ALBERTA TRANSPORTATION
GEOHAZARD ASSESSMENT PROGRAM
PEACE REGION – GRANDE PRAIRIE DISTRICT
2019 CALL OUT

THURBER ENGINEERING LTD.

Site Number	**Location**	**Name**	**Hwy**	**km**
GP06B	N of Grande Cache	Tear Drop Slides	40:36	21.8
Legal Description		**UTM Co-ordinates (NAD 83)**		
NW30-58-7-W6		11U N 5,990,745	E 366,610	

	Date	**PF**	**CF**	**Total**
Previous Inspection:	June 8, 2019	9	4	36
Current Inspection:	July 12, 2019	14	5	70
Road AADT:	900		**Year:**	2018
Inspected By:	Barry Meays, Nicole Wilder (Thurber) Ed Szmata, Dwayne Lowen (AT)			
Report Attachments:	☑ Photographs	☑ Plans		☑ Maintenance Items

Primary Site Issue:	Landslide in a 20 m high, 2H:1V highway embankment fill.	
Dimensions:	About 190 m wide along highway, by ~40 m long from highway down to toe.	
Date of any remediation:		
Maintenance:	Crack Sealing and Patching. SB lane closed to traffic on July 12, 2019 due to ongoing rapid landslide movements. Gravel added to west shoulder and traffic lights currently in place to manage traffic on one lane of open roadway	
Observations:	**Description**	**Worse?**
☑ Pavement Distress	Two scarp cracks (135 m long, and 30 m long) separated by about 25 m, run along the highway in both the southbound and northbound lanes, and are likely linked as one larger slide, affecting an approximate total 190 m length of pavement. Three dips also exist in the pavement on the east side of the scarp cracks. The longer 135 m long crack has moved rapidly, and is braided at some locations, and the shoulder and guardrail have dropped.	☑
☑ Slope Movement	Slight creep movements were previously documented to continue downslope in the east embankment fill ~ 8 to 10 m deep near the outside shoulder. Three embankment fill slumps (11 m/8m/19m wide) exist downslope of the highway. However, no visible recent or fresh toe pushes or bulges were observed on the downstream embankment during this Call Out visit. The 600 mm drop slump that was longer in 2018 with an apparent bulge, near the south end of the pavement crack, was not observed during this visit. The backslope slump scarp near the north end of the site was observed to have some added freshness at some locations, along with significant seepage.	☑
☐ Erosion		☐
☑ Seepage	Light to heavy seepage was observed from two separate areas of the cut backslope west of and above the highway. No seepage was observed from either the highway surface or the embankment fill slope east of the highway during this Call Out visit.	☑

☐ Bridge/Culvert Distress		☐
☑ Other	A steady stream of water was flowing northwards along the west highway ditch.	☐

Instrumentation July 8, 2019: Inclinometer SI-2 = 16 mm/yr @ 3 to 8 m depth.
Piezometers: PN-2 = 6.6m BGS July 8, = 2.6m BGS July 12; **PN-3** = 3.6m BGS July 8, = 0.3m BGS July 12; **PN-4** = 3.7 m Above GS July 8, = 4.7 m Above GS July 12.

Assessment:

Two obvious scarp cracks exist over a total of ~190 m length (separated by a distance of 25 m) of highway surface straddling both lanes. Dips/settlement exist at three locations on the downslope side of the scarp. At the south end, a scarp crack was identified, and would appear to form a natural progression of the south end of the slide zone.

The majority of the larger 135 m long crack had moved significantly (cracks measured up to 150 mm wide by up to 160 mm elevation drop by up to 460 mm deep) in the few days prior to this July 12, 2019 Call Out visit (with dissipating movement towards both ends of this crack), and no significant movement on the most southerly 30 m long crack zone. The worst area was where the crack propagates towards the east guardrail, where the guardrail is damaged and a 300 mm wide by 400 mm drop by 800 mm deep crack exists. The north boundary of the slide zone is still not clear, as the crack disappears into the west shoulder.

Seepage was also observed emanating from two areas of the west cut backslope above the west ditch during this visit. Light seepage was observed from a location about 20 m west of the bedrock exposure near the south end of the crack, while moderate to heavy seepage was observed from the backslope scarp north of the north end of the crack. A steady stream of runoff water was also running northwards along this upslope west highway ditch above the slide crack.

Information obtained from AT during this visit indicated that the movements were observed to have recently accelerated, with 50 to 100 mm movements noticed on July 9, with much more movement on July 10. It was further indicated that the Grande Cache area had received substantially more precipitation than the Grande Prairie area (where about 125 mm was documented in the last several weeks). Aggressive slide movements have reportedly continued since our callout visit resulting in further deformation and cracking of the road surface, with some additional activity at the north end of the slide zone where the slide scarp crack crosses into the west ditch.

Piezometer PN-4, which had indicated pore pressures of 1 m to 3 m above ground surface over the last year, had recently shown an increase to 3.7 m above ground surface (July 8) and 4.7 m above ground surface (July 12). PN-3 and PN-2 also indicated increased pore water pressures on July 12 to about 0.3 m BGS and 2.3 m BGS, respectively. The latest readings are shown on the attached cross-sections figure, while all of the historic pore pressure readings are charted on the attached chart.

There are also 3 relatively small embankment slumps downslope of the highway surface further south of the scarp crack and backslope scarp. These slumps were anticipated to be separate, shallow fill instabilities caused by previous groundwater seepage and have self-healed due to lack of activity, but they (especially the south one) may possibly be linked and form part of the larger slide in the pavement. A trace of seepage was observed from the scarp crack in the highway during a previous inspection, however no seepage was observed either from the pavement surface or the steep downslope highway embankment during this Call Out visit.

Some additional recent information was obtained from Alberta Transportation, which included the previous borehole logs plotted on cross-sections (replicated on the attached X-Sections figure), some previous inclinometer plots (attached), and a 1998 preliminary report which outlined two potential remedial measures: grade lowering and drainage. SI-1 (south end) became "blocked" at 9 m before any significant information was obtained; SI-3 (north end downslope edge hwy.) showed some minor fluctuating movements between 9 to 11 m; and SI-4 (north end upslope ditch) showed only indecisive movements.

It was reported in 2016 that the slide has been exhibiting slow, creep movements for a long time. The single inclinometer record has been monitored semi-regularly since 1998, with no large movements recorded. The depth of movement is shown between 3 to 8 m at the downslope (east) shoulder in SI-2 near the center of the slide (see attached), with the most recent recorded movement that had increased to 16 mm/yr (July 8, 2019). Also, there are no operational instruments downslope of the road shoulder to identify the shape/depth of the slide. This adds some uncertainty to the size/shape/extent of the slide affecting the highway.

The slide affecting the pavement is probably the result of an overly steep (2H:1V) fill, aggravated by seasonal rises in the groundwater table and surface infiltration. The slide is now moving very rapidly, based on the information above, and the most recent crack sealing/patching tore apart within a few days (see Photos 21 and 22). The significant amount of rain over the last month has resulted in a big increase to the water table level that is likely the main cause of the high rate of landslide movements that are currently occurring.

Recommendations:

Geotechnical Investigation:
The old SI's were located on a previous visit and except for SI-2 are either broken or are no longer readable. The old logs were found from the job files, and contain no additional soil description other than that shown on the cross-sections provided by AT. SI-1 and SI-3/SI-4 do not add any significant information regarding the slide movements (-3 and -4 may be near/outside the north zone of movement or are not deep enough). Also, the boundary of the slide scarp in the pavement needs to be more completely delineated (to see if the two cracks are joined), and whether the backslope scarp, or possibly some of the 3 downslope embankment slumps are also linked and form part of one larger slide.

It is therefore recommended that some additional boreholes should be drilled, and instrumentation installed to provide information on the soil and groundwater conditions, to carry out detailed slope stability analyses, and to confirm slope stabilization design measures. Three test holes along the upslope ditch (to ~ 15 m), four test holes along the downslope side of the highway (to ~25 m), and two test holes along the downstream toe (to ~ 10 m) to define the current slide are recommended, complete with slope inclinometer and nested vibrating wire piezometer installations. Access notes are shown on the cross-sections figure. Additional test holes adjacent to the highway could be considered to define the lateral slide extents to the north and south of the current slide zone. Newer LiDAR should also be obtained, along with performing an updated topographic site survey.

A preliminary engineering report would then be prepared elaborating on the remedial repair options discussed below.

Maintenance:
Perform crack filling, milling, and ACP levelling patches of the pavement in the zones of minor movement at the two slide areas to remedy the cracking and settlement as required.

Short Term:
Continue monitoring the instruments and visually monitor both slides and the embankment fill slumps for progression of slide movements. Since the movements are continuing at a high rate, the following should be undertaken:

- Post warning/speed reduction/one lane traffic signs and/or barricades around the distressed area, utilizing traffic lights. It is understood that this was completed by AT on July 12, 2019.
- If movements extend further to the west in the road, construct a detour by filling the ditch with gravel over a culvert to allow one full lane of traffic. A shallow ditch upslope of the driving surface would be needed to capture runoff and seepage from the backslope above
- Erect jersey barriers around the power poles in the upslope ditch to prevent vehicle collisions on the poles
- An emergency overflow should be installed upslope of the filled in ditch to prevent water from crossing the highway during rain events. It could consist of a cross culvert, with the outlet joined to a hose that directs the water down into the flatter area below the toe berm.

Medium to Long Term:
Three remedial options are provided below for consideration. The lateral extent of these measures, and associated costs, would have to be re-evaluated after the geotechnical investigation described above is

undertaken. Reconstruction of the entire pavement surface would need to be undertaken for all three options, since the pavement is now badly damaged by the slide movements.

As was discussed in the 1998 preliminary report and follow-up letter, the grade lowering option was not recommended (mostly due to cost). However, considering the urgency of the repairs and speed of the slide, this is now considered to be a viable consideration.

Option 1 – Horizontal Drains

The drains would have to be installed with an air track drill from the toe of the embankment slope. This option was described somewhat in the follow up to the 1998 preliminary report. Horizontal drains could be installed in clusters of 2, with each cluster containing a steeply inclined (~40 m long) and a flatly inclined (~60 m long) drain. 20 clusters at a 10 m spacing/cluster would cover a 200 m slide length, resulting in an approximate 2,000 m of drain length. One drawback with the drain installation is that they could shear off due to this fast-moving slide prior to the scheme's overall effectiveness taking place. The effectiveness of the drains is not as certain as the other two options. On their own they will likely not improve the factor of safety to as high a value as the other two options and their effectiveness will depend on whether the installations are able to tap into the water bearing seams. Their effectiveness could also diminish over time. The drains are the cheapest option that could be tried to see if they provide enough improvement before spending more money on one of the other options, but this could draw out the timeline for getting the road fully back into service.

