Klohn Crippen Berger

September 21, 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 S036; H800:02, km 9.05 Belly River
Section C – 2022 Spring Readings

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1 GENERAL

Two slope inclinometers (SIs) (SI11-1 and SI11-2) and six vibrating wire piezometers (VWPs) (VW10-6701, VW10-6706, VW12-7899, VW12-7983, VW12-7888, and VW7051) were read at the S036 site in Southern Region on July 7, 2022, by Mr. Guerin White, 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 800:02 km 9.05, approximately 9 km south of the Village of Hill Spring, Alberta, on the east side of the Belly River, in the Blood Tribe 148 Reserve. A permit was issued by Blood Tribe Land Management to Mr. White before the instrumentation readings were completed. The approximate site coordinates are 5454362 N, 308507 E (UTM Zone 12, NAD 83) and the legal land description for the site is NW 18-03-27-W4. A site plan is presented in Figure 1.

The geohazard at the S036 site consists of a landslide approximately 200 m long, on the outside (south) bend of the Belly River riverbank. Previous remedial actions at the site include:

- In 2010, a section of the slide (approximately 40 m to 50 m in length) was excavated to a 1H:1V slope and two to three rows of soil nails (approximately 6 m long) were installed in the excavated slope face to temporarily stabilize the slide. The soil nails were installed with 1 m vertical and horizontal spacing. The total number of soil nails installed is unknown.
- In 2012, the site was repaired by armouring the riverbank and channel with riprap, constructing a flow control structure, improving drainage, rebuilding the embankment slope, and buttressing the slope with a toe berm.

In 2011 and 2012, geotechnical site investigations, which included installing instruments, were conducted at the S036 site by a previous consultant to support design, construction, and post-construction monitoring. The encountered stratigraphy has not been provided to KCB.

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CANADA BEST MANAGED COMPANIES Platinum member

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

In 2011, two SIs and eight VWPs were installed at the site by a previous consultant to monitor movement and groundwater conditions, respectively. In 2012, four additional VWPs were installed to monitor the performance of the drainage system installed below the toe berm during 2012 construction. Some of the VWPs are now inoperable.

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

KCB changed the SI reading equipment in 2016 when KCB took over the readings from the previous consultant, 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 operable VWPs were read using an RST VWP readout box.

Table 1.1 Instrument Installation Details

Instrument ID	Instrument Type	Date Installed	UTM Coordinates[2] (m)		Ground Surface Elevation (m)	Stick Up (m)	Depth[2] (mbgs[3])	Condition
			Northing	Easting				
SI11-01	SI	Mar. 2011	5454320	308550	1208.0	0.0	20.0	Operable
SI11-02	SI	Mar. 2011	5454411	308585	1208.0	0.0	20.0	Operable
VW10-6701	VWP	Mar. 16, 2011	5454314	308529	1208.0	N/A	10.8	Operable
~~VW10-6703~~	~~VWP~~	~~Mar. 2011~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~N/A~~	~~Unknown~~	~~Inoperable~~
VW10-6706	VWP	Mar. 16, 2011	5454289	308507	1210.5	N/A	11.6	Operable
~~VW10-6707~~	~~VWP~~	~~Mar. 2011~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~N/A~~	~~Unknown~~	~~Inoperable~~
~~VW10-6708~~	~~VWP~~	~~Mar. 2011~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~N/A~~	~~Unknown~~	~~Inoperable~~
~~VW10-6709~~	~~VWP~~	~~Mar. 2011~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~N/A~~	~~Unknown~~	~~Inoperable~~
~~VW10-6711~~	~~VWP~~	~~Mar. 2011~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~N/A~~	~~Unknown~~	~~Inoperable~~
~~VW10-6715~~	~~VWP~~	~~Mar. 2011~~	~~Unknown~~	~~Unknown~~	~~Unknown~~	~~N/A~~	~~Unknown~~	~~Inoperable~~
VW12-7899	VWP	Dec. 11, 2012	5454370	308589	1193.0	N/A	3.4	Operable
VW12-7983	VWP	Dec. 11, 2012	5454355	308523	1199.0	N/A	8.3	Operable
VW12-7888	VWP	Dec. 11, 2012	5454393	308527	1193.0	N/A	3.5	Operable
VW12-7051	VWP	Dec. 11, 2012	5454385	308539	1198.0	N/A	3.3	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).

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2 INTERPRETATION

2.1 General

For the operable SIs, the cumulative displacement, incrementation displacement, and displacement-time data was plotted in the A-direction (i.e., in the direction of the A0-grooves) and in the X-direction (i.e., the direction of maximum movement obtained at a skew angle from the A0-grooves). SI11-01 and SI11-02 have skew angles of 30° and 200°, respectively, measured clockwise from the A0-grooves.

For the operable VWPs, the recorded porewater pressures were converted to an equivalent water/piezometric elevation and plotted relative to ground surface each instruments tip elevation. The VWP readings are taken from one central monitoring station located on the toe berm, where all the VWP cables have been trenched to.

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 TWP003-27-W4.

The SI and piezometer data plots are included in Appendix I, and a summary of the SI and piezometer data is proved in Table 2.1 and Table 2.2, respectively. The SI data plots only includes data obtained by KCB.

2.2 Zones of Movement

Movement has been recorded in SI11-01 from an approximate depth of 7 m to 10 m below ground surface (approximately El. 1198 m to El. 1201 m). Shallow movement from ground surface to approximately 2 m below ground surface (El. 1206 m) was also recorded between June 2021 and July 2022.

Movement has been recorded in SI11-02 from an approximate depth of 16 m to 20 m below ground surface (approximately El. 1192 m to El. 1196 m).

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Table 2.1 Slope Inclinometer Reading Summary

Instrument ID	Date				Ground Surface Elevation (m)	Depth of Movement (mbgs[1])	Direction of Movement[2]	Movement (mm)				Rate of Movement (mm/year)		
	Initialized (Re-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
								Before Re-Initialization	After Re-Initialization	Total				
SI11-01	May 5, 2011 (May 27, 2016)[3]	May 15, 2020	Jun. 16, 2021	Jul. 7, 2022	1208	0.5 – 4.0	X-Direction, 30°	Unknown	5.6	5.6	1.4	2.7	4.5	8.8
		Oct. 21, 2018				7.0 – 10.0		16.0[3]	2.5	18.5	-1.8	20.6	0.3	-1.3
SI11-02	May 5, 2011	Sep. 15, 2016	Jun. 16, 2021	Jul. 7, 2022	1208	12.0 – 16.0	X-Direction, 200°	N/A	N/A	3.3	-1.2	4.2	-0.6	-0.9

Notes:
[1] Meters below ground surface (mbgs).
[2] Skew angle of X-direction measured clockwise from the A-direction.
[3] SI11-01 was re-initialized in May, 2016 when KCB took over the instrument readings from the previous consultant and changed the SI reading equipment. Movement recorded before 2016 was taken from reports prepared by the previous consultant.

Table 2.2 Vibrating Wire Piezometer Reading Summary

Instrument ID	Date			Ground Surface Elevation (m)	Tip 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)
VW10-6701	Mar. 16, 2011	Jun. 16, 2021	Jul. 7, 2022	1208.0	10.8	8.9	9.3	-0.5
VW10-6706	Mar. 16, 2011	Jun. 16, 2021	Jul. 7, 2022	1210.5	11.6	5.9	6.1	-0.2
VW12-7899	Dec. 11, 2012	Jun. 16, 2021	Jul. 7, 2022	1193.0	3.3	0.4	0.3	0.1
VW12-7983	Dec. 11, 2012	Jun. 16, 2021	Jul. 7, 2022	1199.0	8.2	7.3	7.0	0.2
VW12-7888	Dec. 11, 2012	Jun. 16, 2021	Jul. 7, 2022	1193.0	3.5	2.8	2.6	0.2
VW12-7051	Dec. 11, 2012	Jun. 16, 2021	Jul. 7, 2022	1198.0.	3.3	2.2	2.0	0.1

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

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2.3 Interpretation of Monitoring Results

Slope Inclinometers

Between March 2011 and October 2015, the previous consultant reported:

- movement in SI11-01 from an approximate depth of 7 m to 10 m below ground surface (approximately El. 1198 to El. 1201 m). This movement was attributed to construction activities at the site in 2012 and not continued movement of the slide mass.
- movement in SI11-02 from an approximate depth of 7 m to 10 m below ground surface (approximately El. 1198 to El. 1201 m). The amount of movement was small (less than 2.5 mm) and likely due to post-installation flexure of the SI casing and/or backfill.

Since KCB took over the instruments readings at the site, the rate of movement recorded in SI11-01 and SI11-02 has been slow (less than 1 mm/year overall) and is currently negligible. The negative rate of movement recorded in these instruments during some readings indicates the rate of movement is within the accuracy of the reading equipment.

The July 2022 data indicates a small amount of movement (less than 6 mm) has occurred in the upper 2 m of SI11-01 since the fall 2021 reading. This movement could be due to instrument noise or reading error, or an indication that the slide is retrogressing towards the highway. More data is needed to assess.

Overall, given the negligible movement that has been recorded in SI11-01 and SI11-02, it appears as though the stabilization work completed in 2012 was successful and is performing well.

Vibrating Wire Piezometers

VW10-6701 and VW10-6706 were installed outside of the active slide zone, between the head of the slide and the west (southbound) lane of the highway. A steady increase (up to approximately 3 m) in water level was recorded in VW10-6701 and VW10-6706 between March 2011 (when the instruments were installed) and May 2012. Without reviewing previous borehole records, construction records for the site, or installation details for the instruments, KCB is unable to assess the cause of the increase in water level at this time. KCB suspects the increase may be attributed to a delayed response to 2010 construction activities, or post-installation instrument stabilization.

Following construction in 2012, water levels recorded in VW10-6701 remained relatively steady until a 1.4 m decrease was recorded between October 2018 and April 2019. The cause of the decrease is unknown. Since April 2019, water levels recorded in VW10-6701 have fluctuated from approximately 8.8 m to 9.4 m below ground surface.

Since May 2012, water levels recorded in VW10-6706 have slowly decreased most likely due to excess porewater pressure dissipation following 2012 construction. In total, a 1.9 m and 0.2 m decrease has been recorded since May 2012 and the June 2021 reading, respectively.

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In 2012, four VWPs (VW12-7983, VW12-7888, VW12-7899, and VW12-7051) were installed within the active slide zone, in drain material below the toe berm as reported by the previous consultant, to monitor the performance of the drain below the toe berm fill. VW12-7888 and VW12-7899 were installed closer to the toe of the embankment, while VW12-7083 and VW12-7051 were installed closer to the head of the slide.

Water levels recorded in VW12-7888 and VW12-7899 have been relatively steady since installation between an approximate depth of 2.6 m to 3.1 m and 0.3 m to 1.1 m, respectively. Whereas water levels recorded in VW12-7051 and VW12-7982 have been steadily increasing (approximately 1.3 m and 1.1 m overall, respectively). The rate of increase recorded in VW12-7982 may be slowing or flattening but more data is needed to assess. Last year and the spring of 2022 were relatively dry.

