July 15, 2024

Alberta Transportation and Economic Corridors
4th Floor, Provincial Building
4920 51 Street
Red Deer, Alberta
T4N 6K8

Tony Penney, P.Eng.
Construction Engineer

Dear Mr. Penney:

CON0022160 Central Region GRMP Instrumentation Monitoring
Site C060; H597:02, km 11.299 Slide East of Blackfalds
Section C – 2024 Spring Readings

1 GENERAL

Two slope inclinometers (SIs) (SI17-C60-01 and SI17-C60-02) and four vibrating wire piezometers (VWPs) (VW42623, VW42624, VW42625, and VW42626) were read at the C060 site in the Central Region on May 15, 2024 by Aden Shipton, 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 597:02, km 11.299, approximately 9 km east of Blackfalds, Alberta. A tributary creek of the Red Deer River is located near the toe of the slope. The approximate site coordinates are 5802987 N, 317570 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the C060 site consists of a slide through the foundation of the highway embankment. The slide is located on the south side (eastbound lane) of Hwy 597:02. Issues at this site developed shortly after construction of the highway was completed in 1976. Previous remedial actions at this site include installation of horizontal drains in November 1983 to lower the groundwater table, construction of a toe berm with a shear key in 1983, construction of a riprap toe berm sometime after 1992, installation of deep horizontal drains in February 2012, and removal of a dip in the highway surface in summer 2012.

In March 2017, KCB conducted a geotechnical site investigation at the C060 site. Drilling was completed by Mobile Augers and Research Ltd. The encountered stratigraphy was as follows: fill (sand overlying medium to high plastic silt and clay), overlying medium plastic silty clay till and/or bedrock (siltstone). It is unclear if the bedrock encountered during the investigation was in situ or rafted in the silty clay till. It also appears that organic materials were not fully removed before fill placement. The encountered stratigraphy was consistent with the stratigraphy encountered during a November 2010 drilling investigation which was also monitored by KCB.

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1.1 Instrumentation

Instrumentation installation details are tabulated in Table 1.1. Instrument locations are presented in Figure 1. All instruments installed before 2010 are inoperable and are not presented on Figure 1 or discussed herein.

In November 2010, KCB installed one standpipe piezometer (SP) (SP10-01) and one SI (SI10-01) in boreholes located on the slope between the highway and the toe berm crest. SI10-01 and a replacement SI (SI12-01) installed in September 2012 were sheared by October 2011 and October 2012, respectively.

In March 2017, KCB installed two SIs (SI17-C60-01 and SI17-C60-02) and four VWPs (VW42623, VW42624, VW42625, and VW42626) to monitor depth of movement and groundwater conditions, respectively. SI17-C60-01, VW42623, and VW42625 were installed in borehole BH17-C60-01, located in the south (eastbound) lane of the highway and are protected by a flush-mounted casing protector. SI17-C60-02, VW42624, and VW42626 were installed in borehole BH17-C60-02, located on the mid-slope bench and are protected by an above-ground casing protector.

The operable SIs were read using the same metric RST Digital MEMS Inclinometer System that has been used to read the SIs since they were re-initialized in 2017, when the SI equipment was changed. The SI data plots presented herein only include data for readings taken with the metric RST equipment.

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

Table 1.1 Instrumentation Installation Details

Instrument ID	Instrument Type	Date Installed	UTM Coordinates[1] (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth (mbgs[2])	Condition
			Northing	Easting				
~~SI10-01~~	~~SI~~	~~Nov. 18, 2010~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~1.1~~	~~31.2~~	~~Inoperable[3]~~
~~SI12-01~~	~~SI~~	~~Sep. 26, 2012~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~1.0~~	~~30.0~~	~~Inoperable[3]~~
SI17-C60-01	SI	Mar. 09, 2017	5802990	317571	883	-0.3	18.4	Operable
SI17-C60-02	SI	Mar. 10, 2017	5802940	317582	873	3.4	16.9	Operable
~~SP10-01~~	~~SP~~	~~Nov. 19, 2010~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~13.9~~	~~Inoperable~~
VW42623	VWP	Mar. 09, 2017	5802990	317571	883	N/A	6.0	Operable
VW42624	VWP	Mar. 10, 2017	5802940	317582	873	N/A	9.3	Operable
VW42625	VWP	Mar. 09, 2017	5802990	317571	883	N/A	13.0	Operable
VW42626	VWP	Mar. 10, 2017	5802940	317582	873	N/A	14.9	Operable

Notes:
[1] Coordinates and ground surfaces elevations for the instruments installed in 2017 were obtained with a handheld GPS during installation.
[2] Meters below ground surface (mbgs).
[3] SI10-01 and SI12-02 have sheared at an approximate depth of 16 m below ground surface.

2 INTERPRETATION

2.1 General

For 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) and, where applicable, in the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). SI17-C60-02 has a skew angle of 19°, measured clockwise from the direction of the A0-grooves.

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

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.

2.2 Zones of Movement

Prior to being sheared, movement was being recorded in SI10-01 at an approximate depth of 16 m below ground surface (approximately elevation 866 m) at an approximate rate of movement of 75 mm/year. SI12-01 was only read once before shearing, but it also sheared at this depth.

Discrete movement is being recorded in SI17-C60-01 at an approximate depth of 13.9 m below ground surface (approximately elevation 869.2 m). Prior to being re-initialized in 2017, distributed movement was being recorded at an approximate depth of 2.3 m (approximately elevation 880.7 m).

Discrete movement is being recorded in SI17-C60-02 at an approximate depth of 12.1 m below ground surface (approximately elevation 860.9 m).

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	Direction of Movement, Skew Angle[2]	Movement (mm)				Rate of Movement (mm/year)		
	Initialized (Re-initialized)[3]	Previous Maximum Cumulative Movement Recorded	Previous Reading	Most Recent Reading				Maximum Cumulative: Before Re-Initialization	Maximum Cumulative: After Re-Initialization	Maximum Cumulative: Total	Incremental Since Previous Maximum Cumulative	Previous Maximum	Most Recent Reading	Change from Previous Reading
SI17-C60-01	Mar. 30,2017 (Sep. 7, 2017)	Sep. 07, 2017	May 10, 2023	May 15, 2024	883	2.3	A-Direction	2.8	N/A – no discernible movement recorded since re-initialized[2]		2.8	N/A – no discernible movement recorded since re-initialized[2]		
		May 10, 2023				12.9 - 14.3	A-Direction	1.8	21.8	23.6	3.2	15.7	3.1	-1.9
SI17-C60-02	Mar. 30,2017 (Jul. 7, 2017)	Jun. 27, 2022	May 10, 2023	May 15, 2024	873	10.6-12.6	X-Direction, 19°	N/A – no discernible movement recorded prior to re-initialized[2]	12.0	12.0	0.3	13.3	0.3	-5.8

Notes:
[1] Meters below ground surface (mbgs).
[2] Skew angle of X-direction measured clockwise from the A-direction.
[3] SI17-C60-01 and SI17-C60-02 were re-initialized in July and September 2017, respectively, when the SI equipment was changed.

Table 2.2 Vibrating Wire Piezometer Reading Summary

Borehole ID	Instrument ID / Serial No.	Date			Ground Surface Elevation (m)	Tip 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)
BH17-C60-01	VW42623	Mar. 09, 2017	May 10, 2023	May 15, 2024	883	6.0	4.9	4.4	0.5
	VW42625	Mar. 09, 2017	May 10, 2023	May 15, 2024	883	13.0	8.1	8.3	-0.2
BH17-C60-02	VW42624	Mar. 10, 2017	May 10, 2023	May 15, 2024	873	9.3	3.2	3.4	-0.2
	VW42626	Mar. 10, 2017	May 10, 2023	May 15, 2024	873	14.9	9.3	9.3	0.0

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

2.3 Interpretation of Monitoring Results

Based on the stratigraphy encountered during the 2010 and 2017 drilling investigations:

- the movement recorded in SI10-01 and SI12-01 (mid-slope) appears to have occurred at the interface between the clay and rafted bedrock.
- the upper and lower zones of movement recorded in SI17-C60-01 appear to be occurring in the embankment fill and at the interface between clay and bedrock. The magnitude and rate of movement being recorded in SI17-C60-01 tends to fluctuate, especially near the bottom of the casing. Based on the stratigraphy encountered during the 2010 drilling investigation, we suspect SI17-C60-01 was terminated in rafted bedrock and the toe of the SI could be moving. Although SI17-C60-01 extends below the suspected failure surface, it may not extend deep enough and the recorded movement, especially near the bottom of the casing, are likely caused by movement of the rafted bedrock in the underlying till.
- the movement recorded in SI17-C60-02 appears to be occurring near the interface between the toe berm fill and underlying foundation materials.

