July 15, 2025

Alberta Transportation and Economic Corridors
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 S004; H02:08, km 6.284 Willow Creek
Section C – 2025 Spring Readings

1 GENERAL

Six vibrating wire piezometers (VWPs) (VW14-01A/B, VW14-02A/B, and VW14-03A/B) , six standpipe piezometers (SPs) (SP-1B/C, SP-5B/C, SP-9B, and SP-10B) and four slope inclinometers (SIs) (SI-1A, SI-5A, SI-9A, and SI-10A) were read on May 23, 2025, by Mr. Shawn Keegan, E.I.T. of KCB. These instruments were read as part of the Southern Region Geohazard Risk Management Program (GRMP). The site is located at Hwy 02:08 km 6.284, north of Fort Macleod, Alberta, approximately 1.9 km north of the junction of RR 264 and Hwy 2. The approximate site coordinates are 5514351 N, 320169 E (UTM Zone 12, NAD 83). A site plan is presented in Figure 1.

The geohazard at the S004 site consists of a landslide at the outside bend of Willow Creek with the slope crest retrogressing into the northbound lane ditch of Hwy 02:08. Previous remedial actions at the site include soil nailing, grading, bioengineering (live staking), and bank armouring in 2008. A guardrail was also installed in 2014.

In 1994 and 2014, geotechnical site investigations, which included the installation of instruments, were conducted at the S004 site by the previous consultants. Based on the files received from the previous consultant, the encountered stratigraphy was as follows: clay till overlying shale bedrock.

1.1 Instrumentation

KCB has been reading the instruments at this site since readings resumed in the fall of 2020 at the request of Alberta Transportation and Economic Corridors (TEC). No readings were completed at this site between 2003 and 2020. Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1. Any instruments not included in Table 1.1 or shown in Figure 1 are assumed to be inoperable and are not presented or discussed herein.

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In 1994 and 2014, 16 SIs and 41 piezometers were installed at the site by the previous consultants to monitor movement and groundwater conditions, respectively. Some of these instruments are now inoperable (e.g., destroyed, sheared, or lost), including several SIs installed within the slide mass (SI-2A through SI-8A, excluding SI-5A).

In June 2023, data loggers were installed on all six VWPs.

The operable instruments are protected by either a flush-mounted or an above-ground casing protector.

The SI equipment was changed in 2020 when KCB began reading the instruments, and again in October 2021 after the previous equipment became inoperable. Currently, the operable SIs were read using a metric RST Digital MEMS Inclinometer System.

The VWPs and SPs were read using an RST VWP readout box and Water Level Meter, respectively.

Table 1.1 Instrument Installation Details

Instrument ID	Instrument Type	Date Installed[1]	UTM Coordinates[2] (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth[1] (mbgs[3])	Condition
			Northing	Easting				
SI-1A	SI	Jul. 1994	5514354	320200	Unknown	0.8	38.9	Operable
~~SI-2A~~	~~SI~~	~~Jul. 1994~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Inoperable[4]~~
~~SI-3A~~	~~SI~~	~~Jul. 1994~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Inoperable[4]~~
~~SI-4A~~	~~SI~~	~~Jul. 1994~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Inoperable[4]~~
SI-5A	SI	Jul. 1994	5514343	320213	Unknown	0.7	38.2	Operable
~~SI-6A~~	~~SI~~	~~Jul. 1994~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Inoperable[4]~~
~~SI-7A~~	~~SI~~	~~Jul. 1994~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Inoperable[4]~~
~~SI-8A~~	~~SI~~	~~Jul. 1994~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Inoperable[4]~~
SI-9A	SI	Jul. 1994	5514472	320115	971.2	0.6	38.7	Operable
SI-10A	SI	Jul. 1994	5514542	320186	971.0	0.8	38.8	Operable
SP-1B	SP	Jul. 1994	5514354	320200	970.0	0.8	Unknown	Operable
SP-1C	SP	Jul. 1994	5514354	320200	970.0	0.6	Unknown	Operable
SP-5B	SP	Jul. 1994	5514343	320213	970.0	0.7	Unknown	Operable
SP-5C	SP	Jul. 1994	5514343	320213	970.0	0.7	Unknown	Operable
SP-9B	SP	Jul. 1994	5514472	320115	971.1	0.6	Unknown	Operable
~~SP-9C~~	~~SP~~	~~Jul. 1994~~	~~5514472~~	~~320115~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~Inoperable[4]~~
VW14-01A	VWP	Jul. 2014	5514310	320229	968.8	N/A	14.7	Operable
VW14-01B	VWP	Jul. 2014	5514310	320229	968.8	N/A	6.0	Operable
VW14-02A	VWP	Jul. 2014	5514449	320122	969.2	N/A	14.8	Operable
VW14-02B	VWP	Jul. 2014	5514449	320122	969.2	N/A	6.1	Operable
VW14-03A	VWP	Jul. 2014	5514367	320141	969.0	N/A	14.9	Operable
VW14-03B	VWP	Jul. 2014	5514367	320141	969.0	N/A	5.9	Operable

Notes:
[1] Instrument installation details taken from reports and data files prepared or provided by the previous consultant(s) or Alberta Transportation.
[2] Coordinates were obtained by KCB with a handheld GPS. The handheld GPS had an accuracy of ±5 m.
[3] Meters below ground surface (mbgs).
[4] Instruments (SI-2A through SI-8A, excluding SI-5A, and SP-9C) located within the slide mass are assumed inoperable.

2 INTERPRETATION

2.1 General

The SI plots presented in the report include cumulative displacement, incremental displacement, and displacement-time data (Appendix I). The displacement-time data is plotted in the A-direction (i.e., the direction of the A0-groove). In 2016, KCB performed a reinitialization of the SI data after taking over the instrument readings. Since October 2021, KCB has been using a new Inclinometer Probe and Reel, which might lead to slight differences in data compared to earlier readings. However, during the review of the SI data for this report, all prior data corrections were removed to facilitate better interpretation of displacement trends.

For the operable SPs, the recorded water levels were converted to equivalent water/piezometric elevations and plotted relative to the ground surface elevation. Screen elevations are not available for the SPs.

For the operable VWPs, 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.

Three data loggers were installed on six VWPs in early June 2023, with one logger per two VWPs in the same borehole. Data were downloaded in May 2024, September 2024, and May 2025 to analyze whether irrigation affects the groundwater. In May 2025, new batteries were inserted into VWP 14-03A/B after the initial batteries failed. It has been observed that the batteries are depleting faster than expected, possibly due to moisture buildup inside the loggers. This issue warrants ongoing monitoring. The loggers are housed in bags and taped, although moisture may still penetrate.

Monthly precipitation data is also plotted with the piezometer data. The data was obtained from the Alberta Climate Information Service (ACIS) database, referencing legal subdivision TWP009-26-W4. At the time of issuing this report, data up to the end of December 2024 was available.

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, Table 2.2, and Table 2.3, respectively. The SI data plots only include data acquired by KCB, as data records obtained by previous consultants have not been provided. Furthermore, SI-10A and SP-10B were first read by KCB during the 2022 Fall reading cycle.

2.2 Zones of Movement

Historical reports from 1999 to 2003, prepared by the previous consultant, indicated that no significant movements had been measured for the operable SIs (SI-1A, SI-5A, SI-9A, and SI-10A) that were recorded. Since these SIs are located outside the slide mass, such stability is not unexpected. Since KCB re-initialized the readings in September 2020 baseline—coinciding with changes to the SI equipment—no apparent movement has been observed in SI-5A, and SI-9A. However, data from SI-SI-10A suggest a possible shear plane at about 6 meters below the ground surface, which could be another block hiving off near the prairie elevation, a kinked casing, or a movement that has ceased

since May 2024. Additional information is still needed to evaluate the movement trends of this instrument.

2.3 Interpretation of Monitoring Results

The SI data obtained with KCB's new SI reading equipment appears relatively noisy (despite good data quality) compared to the baseline reading obtained with KCB's old SI reading equipment and is difficult to interpret, especially for SI-5A (the instrument has been read multiple times during both the spring and fall readings since 2022). It is unclear whether the noise is due to changes in the SI reading equipment, the low rate of movement being recorded by these instruments, or installation issues (e.g., a kinked or tilted casing). Based on the plots for these instruments, it is noted that the casing for:

- SI-1A is "wavy" with kinks at approximately 22 m, 28 m, 30 m and 36 m below the ground surface.
- SI-5A is tilted approximately 1.0 m in the A-direction and 1.7 m in the B-direction, and there is also a kink in the casing at approximately 22 m below the ground surface.
- SI-9A is "wavy" with kinks at approximately 5 m, 11 m, and 25 m below the ground surface.
- SI-10A is "wavy" with kinks at approximately 6 m and 25 m below the ground surface.

The SI data plots presented herein include data for readings taken with both our new and old SI reading equipment. More data is needed to assess if the instruments need to be re-initialized.

Data is not available for the SIs and PNs between 1994 and 2020 or the VWPs between 2015 and 2020. More data is needed to assess long-term trends for these instruments, especially in response to prolonged or heavy periods of rainfall or freshet infiltration.

The nature of sliding (back tilting blocks) observed on site suggests a combination of rotational failure and failure along a weak layer at depth. The right (south) flank of the slide appears to be retrogressing faster than other areas of the slide.

Since KCB took over reading the instruments in 2020, decreasing water levels have generally been recorded in most of the piezometers. The spring 2025 SP readings show a general trend of consistent water levels, other than SP-10B, which increased by 1 m. The VWPs show a decrease in water levels in the Spring 2024 readings compared to the Fall 2024 readings.

Overall, measured groundwater levels from the VWPs declined from fall 2024 to spring 2025, with the largest drop of 1.0 m recorded at VWP14-01B. Rainfall data from station T009R26W4 only covers up to December 31, 2024, at the time this report was written. The available data suggest that rainfall and snowmelt contribute to rising water levels in the VWPs, although levels generally decrease during the summer season. VWP14-01B is the most responsive to precipitation, showing sharp increases in water level following rainfall events.

Based on the VWP data logged so far, irrigation does not seem to impact water levels. However, additional data is necessary to identify trends and understand how seasonal changes in water levels may influence slope stability. It is also important to note that the VWPs are located outside the slide mass, possibly indicating higher groundwater levels than within the slide itself.

The highest recorded water level increase is from the 1994 reading for SP-05C; however, this was most likely inaccurate, as it is approximately 10 m lower than the previous and current readings.

Water levels recorded in the nested VWPs installed between the highway and crest of the slide (VW14-01A/B and VW14-02A/B) varied from an approximate depth of 1.3 m to 3.4 m below ground surface in the upper “B” tips and 7.0 m to 12.1 m below ground surface in the lower “A” tips. Both the upper “A” tips have a similar elevation (El. 962.8 m and El. 963.1 m, respectively), and both the lower “B” tips have a similar tip elevation (El. 954.1 m and El. 954.4 m, respectively).

Water levels recorded in the nested VWPs installed in the median ditch of Hwy 02:08 (VW14-03A/B) were at approximate depths of 0.9 m and 5.5 m below ground surface in the upper “B” tip and the lower “A” tip, respectively, as of the most recent readings.

The data recorded in the piezometers, specifically the upper versus lower SP screens/VWP tips, indicate that there could be two independent water levels, which may suggest the presence of a perched water table.

Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	Direction of Movement	Movement (mm)				Rate of Movement (mm/year)		
	Initialized[2] (Re-initialization)[3]	Previous Maximum Cumulative Movement Recorded[2]	Previous Reading	Most Recent Reading				Maximum Cumulative			Incremental Since Previous Maximum Cumulative	Previous Maximum	Most Recent Reading	Change from Previous Reading
								Initialization	Re-Initialization	Total				
SI-1A	1994 (Sep. 23, 2020)	N/A	September 24, 2024	May 23, 2025	970.0	2.0 m – 30.0 m	A-Direction	N/A	2.6	2.6	1.0	5.4	1.5	-3.9
SI-5A	1994 (Sep. 23, 2020)	June 15, 2023	September 24, 2024	May 23, 2025	970.0	14.1 m – 38.6 m	A-Direction	N/A	-4.6	-4.6	9.6	22.5	-14.6	7.9
SI-9A	1994 (Sep. 23, 2020)	N/A	September 24, 2024	May 23, 2025	971.2	N/A		N/A				N/A		
SI-10A[3]	1994 (Sep. 23, 2020)	May 15, 2024	September 24, 2024	May 23, 2025	971.0	4 m – 6 m	X-Direction 45°	N/A	1.03	1.03	0.3	1.6	0.5	1.1

Notes:
[1] Meters below ground surface (mbgs).
[2] Movement recorded before 2020 was taken from reports prepared by the previous consultant.
[3] SI#1A, 5A, 9A, and 10A were re-initialized in September-2020 when KCB took over the readings from the previous consultant and changed the SI reading equipment.
[4] no discernible movement recorded since re-initialization, and historical data was not provided for KCB's review.