Without reviewing stratigraphy or construction records for the site or installation details for the instruments, it is difficult to assess the cause of the increase recorded in VW12-7051 and VW12-7982.

Overall, the July 2022 readings of the VWPs were consistent with historical trends observed in these instruments.

3 RECOMMENDATIONS

3.1 Future Work

All operable instruments should continue to be read once per year (spring).

KCB and AT must continue to obtain permission from the Blood Tribe to access the slide area during the bi-annual site inspections and annual instrumentation 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 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.

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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.

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

James Lyons, P.Eng.
Civil Engineer

JL:bb

ATTACHMENTS
Figure
Appendix I Instrumentation Plots

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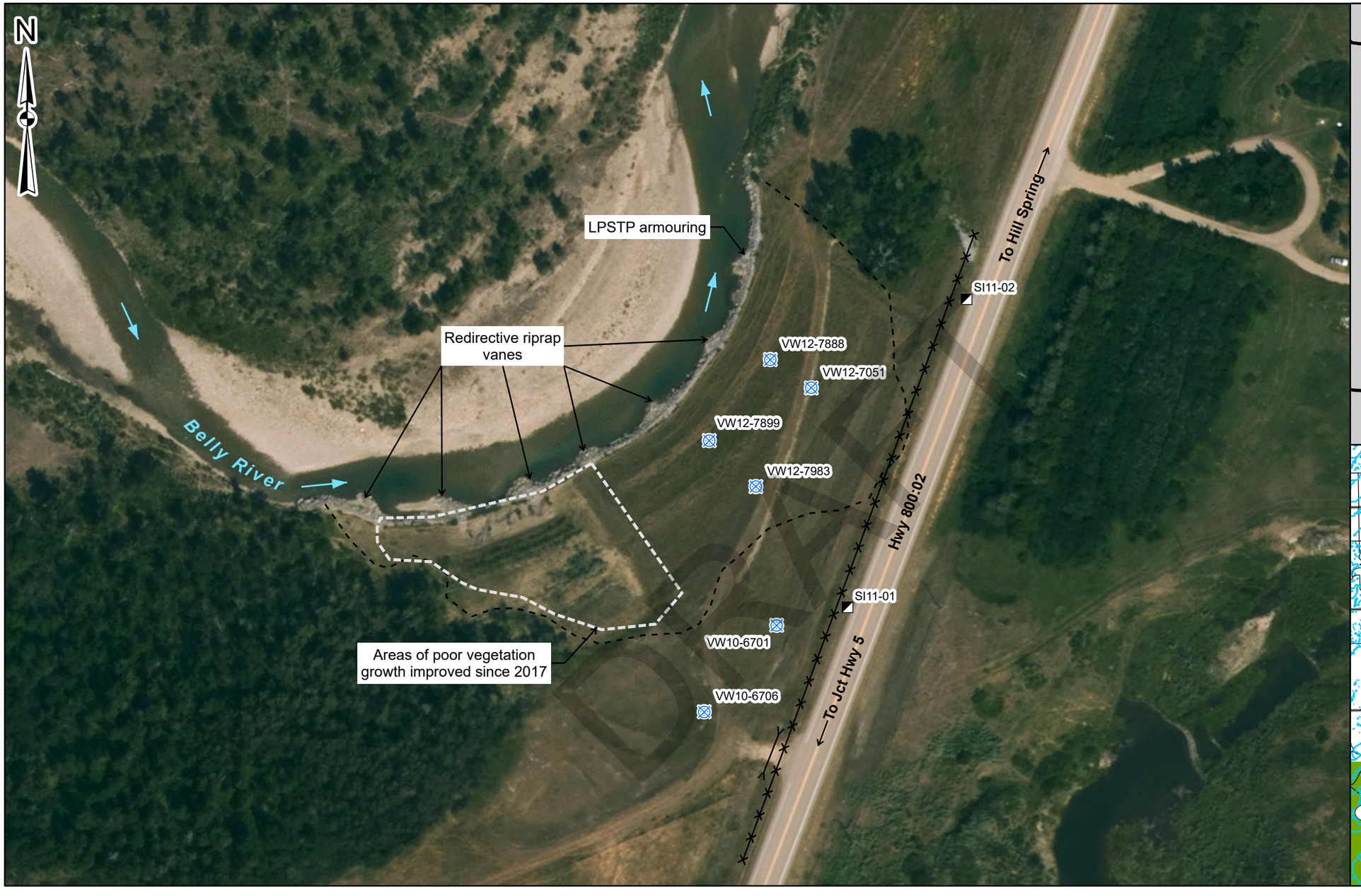
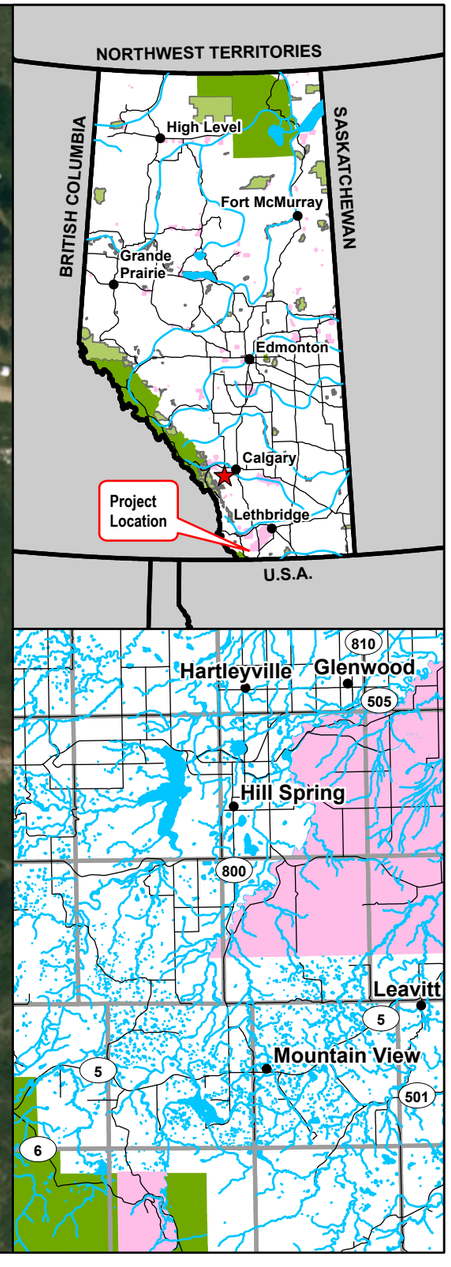
FIGURE





Legend

- Slope Inclinometer (SI)
- Vibrating Wire Piezometer (VW)
- Flow Direction
- Slide Area
- Fence
- Culvert
- Repair Area

0 50 Metres

NOTES:
1. HORIZONTAL DATUM: NAD83
2. GRID ZONE: UTM ZONE 12N
3. IMAGE SOURCE: TOWN OF CARDSTON, TOWN OF PINCHER CREEK, MAXAR
4. LPST = LONGITUDINAL PEAKED STONE TOE PROTECTION

CLIENT: Alberta

Klohn Crippen Berger

PROJECT: SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE: Site Plan
S036 - Belly River
Hwy 800:02, km 9.05

SCALE	PROJECT No.	FIG No.
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APPENDIX I

Instrumentation Plots

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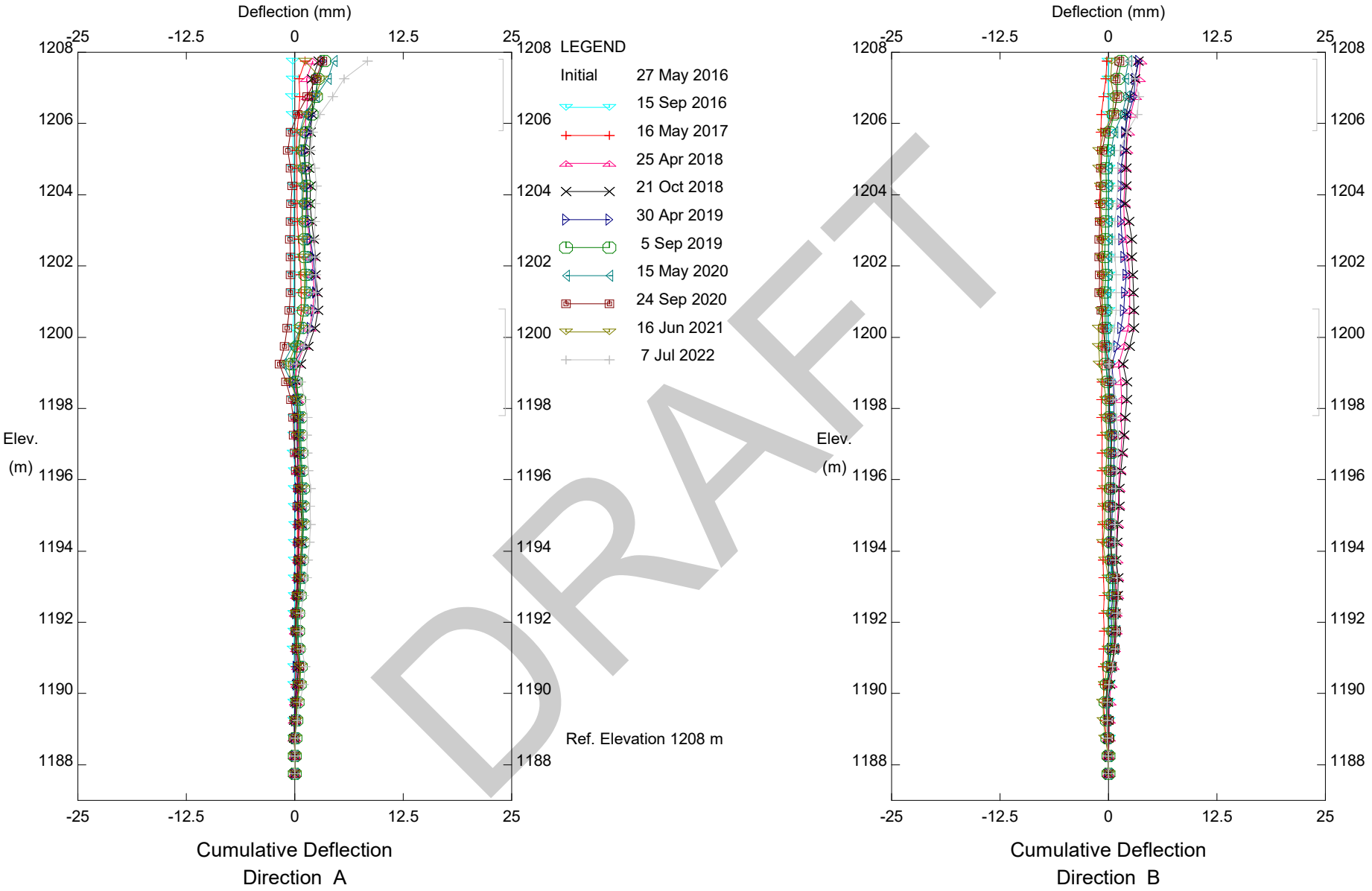

