

November 29, 2024

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 S012; H742:02, km 4.319 Spray Lakes Road
Section C – 2024 Fall Readings**

1 GENERAL

Six vibrating-wire-inline (VWI) extensometers (E1 through E6) consisting of twenty-four individual instruments were read at the S012 site in the Southern Region on September 16, 2024, by Mr. Bradley Lawson, 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 S012 site is located on Hwy 742:02, km 4.319 within the Town of Canmore limits and approximately 0.5 km northwest of the Spray Lakes Road and Three Sisters Parkway Junction. The approximate site coordinates are 5659724 N, 614296 E (UTM Zone 11, NAD 83). A site plan is presented in Figure 1.

The S012 site is located above a series of coal-mine voids associated with the abandoned coal-mine workings from the Canmore Mines Ltd. – No. 1. Mine. The No. 2 seam portion of the No. 1 mine is partially located beneath the S012 site (i.e., underlying Spray Lakes Road). The No. 2 seam is inclined at an angle of approximately 35° from horizontal with the upper portions of the coal mine void, and associated post-mining roof collapse, being within approximately 3 m to 4 m of the highway surface. In 2021, the risk of highway collapse into the coal-mine void was mitigated by drilling twenty-five 0.5-m-diameter boreholes through the highway surface to intercept the coal-mine voids and areas of post mining collapse that were closest to the highway surface, then backfilling the encountered coal-mine voids and boreholes with controlled low strength (CLS) concrete.

The shallow coal mine voids closest to the highway were backfilled because this portion of the coal-mine void was judged to have a greater likelihood of a brittle failure and collapse into the coal-mine void. Areas with greater roof thickness would be less likely to collapse suddenly to surface but instead were considered to have greater potential to progressively collapse over a longer period of time which could be monitored with extensometers. Therefore, coal-mine voids at depth with roof thickness greater than approximately 19 m were not backfilled with concrete. The greater depths of

coal-mine voids were also not backfilled with concrete due to potential environmental impacts to Canmore Creek water quality associated with groundwater flows through the lower elevations of the coal mine which flowed to the mine portal, located a few meters from Canmore Creek.

Previous investigations at the S012 site include geotechnical site investigations completed in 2002 and 2007 by previous consultants. KCB completed a geophysical survey and geotechnical site investigation in 2017 and 2018, respectively, to support design and construction work.

1.1 Instrumentation

Six VWI extensometers bundles were installed by A&A Paving Ltd. and their instrumentation subconsultant RST Instruments Ltd. (RST) in September 2021 to monitor for vertical displacement of the roof over the coal-mine voids in the years after construction. Three extensometers were installed in the eastbound (south) lane and three extensometers in the westbound (north) lane of Hwy 742:02. The extensometers were installed at depths varying from approximately 2 mbgs to 20 mbgs, based on the estimated thickness of the bedrock “roof” above the coal-mine void. One pair of VWIs (E1/E2) were installed above the backfilled-concrete coal-mine void and two pairs (E3/E4 and E5/E6) were installed over portions of the coal-mine void that were not backfilled with concrete. In total, twenty-four individual extensometers were installed in six boreholes labelled E1 to E6.

Each extensometer was comprised of a set number of inflatable hydraulic anchors connected in series by flexible metal rods sheathed in polyvinyl chloride (PVC) pipe. The cable leads for each anchor were routed up through the borehole and into PVC pipe that was placed in trenches excavated below the granular base course. All extensometer cables were trenched to a precast concrete vault installed on the north (westbound) slope of the highway, which provided a protective headbox for the cable leads and two multi-channel data loggers (RST Instruments Model No. DT2040 and DT2055B). The data loggers were configured to collect readings every 24 hours, which should allow for near-continuous monitoring for up to 5 years before the datalogger batteries need to be replaced. Additional installation details are included in the Final Details Report (report issued on May 1, 2023).

Data is collected from the data loggers by connecting the data loggers to a laptop (using an RST Instrument’s USB cable) and using RST Instrument’s DT Logger Host software.

The VWI extensometers were first read in October 2021. Instrumentation installation details are tabulated in Table 1.1. Instrument locations are shown in Figure 1.

