Our File: EA1415-01

CanZinc responded to the first round of information requesst (IR) on May 9th, 2016. Some of the responses were not input into the online review system table but rather input as an attachment. The IR responses that were attachments to individual IRs have been compiled here into one pdf document to assist parties. The individual IR responses included are:

DFN 15
DFO 3
DFO 4
DFO 9
GNWT 1
GNWT 27
MVEIRB 2
MVEIRB 4
MVEIRB 5
MVEIRB 7
MVEIRB 9
MVEIRB 11
MVEIRB 12
MVEIRB 13
MVEIRB 41
Oboni 1
Oboni 7
Parks Canada 21
Parks Canada 25
Parks Canada 46

Mackenzie Valley Environmental Impact Review Board

Box 938, #200 Scotia Centre 5102-50th Avenue Yellowknife, NT X1A 2N7 Phone 867-766-7050 Fax 867-766-7074 Toll Free 1-866-912-3472

REPLY TO DFN IR15

The remark about covers is more appropriate to vents placed in the road grade for the purpose of winter cooling, not for culverts meant to carry surface water. Covers over drainage culverts during the thaw season could interfere with the proper flow of surface water drainage, thus blocking the water and causing it to pond rather than simply flowing through the culvert. The presence of insulation may be helpful in summer, but could be counter-productive in winter when insulation would tend to reduce cooling of the fill and subgrade soils; therefore, the decision whether to use insulation and the design of the insulation configuration would need to be site-specific based on the conditions at each site. Also, because cold air settles, cold air circulating in culverts in the winter tends to result in frost heave. This problem can be reduced by replacing some of the frost-susceptible soil with frost-stable soil.

Movement of surface water is as much or more of an issue than warm air at sites with ice-rich permafrost, because moving water is an effective conductor of heat and tends to encourage thermal erosion. Generally, the Transportation Association of Canada (TAC 2010) recommends that cross drainage should not be diverted or intercepted by the road embankment, but instead allowed to pass through the embankment at every definable water course or natural terrain depression, and at intervals not longer than 300 to 500 m. Exceptions to this recommendation sometimes occur in locations where there is thaw-sensitive permafrost beneath the proposed crossing location, but the decision whether to divert the water flow elsewhere, or to mitigate the effects of water flow under the embankment at that location is necessarily contingent on site-specific conditions. Consideration will be given to the possible problems introduced by concentrating water flows in locations with less ground ice content (if available) as compared to having smaller water flows in more frequent cross-drains. Mitigations that are helpful in counteracting the effects of water flow through culverts will also be helpful in counteracting the effects of warm air in culverts. See Tetra Tech EBA's response to MVRB IR13, in which mitigations for major and minor stream crossings were discussed. TAC (2010) provides additional guidelines that may be applicable to the use and site-specific mitigation of culverts, including:

- Designing culverts to have a slight camber, such that the middle of the culvert has some vertical distance that compressible or thaw-sensitive soils can settle before a dip in the culvert can occur;

- Over-excavate beneath the proposed culvert location and replace compressible or thaw-sensitive soils with frost/thaw-stable granular soils, thus providing the culvert with an engineered bedding layer to help mitigate differential seasonal movements. This and the following option may be the most applicable in crossings underlain by thaw-sensitive soils where the crossing cannot be moved;

- Increase over-excavated depth beneath ice-rich soils and replace with frost/thaw-stable soils; install clay cutoff or equivalent at each end of culvert to limit groundwater flow beneath culvert;

- Culverts should be generously sized to compensate for design uncertainties, ice/snow/sediment blockage, and possible settlement (thaw- or subgrade-related);

• Use thicker-walled culverts, and riveted or bolted culverts instead of spiral culverts, to help counteract loss of lateral restraint due to thawing soils, or forces resulting from winter icing or frost heave;

• Use “chimney” design to draw cold air down into culvert via convection, boarding up the culvert ends to prevent snow from blowing in, thus making the ground much colder in winter and counteracting summer thaw;

• Use permeable rockfill embankment instead of culvert, or in addition to culvert; and/or

• Divert water flows to keep them away from the embankment until an appropriate cross-drainage location is reached.

The option(s) most applicable to specific culvert locations will be determined at the time of detailed design. It should be noted that these options may not preserve the permafrost beneath the culvert, but should help to reduce the amount of seasonal or thaw-related movements, as well as reducing the susceptibility of the culvert to damage.

TABLE DFO 1-1:   ACCESS ROAD CREEK CROSSINGS

Km	Stream Name	Fish	Comment	Crossing
2.9	Prairie Trib.	N	Very steep slope	C
3.3	Prairie Trib.	N		C
4.4	Prairie Trib.	N	Poorly defined small channel with little flow	C
6.1	Casket Creek	Y	Defined channel above fan, enough flow for fish	B
6.15	Casket Trib.	N	Stream off hillside discharges to alluvium. Poorly defined channel above and below road.	C
6.6	Prairie Trib.	N	Very steep slope	C
9.3	Funeral Trib.	N	Very steep and cut-off by existing road bed.	C
9.75	Funeral Trib.	N		C
9.85	Funeral Trib.	N		C
10.2	Funeral Trib.	N		C
10.7	Funeral Trib.	N		C
10.95	Funeral Trib.	N		C
11.05	Funeral Trib.	N		C
11.7	Funeral Trib.	N		C
13.3	Funeral Trib.	N	Very steep section downstream. Electro-shocked.	C
13.4	Funeral Trib.	N		C
14.85	Funeral Trib.	N		C
15.2	Funeral Trib.	N		C
15.8	Funeral Trib.	N		C
18.45	Sundog Trib.	N	Very steep. 10 m falls downstream. Electro-shocked.	C
20.5	Sundog Trib.	N	10 m falls downstream @km 25.5. Electro-shocked.	C
23.4	Sundog Creek	N	10 m falls @km 25.5. Electro-shocked. Canyon.	B
25.3	Sundog Trib.	N	Very steep, incised rock chute.	B
26.6	Sundog Trib.	N	Very steep chute.	C
27.3	Sundog Trib.	N		C
28.3	Sundog Creek	Y	Grayling observed in pools. Studies downstream.	B
28.8	Sundog Creek	Y		B
28.6	Sundog Trib.	Y	Assumed to be accessible to fish.	B
29.1	Sundog Trib.	N	Very steep, crossing rock or talus, usually with a fan of variable size at the toe of the slope.	C
29.9	Sundog Trib.	N		C
30.2	Sundog Trib.	N		C
30.5	Sundog Trib.	N		C
31.0	Sundog Trib.	N		C
31.3	Sundog Trib.	N		C
31.7	Sundog Trib.	N		C
32.4	Sundog Trib.	N		C
32.5	Sundog Trib.	N		C
36.8	Sundog Trib.	N		C
37.1	Sundog Trib.	N		C
37.9	Sundog Trib.	N		C

TABLE DFO 1-1: ACCESS ROAD CREEK CROSSINGS

Km	Stream Name	Fish	Comment	Crossing
39.4	Sundog Trib.	Y	Grayling observed in pools. Studies downstream.	B
40.1	Sundog Trib.	N	Poorly defined channels and habitat at crossings, no defined connections to main stem.	C
40.3	Sundog Trib.	N		C
43.15	Sundog Trib.	N	Long, rock chute downstream. Electro-shocked.	C
45.5	Polje Trib.	N	Grassy swale. No defined channel.	C
45.8	Polje Creek	Y	Fish caught by Beak, 1982.	C
46.5	Polje Trib.	N	Wetland. Small, poorly defined channel.	C
47.2	Polje Trib.	N	Swale.	C
48.05	Polje Trib.	N	Multiple slumps blocking channel.	C
48.6	Polje Trib.	N	No channel at all	C
49.6	Polje Trib.	?	Small accessible channel, poor habitat.	C
50.7	Polje Trib.	N	Wetland. Small, poorly defined channel.	C
50.8	Polje Trib.	N		C
53.4	Polje Trib.	N	Grassy swale. No defined channel.	C
53.5	Polje Trib.	Y	4-5 feet wide braided channel off main stem.	B
53.55	Polje Creek	Y	Fish caught by Beak, 1982. Also, see Bathurst, 2005.	B
56.35	Polje Trib.	N	Small channel, wetland without defined channel downstream.	C
56.45	Polje Trib.	N		C
60.4	Polje Trib.	N	Drains into Polje system with no channel outlet.	C
61.5	Polje Trib.	N		C
63.6	Polje Trib.	N	Inlet to Mosquito L., part of Polje system. Wetland, poor habitat.	C
67.1	Tetcela Trib.	N	Headwater swale, steep incised channel d/s.	C
71.05	Tetcela Trib.	N		C
85.45	Tetcela Trib.	N	Densely vegetated. Steep d/s. Poor habitat.	C
86.9	Tetcela Trib.	N	No defined channel.	C
87.25	Tetcela Trib.	Y	Major trib. Multiple fish species d/s, Beak 1982.	B
89.8	Tetcela Main stem	Y	Multiple fish species, Beak 1982.	B
91.3	Fishtrap Trib.	N	Wetland stream, part of large wetland system forming headwaters to Fishtrap Creek. Poor fish habitat, multiple beaver ponds downstream. No fish, Beak 1982.	C
92.1	Fishtrap Trib.	N		C
92.4	Fishtrap Trib.	N		C
93.0	Fishtrap Trib.	N		C
93.5	Fishtrap Trib.	N		C
93.9	Fishtrap Trib.	N		C
94.2	Fishtrap Trib.	N		C
94.9	Fishtrap Creek	N		C
96.9	Fishtrap Trib.	N		C
97.5	Fishtrap Trib.	N		C
98.3	Fishtrap Trib.	N		C
98.6	Fishtrap Trib.	N		C

TABLE DFO 1-1: ACCESS ROAD CREEK CROSSINGS

Km	Stream Name	Fish	Comment	Crossing
103.4	Un-named Ck Trib.	N	Drain into a large headwater wetland sytem that flows north. Poor fish habitat. Multiple beaver ponds.	C
104.9	Un-named Ck Trib.	N		C
105.1	Un-named Ck Trib.	N		C
105.2	Un-named Ck Trib.	N		C
106.4	Un-named Ck Trib.	N		C
106.8	Un-named Ck Trib.	N		C
107.2	Un-named Ck Trib.	N		C
108.95	Un-named Ck Trib.	N		C
109.05	Un-named Ck Trib.	N		C
109.2	Un-named Ck Trib.	N		C
110.3	Un-named Ck Trib.	N		C
110.35	Un-named Ck Trib.	N		C
110.6	Un-named Ck Trib.	N		C
110.8	Un-named Ck Trib.	N		C
111.75	Un-named Ck Trib.	N		C
112.3	Un-named Ck Trib.	N		C
112.5	Un-named Ck Trib.	N		C
112.95	Un-named Ck Trib.	N		C
114.2	Un-named Ck Trib.	N		C
115.8	Un-named Ck Trib.	N		C
116.0	Un-named Ck Trib.	N		C
118.5	Un-named Ck Trib.	N		C
122.1	Grainger Trib.	Y	Just upstream of fish-bearing Gap Lake.	B
123.1	Grainger River	Y	Grayling observed in pools. Fish caught, Beak 1982.	B
103.8	Un-named Ck Trib.	N	Drain into a large headwater wetland sytem that flows north. Poor fish habitat. Multiple beaver ponds. Main stem crossing at Km 111.7. Debris flow crossings at Km 112.3, 112.45 and 112.6.	C
105.2	Un-named Ck Trib.	N		C
105.3	Un-named Ck Trib.	N		C
105.4	Un-named Ck Trib.	N		C
106.3	Un-named Ck Trib.	N		C
106.7	Un-named Ck Trib.	N		C
109.4	Un-named Ck Trib.	N		C
109.7	Un-named Ck Trib.	N		C
110.7	Un-named Ck Trib.	N		C
111.7	Un-named Creek	N		C
112.0	Un-named Ck Trib.	N		C
112.3	Un-named Ck Trib.	N		C
112.45	Un-named Ck Trib.	N		C
112.6	Un-named Ck Trib.	N		C
113.0	Un-named Ck Trib.	N		C
114.0	Un-named Ck Trib.	N		C
114.55	Un-named Ck Trib.	N		C
114.9	Un-named Ck Trib.	N		C
115.05	Un-named Ck Trib.	N		C
115.15	Un-named Ck Trib.	N		C
117.05	Un-named Ck Trib.	N		C

TABLE DFO 1-1:   ACCESS ROAD CREEK CROSSINGS

Km	Stream Name	Fish	Comment	Crossing
119.0	Grainger Trib.	N	Mountain outwash fan just below gorge. Braided at main stem. Likely only flows at high water.	C
119.2	Grainger Trib.	N	Wetland trib. to outwash fan.	C
124.5	Grainger River	Y	Grayling observed in pools. Fish caught, Beak 1982.	B
126.2	Grainger Trib.	?	Wetlands at Grainger main stem confluence. Poorly	C
126.7	Grainger Trib.	N	No channel downstream.	C
130.7	Grainger Trib.	?	Road crosses near headwaters of streams. Small channels. No obvious signs of downstream beaver dams. May have reasonable connection to Grainger main stem. Fish presence possible but unlikely.	C
132.7	Grainger Trib.	?		C
134.5	Grainger Trib.	?		C
134.8	Grainger Trib.	?		C
135.5	Grainger Trib.	?		C
135.95	Grainger Trib.	?		C
136.5	Grainger Trib.	?		C
137.2	Grainger Trib.	?		C
139.6	Liard Trib.	N	Headwater streams. Small channels with poor habitat. Often include steep cobbly sections downstream. Beaver habitat downstream very common e.g. multiple dams downstream of 144. Channel outlets to Liard River also hanging, limiting migration.	C
140.1	Liard Trib.	N		C
140.5	Liard Trib.	N		C
141.8	Liard Trib.	N		C
144.0	Liard Trib.	N		C
146.3	Liard Trib.	N		C
149.3	Liard Trib.	N		C
150.3	Liard Trib.	N		C
151.1	Liard Trib.	N		C
152.2	Liard Trib.	N	No channel.	C
154.4	Liard Trib.	N	As for 139.6-151.1.	C
159.7	Liard River	Y		Ba./IB
163.95	Liard Trib.	N	Hanging wetland channel.	C
165.4	Liard Trib.	N		C
172.0	Liard Trib.	N	Wetland exit of old channel, hanging.	C

Fish: N=No Y=Yes ?=Uncertain

Crossings: C=Culvert B=Bridge Ba.=Barge IB=Ice Bridge

Crossings that would not occur with revised alignment

Crossings on revised alignment

TABLE DFO 2-1: FISH-BEARING CROSSINGS HABITAT

Road Km	Stream Name	Fish	Crossing Type	Habitat (m^2) Lost	Habitat (m^2) Altered	Comment
6.1	Casket Creek	Y	B	0	0	Bridge and causeway exist. New armoured footings replace existing gabion baskets.
28.3	Sundog Creek	Y	B	112.5	0	NE abutment partially on seasonally wet part of floodplain, 15 x 7.5.
28.8	Sundog Creek	Y	B	0	0	Abutments above normal HWM.
28.6	Sundog Trib.	Y	B	0	0	Abutments above normal HWM.
39.4	Sundog Trib.	Y	B	200.0	0	15 x 5 for abutments, 25 x 5 for lost channel on western approach.
45.8	Polje Trib.	Y	C	0	9.6	19.2 l x 0.5 w
49.6	Polje Trib.	?	C	0	23.04	19.2 l x 1.2 w
53.5	Polje Trib.	Y	B	0	0	Abutments above normal HWM.
53.55	Polje Creek	Y	B	0	0	Abutments above normal HWM.
87.25	Tetcela Trib.	Y	B	0	0	Abutments above normal HWM.
89.8	Tetcela Main stem	Y	B	0	0	Abutments above normal HWM.
122.1	Grainger Trib.	Y	B	0	0	Abutments above normal HWM.
123.1	Grainger River	Y	B	0	0	Abutments above normal HWM.
124.5	Grainger River	Y	B	150.0	0	15 x 5, each abutment
126.2	Grainger Trib.	?	C	0	14.7	21 l x 0.7 w
130.7	Grainger Trib.	?	C	0	17.85	Habitat Km 131.3. 21 l x 0.85 w
132.7	Grainger Trib.	?	C	0	35.7	Habitat Km 133.7. 21 l x 1.7 w
134.5	Grainger Trib.	?	C	0	18.9	Habitat Km 135.6. 21 l x 0.9 w
134.8	Grainger Trib.	?	C	0	14.7	Ref. Allnorth 21 l x 0.7 w
135.5	Grainger Trib.	?	C	0	14.7	Ref. Allnorth 21 l x 0.7 w
135.95	Grainger Trib.	?	C	0	14.7	Habitat Km 136.7. 21 l x 0.7 w
136.5	Grainger Trib.	?	C	0	14.7	Ref. Allnorth 21 l x 0.7 w
137.2	Grainger Trib.	?	C	0	14.7	Ref. Allnorth 21 l x 0.7 w
159.7	Liard River	Y	Ba./IB	0	2,378.8	north ramp 1,268.75, south ramp 1,110
Totals				350.0	2,572.0	

Fish: Y=Yes ?=Uncertain

Crossings: C=Culvert B=Bridge Ba.=Barge IB=Ice Bridge

Crossings that would not occur with revised alignments (shaded tan: 28.3, 28.8, 122.1, 123.1)

Crossings on revised alignment (shaded blue: 28.6)

MEMORANDUM

TO David Harpley **DATE** March 28, 2016

CC

FROM Chris Madland **REFERENCE No.** DFO_Dust_IR1

DEPARTMENT OF FISHERIES AND OCEANS DUST DEPOSITION IR RESPONSE

Pre-amble: The Developer states that "The primary dust-related effects… are anticipated to occur within about 10 m of the main development" and "effects on waterbodies from dust are expected to be minimal. The road is proximal to or crosses many stream, but the limited amount of dust will be carried in flowing water and settle as sediment, adding only a small increment to the bed load" (DAR Main Report, p. 239-40).

Information Request: Please provide the predicted dust deposition rates (e.g., in mg/dm^2/day), the affected water bodies and the areas of the affected water bodies located within 10 m of the road that may be subject to dust deposition, and the incremental addition of dust to the total suspended solids (TSS) load of water courses as a result of construction, operation and decommissioning of the all-weather access road.

Response:

Dust deposition values proximal to the road in or near waterbodies or on land were not quantified in the DAR. The methodology for assessing air quality near the road made use of a screening level air quality model that predicted the transport and resulting ambient concentrations of entrained dust relative to distance from the road. This methodology was used because the emissions from the road were considered to be minimal, transient and ephemeral. Further, they were considered as minor emission sources when considered in the context of the operation as a whole.

This issue has however been assessed in detail, and quantified in other Developer's Assessment Reports in the Northwest Territories recently. A contemporary example is provided in the work completed for the Dominion Diamond Jay Project. The Jay Project is a large, open pit diamond mine that includes a considerable amount of unpaved road transport of ore. Unpaved roads on and near the Jay project are adjacent to, and cross, waterbodies in a way similar to the Prairie Creek Mine access road. The traffic volumes and activity level at the Jay Project are considerably greater than those planned at Prairie Creek. In this sense, the Jay Project assessment serves as a very conservative analog.

During the regulatory phase of the Jay Project, an information request was presented by Kevin O'Reilly of the Independent Environmental Monitoring Agency; DAR-IEMA-IR2-02, pg 102 of 302 (Review Board 2015). Mr. O'Reilly asked specifically that the developer *"...verify the accuracy of its impact predictions and significance determinations on water quality, aquatic biota, vegetation and wildlife as a result of the increased area of dust deposition exceedances."*

The response provided to Mr. O'Reilly and accepted by the Board is directly applicable to DFO IR7 that is the subject of this response. The salient and directly applicable part of the response, the component related to deposition to water bodies, is reproduced here.

"The small changes to the projected TSS concentrations from dust deposition relative to values reported in the DAR do not alter the conclusions in the DAR. As per the response to Round 1 Information Request DAR-IEMA-IR14, and the findings of dust deposition studies undertaken at Diavik (DDMI 2009, 2011) and Ekati (Rescan 2012), it is maintained that the deposition of dust sourced from Project activities has negligible potential to result in adverse changes to water quality in adjacent waterbodies. Overall, therefore, changes in the air quality predictions (i.e., air deposition effects to lakes within close proximity to Project activities) as a result of the Jay Project Air Quality Assessment Update (Golder 2015) do not alter the pathway analysis, assessment of the results, impact classification, nor determination of significance for water quality presented in Section 8 of the DAR."

It should be noted specifically that the Prairie Creek Mine and access road will be collectively a considerably smaller development than the aforementioned Dominion Diamonds Jay Project which presents a *"negligible potential to result in adverse changes to water quality in adjacent waterbodies."* The Jay Project's quantified dust deposition assessment was based on the passage of 840 rock-trucks per day and 55 road-train ore hauling trips per day along its various roadways, compared to the Prairie Creek Project with an expected passage of 15 transport vehicles per day.

References

DDMI (Diavik Diamond Mines Inc.). 2009. Aquatic Effects Monitoring Program. 2008 Annual Report. Yellowknife, NWT. April 2009.

DDMI. 2011. Lakebed Sediment, Water Quality and Benthic Invertebrate Study. A154 Dike: Year 4 Results. A418 Dike: Year 2 Results. Yellowknife, NWT. August 2011.

Golder (Golder Associates Ltd.). 2015. Technical Memorandum: Jay Project Air Quality Assessment Update. Issued January 19, 2015.

Rescan (Rescan Environmental Services Ltd.) 2012. Ekati Diamond Mine, 2012 Aquatic Effects Monitoring Program Re-evaluation. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.

Review Board (Mackenzie Valley Environmental Impact Review Board) 2015. EA1314-01 Jay Project, Dominion Diamond Ekati Corporation Developer's Assessment Report – Responses to Round 2 Information Requests. Accessed online March 24, 2016, http://reviewboard.ca/upload/project_document/EA1314-01_01_Jay_Project_Round_2_IR_Responses.PDF

REPLY TO GNWT IR1

We draw your attention to the last paragraph on p. 123 of the DAR which states "Camp sites were likely established and utilized all along the travelled routes (Band members indicated that such camps were only temporary and were used perhaps only for 1 night while on a harvesting expedition, and that the locations were moreoless at random and not in common, frequently used locations (January 20, 2015))". This is important because potential heritage resource locations are related to the locations of traditional activity, and given that camp locations were 'at random, such resources could be anywhere in the area. However, in Section 5.3, third paragraph on P. 127 of the DAR, we noted that "CZN held meetings with the NDDB in July and August 2009 as part of a TK addendum. One area of concern was as follows: “Given that the ancestors of the Nahanni people are known to have travelled overland to a greater extent than via waterways, the mountain passes that provide easy access into and between valleys are potential areas for pre-historic and historic artifacts. For this reason, it would be useful to carry out archaeological work”. It was agreed that archaeological work should be undertaken in key areas of the Prairie Creek access road, primarily at the Second Gap area in the Nahanni Range, but also at Wolverine Pass in the Silent Hills, and at the crossings of the Tetcela River. CZN engaged Points West Heritage Consulting Ltd. to undertake an Archaeological Impact Assessment (AIA) of the noted key areas." Section 5.3 provides a summary of salient cultural information extracted from the TK Assessment Report Addendum completed for the NDDB (Crosscurrents, August 2009), which is on the Registry, and the full TK study was provided to the Board also. Section 5.3 also documents CZN's engagement with the Band on cultural issues. Two AIA's were completed, during which the consultants engaged with elders regarding cultural site locations. These AIA reports are on the registry for EA0809-002 and thus available to EA1415-001. Therefore, relevant research pertaining to cultural and spiritual sites and activities was provided in the DAR, directly and by reference to previous studies. The information referred to above illustrates that considerable efforts have been undertaken to identify cultural and spiritual sites in the area. The area was treated as a whole, although the road alignment represents a narrow linear feature in it. The same information would be relevant and appropriate for any other development in the area, including the all season road and facilities. We investigated the locations of highest potential for heritage resources based on TK, and found nothing.The information applies equally to both roads, and for any other proposed development in the area. To mitigate for the potential of heritage resource presence within the development footprint, we have proposed to produce a brochure of heritage resources for road investigation and construction crews, which will include members from Nahanni Butte (see engagement record posted to the Registry on March 21, 2016. Therefore, we will effectively be completing AIA's in ALL areas of new disturbance. The NBDB's April 19, 2016 letter indicates their agreement with this approach.

TETRA TECH EBA

TECHNICAL MEMO

ISSUED FOR USE

To:	David Harpley, Canadian Zinc Corporation	**Date:**	April 29, 2016
c:	Alan Taylor, Canadian Zinc Corporation	**Memo No.:**	4
From:	Rita Kors-Olthof, Nigel Goldup	**File:**	Y14103320-01.003
Subject:	Responses to Information Requests from the Government of the Northwest Territories Prairie Creek Mine Site Proposed All-Season Access Road, EA1415-01 Technical Review		

1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) provides, in this technical memo, the response to an information request (IR) to Canadian Zinc Corporation (CZN) from the Government of the Northwest Territories. This memo specifically addresses those requests that pertain to permafrost information. The information request is shown in italics, followed by Tetra Tech EBA's response in regular text.

2.0 RESPONSE TO INFORMATION REQUEST - GNWT IR 27

GNWT IR 27: DAR ADDENDUM – APPENDIX F PERMAFROST

Comment *Collection of snow along the sides of the road is identified as potentially resulting in warmer ground temperatures, which could lead to thawing permafrost and ponding of water along the toe of the road embankment. This effect has been identified on several highways in the NWT and Yukon (e.g. Dempster Highway, Alaska Highway). Mitigation methods to minimize the accumulation of snow and potential impacts to permafrost are not identified.*

Recommendation

1. *GNWT recommends that CZN identify mitigation methods that could be implemented to reduce snow accumulation adjacent to the road.*
2. *GNWT recommends that CZN identifies areas that are likely susceptible to permafrost degradation due to snow accumulation, and incorporate mitigation methods into the design.*

Tetra Tech EBA (2015a) noted that snow drifting or plowing could result in the build-up of snow along the road sides, even if the road travelling surface is clear. With the currently-available information, generic or typical mitigations can be considered on the basis of terrain mapping, primarily where the presence of permafrost has been identified (generally in poorly-drained areas and on slopes with northern aspects) (Tetra Tech EBA 2015c, 2016e). In road sections where site-specific recommendations would be prudent, such recommendations are best left to detailed design when more site-specific details are available, for example, incorporating local wind characteristics as well as surface and subsurface characteristics. Further identification or fine-tuning of possible requirements for mitigative measures should be considered as a result of performance monitoring, as snowfall and the formation of snow drifts or accumulation of plowed snow may not be consistent from year to year.

Tetra Tech EBA (2015a, 2015b, 2016d) have noted some design and construction mitigations that could be implemented in sections of road embankments that cross terrain with suspected ice-rich soils, and some of these are equally applicable to snow-drifting or plowed snow accumulations, as follows:

Tetra Tech EBA Inc.
Box 2244, 201, 4916 - 49 Street
Yellowknife, NT X1A 2P7 CANADA
Tel 867.920.2287 Fax 867.873.3324

- Additional embankment width can help to keep early thaw along/under embankment toes at a distance from the highest loaded area; and
- Additional embankment width and thickness, or the incorporation of "corduroy" log structures, can help distribute loads, as well as reduce potential flexing of thaw-sensitive subgrade soils and creep of ice-rich subgrade soils.

Tetra Tech EBA (2015a, 2015b, 2016d) also noted that, in areas where snow drifting proves to be an issue along the road, strategies to reduce snow drifting can be designed and installed (TAC 2010), such as:

- Installation of snow fencing to keep snowdrifts in locations upwind of the road embankment, so as to reduce the amount of snow likely to be captured in the vicinity of the embankment; and
- Flatten the side slopes of the embankment so that snow is less likely to accumulate there, and/or so that snow clearing can take place beyond the crest (edge of the travelling surface) and onto the side slopes. Slope gradients of 6 horizontal to 1 vertical (6H:1V) have been shown to collect little or no snow. The impact of increasing the footprint of the embankment will need to be weighed against the impact of possible increased water ponding along the toe of a standard embankment.

It is possible that the above-described mitigations will not entirely remove the problem, but they could move the problem further from the load-bearing portion of the road embankment. This result would decrease the likelihood that permafrost thaw would affect road operations and, assuming that the snow will have a wider deposition zone than without mitigation, also potentially reduce the depth of thaw.

Tetra Tech EBA (2015a) have recommended that cutslopes be avoided in thaw-sensitive terrain if at all possible. In addition to the challenges discussed in earlier documents with respect to mitigating potentially-thawing cutslopes, it is noted that cutslopes can also result in road sections where snow tends to drift. Where such drifts cross the road, they can readily be dealt with by plowing. In cases where excessive snow remains on the cutslope itself, equipment should be mobilized to remove the excess snow and dispose of it appropriately.

Plowed snow can result in the same types of issues as drifted snow. Aside from flattening the embankment side slopes to facilitate plowing on the slopes, other mitigations could include:

- Installation of snow sheds on the side slopes to maximize heat extraction from the side slopes in winter, and the same sheds would provide shading from the sun in summer (TAC 2010); and
- Cooling systems, including air ducts and thermosyphons, could also be considered to help counteract the effects of snow accumulation if/as applicable to a particular section of road (TAC 2010).

Results from various experimental road and railway sections in northern Canada will be of value in assessing the most appropriate mitigations during detailed design (TAC 2010).

3.0 LIMITATIONS OF MEMO

This memo and its contents are intended for the sole use of Canadian Zinc Corporation and their agents. Tetra Tech EBA Inc. 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, 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's Services Agreement. Tetra Tech EBA's General Conditions are attached to this memo.

4.0 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.

REGISTERED PROFESSIONAL ENGINEER
M.I. KORS-OLTHOF
LICENSEE
Apr 29/16
NWT/NU

REGISTERED PROFESSIONAL ENGINEER
N.J. GOLDUP
LICENSEE
APRIL 29 2016
NWT/NU

Prepared by:
Rita Kors-Olthof, P.Eng., P.E.
Senior Geotechnical Engineer, Arctic Region
Engineering Practice
Direct Line: 403.763.9881 (cell)
Rita.Kors-Olthof@tetratech.com

Reviewed by:
Nigel Goldup, P.Eng.
Regional Manager, Arctic Region
Engineering Practice
Direct Line: 780.451.2130 x301
Nigel.Goldup@tetratech.com

/kla

Attachments: Tetra Tech EBA's General Conditions

PERMIT TO PRACTICE
TETRA TECH EBA INC.
Signature
Date April 29, 2016
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

REFERENCES

Canadian Standards Association (CSA), 2010. Technical Guide – Infrastructure in Permafrost. A Guideline for Climate Change Adaptation. CSA Reference Number: Plus 4011-10.

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Transportation Association of Canada (TAC), 2010. Development and Management of Transportation Infrastructure in Permafrost Regions.

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA’s Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA’s Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA’s instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

TECHNICAL MEMO

TETRA TECH EBA

ISSUED FOR REVIEW

To:	David Harpley VP Environmental & Permitting Affairs	**Date:**	April 18, 2016
c:	Nigel Goldup	**Memo No.:**	03
From:	Shirley McCuaig	**File:**	Y14103320-01
Subject:	Remaining IRs from MVRB Proposed Prairie Creek All Season Road		

This 'Issued for Review' document is provided solely for the purpose of client review and presents our interim findings and recommendations to date. Our usable findings and recommendations are provided only through an 'Issued for Use' document, which will be issued subsequent to this review. Final design should not be undertaken based on the interim recommendations made herein. Once our report is issued for use, the 'Issued for Review' document should be either returned to Tetra Tech EBA or destroyed.

1.0 INTRODUCTION

This technical memo provides Tetra Tech EBA Inc.'s (Tetra Tech EBA) responses to several information requests directed at Canadian Zinc Corporation (CZN) from the Mackenzie Valley Review Board (MVRB) regarding CZN's Developer's Assessment report. This memo specifically addresses those requests that pertain to the location of permafrost and related issues along the proposed all season road route for the Prairie Creek Mine. The information requests are shown in each section in italics, followed by Tetra Tech EBA's responses in regular text.

2.0 RESPONSES TO INFORMATION REQUESTS

2.1 MVRB IR 2

Characterization of permafrost; Project description and potential accidents and malfunctions.

This information request consists of several different questions, which are addressed in order.

At the beginning of the description the following sentence requests more information: *"it is not clear that the full set of permafrost sub-classes were used in the terrain mapping".*

There are only six permafrost subclasses in the Howes and Kenk (1997) terrain stability mapping system. As they refer to very specific features, such as patterned ground, the feature must be present in order to assign the polygon a permafrost subclass. In the project area, only creep is present (-Fc), and it is only present in some locations. If no subclasses apply to a particular area, then it is perfectly acceptable to use only the main designation of –X, as per page 70 of Howes and Kenk (1997), which says "subclasses can be used, where appropriate".

i) *"At Km 56, the thermokarst symbol is shown on the map but the presence of permafrost and this process are both not highlighted in the polygon mapping letters."* This was discussed on our conference call with MVRB in January 18, 2016. The very small pond may or may not be a thermokarst pond. As there is no other evidence of permafrost within the polygon on the air photos, we do not feel that it is appropriate to assign the entire polygon a permafrost class and a thermokarst subclass, especially given that we are uncertain whether or not the pond formed by permafrost thaw. The small thermokarst symbol should suffice, and its uncertainty is explained in the Section 3.3.1 of Tetra Tech EBA (2015).

Tetra Tech EBA Inc.
Box 2244, 201, 4916 - 49 Street
Yellowknife, NT X1A 2P7 CANADA
Tel 867.920.2287 Fax 867.873.3324

The kettle symbol that was adjacent to the small pond (indicating the pond might also be a kettle) in the original figures has been removed as it caused some confusion. Revised Figure A09 attached.

ii) "*At WP 30 and also on Figure A08: at KP 047.5 Km, there is a thermokarst symbol but the terrain unit letter for thermokarst (t or e) is not used*." The point symbols at these locations represent small landslide scars. The generic "Landslide and Active Layer Failure Scar (small)" on the legend has been changed to "Landslide (small)" and Figure A08 revised.

iii) "*At KP 122 Km, permafrost and thermokarst features were identified in the previous mapping but don't seem to be reflected in the terrain mapping*." It appears that the dark feature north of KP122 on the Rutter and Boydell (1981) map has been assumed to have a hatch pattern indicating patterned ground. However, the area covered by the dark feature is a small lake on all sets of air photos, as well as on the Rutter and Boydell map. The resolution of the map as downloaded from the Geological Survey of Canada website is such that the dark lake colouring resembles a hatched pattern.

iv) *"At KP 92.5 Km, there are ponds that have been previously identified as thermokarst ponds but are not highlighted as such in the mapping*". These ponds are not identified as thermokarst in Rutter and Boydell (1981); however, the area does appear to be underlain by permafrost, and there is some change in pond shape between 1949 and 1994. The large pond has expanded about 12 m on average (in various directions), while two of the smaller ponds have grown about 2 m. The smallest pond has decreased in size by about 2 m. We have added thermokarst symbols to the ponds and -Xt to the label of the polygons that they lie within. The nearby stream between KP95 and 98 has some bank edge ponds that resemble thermokarst ponds. We have also labelled these as -Xt. Figures A13 and A14 have been revised.

v) *"According to Table 6.3-1, three realignments were proposed between KP 105 km and KP 109 km to avoid areas of permafrost creep; however, the areas of permafrost creep (solifluction?) in these areas do not seem to be shown in the mapping"*. The error in the table has been fixed. Please see the revised Table 6.3.1 at the end of this document.

vi) *"At KP 134 Km, a thermokarst pond is described in the text but is not mapped as such".* A thermokarst point symbol was shown on Figure A21 at the edge of the map area in our previous submission (Tetra Tech EBA 2015). A new polygon with a –Xt class and subclass has been added to surround the pond in order to make it more visible. Figure A21 has been revised.

vii) *"At KP 141 to 144 Km, the Rutter and Boydell, 1981 mapping shows permafrost features around the lakes but this is not incorporated into the polygon mapping".* These features are again lakes (see response iii). They appear larger and offset from our lakes due to the scale and manual nature of the mapping done by Rutter and Boydell (1981).

viii) *"At KP 118.5 Km, permafrost is described in the text but does not appear to be included in the polygon mapping. Additional mapping characterizations and ground-truthing are needed to understand the nature and extent of permafrost at the site".* A permafrost process designation has been added to the polygon in question. Figure A19 has been revised.

Recommendation

1. *Please update the terrain stability mapping to accurately reflect all of the observations made along the alignment related to permafrost and permafrost features. The terrain stability mapping should clearly depict the permafrost distribution along the alignment.*

The remainder of the route was reviewed and permafrost areas (generally of low slope angle comprising organic or fine-grained deposits) were mapped in addition to the potentially unstable permafrost areas already mapped. These are generally found on slopes with northern aspects, or in flat, poorly drained areas. Relevant map figures are attached. These areas will require standard permafrost mitigation methods (e.g., increased embankment thickness, drainage control, etc., as discussed in Dore et al. 2010) to protect the permafrost from thawing during road construction and operation.

High elevation areas are dominated by rapid mass movement processes, which remove or obscure features which might indicate the presence of permafrost. However, by virtue of their occurrence at these elevations (e.g., upper slope areas between KP0 and 35), it can be assumed that permafrost-related processes occur, but are secondary or tertiary to mass movement processes such as rock fall and rock slides. In addition, the coarse nature of the debris at high elevations likely influences the permafrost: greater permafrost depths are expected in coarse-grained deposits. These areas have not been identified with –X on the mapping, as it is not certain where permafrost is or if it is near surface. It is expected that permafrost with higher ice contents will be present at somewhat lower elevations on north-facing slopes. However, the route remains at low elevations throughout the mountainous areas and therefore the high elevation areas will not require mitigation for permafrost. Mass movement processes such as rockfall are the main concern for the route in these areas.

Flat to gently sloping high elevation areas that do show some permafrost features have been updated by adding -X, (i.e., permafrost processes) to the polygon labels. The appropriate map figures have been revised and are included in with this memo. The most common feature in these areas is patterned ground (soil stripes, -Xr), but many flatter high elevation areas do not exhibit any permafrost features identifiable on the air photos. It is suspected that these units consist of coarse-grained material and that permafrost exists at depth rather than near their surfaces or that bedrock is near surface, as mentioned above.

There are a number of areas underlain by permafrost within the route corridor between KP129 and 159. The –X permafrost process has been added to the polygon labels of the Rutter and Boydell (1981) mapping where necessary. These polygons are large due to the mapping scale; about 10 - 50% of the area they cover is underlain by permafrost. As all of this permafrost exists within organic deposits, mitigation for permafrost will be required each time an organic deposit is encountered during construction within this stretch of the route.

The presence of permafrost between KP159 and 184 has already been determined for this portion of the route in our report “Terrain Mapping, KP159 – 184, Proposed Prairie Creek All Season Road”, dated February 29, 2016.

Recommendation 2 has been deleted from the IRs.

2.2 MVRB IR 5

Project description and terrain mapping; Tetra Tech Terrain Mapping Report

“It is implied that there are no areas of ‘potentially unstable’ or ‘unstable’ terrain in the areas covered by the Rutter and Boydell, 1981 mapping. However, this is considered unlikely to be the case based on the existing evidence. For example, the earlier work undertaken by Tetra Tech highlighted debris slides and tension cracks downslope from KP 84 Km to KP 85 Km, but this area is not mapped as ‘potentially unstable’ or ‘unstable’. At KP 157 Km,

tension cracks were mapped in the area but the area upslope of the "unstable" terrain was not identified as an area of potentially unstable."

The majority of the Rutter and Boydell (1981) mapping was reviewed for our last report (Tetra Tech EBA 2015) and any areas of concern have already been mapped as potentially unstable or unstable according to the established guidelines described therein. The two exceptions described above are minor errors in the mapping and have been revised as discussed below.

The tension cracks at KP157 have now been incorporated into the unstable polygon below. Figure A25 has been revised.

Rutter and Boydell (1981) have the KP84 - 85 area mapped as till and colluvium, which is accurate. Tension cracks and slides previously mapped by Tetra Tech EBA have been added to this file and modified to match the more accurate 3D images available in PurVIEW.

The area between KP66 and 76 was not mapped previously. Air photos from 1994 were viewed in hard copy and mapped using a standard stereoscope. Linework was then digitized in ArcGIS. Only the areas that differ from the Rutter and Boydell (1981) mapping are mapped. Several new polygons and mass movement linear symbols have been added. Permafrost processes were identified in some locations. The relevant figures have been revised to reflect the new mapping.

We note that, possibly due to the occasional instability of ArcGIS or perhaps due to data loss caused by data transfers between offices, some of our prior map edits did not appear on the final figures for the DAR. This has been corrected and the appropriate map figures supplied.

3.0 LIMITATIONS OF REPORT

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

4.0 CLOSURE

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

Tetra Tech EBA Inc.

Prepared by:

Shirley McCuaig, Ph.D., P.Geol.
Senior Terrain Geologist, Geotechnical Engineering
Direct Line: 780.451.2130 x381
shirley.mccuaig@tetratech.com

Reviewed by:

Vladislav Roujanski, Ph.D., P.Geol.
Senior Geologist/Geocryologist, Arctic Group
Direct Line: 780.451.2130 x289
vladislav.roujanski@ tetratech.com

/my

REFERENCES

Dore, G., McGregor, R., Hayley, D.W., Wilkins, G., Hoeve, E., Grozic, E., Roujanski, V., and Jensen, A. 2010. *Guidelines for Development and Management of Transportation Infrastructure in Permafrost Regions.* Transportation Association of Canada.

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Tetra Tech EBA Inc. (Tetra Tech EBA) 2015. Mapping Summary Report: Proposed Prairie Creek Mine All-Season Road, Northwest Territories. Report prepared for Canadian Zinc Corporation, December, 2015.

