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Dear Mark,

RE: EOR Response to Written Comments of Colleen Elliott relating to the DEIS

1.0 INTRODUCTION

Montana Resources, LLP (MR) requested comments from the Engineer of Record (EOR) of the Yankee Doodle Tailings Impoundment (YDTI) in relation to the April 18, 2019 letter from Dr. Colleen Elliott, P.G. to Mr. Craig Jones (Department of Environmental Quality, DEQ). The letter provides written comments the Draft Environmental Impact Statement (DEIS) prepared by DEQ in relation to the planned continued use of the YDTI. The MR request was initiated by a letter from Dan Walsh of the DEQ to Mark Thompson of MR on June 4, 2019, which requested a written response from the EOR and Independent Review Panel (IRP) in relation to comments contained in the letter.

Knight Piésold's (KP's) involvement at the YDTI commenced in 2012. KP's responsibilities for the on-going design and development of the YDTI were formalized in 2015, when Mr. Ken Brouwer, P.E. agreed to accept the role of EOR for the YDTI. KP has since been actively involved in the design and development of the YDTI and has worked closely with MR to achieve the fundamental objective of on-going continuous improvement of the safety of the impoundment. The EOR is supported by the extensive team of technical specialists at KP, by independent external specialists as appropriate, and by an Independent Review Panel (IRP) consisting of three internationally renowned experts. External specialists, Dr. Linda Al Atik and Dr. Nick Gregor, were retained by KP to perform the updated Seismic Hazard Assessment (SHA) for the Design Document supporting the Permit Amendment Application.

KP recognizes Dr. Elliott's credentials and experience, and KP referenced her work (MBMG, 2009) in preparation of the Site Characterization Report (KP, 2017), which was one of twelve reports that comprise the Design Document. The Design Document was reviewed by the IRP, as required by State law and as stipulated in Montana Code Annotated (MCA) 82-4-377. The IRP, consisting of three independent review engineers, provides an important role in the review of the EOR's design, as well as in assessing the practicable application of current technologies in the design. The following three distinguished international experts constitute the IRP for the YDTI and were responsible for the review of the Design Document:

- Mr. James Swaisgood, P.E. – Dam and Seismic Specialist
- Dr. Leslie Smith, P.Geo, - Hydrogeology Specialist
- Dr. Dirk van Zyl, P.E., - Tailings and Geotechnical Specialist

2.0 COMMENT SUMMARY

Dr. Elliott expressed concern in her letter about the method used to estimate the Magnitude (M) 6.5 maximum credible earthquake (MCE) on the Continental Fault and faults connected to it. She notes that site-specific probabilistic and deterministic hazard analyses were performed for the YDTI using pre-2010 geologic data (MBMG, 2009) for the fault structures in the vicinity of the project area. She goes on to comment about the potential for earthquakes greater than M7 within the Intermountain Seismic Belt and that the existing 100 years of seismic records are not a realistic reflection of earthquake potential in Montana, particularly for the Continental Fault.

Dr. Elliott states that any seismic assessment must consider all possible earthquakes in the area and requires information based on the length of a fault that might rupture and ***the history of rupture on the fault (her emphasis)***. She notes that the rupture patterns and connectivity between the nearest potentially active faults have not been collected even though it is possible to do so, and suggests that additional study be performed on the faults to provide assurance that MR have collected all possible information about the movement histories of the faults that intersect the YDTI.

3.0 REFERENCES TO DEIS CONTENT

The DEIS provides a general synopsis with a limited discussion of geologic setting, faults, and seismic hazard for the YDTI. The available information in the DEIS is summarized in two sections:

- DEIS 3-8, there is a discussion regarding the general location of the fault structures in the vicinity of the project area
- DEIS 3-21, where it states *'Analyses were performed to determine an estimate of the embankment crest settlement and deformation during the Maximum Credible Earthquake (MCE) condition. The seismic hazard analysis used a magnitude 6.5 earthquake on the Richter scale as the MCE'*

4.0 SUMMARY OF DESIGN DOCUMENT INFORMATION

4.1 GENERAL

Additional information on the Seismic Hazard Assessment (SHA) for the YDTI is provided in the Design Document. The SHA included a review of available literature for the area, seismic source characterization, the approach used to update the SHA, and how the uncertainty related to the activity of the fault structures in the vicinity of the project area was incorporate within the assessment. It is unclear from Dr. Elliott's comments if she had an opportunity to review the contents of the Design Document and in particular the SHA (Al Atik, L. and Gregor, N., 2016), which is contained in Appendix B of the Site Characterization Report (KP, 2017). A brief summary of the information from the Design Document is provided below, and more information on the methods used to perform the SHA is available in the referenced documents.

