

SITE NUMBER AND NAME: NC014 – North of Fort Assiniboine	HIGHWAY AND KM: 661:02, km 1.8	PREVIOUS INSPECTION: June 14, 2022	CURRENT INSPECTION: May 31, 2023
LEGAL DESCRIPTION: NW-01-62-06-W5	NAD83 COORDINATES: UTM11U 6023391N, 644779E		RISK ASSESSMENT: PF: 8 CF: 10 Total: 80
AVERAGE ANNUAL DAILY TRAFFIC (AADT): 190 (2022)		CONTRACTOR MAINTENANCE AREA (CMA): 508	


<p>SUMMARY OF INSTRUMENTATION: Six standpipes functional and being monitored. No land access agreement for 2 slope inclinometers and 7 standpipe piezometers.</p> <p>LAST READING DATE: May 15, 2023</p>	<p>INSPECTED BY: Stantec: Leslie Cho and Sonja Pharand TEC: Rocky Wang, Amy Driessen and Dean Kokotyn</p>
<p>PRIMARY SITE ISSUE: Slope creep movements causing pavement distress to a side hill alignment due to seasonal high groundwater levels; a localized active landslide causing a severe deterioration of the highway southbound lane (SBL) within the mid-hill slope section.</p>	
<p>APPROXIMATE DIMENSIONS: About 250 m long (midslope section)</p>	
<p>DATE OF ANY REMEDIAL ACTION: No remediation undertaken. Maintenance work includes spray patch and manhole cleaning in 2014; patching of mid hill slope section in 2017. A dewatering pilot test was conducted in 2018 to assess the effectiveness of a gravity well to drain the upper sand aquifer to a lower sand and gravel aquifer. The pilot test was unsuccessful due to high clay and silt content in the upper aquifer as well as difficulty developing the well in the upper aquifer.</p>	

ITEM	CONDITION EXISTS		DESCRIPTION AND LOCATION	NOTICEABLE CHANGE FROM LAST INSPECTION	
	YES	NO		YES	NO
Pavement Distress	X		Increased depression in the SBL of the mid-hill slope area. 10 mm depression in the SBL within the upper slope area. Multiple non-landslide related cracks throughout pavement on hill.	X	
Slope Movement	X		Mid-hill slope section: 10 to 50 mm wide reflective cracks with up to 50 mm differential across crack surface. Creep movement with open cracks to the north and south of mid-hill slope section. Upper slope section of the hill (north of mid-hill slope section): uneven guardrail; head scarp crack and graben feature downslope of the highway. Small dormant slump along highway backslope.	X	
Erosion	X		Erosion along east highway shoulder		X
Seepage		X			
Bridge/Culvert Distress		X			

