TETRA TECH

TECHNICAL MEMO

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To:	David Harpley	**Date:**	October 24, 2016
c:	Alan Taylor	**Memo No.:**	2
From:	Rita Kors-Olthof, Kevin Jones	**File:**	YARC03070-01.001
Subject:	GoC – PCA #5 – Borrow Sources – Development and Management 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 Government of Canada, Parks Canada Agency (GoC – PCA) #5: Borrow Sources – Development and Management. This information request is related to the evaluation of permafrost conditions at proposed borrow sources, criteria for use, recommendations for permafrost-related mitigation and monitoring, and reclamation strategies.

2.0 DETAILS OF INFORMATION REQUEST

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

Comment: *CZN has indicated that each borrow source will be evaluated for permafrost and ground ice during a detailed borrow site plan and design and that where permafrost is encountered, the borrow source will not be used or if used the development, monitoring and reclamation of the borrow pit will be guided by a geotechnical engineer. Parks Canada remains concerned over the potential for long-lasting effects to the delicate ground thermal regime if permafrost is allowed to degrade, and the effects to the surrounding terrain if massive ground ice was allowed to melt.*

Recommendation:

1. *Please provide a draft permafrost mitigation and monitoring plan for borrow sources and identify specific reclamation strategies for situations where permafrost could be encountered.*
2. *Please describe the criteria that will be used to determine if a borrow pit where permafrost is encountered will be used as borrow.*

3.0 SCOPE OF WORK AND METHODOLOGY

CZN has requested that Tetra Tech not prepare an entire draft permafrost mitigation and monitoring plan at this time, because individual borrow source development and management plans are to be prepared for each borrow source that will incorporate site-specific recommendations relating to permafrost at each borrow source.

To address the present scope, Section 4.0 presents the requirements of borrow source evaluations that will permit the development of site-specific development criteria, Sections 5.0 and 6.0 present some considerations and criteria for use as borrow, Sections 7.0 and 8.0 provide recommendations for permafrost-related mitigations and monitoring, and Section 9.0 provides reclamation strategies.

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4.0 BORROW SOURCE EVALUATION

GoC – PCA requested a description of the criteria to be used to determine if a borrow pit where permafrost is encountered will be used as borrow. The following describes the possible requirements of borrow source evaluation to allow the determination of the appropriate site-specific criteria for use of a specific borrow source. The goal is that ice-poor materials should be used as borrow, and ice-rich materials should either be rejected or improved before use. This includes consideration of the overburden and underburden materials in a particular proposed borrow source, such that the removal of either overburden or borrow materials does not result in the inadvertent degradation of massive ice or high-ice-content permafrost. A borrow source investigation, therefore, could include the following:

- A desktop review of proposed borrow source area, including review of quaternary surficial deposits mapping and reports, air photos, and other possible information sources (TAC 2010);
- A field overview and foot traverse of the site to identify possible areas of concern that need either protection from development or proactive management during borrow source development, operations and reclamation. Items of interest could include characteristics of site access, topography, landforms, vegetation, surface water drainage features and natural drainage patterns, wetlands, water bodies, signs of erosion, evidence of groundwater influence (e.g. springs or sinkholes), presence of patterned ground or thermokarst, description of nearby slopes, and descriptions of soil or rock exposures. Shallow hand-dug test holes can be used to help direct follow-up investigations with heavy equipment (after TAC 2010).
- Sufficient number of test holes to obtain good coverage of the deposit and allow the thickness, extent and quality of the deposit to be determined (TAC 2010). Depths should be sufficient to determine the engineering characteristics of overburden (usually soils, including peat/topsoil and mineral soils; sometimes rock), borrow soils (or rock), and underburden soils (or rock). Overburden and underburden are layers of material that respectively overlie and underlie the desired borrow materials. Test holes are typically spaced at intervals of about 50 m apart (TAC 2010). Spacing of test holes should be adjusted to suit the landforms, soil types and terrain. Spacing may also need to be adjusted depending on the consistency of the findings. If the findings are variable or inconclusive, additional test holes may be needed.
- Sufficient numbers of samples obtained from each test hole. A minimum of one sample should be obtained from each test hole if the soil is uniform, otherwise a minimum of one sample should be obtained for each soil unit in the test hole (TAC 2010). Additional samples may be needed to document changes in soil characteristics or ice content or ice description/distribution in the same unit. In order to characterize the soils beneath the proposed borrow layer, test holes may need to extend up to 3 m below the anticipated base of the proposed borrow pit, or 3 m below the identified base of suitable borrow materials, depending on the findings and/or the proposed long-term use of the borrow source. The depth of investigation could be less if bedrock is encountered, or the borrow material also consists of bedrock (i.e. a proposed quarry), or if adjacent test holes are highly consistent with each other. The soils/rocks are logged in the field for each test hole, along with observed surface conditions, groundwater conditions and permafrost conditions.
- Representative samples from the test holes should be tested in the laboratory to determine soil moisture contents and engineering properties including grain size characteristics, plasticity and optimum moisture content. The test results are used to determine the suitability of the proposed borrow materials as borrow, as well as the susceptibility of either overburden or underburden to disturbance, including physical disturbance as well as thermal disturbance. Depending on the proposed uses of the materials, other tests may also be recommended (TAC 2010).

