November 30, 2022

Alberta Transportation
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 S008; H762:02, km 2.125 Fisher Creek Pile Wall
Section C – 2022 Fall Readings

1 GENERAL

Five slope inclinometers (SIs) (Pile 15, Pile 29, Pile 36, Pile 43, and Pile 49) were read at the S008 site in Southern Region on September 21, 2022, by Mr. Gabriel Bonot, E.I.T. of Klohn Crippen Berger Ltd. (KCB). These instruments were read as part of the Southern Region Geohazard Risk Management Program (GRMP). The site is located on Hwy 762:02 km 2.125, south of Bragg Creek, Alberta, approximately 2 km north of the Hwy 549 intersection. The approximate site coordinates are 5627342 N, 678866 E (UTM Zone 11, NAD 83). A site plan is presented in Figure 1.

The geohazard at the S008 site consists of a landslide approximately 130 m in length on the west slope of the highway embankment. In January 2017, a cast-in-place pile wall consisting of fifty-seven (57) 1.2-m-diameter piles was installed to a depth of 16 m to 18 m below ground surface and anchored in bedrock. In the fall of 2017, a high-tension-cable-barrier (HTCB) was installed along the west (southbound lane) shoulder of the highway. A pavement patch was placed north of the pile wall between the spring and fall 2022 readings.

Geotechnical site investigations, some of which included installing instruments, were conducted at the S008 site in 1988, 2001, 2002, and 2007 by previous consultants. Generally, the encountered stratigraphy was as follows: fill, overlying clay with organics or silty clay, overlying high plastic clay, overlying clay till, overlying rafted bedrock (sandstone), overlying clay till.

1.1 Instrumentation

KCB has been reading the instruments at this site since 2016. Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1. Any instruments not included in

Klohn Crippen Berger Ltd.
500 - 2618 Hopewell Place NE ▪ Calgary AB T1Y 7J7 ▪ Canada
t 403.274.3424 ▪ f 403.274.5349 ▪ www.klohn.com

Table 1.1 or shown in Figure 1 are assumed to be inoperable and are not presented or discussed herein.

Between 1988 and 2007, 17 SIs and 6 piezometers were installed at the site by the previous consultants to monitor movement and groundwater conditions, respectively. All of these instruments are now inoperable (e.g., destroyed, sheared, or lost). Between December 2016 and January 2017, 5 SIs (Pile 15, Pile 29, Pile 36, Pile 43, and Pile 49) were installed within the pile wall.

The operable SIs are protected by above-ground casing protectors.

KCB changed the SI reading equipment in October 2021 after the previous equipment became inoperable. Currently, KCB is reading the SIs with a metric RST Digital MEMS Inclinometer System.

Table 1.1 Instrument Installation Details

Instrument ID[1]	Instrument Type	Date Installed	UTM Coordinates[2] (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth[3] (m)	Condition
			Northing	Easting				
Pile 15	SI	Dec. 2016	5627372	678862	1302.6	1.0	18.0	Operable
Pile 29	SI	Jan. 2017	5627354	678861	1304.7	1.0	18.0	Operable
Pile 36	SI	Jan. 2017	5627335	678861	1305.7	1.0	18.0	Operable
Pile 43	SI	Jan. 2017	5627318	678861	1306.5	1.0	16.0	Operable
Pile 49	SI	Jan. 2017	5627281	678864	1307.2	1.0	16.0	Operable

Notes:
[1] Instrument ID is the same as the pile number in which the SI was installed.
[2] Coordinates were obtained by KCB with a handheld GPS (accuracy of ±5 m).
[3] Meters below ground surface (mbgs). Bottom reading depth for SIs.

2 INTERPRETATION

2.1 General

For the operable SIs, the cumulative displacement, incremental displacement, displacement-time data was plotted in the A-direction (i.e., the direction of the A0-grooves) and, where applicable, the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). The SIs installed in Piles 36 and 49 have skew angles of 340° and 330°, respectively, measured clockwise from the direction of the A0-grooves.

The SI data plots are included in Appendix I, and a summary of the SI data and a comparison of the current and historical SI data is provided in Table 2.1 and Table 2.2, respectively.

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 Reading	Previous Maximum Cumulative Movement Recorded	Most Recent Reading				Before Re-Initialization	After Re-Initialization	Total[3]	Previous Maximum[4]	Most Recent Reading	Change from Previous Reading
Pile 15	Dec. 16, 2016 (Oct. 7, 2021)	May 02, 2022	Oct. 07, 2021	Sep. 21, 2022	1302.6	0.3 – 9.8	A-Direction	24.7	2.1	26.8	80.5	9.8	12.8
			Jun. 17, 2021			9.8 – 17.3	A-Direction	7.7	-2.0	5.7	204.4	-0.9	2.0
Pile 29	Jan. 13, 2017 (Oct. 7, 2021)	May 02, 2022	Oct. 07, 2021	Sep. 21, 2022	1304.7	0.2 – 10.7	A-Direction	9.4	0.1	9.5	90.6	1.9	3.1
Pile 36	Jan. 27, 2017 (Oct. 7, 2021)	May 02, 2022	Oct. 07, 2021	Sep. 21, 2022	1305.7	0.3 – 10.8	X-Direction, 340°	13.7	0.2	13.9	90.3	2.4	3.7
			Oct. 07, 2021			10.8 – 17.3	X-Direction, 340°	3.9	-0.6	3.3	97.8	1.4	3.4
Pile 43	Jan. 19, 2017 (Oct. 7, 2021)	May 02, 2022	Sep. 22, 2020	Sep. 21, 2022	1306.5	0.3 – 7.8	A-Direction	6.3	0.2	6.5	129.9	1.7	2.5
Pile 49	Jan. 05, 2017 (Oct. 7, 2021)	May 02, 2022	May 15, 2020	Sep. 21, 2022	1307.2	0.3 – 7.8	X-Direction, 330°	6.8	-0.2	6.6	119.9	2.8	5.2

Notes:
[1] Meters below ground surface (mbgs).
[2] Skew angle of X-direction measured clockwise from the A-direction.
[3] All SIs were re-initialized in October 2021 when KCB changed the SI reading equipment after the previous equipment became inoperable. The total maximum cumulative movement recorded does not include any movement that occurred between June 17, 2021 (the last reading obtained with KCB's old SI equipment) and October 7, 2021 (the first reading obtained with KCB's new SI equipment).
[4] The previous maximum rates of movement were reported by the previous consultant in July 2017. However, it appears that the high rate of movement was attributed to readings when the SI equipment was changed.

Table 2.2 Comparison of Current and Historical Slope Inclinometer Readings

Instrument ID / Pile No.	Closest Historic SI	Approximate Distance Between Pile and Historical SI[1] (m)	Approximate Depth of Movement Recorded in Historical SI (mbgs[2])
Pile 15	SI2007-4	5	10.4
Pile 29	SI2007-3	5	4.7
Pile 36	SI2007-2	8	7.5
Pile 43	SI2007-2	10	7.5
Pile 49	SI2007-1	2	2.8

Notes:
[1] Locations estimated from Tetra Tech's Issued for Tender drawings dated July 2016.
[2] Meters below ground surface (mbgs).

The SI data obtained with KCB's new metric SI reading equipment is not consistent with the data obtained with KCB's old imperial SI reading equipment. The general trend is the same, but the data obtained with the new equipment is relatively noisy compared to the data obtained with the old equipment. The noise is likely a result of the reading units being changed from imperial to metric, and the interpolation that occurs when converting GTILT files from imperial to metric units. These instruments were re-initialized to the October 2021 reading (i.e., the first reading with our new SI reading equipment) after the May 2022 readings.

The SI data plots presented herein include data for readings taken with the new metric SI reading equipment only.

2.2 Zones of Movement

Historically, distributed movement has been recorded in the SIs installed in the pile wall from the top of casing to an approximate depth of:

- 9.8 m below ground surface in Pile 15 with some minor deflection (less than 10 mm) being recorded to an approximate depth of 17.3 m below ground surface (i.e., bottom of casing);
- 10.7 m below ground surface in Pile 29;
- 10.8 m below ground surface in Pile 36 with some minor deflection (less than 5 mm) being recorded to an approximate depth of 17.3 m below ground surface (i.e., bottom of casing);
- 7.8 m below ground surface in Pile 43; and
- 7.8 m below ground surface in Pile 49 with some minor deflection (less than 5 mm) being recorded to an approximate depth of 15.3 m below ground surface (i.e., bottom of casing).

Since being re-initialized to the October 2021 reading, no discernible movement has been recorded in Pile 29, Pile 43, or Pile 49.

The piles are approximately 16 m to 18 m deep and the SIs are approximately 15.8 m to 17.9 m deep.

2.3 Interpretation of Monitoring Results

The pile-wall Issued for Tender (IFT) drawings issued to AT in July 2016 indicate the depth of recorded pre-repair movement varied from approximately 3 m to 10 m below the highway. The observed upper zone of movement recorded in the pile-wall SIs appears to be occurring at a similar depth (varies from approximately 8 m to 11 m below ground surface). Based on stratigraphy shown on the SI data plots, the recorded movement corresponds to where the pile wall is installed in high plastic clay, silty clay, and clay and gravel fill. The SI data indicates the piles have intercepted the failure surface and deflected, transferring load to depths below the failure plane as the pile stabilize the slide mass.

The September 2022 data obtained from the pile-wall SIs indicates that the tops of the piles have deflected up to 27 mm since installation. In the spring of 2017, shortly after construction of the pile

wall, the maximum rate of movement recorded in these SIs was up to approximately 205 mm/year. The rate of movement has since decreased and is currently negligible. The negative rate of movement recorded in these instruments during some readings indicates the rate of movement is within the reading accuracy of the SI equipment and instruments. KCB anticipated that the rate of movement shortly after installation would be highest and would decrease as the pile wall picked up load stabilizing the sliding mass. More data is needed to assess long-term trends for the pile-wall SIs. Increased movement or additional displacements of the pile wall may occur in response to heavy or prolonged rainfall or freshet infiltration, resulting in higher groundwater conditions.

Initial movement (less than 10 mm) was recorded in the base of Pile 15, Pile 36, and Pile 49 in early 2017, within six months of pile wall installation. Those movements have since attenuated and are no longer discernible.

Observations made during the last three Section B inspections include:

- July 2020 – new pavement cracking and an area of settlement (i.e., a dip) were observed in the east (northbound) lane, approximately 24 m north of the existing pile wall.
- July 2021 – the severity of the pavement cracking had increased since the July 2020 inspection. The length of the pavement crack was approximately 11 m.
- July 2022 – the severity of the pavement cracking has continued to increase since the July 2021 inspection. The length of the pavement cracking had increased to approximately 16 m. The pavement cracking was within 0.4 m of the highway centerline and settlement of up to 50 mm was observed in the west (southbound) lane.

The pavement distress north of the pile wall could indicate the slide is outflanking the pile wall at its north extent. Between the spring and fall 2022 readings, a new pavement patch was placed north of the pile wall, in the area where pavement cracks were observed during the previous three Section B inspections.

3 RECOMMENDATIONS

3.1 Future Work

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

KCB recommends that instrument readings should include photographs of the pile wall and pavement surface, to aid with instrument evaluation.

KCB recommends that a borehole be drilled approximately 24 m north of the existing pile wall where pavement distress is observed. A SI should then be installed in the borehole to monitor movement at this location.

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 or maintenance is 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.

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.

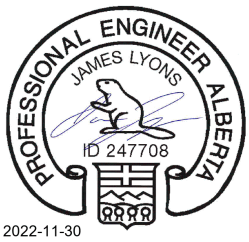
Use of or reliance upon this instrument of service by the Client is subject to the following conditions:

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.



