KCB Consultants Ltd.

March 24, 2020

Resolution Copper Mining LLC
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Ms. Victoria Peacey
Senior Manager – Permitting and Approvals

Dear Ms. Peacey:

Skunk Camp Tailings Storage Facility
Response to Geo-Subsidence/Seismic Working Group
Action Items #GS-2 and #GS-10 Related to Seismicity
Doc. # CCC.03-81600-EX-LTR-00016 – Rev. 0

1 INTRODUCTION

In response to Geo-Subsidence/Seismic Working Group Action Items #GS-2 and #GS-10 regarding seismic hazard and design criteria submitted by Dr. Emerman (2019) and Dr. Chambers (2019), this letter summarizes the seismic design basis, criteria and parameters for the Skunk Camp TSF and highlights key elements of a site-specific seismic hazard analysis (SHA) completed by LCI (2020).

2 SUMMARY OF PUBLIC COMMENTS ON SEISMIC HAZARD

Comments related to seismic design criteria submitted by Dr. Emerman (2019) and Dr. Chambers (2019) are summarized below. These excerpts are included below for reference and so direct responses and clarifications can be made with specific reference to the Skunk Camp DEIS design (KCB 2018) and the Skunk Camp site-specific Seismic Hazard Assessment (SHA) (LCI 2020).

Summary of Emerman (2019) Comment:

Dr. Emerman's report (2019) presents a runout analysis based on a statistical model using historical tailings dam failures (Larrauri and Lall, 2018) and estimates of the potential impacts on population centers. Based on these results, Dr. Emerman states:

> *"Since the failure of any the proposed tailings storage facilities would result in the probable loss of human life, the tailings storage facilities should be designed to withstand the Maximum Credible Earthquake (MCE), rather than the 5000-year earthquake that was proposed by Rio Tinto",*

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and seeks clarification from Rio Tinto on the following question:

> *"Why has Rio Tinto proposed designing the tailings storage facilities for the 5000-year earthquake, rather than the Maximum Credible Earthquake, even though all proposed sites are clearly upslope from local population centers?"*

Excerpt:

A common choice for the seismic design criterion is the Maximum Credible Earthquake (MCE), defined as "the largest earthquake magnitude that could occur along a recognized fault or within a particular seismotectonic province or source area under the current tectonic framework" (FEMA, 2005). According to the U.S. Army Corps of Engineers, "for critical features, the MDE is the same as the MCE" (USACE, 2016). In a similar way, according to the Federal Emergency Management Agency, "for high-hazard potential dams, the MDE usually is equated with the controlling MCE" (FEMA, 2005). The same federal agency has clarified that "dams assigned the high hazard potential classification are those where failure or misoperation will probably cause loss of human life" (FEMA, 2013). Perhaps most relevant are the recommendations of the Arizona Department of Environmental Quality (n.d.), which state "where human life is potentially threatened, the maximum credible earthquake (MCE) should be used."

Table 1. Predicted Runout following Tailings Dam Failure

Alternative	Name	Tailings Type	Impounded Volume[1] (million yd^3)	Dam Height[2] (ft)	Spill Volume[3] (million yd^3)	Runout[3] (mi)
2	Near West	Thickened	1315.45	520	309.1	266.7
3	Near West	Thickened	1315.45	510	309.1	263.9
4	Silver King	Filtered	1188.98	1040	280.8	370.3
5	Peg Leg	Thickened	1315.45	310	309.1	201.2
6	Skunk Camp	Thickened	1315.45	490	309.1	258.2

[1]Impounded volumes from USDA (2017b).
[2]Dam heights from SWCA Environmental Consultants (2018).
[3]Spill volume and runout calculated from statistical model in Larrauri and Lall (2018).

The MCE is simply the largest earthquake that is theoretically possible at a given location, with no defined return period or probability of occurrence (USACE, 2016). However, some insight into the difference between the 5000-year earthquake and the MCE can be gained by considering the guidelines of the Canadian Dam Association (2013). These guidelines classify dams into five categories, based upon the consequences of failure. The three dam classes with the highest failure consequences are high, very high and extreme, corresponding to loss of life of 10 or fewer persons, 100 or fewer persons, and more than 100 persons, respectively (Canadian Dam Association, 2013). These guidelines use two approaches for determining the safety criteria for dam design. Using a risk-informed approach, dams in the very high- and extreme-consequence categories should be designed to withstand a 10,000-year event. Using a standards-based approach, dams in the extreme-consequence category should be designed to withstand either the MCE or the 10,000-year earthquake (Canadian Dam Association, 2013). The above suggests an equivalence between the MCE and the 10,000-year earthquake, although the same guidelines emphasize that the MCE has no associated return period (Canadian Dam Association, 2013). On the other hand, in the context of discussing criteria for determining the MCE at a particular location, FEMA (2005) states, "For high-hazard potential dams, movement of faults within the range of 35,000 to 100,000 years BP is considered recent enough to warrant an 'active' or 'capable' classification." In summary, it is important to note that the MCE can be much stronger than the 5000-year earthquake and can be as rare as a 100,000-year earthquake, with a corresponding annual exceedance probability of 0.001%.