- While the use of conventional auger drills can result in lower site impacts than some other investigative methods due to relatively small volumes of disturbed soils being generated, caution is required in the interpretation of borehole findings. For example, refusal may be interpreted as being possible bedrock, when it may in fact be frozen soil (TAC 2010). Refusal may be more likely in materials with high ice content. Therefore, depending on the area being investigated, consideration could be given to drilling some of the boreholes with equipment that can penetrate frozen materials, or excavating test pits, which could allow visually evaluating the permafrost conditions at the base. A representative number of test pits may also be helpful to obtain larger bulk samples and better assess the capability of equipment in excavating the borrow source. It is anticipated that the results of the terrain stability mapping will assist in decision-making as to the suitability of various site investigation methods at specific borrow sources.
- Ground temperature cables could be installed at selected locations to help estimate the thaw rate of exposed soils (TAC 2010). Such provisions would be considered more important in ice-rich ground conditions where thaw could result in significant settlements, thermokarst ponding, or stability issues, and less important in relatively thaw-stable materials.
- The elevation of the groundwater table, if encountered, should be carefully documented (TAC 2010).

5.0 CONSIDERATIONS FOR DEVELOPMENT OF A BORROW SOURCE

The following discussion describes some possible characteristics of borrow sources that should be considered in the decision whether or not to accept a borrow source proposed for use on the proposed Prairie Creek all-season road, or in determining what site-specific procedures may be necessary to reduce the likelihood of adverse effects from using the borrow source.

- Borrow sources that would likely be considered acceptable for use without specific measures to protect permafrost and/or manage possible meltwater:
  - Overburden, borrow material, and underburden do not contain excess visible ice. That is, if any of these layers were to thaw as a result of the borrow operations, significant thaw settlement would not be expected, nor should there be significant runoff of meltwater from any of these layers if they do thaw.
  - Removal of either overburden or borrow material would not be anticipated to result in significant changes in the stability of a borrow site, for example, on a slope, nor would it be expected to affect the performance of the road if the borrow area is adjacent to the road.
- Borrow sources that will likely need additional measures to protect permafrost, improve borrow material characteristics, and/or manage meltwater:
  - Overburden, borrow material, and/or underburden layers contain excess visible ice. Considerations include possible challenges in the removal and management of overburden and borrow materials, and/or in the performance of overburden, borrow and underburden materials, as follows:
    - Thawing overburden materials could result in difficulty maintaining stockpile integrity or stockpiles could create silty meltwater runoff that needs to be treated by settling and/or filtering before it can be allowed to flow offsite.
    - Borrow material containing excess ice may need thawing and draining, with similar management of meltwater, and often requires more than one season to produce useable material. Additional preparation including air-drying or blending with drier materials may also be needed.

