November 19, 2021

Alberta Transportation
4th Floor, Provincial Building
4920 – 51st Street
Red Deer, Alberta
T4N 6K8

Tony Penney, P.Eng.
Construction Engineer

Dear Mr. Penney:

CON0022160 Central Region GRMP Instrumentation Monitoring
Site C055-I; H861:02, km 26.000 Galahad Slide
Section C – 2021 Fall Readings

1 GENERAL

One slope inclinometer (SI) (SI17-C55-02) and two vibrating wire piezometers (VWPs) (VW42620 and VW42621) were read at the C055-I site in the central region on September 17, 2021 by Mr. James Lyons, E.I.T. of Klohn Crippen Berger Ltd. (KCB). These instruments were read as part of the central region geohazard risk management program (GRMP). The site is located on Hwy 861:02, km 26.000, approximately 1 km south of Battle River crossing and about 7 km south of Galahad, Alberta. At the site location, Hwy 861:02 transverses the south slope of the Battle River valley. The approximate site coordinates are 5811270 N, 437304 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the C055-I site consists of two slides, one upper and one lower, along the south slope of the Battle River valley that affect the north side (southbound lane) of Hwy 861:02. The slides appear to be moving independently of each other. In 2013, the highway was realigned south (upslope) towards the backslope, and a culvert was installed to convey ditch flows. The site has required ongoing fill placement at the head of the slide to maintain the road surface.

In March 2017, KCB conducted a geotechnical site investigation at the C055-I site. Drilling was completed by Mobile Augers and Research Ltd. The encountered stratigraphy was as follows:

- fill (granular), overlying medium plastic silty clay till, and overlying bedrock (mudstone and sandstone) at the location of SI17-C55-01 (crest of the slope)
- high plastic silty clay, overlying high plastic clay and silt till, and overlying bedrock (mudstone) at the location of SI17-C55-02 (toe of the slope)

The encountered stratigraphy was consistent with the stratigraphy encountered during a June 2013 drilling investigation.

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1.1 Instrumentation

Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1.

In 2013, KCB installed one standpipe (SP) (SP13-01). The instrument was lost due to ongoing road maintenance. In March 2017, KCB installed two slope inclinometers (SIs) (SI17-C55-01 and SI17-C55-02) and two vibrating wire piezometers (VWPs) (VW42620 and VW42621) to monitor depth of movement and groundwater conditions, respectively. SI17-C55-01 and VW42620 were installed in a borehole located on the north shoulder of Hwy 861:02; and SI17-C55-02 and VW42621 were installed in a borehole located at the toe of the slope. By July 2017, SI17-C55-01 was sheared at an approximate depth of 7.8 m below ground surface.

The instruments are protected by aboveground casing protectors.

The operational SI was read using the same metric RST Digital MEMS Inclinometer System that has been used to read the SI since it was re-initialized in July 2017 when the SI equipment was changed.

The VWPs were read using an RST VW2106 vibrating wire readout.

Table 1.1 Instrumentation Installation Details

Instrument ID	Instrument Type	Date Installed	Coordinates[1] (m)		Ground Surface Elevation[1] (m)	Stick Up (m)	Depth (mbgs[2])	Condition
			Northing	Easting				
~~SI17-C55-01~~	~~SI~~	~~Mar. 20, 2017~~	~~5811267~~	~~437298~~	~~674~~	~~1.0~~	~~10.7~~	~~Inoperable[3]~~
SI17-C55-02	SI	Mar. 21, 2017	5811329	437306	663	0.9	16.8	Operational
~~SP13-01~~	~~SP~~	~~Jun. 21, 2013~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~9.7~~	~~Inoperable~~
VW42620	VWP	Mar. 20, 2017	5811267	437298	674	N/A	6.9	Operational
VW42621	VWP	Mar. 21, 2017	5811329	437306	663	N/A	10.8	Operational

Notes:
[1] Coordinates and ground surface elevations for instruments installed in 2017 were obtained by KCB with a handheld GPS during installation.
[2] Meters below ground surface (mbgs).
[3] SI17-C55-01 has sheared at an approximate depth of 7.8 m below ground surface.

