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Project Memorandum

To:	**SWCA Environmental Consultants**		
Attention:	**Chris Garrett, P.HGW.**		
From:	**Mark Zellman, PG, CPG, and Diana Cook, Ph.D., PE**	**Date:**	**June 30, 2020**
Subject:	**Resolution Copper Project EIS –Assessment of Surface Faulting Investigations at the Skunk Camp TSF Location**		
Project No.:	**1704007**		

1.0 INTRODUCTION

1.1. Project and Environmental Impact Statement Summary

Resolution Copper Mining LLC (RCM) is proposing to develop the Resolution Copper Project (the Project), an underground copper mine, near the town of Superior, Arizona.

The US Department of Agriculture Tonto National Forest (TNF) completed a Draft Environmental Impact Statement (EIS) for the Project (USFS 2019). The TNF is the lead Federal agency for the EIS, and SWCA Environmental Consultants (SWCA) is the TNF's third-party EIS contractor. BGC Engineering USA, Inc. (BGC) is providing geological and geotechnical expertise to SWCA and the TNF.

Five tailings storage facility (TSF) design alternatives, plus one "no action" alternative, have been developed for the Project. In their Draft EIS, the TNF identified "Alternative 6 (Skunk Camp) – North Option" as their preferred TSF design alternative (USFS 2019).

RCM and its consultants have described the potential for Quaternary-active faulting near the Skunk Camp TSF in the following project reports:

- Montgomery & Associates. (2018, July 20). *Results of Site Reconnaissance* [Technical Memorandum]. Prepared for Resolution Copper.
- Klohn Crippen Berger Consultants Ltd. (KCB). (2019, November 1). *Skunk Camp Site Investigation* [Report]. Prepared for Resolution Copper Mining LLC.
- Lettis Consultants International, Inc. (LCI). (2020, January 6). *Site-Specific Seismic Hazard Analysis and Development of Time Histories for Resolution Copper's Proposed Skunk Camp Tailings Storage Facility, Southern Arizona* [Report]. Prepared for Resolution Copper.

BGC reviewed these documents and, on March 18, 2020, submitted a draft memorandum with review comments to RCM. KCB and LCI provided responses to BGC's comments through the following two documents:

- KCB (2020, May 14). *Response to March 18, 2020 letter from BGC Re: Resolution Copper Project EIS – Assessment of Surface Faulting Investigations at the Skunk Camp TSF Location Doc # CCC.03-81600-Ex-TR-00016-Rev.0* [Letter Report]. Prepared for Resolution Copper.
- LCI (2020, April 29). *Response to BGC's Review Comments on Assessment of Surface Faulting Investigations at the Skunk Camp Location* [Memorandum]. Prepared for Resolution Copper.

LCI has since submitted a revised version of the LCI (January 6, 2020) report. It includes revisions to the background text and a figure based on the information included in the LCI (April 29, 2020) memo that responds to BGC comments. The following report was used to assess LCI's active fault assessment at the proposed Skunk Camp TSF site because it supersedes the previous version:

- Lettis Consultants International, Inc. (LCI). (2020, May 19). *Site-Specific Seismic Hazard Analysis and Development of Time Histories for Resolution Copper's Proposed Skunk Camp Tailings Storage Facility, Southern Arizona*, Rev. 2 [Report]. Prepared for Resolution Copper.

1.2. Scope and Objectives

BGC has performed a desktop review of the consultant documents listed above, published geological maps covering the surrounding area (Cornwall, Banks, & Phillips, 1971; Richard & Spencer, 1998), and the U.S. Geological Survey's (USGS) Quaternary Fault and Fold Database (USGS & AZGS, 2020). BGC also communicated with Dr. Phillip Pearthree of the Arizona Geological Survey (AZGS) to discuss whether there are known or suspected Quaternary faults in the Skunk Camp vicinity that are absent from the USGS database. The objective of BGC's review was to provide opinions on whether:

- The Project's investigations of the potential for Quaternary-active faulting were consistent with accepted industry practices and applicable regulations.
- The analyses and conclusions are appropriate and defensible.
- Supplemental investigations or analyses are warranted.