- For much of the road, although borrow materials will be transported for placement into the road embankment while frozen during winter construction, it should be recognized that the embankment is highly unlikely to remain frozen in the long-term. Therefore, suitable characterization of material properties will be needed during borrow acquisition to reduce the possibility of unsuitable material being placed in the embankment and subsequently failing when it thaws.
- Underburden layers containing excess ice may also require a solution to mitigate potential effects to the permafrost. The intent of the mitigation(s) would be that the underburden should perform no worse after borrow source development than it would have done without borrow source development. This does not necessarily mean that it will not thaw, but if it thaws (for example, due to climate change), it should thaw at a rate comparable with similar undisturbed terrain.

– If removal of overburden or borrow would result in slope stability or thermokarst issues by virtue of the borrow site location, thawing of subgrade materials, and/or water runoff issues, then additional management and permafrost protection strategies will be needed. The same considerations would apply to potential effects of the borrow source on adjacent road sections or other resources. In some cases, the most appropriate management/protection strategy may be to implement a buffer strip or protection zone.

– If the proposed pit area has a stream or other water body in it, buffer strips or protection zones will need to be designated (INAC 2009, TAC 2010). In the Mackenzie Valley, guidelines suggest buffer strips of at least 100 m width between quarry developments and the ordinary high water mark of water bodies (INAC 2009).

6.0 CRITERIA FOR DEVELOPMENT OF A BORROW SOURCE

Specific measurable criteria to assist in decision-making in the appropriate development and management of each borrow source will depend on the site-specific findings at that borrow source, including fines content, soil moisture content, Atterberg Limits, and the optimum moisture content associated with Standard Proctor maximum dry density, and/or the presence of massive ice. Some sample criteria are as follows:

- Soil moisture contents in clayey or silty layers should ideally not exceed the plastic limit of the soil by more than 3%. If it does, additional requirements for stockpile management, drainage and treatment of seepage or meltwater, and/or permafrost mitigation may be required. If the soil moisture content exceeds the liquid limit of the soil, it is highly likely that excess ice will be present, and also likely that the soils will be unmanageable when thawed, making them very difficult to stockpile and to drain the meltwater. These soil types should not be used for road embankment materials but may be present as overburden or underburden. Borrow pit operations should take place when it is possible for equipment to travel on the material without difficulty, or additional site access preparation will be needed. Some borrow sources may not be accessible at all times of the year.

- Soil moisture contents in sandy or gravelly layers should ideally not exceed about 3% over optimum moisture content (and may need drying if they are more than about 1% over optimum). Sandy or gravelly soils may also need thawing, and possibly drainage of meltwater if they are more than 3% over optimum. Increasingly higher soil moisture contents indicate an increasing likelihood that some excess ice may be present, and/or that the material will not be suitable for use in the embankment without significant preparation and management.

- Borrow sources, or portions thereof, with massive ice in any of the above-listed layers may need to be rejected, unless it can be shown that the extent of massive ice is very limited, such that it can be over-excavated and thawed in a more suitable place. In the case of underburden, the area would need to be swiftly reclaimed after extraction of the borrow material, in such a way that would protect the permafrost.

Additional site-specific information will need to be collected during the detailed design phase so that an appropriate pit design, development and management plan, and reclamation protocol can be prepared for each borrow source.

7.0 PERMAFROST MITIGATION OPTIONS

In an ideal situation, a borrow source investigation would encounter all the conditions that should be noted in order to decide whether a site should be developed or not, or to determine in advance what mitigations are likely to be needed at a particular borrow source. However, due to the natural variability in soils, rock, and permafrost conditions, there remains the possibility that materials with higher-than-expected ice content could be encountered during borrow source development. That possibility means that options and contingency plans for permafrost mitigation and monitoring should be considered for each borrow source in accordance with the findings at each location. Some sites may be more prone to findings of higher ice contents than others. For example, if a borrow source includes layers that have a relatively high fines content, and/or thick layers of peat, and/or relatively high soil moisture contents, and/or the site is close to a slope, some additional mitigations may need to be implemented and such possibilities considered ahead of time. Those mitigations, including such items as stockpiling materials that need to thaw and drain, as well as designating suitable areas for the treatment and disposal of drainage water, will be part of a well-organized borrow source layout plan and proposed sequence of operations (INAC 2009, TAC 2010).

