

The upper slope along the crest above the landslide terrace is considered to be a transitional to mature slope with short-term stability and marginal long-term stability. The upper slope face has not been assessed in detail, but there are likely steepened scarp areas which may be prone to small, shallow slumps. Long-term, the lacustrine clay slope above the terrace is expected to flatten back to inclinations of 3.5H:1V or 4H:1V. In the high bank area to the north of the landslide site, relatively large failures in the upper lacustrine soils are considered to be possible. At the time of residential development these conditions will need to be reviewed to provide development setbacks and buffer areas along the crest for the proposed residential development in the upland areas above the landslide site and high bank slopes on this quarter section.

9/10.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

PF(7) * CF(1) = 7 - Upland Above the Crest
PF(7) * CF(6) = 42 - Erosional Run-out in the River

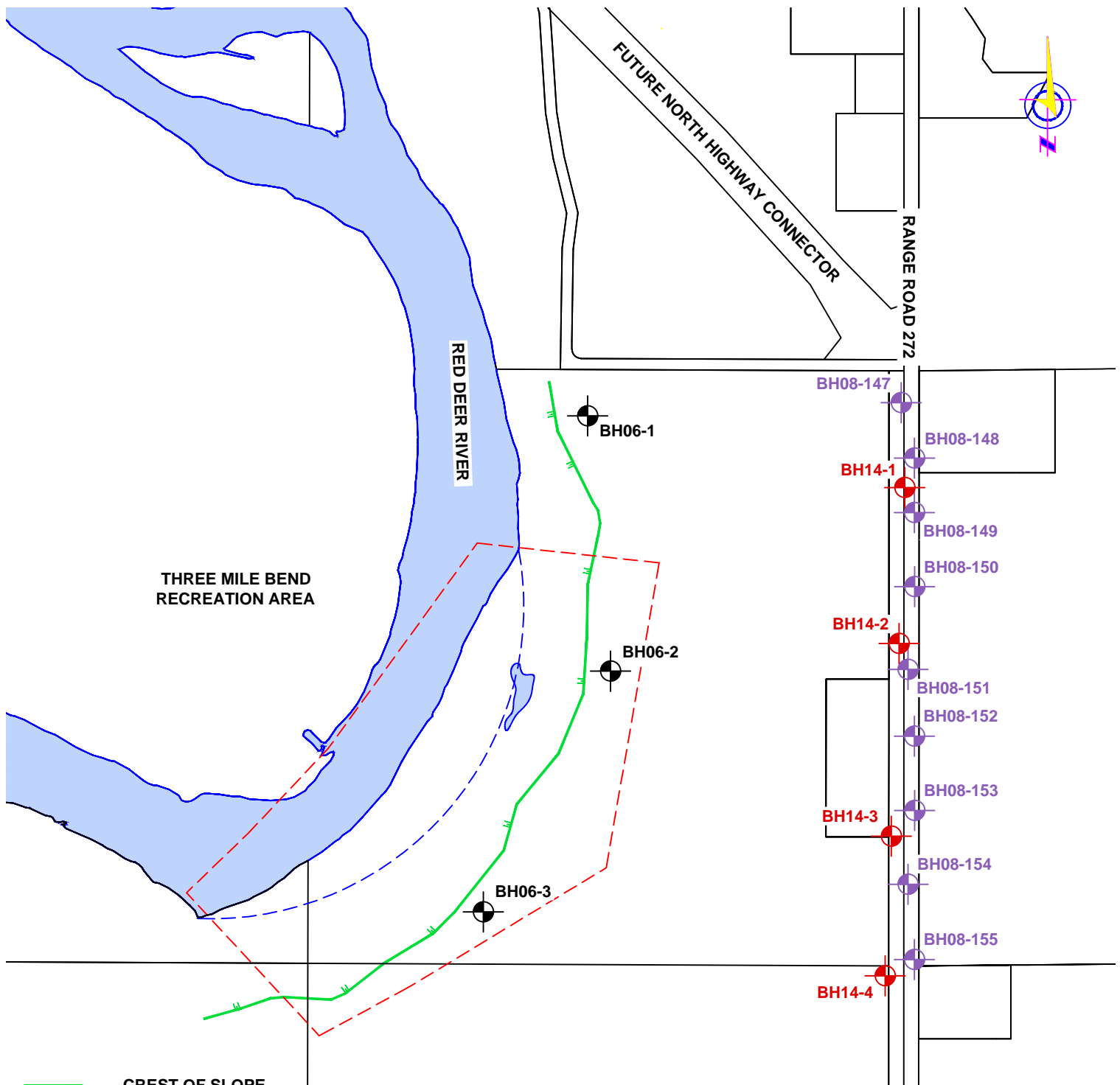
A Probability Factor of 7 is considered appropriate since the upper slope and slope face is inactive, but there is: moderate potential for slope flattening in the upper slope above the landslide; and high potential for landsliding in steeper upper slope areas north and south of the old landslide site. A Consequence Factor of 1 is considered appropriate for the upland area since it is currently undeveloped and development restrictions can be applied to future residential and recreational developments to minimize the impacts of expected crest regression. The higher Consequence Factor for the colluvium slopes along the river shoreline is based on natural erosion impacts.

9/10.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake periodic visual site inspections of the slope every five years to identify any significant changes, if present. The current issue would be safety hazards for parkland users within the old slide area due to the uneven terrain.

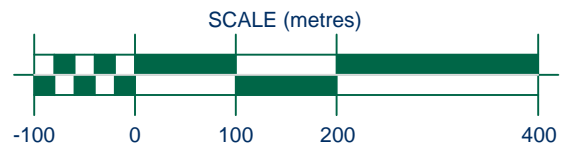
9/10.10 ATTACHMENTS

Figure 9/10-1 - Site Plan
Figure 9/10-2 - 2016 Contour Plan
Figure 9/10-3 - Cross Section Profile
Figure 9/10-4 - Aerial Photographs
Figure 9/10-5 - Site Photographs
Figure 9/10-6- Survey Marker Plan
Figure 9/10-7 - Photograph Plan
Figure 9/10-8 - Stability Analysis Run
Table 9/10-4 - List of Survey Markers
Table 9/10-5 - List of Photographs
Site Inspection Record (October 15, 2018)

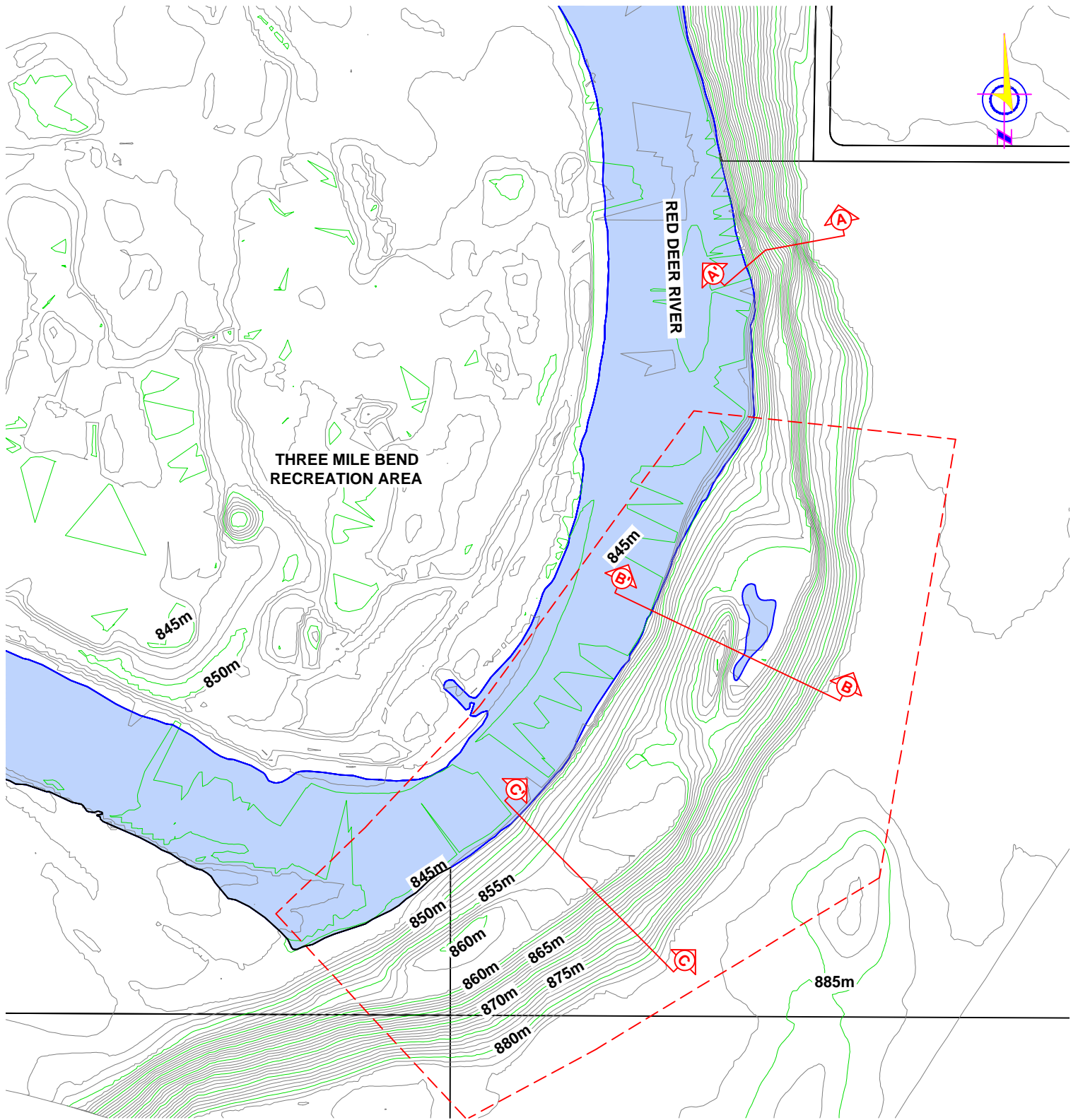


- CREST OF SLOPE
- - - TENSION CRACKS THROUGHOUT THE AREA
- - - ESTIMATED FORMER RIVER BED
- 2006 BOREHOLE LOCATIONS (PG FILE #RD2021)
- 2008 BOREHOLE LOCATIONS (REFERENCE #89)
- 2014 BOREHOLE LOCATIONS (PG FILE #RD4775)

ALL BOREHOLE LOCATIONS ARE APPROXIMATE.

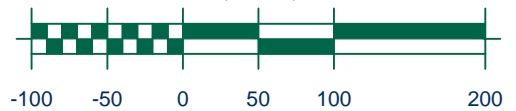


	CLIENT:		SITE PLAN	
			CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)	
	DRAWN:	CHK'D:	REV #:	DATE:
	PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.
1:7500		RD6500-9/10		FIGURE 9/10-1



TENSION CRACKS THROUGHOUT THE AREA

SCALE (metres)



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



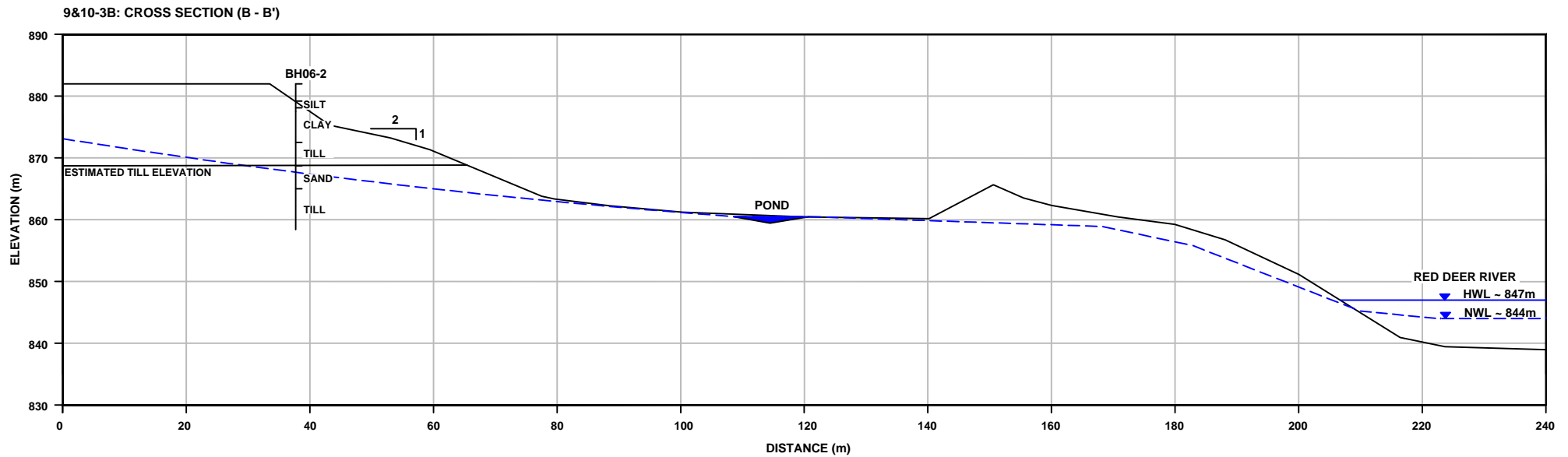
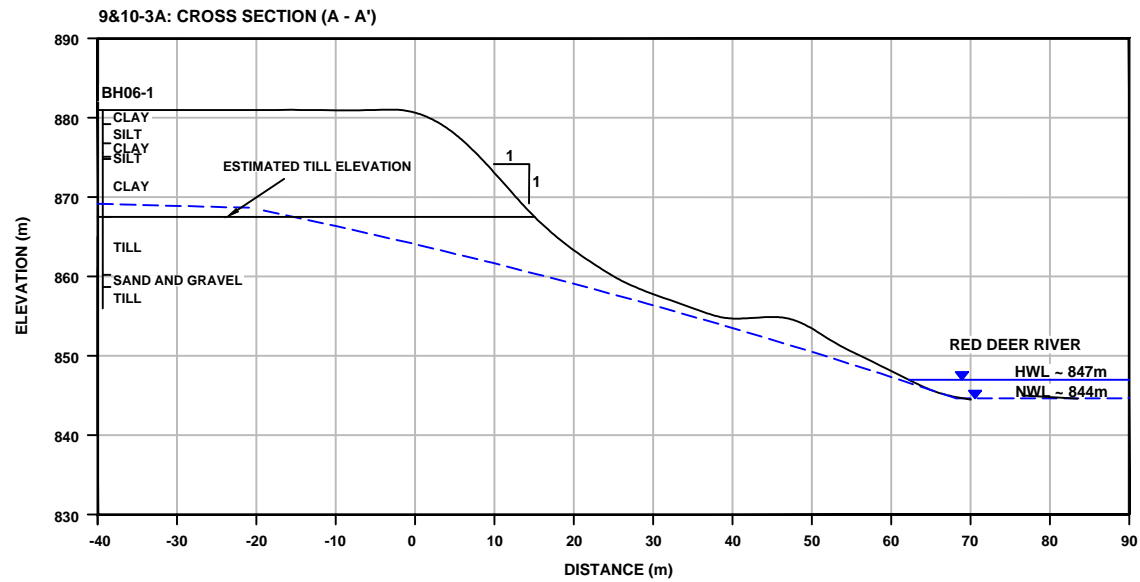
CLIENT:



CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-2	



PROFILE BASED ON 2006 TOTAL STATION SURVEY (PG FILE #RD2021)



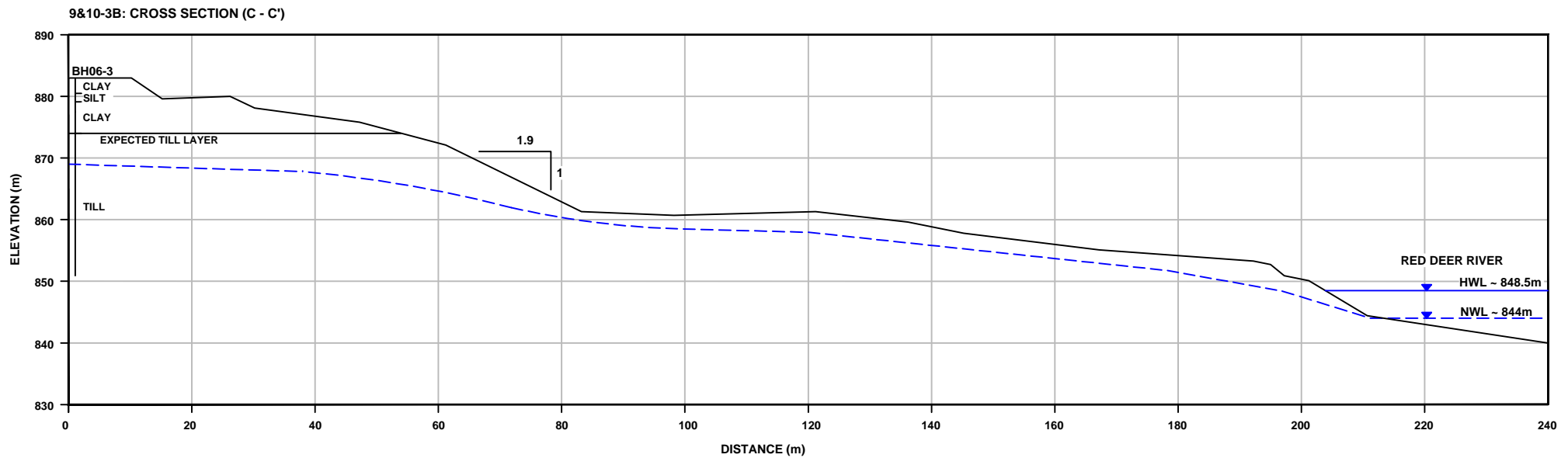
CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-3A	



PROFILE BASED ON 2006 TOTAL STATION SURVEY (PG FILE #RD2021)



CLIENT:



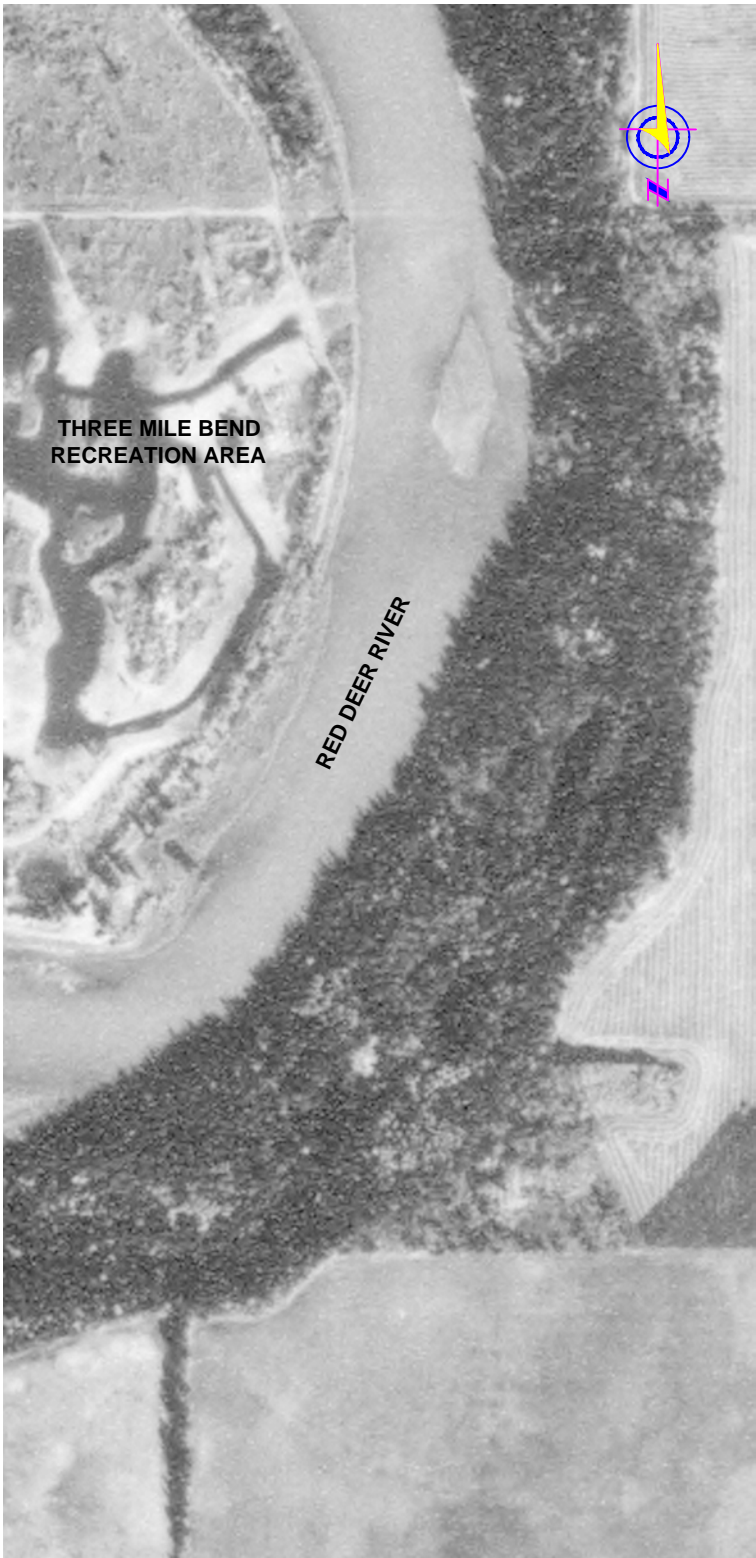
CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)

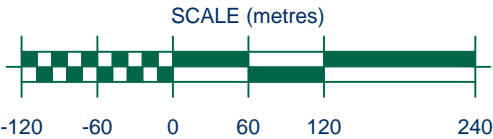
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-3B	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED APRIL 30, 1949.



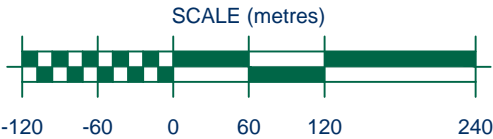
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 23, 1985.



	<p>CLIENT:</p> 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:6000	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-4A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:6000	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-4B	



PHOTOGRAPH 59 (2018): MID-SLOPE RIDGE NEAR POND (FORMED DUE TO THE MOVEMENT OF SLOPE OVER THE YEARS), FACING SOUTHWEST



PHOTOGRAPH 72 (2018): NORTH RIDGE AND SLOPE ADJACENT TO POND, FACING SOUTHWEST



PHOTOGRAPH 68 (2018): POND, PHOTO TAKEN FROM NORTHWEST CORNER, FACING SOUTH

	CLIENT: 	SITE 9&10 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-5A	



PHOTOGRAPH 104 (2018): SLOPE FACE AT AN OVER-STEEPENED AREA, LOOKING UP THE SLOPE, FACING EAST



PHOTOGRAPH 180 (2018): RIDGE WITH STANDING WATER, LOOKING ALONG THE RIDGE, FACING SOUTH



PHOTOGRAPH 253 (2018): SLOPE ALONG THE RIVER, FACING SOUTHWEST


	CLIENT:		SITE 9&10 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
NTS		RD6500-9/10		FIGURE 9/10-5B		

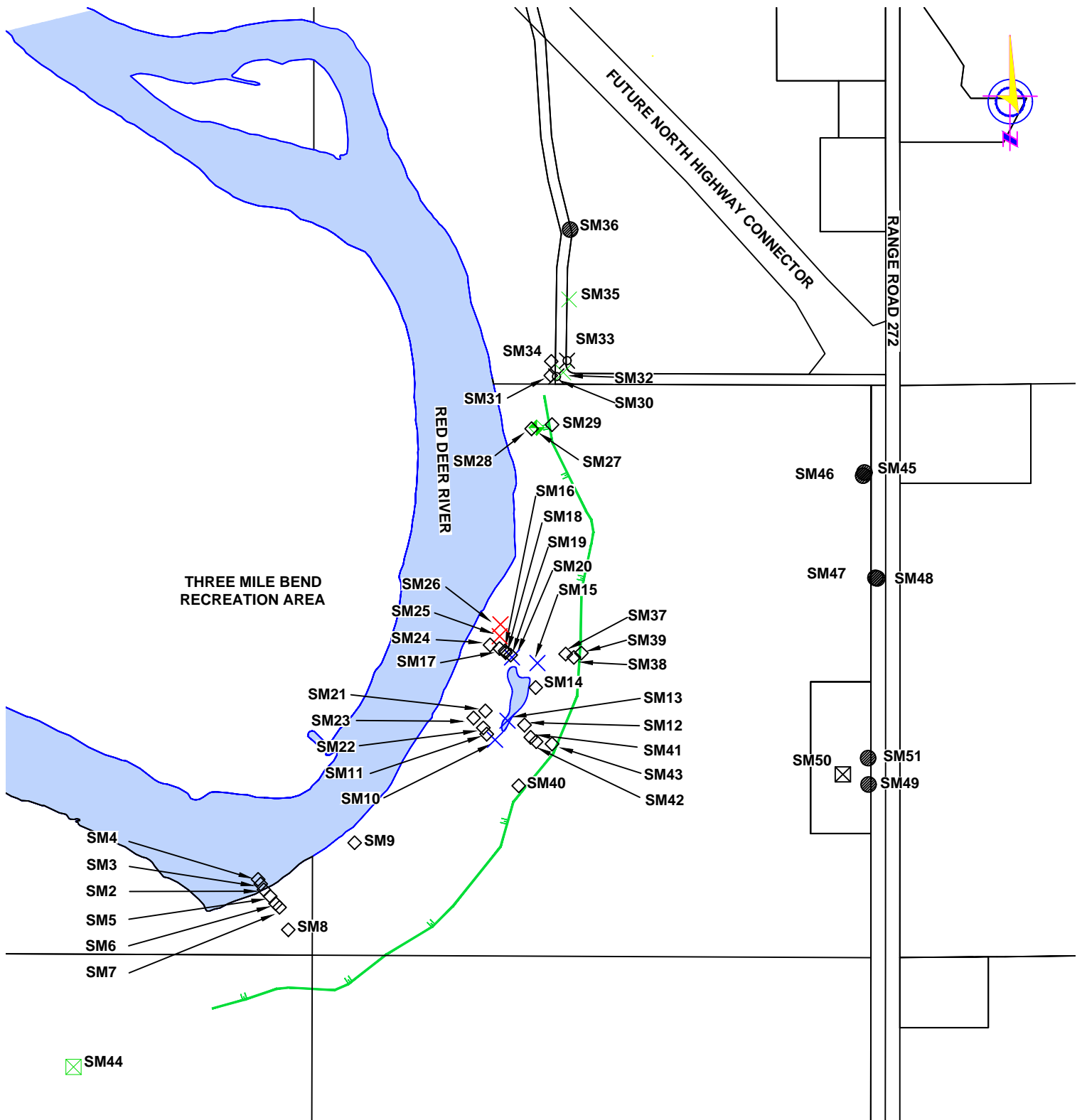


PHOTOGRAPH 271 (2018): NON-VERTICAL TREES ACROSS THE SLOPE, FACING WEST



PHOTOGRAPH 277 (2018): EAST RIVER BANK, TAKEN FROM THREE MILE BEND, FACING EAST

	CLIENT: 	SITE 9&10 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-5C	



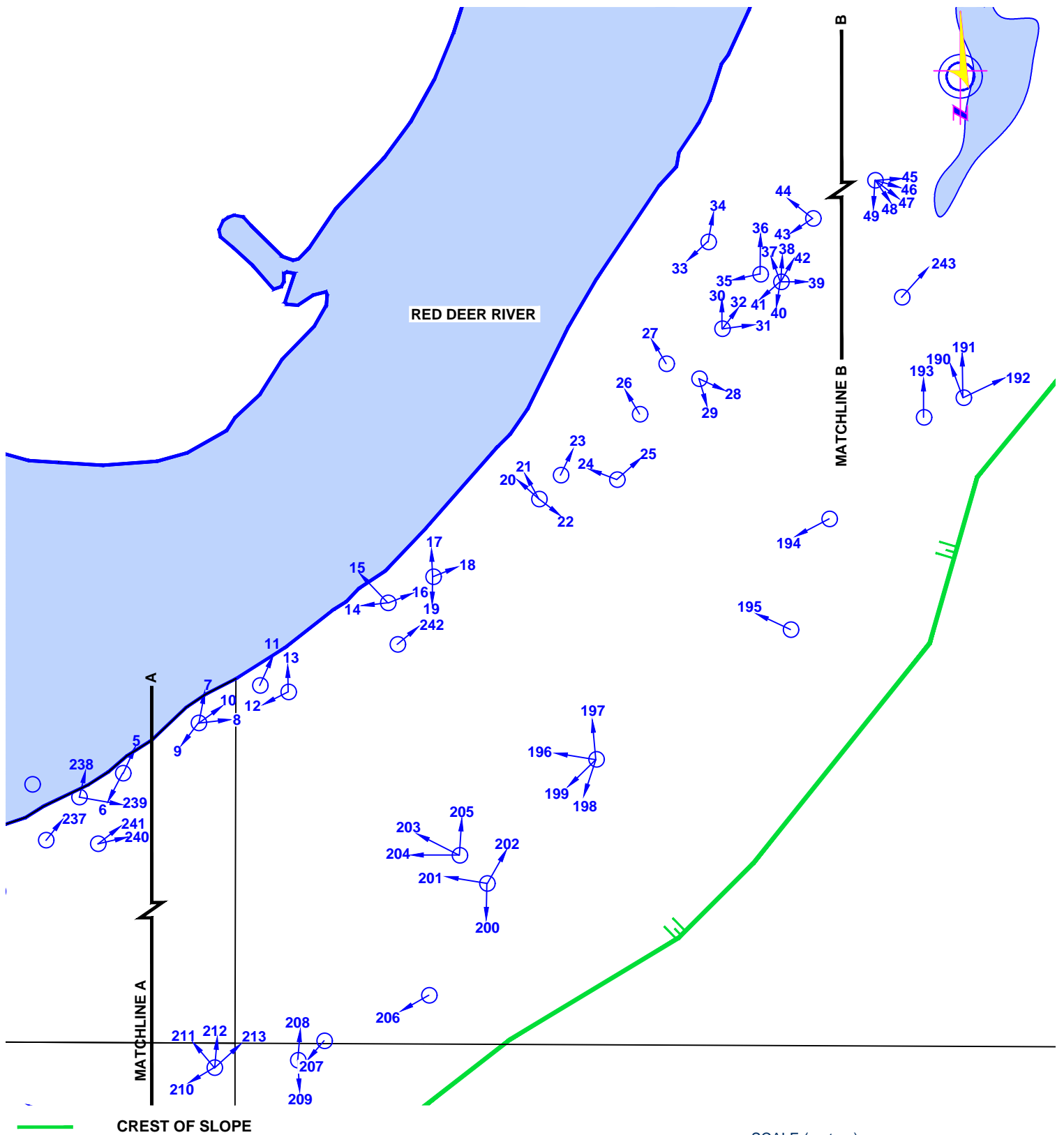
CLIENT:



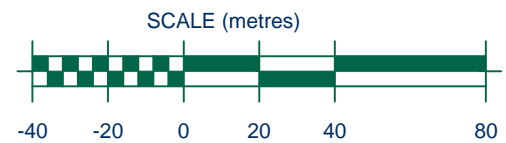
SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)

DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:7500	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



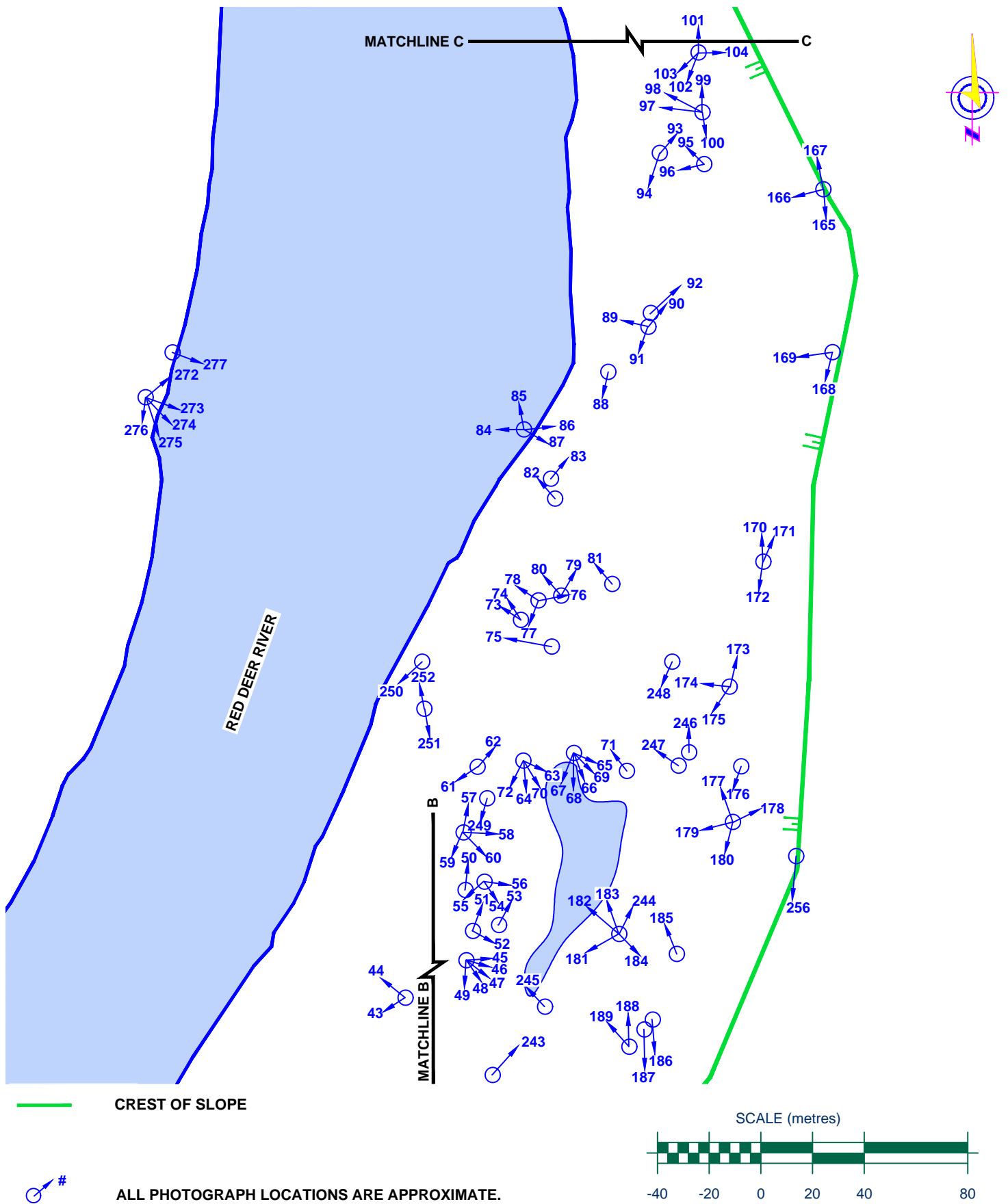
CLIENT:





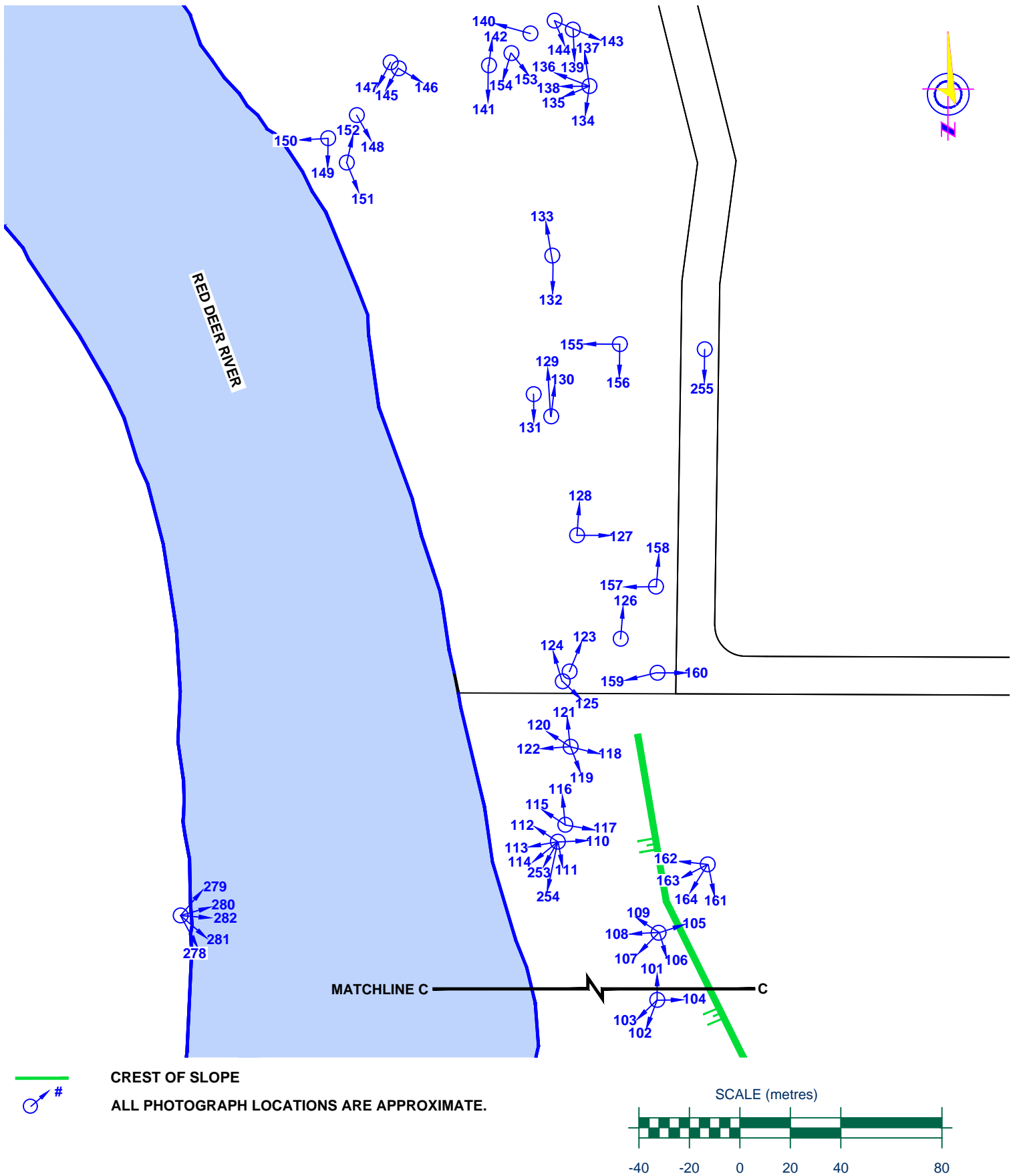
PHOTOGRAPH PLAN



CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)

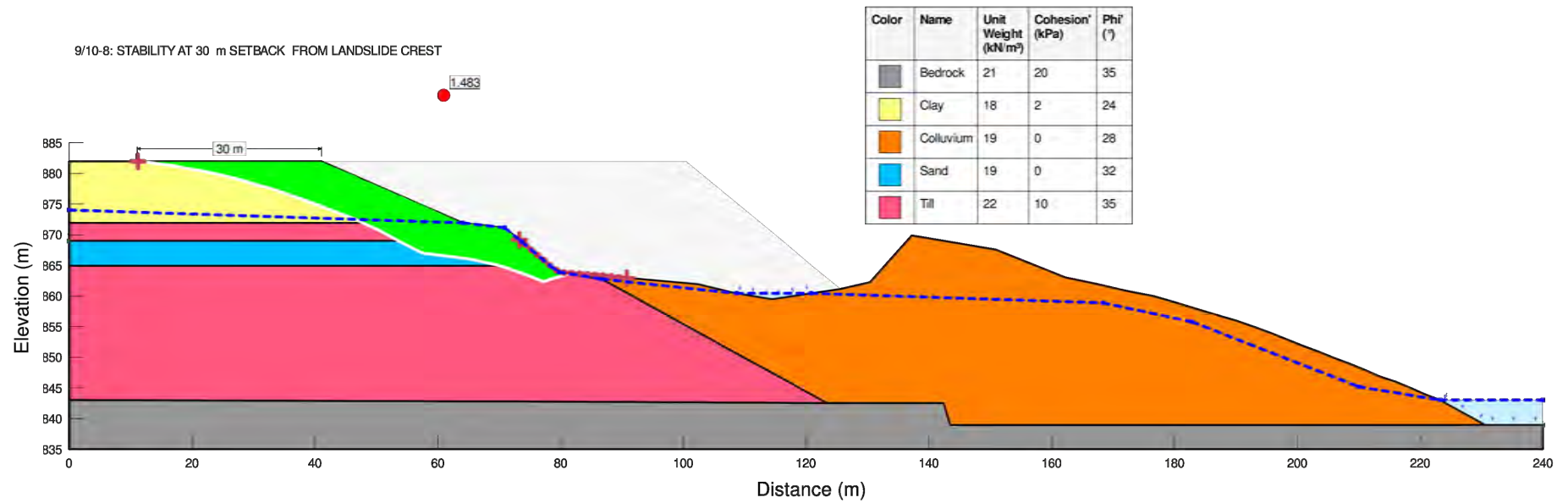
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-7B	



	<p>CLIENT:</p> 	<p>PHOTOGRAPH PLAN</p>			
		<p>CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)</p>			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:2000	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-7C	



	<p>CLIENT:</p> 	<p>PHOTOGRAPH PLAN</p>			
		<p>CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)</p>			
		<p>DRAWN: PS</p>	<p>CHK'D.: MDB</p>	<p>REV #: 2</p>	<p>DATE: APRIL 2019</p>
		<p>SCALE: 1:2000</p>	<p>JOB NO. RD6500-9/10</p>	<p>DRAWING NO. FIGURE 9/10-7D</p>	



	CLIENT: 		STABILITY ANALYSIS RUN					
			CITY OF RED DEER SLOPE STABILITY EVALUATION EAST RED DEER RIVER BANK (OPPOSITE 3 MILE BEND)					
			DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019		
			SCALE: AS SHOWN	JOB NO. RD6500-9/10	DRAWING NO. FIGURE 9/10-8			

SITE #9/10 - EAST RED DEER RIVER BANK (OPPOSITE THREE MILE BEND)

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 9/10-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM9/10-001	Bollard	5797157.76	310447.04	874.72				
#SM9/10-002	Ridge	5797657.40	310518.44	861.71				
#SM9/10-003	Toe	5797665	310514	854.7				
#SM9/10-004	Ridge	5797672	310510	854.5				
#SM9/10-005	Toe	5797648	310527	849.6				
#SM9/10-006	Ridge	5797638.65	310535.38	866.19				
#SM9/10-007	Toe	5797632.80	310540.25	862.02				
#SM9/10-008	Toe	5797602	310553	848.7				
#SM9/10-009	Drain ditch	5797723	310645	856.3				
#SM9/10-010	Pond	5797867	310842	863.6				
#SM9/10-011	Toe	5797875.27	310830.24	861.70				
#SM9/10-012	Toe	5797888.01	310883.03	863.88				
#SM9/10-013	Pond	5797894.20	310859.40	860.46				
#SM9/10-014	Toe	5797940	310899	836.0				
#SM9/10-015	Pond	5797975	310901	864.4				
#SM9/10-016	Ridge	5797991.78	310855.95	868.09				
#SM9/10-017	Toe	5797995.11	310848.21	864.08				
#SM9/10-018	Toe	5797989	310857	853.9				
#SM9/10-019	Toe	5797985.88	310863.65	860.94				
#SM9/10-020	Pond	5797982.76	310865.61	860.42				
#SM9/10-021	Ridge	5797907.63	310828.43	870.58				
#SM9/10-022	Ridge	5797884.01	310825.50	869.86				
#SM9/10-023	Ridge	5797897.87	310811.93	867.69				
#SM9/10-024	Ridge	5798000	310835	853.0				
#SM9/10-025	Tension crack	5798012.47	310848.43	861.42				
#SM9/10-026	Tension crack	5798029	310850	852.1				
#SM9/10-027	Bench	5798304.32	310900.02	871.93				
#SM9/10-028	Ridge	5798302.67	310893.03	869.24				
#SM9/10-029	Crest	5798308.44	310921.65	881.36				
#SM9/10-030	Power pole	5798375.88	310927.61	881.46				
#SM9/10-031	Crest	5798377.26	310919.82	881.19				
#SM9/10-032	Possible drone pt1	5798381.53	310937.43	881.35				
#SM9/10-033	Power pole	5798398.04	310942.71	881.34				
#SM9/10-034	Crest	5798397.03	310920.56	880.34				
#SM9/10-035	Possible drone pt2	5798483.74	310945.58	881.14				
#SM9/10-036	Well	5798581.49	310946.89	880.70				
#SM9/10-037	Ridge	5797987	310941	875.5				
#SM9/10-038	Toe	5797982.69	310952.18	876.44				
#SM9/10-039	Crest	5797988.72	310962.64	882.13				
#SM9/10-040	Crest	5797802.95	310874.99	881.85				
#SM9/10-041	Ridge	5797870.77	310891.83	871.17				
#SM9/10-042	Toe	5797864.75	310899.47	872.07				
#SM9/10-043	Crest	5797861.49	310921.56	882.29				
#SM9/10-044	Post	5797409.53	310252.21	882.06				
#SM9/10-045	MH	5798241.47	311358.56	881.44				
#SM9/10-046	MH	5798236.89	311356.87	881.50				
#SM9/10-047	MH	5798094.09	311374.08	881.50				
#SM9/10-048	MH	5798093.06	311376.53	881.44				
#SM9/10-049	MH	5797804.68	311364.26	882.79				
#SM9/10-050	Building	5797819.12	311328.56	883.82				
#SM9/10-051	MH	5797841.79	311363.86	882.96				

TABLE 9/10-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING			
#P9/10-059	Mid-slope ridge near pond	5797943	310828	SW	Y*	
#P9/10-068	Pond	5797973	310870	S	Y*	
#P9/10-072	North ridge and slope adjacent to pond	5797970	310851	SW	Y*	
#P9/10-104	Slope face at an over steepen area	5798244	310919	E	Y*	
#P9/10-180	Ridge with standing water	5797947	310932	S	Y*	
#P9/10-253	Slope along the river	5798307	310879	SW	Y*	
#P9/10-271	Non vertical trees across the slope	5797637	310485	W	Y*	
#P9/10-277	East river bank	5798128	310715	E	Y*	

Notes:

* Provided in the report

All measurements in metres

Less accuracy due to tree cover

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	9&10	
Site Name	Mckenzie Trails Area – East Red Deer River	
Legal Land Description	NE 27-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	310900 m E, 5797967 m N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 31, 2018	7	1	7
Inspected By:	Bryden Lutz			
Report Attachments:	271 Site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded at south, angular south of power line in north, rounded north of power line		
Slope Movement	<ul style="list-style-type: none"> Tension cracking (photo 31, 68) and non-vertical trees (photo 33, 297) in lower 1/3 of site in south 600 m Lots of terraces with vertical slope faces experiencing crest regression and vegetation overhang (photo 27, 83) 		
Erosion	<ul style="list-style-type: none"> Erosion of toe by river Erosion down cutting from 2 surface drainage channels, 1 north and 1 south of pond area 		
Seepage	Terrace above pond area was wet and marshy at surface (photo 206)		
Distress	No manmade structures		
Other	BMX trail throughout slope area, well maintained		
Instrumentation:	<ul style="list-style-type: none"> Piezometer water level measure on Nov 19, 2018 		
Other Comments:	<ul style="list-style-type: none"> 		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none"> - Evidence of slope movement through south 600 m of site from pond elevation (860 m) and below. This area has many terraces with non-vertical trees, tension cracks, and terrace crest regression throughout. - Upper terrace and crest appear moderately stable, some potential for movement over pond area due to high ground water (marshy at terrace surface) - North part of site, south of power lines, has recent slide activity (near vertical) face, trees at toe at least 30 years (no access to toe, based on estimated diameter)
Assessment	<ul style="list-style-type: none"> - Expect more slow movement of colluvium in south part of site, possible conditions for larger failure on north area near "recent" slide if high ground water conditions occur.
Recommendations	<ul style="list-style-type: none"> - No development trail development should be planned on the lower colluvium on the south half of the site. Any trails on the north of the site should have a proper setback from the crest.

SITE #11

River Bend Escarpment



SITE #11 - RIVER BEND ESCARPMENT

11.1 SITE DESCRIPTION

Site #11 is a 200 m long river bank in the southwest corner of the River Bend Golf & Recreation Area (River Bend) in northeast Red Deer. The bank slope borders the River Bend Maintenance Yard just south of the pedestrian bridge over the Red Deer River, as shown on Figure 1 of the main report. The Site Plan is shown on Figure 11-1. A 2016 Contour Plan is provided on Figure 11-2. Representative cross-sections of the river bank are provided on Figure 11-3.

This site is the outside bank of a minor bend in the river which changes the flow an estimated 45° from a northeast to a northwest direction on a radius of about 450 m. The City of Red Deer Waste Water Treatment Plant is located on the inside bend across the river from the site. The bank of the river north of the site is armoured to protect the pedestrian bridge. The closest development is the maintenance building about 40 m from the crest of the river bank surrounded by a gravel yard which is about 18 m from the crest. Discovery Canyon and River Bend Golf Course are located to the north of the maintenance yard.

The average crest elevation in the area is about 849 m and the toe of the riverbank is about 842 m, so the river bank is 6 to 8 m high. The bank has a slope shoreline covered with gravel and bedrock debris from erosion below a section of near vertical bedrock exposures and a slightly rounded crest area. The average inclination from shore to crest ranges from 1H:1V to 1.5H:1V as shown on Figure 11-3. The maintenance yard is separated from the crest by a small grassed strip and a line of immature trees along the crest. Most of the slope face is relatively free from vegetation. Aerial photographs showing the site in 1949, 2005 and 2016 are provided on Figure 11-4A and 11-4B. Representative photographs from the site are provided on Figures 11-5A and 11-5B.

11.2 REFERENCES

There was limited geotechnical information and no site specific reference reports for this site.

11.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

The site profile was verified by logging the face of the exposed river bank (see Figure 11-3) and observations were compared to file information for the local area. No slope inclinometers or other instrumentation has been installed in this area.

11.4 2018 REVIEW

Aerial photography is provided on Figures 11-4A and 11-4B for the years listed in the following table. The aerials show this bend in the river has been relatively stable for over 65 years.

TABLE 11-1: AERIAL PHOTOGRAPHS

Year	Description
1949	Shows the site condition over 65 years ago.
2005	Shows the site condition shortly after the 2005 flood peaked.
2016	Shows the present Site condition.

The River Bend site was visited on October 22 and November 8, 2018. A copy of the field inspection record is attached at the end of this appendix.

The City ortho-contours from 2016 aerial photography were reviewed for this study. A control survey of the site was performed in 2018. A record of survey control points and data for Site #11 is appended in Table 11-4. A reference drawing of survey reference points is provided on Figure 11-6.

Photographs were taken during the site visits between 2006 and 2018. A list of available photos at this site is appended in Table 11-5. Selected site photographs are provided on Figures 11-5A and 11-5B; along with a reference drawing of all photo locations which is provided on Figure 11-7.

11.5 SUBSURFACE PROFILE

The soil profile observed in the face of the exposed bank at the River Bend site was, in descending order: topsoil, silt, sand and clay deposits, gravel and weathered bedrock. The presence of gravel and the depth to bedrock varies, but the bedrock is unusually shallow in this location. The soil profile log is shown on the cross-section of the river bank slope is shown on Figure 11-3. The following is a brief description of the soil types encountered excluding the surficial topsoil and pavement materials.

1. **Surficial Materials.** The local recreation areas have a thin layer of topsoil. The maintenance yard and access roads are a mix of gravel surfaced areas and roadway/parking pavements with a thin asphalt layer and gravel base on the native subgrade.
2. **Alluvial Silt, Sand and Clay.** The native subgrade is expected to be silty sand or silty clay to a depth of 1 to 3 mbg which corresponds to an elevation of about 847 to 848 m.
3. **Gravel.** A thin layer of coarse grained sand and gravel was typically found below the alluvial soil layer. The thickest gravel was found relatively close to grade and was up to 1.5 m thick. This gravel was dry.

4. **Bedrock.** Weathered silt-stone and clay shale bedrock was encountered below the gravel deposits at variable elevations ranging from 845 to 847 m. The exposed bedrock was highly weathered (see the photo on Figure 11-5B).
5. **Colluvium.** The sloped shoreline beach was littered with a mixture of erosional silty clay, gravel and bedrock materials that have spalled from the face of the river bank.
6. **Groundwater and River Surface.** Groundwater levels at this site are linked to the river surface elevations. The normal Red Deer River surface levels in this area are at an elevation of about 842 m \pm 0.5 m. The 1:100 year flood levels are about 2.5 to 3 m higher than normal levels.

For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix A. The following effective strength parameters were assumed for this site.

TABLE 11-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil Unit	Unit Weight kN/m ³	Shear Strength kPa	Cohesion, c' kPa	ϕ' Degree
Fine Alluvial Clay Deposits	19	50	1	25
Alluvial Silt and Sand	20	0	0	32 - 35
Gravel	21.5	0	0	35 - 40
Bedrock	21	300	10	30 - 40

11.6 BACKGROUND

The crest area above the river bank in the River Bend area is an 18 m wide strip of grassed area beside the River Bend Maintenance Yard. There was evidence of minor bank scour and peak water levels during normal floods will rise above the top of the current beach and attack the exposed bedrock. There does not appear to have been a lot of regression from this attack which can be attributed to the strength of the exposed gravel and bedrock in the river bank. There is no evidence of landsliding along river bank in this area. The concern at this site is the proximity of the river bank crest to the maintenance yard and the potential for bank scour to attack the south flank of the pedestrian bridge abutment.

11.7 REVIEW OF STABILITY ASSESSMENT

The river bank along River Bend has a minor bend, but is not subject to major erosion in the exposed bedrock on the river bank. There is very little evidence of channel shifting in this area going back to 1949.

Historical stability analysis against landsliding was not available for this site. The site was assessed using the *SLOPE/W* computer program based on recent survey information as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 11-3: 2018 SLOPE STABILITY ESTIMATES

Slope Case	Estimated Factor of Safety
Slope Face Stability	<1.1
Crest	< 1.0
1.9H:1V Line Extended Back from Bank Toe on the Shoreline	1.3
2.3H:1V Line Extended Back from Bank Toe on the Shoreline	1.5
Closest Structure (Maintenance Building)	>>2.0

A selected computer slope run for the cross section on Figure 11-3 is provided on Figure 11-8.

The existing crest area and steeper sections of the slope face along this exposed river bank are considered to be stable in the short-term and marginally stable in the long-term. The apparent stability levels for these steep faces are attributed to the presence of dense gravel and shallow bedrock within the bank profile. Rotational landslides have not occurred in river bank in this area, but minor spalling probably occurs on an infrequent basis after flood events. The potential for a landslide and significant loss of upland area above this site is very low. A preliminary set back to provide a buffer for permanent development is considered to be 8 m from the crest or on a line extended up at 2.3H:1V from the shore of the river bank.

11.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(7) * CF(1) = 7$$

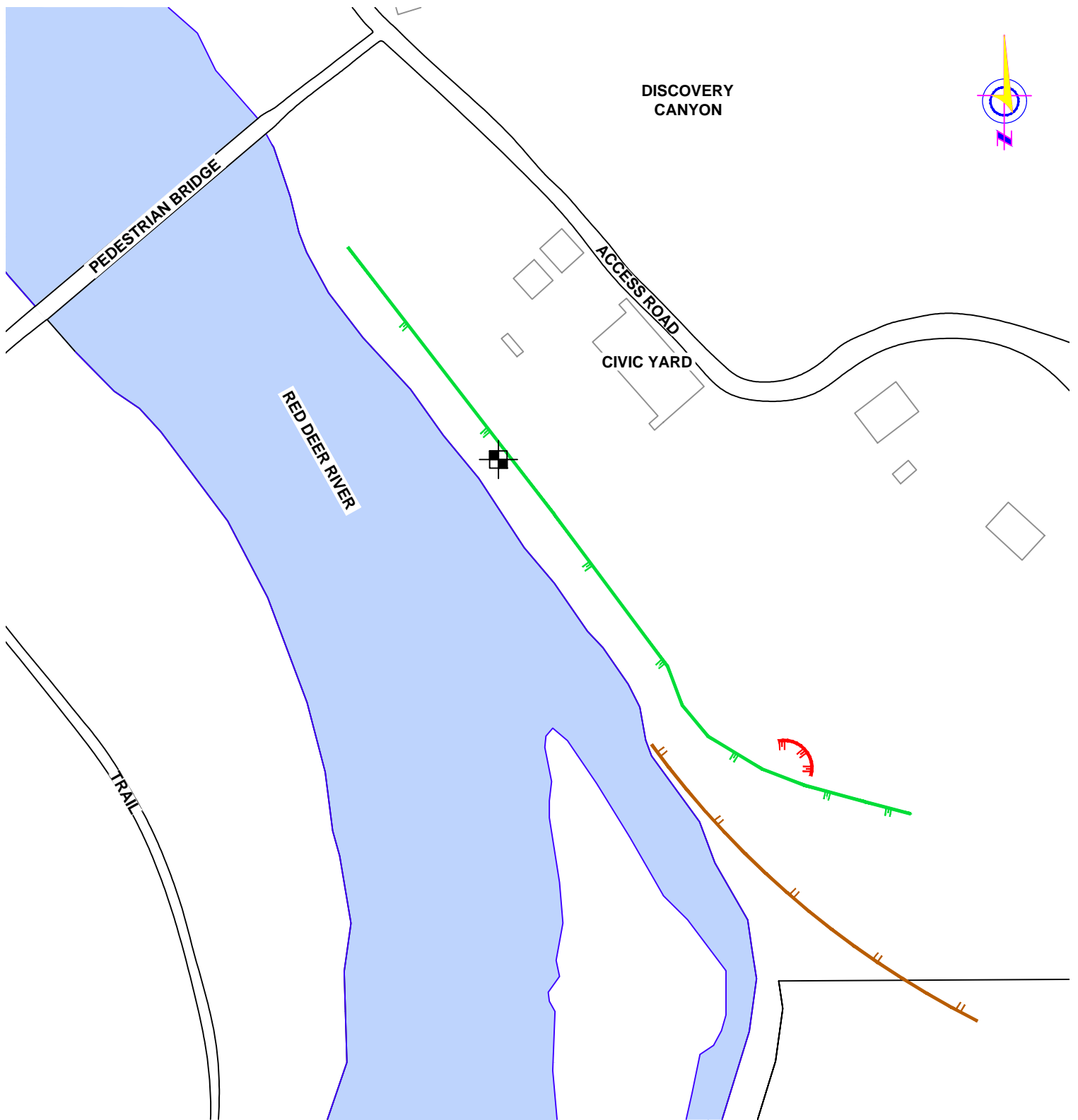
A Probability Factor of 7 is considered appropriate since there is no active landsliding at the site and erosion has been minimal over an extended period. However, the potential for a small localized slide or erosion after a period of flooding is considered to be high. A Consequence Factor of 1 is considered appropriate since the expected size of landslide or the amount of erosion in the exposed river bank slope would have minimal impact on the landscaped flood plain area above the bank and no affect on the nearby maintenance yard.






11.9 RECOMMENDATIONS

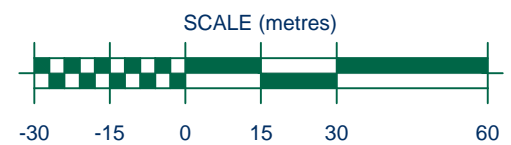
The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an “as required” basis (e.g. after major flood events) to identify any significant changes, if present. Inspections should include control surveys along the crest relative at fixed points to verify regression rates.

11.10 ATTACHMENTS

Figure 11-1 - Site Plan
Figure 11-2 - 2016 Contour Plan
Figure 11-3 - Log of Exposed Bank & Cross Section Profile
Figure 11-4 - Aerial Photographs
Figure 11-5 - Site Photographs
Figure 11-6 - Survey Marker Plan
Figure 11-7 - Photograph Plan
Figure 11-8 - Stability Analysis Run
Table 11-4 - List of Survey Markers
Table 11-5 - List of Photographs
Site Inspection Record (October 22, 2018)



-  EXISTING BUILDING
-  CREST OF SLOPE
-  TOE OF SLOPE
-  SLUMP
-  LOG OF EXPOSED BANK



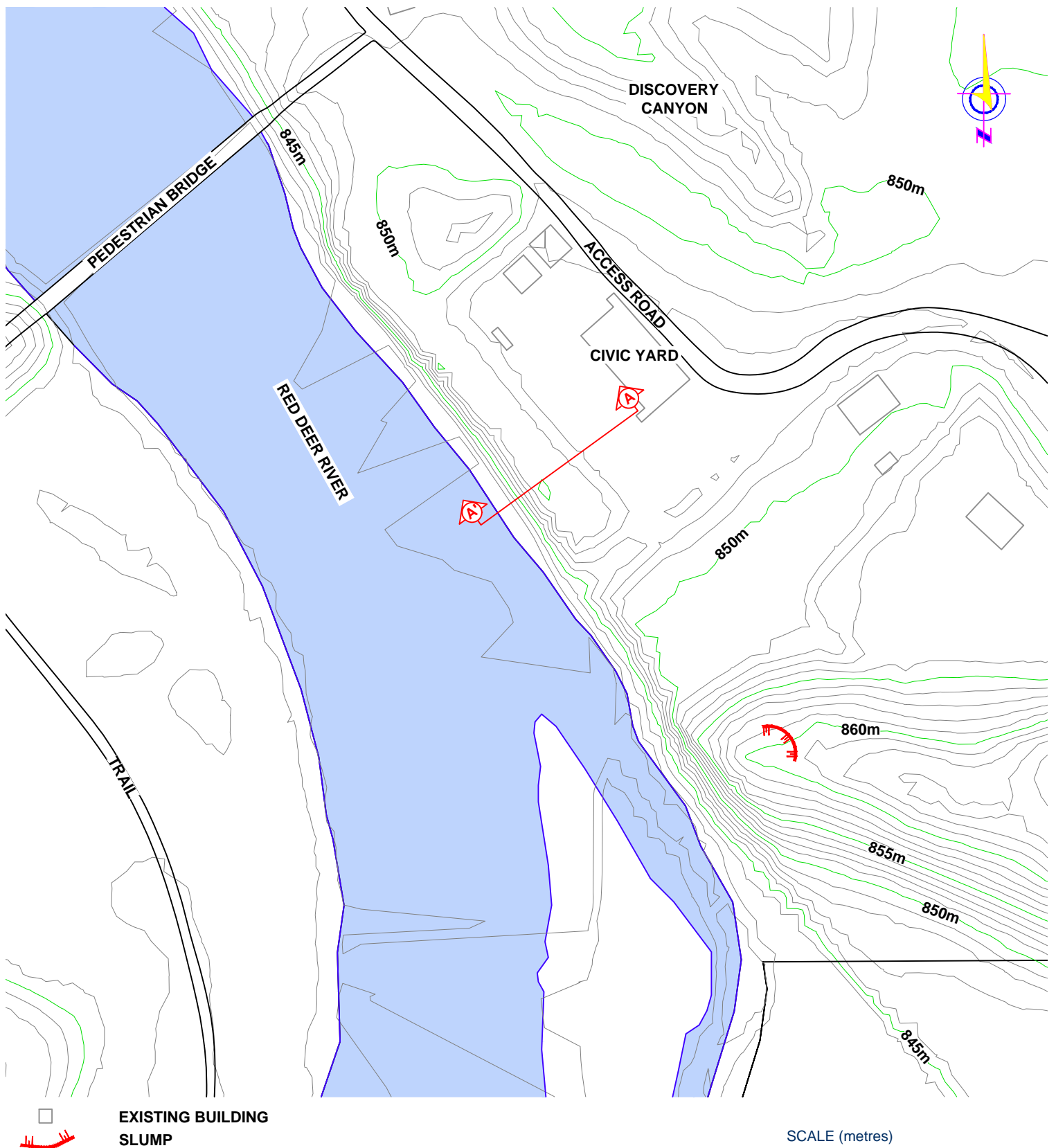
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND ESCARPMENT

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-11	DRAWING NO. FIGURE 11-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



CLIENT:



CONTOUR PLAN

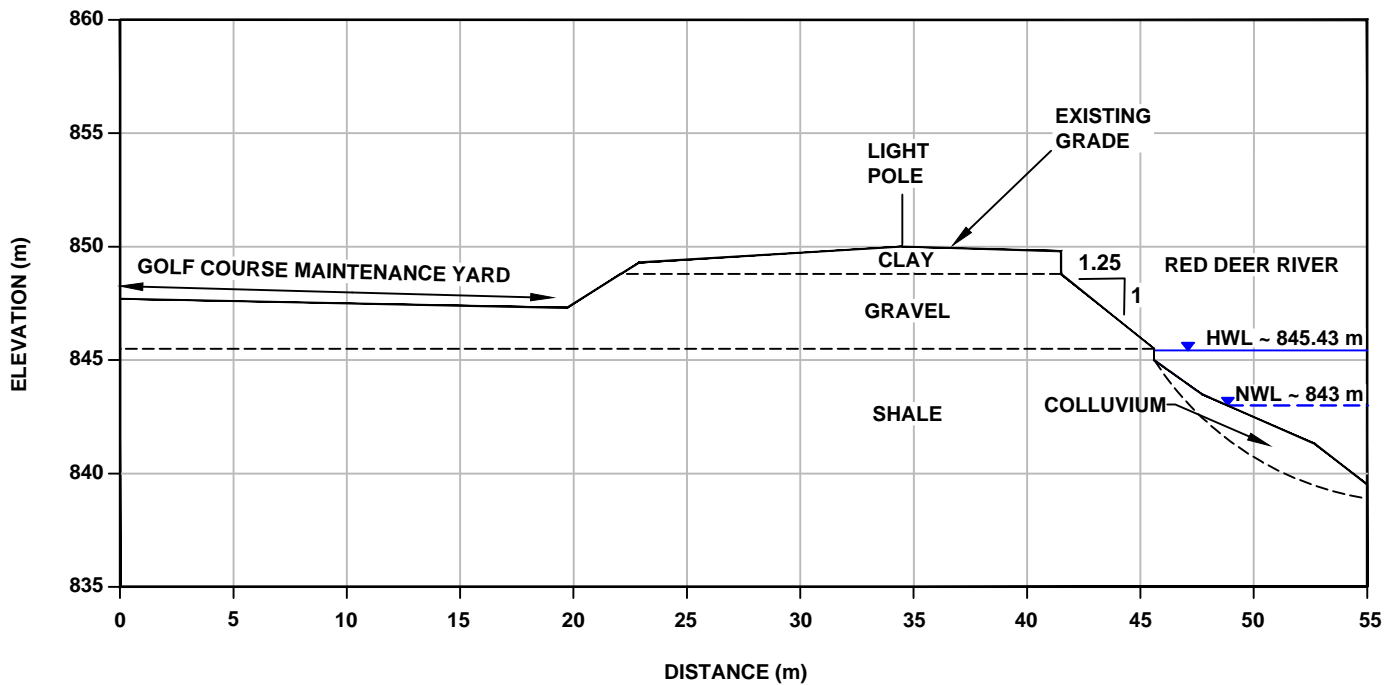
CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVER BEND ESCARPMENT

DRAWN: NC	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-11	DRAWING NO. FIGURE 11-2	

11-3: VISUAL LOG OF EXPOSED SLOPE FACE



11-3: CROSS SECTION (A - A')



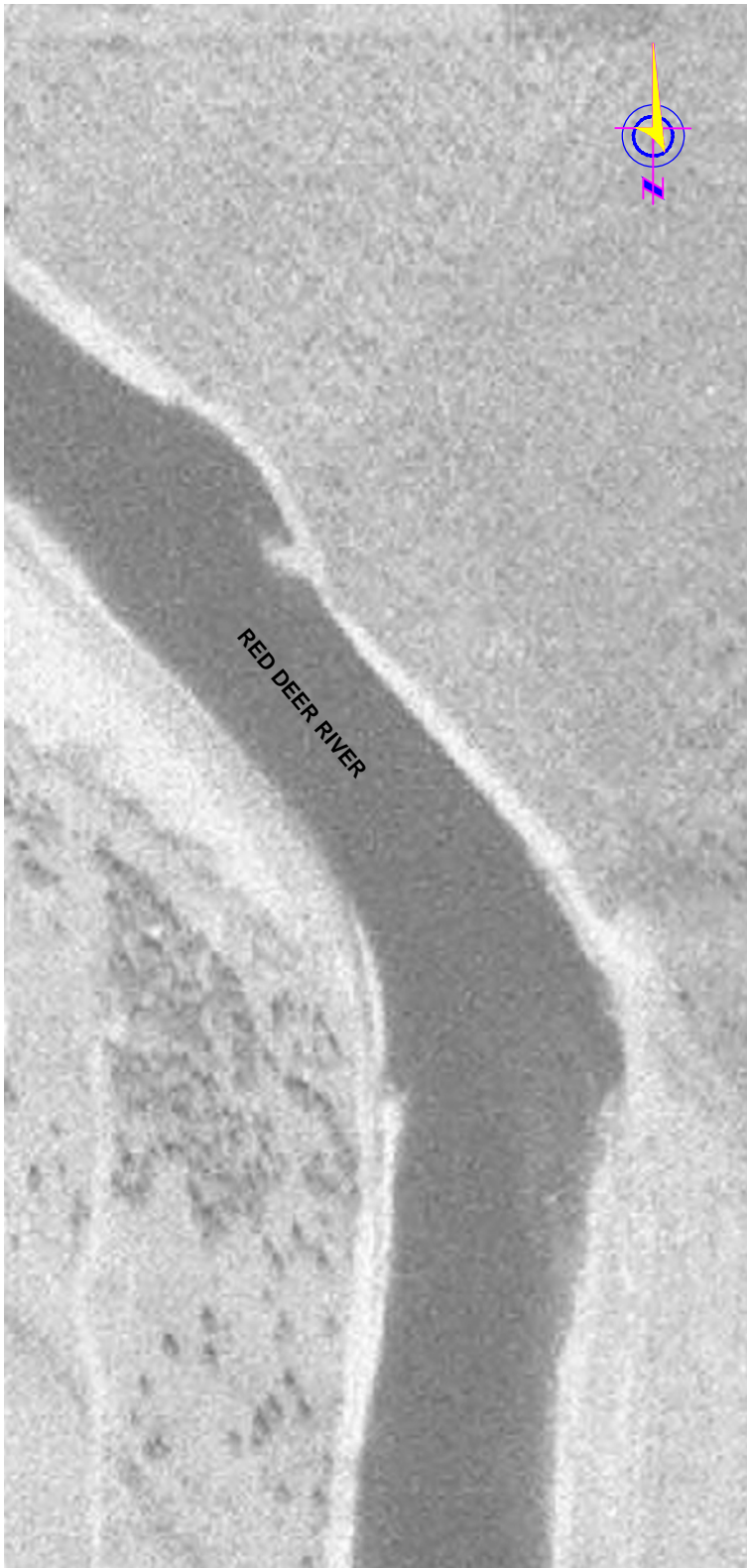
CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVER BEND ESCARPMENT

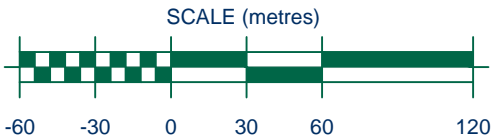
DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-11	DRAWING NO. FIGURE 11-3	



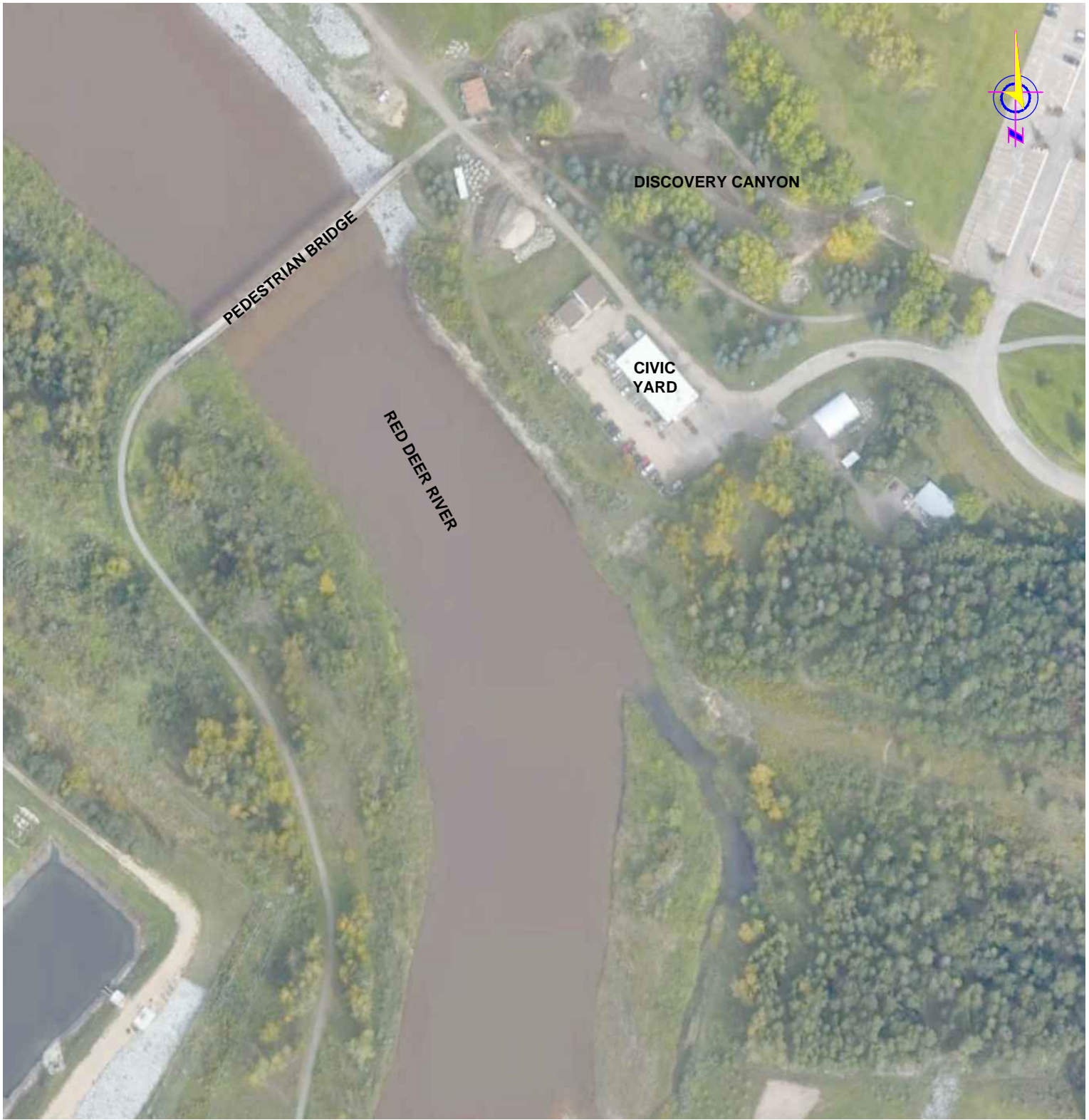
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED APRIL 30, 1949.



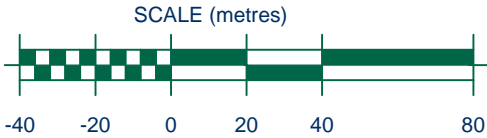
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED JUNE 20, 2005.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND ESCARPMENT			
		DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:3000	JOB NO. RD6500-11	DRAWING NO. FIGURE 11-4A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND ESCARPMENT			
			DRAWN:	CHK'D.:	REV #:	DATE:
			RS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		1:2000	RD6500-11		FIGURE 11-4B	



**PHOTOGRAPH 1 AND 2 PANO (2016): EAST BANK, TAKEN FROM
EAST ABUTMENT OF PEDESTRIAN BRIDGE, FACING SOUTHEAST**



**PHOTOGRAPH 1 AND 2 PANO (2018): EAST BANK, TAKEN FROM
EAST ABUTMENT OF PEDESTRIAN BRIDGE, FACING SOUTHEAST**



CLIENT:



SITE 11 PHOTOGRAPHS

CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND ESCARPMENT

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: NTS	JOB NO. RD6500-11	DRAWING NO. FIGURE 11-5A	



PHOTOGRAPH 4 (2018): EAST RIVER BANK FROM RIVER ACCESS ON THE WEST SIDE OF RIVER, FACING NORTH



PHOTOGRAPH 8 (2018): VERTICAL SANDSTONE ESCARPMENT OF EAST RIVER BANK AT THE NORTH END OF STUDY AREA, FACING SOUTHEAST



PHOTOGRAPH 18 (2018): CROSS COUNTRY SKI TRAIL BETWEEN CREST OF SLOPE AND GOLF COURSE MAINTENANCE YARD AT NORTH END OF STUDY AREA, FACING NORTHWEST



PHOTOGRAPH 37 (2014): EAST RIVER BANK FROM AERIAL PHOTOGRAPH OVER 78A STREET CLOSE, FACING NORTHEAST



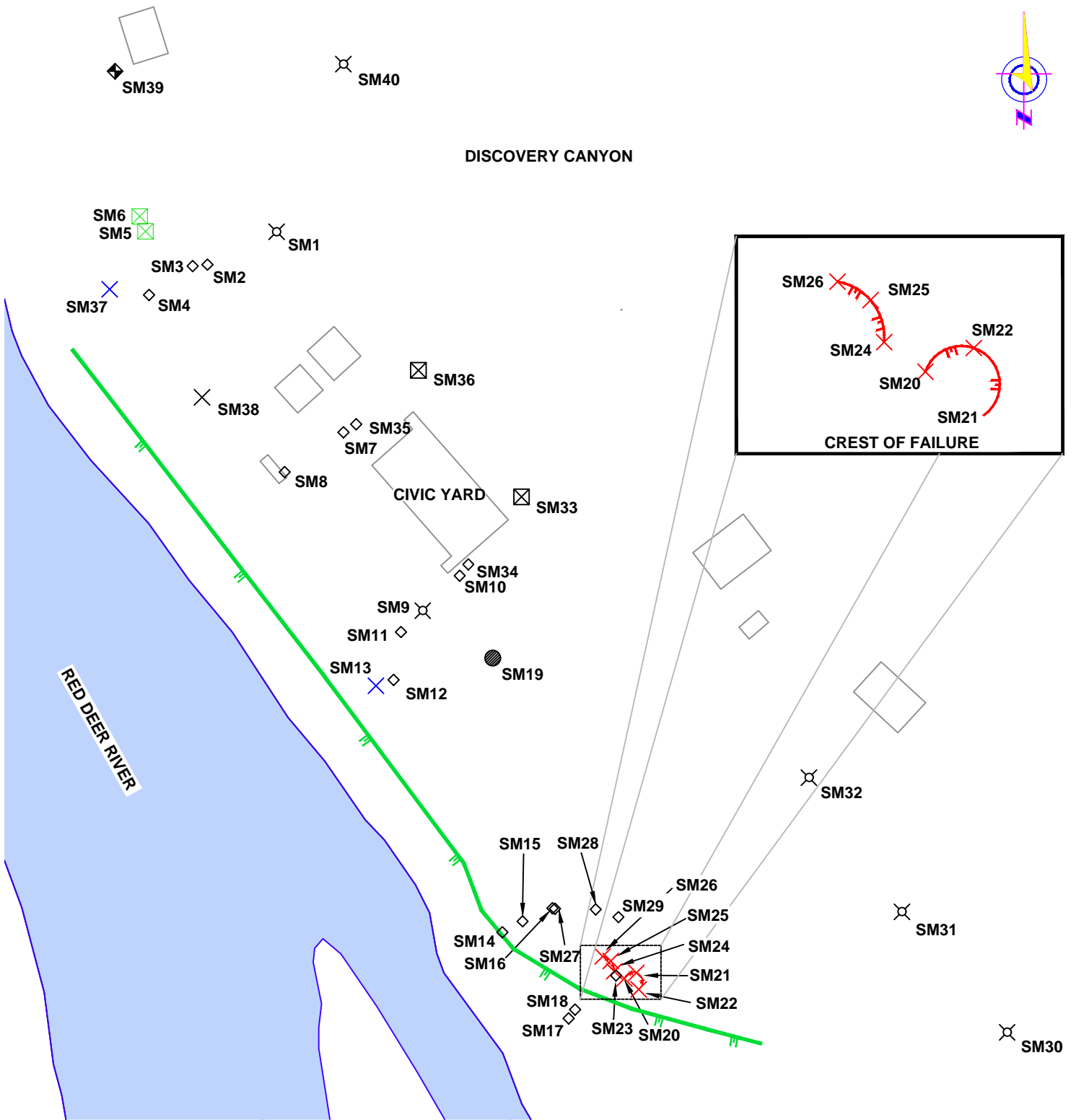
CLIENT:



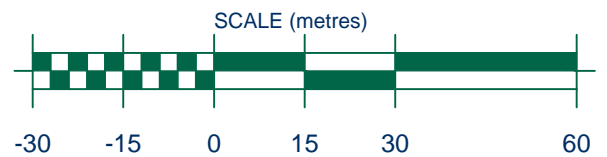
SITE 11 PHOTOGRAPHS

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVER BEND ESCARPMENT

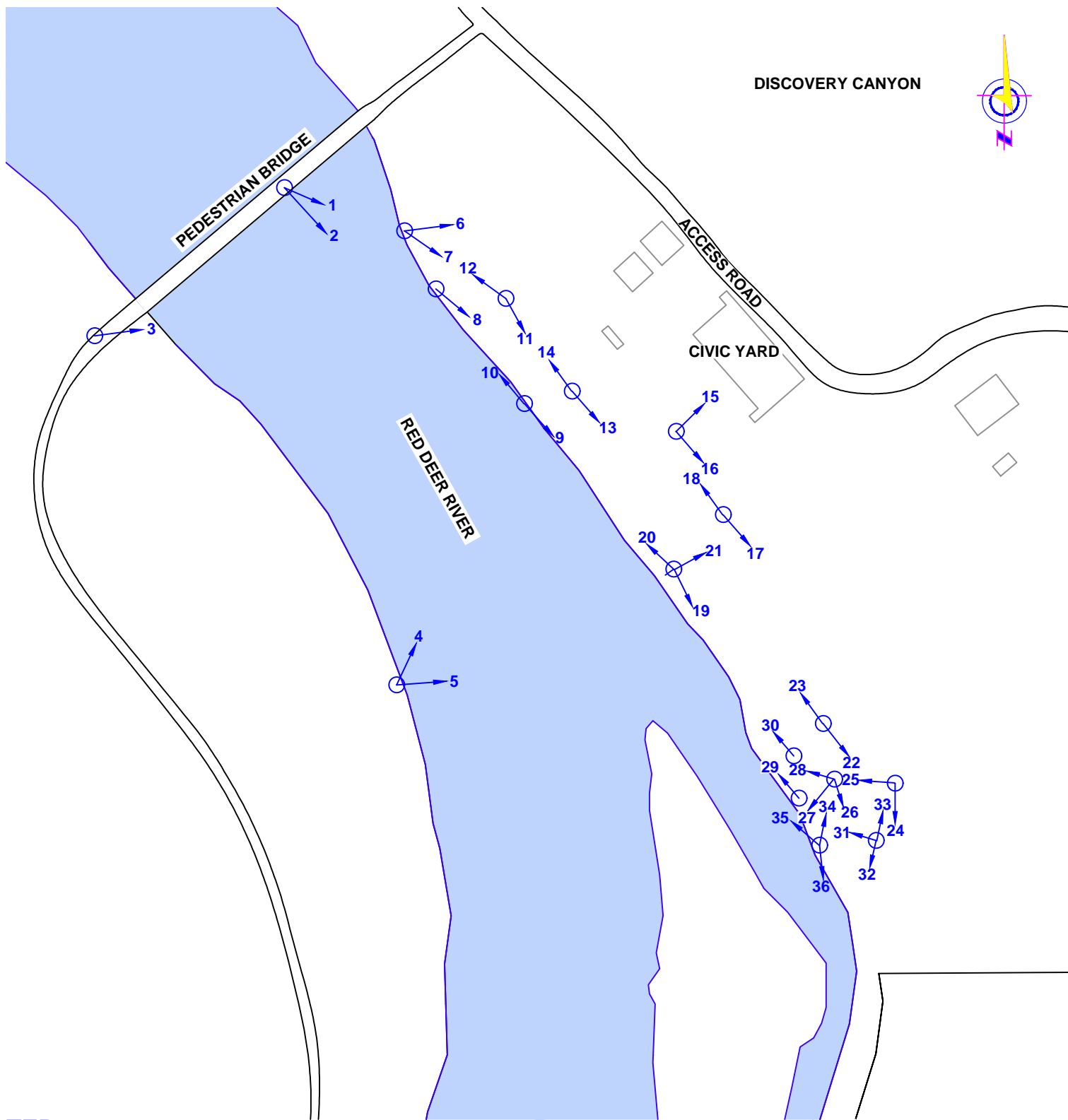
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: NTS	JOB NO. RD6500-11	DRAWING NO. FIGURE 11-5B	



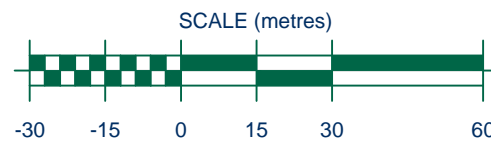
- | | | | |
|--|-------------------|--|------------------------|
| | CREST OF SLOPE | | BRIDGE |
| | EXISTING BUILDING | | CREST POINT OF FAILURE |
| | CULVERT | | FAILURE |
| | LIGHT POLE | | WATER |
| | SURVEY LAND POINT | | BUILDING CORNER |
| | DUMP PILE | | |



	CLIENT:		SURVEY MARKERS	
			CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND ESCARPMENT	
	DRAWN:	CHK'D:	REV #:	DATE:
	RS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.
1:1250		RD6500-11		FIGURE 11-6



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



CLIENT:



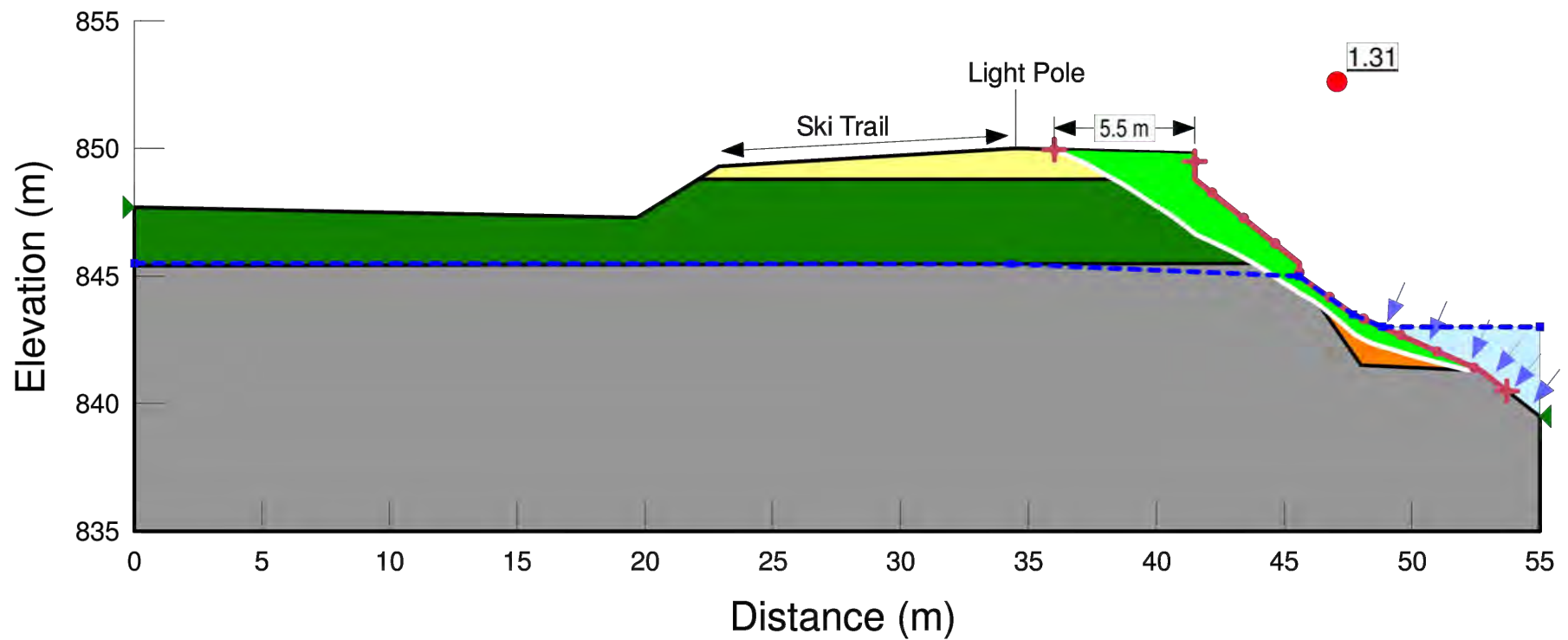
PHOTOGRAPH PLAN



CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVER BEND ESCARPMENT

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-11	DRAWING NO. FIGURE 11-7	

11-8: STABILITY AT 1.9H:1V FROM TOE

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Alluvial Clay	19	1	25
	Bedrock	21	10	40
	Colluvium	18	0	28
	Gravel	21.5	0	35



	<div>CLIENT:</div> 	STABILITY ANALYSIS RUN			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND ESCARPMENT			
		DRAWN:	CHK'D.:	REV #:	DATE:
		RS	MDB	2	APRIL 2019
		SCALE:	JOB NO.	DRAWING NO.	
AS SHOWN	RD6500-11	FIGURE 11-8			

SITE #11 - RIVER BEND ESCARPMENT

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 11-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM11-001	Light pole	5799814.13	309980.80	851.10				
#SM11-002	Upper crest	5799806.60	309964.99	850.80				
#SM11-003	Dip	5799806.24	309961.59	849.53				
#SM11-004	Crest	5799799.64	309951.58	849.24				
#SM11-005	Dump pile	5799814.25	309950.75	849.27				
#SM11-006	Dump pile	5799817.66	309949.43	848.94				
#SM11-007	Crest	5799768.15	309996.15	849.83				
#SM11-008	Crest	5799759.07	309982.67	849.77				
#SM11-009	Light pole	5799727.34	310014.29	849.96				
#SM11-010	Crest	5799735.31	310022.78	849.34				
#SM11-011	rest	5799722.42	310009.33	849.80				
#SM11-012	Toe	5799711.46	310007.63	843.52				
#SM11-013	Water	5799710.12	310003.58	841.30				
#SM11-014	Bbank	5799653.63	310032.55	842.35				
#SM11-015	Mid	5799656.12	310037.19	843.72				
#SM11-016	Base	5799659.11	310044.05	848.76				
#SM11-017	Bank	5799633.89	310047.75	842.53				
#SM11-018	Mid	5799635.91	310049.23	843.66				
#SM11-019	Culvert	5799716.45	310030.31	846.95				
#SM11-020	Slump	5799643.04	310060.50	856.32				
#SM11-021	Slump	5799644.37	310063.24	857.68				
#SM11-022	Slump	5799640.55	310063.80	856.16				
#SM11-023	Crest	5799643.71	310058.61	856.12				
#SM11-024	Slump2	5799644.71	310058.17	856.50				
#SM11-025	Slump2	5799647.07	310057.41	857.02				
#SM11-026	Slump2	5799648.13	310055.53	856.62				
#SM11-027	Crest	5799659.01	310044.63	852.81				
#SM11-028	Mid	5799658.85	310053.95	857.17				
#SM11-029	Crest	5799657.09	310059.15	859.20				
#SM11-030	Light pole	5799630.71	310148.21	864.11				
#SM11-031	Light pole	5799658.34	310124.09	860.00				
#SM11-032	Light pole	5799689.07	310102.79	853.38				
#SM11-033	Building	5799753.39	310036.93	847.67				
#SM11-034	Toe	5799737.88	310024.76	847.30				
#SM11-035	Toe	5799770.00	309999.05	847.53				
#SM11-036	Building	5799782.41	310013.32	847.63				
#SM11-037	Water	5799800.95	309942.56	841.32				
#SM11-038	Toe	5799776.21	309963.73	841.95				
#SM11-039	Bridge	5799850.93	309943.81	849.90				
#SM11-040	Light pole	5799852.54	309996.12	850.07				

TABLE 11-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD			COMMENT
		NORTHING	EASTING		2014	2016	2018	
#P11-001&002	East bank	5799802	309888	SE		Y*	Y*	
#P11-004	East bank	5799662	309919	N			Y*	
#P11-008	Vertical sandstone escarpment of east bank	5799773	309931	SE			Y*	
#P11-018	Trail b/w crest & golf course yard	5799710	310011	NW			Y*	
#P11-037	East river bank (Aerial)			NE	Y*			

Notes:

2014 Aerial Photograph from Alberta Environment and Parks

2016 Photograph from proposal in site reference list

* Provided in the report

All measurements in metres

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	11	
Site Name	Riverbend Escarpment	
Legal Land Description	NW 34-38-27-W4M	
Address	3800 River Bend Drive	
UTM Coordinates (approx. site center)	310120 E, 5799820 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 22, 2018	9	1	9
Inspected By:	Bryden Lutz - PGEO Trevor Allen - PGEO			
Report Attachments:	37 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Angular	N/A	
Slope Movement	Crest regression (overhanging vegetation), loose colluvium on flatter angles at bottom 1/3 of slope	N/A	
Erosion	Toe erosion from river possible as site on outside near bend. Erosion would be slow as riverbed well into bedrock.	N/A	
Seepage	None observed	N/A	
Distress	None observed	N/A	
Other	Knoll on south side of site appears protected from most annual toe erosion due to river alignment and small protruding island. Likely only eroded during high water events.	N/A	
Instrumentation:	N/A		
Other Comments:			

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Only use near crest is a new ski trail, with estimated setback of 6 to 8 m.- No vegetation on slope face.- Bedrock at river elevation should make erosion slow.
Assessment	<ul style="list-style-type: none">- Any movement is expected to be small and not impact the new ski trail.
Recommendations	<ul style="list-style-type: none">- Consideration for site visits as every 3 to 5 years or after flooding.

SITE #12



**River Bend Northeast Escarpment
(Red Deer County)**

SITE #12 - RIVER BEND NE ESCARPMENT (RED DEER COUNTY)

12.1 SITE DESCRIPTION

Site #12 is the southeast river valley slope within SE 1-39-27-W4M in Red Deer County immediately northeast of the City, as shown on Figure 1 of the main report. This is a 700 m long section of high bank slope on the outside bend of the river starting just east from the 30th Avenue entrance to the River Bend Recreation Area (River Bend). The upland area above the slope is undeveloped farmland which has an acreage parcel in the southwest corner overlooking the river. The Site Plan is shown on Figure 12-1. A 2016 Contour Plan is provided on Figure 12-2. A cross-section of the high bank at this river bend is provided on Figure 12-3. Aerial photographs showing the site in 1949 and 2016 are provided on Figures 12-4A and 12-4B. Eight selected representative photographs from the site are provided on Figures 12-5A and 12-5B.

The predominant feature for this area is the river bend which turns southerly river flows sharply about 180° to the north on a bend with a radius of about 550 m. Site #12 is located in the south high bank on the east half of this bend. From review of available topography and aerial photographs this section of river valley slope appears to have evidence of one large ancient landslide and one or two smaller slides to the north. The normal river surface at the shoreline in this area is at elevation 841 m and the crest of the slope is at 880 to 881 m, making the overall slope up to 40 m high. The site is bounded by a mature river valley slope bordering the flood plain at the River Bend Recreation Area to the south; and the high bank slope of the river to the north on the neighboring quarter section. The high bank to the north has an inclination of between 1H:1V to 1.25H:1V which is considered to be similar to the profile of the pre-slide high bank prior to the landslides at the subject site.

The larger of the old landslide areas appears to have produced a large block of colluvium covering the toe below an elevation of 855 m. The top of the old colluvium block is up to 40 m wide and has a shallow grade drop sloping down to an elevation of about 847 m. Below 847 m, the surface steepens into the main river bank which is slightly flatter than 1H:1V. The scarp slope above the colluvium is about 1.5H:1V to 2H:1V to an elevation of about 870 m which if expected to correspond to the top of the local till deposits. The slope above this elevation has undergone slope flattening and averages between 3H:1V and 4.5H:1V; getting slightly steeper from west to east. The upper slopes on the flanks of the two smaller slide areas appears to be slightly steeper; in the order of 3H:1V. The slope face was moderately to heavily treed. The colluvium terrace near the base of the slope is vegetated with brush and strewn with dead fall, but only lightly treed.

12.2 REFERENCES

There are limited report references for this site. ParklandGEO has private file information from a site investigation at the acreage at the top of the slope in the southwest corner of the quarter section.

12.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

File records on two shallow boreholes and the water well record for the local acreage were reviewed. The borehole locations are shown on Figure 12-1. No slope inclinometers or other instrumentation has been installed at this site.

12.4 2018 REVIEW

Aerial photography is provided on Figures 12-4A and 12-4B for the years listed in the following table. The aerials suggest the river bank and shoreline has not experienced much change in over 65 years.

TABLE 12-1: AERIAL PHOTOGRAPHS

Year	Description
1949	Shows the original site condition over 65 years ago.
2000	Shows the site condition over 15 years ago.
2016	Shows the present Site condition.

Site #12 was visited on October 24 and November 13, 2018. A copy of the field inspection record is attached at the end of this appendix.

The reviewed site survey information includes a survey profile down the slope from the 2005 site investigation, as shown on Figure 12-3; as well as the City's 2016 ortho-contours. A record of survey control points and data for this site is appended in Table 12-4. A reference drawing of survey reference points is provided on Figure 12-6.

Photographs were taken during the 2018 site visit. A list of available photos at this site is appended in Table 12-5. Selected site photographs are provided on Figures 12-5A and 12-5B; along with a reference drawing of all photograph locations which is provided on Figure 12-7.

12.5 BACKGROUND

Site #12 is undeveloped, privately owned farmland with an acreage site that is currently outside of the City limits northeast of the River Bend Recreation Area. It is understood the City of Red Deer's current interest in the property is planning for an extension of the City of Red Deer's river valley park system north of the current City limits at River Bend. There is little geotechnical background information on this property, but it is the site of a relatively large landslide which has created a sloped terrace near the base of the original high river bank escarpment. The slide is old enough that flows have removed most of the colluvium along the bank, so that the river bend is not severely restricted or different from the original channel. The upper slope above the slide terrace has an average inclination flatter than 3H:1V, so the clay slope face has undergone significant flattening. Trees and other vegetation fringe the crest along the edge of the farmland. Based on aerial photographs, the location of this crest has not changed significantly over the last 65 years.

12.6 SUBSURFACE PROFILE

Based on the limited geotechnical data, the expected soil profile in the crest area at Site #12 was, in descending order: topsoil; silt, sand and clay; clay till; and bedrock which is considered to be typical for northeast Red Deer. Copies of the three 2006 boreholes are attached. The following is a brief description of the soil types expected at this site.

1. **Topsoil.** The thin topsoil layer should be present in the farmland east of the crest. Organics will be mixed in with the colluvium at the base of the slope.
2. **Silt, Sand and Clay.** Glacio-lacustrine silt, sand and clay deposits are expected below the topsoil to an elevation of about 867 m. The moisture contents in these soils ranged from 18 to 35 percent.
3. **Till.** Clay till was found below the lacustrine deposits in the upland area. Based on the slope profile and limited deep borehole data, the top of the till elevation ranges from 867 to 870 m (see Figure 12-3). The till observed was a silty sandy clay soil which was very stiff, low to medium plastic and had a typical moisture contents of about 15 percent. The local till deposits are expected to have layers of sand till and gravel till.
4. **Bedrock.** Based on groundwater well records in the area bedrock is expected to be present at an elevation of 845 to 847 m which is within 35 m of grade below the crest.
5. **Groundwater.** In 2005, groundwater at the crest was encountered at 867 m, which is a about 7 mbg. The groundwater elevation in the upland area to the southeast at 30th Avenue is expected to be about 880 m which is 2 to 4 mbg.

The following effective strength parameters were assumed for this site.

TABLE 12-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Colluvium	18	0	25
Silt & Clay	20	0 - 5	25 - 28
Clay Till	21	2 - 10	30
Sand and Gravel	21.5	0	40
Bedrock	20	20-30	38

12.7 REVIEW OF STABILITY ASSESSMENT

The river bank below Site #12 appears to consist of an old colluvium mass which will be subject to long-term regression, but this will not affect the stability of the mid and upper slope at this site for the foreseeable future.

Limited historical stability analysis was available for this site. A preliminary estimate of stability along the crest has been undertaken for Site #12 using the *SLOPE/W* computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 12-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Shallow Failure in Upper Slope Face	1.0 - 1.3	-
9 m From Crest Above Landslide Areas	1.5	Figure 12-8
62 m From Crest in High Bank Areas	1.5	-

A stability analysis run for the reconstructed slope is provided in Figure 12-8.

The current upper slope above the old landslide terrace is considered to be a transitional to mature slope with short-term stability and marginal long-term stability. The observed colluvium bank slopes along the shoreline are considered to be marginally stable in the long-term. This assessment may change with time if the shoreline is subject to eastward regression due to river action.

Under the present conditions, the upper lacustrine clay slope above the terrace at this site is expected to flatten back to 3.5H:1V or 4H:1V in the upper lacustrine deposits. These expected slope angles are similar to, or slightly flatter than, the present inclinations observed. The slope face has not been assessed in detail, but there are likely steepened areas which may be prone to small shallow “slump-type” failures which may have impacts along the upland crest. These types of failures will likely require a major change in conditions such as significant wetting or deforestation from due to clearing, forestry or fire. At the time of future development, the local conditions will need to be reviewed based on a combination of slope stability and regression potential, to provide development set backs and buffer areas along the crest for residential development in the upland areas above the old landslide area and high bank slopes to the north.

12.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(7) * CF(1) = 7$$

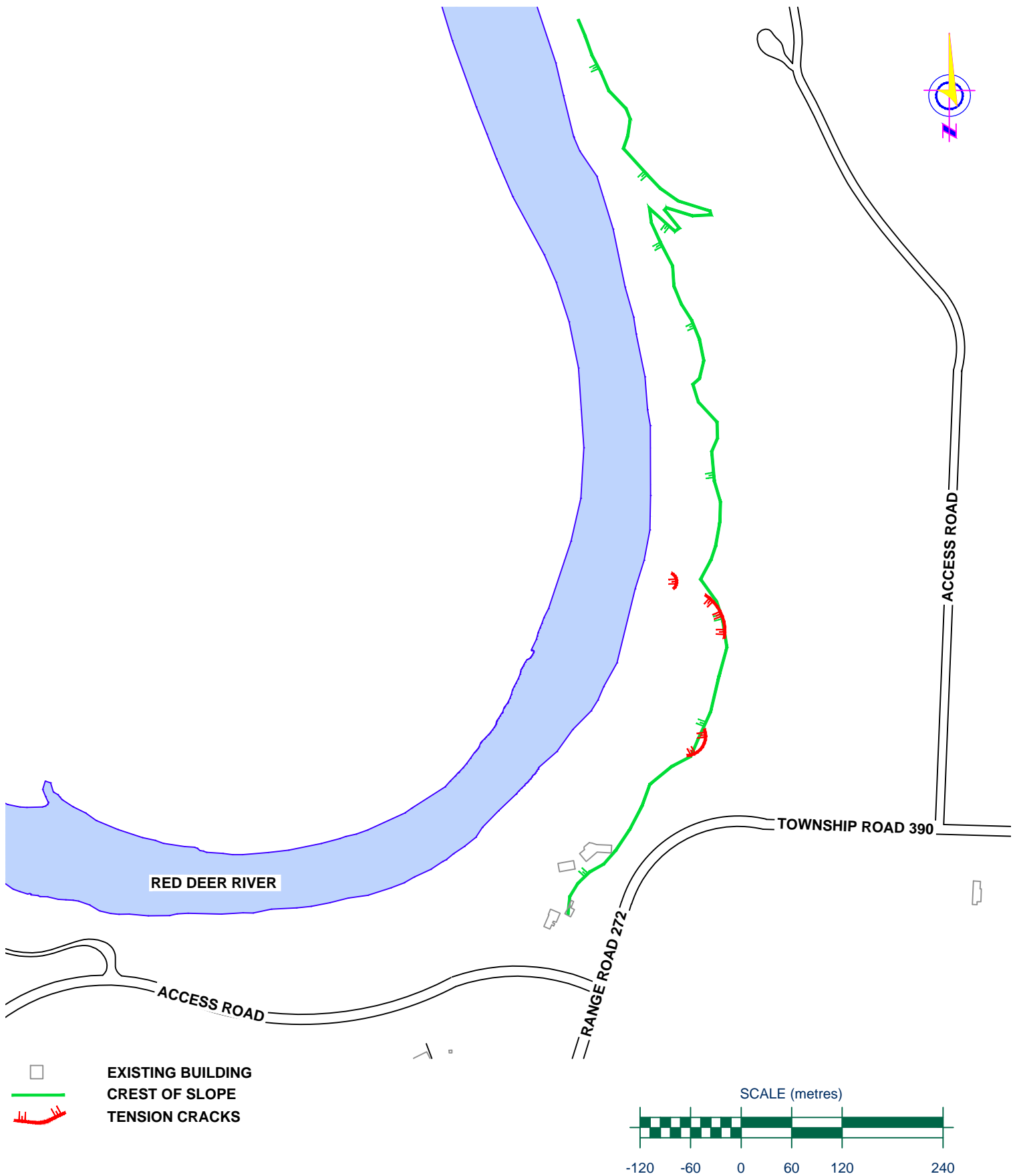
A Probability Factor of 7 is considered appropriate since the upper slope and slope face is not actively sliding but there is moderate potential for slope flattening landslides in the upper slope along the crest area above the landslide; and high potential for landsliding in steeper upper slope areas between the failure bowls and to the north end of the site. A Consequence Factor of 1 is considered appropriate since the area is currently undeveloped and development restrictions can be applied to future residential and recreational developments to minimize the consequences of expected slope movements.



