 Bq/L, and for gross beta between <0.11 Bq/L (below the limit of reporting) and 0.35 Bq/L.

Table 4-2 Summary of Gross Alpha & Gross Beta Activity Concentrations During Process Water Discharge 2024

Location	ID	Date	Gross Alpha (Bq/L) WHO screening level = 0.5 Bq/L	Gross Beta (Bq/L) WHO screening level = 1.0 Bq/L
Upstream	S46	30/04/2024	0.05	0.03*
Mandena Mine	WMC-603	30/04/2024	0.85	0.74*
First Downstream	S42	30/04/2024	0.17	0.11*
Second Downstream	S41	30/04/2024	0.11	0.07*
Upstream	S46	18/06/2024	0.04	<0.03*
Mandena Mine	WMC-603	18/06/2024	0.55	0.50*
First Downstream	S42	18/06/2024	0.29	0.35*
Second Downstream	S41	18/06/2024	0.19	0.18*
Upstream	SW15	20/11/2024	<0.03	<0.03
Mandena Mine	WMC-603	20/11/2024[3]	0.62	0.69
First Downstream	SW07	20/11/2024	0.18	0.23
Second Downstream	SW06	20/11/2024	0.29	0.36
End of MMM River	SW04	20/11/2024	0.09	0.21
Andrakaraka	SW11	21/11/2024	<0.03	0.05
Emanaka	SW12	21/11/2024	<0.08	0.21

Shading indicates location is not a plausible drinking water location

*Corrected for ^{40}K

[3] The water sample was collected at WMC603 on the afternoon of 19/11/2024

All results for plausible drinking locations were below screening levels.

[3] The water sample was collected at WMC603 on the afternoon of 19/11/2024

4.2.2.1 QAQC Blind Duplicate Comparison

The results for the blind duplicate comparison for the primary sample SW-07 and the blind duplicate SW-00 are presented in Table 4-3, the gross alpha results reported the same value (0 % variance), the gross beta reported a variance of 16 % which demonstrates excellent comparability between results.

Table 4-3 QAQC Blind Duplicate Comparison Result

Primary Sample (SW-07) Gross Alpha (Bq/L)	Duplicate (SW-00) Gross Alpha (Bq/L)	% Difference (RPD)	Primary Sample (SW-07)Gross Beta (Bq/L)	Duplicate (SW-00) Gross Beta (Bq/L)	% Difference (RPD)
0.18	0.18	0	0.23	0.27	16 %

A graphical representation of gross alpha and gross beta concentrations measured during wastewater

4.2.2.2 Dilution rates in the MMM River

Dilution rates within the MMM River indicated by the gross alpha/beta results were relatively high.

A summary of the percentage reductions in activity concentrations measured between the discharge sample at the discharge point WMC-603 and those measured in samples within the MMM River is presented in Table 4-4.

Table 4-4 Measured Dilution Activity/Concentration Reduction in the MMM River Samples

Date	Location	Discharge Volume m3 for the day	Monthly Rainfall Measured mm	% Reduction Gross Alpha	% Reduction Gross Beta
30 April 24	S42 southern point of the drainage channel and the MMM river	31,355	135	80%	85%
	S41 - 250 m south of S42			87%	85%
18 June 24	S42 southern point of the drainage channel and the MMM river	35,734	284	47%	30%
	S41 - 250 m south of S42			65%	64%
20 November 24	SW07 adjacent S42 southern point of the drainage channel and the MMM river	3,074	71	70%	66%
	SW06 – 320 m south of SW07			53%	47%

A graphical representation of gross alpha and gross beta concentrations measured during wastewater discharge is presented in Figure 4-1 and Figure 4-2.

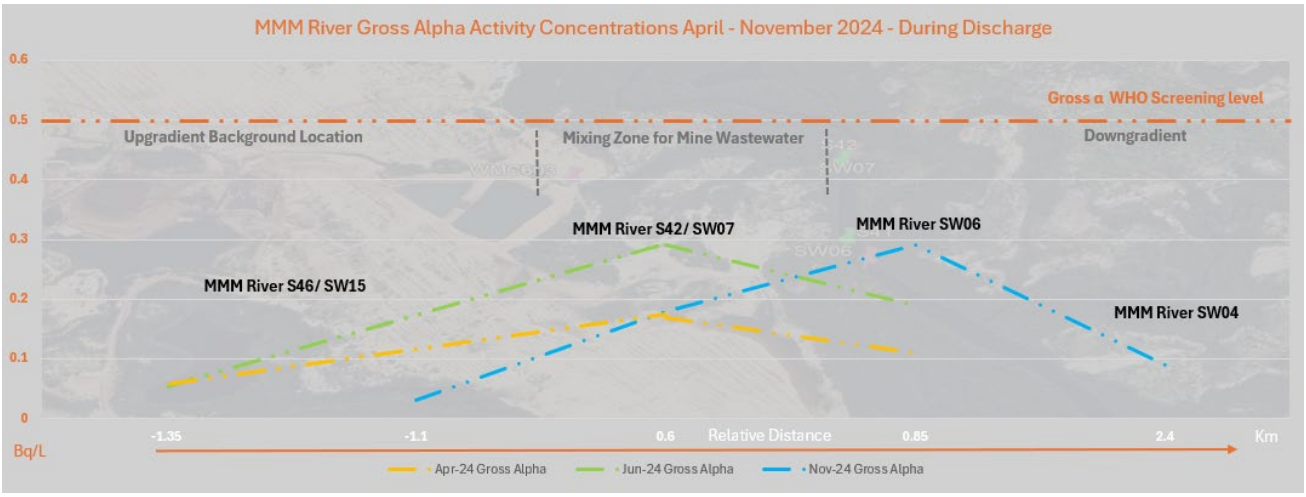

Figure 4-1 MMM River Gross Alpha Activity Concentrations during process water discharge 2024

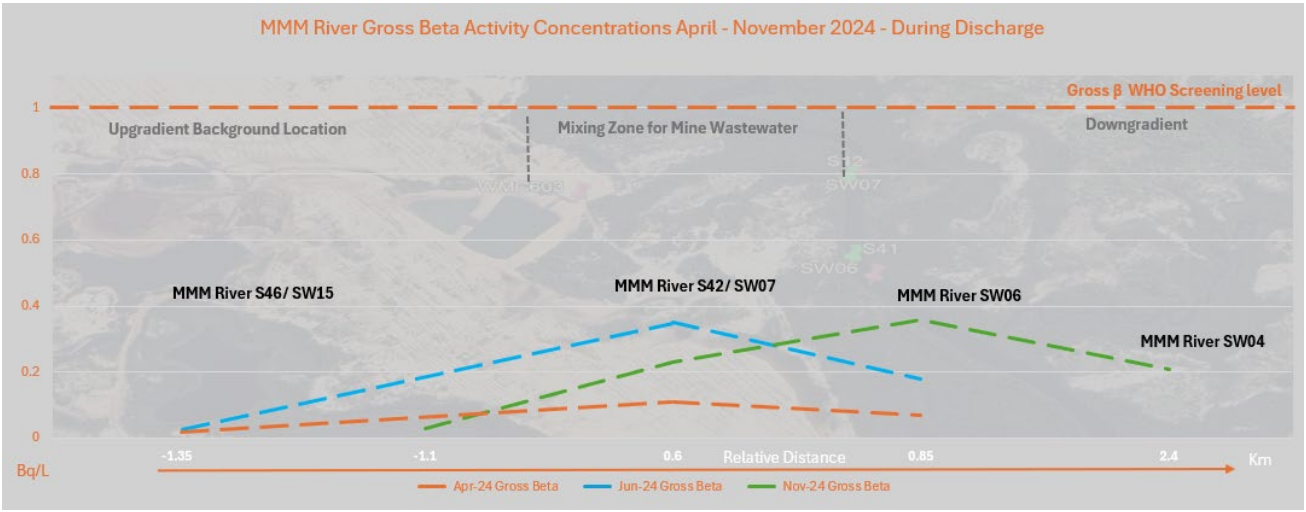

Figure 4-2 MMM River Gross Beta Activity Concentrations during process water discharge 2024

4.2.3 Groundwater Sampling Results

Results for gross alpha and beta analysis of ground water samples are summarised in Table 4-5.

Results for community wells in Andrakaraka and Emanaka were low and below relevant screening levels.

Table 4-5 Gross Alpha and Gross Beta Activity Concentrations in Groundwater During the November 2024 Monitoring Event

Location	ID	Date	Gross Alpha (Bq/L) WHO screening level = 0.5 Bq/L	Gross Beta (Bq/L) WHO screening level = 1.0 Bq/L
Mandena SW	GWBH-10	25/11/2024	0.92	1.04
Mandena SE	GWBH-15	25/11/2024	0.80	1.36
Andrakaraka	ACW	21/11/2024	0.18	0.09
Emanaka	ECW	21/11/2024	<0.03	0.07

Shading indicates location is not a plausible drinking water location

The certified laboratory report from ANSTO including a summary of the laboratory methods and QA/QC standards are included in Attachment B.

4.3 Water Results Data Conclusion

The results for the gross alpha and gross beta activity concentration analysis of water from samples collected in April, June and November 2024 during discharge of treated mine process water confirms that levels measured at the nearest possible drinking water location adjacent to the intersection of the seepage channel and at locations down gradient of the discharge channel are below the WHO screening levels.

Similarly, the concentrations measured in surface water adjacent to the critical community groups at Andrakaraka and Emanaka were also below the WHO screening levels. In accordance with the guidance provided by the WHO, no additional analysis of individual radionuclides is required.

Consistent with the conclusions made in the JBS&G study, radiation levels in drinking water in the adjacent receiving environment and communities to the Mandena mine are low (noting the term is applied to a broad area of surface water catchment of the MMM River, locations within the southern lakes and individual community groundwater bores).

5. Recommendations

The initial post-study monitoring event was intended as the initiation of an ongoing monitoring program that will enable QMM to continually build and improve knowledge of any potential operational impact to community exposures.

To acquire information that will improve the understanding of the potential operational impact to the ingestion pathway via drinking water, the following recommendations are offered to QMM:

- Gross alpha and beta activity analysis in water should be carried out twice a year. Samples should be collected during process water discharge into the MMM River.
- Water monitoring should be extended to any new water system affected or to be affected by mining operations. The river west of Mandena (Enandrano River) should therefore be integrated into the water monitoring program, as QMM's activities progress towards the west.
- A complete set of surface water samples should be collected biannually during discharge of process water comprising of one sample at the discharge point (WMC-603), an upgradient sample (SW-15), three downgradient samples within the MMM river (SW07, SW06 and SW04) and one surface water sample adjacent to Andrakaraka (SW11) and Emanaka (SW12).
- The discharge and MMM river samples should be analysed for gross alpha and gross beta activity and results compared to the WHO screening levels. If there is an exceedance of the screening levels within the MMM river samples and that exceedance is not delineated by a downgradient sample location result, this will trigger analysis of the surface water samples collected adjacent to Andrakaraka (SW11) and Emanaka (SW12).
- Any exceedance of screening levels in the Andrakaraka and Emanaka surface water samples would trigger more detailed assessment and potentially additional radionuclide analysis, in accordance with the GDWQ such as alpha spectrometry.
- Any exceedances from samples within the MMM river would also trigger a review of the discharge of process water to identify the reason for the elevated concentrations.

