November 30, 2022

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

Ed Szmata
Construction Technologist

Dear Mr. Szmata:

CON0022166 Peace Region (Grande Prairie District – South) GRMP Instrumentation Monitoring Site GP034; H40:38, km 21.016 Slide 2.9 km South of Kakwa River Bridge
Section C – 2022 Fall Readings

1 GENERAL

Two slope inclinometers (SIs) (SI17-2 and SI17-3) and six pneumatic piezometers (PNs) (PN17-2A/B, PN17-3B, PN17-5B, and PN17-6A/B,) were read at the GP034 site in the Peace Region (Grande Prairie District – South, GP South Region) on September 27, 2022 by Messrs. Gabriel Bonot, E.I.T. and Guerin White, 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 in 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 edge of the Kakwa River.

Previous remedial actions completed at the GP034 site include the enlargement of an existing toe berm in 2020. Foundation movements and cracking of the asphalt in response to toe berm construction resulted in work being halted. Cracking of the asphalt continued into the spring and fall of 2021.

In 2017, a geotechnical site investigation, which including installing instruments, was conducted at the GP034 by the previous consultant. The encountered stratigraphy was as follows: clay fill, overlying rafted clay shale, overlying clay till, overlying bedrock consisting of siltstone and sandstone.

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 in Figure 1. Any

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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 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).

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[1]	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	1.0	16.8	Operable
SI17-3	SI	Feb. 07, 2017	6028714	399799	854.6	0.8	18.5	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	851.62	N/A	10.2	Operable
~~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~~
PN17-5B	PN	Feb. 06, 2017	6028627	399835	870.3	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 AT . Coordinates and ground surface elevations were confirmed by KCB with a handheld GPS (accuracy of ± 5 m).
[2] Ground surface elevations were measured prior to construction and need to be re-surveyed.
[3] Meters below ground surface (mbgs). Bottom casing depth for SIs and tip elevation for piezometers.
[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, PN17-1B, PN17-4A, and PN17-4B were destroyed in 2020 during construction.
[7] PN17-3A and PN17-5A are inoperable (readings did not stabilize in 2021 or 2022).
[8] PN17-6B stabilized during the September 2022 readings for the first time since November 2020.

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 each instruments tip elevation.

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.

In 2021, KCB reviewed the instrumentation data provided by the previous consultant and removed corrections applied to the historical SI data based on our experience. The SI data obtained by KCB is consistent with the data obtained by the previous consultant. No re-initialization of the SIs is recommended. The SI data plots presented herein include data for readings taken with both the previous consultants' and KCB's SI reading equipment.

The piezometer data obtained by KCB is consistent with the data obtained by the previous consultant.

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	Jun. 21, 2022	Jun. 21, 2022	Sep. 27, 2022	865.9	9.3 – 10.8	X-Direction, 15°	42.7	0.8	211.6	3.0	-6.0
SI17-3	Feb. 08, 2017	Jun. 21, 2022	Jun. 21, 2022	Sep. 27, 2022	854.6	0.0 – 4.5	X-Direction, 35°	253.1	-0.1	5519.4	-0.5	-5.9
						13.0 – 14.5	X-Direction, 35°	67.6	2.5	866.9	9.3	2.3

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

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	Jun. 21, 2022	Sep. 27, 2022	865.9	7.9	5.2	6.5	-1.3
PN17-2B	37439	Feb. 08, 2017	Jun. 21, 2022	Sep. 27, 2022	865.9	10.0	7.1	8.7	-1.6
PN17-3B	37440	Feb. 07, 2017	Jun. 21, 2022	Sep. 27, 2022	851.6	10.2	5.7	6.0	-0.3
PN17-5B	37437	Feb. 06, 2017	Jun. 21, 2022	Sep. 27, 2022	870.3	14.9	4.6	N/A – did not stabilize on Sept. 27, 2022	
PN17-6A	37444	Feb. 09, 2017	Jun. 21, 2022	Sep. 27, 2022	857.3	6.0	0.8	3.7	-2.9
PN17-6B	37433	Feb. 09, 2017	Nov. 24, 2020	Sep. 27, 2022	857.3	12.0	10.3	6.8	3.5

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

2.2 Zones of Movement

Discrete movement (i.e., 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 (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 (elevation 841.6 m to 840.1 m) in a clay foundation unit overlying bedrock (clay shale).

Distributed movement is also being recorded in SI17-3 from the top of the casing to an approximate depth of 4.5 m below ground surface in the fill placed during late-2020 construction.

2.3 Interpretation of Monitoring Results

The rate of deep foundation movement being recorded in SI17-2 and SI17-3 was relatively slow and steady (less than 5 mm/year) between February 2017 (installation date) and October 2020 but increased up to approximately 212 mm/year and 5519 mm/year, respectively, when construction began in late-2020. Since January 2021, the rate of deep foundation movement recorded in SI17-2 and SI17-3 has decreased significantly and is currently less than 10 mm/year.

The deep foundation movements recorded in the SIs are consistent with the GP034 site being a sidehill embankment fill in landslide terrain along the Kakwa River valley slopes.

Since November 2020, shallow movements have been recorded in the upper 5 m of SI17-3, in the clay fill placed during late-2020 construction. This shallow movement is believed to be causing the pavement cracking observed on site and may be an extension upwards along the backscarp, associated with deeper movement. The rate of shallow movement recorded in SI17-3 in late-2020 is difficult to ascertain due to the SI casing being extended in November 2020. Between December 2020 and April 2021, the rate of movement decreased to approximately 15 mm/year, before increasing to approximately 230 mm/year in June 2021. Since September 2021, the rate of movement recorded is now less than 10 mm/year. Increased movement, which could impact the highway, may occur in response to periods of heavy or prolonged rainfall, resulting in higher groundwater conditions.

Overall, since late-2020, the water level recorded in the piezometers has increased between approximately 1 m and 10 m (largest increase of 10 m recorded in PN17-5B). A large increase of 8.2 m was recorded in PN17-6A between November 2020 and June 2021. However, the water level steadily decreased approximately 6.8 m between June 2021 and September 2022. The recorded increases are likely due to excess porewater pressure generation during toe-berm enlargement in 2020.

A short-term decrease (up to approximately 1.5 m) was recorded in some piezometers between the spring and fall 2021 readings, likely due to a dry summer in 2021. Between June and September 2022, the recorded water levels decreased between approximately 0.3 m and 2.8 m, excluding PN17-6B, where an increase of approximately 3.5 m was recorded. It is anticipated that construction-induced excess porewater pressures being recorded in these instruments will continue to decrease.

The elevated porewater pressures recorded in PN17-5B (did not stabilize in September 2022) and PN17-6B, installed depth near approximate elevations of 855 m and 845 m, respectively, are potentially attributing to the increased rate of movement recorded in SI17-2 at an approximate depth of 10 m below ground surface. The time required for excess porewater pressures to decrease could take several months, with accompanied continued movement in the foundation.

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 Repairs and Maintenance

PN17-3A and PN-5A have not stabilized since the spring 2021 readings. KCB inspected the instruments but did not observe any damage to the instruments above ground surface. It is recommended that these instruments be replaced.

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 (Client) for the specific application to GP 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.

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
2022-11-30

James Lyons, P.Eng
Civil Engineer

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

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PERMIT TO PRACTICE
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RM SIGNATURE:
RM APEGA ID #: 187607
DATE: 30 Nov. 2022
PERMIT NUMBER: P009196
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE

Legend

- Pneumatic Piezometer (PN)
- Slope Inclinometer (SI)
- Crest

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

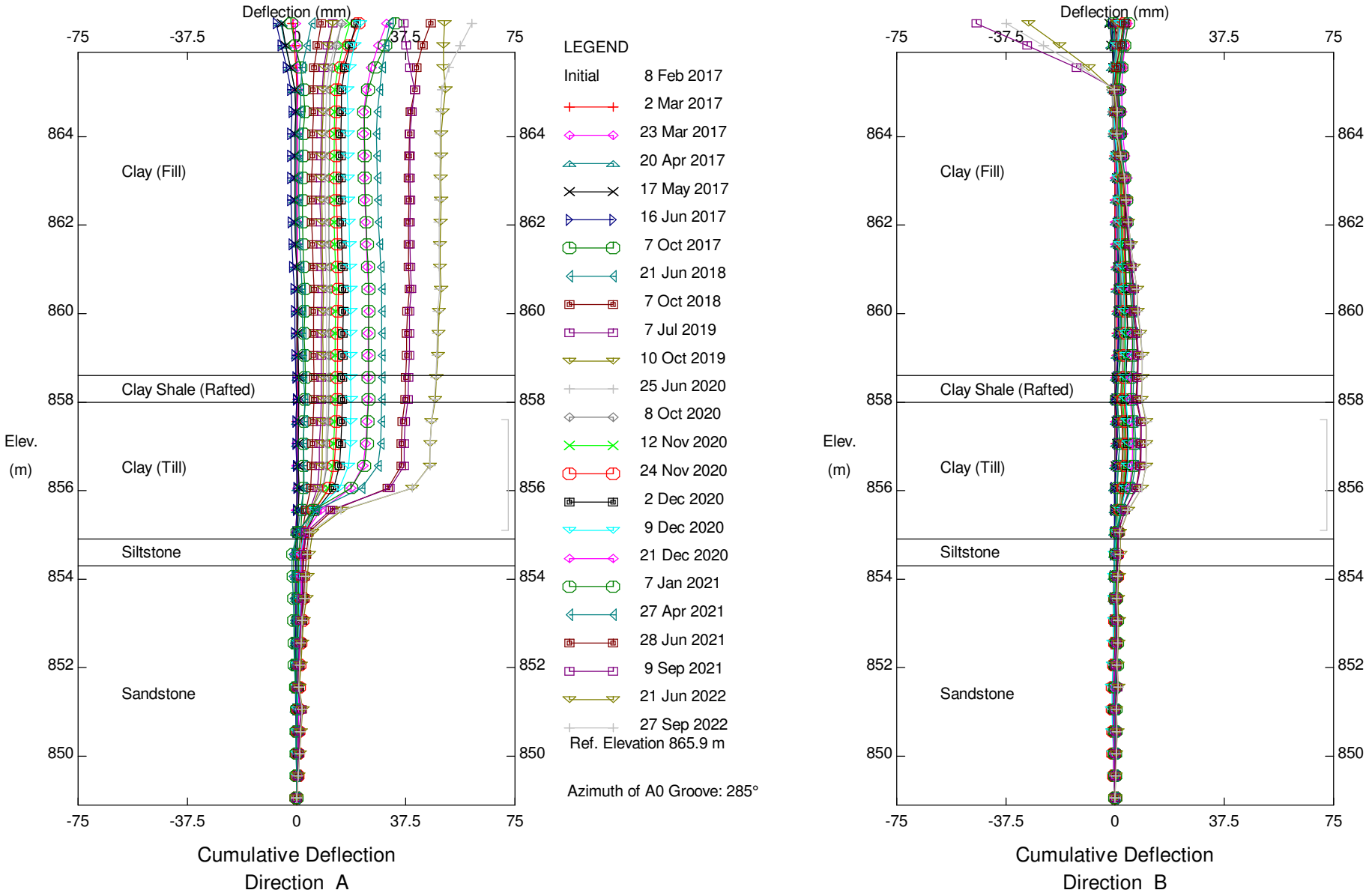
TITLE: Site Plan
GP034 - Slide South of Kakwa River Bridge
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
1:2,000	A05116A01	1