12.9 RECOMMENDATIONS

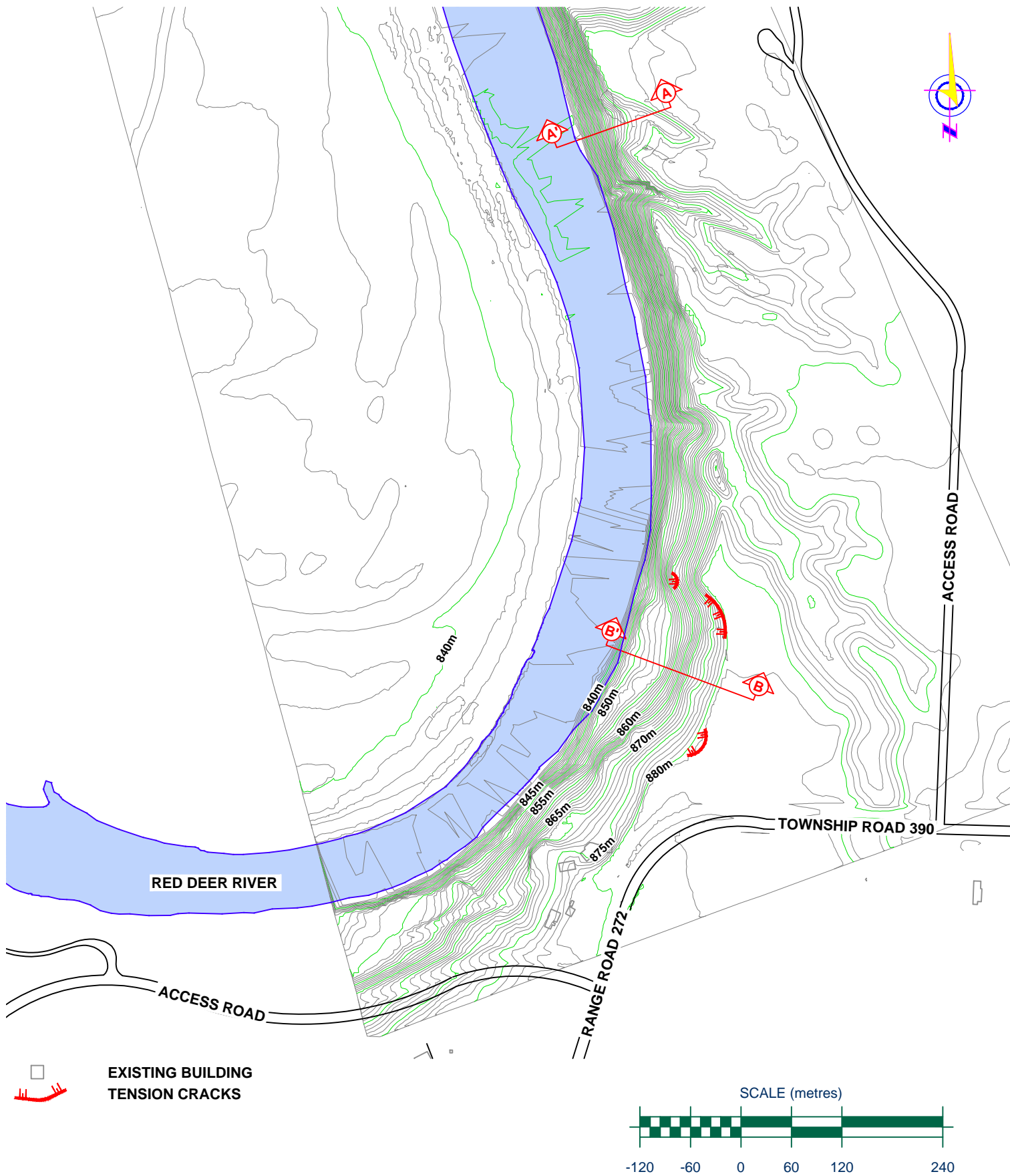
This area is not currently within the City boundaries. The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an “as required basis” to identify and document any significant changes to aid in future assessments prior to site development.

12.10 ATTACHMENTS



Figure 12-1 - Site Plan
Figure 12-2 - 2016 Contour Plan
Figure 12-3 - Cross Section Profile
Figure 12-4 - Aerial Photographs
Figure 12-5 - Site Photographs
Figure 12-6- Survey Marker Plan
Figure 12-7 - Photograph Plan
Figure 12-8 - Stability Analysis Run
Table 12-4 - List of Survey Markers
Table 12-5 - List of Photographs
Site Inspection Record (October 24, 2018)

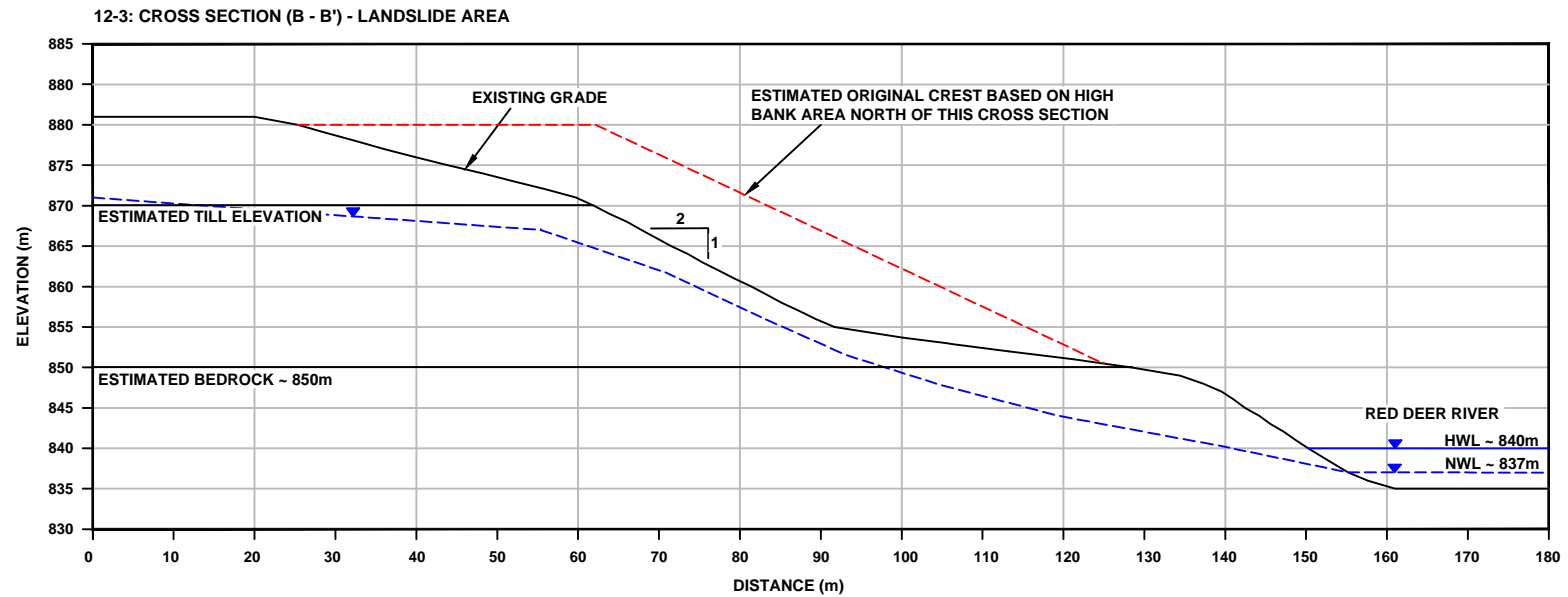
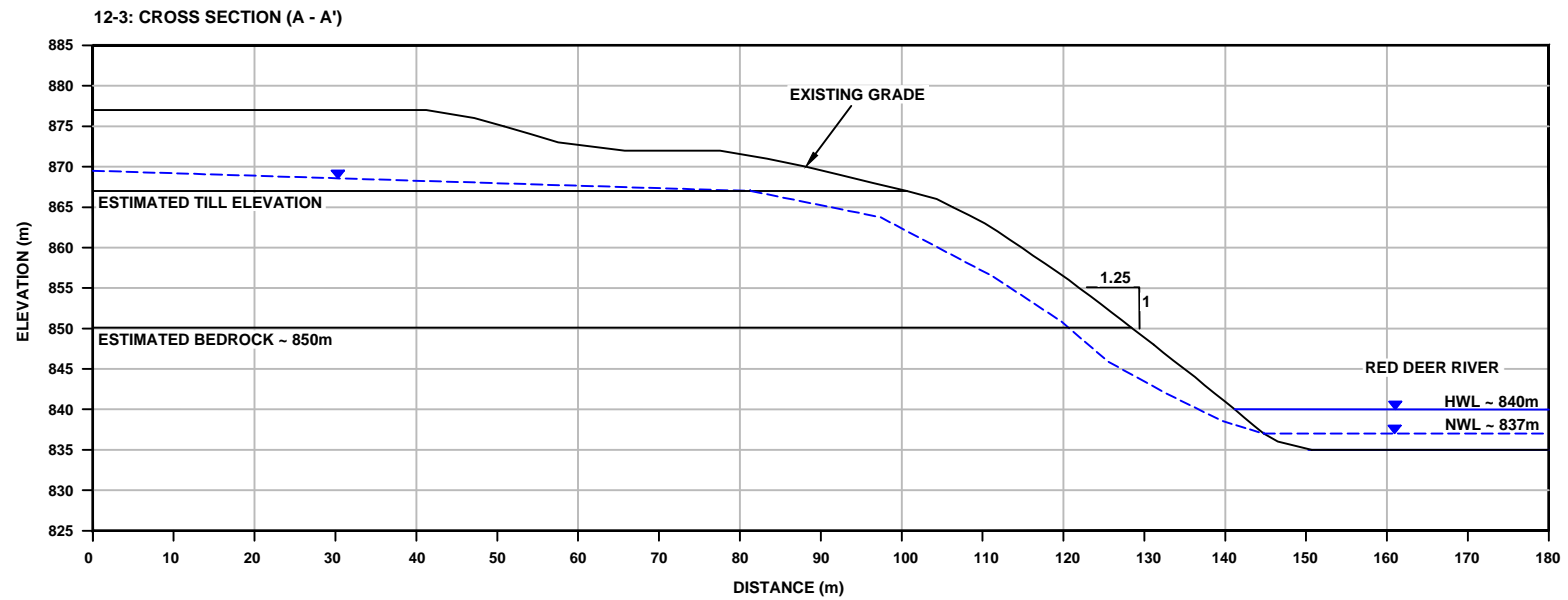


	CLIENT:						SITE PLAN	
							CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND NORTHEAST ESCARPMENT	
	DRAWN:	RS	CHK'D.:	MDB	REV #:	2	DATE:	APRIL 2019
	SCALE:	1:6000	JOB NO.	RD6500-12	DRAWING NO.	FIGURE 12-1		



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.

	<div>CLIENT:</div> <div></div>	<div>CONTOUR PLAN</div>			
		<div>CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND NORTHEAST ESCARPMENT</div>			
		<div>DRAWN:</div> <div>NC</div>	<div>CHK'D.:</div> <div>MDB</div>	<div>REV #:</div> <div>2</div>	<div>DATE:</div> <div>APRIL 2019</div>
		<div>SCALE:</div> <div>1:6000</div>	<div>JOB NO.</div> <div>RD6500-12</div>	<div>DRAWING NO.</div> <div>FIGURE 12-2</div>	



2016 ORTHO PROVIDED BY THE CLIENT.



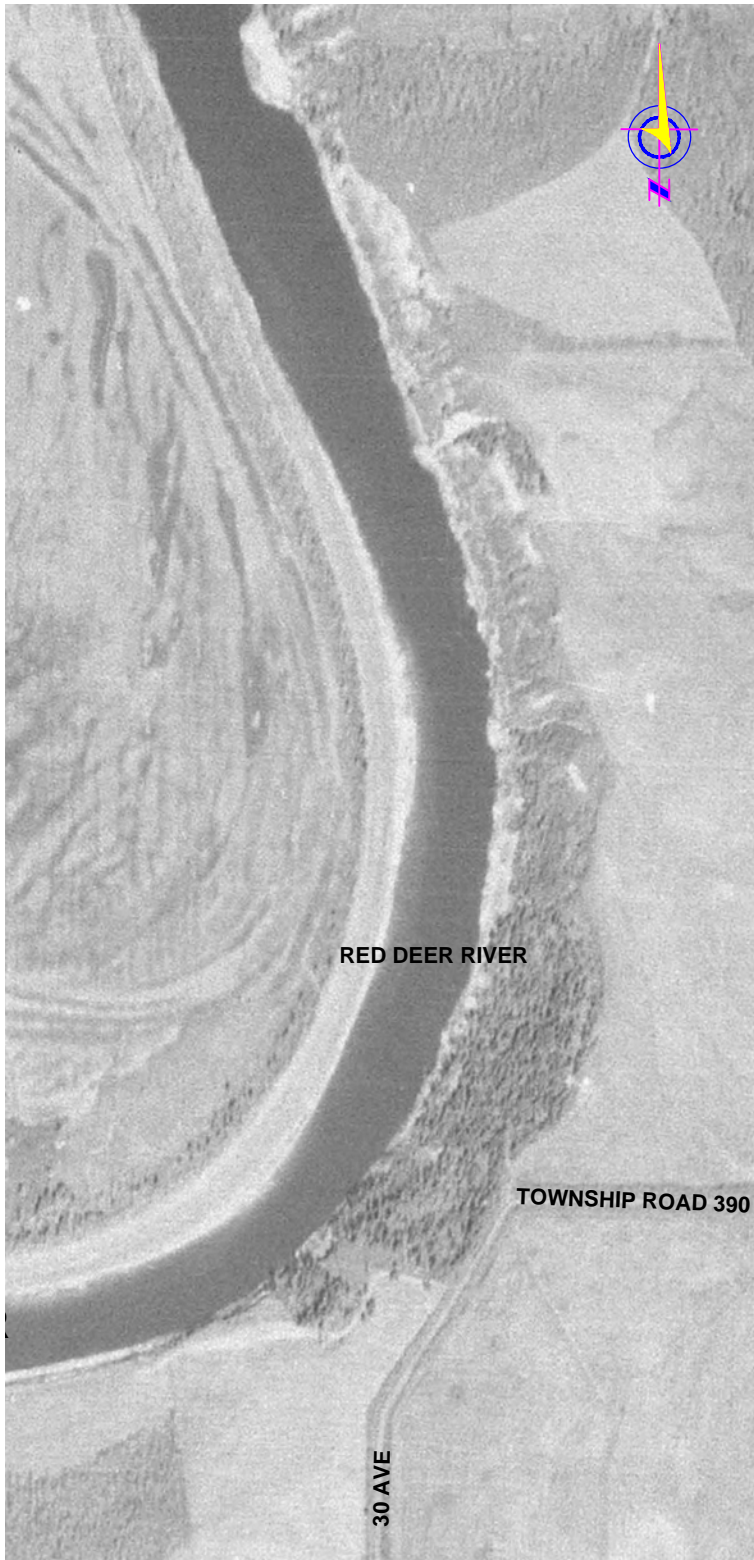
CLIENT:



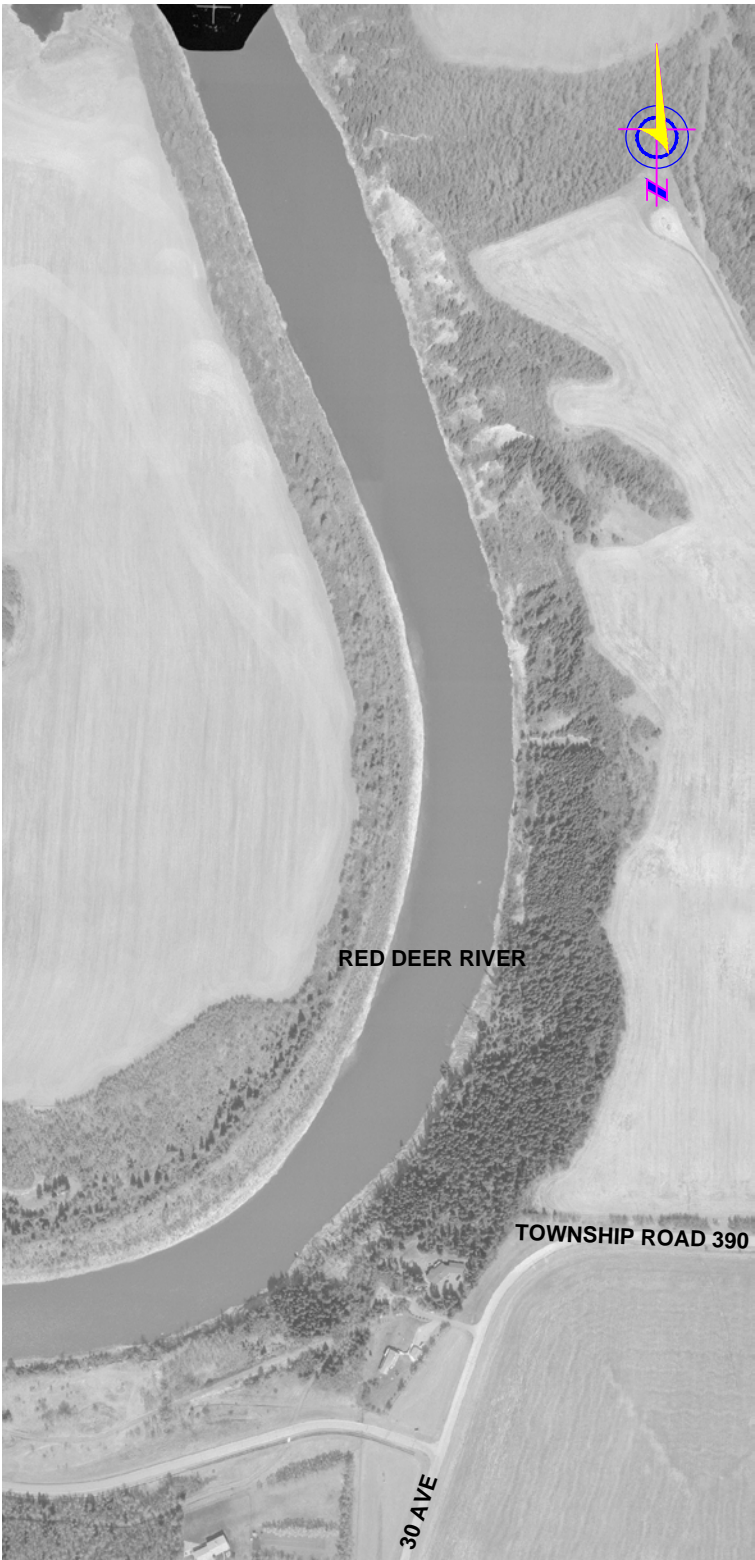
CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVER BEND NORTHEAST ESCARPMENT

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-12	DRAWING NO. FIGURE 12-3	

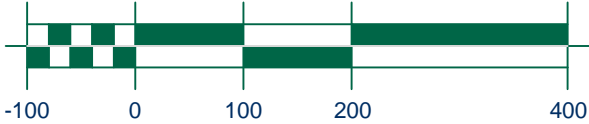


NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED APRIL 30, 1949.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED MAY 15, 2000.

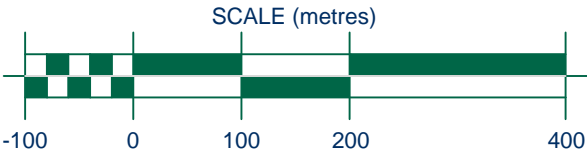
SCALE (metres)



	<p>CLIENT:</p> 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND NORTHEAST ESCARPMENT			
		DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:7000		JOB NO. RD6500-12		DRAWING NO. FIGURE 12-4A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND NORTHEAST ESCARPMENT			
			DRAWN:	CHK'D.:	REV #:	DATE:
			RS	MDB	2	APRIL 2019
			SCALE:		JOB NO.	
1:7000		RD6500-12		FIGURE 12-4B		



PHOTOGRAPH 14 (2018): OLD SLIDE BY THE EAST RIVER BANK (CENTER/SOUTH PROPERTY), FACING WEST



PHOTOGRAPH 20 (2018): DRAINAGE DITCH (SOUTH END), FACING EAST



PHOTOGRAPH 28 (2018): TREE WITH THE PISTOL BUTT, LOOKING SOUTHEAST



PHOTOGRAPH 40 (2018): STEEP SLOPE BY THE EAST RIVER BANK, FACING NORTHWEST



PHOTOGRAPH 41 (2018): SLOPE AND UPROOTED TREE FROM ABOVE THE DRAINAGE DITCH, FACING NORTH



PHOTOGRAPH 43 (2018): DRAINAGE DITCH (NORTH END), FACING NORTHWEST

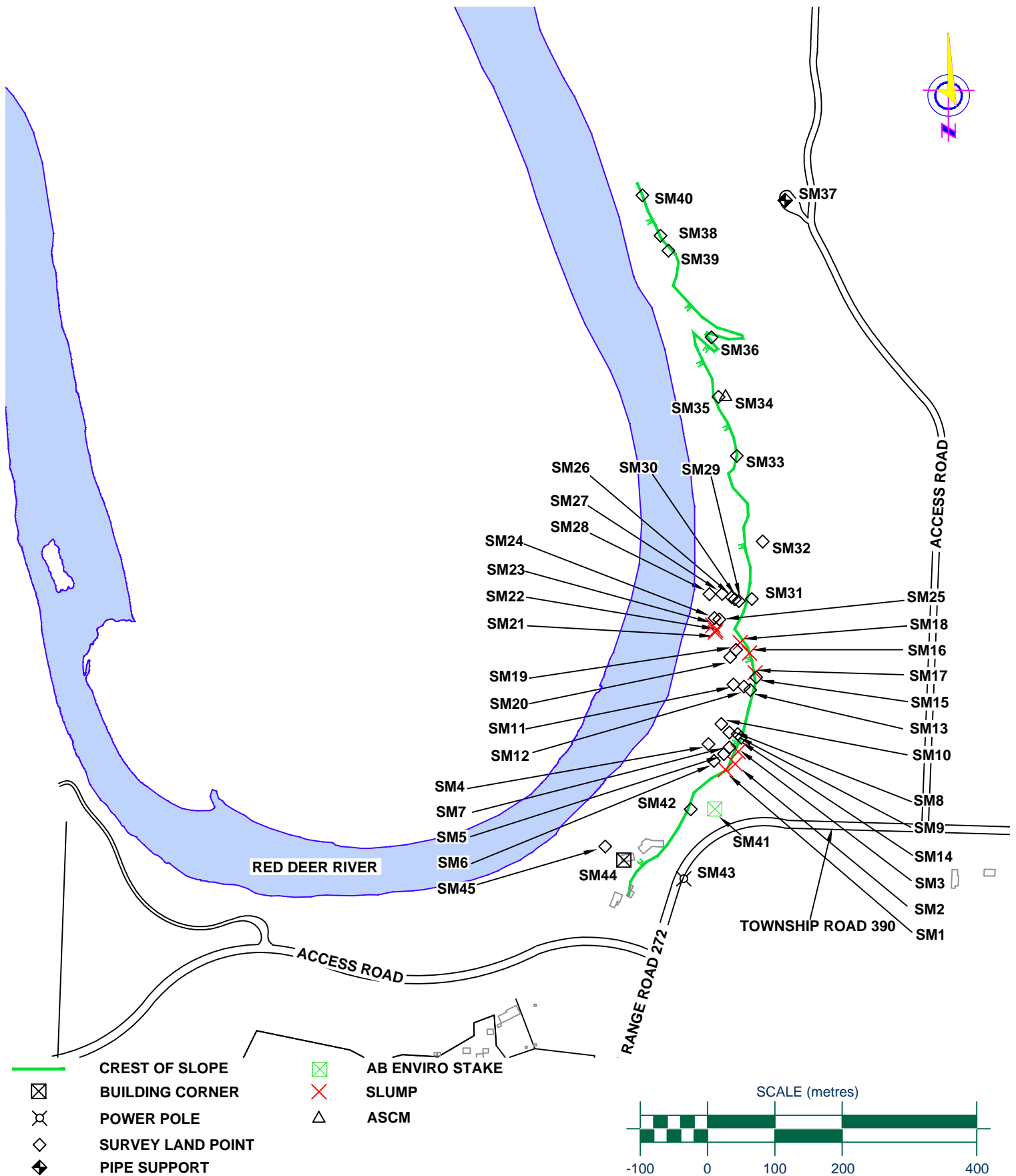


PHOTOGRAPH 49 (2018): SLOPE ALONG THE EAST RIVER BANK, LOOKING SOUTH FROM NORTH END



PHOTOGRAPH 65 (2018): OLD SLIDES IN THE SOUTH EXTENT OF STUDY AREA, FACING SOUTHWEST

	CLIENT:		SITE 12 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND NORTHEAST ESCARPMENT			
	DRAWN:	CHK'D.:	REV #:	DATE:		
	PS	MDB	2	APRIL 2019		
	SCALE:	JOB NO.		DRAWING NO.		
	NTS	RD6500-9&10		FIGURE 12-5B		



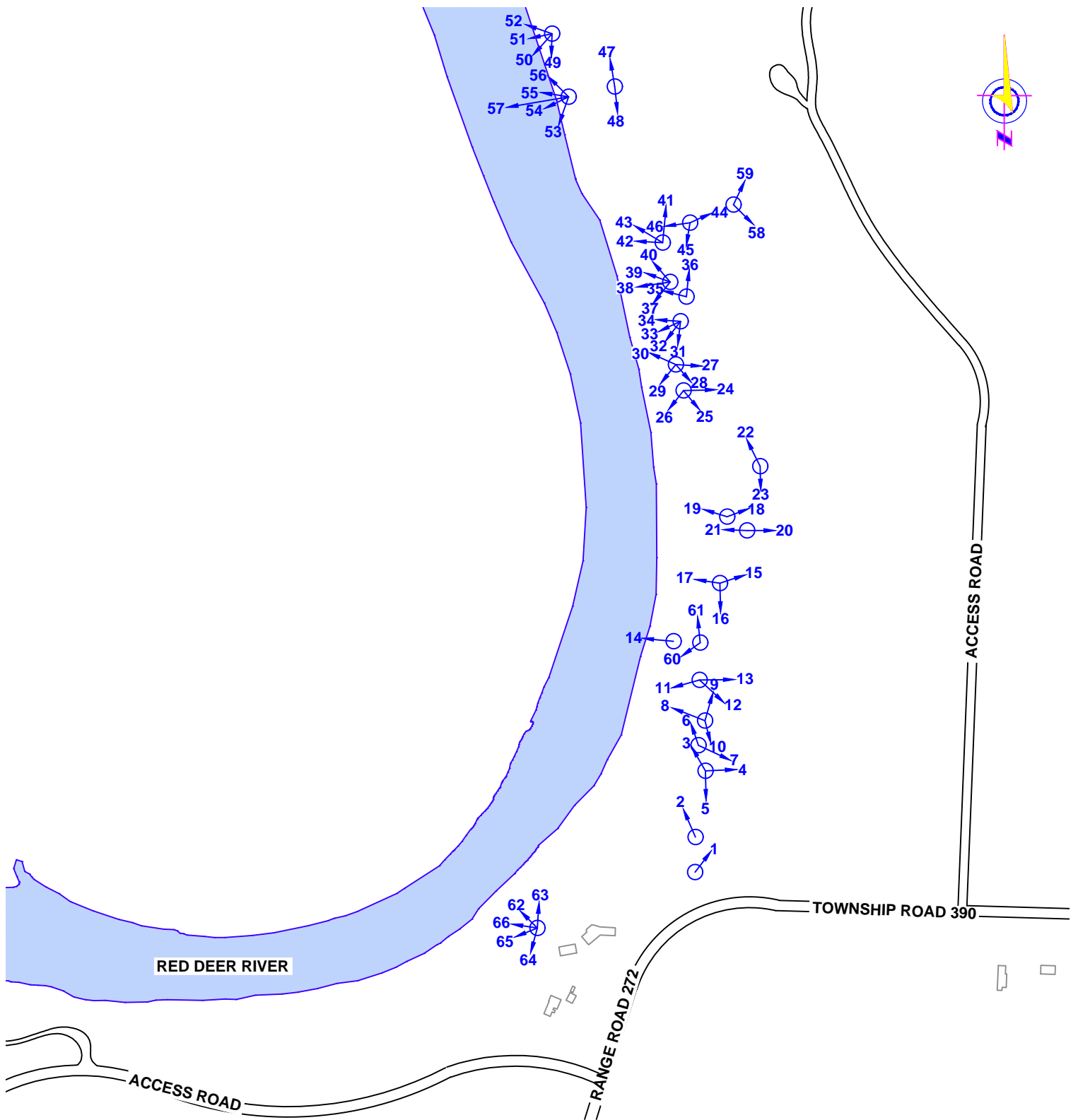
CLIENT:



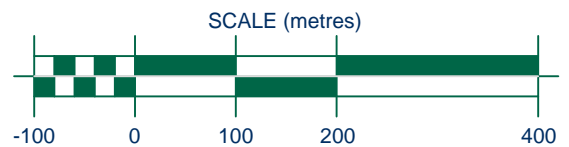
SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVER BEND NORTHEAST ESCARPMENT

DRAWN: RS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:7500	JOB NO. RD6500-12	DRAWING NO. FIGURE 12-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



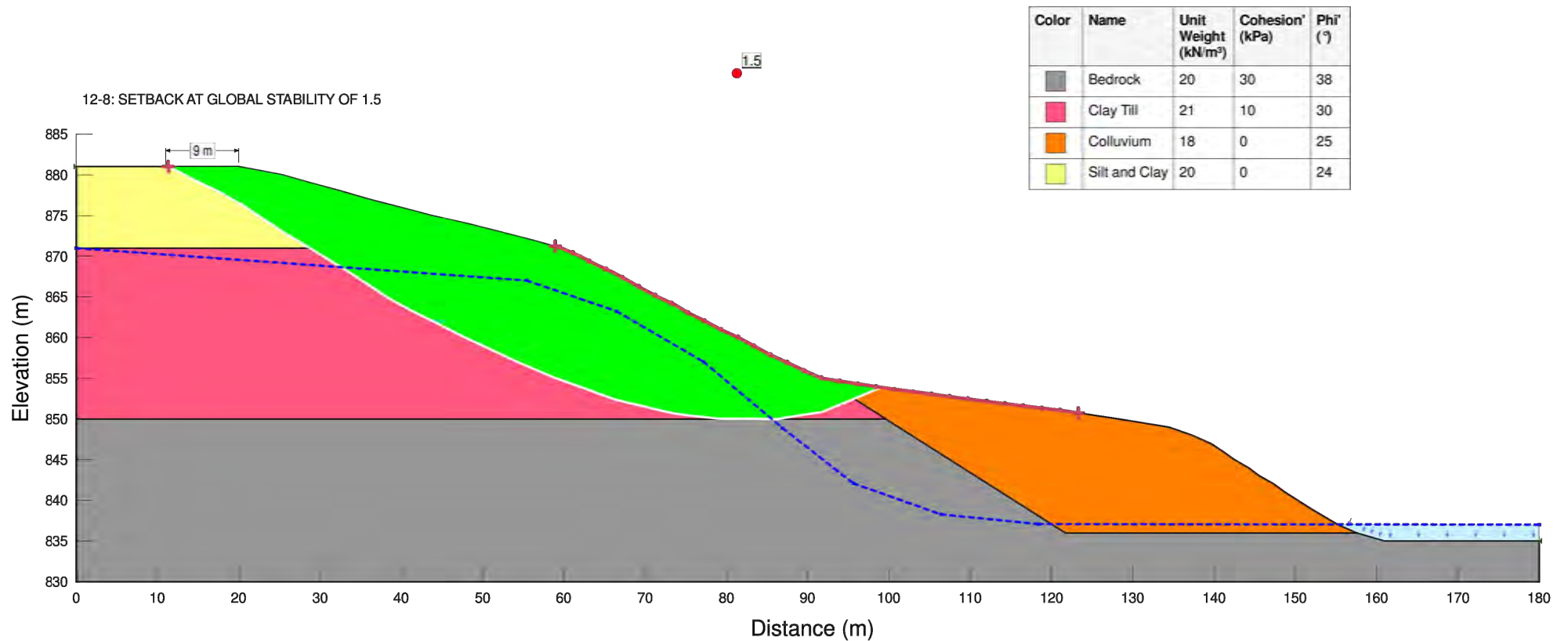
CLIENT:




PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVER BEND NORTHEAST ESCARPMENT

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:7500	JOB NO. RD6500-12	DRAWING NO. FIGURE 12-7	



	CLIENT: 	STABILITY ANALYSIS RUN			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVER BEND NORTHEAST ESCARPMENT			
		DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: AS SHOWN	JOB NO. RD6500-12	DRAWING NO. FIGURE 12-8	

SITE #12 - RIVER BEND SLOPE IN NE COUNTY

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 12-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018						COMMENT
		NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	
#SM12-001	Slump	5800036.87	311632.70	880.84				
#SM12-002	Slump	5800045.57	311647.18	880.67				
#SM12-003	Slump	5800063.72	311651.67	880.55				
#SM12-004	Ridge	5800075.07	311607.53	868.19				
#SM12-005	Mid	5800060.14	311630.47	875.57				
#SM12-006	Ridge	5800049.95	311615.66	875.49				
#SM12-007	Ridge	5800069.80	311638.73	876.42				
#SM12-008	Ridge	5800092.30	311638.59	875.70				
#SM12-009	Toe	5800089.88	311651.00	876.80				
#SM12-010	Ridge	5800105.06	311626.72	870.09				
#SM12-011	Ridge	5800163.72	311644.78	869.51				
#SM12-012	Ridge	5800160.79	311660.42	874.80				
#SM12-013	Toe	5800155.70	311669.72	875.59				
#SM12-014	Ridge	5800084.81	311656.32	880.87				
#SM12-015	Ridge	5800174.48	311678.65	880.45				
#SM12-016	Slump	5800210.63	311668.51	880.13				
#SM12-017	Slump	5800181.31	311677.00	880.40				
#SM12-018	Slump	5800226.22	311654.60	880.12				
#SM12-019	Mid	5800215.50	311648.57	873.68				
#SM12-020	Ridge	5800204.58	311639.87	868.46				
#SM12-021	Slump	5800241.77	311617.46	867.09				
#SM12-022	Slump	5800244.65	311618.19	867.67				
#SM12-023	Slump	5800252.09	311613.98	866.47				
#SM12-024	Ridge	5800263	311617	867.8				
#SM12-025	Toe	5800261	311624	868.1				
#SM12-026	Ridge - 0.3m above - 4m from Crest	5800294	311642	871.5				
#SM12-027	Toe	5800299	311628	856.8				
#SM12-028	Ridge	5800298	311609	861.1				
#SM12-029	Toe	5800288.21	311652.69	868.73				
#SM12-030	Hump	5800291	311647	870.5				
#SM12-031	Ridge	5800291.24	311672.14	879.54				
#SM12-032	Drain ditch	5800376.90	311688.33	873.20				
#SM12-033	Ridge	5800504.66	311649.51	879.78				
#SM12-034	ASCM	5800592.35	311632.93	878.37				
#SM12-035	Crest	5800592.53	311622.43	878.67				
#SM12-036	Drain ditch	5800681.08	311612.11	870.39				
#SM12-037	Pipe support - west side	5800885.26	311721.78	878.84				
#SM12-038	Crest	5800832.58	311535.99	875.37				
#SM12-039	Crest	5800810.26	311547.84	873.87				
#SM12-040	MidCrest - no tree	5800892.27	311508.57	872.70				
#SM12-041	AB enviro stake	5799978.27	311617.00	880.82				
#SM12-042	Crest	5799978	311581	877.6				
#SM12-043	Power pole	5799874.45	311570.60	880.45				
#SM12-044	Building	5799902.15	311481.39	875.13				
#SM12-045	Crest	5799922.13	311453.36	870.44				

TABLE 12-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P12-014	Old slide by the east river bank	5800253	311624	W	Y*	
#P12-020	Drainage ditch (south end)	5800386	311691	E	Y*	
#P12-028	Tree with the pistol butt	5800564	311617	SE	Y*	
#P12-040	Steep slope by the east river bank	5800649	311608	NW	Y*	
#P12-041	Slope and uprooted tree	5800696	311587	N	Y*	
#P12-043	Drainage ditch (north end)	5800697	311595	NW	Y*	
#P12-049	Slope along the east river bank	5800933	311479	S	Y*	
#P12-065	Old slides in the south extent of study area	5799935	311448	SW	Y*	

Notes:

* Provided in the report

All measurements in metres

Less accuracy due to tree cover

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	12	
Site Name	River Bend NE Escarpment (Red Deer County)	
Legal Land Description	SW 1-39-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	311962 E, 5800222 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 24, 2018	7	1	7
Inspected By:	Bryden Lutz - PGEO Scott Furlong - PGEO			
Report Attachments:	64 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded for the south 700 m, angular to north (where river straightens)	N/A	
Slope Movement	<ul style="list-style-type: none"> Steep area at north is showing toe and crest regression, almost no vegetation South end near sharp corner of river shows significant terracing from old failure and regression due to continual erosion. South half of site has terracing and non-vertical trees, with occasional areas of larger slumps. 	N/A	
Erosion	Deep downcutting from 2 erosions channels on slope face (see photos). Toe erosion from river at the south of site (near bend).	N/A	
Seepage	None observed	N/A	
Distress	None observed	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments:			

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none"> - South slope appears active through small slides of old terraces, with occasional slump areas that go to crest. Trees in the south lower terraced area indicate ages of at least 45 years. Trees at north end of terrace along ridge (south ½ of site) are at least 10 years old.
Assessment	<ul style="list-style-type: none"> - Crest at the south ½ to ¾ is likely stable due to large colluvium buffer at toe from previous failures. Slope below 1st terrace is considered active with potential for slides to go all the way to the crest. - Drainage downcut channels have potential to initiate large slides in adjacent areas. - North slope undergoing slow toe erosion and associated crest regression.
Recommendations	<ul style="list-style-type: none"> - No trails should connect below house at south end of site to River bend recreation area. Trails should connect east or just west of TWP 390 and run crest. Trails could be considered at 1st upper terrace but geometer may be difficult due to steep slides in area and are at risk from continued crest regression in the north and toe erosion throughout.

SITE #13

Westerner Park South of 19th Street



SITE #13 - WESTERNER PARK SOUTH OF 19 STREET

13.1 SITE DESCRIPTION

Westerner Park is located in south Red Deer at 4847 - 19th Street, as shown on Figure 1 of the main report. The surrounding land use is a mixture of residential subdivision to the north, commercial properties to the west and south; and a creek valley and the former City of Red Deer landfill to the east. Highway 2 is located 150 m west of the Westerner. The park development includes the central building complex housing the Centrium and several exhibition halls; the race track and grandstand along the south side of the park, and several out buildings along the east property line behind the exhibition halls. The west and north areas of the site are parking lots with a couple of smaller buildings including the Westerner Park Offices. A small campground is located in the north east corner of the site.

The subject area for this study is along the top of bank area on the west side of the Piper Creek valley in close proximity to several of out buildings, as shown on the Site Plan (Figure 13-1). Piper Creek meanders within a 100 to 200 m wide valley and two of the meander loops come to the base of the west creek valley slope near the Westerner property line. A 2016 Contour Plan is provided on Figure 13-2. Cross-sections of these creek banks are provided on Figure 13-3. The elevation at the top of the slope is about 887 to 888 m and the toe is about 884 m, so the creek valley slope is about 3 to 4 m high. The average inclination from creek flood plain to crest ranges from 1.9H:1V to 11H:1V as shown on Figure 13-3. Aerial photographs are provided on Figure 13-4. The maintenance buildings are separated from the crest by a narrow vegetated strip of grass and trees. Most of the valley slopes are also vegetated with brush and grass. Representative photographs from the site are provided on Figure 13-5.

13.2 REFERENCES

There is considerable geotechnical information available for the Westerner Park development to the west of the site, but no site specific reference reports are available along the creek valley.

13.3 2018 REVIEW

Aerial photography is provided on Figure 13-4 for the years listed in the following table. Aerial photographs going back to the 1960's show the creek channel in this area has been relatively stable for the past fifty years.

TABLE 13-1: AERIAL PHOTOGRAPHS

Year	Description
2001	Shows the site condition 18 years ago
2016	Shows the present Site #13 condition.

The Westerner Park site was visited on October 31 and November 15, 2018. A copy of the field inspection record is attached at the end of this appendix.

The ortho-contours from 2016 City aerial photography was reviewed for this study. A control survey of the site was performed in 2018. A record of survey control points and data for Site #13 is appended in Table 13-4. A reference drawing of survey points is provided on Figure 13-6.

Selected site photographs from 2018 are provided on Figure 13-5. A reference drawing of photograph locations on Figure 13-7.

13.4 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

On October 17, 2018, three boreholes were drilled at the site to depths up to 9.5 m below grade. The borehole locations are shown on Figure 13-1. Stand pipes were installed in Boreholes 1 and 3. They were measured at completion of drilling and on November 15, 2018. The ground surface elevations at the boreholes were surveyed using a Trimble GeoXH 2008 Series GPS receiver and a Trimble Zephyr GPS antenna.

13.5 SUBSURFACE PROFILE

Historically, this area of south Red Deer was covered with a number of large sand dune formations which overlay the native glacio-lacustrine deposits common to the Glacial Lake Red Deer footprint. Most of these sand deposits have been used for local site development and construction, including the site development of Westerner Park in the 1980's. Remnants of these surficial deposits are typically found in at the Westerner site.

The 2018 boreholes were drilled in both pavement and landscaped areas at this site. The soil profile encountered was in descending order: asphalt and gravel pavement and/or sand; silty clay and clay till with sand lenses. Borehole profiles for the slope is shown on cross sections in Figure 13-3. The detailed soil conditions encountered at the borehole locations are described on the borehole logs provided in this appendix. The terminology and symbols used on the borehole logs are provided in Appendix C. The following is a brief description of the soil types encountered.

1. **Pavement Structure.** Asphalt Pavement 60 mm thick over 240 mm of gravel was encountered in Borehole 13. A 200 mm thick layer of surficial gravel was encountered in Borehole 2 and 3.
2. **Clay Fill.** Clay fill was encountered below the asphalt or gravel pavement structure in Borehole 2 and 3. The fill layer was about 200 to 400 mm thick. The firm medium plastic clay contained some silt, little to some sand and trace gravel.

3. **Sand.** Sand was encountered down to an elevation of about 887m or about 0.3 to 0.6 m below grade extended to an elevation of about 883 to 885 m. The silty sand deposits were fine grained and compact. The moisture content of the deposits ranged from 8 to 19 percent.
4. **Silty Clay.** Clay was encountered below the sand in each borehole at an elevation of about 883 to 885 m and extended to an elevation of about 882 to 883 m. The firm, low to high plastic soils had moisture contents of the deposits ranged from 15 to 26 percent.
5. **Till.** Till was encountered below the sand and clay at an elevation of 882 to 883 m in all boreholes and extended beyond the depth drilled. The till was a mixture of varying amounts of clay, sand, silt and gravel and with occasional coal inclusions. The sand till was dense to very dense with moisture contents ranged from about 10 to 17 percent.
6. **Till Inclusions.** Thick sand lenses were encountered within the till in Boreholes 1 and 2.
7. **Groundwater.** Groundwater levels in Nov 2018 were 3.9 to 4.6 mbg with an elevation ranging from 882.8 to 883.7 m. Seasonal perched groundwater is expected in upper sandy soils.

The following effective strength parameters were assumed for this site.

TABLE 13-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Clay Fill	18	0	24 - 26
Sand	19	0	30 - 32
Clay	18	0 - 2	25 - 28
Sand Till	22	0 - 5	30 - 35

13.6 BACKGROUND AND SLOPE ISSUES

There are no known records of slope instability in this location since the Westerner Park area was developed; and no obvious signs of instability were detected during the site visits on in October and November, 2018. The vegetation on the slope face below the property is heavy. The trees in the area are generally growing straight vertical. The concern at this slope is the proximity of the Westerner buildings to the crest of the creek valley; and whether a possible landslide event is likely to impact building foundations.

13.7 REVIEW OF STABILITY ASSESSMENT

Stability analysis against landsliding was carried out using the SLOPE/W computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 13-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Shallow Slope Face Failure	1.1	-
A Point About 4 m From Crest	1.5	Figure 13-8
At Existing Building (5 m from crest)	~ 1.6	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

The long-term assessment at this site is that the potential for a slope movement is low under present normal conditions with reasonable variation and the risk of ongoing face regression has been reduced. The FS against a small shallow “slump-type” failure on the slope face is estimated to be at least 1.1. Isolated small slumps are considered to be the most likely mode of slope failure. but with the present vegetation cover it would take unusually wet conditions combined with bank under mining by the creek to cause a shallow slump in the slope face. For the representative slope profile under reasonably adverse soil moisture and groundwater conditions, a point about 4 m back from the current location of the crest is considered to be stable in the long-term. The risk to the building which is more than 5 m from the crest is considered to be low.

13.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(7) * CF(2) = 14$$

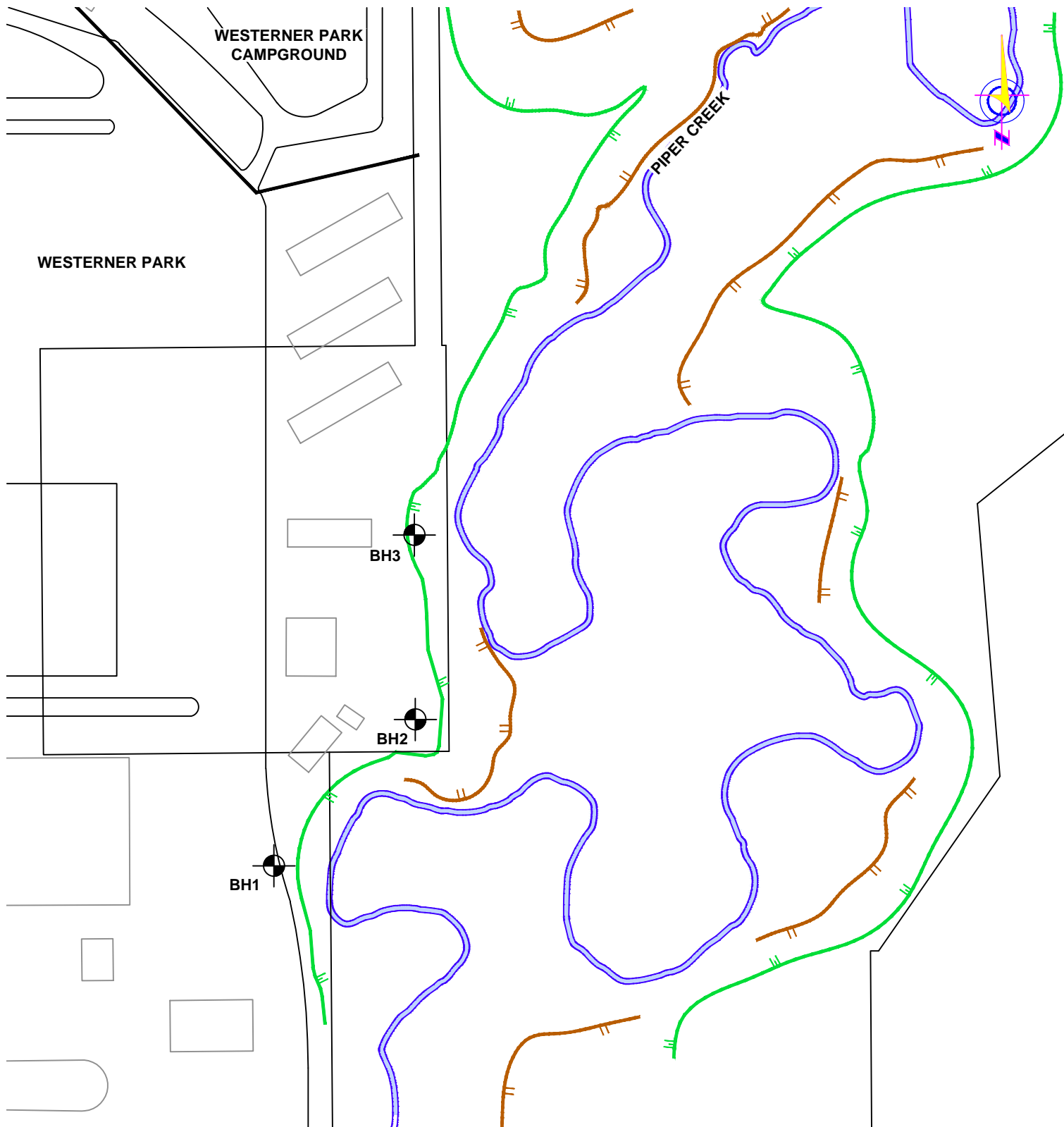
A Probability Factor of 7 is considered appropriate since there is no active slide at the site and the potential for a slide is considered to be moderate. A Consequence Factor of 2 is considered appropriate since the expected size of landslide in the creek bank at this site might impact the fence line, but would not affect the nearby structures.

13.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an “as required” basis to identify any significant changes (e.g. after major flood events). Inspections should include control surveys along the crest relative at fixed points to verify regression rates, if observed.

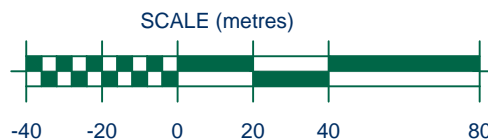
13.10 ATTACHMENTS

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Figure 13-8 - Stability Analysis Run
Table 13-4 - List of Survey Markers
Table 13-5 - List of Photographs
Borehole Logs for 18-01 to 18-03
Site Inspection Record (October 30, 2018)



- CREST OF SLOPE
- TOE OF SLOPE
- EXISTING BUILDING
- 2018 BOREHOLE LOCATIONS

ALL BOREHOLE LOCATIONS ARE APPROXIMATE.



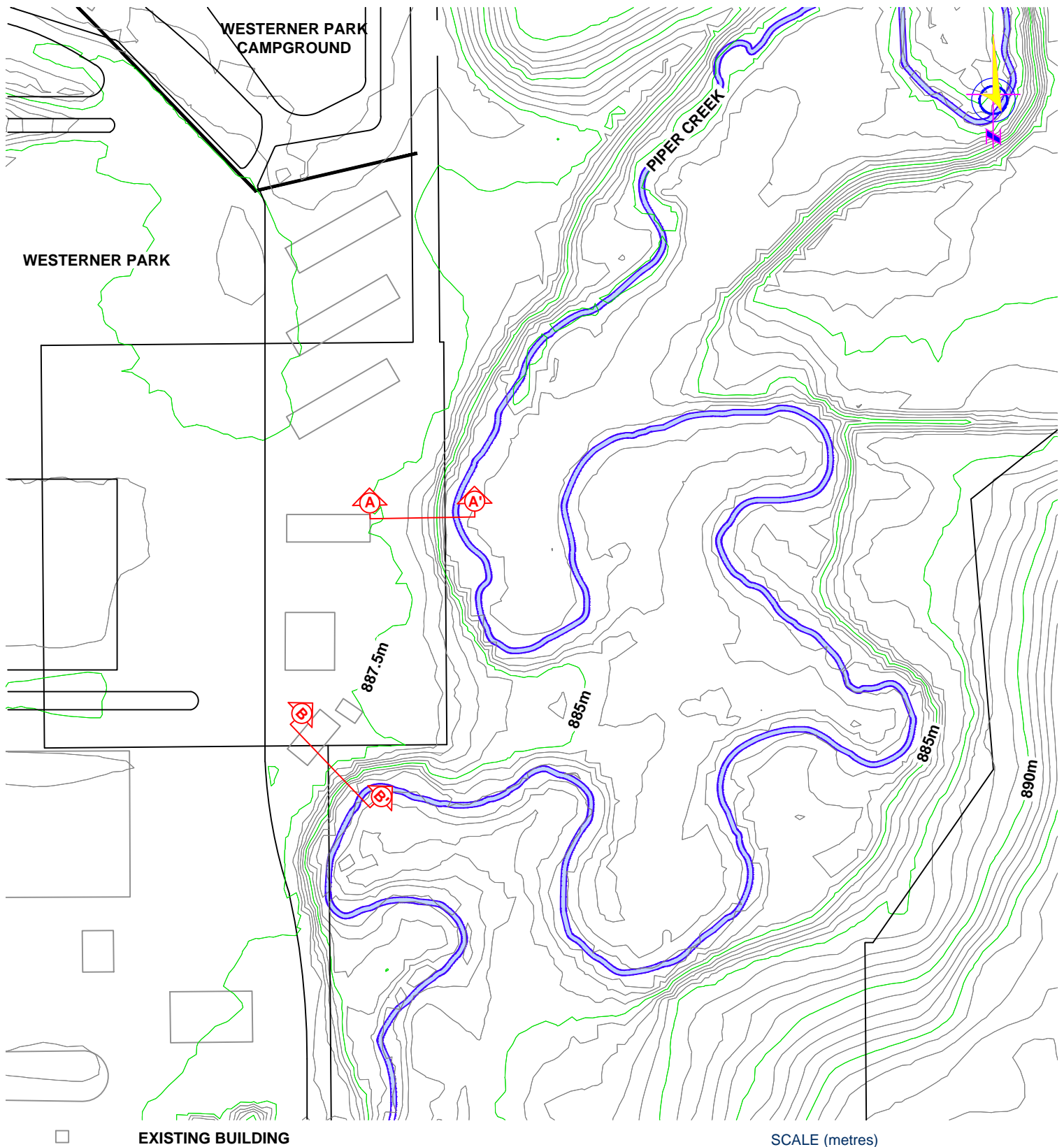
CLIENT:



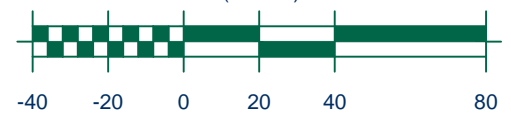
SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION WESTERN PARK

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-13	DRAWING NO. FIGURE 13-1	



SCALE (metres)



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT



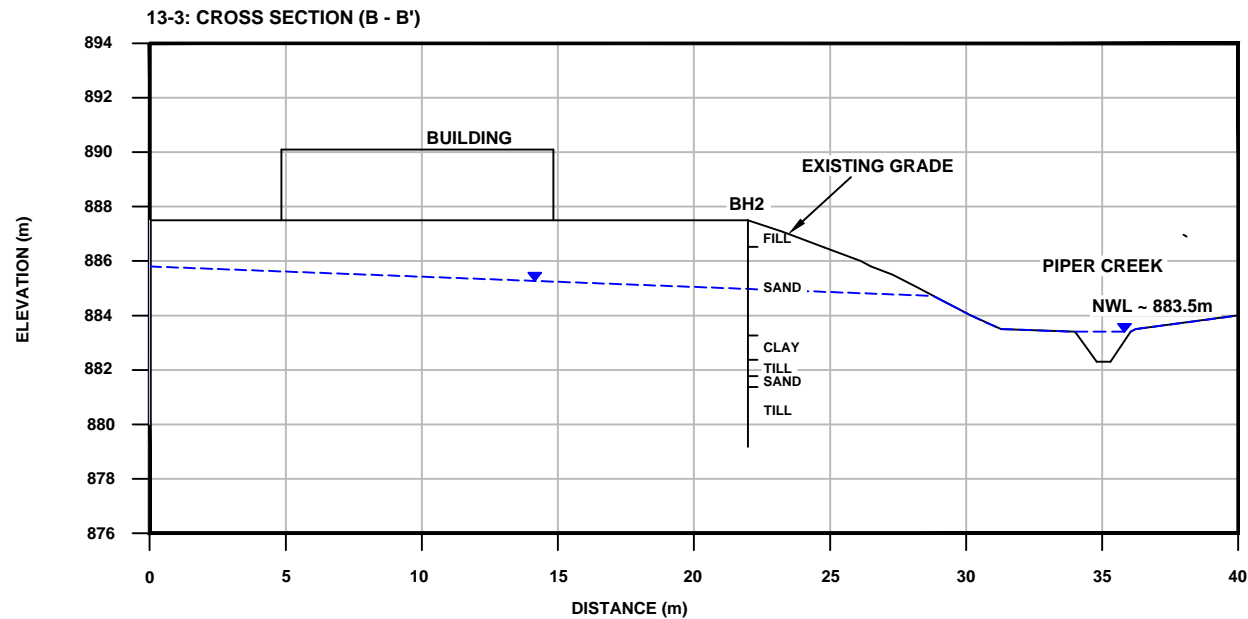
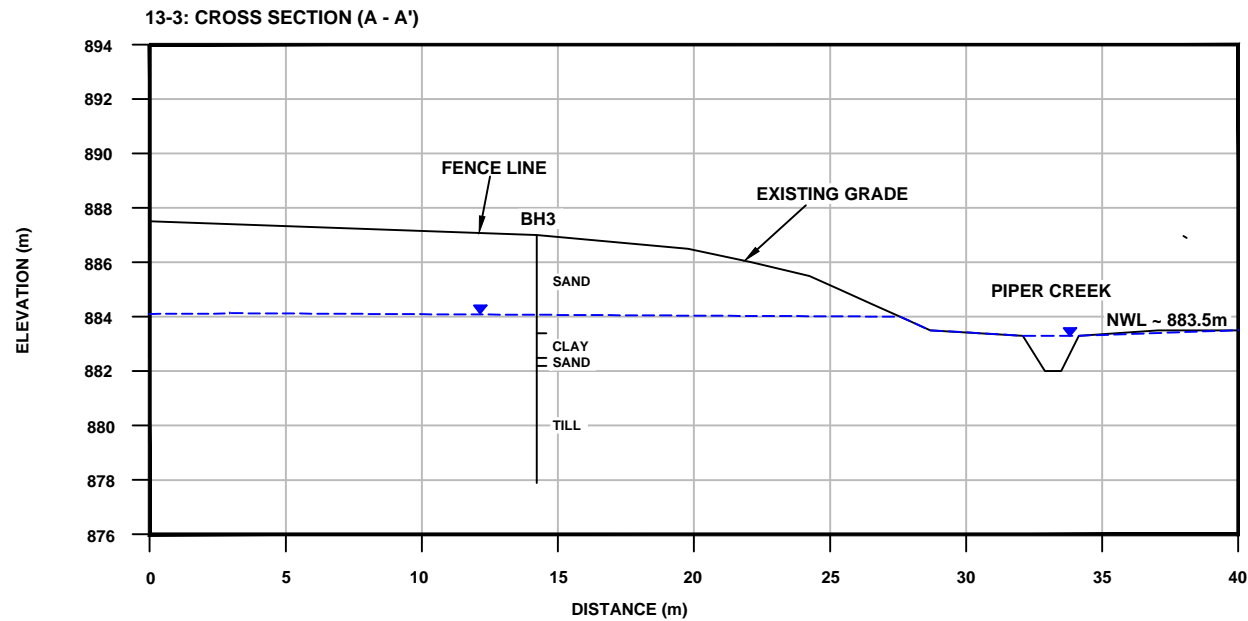
CLIENT:



CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
WESTERN PARK

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-13	DRAWING NO. FIGURE 13-2	



2016 ORTHO PROVIDED BY THE CLIENT.



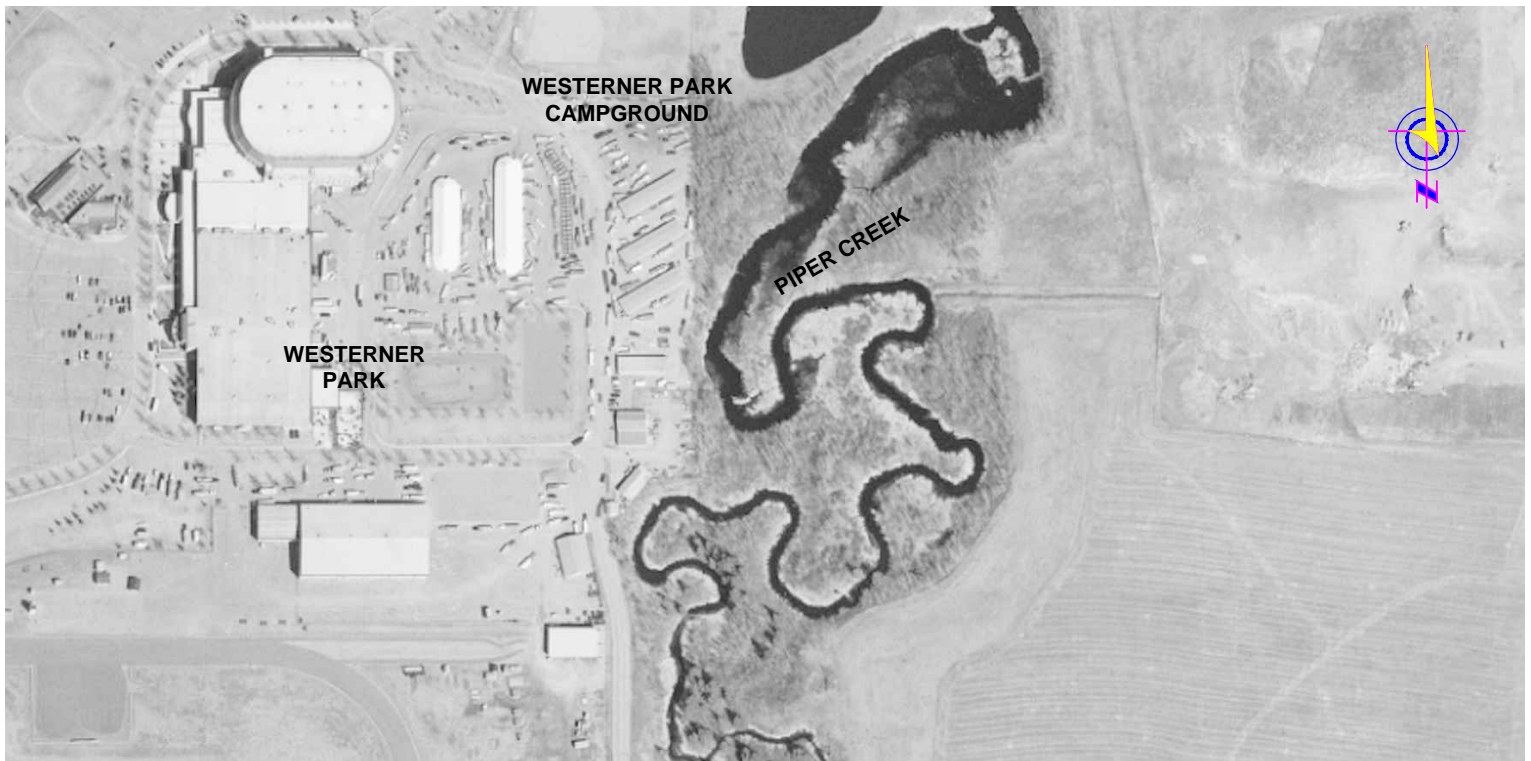
CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
WESTERNER PARK

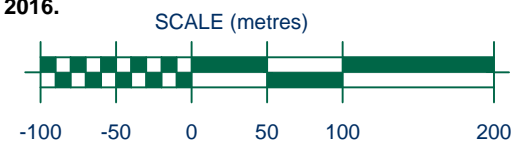
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-13	DRAWING NO. FIGURE 13-3	





NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001 (SITE IS IN SPRING FLOOD).



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION WESTERNER PARK			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:5000	JOB NO. RD6500-13	DRAWING NO. FIGURE 13-4	



PHOTOGRAPH 1 (2018): SLOPE AT NORTH END OF STUDY AREA, FACING WEST AT PIPER CREEK AND SLOPE FROM FLOOD PLAIN



PHOTOGRAPH 45 (2018): SLOPE AT SOUTH END OF STUDY AREA, FACING NORTH ACROSS PIPER CREEK AT SLOPE AND WESTERNER PARK MAINTENANCE BUILDING FROM FLOOD PLAIN

	<p>CLIENT:</p> 	<p>SITE 13 PHOTOGRAPHS</p>			
		<p>CITY OF RED DEER SLOPE STABILITY EVALUATION WESTERNER PARK</p>			
		<p>DRAWN:</p> <p>PS</p>	<p>CHK'D.:</p> <p>MDB</p>	<p>REV #:</p> <p>2</p>	<p>DATE:</p> <p>APRIL 2019</p>
		<p>SCALE:</p> <p>NTS</p>	<p>JOB NO.</p> <p>RD6500-13</p>	<p>DRAWING NO.</p> <p>FIGURE 13-5A</p>	

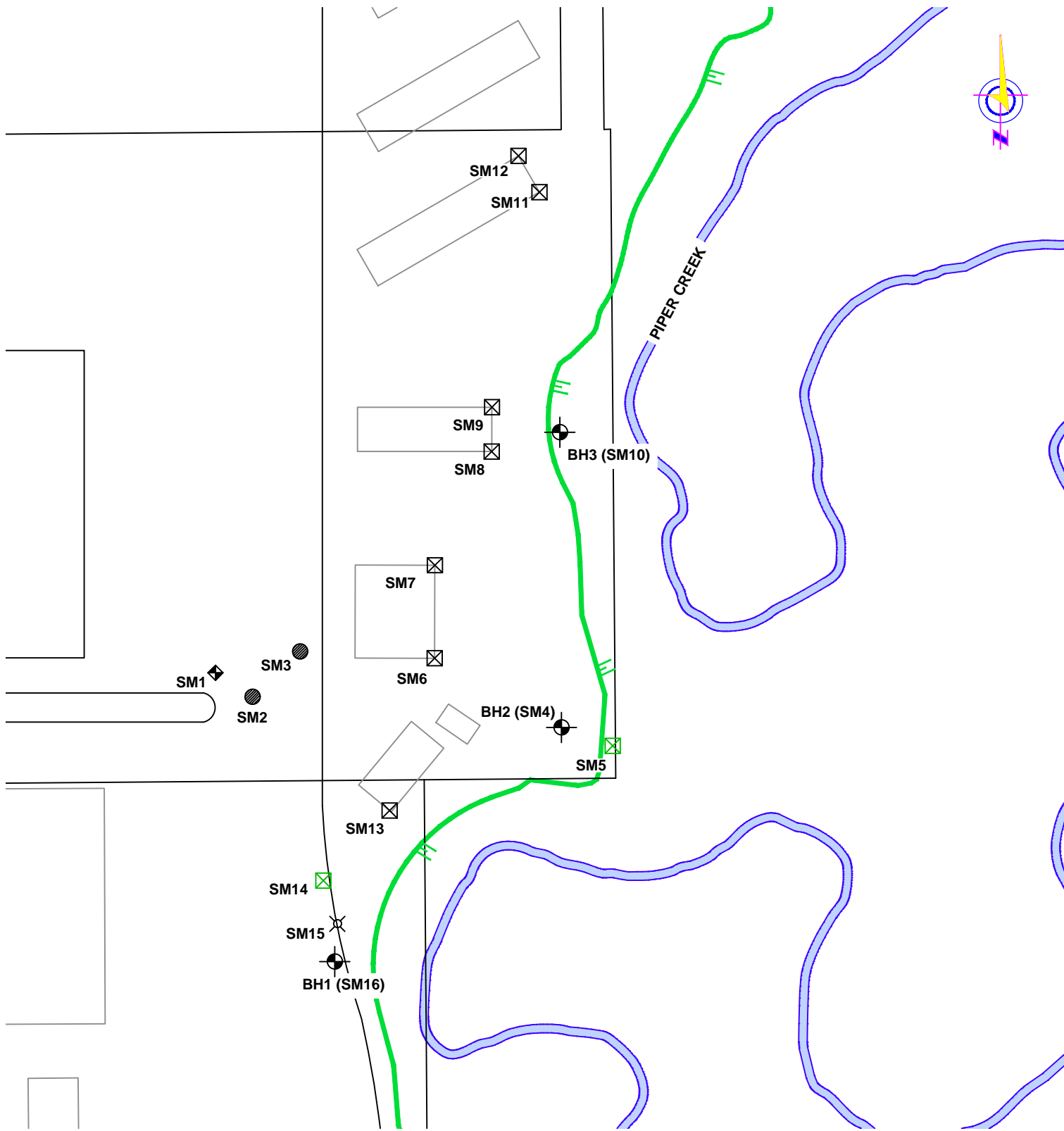


PHOTOGRAPH 52 (2018): SOUTHWEST BANK AND ELBOW OF PIPER CREEK AT SOUTH END OF STUDY AREA, FACING SOUTHWEST

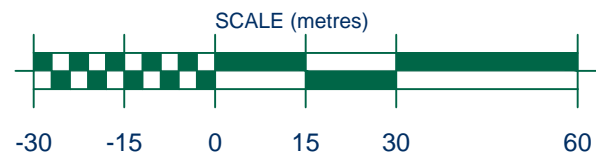


PHOTOGRAPH 58 (2018): PIPER CREEK SLOPE AND FLOOD PLAIN FROM TOP OF CREEK VALLEY (BEHIND MAINTENANCE BUILDING), FACING SOUTHWEST AT SOUTH END OF SOUTH AREA

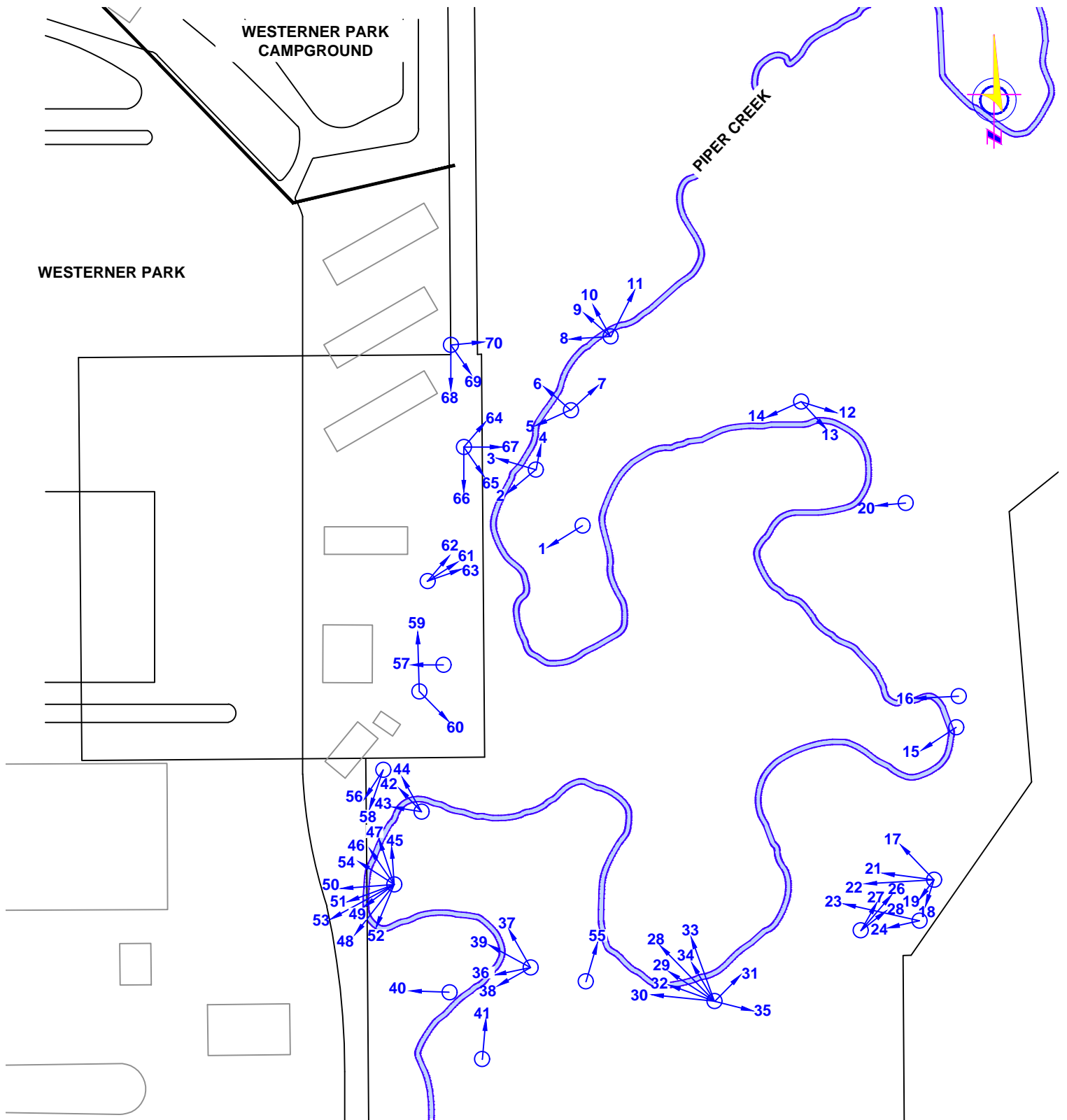
	CLIENT:			SITE 13 PHOTOGRAPHS			
				CITY OF RED DEER SLOPE STABILITY EVALUATION WESTERNER PARK			
				DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
				SCALE: NTS	JOB NO. RD6500-13		DRAWING NO. FIGURE 13-5B



- CREST OF SLOPE
- BUILDING CORNER
- MANHOLE
- FIRE HYDRANT
- FENCE CORNER
- BOREHOLE
- LIGHT POLE



	CLIENT:					
			SURVEY MARKERS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION WESTERN PARK			
	DRAWN:	CHK'D:	REV #:	DATE:		
RS		MDB	2	APRIL 2019		
SCALE:	JOB NO.		DRAWING NO.			
1:1250	RD6500-13		FIGURE		13-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



CLIENT:



PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
WESTERNER PARK

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-13	DRAWING NO. FIGURE 13-7	






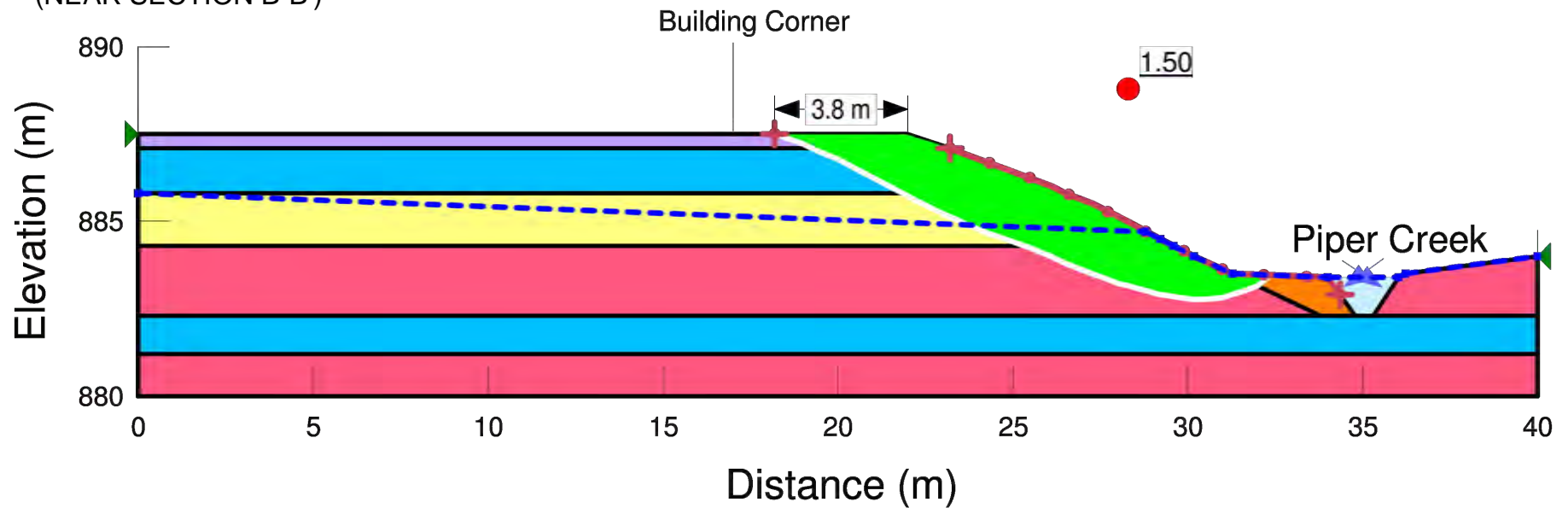
Color	Name	Unit Weight (kN/m ³)	Cohesion' (kPa)	Phi' (°)
	Clay	18	2	25
	Colluvium	18	0	25
	Fill	18	0	25
	Sand	19	0	32
	Till	22	0	35

FIGURE 13-8: SETBACK FOR GLOBAL STABILITY OF 1.5
(NEAR SECTION B-B')



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
WESTERNER PARK

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-13	DRAWING NO. FIGURE 13-8	

SITE #13 - WESTERNER PARK, SOUTH OF 19 STREET

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 13-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018						COMMENT
		NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	
#SM13-001	FH	5789902.73	308536.84	887.17				
#SM13-002	MH	5789897.08	308545.51	887.10				
#SM13-003	CB MH	5789907.73	308556.70	886.71				
#SM13-004	BH2	5789889.89	308618.09	887.25				
#SM13-005	Fence	5789887.02	308625.06	886.97				
#SM13-006	Building	5789908.28	308591.06	887.58				
#SM13-007	Building	5789930.06	308591.94	887.64				
#SM13-008	Building	5789954.89	308605.58	887.80				
#SM13-009	Building	5789967.34	308606.17	887.81				
#SM13-010	BH3	5789959.20	308617.70	887.45				
#SM13-011	Building	5790016.15	308619.39	887.74				
#SM13-012	Building	5790024.79	308614.84	887.72				
#SM13-013	Building	5789872.15	308577.61	890.36				
#SM13-014	Fence	5789853.97	308562.17	887.95				
#SM13-015	Light pole	5789843.79	308565.45	887.80				
#SM13-016	BH1	5789834.92	308564.84	887.65				

TABLE 13-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P13-001	Slope at north end of study area	5789979	308676	W	Y*	
#P13-045	Slope at south end of study area	5789826	308613	N	Y*	
#P13-052	Southwest bank and elbow of Piper Creek	5789824	308587	SW	Y*	
#P13-058	Piper creek slope and flood plain	5789885	308602	SW	Y*	

Notes:

* Provided in the report

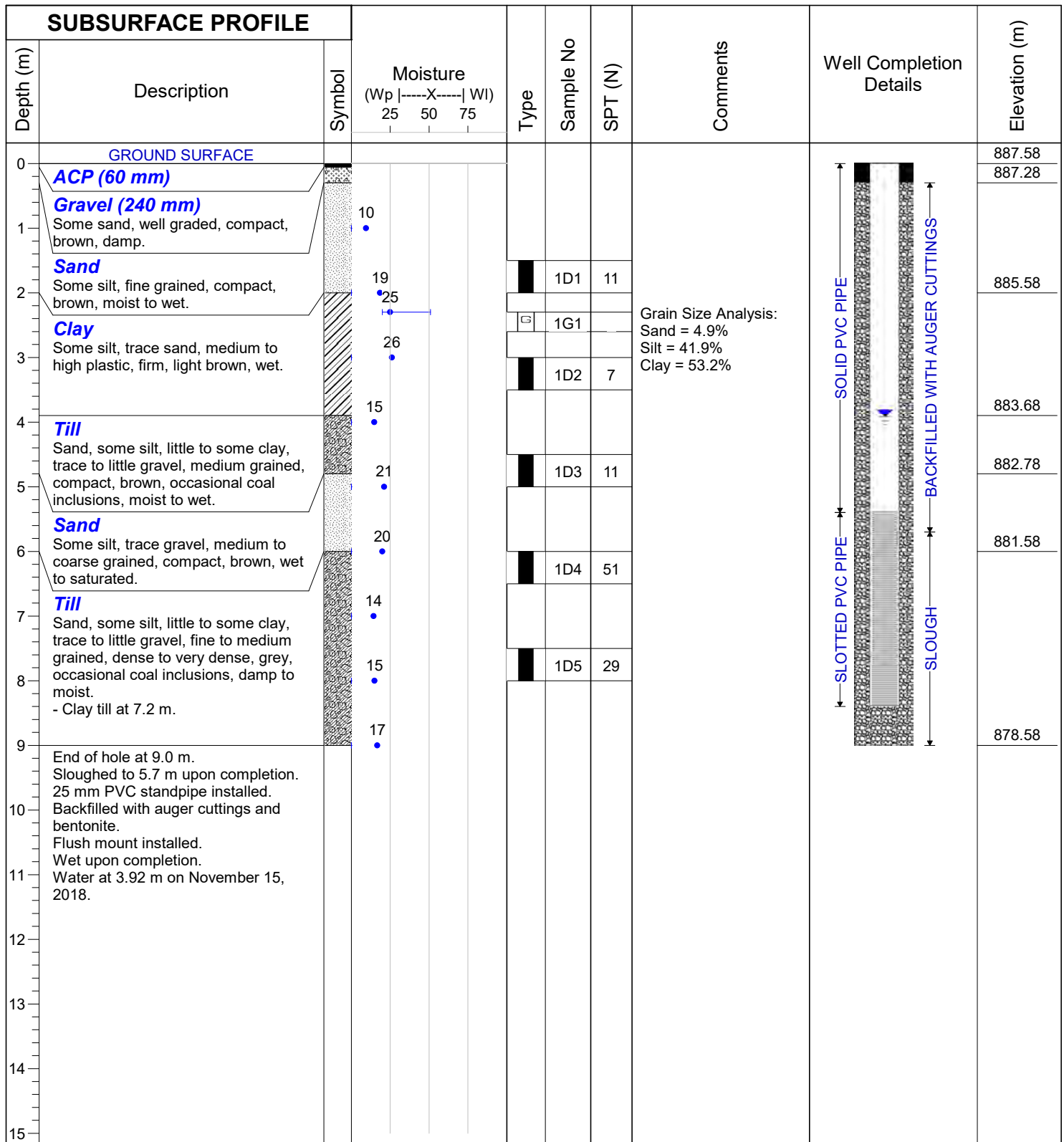
All measurements in metres



CLIENT: City of Red Deer
 SITE: Westerner Park South of 19 Street
 NOTES:

BOREHOLE NO.: 01

PROJECT NO.: RD6500-13
 BH LOCATION:



LOGGED BY: BL
 CONTRACTOR: Dark Horse Drilling Ltd.
 RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem
 DATE: October 17, 2018
 CALIBRATION:

GROUND ELEVATION: 887.58 m
 NORTHING: 5789834.99 m
 EASTING: 308565.06 m



CLIENT: City of Red Deer
 SITE: Westerner Park South of 19 Street
 NOTES:

BOREHOLE NO.: 02

PROJECT NO.: RD6500-13
 BH LOCATION:

SUBSURFACE PROFILE						Comments	Well Completion Details	Elevation (m)
Depth (m)	Description	Symbol	Moisture (Wp ----X----- WI) 25 50 75	Type	Sample No	SPT (N)		
0	GROUND SURFACE							887.17
0	Gravel Some sand, well graded, compact, brown, damp to moist.		17		2G1			886.52
1	Fill Clay, some silt, little to some sand, trace gravel, medium plastic, firm, grey, moist. - Trace organic, black staining, rootlets from 0.6 to 0.65 m.		13		2D1	7		
2			14		2G2			
3	Sand Some silt, fine grained, loose to compact, brown, damp. - Wet at 3.9 m.		19		2D2	8	Grain Size Analysis: Sand = 56.9% Silt = 23.9% Clay = 19.2%	883.27
4	Clay Some silt, trace sand, medium plastic, firm, brown, wet.		13		2D3	12		882.37
5	Till Sand, some silt, little to some clay, trace to little gravel, fine grained, compact to dense, brown, occasional coal inclusions, damp to moist.		10					881.77
6			17					881.37
7	Sand Some silt, medium to coarse grained, compact, grey, wet to saturated.							
8	Till Sand, some silt, little to some clay, trace to little gravel, fine grained, dense to very dense, grey, occasional coal inclusions, damp to moist. - Clay till at 7.1 m.				2D4	22		879.17
9	End of hole at 8.0 m. Backfilled with auger cuttings and bentonite cap. Wet upon completion.							
10								
11								
12								
13								
14								
15								

LOGGED BY: BL
 CONTRACTOR: Dark Horse Drilling Ltd.
 RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem
 DATE: October 17, 2018
 CALIBRATION:

GROUND ELEVATION: 887.17 m
 NORTHING: 5789889.91 m
 EASTING: 308618.13 m

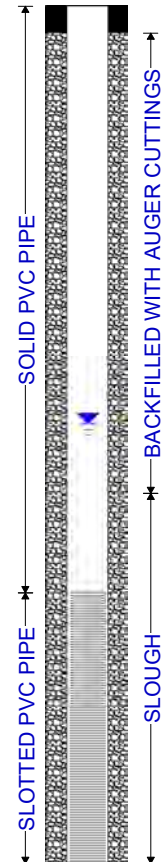


CLIENT: City of Red Deer
 SITE: Westerner Park South of 19 Street
 NOTES:

BOREHOLE NO.: 03

PROJECT NO.: RD6500-13
 BH LOCATION:

SUBSURFACE PROFILE						Comments	Well Completion Details	Elevation (m)
Depth (m)	Description	Symbol	Moisture (Wp ----X---- WI) 25 50 75	Type	Sample No	SPT (N)		
0	GROUND SURFACE							887.39
0	Gravel Some sand, well graded, compact, brown, damp to moist.							886.99
1	Fill Clay, some silt, little to some sand, trace gravel, medium plastic, firm, grey, moist.				3D1	10		
2	Sand Some silt, fine grained, compact, brown, dry to damp. - White brown at 0.6 m.				3D2	13	Grain Size Analysis: Sand = 59.3% Silt = 26.4% Clay = 14.3%	
3								
4	Clay Some sand, some silt, low plastic, firm, brown, wet. - Trace sand, medium plastic at 4.7 m.				3D3	12		883.39
5								882.49
6	Sand Some silt, coarse grained, compact, brown, wet to saturated.				3D4	33	Grain Size Analysis: Sand = 44.4% Silt = 44.7% Clay = 11.0%	882.09
7	Till Sand, some silt, little to some clay, trace to little gravel, fine to medium grained, dense to very dense, brown, damp to moist.							
8	- Clay till at 8.0 m.							
9	- Sand till at 9.2 m.				3D5	61		877.89
10	End of hole at 9.5 m. Sloughed to 5.4 m upon completion. 25 mm PVC standpipe installed. Backfilled with auger cuttings and bentonite cap.							
11	Wet upon completion. Water at 4.63 m on November 15, 2018.							
12								
13								
14								
15								



LOGGED BY: BL
 CONTRACTOR: Dark Horse Drilling Ltd.
 RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem
 DATE: October 17, 2018
 CALIBRATION:

GROUND ELEVATION: 887.39 m
 NORTHING: 5789959.16 m
 EASTING: 308617.75 m

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Site Number	13	
Site Name	Westerner Park – Piper Creek	
Legal Land Description		
Address	4847A 19 th Street, Red Deer	
UTM Coordinates (approx. site center)	308600 m E, 578990 m N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	2
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 31, 2018	7	2	14
Inspected By:	Bryden Lutz			
Report Attachments:	70 site photos taken 3 Borehole Logs			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded		
Slope Movement	None observed		
Erosion	Piper creek located at toe, no evidence of recent erosion		
Seepage	None observed		
Distress	None observed		
Other			
Instrumentation:	<ul style="list-style-type: none"> Piezometer water level measure on Nov 15, 2018 with survey 		
Other Comments:	<ul style="list-style-type: none"> Possible storm water discharge pipe near slope toe on south end of site Boreholes drilled on October 17, 2018 		

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Discussion	<ul style="list-style-type: none"> - Piper creek meanders through wide creek valley with lots of sharp bends - Very sharp bend at toe of creek at south end of site on outer bank, evidence of colluvium at toe in this area about 1 to 2 m wide - No trees on slope face in 2 study areas, but trees along crest in these areas.(based on aerial this is typical of areas slopes immediately adjacent to creek) - Westerner park uses SW corner of gated maintained area as snow storage in winter
Assessment	<ul style="list-style-type: none"> - Slope appears generally stable - Small to moderate erosion of slope toes area from piper creek is expected during high water events. This erosion could cause minor slope regression in the medium to long term.
Recommendations	<ul style="list-style-type: none"> - Consideration for periodic site visits, maybe every 5 years or following high water events.

SITE #14



**Riverside Heavy Industrial Park
Former Dry Waste Site**

SITE #14 - RIVERSIDE HEAVY INDUSTRIAL PARK - DRY WASTE SITE

14.1 SITE DESCRIPTION

Site #14 is a slope of the west river valley in Riverside Heavy Industrial Park in the centre of Section 33-38-27-W4M. The site was originally part of the valley wall located as shown on the Figure 1 of the main report. The Site Plan is provided on Figure 14-1 attached.

The site has been subject to significant disturbance from the original valley wall condition. The original slope face was a clay borrow area used during the construction of the nearby sewage treatment plant and industrial subdivision in the mid-1970s. Clay material was excavated from the slope to the approximate elevation of the river valley flood plain. The west cut slope was left steepened and vegetated with short prairie grasses.

In the summer of 1991, a localized area of the cut slope experienced a rotational landslide which deposited colluvium at the base of the slope. The site was subsequently converted to a dry waste disposal site, where the dry waste material was used as a stabilizing toe berm for the cut slope. The disposal site was closed in 2011 when the dry waste was covered with a clay cap and vegetated with natural grasses. The location of the landslide is shown on Figure 14-1 and the 2016 contour drawing on Figure 14-2. A plan of the site based on 1993 slope after the landslide is provided on Figure 14-3. Profile cross-sections of the site are provided on Figure 14-4.

The site is bounded on the north and east sides by an existing drainage ditch and the Canadian National Railway line. Small slough areas are present in the immediate toe areas to the north and south. The site is surrounded to the south and east by the Riverside Heavy Industrial Park. The development above the slope to the west is part of a light industrial subdivision. The closest commercial property in this subdivision is located about 80 m from the crest of the current slope. An existing power line Right of Way is aligned parallel to the slope about 70 m from the crest. A stand of poplar trees is located between the crest and the powerline. The site development over time is shown on the aerial photos provided on Figure 14-5A and 14-5B. Six representative site photographs going back to 1992 are provided on Figure 14-6A and 14-6B.

14.2 REFERENCES

The references from Appendix B which apply to Site #14 - Riverside Heavy Industrial Site include References #65 and #66. A site investigation for the slope failure site was performed for the City of Red Deer in 1993 (Reference #65).

14.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

The site was last investigated in June 1993 when six boreholes were drilled including 1 deep borehole at the crest and 5 shallow boreholes at the base. The deep borehole was drilled to a depth of 22.5 m; the approximate elevation of the toe of the slope. The shallow holes ranged from 3.4 m to 7.0 m deep. The borehole locations are shown on Figure 14-7. This investigation was done prior to re-construction of the slope as a dry waste disposal site.

In August 1993, a topographic survey of the area was conducted by the City of Red Deer based on a geodetic datum.

No instrumentation is currently installed in at this site.

14.4 2018 REVIEW

Aerial photography is provided on Figures 14-4A and 14-4B, for the following years:

TABLE 14-1: AERIAL PHOTOGRAPHS

Year	Description
1982	Shows the site condition following the borrow activity prior to the landslide
1991	Shows the original landslide in the cut slope.
2002	Shows the dry waste site operations.
2016	Shows the present Site condition.

Site #14 was visited on October 30, 2018. A copy of the field inspection record is attached at the end of this appendix.

The site topographic information reviewed includes: historical profiles, historical ortho-contours and recent ortho-contours provided by the City of Red Deer based on 2016 aerial photography. A record of survey control points and data for Site #14 is appended in Table 14-4. A reference drawing of survey reference points is provided on Figure 14-8.

Photographs were taken during the site visits. A list of available photographs taken at this site is appended in Table 14-5. Selected site photographs from 1992, 2011, 2014 and 2018 are provided on Figure 14-6A and 14-6B; along with a reference drawing of all photograph locations which is provided on Figure 14-9.

14.5 ORIGINAL SUBSURFACE PROFILE

The slope that failed in 1991 was a cut slope created by the borrow operations during the 1970's. Therefore, the subsurface profile of the site was similar to the upland area above the slope; not profile in the river flood plain. Borrow activities removed all but about 3 m of the clay till above bedrock. The original soil profile of the slope from the crest was, in descending order; silty lacustrine clay and clay till. The soil profile encountered at the base of the slope was clay till over bedrock. In the adjacent river valley away from the toe of the slope, the soil profile is clay overlying the typical gravel deposits. The following is a brief description of the soil types at this site.

1. **Topsoil.** Topsoil deposits ranging from 50 mm and 200 mm thick were encountered at the borehole locations.
2. **Lacustrine Silt.** A 1.75 m thick layer of stiff, low plastic silt was encountered below the topsoil at the crest of the slope. This silt was relatively dry with moisture contents less than 11 percent.
3. **Lacustrine Clay.** Deposits of lacustrine silty clay with occasional layers of silt and sand layers were encountered below the silt deposits at the crest and extended to a depth of 11.4 m. The clay was medium to high plastic and stiff to very stiff. The moisture contents of this soil increased with depth from 11 to 30 percent.
4. **Clay Till.** Clay till was found below the lacustrine deposits at the crest at an elevation of about 860 m; and below the topsoil in the cut areas at the toe of the slope. This medium plastic till was very stiff to hard. Moisture contents ranged between 8 and 23 percent.
5. **Bedrock.** The local bedrock formation was encountered below the till at an elevation ranging from 843 m to 844.5 m. The local bedrock was very dense siltstone and sandstone. Moisture contents in the bedrock ranged from 4 to 16 percent.
6. **Clay Cap.** The clay cap for the former dry waste site was constructed with locally available medium to high plastic clay (glacio-lacustrine and till deposits). City Environmental Services should be contacted to verify closure records for the dry waste site.
7. **Dry Waste.** The dry waste at this site consisted of clean fill (soil and gravel), concrete, asphalt.
8. **Groundwater.** The groundwater table west of the crest is found in the lacustrine deposits about 3 to 4 m below grade at an elevation of about 868 m. The groundwater table at the crest in 1993 was at elevation 863 which is typical as the water table drops into the river valley. In the river valley, the groundwater table is typically found in the gravel layer about 3 to 4 m below grade at an elevation of about 842 m.

The following soil effective soil parameters were used to review the slope stability for this site.

TABLE 14-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Clay Cap	20	0	25
Dry Waste	22	0	35
Clay	20	2	25
Clay Till	21	5	32
Sand and Gravel	21.5	0	40
Bedrock	21	20	35

The soil profiles for the Site #14 are shown on slope cross sections on Figure 14-4. The profiles include the original pre borrow site slope, the 1991 pre-slide profile, the slide profile and the the current profile. For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix B.

14.6 BACKGROUND

The valley slope adjacent to the flood plain in this area has a height of about 22 to 25 m and the original natural slope angles were about 4H:1V prior to borrow activities in the 1970s. The borrow site slope to the west of the area had been steepened to an angle of about 2.5H:1V as shown on Figure 14-4A. The inclination of the cut was consistent for both the clay and clay till layers. The length of the steepened portion of the slope was about 250 m as shown on Figure 14-3. The base of the old borrow area was relatively level with an overall relief of 1 to 2 m sloping gently away from the toe of the slope.

During the summer of 1991, a 60 m wide landslide occurred near the centre of the steepened cut slope. The failure resulted in accumulation of colluvium at the base of the slope and a steep 6 m main scarp in the upper slope located about 10 m behind the cut slope crest. The failure area is illustrated on Figures 14-1 and 14-2; and can be seen on the 1991 aerial on Figure 14-5A.

Slope stability analysis was conducted for the failed section of cut slope. The post-landslide profile indicated that the failure zone was limited to the upper clay soils above the till. The assessment confirmed that the borrow pit slope was cut too steep for the long-term stability of the upper clay, but the till portion of the slope was expected to remain stable. This landslide was considered to be the beginning of a long-term flattening process in the upper clay cut slope. This slope was expected to gradually regress to an angle of about 3.5H:1V or 4H:1V along the entire cut face. Natural regression of the slope to 4H:1V was expected to create a final crest about 20 m west of the original cut slope crest. Based on this estimate, it was assessed the regression might extend back to the power line poles.

Stabilization measures were recommended to protect the power line. Several options were discussed and the City of Red Deer decided to reconstruct the slope using dry waste as a toe berm. Dry waste materials were used to provide short-term slope stabilization of the cut slope and allow in-filling of the base area at the toe with clean fill and dry waste material over a period of years. The facility design was based on maintaining a FS of at least 1.2. Additional development recommendations were given in Reference #66.

The site was operated from 1994 to 2011. Upon closure, the site was capped with medium plastic clay cap at least 1 m thick compacted to at least 95 percent of Standard Proctor Maximum Dry Density (SPMDD - ASTM D698). The design inclination for the outside face of the slope was 5H:1V. The 2016 survey information confirms the slope to actually be 4H:1V.

14.7 STABILITY ASSESSMENT

Previous reports provided limited historical stability information. A review of current stability against landsliding at this site was carried out using the *SLOPE/W* computer program to evaluate the FS for a representative slope profile model. The original landslide was modelled to verify the soil parameters for the native soil. It was assumed the clay cap would have soil at least as strong as the lacustrine clay. The dry waste was modelled as gravel. A drainage blanket base was provided across the base of the dry waste area and dry waste is usually quite permeable, so groundwater is not expected to impact the clay cover layer. Wetting of the clay cap will be limited to normal precipitation and snow melt infiltration and run-off.

The following table summarizes the results of the slope stability analysis for current conditions.

TABLE 14-3: 2018 SLOPE STABILITY ESTIMATE

Case	Estimated Long-term Factor of Safety	
	Shallow Failure	Deep Failure
Power Line	---	>3
Crest	2.1	2.7
Slope Face	1.8	---
Toe Area	2.7	---

The shallow slope face slump case was also checked with an infinite slope calculation which also yielded a FS of 1.8. A representative stability analysis run for the governing slope model at this site is provided on Figure 14-10 in this appendix.

Overall, Site #14 is a reconstructed former landslide site has experienced no major slope movements since the former dry waste disposal site was closed and reclaimed in 2011. The reconstructed crest and slope face of the former dry waste site is considered to be stable. Locally steepened slope face areas of the slope may be possible to subsidence from settlement of the buried dry waste, resulting in possible minor slumping of the face in the case of extreme, localized surface wetting.

14.8 RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(1) * CF(1) = 1$$

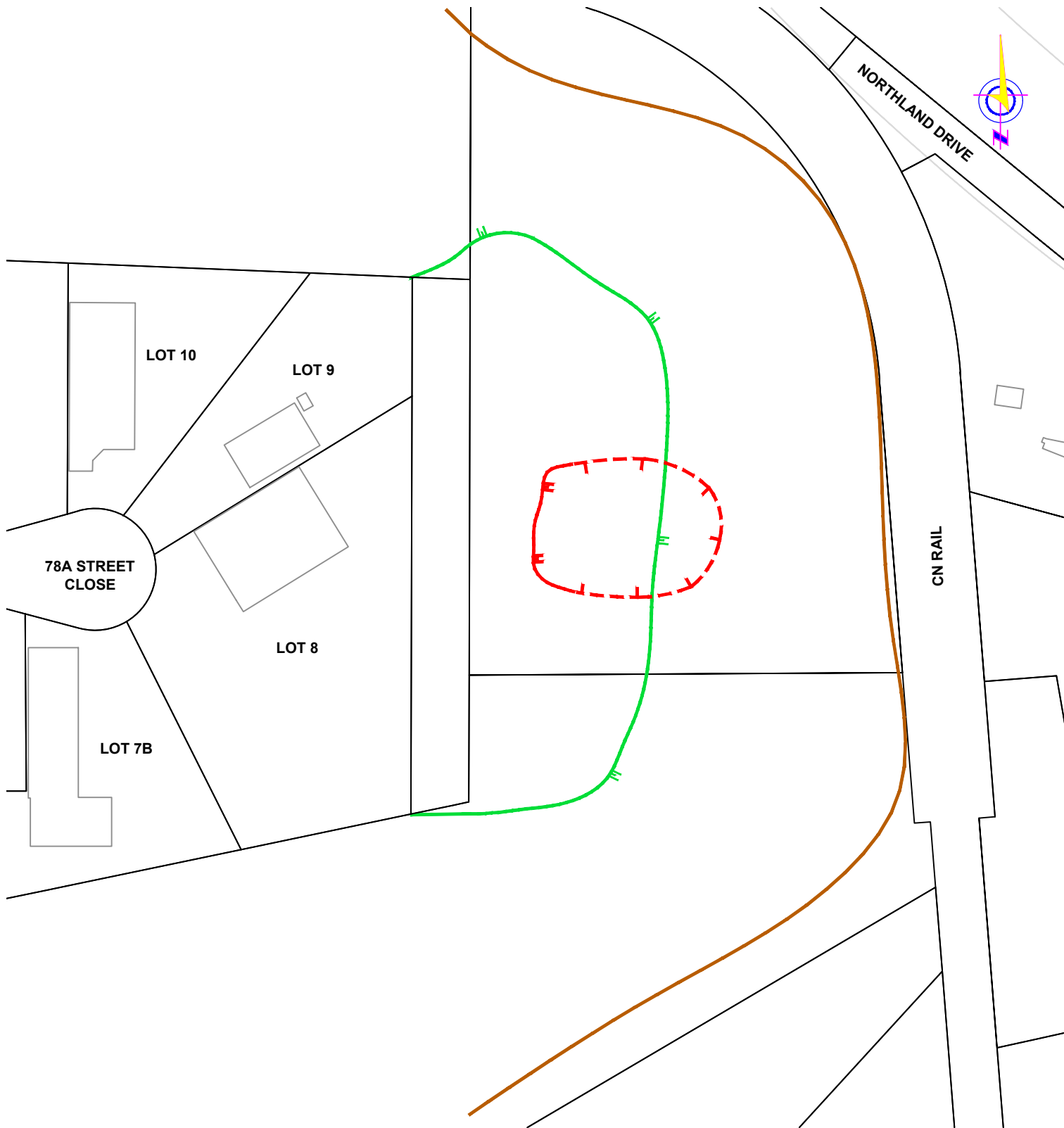
A Probability Factor of 1 is considered appropriate since the landslide site slope has been completely rebuilt as a dry wasteland. The probability of a landslide at the site is very low, although minor surface slumping of the clay landfill cap layer is possible. A Consequence Factor of 1 is considered appropriate since the expected size of slumping at this site would be localized to parkland on the slope face. The risk to the nearby rail line at the toe of the slope; the power line and private property in the upland above the slope is negligible.






14.9 RECOMMENDATIONS

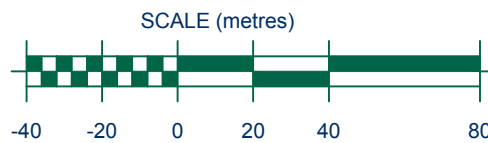
The recommended course of action at this site is to undertake visual site inspections of the slope face on an as required basis to identify any significant changes, if present.

