

December 1, 2023

Alberta Transportation and Economic Corridors
2nd Floor, 803 Manning Road N.E.
Calgary, Alberta
T2E 7M8

Alex Frotten, P.Eng.
Construction Engineer – Delivery Services Division (Southern Region)

Dear Mr. Frotten:

CON0022161 Southern Region GRMP Instrumentation Monitoring
Site S004; H02:08, km 6.284 Willow Creek
Section C – 2023 Fall Readings

1 GENERAL

Six vibrating wire piezometers (VWPs) (VW14-01A/B, VW14-02A/B, and VW14-03A/B), six standpipe piezometers (SPs) (SP-1B/C, SP-5B/C, SP-9B, and SP-10B) and four slope inclinometers (SIs) (SI-1A, SI-5A, SI-9A, and SI-10A) were read on October 11, 2023, by Mr. Bradley Lawson, E.I.T. of KCB. These instruments were read as part of the Southern Region Geohazard Risk Management Program (GRMP). The site is located at Hwy 02:08 km 6.284, north of Fort Macleod, Alberta, approximately 1.9 km north of the junction of RR 264 and Hwy 2. The approximate site coordinates are 5514351 N, 320169 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the S004 site consists of a landslide at the outside bend of Willow Creek with the slope crest retrogressing into the northbound lane ditch of Hwy 02:08. Previous remedial actions at the site include soil nailing, grading, bioengineering (live staking), and bank armoring in 2008. A guardrail was also installed in 2014.

In 1994 and 2014, geotechnical site investigations, which included installing instruments, were conducted at the S004 site by the previous consultants. Based on files received from the previous consultant, the encountered stratigraphy was as follows: clay till, overlying bedrock (shale).

1.1 Instrumentation

KCB has been reading the instruments at this site since readings resumed in the fall of 2020 at the request of Alberta Transportation. No readings were completed at this site between 2003 and 2020. Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1. Any instruments not included in Table 1.1 or shown in Figure 1 are assumed to be inoperable and are not presented or discussed herein.

In 1994 and 2014, 16 SIs and 41 piezometers were installed at the site by the previous consultants to monitor movement and groundwater conditions, respectively. Some of these instruments are now inoperable (e.g., destroyed, sheared, or lost), including several SIs installed within the slide mass (SI-2A through SI-8A, excluding SI-5A).

In June 2023, data loggers were installed on all six VWPs.

The operable instruments are protected by either a flush-mounted or an above-ground casing protector.

The SI equipment was changed in 2020 when KCB began reading the instruments, and again in October 2021 after the previous equipment became inoperable. Currently, KCB is reading the SIs with a metric RST Digital MEMS Inclinometer System.

The VWPs and SPs were read using an RST VWP readout box and Water Level Meter, respectively.

Table 1.1 Instrument Installation Details

Instrument ID	Instrument Type	Date Installed ¹	UTM Coordinates ² (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth ¹ (mbgs ³)	Condition
			Northing	Easting				
SI-1A	SI	Jul. 1994	5514354	320200	Unknown	0.8	38.9	Operable
SI-2A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-3A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-4A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-5A	SI	Jul. 1994	5514343	320213	Unknown	0.7	38.2	Operable
SI-6A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-7A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-8A	SI	Jul. 1994	Unknown	Unknown	Unknown	Unknown	Unknown	Inoperable ⁴
SI-9A	SI	Jul. 1994	5514472	320115	971.2	0.6	38.7	Operable
SI-10A	SI	Jul. 1994	5514542	320186	971.0	0.8	38.8	Operable
SP-1B	SP	Jul. 1994	5514354	320200	970.0	0.8	Unknown	Operable
SP-1C	SP	Jul. 1994	5514354	320200	970.0	0.6	Unknown	Operable
SP-5B	SP	Jul. 1994	5514343	320213	970.0	0.7	Unknown	Operable
SP-5C	SP	Jul. 1994	5514343	320213	970.0	0.7	Unknown	Operable
SP-9B	SP	Jul. 1994	5514472	320115	971.1	0.6	Unknown	Operable
SP-9C	SP	Jul. 1994	5514472	320115	Unknown	Unknown	Unknown	Inoperable ⁴
VW14-01A	VWP	Jul. 2014	5514310	320229	968.8	N/A	14.7	Operable
VW14-01B	VWP	Jul. 2014	5514310	320229	968.8	N/A	6.0	Operable
VW14-02A	VWP	Jul. 2014	5514449	320122	969.2	N/A	14.8	Operable
VW14-02B	VWP	Jul. 2014	5514449	320122	969.2	N/A	6.1	Operable
VW14-03A	VWP	Jul. 2014	5514367	320141	969.0	N/A	14.9	Operable
VW14-03B	VWP	Jul. 2014	5514367	320141	969.0	N/A	5.9	Operable