2 INTERPRETATION

2.1 General

For the operational SI, the cumulative displacement, incremental displacement, and displacement-time data was plotted in the A-direction (i.e., the direction of the A0-grooves). The A0-grooves in the SI are aligned approximately perpendicular to the highway and the direction of maximum movement, in the downslope direction.

For the operational 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.

The SI and piezometer plots are included in Appendix I, and a summary of the SI and piezometer data is provided in Table 2.1 and Table 2.2, respectively. The SI data plots presented herein only include data for readings taken with the metric RST equipment that was used to reinitialize the SI.

2.2 Zones of Movement

Between March and May 2017, movement was recorded in SI17-C55-01 (crest of slope) at an approximate depth of 7.8 m below ground surface (elevation 666.2 m) at the interface between silty clay and bedrock (mudstone), at an approximate rate of 12 mm/year. By July 2017, SI17-C55-01 was sheared at this depth and could not be read.

No discernible movement has been recorded in SI17-C55-02 (toe of slope).

2.3 Interpretation of Monitoring Results

Previous assessments of the slope failure suggest that movement is likely in response to periods of heavy or prolonged rainfall, and the presence of discharging groundwater springs. For example, in June 2011 and June 2013, the slides reactivated after a period of heavy rainfall. Visual observations (e.g., signs of frequent grading and guard rail settlement) indicate that the road surface is still deflecting due to slide movement.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	Direction of Movement[3]	Movement (mm)				Rate of Movement (mm/year)		
	Initialized (Re-initialized)	Previous Maximum Cumulative Movement Recorded	Previous Reading	Most Recent Reading				Maximum Cumulative			Incremental Since Previous Maximum Cumulative	Previous Maximum	Current	Change from Previous Reading
								Before Re-Initialization	After Re-Initialization	Total				
~~SI17-C55-01[2]~~	~~Mar. 30, 2017~~	~~May 12, 2017~~	~~May 12, 2017~~	~~N/A – inoperable[2]~~	~~674~~	~~7.8 – 8.8~~	~~A-direction~~	~~1.4~~	~~N/A~~	~~1.4~~	~~N/A – inoperable[2]~~	~~11.7~~	~~N/A – inoperable[2]~~	
SI17-C55-02	Mar. 30, 2017 (Jul. 18, 2017)[2]	N/A - no discernible movement recorded	Sep. 18, 2019	Sep. 17 2021	663	N/A – no discernible movement recorded								

Notes:
[1] Meters below ground surface (mbgs).
[2] SI17-C55-01 has sheared at an approximate depth of 7.8 m below ground surface.

Table 2.2 Piezometer Reading Summary

Instrument ID	Date Installed	Date of Previous Reading	Date of Most Recent Reading	Ground Surface Elevation (m)	Tip Depth (mbgs[1])	Previous Water Level (mbgs[1])	Current Water Level (mbgs[1])	Change from Previous Reading (m)
VW42620	Mar. 20, 2017	Sep. 18, 2019	Sep. 17, 2021	674	6.9	3.4	4.5	-1.1
VW42621	Mar. 21, 2017	Sep. 18, 2019	Sep. 17, 2021	663	10.8	2.4	3.5	-1.1

Note:
[1] Meters below ground surface (mbgs).

3 RECOMMENDATIONS

3.1 Future Work

Readings of the operational VWPs can be reduced from twice a year, once in the spring and once in the fall, to once a year in the spring. Readings of the SI at the toe of the slope (SI17-C55-02) can be discontinued as the extent of slide movement does not impact it.

Remedial options are currently being assessed by KCB and Alberta Transportation, and may include construction of a toe berm, reconstruction of the upper slope with geosynthetic-reinforced fill, and/or installation of subsurface drainage.

