TETRA TECH

TECHNICAL MEMO

ISSUED FOR USE

To:	David Harpley	**Date:**	October 24, 2016
c:	Alan Taylor	**Memo No.:**	1
From:	Rita Kors-Olthof, Kevin Jones	**File:**	YARC03070-01.001
Subject:	MVEIRB #11 – Terrain Instability (Related to Undertaking #40) Response to Second Round Information Request EA1415-01 Prairie Creek Mine All-Season Road		

1.0 INTRODUCTION

This technical memo has been prepared for Canadian Zinc Corporation (CZN) by Tetra Tech EBA Inc. (Tetra Tech) to respond to the Second Round Information Request from the Mackenzie Valley Environmental Impact Review Board (MVEIRB) #11: Terrain instability and avalanche mitigation. This information request is related to Undertaking #40 from the Technical Sessions of June 13 to 16, 2016, previously discussed in Tetra Tech's Memo No. 6, dated July 11, 2016 (Tetra Tech 2016).

2.0 DETAILS OF INFORMATION REQUEST

MVEIRB provided the following commentary and recommendations/requests to CZN for additional information, in turn provided to Tetra Tech on September 26, 2016:

Comment: *CanZinc was asked to provide general information regarding the appropriate mitigations for the range of instability conditions that are expected along the route. CanZinc has highlighted a range of mitigations, including the need for inspections, monitoring, and maintenance - these play a key role in risk management. One reservation with respect to the highlighted mitigation methods relates to areas where there is the possibility of deep-seated instability, either in soil or bedrock, in the terrain directly upslope from the alignment. Road drainage control has limited effect in this case. The scale of instability may make it challenging to buttress the slope without adding adverse loading. CanZinc has highlighted the importance of avoiding exposing ice-rich permafrost in order to mitigate potential adverse effects associated with permafrost degradation. This is an important strategy and for this strategy to be successful, additional ground truthing /site investigation will be needed prior to site disturbance.*

Recommendation:

1. *CanZinc to describe additional mitigation options for locations of potential deep-seated instability in soil or bedrock. Please consider the following mitigative options, as appropriate:*
   a. *utilization of full-bench/ end-haul construction technique to mitigate the risk of debris slides in un-compacted fill;*
   b. *raising design bridge deck elevations and modifying culvert designs to accommodate the passage of debris floods and debris flows;*
   c. *utilization of enlarged drainage ditches or barriers/fences to mitigate rock fall risks;*
   d. *installation of rock bolts to mitigate the rock slide risk;*
   e. *construction of deflection berms to mitigate the risk from debris flows/floods; and*
   f. *at the crossing points of creeks that are susceptible to debris floods/flows, if the road is routed towards the fan apex, ensure the road is designed such that it can't become a conduit for flow in the event of a channel avulsion.*
2. *Please also note possible mitigation methods for snow avalanche hazards.*

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3.0 SCOPE OF WORK AND METHODOLOGY

Tetra Tech presents in this technical memo some additional options for mitigation, as requested in Item 1 of MVEIRB's information request as reproduced above. It is noted that these additional mitigation options, while potentially useful, do not necessarily reduce the likelihood of deep-seated slope failures in soils and/or bedrock. The additional mitigation options are discussed below, organized by section for each sub-item from MVEIRB's suggested list.

The discussion of mitigations for snow avalanche hazards (Item 2 above) is not within Tetra Tech's scope, and is not provided in this memo.

4.0 FULL BENCH / END HAUL TO MITIGATE FILL SLOPE FAILURES

MVEIRB has suggested considering the use of full-bench / end-haul construction technique to mitigate the risk of debris slides in uncompacted fill. Based on Tetra Tech's experience, this recommendation likely has its roots in the observations of the historical performance of forest access roads, mine access roads and other remote access roads in mountainous terrain. Tetra Tech notes that fill slopes on older access roads have been particularly prone to failure, not just because they were constructed of uncompacted fill, but specifically because they were composed of sidecast fill. This method of construction typically resulted in roughly balanced cuts and fills, where the fills were placed simply by pushing them with a bulldozer over the outside edge of the cut. The resulting fill slopes are thus formed in layers approximately parallel to the original slope, with subsequent layers pushed out at progressively steeper gradients as the road grade is widened. This method results in an inherently unstable slope configuration, with the following typical issues:

- Production of a likely failure surface within the weak organic layer that usually remains on the slope beneath the fill;
- Burial of wood and brush waste in the toe of the fill creating another source of material that can fail on the slope;
- Poor bond and likely sliding surface between the fill and the original slope;
- Poor bond and likely sliding surfaces between subsequent layers of fill; and
- Likelihood of water from the road surface entering the fill, lubricating sliding surfaces and generally increasing the soil porewater pressures.

