Exhibit 2

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Scoping Comments

The EIS should review all of the hydrologic impacts on both surface water and groundwater that were predicted in the original EIS documents for the East Boulder and Stillwater mines. The EIS should compare the predictions with the hydrologic impacts that actually occurred. The EIS should fully account for all discrepancies and should discuss the possibility that the predictions for the Lewis Gulch Tailings and Dry Fork Waste Rock Expansion will differ from the predictions.

The post-closure dam breach assessment should take into account the long-term degradation of the tailings storage facility that will take place during the decades and centuries following the cessation of monitoring, inspection and maintenance of the Lewis Gulch TSF. If it is believed that the Lewis Gulch tailings storage facility will not degrade in the absence of maintenance, there should be a detailed discussion as to why this tailings storage facility will differ from every other engineered structure.

This inevitable degradation and ultimate failure has been discussed extensively by Dr. Steven Vick, the author of the standard textbook Planning, Design, and Analysis of Tailings Dams (Vick, 1990) and one of the members of the expert panel that reviewed the tailings dam failure at the Mount Polley mine (Independent Expert Engineering Investigation and Review Panel, 2015). In a conference presentation, Vick (2014a) concluded that “System failure probabilities much less than 50/50 are unlikely to be achievable over performance periods greater than 100 years … system failure probability approaches 1.0 after several hundred years.” Vick (2014a) continued, “For closure, system failure is inevitable … so closure risk depends solely on failure consequences.” In the accompanying conference paper, Vick (2014b) elaborated, “Regardless of the return period selected for design events, the cumulative failure probability will approach 1.0 for typical numbers of failure modes and durations. This has major implications. For closure conditions, the likelihood component of risk becomes unimportant and only the consequence component matters … This counterintuitive result for closure differs so markedly from operating conditions that it bears repeating. In general, reducing failure likelihood during closure—through more stringent design criteria or otherwise—does not materially reduce risk, simply because there are too many opportunities for too many things to go wrong. In a statistical sense, all it can do is to push failure farther out in time. System failure must be accepted as inevitable, leaving reduction of failure consequences as the only effective strategy for risk reduction during closure.”

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, “Furthermore, it is assumed that this scenario [Rainy Day Breach] occurs coincident with a 1,000-year flood event in the Upper East Boulder sub basin and 500-year flood events in the Boulder River sub basin and the Yellowstone River.” The above choice of storm

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return periods was not justified and does not seem logical. It is certainly possible that, if a 1000-year flood were occurring in the Upper East Boulder sub basin, then a 1000-year flood event would also be occurring in the Boulder River sub basin and the Yellowstone River. Appendix C1 in the same document further states, "Rainy Day Breach - This considered an overtopping failure for a PMF [Probable Maximum Flood] event superimposed on a full TSF with an average operating pond immediately prior to the installation of the interim spillway, along with coincidental 1,000-year or 500-year flood events within the East Boulder River and the remainder of the Boulder Sub Basin, and for the Yellowstone River, respectively." In the same way, it is certainly possible that, if the Lewis Gulch TSF were receiving the PMF, then the Upper East Boulder River, Boulder River, and Yellowstone River would all be experiencing the PMF at the same time. The calculation of the PMF in the Upper East Boulder River, Boulder River, and Yellowstone River should include the stormwater that would be discharged into the East Boulder River due to a PMF event at the mine site.

According to the Canadian Dam Association (2021), "Flood induced or rainy day scenario … A flood that is equal or larger than the inflow design flood (IDF) for the TSF is typically used for this scenario." Since the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "The IDF is the Probable Maximum Flood (PMF) resulting from the Probable Maximum Precipitation (PMP) event plus snowmelt," the rainy day scenario should consider the simultaneous Probable Maximum Flood (PMF) in the Upper East Boulder sub basin, the Boulder River sub basin, and the Yellowstone River, as well as within the watershed of the Lewis Gulch TSF.

The estimation of the PMF should take climate change into account. The necessity to take climate change into account in the dam breach assessment occurs in two requirements of the Global Industry Standard on Tailings Management (GISTM). According to the GISTM, "Requirement 3.3: For new tailings facilities, use the knowledge base, including uncertainties due to climate change, to assess the social, environmental and local economic impacts of the tailings facility and its potential failure throughout its lifecycle … Requirement 3.4: … If new data indicates that the impacts from the tailings facility have changed materially, including as a result of climate change knowledge or long-term impacts, the Operator shall update tailings facility management to reflect the new data using Adaptive Management best practices" (ICMM-UNEP-PRI, 2020).

It is noteworthy that, as a Company Member of International Council on Mining & Metals (ICMM), Sibanye-Stillwater is obligated to implement the GISTM by August 2023 (ICMM, 2020, 2022a). Some relevant Association Members of ICMM include Minerals Council South Africa, Mining Industry Associations of Southern Africa (MIASA), National Mining Association – USA, and the USA-based Society for Mining, Metallurgy, and Exploration (ICMM, 2022b).

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In the sentence "The IDF is the Probable Maximum Flood (PMF) resulting from the Probable Maximum Precipitation (PMP) event plus snowmelt," the phrase "plus snowmelt" requires clarification in the EIS. For consistency with the PMP, "plus snowmelt" should refer to a rain-on-snow event in which the snowpack is the largest snowpack that is theoretically possible at a given location (the snowpack equivalent to the PMP).

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "the study does not include estimates of downstream consequences (loss of life, environmental, cultural, and/or economic values) within the inundation extents; however, the results of this study can be used for these assessments." All the preceding omissions should be fully discussed in the EIS. The downstream consequences of a post-closure dam breach should take into account the possibility that there could be no personnel at the TSF or the mine site during the post-closure phase.

For reference, the most recent guidelines of the Mining Association of Canada (2021) describe the requirements of a dam breach assessment (inundation study) as follows: "For tailings facilities that pose a risk of inundation of downstream areas in the event of a failure, the ERP [Emergency Response Plan] and the EPP [Emergency Preparedness Plan] need to take into account inundation mapping. The area that could be inundated needs to be clearly defined, describing the maximum extent of flooding, flood depths, and time to maximum depth. Maps of potentially inundated areas need to be developed and included in the ERP and the EPP, identifying any downstream mine site infrastructure, communities, residences, farms, recreational facilities, roads, railways, bridges, powerlines, other infrastructure, or other features (e.g., wildlife habitat) that could be impacted in the event that an emergency occurs. The scope of an EPP encompasses all COI [Communities of Interest] and local authorities that could be potentially impacted by an inundation event … Procedures need to be established and implemented for regularly scheduled review and testing of ERPs and EPPs to ensure that the plans are up-to-date and adequate, and that all relevant personnel, including external parties, are familiar with the plans and their roles and responsibilities if an emergency occurs."

Along the lines of the previous two paragraphs, the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "Critical infrastructure which would be affected by the breach include numerous bridges along the East Boulder and Boulder River and Highway 298 and Highway 90." Among many other considerations, the EIS should consider the impact on rescue operations that would result from damages to numerous bridges along the East Boulder and Boulder River, as well as flooding of Highway 298 and Highway 90.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "The purpose of the dam breach assessment is to … Assess the

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potential downstream impacts from an unplanned release of water and tailings considering a hypothetical breach of the TSF under worst case scenarios." Although the EIS is not required to consider the literal "worst-case scenario," the EIS should clarify the credible scenarios that have the greatest consequences. The loss of 100% of the stored tailings is certainly a credible scenario, since previous tailings dam failures have released 100% of the stored tailings. Some examples of total losses of tailings include the failure of the El Cobre New Dam in Chile in March 1965 (350,000 cubic meters), and the failures at the Pittston Coal mine in Buffalo Creek, West Virginia, in February 1972 (500,000 cubic meters), the United Nuclear uranium mine in Churchrock, New Mexico, in July 1979 (370,000 cubic meters), and the Louyang Xiangjiang Wanji aluminum mine in China in August 2016 (2 million cubic meters) (Center for Science in Public Participation, 2022). According to Safety First: Guidelines for Responsible Mine Tailings Management, "Worst-case tailings failure scenarios must consider the loss of all tailings at full tailings facility buildout, and the results must be made public prior to permitting" (Morrill et al., 2022).

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "The dam breach assessment following closure was completed for two different tailings conditions: … long-term closure conditions when the impounded tailings are fully drained, partially saturated, and no longer potentially liquefiable." The EIS should predict when the long-term closure conditions will become effective. In other words, the EIS should carry out a prediction as to when the tailings will no longer be potentially liquefiable.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states "The TSF embankments will be constructed of compacted Random Fill (glacial drift, comprising sandy gravel with frequent cobbles and boulders). For the purposes of this study, this material is considered to be non-erodible." The EIS should take into consideration the possibility that erosion of the embankment could occur. It is difficult to see how non-erodibility of the TSF embankment can be reconciled with the description of the "Rainy Day Scenario" in the same document that includes "a localized slump occurring in the northeast embankment crest just as the full PMF volume is stored, such that stored water overtops the embankment and causes *massive erosion* and the subsequent release of impounded water and tailings" (emphasis added).

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "Given the robust design to the Lewis Gulch TSF, it is difficult to imagine a realistic scenario that would result in partial or complete failure of the TSF embankments during operations or following closure." Language such as "realistic scenario" should be avoided in the EIS. The issue is not whether a failure mode is "realistic" (which is a poorly-defined term), but whether it is "credible." Requirement 2.3 of the GISTM is to "Develop and document a breach analysis for the tailings facility using a methodology that considers

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credible failure modes, site conditions, and the properties of the slurry" (ICMM-UNEP-PRI, 2020). In this respect, a credible failure mode is any failure mode that is physically possible (Morrill et al., 2022). According to the GISTM, "The term 'credible failure mode' is not associated with a probability of this event occurring" (ICMM-UNEP-PRI, 2020).

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility considers the following three failure modes:
1) "Rainy Day Scenario - The failure mode was modelled as a localized slump occurring in the northeast embankment crest just as the full PMF volume is stored, such that stored water overtops the embankment and causes massive erosion and subsequent release of impoundment water and tailings"
2) "Sunny Day Scenario - The failure mode was modelled as an earthquake event that causes a rupture in the TSF embankment and results in piping followed by massive erosion and the release of impounded water and tailings"
3) "Post Closure - The failure mode was modelled as an earthquake event that causes a rupture in the TSF embankment."

The above is not a complete list of failure modes. The EIS should consider all credible failure modes. As explained previously, a credible failure mode is any failure mode that is physically possible. In other words, every imaginable failure mode should be considered and that failure mode should be removed from further consideration only after it has been demonstrated that the failure mode is physically impossible. According to the SME (Society for Mining, Metallurgy, and Exploration) Tailings Management Handbook – A Life-Cycle Approach, "An example of a non-credible failure mode is a sudden slope failure of a drained, non-liquifiable tailings facility in an arid climatic setting, where there is no mechanism for re-saturation" (Clohan and Kidner, 2002). It is important to note the extent of restriction in the above example in that the lack of a credible failure mode would require no further addition of saturated or near-saturated materials, as well as the physical impossibility of any further tailings consolidation (which could cause the re-saturation of unsaturated pores by reducing pore sizes).

The following is a partial list of possible failure modes, all of which should be considered in the EIS, unless the EIS also includes a convincing demonstration that a particular failure mode is non-credible (i.e., physically impossible):
1) static liquefaction of the embankment
2) dynamic liquefaction of the embankment
3) failure of the foundation
4) overtopping due to settling of the dam crest
5) overtopping due to landsliding into the tailings pond
6) slumping (slope failure) of the embankment
7) internal erosion unrelated to seismic activity (such as construction deficiencies)

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8) slippage of liner over foundation (for example, due to upwelling of groundwater)
9) erosion of the toe of the dam by high water from the East Boulder River

As stated previously, it should be borne in mind that, according to the GISTM, "The term 'credible failure mode' is not associated with a probability of this event occurring" (ICMM-UNEP-PRI, 2020).

