REVIEW OF DAIRI PRIMA MINERALS TAILINGS STORAGE FACILITY DESIGN

Prepared for

BAKUMSU (Bantuan Hukum dan Advokasi Rakyat Sumatera Utara)

Report by

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SUMMARY

The Tailings Storage Facility (TSF) proposed by Dairi Prima Minerals (DPM) is to be located in an area of very high seismicity, very high rainfall, landslides, and on an extensive depth of weak volcanic ash of poor bearing capacity and potentially susceptible to earthquake shaking. These site conditions represent worst case scenarios in every respect, making the proposed tailings dam highly susceptible to failure, which would put the lives of a large number of people living in 11 villages downstream at risk, destroy livelihoods and crops, and cause severe environmental harm. DPM has over-estimated the proportion of tailings that will be accommodated as cemented underground backfill and hence has substantially under-estimated the proportion of tailings required to be stored in the TSF.

Given the extreme site conditions, the TSF proposed for an 8-year mine life, which is the focus of DPM's 2022 EIA Addendum, has inadequate stability according to the ANCOLD Guidelines on Tailings Dams. Further, the proposed 8-year mine life is misleading because the 2019, 2021 and 2022 EIA addenda allude to a possible mine life of up to 30 years. Further, a 2019 stock exchange disclosure statement[1] implies a 17-year mine life. Should the mine life be extended beyond 8 years, a much higher and larger TSF would be needed. DPM provided no details of the design for the ultimate TSF and little detail about closure of the TSF to ensure its stability in perpetuity. Given the inadequate stability of the 8-year TSF, the stability of the very much larger ultimate TSF would be inadequate and unacceptable.

DPM has not made sufficient data available to enable a full independent review of the proposed 8-year TSF. The only slope stability calculation provided by DPM for the tailings dam does not meet the minimum ANCOLD requirements and there is also no analysis of the impacts of a possible tailings dam failure, as required under ANCOLD.

The TSF will contain highly sulfidic tailings and will release untreated high sulfate and dissolved metal-laden water into streams an estimated 15% of the time. The TSF has only been designed for a 1 in 100-year flood event. Under ANCOLD, a 1 in 1,000-year flood needs to be accommodated during operation, and a 1 in 10,000-year flood needs to be accommodated post-closure.

DPM has analysed the tailings dam for only a 1 in 200-year earthquake. ANCOLD requires design for the 1 in 1,000-year Operational Basis Earthquake and the 1 in 10,000-year Maximum Design Earthquake for closure.

The proposed TSF does not comply with the ANCOLD Guidelines on Tailings Dams, as claimed by DPM. As such, it does not meet international expectations and requirements for tailings dam design, nor the safety and environmental standards applicable in Indonesia and China. The design information provided by DPM is grossly insufficient and inadequate to allow expert or regulator review. The proposed TSF should, therefore, be rejected.

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[1] http://pdf.dfcfw.com/pdf/H2_AN201904181320531728_1.pdf . Announcement of China Nonferrous Metal Industry's Foreign Engineering and Construction (NFC) on Fixed Asset Investment of its Controlling Subsidiary. Date: April 19, 2019.

EXECUTIVE SUMMARY

The proposed DPM Lead-Zinc Mine is located in the wet tropics of Northern Sumatra, Indonesia, in an area of very high seismicity, very high rainfall, landslides, and on an extensive depth of weak volcanic ash of poor bearing capacity and potentially susceptible to earthquake shaking. I agree with previous reports by Dr Emerman and Mr Meehan that these site conditions represent worst case scenarios in every respect (very high seismicity, wet climate, and unstable foundations), making the proposed tailings dam highly susceptible to failure.

Failure of the tailings dam would put the lives of a large number of people living in 11 villages downstream at risk, destroy livelihoods and crops, and cause severe environmental harm. As a result, the proposed tailings dam has an “Extreme” Consequence Category, requiring design for 1 in 10,000-year flood and earthquake loadings under the Australian National Committee on Large Dams Guidelines on Tailings Dam (ANCOLD, 2012 and 2019). The same would be required under the Canadian Dam Association Dam Safety Guidelines (CDA, 2007 and 2013) and the Global Industry Standard on Tailings Management (GISTM, 2020).

In all three EIA Addenda, DPM claimed that global geotechnical engineering consultant Knight Piésold designed the TSF. DPM also claimed that Knight Piésold and global geotechnical consultant Golder provided analysis and borehole data in 2008 and 2004, respectively. In none of the EIA Addenda were these designs and data provided and any input from these consultants pre-dated the current TSF location and design. Hence, neither of these consulting companies are responsible for the tailings dam design submitted by DPM.

DPM claims that the current TSF design complies with the ANCOLD Guidelines on Tailings Dams. However, the only slope stability calculation provided by DPM for the tailings dam does not meet the minimum requirements of ANCOLD and there is no analysis of the impacts of a possible tailings dam failure, as is required under ANCOLD.

The very high rainfall of the site makes TSF water management challenging, with both incident rainfall and rainfall runoff from the natural slope above the proposed TSF contributing large volumes of water to be managed. DPM has limited the flood design for the TSF to a 1 in 100-year flood event. Under the ANCOLD Guidelines on Tailings Dams, a 1 in 1,000-year flood needs to be accommodated during operation, and a 1 in 10,000-year flood needs to be accommodated post-closure. Hence, for flood design, it is clear that the DPM TSF design does not comply with ANCOLD.

The TSF will contain highly sulfidic tailings and will release untreated high sulfate and dissolved metal-laden water into streams an estimated 15% of the time. This clearly does not satisfy ANCOLD, nor would it meet any reasonable standard.

The earthquake loading reported by DPM was a Peak Ground Acceleration of 0.26 times gravity, which corresponds to about a 1 in 200-year earthquake. Under the ANCOLD Guidelines on Tailings Dams, the design should be for a 1 in 1,000-year Operational Basis Earthquake. The ANCOLD requirement for this “Extreme” Consequence Category tailings dam is to design for 1 in 10,000-year flood and earthquake loadings. The risk of a catastrophic tailings dam failure would continue to pose a threat to local communities in perpetuity, long after the mine is closed. Hence, for earthquake design, it is clear that the DPM TSF design does not comply with ANCOLD.

There is also considerable confusion about the required storage capacity of the TSF and the required height of the tailings dam, which have varied over time, will likely be staged, and depend on the presumed proportion of tailings that can be accommodated as cemented underground backfill. DPM has over-estimated the proportion of tailings that will be accommodated as cemented underground backfill. DPM claim that 70 to 75% of the tailings will be used for backfill when less than 50% is typical within the industry. Hence, DPM has substantially under-estimated the proportion of tailings required to be stored in the TSF.

I estimate that the required 8-year TSF storage capacity will be approximately 2.4 million cubic metres, 40% higher than DPM's estimate of 1.67 million cubic metres. A possible 30-year TSF storage capacity could be approximately 12 million cubic metres of tailings. Clearly, the increase in the required 8-year TSF storage capacity and a possible tripling of the tailings dam height over 30 years has severe implications for the safety of the population at risk downstream.

Little detail is given about materials for the construction of the tailings dam (simply soil and tunnel excavation waste rock), and a shortfall of material is expected (to be met by un-named third parties). DPM infers that the dam will be constructed in stages in the downstream direction, requiring large volumes of fill. Tunnel excavation waste rock is presumably only available for the first stage, which will exacerbate the expected shortfall in construction material for later stages. The use of unsuitable construction materials would exacerbate the risk of TSF collapse.

No design (strength) parameters are provided for the different materials (including the strengthening of the alluvium and upper Tuff). No indication is provided about the location of the phreatic surface (water surface within the tailings and dam; the higher the phreatic surface, the lower the stability of the dam), which would be expected to be high due to the very high rainfall at the site. There are also no calculations provided for other loading cases (including static loading in the short- and long-terms). Little is reported by DPM about the alluvium in the foundation or "improvement" of the alluvium and the extensive depth of weak Tuff beneath the dam, except that stone columns are proposed but not extending to the full depth of the weak Tuff requiring improvement.

The proposed sediment pond for the settling of suspended solids and the treatment of acid and metalliferous seepage and runoff are considered to be of inadequate capacity to handle the likely high suspended sediment loads and flow rates, and to provide the required retention time, and neither activated carbon nor lime treatment is adequately investigated in DPM's EIA Addenda.

There is no recommendation or plan for monitoring of the tailings dam during operations or post-closure, and no Emergency Response Plan including in the EIA Addenda. Towards closure, the tailings and decant pond are reported by DPM to be directed towards the northern end of the dam, although it is not clear whether this will lead to super-elevated and likely liquefiable tailings (in the event of a large earthquake) that could overtop the dam.

Limited details are provided about the proposed eventual cover over the tailings and its proposed function and revegetation. No details are provided about how a cover would be placed on wet tailings at closure, and what proportion of the tailings would be covered by water and over what period of the year. There are also no details provided about the ongoing effectiveness of the upstream toe drain, and whether it will continue to need to be operated (pumped) post-closure.