- Gross alpha and beta activity analysis in water should be carried out for the groundwater wells at Andrakaraka and Emanaka with results compared against the WHO guidelines, with any exceedance triggering more detailed analysis, in accordance with the GDWQ such as alpha spectrometry.
- It is recommended that additional volumes of water (1L) are provided to the laboratory for the surface water samples until it is confirmed that gross alpha and beta activity in water at potential exposure sites are consistently below WHO screening levels. This contingency volume can be used for alpha spectrometry analysis, if required.

5.1 Proposed Monitoring

Proposed water monitoring has been outlined below in Table 5-1.

Table 5-1 Proposed EMP monitoring requirements

Relevant Reference for amendment/addition	Description of potential impact	Indicator	Monitoring location	Parameter	Frequency
Water Quality					
Discharge water / Surface water					
IGW05 IGW06 IGW07	Changes in the radiological quality of surface waters systems following the release of water.	Surface water quality Gross alpha and beta activity at the discharge point Discretionary analysis for individual radionuclides (alpha spectrometry) if appropriate.	Discharge point WMC-603 and any other new discharge points reporting to surface water systems on MMM River or Enandrano River)	Gross alpha and beta activity	Bi-annually (every 6 months during a discharge event)
Surface water					
IGW05 IGW06 IGW07	Changes in the radiological quality of surface waters systems following the release of water.	Surface water quality Gross alpha and beta activity within the MMM river initially, extending to analysis of the Andrakaraka and Emanaka samples if exceedances identified within the MMM river samples. Discretionary analysis for individual radionuclides (alpha spectrometry) if appropriate.	Surface water sampling 1 x upstream of each discharge point 3 x downstream of each discharge point 1 x adjacent to Andrakaraka and Emanaka	EC TDS pH Gross alpha and beta activity	Bi-annually (every 6 months during a discharge event) Must be within 48 hours of discharge sample being collected.

Relevant Reference for amendment/addition	Description of potential impact	Indicator	Monitoring location	Parameter	Frequency
Social					
Groundwater					
IGW05	Modification of groundwater quality due to water infiltration from dredging basin (pH, turbidity, suspended solids, etc.);	Groundwater quality Gross alpha and beta activity concentrations below the WHO screening levels	Community wells within Emanaka and Andrakaraka	Gross alpha and beta activity	Annually

6. Limitations

This report has been prepared for use by the client who has commissioned the works in accordance with the project brief only, and has been based in part on information obtained from the client and other parties.

The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose.

JBS&G accepts no liability for use or interpretation by any person or body other than the client who commissioned the works. This report should not be reproduced without prior approval by the client, or amended in any way without prior approval by JBS&G, and should not be relied upon by other parties, who should make their own enquires.

Sampling and chemical analysis of environmental media is based on appropriate available guidance documents made and approved by the relevant regulatory authorities. Conclusions arising from the review and assessment of environmental data are based on the sampling and analysis considered appropriate based on the regulatory requirements.

Limited sampling and laboratory analyses were undertaken as part of the investigations undertaken, as described herein. Conditions between sampling locations and media may vary, and this should be considered when extrapolating between sampling points. Chemical analytes are based on the information detailed in the site history. Further chemicals or categories of chemicals may exist at the site, which were not identified in the site history and which may not be expected at the site.

The conclusions and recommendations reached in this report are based on the information obtained at the time of the investigations.

This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown information pertaining to the site, JBS&G reserves the right to review the report in the context of the additional information.

Attachment A Calibration Certificates

Étalonnage sonde PRO QUATRO - MP002

DATE : 19/11/24 HEURE : 09:10
NOM de l'analyste : MAXIME
SONDE no: pH:01 / Cond:01 / OD:01 / ORP:01

CONDUCTIVITE

Standard (µS/cm)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à
200	BCCL2696	30/06/25	26,4	213,3	200

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
BCCL2696	30/06/25	200	200,0	±10 µS/cm

POTENTIEL OxydoRéduction

Standard (mV)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à
200	A4212	31/07/25	22,7	207,0	200

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
A4212	31/07/25	200	200,1	±10 mV

OXYGENE DISSOUT

Standard (%)	No Lot*	Date de préparation*	Température (°C)	Valeur lue
100%	-	-		

*Note : Remplir uniquement si on utilise un standard et non requis pour étalonnage à 0.100%

pH

Standard	No Lot	Date d'expiration	Potentiel (mV)	Température (°C)	Ajusté à
4,01	21806409	31/07/27	170,9	21,0	4,0
7,00	20907414	31/08/27	-2,1	21,3	7,0
10,01	21912214	31/01/26	-173,0	21,0	10,0

			Conforme (O/N)	Initiale	Commentaire
Potentiel pH 7	-2,1	± 50 mV	O	MAXIME	
Pente	98,21	Entre 95% et 103%	O	MAXIME	

Vérification pH 7

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
20907414	31/08/27	7,00	7,00	±0,05

Étalonnage sonde PRO QUATRO - MP002

DATE : 20/11/24 HEURE : 06:10
NOM de l'analyste : MAXIME
SONDE no: pH:01 / Cond:01 / OD:01 / ORP:01

CONDUCTIVITE

Standard (µS/cm)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
BCCL3696	31/07/25	200	201	±10 µS/cm

POTENTIEL OxydoRéduction

Standard (mV)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
A4212	31/07/25	200	199	±10 mV

OXYGENE DISSOUT

Standard (%)	No Lot*	Date de préparation*	Température (°C)	Valeur lue
100 %	-	-	23,9	99,8

*Note : Remplir uniquement si on utilise un standard et non requis pour étalonnage à 0-100%

pH

Standard	No Lot	Date d'expiration	Potentiel (mV)	Température (°C)	Ajusté à

			Conforme (O/N)	Initiale	Commentaire
Potentiel pH 7		± 50 mV			
Pente		Entre 95% et 103%			

Vérification pH 7

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
2090741H	31/08/27	7,00	7,01	±0,05

Nom de votre service ici

LABORATOIRE

Étalonnage sonde PRO QUATRO – HP002

DATE : 21/11/24 HEURE : 06:05

NOM de l'analyste : AB.01 / Cond:01 / DO:01 / ORP:01

SONDE no:

CONDUCTIVITE

Standard (µS/cm)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
Ecl 2696	30/06/25	1413	1403	±10 µS/cm

POTENTIEL OxydoRéduction

Standard (mV)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
A4212	31/03/25	200	201	±10 mV

OXYGENE DISSOUT

Standard (%)	No Lot*	Date de préparation*	Température (°C)	Valeur lue
100	–	–	23,1	100,2

*Note : Remplir uniquement si on utilise un standard et non requis pour étalonnage à 0.100%

pH

Standard	No Lot	Date d'expiration	Potentiel (mV)	Température (°C)	Ajusté à

			Conforme (O/N)	Initiale	Commentaire
Potentiel pH 7		± 50 mV			
Pente		Entre 95% et 103%			

Vérification pH 7

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
2907414	31/08/27	7,00	7,02	±0.05

Étalonnage sonde PRO QUATRO - MP002

DATE : 25/11/24 HEURE : 08:19

NOM de l'analyste : MAXIME

SONDE no: AU.01 / Cond.01 / OD.01 / ORP.01

CONDUCTIVITE

Standard (µS/cm)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à
200	BCCL2696	30/06/25	26,9		200

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
BCCL2696	30/06/25	200	200,5	±10 µS/cm

POTENTIEL OxydoRéduction

Standard (mV)	No Lot	Date d'expiration	Température (°C)	Lecture Avant Cal	Mis à
200	A4212	31/07/25	26,4	194,5	200

Vérification

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
A4212	31/07/25	200	200	±10 mV

OXYGENE DISSOUT

Standard (%)	No Lot*	Date de préparation*	Température (°C)	Valeur lue
100 /	-	-	26,2	99,8

*Note : Rempli uniquement si on utilise un standard et non requis pour étalonnage à 0-100%

pH

Standard	No Lot	Date d'expiration	Potentiel (mV)	Température (°C)	Ajusté à
4,01	21806403	31/07/27	173,8	26,2	4,01
7,00	20907419	31/08/27	- 1,2	25,9	7,00
10,01	21912219	31/07/26	- 174,6	25,2	10,01

			Conforme (O/N)	Initiale	Commentaire
Potentiel pH 7	- 1,2	± 50 mV	O	Maxime	
Pente	92,78 %	Entre 95% et 103%	O	Maxime	

Vérification pH 7

No Lot	Date d'expiration	Valeur Std	Valeur Lue	Tolérance
20907419	31/08/27	7,00	7,00	±0,05

Attachment B 2024 Laboratory Results

Australian Government

ANSTO
Science. Ingenuity. Sustainability.

JBS&G
Attn: Dean O'Broin
100 Hutt St
Adelaide, SA 5000

7th March 2025

Dear Dean,

Please find enclosed a final report for gross alpha and gross beta analyses performed on 21 water samples received 13/12/24 & 20/01/25. The ANSTO project code for these samples is 2024em0010. Please quote this number in any further correspondence regarding these results.

Please contact me if you have any queries regarding your results.

Yours sincerely,

Alicea Gedz
Senior Scientist Environmental Monitoring
Phone: 02 9717 9897
Email: age@ansto.gov.au

Australian Government

ANSTO
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Certificate of Analysis

Client Organisation:	JBS&G
Contact:	Dean O'Broin
Number of Samples Received:	21
Number of Samples Reported:	21
ANSTO Project Number:	2024em0010

Methods

I-4558 Determination of Gross Alpha and Gross Beta Radioactivity in Waters – Thick Source Method

This method is based on the following ISO standards:
9696:2017 Water quality – Gross alpha activity – Test method using thick source
9697:2018 Water quality – Gross beta activity – Test method using thick source

QA/QC:
Determined activities are referenced against americium-241 standards for alpha activity and potassium-40 standards for beta activity. Detector background counts were taken between sample counting.
The ANSTO Environmental Monitoring Laboratory is benchmarked against international standards and regularly participates in relevant national and international proficiency exercises.

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Results

Table 1. RADIOACTIVITY IN WATER

Sample Description	ANSTO ID	Date Sampled	Radioactivity (Bq/L)			
			Gross Alpha	Gross Beta	Calculated ^{40}K	Gross Beta (^{40}K Corrected)
S41	C1020	30/04/2024	0.11 ± 0.01	0.09 ± 0.01	0.019	0.07 ± 0.01
S42	C1021	30/04/2024	0.17 ± 0.02	0.14 ± 0.01	0.022	0.11 ± 0.01
S46	C1022	30/04/2024	0.05 ± 0.01	0.04 ± 0.01	0.014	0.03 ± 0.01
WMC603	C1023	30/04/2024	0.85 ± 0.04	0.80 ± 0.02	0.063	0.74 ± 0.02
S41	C1024	18/06/2024	0.19 ± 0.02	0.21 ± 0.01	0.028	0.18 ± 0.01
S42	C1025	18/06/2024	0.29 ± 0.02	0.39 ± 0.02	0.039	0.35 ± 0.01
S46	C1026	18/06/2024	0.04 ± 0.01	0.03 ± 0.01	0.017	< 0.03
WMC603	C1027	18/06/2024	0.55 ± 0.03	0.55 ± 0.02	0.050	0.50 ± 0.02
SW-04	C1033	20/11/2024	0.09 ± 0.03	0.21 ± 0.02		
SW-15	C1034	20/11/2024	< 0.03	< 0.03		
WMC-603	C1035	19/11/2024	0.62 ± 0.03	0.69 ± 0.02		
GWBH-15*	C1036	25/11/2024	0.80 ± 0.04	1.36 ± 0.03		
GWBH-10*	C1037	25/11/2024	0.92 ± 0.09	1.04 ± 0.05		
SW-00	C1038	20/11/2024	0.18 ± 0.01	0.27 ± 0.01		
SW-06	C1039	20/11/2024	0.29 ± 0.02	0.36 ± 0.01		
SW-07	C1040	20/11/2024	0.18 ± 0.01	0.23 ± 0.01		
SW-08	C1041	20/11/2024	0.03 ± 0.01	0.04 ± 0.01		
ACW	C1042	21/11/2024	0.18 ± 0.01	0.09 ± 0.01		
ECW	C1043	21/11/2024	< 0.03	0.07 ± 0.01		
SW-11	C1044	21/11/2024	< 0.03	0.05 ± 0.01		
SW-12	C1045	21/11/2024	< 0.08	0.21 ± 0.03		

Notes:
Samples denoted with * were filtered prior to analysis using a 0.45 µm, 800 cm^2 groundwater filter.