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

3.2 Instrument Repairs

No instrument repairs are required.

4 CLOSING

This report is an instrument of service of Klohn Crippen Berger Ltd. (KCB). The report has been prepared for the exclusive use of Alberta Transportation (Client) for the specific application to the Central Region Geohazard Risk Management Program (Contract No. CON0022160) and it may not be relied upon by any other party without KCB's written consent.

KCB has prepared this report in a manner consistent with the level of care, skill, and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCB makes no warranty, express or implied.

Use of or reliance upon this instrument of service by the Client is subject to the following conditions:

1. The report is to be read in full, with sections or parts of the report relied upon in the context of the whole report.
2. The observations, findings, and conclusions in this report are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to precisely represent conditions at any other time.
3. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the report.

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

Yours truly,

KLOHN CRIPPEN BERGER LTD.

2021-11-22

Courtney Mulhall, M.Sc., P.Eng.
Geotechnical Engineer

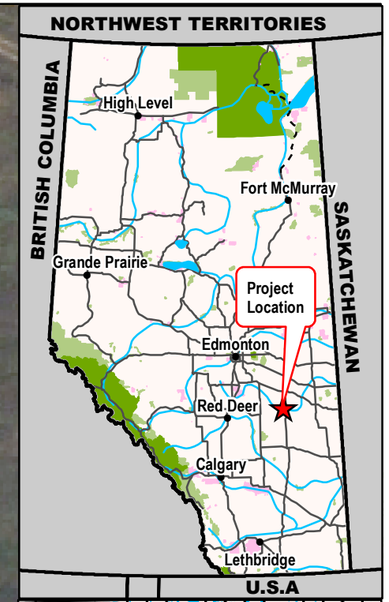
Chris Gräpel, M.Eng., P.Eng.
Senior Civil Engineer, Associate

CM:ap

Attachments
Figure
Appendix I Instrumentation Plots

PERMIT TO PRACTICE
KLOHN CRIPPEN BERGER LTD.
RM SIGNATURE:
RM APEGA ID #: 187607
DATE: 22 Nov. 2021
PERMIT NUMBER: P009196
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

FIGURE



Legend

- ~~Slope Inclinometer, Inoperable~~
- Slope Inclinometer, Operable
- ~~Standpipe Piezometer, Inoperable~~
- Vibrating Wire Piezometer, Operable
- Guardrail
- Culvert
- Scarp

Meters
0 50

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM Zone 12N
3. IMAGE SOURCE: Abacus Datagraphics Ltd. Image dated July 14, 2014 to October 10, 2014
4. Location of instruments is approximate (not surveyed)
5 Strikethrough indicates instrument is inoperable

CLIENT: Alberta Government

Klohn Crippen Berger

PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
C055 - Galahad Slide
Hwy 861:02, km 26.000