Table 2.2 Standpipe Piezometer Reading Summary

Instrument ID	Geologic Installation Unit	Date			Ground Surface Elevation (m)	Screen 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)
SP-1B	Clay Shale	Jul. 1994	September 24, 2024	May 23, 2025	970.0	Unknown	13.8	13.7	0.1
SP-1C	Not Provided	Jul. 1994	September 24, 2024	May 23, 2025	970.0	Unknown	15.8	15.8	0.0
SP-5B	Clay Shale	Jul. 1994	September 24, 2024	May 23, 2025	970.0	Unknown	13.6	13.4	0.2
SP-5C	Till Above Clay Shale	Jul. 1994	September 24, 2024	May 23, 2025	970.0	Unknown	3.3	3.0	0.3
SP-9B	Clay Shale	Jul. 1994	September 24, 2024	May 23, 2025	971.2	Unknown	13.7	13.6	0.1
SP-10B	Unknown	Jul. 1994	September 24, 2024	May 23, 2025	971.0	Unknown	14.4	13.3	1.0

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

Table 2.3 Vibrating Wire Piezometer Reading Summary

Instrument ID	Serial No.	Date			Ground Surface Elevation (m)	Screen 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)
VW14-01A	1400848	Jul. 2014	September 24, 2024	May 23, 2025	968.8	14.7	12.0	12.0	0
VW14-01B	1400846	Jul. 2014	September 24, 2024	May 23, 2025	968.8	6.0	2.4	3.4	1.0
VW14-02A	1400849	Jul. 2014	September 24, 2024	May 23, 2025	969.2	14.8	7.2	7.5	0.3
VW14-02B	1400248	Jul. 2014	September 24, 2024	May 23, 2025	969.2	6.1	2.2	2.9	0.7
VW14-03A	1400843	Jul. 2014	May 15, 2024	September 24, 2024	969.0	14.9	5.5	6.1	-0.6
VW14-03B	1400842	Jul. 2014	May 15, 2024	September 24, 2024	969.0	5.9	0.9	2.0	-1.1

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

3 RECOMMENDATIONS

3.1 Future Work

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

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

The VW14-03 Datalogger battery was replaced during the most recent readings. Some troubleshooting was necessary to connect the datalogger to the computer and download data; no new data has been added since the previous reading in September 2024. The inside of the datalogger also showed signs of possible water damage. It is unclear whether the datalogger is not collecting new readings because of water damage or a dead battery.

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 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.

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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.

Jorge Rodriguez, Ph.D., M.Sc., P.Eng.
Geotechnical Engineer

JR:bb

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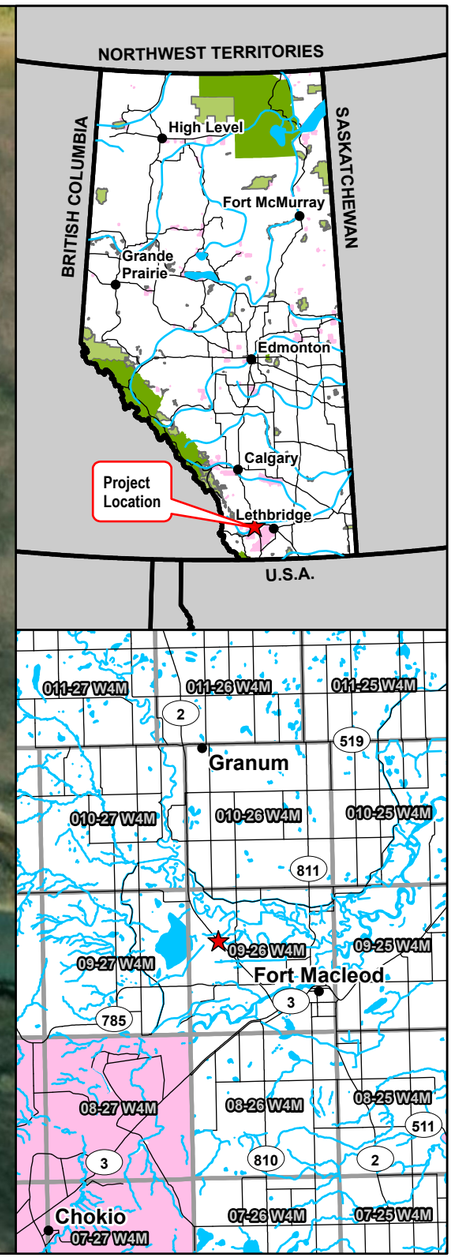
ATTACHMENTS
Figure
Appendix I Instrumentation Plots

FIGURE



Legend

- Slope Inclinometer (SI)
- Standpipe Piezometer (SP)
- Vibrating Wire Piezometer (VW)
- Flow Direction
- Scarp
- Fence

0 100 Metres

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 12N
3. IMAGE SOURCE: MD OF WILLOW CREEK NO. 26, TOWN OF CARDSTON, MAXAR

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
S004 - Willow Creek (North of Ft. Macleod)
Hwy 2:08, km 6.284

SCALE	PROJECT No.	FIG No.
1:2,000	A05116A03	1

File: Z:\AC\GY\Alberta\A05116A03 ABT Southern Region GRMP\400 Drawings\2022\Section C\Section C - Spring 2022\Section C - Spring 2022.aprx Date: Time: Creator: : aharrison

APPENDIX I

Instrumentation Plots

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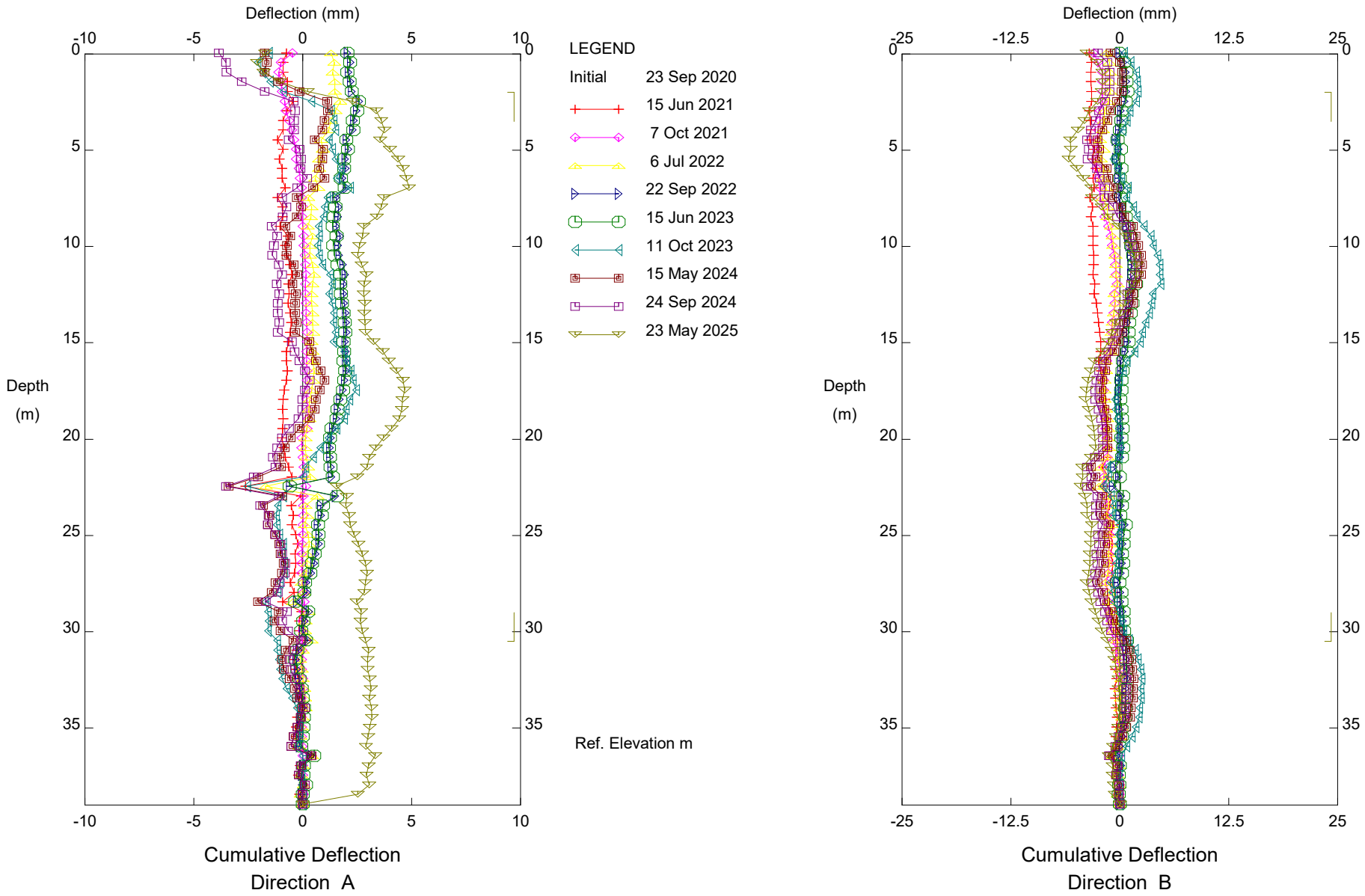

S004; H02:08, Willow Creek, Inclinometer SI-1A

Alberta Transportation

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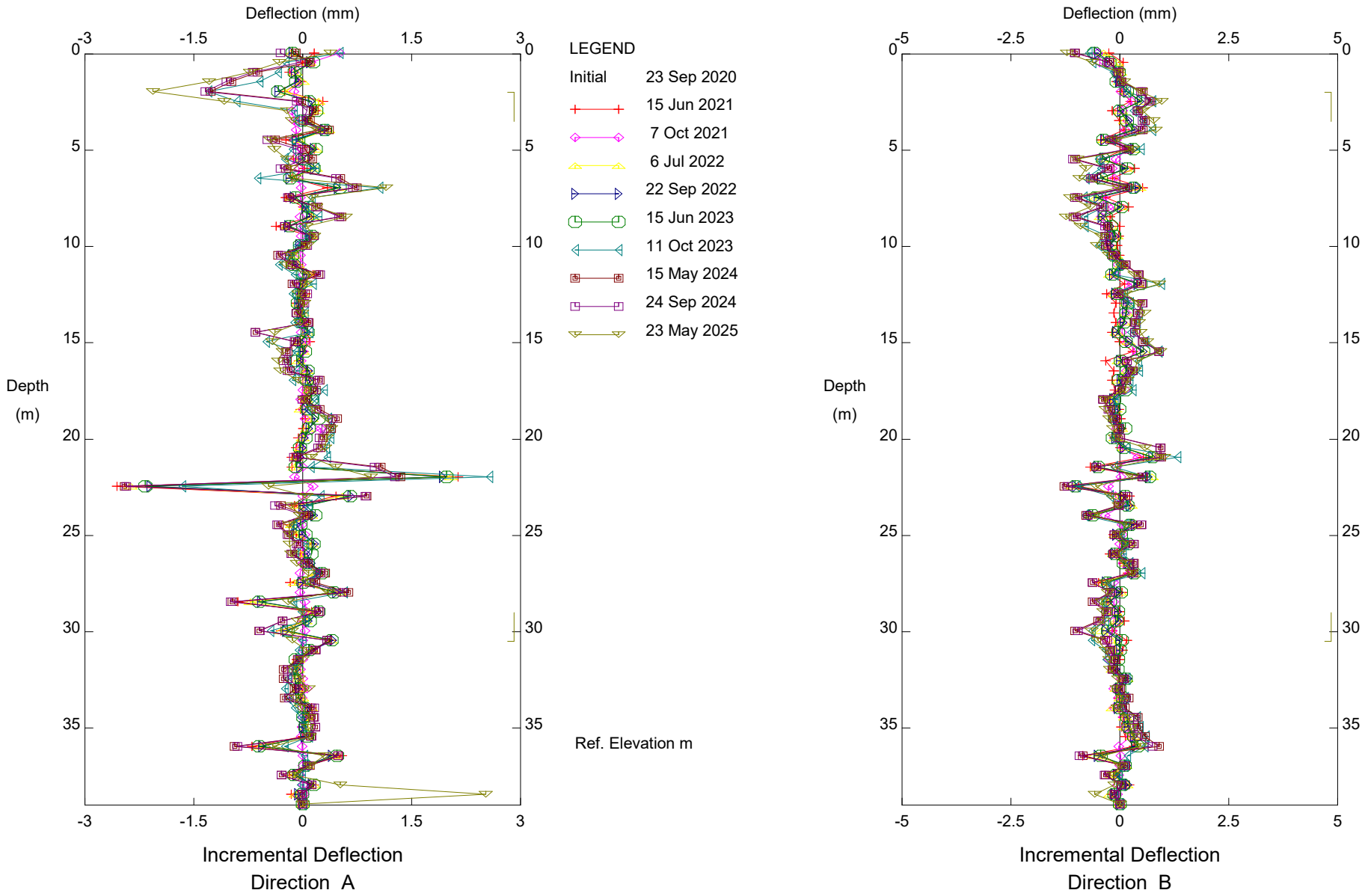
Klohn Crippen Berger - Calgary