The possibility of erosion of the dam toe by rising floodwaters of the East Boulder River deserves particular consideration. High water from the East Boulder River (which would generally be accompanied by high precipitation onto the dam face) could damage the toe without causing failure of the dam at that time. The EIS should fully consider the toe erosion that could result from the Probable Maximum Flood along the East Boulder River. An important factor in the post-closure phase (after monitoring, inspection and maintenance have ceased) is the lack of repairs after damages have occurred. This lack of repairs would cause the dam to be more vulnerable to all modes of failure, especially to a subsequent event of rising floodwaters from the river accompanied by high precipitation onto the dam. Oboni et al. (2014) have discussed the significance for the survivability of tailings dams of near-failures without subsequent repairs during the post-closure phase when maintenance has ceased.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "The consolidation and flowability assessment completed for the Nye TSF … is believed to be reasonably representative of conditions at the Lewis Gulch … The tailings are expected to behave as follows: … The tailings solids content may vary from approximately 67% (by mass) at surface for recently deposited saturated tailings to greater than 75% (by mass) at depth for more consolidated saturated tailings." The EIS should include a rigorous analysis as to how and why the tailings at the Nye TSF will be similar to and different from the tailings at the Lewis Gulch TSF. The EIS should include an analysis of tailings from a pilot project that would produce tailings similar to what would be produced for the Lewis Gulch TSF.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "This tailings densification and stabilization [after closure] will be enhanced by surface capping while further consolidation drainage can be accelerated by using wick drains if needed." The EIS should predict how many years will pass before the decision to install wick drains would be necessary. The EIS should evaluate the ability of the mining company to still be carrying out maintenance of the TSF at the time when a decision to install wick drains would be necessary.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "In the event of a hypothetical dam breach in the longer term after closure, the consolidated tailings would develop steeper residual and mobilized slopes as

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compared to the looser unconsolidated and more recently deposited saturated tailings." Although not directly related to the preceding quote, the EIS should present a plan for stabilizing the remaining tailings after a dam breach. The EIS should furthermore evaluate the ability of the mining company to still be carrying out maintenance of the TSF at the time when it would be necessary to stabilize the remaining tailings after a dam breach.
The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "After closure, the supernatant pond will be removed, and a closure cap will be constructed to provide long-term water management and mitigate the potential for water to pond on the tailings surface. Therefore, the most relevant TSF breach scenario after closure would be Class 2 (Table 3.1). During the early years following closure it is likely that a portion of the tailings will be saturated and potentially liquefiable (i.e. Class 2A). With time and ongoing drainage, a non-liquefiable (non-fluid) tailings mass (i.e. Class 2B) may progressively develop." Another scenario is that a non-liquefiable tailings mass could be mobilized into fluid-like behavior after falling into the East Boulder River. The EIS should evaluate the preceding scenario in terms of whether it is physically possible (i.e., credible). If the EIS cannot demonstrate that the preceding scenario is non-credible, then the consequences of the preceding scenario should be fully investigated.

In terms of the importance of mixing with the East Boulder River, even with regard to filtered tailings, Klohn Crippen Berger (2017) wrote, "Failure, if it occurs, would likely be local slumping and consequences would restricted to the local area (or the distance equivalent to roughly 10 times the height) unless the material slumps into a water body … When large water ponds are located downstream of high-density thickened/paste or filtered facilities, cascading failures are possible and should be accounted for when developing the risk profile of tailings facility management." A similar concept was even expressed in Appendix A1 of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility that stated, "higher runouts were observed for the following conditions (Small et al., 2017): … Tailings facilities with a downstream source of water that can mix with the breach material (i.e. a pond or a river) and propagate downstream transport … The runout distance for mobilized tailings may increase if the tailings flow along steep downstream slopes, or encounter and mix with downstream waterbodies."

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "The post-closure dam breach assessment is included in Appendix D. Three cases were considered depending on the magnitude of the breach, as described below:
• Case A - Slump of embankment materials that does not result in the release of impounded tailings and water.
• Case B - Hypothetical removal of the embankment followed by the flow of liquefied tailings (i.e. Class 2A breach).

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• Case C - Hypothetical removal of the embankment followed by slumping of non-liquefiable tailings (i.e. Class 2B breach)."
Along the lines in the previous paragraph, there should be a Case D - Hypothetical removal of the embankment followed by slumping of non-liquefiable tailings into the East Boulder River followed by mixing with river water and mobilization of the tailings into a fluid-like mass.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "Tailings and water released during the Rainy Day scenario were routed downstream as a Newtonian fluid … Two phases of flow were evaluated for the Sunny Day scenario, as follows: … Phase 1 - Includes the initial breach outflow comprised of water impounded on the tailings surface, eroded tailings, and eroded embankment materials. The Phase 1 flow was routed downstream as a Newtonian fluid." The EIS should consider the range of possible rheologies with the appropriate ranges of parameters for each rheology. The EIS should fully consider the consequences of downstream routing based on each rheology with the appropriate range of parameters. If the authors of the EIS conclude that the assumption of a Newtonian fluid is the most conservative assumption in all respects, that conclusion should be fully justified. Nothing in the document states the viscosity that was assumed for the Newtonian fluid, either in terms of whether the viscosity of water was assumed or a higher viscosity that might depend upon the sediment concentration. The choice of viscosity should be fully justified in the EIS, especially the possibility that the viscosity might depend upon the sediment concentration.

Figure 4.1 in the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility shows residual slopes of 7% for the rainy day scenario and 3% for the sunny day scenario. The EIS should fully justify these assumptions. Sensitivity analyses should be carried out to assess the impact of these assumptions. The EIS should fully justify all of the other assumptions in Table 4.1 Released Volume from the Lewis Gulch TSF, as well as carry out sensitivity analyses to assess the impact of these assumptions. As discussed previously, the EIS should consider the credible scenario of loss of 100% of stored tailings. If the authors of the EIS conclude the loss of 100% of stored tailings is non-credible (i.e., physically impossible), they should fully explain why loss of 100% of stored tailings could have occurred in other tailings dam failures (e,g., El Cobre New Dam in Chile in March 1965, Pittston Coal mine in Buffalo Creek, West Virginia in February 1972, United Nuclear uranium mine in Churchrock, New Mexico in July 1979, Louyang Xiangjiang Wanji aluminum mine in China in August 2016), but not in the failure of the Lewis Gulch TSF.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "The main components used for defining the breach outflow hydrograph include the breach mechanism (e.g. piping or overtopping), the breach parameters (time to failure, width of breach, and side slopes of breach), and the volume of materials released

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in the breach." The document adds, "The selected parameters … have a considerable impact on the results." The time to failure is a very critical factor. Breaches that result from overtopping or internal erosion typically develop over hours, while breaches due to static or dynamic liquefaction typically develop over seconds. Among other scenarios, the EIS should develop a dam breach assessment based upon the breach that could develop in seconds due to static liquefaction.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "There are no industry standards [for breach parameters] for tailings dams, and the equations typically referenced are empirical and largely based on past failures of water retaining dams often less than 100 ft. high." This is correct, but the document does not even make any attempt to consider appropriate breach parameters for tailings dams. At this point, there is enough data on tailings dam failures to develop appropriate breach parameters for tailings dams and this should be done in the EIS.

In addition to numerical computations of tailings spills, the EIS should consider empirical relations among dam height, stored volume, release volume, and runout distance from historical tailings dam failures. The most up-to-date empirical relations can be found in Piciullo et al. (2022). The EIS should fully discuss discrepancies and common features between empirical relations and numerical computations for a dam breach at the Lewis Gulch TSF.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "The East Boulder River is generally 40 to 60 ft. wide along this reach of the river and appears shallow based on the presence of boulders that were identified using aerial imagery. Similarly, the Boulder River is generally 100 to 150 ft. wide between the East Boulder and Yellowstone Rivers and appears shallow based on the presence of boulders that were identified using aerial imagery." The dam breach assessment in the EIS should rely upon actual measurements of the shape and depth of the East Boulder and Boulder Rivers and river valleys, and not only upon assumptions made based upon aerial photographs.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "The likelihood of a dam breach occurring at any time is exceptionally low, but the likelihood of it occurring following closure is lower than during operations … Thus, the likelihood of a dam breach occurring following closure is considered to be very low." The EIS should include quantitative estimates of the annual probability of failure during both operation and closure. These estimates should be fully justified and should be compared with acceptable probabilities of failure in widely-recognized dam safety risk guidelines (e.g., Canadian Dam Association, 2013; USACE, 2014; FERC, 2016). The EIS should fully discuss the maximum risk reduction that could be achieved through ALARP (As Low As Reasonably Practicable) principles. For reference, according to FERC (2016), "The application of ALARP

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considerations mean that actions should be taken to reduce risk below the tolerable risk reference line until such actions are impracticable or not cost effective." Qualitative estimates of the annual probability of failure (such as "exceptionally low" or "very low") should be avoided throughout the EIS.

The cross-sections in Figure 5.1 in the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility show very short-distance transport of the slumped material simply because the failure surfaces are assumed to be very shallow. Any assumption in the EIS as to the failure surface of the embankment should be justified in terms of a rigorous limit equilibrium analysis. In any event, a deep failure surface should be assumed for the purpose of investigating all credible scenarios. It is particularly important to consider all credible scenarios that would carry any slumped material into the East Boulder River, where they could be mobilized into a fluid-like mass.

It is clear from Figure 5.1 of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility that the outcome of a volume balanced geometrical method is highly dependent upon the assumed final slope angle of the slumped material. This assumption is also clarified in the statement that "The geometrical analyses incorporated a material volume balance to approximate the potential flow or slumping of materials at defined residual or settled slope angles." The EIS should fully justify any assumed final angles of slumped materials. Sensitivity analyses should be carried out to assess the impact of these assumptions.

In addition to the above, the EIS should be cautious about the use of simplified methodologies such as the volume balanced geometrical method. The authors of the EIS should note that such simplistic methodologies are not even mentioned in standard references on tailings dam or waste dump failures, such as Guidelines for Mine Waste Dump and Stockpile Design (Hawley and Cunning, 2017) or Technical Bulletin—Tailings Dam Breach Analysis (Canadian Dam Association, 2021). If the authors of the EIS choose to use the volume balanced geometrical method, they should fully explain why such a simplistic methodology is not applicable to tailings dams and waste dumps in general, but would be applicable to the Lewis Gulch TSF.

Along the above lines, the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states that "The subsequent Phase 2 flow of tailings (solids and interstitial water) was evaluated using volume balanced geometrical methods … The geometric models assume that approximately half of the mobilized tailings would flow upstream while the remainder would flow downstream." From a purely geometric standpoint, it is correct that half of the tailings would flow downstream, while half would flow upstream. However, the EIS should consider dynamic models in which gravity would force a greater portion of the tailings to flow downstream.