The rate of movement in SI17-C60-01 has been relatively steady (less than 7 mm/year) since installation, except for between May 2020 and September 2020 when the rate of movement increased to approximately 16 mm/year before decreasing to 1 mm/year in June 2021. A steady rate of movement (less than 6 mm/year) has also been recorded in SI17-C60-02 since installation apart from an increase to approximately 14 mm/year between May and September 2020. The increased rate of movement recorded in both slope inclinometers between May and September 2020 is likely attributed to wet weather during the summer months. The May 2024 readings for both SI17-C60-01 and SI17-C60-02 are consistent with their historical trends.

Some minor movement has been recorded in the B-direction of SI17-C60-01 and SI17-C60-02, which has been attributed to poor grout backfill and casing settlement, respectively.

Water levels recorded in VW42625, VW42624, and VW42626 (lower piezometer below highway, and piezometers below toe berm crest) have been relatively steady (typically ±0.5 m) since they instruments were installed in 2017, excluding higher-than-typical water levels recorded in September 2020 after wet weather during the summer months. Water levels recorded in VW42623 (upper piezometer below highway) appear to fluctuate seasonally with the spring readings being lower than fall readings. However, since the reading frequency was reduced to spring readings only in 2021, fluctuations between seasons are no longer captured.

Previous assessments of the slope failure and the current instrumentation data suggests that movement is likely in response to periods of heavy or prolonged rainfall, high groundwater conditions, creek erosion at the toe of the slope, and the presence of a rafted bedrock or a weak bedrock layer below the highway. KCB understands that historic rural road construction practices in Alberta often included placing poor quality and/or uncompacted fill below the slopes of the embankment and did not include foundation preparation. As a result, there is a relatively high likelihood that the embankment slopes are weaker due to lack of compaction, and more susceptible to failure due to weak layers (e.g., soft and/or organic soils) left in the foundation.

Current instrumentation data indicates movement is occurring below the crest of the highway embankment and below the crest of the toe berm. As the upper portion of the slide continues to move, load will be placed on the lower portion of the slide below the toe berm causing movement of the embankment toe and slope.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read once per year (spring).

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

Remedial options that have been discussed between KCB and Alberta Transportation and Economic Corridors (TEC) include:

- extending the corrugated-steel-pipe (CSP) slope drain to discharge surface water runoff into the creek and not the toe berm surface;
- installing a drainage system on the west abutment to intercept any groundwater that may be entering the embankment from the original valley slope;
- enlarging the toe berm and passing creek flows with a culvert;
- placing additional riprap at the toe of the slope; and
- installing a pile wall or a double row of pile walls at the head of the slide.

Currently, unless movements accelerate and impact the highway surface, TEC has no plans of repairing this site. Since SI17-C60-01 is recording movement below the highway surface, TEC should inspect the road surface regularly for signs of pavement distress (e.g., cracking and/or settlement).

3.2 Instrument Repairs and Maintenance

No additional instrument repairs or maintenance is required.

4 CLOSING

This report is an instrument of service of Klohn Crippen Berger (KCB). The report has been prepared for the exclusive use of Alberta Transportation and Economic Corridors (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. The report is based on information provided to KCB by the Client or by other parties on behalf of the client (Client-supplied information). KCB has not verified the correctness or accuracy of such information and makes no representations regarding its correctness or accuracy. KCB shall not be responsible to the Client for the consequences of any error or omission contained in Client-supplied information.
4. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the report.
5. This report is electronically signed and sealed and its electronic form is considered the original. A printed version of the original can be relied upon as a true copy when supplied by the author or when printed from its original electronic file.

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

Yours truly,

KLOHN CRIPPEN BERGER LTD.

PROFESSIONAL ENGINEER ALBERTA
JAMES LYONS
ID 247708
2024-07-15

James Lyons, P.Eng.
Civil Engineer

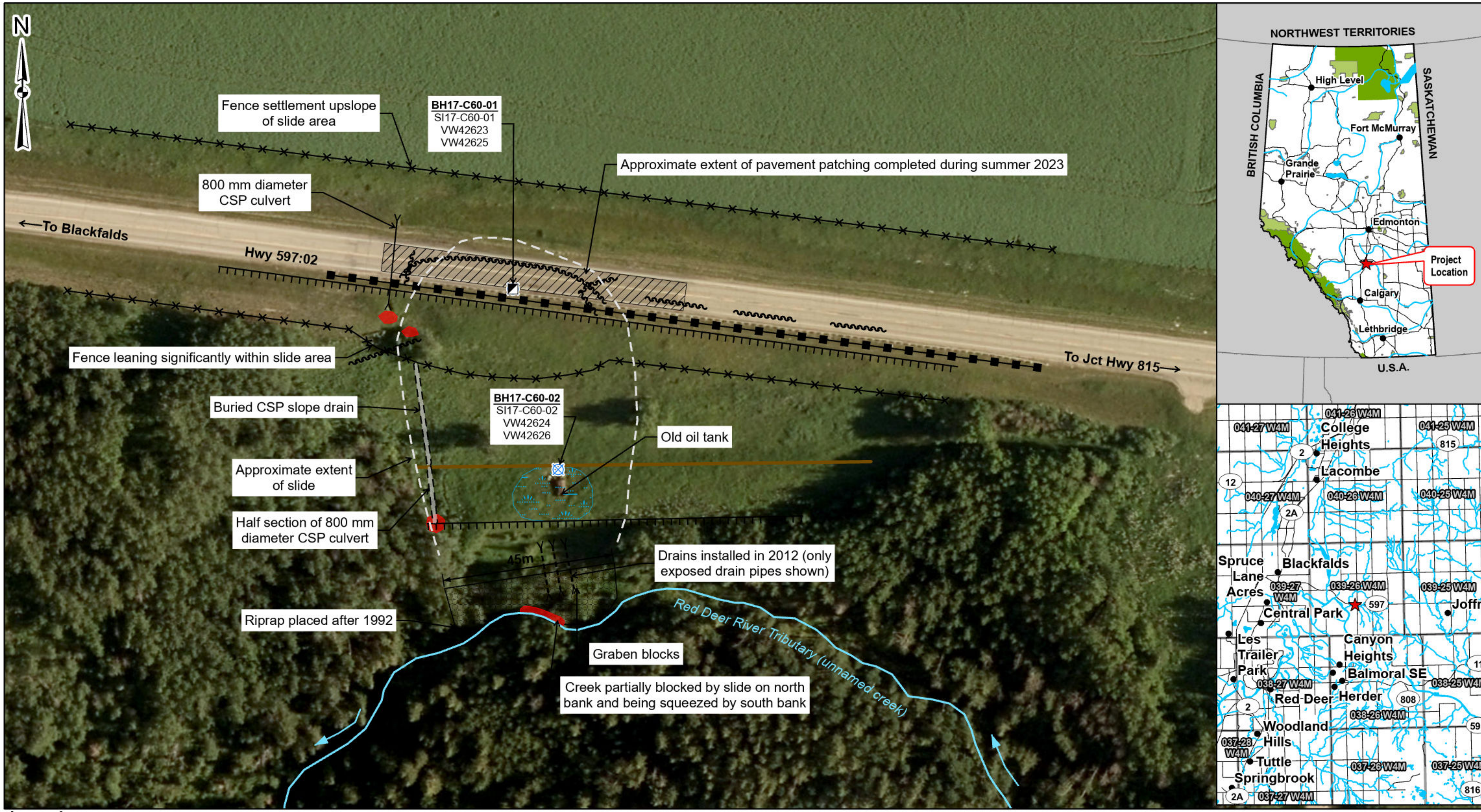
Aden Shipton, E.I.T.
Civil Engineer in Training

