

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 S004; H02:08, km 6.284 Willow Creek
Section C – 2022 Fall Readings

1 GENERAL

Four slope inclinometers (SIs) (SI-1A, SI-5A, SI-9A, and SI-10A), six standpipe piezometers (SPs) (SP-1B/C, SP-5B/C, SP-9B, and SP-10B), and six vibrating wire piezometers (VWPs) (VW14-01A/B, VW14-02A/B, and VW14-03A/B) were read at the S004 site in Southern Region on September 22, 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 at Hwy 02:08 km 6.284, north of Fort Macleod, Alberta, approximately 1.9 km north of the junction of Range Road 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 east (northbound) lane ditch of Hwy 02:08. Previous remedial actions at the site include soil nailing, grading, bioengineering (live staking), and bank armoring in 2008. A guardrail was also installed in 2014.

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

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 (AT). 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.

In 1994 and 2014, 16 SIs and 41 piezometers were installed at the site by the previously 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).

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, KCB is reading the SIs with 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	39.5	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	39.0	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	Unknown	0.6	39.5	Operable
SI-10A	SI	Jul. 1994	5514542	320186	Unknown	Unknown	Unknown	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
SP-10B	SP	Jul. 1994	5514503	320129	Unknown	0.5	Unknown	Operable
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 AT.
- 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, and tip or screen depth for piezometers.
- 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

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).

For the operable SPs, the recorded water levels were converted to an equivalent water/piezometric elevation and plotted relative to 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 each instrument's tip elevation.

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.

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 September 2022 reading was the first time KCB read SI-10A and SP-10B. The SI data plots only include data obtained by KCB. Data obtained by previous consultants has not been provided to KCB.

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 was read twice during both the spring and fall 2022 readings). It is unclear if the noise is due to changing the SI reading equipment, the low rate of movement being recorded in these instruments, or installation issues (e.g., casing kinked or titled). Based on the data plots for these instruments, it is noted that the casing for:

- SI-1A is "wavy" with kinks at approximately 22 m, 28 m, and 36 m below 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 ground surface; and
- SI-9A is "wavy" with kinks at approximately 5 m, 11 m, and 25 m below ground surface.

The SI data plots presented herein include data for readings taken with both KCB's new and old SI reading equipment. SI-5A was re-initialized to the October 7, 2021 reading due to the readings not aligning well with the previous readings taken with KCB's old SI reading equipment. Moving forward, only the re-initialized plots will be included.

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 (Re-initialized) ^{2,4}	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
								Before Re-Initialization	After Re-Initialization	Total				
SI-1A	1994 (Sep. 23, 2020)	N/A – no discernible movement recorded since re-initialization and historical data not provided for KCB's review ²	Jul. 06, 2022	Sep. 22, 2022	Unknown	N/A – no discernible movement recorded since re-initialization and historical data not provided for KCB's review ²								
SI-5A	1994 (Sep. 23, 2020) (Oct. 7, 2021)		Jul. 06, 2022	Sep. 22, 2022	Unknown									
SI-9A	1994 (Sep. 23, 2020)		Jul. 06, 2022	Sep. 22, 2022	Unknown									
SI-10A ³	Unknown (Sep. 22, 2022)		Unknown	Sep. 22, 2022	Unknown									

Notes:

¹ Meters below ground surface (mbgs).

² All SIs were re-initialized to the September-2020 readings when KCB took over the readings at the site and changed the SI reading equipment. Data recorded before September 2020 has not been provided to KCB for review. Historical reports prepared by the previous consultant between 1999 and 2003 did not report significant movements in these SIs.

³ SI-10A read by KCB for the first time in September 2022. Previous data for instrument has not been provided to KCB.

⁴ SI-5A was re-initialized to the October 7, 2021 reading due to the readings not aligning with the previous readings.

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	May 04, 2022	Sep. 22, 2022	970.0	Unknown	14.8	14.6	0.2
SP-1C	Not Provided	Jul. 1994	May 04, 2022	Sep. 22, 2022	970.0	Unknown	16.5	16.3	0.2
SP-5B	Clay Shale	Jul. 1994	May 04, 2022	Sep. 22, 2022	970.0	Unknown	14.6	14.4	0.2
SP-5C	Till Above Clay Shale	Jul. 1994	May 04, 2022	Sep. 22, 2022	970.0	Unknown	3.8	3.8	0.0
SP-9B	Clay Shale	Jul. 1994	May 04, 2022	Sep. 22, 2022	971.2	Unknown	14.5	14.5	0.0
SP-10B ²	Unknown	Jul. 1994	Unknown	Sep. 22, 2022	Unknown	Unknown	Unknown	14.2	N/A

Notes:

¹ Meters below ground surface (mbgs).

² SI-10A read by KCB for the first time in September 2022. Previous data for instrument has not been provided to KCB.

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	May 04, 2022	Sep. 22, 2022	968.8	14.7	12.3	12.0	0.3
VW14-01B	1400846	Jul. 2014	May 04, 2022	Sep. 22, 2022	968.8	6.0	5.4	2.8	2.6
VW14-02A	1400849	Jul. 2014	May 04, 2022	Sep. 22, 2022	969.2	14.8	7.3	7.1	0.2
VW14-02B	1400248	Jul. 2014	May 04, 2022	Sep. 22, 2022	969.2	6.1	-0.2	2.1	-2.3
VW14-03A	1400843	Jul. 2014	May 04, 2022	Sep. 22, 2022	969.0	14.9	5.9	5.0	0.9
VW14-03B	1400842	Jul. 2014	May 04, 2022	Sep. 22, 2022	969.0	5.9	2.5	1.5	1.0

Notes:

¹ Meters below ground surface (mbgs).

2.2 Zones of Movement

KCB has assumed all instruments located within the slide mass are damaged (e.g., sheared) due to slide movements.

Data recorded before September 2020 for the operable SIs (SI-1A, SI-5A, SI-9A, and SI-10A) has not been provided to KCB for review. However, historical reports prepared by the previous consultant between 1999 and 2003 did not report significant movements in these SIs, which is not considered unusual because these SIs are located outside the slide mass. No discernible movement has been recorded in SI-1A and SI-9A since they were re-initialized to the September-2020 readings (i.e., when KCB took over the readings at the site and changed the SI reading equipment).

Distributed movement has been recorded in SI-5A from an approximate depth of 14 m to the base of the instrument. However, given the data is difficult to interpret, more data is needed to assess the movement trends for this instrument.

Four wooden stakes located at the crest of the slide are used to estimate slide retrogression. These stakes are susceptible to being knocked over or disturbed. During the July 8, 2021 Section B inspection, it was estimated that the slide has retrogressed between 2.3 m and 3.5 m into the east (northbound lane) ditch since 2016. No additional retrogression was observed during the May 19, 2022 Section B inspection.

2.3 Interpretation of Monitoring Results

No data is 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, an overall decrease of 0.6 m to 1.7 m has been recorded in the SPs. This decrease in water level could be attributed to dry weather from late-2020 until early 2022. Between the spring and fall 2022 readings, a 0.2 m to 0.3 m increase was recorded in SP-01B, SP-01C, and SP-05B likely in response to wet weather in mid-2022. Screen elevations have not been provided for the SPs, which makes data interpretation difficult. The 1994 reading for SP-05C was most likely bad as it is approximately 10 m lower than the previous and current readings.

VWP instrument IDs ending in “A” and “B” denote the deeper and shallower instrument, respectively, as there are four boreholes containing two VWPs each (i.e., nested tips). The shallow VWPs are installed around elevation 963 m, and the deeper VWPs are installed around elevation 954 m.

Generally, relatively steady water levels (± 0.3 m) have been recorded in the deeper VWPs (VW14-01A and VW14-02A) since KCB took over the readings in 2020, except VW14-03A which is installed below

the highway median. The other VWP's are installed at the crest of slide where water can drain more freely. VW14-03A may have more response to changes in precipitation due to water ponding and infiltrating into the highway median.

The upper VWP's (VW14-01B through VW14-03B) appear to more be response than the lower VWP's to changes in groundwater conditions. The 2.6 m to 1.0 m increase recorded in VW14-01B and VW14-03B between the spring and fall 2022 readings could be due to wet weather in mid-2022. It is unclear why a similar increase was not recorded in VW14-02B.

A 2.9 m increase was recorded in VW14-02B between the fall 2021 and spring 2022 readings followed by a 2.3 m decrease between the spring and fall 2022 readings. These readings are inconsistent with readings from the other piezometers at this site. More data is needed to assess trends for this instrument.

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

Based on the limited stratigraphy information provided for the site, it appears one water level may be confined to the till, and one may be confined to the underlying clay shale bedrock. However, KCB is unable to confirm this without the drilling and installation records for the instruments.

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.

There is likely a seasonal variation in water level due to irrigation activity across the highway that may not be captured with spring and fall readings. A data logger could be installed in one or more of the SPs to assess for short-term fluctuations (e.g., increases and decreases) in groundwater level that could be occurring in response to irrigation, or periods of heavy or prolonged rainfall or freshet infiltration between readings.

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 are required. However, during the fall 2022 readings, a 4" diameter polyvinyl-chloride (PVC) pipe was installed at SP-1C. To protect this instrument, the annulus between the instrument and PVC pipe should be backfilled with granular material (gravel or sand).

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.