TABLE

Table 6.3-1 Summary of Realignments and Mitigations Where Realignments Not Feasiblable

Table 6.3-1: Summary of Realignments and Mitigations Where Realignments Not Feasible

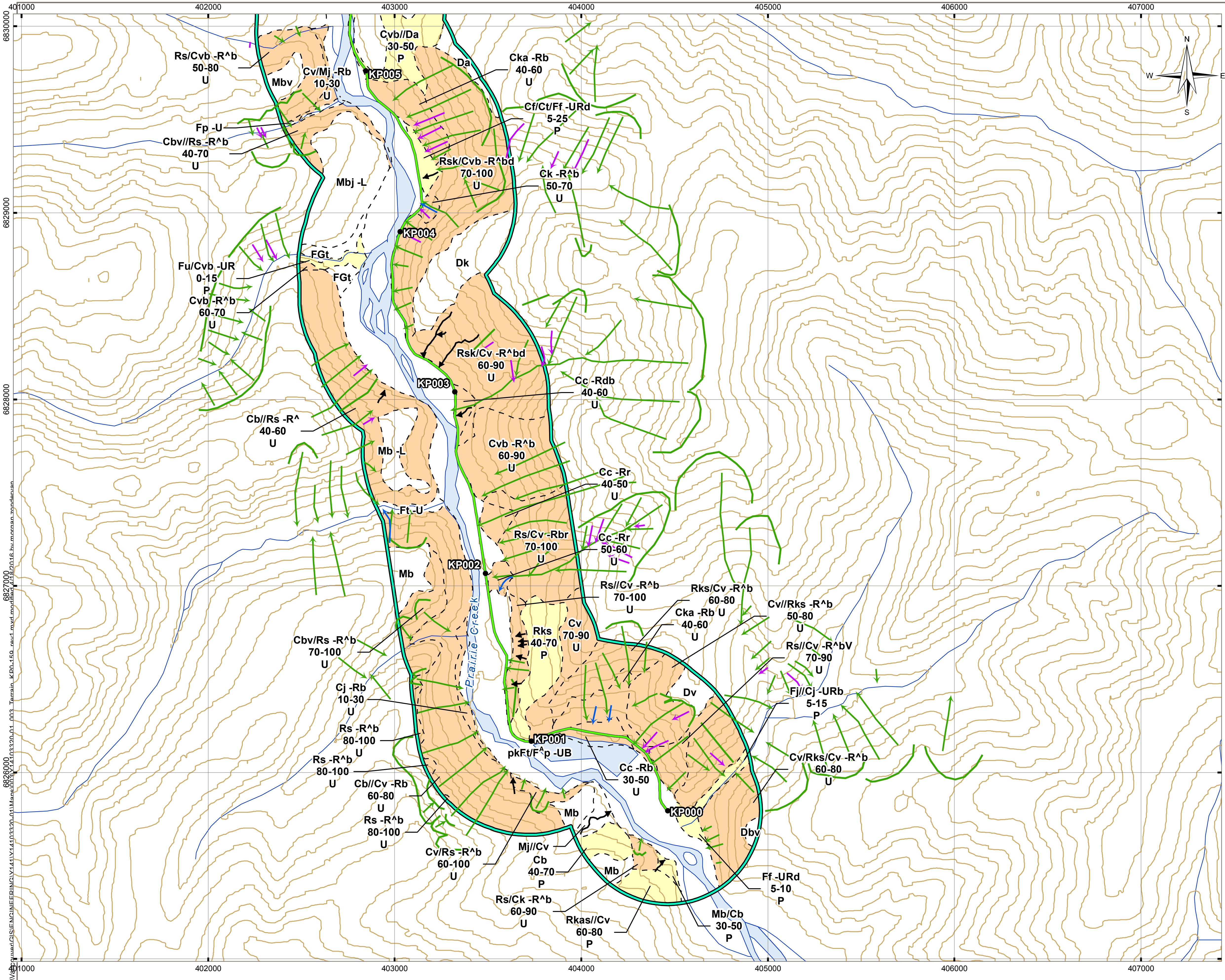
Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Realignment and/or Other Mitigations
1.85	2.00	0.15	Protection should be considered to limit possible intrusion of fluvial fan at airstrip.
4.06	4.45	0.39	Rockfall mitigation should be considered at cut slopes. Use of backup borrow sites BP 4A and BP 4B may increase risk at road.
5.67	6.12	0.45	Realignment not possible due to fish habitat enhancement/protection. Implement rockfall mitigation instead. Casket Creek flood mitigations.
16.30	17.37	1.07	Further realignment not possible due to grades. Rockfall mitigation and/or administrative controls.
22.99	23.36	0.37	Slight realignment south to avoid downslope instabilities.
24.88	25.15	0.27	Slight realignment south to avoid downslope instabilities.
28.30	29.08	0.78	Mitigation options to be determined with slope stability evaluation: proposed as rockfall mitigation starting at KP028.3, buttressing and erosion protection at KP028.7, or realigning route and stream crossing location.
38.74	42.95	4.21	Consideration of first of two suitable realignments to the south to avoid slide area, decision at detailed design to be based on constructability.
39.59	42.95	3.36	Consideration of second of two suitable realignments.
42.07	42.95	0.88	Realignment south to avoid slide area - shown as part of preceding realignments.
45.35	46.31	0.96	Realignment south to avoid permafrost/organic area.
49.90	50.40	0.50	Grade issues prevent realignment at west end. Mitigations at slide area to be determined based on slope stability evaluation. Realignment in east end of section.
54.44	55.25	0.81	Short realignment west to avoid rockfall area.
55.46	55.77	0.31	Short realignment southwest to avoid rockfall area.
56.18	59.33	3.15	Realignment downslope, then upslope on terrace, to avoid instabilities along crest of slope.
60.94	61.55	0.61	Short realignment to avoid gully with colluvium.
83.60	85.80	2.20	Realignment not suitable south or north, drainage control important.
86.55	86.80	0.25	Realignment south not suitable due to wet area and stream. Mitigation of slide above road may be needed; stabilization proposed.
96.00	102.00	6.00	Road in most suitable location, other mitigations may be needed, e.g., drainage. To be determined with slope stability evaluation.
109.84	110.17	0.33	Original Alignment – shift alignment west to avoid rockfall.
111.04	111.38	0.34	Original Alignment – shift alignment west to avoid wet area.
113.59	114.44	0.85	Original Alignment – shift alignment west to avoid rockfall.
114.95	115.67	0.72	Original Alignment – shift alignment northeast to avoid slide and gully.
116.00	116.49	0.49	Original Alignment – shift alignment northeast to avoid slide.
117.47	117.81	0.34	Original Alignment – small shift northeast out of tight spot at ridge and wetland.
118.37	119.41	1.04	Original Alignment – shift southwest to avoid unstable slope of meltwater channel.
104.40	105.33	0.93	Alternative Alignment – shift alignment east into permafrost creep area to avoid more hazardous slide area.
105.79	106.50	0.70	Alternative Alignment – shift alignment east into permafrost creep area to avoid more hazardous slide area.

Table 6.3-1: Summary of Realignments and Mitigations Where Realignments Not Feasible

Road Section Start KP (km)	Road Section End KP (km)	Distance (km)	Realignment and/or Other Mitigations
107.00	108.63	1.63	Alternative Alignment – shift alignment east into permafrost creep area to avoid more hazardous slide area.
111.90	115.65	3.75	Alternative Alignment – shift alignment west to skirt toe of unstable area, yet stay high enough to keep route on dry ground.
116.95	118.00	1.05	Alternative Alignment – shift alignment south to avoid colluvium.
118.30	118.70	0.40	Alternative Alignment – shift alignment southwest to avoid organic-rich area.
118.70	119.30	0.60	Alternative Alignment – shift alignment northeast to avoid debris slides and steep ground.
123.31	123.66	0.35	Minor shift of alignment to north to reduce erosion potential.
124.11	124.45	0.34	Minor shift of alignment to north to reduce erosion potential.
127.77	129.22	1.45	Shift alignment northeast to avoid series of meltwater channels.
133.15	136.22	3.07	Shift of route alignment northeast to avoid permafrost creep, steep-sided gully.
141.41	143.26	1.85	Minor shift of route east to avoid crest of meltwater channel.
153.62	158.27	4.65	Shift of alignment to west to avoid crests of large debris slide and earthflows.
158.27	159.32	1.05	Mitigations required beyond KP158.27 along descent to Liard River, where alignment cannot be moved due to instabilities upslope.

FIGURES

Modified Terrain Stability Mapping Figures



LEGEND

- 1 km Buffer

Field Site

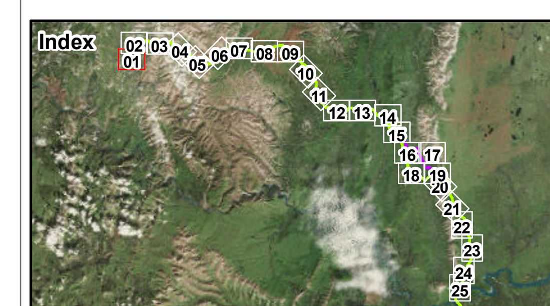
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

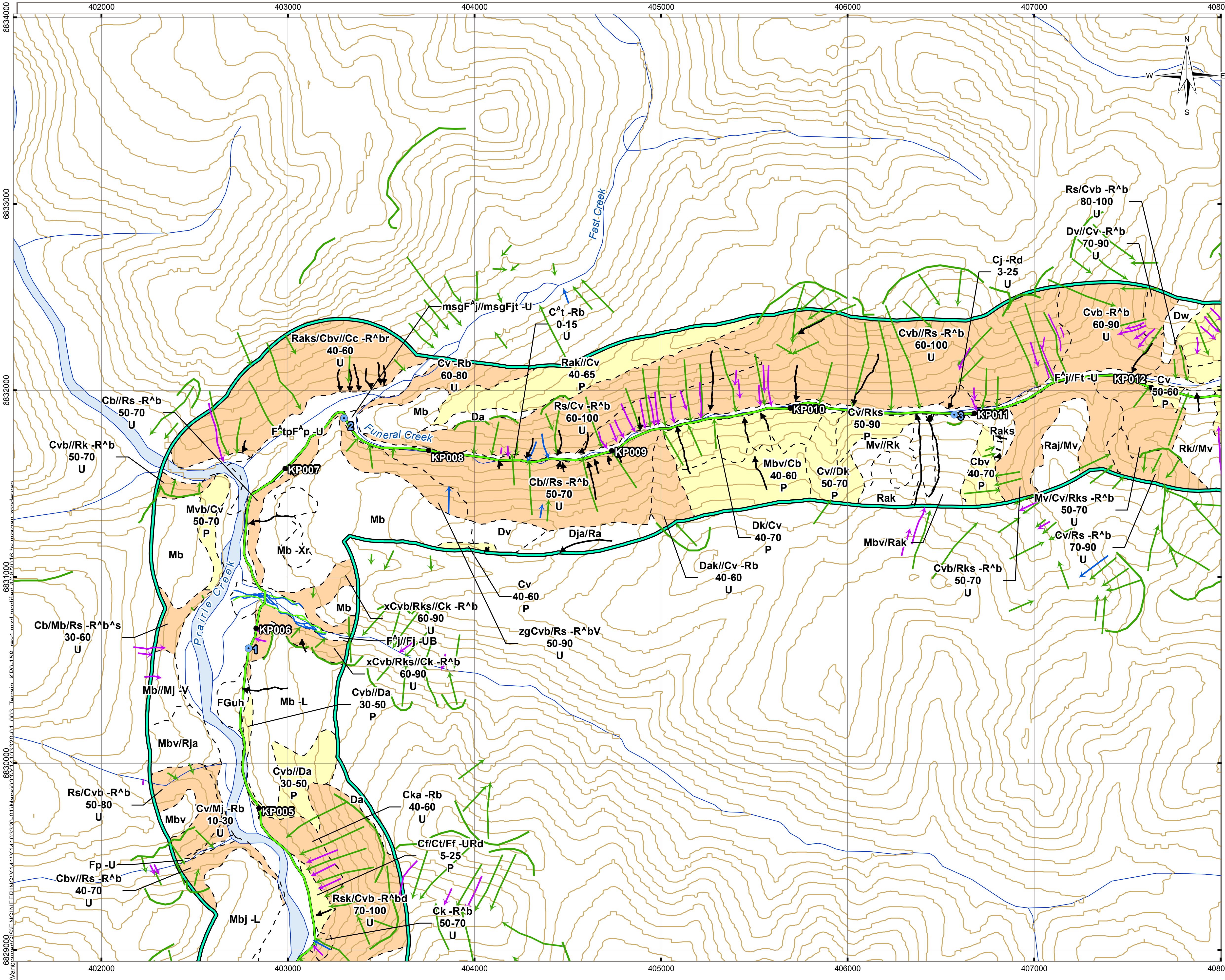
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A01



LEGEND

- 1 km Buffer

Field Site

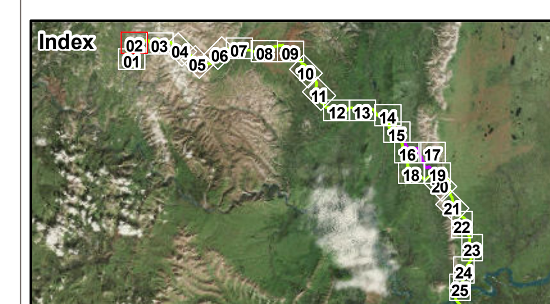
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- River Position (1949)
- River Position (1994)
- River Position (Post-1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

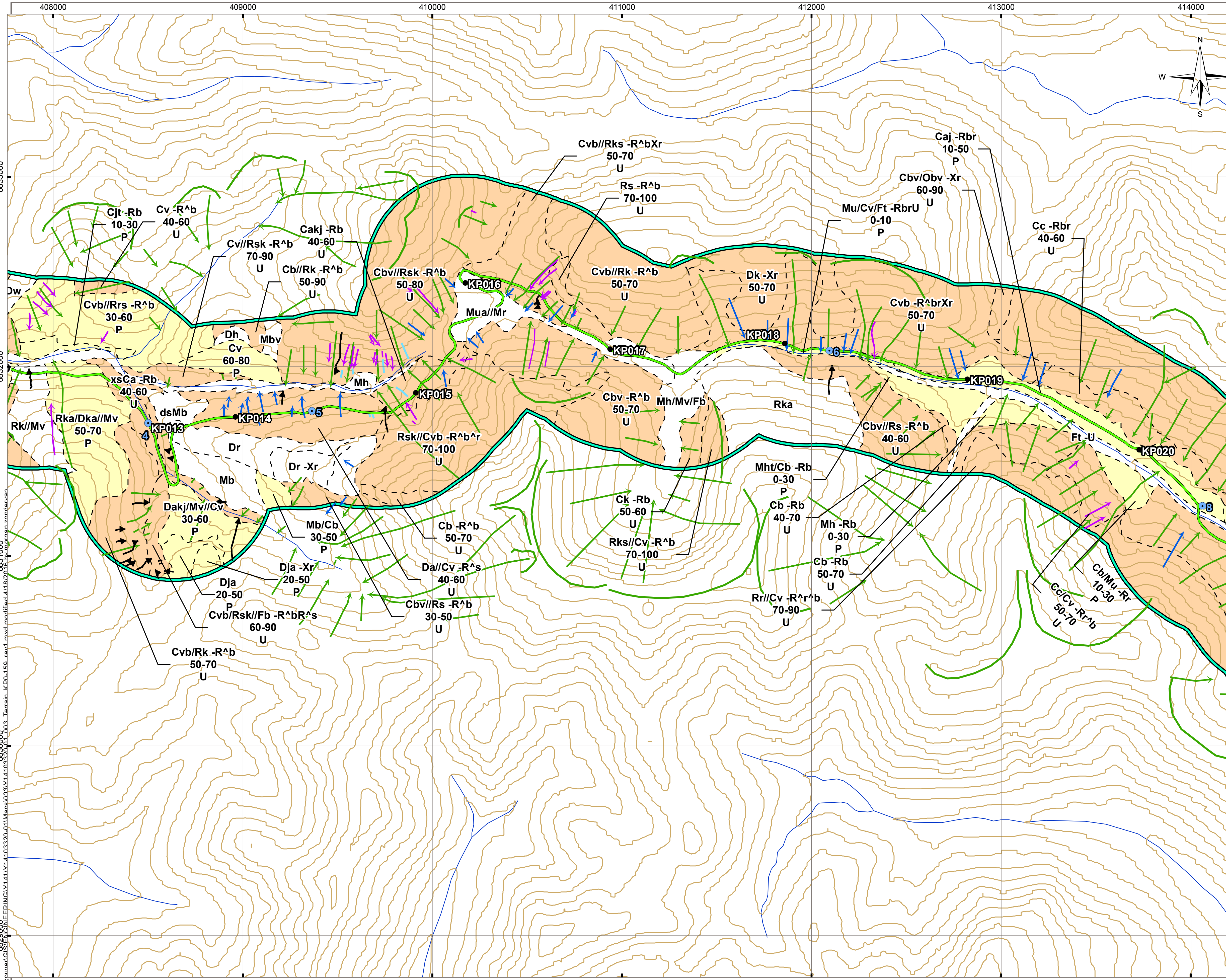
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A02



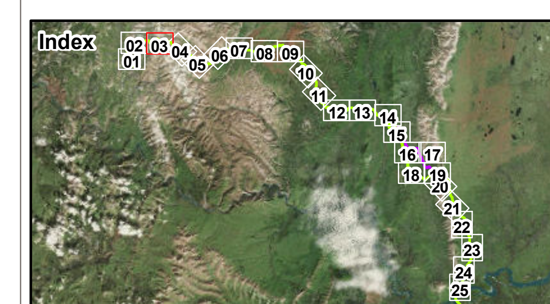
LEGEND

1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Gully
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1982)
- River Position (Post-1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

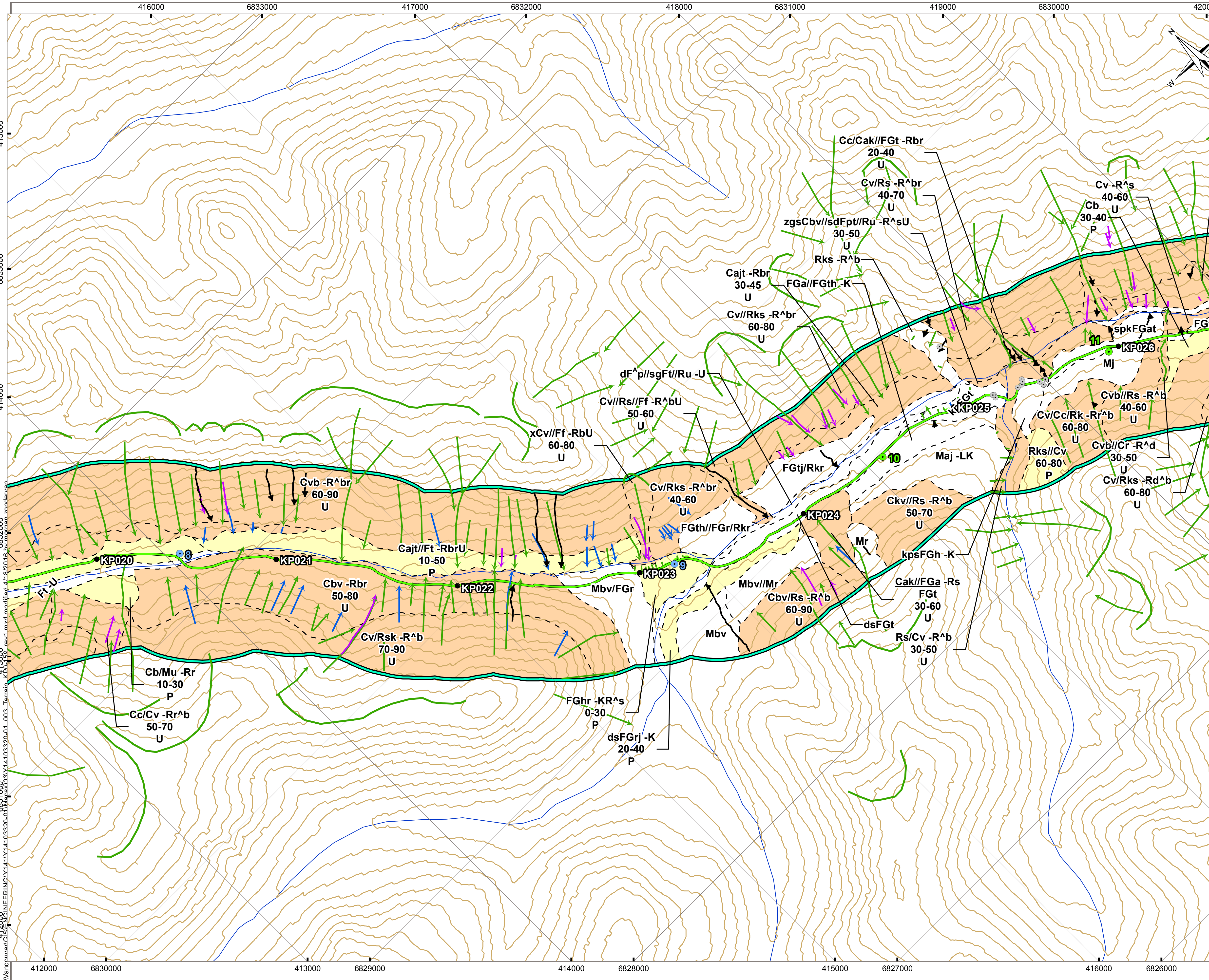
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A03

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003\Y14103320-01_003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by morgan.zondervan



LEGEND

1 km Buffer

Field Site

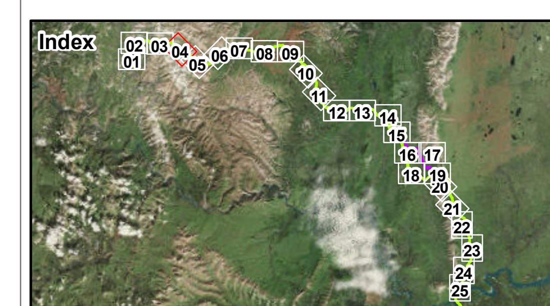
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000 — 400 200 0 400 Metres

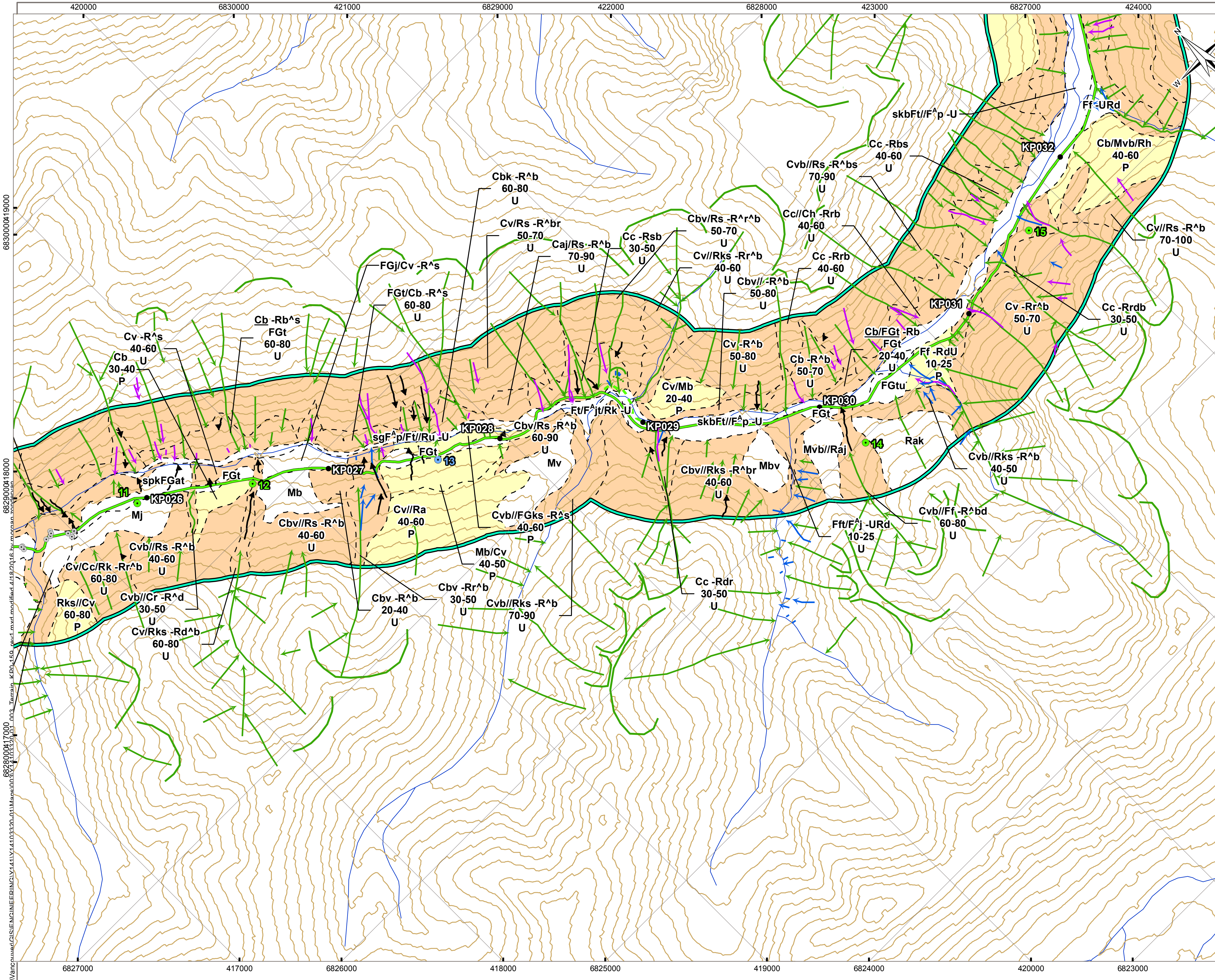
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A04



LEGEND

- 1 km Buffer

Field Site

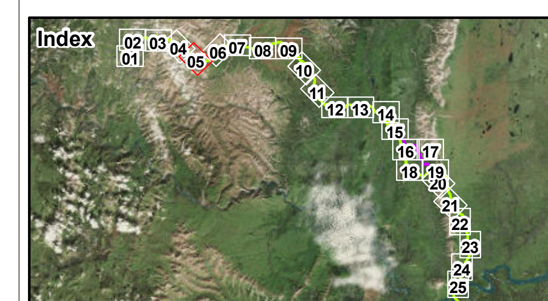
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Slide Block (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

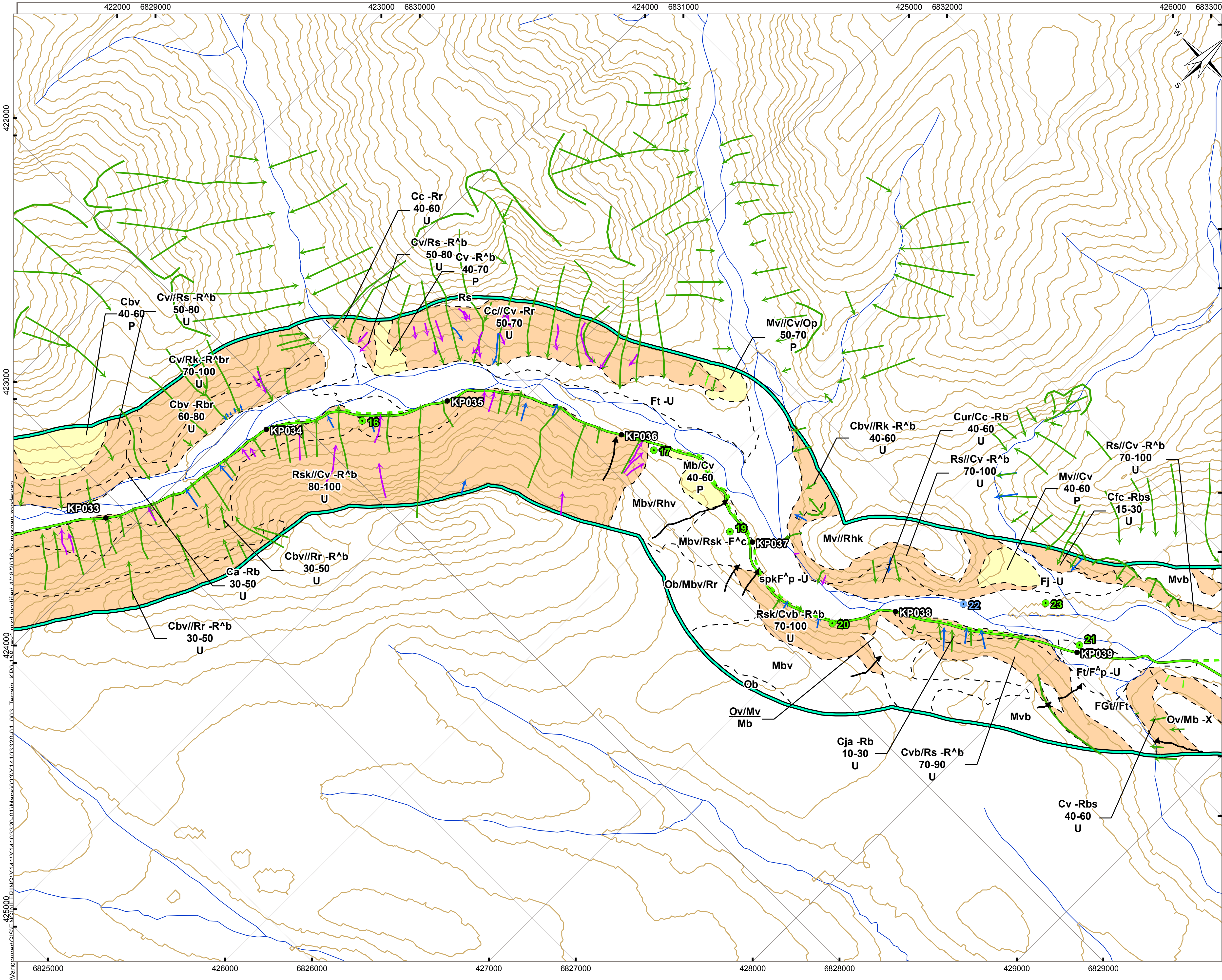
Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

FILE NO.				
Y14103320-01_003_Terrain_KP0-159_rev1.mxd				
PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1
OFFICE	DATE			
Tt EBA-VANC	April 18, 2016			

Figure A05

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by morgan.zondervan



LEGEND

- 1 km Buffer

Field Site

- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- River Position (1949)
- Contour (40 m)
- Watercourse
- Waterbody

Index

NOTES

Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS

ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

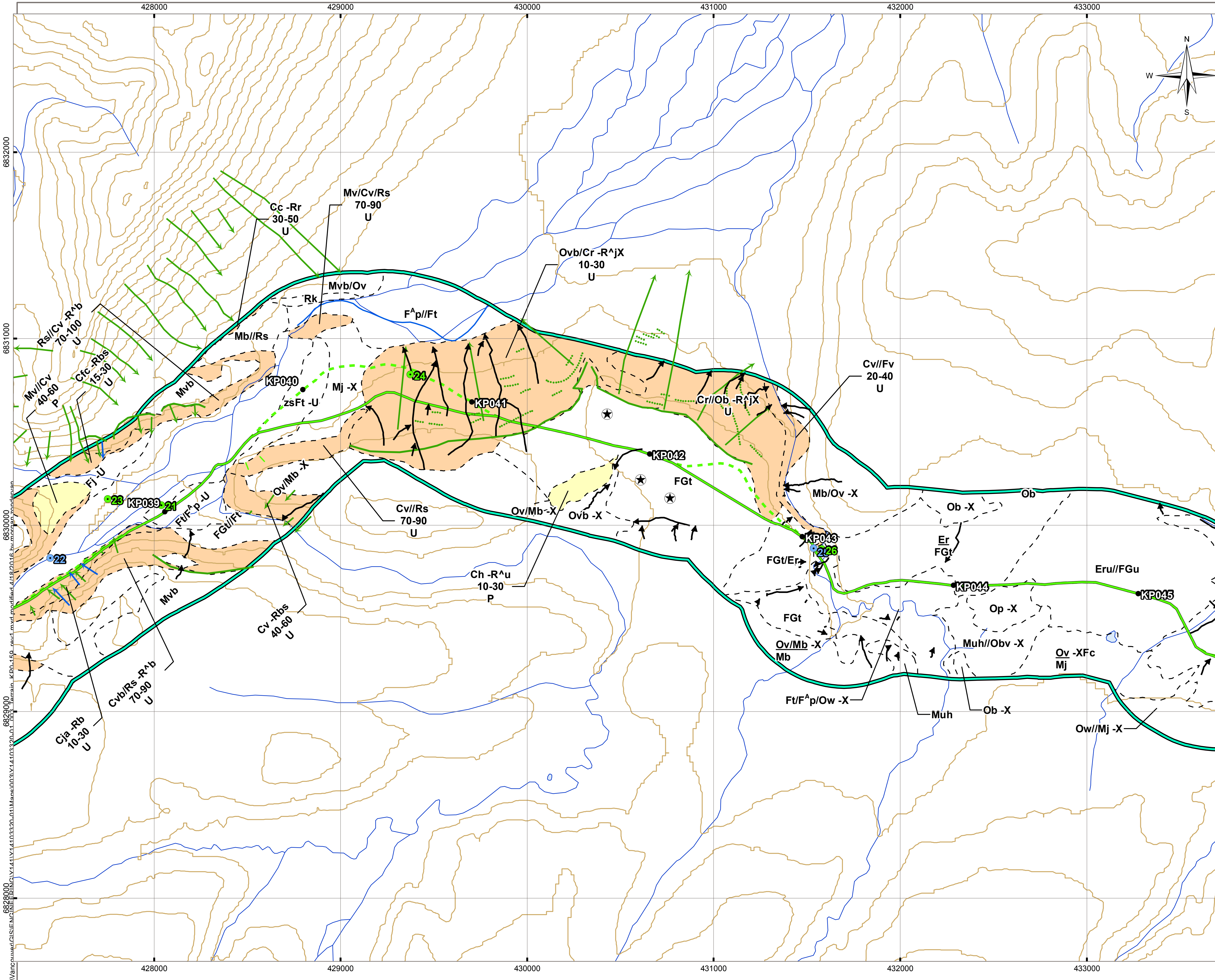
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A06



LEGEND

1 km Buffer

Field Site

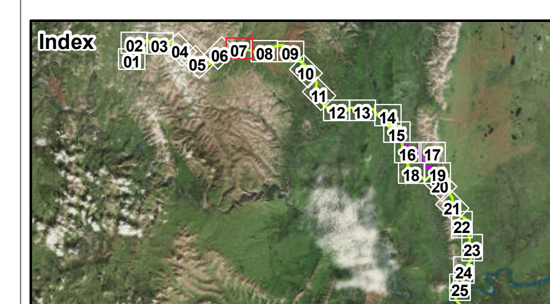
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Possible Sinkhole or Kettle
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Head Scarp Large (1949)
- Slide Block (1949)
- River Position (1949)
- River Position (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES

Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS

ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

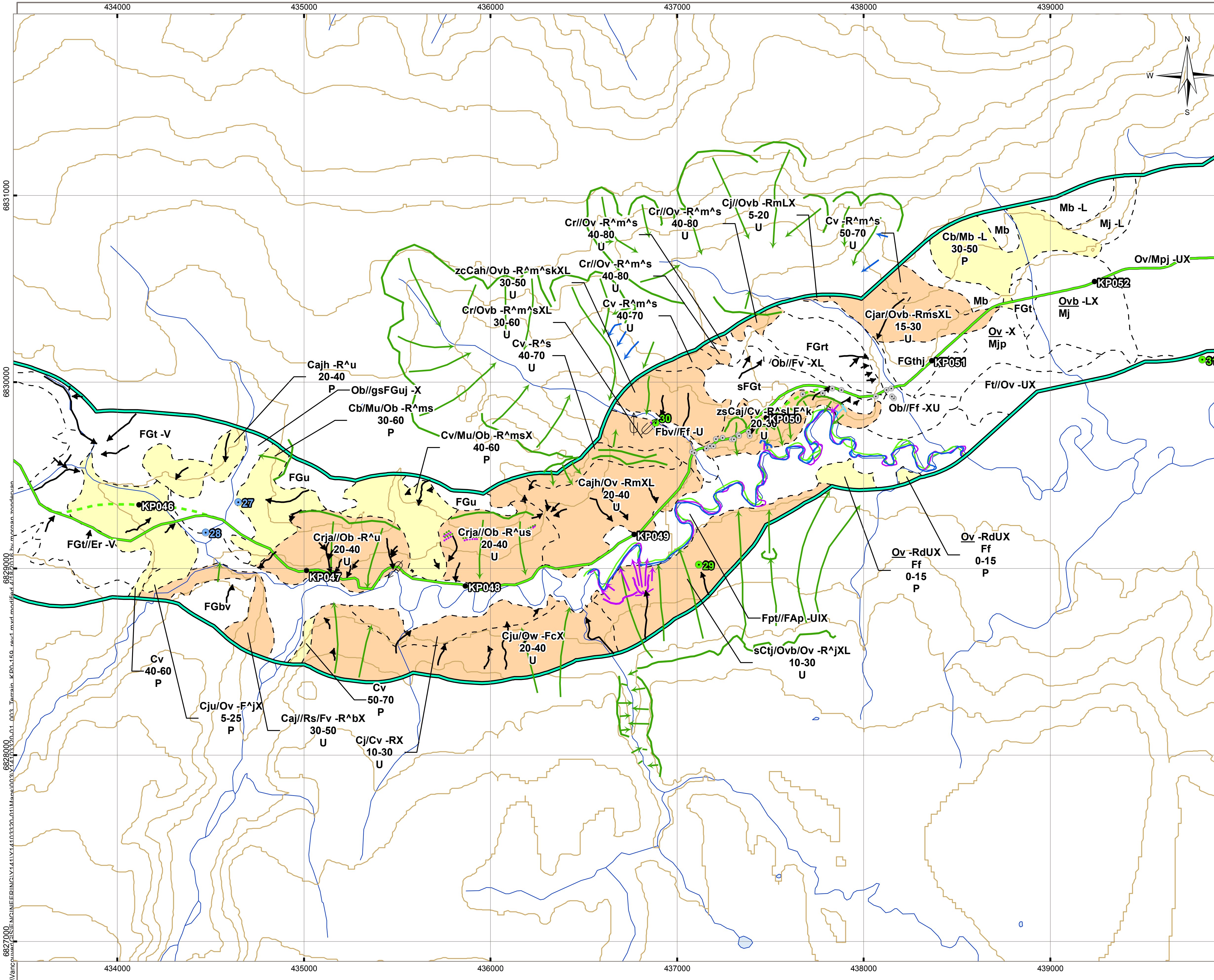
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A07

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003\Y14103320-01_003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by mzandevan



LEGEND

1 km Buffer

Field Site

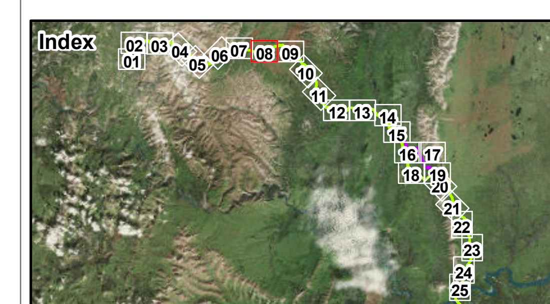
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide (small)
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1982)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1982)
- Landslide Head Scarp Large (1994)
- Landslide Head Scarp Large (2012)
- Slide Block (1949)
- Slide Block (Post-1994)
- River Position (1949)
- River Position (1982)
- River Position (1994)
- River Position (Post-1994)
- Tension Crack (Post-1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

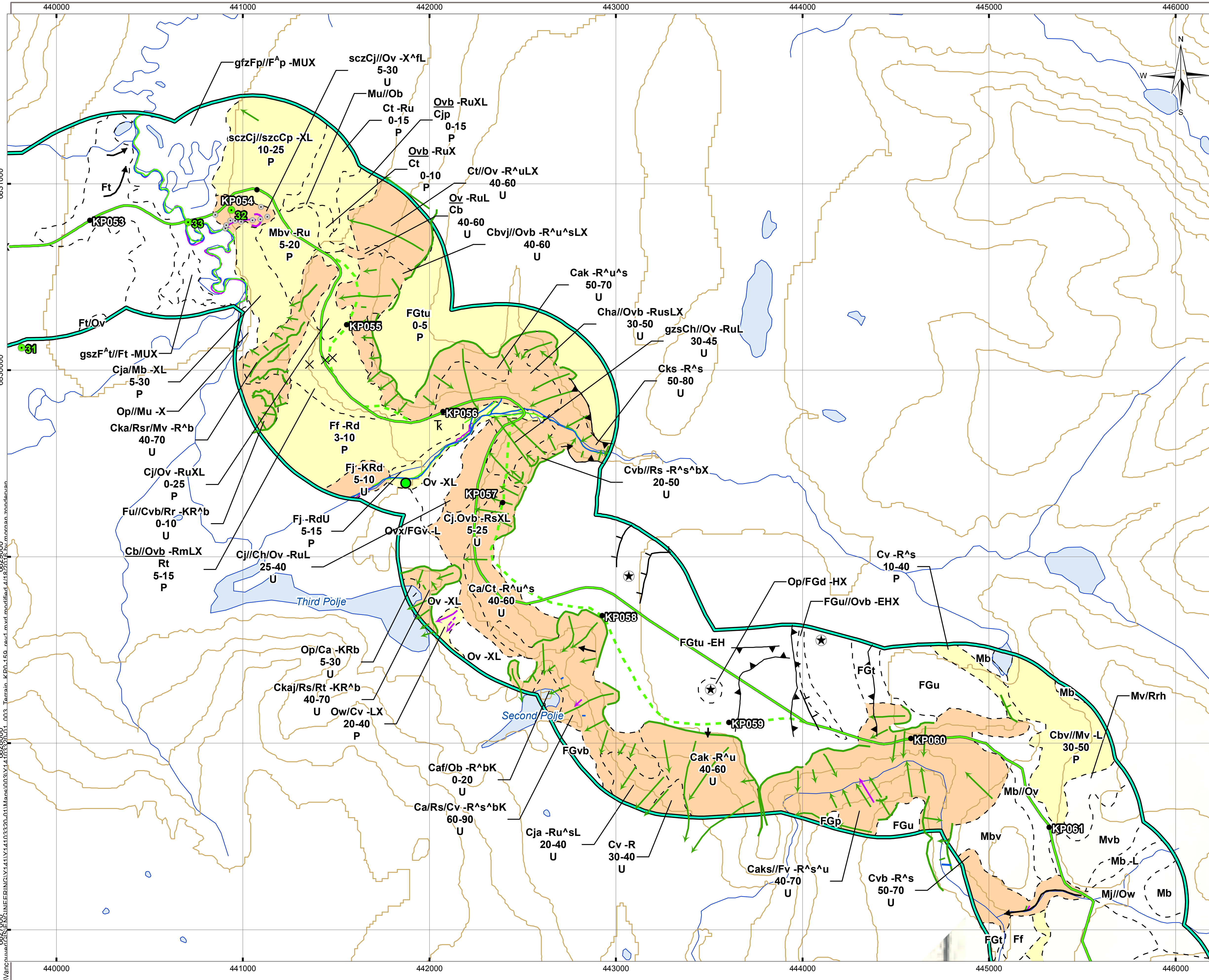
PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