APPENDIX I

Instrumentation Plots

Klohn Crippen Berger - Calgary



GP034; H40:38, Inclinometer SI17-2

Alberta Transportation

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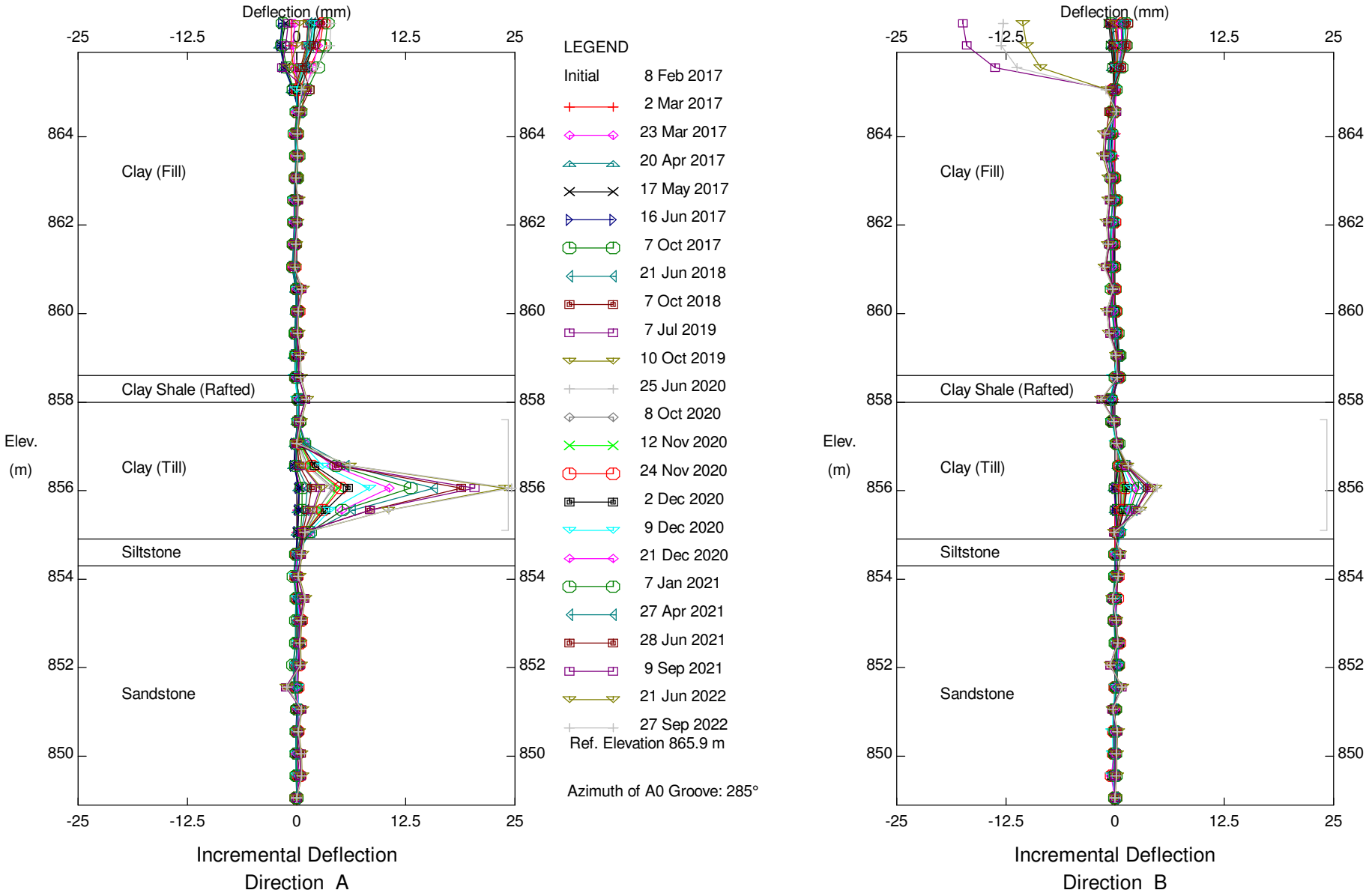

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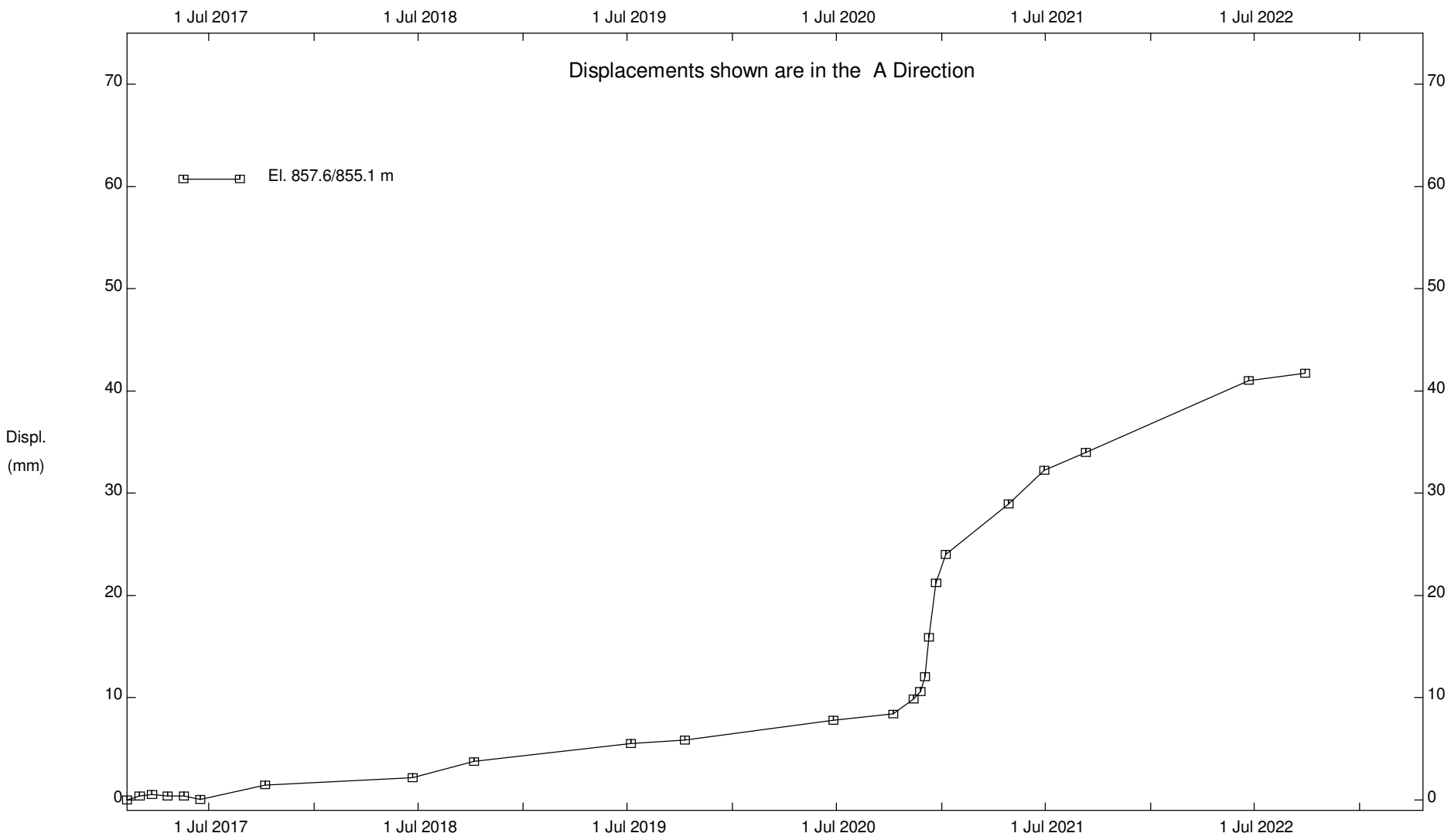
Klohn Crippen Berger - Calgary