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

ATTACHMENTS

Figure
Appendix I Instrumentation Plots

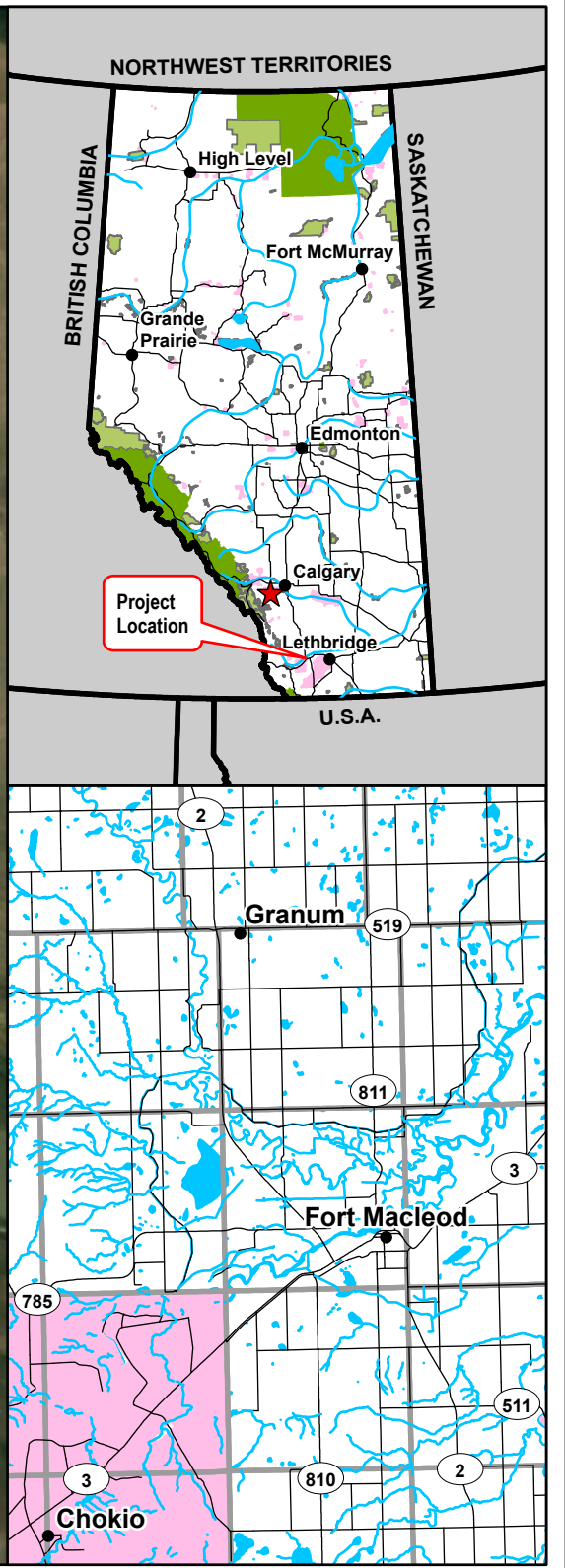
FIGURE



Head scarp 11.5 m away from guardrail.
Buried cables in the slide

Riverbank has been pushed laterally into river by landslide

2008 bank armouring (LPSTP)



Legend

- ▣ Slope Inclinator (SI)
- ⊕ Standpipe Piezometer (SP)
- ⊗ Vibrating Wire Piezometer (VW)
- Flow Direction
- ⊥ Scarp
- ⊗ Fence



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

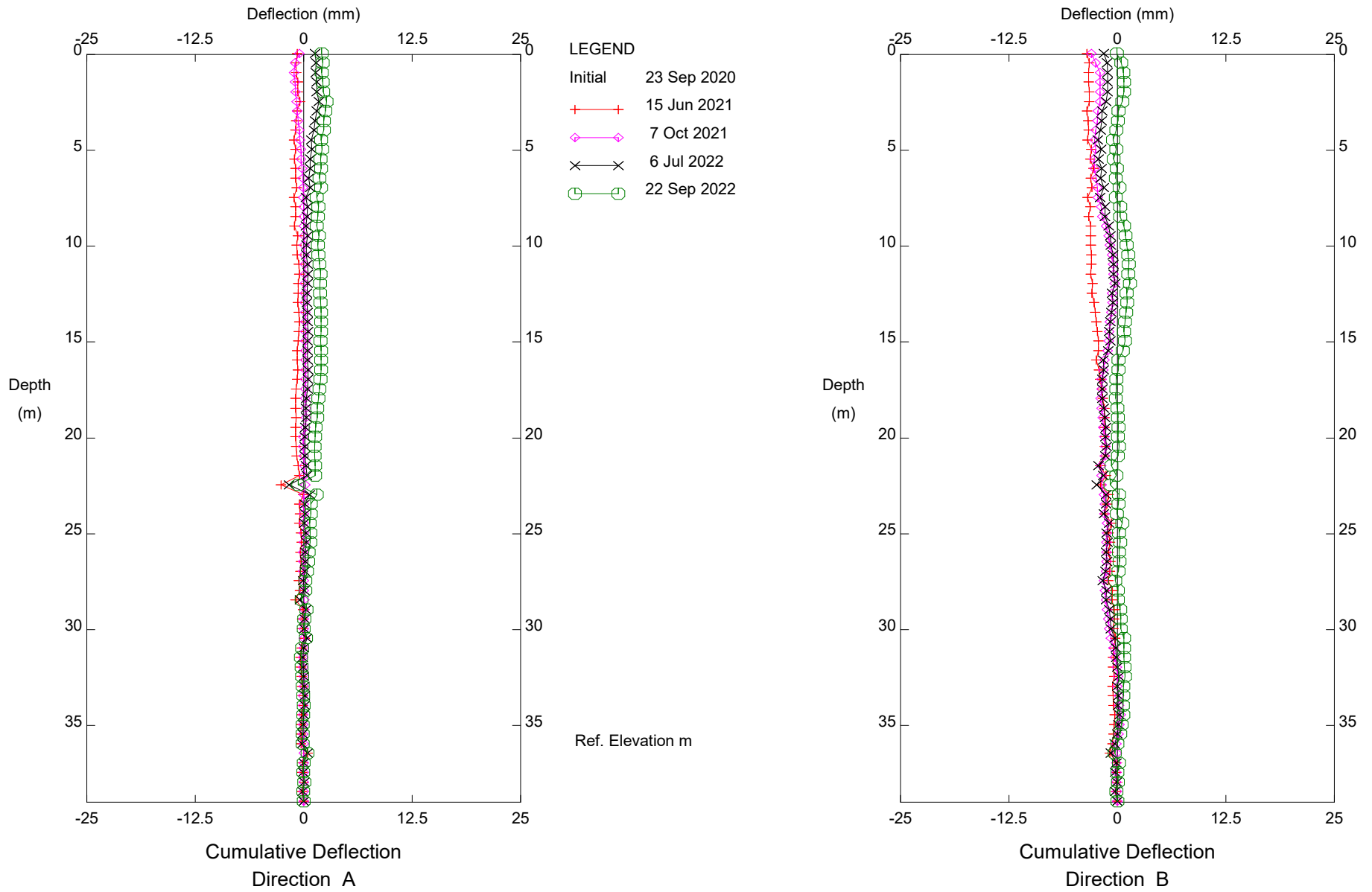
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TITLE Site Plan S004 - Willow Creek (North of Ft. Macleod) Hwy 2:08, km 6.284		
SCALE 1:2,000	PROJECT No. A05116A03	FIG No. 1