FILE NO.				
Y14103320-01_003_Terrain_KP0-159_rev1.mxd				
PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1
OFFICE	DATE			
Tt EBA-VANC	April 18, 2016			

Figure A08



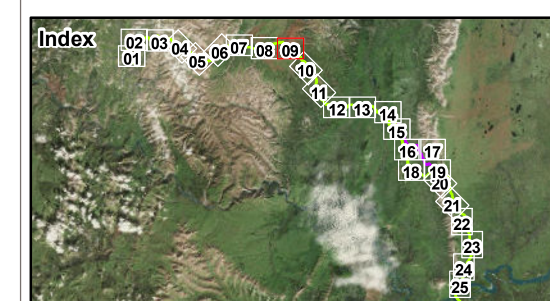
LEGEND

- 1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Escarpment
- Gully
- Meltwater channel (major)
- Bedrock Outcrop
- Karst Depression
- Possible Sinkhole or Kettle
- Thermokarst Terrain
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1994)
- Landslide Head Scarp Large (2012)
- River Position (1949)
- River Position (1994)
- River Position (Post-1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A09

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LEGEND

1 km Buffer

Field Site

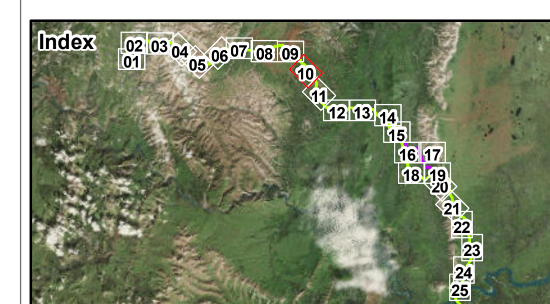
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Possible Sinkhole or Kettle
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1994)
- Slide Block (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

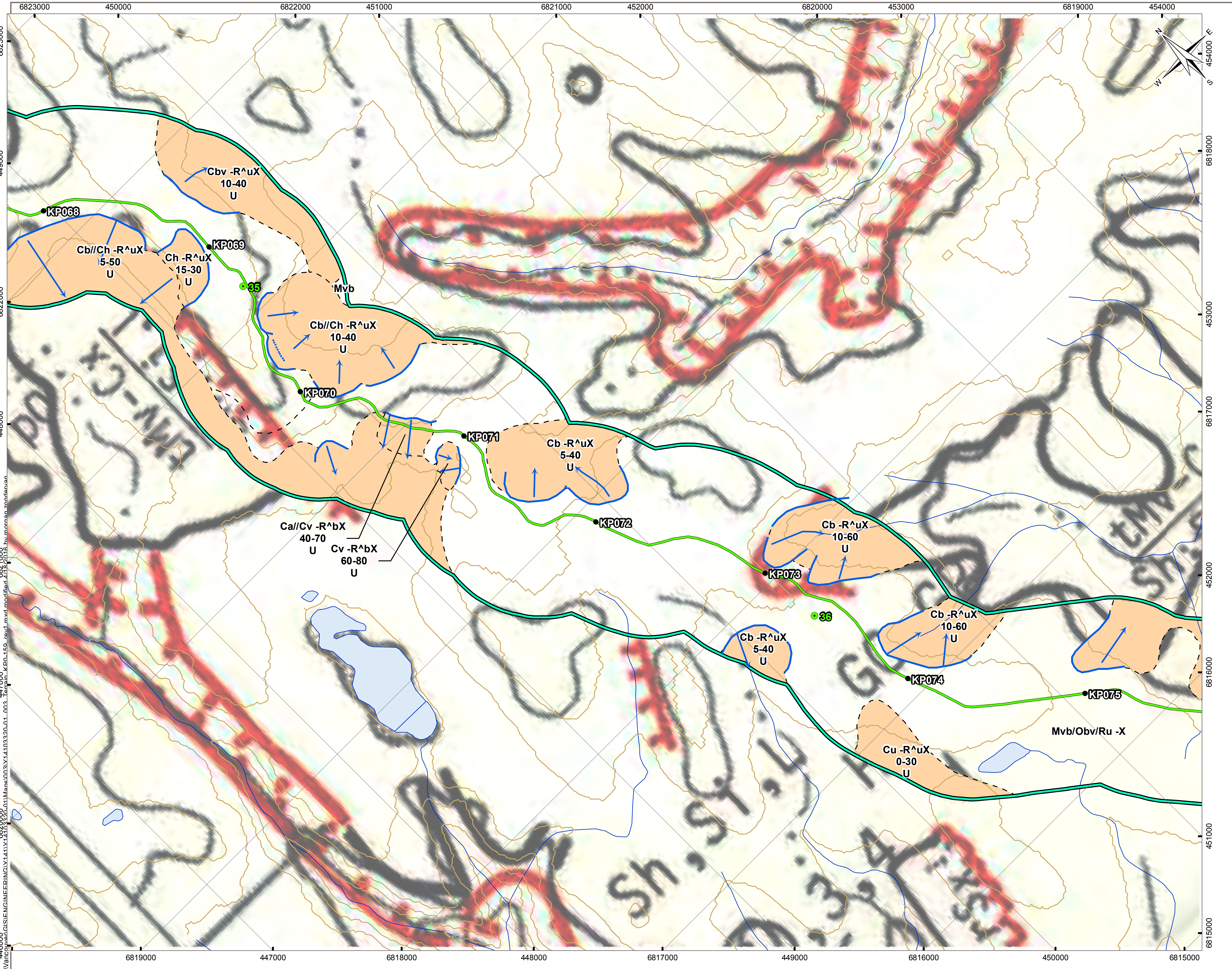
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A10



LEGEND

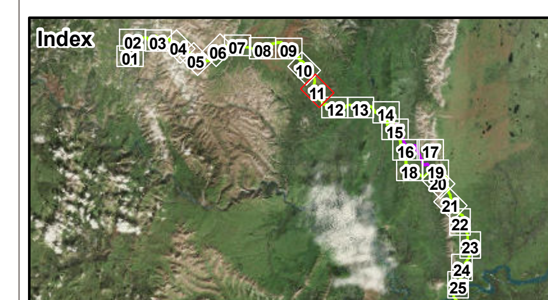
- 1 km Buffer

Field Site

- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)
- Landslide Failure Scar Large (1994)
- Landslide Head Scarp Large (1994)
- Slide Block (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

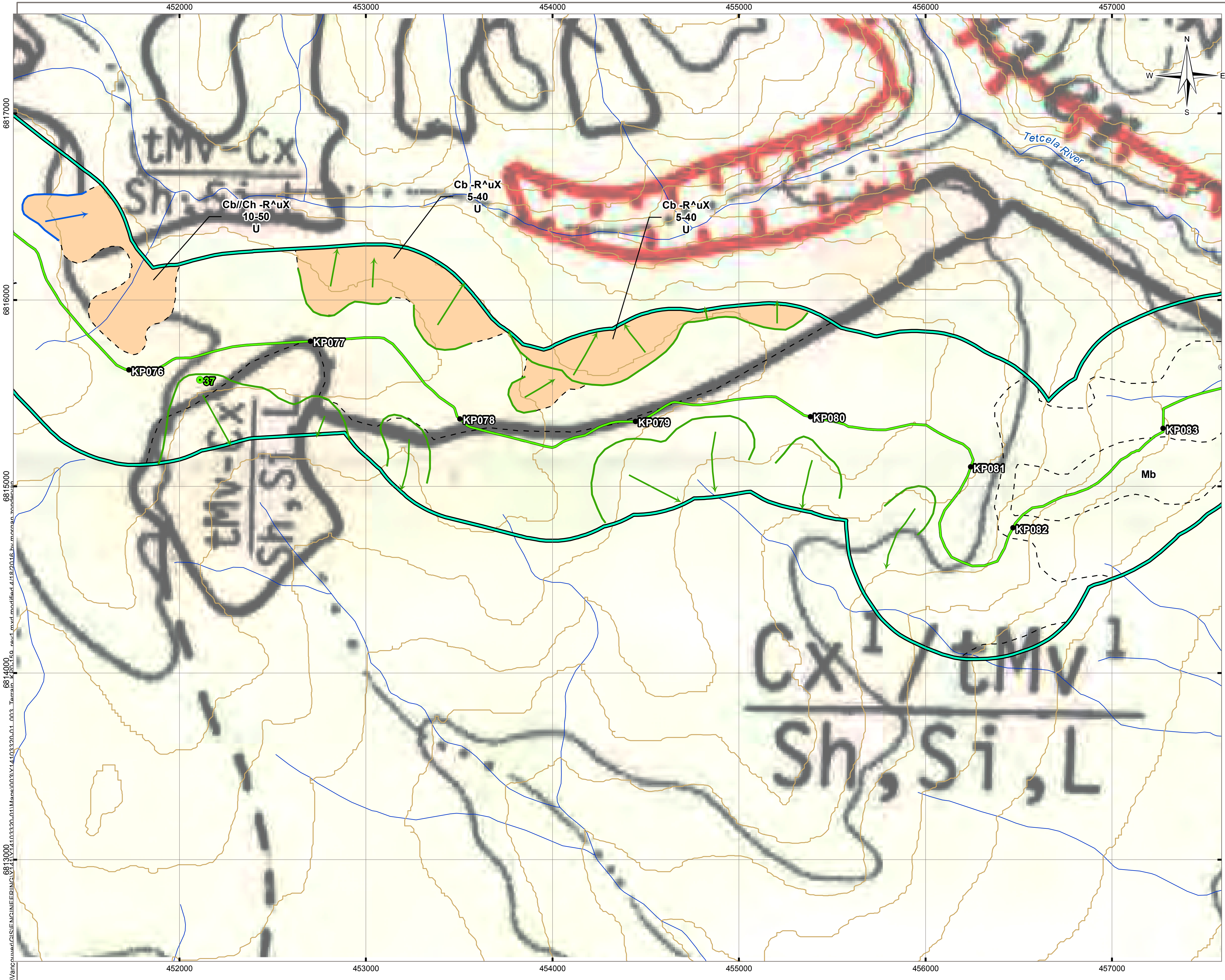
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A11



LEGEND

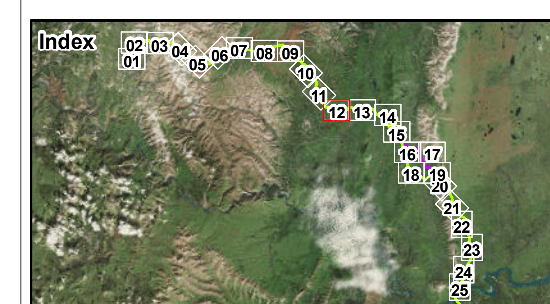
- 1 km Buffer

Field Site

- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION UTM Zone 10
DATUM NAD83
CLIENT CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

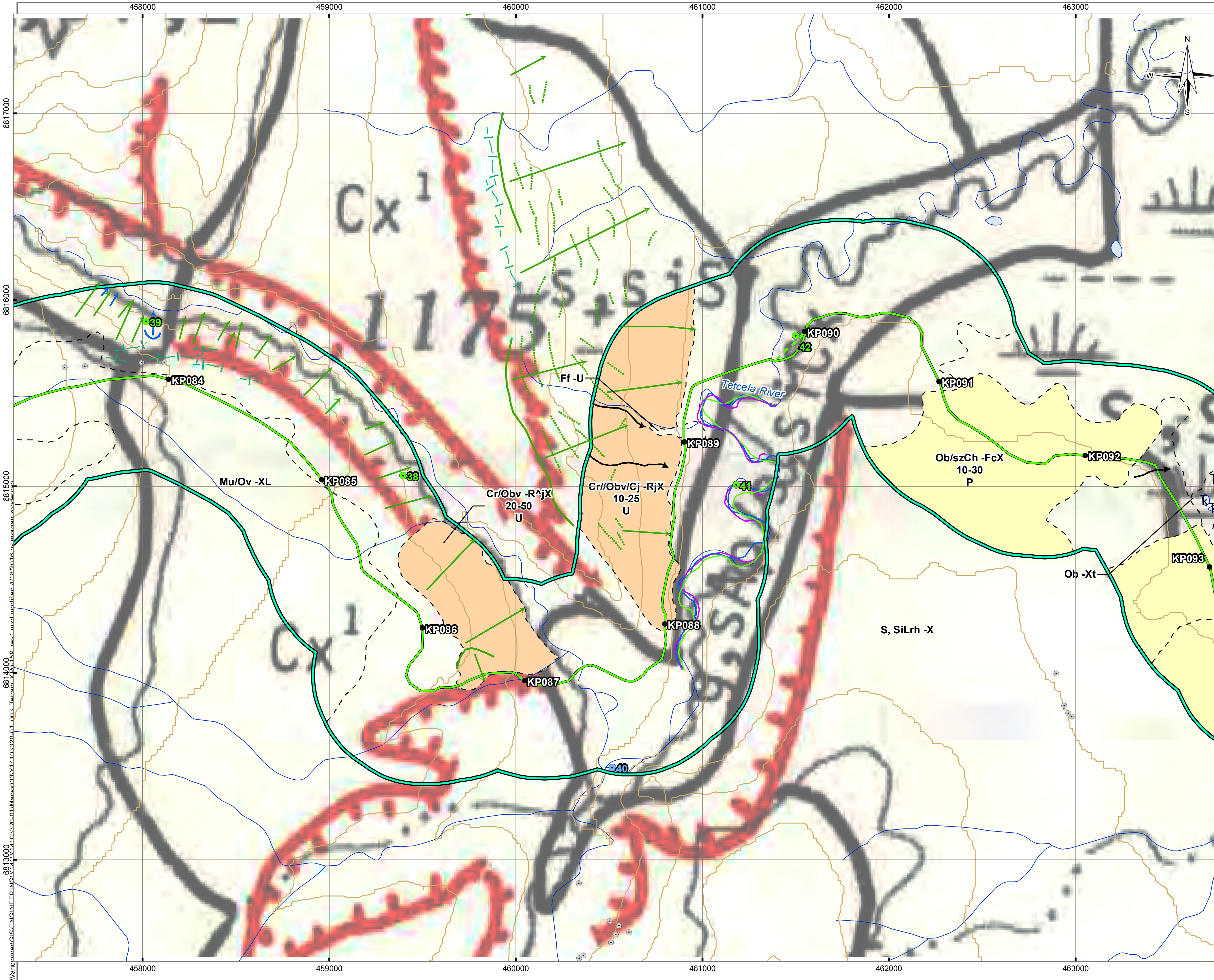
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE Tt EBA-VANC
DATE April 18, 2016

Figure A12



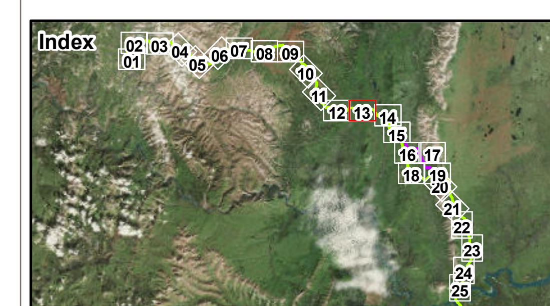
LEGEND

1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Gully
- Thermokarst Terrain
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1994)
- Slide Block (1949)
- River Position (1949)
- River Position (1994)
- River Position (Post-1994)
- Tension Crack (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

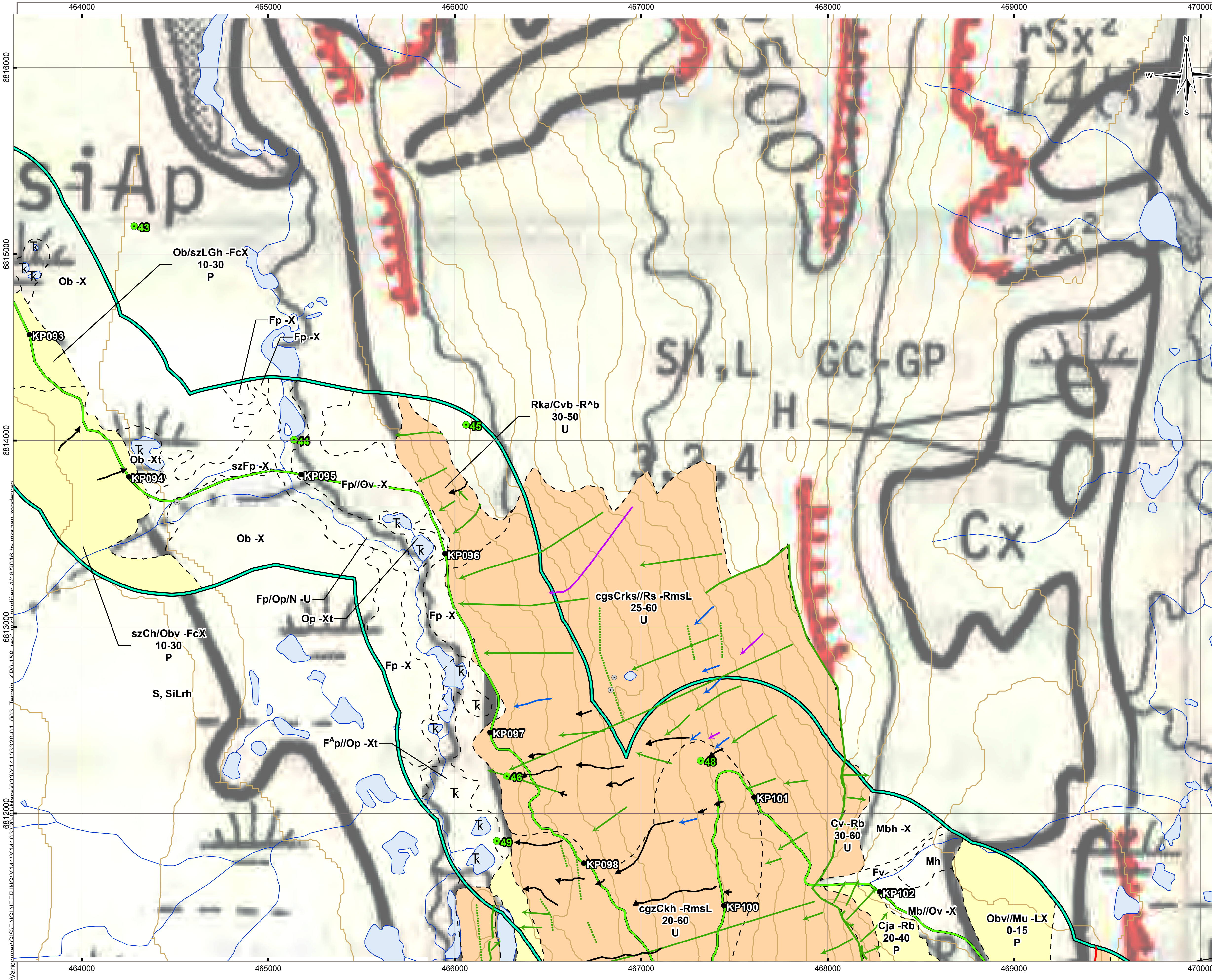
PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000 (400 200 0 400 Metres)

TETRA TECH EBA

FILE NO.				
Y14103320-01_003_Terrain_KP0-159_rev1.mxd				
PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1
OFFICE	DATE			
Tt EBA-VANC	April 18, 2016			

Figure A13



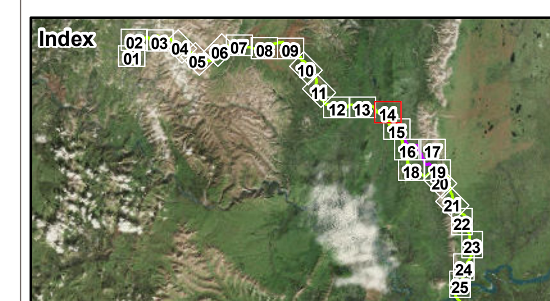
LEGEND

1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Gully
- Thermokarst Terrain
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1962)
- Slide Block (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

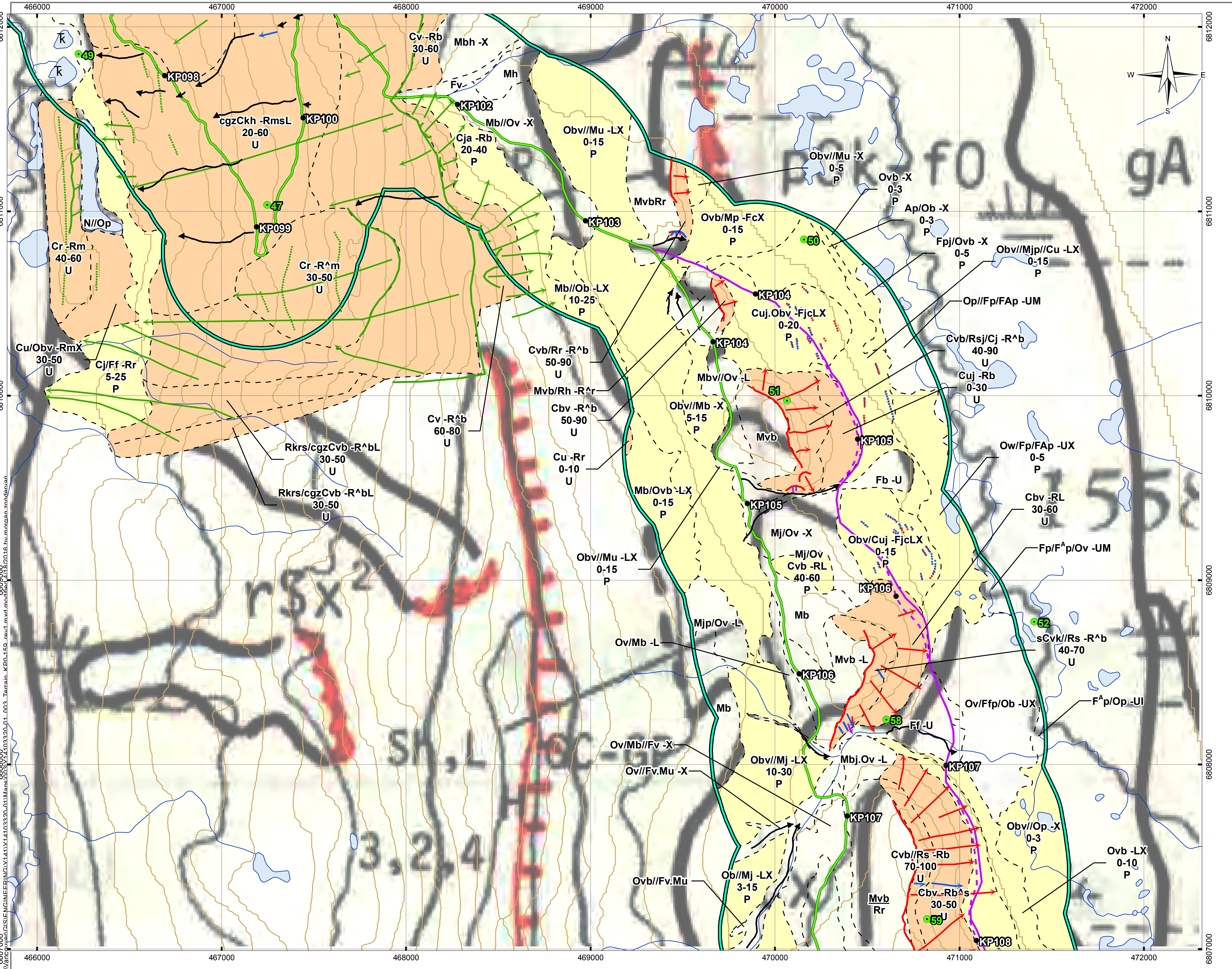
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A14



LEGEND

1 km Buffer

Field Site

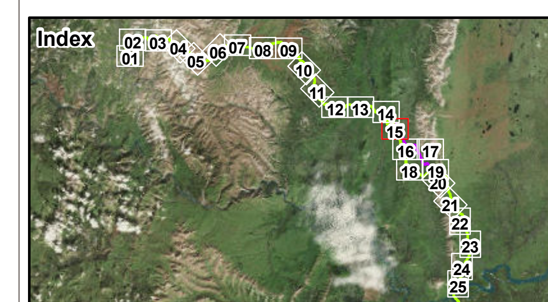
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Thermokarst Terrain
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1962)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1962)
- Landslide Head Scarp Large (1994)
- Slide Block (1949)
- Slide Block (1962)
- Slide Block (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES

Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS

ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

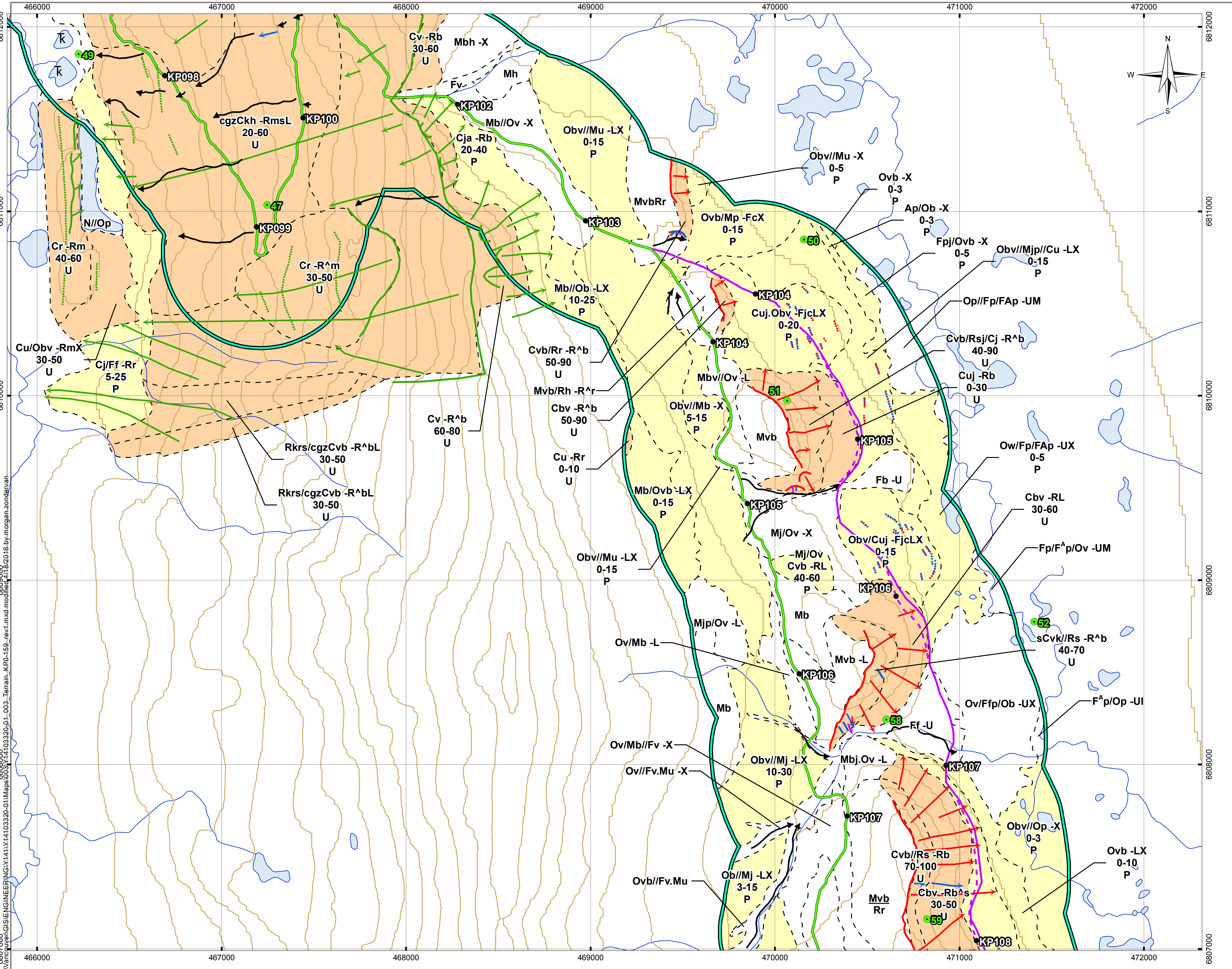
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A15a

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003\Y14103320-01_003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by morgan.zondervan



LEGEND

1 km Buffer

Field Site

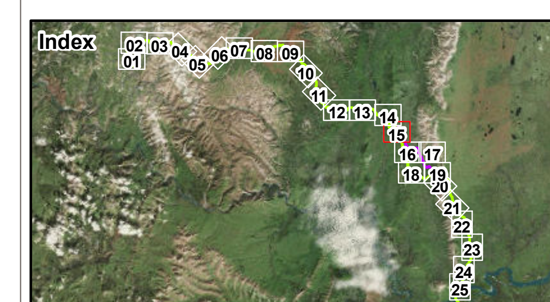
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Thermokarst Terrain
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1962)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1962)
- Landslide Head Scarp Large (1994)
- Slide Block (1949)
- Slide Block (1962)
- Slide Block (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

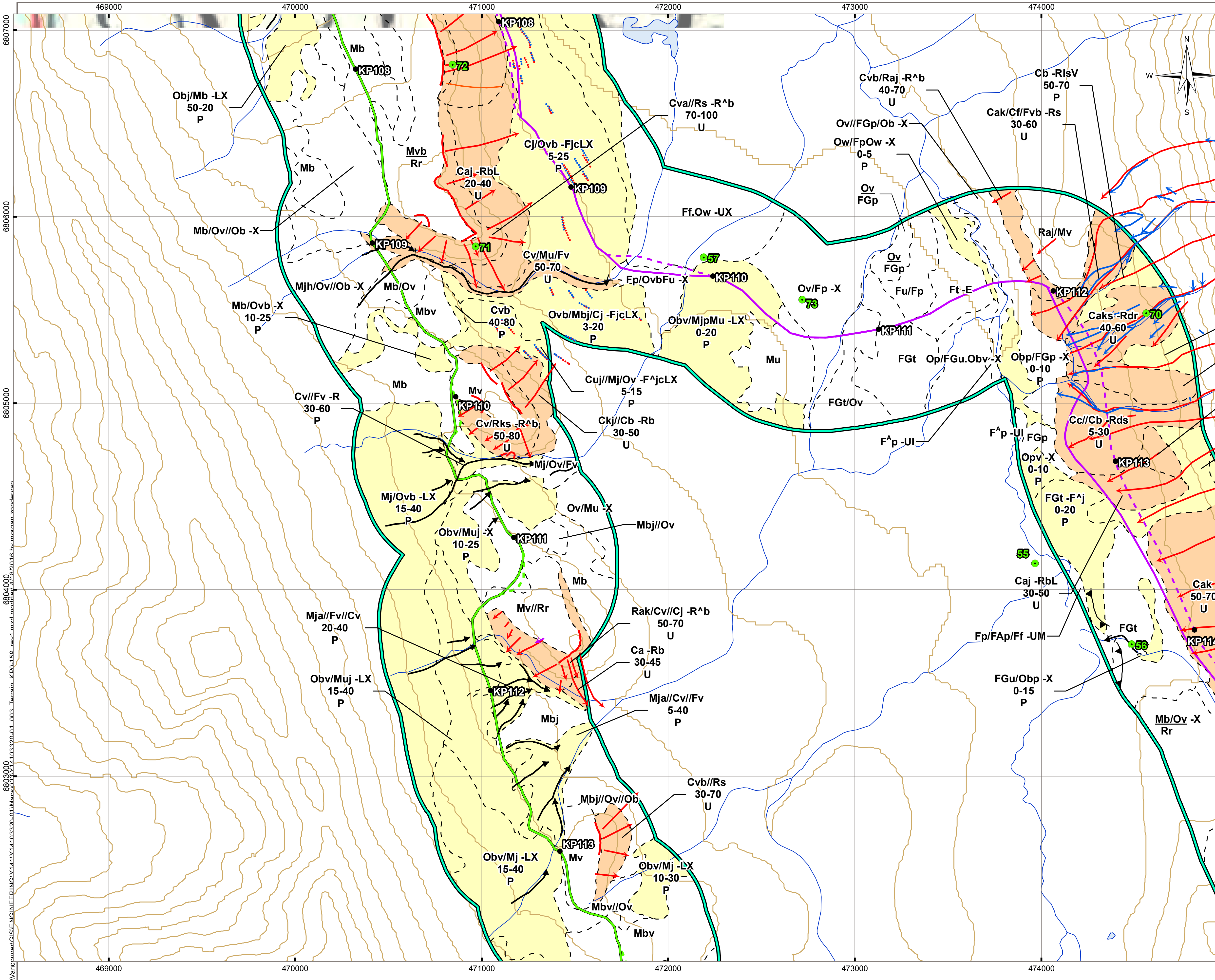
Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

FILE NO.				
Y14103320-01_003_Terrain_KP0-159_rev1.mxd				
PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1
OFFICE	DATE			
Tt EBA-VANC	April 18, 2016			

Figure A15b

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003\Y14103320-01_003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by morgan.zondervan



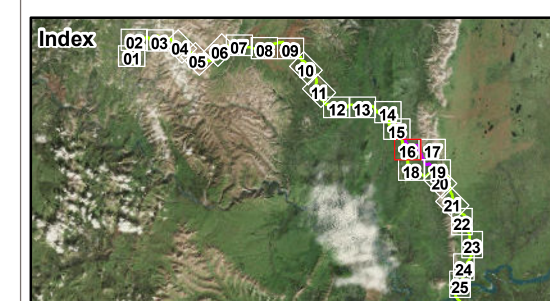
LEGEND

1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Gully
- Meltwater channel (major)
- Landslide Failure Scar Large (1962)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1962)
- Slide Block (1962)
- Slide Block (1994)
- River Position (1962)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

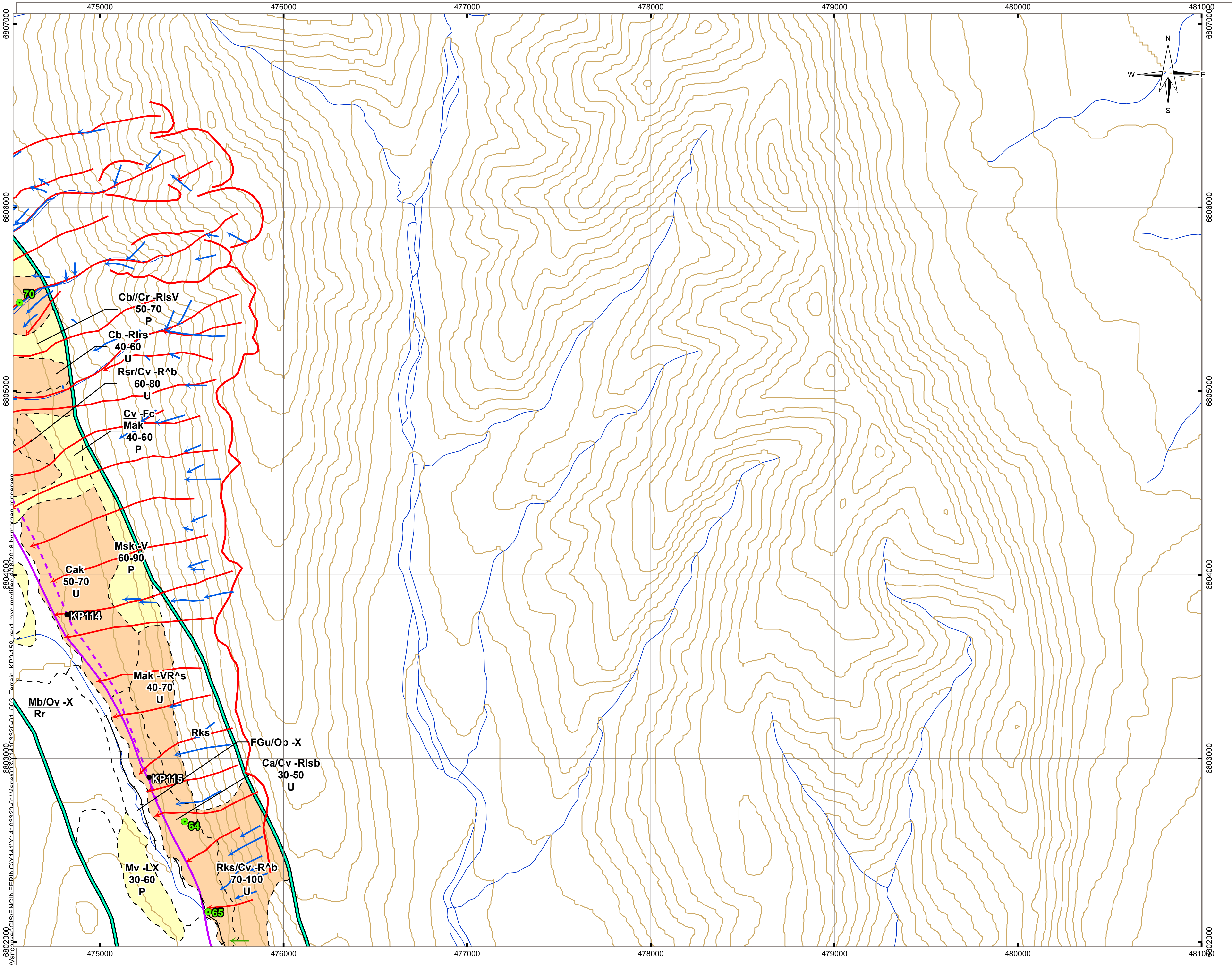
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A16

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003\Y14103320-01_003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by morgan.zondervan



LEGEND

1 km Buffer

Field Site

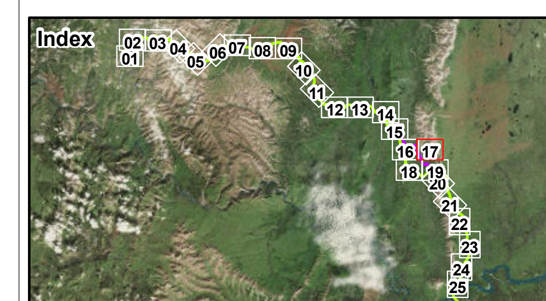
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Meltwater channel (minor)
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1962)
- Landslide Failure Scar Large (1994)
- Landslide Head Scarp Large (1962)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

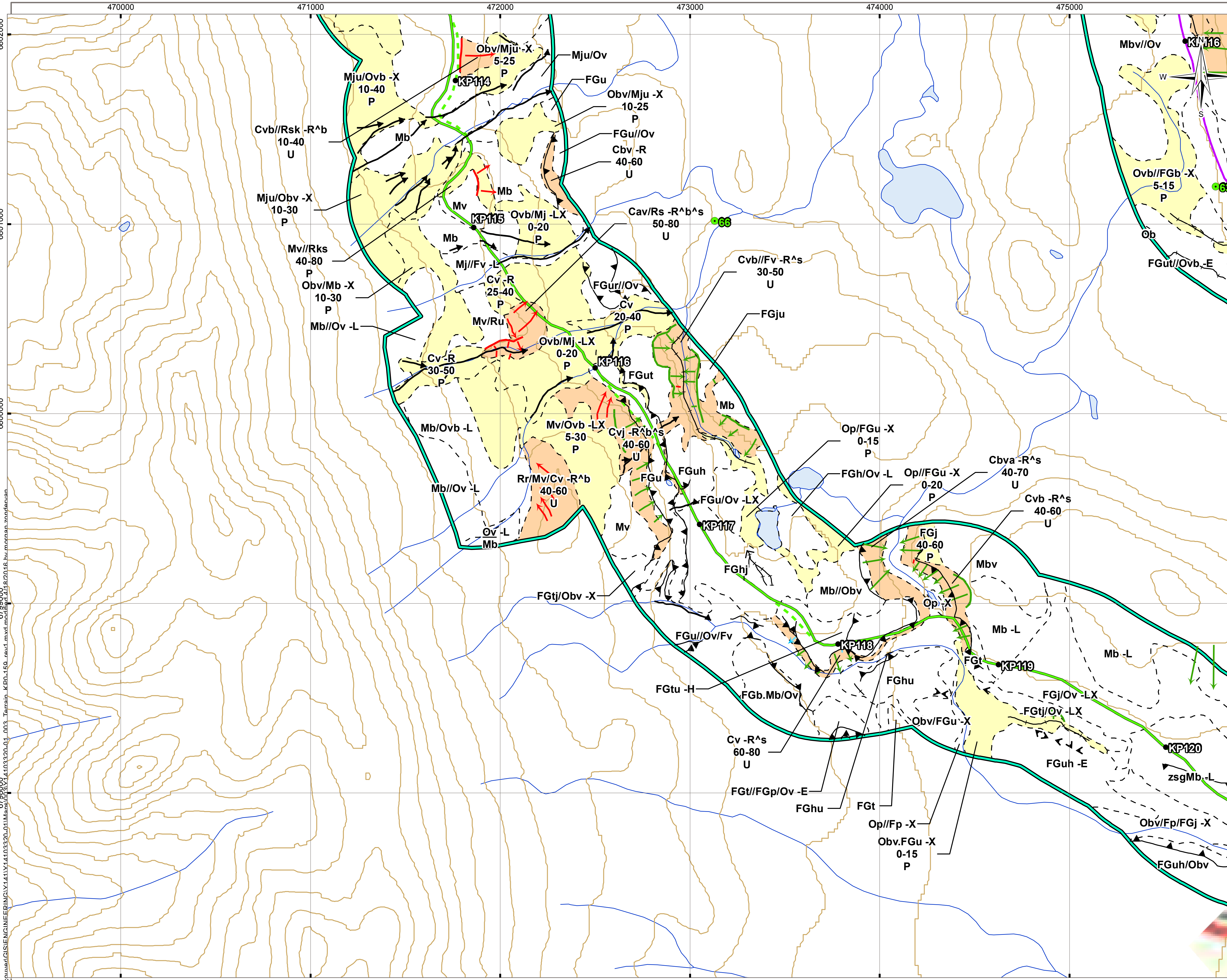
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A17