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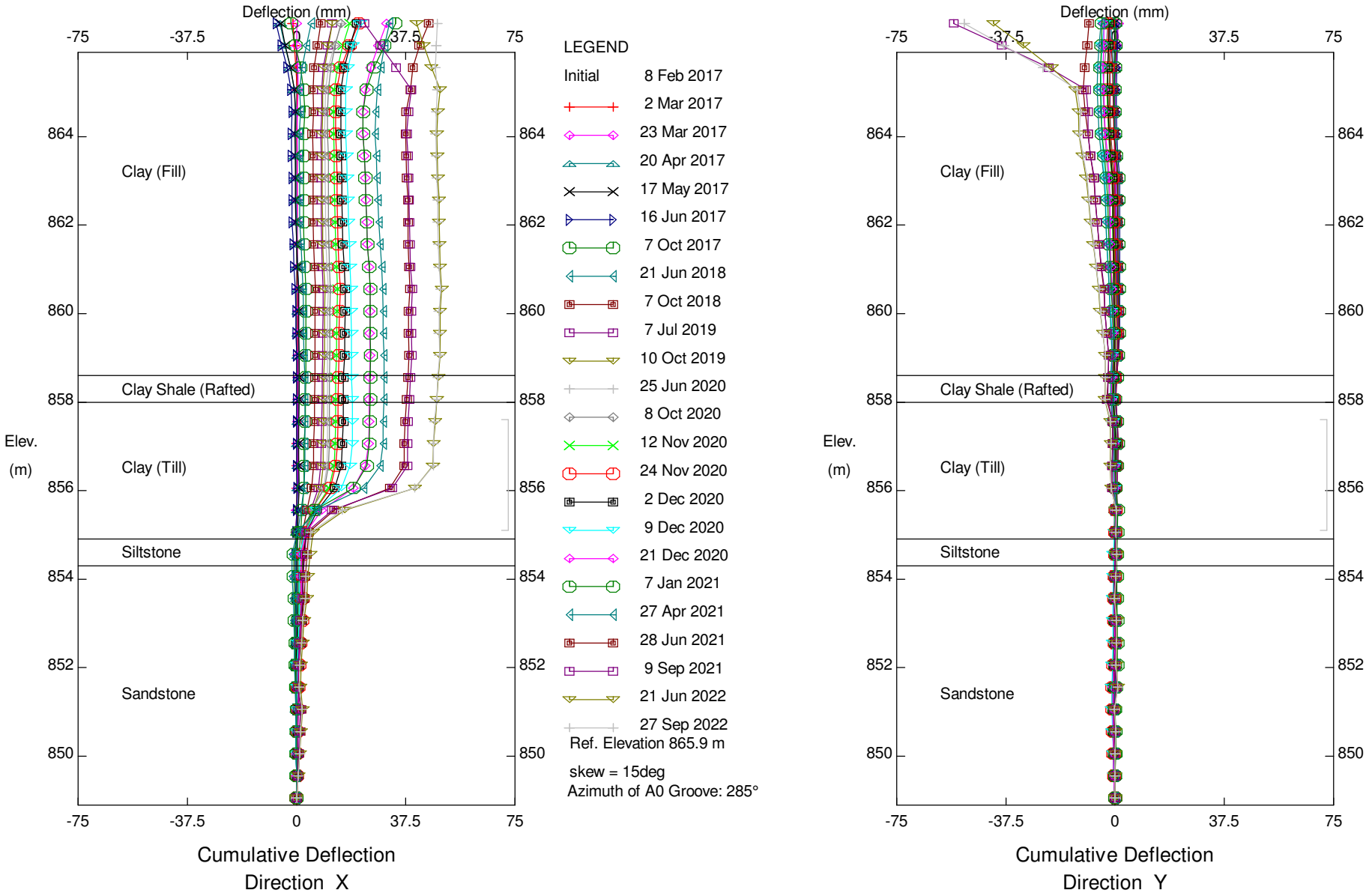
Klohn Crippen Berger - Calgary



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Alberta Transportation

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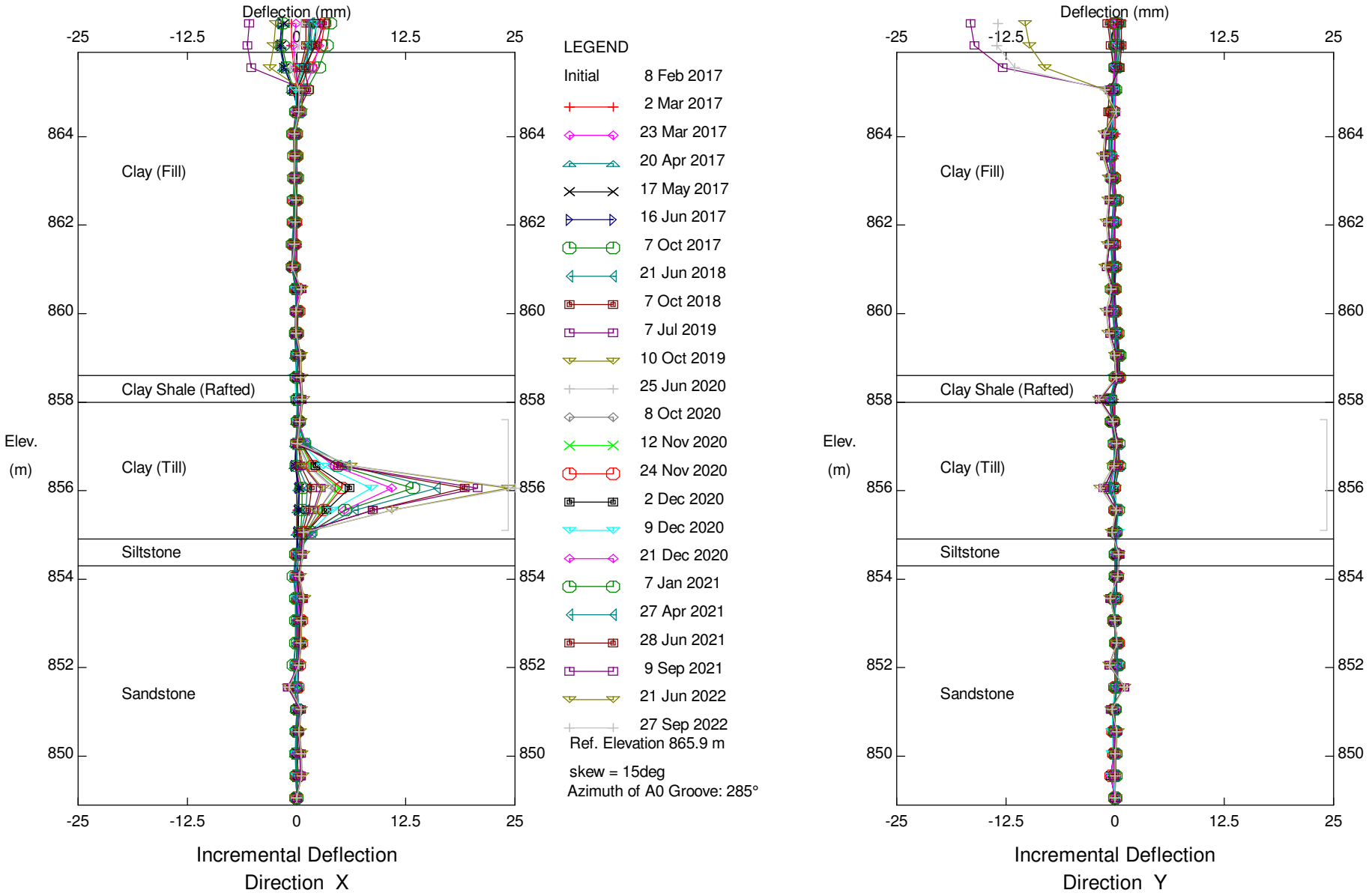

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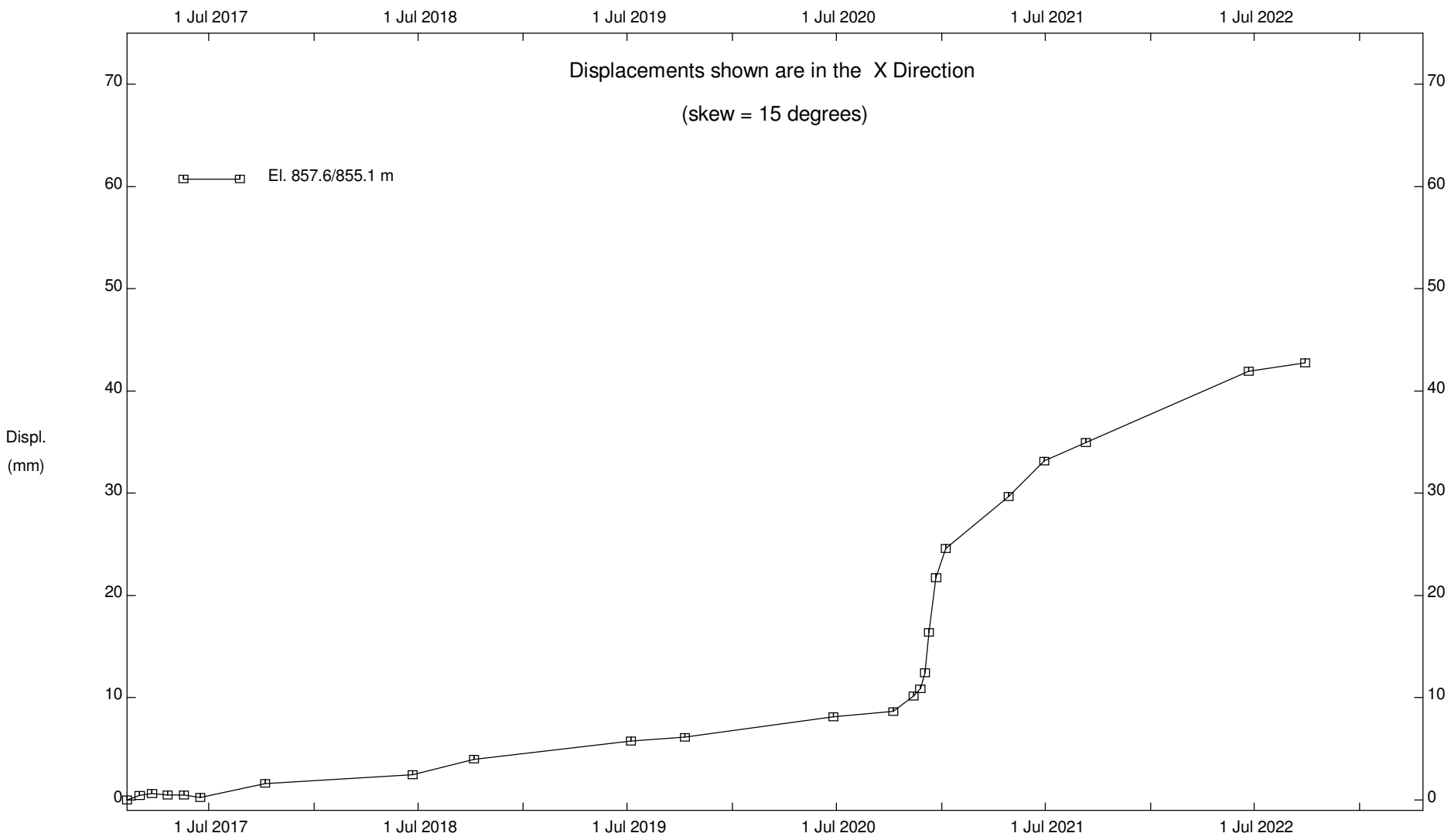
Alberta Transportation