14.10 ATTACHMENTS

Figure 14-1 - Site Plan
Figure 14-2 - 2016 Contour Plan
Figure 14-3 - 1993 Site Plan
Figure 14-4 - Cross Section Profiles
Figure 14-5 - Aerial Photographs
Figure 14-6 - Site Photographs
Figure 14-7 - Borehole Plan
Figure 14-8 - Survey Marker Plan
Figure 14-9 - Photograph Plan
Figure 14-10 - Stability Analysis Run
Table 14-4 - List of Survey Markers
Table 14-5 - List of Photographs
Site Inspection Record (October 31, 2018)



-  EXISTING BUILDING
-  CURRENT CREST OF SLOPE
-  CURRENT TOE OF SLOPE
-  1991 SLOPE FAILURE SCARP
-  1991 SLOPE FAILURE RUN-OUT



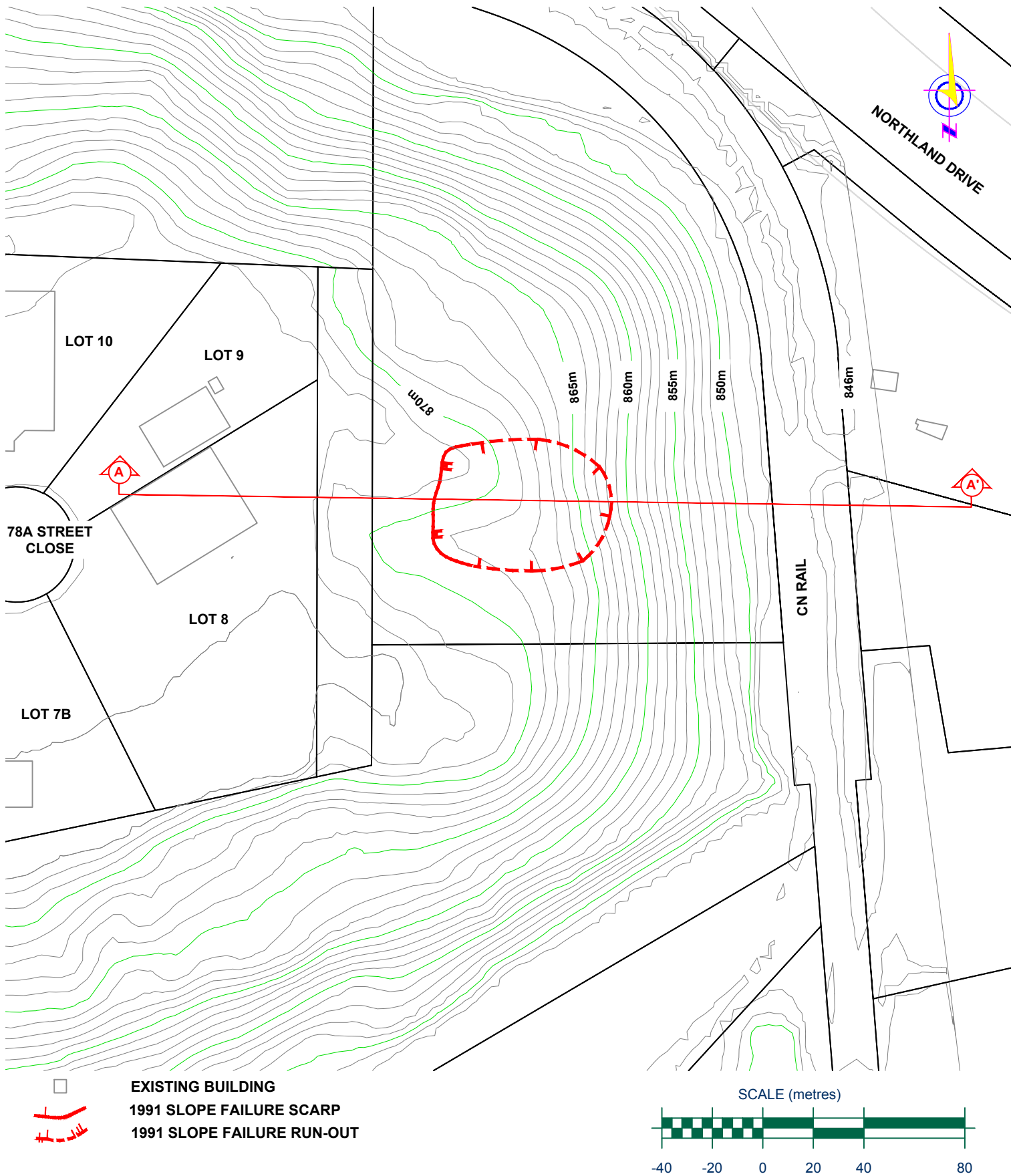
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVERSIDE HEAVY INDUSTRIAL SITE

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



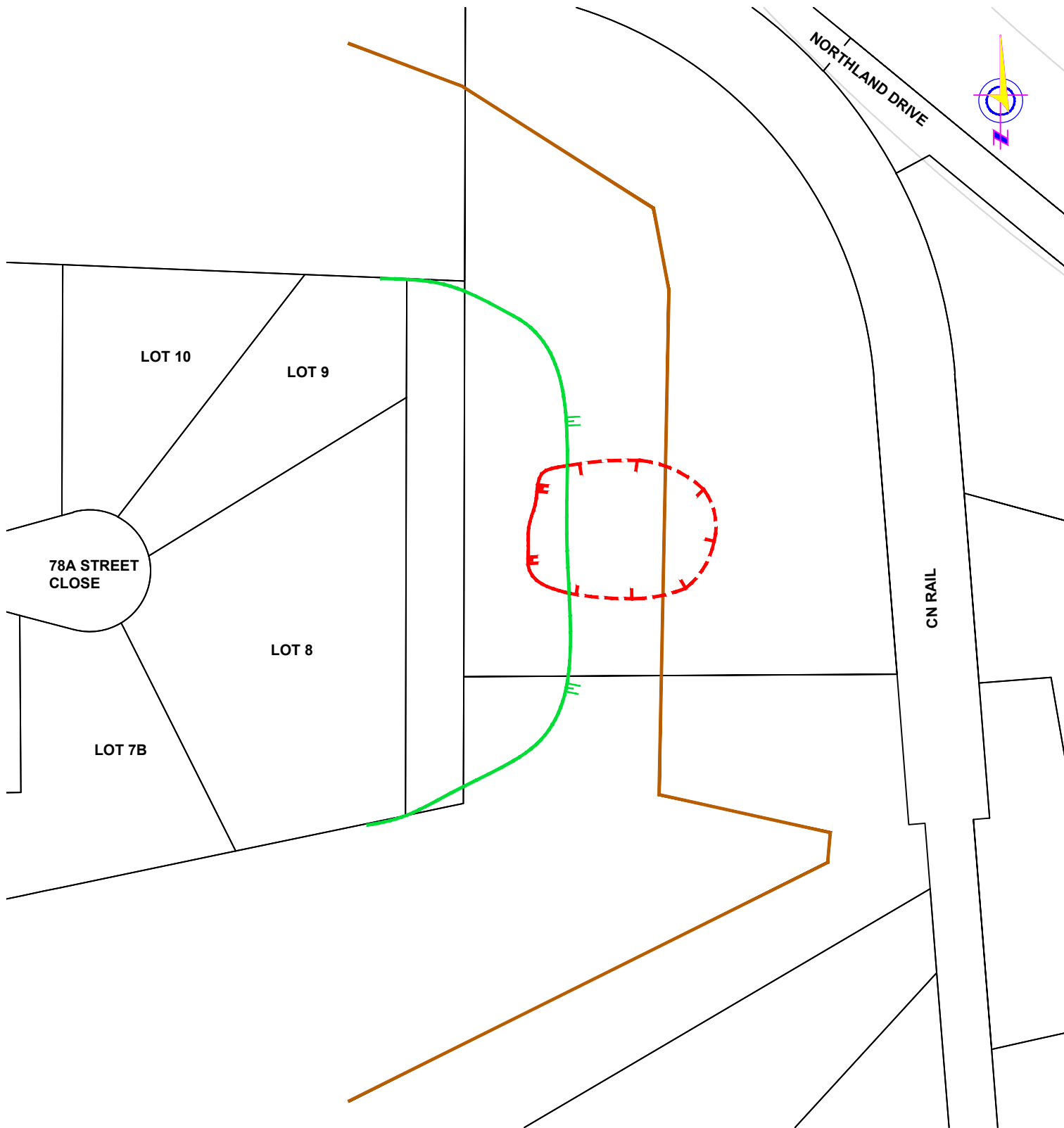
CLIENT:








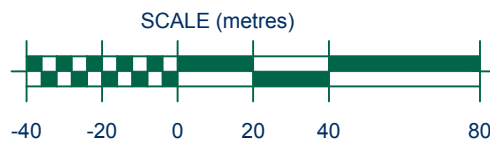
CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
 RIVERSIDE HEAVY INDUSTRIAL SITE

DRAWN: NC	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-2	



-  EXISTING BUILDING
-  CREST OF SLOPE IN 1993
-  TOE OF SLOPE IN 1993
-  1991 SLOPE FAILURE SCARP
-  1991 SLOPE FAILURE RUN-OUT



CLIENT:

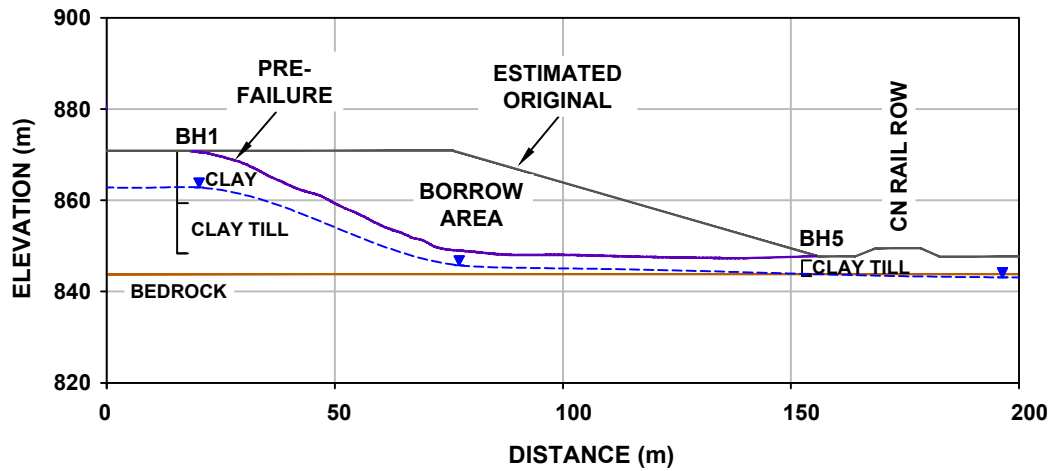


1993 SITE PLAN

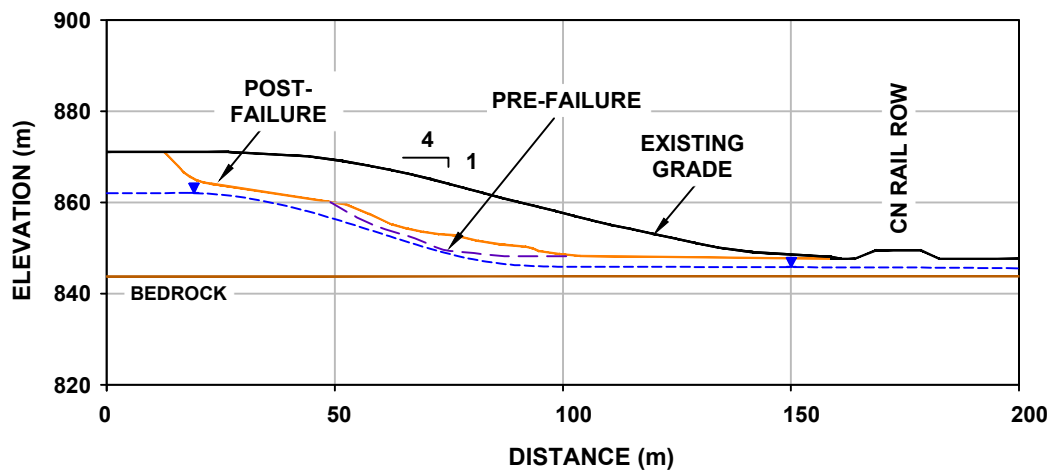
CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVERSIDE HEAVY INDUSTRIAL SITE

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-3	

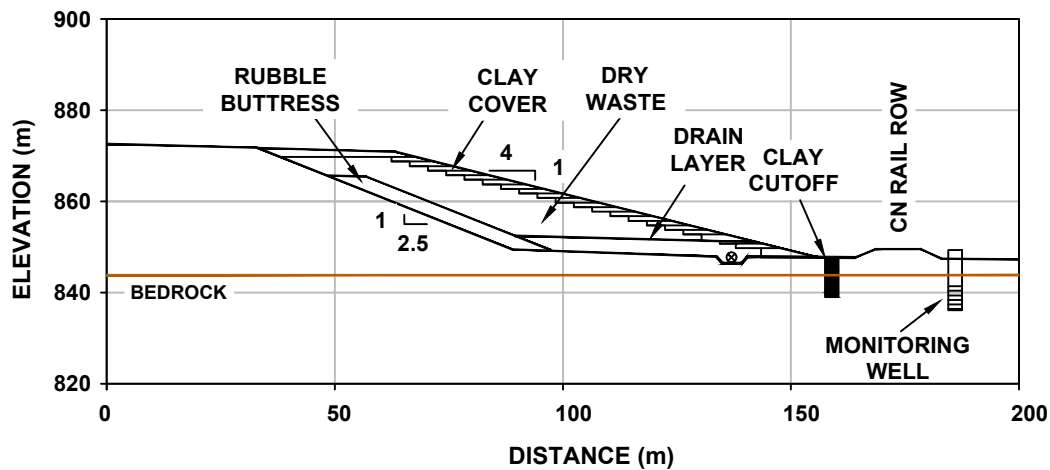
14-4A: CROSS SECTION (A - A') - ESTIMATED ORIGINAL AND PRE-FAILURE GRADE





14-4B: CROSS SECTION (A - A') - POST-FAILURE AND EXISTING GRADE



14-4C: CROSS SECTION (A - A') - DESIGN CROSS SECTION*

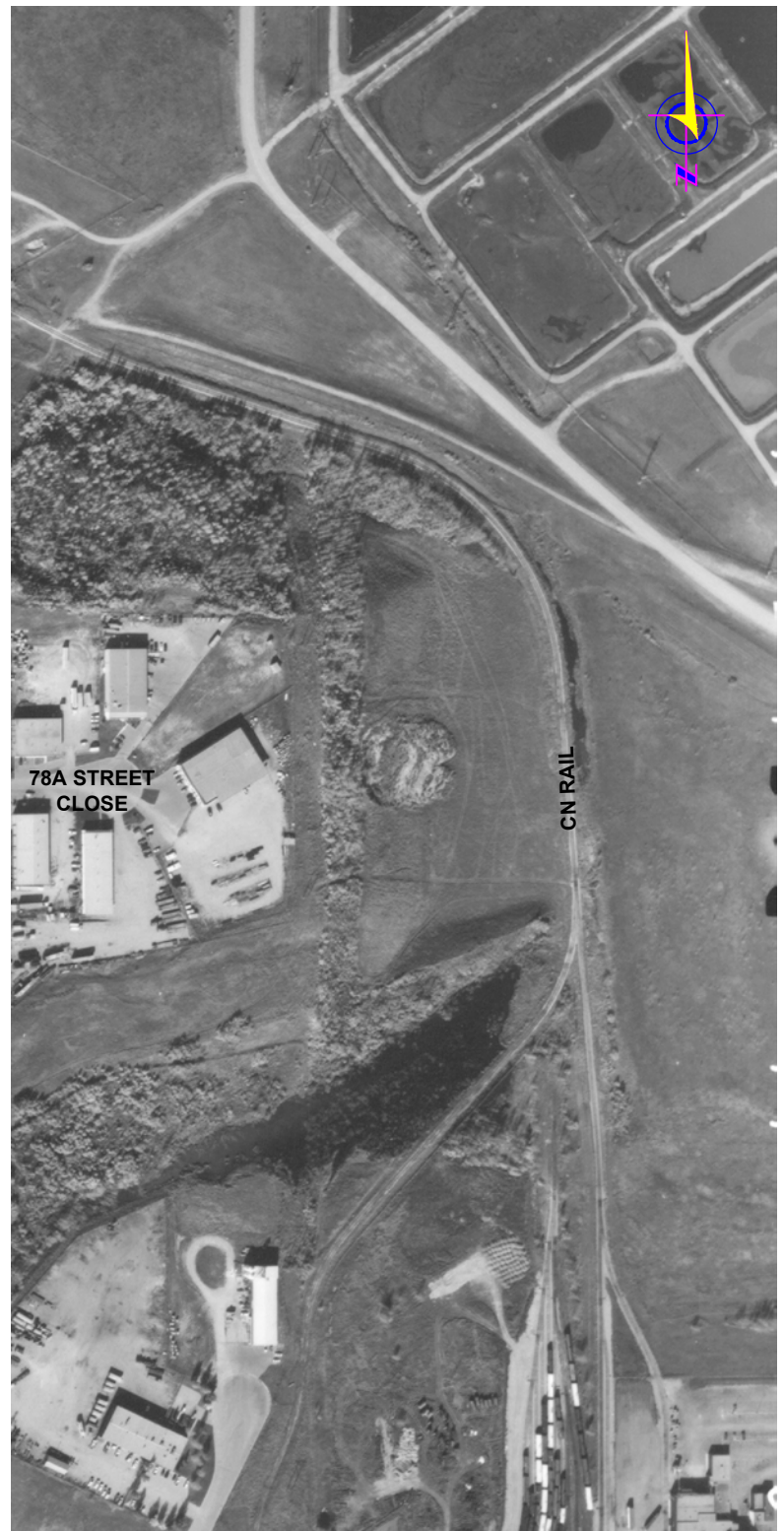


NOTES: BOREHOLES AND SCHEMATIC DESIGN CROSS SECTION FOR PROPOSED DRY WASTE DISPOSAL SITE (REFERENCE #62 AND #63)

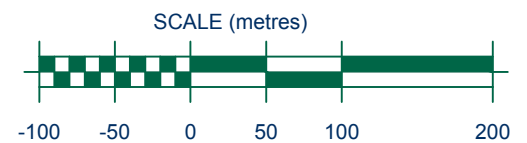
	CLIENT:		CROSS SECTION A - A'			
			CITY OF RED DEER SLOPE STABILITY EVALUATION RIVERSIDE HEAVY INDUSTRIAL			
			DRAWN:	CHK'D:	REV #:	DATE:
			NC	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
AS SHOWN		RD6500-14		FIGURE 14-4		





NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 30, 1982.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 27, 1991.

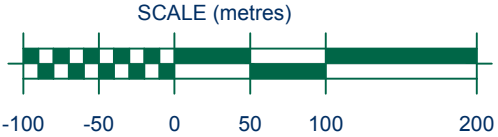


	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVERSIDE HEAVY INDUSTRIAL SITE			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:5000	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-5A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED JUNE 23, 2002.

NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVERSIDE HEAVY INDUSTRIAL SITE			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:5000	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-5B	



PHOTO 1 (2018): SLOPE AND TRANSMISSION LINE RIGHT OF WAY, TAKEN FROM WEST EDGE OF RAIL TRACKS NEAR 7794 47 AVE CLOSE, FACING NORTH



PHOTO 5 (2018): SLOPE AND SLOUGH AREA AT THE TOE, TAKEN FROM RAILWAY TRACKS, FACING NORTH



PHOTO 18 (1992): CUT SLOPE AREA AND SLOPE FAILURE, FACING SOUTHWEST (HBT AGRA)



PHOTO 19 (1992): CLOSE UP OF FAILURE, FACING SOUTHWEST (HBT AGRA)

	CLIENT: 	SITE 14 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVERSIDE HEAVY INDUSTRIAL			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-6A	

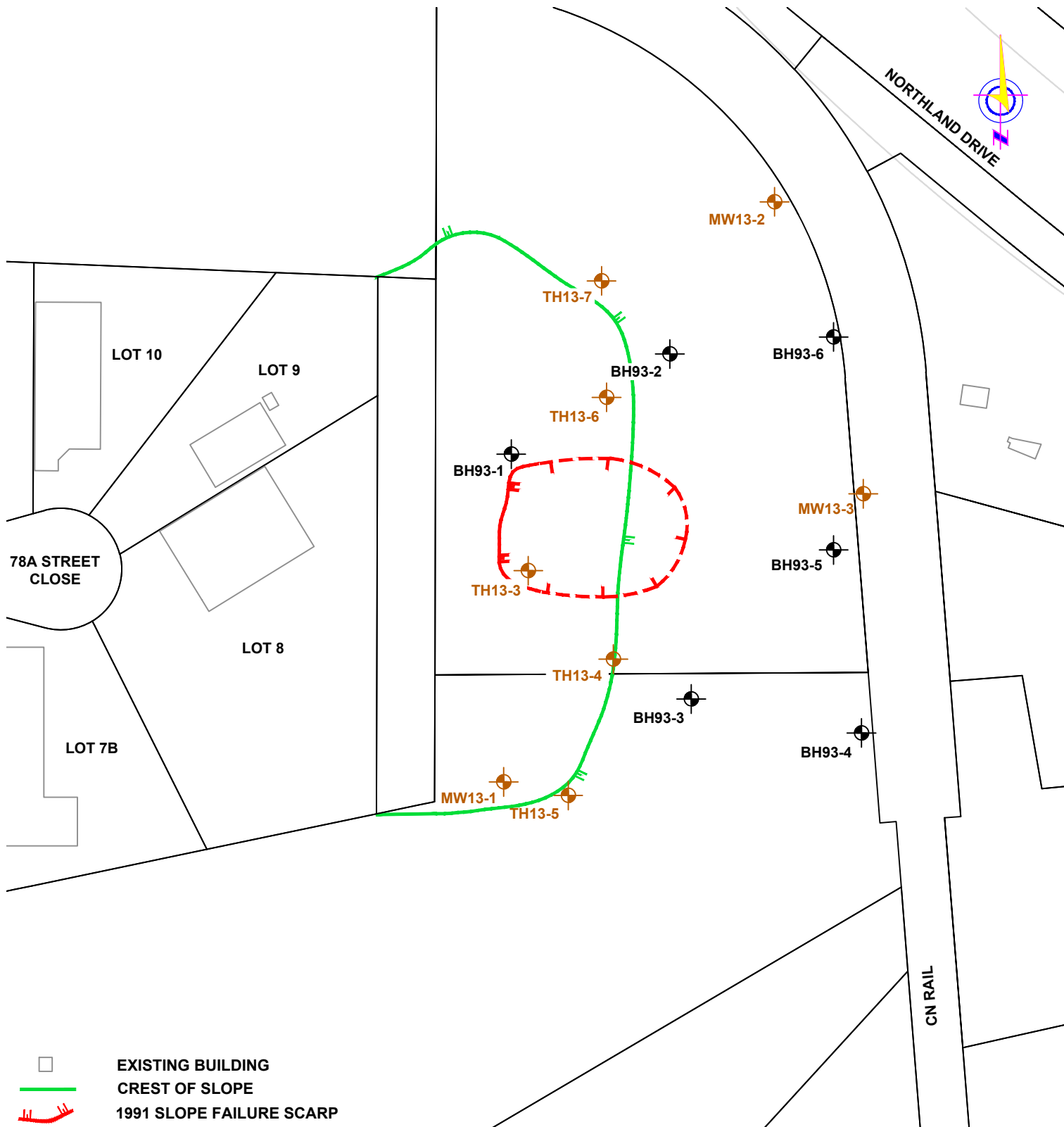


PHOTO 20 (2011): REMEDIATED SLOPE SHORTLY AFTER CONSTRUCTION, TAKEN FROM AERIAL LOCATION OVER RED DEER RIVER, FACING WEST



PHOTO 21 (2014): REMEDIATED SLOPE, TAKEN FROM AERIAL LOCATION OVER 77 STREET, FACING NORTHEAST (STANTEC)

	CLIENT: 	SITE 14 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION RIVERSIDE HEAVY INDUSTRIAL			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-6B	



- EXISTING BUILDING
- CREST OF SLOPE
- 1991 SLOPE FAILURE SCARP
- 1991 SLOPE FAILURE RUN-OUT
- 1993 BOREHOLE LOCATIONS (REFERENCE #65)
- 2013 BOREHOLE LOCATIONS (TIAMAT, FILE NO. 12-435, 2014)

ALL BOREHOLE LOCATIONS ARE APPROXIMATE.



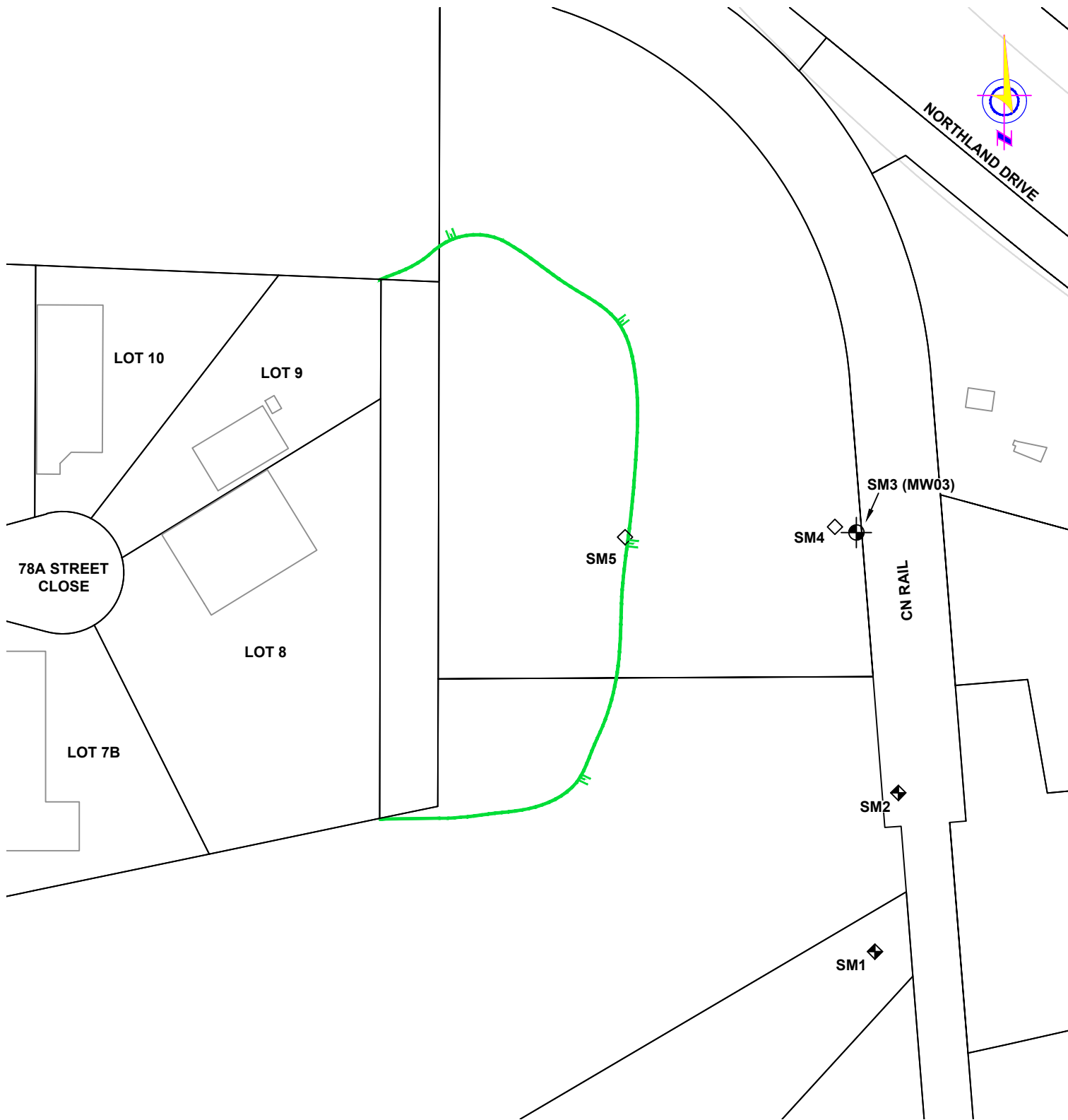
CLIENT:



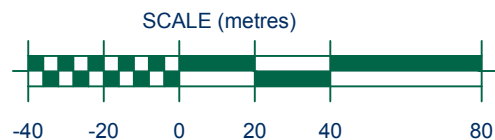
BOREHOLE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVERSIDE HEAVY INDUSTRIAL SITE

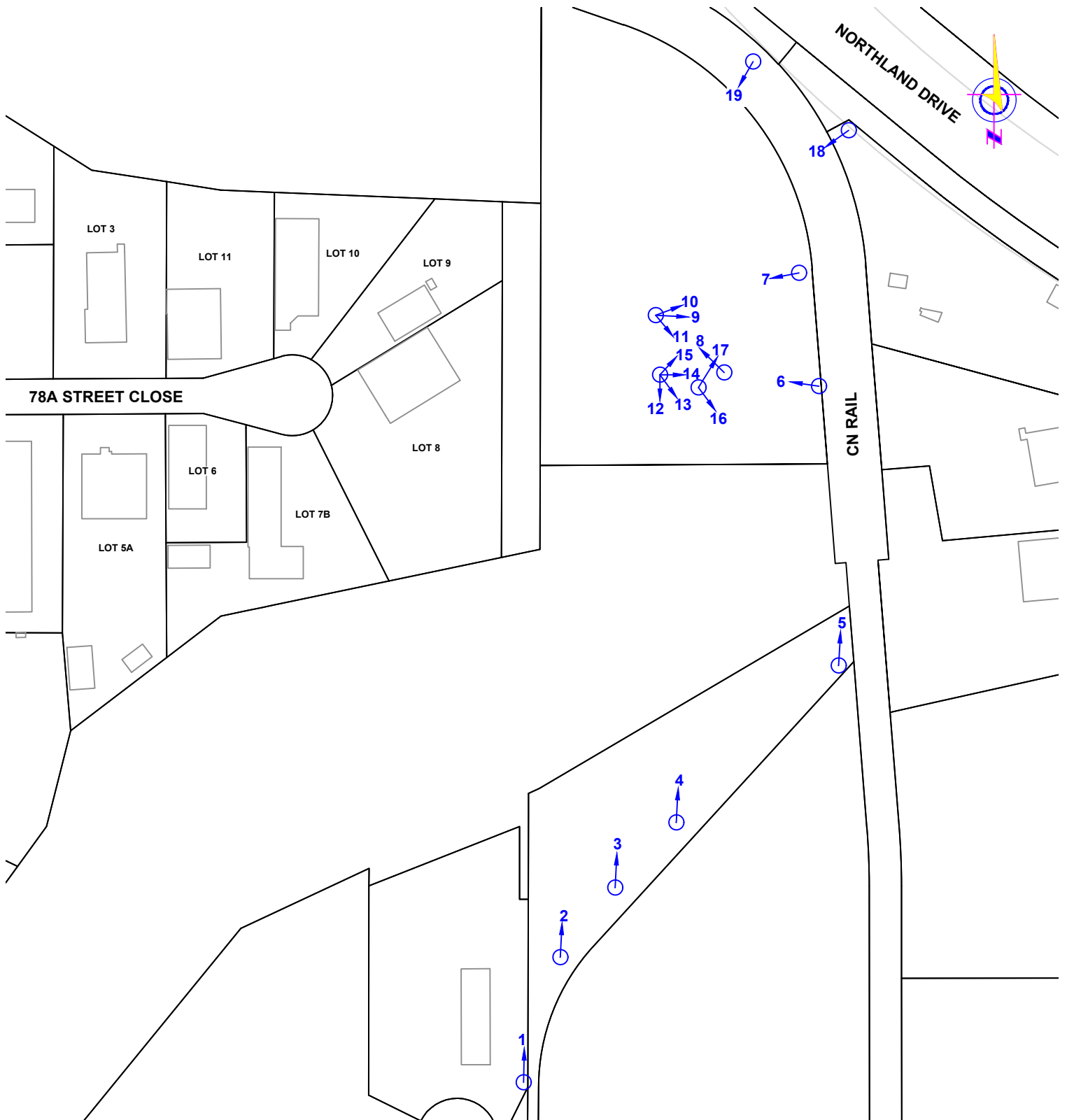
DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-7	



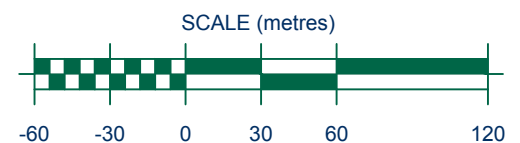
- CREST OF SLOPE
- ◇ SURVEY LAND POINT
- ◆ SWITCH / DERAILER
- ⊙ MONITORING WELL



	CLIENT:		SURVEY MARKERS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION RIVERSIDE HEAVY INDUSTRIAL SITE			
			DRAWN:	CHK'D.:	REV #:	DATE:
			NC	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
1:2000		RD6500-14		FIGURE 14-8		



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE



CLIENT:



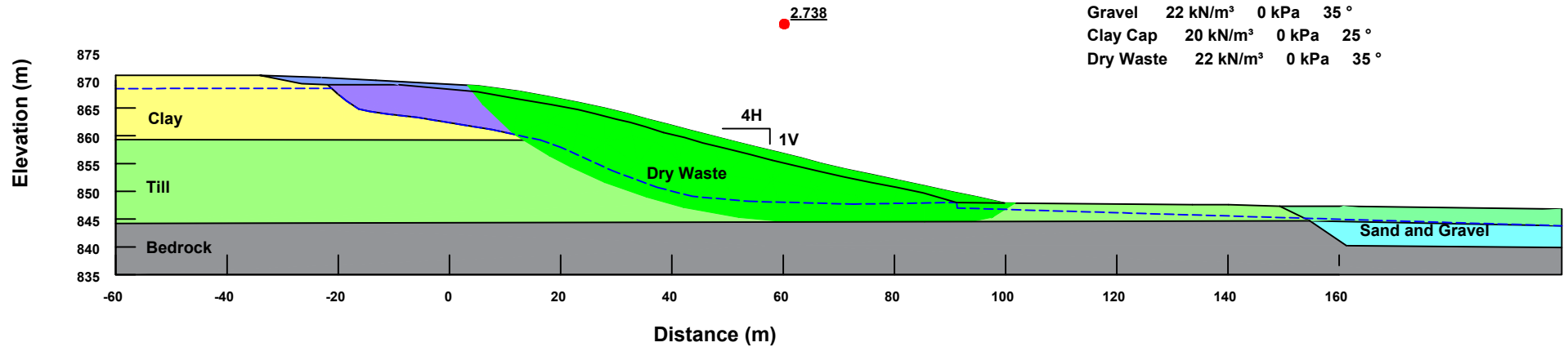
PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
RIVERSIDE HEAVY INDUSTRIAL SITE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:3000	JOB NO. RD6500-14	DRAWING NO. FIGURE 14-9	



RD6500 - Site 14
Dry Waste Site - Global High GWT

Clay	20 kN/m ³	2 kPa	25 °
Till	20 kN/m ³	5 kPa	32 °
Bedrock	21 kN/m ³	20 kPa	35 °
Sand and Gravel	21.5 kN/m ³	0 kPa	40 °
Gravel	22 kN/m ³	0 kPa	35 °
Clay Cap	20 kN/m ³	0 kPa	25 °
Dry Waste	22 kN/m ³	0 kPa	35 °



-- -- ESTIMATED HIGH GROUNDWATER TABLE
■ ESTIMATED SLIP SURFACE

SOIL AND GROUNDWATER TABLE BASED ON REFERENCE #65 AND 66

			STABILITY ANALYSIS RUN	
			CITY OF RED DEER SLOPE STABILITY EVALUATION RIVERSIDE HEAVY INDUSTRIAL SITE	
			DRAWN: NC	CHK'D.: MDB REV #: 2 DATE: APRIL 2019
			SCALE: AS SHOWN	JOB NO. RD6500-14 DRAWING NO. FIGURE 14-10

SITE #14 - RIVERSIDE HEAVY INDUSTRIAL SITE

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 14-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM14-001	Derailer	5799157.01	309169.33	847.71				
#SM14-002	Switch	5799216.45	309178.10	847.47				
#SM14-003	MW03	5799312.91	309164.09	847.74				
#SM14-004	Toe	5799316.08	309154.35	848.35				
#SM14-005	Crest	5799312.25	309065.55	868.66				

TABLE 14-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD				COMMENT
		NORTHING	EASTING		1992	2011	2014	2018	
#P14-001	Slope and Transmission Line ROW	5798909	308996	N				Y*	
#P14-005	Slope and Slough Area at Toe	5799146	309175	N				Y*	
#P14-018	Cut Slope and Slope Failure	5799449	309181	SW	Y*				
#P14-019	Close up of Failure	5799488	309126	SW	Y*				
#P14-020	Remediated Slope after Construction			W		Y*			Taken from airplane
#P14-021	Remediated Slope			NE			Y*		Taken from airplane (Stantec)

Notes:

1992 Photographs from Reference #62

2011 Photograph from Reference #90

2014 Photographs from Reference #90

* Provided in the report

All measurements in metres

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Site Number	14	
Site Name	Riverside Heavy Industrial	
Legal Land Description	SE/NE 33-38-37-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	309100 m E, 5799300 m N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 30, 2018	1	1	1
Inspected By:	Bryden Lutz Mark Brotherton			
Report Attachments:	17 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded		
Slope Movement	None observed		
Erosion	None observed		
Seepage	None observed		
Distress	None observed		
Other			
Instrumentation:	<ul style="list-style-type: none"> Locked environmental well near toe 		
Other Comments:	<ul style="list-style-type: none"> 		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Slope face is prairie grasses, with not shrubs or trees- Slope if fairly gradual, estimated to be 3.5-4.5H:1V
Assessment	<ul style="list-style-type: none">- Slope and slope face appears to be stable
Recommendations	<ul style="list-style-type: none">- Consideration for periodic site visits as required (or maybe every 5 years) or following significant cumulative rainfall seasons

SITE #15

Three Mile Bend Park



SITE #15 - THREE MILE BEND PARK

15.1 SITE DESCRIPTION

Three Mile Bend Recreation Area is a 55 hectare natural area located on the inside bend of a large loop of the Red Deer River within N 27 and S-34-38-27-W4M, as shown on Figure 1 of the main report. The park is a wooded flood plain east of the Civic Yards which has a series of paths and trails around a number of clearings and ponds from former gravel pit operations at the site which have been connected by channels. The west bank of the Red Deer River borders the site to the north, south and east. There are four main bank locations around the park which are areas of concern. The Site Plan is shown on Figure 15-1. A 2016 Contour Plan is provided on Figure 15-2. Representative cross-sections of the bank are provided on Figures 15-3A and 15-3B.

The shoreline around the park is about 2.4 km long and the river surface around this bend drops about 3 m through this stretch with normal surface elevations of about 847 m at the south entrance of the park and 844 m at the north park boundary near the north end of the Civic Yards. The river approaches the area from the south and takes a sharp east turn with the force of the river directed into the river bank below the park entrance road. The river then travels about 700 m east before turning north on a 90° bend with a radius of about 300 m. The river straightens slightly and then bends to the northwest before finishing with a final sharp bend to the north at the northwest corner of the park. The river shoreline around this flood plain area has several sections with flat gravel beaches extending out into the river.

There are several small sand bars in the river and a large island northeast of the park where the river has scoured out a channel on the far bank. The outside bend of the river on the east side transitions from low lying flood plain to the south; into a large high bank landslide to the east (Site #9/10); followed by an undisturbed high bank slope to the northeast and a low lying flood plain to the north. The channel around the bend in the southeast corner of the park has been constricted by the flow of landslide material into the river channel from the opposite river bank.

Development at the site consists of a rest-room, a ski jump training facility, the main access road, parking area, paths, river accesses and trails. There is a path around the perimeter near the top of the bank for most of the park, with the closest approaches on the south and east sides. Some of the crest areas are heavily wooded. The river bank ranges from vegetated slopes of about 3H:1V to steepened exposed soil banks, including sections with near vertical cuts and occasional erosion channels which have been scoured back into the flood plain. Aerial photographs showing the park development and vegetation at the site are provided on Figures 15-4A and 15-4B. Site photos are provided on Figure 15-5A to 15-5F.

15.2 REFERENCES

The references from Appendix B which apply to Site #15 are the river studies #3 and #7. No site specific geotechnical reference reports were available for Three Mile Bend Park.

15.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

On November 8, 2018, a borehole was drilled at each of the four areas of concern at the site. The boreholes were to depths up to 5.3 m below grade at the locations shown on Figure 15-1. Stand pipes were installed in all boreholes. They were measured at completion of drilling and on November 19, 2018. The ground surface elevations at the boreholes were surveyed using a Trimble Geo 7x GPS receiver and a Trimble Zephyr GPS antenna.

15.4 2018 REVIEW

Aerial photography is provided on Figures 15-4A and 15-4B for the years listed in the following table. Aerial photographs going back to the 1960's show the river channel in this area has been relatively stable for the past fifty years, but the west shoreline and islands in the river have undergone some modification.

TABLE 15-1: AERIAL PHOTOGRAPHS

Year	Description
1985	Shows the original site condition during initial to park development.
2001	Shows the condition of the site after park development.
2005	Shows the site condition shortly after the 2005 flood peaked.
2016	Shows the present Site #15 condition.

The Three Mile Bend Park site was visited on October 31 and November 8, 2018. A copy of the field inspection record is attached at the end of this appendix.

The ortho-contours from 2016 City aerial photography was reviewed for this study. A control survey of the site was performed in 2018. A record of survey control points and data for Site #15 is appended in Table 15-4. A reference drawing of survey reference points is provided on Figures 15-7A to 15-7D.

Selected site photographs from 2018 are provided on Figures 15-5A to 15-5F. A list of available photos at this site is appended in Table 15-5. A reference drawing of photograph locations on Figure 15-7A to 15-7.

15.5 SUBSURFACE PROFILE

The soil profile encountered at this site was in descending order: topsoil, silt and sand, over gravel. Borehole profiles for the four bank areas are shown on Figure 15-3A and 15-3B cross sections. The detailed soil conditions encountered at the borehole locations are described on the borehole logs provided in this appendix. The terminology and symbols used on the borehole logs are provided in Appendix C.

The following is a brief description of the soil types encountered.

1. **Topsoil.** A 200 to 300 mm thick layer of topsoil was encountered in Borehole 1 and 3..
2. **Silt.** Silt was encountered below the topsoil in Boreholes 1 and 3; and extended to depths of 1.2 to 1.5 m below grade. The firm, medium plastic clay contained some silt, little to some sand and trace gravel.
3. **Sand.** Sand was encountered below the silt in Boreholes 1 and 3 and at surface in Boreholes 2 and 4. The sand extended to a depth between 0.5 to 4.0 m below grade. The silty sand deposits contained trace to some gravel and were fine to medium grained and compact. The moisture content of the deposits ranged from 4 to 9 percent.
4. **Gravel.** Gravel deposits were encountered below the sand in all boreholes and extended beyond the depths drilled (ie. 3.5 to 5.2 mbg) which is below elevation 844 m. These dense to very dense deposits were coarse grained; well graded with trace fines. The gravel was dry with moisture contents from 3 to 9 percent.
5. **Bedrock.** Bedrock was not encountered, but based on local experience, the observed auger refusal encountered at 844 m was likely in the top of the formation.
6. **Groundwater.** Groundwater levels in Nov 2018 were 3.2 mbg in Borehole 1 which corresponds to a level slightly higher than the river surface elevation at this location. The other borehole were competed above the river surface elevations and were dry at the time of measurement.

The following effective strength parameters were assumed for this site.

TABLE 15-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Sand	19	0	30 - 32
Clay	20	0 - 2	25 - 28
Gravel	22	0	38
Weathered Bedrock	21	10	30 - 40

15.6 SLOPE ISSUES & BACKGROUND

There was evidence of ongoing bank scour on both sides of the river in this area including some localized scour of the west bank. The river bank under the entrance road in the southwest corner is under significant attack, but the shoreline consists of exposed gravel supplemented with some minor armouring which appears to be weathering this attack for now. In Area #3, on the east side of the park, a section of path has been undermined by a bank wash-out which was first noticed after the 2005 flood (see one of the photographs in Figure 15-5D). Other than those issues, there does not appear to be active regression of the west river bank around the park going back to 1949, because the force of the bend is concentrated on the far east river bank. Peak water levels during normal floods will rise above the current beach and attack the exposed bank. In some areas major floods levels rise above the banks and inundate the flood plain, as shown on the 2005 aerial on Figure 15-4B. The ponds in the park are groundwater features hydraulically connected to the river through a gravel layer which covers the site, so pond levels also rise significantly during periods of flood, contributing to subgrade weakening. In many areas, the main path around the perimeter of the park is in close proximity of the river bank. The bank materials appear to be either alluvial fines or gravel deposits which are subject to erosion potential ranging from heavy to light, respectively. The concern at this site is future bank scour will wash out sections of the path; and these four identified areas are considered to be the sites at the highest risk.

15.7 REVIEW OF STABILITY ASSESSMENT

The river bank around Three Mile Bend is an inside bend which is not subject to major regression.

Historical stability analysis against landsliding was not available for this site. The site was assessed using the *SLOPE/W* computer program based on recent survey information as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 15-3: 2018 SLOPE STABILITY ESTIMATE

Site	Case	FS	Figure
Site 1 - SW	Entrance Road	1.4	-
Site 1 - SW	Trail Edge	1.0 - 1.1	-
Site 2 - SE	Trial Edge	1.7	-
Site 3 - West	Trail Edge	< 1.0	Figure 15-8
Site 3 - West	5 m Setback from Crest	1.3	-
Site 4 - North	Trail Edge	1.7	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

The existing river bank slopes around are considered to be stable in the short-term; including exposed clay areas with near vertical faces. In the long-term, the stability of river banks around the park are considered to range from unstable to marginally stable. Only some of the flattest bank areas would be considered close to stable, but these bank profiles could be subject to change during major flood events. The steeper faces of the banks are at the highest risk of landsliding. The most likely bank failure will be a small block slide or a wash out like that observed at Area #3 on the east side of the park. A preliminary set back to provide a stable for park development is considered to be 5 m from the crest or on a line extended up at 2.3H:1V from the shore of the river.

15.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(7) * CF(4) = 20$$

A Probability Factor of 7 is considered appropriate since there is active sliding at the site and the potential for a future slide is considered to be moderate. A Consequence Factor of 4 is considered appropriate since the expected size of landslide in the upper slope at this site would require detouring the current trail and damage the existing stair access to the toe area, but would not affect the nearby structures.

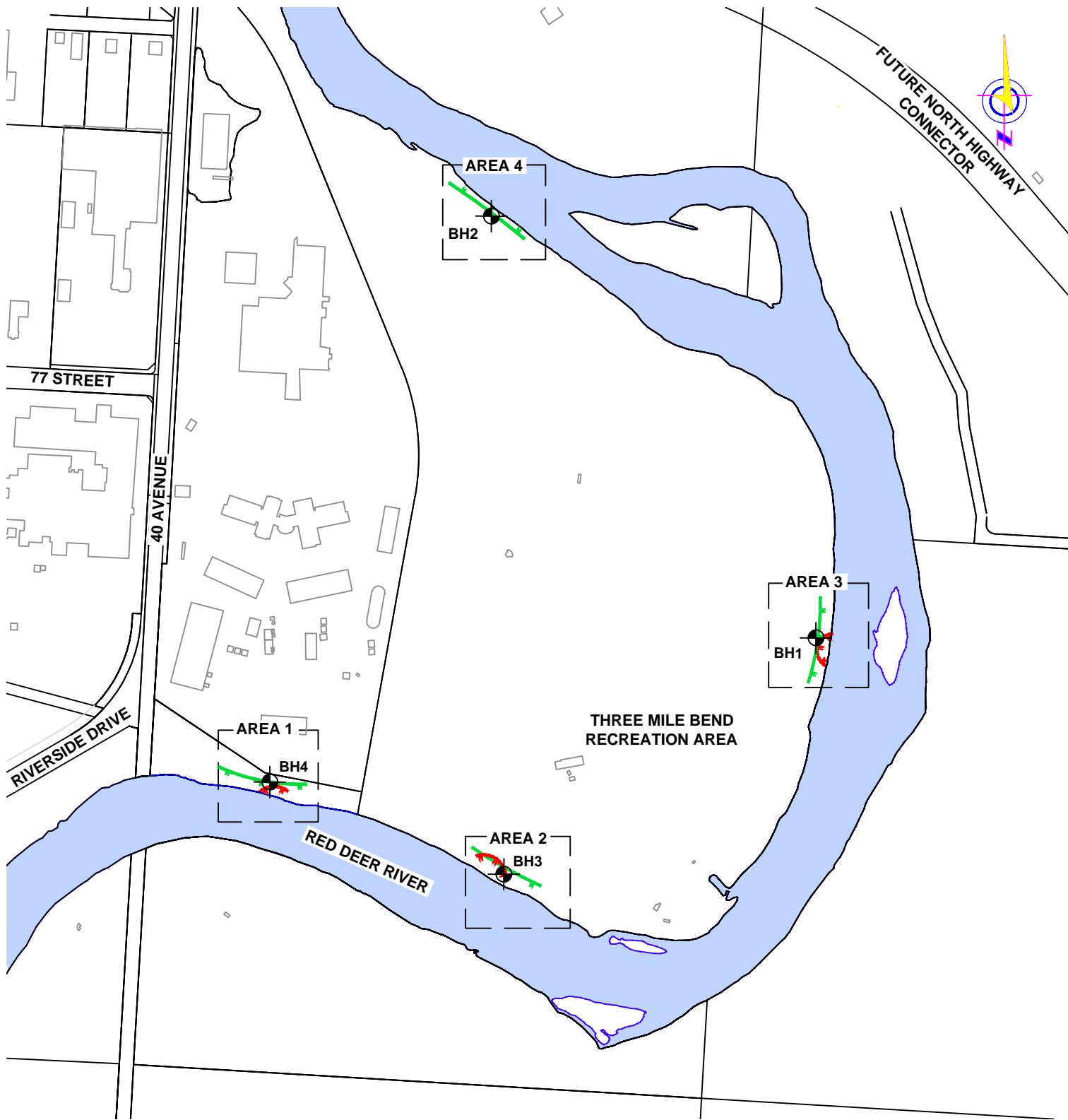
15.9 RECOMMENDATIONS




The washed out slope below the existing path at Areas #15-3 should be reconstructed with a gravel face and some protective rip rap.

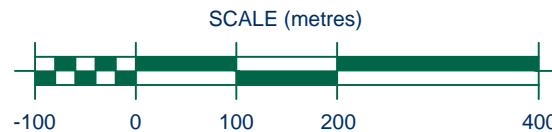
The recommended monitoring action for Three Mile Bend is to undertake annual visual site inspections of the slope and additional visits on an as required basis to identify any significant changes (e.g. after major flood events). Inspections should include control surveys along the crest relative at fixed points to verify regression rates.

15.10 ATTACHMENTS

Figure 15-1 - Site Plan
Figure 15-2 - 2016 Contour Plan
Figure 15-3 - Cross Section Profiles
Figure 15-4 - Aerial Photographs
Figure 15-5 - Site Photographs
Figure 15-6 - Survey Marker Plan
Figure 15-7 - Photograph Plan
Figure 15-8 - Stability Analysis Run
Table 15-4 - List of Survey Markers
Table 15-5 - List of Photographs
Borehole Logs 15-1 to 15-14
Site Inspection Record (October 31, 2018)



-  CREST OF SLOPE
-  TENSION CRACKS
-  2018 BOREHOLE LOCATIONS



ALL BOREHOLE LOCATIONS ARE APPROXIMATE.

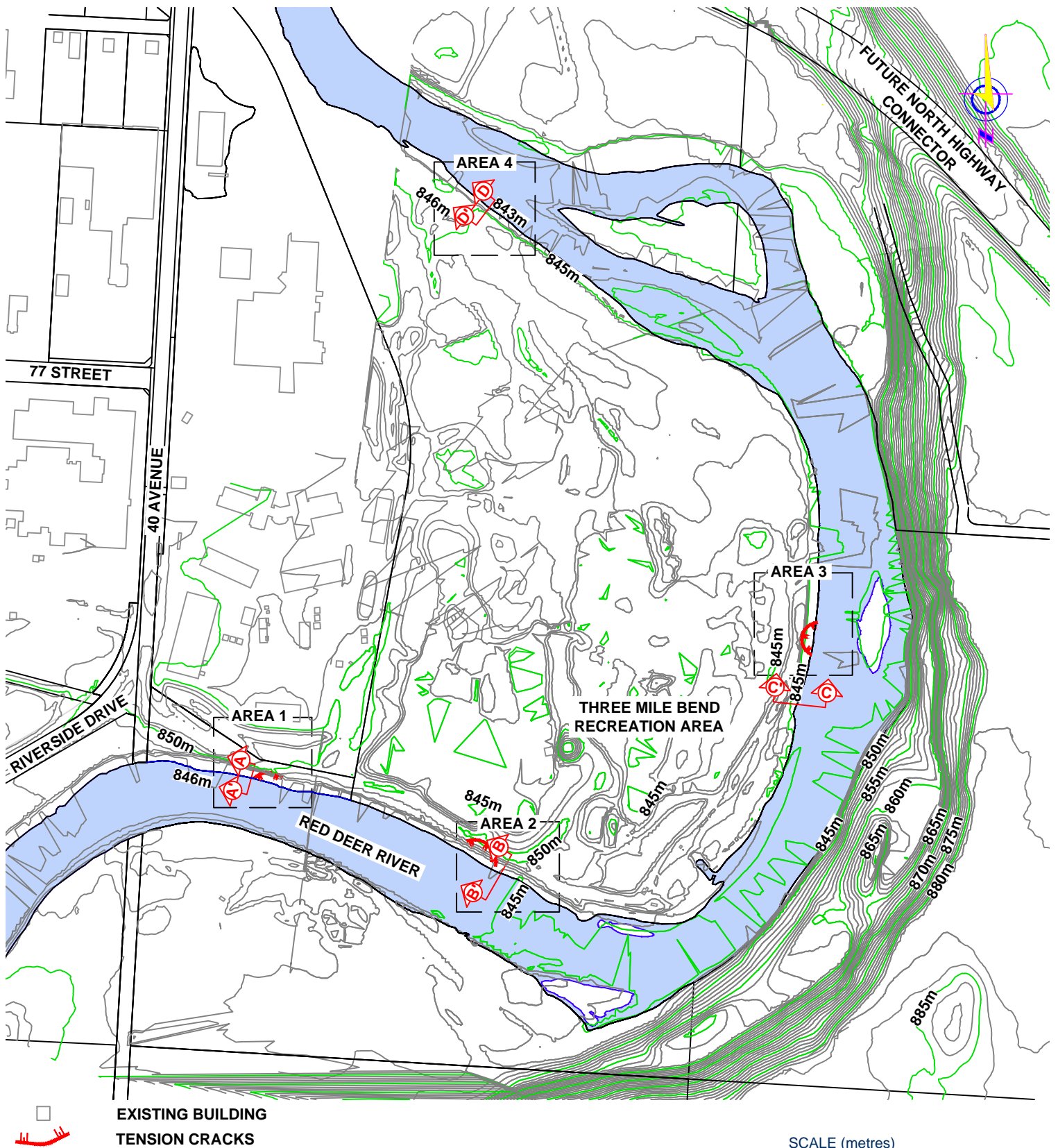
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK

DRAWN: NC	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:7500	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



CLIENT:

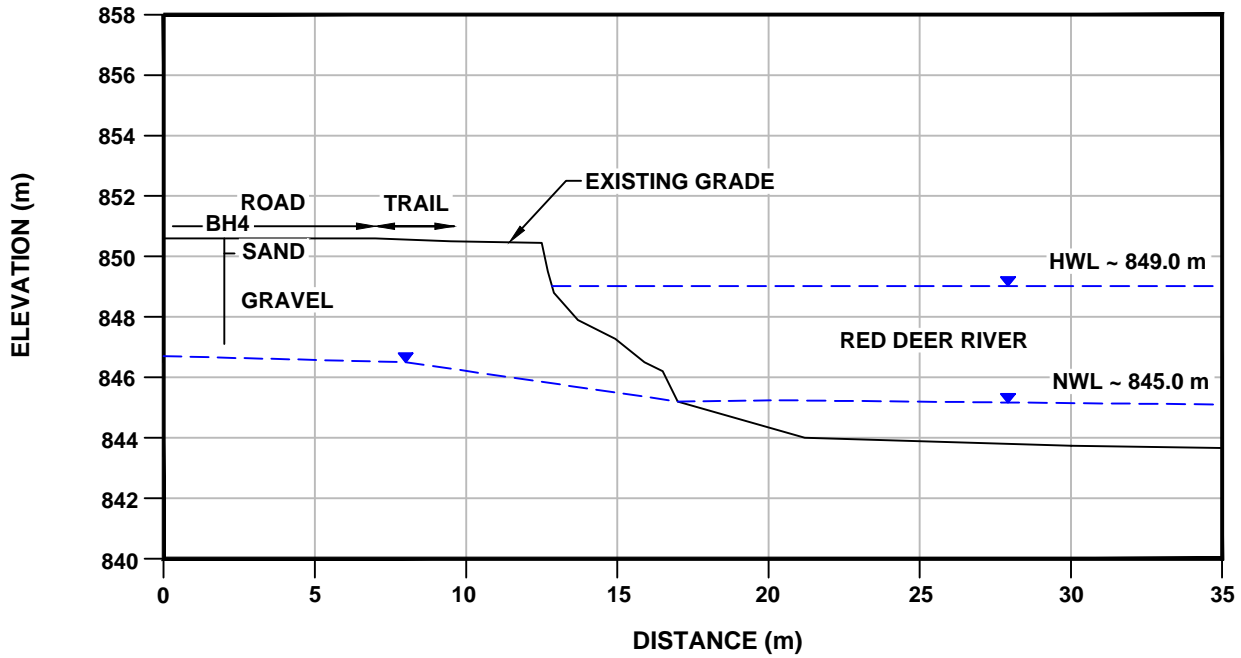


2016 CONTOUR PLAN

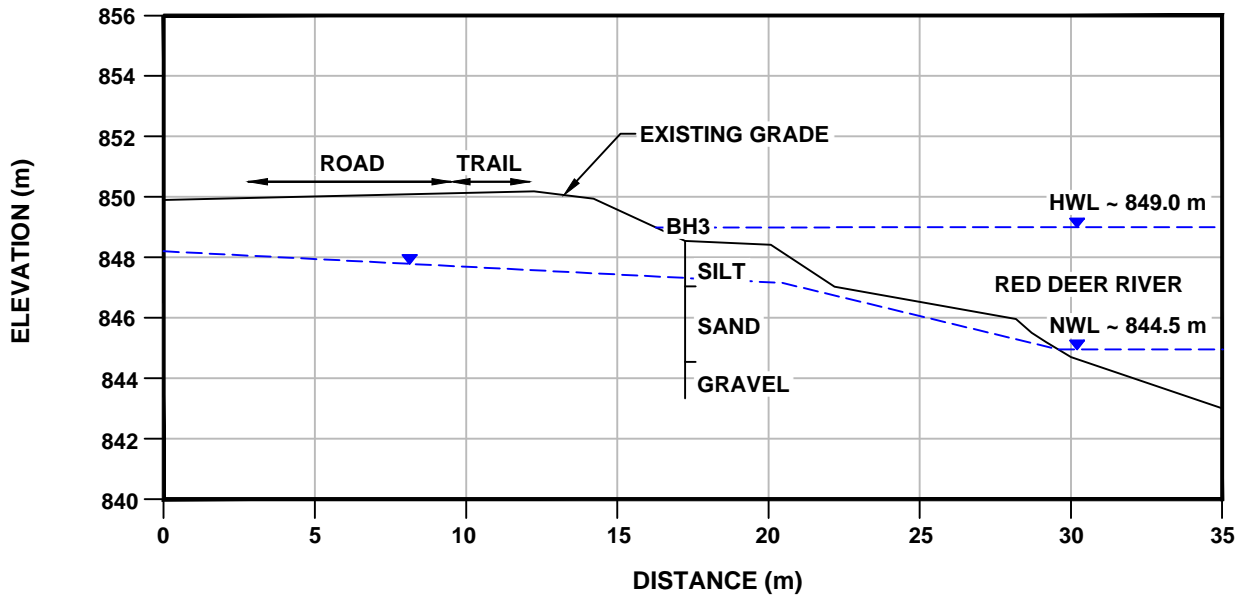
CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:7500	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-2	

15-3A: CROSS SECTION (A - A')



15-3B: CROSS SECTION (B - B')



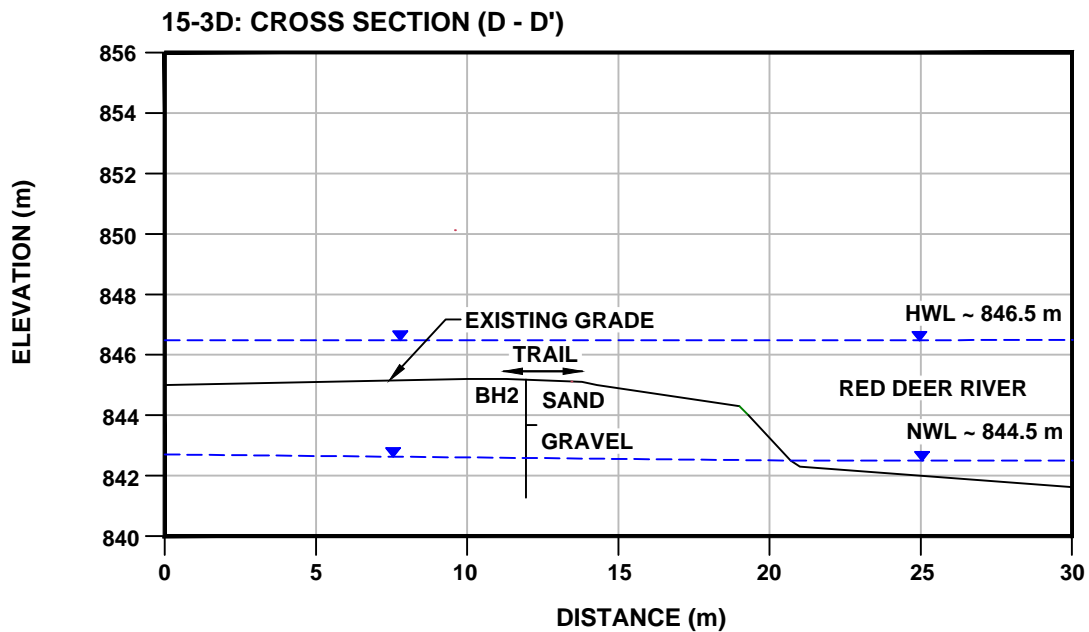
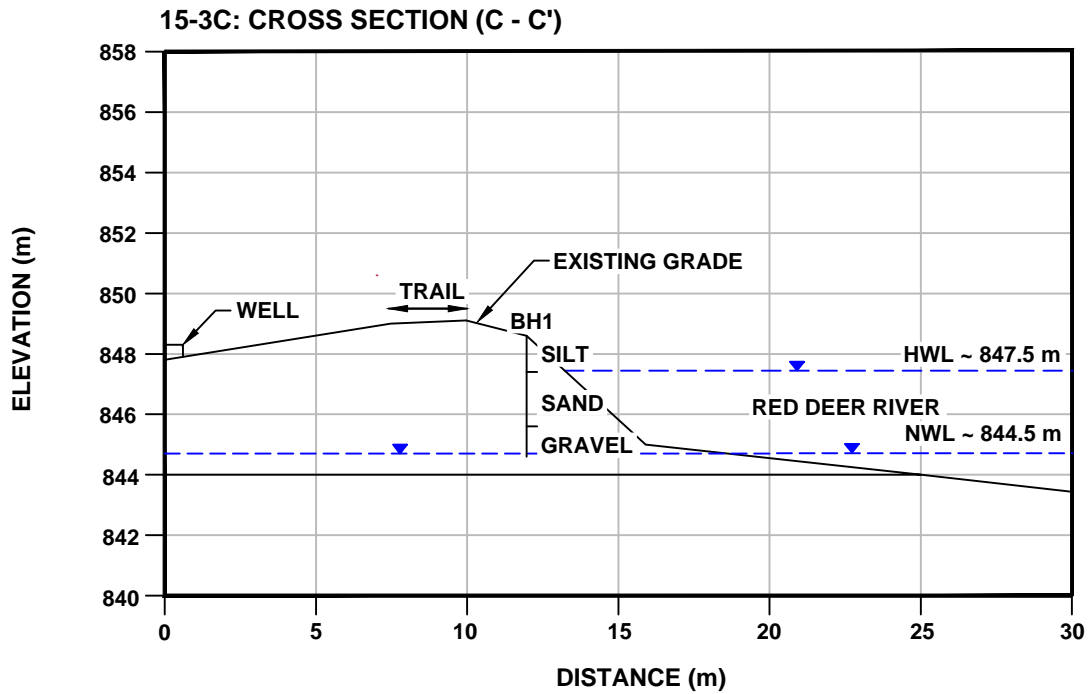
CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-3A&B	



CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

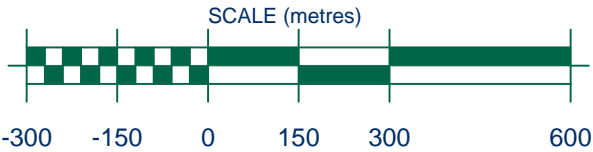
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-3C&D	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED APRIL 15, 1985.



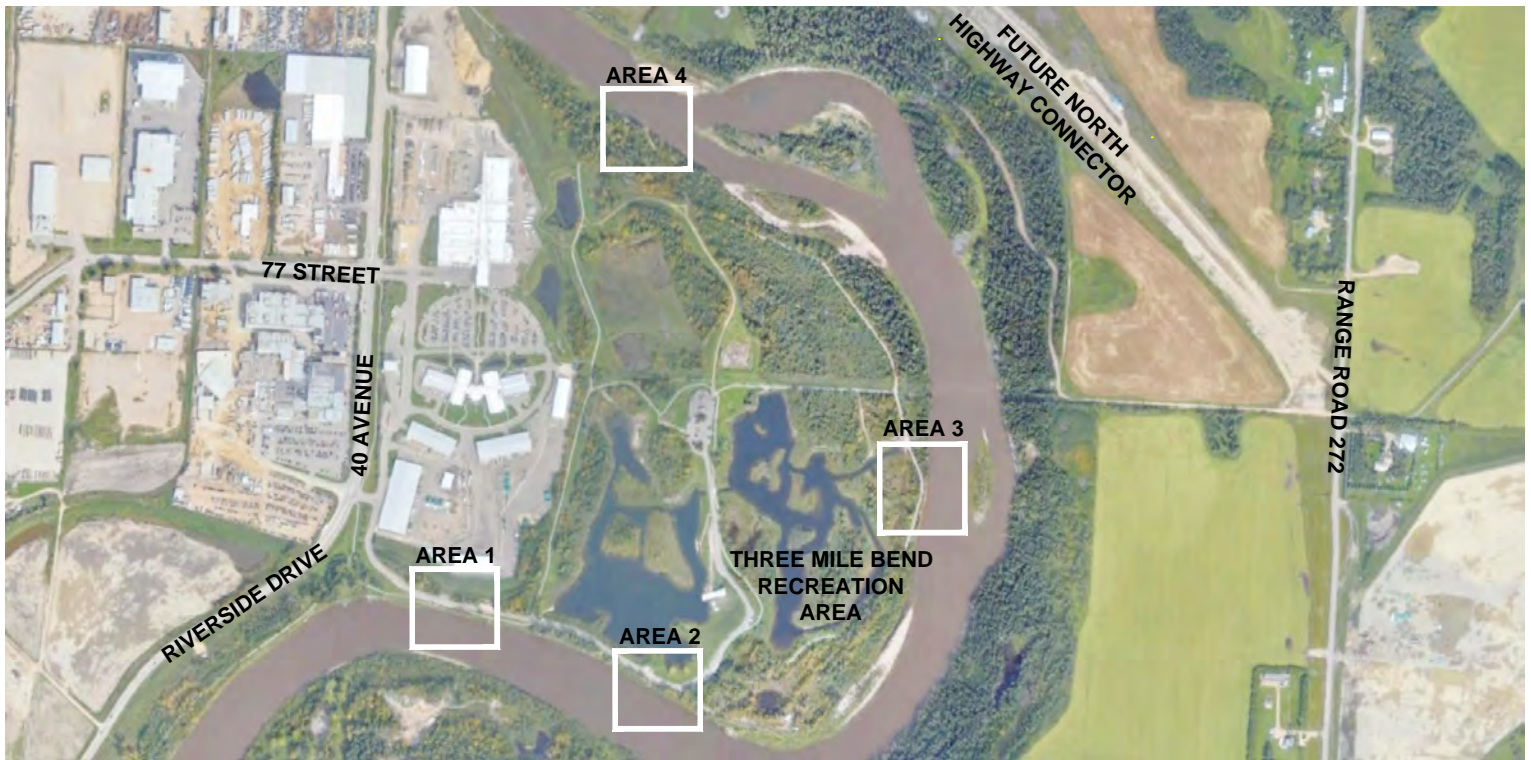
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



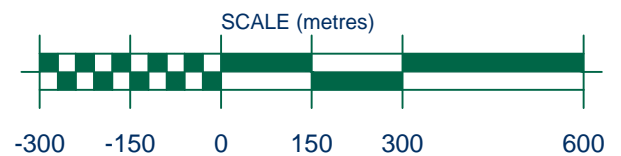
	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK			
		DRAWN: NC	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:12500	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-4A	





NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED JUNE 20, 2005.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK			
			DRAWN:	CHK'D:	REV #:	DATE:
			NC	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
1:12500		RD6500-15		FIGURE 15-4B		



PHOTOGRAPH 2 (2005): NORTH RIVER BANK AT THE ELBOW OF RIVER, NEAR THE WEST END OF STUDY AREA 1, FROM CENTER OF RIVER, FACING NORTH



PHOTOGRAPH 2 (2018): NORTH RIVER BANK AT WEST END OF STUDY AREA 1, FROM RIVER ACCESS AT MCKENZIE RECREATION AREA, FACING NORTH



PHOTOGRAPH 8 (2018): NORTH RIVER BANK VERTICAL CUT AND BENCH IN THE CENTER OF STUDY AREA 1, FACING WEST



PHOTOGRAPH 21 (2018): NORTH RIVER BANK AT WEST END OF STUDY AREA 1 FROM THE EDGE OF PEDESTRIAN TRAIL, FACING EAST

	CLIENT:				SITE 15 AREA 1 PHOTOGRAPHS			
	CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK							
	DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019				
	SCALE: NTS		JOB NO. RD6500-15		DRAWING NO. FIGURE 15-5A			



PHOTOGRAPH 28 (2018): NORTH RIVER BANK AT WEST OF STUDY AREA 1 FROM THE EDGE OF PEDESTRIAN TRAIL, FACING EAST

	CLIENT:			SITE 15 AREA 1 PHOTOGRAPHS	
				CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK	
				DRAWN: PS	CHK'D.: MDB
				REV #: 2	DATE: APRIL 2019
SCALE: NTS		JOB NO. RD6500-15		DRAWING NO. FIGURE 15-5B	



PHOTOGRAPH 31 (2005): NORTH RIVER BANK AND WASTE CONCRETE BLOCKS AT THE EAST END OF STUDY AREA 2, FROM THE CENTER OF RIVER, FACING NORTHEAST



PHOTOGRAPH 31 (2018): NORTH RIVER BANK AND WASTE CONCRETE BLOCKS AT THE EAST END OF STUDY AREA 2, FROM SOUTH SIDE OF RIVER NEAR MCKENZIE RECREATION AREA, FACING NORTHEAST



PHOTOGRAPH 45 (2018): NORTH RIVER BANK FROM WEST END OF STUDY AREA 2, FACING EAST ALONG THE RIVER



PHOTOGRAPH 66 (2018): NORTH RIVER BANK FROM EAST END OF STUDY AREA 2 NEAR FENCE FOR OIL LEASE, FACING WEST AGAINST THE FLOW OF THE RIVER

	CLIENT:		SITE 15 AREA 2 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK			
	DRAWN:	CHK'D:	REV #:	DATE:		
	PS	MDB	2	APRIL 2019		
SCALE:		JOB NO.		DRAWING NO.		
NTS		RD6500-15		FIGURE 15-5C		



PHOTOGRAPH 84 (SHORTLY AFTER 2006 FLOODING): WASHOUT AND UNDERMINING PEDESTRIAN TRAIL AT NORTH END OF STUDY AREA 3, TAKEN FROM RIVER BACK TOE FACING WEST



PHOTOGRAPH 84 (2018): WASHOUT AND UNDERMINING PEDESTRIAN TRAIL, FACING WEST



PHOTOGRAPH 93 (2018): PEDESTRIAN PATH AND FENCE AT THE CREST OF SLOPE NEAR WASHOUT AREA OF STUDY AREA 3, FACING SOUTH



PHOTOGRAPH 96 (2018): PEDESTRIAN PATH AND FENCE NEAR THE CREST OF SLOPE AT STUDY AREA 3, FACING NORTH



PHOTOGRAPH 116 (2018): VERTICAL CUT OF WEST RIVER BANK AT THE NORTH END OF STUDY AREA 3, FACING SOUTH



PHOTOGRAPH 118 (2018): VERTICAL CUT OF WEST RIVER BANK AT THE NORTH END OF STUDY AREA 3, FACING NORTH

	CLIENT:			SITE 15 AREA 3 PHOTOGRAPHS			
				CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK			
				DRAWN:	CHK'D.:	REV #:	DATE:
				PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.			
NTS		RD6500-15		FIGURE 15-5E			



PHOTOGRAPH 128 (2018): CREST OF SOUTH RIVER BANK AT THE EAST END OF STUDY AREA 4, FACING WEST WITH THE FLOW OF RIVER



PHOTOGRAPH 136 (2018): SOUTH RIVER BANK AT THE WEST END OF STUDY AREA 4, FACING WEST WITH THE FLOW OF RIVER

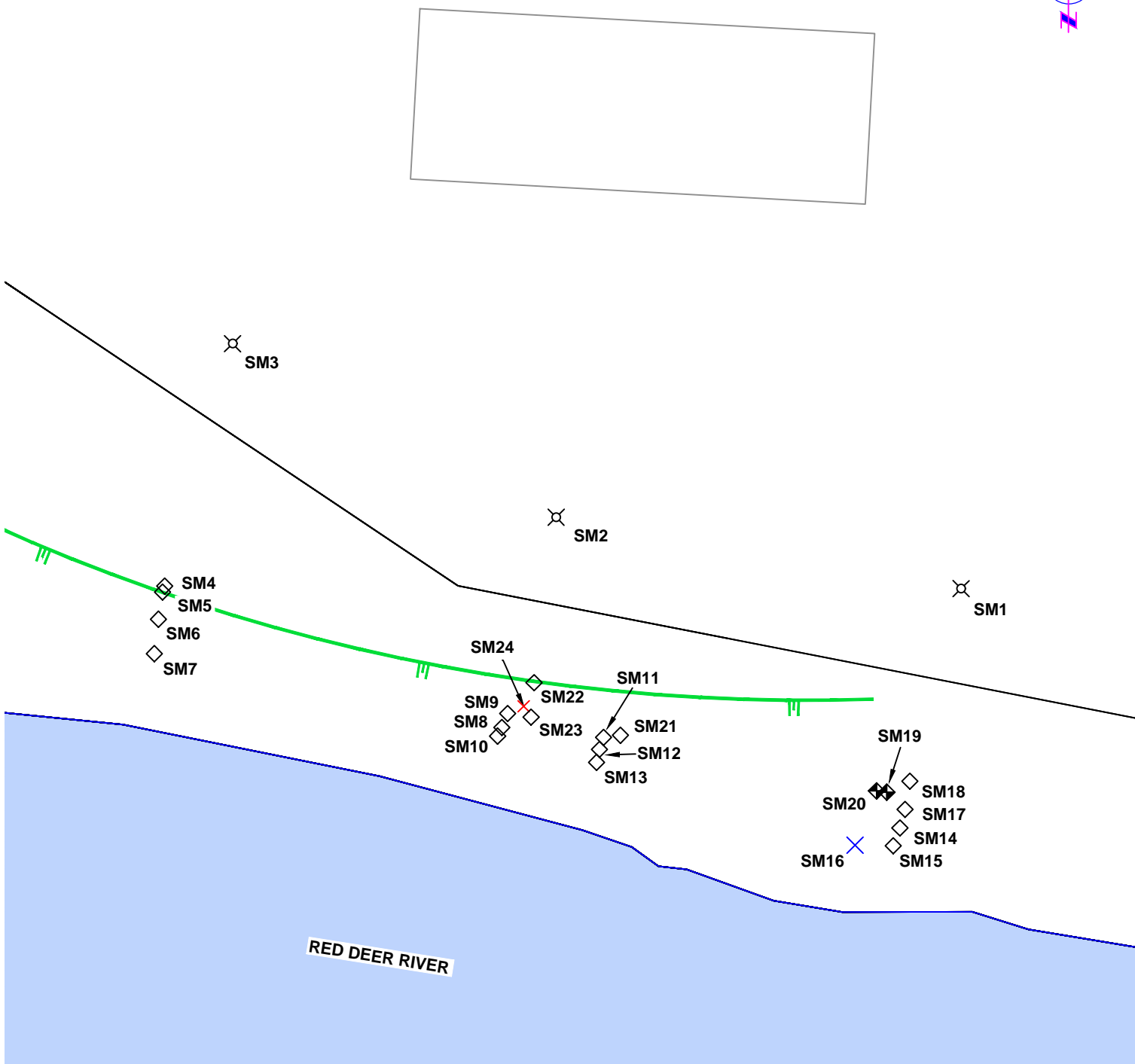


PHOTOGRAPH 137 (2018): SOUTH RIVER BANK AND GEOTEXTILE AT THE CENTER OF STUDY AREA 4, FACING EAST AGAINST THE FLOW OF RIVER



PHOTOGRAPH 141 (2018): PEDESTRIAN PATH, FENCE AND CREST AREA AT THE WEST END OF STUDY AREA 4, FACING EAST

	CLIENT:		SITE 15 AREA 4 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK			
	DRAWN:	CHK'D:	REV #:	DATE:		
	PS	MDB	2	APRIL 2019		
	SCALE:	JOB NO.		DRAWING NO.		
	NTS	RD6500-15		FIGURE 15-5F		



CLIENT:



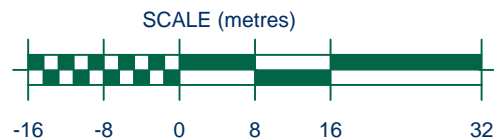
AREA 1 SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: RS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:800	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-6A	



- CREST OF SLOPE
- ⊠ FENCE POST / BOLLARD
- ◇ SURVEY LAND POINT
- ✗ CRACK



CLIENT:

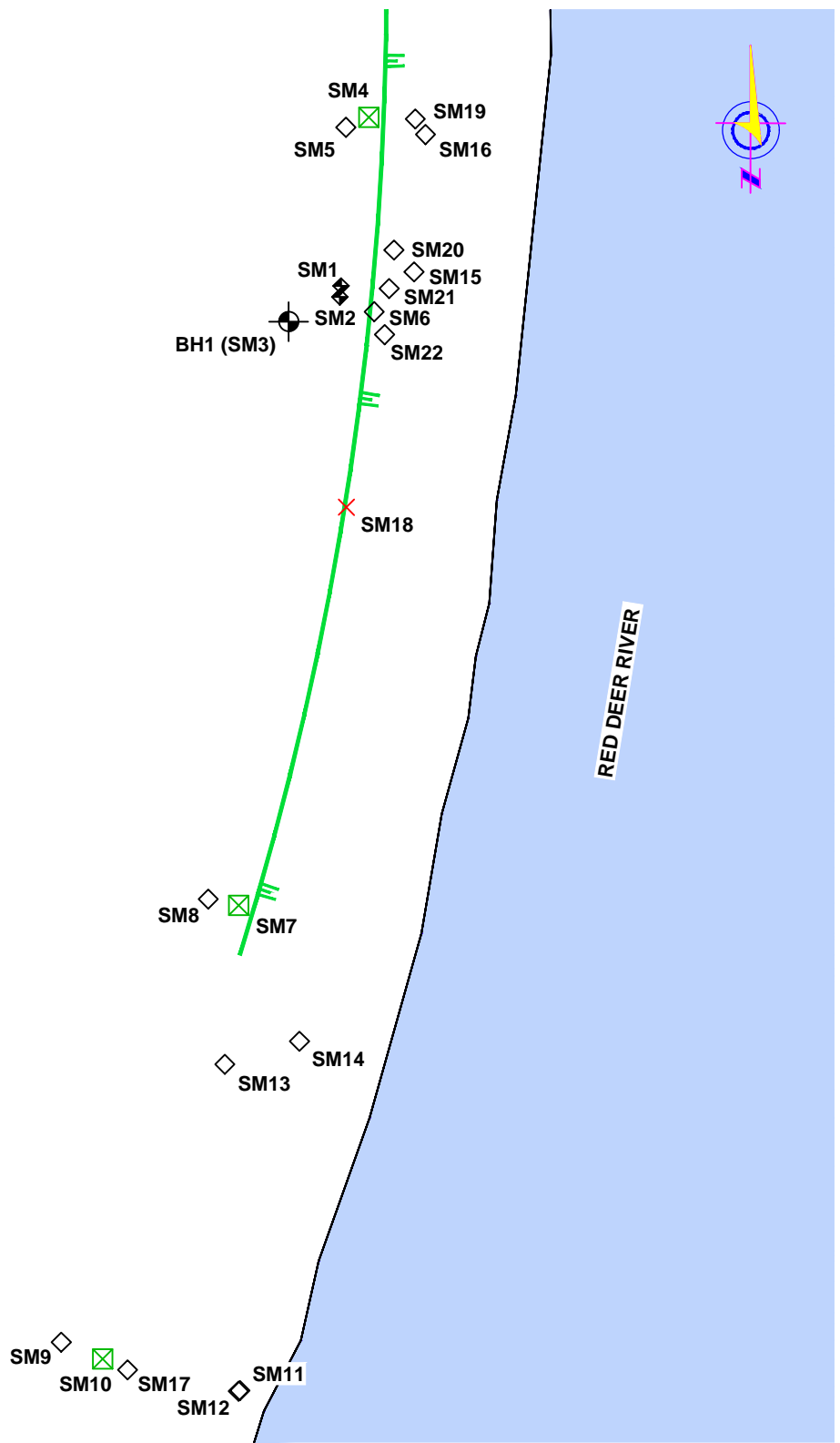








AREA 2 SURVEY MARKERS

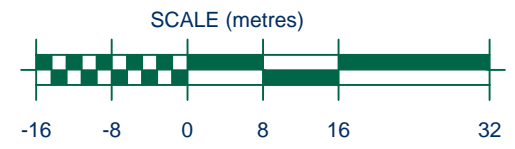
CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:800	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-6B	

THREE MILE BEND
RECREATION AREA



-  CREST OF SLOPE
-  FENCE POST
-  SURVEY LAND POINT
-  WASHOUT
-  BENCH CORNER
-  BOREHOLE



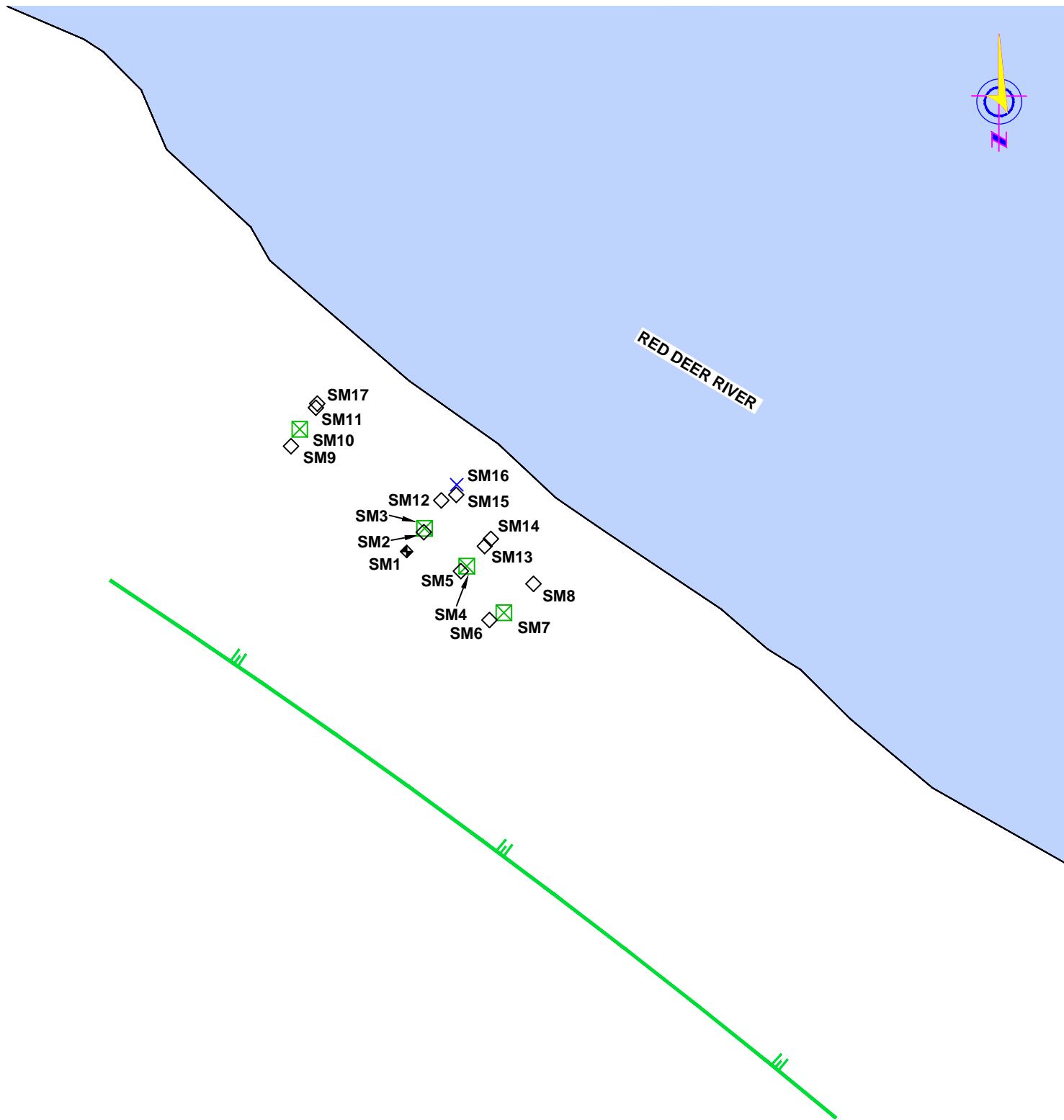
CLIENT:



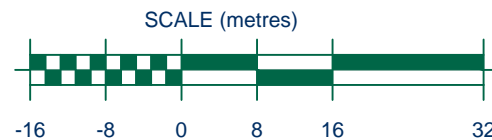
AREA 3 SURVEY MARKERS



CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

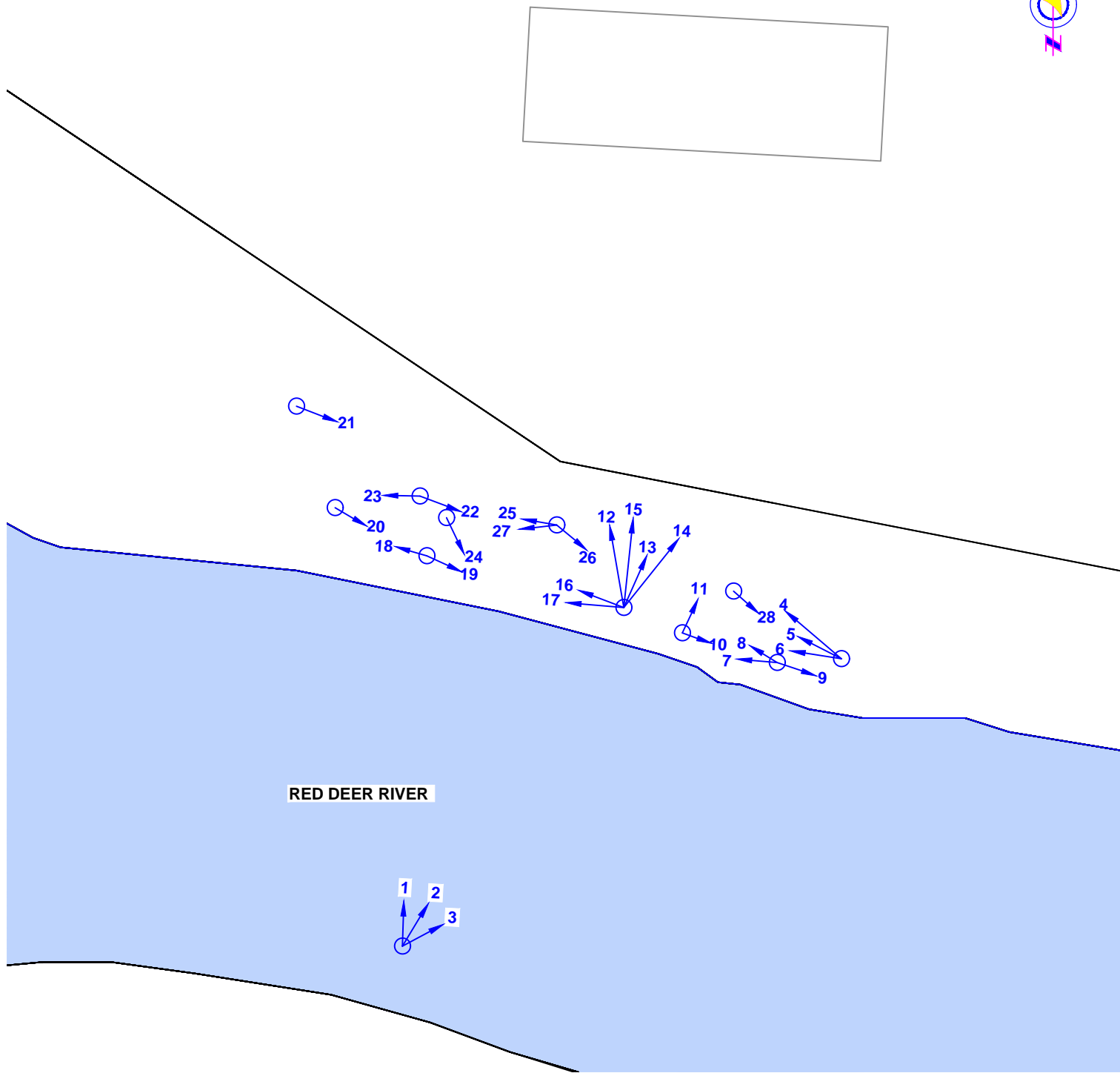
DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:800	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-6C	



- CREST OF SLOPE
- ⊠ FENCE POST
- ◇ SURVEY LAND POINT
- × WATER
- ◆ BENCH CORNER

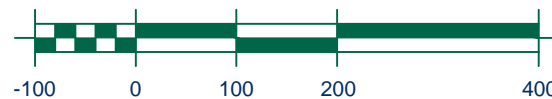


	CLIENT:		AREA 4 SURVEY MARKERS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION THREE MILE BEND PARK			
			DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
	SCALE: 1:800		JOB NO. RD6500-15		DRAWING NO. FIGURE 15-6D	



RED DEER RIVER

SCALE (metres)



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.