From my experience, tailings dam design in Indonesia generally follows the ANCOLD Guidelines on Tailings Dams. Compliance with ANCOLD is well accepted in law as the approach that a "reasonable tailings dam design engineer" would be expected to take. As a member of the Working Party for the ANCOLD Guidelines on Tailings Dams, I am very familiar with its intent and can state that DPM's proposed 8-year TSF design does not comply with ANCOLD, as falsely claimed by DPM. The site is located in an area of very high seismicity, very high rainfall, landslides, and located on weak foundations of poor bearing capacity and potentially susceptible to earthquake shaking. Further, the proposed TSF is located upstream of a substantial population, in addition to cropping land and environmental values. Under these conditions, ANCOLD would assign an "Extreme" Consequence Category for this dam, which DPM has not designed for. The ultimate height of the dam, which may be three times higher than has been considered, would also not comply with ANCOLD, and DPM's emergency response and closure plans are grossly inadequate. The design information provided is grossly insufficient and inadequate to allow expert or regulator review, and the proposed TSF should be rejected on multiple grounds.

TABLE OF CONTENTS

1. INTRODUCTION

Dr David John Williams was requested by Bantuan Hukum dan Advokasi Rakyat Sumatera Utara (BAKUMSU) to review the design for a Tailings Storage Facility (TSF) for Dairi Prima Minerals (DPM) Mine in North Sumatra, with reference to other reports prepared by Dr Steven Emerman and Mr Richard Meehan.

2 SCOPE OF WORK AND REPORT

The scope of work included:

- Review of documents, including digital translation of Indonesian documents.
- Communication with Dr Emerman and Mr Meehan.
- Potentially liaising with an Indonesian civil engineer who may be able to visit the DPM site.
- Preparation of a Draft Report for comment.
- Finalising the Report.

The Report includes Summary, Executive Summary, text, my qualifications and experience, and references and appendices. The report primarily reviews the DPM 2022 EIA Addendum that was the subject of the Indonesian Ministry of Environment and Forestry's Environmental Approval for DPM. Of particular issue is DPM's claimed compliance with The Australian National Committee on Large Dams (ANCOLD, 2012 and 2019) Tailings Dam Guidelines, including the stability of the proposed TSF. My review of reports by Dr Emerman and Mr Meehan is also included.

3 DOCUMENTS PROVIDED BY BAKUMSU

The documents provided by BAKUMSU included:

- Extracts (in Indonesian) of the DPM 2022 EIA Addendum.
- 2020, 2021 and 2023 Reports by Dr Emerman.
- 2020, 2021 and 2023 Reports by Mr Meehan.
- 2019 and 2021 Draft DPM EIA Addenda.
- NGO submission to the Indonesian Environmental Impacts Assessment committee hearing.

4 BACKGROUND

Local community people, supported by NGO and independent lawyers, and reports by international experts, took the Ministry of Environment and Forestry (the Ministry) to court for providing Environment Approval to the DPM Mine. The Jakarta Administrative Court (High Court) decided in favour of the community. However, the Ministry and DPM lodged an appeal to the High Court, which ruled in their favour. At the time of writing, an appeal by communities against the High Court decision was lodged at the Supreme Court. Following the Supreme Court review, the case is expected to go to "Judicial Review" by the Indonesian Supreme Court.

The decision of the High Court, Number 265/B/LH/2023/PT.TUN.JKT, dated 22 November 2023, accepted the Ministry and DPM's appeal, and cancelled the previous Court ruling in favour of the people of Dairi, as follows:

1. PT Dairi Prima Mineral is the holder of the Decision regarding the Environmental Feasibility of Zinc and Lead Mining Activities in North Sumatra, dated 11 August 2022.
2. DPM has fulfilled the procedures and requirements in the mining industry as per the applicable laws and regulations by involving all elements of the community in the preparation of the Environmental Impact Assessment Addendum.
3. Most of the local communities do not object to the presence of a mining company (DPM) in their area considering that it will increase the income of community members and reduce unemployment as explained by witnesses Jacobus Sirait and Nurhayati Purba in the trial on 27 June 2023.
4. The lawsuit of Dairi residents does not represent the voice of all residents in Dairi Regency because most of them do not object to DPM's presence in their area.
5. The issuance of the Decision regarding the Environmental Feasibility of the DPM Mine in North Sumatra has gone through a very comprehensive consideration by requiring DPM to complete the EIS Addendum with a Recommendation Letter from the Head of the Dam Engineering Centre and a Recommendation Letter from the Director of Environmental Engineering of the Ministry of Energy and Mineral Resources.

5 REVIEW OF SUPPLIED REPORTS

The following sections discuss the key findings of the supplied reports in order from the most recent.

5.1 DPM 2022 EIA Addendum

Excerpts of the DPM 2022 EIA Addendum were provided in Indonesian, relevant parts of which I translated using Google translate. The Addendum was not structured in a logical order, which has been redressed in the discussion below.

The key findings relevant to the TSF (with my comments in ***bold italics***) are given in the following sections.

5.1.1 Tailings Storage Facility

- The TSF is located in an area of undulating ground generally sloping at up to 12 percent, increasing to 24 percent towards the west.
- The relocated TSF is located on protected forest and dryland agriculture. ***The TSF was apparently relocated for environmental reasons, although the new location impacts an area of protected forest.***
- DPM claims to have considered risks arising from seepage and landslide, acknowledging the high rainfall, earthquakes, soil liquefaction ***(presumably of the deep tuff volcanic ash in the foundation)*** and shallow groundwater.
- DPM drilled 28 boreholes at the TSF location, ranging in depth from 7.6 to 80.0 metres with an average depth of 40.0 metres.
- The TSF site is underlain by:
    - Up to 3 metres of topsoil and plastic (clayey) residual soil.
    - Weathered soft sandy tuff to about 16 metres depth, which softens on exposure to water.
    - Medium weathered tuff to about 53 metres depth, which is rather difficult to soften by wetting.
    - Slightly weathered tuff to about 63.5 metres depth.
    - Overall, the Toba tuff extends down to 80 metres depth and is of very low Rock Quality Designation.
- The general layout of the final TSF is shown in Figure 1 (reproduced from Figure 2.45 in the Addendum).
- The capacity of the TSF is approximately 1.67 million cubic metres to an elevation of about 605 metres above sea level (a maximum height of 28 metres), which will be built in several stages in the downstream direction, requiring large volumes of fill. This is to accommodate 25 to 30% of the tailings production with the remaining 75 to 70% delivered as paste backfill in underground stopes (mining voids, to provide support).