Klohn Crippen Berger - Calgary



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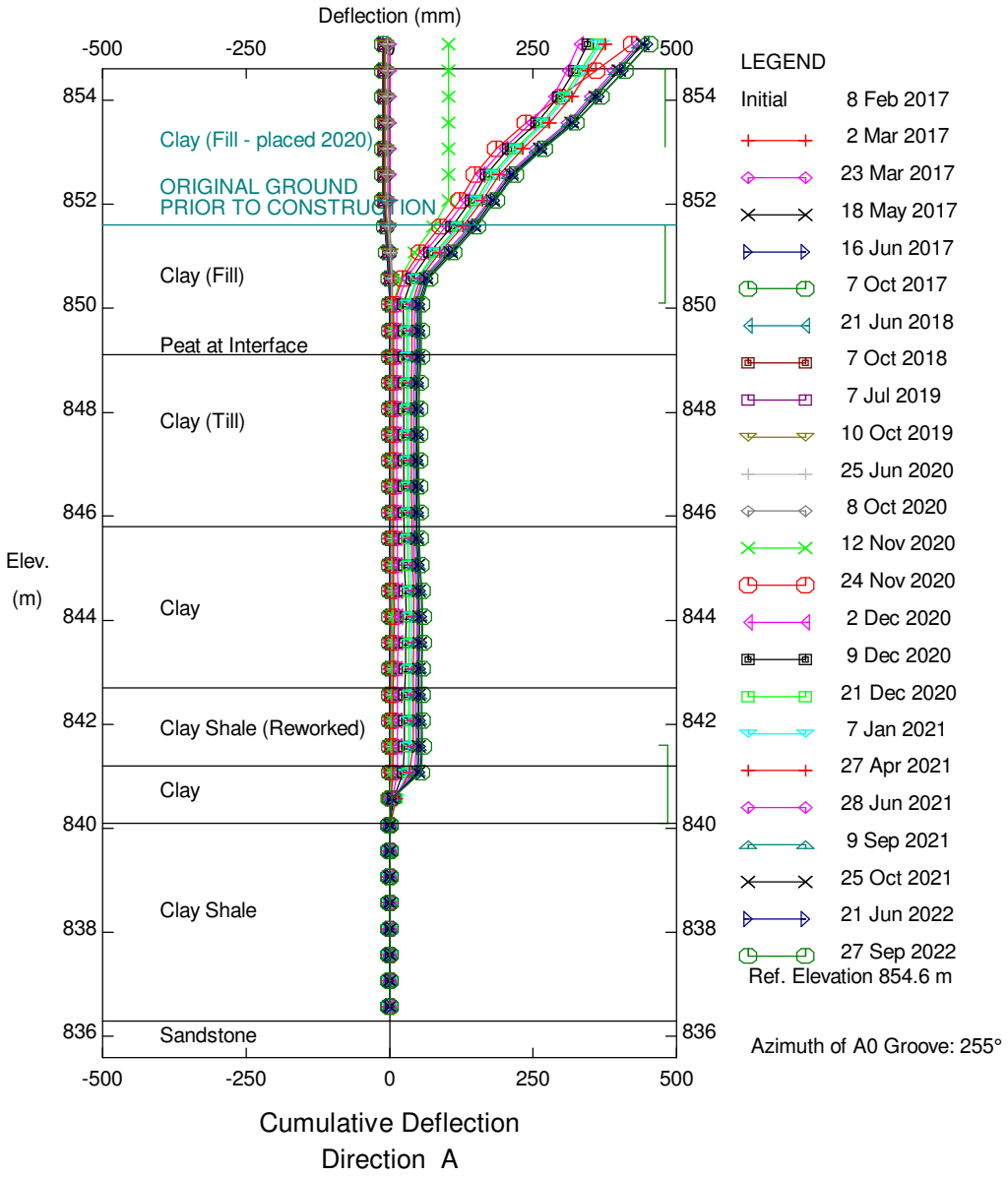
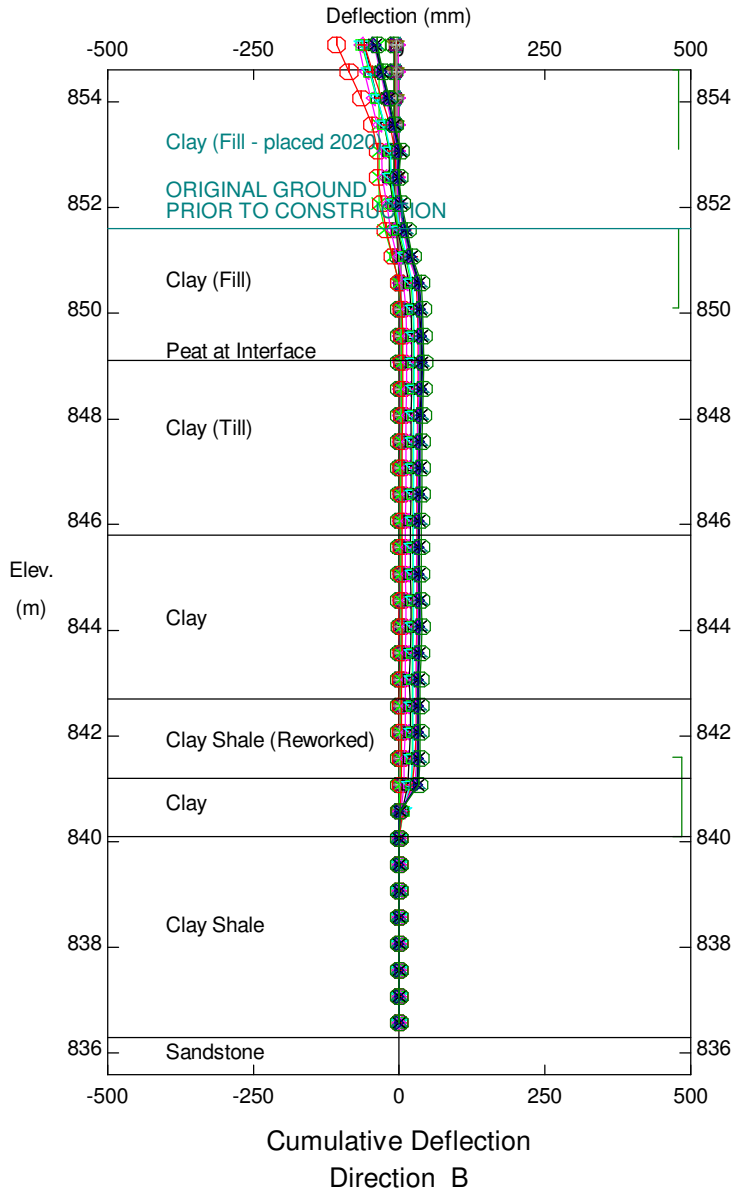
Klohn Crippen Berger - Calgary





GP034; H40:38, Inclinometer SI17-3

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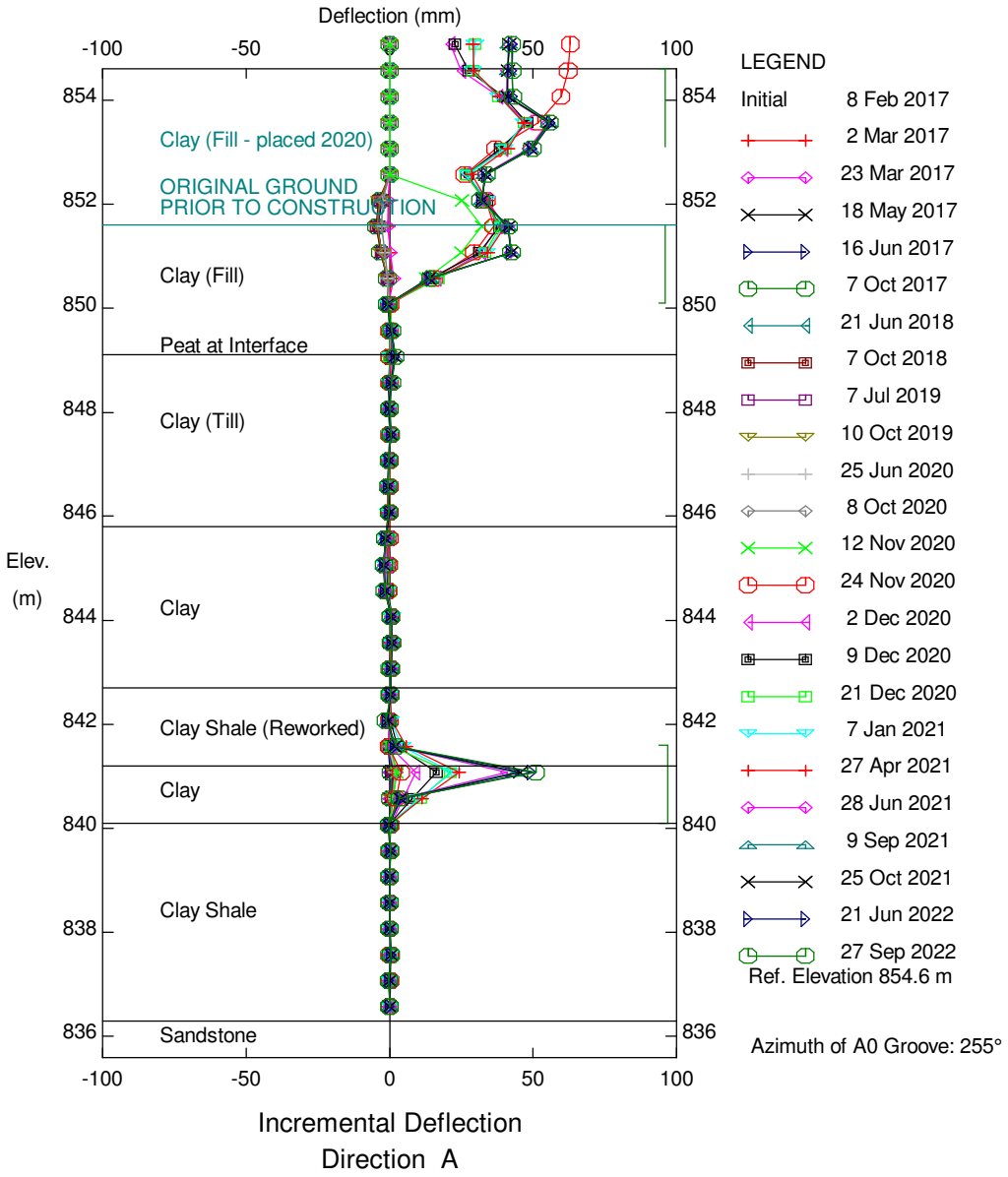


