Hydrologic Aspects of the Updated Addendum to the Environmental Impact Statement for the DPM Lead-Zinc Mine, North Sumatra, Indonesia

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LIGHTNING SUMMARY

A previous report evaluated the hydrologic aspects of the Environmental Impact Statement (EIS) Addendum for an underground lead-zinc mine in North Sumatra, Indonesia, by PT. Dairi Prima Mineral, an Indonesian company with majority ownership by a Chinese state-owned company. The updated Addendum does not change any of the hydrologic aspects of the project, but provides clarification regarding the design flood and post-closure plan for the tailings dam, and the availability of non-acid-generating waste rock for dam construction. The clarifications reinforce the previous recommendation for rejection of the mine as proposed in the EIS Addendum.

ABSTRACT

A previous report evaluated the hydrologic aspects of the October 2019 version of the Environmental Impact Statement Addendum for an underground lead-zinc mine in North Sumatra, Indonesia, by PT. Dairi Prima Mineral, an Indonesian company with majority ownership by a Chinese state-owned company. The mine would operate for eight years and would permanently store 1.3-1.6 million metric tons of mine tailings behind a 25-meter-high dam. Non-acid-generating (NAG) waste rock would be used to construct the tailings dam and to confine any potentially acid-generating (PAG) waste rock that would be stored in a free-standing waste dump. Hydrologic shortcomings of the plan for the DPM mine included:

1) the location of the tailings dam less than 1000 meters upstream from numerous homes and houses of worship;
2) the design of the tailings dam to accommodate only a 100-year flood (as opposed to international guidelines and Indonesian regulations that require design for the Probable Maximum Flood or the 10,000-year flood);
3) the measurement of baseline water quality without consideration of potential contaminants or the likely sites of emergence of contaminated groundwater;
4) the measurement of baseline surface water and groundwater discharge on non-representative dates and claims that trends existed that were not statistically significant;
5) the lack of discussion of the impact of water consumption on downstream users;
6) the lack of an adequate and detailed plan for the closure of the tailings dam;
7) the lack of an adequate and detailed plan for the prevention of acid mine drainage;
8) the numerous examples of contradictory data among tables, graphs and maps.

An updated Addendum, dated April 2021, does not change any of the hydrologic aspects of the project and does not allay any concerns about hydrology and waste management. It does, however, provide clarification as to how and why particular decisions were made. The update clarifies that the 100-year flood was determined from monthly precipitation, as opposed to the standard practice of determining rare floods based on storm durations of 24-72 hours. In this report, historic daily precipitation data from the Polonia weather station (102 kilometers northeast of the mine site) was used to illustrate the principle that storms of duration 24-72 hours are much more extreme, relative to average precipitation, than month-long rainy periods. In particular, the ratio of the 100-year precipitation to the average precipitation at Polonia is 153.2, 83.1, 56.7, 26.8, and 9.8 for storms with durations of 24 hours, 48 hours, 72 hours, 7 days and 30 days, respectively. On that basis, the design for an extreme storm of 24-hour duration is much more conservative (more protective of people and the environment) than the design for an extreme rainy period of 30-day duration. The April 2021 updated Addendum clarifies that, after closure, the tailings pond water will flow through the emergency spillway and enter downstream waterways without treatment whenever monthly rainfall exceeds 322.7 mm. Based on monthly precipitation data from the mine site, flow through the spillway will be occurring 15% of the time.

The April 2021 updated Addendum clarifies that the assumption that the waste rock would be NAG is based upon only two samples from the hanging wall and two samples from the footwall. There is no information as to what criteria were used to distinguish NAG from PAG samples. Since the waste rock would include acid-generating sulfide minerals such as pyrite, galena, and sphalerite, the acid-generating status would depend upon the sulfide concentration in a particular sample. Based on standard practice, the fraction of waste rock that would be NAG or PAG should be determined from hundreds of samples. The update does not provide any plan for separating NAG and PAG waste rock. The update repeats the contradictory data from the previous version and introduces new contradictions, as well as arithmetic errors. The clarifications further illustrate that the plans for the DPM mine are fundamentally flawed and reinforce the previous recommendation for rejection of the mine as proposed in the EIS Addendum.

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OVERVIEW

A previous report by the author evaluated the hydrologic aspects of the Environmental Impact Statement (EIS) Addendum, released in October 2019, for an underground lead-zinc mine in North Sumatra, Indonesia, by the Indonesian mining company PT. Dairi Prima Mineral (DPM, 2019; Emerman, 2020). The proposed mine is called *Proyek Anjing Hitam* [Black Dog Project] in DPM (2019), but is more commonly referred to as the DPM mine, which is the name that will be used in this report. The majority owner of PT. DPM is China Nonferrous Metal Industry's Foreign Engineering and Construction Co., a part of the China Nonferrous Metal Mining Group, which is a Chinese state-owned company. The minority owner is Bumi Resource Minerals, the non-coal subsidiary of the Indonesian mining company Bumi Resources. The mine would operate for eight years and would process one million metric tons of ore annually, resulting in the annual export of 103,000 metric tons of lead concentrate (64% lead) and 225,000 metric tons of zinc concentrate (54% zinc). The plan is to store 70-75% of the tailings underground as paste backfill with the remaining 25-30% (1,344,000 – 1,612,800 metric tons) permanently stored aboveground as a tailings deposit confined by a tailings dam with a height of 25 meters. Non-acid-generating (NAG) waste rock would be used to construct the tailings dam and to confine any potentially acid-generating (PAG) waste rock in a free-standing waste dump.

Emerman (2020) made the following observations regarding the EIS Addendum (DPM, 2019):

1) The plan to store 70-75% of the tailings underground as paste backfill would represent a theoretical maximum percentage and was not justified in terms of the mining sequence.
2) The tailings dam would be located less than 1000 meters upstream from numerous homes and houses of worship, which would make the project illegal in China.
3) The tailings dam would be designed to accommodate only a 100-year flood, although, according to internationally-recognized guidelines and Indonesian regulations, due to the probable loss of life in the event of dam failure, the dam should be designed to withstand either the 10,000-year flood or the Probable Maximum Flood (PMF), which is significantly rarer than even a 10,000-year flood.
4) There is no basis for determining even the 100-year flood since the closest weather station to the tailings dam with at least 30 years of rainfall data is 102 kilometers to the northeast with an elevation 545 meters lower than the dam.
5) The sites for measurements of baseline water quality were only in the southeastern portion of the mine project and were chosen without consideration of the likely sites of emergence of contaminated groundwater.
6) Water quality parameters were chosen without a geochemical analysis of tailings and waste rock and, thus, without consideration for potential contaminants.
7) Baseline surface water and groundwater discharge measurements were also made only in the southeastern portion of the mine project and on dates that were not shown to be representative. Claims that groundwater discharge has been decreasing were not statistically significant and could be used to claim that future decreases in groundwater discharge were unrelated to mining activity.
8) There was no discussion of the source of water for the mine, the rate of water consumption, or how water consumption could impact downstream users. However, based on global trends in lead-zinc mining, the projected annual water consumption is 0.5-5 million cubic meters, or 6-66% of the discharge of the stream that supplies water to Parongil village.

9) The EIS Addendum acknowledged the likelihood of acid mine drainage, but did not include adequate or detailed plans for the prevention of groundwater or surface water contamination. In particular, although the NAG waste rock had a key role in constructing the dam for the PAG tailings and for confining the PAG waste rock in a waste dump, there was no indication that any NAG waste rock existed.
10) The EIS Addendum was devoid of any contingency plans, in contrast to almost any other mining project.
11) The EIS Addendum included no quantitative predictions of adverse impacts on the environment that are likely to occur despite the use of environmental controls, with the lack of attention to the environmental impact of dewatering of the underground mine being just one of many examples.
12) The EIS Addendum contained numerous examples of contradictory data among tables, graphs and maps.

In response to the preceding observations, Emerman (2020) recommended rejection of the proposal without any further consideration.

In April 2021 PT. Dairi Prima Mineral submitted an updated EIS Addendum (DPM, 2021). The objective of this report is to answer the following question: In terms of the impact of hydrology on the mining project and the impact of the mining project on the local and regional hydrology, does the updated Addendum now provide sufficient protection for people and the environment? Before discussing the methodology for addressing the objective, I will first review the aspects of the updated Addendum (DPM, 2021) that distinguish it from the original Addendum (DPM, 2019). For aspects of the updated Addendum (DPM, 2021) that do not differ from the original Addendum (DPM, 2019), the reader is encouraged to consult both the earlier review (Emerman, 2020) and the earlier Addendum (DPM, 2019).

SUMMARY OF UPDATED ADDENDUM

The updated Addendum (DPM, 2021) does not alter the hydrologic aspects of the proposed DPM mine in any significant way. In some cases, there is additional detail regarding the mining plan, such as the particular plant species that will be grown on the tailings pond after dam closure. By and large, in terms of hydrology, the purpose of the updated Addendum is to provide clarification as to how and why particular decisions were made. Three examples of clarifications will be given in this report.

The first example is a clarification of the meaning of the 100-year flood (flood with an annual exceedance probability of 1%) that the tailings dam would be designed to accommodate. Emerman (2020) wrote, “In all cases, it is the 24-hour storm that is most critical in determining the flood of a given return period, so that daily precipitation records in or close to the watershed of interest are the most relevant.” However, the original Addendum (DPM, 2019) never actually specified the duration of the storm that would be the basis for the calculation of the 100-year flood. According to the updated Addendum (DPM, 2021), “*TSF didesain untuk menampung kondisi banjir dengan periode ulang 1 hingga 100 tahun untuk curah hujan bulanan*” [The TSF [Tailings Storage Facility] is designed to accommodate flood conditions with a return period of 1 to 100 years for monthly rainfall]. The corresponding sentence in the original Addendum was “*TSF didesain untuk menampung kondisi banjir dengan periode ulang 1 hingga 100 tahun*” [The TSF is designed to accommodate flood conditions with return periods of 1 to 100 years] (DPM, 2019). The updated Addendum also states “*Rancangan TSF dilakukan oleh konsultan Knight*

Piesold, dimana TSF mampu menampung curah hujan maksimum bulanan untuk durasi 100 tahun" [The design of the TSF was carried out by consultant Knight Piésold, where the TSF is able to accommodate the maximum monthly rainfall for a duration of 100 years] with no corresponding sentence in the original Addendum (DPM, 2019).