Table 1.1 Vibrating Wire Inline Extensometer Instrument Installation Details¹

Instrument IDs	Serial No.	Anchor Depth (mbgs)	Above Concrete-Backfilled Coal-Mine Void (Y/N)	Approximate Roof Thickness (m) ⁴	Approximate Roof Thickness from Anchor Location (m) ⁴	Date Installed	UTM Coordinates ¹ (m)		Total Depth ² (mbgs)	Condition
							Northing	Easting		
E1	ME4206	2	Y	6.5	4.5	Sep. 16, 2021	5659731	614290	4.5	Operational
	ME4210	4	Y		2.5					
E2	ME4205	2	Y	4.5	2.5	Sep. 10, 2021	5659725	614291	4.6	Operational
	ME4190	4	Y		0.5					
E3	ME4207	2	N	26.7	24.7	Sep. 16, 2021	5659738	614272	18.6	Operational
	ME4202	6	N		20.7					
	ME4196	10	N		16.7					
	ME4193	14	N		12.7					
	ME4197	18	N		8.7					
E4	ME4204	2	N	23.0	21.0	Sep. 10, 2021	5659732	614275	18.5	Operational
	ME4203	6	N		17.0					
	ME4198	10	N		13.0					
	ME4199	14	N		9.0					
	ME4191	18	N		5.0					
E5	ME4208 ³	4	N	N/A	N/A	Sep. 16, 2021	5659743	614257	20.6	Operational ³
	ME4212	8	N	N/A	N/A					
	ME4189	12	N	N/A	N/A					
	ME4201	16	N	N/A	N/A					
	ME4192	20	N	N/A	N/A					
E6	ME4209	4	N	N/A	N/A	Sep. 10, 2021	5659736	614259	20.3	Operational ³
	ME4211 ³	8	N	N/A	N/A					
	ME4200	12	N	N/A	N/A					
	ME4195	16	N	N/A	N/A					
	ME4194	20	N	N/A	N/A					

Notes:

¹ Information obtained from KCB's Issued for Record (IFR) drawings.

² Meters below ground surface (mbgs).

³ ME4208 and ME4211 have recorded irregular temperature readings since April 29, 2022 and June 28, 2022, respectively, and are currently inoperable.

⁴ The estimated roof thickness is the thickness of material from ground surface to the top of the concrete-backfilled coal-mine void or open void, and was estimated from the IFR drawings (RD-27814-C and RD-27815-C). E5 and E5 are believed to be located outside of the area with coal-mine voids.

2 INTERPRETATION

2.1 General

The VWI extensometers record data (B-units and temperature in degrees Celsius) every 24 hours. The B-units and temperature readings are then used to calculate linear displacement in millimeters using RST's corrected linear displacement formula found in their extensometer manual (RST 2022). The linear displacement is relative to the initial displacement reading recorded by RST's field representative during extensometer installation in September 2021. Positive linear displacement indicates that the extensometer is being stretched (i.e., lengthened) and negative displacement indicates the extensometer is being contracted (i.e., shortened) (e-mail from RST dated November 24, 2022).

Extensometers in the same borehole were plotted on the same data plot and the extensometer plots are included in Appendix I.

Table 2.1 VWI Extensometer Reading Summary

Instrument ID	Serial No.	Anchor Depth ² (mbgs) ¹	Ground Surface Elevation ² (m)	Date			Differential Linear Displacement ³ (mm)				
				Initialized	Reading Frequency	Previous Data Download	Most Recent Data Download	Net Movement Since Initialization	Maximum	Minimum	Variation between Min. and Max.
E1	ME4206	2	1357.1	Oct. 1, 2021	Every 24-hours	May 9, 2024	Sep. 16, 2024	-0.5216	-4.0425	-5.5140	1.4715
	ME4210	4						-0.0325	0.3476	-0.5614	0.909
E2	ME4205	2	1357.0	Oct. 1, 2021		May 9, 2024	Sep. 16, 2024	-0.2802	0.5549	-0.4912	1.0461
	ME4190	4						-0.4069	-0.0312	-0.4795	0.4483
E3	ME4207	2	1357.8	Oct. 1, 2021		May 9, 2024	Sep. 16, 2024	-1.2291	-0.6797	-3.0409	2.3612
	ME4202	6						0.1102	0.1848	0.0284	0.1564
	ME4196	10						-0.1504	-0.0163	-0.1689	0.1526
	ME4193	14						0.0278	0.0531	-0.0035	0.0566
E4	ME4197	18	1357.6	Oct. 1, 2021		May 9, 2024	Sep. 16, 2024	-0.0270	-0.0084	-0.0424	0.034
	ME4204	2						0.7774	1.4121	-1.3574	2.7695
	ME4203	6						-0.7580	-0.0624	-1.0097	0.9473
	ME4198	10						-0.0047	0.2018	0.0185	0.1833
E5	ME4199	14	1358.5	Oct. 1, 2021		May 9, 2024	Sep. 16, 2024	-0.6427	-0.1599	-0.8033	0.6434
	ME4191	18						0.0067	0.0738	0.0091	0.0647
	ME4208 ⁴	4						N/A – irregular data			
	ME4212	8						0.0760	0.1134	-0.0009	0.1143
	ME4189	12						-0.0777	0.0003	-0.1006	0.1009
E6	ME4201	16	1358.4	Oct. 1, 2021		May 9, 2024	Sep. 16, 2024	-0.0151	0.0205	-0.0123	0.0328
	ME4192	20						-0.1176	-0.0081	-0.1258	0.1177
	ME4209	4						-0.5874	1.0825	-0.8001	1.8826
	ME4211 ⁴	8						N/A – irregular data			
	ME4200	12						-0.0617	0.0423	-0.0292	0.0715
E6	ME4195	16	1358.4	Oct. 1, 2021		May 9, 2024	Sep. 16, 2024	-0.1219	-0.0198	-0.1418	0.122
	ME4194	20						-0.1284	0.0729	-0.0969	0.1698

Notes:

¹ Meters below ground surface (mbgs). Depth of instrument tip.