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Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "Following Table B.1, materials with high sediment concentrations (e.g. 65% by volume, or greater) would be expected to behave as a landslide (solid) and mobilize via block sliding. Conversely, materials with low sediment concentrations (e.g. 20% by volume, or less) will behave as a water floods (fluid) … In general, materials from hard rock mines with less than approximately 30% volumetric solids concentration are expected to behave similar to Newtonian fluids and flow under very small applied shear stresses (e.g. flow like water). Conversely, materials with greater than approximately 30% volumetric solids concentration are expected to behave as non-Newtonian fluids." The preceding assumption that materials with less than 30% volumetric solids concentration will behave like Newtonian fluids, while materials with greater than 30% volumetric solids concentration will behave like non-Newtonian fluids should be fully justified in the EIS. It should be noted that, contrary to the quote, this information does not appear in Table B.1.

Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "In general, materials that are modeled as a Newtonian fluid are likely to flow farther, propagate faster, and potentially result in deeper flows compared to materials that are modeled as non-Newtonian fluids that incorporate the appropriate material rheology characteristics." This statement may be true, but it is not necessarily true. In particular, a non-Newtonian fluid could easily have a lower viscosity than a Newtonian fluid. If these assumptions regarding Newtonian and non-Newtonian fluids are made in the EIS, they should be fully justified. In particular, any statement in the EIS that the assumption of a Newtonian fluid will produce the most conservative outcomes in all respects should be fully justified.

Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "The volume of tailings that could potentially be released during a dam breach was evaluated by estimating the following quantities: … Residual Tailings - The volume of tailings that could be mobilized as a result of removal of the confining embankment and subsequent slumping to achieve a stable static slope angle with a factor of safety of 1.0." The preceding assumption that a static slope angle with a factor of safety of 1.0 is stable is not consistent with the consideration of all credible failure scenarios. A slope with a factor of safety equal to 1.0 still has a 50% probability of failure, so that its failure is certainly credible. A factor of safety equal to 1.0 simply indicates a distribution of possible factors of safety with a mean value equal to 1.0. As discussed previously, the EIS should consider the credible scenario that would include loss of 100% of the stored tailings.

Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "The volume of eroded tailings was estimated by setting the solids content of the eroded tailings, including interstitial water, pond water, and PMF water (for

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the Rainy Day scenario only), to 50% by mass assuming complete mixing. This approach is based on back-calculations for the Mt. Polley TSF failure (Martin et al., 2019) using the method proposed by Fontaine and Martin (2015)." This may have been accurate for the Mount Polley failure, but no publication has demonstrated that it would be an accurate assumption for all tailings dam failures. It should be recalled that there have been cases of loss of 100% of stored tailings. The EIS should consider the credible scenario of loss of 100% of the stored tailings plus all interstitial water plus all pond water plus the PMF water (for the Rainy Day scenario).

Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "This assumption implies that the extreme storm event that causes the dam breach would not be coincident with an extreme earthquake event, and that mass liquefaction of the tailings would not occur. It is common approach in dam breach studies not to combine two extreme events that have a very low probability of occurrence, as a coincidental occurrence of such events would have an even lower probability." The common approach in dam breach studies is to consider all credible failure modes. According to the Global Industry Standard on Tailings Management, "The term 'credible failure mode' is not associated with a probability of this event occurring" (ICMM-UNEP-PRI, 2020). Therefore, the probability of occurrence of a simultaneous extreme seismic event and extreme storm event is completely irrelevant. The EIS should consider all credible failure modes, meaning all failure modes that are physically possible, without regard to their probability of occurrence, including the credible failure mode of a simultaneous extreme seismic event and extreme meteorological event.

Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "The residual slope for the tailings is modelled at 7% (4°). This residual slope angle was selected to achieve a Factor of Safety (FoS) of 1.0 for a saturated infinite slope of tailings with an undrained shear strength ratio of 0.1. The undrained shear strength ratio was based on measurements on the tailings as part of site investigations completed at the nearby Nye TSF. The tailings deposited in the Lewis Gulch TSF will have similar characteristics to those previously deposited at the Nye TSF (KP, 2020b)." For the purpose of a dam breach assessment, the assumption of a residual slope of 7% is inadequate and is too high for the following reasons:
1) A slope with a factor of safety of 1.0 still has a 50% probability of failure.
2) The residual slope was not based upon the tailings that would be stored in the Lewis Gulch TSF.

In response to the preceding concern, the following actions are recommended for the EIS:
1) A much smaller factor of safety (corresponding to a much smaller probability of failure) should be chosen.
2) Sensitivity analyses should be carried out to assess the impact of the choice of residual slope.

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3) A pilot project should produce tailings representative of the tailings that will be stored at the Lewis Gulch TSF and the undrained shear strength ratio should be measured on those tailings.
4) Any assumptions that there will be no measurable differences between the tailings stored in the Nye TSF and the tailings that would be stored in the Lewis Gulch TSF should be fully justified.
5) The dam breach study should be carried out under the assumption of loss of 100% of the stored tailings.

Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility assumes that, for the tailings that would be stored at the Lewis Gulch TSF, the undrained shear strength ratio would be 0.1, while the liquefied shear strength ratio would be 0.05. It would certainly be unusual for the peak shear strength ratio to be only twice as great as the liquefied shear strength ratio. The EIS should fully justify this assumption. The EIS should compare the assumed peak and liquefied shear strength ratios to the peak and liquefied shear strength ratios for tailings that are available in the literature, and should fully account for the unusual nature of the tailings that would be stored in the Lewis Gulch TSF.

Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "It is assumed that a Sunny Day dam failure event could be initiated by, or coincident with, an earthquake event that would result in liquefaction of the entire tailings mass. The residual slope for the liquefied tailings is 3% (1.7°). This residual slope angle was selected to achieve a Factor of Safety (FoS) of 1.0 for a saturated infinite slope of tailings with a liquified strength ratio of 0.05. The liquefied strength ratio was based on measurements on the tailings as part of site investigations completed at the nearby Nye TSF (KP, 2020b)." For the purpose of a dam breach assessment, the assumption of a residual slope of 7% is inadequate and is too high for the following reasons:
1) A slope with a factor of safety of 1.0 still has a 50% probability of failure.
2) The residual slope was not based upon the tailings that would be stored in the Lewis Gulch TSF.

In response to the preceding concern, the following actions are recommended for the EIS:
1) A much smaller factor of safety (corresponding to a much smaller probability of failure) should be chosen.
2) Sensitivity analyses should be carried out to assess the impact of the choice of residual slope.
3) A pilot project should produce tailings representative of the tailings that will be stored at the Lewis Gulch TSF and the undrained shear strength ratio should be measured on those tailings.

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4) Any assumptions that there will be no measurable differences between the tailings stored in the Nye TSF and the tailings that would be stored in the Lewis Gulch TSF should be fully justified.
5) The dam breach study should be carried out under the assumption of loss of 100% of the stored tailings.

Table B.3 in Appendix B of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility clarifies that the shortest breach development time that was considered was 0.1 hour (6 minutes). Figure B.2 then shows the enormous difference in breach hydrographs between a breach with a development time of 0.16 hours and a breach with a development time of 0.5 hours. However, tailings dam failures due to liquefaction can develop over seconds. On that basis, the EIS should consider much shorter breach development times, such as breach development times of 10 seconds.

Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "For ungaged rivers, the peak discharge for different return periods was calculated based on the unit runoff for the nearest active USGS gauge." This is not a proper procedure and the assumption that the peak discharge at a single gaging station could be used to estimate the peak discharge at a nearby ungaged stream site has no basis in the hydrologic literature, regardless of any similarity in watershed characteristics. In fact, Singh (2014) concluded, "No single metric or set of metrics of hydrologic similarity have been demonstrated to consistently select a suitable donor catchment" [gaged watershed that can be regarded as a proxy for an ungaged watershed]. There have been hundreds of studies on the use of streamflow records at gaging stations and watershed characteristics to predict peak flow statistics on ungaged streams, largely by the U.S. Geological Survey and its partnering agencies (e.g., Sherwood, 1993, 1994; Jennings et al., 1994; Holnbeck and Parrett, 1996; Wiley and Curran, 2003; Singh, 2014; Ziegeweid et al., 2015; Rojas-Sema et al., 2016; Pool et al., 2017; Sloto et al., 2017). However, these studies have generally used streamflow records from a very large number of gaging stations (e.g., 226 stations in Wiley and Curran (2003), 229 stations in Sloto et al. (2017)), to generate regression equations for predicting low-frequency stream statistics for ungaged streams within the same region. The authors of the EIS should consult the literature on the estimation of peak discharge and should fully justify their chosen methodology. The estimation of peak discharge at both gaged and ungaged sites should take climate change into account.

The development of the EIS should include the installation of temporary stream gages at the ungaged sites that were considered in the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility. Streamflow data from the temporary stream gages should be collected over at least three years. The relatively short streamflow records from the temporary stream gages should be used to establish possible correlations with

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streamflow records from active USGS stream gages. These correlations should be combined with existing predictive methods for ungaged sites (see reference list in previous paragraph) in order to predict the peak discharge and mean annual discharge at the ungaged sites with as much accuracy as possible. The methodology for predicting the peak discharge and mean annual discharge at the ungaged sites should be fully documented and justified. If the Lewis Gulch TSF is constructed, these stream gages should be maintained permanently and the results should be used for regular updating of the dam break assessment. The maintenance and calibration of the stream gages should follow standard procedures of the U.S. Geological Survey.

Because of the possibility of erosion of the dam toe by floodwater from the East Boulder River, it is particularly important to determine the stage-discharge relationship on the East Boulder River just below the site of the Lewis Gulch TSF. Thus, it is crucial to establish a temporary stream gage at this site and to maintain the stream gage permanently if the Lewis Gulch TSF is constructed.

Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, “Initial HEC-RAS model runs that used the mean annual discharge (MAD) of the Boulder River resulted in overbank flooding which indicated that the river channels were not captured to a sufficient level of detail in the DEM. Therefore, the DEM model was modified by manually adjusting the depth of the East Boulder, Boulder, West Boulder and Yellowstone River channels in order to develop a more realistic river channel topography for the HEC-RAS model.” In the EIS, any such adjustments should be calibrated using actual measurements of the river channel topography.

Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, “The topography along the East Boulder River channel was lowered evenly by 7 ft. to accommodate approximate discharges up to the 2-year flood event within the banks of the East Boulder River as the 2-year flood event is typically retained within the banks of the river (i.e. bankfull discharge). Similarly, the Boulder, West Boulder and Yellowstone Rivers were incised by 10 ft.” Any such assumptions should be fully justified in the EIS. It is certainly not always the case that two-year flood events are retained within the river banks.

Table C1.1 in Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility provides “Estimated Mean Annual Discharge” at six locations, but the methodology for carrying out the estimations is not explained. If the authors of the EIS choose to use these estimates or to carry out their own estimates, they should fully explain and justify the methodology. In addition, any estimates should include a range of uncertainty with justification. For the purpose of estimating mean annual discharge at ungaged sites, the authors of the EIS should take under consideration the hundreds of studies on the use of

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streamflow records at gaging stations and watershed characteristics to predict annual and monthly flow statistics on ungaged streams, largely by the U.S. Geological Survey and its partnering agencies (e.g., Parett and Cartier, 1990; Hess and Bohman, 1996; Wiley and Curran, 2003; Singh, 2014; Breaker, 2015; Martin et al., 2016; Rojas-Sema et al., 2016; Gotvald, 2017; Pool et al., 2017; Sloto et al., 2017).

Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "The National Land Cover Dataset, produced by the Multi-Resolution Land Characteristics Consortium (MRCL, 2011), and downloaded from the United States Department of Agriculture (USDA, 2019) was used to define unique Manning's roughness coefficient (n-values) areas throughout the model domain." The authors of the EIS should note that most estimates of the Manning roughness coefficient were developed from observations on low-gradient streams (e.g., Meyer-Peter and Müller, 1948; Cowan, 1956; Chow, 1959; Fasken, 1963; Barnes, 1967; Limerinos, 1970; Riggs, 1976; Dingman, 1984, 2009; French, 1985; Chang, 1988; Arcement and Schneider, 1989; Hicks and Mason, 1991; Dingman and Sharma, 1997). The authors of the EIS should carefully consider the appropriate values of the Manning roughness coefficient in high-gradient streams (e.g., Jarrett, 1984, 1985; Marchand et al., 1984; Bathurst, 1985; Marcus et al., 1992; Reid and Hickin, 2008; Asano et al., 2012; Ivie et al., 2014; Zink and Jennings, 2014; Ostraff et al., 2018) and should fully justify their assumptions.

Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "The calibration analyses determined that a Manning's n value of 0.055 best simulated the observed velocities at high velocity/discharge levels." The EIS should compare the value of the Manning roughness coefficient n = 0.055 with the measured values of the Manning roughness coefficient for streams with similar characteristics, including stream gradient. The EIS should fully account for any discrepancies between the calibration value (n = 0.055) and the value that would be expected for streams with similar characteristics.

Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "Embankment fill affected by the [Rainy Day] breach event would displace downstream and could form a temporary dam in the East Boulder River channel. Over time, the temporary dam would cause approximately 0.5 Mft^3 of water to backwater in the East Boulder River, under a conservative assumption that all embankment material deposits in this area. Assuming 1 in 1,000 flood conditions in the East Boulder River, it would take less than an hour for this volume of water to backwater. The consequences of a secondary dam breach of the temporary dam in the river channel would be significantly less than the initial flood event from a TSF breach." The EIS should evaluate the impacts of secondary dam breaches upon rescue and recovery operations. Such an evaluation should take into account the predictability or unpredictability of the timing of secondary dam breaches.

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Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "Mobilized tailings flowing upstream [in Phase 2 of the Sunny Day breach event] would deposit at the residual slope angle, estimated to be 2%, and would further block the East Boulder River causing additional backwatering. A secondary dam breach of the temporary river dam would then be expected to occur sometime after the initial TSF breach event. It is estimated that the temporary dam formed by the displaced embankment fill and settled tailings would cause approximately 12 Mft^3 of backwatering in the East Boulder River. Assuming Mean Annual Discharge (MAD) flow conditions (56 cfs), it would take between 2 to 3 days for this volume of water to collect. The estimated backwatering volume of 12 Mft^3 is less than the Phase 1 breach volume modelled for the Sunny Day Scenario. As such, the consequences of a secondary dam breach of the temporary river dam are expected to be less severe than those modeled for the Sunny Day Scenario." The EIS should evaluate the impacts of secondary dam breaches upon rescue and recovery operations. Such an evaluation should take into account the predictability or unpredictability of the timing of secondary dam breaches.

Appendix D of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "Mobilized tailings flowing upstream [following Case B for the post-closure breach] would deposit at the residual slope angle and would further block the East Boulder River causing additional backwatering. A secondary dam breach of the temporary river dam would then be expected to occur sometime after the initial TSF breach event. It is estimated that the temporary dam formed by the displaced embankment fill and settled tailings would cause approximately 16 Mft^3 of backwatering in the East Boulder River. Assuming Mean Annual Discharge (MAD) flow conditions (56 cfs), it would take approximately 3 days for this volume of water to collect. The estimated backwatering volume of 16 Mft^3 is less than the Phase 1 breach modelled for the Sunny Day Scenario, described in the main report. As such, the consequences of a secondary dam breach of the temporary river dam are expected to be less severe and within the inundation extents of those modeled for the Sunny Day scenario." The EIS should evaluate the impacts of secondary dam breaches upon rescue and recovery operations. Such an evaluation should take into account the predictability or unpredictability of the timing of secondary dam breaches. In the case of secondary dam breaches following a post-closure breach, particular attention should be paid to the consequences of a lack of personnel at the mine site or the Lewis Gulch TSF.

For each credible failure scenario, the EIS should delineate the "self-rescue zone," or the zone in which rescue from the outside would be possible in the event of dam failure. The EIS should clarify the population of the self-rescue zone. The EIS should estimate the time required for complete evacuation (including the disabled, elderly, children, etc.) for each downstream community that could be impacted by failure of the Lewis Gulch TSF. The EIS should compare the time required for complete evacuation with the tailings flood arrival time for each downstream community that could be impacted by failure of the Lewis Gulch TSF. The EIS

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should estimate the potential loss of life in the event of dam failure and should fully justify the methodology for carrying out that estimation.

Appendix D of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "In addition, continued operation of the Basin Underdrain during and following closure is expected to continue to decrease the tailings water content and reduce the potential for the tailings to flow." The EIS should provide a detailed plan for post-closure monitoring, inspection, and maintenance of the Basin Underdrain. The EIS should explain the consequences of inadequate monitoring, inspection, and maintenance of the Basin Underdrain. The EIS should develop a timeline for the events that will be expected to occur following the cessation of adequate monitoring, inspection, and maintenance of the Basin Underdrain.

Appendix D of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "Assuming that a post-closure dam breach was possible, it would be classified as Class 2A or 2B (Table 3.1) depending on the saturation level, the liquefaction potential, and the potential mobility of the impounded tailings." The post-closure dam breach could be classified as Class 1A or 1B if a supernatant water were present near the dam crest. The EIS should fully evaluate the circumstances under which a supernatant pond could still be present in the post-closure phase, despite the intention to drain the pond. One possibility is that differential settling could create enough topography for a supernatant pond to re-form. The consequences of a post-closure Class 1A or Class 1B dam breach should be fully investigated unless the EIS can convincingly demonstrate that the re-formation of a supernatant pond is non-credible (i.e., physically impossible).

Appendix C of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "For simplicity, the downstream flow of tailings is not shown in Figure C1.7." In a similar way, Appendix D of the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility states, "For simplicity, the downstream flow of tailings is not shown in Figure D.2." The EIS should include whatever additional maps are necessary to show the downstream flow of tailings.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility considers only the initial runout of water and tailings, that is, the initial event that results from the release of gravitational potential energy as the tailings and water fall out of the TSF. The EIS should investigate, in addition, the long-term impact of the migration of tailings down the East Boulder River, Boulder River and Yellowstone River due to normal fluvial processes. The EIS should especially investigate the transport of coarser tailings as bedload through the river system. This investigation should involve a consideration of the variety of possible sediment transport equations with full justification as to the particular sediment

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transport equations that are chosen. The work on bedload transport by Bagnold (1966, 1977, 1980, 1986) and Martin and Church (2000) would be useful starting points.

The document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility considers only the depth of water (or the depth of the tailings flood), but not the depths of deposited tailings. The EIS should predict the depths of deposited tailings and other solid material (such as eroded embankment fill) in addition to the depth of the tailings flood. In fact, such predictions are a requirement of the Global Industry Standard on Tailings Management. Requirement 2.3 includes the requirement "When flowable materials (water and liquefiable solids) are present at tailings facilities with Consequence Classification of 'High', 'Very High' or 'Extreme', the results [of a breach analysis] should include estimates of the physical area impacted by a potential failure, flow arrival times, depth and velocities, and *depth of material deposition*" (emphasis added) (ICMM-UNEP-PRI, 2020).

The need for regular updating of the dam break assessment is mentioned numerous times throughout the Global Industry Standard on Tailings Management In addition to what was stated in the previous paragraph, Requirement 2.3 includes the need to "Update [the breach analysis] whenever there is a material change either to the tailings facility or the physical area impacted" (ICMM-UNEP-PRI, 2020). Requirement 2.4 states "In order to identify the groups most at risk, refer to the updated tailings facility breach analysis to assess and document potential human exposure and vulnerability to tailings facility credible failure scenarios. Update the assessment whenever there is a material change either to the tailings facility or to the knowledge base" (ICMM-UNEP-PRI, 2020). Requirement 10.1 states "Conduct and update risk assessments with a qualified multi-disciplinary team using best practice methodologies at a minimum every three years and more frequently whenever there is a material change either to the tailings facility or to the social, environmental and local economic context." Requirement 13.1 states "As part of the TMS [Tailings Management Systems], use best practices and emergency response expertise to prepare and implement a site-specific tailings facility Emergency Preparedness and Response Plan (EPRP) based on credible flow failure scenarios and the assessment of potential consequences. Test and update the EPRP at all phases of the tailings facility lifecycle at a frequency established in the plan, or more frequently if triggered by a material change either to the tailings facility or to the social, environmental and local economic context."

The EIS should include a detailed plan for the regular updating of the dam break assessment if the Lewis Gulch TSF is constructed. The updating should occur at least once every three years and should be based on the following:
1) Additional streamflow data that could affect estimates of peak discharge or mean annual discharge
2) Additional knowledge about climate change

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3) Changes in land use in the relevant watersheds that could affect peak discharge and mean annual discharge
4) Changes in the downstream physical topography
5) Changes in the downstream infrastructure, such as highways and bridges
6) Changes in the social and economic context of the Lewis Gulch TSF that would affect the consequences of tailings dam failure

All estimations of hydrologic parameters in the EIS should take climate change into account. These hydrologic parameters include, but are not limited to the following:

1) peak discharge (500-year, 1000-year, and Probable Maximum Flood) at relevant gaged and ungaged sites on East Boulder River, Boulder River and Yellowstone River
2) mean annual discharge at relevant gaged and ungaged sites on East Boulder River, Boulder River and Yellowstone River
3) peak discharge (Probable Maximum Flood) into East Boulder River from stormwater generated at mine site
4) peak flow rate due to short-duration, high-intensity events in Lewis Gulch
5) low-flow and high-flow statistics for East Boulder River
6) minimum low flow and the 7Q10 value for East Boulder River
7) supernatant tailings pond of Lewis Gulch TSF
8) underdrain flow from the Lewis Gulch TSF both during operation and after closure
9) seepage through the base of the Lewis Gulch TSF both during operation and after closure
10) flow through the underdrain of the Dry Fork WRSA
11) seepage through the base of the Dry Fork WRSA both during operation and after closure
12) Probable Maximum Flood including 100-year snowpack in the watershed of the Lewis Gulch TSF
13) Probable Maximum Flood including probable maximum snowpack in the watershed of the Lewis Gulch TSF
14) all aspects of water balance of the Lewis Gulch TSF during both operation and closure
15) all aspects of water balance of the East Boulder TSF during both operation and closure
16) all aspects of water balance of the Dry Fork WRSA during both operation and closure
17) all aspects of the water balance for all relevant aquifers
18) magnitude of 100-year, 24-hour precipitation event for use in stormwater calculations for Lewis Gulch TSF
19) magnitude of 25-year, 100-year, and 200-year 24-hour precipitation events for use in stormwater calculations for Dry Fork WRSA
20) peak flow rates from stormwater from 25-year, 100-year, and 200-year storms for design of diversion channels for Lewis Gulch TSF, Dry Fork WRSA and Stage 6 Embankment
21) magnitude of wave run-up in tailings pond
22) groundwater levels in vicinity of Dry Fork WRSA and Lewis Gulch TSF

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Effects of climate should involve a variety of approaches, including both downscaled climate models and historical trends in precipitation and streamflow statistics. The use of climate models should rely on a variety of models. The full range of possible results should be presented. Choices of the most-likely results should be fully justified with proper attention to the range of uncertainty. Climate change projections should be carried out through the year 2100. The EIS should discuss the consequences of an inability to project climate changes past 2100. A useful starting point is the chapter on "Climate and Hydrology" in the SME (Society for Mining, Metallurgy, and Exploration) Tailings Management Handbook – A Life-Cycle Approach (Muñoz and Hoekstra, 2022).