Notes:

¹ Instrument installation details taken from reports and data files prepared or provided by the previous consultant(s) or Alberta Transportation.

² Coordinates were obtained by KCB with a handheld GPS. The handheld GPS had an accuracy of ±5 m.

³ Meters below ground surface (mbgs).

⁴ Instruments (SI-2A through SI-8A, excluding SI-5A, and SP-9C) located within the slide mass are assumed inoperable.

2 INTERPRETATION

2.1 General

For the operable SIs, the cumulative displacement, incremental displacement, and displacement-time data was plotted in the A-direction (i.e., the direction of the A0-grooves).

For the operable SPs, the recorded water levels were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation. Screen elevations are not available for the SPs.

For the operable VWPs, the recorded porewater pressures were converted to an equivalent water/piezometric elevation and plotted relative to ground surface elevation and each instrument's tip elevation.

Monthly precipitation data is also plotted with the piezometer data. The data was obtained from the Alberta Climate Information Service (ACIS) database, referencing legal subdivision TWP009-26-W4.

The SI and piezometer data plots are included in Appendix I, and a summary of the SI and piezometer data is provided in Table 2.1, Table 2.2, and Table 2.3, respectively. The September 2022 reading was the first time KCB read SI-10A and SP-10B. The SI data plots only include data obtained by KCB. Data obtained by previous consultants has not been provided to KCB.

The SI data obtained with KCB's new SI reading equipment appears relatively noisy (despite good data quality) compared to the baseline reading obtained with KCB's old SI reading equipment and is difficult to interpret, especially for SI-5A (the instrument was read twice during both the spring and fall readings in 2022 and 2023). It is unclear if the noise is due to changing the SI reading equipment, the low rate of movement being recorded in these instruments, or installation issues (e.g., casing kinked or tilted (SI-1A is tilted approx. 0.3 m, SI-5A is tilted approx. 1.7 m, SI-9A is tilted approx. 0.4 m, and SI-10A is tilted approx. 0.4 m)). Based on the plots for these instruments, it is noted that the casing for:

- SI-1A is “wavy” with kinks at approximately 22 m, 28 m, and 36 m below ground surface;
- SI-5A is tilted approximately 1.0 m in the A-direction and 1.7 m in the B-direction, and there is also a kink in the casing at approximately 22 m below ground surface; and
- SI-9A is “wavy” with kinks at approximately 5 m, 11 m, and 25 m below ground surface.
- SI-10A is “wavy” with kinks at approximately 5 m and 25 m below ground surface.

The SI data plots presented herein include data for readings taken with both our new and old SI reading equipment. More data is needed to assess if the instruments need to be re-initialized.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs ¹)	Direction of Movement	Movement (mm)			Rate of Movement (mm/year)			
	Initialized (Re-initialized) ^{2,4}	Previous Maximum Cumulative Movement Recorded	Previous Reading	Most Recent Reading				Maximum Cumulative			Incremental Since Previous Maximum Cumulative	Previous Maximum	Most Recent Reading	Change from Previous Reading
								Before Re-Initialization	After Re-Initialization	Total				
SI-1A	1994 (Sep. 23, 2020)	N/A – no discernible movement recorded since re-initialization and historical data was not provided for KCB’s review ²	Jun. 14, 2023	Oct. 11, 2023	970.0	4 m – 6 m	X-Direction 45°	N/A	-0.3	-0.3	-1.2	0	-5.3	-25.3
SI-5A	1994 (Sep. 23, 2020)		Jun. 14, 2023	Oct. 11, 2023	970.0									
SI-9A	1994 (Sep. 23, 2020)		Jun. 14, 2023	Oct. 11, 2023	971.2									
SI-10A ³	1994 (Sep. 22, 2022)		Jun. 14, 2023	Oct. 11, 2023	971.0									

