September 6, 2016

Alberta Transportation
2nd Floor, 803 Manning Road NE
Calgary, Alberta
T2E 7M8

Ross Dickson
Project Service Technologist - Construction

Dear Mr. Dickson:

CON0017609 Southern Region GRMP - Call-Out Reports
S050 - Hwy 549:02-01 Embankment Earth Slide (km 4.831)
DRAFT

1 INTRODUCTION

As part of the Geohazard Risk A Management Plan (GRMP) Contract for Southern Region, Klohn Crippen Berger Ltd. (KCB) was requested by Alberta Transportation (AT) to conduct a call-out inspection of an embankment earth slide on the north side of Highway 549, km 4.831 approximately 12 km West of Millarville, Alberta along H549.

The site was located with a hand held GPS located at 50° 45.03567'N, 114°28.99383'W (WGS 84) on Highway 549:02 (km 4.831) in Contractor Maintenance Area (CMA) 27 where Volker Stevin is the maintenance contractor (MC).

The site was inspected on June 15, 2016 by Chris Gräpel, M.Eng., P.Eng., Tim Keegan, PhD., P.Eng., and Andrew Brunsdon, P.Eng. of KCB, with Mr. Ross Dickson, Roger Skirrow, P.Eng., Manny Siddons, Field Technician, and Mike McIntyre, MCI of AT. A key plan of the location is presented in the appended Figure 1 and an overall site plan of the area is presented in appended Figure 2. Photographs from the inspection are included both in Figure 2 and in Appendix I for reference.

This call-out report represents the first documented engineering site visit to the A050 - Embankment Earth Slide. This report was prepared by KCB for AT Southern Region under Contract No. CON0017609. The results of our site inspections, assessments, and our recommendations for remediation works are presented herein.

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2 BACKGROUND

A review of readily available topographic, geologic, and surficial soil maps indicates that the highway is situated in the eastern edge of the Rocky Mountain foot hills constructed in an area of shallow sedimentary bedrock covered by varying thicknesses of moraine, deposits, with a veneer of glaciolacustrine deposits in low areas in the vicinity of the site. The local bedrock is part of either Belly River/St. Mary River Succession (bedded chloritic & feldspathic sandstone and blocky grey sandstone with some tuff and thin coal seams) or the Alberta Group (fissile silty shale and cherty sandstone). (Alberta Geological Survey, 2013).

The average annual daily traffic (AADT) along Hwy 549 near the site is 220 westbound, 900 eastbound (Reference No. 65170).

3 SITE OBSERVATIONS

The basic arrangement of the various features observed at the site during the June 15th, 2016 site inspection are presented in Figure 2. The following observations were made during the site visit:

- A head scarp, on the left flank of the mobilized slide, encroaches within 2 m of the pavement edge. The scarp shows a drop of approximately 0.7 m and is inferred to have caused minor subsidence of the shoulder with a new scarp forming at the current edge of pavement. There were no cracks or subsidence observed in the pavement at the June 15, 2016 inspection.
- A lower scarp, observed on the right flank of the mobilized slide approximately 3 m inside the fence line, shows a total drop of approximately 1.5 m.
- The downhill extent of the slide mass is indicated by an observed toe bulge (Figure 2, Photo C) that has evidence of recent movement. At the center of the slide, the toe bulge is approximately 20 m beyond the toe of the embankment. The location of the slide toe being this far beyond the slope toe suggests the rupture surface is either deep seated rotational or translational following a shallow sub horizontal surface. The lack of back tilting grabens and the observation of a toe roll as opposed to an up thrusting toe area suggests a translational or lateral spreading type movement.
- The bent and tilting of approximately 10 year old trees in the toe bulge area (Figure 2, Photo C) are indication that historic slide movements occurred and were slow and incremental enough to allow the trees to bend toward vertical during earlier growth. The tilting of the entire previously bent tree, with no apparent growth bending towards vertical, infers the recent movements were within the last few years. This is consistent with the observation of fresh disturbed ground exposed in the head scarps and toe bulge and the comparison between the 2015 air photos and the condition of the scarps during the site inspection.
- A number of springs are apparent beyond the toe of the embankment indicates high water table and possibly artesian groundwater.