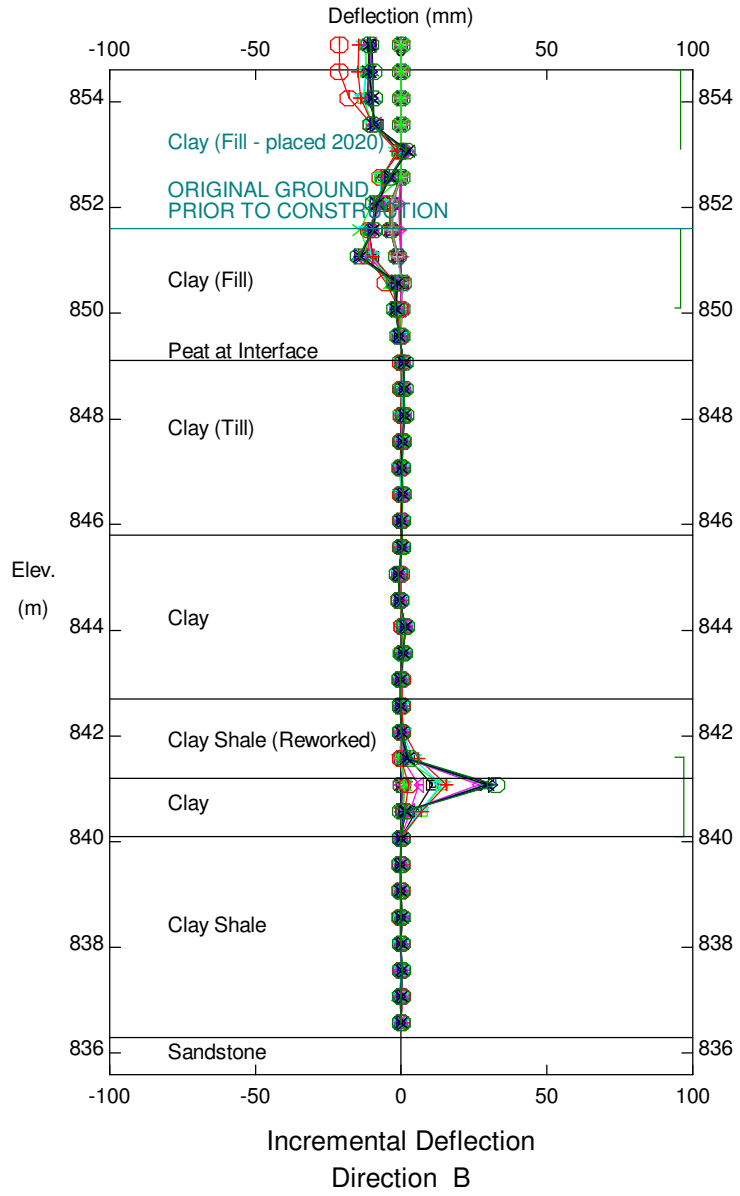
LEGEND

Initial	8 Feb 2017
	2 Mar 2017
	23 Mar 2017
	18 May 2017
	16 Jun 2017
	7 Oct 2017
	21 Jun 2018
	7 Oct 2018
	7 Jul 2019
	10 Oct 2019
	25 Jun 2020
	8 Oct 2020
	12 Nov 2020
	24 Nov 2020
	2 Dec 2020
	9 Dec 2020
	21 Dec 2020
	7 Jan 2021
	27 Apr 2021
	28 Jun 2021
	9 Sep 2021
	25 Oct 2021
	21 Jun 2022
	27 Sep 2022

Ref. Elevation 854.6 m

Azimuth of A0 Groove: 255°

Incremental Deflection
Direction A



Incremental Deflection
Direction B

GP034; H40:38, Inclinometer SI17-3

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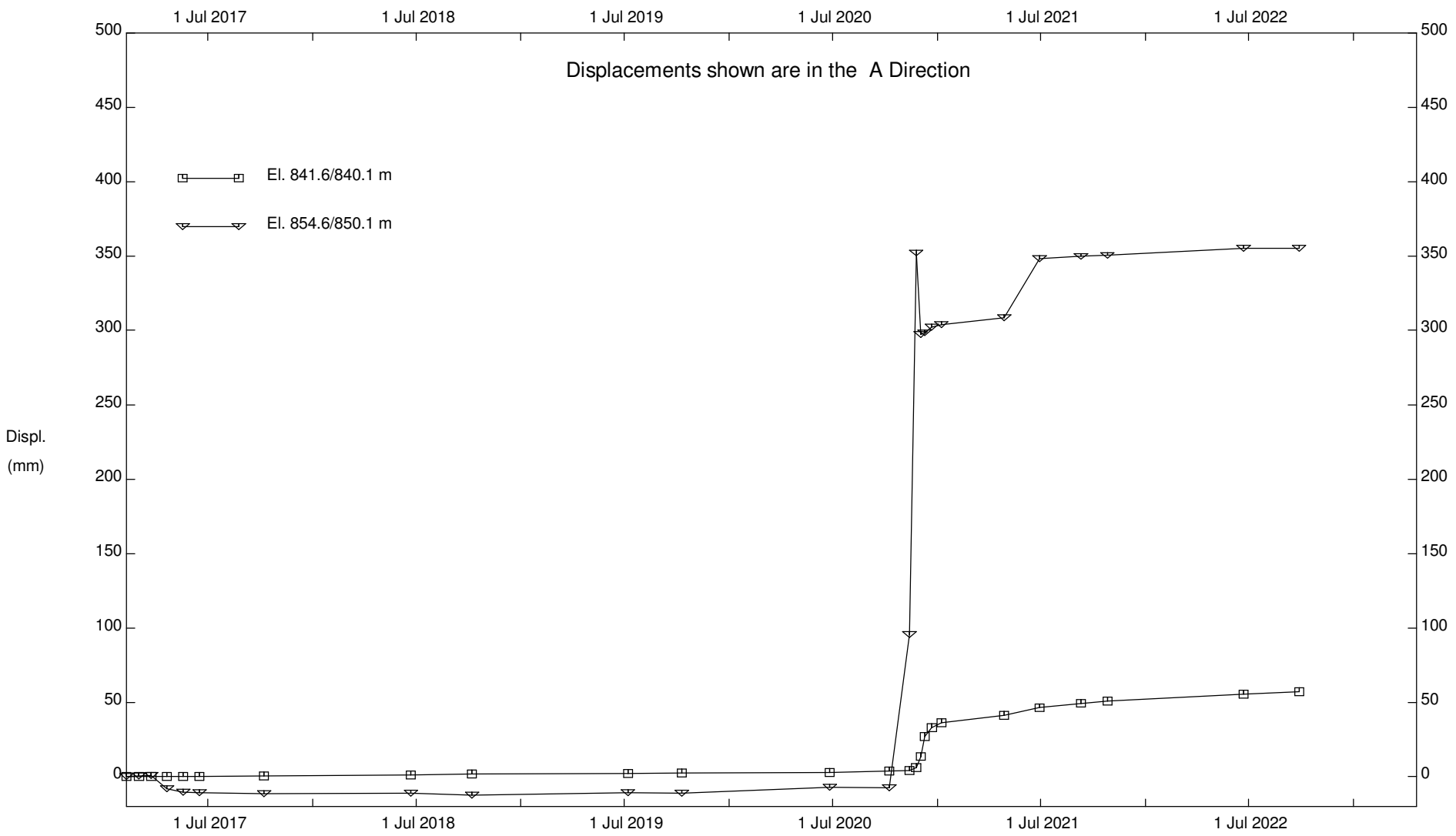