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Summary of Chambers (2019) Comment:

Dr. Chambers (2019) acknowledged the use of the 10,000-year return period for the TSF designs as the appropriate choice for the design event. The following additional comments were made on the lack of a site-specific seismic hazard assessment:

> *"Cornwall, Banks and Phillips (1971), map an extensive fault structure running the length of Dripping Spring Wash. This fault is not mentioned in the Wong et al [URS 2013] report or the DEIS [Forest 2019]. This fault most probably bisects the dams and impoundments."*
>
> *"The DEIS does not specify the location of the 1:10,000-year event or the assumed magnitude of this event. In the Wong et al report [URS 2013) it is noted that the values calculated for the PGA are "significantly lower" than the values from the USGS Probabilistic Seismic Hazard Analyses (PSHA) and (USGS 2008). The USGS National Seismic Hazard Maps are typically used to develop the Probabilistic Seismic Hazard Analyses (PSHA) for a mine location. The US Forest Service should require the use of the most conservative estimates for seismic events because of the extremely long time period for which tailings facilities are planned to function."*
>
> *"In addition, the USGS has updated its National Seismic Hazard Maps (USGS 2014) since the Wong et.al. report [URS 2013] was written. At a minimum the seismic study needs to be updated to reflect current information, and to include an analysis of the Preferred Alternative Site, which was not included in the 2013 report."*

Dr. Chambers makes the following recommendation:

> *"The EIS must use up to date information, make conservative assumptions about the size and location of the maximum credible earthquake, and must disclose the location and magnitude of the maximum credible earthquake used for the design earthquake for the tailings dam."*

Excerpt:

Seismic Risk

Use of the 1:10,000 year return period earthquake as the design earthquake for the tailings dams, as is done for the Preferred Alternative, is the appropriate choice for the design event. Too many agencies use a lesser earthquake as the design event for a structure that is meant to function in perpetuity, so it is good to see the US Forest Service require the appropriate design earthquake.

The seismic analysis for the EIS is largely based on a report by Wong et. al (2013). The Wong et. al (2013) report was focused on analyzing four specific sites that were under consideration at that time: the Far West Tailings Management Area: Far West 1 and Far West 2; the Near West Tailings Management Area; and, the Pinto Valley Operations (PVO) Tailings Management Area. The Proposed Alternative 6 (Skunk Camp) was not analyzed in this report.

The Preferred Alternative, Alternative 6 (Skunk Camp) – North Option, would occupy the upper portion of Dripping Spring Valley, the northeastern slopes and foothills of the Dripping Spring Mountains, and the southwestern foothills of the Pinal Mountains, including a 4-mile reach of Dripping Spring Wash, a 3.5-mile reach of Stone Cabin Wash, and a 4.8-mile reach of Skunk Camp Wash.

Cornwall, Banks, and Phillips (1971), map an extensive fault structure running the length of Dripping Spring Wash. This fault is not mentioned in the Wong et al (2013) report or the DEIS (2019). This fault most probably bisects the dams and impoundments, so should merit further investigation and discussion in the DEIS.

The DEIS does not specify the location of the 1:10,000 year event, or the assumed magnitude of this event. In the Wong et al report (2013) it is noted that the values calculated for the PGA are "significantly lower" than the values from the USGS Probabilistic Seismic Hazard Analyses (PSHA) and (USGS 2008). The USGS National Seismic Hazard Maps are typically used to develop the Probabilistic Seismic Hazard Analyses (PSHA) for a mine location. The US Forest Service should require the use of the most conservative estimates for seismic events because of the extremely long time period for which tailings facilities are planned to function.

In addition, the USGS has updated its National Seismic Hazard Maps (2014) since the Wong et. al. report (2013) was written. At a minimum the seismic study needs to be updated to reflect current information, and to include an analysis of the Preferred Alternative site, which was not included in the 2013 report.

The EIS must use up to date information, make conservative assumptions about the size and location of the maximum credible earthquake, and must disclose the location and magnitude of the maximum credible earthquake used for the design earthquake for the tailings dam.

3 RESPONSE TO PUBLIC COMMENTS ON SEISMIC HAZARD

3.1 Skunk Camp Site Specific Hazard Assessment

Design Ground Motions

The Skunk Camp site-specific SHA includes a seismic hazard analysis (PSHA) and a deterministic seismic hazard analysis (DSHA) (LCI 2020). The SHA is built on previous studies for other proposed TSF locations, including RCM’s Near West site (Wong et al 2017) and a copy was submitted to the Tonto National Forest on January 8, 2020 in preparation for the Failure Modes and Effects Analysis (FMEA) workshop.