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S036; H800:02, Belly River, Inclinometer SI11-01

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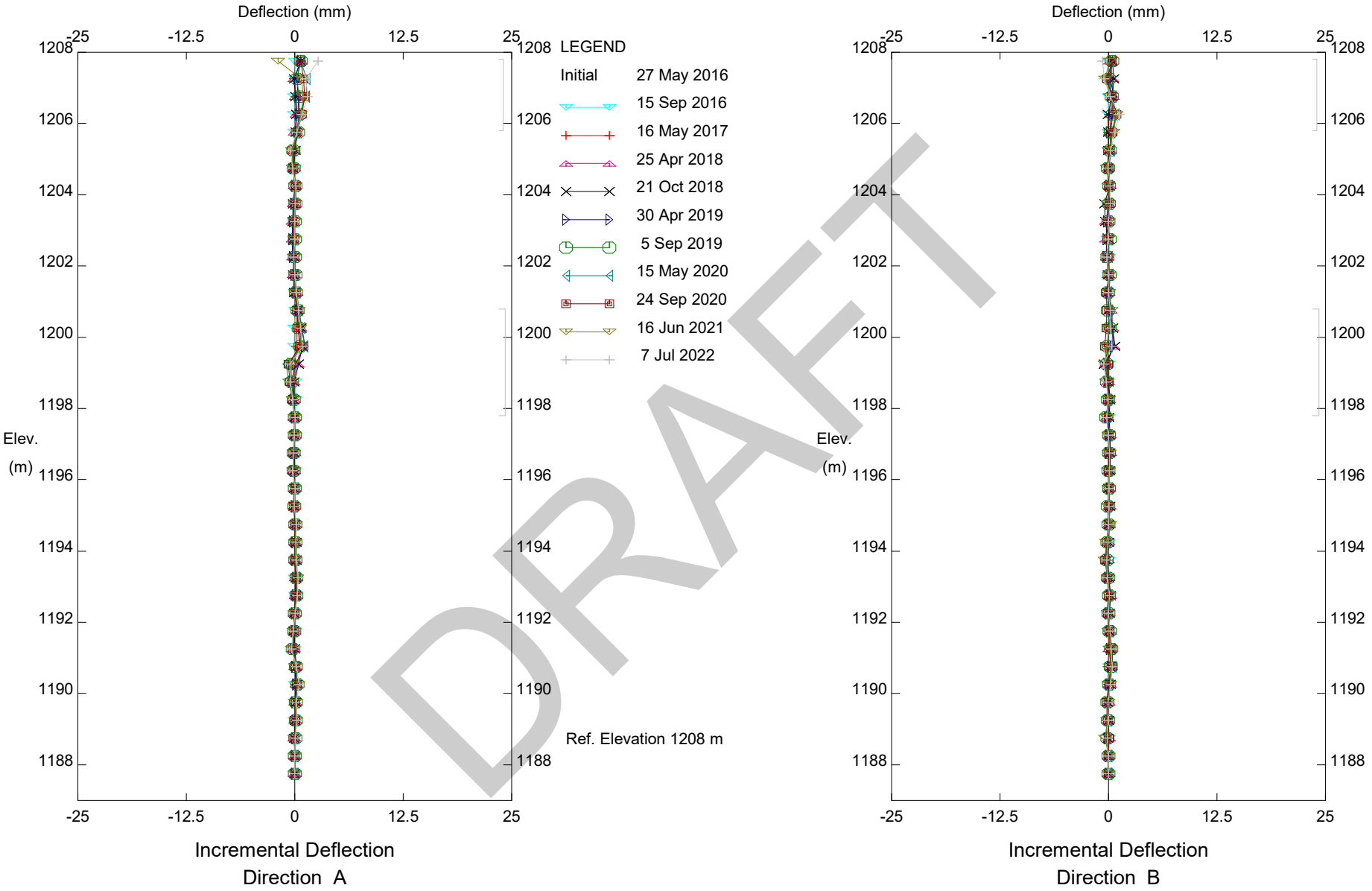

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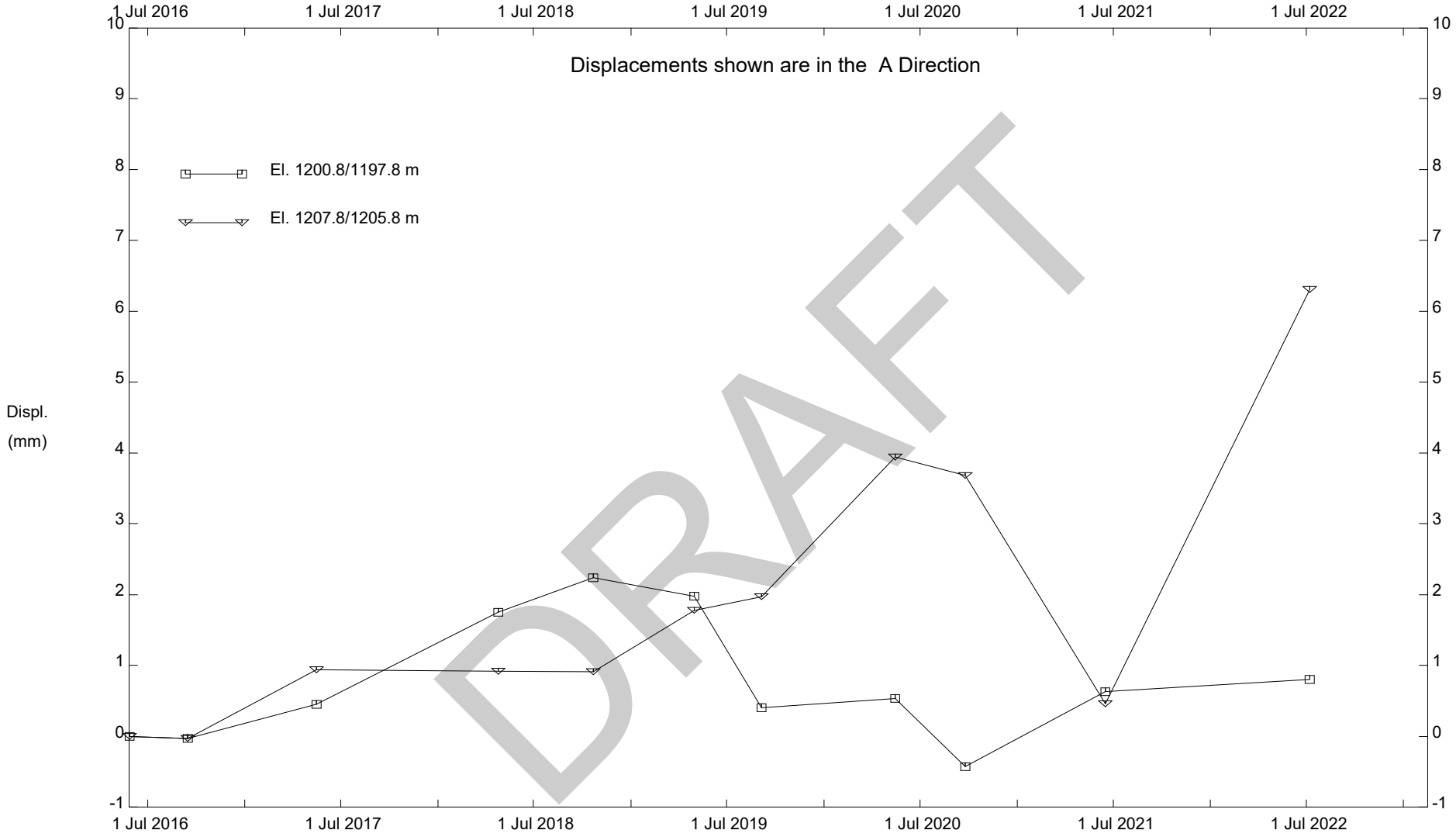

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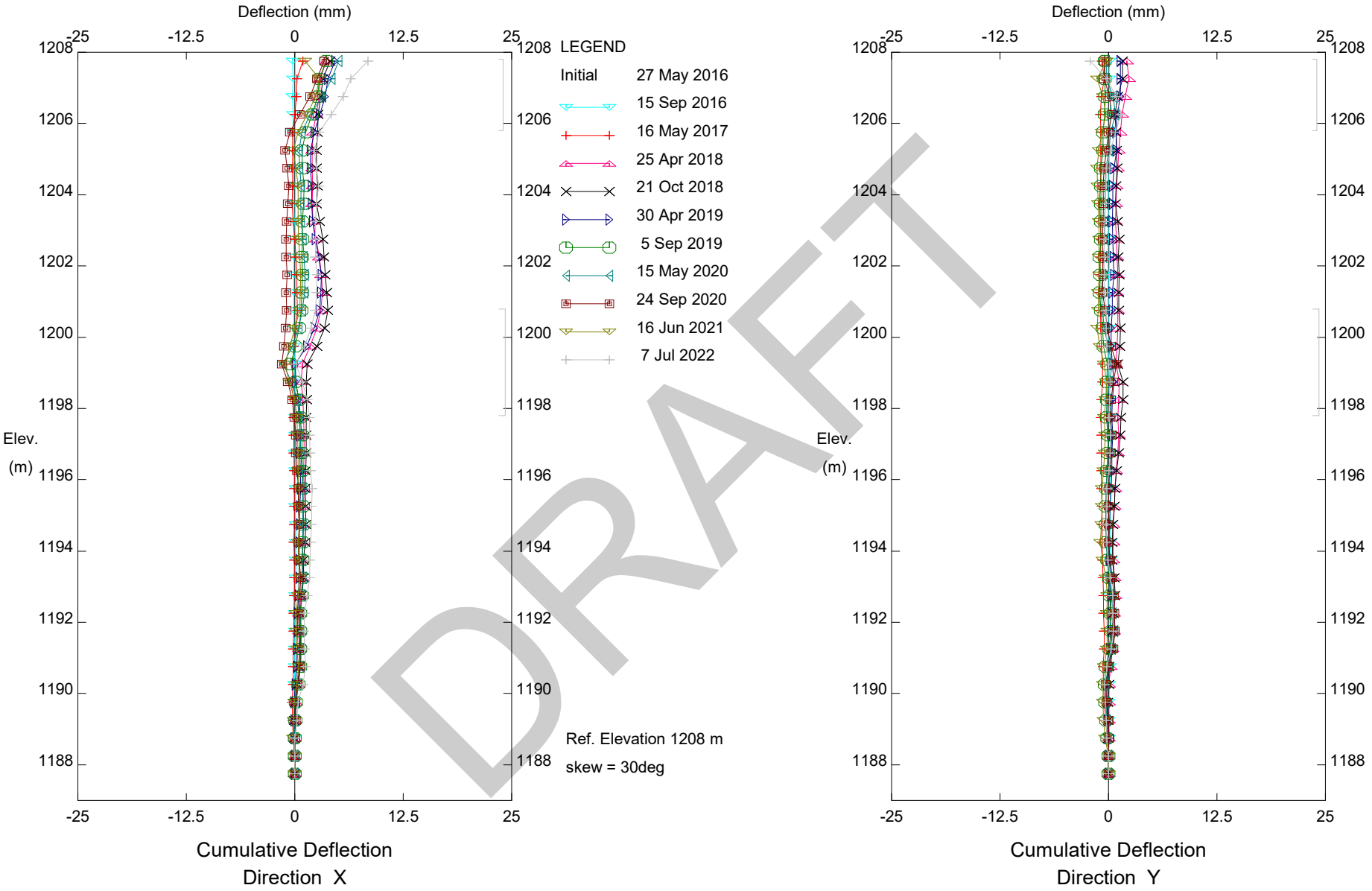

