Fingerboards Mineral Sands Project:
Provision of Expert Advice to the Inquiry and Advisory Committee
K.H. Joyner Ph.D.

My name is **Kenneth Henry Joyner**, and I reside [redacted] Heathmont 3135 Victoria.

My formal qualifications are:

- B.Sc. Hons (La Trobe) 1970: H1.
- Ph.D. (La Trobe) 1975: "Phase Height Measurements on the Ionosphere".

My Professional Affiliations are:

- Fellow of the Australian Radiation Protection Society.
- Member of the Bioelectromagnetics Society (USA).
- Senior Member of the Institute of Electrical & Electronics Engineers (IEEE)
- Member of the IEEE Standards Association
- Member of Institute of Engineers Australia (Certified Practising Engineer)
- I was a member of the Radiation Advisory Committee for 17 years retiring in 2020. The Radiation Advisory Committee is established under the *Radiation Act 2005* and the committee's function is to consider, advise and report to the Minister for Health or the Secretary of the department on any matters relating to the administration of the Act and Radiation Regulations 2017.

My major area of expertise relates to non-ionizing or electromagnetic radiation but in the 45 years since graduating I have delivered university undergraduate courses in nuclear physics, been involved in the identification and disposal of radioactive sources, conducted in-building radon measurements and through my 17 year tenure on the Radiation Advisory Committee I have been involved in

- The promotion of radiation safety procedures and practices.
- Recommendation of the criteria for the licensing of persons and the qualifications, training or experience required for licensing.
- Recommendation of which radiation sources should be prescribed as prescribed radiation sources.
- Recommendation of the nature, extent and frequency of tests to be conducted on radiation apparatus and sealed radioactive sources.
- Codes of practice, standards or guidelines with respect to particular radiation sources, radiation practices or uses.

Specifically for electromagnetic radiation I have been directly involved in the justification, limitation and optimisation of human exposure which mirrors the principle of protection in the Victorian *Radiation Act 2005* that persons and the environment should be protected from unnecessary exposure to radiation through the processes of justification, limitation and optimisation.

Scope of Work

The Inquiry and Advisory Committee (IAC) for the Fingerboards Mineral Sands Project has requested that I review the Environment Effects Statement (EES) *Appendix A011 Radiation Assessment Report* with a view to providing advice on:

1. The methodology employed in the report including characterisation of the likely sources of radiation.

2. Identification and acceptability of applicable standards and the regulatory regime.

3. The identification of potential impacts from radiation.

4. The proposed management framework for risk from radiation, and

5. Any other relevant matters related to the radiation report you consider the IAC should be aware of.

Subject to your advice above, the IAC would also appreciate your advice on:

6. How the report has been translated into the *Environmental Management Framework.*

'I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Inquiry and Advisory Committee.'

The methodology employed in the report including characterisation of the likely sources of radiation

Baseline or Background Radiation Levels

1. The report[1] (hereafter designated as Report) describes the baseline radiation levels and assesses the radiological impacts associated with the proposed Fingerboards Mineral Sands Project. The baseline or background radiation assessment covers the project area, including assessments of the radionuclide content in air, soil, vegetation, surface water and groundwater.

2. The Report goes into considerable detail covering the measurements of
   - Terrestrial gamma radiation levels.
   - Radionuclide content of surface soils.
   - Radionuclide content of surface and groundwater sources.
   - Ambient long-lived radionuclide concentrations in airborne dust.
   - Ambient radon concentrations.
   - The Radionuclide content of crops.

3. SGS Radiation Services (hereafter referred to as SGS) prepared the Report and carried out background radiation measurements in May 2017, May 2018 and again in September 2018. The last analytical laboratory report included was dated 28 August 2019.

4. SGS has NATA[2] accreditation for compliance with ISO/IEC 17025 and meets the criteria for determining a facility's competence based on the relevant international standard (e.g. ISO/IEC 17025) and include: the qualifications, training and experience of staff; correct equipment that is properly calibrated and maintained; adequate quality assurance procedures; appropriate sampling practices, and so on.