² Information obtained from KCB's Issued for Record (IFR) drawings.

³ Positive linear displacement indicates extensometer is being lengthened and negative displacement indicates extensometer is being shortened. Lengthening could indicate roof material collapse at lower elevations or could indicate heave at surface.

⁴ ME4208 and ME4211 have recorded irregular temperature readings since April 29, 2022 and June 28, 2022, respectively, and are currently inoperable.

2.2 Interpretation of Monitoring Results

RST's field representative recorded an initial reading for the extensometers during installation in September 2021. RST returned to site and connected the extensometers to two multi-channel data loggers on October 1, 2021 (approximately two weeks after the initial reading).

Continued collapse of the bedrock "roof" into the coal-mine void would initially result in sustained non-recoverable deformation (extension) of the lower elevation extensometer anchors. The extensometer data was reviewed to assess if the placement of concrete in the coal-mine void has arrested the roof collapse mechanism and also to assess if roof collapse is occurring into the open coal mine void at greater depths where concrete was not placed.

Observations made on the extensometer data since installation include:

- The maximum positive (i.e. lengthening) net displacement (difference between current reading and initial reading) in the extensometers is 0.78 mm, recorded in E4 ME4204 (2 mbgs). Only 3 other extensometers recorded net positive displacement, which are E3 ME4202 (6 mbgs), E4 ME4191 (18 mbgs), and E5 ME4212 (8 mbgs). All other extensometers have recorded negative (i.e., shortening) net displacement since the initial readings with a maximum of -1.23 mm, recorded in E3 ME4207 (2 mbgs).
- E5 ME4208 (4 mbgs) and E6 ME4211 (4 mbgs) have recorded irregular temperature readings since April 29, 2022 and June 28, 2022, respectively, and are inoperable. E5 and E6 are both located at the west extent of the repair site in the westbound and eastbound lanes, respectively.

The shallow extensometers (2 mbgs to 4 mbgs) have recorded the most linear displacement fluctuations. Most of the extensometers with anchors installed below 4 mbgs have recorded little to no displacement or displacement fluctuations since installation. The change in displacement (lengthening and contracting) recorded in the shallow extensometers appears to be due to seasonal temperature changes.

3 RECOMMENDATIONS

3.1 Future Work

The data from the operational instruments should continue to be downloaded twice a 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.

If the extensometer data indicates roof collapse is starting to occur, especially in areas where concrete backfilling was not conducted, the frequency of datalogger downloading will need to be increased to more frequent intervals (or be automated with data sent via a cellular signal) to provide the opportunity for more frequent data review. A detailed review of the extensometer will be

completed in discussion with RST to help better understand the movement fluctuations measured in the shallow extensometers and how temperature fluctuation contributes to this movement.

The concrete enclosure that the data loggers are stored in was damaged, and the steel plate cover is no longer able to be properly secured to the concrete. This damage was caused between the spring 2024 and fall 2024 readings. The MCI confirmed that a HMC subcontractor that was cutting the grass was responsible for the damage to the data logger enclosure. They will repair the enclosure based on recommendations from KCB and TEC.

3.2 Instrument Repairs and Maintenance

The connection between the cable leads for E5 ME4208 and E6 ME4211 and the RST data loggers were inspected and reconnected during the 2023 and 2024 instrument readings to check if a poor connection was attributing to the irregular data being recorded for those two instruments. After completing this, the instruments were still recording irregular data. KCB will continue to trouble shoot why these instruments are recording irregular data.

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 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.

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.