AREA 1 PHOTOGRAPH PLAN

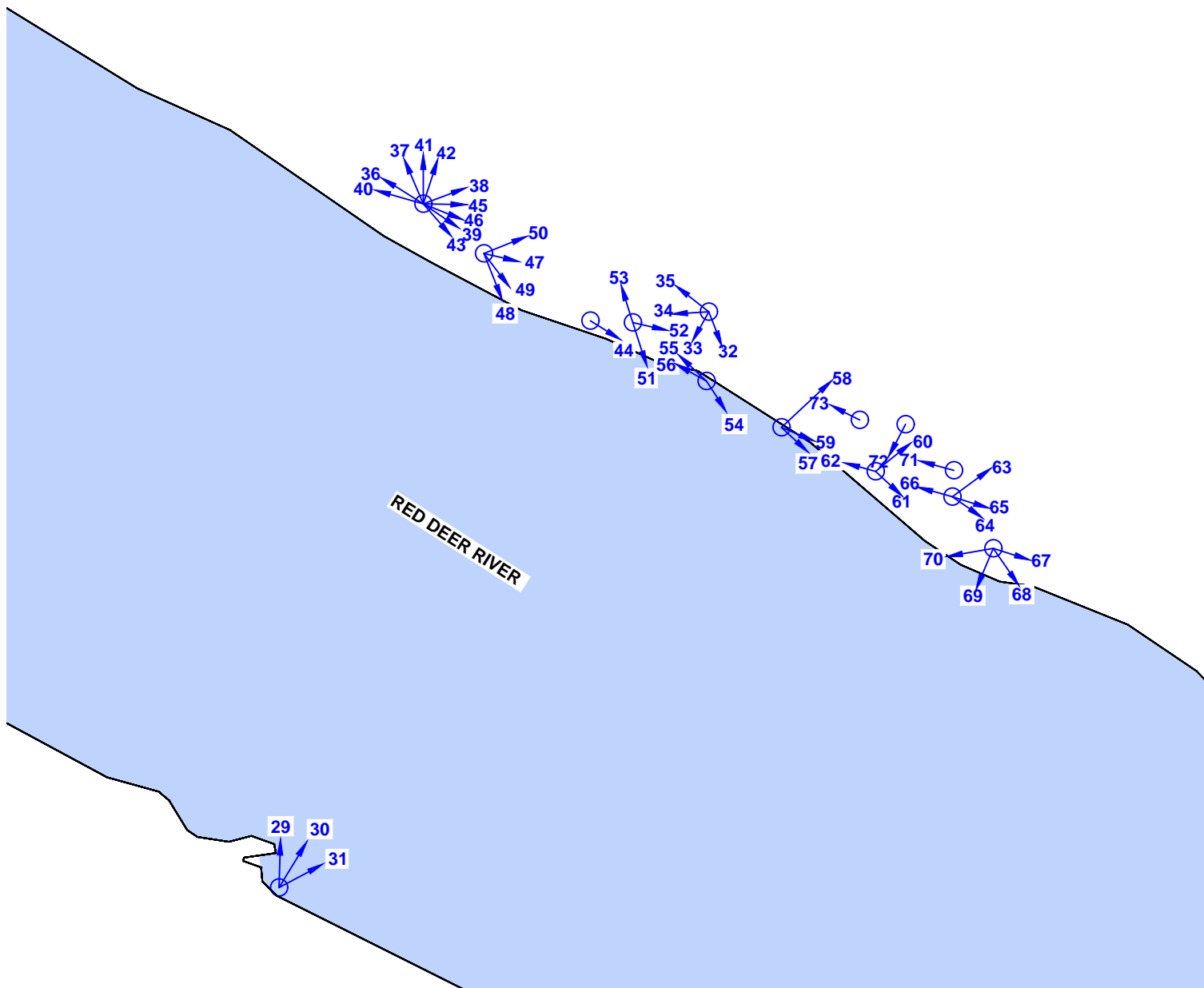
CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-7A	

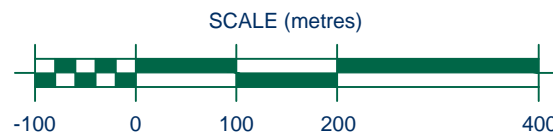


CLIENT:





ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



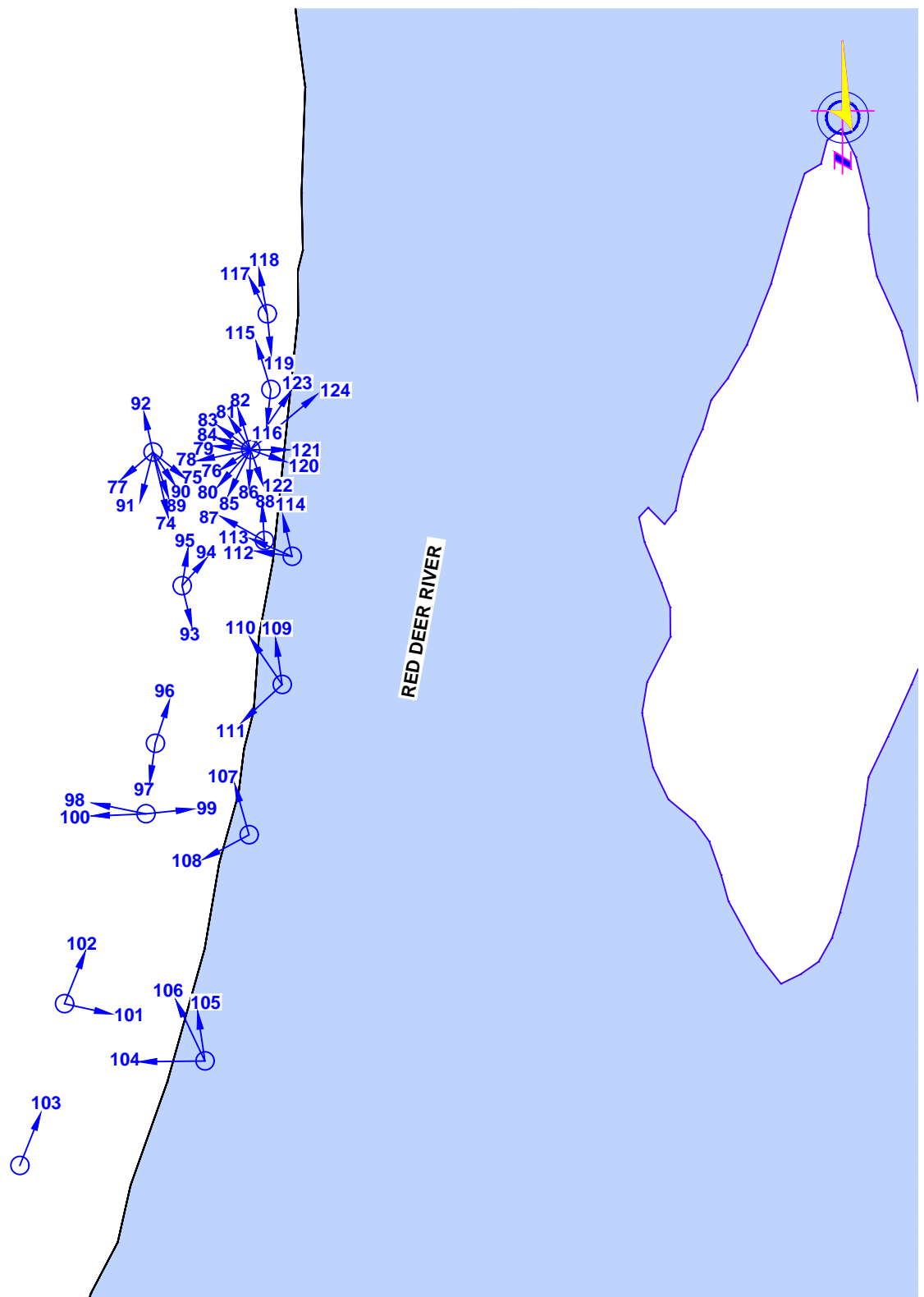
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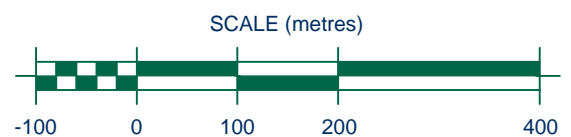
AREA 2 PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1000	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-7B	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



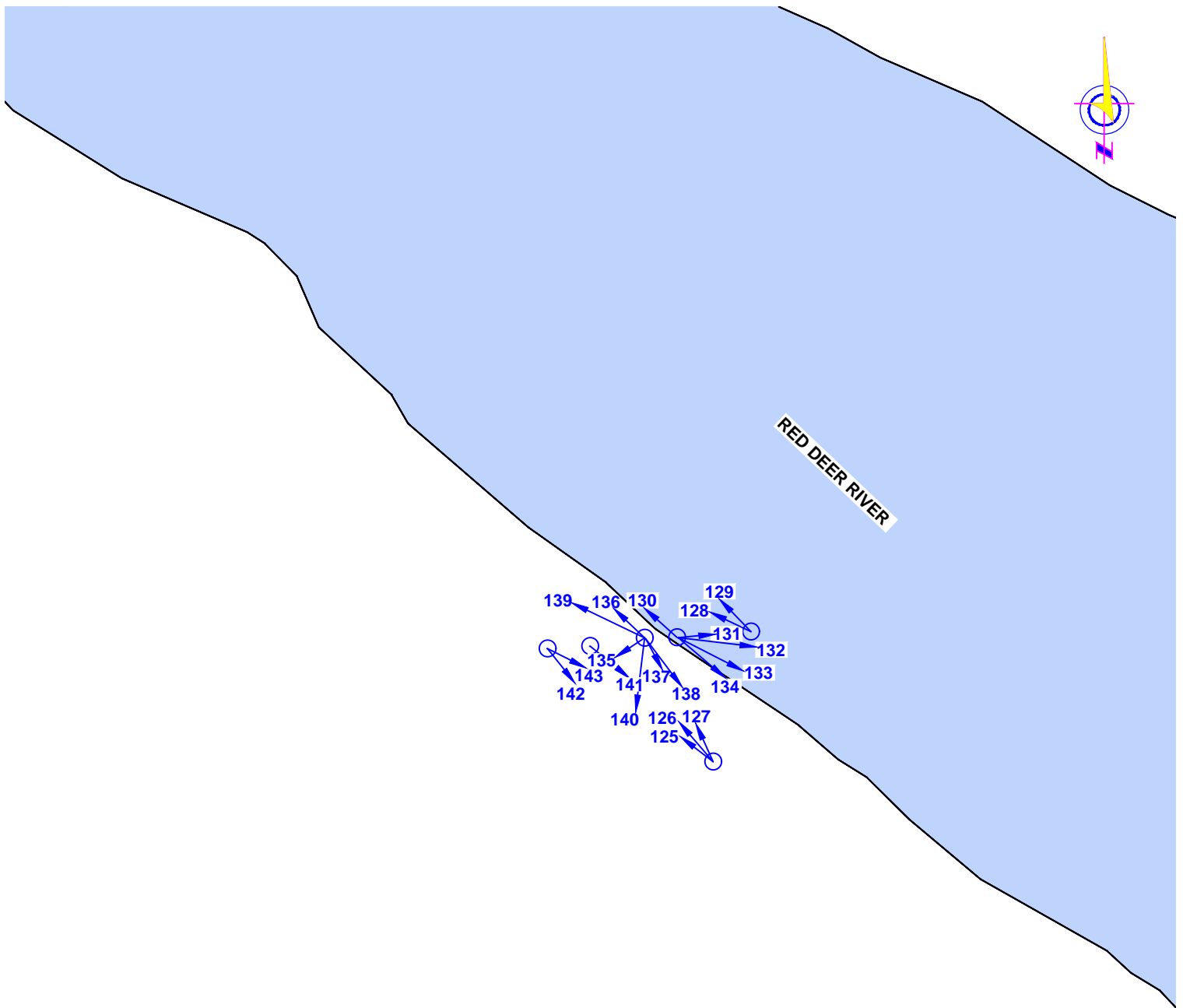
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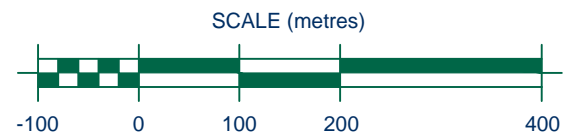
AREA 3 PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1000	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-7C	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



CLIENT:



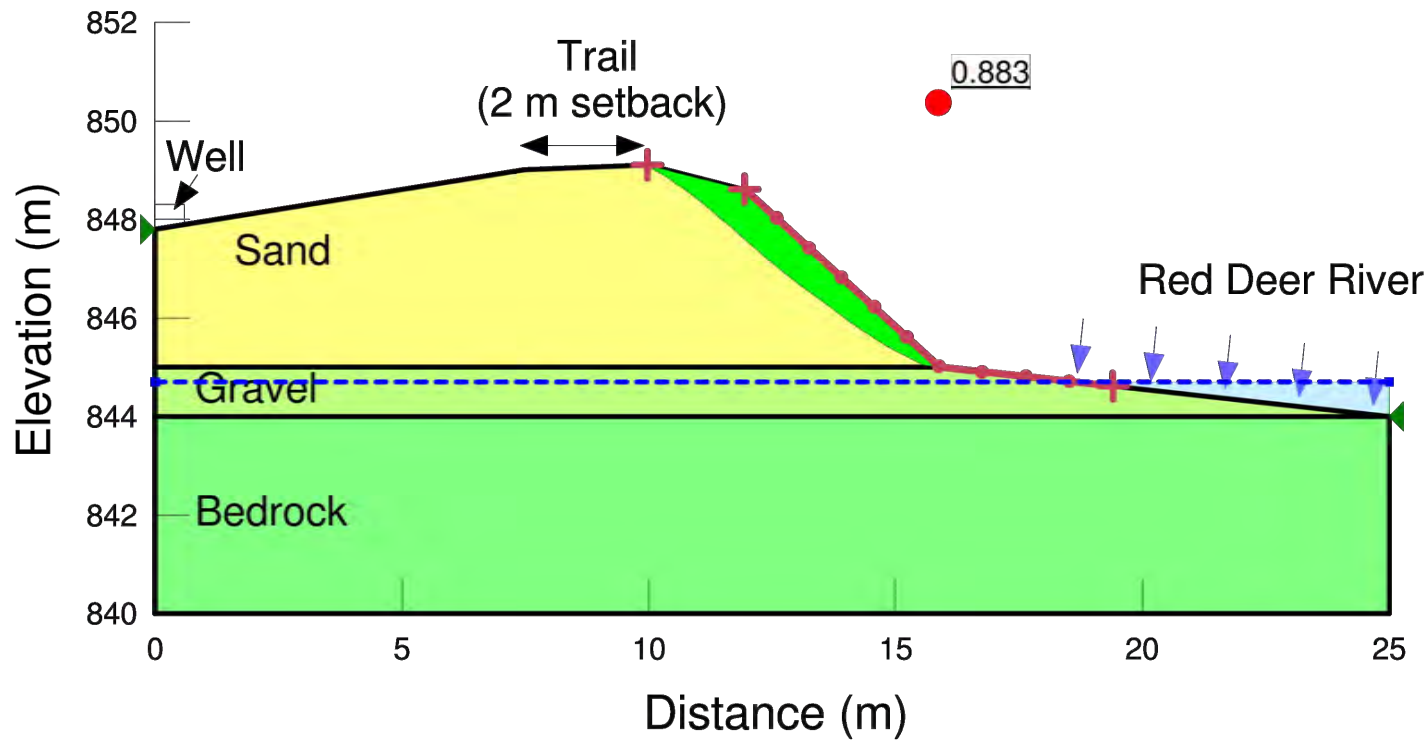
AREA 4 PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1000	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-7D	

RD6500 - Site 15-3
Trail Edge - No Vegetation

Sand 18 kN/m³ 0 kPa 33 °
Gravel 22 kN/m³ 0 kPa 38 °
Weathered Bedrock 24 kN/m³ 30 kPa 35 °



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
THREE MILE BEND PARK

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-15	DRAWING NO. FIGURE 15-8	

SITE #15 - 3 MILE BEND

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 15-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
AREA 1								
#SM15-1-001	Power Pole	5798027.00	310009.15	851.11				
#SM15-1-002	Power Pole	5798037.03	309952.25	850.38				
#SM15-1-003	Power Pole	5798061.43	309906.78	852.19				
#SM15-1-004	Trail	5798027.32	309897.22	851.93				
#SM15-1-005	Crest	5798026.48	309896.92	851.75				
#SM15-1-006	Mid	5798022.69	309896.34	849.09				
#SM15-1-007	Bank	5798017.84	309895.77	847.00				
#SM15-1-008	Bank	5798007.46	309944.59	847.27				
#SM15-1-009	Mid	5798009.43	309945.41	848.82				
#SM15-1-010	Bank	5798006.26	309944.01	846.22				
#SM15-1-011	Base	5798006.07	309958.90	848.31				
#SM15-1-012	Mid	5798004.40	309958.33	847.62				
#SM15-1-013	Bank	5798002.58	309957.92	846.97				
#SM15-1-014	Mid	5797993.35	310000.53	846.77				
#SM15-1-015	Bank	5797990.84	309999.61	846.47				
#SM15-1-016	Water	5797990.95	309994.25	845.24				
#SM15-1-017	Crest	5797995.96	310001.27	848.26				
#SM15-1-018	Trail	5797999.91	310001.95	848.45				
#SM15-1-019	Bench	5797998.40	309998.71	848.35				
#SM15-1-020	Bench	5797998.58	309997.27	848.38				
#SM15-1-021	Crest	5798006.37	309961.26	850.15				
#SM15-1-022	Trail	5798013.77	309949.12	850.50				
#SM15-1-023	Crest	5798008.92	309948.73	850.45				
#SM15-1-024	Top failure	5798008.72	309948.82	849.65				
AREA 2								
#SM15-2-001	Post	5797911.66	310271.86	850.10				
#SM15-2-002	Trail	5797901.15	310266.96	850.02				
#SM15-2-003	Toe	5797896.44	310264.09	848.12				
#SM15-2-004	Bank	5797890.76	310262.02	846.25				
#SM15-2-005	Mid	5797894.36	310263.36	846.87				
#SM15-2-006	Dash crack	5797904.72	310267.94	850.18				
#SM15-2-007	Pole	5797897.05	310306.31	849.90				
#SM15-2-008	Trail	5797885.75	310301.58	850.18				
#SM15-2-009	Crest	5797883.86	310301.07	849.94				
#SM15-2-010	Mid	5797880.92	310300.33	848.04				
#SM15-2-011	Ledge	5797878.12	310299.88	848.41				
#SM15-2-012	Mid	5797876.28	310298.87	847.03				
#SM15-2-013	Bank	5797871.03	310295.96	845.96				
#SM15-2-014	Bank	5797847.27	310344.00	846.45				
#SM15-2-015	Mid	5797849.43	310345.34	847.11				
#SM15-2-016	Fence	5797852.42	310346.10	848.77				
#SM15-2-017	Crest	5797850.97	310346.84	849.00				
AREA 3								
#SM15-3-001	Bench	5798231.51	310713.25	849.05				
#SM15-3-002	Bench	5798230.22	310713.10	849.03				
#SM15-3-003	BH1	5798228.00	310707.14	847.81				
#SM15-3-004	Fence	5798251.10	310716.47	848.50				
#SM15-3-005	Trail	5798249.94	310713.80	848.48				
#SM15-3-006	Trail	5798228.50	310717.10	849.07				
#SM15-3-007	Fence	5798159.51	310701.33	847.96				
#SM15-3-008	Trail	5798160.23	310697.78	847.89				
#SM15-3-009	Trail	5798108.72	310680.70	849.27				
#SM15-3-010	Fence	5798106.81	310685.51	849.08				
#SM15-3-011	Toe	5798103.10	310701.49	844.66				
#SM15-3-012	Toe	5798103.04	310701.30	845.12				
#SM15-3-013	Slope	5798141.02	310699.73	847.29				
#SM15-3-014	Toe	5798143.69	310708.41	844.52				
#SM15-3-015	Toe	5798233.13	310721.72	845.32				
#SM15-3-016	Toe	5798249.09	310723.07	845.28				
#SM15-3-017	Toe	5798105.50	310688.41	847.16				
#SM15-3-018	3m wide Washout	5798205.79	310713.87	848.21				
#SM15-3-019	Crest	5798250.91	310721.87	848.18				
#SM15-3-020	Crest	5798235.67	310719.38	848.78				
#SM15-3-021	Crest	5798231.20	310718.84	848.51				
#SM15-3-022	Crest	5798225.83	310718.30	848.92				
AREA 4								
#SM15-4-001	Bench	5798810.60	310241.16	845.23				
#SM15-4-002	Trail	5798813.41	310243.68	845.07				
#SM15-4-003	Fence	5798814.00	310243.80	845.03				
#SM15-4-004	Fence	5798808.44	310249.99	845.41				
#SM15-4-005	Trail	5798807.69	310249.12	845.32				
#SM15-4-006	Trail	5798800.52	310253.33	845.64				
#SM15-4-007	Fence	5798801.60	310255.44	845.62				
#SM15-4-008	Crest	5798805.84	310259.79	845.47				
#SM15-4-009	Trail	5798826.03	310224.16	844.82				
#SM15-4-010	Fence	5798828.55	310225.46	844.74				
#SM15-4-011	Crest	5798831.70	310227.81	844.47				
#SM15-4-012	Crest	5798818.08	310246.21	844.30				
#SM15-4-013	Crest	5798811.42	310252.62	845.40				
#SM15-4-014	Toe	5798812.43	310253.52	843.15				
#SM15-4-015	Toe	5798818.90	310248.43	842.31				
#SM15-4-016	Water	5798820.41	310248.52	842.18				
#SM15-4-017	Toe	5798832.30	310228.04	842.66				

TABLE 15-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD			COMMENT
		NORTHING	EASTING		2005	2006	2018	
#P15-002	North river bank at the elbow of river	5797946	309928	N	Y*		Y*	Near the west end of study area 1
#P15-008	North river bank vertical cut and bench	5797999	309988	W			Y*	In the center of study area 1
#P15-021	North river bank	5798029	309906	E			Y*	At the west end of study area 1
#P15-028	North river bank	5798001	309979	E			Y*	At the west end of study area 1
#P15-031	North river bank and waste concrete block	5797797	310248	NE	Y*		Y*	At the east end of study area 2
#P15-045	North river bank	5797892	310257	E			Y*	From the west end of study area 2
#P15-066	North river bank	5797827	310355	W			Y*	From the east end of study area 2
#P15-084	Washout undermining pedestrian trail	5798236	310727	W		Y*	Y*	At north end of study area 3
#P15-093	Pedestrian path and fence at crest	5798209	310717	S			Y*	Near washout area of study area 3
#P15-096	Pedestrian path and fence at crest	5798181	310712	N			Y*	Study Area 3
#P15-116	Vertical cut of west river bank	5798233	310719	S			Y*	At the north end of study area 3
#P15-118	Vertical cut of west river bank	5798243	310697	N			Y*	At the north end of study area 3
#P15-128	Crest of south river bank	5798822	310262	W			Y*	At the east end of study area 4
#P15-136	South river bank	5798821	310244	W			Y*	At the west end of study area 4
#P15-137	South river bank and geotextile	5798821	310244	E			Y*	At the center of study area 4
#P15-141	Pedestrian path, fence and crest area	5798840	310240	E			Y*	At the west end of study area 4

Notes:

2005 Photographs from Reference #7

2006 Photograph from Reference #6

* Provided in the report

All measurements in metres

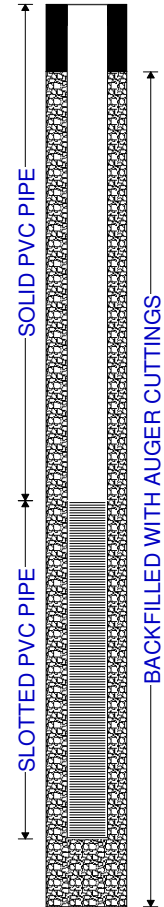


CLIENT: City of Red Deer
SITE: 3 Mile Bend
NOTES:

BOREHOLE NO.: 1

PROJECT NO.: RD6500-15
BH LOCATION:

SUBSURFACE PROFILE						Comments	Well Completion Details	Elevation (m)
Depth (m)	Description	Symbol	Moisture (Wp -----X----- Wl) 25 50 75	Type	Sample No	SPT (N)		
0	GROUND SURFACE							0.00
	Topsoil Black, organic, moist.							-0.20
	Silt Some sand, little clay, trace organic, non plastic, soft, damp.			G	1G1			
1								-1.20
	Sand Some silt, little clay, trace gravel, compact, fine to medium grained, damp.				1D1	11		
2								
3	Gravel Some sand, little silt, medium to coarse grained, rounded, brown, occasional cobbles, damp.				1D2	19		-3.00
				G	1G2			
4	Auger refusal at 4.0 m. Sloughed to 3.7 m upon completion. 25 mm PVC standpipe installed. Backfilled with auger cuttings and sand. Dry upon completion.							-4.00
5								
6								



LOGGED BY: AS
CONTRACTOR: Dark Horse Drilling Ltd.
RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem
DATE: November 8, 2018
CALIBRATION:

GROUND ELEVATION:
NORTHING:
EASTING:



CLIENT: City of Red Deer
SITE: 3 Mile Bend
NOTES:

BOREHOLE NO.: 2

PROJECT NO.: RD6500-15
BH LOCATION:

SUBSURFACE PROFILE			Moisture (Wp -----X----- Wl) 25 50 75	Type	Sample No	SPT (N)	Comments	Well Completion Details	Elevation (m)
Depth (m)	Description	Symbol							
0	GROUND SURFACE								0.00
	Sand Some silt, some gravel, medium grained, compact to dense, brown, damp. - Occasional rootlets to 0.6 m.			G	2G1			<p>SOLID PVC PIPE</p> <p>SLOTTED PVC PIPE</p> <p>BACKFILLED WITH AUGER CUTTINGS</p>	
1									
	Gravel Some sand, little silt, medium to coarse grained, rounded, brown, occasional cobbles, damp.				2D1	28	Poor recovery		-1.50
2				G	2G2				
3					2D2	20			
4	Auger refusal at 3.9 m. Sloughed to 3.7 m upon completion. 25 mm PVC standpipe installed. Backfilled with auger cuttings and sand. Dry upon completion.								-3.90
5									
6									

LOGGED BY: AS
CONTRACTOR: Dark Horse Drilling Ltd.
RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem
DATE: November 8, 2018
CALIBRATION:

GROUND ELEVATION:
NORTHING:
EASTING:

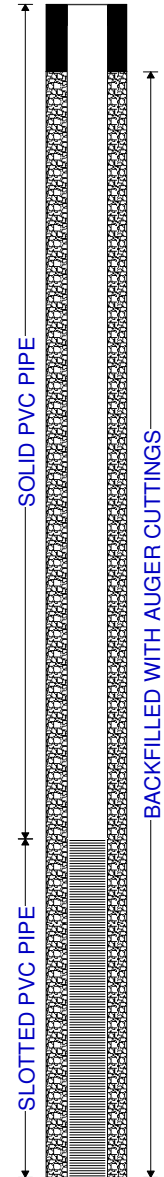


CLIENT: City of Red Deer
SITE: 3 Mile Bend
NOTES:

BOREHOLE NO.: 3

PROJECT NO.: RD6500-15
BH LOCATION:

SUBSURFACE PROFILE						Comments	Well Completion Details	Elevation (m)
Depth (m)	Description	Symbol	Moisture (Wp -----X----- Wl) 25 50 75	Type	Sample No	SPT (N)		
0	GROUND SURFACE							0.00
	Topsoil Black, organic, moist.							-0.30
	Silt Some sand, some to little clay, trace gravel, trace organic, low to non plastic, soft to firm, brown, damp.			G	3G1			
1								
	Sand Some silt, some gravel, fine to medium grained, compact to dense, brown, damp.				3D1	11	Poor recovery	-1.50
2								
				G	3G2			
3								
					3D2	19		
4	Gravel Some sand, little silt, medium to coarse grained, rounded, brown, occasional cobbles, damp.							-4.00
5								
	Auger refusal at 5.2 m. No slough upon completion. 25 mm PVC standpipe installed. Backfilled with auger cuttings and sand. Dry upon completion.							-5.20
6								



LOGGED BY: AS
CONTRACTOR: Dark Horse Drilling Ltd.
RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem
DATE: November 8, 2018
CALIBRATION:

GROUND ELEVATION:
NORTHING:
EASTING:

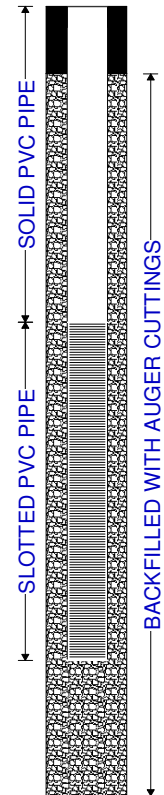


CLIENT: City of Red Deer
SITE: 3 Mile Bend
NOTES:

BOREHOLE NO.: 4

PROJECT NO.: RD6500-15
BH LOCATION:

SUBSURFACE PROFILE						Comments	Well Completion Details	Elevation (m)
Depth (m)	Description	Symbol	Moisture (Wp -----X----- Wl) 25 50 75	Type	Sample No	SPT (N)		
0	GROUND SURFACE							0.00
	Sand Some silt, some gravel, fine to medium grained, compact to dense, brown, damp to moist. - Occasional rootlets to 0.4 m.							
1	Gravel Some sand, little silt, medium to coarse grained, rounded, brown, occasional cobbles, damp.			G	4G1			-0.50
2								
					4D1	20		
3				G	4G2			
					4D2	35		
4	Auger refusal at 3.5 m. Sloughed to 2.9 m upon completion. 25 mm PVC standpipe installed. Backfilled with auger cuttings and sand. Dry upon completion.							-3.50
5								
6								



LOGGED BY: AS
CONTRACTOR: Dark Horse Drilling Ltd.
RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem
DATE: November 8, 2018
CALIBRATION:

GROUND ELEVATION:
NORTHING:
EASTING:

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	15-01	
Site Name	3 Mile Bend – Area 1	
Legal Land Description	NW 27-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	309950 m E, 5798010 m N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	1 - Installed Nov 8, 2018
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 31, 2018	9	6	56
Inspected By:	Bryden Lutz			
Report Attachments:	30 Site photos taken 1 Borehole Logs			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Angular		
Slope Movement	Crest regression (vegetation overhanging crest – photo 28)		
Erosion	Erosion of river bank (near outside bend of river)		
Seepage	None observed		
Distress	Possible cracking of trail related to slope at east end of site (where slope becomes more gradual), crack is partially parallel to slope with many divergent crack angles		
Other			
Instrumentation:	<ul style="list-style-type: none"> Piezometer water level measure on Nov 19, 2018 		
Other Comments:	<ul style="list-style-type: none"> 		

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Discussion	<ul style="list-style-type: none">- Near vertical slope face below crest in vegetated area. Slope face shows till overlying gravel, photo 25- Slope crest is regressing, trees and vegetation in this area is helping to hold the slope in place and slow down regression
Assessment	<ul style="list-style-type: none">- Expect vertical face to fail, could impact trail
Recommendations	<ul style="list-style-type: none">- Annual site inspections, may need to realign trail in the medium term

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	15-02	
Site Name	3 Mile Bend – Area 2	
Legal Land Description	NW 27-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	310305 m E, 5797880 m N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	1 - Installed Nov 8, 2018
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 31, 2018	9	6	56
Inspected By:	Bryden Lutz			
Report Attachments:	45 Site photos taken 1 Borehole Logs			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded		
Slope Movement	None overserved		
Erosion	Erosion of river bank		
Seepage	None observed		
Distress	None observed		
Other			
Instrumentation:	<ul style="list-style-type: none"> Piezometer water level measure on Nov 19, 2018 		
Other Comments:	<ul style="list-style-type: none"> 		

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Discussion	<ul style="list-style-type: none">- Slope is fairly gradual- Road and trail seem to be a reasonable distance from slope
Assessment	<ul style="list-style-type: none">- Slope appears to be stable, expect minor regression at river bank from erosion
Recommendations	<ul style="list-style-type: none">- Periodic site inspections (every 3-5 years) and after flooding

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	15-03	
Site Name	3 Mile Bend – Area 3	
Legal Land Description	NE 27-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	310305 m E, 5797880 m N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	1 - Installed Nov 8, 2018
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 31, 2018	9	6	56
Inspected By:	Bryden Lutz			
Report Attachments:	45 Site photos taken 1 Borehole Logs			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Angular		
Slope Movement	Washouts in multiple locations (photo 97)		
Erosion	Erosion of toe by river		
Seepage	None observed		
Distress	None observed		
Other			
Instrumentation:	<ul style="list-style-type: none"> Piezometer water level measure on Nov 19, 2018 		
Other Comments:	<ul style="list-style-type: none"> 		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Vertical slope toe cut is largest at the north of the area, trail pulls away from crest past bench/ washout area.- Main washout appears to be slowly undermining trail – photo 91- Area appears to experience significant toe erosion in the spring
Assessment	<ul style="list-style-type: none">- Expect slope to fail into trail area at washout in the near future- Likely too expensive to armour and re-support toe- May need to realign trail in the medium term
Recommendations	<ul style="list-style-type: none">- Site inspections on an annual basis- Consider designing trail realignment before existing trail is impacted

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	15-04	
Site Name	3 Mile Bend – Area 4	
Legal Land Description	SW 34-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	310240 m E, 5798820 m N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	1 - Installed Nov 8, 2018
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 31, 2018	9	6	56
Inspected By:	Bryden Lutz			
Report Attachments:	19 Site photos taken 1 Borehole Logs			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Angular		
Slope Movement	Crest regression – photo 141		
Erosion	Erosion of toe by river		
Seepage	None observed		
Distress	None observed		
Other			
Instrumentation:	• Piezometer water level measure on Nov 19, 2018		
Other Comments:	• Filter fabric draped over crest, not sure if to try to limit erosion or other use		

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Discussion	<ul style="list-style-type: none"> - Significant toe erosion creating vertical slope face - Trail has fence are a fair distance from crest (about 3 times the height of the slope) - Geofabirc draped over slope crest for unknown reason. Could be an attempt to limit erosion?
Assessment	<ul style="list-style-type: none"> - No expected impact on trail system
Recommendations	<ul style="list-style-type: none"> - Leave slope "as is" to regress - Site inspections on a periodic basis, maybe every 3 to 5 years or after flood events

SITE #16



Garden Heights Above 67th Street

SITE #16 - GARDEN HEIGHTS

16.1 SITE DESCRIPTION

The Site #16 - Garden Heights site is the south slope of the last block developed in the southwest corner of Garden Heights subdivision, as shown on Figure 1 of the main report. The site is bounded by Red Deer River valley to the west, 67th Street to the south and the previously developed phases of Garden Heights subdivision to the north and east. The area of concern is the 140 m long slope overlooking 67th Street. This is the site of a historical landslide which occurred during cut slope grading for the construction of 67th Street in 1986. Prior to 67th Street, there was an old east-west access road located about 10 to 15 m south of the current slope crest. The slope above this road to the north was considered to be an old cut slope. This road provided access into the river valley on the alignment of the current MacKenzie Trail access road at the base of the hill just north of 67th Street. The old road alignment has been used as a right-of-way for an underground service line which was related to the 1986 landsliding (see Figure 16-5B). An ATCO high pressure pipeline is located along the crest of this slope. The Site Plan is shown as shown on Figure 16-1. The current slope contours are shown on Figure 16-2. A representative cross-section through the center of the landslide area is provided in Figure 16-3.

The upland subdivision area is relatively level at an elevation of 882 to 883 m. The river valley slope along the west boundary in this corner of the subdivision was about 34 m high with a crest elevation dropping to 849 m at the toe. The grade of 67th Street below the site to the south drops from an elevation of about 875 to 865 m with an estimated grade of 5 percent. This grade drop was created with a cut/fill operation which removed soil from the upper slope area and placed it over the toe of the slope to create the approach embankment down to the east abutment of the 67th Street bridge. The upper natural slopes of the river valley range from about 3.5H:1V to 5.6H:1V and the cut slope is about 4H:1V perpendicular to 67th Street. The river valley slope in this area is moderately to heavily treed with mature spruce and poplar trees. The cut slope has light tree cover in the east part of the area and a grassed slope in the west half of the area. Site aerial photographs are shown on Figure 16-4B and 16-4C and site photographs are provided on Figures 16-5A and 16-5B.

16.2 REFERENCES

The references from Appendix B which apply to Site #16 - Garden Heights include References #67, #68 and #69. Reference #67 describes the 1986 landslide. The most recent site investigation for the slope was performed at the crest of the river valley slope and 67th Street cut slope for final block of Garden Heights development in 2015 (Reference #69). The other reference was the main subdivision report prepared for the City of Red Deer which included a detailed top-of-slope assessment for the river valley.

16.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

In 1985, several boreholes were drilled on the slope and along the 67th Street alignment. On August 28, 2015, two boreholes were drilled at the location shown on Figure 16-1. One borehole near the crest was drilled to a depth of 19.5 m below grade. No slope inclinometers or other instrumentation has been installed in this area.

16.4 2018 REVIEW

Aerial photography is provided on Figures 16-4A and 16-4B for the years listed in the following table. The aeriels show the slope has not experienced any further landsliding since 67th Street was constructed in 1986.

TABLE 16-1: AERIAL PHOTOGRAPHS

Year	Description
1985	Shows the original site condition prior to 67 th Street construction and 1986 landslides.
1986	Shows the road cut for 67 th Street during construction.
2001	Shows the site condition over 15 years ago.
2016	Shows the present Site condition.

The Garden Heights site was visited on October 24 and November 8, 2018. A copy of the field inspection record is attached at the end of this appendix.

The ortho-contours from 2016 City aerial photography was reviewed for this study. A control survey of the site was performed in 2018. A record of survey control points and data is appended in Table 16-4. A reference drawing of survey reference points is provided on Figure 16-6.

Selected site photographs from 2018 are provided on Figures 16-5A and 16-5B. A list of available photos at this site is appended in Table 16-5. A reference drawing of photograph locations is provided on Figure 16-7.

16.5 SUBSURFACE PROFILE

The soil profile encountered was, in descending order: topsoil; glacio-lacustrine silt and clay; and sand and gravel. This is considered to be the typical upland soil profile in this area. The closest borehole profile is shown on the Figure 16-3 cross section. The following is a brief description of the soil types encountered.

1. **Topsoil.** The site originally had about 300 mm topsoil. The slope face and developed upland areas have been landscaped with topsoil and grass.

2. **Silt, Sand and Clay.** The upper slope soils are interbedded lacustrine clay and silt which is present to a depth of 16.7 mbg or about 865 m. The silty clay was stiff, low to medium plastic and wet with typical moisture contents of 20 to 35 percent.
3. **Sand.** A 1 m thick sand layer was encountered below the lacustrine deposits. This sand was a compact, coarse grained and wet with a moisture content of 18 percent.
4. **Till.** Till was encountered below the sand layer and it extended beyond the depth drilled (ie. Elevation 862 m). The local till is a mixture of sand and silt with some clay, trace amounts of gravel and occasional coal inclusions. The till encountered was a sand till that was non plastic, dense and moist with moisture contents of 10 to 14 percent.
5. **Bedrock.** Bedrock was not encountered within the depths drilled. Based on local water well records the bedrock formation is expected to be 35 to 40 m below grade at an elevation of about 845 m.
6. **Groundwater.** Groundwater table was encountered below the crest area about 17 m below grade at elevation 865.5 m in September 2015. The groundwater in the upland area to the east is expected to be as shallow as 3 to 5 m below grade. In 1986, there was evidence of seepage in shallow excavations which was suggestive of shallow perched groundwater conditions at the time the road cut was being made.

TABLE 16-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Shear Strength (kPa)	Cohesion, c' (kPa)	Phi, φ' (Degrees)
Silt	18	25	0 - 2	27
Clay	19.5	50	0 - 5	23 - 25
Sand and Till	21	0	0	32
Bedrock	21	300	30	40

16.6 SLOPE ISSUES (BACKGROUND & CHRONOLOGY)

This site was originally a mature slope of the Red Deer River valley located about 550 m east of the river. It was the site of a local access road down into the river valley. Going back to 1949, the slope face in this area was grassed and sparsely treed.

In 1986, the City of Red Deer began construction on the east approach to the 67th Bridge which was under construction at the time. The new road alignment was constructed by cutting into the upper slope perpendicular to the river valley wall and using the material for a fill embankment on the lower slope to the west. The original slopes north and south of 67th Street above an elevation of between 860 and 865 m were subject to 4H:1V cuts. The rough cuts for the road were completed in August of 1986.

As part of the 1986 construction, a 2.5 to 3 m deep storm sewer was installed on the road cut parallel to the former access road alignment. 1986 during the storm line installation, tension cracks were observed about half way up the slope below an elevation of about 875 to 877 m. Inspection of the excavation indicated several horizontal failure planes along the north wall of the trench. The base of the trench was measured to be at 866.5 m. An investigation found evidence of slickensides within the surficial soil which is indicative of ancient surficial landslide movement as suggested in the original soil report for the road project. Survey hubs were established to measure movements. On the basis of the visual inspection and survey data the block moved 100 to 200 mm downslope and failure scarps started to progress up-slope.

The landslide was assessed to have potential for both shallow and deeper seated failures due to wet, weak high plastic clay soils near the toe of the road cut. The recommended work undertaken included: providing french drains down the slope face in the upper slope, removing weak soils from the toe area and replacing them with free draining gravel tied to a drain trench at the toe of the cut slope just north of 67th Street. Since the stabilization work was completed in 1986, this upper slope area has not been subject to any observed instabilities.

16.7 REVIEW OF STABILITY ASSESSMENT

Stability analysis against landsliding was carried out for the subdivision in 2015 using *GeoStudio SLOPE/W* computer program to evaluate the factor of safety for the representative slope models including the 67th Street cut-slope. Stability analysis against landsliding was verified using the *SLOPE/W* computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 16-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Slope Face	< 1.0	-
Slump on Slope Face - Short-term	1.1	-
Failure through ATCO line (assumed location)	1.28	Figure 16-8
Property Line	1.3	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

Site #16 is an engineered cut slope with remedial sub-drainage measures and a landscaped slope face above the road. This slope has not experienced major instability since construction over 32 years ago). The long-term assessment is that the potential for a major slope movement at this site is low under present normal conditions with reasonable variation and the risk of ongoing face regression has been reduced. The FS against a small shallow “slump-type” failure on the slope face is estimated to be at least 1.1. There are some over-steepened areas above the old access road cut which are marginally stable at the present time and could be subject to a small slide.

These two modes of slope failure as considered to be possible, but with the present vegetation cover it would take unusually wet conditions to cause this movement. In review of development in the area private lots are not at risk, but there is some risk to local City of Red Deer and ATCO services.

16.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

PF(7) * CF(6) = 42 - ATCO Gas Line/ City Storm Sewer

A Probability Factor of 7 is considered appropriate since there is no active landsliding in the upper slope along the entire top-of-bank and cut slope area, but there is a high probability of small slide in the cut slope area near the southwest corner of the site. A Consequence Factor of 6 is considered appropriate due to the proximity of steepened slope areas to the buried ATCO gas line.

PF(7) * CF(1) = 7 - Other Subdivision Development

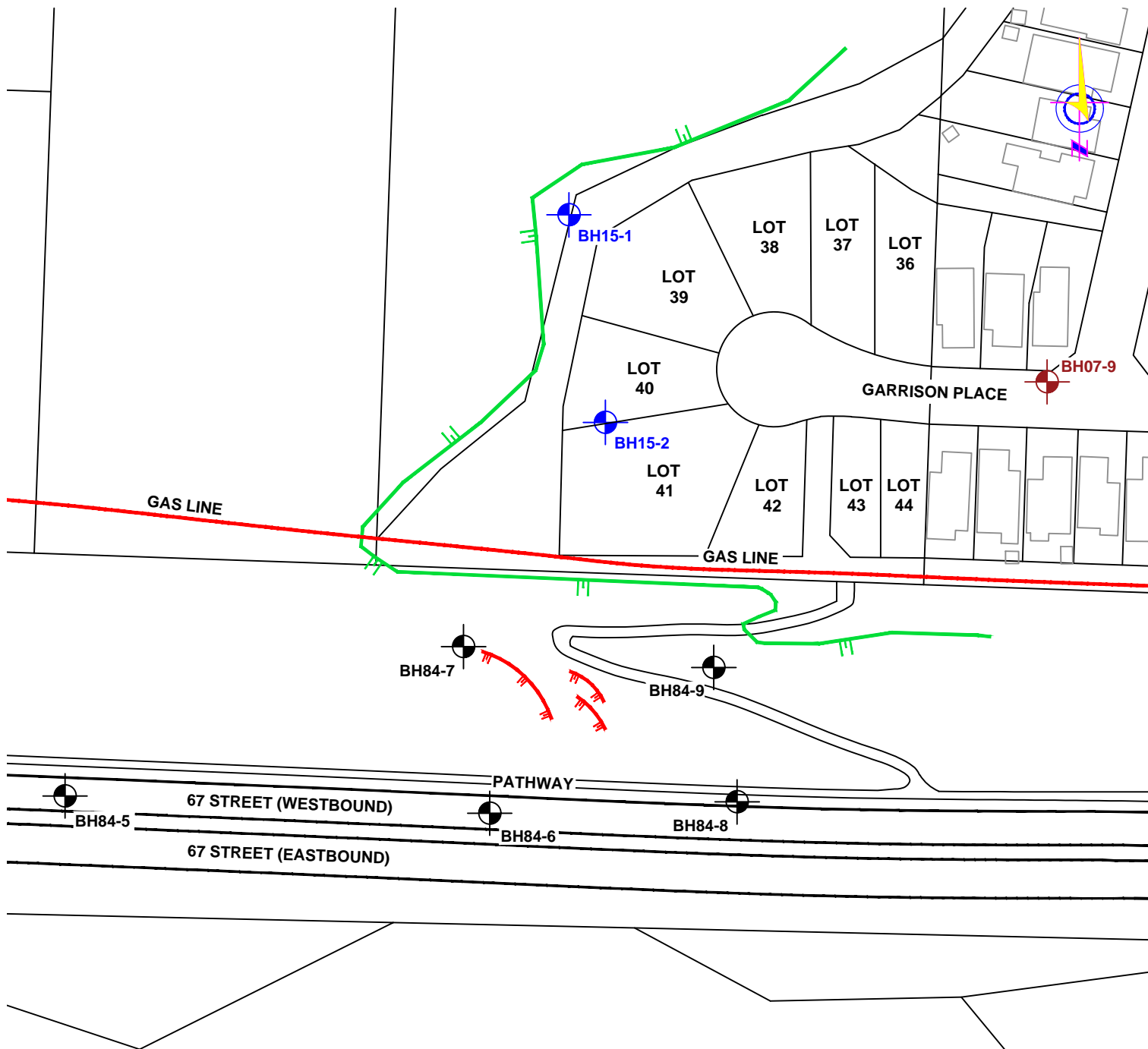
A Probability Factor of 7 is considered appropriate due to the high probability of small slide in the cut slope area near the southwest corner of the site. A Consequence Factor of 1 is considered appropriate since the potential slide areas are well away from private property and permanent residences. The sliding impacts would be limited to the reserve buffer areas provided by development setbacks for the subdivision.








16.9 RECOMMENDATIONS

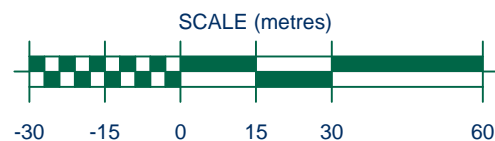
The recommended monitoring action for Site #16 - Garden Heights is to undertake annual visual site inspections of the slope to identify any significant changes, if present. Inspections should include control surveys along the crest relative at fixed points to verify regression rates.

16.10 ATTACHMENTS

Figure 16-1 - Site Plan
Figure 16-2 - 2016 Contour Plan
Figure 16-3 - Cross Section Profiles
Figure 16-4 - Aerial Photographs
Figure 16-5 - Site Photographs
Figure 16-6 - Survey Marker Plan
Figure 16-7 - Photograph Plan
Figure 16-8 - Stability Analysis Run
Table 16-4 - List of Survey Markers
Table 16-5 - List of Photographs
Site Inspection Record (October 24, 2018)



-  EXISTING BUILDING
-  CREST OF SLOPE
-  TOE OF SLOPE
-  1986 LANDSLIDE SCARPS
-  1984 BOREHOLE LOCATIONS (REFERENCE #67)
-  2007 BOREHOLE LOCATIONS (REFERENCE #68)
-  2015 BOREHOLE LOCATIONS (REFERENCE #69)



ALL BOREHOLE LOCATIONS ARE APPROXIMATE.

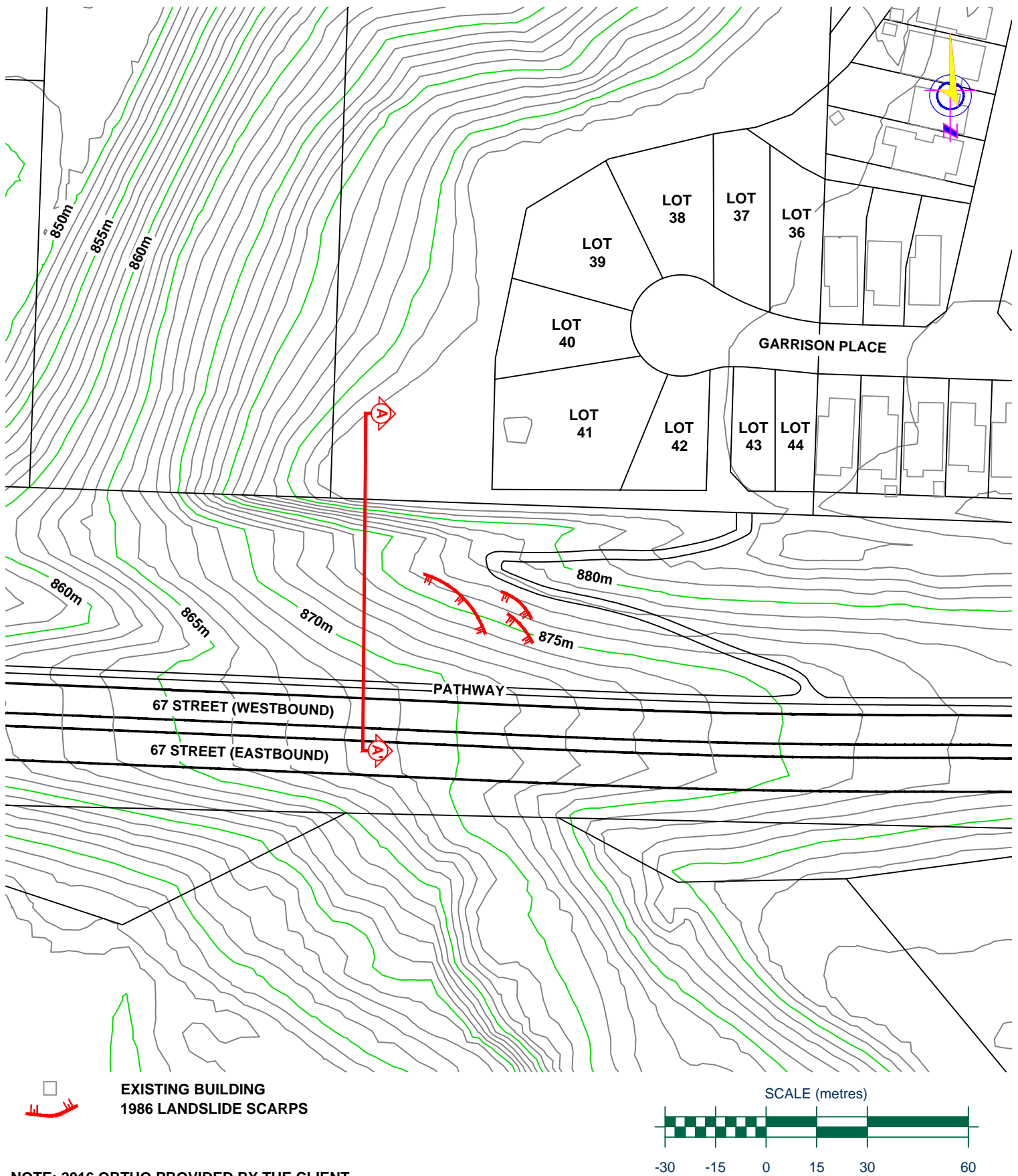
CLIENT:





SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION GARDEN HEIGHTS

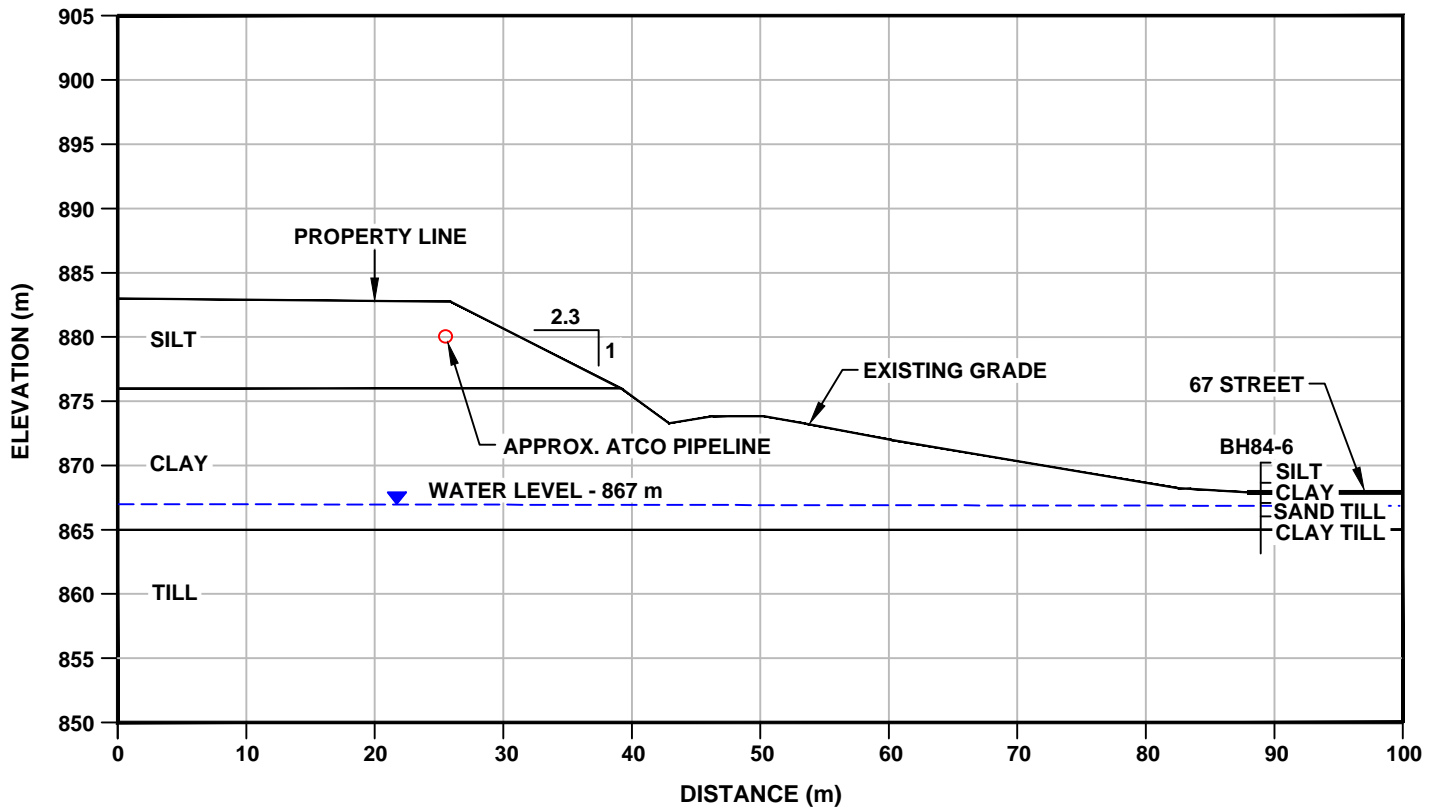
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-16	DRAWING NO. FIGURE 16-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.

	<div>CLIENT:</div> <div></div>	<div>CONTOUR PLAN</div>			
		<div>CITY OF RED DEER SLOPE STABILITY EVALUATION GARDEN HEIGHTS</div>			
		<div>DRAWN:</div> <div>NC</div>	<div>CHK'D.:</div> <div>MDB</div>	<div>REV #:</div> <div>2</div>	<div>DATE:</div> <div>APRIL 2019</div>
		<div>SCALE:</div> <div>1:1500</div>	<div>JOB NO.</div> <div>RD6500-16</div>	<div>DRAWING NO.</div> <div>FIGURE 16-2</div>	

16-3: CROSS SECTION (A - A')



CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
GARDEN HEIGHTS

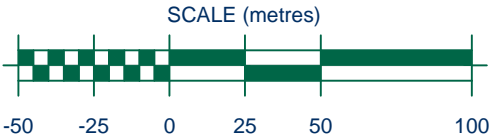
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-16	DRAWING NO. FIGURE 16-3	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED APRIL 15, 1985.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED OCTOBER 16, 1986.



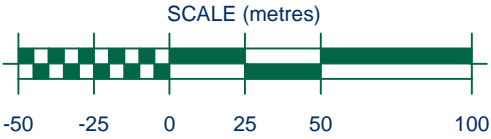
	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GARDEN HEIGHTS			
	DRAWN:	CHK'D:	REV #:	DATE:		
	RS	MDB	2	APRIL 2019		
	SCALE:	JOB NO.		DRAWING NO.		
	1:2500	RD6500-16		FIGURE 16-4A		



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GARDEN HEIGHTS			
			DRAWN:	CHK'D.:	REV #:	DATE:
			RS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		1:2500	RD6500-16		FIGURE 16-4B	



PHOTOGRAPH 4 (2018): CREST NEAR THE STEEPEST POINT OF SLOPE, FACING EAST



PHOTOGRAPH 7 (2018): NEWLY CONSTRUCTED STRAIGHT FENCE PARALLEL TO SLOPE, FACING EAST



PHOTOGRAPH 13 (2018): EAST EXTENT OF SLOPE CREST, FACING NORTHWEST



PHOTOGRAPH 16 (2018): TRAIL SWITCH BACK, TAKEN FROM FROM STORM SEWER VAULT AREA, FACING SOUTHEAST



PHOTOGRAPH 19 (2018): SLOPE FACE FROM WEST EXTENT, FACING NORTHEAST



PHOTOGRAPH 20 (2018): SLOPE ALONG STORM SEWER / OLD ROAD ROW ALIGNMENT, FACING EAST

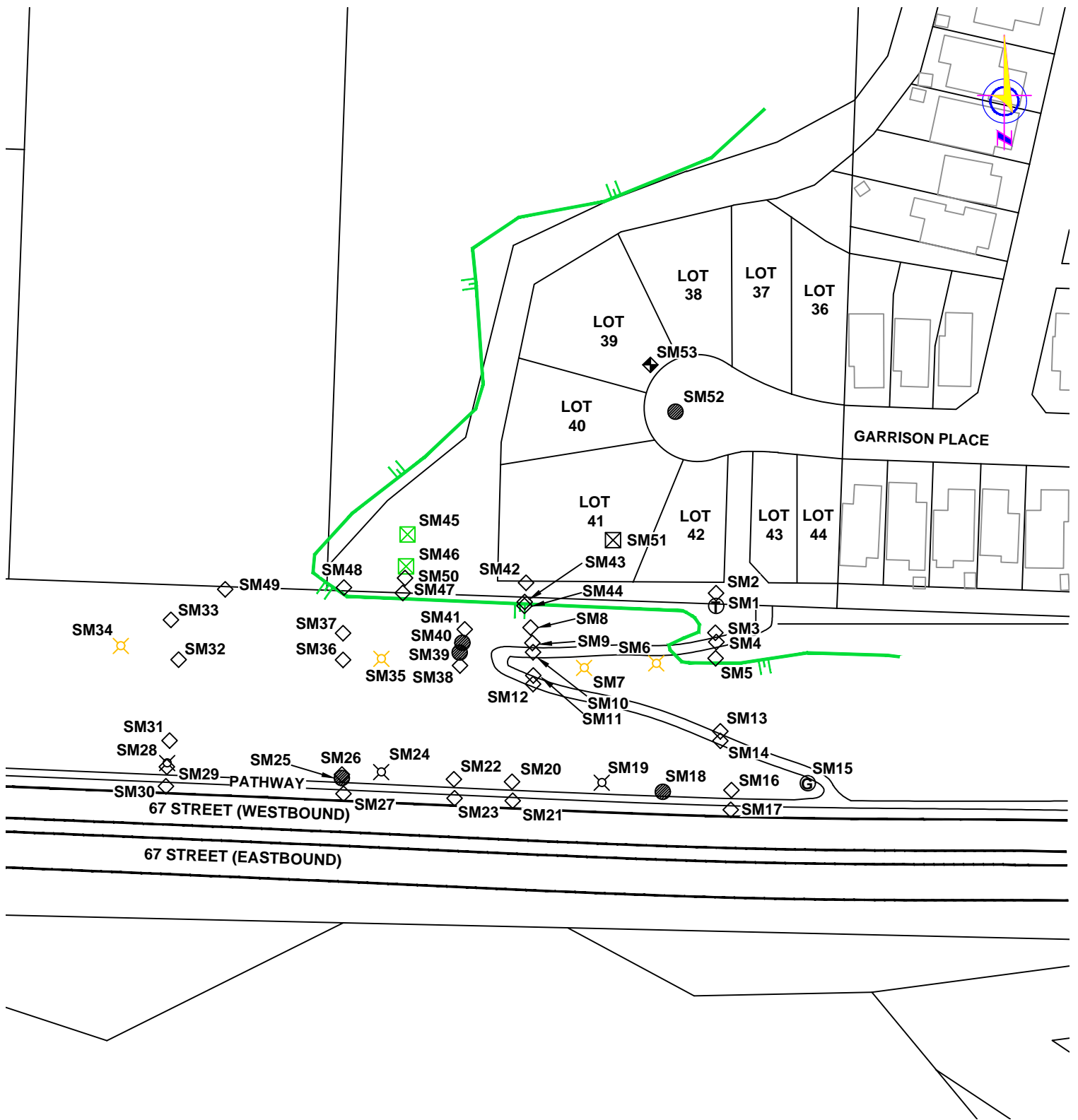


PHOTOGRAPH 21 (2018): BARREN UPPER SLOPE FACE, FACING NORTH

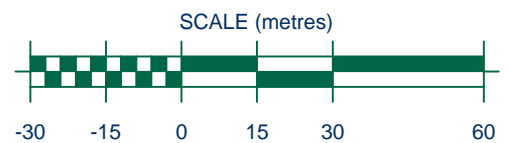


PHOTOGRAPH 24 (2018): STEEP SLOPE IN THE WEST EXTENT OF STUDY AREA, FACING NORTHWEST

	CLIENT:		SITE 16 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GARDEN HEIGHTS			
	DRAWN:	CHK'D.:	REV #:	DATE:		
	PS	MDB	2	APRIL 2019		
SCALE:	JOB NO.		DRAWING NO.			
NTS	RD6500-16		FIGURE 16-5B			



- | | | |
|---------------------|----------------|---------------|
| ⊠ DECK CORNER | ◆ FIRE HYDRANT | Ⓞ GARBAGE BIN |
| ● MANHOLE | ⚡ POWER POLE | |
| ⦿ LIGHT POLE | ⊠ FENCE CORNER | |
| ◇ SURVEY LAND POINT | Ⓢ TELUS | |



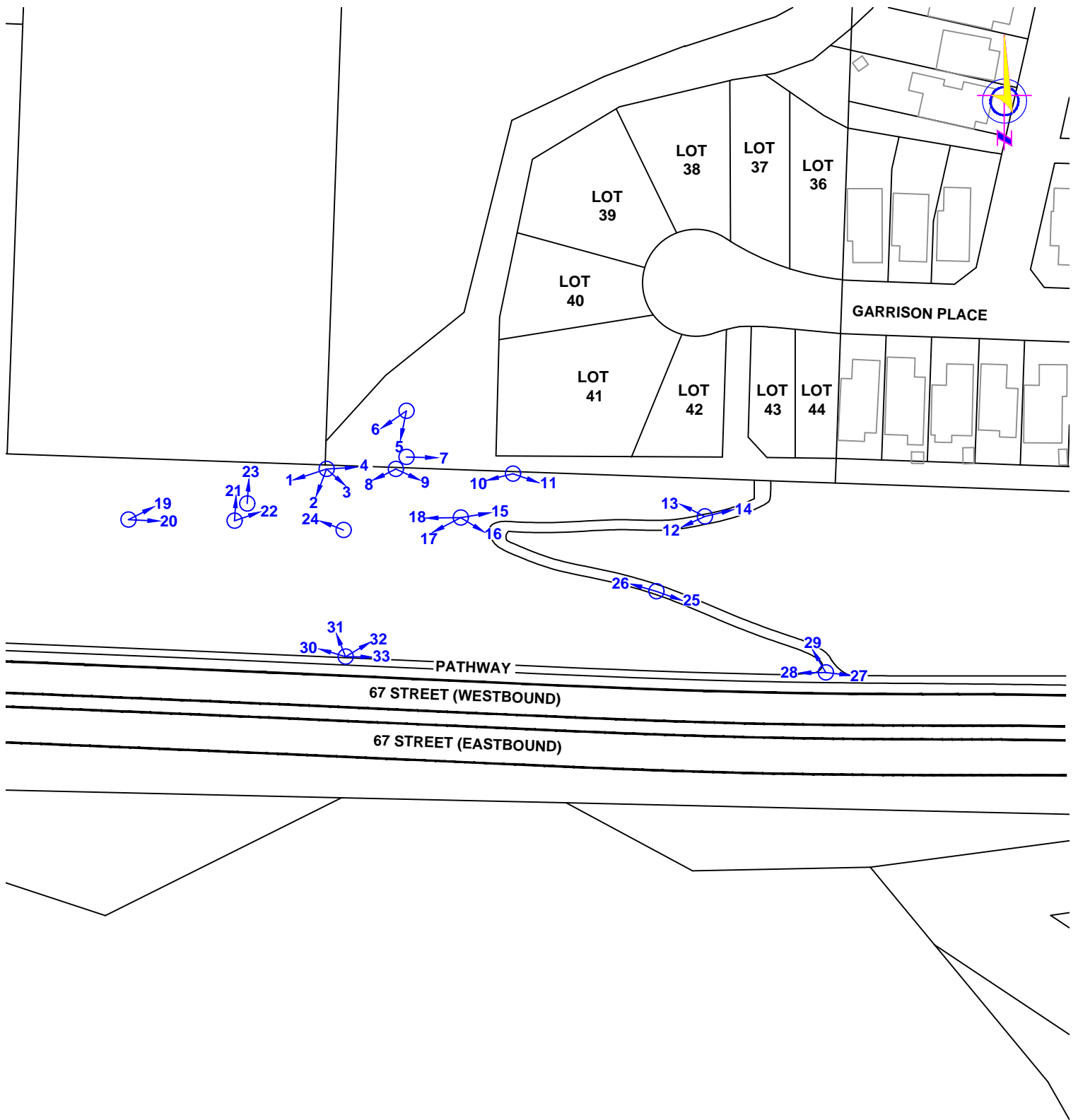
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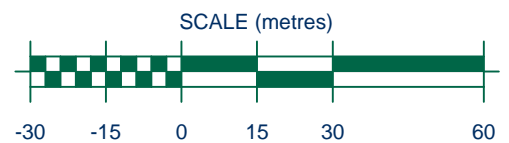
SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
GARDEN HEIGHTS

DRAWN: NC	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-16	DRAWING NO. FIGURE 16-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



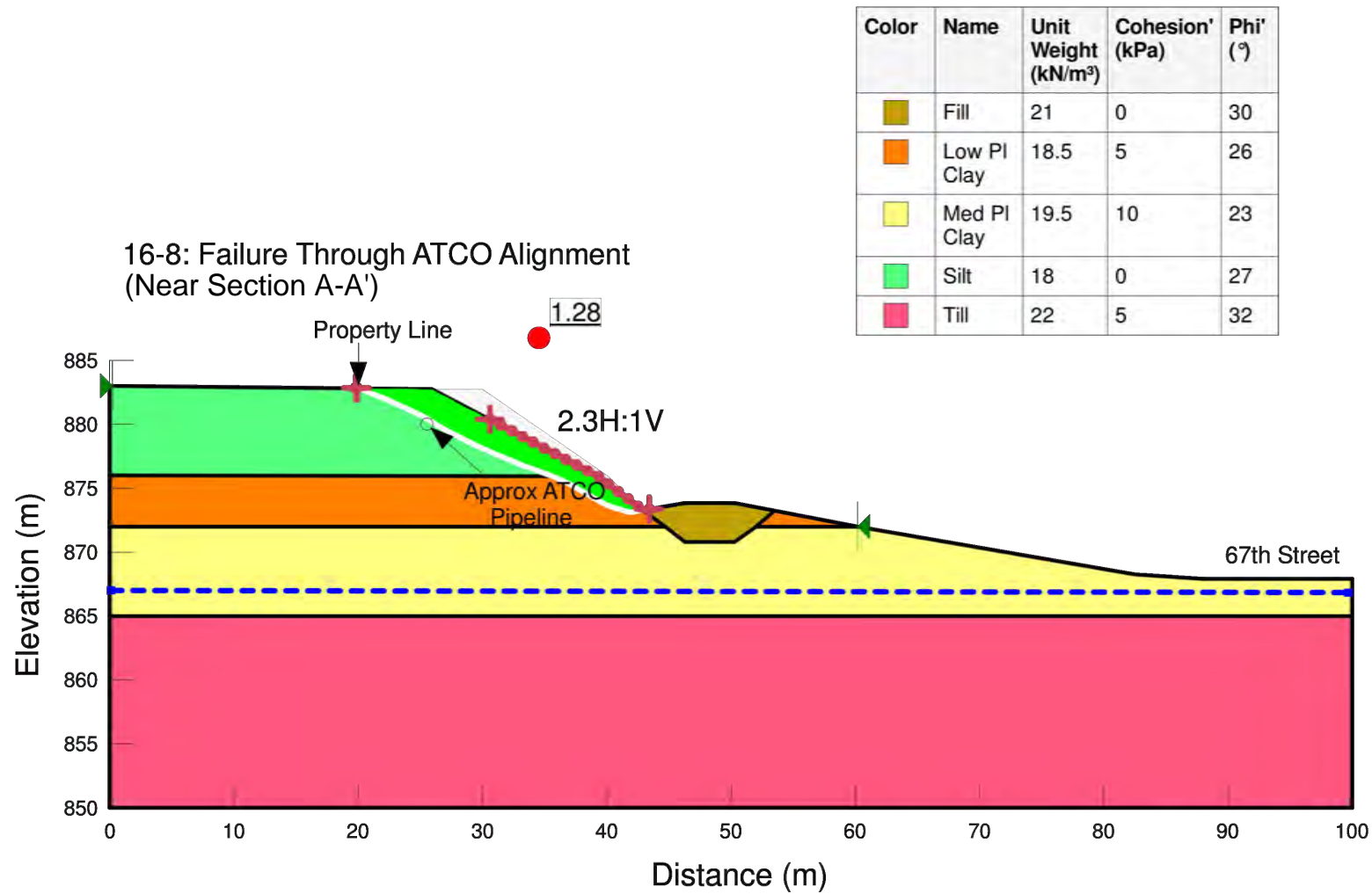
CLIENT:





SITE 16 PHOTOGRAPHS

CITY OF RED DEER SLOPE STABILITY EVALUATION
GARDEN HEIGHTS

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-16	DRAWING NO. FIGURE 16-7	



	CLIENT: 	STABILITY ANALYSIS RUN			
		CITY OF RED DEER SLOPE STABILITY EVALUATION GARDEN HEIGHTS			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: AS SHOWN		JOB NO. RD6500-16	DRAWING NO. FIGURE 16-8

SITE #16 - GARDEN HEIGHTS

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 16-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM16-001	Telus	5796801.43	310022.29	882.70				
#SM16-002	Trail	5796804.99	310022.28	882.91				
#SM16-003	Trail	5796793.88	310022.06	882.58				
#SM16-004	Trail	5796791.31	310022.37	882.55				
#SM16-005	Crest	5796786.70	310022.15	882.27				
#SM16-006	Pole	5796785.30	310005.56	881.40				
#SM16-007	Pole	5796784.05	309985.31	880.13				
#SM16-008	Toe	5796795.33	309970.24	878.74				
#SM16-009	Trail	5796791.02	309970.74	879.41				
#SM16-010	Trail	5796788.45	309970.91	879.40				
#SM16-011	Trail	5796781.91	309970.99	878.17				
#SM16-012	Trail	5796779.48	309970.94	878.09				
#SM16-013	Trail	5796766.23	310023.48	876.91				
#SM16-014	Trail	5796763.56	310023.48	876.84				
#SM16-015	Garbage	5796751.65	310048.00	875.56				
#SM16-016		5796749.73	310026.58	874.35				
#SM16-017	Curb	5796744.20	310026.42	874.01				
#SM16-018	MH	5796749.20	310007.36	873.44				
#SM16-019	Light Pole	5796751.82	309990.24	872.69				
#SM16-020		5796752.07	309965.00	871.19				
#SM16-021		5796746.71	309965.21	870.79				
#SM16-022		5796752.76	309948.73	870.22				
#SM16-023	Curb	5796747.44	309948.94	869.82				
#SM16-024	Light Pole	5796754.80	309928.37	869.15				
#SM16-025	MH	5796753.08	309917.30	868.19				
#SM16-026	Trail	5796754.06	309917.32	868.23				
#SM16-027	Curb	5796748.68	309917.73	867.91				
#SM16-028	Light Pole	5796757.32	309868.31	865.27				
#SM16-029		5796756.26	309868.20	865.41				
#SM16-030	Curb	5796750.82	309867.94	865.14				
#SM16-031	Toe	5796763.63	309868.96	863.80				
#SM16-032	Crest	5796786.32	309871.47	868.04				
#SM16-033	Toe	5796797.51	309869.39	867.64				
#SM16-034	Pole	5796790.22	309855.29	866.13				
#SM16-035	Pole	5796786.59	309928.41	875.26				
#SM16-036	Crest	5796786.29	309917.64	873.84				
#SM16-037	Toe	5796793.69	309917.60	873.29				
#SM16-038	Crest	5796784.70	309950.45	877.73				
#SM16-039	MH	5796788.32	309950.37	878.16				
#SM16-040	MH	5796791.04	309951.09	878.18				
#SM16-041	Toe	5796794.86	309951.79	877.21				
#SM16-042	Vault	5796807.89	309968.95	882.87				
#SM16-043	Ground	5796802.52	309968.57	882.72				
#SM16-044	Crest	5796801.44	309968.54	882.49				
#SM16-045	Fence	5796821.48	309935.75	882.97				
#SM16-046	Fence	5796812.54	309935.33	882.87				
#SM16-047	Crest	5796805.04	309934.37	882.76				
#SM16-048	Crest	5796806.58	309917.88	882.76				
#SM16-049	Crest	5796806.09	309884.58	876.25				
#SM16-050	Trail	5796809.25	309935.02	882.98				
#SM16-051	Deck	5796819.93	309993.40	882.94				
#SM16-052	MH	5796855.94	310010.91	885.12				
#SM16-053	FH	5796869.10	310003.91	885.36				

TABLE 16-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P16-004	Crest near the steepest point of slope	5796805	309914	E	Y*	
#P16-007	Newly constructed straight fence parallel	5796808	309936	E	Y*	
#P16-013	East extent of slope crest	5796791	310020	NW	Y*	
#P16-016	Trail switch back	5796791	309951	SE	Y*	
#P16-019	Slope face from west extent	5796790	309858	NE	Y*	
#P16-020	Slope along storm sewer/old road row	5796790	309858	E	Y*	
#P16-021	Barren upper slope face	5796790	309888	N	Y*	
#P16-024	Steep slope in west extent of study area	5796788	309918	NW	Y*	

Notes:

* Provided in the report

All measurements in metres

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	16	
Site Name	Garden Heights/ 67 th Street	
Legal Land Description		
Address	N/A	
UTM Coordinates (approx. site center)	309950 E, 5796820 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 24, 2018	7	10	70
Inspected By:	Bryden Lutz - PGEO			
Report Attachments:	33 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Angular	N/A	
Slope Movement	Tension crack near west edge crest (0.3 m back), loose soil on face, no vegetation on face until bottom third.	N/A	
Erosion	None observed	N/A	
Seepage	None observed	N/A	
Distress	None observed	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments: <ul style="list-style-type: none"> ATCO high pressure vault noted near crest. The pipeline appears to run parallel to crest between crest and trail at unknown depth. 			

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none"> - Slope originally cut to make road and install services (road removed when 67th built circa 1986). - Slope appears to have been stable since being cut with slow erosion related to weather events. Slope is still too steep for vegetation growth or has an active face. - ATCO high pressure line may be located at crest inside the subdivision property setback.
Assessment	<ul style="list-style-type: none"> - Area could be at high risk due to pipeline, needs further analysis and information.
Recommendations	<ul style="list-style-type: none"> - Check depth and location of pipeline, re-assess risk due to pipeline. If risk is high consider moving pipeline or removing pipeline from service.

SITE #17



**Gaetz Avenue West Service Road
North of 37th Street**

SITE #17 - GAETZ AVENUE WEST SERVICE ROAD N. OF 37TH STREET

17.1 SITE DESCRIPTION

Site #17 is the west slope between the Gaetz Avenue West Service Road north of 37th Street and Gaetz Avenue at the top of the south hill bordering downtown Red Deer, as shown on Figure 1 of the main report. This cut slope borders the west side walk along Gaetz Avenue as the grade of the road drops into the downtown area. The crest of the slope is bordered by a guard rail just behind the curb of the service road which ties into 39th Street. The Site Plan is shown on Figure 17-1. A 2016 Contour Plan is provided on Figure 17-2. Representative cross-sections of the cut slope are provided on Figure 17-3.

The guard rail beside the road has overturned about 20° from vertical. There are also tension cracks in the road surface which was rebuilt in 2014. The crest elevation in the area is about 878 m and the toe of the cut slope varies from a couple of metres to over 6 m as the Gaetz Avenue grade begins dropping downslope in the area. The average inclination from toe to crest ranges from 1.6H:1V to 2.3H:1V as shown on Figure 17-3. The slope appears to get slightly flatter moving down hill, so the steepest sections are not the highest. The slope face is grassed and has a few small bushes. There is a transformer and underground service lines near the top of the slope. Local development in the upland area along the service road is a mix of single family and apartment residences.

17.2 REFERENCES

No site specific geotechnical reference reports were available for this site.

17.3 2018 REVIEW

Aerial photography is provided on Figure 17-4 for the years listed in the following table. Aerial photographs show this area has been relatively stable for the past twenty years.

TABLE 17-1: AERIAL PHOTOGRAPHS

Year	Description
2001	Shows the site condition 18 years ago.
2016	Shows the present Site #17 condition including visible tension cracks.

The Gaetz Avenue West Service Road site was visited on October 15 and November 8, 2018. A copy of the field inspection record is attached at the end of this appendix.

Photographs were taken during the site visits. A list of available photos at this site is appended in Table 17-5. Selected site photographs are provided on Figures 17-5; along with a reference drawing of all photograph locations which is provided on Figure 17-7.

The ortho-contours from 2016 City aerial photography was reviewed for this study. A control survey of the site was performed in 2018. The ground surface elevations at the boreholes were surveyed using a Trimble GeoXH 2008 Series GPS receiver and a Trimble Zephyr GPS antenna. A record of survey control points and data for Site #17 is appended in Table 17-4. A reference drawing of survey reference points is provided on Figure 17-6.

17.4 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

On October 19, 2018, two boreholes were drilled at the site to depths up to 14.4 m below grade. The borehole locations are shown on Figure 17-1. A slope inclinometer (SI) was installed in Borehole 1 near a guard rail on the east side of the road. The SI is protected by a metal cover pipe. A stand pipe was installed in Borehole 2. The standpipe was measured at completion of drilling and on November 8, 2018.

17.5 SUBSURFACE PROFILE

The boreholes were drilled in the landscaped area beside the road. The soil profile encountered at this site was in descending order: topsoil; lacustrine silt and clay; till; a coarse grained sand and gravel; and weathered silt-stone bedrock. The detailed soil conditions encountered at the borehole locations are described on the borehole logs provided in this appendix. The borehole profiles are shown on the cross sections in Figure 17-3. The terminology and symbols used on the borehole logs are provided in Appendix C. The following is a brief description of the soil types encountered.

1. **Topsoil.** A 150 mm thick layer of topsoil was encountered in both boreholes.
2. **Silt and Clay.** Glacio-lacustrine silt and clay was encountered below the topsoil in both boreholes and extended to an elevation of about 870 m. The firm, non to medium plastic soils had moisture contents of the deposits ranged from 18 to 31 percent.
3. **Till.** Silty, sandy, clay till was encountered below the silt and clay at an elevation of 870 m in Boreholes 1 and 2 and extended to an elevation of about 865 m in Borehole 1. The stiff to very stiff till was low to medium plastic with moisture contents ranged from about 12 to 21 percent.
4. **Gravel.** Gravel deposits were encountered below the till in Borehole 1 and extended beyond the depth drilled (ie. 863.38 m). The dense to very dense deposits were fine to medium grained with trace fines and moisture contents around 8 percent.
5. **Groundwater.** The groundwater level in November 2018 was about 6 mbg in Borehole 2. As shown on the cross section the groundwater is relatively shallow compared to the road grade at this location.

The following effective strength parameters were assumed for this site.

TABLE 17-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Clay	20	0 - 2	24 - 28
Sand Till	21	0 - 5	30 - 35
Sand and Gravel	217.5	0	35 - 40

17.6 BACKGROUND AND SLOPE ISSUES

The slope at this site is a constructed cut-slope. There are no known records of slope instability at this location, but there is visual evidence of slope movement in the form of overturning guard rail posts and tension cracks in the adjacent pavement. This service road was reconstructed in 2014, with a thick asphalt and geo-grid reinforced gravel pavement. So these tension cracks are relatively new, indicating the possibility of a slow eastward creep of this slope. The concern is that ongoing creep will eventually destabilize the slope to the point of causing a localized landslide that would impact City road and services; and access to local residents.

17.7 REVIEW OF STABILITY ASSESSMENT

Stability analysis against landsliding was carried out using the SLOPE/W computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 17-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Shallow Slope Face Failure	~ 1.0	-
Crack at Centre of Road (Spring Condition)	~ 1.1	-
Cracks 2 m from Curb (Normal GWT)	~ 1.1	-
7.5 m from Crest (Spring Condition)	1.5	Figure 17-8
At Existing Building (20 m from crest)	> 2.0	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

The analysis suggests the slope is marginally stable, supporting the observation it is susceptible to slow creep during wet periods such as spring snow-melt and periods of prolonged or heavy precipitation. The cut slope was constructed slightly steeper than the upper lacustrine soil would allow for full stability. The present risk of a small shallow “slump-type” failure on the slope face is

considered to be moderate. With the current vegetation cover it would take unusually wet conditions to cause a slump in the slope face, but the risk of a small landslide may increase as the slope continues to creep and steepen. A small landslide at this site could impact the local services and take out a portion of the service road, but it would not extend far enough back to impact private property. The debris from a small slide would likely run out over the lower sidewalk.

17.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(9) * CF(6) = 56$$

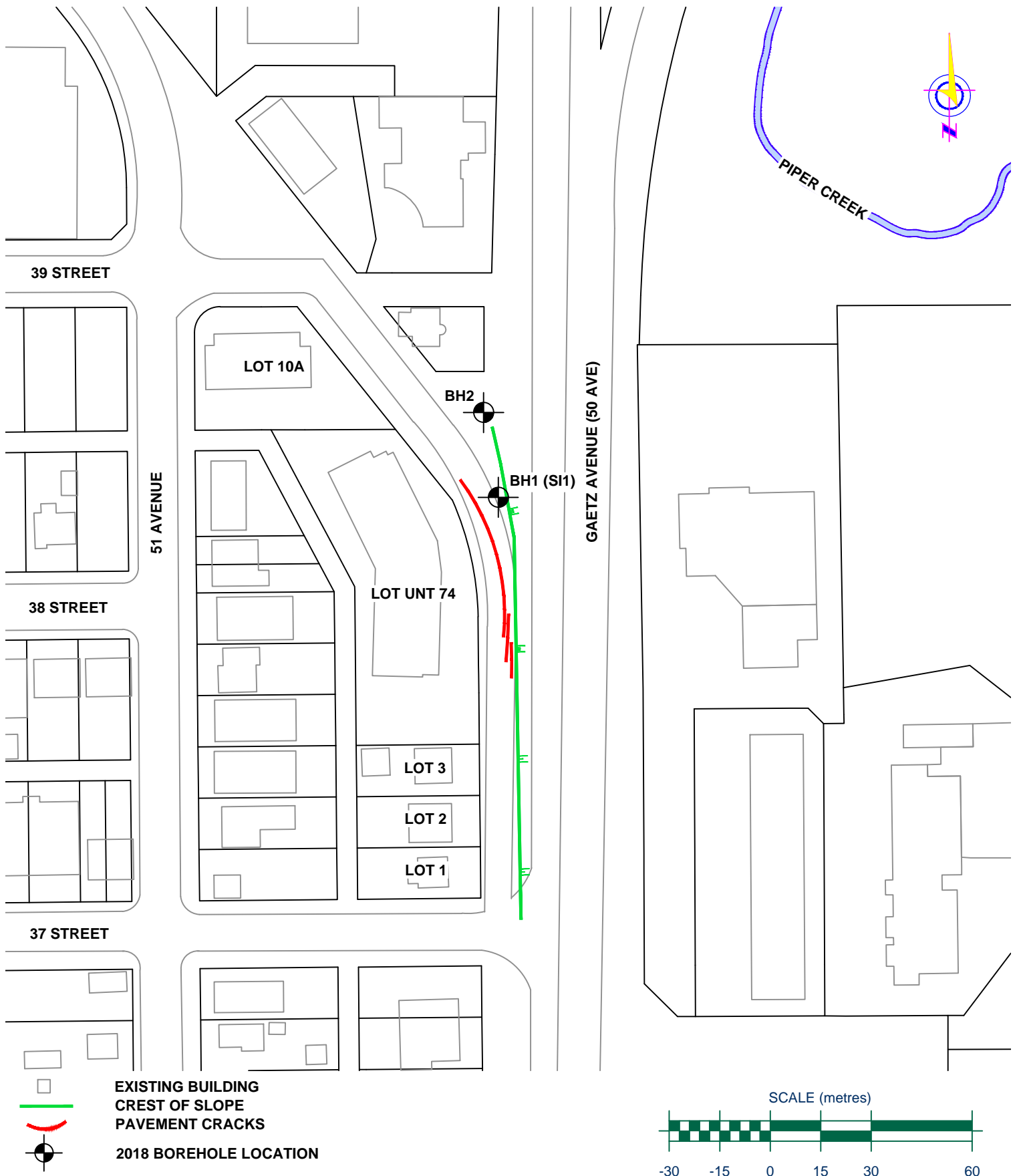
A Probability Factor of 9 is considered appropriate since there is no active slide at the site and the potential for a slide is considered to be moderate. A Consequence Factor of 6 is considered appropriate since the expected size of landslide in this slope could impact services on the slope, the edge of the service road at the crest and the sidewalk along Gaetz Avenue, but a small slide would likely not require road closures.

17.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake visual site inspections of the slope on an annual basis for a few years to identify any significant changes and obtain slope indicator data to confirm whether the slope is experiencing any movement. The frequency of inspections could be reduced once enough data has been obtained to quantify movement. Inspections should include control surveys along the crest relative at fixed points to verify possible impacts of creep, if observed. If movement is confirmed, the City of Red Deer could consider reconstruction of the steepest slope sections with a mechanically stabilized earth (MSE) wall.

17.10 ATTACHMENTS

Figure 17-1 - Site Plan
Figure 17-2 - 2016 Contour Plan
Figure 17-3 - Cross Section Profiles
Figure 17-4 - Aerial Photographs
Figure 17-5 - Site Photographs
Figure 17-6 - Survey Marker Plan
Figure 17-7 - Photograph Plan
Figure 17-8 - Stability Analysis Run
Figure 17-9 - 2018 Slope Indicator Plots
Table 17-4 - List of Survey Markers
Table 17-5 - List of Photographs
Borehole Logs for 17-01 and 17-02
Site Inspection Record (October 30, 2018)



ALL BOREHOLE LOCATIONS ARE APPROXIMATE.



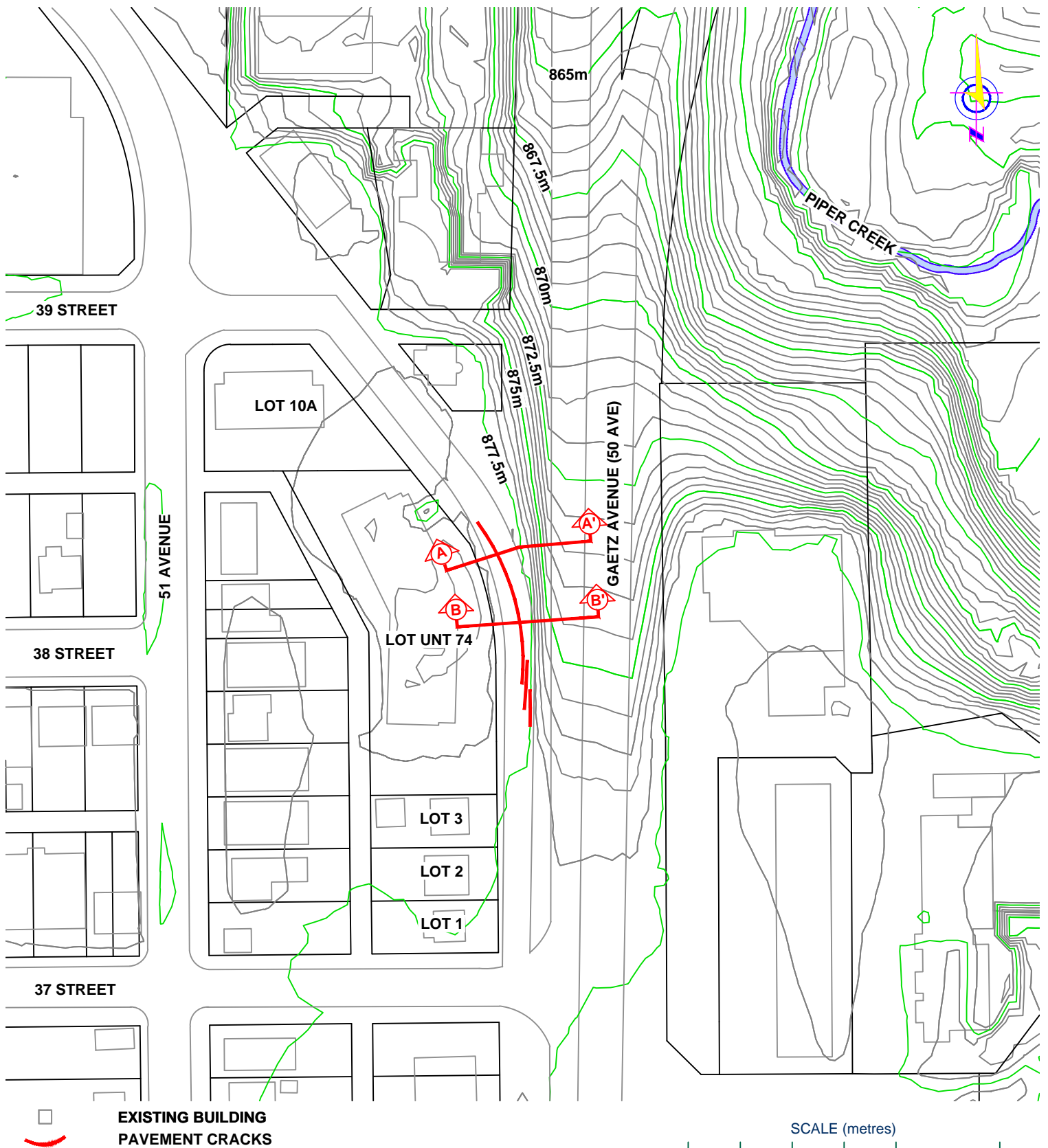
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ AVENUE WEST SERVICE ROAD N. OF 37TH ST

DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-17	DRAWING NO. FIGURE 17-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



CLIENT:

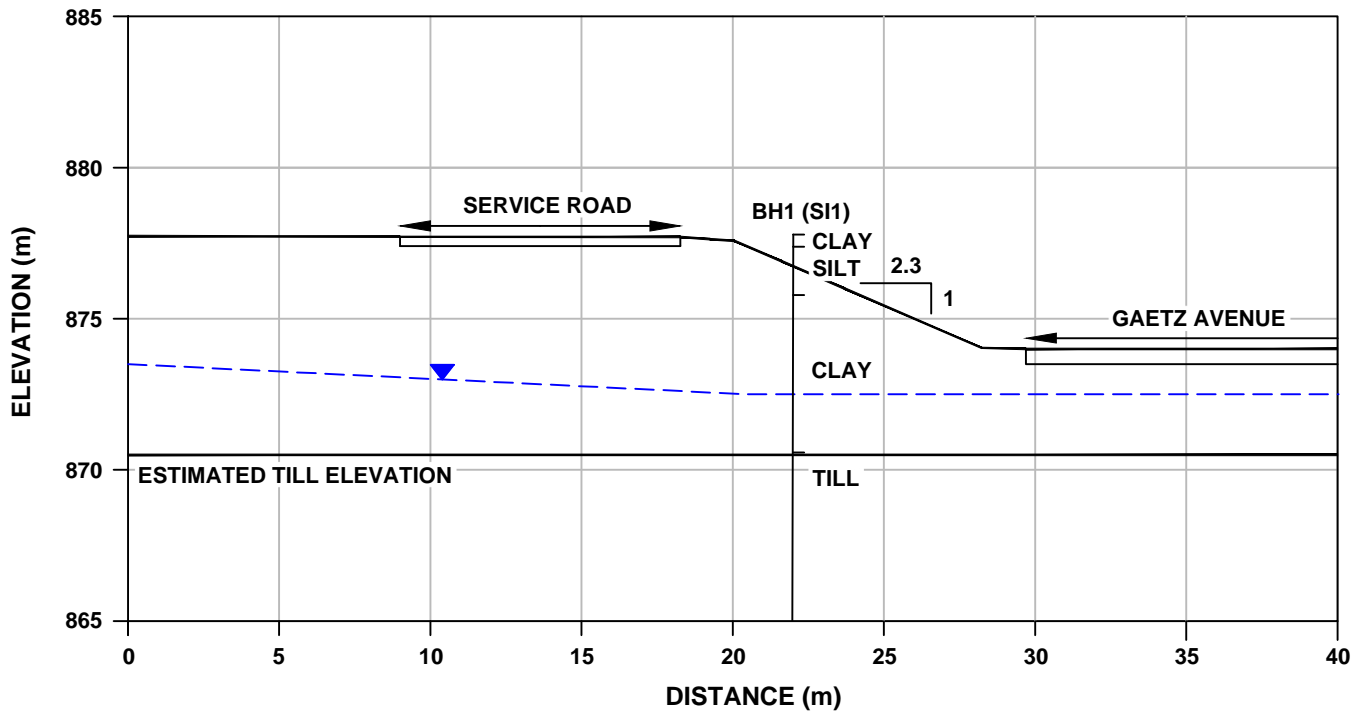


CONTOUR PLAN

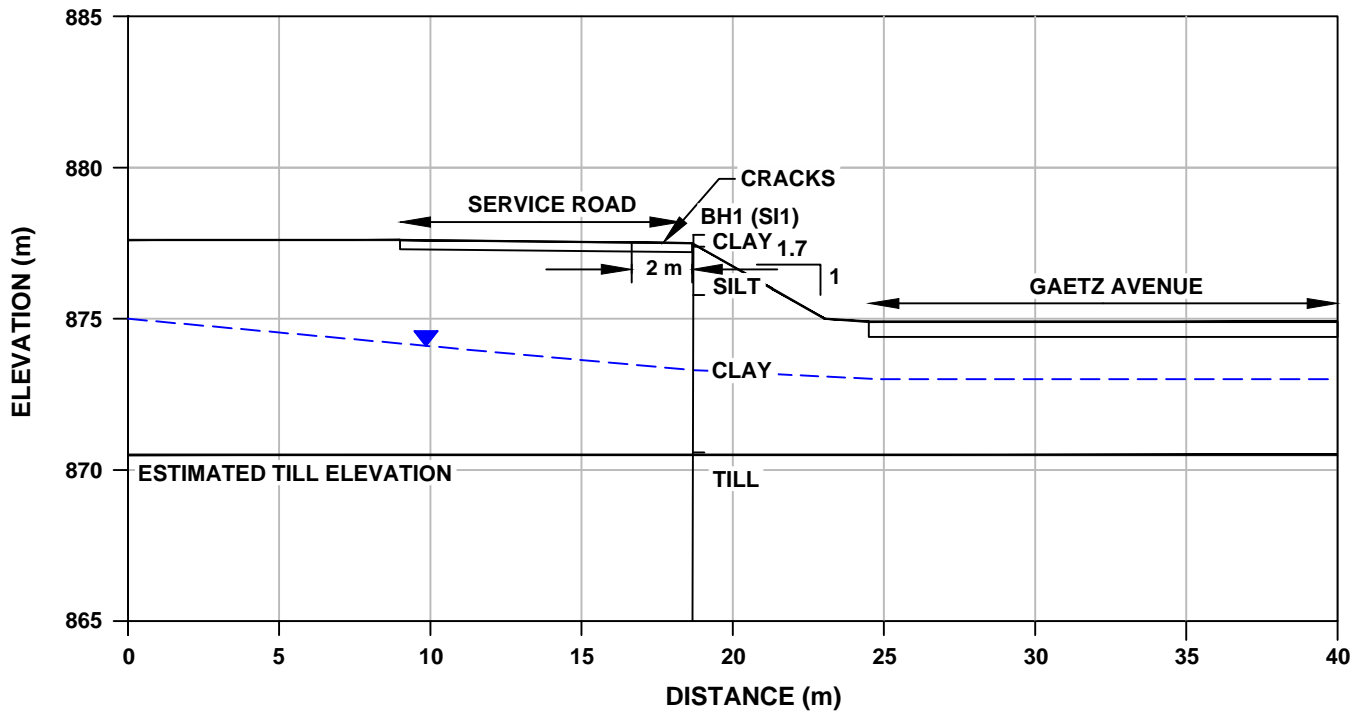
CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ AVENUE WEST SERVICE ROAD N. OF 37TH ST

DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-17	DRAWING NO. FIGURE 17-2	

17-3A: CROSS SECTION (A-A')



17-3B: CROSS SECTION (B-B')



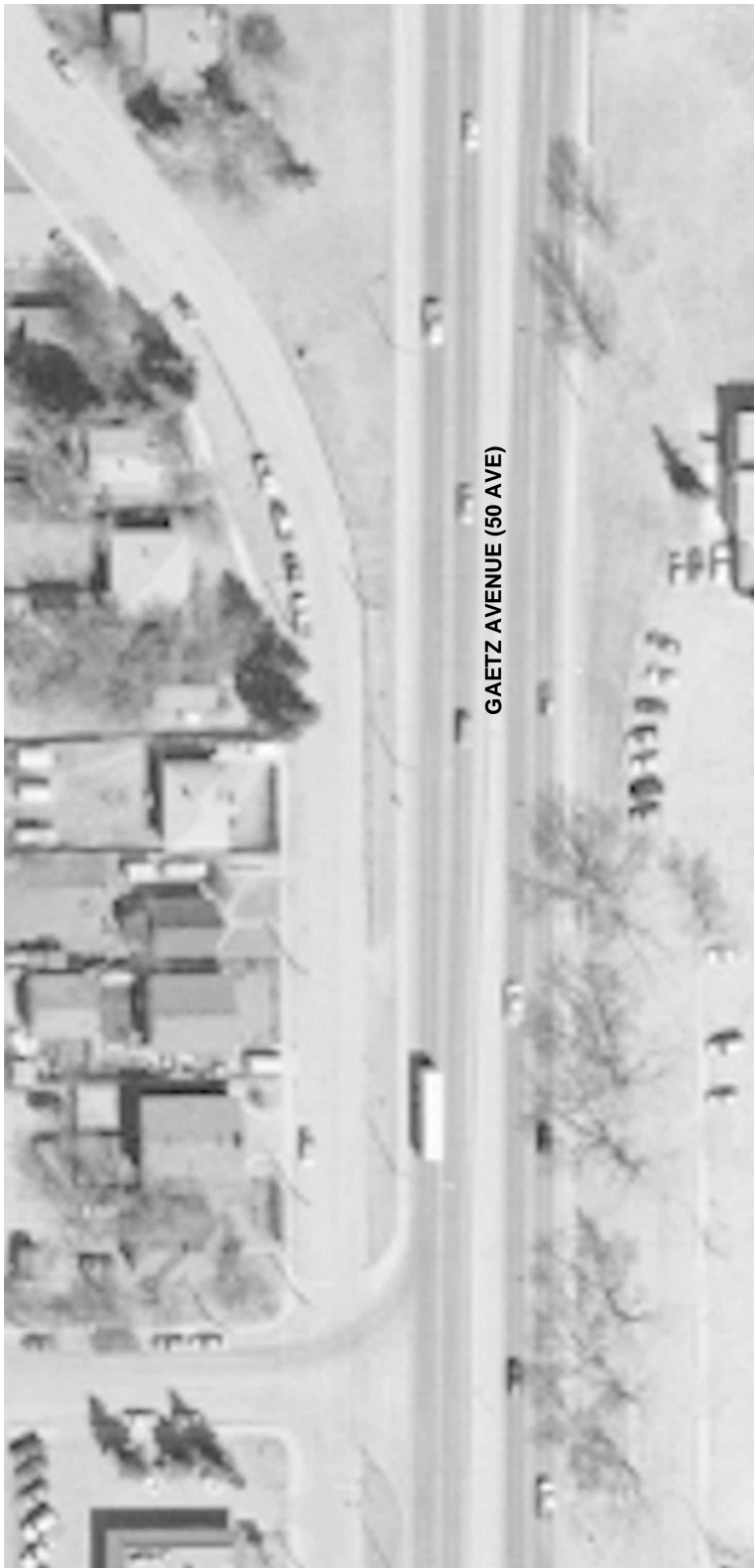
CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ AVENUE WEST SERVICE ROAD N. OF 37TH ST

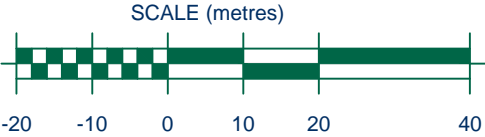
DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-17	DRAWING NO. FIGURE 17-3	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ AVENUE WEST SERVICE ROAD N. OF 37 TH ST			
		DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:1000	JOB NO. RD6500-17	DRAWING NO. FIGURE 17-4	



PHOTOGRAPH 7 (2018): SEALED CRACKS AND ROTATED GUARD RAIL ON SERVICE ROAD AT THE CREST OF SLOPE, FACING NORTH

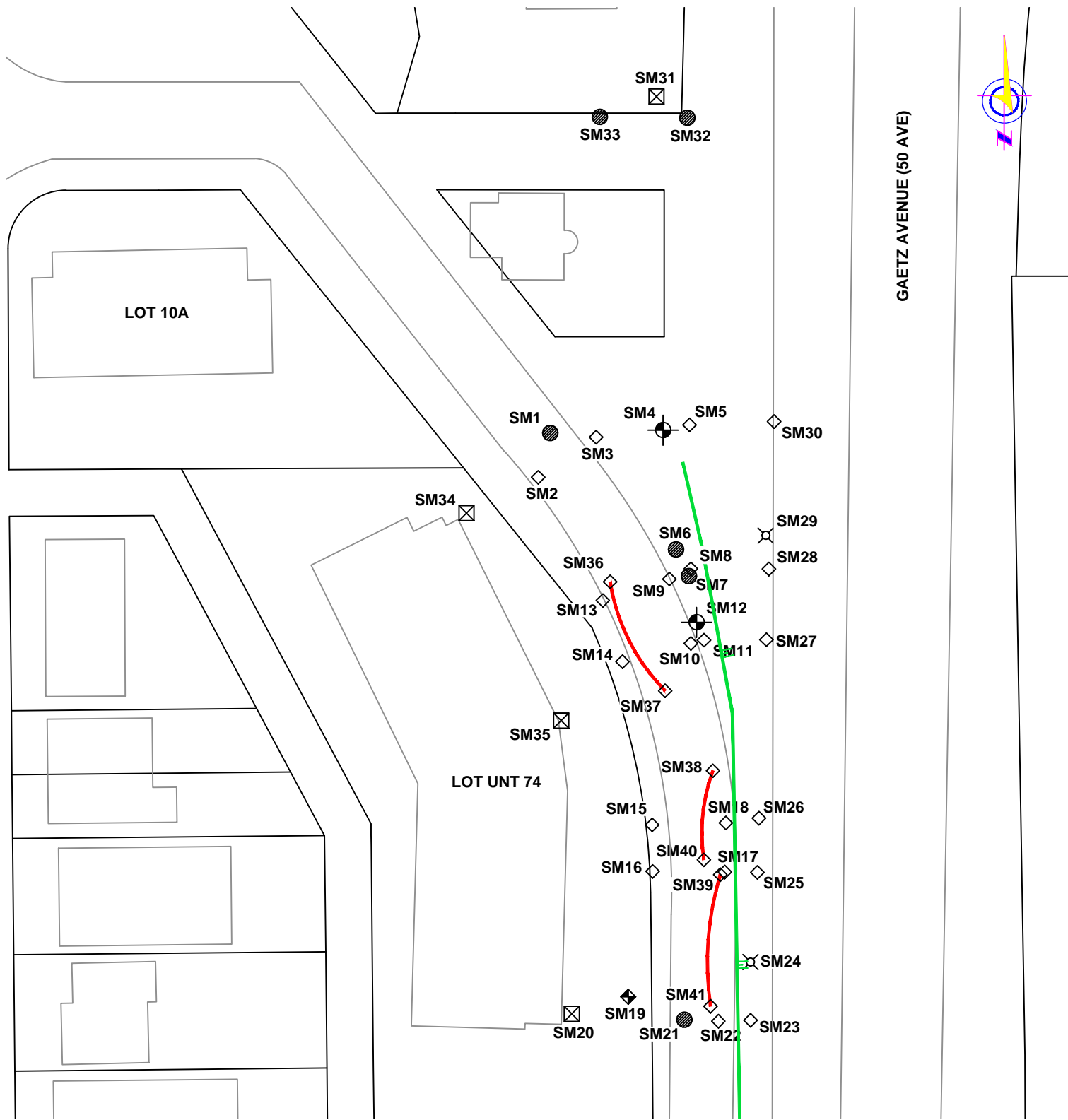


PHOTOGRAPH 11 (2018): TOE OF THE SLOPE, TAKEN FROM SIDEWALK ON WEST SIDE OF GAETZ AVE, FACING SOUTH



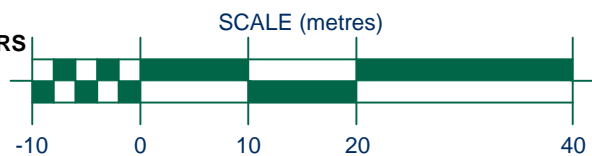
PHOTOGRAPH 16 (2018): SLOPE OF INTEREST BETWEEN GAETZ AVE AND SERVICE ROAD, TAKEN FROM CORNER OF NORTHWEST PARKING LOT AT 3731 50TH AVE, FACING WEST

	CLIENT:		SITE 17 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ AVENUE WEST SERVICE ROAD N. OF 37 TH ST			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		NTS	RD6500-17		FIGURE 17-5	



- ⊠ BUILDING CORNER
- MANHOLE / VALVE
- ⊗ LIGHT POLE
- ◇ SURVEY LAND POINT

- ⬢ FIRE HYDRANT
- ⊕ BOREHOLE / SLOPE INCLINOMETERS
- CRACK



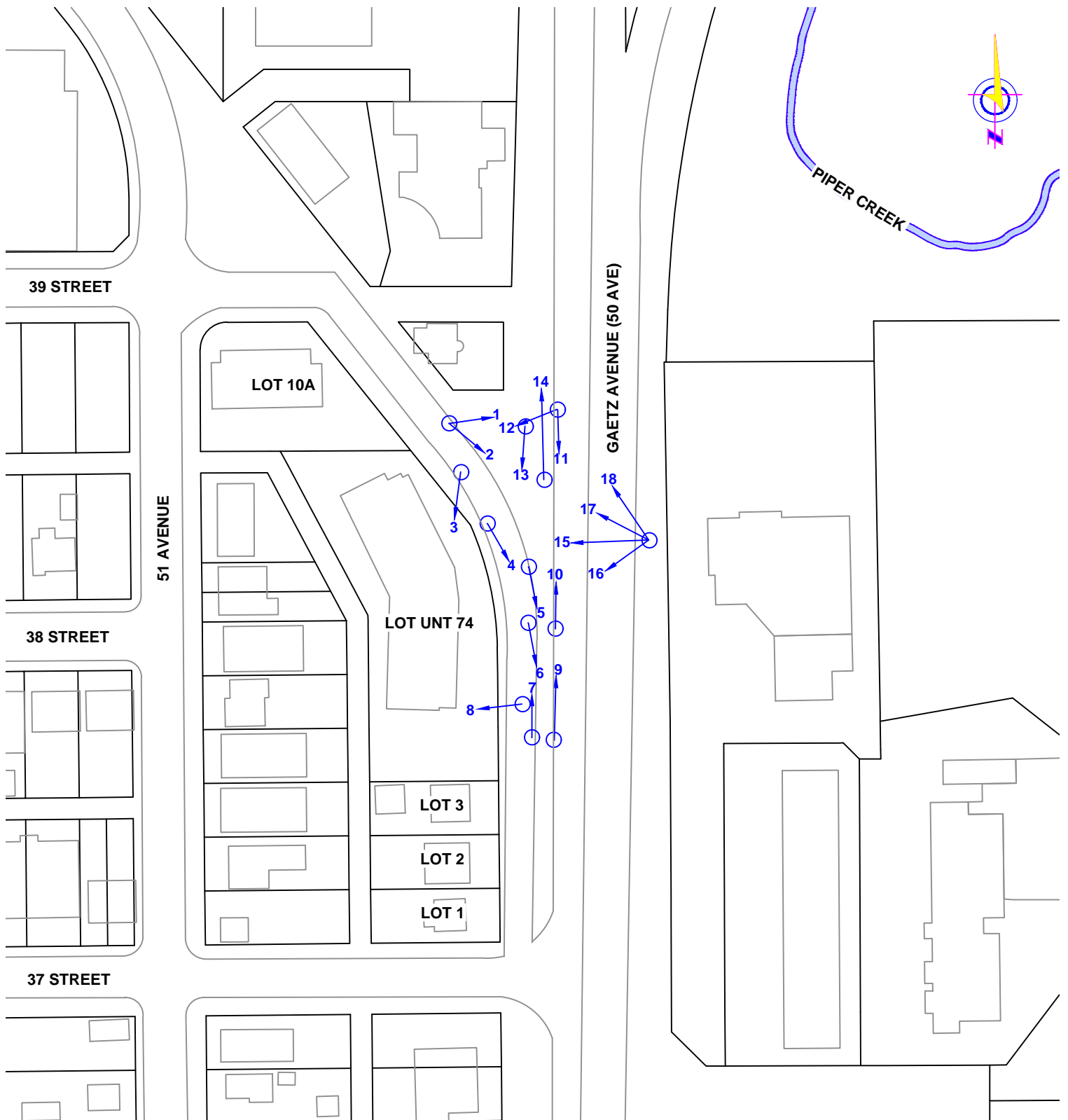
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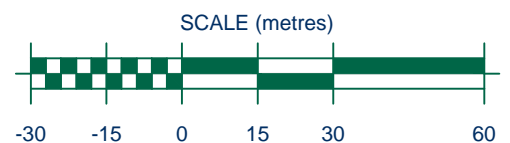
SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ AVENUE WEST SERVICE ROAD N. OF 37TH ST

DRAWN: RS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:700	JOB NO. RD6500-17	DRAWING NO. FIGURE 17-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



CLIENT:



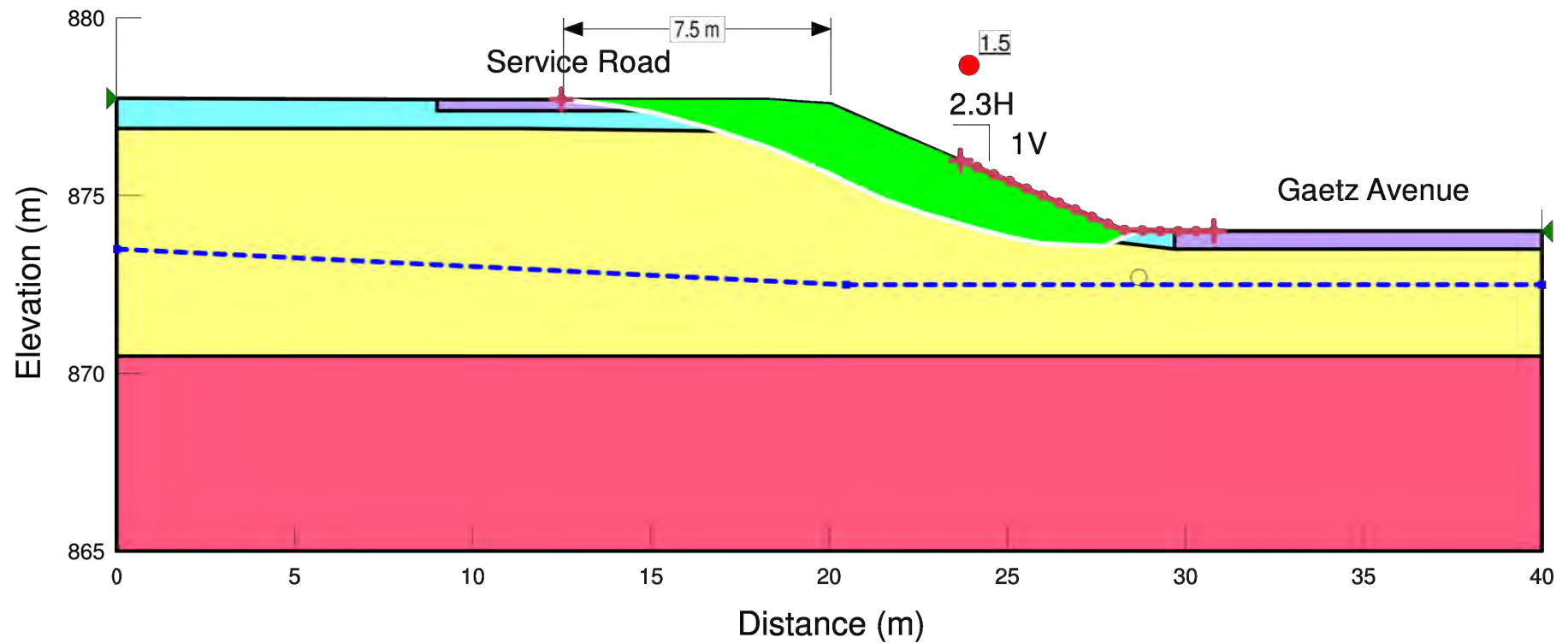
PHOTOGRAPH PLAN



CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ AVENUE WEST SERVICE ROAD N. OF 37TH ST

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-17	DRAWING NO. FIGURE 17-7	

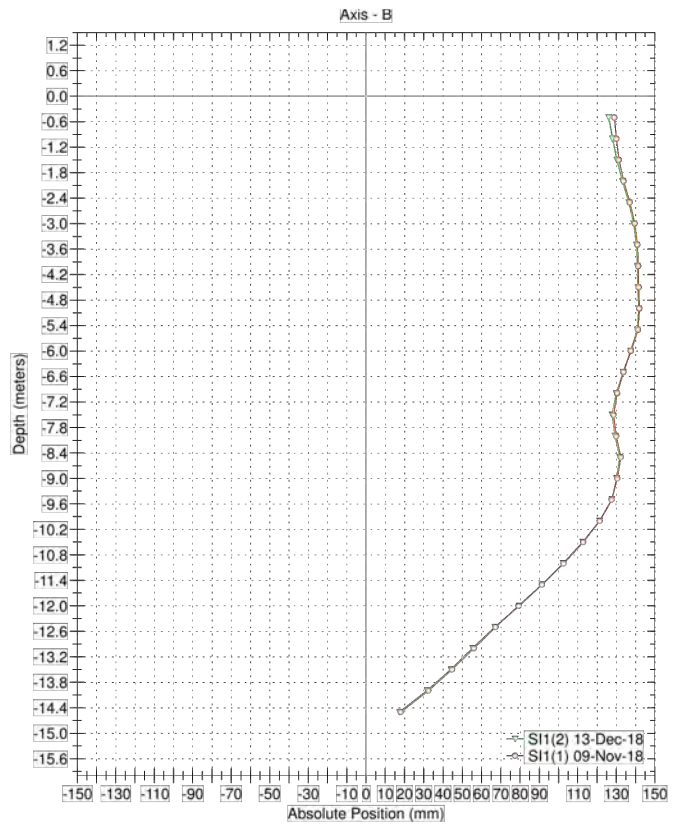
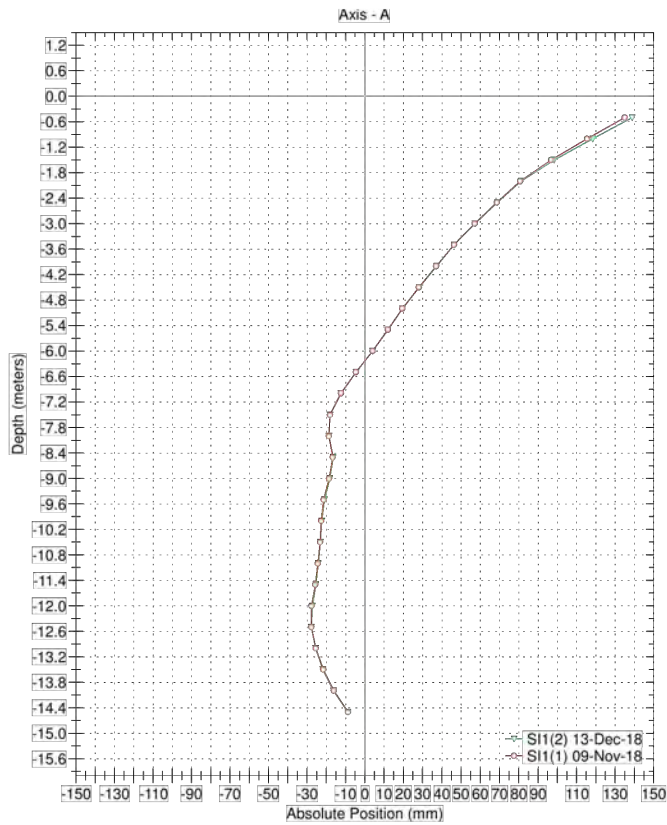
Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay	20	0	24
	Fill	22	0	35
	Sand Till	21	0	35
	Wet Clay	20	0	24

17-8: SETBACK FOR STABILITY OF 1.5 SATURATED SPRING CONDITION

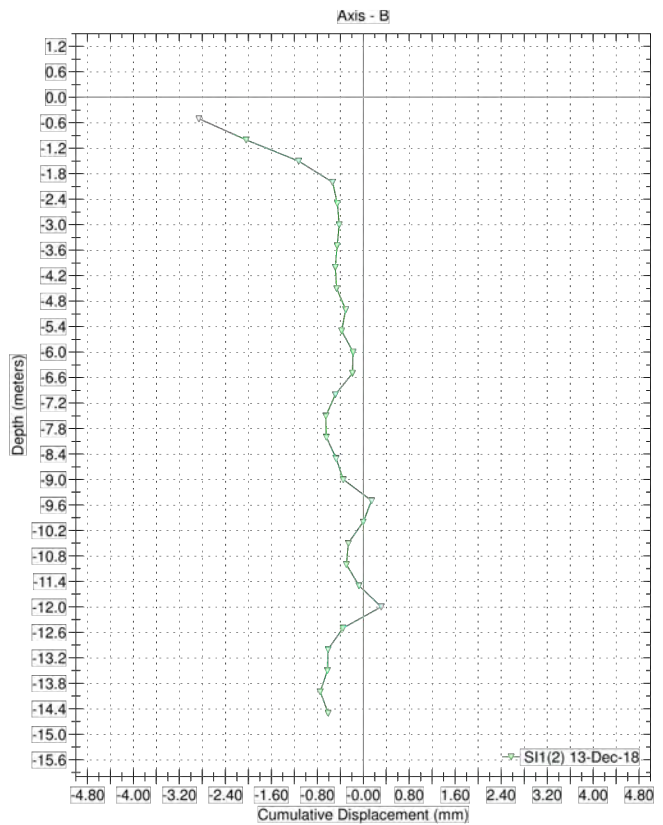
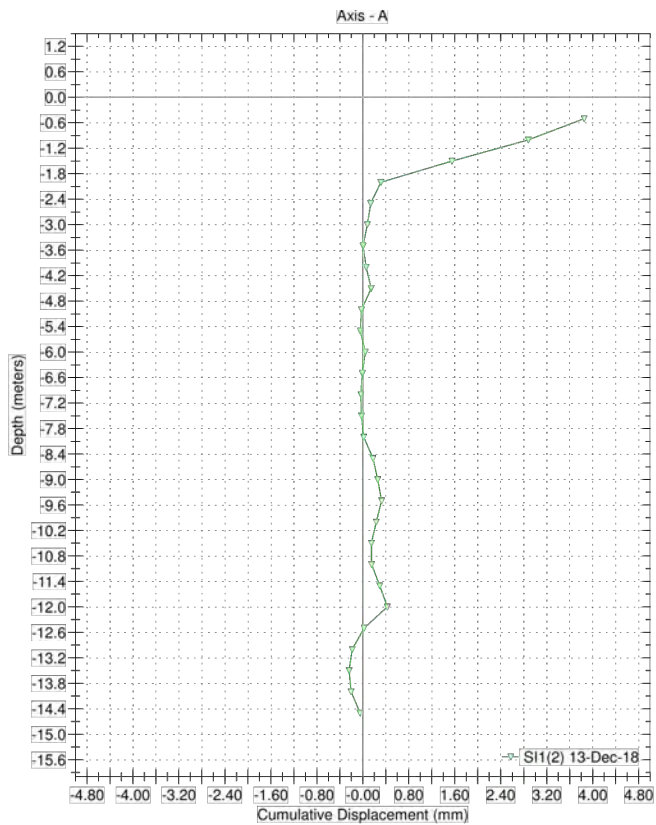


	CLIENT: 	STABILITY ANALYSIS RUN			
		CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ AVENUE WEST SERVICE ROAD N. OF 37 TH ST			
		DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: AS SHOWN	JOB NO. RD6500-17	DRAWING NO. FIGURE 17-8	

ABSOLUTE POSITION



CUMULATIVE DISPLACEMENT



CLIENT:



SLOPE INDICATOR MEASUREMENTS

CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ AVENUE WEST SERVICE ROAD N. OF 37TH ST

DRAWN:	CHK'D:	REV #:	DATE:
PS	MDB	2	APRIL 2019
SCALE:	JOB NO.	DRAWING NO.	
AS SHOWN	RD6500-17	FIGURE 17-9	

SITE #17 - GAETZ AVENUE WEST SERVICE ROAD NORTH OF 37TH STREET

CITY OF RED DEER Slope EVALUATION STUDY

TABLE 17-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018						COMMENT
		NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	
#SM17-001	MH	5793578.00	307911.46	877.98				
#SM17-002	Curb	5793572.20	307909.90	877.87				
#SM17-003	Curb	5793577.46	307917.48	877.84				
#SM17-004	BH2	5793578.36	307926.25	877.39				
#SM17-005	Crest	5793579.06	307929.72	876.61				
#SM17-006	MH	5793562.73	307927.93	877.82				
#SM17-007	MH	5793559.23	307929.63	877.72				
#SM17-008	Crest	5793560.20	307929.89	877.63				
#SM17-009	Curb	5793558.86	307927.08	877.75				
#SM17-010	Curb	5793550.42	307929.89	877.70				
#SM17-011	Crest	5793550.85	307931.62	877.58				
#SM17-012	Sl1	5793553.17	307930.64	877.78				
#SM17-013	Curb	5793556.04	307918.36	877.77				
#SM17-014	Curb	5793548.02	307920.93	877.71				
#SM17-015	Curb	5793526.65	307924.82	877.61				
#SM17-016	Curb	5793520.55	307924.89	877.56				
#SM17-017	Curb	5793520.47	307934.35	877.50				
#SM17-018	Curb	5793526.90	307934.47	877.47				
#SM17-019	FH	5793504.11	307921.69	877.67				
#SM17-020	Building	5793501.88	307914.29	877.89				
#SM17-021	Valve	5793501.08	307929.02	877.58				
#SM17-022	Curb	5793500.91	307933.50	877.47				
#SM17-023	Sidewalk	5793501.03	307937.72	876.01				
#SM17-024	Light pole	5793508.65	307937.70	875.90				
#SM17-025	Sidewalk	5793520.42	307938.61	875.32				
#SM17-026	Sidewalk	5793527.52	307938.81	875.05				
#SM17-027	Sidewalk	5793550.91	307939.80	874.04				
#SM17-028	Sidewalk	5793560.17	307940.12	873.65				
#SM17-029	Light pole	5793564.56	307939.69	873.67				
#SM17-030	Sidewalk	5793579.50	307940.79	872.72				
#SM17-031	Building	5793622.10	307925.39	873.98				
#SM17-032	Valve	5793619.29	307929.42	873.85				
#SM17-033	Valve	5793619.41	307917.95	875.62				
#SM17-034	Building	5793567.49	307900.50	878.21				
#SM17-035	Building	5793540.30	307912.91	878.94				
#SM17-036	Crack1	5793558.50	307919.32	877.82				
#SM17-037	Crack1	5793544.21	307926.53	877.80				
#SM17-038	Crack2	5793533.73	307932.78	877.60				
#SM17-039	Crack2	5793520.11	307933.75	877.56				
#SM17-040	Crack3	5793522.06	307931.60	877.64				
#SM17-041	Crack3	5793502.86	307932.48	877.53				

TABLE 17-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P17-007	Sealed cracks and rotated guard rail	5793494	307933	N	Y*	
#P17-011	Toe of the slope	5793589	307937	S	Y*	
#P17-016	Slope b/w Gaetz ave & service road	5793548	307964	W	Y*	

Notes:

* Provided in the report

All measurements in metres



CLIENT: City of Red Deer

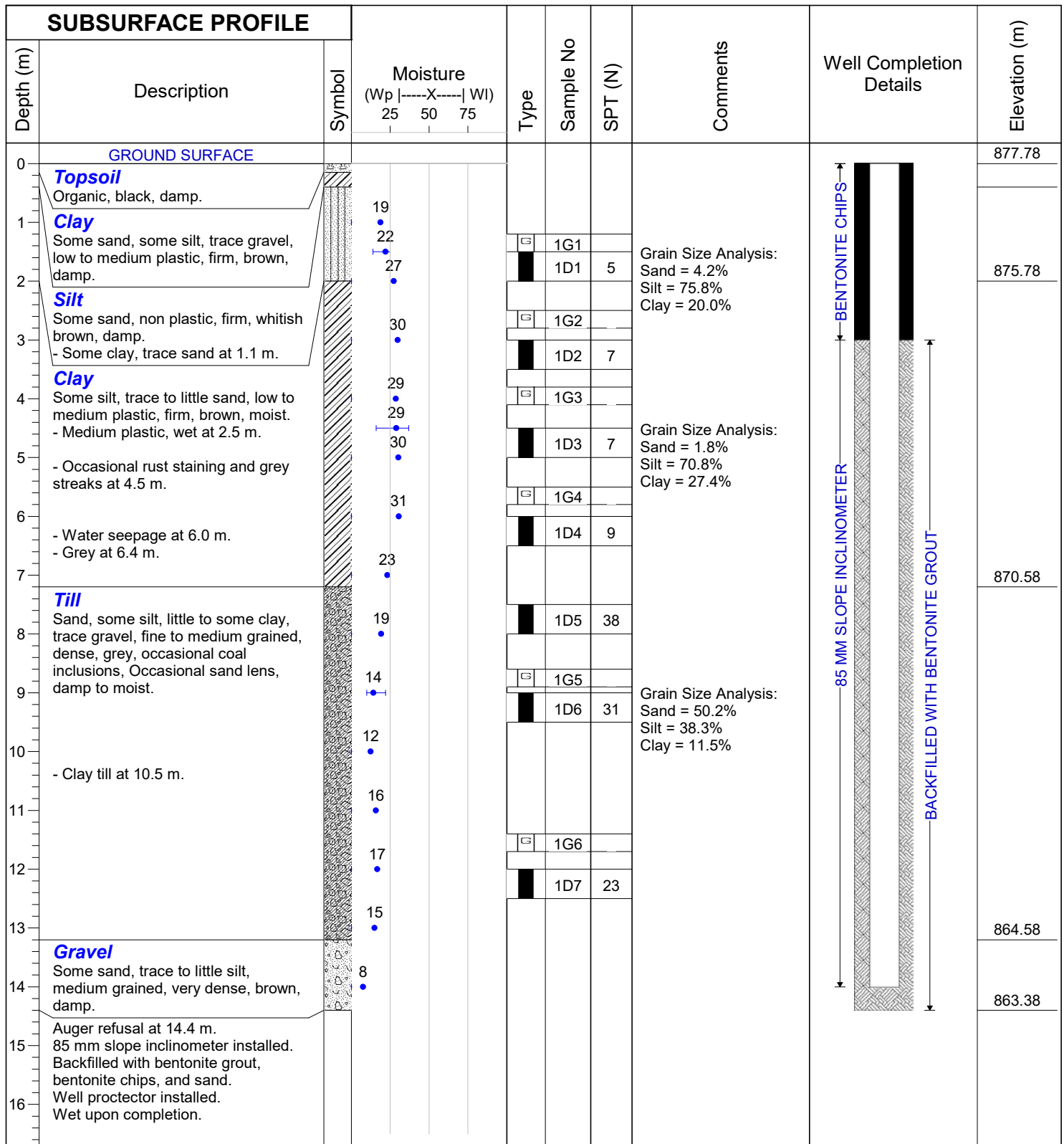
SITE: Gaetz West Service Road North of 37 St

NOTES:

BOREHOLE NO.: 01

PROJECT NO.: RD6500-17

BH LOCATION:



LOGGED BY: BL

CONTRACTOR: Dark Horse Drilling Ltd.

RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem

DATE: October 19, 2018

CALIBRATION:

GROUND ELEVATION: 877.78 m

NORTHING: 5793553.17 m

EASTING: 307930.64 m



CLIENT: City of Red Deer

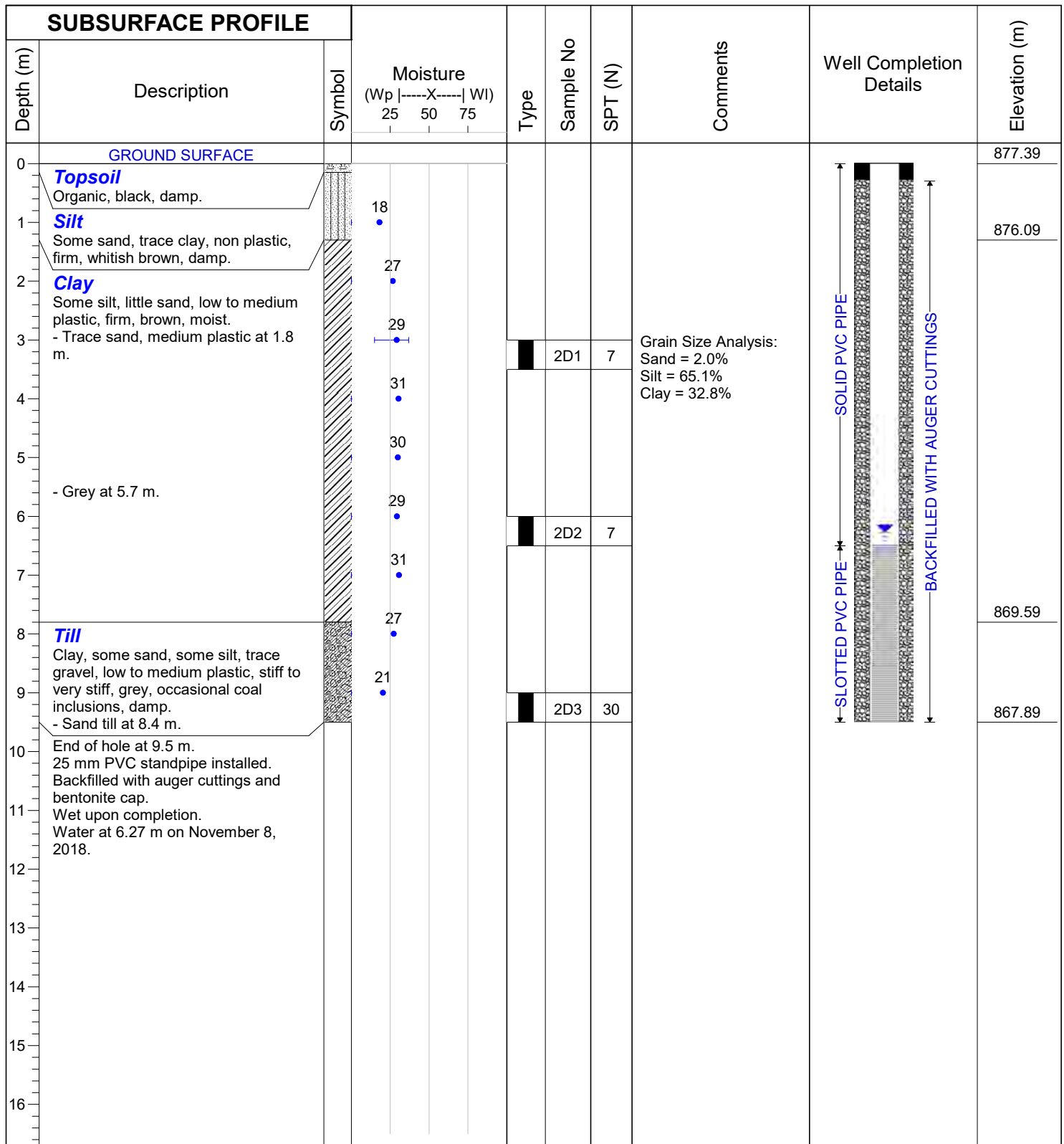
SITE: Gaetz West Service Road North of 37 St

NOTES:

BOREHOLE NO.: 02

PROJECT NO.: RD6500-17

BH LOCATION:



LOGGED BY: BL

CONTRACTOR: Dark Horse Drilling Ltd.

RIG/METHOD: Geoprobe 7822DT/ 150 mm Solid Stem

DATE: October 19, 2018

CALIBRATION:

GROUND ELEVATION: 877.39 m

NORTHING: 5793578.36 m

EASTING: 307926.25 m

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Site Number	17	
Site Name	Gaetz Ave West Service Road	
Legal Land Description	N/A	
Address	N/A	
UTM Coordinates (approx. site center)	307930 m E, 5793560 m N	
Operational Site Instrumentation	Slope Indicator	1 - Installed 19, 2018
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	1 - Installed 19, 2018
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A			
Current Inspection:	October 15, 2018	9	6	56
Inspected By:	Bryden Lutz Mark Brotherton			
Report Attachments:	18 Site photos taken 2 Borehole Logs Inclinometer Data			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded		
Slope Movement	None observed		
Erosion	None observed		
Seepage	None observed		
Distress	Cracking (creep) in asphalt near crest Rotation of guard rail		
Other			
Instrumentation:	<ul style="list-style-type: none">Piezometer water level measure on Nov 8, 2018Slope inclinometer read on Nov 8 and December 13, 2018		
Other Comments:			
<ul style="list-style-type: none">Any slow creep in the toe over sidewalk is unlikely to be noticed as it would be removed by city crews completing snow removal with skidsteers			

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Discussion	<ul style="list-style-type: none"> - Area to south is steepest, guard rail in this area has rotated and cracks are parallel to slope face in road. Back of curb in this area is exposed; possible evidence soil has pulled away. - Additional semi-circle crack in road near front of building entrance (previously sealed) - Slope face shows no signs of movement - Slope toe overlaps edge of sidewalk to gaetz ave
Assessment	<ul style="list-style-type: none"> - Slope has slow movement to south ½ of site, if fails will impact service road and block part of gaetz ave south bound.
Recommendations	<ul style="list-style-type: none"> - Consideration for stabilization, possible options are construction of a wall or regrading slope and reducing road width (likely to 1 lane making it a 1 way)

SITE #18



Edgar Industrial Snow Storage Site

SITE #18 - EDGAR INDUSTRIAL SNOW STORAGE SITE

18.1 SITE DESCRIPTION

Site #18 is the slope along the west boundary of the City of Red Deer's Snow Storage Site in Edgar Industrial Park in northeast Red Deer, as shown on Figure 1 of the main report. This slope forms the east side of the CP Rail right-of-way at the CP Rail Yard which was constructed in the early 1990s. The rail yard is located immediately southwest of the site. Plans for the general vicinity around the site and for Site #18 are provided on Figures 18-1 and 18-2. A 2016 Contour Plan is provided on Figure 18-3. Representative cross-sections of the cut slope along the west property line are provided on Figure 18-4.

In the early 1990s, the CP Rail main line between Calgary and Edmonton was moved from the center of Red Deer to the present alignment which borders the City to the west up to the Red Deer River crossing and then cuts across the northwest corner of the City through Edgar Industrial Park. The main line was constructed with a rising grade from the Red Deer River valley, through a tunnel under Highway 2 up to an at-grade crossing at Highway 11A. The right-of-way provided was constricted so the cuts required to accommodate the rail grades were relatively steep for the native soils.

The elevation at the top of the cut slope at the Snow Storage Site is about 883 m and the toe in the ditch along the side of the rail line ranges from 879 to 880 m in this area, so the cut slope is about 4 to 5 m high. The average cut slope inclination ranges between 1.5H:1V and 2.5H:1V. The slumped areas have slopes as flat as 4H:1V as shown on the Figure 18-4 cross sections. The slope face is grassed. The Snow Storage Site is a fenced enclosure with the fence about 1.5 to 7 m back from the crest of the cut slope. The surface of the Snow Storage Site is graded to the south. The surface of the site is an exposed clay subgrade fringed by grassed areas along the fence lines. Aerial photographs showing the site in 2001 and 2016 are provided on Figure 18-5. Representative photographs from the site are provided on Figure 18-6.

18.2 REFERENCES

References #70 to #73 listed in Appendix B apply to Site #18. These reports are the geotechnical report for the CP Rail relocation project, two general geotechnical investigations for Edgar Industrial Park and a water line project for the nearby Athletic Park.

18.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

Limited site specific information was available at this site for the Snow Storage Site or the rail line. A couple of boreholes from the geotechnical investigations for CP Rail and Edgar Industrial Park development were present near the site.

18.4 2018 REVIEW

Aerial photography is provided on Figures 18-5 for the years listed in the following table. The 2016 aerial shows the second most recent and largest slump at the site which occurred in 2014.

TABLE 18-1: AERIAL PHOTOGRAPHS

Year	Description
2001	Shows the site condition 18 years ago prior to any slumping in the area.
2016	Shows the Site #18 condition after the first slump.

Site #18 was visited on October 30 and November 27, 2018. A copy of the field inspection record is attached at the end of this appendix.

The site topography reviewed for this assessment included the City's 2016 ortho-contours. A record of survey control points and data for Site #18 is appended in Table 18-4. A reference drawing of survey reference points is provided on Figure 18-7.

Selected site photographs from 2018 are provided on Figure 18-6. A summary of site photographs is provided in Table 18-5 and a reference drawing of the site photograph locations is provided on Figure 18-8.

18.5 BACKGROUND AND SLOPE ISSUES

The right-of-way for the rail relocation project was set to accommodate 2H:1V cut slopes. Slope stability issues along the rail alignment were observed during the initial grading for the project. Major slumps have occurred to the north and south of Site #18. The largest slumps occurred on the higher cut slopes about 800 to 900 m to the southwest of the site, as shown on Figure 18-1. At the time of construction, it was determined that the lacustrine soils in this area of Red Deer would be unstable at 2H:1V in the long term. However, there was no room to increase the right-of-way, so it was decided to keep the 2H:1V slopes and handle slumps as a maintenance issue. The slope along the west site boundary has experienced two small slumps in the past five years. From aerial photos on the City web map the surface drainage from the snow pile area at the north end of the site appears to be directed towards larger slump area from 2014.

18.6 SUBSURFACE PROFILE

The soil profile expected at this site is in descending order: topsoil; sand; lacustrine sand, silt and clay; clay till. The following is a brief description of the soil types encountered.

1. **Topsoil.** The slope face is topsoiled and grassed.

2. **Sand.** Most of Edgar Industrial Park area has a thin blanket of relatively clean, fine sand. The depth of the sand can vary depending on the topography of the underlying lacustrine sediments. The sand is general dry with moisture contents less than 10 percent.
3. **Sand, Silt and Clay.** Extensive glacio-lacustrine deposits are present below the sand extending to depths of over 10 to 15 m. These deposits are firm to medium plastic and wet with typical moisture contents of 25 to 35 percent. Sandier non to low plastic deposits are often found in this area when the deposits extend more than 8 to 10 m in depth.
4. **Clay Till.** Silty, sandy, clay till is present below the lacustrine deposits. The depth of till at this site was unconfirmed, but could be up to 18 m below grade. The local till is very stiff, medium plastic and has a typical moisture contents of about 15 percent.
5. **Groundwater.** The groundwater table in this area is normally 3 to 5 mbg and the rail cuts at the new yards to the southwest experienced springs during construction. The cut slopes along the rail right-of-way probably moderate the levels by drawing the water table down into the rail side ditches. However, the snow melt from the snow dump is expected to cause infiltration which is likely to create mounding in the groundwater table around the site.

The following effective strength parameters were assumed for this site.

TABLE 18-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Sand	21.5	0	38
Clay	20	0 - 2	24 - 28
Rail Ballast	22	0	35 - 40

18.7 STABILITY ASSESSMENT

Stability analysis against landsliding was carried out using the SLOPE/W computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 18-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Shallow Slope Face	~ 1.0	-
At the Crest	~ 1.0	-
At the Fence Line of the Snow Storage Site	1.1 - 1.3	Figure 18-9
Inner Slope Face - Towards Snow Storage Site	1.6	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

The analysis confirms that the 2H:1V cut slopes at this site are marginally stable in the short-term and unstable in the long-term. The risk of a small shallow “slump-type” failure on this cut slope is estimated to be high under wet conditions such as spring thaw and periods of wet weather. The slump visible in the 2016 Aerial Photo on Figure 18-5 is considered to be typical of the largest slide expected. Based on that observation, a localized landslide at this site could extend far enough back to impact the fence line and might run-out to the ballast of the rail tracks.

18.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(7) * CF(2) = 14$$

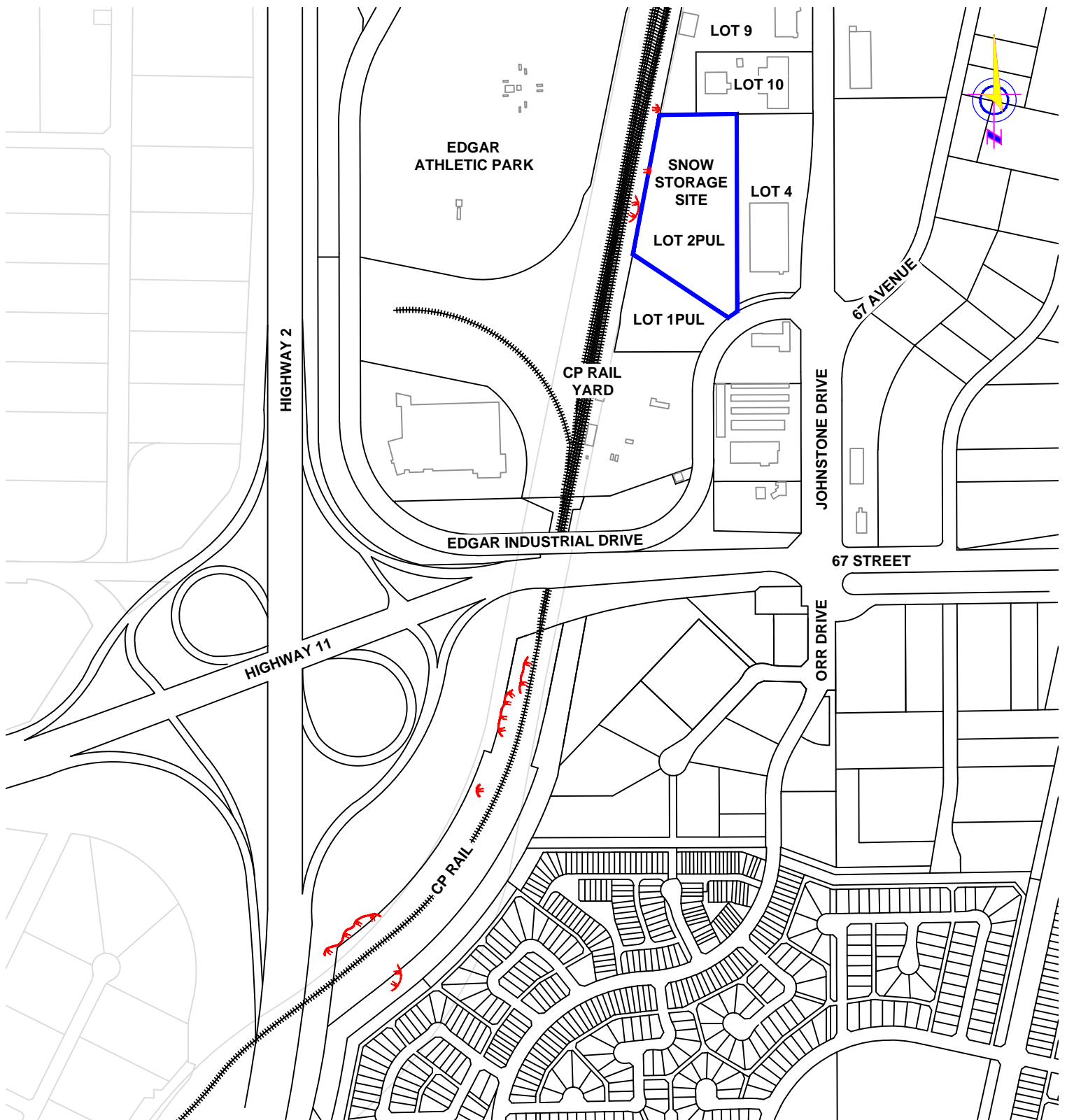
A Probability Factor of 7 is considered appropriate since there is no active slide at these historical sites, but the potential for a slide is considered to be high. A Consequence Factor of 2 is considered appropriate since the expected size of landslide in the cut slope at this site would need to be larger than normal to impact the Snow Storage Site fence and the slumping along the CP Rail right-of-way is an accepted maintenance issue.


18.9 RECOMMENDATIONS

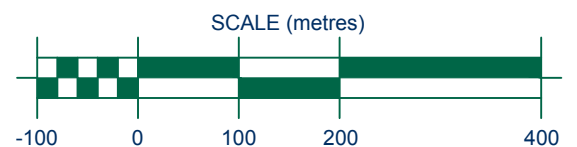
The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an “as required” basis to identify any significant changes, if present. Inspections should include control surveys along the crest relative at fixed points.

18.10 ATTACHMENTS

Figure 18-1 - Area Plan
Figure 18-2 - Site Plan
Figure 18-3 - 2016 Contour Plan
Figure 18-4 - Cross Section Profiles
Figure 18-5 - Aerial Photographs
Figure 18-6 - Site Photographs
Figure 18-7 - Survey Marker Plan
Figure 18-8 - Photograph Plan
Figure 18-9 - Stability Analysis Run
Table 18-4 - List of Survey Markers
Table 18-5 - List of Photographs
Site Inspection Record (October 30, 2018)



 SLUMP



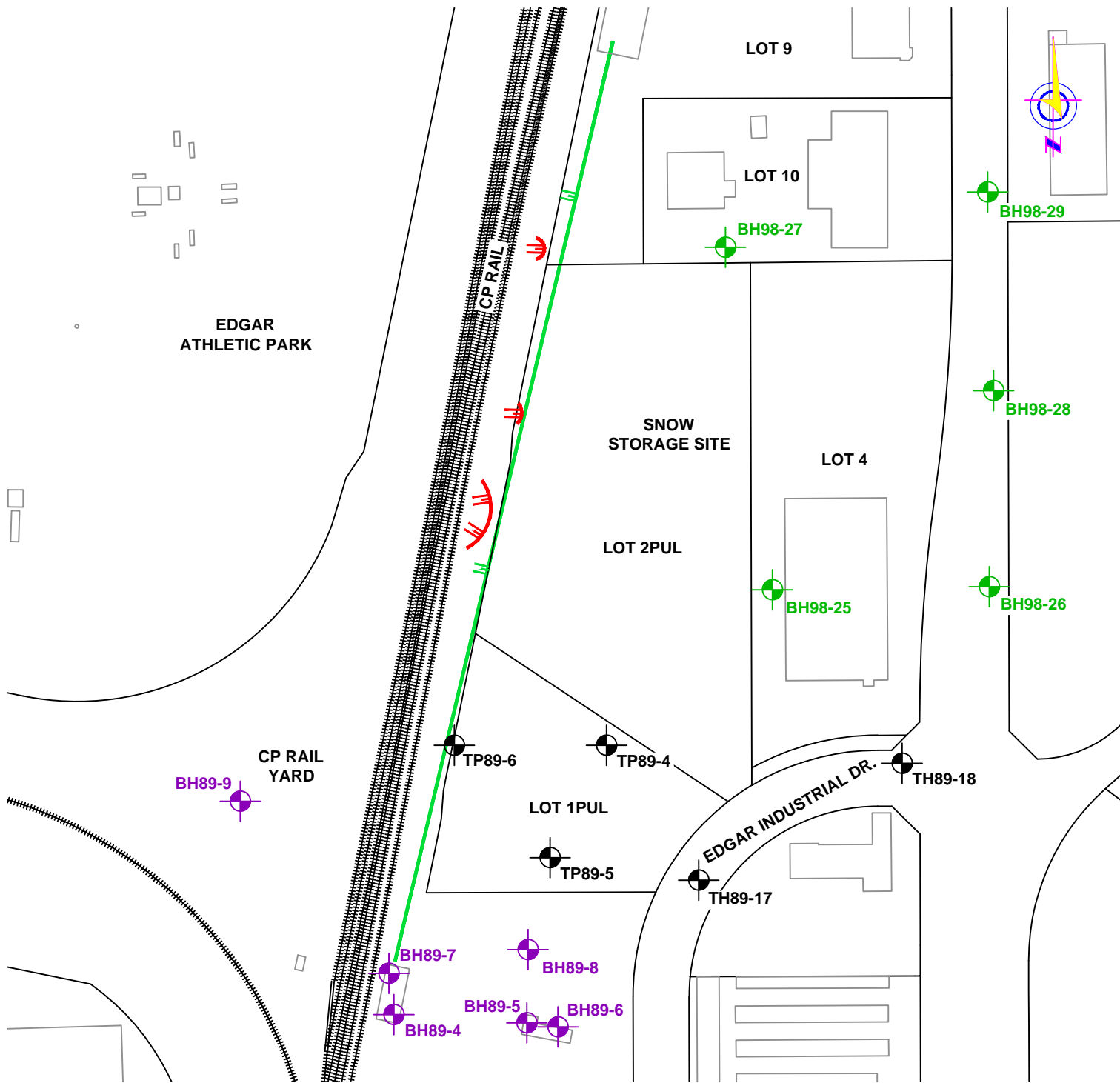
CLIENT:









AREA PLAN

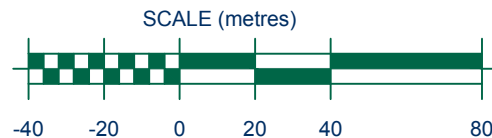
CITY OF RED DEER SLOPE STABILITY EVALUATION
EDGAR INDUSTRIAL SNOW STORAGE SITE

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:7500	JOB NO. RD6500-18	DRAWING NO. FIGURE 18-1	

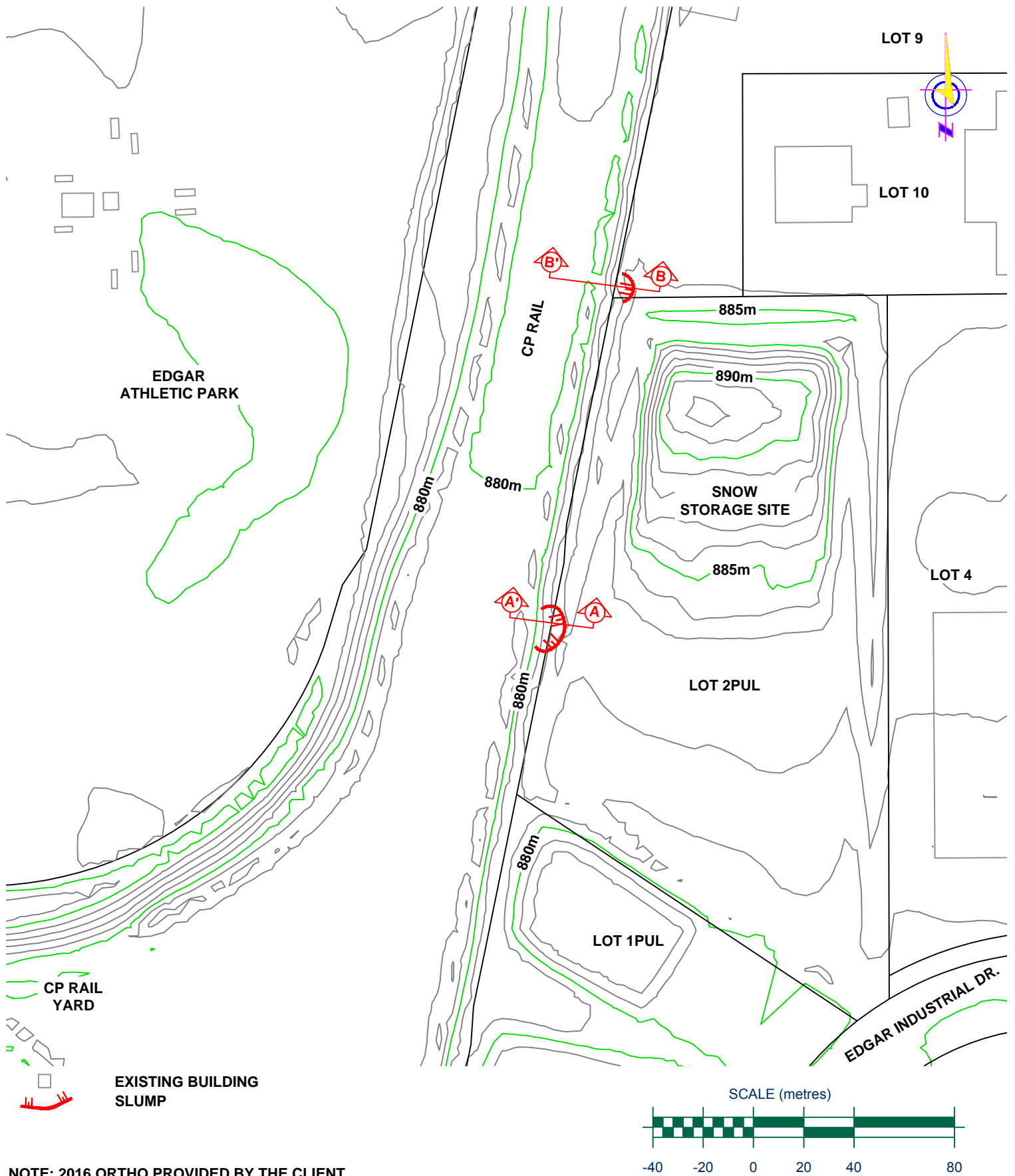




-  EXISTING BUILDING
-  CREST OF SLOPE
-  SLUMP
-  1989 BOREHOLE LOCATION (REFERENCE #71)
-  1989 BOREHOLE LOCATION (REFERENCE #71)
-  1998 BOREHOLE LOCATION (REFERENCE #71)

ALL BOREHOLE LOCATIONS ARE APPROXIMATE.

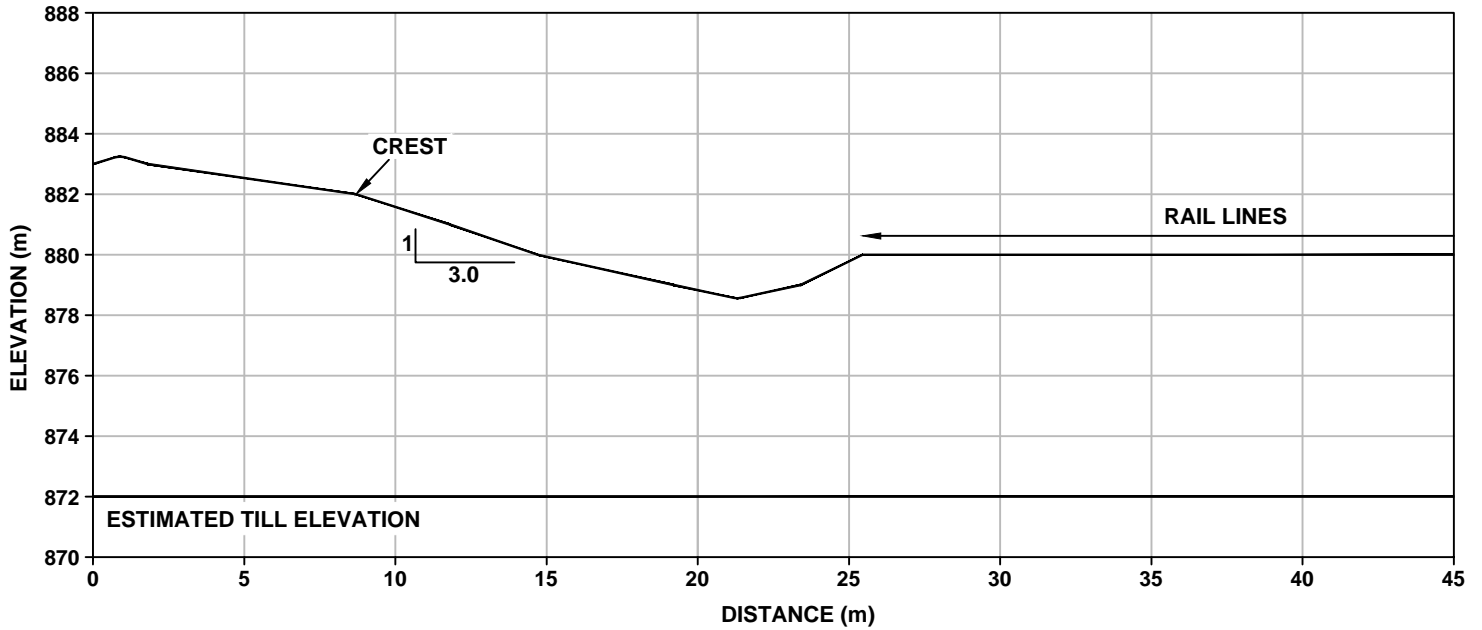


	CLIENT: 	SITE PLAN			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EDGAR INDUSTRIAL SNOW STORAGE SITE			
		DRAWN: RS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:3000	JOB NO. RD6500-18	DRAWING NO. FIGURE 18-2	

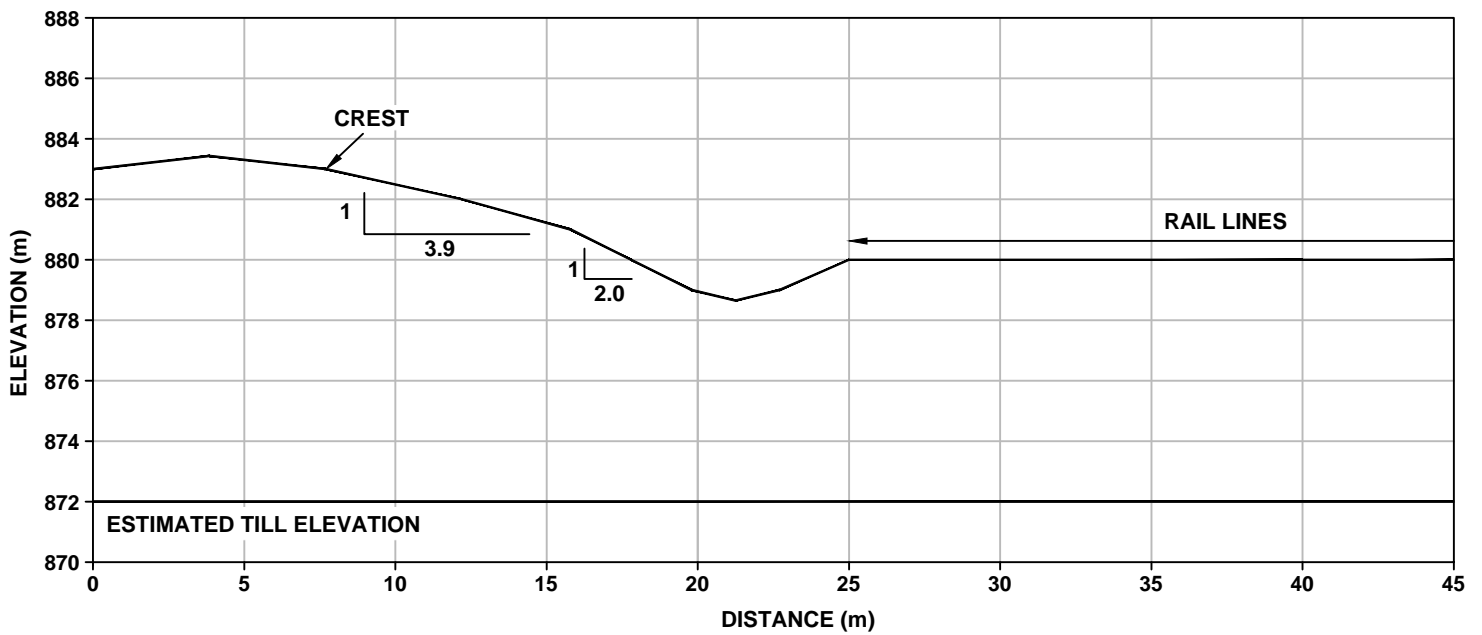


	<p>CLIENT:</p> 	<p>CONTOUR PLAN</p>			
		<p>CITY OF RED DEER SLOPE STABILITY EVALUATION EDGAR INDUSTRIAL SNOW STORAGE SITE</p>			
		<p>DRAWN: NC</p>	<p>CHK'D.: MDB</p>	<p>REV #: 2</p>	<p>DATE: APRIL 2019</p>
		<p>SCALE: 1:2000</p>	<p>JOB NO. RD6500-18</p>	<p>DRAWING NO. FIGURE 18-3</p>	



18-4A: CROSS SECTION (A - A') - SLUMP 1



18-4B: CROSS SECTION (B - B') - SLUMP 2



PROFILES SHOWN WERE CREATED USING TRIMBLE SURVEY DATA OBTAINED ON DECEMBER 14, 2018.

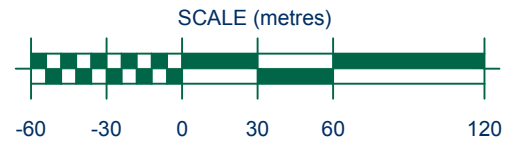
	CLIENT:		CROSS SECTION PROFILE			
			CITY OF RED DEER SLOPE STABILITY EVALUATION EDGAR INDUSTRIAL SNOW STORAGE SITE			
			DRAWN:	CHK'D.:	REV #:	DATE:
	RS	MDB	2	APRIL 2019		
SCALE:	JOB NO.		DRAWING NO.			
AS SHOWN	RD6500-18		FIGURE 18-4			





NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EDGAR INDUSTRIAL SNOW STORAGE SITE			
		DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:3000	JOB NO. RD6500-18	DRAWING NO. FIGURE 18-5	



PHOTOGRAPH 4 (2018): SLOPE ALONG THE RAILWAY LINE, LOOKING ACROSS THE SLOPE, FACING SOUTH

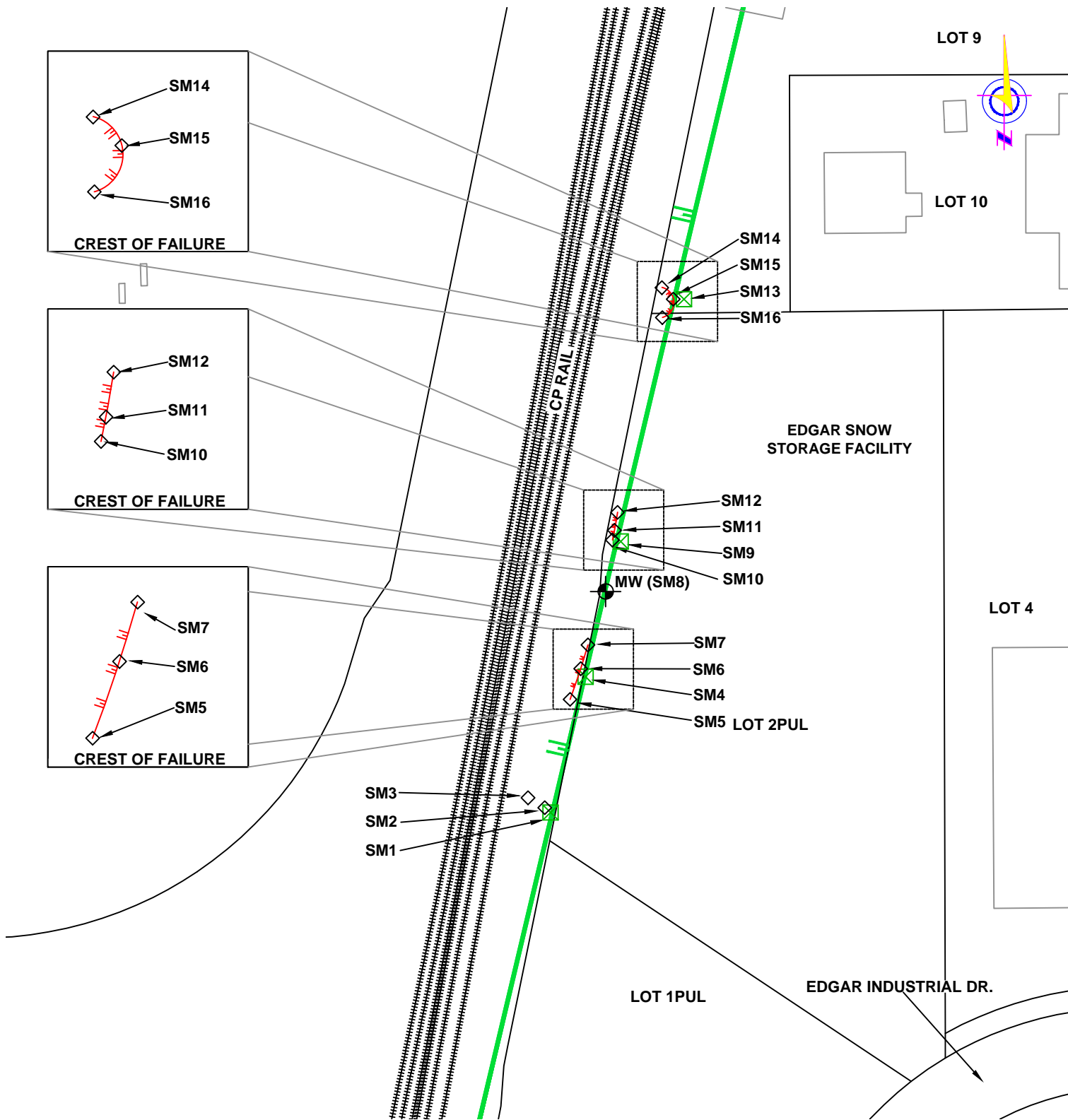


PHOTOGRAPH 10 (2018): SLOPE ALONG THE RAILWAY LINE, LOOKING DOWN THE SLOPE, FACING WEST

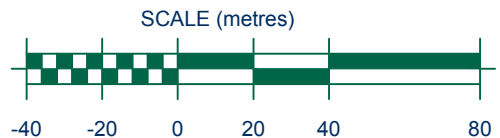


PHOTOGRAPH 12 (2018): SLOPE ALONG THE RAILWAY LINE, LOOKING ACROSS THE SLOPE, FACING NORTH

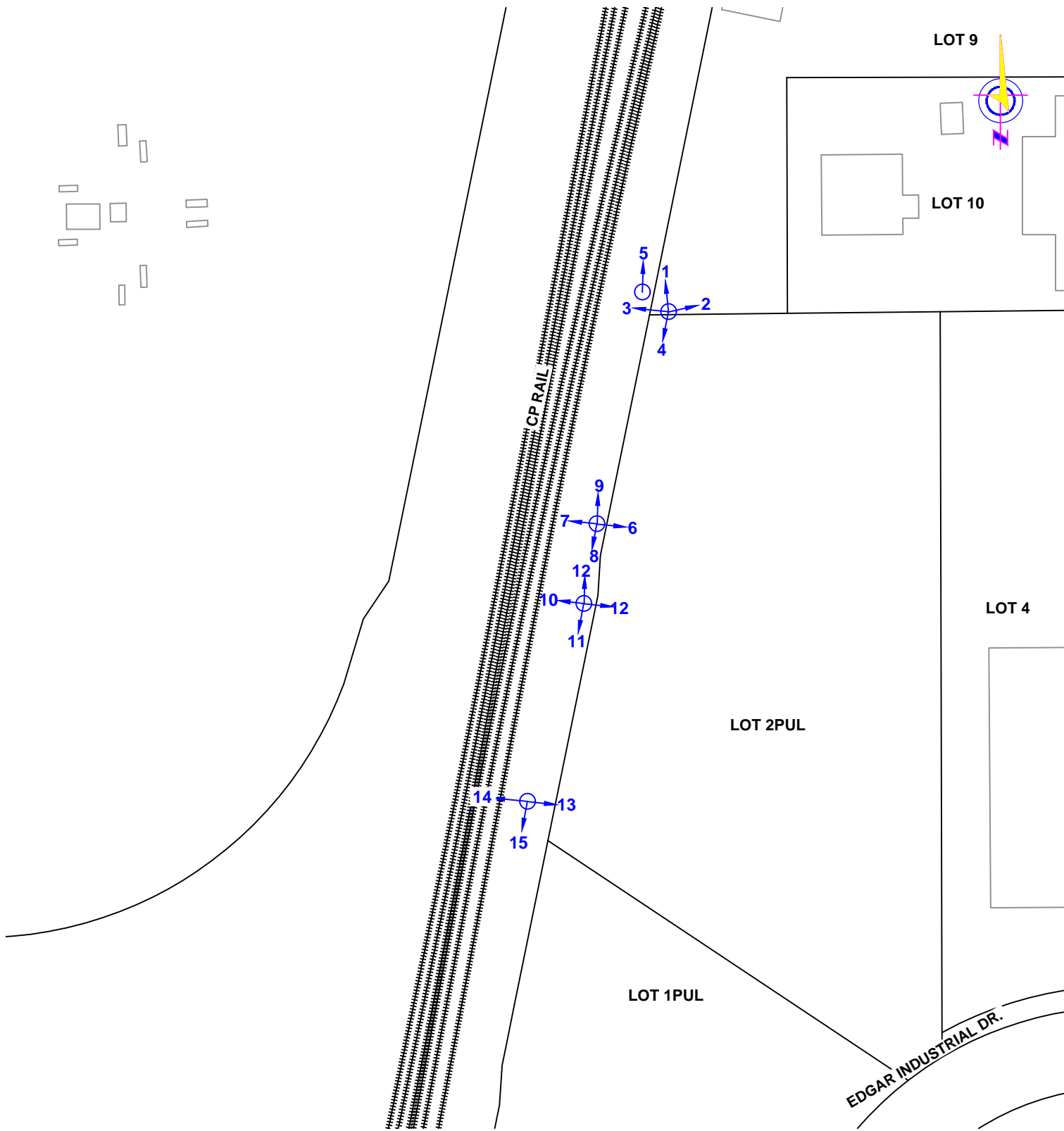
	CLIENT:		SITE 18 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION EDGAR INDUSTRIAL SNOW STORAGE SITE			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
NTS		RD6500-18		FIGURE 18-6		



- CREST OF SLOPE
- SURVEY LAND POINT
- MONITORING WELL
- FENCE CORNER
- CREST OF FAILURE

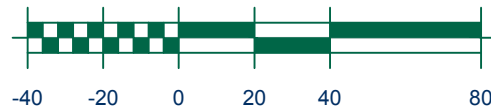


	CLIENT:				
	SURVEY MARKERS				
	CITY OF RED DEER SLOPE STABILITY EVALUATION EDGAR INDUSTRIAL SNOW STORAGE SITE				
	DRAWN:	CHK'D:	REV #:	DATE:	
NC	MDB	2	APRIL 2019		
SCALE:		JOB NO.		DRAWING NO.	
1:2000		RD6500-18		FIGURE 18-7	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.

SCALE (metres)



CLIENT:



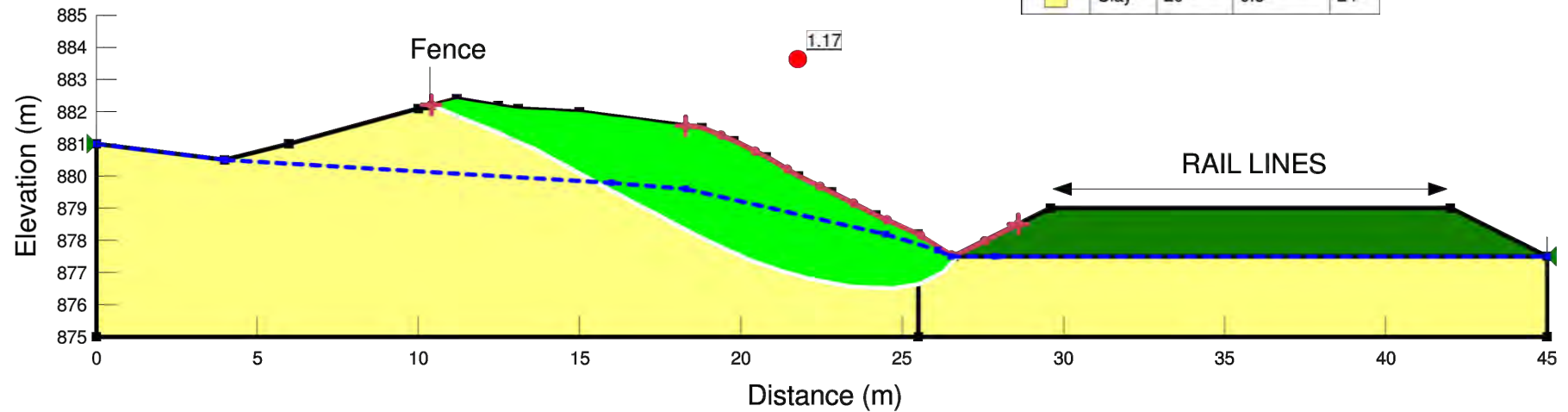
PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
EDGAR INDUSTRIAL SNOW STORAGE SITE

DRAWN: PS	CHK'D.: MDB	REV #: 1	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-18	DRAWING NO. FIGURE 18-8	

18-9: STABILITY AT FENCE LINE
SEASONALLY RAISED WATERTABLE - SNOW STORAGE RUNOFF

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
■	Ballast	20	0	38
■	Clay	20	0.5	24



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
EDGAR INDUSTRIAL SNOW STORAGE SITE

DRAWN: RS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-18	DRAWING NO. FIGURE 18-9	

SITE #18 - EDGAR INDUSTRIAL SNOW STORAGE SITE

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 18-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018						COMMENT
		NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	
#SM18-001	Fence	5797413.90	305385.47	882.13				
#SM18-002	Crest	5797415.72	305383.30	882.05				
#SM18-003	Crest	5797419.43	305377.03	881.39				
#SM18-004	Fence	5797464.73	305398.63	883.29				
#SM18-005	Slump	5797456.27	305392.76	882.30				
#SM18-006	Slump	5797467.76	305396.78	882.47				
#SM18-007	Slump	5797476.66	305399.49	882.81				
#SM18-008	Old well	5797496.62	305406.10	883.65				
#SM18-009	Fence	5797515.38	305411.76	884.02				
#SM18-010	Slump2	5797515.92	305408.65	883.07				
#SM18-011	Slump2	5797519.58	305409.39	883.01				
#SM18-012	Slump2	5797526.30	305410.54	882.80				
#SM18-013	Fence	5797606.11	305435.41	884.32				
#SM18-014	Slump3	5797610.43	305427.13	882.63				
#SM18-015	Slump3	5797606.14	305431.42	882.95				
#SM18-016	Slump3	5797599.21	305427.31	882.66				

TABLE 18-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P18-004	Slope along the railway line	5797602	305430	S	Y*	
#P18-010	Slope along the railway line	5797492	305399	W	Y*	
#P18-012	Slope along the railway line	5797492	305399	N	Y*	

Notes:

* Provided in the report

All measurements in metres

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	#18		
Site Name	Snow Storage Site		
Legal Land Description	-		
Address	Edgar Industrial Park		
UTM Coordinates	-		
Operational Site Instrumentation	Slope Indicator		0
	Pneumatic Piezometers		0
	Vibrating Wire Piezometers		0
	Standpipe Piezometers		0
Date of Last Instrumentation Readings	-		

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	-	-	-	-
Current Inspection:	October 30, 2018	7	2	14
Inspected By:	Trevor Allen - PGEO Alex Thomson – PGEO (November 27, 2018)			
Report Attachments:	Site and Contour Plans Cross Sections Photographs			


Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded	N/A	
Slope Movement	2 Slump Failures	N/A	
Erosion	-	N/A	
Seepage	-	N/A	
Distress	-	N/A	
Other	-	N/A	
Instrumentation:	•		
Other Comments:	•		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Slope face has grasses and some small shrubs
Assessment	
Recommendations	<ul style="list-style-type: none">- Consideration for site visits as required every 5 years

SITE #19



Former Elks Club & 36th Street Landslide Sites

SITE #19 - FORMER ELKS CLUB AND 36TH STREET LANDSLIDE SITES

19.1 SITE DESCRIPTION

Site #19 is a section of the west creek valley slope overlooking Piper Creek and Rotary Park east of Gaetz Avenue, as shown on Figure 1 of the main report. This slope borders the creek 300 to 700 m upstream of the confluence of Piper and Waskasoo Creek on the south side of downtown Red Deer. The south hill development overlooking this slope includes a restaurant building formerly known as the Elks Club, a fifteen storey apartment building (Checkmate Court); and two private residences on 49th Avenue and 36th Street. The Site Plan is shown on Figure 19-1. A 2016 Contour Plan is provided on Figure 19-2. Representative cross-sections of the cut slope are provided on Figure 19-3.

Piper Creek meanders within the wide creek valley at the toe of the slope and comes into close proximity to the toe in a couple of areas. The elevation at the top of the slope is about 877 m and the toe is about 860 m, so this creek valley slope is about 17 m high. The average inclination from of the natural slope creek flood plain to crest ranges from 1.5H:1V to 2.5H:1V as shown on the Figure 19-3 cross sections. The steepest slope is on the east boundary at 4806 - 36th Street. The slope below the former Elks building has been modified with a large gravel toe berm that created a terrace at about elevation 868 m. The slope face below the former Elks building is grassed; and the face of the toe berm, the creek valley flood plain and the slope face to the south of the toe berm are heavily vegetated with brush and trees.

19.2 REFERENCES

References #1 and 2 listed in Appendix B apply to Site #19. These are the preliminary and final Waskasoo Creek Slides reports from 1970/1971 which identified two sites in this area as slopes of concern. Site E was the yard at 4806 - 36th Street and Site F was the landslide site at the Elks Club slope.

19.3 2018 REVIEW

Aerial photography is provided on Figures 19-4A and 19-4B for the years listed in the following table. These aerial photographs show this extent of the historical slide at the former Elks site.

TABLE 19-1: AERIAL PHOTOGRAPHS

Year	Description
1962	This shows the Elks site prior to the mid 1960s landslide
1969	This shows the Elks site shortly after the landslide and indicates the extent of the berm
2001	Shows the site condition 18 years ago.
2016	Shows the present slope conditions in the area.

Site #19 was visited on October 30 and November 7, 2018. A copy of the field inspection record is attached at the end of this appendix.

Photographs were taken during the site visits. A list of available photos at this site is appended in Table 19-5. Selected site photographs are provided on Figures 19-5; along with a reference drawing of all photograph locations which is provided on Figure 19-7.

The site topography reviewed for this assessment included the 1970 survey profiles, the 2016 City ortho-contours and the 2018 contours from the drone survey. A record of survey control points and data for Site #13 is appended in Table 19-4. A reference drawing of survey reference points is provided on Figure 19-6.

19.4 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

No site specific geotechnical reference reports were available crest areas of the slope at this site, but there is considerable geotechnical information for the area including the 14.4 m deep borehole drilled for Site #17 about 80 m west of the former Elks site on the west side of Gaetz Avenue.

19.6 BACKGROUND AND SLOPE ISSUES

Reference #1 documents a major landslide at the former Elks Lodge site in the mid 1960s. The description is as follows, *"the slide at this location extended to the point where it has removed a pile support from the northeast corner of the building and has flowed to within 50 feet or so of Piper Creek. Sliding movement in this area was evident on the 1966 airphotos."* Further anecdotal information suggests when the crest of the slope began to drop, the Elks Club began trucking in and placing pit run gravel on the base of the slope until the landslide stopped moving. The landslide was believed to be caused by a combination of wet weather and grading activity at the crest around the building. The walls and floor in the northeast corner of the current building are structurally supported above a void space which is enclosed by skirting.

References #1 and #2 also document a small block slide at 4806 - 36th Street. It was concluded that fill was placed over the crest of the river valley slope to add yard area at this property; and the over-steepened fill slid down to the banks of the creek. Although the creek was close to the toe of the slope, the study concluded that toe erosion was not a contributing factor for this landslide.

There are no records of slope instability for the creek valley slope between these two locations.

19.5 SUBSURFACE PROFILE

The soil profile expected at this site is, in descending order: topsoil; lacustrine silt and clay; till; and weathered silt-stone bedrock. The borehole profile from Site #17 is shown on the cross sections in Figure 19-3.

The following is a brief description of the soil types encountered in Borehole 17-01.

1. **Topsoil.** The slope below the former Elks Lodge is topsoiled and grassed.
2. **Silt and Clay.** Glacio-lacustrine silt and clay is expected to extend down to an elevation of about 870 m. The deposits in this area are firm, low to medium plastic soils had wet with typical moisture contents of 20 to 35 percent.
3. **Clay Till.** Silty, sandy, clay till is common in the area at an elevation of about 870 m. The local till is expected to extend below an elevation of 860 m. The local till is very stiff, medium plastic and has a typical moisture contents of about 15 percent.
4. **Gravel.** Pit run gravel fill is expected to be present in the toe berm below the former Elks Lodge. Native coarse gravel deposits may also be present within or below the till and in the flood plain area of south downtown along Waskasoo Creek.

The following effective strength parameters were assumed for this site.

TABLE 19-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Clay	20	0 - 2	24 - 28
Fill	20	0	23 - 25
Clay Till	21	0 - 5	28 - 32
Colluvium	18	0	18 - 22
Sand and Gravel	21.5	0	38

19.7 REVIEW OF STABILITY ASSESSMENT

Stability analysis against landsliding was carried out using the SLOPE/W computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 19-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Shallow Slope Face at Former Elks Lodge site	~ 1.1	-
NE Corner of Former Elks Lodge Building	~ 1.1	Figure 19-8
Slope Face @ 4806 - 36 th Street	~ 1.0	-
Existing House @ 4806 - 36 th Street	1.3	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

The analysis suggests this mature creek valley slope ranges from marginally stable to stable. The risk of a small shallow “slump-type” failure on the slope face is estimated to be moderate in upper areas of the slope which have been disturbed by grading or fills. With the present vegetation cover it would take unusually wet conditions to cause a shallow slump in the slope face. A small landslide at this site could extend far enough back to impact private property including the former Elks Club building. The risk of a larger, deep seated landslide is considered to be low, since the original creek valley slope is mature and stabilization measures at the former Elks site appear to be effective, since the landslide has not demobilized in over 50 years.

19.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(3) * CF(10) = 30$$

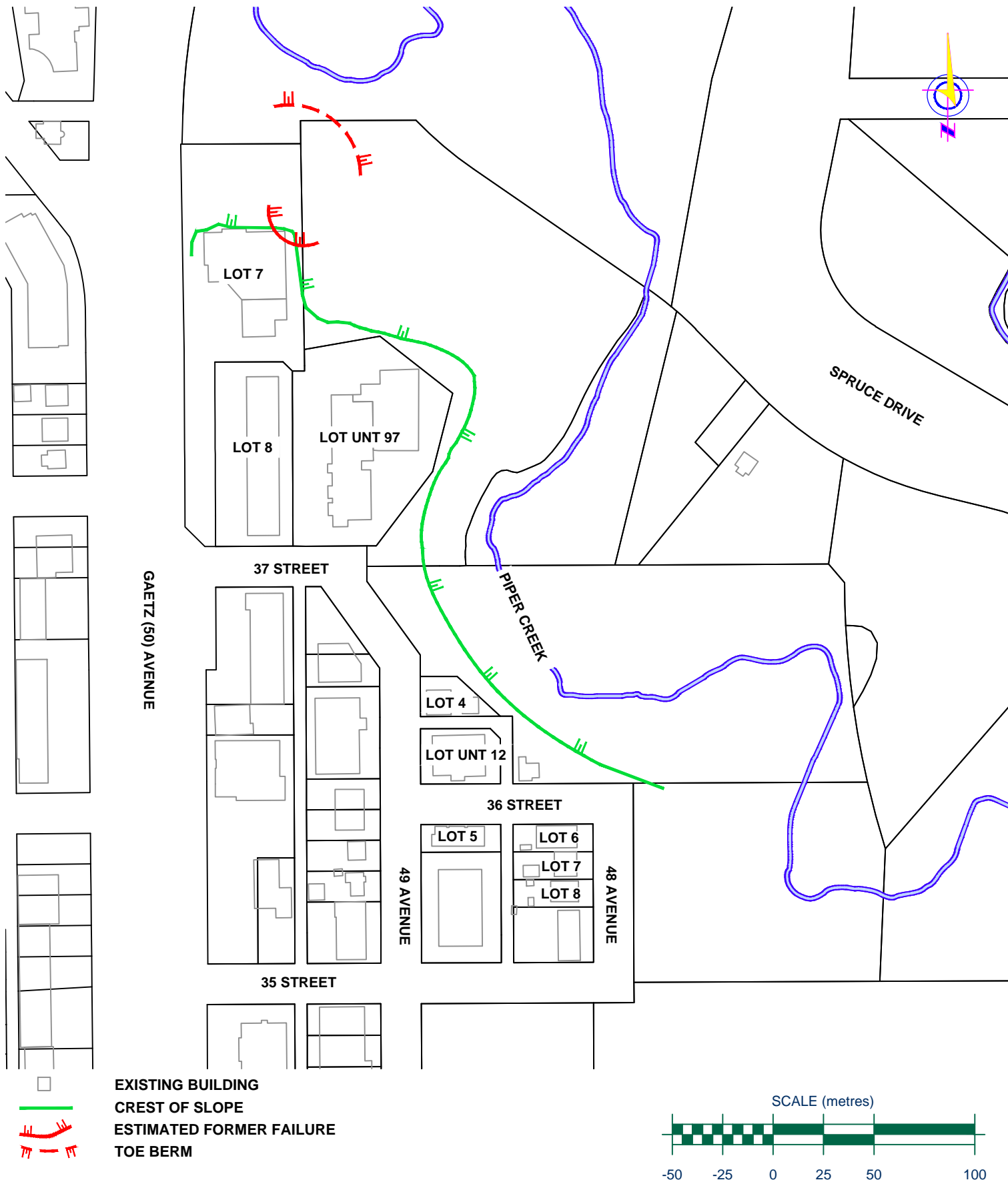
A Probability Factor of 3 is considered appropriate since there is no active sliding at these historical landslide sites and the potential for a slide is considered to be low to moderate. A Consequence Factor of 10 is considered appropriate since the expected size of landslide in the upper slope in this area could impact private property including a nearby structure.

19.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an “as required” basis to identify any significant changes, if present. Inspections should include control surveys along the crest relative at fixed points.

19.10 ATTACHMENTS

Figure 19-1 - Site Plan
Figure 19-2 - 2016 Contour Plan
Figure 19-3 - Cross Section Profiles
Figure 19-4 - Aerial Photographs
Figure 19-5 - Site Photographs
Figure 19-6 - Survey Marker Plan
Figure 19-7 - Photograph Plan
Figure 19-8 - Stability Analysis Run
Table 19-4 - List of Survey Markers
Table 19-5 - List of Photographs
Site Inspection Record (October 30, 2018)



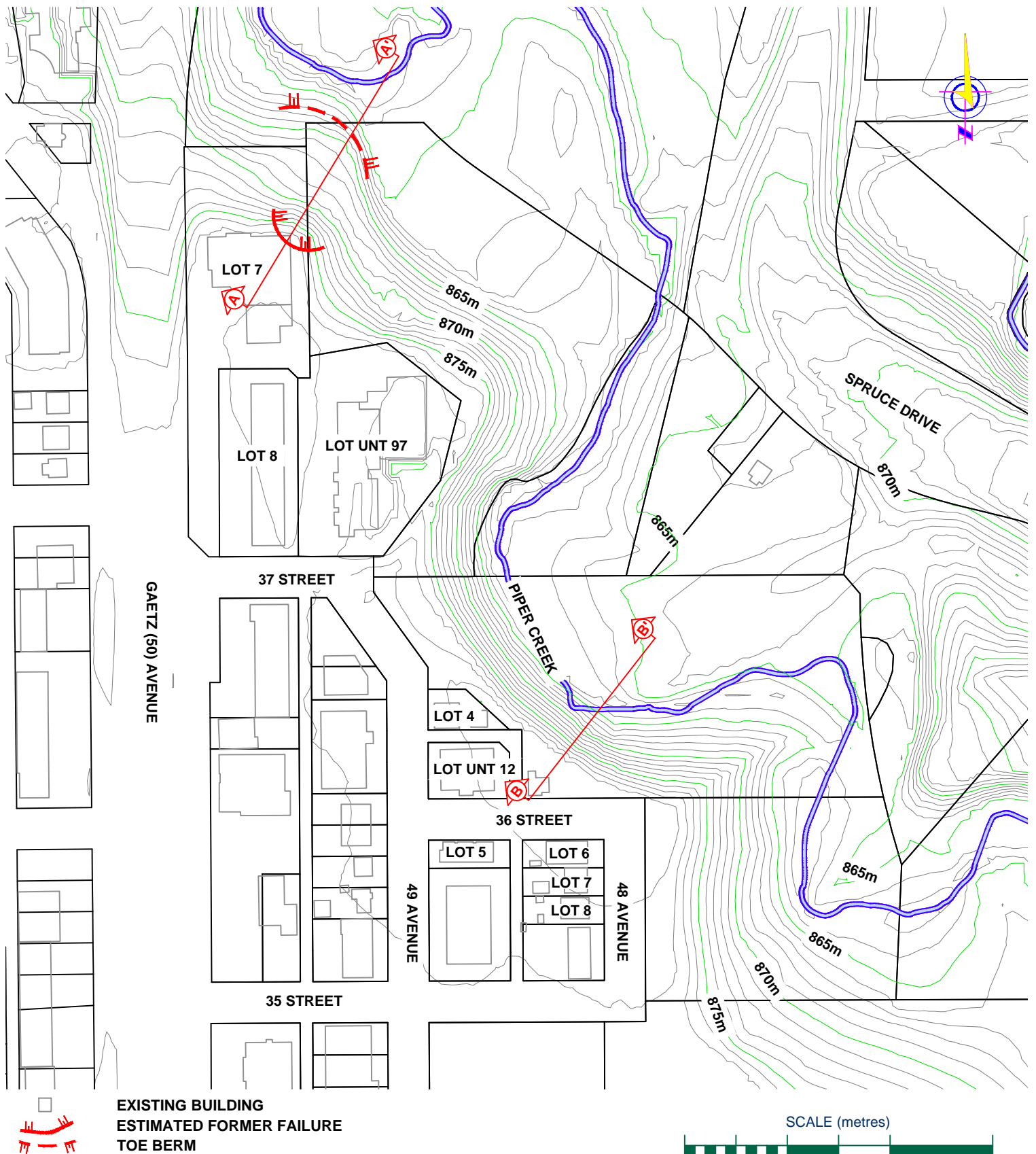
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-19	DRAWING NO. FIGURE 19-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT



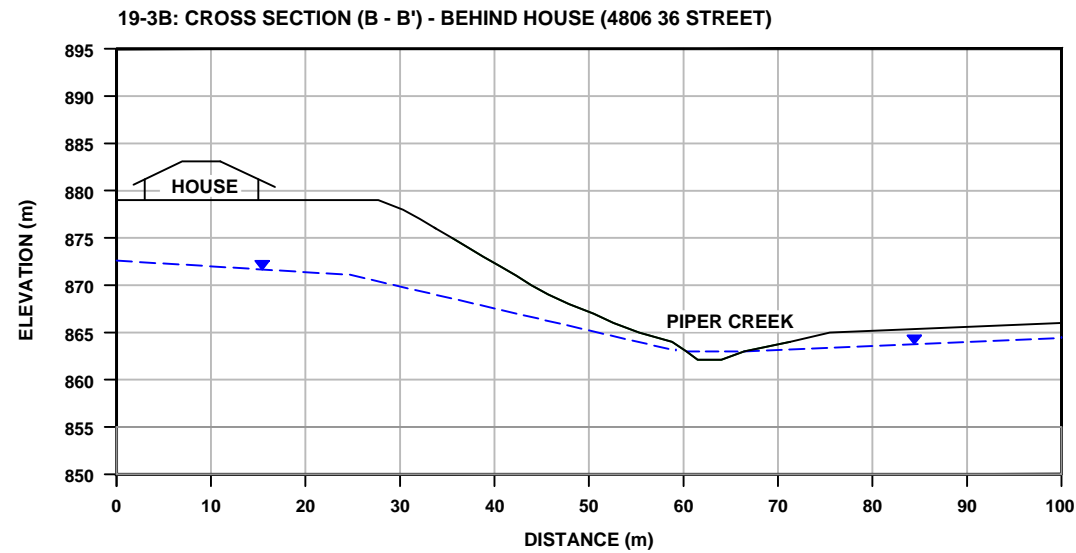
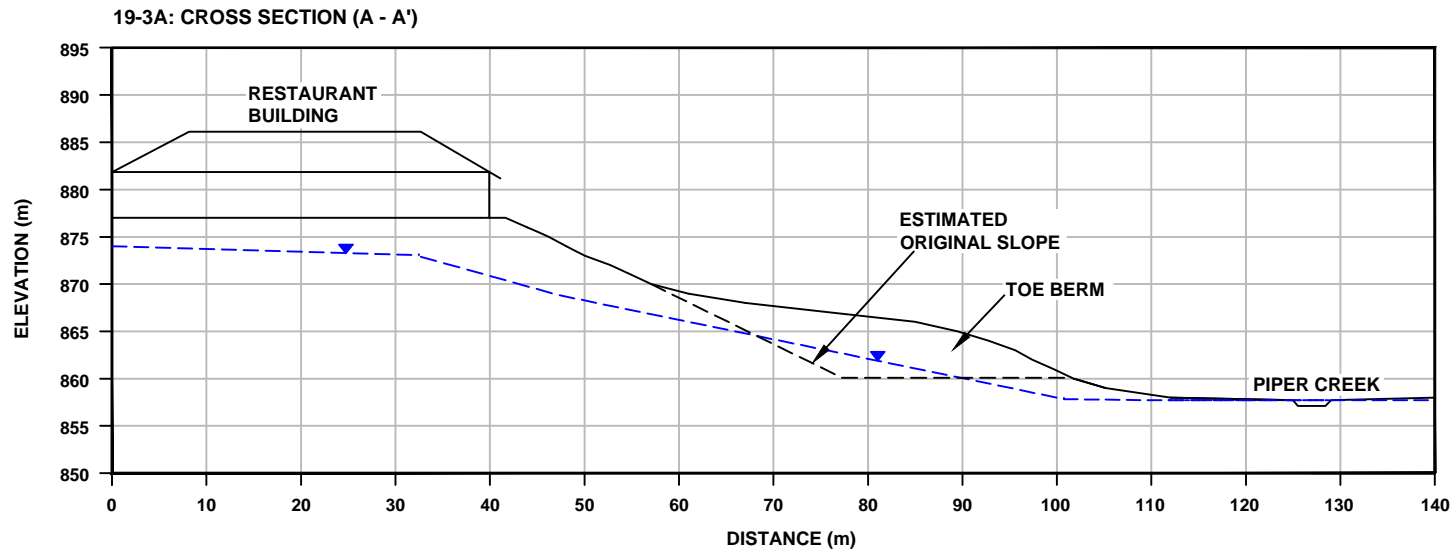
CLIENT:



CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
 FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-19	DRAWING NO. FIGURE 19-2	



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.

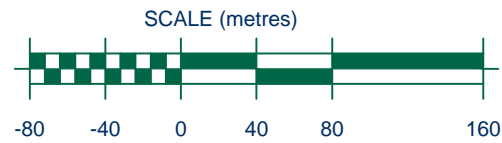
	<div>CLIENT:</div> 	<div>CROSS SECTION PROFILE</div>			
		<div>CITY OF RED DEER SLOPE STABILITY EVALUATION FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES</div>			
		DRAWN:	CHK'D.:	REV #:	DATE:
		PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.	DRAWING NO.	
AS SHOWN	RD6500-19	FIGURE 19-3			



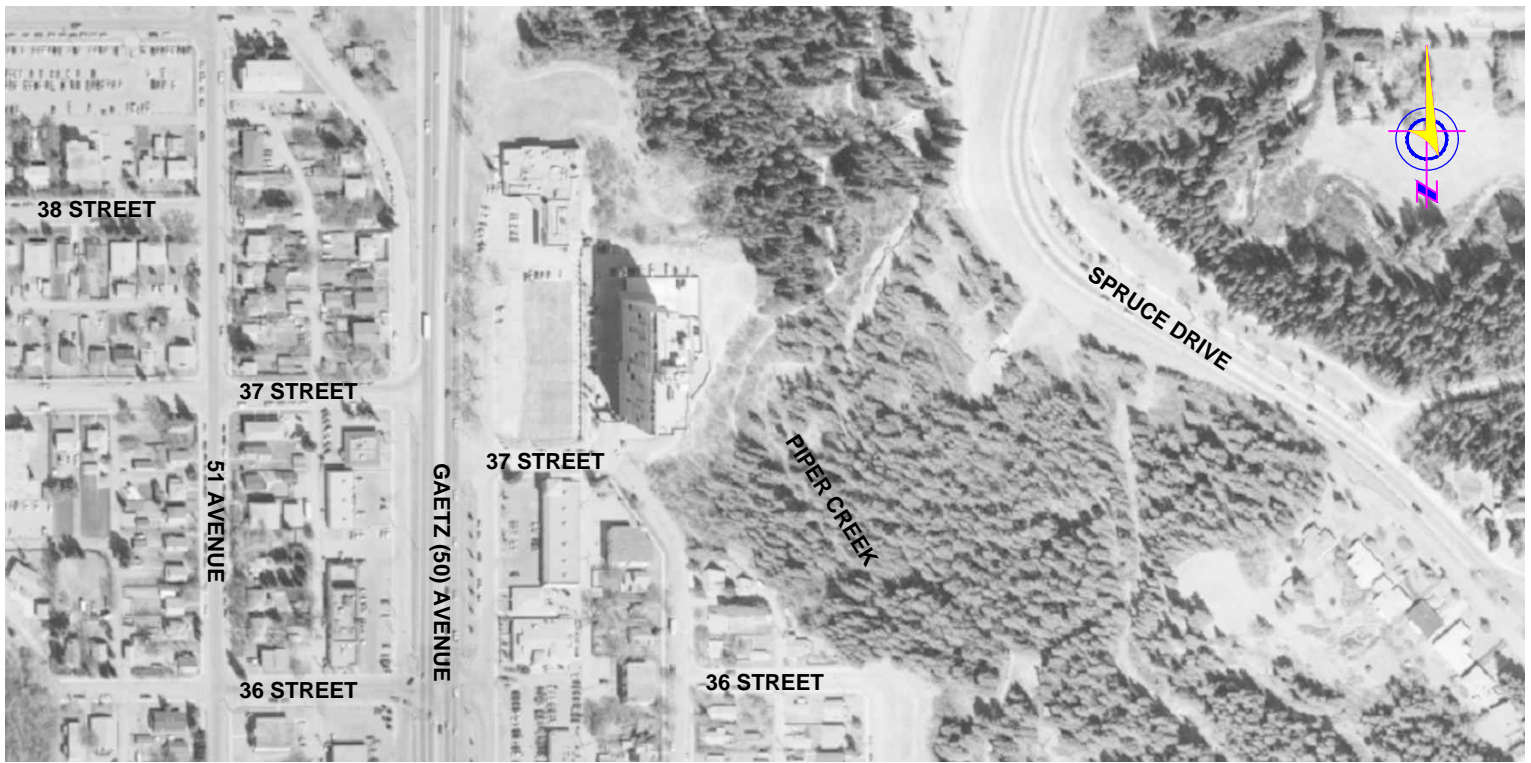
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED AUGUST 1, 1962.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED JULY 2, 1969.



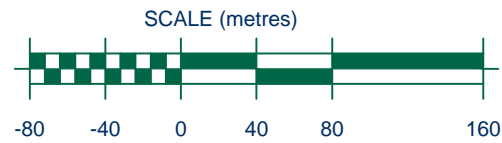
	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		1:4000	RD6500-19		FIGURE 19-4A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



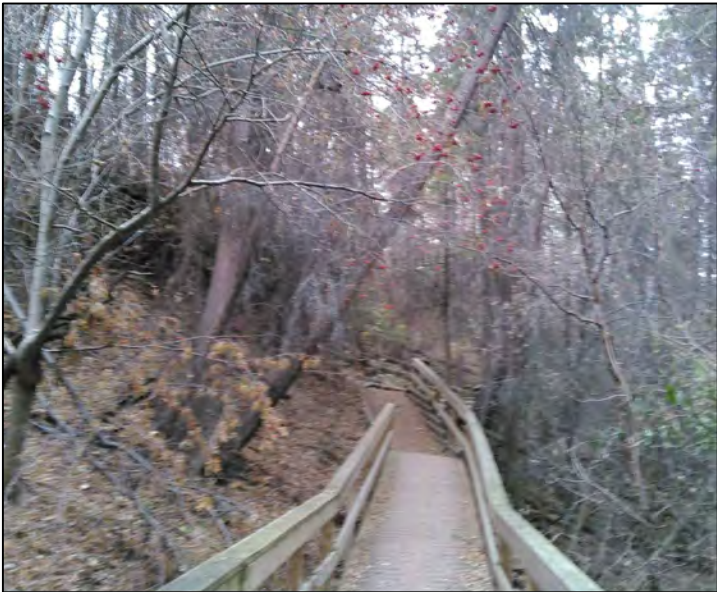
	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		1:4000	RD6500-19		FIGURE 19-4B	



PHOTOGRAPH 6 (2018): CREST OF THE SLOPE, FACING NORTHEAST

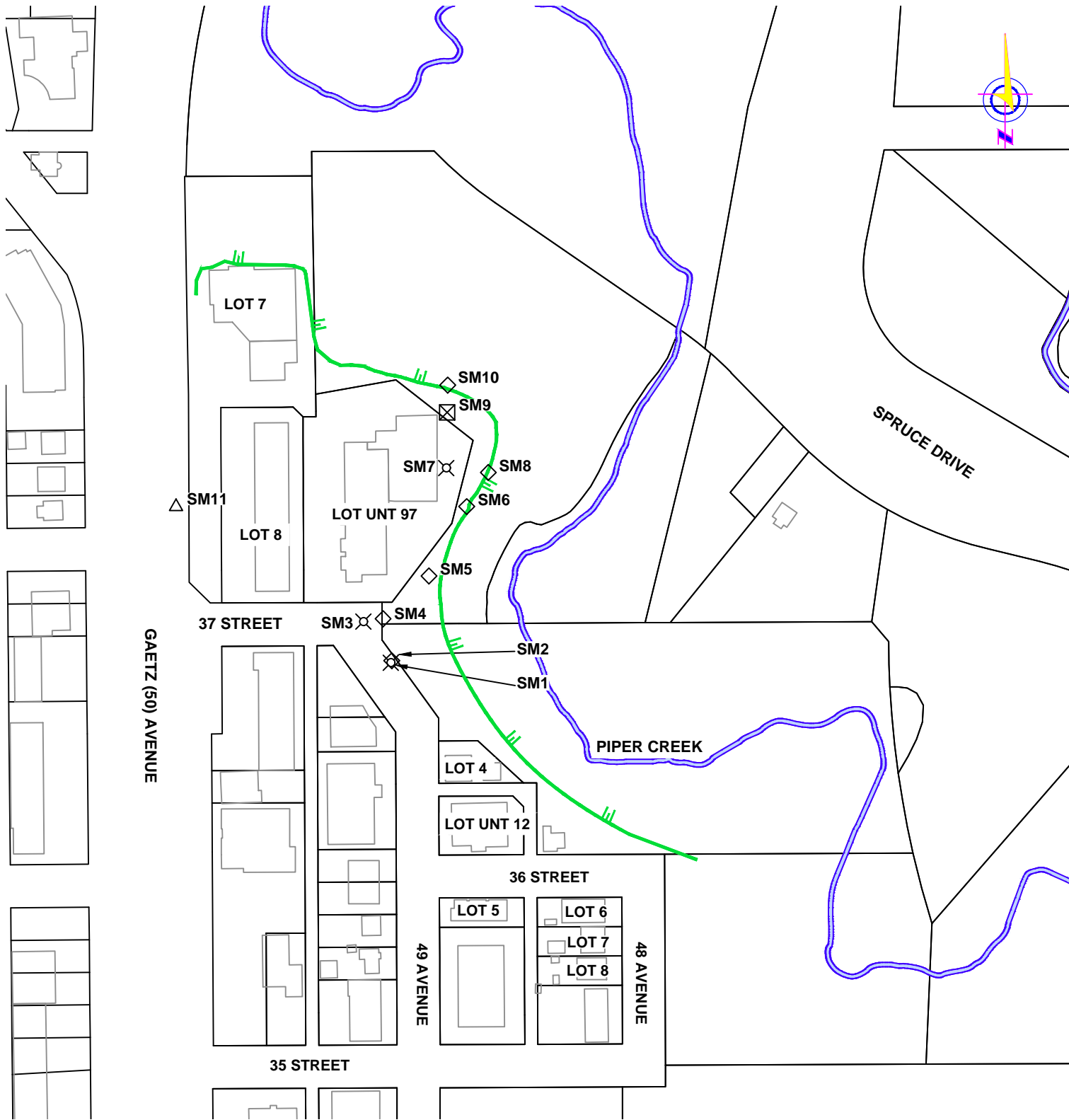


PHOTOGRAPH 15 (2018): SLOPE FACE, TAKEN FROM CREST OF THE SLOPE, FACING NORTH

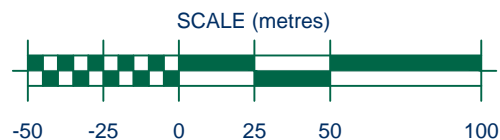




PHOTOGRAPH 33 (2018): SLANTED TREES CLOSE TO THE TOE OF THE SLOPE, FACING NORTHWEST

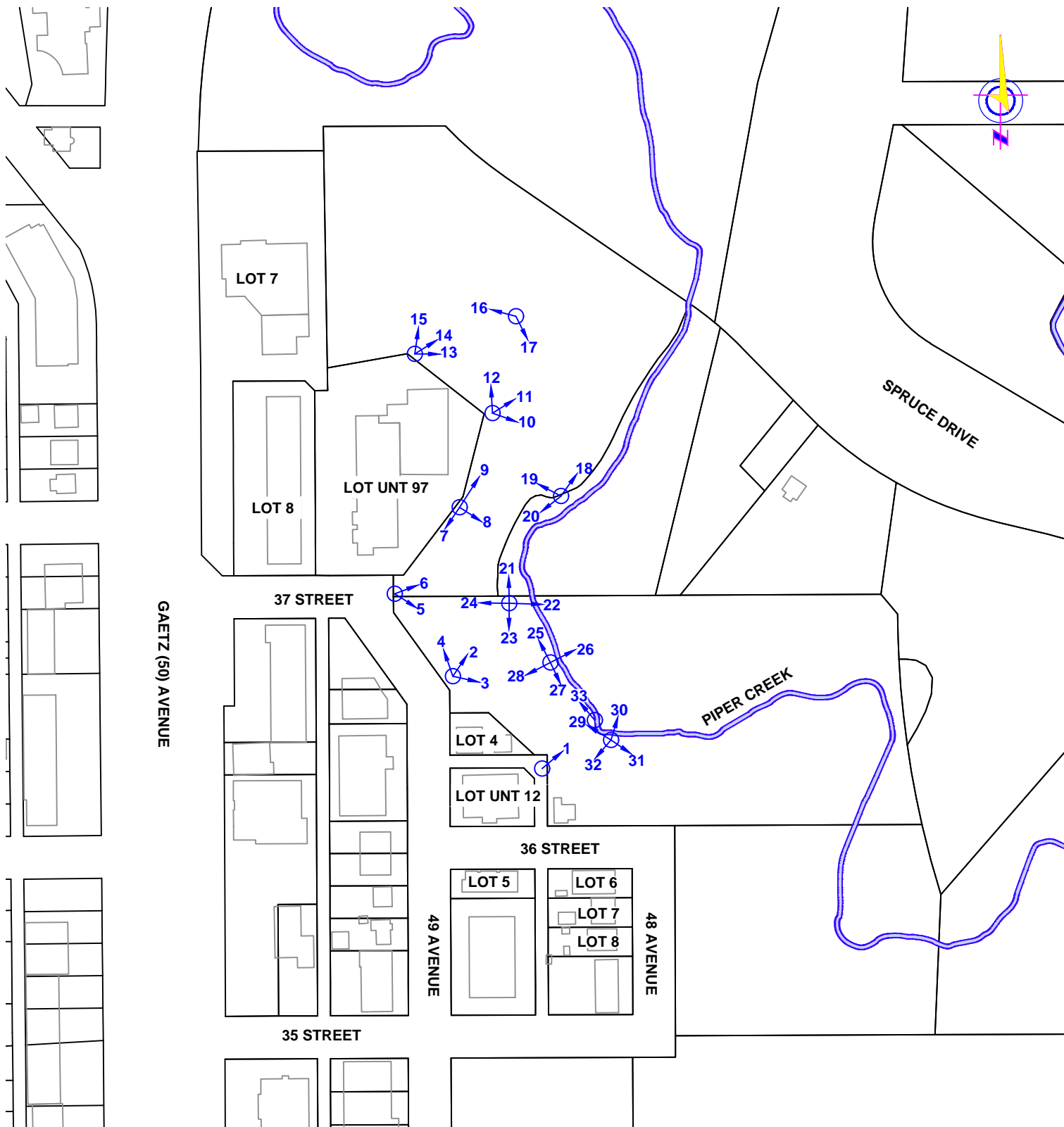
	CLIENT: 	SITE 19 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-19	DRAWING NO. FIGURE 19-5	



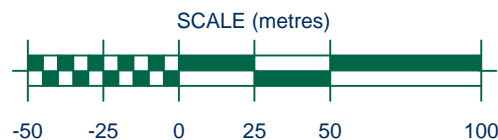
- CREST OF SLOPE
- PARKING LOT CORNER
- LIGHT POLE
- SURVEY LAND POINT
- ASCM



	CLIENT:						SURVEY MARKERS			
							CITY OF RED DEER SLOPE STABILITY EVALUATION FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES			
	DRAWN:		CHK'D.:		REV #:		DATE:			
	PS		MDB		2		APRIL 2019			
	SCALE:		JOB NO.				DRAWING NO.			
1:2500		RD6500-19				FIGURE 19-6				



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE



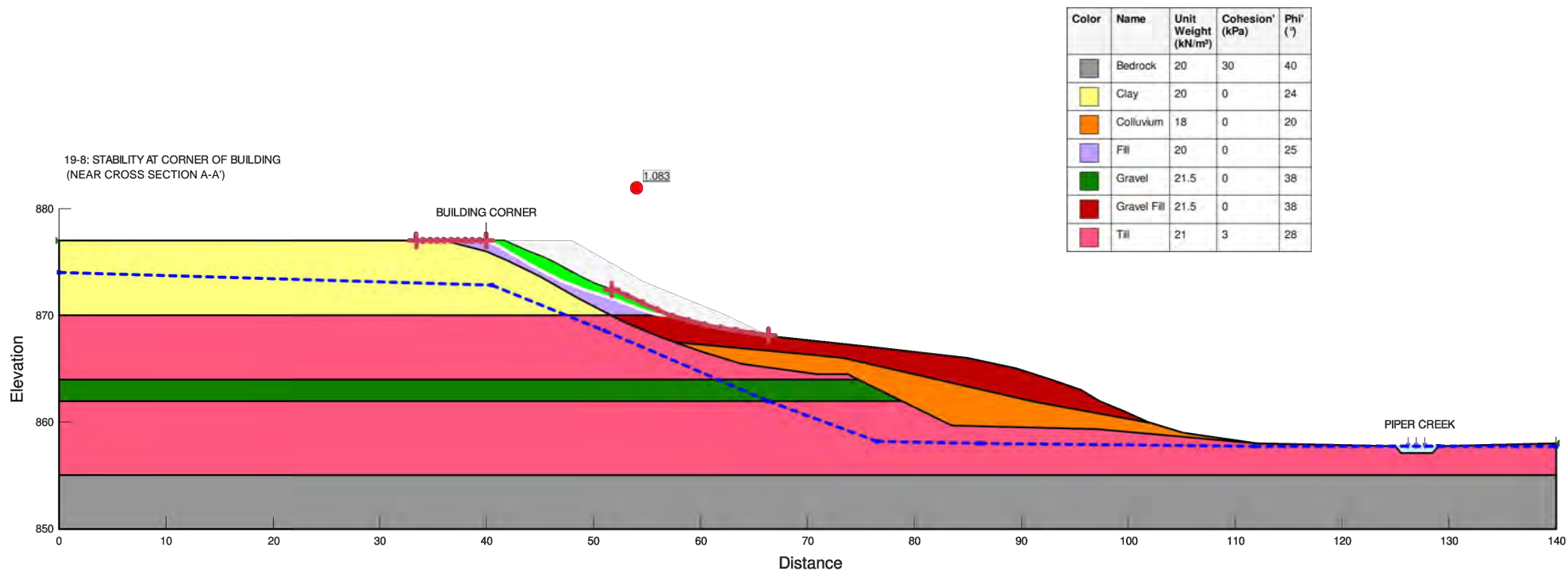
CLIENT:



PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-19	DRAWING NO. FIGURE 19-7	



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-19	DRAWING NO. FIGURE 19-8	

SITE #19 - FORMER ELKS CLUB & 36 STREET LANDSLIDE SITES

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 19-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018						COMMENT
		NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	
#SM19-001	West corner of light pole base	5793364.29	308060.74	878.38				
#SM19-002	Crest	5793365.24	308061.19	878.29				
#SM19-003	West corner of light pole base	5793383.54	308047.93	878.14				
#SM19-004	Crest	5793384.86	308057.14	878.69				
#SM19-005	Crest off south building	5793404.90	308078.60	877.14				
#SM19-006	Crest mid building	5793437.32	308096.26	876.63				
#SM19-007	SE corner of light pole	5793455.32	308086.69	877.54				
#SM19-008	Crest off light pole	5793453.29	308106.34	876.96				
#SM19-009	NE corner of parking lot wall	5793481.35	308087.07	877.34				
#SM19-010	Crest off parking lot wall	5793494.12	308087.36	876.08				
#SM19-011	ASCM 301283	5793437.28	307960.31	877.44				

TABLE 19-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P19-006	Crest of the slope	5793384	308057	NE	Y*	
#P19-015	Slope face from crest of slope	5793496	308067	N	Y*	
#P19-033	Slanted trees close to the toe of the slope	5793324	308151	NW	Y*	

Notes:

* Provided in the report

All measurements in metres

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	#19		
Site Name	Former Elks Club		
Legal Land Description	-		
Address	-		
UTM Coordinates	-		
Operational Site Instrumentation	Slope Indicator		0
	Pneumatic Piezometers		0
	Vibrating Wire Piezometers		0
	Standpipe Piezometers		0
Date of Last Instrumentation Readings	-		

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	-	-	-	-
Current Inspection:	October 30, 2018	3	10	30
Inspected By:	Trevor Allen - PGEO Alex Thomson – PGEO (November 7, 2018)			
Report Attachments:	Site and Contour Plans Cross Sections Photographs			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded	N/A	
Slope Movement	Photo 33	N/A	
Erosion	Yes	N/A	
Seepage	-	N/A	
Distress	-	N/A	
Other	8 inch diameter tree – Photo 19	N/A	
Instrumentation:	•		
Other Comments:	•		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Slope face has grasses, shrubs and trees
Assessment	
Recommendations	<ul style="list-style-type: none">- Consideration for site visits as required

SITE #20

Parkland Mall Slope Landslides



SITE #20 - PARKLAND MALL SLOPE LANDSLIDES

20.1 SITE DESCRIPTION

Parkland Mall is located in the southeast corner of the intersection of Gaetz Avenue and 67th Street, as shown on Figure 1 of the main report. The mall site is subdivided into two properties with legal addresses of Lot 1, Block 7, Plan 962-3939 (east) and Lot 2, Block 7, Plan 782-0689 (west), Red Deer, Alberta. The mall site is a triangular shaped upland area above the Red Deer River valley in the northwest corner of NW 21-38-27-W4M. The Parkland Mall slope runs from Gaetz Avenue at the west to the northeast corner of the quarter-section which overlooks 67th Street. The Site Plan of the landslide site is shown as shown on Figure 20-1.

Prior to mall development the area had several dune formations that were mined for local construction material. The mall has undergone phased construction since the late 1960s, including a major expansion to the east in the 1980s and building re-configurations in the late 1990s and early 2000s. The current site development includes a central shopping mall building with large parking lots to the east and west. There is a small parking area, loading area and access road to the south along the top-of-slope. An access road is provided between the west and south parking lots at the southwest corner of the mall with a 4 m high, piled supported concrete retaining wall which is tied back into the foundation of the mall. The mall property is relatively level with shallow grades to drain water in the parking lot away from the building and the slope. The surface elevation of mall property ranges between 876.5 m and 878.7 m.

The current slope contours are shown on Figure 20-2. Representative cross-sections along the crest and down the slope are provided in Figures 20-3 and 20-4. The slope is 22 to 25 m high with a profile that has been complicated by geological processes, man-made disturbances and failures. Signs of disturbance and slope failures include terracing, toe bulges, exposed scarps and tipped trees in several localized areas. In general, the upper slope has shallower slope angles of 3.5H to 7H:1V; and the lower slope is steeper with inclinations of up to 1.5H:1V.

- The slope below the paved access road and retaining wall in the southwest corner of the mall is the old haul road which was used for a natural gas line right-of-way. Historical records suggest this area was subject to a landslide in the 1970s. The pre-development profile slope had a relatively shallow upper slope of about 4H:1V and the lower slope was about 2H:1V.
- The slope below the south parking lot is fringed by fill with shallow slopes or MSE walls at the crest. The pre-development profile in this area had a steepened area of about 2.5H:1V in the middle where a large sand dune formation intersected the crest. This dune location is shown by the deep sand in the centre of the crest cross-section on Figure 20-4. The lower slope has an average angle of about 2.7H:1V. This slope is traversed by an old haul road. There is colluvium at the bottom of the slope below the southeast corner of the mall building which was identified as an old failure (Reference #76).

- The river valley slope below the east parking lot had a pre-development profile of a 3H:1V upper slope above a 2H:1V lower slope. This area is notable for a flatter sewer line right-of-way which was constructed up the slope in the 1980s. Survey data from 1952 and 1977 suggests a small landslide occurred below the east corner of the parking lot (i.e. the slope to the southeast). The toe of the slope at the east end of the parking lot was over-filled during 67th Street road embankment construction in 1986.

The break point between the upper and lower slopes along this river valley slope occurs at an elevation of 864 to 867 m which is the approximate elevation of the top of the clay till below the crest (see Figures 20-3 and 20-4).

Vegetation on the slope face is moderate to heavy with some sparsely vegetated exposures. The slope face is traversed by a several paths/trails; as well as three former haul/access roads; the sewer right-of-way and a cut-line for a power line where the vegetation on the slope face was cleared. The unvegetated areas of slope expose either fine sand or very stiff clay. A wide flood-plain is present at the toe of the slope and the Red Deer River is located 350 to 600 m to the southeast. Access to the toe is open via 63rd Street in Riverside Light Industrial Park. There is a shallow low-lying area between the toe of the slope and this street along most of this slope. Historical aerial photographs are shown on Figure 20-5A and 20-5B and site photographs are provided on Figures 20-6A to 20-6D.

20.2 REFERENCES

The references from Appendix B which apply to Site #20 - Parkland Mall Slope include References #74 to #79. The most recent site investigation for the Parkland Mall slope was performed in 2000 for the proposed parking lot redevelopment (Reference #79). This report provides a very detailed description of the slope based the review of on 14 cross sections. Other recent file information related to that project included photographs and descriptions from annual slope reviews over the period of 2002 to 2012.

20.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

In total, 48 boreholes have been drilled at Parkland Mall between 1969 and 2000; including numerous boreholes drilled along the toe of the slope. The locations of these boreholes are shown on Figure 20-7. The borehole depths at the crest range up to 21.5 m deep. No slope inclinometers or other instrumentation has been installed in this area.

20.4 2018 REVIEW

Aerial photography is provided on Figures 20-5A and 20-5B, for the years listed in following table. The 2001 aerial photo shows the final extent of disturbance on the slope face.

TABLE 20-1: AERIAL PHOTOGRAPHS

Year	Description
1969	Shows the original site condition just prior to mall development.
1975	Shows the condition of the site just after the first phase of mall development.
2001	Shows the condition site just after the last major phase of mall development.
2016	Shows the present site condition including the re-configured parking along the crest.

The Parkland Mall Slope site was visited on October 30 and November 15, 2018. A copy of the field inspection record is attached at the end of this appendix.

The ortho-contours from 2016 City aerial photography was reviewed for this study. Historical survey information for the slope was compiled from two primary sources: the 1952 City topography maps and survey data from the 2000 slope assessment (Reference #79). A control survey of the site was performed in 2018. A record of survey control points and data is appended in Table 20-4. A reference drawing of survey reference points is provided on Figure 20-8.

Selected site photographs from 2000 to 2018 are provided on Figures 20-6A to 20-6D. A summary of site photos is provided on Table 20-5. A reference drawing of photograph locations is provided on Figure 20-9.

20.5 BACKGROUND

This Parkland Mall slope has been subject to significant past disturbance. In the 1940s, it is understood this slope was used as a target for artillery practice from the army base across the river. In the 1950s and 1960s, trails were made in the slope from the Riverside Light Industrial area to access the sand deposits on the face and upland area. The river valley slope south of the mall appears to have experienced slope movements at three locations as shown on Figure 20-1, including the previously noted slide at the old access road in the southwest. The other two slides appear to be natural slumps; with the one at the east end being relatively recent (i.e. since 1952). There have been no instabilities related to the 2002 parking lot fills in the middle and east end of the slope. From aerial photographs and site observations there was no evidence of deep seated slide in the deeper till or bedrock in the vicinity and there was no active river erosion at the toe of this slope. None of the past landslides have run out to 63rd Street at the toe.

The mall site has experienced significant grading. Much of the post-glacial dune material was removed or levelled during site grading for the mall. Fill thickness along the crest were estimated for Reference #79 based on a comparison of 1952 contours to existing perimeter grades. Areas

with grades of 877 m or lower within the mall property appear to have been filled in with sand. The largest fills were estimated to be 4 to 7 m high in the southwest corner of the site. Historical boreholes indicate buried organics under the fill in this area, suggesting some fill placement was uncontrolled. This crest fill was considered to be the cause of the 1970s landslide at the southwest slope access road. Site fills were successfully placed along the crest to provide parking stalls south of the second phase of the mall completed in the late 1970s. The crest areas below the fills were generally rounded and landscaped with grass. The face inclination of the original fill slopes was up to 1H:1V. The parking lot improvement in the early 2000s included construction of several sections of mechanically stabilized earth (MSE) walls.

20.6 SUBSURFACE PROFILE

The original slope soil profile consists of till below an elevation of 864 to 867 m extending out to the face of lower slope in most of the area. The till was overlain by silty lacustrine clay which extends up from the top of the till at the slope face at an estimated inclination of about 4H:1V. This lacustrine clay slope was overlain by wind blown sand deposits. One large dune was draped over the crest in the middle of the site resulting in an unusually steep 1.5H:1V to 2H:1V slope above the flatter silty clay deposits. The following is a brief description of the soil types encountered.