Report prepared by:

Alicea Gedz
04/03/25

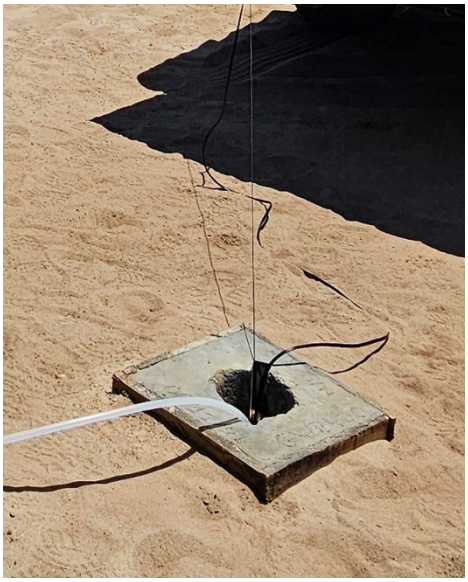
Report checked by:

Rachel Oshannessy
07/03/25

Attachment C Water Sampling

	
SW15	**SW08**
	
SW07	**SW06**
	

SW04	SW11
	
SW12	

	
GHBH10	GWBH15

	
ECW	**ACW**

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Appendix B Terrestrial Gamma Review

Appendix B | Terrestrial Gamma

Rio Tinto | QMM

Report

JBS&G 68011 | 166,245 | Rev1

30 May 2025

We acknowledge the Traditional Custodians of Country throughout Australia and their connections to land, sea and community.

We pay respect to Elders past and present and in the spirit of reconciliation, we commit to working together for our shared future.

Caring for Country The Journey of JBS&G
Artist: Patrick Caruso, Eastern Arrernte

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Abbreviations

Term	Definition
ANSTO	Australian Nuclear Science and Technology Organisation
JBS&G	JBS&G Australia Pty Ltd
MMM	Mandromondromotra
NORM	Naturally Occurring Radioactive Materials
QMM	QIT Madagascar Minerals
REC	Rare Earth Concentrate
SOP	Standard operating procedure
The study	Community Radiation Study
WHO	World Health Organisation

1. Introduction

JBS&G Australia Pty Ltd (JBS&G) was engaged by QIT Madagascar Minerals (QMM) to undertake a Community Radiation Study ("the study") at the Mandena Mineral Sands Mine in Southern Madagascar (refer Figure 1-1). The study commenced in 2019 and was one of the largest studies of its type ever undertaken.

JBS&G designed a robust quality assured detailed environmental impact investigation based on a source, pathway, receptor model, targeting sampling of multiple media including soil, direct gamma, radon/thoron, surface water, groundwater, dust, fruit, vegetables, and biota (fish and prawns). The study was initially designed with four quarterly sampling events over 12 months, however due to Covid-19 and global logistical issues, the study extended to five sampling events over four years. The study assessed 26 potential exposure pathways including Direct Gamma (4), Inhalation (2) and Ingestion (20).

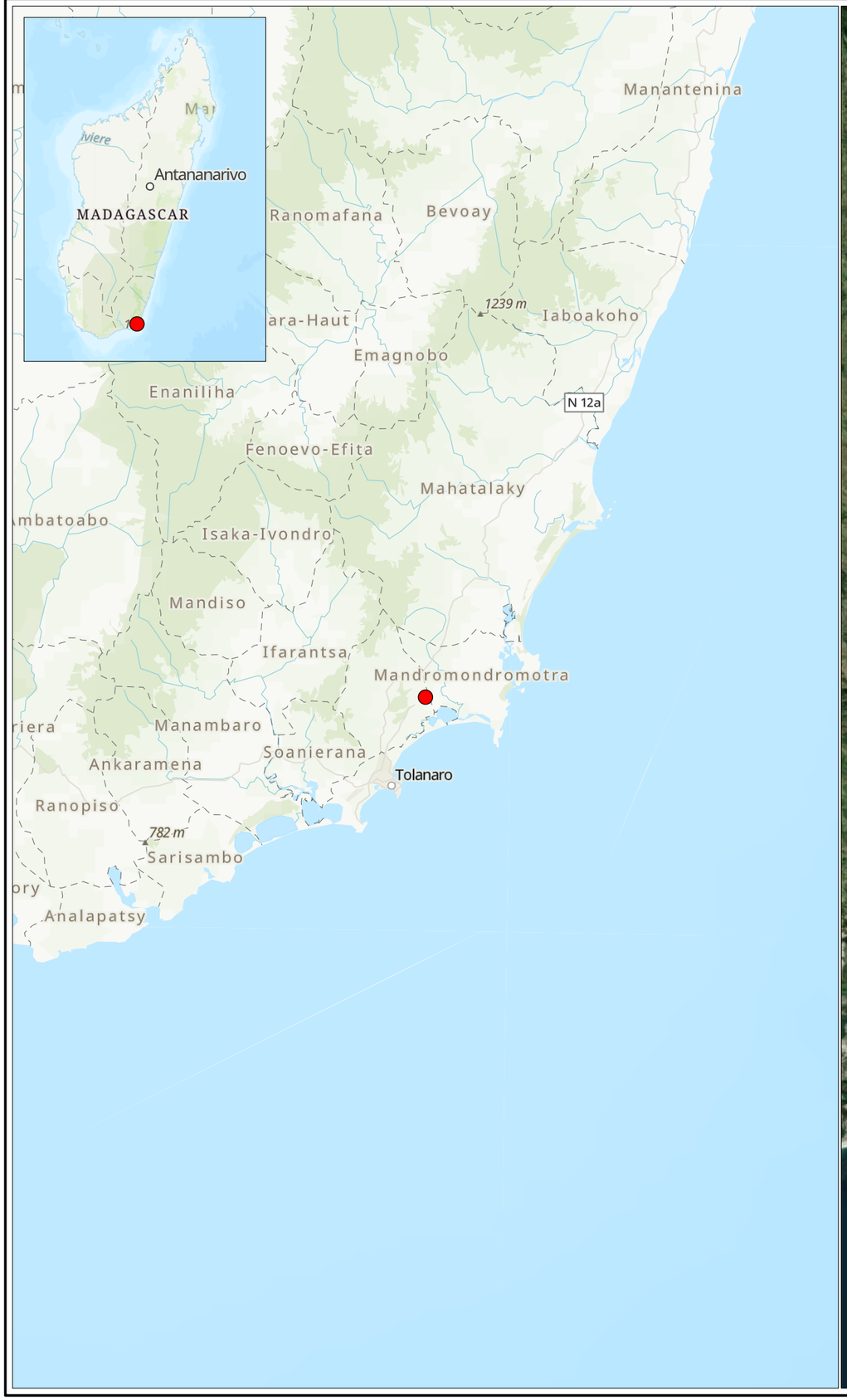
The final study report[1], delivered in 2023, concluded that the contribution to a community member radiation dose from the mining operation did not exceed 1 mSv per year above natural background through all the exposure pathways assessed. The study recommended that future monitoring should focus only on specific pathways necessary to demonstrate levels remain low. The study also recommended that for those pathways identified on which mining may have an ongoing influence, discussions should occur with key stakeholders and regulators to determine the best approach towards a monitoring program. This could include ongoing gamma monitoring of revegetated mined areas, as well as the potential for impact from mine water discharges, water treatment plant residues and local dust levels as the mine continues to expand closer to local communities.

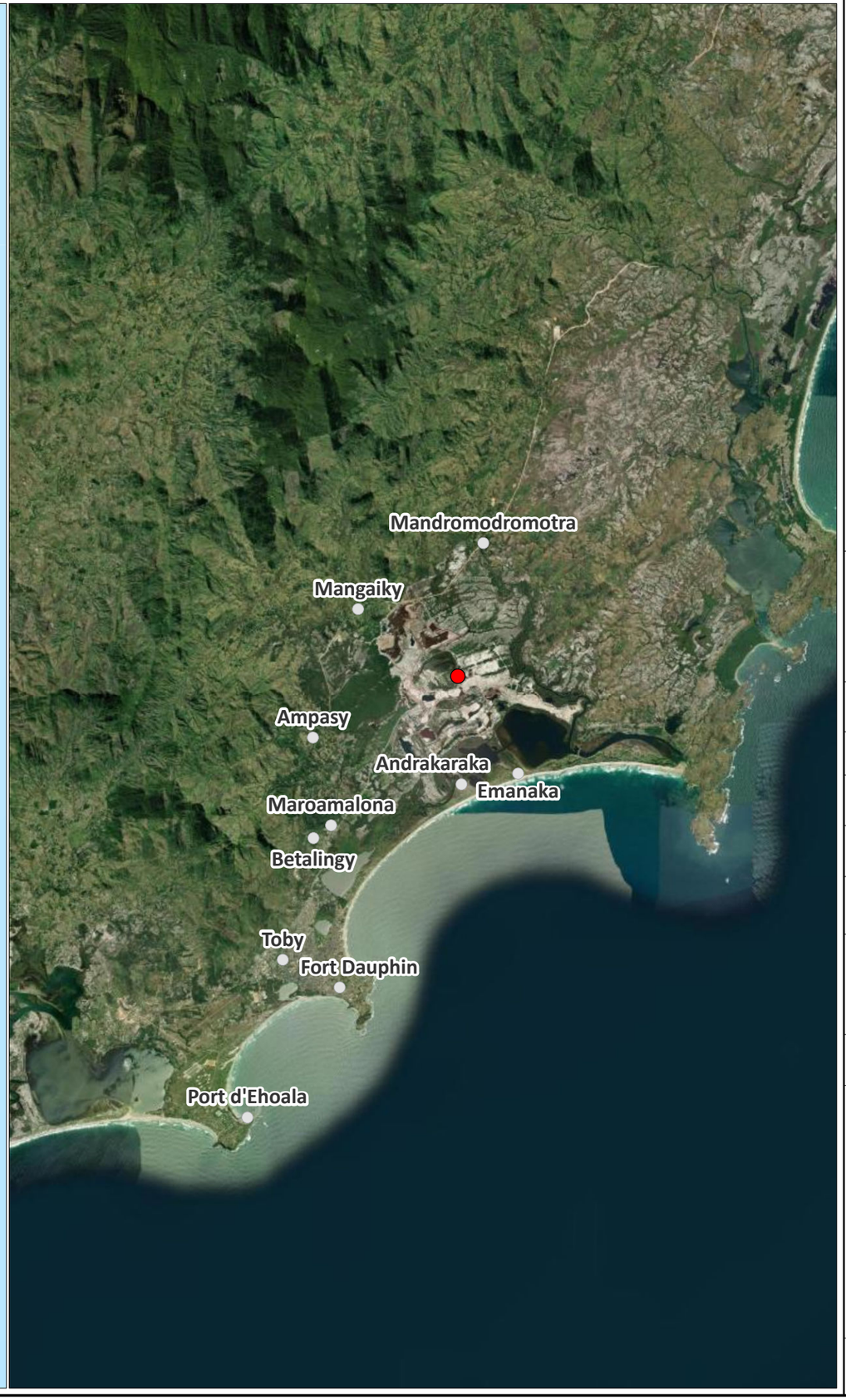
QMM engaged JBS&G in October 2024 to visit the Mandena site and surrounds to undertake an initial post-study environmental radiation monitoring event and to provide recommendations for an ongoing environmental radiation monitoring program which could be incorporated into the broader mine environmental monitoring program. This site inspection was completed in November 2024.