5. I have sighted the two relevant NATA Scope of Accreditation documents covering the period of the measurements and I am of the view that measurements reported have been performed by competent operators with calibrated and well-maintained equipment.

6. With regard to the extent and number of measurements the Report acknowledges that due to the size of the Project Area as well as access issues, integrated fixed measurements of absorbed dose rate ($nGy \cdot h^{-1}$) could not be collected across a sampling grid of the entire assessment area. However, provision will be made to conduct a finer grid survey of key areas of the project area closer to the start-up date as part of the Future Work plan.

7. Should the project be approved this would be a practicable and timely approach to characterizing the absorbed dose rate over the project area in finer detail.

[1] Environment Effects Statement (EES) Appendix A011 Radiation Assessment Report.

[2] NATA – National Association of Testing Authorities Australia. NATA accreditation provides a means of determining, formally recognising and promoting the competence of facilities to perform specific types of testing, inspection, calibration, and other related activities.

Analysis of Mine and Process Materials

8. Based on the analysis of materials collected by SGS and data supplied by Kalbar, SGS concluded that the most significant external radiation exposures are expected to arise from the direct handling of the heavy mineral concentrate (HMC).

9. I have read the report supplied by Kalbar, and I agree with the conclusion of SGS that the most significant external radiation exposures are expected to arise from the direct handling of the heavy mineral concentrate (HMC).

10. The management of the tailings requires further consideration. It is not clear if the tailings will be stored in a dam or dams whilst awaiting the backfilling into the pit? There are repeated references to 'process water dams for reuse as mine process water' in Table 22 "Event consequences and likelihood - October 2018" – will the process water dams be used to store the tailings?

11. Tailings dams will mitigate dust but as with the process water dams, flooding will need to be considered in the Radioactive Waste Management Plan (RWMP).

12. Also, to be included in the RWMP will be measurement of the maximum activity concentration of the sand tailings.

Identification and acceptability of applicable standards and the regulatory regime

13. The Regulatory Framework discussion presented in the Report provides an overview of the relevant State and Commonwealth Acts, Radiation Regulations and Codes of Practice/Guidelines. However, I understand that the Victorian Government is in the process of varying the licences for the transport of radioactive materials and applying the 2019 version of the Code of Practice for the Safe Transport of Radioactive Material (RPS C-2 2019) and not the 2014 version which is referenced in the Report. The Report also makes reference to the 2016 version of the Code for Radiation Protection in Planned Exposure Situations RPS C-1 which has been updated to the 2020 version - RPS C-1 (Rev.1). Both RPS C-1 (2016) and RPS C-1 Rev.1 (2020) set out the requirements in Australia for the protection of occupationally exposed persons, the public and the environment in planned exposure situations but the 2020 version should be referenced.

14. For Victoria, the regulation of radiation protection and radioactive waste management are covered by the Victorian *Radiation Act 2005* and the *Radiation Regulations 2017.* Radiation protection and radioactive waste management are not covered by the Victorian *Environment Protection Act 1970* except where a condition of pollution or environmental hazard occurs or is likely to occur.

15. The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC) *Act* provides the legal framework to protect and manage matters of national significance including important flora, fauna, ecological communities and heritage places.

16. Whilst noting the update to the 2019 version of the Transport Code and the 2020 version of the Code for Radiation Protection in Planned Exposure Situations RPS C-1 (Rev.1), the Report lists the relevant Australian Codes of Practice which will likely be included in any conditions issued under the Victorian Radiation Act. These Codes provide the philosophy, principles and recommendations in the current international radiation and waste safety standards and guidelines.