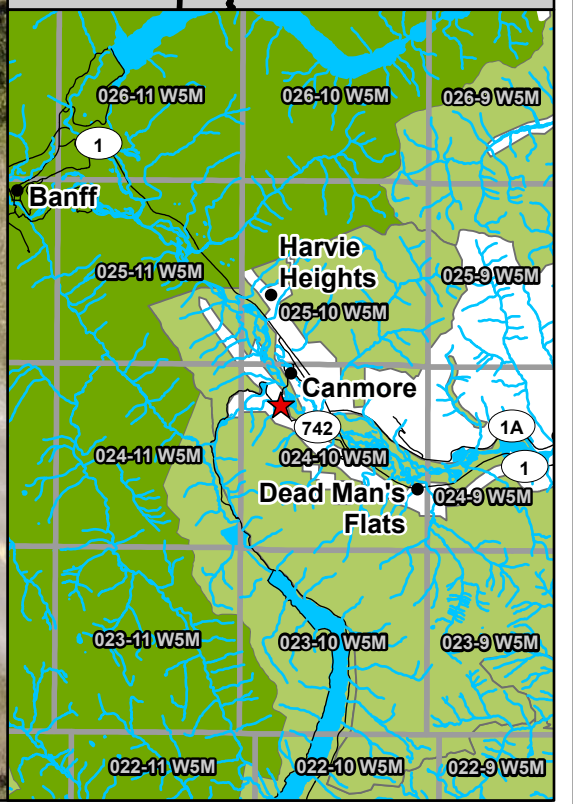
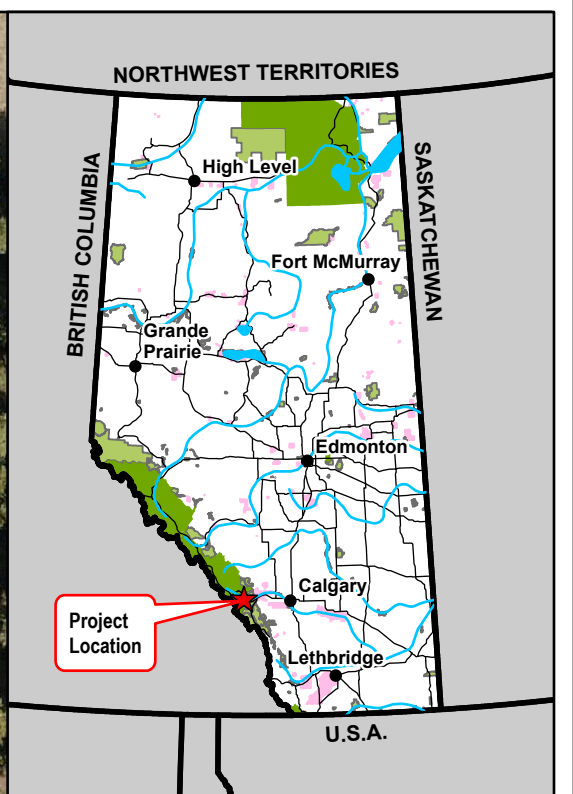
Peter Roy, P.Eng.
Civil Engineer

PR:kb

ATTACHMENTS

Figure
Appendix I Instrumentation Plots

FIGURE



File: \\nt.kohn.com\ProjData\AIC\Alberta\A05 116A03 ABT Southern Region GRMP\400 Drawings\2022\Section C - Spring 2022.aprx Date: Time: Creator: aharrison

- Legend**
- Readout Location (Concrete Vault)
 - ⬇ Vibrating Wire Inline Extensometer
 - Approximate Extent of Voids
 - Approximate Location of Coal Mine Shafts

Borehole ID	E1	E2	E3	E4	E5	E6
Extensometer Serial Number	ME4206	ME4190	ME4193	ME4191	ME4189	ME4194
	ME4210	ME4205	ME4196	ME4198	ME4199	ME4195
			ME4197	ME4199	ME4201	ME4200
			ME4202	ME4203	ME4208	ME4209
			ME4207	ME4204	ME4212	ME4211