JL:bb

PERMIT TO PRACTICE
KLOHN CRIPPEN BERGER LTD.
RM SIGNATURE:
RM APEGA ID #: 58463
DATE: July 15 2024
PERMIT NUMBER: P009196
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE



Legend

- Slope Inclinometer
- Vibrating Wire Piezometer
- Slide Extent
- Top of Slope
- Crack
- Culvert
- Drain
- Fence
- Guardrail
- Measure
- Top of Berm Upslope Crest
- Flow Direction
- Watercourse
- Buried CSP
- Wet Area
- Erosion
- Riprap
- Pavement Patch

0 50 Metres

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 12N
3. IMAGE SOURCE: 2022 MICROSOFT CORPORATION, 2022 MAXAR CNES, DISTRIBUTION AIRBUS DS
4. LOCATION OF INSTRUMENTS IS APPROXIMATE (NOT SURVEYED)

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
C060 - Slide East of Blackfalds
Hwy 597:02, km 11.299

SCALE	PROJECT No.	FIG No.
1:1,000	A05116A02	1

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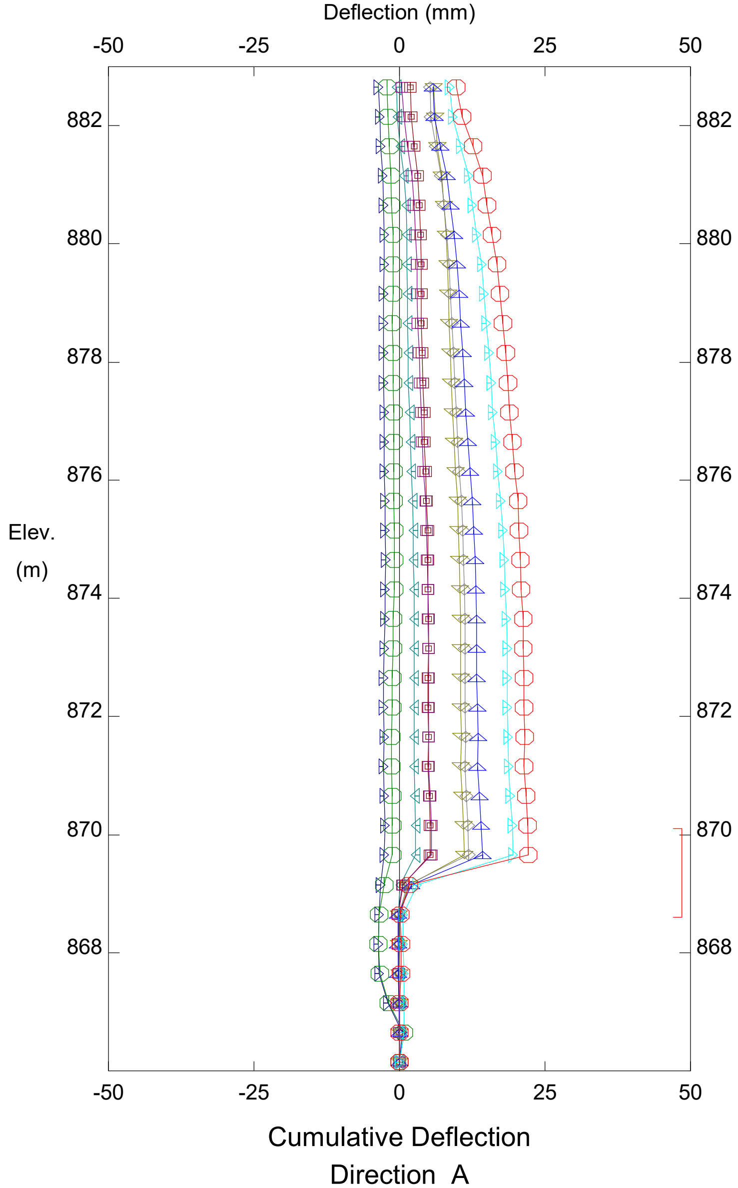
APPENDIX I

Instrumentation Plots

Klohn Crippen Berger - Calgary



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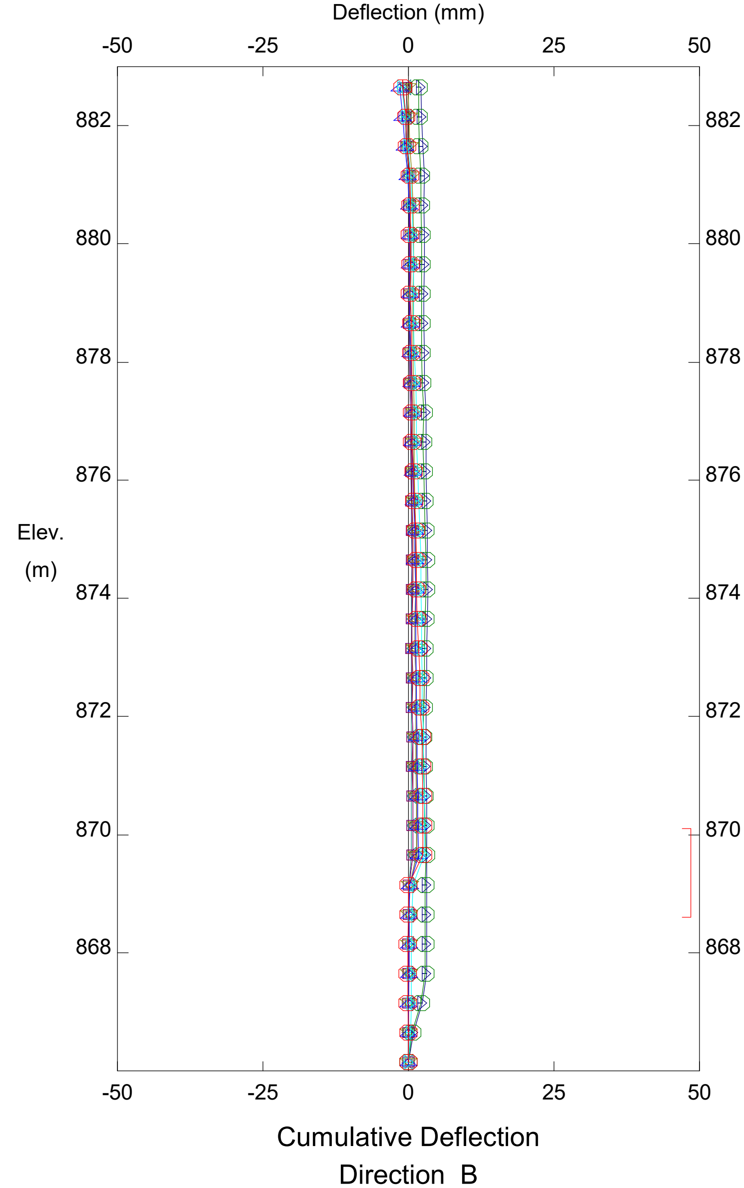
	6 Sep 2018
	15 May 2019
	15 Sep 2019
	6 May 2020
	9 Sep 2020
	14 Jun 2021
	25 Jun 2022
	10 May 2023
	15 May 2024