17. With respect to non-human biota living in natural habitats the Report states that under the Victorian *Radiation Act 2005* Kalbar will be required to commence preliminary assessments of potential radiation doses and the impact on the environment using the ARPANSA guidance document Guide for Radiation Protection of Environments RPS G-1 2015. Neither the EPBC *Act* nor the RPS G-1 cover domestic farm animals; in fact, RPS G-1 defines wildlife as 'Any wild animal or plant living within its natural environment. This excludes stock, farmed, feral or domesticated species.' In my view it is important to include stock, farmed and domestic species in the risk assessment as the Critical Group (Section 9.2.6 of the Report) has been identified as residents in the farming district directly north of the project and south of the Mitchell River. Exposure via ingestion of vegetables or soils has been considered as an exposure pathway for humans (Section 9.2.3 of the Report) but clearly grazing animals will consume significant amounts of grasses daily and it is my view that the impact on downstream dairy and beef/lamb production should be considered in the risk assessment.

18. The Report also discusses the transport regulatory requirements and concludes that the *Radiation Act 200*5 would extend to the transport of HMC on Australian roads and rail and a Victorian Management Licence will be required for this activity. There is one comment in the Report which should be included in the Radiation Management Plan which relates to process controls for ensuring the total concentrations of uranium and thorium contents of HMC remain below 10 $Bq.g^{-1}$ limit to ensure exemption with the need to comply with shipping, documentation and placarding requirements.

19. The Report includes a discussion of Dose Limits for both occupational exposure and members of the general public and makes reference to the ALARA principle without clarification of the principle. With reference to the clarification of the ALARA principle it is important to state the full text of the Radiation Protection Principle in Section 7 of the Victorian *Radiation Act 2005* which stipulates that persons and the environment should be protected from unnecessary exposure to radiation through the processes of justification, limitation and optimisation where—

    (a) justification involves assessing whether the benefits of a radiation practice or the use of a radiation source outweigh the detriment;

    (b) limitation involves setting radiation dose limits, or imposing other measures, so that the health risks to any person or the risk to the environment exposed to radiation are below levels considered unacceptable;

    (c) optimisation—

        (i) in relation to the conduct of a radiation practice, or the use of a radiation source, that may expose a person or the environment to ionising radiation, means keeping—

            (A) the magnitude of individual doses of, or the number of people that may be exposed to, ionising radiation; or

            (B) if the magnitude of individual doses, or the number of people that may be exposed, is uncertain, the likelihood of incurring exposures of ionising radiation

        — as low as reasonably achievable taking into account economic, social and environmental factors.

20. Frequently when discussing the ALARA principle the qualifiers of taking into account economic, social and environmental factors are omitted and ALARA is often interpreted as low as technically achievable which is not correct.

21. The radiation dose limits are mandated in the Victorian *Radiation Regulations (2017)* as follows:

Schedule 4—Radiation dose limits

Regulation 11

Table A—Ionising radiation dose limits for occupational exposure

Circumstance	*Dose limit*
Receipt of ionising radiation doses in any 60 month period	Effective dose of 100 millisievert
Receipt of ionising radiation doses in any 12 month period	Effective dose of 50 millisievert
Receipt of ionising radiation to the lens of an eye of a person in any 60 month period	Equivalent dose of 100 millisievert
Receipt of ionising radiation to the lens of an eye of a person in any 12 month period	Equivalent dose of 50 millisievert
Receipt of ionising radiation to the skin of a person in any 12 month period	Equivalent dose of 500 millisievert averaged over 1 cm^2 of any part of the skin regardless of the total area exposed
Receipt of ionising radiation to the hands and feet of a person in any 12 month period	Equivalent dose of 500 millisievert

Table B—Ionising radiation dose limits for public exposure

Circumstance	*Dose limit*
Receipt of ionising radiation doses in any 12 month period	Effective dose of 1 millisievert
Receipt of ionising radiation to the lens of an eye of a person in any 12 month period	Equivalent dose of 15 millisievert
Receipt of ionising radiation to the skin of a person in any 12 month period	Equivalent dose of 50 millisievert averaged over 1 cm^2 of any part of the skin regardless of the total area exposed

The whole-body effective dose limits for occupational exposure referenced in the Report are equivalent to those in the Schedule 4 above – the 20 mSv per year averaged over 5 years is equivalent to the 100 mSv in any 60-month period for occupational exposure. The 50 mSv effective dose in any 12-month period also appears in Table 4 above.