Ball Park Cost $1.5 Million

Option 2 – Grade Lowering

This option would involve lowering the existing road surface by about 2 or 3 m. It would need to extend a sufficient distance in each direction from the slide in order to meet existing design parameters and match existing gradelines (an assumed length of 1.0 km is assumed). A temporary detour could be located on the upslope side of the highway while the highway is lowered in stages starting from the east side and working to the west. There is a single strand power line on the west side of the west ditch that would need to be relocated.

The lowered gradeline would make the upslope inclinations steeper. This would require cutting the backslope back and disposing of the excess material. There is an existing slump in part of the backslope indicating that the inclination of the cut should not exceed what is there already. There are some existing rock outcrops in two locations suggesting that some heavy ripping of rock might be required or that a few local sections could be left a bit steeper.

Then this entire 1 km length of highway would need to be resurfaced. Depending on the FOS the drainage measures in Option 1 might also be required.

The lowered gradeline would allow some subsequent flattening of the downslope embankment. If further improvements to achieve stability was required, additional fill placement to flatten the slope or possibly construct a toe berm in front of the railway tracks could be undertaken. The current embankment sideslope inclinations vary from about 1.7H:1V (south) to 2.1H:1V (north). If the slopes were able to be flattened up to the edge of the railway track embankment fill, this would allow inclinations of about 2.4H:1V (south) to 3.2H:1V (north). However, there is a high voltage power line located along the toe of the highway embankment and then a gas line between the power line and railway tracks which would make placement of a toe berm difficult. The power line might need to be raised and approval would be needed to place fill over the gas line.

(no costs for dealing with high voltage power line or gas line) Ball Park Cost $6 Million

Option 3 – Pile Wall

Based on the information from existing slope inclinometer SI-2, an approximate 8 to 9 m slide depth is anticipated. This would be similar to the pile wall constructed at Judah Hill (Sunshine Slide), where 2 rows of tie-backs were required together with a 2 m deep waler and 18 m long tangent piles of 1.2 m diameter. The length of this pile wall would need to be about 200 m. The highway pavement would need to be reconstructed over the 200 m length.

Ball Park Cost $9Million

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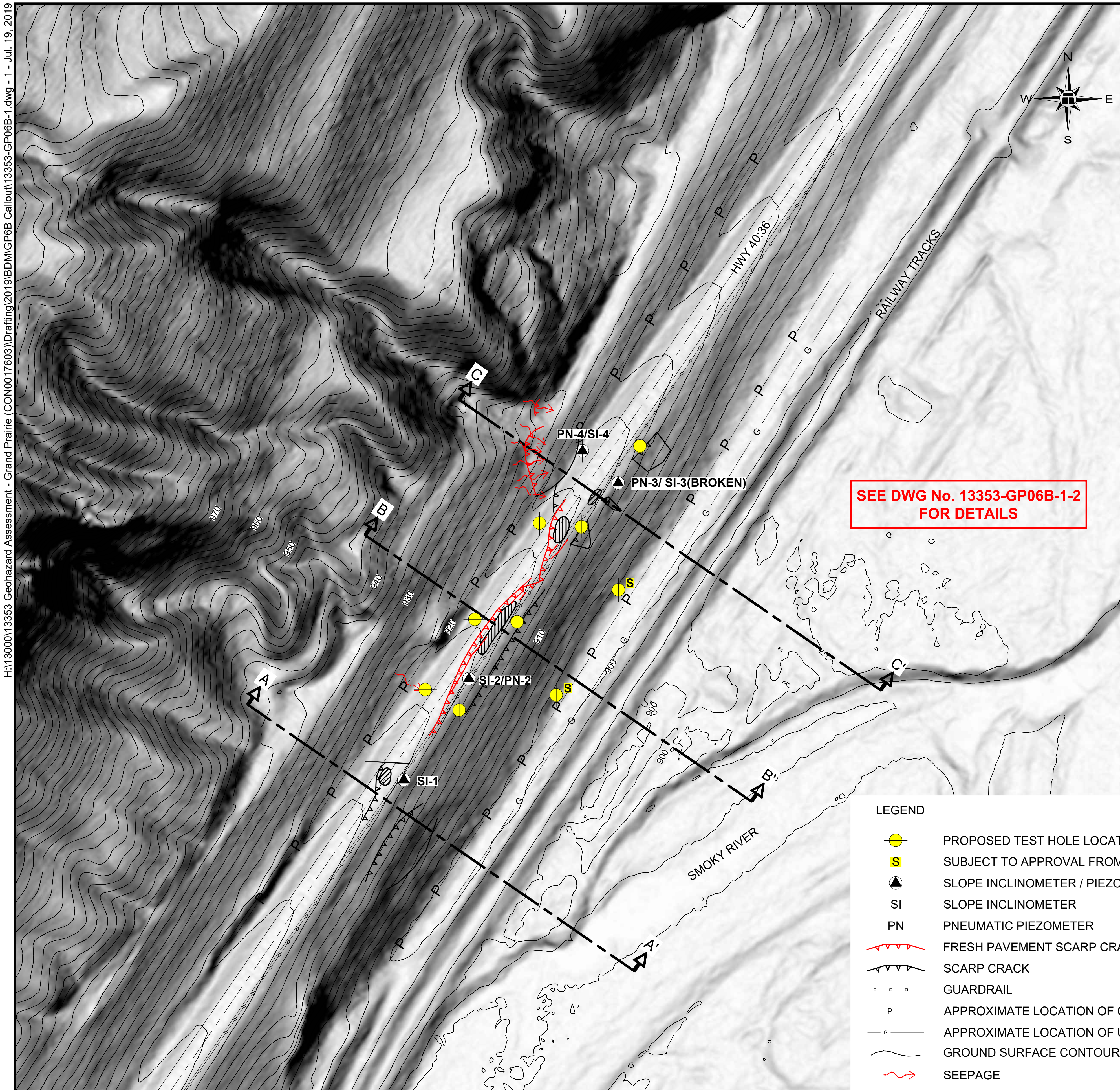

KEY MAP

SCALE 1:30 000

NOTES :

1. FEATURE LOCATIONS ARE APPROXIMATE
2. PREVIOUS OBSERVATIONS SHOWN IN BLACK
3. JULY 12, 2019 FEATURES SHOWN IN RED

0 20 40 60 80 100 120m

SCALE 1:2000

LIDAR PROVIDED BY ALBERTA TRANSPORTATION ;
ESRI IMAGERY FROM ESRI WORLD IMAGERY (DOWNLOADED 2016-12-23)

LEGEND

- PROPOSED TEST HOLE LOCATION
- S — SUBJECT TO APPROVAL FROM UTILITY COMPANIES
- SLOPE INCLINOMETER / PIEZOMETER
- SI — SLOPE INCLINOMETER
- PN — PNEUMATIC PIEZOMETER
- FRESH PAVEMENT SCARP CRACK
- SCARP CRACK
- GUARDRAIL
- P — APPROXIMATE LOCATION OF OVERHEAD POWER LINE
- G — APPROXIMATE LOCATION OF UNDERGROUND GAS LINE
- GROUND SURFACE CONTOUR (2m INTERVAL)
- SEEPAGE

Alberta Transportation

PEACE REGION (GRANDE PRAIRIE)
GP06B-1: HWY 40:36 TEAR DROP SLIDES

JULY 12, 2019 CALLOUT PLAN

DWG No. 13353-GP06B-1-1

DRAWN BY	KLW
DESIGNED BY	BDM
APPROVED BY	DWP
SCALE	1:2000
DATE	JULY 12, 2019
FILE No.	13353

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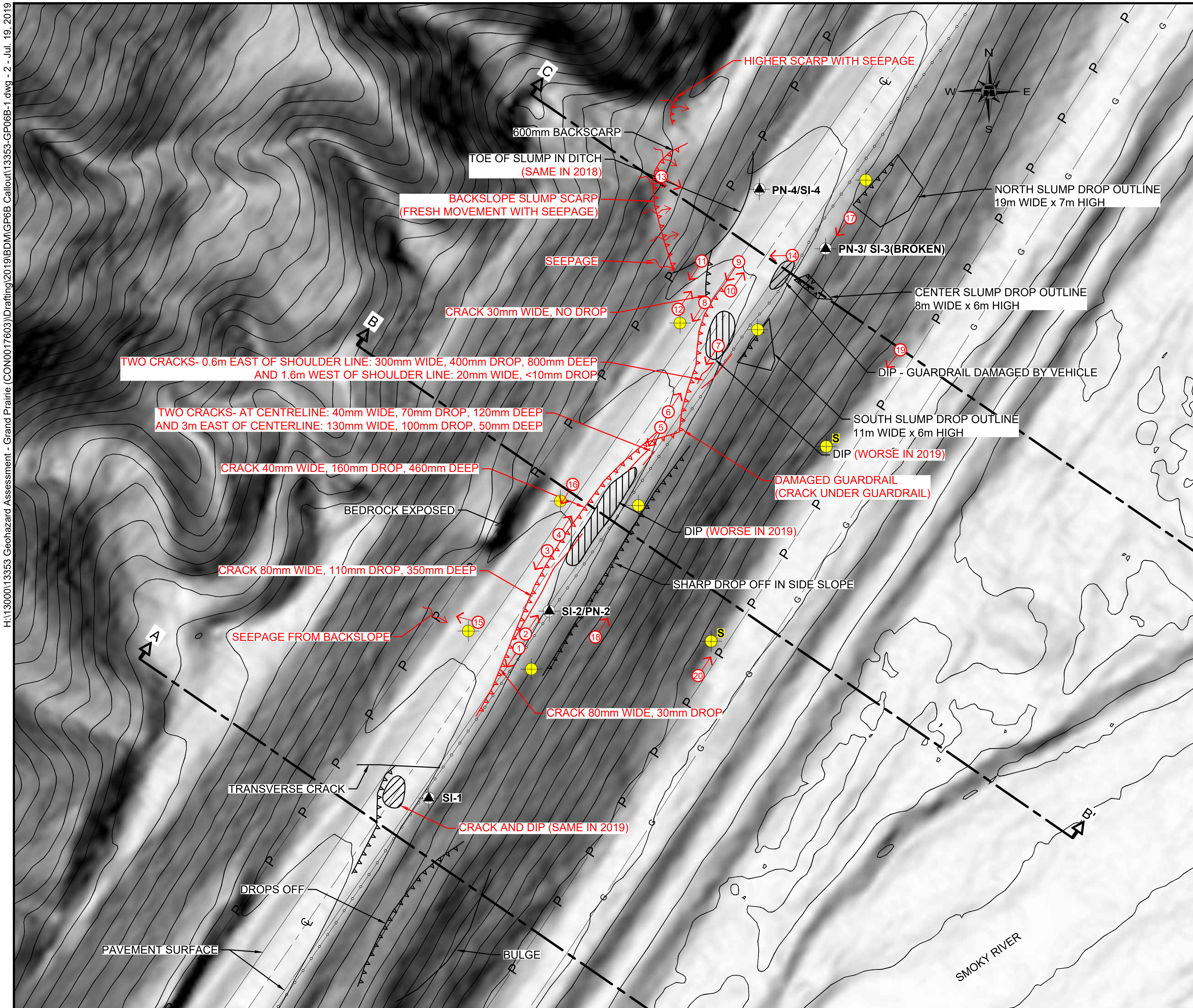