Estimations of the magnitudes of extreme events should take into account recent storm events, such as the storm on June 13, 2022, which is tentatively being called a 500-year storm. As much as possible, estimations of the magnitudes of extreme events should involve local precipitation records. When non-local precipitation records are used, appropriate adjustments should be used for differences in elevation and the microclimatic conditions at the site of the Lewis Gulch TSF. For this purpose, the EIS should fully describe the microclimatic conditions at the site of the Lewis Gulch TSF and the non-local sites from which precipitation records are obtained.

The document East Boulder Mine 2020 Water Management Plan Revision states, "SMC may not reduce water levels in the East Boulder River below the 5 cfs minimum historic low flows …. SMC must discharge adit water to groundwater if the adit flow rate would cause an increase in streamflow greater than 15 percent of the 7Q10 value …" The EIS should fully explain the methodology for developing estimates for the minimum historic low flow and the 7Q10 value. In general, the estimates should be developed from temporary stream gages that should be installed in the East Boulder River and from streamflow records at neighboring gage sites, using methodologies developed by the U.S. Geological Survey and partnering agencies, as described above. The EIS should analyze the impact of climate change on the minimum low flow and the 7Q10 value.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The East Boulder Mine is designed as a zero-discharge stormwater facility so that stormwater runoff drains internally within the East Boulder Mine site. To date, all controls have functioned as designed and there have been no stormwater discharges from the designated stormwater outfalls for the mine." The EIS should discuss the circumstances under which stormwater will be discharged into the East Boulder River (such as an extreme storm event with a particular return period or the Probable Maximum Flood), both taking and not taking climate change into account.

The document East Boulder Mine 2020 Water Management Plan Revision states ,"The Lewis Gulch TSF and the Dry Fork WRSA will add two new outfalls as construction progresses and will be incorporated into the stormwater plan." As above, the EIS should discuss the

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circumstances under which stormwater will be discharged into the East Boulder River (such as an extreme storm event with a particular return period or the Probable Maximum Flood), both taking and not taking climate change into account.

The document East Boulder Mine 2020 Water Management Plan Revision states, "During mine development, groundwater is encountered when joints, faults, and shear zones are intersected. Each water-bearing fissure is evaluated when intersected and the decision to seal or grout off the inflows is made depending on the volume and the expected duration of the discharge. Various grouting techniques are used to seal those inflows that require containment. In the case of a drill hole that intersects a water bearing structure, a packer may be installed in the drill hole. Whenever hydrogeological evidence suggests a need, a probe hole is drilled ahead of drift advance to check for structural concerns and possible water bearing zones. Water collected from the fissures is allowed to drain to the mine water handling system."

The EIS should thoroughly investigate the possibility that the future entry of groundwater into the underground mine will overwhelm the water management capacity of the mine. This investigation should include hydrogeologic evidence regarding the characteristics of the joints, faults, and shear zones that are likely to be encountered in future expansion. The EIS should include observations that will be carried out in the course of expansion of the mine that will indicate the possibility that the future entry of groundwater into the underground mine will overwhelm the water management capacity of the mine. The EIS should develop a set of preplanned actions that will be executed in response to adverse observations that will indicate the possibility that the future entry of groundwater into the underground mine will overwhelm the water management capacity of the mine.

The EIS should analyze the expected and shortest reasonable lifetimes of the various grouting techniques that will be used to seal joints, faults, and shear zones. The EIS should analyze the consequences of grout failure both during operation and after closure. The EIS should describe the observations that will be carried out to assess the ongoing ability of the grouts to prevent groundwater flow. The EIS should include a set of preplanned actions that will be executed in response to observations that indicate the possibility of grout failure.

The EIS should take note of previous impacts of dewatering the Stillwater mine on both surface water and shallow aquifers. According to Blodgett and Kuipers (2002), "The Stillwater Mine is a platinum group metal mine located in Montana. The underground mine began operation in 1986 and drove an adit to access ore reserves. At 4,000 ft the adit encountered a large inflow of water that peaked at 884 gpm and within a few months decreased to a steady-state of approximately 200 gpm where it has remained. A small watershed containing a several springs and a perennial stream was located a vertical distance of 830 ft above the adit. The springs and stream both dried

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up and have remained dry ever since. In 1994 the ongoing mining operations resulted in the drying of three additional springs in another basin.

"Other workings at Stillwater exhibited particular behaviors. When a tunnel below the Stillwater River connecting the east and west side workings was constructed water began draining at a peak of 350 gpm from the above lying ground water aquifer. Above lying strata consists of 790 ft of fractured bedrock overlain by 310 ft of unconsolidated glacial and alluvial sediments. Despite grouting efforts, heads in the above lying bedrock zone dropped over 120 ft. and a large downward gradient was produced between the alluvial aquifer and the bedrock aquifer. However, water levels in the sediments representing the alluvial aquifer were not affected due to the low permeability of the sediments near the bedrock contact and the large permeability contrast between the sediments and underlying bedrock (Gurrieri, 2001)."

The EIS should fully investigate the possibility that the intersection of the underground mine with joints, faults, and shear zones could cause the drainage of streams, springs, wetlands, or shallow aquifers. The EIS should establish a set of observations that will determine whether the drainage of streams, springs, wetlands, or shallow aquifers is imminent or in progress. The EIS should develop a set of preplanned actions ready for execution in the event that observations indicate that the drainage of streams, springs, wetlands, or shallow aquifers is imminent or in progress.

The EIS should fully investigate the possibility that the expansion of the underground mine could cause surface subsidence. The EIS should fully investigate the possible impact of surface subsidence upon the Lewis Gulch TSF and the Dry Fork WRSA. The EIS should establish a set of observations that will determine whether surface subsidence is occurring. The EIS should develop a set of preplanned actions ready for execution in the event that observations indicate that surface subsidence is occurring.

The document East Boulder Mine 2020 Water Management Plan Revision states, "In the event that the underground mine becomes full and underground inflow continues water can be pumped to the recycle pond (1.17 MG capacity following the relocation to Soil Stockpile 'C' during Stage 6 TSF Expansion) or to the Stage 6 TSF or Lewis Gulch TSF supernatant pond, pending which TSF is operational." The EIS should develop a plan ready for execution in the event that both the underground mine and the TSF supernatant ponds are full simultaneously.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The PMF is theoretically the largest maximum flood resulting from the 24-hour Probable Maximum Precipitation (PMP) and the coincidental melt of the 100-year snowpack." The coincidental melt of the 100-year snowpack is not a standard part of the definition of the Probable Maximum Flood. A more logical choice, which would be consistent with the goal of designing for all

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credible scenarios, would be the probable maximum snowpack, or the largest snowpack that is theoretically possible at a given location. The authors of the EIS should either estimate the probable maximum snowpack (preferred) or should rigorously justify the choice of the 100-year snowpack.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The potential leakage through the lining system was evaluated for six filling levels within the TSF ranging from initial tailings deposition at 6,139 feet, up to the maximum filling level of 6,234 feet. The seepage analyses consider leakage due to the presence of geomembrane defects and due to permeation through the geomembrane." The EIS should evaluate the seepage through the liner that would occur due to a failure of the underdrain system (which would raise the hydraulic head on the liner). The EIS should also rigorously predict the density of liner defects based upon similar projects using both a most-likely scenario and the scenario with the largest reasonable density of liner defects. The EIS should estimate the seepage through the liner due to the combination of the scenario with the largest reasonable density of liner defects, but with a functioning underdrain system. The EIS should estimate the seepage through the liner that would result from the scenario with the largest reasonable density of liner defects plus a non-functioning underdrain system.

The EIS should thoroughly review the current knowledge regarding the lifetimes of liners. The EIS should evaluate the consequences of substantial liner degradation both during the operating and post-closure phases. The EIS should predict the consequences of eventual liner failure sometime in the future, taking into account that liner failure could occur after the cessation of monitoring, inspection and maintenance of the Lewis Gulch TSF.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The TSF will also be designed to accommodate a wet freeboard to store the IDF and a dry freeboard for wave run-up in accordance with the legislation." The EIS should rigorously justify the choice of height for wave run-up in the Lewis Gulch TSF, not only in terms of the legislation, but in terms of the best practices among other water-retention and tailings dam operators. The EIS should consider how climate change could affect wind speeds and durations, and thus the magnitude of the wave run-up.

The document East Boulder Mine 2020 Water Management Plan Revision states, "Water management for the Dry Fork WRSA has been designed to provide storage for the 1 in 25 year, 24-hour precipitation event (3.8 inches) in order to minimize potential for discharge to the East Boulder River." The EIS should fully justify the use of the 25-year return period for design of the Dry Fork WRSA or should choose a more appropriate return period, especially considering that the diversion ditches for the Lewis Gulch TSF have been designed for the 100-year event and the Lewis Gulch TSF has been designed for the PMF. There should be some consistency and logic among the choices of extreme storm return periods and that should be explained and justified in the EIS.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The Lewis Gulch and Dry Fork Creek Updated Baseline Hydrogeologic Monitoring Report suggests that there is potential for groundwater levels to reach the base of the Dry Fork WRSA on the eastern side in the Stage 3 area during peak runoff season by extending the June 2020 potentiometric trends." The EIS should collect additional baseline data on groundwater levels (preferably over at least three years) in order to evaluate the potential for groundwater to reach the base of either the Dry Fork WRSA or the Lewis Gulch TSF. The EIS should carry out projections for future groundwater levels on the basis of climate change. The EIS should fully evaluate the consequences of groundwater intersecting the base of either the Dry Fork WRSA or the Lewis Gulch TSF during both the operation and the post-closure phases.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The Dry Fork WRSA will include appropriate diversions of stormwater runoff from areas adjacent to the facility … All diversions have been sized to safely pass runoff resulting from the 1 in 100 year, 24-hour precipitation event (4.6 inches) … Additionally, a swale that has been size to convey runoff resulting from the 1 in 200 year 24-hour precipitation event (5.0 inches) will also be installed at the lowest section of the Stage 1 Dry Fork WRSA Containment Berm crest." Throughout this document, the various design storm return periods (25-year, 100-year, 200-year) appear to be completely random and are never justified. The EIS should fully justify the choices of design storm return periods for the various components of the water management infrastructure and there should be consistency among the choices.

Throughout the document East Boulder Mine 2020 Water Management Plan Revision, all diversion infrastructure is discussed in terms of ability to convey a particular volume of water. For example, the document states, "The Stage 6 TSF will include appropriate diversions of stormwater runoff from the upstream catchment area … All diversions have been sized for a 1 in 100 year, 24-hour precipitation event (4.6 inches) … The Lewis Gulch TSF will include appropriate stormwater management measures which will include diversions of stormwater runoff from the upstream catchment area … All diversions have been sized for a 1 in 100 year, 24-hour precipitation event (4.6 inches) … The Dry Fork WRSA will include appropriate diversions of stormwater runoff from areas adjacent to the facility … All diversions have been sized to safely pass runoff resulting from the 1 in 100 year, 24-hour precipitation event (4.6 inches)."