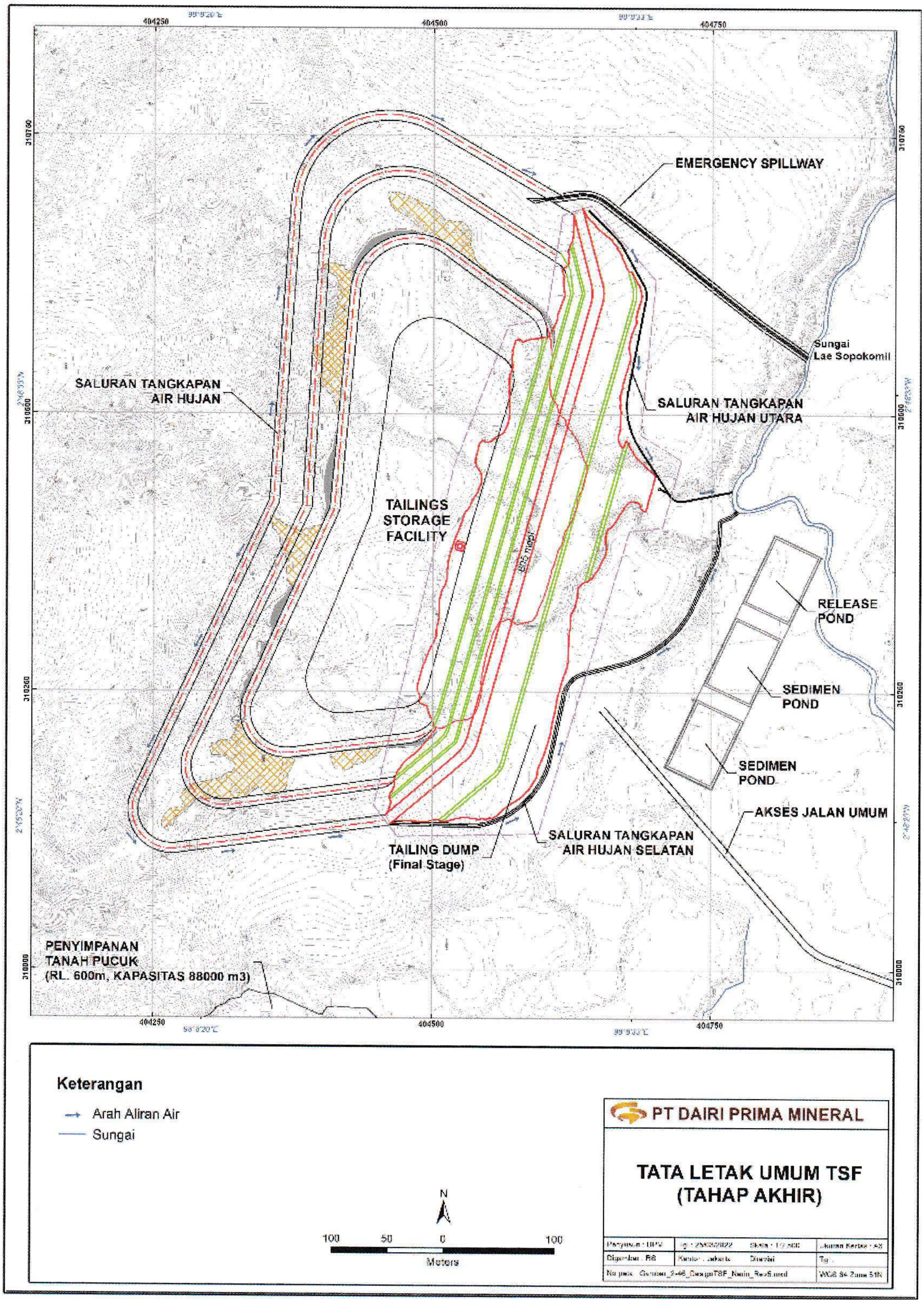

Figure 1 Proposed general layout of final TSF

- ***Published experience (Sivakugan et al. 2015) suggests that the proportion of tailings required for underground backfilling is typically less than 50% of the total tailings produced, due to its much lower density and higher porosity compared with the natural rock it replaces and the need to keep operating sections of the underground mine open. Hence, approximately 2.4 million cubic metres of tailings storage capacity will initially be required (a 40% increase on DPM's estimated initial storage requirement for 1.67 million cubic metres).***
- DPM proposes to excavate 454,000 cubic metres of material from beneath the tailings dam itself, including:
    - An average thickness of 0.5 metres of topsoil, which will be stockpiled for later use.
    - A 1.2 to 16 metre thickness of soft Toba tuff.
    - ***The thickness of unsuitable foundation material is well in excess of the proposed depth of excavation. Further, it is unknown where the unsuitable excavated material will be placed.***
- To increase the low bearing capacity of the tuff foundation, stone columns are proposed, which will also improve drainage and speedup the consolidation of the tuff under the loading imposed by the dam. ***The depth, specifications and construction of the stone columns are not detailed.***
- The tailings dam will be raised progressively using the downstream construction method and is estimated to require 526,000 cubic metres of rock fill and is proposed to be constructed mainly (about 82%) using waste rock from the underground mine development tunnels, plus other sources including third parties, with technical specifications in accordance with the design***, which are not specified.***
- The emergency spillway is proposed on the north side of the TSF and will discharge to the Sopokomil River, which it is inferred ***(without supporting calculations)*** would correspond to a 1 in 500-year flood generating a spillway flow rate of 2.97 cubic metres per second ***(256,600 cubic metres per day, equivalent to 1 metre depth of water over an area of 257 ha, about ten times the footprint of the TSF).***
- As shown in Figure 2 (reproduced from Figure 2.48 in the Addendum), the tailings dam is proposed to have a double high density polyethylene (HDPE) liner separated by a drainage layer on the upstream face underlain by a low permeability (compacted soil) layer, which is to also underlie the base of the TSF and dam. Water collected in the drainage layer is proposed to be pumped back to the tailings. ***Details of the thickness and specifications of the drainage layer and of the thickness and permeability of the low permeability layer are not specified. The drainage layer would presumably need to be pumped to relieve hydraulic head on the lower HDPE, possibly in perpetuity post-closure.***

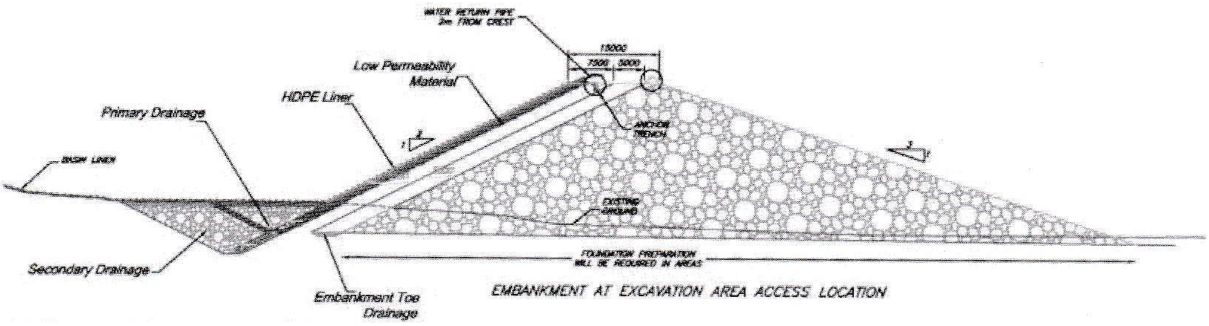

Figure 2 TSF cross-section showing upstream HDPE liner and drainage system

- A V-shaped drain is proposed at the upstream toe of the dam to aid consolidation of the tailings, with a collection pipe up the upstream face of the dam. ***Clearly, the water collected in the drain would need to be pumped to the surface for return to the processing plant. However, the top of the drain would blind off with consolidated tailings and become increasingly less effective. On the other hand, continued effectiveness of the drain post-closure would require ongoing pumping.***
- DPM provided just a single slope stability plot for the initial 28 metre high tailings dam (reproduced from DPM Figure 2.44 as Figure 3), for earthquake loading, giving a calculated factor of safety of 1.15 for a Peak Ground Acceleration (PGA) of 0.26 times gravity***, which corresponds to about a 1 in 200-year earthquake and is lower than the 1 in 1,000-year ANCOLD Operational Basis Earthquake (OBE).***

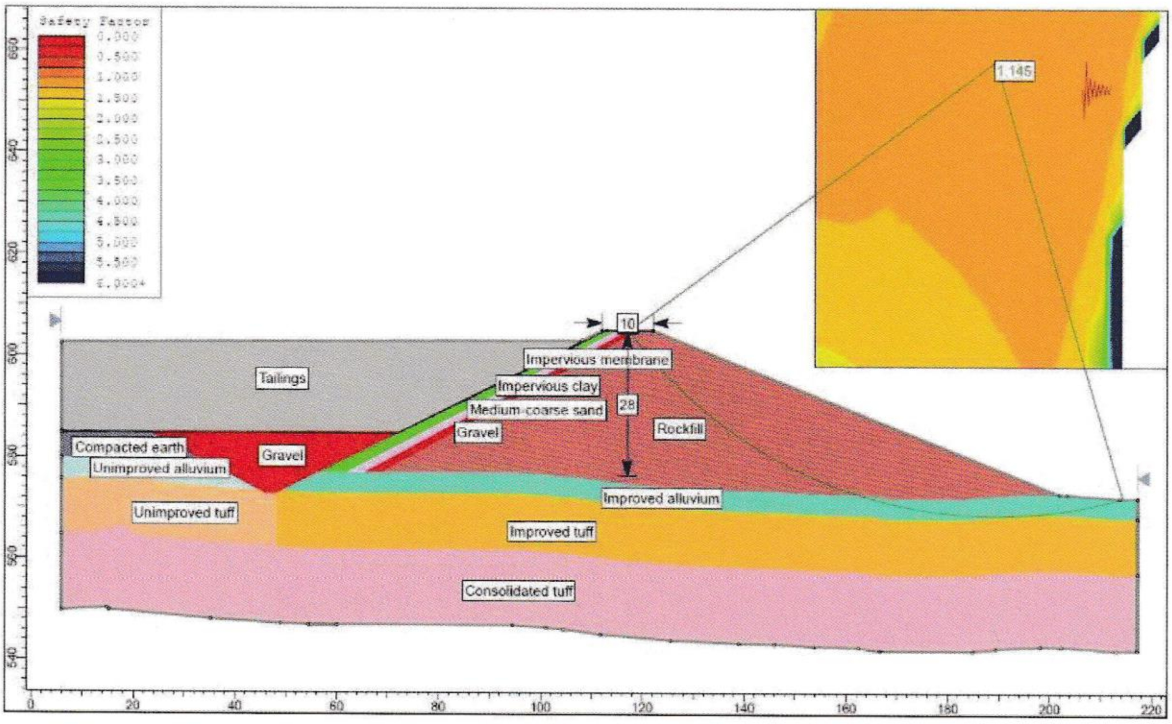

Figure 3 Calculated factor safety for a peak ground acceleration of 0.26 times gravity