The meaning of "*periode ulang 1 hingga 100 tahun untuk curah hujan bulanan"* [return period of 1 to 100 years for monthly rainfall] is not entirely clear. In the first place, there is no need to design a dam to withstand storms with return periods of 1 to 100 years. If a dam has been designed to withstand a storm with a return period of 100 years, then, of course, it can withstand a storm with any shorter return period. In the second place, the phrase cannot logically refer to the storm that is literally confined to a particular month, such as a January storm or a February storm. The phrase most likely refers to storms of 30-day duration (not necessarily confined to a particular month of the calendar) with an annual exceedance probability of 1%. The possibility that "monthly rainfall" literally refers to calendar months will be raised in the Discussion section.

Embankment dams, however, typically fail by overtopping due to single-day or multi-day storms (storm durations of 24-72 hours), rather than by longer, unusually wet rainy periods (over durations such as 30 days). The reason is that unusually wet rainy periods without single-day to multi-day extreme storms would leave ample time to take proper evasive action to avoid dam failure. On that basis, the question arises as to whether design for a 100-year storm with a duration of 30 days is as conservative (as protective of people and the environment) as design for the 100-year storm with a duration of 24 hours. It is noteworthy that, just as the original Addendum (DPM, 2019) was devoid of any contingency plans, the updated Addendum (DPM, 2021) is devoid of any plans for actions that would be taken to prevent tailings dam failure during an excessively wet rainy season.

The second example is a clarification in the updated Addendum (DPM, 2021) of the conditions under which toxic and acidic water from the tailings pond will overflow the tailings dam and enter downstream water bodies without treatment following closure of the tailings storage facility. According to DPM (2021), "*Wet tailing area di sisi utara TSF akan terbentuk setelah pasca operasional. Area ini akan berfungsi sebagai pengumpul air hujan yang jatuh di area TSF, dan jika curah hujan melebihi curah hujan rerata bulanan tertinggi (322,7 mm) maka dirancang air akan melimpas melalui emergency spillway eksiting dan menuju lae sopokomil … Semi wet tailing area akan terbentuk di sekitar wet tailing area. Pada keadaan curah hujan melebihi curah hujan rerata bulanan tertinggi (322,7 mm) maka air akan melimpas menuju spillway eksisting dan menuju Lae Sopokomil* [Wet tailings area on the north side of the TSF will be formed post-operation. This area will function as a collector of rainwater that falls in the TSF area, and if the rainfall exceeds the highest average monthly rainfall (322.7 mm), it is designed so that the water will overflow through the existing emergency spillway and flow into Lae Sopokomil … A semi-wet tailings area will be formed around the wet tailings area. If the rainfall exceeds the highest average monthly rainfall (322.7 mm), the water will run off towards the existing spillway and towards Lae Sopokomil].

The diagram of the emergency spillway from DPM (2021) (see Fig. 1) clarifies that any tailings pond water that flows through the emergency spillway will enter downstream waterways with no passive or active treatment for the removal of contaminants. The only treatment will be the removal of sediment (fine tailings) due to the passage of the spillway flood through a sediment trap, which would be only a geotextile fence across a constructed channel (see Fig. 1). There is no discussion in DPM (2021) of the circumstances under which obstruction of the flow by the geotextile will cause overtopping of the fence and/or the banks of the constructed channel followed by entry of the tailings pond water into downstream waterways without even any sediment (fine tailings) removal. There is also no discussion of the time that will be required for the geotextile to become clogged with fine tailings or any procedures for cleaning or replacement of the geotextile. Of course, once the geotextile becomes clogged, there will be a continuous overtopping of the fence and/or the banks of the constructed channel. Finally, there is no discussion of the dimensions or slope of the constructed channel that should be required to accommodate the overflow that will occur whenever the monthly rainfall exceeds 322.7 mm.

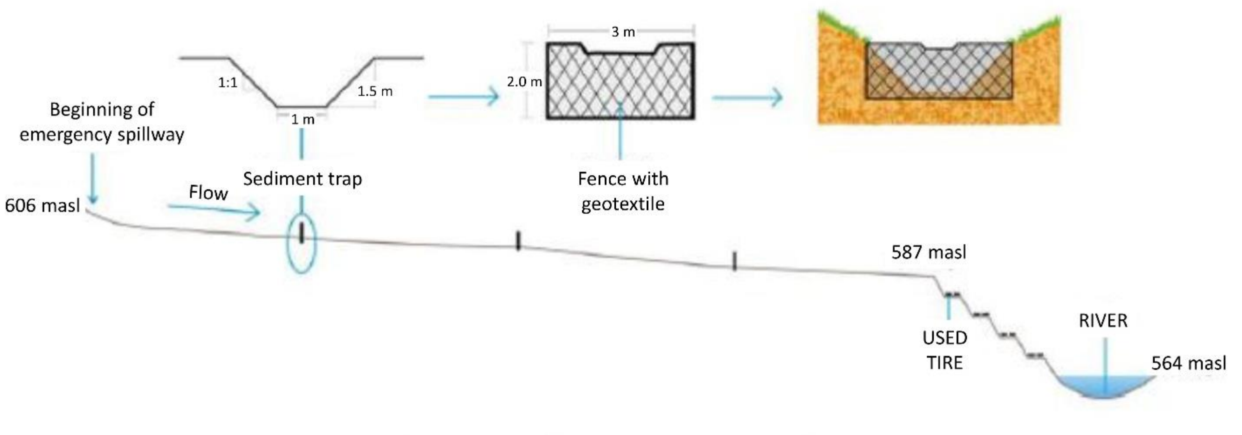

Figure 2.49 Emergency Spillway Diagram

Figure 1. The above figure clarifies that any tailings pond water that flows through the emergency spillway will enter downstream waterways with no passive or active treatment for the removal of contaminants. There is no discussion of the circumstances under which obstruction of the flow by the geotextile will cause overtopping of the fence and/or the banks followed by entry of the tailings pond water into downstream waterways without even any sediment (fine tailings) removal. There is also no discussion of the time that will be required for the geotextile to become clogged with fine tailings or any procedures for cleaning or replacement of the geotextile. Figure from DPM (2021) with overlay of English labels.

The third example of a clarification is the evidence for the assumption that NAG waste rock would be available for constructing the tailings dam and for confining any PAG waste rock in a waste dump. DPM (2021) reported static tests of six rock samples for acid-generating potential, including two samples from the ore body (SOP-329 OZ Sju2 and SOP-330 OZ Sju2), two samples from the hanging wall of the waste rock (SOP-329 HW and SOP-330 HW), and two samples from the footwall of the waste rock (SOP-329 FW and SOP-330 FW) (see Fig. 2). Static tests are used as a screening tool and, unlike short-term leach tests or long-term kinetic tests, do not take into account the reaction rates (either oxidation or neutralization) or the availability of minerals for chemical reactions. DPM (2021) found that all samples of the ore body were PAG, while all samples of the waste rock were NAG (see Fig. 2).

Although all six samples were measured by two different labs (Intertek and ITB) (see Fig. 2), DPM (2021) did not provide any information as to what lab procedures were used or what were the criteria for categorizing samples as either NAG or PAG. A common static test for acid rock drainage is acid-base accounting, in which the sulfide (or sulfur) content of waste rock leads to the acidity potential (AP). In the same way, the carbonate content or the content that will react with acid leads to the neutralization potential (NP). Both AP and NP are expressed in units such as grams of calcium carbonate ($CaCO_3$) equivalent per metric ton of rock. The net neutralization potential (NNP) is calculated as NP – AP, while the neutralization potential ratio (NPR) is the ratio NP/AP.

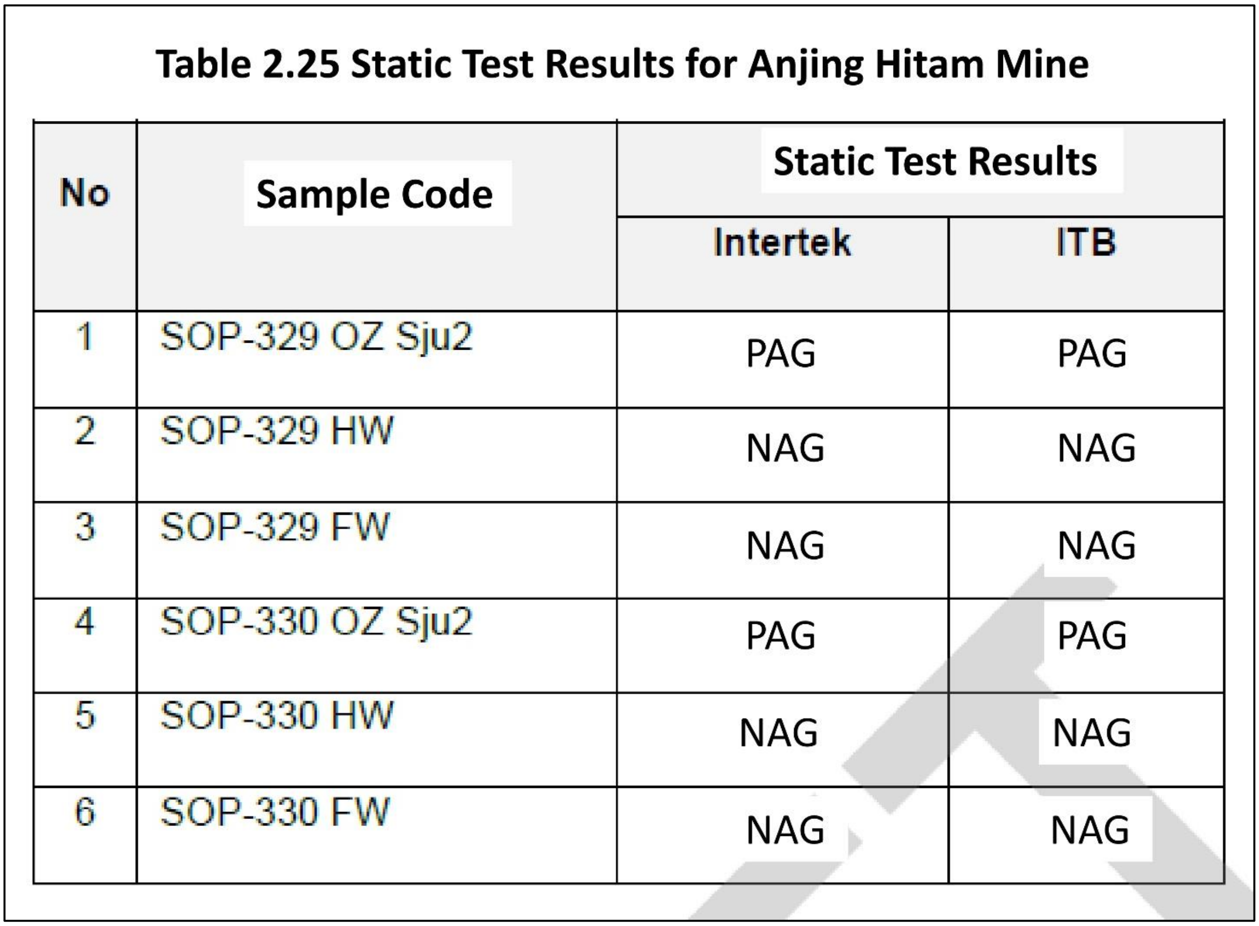

Table 2.25 Static Test Results for Anjing Hitam Mine

No	Sample Code	Static Test Results	
		Intertek	ITB
1	SOP-329 OZ Sju2	PAG	PAG
2	SOP-329 HW	NAG	NAG
3	SOP-329 FW	NAG	NAG
4	SOP-330 OZ Sju2	PAG	PAG
5	SOP-330 HW	NAG	NAG
6	SOP-330 FW	NAG	NAG