BGC has not completed any field assessments or independent analysis of surface faulting at the subject location.

This memorandum provides a background of relevant state regulations and guidelines for assessing fault-related geohazards around tailings facilities, summarizes published geological mapping around the Skunk Camp TSF site, evaluates the Project's assessments of Quaternary faulting, and provides recommendations to fill key knowledge gaps.

2.0 BACKGROUND

2.1. Summary of Applicable Regulatory Guidance

With respect to the design of tailing facilities, the Arizona Mining Guidance Manual (ADEQ, 2004):

- Defines active faults as those which have experienced activity within the past 35,000 years.
- States that active faults within 200 kilometers of a site should be included in the evaluation of the Maximum Possible Earthquake (MPE) and the Design Earthquake.
- States that tailing facilities should generally not be located on active faults. Where active faults occur adjacent to a proposed tailing facility site, caution must be taken to assure that the fault location is well-defined. Where a facility is to be located on an active fault, the applicant must evaluate aquifer loadings for an assumed ground rupture to demonstrate that the proposed location is feasible.
- Recommends aerial photographs be utilized to confirm the absence of faults in the immediate site vicinity, or to precisely locate nearby faults, if present.
- Recommends trenching studies to investigate offsets and age of recent movement when necessary.

2.2. Nearby Mapped Faults

The Skunk Camp TSF site is located approximately 14 miles southeast of Superior, Arizona, in the Dripping Springs Wash basin (See LCI, 2020, May 19; Figures 10 and 11). The site overlies the border between Gila and Pinal Counties.

Cornwall et al. (1971) show the Ransome and Dripping Springs[1] faults within the Dripping Springs Wash basin and along its western margin, cutting through the footprint of the proposed Skunk Camp TSF (See LCI, 2020, May 19; Figure 11). The Ransome fault is shown as a north-trending and steeply west-dipping (dip angle 70°) normal fault. The Dripping Springs fault is shown as a northwest-trending and northeast-dipping normal fault. In most locations the faults are symbolized with dotted lines to indicate that the structures are concealed by surficial deposits. In some locations the faults are symbolized with solid lines, indicating that they cut and therefore are younger than the surficial deposits. Miocene and Pliocene conglomerate, Pleistocene to Holocene pediments, and Pleistocene to Holocene alluvium are depicted as cut in places by faults. These mapping relationships imply that the Ransome and Dripping Springs faults could have been active within the past 35,000 years.

Richard and Spencer (1998) mapped the Ransome fault within the Dripping Spring Mountains, south of Dripping Springs Wash. The fault is depicted as concealed by Tertiary to Quaternary basin-fill deposits within Dripping Springs Wash.

[1] The Dripping Springs fault is shown as unnamed by Cornwall et al. (1971) but assigned that name by KCB (2019, November 1) and LCI (2020, May 19).

The USGS Quaternary Fault and Fold Database shows the nearest Quaternary fault to be over 50 km (~ 30 miles) from the proposed Skunk Camp TSF (USGS & AZGS, 2020).

3.0 PROJECT REPORTS RELEVANT TO QUATERNARY FAULTING

The following summaries are compiled from information included in the Montgomery & Associates (2018), KCB (November 1, 2019), and LCI (May 19, 2020) site investigation reports and supplemental documents provided by KCB (May 14, 2020) and LCI (April 29, 2020) in response to BGC's draft review comments.

3.1. Montgomery & Associates

Montgomery & Associates (2018) report the results of their site reconnaissance of hydrogeologic features. They discuss the faults mapped by Cornwall et al. (1971), show their locations relative to the Skunk Camp TSF, and describe their inferred ages based on mapped cross-cutting relationships. The memorandum does not describe field-based investigation of the mapped faults.

3.2. KCB Consultants, Ltd.

KCB provide details for their geotechnical and hydrogeological site investigations of the Skunk Camp TSF and address Quaternary faulting as part of their site investigations. They performed visual inspection and field-based mapping between November 20 and 25, 2018, and visited sites where Cornwall et al. (1971) mapped faults through Quaternary deposits. KCB used mapping by Cornwall et al. (1971) to guide their field reconnaissance.