Notes:
¹ Meters below ground surface (mbgs).
² All SIs were re-initialized to the September-2020 readings when KCB took over the readings at the site and changed the SI reading equipment. Data recorded before September 2020 has not been provided to KCB for review. Historical reports prepared by the previous consultant between 1999 and 2003 did not report significant movements in these SIs.
³ SI-10A read by KCB for the first time in September 2022. Previous data for the instrument has not been provided to KCB.
⁴ SI-5A was re-initialized to the October 7, 2021 reading due to the readings not aligning with the previous readings.

Table 2.2 Standpipe Piezometer Reading Summary

Instrument ID	Geologic Installation Unit	Date			Ground Surface Elevation (m)	Screen Depth (mbgs ¹)	Water Level		
		Installed	Previous reading	Most Recent Reading			Previous Reading (mbgs ¹)	Most Recent Reading (mbgs ¹)	Change from Previous Reading (m)
SP-1B	Clay Shale	Jul. 1994	Jun. 14, 2023	Oct. 11, 2023	970.0	Unknown	13.5	13.8	-0.3
SP-1C	Not Provided	Jul. 1994	Jun. 14, 2023	Oct. 11, 2023	970.0	Unknown	14.8	16.0	-1.2
SP-5B	Clay Shale	Jul. 1994	Jun. 14, 2023	Oct. 11, 2023	970.0	Unknown	13.4	13.6	-0.2
SP-5C	Till Above Clay Shale	Jul. 1994	Jun. 14, 2023	Oct. 11, 2023	970.0	Unknown	3.3	3.3	0.0
SP-9B	Clay Shale	Jul. 1994	Jun. 14, 2023	Oct. 11, 2023	971.2	Unknown	13.8	13.8	0.0
SP-10B	Unknown	Jul. 1994	Jun. 14, 2023	Oct. 11, 2023	971.0	Unknown	13.9	14.4	-0.5

Notes:
¹ Meters below ground surface (mbgs).

Table 2.3 Vibrating Wire Piezometer Reading Summary

Instrument ID	Serial No.	Date			Ground Surface Elevation (m)	Screen Depth (mbgs ¹)	Water Level		
		Installed	Previous reading	Most Recent Reading			Previous Reading (mbgs ¹)	Most Recent Reading (mbgs ¹)	Change from Previous Reading (m)
VW14-01A	1400848	Jul. 2014	Jun. 14, 2023	Oct. 11, 2023	968.8	14.7	11.8	12.3	-0.5
VW14-01B	1400846	Jul. 2014	Jun. 14, 2023	Oct. 11, 2023	968.8	6.0	3.3	4.3	-1.0
VW14-02A	1400849	Jul. 2014	Jun. 14, 2023	Oct. 11, 2023	969.2	14.8	6.9	7.5	-0.6
VW14-02B	1400248	Jul. 2014	Jun. 14, 2023	Oct. 11, 2023	969.2	6.1	2.2	3.2	-1.0
VW14-03A	1400843	Jul. 2014	Jun. 14, 2023	Oct. 11, 2023	969.0	14.9	4.7	5.7	-1.0
VW14-03B	1400842	Jul. 2014	Jun. 14, 2023	Oct. 11, 2023	969.0	5.9	1.6	2.7	-1.1

Notes:
¹ Meters below ground surface (mbgs).

2.2 Zones of Movement

KCB has assumed all SIs located within the slide mass are damaged (i.e., sheared) due to slide movements.