- ***The design earthquake magnitude of 7.7 estimated by DPM's consultants and the resulting PGA of 0.5 times gravity are both well above the accepted thresholds for the liquefaction or strain-softening of susceptible materials such as tailings and the weak Tuff foundation beneath the tailings dam (Green and Julian Bommer, 2018 giving a threshold magnitude of 4.5 to 5 and Williams, 1992 and de Magistris et al. 2035 giving a threshold PGA of 0.09 to 0.13 times gravity).***
- ***The minimum factor of safety recommended by ANCOLD (2012 and 2019) for earthquake loading is 1.0 to 1.2, with the upper end of this range being applicable to this site, given the paucity of data. Clearly, this one slope stability plot does not satisfy ANCOLD, and an appropriate selection of PGA would certainly also not.***
- ***For a "High" or "Extreme" Consequence Category, ANCOLD (2012 and 2019) specifies a 1 in 1,000-year return interval for the OBE during the operational phase of the TSF only***, for which DPM quotes a PGA of 0.47 times gravity.
- ***The Maximum Design Earthquake (MDE) PGA for a "High" or "Extreme" Consequence Category would be higher again and would apply post-closure.***
- DPM quotes an MDE PGA of 0.489 times gravity, rising to 0.69 times gravity, which is stated by DPM to meet Indonesian requirements. DPM presents no analyses for any PGA values greater than 0.26 times gravity***, despite quoting values far higher than this, which would have a far more damaging effect.***

5.1.3 Tailings Deposition

- The tailings to be stored in the TSF are proposed to be pumped a distance of 3.2 kilometres from the processing plant to the TSF at a solids content 65% by mass, requiring thickening***, which is not specified (65% solids is a high solids content to achieve by high rate or compression thickening).***
- The tailings to be used as underground backfill is proposed to be pumped a distance of 600 metres from the thickener to a paste plant***, for which the expected % solids is not specified.***

5.1.3 Water Management and Quality

- The TSF is located in about a 33 hectare catchment and covers an area of 19 hectares.
- DPM has restricted the design of the TSF to accommodate only a 1 in 100-year rainfall event***, despite the high rainfall of the site and their acknowledgement that spillway discharge and seepage are risks.***
- An emergency spillway is proposed on the north side of the dam, which DPM expects would discharge rainfall events greater than the 1 in 500-year storm directly to the Sopokomil River. ***Spillway discharge would deliver contaminated tailings water to the river.***
- Sediment traps in the form of fences covered in geotextile are proposed, which are intended to allow flow to continue. ***However, the geotextile cover would silt-up and dam both sediment and water, before overtopping.***

- The tailings will be high in sulfides that will oxidise on exposure to the atmosphere and are expected to contain average concentrations of 470 milligrams per litre (mg/L) of sulfate, 2.31 mg/L of magnesium, 0.09 mg/L of copper, 0.18 mg/L of lead and 0.08 mg/L of zinc, all of which are above the water quality standard for the Sopokomil River, with an average pH of 9.4.

5.1.4 Post-Closure

- DPM proposes that post-closure decant water will be removed from the surface of the TSF to allow desiccation and strength gain to enable trafficking. ***However, desiccation occurs only to a limited depth (typically less than 600 millimetres, refer to Williams et al. 2018) and the effect reduces exponentially with depth. In the wet climate of the site, there is no guarantee that desiccation would be sufficient to render the tailings surface trafficable.***
- DPM proposes to treat the excess decant water using charcoal or activated carbon prior to settling and discharge to the river***, which is not a recognised treatment approach for acid and metalliferous water according to Ighaloa et al (2020), for example, and would not guarantee water of acceptable quality for discharge to the river.***
- DPM proposes that post-closure the tailings surface footprint will be reshaped to direct rainfall runoff northwards towards the decant pond***, which presumes without evidence that the tailings surface will be trafficable.***
- Over the three years following closure, DPM proposes that dry tailings areas will be covered with a growth medium and revegetated***, although the design of the cover, cover materials, and plant species are not clearly specified:***
    - DPM proposes an initial 60 to 120 centimetre cover of compacted sandy clay***, which would have a low permeability (not increased permeability as claimed by DPM).***
    - This layer is proposed to be covered by 30 centimetres of topsoil and 5 centimetres of straw to provide nutrients.
    - Initial legume revegetation is proposed, followed by acacias to increase transpiration to greater than 3 millimetres per day.
- A wet tailings area and pond will remain post-closure at the northern end of the TSF adjacent to the spillway, where rainfall runoff will collect and spill to the Sopokomil River when the rainfall exceeds to highest recorded monthly rainfall of 322.7 millimetres. ***This is an unusual way of specifying a spill event, which is normally expressed in terms of a rainfall exceeding a certain return interval. DPM previously specified a spill as exceeding the 1 in 500-year flood.***
- Post-closure, DPM proposes covering the wet tailings area with 1.2 metres of soil and planting with aquatic plants capable of absorbing residual dissolved metals. ***DPM does not describe how any soil cover could be placed in the wet tailings area, which would have very low bearing capacity. Without a cover, tailings would form the substrate, which may not support plants and would likely continue to release dissolved metals.***

- Between the dry and wet tailings areas, the tailings surface will alternate between wet (during the wet season) and dry (during the dry season if there is sufficient spill and evapotranspiration).
- Post-closure, DPM proposes planting aquatic plants, ***although DPM does not specify a cover, which would also be difficult to place.***
- Post-closure, DPM proposes the ongoing monitoring of seepage, which would be pumped back to the TSF. ***Given the wet climate of the site and the periodic (if not permanent) ponding on the TSF, seepage would be expected to continue in perpetuity, requiring ongoing pump-back. DPM has made no acknowledgement of the expected need to pump-back in perpetuity and hence has accepted no responsibility for it.***

5.2 Reports by Dr Emerman

Dr Emerman reviewed the hydrological (surface water) aspects of the proposed DPM TSF in reports dated August 2020, August 2021 and June 2023.

5.2.1 August 2020 Report

Dr Emerman reported that the proximity of the proposed tailings dam to populated areas would make the location illegal in China. The proposed tailings dam would be located less than 1,000 metres upstream of numerous homes and places of worship, which would be illegal in China. The design of the tailings dam to accommodate only a 100-year flood (the scale of which is not specified by DPM) is inconsistent with international guidelines and apparently also inconsistent with Indonesian regulations that require design for the Probable Maximum Flood, which would be significantly rarer than even a 10,000-year flood. Dr Emerman also referred to cases of acid mine drainage from lead-zinc mines in China inevitably impacting the environment.

The raw water requirement is not specified by DPM but is estimated by Dr Emerman to be 0.5 to 5 to million cubic metres per annum or 6 to 66% of the streamflow to Parongil Village (processing 1 ton of Zinc ore would be expected to require 0.612 cubic metres of water, and 1 ton of Lead ore 0.182 cubic metres of water, equivalent to about 20 cubic metres of water for 1 ton of Zinc concentrate, and over 7 cubic metres of water for 1 ton of Lead concentrate). DPM considered only the first 8 years of operation with the tailings contained in a tailings dam up to 25 metres high.

Baseline surface and groundwater quality data are limited in the number of metals tested for and areal coverage (and not reliably located), and contradictory data are reported. No geochemical testing of the expected waste rock (to be used in the construction of the tailings dam) or tailings has been carried out. There will also be a surface waste rock dump containing potentially acid generating waste rock, but no mention is made of its encapsulation by non-acid generating waste rock, if it exists, to limit acidic drainage.

It is not clear to what extent the tailings would have a water cover, during operations and/or post-closure, which would limit the ingress of oxygen and hence the generation of acidic drainage. There is no long-term prevention methodology offered for acidic drainage. There is no contingency plan, or any other plans (implying no Emergency Response Plan). There is no closure plan for the TSF.

5.2.2 August 2021 Report

Dr Emerman reported that the 2021 EIA Addendum submitted by DPM does not change any of the hydrologic aspects of the proposed tailings dam, although it provides clarification regarding the proportion of tailings to be stored in the underground mine, the design flood, the post-closure plan for the TSF, and the availability of non-acid-generating waste rock for dam construction. However, the clarifications do not change Dr Emerman's recommendation for rejection of the proposed TSF on hydrological grounds; that is, the severe impact of flooding and acid mine drainage.

DPM claims that 70 to 75% of the tailings will be used as backfill in the underground mine, which is contrary to the opinions of both myself and Dr Emerman, based on published experience, that suggest that less than 50% of the tailings can be used as underground backfill.

The proposed tailings dam is designed to withstand only a 100-year flood and would not protect people and the environment downstream. Following closure of the tailings dam, the flow of toxic and acidic tailings pond water through the emergency spillway and into downstream water bodies without treatment for removal of contaminants would occur 15 per cent of the time and is unacceptable.