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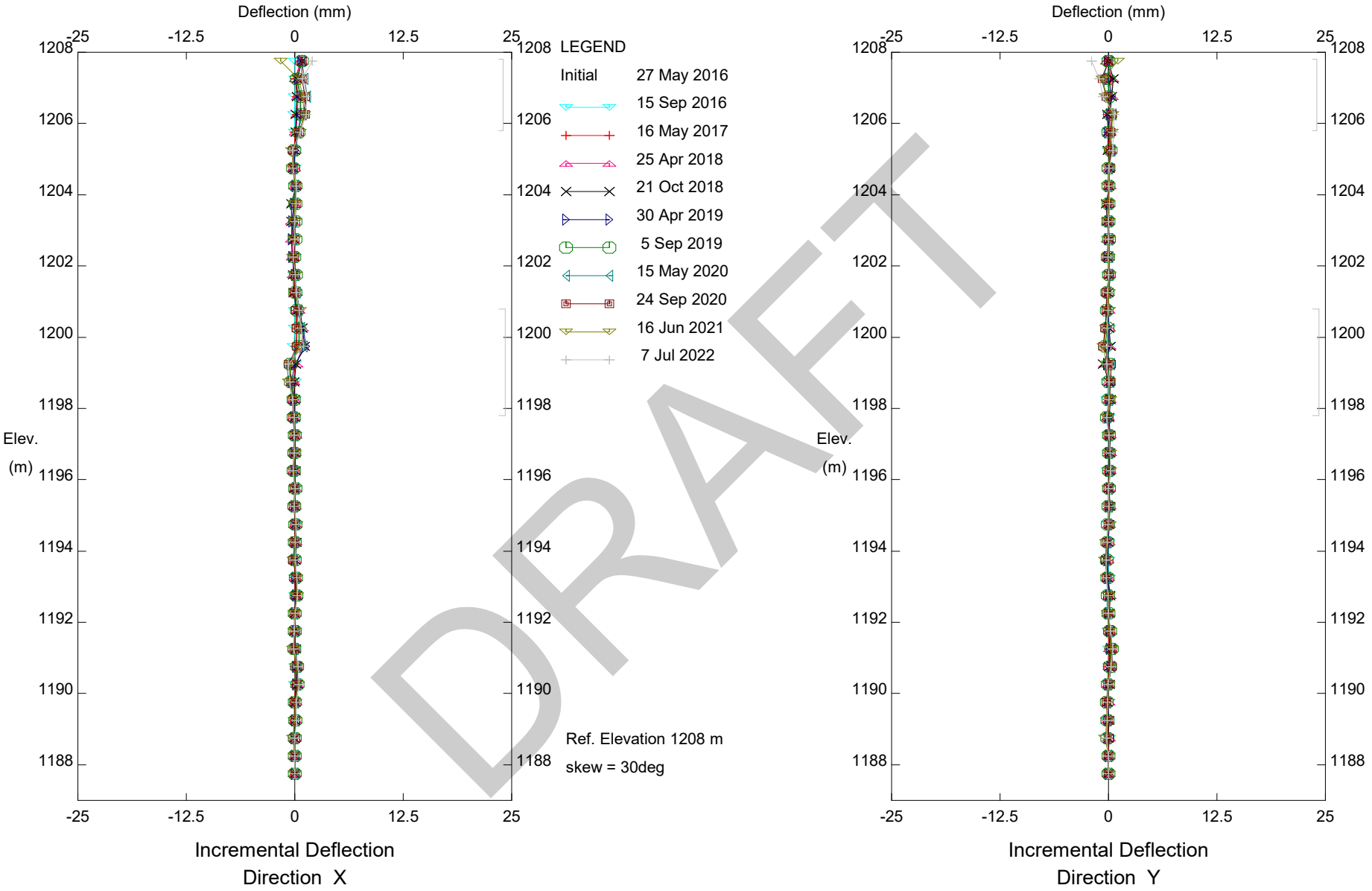

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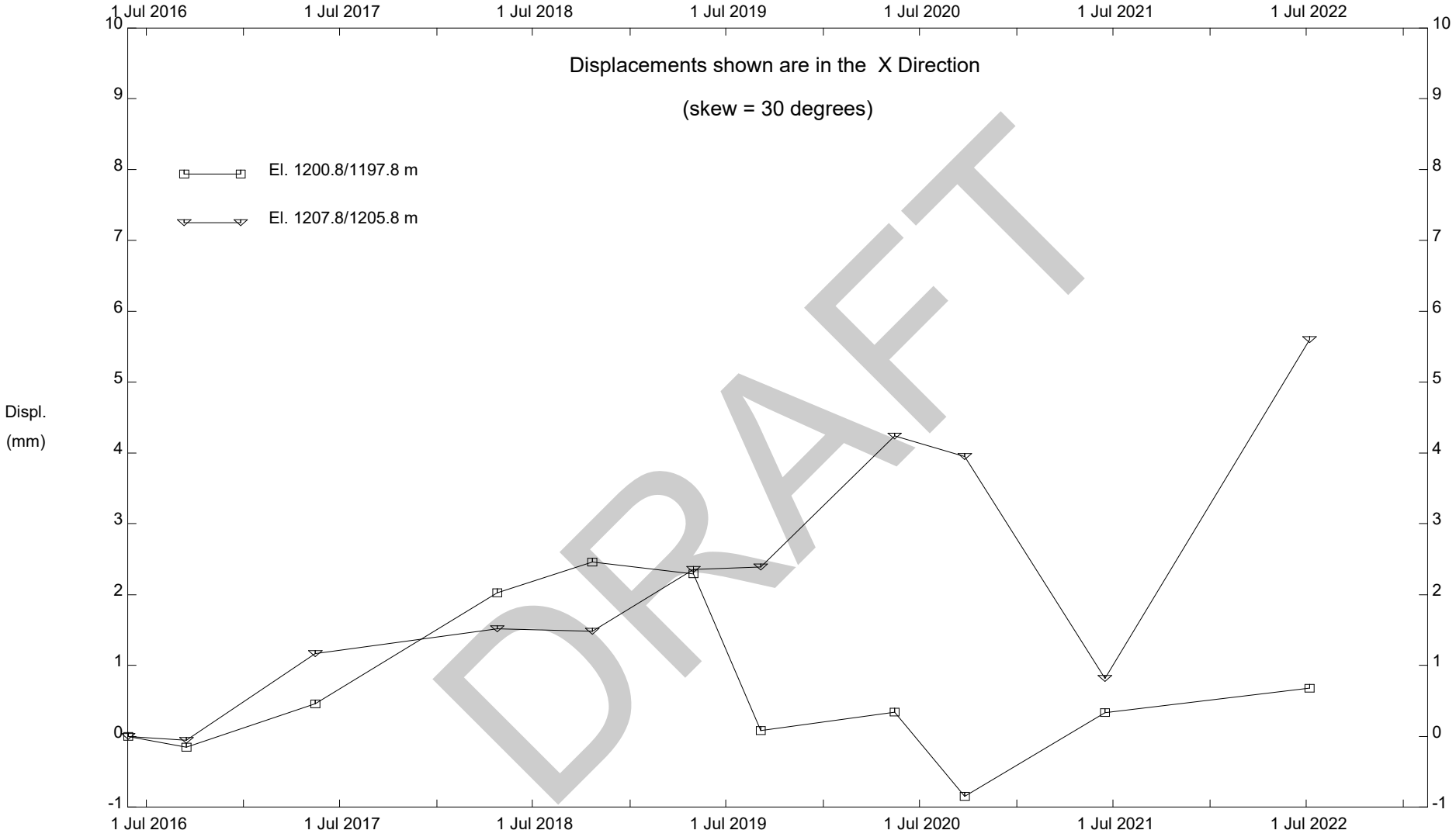

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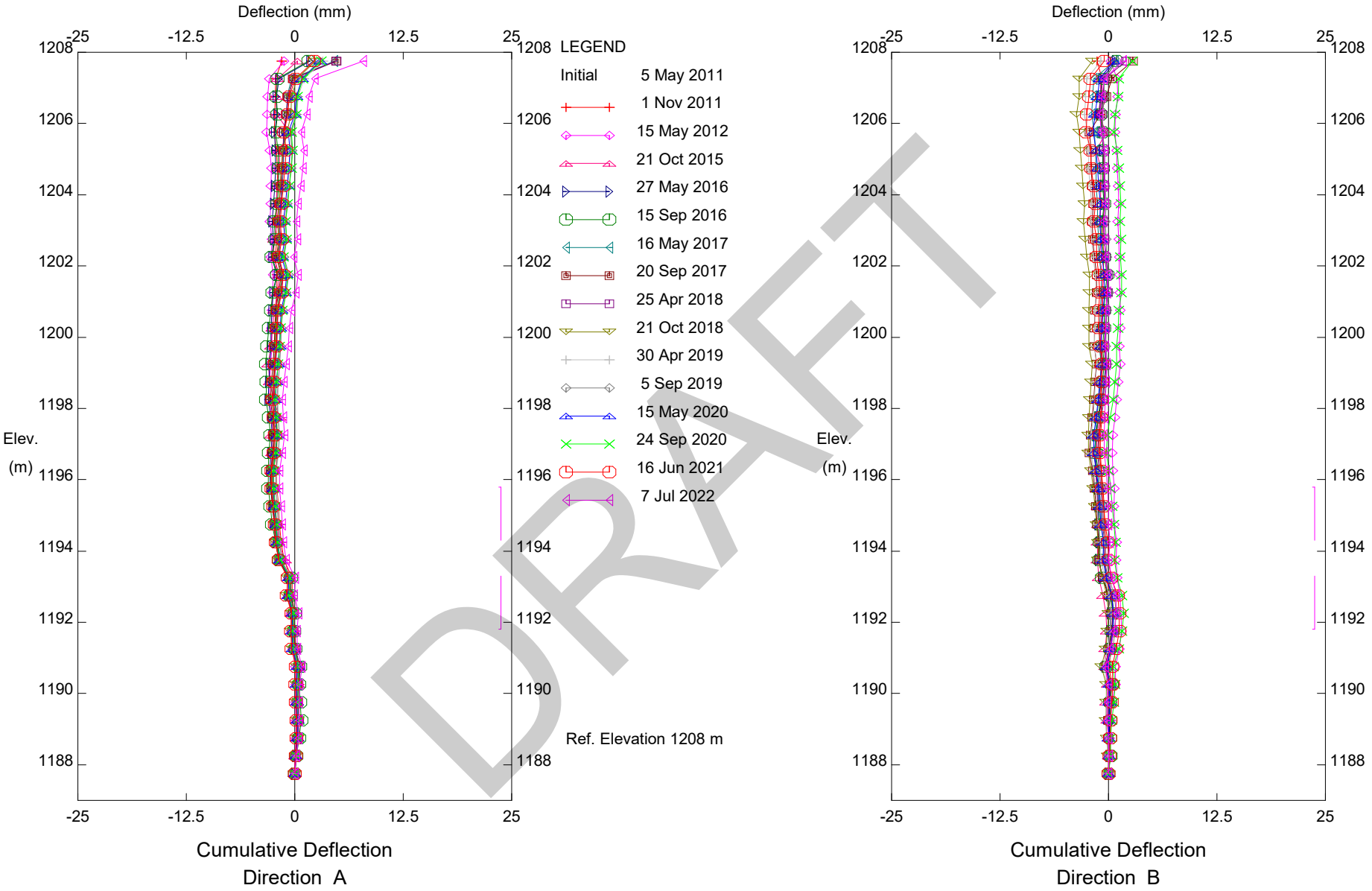