2022-11-30

James Lyons, P.Eng.
Civil Engineer

Reviewed by: Chris Gräpel, M.Eng., P.Eng.
Senior Civil Engineer, Associate

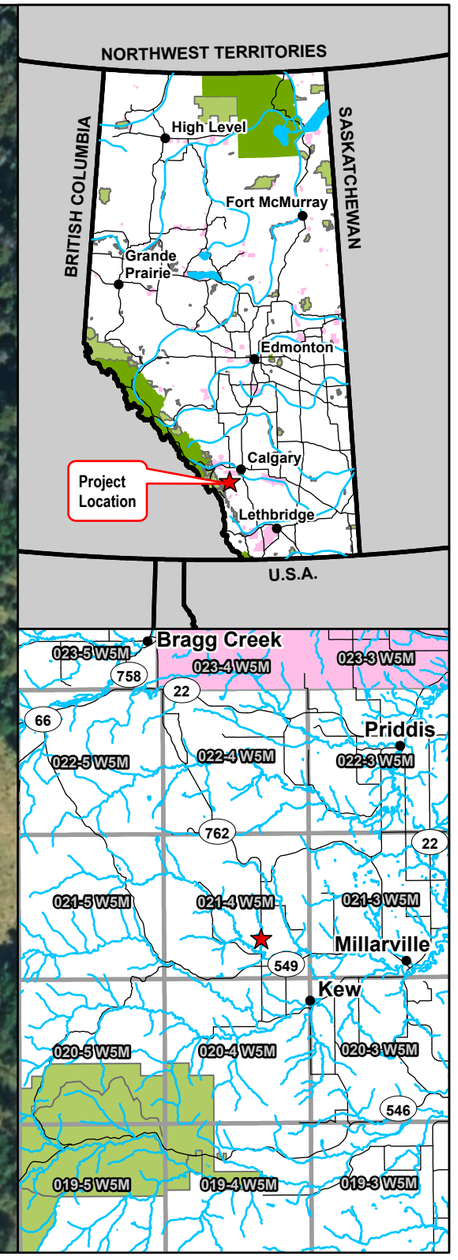
Cc: Peter Roy, P.Eng.
Civil Engineer, Project Manager

JL:bb

PERMIT TO PRACTICE
KLOHN CRIPPEN BERGER LTD.
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

- Slope Inclinometer (SI)
- Crack
- Fence
- Site Extent

0 50 Metres

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 12N
3. IMAGE SOURCE: AB COUNTY, CHALLENGER GEOMATICS LTD.

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
S008 - Fisher Creek Pile Wall
Hwy 762:02, km 2.125

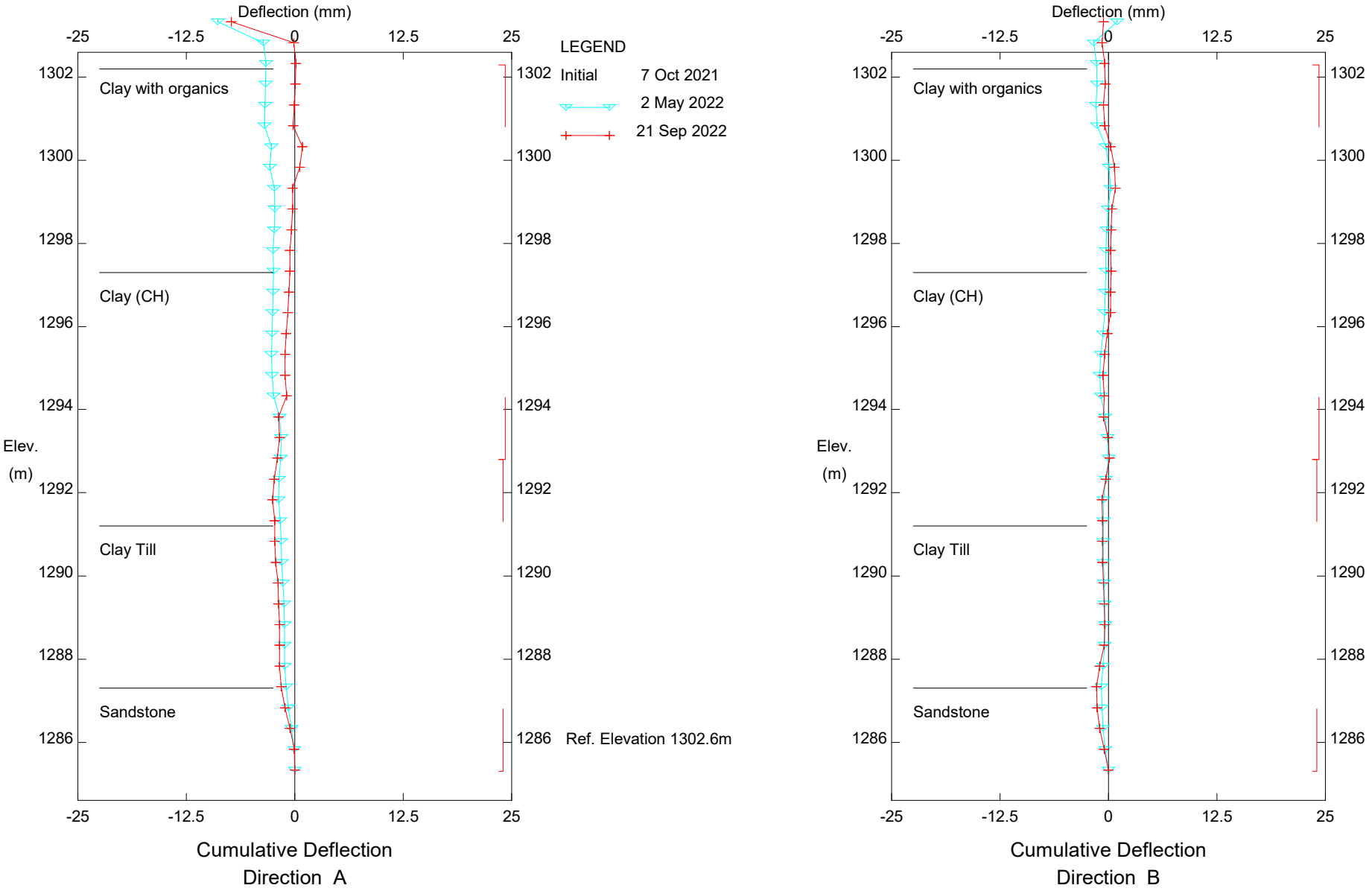
SCALE	PROJECT No.	FIG No.
1:1,500	A05116A03	1

File: Z:\AC\GY\Alberta\A05116A03 ABT Southern Region GRMP400 Drawings\2022\Section C\Section C - Spring 2022\Section C - Spring 2022.aprx Date: Time: Creator: aharrison

APPENDIX I

Instrumentation Plots

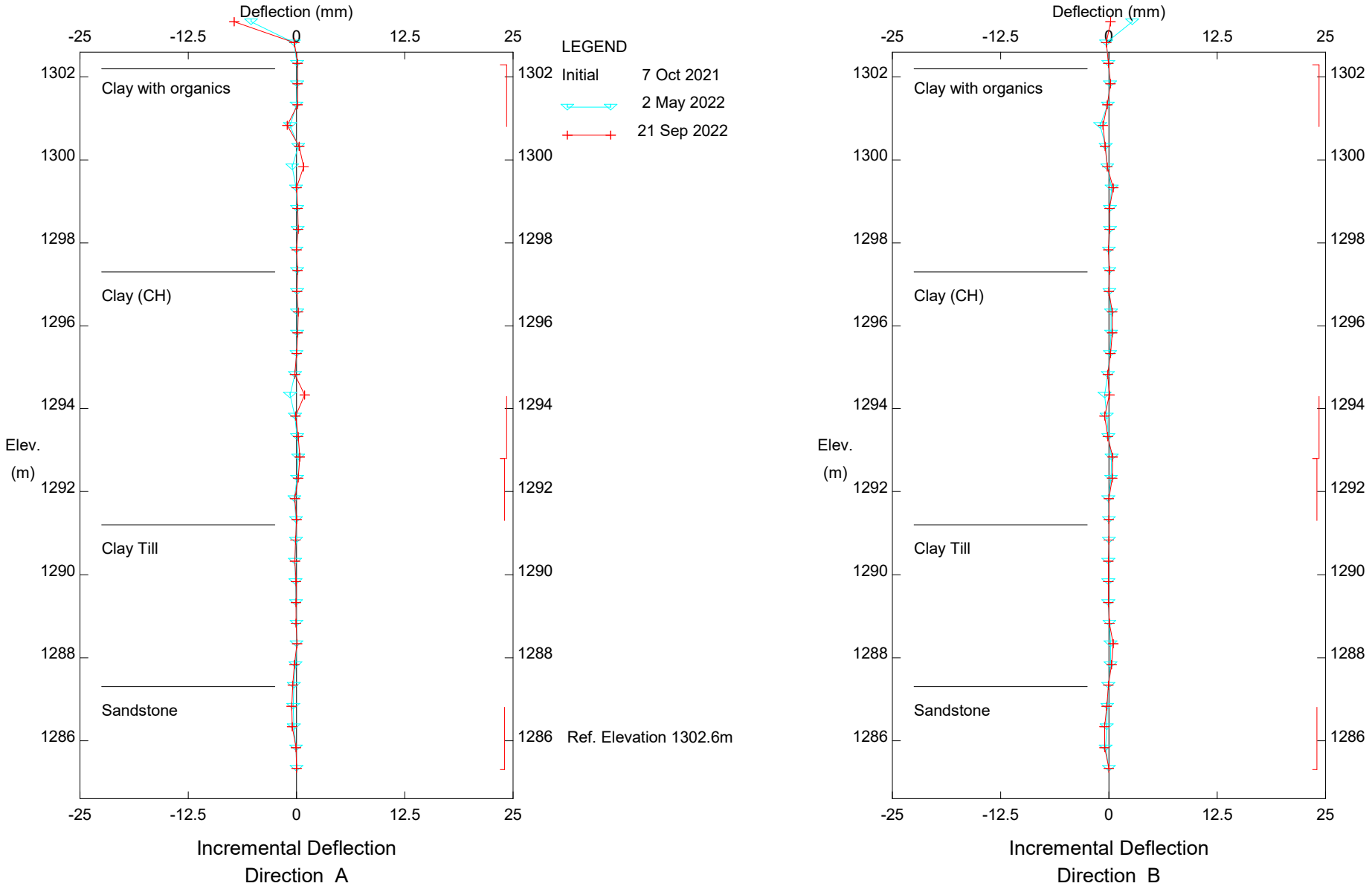
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE15