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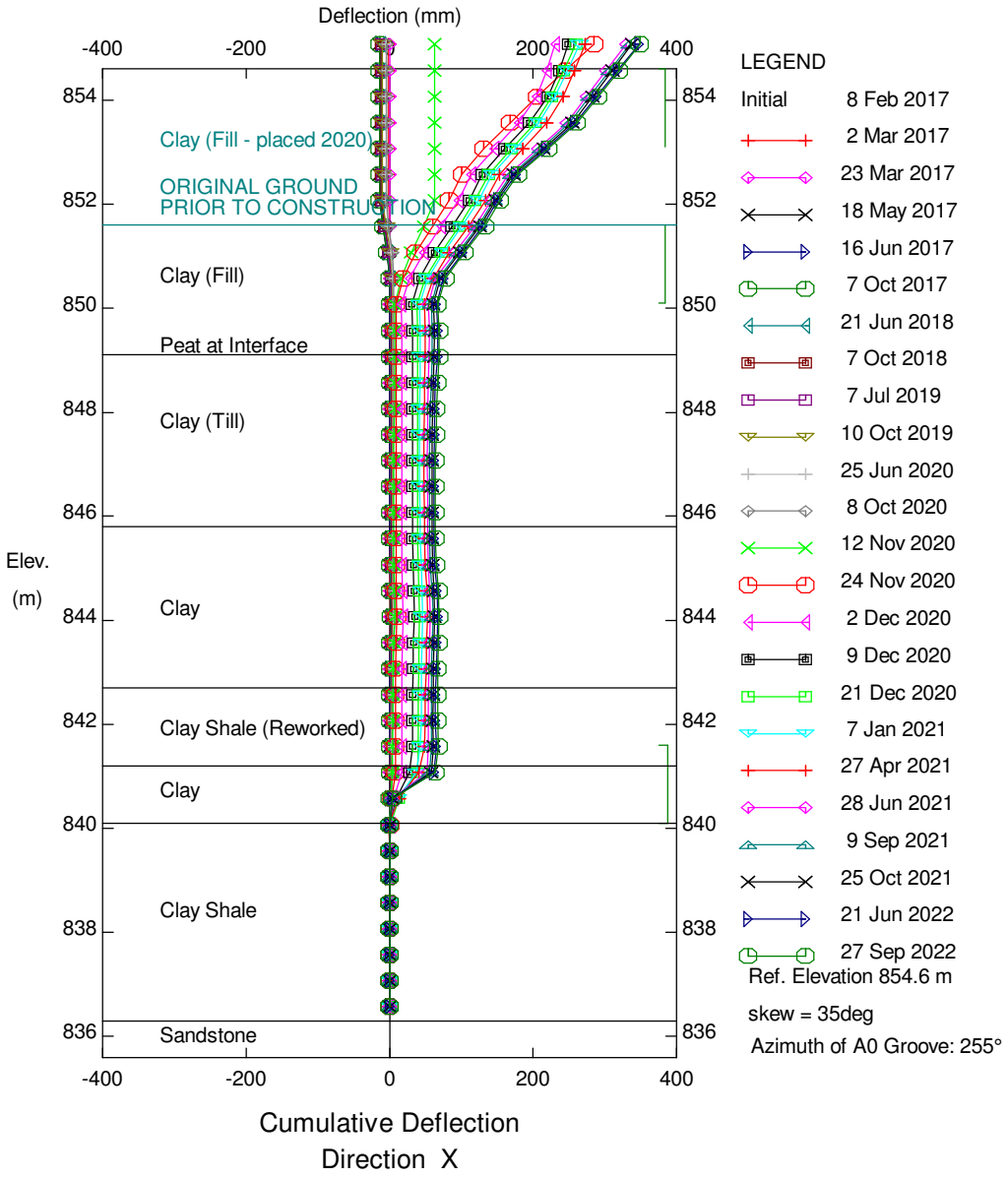
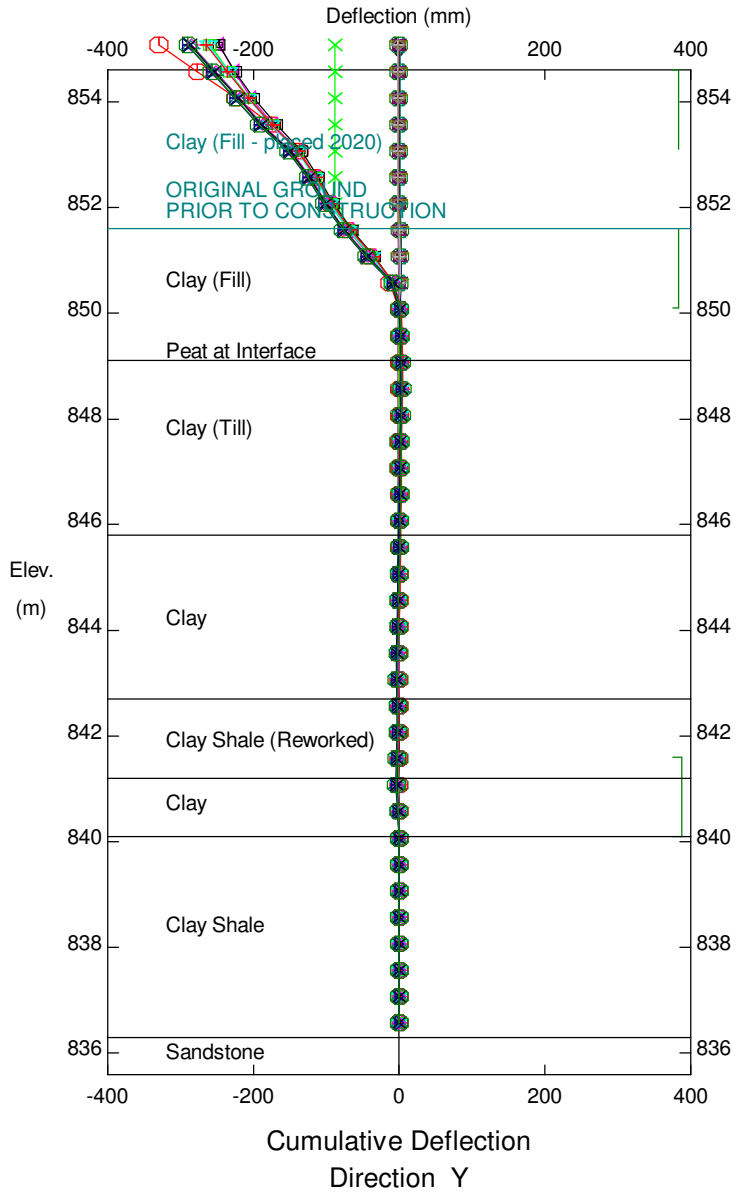
Klohn Crippen Berger - Calgary





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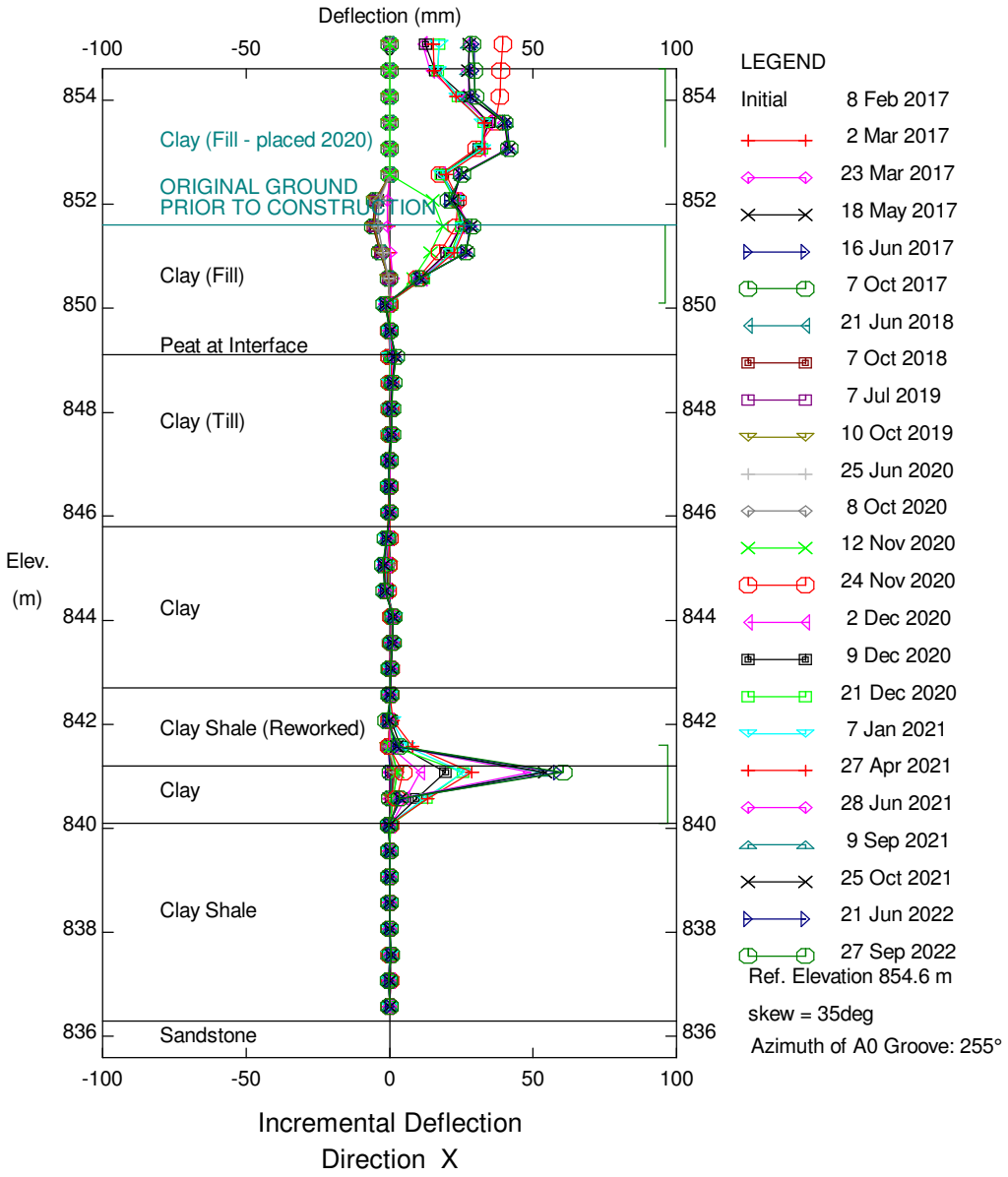