- The active earth embankment slide is centered on the approximate 600 mm dia. CMP culvert. Two sink holes or collapse structures have formed above the culvert at two locations on the north facing slope as shown in Figure 2. These are inferred to have been caused by damage and/or collapse of the culvert, causing loss of overlying soil into the culvert.
- As shown in Photos 3 and 4, the invert of the galvanized CMP culvert has apparently corroded out and has not conveyed water through to the outlet in some time. Although Photo 4 shows the bottom has been corroded out some distance upstream, it is unclear how far this extends upstream under the embankment. The open bottom of the culvert infers that most or all of the water entering the culvert inlet escapes from the culvert and flows on the outside of the culvert saturating and eroding the embankment fill and foundation deposits. This has obviously been occurring for some time and likely explains the observation of springs and ponding water outside the toe of the embankment slope. Water flowing outside the culvert is also the likely cause of internal erosion and the formation of the collapse structures (sink holes). Influx of water into the foundation deposits is also the likely cause of the embankment earth slide.
- This type of internal corrosion of galvanized pipe is most often associated with acidic water. The corrosion of copper, galvanized steel, and lead pipes can increase considerably by acidification of the water flowing through them, and the concomitant drop in pH and hydrogen carbonate concentrations and rise in sulfate concentrations. This is particularly manifest if the pH falls below about 7.0 (Kucera, 1988).
- The culvert, which drains south to north through the culvert, conveys eastbound flows from the south highway ditch. There is a ditch block just east of the culvert inlet to the culvert that directs ditch flows through the culvert. West of the site the highway, and the south ditch, pass through a bedrock through-cut (see Photos 1, 6 and 7). Photo 7 illustrates the bedrock exposed in the south cut slope of this through-cut. The exposed bedrock is likely part of the Belly River/St. Mary River Succession (bedded chloritic & feldspathic sandstone and blocky grey sandstone with some tuff and thin coal seams). One possibility is that this bedrock, particularly the coal seams, is releasing low pH water that could be corroding the culvert at the S50 site.

4 ASSESSMENT

The primary concerns with this site are related to the outflow of water from a significantly corroded, damaged, and leaking culvert and the remobilization of an embankment earth slide that appears to involve the foundation deposits and extends out beyond the road allowance. The primary failure modes surmised from our understanding of the site include:

1. internal erosion or piping along the corroded culvert or elsewhere caused by water leaking from the culvert;
2. structural collapse of the culvert; and

3. reactivation and/or retrogression of the pre-existing earth embankment slide;

The root cause (initiating event) common to all three of these potential failures (hazards) is the corrosion and damage to the culvert. The preparatory and trigger causal factors that contribute to the relatively high likelihood that the embankment will continue to destabilize are described as follows:

- Possible acidification of the drainage water (possibly occurring as the water flows over or through the local bedrock, to be investigated) acidic water flowing through culvert causing progressive corrosion, leakage; and weakening of the culvert.
- Water flowing out of the culvert causing erosion around the annulus of the culvert.
- Structural collapse of the culvert will likely result from continued corrosion and erosion of the exposed soils at the invert during culvert discharge. Collapse of the culvert will either result in sinkhole formation that extends to the road surface or collapse of the asphalt along the length of the culvert. The build-up of ditch water due to a blocked or collapsed culvert will result in ponded water adjacent to the embankment that will overtop the ditch block and flow further downslope, potentially causing other drainage related issues elsewhere.
- Continued concentrated recharge of water into the embankment fill and foundation deposits increasing pore pressures that could support potentially rapid mobilization of slide retrogression blocks involving the roadway.
- Possibility of additional strain softening along the rupture surface in the foundation deposits which could have happened already based on the estimated magnitude of movements at the toe of the slide.
- Triggers for additional movement or acceleration of movement include prolonged periods of rain, short periods of heavy rain, snowmelt; and ponded water forming at inlet of culvert due to culvert, blockage or collapse.

5 RISK LEVEL

Risk levels have not been prepared for this site to date.