The 2023 JBS&G study identified the water pathway as potentially the most significant pathway (for mine related exposure), in terms of both direct and indirect ingestion, and as such was the focus of the 2024 monitoring. Other pathways of focus included both external and inhalation pathways via terrestrial gamma and dust. Separate appendices have been prepared which detail each of the pathways.

This Appendix covers the External Pathway, focusing on terrestrial gamma.

[1] JBS&G 2023 Mandena Community Radiation Study, Reference 57082/153,352 18 August 2023.





Legend

- Site Location
- Communities

JBS&G

Job No: 68001

Client: Rio Tinto

Version: FINAL	Date: 28/05/2025
Drawn By: RT	Checked By: DO

Scale: 1:150,000

0 2.5 5
km

Coord. Sys. WGS 1984 UTM Zone 38S

QMM Mandena Mineral Sands Mine, Madagascar

SITE LOCATION

FIGURE 1

File Name: C:\Users\rtandon\JBS&G Australia\JBS&G - DCS - Internal - Documents\Projects\Rio Tinto\68011 Madagascar QMM\GIS\02_MapProjects\68011_RioTinto_Madagascar_ExcecutiveSummary.aprx
Reference: ESRI Topographic & Imagery Basemap - Accessed Imagery: 23/07/21

2. Background and Scope

JBS&G acknowledge the feedback provided by the Andrew Lees Trust (ALT) from a review undertaken by Dr Stella Swanson of the JBS&G study report[2] and the recommendations therein. The initial post study site visit scope was designed as a starting point for the establishment of a longer term robust environmental monitoring dataset. It is acknowledged that the environmental radiation dataset gathered for the Mandena mine and surrounding environment will be improved with increased levels of confidence gained over time, and additional interpretation of trends once sufficient data has been established.

One of the objectives of the post-study monitoring event was to examine and monitor the other important environmental sources and pathways by undertaking surveys and observational visits across the mine to examine if the assumptions and observations included in the JBS&G study remain representative of the operational site and surrounding conditions for the potential for exposure to critical[3] community groups.

This scope of this report focuses on the External pathway (terrestrial gamma ray) – refer **Table 2-1**.

Table 2-1: Key Environmental pathways and media summary

Pathway	Media	Activity/Item	Objective/method/analysis
External	Terrestrial gamma	Radiation Survey Meters.	Provision of three radiation survey meters with sufficient sensitivity to undertake ongoing pre and post mining gamma surveys at low environmental radiation levels.
		Review of current gamma surveys.	Review of QMM gamma survey practices and procedures to provide recommendations including revision of grid densities and / or survey procedures as required.

3. Methodology and Tasks Undertaken

3.1 Selection of gamma survey meters

The QMM HSE team own two calibrated gamma survey meters. A review of available equipment was undertaken to ensure selection and supply of appropriate equipment. JBS&G identified that more suitable models are available for environmental surveys.

Options for monitors were assessed against criteria including:

- Appropriate energy response and sensitivity for environmental survey
- Suitability for the mining environment
- Availability and cost for any potential repair or replacement in the future.

[2] Swanson Environmental Strategies 2024, Review of the JBS&G 2023 Report: Mandena Community Radiation Study, Submitted to the Andrew Lees Trust 18 March 2024.

[3] Critical communities are defined from a radiological assessment perspective as those groups that by their location or lifestyle are most at risk of being exposed to radiological dose from any particular pathway (IAEA General Safety Requirements Part 3).

Subsequently, two Thermo Scientific RadEye PRD4 monitors and one Radiacode 103 were provided to QMM, with electronic copies of standard operating procedures (SOPs) and product manuals. Calibration intervals have been staggered to ensure availability of at least one calibrated instrument at all times.

3.2 Data Review

Whilst onsite, JBS&G engaged with site-based teams to understand the activities and sequencing for area clearance prior to mining, and closure and release of areas following mining, as the design of gamma dose rate surveys is dependent on the various stages of operations (timing, measurement spacing, grid orientation, etc.).

During the review of QMM gamma survey information, a change was noted in available data. Gamma surveys were ceased within the Mining Lease in 2020 following a change in operations to recover rare earth concentrate (REC) as a product stream in 2017. The justification for the reduction in monitoring was the assumption that the removal of REC has reduced the net radioactivity of post-mining spoil and thus the ongoing monitoring was redundant. Although technically correct, the collection of pre and post mining gamma levels would quantitatively support this assumption.

3.3 Gamma Survey

Pre and post mining environmental gamma surveys are easily implemented and provide valuable information to determine pre-existing conditions and assess any operational impact on local gamma dose rates. Whilst onsite, surveys were undertaken on foot by JBS&G, using calibrated instruments with a suitable range and sensitivity, held one metre above natural ground level.

For all survey measurements undertaken by JBS&G, calibration or correction factors are applied according to the most recent calibration record.

3.3.1 Regional Surveys

Historical regional gamma dose rate surveys have identified highly variable gamma dose rate levels in the Fort Dauphin area. JBS&G completed an opportunistic comparative regional gamma dose survey during the November 2024 field works using dose rate logging survey meters which also record GPS location data. The results and observations are presented in **Section 4.2.1**.

Some of the data was acquired on foot, and some data was logged while travelling by car. Data acquired from within a car can be significantly impacted by shielding effects from the vehicle. This dataset therefore provides an underestimate of real dose rates in places and can only be considered indicative of general radiation levels in the region.

3.3.2 Rehabilitated Area Survey

Two rehabilitated areas within the mine footprint were surveyed using calibrated dose rate survey meters. The primary survey instrument was selected for its appropriate energy response to environmental radiation and was used to record dose rates on a grid (oriented to cardinal directions). A secondary calibrated meter was used to automatically log dose rates at 5 m intervals to collect data at a higher density. The secondary instrument produced a map of the survey path, and provided infill data to support the primary survey

Both areas were surveyed by foot, with personnel walking on an east-west grid and trialling variable spacing. All measurements were taken at a height of 1 m above natural ground level.

The post mining areas were located:

- Within a central location in the Mandena mine perimeter; and

- In the North Snake area.

The central Mandena area was revegetated with acacias and native trees.

The North Snake rehabilitated area has been selected by QMM to host a trial orchard of fruit trees (pineapple and mango).

3.3.3 Unmined Area Survey

An unmined area to the southwest of the Mandena mine entrance was surveyed using the same calibrated meters, with measurements taken 1 m above natural ground level at each location.

The area is targeted for mining development in 2025 and 2026 and consists of a dense coastal forest in low areas. Higher ground has been affected by deforestation, with multiple charcoal pits observed.

Due to the density of vegetation, a grid survey could not be completed, and measurements were taken at approximately 50 m intervals along paths and in accessible areas.

4. Results

4.1 Data Review Outcomes

Characterisation of natural radiation levels in all new mining areas (prior to excavation of heavy mineral sands) would enable the operation to establish pre-existing conditions and provide a local benchmark for remediation. By repeating measurements at the same locations after rehabilitation (following backfill and final landform), remediation can be validated or alternatively, localised areas requiring further remediation can be identified early.

4.2 Gamma Survey Results

During the November 2024 monitoring event, JBS&G carried out the following surveys:

- Across the region (opportunistically);
- In rehabilitated areas – post mining survey; and
- In an unmined area – pre mining survey.

Results of the surveys are summarised in **Table 4-1.**

Table 4-1: Summary of gamma dose rates for each area surveyed in November 2024

Area	Description	Points	Dose rate at 1 m (uSv/h)				
			average	median	min	max	St Dev
Anosy region	Regional survey using 4 x Radiacode 103 devices.	48,247	0.24	0.16	0.003	13	0.46
Mandena	An area rehabilitated in 2014 and an area rehabilitated in 2023 (post mining), both within the ML.	1,197	0.09	0.05	0.03	0.51	0.08
Snake North	Area rehabilitated in North Snake currently being used in a rehabilitation trial (fruit production of pineapples and mango trees).	430	0.20	0.20	0.04	0.50	0.08
2025 mine plan	Unmined area survey (pre mining) within the ML.	999	0.04	0.04	0.03	0.10	0.01

4.2.1 Regional Survey

JBS&G undertook continual gamma dose rate survey across the region using survey meters that log dose rate and positional data (noting many results were recorded from within vehicles, resulting in probable attenuation of natural gamma levels).

The data set recorded dose rates ranging from 0.02 to 13 uSv/h (based on more than 48,000 points, refer **Figure 4-2**). The range of measured dose rates is larger than the range established by SENES in the 2000 baseline. The highest dose rates are associated with the presence of heavy mineral sands in coastal areas and beaches in Fort Dauphin. The regional survey also confirmed the presence of dose rates above 3 uSv/h in Evatraha.