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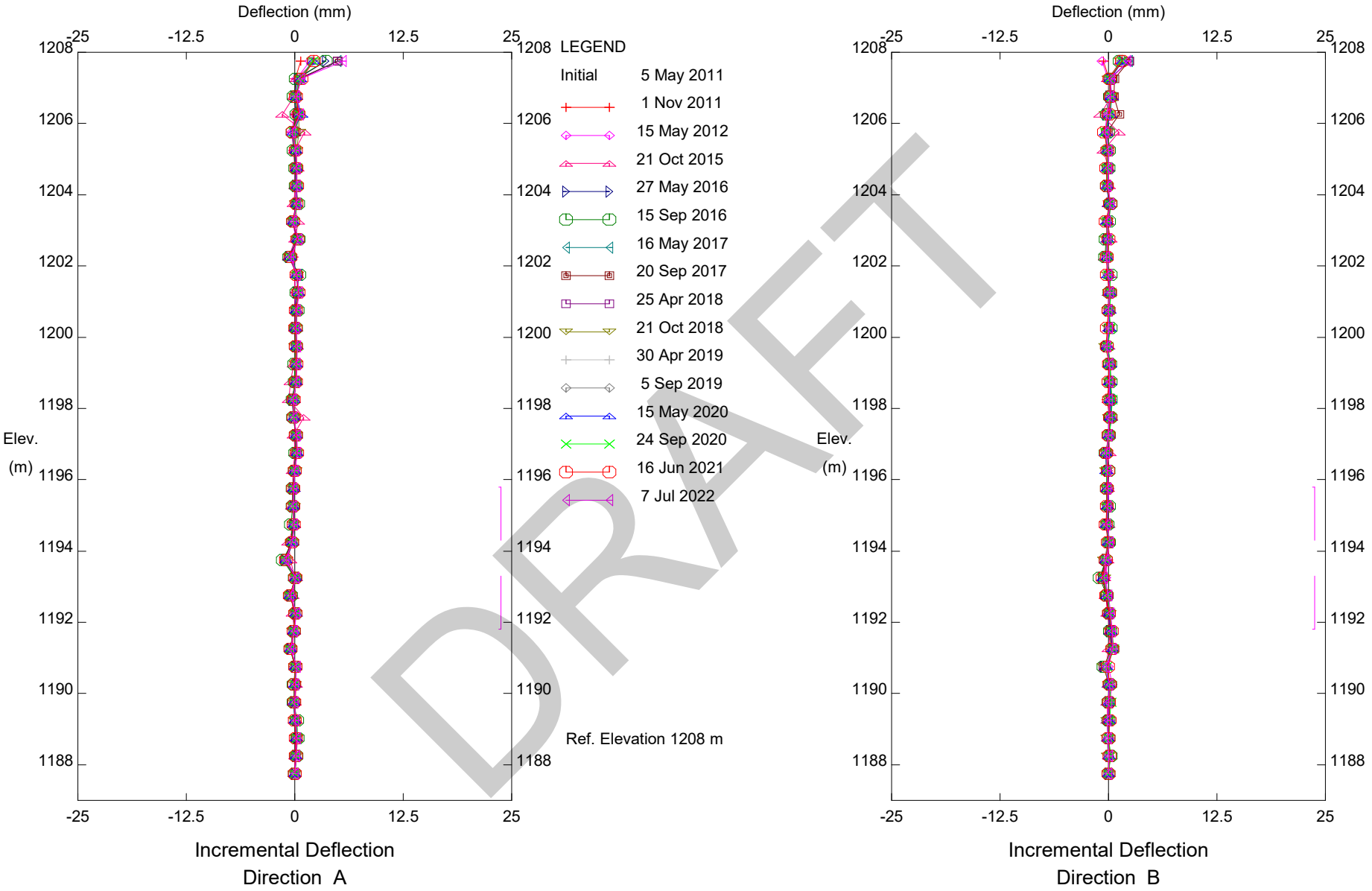

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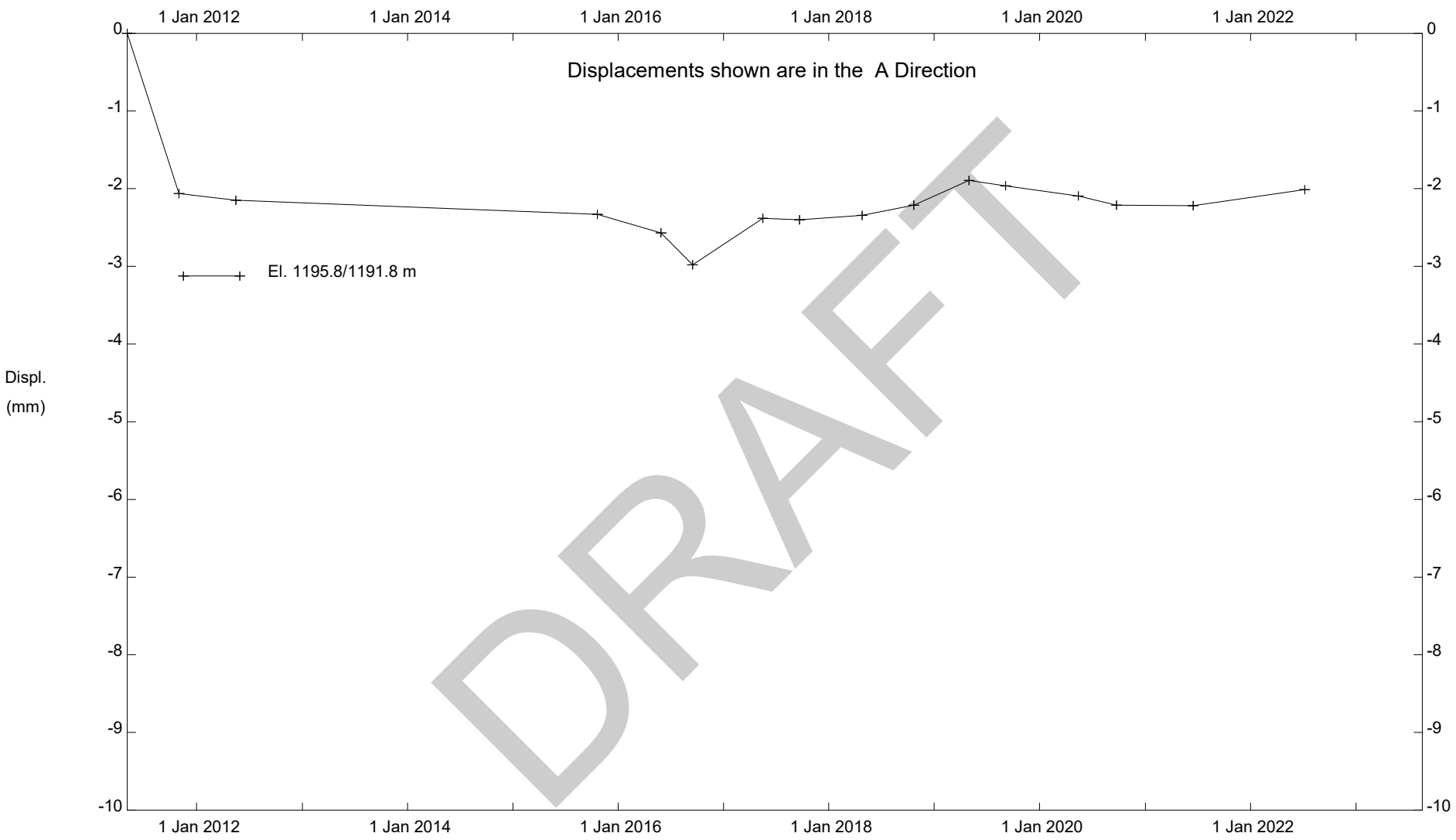