Figure 2. DPM (2021) tested six rock samples for acid-generating potential, including two samples from the ore body (SOP-329 OZ Sju2 and SOP-330 OZ Sju2), two samples from the hanging wall of the waste rock (SOP-329 HW and SOP-330 HW), and two samples from the footwall of the waste rock (SOP-329 FW and SOP-330 FW). DPM (2021) found that all samples of the ore body were potentially acid-generating (PAG), while all samples of the waste rock were non-acid-generating (NAG). Although all samples were measured by two labs (Intertek and ITB), no information was provided regarding the criteria for separating PAG and NAG samples. According to Maest et al. (2002), minimum sample numbers of each rock type should be 3, 8, 26 and 80 when the expected mass of exposed waste of each rock type is less than 10,000 metric tons, less than 100,000 metric tons, less than 1,000,000 metric tons, and less than 10,000,000 metric tons, respectively. Since the expected mass of waste rock is 1.77 million metric tons, the minimum number of samples should have been 80 even if all waste rock were the same rock type. However, the minimum number of samples per “rock type” should refer not only to broad categories (such as dolostone), but should refer to specific assemblages of minerals. According to Maest et al. (2002), “The minimum number of samples suggested [above] should be applied to each different type of mineralogy (for example, addressing the range of hydrothermal and supergene alteration for each lithology), rather than to each rock type.” On the above basis, hundreds of samples should be required to determine the acid-generating potential of the waste rock at the DPM mine. Table from DPM (2021) with overlay of English labels.

There are no fixed thresholds for NNP or NPR for separation of PAG and NAG materials. In fact, recommended thresholds for PAG materials range from NPR < 1 to NPR < 4 (Morin and Hunt, 1994; White et al., 1999; Maest et al., 2002). By comparison with kinetic data on depletion rates of neutralizing minerals, Scharer et al. (2000) concluded that heterogeneous waste rock piles with NPR has high as 5.0 may still generate acid mine drainage in the long term. In general, the choice of an appropriate threshold should depend upon the consequences of being wrong, that is, the consequences of assuming that waste rock will be NAG when it will actually be PAG. Moreover, the standard practice is that final decisions regarding project feasibility or appropriate mitigation measures are not based upon static tests alone, which are only a screening tool and a guide for the selection of appropriate short-term leach tests and kinetic tests. Further information about the updated Addendum (DPM, 2021) will be provided in the Results section.

METHODOLOGY

Based upon the preceding summary of the updated Addendum (DPM, 2021), the objective of this report can be subdivided into the following questions:

1) For the site of the proposed DPM mine, to what degree are 100-year storms with durations of 24-72 hours more extreme than 100-year storms with durations of 30 days?
2) Following closure of the tailings storage facility, how often will toxic and acidic tailings pond water be flowing into downstream water bodies without treatment?
3) Do the static tests provide adequate evidence for the existence of sufficient NAG waste rock for construction of the tailings dam and for confining any PAG waste rock in a free-standing waste dump?

The second question was addressed by comparing the design overflow rainfall (monthly rainfall of 322.7 mm) with the monthly precipitation recorded at the mine site weather station between 2008-2019 (DPM, 2021; see Figs. 3a-b). The third question was addressed by comparison of the sampling strategy described in DPM (2021) with the standard sampling strategy reviewed by Maest et al. (2002).

The first question was addressed based on daily precipitation data from the weather station at Polonia, 102 kilometers to the northeast. The results from Polonia should be regarded only as an illustration of a general principal and not as representative of the mine site, since the Polonia weather station has an elevation of only 35 meters above sea level, or 555 meters lower than the mine site weather station (NOAA-NESDIS-NCDC, 2021). (The mine site weather station is 590 meters above sea level, while the base of the tailings dam would be 580 meters above sea level.) Although there is a weather station at the mine site, precipitation-frequency relationships could not be developed for the mine site since DPM (2019, 2021) has provided only monthly (rather than daily) precipitation data for the mine site weather station. The Polonia weather station has been in operation since 1946 (NOAA-NESDIS-NCDC, 2021) with daily precipitation data available since 1958 (WMO, 2021), which should be sufficient for the reliable estimation of 100-year storms. It should be noted that the use of the Polonia precipitation record for illustrative purposes is only an idea of this report, and there is no indication that these data were considered for design of the tailings dam in either the original or updated Addenda (DPM, 2019, 2021). The source of input data for the design of the tailings dam will be addressed in the Discussion section.

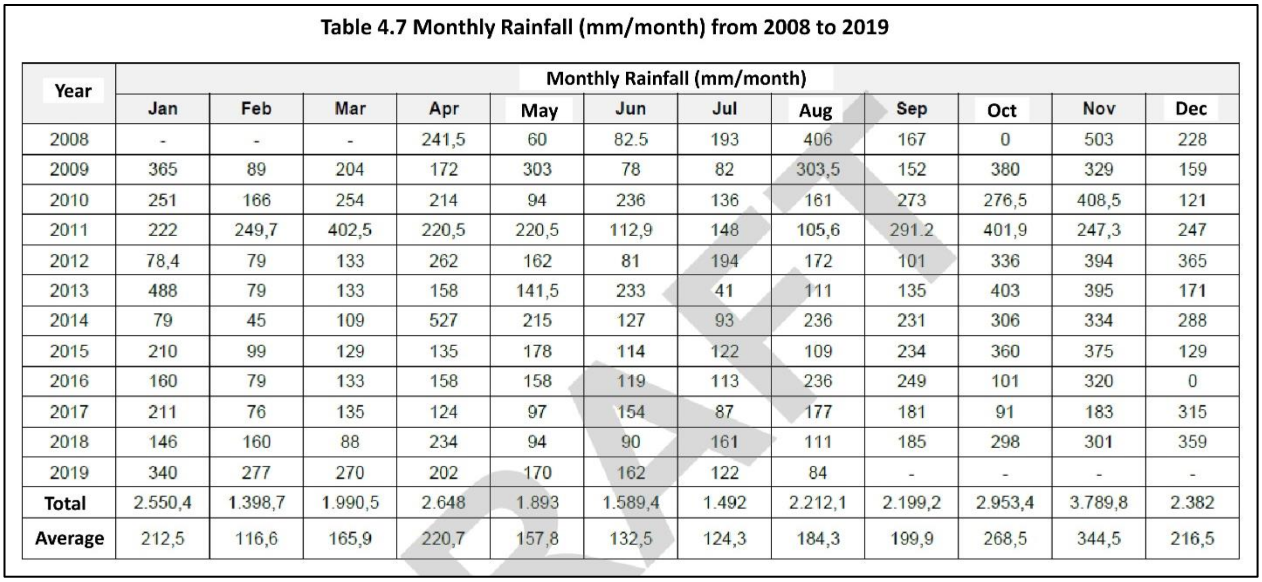

Table 4.7 Monthly Rainfall (mm/month) from 2008 to 2019

Year	Monthly Rainfall (mm/month)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	-	-	-	241,5	60	82.5	193	406	167	0	503	228
2009	365	89	204	172	303	78	82	303,5	152	380	329	159
2010	251	166	254	214	94	236	136	161	273	276,5	408,5	121
2011	222	249,7	402,5	220,5	220,5	112,9	148	105,6	291.2	401,9	247,3	247
2012	78,4	79	133	262	162	81	194	172	101	336	394	365
2013	488	79	133	158	141,5	233	41	111	135	403	395	171
2014	79	45	109	527	215	127	93	236	231	306	334	288
2015	210	99	129	135	178	114	122	109	234	360	375	129
2016	160	79	133	158	158	119	113	236	249	101	320	0
2017	211	76	135	124	97	154	87	177	181	91	183	315
2018	146	160	88	234	94	90	161	111	185	298	301	359
2019	340	277	270	202	170	162	122	84	-	-	-	-
Total	2.550,4	1.398,7	1.990,5	2.648	1.893	1.589,4	1.492	2.212,1	2.199,2	2.953,4	3.789,8	2.382
Average	212,5	116,6	165,9	220,7	157,8	132,5	124,3	184,3	199,9	268,5	344,5	216,5

Figure 3a. DPM (2021) is marred by numerous contradictions among data in the text, tables and maps, as well as arithmetic errors. For example, based upon the data in the table above, the average monthly rainfalls at the mine site weather station for January, February and March should be 231.9 mm, 127.2 mm, and 181.0 mm, respectively. As a second example, Table 3.1 (see Fig. 3b) of DPM (2021) states the monthly rainfalls at the mine site weather station for July 2012 and November 2012 as 134 mm and 334 mm, respectively, while Table 4.7 (see above) states the monthly rainfalls for July 2012 and November 2012 as 194 mm and 394 mm, respectively. No attempt was made in this report to document all contradictory information and arithmetic errors. Table from DPM (2021) with overlay of English labels.