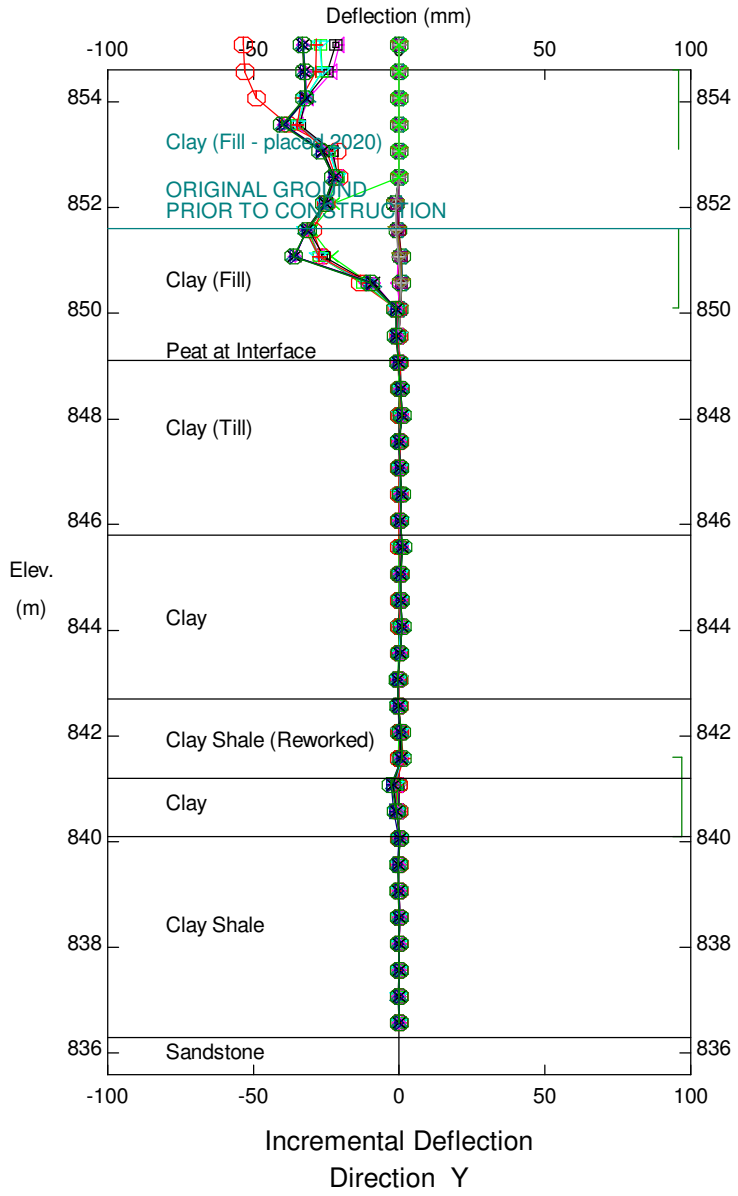

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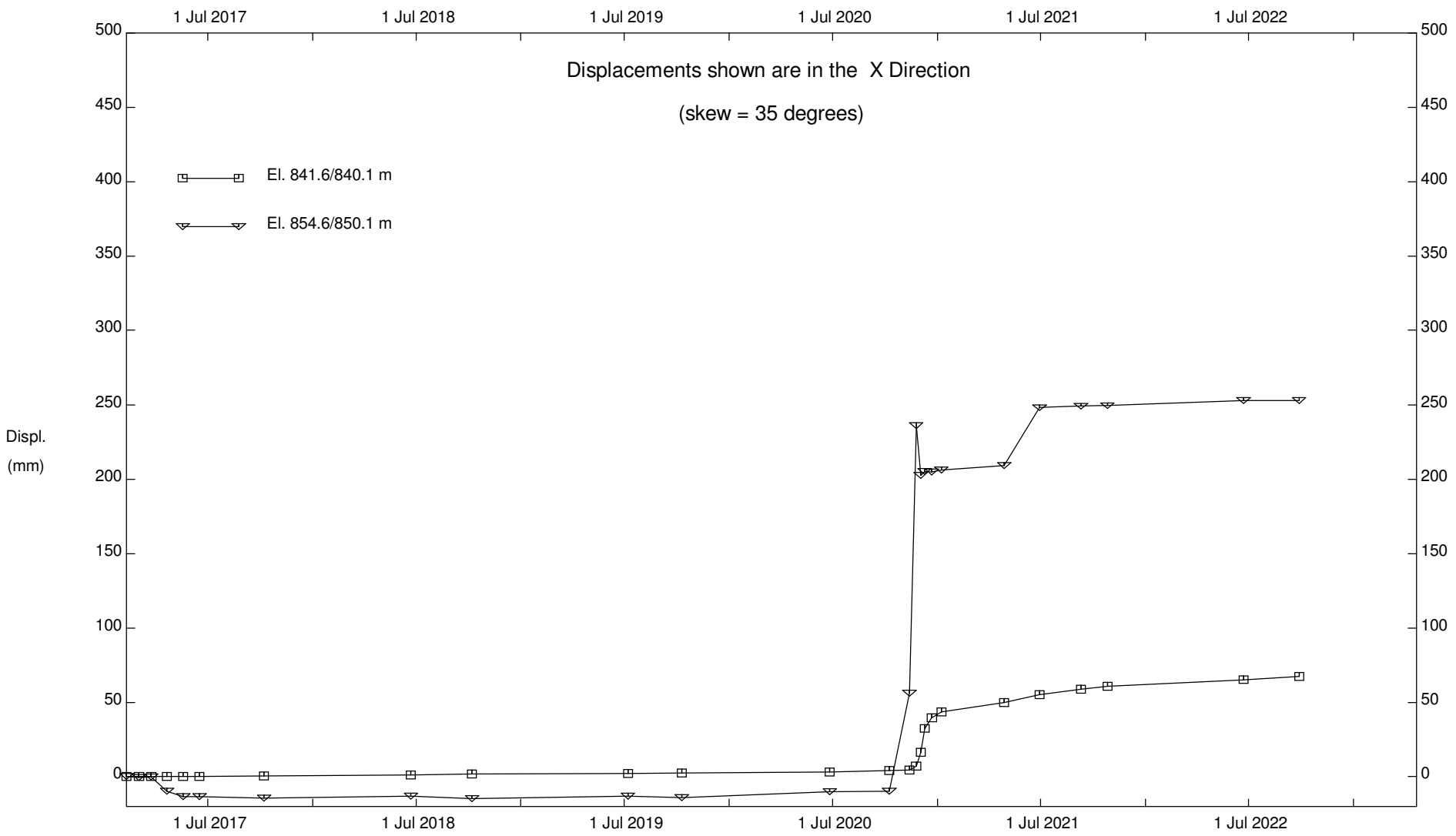

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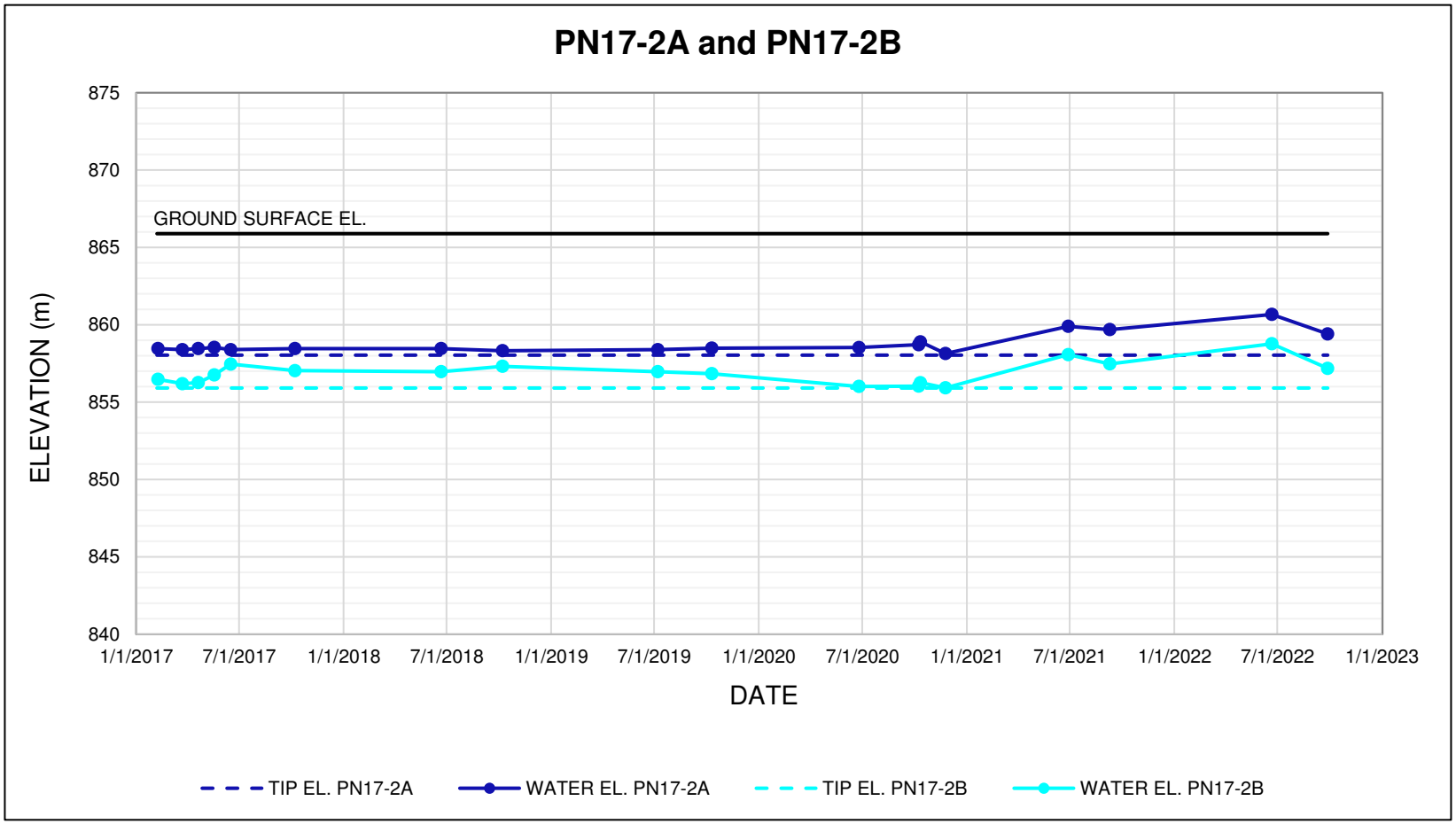


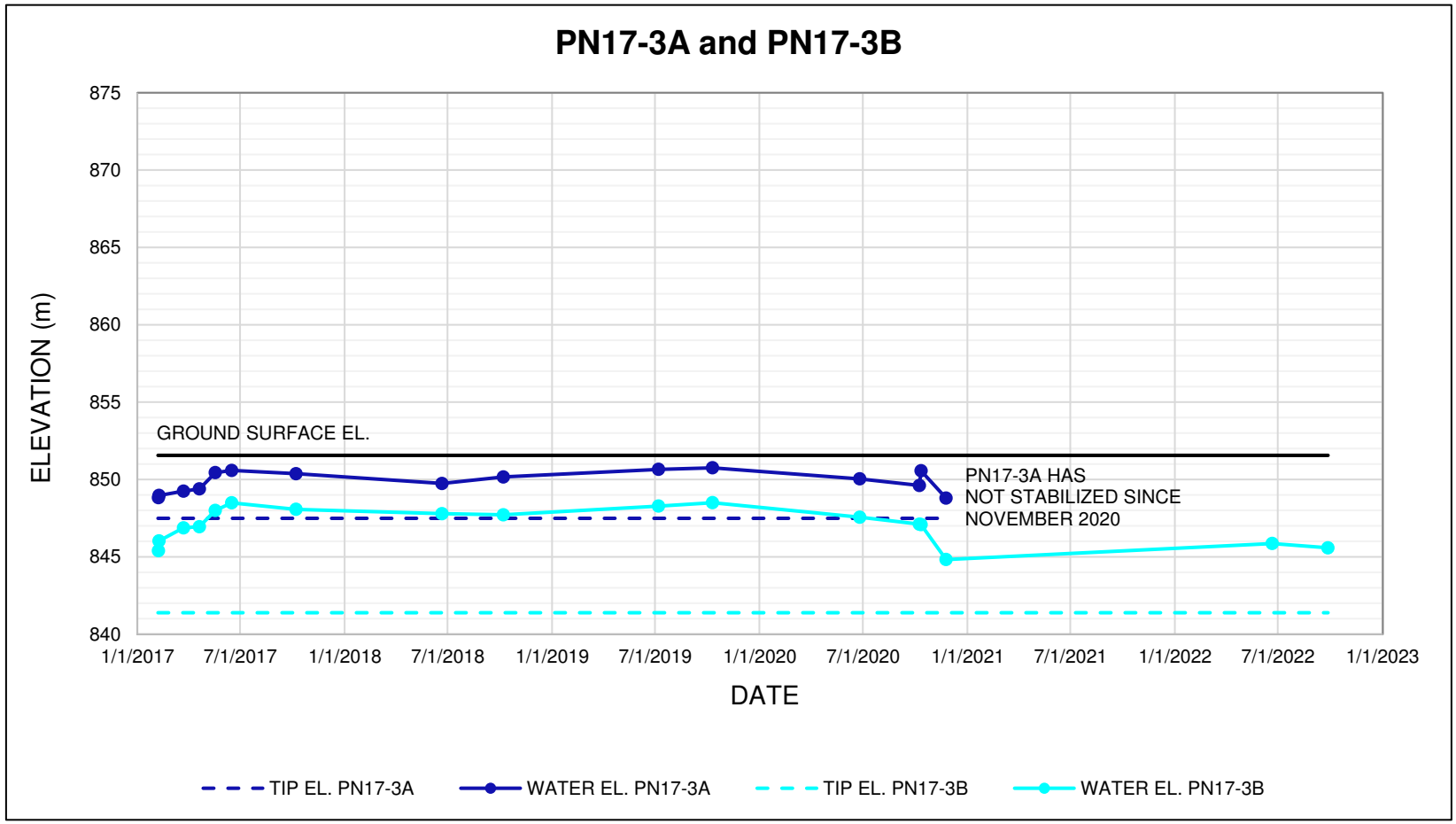
Notes:
1. Piezometer data obtained before June 28, 2021 was provided to Klohn Crippen Berger Ltd. by Alberta Transportation on June 25, 2021.
2. Ground surface elevation measured prior to construction and needs to be updated.