LEGEND

- PROPOSED TEST HOLE LOCATION
- S SUBJECT TO APPROVAL FROM UTILITY COMPANIES
- SLOPE INCLINOMETER / PIEZOMETER
- SI SLOPE INCLINOMETER
- PN PNEUMATIC PIEZOMETER
- FRESH PAVEMENT SCARP CRACK
- SCARP CRACK
- GUARDRAIL
- APPROXIMATE LOCATION OF OVERHEAD POWER LINE
- APPROXIMATE LOCATION OF UNDERGROUND GAS LINE
- GROUND SURFACE CONTOUR (2m INTERVAL)
- SEEPAGE
- DIRECTION AND NUMBER OF PHOTO

NOTES :

1. FEATURE LOCATIONS ARE APPROXIMATE
2. PREVIOUS OBSERVATIONS SHOWN IN BLACK
3. JULY 12, 2019 FEATURES SHOWN IN RED

0 10 20 30 40 50 60m

SCALE 1:1000

LIDAR PROVIDED BY ALBERTA TRANSPORTATION

Alberta Transportation

PEACE REGION (GRANDE PRAIRIE)
GP06B-1: HWY 40:36 TEAR DROP SLIDES

JULY 12, 2019 CALLOUT PLAN

DWG No. 13353-GP06B-1-2

DRAWN BY	KLW
DESIGNED BY	BDM
APPROVED BY	DWP
SCALE	1:1000
DATE	JULY 12, 2019
FILE No.	13353

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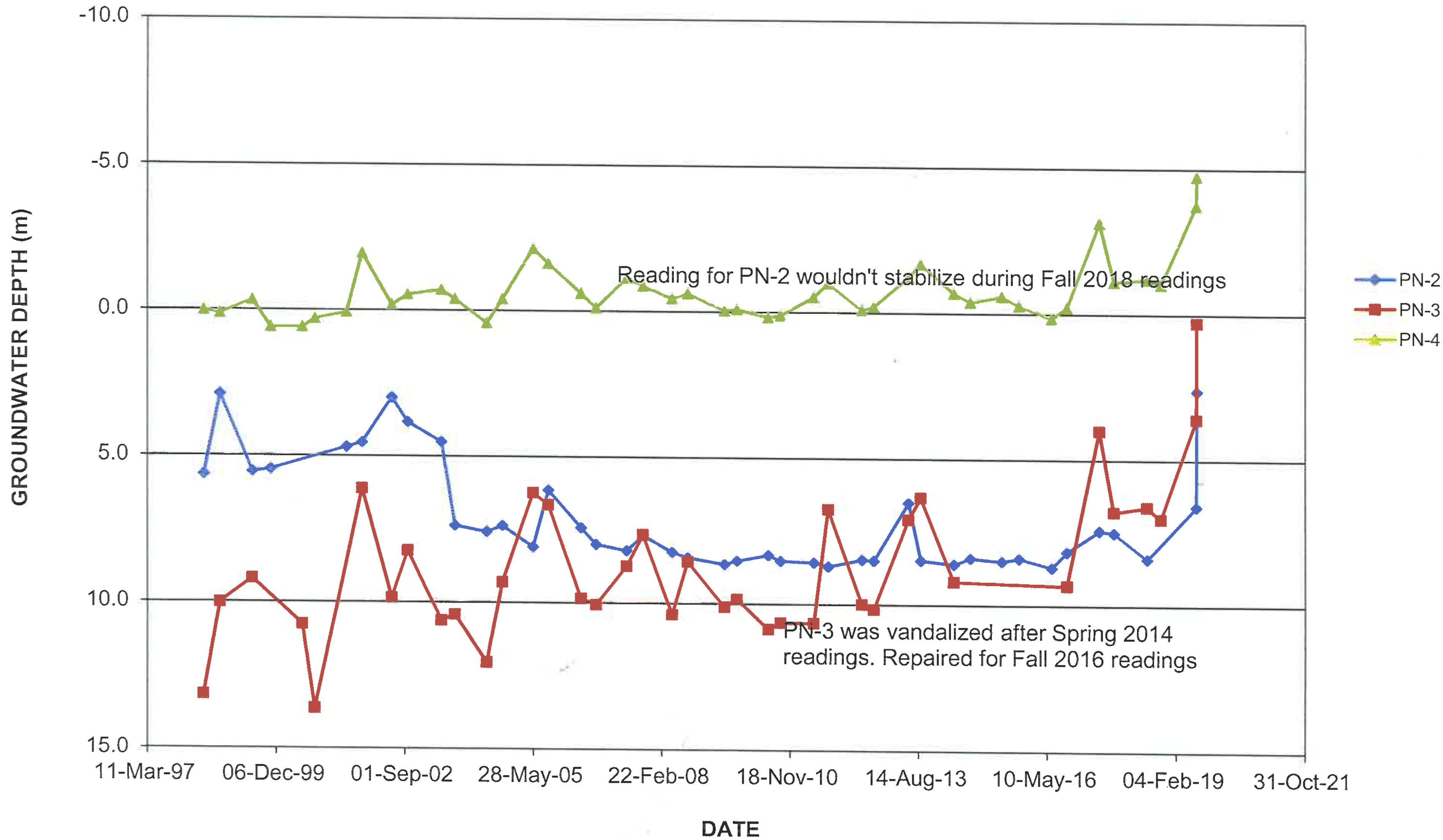
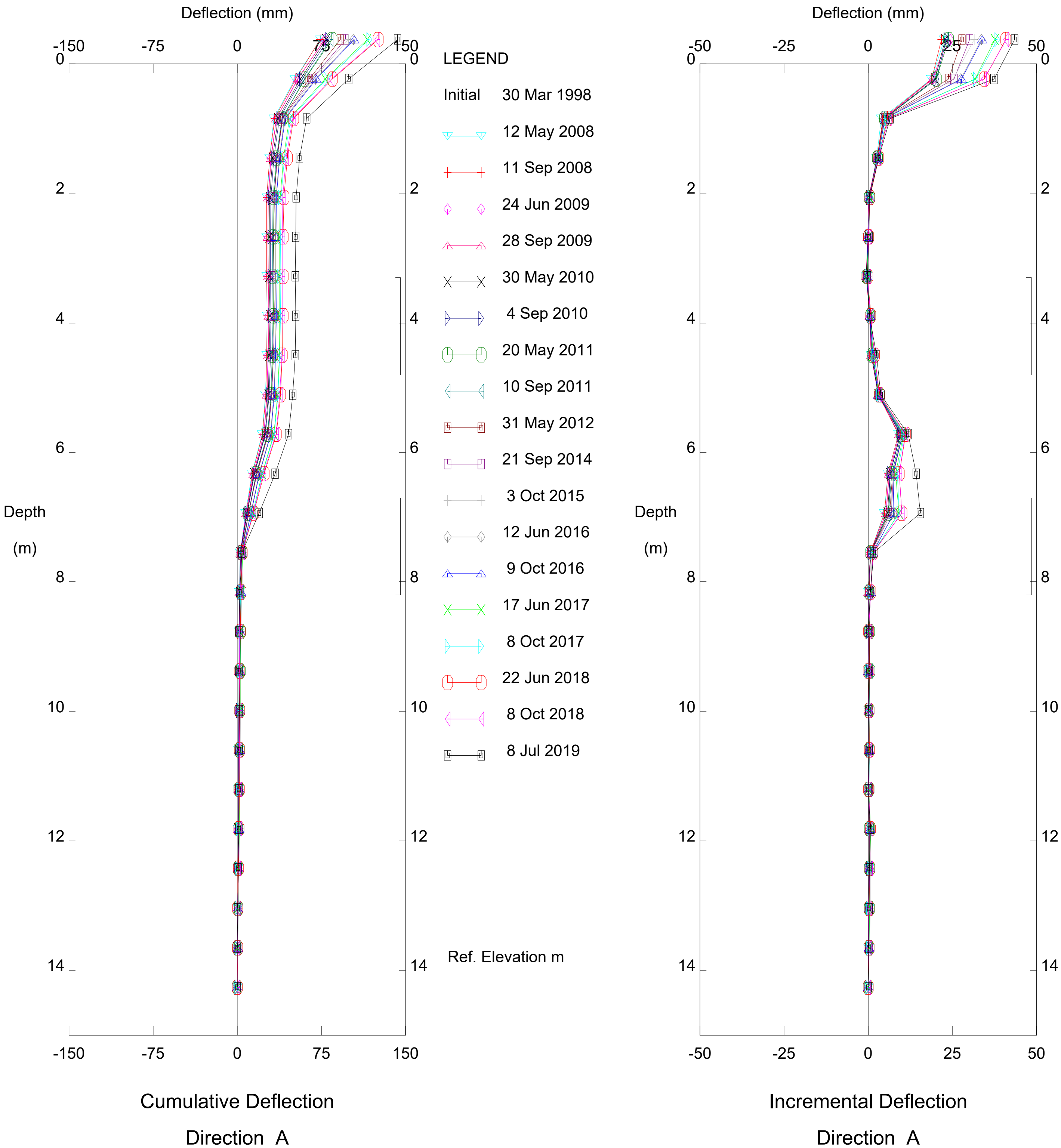
Latest – Incl. Callout Rdngs, July/Aug 2019