SCALE	PROJECT No.	FIG No.
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Date: October 21, 2021
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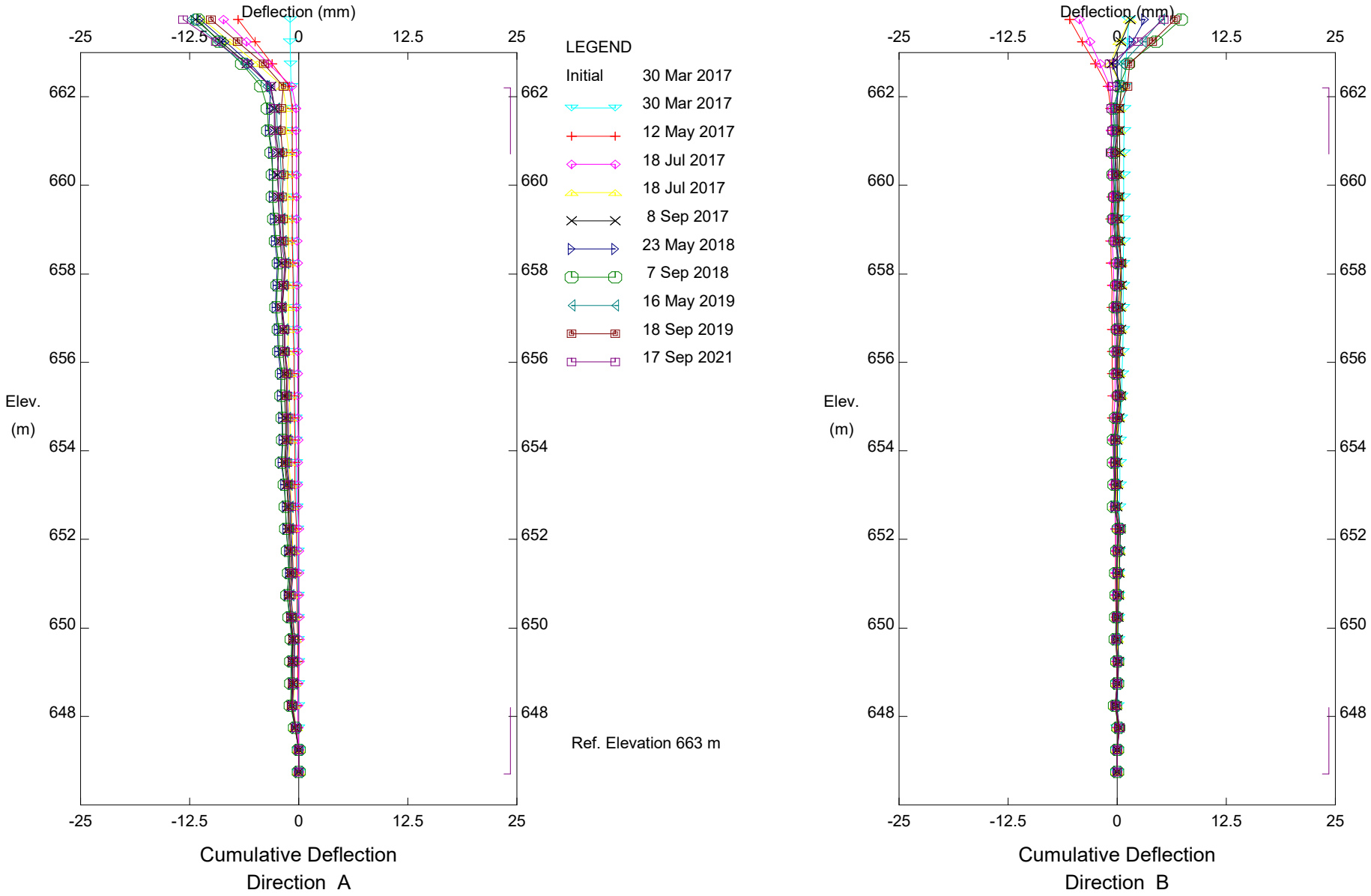
APPENDIX I

Instrumentation Plots

Klohn Crippen Berger - Calgary



C055; H861:02, Galahad Slide, Inclinometer SI17-C55-02

Alberta Transportation

Instrument re-initialized in July 2017 when the SI equipment was changed.