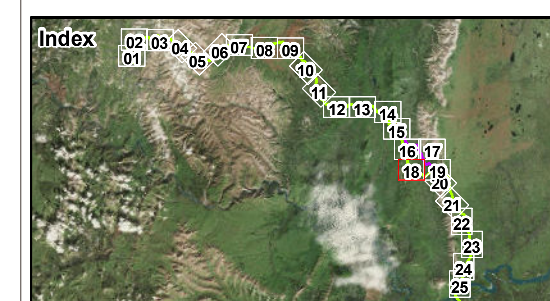
LEGEND

1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Esker, direction of paleoflow unknown
- Gully
- Meltwater channel (major)
- Meltwater channel (minor)
- Meltwater channel (minor, flow indicated)
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1962)
- Landslide Failure Scar Large (1982)
- Landslide Head Scarp Large (1949)
- Landslide Head Scarp Large (1962)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

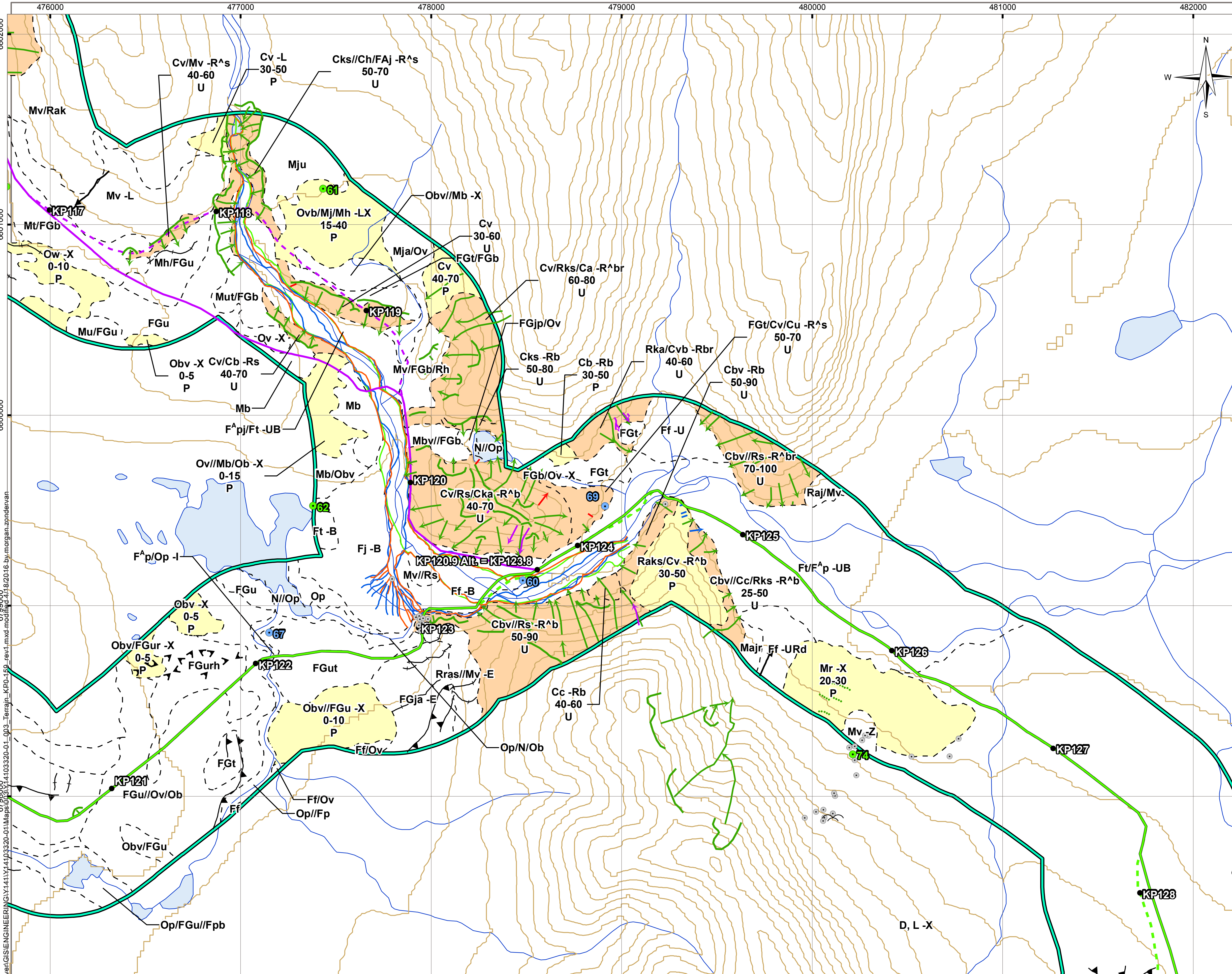
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A18

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003\Y14103320-01_003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by morgan.zondervan



LEGEND

1 km Buffer

Field Site

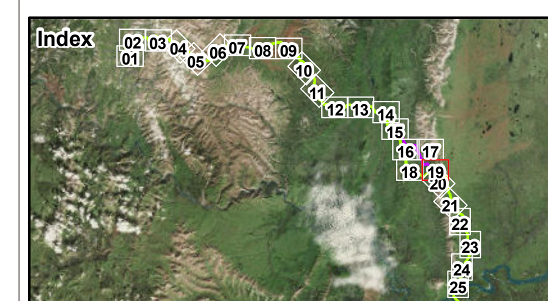
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Esker, direction of paleoflow unknown
- Gully
- Meltwater channel (major)
- Meltwater channel (minor)
- Relic Patterned Ground
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1962)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Slide Block (1949)
- River Position (1949)
- River Position (1962)
- River Position (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

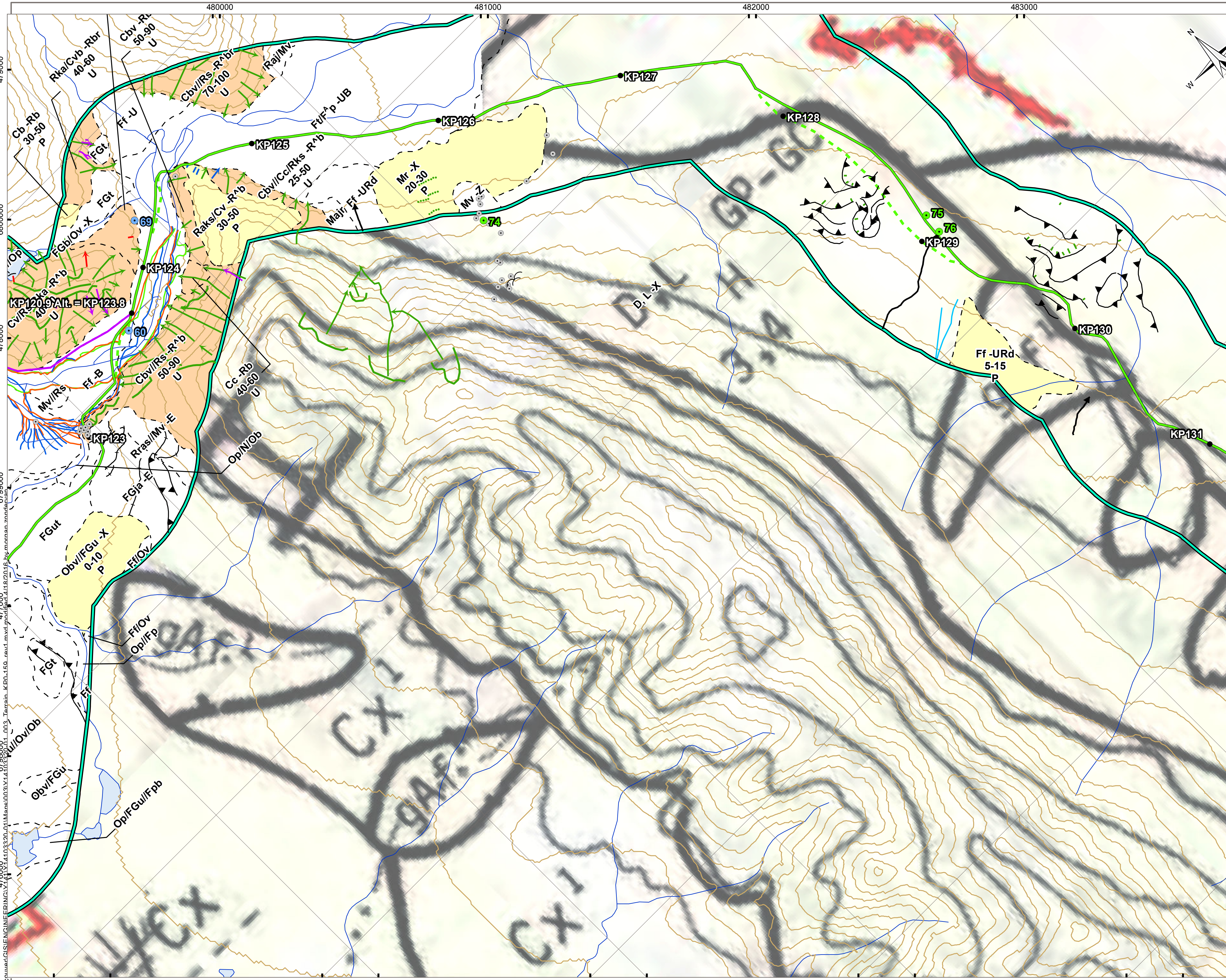
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A19



LEGEND

- 1 km Buffer

Field Site

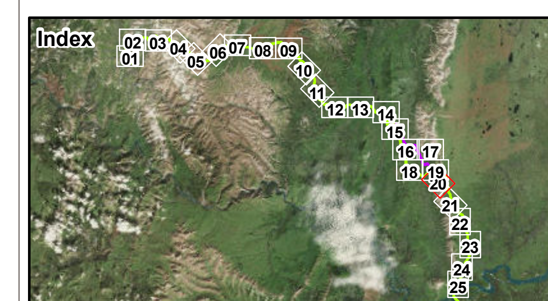
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Meltwater channel (major)
- Meltwater channel (minor)
- Relic Patterned Ground
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (1962)
- Landslide Failure Scar Large (1994)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- Slide Block (1949)
- River Position (1949)
- River Position (1962)
- River Position (1982)
- River Position (1994)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

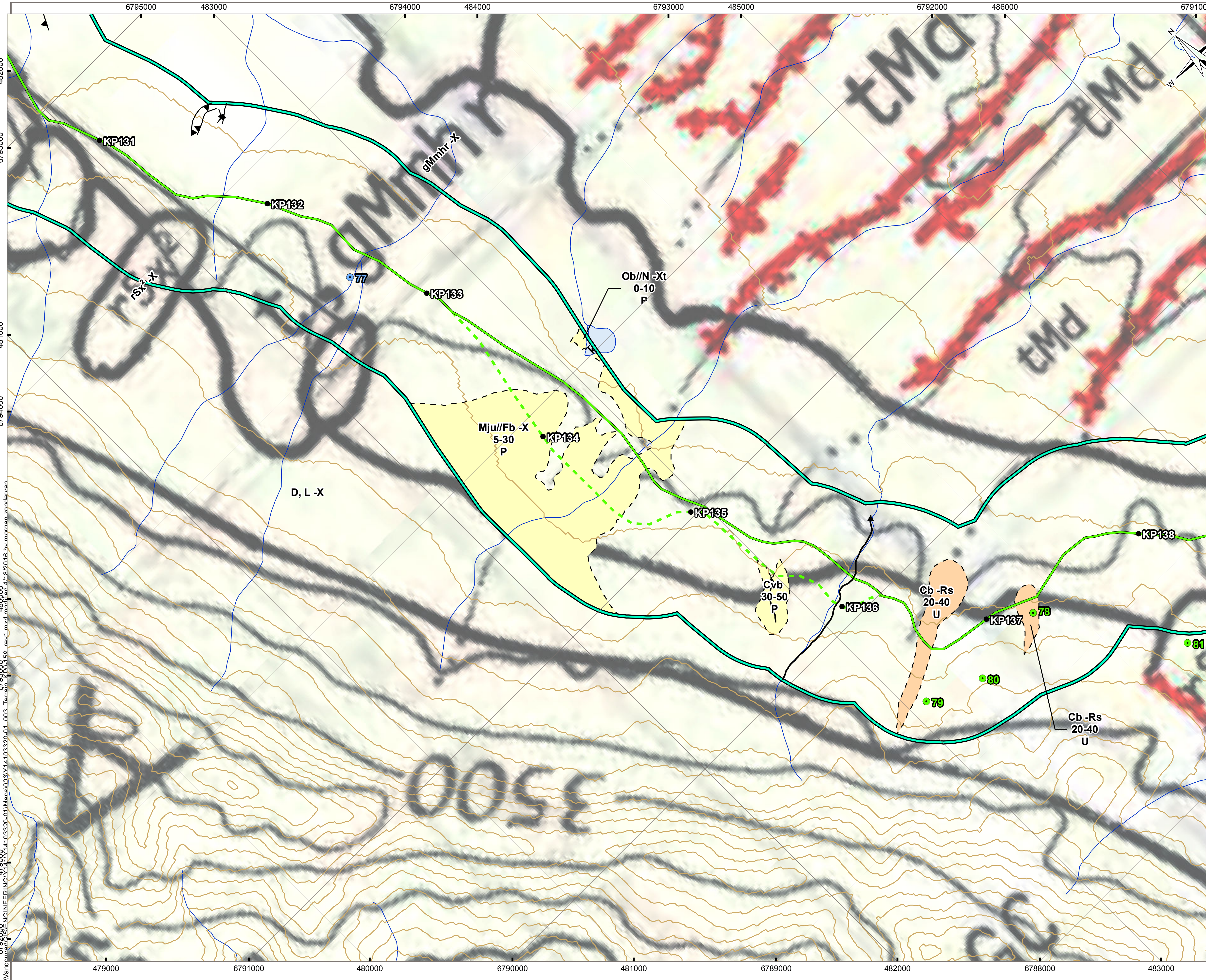
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A20



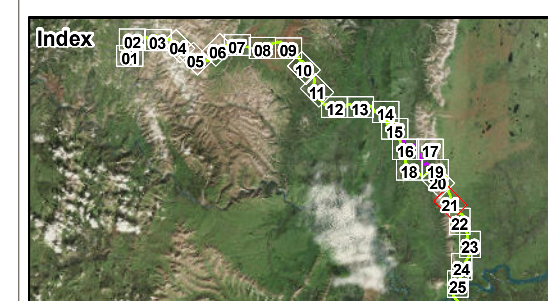
LEGEND

- 1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Gully
- Meltwater channel (major)
- Thermokarst Terrain
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

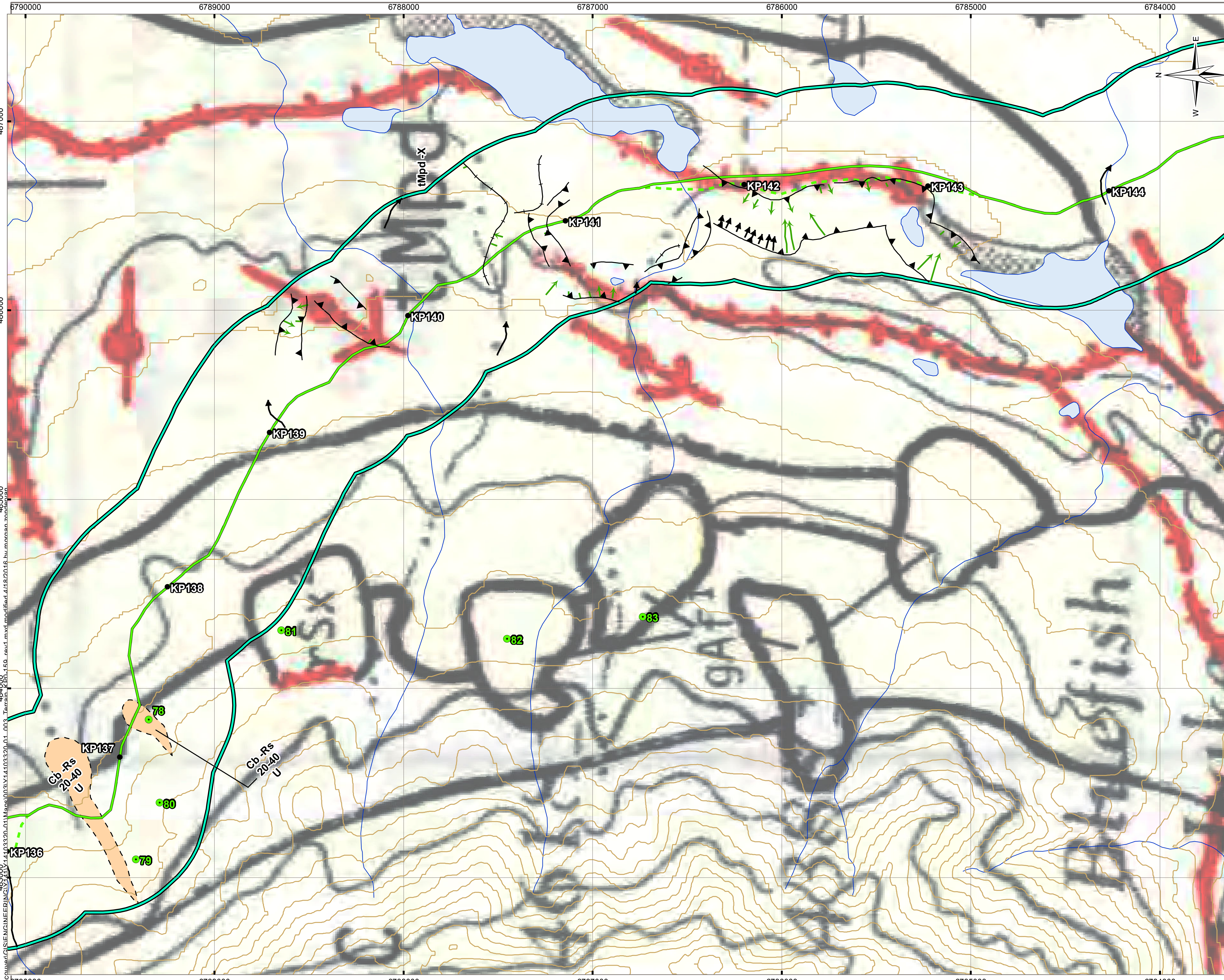
TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A21



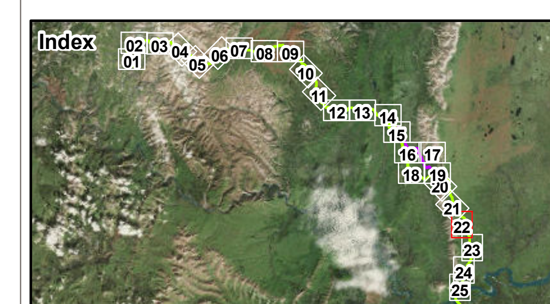
LEGEND

- 1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Gully
- Meltwater channel (major)
- Meltwater channel (minor)
- Landslide Failure Scar Large (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A22

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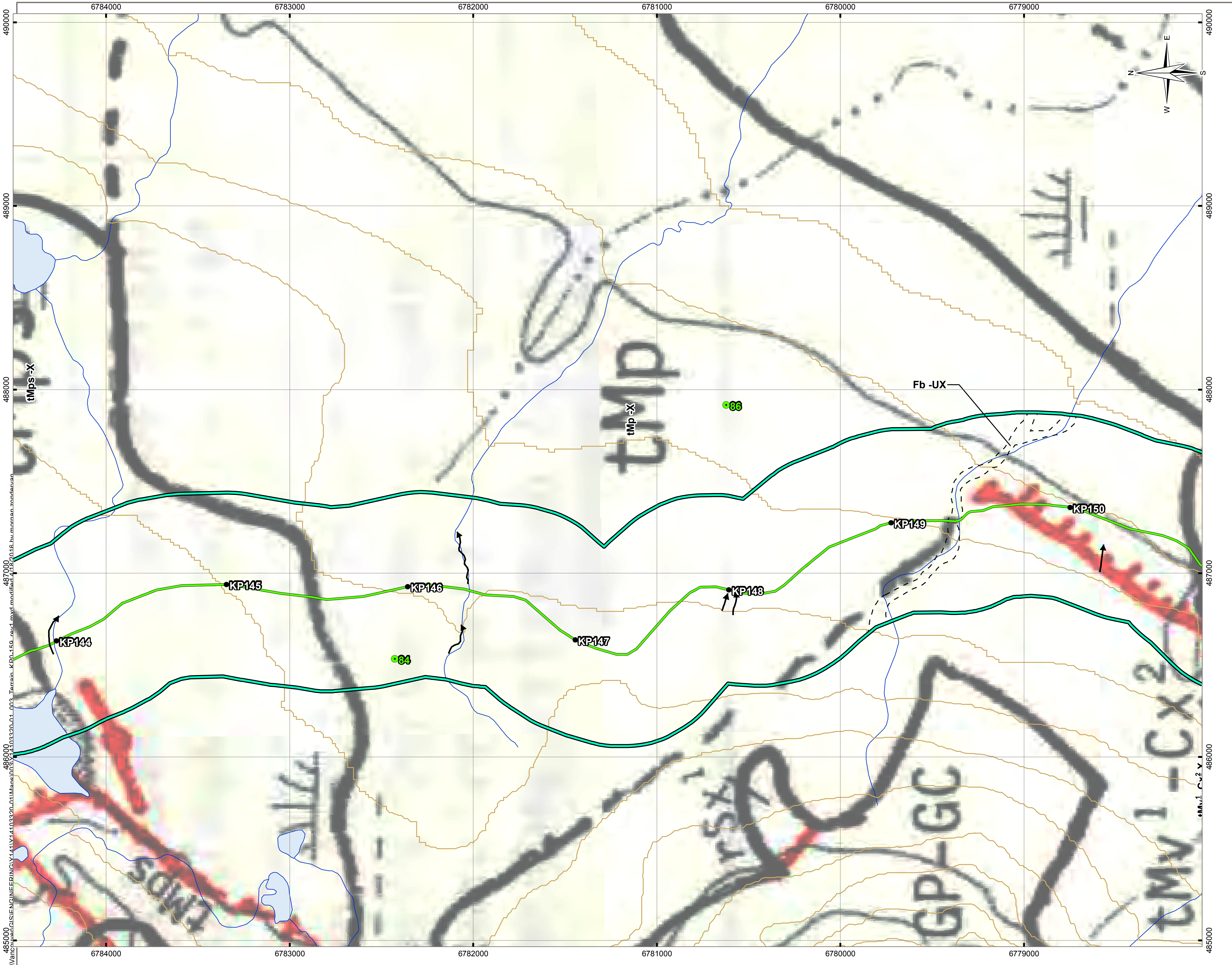


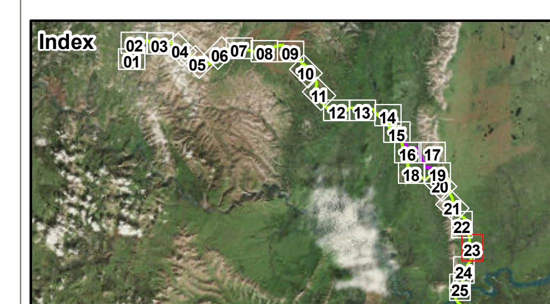
LEGEND

1 km Buffer

Field Site
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class
- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology
- Gully
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

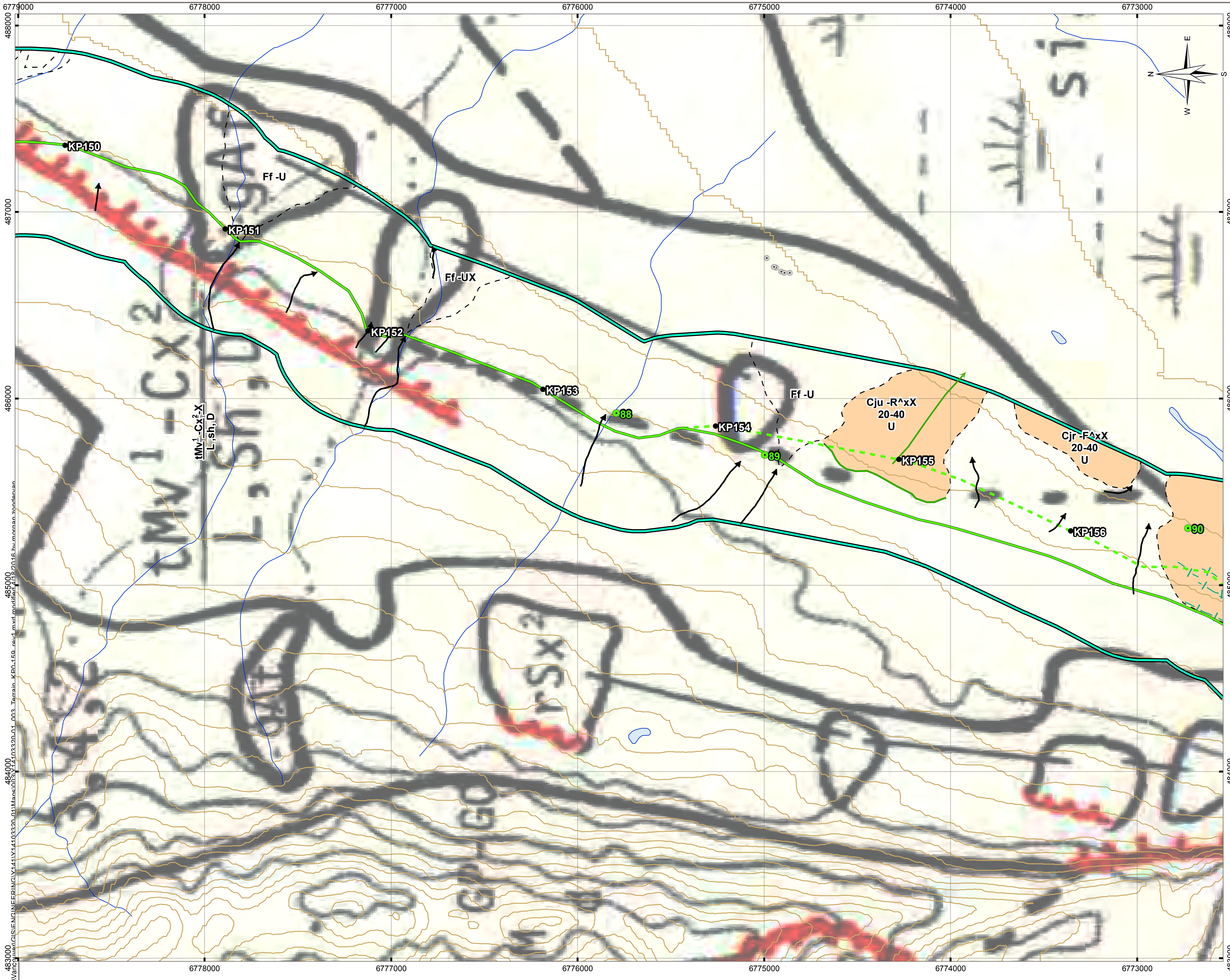
FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A23



LEGEND

1 km Buffer

Field Site

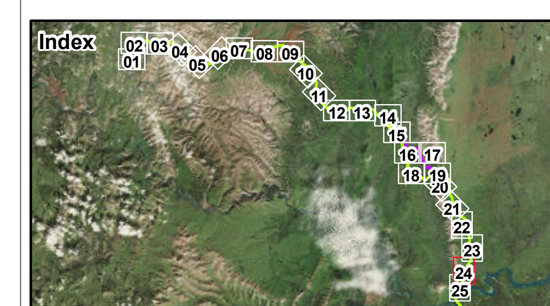
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide Failure Scar Large (1949)
- Landslide Head Scarp Large (1949)
- Tension Crack (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES

Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS

ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000

400 200 0 400

Metres

FILE NO.

Y14103320-01_003_Terrain_KP0-159_rev1.mxd

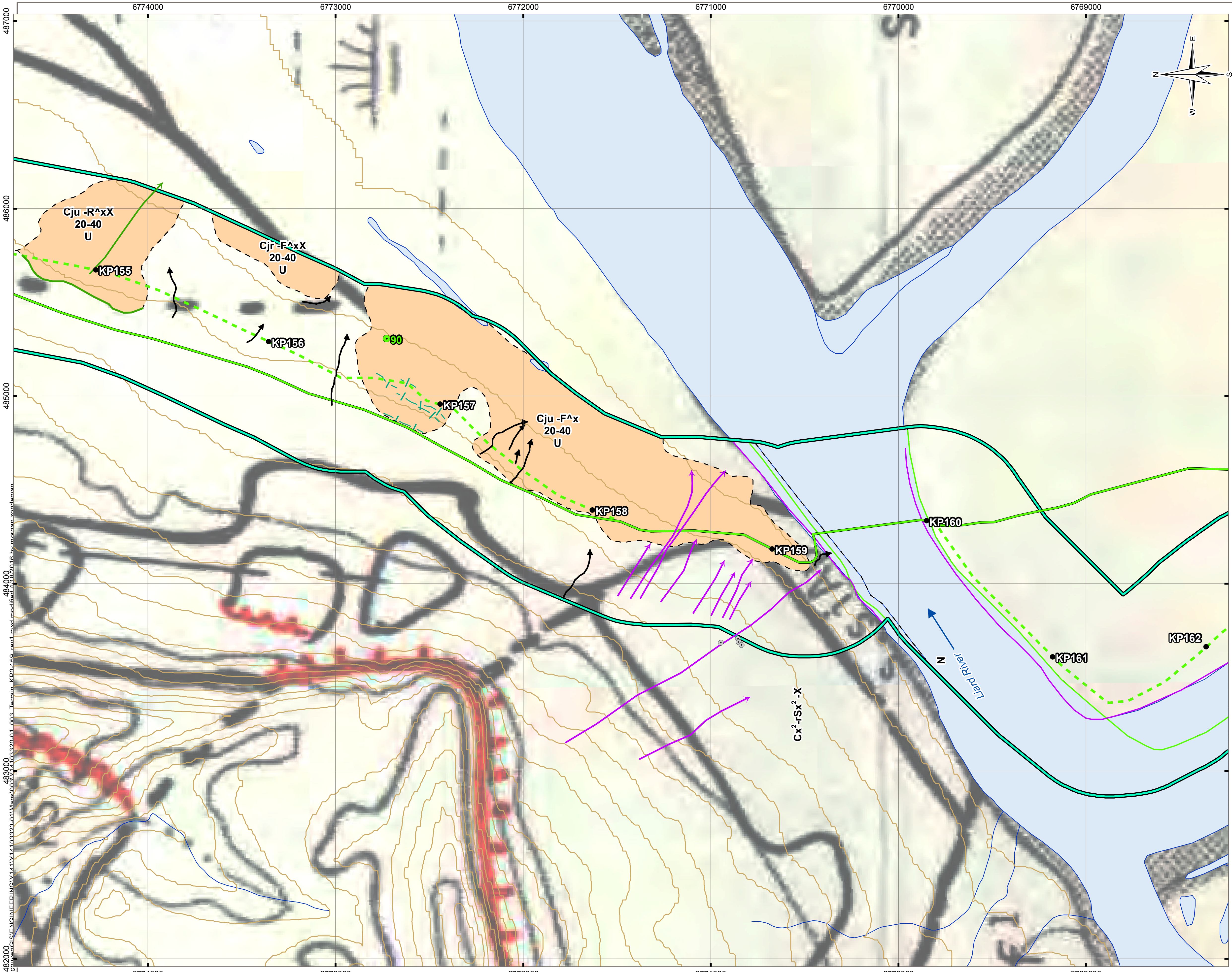
TETRA TECH EBA

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A24

Q:\Vancouver\GIS\ENGINEERING\Y141\Y14103320-01\Maps\003\Y14103320-01_003_Terrain_KP0-159_rev1.mxd modified 4/18/2016 by morgan.zondervan



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LEGEND

1 km Buffer

Field Site

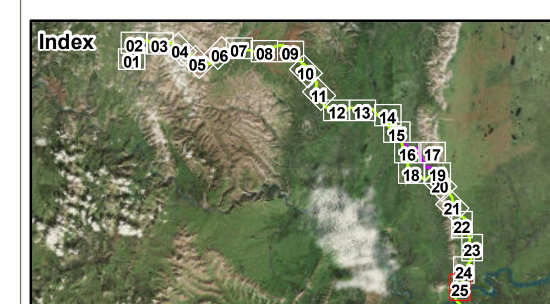
- Ground-based Observation
- Airborne Observation
- TFSA
- Terrain Boundary

Slope Stability Class

- P Potentially Unstable Terrain
- U Unstable Terrain
- Prairie Creek Access Road (Apr 5, 2016)
- Prairie Creek Access Road (Feb 24, 2015)
- Alternative Alignment (Apr 5, 2016)
- Alternative Alignment (July 30, 2015)

Geology

- Gully
- Landslide Failure Scar Large (1949)
- Landslide Failure Scar Large (2012)
- Landslide Head Scarp Large (1949)
- River Position (1949)
- River Position (Post-1994)
- Tension Crack (1949)
- Contour (40 m)
- Watercourse
- Waterbody



NOTES
Base data source: CanVec; GeoBase.
Surficial Geology based on Hawes, 1980 and 1981

STATUS
ISSUED FOR REVIEW

PRAIRIE CREEK ALL-SEASON ROAD

Modified Terrain Stability Mapping

PROJECTION	DATUM	CLIENT
UTM Zone 10	NAD83	CANADIAN ZINC CORPORATION

Scale: 1:20,000
400 200 0 400
Metres

TETRA TECH EBA

FILE NO.
Y14103320-01_003_Terrain_KP0-159_rev1.mxd

PROJECT NO.	DWN	CKD	APVD	REV
Y14103320-01.003	MEZ	SL	SMC	1

OFFICE	DATE
Tt EBA-VANC	April 18, 2016

Figure A25

APPENDIX A
TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA's Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA's Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA's instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

REPLY TO BOARD IR'S 4 AND 7
CHANNEL CROSSINGS AND MEANDER BENDS

IR4 – CHANNEL CROSSINGS

1. An updated list of major and minor crossings is provided with our reply to DFO IR1, and includes the alternate alignment.

2. Each of the major crossings is discussed below. The information is in addition to that provided by Allnorth in the DAR Addendum, Appendix A, Table 2, and should be read in conjunction with it.

Km 6.1, Casket Creek

Casket Creek is about 5 m wide, within a floodplain about 80 m wide. See photo below showing existing bridge crossing under construction. The channel is stable during low to medium flows, but secondary channels to the north carry water during high flows. There is a smaller tributary creek that enters the floodplain on the north side, but is dry except during high flows. The main channel can carry a significant bedload during high flows, as evidenced by the alluvial fan material in the floodplain and upon entering the Prairie Creek valley. During high flows, there are multiple braided channels downstream of the crossing location. See 2nd photo below.

The proposed crossing design consists of a larger span to replace the existing span. The southern abutment is rock. The crossing location is at the point where the floodplain enters the Prairie Creek valley. Crossing the floodplain is not ideal, but is the best location considering the less suitable terrain upstream and downstream. The crossing design includes armour elements to train the main channel under the bridge, and prevent a back eddy. Culverts will be placed in the northern approach to carry water during high flows that departs from the main channel upstream. A culvert is also provided for the northern tributary channel. The road bed on the alluvial fan will be at a lower elevation than the bridge and armoured against erosion from high flows. In the event of very high flows, water will be able to flow over the road bed in addition to under the bridge and through the culverts carrying bedload. This design minimizes the risk of damage to road structures. The design also provides flow paths for water during all flows, and outlets for bedload movement beyond the road alignment without upstream accumulation. Avulsion of the main channel is unlikely given that the channel enters the floodplain on the south side upstream. An air photo image from 1949 is attached (Km 6), with a comparable one from 2012 for comparison. These show that the main channel has remained relatively stable along the south side of the floodplain. However, monitoring during high flows will occur, and additional channel training implemented if necessary to avoid an avulsion to the north.

Km 20.5, upper Sundog tributary

The stream at this non-fish bearing crossing is about 5 m wide, and the width at the high water mark (HWM) about 10 m. The photo below shows that the channel is confined by slopes on both sides, with little risk of overbank flooding or avulsion. The crossing location was moved just upstream from the winter road location to allow a more perpendicular crossing alignment. Large culverts with armour will allow passage of high flows and moderate bedload without erosion or channel constriction.

Km 23.4, upper Sundog Creek

The photo above shows the rock abutments of the proposed span structure where the creek about 7 m wide flows through a deep canyon at its narrowest point (13 m). All structures will be >5 m above the HWM avoiding any interaction with, and effects on, the stream.

Km 25.3, upper Sundog tributary

The photo in the Allnorth report shows the alignment of the proposed span structure with abutments on rock crossing an incised, steeply-dipping tributary. The creek is about 4 m wide and width at the HWM 14 m. All structures will be >5 m above the HWM avoiding any interaction with, and effects on, the stream. This crossing is necessitated by moving the road alignment to the south side of Sundog Creek to avoid the talus slopes on the north side. The crossing location is dictated by the grade of the approaches, and is preferable to upstream or downstream.

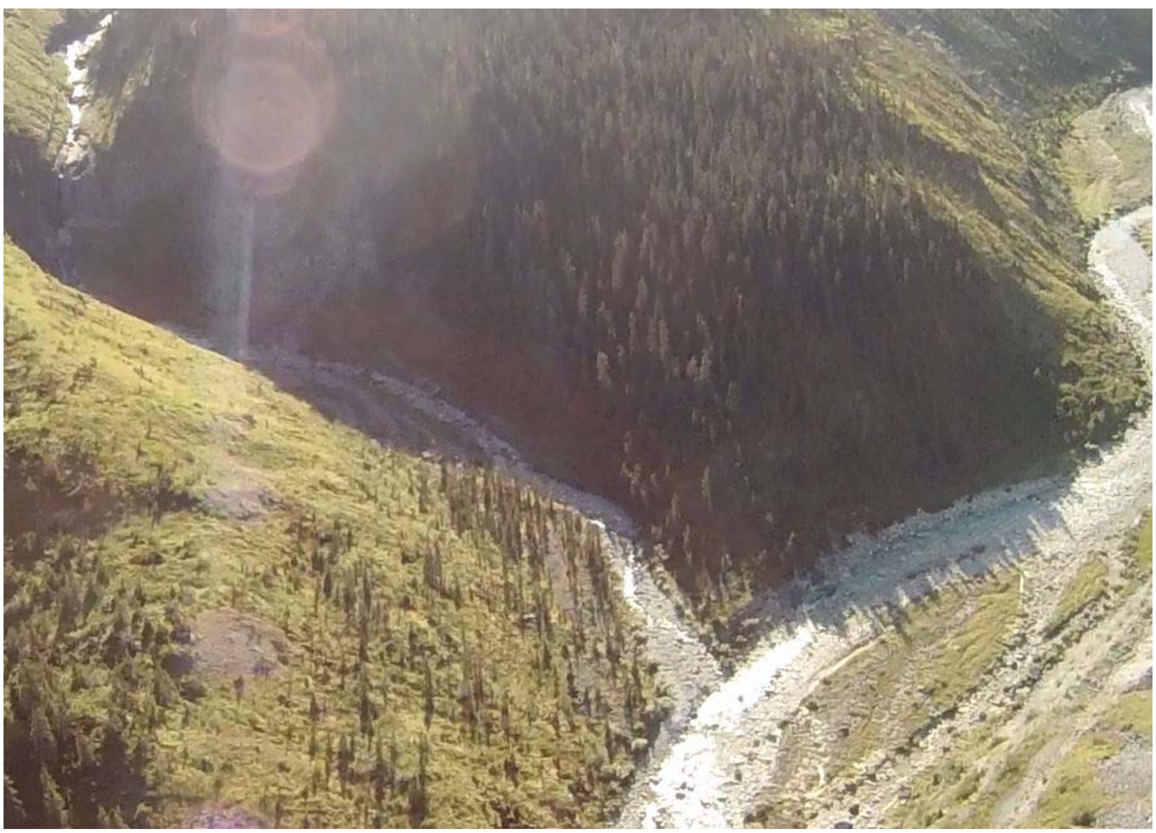
Km 28.3, upper Sundog Creek

This crossing location is dictated by the previously proposed eastern end of the road re-alignment where the road crosses to the north bank to re-join the old winter alignment. The channel width here is 7 m, and width at the normal HMW 12 m. However, there is a valley bottom width of 45-50 m, and evidence of past high flows that occupied another channel on the south side, and formed a wider channel on the north side. See photo below looking upstream. The crossing design accounts for these issues (see photo in Allnorth report). The upstream inlet to the old southern channel will be blocked by an armoured berm. Overbank flooding on the north side will be prevented by extending the northern bridge abutment west with armour, training all flow under the bridge, which will be of sufficient height to allow the constricted water to pass with a higher water level. These elements, together with armoured abutments, will prevent channel avulsion, flooding and damage to the crossing structure, and will allow passage of high flows and moderate bedload. The crossing structures will not alter the shape and hydraulics of the channel, and so bed material accumulation will not occur, as is the case at present.

The crossing at Km 28.8 discussed below was deemed to be a hazard risk due to the unstable slope on the east side of the northern approach. Moving the crossing location upstream is not ideal because of the slopes of the approaches which would necessitate a very long span. Consequently, Allnorth have proposed an alternate approach consisting of retaining the re-alignment on the south side of the valley from Km 28 to 29. Approximately 2500 m^3 of rock will need to be removed to build the road bed over this section, as well as a tributary crossing at Km 28.6. This change will eliminate the need for the main stem crossings at Km 28.3 and 28.8. Tetra Tech EBA previously prepared a magnitude and frequency analysis for terrain hazards, which was submitted with CZN’s reply to the Reasons for Decision on Adequacy of the DAR. An updated version of the analysis reflecting the extension of the road re-alignment to Km 29 has been uploaded to the on-line response system.