Other	X		Two sinkholes in ravine. Two new sinkholes in east ditch within mid-hill slope section.		X
COMMENTS					
<ul style="list-style-type: none"> • Highway cracking was observed along the mid hill slope and upper slope sections where landslide activity is apparent and in other areas mostly due to traffic use (Photo 1). • The water level in MH#1 was at ground surface. Water from the drainage channel adjacent to the MH appeared to be ponding and flowing into MH#1 (Photo 2). Siltation may be a problem at MH#1. • The mid hill slope section (Photos 3 and 4) had 10 to 50 mm wide reflective cracks. A more apparent dip towards the southwest was observed and is estimated to be about 25 to 50 mm deep. • At the upper slope section (Photo 5), a head scarp and graben were observed downslope of the guardrail. The guardrail also appeared to be slightly sagging and shifting laterally. Pavement cracks upslope from the graben were up to 80 mm wide. A slight dip in the pavement towards the west was also observed. • Both functional SIs are located above the highway backslope and outside the landslide area. Both instruments showed no movement. Readings on these SIs have stopped since land access permissions have not been agreed upon with the private landowner since Spring 2021. • The piezometers show water levels have been relatively consistent with spring 2023 readings ranging from 2.1 m bgs to 26.4 m bgs. A slight trend of increasing water levels seems to be developing in most piezometers since 2006. • Numerous sand outcrops were observed downslope of the upper slope landslide graben. The two small sand outcrops closest to the ravine formed depressions up to 0.5 m deep. • A gully with exposed sand has formed south from the upper slope section near the sand outcrops, down to the bench (Photo 7). • The two sinkholes in the ravine downslope of the highway between the upper and mid slope appear to have increased in size since the 2022 site inspection. The north sinkhole was measured to be 600 mm deep by 1 m in diameter, and the south sinkhole was measured at 400 mm deep by 1 m in diameter (Photo 6). • The sinkhole in the east ditch near the centre section of the corner was not observed and may have been infilled. • Two new sinkholes were observed in the east ditch near the mid-hill landslide area. The northernmost sinkhole was approximately 0.5 m deep, 0.7 m wide and 1.0 m long. The other sinkhole, southeast from the utility box, was measured to be 0.9 m deep, 1.2 m wide and 1.5 m long (Photo 8). • A perforated subdrain was observed at surface along the east ditch. The subdrain was infilled with soil and does not appear functional. The actual alignment and extents of the subdrain is currently unknown. It is possible that the sinkholes in the east ditch are related to the old subdrain. • Several homes exist near the base of the landslide representing a public safety issue along with potential loss of privately owned structures. As such, the Consequence Factor remains at 10. 					
RECOMMENDATIONS					
<ul style="list-style-type: none"> • All pavement cracks should be sealed to reduce surface water infiltration into the landslide mass. • All culverts and manholes should be inspected to reduce the risk of water seeping into the slope. This could consist of cleaning and flushing to promote water flow. • The sinkholes should be backfilled and capped with clay to reduce further erosion and surface water infiltration into the slope. • Slope inclinometers within the slide mass are no longer functioning. Slope movement can be monitored by installing replacement inclinometers and/or considering InSAR or LiDAR change detection methods. • Preliminary remediation options may include: <ul style="list-style-type: none"> – Constructing a concrete pile wall from the upper slope section to the mid-hill section, approximately 160 m long. The high-level cost for a concrete pile wall is \$3.1 million to \$4.2 million, excluding engineering. – Reconstructing the highway with lightweight fill such as EPS geofoam or lightweight cellular concrete. The high-level cost for this option is \$730,000 to \$1.1 million excluding engineering. – Installing a new subdrain along the east ditch. The high-level cost for this option is \$400,000 to \$500,000 excluding engineering. – Maintenance, monitoring and surveillance approach: Given the low volume and low speed nature of this highway, it may be preferential for TEC to continue maintaining the highway by placing asphalt patches and sealing cracks as well as maintaining the existing manholes and subdrainage system. This approach carries some risk in that the rate of slope movement can suddenly increase. If this approach is adopted, increased monitoring of the site is recommended consisting of additional slope inclinometers below the 					

landslide headscarp, which can be fitted with near real-time monitoring using shape-accelerometer arrays (SAAs), and/or near real-time GPS monitoring (Geocubes) and/or InSAR satellite imagery to determine historical/present ground deformation rates. Adopting a surveillance and monitoring program to threshold values would provide asset protection of the site and allow suitable timing for remediation.

- The site should continue to be inspected annually.
- Instrumentation monitoring should continue annually in the spring and fall.

PREPARED BY: Sonja Pharand, P.Eng.	PREPARED BY: Leslie Cho, M.Eng., P.Eng.
	
REVIEWED BY: Xiteng Liu, M.Sc., P.Eng., PMP	PERMIT TO PRACTICE

2023 Site Inspection Photos at NC014



Photo 1: Pavement cracking southeast of mid-hill landslide. Looking northwest.



Photo 2: Pooling/flowing water adjacent to MH#1. Water entering culvert at ground surface. Looking northeast.

2023 Site Inspection Photos at NC014



Photo 3: Pavement cracking at south extent of mid-slope landslide. Looking northwest.



Photo 4: Pavement cracking at mid to north extent of mid-slope landslide. Looking northwest.