FIGURE GP006B-1-1
PIEZOMETER DATA FOR SHEEP CREEK RR TRACK EMBANKMENT



Thurber Engineering Ltd



GP006B-1 Sheep Creek Embankment, Inclinometer SI-02

Alberta Transportation

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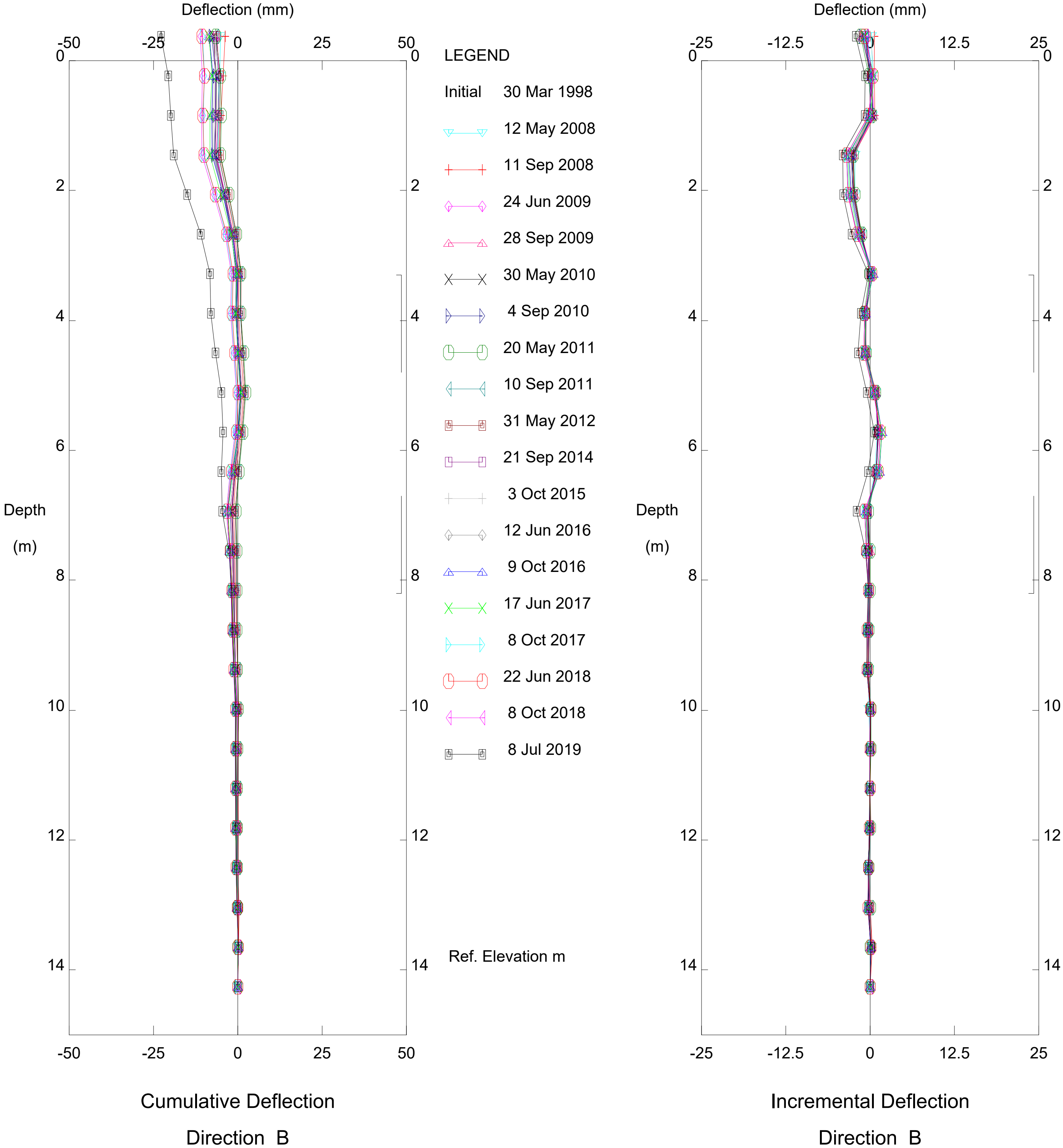
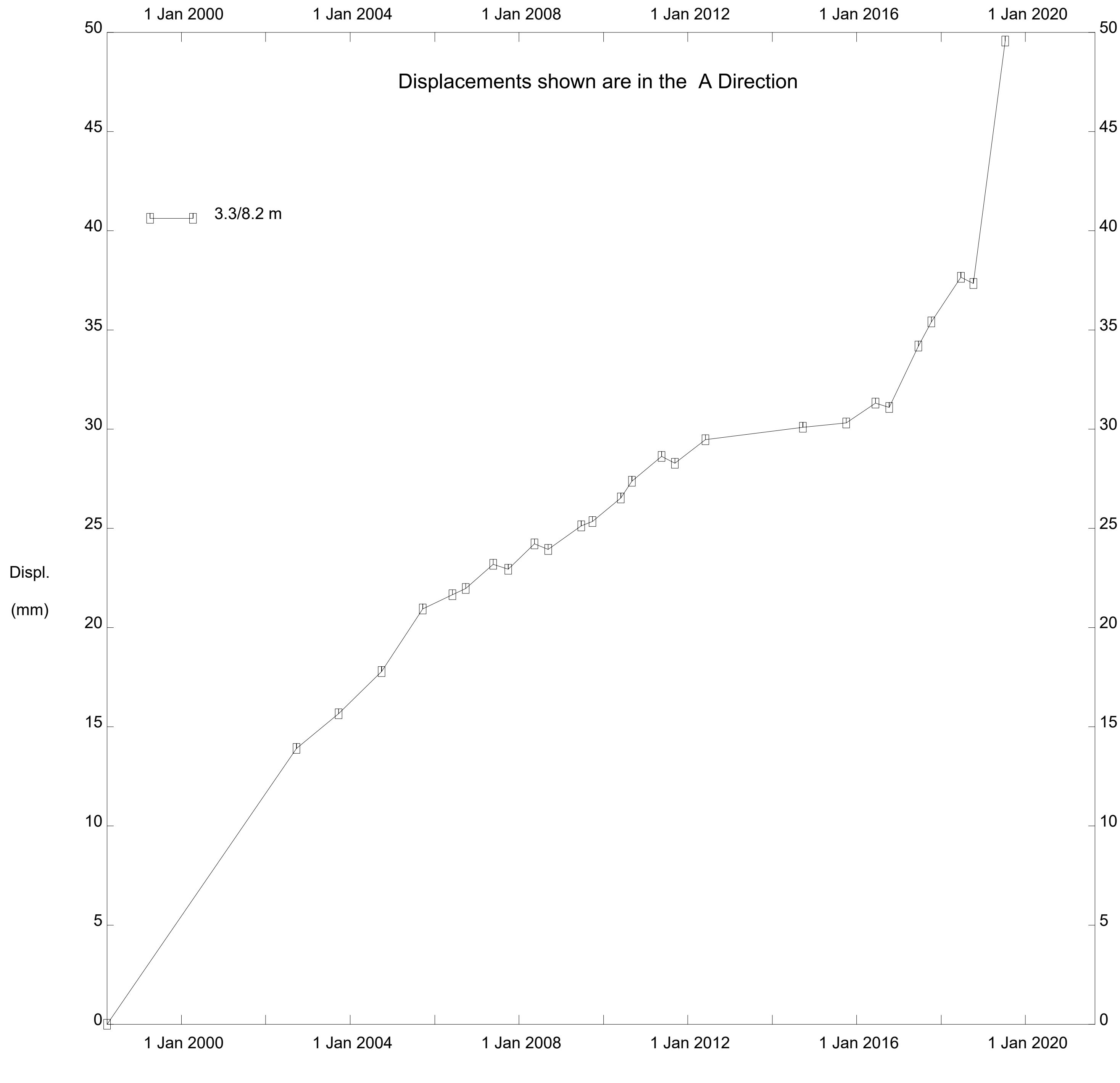


GP006B-1 Sheep Creek Embankment, Inclinometer SI-02

Alberta Transportation

Thurber Engineering Ltd



GP006B-1 Sheep Creek Embankment, Inclinometer SI-02

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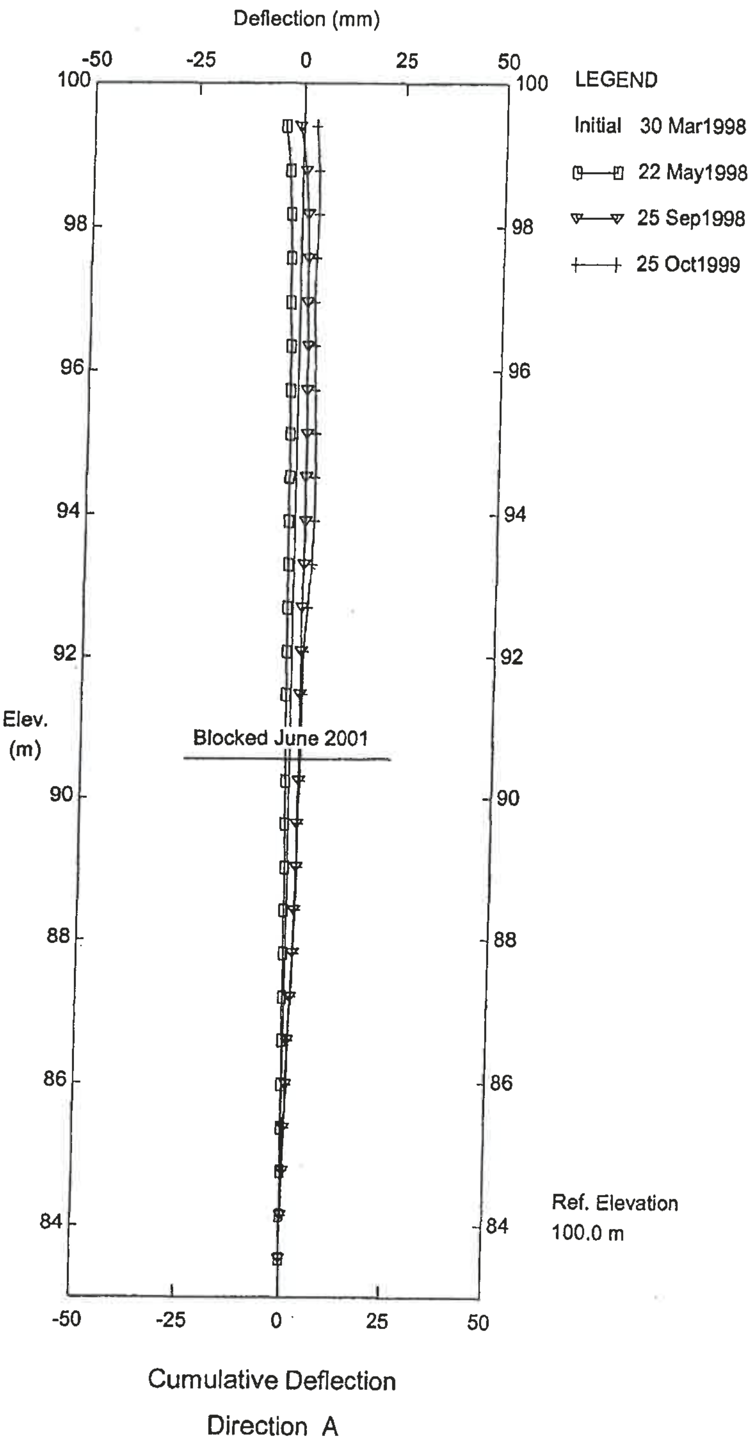
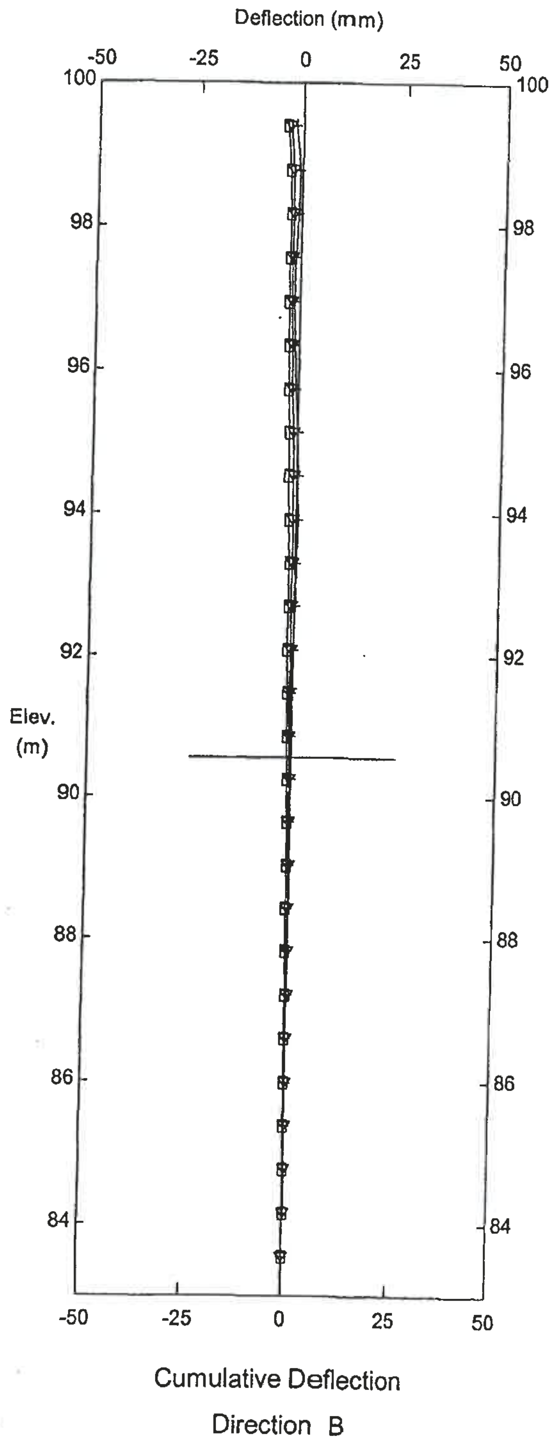
SI-1 (1999)