The PSHA seismic source model included the most recent seismic records and ground motion prediction equations, consistent with, or more recent than, the inputs to the 2014 seismic hazard maps. Site-specific inputs included:

- a total of 47 local and regional active faults surrounding the project area that may be significant in terms of ground motions, including Quaternary faults within 200 km of the Skunk Camp site and more active faults further than 200 km, in Southern and Baja California (due to the generally low seismic hazard local to Skunk Camp);
- evaluation of historical and contemporary seismicity; and
- available geological, geophysical and geotechnical information from the 2019 Skunk Camp site investigation (KCBCL 2019).

Additional information on the PSHA is provided in the LCI (2020) report.

The DSHA was performed for the closest fault sources to the project area using the NGA-West 2 (LCI 2020) ground motion models. The nearest identified seismic source to the Skunk Camp site is the Whitlock Wash fault with a potential rupture distance of 52 km from the TSF site; a DSHA for a moment magnitude **M** 6.9 earthquake was performed for this scenario (LCI 2020). The ground motions from DSHA of the ten controlling deterministic earthquakes were compared to the uniform hazard spectra (UHS) from the PSHA and were found to result in lower ground motions. A list of the ten deterministic sources identified is provided in LCI (2020).

Because the probabilistic hazard results were larger than the deterministic results, design earthquake ground motions were selected based on the results of the PSHA in accordance with the approach adopted in other low-seismicity regions, such as Canada (CDA 2007). A peak ground acceleration (PGA) of 0.16g was calculated for the 10,000-year return period earthquake, which is associated with a moment magnitude of **M** 5.5 and rupture distance of approximately 9 miles.

MCE can only be calculated for a well-known seismic source such as a known fault using a deterministic analysis for the closest active faults. That is why, often in low seismic areas, the DSHA is compared to the PSHA to select ground motions for design.

Dripping Springs Fault Investigation

Dripping Springs fault is a normal fault that extends parallel to and is within the Dripping Springs Wash. Reconnaissance-level fault investigations of the Tertiary-age faults at the Skunk Camp site, including the Dripping Springs Fault, Ransome Fault, and other unnamed faults, were performed by KCBCL (2019) and LCI (2020) to assess the likelihood of the faults being active in the Quaternary period (2.6 Ma to present). Specific objectives included:

- Critical evaluation of previously mapped faults in the Skunk Camp area that suggest possible Quaternary activity. This included desktop studies of geologic maps, scientific literature, site investigation reports, air photos and topographic data.
- Observations of geologic and geomorphic conditions at the Skunk Camp site for possible evidence of unrecognized Quaternary-active faults.

Details of the fault investigation are summarized in LCI (2020). Field observations and desktop studies concluded that Quaternary-active faults are highly unlikely at the Skunk Camp site. Geomorphic evidence observed in the Dripping Spring Mountains and Dripping Spring Valley strongly suggests the absence of active faulting. The most recent AGS geologic map (Richard and Spencer, 1988) does not show the investigated faults as possibly Quaternary-active and the faults do not appear in the USGS Quaternary Fault and Fold or AGS active faults databases.

3.2 Skunk Camp Seismic Design Criteria

The Skunk Camp TSF is designed for the mean 10,000-year return period earthquake (KCB 2018), based on the PSHA. This design criterion is consistent with the Arizona Administrative Code (A.A.C.) R12-15-1216 and supplemented with MEM (2016) and CDA (2007).

The MCE is typically associated with a well-known seismic source such as a known fault. As discussed above, the MCE was calculated using a deterministic analysis (DSHA) for the closest active faults and was compared with the 10,000-year return period from a probabilistic analysis (PSHA). The probabilistic hazard results were higher than the deterministic results, so the 10,000-year return period event was adopted in place of the MCE. This is a typical approach in low-seismicity regions.

The TSF design has also adopted the following geotechnical design philosophy:

All potentially liquefiable contractive (i.e., undrained, non-compacted) tailings are assumed to liquefy regardless of the triggering mechanism.

In addition to these design assumptions, the following favorable conditions at the Skunk Camp site contribute to the robustness of the TSF design:

- well-draining, dense foundation materials;
- embankment underdrain systems and availability of local granular borrow material to construct them;
- the ability to flatten the embankment and build downstream if required as a contingency;
- low-relief basin topography (average ~3% slope down Dripping Springs Wash); and
- semi-arid climate (net evaporative losses and low precipitation) resulting in drier conditions within the tailings and a net-deficit water balance, such that water would not accumulate over time.

4 CLOSING

This letter is an instrument of service of KCB Consultants Ltd. (KCBCL). The letter has been prepared for the exclusive use of Resolution Copper Mining LLC (Client) for the specific application to the Resolution Copper Project, and it may not be relied upon by any other party without KCBCL's written consent. KCBCL has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCBCL makes no warranty, express or implied.

Yours truly,

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JW:dl

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