In their investigation of the Ransome fault, KCB found no evidence for the fault in bedrock outcrops immediately south of Haley Spring where Cornwall et al. (1971) shows the fault is located (see KCB 2019, November 1; Figure V11-3.3). Instead, KCB places the fault about 300 feet to the west based on their observation of a 15-foot-wide shear zone. They visually inspected Quaternary and Tertiary deposits that overlie the observed shear zone for evidence of Quaternary activity. KCB reports finding no geomorphic or stratigraphic evidence for Quaternary activity of the Ransome fault (see KCB, November 1, 2019, Appendix VII-3.2 and VII-A, and KCB, May 14, 2020).

KCB performed three tasks to investigate the Dripping Springs fault. They: 1) collected seismic refraction and electrical resistivity geophysical data across a 1500-foot-long spread (profile line SL-4), 2) drilled two angled borings (DH18-8 and DH19-8B) to intersect the fault at depth, and 3) performed field-based visual inspection for evidence of surface faulting. They interpreted a fault based on an anomaly in the electrical resistivity SL-4 profile between stations 850 feet and 950 feet (see KCB, November 1, 2019; Figure 4.1) and used that inferred location and the mapping by Cornwall et al. (1971) to target the two angled borings. KCB states that their borehole found no conclusive evidence of faulting.

KCB concludes that Quaternary faulting is absent at the Skunk Camp site. They state that Tertiary deposits that thicken towards the Dripping Springs Basin could suggest Tertiary faulting, but an

absence of any surface expression suggests no Quaternary activity on any candidate Tertiary structures.

3.3. Lettis Consultants International, Inc.

LCI performed a desktop and field-based assessment to investigate the possible Quaternary and Tertiary faults through Quaternary and Miocene to Pliocene units, as mapped by Cornwall et al. (1971). LCI's desktop study involved a review of available published information including aerial imagery and high-resolution topographic data produced from photogrammetry and lidar as shown in Figure 1 of their April 29, 2020, memorandum. Their work included a review of mapping by Richard and Spencer (1998), which post-dates mapping by Cornwall et al. (1971) and covers portions of the Skunk Camp TSF and the faults in question. They also spoke with Dr. John Spencer to discuss his map and field observations.

LCI performed field reconnaissance from November 4-6, 2019. During that time, they focused their efforts on assessing lineaments they identified during their desktop analysis (see LCI, May 19, 2020; Figure 13), areas where Cornwall et al. (1971) mapped faults within the basin-fill deposits, and where Richard and Spencer (1998) mapped faults in bedrock adjacent to basin-fill deposits. GPS track logs overlying mapping by Cornwall et al. (1971) and Richard and Spencer (1998) are shown in Figures 11 and 12, respectively, of their May 19, 2020, report. LCI also visited a lineament they mapped during their desktop analysis (see LCI, May 19, 2020; Figure 13).

Based on their assessment, LCI concludes that Quaternary faulting is highly unlikely at the site based on an absence of geomorphic evidence. However, due to 1) regional slip rates that are exceeded by rates of erosion, and 2) a lack of Tertiary and younger exposures, LCI states they are unable to completely rule out Quaternary faulting at the site.

LCI excluded the Dripping Springs, Ransome and other local unnamed faults near the TSF footprint from their seismic hazard assessment for the following reasons stated in their report (LCI, May 19, 2020; Section 4.3):

- The gross-scale geomorphology of the Dripping Springs Mountains and Dripping Springs Valley strongly suggest the absence of active tectonics.
- Evidence for Quaternary activity on the Dripping Springs and Ransome faults appears only on ca. 1960's to 1970's geologic maps. Maps produced more recently (e.g., Richard and Spencer, 1998) do not show the faults as possibly Quaternary-active.
- Neither the Dripping Springs or Ransome faults are included in the U.S. Geological Survey (USGS) Quaternary Fault and Fold Database, and they are not included in the tabulations of active faults developed by the Arizona Geological Survey (AGS).
- LCI's field reconnaissance fault investigation is consistent with the prior geologic reconnaissance performed by KCB which also did not identify Quaternary faulting in the area.