EBA Engineering Consultants Ltd. - Edmonton, AB





GP-6b; Sheep Creek Embankment, Inclinometer SI-01

107-7100131.003

Hwy 40:38

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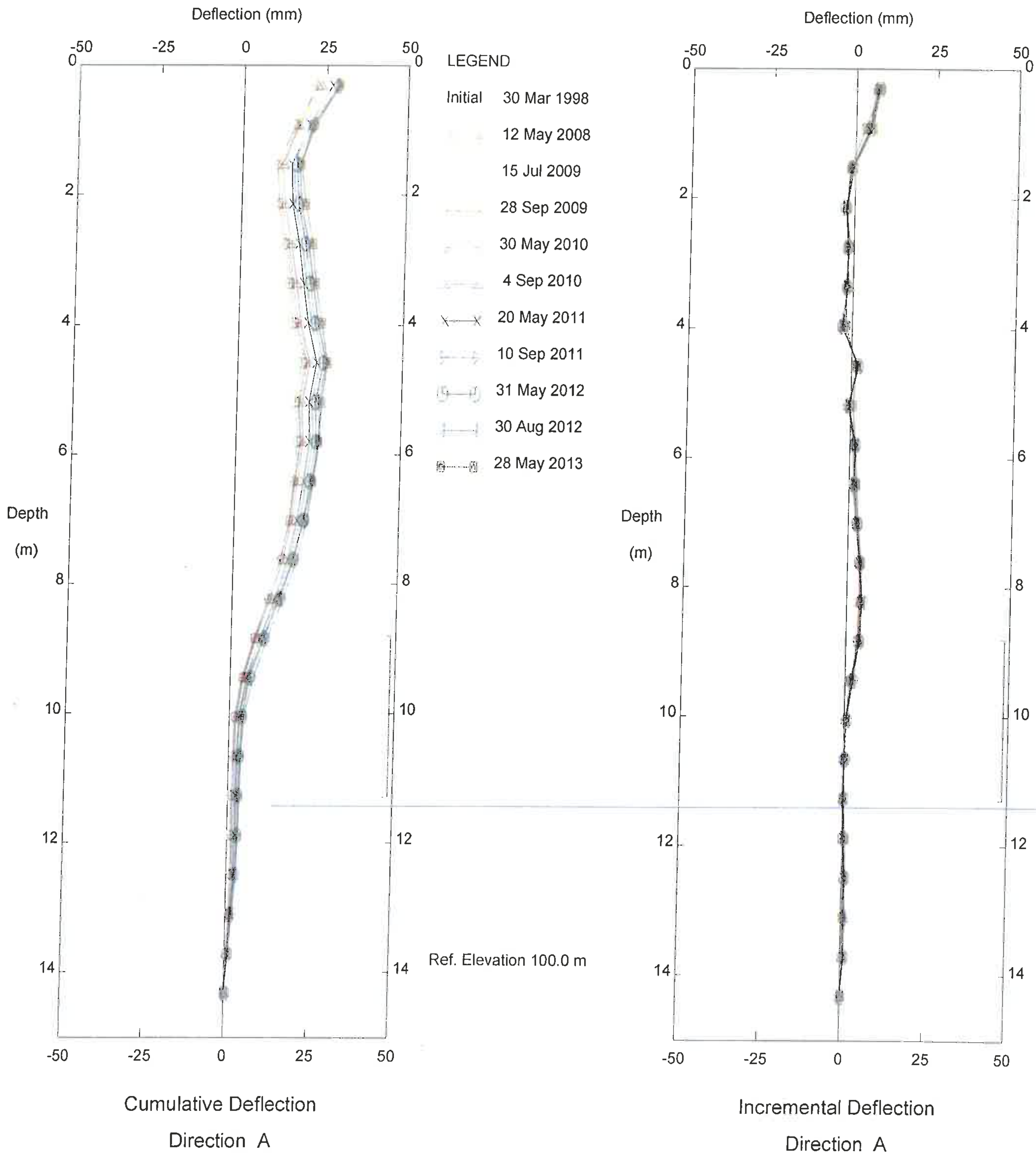
SI-3 (2013)

Karl Engineering Consultants - Edmonton, AB



GP-6b; Sheep Creek Embankment, Inclinometer SI-03

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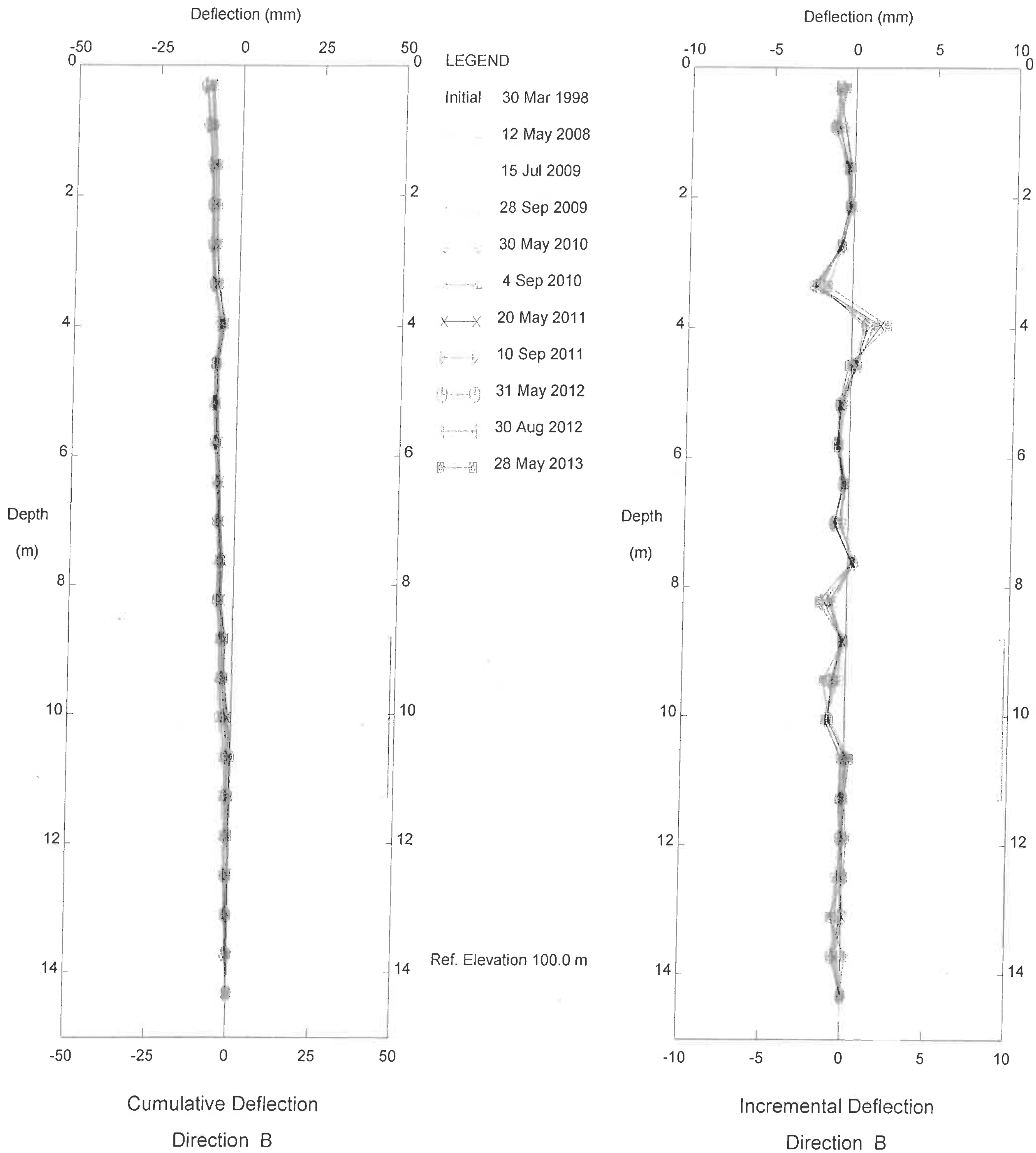
Karl Engineering Consultants - Edmonton, AB