Alberta Transportation

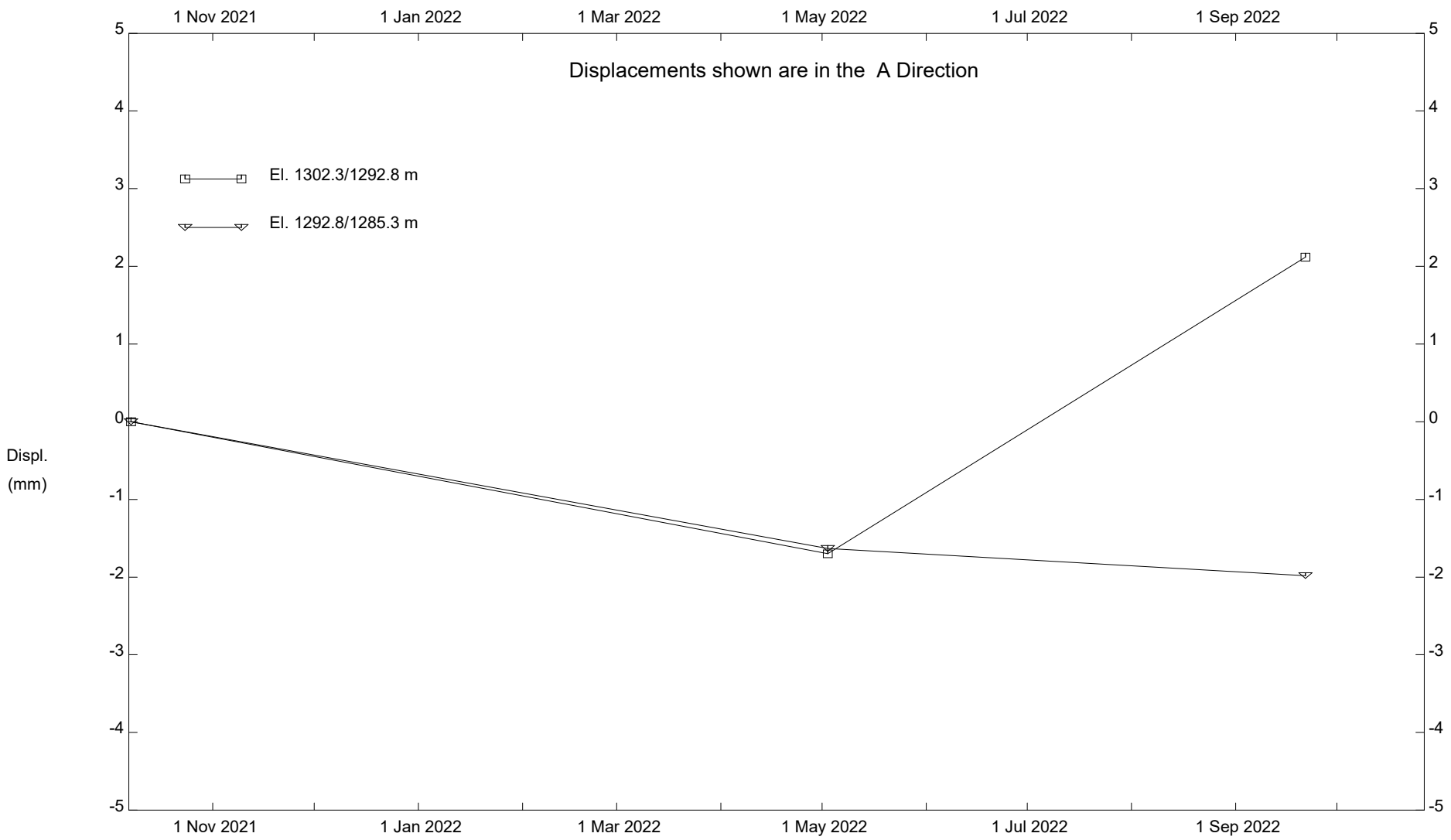
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE15

Alberta Transportation

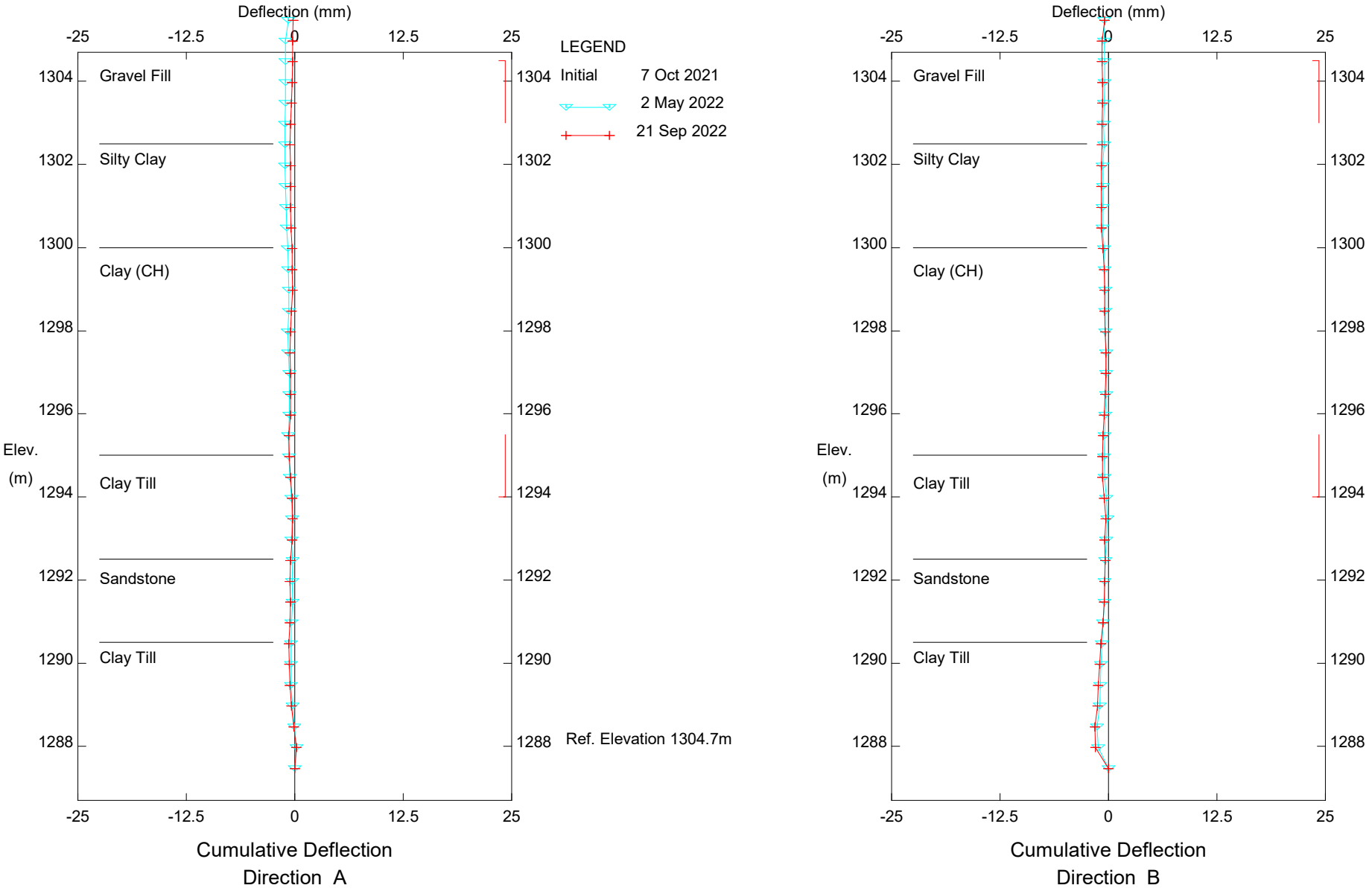
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE15

Alberta Transportation

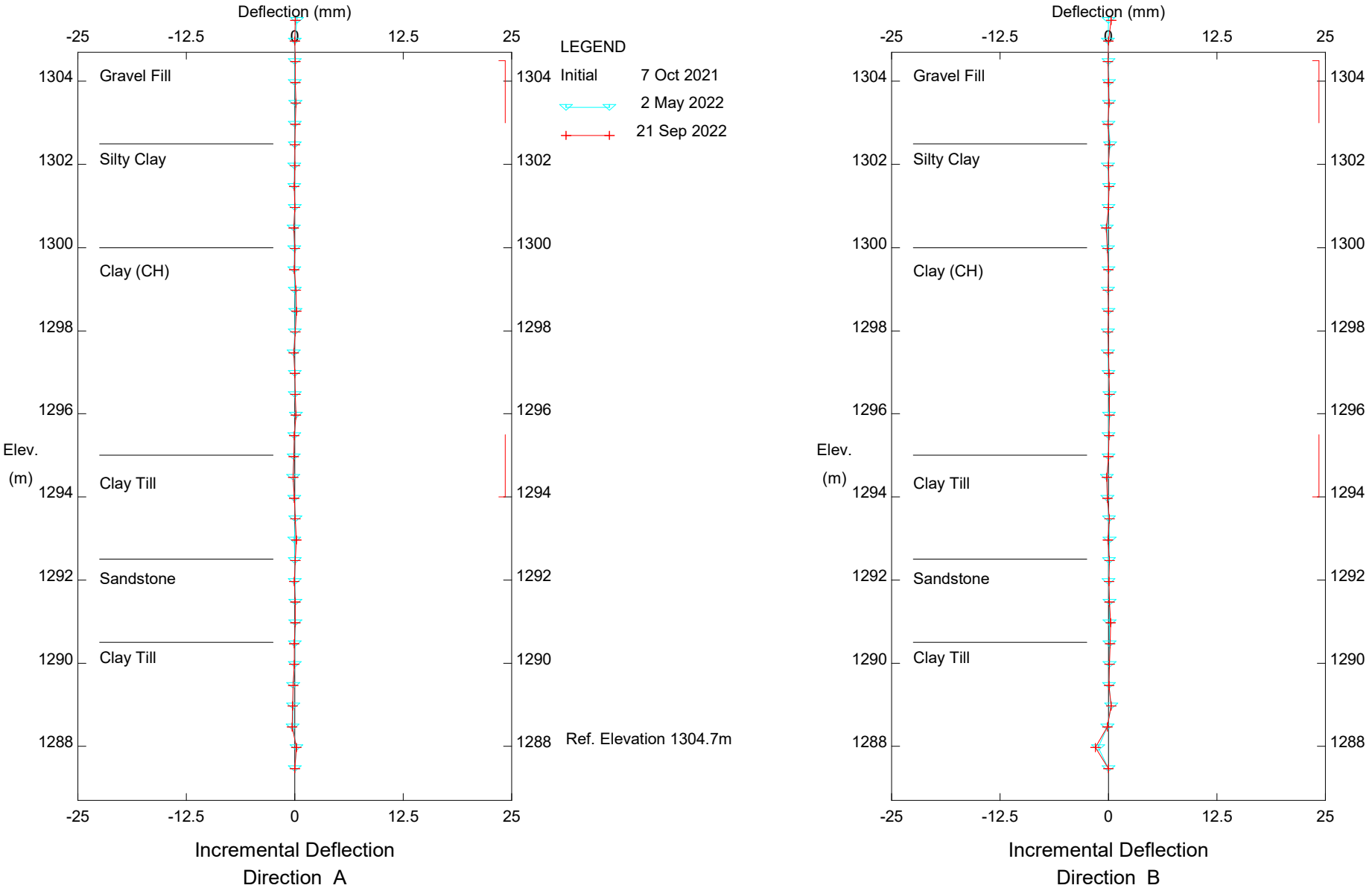
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE29

Alberta Transportation

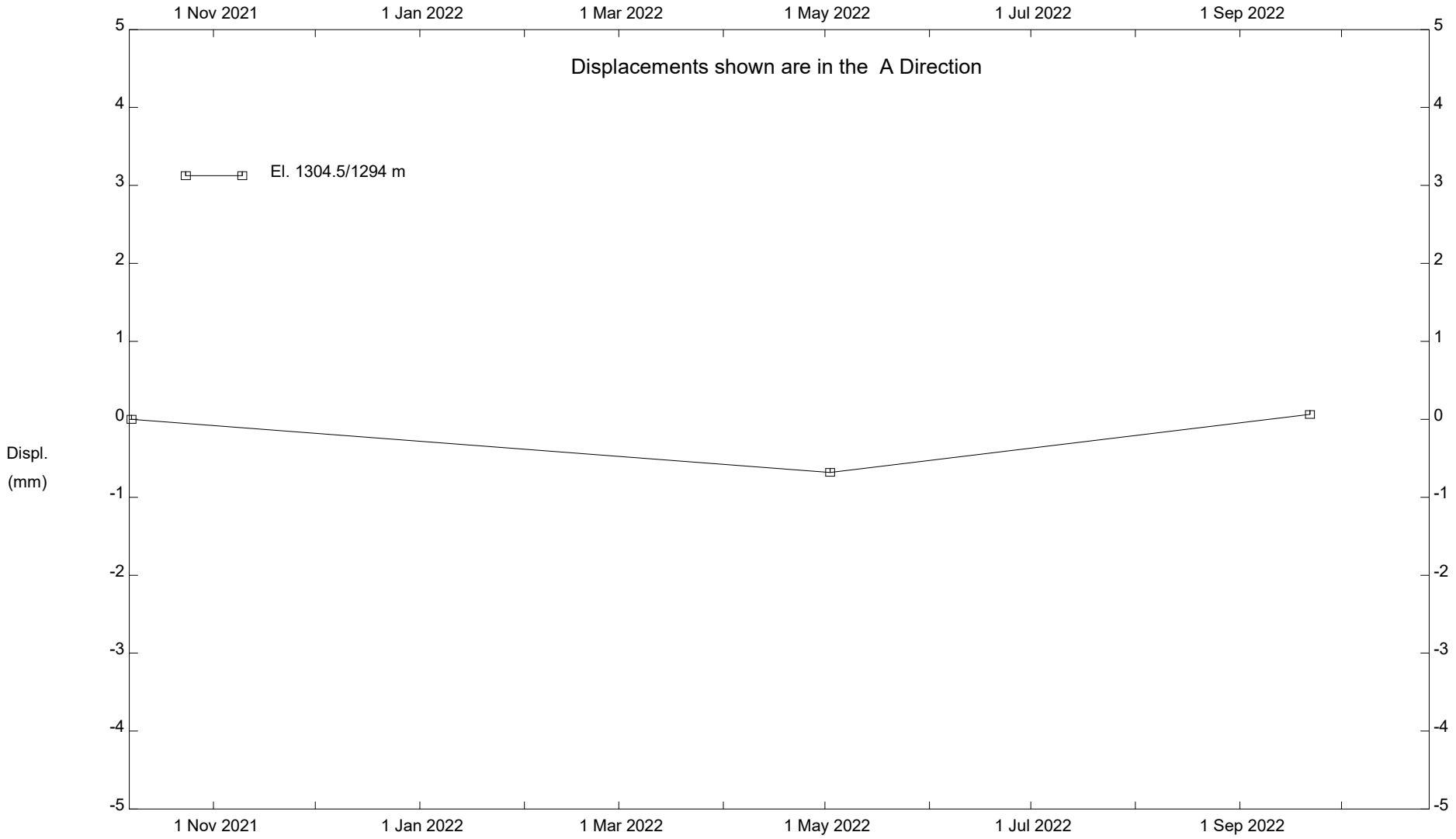
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE29

