December 2, 2024

Alberta Transportation and Economic Corridors
Main Floor, Provincial Building
9621 – 96th Avenue
Peace River, Alberta
T8S 1T4

Robert Senior
Construction Technologist

Dear Mr. Senior:

CON0022166 Peace Region (Grande Prairie District – South) GRMP Instrumentation Monitoring Site GP034; H40:38, km 21.016 Slide South of Kakwa River
Section C – 2024 Fall Readings

1 GENERAL

Two slope inclinometers (SIs) (SI17-2 and SI17-3) and four pneumatic piezometers (PNs) (PN17-2A/B, and PN17-6A/B) were read at the GP034 site in the Peace Region (Grande Prairie District – South) (GP South Region) on October 18, 2024, by Courtney Mulhall, P.Eng. and Min Hou, E.I.T. of Klohn Crippen Berger Ltd. (KCB). These instruments were read as part of the GP South Region Geohazard Risk Management Program (GRMP). The site is located on Hwy 40:38, km 21.016. The approximate site coordinates are 6028755 N, 399896 E (UTM Zone 11, NAD 83). A site plan is presented on Figure 1.

The geohazard at the GP034 site consists of a landslide in a 25-m-high sidehill highway embankment fill, approximately 500 m upslope (east) from the Kakwa River.

Previous remedial actions completed at the GP034 site include the enlargement of an existing toe berm in late 2020, which is not shown on the available imagery shown on Figure 1. Foundation movements and cracking of the asphalt in response to toe berm construction resulted in work being halted. Significant asphalt cracking continued into the spring and fall of 2021.

In 2017, a geotechnical site investigation, which included installing instruments, was conducted at the site by the previous consultant. The encountered stratigraphy was as follows: clay fill, overlying rafted clay shale, overlying clay till, and overlying bedrock consisting of siltstone and sandstone.

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1.1 Instrumentation

KCB has been reading the instruments at this site since the spring of 2021. Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown on Figure 1. Any instruments not included in Table 1.1 or shown on Figure 1 are assumed to be inoperable and are not presented or discussed herein. It is noted that the ground surface elevations provided for the instruments were measured prior to construction and need to be re-surveyed

In 2017, 4 SIs and 12 piezometers were installed at the site by the previous consultant to monitor movement and groundwater conditions, respectively. Some of these instruments are now inoperable (e.g., destroyed, sheared, or lost), as detailed in Table 1.1 (see table notes), with recommendations for replacement made in Section 0.

The instruments are protected by above-ground casing protectors.

The operable SIs were read using the same metric RST Digital MEMS Inclinometer System that has been used to read the SIs since KCB took over the readings in June 2021. The operable PNs were read using an RST C109 pneumatic piezometer readout.

Table 1.1 Instrumentation Installation Details[1]

Instrument ID	Instrument Type	Date Installed	UTM Coordinates (m)		Ground Surface Elevation[2] (m)	Stick Up (m)	Depth (mbgs[3])	Condition
			Northing	Easting				
SI17-2	SI	Feb. 08, 2017	6028705	399849	865.9	0.9	16.8	Operable
SI17-3	SI	Feb. 07, 2017	6028714	399799	854.6	0.7	18.0	Operable
~~SI17-5~~	~~SI~~	~~Feb. 06, 2017~~	~~6028627~~	~~399835~~	~~870.3~~	~~0.7~~	~~15.5~~	~~Inoperable[4]~~
~~SI17-6~~	~~SI~~	~~Feb. 09, 2017~~	~~6028647~~	~~399786~~	~~857.3~~	~~0.8~~	~~17.5~~	~~Inoperable[4]~~
~~PN17-1A~~	~~PN~~	~~Feb. 07, 2017~~	~~6028699~~	~~399878~~	~~865.4~~	~~N/A~~	~~4.6~~	~~Inoperable[6]~~
~~PN17-1B~~	~~PN~~	~~Feb. 07, 2017~~	~~6028699~~	~~399878~~	~~865.4~~	~~N/A~~	~~8.0~~	~~Inoperable[6]~~
PN17-2A	PN	Feb. 08, 2017	6028705	399849	865.9	N/A	7.9	Operable
PN17-2B	PN	Feb. 08, 2017	6028705	399849	865.9	N/A	10.0	Operable
~~PN17-3A~~	~~PN~~	~~Feb. 07, 2017~~	~~6028714~~	~~399799~~	~~851.6~~	~~N/A~~	~~4.1~~	~~Inoperable[7]~~
~~PN17-3B~~	~~PN~~	~~Feb. 07, 2017~~	~~6028714~~	~~399799~~	~~851.6~~	~~N/A~~	~~10.2~~	~~Inoperable[7]~~
~~PN17-4A~~	~~PN~~	~~Feb. 08, 2017~~	~~6028620~~	~~399864~~	~~870.3~~	~~N/A~~	~~5.0~~	~~Inoperable[6]~~
~~PN17-4B~~	~~PN~~	~~Feb. 08, 2017~~	~~6028620~~	~~399864~~	~~870.3~~	~~N/A~~	~~9.0~~	~~Inoperable[6]~~
~~PN17-5A~~	~~PN~~	~~Feb. 06, 2017~~	~~6028627~~	~~399835~~	~~870.1~~	~~N/A~~	~~12.0~~	~~Inoperable[7]~~
~~PN17-5B~~	~~PN~~	~~Feb. 06, 2017~~	~~6028627~~	~~399835~~	~~870.1~~	~~N/A~~	~~14.9~~	~~Inoperable[7]~~
PN17-6A	PN	Feb. 09, 2017	6028647	399786	857.3	N/A	6.0	Operable
PN17-6B	PN	Feb. 09, 2017	6028647	399786	857.3	N/A	12.0	Operable[8]

Notes:

[1] Instrument installation details taken from reports and data files prepared or provided by the previous consultant(s) or TEC. Instrument coordinates and stick ups (where applicable) were confirmed by KCB with a handheld GPS (accuracy of ± 5 m) and tape measure, respectively.

[2] Ground surface elevations were measured prior to construction and need to be re-surveyed.

[3] Meters below ground surface (mbgs). Bottom reading depth for operable SIs and tip depth for piezometers. Either bottom reading or casing depth for inoperable SIs.

[4] SI17-5 and SI17-6 have sheared at an approximate depth of 7.3 m and 6.7 m below ground surface, respectively.

[6] PN17-1A/B and PN17-4A/B were destroyed in 2020 during construction.

[7] PN-3A/B and PN-5A/B do not stabilize and are no longer being read.

[8] PN17-6B did not stabilize between the November 2020 and September 2022.

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) and the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). SI17-2 and SI17-3 have skew angles of 15° and 35°, respectively, measured clockwise from the direction of the A0-grooves.

For the operable PNs, the recorded porewater pressures 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 data 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 include data for readings taken with both the previous consultants' and KCB's SI reading equipment.

2.2 Zones of Movement

Discrete movement (i.e., movement occurring on a defined failure plane) is being recorded in:

- SI17-2 between an approximate depth of 9.3 m and 10.8 m below ground surface (approximately elevation 856.6 m to 855.1 m) at the bottom of a clay till foundation unit overlying bedrock (siltstone); and
- SI17-3 between an approximate depth of 13.0 m and 14.5 m below ground surface (approximately elevation 841.6 m to 840.1 m) in a clay foundation unit overlying bedrock (clay shale).

Shallow distributed movement is also being recorded in the upper 4.5 m of SI17-3 in the toe berm fill placed in late 2020.

2.3 Interpretation of Monitoring Results

Slope Inclinometers

The rate of foundation movement being recorded in SI17-2 and SI17-3 was relatively slow and steady (less than 5 mm/year) between February 2017 (installation/initialization) and October 2020 but increased up to approximately 212 mm/year and 867 mm/year, respectively, when toe berm construction began in late 2020. Since January 2021, the rate of foundation movement recorded in SI17-2 and SI17-3 has been decreasing and is currently less than 5 mm/year.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation[1] (m)	Depth of Movement (mbgs[2])	Direction of Movement, Skew Angle[3]	Movement (mm)		Rate of Movement (mm/year)		
	Initialized	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
SI17-2	Feb. 08, 2017	May 23, 2024	May 23, 2024	Oct. 18, 2024	865.9	8.3 – 10.8	X-Direction, 15°	49.8	0.7	211.6	1.9	-2.7
SI17-3	Feb. 08, 2017	May 23, 2024	May 23, 2024	Oct. 18, 2024	854.6	0.0 – 4.5	X-Direction, 35°	256.1	0.3	5,519.4	0.7	-2.8
		May 23, 2024				13.0 – 14.5	X-Direction, 35°	76.1	1.6	866.9	4.1	1.4

Notes:
[1] Ground surface elevations were measured prior to construction and should be surveyed.
[2] Meters below ground surface (mbgs).
[3] Skew angle of the X-direction measured clockwise from the A-direction. The azimuths of the A0-grooves in the SIs were measured by KCB with a magnetic compass in spring 2022.

Table 2.2 Pneumatic Piezometer Reading Summary

Instrument ID	Serial No.	Date			Ground Surface Elevation[1] (m)	Tip Depth (mbgs[2])	Water Level		
		Installed	Previous Reading	Most Recent Reading			Previous Reading (mbgs[2])	Most Recent Reading (mbgs[2])	Change from Previous Reading (m)
PN17-2A	37443	Feb. 08, 2017	May 23, 2024	Oct. 18, 2024	865.9	7.9	5.7	4.9	0.8
PN17-2B	37439	Feb. 08, 2017	May 23, 2024	Oct. 18, 2024	865.9	10.0	7.7	6.6	1.1
PN17-6A	37444	Feb. 09, 2017	May 23, 2024	Oct. 18, 2024	857.3	6.0	2.1	0.3	1.8
PN17-6B	37433	Feb. 09, 2017	May 23, 2024	Oct. 18, 2024	857.3	12.0	8.2	7.6	0.6

Notes:
[1] Ground surface elevations were measured prior to construction and should be surveyed.
[2] Meters below ground surface (mbgs).

The shallow fill movement being recorded in SI17-3, since toe berm construction in late 2020, is believed to be causing the cracks observed in the pavement surface and along the highway embankment and may be an extension upwards along the backscarp, associated with deeper movement. The rate of shallow movement recorded between late 2020 and September 2021 is difficult to assess due to the SI casing being extended in November 2020 and the SI reading equipment being changed in four times between November 2020 and June 2021. The maximum rate of movement recorded during toe berm construction was approximately 5,519 mm/year. Since September 2021, the rate of shallow fill movement recorded in SI17-3 has been decreasing and is currently less than 5 mm/year.

Increased movement, which could impact the highway, may occur in response to precipitation and freshet infiltration, resulting in higher groundwater conditions.