Risk levels for AT GRMP sites are determined according to the following:

Risk Level (RL) = Probability Factor (PF) x Consequence Factor (CF)

Where:

- PF varies from 1 (inactive, very low probability of slide occurrence) to 20 (catastrophic slide is occurring); and
- CF varies from 1 (minor consequences, no impact to driver safety, maintenance) to 10 (safety of public at risk, loss of infrastructure, rapid mobilization of large slides).

It is important to note that the GRMP Risk Level system was developed primarily for landslides and therefore the risk level associated with this site (combination of landslide and erosion) was interpreted from the existing scale by considering both slide terminology and erosion (i.e., inactive slide with high probability of remobilizing was combined with inactive erosion with high probability of remobilizing).

A risk level for this site is assessed as follows:

PF (14) x CF (5) = RL (70)

The probability factor of 14 reflects that:

- Ground conditions and "potentially active" and "active" destabilizing processes, described in Section 4, are still prevalent at the site and involve high rates of erosion and movement that is steady and potentially increasing.
- It is expected that embankment instability will continue with future corrosion of the culvert; internal erosion; rainfall; snow melt; and icing.
- This being a new site, there are still considerable unknowns and uncertainty regarding this geohazard which, on its own, increases the relative likelihood of failure.

The consequence factor of 5 reflects that all three failure modes can occur rapidly and can result in downward collapse of the road surface. The following consequences can be expected:

- abrupt drop off of the road surface resulting a significant danger to traffic safety; and
- complete loss of embankment is likely from the failure modes resulting in costly repair and direct and unavoidable closure of the road.

6 DISCUSSION

In general, the geohazard at site S050 can be thought of as a geohazard scenario. The initiating process appears to be the flow of suspected acidic water resulting in the corrosion of the bottom of the galvanized culvert. This led to leakage and internal erosion around the culvert that eventually led to sink holes above the culvert and excessive leakage of water into the embankment fill and foundation deposits. Phreatic surface and pore pressure built up in the embankment fill and foundation deposits apparently destabilized the north slope of the embankment resulting in an earth embankment slide that involves the foundation deposits with a toe bulge that daylights approximately 15 m outside the toe of the embankment.

Managing this as a chain of hazardous processes the remediation is required to address the following destabilizing processes and conditions:

- corrosion of the culvert, causing infiltration of water into the embankment and loss of support for the culvert structure that could result in collapse;

- concentrated recharge of water into the embankment fill and foundation deposits; and
- a destressed and cracked embankment slope and foundation (subject to remobilization due to water filling cracks).

7 RECOMMENDATIONS

7.1 General

The repair of the slide and erosion will require an engineered design to be prepared so that the local maintenance contractor can construct repairs. The proposed short-term and long-term repair recommendations for the embankment earth slide and damaged culvert are discussed in the following subsections.

7.2 Short Term

In the short term the MCI should continue to monitor the retrogression of the head scarp towards the highway and install hazard signs and impose a speed reduction before the head scarp encroaches further into the pavement due to ongoing movement of the slide. To avoid water entering cracks in the slide mass, runoff from the paved surface into the slide area should be intercepted and directed eastward by construction of an asphalt curb along the north edge of the pavement. As well the scarps should be sealed off at surface by grading them closed with an excavator. If the head scarp drops any further on the north edge, such that it presents a danger to road users and mitigation measures, a temporary guardrail or HTCB should be installed until the landslide repair is completed.

Given the very poor and worsening condition of the culvert due to continued flow of presumably acidic water through the culvert and the realization that all three failure modes are driven by water flowing through the compromised culvert, the short term action should involve stopping flow through the culvert. This can be accomplished by blocking the existing culvert inlet and removing the ditch block, just east of the inlet, which will route the ditch flows eastward down the south ditch. The downstream impact of doing this should be assessed and mitigated as required. This should be followed by installation of a new culvert, as soon as practicable, and, finally, abandonment by either removal or filling of the compromised culvert.

Given that the primary climatic triggers for the failure modes occur predominantly in the Spring of the year, the timing for the short term remediation should be in the Fall of 2016 prior to freeze up, I.e. mid-November. As such the remediation of the damaged culvert is considered short term action.

Replacement of the damaged culvert will require an engineering investigation and design that involves a geotechnical and hydro-technical assessment; chemical analysis of the drainage water; and design of location, size, type, and configuration of culvert.