NOTES:
 1. HORIZONTAL DATUM: NAD83
 2. GRID ZONE: UTM ZONE 12N
 3. IMAGE SOURCE: TOWN OF CANMORE, ESRI BASEMAP

CLIENT

Alberta

Klohn Crippen Berger

PROJECT
SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM

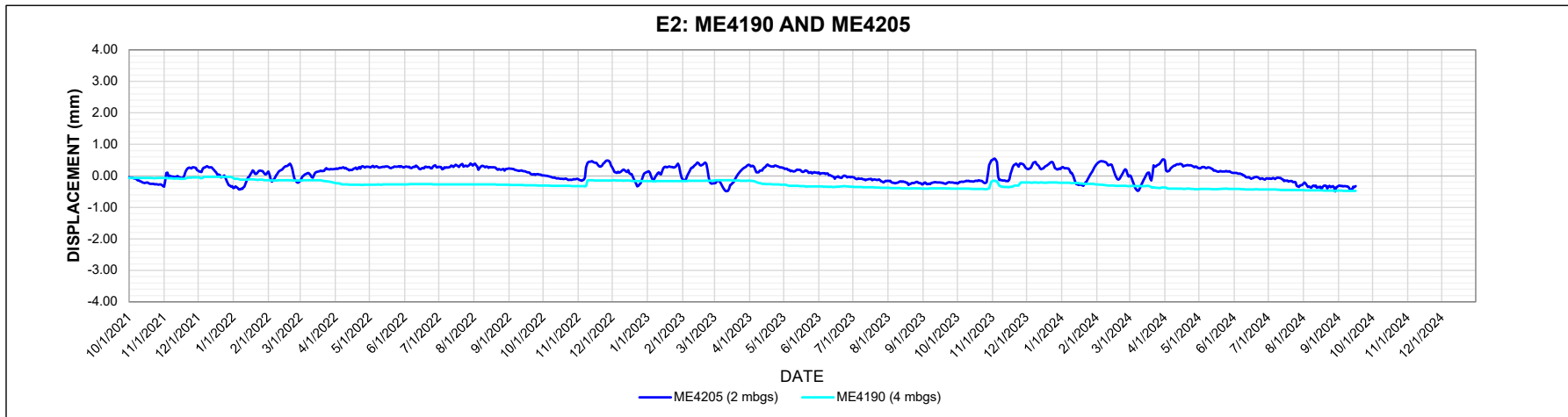
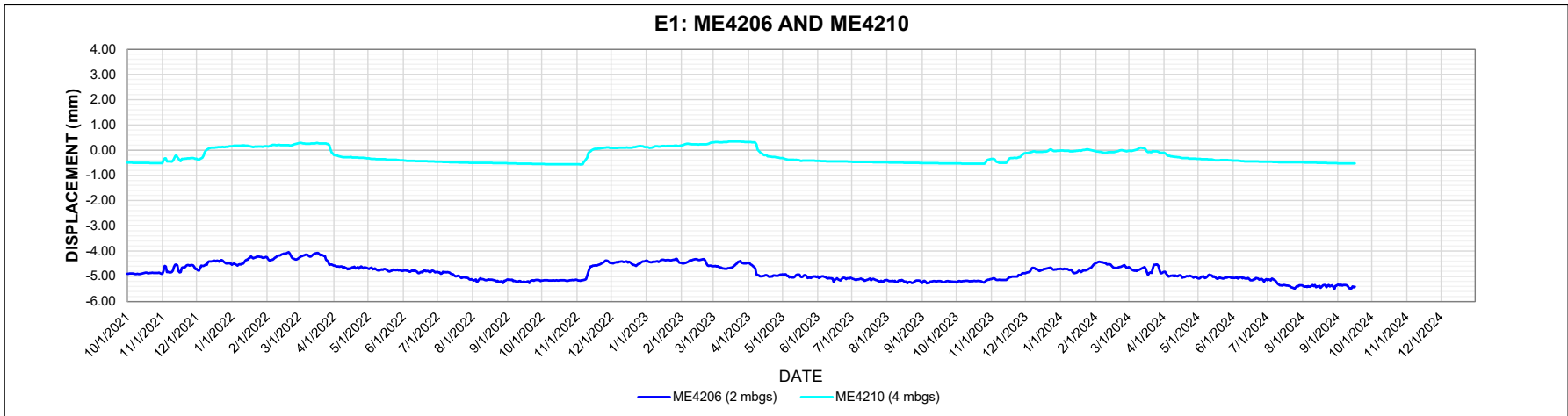
TITLE
Site Plan
S012 - Spray Lakes Road
Hwy 742:02, km 4.319