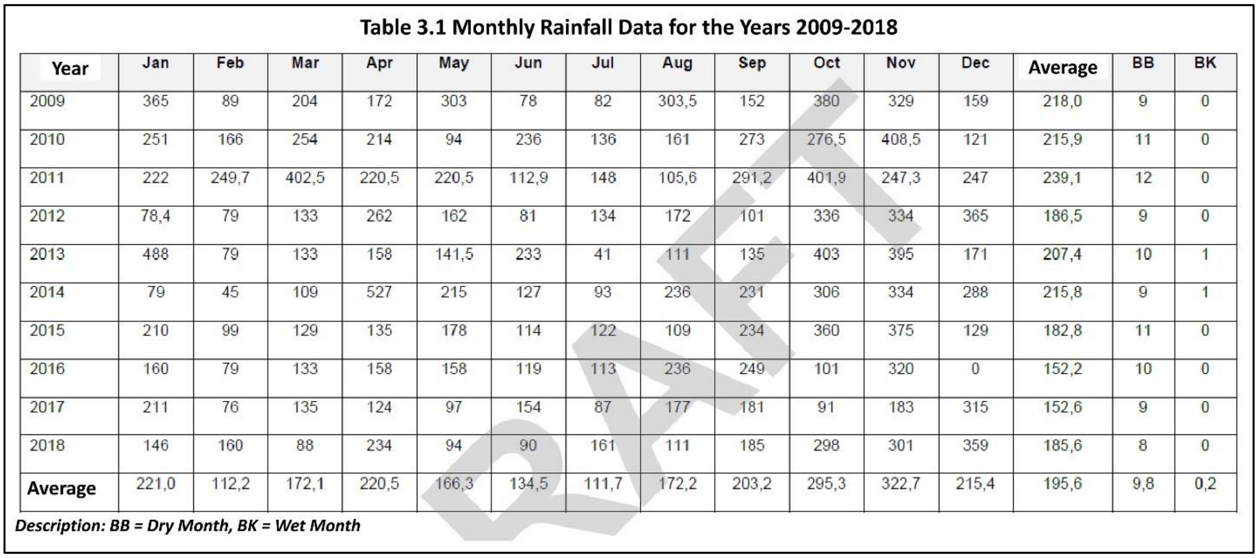

Table 3.1 Monthly Rainfall Data for the Years 2009-2018

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	BB	BK
2009	365	89	204	172	303	78	82	303,5	152	380	329	159	218,0	9	0
2010	251	166	254	214	94	236	136	161	273	276,5	408,5	121	215,9	11	0
2011	222	249,7	402,5	220,5	220,5	112,9	148	105,6	291,2	401,9	247,3	247	239,1	12	0
2012	78,4	79	133	262	162	81	134	172	101	336	334	365	186,5	9	0
2013	488	79	133	158	141,5	233	41	111	135	403	395	171	207,4	10	1
2014	79	45	109	527	215	127	93	236	231	306	334	288	215,8	9	1
2015	210	99	129	135	178	114	122	109	234	360	375	129	182,8	11	0
2016	160	79	133	158	158	119	113	236	249	101	320	0	152,2	10	0
2017	211	76	135	124	97	154	87	177	181	91	183	315	152,6	9	0
2018	146	160	88	234	94	90	161	111	185	298	301	359	185,6	8	0
Average	221,0	112,2	172,1	220,5	166,3	134,5	111,7	172,2	203,2	295,3	322,7	215,4	195,6	9,8	0,2

Description: BB = Dry Month, BK = Wet Month

Figure 3b. DPM (2021) is marred by numerous contradictions among data in the text, tables and maps, as well as arithmetic errors. For example, Table 3.1 of DPM (2021) states the monthly rainfalls at the mine site weather station for July 2012 and November 2012 as 134 mm and 334 mm, respectively, while Table 4.7 (see Fig. 3a) states the monthly rainfalls for July 2012 and November 2012 as 194 mm and 394 mm, respectively. No attempt was made in this report to document all contradictory information and arithmetic errors. Table from DPM (2021) with overlay of English labels.

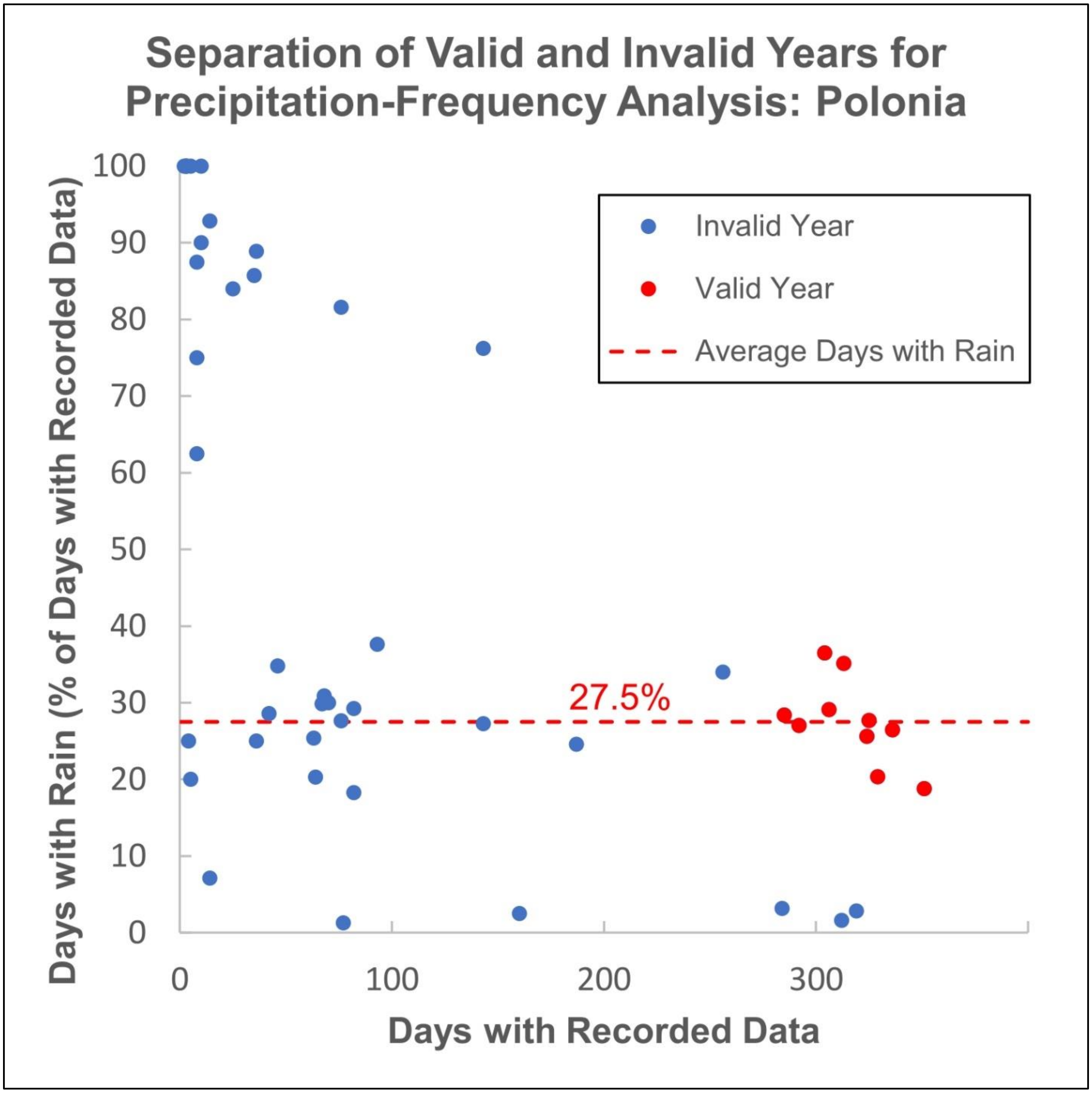

Figure 4. Although daily precipitation data are available for the Polonia weather station from 1958, only the data from ten years (1979-1980, 1993-1998, 2003-2004) were regarded as valid for precipitation-frequency analysis (see Table A1). Each of the 10 valid years has at least 285 days (78% of the year) of recorded data (see Table A1). Although 1974, 1977 and 1978 had 284, 312 and 319 days of recorded data, respectively, they also had only 9 days (3.2% of recorded data), 5 days (1.6% of recorded data) and 9 days (2.8% of recorded data) of non-zero precipitation, respectively (see Table A1). The years 1974, 1977 and 1978 were regarded as invalid based on the conclusion that many of the days with zero entered for the precipitation amount were actually days with no recorded data. For the 10 valid years, the average number of days with non-zero precipitation was 27.5% of the days with recorded data. By comparison, 50.5% of the days had non-zero precipitation at the mine site weather station (see Table A2), which is consistent with its higher elevation (590 meters above sea level, compared with 35 meters above sea level for Polonia). Data for Polonia from WMO (2021).

The problem is that the 63 years of daily precipitation records have a great deal of missing data (see Table A1 in Appendix), which is actually true for all weather stations in Indonesia (WMO, 2021). For the Polonia weather station, ten years (1979-1980, 1993-1998, 2003-2004) had at least 285 days (78% of the year) of recorded data and were regarded as valid for precipitation-frequency analysis (see Fig. 4 and Table A1). Although 1974, 1977 and 1978 had 284, 312 and 319 days of recorded data, respectively, they also had only 9 days (3.2% of recorded data), 5 days (1.6% of recorded data) and 9 days (2.8% of recorded data) of non-zero precipitation, respectively (see Fig. 4 and Table A1). The years 1974, 1977 and 1978 were regarded as invalid based on the conclusion that many of the days with zero entered for the precipitation amount were actually days with no recorded data. For the 10 valid years, the average number of days at Polonia with non-zero precipitation was 27.5% of the days with recorded data. By comparison, 50.5% of the days had non-zero precipitation at the mine site weather station (see Table A2 in Appendix), which is consistent with its higher elevation.

The return periods for extreme precipitation events with durations of 24 hours, 48 hours, 72 hours, 7 days, and 30 days were calculated for Polonia using standard methods described by Watson and Burkett (1995). Each year was assigned a ranking number *M* with the years ranked in order from the year with the highest precipitation for a given storm duration (*M* = 1) to the lowest precipitation for the same storm duration (*M* = 10). The return period for each precipitation event was then calculated as

$$T = \frac{n+1}{M} \tag{1}$$

where *T* is the return period in years and *n* is the number of years (*n* = 10). In all cases, the best fit to rainfall amount as a function of return period was a logarithmic function. The logarithmic function was then used to calculate the 100-year precipitation event for storms with durations of 24 hours, 48 hours, 72 hours, 7 days, and 30 days.