Despite these issues, it should be recognized that the use of full-bench / end-haul techniques is not the blanket solution for all possible fill instability problems. This fact was noted during the implementation of the British Columbia Forest Practices Code in the late 1990's, when a great many road sections were constructed with full-bench / end-haul techniques to compensate for the earlier sidecast fill issues, only to discover that fill slope problems had been replaced with cut slope problems.

Therefore, some additional caveats need to be applied in deciding which design solutions are most appropriate for a particular road section. In locations where the additional loads resulting from a fill slope are more likely than the removal of toe support from the cut slope to contribute to slope instabilities, full-bench / end-haul techniques should be considered. In locations where the stability of the cut slope would be at a higher risk with a full-bench cut, other strategies need to be considered. Sometimes, it may indeed be most suitable to have a full-bench cut, but additional support of the cut slope with a retaining structure or rock fill ballast may also be required.

In other cases, it may be more practical and less risky to maintain a balanced cut and fill, but to notch the fill into mineral soils (not the organic soils), and to build up the soil in compacted horizontal lifts, with appropriate attention to compaction specifications. Organic debris (including trees and brush from clearing the route) should not be incorporated into a fill whose integrity is necessary to maintain the stability of the slope. The presence or absence of permafrost soils, and particularly permafrost soils with significant ice content, will also be an important factor in the preferred design for a specific road section.

For example, if permafrost soils are encountered, but they have low ice content, meaning similar soil moisture content to that of unfrozen soils, then design and construction could proceed similar to that for unfrozen soils. However, if permafrost soils are encountered that have high ice content, then cut slopes should be avoided and the road should ideally be a fill-only embankment. In general, areas of high ice content along the route are also likely to be the lower-lying, gently-sloped areas. However, if there are sections of slope with higher ice content, a site-specific design will be required. The embankment would need to be more self-supporting from the toe of slope or from low-ice content zones on the slope. This configuration could potentially result in minor changes in alignment to allow the route to be placed on lower-gradient slope sections, or to climb slope sections while reducing transverse loading on the higher ice-content sections of the slope. The present design, for instance, is preferentially routed along higher and drier slope sections.

Additional site-specific information will need to be collected during the detailed design phase so that the current designs can be confirmed and appropriate alternative designs can be produced if/as needed along the road.

5.0 ACCOMMODATING DEBRIS FLOODS AND DEBRIS FLOWS

MVEIRB has suggested raising design bridge deck elevations and modifying culvert designs to accommodate the passage of debris floods and debris flows. This suggestion may indeed be appropriate for some crossings, but the resulting configuration will need to be weighed against other factors in the design of a particular crossing.

For example, a raised bridge deck elevation would necessarily entail much larger embankments for the approaches, with the accompanying larger footprint. A raised bridge deck could also mean a significantly steeper road grade on the approaches, unless the elevated approaches are extended for a greater distance from the ends of the bridge. A modified culvert design could also be considered. For instance, instead of a round metal culvert, a deep and wide rectangular concrete culvert could be used to increase the volume of debris that could be passed under the road. However, just because the opening is larger, does not necessarily mean that it is proof against becoming plugged. Increasing the size, however, once again means the likelihood of increasing the embankment height and the associated footprint.

The location of a debris flow or debris flood channel is not entirely predictable, due to the possibility of a channel avulsion upslope. For this reason, stream crossing locations being considered for enhanced crossings will need to have upslope characteristics taken into account, a task that will need to be further carried out at the time of detailed design.

6.0 ADDITIONAL MITIGATIONS FOR ROCK FALLS

MVEIRB has suggested the utilization of enlarged drainage ditches or barriers/fences to mitigate rock fall risks. The practicality of, and choice between, such mitigations will largely depend on the room available on the upslope side of the road.