2023 Site Inspection Photos at NC014



Photo 5: Landslide at uphill section. Looking northwest.



Photo 6: Two sinkholes in ravine. Looking southeast.

2023 Site Inspection Photos at NC014

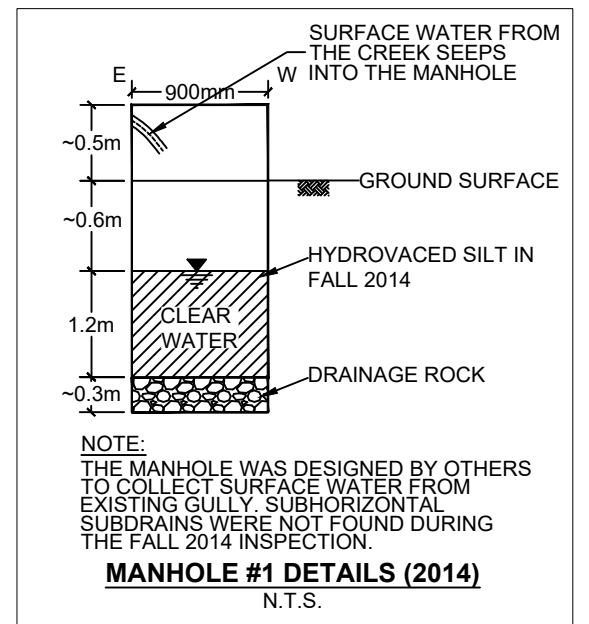
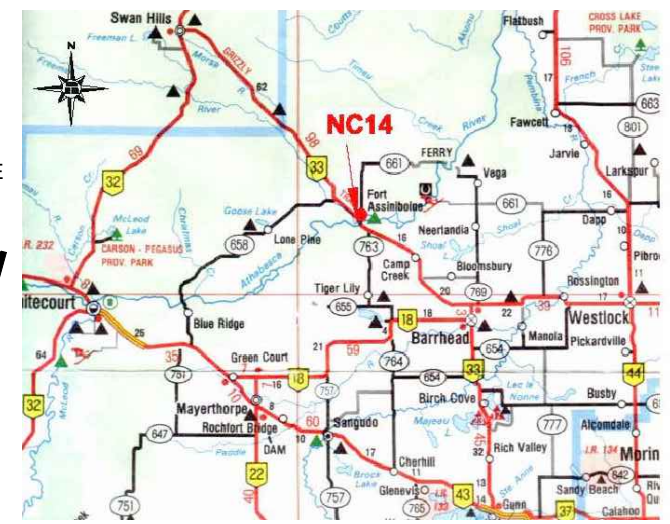
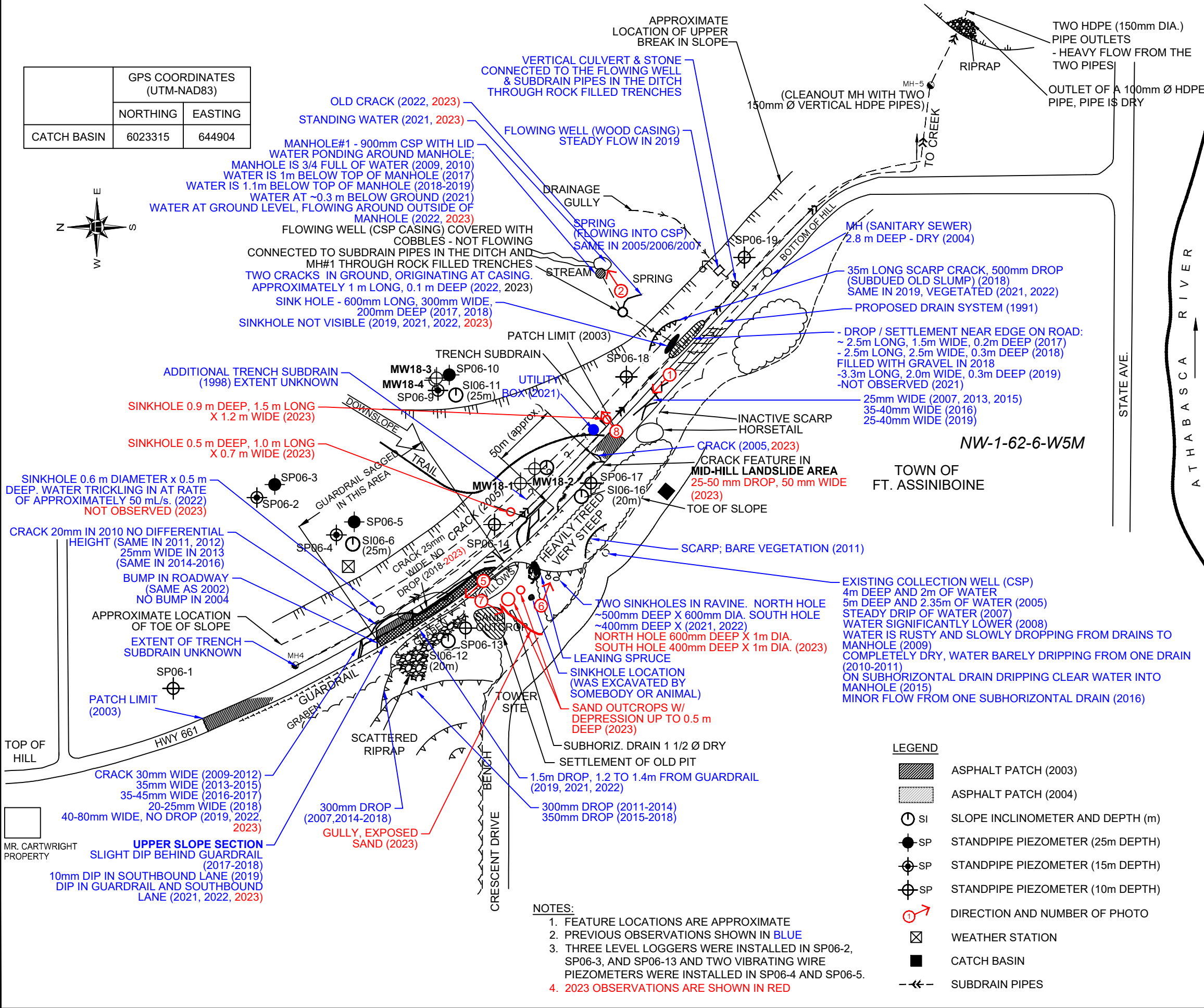
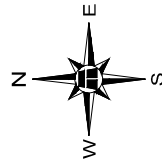