The design of diversion channels to accommodate a particular volume of water (such as 4.6 inches of water deposited over the catchment area) is not a proper procedure. The function of a diversion channel is to convey water and not overflow during an extreme storm. Therefore, the

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channel must have the capacity to convey stormwater at the rate at which stormwater enters the channel. In other words, the diversion channel must have the ability to convey water at the peak flow rate of the stormwater. The peak flow rate of a storm occurs when the storm duration is equal to the time of concentration of the watershed (the maximum time required for water to travel from any point on the watershed to the outlet). Thus, the volume of stormwater generated over 24 hours is irrelevant for the design of channels. The volume of water would be relevant only for the design of ponds that are designed to contain the stormwater for some period of time. The most common procedure for calculating the peak flow rate is the Rational Equation, although there are other recognized procedures. In summary, the EIS should specify the dimensions of diversion channels in terms of the peak flow rate that would occur for a given return period. In any event, the appropriate return period for calculation of peak flow rate should be fully justified in the EIS and should be consistent with other choices for design storm return periods.

The document East Boulder Mine 2020 Water Management Plan Revision states, "A containment berm will be constructed around the toe of the Dry Fork WRSA using random fill to facilitate collection of meteoric water that percolates through the waste rock." The EIS should be more specific than "random." The EIS should specify and justify the choice of construction material.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The Underdrain Collection Pipework [for the Dry Fork WRSA] will be directly installed over top of the liner system … Minimal seepage is expected given that the Dry Fork WRSA will be operated in a drained condition with minimal head." The EIS should evaluate the water table height and the seepage that would occur due to a failure of the underdrain collection system. The EIS should evaluate the consequences of the resulting water table height and seepage rate during the operation and post-closure phases.

The document East Boulder Mine 2020 Water Management Plan Revision states, "Foundation drains will be installed below the Dry Fork UCS to provide drainage for groundwater below the UCS [Underdrain Collection Pipework]. The EIS should evaluate the consequences of failure of the foundation drains.

The document East Boulder Mine 2020 Water Management Plan Revision states, "The UCP [Underdrain Collection Pond] will include a geosynthetic lining system … The UCP has been designed to store runoff from the lined portion of the Stage 3 Dry Fork WRSA resulting from a 1 in 25 year, 24-hour precipitation event. A spillway will be installed across the crest and downstream slope of the UCP berm to account for runoff greater than the design storage. All water conveyed from the spillway outlet will flow into the spillway outlet channel to the East Boulder River Floodplain, where it will infiltrate or flow directly into the East Boulder River. A seepage analysis was also conducted for the UCP, and liner leakage is estimated at 0.1 to 0.2 gpm."

The EIS should estimate the density of liner defects both in terms of the most-likely scenario and the scenario with the greatest reasonable density of liner defects. The seepage through the liner should be estimated for the scenario with the greatest reasonable density of liner defects and the consequences of such seepage should be evaluated. The EIS should evaluate the choice of design for a 25-year, 24-hour precipitation event. The EIS should seek consistency among the design storm return periods for the various components of the water management infrastructure and should fully justify all of the choices. The EIS should evaluate the consequences of the flow from the UCP into the East Boulder River.

According to the document East Boulder Mine Climatological Site Conditions, "A review of the long-term (70+ year) climate records for the NOAA climate station at Mystic Lake indicates that while there is a statistically significant increasing trend in average annual temperature, there are no apparent trends in annual precipitation or annual extreme daily precipitation. Accordingly, the effects of slightly warmer temperatures should be considered when evaluating future climate conditions but increasing storm severity does not appear to be a concern. These two effects are directly relevant to the determination of the IDF volume, since they suggest no increase in the PMP but a possible decrease in the snowpack depth and associated PMF runoff." The EIS should fully evaluate the relevance of climatic data from the Mystic Lake station for the site of the Lewis Gulch TSF, including the microclimatic conditions at the Lewis Gulch TSF. The impact of climate change upon extreme storm events should not be based upon statistical trends alone, but should include a full consideration of the range of climate models.

The document East Boulder Mine Climatological Site Conditions continues, "Given the uncertainty associated with climate change projections, no climate change adjustment was applied to the 100-year snowpack, the PMP, the other design storm depths in this report." The conclusion is backwards. Given the uncertainty in climate change projections, there should be considerable uncertainty in the "100-year snowpack, the PMP, [and] the other design storm depths." In light of this uncertainty and the consequences of mistakes (non-conservative designs that could result in failure), the design of the Lewis Gulch TSF should be ultraconservative.

According to the document East Boulder Mine Climatological Site Conditions, "The two wettest years in the period of record for Mystic Lake had total annual precipitation amounts of approximately 34.3 in. (2017) and 35.6 in. (2019), which are 36 and 41 percent greater than the longterm average, respectively." From the standpoint of relying solely on historical trends for the assessment of climate change, the EIS should consider the fact that the two wettest years occurred near the end of the period of record-keeping. The EIS should include a full statistical discussion of the significance for trend analysis of major changes near the end of the period of

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record-keeping. The EIS should establish a procedure for continuous updating of climate change projections based upon new climatic data. The EIS should describe how updated climate change projections should be taken into account in the operation and closure of the Lewis Gulch TSF.

According to the document East Boulder Mine Climatological Site Conditions, "The estimated storm depths are similar for the two estimation methods, with the USGS approach producing slightly lower values for all return periods except 1,000 years. The estimated storm depths using the NOAA Atlas 2 values have been used for sizing the existing storm water management measures at EBM, and based on the above review, continue to be appropriate and therefore will continue to be used for sizing the storm water management measures." The EIS should use the most conservative estimation. This means that the USGS method should be used for estimation of the 1000-year event.

The document East Boulder Mine Climatological Site Conditions states, "The 72-hour PMP is sometimes used for determining storm freeboard for high hazard dams, but there is no strong rationale for its use in preference to the 24-hour PMP, other than it is more conservative from a dam safety perspective. However, it's use is becoming somewhat of a standard in tailings dam designs, particularly for those structures that have no operational spillway. In this case, however, the PMF that has been selected for the design of the Lewis Gulch TSF expansion is the flood resulting from the 24-hour PMP of 29 in. plus the complete melt of the 1 in 100-year snowpack of 18 in., for a total PMF runoff depth of 47 in." The EIS should require the use of the more conservative 72-hour PMP. The EIS should consider that the use of the 72-hour PMP is a minimum requirement in many jurisdictions with high rainfall and high snowfall, such as British Columbia. For example, according to Ministry of Energy and Mines (British Columbia), 2017), "a facility that stores the inflow design flood shall use a minimum design event duration of 72 hours."

The document East Boulder Mine Climatological Site Conditions states, "The use of the 24-hour PMP for the determination of the PMF is believed to be a rational and appropriately conservative basis for the design of the Lewis Gulch TSF expansion because: The likelihood of the PMP occurring coincident with a 100-year snowpack is exceptionally improbable." The EIS should consider all credible failure modes and should bear in mind the statement in the GISTM that "The term 'credible failure mode' is not associated with a probability of this event occurring" (ICMM-UNEP-PRI, 2020).

The document East Boulder Mine Climatological Site Conditions states, "The 24-hour PMP value indicated by HMR 55A appears to be very conservatively estimated when compared to the long-term historical precipitation records for the nearby NOAA climate station at Mystic Lake. The largest daily precipitation event in the 71-year record (1948-2018) for Mystic Lake is 3.5 in., which equates to a 24-hour depth of approximately 4.0 in … Furthermore, use of the statistics from this dataset with the Hershfield equation (Hershfield, 1977), which is commonly used to develop preliminary estimates of the PMP, indicates a 24-hour PMP value in the order of 15 in. This value is approximately half that of the PMP indicated in HMR 55A." It is well-known that PMP estimates using HMR 55A are much greater than PMP estimates using the much older Hershfield Equation. Therefore this argument is irrelevant. The largest daily precipitation for the last 71 years at Mystic Lake is also irrelevant.

The document East Boulder Mine Climatological Site Conditions states, "In this case, however, the PMF that has been selected for the design of the Lewis Gulch TSF expansion is the flood resulting from the 24-hour PMP of 29 in. plus the complete melt of the 1 in 100-year snowpack of 18 in., for a total PMF runoff depth of 47 in … The PMP depth of 47 in. is enormous. To put it in proper perspective, it is 75% greater than the average annual precipitation of 27 in., and is greater than the 1 in 10,000-year annual precipitation value of 45 in." This point is also irrelevant. In fact, the PMP should be much larger than the 10,000-year event, which suggests that the use of the 24-hour PMP has underestimated the IDF (Inflow Design Flood). According to the U.S. Army Corps of Engineers "the PMF does not incorporate a specific exceedance probability, but is generally thought to be well beyond the 10,000 year recurrence interval" (USACE-HCE, 2003).

The document East Boulder Mine Climatological Site Conditions uses Figure 2.7 (a graph of annual extreme daily precipitation at the Mystic Lake station) to argue that "increasing storm severity does not appear to be a concern" and that "they suggest no increase in the PMP." The preceding is not a proper procedure for determination of statistical trends in extreme events. Figure 2.7 shows only a lack of statistical significance in trends in the magnitude of the 1-year event, but is not relevant to any more extreme events. There are various procedures for determining trends in extreme storm events, but here are two simple examples:

1) Calculate the predicted magnitudes of extreme events (10-year, 25-year, 100-year, etc.) using the data from 1949-1958, 1959-1968, 1969-1978, etc., and ask whether these magnitudes show a statistically significant trend.
2) Calculate the predicted magnitudes of extreme events (10-year, 25-year, 100-year, etc.) using the data from 1949-1958, 1949-1968, 1949-1978, etc., and ask whether these magnitudes show a statistically significant trend.

In summary, the EIS should use much more relevant and sophisticated methods for determining whether there are statistically significant trends in the magnitudes of extreme precipitation events.

As discussed earlier, the stormwater diversion channels should be designed based on the peak flow rate, not on the volume of water that is generated during a storm. The peak flow rate does not depend upon an arbitrary duration of time, but upon the storm duration that is equal to the time of concentration of each watershed. For example, if a watershed that is captured by a particular diversion channel has a time of concentration of 30 minutes, then the relevant storm duration is 30 minutes. On that basis, the EIS should determine whether there are statistically significant trends in the short-duration high-intensity events that could cause overflow of the stormwater channels. If such trends exist, then the EIS should take full account of climate change in the design of stormwater diversion channels.

The EIS should carry out sufficient piezometric measurements and field observations so as to determine the groundwater flow pathways in the vicinity of the Lewis Gulch TSF and Dry Fork WRSA. Special attention should be paid to ephemeral springs. These groundwater flow pathways should be used for design of the underdrains for the Lewis Gulch TSF and Dry Fork WRSA (for the purpose of preventing upwelling beneath the liner).

The EIS should fully delineate the watershed of Lewis Gulch and determine the peak flow rate during a short-duration, high-intensity event. The peak flow rate should be used to assess the possibility of slumping of embankment material and tailings into the East Boulder River with subsequent mobilization into a fluid-like mass due to mixing with the stream water.

The EIS should evaluate the potential loss of groundwater recharge due to construction of the Lewis Gulch TSF and Dry Fork WRSA, as well as their associated infrastructure.

The EIS should estimate the water consumption rate of the East Boulder mine, taking into account any changes due to the mine expansion, based upon a full consideration of all components of the water balance. The estimation should be compared with global trends in water consumption by platinum-palladium mines and hard rock mines in general. Any discrepancies between estimates specific to the East Boulder mine and estimates based on global trends should be explained.

The EIS should carry out sufficient groundwater modeling in order to show the likely sites of emergence of seepage from the Lewis Gulch TSF and Dry Fork WRSA. Following that groundwater modeling, water quality monitoring of groundwater and surface water should be carried out at those sites, as well as monitoring of the depth to the water table. Note that, prior to any determination of likely emergence sites, there is no basis for the determination of appropriate sites for water quality or piezometric monitoring.

