

October 31, 2019

Reference No. 18113464-007-L-Rev0

Aaron Sangha

Teck Alaska Incorporated
Red Dog Operations
3105 Lakeshore Drive
Building A, Suite 101
Anchorage, AK 99517

ADDENDUM TO 2019 ANNUAL PERFORMANCE REPORT FOR TAILINGS BACK DAM, RED DOG MINE, ALASKA

Mr. Sangha:

Golder Associates Inc. (Golder) is pleased to present to Teck Alaska Incorporated (TAK) this addendum to the 2019 Annual Performance Report (Golder 2019) for the Tailings Back Dam (TBD) at the Red Dog Mine in northwest Alaska. This addendum includes the inspection and reporting requirements per the *Guideline for Tailings and Water Retaining Structures* (TWRS Guidelines) dated November 2014 by Teck Resources, Inc. (Teck), which is beyond what is required by the Alaska Department of Natural Resources Dam Safety and Construction Unit (ADNR Dam Safety). We understand that Teck recently updated the TWRS Guidelines in January 2019, however, TAK directed Golder to utilize the 2014 document for the 2019 Annual Performance Review. The January 2019 TWRS Guidelines will be applied and referenced in future reporting efforts. The tasks associated with this addendum included:

- Performing a Task 1 visual inspection under the consideration of “Technical Bulletin: Surveillance of Dam Facilities,” by the Canadian Dam Association (CDA) dated 2007.
- Completing a close-out meeting onsite with tailings management personnel that summarized: site observations, dam performance, and identified immediate maintenance or corrective actions. These immediate concerns were documented in writing within one week of the site inspection.
- Review and confirmation of consequence classification (hazard potential classification) and recommended schedule for the next dam safety review.
- A review and evaluation of the Operations and Maintenance (O&M) Manual and the Emergency Action Plan (EAP).
- Summary and priority ranking of outstanding key issues and recommended actions, including recommendations from previous dam safety inspections.

These tasks are described in the following sections and associated attachment. Data and additional information referenced in this document as presented, unless otherwise specified, are described in more detail in the 2019 Tailings Back Dam Annual Performance Report (2019 TBD APR, Golder 2019).

1.0 VISUAL INSPECTION AND CLOSE OUT MEETING

The visual inspection performed on June 22, 2019 was completed in general compliance with the Technical Bulletin: Surveillance of Dam Facilities (CDA 2007) and included a close-out meeting and presentation to TAK on June 24, 2019 following completion of all scheduled structure performance inspections onsite. The presentation summarized the results of the visual investigation, the instrumentation data review, conclusions on the performance of the TBD, and preliminary recommendations. A copy of the presentation was provided to TAK following the close-out meeting and an e-mail summarizing the recommended immediate maintenance or corrective actions was sent to TAK on July 7, 2019 (Anderson 2019). The 2019 TBD APR (Golder 2019) concluded that the dam is being maintained in a satisfactory condition and performing as designed as well as provides recommendations for consideration in an upcoming revision to the O&M Manual.

2.0 HAZARD POTENTIAL CLASSIFICATION REVIEW

The TBD is classified as a Class II significant hazard potential by ADNR Dam Safety based on anadromous fish habitats located downstream of the TBD in Bons Creek. The TBD is currently permitted to a dam crest elevation of 986 feet, congruent with its Stage III configuration. The completion of the Stage IV construction will raise the structure to a dam crest elevation of 996 feet, with the planned ultimate Stage V configuration to achieve a dam crest elevation of 1,006 feet.

During a feasibility-level study of the ultimate Stage V configuration, the hazard potential classification of the TBD was elevated to a Class I high hazard potential when considering both the Stage IV and Stage V dam configurations at dam crest elevations of 996 feet and 1,006 feet, respectively (Golder 2018a). This increase in classification was based on a qualitative assessment that evaluated the potential loss of life at the downstream Emulsion Plant and Blaster's Garage mine facilities and contractor construction camp. A recently completed dam breach and inundation study modeling failure of the TBD (GAL 2018) in both a "sunny day" and "flood stage" dam breach scenarios assessed the TBD at its ultimate Stage V configuration of dam crest elevation 1,006 feet. Results found that the Emulsion Plant and Blaster's Garage mine facilities became inundated in both scenarios, while the contractor construction camp was not impacted in either scenario.