DPM's claim that non-acid-generating waste rock from the underground mine will be available for construction of the tailings dam and for confining the potentially acid-generating waste rock in a free-standing waste dump was based upon only four rock samples. This number of samples is insufficient to support such a claim. The ratio of non-acid-generating to potentially acid-generating waste rock would need to be confirmed and high to justify this claim. If there is insufficient non-acid-generating waste rock to encapsulate potentially acid-generating waste rock, downstream contamination in this very high rainfall area would be severe. Dr Emerman found numerous contradictions among the tables, graphs and maps in the updated Addendum, as well as arithmetic errors.

5.2.3 June 2023 Report

Compared with the 2021 EIA Addendum, the significant changes to the hydrological aspects contained in the 2022 EIA Addendum submitted by DPM are the increase in the height of the tailings dam from 25 to 28 metres and the increase in the tailings storage from 1.2 to 1.67 million cubic metres.

The downstream population at risk includes numerous homes and houses of worship within 1,000 metres and about Parongil village with a population of 2010 located about 1,800 metres downstream of the tailings dam. For this level of risk, the design of the tailings dam for a 100-year flood is non-compliant with the ANCOLD (2012 and 2019) Guidelines on Tailings Dams that require design for the Probable Maximum Flood.

The close proximity to populated areas would be illegal under Chinese regulations. Under the National Standards of the People's Republic of China (2020), the tailings dam at the DPM Mine would have an initial height of at least 28 metres and an initial stored volume of up to approximately 2.4 million cubic metres (for 50% of the tailings produced), so that it would be a Class III dam based on its height and a Class IV dam based on its stored volume.

The 2022 EIA Addendum contains less rainfall and baseline data than previous versions and even contradicts data in previous versions. Dr Emerman recommended that the proposed TSF be rejected without further consideration.

5.3 Reports by Mr Meehan

Mr Meehan reviewed the safety of the proposed DPM TSF in reports dated April and July 2020, May 2021 and June 2023.

5.3.1 April 2020 Report

The DPM Mine is located in an area of very high earthquake risk, and very high flood and landslide hazard. With a catchment of about 10 square kilometres, a 1 square kilometre TSF would have to handle in the order of 5 to 10 metres of water level rise in an extreme storm. Landslides would place even further risk to the TSF. The location of the tailings dam has complex geology comprising sedimentary rocks and more-recent volcanic ash (Toba tuff), which present significant concerns for its foundation.

Mr Meehan estimated the annual rainfall of the site to be 3,000 to 5,000 millimetres, with daily rainfall of 300 millimetres common, and 500 millimetres per day likely. He noted that there is no geotechnical investigation, and no detailed tailings dam design. The stability of the tailings dam over 10,000 years post-closure (as required under ANCOLD, 2012 and 2019) is questioned, as is potential acid and metalliferous seepage and runoff, because of the high sulfide Zinc-Lead orebody.

In addition to the very high earthquake, flood, and landslide risks, and the poor dam foundation conditions, Mr Meehan found that the design information about the proposed TSF was limited, and the regulatory environment is weak. As a result, he concluded that the proposed DPM TSF presents a high risk of catastrophic failure, placing communities, cropping land and the environment downstream at serious risk.

Mr Meehan considered the data gaps to be the tailings volume to be stored; TSF site, foundation and design details; and TSF monitoring and safety review during operations and post-closure. Further, Mr Meehan considered the proposed DPM TSF almost certain to result in a human and environmental disaster on the scale of the El Cobre, Aberfan, and Brumadinho disasters.

5.3.2 July 2020 Report

In the Environmental Impact Assessment (EIA) Addendum dated October 2019, the proposed mine was much reduced from the original 30 million (dry) ton, 30-year mine life to about 6 million (dry) tons, reducing the TSF to a hillside, off-stream storage for about 1.2 million cubic metres of tailings located 3 kilometres downstream of the mine.

The proposed TSF design also depends on the permanent integrity of a "geomembrane" (plastic) seepage barrier and internal drain system to limit seepage and so maintain downstream water quality. Mr Meehan did not consider that this design would limit seepage and maintain downstream water quality in the long-term, potentially leading to lead-contaminated water downstream.

5.3.3 May 2021 Report

The 2021 EIA Addendum submitted by DPM requested approval for a 1.2 million cubic metres TSF, with a long-term plan to expand this about five-fold to 6 million cubic metres. New boreholes found that the weak tuff extends to 50 metres depth or more, with implications for the stability of the tailings dam.

Insufficient and inadequate details were provided by DPM to enable a review. DPM claimed that Knight Piésold and Golder provided analysis and borehole data in 2008 and 2004, respectively, but these were not provided in the EIA Addenda and pre-date those Addenda.

DPM proposed stone columns and improvement of the weak tuff to 10 metres depth, which would be impractical and to insufficient depth.

5.3.4 June 2023 Report

In his June 2023 Report, Mr Meehan reviewed the 2022 EIA Addendum submitted by DPM, which he found still did not contain important information sufficient to evaluate the safety of the proposed TSF. The latest addendum specified a TSF initially storing 1.67 million cubic metres of tailings with the potential to ultimately expand five-fold, located next to and above the Sopokomil Village.

The geology of the new proposed TSF is poorly understood, particularly the depth and strength of the tuff, although DPM acknowledged that the foundation includes "earthquake-prone, liquefiable soil", "soft", and subject to "settlement". DPM has progressively shifted the proposed location of the TSF after successive borehole investigations revealed unstable foundation materials. In their EIA 2022 Addendum, DPM proposed ground improvement to only 16 metres depth while acknowledging that the weak tuff was in excess of 50 metres deep. The foundation with shallow ground improvement, if this were even possible, would still be susceptible to earthquake-induced failure.

The design earthquake of magnitude 7.7 was estimated by DPM's consultants to result in a peak ground acceleration of 0.5 times gravity, compared with Mr Meehan's estimate of 0.5 to 1 times gravity. Mr Meehan considers 0.5 times gravity to be a reasonable design value for a stable rock foundation, but the foundation comprises an average 30 metre depth of weak unconsolidated tuff (too deep to be excavated or reinforced) that would be expected to magnify rock shaking to 1 times gravity.

DPM has not complied with ANCOLD (2012 and 2019). Only a single calculation of factor of safety was presented, and this was for less than the earthquake loading according to the Consequence Category based on ANCOLD. Other loading cases required by ANCOLD were not reported, no earthquake deformation analysis was reported as required by ANCOLD for the very high earthquake loading, and there has been no independent Third Party Review of the TSF design. Further, none of the three EIA addenda provided sufficient information to enable such a review. Mr Meehan concluded that the proposed TSF design is inadequate in terms of stability and maintaining downstream water quality.

5.4 Agreement with Dr Emerman and Mr Meehan

Dr Emerman is an internationally-recognised expert in hydrology related to mining and Mr Meehan is an internationally-recognised expert in the stability of tailings dams. I am an internationally-recognised expert in the design of tailings dams. I am in total agreement with the reviews of the proposed DPM TSF undertaken by Dr Emerman and Mr Meehan. This recognises the lack of information provided by DPM to undertake a review, while supporting the collective view that there is sufficient information provided by DPM to demonstrate that the TSF does not satisfy the requirements of ANCOLD 2012 and 2019), as claimed by DPM. Equally, it would not be possible for any reviewer or regulatory body to make a responsible decision about the safety of the proposed TSF based on the limited information that DPM has provided.

5.5 Draft 2019 and 2021 DPM EIA Addenda

The original proposal presented in the 2005 EIA was for a 30 million (dry) ton underground mine with a 30-year mine life. The majority of the tailings were proposed to be used as cemented underground backfill, with the remaining wet tailings to be stored in a TSF located 2 kilometres from the mine with a footprint of 100 ha. ***The ultimate height of the original tailings dam was not given but is estimated to be approximately 75 m.***

The draft 2019 and 2021 DPM EIA Addenda described briefly in the following sections, preceded the Final 2022 EIA Addendum.

5.5.1 2019 EIA Addendum

The 2019 EIA Addendum downsized the proposal to a 6 million (dry) ton underground mine with an 8-year mine life, reducing the volume of wet tailings to be stored to 1.0 million cubic metres with a corresponding reduction in the footprint and height (to a maximum of 25 metres) of the tailings dam from that originally proposed. Further, the TSF location was moved to 3 kilometres from the mine to the location that is currently proposed.

All three experts agree that the major issue with the proposed TSF is its location in a region of very high seismicity, very high rainfall, and unstable foundations. The proposed tailings dam is located above the complex of faults that produced the 2004 9.1-magnitude earthquake and associated tsunami. Rainfall data are limited, and the site would be expected to receive annual rainfall of between 3.0 metres and 5.0 metres. Information on the site geology and landslides is also limited, although landslides are common given the very high rainfall and weak weathered Toba tuff to extensive depth.