Piezometers

Before toe berm construction, relatively steady porewater pressures were recorded in PN17-2A/B (located below highway shoulder, outside toe berm footprint) and PN17-6A/B (located below toe berm crest, downslope of highway). Following toe berm construction in late 2020:

- **PN17-6A:** Porewater pressures recorded in this instrument increased approximately 4.7 m between October 2020 and June 2021 before decreasing approximately 4.0 m between June 2021 and June 2022. This increase and decrease are most likely due to construction-induced porewater pressure response followed by post-construction porewater pressure dissipation, respectively. Since June 2022, porewater pressures recorded in PN17-6A have been fluctuating (approximately 1.4 m to 2.9 m reading to reading, with the spring reading higher than the fall reading) likely in response to seasonal variations in freshet and precipitation infiltration.
- **PN17-6B:** This instrument did not stabilize between November 2020 and September 2022. Since September 2022, porewater pressures recorded in this instrument have been relatively steady and approximately 2 m higher than readings obtained before toe berm construction in late 2020.
- **PN17-2A/B:** Porewater pressures recorded in these instruments have been fluctuating from tip elevation (i.e., dry) to approximately 3.0 m and 3.4 m above tip elevation, respectively, likely due to seasonal variations in precipitation and freshet infiltration.
    - It is unclear if the increase recorded between October 2020 and June 2022 (approximately 1.8 m and 2.5 m, respectively) and the subsequent decrease recorded between June 2022 and June 2023 (approximately 1.8 m and 2.7 m, respectively) was influenced by toe berm construction (similar to PN17-6A, see above) since the instruments are installed outside the toe berm footprint, or just seasonal variations.

- It is unclear if the increase recorded since June 2023 (approximately 2.1 m and 3.2 m approximately, respectively) is being influenced by increased water infiltration into cracks that have formed in the pavement surface and along the highway embankment associated with the shallow movements recorded in SI17-3 (see above), which is located downslope of PN17-2A/B, or just seasonal variations.

Currently, the porewater pressures recorded in PN17-2A/2B/6A/6B are between approximately elevation 849.7 m and 861.0 m, which is just below to above the zone of movement recorded in SI17-3 between approximately elevation 850.1 m and 854.6 m. Increases in groundwater level could trigger increased movement, which could impact the highway.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read twice per year (spring and fall). Spring readings should be completed after late-May or early-June, due to the risk of water inside the instrument casings being frozen earlier in the year.

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

3.2 Instrument Installs, Repairs, and Maintenance

PN17-1A/B and PN-4A/B were destroyed in 2020 during construction, and PN-3A/B and PN-5A/B have also become inoperable (i.e., readings do not stabilize). Replacement of these instruments should be considered if repair work were to be resumed.

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 Peace Region (Grande Prairie District – South) Geohazard Risk Management Program (Contract No. CON0022166), 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.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

PROFESSIONAL ENGINEER ALBERTA
COURTNEY E. MULHALL
2024 Dec. 03
ID#153449

PERMIT TO PRACTICE
KLOHN CRIPPEN BERGER LTD.
RM SIGNATURE:
RM APEGA ID #: 187607
DATE: 3 Dec. 2024
PERMIT NUMBER: P009196
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

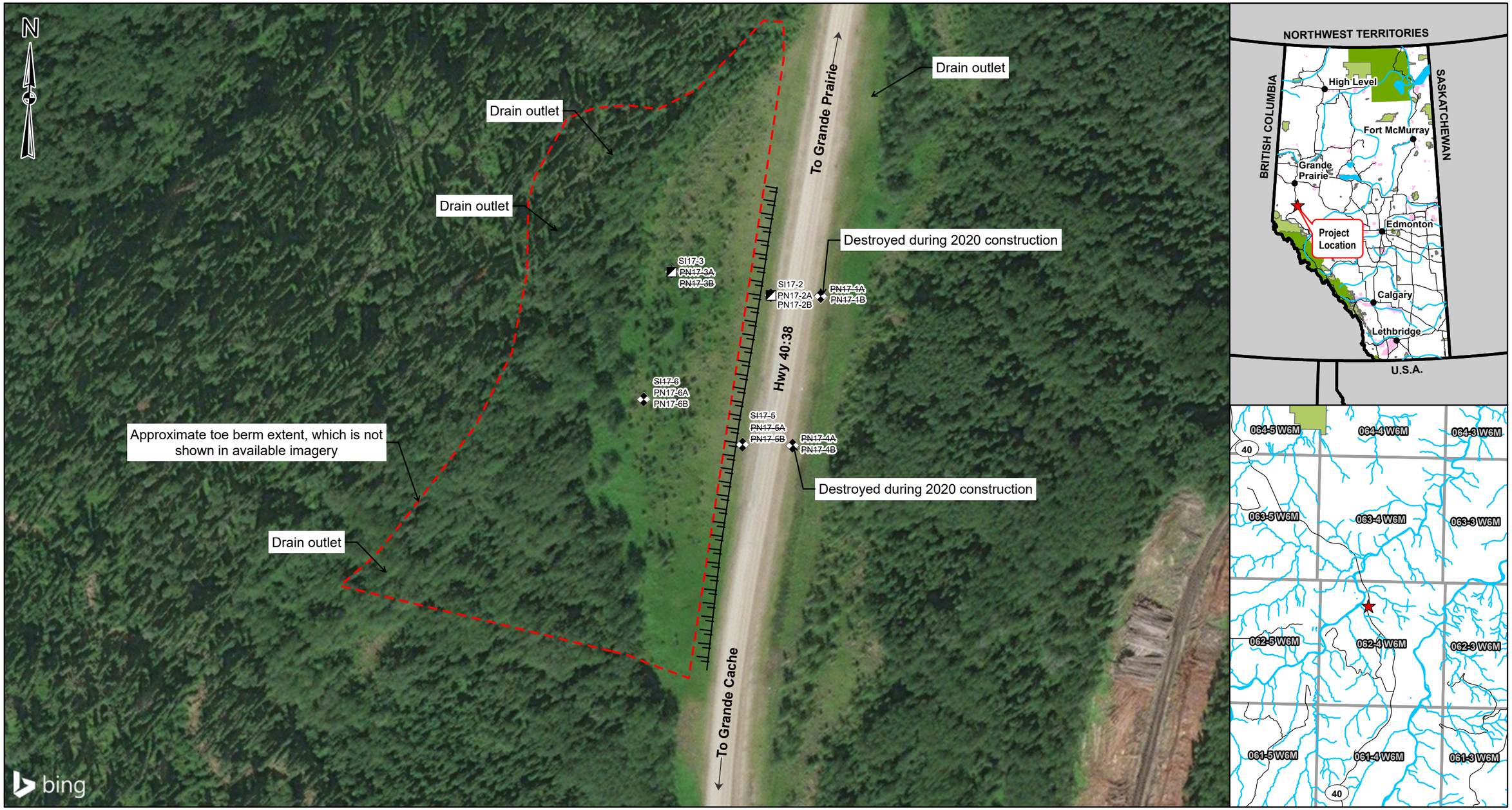
Courtney Mulhall, M.Sc., P.Eng.
Geotechnical Engineer

CM/EV:bb

Cc: Chris Grapel, M.Eng., P.Eng.

ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE



Legend

- Approximate Pneumatic Piezometer (PN) Location
- Approximate Slope Inclinometer (SI) Location
- Crest
- Approximate Extent of Toe Berm

0 100 Metres

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 11N
3. IMAGE SOURCE: 2022 MICROSOFT CORPORATION, 2022 MAXAR, CNES
4. INSTRUMENT LABELS THAT ARE INDICATED WITH STRIKE THROUGH TEXT ARE INOPERABLE.

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: PEACE REGION (GRANDE PRAIRIE DISTRICT-SOUTH) GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
GP034 - Slide South of Kakwa River
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
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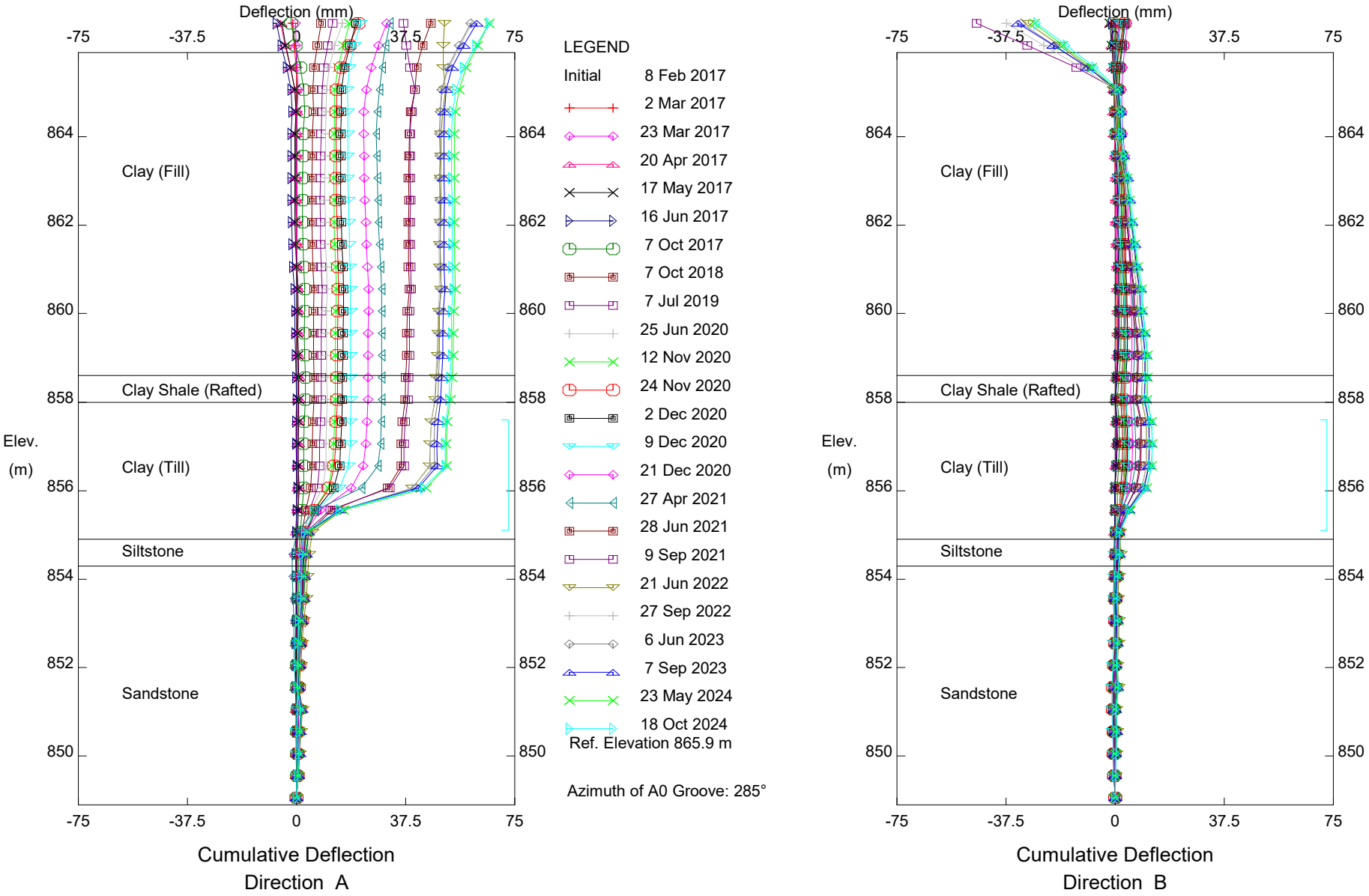
APPENDIX I