1. **Surficial Materials.** The surface at the crest of the slope is either: landscaped and grassed; MSE wall fill; or asphalt pavement.
2. **Sand.** Fine grained sand with a trace of silt was encountered below the pavement and topsoil at the crest. The surficial sand deposits are dry. The transition between the fill and the native sand is very difficult to identify, but fill thickness estimated from historical topography are discussed in Reference #79. The sand was loose to medium dense with moisture contents of less than 10 percent in the crest area.
3. **Silt, Sand and Clay.** Inter-bedded silt and clay with traces of fine sand were encountered below the sand in the crest areas. These lacustrine materials are typical subgrade soils in north Red Deer. The silt and clay layers were low to medium plastic and stiff to very stiff with moisture contents ranging from 15 to 38 percent.
4. **Till.** Both sand and clay till were encountered below the silt and clay. The low plastic sand till was a very sandy, silty, clay mixture with inclusions of gravel, coal, shale pieces and thin sand seams. The clay till was medium plastic. The till was very stiff to hard and moisture contents ranged from 12 to 26 percent with a typical value of about 17 percent.
5. **Bedrock.** Bedrock was not encountered within the depths drilled. The local silt-stone and shale bedrock in this area is expected to be found at an elevation of 845 to 850 m.
6. **Groundwater.** In late 2000, the groundwater levels along the crest were at 870 m; about 8 to 10 m below grade. Back from the crest, the groundwater levels rise to depths of 1.5 to 3 m below grade which corresponds to an elevation of about 876 m.

The following effective strength parameters were assumed for this site.

TABLE 20-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Elevation (m)	Unit Weight (kN/m ³)	Shear Strength (kPa)	Cohesion, c' (kPa)	Phi, ϕ' (Degrees)
Sand/Sand Fill	Varies	21.5	0	0	40
Silt & Sand	Above 877	19.5	0	0	28
Lower Clay	865 - 877	19	25	0 - 3	21 - 25
Till	Below 865.2	21	100	10 - 15	27 - 30

Soil profiles for the slope is shown on the Figure 20-3 and 20-4 crest and slope cross-sections. For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix B.

20.7 REVIEW OF STABILITY ASSESSMENT

Stability analysis was performed for this site in 1977 and 2000 (References #76 and #79. Stability analysis to verify current conditions was carried out using the SLOPE/W computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 21-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
At Parking Lot Roadway	1.4	-
At Mall Closest Point (15 m from Crest)	1.5	Figure 20-10
Shallow Slope Face Failure	~ 1.2	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above. Note, there was insufficient design or construction information to quantify the stability of the access road retaining wall at the southwest corner of the building. However, it is understood this wall was an engineered structure which was prepared with full knowledge of the local landslide history at this location.

The most recent slope instabilities at this site were due to slope face disturbances. Overall, the slope is considered to be stable in the short-term and at least marginally stable in the long-term. The most critical areas were the localized steepened faces in the lower two-thirds of the slope; similar the toe slide in the middle of the slope (see Figure 20-1). Slope face stability will be governed by shallow slumping in the surficial deposits, but it would take significant wetting of the slope face to cause failure. The mall building was developed with suitable set-back buffers to eliminate the risk of a landslide affecting the structure. The placement of fills at the crest, including the MSE wall fill placed in 2002 have had no observable impact on these critical locations.

20.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

1. **PF(1) * CF(10) = 10** - Retaining Wall At SW Corner of the Mall

The retaining wall is understood to be designed to provide a FS greater than 1.5 for the access road and adjacent building independent of any landslide activity below the wall, so a Probability Factor of 1 is considered appropriate. A Consequence Factor of 10 is considered appropriate since failure would impact the road and mall building.

2. **PF(3) * CF(2) = 6** - South Parking Lot and MSE Walls

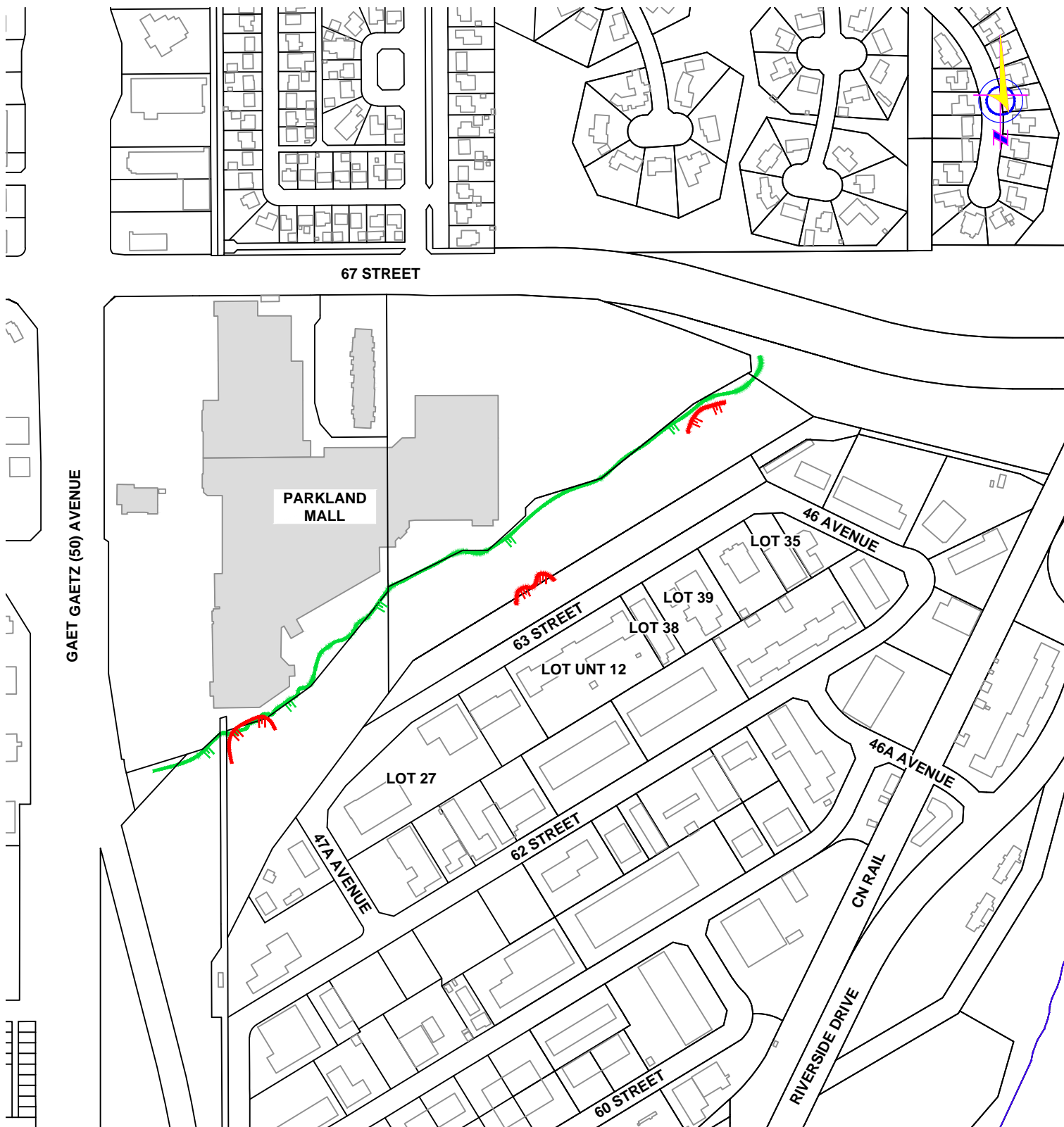
A Probability Factor of 3 is considered appropriate since there is no active landsliding in the upper slope along the entire top-of-bank, and probability of small slide in the area is low to moderate. A Consequence Factor of 2 is considered appropriate since the expected size of small landslide in the upper slope at this site might require reconstruction of MSE walls or edge of the parking lot pavement, but it would be well away from the structure.

20.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an "as required" basis to identify any significant changes, if present. Inspections should include control surveys along the crest relative at fixed points to verify movements along the crest, if observed.

20.10 ATTACHMENTS

Figure 20-1 - Site Plan
Figure 20-2 - 2016 Contour Plan
Figure 20-3 - Crest Cross Section Profile
Figure 20-4 - Slope Cross Section Profiles
Figure 20-5 - Aerial Photographs
Figure 20-6 - Site Photographs
Figure 20-7 - Borehole Plan
Figure 20-8 - Survey Marker Plan
Figure 20-9 - Photograph Plan
Figure 20-10 - Stability Analysis Run
Table 20-4 - List of Survey Markers
Table 20-5 - List of Photographs
Site Inspection Record (October 30, 2018)

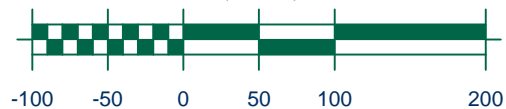


EXISTING BUILDING

 CREST OF SLOPE

 HISTORICAL FAILURES

SCALE (metres)



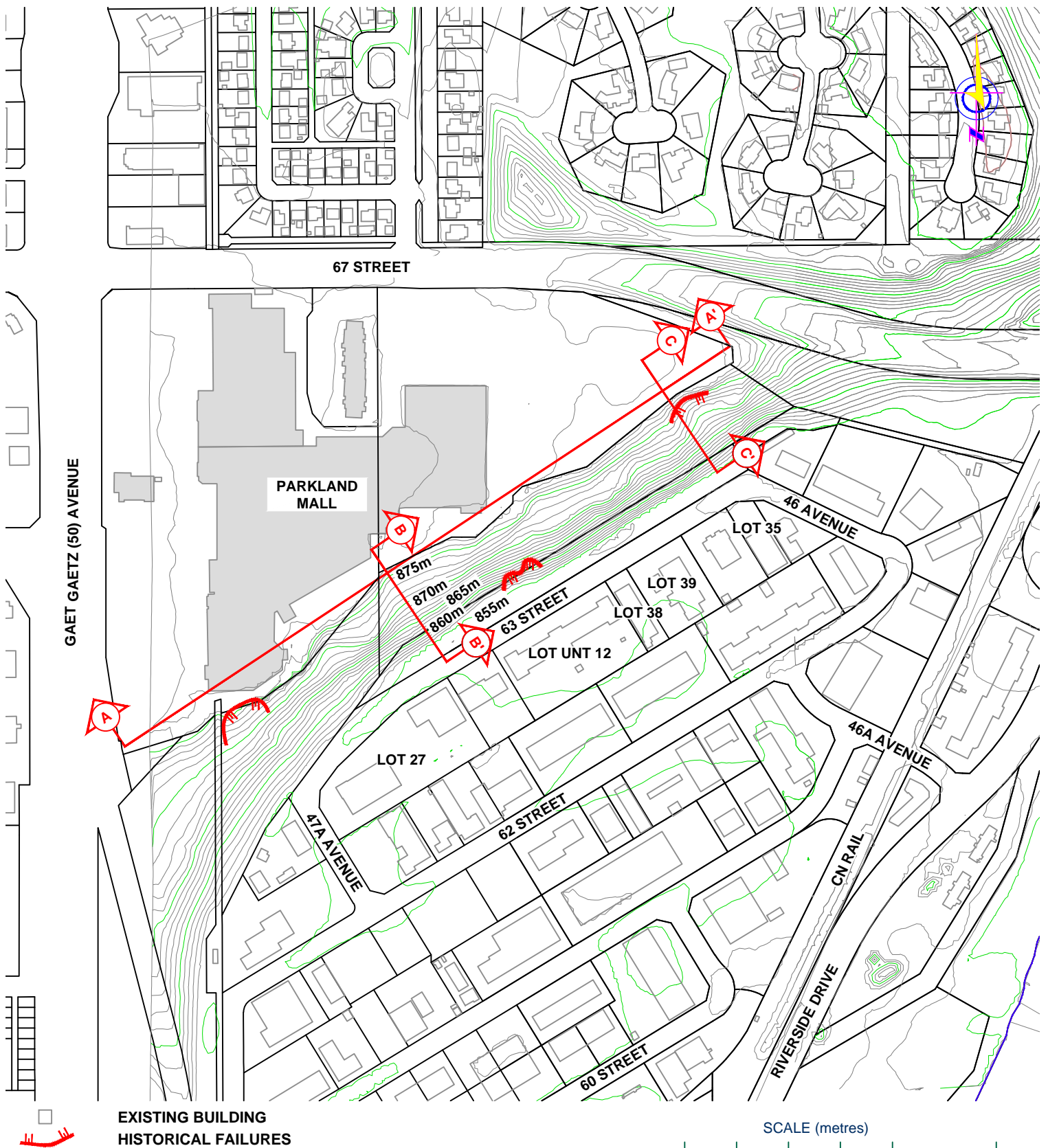
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
PARKLAND MALL SLOPE LANDSLIDES

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



CLIENT:

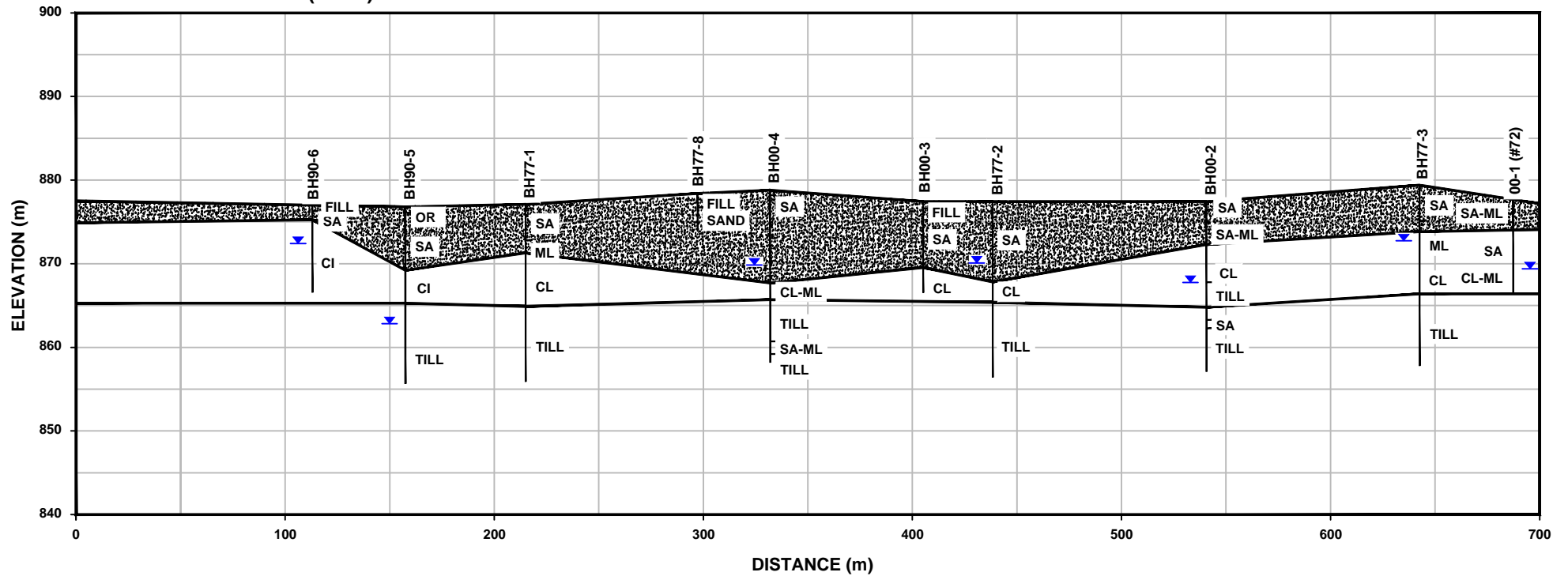


CONTOUR PLAN



CITY OF RED DEER SLOPE STABILITY EVALUATION
PARKLAND MALL SLOPE LANDSLIDES

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-2	

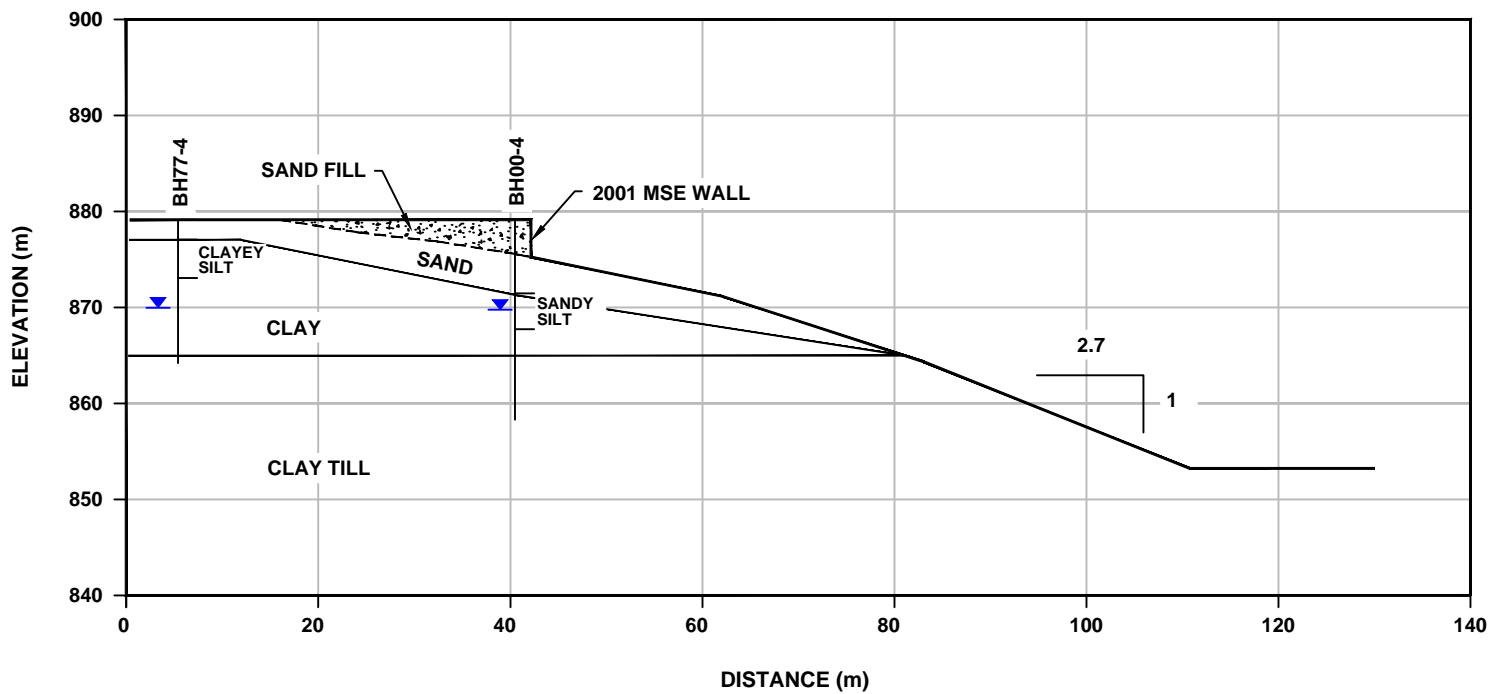
20-3: CROSS SECTION (A - A') - ALONG CREST



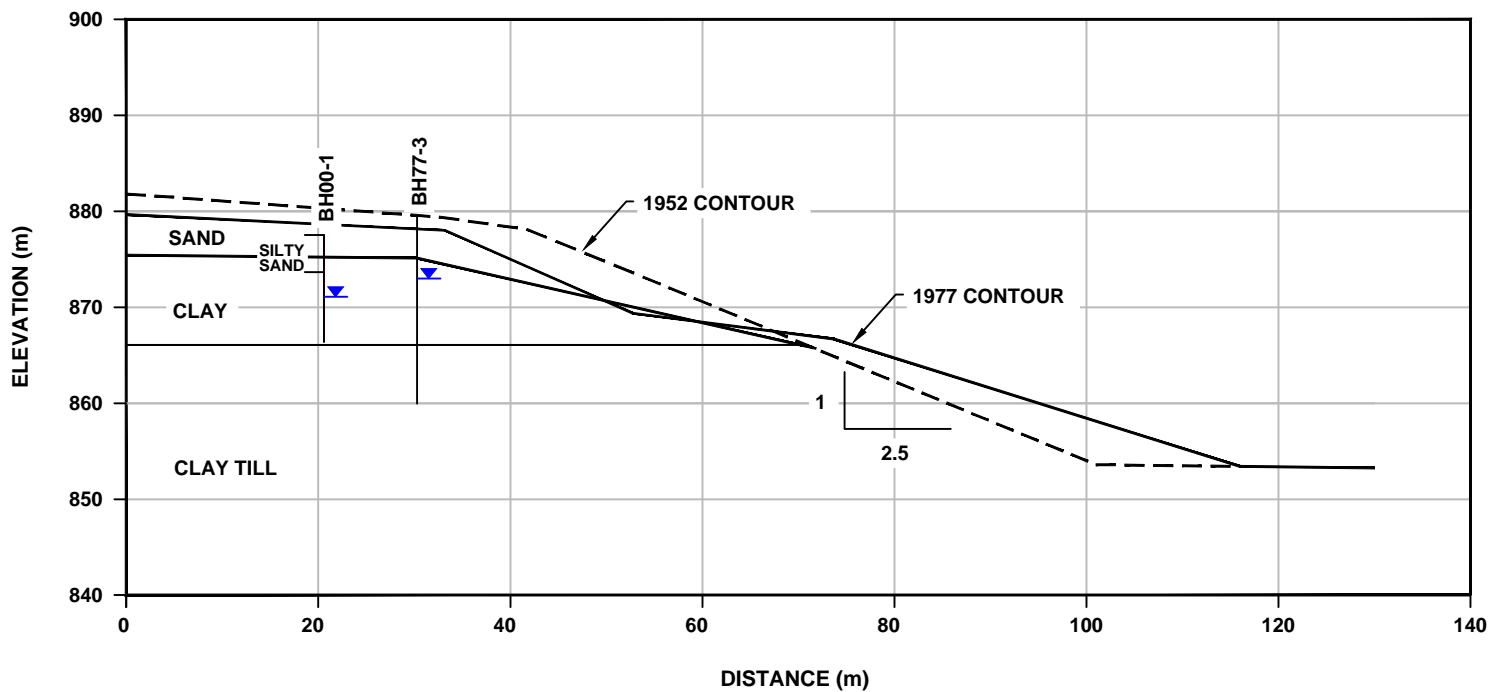
NOTE:
EXAGGERATION: 1H:4V

	CLIENT:			CREST CROSS SECTION PROFILE			
				CITY OF RED DEER SLOPE STABILITY EVALUATION PARKLAND MALL SLOPE LANDSLIDES			
				DRAWN:	CHK'D.:	REV #:	DATE:
				NC	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.			
AS SHOWN		RD6500-20		FIGURE 20-3			

20-4A: CROSS SECTION (B - B')



20-4B: CROSS SECTION (C-C')



NOTE:
EXAGGERATION: 1H:1V
PROFILES FROM REFERENCE #79 (FIGURE 6)



CLIENT:



SLOPE CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
PARKLAND MALL SLOPE LANDSLIDES

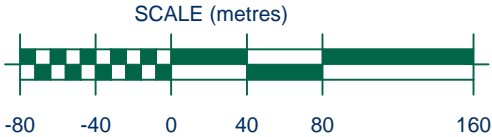
DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-4	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED JULY 2, 1969.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED NOVEMBER 17, 1975.



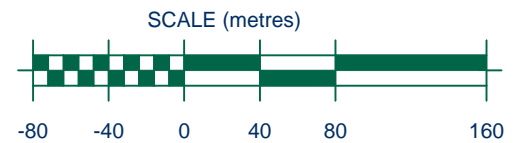
	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION PARKLAND MALL SLOPE LANDSLIDES			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:4000	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-5A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION PARKLAND MALL SLOPE LANDSLIDES			
			DRAWN:	CHK'D:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		1:4000	RD6500-20		FIGURE 20-5B	



PHOTOGRAPH 1 (2002): CREST OF SLOPE, TAKEN FROM NORTHEAST SIDE OF MALL PARKING LOT, FACING SOUTHWEST



PHOTOGRAPH 1 (2018): CREST OF SLOPE, TAKEN FROM NORTHEAST SIDE OF MALL PARKING LOT, FACING SOUTHWEST



PHOTOGRAPH 7 (2018): SLOPE FACE IN THE NORTHEAST CORNER OF THE STUDY AREA, FACING SOUTHWEST

	CLIENT:		SITE 20 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION PARKLAND MALL SLOPE LANDSLIDES			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		NTS	RD6500-20		FIGURE 20-6A	



PHOTOGRAPH 8 (2000): CREST OF SLOPE ALONG THE SIDE OF PARKING LOT, TAKEN FROM EAST SIDE OF MALL PARKING LOT, FACING NORTHEAST



PHOTOGRAPH 8 (2018): CREST OF SLOPE ALONG THE PARKING LOT, TAKEN FROM EAST SIDE OF MALL PARKING LOT, FACING NORTHEAST



PHOTOGRAPH 9 (2000): CREST OF SLOPE ALONG THE PARKING LOT, TAKEN FROM SOUTHEAST SIDE OF MALL PARKING LOT, FACING SOUTHWEST



PHOTOGRAPH 9 (2002): RETAINING WALL ALONG THE EAST SIDE OF PARKING LOT, FACING SOUTHWEST

	CLIENT: 	SITE 20 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION PARKLAND MALL SLOPE LANDSLIDES			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-6B	



PHOTOGRAPH 9 (2018): RETAINING WALL ALONG THE EAST SIDE OF PARKING LOT, FACING SOUTHWEST



PHOTOGRAPH 12 (2000): SOUTHEAST SIDE OF MALL PARKING LOT, FACING NORTHEAST



PHOTOGRAPH 12 (2002): RETAINING WALL AND CREST OF SLOPE ALONG THE SOUTHEAST SIDE OF MALL PARKING LOT, FACING NORTHEAST



PHOTOGRAPH 12 (2018): RETAINING WALL AND CREST OF SLOPE ALONG THE SOUTHEAST SIDE OF MALL PARKING LOT, FACING NORTHEAST



CLIENT:



SITE 20 PHOTOGRAPHS

CITY OF RED DEER SLOPE STABILITY EVALUATION
PARKLAND MALL SLOPE LANDSLIDES

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: NTS	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-6C	



PHOTOGRAPH 18 (2018): RETAINING WALL AND CREST OF SLOPE ALONG THE SOUTHEAST SIDE OF MALL PARKING LOT, FACING SOUTHWEST

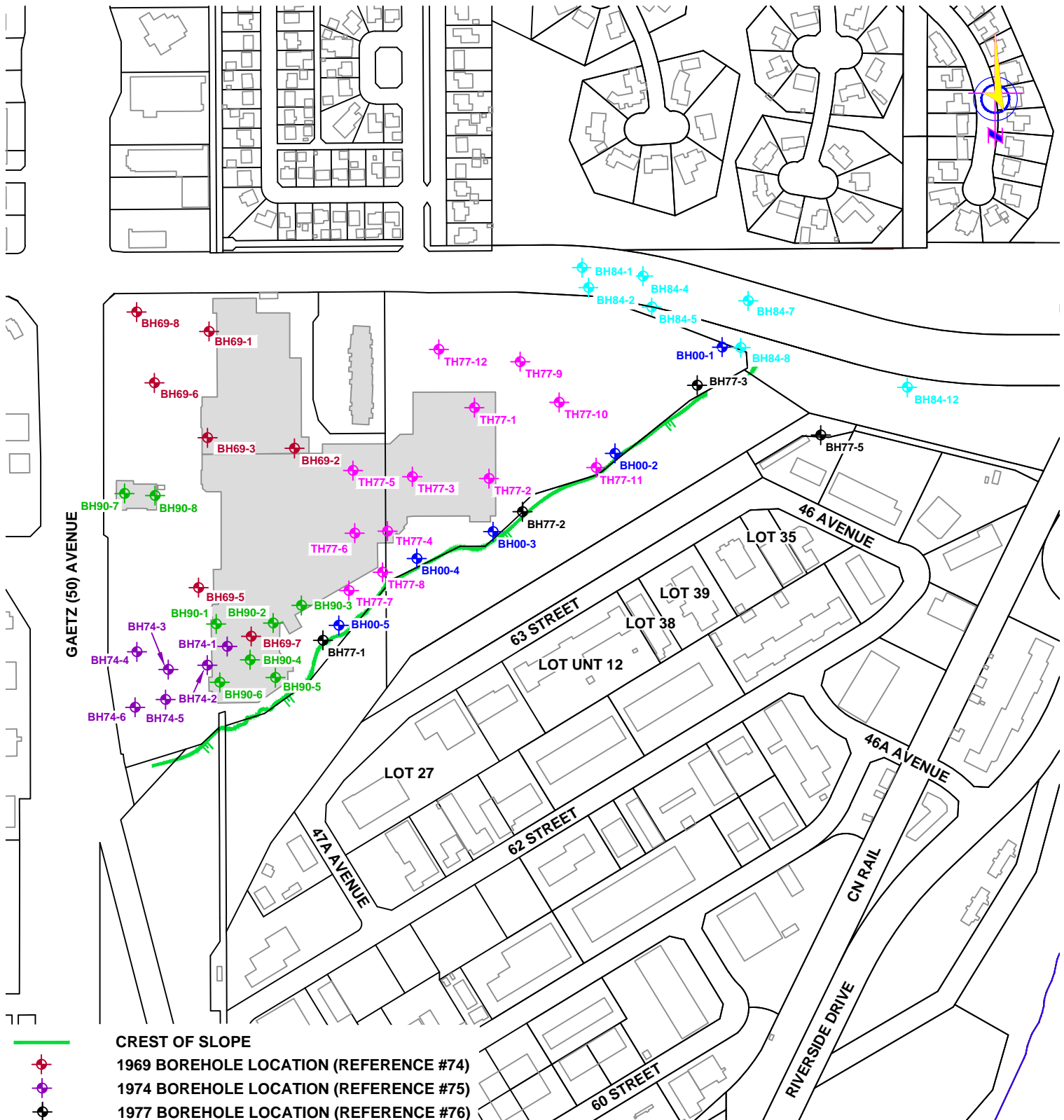


PHOTOGRAPH 23 (2018): RETAINING WALL AND CREST OF SLOPE ALONG THE SOUTHEAST SIDE OF MALL PARKING LOT, FACING NORTHEAST



PHOTOGRAPH 39 (2018): SLOPE IN THE NORTH SIDE OF STUDY AREA, FACING NORTHWEST

	CLIENT:		SITE 20 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION PARKLAND MALL SLOPE LANDSLIDES			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
NTS		RD6500-20		FIGURE 20-6D		

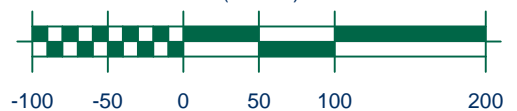


CREST OF SLOPE

- ◆ 1969 BOREHOLE LOCATION (REFERENCE #74)
- ◆ 1974 BOREHOLE LOCATION (REFERENCE #75)
- ◆ 1977 BOREHOLE LOCATION (REFERENCE #76)
- ◆ 1977 BOREHOLE LOCATION (REFERENCE #77)
- ◆ 1984 BOREHOLE LOCATION (REFERENCE #61)
- ◆ 1990 BOREHOLE LOCATION (REFERENCE #78)
- ◆ 2000 BOREHOLE LOCATION (REFERENCE #79)

ALL BOREHOLE LOCATIONS ARE APPROXIMATE.

SCALE (metres)



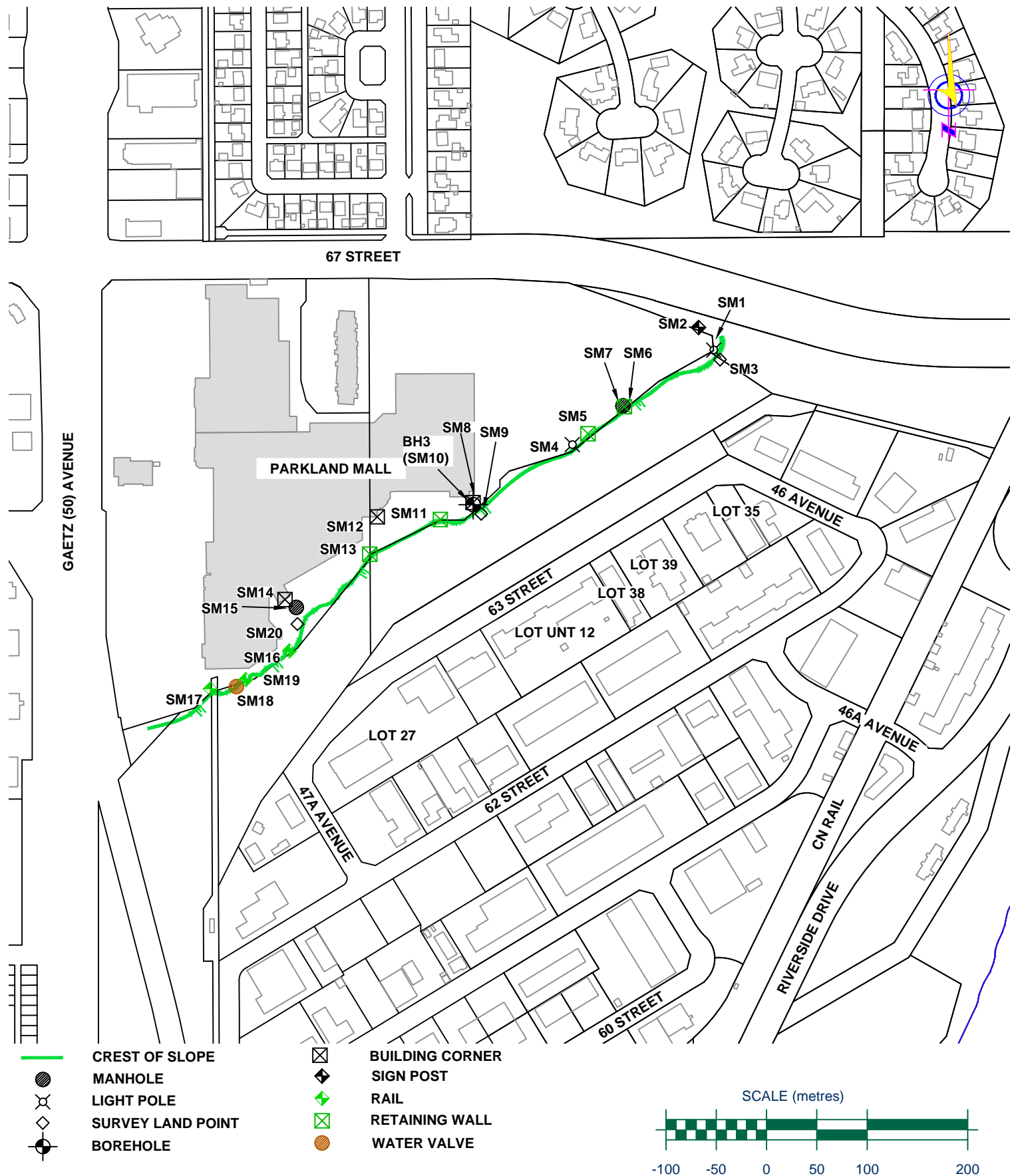
CLIENT:



BOREHOLE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
PARKLAND MALL SLOPE LANDSLIDES

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-7	



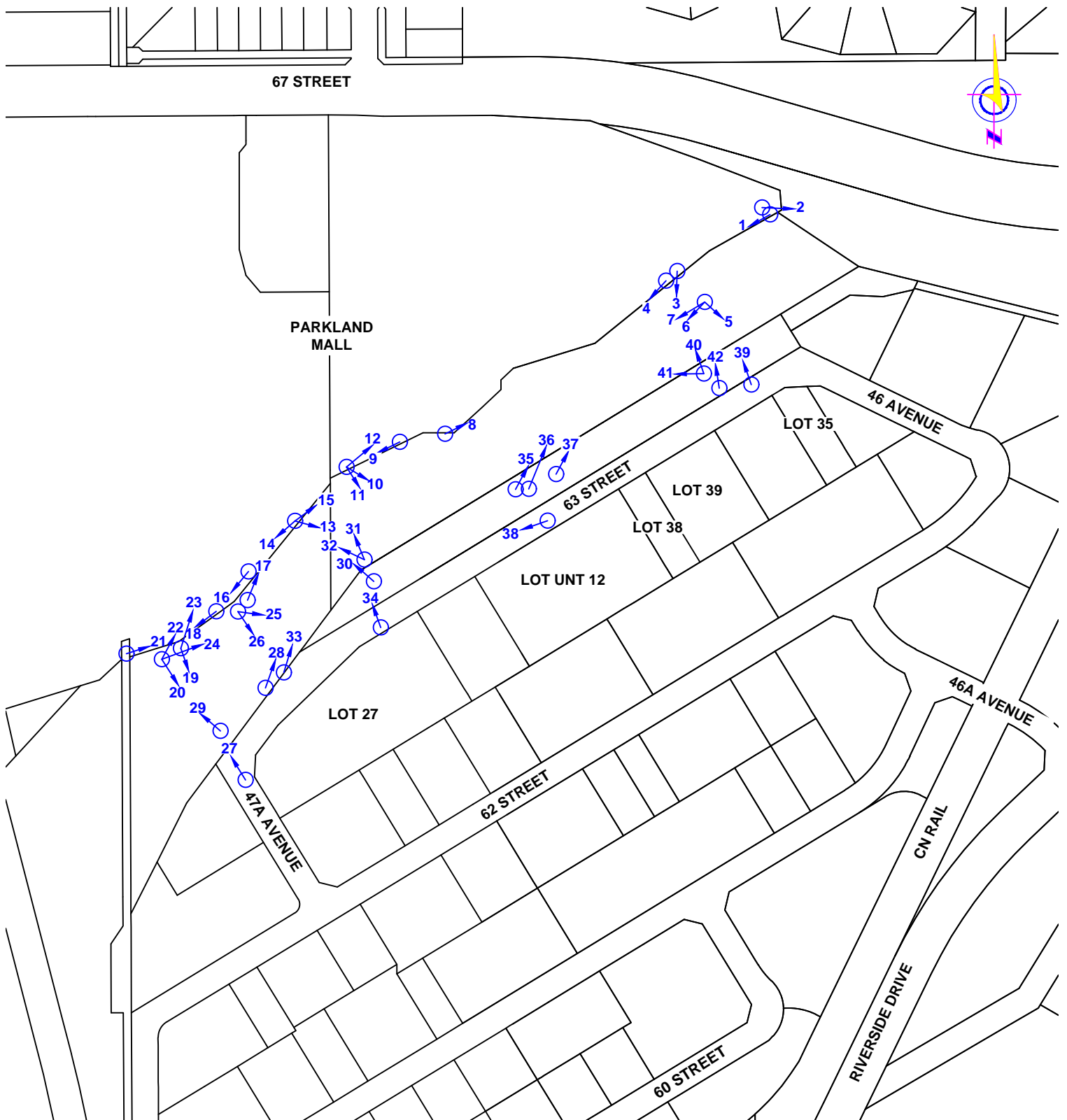
CLIENT:



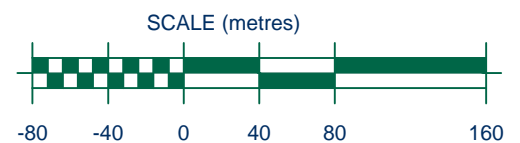
SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
PARKLAND MALL SLOPE LANDSLIDES

DRAWN: RS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-8	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.



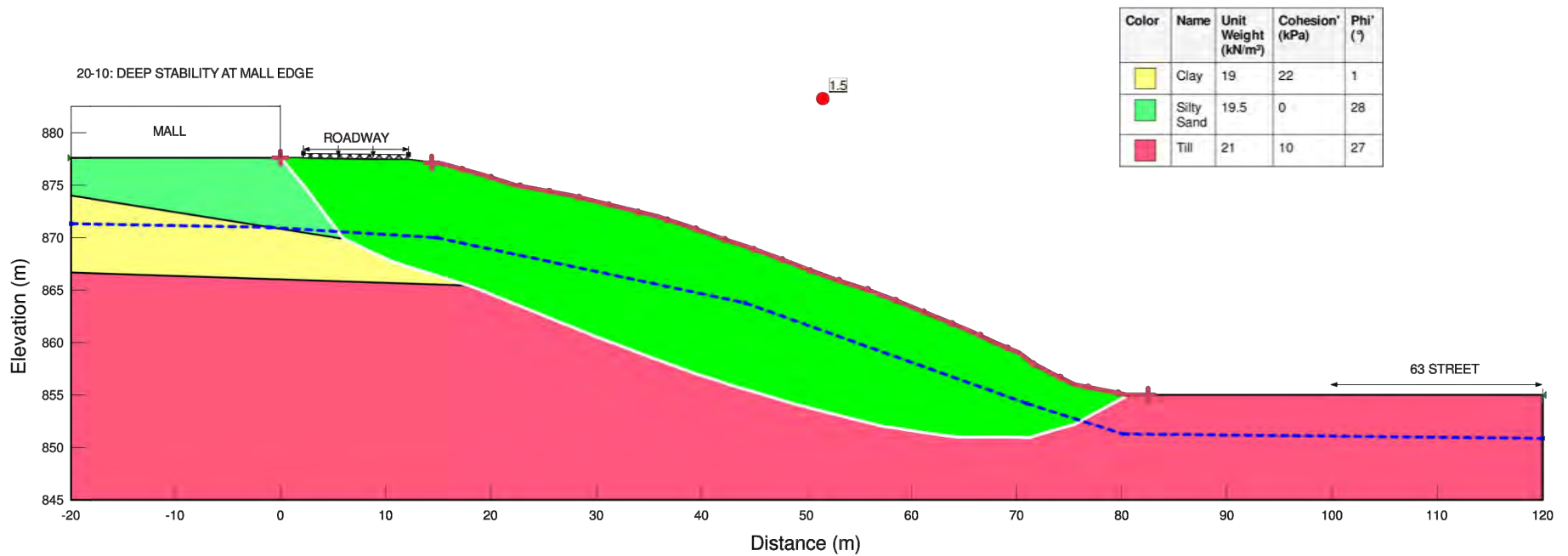
CLIENT:



PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
PARKLAND MALL SLOPE LANDSLIDES

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:4000	JOB NO. RD6500-20	DRAWING NO. FIGURE 20-9	



	CLIENT: 	STABILITY ANALYSIS RUN			
		CITY OF RED DEER SLOPE STABILITY EVALUATION PARKLAND MALL SLOPE LANDSLIDES			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1000		JOB NO. RD6500-20		DRAWING NO. FIGURE 20-10	

SITE #20 - PARKLAND MALL SLOPE LANDSLIDES

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 20-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM20-001	Light pole	5796744.97	308718.34	879.21				
#SM20-002	Sign	5796767.42	308703.24	879.06				
#SM20-003	Crest	5796735.39	308724.41	878.21				
#SM20-004	Light pole	5796650.94	308577.79	878.64				
#SM20-005	Ret wall	5796661.72	308593.33	878.88				
#SM20-006	Ret wall	5796688.56	308629.53	878.75				
#SM20-007	MH	5796689.40	308627.93	878.83				
#SM20-008	Building	5796613.30	308479.05	877.61				
#SM20-009	Crest	5796602.00	308487.07	877.37				
#SM20-010	Monitoring Well	5796611.08	308479.17	877.33				
#SM20-011	Ret wall	5796587.61	308444.65	877.61				
#SM20-012	Building	5796592.90	308381.14	877.70				
#SM20-013	Ret wall	5796556.72	308373.89	877.62				
#SM20-014	Building	5796516.92	308292.24	877.10				
#SM20-015	MH	5796508.89	308303.20	877.01				
#SM20-016	Rail	5796465.82	308296.59	876.26				
#SM20-017	Rail	5796428.05	308217.95	876.28				
#SM20-018	Water valve	5796430.31	308243.77	873.91				
#SM20-019	Rail	5796437.35	308253.33	876.29				
#SM20-020	Crest	5796492.40	308304.40	876.20				

TABLE 20-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD			COMMENT
		NORTHING	EASTING		2000	2002	2018	
#P20-001	Crest of slope in northeast side of mall parking lot	5796741	308709	SW		Y	Y*	
#P20-007	Slope face in the northeast corner of the study area	5796675	308660	SW			Y*	
#P20-008	Crest of slope along the east side of mall parking lot	5796575	308464	NE	Y*		Y*	
#P20-009	Crest of slope along the southeast side of parking lot	5796569	308429	SW	Y*	Y*	Y*	
#P20-012	Southeast side of mall parking lot	5796550	308389	NE	Y*	Y*	Y*	
#P20-018	Retaining wall and crest along the SE side of mall parking lot	5796441	308290	SW			Y*	
#P20-023	Retaining wall and crest along the SE side of mall parking lot	5796413	308264	NE			Y*	
#P20-039	Slope in the north side of study area	5796405	308249	NW			Y*	

Notes:

2000 Photographs from Reference #79

2002 Photographs from PG File #RD0607

* Provided in the report

All measurements in metres

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Site Number	20	
Site Name	Parkland Mall Slides	
Legal Land Description		
Address	6359 50 th Avenue, Red Deer	
UTM Coordinates (approx. site center)	308440 E, 5796600 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 30, 2018	5	2	10
Inspected By:	Bryden Lutz - PGEO Mark Brotherton - PGEO			
Report Attachments:	46 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded	N/A	
Slope Movement	None observed	N/A	
Erosion	None observed	N/A	
Seepage	None observed	N/A	
Distress	Cracking in asphalt at road I/S west of retaining wall and runs parallel to slope.	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments:	•		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Slope is generally well treed, except areas of old haul road, power line and pedestrian trail.
Assessment	<ul style="list-style-type: none">- No movement is expected.
Recommendations	<ul style="list-style-type: none">- Consider site inspections every 5 years.

SITE #21

67th Street Landslide Below the Pines Subdivision



SITE #21 - PINES SUBDIVISION SLOPE ABOVE 67TH STREET

21.1 SITE DESCRIPTION

Site #21 is a historical landslide site on the slope north of 67th Street below the south boundary of the Pines subdivision, as shown on Figure 1 of the main report. The slope area which failed is 450 to 540 m east of the Pamelly Avenue intersection, as shown on the Site Plan (Figure 21-1). Historically, this slope area was part of the river valley slope is just northeast of a ravine in the valley wall. The ravine was located at the east end of the Parkland Mall property. The west approach of the 67th Street down to the CN Rail Overpass and the 67th Street Bridge over the Red Deer River was partially aligned down through this ravine during the construction in 1986. The road was straightened in a east-west orientation which resulted in re-grading of the north ravine slope face at the subject site. So the current slope profile has been created by a combination of man-made disturbance on the slope face due to site activity prior to construction going back to the 1960s, and regrading related to the 67th Street construction efforts including the rehabilitation of the local landslide which occurred during construction.

The average crest elevation at the site was about 883 with a couple of localized knobs up to 885 m. The site overlooks the north end of Riverside Light Industrial Park which is located in the flood plain. The original slope face had a 10 to 20 m wide terrace or bench located at an elevation of between 875 to 878 m. The toe of the slope at the north edge of the river valley originally about 200 m to the west of the Red Deer River graded down from an elevation 855 m to the river flood plain at 850 m. The slight grade at the toe of the slope below 855 m was likely colluvium from very old landslides or erosion.

The current slope north of 67th Street was graded to about 3H:1V by removing much of the mid-slope bench material and placing it at the toe of the slope to create a new bench for 67th Street. The 67th Street alignment translates down the face of the north ravine slope with a grade drop of about 4 percent between elevations 877 m and 863 m below the landslide area. The road grade flattens out below 863 m down to the CN Rail bridge abutment at 860 m. There is a 15 m wide toe berm above 67th Street at the landslide site which has a top elevation of 870 m. The 67th Street bench is about 30 m wide. The fill slope to the south 67th Street bench has an average slope of about 3H:1V down to the flood plain. The 2016 slope contours are shown on Figure 21-2. A representative cross-section through the center of the landslide area is provided in Figure 21-3.

The development around this four lane arterial road includes: light industrial lots at the toe of the slope, the east parking lot of Parkland Mall at the top of the slope to the south of the of the road; and the Pines residential subdivision at the top of the slope to the north of the road. A bike path is present north of 67th Street but is aligned over the toe berm away from the road. A power line runs almost perpendicular up the slopes in the Pines through the center of the study area. The upper slope face is traversed by a series of old and existing paths and roads. Historical aerial photographs are shown on Figure 21-4A and 21-4B and site photographs are provided on Figures 21-5A and 21-5B.

21.2 REFERENCES

Full reference information for the Site #21 - Pines and 67th Street Slope was limited. There are records of a geotechnical report on the landslide in the City of Red Deer archives, but the report copy could not be located. The references from Appendix B which have information for Site #21 -include References #61 and #67. The most recent site investigation for the site was performed for the 67th Street project in 1985 prior to road construction (Reference #61). The information included borehole and survey contour data of the original slope. Other anecdotal information was available in the file information for the 67th Street landslide on the east side of the river valley (Reference #67 from Site #16).

21.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

Prior to construction in 1986, six boreholes were drilled in the vicinity of this landslide site for the road and bridge project (Reference #61). The log for Borehole #6 was reproduced in Reference #67. The locations of these boreholes are shown on Figure 21-6. No slope inclinometers or other instrumentation has been installed in this area.

21.4 2018 REVIEW

Aerial photography is provided on Figures 21-4A and 21-4B, for the years listed in following table. The 1986 aerial photo is the only evidence of the landslide location that is presently available.

TABLE 21-1: AERIAL PHOTOGRAPHS

Year	Description
1985	Shows the original site condition prior to the road construction.
1986	Shows the condition shortly after the 1986 landslides. The landslide scarps are visible.
2001	Shows the condition of the final 67 th alignment with the toe berm in place.
2016	Shows the present site condition.

The Pines and 67th Street slope site was visited on October 30 and November 13, 2018. A copy of the field inspection record is attached at the end of this appendix.

The ortho-contours from 2016 City aerial photography were reviewed for this study. Historical survey information for the slope was compiled from two primary sources: the 1952 City topography maps for the area and survey data provided for Reference #61 by the City of Red Deer's municipal consultant for the road project (Delcan Western Ltd.). A control survey of the site was performed in 2018. A record of survey control points and data is appended in Table 21-4. A reference drawing of survey reference points is provided on Figure 21-7.

Selected site photographs from 2018 are provided on Figures 21-5a and 21-5b. A reference drawing of photograph locations on Figure 21-8.

21.5 SLOPE BACKGROUND

This site was originally the north slope of a wide ravine which entered the Red Deer River valley slightly southeast of the alignment of the 67th Street road allowance. Going back to 1949, the slope face in this area was relatively free of tree cover. In the 1960s, dune formations in the upland areas around the present Parkland Mall site and above this slope face area in the Pines property were subject to borrow activity to mine sand. This activity left some old trails on the slope face. There was evidence of old failure scarps in the upper slope which provided terrain that was incorporated into the local trail system.

Based on local anecdotal knowledge and a review of the pre- and post-construction surveys for this area, in 1986 the City of Red Deer began construction on the west approach to the 67th Bridge which was under construction. The new alignment cut into the north valley slope on an oblique angle to the river valley. The downslope side of the embankment was provided with a fill which was cut from a mid slope bench in the slope face (see Figure 21-3). The elevation of the transition from the approach fill to the cut at the landslide site was at 865 m on the north side of the valley wall (i.e. the road subgrade). The maximum depth of cut occurs about 450 m east of Pamelly Avenue where the cut slope was up to about 12 m high. The cut slopes were designed an inclination of 3H:1V.

During grading of the new slope face in the summer of 1986 the slope started to slide. Based on the 1986 aerial photographs, the scarps of the slide occurred at an estimated elevation of between 875 to 880 m. The bulge of the slide was estimated to be just above the road bench at about 865 to 870 m. To stabilize the slide a gravel toe berm was placed on the north side of the road. The toe berm was placed to an elevation of 870 m; and the face of the berm had a slope of 2.5H:1V (based on current survey information). To accommodate the toe berm, the center-line of 67th Street at this location was moved about 10 m south of the original alignment.

The landslide site has been stabilized by the gravel berm and the upper slope face has not been subject to any observed instabilities since the remedial work was completed in 1986.

21.5 SUBSURFACE PROFILE

This slope profile at this site has been subject to significant grading. The original slope soil profile was considered to be local till below an elevation of 865 to 870 m extending out to the lower river valley slope. The till was overlain by silty lacustrine clay which extended up from the top of the till at an estimated inclination of between 4H:1V and 6H:1V from the slope face. This lacustrine clay was draped with wind blown sands which created a steepened slope face with inclinations in the order of 1.5H:1V to 2H:1V. The toe of the till slope was covered with a wedge of erosional colluvium. The sand slope face appears to have been mined for sand borrow, similar to the nearby Parkland Mall site. The majority of the slope reconfiguration undertaken in 1986 was believed to be moving sand deposits from the upper face to the toe area below the road. A toe berm was placed north of 67th Street to stop the slope movement caused by construction.

The following is a brief description of the soil types encountered.

1. **Colluvium.** Sand colluvium from the landslide on the upper slope face was expected to be re-graded or removed to place the gravel berm. Ancient colluvium in the toe area would have been buried by the 67th Street embankment fill, but would have consisted of a mixture of silt, sand and clay with traces of organics.
2. **Engineered Fill Berm.** The engineered fill north of 67th Street is understood to be select pit run gravel provided with drainage trenches filled with clean rock. The toe berm was covered with a silty clay cap and landscaped topsoil fill.
3. **Wind-Blown Sand.** The sand on the slope face was dry, windblown deposits which are remnant dune material. This loose to medium dense sand has traces of silt and the relative density increases with depth. The expected soil moisture content would be less than 10 percent with possible wetter sand below the groundwater table.
4. **Silt, Sand and Clay.** The soil below the sand is lacustrine silt and clay above an elevation of about 865 m. The upper soils are expected to be drier silty soil and the lower lacustrine deposits are expected to medium plastic clay with a moisture content of about 25 with a layer of wetter high plastic clay.
5. **Till.** The till found below elevation 870 m is a low plastic sand till with moisture contents in the order of 15 percent. The deeper deposits are stiff to very stiff medium plastic clay till.
6. **Bedrock.** The local bedrock formation in this areas is expected at an elevation of 845 to 850 m which is more than 15 m below the base of the 1986 landslide.
7. **Groundwater.** At the time of the 1985 road site investigation the groundwater table was found at an elevation of 865.5 m in Borehole 6 near the landslide site, which would be in the clay deposits. Groundwater observations from the landslide report on the east side of the river at the similar time of construction suggest that 1986 groundwater levels were higher than those found in 1985 boreholes.

The following effective strength parameters were assumed for this site.

TABLE 21-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Elevation (m)	Unit Weight (kN/m ³)	Shear Strength (kPa)	Cohesion, c' (kPa)	Phi, ϕ' (Degrees)
Gravel Fill	Varies	21.5	0	0	38
Silt & Sand	Above 878	19.5	0	0	28 - 30
Lower Clay	865 - 878	19	25	0 - 1	20 - 23
Till	Below 865.2	21.5	100	10 - 15	27 - 30

Soil profiles for the slope is shown on the Figure 21-3 cross-sections. For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix A.

21.7 STABILITY ASSESSMENT

Stability analysis against landsliding was carried out using the SLOPE/W computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 21-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Pre-Development Slope	1.1	-
1986 Construction Slide	~ 0.9	-
Global Stability of Current Slope	1.3	Figure 21-9

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

Site #21 is an engineered slope with a landscaped slope face and a stabilization berm between the road and the top of the slope and a large sand fill slope below the road. The upper slope has not experienced major instability in over 30 years since construction. The long-term assessment at this site is that the potential for a slope movement is low under present normal conditions with reasonable variation and the risk of ongoing face regression has been reduced. The FS against a small shallow “slump-type” failure on the slope face is estimated to be at least 1.1. This is considered to be the most likely mode of slope failure, but with the present vegetation cover it would take unusually wet conditions to cause a shallow slump in the upper sand slope face. For the representative slope profile under reasonably adverse soil moisture and groundwater conditions, a point about 5 m back from the current location of the crest is considered to be stable in the long-term. In review of development in the area private lots are not at risk.

21.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

PF(1) * CF(2) = 2 - 67th Street

A Probability Factor of 1 is considered appropriate. The old landslide has been stabilized by an engineered stabilization berm which provides a FS greater than 1.3 for the road. The type of failure that might be expected to impact the road would be a surficial slump of the landscaped fill of the toe berm which might flow out to the road and would not require a road closure. Therefore, a Consequence Factor of 2 is considered appropriate.

PF(3) * CF(4) = 12 - Pines Subdivision

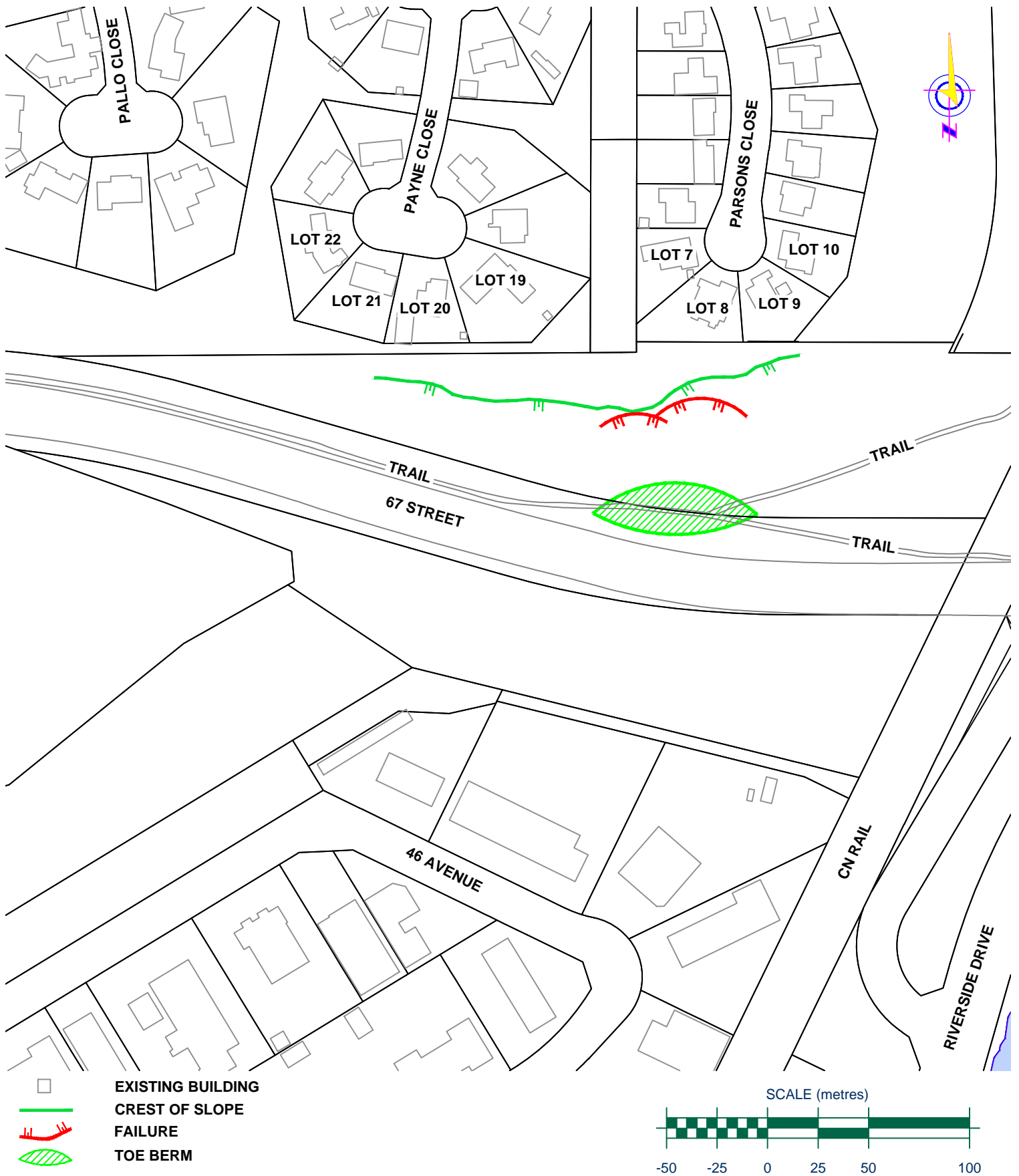
A Probability Factor of 3 is considered appropriate since there is no active landsliding in the upper slope along the entire top-of-bank, and probability of small slide in the area is low. A Consequence Factor of 4 is considered appropriate since the expected size of small landslide in the upper slope at this site is unlikely to affect private property, but it may impact the power line which has tower near the crest of the slope above scarp of the former landslide. The risk to local private property is considered to be negligible.

21.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an "as required" basis to identify any significant changes, if present. Inspections should include control surveys along the crest relative at fixed points to verify movements along the crest, if observed.

21.10 ATTACHMENTS

Figure 21-1 - Site Plan
Figure 21-2 - 2016 Contour Plan
Figure 21-3 - Cross Section Profiles
Figure 21-4 - Aerial Photographs
Figure 21-5 - Site Photographs
Figure 21-6 - Borehole Plan
Figure 21-7 - Survey Marker Plan
Figure 21-8 - Photograph Plan
Figure 21-9 - Stability Analysis Run
Table 21-4 - List of Survey Markers
Table 21-5 - List of Photographs
Site Inspection Record (October 30, 2018)



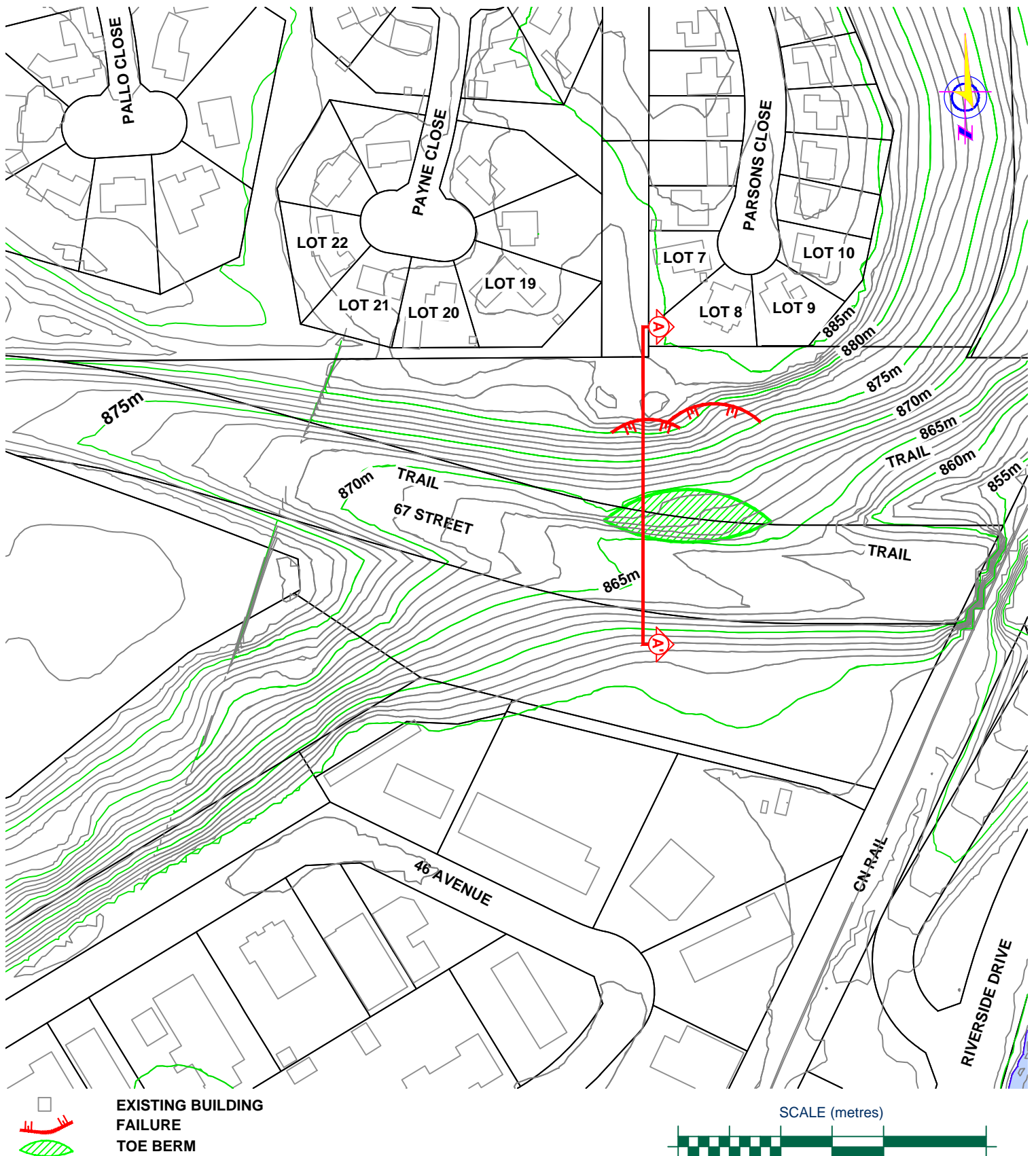
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
67TH ST LANDSLIDE BELOW THE PINES SUBDIVISION

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



CLIENT:

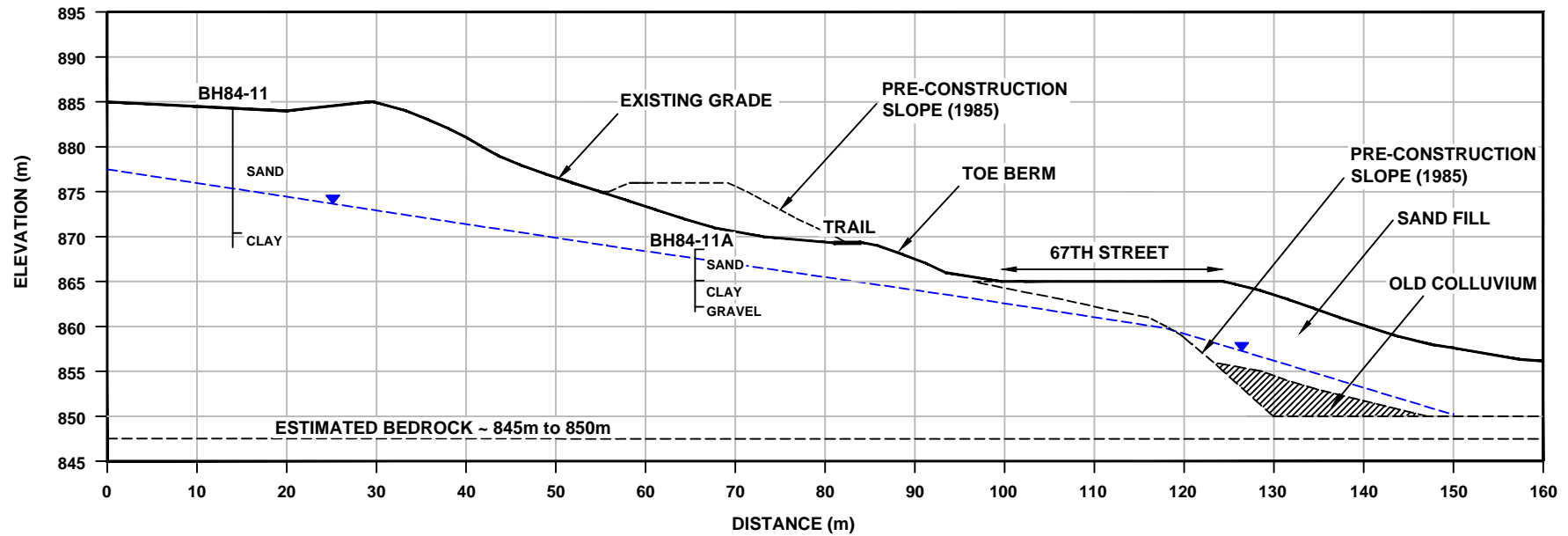


CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
 67TH ST LANDSLIDE BELOW THE PINES SUBDIVISION

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-2	

21-3: CROSS SECTION (A - A')



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



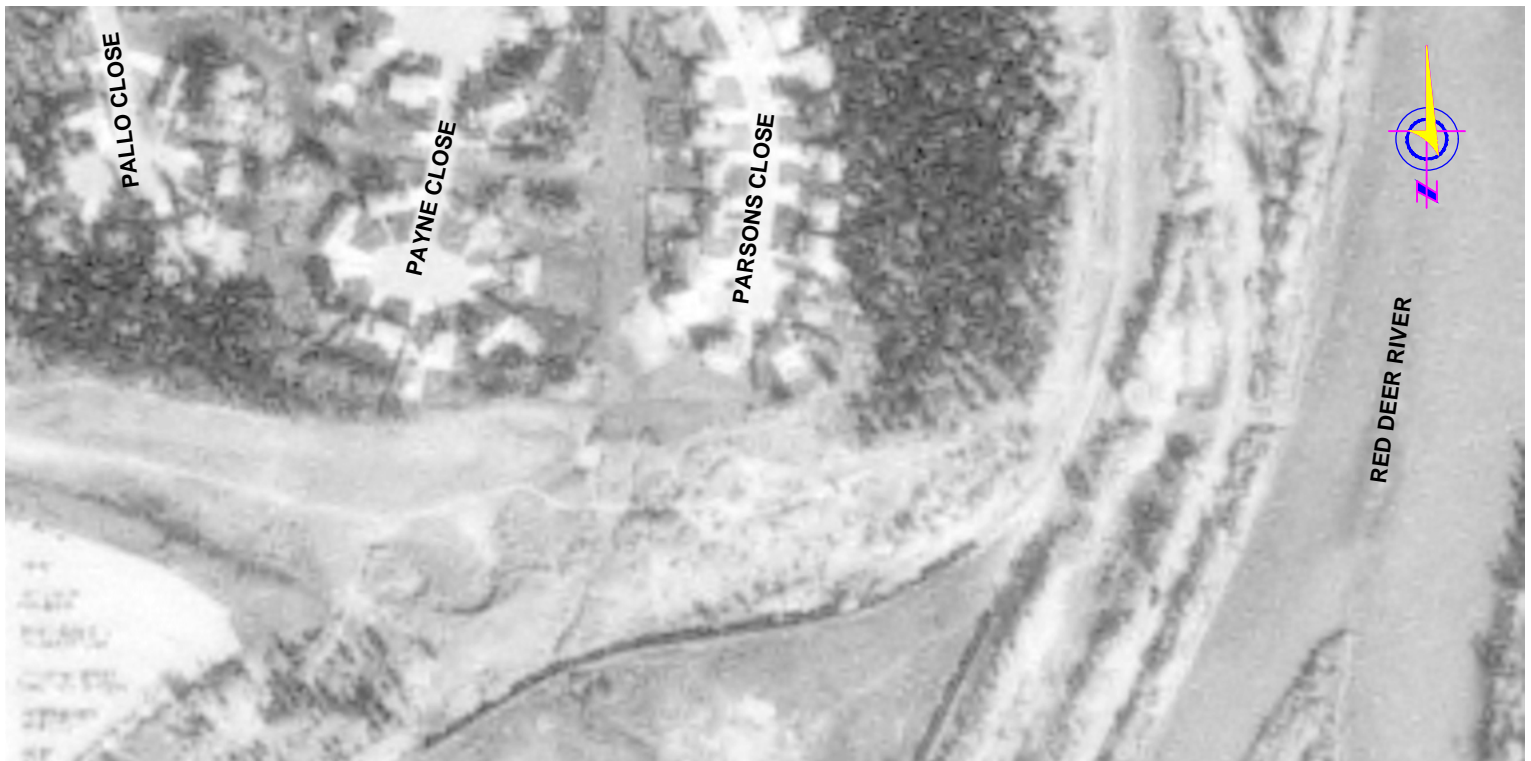
CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
67TH ST LANDSLIDE BELOW THE PINES SUBDIVISION

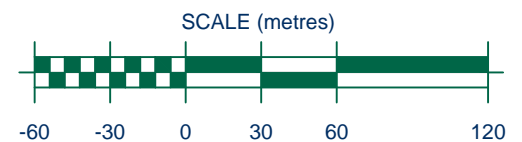
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-3	





NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 23, 1985.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED OCTOBER 15, 1986.



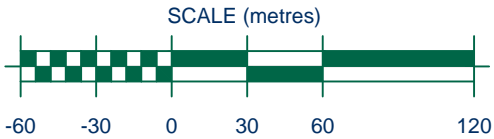
	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION 67 TH ST LANDSLIDE BELOW THE PINES SUBDIVISION			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:4000	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-4A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION 67 TH ST LANDSLIDE BELOW THE PINES SUBDIVISION			
			DRAWN:	CHK'D:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		1:3000	RD6500-21		FIGURE 21-4B	



PHOTOGRAPH 1 (2018): SLOPE ALONG 67 STREET, TAKEN FROM ACROSS THE STREET, FACING EAST



PHOTOGRAPH 5 (2018): SLOPE FACE LOOKING ACROSS THE SLOPE, FACING EAST



PHOTOGRAPH 24 (2018): SLOPE FACE LOOKING DOWN THE SLOPE, FACING SOUTH



PHOTOGRAPH 26 (2018): SLOPE FACE LOOKING ACROSS THE SLOPE, FACING WEST

	CLIENT: 	SITE 21 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION 67 TH ST LANDSLIDE BELOW THE PINES SUBDIVISION			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-5A	



PHOTOGRAPH 28 (2018): CREST OF SLOPE LOOKING ACROSS THE SLOPE, FACING EAST

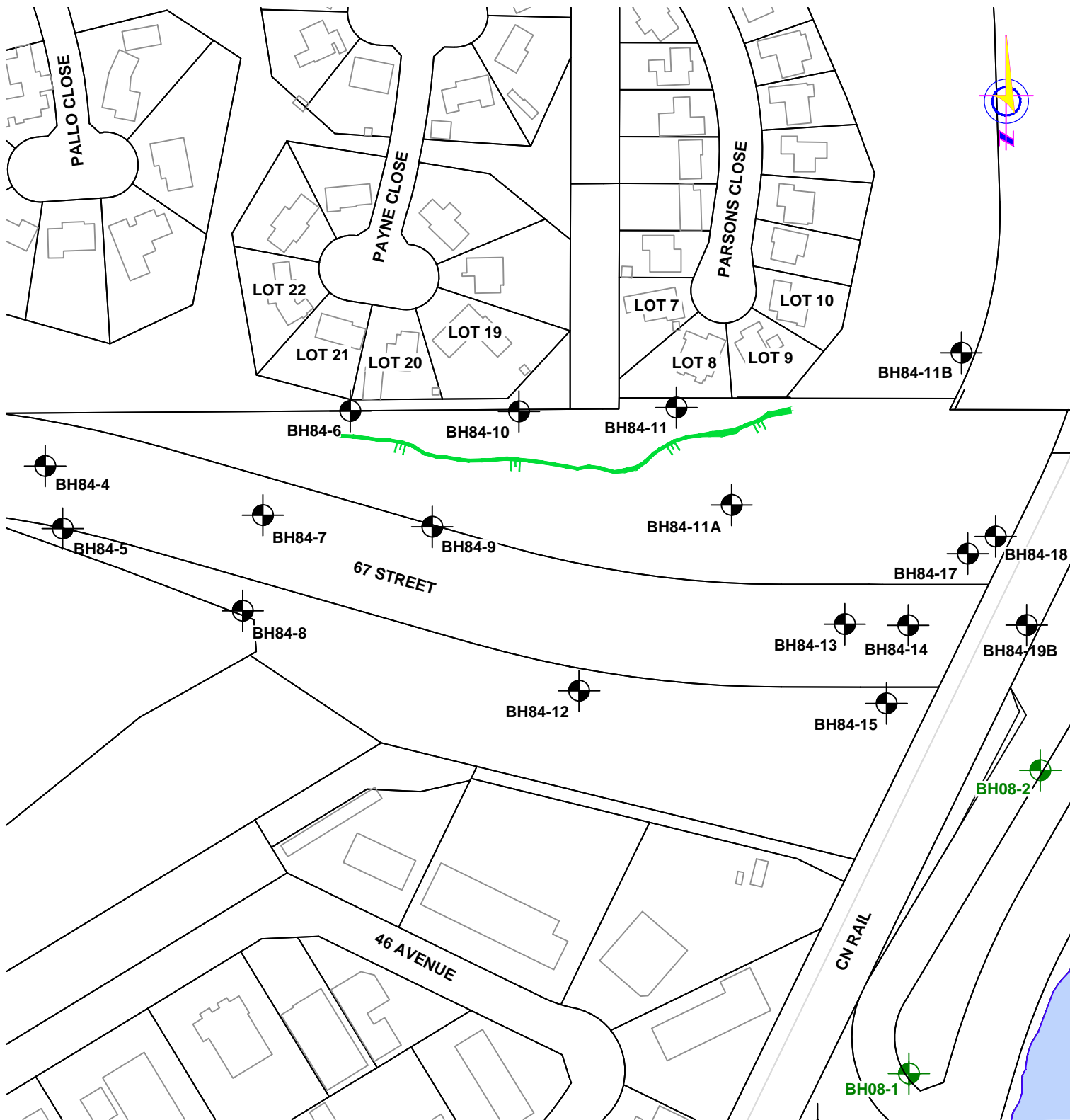


PHOTOGRAPH 32 (2018): SLOPE FACE LOOKING ACROSS THE SLOPE, FACING NORTHWEST



PHOTOGRAPH 36 AND 37 (PANO) (2018): SLOPE FACE AND WALKING TRAIL ALONG 67 STREET, FACING WEST

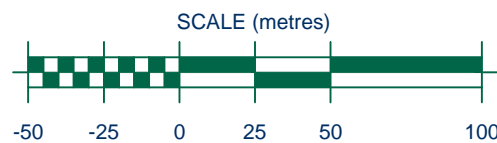
	CLIENT: 	SITE 21 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION 67 TH ST LANDSLIDE BELOW THE PINES SUBDIVISION			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-5B	



1984 BOREHOLE LOCATIONS (REFERENCE #61)



2008 BOREHOLE LOCATIONS (PG FILE #RD2962)



ALL BOREHOLE LOCATIONS ARE APPROXIMATE.



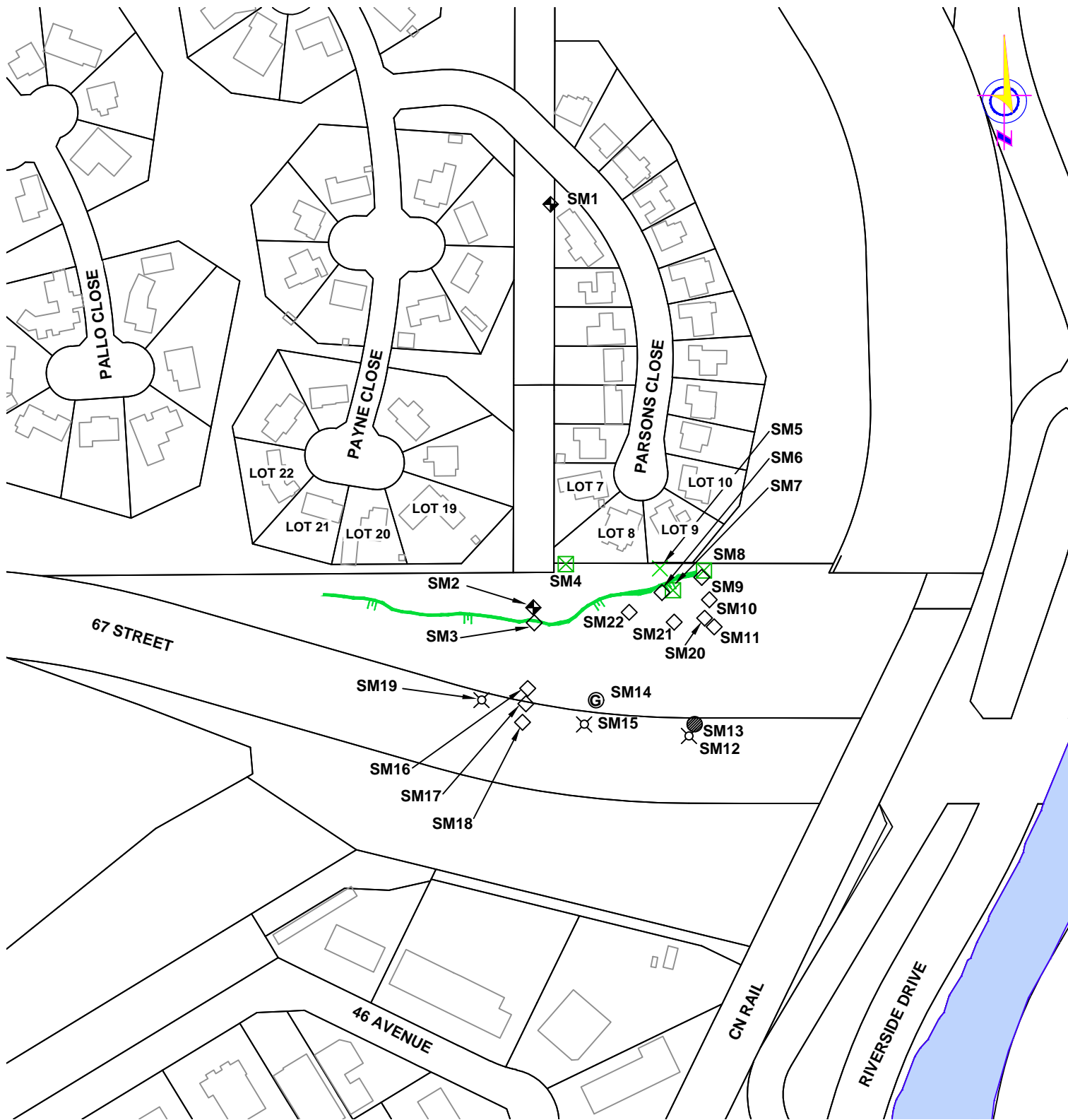
CLIENT:



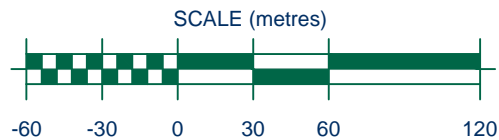
BOREHOLE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
67TH ST LANDSLIDE BELOW THE PINES SUBDIVISION

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-6	



- | | | | |
|--|-------------------|--|---------------|
| | CREST OF SLOPE | | PROPERTY LINE |
| | STORM DRAIN | | GARBAGE BIN |
| | LIGHT POLE | | FENCE CORNER |
| | SURVEY LAND POINT | | |
| | TRANSFORMER | | |



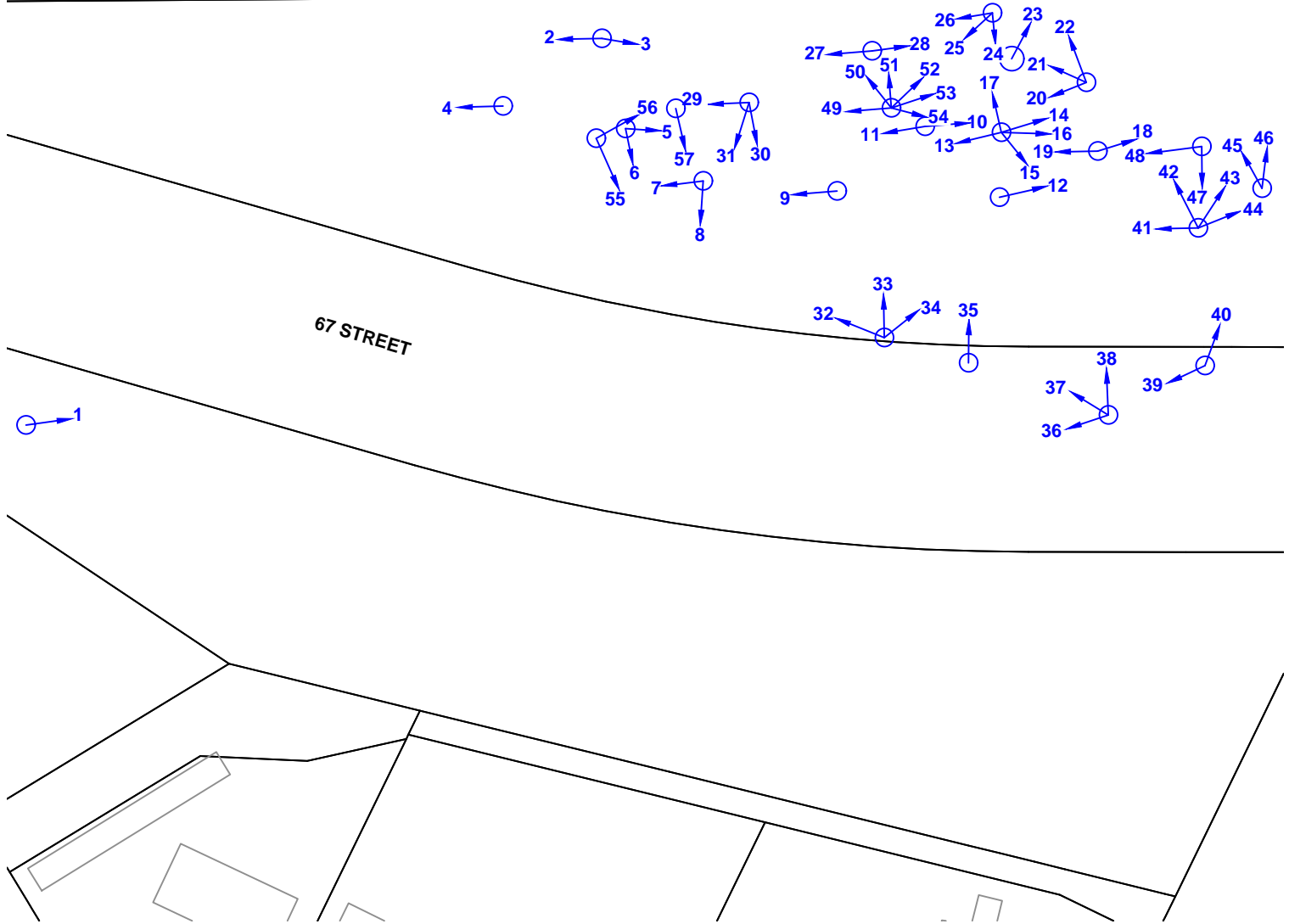
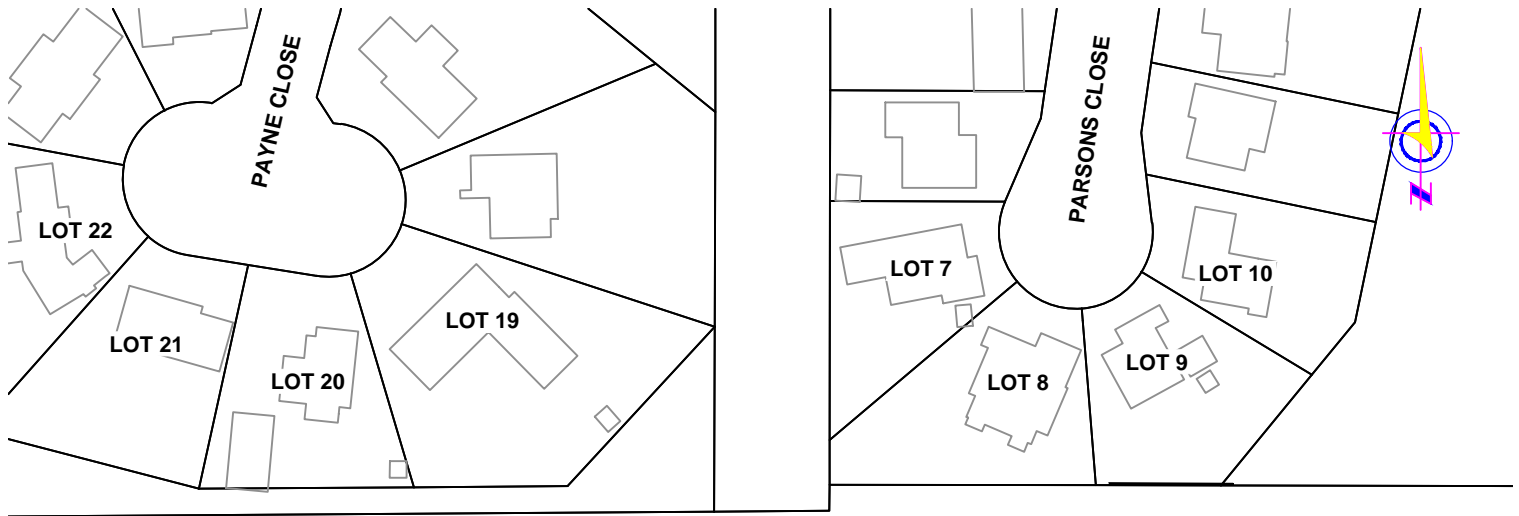
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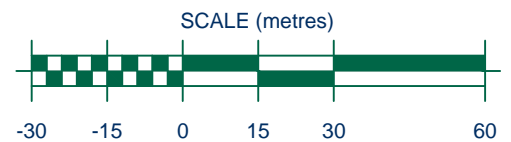
SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
67TH ST LANDSLIDE BELOW THE PINES SUBDIVISION

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:3000	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-7	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE.









CLIENT:



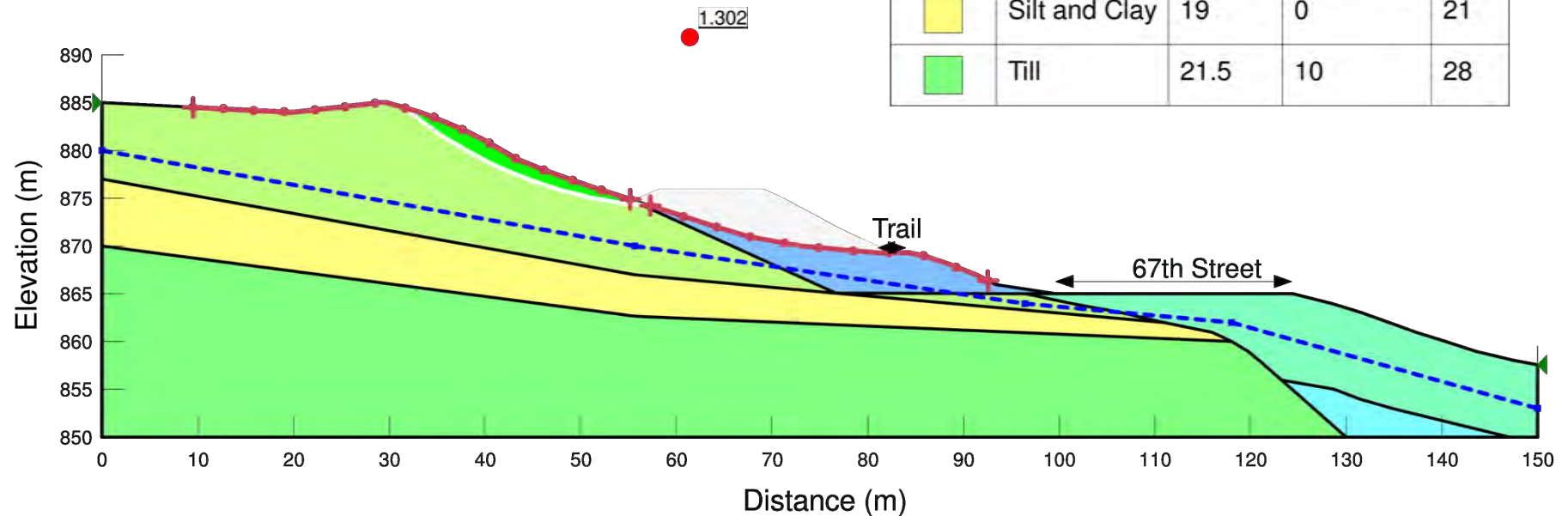
PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
67TH ST LANDSLIDE BELOW THE PINES SUBDIVISION

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-8	

Color	Name	Unit Weight (kN/m ³)	Cohesion' (kPa)	Phi' (°)
	Colluvium	19	0	25
	Gravel Fill	21.5	0	38
	Sand Fill	19	0	30
	Silt & Sand	19.5	0	28
	Silt and Clay	19	0	21
	Till	21.5	10	28

21-9: GLOBAL STABILITY OF CURRENT SLOPE
(AT CROSS SECTION A-A')



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
67TH ST LANDSLIDE BELOW THE PINES SUBDIVISION

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-21	DRAWING NO. FIGURE 21-9	

SITE #21 - 67TH STREET LANDSLIDE BELOW THE PINES SUBDIVISION

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 21-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018						COMMENT
		NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	
#SM21-001	Transformer	5797057.80	308888.35	887.71				
#SM21-002	Transformer	5796831.04	308878.66	884.23				
#SM21-003	Crest	5796822.50	308879.22	883.07				
#SM21-004	Fence	5796855.50	308896.90	884.19				
#SM21-005	Property line	5796853.09	308949.85	885.17				
#SM21-006	Crest	5796839.55	308950.98	884.86				
#SM21-007	Old post	5796840.82	308957.13	884.53				
#SM21-008	Fence	5796851.94	308974.63	885.14				
#SM21-009	Crest	5796848.09	308973.39	884.77				
#SM21-010	Mid	5796835.49	308977.64	877.43				
#SM21-011	Toe	5796820.23	308980.40	872.17				
#SM21-012	Light pole	5796758.83	308966.17	863.99				
#SM21-013	Storm drain	5796765.42	308969.30	864.45				
#SM21-014	Garbage	5796778.84	308913.82	868.36				
#SM21-015	Light pole	5796765.38	308907.25	865.92				
#SM21-016	Toe	5796785.58	308875.50	870.14				
#SM21-017	Ridge	5796776.95	308874.47	869.54				
#SM21-018	Curb	5796766.61	308872.52	864.81				
#SM21-019	Light pole	5796779.02	308849.50	868.10				
#SM21-020	Lower slump end	5796824.86	308974.84	873.85				
#SM21-021	Mid slump	5796822.64	308957.72	876.22				
#SM21-022	Slump start	5796828.15	308932.46	878.03				

TABLE 21-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P21-001	Slope face	5796751	308732	E	Y*	
#P21-005	Slope face	5796820	308872	E	Y*	
#P21-024	Slope face	5796847	308958	S	Y*	
#P21-026	Slope face	5796847	308958	W	Y*	
#P21-028	Crest of slope	5796838	308930	E	Y*	
#P21-032	Slope face	5796771	308932	NW	Y*	
#P21-036/037	Slope face and walking trail along 67 St	5796753	308985	W	Y*	

Notes:

* Provided in the report

All measurements in metres

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Site Number	21	
Site Name	67 th Street landslide below Pines	
Legal Land Description	NE 21-38-27-W4M	
Address	6359 50 th Avenue, Red Deer	
UTM Coordinates (approx. site center)	308890 E, 5796830 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 30, 2018	3	6	18
Inspected By:	Bryden Lutz - PGEO			
Report Attachments:	84 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded on west, angular to east (past stabilized area)	N/A	
Slope Movement	Small slumping in area east of study area	N/A	
Erosion	None observed	N/A	
Seepage	None observed	N/A	
Distress	None observed	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments:			
<ul style="list-style-type: none">Slope face in study/ stabilized area is rough (like many small game trails) could be from movement before stabilization.			

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none"> - Large quantity of gravel was placed to recreate terrace of slope at 67th street to stabilize native slope circa 1986. - No evidence of movement of slope in area above gravel fill. - Possible crest regression occurring east of gravel fill stabilized area.
Assessment	<ul style="list-style-type: none"> - Continued slope regression could (long term) impact properties lines at east of site/ east of gravel fill (36, 40 parson close) - Slope in area of gravel fill appears stabilized.
Recommendations	<ul style="list-style-type: none"> - Should consider looking/ studying slope to east of current study area. - Consider site inspections every 5 years (maybe in conjunction with Parkland Mall).

SITE #22



77th Street South Slope East of Gaetz Avenue

SITE #22 - 77TH STREET SOUTH SLOPE EAST OF GAETZ AVENUE

22.1 SITE DESCRIPTION

The Site #22 - Slopes South of 77th Street includes the natural river valley slope overlooking 45th Avenue Close south of 77th Street and the south cut slope for 77th Street, as shown on Figure 1 of the main report. The crest of this slope is about 750 m long and is bordered in the uplands to the west by Northlands Industrial Park; and to the south by a large undeveloped park area at the north end of the Pines residential subdivision. The natural treed slope to the south of 77th Street has some irregular landforms, including ravines and terraces. The north slope overlooking 77th Street is a cut slope constructed in the mid 1970s. The Site Plan is shown on Figure 22-1. A 2016 Contour Plan is provided on Figure 22-2. Representative cross-sections of the cut slope and natural slopes are provided on Figure 22-3.

The crest elevation in the Northlands Industrial Park area is 872 to 873 m and the elevation at the north end of the Pines Subdivision to the immediate south is about 883 m. For the natural slope the toe of the slope is about 850 m, so this slope area is up to 23 m high except at the south end where it rises to over 30 m high. There is a small slough at the toe of the slope at the northeast end of the site; and a run-off ditch feeding into the slough is present at the toe of the slope on the west side of 45th Avenue Close. Access to the toe area is via 45th Avenue Close in Riverside Heavy Industrial Park. A wide flood plain is present east of the slope and the Red Deer River is located 350 to 600 m to the southeast. The natural slope area appears to have a mid slope bench about 20 to 40 m wide with a gentle grade drop through an elevation range of 868 to 860 m. The slope above the bench is between 4H:1V and 6H:1V and the slope below the bench is between 2H:1V and 3H:1V. This bench is considered to be a natural river terrace, not the top of a landslide.

In the south area of site, the bench area is crossed by a ravine running downslope in a northeast direction into the slough. This ravine isolates the south bench area which borders 45th Avenue Close from the Northlands Industrial Park slope. The upper slope above the bench south of the ravine is tied in to the river valley slope under the Pines subdivision. At inclinations of about 3H:1V, this area is considerably steeper than the upper slope below Northlands Industrial Park.

The construction of 77th Street in the 1970s made use of existing large ravine in the river valley wall to provide access from Gaetz Avenue down into Riverview Heavy Industrial Park in the flood plain. Between elevations 870 m and 855 m the road drops at about 4 percent grade before levelling off into the 77th Street road embankment in the flood plain. The south side of the ravine was deforested and possibly steepened up to 3H:1V to make space for the road allowance cut. The cut slope was up to 20 m high. Anecdotal information suggests this slope exhibited instability from the time of construction. In 2018, there was a long narrow slump about three-quarters of the way up the slope 320 m east of Gaetz Avenue. Based on aerial photos current slump is likely a reactivation of one of two older slumps. Approximate locations of both slumps are shown on Figure 22-1. The slope north of 77th Street appears to be the original ravine slope, except for a small section of possible cut 250 to 300 m east of Gaetz Avenue.

The natural slope face has moderate to heavy tree cover with some sparsely vegetated exposures and one grassed cut line for a power transmission line. The natural slope face is traversed by a several paths/trails; as well as old access roads up the slope and an old rail line embankment along the lower slope. The cut slopes along 77th Street are landscaped and vegetated with prairie grass and a few small bushes. Aerial photographs showing the site are provided on Figures 22-4A and 22-4B. Representative photographs from the site are provided on Figures 22-5A to 22-5C.

22.2 REFERENCES

There were no site specific reference reports for this site. ParklandGEO has some old private project files for sites in Northlands Industrial Park and the Riverside Heavy Industrial Park which provide basic geotechnical information for the upland area and the flood plain.

22.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

There is limited geotechnical information and no publicly available borehole data for this site. No slope inclinometers or other instrumentation has been installed in this area.

22.4 2018 REVIEW

Aerial photography is provided on Figures 22-4A and 22-4B for the years listed in the following table. Historical aerals show possible areas of landsliding.

TABLE 22-1: AERIAL PHOTOGRAPHS

Year	Description
1973	Shows the original site condition of the ravine and slope prior to 77 th Street construction.
1991	Shows the road cut for the 77 th Street construction including signs of two landslides.
2001	Shows the site condition over 15 years ago with no sign of the old landslide..
2016	Shows the present Site condition.

The 77th Street site was visited on October 30 and November 26, 2018. A copy of the field inspection record is attached at the end of this appendix.

The ortho-contours from 2016 City aerial photography was reviewed for this study. It is worth noting that the tree cover for this area has resulted in a lack of detail for the natural slope; particularly lack of definition for the ravine in the south part of the site. A control survey of the site was performed in 2018. A record of survey control points and data is appended in Table 22-4. A reference drawing of survey reference points is provided on Figure 22-6.

Selected site photographs from 2018 are provided on Figures 22-5A to 22-5C. A photograph summary is provided in Table 22-5. A reference drawing of photograph locations on Figure 22-7.

22.5 SUBSURFACE PROFILE

The upland soil profile at this site is expected to be, in descending order: topsoil: silty glacio-lacustrine and clay till with some possible wind-blown sand at the crest of the natural slope area. The clay till is expected to be present at an elevation of about 865 m, which corresponds to the top of the mid slope bench. The soil profile at the toe of this river terrace is expected to be, in descending order: a thin layer of fine alluvial silts; gravel; clay till and bedrock. The expected soil profiles for the slope are shown on the Figure 22-3 cross sections. The following is a brief description of the soil types encountered.

1. **Topsoil.** The natural slope is expected to have a thin layer of topsoil and the cut slope has been landscaped with topsoil and wild grass.
2. **Silt, Sand and Clay.** The upper slope soils are expected to be interbedded lacustrine clay and silt which is typically stiff, low to medium plastic and wet with typical moisture contents of 20 to 35 percent.
3. **Clay Till.** Till is commonly encountered below the lacustrine deposits. The till encountered in the area is a clay till which is medium plastic, very stiff and moist with a typical moisture content of about 17 percent.
4. **Alluvial Deposits.** The soil overlying the till at the toe of the slope is expected to alluvial, silt, sand and clay which transitions in coarse gravel. These deposits are expected to be 3 to 6 m deep; with the transition into gravel about elevation 850 m.
5. **Bedrock.** The top of the bedrock formation is expected to be found at an elevation of about 848 m.
6. **Groundwater.** The normal groundwater table along the west side of the Riverside Heavy Industrial Park is 3 to 5 mbg. The normal groundwater table in Northlands Industrial Park is typically 2 to 4 mbg. However, the depth to groundwater will drop below the crest area as water table drops to form a hydraulic connection with the shallow groundwater in the flood plain. Based on the unusual terrain in this area, springs in the slope may be expected during periods of snow-melt and wet weather.

The following table summarizes the estimated soil parameters used for stability analysis.

TABLE 22-1: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Shear Strength (kPa)	Cohesion, c' (kPa)	Phi, ϕ' (Degrees)
Sand	19.5	0	0	30
Silt and Clay	19.5	50	0 - 7	20* - 24
Clay Till	21	0	0	32
Gravel	21.5	0	0	38
Bedrock	21	300	30	40

* Denotes the residual strength along the original slip surfaces in the cut slope.

22.6 SLOPE BACKGROUND AND ISSUES

The south cut slopes overlooking 77th Street have been subject to shallow slumps at two areas in the past 40 years since the road was constructed. The west slump was a long narrow failure about two-thirds of the way up the slope and the east slump was a larger crescent shaped slide which cut across the existing bike path. The initial road cut along the south side of the original ravine were considered to be too steep for the native soils in the upper slope. The grade was flattened as much as the road right-of-way would allow and the original landslide sites were re-graded and landscaped. In 1979, a 300 mm sub-drainage pipe was installed in the ditch immediately south of 77th Street as shown on Figure 22-1. In 1991, two slumps re-occurred at the site as shown in the 1991 Aerial on Figure 22-4A. These areas were provided with french drains up the slope to the slide areas as shown on Figure 22-1. These slope drains were tied into the 1979 sub-drain in the south ditch. Both areas was re-graded and the bike path was realigned to the east of slide area. The long narrow west failure appears to have slumped again and is currently visible at the site. The east failure is no longer visible in the field or on more recent aerial imagery.

There are no records or observations of major recent slope instability within the natural slope area. The top-of-slope has been provided with a 15 to 20 m wide development buffer from the crest of the slope to protect private property in Northlands Industrial Park.

22.7 REVIEW OF STABILITY ASSESSMENT

Stability analysis against landsliding was verified using the *SLOPE/W* computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 22-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Present Cut Slope - Former Slump Areas - 15 m high	~ 1.0	-
Present Unfailed Cut Slope Area - 15 m High	1.15	-
Natural Area - Steepened Sand Crest Area	1.0 - 1.1	-
Natural Area - Upper Slope	1.6	Figure 22-8
Natural Area - Upper Slope (Spring at Terrace)	1.1	-
Natural Area - Face of Lower Till Bench	~ 1.3	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

The natural slope area is a mature slope which is under limited stress from development. The slope face has been used for passive recreational purposes, but the main paths along the slope are located on the mid slope bench and the main paths up the slope are restricted to old access roads from the flood plain. The upper slope in the lacustrine soils is relatively shallow at 4H:1V or flatter which suggests the presence of silty lacustrine clay soils which are possibly weaker than normal for Red Deer. The current slope is considered to be stable in the long-term. The local light industrial lots to the west are not at risk due the provision of a wide development buffer.

The face of the river terrace bench along 45th Avenue Close is relatively steep, but the exposed soil is very stiff clay till. This slope is considered to be stable in the short-term and marginally stable in the long-term. A small, localized block failure could occur in this slope; and it would likely fill in the existing road side ditch or even spill out onto the edge of 45th Avenue Close. However, this river terrace is isolated from the main slope by the bench area, so any instability along this slope would not have any impact on the upper slope.