GP-6b; Sheep Creek Embankment, Inclinometer SI-03

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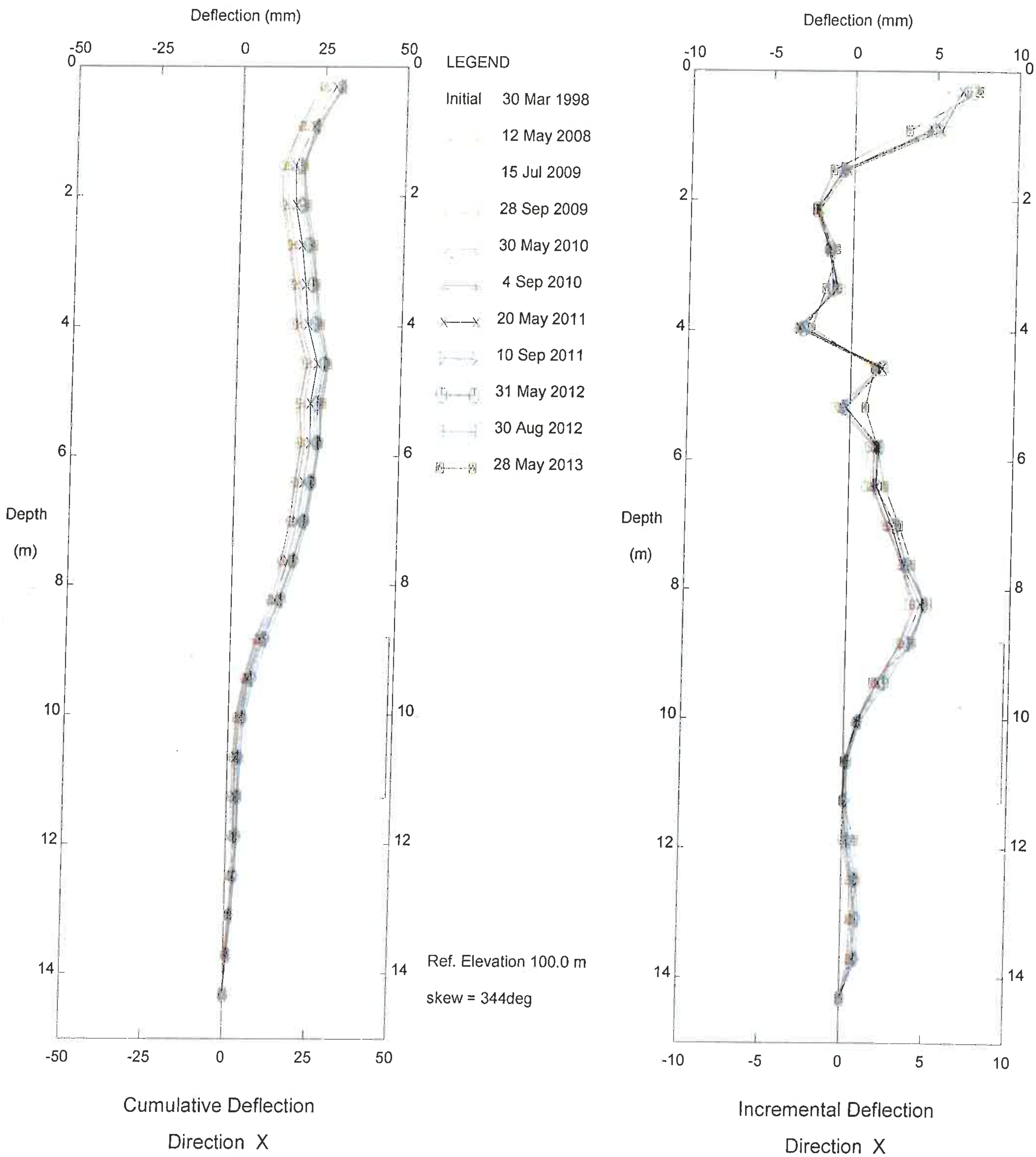
Karl Engineering Consultants - Edmonton, AB



GP-6b; Sheep Creek Embankment, Inclinometer SI-03

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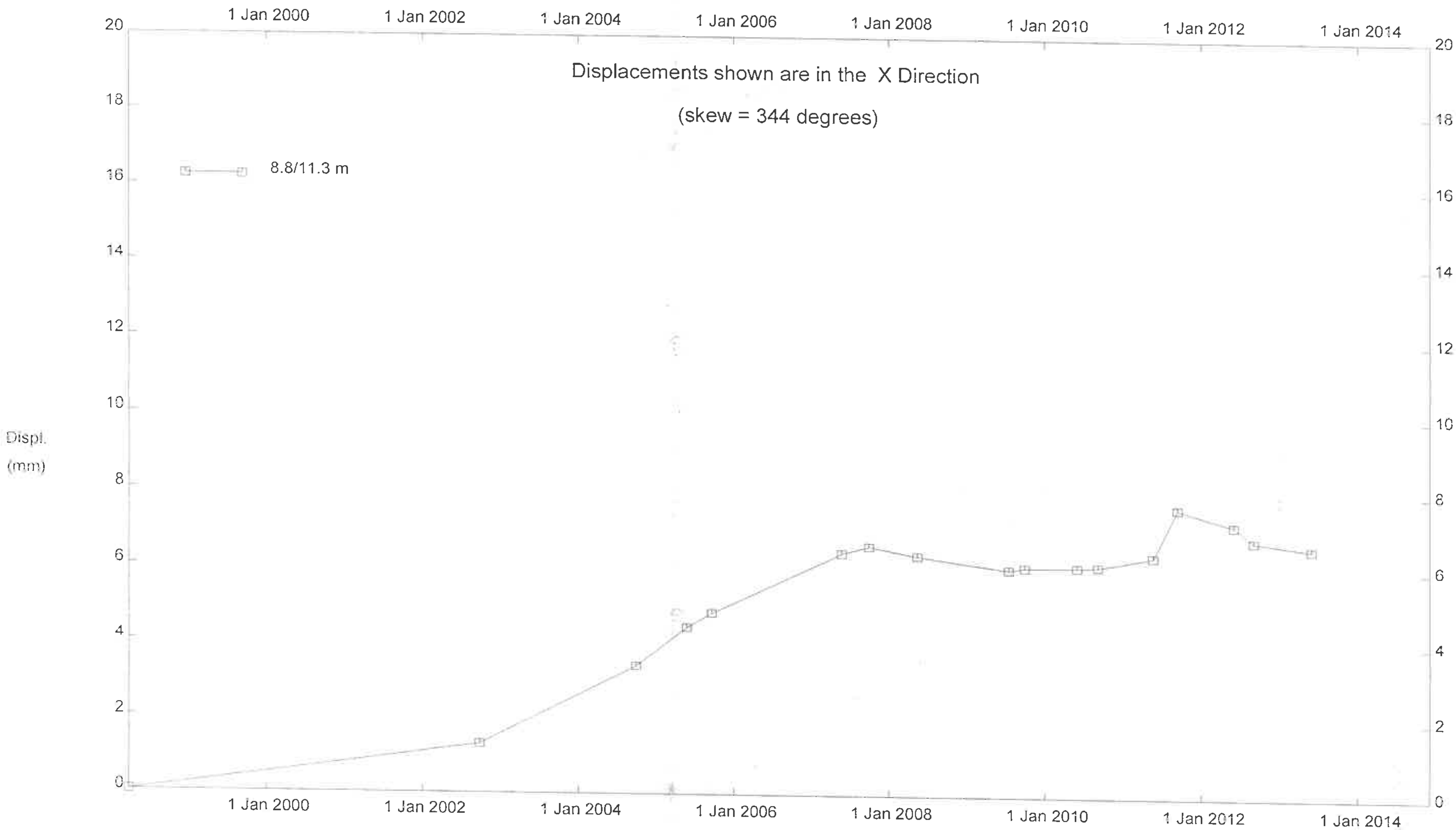
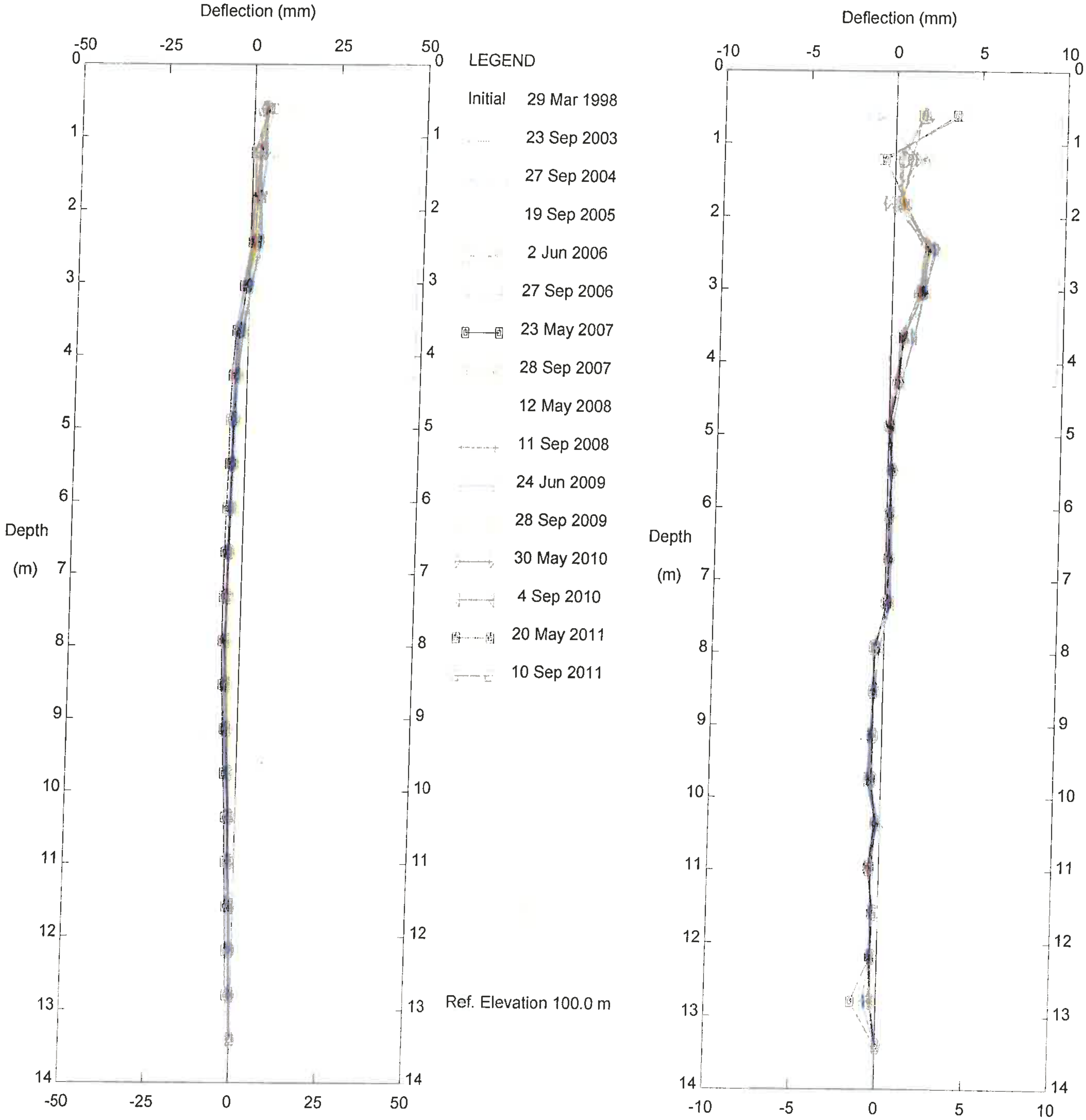


GP-6b; Sheep Creek Embankment, Inclinometer SI-03

SI-4 (2011)