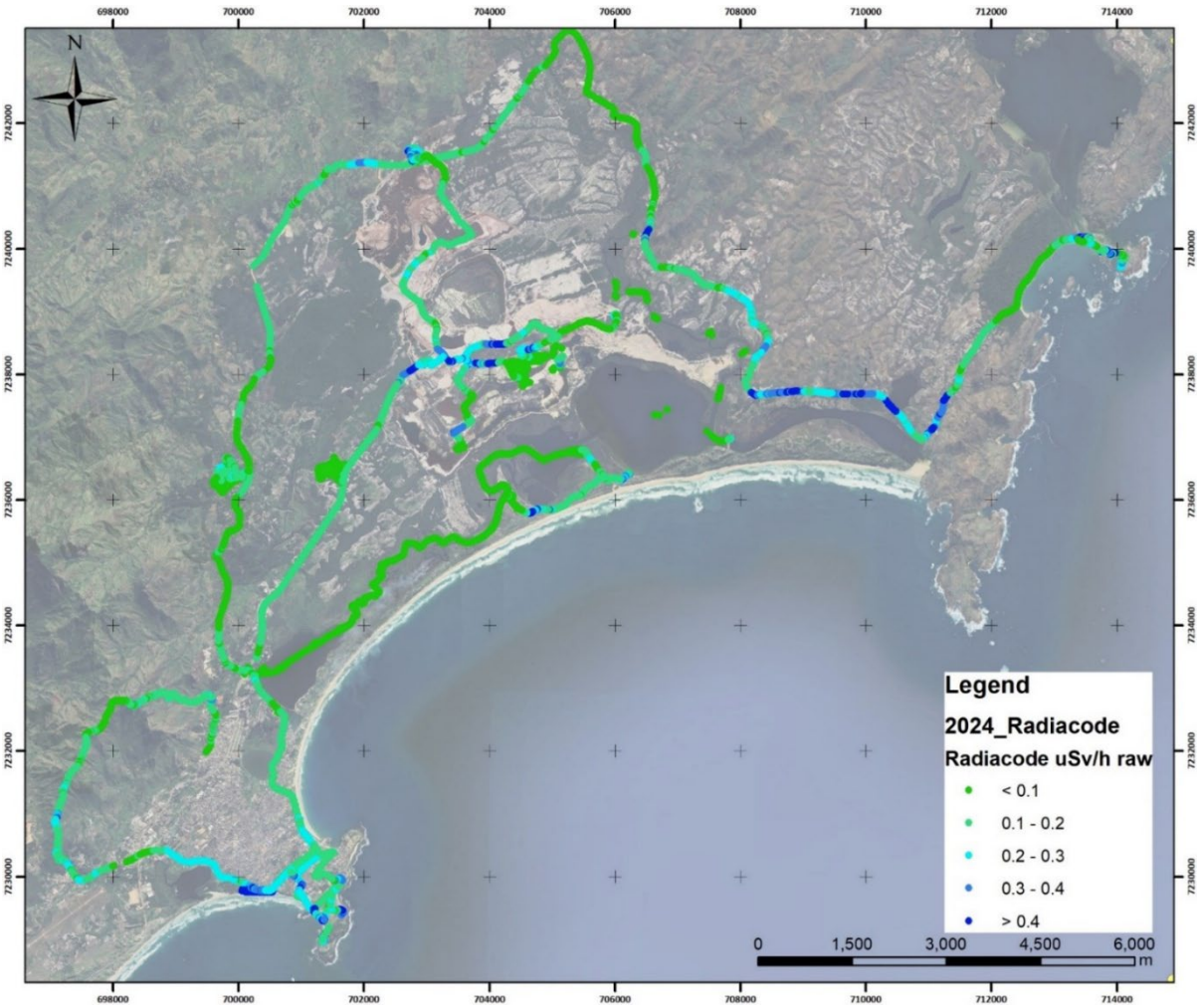


Figure 4-1: 2024 gamma dose rate data across the Fort Dauphin area

4.2.2 Rehabilitated Areas Survey

The rehabilitated post-mining area surveyed within the Mandena mine footprint included an area that had been rehabilitated in 2023 and measured relatively low dose rates (less than 0.1 uSv/h in cleared vegetation on Figure 4-2) compared to a zone rehabilitated in 2014 (generally more than 0.2 uSv/h in forested areas). This likely reflects the operational change to remove and recover REC in 2017. Note that REC has the highest thorium content of the QMM Mandena product streams.

Surface material in the southern areas was pale, loose sands. Re-vegetation has been generally successful, with more established plants in the 2014 rehabilitation areas.

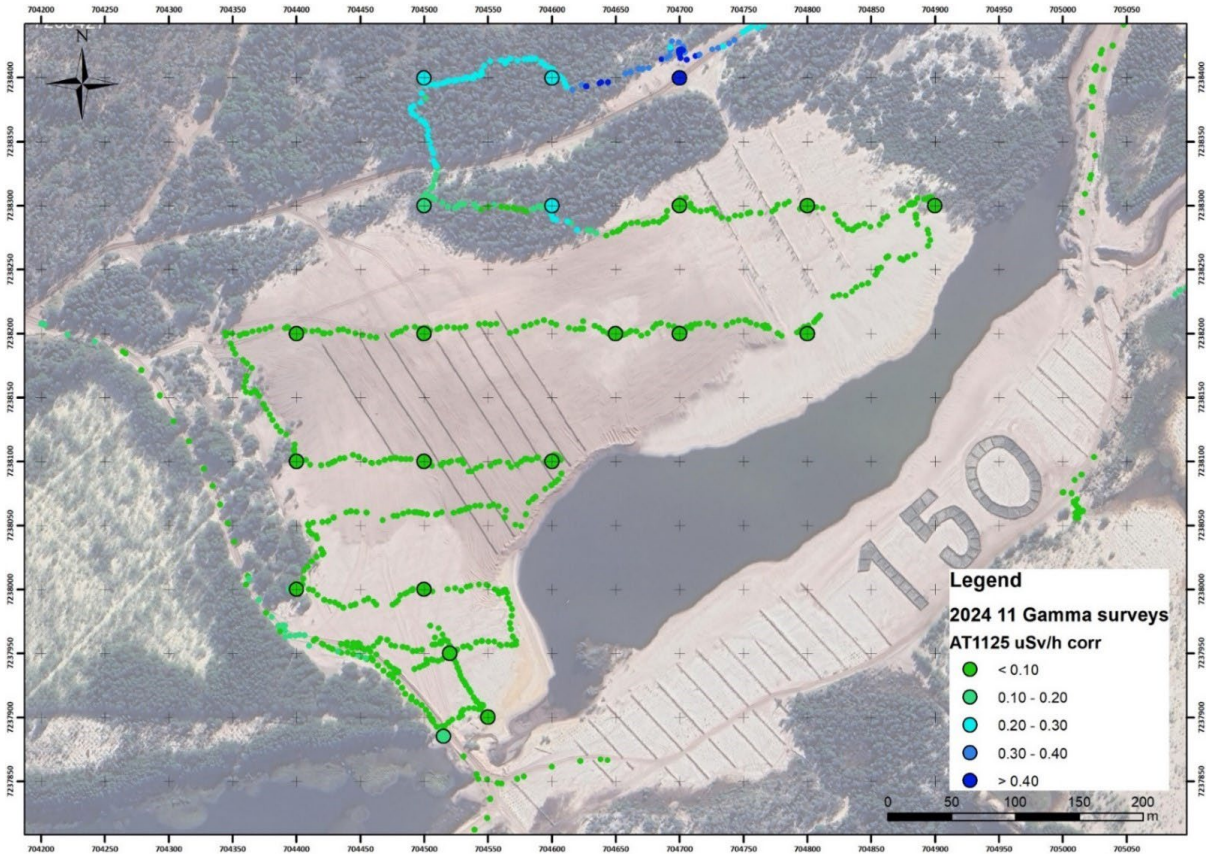


Figure 4-2: 2024 gamma dose rate survey on a 2023 rehabilitated area within the mine perimeter

A second survey was undertaken within a rehabilitated area in Snake North and measured a higher median dose rate (0.20 uSv/h, **Figure 4-3**), which is comparable to dose rates recorded in nearby areas in the baseline surveys (SENES 2001 and INSTN 2014, **Figure 4-3**, **Figure 4-4**).

The Snake North survey was carried out on a rehabilitated zone which is currently being used to trial fruit production (pineapple and some mango trees).

The surface of the rehabilitated area in Snake North is a mid-brown coloured, very fine sand. It includes large fragments (approx. 200 mm diameter) of thinly stratified dark brown sand, and mid-sized fragments (approx. 100 mm diameter) of pale sedimentary material. This differs markedly from the very pale (white) loose sands observed in the southern remediation areas described above.

The absence of a pre-mining baseline survey highlights an opportunity for QMM. Completion of pre and post mining surveys can be used to demonstrate the pre and post mining dose rates are comparable, and support release of mining areas. Further discussion is included in **Section 4.3** and recommendations are included in **Section 5**.

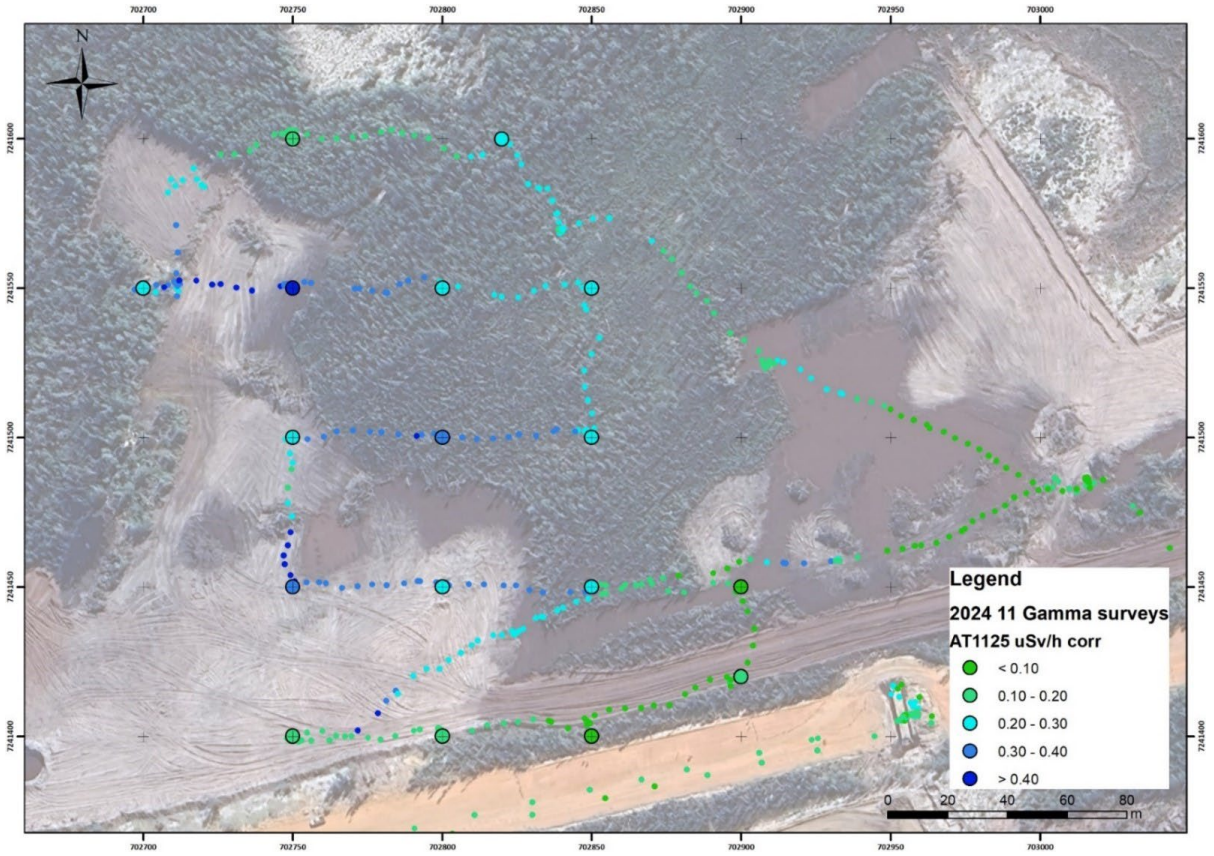


Figure 4-3: 2024 gamma dose rate survey on a 2023 rehabilitated area in North Snake