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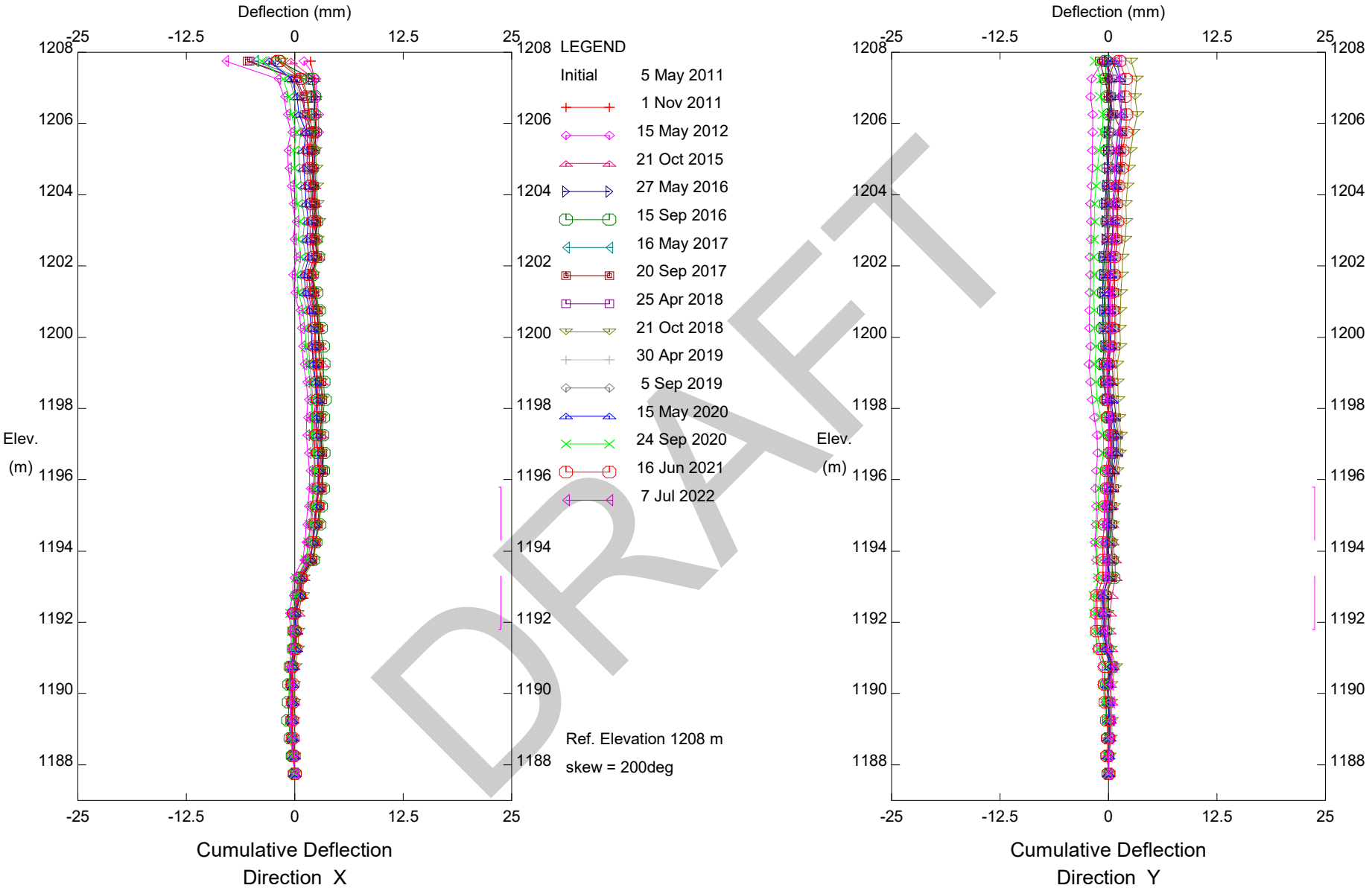

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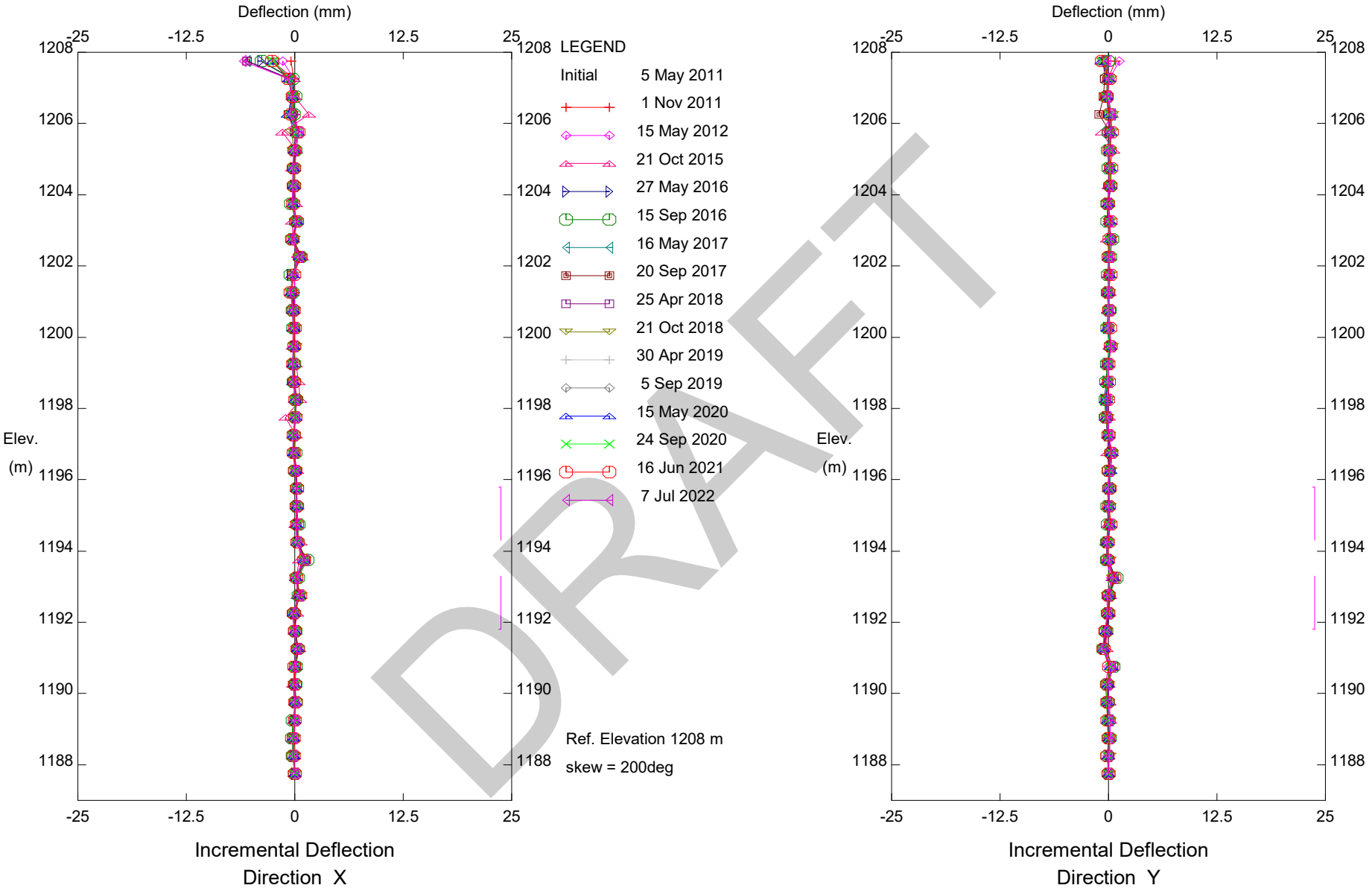

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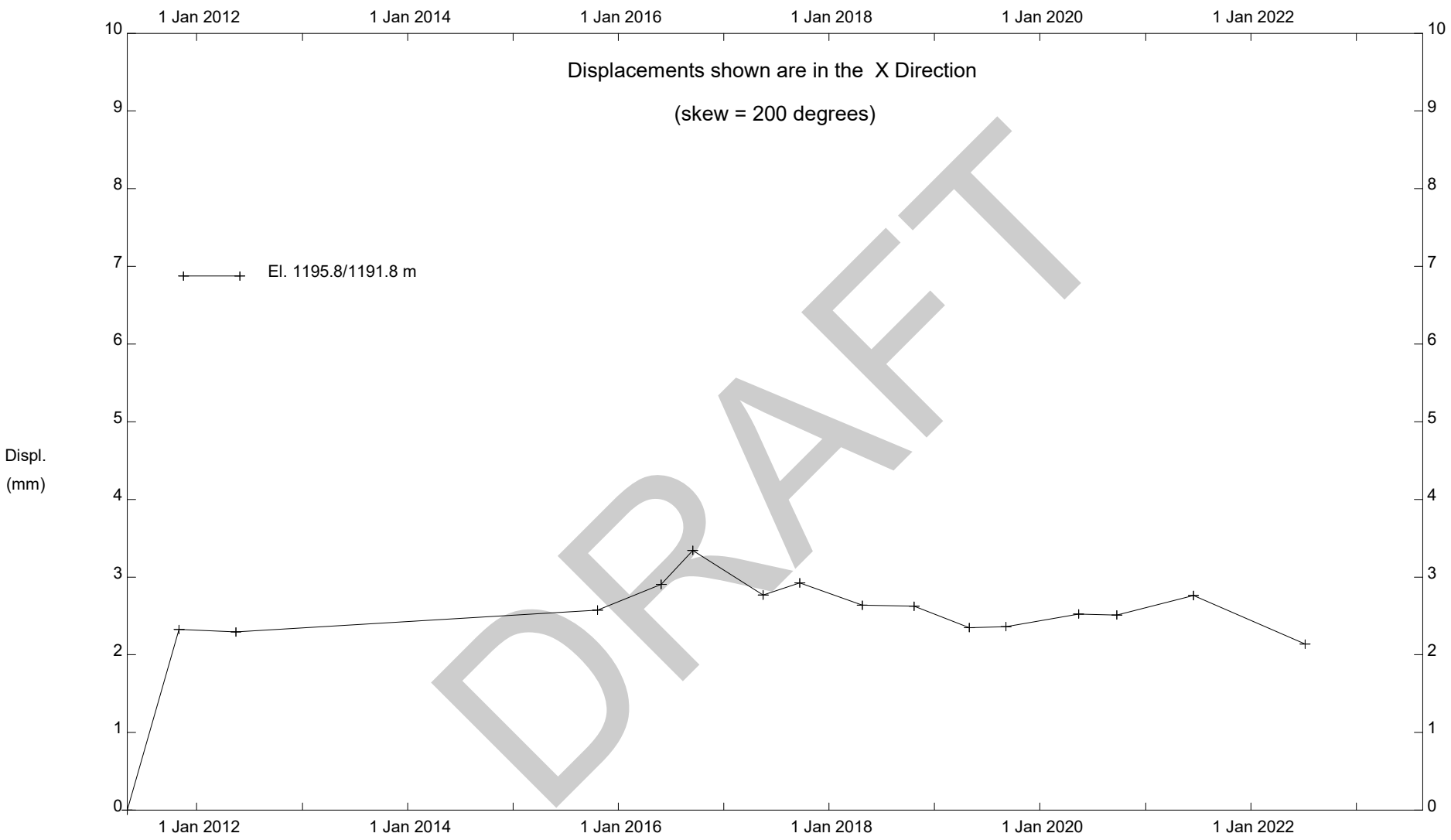