Photo 7: Sand exposed in erosion channel heading downslope to the bench. Looking southwest.



Photo 8: New sinkhole southeast from the utility box in the east ditch near the mid-hill landslide area. Looking northeast.

CATCH BASIN	GPS COORDINATES (UTM-NAD83)	
	NORTHING	EASTING
	6023315	644904



- NOTES:**
1. FEATURE LOCATIONS ARE APPROXIMATE
 2. PREVIOUS OBSERVATIONS SHOWN IN BLUE
 3. THREE LEVEL LOGGERS WERE INSTALLED IN SP06-2, SP06-3, AND SP06-13 AND TWO VIBRATING WIRE PIEZOMETERS WERE INSTALLED IN SP06-4 AND SP06-5.
 4. 2023 OBSERVATIONS ARE SHOWN IN RED

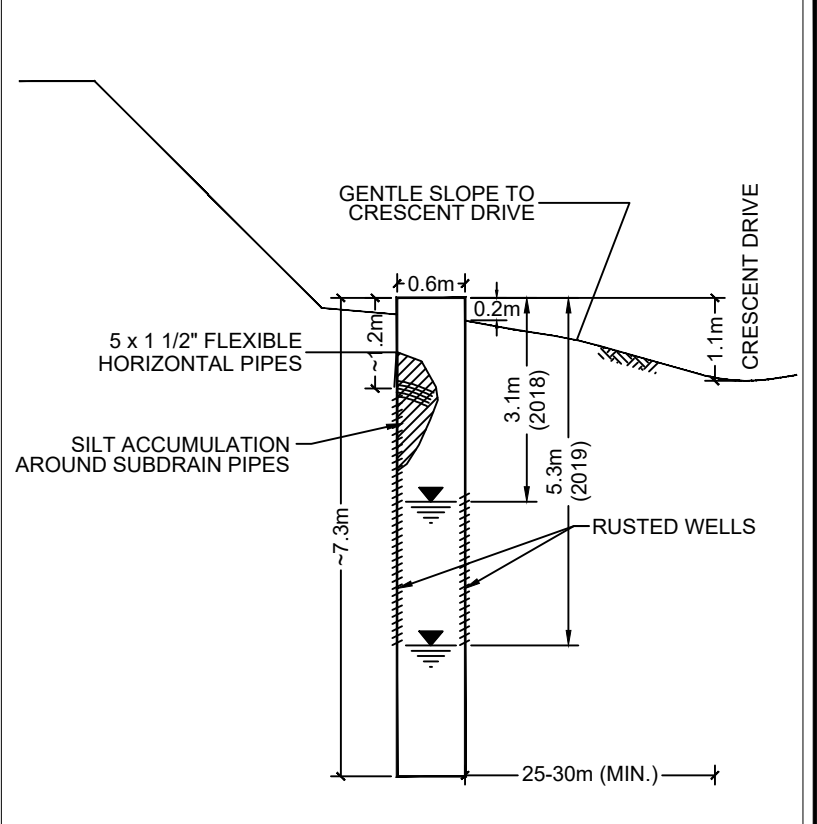
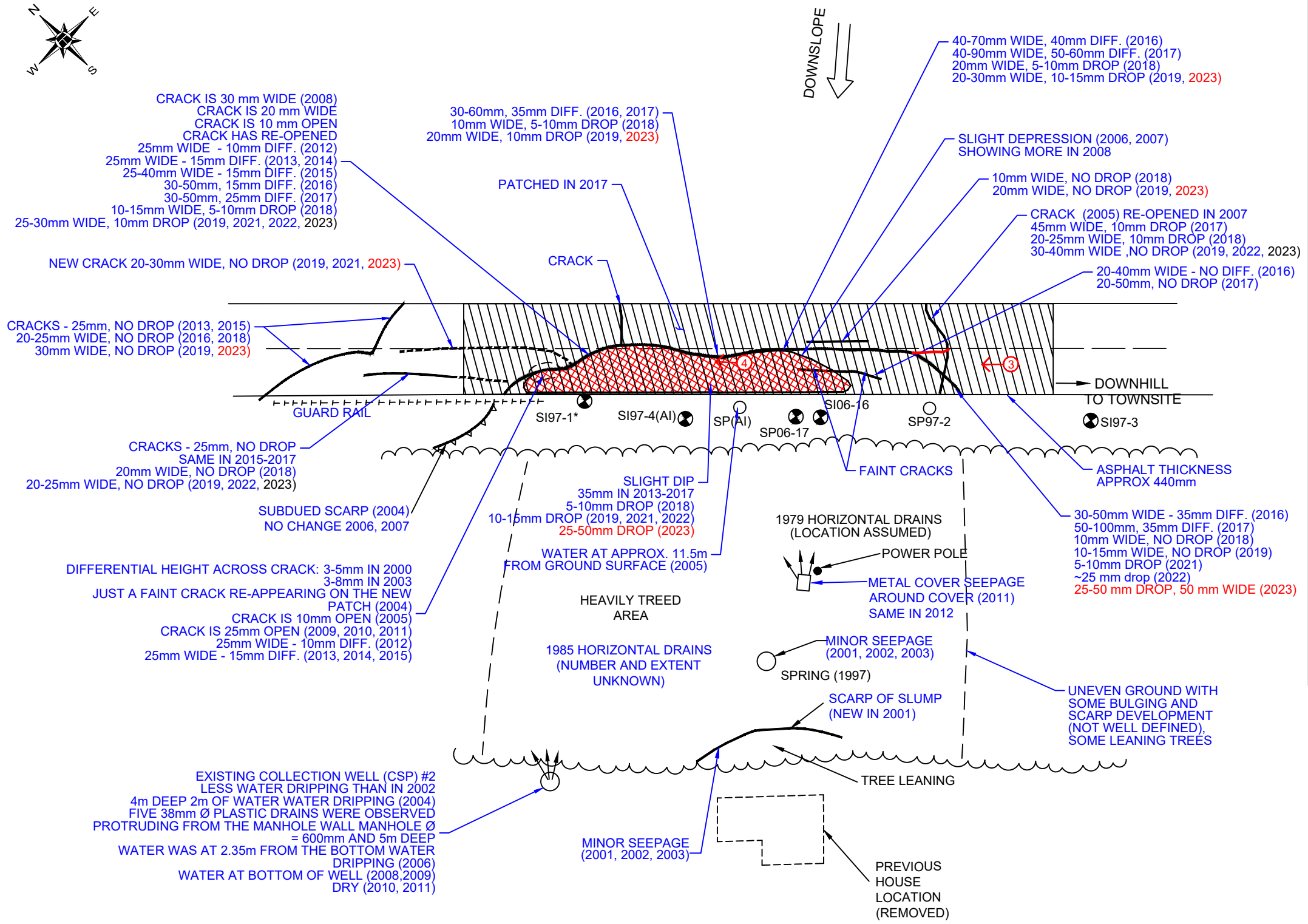
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Stantec