Initial thoughts are that the new culvert should be installed outside the slide mass, bored in place, and be a smooth wall steel or corrugated plastic culvert. Given the condition of the existing culvert and the voids that have formed around the culvert, it seems more practical to remove the culvert than attempt to fill it. However removal by open cut and backfill will likely disturb an already compromised/failed embankment slope. It is therefore recommended that the culvert be removed and backfilled in conjunction with the failed embankment slope remediation in 2017. The site will need to be protected through the winter months using the provisions outlined above involving monitoring, signage, barricades, and speed reduction.

A rough order of magnitude construction cost estimate for installation of a new culvert, subject to confirmation with investigation and design work, is $250,000 to $300,000.

Recommended long-term actions for the subject site are discussed in the following section.

7.3 Long Term

The embankment earth slide remediation, considered a 2017 project, will require an engineering design to be prepared so that the local maintenance contractor can construct repairs. The geotechnical investigation envisioned for the design consists of a series of hollow or solid stem auger boreholes drilled through the slide mass and at the head of the slide (through the east bound lane) to assess fill and soil/bedrock conditions and to install instrumentation to monitor depth to groundwater within the embankment fill and foundation soils and bedrock and to assess the depth and kinematic character of movement across the slide mass. Disturbed and undisturbed samples would be taken to complete an index and strength testing laboratory program to develop material parameters to use in the design of landslide repair. Water samples will also be collected from local surface and groundwater sources and submitted for chemical analyses. The rough order of magnitude costs for preliminary engineering for both the damaged culvert and embankment earth slide remediation design including surveying, drilling investigation, and assessment of design options and final design, including preparing a set of drawings, a Class C cost estimate and special provisions for maintenance contractor repair work is between $50,000 to a $70,000. The timing of repair may necessitate maintenance contractor completing the work. Tendering costs will be in addition to the rough order of magnitude costs presented herein. A detailed proposal for further engineering services can be prepared upon request and after discussion with AT.

Based on our site observations and subject to change based on the results of the investigation and the effectiveness of the damaged culvert remediation, the following options were discussed with AT on site and are considered candidates for implementation:

- Installation of a granular shear key/drain that intercepts the basal rupture surface between the toe of the fill and the toe bulge. Note this is outside the road right-of-way.
- Construction of a weighting berm over the granular shear key and against the failed embankment slope.
- Reconstruction of the embankment slope and reinstatement of the road shoulder.
- Installation of finger drains into the failed embankment to promote drainage out of the embankment fill.

A rough order of magnitude construction cost estimate for remediation of the embankment earth slide, subject to confirmation with investigation and design work, is $100,000 to $150,000.

8 CLOSING

This is a draft report only and we solicit your review and comments within 4 weeks of submission. Upon issue of the final report, we request that all draft reports be destroyed or returned to Klohn Crippen Berger Ltd. This draft report should not be relied upon as a final document for design and/or construction.

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Alberta Transportation for the specific application to the CON0017609 Southern Region GRMP - Call-Out Report: S050 - Hwy 549:02-01 Embankment Earth Slide and Damaged Culvert (km 4.831). The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours Truly,

KLOHN CRIPPEN BERGER LTD.