SCALE 1:600 PROJECT No. A05116A03 FIG No. 1



APPENDIX I

Instrumentation Plots



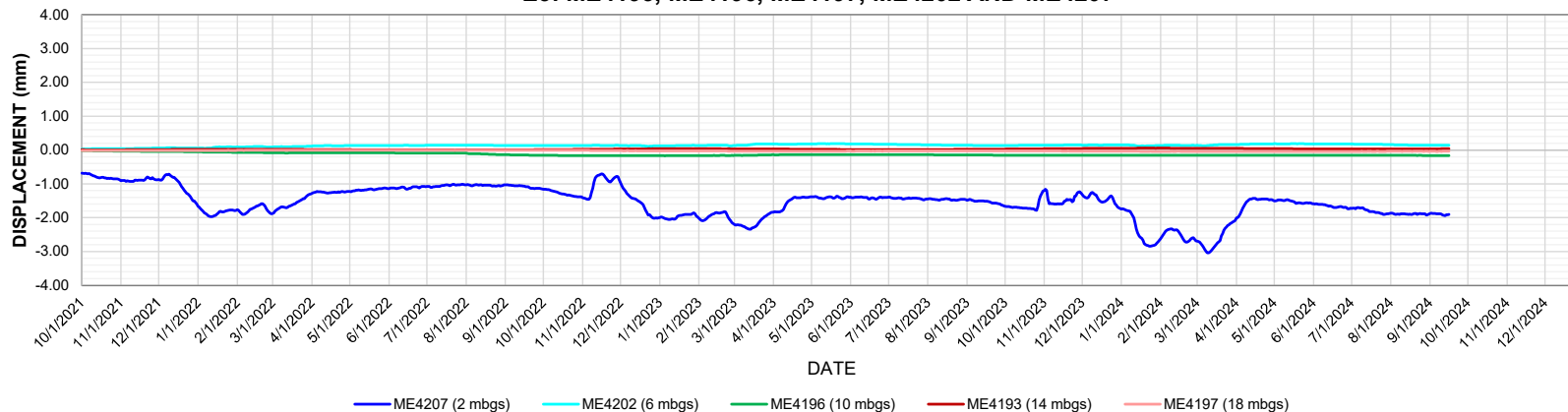
NOTES:
 1. VIBRATING WIRE INLINE EXTENSOMETERS WERE INSTALLED IN SEPTEMBER 2021. THE FIRST READINGS WERE TAKEN IN OCTOBER 2021.
 2. INITIAL LINEAR DISPLACEMENT IS RELATIVE TO THE INITIAL DISPLACEMENT RECORDED DURING INSTALLATION IN SEPTEMBER 2021.
 3. POSITIVE LINEAR DISPLACEMENT INDICATES THE EXTENSOMETER IS BEING LENGTHENED AND NEGATIVE DISPLACEMENT INDICATES EXTENSOMETER IS BEING CONTRACTED.
 4. EXTENSOMETERS DEPTHS REPRESENT ANCHOR DEPTHS OBTAINED FROM ISSUED FOR RECORD DRAWINGS. DEPTHS ARE IN METERS BELOW GROUND SURFACE.

CLIENT

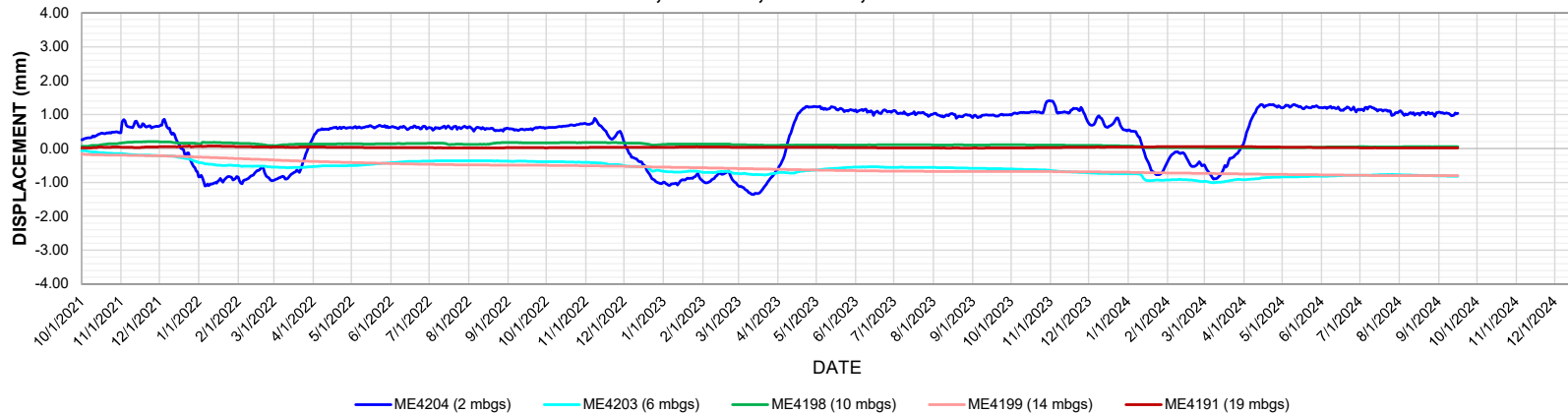



PROJECT	SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
TITLE	VWI Extensometer Data S012 - Spray Lakes Road Hwy 742:02, km 4.319	
SCALE	PROJECT No.	FIG No.
AS SHOWN	A05116A03	I-1

E3: ME4193, ME4196, ME4197, ME4202 AND ME4207



E4: ME4191, ME4198, ME4199, ME4203 AND ME4204



NOTES:
 1. VIBRATING WIRE INLINE EXTENSOMETERS WERE INSTALLED IN SEPTEMBER 2021. THE FIRST READINGS WERE TAKEN IN OCTOBER 2021.
 2. INITIAL LINEAR DISPLACEMENT IS RELATIVE TO THE INITIAL DISPLACEMENT RECORDED DURING INSTALLATION IN SEPTEMBER 2021.
 3. POSITIVE LINEAR DISPLACEMENT INDICATES THE EXTENSOMETER IS BEING LENGTHENED AND NEGATIVE DISPLACEMENT INDICATES EXTENSOMETER IS BEING CONTRACTED.
 4. EXTENSOMETERS DEPTHS REPRESENT ANCHOR DEPTHS OBTAINED FROM ISSUED FOR RECORD DRAWINGS. DEPTHS ARE IN METERS BELOW GROUND SURFACE.