Ref. Elevation 883 m



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-01

Alberta Transportation

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

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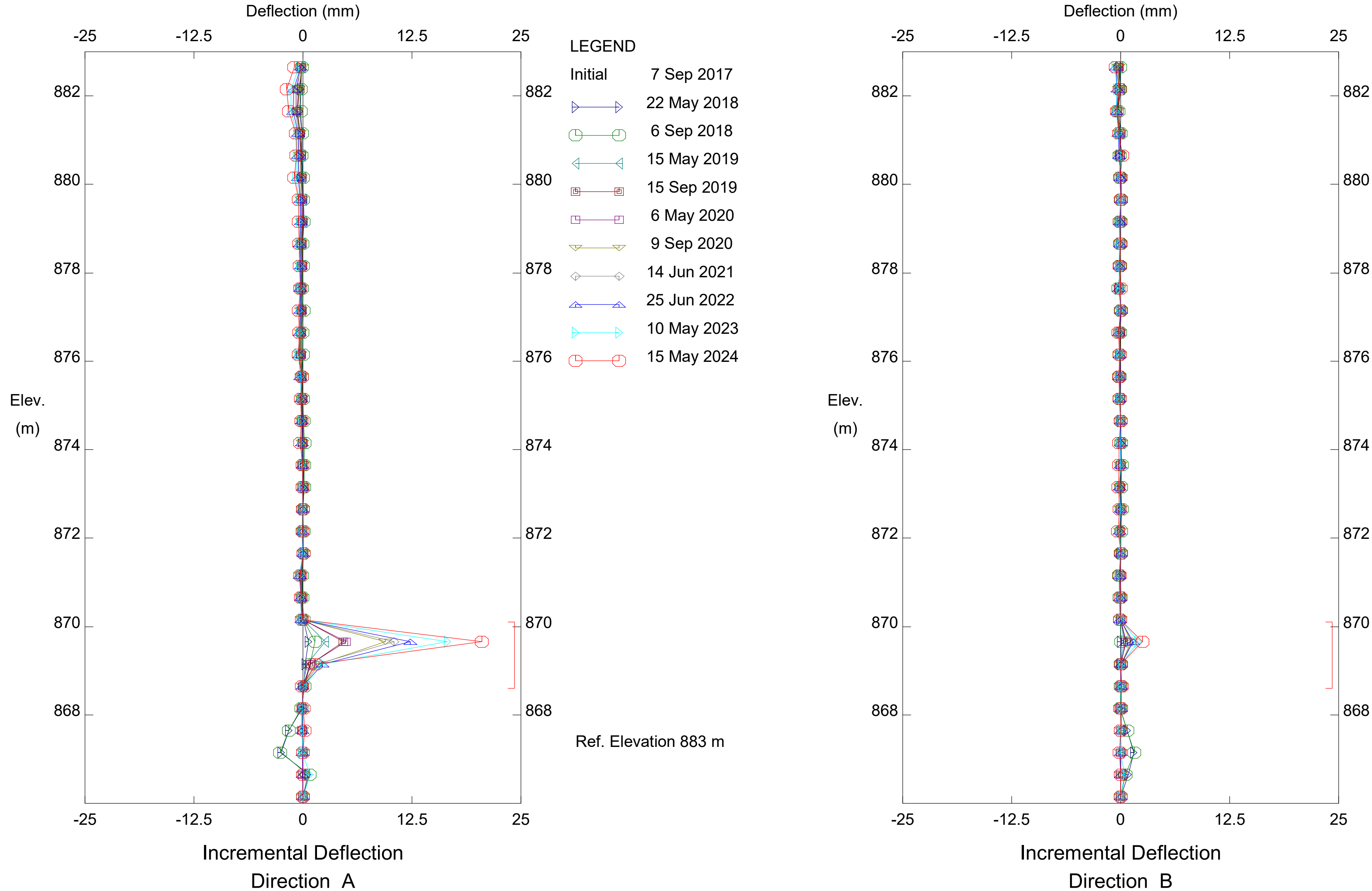
Klohn Crippen Berger - Calgary



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Alberta Transportation

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

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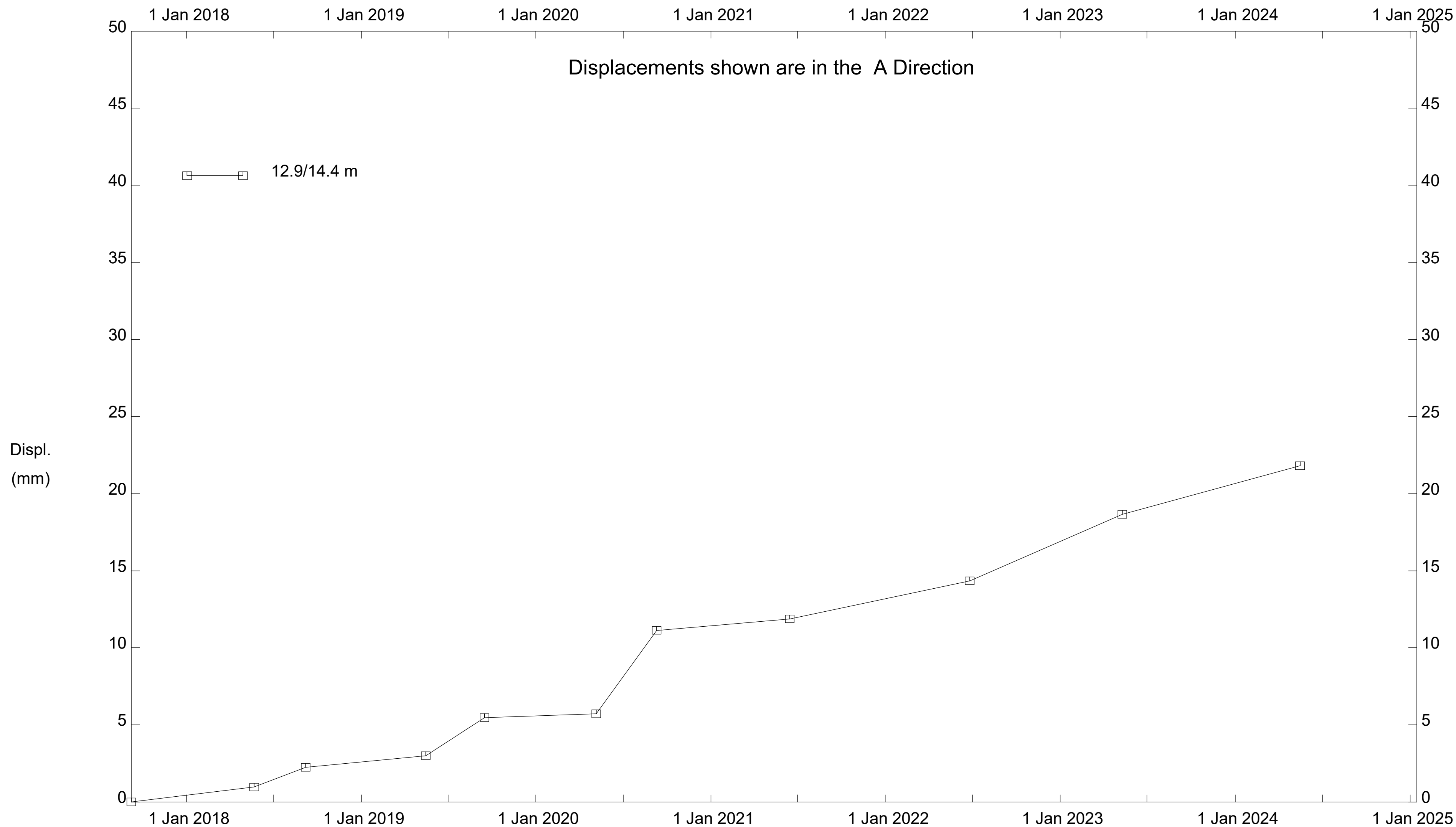
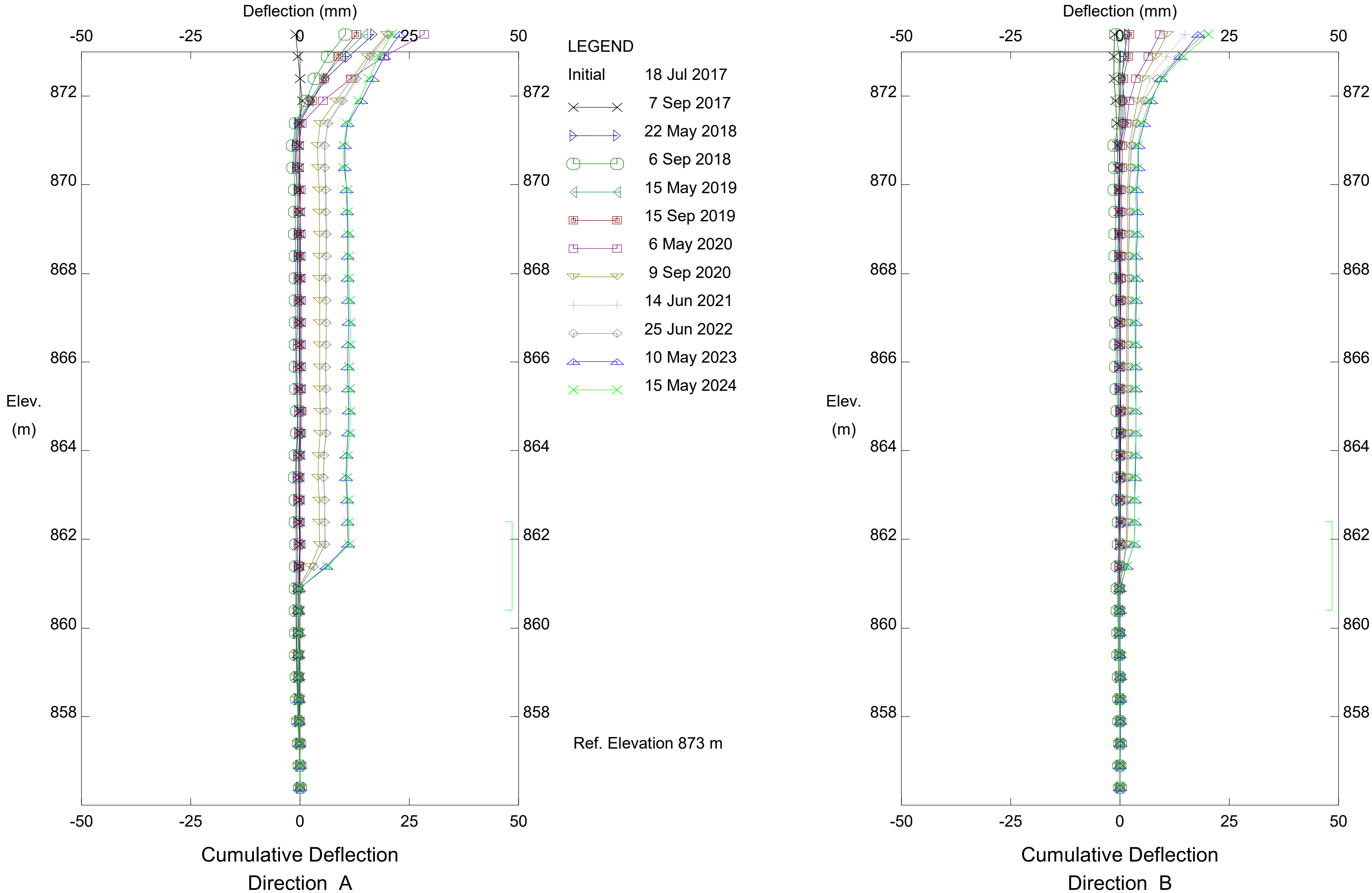
Klohn Crippen Berger - Edmonton