Tim Keegan Ph.D., P.Eng.
Senior Geological Engineer, Principal

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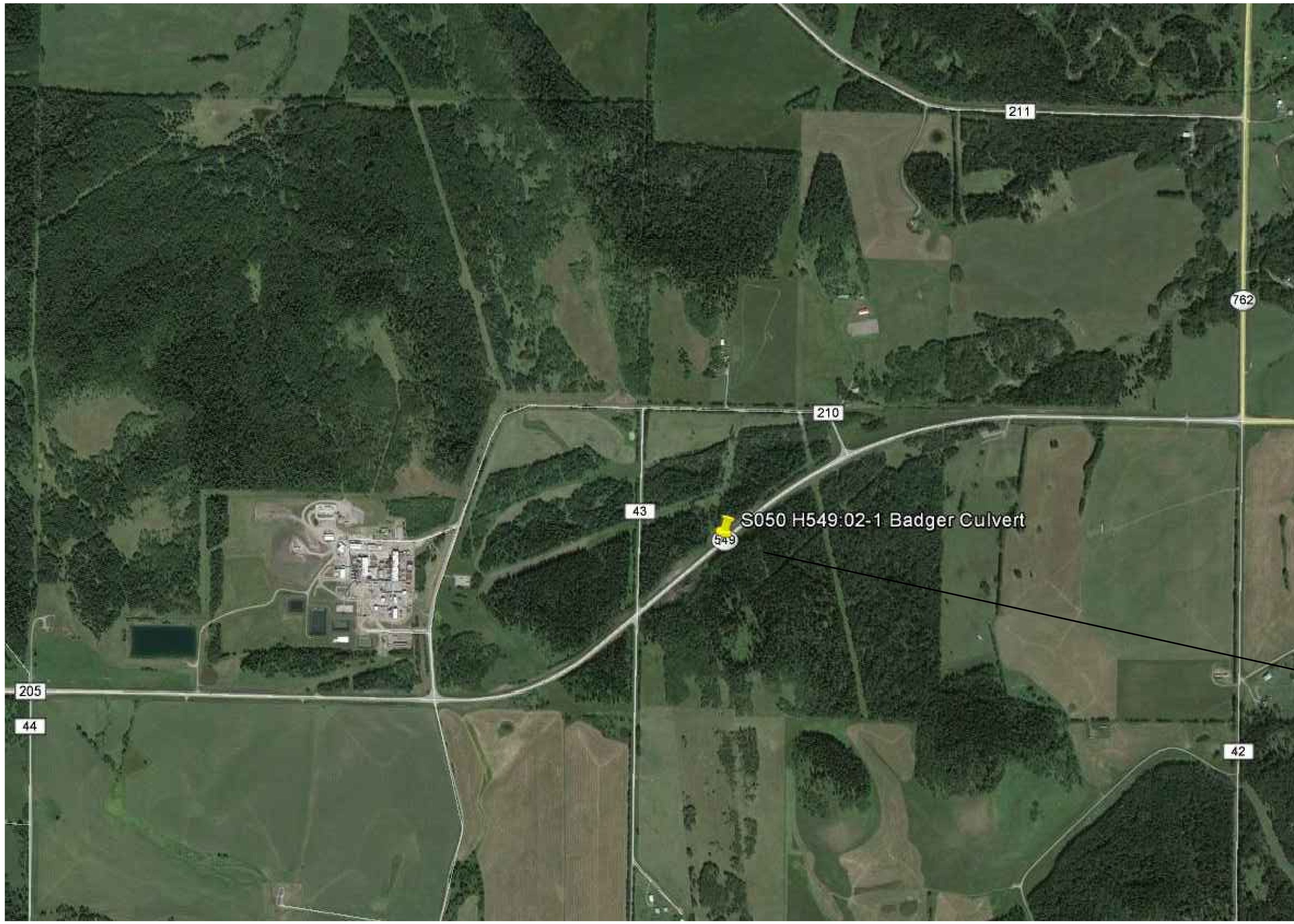
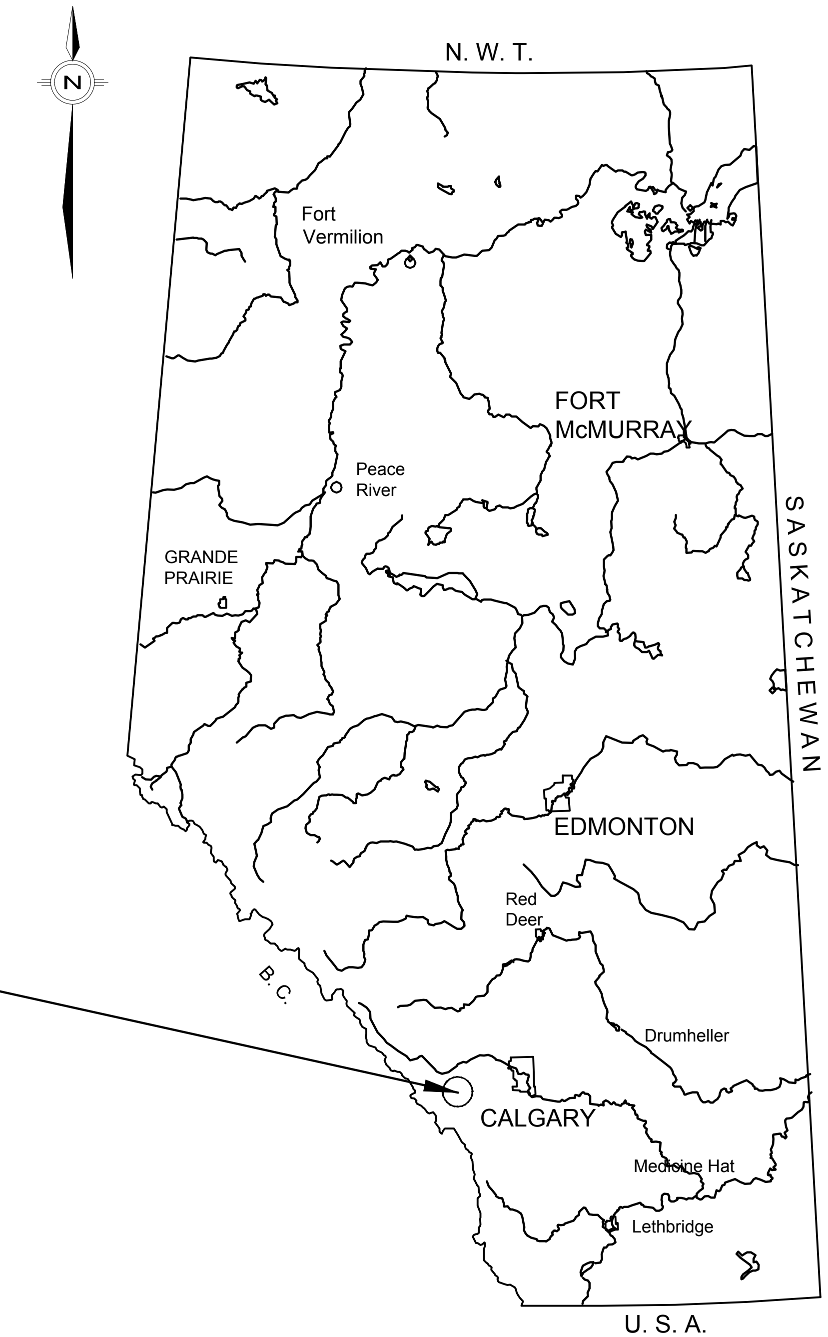
FIGURE