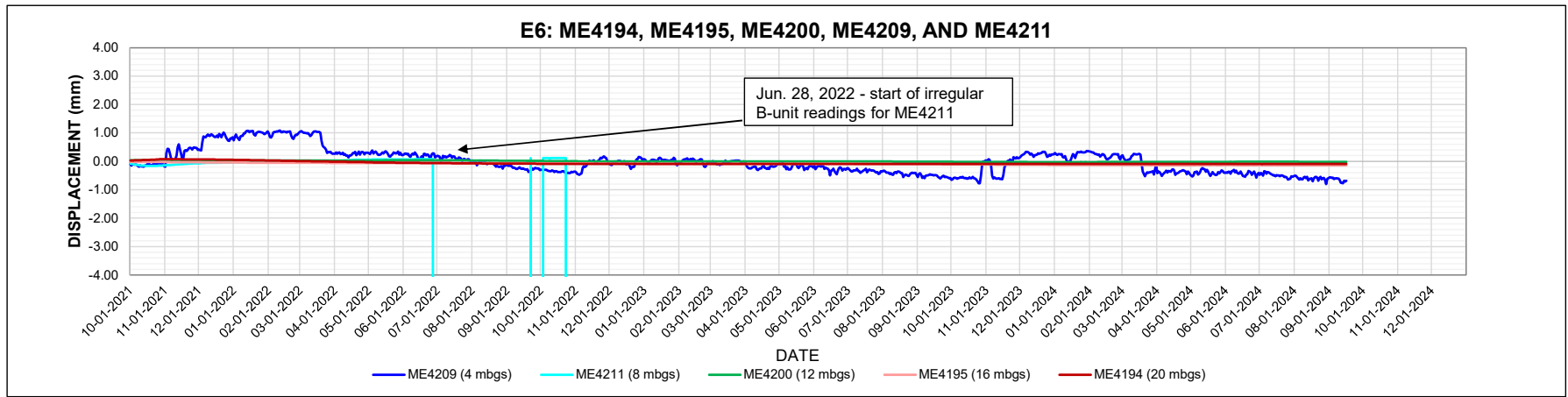
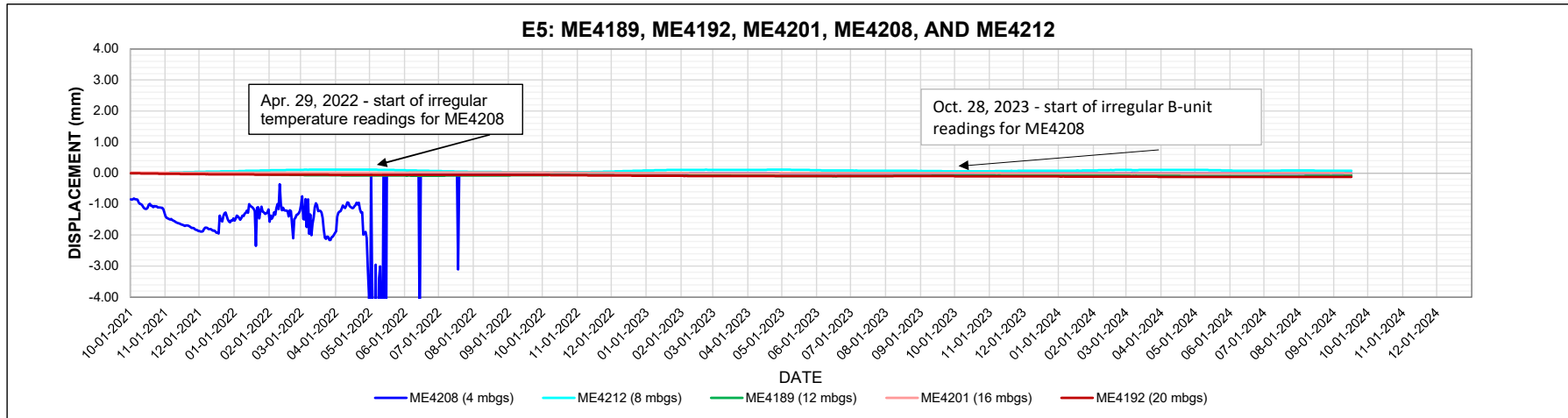
CLIENT




PROJECT
SOUTHERN REGION GEOHAZARD RISK
MANAGEMENT PROGRAM

TITLE
VWI Extensometer Data
S012 - Spray Lakes Road
Hwy 742:02, km 4.319

SCALE AS SHOWN PROJECT No. A05116A03 FIG No. I-II



NOTES:

1. VIBRATING WIRE INLINE EXTENSOMETERS WERE INSTALLED IN SEPTEMBER 2021. THE FIRST READINGS WERE TAKEN IN OCTOBER 2021.
2. INITIAL LINEAR DISPLACEMENT IS RELATIVE TO THE INITIAL DISPLACEMENT RECORDED DURING INSTALLATION IN SEPTEMBER 2021.
3. POSITIVE LINEAR DISPLACEMENT INDICATES THE EXTENSOMETER IS BEING LENGTHENED AND NEGATIVE DISPLACEMENT INDICATES EXTENSOMETER IS BEING CONTRACTED.
4. EXTENSOMETERS DEPTHS REPRESENT ANCHOR DEPTHS OBTAINED FROM ISSUED FOR RECORD DRAWINGS. DEPTHS ARE IN METERS BELOW GROUND SURFACE.

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PROJECT
SOUTHERN REGION GEOHAZARD RISK
MANAGEMENT PROGRAM

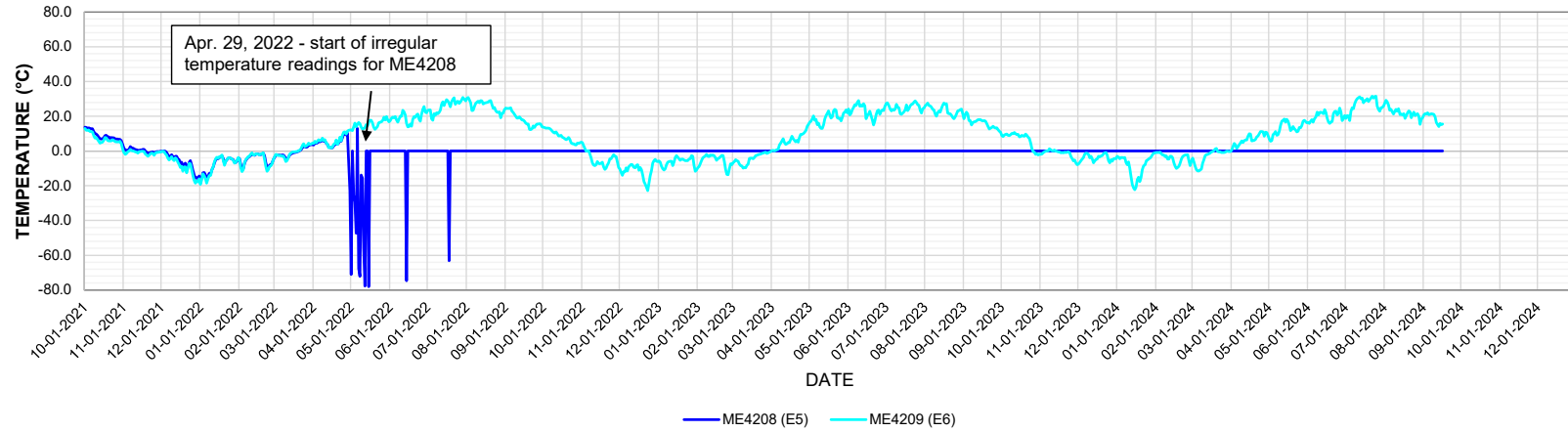
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VWI Extensometer Data
S012 - Spray Lakes Road
Hwy 742:02, km 4.319

SCALE
AS SHOWN

PROJECT No. A05116A03

FIG No. I-III

TEMPERATURE DATA FOR ME4208 (E5) (4 mbgs) AND ME4209 (E6) (4 mbgs)



NOTES:
 1. VIBRATING WIRE INLINE EXTENSOMETERS WERE INSTALLED IN SEPTEMBER 2021. THE FIRST READINGS WERE TAKEN IN OCTOBER 2021.
 2. INITIAL LINEAR DISPLACEMENT IS RELATIVE TO THE INITIAL DISPLACEMENT RECORDED DURING INSTALLATION IN SEPTEMBER 2021.
 3. POSITIVE LINEAR DISPLACEMENT INDICATES THE EXTENSOMETER IS BEING LENGTHENED AND NEGATIVE DISPLACEMENT INDICATES EXTENSOMETER IS BEING CONTRACTED.
 4. EXTENSOMETERS DEPTHS REPRESENT ANCHOR DEPTHS OBTAINED FROM ISSUED FOR RECORD DRAWINGS. DEPTHS ARE IN METERS BELOW GROUND SURFACE.

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PROJECT	SOUTHERN REGION GEOHAZARD RISK MANAGEMENT PROGRAM	
TITLE	VWI Extensometer Data S012 - Spray Lakes Road Hwy 742:02, km 4.319	
SCALE AS SHOWN	PROJECT No. A05116A03	FIG No. I-IV