Km 28.6, upper Sundog tributary

As explained above, this tributary crossing is necessitated by extending the road re-alignment on the south side of Sundog Creek. The creek valley is incised, but as shown in the photo below, the valley bottom is quite broad near the mouth, and the banks of the creek are quite shallow. At the crossing location, the creek is about 3.5 m wide, and width at the HWM is 8 m. The west side of the crossing has a rock slope, and just upstream there is rock in the east bank. The crossing will consist of a span with abutments on stable rocky banks above the HWM. There is no avulsion risk, and no restriction on bedload movement.



From an effects perspective, this crossing and the alignment it is part of, represents a net reduction in potential effects because two main stem crossings are eliminated, and some unstable slope portions on the north side are also avoided. As such, the potential for sediment, erosion and environmental effects on road structures is reduced. The crossing approaches require blasting, but as for other areas, this would be done at a time of low flow, and checks will be made that wildlife and fish are not proximal to the blast location. The tributary is likely accessible to fish from the main stem, so it will be assumed that fish could be present at the crossing location.

Km 28.8, upper Sundog Creek

The crossing location was to be moved upstream by about 100 m in response to a terrain hazard identified on the east side of the northern approach at the previous location. However, this crossing will no longer be needed. At the revised crossing location, the stream is about 9 m wide, and width at the HWM 17 m. The floodplain is only slightly greater than the HWM width here due to a narrowing of the valley as a result of a rock spur on the south side. The revised crossing design would consist of a relatively straight-forward, but long, span with no overbank flooding or channel avulsion issues. The design would also not interfere with natural bedload movement. The first photo below shows the old winter crossing location on the right, and the proposed revised location in the centre. The second photo is a closer shot of the revised crossing.

Km 39.4, lower Sundog tributary

A bridge is proposed at Km 39.4 to cross a major tributary of Sundog Creek just upstream of Cat Camp. The crossing location is on the historical floodplain of the main stem. The tributary from the south enters the floodplain via a gorge in bedrock. Once at the floodplain, the tributary abuts a rock wall on the east side, as shown in the photo below which looks south. The crossing is proposed after the rock wall ends and at a location where the channel is narrower after two braided channels merge (see 2nd photo). A stabilized ‘island’ is used for the western abutment, and stabilized old floodplain next to Cat Camp is used for the eastern abutment. At this location, the stream width is 8 m, and width at the normal HWM 15 m. A crossing location at the ‘nose’ of the rock wall is not preferred because of complications with a braided channel and the close proximity of a crossing of a secondary channel off the main stem on the western approach.

The risk of avulsion of the tributary is considered low because of the rock wall on the eastern side and propensity of the stream to flow along the wall. The channel is straight and normal bed load movement is assured. However, there are risks posed by the braided streams of the main stem upstream. An old high flow channel is visible from Km 38.85-38.95, but is now stable and vegetating. The road bed will be elevated and armoured over this section (see Allnorth report). After a large, stable island, there are two high water channels at Km 39.25 and 39.35 crossed by the road. The entrance to the larger 1st channel will be filled and armoured. The 2nd channel will be filled to complete the road bed, and the slope armoured.

Air photos of the crossing areas are attached for 1949 and 2012 (Km 40). These show that the channels in the area, including the tributary, have remained quite stable. One exception is the Km 38.9-39 Sundog main stem side channel which was active in 1949. However, the other side channels have not changed significantly.

Km 43.15, lower Sundog tributary

This non-fish bearing crossing is in vegetated, open terrain. See photo below. The winter crossing crosses a broader part of the floodplain where overbank high flow has occurred in the past. The proposed all season crossing is about 15 m to the west (right) where the channel is more confined between stands of trees. At this location, the channel is about 5 m wide, and width at the HMW about 7 m. The approaches are also considerably drier. There is little risk of channel avulsion or overbank flooding at the proposed crossing location, as indicated by the lack of evidence of this. The crossing design includes large culverts, but flows and the limited bedload would easily pass through the reach with no constriction or accumulation, respectively.

Km 53.55, Polje Creek

Polje Creek is a tributary of Sundog, and drains the Poljes. The channel is incised with banks 1-1.5 m high. Channel width is 6-7 m. The crossing location was chosen because of the straight and narrow channel, and absence of interfering meander bends and ox-bows on the approaches. The proposed span and abutments will be well above the stream due to the incised channel. Bedload is gravel and some cobble, and will pass easily.

The air photos of this crossing location attached show that, while there has been some change in the shape of the channel bends upstream and downstream since 1949, the channel at the crossing location has remained stable.

Km 87.25, Tetcela tributary

This crossing is of a large tributary to Tetcela River. The channel is about 7 m wide, and the floodplain between slightly incised banks (0.5 m) is about 11 m wide. The banks are heavily vegetated and stable (see photo in Allnorth report). The crossing location is upstream of the winter crossing, and was selected due to its narrower and unbraided nature. Bedload is coarse cobble, but crossing structures will not interfere, being above the HWM. The air photos attached (Km 87) show that the channel has not changed significantly since 1949.

Km 89.8, Tetcela River

The proposed crossing location is also the old winter crossing location, but a few metres upstream. The channel and floodplain is about 25 m wide. See photo below looking south. Just downstream of the eastern abutment is an area where flooding occurred relatively recently judging from the river bank and absence of vegetation. The bridge approach will be armoured in this area against back-eddy erosion. Bedload is silt and sand and will pass easily. As noted by Allnorth, there are vegetated old meander channels in the area, downstream on the east side for example. There have been no significant changes to the current channel since the 1981 winter road. However, the 1949 air photo (Km 90) shows that changes have occurred since that time. The channel had a downstream flow direction just east of north in 1949, now it is just west of north. This process took approximately 30 years. Erosion of the eastern bank upstream is possible, but this is at about 75 m from the crossing. Erosion of the western bank downstream is also possible, started just beyond the crossing. These longer term processes could eventually affect the crossing, and should be monitored. Bank armouring may be required in future to protect the crossing abutments.

Km 118.1 originally, now Km 119, Grainger tributary

This crossing is on the preferred alternate road alignment, and is of a debris flow channel that only appears to flow during prolonged rainfall. The bedload is coarse cobble, so it is possible that lower flows move within the cobble and are not visible. Regardless, during high water, it is a high energy system. The proposed crossing location has been moved 1.2 km downstream to accommodate an alignment change. This was in response to terrain mapping which identified an unstable area on the eastern bank. A detour around this area is impractical because of grades. The new crossing location avoids the unstable area. The 2012 LiDar shows the crossing to be dry at the time of air photo capture. At least two channels about 3 m wide are visible on the east side of the crossing, within a floodplain area about 37 m wide. The photo below shows that there is old floodplain on the western approach about 30 m wide. There is even older floodplain on the eastern approach, as indicated by mature tree cover, however there are channels in this floodplain which periodically have carried water. Multiple large culverts are proposed across the active floodplain, large enough to pass high water flows and bedload. In addition, the western approach will be armoured against high water flows departing from the floodplain, and the eastern approach will need to address the channels in the old floodplain. The 1949 air photo shows the eastern floodplain area as inactive at the time, but with less vegetation than at present. The eastern abutment of the crossing location is visible as a stable 'island'. Hence, the active channels at the crossing location seem to be stable in terms of alignment.

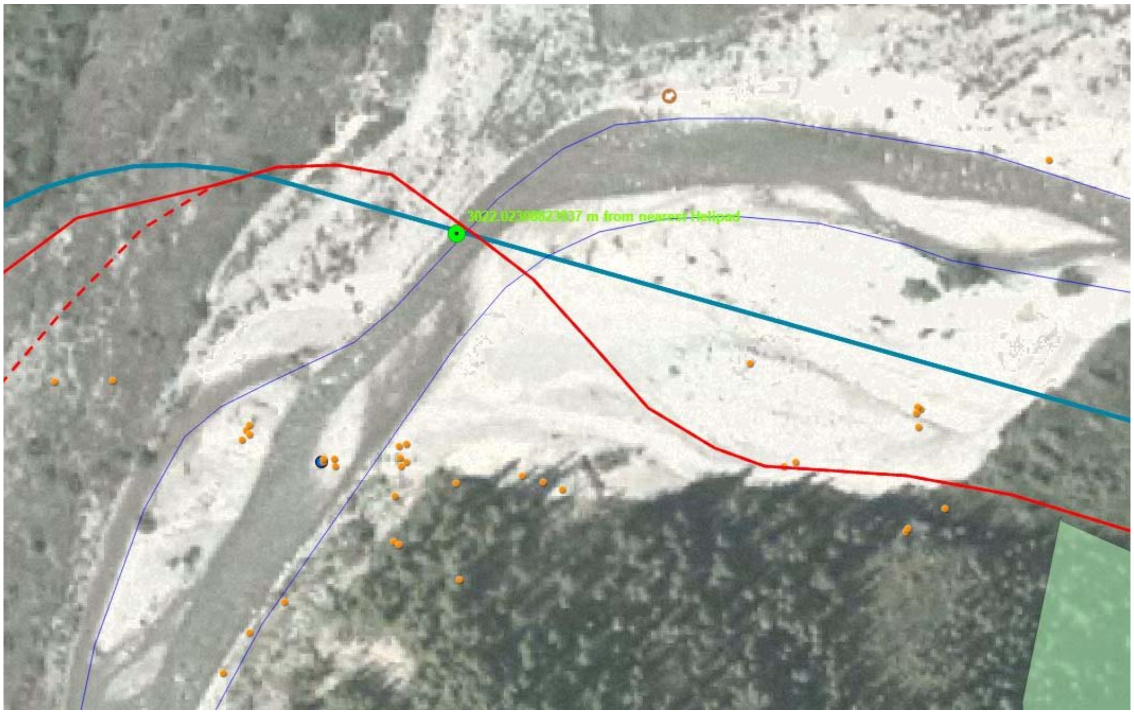
Km 123.1, Grainger River

The upper main stem crossing of the Grainger River is on the original route and would not be needed with adoption of the preferred alternate route. The channel is about 5 m wide, and the width at the HWM 7 m. Photos in the Allnorth report show the crossing location, with the abutments on stabilized old floodplain, and the road grade increasing in elevation to the south to climb a rock bluff. The crossing is immediately downstream of the confluence between the northern debris flow tributary and the discharge from Gap Lake to the west. Evidence of flooding in this area is visible. However, no recent flooding is indicated at the crossing location, where the banks have mature trees. However, the abutments and banks would be armoured as a precaution against overbank flooding. Bedload is sand to gravel size. Deposits of larger material occur upstream in the form of a fan from the debris flow channel. Air photos (Km 123) show that the channel at the crossing location has not changed significantly since 1949. Interestingly, the photos show that the northern outwash channel used to flow to the south-east, with a broad fan crossing the original road alignment. The outwash channel now flows south, and the former channel has stabilized and is vegetating. This area would be avoided entirely by the preferred alternate route.

Km 124.5, Grainger River

The photo below is from 2012 and was taken at about the same time as the LiDar. The Grainger main stem flows through the Grainger Gap, abuting a rock wall on the south side. To the north, old stabilized floodplain exists. After exiting the confines of the Gap, the floodplain widens. The floodplain to the south was recently in use. The 2nd photo below from 2005 shows the channel against the bank. Another channel to the north was also in use not too long ago. The 3rd photo below is a screen-shot from the LiDar, and shows the proposed crossing location. The stream is about 7 m wide, and the floodplain up to 60 m wide. The crossing is proposed where there is a narrower, single channel. It is downstream of a side channel and braid of the main channel. This places the crossing in the zone where the channel has migrated in the past. However, this migration will be prevented by an armoured berm extending upstream of the eastern abutment to the nose of the rock wall, and a similarly armoured berm extending upstream from the western abutment. Therefore, flows will be trained under the bridge. A straight run of the channel through the crossing section will avoid bedload accumulation. This may occur downstream as the channel widens and loses energy, but this is the natural situation. The design approach does not constrict the channel other than to maintain channel position as at present. The risk of channel avulsion at the crossing is limited because of the rock wall to the east, and stabilized old floodplain to the west. Ab abnormally high water event may lead to overbank flows on the west side upstream. Culverts and/or armour will be provided in the western approach to mitigate this risk.

The air photos (Km 125) show that the hydrology in the area of the crossing location has changed since 1949. In 1949, the floodplain area and channels south-west of the crossing were active and un-vegetated. This area is now vegetated. Despite these differences, the channel at the crossing location does not appear to have changed significantly. The engineering works described above should ensure that his remains the case.



3. Avulsion hazards are discussed below with reference to the Km 29-33 road section adjacent to lower Sundog Creek. The section from Km 33-38 was addressed by Allnorth in their March 18, 2016 report, submitted with our response to the Reasons for Decision (RfD) on Adequacy of the DAR. The lack of avulsion hazard along Prairie and Funeral Creeks is explained in our reply to Board IR7 below. For other road sections parallel to watercourses, such as Tetcela and Grainger Rivers, the road is set well back from the river bank and not at risk.

The Km 29-33 road section is discussed with reference to the maps contained in the DAR, Appendix 1, Appendix I. The map on page 9 shows the section. Along this section, the road can be set well back from the creek by using stabilized and vegetated old floodplain, as the winter road alignment did previously for the most part. The winter road alignment is visible in many places, and has not been affected by the creek since construction. There are a few places where the proposed all season road alignment is proximal to the creek. The IR refers to Km 30.6, however the locations where the road is in closest proximity to the creek are Km's 29.8, 31.2 and 31.6. The photo below shows the Km 29.8 location. Note that the winter road is visible on the vegetated bank, but the alignment has been buried under a debris fan. The all season road will cut through the debris fan and maintain the alignment on the bank well away from the creek. The debris fan crossing will include large culverts to pass the material. The 2nd photo below, looking south, shows the Km 31.2 and 31.6 locations. The Km 31.2 location on the right appears to be the closest to the creek. However, vegetated bank is visible, and the all season road will be about 8 m from the creek. For the Km 31.6 location, the old winter road is visible st back from the creek. Therefore, these photos show that the risk of channel avulsion affecting the road over this section is low, and that the better resolution than the maps in the appendix provides a clearer impression of this.

IR7 – MEANDER BENDS

In this description, the erosion risks at meander bends are discussed. Road sections along Prairie and Funeral Creeks are considered, along with the Polje Creek and Tetcela River crossings. The Liard River crossing was addressed by Tetra Tech EBA in their March 11, 2016 terrain mapping report, submitted as part of our response to the RfD on Adequacy.

The photo below is at Km 3.6. Sections of the road along Prairie and Funeral Creeks were subject to erosion during the flood events in 2006 and 2007. Note, Cadillac did not armour the road, and erosion prior to these dates had not occurred. CZN re-established the road after the events by installing anchored gabion baskets to rock ledges, and re-building the road bed behind.

The photo below shows Km 4.2. A meander of Prairie Creek eroded the winter road away at this location. CZN re-built the road by re-aligning it back from the creek. The main channel has since moved to the west side of the floodplain.

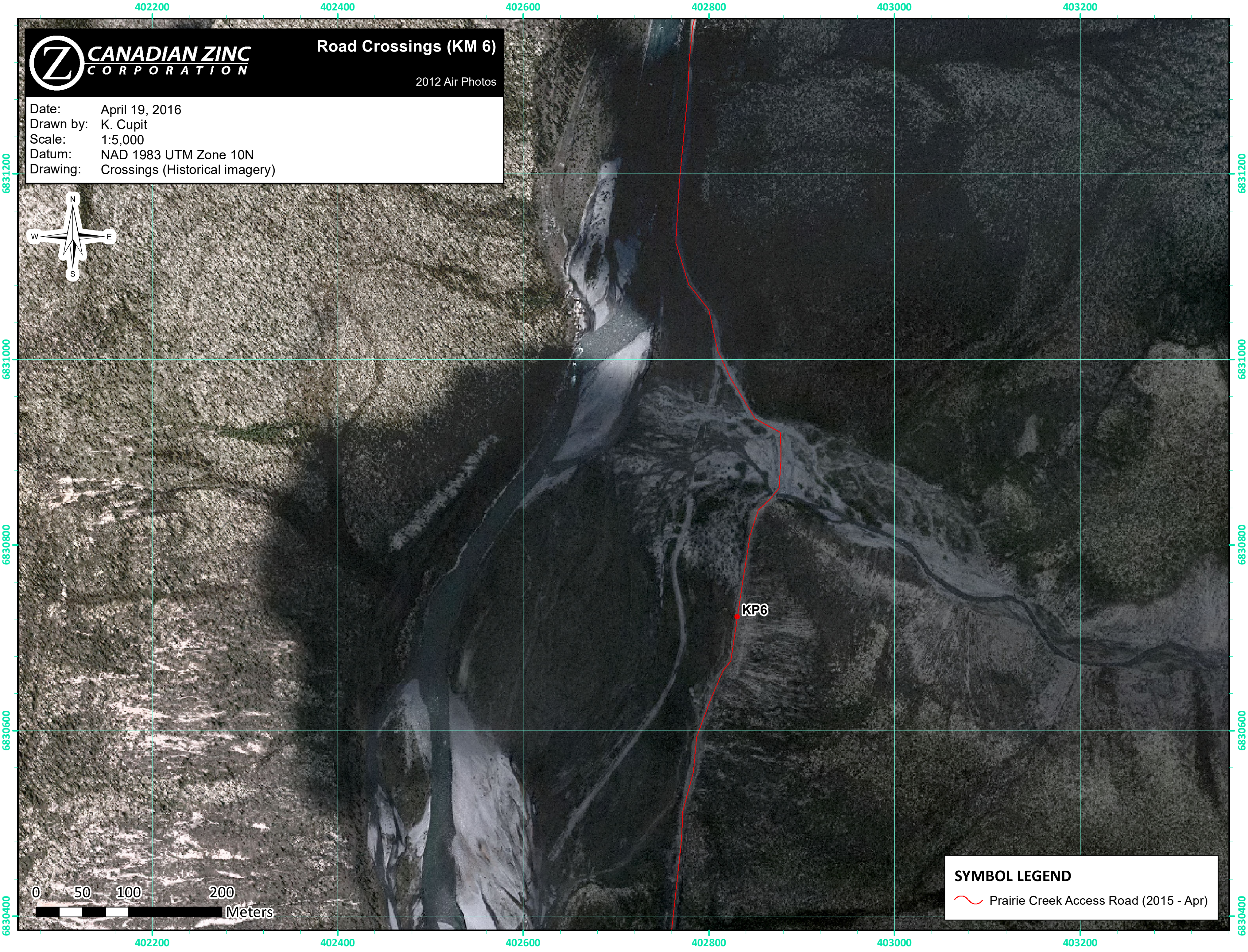
The photo below shows the road section Km 5.3-5.7. The first part is another portion of the road that was eroded and re-built with gabions and armour. The 2nd part is a road re-alignment built because the creek completely removed the old winter alignment at Km 5.7 where a spur projects west into the valley.

The photo below shows the road section Km 6.4-6.7, where the road is set back from Prairie Creek.

The photo below is at about Km 8.4. This is one of several locations along Funeral Creek where the road was eroded at meander bends during the 2006-2007 flood events, and where armour was subsequently placed.

The purpose of the discussion above is to demonstrate that erosion risks at meanders bends adjacent to Prairie and Funeral Creeks manifested themselves previously and have been addressed. Regarding the Polje Creek crossing location, historical air photos show that the present channel has been stable for some time, and this is not likely to change during the life of the project. The same is true for the Tetcela crossings, even at Km 89.8 where some changes in the channel have occurred since 1949.


CANADIAN ZINC CORPORATION
Road Crossings (KM 6)
1949 Air Photos
Date: April 19, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
W
E
S
KP6
0 50 100 200
Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
402200
402400
402600
402800
403000
403200
6831200
6831000
6830800
6830600
6830400


CANADIAN ZINC CORPORATION
Road Crossings (KM 6)
2012 Air Photos
Date: April 19, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
W
E
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KP6
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
0 50 100 200
Meters
402200
402400
402600
402800
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403200
6831200
6831000
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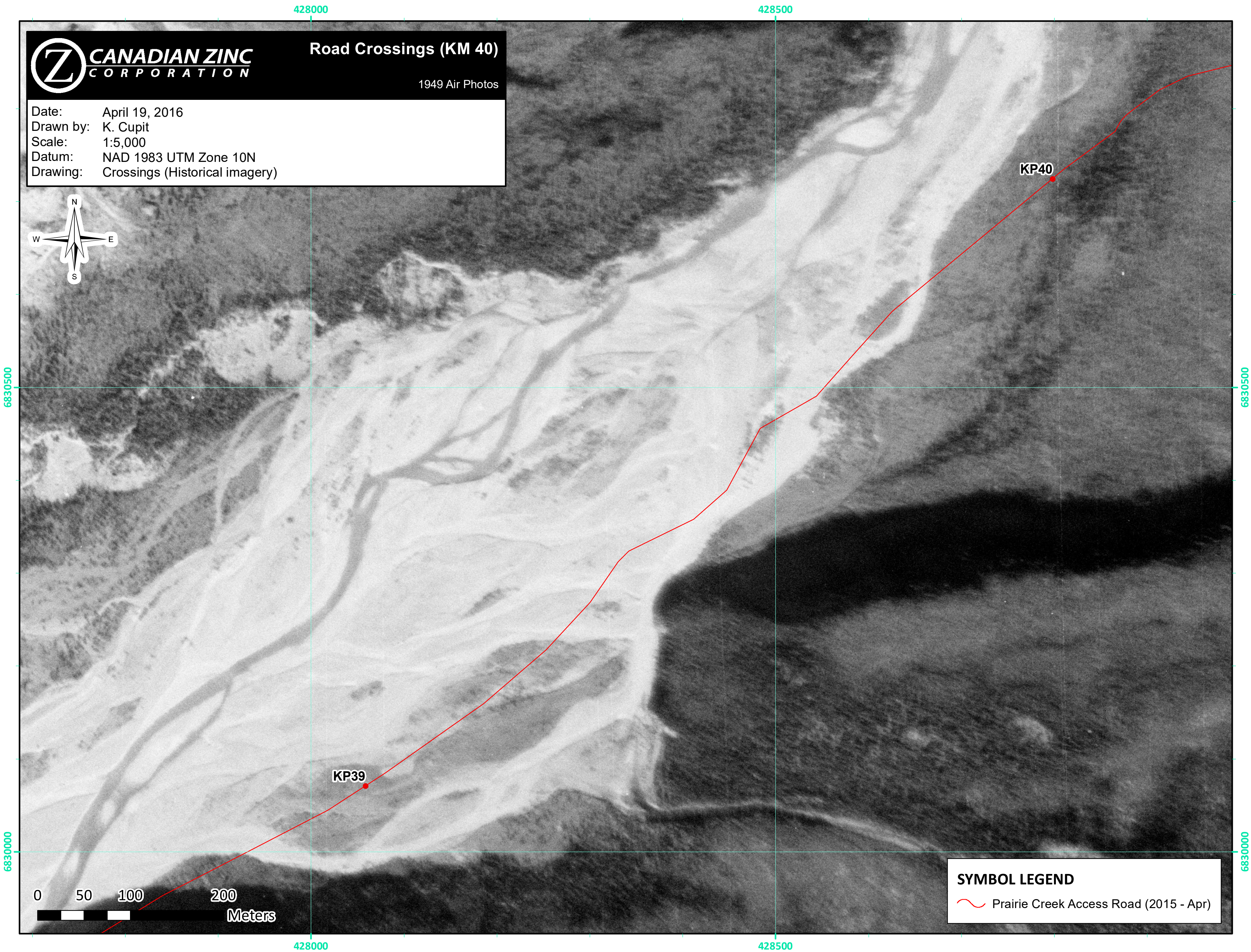
6830400


CANADIAN ZINC
CORPORATION
Road Crossings (KM 40)
1949 Air Photos
Date: April 19, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
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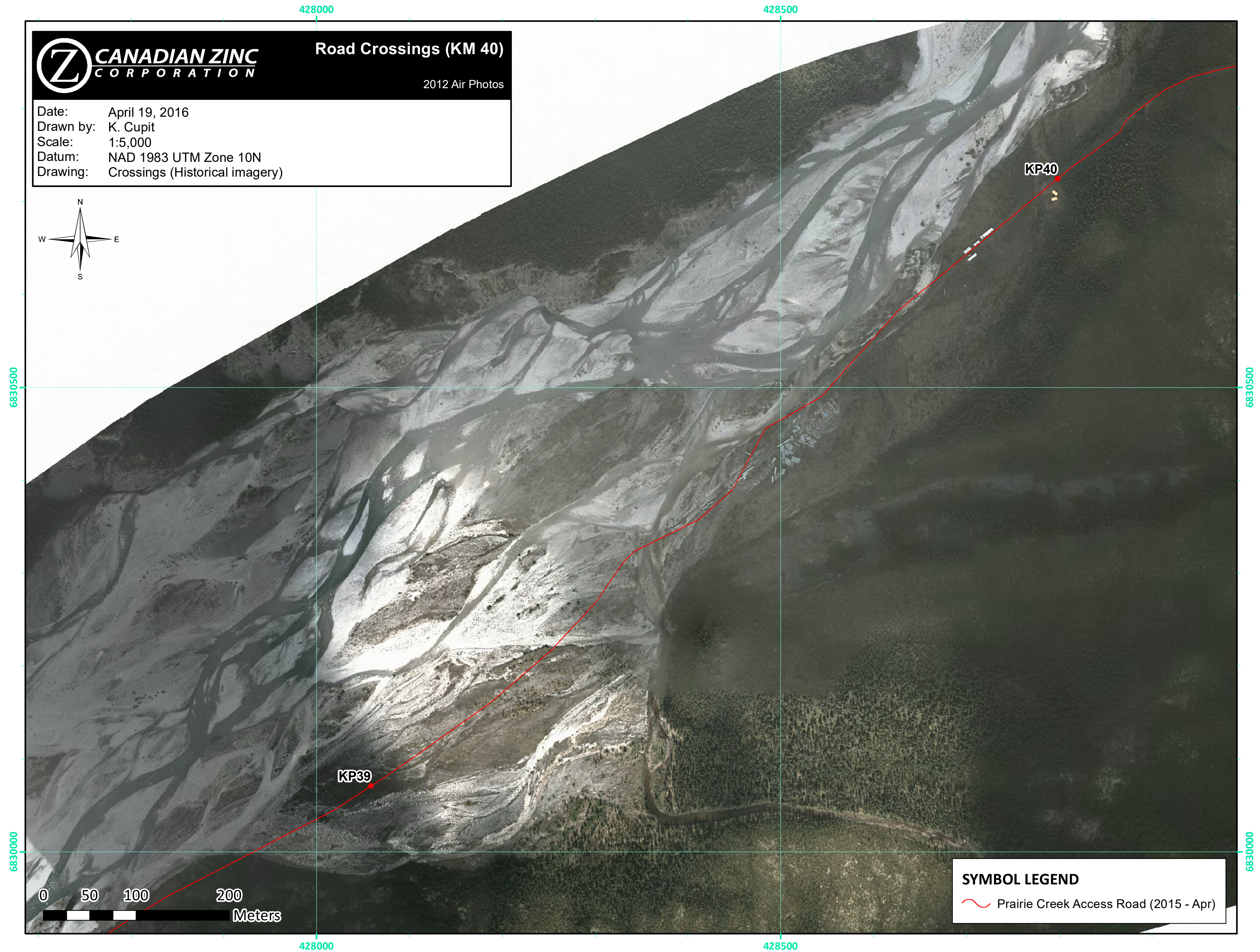
428000
428500
6830500
6830000
KP40
KP39
0
50
100
200
Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)

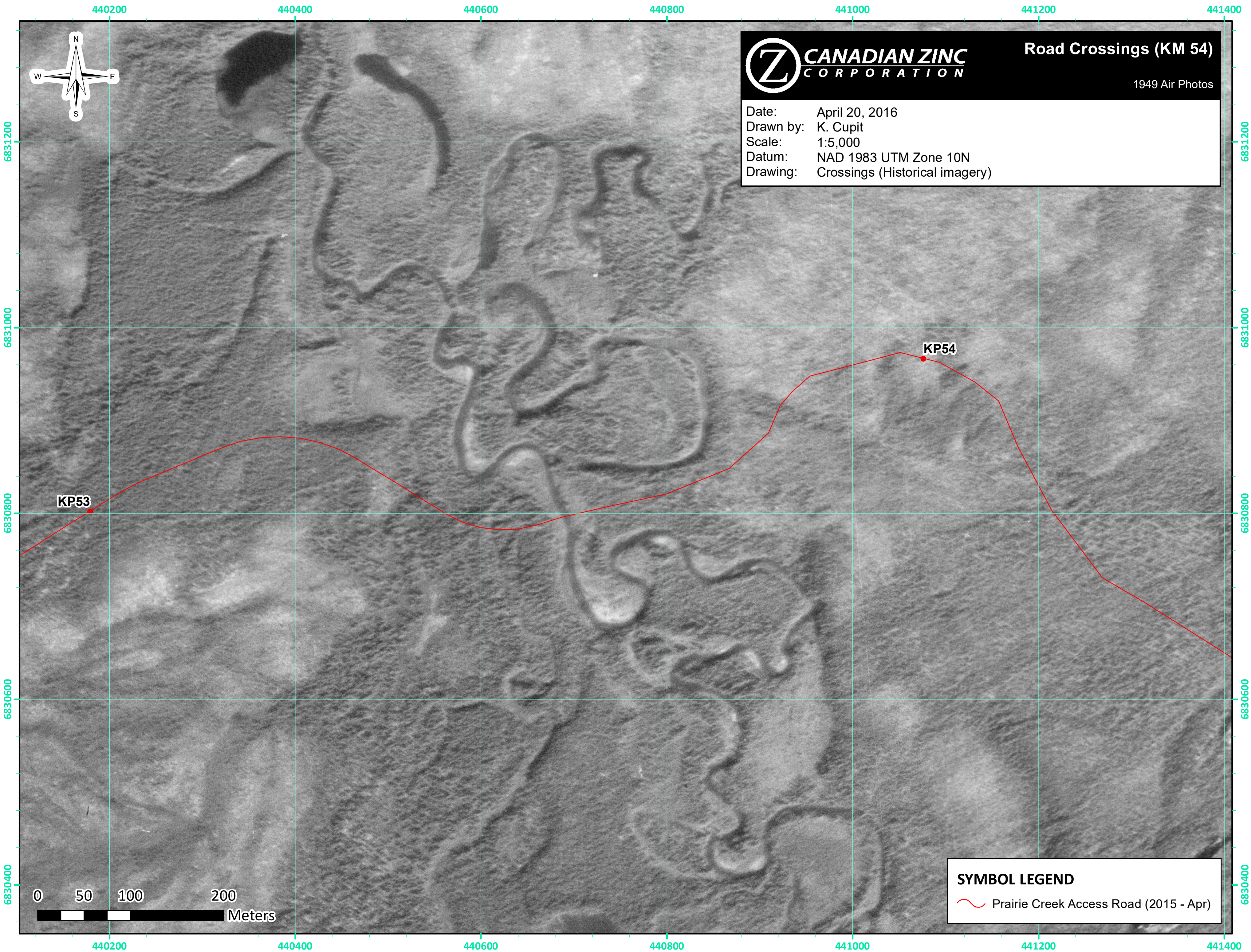
Road Crossings (KM 40)

CANADIAN ZINC CORPORATION

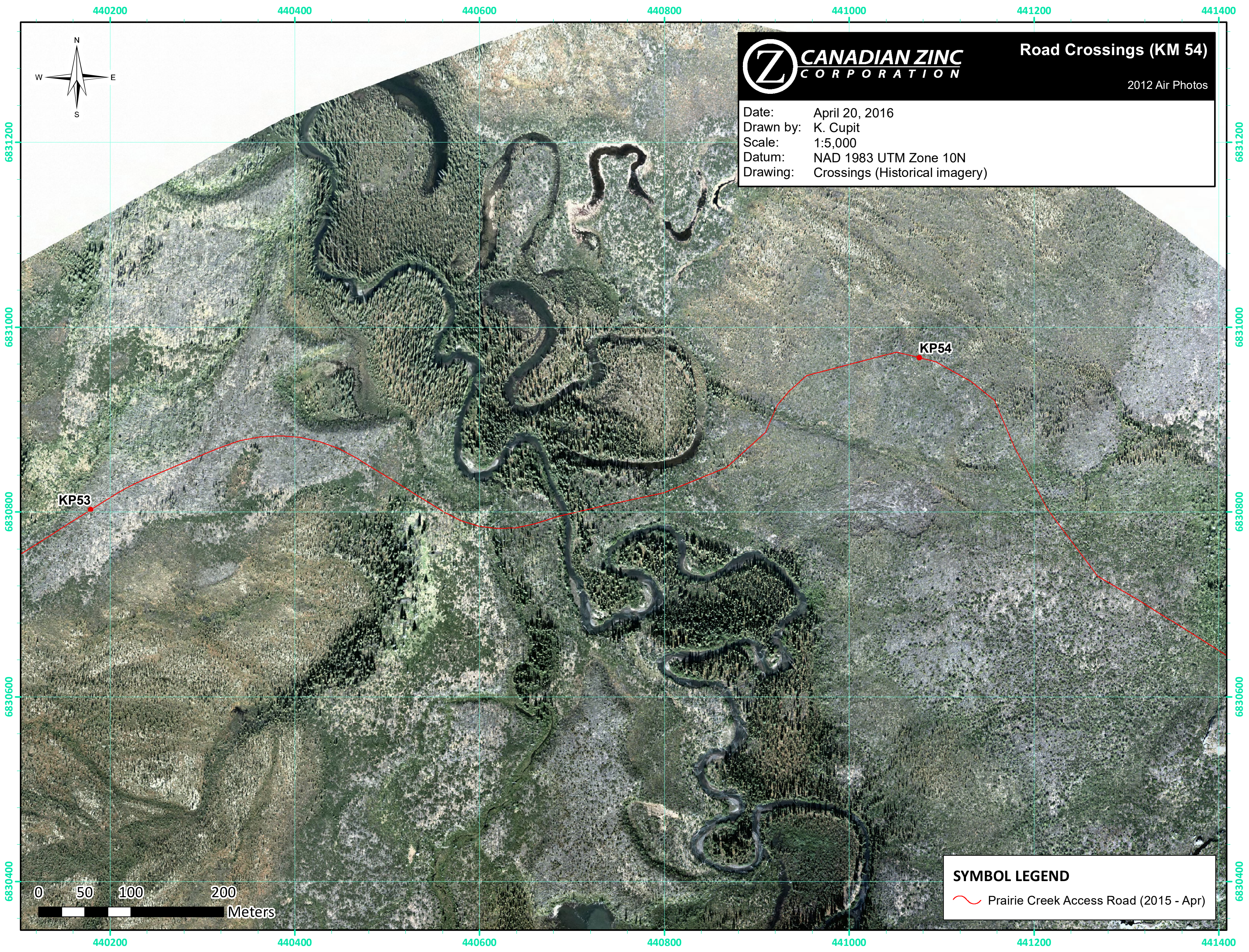
2012 Air Photos

Date: April 19, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)





CANADIAN ZINC CORPORATION
Road Crossings (KM 54)
1949 Air Photos
Date: April 20, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
S
E
W
KP53
KP54
440200
440400
440600
440800
441000
441200
441400
6831200
6831000
6830800
6830600
6830400
0 50 100 200
Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)


CANADIAN ZINC CORPORATION
Road Crossings (KM 54)
2012 Air Photos
Date: April 20, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
KP53
KP54
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
0 50 100 200 Meters
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441400
6831200
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6830800
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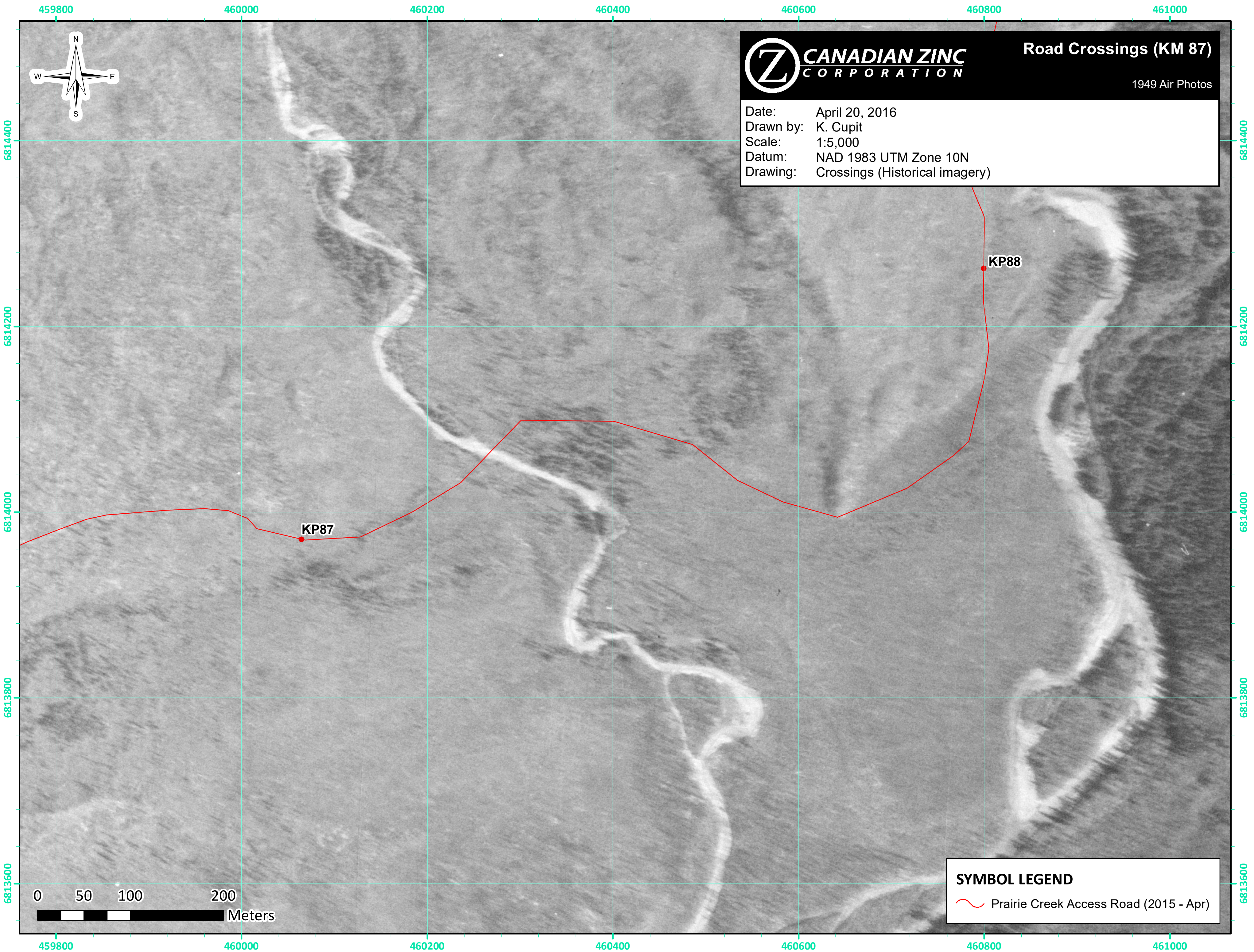
6830400