The cut slope south of 77th Street has an inclination of between 3H:1V and 4H:1V. This is slightly steeper than the stable upper lacustrine clay slopes in the natural area to the south. This cut slope is considered to be marginally stable in the short-term. The long-term assessment at this site is that the potential for small shallow slope movements is moderate to high. The long-term FS against a small shallow “slump-type” failure on the cut slope is estimated to be just above 1.0. A small localized slump in the crest area would likely damage the fence along the private property line, but would not significantly impact the adjacent property.

22.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

1. **PF(7) * CF(4) = 28** - Slope At 77th Street Road Cut

A Probability Factor of 7 is considered appropriate since there is no active landsliding in the upper cut slope area, but there is a high probability of future slide occurring. A Consequence Factor of 4 is considered appropriate since a small slide would likely be confined to the slope face with minimal impact to 77th Street or local private property.

2. **PF(5) * CF(4) = 20** - Slope Along 45th Avenue Close

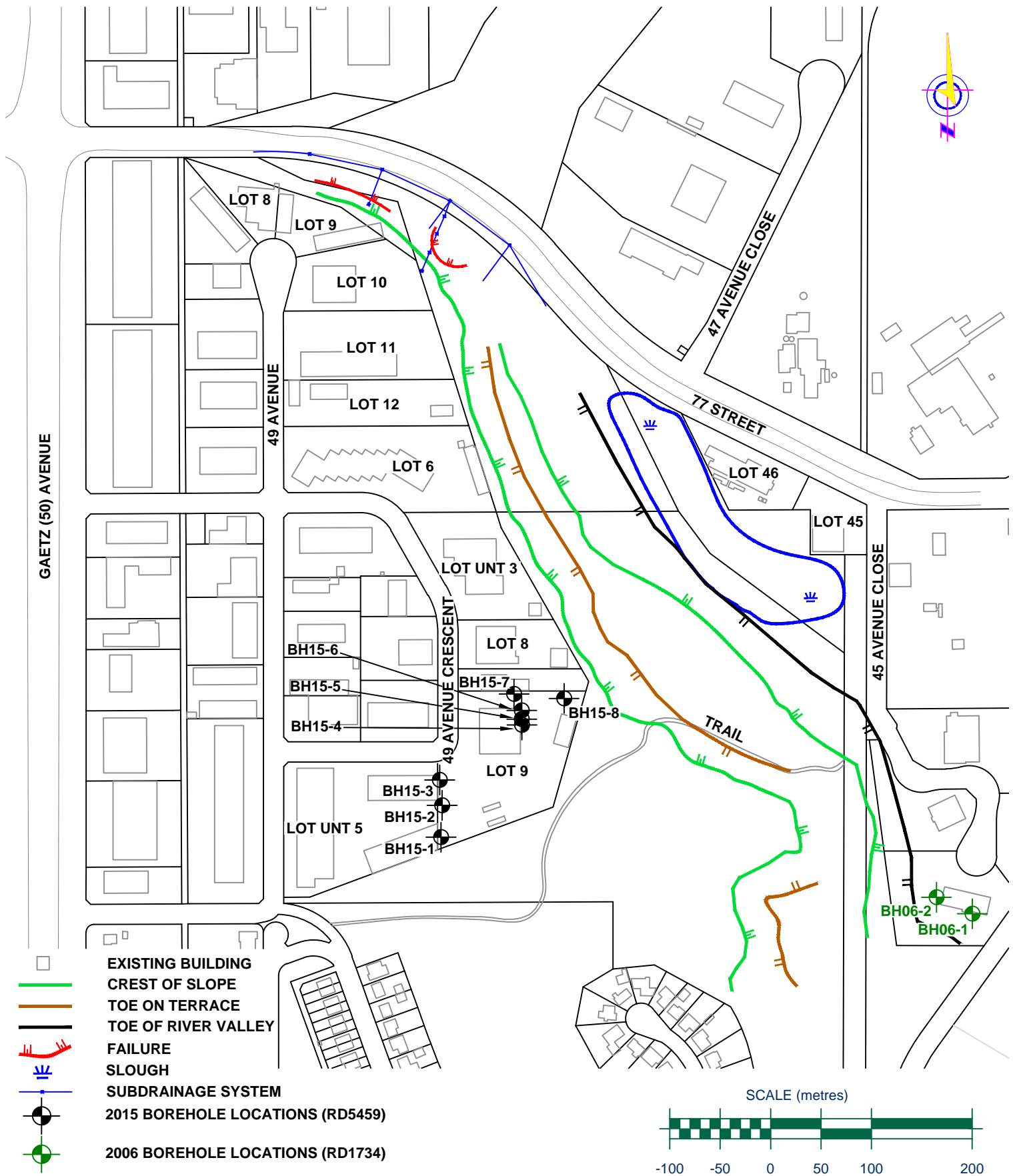
A Probability Factor of 5 is considered appropriate due to the moderate probability of small slide exposed slope at the toe of this river terrace. A Consequence Factor of 4 is considered appropriate since the potential run-out from slide could spill out on the edge of 45th Avenue Close, but would not result in a road closure.

22.9 RECOMMENDATIONS

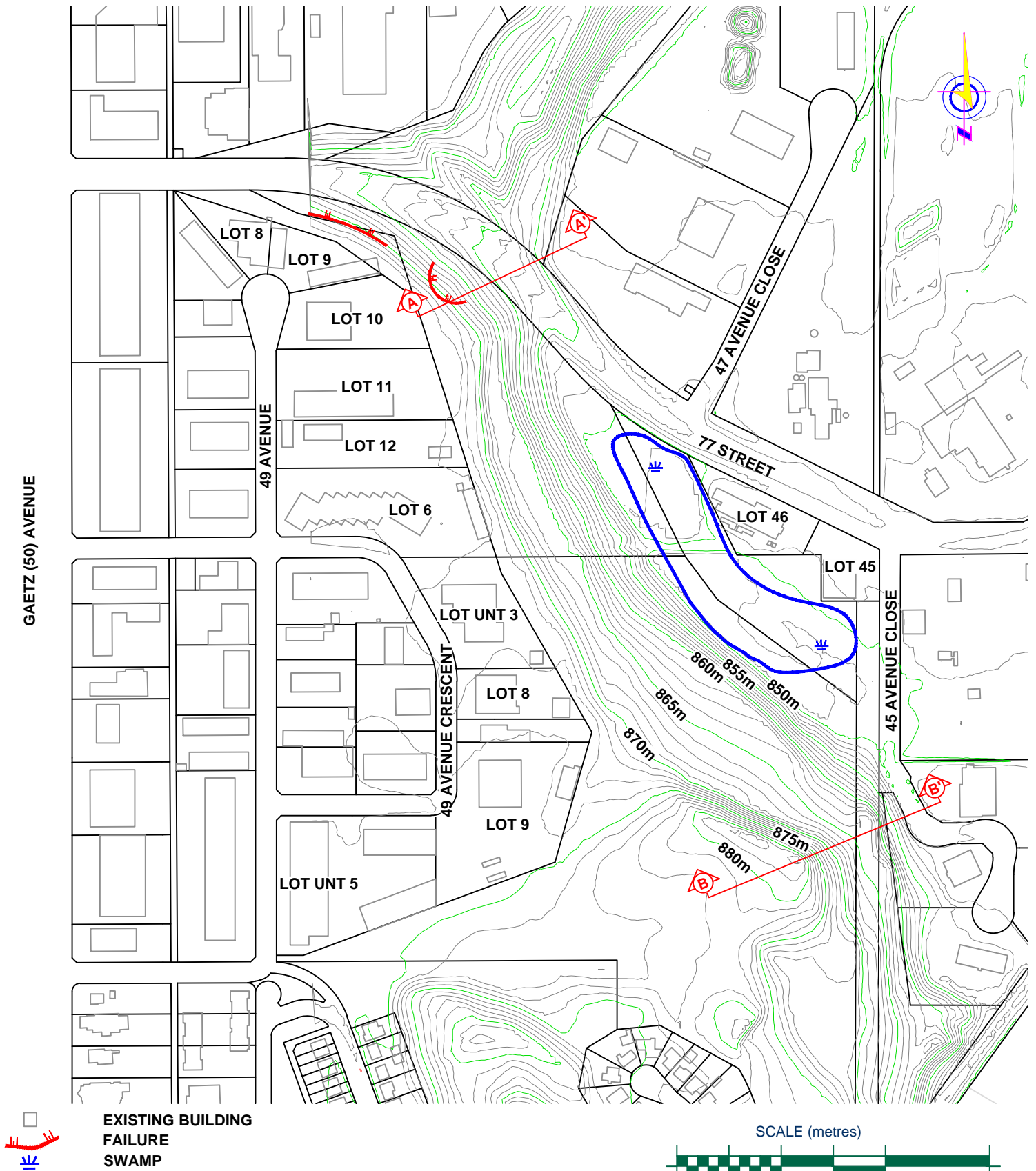
The recommended monitoring action for Site #22 at 77th Street is to undertake annual visual site inspections of the slope to identify any significant changes, if present. Inspections should include control surveys along the crest relative at fixed points to verify regression rates.

22.10 ATTACHMENTS

Figure 22-1 - Site Plan
Figure 22-2 - 2016 Contour Plan
Figure 22-3 - Cross Section Profiles
Figure 22-4 - Aerial Photographs
Figure 22-5 - Site Photographs
Figure 22-6 - Survey Marker Plan
Figure 22-7 - Photograph Plan
Figure 22-8 - Stability Analysis Run
Table 22-4 - List of Survey Markers
Table 22-5 - List of Photographs
Site Inspection Record (October 30, 2018)



	CLIENT:		SITE PLAN	
			CITY OF RED DEER SLOPE STABILITY EVALUATION SLOPES SOUTH OF 77 STREET	
	DRAWN:	CHK'D:	REV #:	DATE:
	PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.
1:5000		RD6500-22		FIGURE 22-1



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT



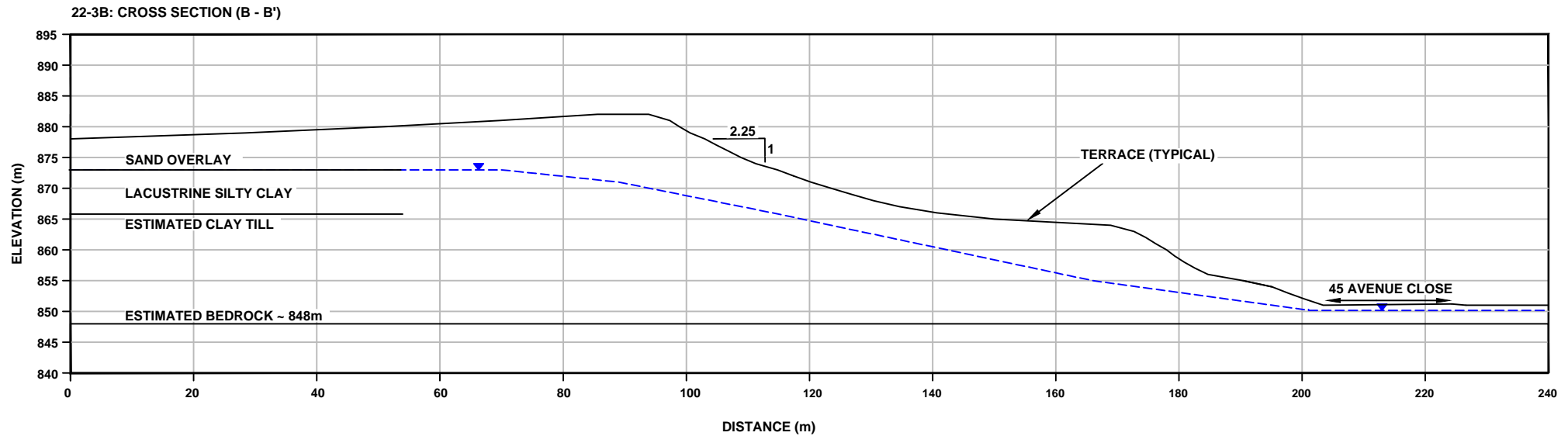
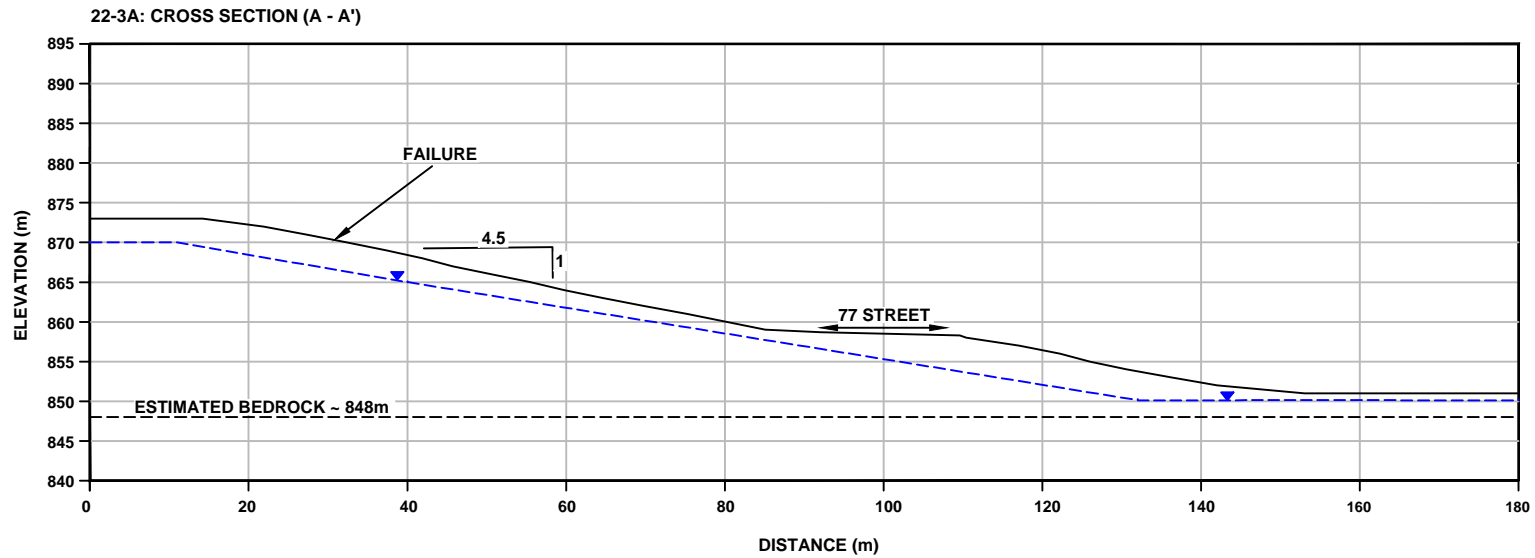
CLIENT:



CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
SLOPES SOUTH OF 77 STREET

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-2	



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
SLOPES SOUTH OF 77 STREET

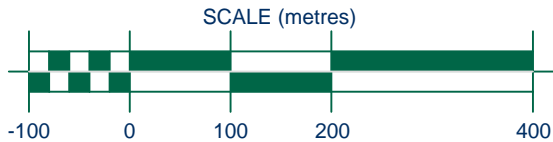
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-3	



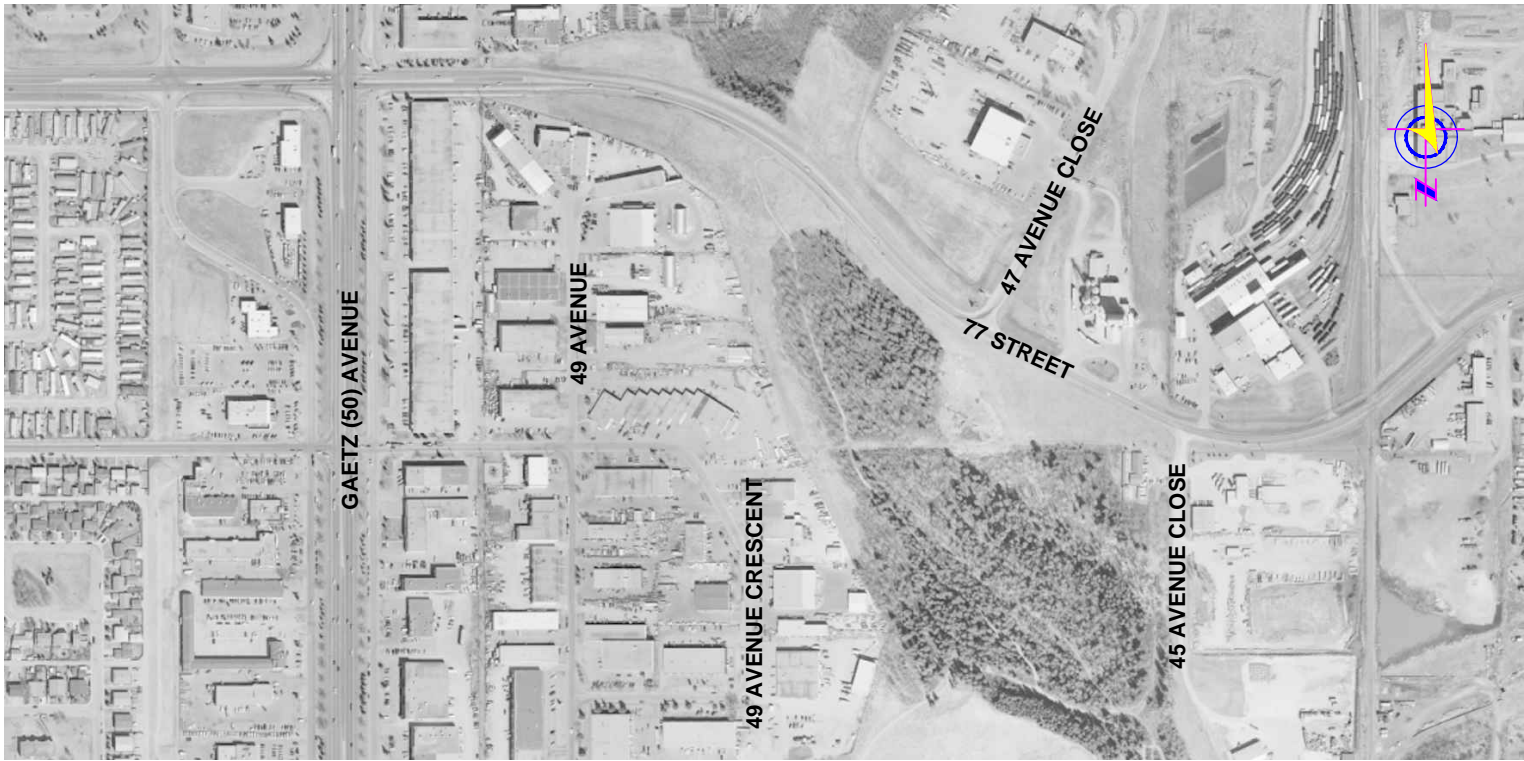
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED APRIL 10, 1973.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 27, 1991.



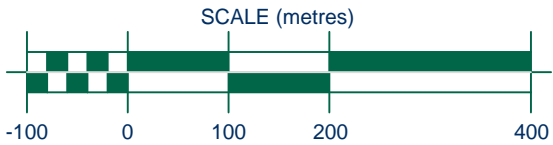
	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION SLOPES SOUTH OF 77 STREET			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:7500	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-4A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2001.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION SLOPES SOUTH OF 77 STREET			
		DRAWN: NC	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:7500	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-4B	



**PHOTOGRAPH 1 (2018): SLOPE ON THE SOUTH OF 77 STREET,
TAKEN FROM ACROSS THE STREET, FACING SOUTH**



**PHOTOGRAPH 19 (2018): CREST OF SLOPE, LOOKING ACROSS
THE CREST, FACING NORTH**



**PHOTOGRAPH 21 (2018): SLOPE ALONG THE POWER LINE,
LOOKING DOWN THE SLOPE, FACING EAST**



CLIENT:



SITE 22 PHOTOGRAPHS

**CITY OF RED DEER SLOPE STABILITY EVALUATION
SLOPES SOUTH OF 77 STREET**

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: NTS	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-5A	



**PHOTOGRAPH 24 (2018): SLOUGH NEXT TO THE TOE OF SLOPE,
FACING NORTHWEST**



**PHOTOGRAPH 35 (2018): TOE OF SLOPE ALONG 45 AVENUE
CLOSE, FACING SOUTH**



**PHOTOGRAPH 36 (2018): TOE OF SLOPE ALONG 45 AVENUE
CLOSE, FACING NORTHWEST**



CLIENT:



SITE 22 PHOTOGRAPHS

**CITY OF RED DEER SLOPE STABILITY EVALUATION
SLOPES SOUTH OF 77 STREET**

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: NTS	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-5B	

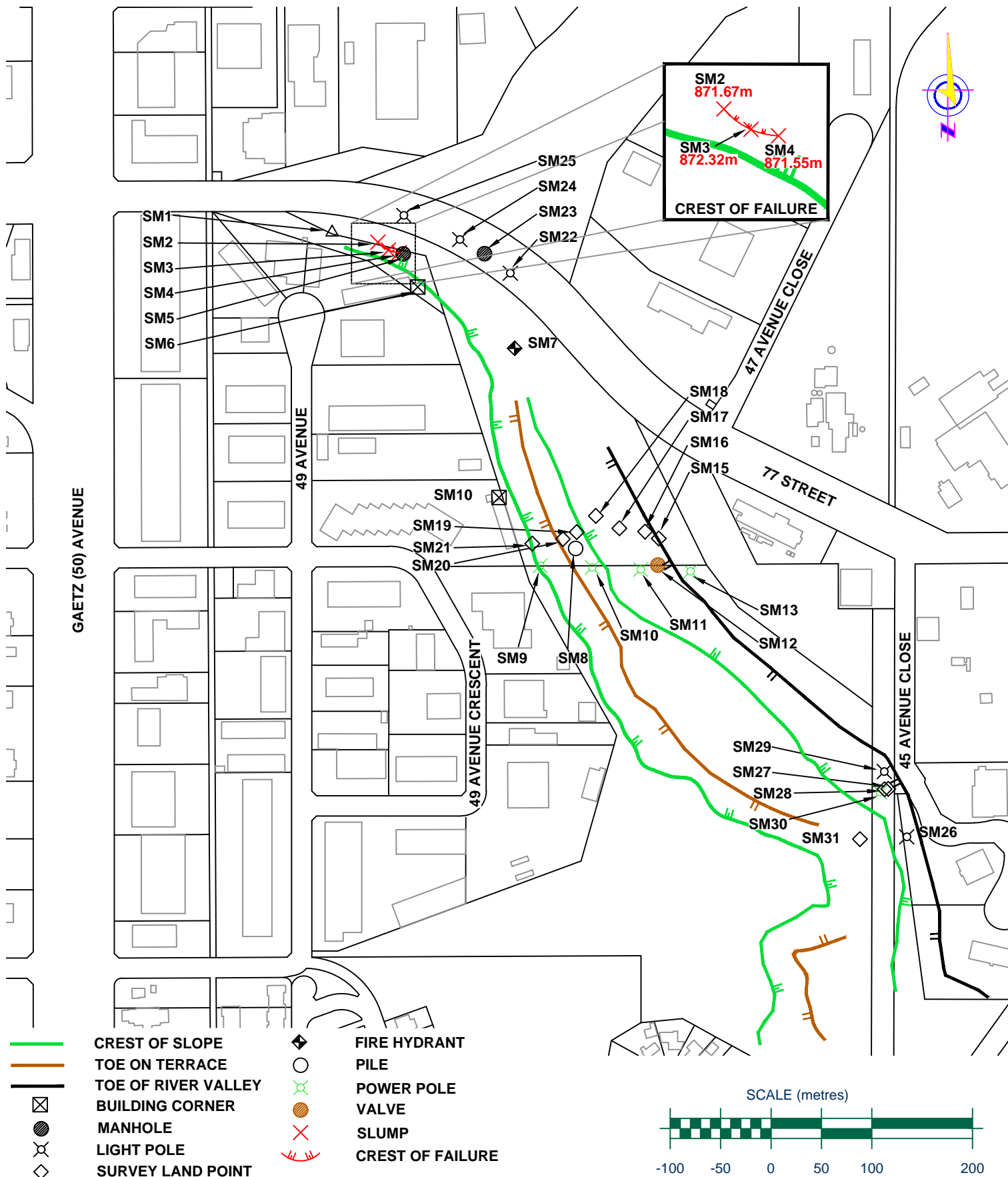


PHOTOGRAPH 50 (2018): VEGETATION GROWN ON THE SLOPE, FACING SOUTH



PHOTOGRAPH 54 (2018): SLOPE ON THE SOUTHEAST SIDE OF STUDY AREA, LOOKING DOWN THE SLOPE, FACING NORTH

	CLIENT:		SITE 22 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION SLOPES SOUTH OF 77 STREET			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
NTS		RD6500-22		FIGURE 22-5C		



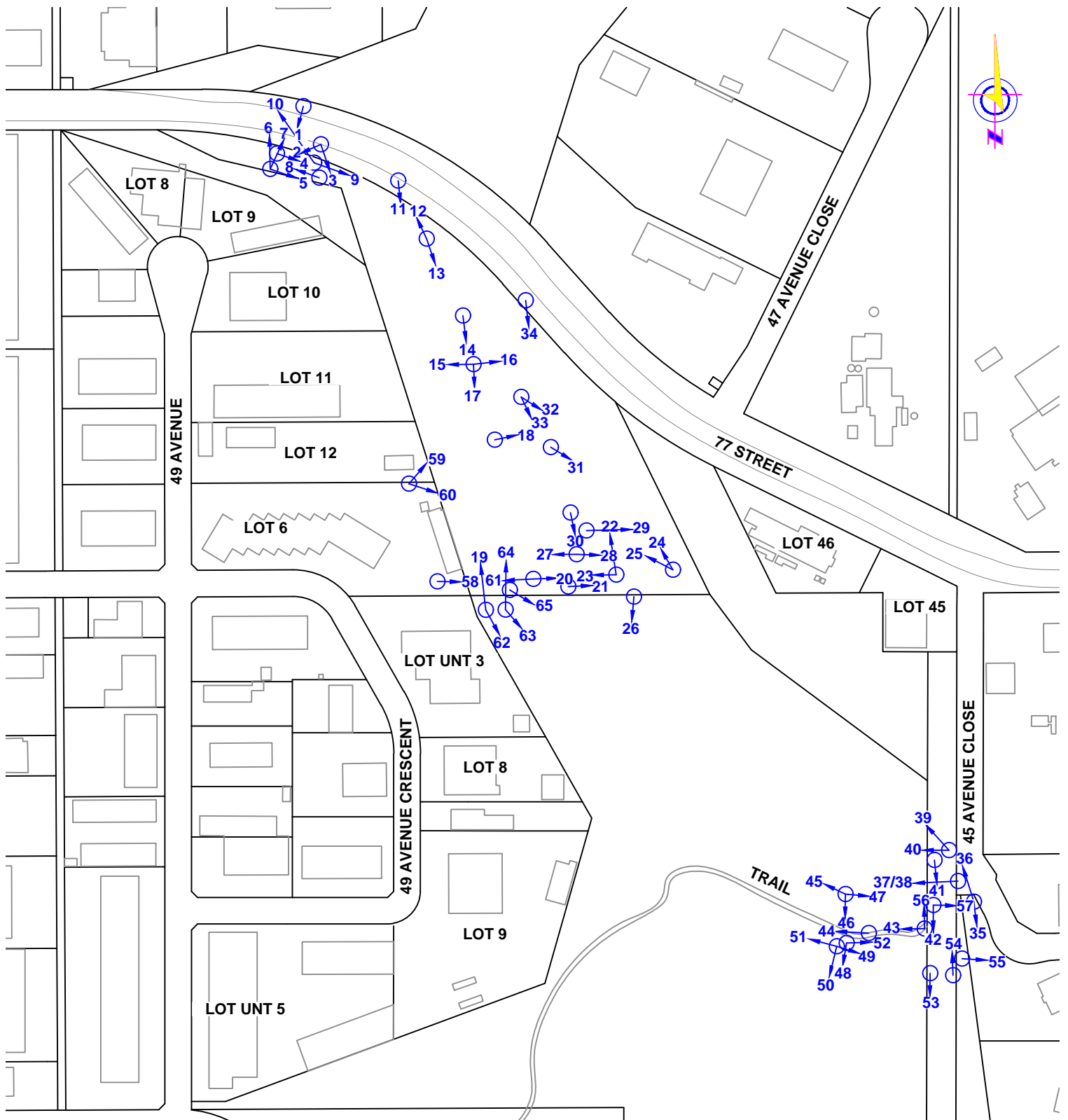
CLIENT:



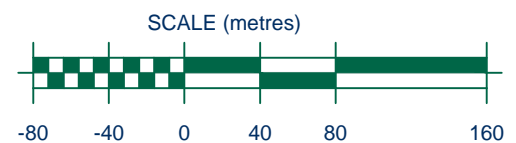
SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
SLOPES SOUTH OF 77 STREET

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:5000	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE



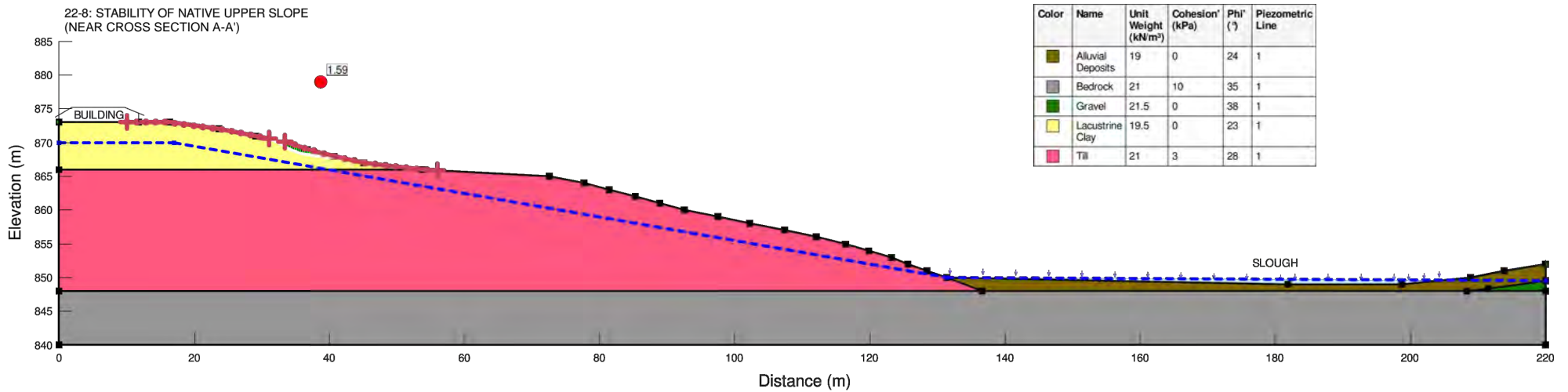
CLIENT:



PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
SLOPES SOUTH OF 77 STREET

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:4000	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-7	



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
SLOPES SOUTH OF 77 STREET

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-22	DRAWING NO. FIGURE 22-8	

SITE #22 -SLOPES SOUTH OF 77 STREET

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 22-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM22-001	ASCM 98256	5798793.01	308414.33	873.43				
#SM22-002	Slump	5798783.25	308459.82	871.67				
#SM22-003	Slump	5798775.30	308470.28	872.32				
#SM22-004	Slump	5798772.86	308480.92	871.55				
#SM22-005	MH	5798771.47	308484.97	871.92				
#SM22-006	Building	5798738.82	308499.42	873.94				
#SM22-007	Sign	5798677.91	308595.51	868.72				
#SM22-008	Pile	5798479.08	308655.87	863.52				
#SM22-009	Pole	5798462.16	308620.95	871.11				
#SM22-010	Building	5798529.81	308580.09	872.91				
#SM22-011	Pole	5798460.32	308672.41	865.62				
#SM22-012	Pole	5798458.39	308720.59	856.02				
#SM22-013	Valve	5798462.65	308737.53	851.68				
#SM22-014	Pole	5798456.54	308769.92	848.53				
#SM22-015	Toe	5798489.13	308738.47	849.15				
#SM22-016	Crest	5798496.03	308724.90	852.40				
#SM22-017	Trail	5798499.31	308699.43	855.74				
#SM22-018	Toe	5798512	308676	853.0				
#SM22-019	Crest	5798495.44	308657.07	865.26				
#SM22-020	Toe	5798488.58	308643.42	865.31				
#SM22-021	Crest	5798484.05	308612.99	871.31				
#SM22-022	Light Pole	5798752.42	308591.19	859.96				
#SM22-023	MH	5798771.75	308565.54	861.04				
#SM22-024	Light Pole	5798785.86	308541.13	862.22				
#SM22-025	Light Pole	5798809.77	308485.60	865.08				
#SM22-026	Light Pole	5798192.98	308984.58	850.44				
#SM22-027	Road	5798240.60	308966.29	850.33				
#SM22-028	Toe	5798240.35	308962.56	849.52				
#SM22-029	Light Pole	5798257.76	308962.22	849.84				
#SM22-030	Power Pole	5798190.78	308938.10	864.26				
#SM22-031	Crest	5798237.33	308957.75	852.88				

TABLE 22-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P22-001	Slope on south of 77 street	5798832	308479	S	Y*	
#P22-019	Crest of slope	5798451	308617	N	Y*	
#P22-021	Slope along the power line	5798468	308679	E	Y*	
#P22-024	Slough adjacent to the toe of slope	5798481	308758	NW	Y*	
#P22-035	Toe of slope along 45 avenue close	5798231	308985	S	Y*	
#P22-036	Toe of slope along 45 avenue close	5798231	308985	NW	Y*	
#P22-050	Vegetation grown on the slope	5798197	308882	S	Y*	
#P22-054	Slope on the SE side of study area	5798175	308970	N	Y*	

Notes:

* Provided in the report

All measurements in metres

Less accuracy due to tree cover

CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT



Site Number	22	
Site Name	77 th Street Cut Slope	
Legal Land Description	NE 21-38-27-W4M	
Address	6359 50 th Avenue, Red Deer	
UTM Coordinates (approx. site center)	308890 E, 5796830 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 30, 2018	5	4	20
Inspected By:	Bryden Lutz – PGEO Mark Brotherton - PGEO			
Report Attachments:	78 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded	N/A	
Slope Movement	None observed	N/A	
Erosion	None observed	N/A	
Seepage	None observed	N/A	
Distress	None observed	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments:			
<ul style="list-style-type: none">Slope face has mature vegetation estimated to be at least 60 years old.Slope face has old terraces from formation conditions that have regressed to likely stable angles.			

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Slope terraces from formation have regressed to stable angles over time.- Cut slope failure does not appear to have mobilized since construction of 77th in 1980s.
Assessment	<ul style="list-style-type: none">- Slope appears to generally be stable.- If toe was cut for 45th avenue close, some slope regression should be expected.
Recommendations	<ul style="list-style-type: none">- Site trip in spring to look for signs of seepage near 45th avenue close

SITE #23



West Park 54th Avenue Landslide

SITE #23 - WEST PARK 54TH AVENUE LANDSLIDE

23.1 SITE DESCRIPTION

Site #23 is located at the east end of 54th Avenue Crescent in West Park, as shown on Figure 1 of the main report. The crescent is a local street which loops around a residential townhouse development and overlooks the Waskasoo Creek valley to the east. Waskasoo Creek is located on the east side of the creek valley in this location. The west slope of the creek valley below the crescent has Taylor Drive at the toe and a mid slope bench which has a bike path which is part of the original 54th Avenue Truck Route constructed in 1981. This former arterial road was converted to a bike path when Taylor Drive was constructed. This slope is man-made with historical fills for West Park development and cuts for the two road construction projects. The Site Plan is shown on Figure 23-1. A 2016 Contour Plan is provided on Figure 23-2.

The crest of the slope at the east curb of the crescent was about 877.8 m. The pre-1981 landslide slope profile at this site had an inclination of about 3.5H:1V. The present slope to the west edge of the bike path at elevation 873.5 m is as steep as 2.5H:1V. The slope from the east edge of the bike path to the west curb of Taylor Drive at about 3.5 m high and up to 3H:1V. A cross-section of the slope is provided on Figure 23-3. Aerial photographs showing the site between 1981 and 2016 are provided on Figures 23-4A and 23-4B. Four representative photographs from the site are provided on Figure 23-5.

23.2 REFERENCES

The references from Appendix B which apply to Site #23 - 54th Avenue Crescent include References #80 and #81. A site investigation for the site was the failure investigation performed in 1981 (Reference #80).

23.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

On September 21, 1981, a trench and test pit were excavated at the landslide site. No slope measurement instrumentation was installed in this area. Additional borehole were drilled along the toe for Taylor Drive in 1991, but the original conditions were significantly altered for construction of the arterial road bed.

23.4 2018 REVIEW

Aerial photography is provided on Figures 23-4A and 23-4B, for the following years:

TABLE 23-1: AERIAL PHOTOGRAPHS

Year	Description
1981	Shows the site condition at the time of the landslide.
1982	Shows the site after completion of the truck route and reconstruction of the slide area.
2016	Shows the present site condition.

Site #23 was visited on October 30 and November 15, 2018. A copy of the field inspection record is attached at the end of this appendix.

The site contours were developed for the assessment using ortho-contours of the site from 2016 aerial photography. Additional reference control points were surveyed on November 15, 2018. A list of survey control points for this site is appended in Table 23-4 and a reference drawing is provided on Figure 23-6

Photographs were taken during the site visits. Selected site photographs from 2018 are attached along with a reference drawing of photograph locations on Figure 23-7. A photograph summary is appended in Table 23-5.

23.5 BACKGROUND

In August 1981, construction of the 54th Avenue Truck Route extension from 32nd to 43rd Streets commenced. In late August, the slope to the east of 54th Avenue Crescent was initially cut. Due to very wet conditions, the road bed at the toe was sub-cut to a depth of about 3 m to allow deep placement of subgrade improvement gravel. On August 23, the first signs of slope movement were observed in the road surface above the crest. A large tension crack appeared in the pavement during the evening of August 24. Up to 2 m of extra gravel was placed at the base of the cut slope to stop the slide. The pavement surface cracks at the back scarp of the landslide is shown on Figure 23-1 and can be seen on the 1981 aerial photo on Figure 23-4A.

It was concluded that a regressive slope failure occurred as a result of unloading the toe of the slope for road construction in a profile with both buried topsoil, fill and weak lacustrine clay. The conditions were complicated by shallow peak groundwater conditions and two outlet pipes for catch basins which directed water into the creek valley in this area at a depth about 2.5 m above the normal water table. These factors resulted in springs in the cut slope. It was assessed that well-drained soils in this profile would be marginally stable at slopes flatter than 1.5H:1V, but cuts in the order of 1H:1V to 1H:2V were made without giving the soil a chance to drain. Slope movement was

initiated at the toe of the cut and sliding of progressively larger wedges of soil continued eastward until a equilibrium condition was achieved. This resulted in tension cracks in the roadway up to 100 to 200 mm wide and vertical drops up to 220 mm. The potential for a deep-seated rotational failure surface was considered to be low and there was no evidence of any bulge or uplift within the subgrade of the truck route west of the slide area. After a brief investigation, the following recommendations for remedial measures were provided and implemented (Reference #80).

1. A 1.8 m deep french drain was installed along the west side of 54th Avenue and tied into the storm water system to lower the groundwater table in the slope face above the road and to provide dewatering of the gravel layers of the road pavement.
2. The 4 m high slope between the 54th Avenue Crescent and the new truck route was constructed with select fill to a design inclination of 2.5H:1V.

This work was completed in a manner that promoted instability in the area and the final slope was grassed.

In 1991/1992 this area was further reconfigured for the construction of Taylor Drive. The lower slope was cut to remove about half of the 54th Avenue truck route, which was converted into a bike path. A 3H:1V slope was cut below this bike path down to an elevation of 871 m for the new arterial road which was built over the old CP Rail right-of-way. This slope was constructed in accordance with recommendations provided in Reference #80 and no issues were observed.

23.6 SUBSURFACE PROFILE

The east end of 54th Avenue Crescent was clay fill up to about 3.0 m thick, built out over the edge of original creek valley slope. The fill was placed on the original topsoil layer. The underlying subgrade was silty lacustrine clay which is typical to the West Park area. The following is a brief description of the soil types encountered.

1. **Clay Fill.** Along the east curb line at the east end of 54th Avenue Crescent there is expected to be up to 3.0 m of silty wet clay fill of medium plasticity.
2. **Buried Topsoil.** Topsoil up to 1.5 m thick was exposed by the 1981 road cut. The material was noted to be organic and wet with a moisture content of about 30 percent.
3. **Glacio-Lacustrine Deposits.** The native subgrade consists of silty, sandy clay deposits present to depth below the road bed of Taylor Drive at toe of the slope (i.e. below 872 m). The clay was stiff and wet with moisture contents of about 30 percent.

4. **Taylor Drive Road Bed.** The road bed for Taylor Drive was constructed by exposing the silty clay subgrade and spreading ballast from the CP Rail embankment across the road bed; supplemented with clean, coarse (pit run) gravel to act as a capillary cutoff to minimize groundwater pumping. The road bed was raised to subgrade elevation with sand fill.
5. **Groundwater.** The groundwater table was not allowed to stabilize, but seepage was coming into the test pit excavation within 2 m of grade within 15 minutes of excavation. A shallow groundwater table is expected in the upland area to the west of the site.

The soil profile for the slope is shown on cross section in Figure 23-3. This profile includes the original 1981 pre-slide profile for the site. For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix B. The following effective strength parameters were assumed for this site.

TABLE 23-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Clay Fill	20	0	22
Buried Organics	17	0	15
Silty Clay	20	0 - 2	25

23.7 REVIEW OF STABILITY ASSESSMENT

Computer stability analysis of this landslide was not carried out in 1982. The stability of the existing slope has been checked using the *SLOPE/W* computer program as part of this review. The 1982 landslide was used to calibrate soil parameters. The following table summarizes the results of the slope stability analysis.

TABLE 23-3: 2018 SLOPE STABILITY ESTIMATE

Case	Estimated Factor of Safety	
	Deep Failure	Figure
Slope Face	---	---
At East Edge of 54 th Avenue Crescent	1.7	Figure 23-8
At West Edge of Taylor Drive	1.9	---

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

The current slope is considered to be stable in the long-term due to the combination of drainage provided along the 54th Avenue Truck Route during slope rehabilitation in 1981 and the stabilization of shallow groundwater conditions for the slope area since Taylor Drive was constructed in the early 1990s. The FS against a small shallow “slump-type” failure on the slope face is estimated to be above 1.1, so excessively wet conditions such as periods of snow-melt and heavy or prolonged rainfall might trigger some slumping in this area. However, some of the wettest years on record in the City over the past 30 years have not caused any slumping in this area.

23.8 RISK RANKING

The risk level for this site has been assessed as follows:

$$PF(3) * CF(2) = 6$$

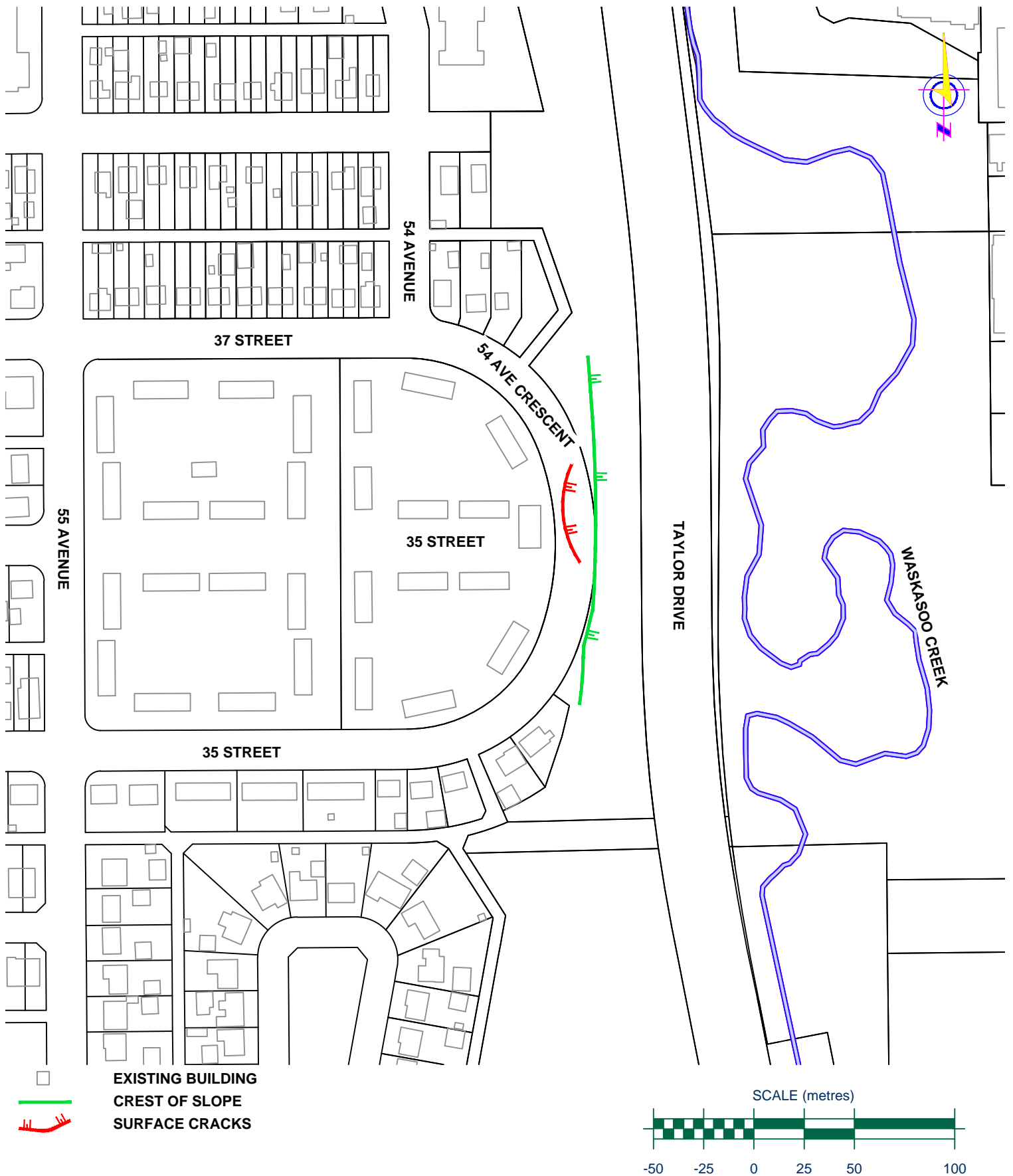
A Probability Factor of 3 is considered appropriate since the landslide site was caused by construction activity and the site was stabilized with a sub-drain at the toe of the slope followed by grading and landscaping. There has been no movement observed at the site since 1981, although the pavement surface does show minimal signs of some deformation in the area of the former scarp. A Consequence Factor of 2 is considered appropriate since the expected size of landslide in the upper slope at this site might affect the east edge of 54th Avenue Crescent, but not to the extent to require a road closure. The risk to private property is negligible.

23.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake periodic visual site inspections on an as required basis to identify any significant changes, if present.

23.10 ATTACHMENTS

Figure 23-1 - Site Plan
Figure 23-2 - 2016 Contour Plan
Figure 23-3 - Cross Section Profile
Figure 23-4 - Aerial Photographs
Figure 23-5 - Site Photographs
Figure 23-6- Survey Marker Plan
Figure 23-7 - Photograph Plan
Figure 23-8 - Stability Analysis Run
Table 23-4 - List of Survey Markers
Table 23-5 - List of Photographs
Site Inspection Record (October 30, 2018)



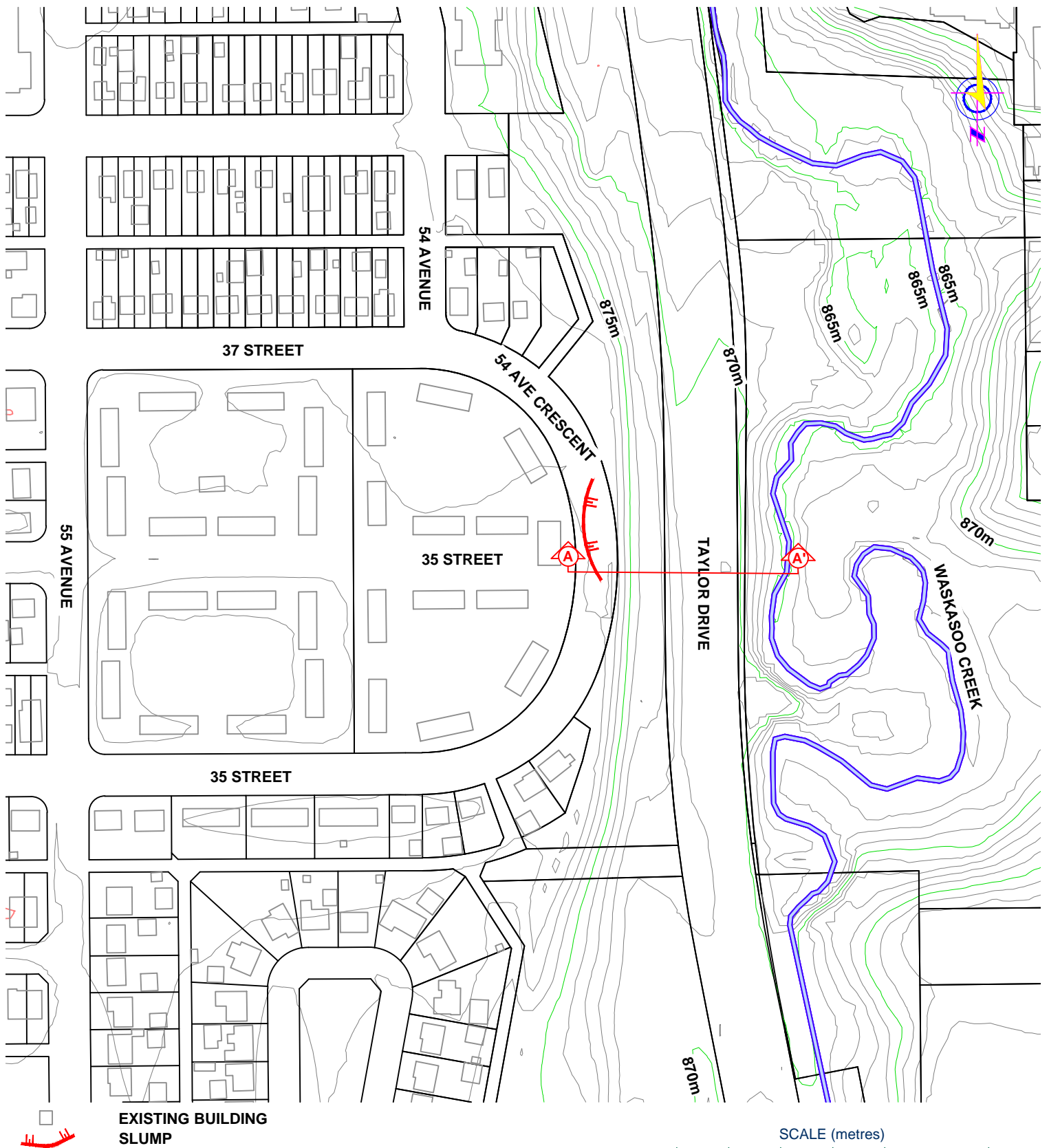
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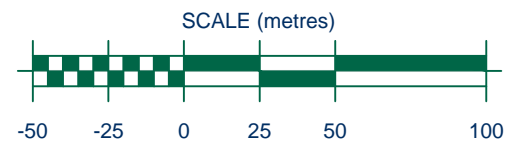
SITE PLAN

**CITY OF RED DEER SLOPE STABILITY EVALUATION
 WEST PARK 54 AVENUE LANDSLIDE**

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-23	DRAWING NO. FIGURE 23-1	



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT



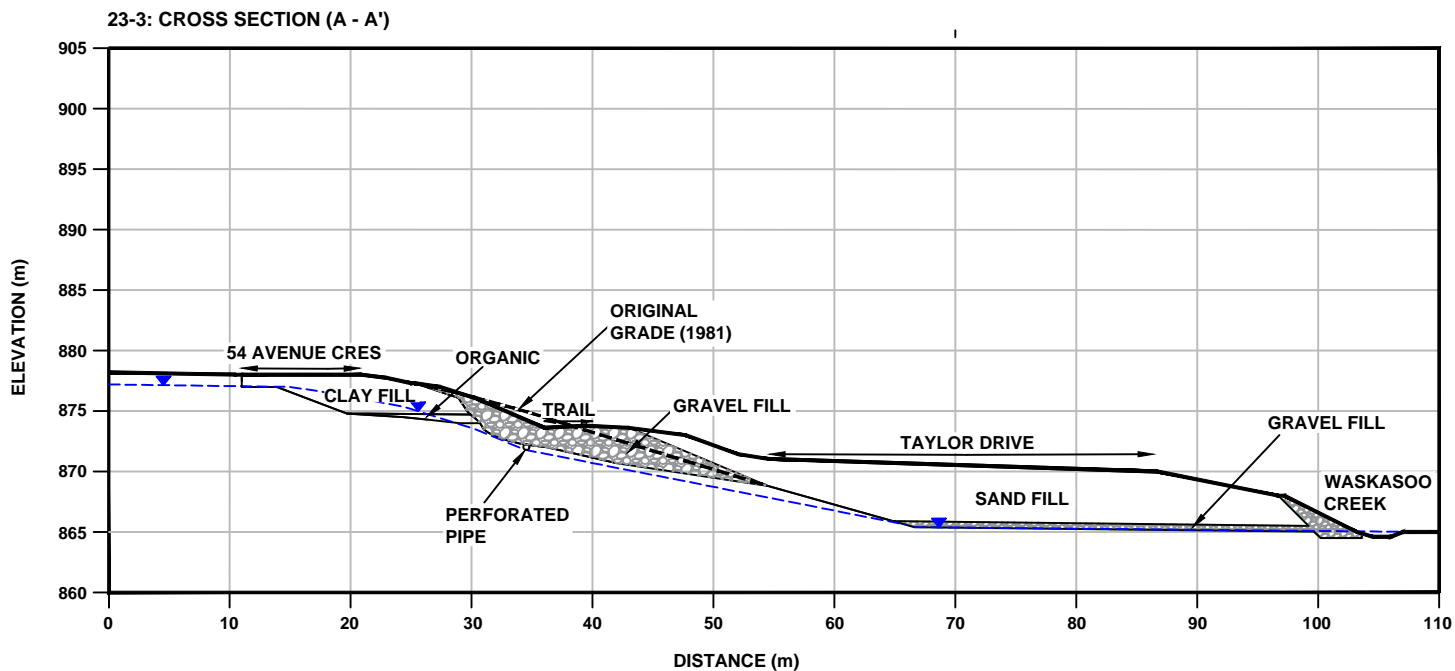
CLIENT:



CONTOUR PLAN

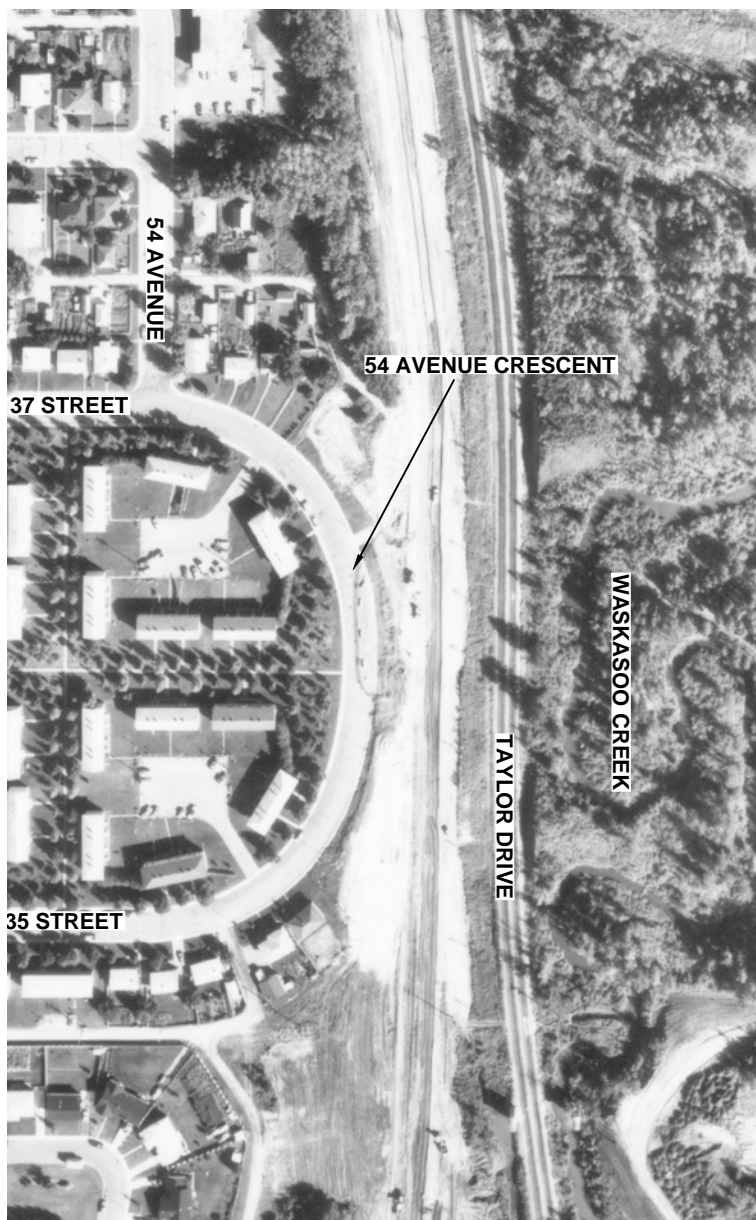
CITY OF RED DEER SLOPE STABILITY EVALUATION
WEST PARK 54 AVENUE LANDSLIDE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2500	JOB NO. RD6500-23	DRAWING NO. FIGURE 23-2	

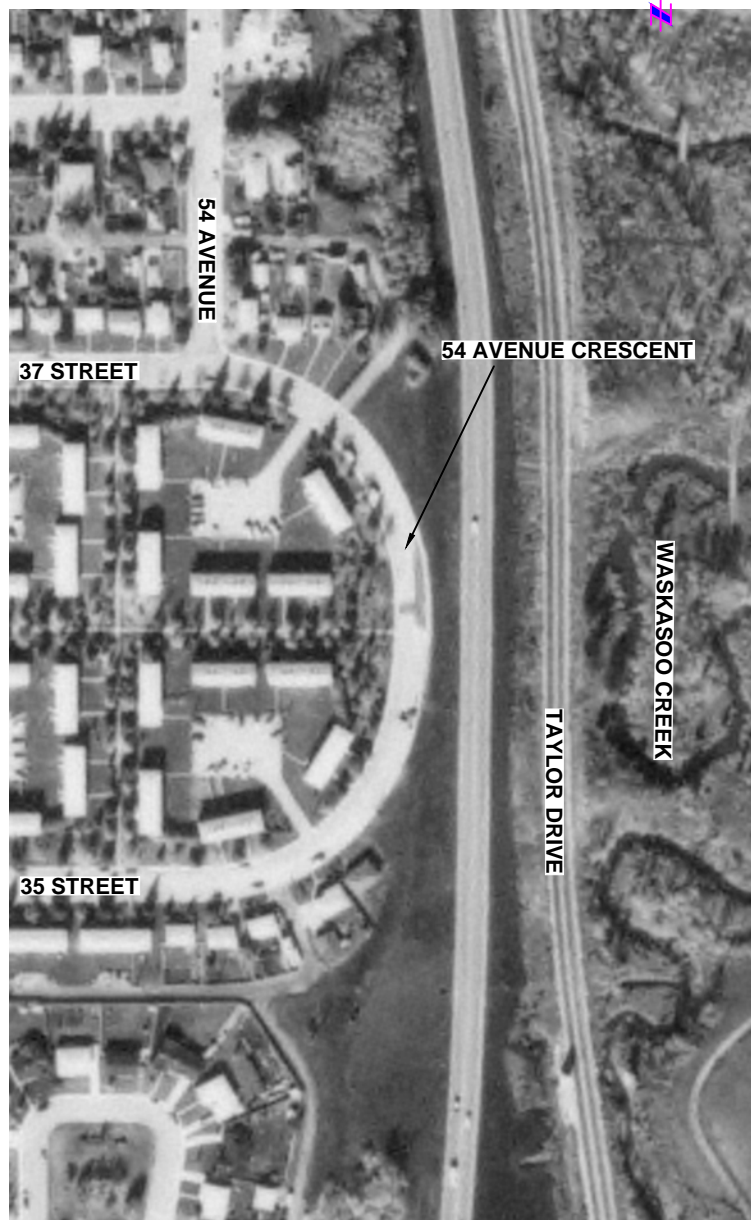


CONTOURS BASED ON 2016 CONTOURS PROVIDED BY THE CLIENT

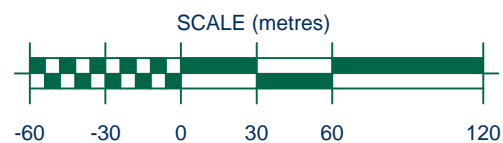
	CLIENT:		CROSS SECTION PROFILE			
			CITY OF RED DEER SLOPE STABILITY EVALUATION WEST PARK 54 AVENUE LANDSLIDE			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
			SCALE:		JOB NO.	
AS SHOWN		RD6500-23		FIGURE 23-3		



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 8, 1981.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 30, 1982.



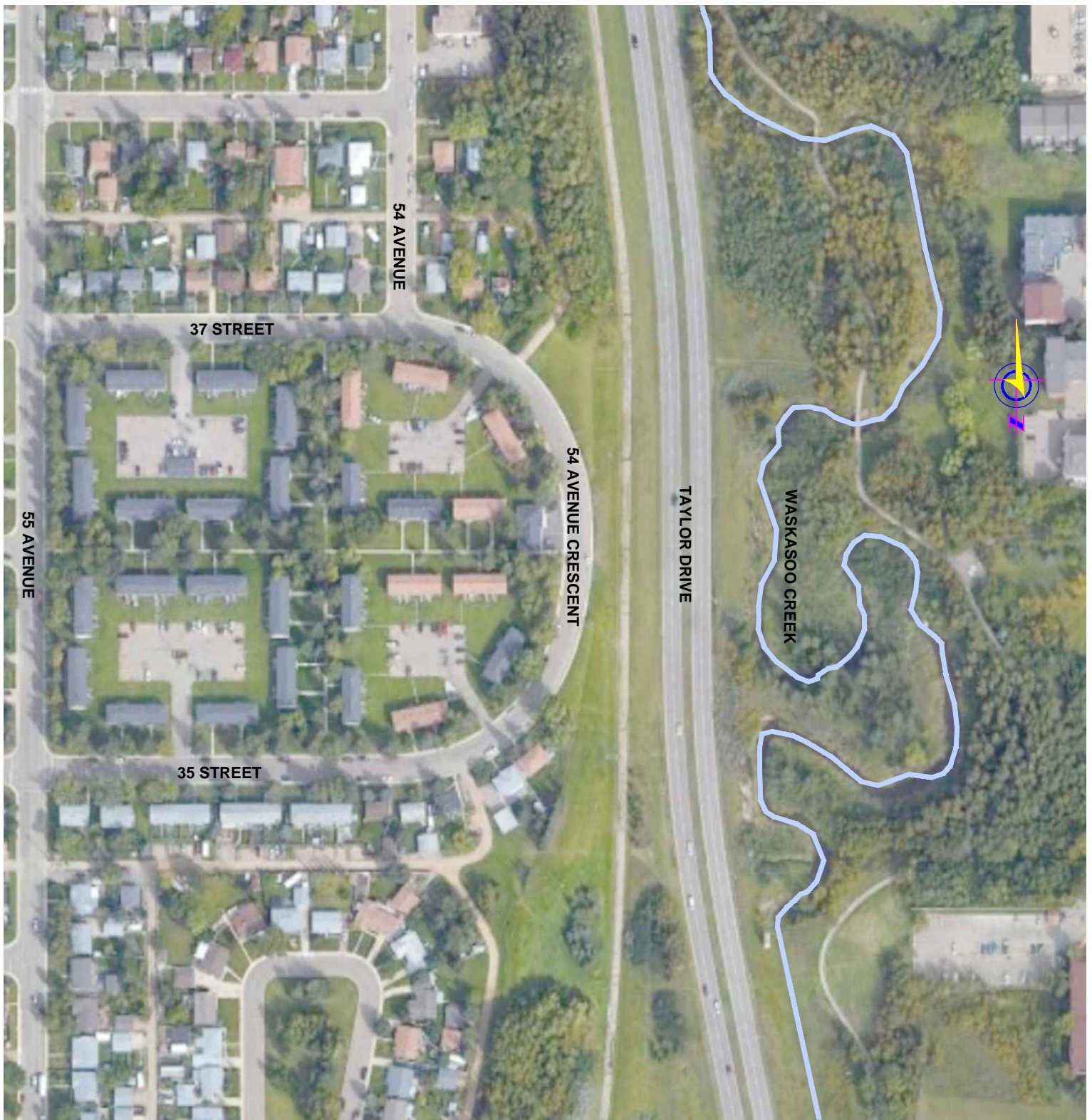
CLIENT:



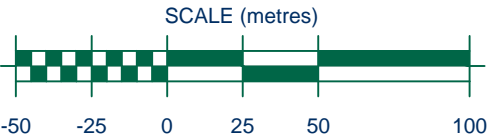
AERIAL PHOTOGRAPHS

CITY OF RED DEER SLOPE STABILITY EVALUATION
WEST PARK 54 AVENUE LANDSLIDE

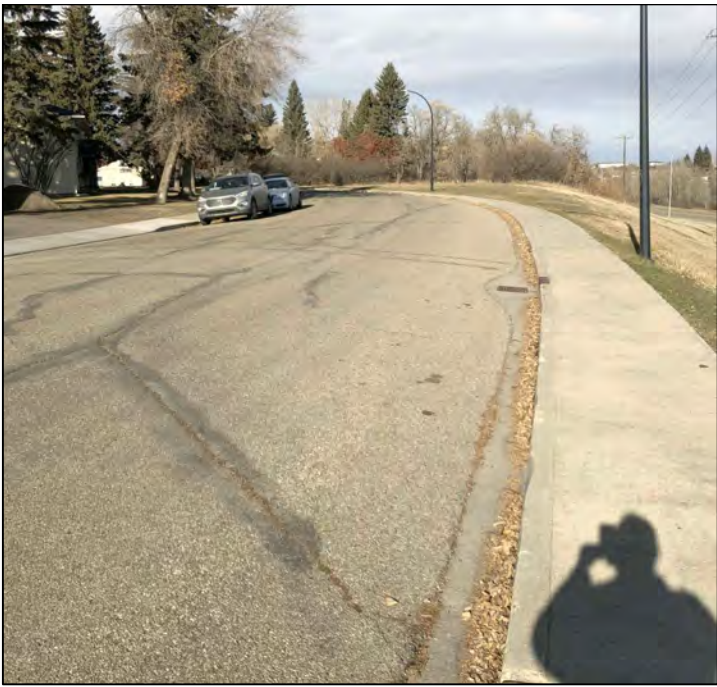
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:3000	JOB NO. RD6500-23	DRAWING NO. FIGURE 23-4A	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION WEST PARK 54 AVENUE LANDSLIDE			
	DRAWN:	CHK'D.:	REV #:	DATE:		
	PS	MDB	2	APRIL 2019		
SCALE:		JOB NO.		DRAWING NO.		
1:2500		RD6500-23		FIGURE 23-4B		



PHOTOGRAPH 3 (2018): 54 AVENUE CRESCENT WITH ADJACENT SLOPE , FACING NORTH



PHOTOGRAPH 4 (2018): SLOPE AND WALKING TRAIL BETWEEN 54 AVENUE CLOSE AND TAYLOR DRIVE, FACING NORTH

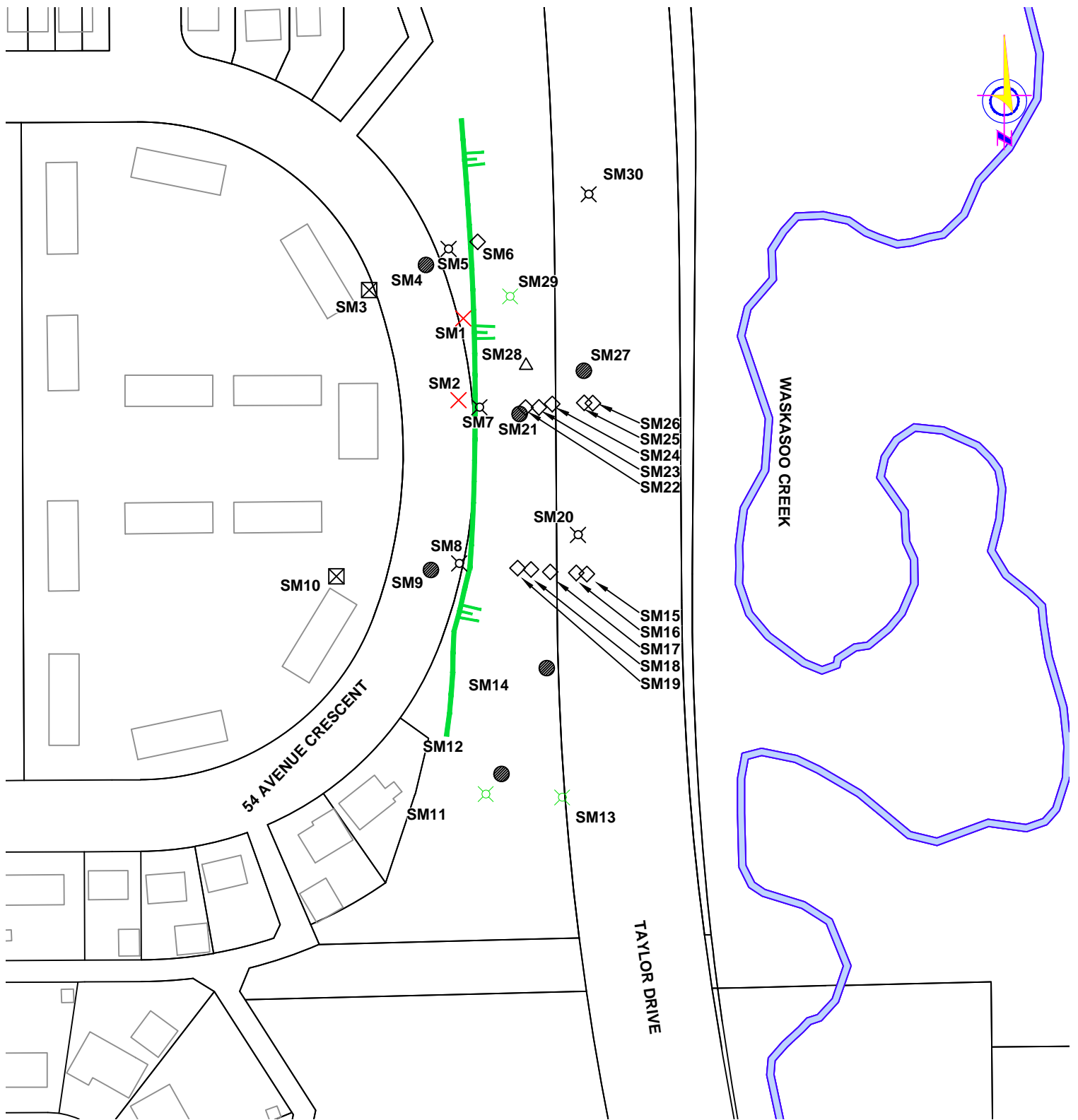


PHOTOGRAPH 10 (2018): SLOPE AND WALKING TRAIL BETWEEN 54 AVENUE CLOSE AND TAYLOR DRIVE, TAKEN FROM ACROSS TAYLOR DRIVE, FACING WEST

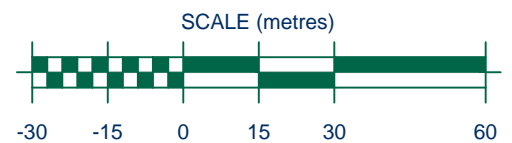


PHOTOGRAPH 28 (2018): SLOPE BETWEEN 54 AVENUE CLOSE AND TAYLOR DRIVE, TAKEN FROM ACROSS TAYLOR DRIVE, FACING NORTHWEST

	CLIENT:		SITE 23 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION WEST PARK 54 AVENUE LANDSLIDE			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
NTS		RD6500-23		FIGURE 23-5		



- | | | | |
|--|------------------------|--|--------------------------|
| | CREST OF SLOPE | | SURVEY LAND POINT |
| | BUILDING CORNER | | CRACK |
| | MANHOLE | | ASCM |
| | LIGHT POLE | | POWER POLE |



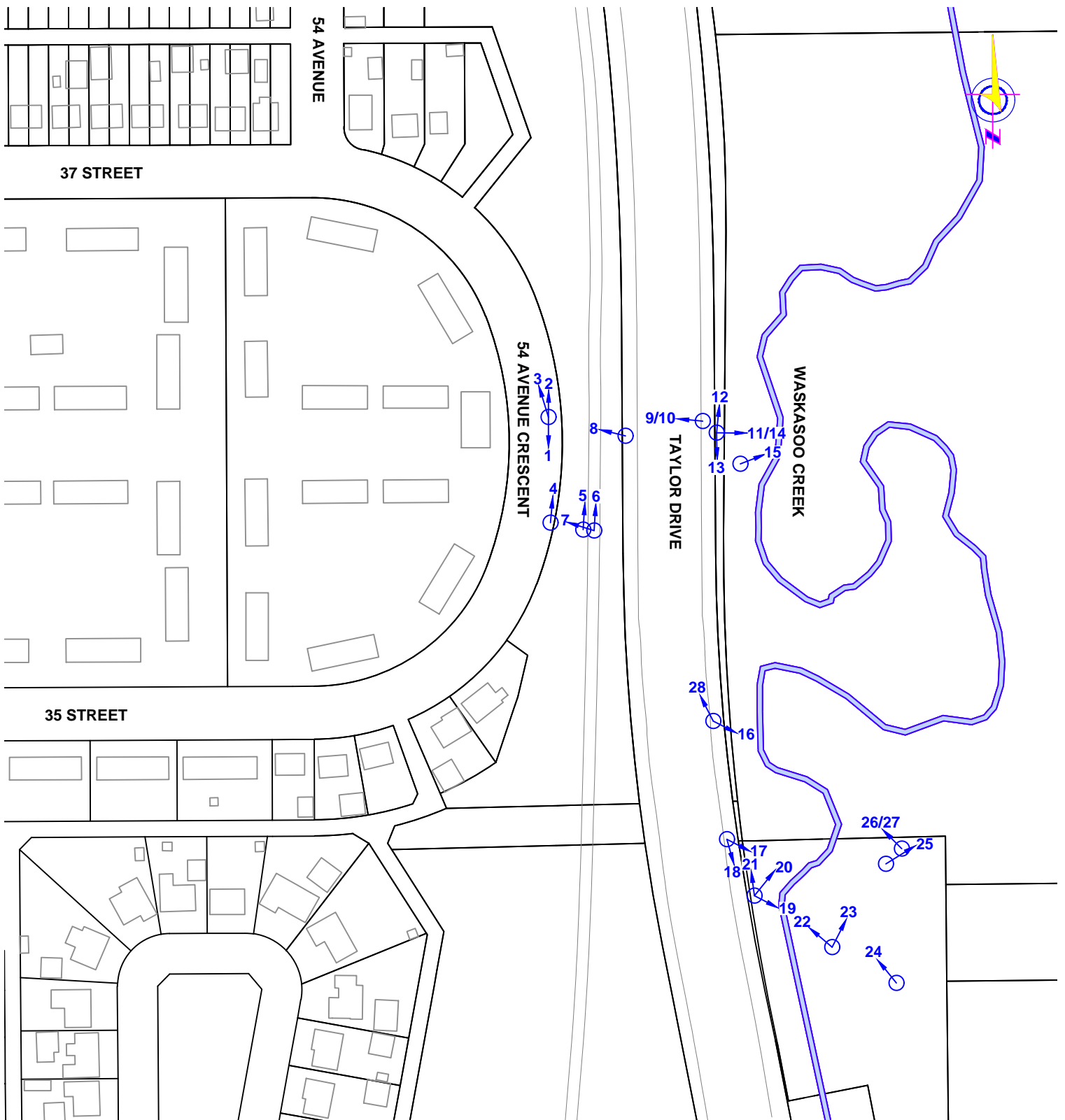
CLIENT:



SURVEY MARKERS

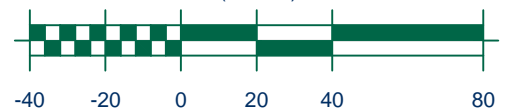
CITY OF RED DEER SLOPE STABILITY EVALUATION
WEST PARK 54 AVENUE LANDSLIDE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-23	DRAWING NO. FIGURE 23-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE

SCALE (metres)



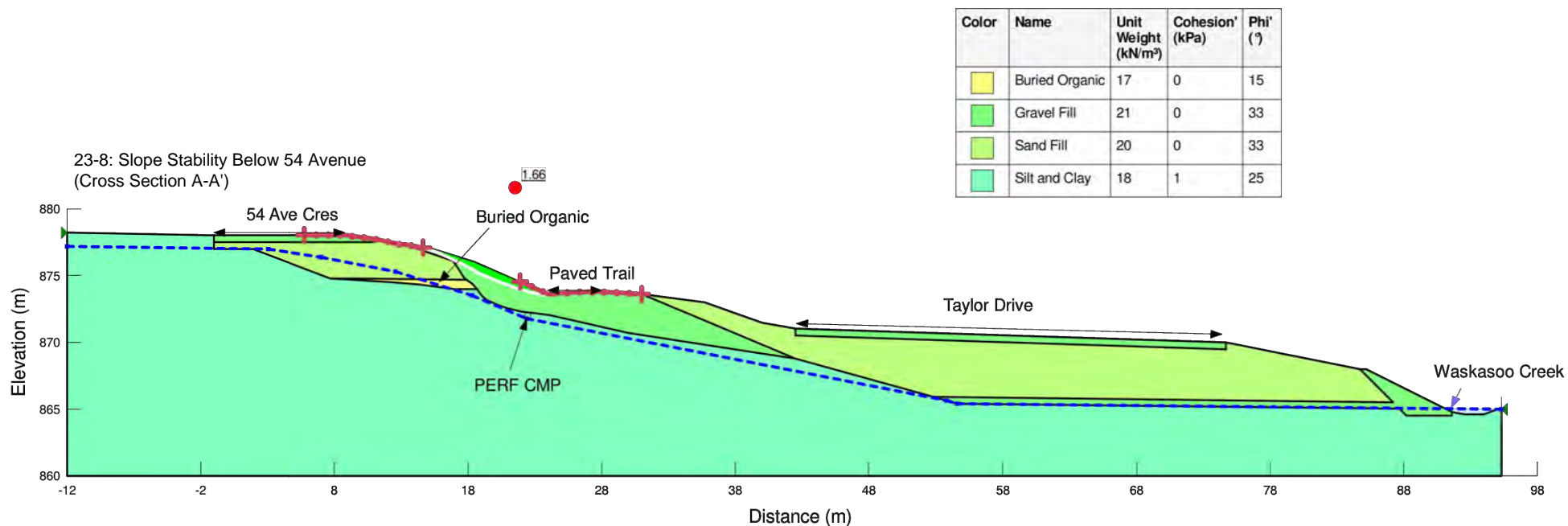
CLIENT:



PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
WEST PARK 54 AVENUE LANDSLIDE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-23	DRAWING NO. FIGURE 23-7	



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
WEST PARK 54 AVENUE LANDSLIDE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-23	DRAWING NO. FIGURE 23-8	

SITE #23 -WEST PARK 54 AVENUE LANDSLIDE

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 23-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM23-001	Crack	5793369.57	307396.40	877.82				
#SM23-002	Crack	5793346.60	307395.05	878.03				
#SM23-003	Building	5793377.54	307370.00	878.14				
#SM23-004	MH	5793384.57	307385.90	877.96				
#SM23-005	Light Pole	5793389.09	307392.25	877.89				
#SM23-006	Crest	5793391.09	307400.45	877.89				
#SM23-007	Light Pole	5793344.61	307400.94	877.74				
#SM23-008	Light Pole	5793300.76	307395.28	878.15				
#SM23-009	MH	5793298.89	307387.26	878.29				
#SM23-010	Building	5793297.12	307360.78	878.69				
#SM23-011	Pole	5793235.97	307402.69	873.43				
#SM23-012	MH	5793241.60	307407.10	872.75				
#SM23-013	Pole	5793235.06	307424.17	872.28				
#SM23-014	MH	5793271.31	307419.83	873.25				
#SM23-015	Curb	5793297.79	307431.09	871.52				
#SM23-016	Toe	5793298.10	307428.11	871.92				
#SM23-017	Ridge	5793298.37	307420.83	873.49				
#SM23-018	Trail	5793299.07	307415.42	873.66				
#SM23-019	Curb	5793299.46	307411.65	873.50				
#SM23-020	Light Pole	5793308.78	307428.62	871.65				
#SM23-021	MH	5793342.71	307412.17	874.11				
#SM23-022	Curb	5793344.53	307413.87	873.63				
#SM23-023	Trail	5793344.58	307417.65	873.78				
#SM23-024	Ridge	5793345.54	307421.37	873.62				
#SM23-025	Toe	5793345.87	307430.35	871.45				
#SM23-026	Curb	5793345.78	307432.79	871.05				
#SM23-027	MH	5793354.83	307430.19	871.29				
#SM23-028	ASCM 323758	5793356.36	307414.05	873.78				
#SM23-029	Pole	5793375.73	307409.54	875.34				
#SM23-030	Light Pole	5793404.43	307431.61	870.46				

TABLE 23-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P23-003	54 Ave Cres and slope	5793342	307394	N	Y*	
#P23-004	Slope and walking trail	5793302	307395	N	Y*	
#P23-010	Slope and walking trail	5793340	307453	W	Y*	
#P23-028	Slope and walking trail	5793227	307457	NW	Y*	

Notes:

* Provided in the report

All measurements in metres

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	23	
Site Name	West Park 54 Avenue Cres Slide	
Legal Land Description	NW 8-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	307420 E, 5793340 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 30, 2018	3	2	6
Inspected By:	Bryden Lutz – PGEO Mark Brotherton - PGEO			
Report Attachments:	78 site photos taken			


Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded	N/A	
Slope Movement	None observed	N/A	
Erosion	None observed	N/A	
Seepage	None observed	N/A	
Distress	Old cracking asphalt of 54 th Avenue likely near old failure.	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments:	•		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- No evidence of slope movement since remediation of construction in 1980s.
Assessment	<ul style="list-style-type: none">- Slope appears stable.
Recommendations	<ul style="list-style-type: none">- Consider site inspections every 5 years.

SITE #24/25



#24A - 1982 Waskasoo Creek Landslide
#24B - Creekside Mobile Homes Park Landslide
#25 - Royal Oaks Apartment Slope Rehabilitation

SITE #24/25 - EAST WASKASOO CREEK VALLEY SLOPES

24.1 SITE DESCRIPTION

Sites #24 and #25 are three slope sites located on the east side of the Waskasoo Creek valley between 32nd and 39th Street in south central Red Deer, as shown on Figure 1 of the main report. Waskasoo Creek meanders within a 100 to 150 m wide valley and comes into close proximity to the east valley slope in several locations. The creek is located east of Taylor Drive which runs the length of the valley. Taylor Drive was built in the early 1990s and part of the work resulted in the shifting sections the creek to the east of the original channel bed in some locations. The original and new creek alignments caused two historical landslides in 1982 and 1991. For simplicity, the number "24" will be used as a designation for all three areas of Sites #24 and #25 in this appendix (i.e. for appendix text sections and figure numbers). The Site Plan is shown on Figure 24-1. Contour Plans from 2016 for the three areas are provided on Figures 24-2A to 24-2C.

The crest along the top of the east creek valley slope in this area ranges between 875 and 878 m. The toe of the slope ranges from about 866 to 870 dropping to the north, making the slope 8 to 10 m high. The present slopes range in inclination from 2H:1V to 5H:1V; with steeper slopes located in the south half of the area from 32nd Street to the north end of the culvert. The creek channel is located in a gently sloped flood plain at distances ranging from a few metres to as much as 110 m away from the toe the east valley wall. The south end of the area is at 32nd Street, where the creek flows under this arterial road through a 3.05 m diameter multi-plate culvert into a straight section of engineered creek bed. The creek channel flows into a second 3.05 m diameter culvert that is located 345 to 490 m north of the centre line of 32nd Street. This culvert discharges into a meandering open flow channel in the valley flood plain. This area is a well treed park that has a few large clearings and a series of paths with a couple of bridges over the creek. A large bridge pier from a former rail bridge is located at the north end of the second culvert.

The creek surface between 32nd and 39th Street drops about 6 m. The 1 to 2 m high creek banks are relatively steep in areas (i.e. averaging 1H:1V to 1.5H:1V with localized steeper sections). The top-of-bank elevations drop from about 866 m near 32nd Street to about 862 m opposite 39th Street. The normal flows in the creeks are less than 1 m deep. The 1:100 year flood surface in this area drops from 870.0 m at 32nd Street to 863.7 m near 39th Street. These peak flow levels can overtop the banks, but do not reach the toe of the valley slope in any of the flood plain areas north of the second culvert. Cross-sections of three site profiles are provided on Figures 24-3A to 24-3C.

The local development in the upland area to the east of the slope is a mixture of single family residences (mobile homes), residential apartments and a hotel complex. The current development was constructed between the late 1960s and 1997. Aerial photographs for these three areas from between 1981 and 2016 are provided on Figures 24-4A to 24-4B. Representative photographs from the site are provided on Figures 24-5A to 24-5E.

24.2 BACKGROUND

There are three documented historical landslide locations along the east slope in this section of the Waskasoo Creek valley. These instabilities are related to residential development along the top-of-slope and/or re-routing of the creek for Taylor Drive construction. The following slope movements occurred between 1982 and 2007.

- **Middle - 1982 Waskasoo Creek Landslide.** This landslide site is located immediately west of the apartment or townhouse complexes built along the crest of the creek valley at the west end of 37th Street. In 1982, the valley wall experienced a large landslide which ran out and blocked/diverted the creek. The slide area was reconstructed and rehabilitated sub-drains and landscaping. The creek bed was stabilized at the new channel location west of the original buried channel.
- **South - 1991 Waskasoo Creek Landslide.** During the construction of Taylor Drive in 1991, the Waskasoo Creek channel was shifted slightly east in the first 500 m north of 32nd Street to make room for the road embankment. This steepened the east creek valley slope to between 2.5H:1V and 3H:1V, causing a large landslide which extended up to the current bike path near the crest between Creekside Mobile Home Park and the old rail bridge pier. This landslide was rehabilitated by installing a long 3.05 m diameter culvert in the creek bed at the toe of the slope below the length of the slide and covering the culvert and lower slope face with a large fill to stabilize the slide area.

Other instabilities occurred at the north of the culvert in areas where westward loops of Waskasoo Creek impinged on the road embankment. The creek bank was heavily armored at the north end of the culvert. In areas with conflicts between the creek loops and Taylor Drive embankment north end of the culvert, steepened 1H:1V banks were constructed with thick gravel buttresses keyed into the creek bed.

- **North - 2007 Royal Oaks Apartment Slope Rehabilitation.** During construction of the Royal Oaks apartment in 1997, the slope overlooking the park area and Waskasoo Creek was excavated and re-graded to level and square off the site to accommodate the underground parking structures for two apartment buildings. The original crest elevation was about 876 m and the parkade floor was constructed at an elevation of about 873.5 m. The apartment foundations are belled cast-in-place concrete piles founded at an elevation of about 868 m; about 4.5 m below the parkade slab. Backfill was then placed against the foundation walls up to about 876.5 m to provide level patio areas for the first floor apartment units. In 2007, the backfill to the south and west of the apartments experienced some tension cracking during a wet period in the spring. The landscaped area around the building was regrading to close and flatten tension cracks.

24.3 REFERENCES

The references from Appendix B which applies to Site #24 is Reference #82 which documents the 1982 landslide. There is anecdotal information, but no available documentation for the 1991 landslide which resulted in the long culvert installation. The site investigation and supplemental slope assessment for the Royal Oaks site is documented in References #83 and #84.

24.4 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

In 1997, boreholes were drilled at the Royal Oaks apartment site at the north end of the area. Based on other local geotechnical experience, the profile found at this site is expected to be relatively consistent along the valley slope. The borehole locations are shown on Figure 24-1. No slope measurement instrumentation was installed in this area.

24.5 2018 REVIEW

Aerial photography is provided on Figures 24-4A to 24-4B at the three old landslide sites for the years listed in the following table:

TABLE 24-1: AERIAL PHOTOGRAPHS

Year	Description
1981	Middle Site - shows the slide and blockage of Waskasoo Creek.
1994	South Site - shows the site conditions after installation of the buried culvert and slope.
1997	South Site - shows original site conditions prior to apartment development.
2016	Shows the present Site condition.

These sites were visited on November 2 and November 27, 2018. A copy of the field inspection record is attached at the end of this appendix.

The site contours were developed for the assessment using ortho-contours of the site from 2016 aerial photography. Historical survey data reviewed included 1982 design drawings with contours for the slope reconstruction at the middle site near 37th Street and 1997 pre-development slope contours at the Royal Oaks site at the north end of the area. Additional reference control points were surveyed on November 27, 2018. A list of survey control points for this site is appended in Table 24-4 and a reference drawing is provided on Figure 24-6.

Photographs were taken during the site visits. A list of available photos at this site is appended in Table 24-5. Selected site photographs are provided on Figures 24-5A to 24-5E; along with a reference drawing of all photograph locations which is provided on Figure 24-7.

24.6 SUBSURFACE PROFILE

The soil profile for these 8 to 10 m high creek valley slope is glacio-lacustrine clay with possible clay till at or just above the toe elevation. The base of the creek valley in this area is expected to be clay till. Many crest areas have been subject to considerable disturbance with possible poorly placed fills and buried organics around some of the apartment developments (see Reference #83). The following is a brief description of the soil types encountered and expected.

1. **Clay Fill.** Clay fill is expected along the valley slope in areas with apartment development (i.e. backfill from the building excavations). This fill material is expected to be the silty clay of medium plasticity which is native to the area.
2. **Topsoil.** The landscaped and natural slopes are expected to have a thin cover of topsoil. Given the age of the local development it is likely that buried organics are present below some of the fill, where present.
3. **Glacio-Lacustrine Deposits.** The majority of these slopes consist of silty, sandy clay deposits to an expected depth of 8 to 10 mbg (i.e. below 868 m). The local clay is stiff, low to medium plastic and wet with moisture contents of about 30 percent.
4. **Clay Till.** The local clay till is typically found below 868 m. This very stiff till is a silty, sandy clay of medium plasticity with a typical moisture content of about 16 percent.
5. **Groundwater.** The groundwater table is expected to be within 2 to 4 m of surface in the upland and creek valley areas. Groundwater will be slightly deeper below crest areas, since the static water table in the upland area is expected to be hydraulically connected to the creek valley water table and creek water surface.

The soil profile for the three slopes are shown on Figure 24-3. For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix B. The following effective strength parameters were assumed for this site.

TABLE 24-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Clay Fill	20	0	22
Gravel Fill	21	0	38
Silty Clay	20	0 - 2	24 - 25
Clay Till	21	2 - 5	30

24.7 REVIEW OF STABILITY ASSESSMENT

Computer stability analysis of the landslide was only carried out for the Royal Oak Apartment site at the north end of the area in 1997 and 2007. The stability of the existing slope in the three areas has been checked using the *SLOPE/W* computer program as part of this review. The 1982 landslide and 2007 slumping was used to calibrate soil parameters. The following table summarizes the results of the slope stability analysis.

TABLE 24-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
North Site - Steepest Slope Face	1 - 1.2	-
North Site at Apartment Parkade Elevation	1.7	-
North Site at Apartment Building Foundation Level	2	Figure 24-8
Middle Site - Reconstructed Slope Face	1.3	-
South Site - Crest Area Above Culvert Fill	1.1	-

A representative stability analysis figure for the governing slope model at this site is provided in this appendix as noted above. The following assessment comments are provided for the three areas:

1. **North Site.** The current slope is considered to have short-term stability and be marginally stable in the long-term. The FS against a small shallow “slump-type” failure on the slope face is estimated to be just above 1.0, so excessively wet conditions such as periods of snow-melt and heavy or prolonged rainfall might trigger some slumping as observed in 2007. Due to the piled foundation configuration and underground parking level, the apartments are not at risk.
2. **Middle Site.** The current slope is considered to be stable in the long-term, due to the combination of regrading and sub-drainage provided during slope rehabilitation in 1980s. The FS against a small shallow “slump-type” failure on the slope face is estimated to be above 1.1, so excessively wet conditions such as periods of snow-melt and heavy or prolonged rainfall might trigger some slumping. However, some of the wettest years on record in the past 35 years have not caused any slumping in this area.
3. **South (Culvert) Site.** The current slope is considered to be stable in the long-term due to the presence of the large, relatively flat toe load placed over the culvert to stop the landsliding in 1991. The back scarp area near the crest of the slope above the bike path is relatively steep in a few areas which are considered to be marginally stable in the long-term. However, these areas are well drained and excessively wet conditions would be required to trigger slumping.

24.8 RISK RANKING

The risk level for these three sites has been assessed as follows:

1. **PF(3) * CF(10) = 30** - Waskasoo Creek 1982 (Middle) and 1991 (South) Sites

A Probability Factor of 3 is considered appropriate since these two landslide sites on the east creek valley slope have been rehabilitated with engineered measures and the potential for future failure is low. There has been no movement observed at these sites since the original failures in 1982 and 1991, respectively. At the south site, the only issue is with the upper slope near the crest. A Consequence Factor of 10 is considered appropriate since the even a small instability could affect private property and structures including several apartment buildings.

2. **PF(5) * CF(8) = 40** - Royal Oaks (North) Site

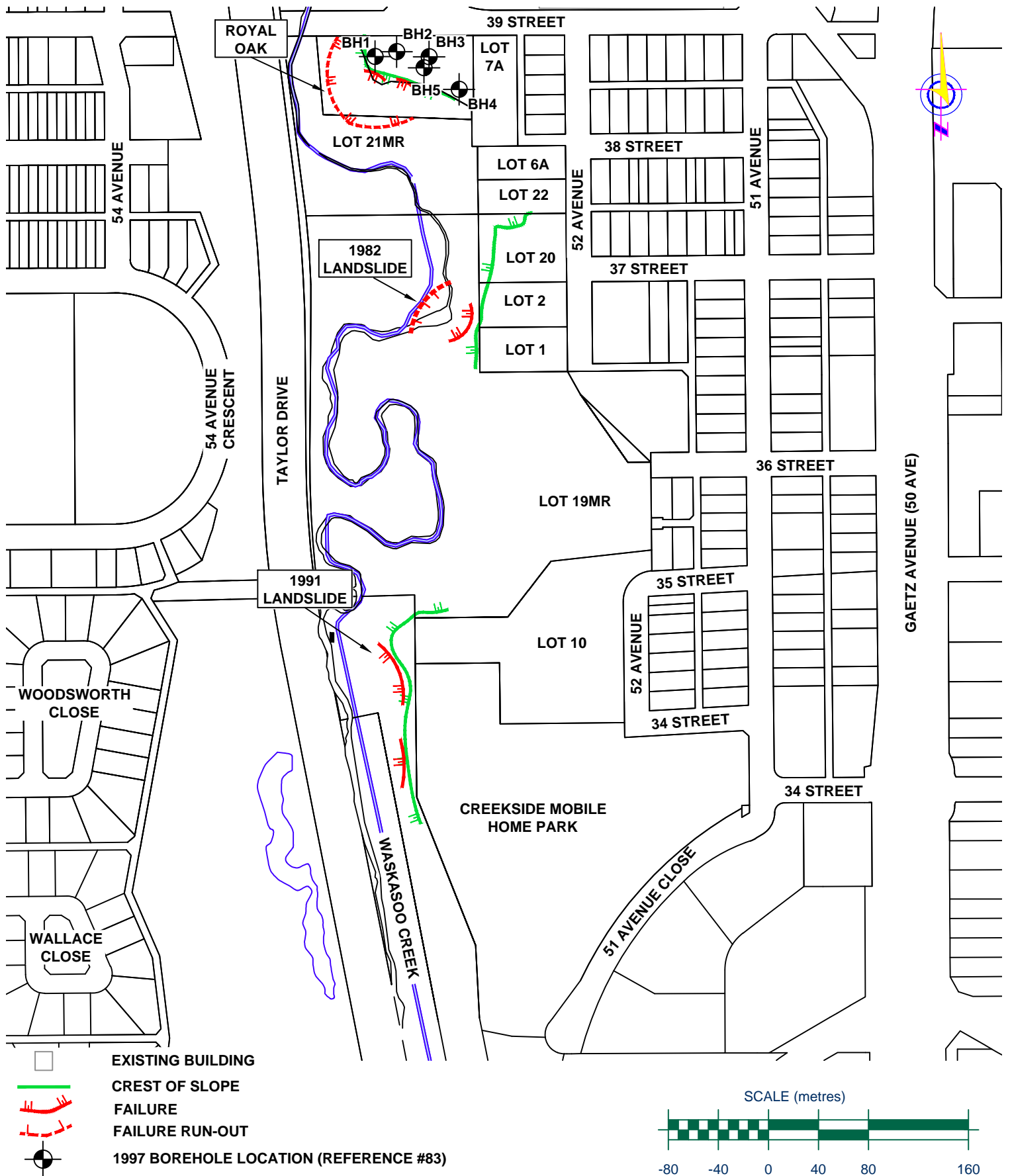
A Probability Factor of 5 is considered appropriate since this slope since the potential for a shallow slump on the re-graded fill face similar to the slumps in 2007 is moderate. A Consequence Factor of 8 is considered appropriate since the expected size of slumping could impact the apartment property, but not the building.



24.9 RECOMMENDATIONS

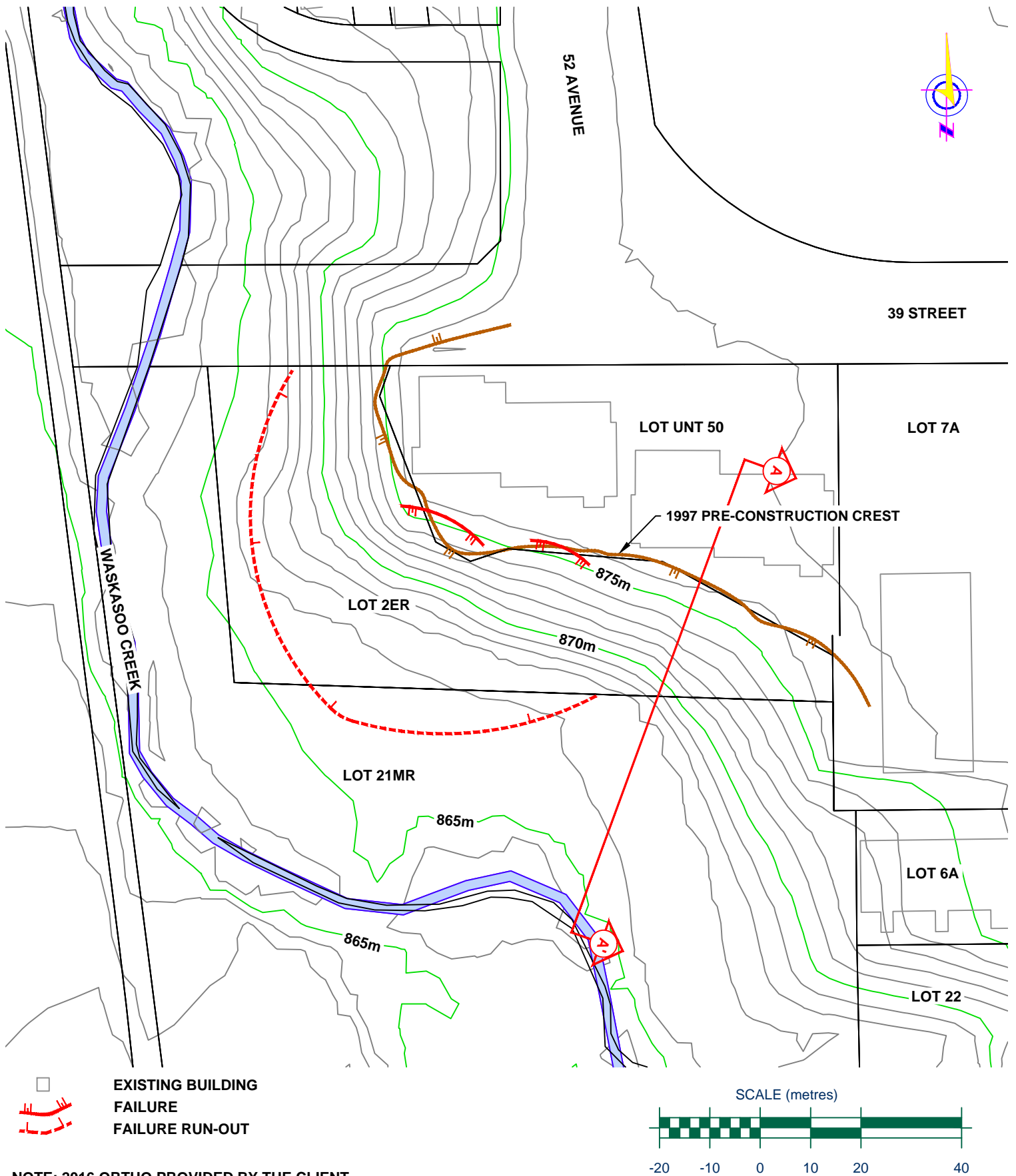
The recommended course of action at this site is to undertake periodic visual site inspections on a five year period for the Royal Oaks slope at the north end of the site; and an as required basis for the other two sites, to identify any significant changes, if present.

24.10 ATTACHMENTS

Figure 24-1 - Site Plan
Figure 24-2 - 2016 Contour Plans
Figure 24-3 - Cross Section Profiles
Figure 24-4 - Aerial Photographs
Figure 24-5 - Site Photographs
Figure 24-6- Survey Marker Plans
Figure 24-7 - Photograph Plans
Figure 24-8 - Stability Analysis Run
Table 24-4 - List of Survey Markers
Table 24-5 - List of Photographs
Site Inspection Record (November 2, 2018)



	CLIENT:		SITE PLAN			
			CITY OF RED DEER SLOPE STABILITY EVALUATION EAST WASKASOO CREEK VALLEY SLOPES			
	DRAWN:	CHK'D.:	REV #:	DATE:		
	NC	MDB	2	APRIL 2019		
	SCALE:	JOB NO.		DRAWING NO.		
1:4000	RD6500-24/25		FIGURE 24-1			



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



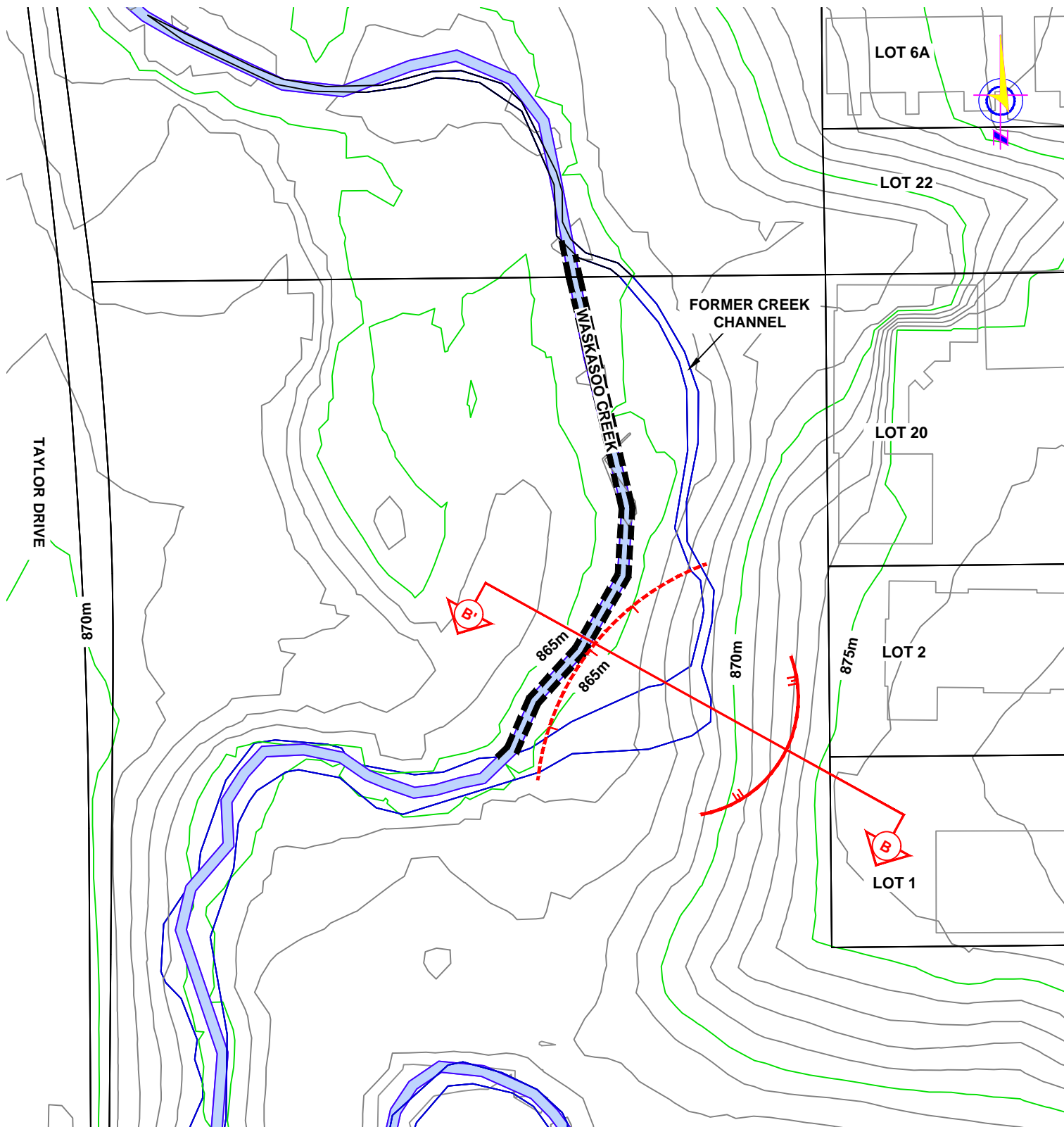
CLIENT:



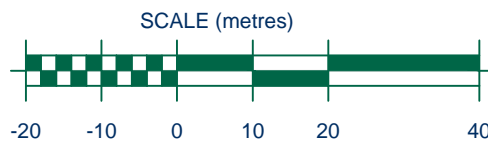
ROYAL OAK CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1000	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-2A	



EXISTING BUILDING
FAILURE
FAILURE RUN-OUT
EXISTING CREEK (DIVERTED)



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.