4.0 BGC REVIEW OF QUATERNARY FAULT INVESTIGATIONS

KCB (2019, November 1) and LCI (2020, May 19) performed studies to investigate the presence of Quaternary and Tertiary faulting adjacent to, and within, the footprint of the Skunk Camp TSF. Additional information about these studies is provided in KCB (2020, May 14) and LCI (2020, April 29). Montgomery and Associates (2018) mentions the faults mapped by Cornwall et al. (1971), but they performed no investigation of the faults and did not discuss them further in their assessment.

Two fundamental questions addressed by KCB and LCI that are relevant for the Skunk Camp TSF location are:

1. Does the Cornwall et al. (1971) map correctly depict Quaternary faults in the Dripping Springs Basin?
2. Are there any other Quaternary faults within or adjacent to the proposed Skunk Camp TSF footprint?

Although ADEQ (2004) defines an active fault as one that shows evidence of movement in the past 35,000 years, KCB, LCI, and this memorandum discuss Tertiary faults in the vicinity of the Project area. The term Tertiary fault refers to a fault that show evidence for activity between 66 million years ago and 2.6 million years. Tertiary faults fall outside the age range of faults considered to be active as defined by ADEQ (2004); however, they are often included in surface faulting studies as candidates for Quaternary activity. Tertiary faults can be ruled out as active faults if overlying Quaternary deposits show no evidence of fault-related deformation.

4.1.1. Quaternary and Tertiary Faults Mapped by Cornwall et al. (1971)

KCB (November 1, 2019, pages 115-116) reports that “no indications of Quaternary faulting have been seen in the results to date” and that there is limited evidence of Tertiary faulting. KCB found no evidence of Quaternary faulting in the locations mapped by Cornwall et al. (1971). KCB (November 1, 2019, page 115) states that evidence for Tertiary faulting is “limited” based on thickened Tertiary Conglomerate deposits close to the Dripping Springs Mountains, on the west side of the basin. Although Tertiary faulting may be responsible for the thickened deposits, they found no surface expression or stratigraphic evidence that would indicate Quaternary activity on any of these postulated Tertiary structures. KCB (2020, May 14) provides additional information to document the absence of stratigraphic and geomorphic evidence for Quaternary activity of the Ransome and Dripping Springs faults.

LCI (May 19, 2020, page 15) reports that their field observations are consistent with “the lack of Quaternary-active faulting in the Project area” and they conclude that “Quaternary-active faults are highly unlikely at the site”. They performed desktop mapping and field-based reconnaissance and found no evidence of Quaternary or Tertiary deposits in the locations mapped by Cornwall et al. (1971) within the Dripping Springs Basin. The Richard and Spencer (1998) map post-dates Cornwall et al. (1971) and does not show these faults cutting Quaternary deposits in the Dripping Springs Valley. LCI contacted Dr. Jon Spencer who mentioned that although his work focused on

mapping geology and structures within bedrock rather than the Quaternary and Tertiary basin deposit, he did perform field checks of younger Quaternary deposits within the Dripping Springs Valley. He stated that he does not recall observing any evidence of Quaternary faulting

BGC is in general agreement with KCB and LCI that there is sufficient evidence to argue against the presence of faults that cut surficial Quaternary or Tertiary deposits in the locations mapped by Cornwall et al. (1971).

4.1.2. Quaternary Faults Within or Adjacent to the Skunk Camp TSF footprint

KCB performed field-based reconnaissance and documented a 15-foot-wide shear zone that they associate with the Ransome fault. They found no stratigraphic or geomorphic evidence to suggest Quaternary activity of this or any other structures within the Skunk Camp TSF footprint.

LCI performed desktop mapping to identify lineaments that might be related to surface faulting in the project area. Through this mapping they identified a 1-km-long topographic/tonal lineament that is not associated with any previously mapped fault. They visited this lineament during field reconnaissance but determined the feature likely has an origin related to erosion.

LCI concludes that Quaternary faulting is highly unlikely at the site based mostly on a lack of geomorphic evidence. However, they state that low-rate faulting, high rates of erosion, and a general lack of Quaternary and Tertiary deposits prevent them from completely ruling out the presence of Quaternary-active faulting.