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-01

Alberta Transportation

Klohn Crippen Berger - Calgary



C060; H597:02, Slide East of Blackfalds, Inclinometer SI17-C60-02

Alberta Transportation

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

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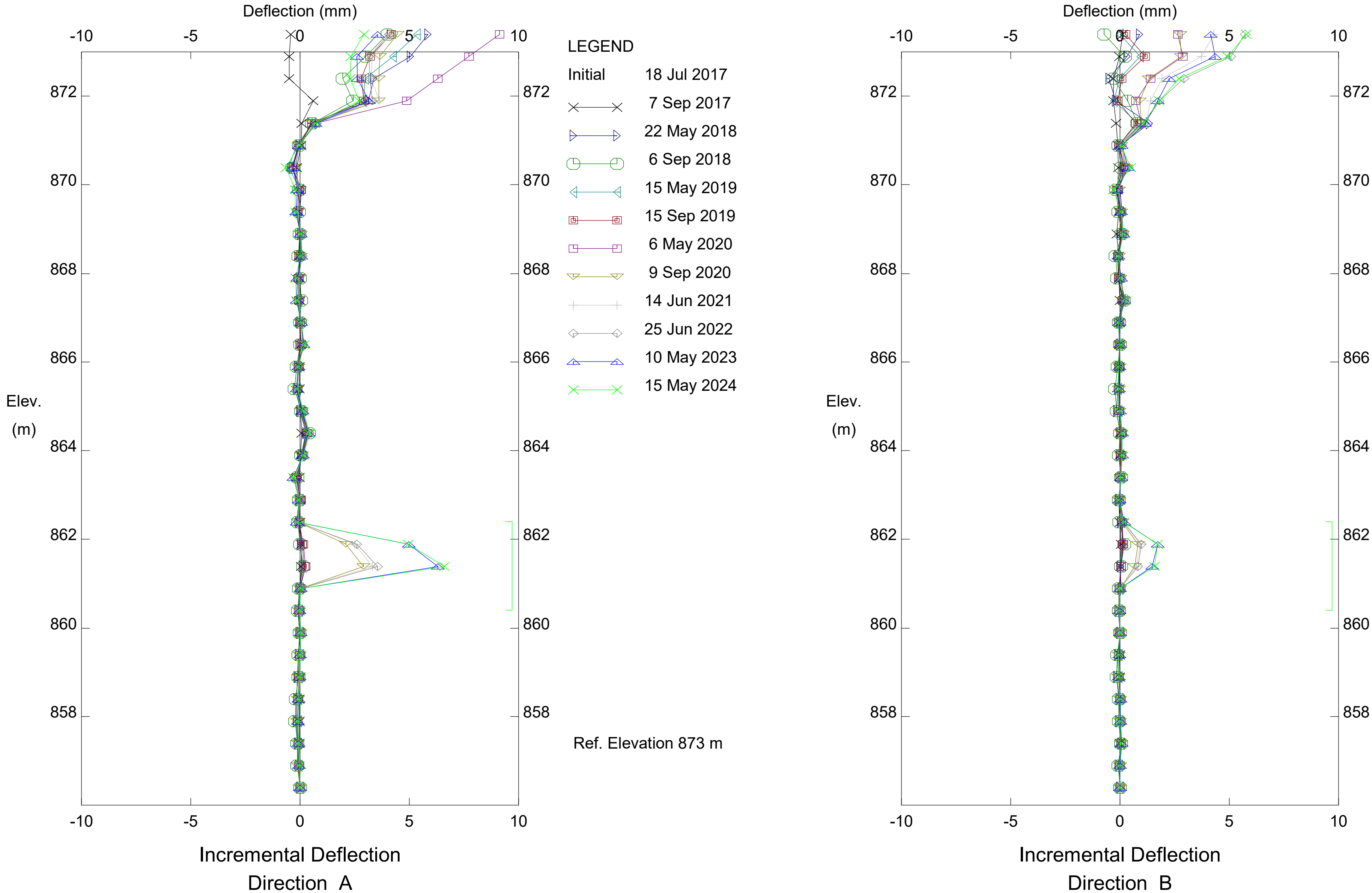
Klohn Crippen Berger - Calgary