Data recorded before September 2020 for the operable SIs (SI-1A, SI-5A, SI-9A, and SI-10A) has not been provided to KCB for review. However, historical reports prepared by the previous consultant between 1999 and 2003 did not report significant movements in these SIs, which is not considered unusual because these SIs are located outside the slide mass. No discernible movement has been recorded in SI-1A, SI-5A, or SI-9A since they were re-initialized to the September-2020 readings when KCB took over the readings at the site and changed the SI reading equipment. The second reading for SI-10A notes a possible shear plane at a depth of approximately 5 m below ground surface, this was not measured in the A direction in the fall 2023 reading; more data is needed to assess movement trends for this instrument.

Distributed movement has been recorded in SI-5A from an approximate depth of 14 m to the base of the instrument. However, given the data is difficult to interpret, more data is needed to assess the movement trends for this instrument.

Four wooden stakes located at the crest of the slide are used to estimate slide retrogression. These stakes are susceptible to being knocked over or disturbed. During the July 8, 2021, Section B inspection, it was estimated that the slide has retrogressed between 2.3 m and 3.5 m into the east (northbound lane) ditch since 2016. No additional retrogression was observed during the June 14, 2023, Section B inspection.

2.3 Interpretation of Monitoring Results

No data is available for the SIs and PNs between 1994 and 2020 or the VWPs between 2015 and 2020. More data is needed to assess long-term trends for these instruments, especially in response to prolonged or heavy periods of rainfall or freshet infiltration.

The nature of sliding (back tilting blocks) observed on site suggests a combination of rotational failure and failure along a weak layer at depth. The right (south) flank of the slide appears to be retrogressing faster than other areas of the slide.

Since KCB took over reading the instruments in 2020, decreasing water levels have generally been recorded in the majority of the piezometers. The fall 2023 readings show a general trend of decreasing water levels. Data loggers were installed on the six VWPs in early June 2023 and data downloaded in October 2023 to collect more data to determine if irrigation is influencing the groundwater at this site. Generally, there was limited groundwater fluctuation noted in the VWP data except for VW14-01B, which is located toward the south end of the site and has a tip elevation of 962.8 m (6 mbgs). VW14-01B measured several sharp groundwater increases up to 2 m. These increases all corresponded with rainfall events based on daily rainfall data from station T009R26W4. Screen elevations have not been provided for the SPs, which makes data interpretation difficult. The

1994 reading for SP-05C was most likely bad as it is approximately 10 m lower than the previous and current readings.

Water levels recorded in the nested VWPs installed between the highway and crest of the slide (VW14-01A/B and VW14-02A/B) varied from an approximate depth of 3.1 m to 4.3 m below ground surface in the upper “B” tips and 7.5 m to 12.3 m below ground surface in the lower “A” tips. Both the upper “A” tips have a similar elevation (El. 962.8 m and El. 963.1 m, respectively), and both the lower “B” tips have a similar tip elevation (El. 954.1 m and El. 954.4 m, respectively).

Water levels recorded in the nested VWPs installed in the median ditch of Hwy 02:08 (VW14-03A/B) were at approximate depths of 2.7 m to 5.7 m below ground surface in the upper “B” tip and the lower “A” tip, respectively.

The data recorded in the piezometers, specifically the upper versus lower SP screens/VWP tips, indicates there could be two independent water levels, which could indicate the presence of a perched water table. The increase in water level readings (1 per hour) that the data loggers will provide will help interpret the groundwater trends at this site moving forward.

Based on the limited stratigraphy information provided for the site, it appears one water level may be confined to the till, and one may be confined to the underlying clay shale bedrock. However, KCB is unable to confirm this without the drilling and installation records for the instruments.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read twice per year (spring and fall).

The site should continue to be inspected by the Maintenance Contract Inspector (MCI) and as part of the Southern Region GRMP Section B inspections.

3.2 Instrument Repairs and Maintenance

No instrument repairs are required.

4 CLOSURE

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the exclusive use of Alberta Transportation (Client) for the specific application to the Southern Region Geohazard Risk Management Program (Contract No. CON0022161), and it may not be relied upon by any other party without KCB's written consent.