Golder asserts that the current Class II significant hazard potential classification is still appropriate for the TBD at its permitted Stage III configuration at dam crest elevation 986 feet, particularly since the Tailings Main Dam is still permitted at a dam crest elevation of 986 feet. TAK is in the process of completing a comprehensive risk assessment of the Red Dog Tailings Storage Facility, which includes the TBD, scheduled for completion during 2020 or 2021. This risk assessment will include Golder's opinions on specific risks related to operations and safety of the TBD and its appurtenant structures.

3.0 REVIEW OF O&M MANUAL AND EAP

The current O&M Manual (Revision 3, Golder 2016) includes an EAP and was revised to generally meet the TWRS Guidelines. The O&M Manual and EAP are considered up-to-date and adequate in their purpose, as there have been no significant changes to the operation of the facility since Revision 3 was issued. The TBD operates as a Class II significant hazard potential structure at its permitted Stage III dam crest elevation of 986 feet.

Following completion of the Stage IV raise to dam crest elevation 996 feet, and any future raises of the structure, the TBD will then operate as a Class I high hazard potential dam. Golder has already considered design parameters commensurate with Class I high hazard potential structures related to seismic and hydrologic parameters and stipulates that changes to the EAP will be necessary once the structure is elevated to operation as a Class I dam (Golder 2018a). Golder recommends separating the EAP and presenting it as a standalone document, prepared and referenced concurrently with the O&M Manual, be implemented in future revisions of both works once the structure begins operation as a Class I high hazard potential dam.

A fourth revision of the O&M Manual is planned for 2019 but may be postponed until the first quarter of 2020 per priority recommendations provided by TAK. This revised O&M Manual will incorporate changes to the monitoring plan and instrumentation array related to completion of the summer 2019 Stage IV construction efforts and Golder's recent 2018 geotechnical investigation at the TBD and Overburden Stockpile (Golder 2018b).

4.0 KEY ISSUES AND RECOMMENDED ACTIONS

Key issues and recommended actions are summarized in Table 1, attached. Each deficiency or non-conformance is discussed in the context of risk to the TBD, an action is recommended, and the timing of the recommended action is given. Each item designated by unique numbers including the year they were made and given a priority based on the descriptions provided in the 2014 TWRS Guidelines.

5.0 CLOSING

The work program followed the standard of care expected of professionals undertaking similar work in the State of Alaska under similar conditions. No warranty expressed or implied is made. Please contact us if you have any questions or comments regarding this report.

Golder Associates Inc.



Bryce A. Hiles, EIT
Geotechnical Engineer



Steven L. Anderson, PE
Associate and Senior Engineering Consultant

BAH/SLA/bah

Attachments: Table 1 – Key Issues and Recommended Actions for the Tailings Back Dam

[https://golderassociates.sharepoint.com/sites/101201/deliverables/3.0 issued/18113464-007-l-td twrs addendum/rev0/18113464-007-l-rev0-red dog 2019 tbd apr twrs addendum-20191031.docx](https://golderassociates.sharepoint.com/sites/101201/deliverables/3.0%20issued/18113464-007-l-td%20twrs%20addendum/rev0/18113464-007-l-rev0-red%20dog%202019%20td%20apr%20twrs%20addendum-20191031.docx)

6.0 REFERENCES

- Anderson, S. L. 2019. Personal communication (e-mail) between Steven L. Anderson, PE (Golder Associates Inc.) and Tyler Oester and Tanna DeRuyter (Teck Alaska Incorporated) regarding: Draft Geomembrane Defect Repair Technical Memorandum and Immediate Maintenance or Corrective Actions, Reference Document 18113464-001-RevA, dated July 7.
- CDA (Canadian Dam Association). 2007. Technical Bulletin: Surveillance of Dam Facilities.
- Golder (Golder Associates Inc.). 2016. Operation and Maintenance Manual, Revision 3, Tailings Back Dam, Red Dog Mine, AK, submitted to Teck Alaska Incorporated, dated October 21. (Project 1545935). Anchorage, AK: Golder.
- Golder. 2018a. Feasibility-Level Design Report – Crest El. 1,006 Feet – Revision 1, Tailings Back Dam, Red Dog Mine, Alaska, submitted to Teck Alaska Incorporated, dated March 29. (Project Number 1665935.3000). Anchorage, AK: Golder.
- Golder. 2018b. Results of 2018 Geotechnical Investigation at the Tailings Back Dam, Proposed Spillway, and Overburden Stockpile, Red Dog Mine, Alaska, prepared for Teck Alaska Incorporated, dated December 10. (Project 1896929). Anchorage, AK: Golder.
- Golder. 2019. 2019 Annual Performance Report for Tailings Back Dam, Red Dog Mine, Alaska, prepared for Teck Alaska Incorporated, dated September 23. (Reference Number 18113464-004-L-Rev0-3000-TBD). Anchorage, AK: Golder.
- GAL (Golder Associates Limited). 2018. Red Dog Tailings Back Dam, 2018 Dam Breach and Inundation Study, prepared for Golder Associates Inc., dated December 10. (Project 1895976). Vancouver, BC, CA: Golder.