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Alberta Transportation

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

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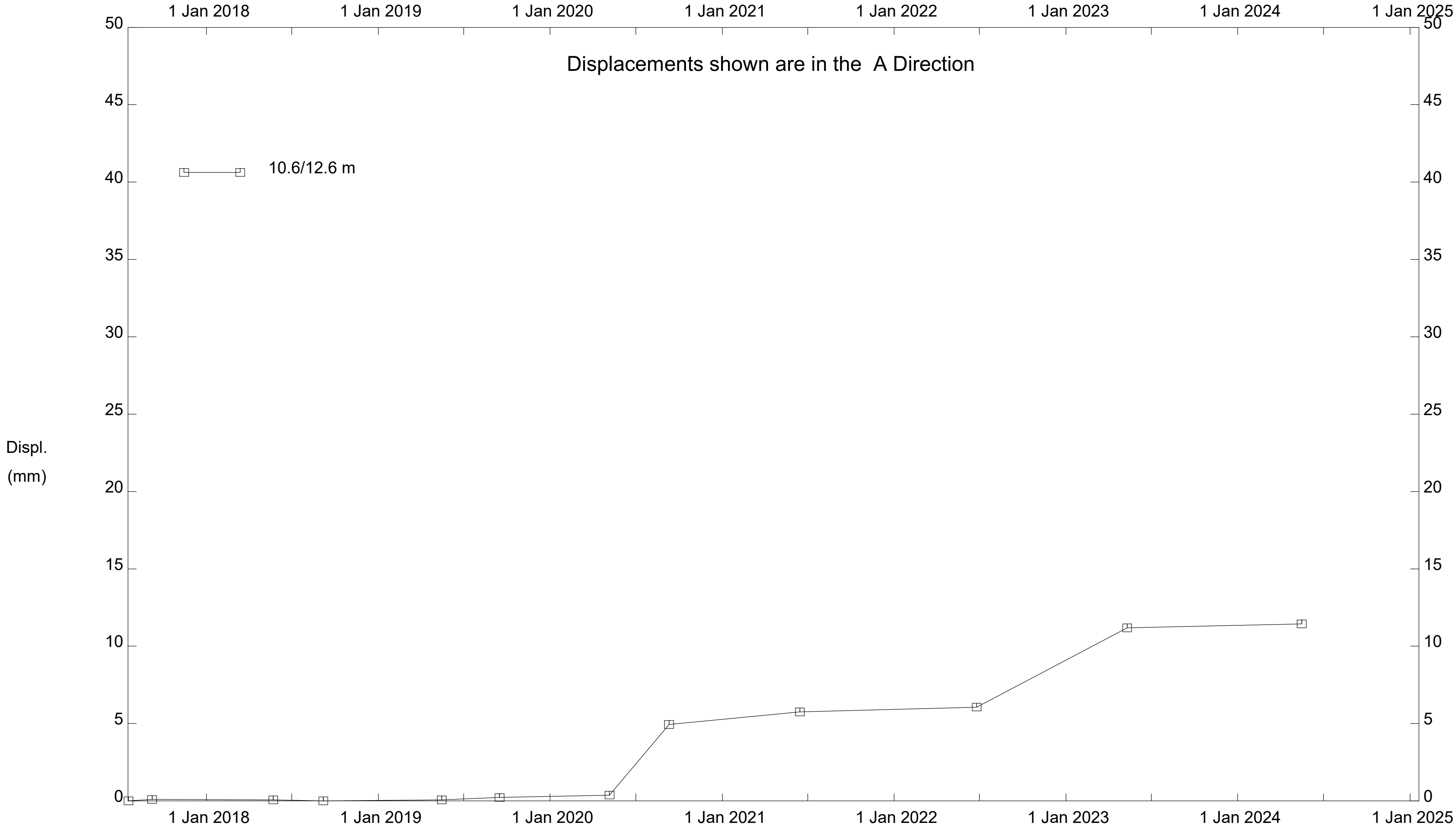
Klohn Crippen Berger - Edmonton



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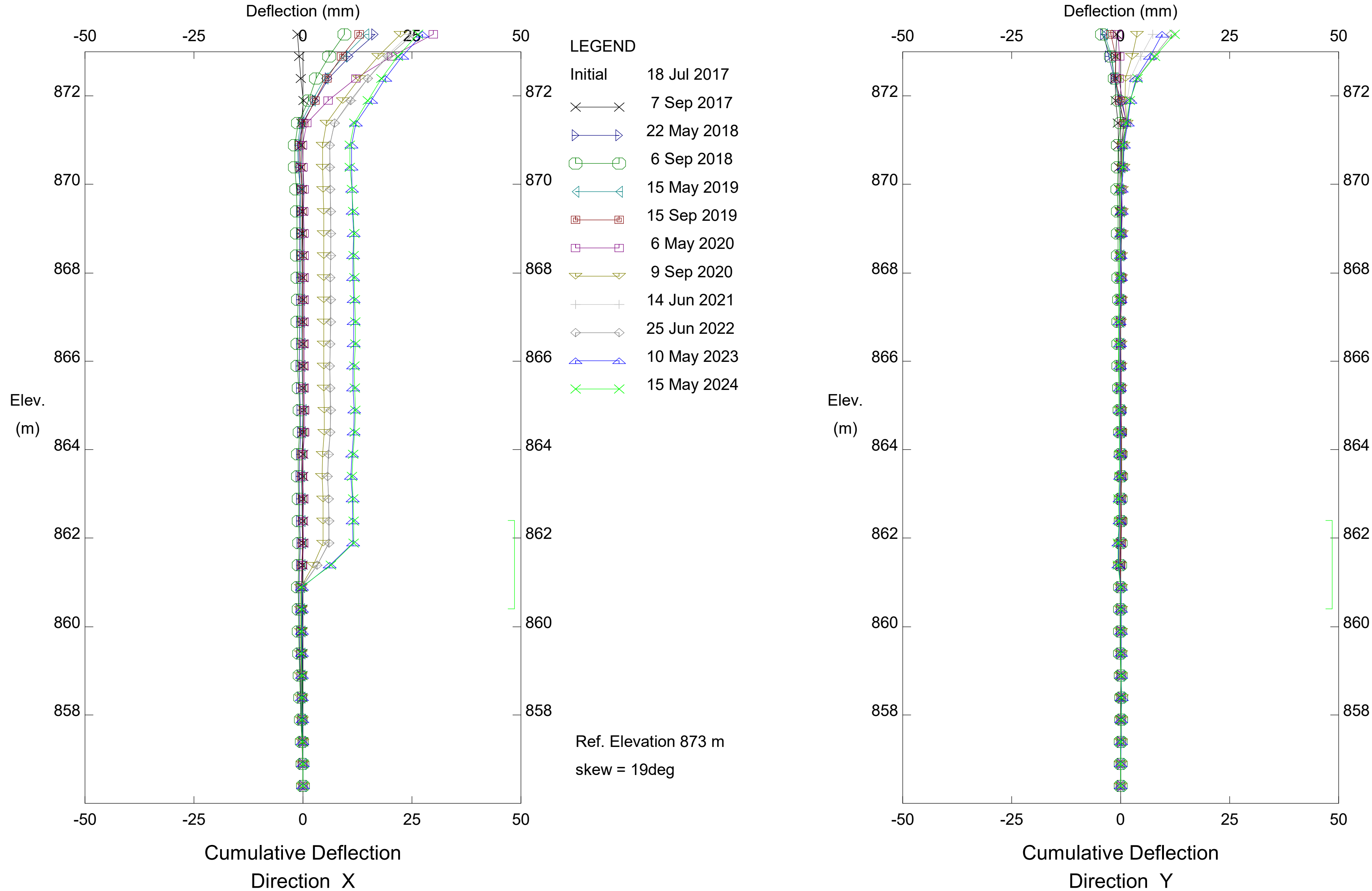
Alberta Transportation

Klohn Crippen Berger - Calgary



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Alberta Transportation

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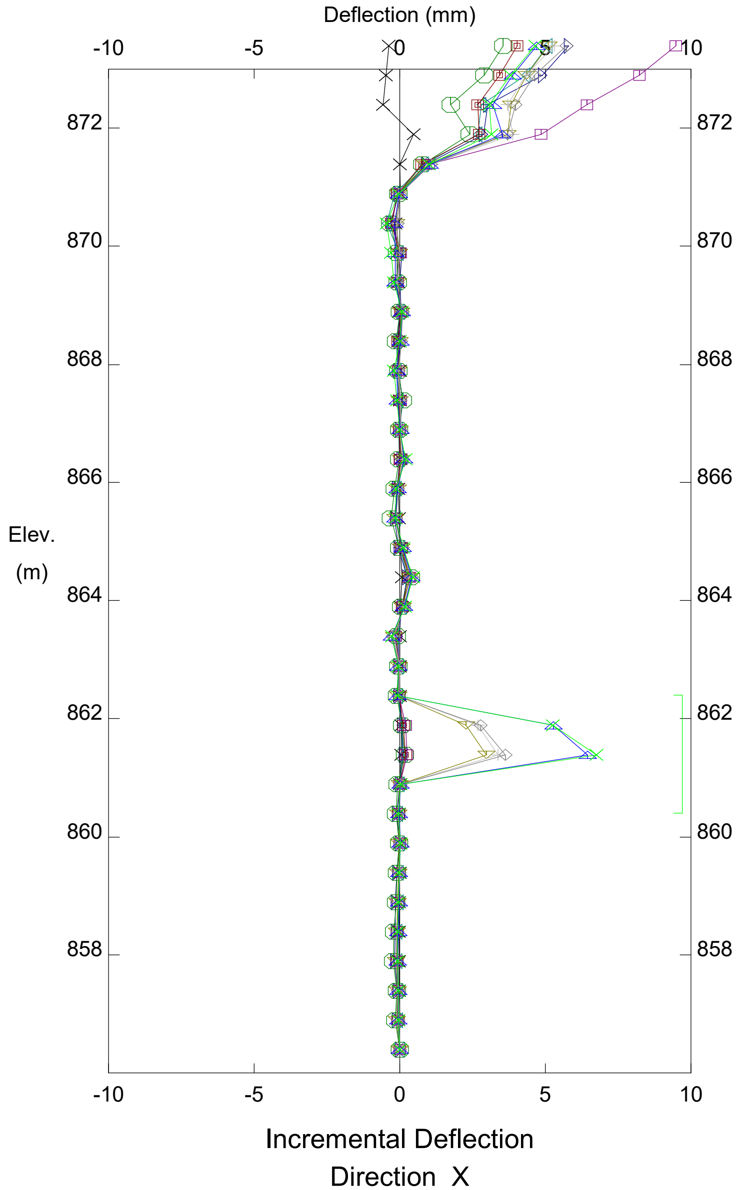
Klohn Crippen Berger - Calgary