TRANSPORTATION AND ECONOMIC CORRIDORS
GEOHAZARD MONITORING PROGRAM
NC014-1: HWY 661:02 FORT ASSINIBOINE (km 1.8)
SITE PLAN SHOWING EXISTING FEATURES

DRAWN	ML	CHECK	XL	APPROVE	LC
DATE	18 JULY 2023	SCALE	AS SHOWN	PROJECT #	123315222

FIGURE - 1



- NOTES:**
- MH #2 HAS NO OUTFLOW PIPE - WATER IS LIKELY PERCOLATING INTO GROUND (2015)
 - MINOR FLOW FROM ONE OF SUBHORIZONTAL DRAINS IN 2016
 - ONE OF THE SUBHORIZONTAL DRAINS IS DRIPPING WATER
 - ONE OF THE DRAINS IS FLOWING. MORE WATER NOTED IN 2018
 - STEADY FLOW FROM ONE OF THE DRAINS; HEAVIEST FLOW SINCE OBSERVED

MANHOLE #2 DETAILS (2014)
N.T.S.

- LEGEND**
- SI SI - SLOPE INCLINOMETER
 - SP SP - STANDPIPE PIEZOMETER
 - DIRECTION AND NUMBER OF PHOTO

- NOTES:**
- FEATURE LOCATIONS ARE APPROXIMATE.
 - PREVIOUS OBSERVATIONS SHOWN IN BLUE
PREVIOUS CRACK PATTERN WAS COVERED BY NEW (2004) ASPHALT PATCH
 - 2023 OBSERVATIONS ARE SHOWN IN RED

MANHOLE NUMBER	GPS COORDINATES (UTM-NAD83)	
	NORTHING	EASTING
MH #1	6023351	644914
MH #2	6023367	644730
METAL COVER	6023374	644771

STANTEC CONSULTING
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TRANSPORTATION AND ECONOMIC CORRIDORS
GEOHAZARD RISK MANAGEMENT PROGRAM
NC014-1: HWY 661:02 NORTH OF FORT ASSINIBOINE
SITE PLAN

DRAWN	KE	CHECK	XL
DATE	18 JULY 2023	SCALE	AS SHOWN
APPROVE	LC	PROJECT #	123315222

FIGURE - 2