Table 1: Key Issues and Recommended Actions for the Tailings Back Dam

Priority	Description
1	A high probability or actual dam safety issue considered immediately dangerous to life, health or the environment, or a significant risk of regulatory enforcement.
2	If not corrected could likely result in dam safety issues leading to injury, environmental impact or significant regulatory enforcement; or, a repetitive deficiency that demonstrates a systematic breakdown of procedures.
3	Single occurrences of deficiencies or non-conformances that alone would not be expected to result in dam safety issues.
4	Best Management Practice – Further improvements are necessary to meet industry best practices or reduce potential risks.

ID	Applicable Regulation or O&M Reference	Deficiency or Non-Conformance	Risk to Structure	Priority	Recommended Action	Recommended Timing for the Action
2016-01	O&M Manual Section 6.0	Unprotected Instrument Cables	SAA and piezometers may become damaged	4	Install cables within protective conduit	Q3 2021
2016-02	O&M Manual Section 6.0	Uninsulated SAA Protective Casing	Frost could penetrate into cut-off wall and increase permeability leading to higher seepage	3	Inspect penetration through board insulation and make repairs to improve seal if necessary. Add insulation on outside of protective casing.	Q3 2020/2021
2016-04	O&M Manual Section 6.0	Pipe penetrations through insulation layer	May lead to increased frost penetration into the cut-off wall and increase permeability leading to higher seepage	Completed	Reroute pipelines over insulation layer	n/a
2017-01	O&M Manual Section 8.0	Hazard potential classification needs to be reviewed	Downstream facilities could be at risk to dam failure	Completed	A qualitative assessment of the effects of a breach in the TBD was completed for current conditions and it was concluded that there is no risk of inundation to downstream developments for the existing TBD configuration. As the TBD is raised, the Emulsion Plant facilities become at risk to inundation and the hazard potential classification should be raised to Class I.	n/a
2017-02	n/a	None - the Observational Method has already been adopted	Mitigation options to prevent dam failure may not be available	Completed	Review whether the Observational Method (Peck, 1969) should be adopted for the existing TBD and future raises to be consistent with the approach adopted for the Tailings Main Dam.	n/a
2017-03	n/a	Design and site characterization information is not summarized	None	Completed	Standalone reports are recommended that summarize key project information applicable to the TBD, specifically for: - Design Basis I Criteria; and - Dam Site Characterization. These documents should be reviewed annually (minimum), then, if appropriate, updated and reissued (with revision control) by the EoR, similar to O&M and emergency planning documents.	n/a
2017-04	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	3	Teck and the EoR are recommended to review and implement, as appropriate, a combination of the following to monitor the permeability performance of the COW: - new surveillance activities or instrumentation; and - additional thresholds and criteria for existing activities. One criteria that should be developed is the allowable horizontal strain (to maintain permeability criteria) which is necessary to relate inclinometer movements to COW performance.	Q1 2020
2017-05	n/a	None - this has already been completed	An understanding of the response of the COW to thaw deformations and the design earthquake has not been developed	Completed	Teck and the EoR should complete the planned deformation model (static and dynamic loading) to confirm design assumptions regarding COW strain (Teck report this is in progress). The model should be calibrated to the observed conditions in the field (i.e. crack) under the existing loads. As part of the deformation analysis, the EoR should characterize the undrained shear strength and pore pressure response to select appropriate design parameters for any soils that could potentially thaw, including the fine-grained ice-rich deposits.	n/a

Table 1: Key Issues and Recommended Actions for the Tailings Back Dam

Priority	Description					
1	A high probability or actual dam safety issue considered immediately dangerous to life, health or the environment, or a significant risk of regulatory enforcement.					
2	If not corrected could likely result in dam safety issues leading to injury, environmental impact or significant regulatory enforcement; or, a repetitive deficiency that demonstrates a systematic breakdown of procedures.					
3	Single occurrences of deficiencies or non-conformances that alone would not be expected to result in dam safety issues.					
4	Best Management Practice – Further improvements are necessary to meet industry best practices or reduce potential risks.					