RESULTS

Design of Tailings Dam for 100-Year Flood

For the Polonia weather station, logarithmic curves were very good fits ($R^2 = 0.85\text{-}0.92$) to the precipitation-frequency plots for storm durations of 24 hours, 48 hours, 72 hours, 7 days, and 30 days (see Fig. 5). Most of the scatter in the data for storm durations of 24 hours, 48 hours, 72 hours, and 7 days arose from the two wettest years, 1979 and 1980, for which the maximum precipitation amounts were similar to each other and much higher than other years (see Tables A3-A4 in Appendix). The years 1979 and 1980 were also the two wettest years for storms with durations of 30 days, although the precipitations were less similar to one another and less radically different from other years, resulting in a better fit to a logarithmic curve (see Fig. 5 and Table A4). The years 1979 and 1980 are not regarded as either El Niño years or La Niña years (Australian Government Bureau of Meteorology, 2021a-b). Typically, El Niño periods are drier than normal on the western side of the Pacific Ocean, while La Niña periods are wetter than normal. Out of the ten valid years for the Polonia weather station (1979-1980, 1993-1998, 2003-2004), the El Niño periods were 1993-1995, 1997-1998 and 2002-2003, while the only La Niña period was 1998-2001 (Australian Government Bureau of Meteorology, 2021a-b). Thus, the use of the Polonia dataset could underestimate the magnitudes of rare precipitation events even at Polonia due to the lack of data from La Niña periods and the bias of data toward El Niño periods.

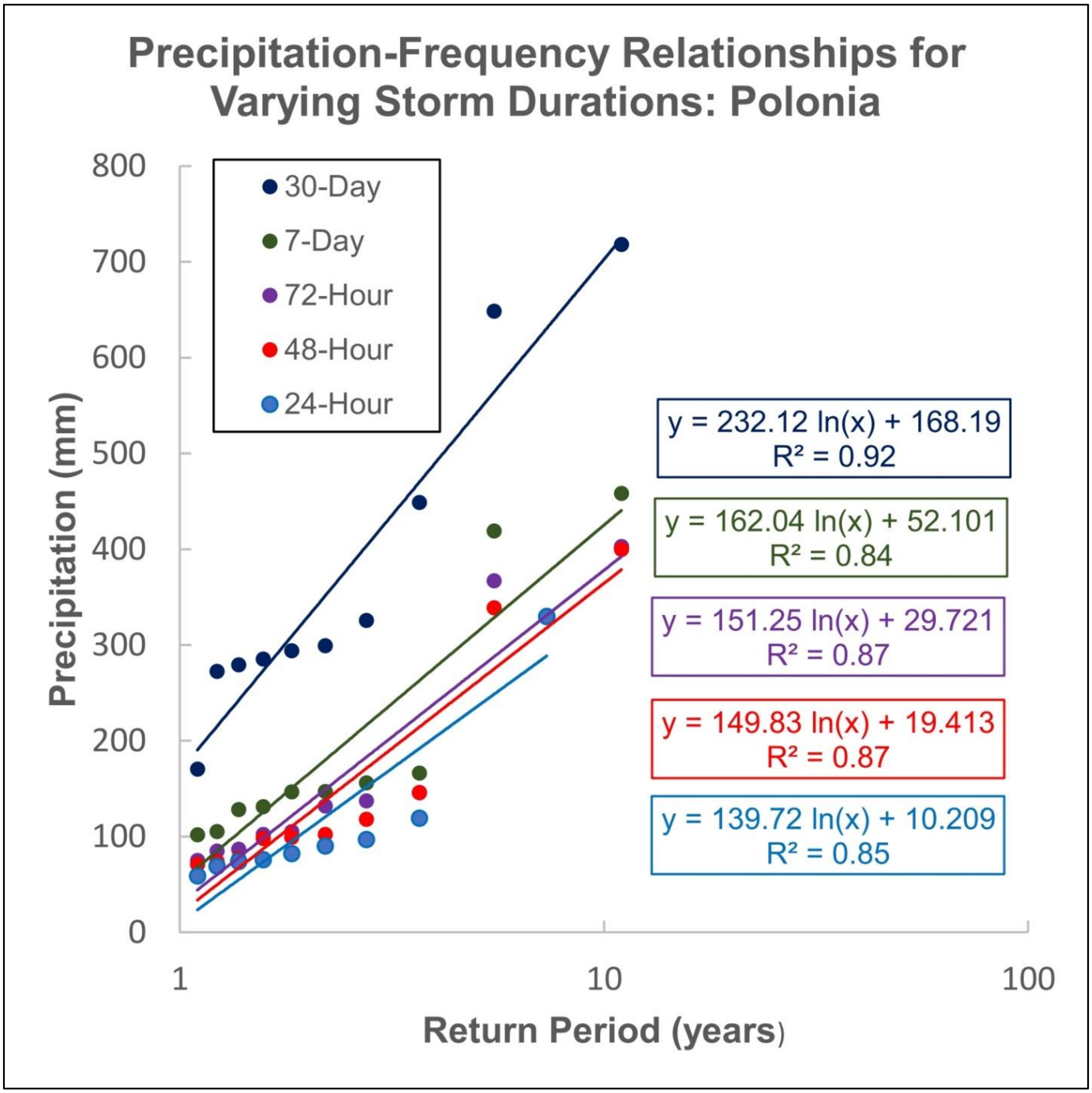

Figure 5. Daily precipitation data for the 10 valid years (1979-1980, 1993-1998, 2003-2004) were used to determine precipitation-frequency relationships for storms with durations of 24 hours, 48 hours, 72 hours, 7 days and 30 days, at the Polonia weather station. Logarithmic curves were the best-fit relationships for all storm durations. Most of the scatter in the data resulted from the two wettest years (1979 and 1980) that had similar precipitation amounts (see Tables A3 and A4). Data for Polonia from WMO (2021).

For the Polonia weather station, the ratio of the predicted precipitation event with a return period of 100 years to the average precipitation is 153.2, 83.1, 56.7, 26.8, and 9.8 for storms with durations of 24 hours, 48 hours, 72 hours, 7 days, and 30 days, respectively (see Table 1). For example, the 100-year storm with a duration of 24 hours is predicted to have 653.6 mm of precipitation, while the average daily precipitation is 4.3 mm. The 100-year rainy period with a duration of 30 days is predicted to have 1237.1 mm of precipitation, while the average precipitation over 30-day periods is 126.2 mm. For comparison, the average monthly precipitation at the mine site weather station was 197.8 mm, which is consistent with its higher elevation (see Fig. 6). It is emphasized that precipitation data from the Polonia weather station is not being used to predict the magnitude of 100-year storms at the mine site, but to illustrate the principle that design for the 100-year storm with duration of 24 hours is far more conservative (more protective of people and the environment) than design for the 100-year rainy period with duration of 30 days. Thus, the design of the tailings dam for the 100-year flood in the updated Addendum (DPM, 2021) is far less conservative (for prevention of tailings dam failure by overtopping) than was assumed to be the case in the review by Emerman (2020) of the original Addendum (DPM, 2019).

Table 1. Comparison of average and 100-year precipitation for varying durations: Polonia

Duration	Average Precipitation[1] (mm)	100-Year Precipitation[2] (mm)	Ratio (100-Year/Average)
24 hours	4.3	653.6	153.2
48 hours	8.5	709.4	83.1
72 hours	12.8	726.3	56.7
7 days	29.8	798.3	26.8
30 days	126.2	1237.1	9.8

[1] Average precipitation based on the years 1979-1980, 1993-1998, and 2003-2004.

[2] Calculated from best-fit logarithmic curves in Fig. 5.

Untreated Overflow from Post-Closure Tailings Dam

Based on a comparison of monthly precipitation data from the mine site weather station for 2008-2019 (see Fig. 3a) and an overflow monthly rainfall of 322.7 mm, the toxic and acidic tailings pond water will be flowing without treatment into downstream water bodies 20 out of every 137 months, or 15% of the time (see Fig. 6). Such a frequent discharge of untreated mine wastewater into downstream water bodies must be regarded as unacceptable by any standard. The basis for the overflow monthly rainfall of 322.7 mm is the statement "*diketahui bahwa pada tahun 2009 hingga tahun 2018, curah hujan rata-rata tertinggi tercatat pada bulan November yaitu 322,7 mm*" [it is known that from 2009 to 2018, the highest average rainfall was recorded in November, which was 322.7 mm]. However, based on the data in Table 4.7 of DPM (2021) (see Fig. 3a), the average monthly rainfall for November for 2009-2018 was 328.7 mm, while the average was 344.5 mm for 2008-2018 (the highest November rainfall was 503 mm in 2008). There is no explanation in DPM (2021) as to how the overflow monthly rainfall could be set so precisely (to the nearest 0.1 mm).

At this point, it is appropriate to point out that, while the original Addendum (DPM, 2019) had numerous examples of contradictory data among tables, graphs and maps, those contradictions have not been resolved in the updated Addendum (DPM, 2021). In fact, the updated Addendum (DPM, 2021) introduces even more contradictory data, including arithmetic errors (or contradictions between lists of numbers and the averages of those numbers). No attempt is made in this report to document every contradiction in the updated Addendum (DPM, 2021). However, some examples are provided with regard to the precipitation data from the mine site weather station in order to illustrate the difficulty in putting these data to use for design of the tailings dam.