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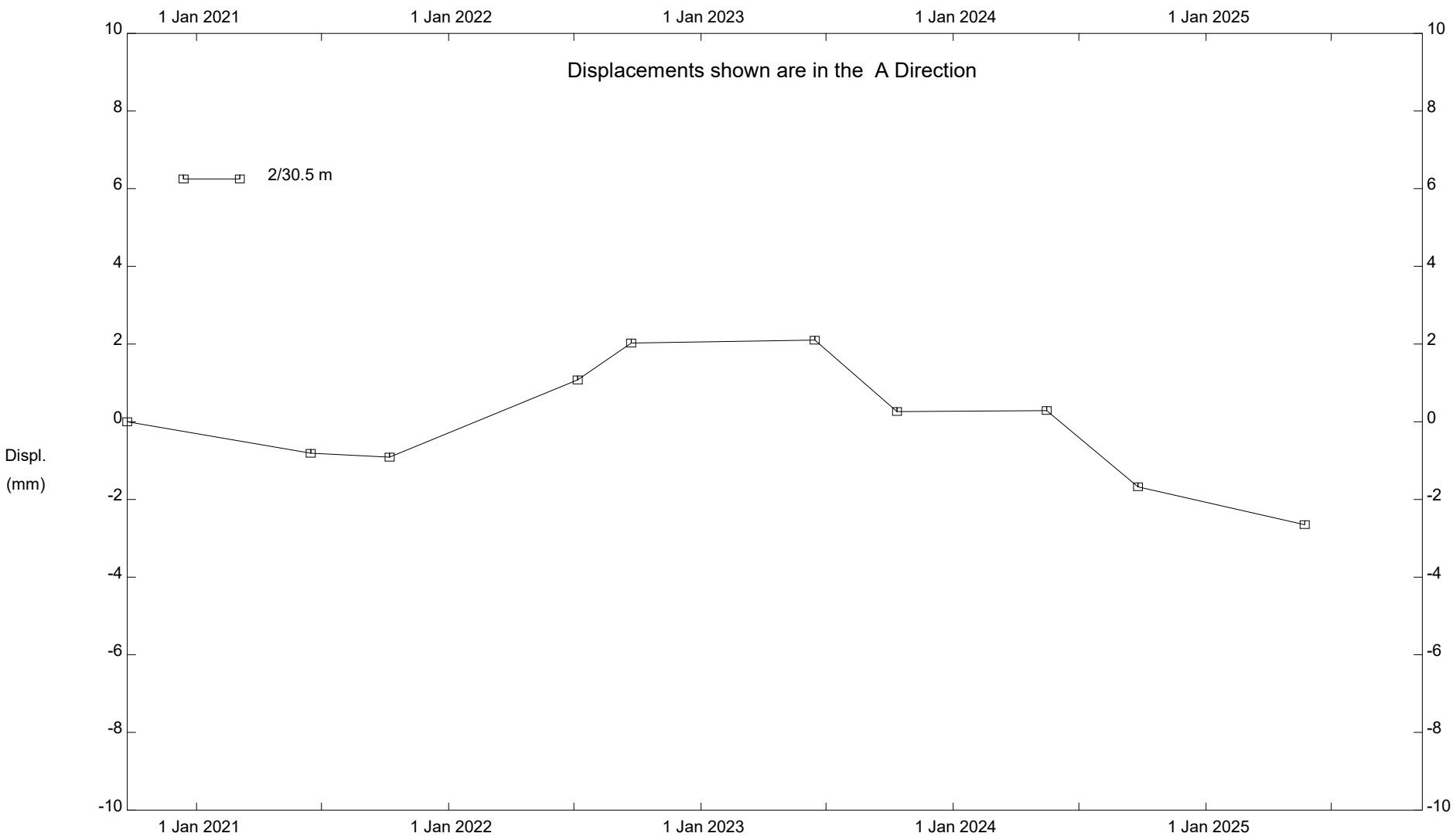

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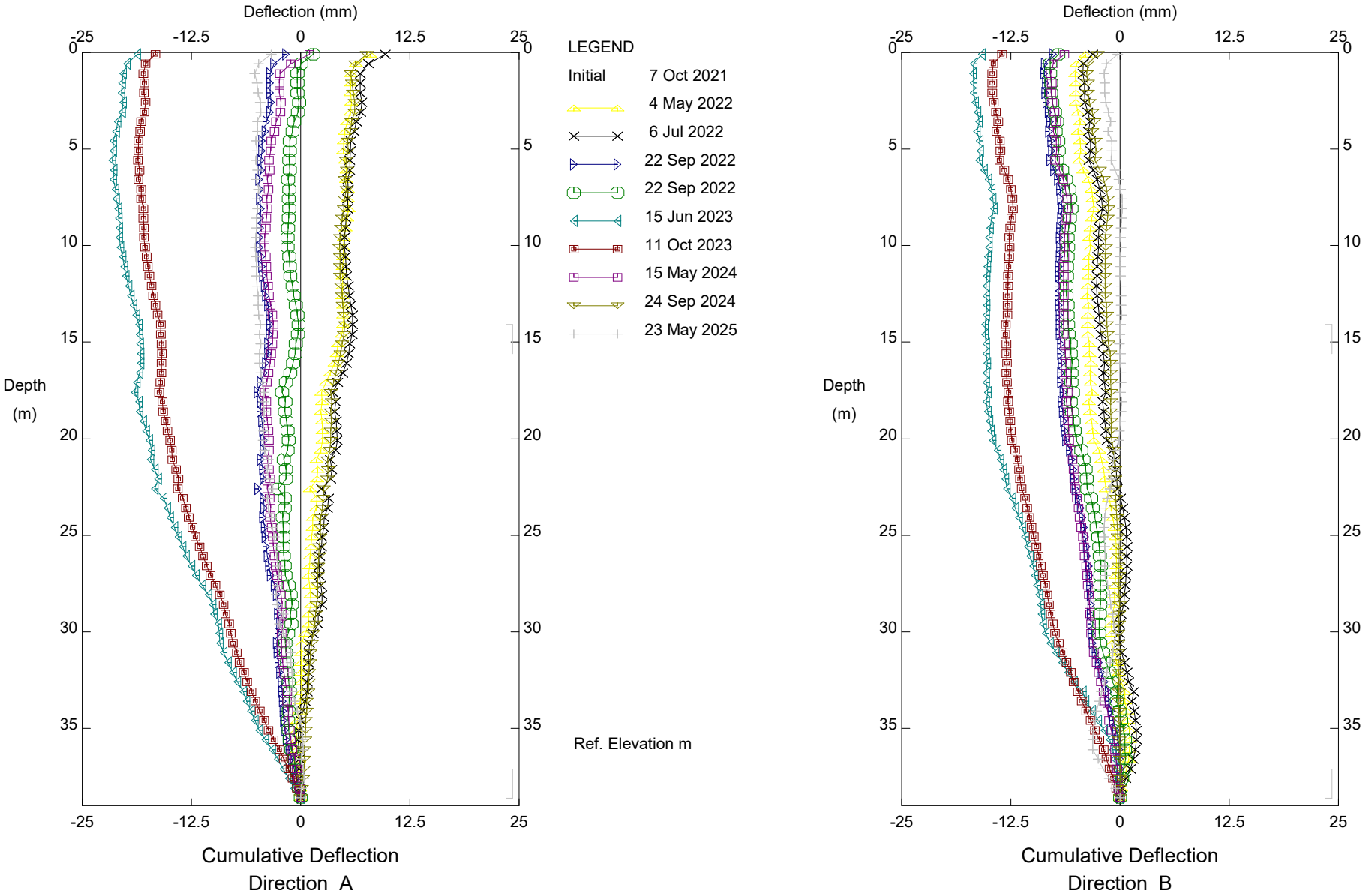

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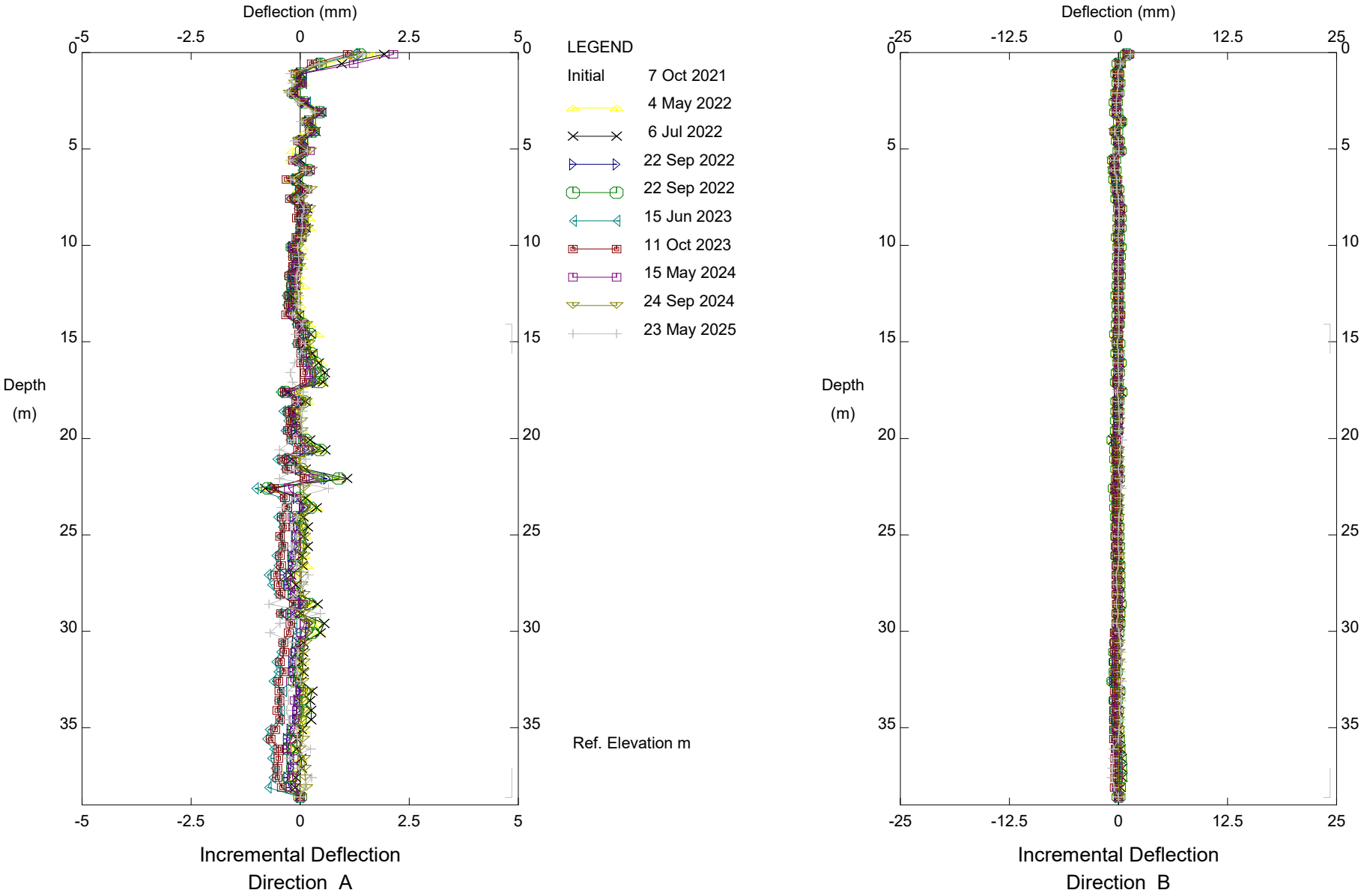