22. As mentioned in *para. 13* above the Report makes reference to an earlier version of the Code for Radiation Protection in Planned Exposure Situations RPS C-1 which has been updated to the 2020 version - RPS C-1 (Rev.1). These codes set out the requirements in Australia for the protection of occupationally exposed persons, the public and the environment in planned exposure situations. The primary means of controlling exposure in planned exposure situations is by good design of facilities, equipment, operating procedures, and thorough training – all of which contribute to optimisation of protection.

23. I am of the view that there is a gap in the applicable regulatory regimes, codes of practice and regulations for the protection of humans and the environment and consideration should be given to including domesticated farm animals and grazing stock certainly in this instance and other instances where agricultural land is possibly impacted.

The identification of potential impacts from radiation.

24. The Report contains a comprehensive discussion of the radiation impacts associated with the project from both the occupational and public perspectives.

Occupational Impact

25. For the occupational exposure assessments I am of the view that methodologies and numerical values used for estimates/calculations of 'External Exposures', 'Internal Exposure from Dust', 'Radon/Thoron Exposure', 'Ingestion Pathway' and the Annual Worker Dose Estimates are appropriate and give confidence in the conclusion 'The prospective doses to employees is estimated to be less than the annual occupational limit of 20 mSv' . In the discussions a number of issues are raised which need to be included in the Radiation Management Plan (RMP).

26. With respect to dust exposure: It is stated that 'Elevated dust concentrations may arise during dry operations. Under the proposed mining operations, the ore is expected to remain damp when mined, and thus dust levels will be suppressed as a consequence'. The process for ensuring the ore will remain damp needs to be included in the RMP.

27. Later in the discussions it is stated 'it does not take into account any dust control systems in place to minimise concentrations as would be the case if dust loadings are high' – dust control systems and the activation process will need to be articulated in the RMP.

28. There is a further reference to 'unplanned circumstances (e.g. a spill of thorium bearing material which is allowed to dry)' – the procedure for managing such unplanned circumstances must also be included in the RMP.

29. With respect to ingestion: It is stated that 'The potential for a notable uptake to occur is highly dependent on hygiene practices adopted on site. If gloves are worn, hands are washed regularly, and general care is taken, this will minimise the potential for an uptake of radioactive material by ingestion'. These hygiene practices should form part of the training of designated employees.

30. With respect to the annual worker dose estimate: The Report states 'If controls and appropriate safe work procedures are adopted for the handling of the concentrate as is proposed (e.g. controlled areas, remote handling, and minimising exposure time by rotating staff)', my recommendation is that such controls and appropriate safe work practices need to be articulated in the RMP and included in the staff training materials.

31. Section 9.1.6 and 9.1.7 Transport of final products by road and rail is outside my area of expertise and I am reluctant to comment in any detail except to highlight my area of concern which relates to the conflict between EPBC *Act* placing the onus on the proponent to be responsible for radiation safety during transportation of the material and the Victorian regulations that place the responsibility on the entity in possession of the material through their management licence. The proponent appears to be willing to

accept some responsibility by extending radiation monitoring programme to wharf facilities at the Port of Melbourne for an initial 12-month period but the responsibility of the radiation safety during transportation of the material needs to discussed and agreed between all parties.

General Public Impact

32. The Report identifies as a result of mining and processing operations, potential sources of exposure to members of the public are the off-site dispersal of airborne dusts or radon, the migration of contaminated groundwater into other water stocks, and long term effects from tailings disposal.

33. It is worthwhile to reiterate the statement in the Report 'To avoid significant radiological impact on members of the public it is essential that best practice with respect to radiation protection is deployed during all stages of mining, processing, transport and handling. This will include the appropriate disposal of tailings.' I have made specific mentions regarding the handling of the tailings in *paras. 10, 11* and *12*.

34. For the public exposure assessments, I am of the view that methodologies and numerical values used for estimates/calculations of the exposures to the public are appropriate.