BGC agrees that the available evidence, as described by KCB and LCI, does not support Quaternary faults in the Project area.

5.0 BGC ASSESSMENT AND RECOMMENDATIONS

BGC has reviewed the KCB and LCI reports and responses to BGC's draft review. Together, these studies meet the ADEQ (2004) guideline for evaluating tailing impoundment sites. LCI met the guidance to use aerial photographs to confirm the absence of faults in the immediate site vicinity. Both LCI and KCB performed field reconnaissance and KCB performed subsurface investigations; these strengthened evidence against Quaternary faulting at the Project site. ADEQ (2004) recommends that faults showing evidence for recent movement are investigated by trenching, but no such faults occur in the Project area.

BGC is generally in agreement with the finding that Quaternary-active faults are absent in the Project area. This finding is consistent with the USGS Quaternary Fault and Fold Database (USGS & AZGS, 2020), which includes no known Quaternary faults in the vicinity of the Skunk Camp site. In addition, Dr. Phillip Pearthree, Director of the Arizona Geological Survey, states in an email to BGC (Dr. P. Pearthree, email communication, February 21, 2020) that he has never visited the faults in question, the faults have not been included in previous Arizona statewide maps of Quaternary faults, and he defers to project-specific field investigations for interpretation of the faults mapped by Cornwall et al. (1971).

BGC has no further questions or recommendations regarding the evaluation of surface faults at the proposed Skunk Camp TSF.

6.0 CLOSURE

BGC Engineering USA Inc. (BGC) prepared this document for the account of SWCA Environmental Consultants. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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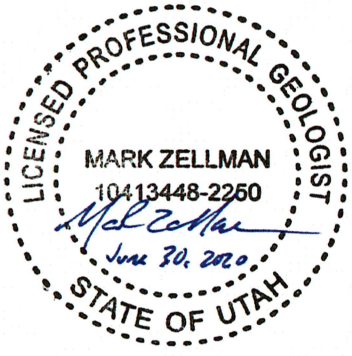
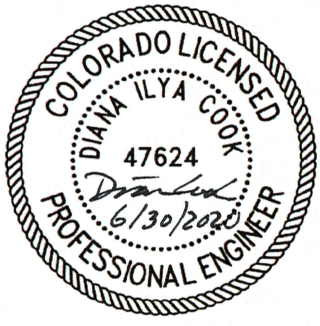
Yours sincerely,

BGC ENGINEERING USA INC.
per:





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REFERENCES

Arizona Department of Environmental Quality (ADEQ). (2004). Arizona Guidance Manual BADCT. Publication #TB 94-01.

BGC Engineering, USA (BGC). (2020, March 18). Resolution Copper Project EIS – Assessment of Surface Faulting Investigations at the Skunk Camp TSF Location – DRAFT. [Draft Memorandum]. Prepared for SWCA Environmental Consultants.

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Klohn Crippen Berger Consultants Ltd. (KCB). (2020, May 14). *Response to March 18, 2020 letter from BGC Re: Resolution Copper Project EIS – Assessment of Surface Faulting Investigations at the Skunk Camp TSF Location, Doc # CCC.03-81600-Ex-TR-00016-Rev.0.* [Letter Report]. Prepared for Resolution Copper.

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Victoria Boyne

From: ResolutionProjectRecord
Subject: FW: Resolution Copper - Skunk Camp PSHA & Surface Faults Memos
Attachments: Resolution_BGC_SkunkCampsPSHAreview_20200701.pdf; Resolution_BGCMemo_SkunkCampSurfaceFaulting_Rev1_20200630.pdf

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From: Derek Hrubes <DHrubes@bgcengineering.ca>
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Subject: Resolution Copper - Skunk Camp PSHA & Surface Faults Memos

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Hi Chris and Donna,

Attached are the finalized BGC review memos for the following:

- Skunk Camp – Specific Seismic Hazard Analyses
- Skunk Camp – Assessment of Surface Faulting Investigations

Please let us know if there is any follow-up required on these items.

Thank you,

BGC ENGINEERING INC.
per:

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