Instrumentation Plots

Klohn Crippen Berger - Edmonton



GP034; H40:38, Inclinometer SI17-2

Alberta Transportation

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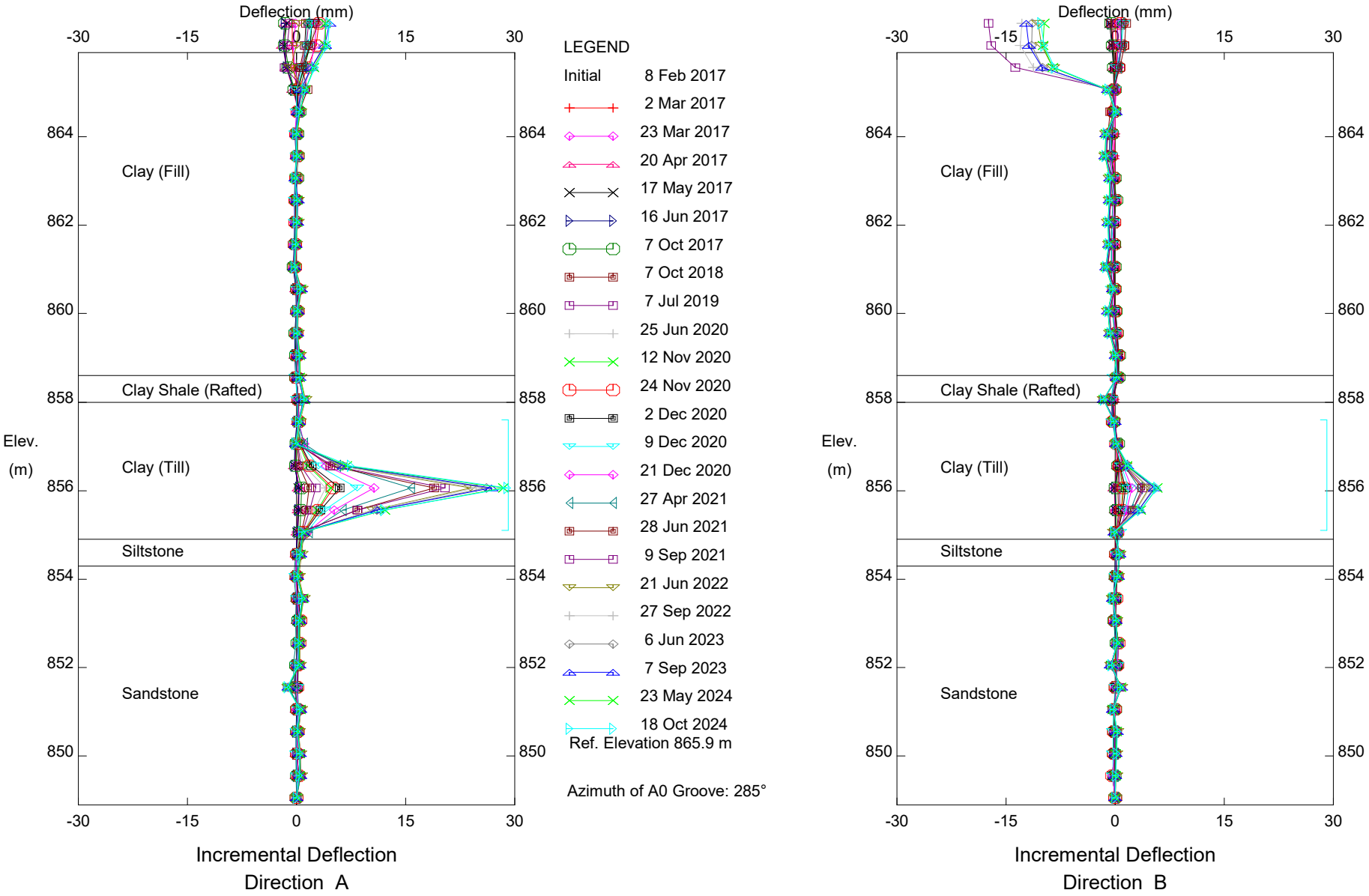

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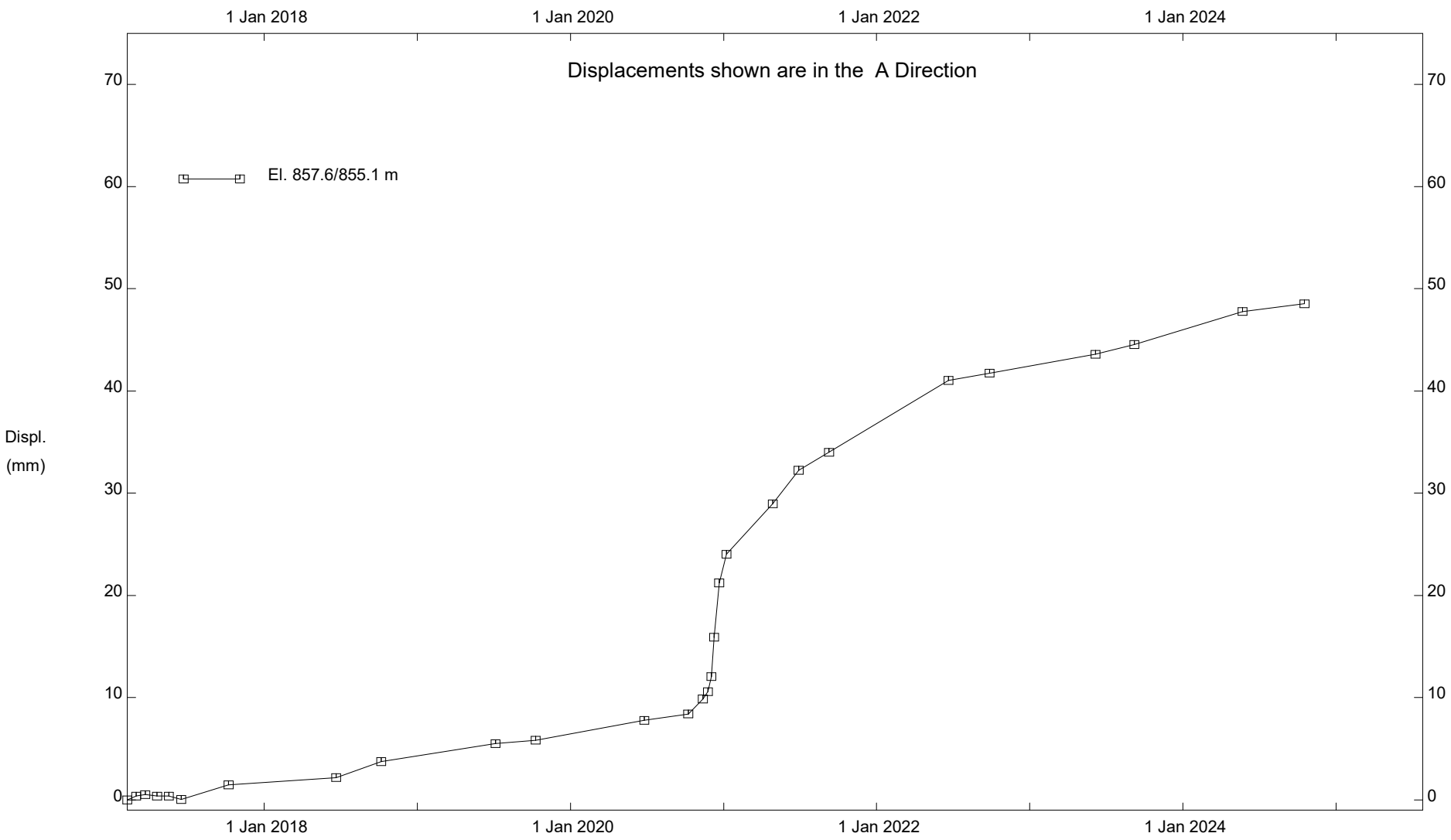
Alberta Transportation