35. As per the recommendation in the Mining Code (RPS 9 2005) the Report identifies the Critical Group as the residents in the farming district directly north of the project and south of the Mitchell River.

36. With regard the exposure to airborne dust inhalation during operations - using conservative assumptions the maximum annual effective dose to a Critical Group member of the public, as a result of dust inhalation is estimated as 29 µSv which is a factor of approximately 35 below the limit of 1 mSv.

37. The analysis of radionuclides in environmental dust should be included in the environmental monitoring program.

38. With regard to the exposure to radon/thoron gas I agree that the dose to a member of the public from this pathway is negligible. I support the inclusion of ongoing radon monitoring in the environmental monitoring program.

39. With regard to exposure via ingestion I agree that it is not plausible that an individual's entire annual diet of vegetables and cereals would originate entirely from one localized crop growing region and as such the prospective annual doses shown in Tables 17 and 18 of the Report represent conservative upper bounds.

40. In the community consultation it could be highlighted that the washing of locally grown crops prior to human consumption would mitigate the potential for any uptake of radioactive contaminants.

41. I have stated previously (*paras.* 17 and 23), clearly grazing animals will consume significant amounts of grasses daily and it is my view that the impact on downstream dairy and beef/lamb production should be considered in the risk assessment.

42. With respect to exposure via consumption of drinking water I am in agreement with the conclusion that the consumption of drinking water would be an inconsequential exposure pathway relative to other pathways assessed. I support the incorporation of the analysis of drinking water into the monitoring program during all phases of construction, operations and post closure.

43. With regard to the exposure during transport I am in agreement with the assessment of the various exposure scenarios but as I have alluded to previously transport of final products by road and rail is outside my area of expertise and I am reluctant to comment on any emergency response plans in the event of an accidental spill during transportation. I am of the view that the parties listed being the Proponent, those responsible for the Municipal Emergency Management Plan, East Gippsland Shire Council and other affected Councils along with the Victorian Department of Health and Human Services (DHHS) need to discuss and agree to the procedures.

44. Table 19 of the Report shows that estimated annual radiation doses for the Critical Group individual from all exposure pathways to 37 µSv for the year 20 operations which is a factor of 27 below the limit of 1 mSv.

45. The Report correctly identifies that compliance with the Mining Code (RPS 9, 2005) will be a condition of the management licence should the project proceed. The criteria on which DHHS Victoria 'may decide to require operations to comply with the Code will depend inter alia on potential doses to workers and to members of the public. Operations would generally be brought under the regulatory framework of the Code where doses to workers are expected to exceed the public limits, and doses to the critical group are likely to exceed some tens of microsieverts [µSv].'

46. The Report contains an extensive discussion and risk-based assessment of the potential threat that the project may pose to health and environment. However, this assessment is dated October 2018 and does not address extremes of weather which may very well impact the risk assessment. Such extremes include bush fires, water over the project site, extreme drought and dust storms all or some of which will occur over the proposed 20-year life of the project. However, procedures for fire management are addressed in the Environmental Management Framework.

47. The Report makes references to and discusses key elements of numerous Plans including:
    a. Radiation Management Plan,
    b. Radiation Monitoring Programme,
    c. Radiation Environment Plan,
    d. Radioactive Waste Management Plan, and
    e. Transport Management Plan