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, “The Dry Fork WRSA will be operated in a drained state with no head on the liner. Seepage estimate calculations require a constant head to be assumed to estimate a seepage rate. Using a minimal head (i.e. 2 ft) to estimate leakage from the collection area the seepage rate would be estimated at less than 0.2 gpm to 1.3 gpm for the Underdrain Collection System and the estimated leakage rate for the Underdrain Collection Pond (UCP) is estimated at 0.1 to 0.2

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gpm." It is not true that seepage cannot be calculated in the absence of an assumed constant head. Such an assumption is needed only in overly simplistic steady-state calculations. The important assumption is not the minimal head (which has not been justified). The EIS should calculate the maximal head that would occur due to failure of the drainage system and use that assumption to estimate the maximum seepage. The EIS should further consider the consequences of the calculated maximum seepage rate.

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, "If surface water quality data exhibits a potential surface water impact, SMC will further investigate and implement additional mitigation measures, such as interceptor trenches, pump back wells, in-situ treatment, bioreactors, berms, ditches, swales, sediment controls or increased collection pond capabilities." The EIS should fully describe the observations that will be carried out that would indicate adverse impacts on surface water quality. The EIS should indicate the preplanned actions that will be executed in response to adverse observations. In this respect, it is worth noting the definition of the Observational Method in the GISTM: "A continuous, managed, integrated, process of design, construction control, monitoring and review that enables previously defined modifications to be incorporated during or after construction as appropriate. All of these aspects must be demonstrably robust. The key element of the Observational Method is the proactive assessment at the design stage of every possible unfavourable situation that might be disclosed by the monitoring programme and the development of an action plan or mitigative measure to reduce risk in case the unfavourable situation is observed. This element forms the basis of a performance-based risk management approach. The objective is to achieve greater overall safety" (ICMM-UNEP-PRI, 2020). It should be noted that an intention to "further investigate and implement additional mitigation measures [with examples]" does not constitute an action plan.

The EIS should consider the possible modes of failure for the tailings delivery pipeline. The EIS should fully evaluate the consequences of failure of the tailings delivery pipeline.

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, "The Montana DNRC has determined that the LAD storage pond would be a high-hazard dam because it would contain more than 50 acre-feet of water, and as such, has the potential to cause loss of life in the event of dam failure (DNRC, 2002). As long as SMC maintains an approved mine operating permit, it is not required to submit an Operation and Maintenance Plan and Emergency Preparedness Plan that comply with DNRC's high hazard dam requirements. Because SMC plans to leave the LAD storage pond in place at post-closure, the reclaimed dam elevation will be reduced to 5717 feet, which would reduce the volume to less than 50 acre-feet and eliminate the high-hazard dam determination."

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Because of the potential loss of life in the event of failure, the risk of failure of the LAD storage pond should be treated just as seriously as the risk of failure of the Lewis Gulch TSF. The EIS should fully evaluate the consequences of failure of the LAD storage pond. The EIS should consider all credible failure modes of the LAD storage pond during both operation and closure. The EIS should include quantitative estimates of the annual probability of failure during both operation and closure. These estimates should be fully justified and should be compared with acceptable probabilities of failure in widely-recognized dam safety risk guidelines (e.g., Canadian Dam Association, 2013; USACE, 2014; FERC, 2016). The EIS should evaluate whether the reduction of the reclaimed dam elevation to 5717 feet above sea level actually substantially reduces the consequences of failure, or only the statutory high-hazard dam determination.

The EIS should fully explain how the ALARP (As Low as Reasonably Practicable) principles will be applied to the Lewis Gulch TSF, the Dry Fork WRSA, and the LAD storage pond. According to USACE (2014), "The application of ALARP considerations mean that actions should be taken to reduce risk below the tolerable risk limit until such actions are impracticable or not cost effective."

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, "The post-closure phase will commence immediately following the closure phase and is assumed to last approximately ten years for the Lewis Gulch TSF and the Dry Fork WRSA. Post-closure monitoring, maintenance and inspection requirements will be reassessed every five years. It is expected that monitoring and maintenance inspections will be completed throughout the post-closure period." The EIS should clarify the length of time over which monitoring and maintenance inspections should be carried out. The EIS should fully clarify the circumstances under which there could be a cessation to monitoring and maintenance inspections. The EIS should assess the ability of the mining company to carry out monitoring and maintenance inspections over the required time period. The EIS should assess the consequences of a cessation of monitoring and maintenance inspections before the end of the required time period.

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, "Localized differential settling, including formation of shallow depressions, may occur [after closure] but will not affect the performance of the reclamation cover and would add to the naturalization of the reclamation cover." The EIS should evaluate the possible amount of differential settling, as well as the possible volume of water that could be stored on top of the closed TSF. The EIS should evaluate the consequences of water stored on top of the closed TSF in terms of the post-closure credible failure modes and post-closure dam break assessment. In particular, the EIS should use the possibility of differential settling to re-evaluate the assumption

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in the document East Boulder Mine—Dam Breach Assessment for the Lewis Gulch Tailings Storage Facility that there will be no supernatant water in the post-closure period.

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, "The final stage of the TSF embankment will be constructed with approximately 2H:1V outside slopes to meet long-term slope stability requirements." The EIS should consider the appropriate slope for the outer embankment during the post-closure period. It should be noted that a slope of 2H:1V is generally regarded as an absolute minimum slope even for an operating dam. Moreover, some dam and levee safety regulations require slopes no greater than 5H:1V, again even for dams and levees that are being actively operated and maintained. For example, according to Ministry of Energy and Mines (British Columbia) (2017), "For a tailings storage facility design that has an overall downstream slope steeper than 2H:1V, the manager shall submit justification by the engineer of record for the selected design slope and receive authorization by the chief inspector prior to construction." According to the U.S. Army Corps of Engineers, "for sand levees, a 1V on 5H landside slope is considered flat enough to prevent damage from seepage exiting on the landside slope" (USACE, 2000). The EIS should fully justify any assumption that such a steep slope could endure indefinitely without monitoring, inspection and maintenance.

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, "A Closure Swale will be constructed at the east corner of the Lewis Gulch TSF to convey storm water runoff from the southeast sloping portion of the cap … The swale is sized to convey the Probable Maximum Flood (PMF) event." The dimensions of the swale should take into consideration the impact of climate change on the PMF during the post-closure period.

According to the document Lewis Gulch Tailings and Dry Fork Waste Rock Expansion Amendment 004, "Physical inspections of the Lewis Gulch and Stage 6 TSFs will be conducted by the Engineer of Record (EOR) on an annual basis during closure (Years 1- 10). Physical inspections of other surface structures including the Dry Fork WRSA, water management features, reclaimed mine entrances, and reclaimed slopes will be conducted by a qualified engineer. If any physical instability of the TSFs or other surface structure is observed during site inspections, the frequency of monitoring may be increased until both stability and safety can be assured." The EIS should clarify what events or observations would constitute a permanent assurance of stability and safety.

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REFERENCES

Arcement, G.J., and V.R. Schneider, 1989. Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water Supply Paper 2339, 44 p. Available online at: https://pubs.usgs.gov/wsp/2339/report.pdf

Asano, Y., S. Hoshino, T. Uchida, and K. Akiyama, 2012. Measuring the flow and Manning's roughness coefficient of mountain streams: Shin Sabo = Journal of the Japan Society of Erosion Control Engineering, vol. 65, pp. 62-68.

Bagnold, R.A., 1966. An approach to the sediment transport problem from general physics: U.S. Geological Survey Professional Paper 422-I, Washington, D.C., 37 p.

Bagnold, R.A., 1977. Bed load transport by natural rivers: Water Resources Research, v. 13, pp. 303-312.

Bagnold, R.A., 1980. An empirical correlation of bedload transport rates in flumes and natural rivers: Proceedings of the Royal Society of London A, v. 372, pp. 453-473.

Bagnold, R.A., 1986. Transport of solids by natural water flow—Evidence for a worldwide correlation: Proceedings of the Royal Society of London A, v. 405, pp. 369-374.

Barnes, H.H., 1967. Roughness characteristics of natural channels: U.S. Geological Survey Water Supply Paper 1849, 219 p. Available online at: https://pubs.usgs.gov/wsp/wsp_1849/pdf/wsp_1849.pdf

Bathurst, D., 1985. Flow resistance estimation in mountain rivers: Journal of Hydraulic Engineering, vol. 111, pp. 625-643.

Blodgett, S. and J.R. Kuipers, 2002. Technical report on underground hard-rock mining—Subsidence and hydrologic environmental impacts: Center for Science in Public Participation, Bozeman, Montana, 50 p. Available online at: http://www.csp2.org/files/reports/Subsidence%20and%20Hydrologic%20Environmental%20Impacts.pdf

Breaker, B.K., 2015. Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015-5031, 24 p. Available online at: https://pubs.usgs.gov/sir/2015/5031/pdf/sir2015-5031.pdf

Canadian Dam Association, 2013. Dam safety guidelines 2007 (2013 edition), 88 p.

Canadian Dam Association, 2021. Technical Bulletin—Tailings dam breach analysis, 68 p.

Center for Science in Public Participation, 2022. TSF Failures from 1915. Available online at: http://www.csp2.org/tsf-failures-from-1915

Chang, H.H., 1988. Fluvial processes in river engineering: Krieger, 432 p.

Chow, V.T., 1959. Open-channel hydraulics. McGraw-Hill, 680 p.

Clohan, D. and E. Kidner, 2022. Chapter 14—Tailings breach studies and inundation mapping: In K.F. Morrison (Ed.), Tailings management handbook—A life-cycle approach (pp. 211-220), Society for Mining, Metallurgy and Exploration, Englewood, Colorado, 1004 p.

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Cowan, W.L., 1956. Estimating hydraulic roughness coefficients: Agricultural Engineering, vol. 37, pp. 473-475.
Dingman, S.L., 1984. Fluvial hydrology. W.H. Freeman and Company, 384 p.
Dingman, S. L., 2009. Fluvial hydraulics. Oxford University Press, 559 p.
Dingman, S.L. and K.P. Sharma, 1997. Statistical development and validation of discharge equations for natural channels: Journal of Hydrology, vol. 199, pp. 13-35.
Fasken, G.B., 1963. Guide for selecting roughness coefficient "n" values for channels: U.S. Soil Conservation Service, 47 p.
FERC (Federal Energy Regulatory Commission), 2016. Risk-informed decision making guidelines—Chapter 3—Risk assessment: Version 4.1, March 2016, 48 p. Available online at: https://www.ferc.gov/sites/default/files/2020-04/chapter-3.pdf
French, R.H., 1985. Open-channel hydraulics: McGraw-Hill, 705 p.
Gotvald, A.J., 2017. Methods for estimating selected low-frequency statistics and mean annual flow for ungaged locations on streams in north Georgia: U.S. Geological Survey Scientific Investigations Report 2017-5001, 25 p. Available online at: https://pubs.usgs.gov/sir/2017/5001/sir20175001.pdf
Hess, G.W. and L.R. Bohman,1996. Techniques for estimating monthly mean streamflow at gaged sites and monthly streamflow duration characteristics at ungaged sites in central Nevada: U.S. Geological Survey Open-File Report 96-559, 18 p. Available online at: https://pubs.usgs.gov/of/1996/0559/report.pdf
Hicks, D.M. and P.D. Mason, 1991: Roughness characteristics of New Zealand rivers: New Zealand National Institute of Water and Atmospheric Research, 329 p.
Holnbeck, S.R. and C. Parrett, 1996. Procedures for estimating unit hydrographs for large floods at ungaged sites in Montana: U.S. Geological Survey Water-Supply Paper 2420, 60 p. Available online at: https://pubs.usgs.gov/wsp/2420/report.pdf
Hawley, M. and Cunning, J., 2017. Guidelines for mine waste dump and stockpile design: CSIRO Publishing, 385 p. Available online at: https://siaia.apambiente.pt/AIA.aspx?ID=3353
ICMM (International Council on Mining & Metals), 2020. New Global Industry Standard on Tailings Management aims to improve the safety of tailings facilities in the mining industry. Available online at: https://www.icmm.com/en-gb/news/2020/new-global-industry-standard-on-tailings-management
ICMM (International Council on Mining & Metals), 2022. Association Members. Available online at: https://www.icmm.com/en-gb/members/member-associations
ICMM-UNEP-PRI (International Council on Mining & Metals-United Nations Environment Programme-Principles for Responsible Investment), 2020. Global industry standard on tailings management—August 2020, 40 p, Available online at: https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard-on-tailings-management.pdf

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Independent Expert Engineering Investigation and Review Panel, 2015b. Report on Mount Polley Tailings Storage Facility breach: Report to Ministry of Energy and Mines and Soda Creek Indian Band, 156 p. Available online at: https://www.mountpolleyreviewpanel.ca/sites/default/files/report/ReportonMountPolleyTailingsStorageFacilityBreach.pdf

Ivie, H.A., S.H. Emerman, D.B. Dastrup, A.W. Simister, J. Selck, D.R. Howard, and A.W. Fletcher, 2014. An improved method for calculating the Manning roughness coefficient for estimation of stream discharge through slot canyons in southern Utah. In J.S. MacLean, R.F. Biek, and J.E. Huntoon (eds.), Geology of Utah's Far South, Utah Geological Association Publication 43, pp. 1-10.