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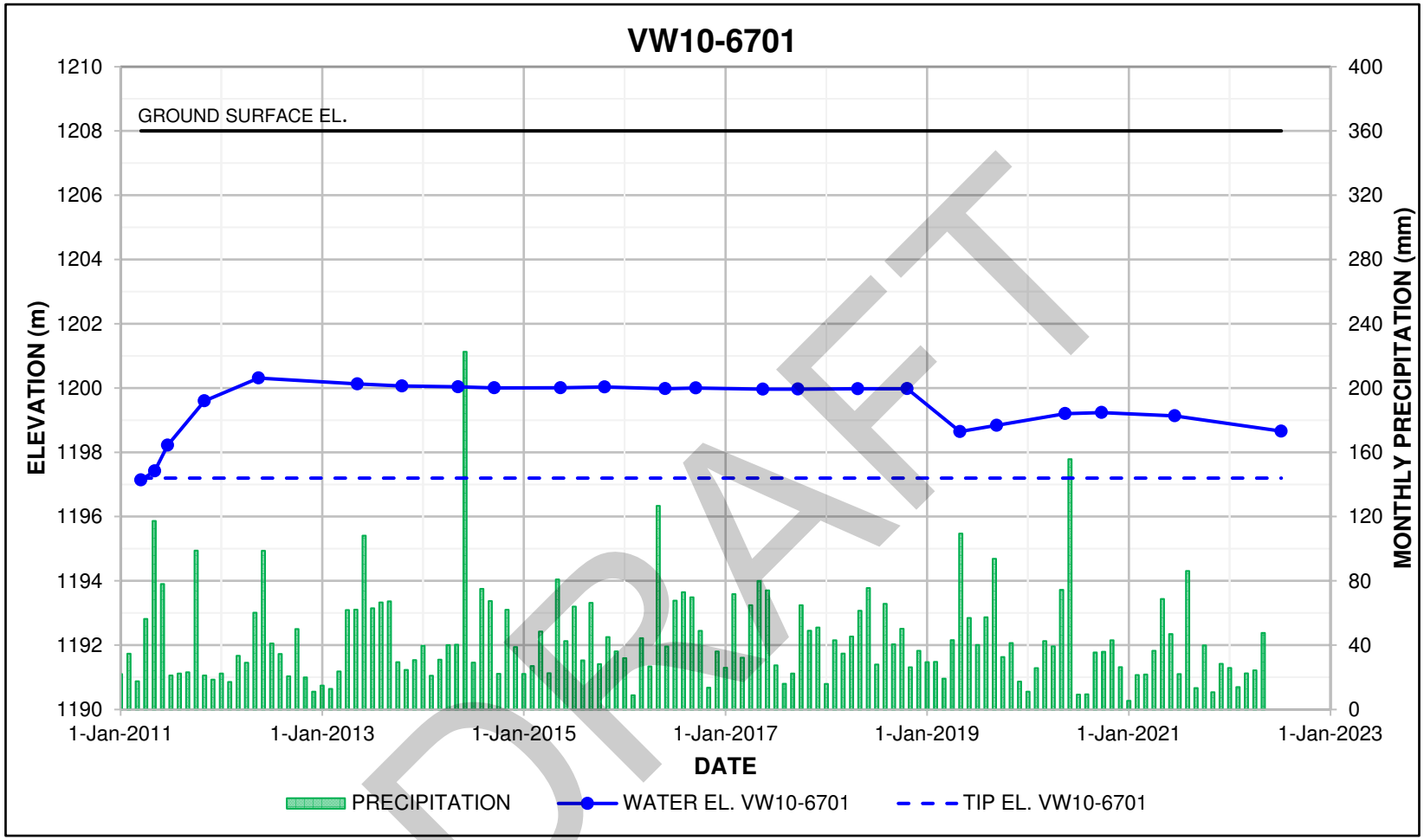

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NOTES:
1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION T003R27W4.

CLIENT
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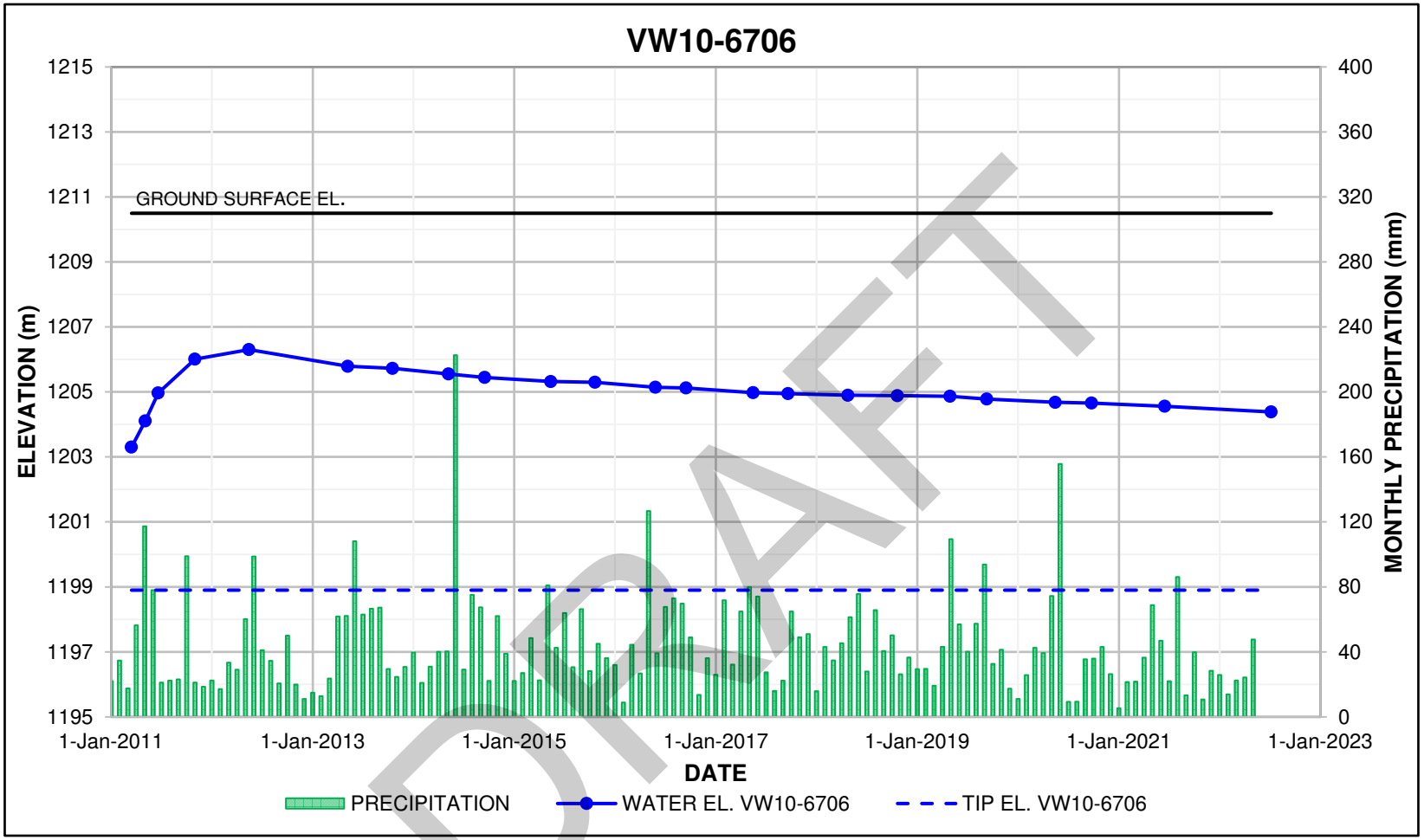
PROJECT
SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
S036 - Belly River
Hwy 800:02, km 9.05

SCALE

PROJECT No. A05116A03

FIG No.



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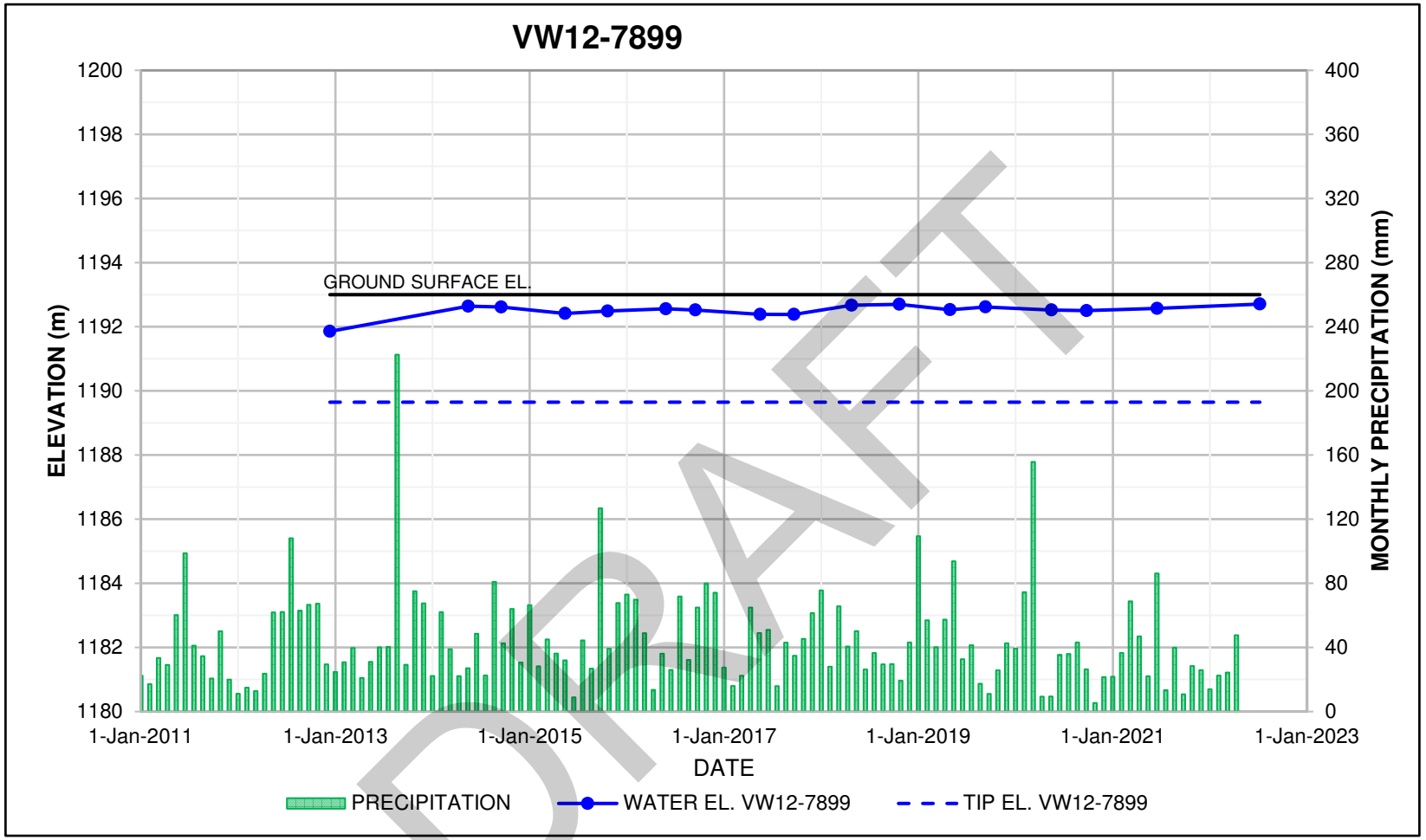