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Please contact the undersigned if you have any questions or comments regarding this report.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

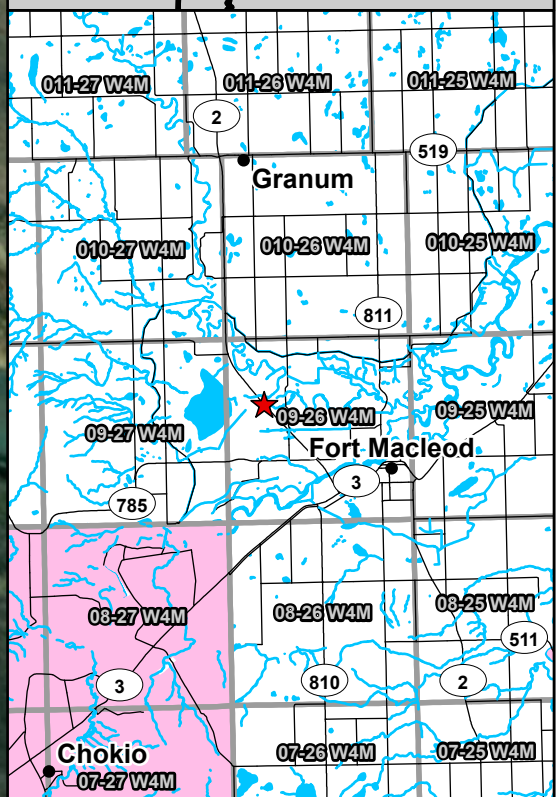
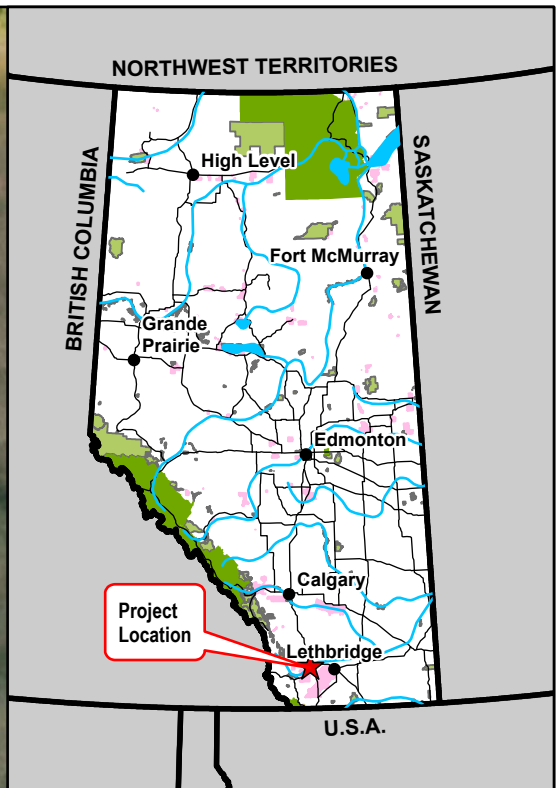
Peter Roy., P.Eng.
Civil Engineer

PR:kb

ATTACHMENTS

Figure
Appendix I Instrumentation Plots

FIGURE



- Legend**
- Slope Inclinerometer (SI)
 - ◆ Standpipe Piezometer (SP)
 - ⊗ Vibrating Wire Piezometer (VW)
 - Flow Direction
 - ┌ Scarp
 - Fence

NOTES:
 1. HORIZONTAL DATUM: NAD83
 2. GRID ZONE: UTM ZONE 12N
 3. IMAGE SOURCE: MD OF WILLOW CREEK NO. 26, TOWN OF CARDSTON, MAXAR

CLIENT

Alberta

Klohn Crippen Berger

PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM		
TITLE Site Plan S004 - Willow Creek (North of Ft. Macleod) Hwy 2:08, km 6.284		
SCALE 1:2,000	PROJECT No. A05116A03	FIG No. 1



APPENDIX I

Instrumentation Plots