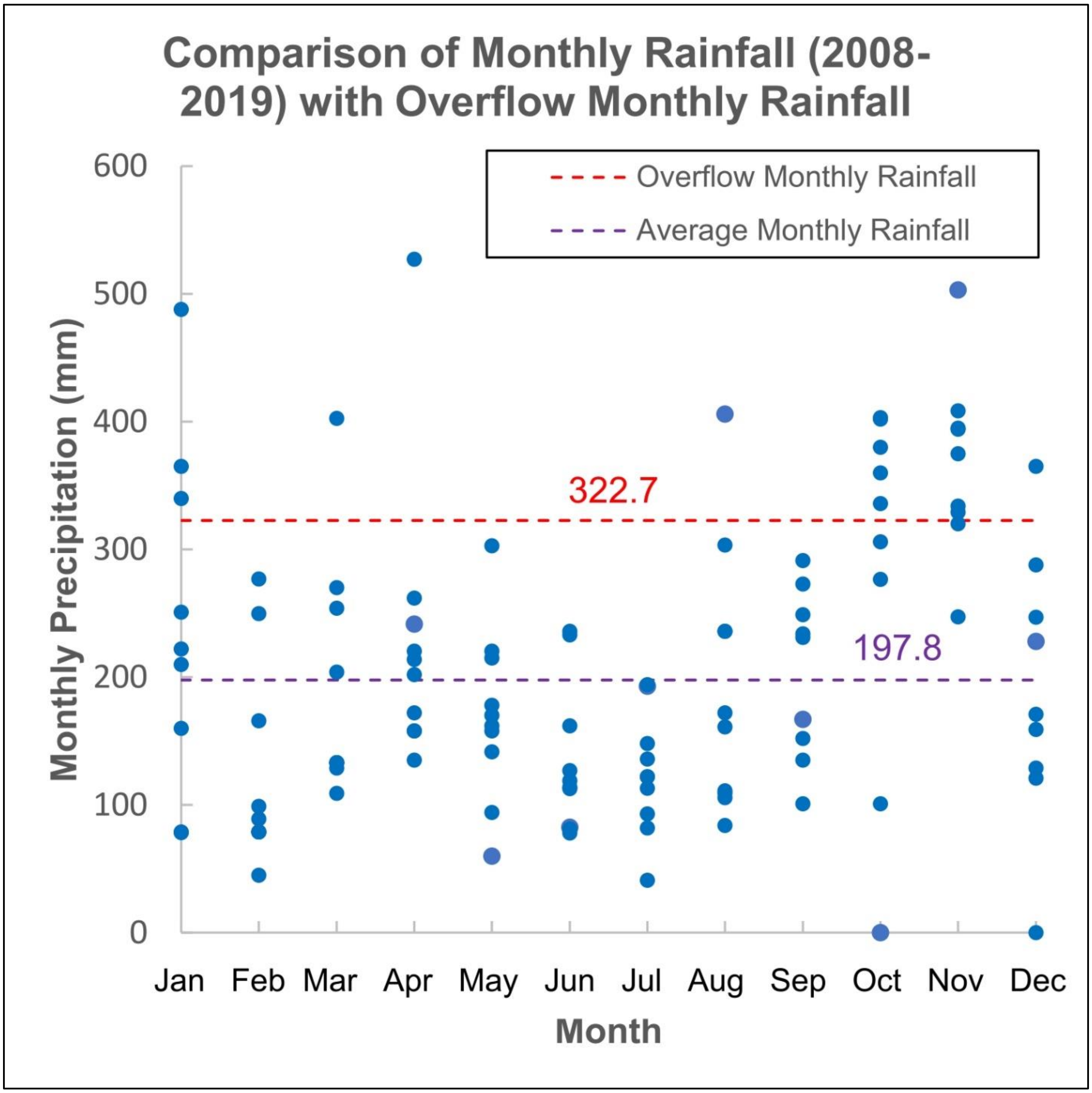

Figure 6. According to DPM (2021), after closure of the tailings dam, the tailings pond water will flow through the emergency spillway and enter the Lae Sopokomil river whenever *"curah hujan melebihi curah hujan rerata bulanan tertinggi (322,7 mm)"* [rainfall exceeds the highest average monthly rainfall (322.7 mm)]. Based on monthly precipitation data from the mine site weather station for 2008-2019 (see Fig. 3a) and an overflow monthly rainfall of 322.7 mm, the tailings pond water will be flowing into downstream water bodies 15% of the time. According to DPM (2021), "*diketahui bahwa pada tahun 2009 hingga tahun 2018, curah hujan rata-rata tertinggi tercatat pada bulan November yaitu 322,7 mm*" [it is known that from 2009 to 2018, the highest average rainfall was recorded in November, which was 322.7 mm]. However, based on the data in Table 4.7 of DPM (2021) (see Fig. 3a), the average monthly rainfall for November for 2009-2018 was 328.7 mm, while the average was 344.5 mm for 2008-2018 (the highest November rainfall was 503 mm in 2008). Based on the same data for 2008-2019, the average monthly rainfall for all months is 197.8 mm (see Fig. 3a). Data from Table 4.7 in DPM (2021).

Table 2a. Contradictions between annual and summary tables: Monthly rainfall

Month and Year	Annual Table[1] (mm)	Summary Table[2] (mm)
April 2008	241	241.5
October 2008	310	0
December 2008	223	228
September 2011	296.7	201.2
October 2011	401	401.9
May 2013	142	141.5
July 2015	114	122
September 2016	101	249
October 2016	249	101

[1] Annual tables are Tables 2.65-2.76 in DPM (2021).

[2] Summary table is Table 4.7 in DPM (2021) (see Fig. 3a). Another alternative summary table is Table 3.1 in DPM (2021) with contradictions with Table 4.7 in DPM (2021) (compare Figs. 3a-b).

Table 2b. Contradictions between annual and summary tables: Rainy days per month

Month and Year	Annual Table[1] (mm)	Summary Table[2] (mm)
September 2009	10	11
December 2009	19	18
September 2011	20	18
October 2011	22	23
November 2011	18	20
December 2011	22	21
November 2012	23	24
December 2012	27	26
May 2013	14	15
October 2013	12	13
March 2014	9	10
April 2014	22	23
August 2014	5	15
April 2015	17	18
June 2015	11	10
September 2015	21	20
September 2016	9	17
October 2016	17	10
December 2016	24	0
October 2017	9	5
April 2018	49	16
July 2018	15	16
December 2018	22	23

[1] Annual tables are Tables 2.65-2.76 in DPM (2021).

[2] Summary table is Table 3.2 in DPM (2021) (see Table A2).

The updated Addendum (DPM, 2021) includes two versions of summary tables of monthly rainfall, with Table 4.7 covering 2008-2019 (see Fig. 3a) and Table 3.1 covering 2009-2018 (see Fig. 3b). These two tables are not consistent internally nor consistent with one another for the overlapping years. Based upon the data in Table 4.7 (see Fig. 3a), the average monthly rainfalls at the mine site weather station for January, February and March should be 231.9 mm, 127.2 mm, and 181.0 mm, respectively, not 212.5 mm, 116.6 mm, and 165.9 mm, respectively, as started in the table. In a comparison of the two tables, Table 3.1 (see Fig. 3b) states the monthly rainfalls at the mine site weather station for July 2012 and November 2012 as 134 mm and 334 mm, respectively, while Table 4.7 (see Fig. 3a) states the monthly rainfalls for July 2012 and November 2012 as 194 mm and 394 mm, respectively.

In addition to two versions of the summary table for monthly precipitation (see Figs. 3a-b), there are also individual tables for each year (Tables 2.65-2.76 in DPM (2021) corresponding to 2008-2019). Of course, there is no need to have both annual tables and a summary table with the same information, but the contradictions between the annual and summary tables make it unclear as to which tables, if any, have the correct information (see Table 2a). In some cases, the contradictions are extreme. For example, Table 2.65 of DPM (2021) states 310 mm of rainfall for October 2008, while Table 4.7 states 0 mm of rainfall for the same time period (see Table 2a). The months September and October 2016 appear to be switched between Table 2.73 and Table 4.7 with no indication as to which table is correct (see Table 2a).

There is only one summary table for days of the month with non-zero precipitation (Table 3.2 in DPM (2021)), although also with individual tables (Tables 2.65-2.76 in DPM (2021) corresponding to 2008-2019) with the same type of, but contradictory, information (see Table 2b). As with monthly precipitation, some of these contradictions are extreme. For example, Tables 2.71 and 2.73 in DPM (2021) state numbers of rainy days as 5, 17, and 24 for August 2014, October 2016 and December 2016, while Table 3.2 in DPM (2021) states numbers of rainy days as 15, 10, and 0 for the same months (see Table 2b). Table 2.75 states 49 rainy days for April 2018 (as opposed to 16 rainy days in Table 3.2), which seems to indicate a considerable lack of quality control (see Table 2b) in either the recording of data or the compilation of data in the EIS Addendum or both (DPM, 2021).

Availability of Non-Acid-Generating Waste Rock

The analysis of only four samples of waste rock for determination of their acid-generating potential would be regarded as insufficient by any standard. The updated Addendum (DPM, 2021) does not indicates the size of the rock samples. However, a published procedure establishes that measurements of neutralization potential and acidity potential were made in samples of two grams (Skousen et al., 2001). On that basis, 4 × 2 grams = 8 grams represents less than 5×10^{-12} (less than one part in five trillion) of the planned 1.77 million metric tons of waste rock (DPM, 2021).

Maest et al. (2002) quoted an earlier work in writing “The principal reason that current methods rarely, if ever, provide a reliable result is the failure to test a representative number of samples in each geologic rock unit …” Maest et al. (2002) repeated the recommendations of another earlier work that, for the geochemical characterization of earth materials for potential environmental impact, the minimum sample numbers of each rock type should be 3, 8, 26 and 80 when the expected mass of exposed waste of each rock type is less than 10,000 metric tons, less than 100,000 metric tons, less than 1,000,000 metric tons, and less than 10,000,000 metric tons, respectively. Since the expected mass of waste rock is 1.77 million metric tons (DPM, 2021), the minimum number of samples should have been 80 even if all waste rock were the same rock type.