Karl Engineering Consultants - Edmonton, AB



Cumulative Deflection
Direction A

Incremental Deflection
Direction A

GP-6b; Sheep Creek Embankment, Inclinometer SI-04

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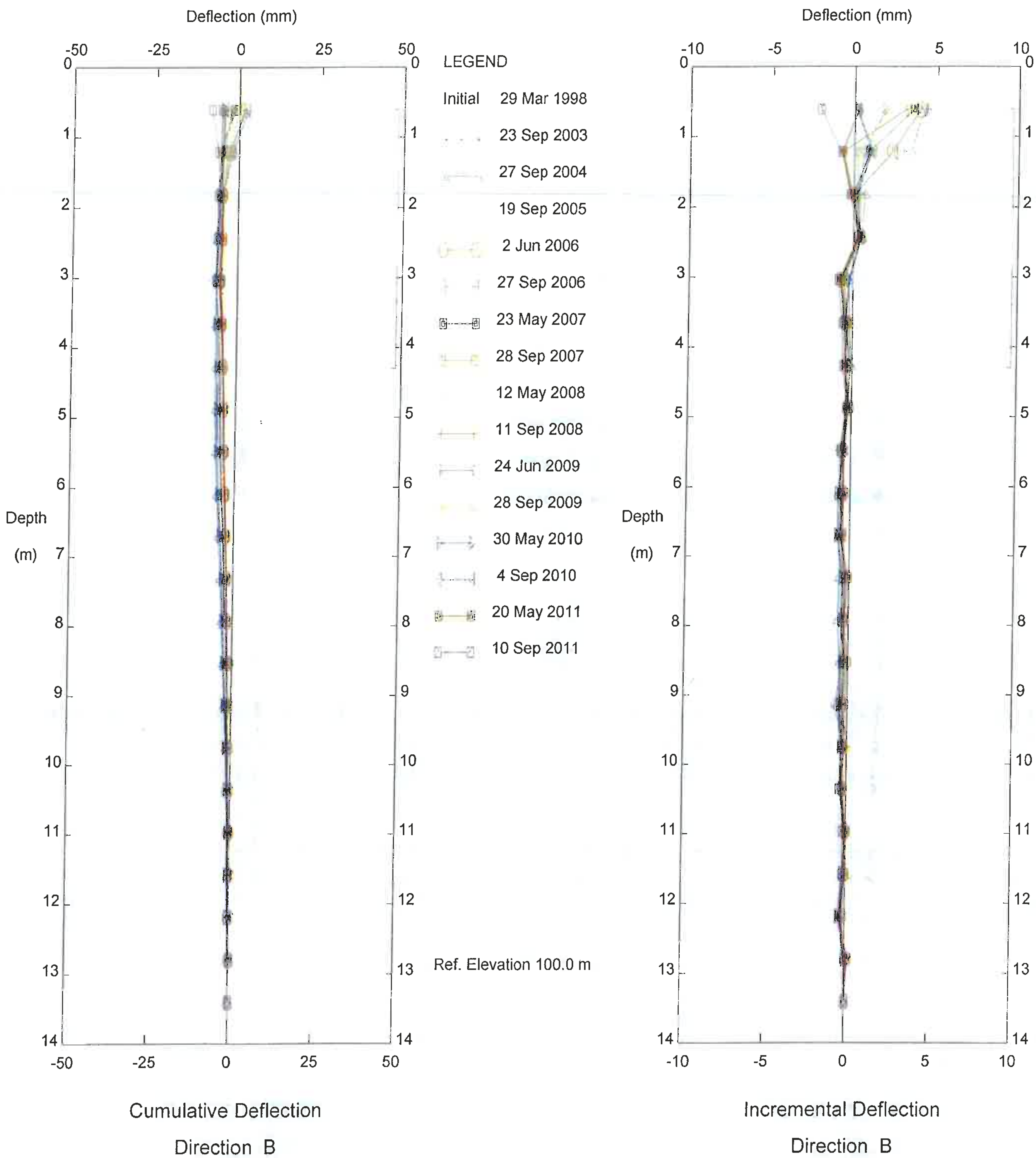

GP-6b; Sheep Creek Embankment, Inclinometer SI-04

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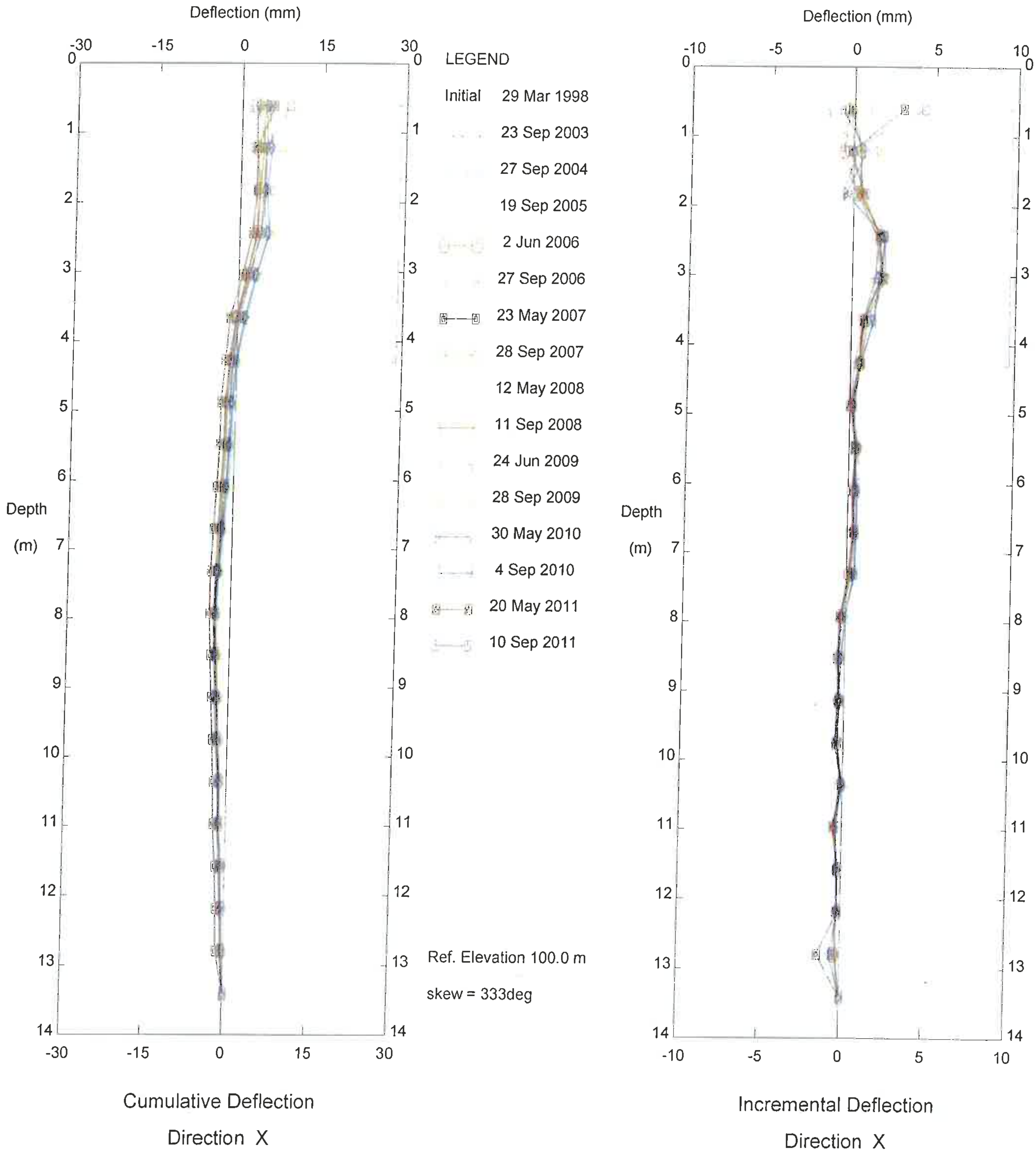

GP-6b; Sheep Creek Embankment, Inclinometer SI-04

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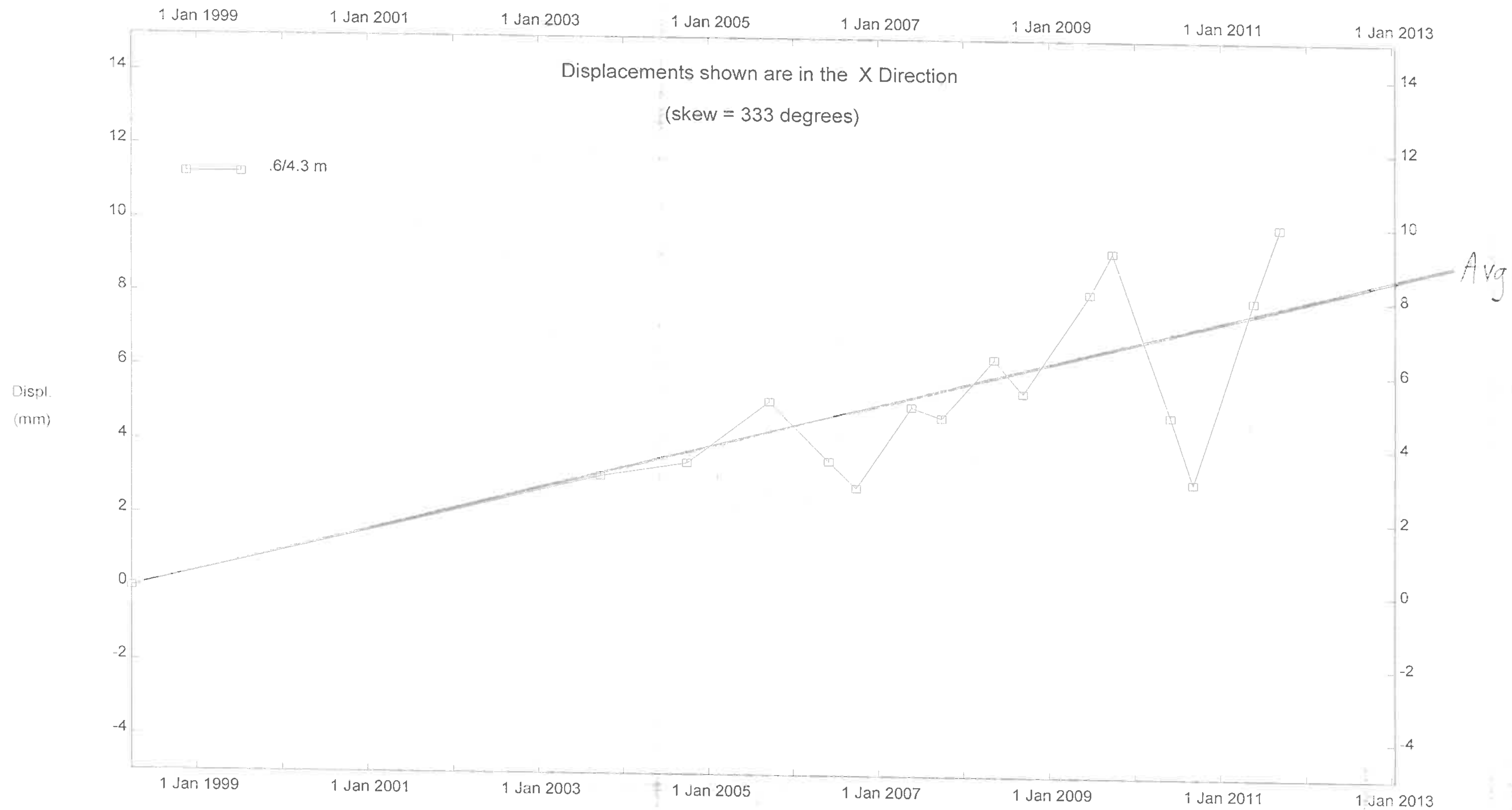