CLIENT
Alberta
Klohn Crippen Berger

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

TITLE
Piezometer Data
GP034 - Slide 2.9 km S of Kakwa River Bridge
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
	A05116A01	



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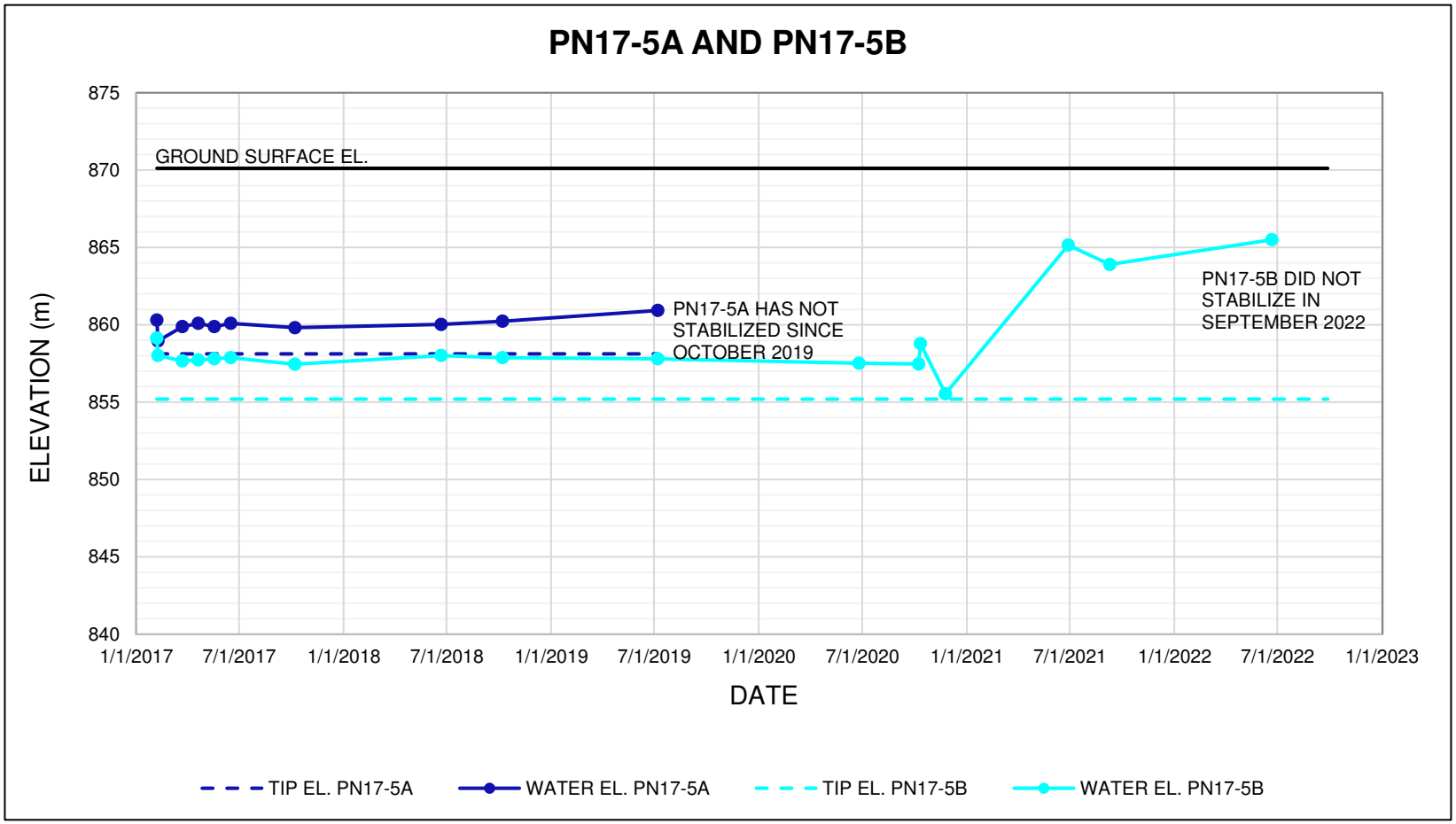

Notes:
1. Piezometer data obtained before June 28, 2021 was provided to Klohn Crippen Berger Ltd. by Alberta Transportation on June 25, 2021.
2. Ground surface elevation measured prior to construction and needs to be updated.

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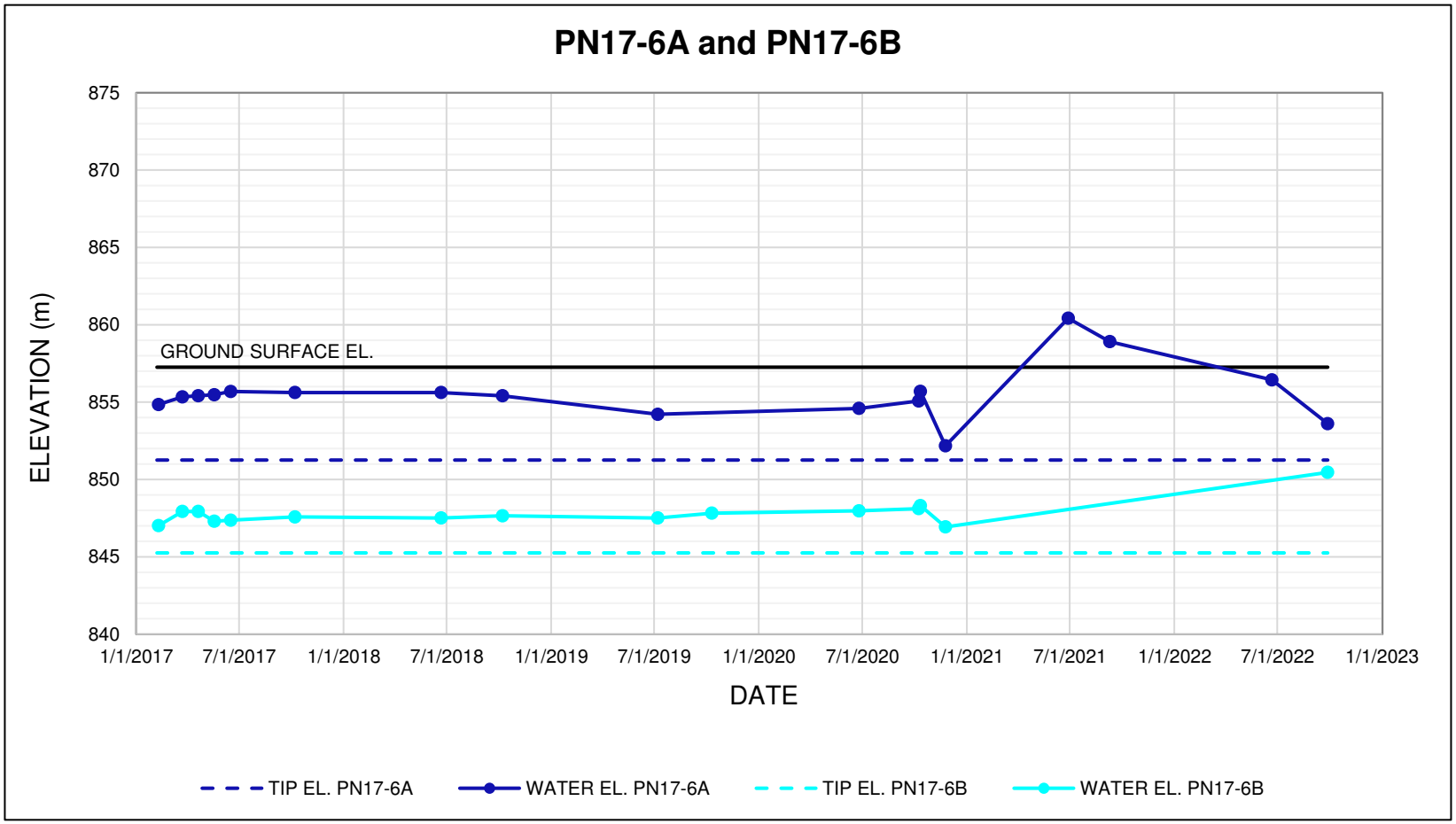
PROJECT
PEACE REGION (GRANDE PRAIRIE DISTRICT - SOUTH)
GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
GP034 - Slide 2.9 km S of Kakwa River Bridge
Hwy 40:38, km 21.016

SCALE	PROJECT No.	FIG No.
	A05116A01	



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