Road Crossings (KM 87)
CANADIAN ZINC CORPORATION
1949 Air Photos
Date: April 20, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
KP87
KP88
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
0 50 100 200 Meters
N
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459800
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460400
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460800
461000
6814400
6814200
6814000
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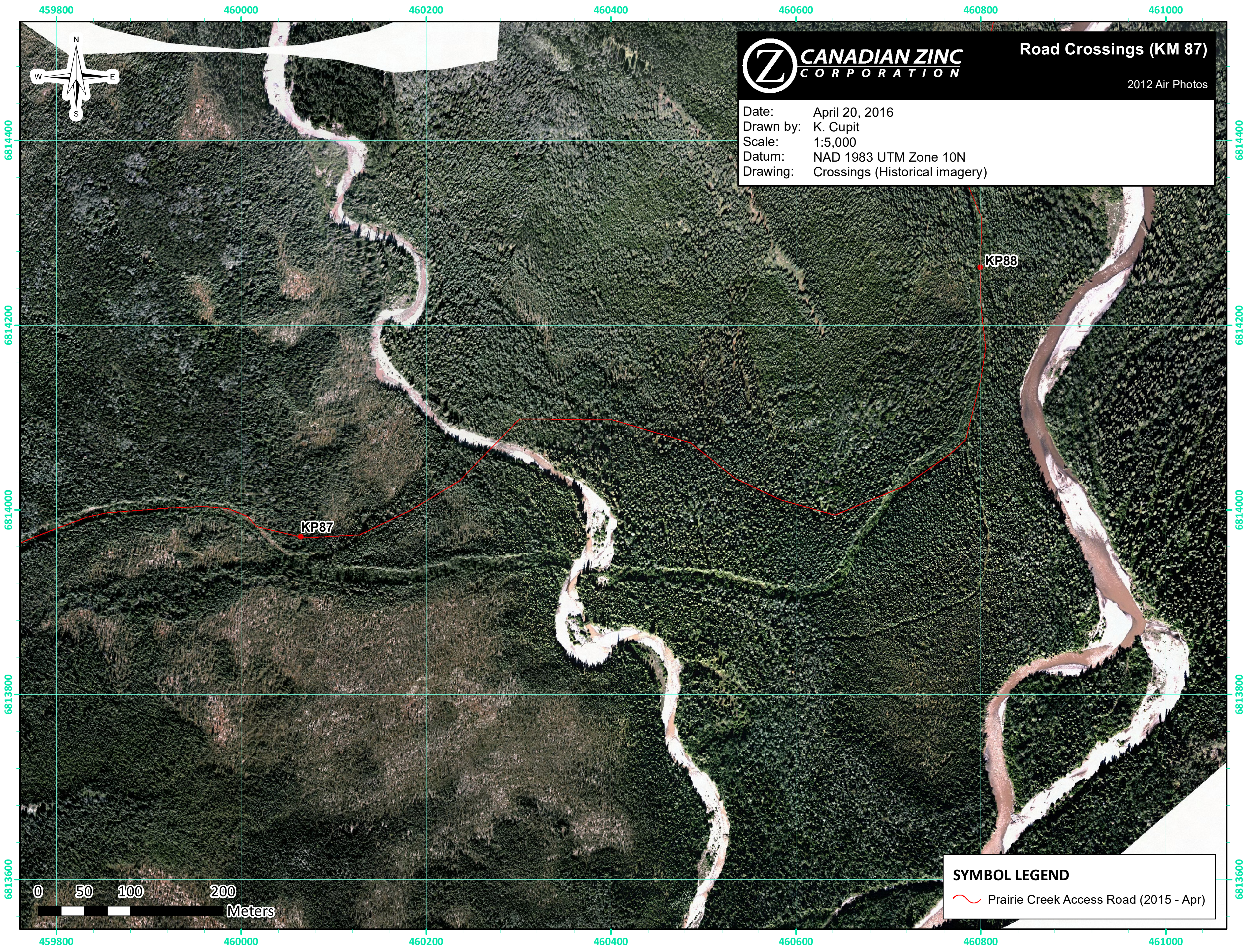
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CORPORATION
Road Crossings (KM 87)
2012 Air Photos
Date: April 20, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
KP87
KP88
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
0 50 100 200
Meters
459800
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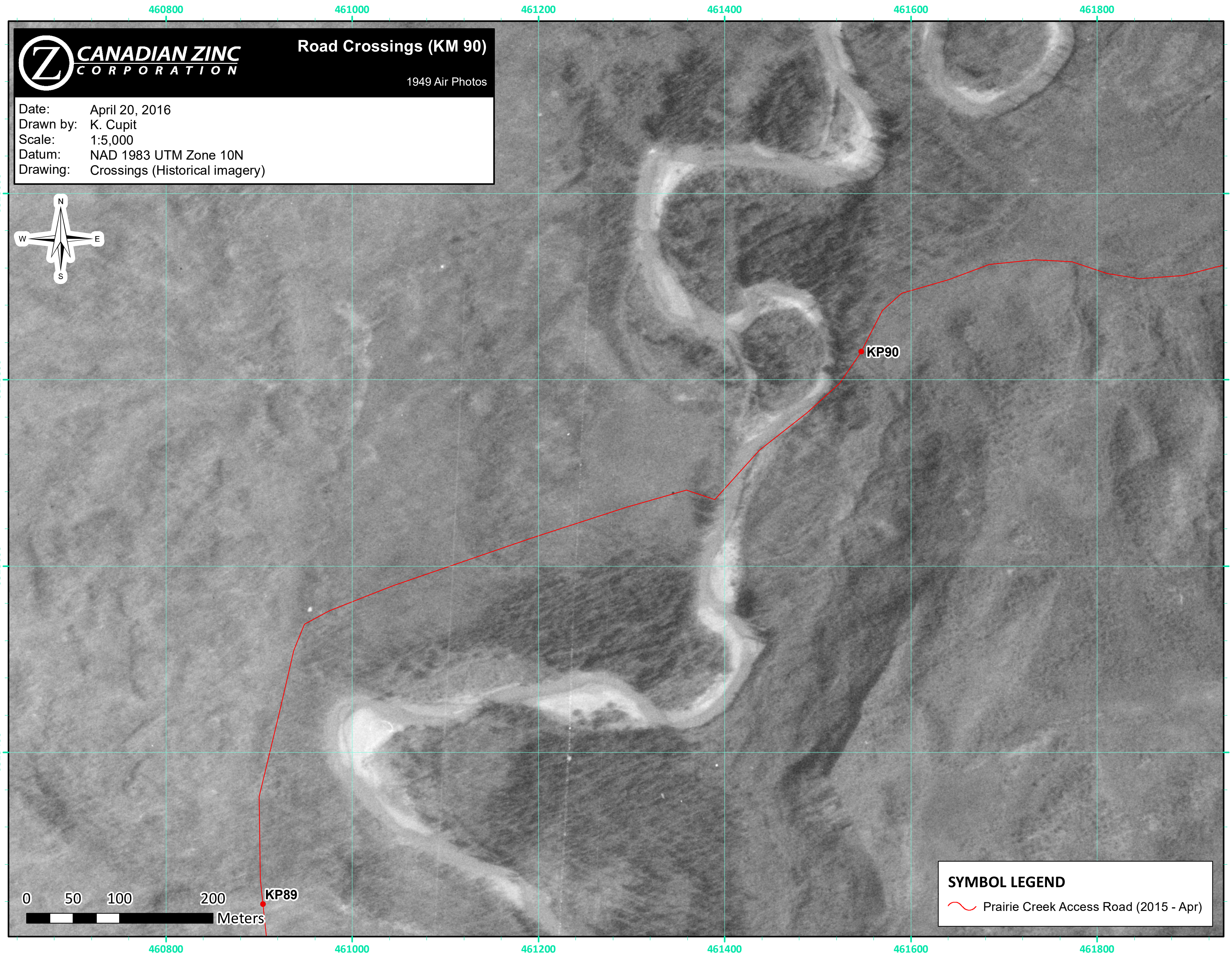
6813600


CANADIAN ZINC CORPORATION
Road Crossings (KM 90)
1949 Air Photos
Date: April 20, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
S
E
W
KP90
KP89
0 50 100 200
Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
460800
461000
461200
461400
461600
461800
6816000
6815800
6815600
6815400

CANADIAN ZINC CORPORATION
Road Crossings (KM 90)
2012 Air Photos
Date: April 20, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
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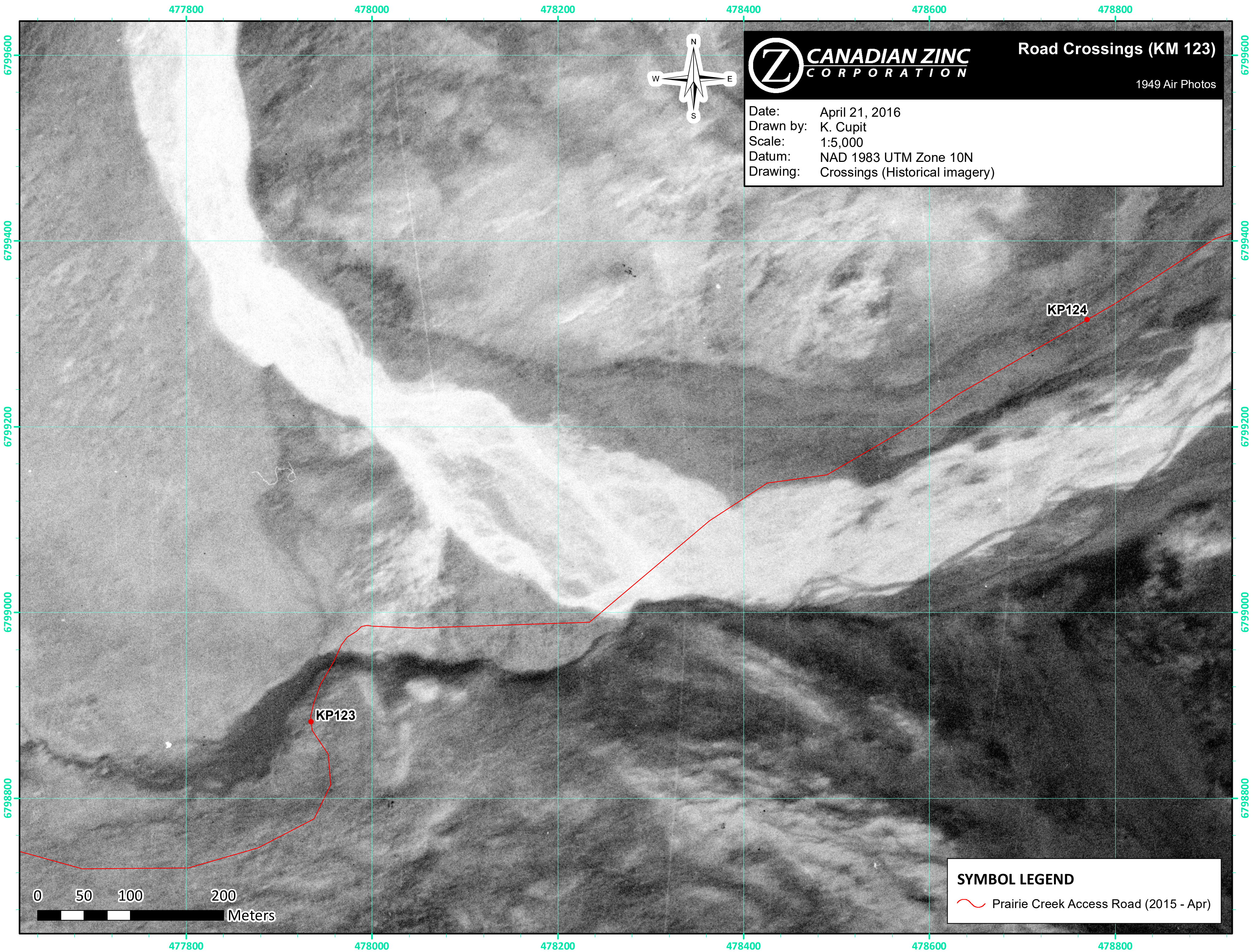
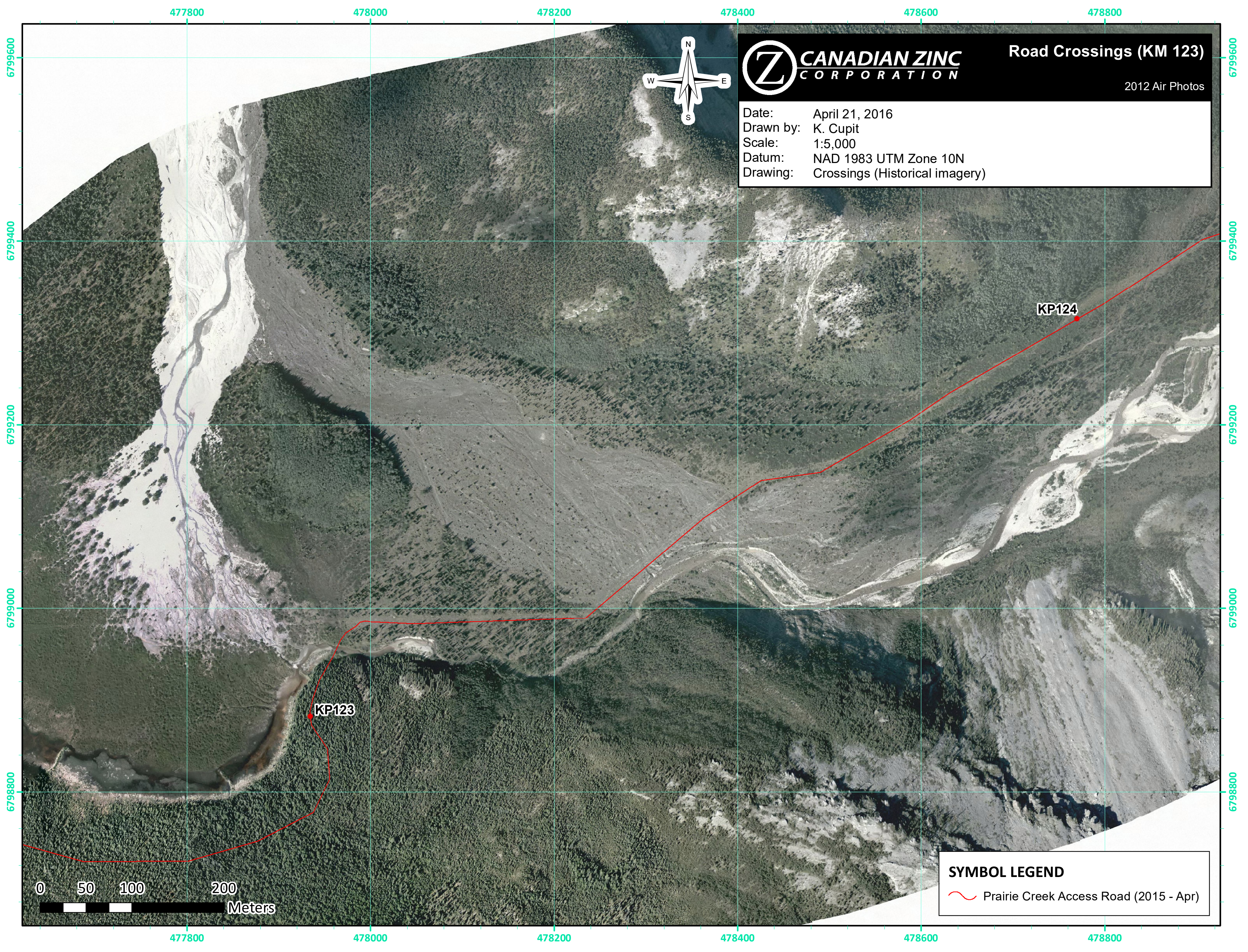
KP90
KP89
0 50 100 200 Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
460800
461000
461200
461400
461600
461800
6816000
6815800
6815600
6815400

CANADIAN ZINC CORPORATION
Road Crossings (KM 119)
1949 Air Photos
Date: April 26, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
S
E
W
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
0 50 100 200 Meters
477200
477400
477600
477800
478000
478200
478400
6800600
6800400
6800200
6800000
6799800


CANADIAN ZINC CORPORATION
Road Crossings (KM 123)
1949 Air Photos
Date: April 21, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
KP124
KP123
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
0 50 100 200 Meters
477800 478000 478200 478400 478600 478800
6799600 6799400 6799200 6799000 6798800



CANADIAN ZINC CORPORATION
Road Crossings (KM 123)
2012 Air Photos
Date: April 21, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
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KP124
KP123
0 50 100 200
Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)
477800
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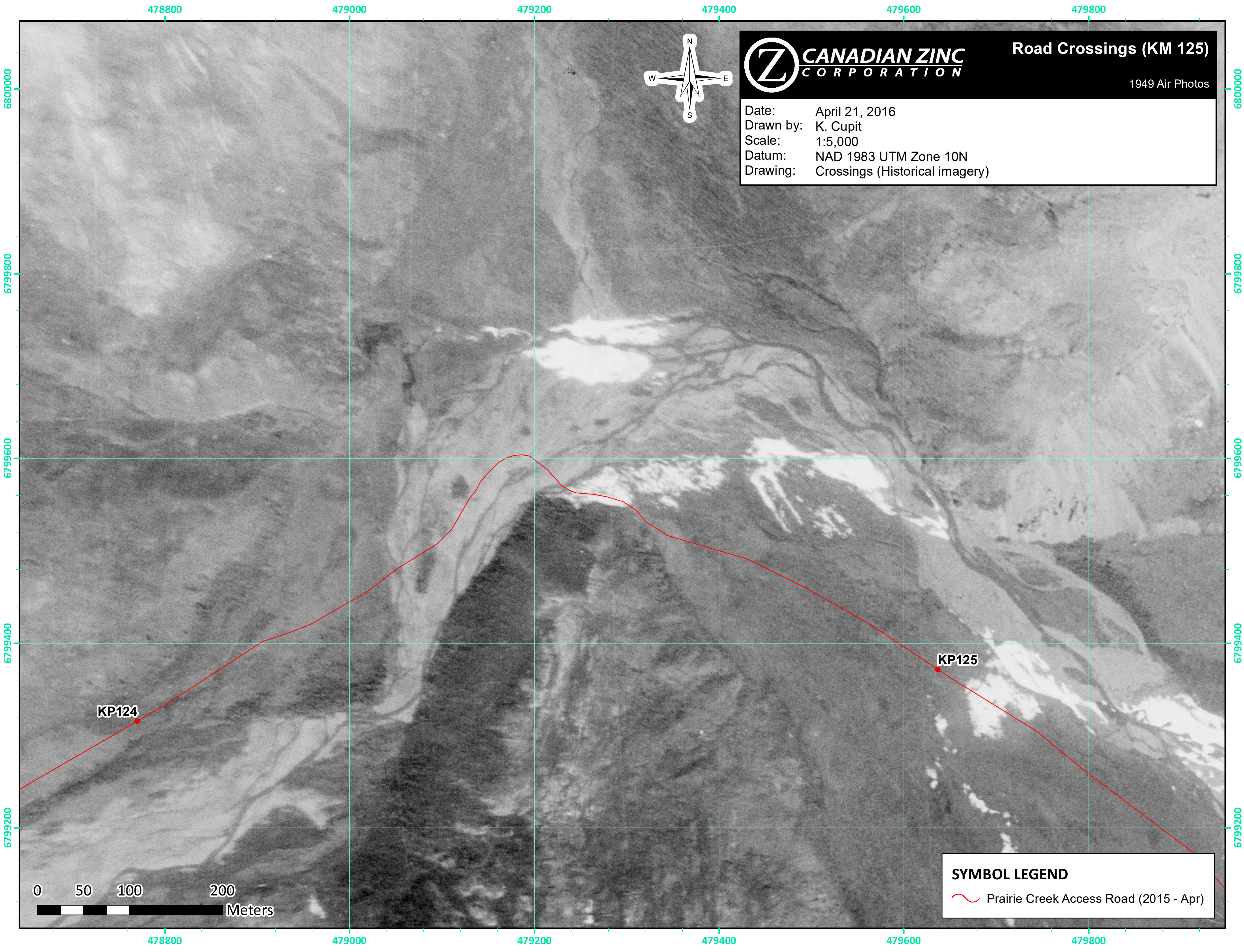
6799400
6799200
6799000
6798800


CANADIAN ZINC CORPORATION
Road Crossings (KM 125)
1949 Air Photos
Date: April 21, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
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KP124
KP125
478800
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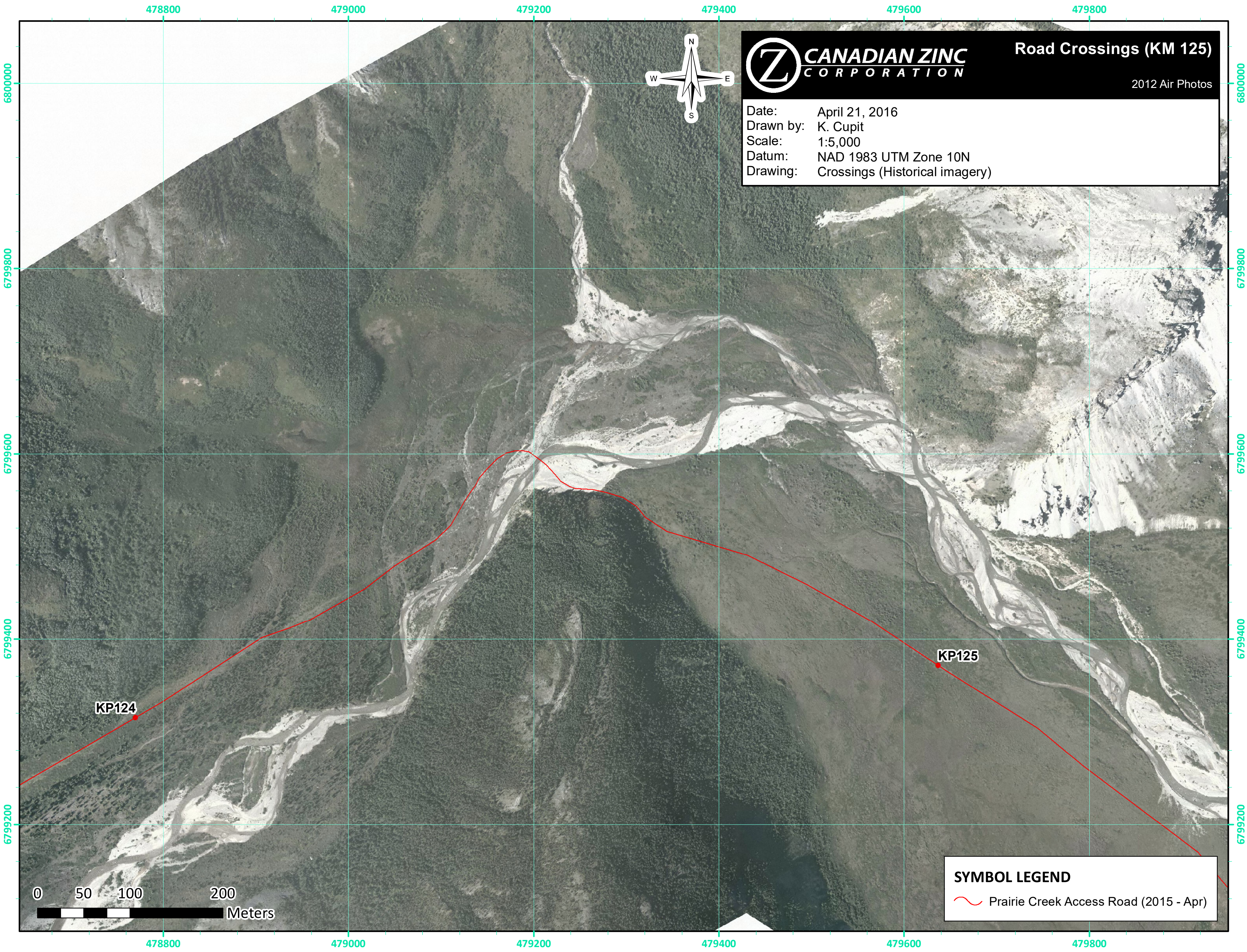
479800
6800000
6799800
6799600
6799400
6799200
0
50
100
200
Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)



CANADIAN ZINC CORPORATION
Road Crossings (KM 125)
2012 Air Photos
Date: April 21, 2016
Drawn by: K. Cupit
Scale: 1:5,000
Datum: NAD 1983 UTM Zone 10N
Drawing: Crossings (Historical imagery)
N
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478800
479000
479200
479400
479600
479800
6800000
6799800
6799600
6799400
6799200
KP124
KP125
0 50 100 200
Meters
SYMBOL LEGEND
Prairie Creek Access Road (2015 - Apr)

REPLY TO BOARD IR9 – ALTERNATIVES COSTING

Comment The alternative analysis cited the net present value results in the cost-benefit analysis. It would be beneficial to understand the assumptions and details of the cost-benefit analysis to understand how the selected alternative was chosen.

Recommendation Please explain:

1. *Why a discount rate of 10% was chosen?*

Ultimately, the discount rate chosen for a particular project is a matter of judgement. However, the concept of weighted average cost of capital (WACC) can help in estimating the appropriate discount rate. WACC is a measurement of an organization's blended cost of equity and after-tax debt. CZN's cost of equity is higher than comparable organizations as the stock price is volatile given the lack of a revenue stream from producing assets. CZN has no debt, however, would face a relatively high cost of debt in the future in order to finance all or part of the Prairie Creek Project. Other factors to consider would include country risk which is relatively low when ranked globally as well as industry comparatives. A large, stable company in a stable jurisdiction might use a rate as low as 6%. A small company in an unstable jurisdiction might use a rate as high as 14%. Given these factors, a rate of 10% was chosen.

2. *What the effect of the discount rate on the relative rankings is?*

Choosing a different discount rate would not change the relative rankings. It would merely change the difference between the rankings. This is illustrated in the revised table below from the DAR Addendum for the Phase 2 road. In their letter dated February 12, 2016 the NBDB observed that the cost of a barge for the Liard River was not included in the comparative costs. We estimate the cost of a suitable barge to be approximately $1 million. Clearly, this will not alter the outcome. Also note that the costs comparisons are still based on an 11 year mine life. As advised, the revised preliminary feasibility for the Mine now envisages a 17 year mine life. This will mean that the cost saving with an all season road will be greater than indicated in the table over the life of the project.

Road	Winter	All Season	Difference
Capital Cost ($M)	2	50	
Annual Maintenance ($M)	2	1	
Annual Haul ($M)	18	12	
Annual Saving on Supplies ($M)		-3	
Annual Increase in Revenue ($M)		-9	
NP C (11 year mine life, 10% discount rate)	**132**	**56**	**76**
NP C (11 year mine life, 6% discount rate)	**160**	**58**	**102**
NP C (11 year mine life, 14% discount rate)	**109**	**55**	**54**

3. *In addition, please provide a more detailed summary spreadsheet or table of the calculations.*

Derivation of the cost assumptions were explained in the DAR Addendum. The capital and maintenance costs for a winter road and all season road were based on bids/estimates received from contractors. These are confidential. For comparison, we noted that a general rule of thumb for all season road cost is $250,000/km. For a 180 km road, this equates to $45 million. Therefore, the $50 million contractor's estimate is plausible. Haul costs were based on rates provided by Allnorth.

Annual supplies costs for a winter road were estimated at approximately $36 million. Annual supplies costs for an all season road were estimated at approximately $33 million, a difference of $3 million.

Annual revenue for a winter road was estimated at approximately $83 million. Annual revenue for an all season road was estimated at approximately $92 million, a difference of $9 million.

REPLY TO BOARD IR11

1. In their cabs.
2. There will be no need for unforced rests along the road. A rest due to bad weather or a road closure will apply to all traffic on that road section, therefore, the driver can simply stop and wait on the road, or turn back.
3. No. The legal limit north of 60^{o} latitude is 15 hours. However, we would expect all drivers to normally complete the journey in less than 13 hours. If there are delays en route, depending on the length and location of the delay, options available include returning to the origin, switching trailers at the Liard River crossing marshalling areas which effectively shortens the journey, or for a limited number of drivers, a period of 8 hours rest at a road maintenance camp or the LTF.

LIST OF ACRONYMS

AANDC	Aboriginal Affairs and Northern Development Canada (now INAC)
ADK	Acho Dene Koe Band
AEMP	Aquatic Effects Monitoring Plan
Ag	Silver
AIA	Archaeological Impact Assessment
AMSL	above mean sea level
AN	Ammonium nitrate
ANFO	Ammonium nitrate-fuel oil
AQMP	Air Quality Monitoring Plan
AR	Adequacy Review (of the DAR)
ATV	All Terrain Vehicle
BC	British Columbia
BCMF	BC Ministry of Forests
BMP	Best Management Practice
BP	Borrow Pit
BPMRP	Borrow Pit Management and Reclamation Plan
Cadillac	Cadillac Explorations Ltd.
CALPUFF	California Puff (Dispersion) Model
CBH4	Navigation Canada Designation for the Prairie Creek Airstrip
Ca	Calcium
CCME	Canadian Council of Ministers of the Environment
CIMP	Cumulative Impact Monitoring Program
CLMP	Contaminant Loading Management Plan
CO	Carbon Monoxide
CO_2	Carbon Dioxide
Cond	Electrical Conductivity
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
Cr	Chromium
CSA	Canadian Standards Association
CZN	Canadian Zinc Corporation
Cd	Cadmium
Cu	Copper
DAR	Developer's Assessment Report
dB and dBA	decibel (measurement of sound pressure level)
DCFN and DFN	Dehcho First Nations
DDH	Diamond drill hole
deg C or ^{o}C	Degrees centigrade
DFO	Department of Fisheries and Oceans
DOT	GNWT Department of Transport
EA	Environmental Assessment
EC	Environment Canada
ENR	GNWT Environment and Natural Resources

List of Acronyms (cont’d)

EOSD	Earth Observation for Sustainable Development
EPA	US Environmental Protection Agency
ESRD	Alberta Environment and Sustainable Resource Development
Fe	Iron
FMEA	Failure Modes and Effects Analysis
FSCP	Fuel Spill Contingency Plan
FTE	Full-time equivalent
GDP	Gross Domestic Product
GHG	Green-house Gases
GNWT	Government of the Northwest Territories
GSC	Geological Survey of Canada
GVW	Gross Vehicle Weight
Ha	hectare (area 100 m by 100 m)
Hg	Mercury
Hz	Hertz
Kg	kilogram
kHz	Kilo-hertz
Km and KP	Kilometre marker along access road, Km 0 is Prairie Creek Site
km	Kilometre
IBA	Impact and Benefits Agreement
ICS	Incident Command System
INAC	Indigenous (formerly Indian) and Northern Affairs Canada
ISMP	Invasive Species Management Plan
ITI	GNWT Industry, Tourism and Investment
JMRFN	Jean Marie River First Nation
JMS	Journey Management System
LiDAR	Light Detection And Ranging
LKFN	Liidlii Kue First Nation
LNG	Liquified Natural Gas
LTF	Liard Transfer Facility
LUP	Land Use Permit
MAA	Multiple Accounts Analysis
m	metre
m^2	1 metre by 1 metre (area)
m^3/day	cubic metres per day (flow volume)
Mg	magnesium
mg/L	milligrams per litre
MOU	Memorandum of Understanding
MTS	Mine Training Society
MVLWB	Mackenzie Valley Land and Water Board
MVRMA	Mackenzie Valley Resource Management Act
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVRB	Mackenzie Valley Review Board
NAG	Non Acid Generating

List of Acronyms (cont'd)

ND	No date or not dated
NDDB	Naha Dehe Dene Band
NAEC	Nahendeh Aboriginal Economic Council
NHC	Northwest Hydraulics Co.
NNPR	Nahanni National Park Reserve
NO_2	Nitrogen Dioxide
NPC	Net Present Cost
NPV	Net Present Value
NT or NWT	Northwest Territories
O_3	Ozone
OC	Organo-chlorine
Pa	Pascal
PAG	potentially acid generating
PAH	Poly-aromatic Hydrocarbons
PAS	Protected Area Strategy
Pb	Lead
PC	Prairie Creek or Parks Canada
PCA	Parks Canada Agency
PDAC	Prospectors and Developers Association of Canada
PDR	Project Description Report
pH	Measurement of water acidity or alkalinity
PM_{10}	Particulate Matter with a micron diameter of 10 or less
$PM_{2.5}$	Particulate Matter with a micron diameter of 2.5 or less
PPE	Personal Protective Equipment
QMP	Quarry Management Plan
RCMP	Road Construction and Maintenance Plan
RCRP	Road Closure and Reclamation Plan
REA	Report of Environmental Assessment
RES	Robertson Environmental Services
ROP	Road Operations Plan
ROW	Right-of-way
RSC	Revised Statutes of Canada
RWED	Resources Wildlife Economic Development
SAC	Socio-economic Advisory Committee
SARA	Species at Risk Act
SARC	San Andreas Resource Corp.
Sb	Antimony
SCP	Spill Contingency Plan
SECP	Sediment and Erosion Control Plan
SEA	Socio-Economic Agreement
SEIA	Socio-Economic Impact Assessment
SKFN	Sambaa K'e First Nation
SNP	Surveillance Network Program
SO_2	Sulphur Dioxide

List of Acronyms (cont'd)

SPL	Sound pressure level
SRAP	Spill Risk Analysis Plan
STP	Sewage Treatment Plant
SVW	Soil, vegetation and wildlife
TAC	Technical Advisory Committee or Transportation Association of Canada
t/d, tpd	Tonnes per day
TDS	Total dissolved solids
TK	Traditional Knowledge
TOC	Total Organic Carbon
TOR	Terms of Reference
TSP	Total Suspended Particulates
TSS	Total Suspended Sediments
TSX	Toronto Stock Exchange
TTF	Tetcela Transfer Facility
UG or u/g	Underground
ug/L	micrograms/litre
µS/cm	microSiemens/cm (measure of conductivity)
USDA	US Department of Agriculture
VC	Valued Component
VFR	Visual Flight Rules
WEMP	Wildlife Effects Monitoring Plan
WF	Water and fish
WMIS	Wildlife Management Information System
WMP	Waste Management Plan or Wildlife Management Plan
WMMP	Wildlife Mitigation and Monitoring Plan
WSC	Water Survey of Canada
WWHPP	Wildlife and Wildlife Habitat Protection Plan
Zn	Zinc

TETRA TECH EBA

TECHNICAL MEMO

ISSUED FOR USE

To:	David Harpley, Canadian Zinc Corporation	**Date:**	April 13, 2016
c:	Alan Taylor, Canadian Zinc Corporation	**Memo No.:**	2
From:	Rita Kors-Olthof, Nigel Goldup	**File:**	Y14103320-01.003
Subject:	Responses to Information Requests from Mackenzie Valley Review Board and Oboni Riskope Associates Inc. Prairie Creek Mine Site Proposed All-Season Access Road, EA1415-01 Technical Review		

1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) provides, in this technical memo, the responses to some of the information requests to Canadian Zinc Corporation (CZN) from the Mackenzie Valley Review Board (MVRB) and Oboni Riskope Associates Inc. (Riskope). This memo specifically addresses those requests that pertain to permafrost and risk analysis information. The information requests are shown in each section in italics, followed by Tetra Tech EBA's responses in regular text.

2.0 RESPONSES TO INFORMATION REQUESTS

2.1 MVRB IR 13

Water crossings and effects of permafrost thaw; DAR section 12:

***Comment**: Section 12 of the DAR (PR#55) states that the impacts of permafrost thaw to infrastructure may be major and potentially significant and could be mitigated.*

***Recommendation**: Please list the potential mitigation options for impacts of permafrost thaw at crossings and along the road.*

It is important for the project reviewers to consider the above-noted comment in context. Tetra Tech EBA have carefully considered the implications of potential permafrost thaw, whether related to climate change or to site disturbance. Furthermore, Tetra Tech EBA have considered the possible impacts of permafrost thaw on the proposed road infrastructure including bridges and culverts, just as would be done for any other proposed project in permafrost terrain, in accordance with the guidelines presented in the Canadian Standards Association's *Technical Guide – Infrastructure in Permafrost. A Guideline for Climate Change Adaptation. Plus 4011-10* (CSA 2010) (Tetra Tech EBA 2015a). As such, we have noted the following primary mitigations as being most appropriate for the project, subject to the consideration of additional site-specific information that is acquired as the project progresses:

- Avoid ice-rich permafrost terrain where possible; and
- Where the route cannot avoid potentially ice-rich permafrost terrain, consider alternative mitigations.

It is noted that the proposed all-season route avoids considerable terrain that is thought to be ice-rich and/or subject to thermokarst processes. For example, between about KP090.6 and KP097, the existing winter route traverses ice-rich and potentially thermokarst-prone areas, with several existing thermokarst features already noted. The

Tetra Tech EBA Inc.
Box 2244, 201, 4916 - 49 Street
Yellowknife, NT X1A 2P7 CANADA
Tel 867.920.2287 Fax 867.873.3324

proposed all-season re-route from KP090.6 to KP095 avoids much of this terrain by staying in the upland areas to the southwest, traversing from sandy mound to sandy mound, thus keeping more of the route in "high and dry" terrain.

Where ice-rich terrain is encountered along the all-season road, the following mitigations may be considered, according to the site-specific requirements for stream crossings or road sections (Tetra Tech EBA 2015a):

- For major stream crossings if/where permafrost is determined to be present:
  - Design foundations for bearing on, or in, a suitable frost-stable (thaw-insensitive) foundation layer (Tetra Tech EBA 2015a). For example,
    - Shallow foundations could be placed on a coarse granular bearing layer that is not influenced by changing thermal regimes;
    - Piles could be driven or drilled into a suitable soil layer that is not influenced by changing thermal regimes; or
    - If bedrock is present, the foundation could be placed on or in bedrock;
  - If no suitable foundation layer is present, and ice-rich permafrost is present, then a foundation might consist of:
    - A combination of shallow or deep foundations, with
    - Possibly thermoprobes, thermopiles or thermosyphons to help maintain cold permafrost temperatures, and
    - Where permafrost areas may not actually thaw during the life of the crossing, but could be prone to higher rates of soil creep (Tetra Tech EBA 2015a), one of the potential mitigations could also include thermosyphons.
- For minor stream crossings, such as culvert crossings in permafrost (Tetra Tech EBA 2015a), mitigations could include:
  - Strategic placement of culverts to reduce the likelihood of water ponding alongside the road embankment;
  - Embankment sections with a free-draining base layer that allow water to permeate through the embankment may also be an option in some locations, supplemented with an overlying culvert to pass spring flows (TAC, 2010);
  - After construction, it would be prudent to carry out regular inspection of the road embankment to determine if additional mitigative measures are required.
- For road sections where thaw-sensitive terrain cannot be avoided (Tetra Tech EBA 2015a, 2015b):
  - Embankments can be designed and constructed with a thickness and width appropriate to the terrain type;
  - In warm permafrost, a thicker embankment may not stop permafrost thaw, but it does provide an additional buffer to reduce flexing of the underlying subgrade;
  - "Corduroy" style embankment-supporting structures using logs may also be appropriate in some locations (Tetra Tech EBA 2015a, 2015b);

- Additional embankment width can help to keep early thaw at the embankment toes further away from the highest loaded area (Tetra Tech EBA 2015a, 2015b);
- In areas where snow drifting proves to be an issue along the road, strategies to reduce snow drifting can be examined, designed and installed (TAC 2010; Tetra Tech EBA 2015a, 2015b), and
- Avoid cutslopes in thaw-sensitive terrain if at all possible. If cutslopes in thaw-sensitive terrain are unavoidable, mitigative solutions are limited and are accompanied by a much greater need for vigilance in monitoring and maintenance to avoid the types of situations described in Section 7.1.1 of the geotechnical report (Tetra Tech EBA 2015a). Depending on the site characteristics, it may be possible to:
  - Protect some cutslopes with a drainage blanket to help mitigate the effects of thaw and meltwater flow (TAC 2010), or
  - Design near-vertical cutslopes to allow the organic layer to be draped over the cutslope to shade and protect it (INAC 2010a). However, these options are not considered to be universal solutions (Tetra Tech EBA 2015a).

Tech Tech EBA's reports provide further information and are listed in the attached References. Sections 6 and 8 of the geotechnical report (Tetra Tech EBA 2015a) and Table 2.8 of the addendum (Tetra Tech EBA 2015b) in particular consider issues related to climate change and potential permafrost thaw, as well as the associated mitigations and/or recommended efforts to obtain sufficient information to design suitable mitigations and monitor their performance.

2.2 Riskope IR 7 – Tolerance / Tolerability to Risks

Preamble:

[ ] *Table 7-3 of the DAR Addendum uses five classes of Qualitative risk levels designated, among others, by a colour-coding.*

Colour-coding is as follows: red indicates "very high" risk, orange is "high" risk, yellow is "moderate" risk, green is "low" risk, and blue is "very low" risk (adapted from British Columbia Ministry of Forests, 2002 not in the reference of the document, but cited in the text). DAR Appendix 2 (PR129) page 69. Although the colour-coding is used as a prioritization or criticality criteria, there is no explicit reference made to corporate or social risk tolerance/tolerability in the reports.

Riskope's Preamble says that "*[a]lthough the colour-coding is used as a prioritization or criticality criteria, there is no explicit reference made to corporate or social risk tolerance/tolerability in the reports*." The first clause is essentially correct; however, regarding the second clause, the geotechnical report states that, "[r]isk tolerance is not addressed in the risk matrix, but should be recognized as a necessary component in making land management decisions, particularly in co-management areas where there may be several stakeholders" (Tetra Tech EBA 2015a).

2.2.1 Item 1

In which manner was the colour coding adapted from BC Ministry of Forestry and based on which criteria, and for what reason?

The colour coding in Tetra Tech EBA's geotechnical report is not from the British Columbia Ministry of Forests, it was added by Tetra Tech EBA in Table 7.2.2-1 of the report solely for additional visual emphasis and ease of interpretation by the reader (Tetra Tech EBA 2015a).

2.2.2 Item 2

Is there a verbiage explaining what each "adjective" (very low to very high) means or can be interpreted (in other words a "scale definition").

The ratings of "very low" to "very high" are subjective qualitative ratings only, appropriate to the level of site-specific data available at the time the ratings were compiled (Tetra Tech EBA 2015a). Tetra Tech EBA's Section 7.2 Qualitative Risk Assessments, defined the assessment parameters (hazard, likelihood, elements of value, consequence, risk and risk tolerance), and provided Table 7.2.1-1 to show the relationship between the parameters used in the qualitative assessment.

The approximate scale definitions for several qualitative parameters are shown in Table 4.4-1 and some of these are appropriate for application in the context of the qualitative risk assessment (Tetra Tech EBA 2015a). For example, a "low" frequency or likelihood suggests that an event may or may not happen during the Project life, but a "high" frequency or likelihood suggests that an event is likely to occur, or that it could be a regular, or even annual, event.

It is noted, however, that magnitude as defined in Table 4.4-1 is not strictly applicable in the context of a slope stability assessment, or assessments of other natural events, because a large-magnitude event may indeed be within the likely range of natural variability. Similar reasoning applies to duration and consequence. Qualifiers may also apply to geographic extent and reversibility when the events have natural causes. Therefore, whether a specific criterion should be considered applicable or not to the analysis depends on the likely contributing cause(s) of a particular event.

The focus of Section 7.2 was on the effects of the environment on the Project (Tetra Tech EBA 2015a). Therefore, where there is a discrepancy between the definitions presented in Table 4.4-1 and Section 7.2.1, the latter applies. When the results of the qualitative analysis are applied to CZN's consideration of spill risks, however, Table 4.4-1 would be the more applicable.

2.2.3 Item 3

Is there any way to reconcile the various qualitative likelihood-consequence evaluations with quantitative values (for example: low could mean a certain expected frequency (range), or a certain probability (range)?

It is possible to correlate slope instability-related qualitative hazard-consequence evaluations with the range of anticipated event frequencies and magnitudes from the magnitude-frequency mapping of slope instabilities (Tetra Tech EBA 2016c).

2.2.4 Item 4

On which basis are the colours allotted to each one of the cells of the matrix?

The colours provide the reader with "at-a-glance" recognition of possible issues in a particular road section. See Item 1.

2.2.5 Item 5

How are the local level of consequences and regional level of consequences in Appendix 2 accounted for in the final risk evaluation?

Tetra Tech EBA's qualitative risk evaluation included in the geotechnical evaluation report (Tetra Tech EBA 2015a) emphasizes the local level of consequences, because it represents the effect of the environment on the proposed road. These values were intended to be applied for use in CZN's spill risk evaluation. Tetra Tech EBA's magnitude-frequency analysis for landslide hazards can be applied to further risk evaluation.

2.2.6 Item 6

Were these colours and their meaning discussed with local authorities and regional authorities?

The colours and their meanings were intended purely for presentation purposes and were defined accordingly in our report (Tetra Tech EBA 2015a).

2.2.7 Item 7

Did local authorities have a say in the colours allotment and scale definitions?

See Item 6.

2.2.8 References

References applicable to the qualitative risk evaluation are presented at the end of this memo. Where the references are available online, website addresses have been confirmed to be current, as shown by the most-recent access date.

The British Columbia Ministry of Forests Engineering Manual (BCMF 2013) refers to the Forest Road Engineering Guidebook (BCMF 2002), both of which have generalized procedures for assessing hazard, consequence and risk that are well-suited to resource roads. The Forest Road Engineering Guidebook, along with the Mapping and Assessing Terrain Stability Guidebook (BCMF 1999), was referenced in previous reports within the collection of documents in the Forest Practices Code Guidebooks as BCMF 2014b (now BCMF 2016a). These documents have some useful guidelines that are highly applicable to the project site.