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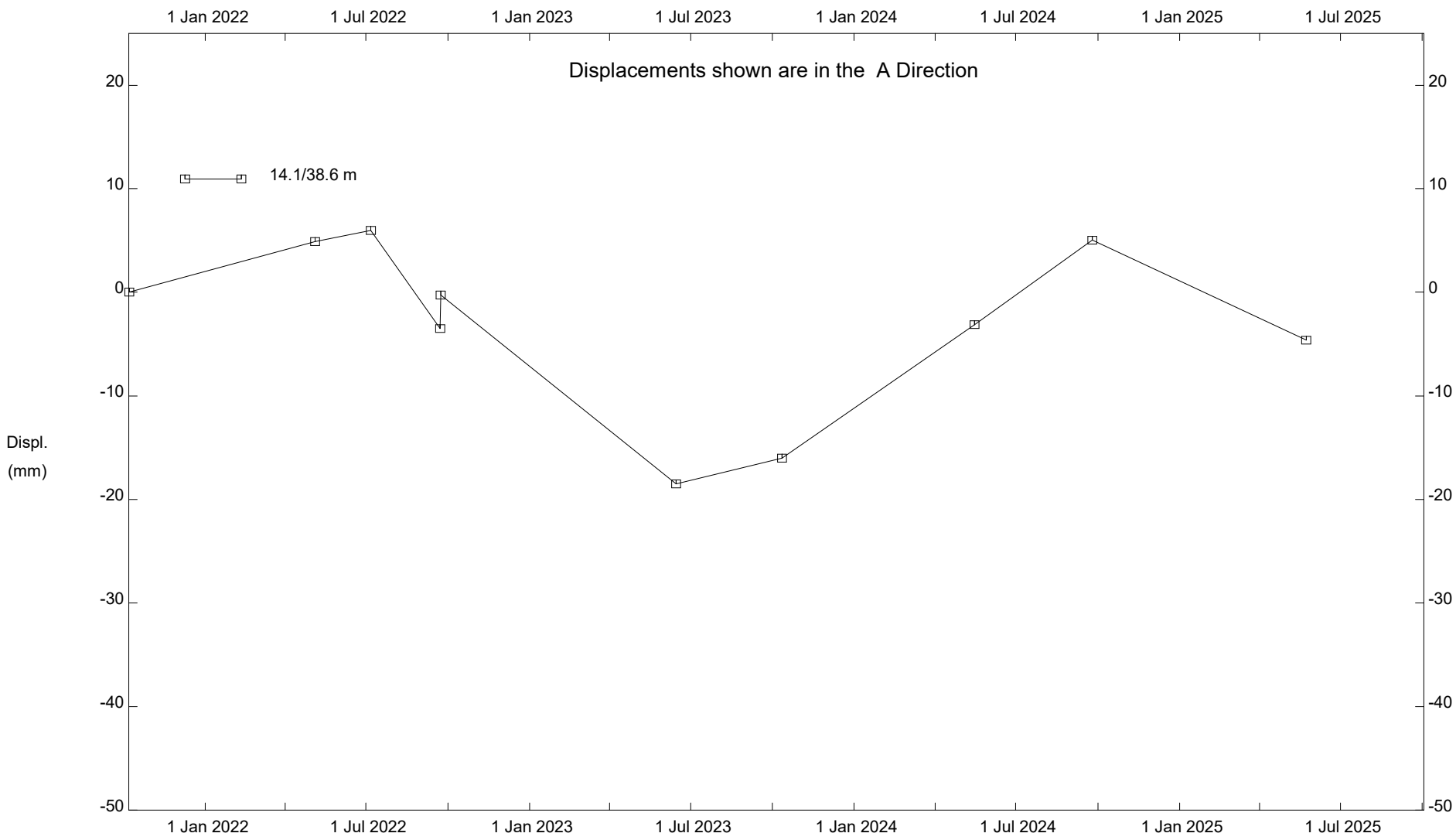

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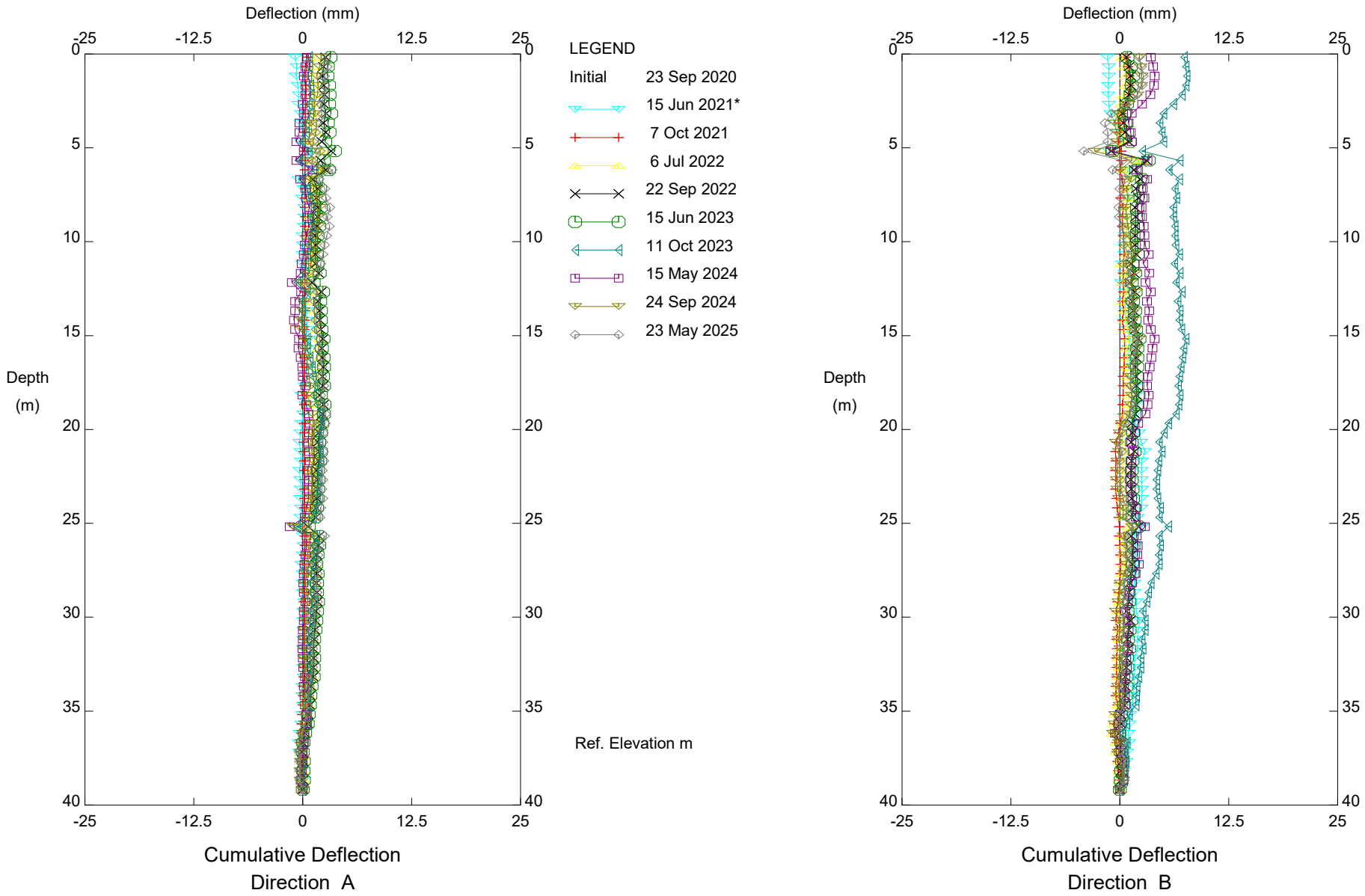

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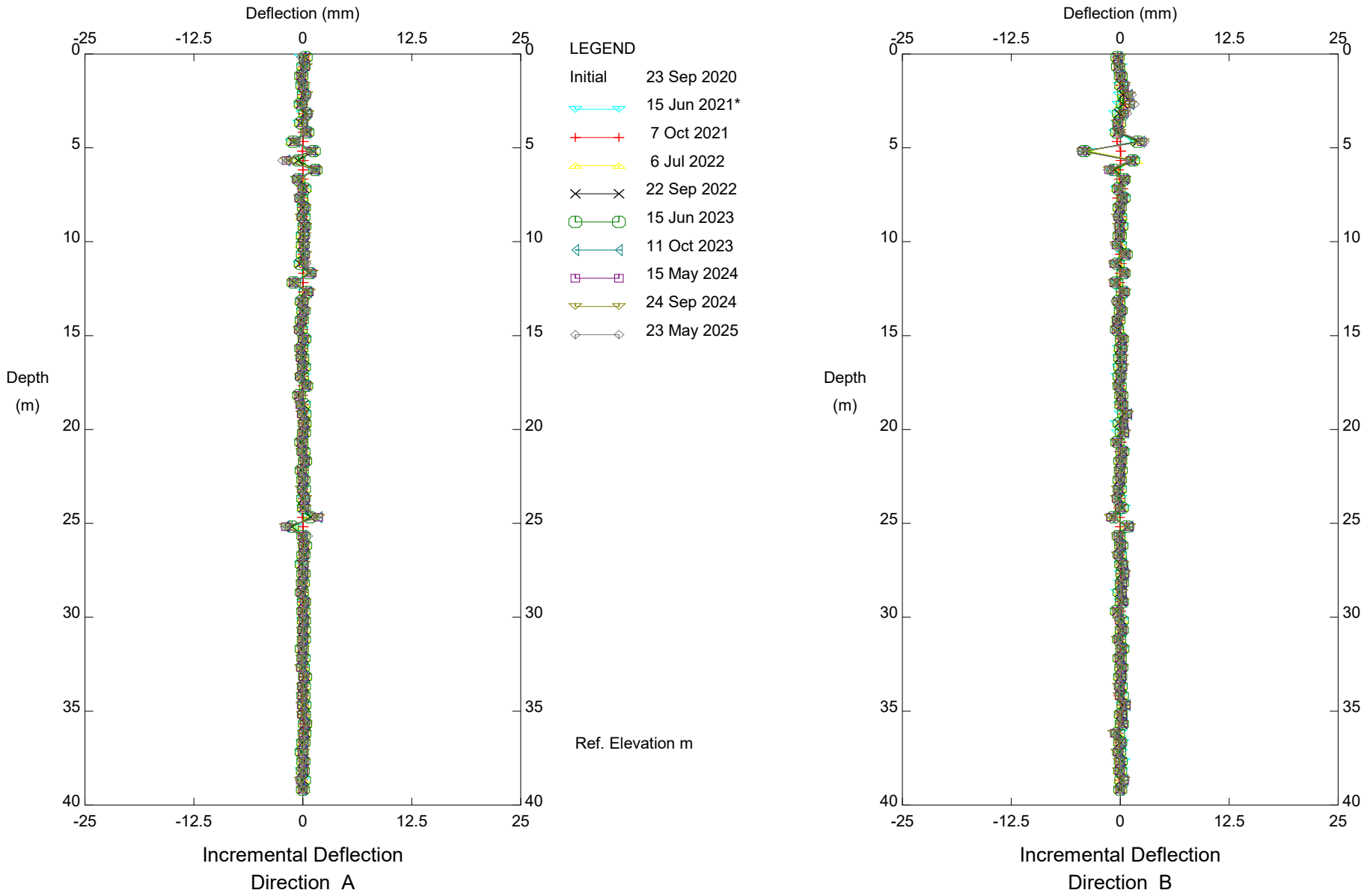

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Sets marked * include zero shift and/or rotation corrections.