Alberta Transportation

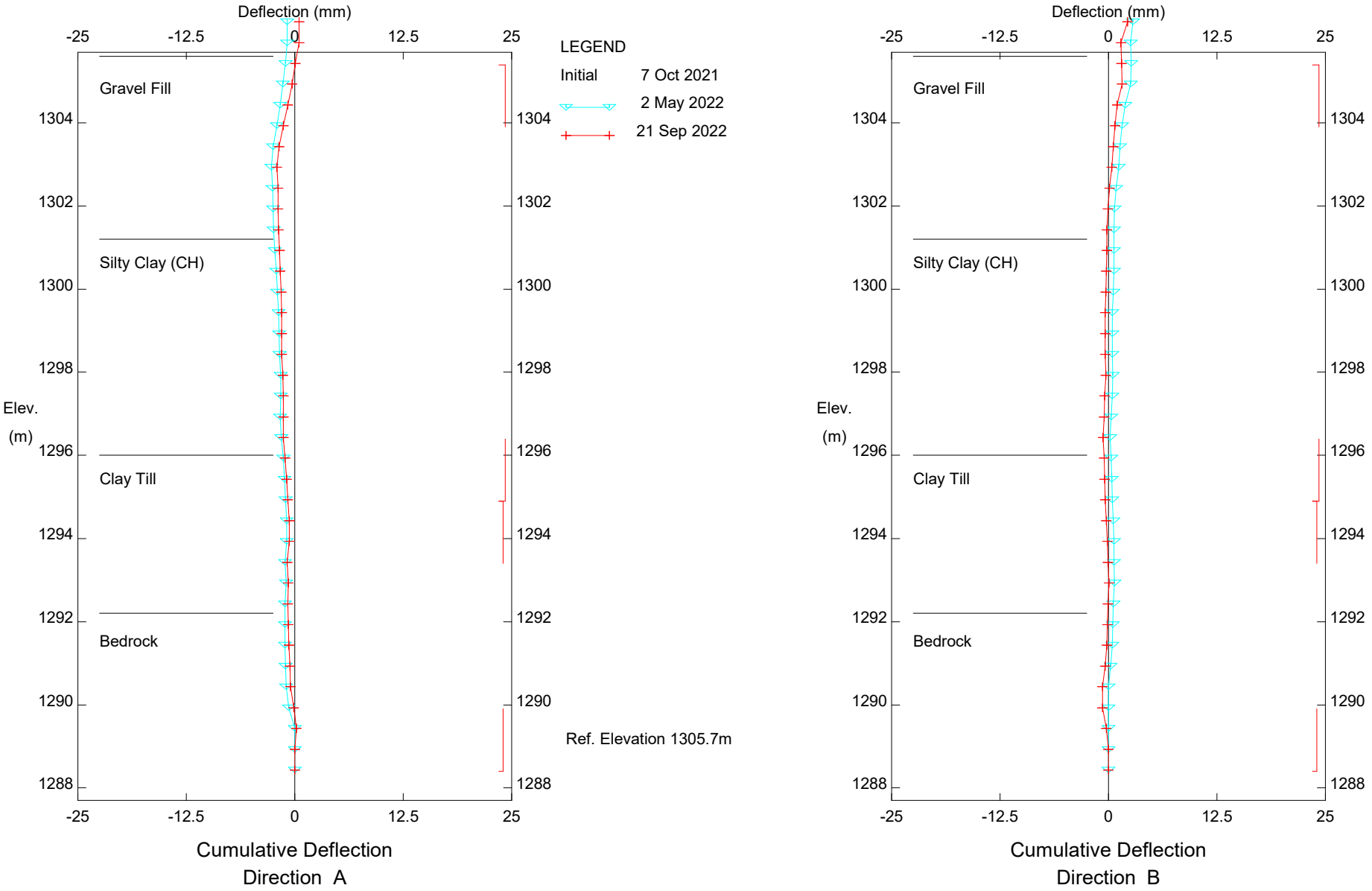
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE29

Alberta Transportation

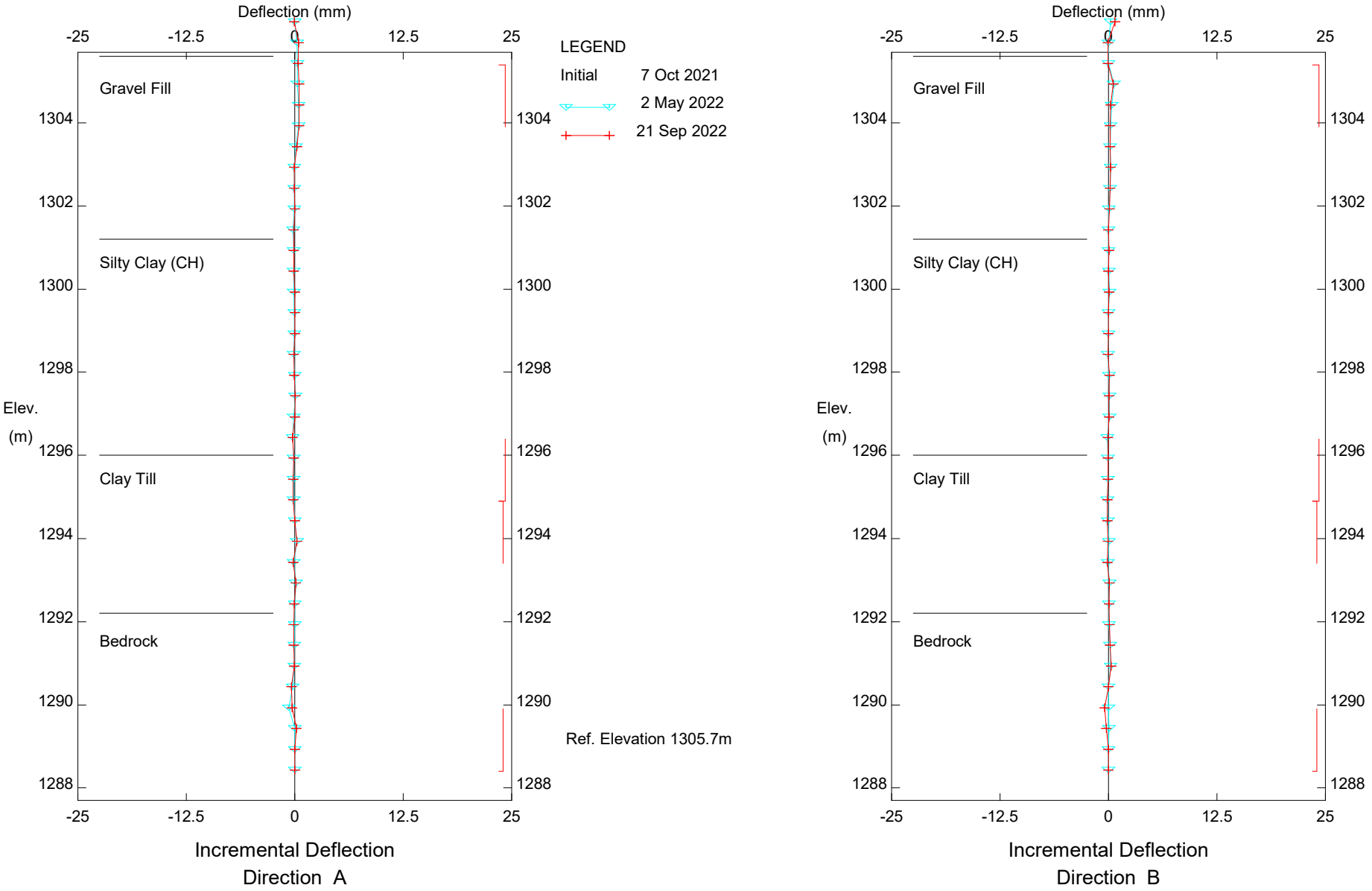
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE36

Alberta Transportation

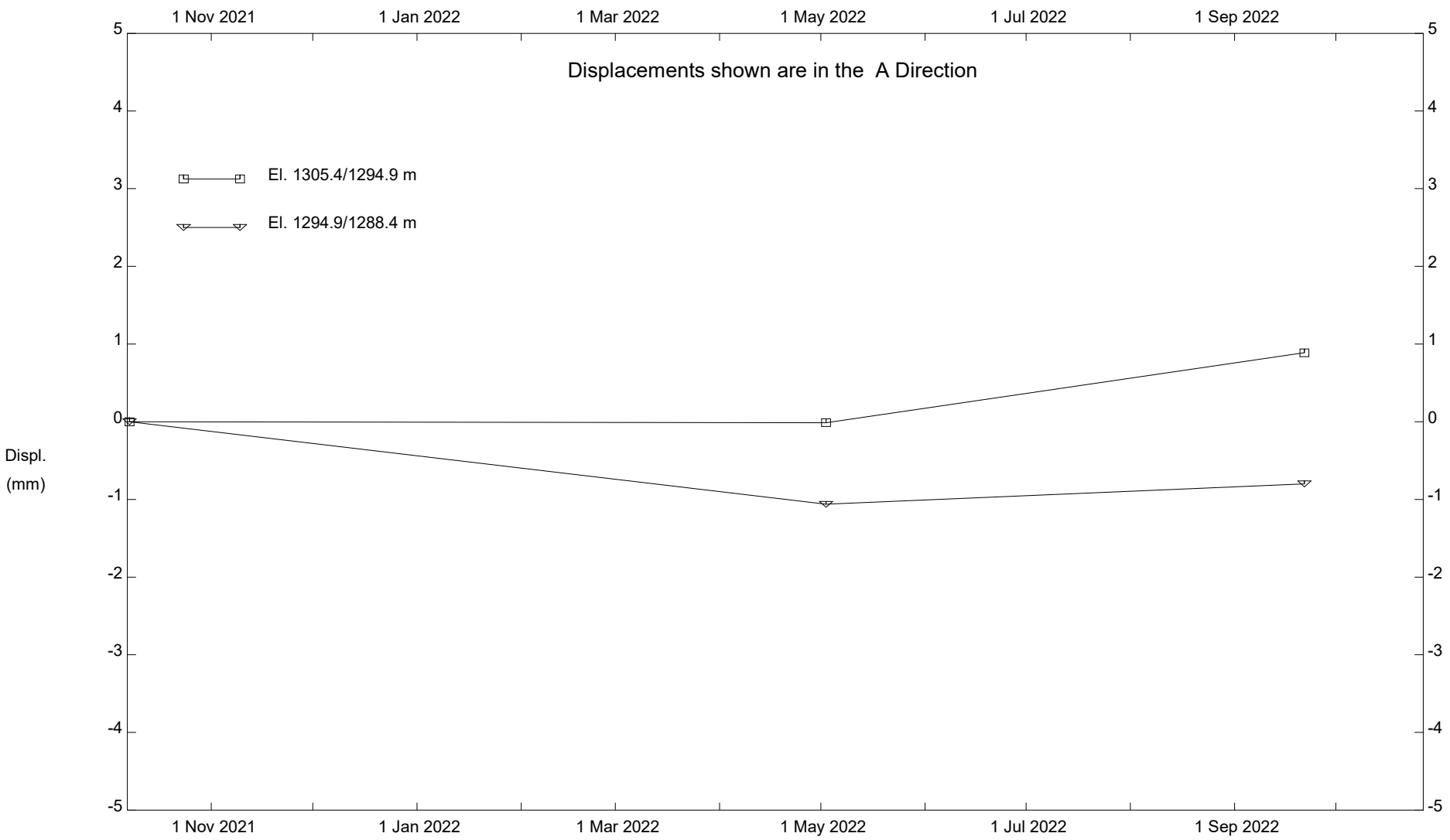
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE36