ID	Applicable Regulation or O&M Reference	Deficiency or Non-Conformance	Risk to Structure	Priority	Recommended Action	Recommended Timing for the Action
2017-06	n/a	Groundwater behavior at the TBD is not well understood	Changing conditions could impact the containment abilities of the TBD system	Will not be adopted	<p>Following installation of the additional instrumentation and better definition regarding future tailings beach development, Teck and the EoR should prepare an updated seepage assessment for the TBD which is calibrated to existing conditions to further understand the long-term seepage regime around the TBD and potential impacts of increasing ground temperatures in Overburden Stockpile foundation.</p> <p>Golder and Teck have discussed a calibrated seepage model including the influences of permafrost and downstream catchments. At this time, Golder and Teck are not planning on pursuing this further due to the limited benefits of such a model and the amount of assumptions required.</p>	n/a
2017-07	O&M Manual Section 3.0	Teck has not designated Responsible Party	In an emergency situation, there could be initial confusion related to the chain of command	2	<p>Recommended inclusions that should be incorporated into the next revision of the O&M manual to improve the document further include:</p> <ul style="list-style-type: none"> - An event-driven inspection criteria should be added to the monitoring program and added to the O&M manual. - Identify the Responsible Position for the TBD, who currently holds that position and their designated alternates. 	Q1 2020
2017-08	n/a	None - this has already been completed	Key correspondence may not be correctly documented and recorded	Completed	Teck is recommended to record key correspondence between Teck and the EoR related to dam safety (operations and maintenance) with a technical memorandum, or similar, to limit the amount of information documented in emails.	n/a
2017-09	O&M Manual Section 6.0	Potential movement between Stations 22+00 and 23+00 is not adequately captured in instrumentation	Damage to the TBD could occur without warning from the monitoring array	3	<p>Install additional inclinometers upstream and downstream of the COW where the continuous crack is present in the downstream slope and thickness of ice-rich soils (including ice lenses) is thickest (between Sta. 21+00 and Sta. 23+00).</p> <ul style="list-style-type: none"> - Inclinometers should be installed at same centreline station. - At least one inclinometer should be installed downstream of the COW in the Select Fill zone. Teck and the EoR may wish to install an additional instrument downstream of the crack, through the Rockfill zone. 	Q3/Q4 2021
2017-10	O&M Manual Section 6.0	None - this has already been completed	The extent of permafrost in the Overburden Stockpile may be less than the design requires	Completed	Install thermistor strings in the Overburden Stockpile west of T-96-008 to confirm extent of permafrost downstream of dam between Sta. 10+00 and Sta. 20+00.	n/a
2017-11	O&M Manual Section 6.0	None - this has already been completed	The groundwater elevation around the Overburden Stockpile may be higher than the design considers	Completed	Install piezometers downstream of the TBD beyond the extent of the Overburden Stockpile (i.e. <Sta. 10+00 and >Sta. 32.00) to confirm that seepage flow is all directed towards the sump in areas where seepage is not constrained by permafrost in the Overburden Stockpile.	n/a
2017-12	O&M Manual Section 6.0	None - this has already been completed	Current program may not adequately address all dam failure modes	Completed	The frequency of data reviews for all key instruments should be reviewed and increased where appropriate to reduce the timeframe that an alert value exceedance can go undetected.	n/a

Table 1: Key Issues and Recommended Actions for the Tailings Back Dam

Priority	Description
1	A high probability or actual dam safety issue considered immediately dangerous to life, health or the environment, or a significant risk of regulatory enforcement.
2	If not corrected could likely result in dam safety issues leading to injury, environmental impact or significant regulatory enforcement; or, a repetitive deficiency that demonstrates a systematic breakdown of procedures.
3	Single occurrences of deficiencies or non-conformances that alone would not be expected to result in dam safety issues.
4	Best Management Practice – Further improvements are necessary to meet industry best practices or reduce potential risks.