The required content of a design document is described in MCA 82-4-376. The design earthquake must be selected to meet the obligations as stipulated in MCA 82-4-376 (2), (m), (i) and (l). The legislation requires a probabilistic and deterministic seismic evaluation for the area and assessment of peak horizontal ground acceleration. The legislation requires either of the following for the expansion of an existing tailings storage facility:

- An analysis showing the proposed design meets the minimum design requirements for a new tailings storage facility, or

- An analysis showing the proposed design does not reduce the original design factors of safety and seismic event design criteria

The legislated requirement for a new tailings storage facility includes for an analysis showing that the seismic response of the tailings storage facility does not result in the uncontrolled release of impounded materials when subject to the ground motion associated with either the 1 in 10,000 year event, or the maximum credible earthquake (MCE), whichever is larger.

The seismic event design criteria for the YDTI were updated periodically by previous engineering consultants involved in the design and assessment of the YDTI. The current criteria were preceded by a study performed by Harding Lawson Associates (HLA) in 1993. HLA prepared a deterministic estimate of the MCE for movement along the Continental Fault and defined the MCE as a Magnitude 6.5 event with a peak bedrock acceleration of 0.6 g.

MR chose to update the seismic event design criteria for the Permit Amendment Application although it was not specifically required by the legislation. The updated seismic hazard assessment was considered prudent practice to demonstrate that the YDTI meets state-of-practice engineering design standards recognizing the close proximity of the Continental Fault and the developments in seismic hazard assessment methods since HLA completed their earlier analysis in 1993.

4.2 SOURCE CHARACTERIZATION

The seismic source characterization for the updated SHA is described by Al Atik, L. and Gregor, N. (2016). The seismicity-based background model used for the SHA at the YDTI was based on the model developed by Petersen et al. (2014) as part of the 2014 update to the National Seismic Hazard Maps (NSHMs). Updates to the NSHMs source model were made to incorporate fault sources from Wong et al. (2005) located in close proximity to the site, but not included in the NSHMs source model. The seismic source model consists of a seismicity-based background source model and a fault-based source model.

The maximum magnitude (Mmax) values used in the 2014 update of the NSHMs are larger than those used in previous studies. This is due to several factors discussed in Petersen et al. (2014); including recognition that there is an incomplete inventory of potential sources, there is possible linkage of short faults into a long rupture, and the NSHMs source model does not include all known fault sources because most of the known Quaternary faults have insufficient information to characterize recurrence rates of moderate to large magnitude earthquakes. The NSHMs model includes a fault as a source of future earthquakes only if the paleoseismic history of this fault has been sufficiently studied and there is evidence of the size, extent of surface rupture, and the timing of the earthquakes. Nearly 75 percent of the Quaternary faults in the Western United States are poorly understood and only characterized by location. These faults are not included in the NSHMs model and Peterson et al. (2014) acknowledges that these uncharacterized faults could generate significant earthquakes.

Al Atik, L. and Gregor, N. (2016) compiled fault sources located within 50 km of the YDTI that were included in the Wong et al. (2005) study, but were not included in the NSHMs model. Of particular importance were the Continental fault, which intersects the YDTI, and the Rocker fault, which is located less than 10 km from the site. A review of a compilation of Quaternary faults in western Montana by Haller et al. (2000) indicated that the Continental fault is poorly studied. The presence of this fault is suggested on the basis of abrupt range-front topography and the reliability of its location is characterized as poor. No information was available on the rates of activity and associated scarps are not known. Wong et al. (2005) assigned inferred slip rates to the Continental fault based on lack of scarps.

The Rocker fault located to the southwest of the site was also included in Wong et al. (2005). Preliminary reconnaissance including a trench investigation has been conducted along some of the fault, but little is known about its rate of activity (Haller et al., 2000). The reliability of this fault is characterized as poor and Wong et al. (2005) inferred slip rates based on the absence of scarps on late Quaternary deposits and the presence of steep facets along the linear range front.

The source parameters of the Continental and Rocker faults used in the SHA are primarily based on Wong et al. (2005). Magnitude recurrence is modeled with the Youngs and Coppersmith (1985) composite model. Maximum magnitudes were estimated based on the Wells and Coppersmith (1994) relationships. Based on a review of more recent publications on the fault (Houston et al., 2013), a dip angle of 70 degrees was assigned to the Continental fault, which leads to almost identical results versus the dip angles based on Wong et al. (2005).

Given the proximity of the Continental and Rocker faults to the YDTI site and because they were included as active sources in past studies, they were included in the seismic source model for the updated study. However, there is no conclusive evidence that these faults are active; particularly the Continental fault. Al Atik, L. and Gregor, N. (2016) recommended that a fault study be carried out to determine whether the Continental fault is indeed active because of the impact of the Continental fault on the results of the hazard analysis for the YDTI, particularly on the deterministic results and estimated fault displacements.