All three experts agree that the social and environmental impact of a tailings dam collapse could be catastrophic. There are approximately 11 villages located around or downstream of the proposed mine and TSF. ***The 2019 draft EIA Addendum did not adequately consider these risks and lacked the necessary information about the seismicity, geology, and hydrology of the proposed tailings dam site.***

5.5.2 2021 EIA Addendum

New boreholes described in the 2021 EIA Addendum found that the weak tuff beneath the tailings dam extends to 50 metres depth or more, with implications for the stability of the tailings dam. DPM proposed stone columns and improvement of the weak tuff to 10 metres depth, which would be impractical and to insufficient depth. DPM reported a factor of safety of 1.15 for the proposed tailings dam on this weak foundation, which is well below the minimum value recommended by ANCOLD (2012 and 2019) of 1.5.

DPM claimed that Knight Piésold and Golder provided analysis and borehole data in 2008 and 2004, respectively, but these were not provided in the EIA Addenda and pre-date those Addenda.

5.6 NGO Submission

The Dairi region in Northern Sumatra is famous for agricultural products through clean processes that are of good quality. Previously, the Jakarta Administrative Court ruled that the Environmental Approval of the DPM Mine was invalid and ordered the Ministry of Environment and Forestry to revoke the permit. However, on appeal by DPM and the Ministry the High Court on 22 November 2023 reversed the Administrative Court decision. The Toba and Pakpak communities claim that the mine will kill people, destroy their agriculture, and damage the environment and will lodge an appeal to the Indonesian Supreme Court.

The Toba and Pakpak communities are being assisted by the North Sumatra People's Legal Aid and Advocacy Association and other NGOs and lodged a submission to the EIA Commission in May 2021. This submission referred to and gave links to reports on the 2019 and 2021 EIA Addenda by experts Dr Emerman and Mr Meehan, which had been provided directly to the Ministry of Environment and Forestry.

DPM subsequently produced the 2022 EIA Addendum, which the Ministry of Environment and Forestry used as a basis for providing Environmental Approval for the DPM Mine, and which Dr Emerman and Mr Meehan also reported on. Dr Willams, after reviewing all three sets of reports related to three versions of the EIA Addenda concurs with Dr Emerman and Mr Meehan that none of the dangers and deficiencies raised (and provided by BAKUMSU to the EIA Commission and the Ministry of Environment and Forestry) were adequately addressed in the 2022 EIA Addendum on which the Ministry of Environment and Forestry issued Environmental Approval. In fact, all three experts contend that the 2022 EIA Addendum contained more errors, inconsistencies and causes for concern than the previous two versions.

All three versions of the EIA Addenda contained DPM’s claim that international design standards were applied, through implementing ANCOLD. All three experts concur that this claim is not substantiated by DPM and there is no evidence for anyone to agree with their claim.

6 EXPERT GEOTECHNICAL REVIEW

This section provides my expert geotechnical review of the proposed design submitted by DPM for the above-ground TSF at their mine in North Sumatra.

6.1 Tailings Dam Location, Design, and Compliance with Good Practice

DPM has apparently relocated the TSF from the Protected Forest to an area used for cropping. While this avoids disturbance to the Protected Forest, it will put at risk a large number of people located in the 11 villages in the valley downstream of the TSF and impact cropping land.

DPM claims to have carried out the tailings dam design in accordance with ANCOLD (2012 and 2019). However, there is no Risk Assessment, which underlies the ANCOLD Tailings Dam Guidelines, and there is no Dam Failure or Environmental Spill Consequence Category Assessment (the former should be "Extreme", given the population, cropping land and environmental values at risk downstream, and the very high seismicity, very high rainfall, and unstable foundations at the site).

No details of required geotechnical, hydrological (surface water), and hydrogeological (groundwater) investigations, analyses and design are provided. The design storm according to ANCOLD (2012 and 2019) has not been calculated and applied. There is no Basis of Design, nor any selection and justification of design parameters (particularly material strengths and permeabilities).

There is no TSF design, and no Third Party Review. DPM has not indicated the extent to which the tailings may be maintained near-saturated or underwater during the operation of the TSF and post-closure, to minimise oxygen ingress and the oxidation of the sulfide tailings. There is no Dam Break and Runout Analysis for any Credible Failure Modes, and Credible Failure Modes are not identified. The expectations of the Global Industry Standard on Tailings Dams (GISTM, 2020) are not mentioned, although these are largely covered under ANCOLD (2012 and 2019).

6.2 Methodology and Criteria Applied

6.2.1 Geotechnical Slope Stability

DPM provided just a single slope stability plot for the initial 8-year 28 metre high tailings dam (see Figure 3), for earthquake loading, with a calculated factor of safety of 1.15 for a PGA of 0.26 times gravity, which corresponds to about a 1 in 200-year earthquake and is lower than the OBE. For a "High" or "Extreme" Consequence Category, ANCOLD (2012 and 2019) specifies a 1 in 1,000-year return interval for the OBE during the operational phase of the TSF only, for which DPM quotes a PGA of 0.47 times gravity, increasing this to 0.69 times gravity, which is stated by DPM to meet Indonesian requirements.

The MDE PGA for this "Extreme" Consequence Category tailings dam would be higher again and would apply post-closure. The minimum factor of safety recommended by ANCOLD (2012 and 2019) for earthquake loading is 1.0 to 1.2, with the upper end of this range being applicable to this site, given the paucity of data. Clearly, this one slope stability plot does not satisfy ANCOLD, and an appropriate selection of PGA would certainly also not.

6.2.2 Tailings Storage Capacity

The proposed initial maximum tailings dam height is 28 metres, although a much higher tailings dam and five-fold increase in storage capacity will ultimately be required. The ultimate dam is estimated to be approximately 75 metres high, which would obviously be far more critical than the initial dam 28 metre high dam and should have been considered in the design. DPM states (without supporting information) that 75 to 70% of the tailings production will be used as cemented tailings paste backfill in underground stopes, leaving only 25 to 30% of the tailings production to be stored in the TSF. However, based on published experience, it is likely that 50% of the tailings production will need to be stored in the TSF, increasing the stored volumes to approximately 2.4 million cubic metres in the short-term and ultimately approximately 12 million cubic metres for the inferred 30-year mine life, requiring a much larger and higher TSF.

6.2.3 Dam Construction Materials and Strength Parameters

Little detail is given about materials for the construction of the tailings dam (simply soil and tunnel excavation waste rock), and a shortfall is expected (to be met by un-named third parties), particularly for the ultimate dam estimated to be approximately 75 metres high. DPM infers that the dam will be constructed in stages in the downstream direction, requiring large volumes of fill. Tunnel excavation waste rock is presumably only available for the first stage, which will exacerbate the expected shortfall in construction material for later stages.

No design (strength) parameters are provided for the different materials (including the strengthening of the alluvium and upper Tuff), no indication is provided in Figure 3 about the location of the phreatic surface (water surface within the tailings and dam; the higher the phreatic surface, the lower the stability of the dam), and no calculations are provided for other loading cases (static loading in the short- and long-terms).

Little is reported by DPM about the alluvium in the foundation, which begs the question as to why it is not being excavated, given that the one critical slip circle provided passes through it. Little detail is provided about the “improvement” of the alluvium and extensive depth of weak Tuff (using stone columns) beneath the dam, which begs the question about the suitability of the selected location for the TSF.

No calculations are provided on possible non-circular (wedge-shaped) slip, which would likely pass more through the apparently critical alluvium, resulting in lower calculated factors of safety. No calculations are provided on possible slip upstream, into the stored tailings, which would be expected to be susceptible to liquefaction on earthquake loading, resulting in little post-liquefaction strength. Clearly, DPM has provided insufficient and inadequate information and analyses to support their TSF design.

6.2.4 Seepage and Water Management

A two-layer High Density Polyethylene (HDPE) liner and leachate collection drain are proposed on the upstream slope of the dam. A single textured HDPE would normally be installed on a slope for the purposes of limiting seepage through a tailings dam constructed with a waste rock shell. Limited details are provided about the design, operation (pumping to the sediment pond), and the required effectiveness of the TSF upstream toe drain (see Figure 2), which DPM appears to be relying on to dewater the deposited tailings slurry. The tailings deposited above the toe drain would be expected to drain and reduce in permeability, progressively and dramatically reducing flow to the drain over time.

DPM (without supporting information) estimated the rate of seepage to average 3% of the river flow. However, what is important is the range from low (limiting dilution of the contaminants) to peak flows (maximising dilution, but also likely to increase seepage flows). Given the very high rainfall at the site from records limited to just a few years, the sediment loads, and flow rates would be high. The proposed capacity of the sediment pond would fill in only about 10 hours and the estimated retention time for treatment (requiring settling of the solids and treatment of the water quality) is only 1 hour. Rainfall runoff at an unspecified rate is also to be treated in the sediment pond further increasing its loading, with no provision for the diversion of clean rainfall runoff. Hence, the sediment pond is considered to be of inadequate capacity and is not considered to provide the required retention time for settling of the suspended sediment and treatment of the contaminated water.

Limited hydrological data and no analysis are provided as a basis for TSF spillway design, which will likely be required to pass extreme storm events, to avoid overtopping of the dam that could cause failure through erosion. No details are provided about the design of the Emergency and Closure Spillways.