General mitigations in higher-ice content areas of a borrow source could include:

- Opening only small areas of the pit at one time;
- Maintaining and restoring positive drainage in the pit during and after extraction of overburden and borrow materials;
- Replacing the overburden soon after extraction of the borrow materials, suitably compacting the fill such that any subsequent settlements should not be attributable to poor compaction, thereby making monitoring of permafrost performance easier; and
- Promoting the restoration of the organic and vegetative cover.

The above-listed mitigations are intended to reduce the overall exposure of potentially high-ice-content layers to physical and thermal erosion. Some additional considerations and mitigations for each layer type are presented below.

If overburden materials have a higher-than-expected ice content, but not so high as to make the material unusable for reclamation, additional provisions may need to be made for stockpile management. Such provisions could include the construction of berms around stockpiles to reduce the likelihood of ingress of surface water and egress of silty thaw water, and the use of settling basins to treat silty thaw water before draining it offsite (INAC 2009). Settling ponds may need to be designed as detention ponds, not retention ponds, in order to protect underlying soils if they are ice-rich. A larger area for stockpiling may be needed if the stockpiled materials require a flatter slope angle for stability. However, if overburden soils have too high an ice content, such that stockpiling will be unmanageable and the quality of reclamation uncertain, it may not be possible to develop that portion of the borrow source.

If the proposed borrow materials have a higher-than-expected ice content, some mitigations may be possible to make the materials useable. However, it should be noted that improvement of marginal materials in cold climates is often more difficult and time-consuming than may be anticipated, as well as potentially being thwarted by weather conditions, especially for materials with a relatively high fines content and/or ice content. Thawing efforts benefit from direct exposure to sun and summer temperatures, and usually require stockpiling on a well-drained surface if subsequent layers of borrow soil are to be exposed and allowed to thaw. Perimeter trenches may be needed to permit drainage from the thawing materials. A contingency plan will be important in order to be prepared to use alternative management methods or to provide extra time for material preparation (TAC 2010). Substitution of other borrow sources can also be considered in a contingency plan.

Thawing stockpiles or designated borrow pit thaw zones may need similar treatment as overburden stockpiles if the thaw water tends to be silty. The thaw water also needs to be drained so as not to create problems with ponding or physical erosion or thermal erosion inside or outside the pit. Pumping may be required, as may provisions for erosion protection and dispersing the drainage water at the pump outlet. Careful planning and management of the sequence of excavation and reclamation of the borrow pit will be needed (TAC 2010, INAC 2009). Too high an ice content may be cause to reject further development of a particular portion of the borrow source, particularly if thaw water cannot be appropriately managed, or if slope stability issues could arise.

It is less likely that higher-than-anticipated ice contents would be observable in underburden soils during pit development, so potential issues may be difficult to predict or prevent. During operation of the borrow source, however, if the base of the pit reveals high-ice-content soils or massive ice, then additional mitigations will be required during reclamation, and the timing of reclamation will be more important than if there were no excess ice. Permafrost mitigation options applicable to borrow source reclamation strategies are presented below in Section 9.0.

8.0 PERMAFROST MONITORING

A general permafrost monitoring program can be planned as part of the borrow source development, management and reclamation plan for each borrow source. The proposed permafrost monitoring program prepared for each applicable borrow source would be adapted or modified as needed according to the findings at the borrow site during development and operations, and could include:

- Installation of ground temperature cables at the base of the pit in areas where higher ice content soils are encountered. Additional cables could be considered for greater depths or where different soil layers need to be monitored;
- Installation of standpipe piezometers at selected locations in the pit if groundwater information is needed;
- Periodic observation of ground surface during operations and after reclamation for areas of disturbed soils that suggest physical and/or thermal erosion;
- Periodic observation of ground surface during operations and after reclamation for local settlements that could suggest thaw settlement;
- Observation of ground surface for possible new ground seepage outlets or surface streams emanating from the borrow pit;
- Inspection of nearby slopes and/or the road for changes in stability that could be associated with changes in the permafrost at the borrow source; and
- Confirmation of the success of reclamation efforts (INAC 2009).