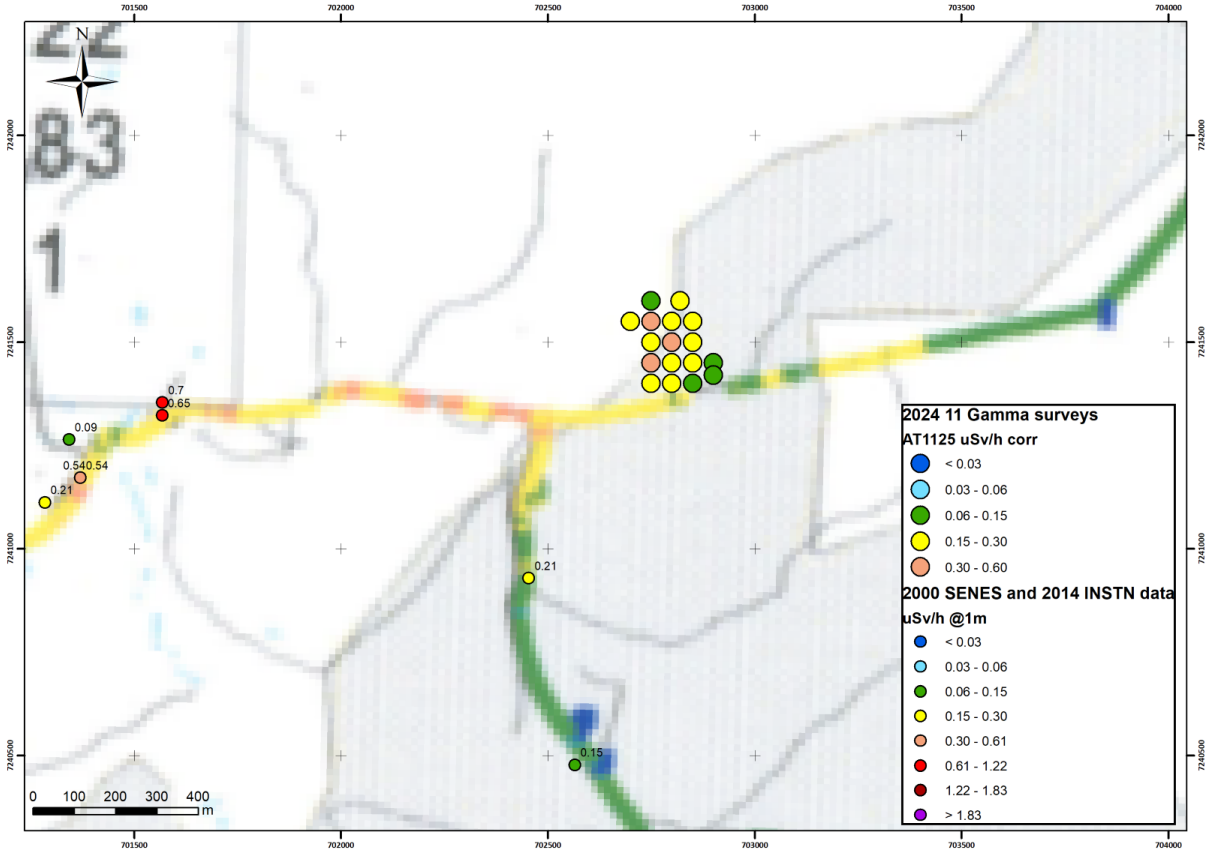


Figure 4-4: 2024 gamma dose rate survey on a 2023 rehabilitated area in North Snake against SENES baseline data ***(original SENES data files not available, hence poor resolution in base figure)***

Note: the colour scale of this map has been modified to match to the SENES survey and is not identical to Figure 4-3.

4.2.3 Unmined Area Survey

A survey of an unmined area to the southwest of the Mandena mine entrance was undertaken and recorded measurements in the lower range of regional background dose rates (typically less than 0.1 uSv/h, **Figure 4-5**), as compared to data sets from JBS&G regional survey (**Figure 4-1**) and historical data sets (SENES 2001 and INSTN 2014).

This survey was generally confined to the top of dunes, as the dense vegetation in lower areas prohibited a grid survey. Some measurements were taken in lower areas where possible. This data did not indicate any association between lower lying areas and higher dose rates, however it is generally considered possible that dose rates may be slightly higher owing to less surface cover in these areas.

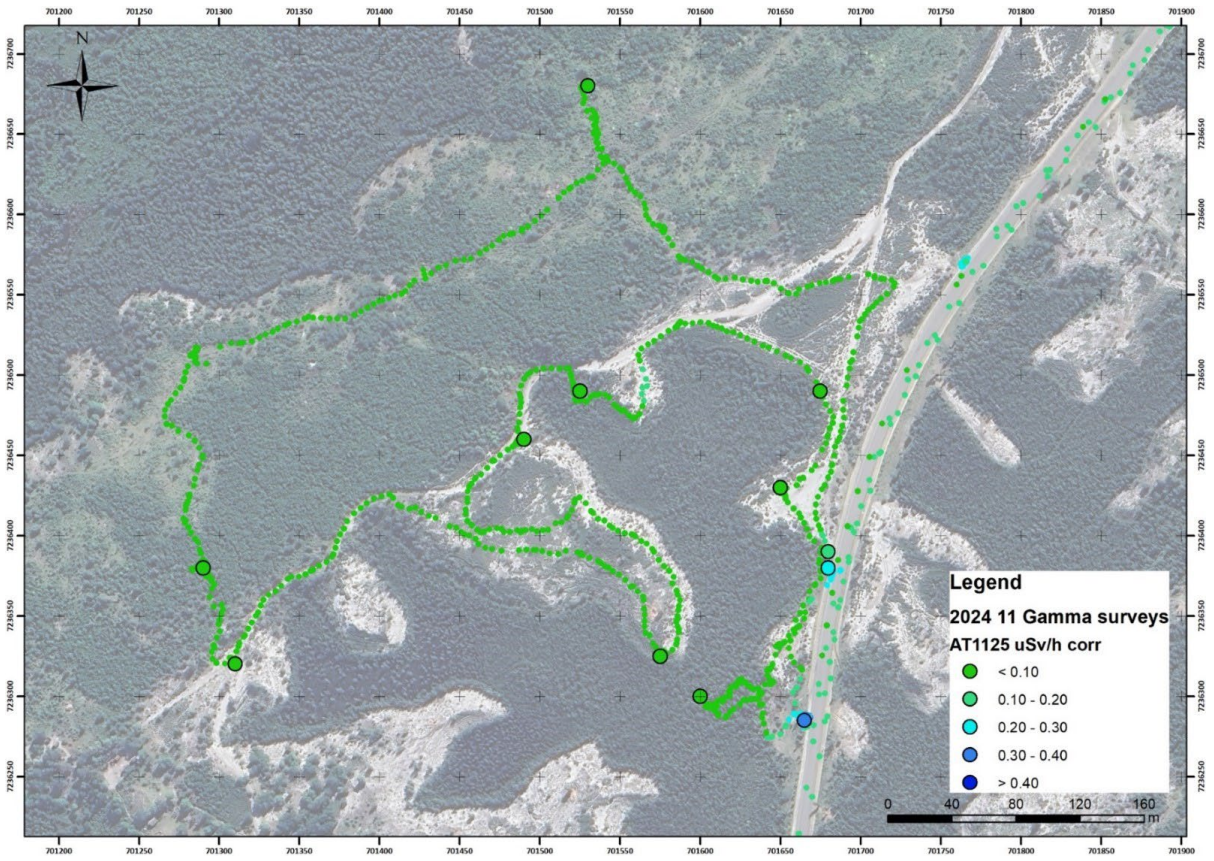


Figure 4-5: 2024 gamma dose rate survey on an unmined area (2025 mining plan)

4.3 Observations – Release of Former Mining Areas

QMM mining operations are extending into areas that are peripheral to the processing plant and infrastructure footprint. These areas are therefore likely to be released shortly after rehabilitation.

The rehabilitation trial orchard of fruit trees (pineapple and mango) in North Snake presents an opportunity for QMM to develop criteria for release and compare key markers in food produced in former mining areas with crops from unmined areas in the same province.

Acquisition of pre-mining dose rate measurements (by undertaking pre-mining gamma surveys) enables comparison and is able to support early identification of small areas that may require further remediation.

5. Recommendations

5.1 Gamma Survey Recommendations

JBS&G recommend that the QMM HSE team recommence pre and post mining gamma surveys, including retrospective post mining surveys for all areas mined since surveys ceased in 2020, and any area rehabilitated before 2020, but not surveyed.

A new set of instruments has been provided to QMM which can assist with the implementation of these pre and post surveys. A draft SOP has been prepared for the implementation of gamma surveys and provided to QMM, which includes advice on grid spacing and estimated time requirements to support scheduling and resourcing. Surveys must be completed on foot (not from a vehicle) to provide reliable, quantitative results facilitating final land release.

JBS&G provides the following recommendations for incorporation into operational practice:

- Implementation of pre and post mining gamma dose rate surveys;
    - Pre-mining area survey shortly following clearing of vegetation, but before excavation;
    - Post-mining area survey post backfill, shortly following the first stages of post-mining landform contouring, and prior to revegetation.
- Finalisation of the SOP (provided as a draft), for inclusion into the QMM Mandena document management system;
- Combined use of ThermoFisher PRD4 and continuous Radiacode 103 survey meters for pre and post mining surveys (noting that all surveys must be undertaken on foot);
- Adoption of a survey spacing of 50 m (GPS locations recorded to enable accurate comparison of pre and post-mining data sets);
- Update of procedures for area closure to adopt localised, deposit-specific closure criteria with specified targets (mean dose rates and maximum dose rates), validated by survey prior to handover for remediation and revegetation.
- The closure criteria (targets, dose constraints, and methodology) should be documented in the Radiation Management Plan or an auxiliary document.
- Accommodate resourcing to ensure survey are undertaken - frequency to be dictated by clearing processes and rehabilitation schedules.
- All current procedures and closure criteria have been developed based on guidance from IAEA documents. This good practice should continue as procedures are regularly updated.

5.2 Release of Former Mining Areas

The published Community Radiation Study (JBS&G, 2023) documented the very low potential dose contribution via the 'ingestion of fruit' pathway. This is due to the very large volumes of fruit that would need to be consumed (unrealistic) and the low radionuclide concentration contained within the fruit.

Any radiation dose associated with the consumption of food produced on post-mining areas is likely to be indistinguishable (and potentially less) from radiation doses received from consuming food produced in the Anosy region due to the removal of REC.

Despite the lack of potential for any significant increase in radiation dose above background from fruit consumption, these facts can be difficult to communicate effectively, and it is recommended that ongoing effort be invested in effective communication collateral and engagement.

It would not be warranted to attempt an ongoing fruit monitoring program to the extent from which a statistically valid dose estimation could be derived. This would involve the destruction of large volumes of fruit which is a valuable nutrient supply to the neighbouring communities. What is recommended in this particular circumstance is minimal data collection (fruit radionuclide analysis) to facilitate effective communication to stakeholders that the risk remains negligible from consuming fruit, including fruit produced on remediated mining areas.

To support release of former mining or operational areas, a limited study of fruit harvested both from the trial food crops in North Snake and similar crops from unmined areas should be undertaken. The acquired data should be used for communication to stakeholders. If however the collected data indicates any potential for a significant change in the potential exposure to communities, such as some fruit having atypical bioaccumulation of a specific radionuclide, then more detailed studies of the foodstuff may be justified.

5.3 Proposed Monitoring

Proposed gamma dose rate monitoring has been outlined below in **Table 5-1**.

Table 5-1 Proposed monitoring requirements.

Ref	Description of potential impact	Indicator	Parameter	Frequency
1	Enhancement of external radiation levels post rehabilitation associated with high levels of NORM at the surface	Dose rate measurements using calibrated meters (Thermo Scientific PRD4 and Radiacode 103)	Dose rate at 1 m above natural ground level, recorded in uSv/h (corrected using calibration factors) The appropriate survey spacing is 50 m for point measurements. However, if any measurements exceed the release threshold, then additional infill measurements should be taken on a tighter grid to enable a suitable coverage of any anomaly.	Systematic surveys for all areas before mining (ideally shortly after vegetation clearance) and directly after rehabilitation (final landform).
2	Community concern	Community sentiment around the safety of eating fruit	Radionuclide concentrations in fruit produced on post mining areas. Limited sampling three (3) per fruit type, to obtain sufficient data to enable ongoing communication of the safe nature of this fruit / absence of risk.	Samples to be analysed from the first crop of each new post mining area. Repeat the analysis as needed i.e. guided by feedback from the community engagement team on broader community sentiment around the safety of consuming fruit.