A sensitivity analysis was conducted to evaluate the impact of including additional faults from Wong et al. (2005), including other prominent nearby faults such as the North-South trending Klepper and East Ridge Faults, located east of Rampart Mountain, and the Northeast-Southwest trending Rampart Fault. This analysis showed that including these additional faults had only a minimal impact on the results and they were not included in the final source model.

4.3 SEISMIC DESIGN PARAMETERS

The potential activity of the Continental Fault and other nearby faults was examined in the Design Document and relied on information compiled by the Montana Bureau of Mines and Geology (MBMG, 2009) and the Seismic Hazard Assessment for the project (Al Atik, L. and Gregor, N., 2016). The Continental Fault was included in the seismic hazard source models for the design of the embankments primarily due to the proximity to the YDTI site and because it was included as an active source in past studies. MR has examined the Continental Fault in areas of the Continental Pit highwalls where it has been exposed, and both the EOR and Jim Swaisgood of the IRP have also had the opportunity to examine an exposure. These investigations have not determined conclusively the fault is inactive (nor that it is active). KP have therefore chosen to maintain a conservative approach and consider the fault to be potentially active for stability analyses conducted to date.

The SHA included derivation of the following seismic response spectra:

- Probabilistic spectra with return periods of 475, 1,000, 2,475, and 10,000 years
- Deterministic 50th (median) and 84th percentile response spectra for the MCE scenarios on the Continental fault with rupture distances of 1.2 and 0.1 km

Site-specific probabilistic and deterministic seismic hazard analyses were performed for the YDTI, which lies within a region characterized by late-Quaternary Basin and Range normal faulting as well as historical seismicity. Two fault sources are located in close proximity to the site: the Continental Fault, which intersects the site has a Mmax of 6.5, and the Rocker Fault, which is located within 10 km southwest of the site with a Mmax of 7.0. At the probabilistic 10,000-year return period, the Continental Fault was found to be the significant contributor. The median and 84th-percentile response spectra for the deterministic analysis for the Continental Fault were significantly larger than for the Rocker Fault. The deterministic MCE spectra exceeded those for the probabilistically-derived 1-in-10,000-year event. As a result, the MCE selected as the design earthquake entails a magnitude 6.5 event with a rupture distance (R_{rup}) of 0.1 km. as shown in Table 1.

Table 1 Summary of Probabilistic and Deterministic Seismic Hazard Analysis

	Probabilistic UHS PSA (g)				Deterministic PSA (g) R_{rup} = 1.2 km		Deterministic PSA (g) R_{rup} = 0.1 km	
Return Period (Years)	475	1,000	2,475	10,000	Median	84th Percentile	Median	84th Percentile
PGA	0.08	0.12	0.20	0.37	0.42	0.78	0.45	0.84

Appropriate earthquake (horizontal acceleration) time-history records were selected as input ground motions for the seismic response analysis. Earthquake records representative of the design events were selected to the extent possible by Al Atik and Gregor (2016). Five representative earthquake time histories were provided for each earthquake event with characteristics as shown in Table 2. The scaled and baseline corrected earthquake time-history records were derived for bedrock with a shear wave velocity of 760 m/s.

Table 2 Parameters of Input Time Series for MCE Design Events

Earthquake	Station	Moment Magnitude	Mechanism	Rupture Distance (km)
Helena, Montana-01	Carroll College	6.0	Strike-slip	2.86
San Fernando	Pacoima Dam	6.6	Reverse	1.81
Imperial Valley-06	El Centro Array #5	6.5	Strike-slip	3.95
Niigata, Japan	NIG020	6.6	Reverse	8.47
L'Aquila, Italy	L'Aquila - Parking	6.3	Normal	5.38

The influence of nearby fault structures and the interaction between the Rocker and Continental Faults were also examined. The probability of rupture propagation across both the Continental and Rocker Faults was found to be very low (Al Atik and Gregor, 2016). The deterministic spectra for the median and 84th-percentile scenarios on the Continental Fault are larger than those for the other three faults (Rampart, Klepper, and East Ridge).

5.0 SUMMARY AND CONSIDERATIONS FOR FUTURE STUDY

The IRP concurred with the approach to the evaluation and accepted the methodology used by Al Atik and Gregor (2016) to develop the seismic design parameters in their Final Report (IRP, 2017). Furthermore, they concluded that although there was uncertainty regarding the potential activity of the Continental Fault, it was prudent engineering to assume it was active and design the YDTI to withstand such an event. The IRP's determination is conclusive and binding for the EOR, the operator (MR) and the DEQ.

Additional studies to evaluate fault activity or inactivity and to corroborate or improve the existing understanding of potential rupture characteristics for Quaternary faults near the YDTI are being considered as part of the fundamental objective of on-going continuous improvement of the safety of the impoundment. MR and KP will provide the IRP and DEQ with on-going updates on any studies related to the seismic hazard assessment.

6.0 REFERENCES

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Yours truly,
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