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APPENDIX I

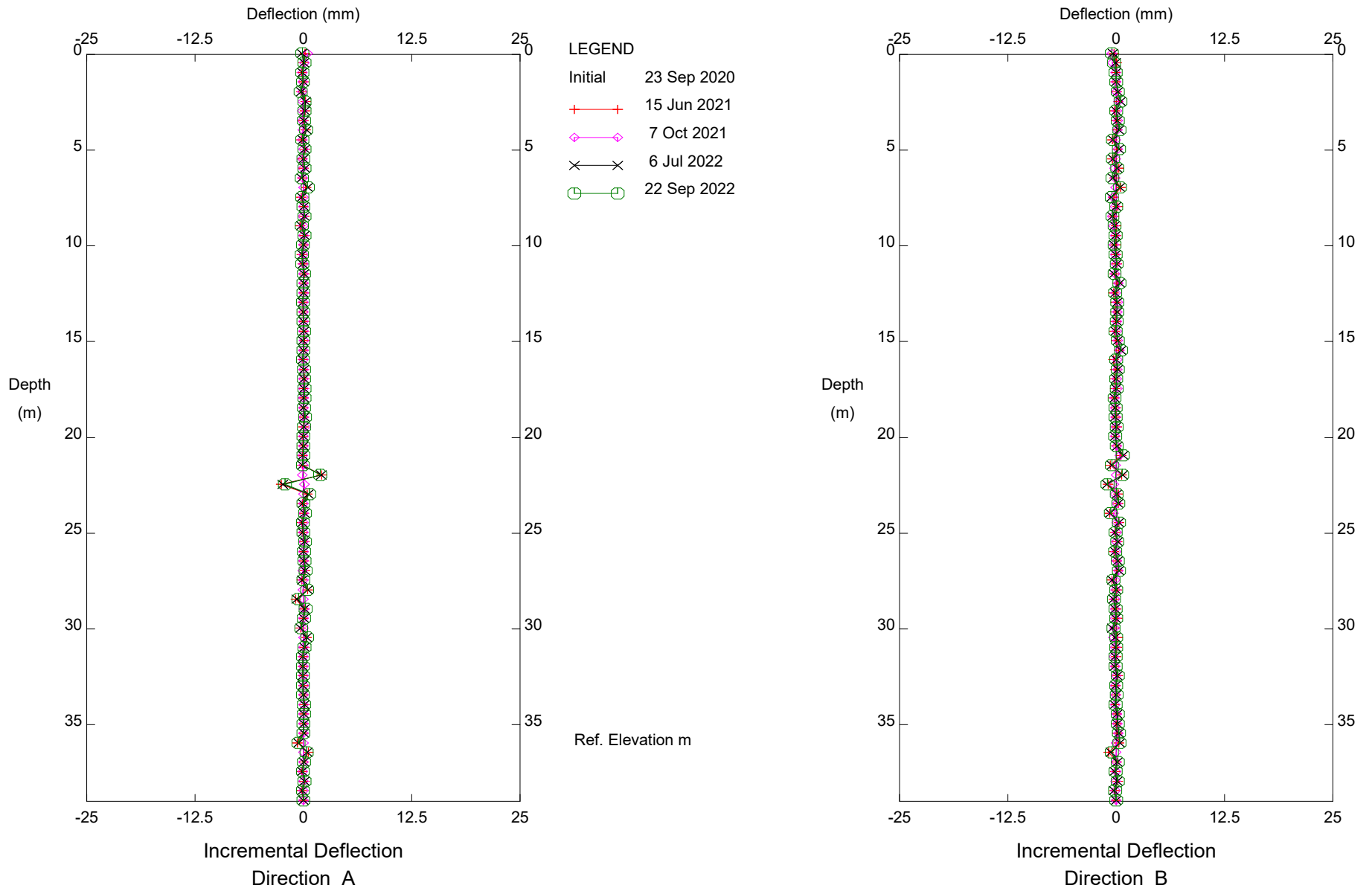
Instrumentation Plots

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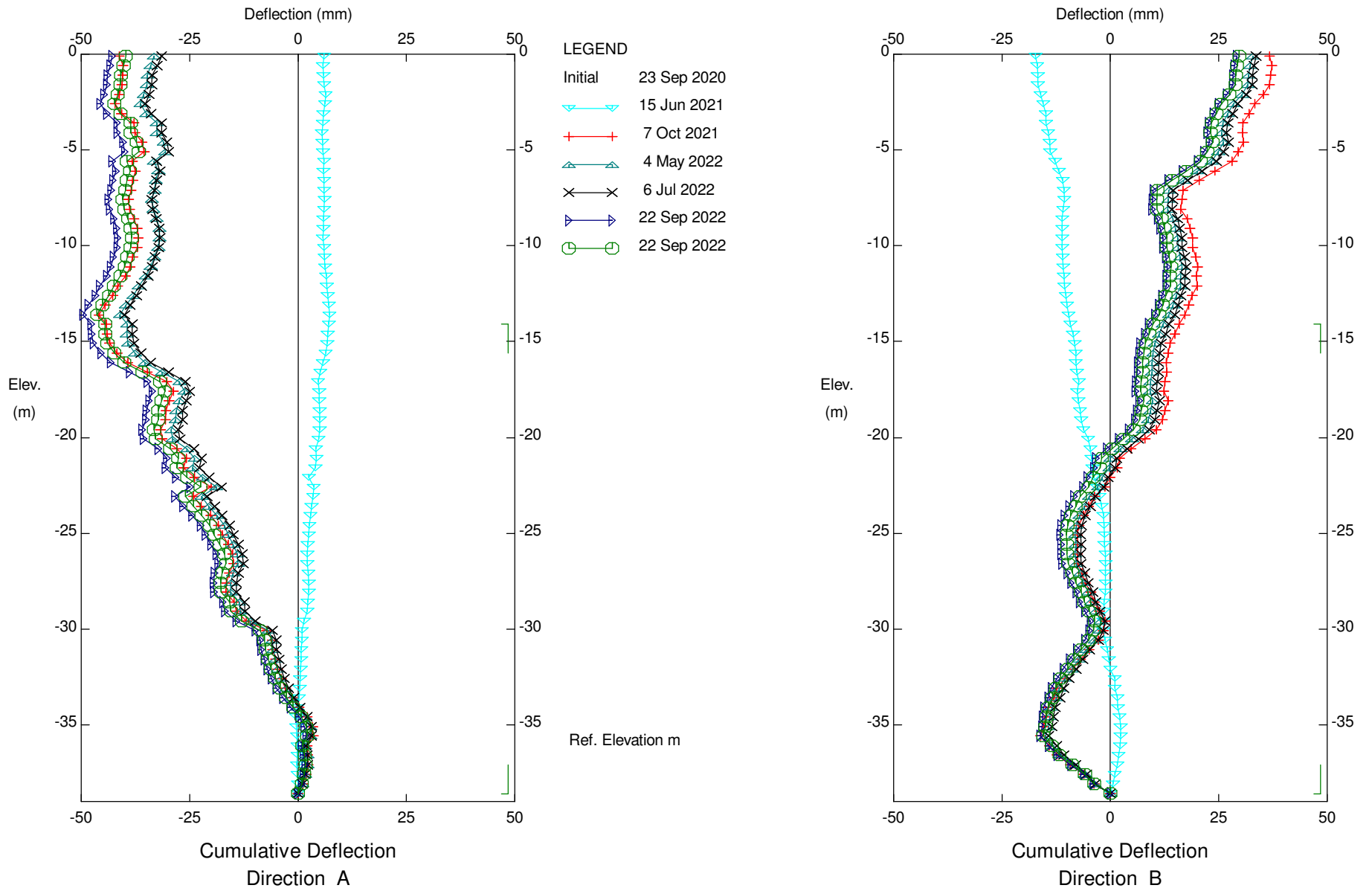
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Alberta Transportation

Klohn Crippen Berger - Edmonton



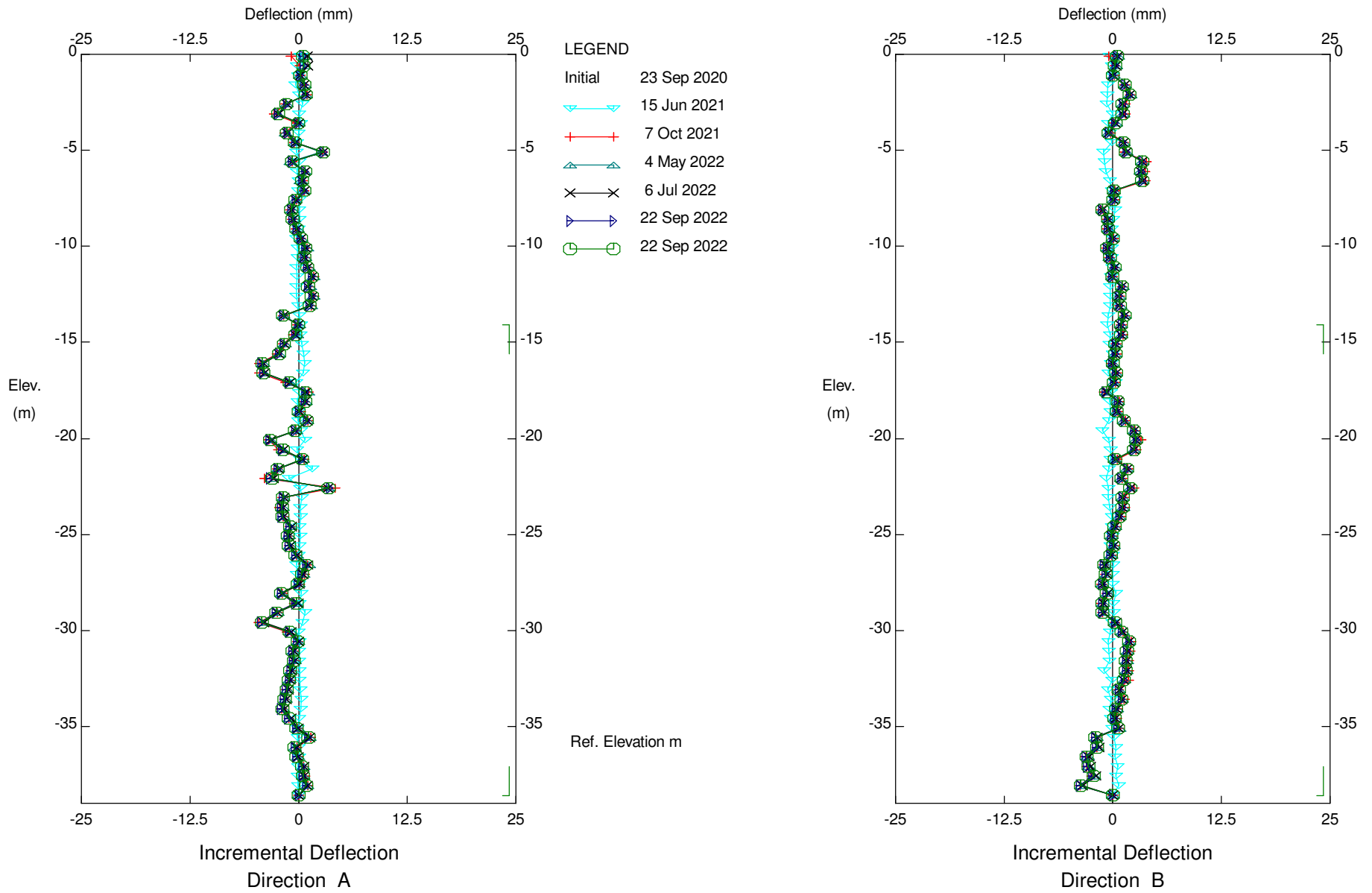
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Alberta Transportation

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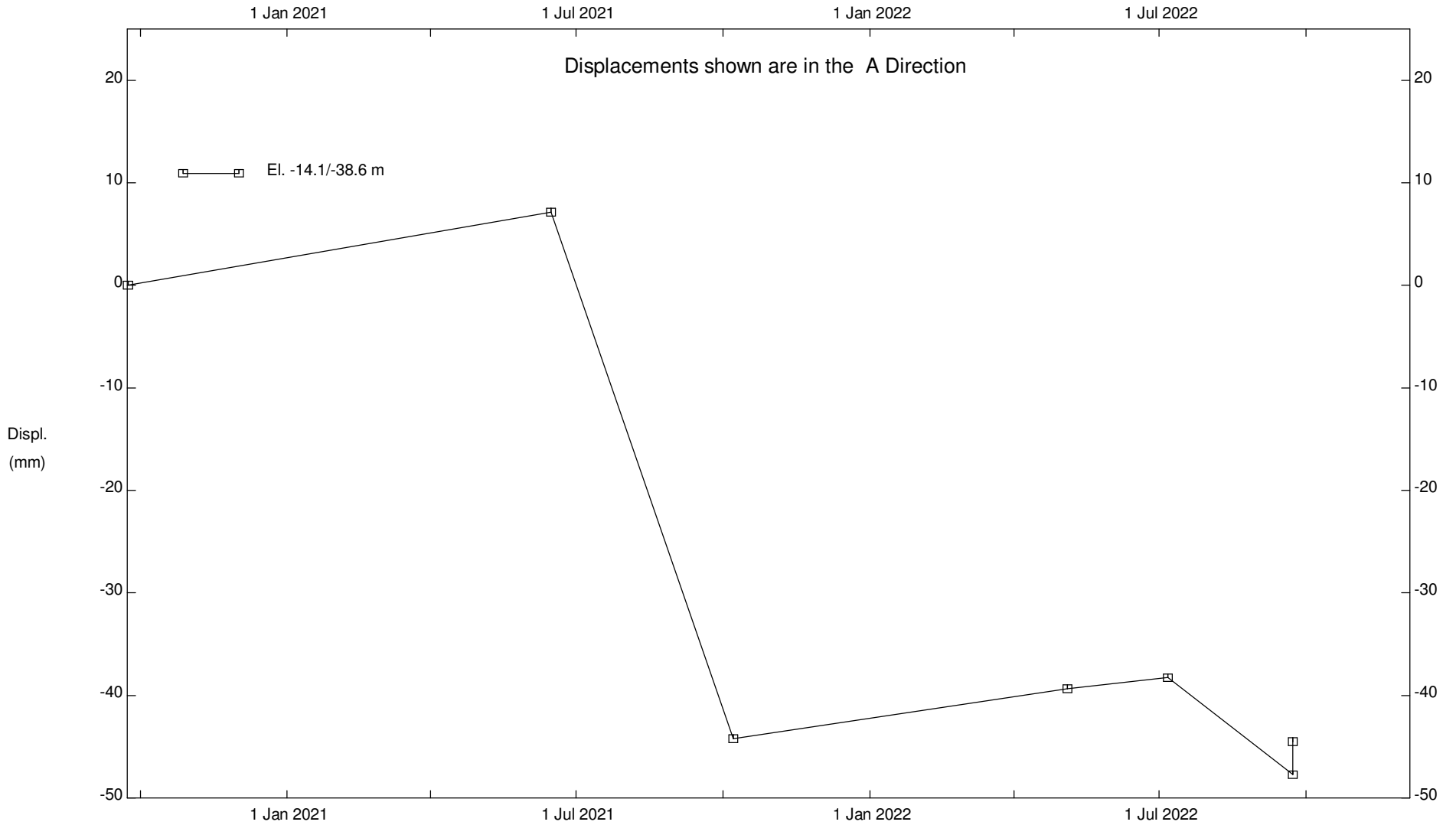
S004; H02:08, Willow Creek, Inclinator SI-5A
 Alberta Transportation