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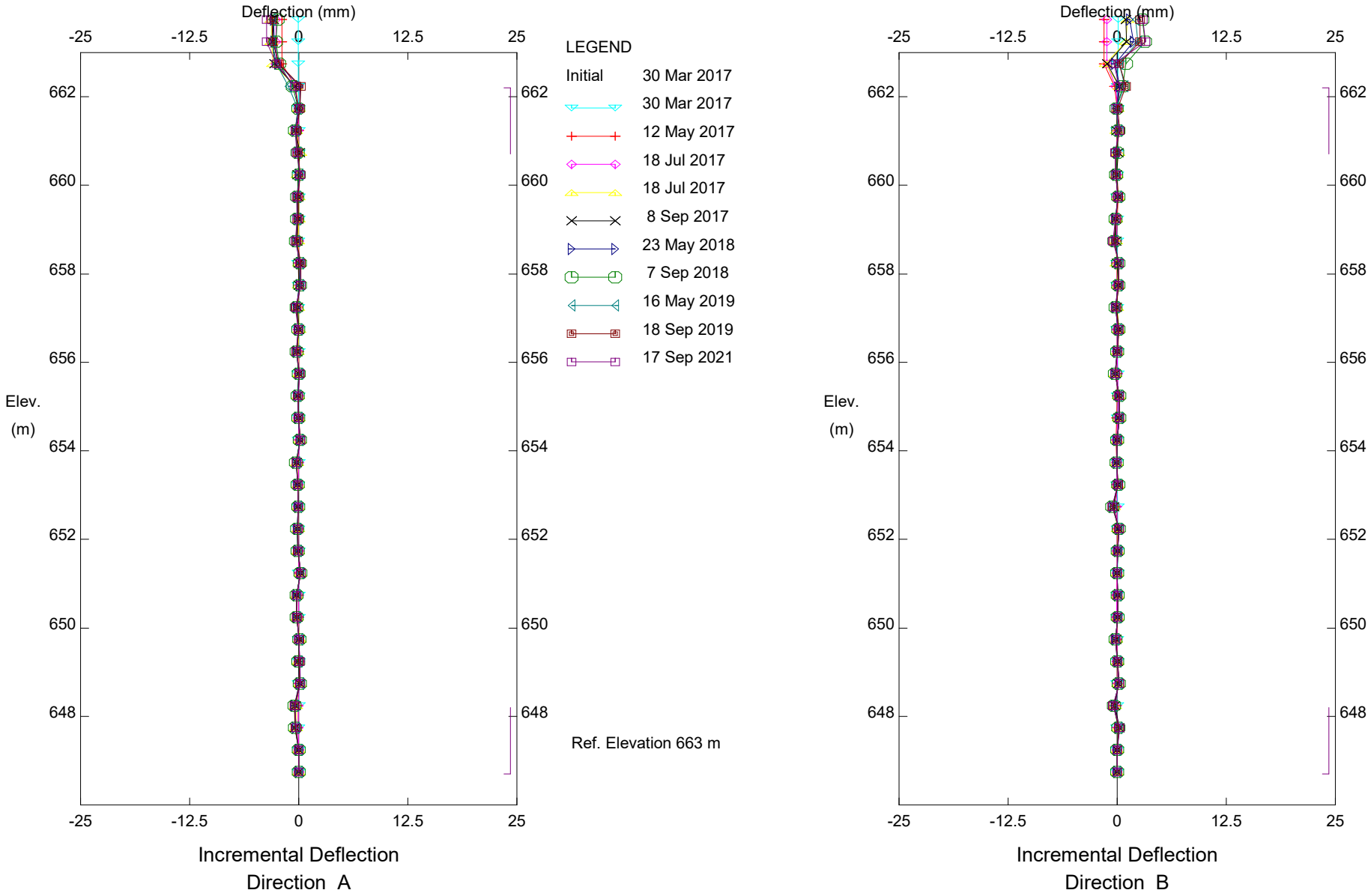
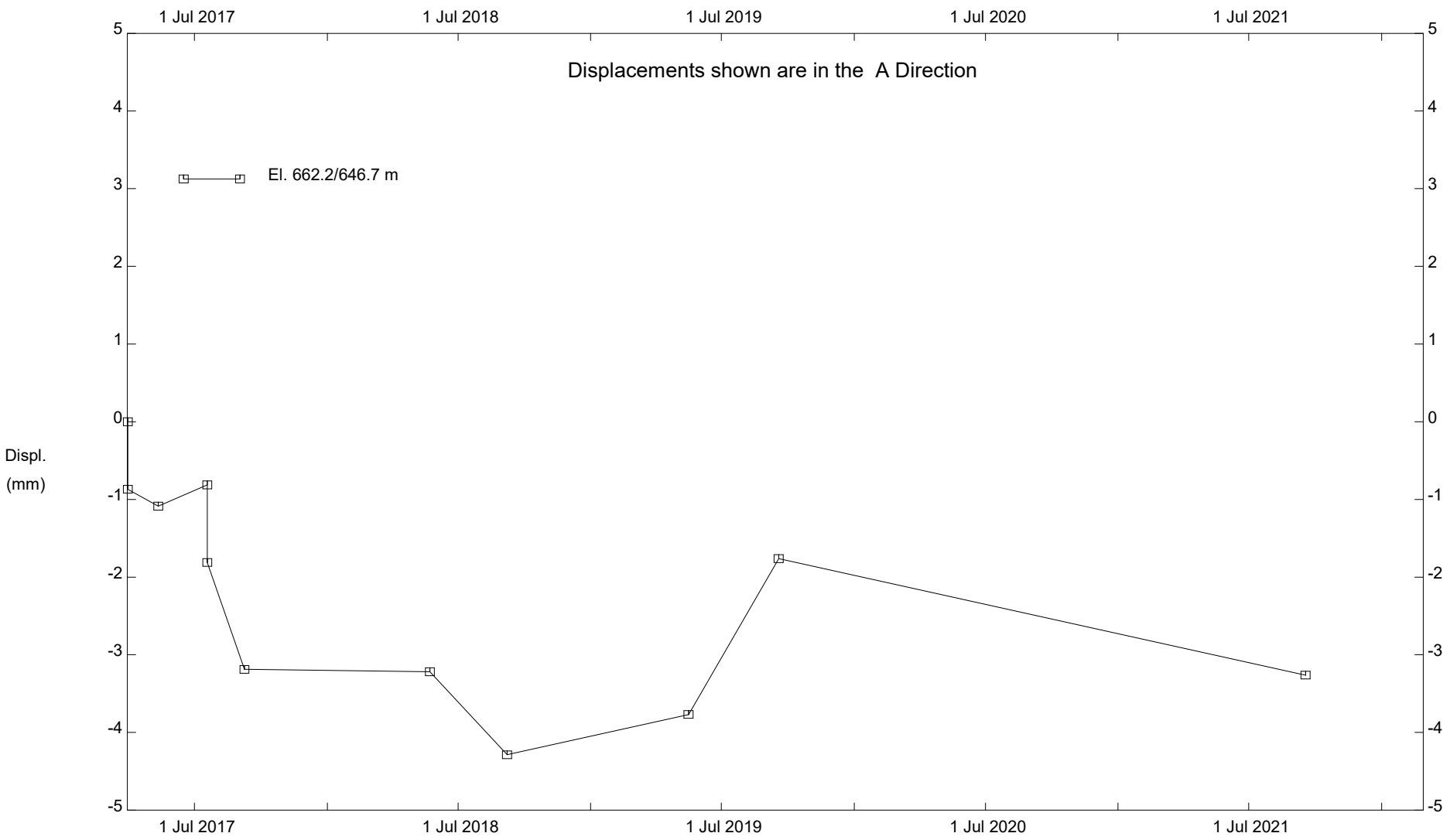