Tetra Tech notes that much of the road route in the western mountainous section has limited width, and in some sections, an ordinary ditch may not be practical. To introduce a ditch, or to increase its width may also have the adverse effect of steepening cut slope gradients or removing toe support from the slope above, which is potentially detrimental to overall slope stability. Similar space and stability issues may exist in these areas for ground-based barriers or fencing solutions, but barrier netting could be considered in a few locations.

There may also be some locations that would benefit from netting that is suspended from higher on the cutslope or above the cutslope, such that the velocity of falling rock is reduced and more likely to fall at the inside edge of the road rather than out on the travelling surface or beyond. Locations where such measures could be successfully implemented will need to be chosen at the time of detailed design, taking into account the likely frequency and anticipated volumes of rock fall at a particular location, as well as the likely success of other measures that could be implemented in addition to or instead of physical solutions. For example, netting may be more useful on blind corners, whereas signage may be more appropriate at locations where sight distances are good in rock fall areas.

Regular inspections and scaling if/as necessary may also be useful mitigations to reduce the risk from rock falls along the road.

7.0 ADDITIONAL MITIGATIONS FOR ROCK SLIDES

MVEIRB has suggested the consideration of rock bolts to mitigate rock slide risks. Rock bolting could be considered in some areas, however, it will not necessarily reduce the risk of deep-seated failures. Rock bolting is primarily intended to reduce the sliding of near-surface rock in localized zones. However, if such risks can be reduced first by other means, that would be much preferred.

For instance, if it is known that constructing a full-bench cut would result in the removal of toe support in an out-dipping rock slope, it would be better to consider other methods of widening the road. Particularly in the western mountainous section of the route, such out-dipping rock slopes tend to run a very long way upslope, suggesting that an excessively long slope would need to be bolted. Cutting further into the existing cut slope to widen the road would result in deeper bolting being required, with an accompanying greater load to be restrained by the bolts.

Suitable protection solutions for existing out-dipping rock slopes along the route should be considered at the time of detailed design. As for the above-noted rock fall sections, physical mitigations may be more appropriate on blind corners, whereas signage may be suitable in areas with good sight distances.

8.0 DEFLECTION BERMS TO MITIGATE DEBRIS FLOW/FLOOD RISKS

MVEIRB has suggested the construction of deflection berms to mitigate the risk from debris flows/floods. The primary intent of a deflection berm for debris flows or floods that are not located along streams that ordinarily cross the road would be to prevent such flows or floods from running up onto the road embankment or across it. Otherwise, such berms would be used to divert flows that would ordinarily cross the road, directing them instead to a designated stream crossing location.

Some analysis and design would be required to determine the necessary height, curvature (if any), and erosion protection for a deflection berm, such that the anticipated debris flow or flood volume would not simply overtop the berm, or entrain the material from the berm. For example, deflection berms would need to be armoured with material of a nominal size larger than any of the debris observed to have been entrained in previous debris flows in the design location. Deflection berms could include armoured levees to reduce the likelihood of upslope channel avulsions, as is further discussed in the next section.

Debris flow/flood locations should be specifically evaluated during detailed design to determine if some benefit would be realized with the use of a deflection berm. The footprint of a berm, and the existing degree of ground disturbance at its proposed location should also be considered when weighing the potential costs and benefits.

9.0 REDUCING LIKELIHOOD OF ROAD DIVERTING DEBRIS FLOWS

MVEIRB has suggested that, at the crossing points of creeks that are susceptible to debris floods/flows, if the road is routed towards the fan apex, the road will need to be designed such that it cannot become a conduit for flow in the event of a channel avulsion. Tetra Tech understands this to mean that the road embankment or ditch could allow a debris flow or flood to follow the upslope side of the road alignment instead of passing under it. Tetra Tech further notes that this requirement also needs to be considered in the event that the stream crossing becomes plugged with debris. Such an occurrence could occur even if the road is located lower on the fan.