Wise et al. (2004) also prepared a Land Management Handbook (No. 56) which provides further guidelines on appropriate risk assessments for resource roads, as well as case histories. This document was previously referred to as BCMF (2004) for whom it was prepared, by BCMF's Research Branch, and was included as one of the many documents in BCMF 2014a (now BCMF 2016b) which consists of BCMF reports and publications.

Also referenced is the Canadian Standards Association's *Technical Guide – Infrastructure in Permafrost. A Guideline for Climate Change Adaptation* (CSA, 2010) which has a similar risk evaluation procedure that incorporates the consideration of permafrost terrain.

The references include Tetra Tech EBA's recent geotechnical and terrain-mapping related reports for the proposed Prairie Creek Mine all-season access road.

3.0 LIMITATIONS OF MEMO

This memo and its contents are intended for the sole use of Canadian Zinc Corporation and their agents. Tetra Tech EBA Inc. 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, 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's Services Agreement. Tetra Tech EBA's General Conditions are attached to this memo.

4.0 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.

Prepared by:
Rita Kors-Olthof, P.Eng., P.E.
Senior Geotechnical Engineer, Arctic Region
Engineering Practice
Direct Line: 403.763.9881 (cell)
Rita.Kors-Olthof @tetratech.com

Reviewed by:
Nigel Goldup, P.Eng.
Regional Manager, Arctic Region
Engineering Practice
Direct Line: 780.451.2130 x301
Nigel.Goldup@tetratech.com

/kla

Attachments: Tetra Tech EBA's General Conditions

PERMIT TO PRACTICE
TETRA TECH EBA INC.
Signature
Date
PERMIT NUMBER: P 018
NT/NU Association of Professional Engineers and Geoscientists

REFERENCES

British Columbia Ministry of Forests, Lands and Natural Resource Operations (BCMF), 1999. Forest Practices Code Guidebooks, Mapping and Assessing Terrain Stability Guidebook. Second Edition. https://www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/terrain/index.htm. August, 1999. Access date: March 30, 2016.

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GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA's Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA's Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA's instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client’s expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

REPLY TO BOARD IR41

The comment to this recommendation states "The ToR sought relevant research pertaining to cultural and spiritual sites and activities, including that conducted by CanZinc and its consultants, the Nahanni Butte Dene Band Traditional Knowledge study, and any other relevant materials. This information was not provided in the DAR." This is not correct. This information was provided or referred to in Sections 5.2, 5.3 and 11.9.3. Section 5.2 provides a summary of traditional harvesting activity. We draw your attention to the last paragraph on p. 123 which states "Camp sites were likely established and utilized all along the travelled routes (Band members indicated that such camps were only temporary and were used perhaps only for 1 night while on a harvesting expedition, and that the locations were moreoless at random and not in common, frequently used locations (January 20, 2015))". This is important because potential heritage resource locations is related to the locations of traditional activity, and given that camp locations were 'at random, such resources could be anywhere in the area. However, in Section 5.3, third paragraph on P. 127, we noted that "CZN held meetings with the NDDB in July and August 2009 as part of a TK addendum. One area of concern was as follows: “Given that the ancestors of the Nahanni people are known to have travelled overland to a greater extent than via waterways, the mountain passes that provide easy access into and between valleys are potential areas for pre-historic and historic artifacts. For this reason, it would be useful to carry out archaeological work”. It was agreed that archaeological work should be undertaken in key areas of the Prairie Creek access road, primarily at the Second Gap area in the Nahanni Range, but also at Wolverine Pass in the Silent Hills, and at the crossings of the Tetcela River. CZN engaged Points West Heritage Consulting Ltd. to undertake an Archaeological Impact Assessment (AIA) of the noted key areas." Section 5.3 provides a summary of salient cultural information extracted from the TK Assessment Report Addendum completed for the NDDB (Crosscurrents, August 2009), which is on the Registry, and the full TK study was provided to the Board also. Section 5.3 also documents CZN's engagement with the Band on cultural issues. Two AIA's were completed, during which the consultants engaged with elders regarding cultural site locations. These AIA reports are on the registry for EA0809-002 and need to be posted on the EA1415-001 registry. Therefore, relevant research pertaining to cultural and spiritual sites and activities was provided in the DAR, directly and by reference to previous studies. The comment goes on to say "To determine the adequacy of CanZinc’s assessment on these valued components, the Review Board needs to understand what specific previous efforts have been made to identify cultural and spiritual sites and whether they address the concerns arising from an all-season road versus a winter road." The information referred to above illustrates that considerable efforts have been undertaken to identify cultural and spiritual sites in the area. The area was treated as a whole, although the road alignment represents a narrow linear feature in it. The same infornatuion would relevant and appropriate for any other development in the area, including the all season road. We investigated the locations of highest potential for heritage resources based on TK, and found nothing. The information applies equally to both roads, and for any other proposed development in the area for that matter. CZN has submitted a number of engagement records for this EA indicating our on-going discussions with the Band re access control and traditional activities. The Jan. 20, 2015, we met with hunters, trappers and elders and discussed the route. It was during this meeting that it was confirmed a grave site on the western shore of the Liard River is several hundred metres from the proposed road crossing, and thus sufficiently far away. We have since had further discussions with the Band about heritage resources. Refer to the meeting record for Mar. 1, 2016. We do not believe it to be practical to investigate the whole area for heritage resources when they could occur randomly, if at all (Section 11.9.3). A practical solution is to produce a brochure of heritage resources for site workers so that if any are identified during development work, they can be protected. Further, we have agreed with the Band to engage their members in road development work, during which they can inspect for heritage resources. The Bands' letter of Apr. 19, 2016 indicates that they are in agreement with this approach.

REPLY TO RISKOPE IR1

1. The designed and constructed road will be code compliant, and will "entirely cover the peculiarities of the vehicles and traffic". The term "good" is intended as a simplification for attributes such as consistent and gentle grade, absence of tight bends and tight corners, avoidance or mitigation of blind spots in terms of on-coming traffic and/or wildlife.

2. The noted codes are specific to the road, not the traffic, vehicles and tranported materials. However, suffice to say that roads in northern BC and farther north built according to the codes carry all types of vehicles and loads, including double trailer logging trucks and remote resource site supply trucks. Allnorth have noted that the Prairie Creek road is not atypical of resource roads in parts of northern BC.

3. There are no records available from the previous owner (Cadillac). All of the information available has been provided, granted most of it is anecdotal. However, we believe the information is relevant and important as an indication of risk, and is not trivial ("the absence of accident records from the early '80s is not a proof of safety of any kind, especially since that total traffic does not even represent one year of service of the new project"). The over 800 loads previously taken into the Mine by winter road, likely with a variety of driving conditions, good and bad, cannot be compared directly with the all season road proposal whereby a low traffic intensity would operate in summer and winter and would avoid poor driving conditions.

4. An all season road will provide considerably greater capacity for haulage compared to the already permitted winter road. A much lower intensity of traffic would operate for a longer period. This means there is sufficient flexibility in the schedule such that haulage in poor driving conditions can be avoided. If weather conditions are poor in terms of visibility (i.e. a low cloud ceiling, fog, white-out or grey-out), hauling can be suspended. If road damage or a rockfall has occurred, hauling can wait for the repairs to be fully completed. If driving conditions change while hauling is in progress and are not suitable, hauling will pause, and if there is then insufficient time to complete the haul when conditions improve, trucks can return to base. Hauling in night time will be minimized, however, given the northern latitude, a significant proportion of winter hauling will necessarily occur in darkness or semi-darkness. Therefore, this will be factored into suitable visibility requirements i.e. weather conditions.

5. a) We anticipate that 2 maintenance crews may be operating on the road at times, a Mine based 'western' crew and a Nahanni Butte-based 'eastern' crew. Each crew could consist of a grader, haul/dump truck and small supervisor truck, although most times it may only be a grader. A loader would be stationed in a borrow pit to provide material for maintenance. However, this loader, and one from the Mine, could be called into action in the unlikely event of an avalanche or slide blocking the road. Assume 2 vehicles on average.

b) Crew changes will be by air, on average one flight per week. Weather delays will usually mean only flight delays. Occasionally, a flight may be diverted to Nahanni Butte, followed by personnel busing to the Mine. There may also be very occasional Mine tours via mini-bus. Assume an average of 1 trip/month.

c) Road operations and road maintenance supervisors will make periodic inspection trips. There will also be environmental monitors. Assume an average of 1.5 vehicles.

d) The vast majority of deliveries will be by back-haul on the concentrate trucks. There will be a very limited number of special deliveries, such as explosives. Assume 1 trip/quarter.

e) The above numbers account for all road activities, either by staff or sub-contractors.

6. All sections of the road will have sign-posted speeds. Road operations will be managed using a Journey Management System. This logs vehicles starting and ending trips, and in the case of concentrate trucks, trip progress (i.e. speeds, stops). We will know from monitoring whether vehicles are exceeding speeds. Supervisors and monitors on the road will also provide oversight.

7. Spill response preparations are procedures are described in section 9.5.2 of the DAR, including responses to specific spills. As noted in section 9.5.1, response times are expected to be within an hour for fiorst responders, and approximately two hours for a larger crew with equipment, in all seasons. Very little hauling is likely to occur at night, and if it does, spill responders will be on call. The noted procedures apply to all of the scenarios listed from a) to f). For the steep sections of the road, refer specifically to the sub-section titled "Spill Control Points". Accidents involving heavy equipment may require a crane and/or winch to effect a full response. However, the first priority is personnel safety and containment of spilled material. Personnel injuries may require an air ambulance. Fixed wing and helicopter support is available in Fort Simpson, 45 minutes air time away. In the very unlikely event of the river barge sinking or capsizing, Nahanni Butte is 10 minutes upstream with many motorized watercraft available. A crane and/or winch may also be required ultimately. While we agree that response teams should be prepared and equiped for all possible scenarios, including those listed, we would caution that while the listed scenarios may have occurred elsewhere, it does not mean these scenarios are likely to occur on the Prairie Creek road. We don't know what road design, conditions, management systems and oversight occurred in connection with the scenarios, but we do know that those adopted for our project will be at the required standards.

TETRA TECH EBA

TECHNICAL MEMO

ISSUED FOR USE

To:	David Harpley, Canadian Zinc Corporation	**Date:**	April 13, 2016
c:	Alan Taylor, Canadian Zinc Corporation	**Memo No.:**	2
From:	Rita Kors-Olthof, Nigel Goldup	**File:**	Y14103320-01.003
Subject:	Responses to Information Requests from Mackenzie Valley Review Board and Oboni Riskope Associates Inc. Prairie Creek Mine Site Proposed All-Season Access Road, EA1415-01 Technical Review		

1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) provides, in this technical memo, the responses to some of the information requests to Canadian Zinc Corporation (CZN) from the Mackenzie Valley Review Board (MVRB) and Oboni Riskope Associates Inc. (Riskope). This memo specifically addresses those requests that pertain to permafrost and risk analysis information. The information requests are shown in each section in italics, followed by Tetra Tech EBA's responses in regular text.

2.0 RESPONSES TO INFORMATION REQUESTS

2.1 MVRB IR 13

Water crossings and effects of permafrost thaw; DAR section 12:

***Comment**: Section 12 of the DAR (PR#55) states that the impacts of permafrost thaw to infrastructure may be major and potentially significant and could be mitigated.*

***Recommendation**: Please list the potential mitigation options for impacts of permafrost thaw at crossings and along the road.*

It is important for the project reviewers to consider the above-noted comment in context. Tetra Tech EBA have carefully considered the implications of potential permafrost thaw, whether related to climate change or to site disturbance. Furthermore, Tetra Tech EBA have considered the possible impacts of permafrost thaw on the proposed road infrastructure including bridges and culverts, just as would be done for any other proposed project in permafrost terrain, in accordance with the guidelines presented in the Canadian Standards Association's *Technical Guide – Infrastructure in Permafrost. A Guideline for Climate Change Adaptation. Plus 4011-10* (CSA 2010) (Tetra Tech EBA 2015a). As such, we have noted the following primary mitigations as being most appropriate for the project, subject to the consideration of additional site-specific information that is acquired as the project progresses:

- Avoid ice-rich permafrost terrain where possible; and
- Where the route cannot avoid potentially ice-rich permafrost terrain, consider alternative mitigations.

It is noted that the proposed all-season route avoids considerable terrain that is thought to be ice-rich and/or subject to thermokarst processes. For example, between about KP090.6 and KP097, the existing winter route traverses ice-rich and potentially thermokarst-prone areas, with several existing thermokarst features already noted. The

Tetra Tech EBA Inc.
Box 2244, 201, 4916 - 49 Street
Yellowknife, NT X1A 2P7 CANADA
Tel 867.920.2287 Fax 867.873.3324

proposed all-season re-route from KP090.6 to KP095 avoids much of this terrain by staying in the upland areas to the southwest, traversing from sandy mound to sandy mound, thus keeping more of the route in “high and dry” terrain.

Where ice-rich terrain is encountered along the all-season road, the following mitigations may be considered, according to the site-specific requirements for stream crossings or road sections (Tetra Tech EBA 2015a):

- For major stream crossings if/where permafrost is determined to be present:
  - Design foundations for bearing on, or in, a suitable frost-stable (thaw-insensitive) foundation layer (Tetra Tech EBA 2015a). For example,
    - Shallow foundations could be placed on a coarse granular bearing layer that is not influenced by changing thermal regimes;
    - Piles could be driven or drilled into a suitable soil layer that is not influenced by changing thermal regimes; or
    - If bedrock is present, the foundation could be placed on or in bedrock;
  - If no suitable foundation layer is present, and ice-rich permafrost is present, then a foundation might consist of:
    - A combination of shallow or deep foundations, with
    - Possibly thermoprobes, thermopiles or thermosyphons to help maintain cold permafrost temperatures, and
    - Where permafrost areas may not actually thaw during the life of the crossing, but could be prone to higher rates of soil creep (Tetra Tech EBA 2015a), one of the potential mitigations could also include thermosyphons.
- For minor stream crossings, such as culvert crossings in permafrost (Tetra Tech EBA 2015a), mitigations could include:
  - Strategic placement of culverts to reduce the likelihood of water ponding alongside the road embankment;
  - Embankment sections with a free-draining base layer that allow water to permeate through the embankment may also be an option in some locations, supplemented with an overlying culvert to pass spring flows (TAC, 2010);
  - After construction, it would be prudent to carry out regular inspection of the road embankment to determine if additional mitigative measures are required.
- For road sections where thaw-sensitive terrain cannot be avoided (Tetra Tech EBA 2015a, 2015b):
  - Embankments can be designed and constructed with a thickness and width appropriate to the terrain type;
  - In warm permafrost, a thicker embankment may not stop permafrost thaw, but it does provide an additional buffer to reduce flexing of the underlying subgrade;
  - “Corduroy” style embankment-supporting structures using logs may also be appropriate in some locations (Tetra Tech EBA 2015a, 2015b);

- Additional embankment width can help to keep early thaw at the embankment toes further away from the highest loaded area (Tetra Tech EBA 2015a, 2015b);
- In areas where snow drifting proves to be an issue along the road, strategies to reduce snow drifting can be examined, designed and installed (TAC 2010; Tetra Tech EBA 2015a, 2015b), and
- Avoid cutslopes in thaw-sensitive terrain if at all possible. If cutslopes in thaw-sensitive terrain are unavoidable, mitigative solutions are limited and are accompanied by a much greater need for vigilance in monitoring and maintenance to avoid the types of situations described in Section 7.1.1 of the geotechnical report (Tetra Tech EBA 2015a). Depending on the site characteristics, it may be possible to:
  - Protect some cutslopes with a drainage blanket to help mitigate the effects of thaw and meltwater flow (TAC 2010), or
  - Design near-vertical cutslopes to allow the organic layer to be draped over the cutslope to shade and protect it (INAC 2010a). However, these options are not considered to be universal solutions (Tetra Tech EBA 2015a).

Tech Tech EBA's reports provide further information and are listed in the attached References. Sections 6 and 8 of the geotechnical report (Tetra Tech EBA 2015a) and Table 2.8 of the addendum (Tetra Tech EBA 2015b) in particular consider issues related to climate change and potential permafrost thaw, as well as the associated mitigations and/or recommended efforts to obtain sufficient information to design suitable mitigations and monitor their performance.

2.2 Riskope IR 7 – Tolerance / Tolerability to Risks

Preamble:

[ ] *Table 7-3 of the DAR Addendum uses five classes of Qualitative risk levels designated, among others, by a colour-coding.*

Colour-coding is as follows: red indicates "very high" risk, orange is "high" risk, yellow is "moderate" risk, green is "low" risk, and blue is "very low" risk (adapted from British Columbia Ministry of Forests, 2002 not in the reference of the document, but cited in the text). DAR Appendix 2 (PR129) page 69. Although the colour-coding is used as a prioritization or criticality criteria, there is no explicit reference made to corporate or social risk tolerance/tolerability in the reports.

Riskope's Preamble says that "*[a]lthough the colour-coding is used as a prioritization or criticality criteria, there is no explicit reference made to corporate or social risk tolerance/tolerability in the reports*." The first clause is essentially correct; however, regarding the second clause, the geotechnical report states that, "[r]isk tolerance is not addressed in the risk matrix, but should be recognized as a necessary component in making land management decisions, particularly in co-management areas where there may be several stakeholders" (Tetra Tech EBA 2015a).

2.2.1 Item 1

In which manner was the colour coding adapted from BC Ministry of Forestry and based on which criteria, and for what reason?

The colour coding in Tetra Tech EBA's geotechnical report is not from the British Columbia Ministry of Forests, it was added by Tetra Tech EBA in Table 7.2.2-1 of the report solely for additional visual emphasis and ease of interpretation by the reader (Tetra Tech EBA 2015a).

2.2.2 Item 2

Is there a verbiage explaining what each "adjective" (very low to very high) means or can be interpreted (in other words a "scale definition").

The ratings of "very low" to "very high" are subjective qualitative ratings only, appropriate to the level of site-specific data available at the time the ratings were compiled (Tetra Tech EBA 2015a). Tetra Tech EBA's Section 7.2 Qualitative Risk Assessments, defined the assessment parameters (hazard, likelihood, elements of value, consequence, risk and risk tolerance), and provided Table 7.2.1-1 to show the relationship between the parameters used in the qualitative assessment.

The approximate scale definitions for several qualitative parameters are shown in Table 4.4-1 and some of these are appropriate for application in the context of the qualitative risk assessment (Tetra Tech EBA 2015a). For example, a "low" frequency or likelihood suggests that an event may or may not happen during the Project life, but a "high" frequency or likelihood suggests that an event is likely to occur, or that it could be a regular, or even annual, event.

It is noted, however, that magnitude as defined in Table 4.4-1 is not strictly applicable in the context of a slope stability assessment, or assessments of other natural events, because a large-magnitude event may indeed be within the likely range of natural variability. Similar reasoning applies to duration and consequence. Qualifiers may also apply to geographic extent and reversibility when the events have natural causes. Therefore, whether a specific criterion should be considered applicable or not to the analysis depends on the likely contributing cause(s) of a particular event.

The focus of Section 7.2 was on the effects of the environment on the Project (Tetra Tech EBA 2015a). Therefore, where there is a discrepancy between the definitions presented in Table 4.4-1 and Section 7.2.1, the latter applies. When the results of the qualitative analysis are applied to CZN's consideration of spill risks, however, Table 4.4-1 would be the more applicable.

2.2.3 Item 3

Is there any way to reconcile the various qualitative likelihood-consequence evaluations with quantitative values (for example: low could mean a certain expected frequency (range), or a certain probability (range)?

It is possible to correlate slope instability-related qualitative hazard-consequence evaluations with the range of anticipated event frequencies and magnitudes from the magnitude-frequency mapping of slope instabilities (Tetra Tech EBA 2016c).

2.2.4 Item 4

On which basis are the colours allotted to each one of the cells of the matrix?

The colours provide the reader with "at-a-glance" recognition of possible issues in a particular road section. See Item 1.

2.2.5 Item 5

How are the local level of consequences and regional level of consequences in Appendix 2 accounted for in the final risk evaluation?

Tetra Tech EBA's qualitative risk evaluation included in the geotechnical evaluation report (Tetra Tech EBA 2015a) emphasizes the local level of consequences, because it represents the effect of the environment on the proposed road. These values were intended to be applied for use in CZN's spill risk evaluation. Tetra Tech EBA's magnitude-frequency analysis for landslide hazards can be applied to further risk evaluation.

2.2.6 Item 6

Were these colours and their meaning discussed with local authorities and regional authorities?

The colours and their meanings were intended purely for presentation purposes and were defined accordingly in our report (Tetra Tech EBA 2015a).

2.2.7 Item 7

Did local authorities have a say in the colours allotment and scale definitions?

See Item 6.

2.2.8 References

References applicable to the qualitative risk evaluation are presented at the end of this memo. Where the references are available online, website addresses have been confirmed to be current, as shown by the most-recent access date.

The British Columbia Ministry of Forests Engineering Manual (BCMF 2013) refers to the Forest Road Engineering Guidebook (BCMF 2002), both of which have generalized procedures for assessing hazard, consequence and risk that are well-suited to resource roads. The Forest Road Engineering Guidebook, along with the Mapping and Assessing Terrain Stability Guidebook (BCMF 1999), was referenced in previous reports within the collection of documents in the Forest Practices Code Guidebooks as BCMF 2014b (now BCMF 2016a). These documents have some useful guidelines that are highly applicable to the project site.

Wise et al. (2004) also prepared a Land Management Handbook (No. 56) which provides further guidelines on appropriate risk assessments for resource roads, as well as case histories. This document was previously referred to as BCMF (2004) for whom it was prepared, by BCMF's Research Branch, and was included as one of the many documents in BCMF 2014a (now BCMF 2016b) which consists of BCMF reports and publications.

Also referenced is the Canadian Standards Association's *Technical Guide – Infrastructure in Permafrost. A Guideline for Climate Change Adaptation* (CSA, 2010) which has a similar risk evaluation procedure that incorporates the consideration of permafrost terrain.

The references include Tetra Tech EBA's recent geotechnical and terrain-mapping related reports for the proposed Prairie Creek Mine all-season access road.

3.0 LIMITATIONS OF MEMO

This memo and its contents are intended for the sole use of Canadian Zinc Corporation and their agents. Tetra Tech EBA Inc. 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, 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's Services Agreement. Tetra Tech EBA's General Conditions are attached to this memo.

4.0 CLOSURE

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

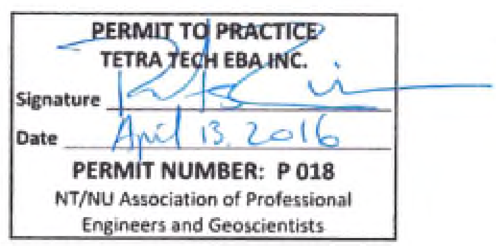
Respectfully submitted,
Tetra Tech EBA Inc.

Prepared by:
Rita Kors-Olthof, P.Eng., P.E.
Senior Geotechnical Engineer, Arctic Region
Engineering Practice
Direct Line: 403.763.9881 (cell)
Rita.Kors-Olthof @tetratech.com

Reviewed by:
Nigel Goldup, P.Eng.
Regional Manager, Arctic Region
Engineering Practice
Direct Line: 780.451.2130 x301
Nigel.Goldup@tetratech.com

/kla

Attachments: Tetra Tech EBA's General Conditions



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GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA’s Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA’s Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA’s instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

Hatfield CONSULTANTS

MEMO

Date: 22 April 2016 HCP Ref No.: CZN7932-NV

From: John Wilcockson (Hatfield Consultants)

To: David Harpley (Canadian Zinc Corp)

Subject: Proposed all-season road, responses to information requests

Canadian Zinc Corp (CZN) has applied for a permit to build and operate an all season road linking the Prairie Creek Mine to Highway 7, just east of the community of Nahanni Butte, NWT. This memo responds to some of the information requests (IRs) posed to CZN by environmental assessment (EA) interveners as well as the Mackenzie Valley Environmental Impact Review Board (MVEIRB). All IRs considered here relate to the aquatic biology of streams either crossed or parallel to the all-season road.

1.0 PARKS CANADA IR # 21 – NOISE

Preamble

(Please note that much of the text in this preamble was copied from the responses to the adequacy review which were presented in the DAR Addendum; however, much of the text is applicable to IR#21, therefore has been re-stated here. Also note that this information was not referred to by Parks Canada in their IR)

We reviewed several documents in order to acquire information about road noise effects on fish:

- The Northern Land use guidelines; access: roads and trails Volume 5 (AANDC 2015);
- Standard specifications for highway construction in British Columbia (BCMOT 2015); and
- The environmental impact statement for construction of the Inuvik to Tuktoyaktuk Highway, NWT, (Kiggiak-EBA Consulting Ltd, 2011).

None of these documents identified traffic noise as a concern to fish. Potential impacts of noise, however, were noted related to percussion effects due to pile driving and blasting. A Canada/Inuvialuit Fisheries Joint Management Committee Report (Stewart 2003) assessed potential effects of dump trucks carrying crushed rock over the Mackenzie River in winter. This report assessed potential impacts related to a large volume of heavy traffic over the river ice. The concern was that noise from these trucks might result in impacts to fish. The study concluded that the noise from the trucks was unlikely to generate sound pressure levels under the ice sufficient to physically damage fish, or to elicit startle or alarm responses (Stewart 2003). However, it stated that the intensity of noise would be sufficient to cause some species that are more sensitive to noise, namely minnows and suckers in the Mackenzie Delta, to avoid the area. Given that the Prairie Creek Mine traffic or construction vehicles will be driving on roads some distance from streams, or driving over structures not in direct contact with water, it is unlikely that noise would be any greater than that reported in the Joint study. The report also indicates that fish become acclimated to continuous sound levels, even when they are very high, unless there is an abrupt change in sound intensity (Stewart 2003).

A recent study showed that blacktail shiner (*Cyprinella venusta*) have difficulty communicating with each other over ambient traffic noise (Holt and Johnson 2015). This study was done on flat (i.e., quiet water) on species that have specialized sensitive hearing structures, required for communication. It is unlikely that the species living in streams adjacent to the Prairie Creek all-season access road, normally in water with riffle morphology, would be affected similarly.

Sections of Funeral Creek are proximal to the proposed all-season road, and the resident fish include bull trout, a salmonid species. Salmonids are known to have simple, non-specialized, relatively insensitive hearing structures (Popper and Hastings 2009, Stewart 2003). The natural noise of riffles and cascades in Funeral Creek would also act to mask the incremental noise of trucks. Furthermore, entrained bubbles as a result of the riffles and cascades in Funeral Creek would act to attenuate any noise produced by passing trucks.

Funeral Creek likely freezes to the bottom in winter, with the exception of perhaps a few deep pools. Only developing bull trout embryos are likely to be present. Therefore, it is significant that research reports "no effects on eggs or fry [of species tested] from noise louder than trucks" (Section 11.4.2 of the DAR).

IR#21 Point 1:

The information evaluating potential negative effects of noise on fish needs to be defined in terms of the specific vehicles that will use the road and the noise levels that these specific vehicles, or classes of vehicles, will produce.

Response:

The Developer's Assessment Report (DAR 2015) indicated that vehicles using the road would consist of vehicles with a noise intensity of ~ 99 dBA in air. In addition, the DAR stated that at 0.5 km from the road, the noise intensity is expected to be reduced to 35 dBA; which is comparable to the level between normal speech and a whisper (Golder 2010 as cited in the DAR 2015).

A document produced by Tetra Tech EBA Inc., (2005) for CZN in reply to Board IRs 32 and 33 lists the heavy equipment that will be required during construction and operation of the all season road, with their estimated associated noise intensities (Table 1).

The sound intensities provided above are for sound transmission in air, and will be different from the associated intensities under water in adjacent creeks. Much of the sound underwater will come directly from the roadbed via the ground to the adjacent creek. However, the data in Table 1 indicate that dump and haul trucks will likely generate the greatest noise.

Estimates of the probable noise intensity underwater adjacent to the road could not be found in available scientific literature. However, given the argument provided in the preamble, we believe the potential for significant effects is low. Also, it is unlikely that the noise intensity would be any greater than that generated by the permitted winter road.

Based on the above information, we believe noise levels from the equipment that will use the road will not significantly impact fish in the adjacent streams.

Table 1 Sound level for individual pieces of equipment at defined distances from the source.

Noise Source	Time Period	Sound Intensity (dBA) at Distances from Source			
		15 m	30 m	60 m	120 m
Bulldozer	Road construction only	85	79	73	67
Loader	Road construction only	85	79	73	67
Crane	Road construction only	83	77	71	65
Moving dump truck or haul truck	Road construction and operation	88	82	76	70
Idling dump truck or haul truck	Road construction	65	59	53	47

Notes:

Reference sound level obtained from OMOE Publication NPC-115, contained in the OMOE Model Municipal Noise Control By-Law 1977.

Reference sound levels obtained from US Department of Transportation. Transit Noise and Vibration Impacts Assessment, Chapter 12: Noise and Vibration, 1977.

Reference sound level obtained from British Standards No. 5228, Second Edition, May 1997.

IR#21 Point 2:

Using GIS tools and best available noise thresholds, calculate: i) lengths of the road where noise thresholds have the potential to affect fish and ii) total area of stream habitats that may be impacted by road traffic noise.

Response:

As discussed in the preamble above, existing literature indicates that effects on fish as a result of road traffic noise are negligible. Therefore, quantification of road lengths and areas is not necessary.

IR#21 Point 3:

Define noise effect thresholds along the all season road including those adjacent to bridges and culverts.

Response:

The DAR provided a threshold of 50 to 70 dB-re-1µPa. A review of the original source (USDoT 2004) indicates that this is the threshold for noise detection by fish, not a threshold for effect. However the DAR also reported that several species had been adversely affected at >180 dB-re-1µPa after two hours or less of exposure (DAR 2015). Hasting and Popper (2005) estimated 195 to 200 dB-re-1µPa as the threshold for physical injury to fish.

Due to the different properties of air and water, sound is transmitted differently. Sound is easily transported in water due to the high density and low elasticity of water, causing high sound propagation (Tetra Tech, 2016). As a result, sound travels approximately five times faster in water than air and travels a much greater distance, causing exposure of aquatic organisms to noise vibrations over longer distances (Slabbekoorn et al 2010). As a result, background noise is common in an aquatic system. Travolga (1974) found that sound has to be at least 10 dB greater than background to be detected by fish.

Scholik and Yan (2002) found background levels of 80 dB-re-1µPa in an open water pond with no exposure to anthropogenic disturbances. This study concluded that noise levels lower than ~ 90 dB-re-1µPa would not result in a strong adverse response for fish that are hearing generalists, represented by most species found in the study area. Furthermore, ambient background noise associated with riffles and rapids would likely result in much higher background noise, thus masking most anthropogenic noises.

Bridges will be in direct contact with road traffic, but not the water. Culverts will not be in direct contact with road traffic. Therefore, the ground would reduce the intensity of vibration before it enters the water, making it unlikely that the noise would be greater than observed during the Joint study (Steward 2003).

Therefore, we do not anticipate that the threshold of >180 dB-re-1µPa for impacts on fish will be exceeded in aquatic habitats anywhere along the length of the all season road.

IR#21 Point 4:

Define potential effects of roads on fish to include those potentially resulting from vibrations of the road surfaces especially those adjacent to bridges and culverts.

Response:

As was discussed in the preamble, Steward (2003) indicated that the intensity of the noise produced by highway trucks driving on the frozen Mackenzie River may be sufficient to cause suckers and minnows to display startle or alarm responses. These fish species are hearing specialists and are invariably more sensitive to noise than hearing generalists. Species most often found adjacent to the proposed all-season road, (i.e., bull trout, Arctic grayling and sculpins), are hearing generalists and are therefore much less sensitive to noise. Minnow species and suckers have only been documented in the Tetcela and Grainger Rivers. The road has fish-bearing crossings of these rivers with two and one clear-span bridges, respectively, which will mitigate vibration from vehicles reaching the water surface and transmission to resident fish. In addition, no critical or unique habitat was identified at the crossings, so fish would have the opportunity to move away from noise without any anticipated effects to the populations of these species.

Steward (2003) stated that fish may become acclimated to continuous sound levels of a consistent frequency, even when sound intensities are very high. However, an abrupt change in sound intensity may still cause an adverse response from acclimated fish. These findings are in agreement with those of Knudsen (1992), who observed acclimation of juvenile Atlantic salmon to noise over time. Road traffic sounds from the proposed all-season road would not be abrupt, but instead fish would experience sound intensity that rises and falls as each truck passes.

Therefore, we do not anticipate any impacts of vibrations from roads or bridges on fish.

IR#21 Point 5:

Evaluate if the road noise thresholds could be reduced by reducing traffic speeds.

Response:

Noise and other vibrations from trucks reduce at slower speeds. Information obtained from the USDoT (2016b) for trucks travelling on paved roads indicated that noise (through air) decreases only slightly at slower speeds (Table 2). Note, the lowest maximum noise level listed in Table 2 is for speeds less than 35 mph, which is about 60 kph. Haul trucks on the all season road are unlikely to exceed this speed in proximity to fish-bearing water.

Ground vibration is also a function of the weight of vehicle, softness of the truck's suspension, and smoothness of the road. Of these variables, smoothness of the road generally has the greatest influence on noise coming from road traffic (Al-Hunaidi and Rainer 1991). Soil absorption is an important determinant of vibration attenuation with distance. Dry sand and gravel soils have the highest capability to absorb vibration, while soft clay or peat have the lowest (Hajek et al 2006). Given the evidence presented thus far indicating negligible risk of impact to resident fish, we do not think such measures are necessary, and will present an unnecessary burden on operations with no significant benefit in terms of effects on fish.

Table 2 Noise intensity associated with a truck moving at different speeds.

Speed	Maximum Noise Level (at 50 ft. from Centerline of Travel)
<35 mph	83 dBA
>35 mph	87 dBA
Stationary	85 dBA

IR#21 Point 6:

Identify if measures will be taken to quantify potential effects of road traffic noise on fish populations and if so, outline what experimental design will be used to assess these potential negative effects (e.g., a before-after, control impact design to assess impact).

Response:

Effects on fish from road noise are not anticipated, therefore, no noise monitoring is proposed.

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2.0 PARKS CANADA IR # 25 – POINT #2 – COLONIZATION OF NEW CHANNEL

Request

Based on knowledge of colonization dynamics of benthos from previously denuded reaches of streams identify the length of time required for benthic macroinvertebrate communities to resemble natural communities [in the new channel, after the Sundog Creek diversion between km 35.5 and 37].

Response:

At KP35.5, CZN proposes to divert Sundog Creek so that it flows away from the proposed all season road and into a former channel. In order to make the former channel the new thalweg, CZN proposes to deepen it.

The stretch of Sundog Creek containing the channel to be diverted tends to be dry between summer and early spring. However, given the observed presence of flowing water upstream and downstream of this stretch in summer, there must be considerable water flow through the coarse alluvial bed material. Colonization of this stretch of creek would be negatively impacted by the loss of surface water flow, as well as bed load movements that likely occur during freshet (May) and especially during heavy rainfall events, which can occur in the summer (July/August), but not always. Recolonization of the stretch would be helped by drift from the upstream, flowing portions of the creek as well as (but likely to a lesser extent) from flying, egg-laying adults (MacKay 1992).

Given that this stretch was (and continues to be) naturally depopulated from periods of bedload movement and periods where the channel is completely dry, it is expected to provide poor benthic invertebrate habitat relative to areas of Sundog Creek upstream and downstream of the stretch under consideration. Therefore, the relative impact on the creek from diverting the creek in this stretch compared to other stretches will be smaller.

We anticipate that use of this section of creek by benthic invertebrates will primarily occur during freshet and end after the channel dries up, thus providing habitat only for approximately two months. A second, much shorter period of inundation would be associated with heavy rain fall events resulting in higher flows and surface water. However, we anticipate that surface flows resulting from rainfall events, which are infrequent, would last for no more than a week. Due to the short period of inundation each year, it is anticipated that limited periphyton communities would develop on the rocks in the reach of interest thus providing only limited sources of food for benthic invertebrates compared to portions of the creek that have flow over longer periods. Rocks with significant periphyton coverage were observed approximately 2 km downstream in a portion of the creek with flowing water in July. Terrestrial (i.e., allochthonous) sources of organic carbon appear to be negligible, given that the creek drains a mountainous area with little vegetation.

We anticipate that the new thalweg should take little time to attain the same level of stability as adjacent natural sections of the creek. Both the new thalweg and natural stretches of creek would experience scour during higher flows. Furthermore, given that the new thalweg is being created in an existing defined, albeit generally former channel, this indicates that the channel was stable when it was last inundated. We anticipate that the habitat in the new thalweg channel will, after one season, approximate the same (poor) benthic invertebrate habitat present in the existing natural dry channel that it will replace. In relation to the reaches of the creek upstream and downstream, the difference in habitat in the new channel compared to the original is considered to be insignificant.

The portion of the existing channel not occupied by the road (in the original thalweg) will provide continued ephemeral aquatic habitat. During freshet and periods of heavy precipitation, the channel is expected to contain surface water fed via subsurface flows. Because the water will be fed from subsurface water, it is not clear whether it would be colonized by drifting invertebrates, however the water would be available to flying, ovipositing adults and crawling invertebrates when wetted. Therefore, as long as invertebrate larvae living in this channel were able to drift out before it dried, the channel would continue to provide additional benthic insect recruitment to Sundog Creek.

The stability of the diversion structure is required to avoid erosion of the all-season road. CZN will monitor and repair the diversion as needed. Therefore, it is likely that the portion of the original channel (with associated habitat) not used by the road will remain during the lifespan of the road.

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3.0 MVEIRB IR # 24 – HABITAT REQUIREMENTS

Request

Please clearly identify where additional information on habitat requirements for each life stage of fish species can be found in the materials provided by CanZinc to date. If it has not been described, please provide the information as requested in the Terms of Reference.

Response:

Unless otherwise cited, information below has been drawn from Minns et al. (2002).

Bull trout

Bull trout are found in Prairie Creek, Casket Creek and Funeral Creek (Hatfield 2015). It has been classified by COSEWIC as a species of Special Concern (SARA 2016) given that its populations can be threatened on a regional basis.

Bull trout typically require clear stream channels that have healthy riparian zones for rearing and spawning. Studies have also found that adults require cold water and will not be found in temperatures greater than 15°C.

Bull trout exhibit two different life-history strategies: migratory and non-migratory. Within the Prairie Creek drainage, it is believed that both life histories exist. Mochnacz et al. (2012) observed both resident populations and populations migrating from the Nahanni River. Individuals have been observed spawning in the smaller tributaries of Prairie Creek in the fall, and it is believed that alevins likely overwinter in the ice-free interstitial areas within the bottom substrates. Monchnacz (2012) has observed resident populations of bull trout in several of the larger tributaries to Prairie Creek, including Funeral Creek.

Both resident and migratory populations at the site use headwater and tributary streams for fall spawning. Spawning areas are typically smaller, cold streams and rivers, with riffle and pool areas that have a close proximity to cover. The spawning substrate is typically cobble (8-32 mm diameter) and gravel containing 22-33 % fine sediment. The spawning depth ranges from 0.18 to 0.54 m with water velocities between 0.12 and 0.66 m/s; this may vary with location and life history. The typical temperature range for spawning is 5 to 9°C. Larger streams also can be used for spawning. Spawning gravels are generally found in areas with groundwater upwelling, which allows for stable temperatures and overwinter flows important for egg incubation. After spawning is complete, migrating adults typically move to larger rivers and major tributaries. The eggs develop in spawning gravels over the winter and fry emerge in spring.

Fry are found amongst cobble, boulders and interstitial habitat in shallow water with velocities lower than 0.10 m/s. Typically, fry are found in shallow depths (up to 15 cm) with an abundance of cover such as submerged vegetation and woody debris.

The young of the year (YOY) are extremely substrate-orientated, with a high dependence on embedded cobble, gravel, boulder with overhanging vegetation and woody debris. YOY will utilize runs, riffles and pools equally, while adults (1 + year old) prefer deep pool areas with sand to pebble substrate. In addition, YOY prefer the channel margins, small side channel and backwater areas, while adults prefer the main channel.

YOY typically utilize pools in the summer, but will move into runs later in the year, and overwinter in pools typically with no overhead cover or surface flow, but with groundwater upwelling and interstitial spaces between gravel and cobble substrates for cover. Typically YOY are associated with small streams for the first two years of life, with adults moving into larger tributaries or lakes.

Bull trout have a slow growth rate, and are typically slow to mature; in addition not all reproductively viable individuals reproduce in consecutive years.

Priairie Creek provides habitat to migratory adults and some overwintering habitat for resident adults. There may also be isolated locations for migratory adult spawning. Funeral and Casket creeks, both major tributaries to Prairie, provide spawning habitat to both resident and migratory adults, as well as rearing habitat for fry and YOY.

Round Whitefish:

Round whitefish are found in Prairie Creek, Tetcela River and Grainger River (Hatfield 2015). They display both lacustrine and riverine life histories.

Spawning can occur in lakes, rivers and clear streams. In the East Arctic region, spawning occurs in late fall (October) in rivers with gravel and cobble substrate that is free of sand with a temperature of ~ 4.5 °C and a depth of 9 m. In the Yukon region, spawning was observed in both fast and slow water, at depths between 70 to 250 cm over substrate of silt, gravel and boulders. The eggs incubate under the ice and hatch in the spring (April and May).

The larvae prefer sand or silt substrates over cobble and gravel and are typically found in backwater areas where the water velocity is zero or only a slight current exists. Lee (1985) found that submergent vegetation is not utilized when present. Instead the larvae were found to use turbidity for cover in most cases; although cobble, boulders and debris, and overhanging vegetation were also used. The larvae will typically migrate downstream to the lower part of the river during their first year; a study in Siberia found that the last few larvae migrated in June. As juveniles mature, they typically migrate to faster and deeper water.

Adult round whitefish will utilize areas with high turbidity if no cover exists, but prefer the following cover types (ordered from most preferred to least preferred): cobble and boulder; undercut banks; overhanging vegetation; debris/deadfall; submergent vegetation; emergent vegetation; and rubble and large gravel. Optimal water velocities were found to range between 0.61 to 0.91 m/s. A study in northern Alaska found that adult whitefish preferred deep pools in large streams that had relatively low velocities (0.17 m/s) with coarse substrate types and undercut banks. Most whitefish mature around the age of 6 to 9 and the oldest fish caught was 12 years old.