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S004; H02:08, Willow Creek, Inclinometer SI-5A
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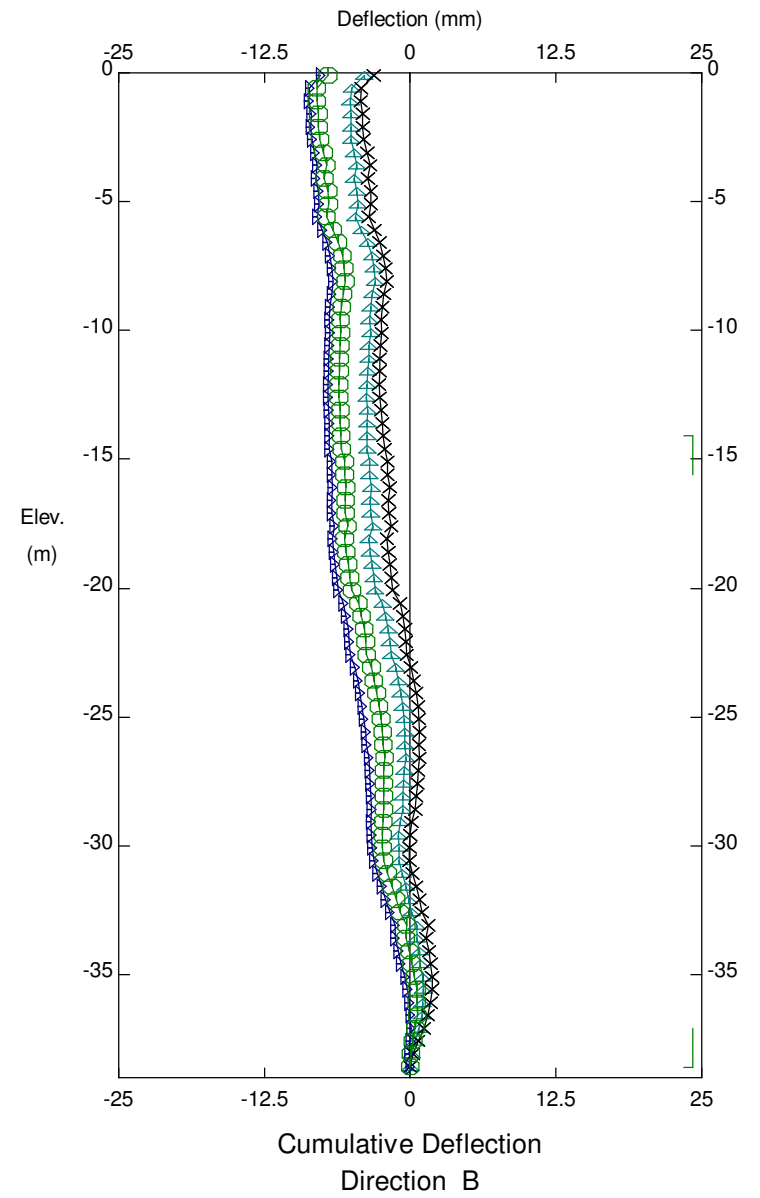
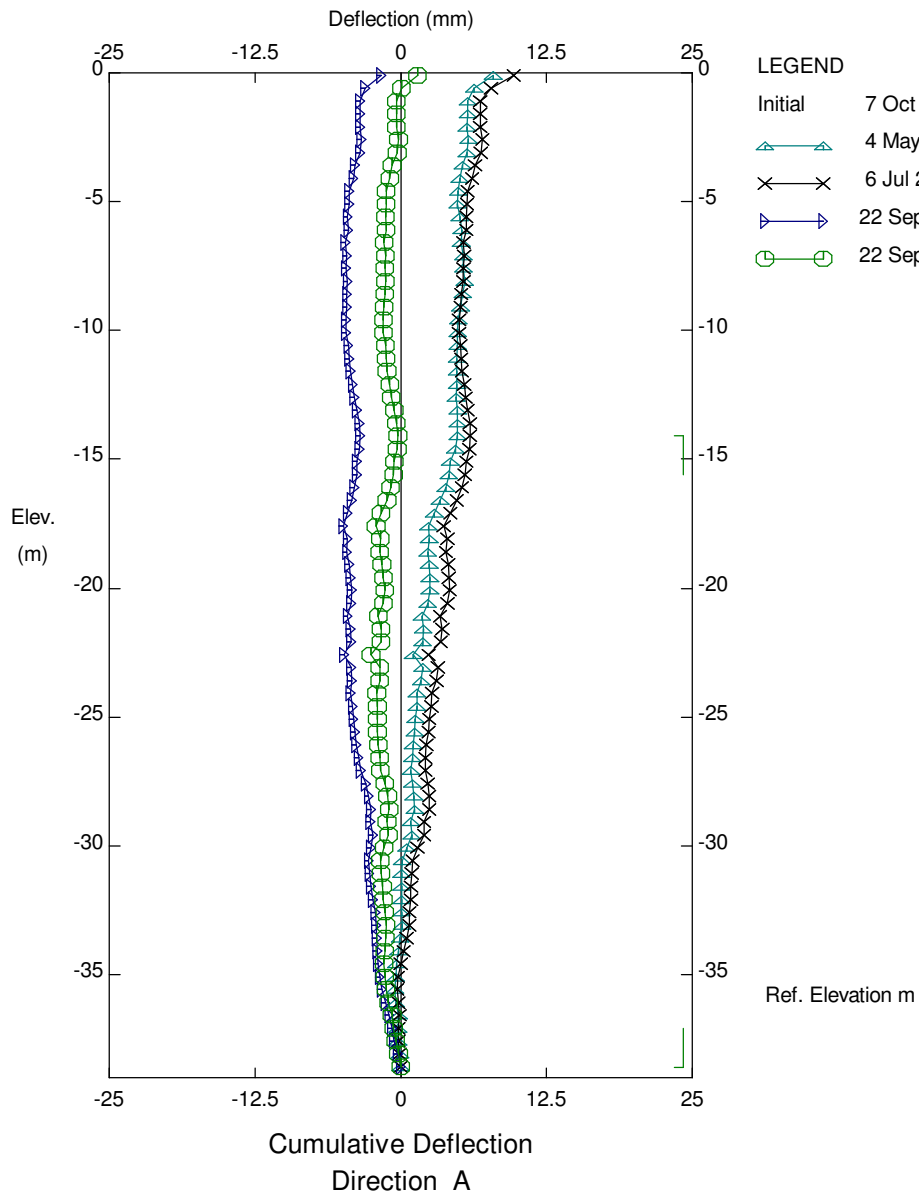
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S004; H02:08, Willow Creek, Inclinometer SI-5A