ID	Applicable Regulation or O&M Reference	Deficiency or Non-Conformance	Risk to Structure	Priority	Recommended Action	Recommended Timing for the Action
2017-13	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	Will not be adopted	<p>Revise the sump pump alert levels as follows:</p> <ul style="list-style-type: none"> - Non-freshet - as discussed in Section 8.5, based on measured values and define criteria for determining "non-freshet" time periods. - Freshet - add an additional alert to identify pumping rates outside of expected behaviour . <p><i>Golder does not agree with the benefits or basis for two separate alert levels.</i></p>	Q4 2018
2017-14	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	3	Displacement thresholds (horizontal and vertical) for inclinometers and survey monuments should be established based on expected movement rates from a calibrated deformation model when complete	Q1 2020
2017-15	n/a	No tailings beach is established at the TBD	The TBD is being subjected to higher seepage gradients and more acidic seepage than if a beach was in place	4	Teck commented that establishing a tailings beach at the TBD is part of their long-term deposition goals which is strongly supported and should be implemented	2020
2017-16	n/a	The COW may have been affected by freeze-thaw cycling	The effects of freeze-thaw cycling on the COW performance are unknown	2	As part of design of the next raise, if completed, the EoR should assess whether freeze-thaw cycles from lateral temperature changes around the insulation layer have impacted the COW performance.	2020
2018-01	n/a	The sump freezes up in cold weather shutting down the pumpback system	The functionality of the TBD pumpback system is required	1	Upgrade the sump pumphouse to prevent freezing of the sump pump / pumpback system.	Q4 2019
2019-01	O&M Manual Section 5.0	Monitor for cracking along dam crest	Cracking may indicate areas of instability or identify locations that require higher regiment of observation	3	Continue to monitor for cracking along the dam crest and watch for correlations with monitoring data collected in nearby SAAs and survey monuments. Consider revision of daily inspection forms in regard to observed cracking during the next O&M Manual revision to reduce possible discrepancies between the daily and weekly/quarterly reporting. Collect a survey of any new cracking observed.	Q1 2020
2019-02	n/a	Monitoring data gap	Missing SAA and VWP data cannot be replicated and may included periods of interest	4	Reconnect the cables for the SAAs and VWPs to the data loggers once Stage IV construction is completed or as soon as is practical.	Q4 2019

Table 1: Key Issues and Recommended Actions for the Tailings Back Dam

Priority	Description
1	A high probability or actual dam safety issue considered immediately dangerous to life, health or the environment, or a significant risk of regulatory enforcement.
2	If not corrected could likely result in dam safety issues leading to injury, environmental impact or significant regulatory enforcement; or, a repetitive deficiency that demonstrates a systematic breakdown of procedures.
3	Single occurrences of deficiencies or non-conformances that alone would not be expected to result in dam safety issues.
4	Best Management Practice – Further improvements are necessary to meet industry best practices or reduce potential risks.

ID	Applicable Regulation or O&M Reference	Deficiency or Non-Conformance	Risk to Structure	Priority	Recommended Action	Recommended Timing for the Action
2019-03	O&M Manual Section 6.0	Monitoring program needs to be updated	Current program may not adequately address all dam failure modes	3	<p>Make the following improvements to the instrumentation in and near the Overburden Stockpile to monitor its performance as a secondary seepage barrier for the system:</p> <ul style="list-style-type: none"> - Replace the three 96 series ground temperature arrays (T-96-21 to T-96-23), which range in length from 105 to 115 feet, with three of the Beaded Stream temperature monitoring arrays that were used along the TBD alignment. - Install VWP's within the standpipe piezometers at G17-03 and G17-04 to monitor groundwater levels. <i>Completed.</i> - Install two of the Beaded Stream temperature monitoring arrays that were used along the TBD alignment at OS-18-11 and at G17-04. <i>Completed</i> - Replace the frozen VWP at P-12-109 with another that is installed with the instrument above the permafrost surface. - Drill and install a new ground temperature array between OS-18-11 and G17-03. - Connect the VWP's and if possible the temperature monitoring arrays into the NavStar data collection system, and incorporate them into the O&M Manual scheduled to be updated in 2019. 	2020
2019-04	n/a	Erosion due to discharge	Further erosion could impact structure stability	2	Repair the erosion observed at the two discharge locations near Station 26+50 and Station 34+00 and extend the discharge pipes into the impoundment or provide rip rap to prevent erosion from occurring in the future	Q4 2019
2019-05	n/a	Undocumented fill placement	Use of non-engineering grade fill or fill not compacted to specifications could affect structure stability	Completed	Remove the undocumented fill at the east abutment prior to fill placement associated with the Stage IV raise construction	n/a

Note: Recommendations that reiterated incomplete recommendations made in previous reports were not repeated in this list.