Alberta Transportation

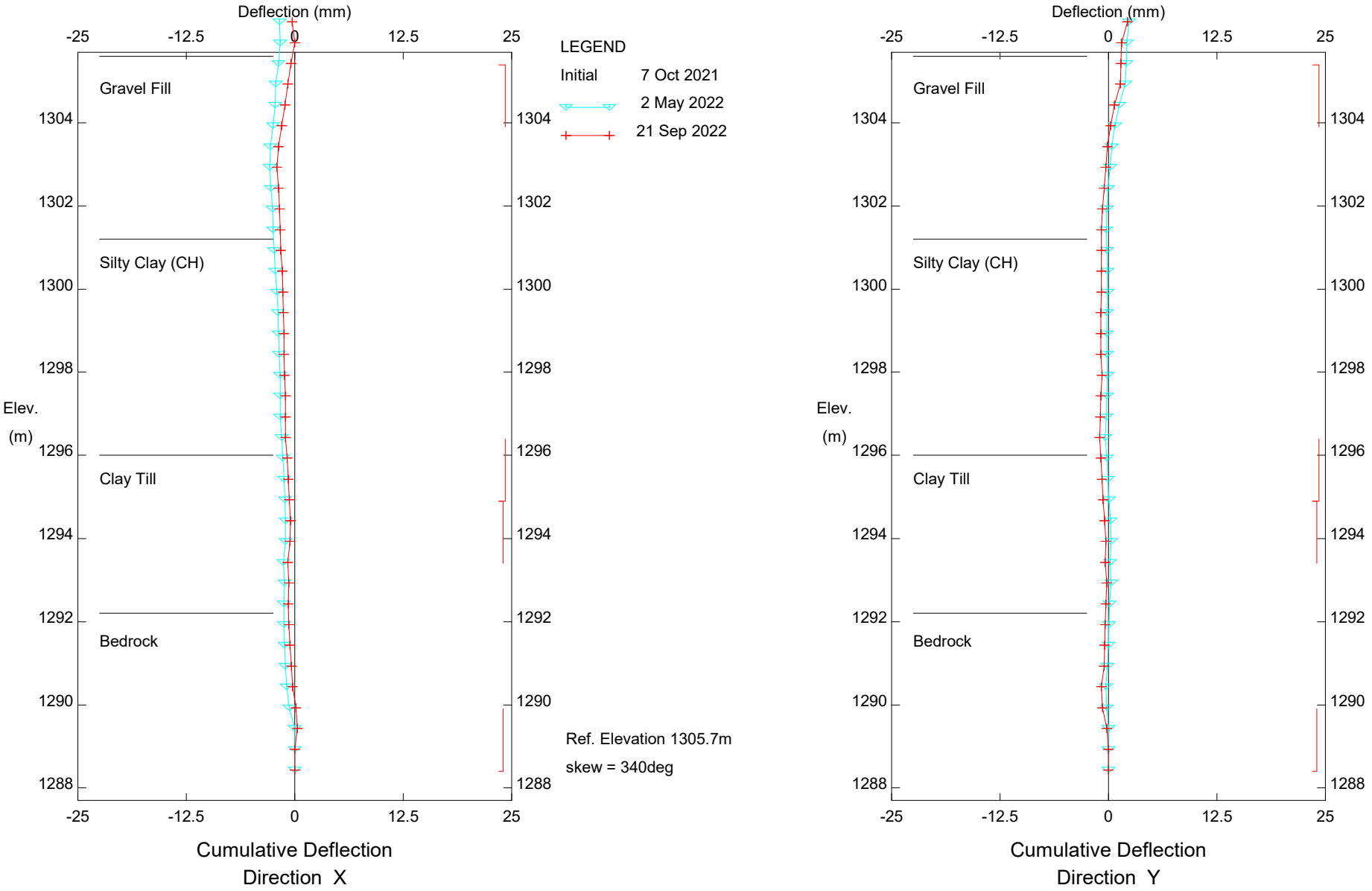
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE36

Alberta Transportation

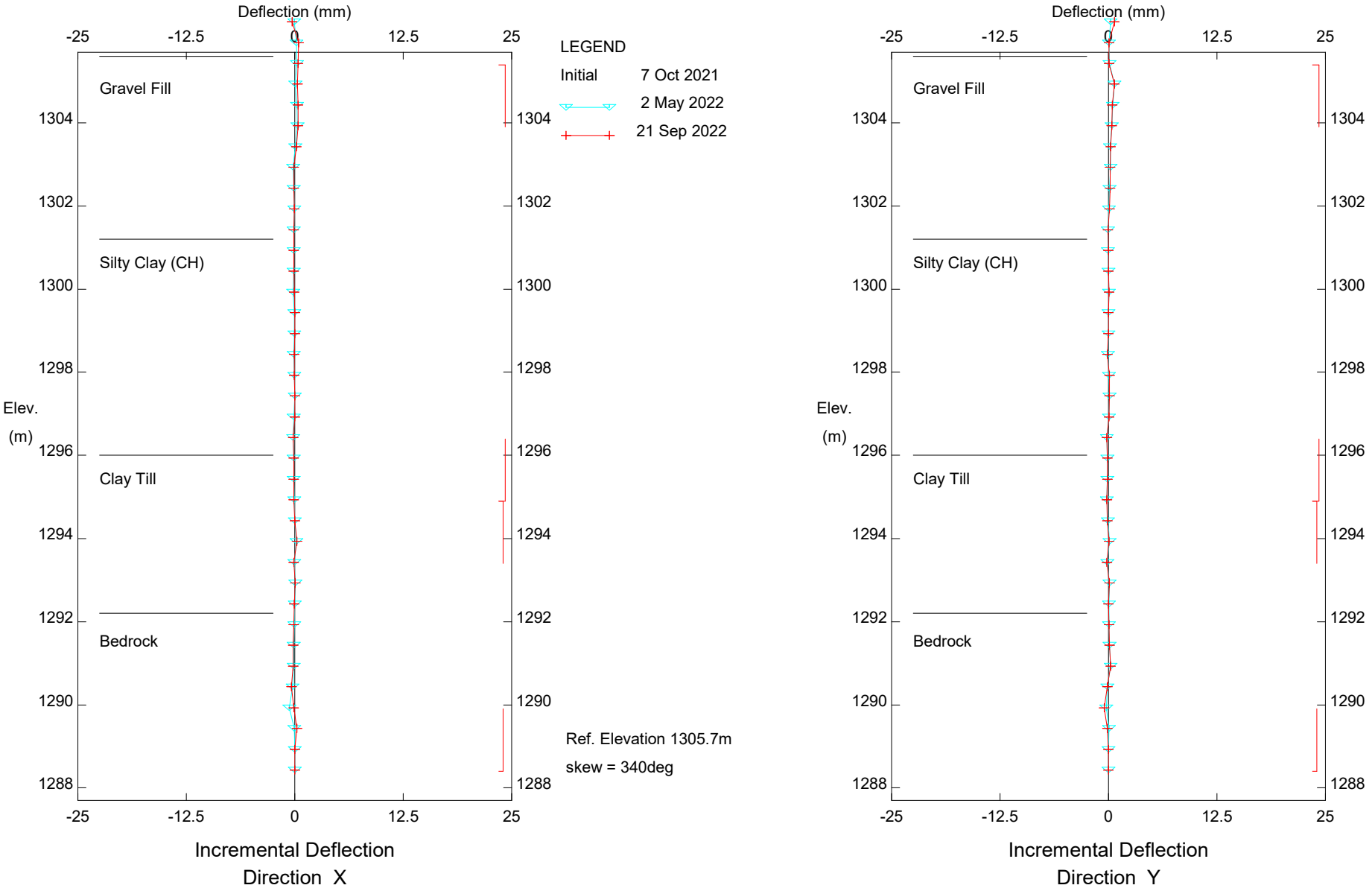
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE36

Alberta Transportation

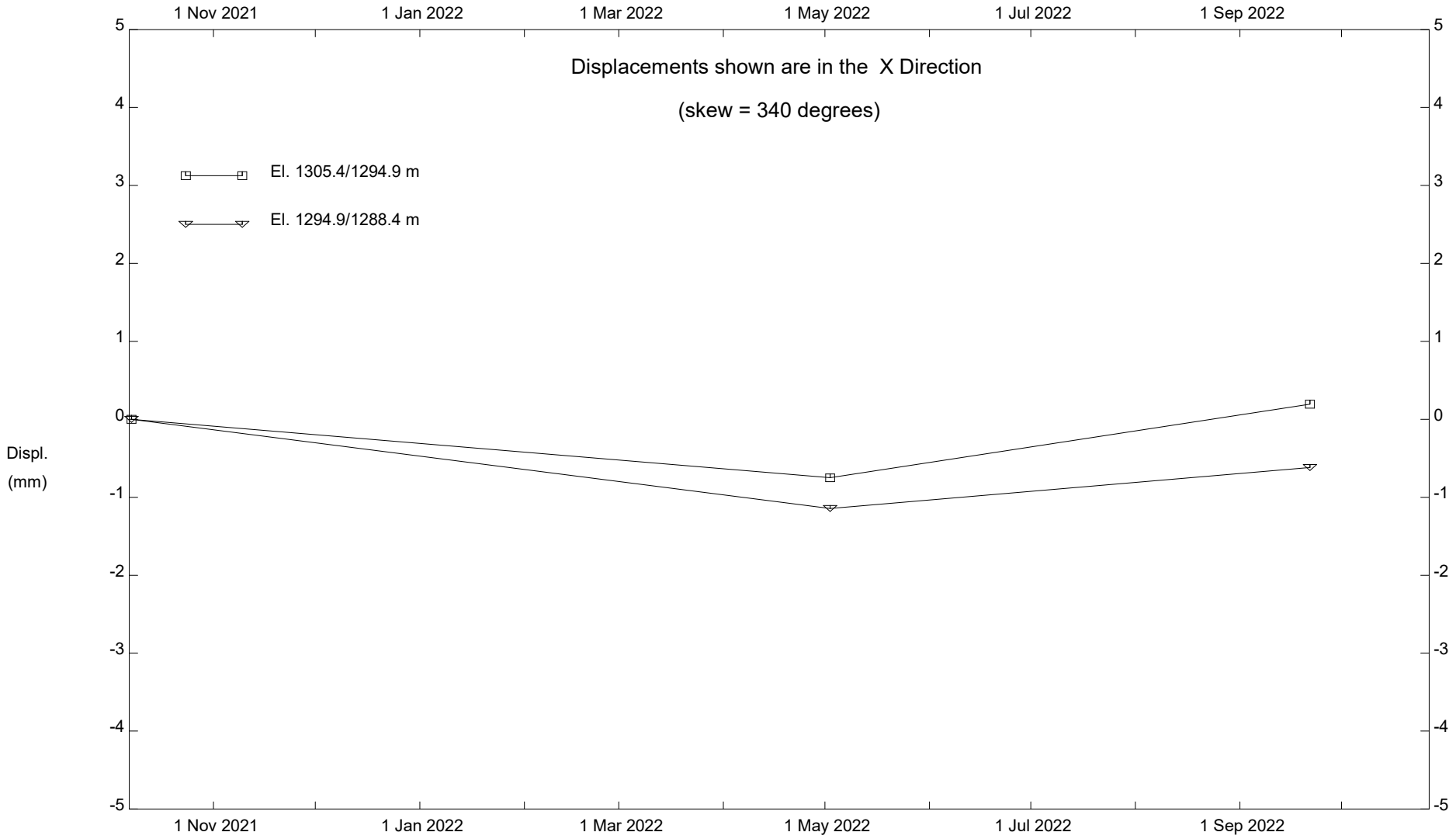
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE36