6.2.5 Tailings Deposition in the TSF

DPM has presumed that the tailings will be deposited in the TSF at 65% solids by mass. DPM has not reported the expected settled tailings density in the TSF. Metalliferous tailings typically readily thicken to 50% solids and achieving 65% solids as expected by DPM would require high rate thickening or centrifuging, which are not discussed by DPM.

The % solids at which tailings are deposited directly affects the volume of water discharged with the tailings, and hence the volume of water that will potentially be released from the TSF, in addition to rainfall runoff. Densification from 50 to 65% solids is equivalent to a reduction in the volume of water in the tailings from about 76 to 30%, with the difference reporting as seepage and supernatant water. This, together with the very high rainfall runoff, will result in high discharges from the TSF of water contaminated by the tailings.

6.2.6 Tailings Geochemistry and Water Treatment

Very limited testing of the natural surface water at the site showed up to 50% of the allowable concentration of dissolved Lead, and up to 70% of the allowable dissolved Zinc. Very limited testing of the natural groundwater at the site showed up to 2.8 times the allowable concentration of dissolved Lead and up to 0.8% of the allowable dissolved Zinc. There is no estimate of the expected chemistry of the tailings or tailings water, only the ore, which is about 38% pyrite, and contains high concentrations of Lead and Zinc, and low concentrations of arsenic, cobalt, nickel, copper and cadmium. The sulfidic tailings are expected to generate acid and metalliferous seepage and runoff with high concentrations of dissolved metals, particularly Lead and Zinc, requiring treatment prior to release to the Sopokomill River.

DPM proposes to use activated carbon to treat the seepage and runoff from the TSF. Activated carbon, sourced from coal among other sources, is traditionally used to purify drinking water, removing organic-based contaminants and inorganic contaminants like free chlorine and monochloramine. While activated carbon can remove low concentrations of certain dissolved metals, and raise the pH of contaminated water, it requires considerable residence time and is most effective at elevated temperatures. Elsewhere, DPM refers to treatment of the acidic drainage with Lime, Alum and flocculant before discharge to the river.

The most common treatment of acid and metalliferous seepage and runoff is the application of lime to raise the pH of the effluent and precipitate dissolved metals. However, lime treatment results in the production of huge quantities of precipitates and unspent lime (up to 90% of the applied lime), which must be stored and settles poorly.

The proposed sediment pond for the settling of suspended solids and the treatment of acid and metalliferous seepage and runoff are considered to be of inadequate capacity to handle the likely high suspended sediment loads and flow rates, and to provide the required retention time, and neither activated carbon nor lime treatment is adequately investigated by DPM. The likely result of any lack of capacity of the sediment ponds would be frequent release of contaminated water well above any acceptable toxicity levels. This would be particularly concerning with regard to lead, which is well known to affect human health, particularly that of children (WHO, 2023).

6.2.7 Monitoring, Emergency Response, and Closure

There is no recommendation by DPM on monitoring of the tailings dam during operations or post-closure, and no Emergency Response Plan. Towards closure, the tailings and decant pond are reported by DPM to be directed towards the northern end of the dam, and it is not clear whether this will lead to super-elevated and likely liquefiable tailings (in the event of a large earthquake) that could overtop the dam.

Limited details are provided about the proposed cover over the tailings, which includes 30 centimetres of topsoil, and its proposed function and revegetation (trees are mentioned by DPM, which would require considerable rooting depth and nutrients). No details are provided about how a cover would be placed on wet tailings at closure, and what proportion of the tailings would be covered by water. It is inferred by DPM that the cover will reduce rainfall runoff by 90%, for which no supporting information is provided, which I consider to be very ambitious. This implies high infiltration and hence increased seepage, which would be of poor quality given the sulfide content of the tailings and would have to be managed and likely treated in perpetuity, along with any drainage and runoff.

No details are provided about the ongoing effectiveness of the upstream toe drain, and whether it will continue to need to be operated (pumped) post-closure.

6.3 Information Gaps and Other Constraints

The paucity of information provided does not allow a full assessment of the proposed TSF design. However, there is sufficient information to demonstrate that the proposed design is grossly inadequate and, despite DPM's repeated claims to the contrary, does not meet ANCOLD (2012 and 2019) recommendations. In particular, there are little or no details provided on: (i) risk and Consequence assessments; (ii) geotechnical, seismic, hydrological and hydrogeological investigations, materials testing, and analyses; (iii) dam stability, with no details provided beyond Year 8; (iv) foundation improvement, bearing capacity and permeability; (v) the upstream toe drain; (vi) thickening and deposition of the tailings; (vii) catchment and dam hydrology and spillway design; or (viii) closure (in perpetuity). The TSF geotechnical investigation, materials testing, analyses, design and closure reported by DPM are grossly inadequate and fall well short of good international industry practice.

6.4 Overall Assessment

My overall assessment of the proposed TSF is that DPM has provided minimal, insufficient and inadequate details to support their design, has not demonstrated a design acceptable under the ANCOLD (2012 and 2019) Tailings Dam Guidelines as claimed by DPM, and the proposed TSF has an extreme risk of failure. Critically, the proposed TSF is located upstream of several thousand villagers and the cropping land on which their livelihoods depend. The TSF investigation, materials testing, analysis, design and closure reported by DPM are grossly inadequate and fall well short of good international industry practice. No details are provided on the ultimate tailings dam, only minimal details are provided on the 8-year TSF and closure of the TSF, and there are no recommendations by DPM on monitoring of the tailings dam during operations or post-closure, and no Emergency Response Plan.

As a result of the downstream population, cropping land and environmental values at risk of a tailings dam failure, and the worst case combination of site settings (very high seismicity, very high rainfall, and unstable foundations), the consequence of a tailings dam failure at the site is "Extreme" according to ANCOLD (2012 and 2019), requiring design for 1 in 10,000-year flood and earthquake loadings.

DPM proposes to settle suspended solids, and treat the acidic drainage and rainfall runoff, in a sediment pond. The sediment pond is considered to be of inadequate capacity to handle the likely high sediment loads and flow rates, and to provide the required retention time, and neither activated carbon nor lime treatment is adequately investigated by DPM.

DPM has provided limited hydrological data and no analysis as a basis for TSF spillway design, which will likely be required to pass extreme storm events, to avoid overtopping of the dam that could cause failure through erosion. DPM has not indicated the extent to which the tailings may be maintained near-saturated or underwater during the operation of the TSF and post-closure, to minimise oxygen ingress and oxidation of sulfides.

Towards closure, the tailings and decant pond are to be directed towards the northern end of the dam, and it is not clear whether this will lead to super-elevated and likely liquefiable tailings that could overtop the dam in the event of an earthquake. No details are provided about how the proposed cover would be placed on wet tailings at closure, and what its function would be. The upstream toe drain, and contaminated water, would have to be managed post-closure and the drainage, seepage and any runoff likely treated in perpetuity.

As a member of the Working Party for the Australian National Committee for Large Dams (ANCOLD, 2012 and 2019) Guidelines on Tailings Dams, it is my conclusion that, despite DPM's claims, they have not implemented or demonstrated compliance with ANCOLD. Hence, DPM's proposed TSF should have been rejected. This is particularly the case given the large population at risk downstream of the proposed TSF, and the risk being heightening by the combination of the very high seismicity, very high rainfall, poor foundation conditions and landslide-prone topography of the site. The risk of the much larger and higher ultimate life-of-mine TSF alluded to by DPM is unacceptably high.

6.5 Recommendations for Regulators

I have been involved in advising mining companies and regulators around the world for much of his 40-year career, as detailed in Section 8. Based on my experience, I offer the following points of advice to mine regulators reviewing DPM's TSF proposal.

- Above-ground TSFs need to be designed, constructed, operated and closed in a way that protects downstream populations, their homes, their livelihoods and environmental values from instability and contamination, both during operations and in perpetuity post-closure:
    - This is critically important when the downstream population at risk is high, and the site experiences very high seismicity, very high rainfall, poor foundation conditions, and landslides, as is the case.
    - It requires a strong commitment from the owner, the designer, and the regulator, which is absent.
- I, Dr Emerman, and Mr Meehan concur that the TSF design presented by DPM is grossly inadequate, is misleading about the scale of the TSF, and should be rejected.
- The TSF design presented cannot responsibly be reviewed, there is no Third Party Review nor could there be, and there is insufficient and inadequate information to allow responsible review by any regulator.

- DPM offered three versions of the EIA Addenda:
    - These presented conflicting information about the scale of the proposed TSF, and grossly inadequate information for the proposal to be responsibly reviewed.
    - It was falsely claimed that Knight Piésold and Golder had designed the TSF, while neither of these consultants considered the current location proposed for the TSF.
    - It was falsely claimed that the TSF design implemented and complied with ANCOLD (2012 and 2019).
    - Geochemical testing was inadequate for the tailings and proposed waste rock construction material expected to generate acid and metalliferous seepage and runoff.
    - The poor foundation conditions beneath the dam extend to far greater depth than the depth of excavation and treatment proposed by DPM.
    - There is likely to be insufficient material for constructing the tailings dam, particularly to the ultimate dam height of approximately 75 m.