Klohn Crippen Berger - Edmonton



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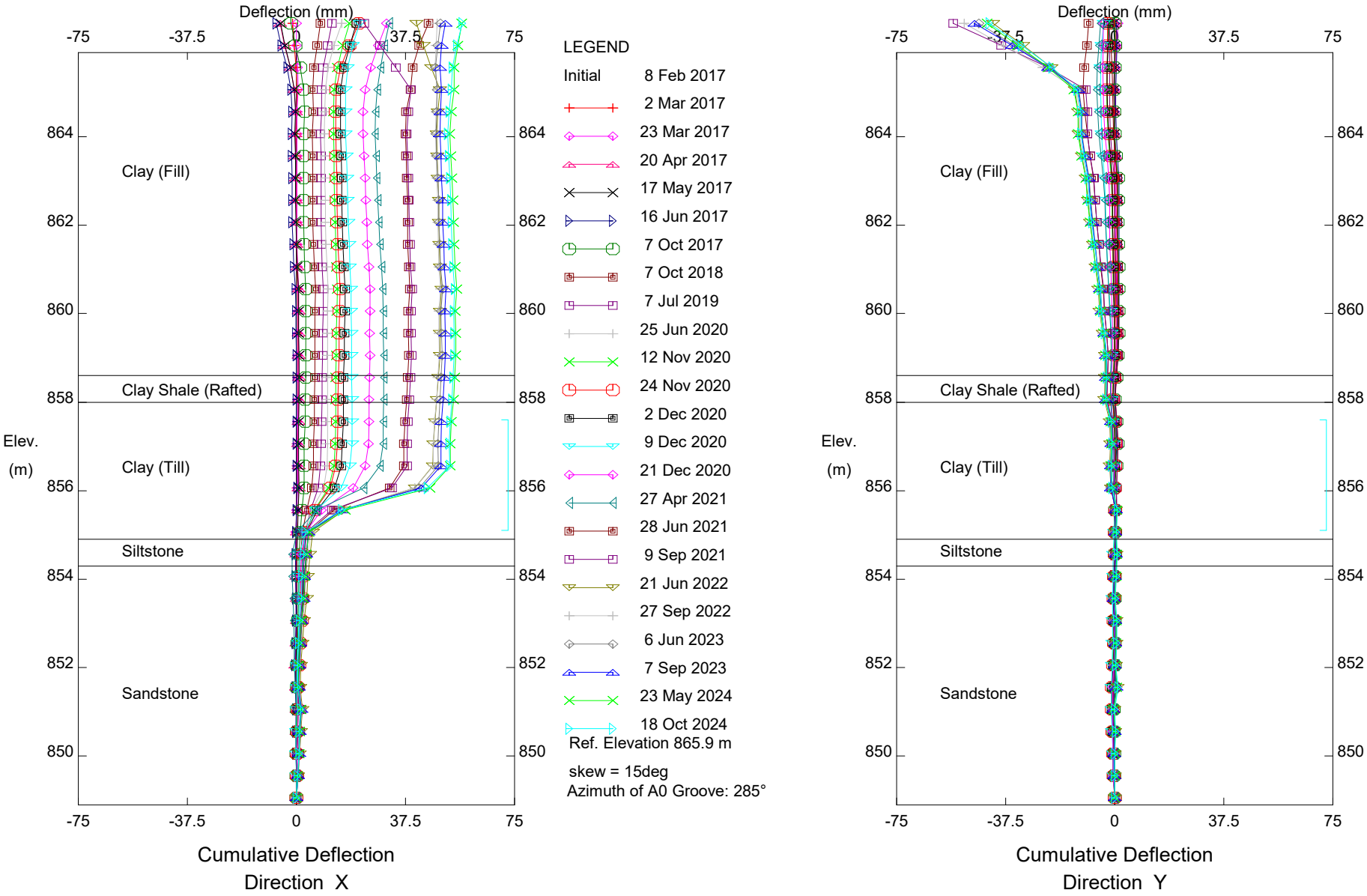

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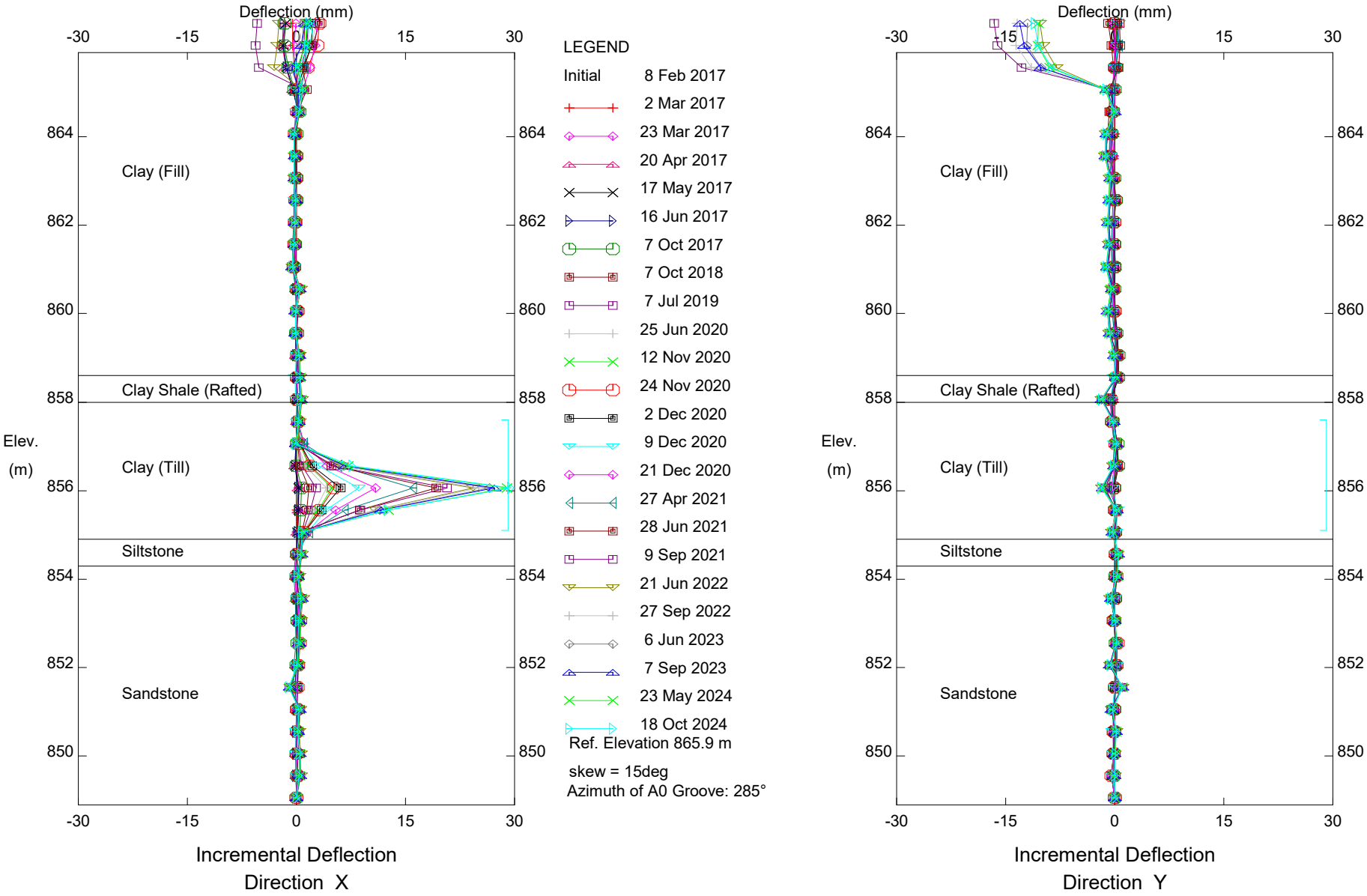
Alberta Transportation

Klohn Crippen Berger - Edmonton



GP034; H40:38, Inclinometer SI17-2

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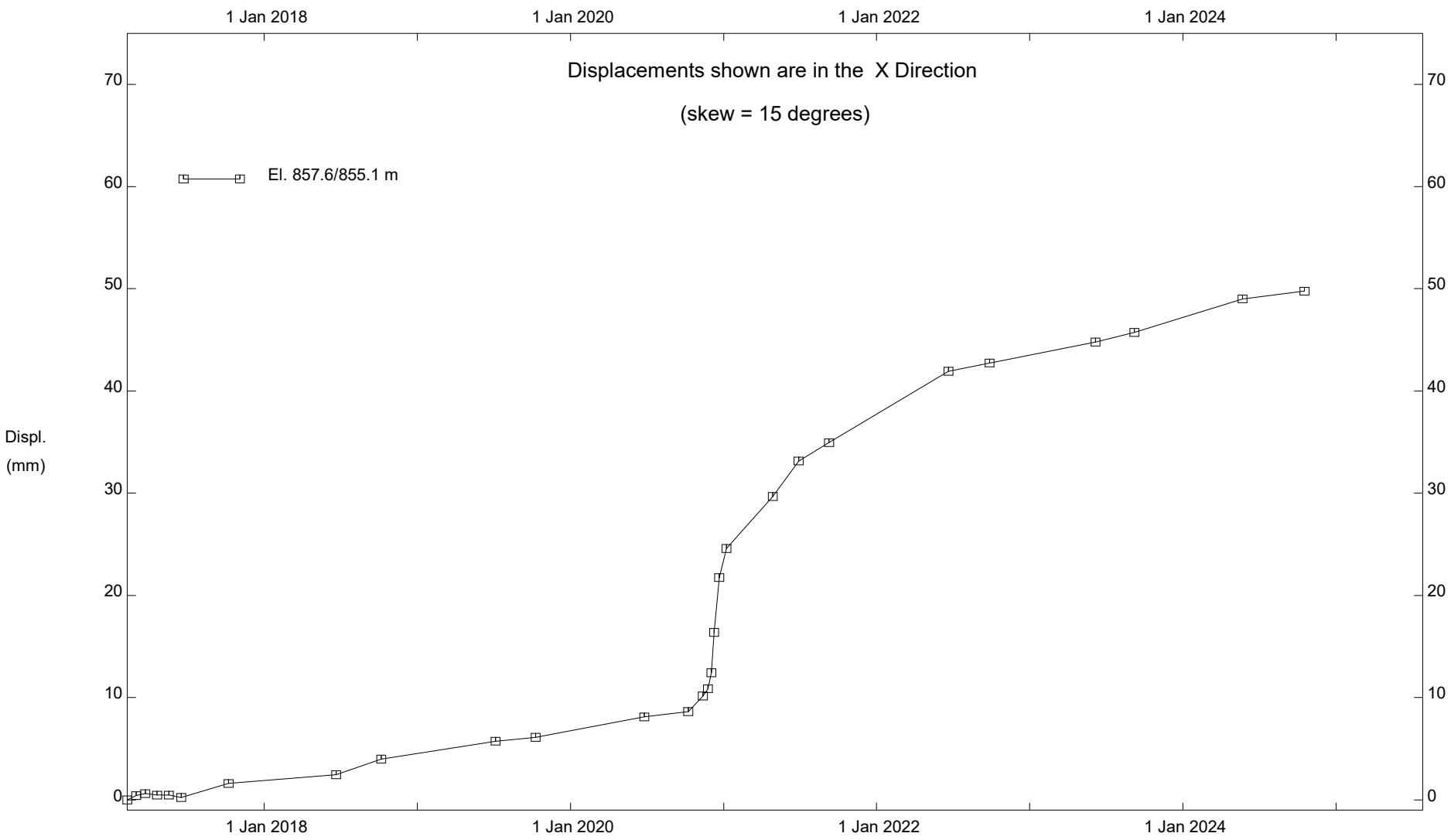