Alberta Transportation

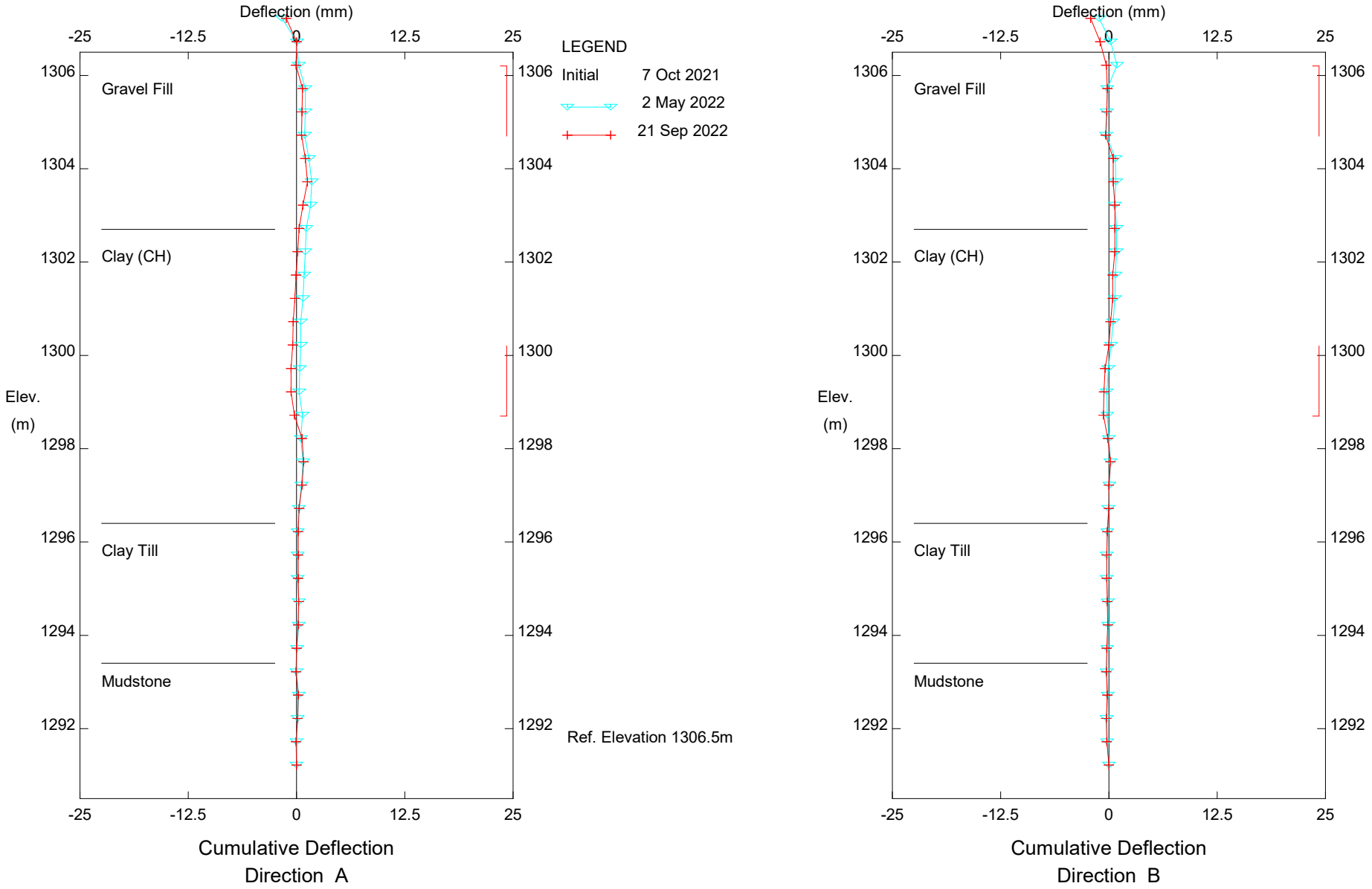
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE36

Alberta Transportation

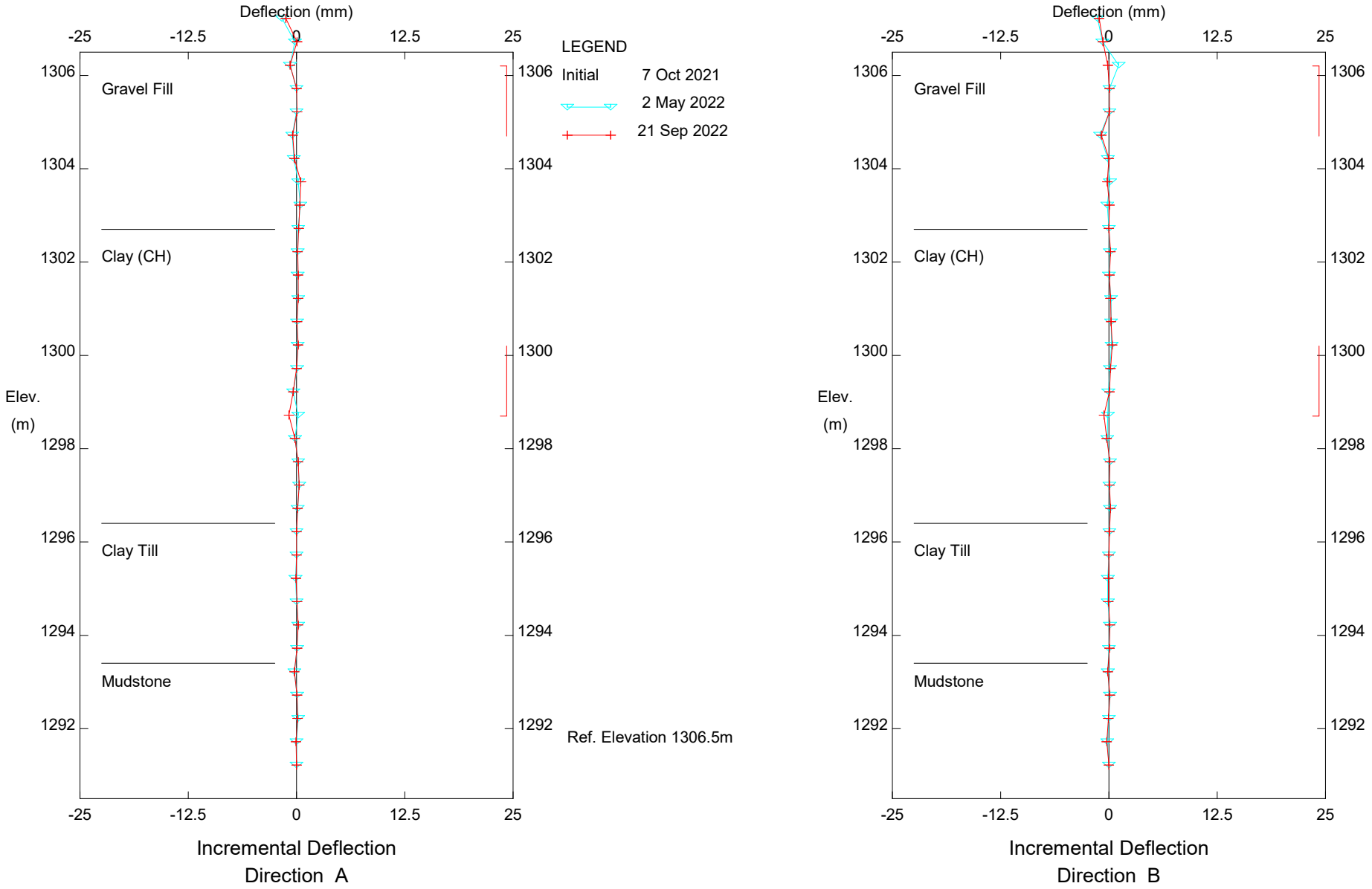
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE43

Alberta Transportation

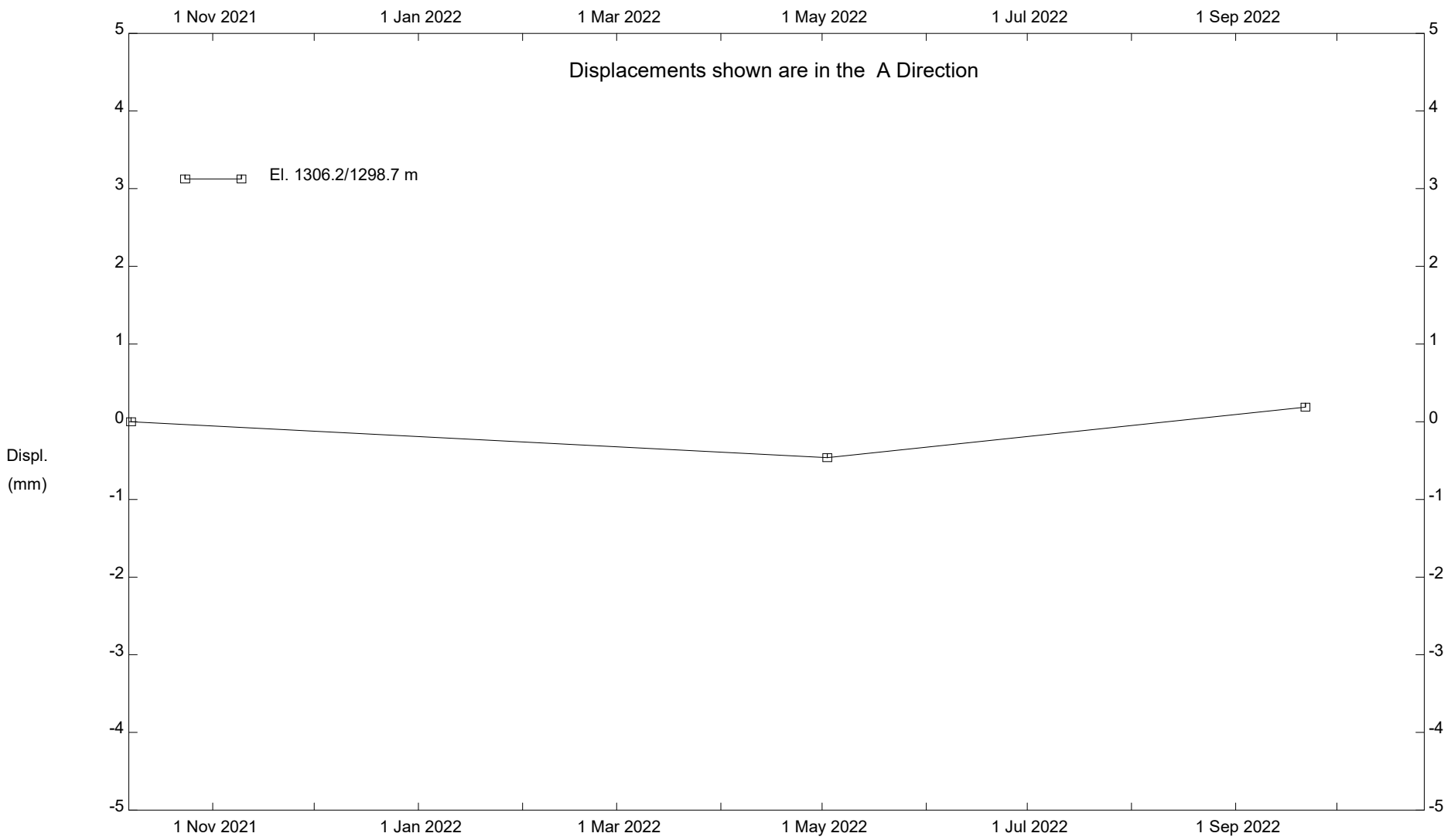
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE43