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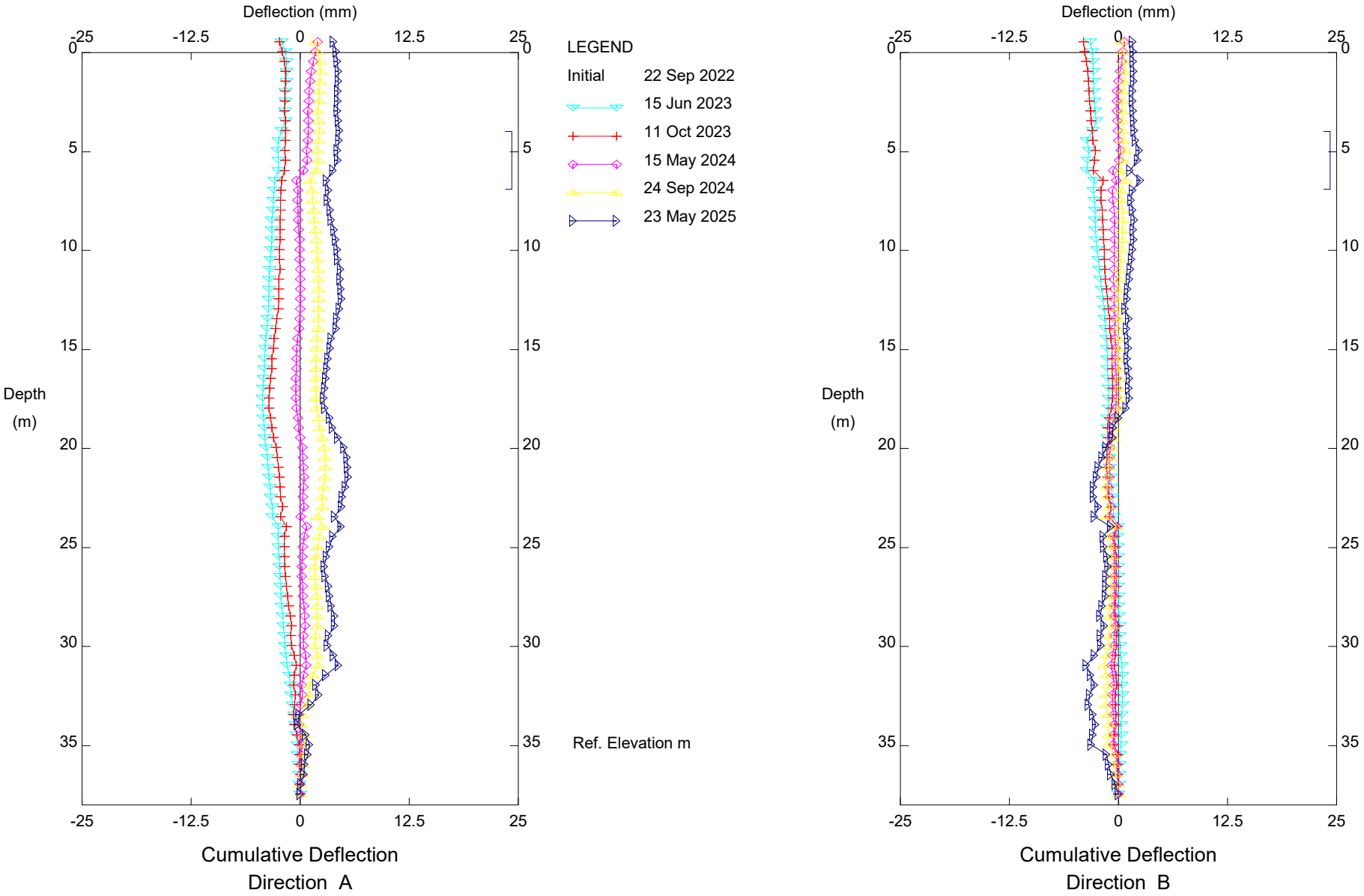

Alberta Southern Region, Inclinometer S04 SI-10A

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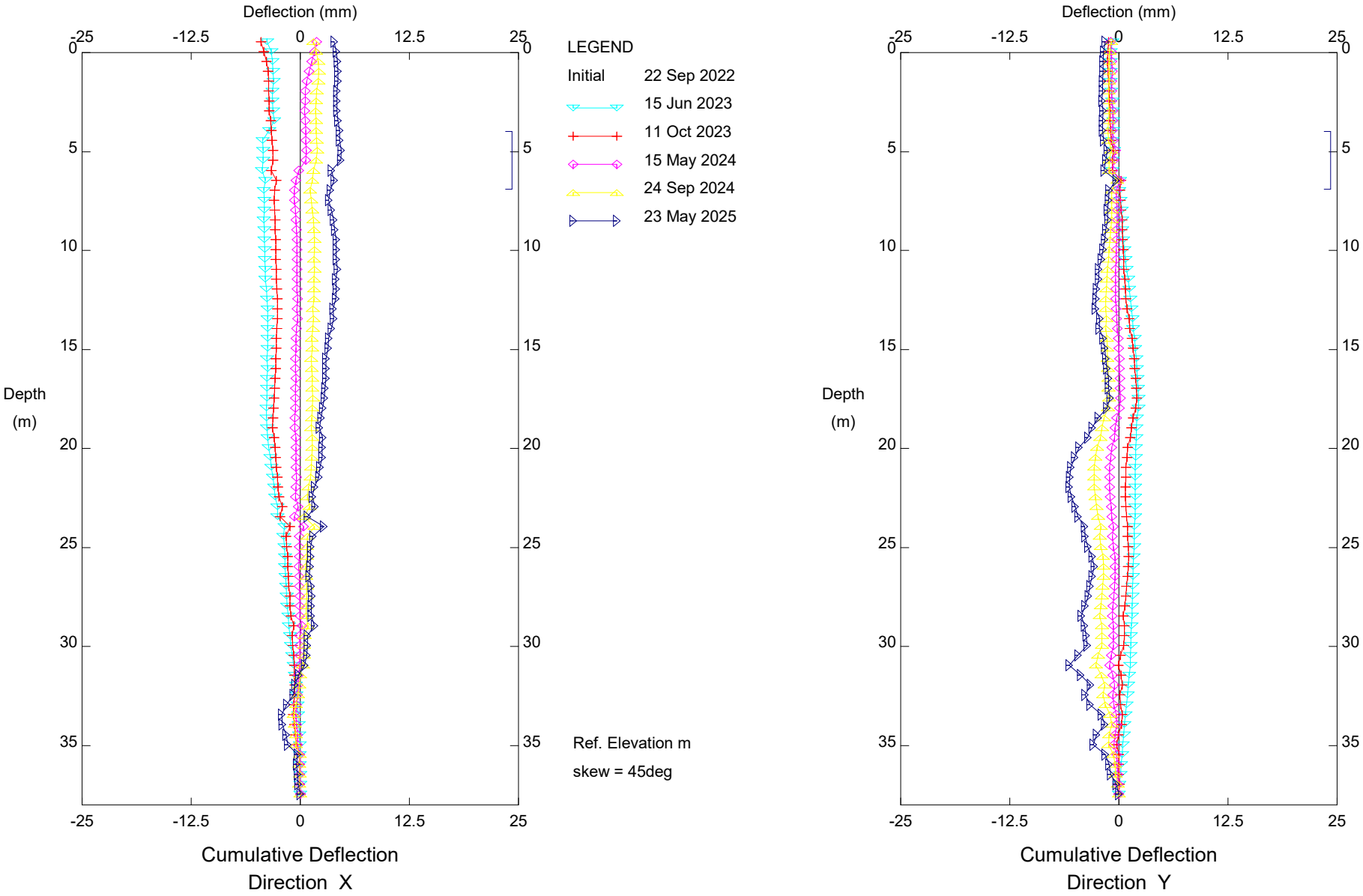

Alberta Southern Region, Inclinometer S04 SI-10A

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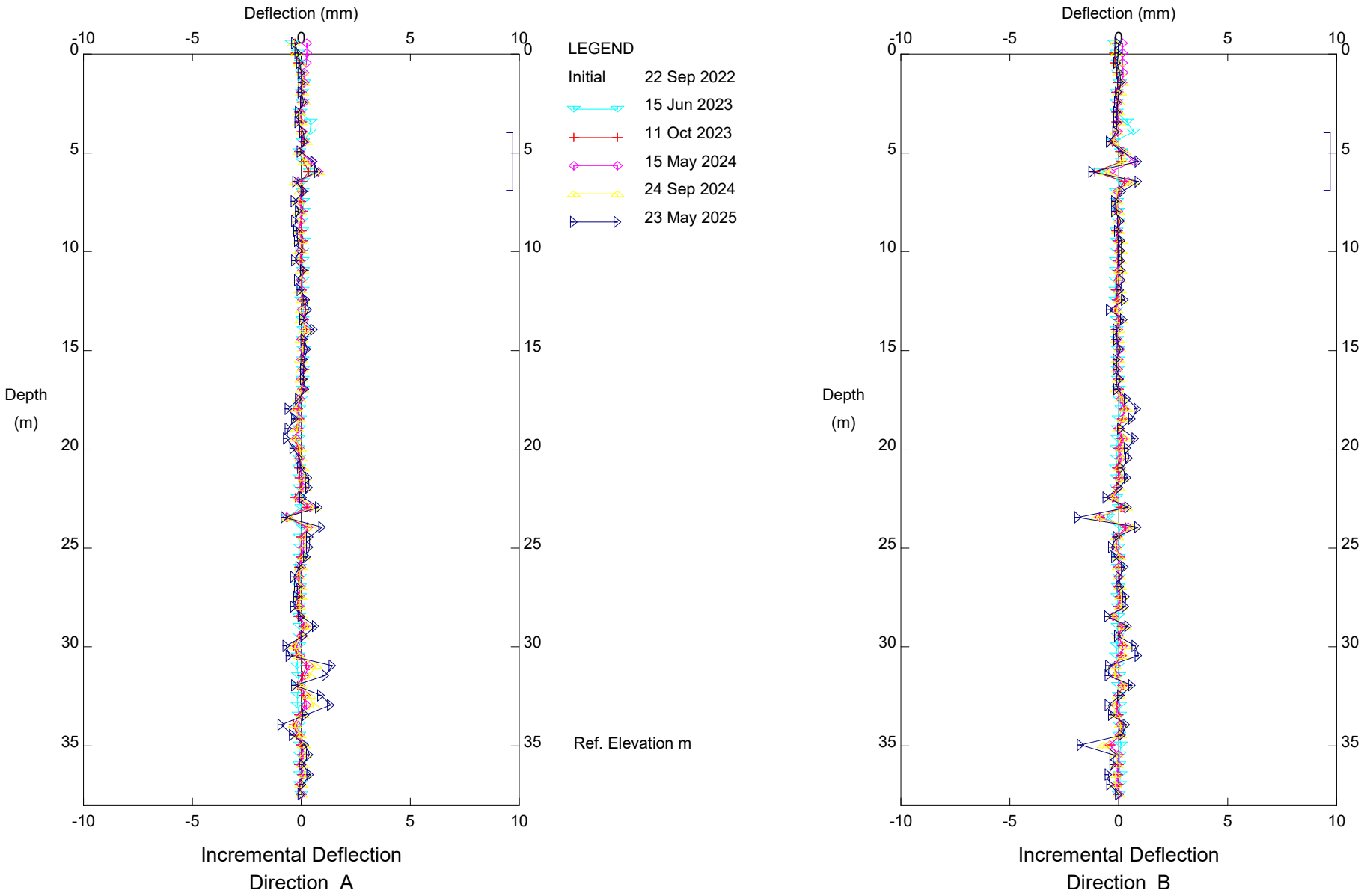