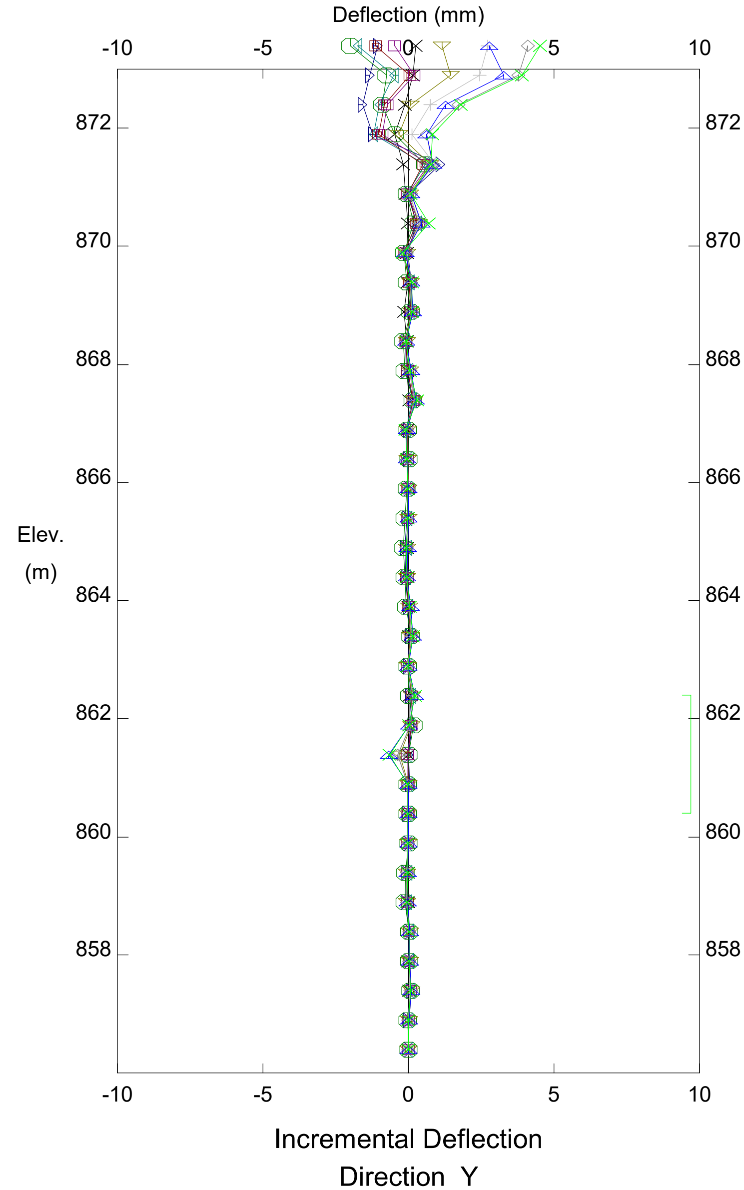


LEGEND

Initial	18 Jul 2017
	7 Sep 2017
	22 May 2018
	6 Sep 2018
	15 May 2019
	15 Sep 2019
	6 May 2020
	9 Sep 2020
	14 Jun 2021
	25 Jun 2022
	10 May 2023
	15 May 2024

Ref. Elevation 873 m

skew = 19deg



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Alberta Transportation

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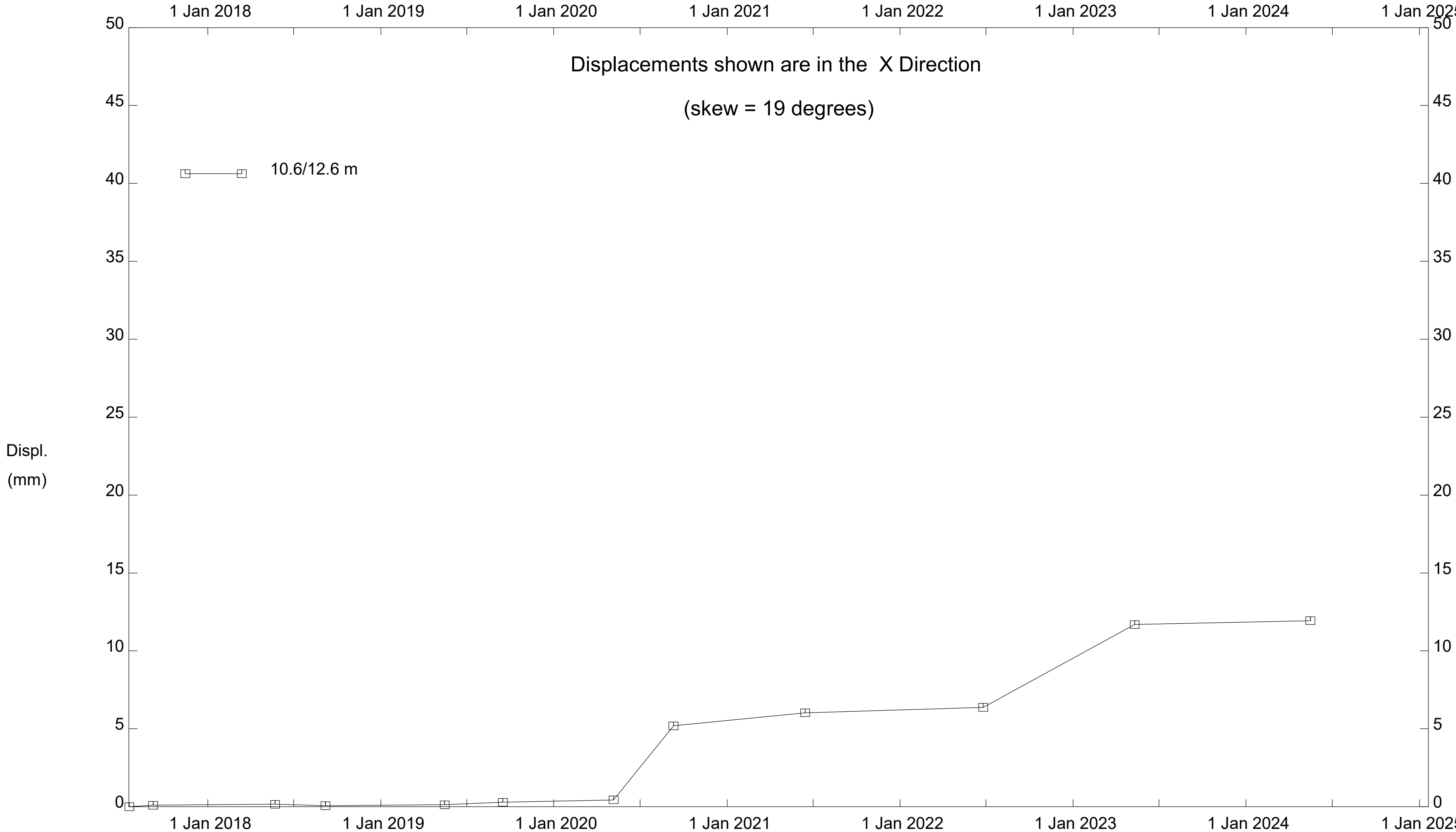
Klohn Crippen Berger - Edmonton