Alberta Transportation

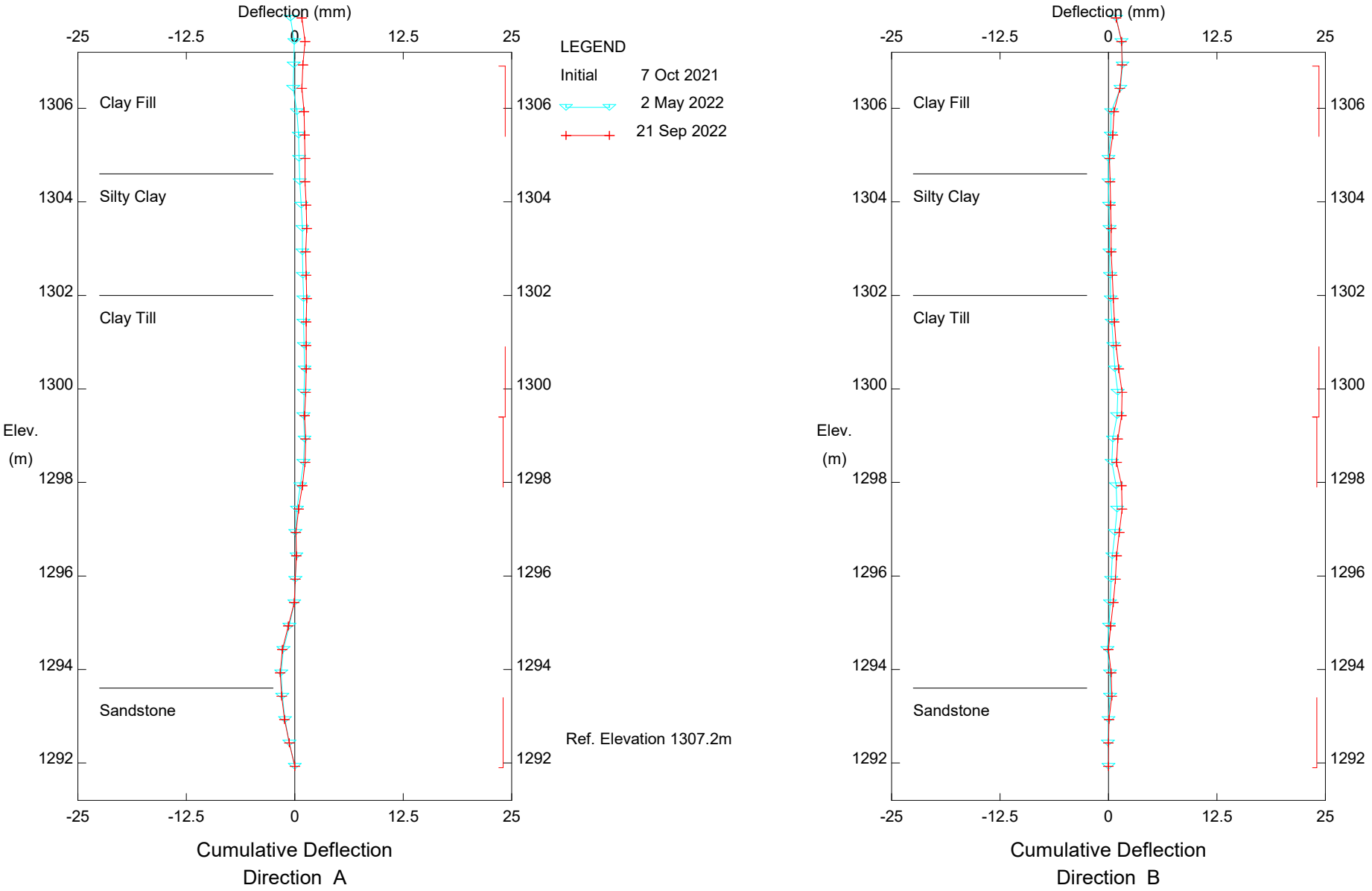
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE43

Alberta Transportation

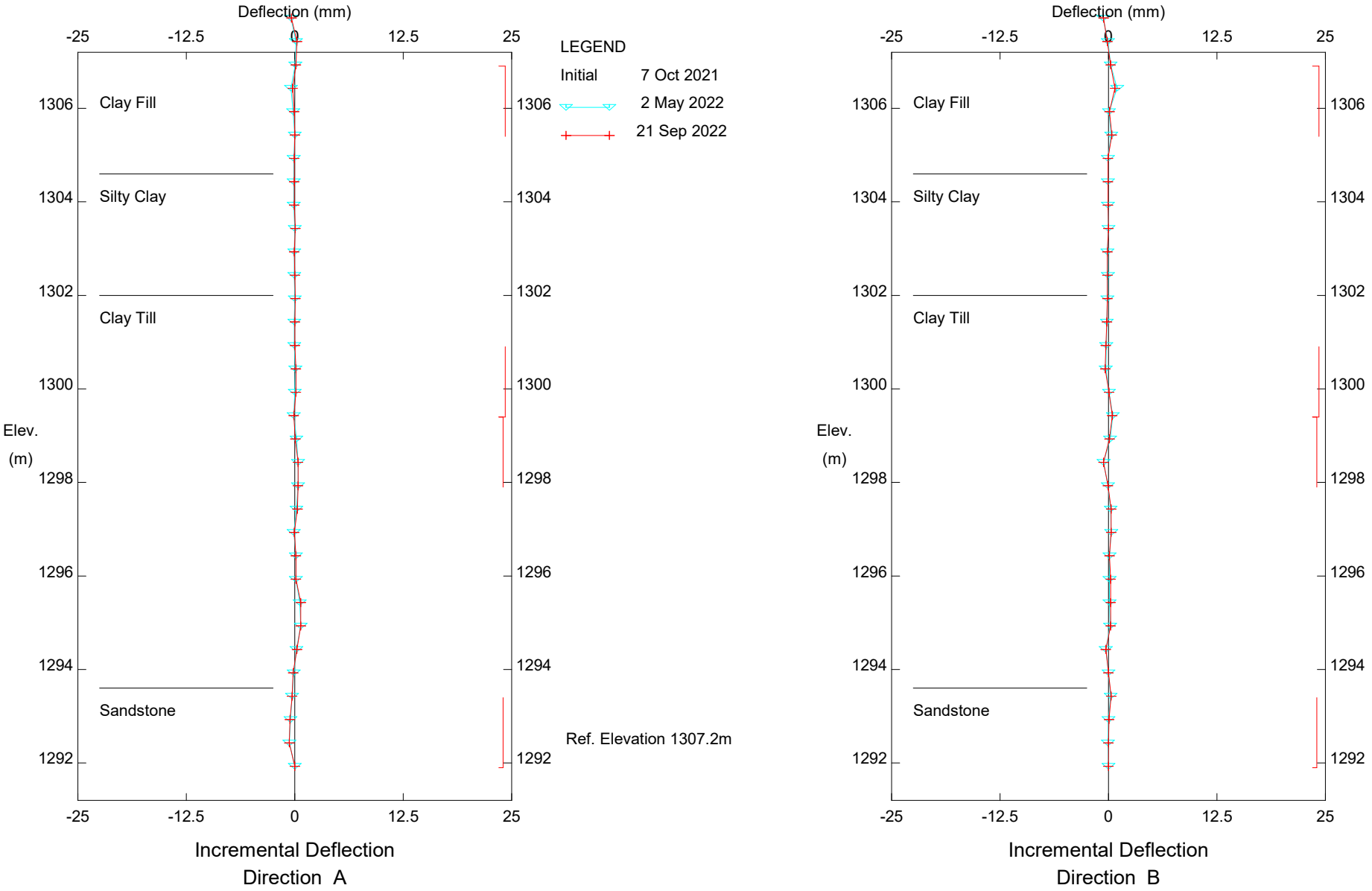
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE49

Alberta Transportation

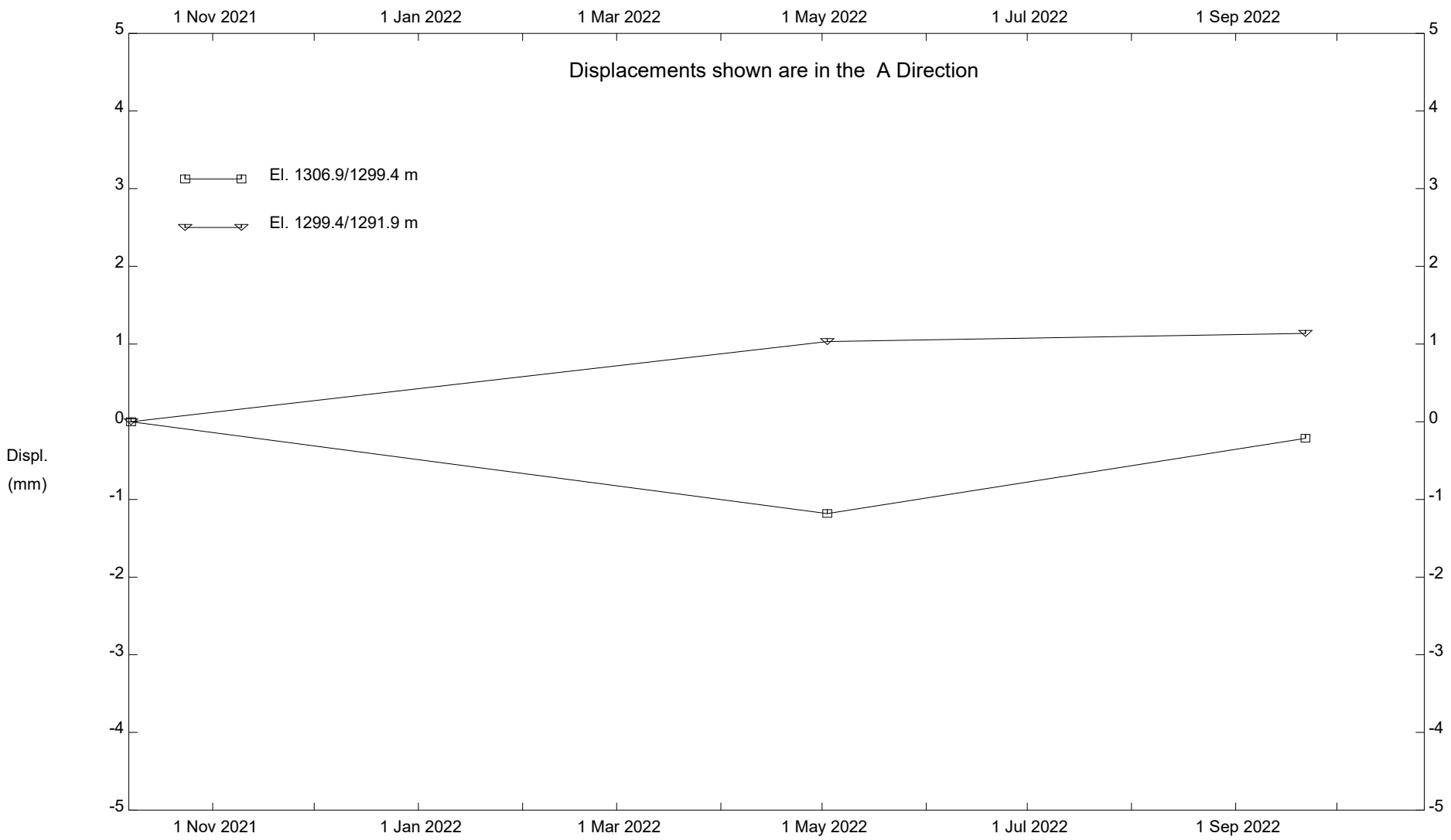
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE49