Alberta Southern Region, Inclinometer S04 SI-10A

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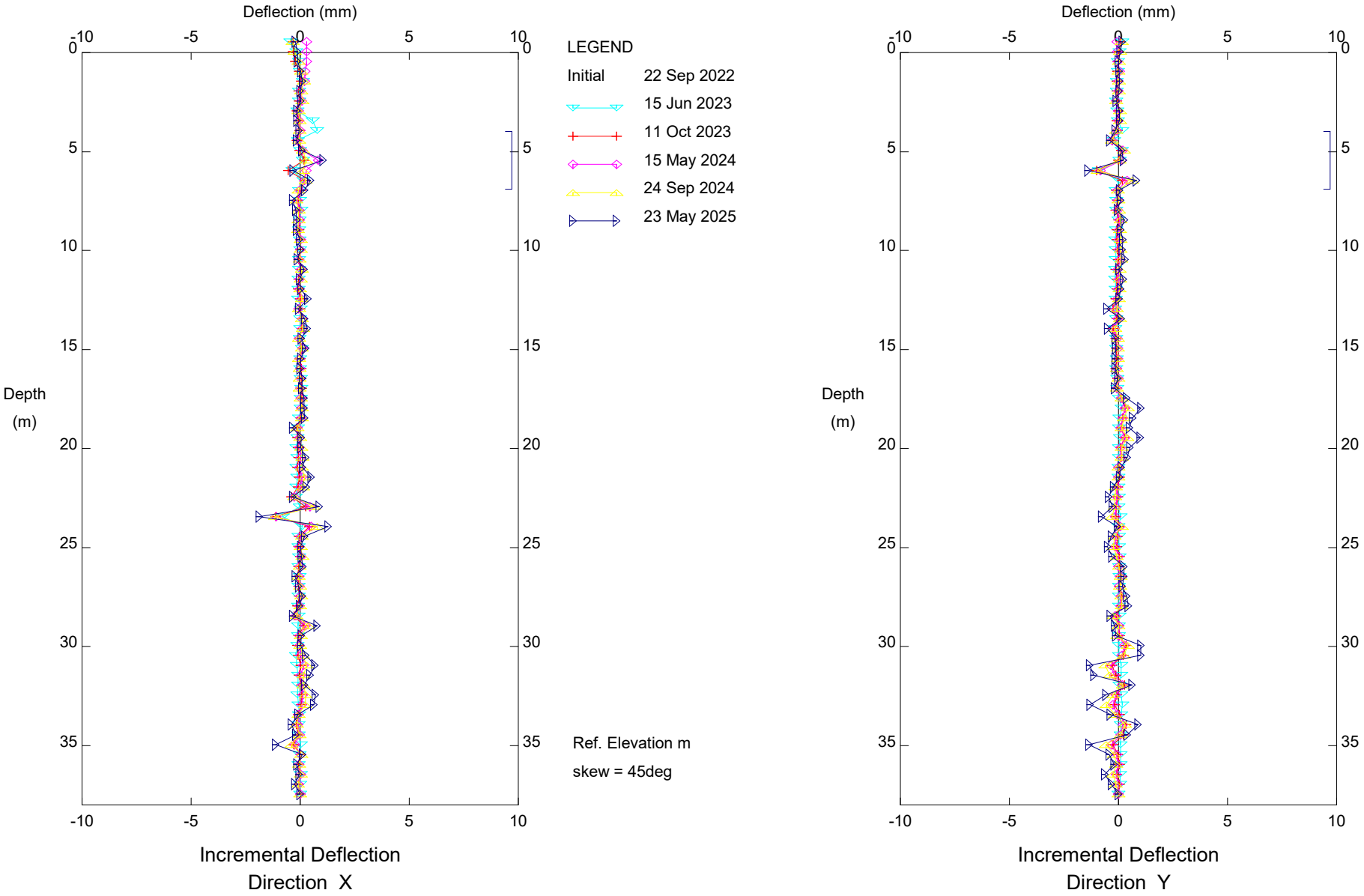
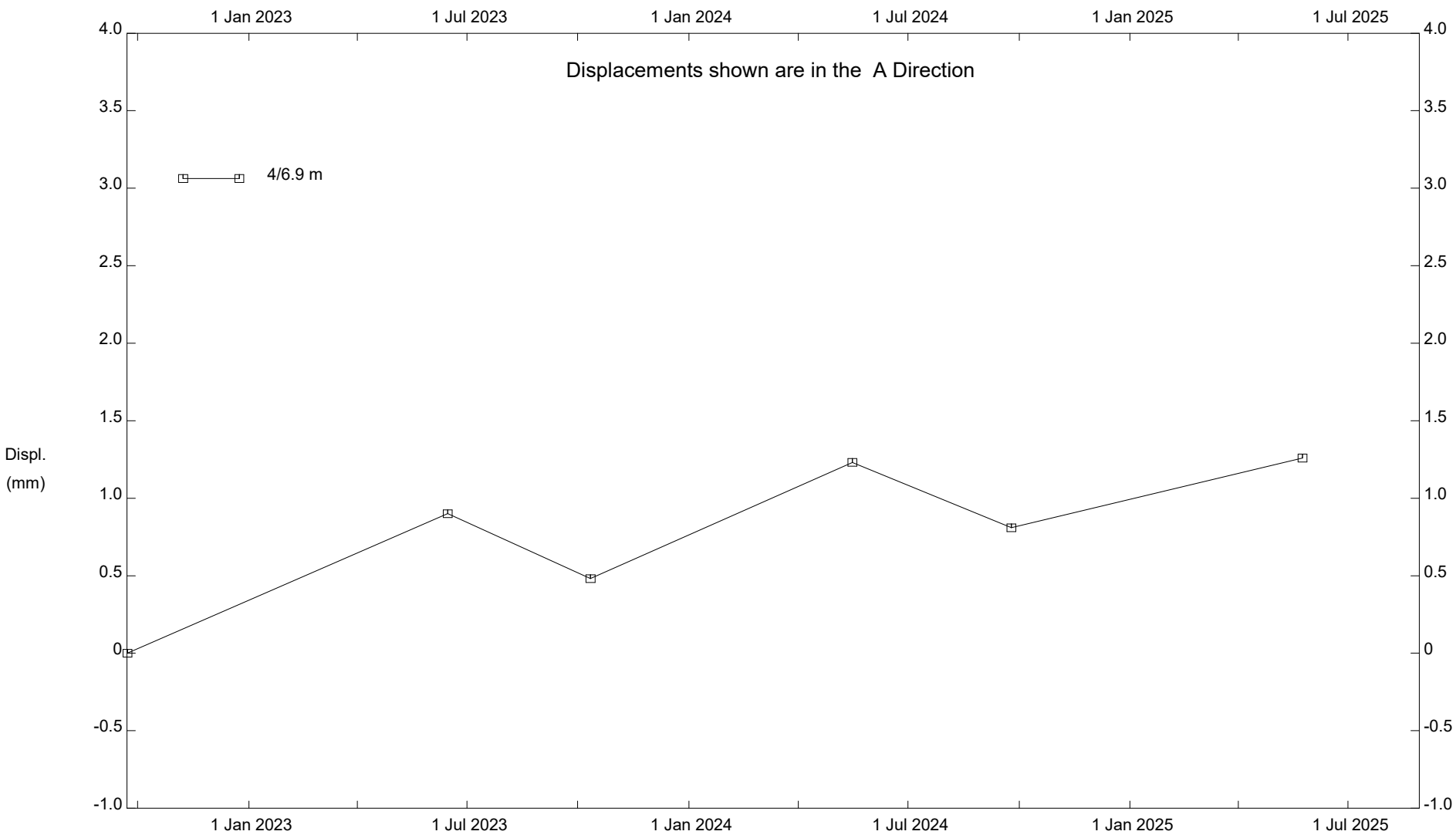
Klohn Crippen Berger - Calgary

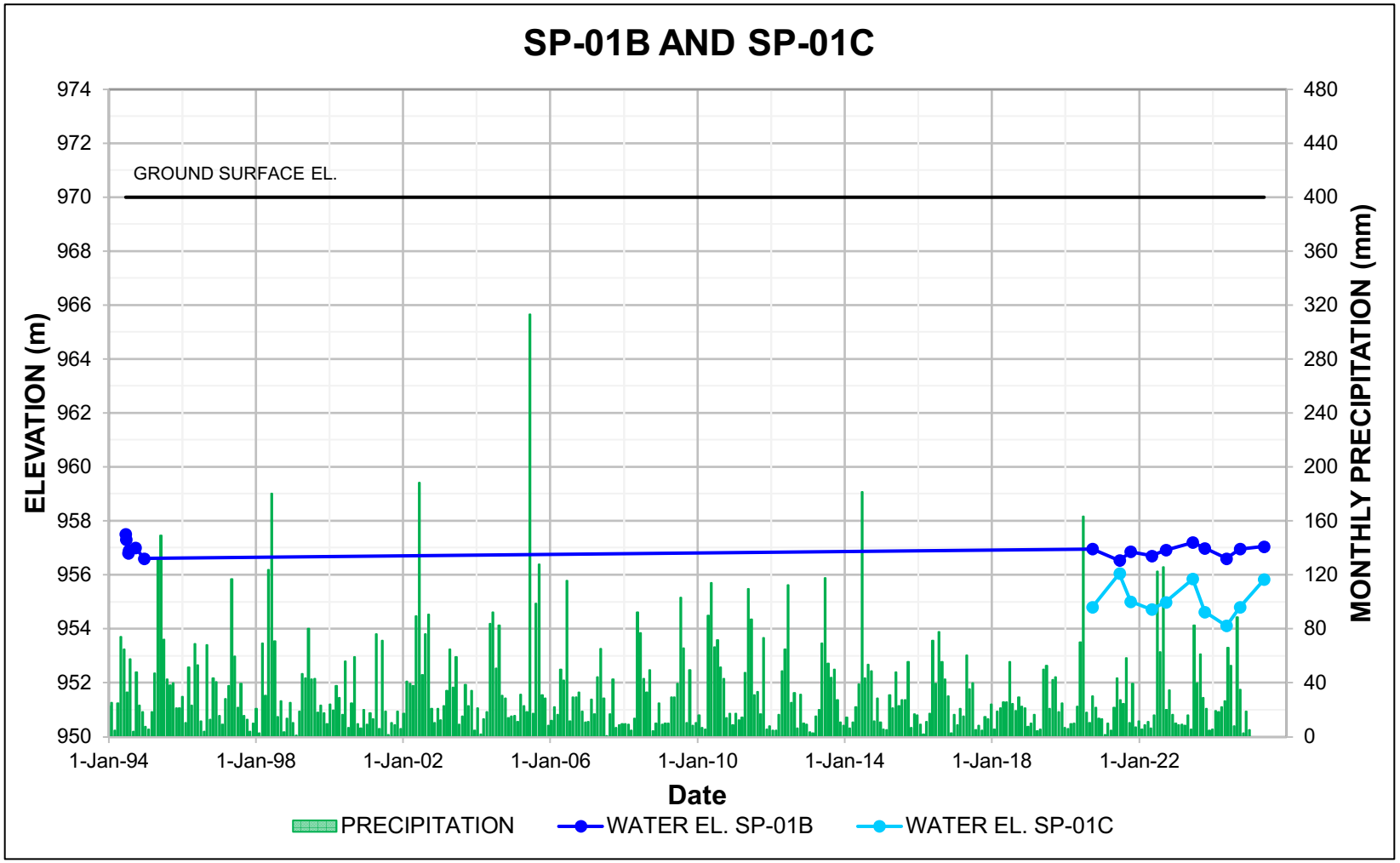


Alberta Southern Region, Inclinometer S04 SI-10A

Klohn Crippen Berger - Calgary



Alberta Southern Region, Inclinometer S04 SI-10A



NOTES:
1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
2. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

CLIENT
Alberta
Klohn Crippen Berger

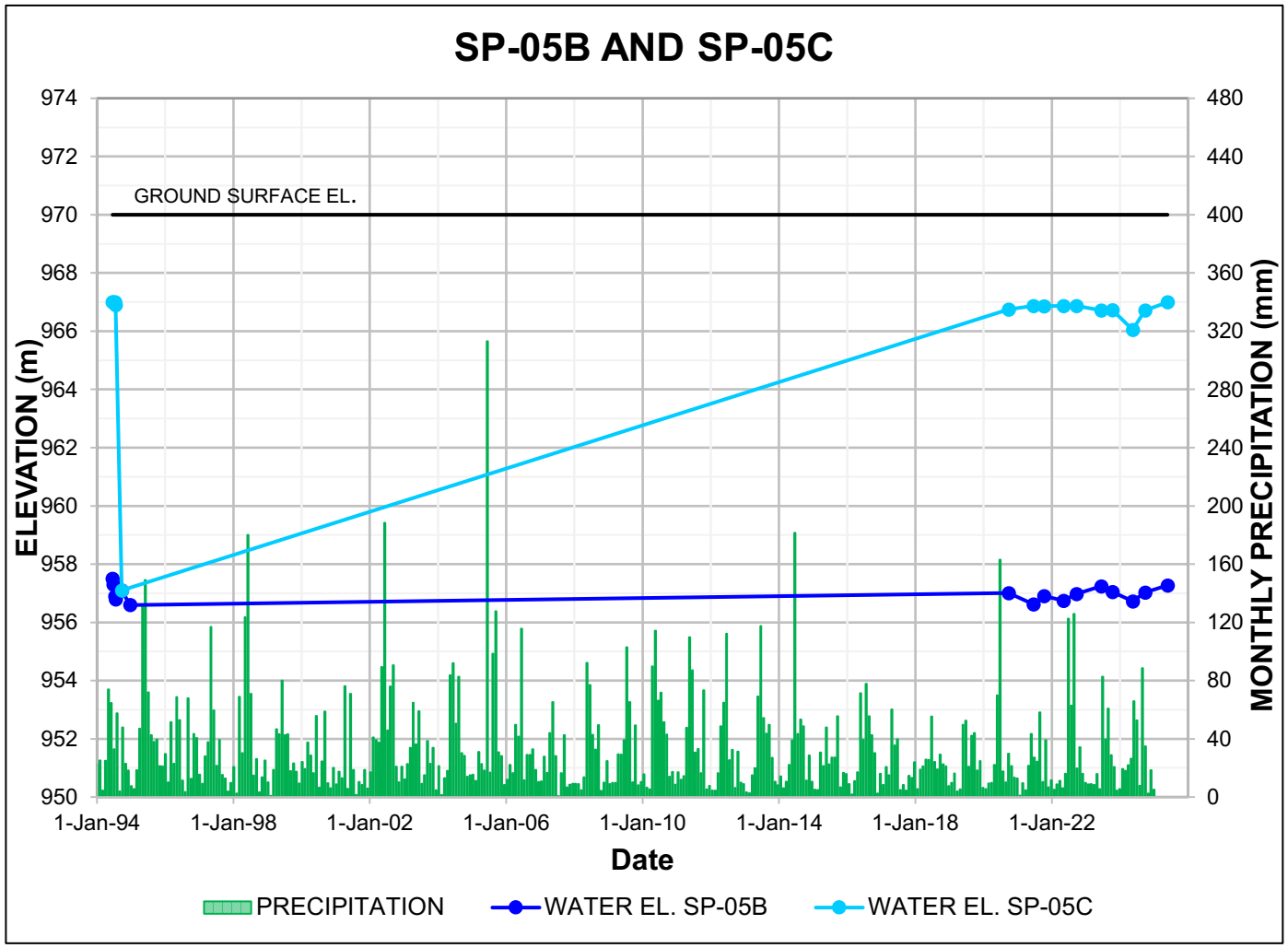
PROJECT
SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Standpipe Piezometer Data
S004 - Willow Creek
Hwy 02:08, km 6.284

SCALE

PROJECT No. A05116A03

FIG No.