C055; H861:02, Galahad Slide, Inclinometer SI17-C55-02

Alberta Transportation

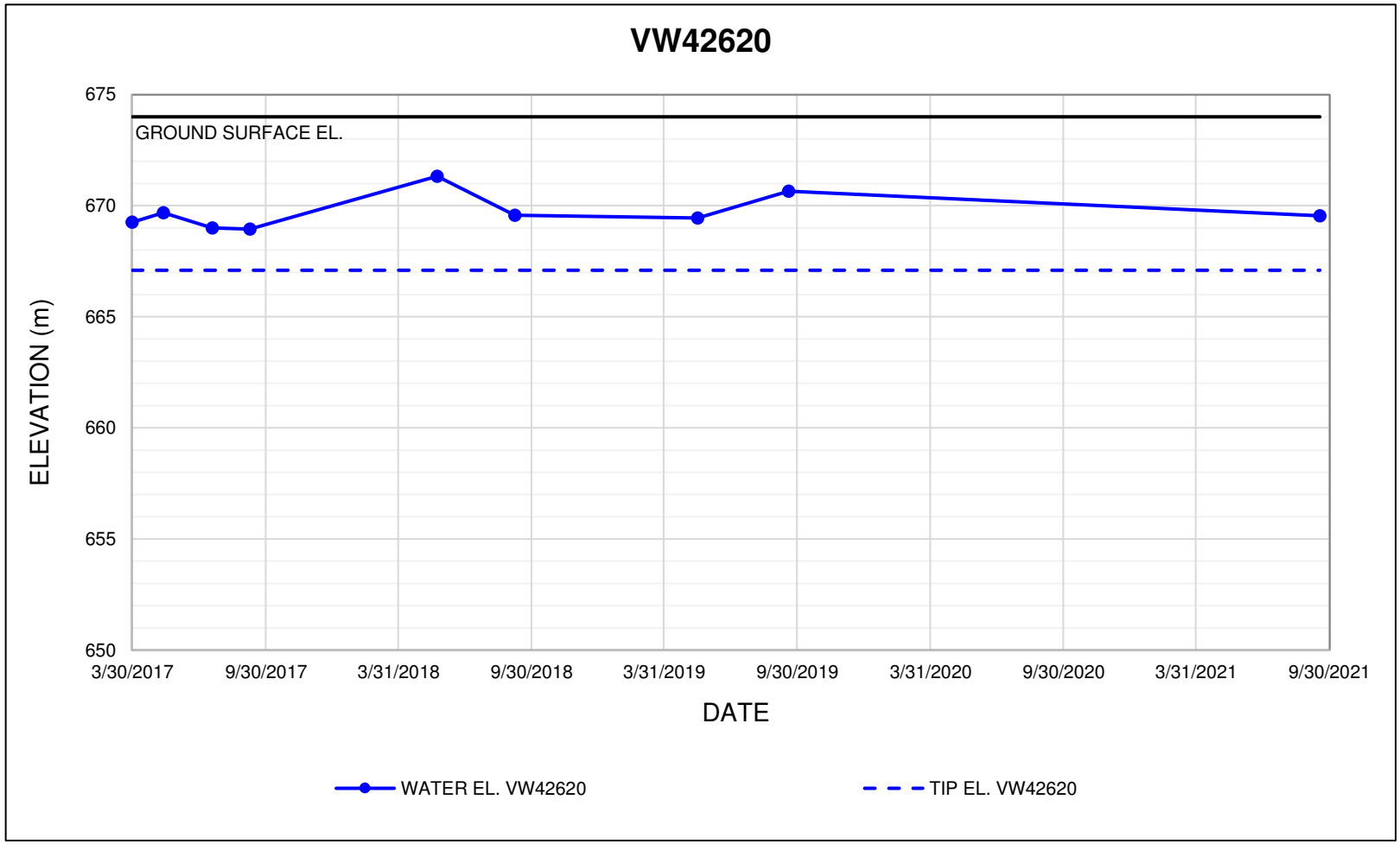
Instrument re-initialized in July 2017 when the SI equipment was changed.

Klohn Crippen Berger - Calgary



C055; H861:02, Galahad Slide, Inclinometer SI17-C55-02

Alberta Transportation



NOTES:
1. GROUND SURFACE ELEVATION OBTAINED WITH A HANDHELD GPS DURING INSTALLATION.