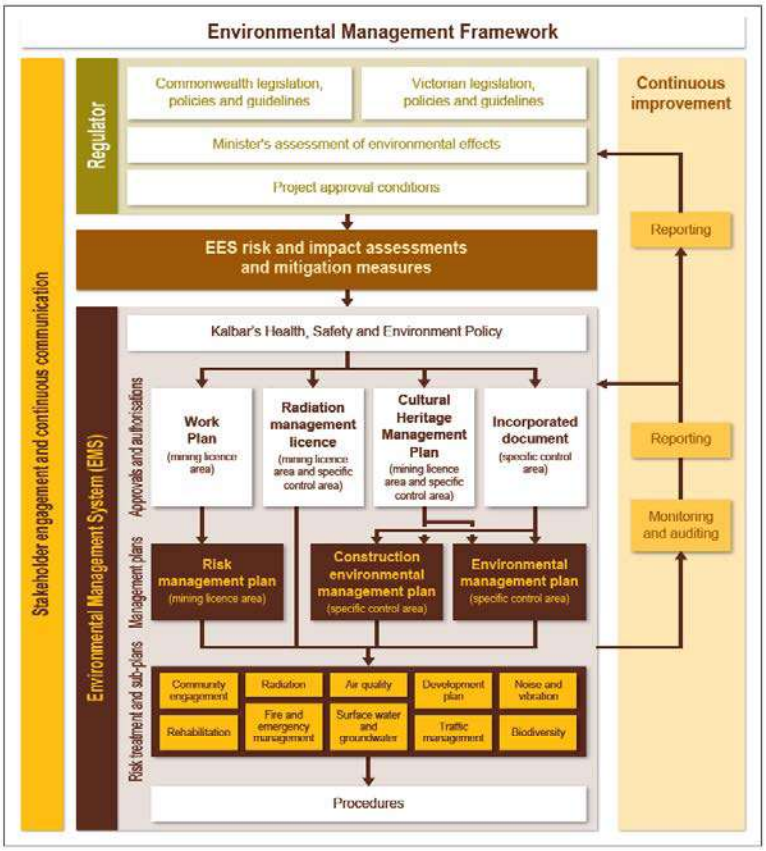
48. The section on Future Work Plan indicates that much of the work which will form the basis of these Plans is yet to be completed. More details regarding the various Plans is provided in the Environmental Management Framework (EMF)[3].

[3] Chapter 12 of the Environmental Effects Statement

The proposed management framework for risk from radiation and how the Report has been translated into the Environmental Management Framework.

49. The Environmental Management Framework (EMF) provides a governance framework for the management of the environmental impacts of the project. The EMF is a comprehensive document and identifies the government roles and responsibilities for activities within the mining licence area and areas subject to specific control overlays. With regard to radiation issues the Victorian DHHS will be responsible for
    - Issue of radiation management licence.
    - Review and approval of radiation management plan, radioactive waste management plan and radiation environment plan.
    - Regulation of compliance with requirements of radiation management licence.
    - Referral authority for airborne and deposited dust risk treatment plan, water quality and hydrology risk treatment plan and mine rehabilitation plan.

50. The EMF includes an instructive diagram which illustrates the various components and how they interact with each other. For ease of illustration I have included the diagrammatic representation below:



51. The radiation related issues form an integral part of the EMF and the various sub plans (Air quality; Surface water and ground water; Radiation; Rehabilitation and Fire and emergency management) contain high level descriptions of the contents of the various plans.

52. The Radiation Management Plan (RMP) and the Radioactive Waste Management Plan (RWMP) cover most of the key items and include appropriate monitoring, auditing and reporting. *Paras*. 26, 27, 28 and 30 contain specific items that should be included in the RMP. *Paras.* 10, 11 and 12 contain specific items which should be covered in the RWMP.

53. The Radiation Environment Plan will be made in accordance with ARPANSA guidance document Guide for Radiation Protection of Environments RPS G-1 2015 but as I point out in *para.* 17 this document specifically excludes stock, farmed, feral or domesticated species. Clearly grazing animals will consume significant amounts of grasses daily and it is my view that the impact on downstream dairy and beef/lamb production should be considered in the risk assessment and form part of the Radiation Environment Plan.

54. The Emergency Preparedness and Response Plan should take into account extremes of weather and include procedures for managing water over the project site, extreme drought and dust storms all or some of which will occur over the proposed 20-year life of the project. The Fire Management Plan appears to be sufficiently comprehensive.

Any other relevant matters related to the radiation report you consider the IAC should be aware of.

55. I do not have anything to add in this Section that I have not already dealt with in my expert witness statement.

[redacted]

Digitally signed by Kenneth H Joyner Ph.D.
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