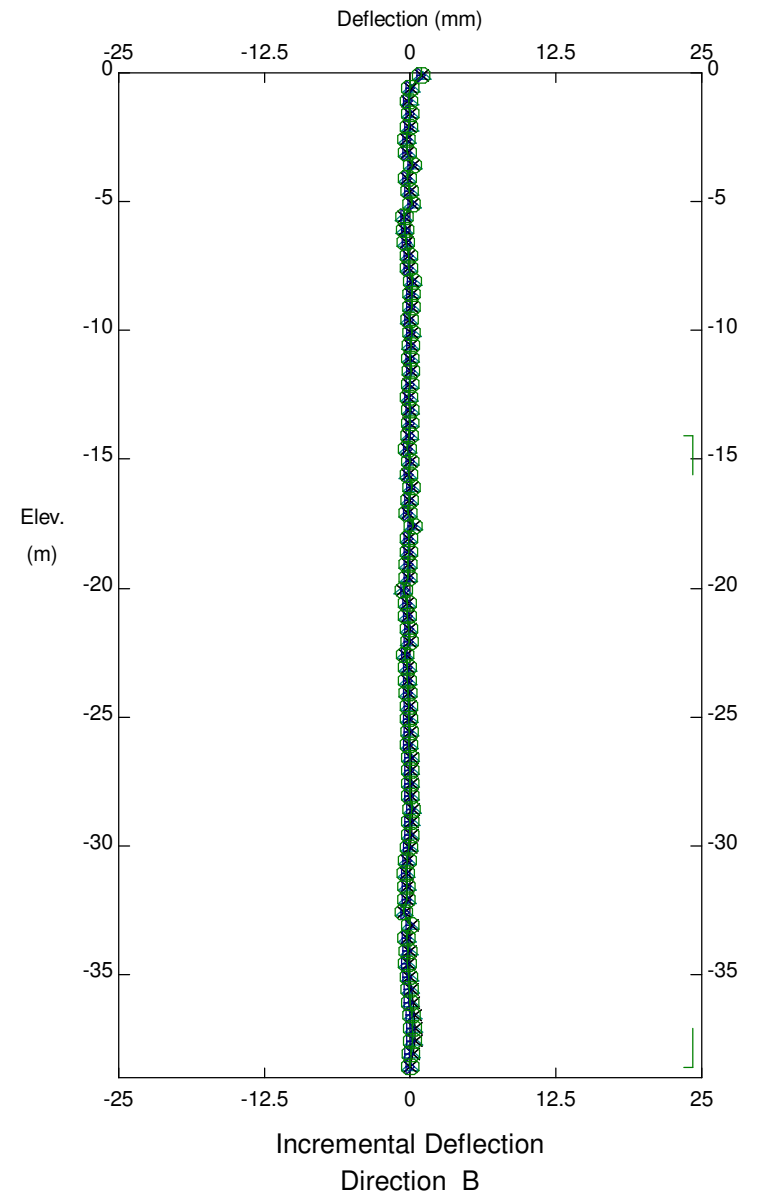
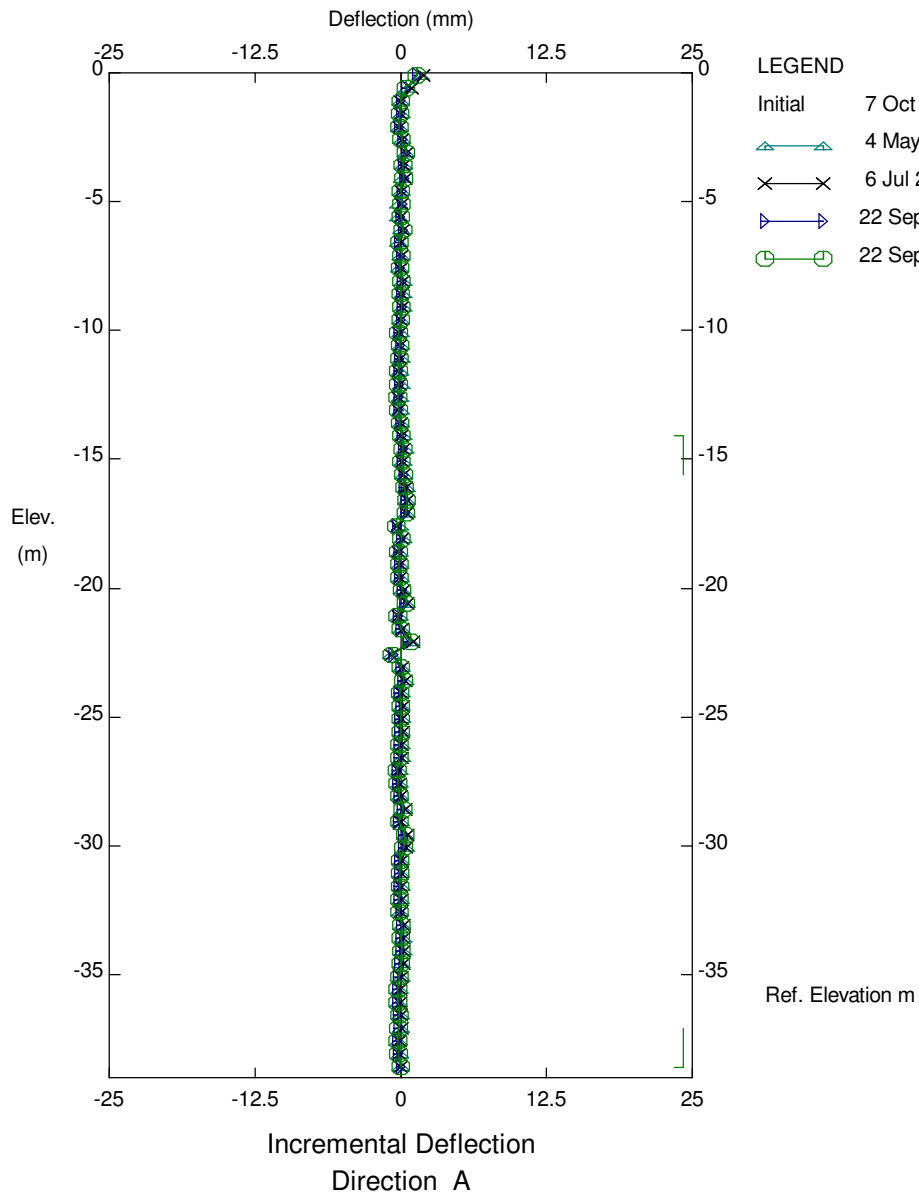
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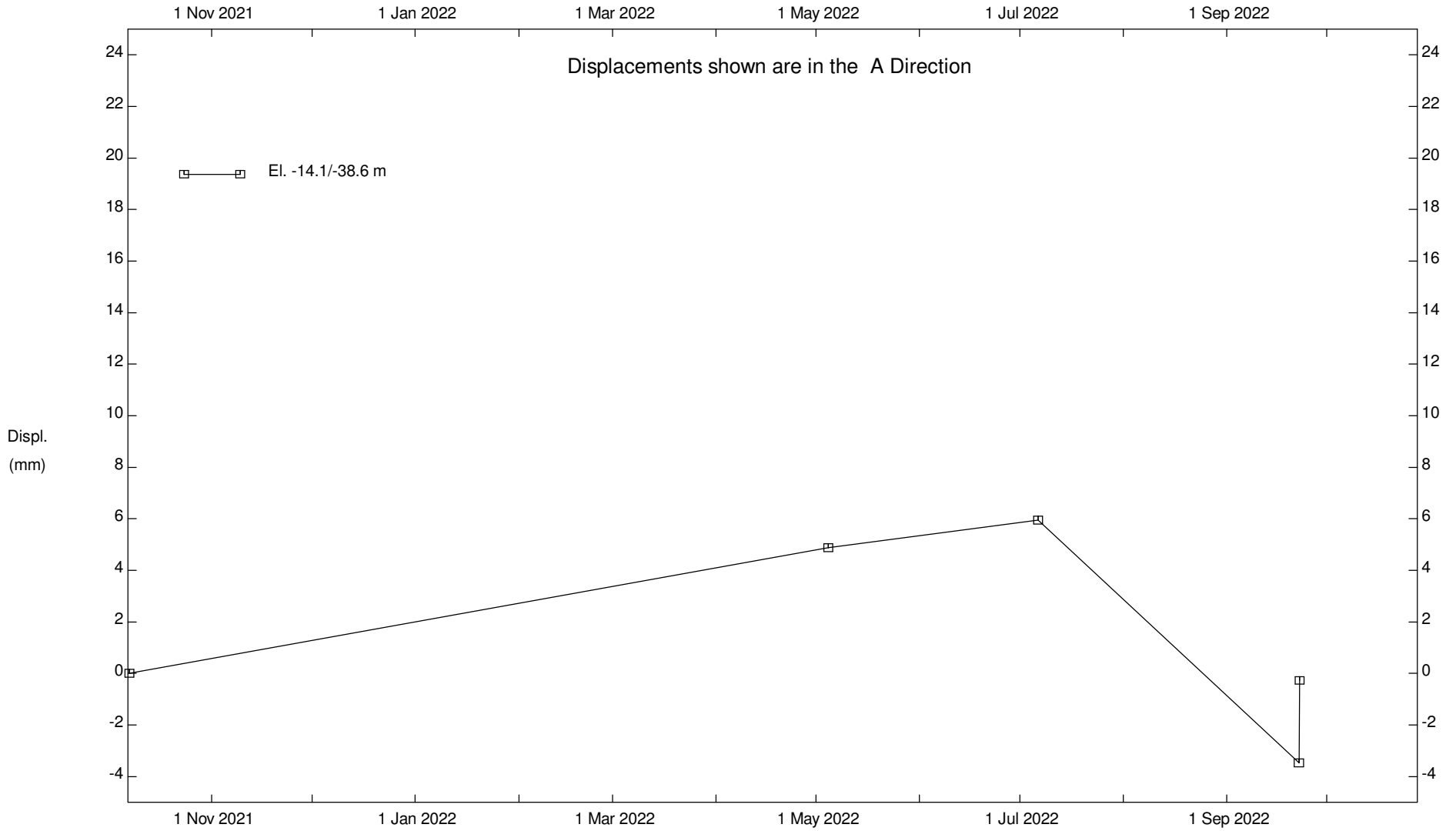
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S004; H02:08, Willow Creek, Inclinator SI-5A
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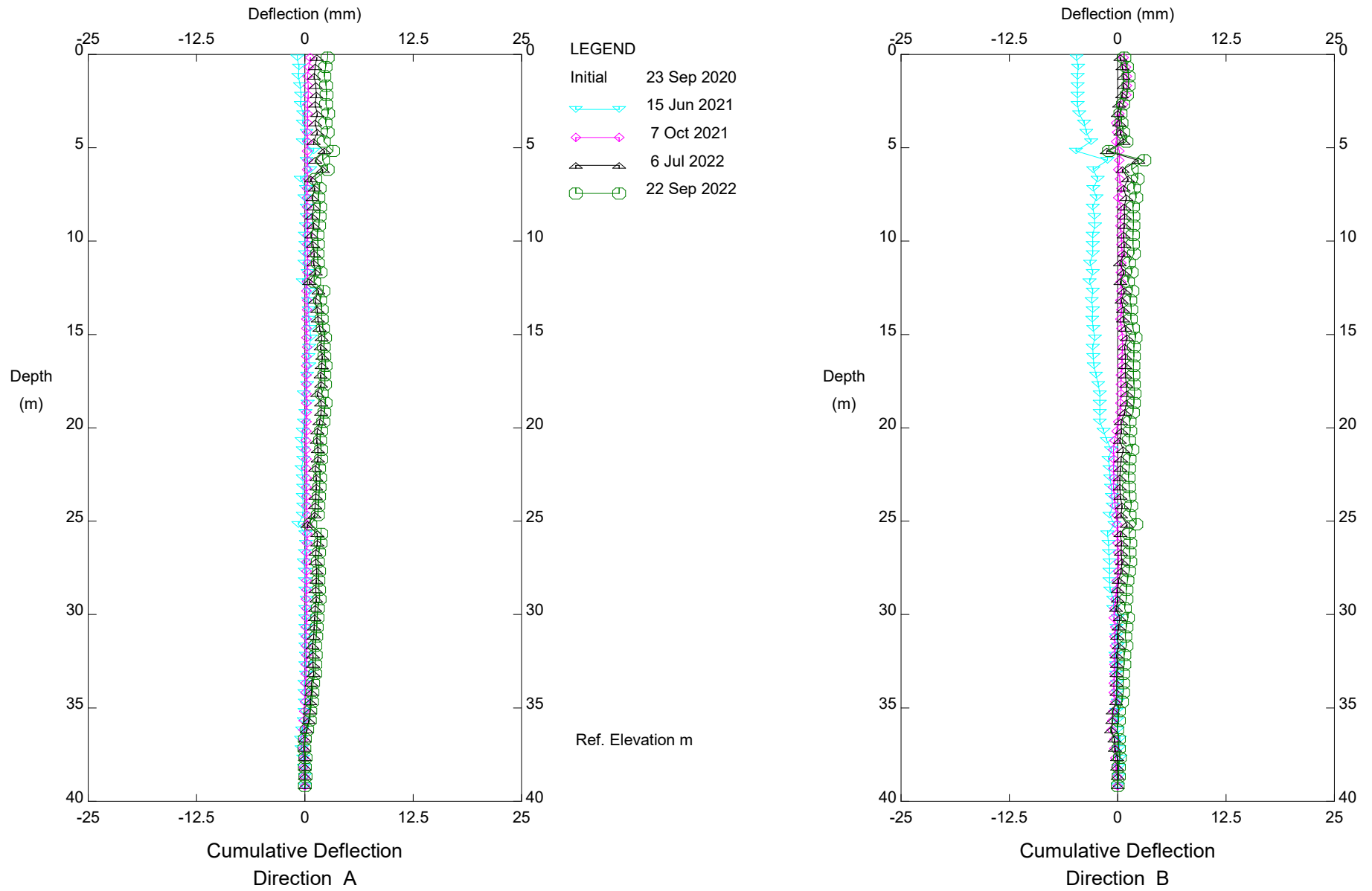