CLIENT Alberta Transportation Klohn Crippen Berger	PROJECT SOUTHERN REGION GEOHAZARD ASSESSMENT TITLE KEY PLAN
	SCALE: AS SHOWN · PROJECT No.: A05115A03 · FIG. No.: FIG 1

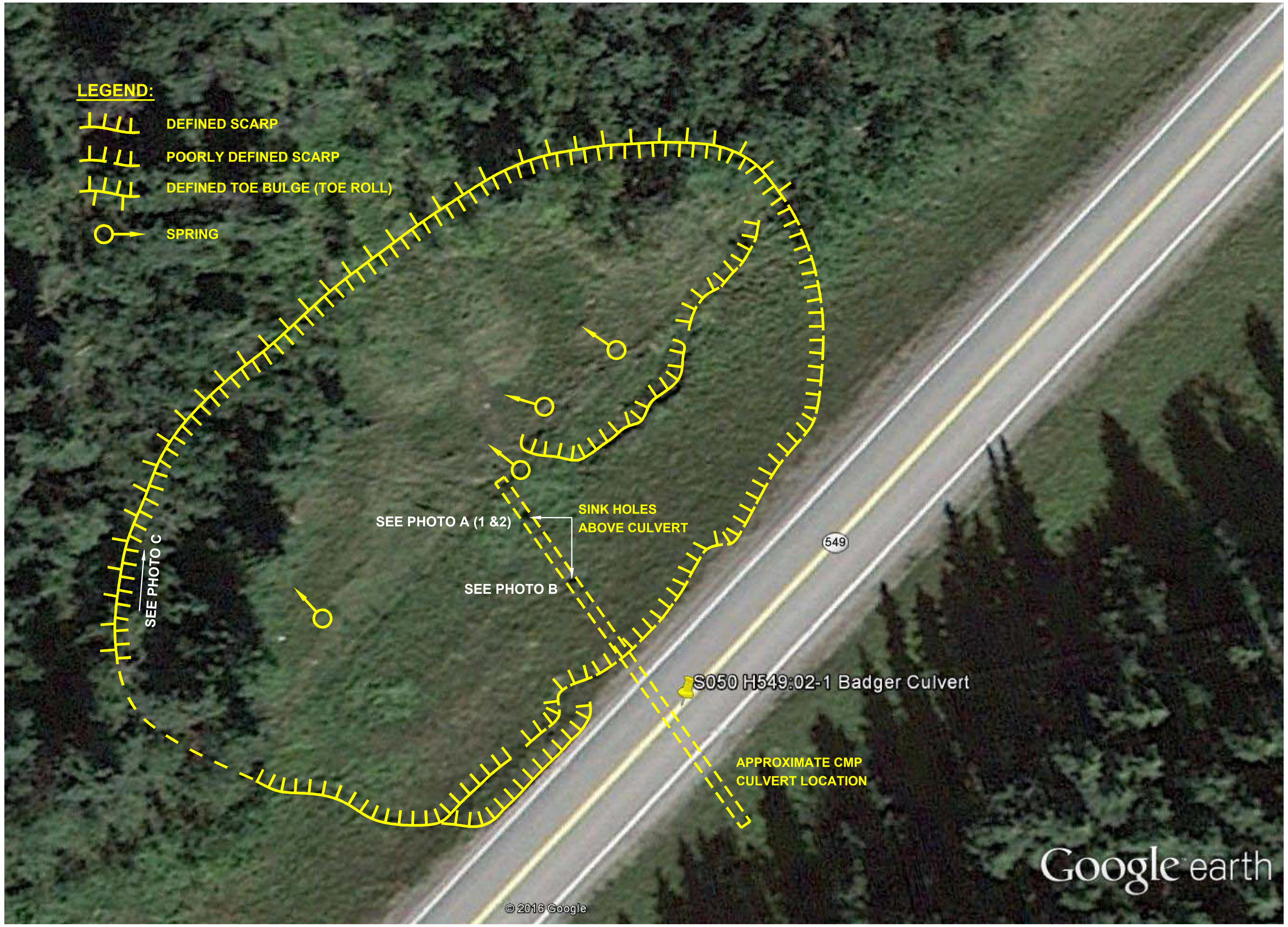



PHOTO A-1


PHOTO A-2


PHOTO B


PHOTO C (TOE BULGE)

SCALE m

10 5 0 10

DRAFT

NOT FOR CONSTRUCTION

CLIENT: Alberta Transportation	PROJECT: SOUTHERN REGION GEOHAZARD ASSESSMENT
Klohn Crippen Berger	TITLE: SO50 H549-02 BADGER CULVERT
	SCALE: AS SHOWN; PROJECT No.: A05115A03; FIG. No.: FIG 2

APPENDIX I

Photographs

Appendix I
Photographs

Photo 1 **North side of Hwy 549:02-01 at km 3.8. Note through-cut in bedrock in the background. Photo westward taken June 15, 2016.**

Photo 2 **Road embankment sloughing on the north side of Hwy 549:02-01 at km 3.8. Photos eastward taken June 15, 2016.**

Photo 3 Damaged culvert at Hwy 549:02-01 at km 3.8. Photo taken southward June 15, 2016.

Photo 4 Damaged culvert at Hwy 549:02-01 at km 3.8. Photo taken southward June 15, 2016

Photo 5 **Upper sinkhole on above culvert on the north side of Hwy 549:02-01 at km 3.8. Photo taken north-westward June 15, 2016.**

Photo 6 **Eastward at south side of Hwy 549:02-01 showing bedrock exposed in the south cut slope of the through cut. Imagery from Google Earth Street View: September 2012.**

Photo 7 **South at the south cut slope of the through-cut west of the site. Sub vertical sedimentary beds (Bedrock is likely part of the Belly River/St. Mary River Succession (bedded chloritic & feldspathic sandstone and blocky grey sandstone with some tuff and thin coal seams). Imagery from Google Earth Street View: September 2012.**