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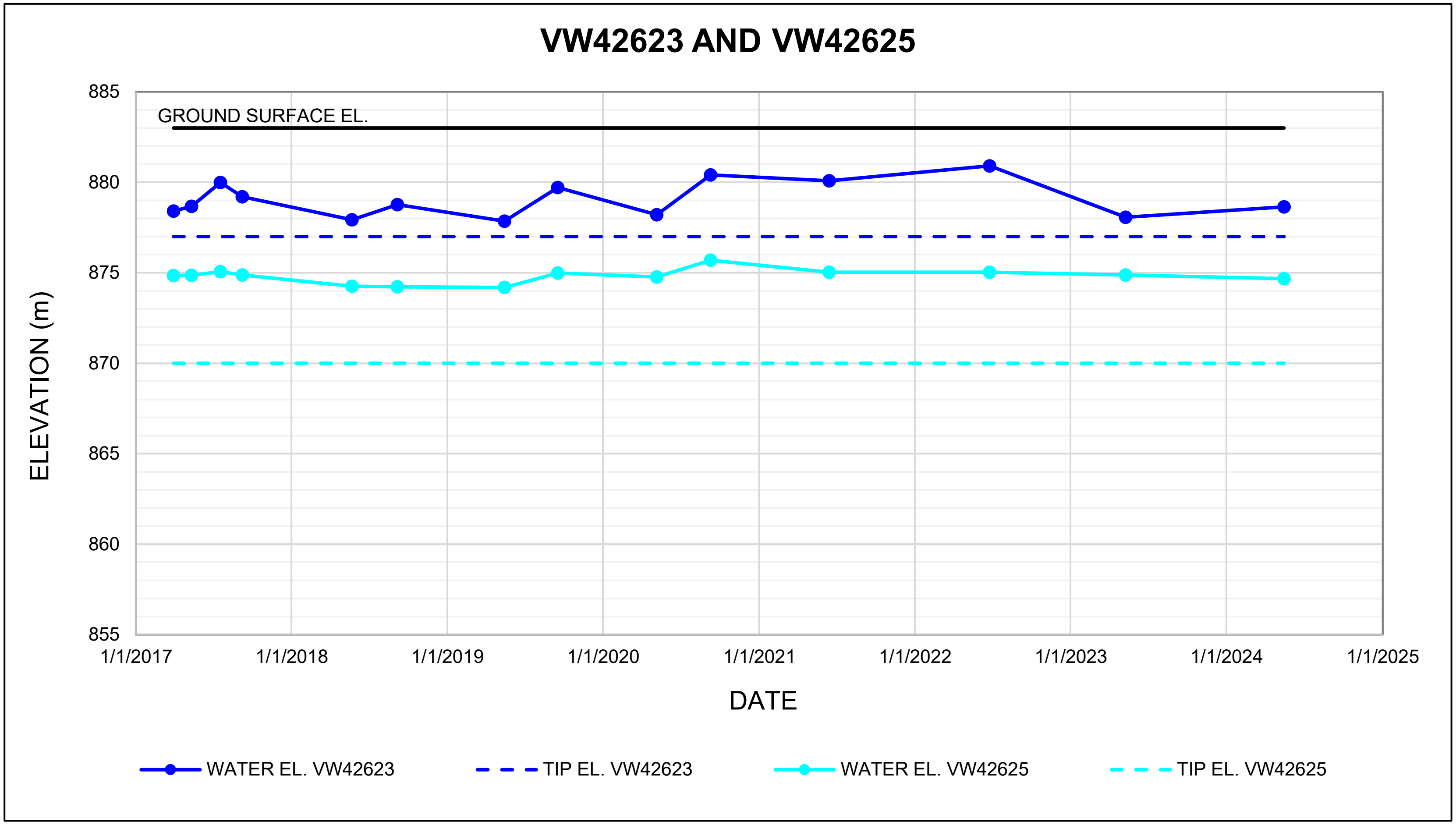
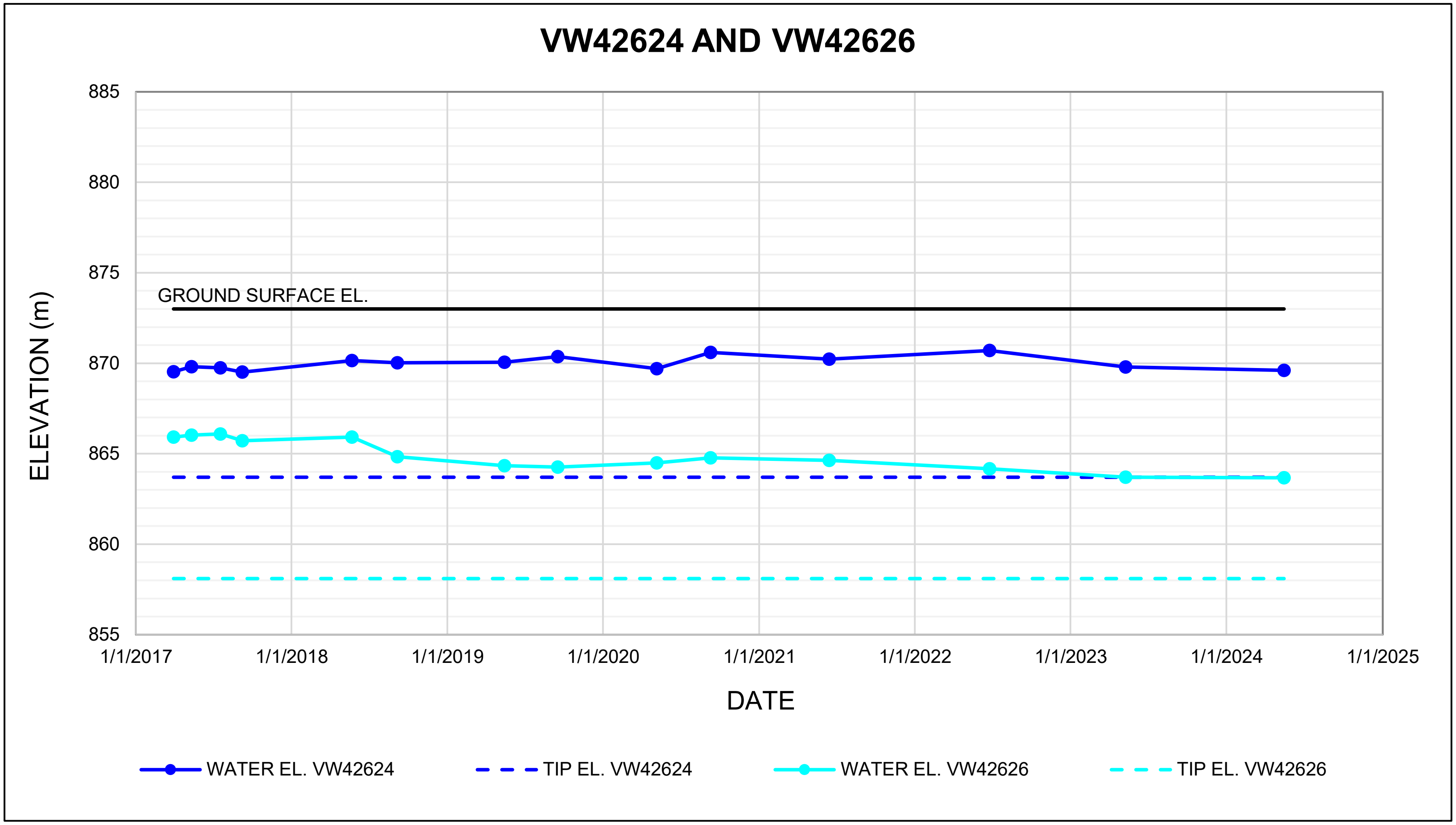
Alberta Transportation



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

CLIENT: Alberta	PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM
Klohn Crippen Berger	TITLE: Piezometer Data C060 - Slide East of Blackfalds Hwy 597:02, km 11.299
	SCALE: / PROJECT No. A05116A02 / FIG No. I-1



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

CLIENT: Alberta	PROJECT: CENTRAL REGION GEOHAZARD RISK MANAGEMENT PROGRAM
Klohn Crippen Berger	TITLE: Piezometer Data C060 - Slide East of Blackfalds Hwy 597:02, km 11.299
SCALE	PROJECT No. A05116A02
FIG No.	I-2