Several alternative mitigations could be considered. Some, but not all, sections of the Prairie Creek route may have sufficient room for a collection basin upslope of the road. However, the old winter road footprint, particularly the all season portion, provides a useful indication of debris flow activity, or lack thereof, since the time of construction in the early 1980's. Some other options that could be considered to limit the potential flow of debris along the road, if necessary, are:

- Increase the number of ditch blocks and culverts, so that sections of the ditch can act as small collection basins if needed, as well as helping to mitigate the potential for upslope debris-flow channel avulsions. The crests of the ditch blocks would be at slightly lower elevation than the road embankment crest, so that flow could access a subsequent ditch section if needed, but in a more controlled manner than with simple unrestricted ditch flow;
- Add additional culverts at staggered locations higher in the fill in each ditch section so that the more-watery flows could still cross the road if the lower culverts are blocked, thus reducing the volume that could travel along the ditch;
- If insufficient capacity is available in the ditch, or if adjacent resources are to be protected from debris flows, perhaps it is then better to assist the flow to go across the road (as it would naturally without the road), in which case additional options might include:
  - Build a swale into the road at the usual debris flow channel location(s), so that overflow will run across the road if the culvert plugs. The steeper the road grades at such swales, the more likely the debris flow could be contained within a short distance at the crossing. However, not all road sections will have enough change in grade at crossings to create significant swales, unless the design includes a thicker embankment. Such a design may or may not be feasible at all locations depending on local availability of suitable materials; also, this configuration may cost more to build and is likely to result in a larger footprint. Note also that closer to the apex of a debris flow fan, slope gradients tend to be steeper than along the toe, so some adjustments may be needed to the overall road grade and/or to the alignment to maintain the necessary road grades.
  - Construction of armoured levees upslope of the ditch blocks to further limit potential debris flows from flowing outside the designated crossing area. These might need to be angled to capture more of the potential upslope avulsions, but the design would also need to consider whether it is better to have multiples of such crossings rather than concentrating debris flows (or even ordinary surface water drainage flows) downslope;
  - This option includes the possibility that the crossing area of the road could be either scoured out or completely buried with debris. However, that might be preferable to having a much larger area of terrain affected by debris flows running along the road.
- Even with ditch blocks and upslope levees, it is possible that debris could still overflow onto the road and then flow down the road itself. Depending on the road grade, outsloping the road could slightly reduce this down-gradient overflow, but is unlikely to prevent it. Incident management could include building a temporary levee on the road itself, possibly beginning atop the next ditch block located down-gradient of the debris flow channel.

The levee could be composed of boulder-sized material (or material large enough not to be plucked out and added to the flow at a particular location), presumably stockpiled nearby as a contingency. Such mid-event containment efforts could, however, entail more risk to personnel and might not be worth that risk. A protocol should be determined to help define a setback line for the temporary levee, such that it is still useful in limiting down-road flow, but not so close that personnel are at risk. It is noted that onsite personnel would have to know what was happening in order to make that decision. If the event happens at night, such a decision might not be possible. Alternatively, barriers could be constructed at the very edge of the known debris flow fan, thus reducing the risk to personnel, and also preventing the debris flow from extending outside the natural fan. This solution would solve the environmental-impact issues related to both upslope channel avulsions and culvert blockage, even if it did not necessarily reduce the overall cost of repairing the infrastructure.

- Debris flow netting or grillage upslope could also be considered at the more severe crossings, so as to limit the size of material that could end up in the ditch or at the culvert(s). Solutions of this type would not necessarily prevent flow down the road, but might help in reducing the volume of debris that would need to be managed along the road. Additional provisions would also be required for the maintenance of these features, including access trails. That could be challenging in some of the tighter gullies, and would also add to the infrastructure footprint. Therefore, consideration of this type of mitigation and associated infrastructure would need to be considered on a cost-benefit basis at the time of detailed design.

10.0 LIMITATIONS OF REPORT

This memo and its contents are intended for the sole use of Canadian Zinc Corporation and their agents. Tetra Tech EBA Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the memo when the memo is used or relied upon by any Party other than Canadian Zinc Corporation and their agents, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this memo is at the sole risk of the user. Use of this memo is subject to the terms and conditions stated in Tetra Tech EBA Inc.'s Services Agreement. Tetra Tech's General Conditions are attached to this memo.

11.0 CLOSURE

We trust this technical memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

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Attachment General Conditions

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Signature
Date OCT. 24, 2016
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REFERENCES

Tetra Tech EBA Inc. (Tetra Tech), 2016. Technical Memo No. 6, Discussion for Undertakings #36, 37, 40 and 44, Questions Arising from the Technical Sessions on June 13-16, 2016, EA1415-01 Proposed Prairie Creek Mine All-Season Road, NT. Prepared for Canadian Zinc Corporation. July 2016. Tetra Tech File: Y14103320.01-008.