NOTES:
1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION TWP009-26-W4.
2. THE 1994 READING FOR SP-05C APPEARS TO BE BAD DATA.
3. THE INSTRUMENTS WERE NOT READ BETWEEN OCTOBER 2015 AND SEPTEMBER 2020.

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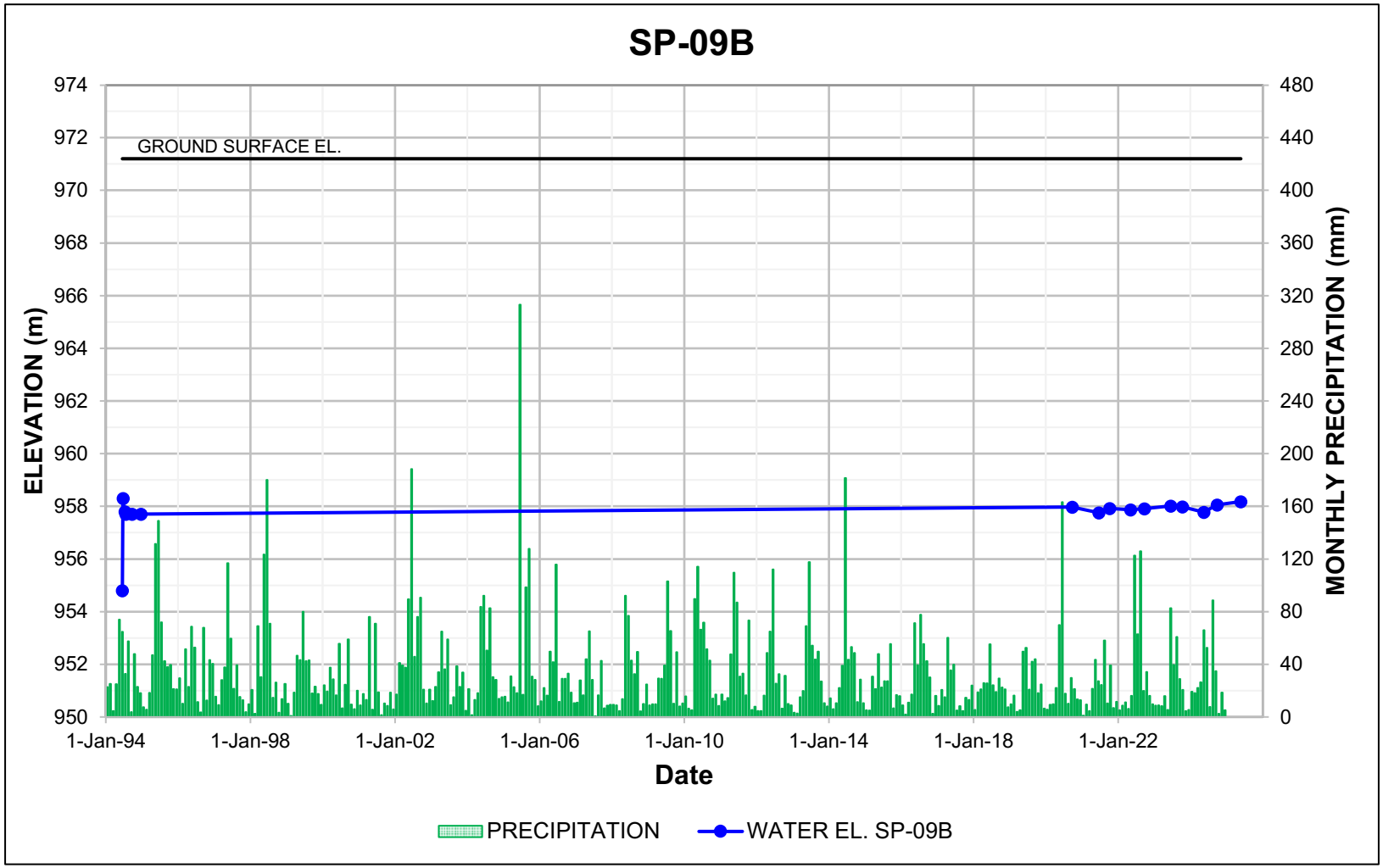
SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Standpipe Piezometer Data
S004 - Willow Creek
Hwy 02:08, km 6.284

SCALE	PROJECT No.	FIG No.
	A05116A03	



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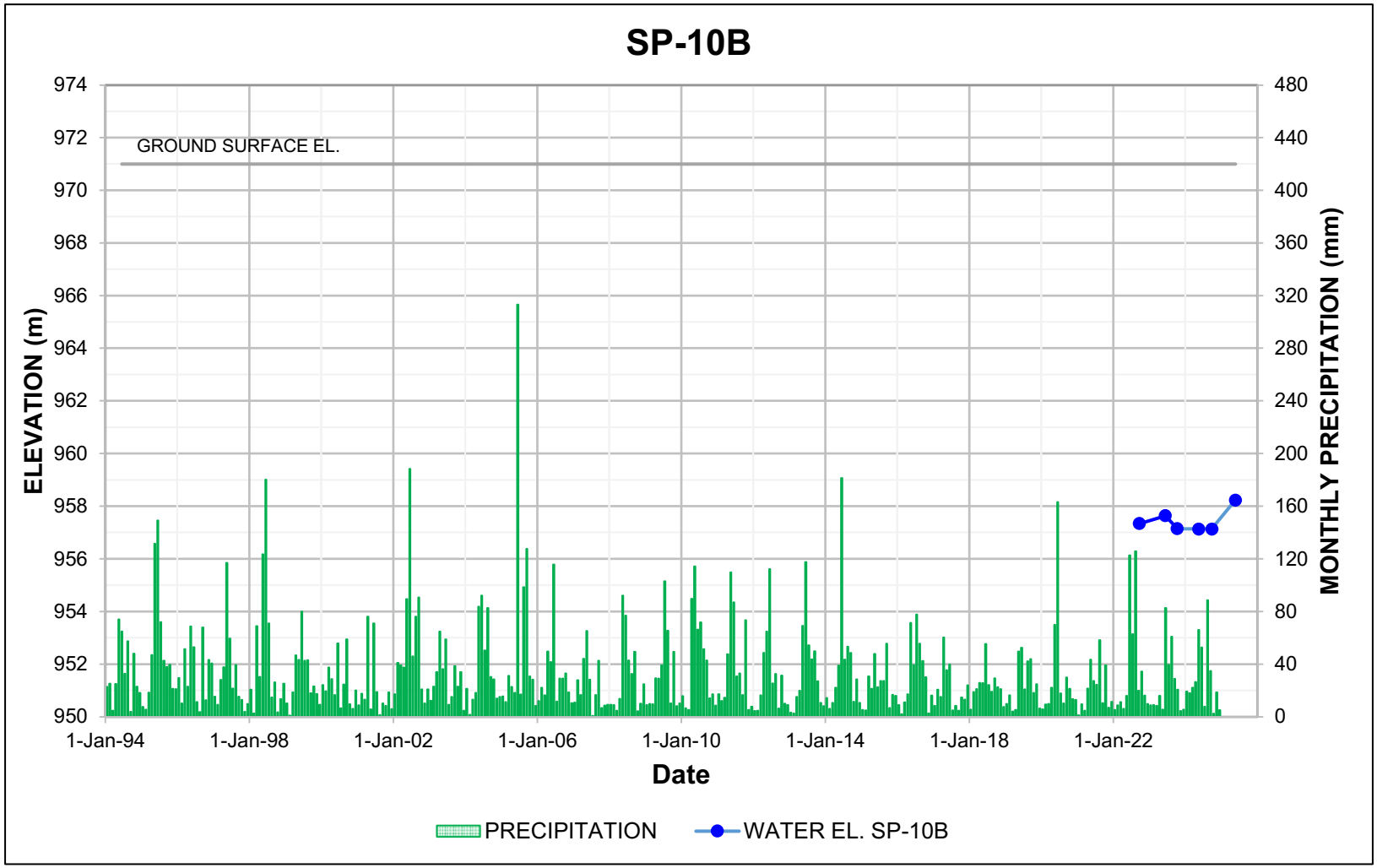
TITLE
Standpipe Piezometer Data
S004 - Willow Creek
Hwy 02:08, km 6.284

SCALE	PROJECT No.	FIG No.
	A05116A03	



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S004 - Willow Creek
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SCALE	PROJECT No.	FIG No.
	A05116A03	