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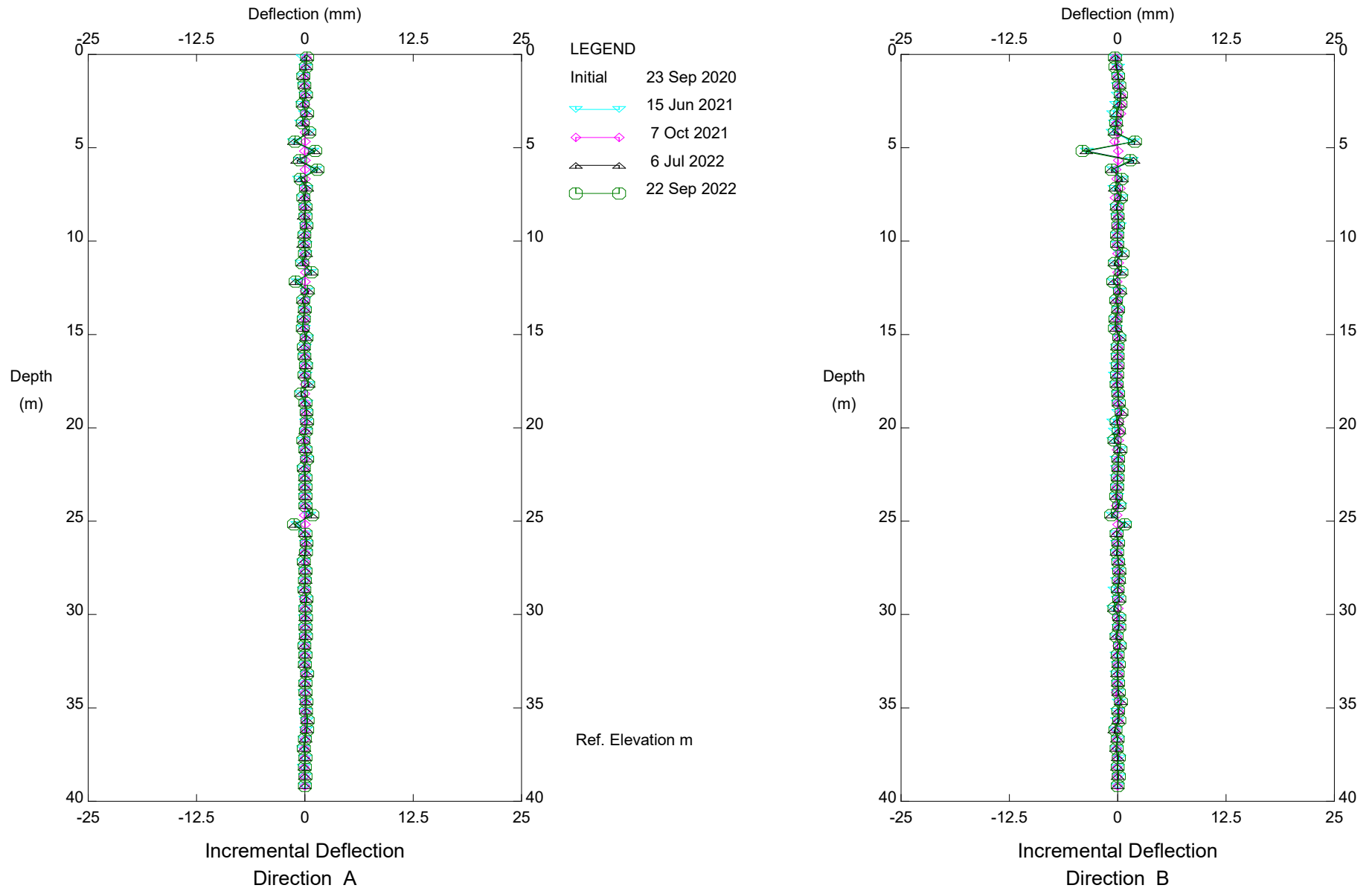
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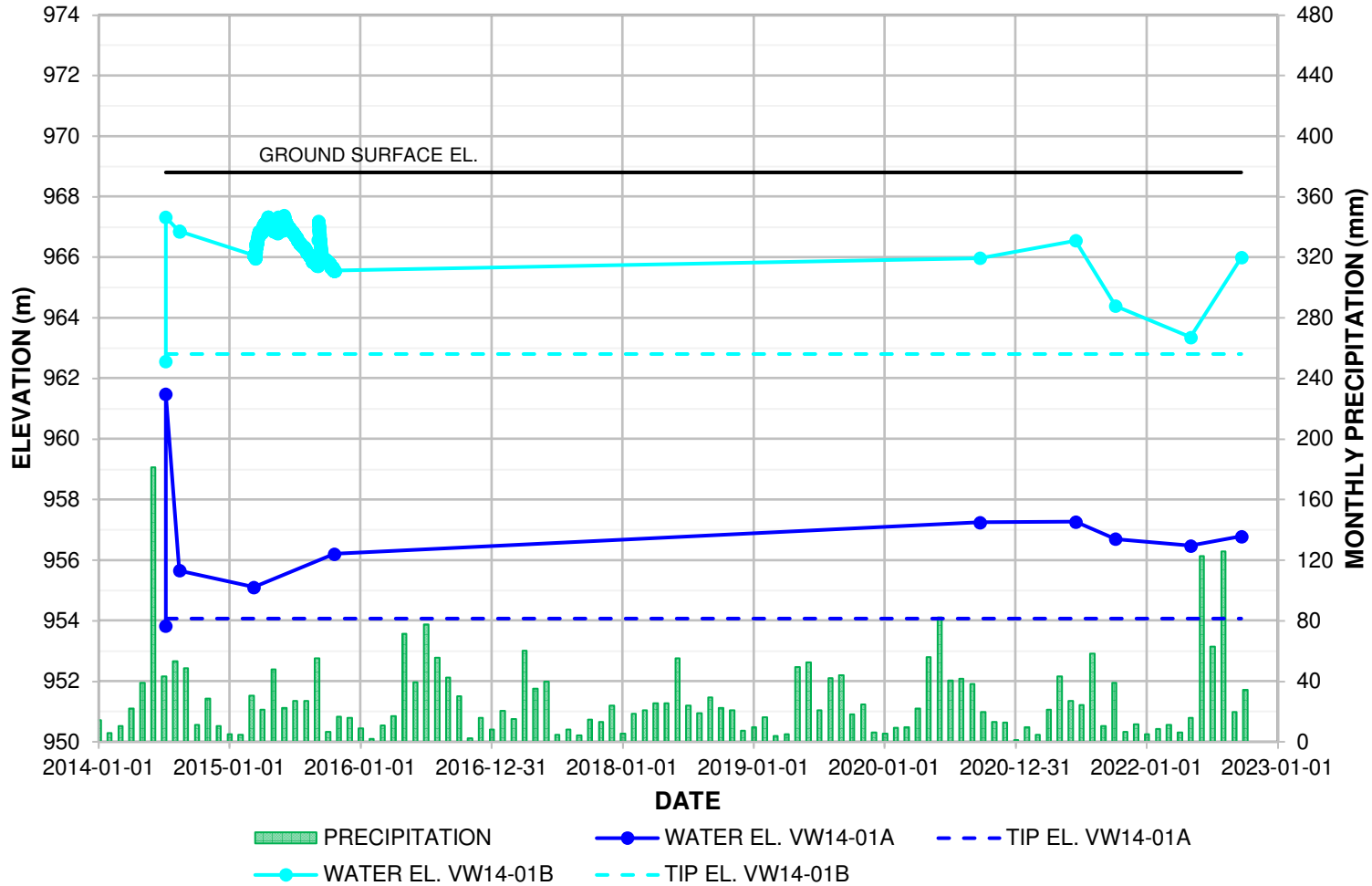
S004; H02:08, Willow Creek, Inclinator SI-9A
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S004; H02:08, Willow Creek, Inclinator SI-9A
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VW14-01A AND VW14-01B