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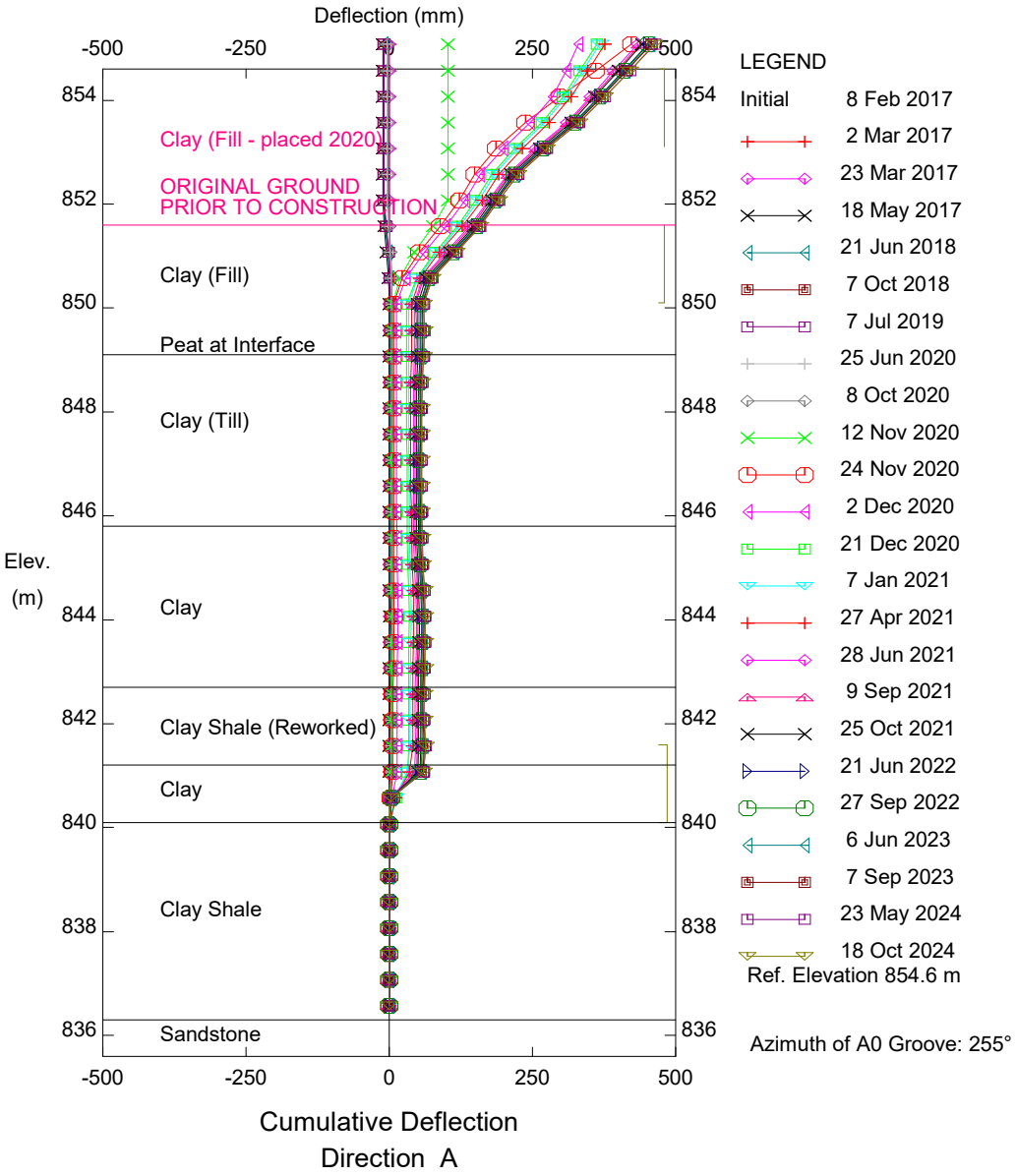
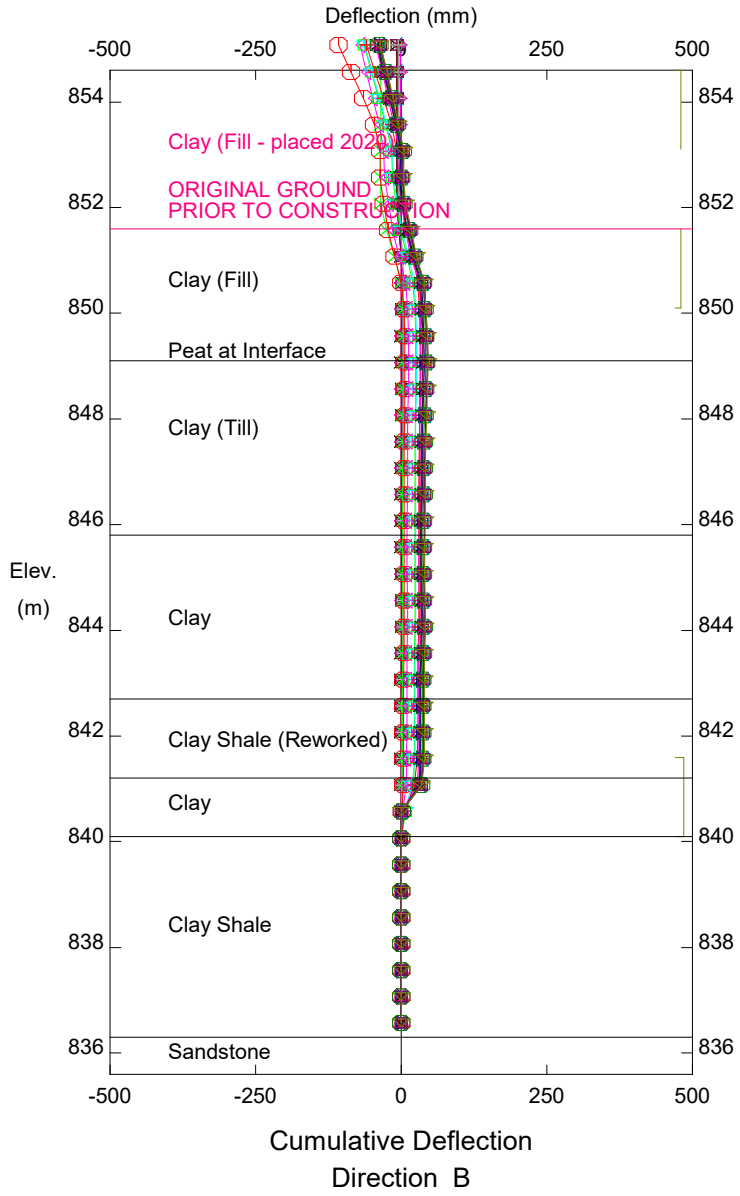
Klohn Crippen Berger - Edmonton





GP034; H40:38, Inclinometer SI17-3

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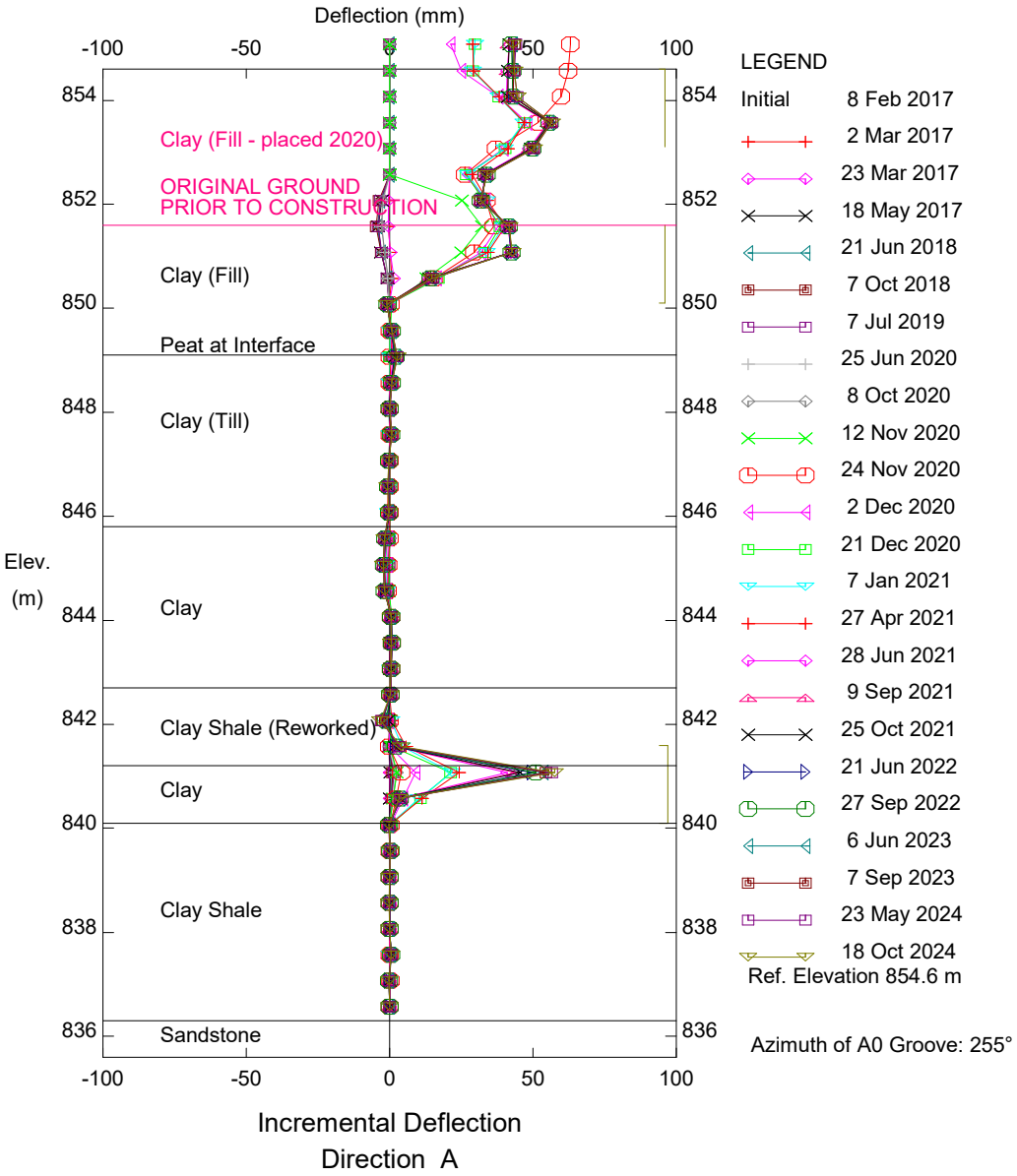