Alberta Transportation

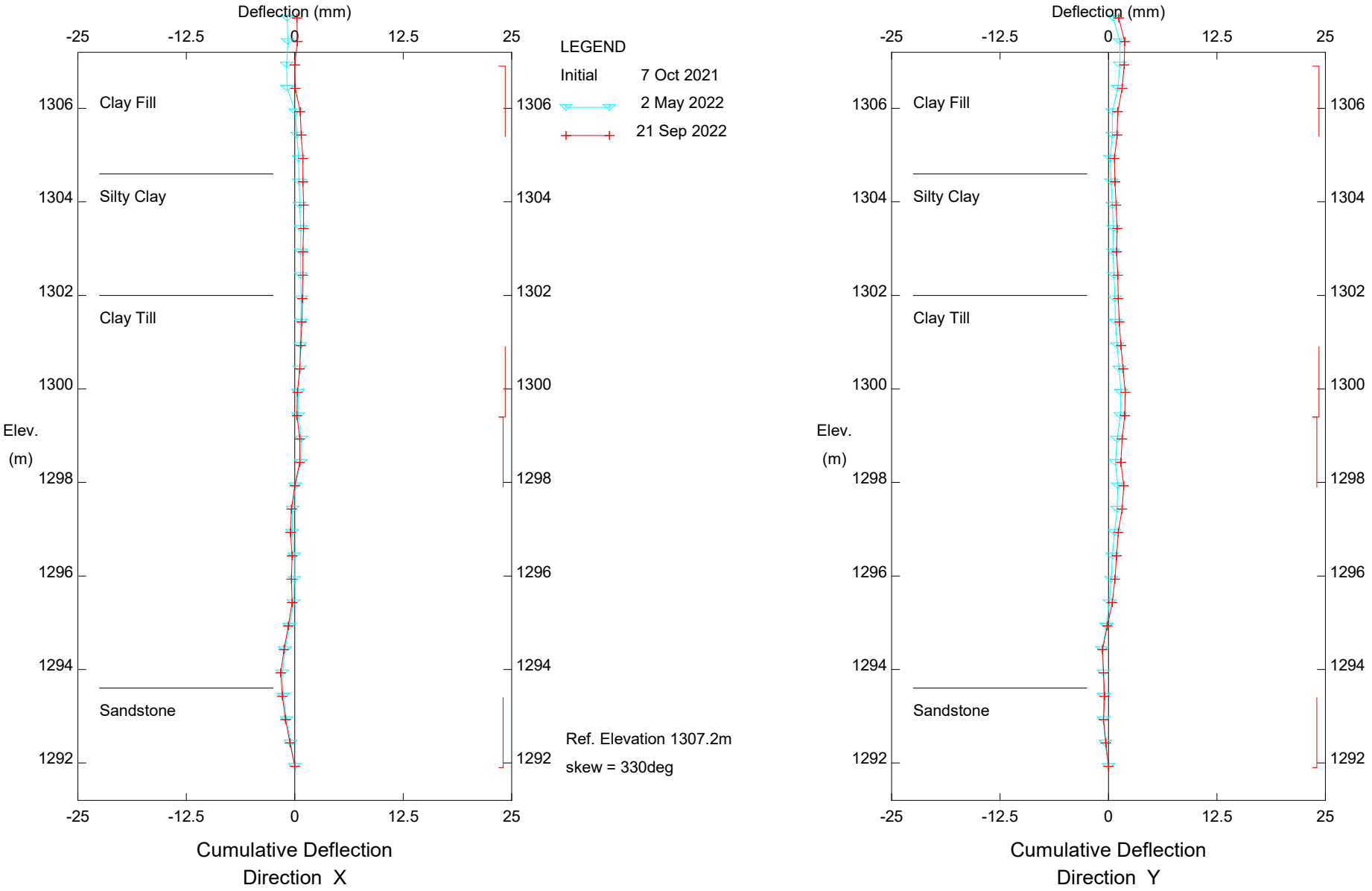
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE49

Alberta Transportation

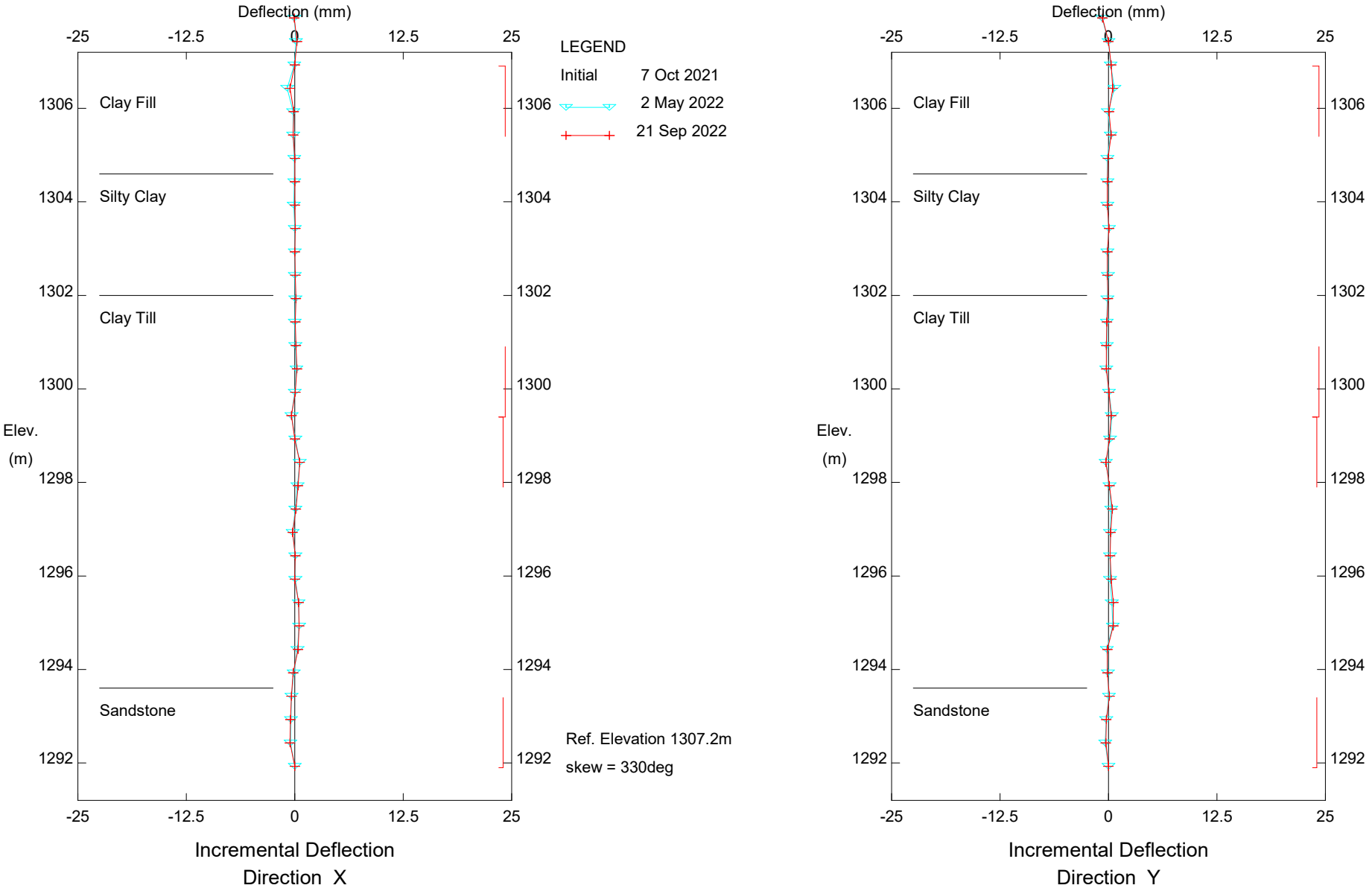
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE49

Alberta Transportation

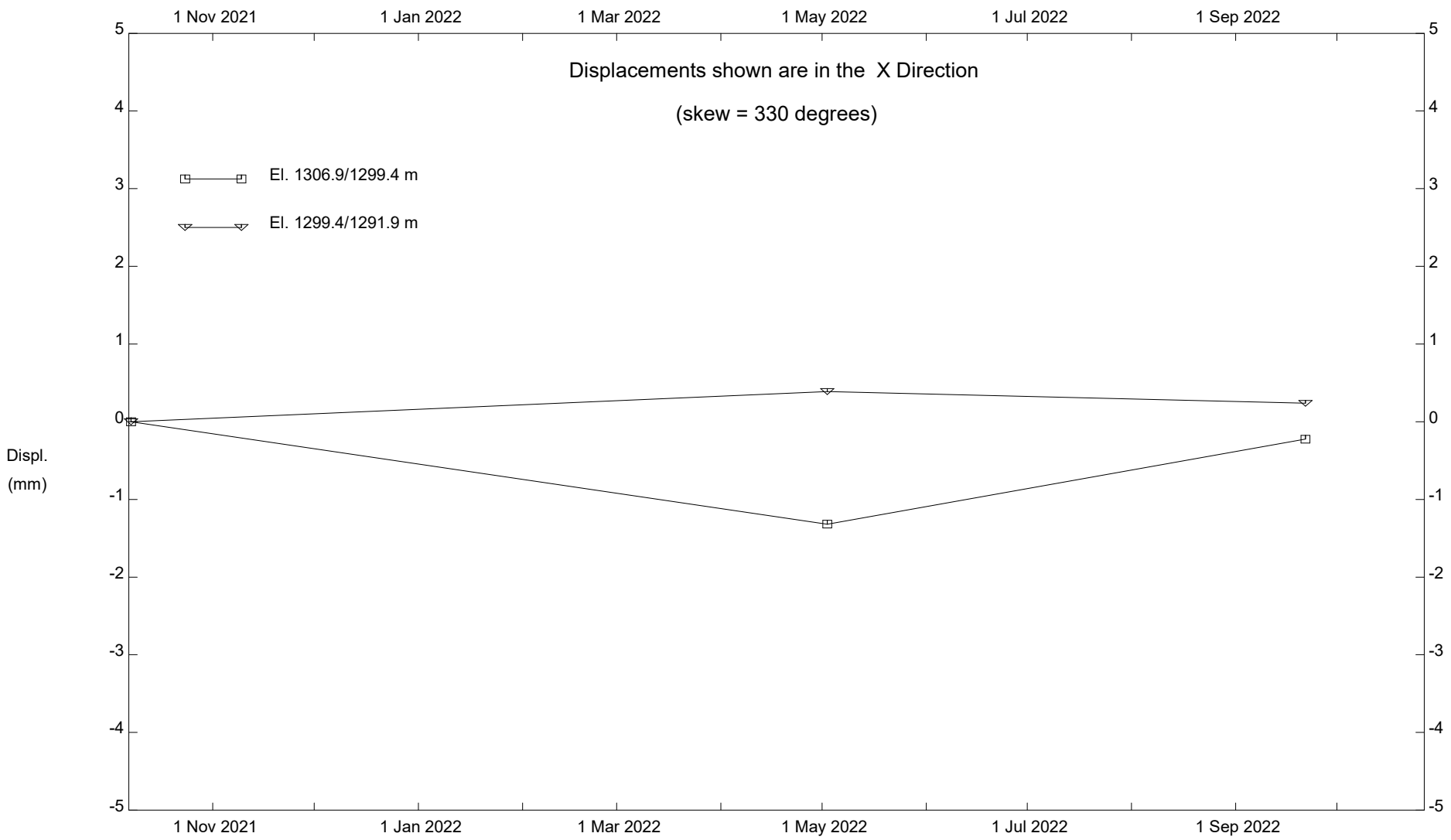
Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE49

Alberta Transportation

Klohn Crippen Berger - Edmonton



S008; H762:02, Fisher Creek, Inclinometer PILE49

Alberta Transportation