CLIENT
Alberta
Klohn Crippen Berger

PROJECT
CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
C055 - Galahad Slide
Hwy 861:02, km 26.000

SCALE	PROJECT No.	FIG No.
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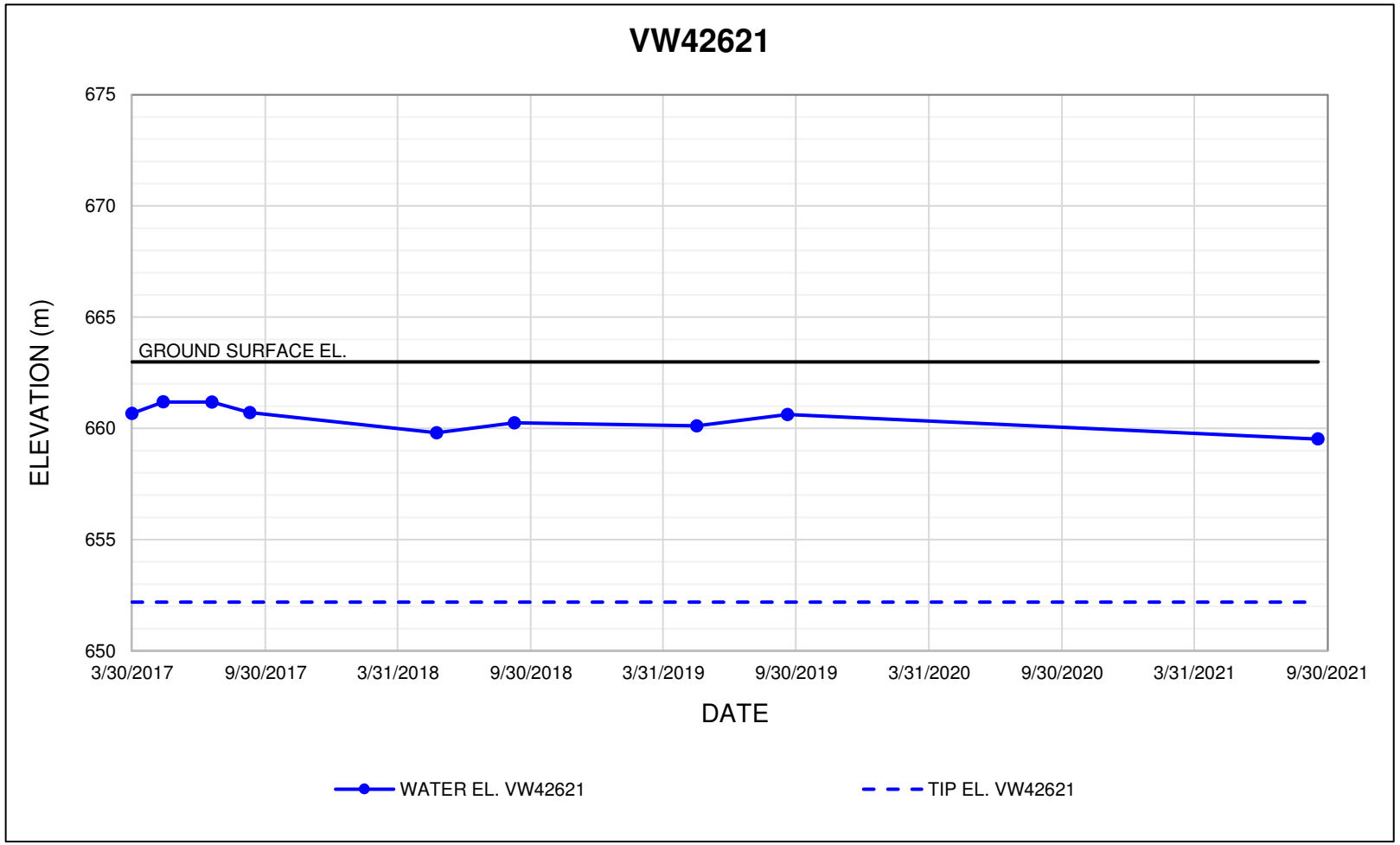

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PROJECT
CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
C055 - Galahad Slide
Hwy 861:02, km 26.000

SCALE	PROJECT No.	FIG No.
	A05116A02	