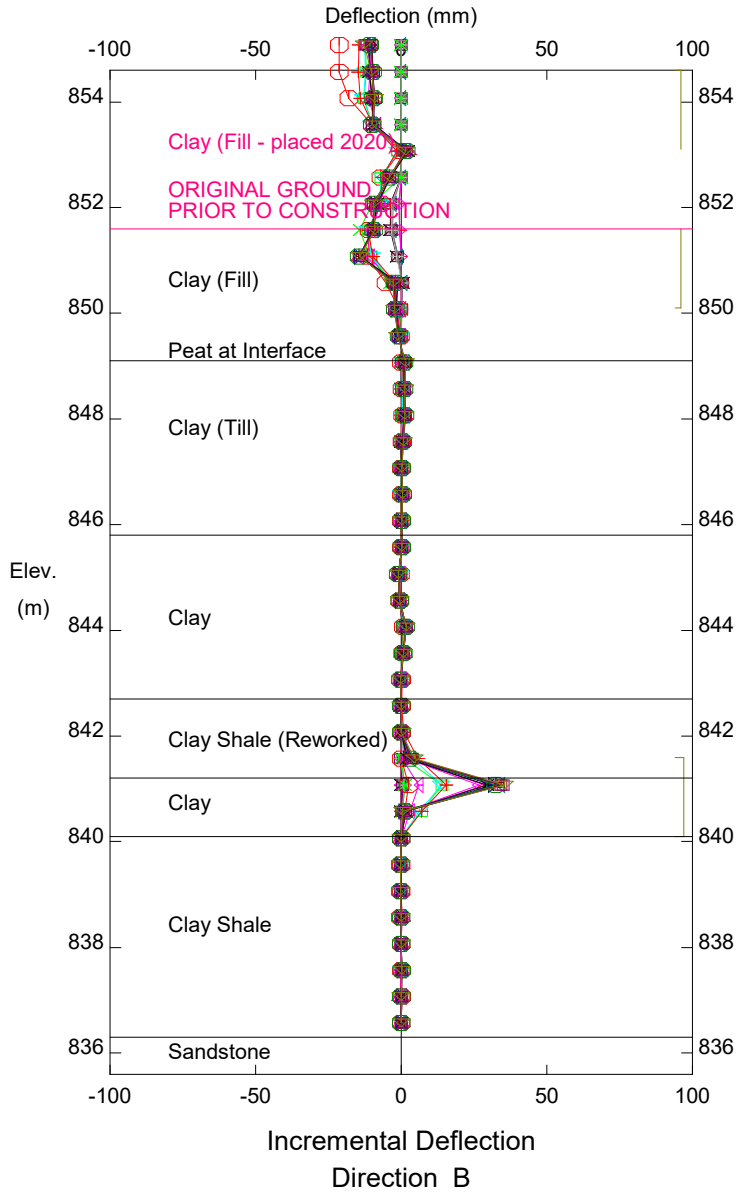

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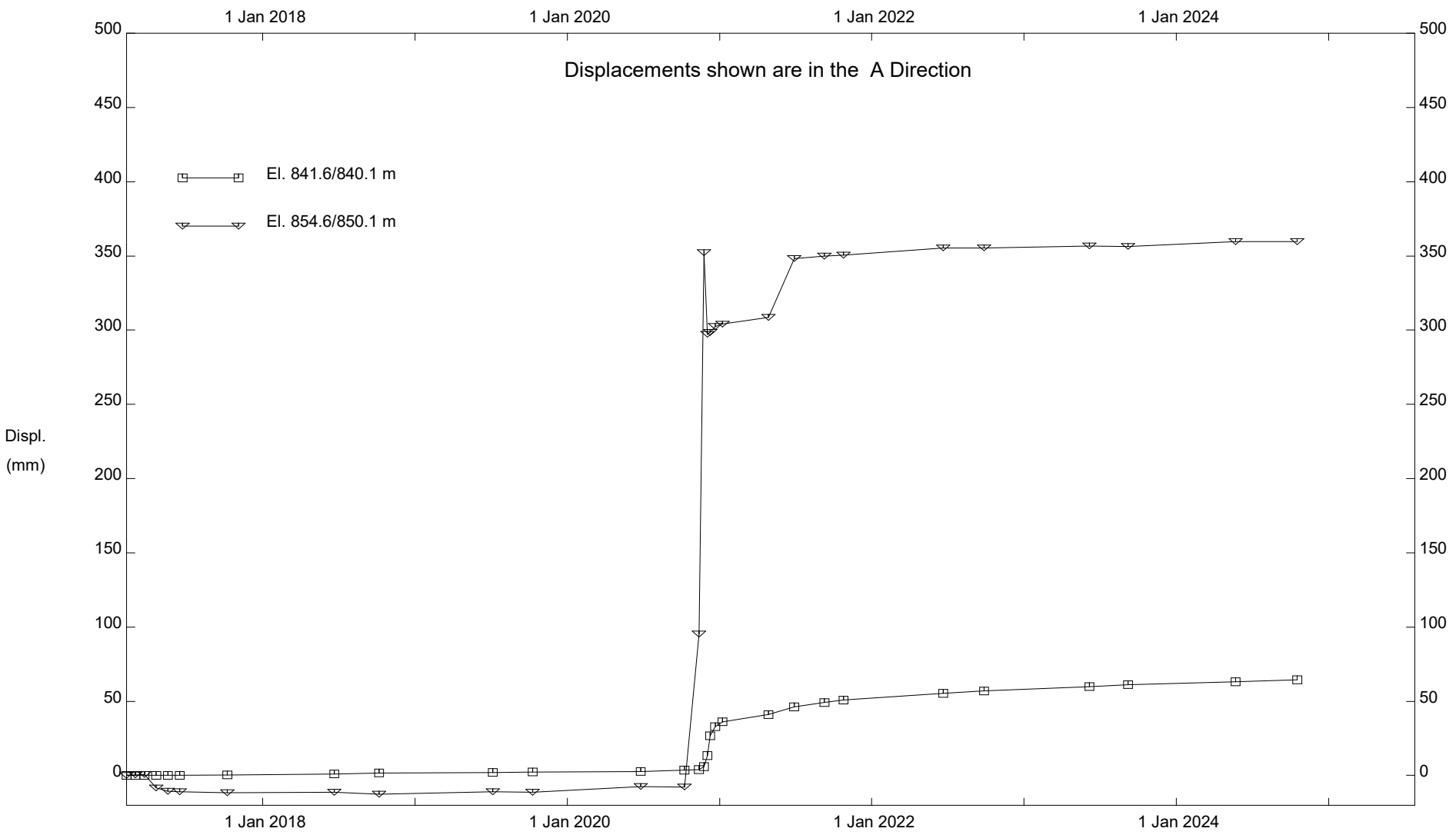

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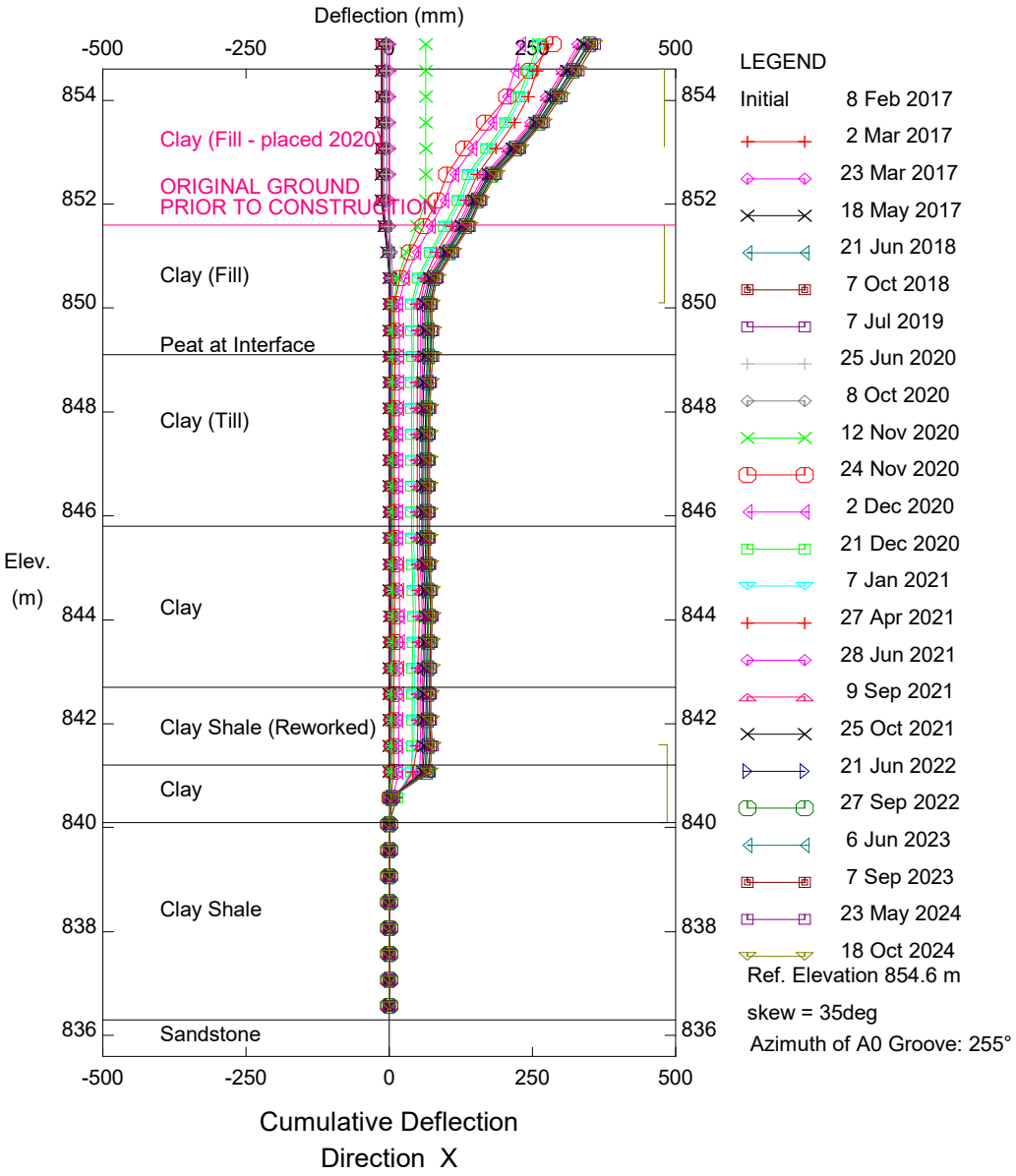
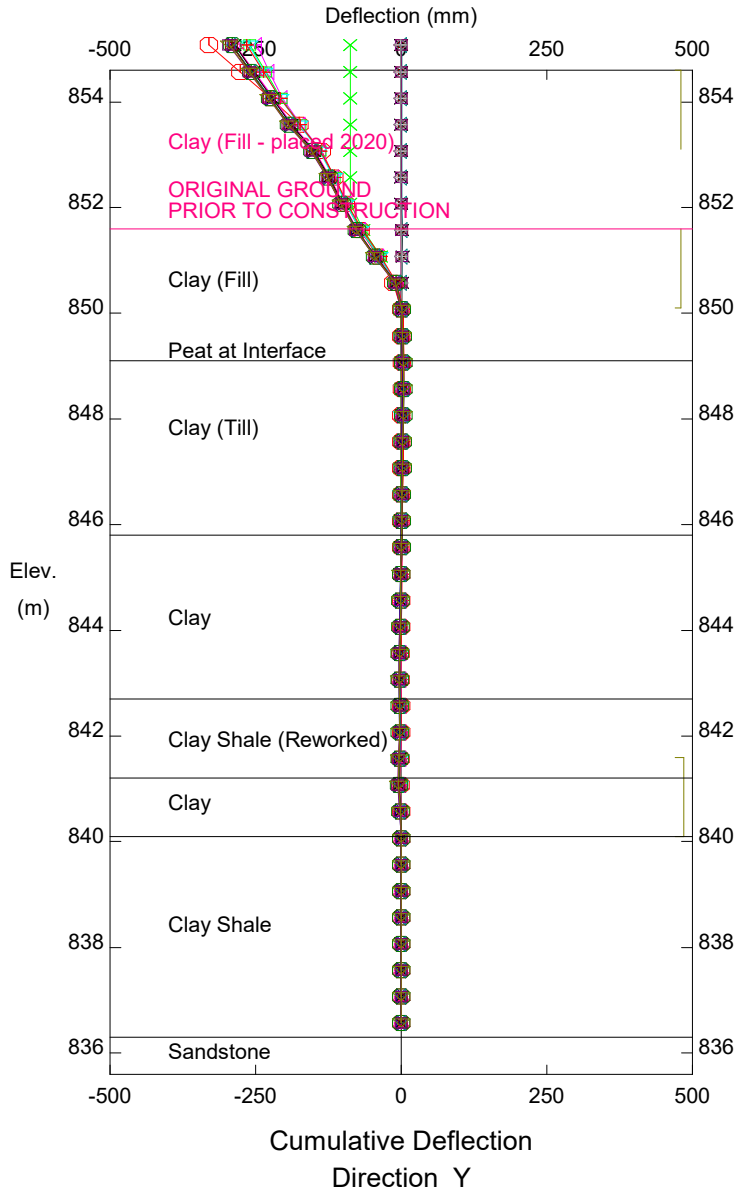
Klohn Crippen Berger - Edmonton