Jarrett, R.D., 1984. Hydraulics of high-gradient streams: Journal of Hydraulic Engineering, vol. 110, pp. 1519-1539.

Jarrett, R.D., 1985. Determination of roughness coefficients for streams in Colorado: U.S. Geological Survey Water-Resources Investigations Report 85-4004, 60 p. Available online at: https://pubs.usgs.gov/wri/1985/4004/report.pdf

Jennings, M.E., W.O. Thomas, and H.C. Riggs, 1994. Nationwide summary of U.S. Geological Survey regional regression equations for estimating magnitude and frequency of floods at ungaged sites, 1993: U.S. Geological Survey Water-Resources Investigations Report 94-4002, 203 p. Available online at: https://pubs.usgs.gov/wri/1994/4002/report.pdf

Klohn Crippen Berger, 2017. Study of tailings management technologies: Report to Mining Association of Canada and Mine Environment Neutral Drainage (MEND) Program, MEND Report 2.50.1, 164 p. Available online at: http://mend-nedem.org/wp-content/uploads/2.50.1Tailings_Management_TechnologiesL.pdf

Limerinos, J.T., 1970. Determination of the Manning coefficient from measured bed roughness in natural channels: U.S. Geological Survey Water Supply Paper 1898-B, 53 p. Available online at: https://pubs.usgs.gov/wsp/1898b/report.pdf

Marchand, J.P., R.D. Jarrett, and L.L. Jones, 1984. Velocity profile, water-surface slope, and bed-material size for selected streams in Colorado: U.S. Geological Survey Open-File Report 84-733, 77 p. Available online at: https://pubs.usgs.gov/of/1984/0733/report.pdf

Marcus, W.A., K. Roberts, L. Harvey, and G. Tackman, 1992. An evaluation of methods for estimating Manning's n in small mountain streams: Mountain Research and Development, vol. 12, pp. 227-239.

Martin, G.R., K.K. Fowler, and L.D. Arihood, 2016. Estimating selected low-flow frequency statistics and harmonic-mean flows for ungaged, unregulated streams in Indiana: U.S. Geological Survey Scientific Investigations Report 2016-5102, 45 p. Available online at: https://pubs.usgs.gov/sir/2016/5102/sir20165102.pdf

Martin, Y. and M. Church, 2000. Re-examination of Bagnold's empirical bedload formulae: Earth Surface Processes and Landforms, v. 25, pp. 1011-1024.

Meyer-Peter, E., and R. Müller, 1948. Formulas for bed-load transport: In Proceedings of the International Association for Hydraulic Research, Second Congress, pp. 39-65.

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Mining Association of Canada, 2021. A guide to the management of tailings facilities—Version 3.2. Available online at: https://mining.ca/wp-content/uploads/2021/03/MAC-Tailings-Guide-Version-3-2-March-2021.pdf

Ministry of Energy and Mines (British Columbia), 2017. Health, safety and reclamation code for mines in British Columbia: Victoria, British Columbia, revised June 2017, 365 p. Available online at: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/mineral-exploration-mining/documents/health-and-safety/code-review/health_safety_and_reclamation_code_2017_rev.pdf

Morrill, J., D. Chambers, S. Emerman, R. Harkinson, J. Kneen. U. Lapointe, A. Maest, B. Milanez, P. Personius, P. Sampat, and R. Turgeon, 2022. Safety first—Guidelines for responsible mine tailings management: Earthworks, MiningWatch Canada, and London Mining Network: Version 2.0, May 2022, 55 p. Available online at: https://41p14t2a856b1gs8ii2wv4k4-wpengine.netdna-ssl.com/assets/uploads/2020/06/Safety-First-Safe-Tailings-Management-V2.0-final.pdf

Muñoz, V. and D. Hoekstra, 2022. Chapter 20—Climate and hydrology: In K.F. Morrison (Ed.), Tailings management handbook—A life-cycle approach (pp. 361-385), Society for Mining, Metallurgy and Exploration, Englewood, Colorado, 1004 p.

Oboni, F., C. Oboni, and J. A. Caldwell, 2014. Risk assessment of the long-term performance of closed tailings facilities: In Tailings and Mine Waste '14—Proceedings of the 18th International Conference on Tailings and Mine Waste, Keystone, Colorado, USA, October 5 – 8, 2014, pp. 65-76. Available online at: https://tailingsandminewaste.com/wp-content/uploads/TMW2014_proceedings.pdf

Ostraff, A.A., S.H. Emerman, N.D. Udy, S.M. Allen, H. Rakotoarisaona, J. Gherasim, A.M. Stallings, J.N. Saldivar, K.L. Larsen, and M. Abbott, 2018. Use of the Manning Equation for predicting the discharge of high-gradient canals and natural streams: In Ramirez, J.A. (ed.), Proceedings of the 38th Annual American Geophysical Union Hydrology Days, Hydrology Days Publications, Fort Collins, Colorado, pp. 44-55. Available online at: http://hydrologydays.colostate.edu/Papers_2018/Ostraff_paper.pdf

Parrett, C. and K.D. Cartier, 1990. Methods for estimating monthly streamflow characteristics at ungaged sites in western Montana: U.S. Geological Survey Water-Supply Paper 2365, 32 p. Available online at: https://pubs.usgs.gov/wsp/2365/report.pdf

Piciullo, L., E.B. Storrøsten, L. Zhongqiang, N. Farrokh, and S. Lacasse, 2022. A new look at the statistics of tailings dam failures: Engineering Geology, vol. 303, 14 p. Available online at: https://www.sciencedirect.com/science/article/pii/S0013795222001429?via%3Dihub

Pool, S., D. Viviroli, and J. Seibert, 2017. Prediction of hydrographs and flow duration curves in almost ungauged catchments; which runoff measurements are most informative for model calibration? Journal of Hydrology, v. 554, pp. 613-622.

Reid, D.E. and E.J. Hickin, 2008. Flow resistance in steep mountain streams: Earth Surface Processes and Landforms, vol. 33, pp. 2211-2240.

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Riggs, H.C., 1976. A simplified slope-area method for estimating flood discharges in natural channels: U.S. Geological Survey Journal of Research, vol. 4, pp. 285-291.

Rojas-Sema, C., L. Lebecherel, C. Perrin, V. Andreassian, and O. Ludovic, 2016. How should a rainfall-runoff model be parametrized in an almost ungauged catchment? A methodology tested on 609 catchments: Water Resources Research, v. 52, pp. 4765-4784.

Sherwood, J.M.,1993. Estimation of peak-frequency relations, flood hydrographs, and volume-duration-frequency relations of ungaged small urban streams in Ohio: U.S. Geological Survey Open-File Report 93-135, 62 p. Available online at: https://pubs.usgs.gov/of/1993/0135/report.pdf

Sherwood, J.M., 1994. Estimation of peak-frequency relations, flood hydrographs, and volume-duration-frequency relations of ungaged small urban streams in Ohio: U.S. Geological Survey Water-Supply Paper 2432, 42 p. Available online at: https://pubs.usgs.gov/wsp/2432/report.pdf

Singh, R., 2014. Identifying dominant controls on hydrologic parameter transfer from gauged to ungauged catchments; a comparative hydrology approach: Journal of Hydrology, v. 517, pp. 985-996.

Sloto, R.A., M.H. Stuckey, and S.A. Hoffman, 2017. Evaluation of the streamgage network for estimating streamflow statistics at ungaged sites in Pennsylvania and the Susquehanna River Basin in Pennsylvania and New York: U.S. Geological Survey Scientific Investigations Report 2016-5149, 102 p. Available online at: https://pubs.usgs.gov/sir/2016/5149//sir20165149.pdf

USACE (U.S. Army Corps of Engineers), 2000. Design and construction of levees: Manual No. 1110-2-1913, 164 p. Available online at: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1913.pdf

USACE (U.S. Army Corps of Engineers), 2014. Safety of dams – Policy and procedures: Engineer Regulation ER 1110-2-1156, Department of the Army. Available online at: http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1156.pdf

USACE-HEC (U.S. Army Corps of Engineers – Hydrologic Engineering Center), 2003. Application of paleohydrology to Corps flood frequency analysis: RD-47, 34 p. Available online at: http://www.hec.usace.army.mil/publications/ResearchDocuments/RD-47.pdf

Vick, S.G., 1990. Planning, design, and analysis of tailings dams: BiTech Publishers, Vancouver, Canada, 369 p. Available online at: https://open.library.ubc.ca/soa/cIRcle/collections/ubccommunityandpartnerspublicati/52387/items/1.0394902

Vick, S.G., 2014a. The use and abuse of risk analysis: PowerPoint presentation at Tailings and Mine Waste Conference 2014, 17 slides.

Vick, S.G., 2014b. The use and abuse of risk analysis: In Tailings and Mine Waste '14 Proceedings of the 18th International Conference on Tailings and Mine Waste, Keystone,

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Colorado, USA, October 5 – 8, 2014, pp. 49-56. Available online at: https://tailingsandminewaste.com/wp-content/uploads/TMW2014_proceedings.pdf

Wiley, J.B. and J.H. Curran, 2003. Estimating annual high-flow statistics and monthly and seasonal low-flow statistics for ungaged sites on streams in Alaska and conterminous basins in Canada: U.S. Geological Survey Water-Resources Investigations Report 03-4114, 69 p. Available online at: https://pubs.usgs.gov/wri/wri034114/pdf/wri034114_v1.10.pdf

Ziegeweid, J.R., D.L. Lorenz, C.A. Sanocki, and C.R. Czuba, 2015. Methods for estimating flow-duration curve and low-frequency statistics for ungaged locations on small streams in Minnesota: U.S. Geological Survey Scientific Investigations Report 2015-5170, 23 p. Available online at: https://pubs.usgs.gov/sir/2015/5170/sir20155170.pdf

Zink, J.M. and G.D. Jennings, 2014. Channel roughness in North Carolina mountain streams: Journal of the American Water Resources Association, vol. 50, pp. 1354-1358.