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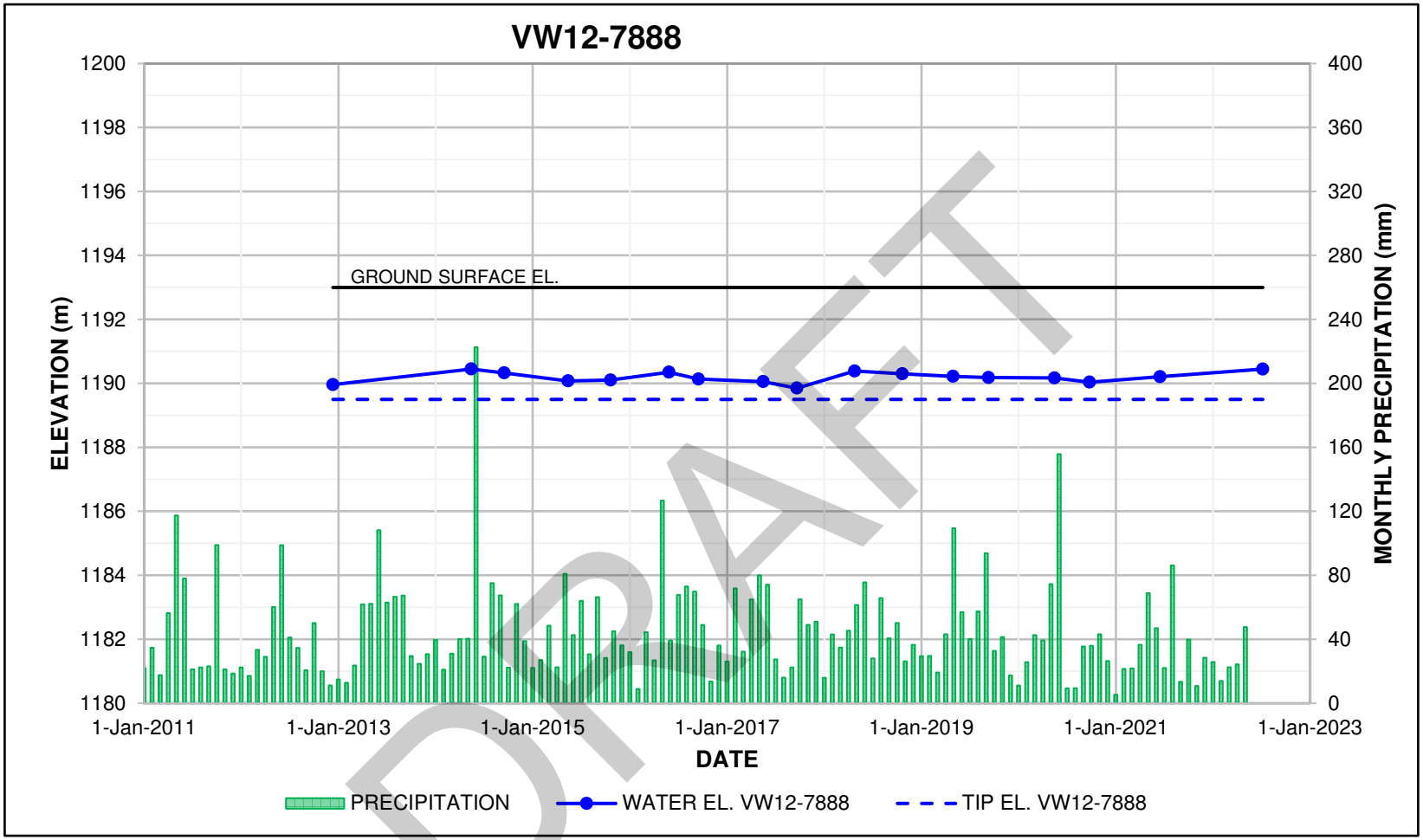

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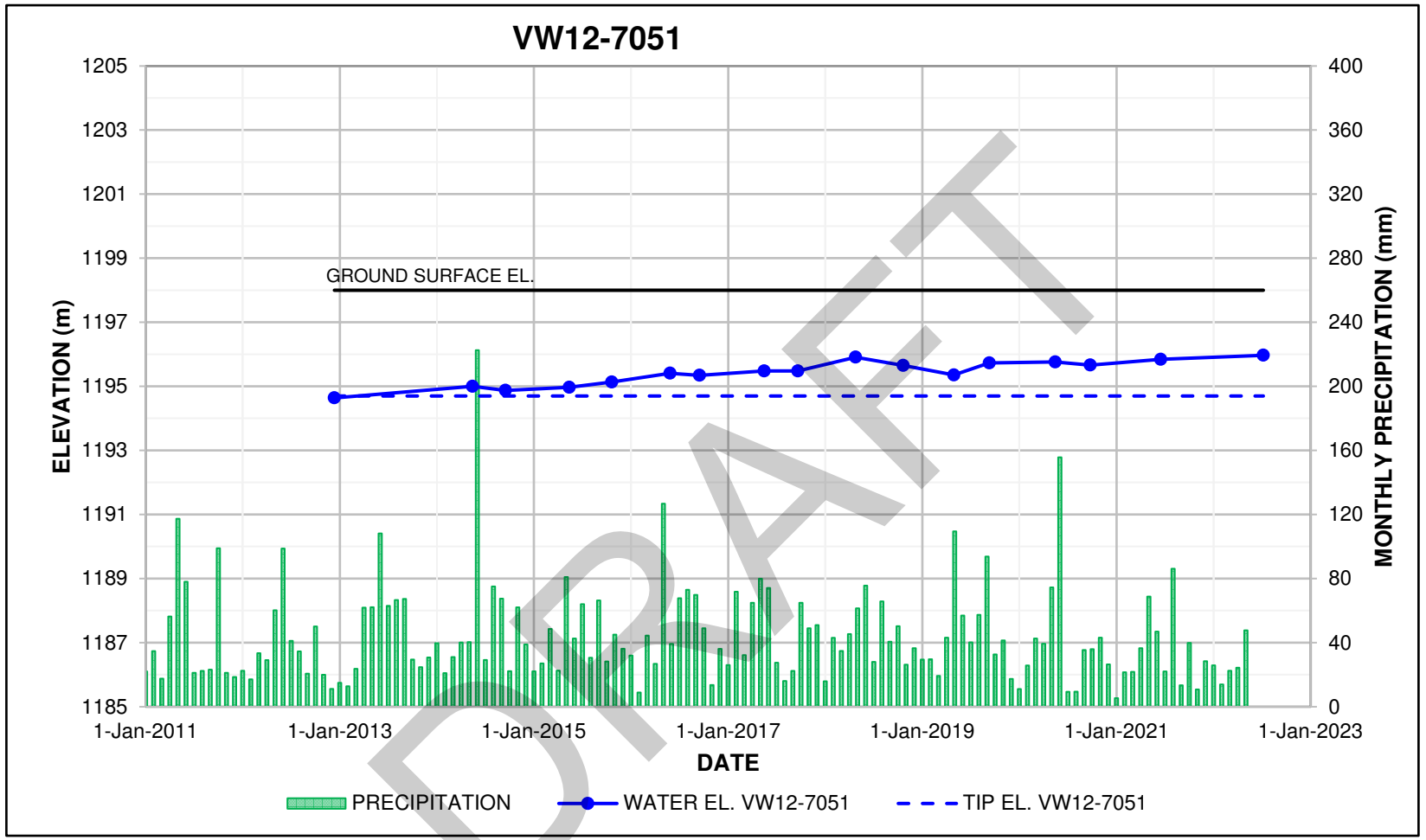
Alberta
Klohn Crippen Berger

PROJECT
SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

TITLE
Piezometer Data
S036 - Belly River
Hwy 800:02, km 9.05

SCALE	PROJECT No.	FIG No.
	A05116A03	



DRAFT

NOTES:
1. MONTHLY PRECIPITATION DATA OBTAINED FROM THE ALBERTA CLIMATE INFORMATION SERVICE (ACIS) DATABASE, REFERENCING LEGAL SUBDIVISION T003R27W4.

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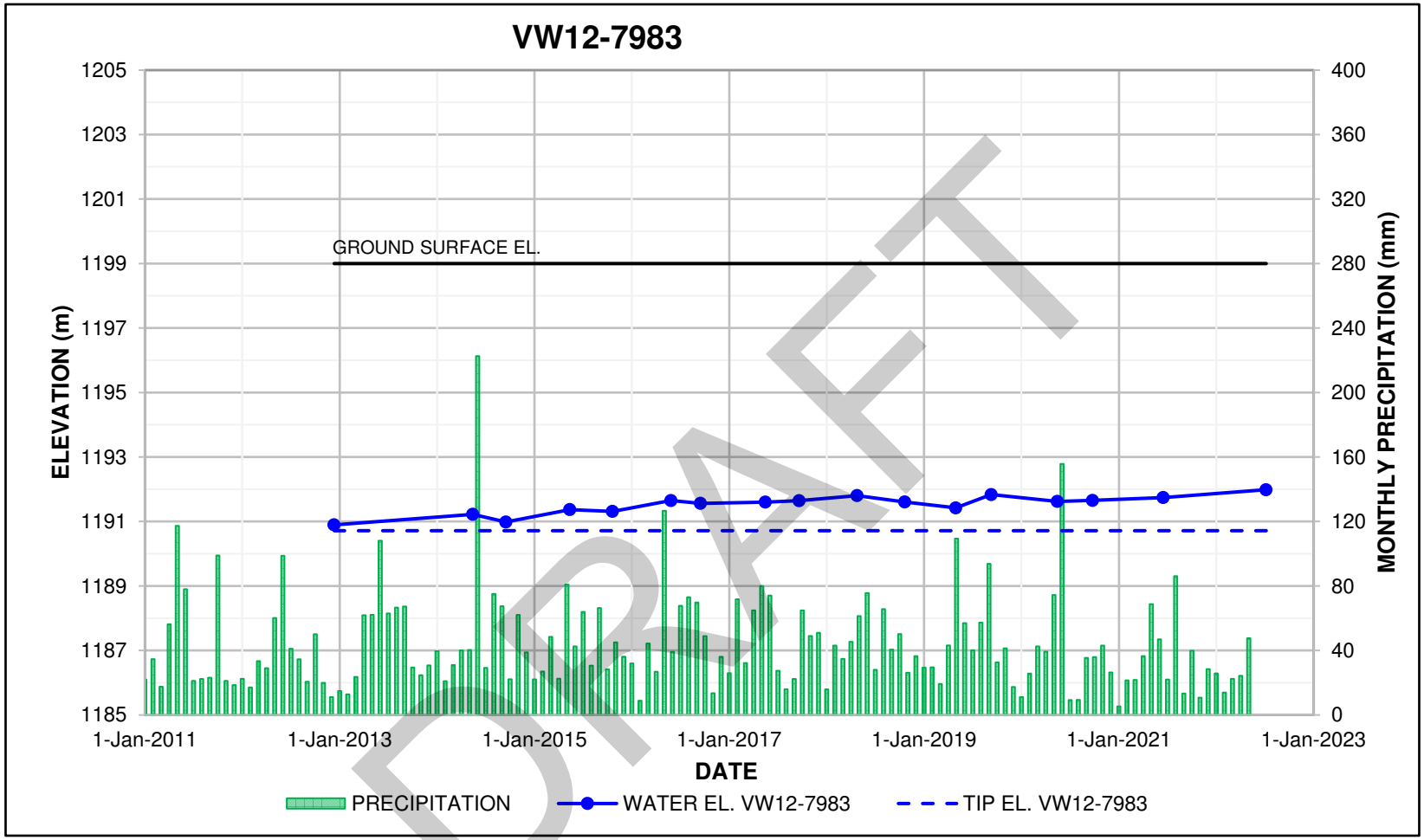

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