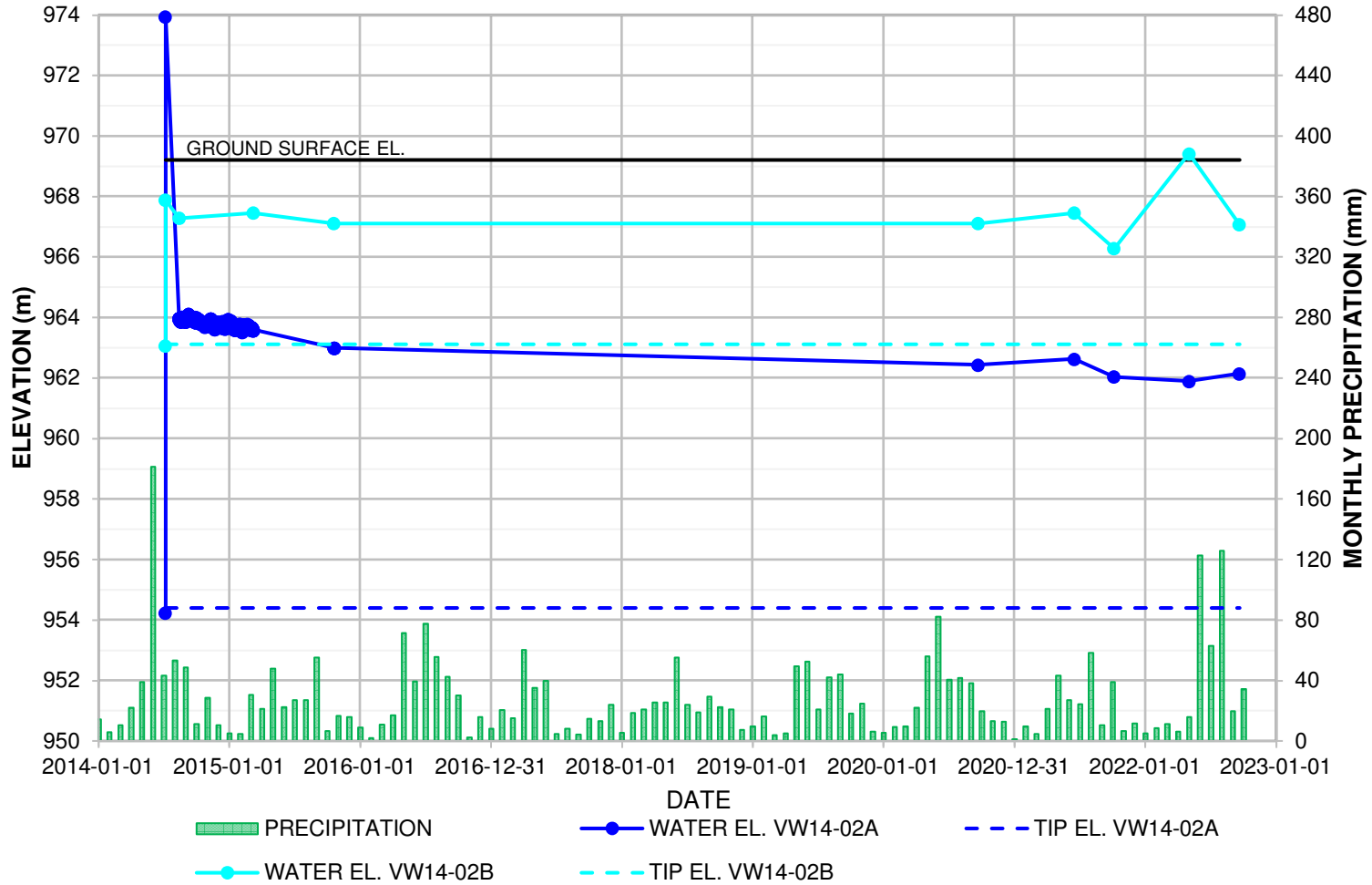


NOTES:

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 	PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
	TITLE Vibrating Wire Piezometer Data S004 - Willow Creek Hwy 02:08, km 6.284	
	SCALE	PROJECT No. A05116A03
	FIG No.	

VW14-02A AND VW14-02B

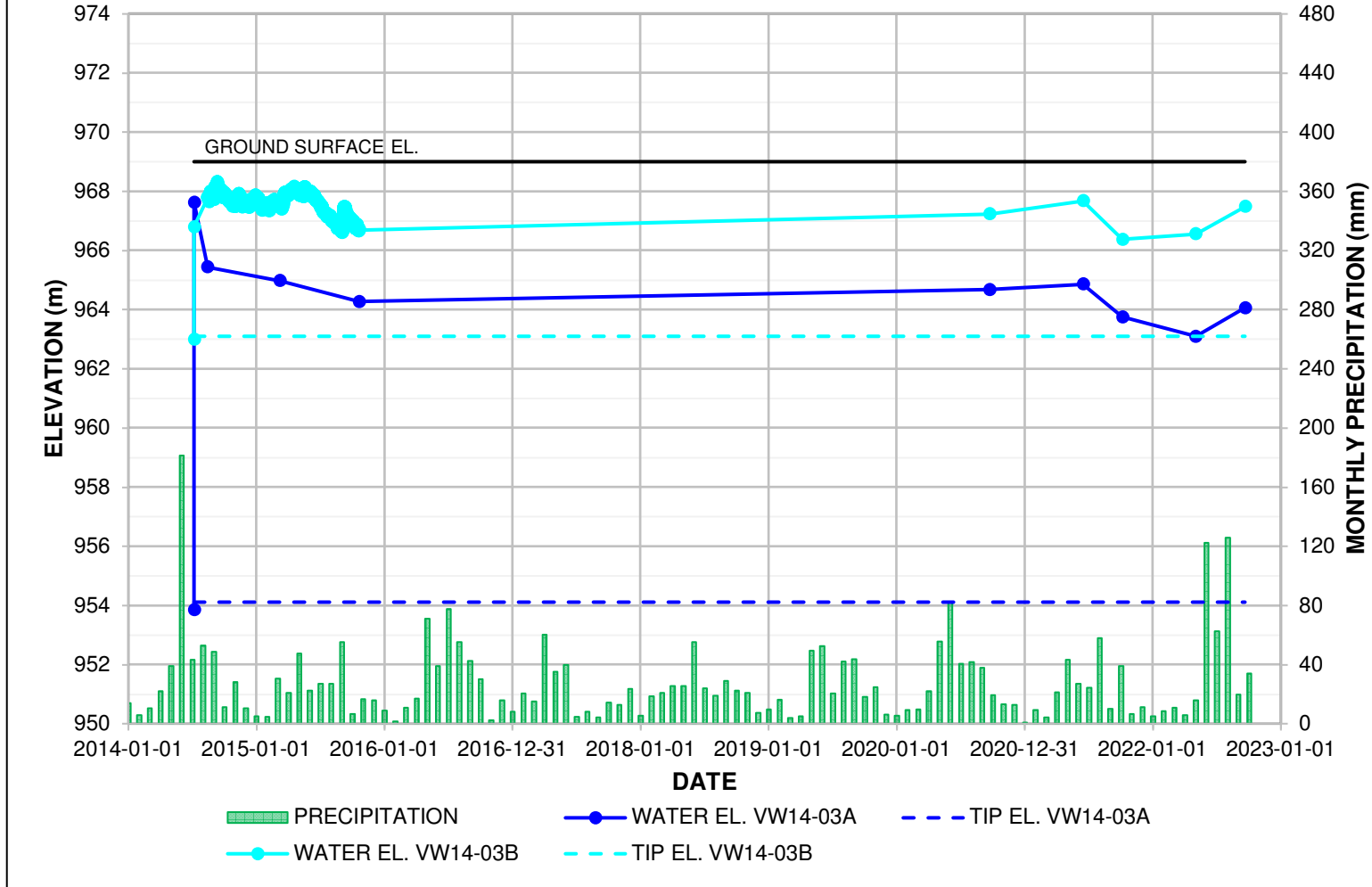


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CLIENT		PROJECT	
 		SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
		TITLE	
		Vibrating Wire Piezometer Data S004 - Willow Creek Hwy 02:08, km 6.284	
SCALE	PROJECT No.	A05116A03	FIG No.