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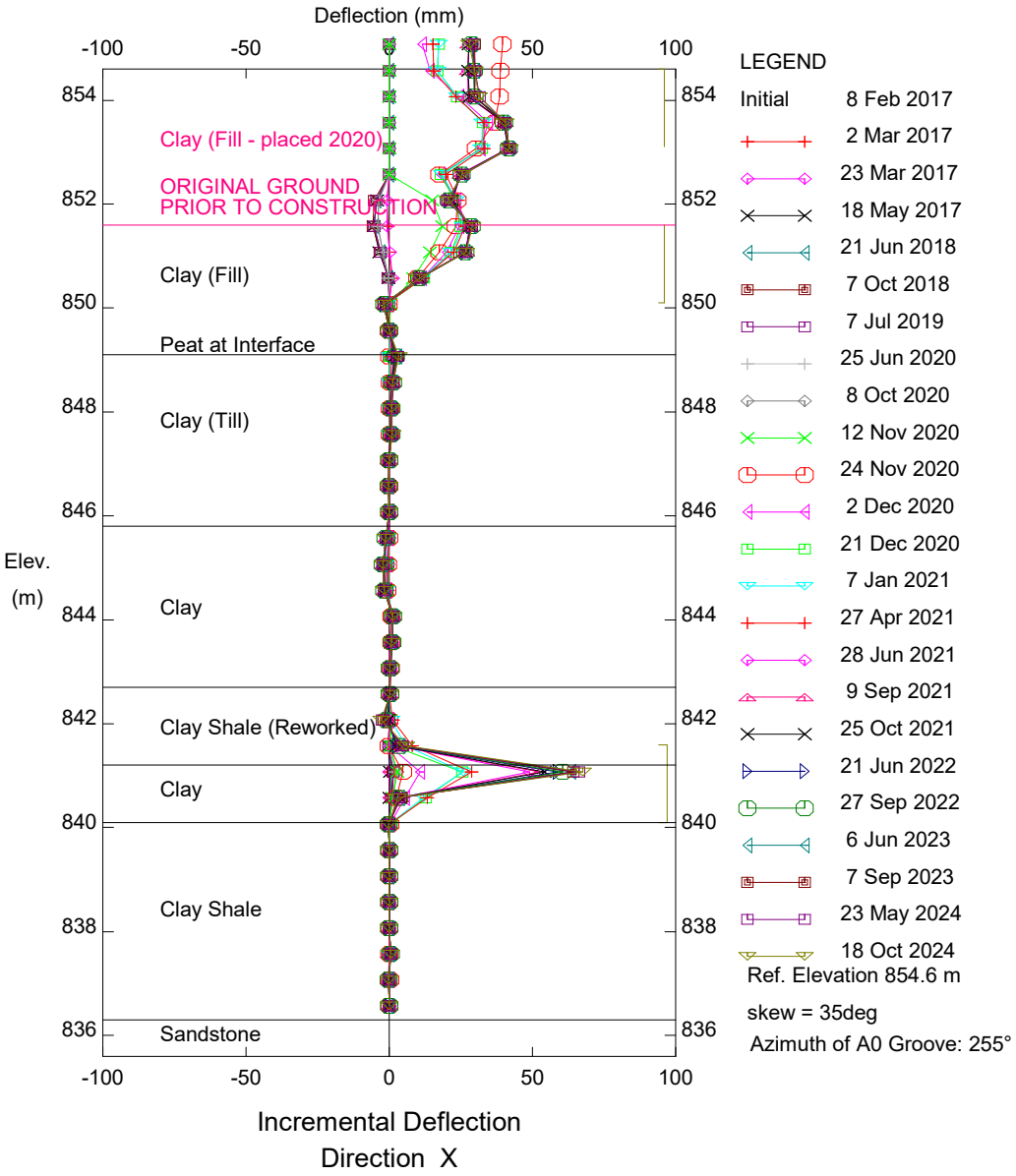

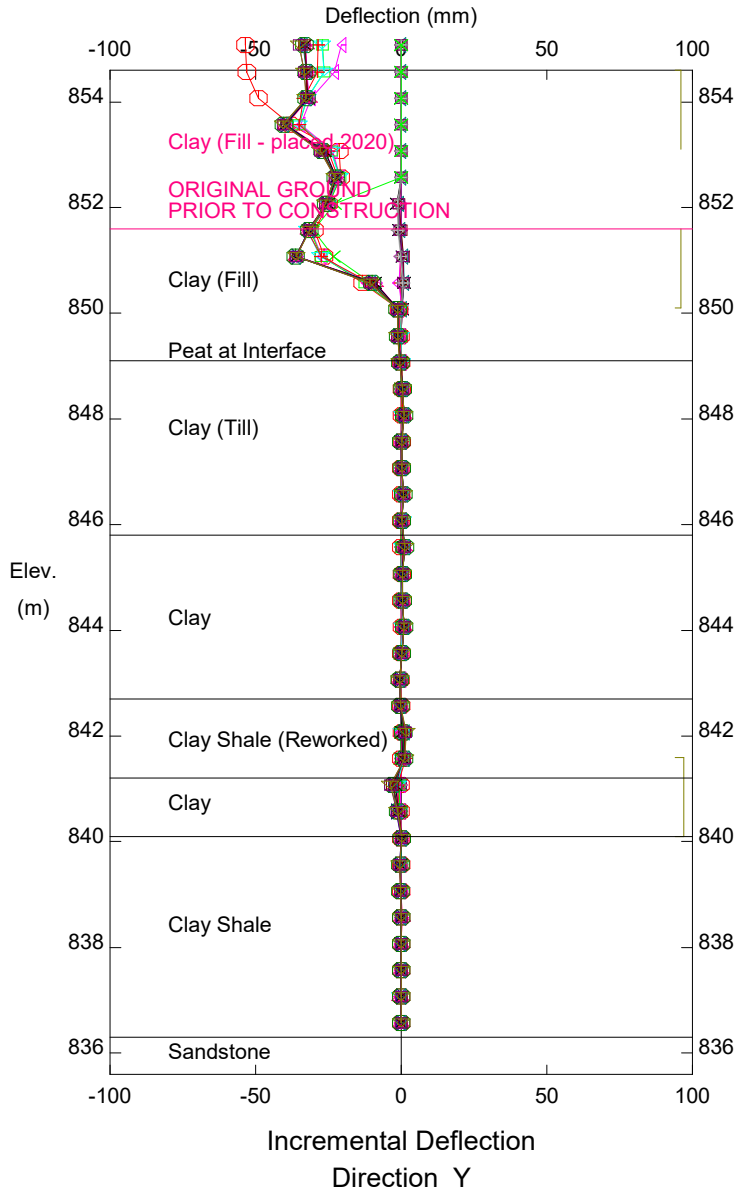

GP034; H40:38, Inclinometer SI17-3

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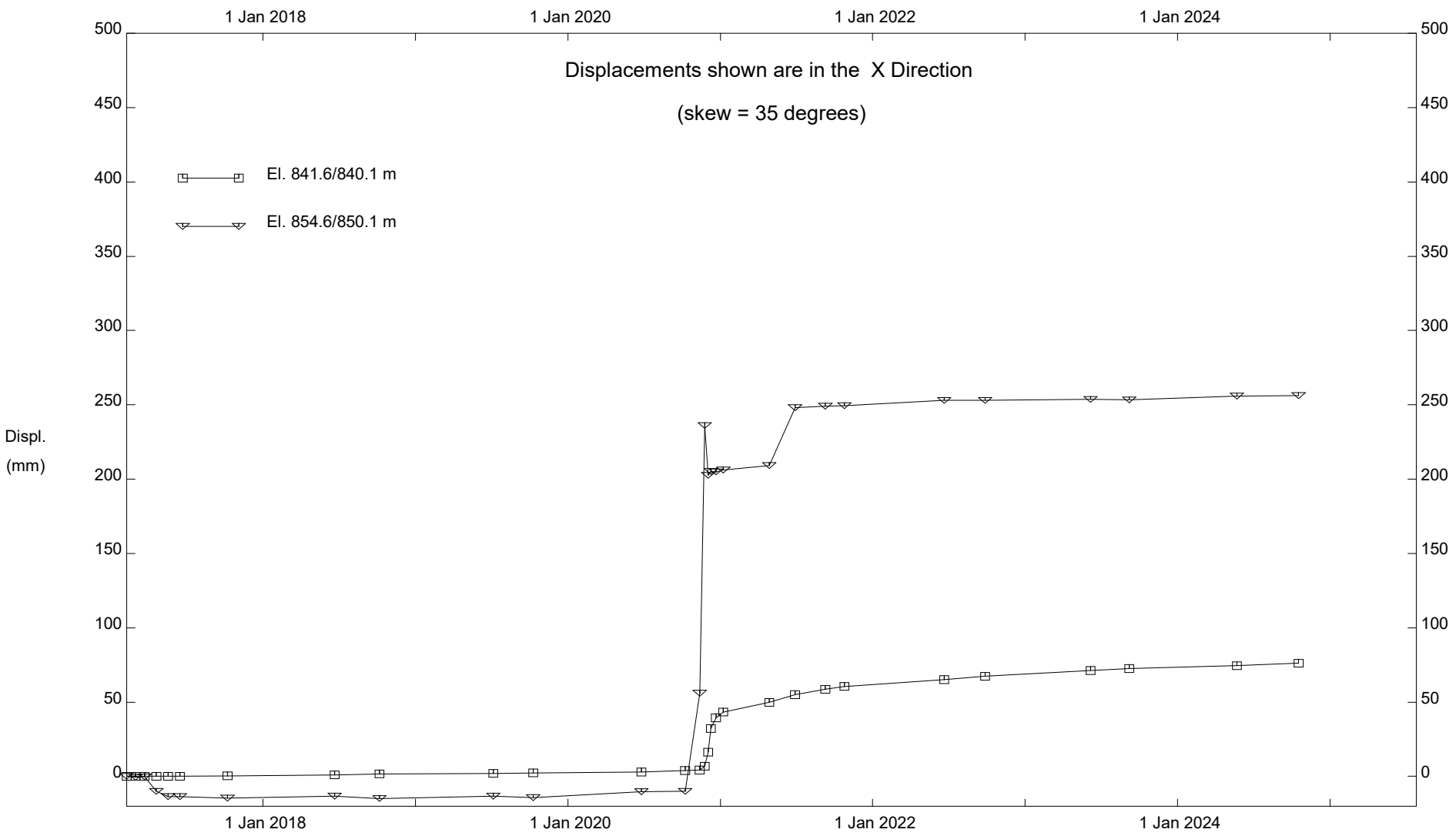