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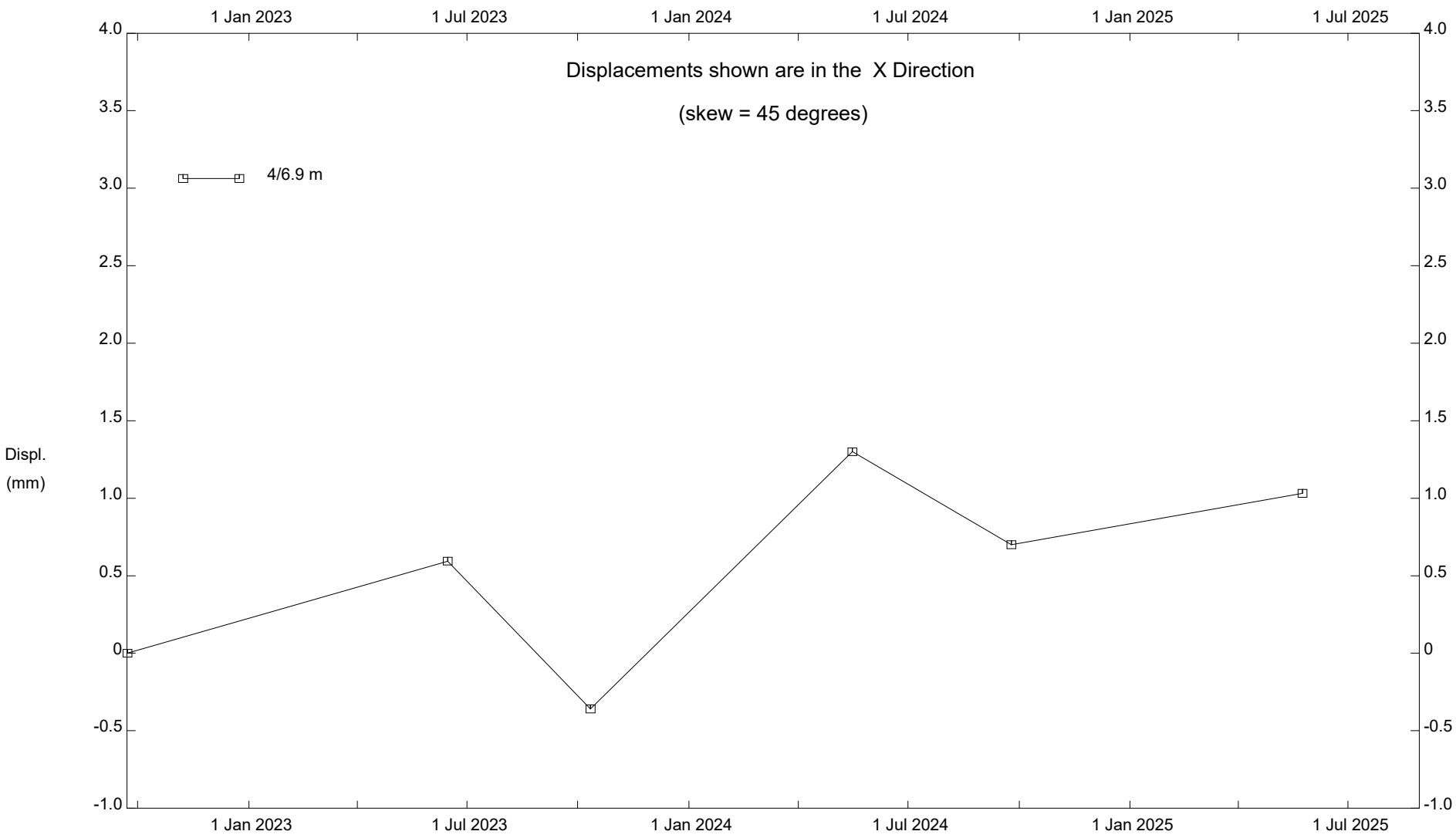
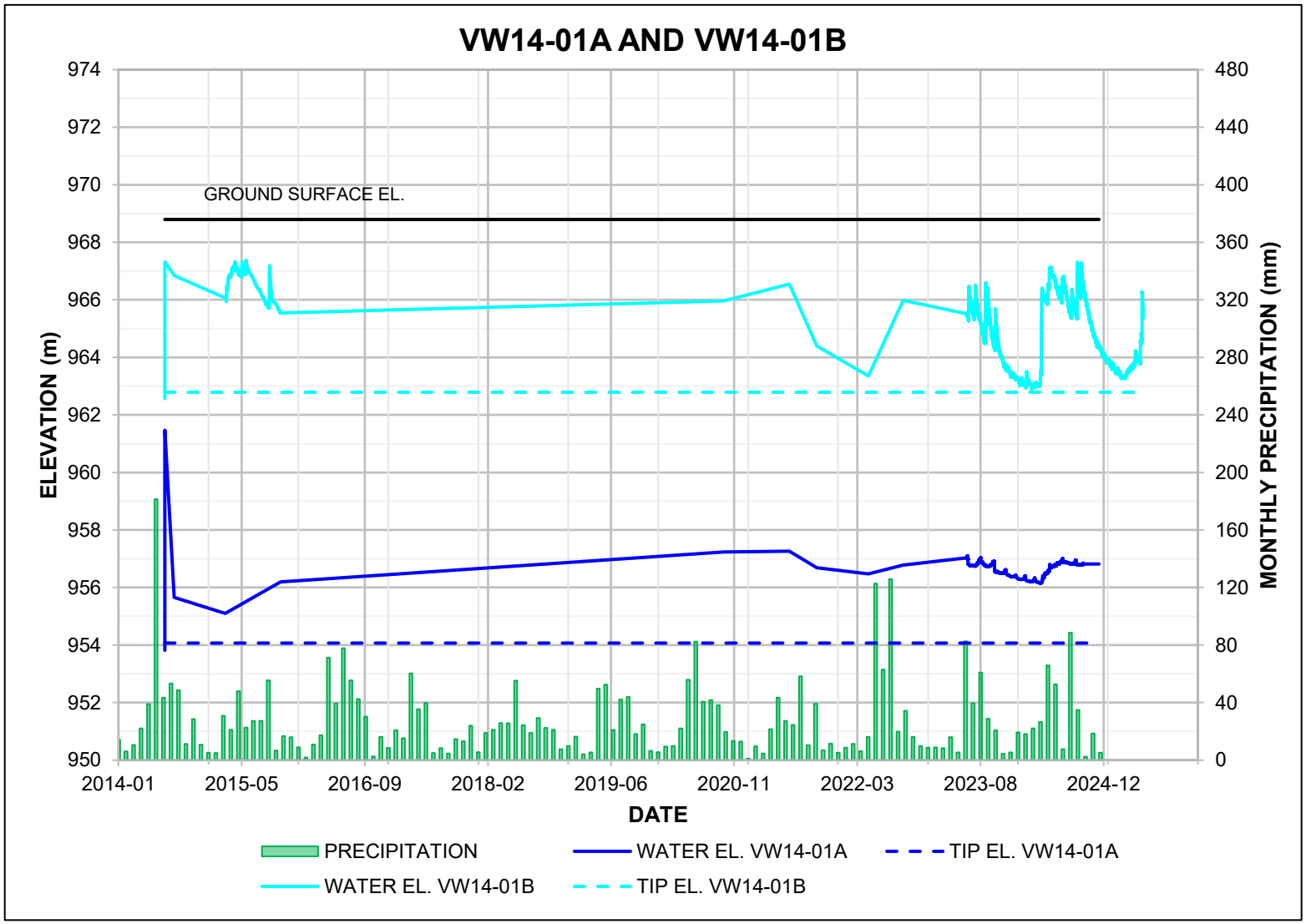


Alberta Southern Region, Inclinometer S04 SI-10A



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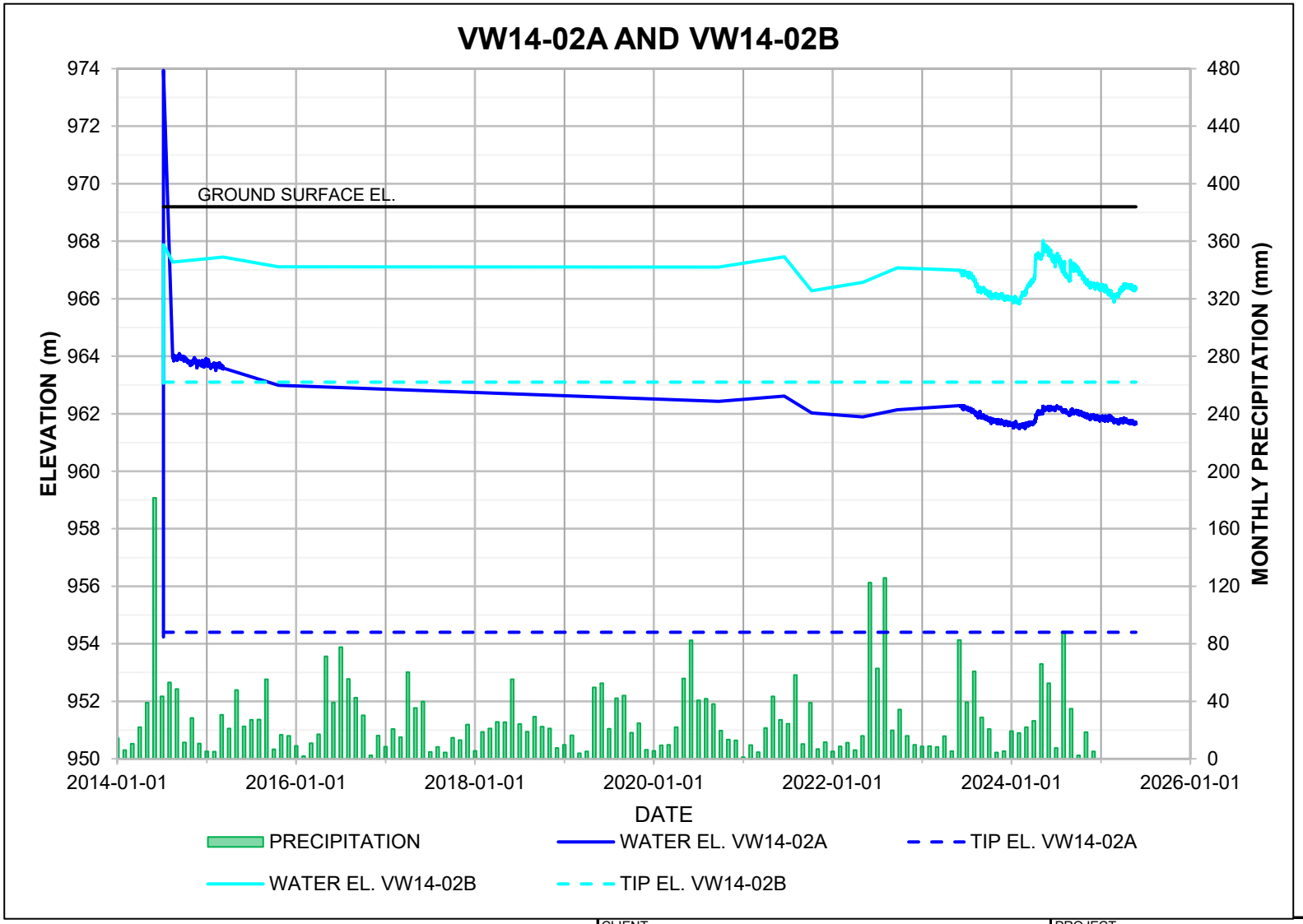
PROJECT
SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Vibrating Wire Piezometer Data
S004 - Willow Creek
Hwy 02:08, km 6.284

SCALE	PROJECT No.	FIG No.
	A05116A03	



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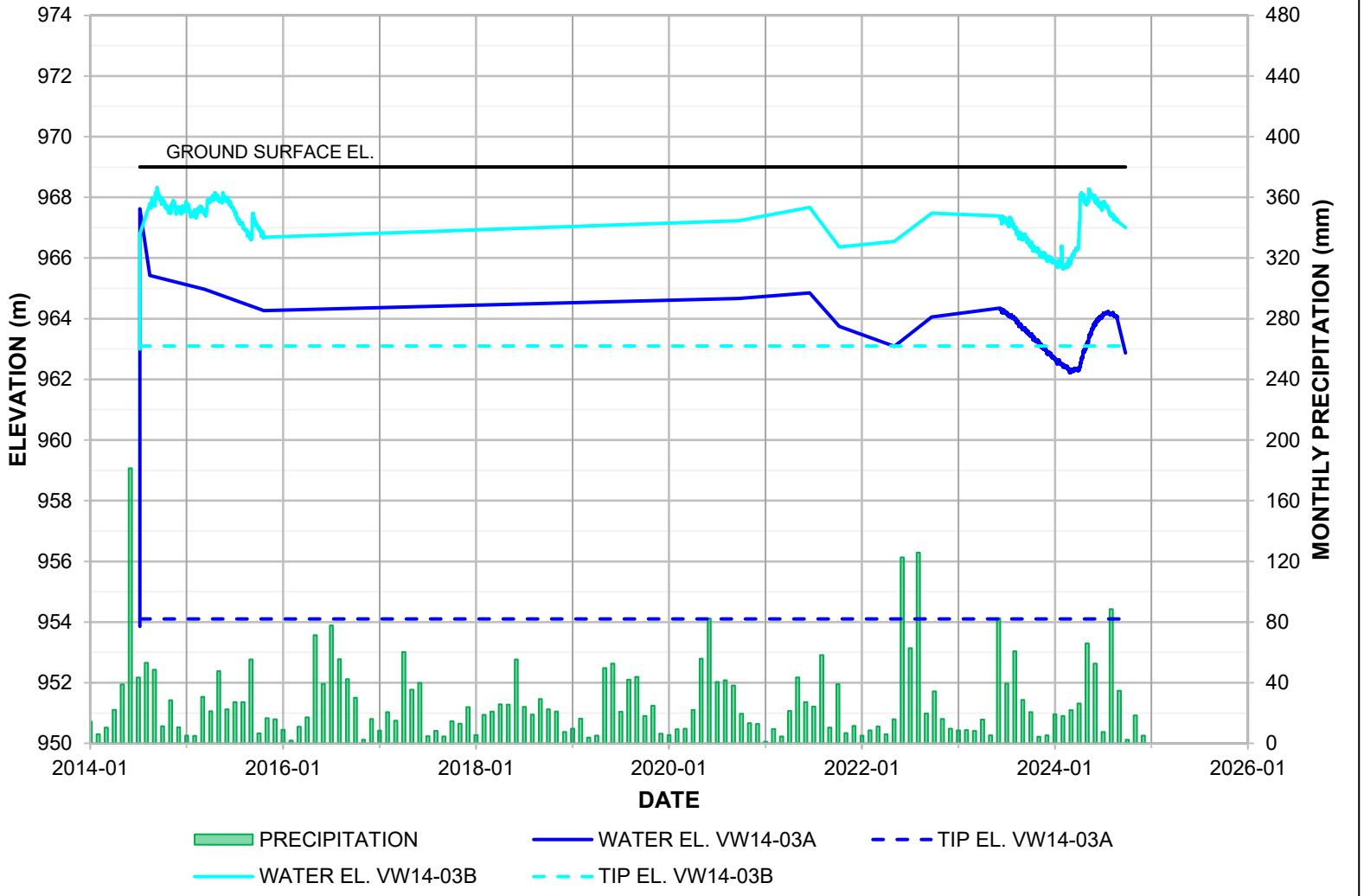
TITLE
Vibrating Wire Piezometer Data
S004 - Willow Creek
Hwy 02:08, km 6.284

SCALE	PROJECT No.	FIG No.
	A05116A03	

VW14-03A AND VW-03B



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SCALE	PROJECT No.	FIG No.
	A05116A03	