VW14-03A AND VW-03B

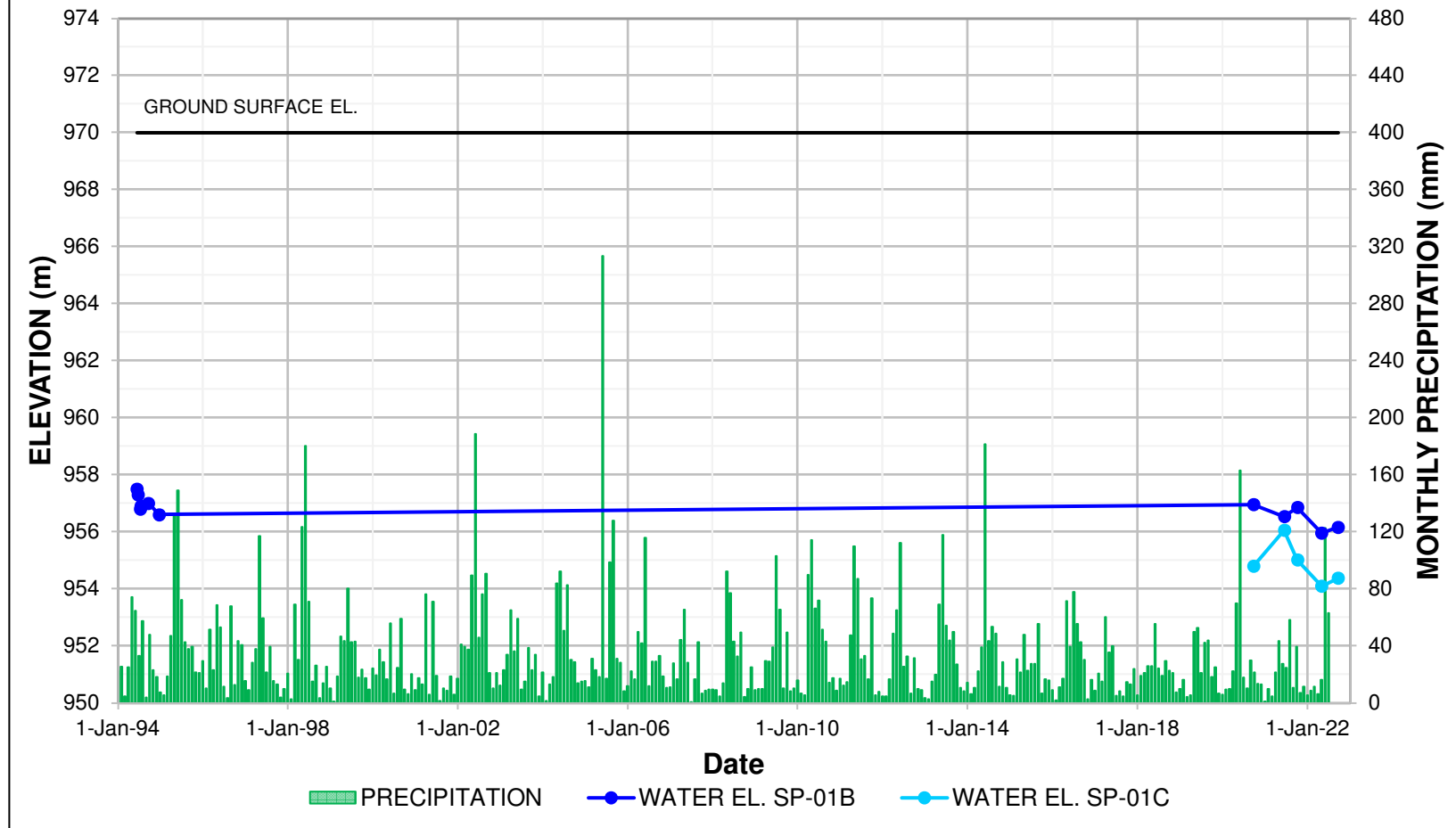


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<p>CLIENT</p> <div style="text-align: center;"> </div>	<p>PROJECT</p> <p style="text-align: center;">SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM</p>
<div style="text-align: center;"> </div>	<p>TITLE</p> <p style="text-align: center;">Vibrating Wire Piezometer Data S004 - Willow Creek Hwy 02:08, km 6.284</p>
<p>SCALE</p>	<p>PROJECT No. A05116A03 FIG No.</p>

SP-01B AND SP-01C

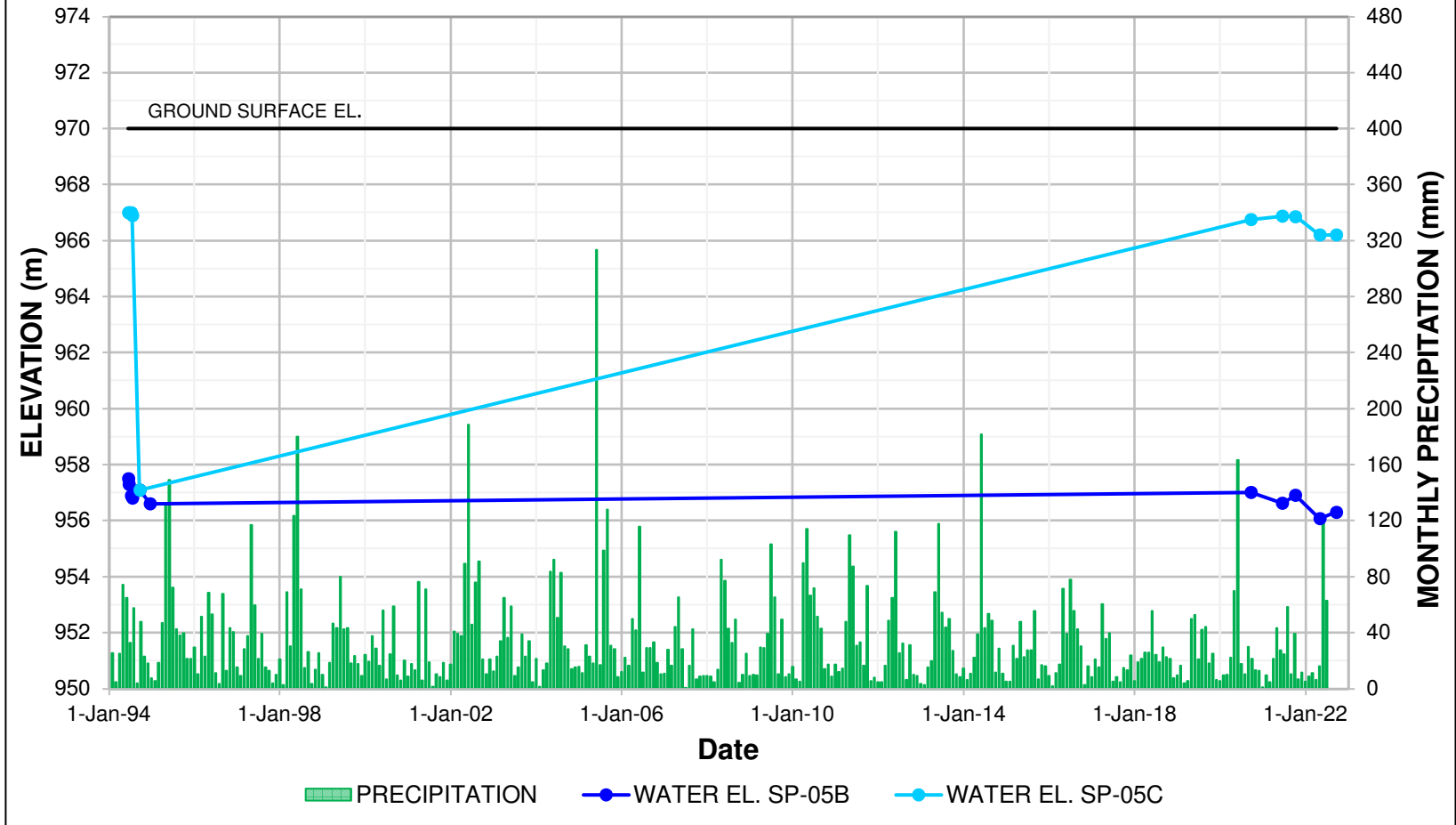


NOTES:

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 	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.

SP-05B AND SP-05C

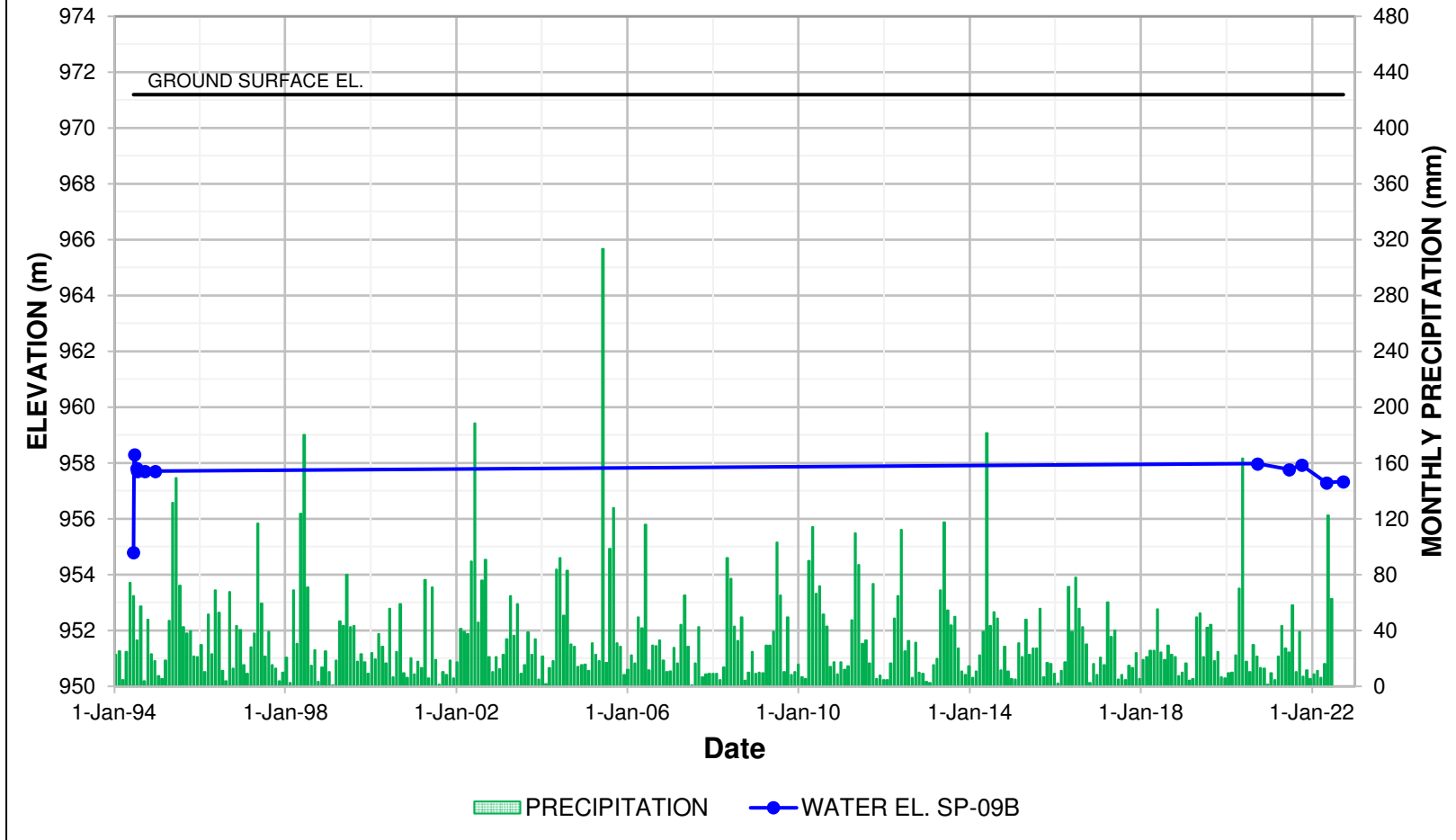


NOTES:



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.

CLIENT 	PROJECT SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM <hr/> TITLE Standpipe Piezometer Data S004 - Willow Creek Hwy 02:08, km 6.284 <hr/> SCALE PROJECT No. A05116A03 FIG No.
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SP-09B



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 	PROJECT 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	