GP-6b; Sheep Creek Embankment, Inclinometer SI-04

2017 Report – X-sections
& Karl Li's Test Holes

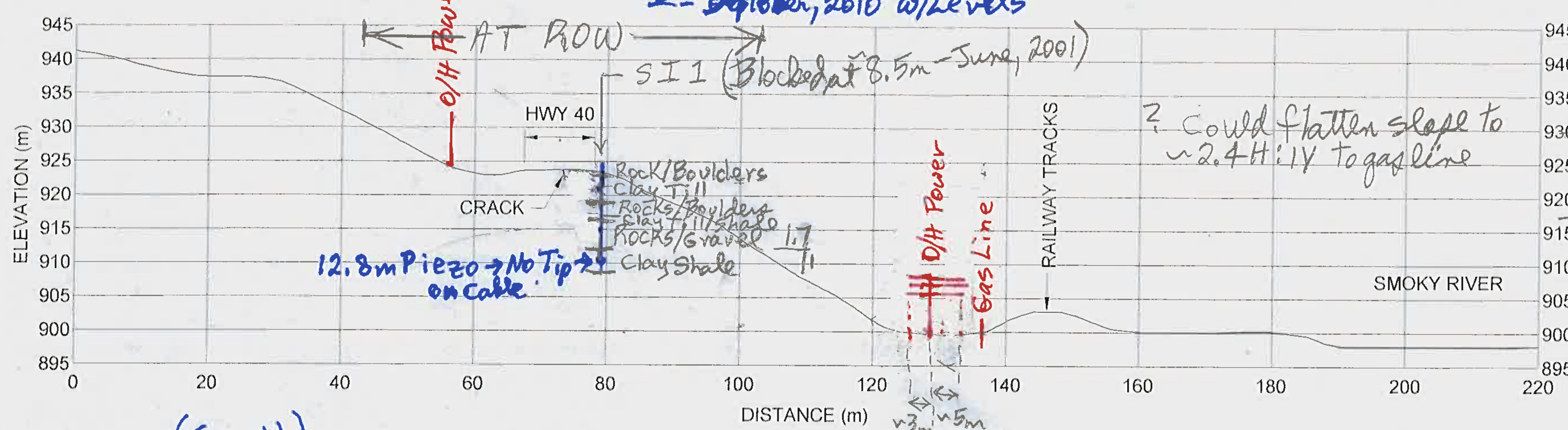
• = Piezo Tips
▼ = July 12, 2019 w/Levels
▼ = ~~September~~, 2010 w/Levels

July 12, 2019
Call Out →
Site Access

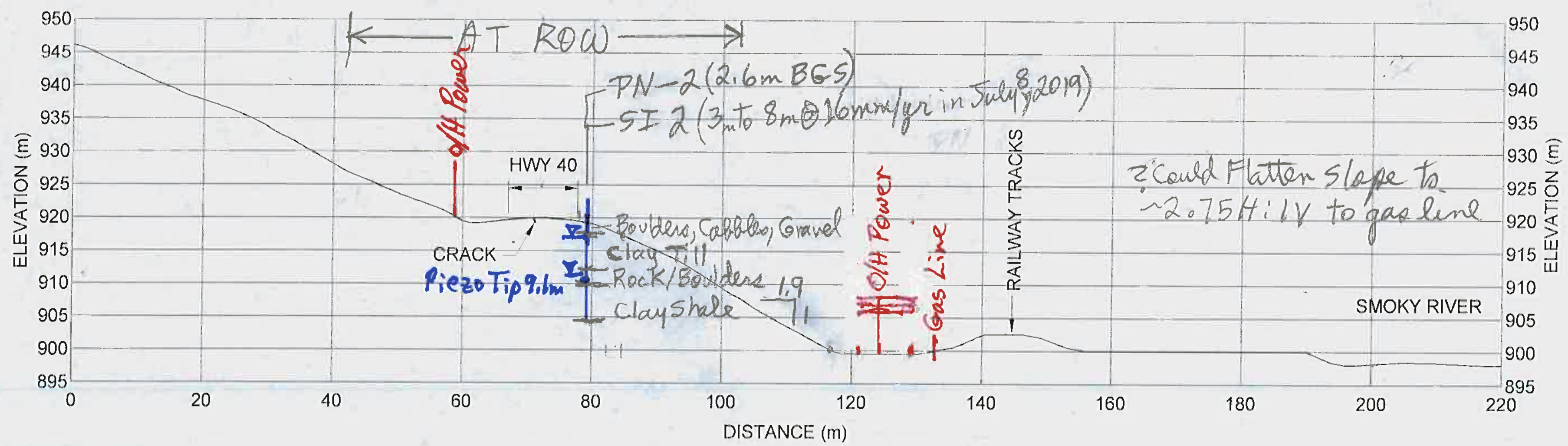
Need some gravel to Level off U/S Ditch/shoulder
A bit of a bench there but need to widen a proper bench.
Only 2m → 5m Available from Slope Toe to Edge of Wire → Need to Notch Toe or Build a Berm at Hole Locations.
Wire then Gas Line, then Tracks on other Side. ∴ No Room to East.

Proposed Test Holes

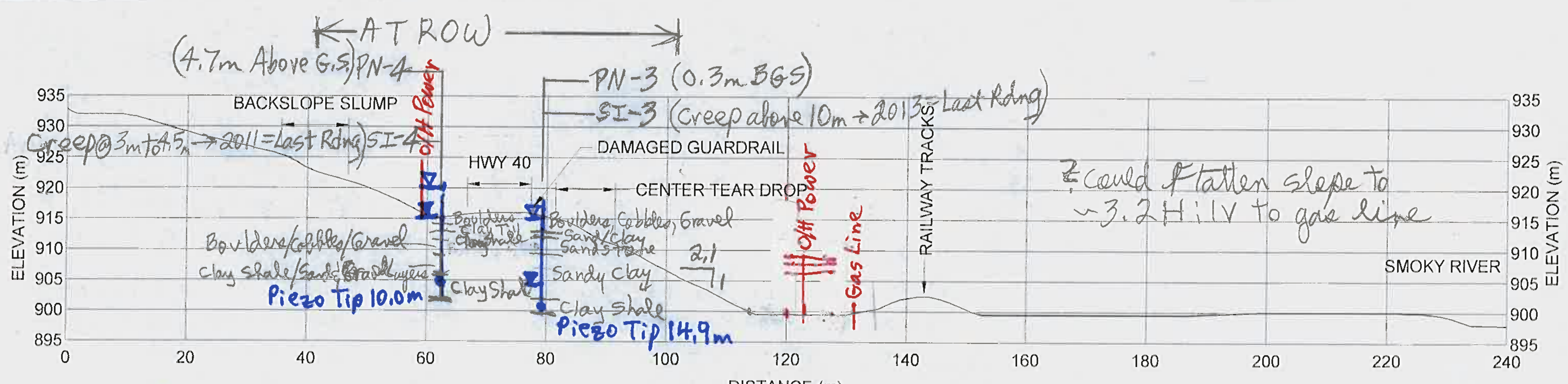
3 Holes U/S Ditch
3 on D/S Edge of Road – active zones (1 just N. of SI 2)
2 at Toe
8 Test Holes. Total



CROSS-SECTION A-A' (South)



CROSS-SECTION B-B'



CROSS-SECTION C-C' (North)

LIDAR PROVIDED BY ALBERTA TRANSPORTATION

Alberta Transportation

PEACE REGION (GRANDE PRAIRIE)
GP06B-1: HWY 40:36 TEAR DROP SLIDES

CROSS-SECTIONS

DWG No. 13353-GP06B-1-2

DRAWN BY	ML
DESIGNED BY	BDM
APPROVED BY	DWP
SCALE	1:1000
DATE	MAY 30, 2017
FILE No.	13353

THURBER ENGINEERING LTD.

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(See over)

Photo 1 – Looking south along the northbound lane at the south end of the fresh, wider, pavement crack. There is an old dip/crack in the highway northbound lane about 40 m further south (visible in the background) which was basically unchanged.

Photo 2 – Looking north at the fresh crack from the same spot as Photo 1.

Photo 3 – Looking south at the fresh cracking about 40 m north of the south end of this crack.

Photo 4 – Looking north at the crack from the same spot as Photo 3.

Photo 5 – Looking south along the east guardrail at the cracking, and the central dipped area on the east side of the crack, where it approaches the east shoulder.

Photo 6 – Looking north along the east guardrail at the crack from the same spot as Photo 5. Note the north dip in the NB lane beyond the last traffic cone.

THURBER

Photo 7 – Looking south from the north dip. Note the bent guardrail at this location.

Photo 8 – Looking south along the west edge of the highway at the crack around the north dip


Photo 9 – Looking south from near the north end of the fresher crack.


Photo 10 – Looking north at the end of the crack where it exits the west edge of the highway.

Photo 11 – Looking south along the west ditch from the north end of the pavement crack. Note the substantial ditch water flowing northwards, and the north seepage area from the west cut backslope directly above the white stone in the ditch.

Photo 12 – Looking north along the west ditch from the white stone, with SI-4 in the background.

Photo 13 – Looking east towards the hwy at heavy seepage from the scarp area on the west cut backslope at the north end of the cracked area.

Photo 14 – Looking southwest at the north seepage/scarp area on the west cut backslope. Note SI-4 in the west ditch.

Photo 15 – Looking west at the south seepage area in the backslope above the west ditch, just south of the bedrock exposure.

Photo 16 – Looking south along the west ditch near the center of the cracked pavement site. Note the bedrock exposure above the ditch. The seepage area identified in Photo 15 is just south of this exposure in front of the trucks. Note the steady ditch flow along the ditch.

Photo 17 – Looking south along the east side of the guardrail from SI-3 at the north end of the site.

Photo 18 – Looking north along the east embankment sideslope, from the south end of the site.

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Photo 19 – Looking south along the embankment toe from the north end of the site. Note the overhead power line and railway track embankment on the left, where an underground gas line also runs between them.

Photo 20 – Looking north along the embankment toe from near the south end of the site. Note the standing water all along this flat area outside the highway embankment toe.

Photo 21 – Looking north along the highway from near the south end of the slide on July 17, 2019 (5 days after cold mix crack sealing).

Photo 22 – Looking south along the highway from near the north end of the slide on July 17, 2019 (5 days after cold mix crack sealing).