6. Limitations

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Appendix C Dust Data Review

Appendix C | Dust Review

Rio Tinto | QMM

Report

JBS&G 68011 | 166,236 | Rev1

25 June 2025

We acknowledge the Traditional Custodians of Country throughout Australia and their connections to land, sea and community.

We pay respect to Elders past and present and in the spirit of reconciliation, we commit to working together for our shared future.

Caring for Country The Journey of JBS&G
Artist: Patrick Caruso, Eastern Arrernte

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Abbreviations

Term	Definition
ANSTO	Australian Nuclear Science and Technology Organisation
JBS&G	JBS&G Australia Pty Ltd
MMM	Mandramondramotra
MMM River	Mandramondramotra River
NORM	Naturally Occurring Radioactive Materials
QMM	QIT Madagascar Minerals
REC	Rare Earth Concentrate
SOP	Standard operating procedure
The study	2023 JBS&G Community Radiation Study
WHO	World Health Organisation

1. Introduction

JBS&G Australia Pty Ltd (JBS&G) was engaged by QIT Madagascar Minerals (QMM) to undertake a Community Radiation Study ("the study") at the Mandena Mineral Sands Mine in Southern Madagascar (refer Figure 1-1). The study commenced in 2019 and was one of the largest studies of its type ever undertaken.

JBS&G designed a robust quality assured detailed environmental impact investigation based on a source, pathway, receptor model, targeting sampling of multiple media including soil, direct gamma, radon/thoron, surface water, groundwater, dust, fruit, vegetables, and biota (fish and prawns). The study was initially designed with four quarterly sampling events over 12 months however due to Covid-19 and global logistical issues, the study extended to five sampling events over four years. The study assessed 26 potential exposure pathways including Direct Gamma (4), Inhalation (2) and Ingestion (20).

The final study report[1], delivered in 2023, concluded that the contribution to a community member radiation dose from the mining operation did not exceed 1 mSv per year above natural background through all the exposure pathways assessed. The study recommended that future monitoring should focus only on specific pathways necessary to demonstrate that levels remain low. The study also recommended that for those pathways identified on which mining may have an ongoing influence, discussions should occur with key stakeholders and regulators to determine the best approach towards a monitoring program. This could include ongoing gamma monitoring of revegetated mined areas, as well as the potential for impact from mine water discharges, water treatment plant residues and local dust levels as the mine continues to expand closer to local communities.

QMM engaged JBS&G in October 2024 to visit the Mandena site, review operations and existing dust data and provide recommendations for ongoing environmental radiation monitoring program which could be incorporated into the broader mine environmental monitoring program. This site inspection was completed in November 2024.

The 2023 JBS&G study identified the water pathway as potentially the most significant pathway (for mine related exposure), in terms of both direct and indirect ingestion, and as such was the focus of the 2024 monitoring. Other pathways of focus included both external and inhalation pathways via terrestrial gamma and dust. Separate appendices have been prepared which detail each of the pathways.

This Appendix covers the Inhalation Pathway, focusing on dust.

[1] JBS&G 2023 Mandena Community Radiation Study, Reference 57082/153,352 18 August 2023.

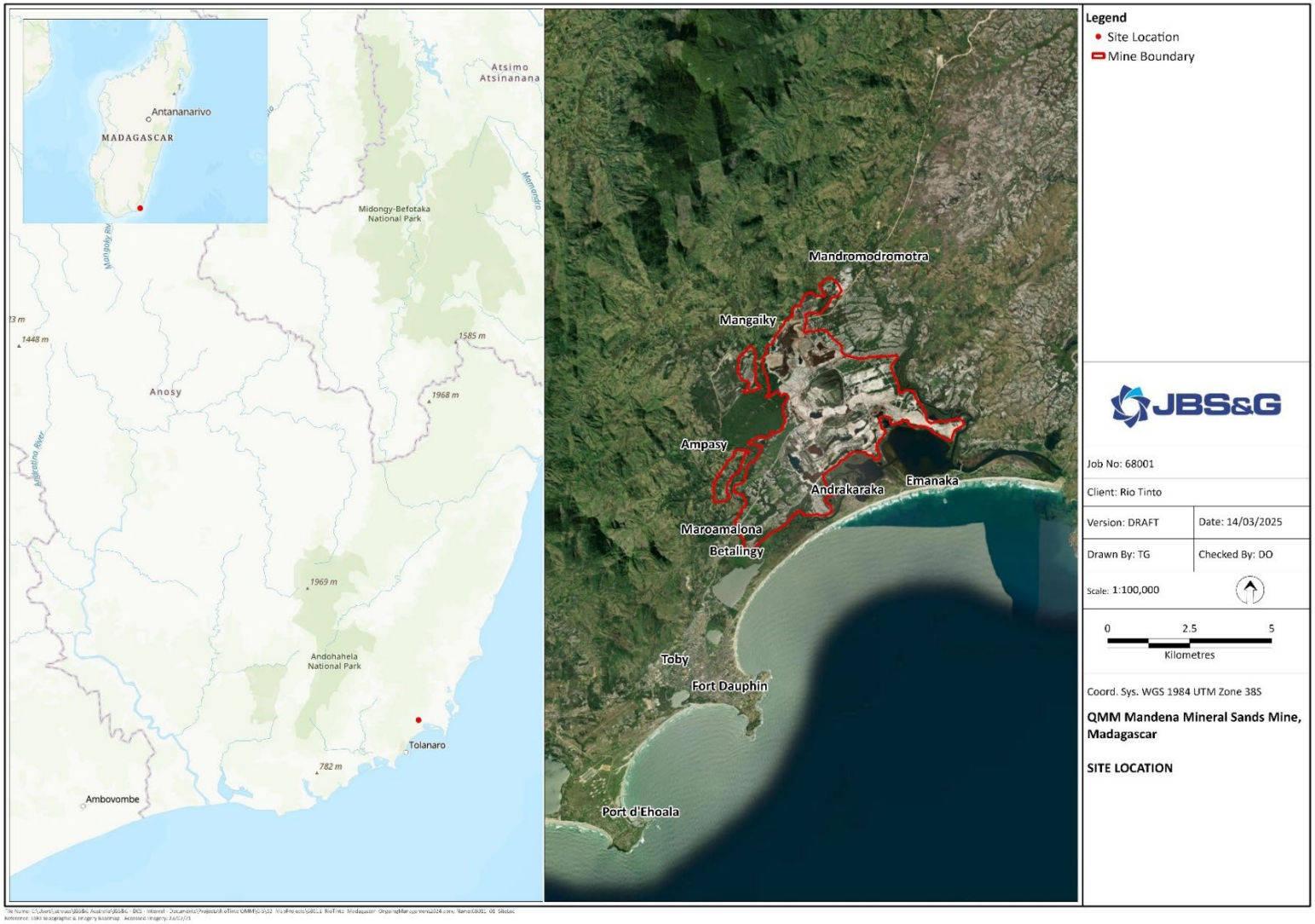


Figure 1-1 Project location

2. Background and Scope

JBS&G acknowledge the feedback provided by the Andrew Lees Trust (ALT) from a review undertaken by Dr Stella Swanson of the JBS&G study report[2] and the recommendations therein. The initial post study site visit scope was designed as a starting point for the establishment of a longer term robust environmental monitoring dataset. It is acknowledged that the environmental radiation dataset gathered for the Mandena mine and surrounding environment will be improved with increased levels of confidence gained over time, and additional interpretation of trends once sufficient data has been established.

One of the objectives of the post-study monitoring event was to examine and monitor the other important environmental sources and pathways by undertaking surveys and observational visits across the mine to examine if the assumptions and observations included in the JBS&G study remain representative of the operational site and surrounding conditions for the potential for exposure to critical community groups.

This scope of this report focuses on the Inhalation pathway (dust as media) – refer **Table 2-1**. In the 2023 JBS&G study, the inhalation pathway was identified as a minor pathway and is unlikely to significantly contribute to community exposure.

Table 2-1: Key Environmental pathways and media summary

Pathway	Media	Activity/Item	Objective/method/analysis
Inhalation	Dust	Review of environmental dust monitoring data.	Undertake a qualitative review and comparison with radiation study radionuclide concentrations and ratios for dust.

3. Methodology

3.1 Dust monitoring data review

The scope of the monitoring event included a qualitative review of data from the QMM dust monitoring program around the Mandena mine. Recent dust particle concentration data was assessed and compared to dust particle concentrations measured during the JBS&G study.

The intent of the review was to reassess and validate key assumptions from the Study and identify the potential for any changes in the mining operations at Mandena to impact identified critical groups (communities) surrounding the mine.

The review examined monitoring locations against current mining operations. Monitoring results were compared to those provided by QMM during the Community Radiation Study. The mine plan (12 month horizon) and longer term strategies were also reviewed in this process to gain an understanding of current and future changes to the mining footprint.

3.1.1 QMM Dust Monitoring

Dust monitoring by QMM around the Mandena mine currently consists of air quality measurements carried out weekly in key fixed stations (for periods of 24 hours). Measured parameters include:

[2] Swanson Environmental Strategies 2024, Review of the JBS&G 2023 Report: Mandena Community Radiation Study, Submitted to the Andrew Lees Trust 18 March 2024.

- Temperature, relative humidity, and pressure;
- SO_2, NO_2, O_3, CO_2;
- PM1, PM2.5, PM10; and
- Wind direction, and wind speed.

As noted in the study report, JBS&G and the QMM HSE team used deposition gauges to collect dust over 18 months between 2020 and 2021 to measure radionuclide concentrations in deposited dust as part of the Community Radiation Study (JBS&G, 2023).

If the mining operations and potential exposure pathways remain constant, it is considered reasonable that the potential dust inhalation exposure pathway can be calculated based on:

- the dust concentration in the air (PM1) measured weekly; and
- radionuclide concentrations in dust as reported by JBS&G (Community Radiation Study, 2023).

For any significant operational change, previous assumptions should be re-visited and monitoring programs reviewed to ensure that they remain valid.

3.1.2 Field observations November 2024

Changes have occurred within and around the Mandena Project since 2021. These operational changes are different to the dust source-pathway-receptor assumptions established within the JBS&G study.

The changes, listed below, have the potential to increase dust concentrations in air and alter radionuclide concentration ratios in the dust in comparison to those established by the initial study:

- Dry mining is now part of QMM extraction processes (this was not considered by the JBS&G community radiation study as mining was water based);
- Extraction areas have moved to the western and north-western ore body boundaries, closer to the communities of Mangaiky and Ampasy, and extraction in these areas uses dry mining methods (refer **Figure 3-1**);
- Truck haulage has increased over the last 3 years (from four to 16 haul trucks) as a consequence of the increase of dry mining. Dust control of these QMM activities is undertaken through the application of water via water haulage trucks;
- The expansion of the mine footprint has increased the site boundary, and public access to rehabilitated areas and active mining fronts is not fully restricted; and
- A major road is under construction in the area that is not the responsibility of QMM. The section linking Ampasy to Mandromondromotra (MMM) is largely completed. The construction of the road and the subsequent traffic (trucks and cars commonly travelling at speed greater than 60 km/h) introduces new sources of background dust that were not present prior to 2024 (refer **Figure 3-3** and **Figure 3-4**). Water haulage trucks have applied water for dust suppression on an irregular basis.