The ubiquitous occurrence of cobble substrates in Prairie Creek, Tetcela River and Grainger River provides good habitat for round whitefish.

Arctic Grayling:

Arctic grayling are found in lower Prairie Creek near its confluence with Nahanni River, Sundog Creek, Polje Creek, Tetcela River and Grainger River (Hatfield 2015). Grayling generally prefer streams with low turbidity, however all of the noted streams can be very turbid during high water.

Arctic grayling spawn in the spring (from mid-May to early June) in clear water. Spawning dates may vary with location, but occurs in water temperatures between 7 and 10°C. Adults typically migrate from larger rivers into smaller streams to spawn and require areas with gravels about 2.5 cm in diameter; a percentage of sandy substrate (<15-20 %) has also been found in spawning areas. Spawning has been recorded within riffles and pools in Alaska; with typical surface water velocities of less than 1.4 m/s. Generally, grayling will spawn during the midday to late afternoon period, over a period of 2-3 weeks. After spawning, the adult grayling will migrate back to summer habitat downstream to larger rivers.

The fry will hatch within 8-32 days at a temperature of 5.8-15.5°C; the length of incubation is highly dependent on temperature and may vary with location. The fry will spend three to five days under the substrate. After emerging from the substrate, fry will reside in pools and side channels of the stream approximately 30 and 50 cm in depth. Preferred bottom substrates consist of boulder, cobble, silt and sand, while preferred velocities are less than 0.8 m/s. The fry will initially school together, but within a three week period individuals will begin to display antagonistic behaviour towards each other. Fry remain in their natal stream for up to 15 months; individuals may then remain in their natal stream feeding or move to other areas of the river system.

YOY reside in areas that have gravel, silt and cobble with some sand in slow-moving water of shallow depth. Studies indicated rocks are the most utilized cover, with cut banks, loose gravel, overhanging vegetation and in-stream vegetation and shade used to a lesser extent. YOY have been captured in both silt substrates with depths of 20-80 cm and riffles areas with depths of 20-30 cm. As fish mature, they will move to deeper and faster water in areas that are close to shore, backwater areas, pools or side channels.

Adults show a preference for areas with cobble and gravel and are commonly found over fine grained and coarse substrates, with an avoidance of medium grained substrates. Adults will often use rocks for cover, with a small percentage (14%) using overhanging vegetation, undercut banks, and deadfall. Typically, individuals reside in water with high velocities, 0.61-1.08 m/s, and in deeper depths (1.10-1.52 m); however, individuals can be found in water with velocities up to 1.3 m/s, depths of 23-91 cm. Adult grayling require deep pools for overwintering.

Grayling may mature in as early as two years, or as late as nine years. Once mature, a grayling is likely to spawn every year.

The above noted habitat is common in the listed streams, accounting for the presence of grayling.in spring and summer. However, as flows subside in the fall and winter, few likely survive in the upper reaches of Sundog Creek, including Polje Creek, and those that do are confined to deep pools.

Slimy Sculpin:

Slimy sculpin are ubiquitous in Prairie Creek, Sundog Creek, Tetcela River and Grainger River (Hatfield 2015). The species is typically found in riverine habitat with rocky or gravelly bottoms. The species has a small home range and does not typically migrate. Spawning occurs in spring, typically between May and June, when temperatures are ~3.5°C. Spawning habitat is typically under a rock, ledge or submerged tree root.

The eggs take four weeks to hatch at a temperature of ~8°C. The fry hatch and will remain in the yolk sac for an additional, 3-6 days. The fry will then leave the nest and move to the nursery area. Typically the nursery area is within cobble and boulder substrate, under 13 to 22 cm of water, with a velocity between 0.06 and 0.56 m/s; however, young have been found in deeper water (10-30 cm), with stronger currents (5-40 cm/s).

Adult sculpin in the Arctic appear to prefer clear streams with gravel substrates. In Wisconsin, adults have been found in rubble, boulder, silt, gravel, bedrock and sand substrates, and within areas with dense submerged aquatic plants and fast currents at an average depth of 13 cm depth. Most adults mature after two years, but maturity can occur between 1 and 3 years of age.

Northern Pike:

Northern pike (pike) have been documented in the Tetcela and Grainger Rivers (Hatfield 2015). Pike are ambush predators and require cover such as aquatic plants, tree stumps, and fallen logs. Pike spawn during the spring in the backwaters of rivers, streams, lakes, and marshes that have aquatic vegetation. Preferred spawning areas have submerged vegetation, with temperatures ranging from 4 to 16°C, with little to no current, and in less than 30 cm of water. Eggs are attached to the submerged vegetation, making the presence of macrophytes a highly important factor. Typically, spawning will occur in areas with mud substrate and a vegetation mat.

Northern Pike fry hatch after 12 to 14 days and immediately attach to the submerged vegetation with an adhesive gland on top of their heads. The fry will remain attached to the vegetation until the yolk sac has been absorbed. Fry develop near where they hatched. Nursery habitat consists of dense submerged and emergent vegetation in back eddies or at the mouths of tributary streams. The fry will remain in the spawning area for several weeks.

In the Mackenzie River, YOY will move into slower water and weedy areas of the main river. YOY northern pike were observed in the main river in July, although some remained in the tributary streams. YOY are typically found in depths less than 2 m, over mud and silt substrate with aquatic vegetation for cover.

Adults can be found in large weedy back eddies and mouths of tributaries that have a high abundance of forage fish. Typically these areas are shallow, and have no velocity, substrate consists of mud and silt substrate, and there is aquatic vegetation. Female northern pike mature between 3 and 8 years, while males mature between 2 and 6 years. Northern pike can live to be up to 15 to 26 years old.

Longnose Sucker:

Longnose Sucker have been documented in the Tetcela River (Hatfield 2015). They are typically found in rivers, lakes and streams with clear or turbid water. The longnose sucker is primarily a bottom-dwelling species

Spawning typically occurs between May and June, when water temperatures range from 8-16 °C. Typical spawning habitat is large rocks 10-50 cm in diameter or sand and gravel less than 1 cm in diameter at depths between 15-54 cm and a velocity between 25-100 cm/s. Mating will typically occur during daylight.

Eggs typically hatch after seven days at a water temperature of 17 °C. The fry will remain in the gravel for one to two weeks before emerging from the substrate and moving downstream. During the downstream migration, fry are commonly in fast flowing water or near the surface. Fry were observed to be most abundant in the mouths of fast flowing creeks, but also in shallow pools where available.

After spawning, adult suckers will disperse downstream within the river system or to lakes. YOY and adults are commonly found in slow water such as back eddies or river mouths. Individuals spawn each year after they have reached maturity. Males mature at age 4-9 and females at 6-12. Long-nose sucker is a long-lived species with a maximum age of 28 years.

Lake Chub:

Lake Chub have been observed in the Tetcela River (Hatfield 2015). This species is a widespread cyprinid, and prefers lakes but can frequently be found in riverine habitats. Lake chub is found in both clear and muddy waters and sometimes in large schools.

Spawning has been observed in the South Nahanni River in May. Spawning typically occurs in shallow areas with slow moving water amongst cobble or boulder substrate. Eggs hatch after 10 days at a temperature range of 8-19 °C. Studies indicate that fry can be found among submerged vegetation, while YOY can be found in areas with rocky bottoms. Adults can be found in a variety of habitats ranging from clear streams and tributary mouths to the turbid waters of the Liard River. Studies indicate that Lake Chub use rocks for cover and have been found at stream mouths in water depths of 1 m or less. Lake Chub mature in their third or fourth year and can live up to five years.

Longnose Dace:

Longnose Dace have been observed in the Tetcela River (Hatfield 2015). This species can occur in either clear or turbid water, but prefers turbulent swift-flowing streams with gravel or boulder substrates, with clear pools. This species does not school.

Information is lacking regarding northern populations, but the southern population spawns from May to July; spawning may occur later for the northern populations. Spawning occurs in riffle areas of streams over gravel substrates.

Eggs hatch after 7-10 days at 15.6°C. New hatchlings live in their egg sacs for seven days. The fry will then live pelagically for approximately four months in shallow water along the banks of rivers. After another four months, individuals will then move to faster, deeper water and will eventually become bottom dwellers. YOY are typically found in depths of 10-19 cm and avoid depths below 20 cm.

Adults can typically be found in rocky sections of tributaries in fast currents with boulder, silt and gravel substrates. Occasionally, individuals can be found over mud, clay, bedrock and detrital substrates. Individuals will mature after between two and three years.

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4.0 MVEIRB IR # 28 – POTENTIAL EFFECT PATHWAYS

Request

Please describe all potential effects pathways of impacts of the road on fish health. Examples of pathways not currently considered include, but are not limited to, the effects of increased sedimentation on survival and emergence and development rates of fish larvae and eggs, gill damage, stress response, reduced resistance to disease and feeding rates, and the potential chronic and acute effects of spills on fish health. If these potential effects are excluded from assessment, please explain this exclusion.

Response:

If an aquatic impact is severe enough, most effects pathways can result in a reduction in fish populations, but the health of individual fish can be an important assessment endpoint for less severe effects. Aspects of fish health (including health indices) can also be used as early measurement indicators of an impact that may later result in a decreased population. Examples of potential road related impacts to fish health effects (and associated causes) are:

- Survival and emergence of fish larvae and eggs – physical smothering from the deposition of fine sediments on spawning gravels or exposure of developing eggs to metals, acid or hydrocabons from a spill.
- Gill damage – often erosion to gill lamellae from the exposure of fish to high TSS for extended periods. However, gill damage can also arise from exposure to caustic substances such as acids;
- Stress response – from blasting, or exposure to high TSS for extended periods;
- Reduced resistance to disease, including parasites – can be a result of prolonged physical stress, but can also be a result of insufficient food for energy needs;
- Increased susceptibility to predation – weak, unhealthy fish may not be able to escape predators;
- Decreased feeding rates – often impacts fish that are visual hunters due to an inability to see prey in water with high turbidity;
- Chronic effects related to accumulation of metals from environment (or spilled concentrate), or cumulative stress associated with multiple periods of high turbidity; and
- Acute effects related to the narcotic effect (polar narcosis) of hydrocarbon spills, significant changes in pH possibly associated with an acid spill and damage to a fishes swim bladder during blasting.

An updated list of potential effect pathways and associated residual effects analysis is provided below:

4.1 ENCROACHMENT ON SUNDOG CREEK

Effect Pathway -in a small number of locations the proposed road will encroach on Sundog Creek, causing loss of fish habitat (rearing habitat for Arctic grayling and sculpin) and possible spawning habitat for sculpin.

Residual Effects Analysis

Possible impact	Loss of fish habitat, possibly including rearing habitat (Arctic grayling and sculpin) and spawning habitat (sculpin). Ultimate impact on fish may be a reduction of fish population.
Significance (High/Moderate/Low) **&** **Rationale**	Low Re-alignment of the creek will result in no net loss of normally wet fish habitat.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Only associated with two locations on Sundog Creek; approximately 50 m long each.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation.
Magnitude (High/Moderate/Low)	Low (channel will be redirected into an existing, currently dry former channel, area affected is very small)
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	Low

4.2 SUNDOG CREEK RE-ALIGNMENT – TEMPORARY BENTHOS LOSS

Effect Pathway – re-alignment of sundog creek down a historical (currently dry) channel will result in temporary reduction in benthic invertebrate biomass as channel stabilizes. Lower quantities of fish food items may impact health of resident fish.

Residual Effects Analysis

Possible impact	Temporary loss of fish habitat as the new channel becomes stable. Lower quantities of fish food items (benthic invertebrates) from this area may result in a reduction of fish health and if severe, possible impact on fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Impact anticipated to have a low magnitude, high reversibility and small geographical range (relative to whole Sundog Creek). Furthermore, the habitat in the new channel will be comparable to what currently exists, therefore no net loss of habitat is anticipated. In addition, the original channel will mostly remain, but will be blind. Lower flows in this blind channel may provide refuge to fish during flood events.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Approximately 1.6 km
Timing (Duration, Frequency, and Extent)	1 to 3 years – construction of road only
Magnitude (High/Moderate/Low)	Low (channel will be redirected into an existing, currently dry channel, area affected is very small relative to the length of Sundog). In addition, this zone of Sundog naturally goes to ground in the summer and fall. Therefore, it is anticipated that the area has a lower natural productivity than areas immediately downstream that have flowing water much of the year.
Reversibility (High/Moderate/Low)	High – benthic invertebrate assemblages should stabilize within three years
Likelihood (High/Moderate/Low)	High

4.3 SUNDOG CREEK RE-ALIGNMENT – TSS AND FISH HEALTH

Effect Pathway – The Sundog diversion may result in a short period where fine materials from the new channel are suspended and result in downstream Sundog Creek water with a higher TSS. The greater TSS has the potential to result in impacts on resident fish health. However, as flows develop in spring, fines are likely to be washed into interstices between cobbles. Also, the duration and area of higher TSS is likely to be short and small, as well as upstream of grayling that may have overwintered in deep pools about 1 km downstream. However, some sculpin may be closer.

Residual Effects Analysis.

Possible impact	A possible elevation in downstream TSS on Sundog Creek could impact fish health, including damage to gills, stress, and reduced resistance to disease. Both Arctic grayling and slimy sculpin are visual hunters, therefore water having higher TSS can result in reduced feeding rates. If the effect occurs over a long period of time, it may decrease reproductive rates and increase mortality rates of fish.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Anticipated short duration and low magnitude of effect
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Impact would occur in Sundog Creek downstream of the new channel. Geographic range likely less than 100 m (note, a major tributary joins immediately downstream of the re-alignment).
Timing (Duration, Frequency, and Extent)	Likely an early spring short pulse of water with higher TSS
Magnitude (High/Moderate/Low)	Low - a substantial proportion of water flowing through this portion of Sundog flows subsurface and will not be influenced by fines exposed in the new channel. As water levels rise in spring, downstream TSS may rise as a result of flow going through the new channel. During a flood event, local mountain streams including Prairie and Sundog Creeks are known to be naturally turbid (Pers Com David Harpley). During flood flows, the incremental input of TSS from the new channel is anticipated to be negligible. Fish living in Sundog Creek likely have adapted to short periods of high TSS water, given that these occur naturally.
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	High

4.4 SUNDOG RE-ALIGNMENT – SPAWNING HABITAT.

Effect Pathway – The Sundog diversion may result in a short period where fine materials from the new channel are suspended and deposited in slower moving water downstream. The deposition of fine material has the potential to smother Arctic grayling spawning habitat, if present. However it is anticipated that the first flush will occur gradually and be diluted by sub-surface flow, as well as flow from a major tributary joining from the north and immediately downstream. Also, Sundog is known to be naturally turbid during freshet and spawning habitat exists in this system despite periods of high TSS. Therefore, the anticipated small incremental amount of fine suspended solids coming off the new channel at any given time should not significantly influence existing downstream grayling spawning habitat.

Residual Effects Analysis.

Possible impact	Deposited materials from the new channel could smother Arctic grayling spawning habitat, resulting in impacts on survival and emergence and development rates of fish larvae and eggs. The ultimate impact could be reductions in Arctic grayling populations
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Low magnitude of effect, small range and high reversibility
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Geographic range of an effect would be small, localized to slower moving water likely within a few hundred metres downstream of the diversion. Some fines may travel further downstream, but anticipated dilution will result in negligible incremental increases in TSS in water (and associated deposition in slower moving water) above background levels >1km downstream of the diversion.
Timing (Duration, Frequency, and Extent)	Early in first spring. Since the deposited material would be similar to material naturally in the creek, It is anticipated that spawning gravels would return to normal during the same freshet.
Magnitude (High/Moderate/Low)	Low - we anticipate that influence on overall spawning habitat in Sundog Creek to be very small.
Reversibility (High/Moderate/Low)	High – the material deposited represents natural Sundog Creek bed material. This is the same material that would be naturally mobilized throughout the creek during natural food events. It is anticipated that any deposits of fine sediments smothering spawning habitat would be washed out during higher flows.
Likelihood (High/Moderate/Low)	Moderate – unlikely that there is sufficient material to be mobilized and then deposited in a small area that is important spawning habitat

4.5 HABITAT FRAGMENTATION.

Effect Pathway – Culverts and or bridges are constructed in a way that may prevent or discourage fish from migrating to complete critical life stages.

Residual Effects Analysis

Possible impact	Fragmentation of fish habitat (i.e., barriers to fish movement). Results in possible impacts to fish populations. Many fish species found in the Nahanni watershed must migrate in order to complete their life cycle.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low We are confident that fish bearing streams have been identified and the selected crossing type will not impede fish passage. (Previously discussed in the DAR 11.6.1, p244, and Item 4.16 and 16.3 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Only associated with crossings, but can affect fish travelling long distances.
Timing (Duration, Frequency, and Extent)	20 years – life of mine + reclamation
Magnitude (High/Moderate/Low)	Low –clear span bridges at major crossings over fish bearing streams. For small creeks, installation of culverts will follow best management practices and will have natural substrate in bottom. Regular inspections to ensure they do not become blocked.
Reversibility (High/Moderate/Low)	High – if a culvert is impeding fish movement, it can be redesigned and replaced.
Likelihood (High/Moderate/Low)	Low

4.6 NOISE

Effect Pathway – Vibrations in aquatic habitat caused by passing vehicles on the all season road may illicit a startle reflex in nearby fish. Fish may not choose to use important habitat. If fish cannot move away from the noise, their health may be impacted as a result of stress.

Residual Effects Analysis

Possible Impact	All season road traffic noise may lead to stress and behavioral change in fish residing in aquatic habitat adjacent to the road. The ultimate impact may be reductions in fish populations in creeks that are either adjacent to or crossed by the all season road. Impact most likely if critical habitat occurs adjacent to the road.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Thresholds of noise under water adjacent to the road are unlikely to elicit a startle reflex in resident fish. It is anticipated that vibrations will be below the threshold expected to result in an effect (previously discussed in the DAR 11.4.2, p241, and item 8.4 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Seven spanned and approximately the same number of culvert crossings of fish bearing and potentially fish-bearing streams, and approximately 14.4 km of road that parallels and is within 30m of a fish bearing stream (Prairie 1.9, Fast 0.2, Funeral 4.8, Sundog 7.1, Polje 0.2, Grainger 0.2). The 30m is a conservative estimate, given that research indicates that there will be no impacts to fish.
Timing (Duration, Frequency, and Extent)	20 years – life of mine + reclamation.
Magnitude (High/Moderate/Low)	Low (clear-span bridges will minimize noise at major crossings; fish will likely not perceive or acclimate to small incremental amount of noise adjacent to roads).
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	Low – based on existing literature and types of fish species (hearing generalists) living in habitat most likely to be influenced by noise.

4.7 SPILLED CONCENTRATE – CHRONIC FISH EXPOSURE

Effect Pathway – A spill of concentrate into one of the creeks adjacent to the road could impact fish health and/or fish tissue concentrations. If the magnitude of the effect is large enough, a reduction in fish populations may be observed.

Residual Effects Analysis

Possible Impact	Spilled concentrate could impact fish health and or fish tissue concentrations of metals. Spill could result in chronic effect on fish health, possibly resulting in decreases in fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Risk of impacts are low due to very low likelihood of a spill, high likelihood of thorough clean-up if one occurred, and low leaching potential of concentrates.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate to high – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush sediments.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.8 SPILLED CONCENTRATE – SPAWNING HABITAT

Effect Pathway – A spill of concentrate into one of the creeks adjacent to the road could impact fish reproduction if concentrate precipitates in spawning habitat. The concentrate could result in physical smothering of developing eggs, or the metals in the concentrate could leach out and impact the development and emergence of larval fish. If the magnitude of the effect is large enough, a reduction in fish populations may be observed.

Residual Effects Analysis

Possible Impact	Fish eggs and developing embryos may be impacted if spilled concentrate settles out in spawning habitat. Developing fish may be affected either by physical smothering or by bioavailable metals leaching from concentrate in sediments – chronic effect
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Due to very low likelihood of a significant spill, high likelihood of thorough clean-up, and small predicted geographic range of effects if a spill occurred.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate to high – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush sediments.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.9 SPILLED CONCENTRATE - BENTHOS

Effect Pathway – A spill of concentrate into one of the creeks adjacent to the road could impact benthic invertebrate habitat if concentrate precipitates out on to bottom substrates. The concentrate could physically smother productive benthic invertebrate habitat, or the metals in the concentrate could leach out and impact benthic invertebrate species assemblages. A significant decrease of benthic invertebrates downstream of a spill could impact fish health of fish dependent on benthic invertebrates as a major source of food.

Residual Effects Analysis

Possible Impact	Possible reduction of benthic invertebrate assemblages in streams downstream of a concentrate spill location. Most likely to impact depositional habitats. Ultimate effect would be a reduction of fish health and population due to reduction in available benthic invertebrates for food – chronic effect.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Low, due to a very low likelihood of a significant spill, high likelihood of thorough clean-up, and low leaching potential of metals in concentrate
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate to high – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush sediments. However, a spill to depositional habitat would take longer to recover.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.10 SPILLED FUEL OR OIL - BENTHIC INVERTEBRATES

Effect Pathway – A spill of fuel or oil into one of the creeks adjacent to the road could impact benthic invertebrate habitat if deposits coat substrates. Hydrocarbons have the potential to physically alter benthic invertebrate habitat, as well as being toxic. A significant reduction in the abundance of benthic invertebrate abundance downstream of a spill could impact fish health of fish dependent on benthic invertebrates as a major source of food.

Residual Effects Analysis

Possible Impact	Possible reduction of benthic invertebrate assemblages in streams downstream of a fuel or oil spill location. Ultimate effect would be a reduction of fish health and population due to reduction in available benthic invertebrates for food – chronic effect.
Significance (High/Moderate/Low)	Low
& **Summary of Rationale**	Low, due to a very low likelihood of a significant spill, high likelihood of thorough clean-up, moderate reversibility of material. Geographical range of effect likely small.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush residues from rocks and sediments. A spill to depositional habitat would take longer to recover.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.11 SPILLED FUEL - FISH

Effect Pathway – A spill of fuel into one of the creeks adjacent to the road could acutely impact fish health. A significant release has the potential of killing fish downstream of a spill site.

Residual Effects Analysis

Possible Impact	Fish mortality and resulting reduction of fish population due to accidental spill of fuel to creeks- acute effect
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Probability of spill of a size that would result in a significant impact is low. Fuel would not reside in the environment for very long (previously discussed in DAR 9.4 & 9.5, p 191 – 200, and Item 6.3 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	Spill could occur anytime during mine operation, however impact of a single spill event should not be long lasting (acute).
Magnitude (High/Moderate/Low)	Low to high, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	High –fuel is not anticipated to reside in creeks for very long. Fuel will stay mostly on the surface of water and will evaporate.
Likelihood (High/Moderate/Low)	Low (with effective mitigation measures, likelihood should be negligible).

4.12 SPILLED ACID

Effect Pathway – A spill of acid into one of the creeks adjacent to the road could acutely impact fish health. A significant release has the potential of killing fish downstream of a spill site.

Residual Effects Analysis

Possible Impact	Fish mortality and resulting reduction of fish population due to accidental spill of acid to creeks- acute effect
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Probability of spill of a size that would result in a significant impact is low. Acid would not reside in the environment for very long (previously discussed in DAR 9.4 & 9.5, p 191 – 200, and Item 6.3 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	Spill could occur anytime during mine operation, however impact of a single spill event should not be long lasting (acute).
Magnitude (High/Moderate/Low)	Low to high, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	High –acid is not anticipated to reside in creeks for very long. Acid is highly soluble in water and will rapidly dilute.
Likelihood (High/Moderate/Low)	Low (with effective mitigation measures, likelihood should be negligible).

4.13 SURFACE EROSION – SPAWNING HABITAT SMOTHERING

Effect Pathway – Road-related surface erosion and associated sedimentation in adjacent creeks may lead to smothering of spawning habitat.

Residual Effects Analysis

Possible Impact	Smothering of spawning habitat can result in impacts on developing fish embryos and the loss of important spawning habitat can result in impacts on fish populations. If smothering occurs while fish eggs are within substrates, developing fish will die due to a lack of oxygen.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Sedimentation of materials eroded from the all season road or its embankments is not anticipated. Times of greatest potential will coincide with periods of high natural TSS in local streams and incremental amount of TSS is anticipated to be negligible. Best management practices of road building will be followed which will mitigate the potential for significant erosion. Adaptive management approaches will mitigate significant erosion if observed. As evidence, there have been no apparent negative effects from the existing road along Prairie and Funeral Creeks.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation. In- frequent, if occurs, despite mitigation measures, would be associated with heavy precipitation.
Magnitude (High/Moderate/Low)	Low (sediment and erosion control plan will mitigate possible impact).
Reversibility (High/Moderate/Low)	High – one season may be required to flush sediments. Fish should quickly recolonize impacted sections.
Likelihood (High/Moderate/Low)	Low for significant events that might result in an effect.

4.14 SURFACE EROSION – BENTHOS SMOTHERING

Effect Pathway – Road-related surface erosion and associated sedimentation in adjacent creeks may lead to smothering of benthic invertebrate habitat.

Residual Effects Analysis

Possible Impact	Smothering of benthic invertebrate habitat could result in a decrease in benthic invertebrate populations, possibly reducing the quantity of fish food available in the creek. Insufficient food can impact fish health and ultimately fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Sedimentation of materials of eroded from the all season road or its embankments is not anticipated. Times of greatest potential will coincide with periods of high natural TSS in local streams and incremental amount of TSS is anticipated to be negligible. Best management practices of road building will be followed which will mitigate the potential for significant erosion. Adaptive management approaches will mitigate significant erosion if observed.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation. In- frequent, if occurs, despite mitigation measures, would be associated with heavy precipitation.
Magnitude (High/Moderate/Low)	Low (sediment and erosion control plan will minimize possible impact).
Reversibility (High/Moderate/Low)	High – one season may be required to flush sediments. Fish should quickly recolonize impacted sections. Bull trout returning to Funeral Creek may take longer to recolonize (therefore “moderate”).
Likelihood (High/Moderate/Low)	Low for significant events that might result in an effect.

4.15 SURFACE EROSION - TSS

Effect Pathway – Road-related surface erosion and associated increases in total suspended sediments in water creeks may lead to impacts on fish health.

Residual Effects Analysis

Possible Impact	Road-related surface erosion may result creek water with a higher TSS downstream. Water with a high TSS has been linked to impacts on fish, including damage to gills, increased stress response, greater resistance to disease and difficulty locating food items.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Anticipated to result in a short-term (acute) exposure and can be corrected using adaptive management.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Can influence all water downstream of the surface erosion.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation. In-frequent, if occurs, despite mitigation measures, would be associated with heavy precipitation.
Magnitude (High/Moderate/Low)	Low (sediment and erosion control plan will minimize possible impact).
Reversibility (High/Moderate/Low)	High – with the cessation of heavy rainfall, surface erosion should stop. CZN will take corrective action where erosion is causing noticeable turbidity increases downstream of the all season road.
Likelihood (High/Moderate/Low)	Low for significant events that might result in an effect.

4.16 REMOVAL OF RIPARIAN VEGETATION – FISH FOOD

Effect Pathway – Removal of riparian vegetation may reduce availability of fish food items (largely terrestrial insects), and consequently impact fish populations.

Residual Effects Analysis

Possible Impact	Riparian vegetation is important habitat for terrestrial invertebrates that often become fish food items. Riparian vegetation also provides organic carbon to streams that many benthic invertebrates will consume. The potential loss of invertebrate food items associated with either of these mechanisms can result in a decrease in food available to fish. A decrease in available food has the potential to impact fish health and possibly fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low The loss of fish food items is anticipated to be negligible (previously discussed in Item 16.4, response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	In most cases, the road will be crossing creeks and therefore the amount of riparian vegetation removed relative to what is available will be minimal. In some cases, the road will parallel creeks and be within 30 m. In the majority of these cases, the existing riparian vegetation is minimal.
Timing (Duration, Frequency, and Extent)	35 years – construction of road, operation and reclamation. Plus time for succession.
Magnitude (High/Moderate/Low)	Low – the removal of vegetation will generally remove a small portion of existing riparian vegetation.
Reversibility (High/Moderate/Low)	Moderate (once road is decommissioned, riparian vegetation will be returned to its natural state). Due to harsh climatic conditions and short growing season, plant growth is slow, therefore it may take several decades for the road surface to return to a vegetated state.
Likelihood (High/Moderate/Low)	Low for significant effects to fish populations.

4.17 REMOVAL OF RIPARIAN VEGETATION - COVER

Effect Pathway – Removal of riparian vegetation may reduce available stream cover. Resulting poorer fish habitat can influence fish behavior and fish health.

Residual Effects Analysis

Possible Impact	Removal of riparian vegetation may result in a reduction of stream cover. Stream serves to protect fish from predation and also acts to regulate diurnal changes in stream temperature. A reduction in cover may result in greater stress to fish and impact fish behavior, fish health and possibly influence fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Most streams along the all season road appear to provide little cover to adjacent streams. Only the smallest streams having little flow tend to have riparian growth providing good cover.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Very small –riparian cover was only observed on very small streams and only where there is a perpendicular crossing, so vegetation removal will be minimal. Also most of these smaller creeks are unlikely to be fish bearing.
Timing (Duration, Frequency, and Extent)	35 years – construction of road, operation and reclamation. Plus time for succession.
Magnitude (High/Moderate/Low)	Low – the removal of vegetation will generally remove a small portion of existing riparian vegetation.
Reversibility (High/Moderate/Low)	Moderate (once road is decommissioned, riparian vegetation will be returned to its natural state). Due to harsh climatic conditions and short growing season, plant growth is slow, therefore it may take several decades for the road surface to return to a vegetated state.
Likelihood (High/Moderate/Low)	Low for significant effects to fish populations.

4.18 BLASTING

Effect Pathway – Blasting adjacent to water bodies has the potential to startle fish if not result in severe health impacts, resulting in death. At its worst, blasting could result in impacts on fish populations.

Residual Effects Analysis

Possible Impact	Percussion waves can damage swim bladders of fish, injuring or killing fish. If significant, fish populations may be impacted.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Application of DFO guidance will avoid impact to fish (previously discussed in Item 16.4, response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Blasting at only two locations where fish are known to exist. No species of special concern at either location.
Timing (Duration, Frequency, and Extent)	Maximum one week per location during construction.
Magnitude (High/Moderate/Low)	Low – because the DFO guidance will be applied. Also most locations will not be fish habitat at the time of blasting. Fish will be encouraged to leave immediate area before and during blasting. Other mitigation procedures as provided in blasting management plan. No species of concern resident at site.
Reversibility (High/Moderate/Low)	High – fish will return to site after blasting has been completed.
Likelihood (High/Moderate/Low)	Low

4.19 OVERHARVESTING

Effect Pathway – Creation of an all season road will provide new access to fisherman. Over-harvesting can result in impacts on fish populations.

Residual Effects Analysis

Possible Impact	Increased access to fishing along the all-season road could affect stocks of traditionally harvested fish species. Most creeks in Nahanni are nutrient poor and therefore fish abundances tend already to be low.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low The low abundance of fish along the all season road, combined with the check-point planned should reduce fishing pressures. In addition, authorized users on CZN business will be prohibited from fishing along the road (previously discussed in DAR 4.5.2, p 100, and Item 6.3, 15.2 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Sections of several larger creeks and two lakes.
Timing (Duration, Frequency, and Extent)	23 years – life of mine + reclamation.
Magnitude (High/Moderate/Low)	Likely low due to low desirability of fish along the road.
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	Low for significant overharvesting (knowing that fish stocks are not highly desirable, controls on use of road will minimize access by fishermen).

4.20 STRANDING

Effect Pathway – the diversion and road encroachment of Sundog Creek may result in the increased potential for fish to be stranded in shallow depressions as flows decrease and water goes to ground after freshet.

Residual Effects Analysis

Possible Impact	The stretch of Sundog Creek where the diversion is planned goes dry in summer and remains dry until freshet unless there is a heavy rainfall even in summer. Currently there is some concern that fish may become stranded as the water in the creek goes to ground. One concern with the diversion of Sundog Creek near km36 is that it has the potential of causing a higher incidence of fish stranding if pools or shallow indentations are created that did not formerly exist. This could also apply at km38, where the road will encroach on the creek Changes in creek hydrology may increase the period of time each year when stranding is possible.
Significance (High/Moderate/Low)	Low
& **Summary of Rationale**	The habitat created by diverting the thalweg into a pre-existing secondary channel will be very similar to the existing channel and therefore no increased incidence of stranding is anticipated. The Mine will also monitor the portion of the existing channel remaining to ensure that fish are not being stranded as flows recede in early summer. Creek profile will be maintained in other encroachment areas.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Small areas along the 1.6km route of the new proposed channel, as well as inside the existing channel (1.4km) which will become a blind channel once the main flow is diverted.
Timing (Duration, Frequency, and Extent)	23 years – life of mine + reclamation.
Magnitude (High/Moderate/Low)	Likely low – it is anticipated that few if any fish would stay in shallow pools and become stranded
Reversibility (High/Moderate/Low)	High – stranded fish can be netted and relocated downstream. Any pools capable of causing stranding can be filled in.
Likelihood (High/Moderate/Low)	Low – this is something that can be monitored and corrected if found to be a problem

John Wilcockson, MSc RPBio
Environmental Specialist
HATFIELD CONSULTANTS

REPLY TO PCA IR25

1. From our replies to DFO IR's 2 and 3: Refer to Table DFO 2-1 attached. No infilling along Prairie, Fast and Funeral Creeks is planned. Any road widening will occur on the opposite side. Road sections requiring protection were armoured previously. The road parallels Sundog Creek over the section Km 17-40. Three crossings of the main stem between Km 23-29 were proposed, but the Km 29 crossing is problemmatic, therefore we propose to keep the road on the south bank between Km 28-29, which will eliminate 2 main stem crossings. Thereafter, the road mostly traverses old floodplain terrain until Cat Camp at Km 40. The road footprint encroaches on ground below the high water mark over the section Km 33-38.1. Details of this encroachment are provided in the Allnorth memorandum dated March 18, 2016 which was provided to the Board as part of our second Adequacy response. Allnorth estimated the total area of encroachment to be 16,090 m2, with 9,749 m2 of this area being utilized during normal, seasonal flow conditions. A habitat assessment by Hatfield Consultants can be found in Appendix 10 of the DAR. Pool habitat exists along limited portions of the southern bank at Km 36.7, 37 and 37.7. The remainder of the habitat is run and riffle. The Km 37.7 pool habitat will be altered (moved north) to accomodate the road. The other pool habitat will not be affected since the road will be above the HWM.

2. See Hatfield document attached to PCA IR21.

3. We will await comments from DFO on whether there will be a net habitat loss or gain from the proposed development.

4. The reach to be re-aligned is completely dry in winter, there are no pools. Pools exist immediately downstream of the re-alignment, but these almost certainly freeze to the bottom in winter.

i) Where a pool needs to be moved (e.g. Km 37.8), any fish present will be relocated to deeper pools downstream.

ii) From our reply to DFO IR5a: The work will be scheduled for late summer/fall conditions when the reach is expected to be dry, based on site visits and historic aerial photos. Excavation of the re-aligned channel into the existing alluvial deposits may encounter subsurface water, but this will not have a surface outlet while construction is in progress. The substrate of the re-alignment consists of coarse gravel to cobble size material. When channels naturally avulse, there would be a period of adjustment of the bedload in the new channel. The same adjustment is anticipated with the re-aligned channel. When water levels rise in the alluvium in spring, flow will occur first in the alluvium, and fines will be carried into interstitial spaces between coarser material. As surface flow commences in the re-aligned channel, some finer material may be mobilized and then re-deposited after a short distance within coarser material. Re-suspension may occur as flows increase, but then such flows will likely already be turbid from bedload suspension upstream. Hence, the TSS increase over natural conditions is not expected to be significant. Large tracts of run and riffle habitat are common downstream, with limited pool habitat about 1 km away near Cat Camp where grayling may over-winter. Any TSS generated from the re-alignment over and above natural conditions is expected to settle before the pool habitat.

iii) The re-alignment will be monitored as flows increase during the first spring after construction for performance and water quality.

REPLY TO PCA IR46 – RECLAMATION AND REVEGETATION

The information below provides a description of reclamation and revegetation progress along the original winter road alignment, and uses this to comment on same for the proposed all season road. The road through the NNPR is discussed by section, and photos are used to show typical conditions for each section.

Km 17-29, Upper Sundog Creek

Alpine terrain over this section is sparsely vegetated. The photo below shows the road crossing rocky slopes and some vegetated patches. Note, this section of the road to Km 26 was the subject of road maintenance several years ago, so was disturbed quite recently. Revegetation where the road crosses the patches will take many years because of the short growing season, but will occur eventually. In the meantime, the road footprint is not dissimilar to the adjacent slopes.

Km 29-40, Lower Sundog

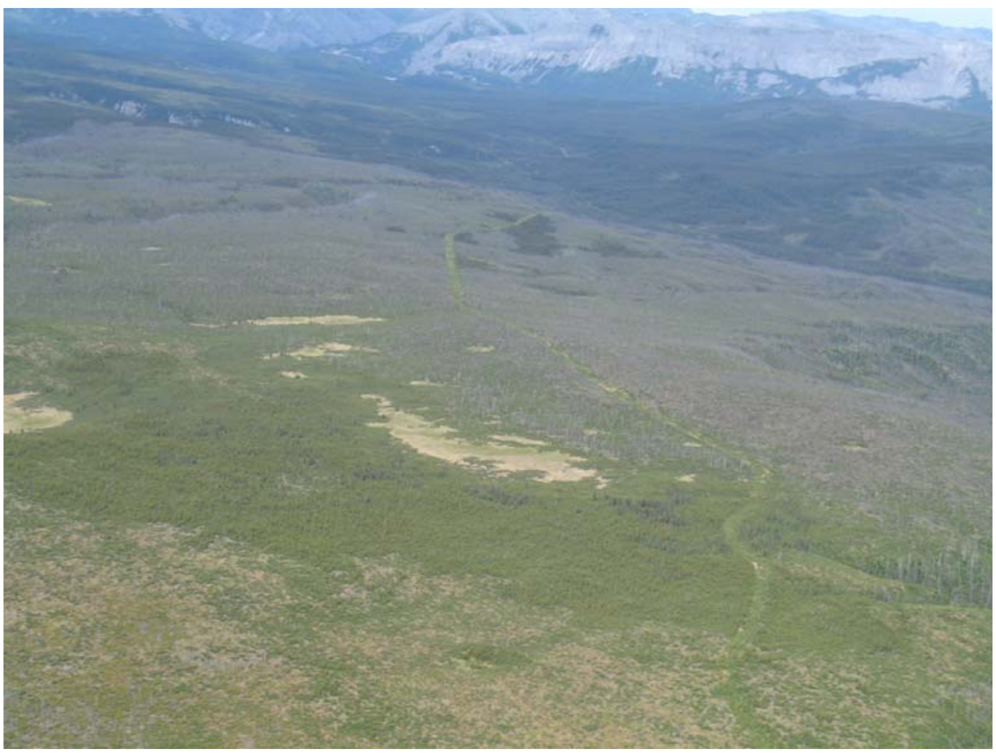
The road crosses the old floodplain section of Sundog Creek. Again, there are gravel sections and vegetated sections. The photo below shows the road which has not been disturbed since 1981. Note, the alignment is still clearly visible, but revegetation is progressing well in more densely wooded areas.

Km 40-54, Polje Creek

This section of the road crosses more wooded, lowland terrain in the catchment of Polje Creek. The western part is well vegetated, but the eastern part is more sparsely vegetated due to relatively recent extensive burns. The photo below is typical of the western section. Under-story vegetation was redeveloped in the road alignment, although tree cover has yet to re-establish. Discontinuous permafrost is likely to be present in places, however as shown in the photo, has not altered drainage or inhibited revegetation significantly. The photo after is another from this area, but more to the east. Scrub bush has re-established comparable to adjacent areas, and tree growth has started but is in the early stages.

Km 54-84, Ram Plateau

Soil cover on the plateau is mostly thin, and therefore the vegetation is generally sparse with some wooded sections. As for other areas, the photo below shows that vegetation has re-established in the alignment, but its composition is not yet as dense or the same as adjacent areas. However, in places, the alignment is not discernible, as in the foreground of the photo.



Further east as the plateau descends to the Tetcela valley, vegetation is more developed. The photo below shows that grasses and low bush dominate in the alignment, but in the foreground tree cover is re-establishing, and in the longer term we would expect the pre-disturbance assemblage to completely return.

Km 84-90, Tetcela valley

The Tetcela valley is densely wooded. The photo below and one of the stream crossings shows that the alignment has revegetated significantly, and that the tree cover is approaching the same density and height as adjacent areas.

Km 90-96, Fishtrap Creek

The road crosses marshy terrain either side of the Fishtrap Creek wetlands. The photo below shows that ground cover has re-established in the alignment, but like other areas, re-developed of tree cover, while it has started, will take longer.

Km 96-102, Silent Hills

The Silent Hills have densely wooded slopes. The photo below from 2009 shows the alignment and switch-backs ascending the slope. Tree regrowth in the alignment is well advanced in places.

Concluding Remarks

It is clear from the above that reclamation by natural invasion is progressing well in most areas of the old winter road inside the NNPR. The exception is in the alpine zone where the road alignment was the subject of recent maintenance work. However, we accept that revegetation in that zone will take longer due to the thin soil cover and higher elevations. This evidence confirms that our general approach to reclamation, facilitating natural invasion, is sound for all areas. From our many surveys in the area, it is clear that there has been little permafrost degradation associated with road construction, and that there has been no significant change in hydrology of the roadbed and surrounding area. Consequently, there has been no significant ecosystem change, and none is expected. The vegetation assemblages within the old winter road alignment are re-establishing. With all season road construction, we envisage a 6-year period of active reclamation work/monitoring, although clearly it will take a longer period for the complete re-establishment of the original vegetation. Therefore, we remain of the opinion that the significance of effects on the ability of habitat to recover is low, with no residual effects.

We anticipate a need to further develop a suitable reclamation plan as a condition of a land use permit.