Monitoring should be carried out on a regular basis to facilitate the timely identification of problem areas and implementation of response plans or contingency plans (INAC 2009). Additional general recommendations for monitoring during operations and reclamation are provided in INAC (2009) and TAC (2010).

9.0 RECLAMATION STRATEGIES FOR PERMAFROST SITES

The decision-making process for development of borrow sources as described above in Sections 5.0 and 6.0 has been preferentially oriented towards encouraging the development of low-ice-content borrow sources and mitigating or reducing problems associated with the development of higher-ice-content borrow sources. Contingencies and recommendations for permafrost mitigation and monitoring in the event that high-ice-content layers are identified during development and operation of the borrow sources have been outlined above in Sections 7.0 and 8.0.

If the permafrost encountered in the borrow sources has low ice content, then reclamation strategies can be consistent with conventional reclamation techniques. However, if permafrost of high ice content has been identified during the development and operation of the borrow source, additional reclamation strategies will need to be implemented.

For a higher-ice-content site, additional backfill may be needed in order to restore the equivalent thickness of overburden on the area, or an equivalent thickness of insulating materials may be needed to replace some of the original overburden thickness. The intent is to essentially mimic the insulating qualities of the cover that existed prior to development. If insufficient materials are available on site, other suitable cover materials could include overburden soils or rock hauled in from other borrow sites along the route.

The configuration of remedial insulating layers would need to be designed on a site-specific basis. Wood chips could be considered as an insulating layer (TAC 2010, INAC 2009). Suitable non-merchantable timber could be retained from the road right-of-way to produce wood chips in selected areas. Air convection embankments, consisting of coarse rock fills to enhance winter cooling (TAC 2010), could also be considered, particularly if post-reclamation monitoring suggests the possibility of thaw settlement.

The likelihood of preservation of high-ice-content zones can be improved if the insulating and/or cooling layers are placed as soon as possible after exposure of the materials, so that no thawed zones are allowed to develop. This effort will be facilitated in borrow sources that are developed and operated in the winter, so that ambient conditions are already cold prior to placement of the additional cover materials.

Provisions for water drainage onsite will have an effect on offsite surface water drainage and so these provisions will need to be considered for both temporary and permanent surface water drainage installations:

- Design site drainage so as not to create new areas of concentrated water drainage that could result in physical and thermal erosion or slope stability concerns offsite as well as onsite; and
- Where possible, sheet flow should be maintained on slopes.

Some additional efforts may also be required to expedite the return of natural vegetation to the site, including peat, brush and trees, as the restoration of surface conditions similar to the original surface conditions may also assist in preserving the permafrost, particularly in the case of vegetation that provides shade. Stockpiling of organic soils will facilitate site restoration. In some cases, it may also be practical to store brush and trees for later use in reclamation (INAC 2009).

It should be noted that even if the equivalent cover thickness and similar vegetation can be restored, it is possible that permafrost thaw and accompanying thaw settlement may not be prevented. However, it is anticipated that the rate of thaw will be reduced significantly.

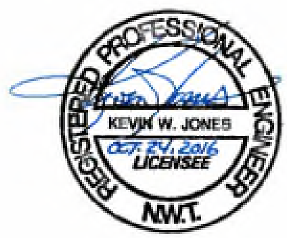
10.0 LIMITATIONS OF REPORT

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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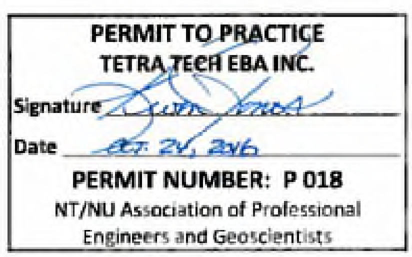

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Attachment General Conditions

REFERENCES

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