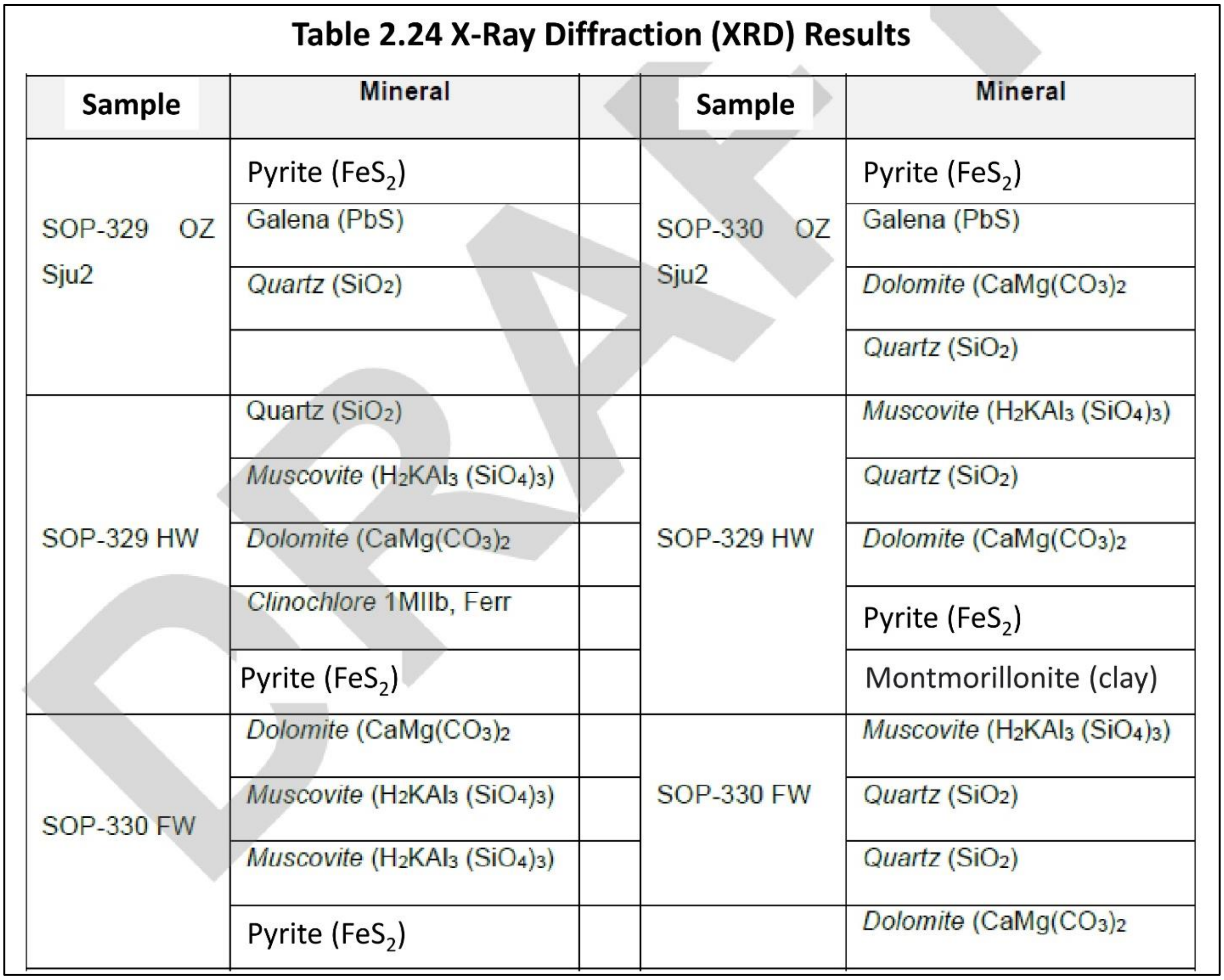

Table 2.24 X-Ray Diffraction (XRD) Results

Sample	Mineral		Sample	Mineral
SOP-329 OZ Sju2	Pyrite (FeS_2)		SOP-330 OZ Sju2	Pyrite (FeS_2)
	Galena (PbS)			Galena (PbS)
	Quartz (SiO_2)			*Dolomite* ($CaMg(CO_3)_2$
				Quartz (SiO_2)
SOP-329 HW	Quartz (SiO_2)		SOP-329 HW	*Muscovite* (H_2KAl_3 ($SiO_4)_3$)
	Muscovite (H_2KAl_3 ($SiO_4)_3$)			*Quartz* (SiO_2)
	Dolomite ($CaMg(CO_3)_2$			*Dolomite* ($CaMg(CO_3)_2$
	Clinochlore 1MIIb, Ferr			Pyrite (FeS_2)
	Pyrite (FeS_2)			Montmorillonite (clay)
SOP-330 FW	*Dolomite* ($CaMg(CO_3)_2$		SOP-330 FW	*Muscovite* (H_2KAl_3 ($SiO_4)_3$)
	Muscovite (H_2KAl_3 ($SiO_4)_3$)			*Quartz* (SiO_2)
	Muscovite (H_2KAl_3 ($SiO_4)_3$)			*Quartz* (SiO_2)
	Pyrite (FeS_2)			*Dolomite* ($CaMg(CO_3)_2$

Figure 7. DPM (2021) carried out X-ray diffraction for mineral identification on six samples, including two samples from the ore body (SOP-329 OZ Sju2 and SOP-330 OZ Sju2), two samples from the hanging wall of the waste rock (SOP-329 HW and SOP-330 HW), and two samples from the footwall of the waste rock (SOP-329 FW and SOP-330 FW). Pyrite was found in three out of the four samples of waste rock. Since pyrite is the most common acid-generating mineral, the acid-generating potential of a sample of waste rock should depend upon the abundance of pyrite. Other acid-generating sulfide minerals within the Jehe dolostone unit (source of the waste rock) include galena, sphalerite and tetrahedrite (Rivai et al., 2021; DPM, 2021). The presence of acid-generating minerals within the waste rock draws into question the assumption of DPM (2019, 2021) that sufficient NAG waste rock will be available to construct a dam for the acid-generating tailings and to construct an embankment to surround the PAG waste rock. It is noteworthy that DPM (2021) does not describe any plan for determining whether waste rock is NAG or PAG. Table from DPM (2021) with overlay of English labels.

However, the waste rock is far from homogeneous, so that even 80 samples might not be enough. The same earlier recommendations stated, “Samples must be representative of all geologic, lithologic, and alteration types and of the relative amounts and particle size of each type of material; the compositional range within mineral assemblages or rock types must be known” (Maest et al., 2002). Maest et al. (2002) were even more insistent that the minimum number of samples per “rock type” should refer not only to broad categories (such as dolostone), but should refer to specific assemblages of minerals. According to Maest et al. (2002), “The minimum number of samples suggested [above] should be applied to each different type of mineralogy (for example, addressing the range of hydrothermal and supergene alteration for each lithology), rather than to each rock type."

The X-ray diffraction data reported in the updated Addendum (DPM, 2021) showed that three out of the four waste rock samples included pyrite, which is the most common acid-generating mineral (see Fig. 7). Other acid-generating sulfide minerals in the Jehe dolostone unit (from which the waste rock would be extracted) include galena, sphalerite and tetrahedrite (Rivai et al., 2019, 2020; DPM, 2021). On that basis, the acid-generating potential of a particular sample of waste rock would be strongly dependent upon the concentrations of sulfide minerals in that sample. It is not unreasonable that potential waste rock could be divided into 10 assemblages of minerals, each consisting of 177,000 metric tons of waste rock (10% of the entire mass of waste rock). Each of those mineral assemblages would require 26 samples for adequate analysis, thus, adding up to 260 samples of waste rock.

In summary, the adequate analysis of the acid-generating potential of the waste rock should have required on the order of hundreds of samples with due attention paid to adequate representation from each assemblage of minerals. At the present time, the expected mass of NAG waste rock or even the existence of any NAG waste rock should be regarded as unknown. It is noteworthy that the updated Addendum (DPM, 2021) does not include any plan for separation of NAG and PAG waste rock, which is perplexing in view of the plan to use NAG waste rock to confine the PAG waste rock in a waste dump. In the same way, there is no plan in terms of how to construct the tailings dam or how to confine the PAG waste rock if not enough NAG waste rock is available.

DISCUSSION

Just as with the original Addendum (DPM, 2019), the updated Addendum (DPM, 2021) provides no information as to the magnitude of the 100-year storm or how the 100-year flood was calculated from the precipitation amount of the 100-year storm. As mentioned in the section Summary of Updated Addendum, DPM (2021) claims that the design of the tailings dam for a 100-year flood was carried out by the global consulting firm Knight-Piésold. However, Knight-Piésold has communicated to Inclusive Development International that "Knight Piésold's last involvement with this project was in 2008. We have not been contacted by anyone since that time regarding this project" and that "TSF location is similar to what KP [Knight-Piésold] designed in 2008 but the configuration of the TSF looks different." The design of the tailings dam for the 100-year flood by Knight-Piésold no later than 2008 is perplexing in terms of the input data for the calculation of the magnitude of the 100-year flood, since there are no precipitation data for the mine site prior to April 2008 (see Fig. 3a).

The original Addendum contradicts the information from the consultants by writing, "*PT. DPM telah menunjuk Knight Piésold Pty Ltd. untuk melakukan pekerjaan investigasi geoteknik yang berkaitan dengan pengembangan kegiatan pertambangan Seng dan Timbal di Kecamatan Silima Pungga-Pungga, Provinsi Sumatera Utara, termasuk dalam lingkup pekerjaan adalah investigasi geoteknik lapangan dan laboratorium untuk desain jalan akses, lokasi pabrik dan Tailings Storage Facility (TSF) di Bondar Begu. Sebanyak 119 pengeboran geoteknik dengan total kedalaman 3.473,62 m telah dilakukan oleh konsultan Golder Associates dan Knight Piesold pada tahun 2010*" [PT. DPM has appointed Knight Piésold Pty Ltd. to carry out geotechnical investigation work related to the development of zinc and lead mining activities in Silima Pungga-Pungga Subdistrict, North Sumatra Province, with the scope of work including field and laboratory geotechnical investigations for access road design, factory locations and Tailings Storage Facility (TSF) in Bondar Begu. A total of 119 geotechnical drillings with a total depth of 3,473.62 m were carried out by consultants Golder Associates and Knight Piésold in 2010] (DPM, 2019). On the other hand, the same document includes a *Tabel 3.23 Hasil Uji Geoteknik oleh Knights Piesold* [Table 3.23 Geotechnical Test Results by Knights Piésold] with the information that all geotechnical sampling was carried out in April 2004. None of the preceding information regarding the timing of the involvement of Knight-Piésold appears in the updated Addendum (DPM, 2021).

It is now appropriate to reconsider the possibility that, in the updated Addendum (DPM, 2021), the 100-year storm based on monthly rainfall literally refers to rainy periods that are confined to months of the calendar. Since the updated Addendum (DPM, 2021) includes only monthly precipitation data, and since all other hydrologic data (such as water quality and stream discharge) are reported as individual rather than aggregate measurements, it is distinctly possible that daily precipitation data from the mine site do not even exist, and the mine site weather station has literally been recording precipitation only at the end of each month. A design of the tailings dam based on storms that were confined to calendar months would be even less conservative than a design based on storms with a duration of 30 days. For example, a very wet rainy period could last from October 15 to November 13 (30 days) without either the month of October or the month of November being especially wet.

The precipitation data from Polonia show that, in any given year, the total rainfall over any 30-day period can be considerably greater than the total rainfall that is confined to a calendar month (see Table 3). For example, in 1995, the wettest month was August with 216.5 mm of rainfall, while the wettest 30-day period was October 18 to November 17 with 325.7 mm of rainfall (see Table 3). In that year, the rainfall amounts for October and November were 168 mm and 210.5 mm, respectively. On average, for each of the ten years of valid data at Polonia, the wettest 30-day period had 28% more rainfall than the wettest calendar month (see Table 3). In summary, the design for a 100-year storm based on monthly rainfall amounts should be regarded as a highly non-conservative approach (non-protective of people and the environment).