The world has seen an understandable backlash against mining because of tailings disasters such as the recent tailings dam failures and loss of life in Brazil. There is real pressure on mining companies at a time when the world needs mining products to aid the transition to non-fossil-fuel-based energy. In this environment, it is imperative that mine regulators demand a high standard of mine project proponents. It is my opinion that this has not been displayed with DPM's proposed TSF, which falls well short of any international standard for tailings dam geotechnical and geochemical safety and protection of life, livelihoods, and the environment.

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8 DR WILLIAMS' QUALIFICATIONS AND EXPERIENCE

8.1 Overview

Dr Williams is a Brisbane-based Geotechnical Engineer and Researcher with over 40 years' consulting, research and teaching experience, specialising in applying geotechnical engineering principles to mine waste management, tailings management in particular, and the closure and capping of mine waste storages.

Dr Williams is internationally recognised for his expertise and experience in mine waste management and mine closure, particularly for his expertise in tailings, and the design, construction, operation, closure and rehabilitation of tailings dams, waste rock dumps and co-disposed and integrated waste storages. He carries out high-level reviews of and provides expert advice, opinion and review on tailings dam designs, waste rock dumps, co-disposed and integrated waste storages, and waste facility closure and value-adding. He was a member of the Expert Panel engaged to investigate the technical causes of the fatal Brumadinho Tailings Dam I failure in Brazil in 2019*: https://bdrb1investigationstacc.z15.web.core.windows.net/assets/Feijao-Dam-I-Expert-Panel-Report-ENG.pdf)*. He is on multiple Independent Technical Review Boards for tailings facilities and their closure worldwide.

Dr Williams has over 300 publications, with about two-thirds in the mine waste field. He authored in 2009 and 2016 the Tailings Management Handbook (https://www.industry.gov.au/sites/default/files/2019-04/lpsdp-tailings-management-handbook-english.pdf), as part of the Commonwealth Leading Practice Sustainable Development Program for the Mining Industry. He is on the Working Party for the Australian National Committee for Large Dams Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure, published in 2012, with an Addendum in 2019, and currently under review.

He initiated in 2020 and largely delivers the highly successful AusIMM online Professional Certificate Course in Tailings Management with assessment (https://www.ausimm.com/courses/professional-certificates/tailings-management/).

8.2 Qualifications

Dr Williams graduated in 1975 with First Class Honours in Civil Engineering from Monash University in Melbourne, Australia. He obtained a doctorate in Geotechnical Engineering from Cambridge University in the United Kingdom in 1979.

Dr Williams is a Fellow of the Institution of Engineers Australia and a Fellow of the Australasian Institute of Mining and Metallurgy. He is a Chartered and Registered Civil Engineer.

8.3 Employment History

2000 – Present:	Independent Consultant.
2007 – Present:	Professor of Geotechnical Engineering, Director of the Geotechnical Engineering Centre, Manager of the Industry-Funded Large Open Pit Project at The University of Queensland.
1983 – 2007:	Lecturer, Senior Lecturer then Associate Professor at The University of Queensland.

1980 – 1983: Geotechnical Engineer with Golder Associates in Melbourne and Brisbane.

1976 – 1979: PhD student, Cambridge University, United Kingdom.

1972 – 1980: Cadet Engineer, then Geotechnical Engineer with the then Country Roads Board of Victoria.

1972 – 1980: Cadet Engineer and Geotechnical Engineer with the then Country Roads Board of Victoria.

8.4 Key Tailings Review and Consulting Roles

- Chair of the Independent Technical Review Board for Fortescue Metal Group's tailings facilities, Western Australia, Australia, from 2023.
- Chair of the Independent Technical Review Board for Sandfire's tailings facilities worldwide, from 2023.
- Chair of the Independent Technical Review Board for BMA's Saraji Mine tailings facilities, Queensland, Australia, from 2023.
- Member of the Independent Technical Review Board for Hidden Valley Tailings Storage Facility 2, Morobe, PNG, from 2023.
- Chair of the Independent Technical Review Boards for Alcoa's tailings facilities worldwide from 2023.
- Chair of the Independent Technical Review Board for Queensland Alumina Limited Red Mud and Ash Dams, Gladstone, Queensland, Australia, from 2022.
- Chair of the Independent Technical Review Board for Glencore's Mount Isa tailings facility, Queensland, Australia, from 2022.
- Chair of the Independent Technical Review Panel for Anglo American Mineral Residue Facilities Management, Queensland, Australia, from 2022.
- Chair of the Independent Technical Review Board for Rio Tinto Aluminium's Yarwun Red Mud Area 2, Gladstone, Queensland, Australia, from 2021.
- Member of the Independent Technical Review Board for the Ranger Mine Pit 3 Capping of Tailings, Northern Territory, Australia, from 2020.
- Geotechnical Expert appointed by MMG for the Rosebery Closure Project in Tasmania, Australia, from 2020.
- Independent Member of the global Alcoa Impoundments Lead Team from 2020.
- Chair of the Independent Technical Review Board for Minera Escondida-BHP's tailings facilities, Chile, from 2019.
- Geotechnical Advisor to Aguamarina, Chile, from 2019 to 2021.
- Member of the Expert Panel commissioned to investigate technical causes of failure of Dam I at the Córrego de Feijão Mine, Minas Gerais, Brazil on 25 January 2019.
- Member of the Independent Technical Review Board for Rio Tinto Alcan Yarwun Residue Management Area Embankment Raise Designs, Gladstone, Queensland, Australia from 2016 to 2021.

- Member of Independent Technical Review Panel of the Life-of-Mine Tailings Storage Facility at Glencore's McArthur River Mine, Northern Territory, Australia from 2015.
- Member of Northern Territory EPA Board, Northern Territory, Australia, from 2012 to 2014.
- Numerous Geotechnical Peer Reviews of mine waste facilities.
- Numerous Geotechnical Peer Reviews of mine closure.
- Numerous Geotechnical Expert Witness roles, including Joint Expert Reports on behalf of mining clients, and giving evidence before the Queensland Land and Planning and Environment Courts, Australia.
- Numerous other Consultancies.

8.5 Tailings Consulting and Research Experience

8.5.1 Consulting in Tailings

- Member of multiple Independent Technical Review Boards for tailings facilities and their closure worldwide, as listed in Section 8.4.
- Member of the Expert Panel engaged to investigate the technical causes of the fatal Brumadinho Tailings Dam I failure in Brazil in 2019, as listed in Section 8.4.
- Numerous Geotechnical Expert Witness roles, including Joint Expert Reports in relation to capping tailings facilities on behalf of mining clients, and appearances before the Queensland Land and Planning and Environment Courts.
- Numerous Geotechnical Peer Reviews of tailings dam and raise designs.
- Numerous Geotechnical Peer Reviews of tailings facility closure.
- Review roles have covered coal tailings, red mud, laterite nickel, gold and metalliferous tailings, in a range of climates including arid, semi-arid, wet temperate, and the wet tropics.
- Numerous studies of tailings settling, consolidation, desiccation and re-wetting in an instrumented column.
- Numerous studies of tailings tested in an instrumented slurry consolidometer.
- Third Party Review of the Cell 2 TSF raise and dam break analysis under the Short-Term Tailings Project, South Walker Creek, in February 2021.
- Geotechnical testing and advice on GeoWaste (combined filtered tailings and scalped waste rock) for Goldcorp in Vancouver in 2018.
- Geotechnical testing and advice on combined centrifuged oil sands fluid fine tailings and shale in Alberta in 2018.
- Geotechnical Reviewer of the breach of the co-disposal dam at Burton Coal in Queensland in 2005.

- Research and review of in-pit thickened tailings disposal at Kidston Gold Mines from 1995 to 2001.
- Investigation of the pumped co-disposal of combined washery wastes developed at Jeebropilly Colliery near Ipswich in 1990.

8.5.2 Research Projects in Tailings

- ACARP Project C20047 on improved dewatering, management and rehabilitation of problematic, clay-rich coal mine tailings from 2011 to 2013.
- NERDDC and ACARP Project C3008 on the characterisation of the deposit formed on the pumped co-disposal of combined washery wastes from 1989 to 1993, which was adopted at numerous coal mines in Australia and Indonesia.

8.6 Tailings Management Training

Dr Williams was taught an undergraduate and postgraduate Course on Mine Waste Management at The University of Queensland for over 20 years.

Dr Williams initiated in 2020 and largely delivers the highly successful AusIMM online Professional Certificate Course in Tailings Management with assessment (https://www.ausimm.com/courses/professional-certificates/tailings-management/). The Course has been delivered eight times over three years to a combined audience of 900 to date and continues to be run twice annually.