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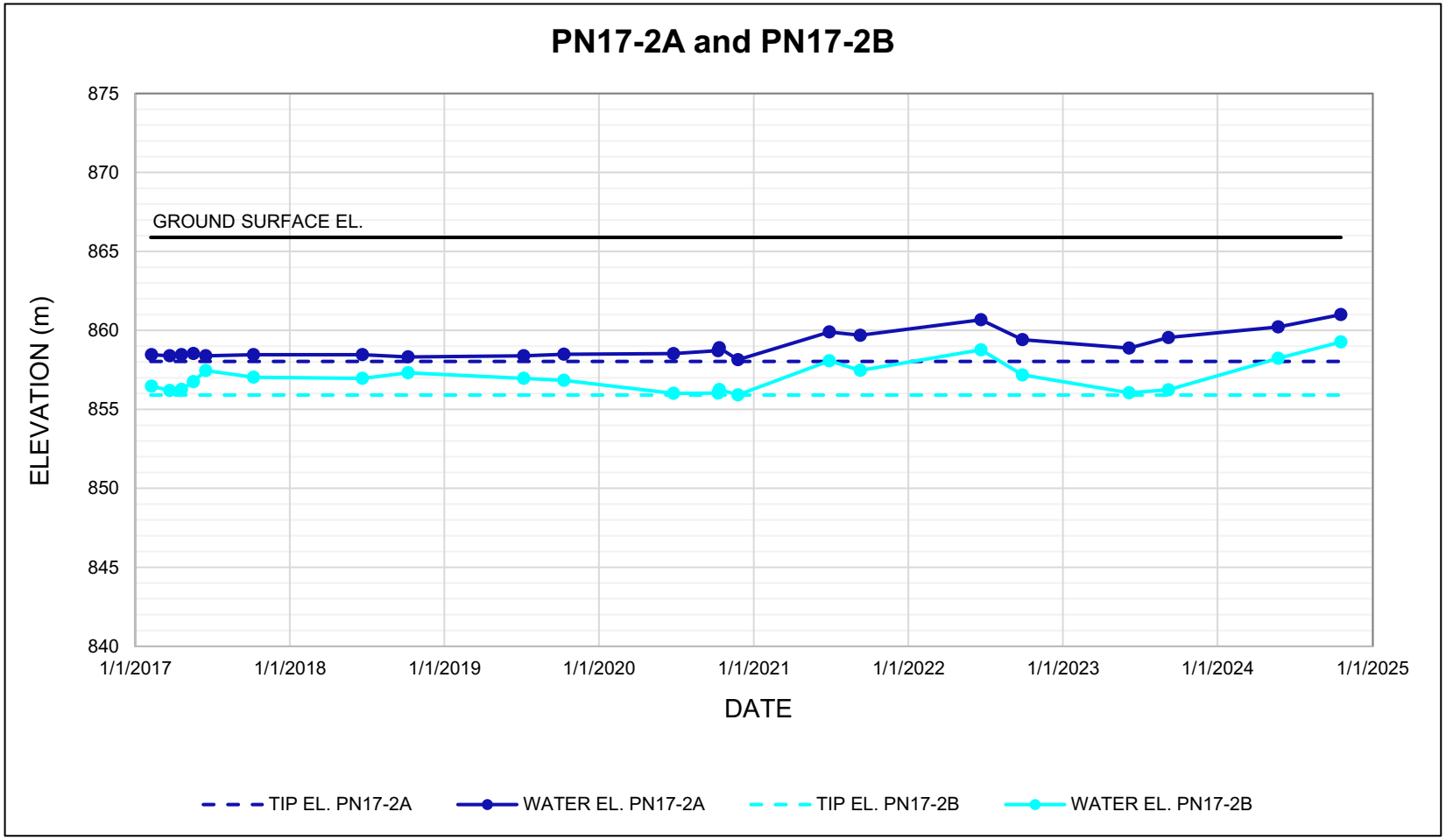

NOTES:
1. PIEZOMETER DATA OBTAINED BEFORE JUNE 28, 2021, PROVIDED TO KLOHN CRIPPEN BERGER LTD. BY ALBERTA TRANSPORTATION AND ECONOMIC CORRIDORS ON JUNE 25, 2021.
2. GROUND SURFACE ELEVATION MEASURED PRIOR TO CONSTRUCTION AND NEEDS TO BE UPDATED.

CLIENT
Alberta
Klohn Crippen Berger

PROJECT
PEACE REGION (GRANDE PRAIRIE DISTRICT - SOUTH)
GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
GP034 - Slide S. of Kakwa River
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
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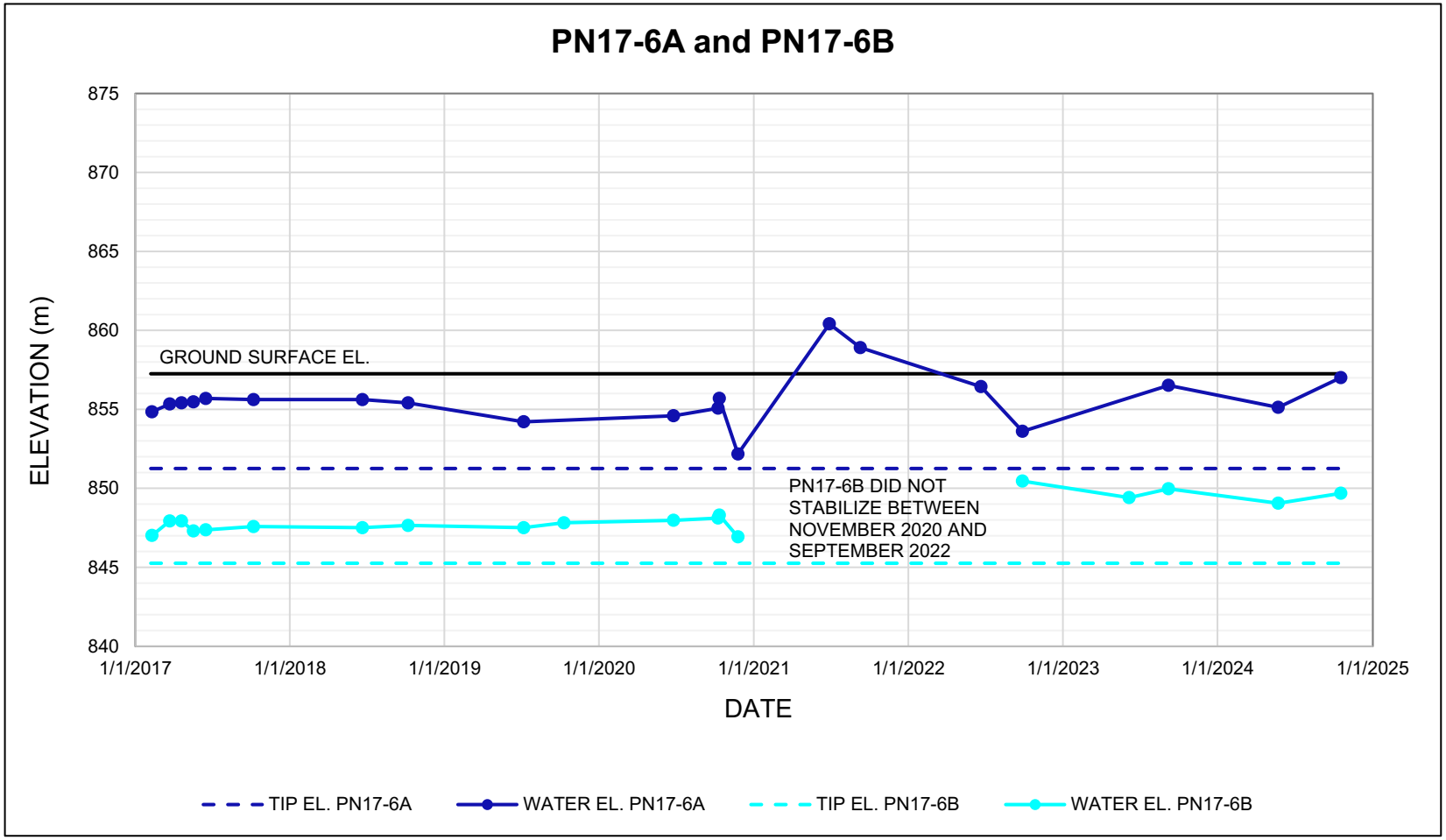

NOTES:
1. PIEZOMETER DATA OBTAINED BEFORE JUNE 28, 2021, PROVIDED TO KLOHN CRIPPEN BERGER LTD. BY ALBERTA TRANSPORTATION AND ECONOMIC CORRIDORS ON JUNE 25, 2021.
2. GROUND SURFACE ELEVATION MEASURED PRIOR TO CONSTRUCTION AND NEEDS TO BE UPDATED.

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: PEACE REGION (GRANDE PRAIRIE DISTRICT - SOUTH) GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Piezometer Data
GP034 - Slide S. of Kakwa River
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
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