The dust data review results and recommendations are presented in **Section 4** and **Section 5**.

Figure 3-1: New dry mining area

Figure 3-2: North Snake rehabilitated zone following dry mining

Figure 3-3: New road section completed between Mangaiky and MMM (not a QMM activity)

Figure 3-4: New road under construction, Mandena to Ampasy section (not a QMM activity)

4. Results

Air quality data for 2022, 2023 and 2024 was provided to JBS&G by the QMM Mandena environmental team and is summarised in **Table 4-1**, with relevant key locations and features depicted in **Figure 4-1**. This data was compared to the 2020 – 2021 data provided by QMM for the Community Radiation Study (JBS&G 2023).

Three stations have been operating on a regular basis between 2022 and 2024, Mangaiky and Ampasy (to the west of the mining area) and MMM (upwind location to the north-east if the mining area).

Analysis of the data provided for the 2022 to 2024 period shows that:

- Measurements are generally about one order of magnitude lower than data provided for the period 2020 – 2021 and are at levels that are more indicative of expected environmental dust in this region. The higher values recorded in 2020-2021 should be investigated to determine the root cause of the reporting error e.g. monitoring instrument fault, data transcription error. It is important to note that even at these higher (in error) recorded values in 2020-2021, the community dose from the dust (inhalation pathway) was still minimal and <0.1mSv/y; and
- Averages and maxima do not show a substantial difference between downwind stations (Mangaiky and Ampasy) and the upwind station (MMM).

Monitoring at Andrakaraka and Toby appears to have ceased at the end of 2023 and the start of 2024 respectively, following relocation of mining activities away from the southern communities.

Additional stations have been added to the 2024 schedule to capture new mining areas (Vatovy, North Snake, Turtle, Mandena and the Port of Ehola)[3]. Three stations from Vatovy (Mamirano, Soanareny and Soarano) had been operational at the time of the review in November 2024.

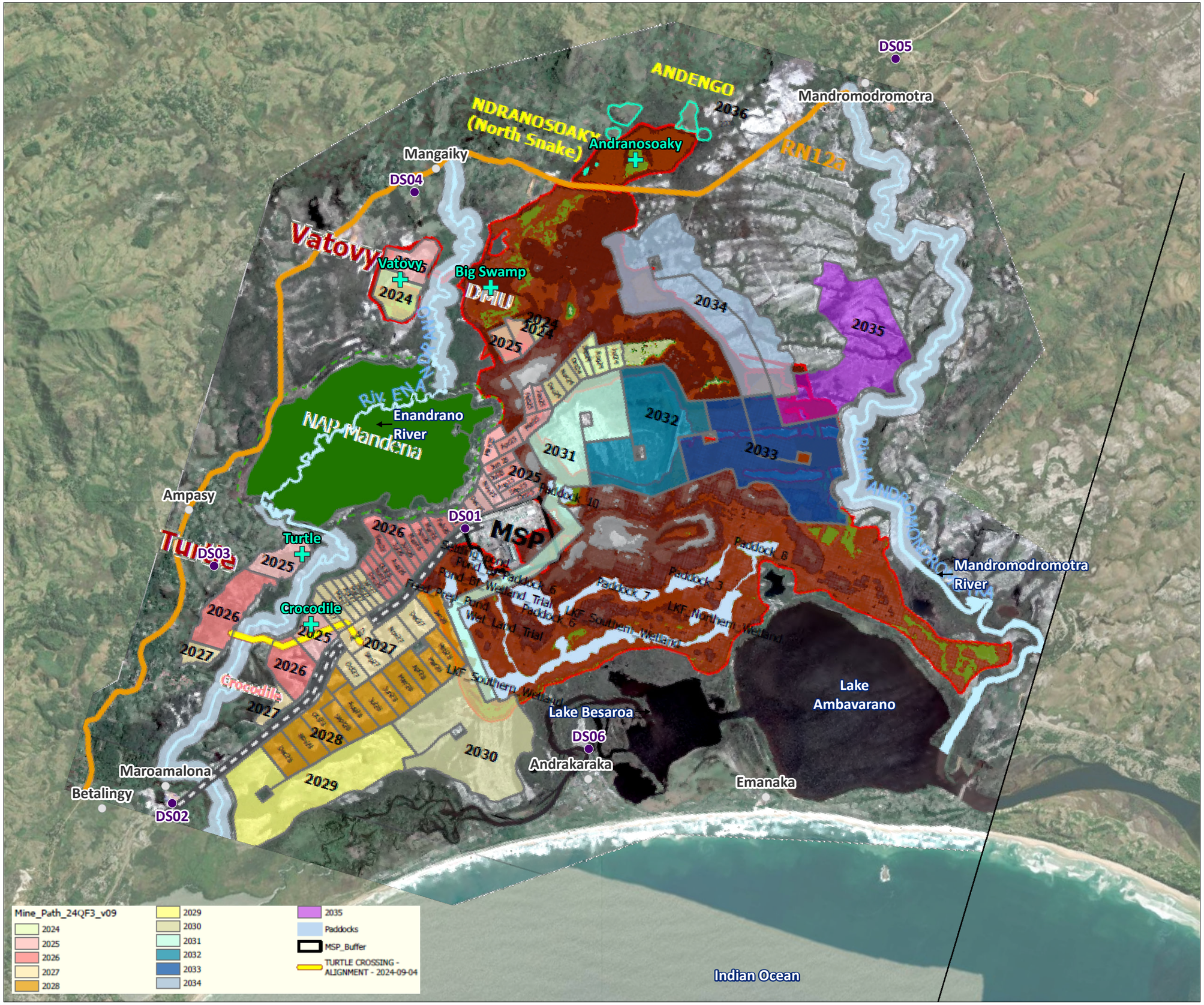
Table 4-1: Summary of air quality data 2022 - 2024

Station	# points			2021* PM1 Data	average PM 1 (ug/m^3)			2021* PM10 Data	average PM 10 (ug/m^3)		
	2022	2023	2024		2022	2023	2024		2022	2023	2024
Ampasy	28	48	34	169	11.4	19.0	9.6	415	24.2	35.1	20.1
MMM	19	47	36	161	9.5	9.6	9.4	354	21.2	21.4	15.6
Mangaiky	27	49	46	191	10.1	11.6	9.2	425	21.3	24.0	16.0
Toby	16	47	1	195	15.1	16.8	8.2	385	32.6	33.9	17.8
Andrakaraka	14	37		181	12.1	15.9		441	26.1	32.3	
Nahampoana		1		n/a		13.0		n/a		25.9	
Mamirano			1	n/a			3.9	n/a			7.5
Soanareny			2	n/a			6.3	n/a			15.1
Soarano			2	n/a			3.4	n/a			7.9

*The original JBS&G report used 2021 dust concentration data provided by the QMM operation which was subsequently established to be erroneously high due to calibration issues with the dust monitoring instruments. Notwithstanding, using the overestimated 2021 dust concentration data in the original JBS&G report, the dust pathway was confirmed as a minor contributor to community dose. Subsequent dust monitoring data provided by QMM from 2022, 2023, and 2024 with independent calibration certification provided for the dust monitoring equipment, confirmed that the actual dust concentrations are substantially lower and confirmed that the inhalation pathway is a very minor contributor to public dose

[3] Noting JBS&G have not been provided with coordinates for these new monitoring locations.

Since doses associated with dust inhalation were estimated to be below 0.1 mSv/y during the 2020 - 2021 period and average gravimetric dust concentration in the air has significantly decreased since, exposures from inhalation of airborne dust are still considered to be negligible.



Legend

- Dust Monitoring Location
- Communities
- Dry Mining Areas

JBS&G

Job No: 68001

Client: Rio Tinto

Version: FINAL	Date: 28/05/2025
Drawn By: RT	Checked By: DO

Scale: 1:35,000

0 1 2
km

Coord. Sys. WGS 1984 UTM Zone 38S

QMM Mandena Mineral Sands Mine, Madagascar

DATA GAP SITE FEATURES PLAN

FIGURE 5

File Name: C:\Users\rtandon\JBS&G Australia\JBS&G - DCS - Internal - Documents\Projects\Rio Tinto\68011 Madagascar QMM\GIS\02_MapProjects\68011_RioTinto_Madagascar_ExcecutiveSummary.aprx
Reference: ESRI Imagery Basemap - Accessed Imagery: 23/07/21

5. Recommendations

5.1 Dust Recommendations

On the basis of the observations made during the November 2024 site visit, review of the 2022-2024 dust monitoring data, and review of the current and future Mandena mine plan, the following recommendations are made:

- Pre 2022 air quality data should be re-evaluated to investigate reasons for the order of magnitude change between older results and the values measured between 2022 and 2024.
- Previous assumptions need to be validated for current conditions. As such, dust deposition (passive) gauges should be re-installed in key communities (Mangaiky, Ampasy and MMM) for the dry windy season to assess radionuclide concentrations in dust and investigate whether changes to mining methods may have impacted the dust inhalation pathway and exposures to critical groups (communities). This requires on-site sample preparation, and analysis of captured dust via alpha spectrometry at an external service provider. Ideally, the passive gauges are installed in a shared location with routine air quality monitoring (to obtain correlated PM1, PM2.5 and PM10 data at that same location).
- Should there be any indication of higher potential doses from the inhalation pathway then introduction of long lived alpha activity in dust using air sampler pumps and alpha counters should be considered. Locations where this methodology could be applied include:
    - at the boundary of active mining areas;
    - within freshly rehabilitated areas trialled for crops; and
    - within active areas potentially accessed by communities.

  This method provides a more direct means of measuring airborne dust activity concentration for assessment of inhalation exposures and is widely used by other operations. Pumps with a higher flow rate than the personal sampling pumps currently used on site would give better resolution for final radionuclide concentration results and should be considered for this monitoring.
- Maintain open and frequent lines of communication with the local community to ensure the application of water for dust suppression is sufficient to minimise local dust generation as a result of the QMM mining operations.
- Ensure these local communities are aware of who is responsible for dust suppression on the public road and provide feedback to this organisation when QMM observes the need for additional dust suppression activities.

5.2 Proposed Monitoring

Proposed air quality monitoring has been outlined below in **Table 5-1**.

Table 5-1 Proposed EMP monitoring requirements

Ref	Description of potential impact	Indicator	Parameter	Frequency
ISA01	**Mining sector:** Changes in ambient air quality (Air pollutants: (PM1, PM2.5, PM10, NO_2 and SO_2) NAP and at	Rate of particles in the air	• PM1, PM2.5 and PM10 • Number of air quality complaints	Quarterly

	the level of villages or hamlets (villages of Soanareny, Soarano, Ankofa, Mangaiky, Mamirano, Enandrano, Emahasoa, Ampasy and Maroamalona) located on the outskirts of the MSP plant area due to mining activities		• NO_2 and SO_2	
ISA02	Changes in ambient air quality (Air pollutants: (P PM1, PM2.5, PM10, NO_2 and SO_2) NAP and at the level of villages or hamlets located on the periphery of the MSP plant area due to stationary sources	Rates of metals and particles at the chimney outlet	• PM 10 (Metals, etc.) • PM1, PM2.5 and PM10 incl. metals) • SO_2, NO_2 • CO, CO2,	*Once every 5 years*
n/a	Changes in mining techniques and mining scale, external factors, focusing on Mangaiky, Ampasy and MMM, located in close vicinity of the dry mining areas	Radionuclide ratios in dust	• Radionuclide activity concentration	Once in the dry months (6 months deployment)

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