Table 3. Yearly maximum precipitation for calendar months and 30-day periods: Polonia[1]

Year	Maximum Precipitation: 30-Day Period (mm)	Maximum Precipitation: Calendar Month (mm)	Precipitation Ratio: 30-Day Period / Calendar Month
1979	718.3	690	1.04
1980	648.4	472.4	1.37
1993	294.1	228.1	1.29
1994	279.1	247.1	1.13
1995	325.7	216.5	1.50
1996	285.4	216.9	1.32
1997	170.4	148.3	1.15
1998	272.5	242.3	1.12
2003	448.7	316.8	1.42
2004	299.3	211.4	1.42
		Average	1.28

[1] Based on daily precipitation data for Polonia in WMO (2021).

As reviewed in the earlier report by Emerman (2020), since the failure of the tailings dam at the DPM mine will result in the probable loss of human life, according to both internationally-recognized guidelines and Indonesian dam safety regulations, the dam should be designed to withstand not only the 100-year flood, but either the 10,000-year flood or the Probable Maximum Flood (PMF), which is considerably rarer than the 10,000-year flood. The analysis of the precipitation data from the mine site weather station and the Polonia weather station in this report illustrate the challenge in calculating the magnitude of the Probable Maximum Precipitation (PMP) or the 10,000-year precipitation event. Based on its numerous contradictions, the monthly precipitation data from the mine site are probably not useful for any purpose. In any event, the calculation of the PMF or the 10,000-year flood for single-day or multi-day storms would require daily precipitation data. The calculation of the PMP or the 10,000-year precipitation event at the mine site from the Polonia precipitation data would involve at least three levels of uncertainty:

1) the extrapolation of the 10,000-year storm from only 10 years of valid data;
2) the extrapolation of a storm at Polonia to the mine site 102 kilometers to the southwest and 555 meters higher in elevation;
3) the extrapolation of precipitation data without significant La Niña phenomena and with a bias toward El Niño phenomena to a year with extreme La Niña phenomena.

One approach would be to trade space for time, essentially combining precipitation data from many weather stations in Indonesia and southeast Asia, taking due account of each station's time limitation, as well as distance and elevation difference from the mine site. Another approach would be to carry out the calculation using data only from Polonia and then to multiply the estimated precipitation amount by a suitably large factor to take into account all of the uncertainties. A useful starting point could be to simply assume that the PMP for a 24-hour storm at the mine site is the maximum recorded 24-hour rainfall of 1825 mm at Foc Foc on the island of Réunion on March 15-16, 1952 (WMO, 2009). The above value is actually reasonable, considering that 10 years of precipitation data from the Polonia weather station predicted 653.6 mm for a 24-hour storm with a return period of 100 years. Further discussion along these lines is beyond the scope of this report.

CONCLUSIONS

The conclusions of this report can be summarized as follows:

1) The design of the tailings dam at the DPM mine to withstand a 100-year flood based on rainy periods with duration of 30 days is not a conservative design (not protective of people and the environment). Historic daily precipitation data from the Polonia weather station (102 kilometers northeast of the mine site) illustrates the principle that storms of duration 24-72 hours are much more extreme, relative to average precipitation, than month-long rainy periods. In particular, the ratio of the 100-year precipitation to the average precipitation at Polonia is 153.2, 83.1, 56.7, 26.8, and 9.8 for storms with durations of 24 hours, 48 hours, 72 hours, 7 days and 30 days, respectively.
2) Based on the design overflow monthly rainfall and monthly precipitation data from the mine site, 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 will be occurring 15% of the time. Such a frequent discharge of

untreated mine wastewater into downstream water bodies must be regarded as unacceptable by any standard.

3) The conclusion that non-acid-generating (NAG) waste rock will be available for construction of the tailings dam and for confining the potentially acid-generating (PAG) waste rock in a free-standing waste dump was based upon only four rock samples. Since the waste rock would include acid-generating sulfide minerals such as pyrite, galena, and sphalerite, the acid-generating status would depend upon the sulfide concentration in a particular sample. Based on standard practice, the fraction of waste rock that would be NAG or PAG should be determined from hundreds of samples. Thus, it is not known whether there will be enough NAG waste rock to construct the tailings dam or to confine the PAG waste rock in a free-standing waste dump. There are no contingency plans for the non-availability of sufficient NAG waste rock, although the consequences could be severe.
4) There are numerous contradictions among the tables, graphs and maps in the updated Addendum, as well as arithmetic errors.

RECOMMENDATIONS

The 2021 EIS Addendum contains many shortcomings and contradictions and does not address any of the concerns raised with regard to the 2019 EIA Addendum. With regard to the hydrological aspects, the design of the tailings storage facility remains fundamentally flawed. It is recommended that the proposal for the DPM lead-zinc mine be rejected without further consideration.

ABOUT THE AUTHOR

Dr. Steven H. Emerman has a B.S. in Mathematics from The Ohio State University, M.A. in Geophysics from Princeton University, and Ph.D. in Geophysics from Cornell University. Dr. Emerman has 31 years of experience teaching hydrology and geophysics, including teaching as a Fulbright Professor in Ecuador and Nepal, and has 70 peer-reviewed publications in these areas. Dr. Emerman is the owner of Malach Consulting, which specializes in evaluating the environmental impacts of mining for mining companies, as well as governmental and non-governmental organizations. Dr. Emerman has evaluated proposed and existing tailings dams in North America, South America, Europe, Africa, Asia and Oceania, and has testified on tailings dams before the U.S. House of Representatives Subcommittee on Indigenous Peoples of the United States and the United Nations Permanent Forum on Indigenous Issues. Dr. Emerman is the Chair of the Body of Knowledge Subcommittee of the U.S. Society on Dams and one of the authors of <u>Safety First: Guidelines for Responsible Mine Tailings Management</u>.

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APPENDIX

Table A1. Daily precipitation data: Polonia[1]

Year[2]	Days with Recorded Data	Days with Non-Zero Precipitation	Days with Non-Zero Precipitation (% of Days with Recorded Data)
1958	25	21	84.0
1959	0		
1960	0		
1961	0		
1962	36	32	88.9
1963	35	30	85.7
1964	143	109	76.2
1965	76	62	81.6
1966	0		
1967	0		
1968	0		
1969	0		
1970	0		
1971	0		
1972	0		
1973	160	4	2.5
1974	284	9	3.2
1975	14	1	7.1
1976	77	1	1.3
1977	312	5	1.6
1978	319	9	2.8
1979	313	110	35.1
1980	304	111	36.5
1981	256	87	34.0
1982	46	16	34.8
1983	82	24	29.3
1984	64	13	20.3
1985	67	20	29.9
1986	82	15	18.3
1987	70	21	30.0
1988	68	21	30.9
1989	36	9	25.0
1990	76	21	27.6
1991	63	16	25.4
1992	143	39	27.3
1993	285	81	28.4
1994	336	89	26.5
1995	325	90	27.7
1996	324	83	25.6
1997	351	66	18.8

1998	329	67	20.4
1999	42	12	28.6
2000	5	1	20.0
2001	0		
2002	93	35	37.6
2003	306	89	29.1
2004	292	79	27.1
2005	187	46	24.6
2006	8	7	87.5
2007	14	13	92.9
2008	10	9	90.0
2009	4	1	25.0
2010	8	6	75.0
2011	5	5	100.0
2012	8	5	62.5
2013	2	2	100.0
2014	3	3	100.0
2015	3	3	100.0
2016	0		
2017	10	10	100.0
2018	0		
2019	0		
2020	3	3	100.0

[1] Based on daily precipitation data for Polonia in WMO (2021).

[2] Years in red boldface were used to develop precipitation-frequency relationships (see Fig. 5).

Table A2. Number of days with rain: DPM mine site[1]

Month	**Number of Days**										
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Days (%)**
January	15	15	22	16	19	6	18	11	15	15	49.0
February	11	15	19	8	8	4	7	8	9	13	36.2
March	17	16	21	11	11	10	10	11	14	13	43.2
April	17	15	20	18	13	23	18	13	18	16	57.0
May	16	11	23	15	15	12	17	13	10	9	45.5
June	6	20	19	6	15	7	10	11	11	9	38.0
July	11	16	16	15	3	7	12	9	9	16	36.8
August	25	17	20	19	7	15	11	13	18	14	51.3
September	11	21	18	10	12	20	20	17	19	15	54.3
October	22	13	23	24	13	27	23	10	5	23	59.0
November	24	26	20	24	22	26	26	26	17	24	78.3
December	18	19	21	26	13	23	12	0	22	23	57.1
Days (%)	52.9	55.9	66.3	52.5	41.4	49.3	50.4	38.8	45.8	52.1	50.5

[1] Table modified from Table 3.2 in DPM (2021).

Table A3. Yearly maximum precipitation over 24, 48 and 72 hours: Polonia[1]

Rank	24-Hour		48-Hour		72-Hour	
	Year	Precipitation (mm)	Year	Precipitation (mm)	Year	Precipitation (mm)
1	1979	329.9	1980	400	1980	403.0
2	1980	329.9	1979	338.8	1979	367.0
3	1994	119.1	1994	146.0	1994	146.0
4	2003	97.0	1993	118.1	2003	137.2
5	1993	89.9	2003	102.1	1993	132.1
6	1995	82.0	1998	99.1	1998	105.2
7	1996	75.9	1995	98.1	1995	102.2
8	2004	73.9	1996	76.9	1997	86.8
9	1998	69.1	2004	73.9	1996	84.8
10	1997	58.9	1997	70.8	2004	75.2

[1] Based on daily precipitation data for Polonia in WMO (2021).

Table A4. Yearly maximum precipitation over 7 and 30 days: Polonia[1]

Rank	7-Day		30-Day	
	Year	Precipitation (mm)	Year	Precipitation (mm)
1	1980	458.1	1979	718.3
2	1979	418.9	1980	648.4
3	1995	166.2	2003	448.7
4	1993	156.2	1995	325.7
5	2003	147.1	2004	299.3
6	1994	146.5	1993	294.1
7	1996	131.0	1996	285.4
8	1998	128.0	1994	279.1
9	2004	105.2	1998	272.5
10	1997	101.8	1997	170.4

[1] Based on daily precipitation data for Polonia in WMO (2021).