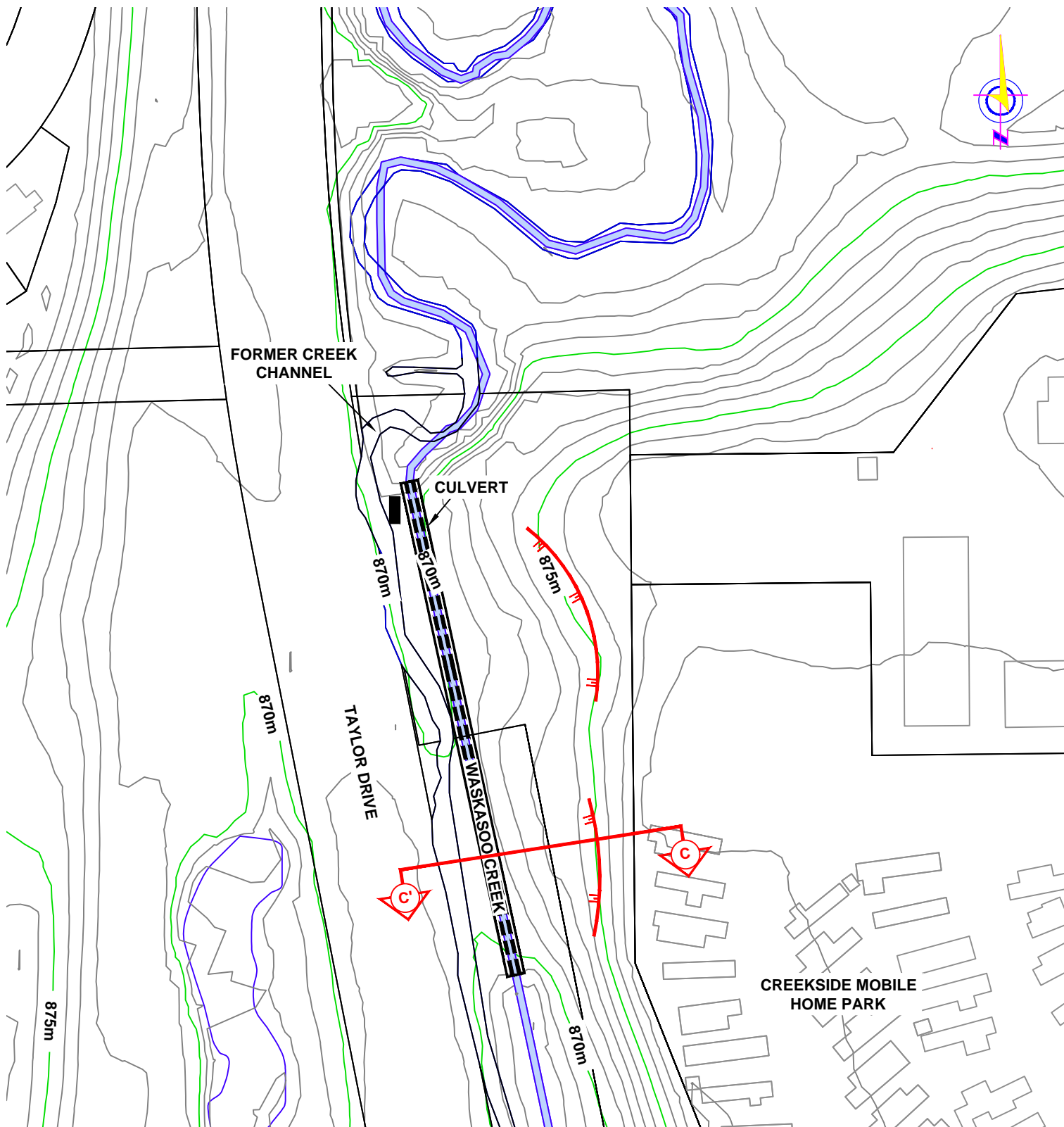
CLIENT:

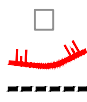


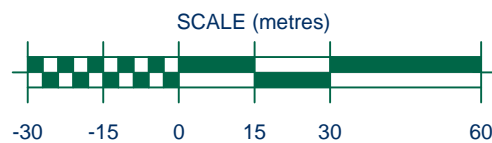
1982 LANDSLIDE CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1000	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-2B	




EXISTING BUILDING
FAILURE
CREEK IN CULVERT



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT.

CLIENT:

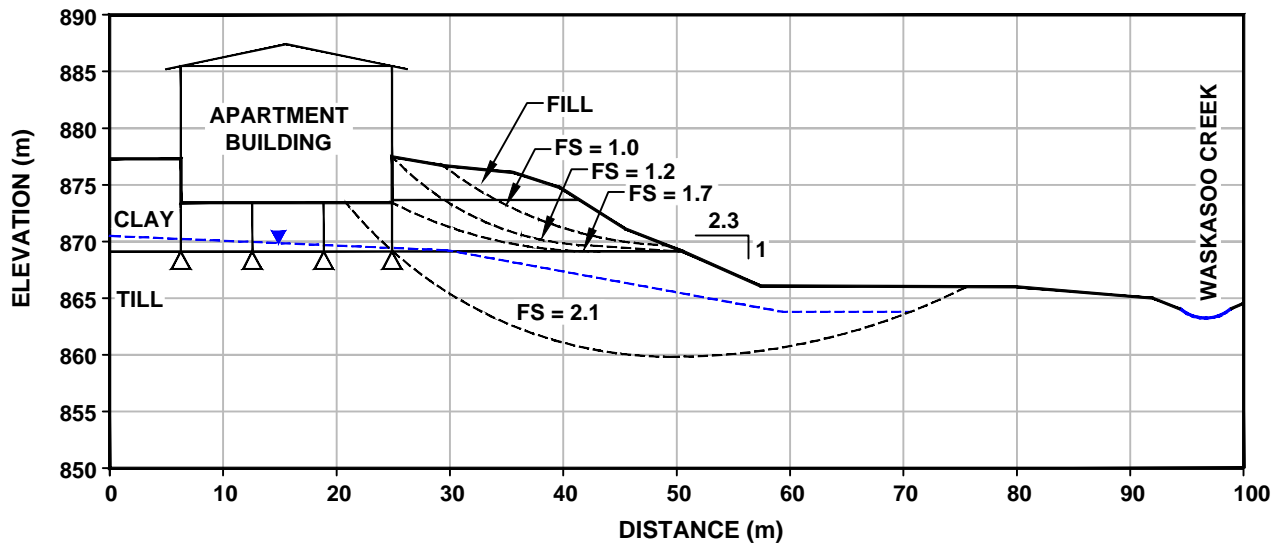


1991 LANDSLIDE CONTOUR PLAN

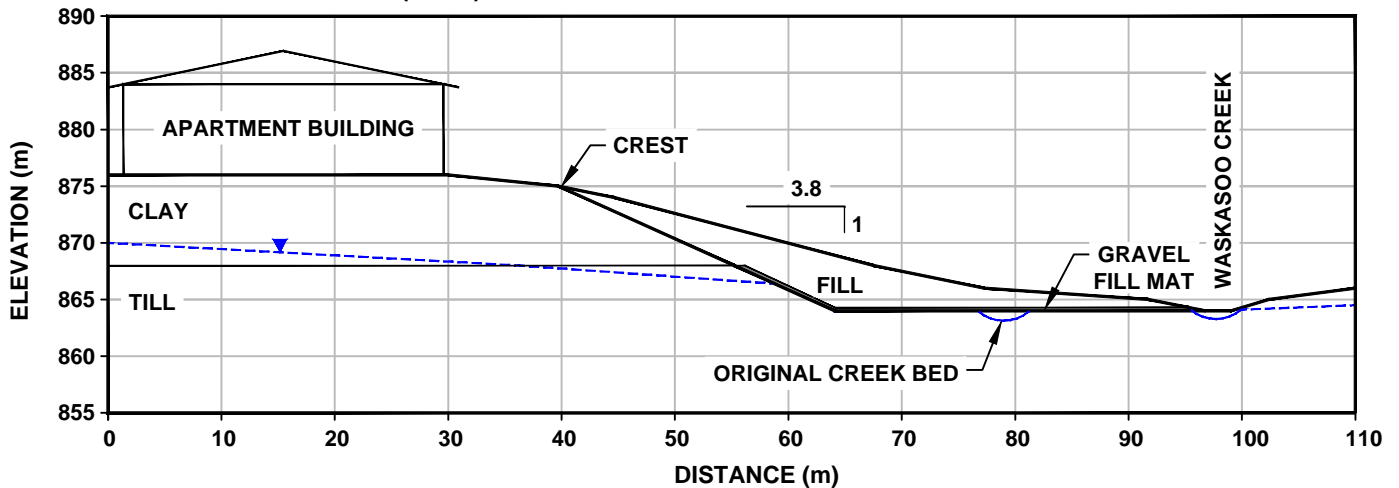
CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES

DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:1500	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-2C	

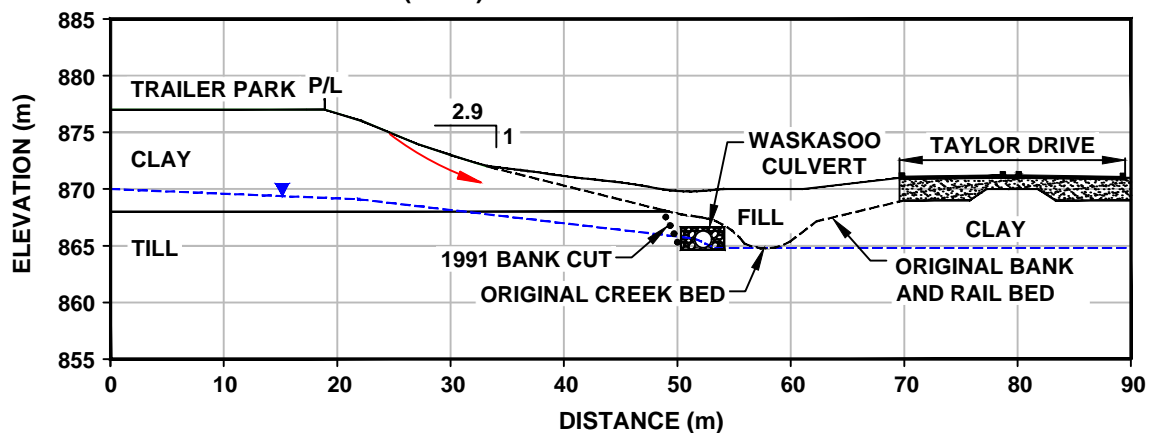
24-3: CROSS SECTION (A - A')



24-3: CROSS SECTION (B - B') - RECONSTRUCTED SLOPE



24-3: CROSS SECTION (C - C')



CLIENT:



CROSS SECTION PROFILES

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES

DRAWN: NC	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-3	

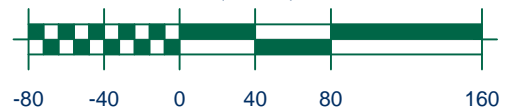




NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 8, 1981.

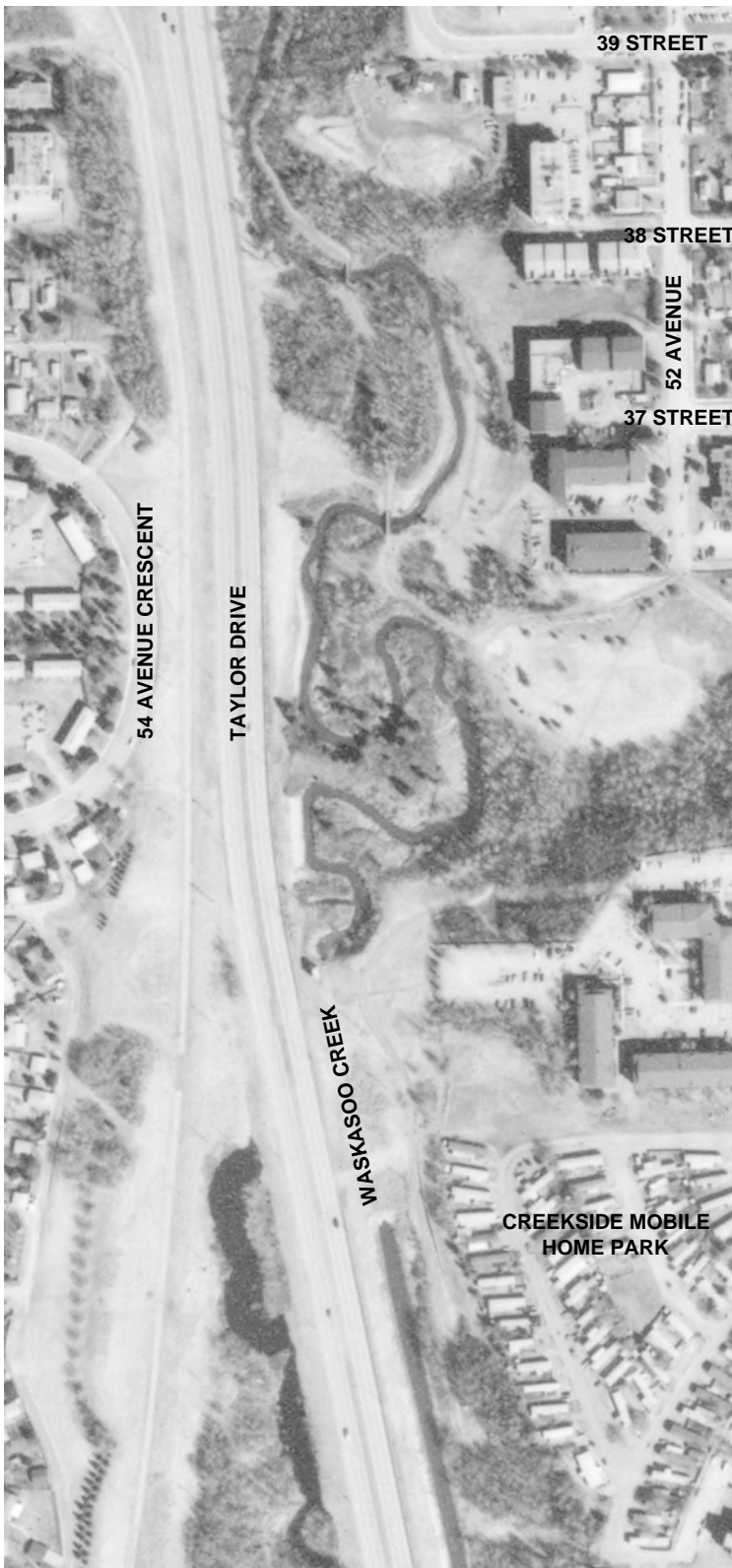


NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED SEPTEMBER 13, 1994.

SCALE (metres)



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EAST WASKASOO CREEK VALLEY SLOPES			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:4000	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-4A	

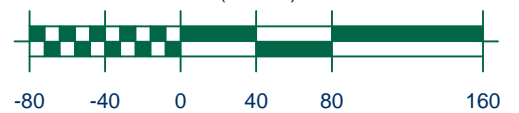




NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED APRIL 28, 1997.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016

SCALE (metres)





	<p>CLIENT:</p> 	<p>AERIAL PHOTOGRAPHS</p>			
		<p>CITY OF RED DEER SLOPE STABILITY EVALUATION EAST WASKASOO CREEK VALLEY SLOPES</p>			
		<p>DRAWN: NC</p>	<p>CHK'D.: MDB</p>	<p>REV #: 2</p>	<p>DATE: APRIL 2019</p>
		<p>SCALE: 1:4000</p>	<p>JOB NO. RD6500-24/25</p>		<p>DRAWING NO. FIGURE 24-4B</p>



PHOTOGRAPH 1 (2018): CREEK AND WETLAND ADJACENT TO THE ROYAL OAK SLOPE, FACING EAST



PHOTOGRAPH 2 (2018): ROYAL OAK SLOPE FACE, LOOKING UP THE SLOPE, FACING NORTH

	CLIENT:		SITE 24/25 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION EAST WASKASOO CREEK VALLEY SLOPES			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.	
		NTS	RD6500-24/25		FIGURE 24-5A	



**PHOTOGRAPH 4 (2018): ROYAL OAK SLOPE FACE, LOOKING
ACROSS THE SLOPE, FACING NORTHWEST**



PHOTOGRAPH 8 (2018): ROYAL OAK CREST OF SLOPE, LOOKING ACROSS THE SLOPE, FACING SOUTHEAST



CLIENT:



SITE 24/25 PHOTOGRAPHS

**CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES**

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: NTS	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-5B	



PHOTOGRAPH 16 (2018): TENSION CRACKS ALONG CREST OF 1982 LANDSLIDE SLOPE, FACING NORTHWEST



PHOTOGRAPH 18 (2012): 1982 LANDSLIDE SLOPE AREA BETWEEN APARTMENTS, FACING WEST



PHOTOGRAPH 18 (2018): 1982 LANDSLIDE SLOPE AREA BETWEEN APARTMENTS, FACING WEST



CLIENT:



SITE 24/25 PHOTOGRAPHS

**CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES**

DRAWN:	CHK'D.:	REV #:	DATE:
PS	MDB	2	APRIL 2019
SCALE:	JOB NO.	DRAWING NO.	
NTS	RD6500-24/25	FIGURE 24-5C	



PHOTOGRAPH 26 (2018): 1982 LANDSLIDE FLOOD PLAIN AND FORMER CREEK ROUTE AREA, FACING EAST



PHOTOGRAPH 28 (2018): REALIGNED WASKASOO CREEK, FACING NORTHEAST (1982 LANDSLIDE)

	CLIENT:		SITE 24/25 PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION EAST WASKASOO CREEK VALLEY SLOPES			
			DRAWN:	CHK'D.:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
NTS		RD6500-24/25		FIGURE 24-5D		



PHOTOGRAPH 67 (2018): 1991 LANDSLIDE SLOPE AND RETAINING WALL ALONG WALKING TRAIL, FACING SOUTHEAST



PHOTOGRAPH 68 (2018): 1991 LANDSLIDE SLOPE FACE, LOOKING ACROSS THE SLOPE, FACING NORTHWEST



PHOTOGRAPH 74 (2018): 1991 LANDSLIDE SLOPE AND PISTOL-BUTT TREE, FACING EAST



PHOTOGRAPH 78 (2018): TOE OF 1991 LANDSLIDE SLOPE, FACING SOUTHEAST



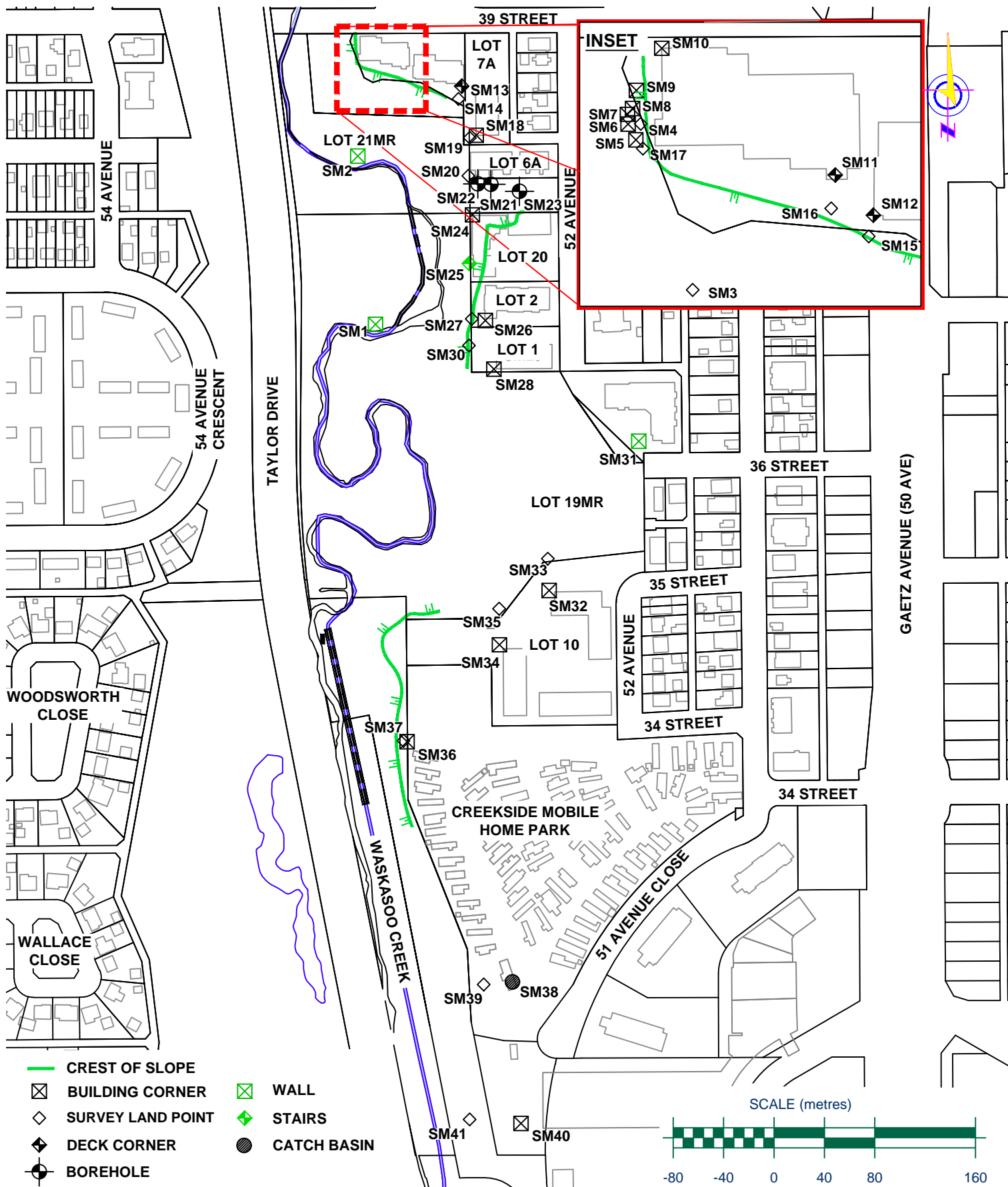
CLIENT:



SITE 24/25 PHOTOGRAPHS

**CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES**

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: NTS	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-5E	



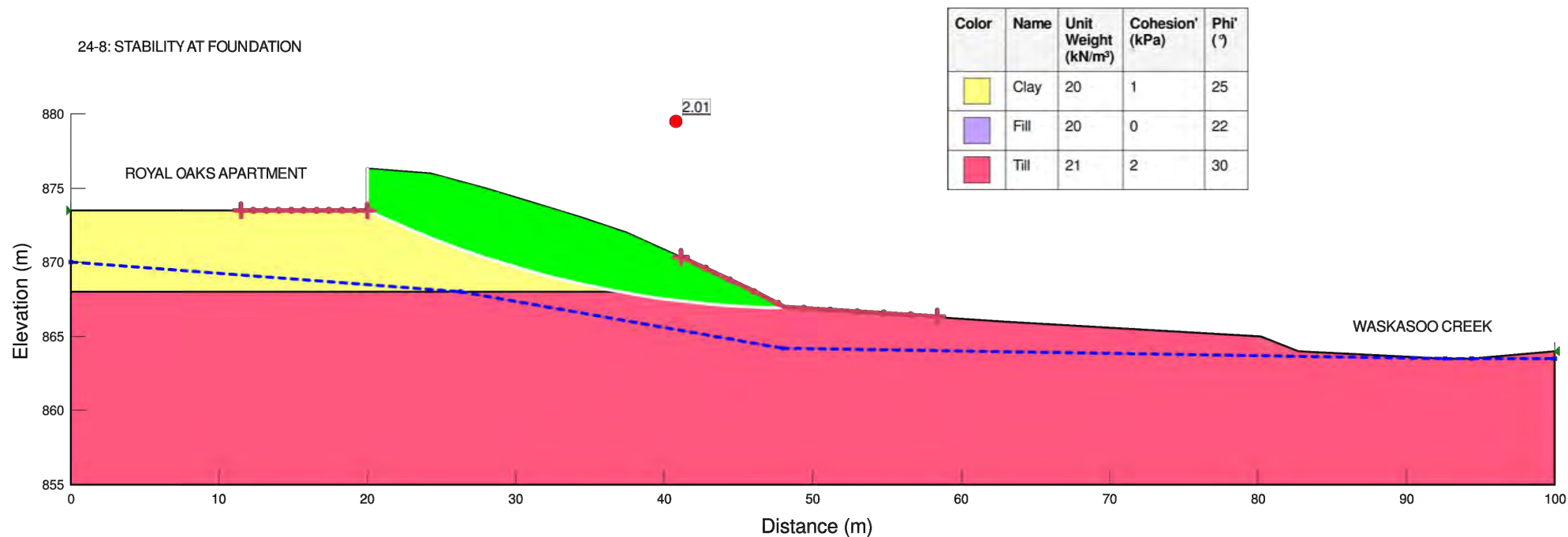
CLIENT:



SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
EAST WASKASOO CREEK VALLEY SLOPES

DRAWN: RS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:4000	JOB NO. RD6500-24/25	DRAWING NO. FIGURE 24-6	

24-8: STABILITY AT FOUNDATION



	<div>CLIENT:</div> <div></div>	STABILITY ANALYSIS RUN			
		CITY OF RED DEER SLOPE STABILITY EVALUATION EAST WASKASOO CREEK VALLEY SLOPES			
		DRAWN:	CHK'D.:	REV #:	DATE:
		NC	MDB	2	APRIL 2019
		SCALE:	JOB NO.		DRAWING NO.
		AS SHOWN	RD6500-24/25		FIGURE 24-8

SITE #24/25 - EAST WASKASOO CREEK VALLEY SLOPES

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 24-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM24-001	Wall	5793392.36	307527.33	867.06				
#SM24-002	Wall	5793525.98	307513.29	865.52				
#SM24-003	Toe	5793573.22	307521.09	864.65				
#SM24-004	Concrete	5793607.62	307520.25	876.74				
#SM24-005	Wall	5793604.45	307519.30	875.95				
#SM24-006	Wall	5793607.59	307517.77	876.13				
#SM24-007	Wall	5793609.45	307517.70	876.08				
#SM24-008	Wall	5793610.68	307518.65	876.26				
#SM24-009	Wall	5793614.28	307519.42	876.43				
#SM24-010	Building	5793622.63	307524.43	877.16				
#SM24-011	Deck	5793597.49	307558.85	876.97				
#SM24-012	Deck	5793589.52	307566.39	876.71				
#SM24-013	Deck	5793581.58	307600.81	877.06				
#SM24-014	Culvert-Crest	5793571.23	307598.22	876.56				
#SM24-015	Crest	5793585.30	307565.48	876.18				
#SM24-016	Crest	5793590.84	307558.03	876.51				
#SM24-017	Crest	5793602.73	307520.68	876.02				
#SM24-018	Building	5793542.60	307612.36	875.16				
#SM24-019	Crest	5793540.60	307607.06	874.36				
#SM24-020	Building-Crest	5793510.47	307606.27	872.85				
#SM24-021	BH1	5793503.64	307623.85	872.98				
#SM24-022	BH6	5793504.00	307613.49	871.94				
#SM24-023	BH	5793497.98	307641.56	872.85				
#SM24-024	Building	5793478.46	307606.67	866.98				
#SM24-025	Stairs	5793440.63	307601.71	873.22				
#SM24-026	Building	5793395.43	307614.51	875.83				
#SM24-027	Crest	5793396.76	307602.90	874.94				
#SM24-028	Building	5793356.79	307621.20	876.32				
#SM24-029	Building	5793374.64	307621.63	876.07				
#SM24-030	Crest	5793375.78	307600.95	875.94				
#SM24-031	Wall	5793294.75	307725.91	877.99				
#SM24-032	Building	5793176.09	307654.72	878.34				
#SM24-033	Wall-crest	5793201.39	307653.25	878.15				
#SM24-034	Building	5793133.02	307615.30	878.24				
#SM24-035	Crest	5793161.67	307614.96	877.59				
#SM24-036	Building	5793055.99	307542.01	877.93				
#SM24-037	Crest	5793056.76	307538.95	877.89				
#SM24-038	CB	5792865.22	307625.59	877.66				
#SM24-039	Crest	5792863.41	307602.75	877.35				
#SM24-040	Building	5792752.95	307632.43	878.81				
#SM24-041	Crest	5792756.34	307591.56	878.06				

TABLE 24-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD		COMMENT
		NORTHING	EASTING		2012	2018	
#P24-001	Creek and wetland adjacent to slope	5793516	307507	E		Y*	Royal Oak
#P24-002	Slope face	5793552	307535	N		Y*	Royal Oak
#P24-004	Slope face	5793576	307530	NW		Y*	Royal Oak
#P24-008	Crest of slope	5793591	307521	SE		Y*	Royal Oak
#P24-016	Tension cracks along crest of slope	5793504	307620	NW		Y*	1982 Landslide
#P24-018	Slope area between apartments	5793493	307642	W	Y*	Y*	1982 Landslide
#P24-026	Flood plain & former creek route area	5793386	307541	E		Y*	1982 Landslide
#P24-028	Realigned Waskasoo Creek	5793385	307528	NE		Y*	1982 Landslide
#P24-067	Slope and retaining wall along trail	5793014	307528	SE		Y*	1991 Landslide
#P24-068	Slope face	5792982	307548	NW		Y*	1991 Landslide
#P24-074	Slope and pistol-butt tree	5792939	307547	E		Y*	1991 Landslide
#P24-078	Toe of slope	5792890	307558	SE		Y*	1991 Landslide

Notes:

2012 Photographs from PG File #RD4167

* Provided in the report

All measurements in metres

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	24/25	
Site Name	Waskasoo Creek Mobile and Royal Oaks	
Legal Land Description	NW 8-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	307560 E, 5793380 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 30, 2018	3	10	30
Inspected By:	Bryden Lutz – PGEO Mark Brotherton - PGEO			
Report Attachments:	71 Royal Oaks photos 39 Waskasoo Creek Mobile photos			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded	N/A	
Slope Movement	Tension cracks between buildings at 3718 52 nd Ave	N/A	
Erosion	<ul style="list-style-type: none"> Erosion at creek bank, but a large buffer from slope toe. Exposed culvert west of north bridge from creek erosion. 	N/A	
Seepage	None observed	N/A	
Distress	Soil piled at trees near toe of 5211 39 th Street	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments:	<ul style="list-style-type: none"> Creek rerouted in 1980s to stabilize slope and straightened through culvert when Taylor Drive built. 		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Minor movement of fill on slope below 5211 39th Street- Signs of old movement at pavement near slope near slope reconstructed/ creek rerouted (very old cracks).
Assessment	<ul style="list-style-type: none">- Slope appears stable.
Recommendations	<ul style="list-style-type: none">- Consider site inspections every 3 years or after high water/ creek flooding event.

SITE #26



North Highway Connector – CN Rail Landslide

SITE #26 - NORTH HIGHWAY CONNECTOR - WEST SLOPE

26.1 SITE DESCRIPTION

Site #26 is the Northlands Drive road cut in the west river valley slope, as shown on Figure 1 of the main report. Northlands Drive will be the future extension of Highway 11A east Gaetz Avenue which is part of the City of Red Deer's North Highway Connector (NHC) project. Northlands Drive is a proposed six lane expressway looping around the northeast corner of the City connecting Highway 11A to Highway 11. This road will be constructed in phases over the next twenty years. Proposed development at Site #26 will include a bridge over the CN Rail line near the base of the river valley slope. The Site Plan of the area is shown as shown on Figure 26-1. For the purposes of discussion, the road stationing from the NHC design drawings will be used with Station 0+000 m located at the center of Gaetz Avenue.

The proposed Northlands Drive alignment is the site of an ancient landslide which had been reactivated on two documented occasions in the past 40 years including during the NHC road embankment construction in 2011. The road embankment has been rough graded to a top width of roughly 50 m. The proposed alignment curves to the southeast moving down slope, crossing the CN Rail line on the lower part of the slope at Station 0+550 m. The current road grades were a cut into the upper slope above elevation 870 m and between Stations 0+250 and 0+480 m. The 4H:1V side slope cuts are to 14 m high. The lower half of the slope is covered with a large embankment between Station 0+480 and 0+880 m. The road embankment has a 26 m wide gap for the rail line. Temporary 11 m high 2H:1V head slopes for the embankments are located on either side of the track. The embankment side slopes are 4H:1V and up to 18 m high with the thickest fills at Station 0+620 m about 70 m east of the rail line. The gap in the embankment will be filled in with future MSE walls to support the proposed overpass bridge above the rail line.

The original crest elevation of the river valley slope in this area was 878 to 879 m and the estimated pre-landslide crest location prior was about 410 m east of Gaetz Avenue. The original toe of the slope was at Station 0+610 m on the west edge of the river flood plain at an elevation of 844 to 846.5 m, making the original slope about 34 m high. The original slope had an average 3.5H to 4H:1V inclination with some steepened sections up to 1.5H:1V. The steepened section just south of the alignment about 370 m west of Gaetz Avenue (ie. 45 m east of the estimated pre-landslide crest) was considered to be the back scarp of the old landslide. The 20 to 50 m wide terrace found between elevations 865 and 874 m was considered to be the top of the old slide mass. An old abandoned rail bed was located parallel to the toe on this terrace. The existing CN Rail line was located on small embankment at an elevation of 856 m, roughly 10 m above the flood plain. The gentle slopes below 870 m were considered to be colluvium. The Red Deer River is located about 400 m east of the site at the closest approach. The 2016 ortho-contours are shown on Figure 26-2. Representative cross-sections through the center of the area are provided on Figure 26-3 for the original, construction and final embankment profile.

Township Road 390 north of the new road alignment provides access to an acreage at the crest of the river valley. Commercial development is located to the northwest and south west of the road allowance. The Red Deer Waste Water Treatment facility and lagoons are located to the east of the site in the river valley. Power lines run almost perpendicular up the slope north of the road embankment and another line is strung across the road embankment trunks for using power poles on either side of the road right-of-way about 60 m west of the rail line. The road was constructed with service right-of-ways at the north edge of the road embankment for City and regional water, sewer and storm trunks. Historical aerial photographs are provided on Figures 26-4A and 26-4B and selected site photographs are provided on Figures 26-5A to 26-5C.

26.2 REFERENCES

The references from Appendix B which have information for Site #26 include References #85 to #91. The most recent site investigation for the site was performed for the NHC project in 2008 prior to embankment construction (Reference #88). Other historical information was available in the construction QA and slope monitoring project files from 2011 to 2012 (Reference #91).

26.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

Prior to construction in 2011, over 40 boreholes had been drilled around this site for five road and servicing projects; including 17 boreholes for design of the NHC - CN Rail Overpass project. This site investigation included installation of four slope indicators which were decommissioned during construction. The locations of the pre-construction boreholes are shown on Figure 26-6. During 2011 construction, additional boreholes were drilled to install five new slope indicators and nine pneumatic piezometers. Four of the 2011 slope indicators are still present at site at the locations shown on Figure 26-1.

26.4 2118 REVIEW

Aerial photography is provided on Figures 26-4A and 26-4B, for the years listed in following table. There was no coverage available during the time of original embankment construction in 2011.

TABLE 26-1: AERIAL PHOTOGRAPHS

Year	Description
2010	Shows the original site condition prior to the road construction.
2013	Shows the condition shortly after the 2011/2012 road construction.
2016	Shows the present site condition.

Site #26 was visited on October 29 and November 20, 2018. A copy of the field inspection record is attached in this appendix.

The ortho-contours from 2016 City aerial photography and 2018 drone survey were reviewed for this study. Historical survey information for the slope was compiled from two primary sources: the 2009 geotechnical report (Reference #88) and the construction plans and surveys provided by ISL Engineering Ltd. in 2011 and 2012. A record of survey control points and data is appended in Table 26-4. A reference drawing of survey reference points is provided on Figure 26-7.

Selected site photographs from 2011 and 2018 are provided on Figures 26-5A to 26-5C. A photograph summary is appended in Table 26-5. A reference drawing of photograph locations is provided on Figure 26-8.

26.5 SLOPE BACKGROUND

This site was an ancient landslide area which created a small ravine in the west river valley wall. The estimated location of the original back scarp is shown on Figure 26-1. The upper slope appears to have failed and flowed out over the toe of the original lower till slope face, spilling colluvium up to 50 m into the flood plain. The colluvium formed a couple terraces, with a wider dipping terrace at about elevation 870m and a smaller terrace at about 856 m. Both terraces were used for rail line beds aligned across the slope face. The upper rail line was abandoned circa 1960 when the lower track was constructed.

In 1990, the lower part of the colluvium slope experienced a small landslide which affected the CN Rail line just north of the proposed Northlands Drive centre-line. CN Rail de-watered the slope face with several shallow trenches on either side of the rail tracks and a fill toe load was placed on top of the old colluvium east of the tracks to stabilize the slope below the rail bed. This created a 20 m wide terrace and a gently graded slope at the toe of the slope east of the rail line.

In 2008, work began on the design of Northlands Drive for the NHC project. One of the main project requirements was to design an overpass for the CN Rail line. The geotechnical assessment for the project verified the rail embankment was built on old colluvium and the profile of the buried lower till slope was defined. The profile for the overpass required a cut to fill transition at an elevation of about 870 m. If a straight fill operation was proposed, this would require embankment fill to be built on top of colluvium materials of suspect quality and stability. Due to the required gap in the embankment for the rail line, the up-slope embankment west of the tracks was considered to be unstable based on this configuration. The design option selected for this project was to sub-cut and remove all of the colluvium on the west side of the tracks with a cut slope graded to 8 percent. This would expose competent clay till at the head slope location west of the tracks; and allow a thick gravel foundation for the future MSE wall to be keyed into the undisturbed till.

The road embankment was then to be brought back up with select clay fill to a final 4 percent design grade west of the rail line. A matching embankment fill with a 6 percent grade was placed on top of the colluvium east of the rail line. To speed up settlement and reduce potentially destabilizing pore pressure development in the foundation soils, wick drains were installed in the head slope areas on both sides of the track; and the clay fill was placed on a thick drainage blanket in areas where the embankments were more than 5 m high. French drains were installed up-slope

subgrade and were tied into a drain in the gravel shear key foundation mat for the future MSE wall. This gravel mat was de-watered by a trenched drain discharging into the natural drainage course in the treed area south of the embankment.

The final embankment configurations were designed to provide a stable configuration upon completion. However, it was expected that the sub-cut slope west of the tracks could become unstable during the construction period, so the west shear key in the till was installed in segments. On May 18, 2011, during the sub-cutting operations, tension cracks were first observed west of the tracks at an elevation of about 860 m. The lower slope had started to slide and several more tension cracks propagated into the side-slope cut areas north and south of the road embankment as shown on Figure 26-1. Five new slope indicators were installed at the site between June and August 2011. The depth of the sliding appeared to be consistent with the estimated depth of the colluvium from the original landslide. The sliding began to slow down as the fill material for the embankment was placed at the bottom of the slope. As filling progressed, tension crack areas were typically sub-cut 1 to 2 m, moisture conditioned and recompacted; sometimes with the addition of gravel fill to dry and stabilize the clay. Slope indicator measurements were taken on a regular basis until June 2012 to monitor slope movements. The area has not had any observed instabilities since the NHC landscaping work was completed in 2012.

26.5 SUBSURFACE PROFILE

Site #26 has experienced both ancient landsliding and significant grading. The slope face below 874 m was covered with a layer of colluvium up to 8 m thick (est.). The original slope soil profile buried by the colluvium was till below an elevation of about 855 to 859 m. The till was overlain by silty lacustrine clay deposits which originally extended up from the top of the till at an estimated inclination of about 4H:1V. This lacustrine clay was draped with wind blown sands creating some steepened upper slope areas. The toe of the slope in the river valley consisted of alluvial silty clay and gravel layers of variable thickness. The local bedrock formation was encountered below the till or gravel. The current road embankment was built with select clay fill placed in 2011. The following is a brief description of the soil types encountered.

1. **Colluvium.** Old sand, silt and clay colluvium was present on the slope face to the north and south of the road embankment and below the road embankment to the east of the tracks. Colluvium was removed from the embankment footprint west of the tracks.
2. **Engineered Fill Berm.** The engineered fill of the road embankment was select, low to medium plastic clay fill, specified to have an internal angle of friction of at least 25° . The fill was placed and compacted to at least 95 percent of Standard Proctor Maximum Dry Density close to Optimum Moisture Content.
3. **Wind-Blown Sand.** The medium fine sand on the upper slope face was dry, windblown deposits. This loose to medium dense sand has traces of silt and the relative density increases with depth. The soil moisture content is typically less than 10 percent with possible wetter sand below the groundwater table.

4. **Silt, Sand and Clay.** The soil below the sand was inter-bedded lacustrine silt and clay. These deposits were medium plastic and wet with an average moisture content of about 25 percent. Strength testing indicates the internal angle of friction for the silty clay was 22.6° to 31° which is considered to be near the upper and lower bounds for this material.
5. **Till.** The till found below elevation 870 m. Both sand and clay tills were encountered in the boreholes. The clay till was medium plastic and very stiff to hard. Typical moisture contents were about 18 percent in the clay till and 12 percent in the sand till. Strength testing indicates the internal angle of friction for the till was 23.6° to 28.5° .
6. **Alluvial Silty and Clay.** In the river valley, the typical surficial deposits were silty clay with some fine sand. These alluvial soils were low to medium plastic and compact or stiff with moisture contents in the 15 to 25 percent range.
7. **Sand & Gravel.** Gravel deposits were encountered below the alluvial silts and clays. These sandy gravel deposits are non-plastic and medium dense to very dense. Moisture contents vary depending on depth relative to the groundwater table and the proportion of fines in the material.
8. **Bedrock.** The local interbedded clay shale and silt stone bedrock was encountered at an elevation of 840 to 845 m.
9. **Groundwater.** The depth to the groundwater table was generally within 4 to 7 m of surface, but there was some deeper variations relative to topographic changes.

The following effective strength parameters were assumed for this site.

TABLE 26-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Elevation (m)	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi, ϕ' (Degrees)
Select Clay Fill	Varies	18	0	25 - 28
Silty Clay Colluvium	Varies	18	0	19 - 25
Upper Sand	Above 872	19	0	30
Lacustrine Clay	860 - 872	19.5	0 - 2	25 - 28
Clay Till	840 - 860	21	2 - 10	28 - 32
Alluvial Silt & Clay	Varies	18	0 - 2	25
Gravel	Varies	21	0	35
Bedrock	Below 840	21	5 - 10	40

For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix B.

26.7 STABILITY ASSESSMENT

26.7.1 Slope Indicator Measurements

This slope has been extensively measured for landslide movement. The existing slope indicators were installed in the slope west of the rail line to monitor 2011 slope movements during construction. The following is a summary of the 2011 installations:

- **SI-A** - Located on the south cut slope down-slope of the initial 2011 tension cracks. SI-A indicated a failure plane about 7.8 mbg (elevation 863 m) which experienced about 50 mm of movement to 2012. There has been less than 10 mm of movement since June 2012.
- **SI-B** - Located above the 2011 tension cracks on the north cut slope. SI-B was installed to monitor the local access road and never registered any movement in 2011/2012.
- **SI-C** - Located near the crest of the west head slope west of the shear key. This SI has experienced minor movements (less than 10 mm in seven years) which are considered to be indicative of frost action and consolidation creep of the embankment, not sliding.
- **SI-E** - Located near the toe of the west head slope east of the shear key. SI-E indicated movement on a failure plane about 2 mbg (elevation 858 m). Surface movement above this zone was in the order of 90 mm with less than 20 mm since June 2012.
- **SI-M** - Located near the northeast corner of the toe of the west head slope. SI-M was close to shearing off about 1.5 mbg in 2012. The SI was completely sheared at this depth in 2018, so no measurement were taken after 2012.

Slope indicators SI-1A, SI-C and SI-E are still operable. SI-B was removed to allow construction of vault for a local service trunk. Overall, the SI readings suggest minor movements are still occurring along the slip plane in the south cut slope and colluvium east of the shear key, but the rate of movements are much less than those observed from June 2011 to June 2012. The road embankment on the slope above the shear key does not appear to be moving (SI-C). All colluvium in this area was removed; including the old slip plane. Slope indicator plots for SI-1A, SI-C, SI-E and SI-M are provided on Figure 26-9A to 26-9D.

26.7.2 Analysis

Extensive stability analysis was undertaken in 2011 for the assessment of the original site conditions and development of the embankment design that was constructed in 2011. For details of that analysis please refer to Reference #88. Stability analysis of the existing conditions seven years after construction, was undertaken using the SLOPE/W computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 26-3: 2018 SLOPE STABILITY ESTIMATE

Case		FS	Figure
Construction Slope	Failure Condition in Colluvium	0.9	-
Existing Road Slope	Global Stability of Road Embankment	1.2	26-10
Existing North Cut Slope	Global Stability in Colluvium	1.3	-
4H:1 Final Side Slope	Shallow Failure in 14 m High East Slope Face	1.5	-
2H:1 Head Slope	Shallow Failure in 11 m High West Slope Face	1.1	-
2H:1 Head Slope	Shallow Failure in 11 m High East Slope Face	1.3	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above. Note, this stability review did not readdress future site MSE wall development for the CN Rail overpass.

26.7.3 Slope Stability Summary

Site #26 is a road grade cut and constructed down the west river valley wall. The site has 4H:1V cuts in the original upper slope and engineered embankment fill slopes flanked by mature river valley slopes to the north and south. The engineered road embankment was designed to stabilize this historical landslide area and these slopes have not experienced major instability over the past seven years since construction was completed. The road embankment has a rough graded top, all of the slopes are grassed and the road side ditches have erosion protection.

The long-term assessment at this site is that the potential for a major slope movement of the embankment is very low under present conditions with reasonable variation. The risk of face instability in the cut slopes has been reduced, because tension cracks were sub-cut and recompacted; and the groundwater table has been lowered by de-watering measures associated with the embankment construction. The FS against a small shallow “slump-type” failure on the cut slopes and the temporary fill head slopes are estimated to be at least 1.1. Shallow slope face slumping is considered to be the most likely mode of slope failure in the area, but with the present vegetation cover it would take unusually wet conditions to cause a shallow slump in the exposed face. The private property to the north and south of the site are not at risk.

26.8 DETAILED RISK RANKING

The risk level for this site has been assessed as follows:

PF(5) * CF(2) = 10 - Road Embankment on the River Valley (Landside) Slope

A Probability Factor of 5 is considered appropriate. The old landslide colluvium has been stabilized by partial removal and placement of a large embankment on the lower slope. However, two of the three slope indicators around the embankment still show minor, but decreasing movements at the old slip plane. The most likely type of slope failure in this embankment would be a surficial slump of the landscaped side slopes which would not require a road closure. Therefore, a Consequence Factor of 2 is considered appropriate.

PF(7) * CF(2) = 14 - Re-Graded Cut Slopes

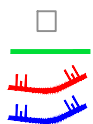
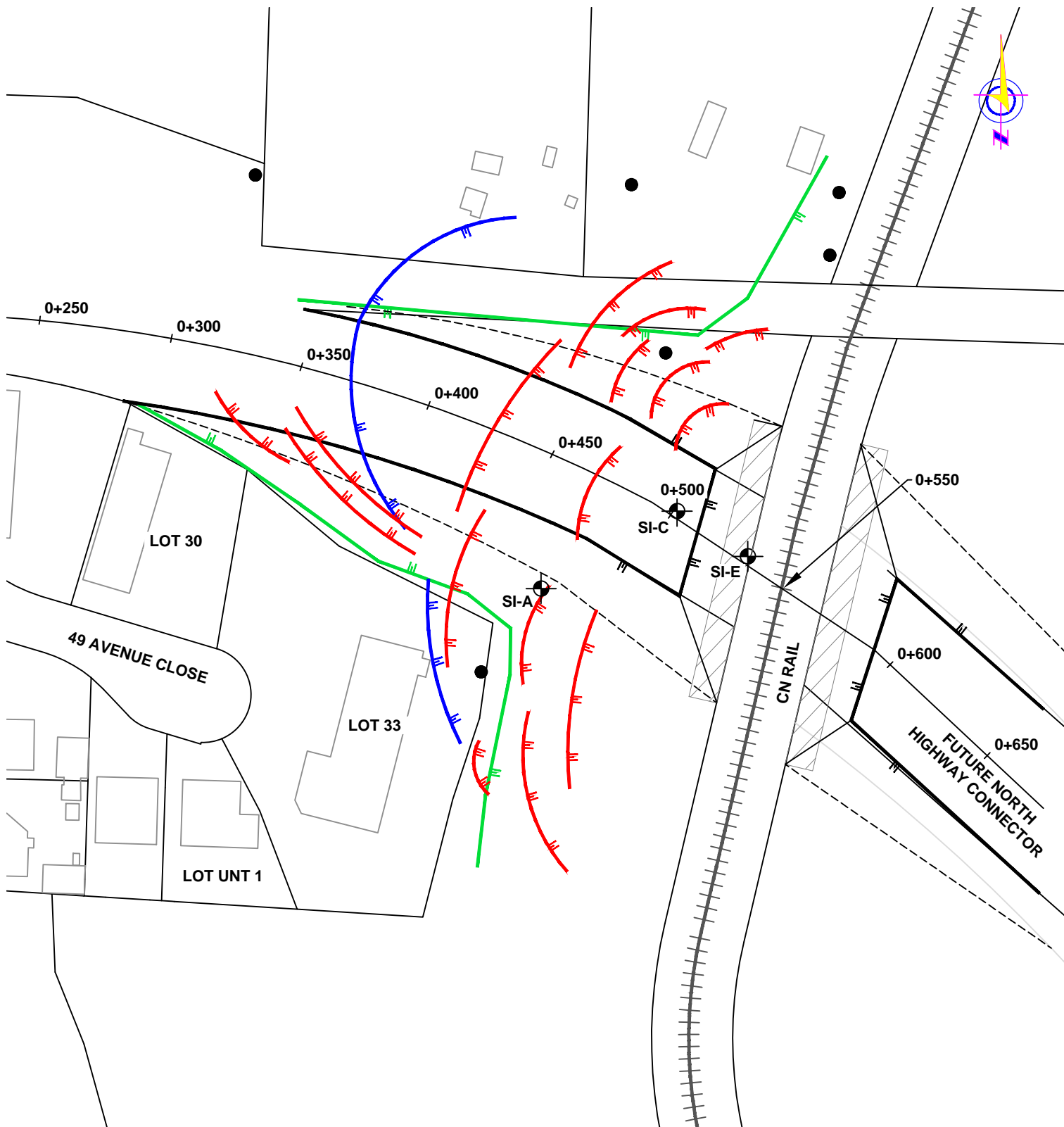
A Probability Factor of 7 is considered appropriate since the upper cut slopes are still experiencing minor movement and the probability of small slide in these areas is moderate to high. A Consequence Factor of 2 is considered appropriate since the expected size of a small slump in these cut slopes is unlikely to affect private property or the future road, but may impact the power poles near the areas of the 2011 sliding.

26.9 RECOMMENDATIONS

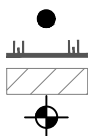
The recommended course of action at this site is to undertake site inspections of the slope on an annual basis to identify any significant changes; with additional inspections on an "as required" basis. All inspections should include slope indicator measurements and control surveys at fixed points to verify movements in the area, if observed.

26.10 ATTACHMENTS

Figure 26-1 - Site Plan
Figure 26-2 - 2016 Contour Plan
Figure 26-3 - Cross Section Profiles
Figure 26-4 - Aerial Photographs
Figure 26-5 - Site Photographs
Figure 26-6 - Borehole Plan
Figure 26-7 - Survey Marker Plan
Figure 26-8 - Photograph Plan
Figure 26-9 - Slope Indicator Plots
Figure 26-10 - Stability Analysis Run
Table 26-4 - List of Survey Markers
Table 26-5 - List of Photographs
Site Inspection Record (October 29, 2018)

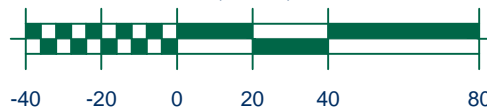


EXISTING BUILDINGS
CREST OF SLOPE
MAJOR 2011 TENSION CRACKS
ANCIENT BACK SCARP



POLES
EMBANKMENT
GRAVEL SHEAR KEY
SLOPE INCLINOMETER

SCALE (metres)



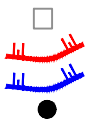
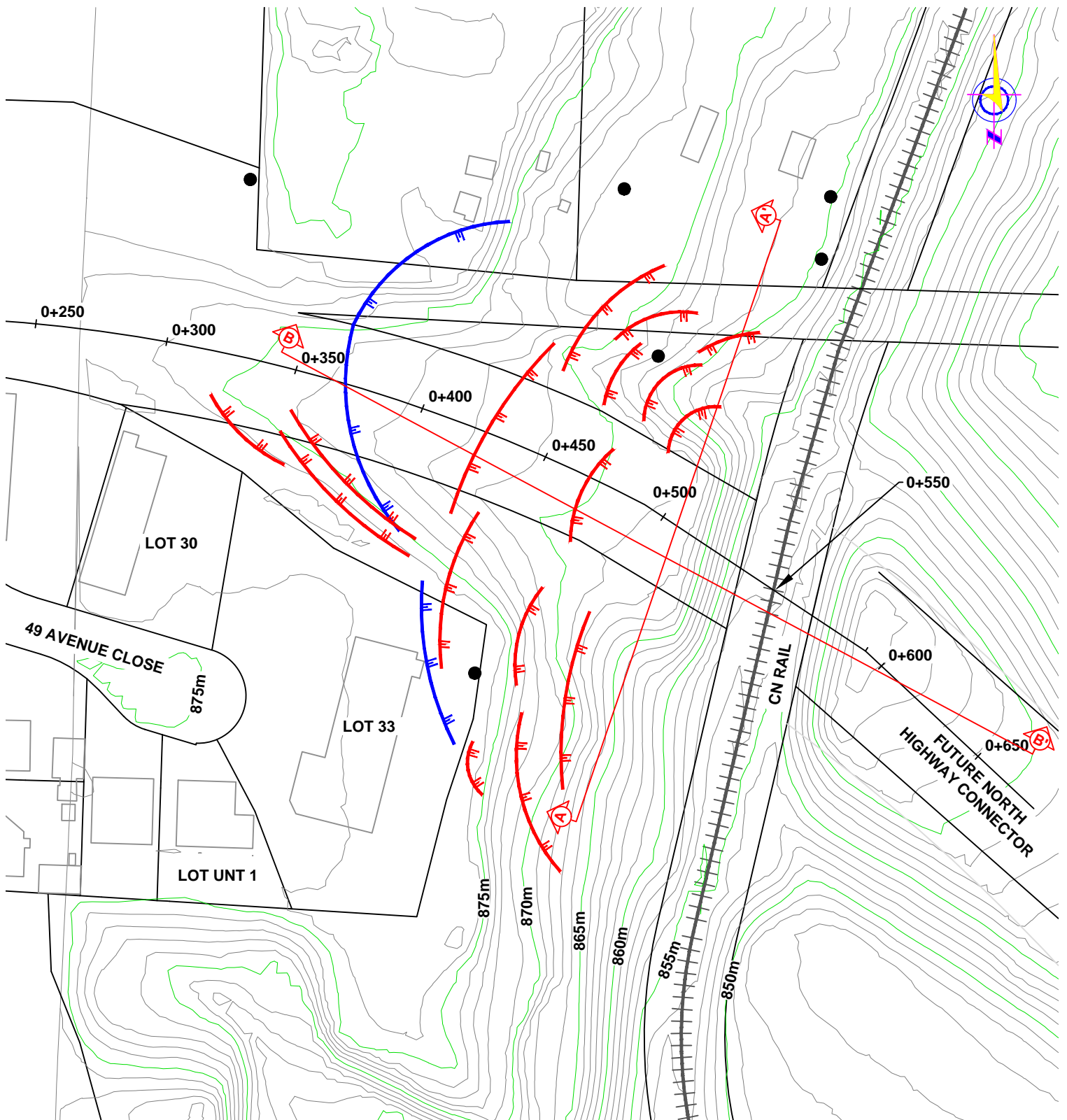
CLIENT:



SITE PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-1	



EXISTING BUILDING
2011 LANDSLIDES
ANCIENT LANDSLIDE
POLES

SCALE (metres)



NOTE: 2016 ORTHO PROVIDED BY THE CLIENT



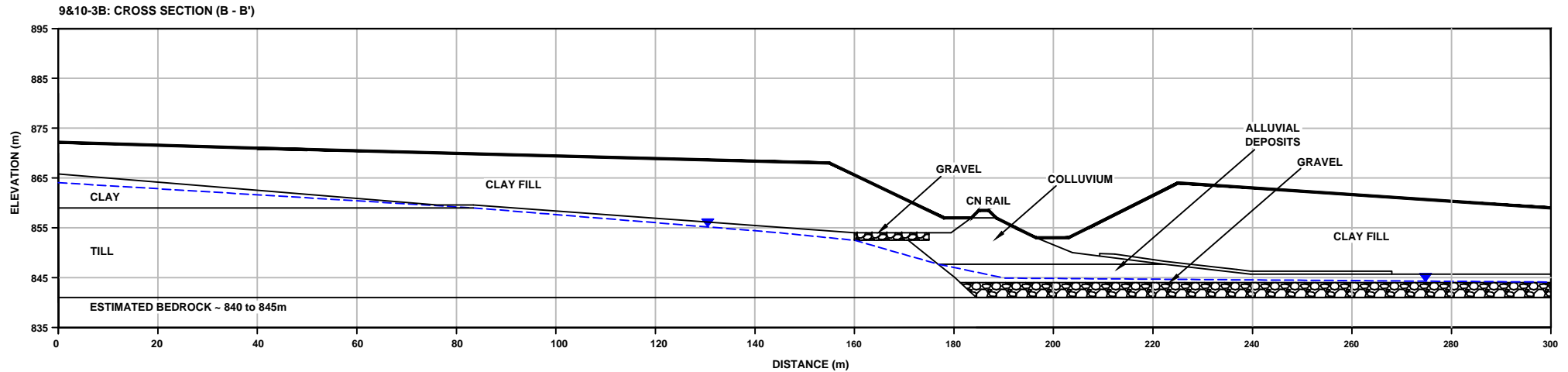
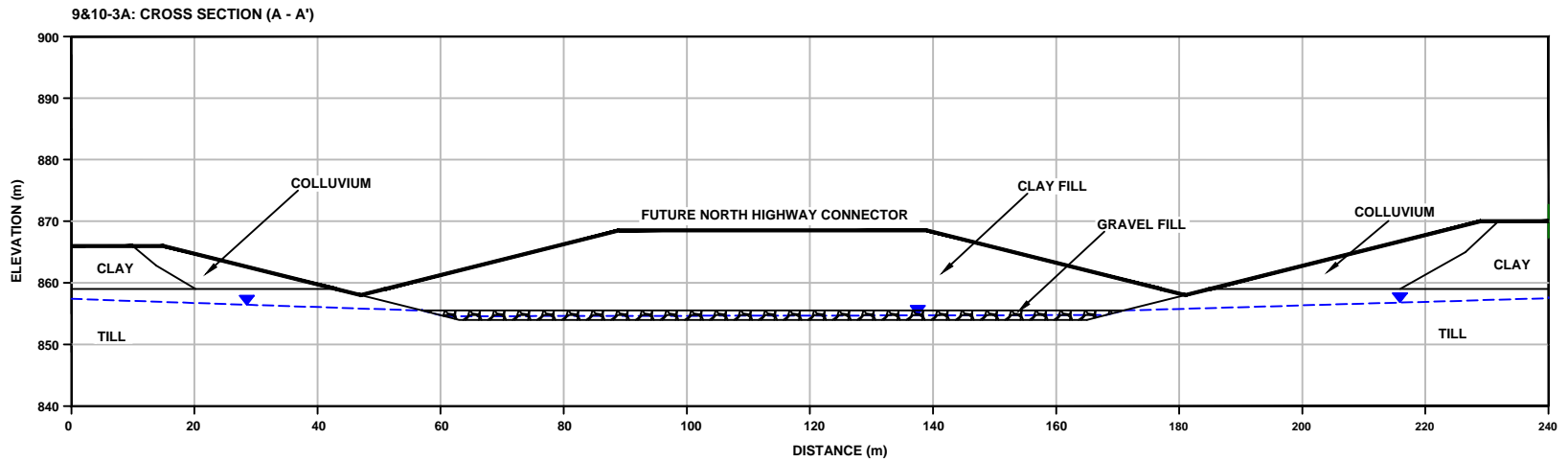
CLIENT:



CONTOUR PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-2	



PROFILE BASED ON ASBUILT PROVIDED BY ISL.



CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

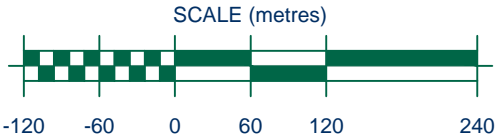
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SCALE: AS SHOWN	JOB NO. RD6500-9&10	DRAWING NO. FIGURE 26-3	



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2010.



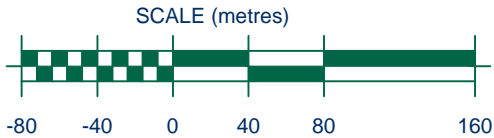
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2013.



	CLIENT: 	AERIAL PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION NORTH HIGHWAY CONNECTOR - WEST SLOPE			
		DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: 1:6000	JOB NO. RD6500-26		DRAWING NO. FIGURE 26-4A



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION NORTH HIGHWAY CONNECTOR - WEST SLOPE			
			DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
			SCALE: 1:4000	JOB NO. RD6500-26		DRAWING NO. FIGURE 26-4B



PHOTOGRAPH 9 (2018): POWER LINE ALIGNMENT ALONG THE CREST OF SOUTH SLOPE, FACING SOUTHEAST



PHOTOGRAPH 18 (2011): POWER LINE ALIGNMENT, FACING NORTHEAST



PHOTOGRAPH 18 (2018): POWER LINE ALIGNMENT, FACING NORTHEAST



PHOTOGRAPH 21 (2018): SOUTH SLOPE FACE, FACING WEST

	CLIENT: 	SITE 26 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION NORTH HIGHWAY CONNECTOR - WEST SLOPE			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-5A	



PHOTOGRAPH 49 (2011): SOUTH SLOPE FACE, FACING SOUTHWEST



PHOTOGRAPH 49 (2018): SOUTH SLOPE FACE, FACING SOUTHWEST



PHOTOGRAPH 50 (2018): NORTH SLOPE AND TOE OF SLOPE ALONG THE RAILWAY LINE, FACING NORTH



PHOTOGRAPH 60 (2018): NORTH SLOPE FACE AND TOE OF SLOPE, FACING SOUTHWEST

	CLIENT: 	SITE 26 PHOTOGRAPHS			
		CITY OF RED DEER SLOPE STABILITY EVALUATION NORTH HIGHWAY CONNECTOR - WEST SLOPE			
		DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
		SCALE: NTS	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-5B	



PHOTOGRAPH 69 (2018): NORTH SLOPE FACE ADJACENT TO THE RAILWAY LINE, LOOKING UP THE SLOPE, FACING WEST

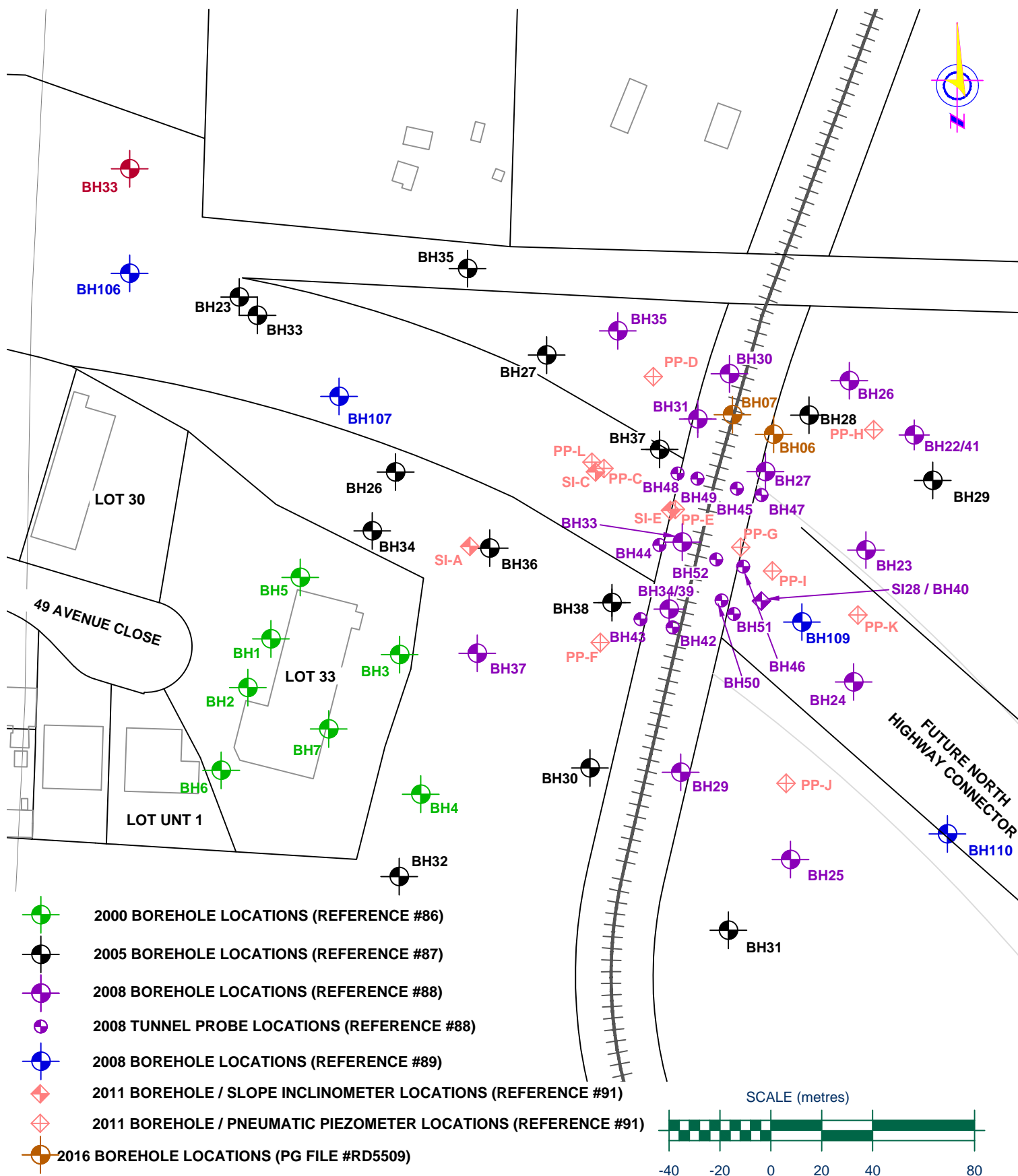


PHOTOGRAPH 77 (2018): NORTH SLOPE, FACING NORTHEAST



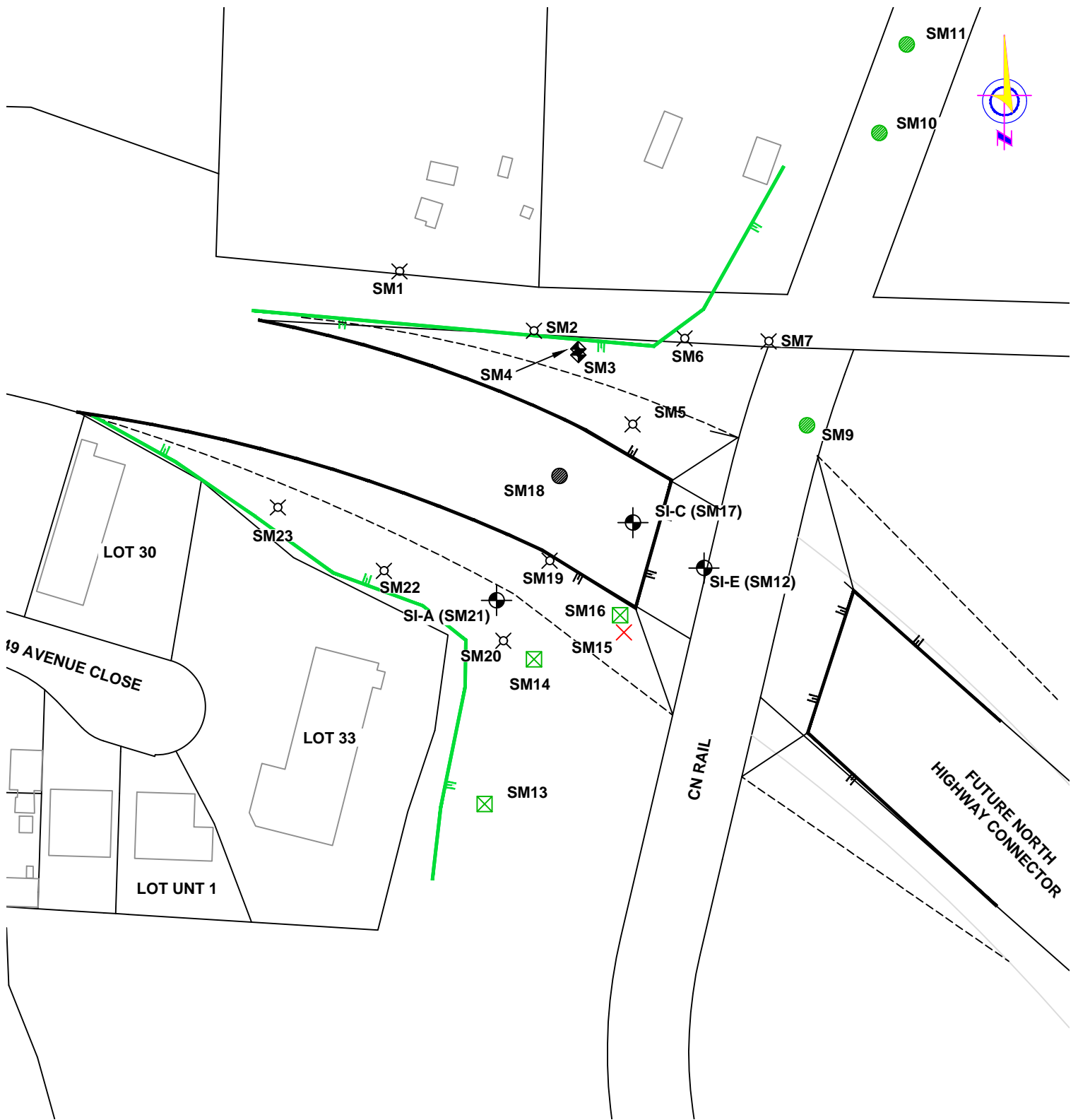
PHOTOGRAPH 85 (2011): NORTH HIGHWAY CONNECTOR SLOPE EMBANKMENT (POST-CONSTRUCTION), FACING WEST

	CLIENT:			SITE 26 PHOTOGRAPHS			
				CITY OF RED DEER SLOPE STABILITY EVALUATION NORTH HIGHWAY CONNECTOR - WEST SLOPE			
				DRAWN:	CHK'D.:	REV #:	DATE:
				PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.			
NTS		RD6500-26		FIGURE 26-5C			



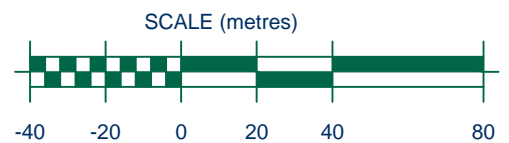
ALL BOREHOLE LOCATIONS ARE APPROXIMATE

	CLIENT:		BOREHOLE PLAN	
			CITY OF RED DEER SLOPE STABILITY EVALUATION NORTH HIGHWAY CONNECTOR - WEST SLOPE	
	DRAWN:	CHK'D:	REV #:	DATE:
	PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.
1:2000		RD6500-26		FIGURE 26-6



- CREST OF SLOPE
- CATCH BASIN
- ⊗ POWER POLE
- CULVERT

- × TOP OF DRAINAGE CHANNEL EROSION
- ⊙ SLOPE INCLINOMETER
- ⊗ FENCE POST / CORNER
- ◆ VALVE



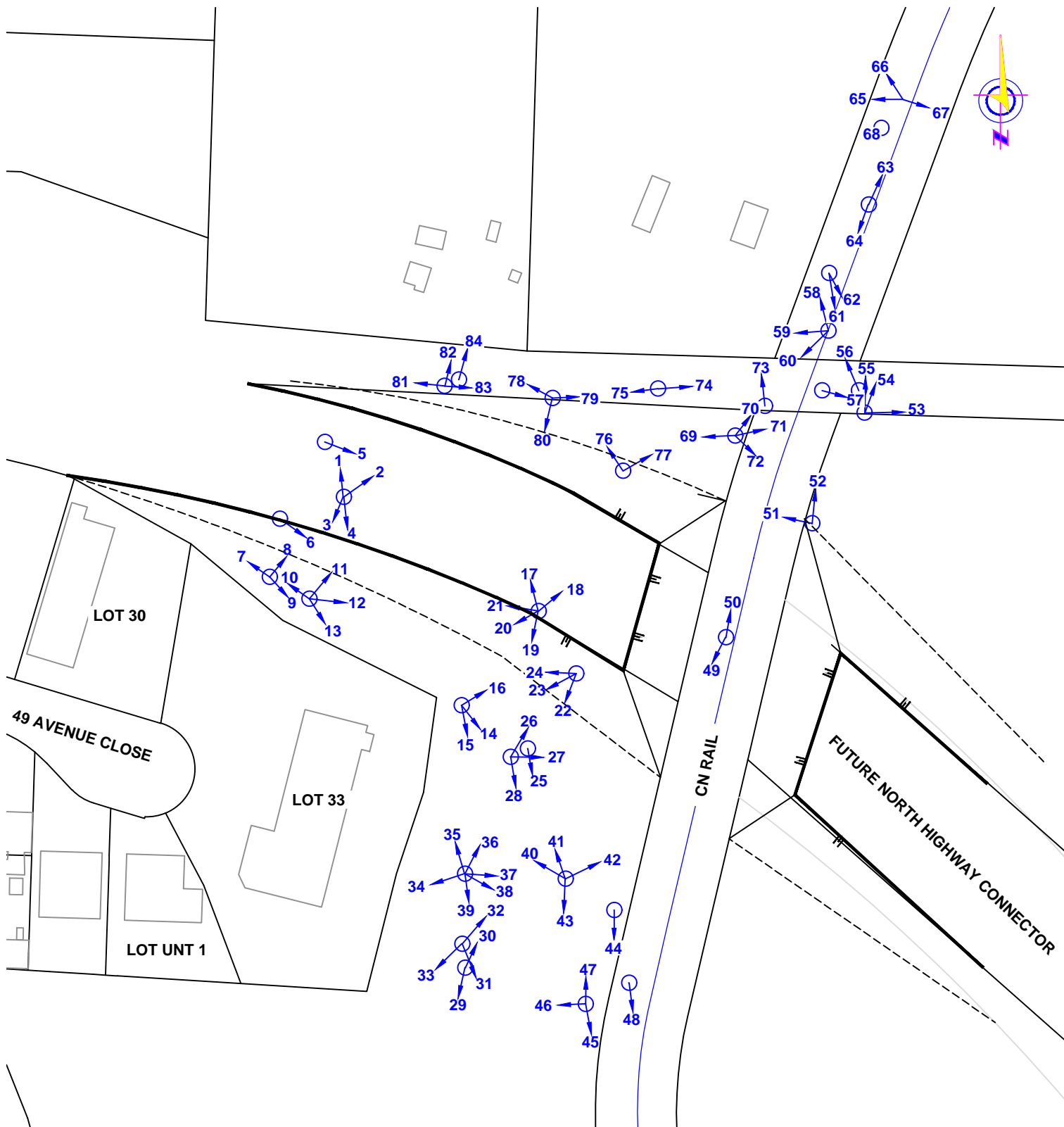
CLIENT:



SURVEY MARKERS

CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-7	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE

SCALE (metres)



CLIENT:

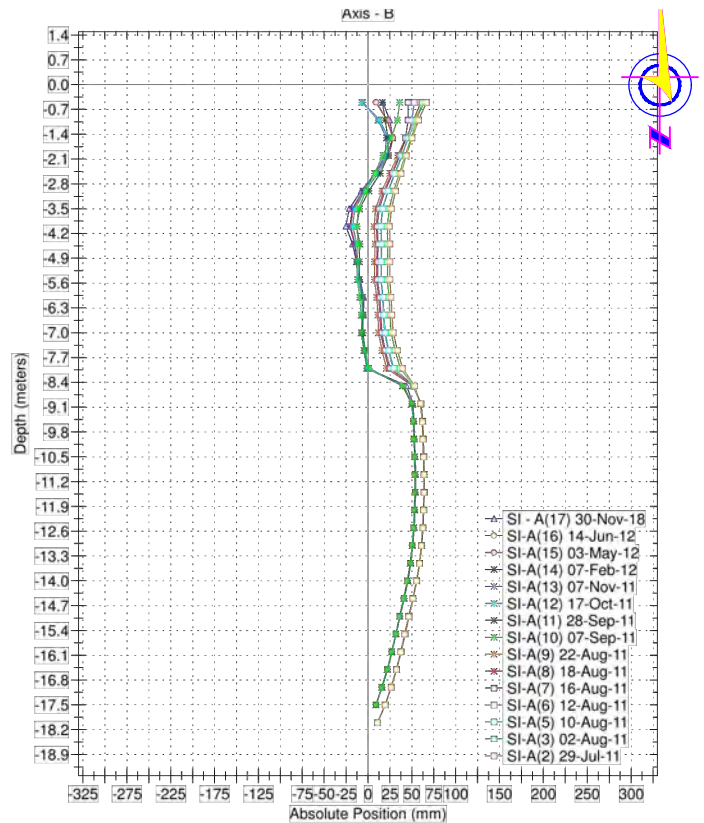
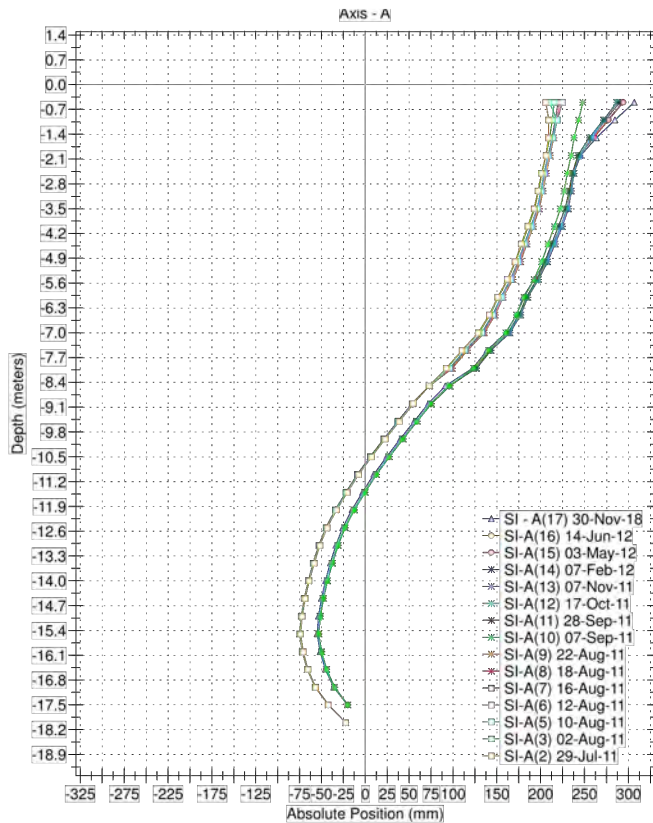


PHOTOGRAPH PLAN

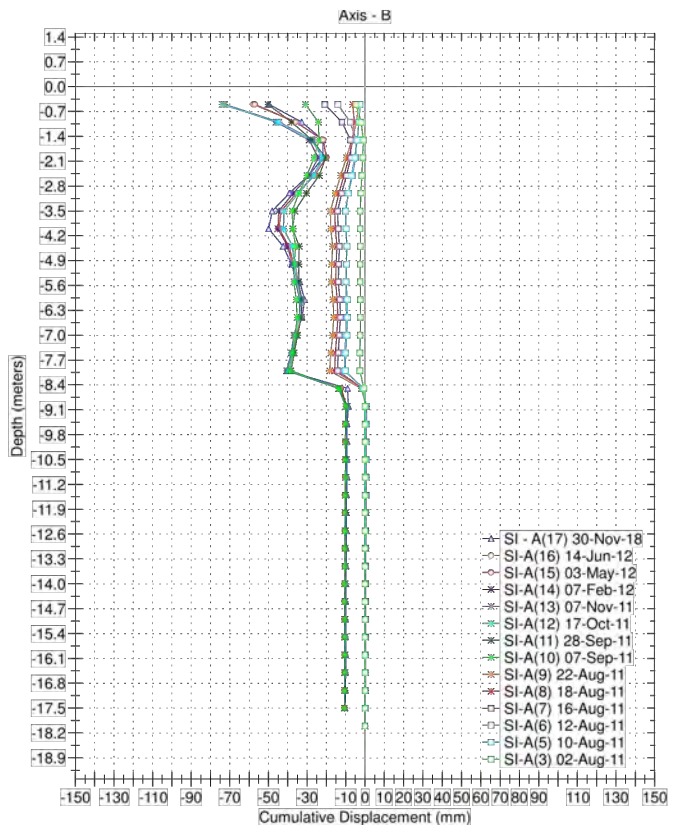
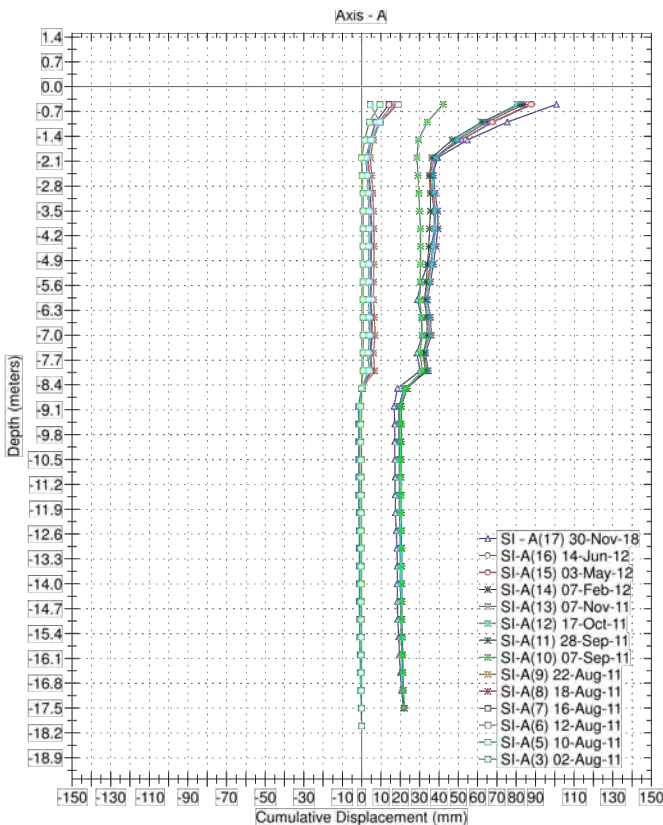
CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:2000	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-8	

ABSOLUTE POSITION



CUMULATIVE DISPLACEMENT



CLIENT:

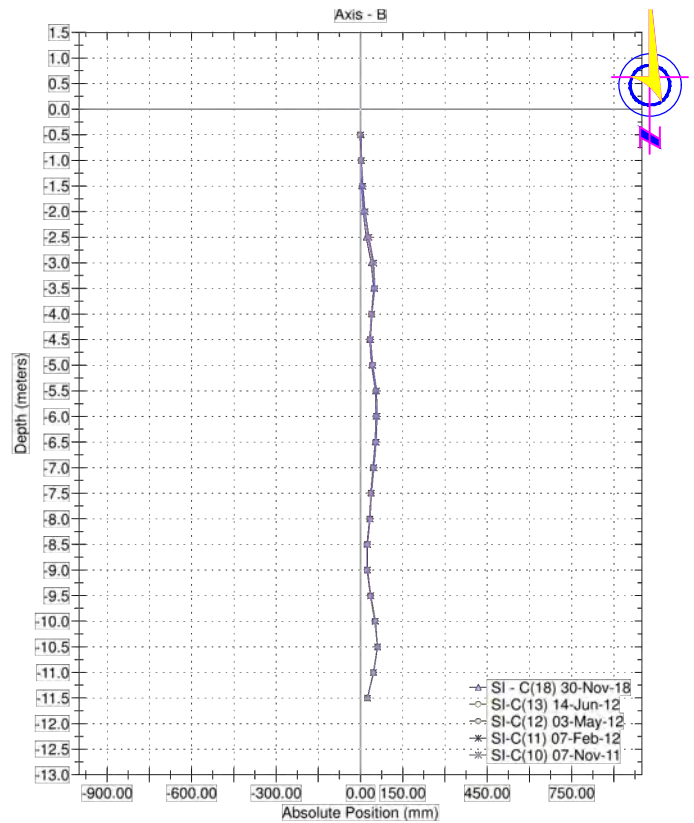
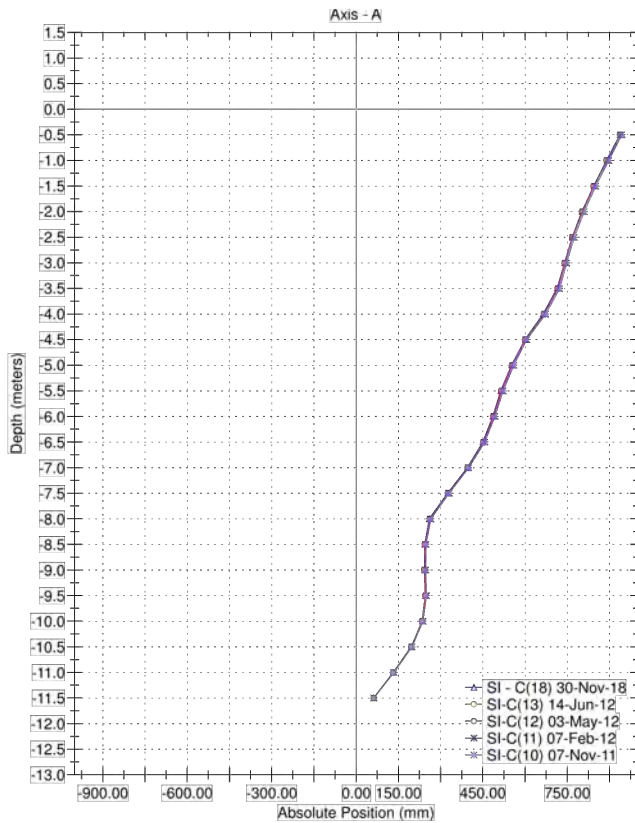


SLOPE INDICATOR MEASUREMENTS

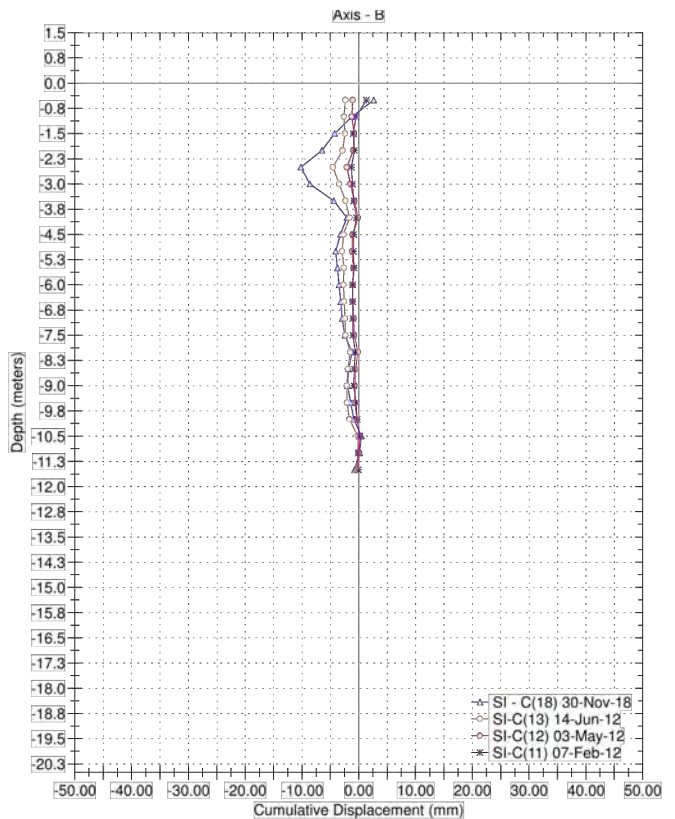
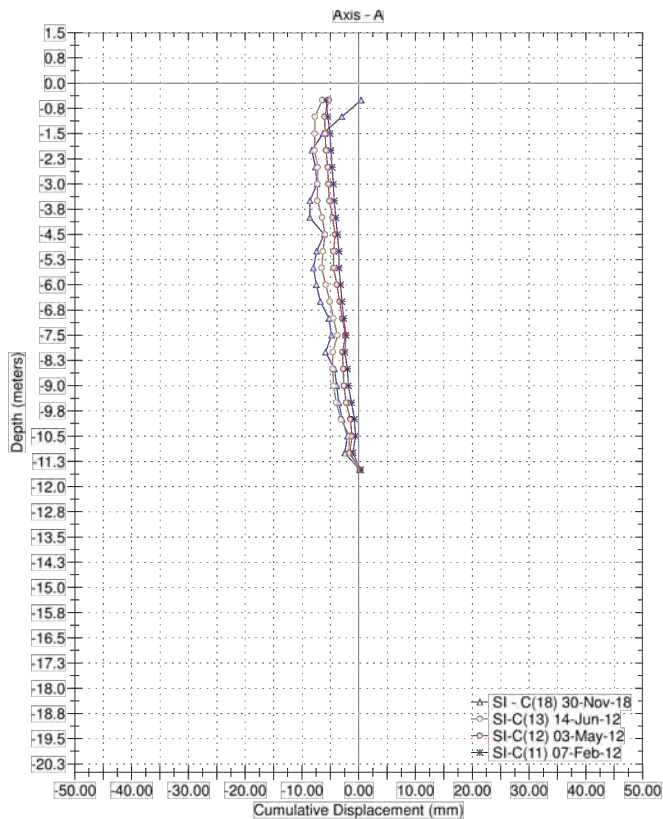
CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN:	CHK'D:	REV #:	DATE:
PS	MDB	2	APRIL 2019
SCALE:	JOB NO.	DRAWING NO.	
AS SHOWN	RD6500-26	FIGURE 26-9A	

ABSOLUTE POSITION



CUMULATIVE DISPLACEMENT



CLIENT:

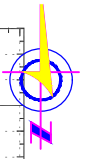
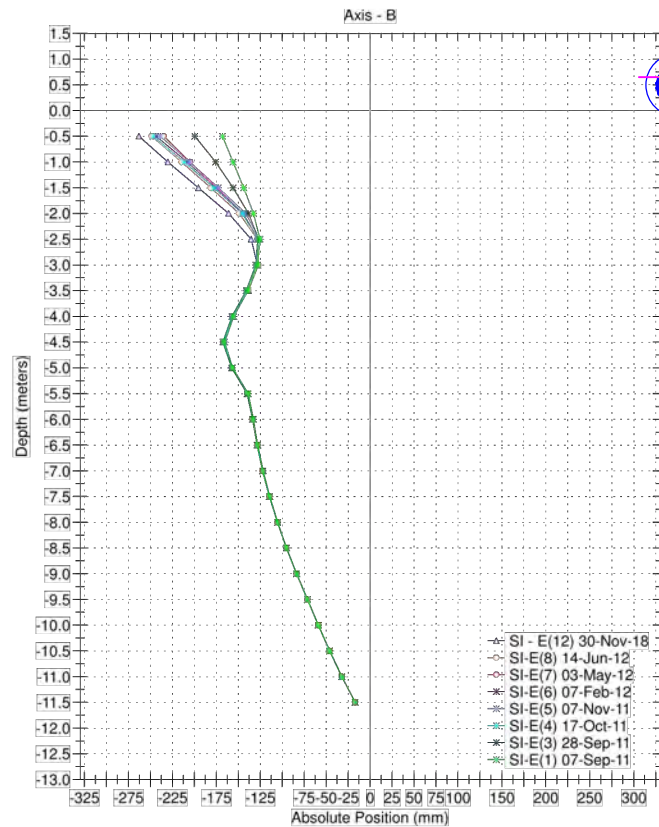
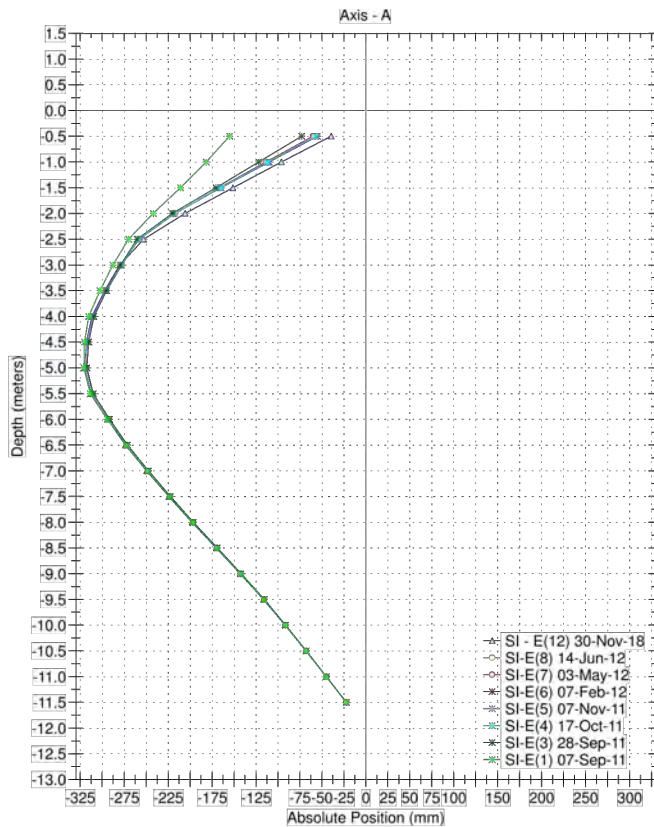


SLOPE INDICATOR MEASUREMENTS

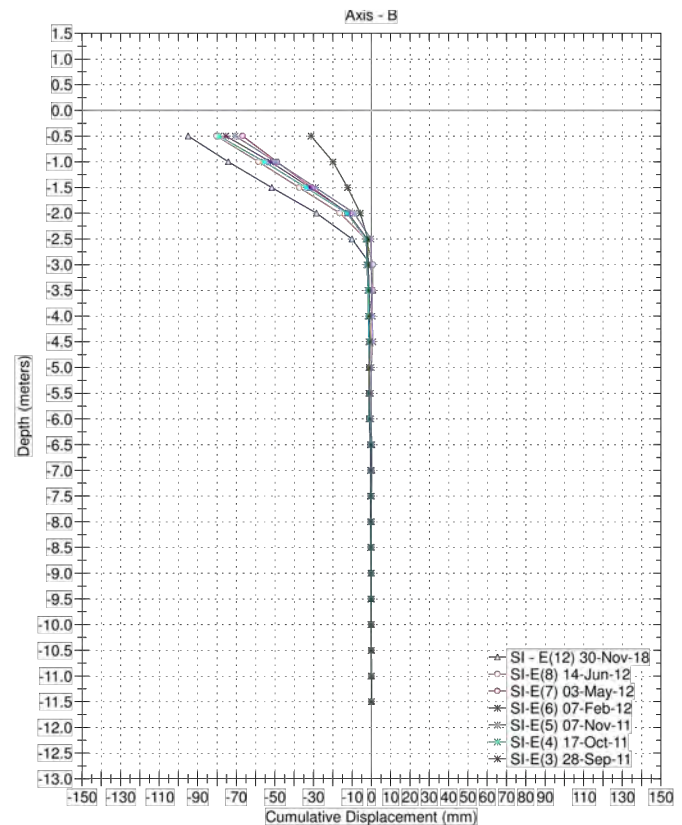
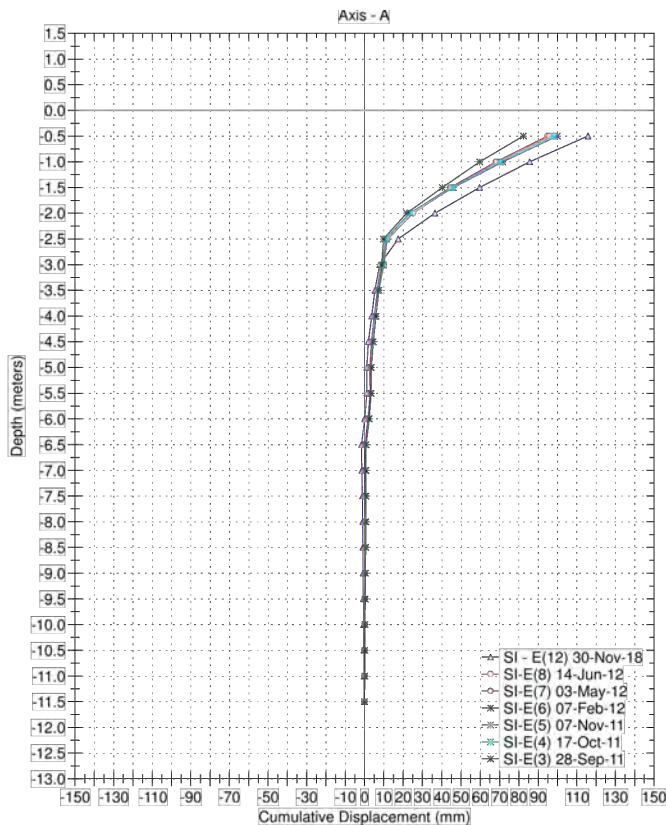
CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN:	CHK'D:	REV #:	DATE:
PS	MDB	2	APRIL 2019
SCALE:	JOB NO.	DRAWING NO.	
AS SHOWN	RD6500-26	FIGURE 26-9B	

ABSOLUTE POSITION



CUMULATIVE DISPLACEMENT



CLIENT:

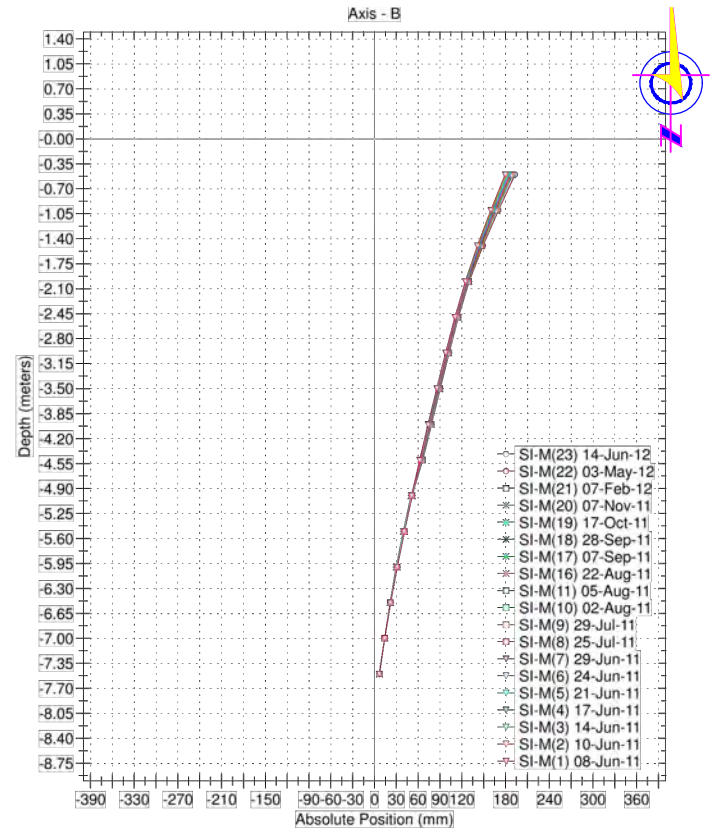
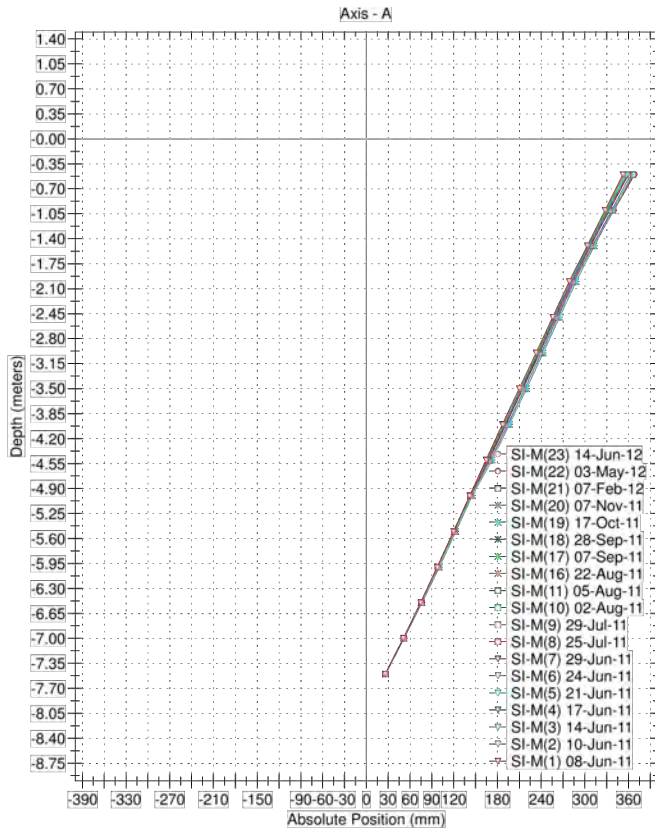


SLOPE INDICATOR MEASUREMENTS

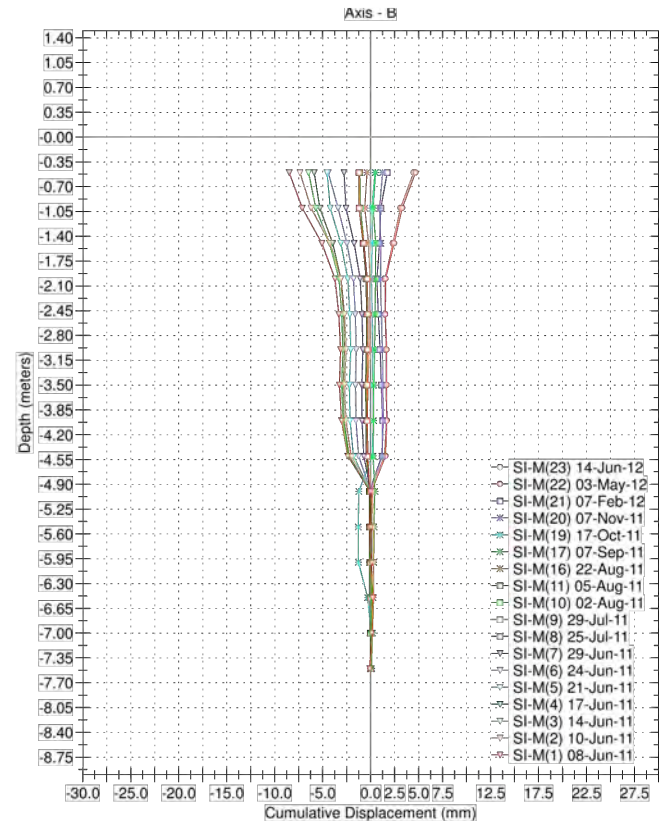
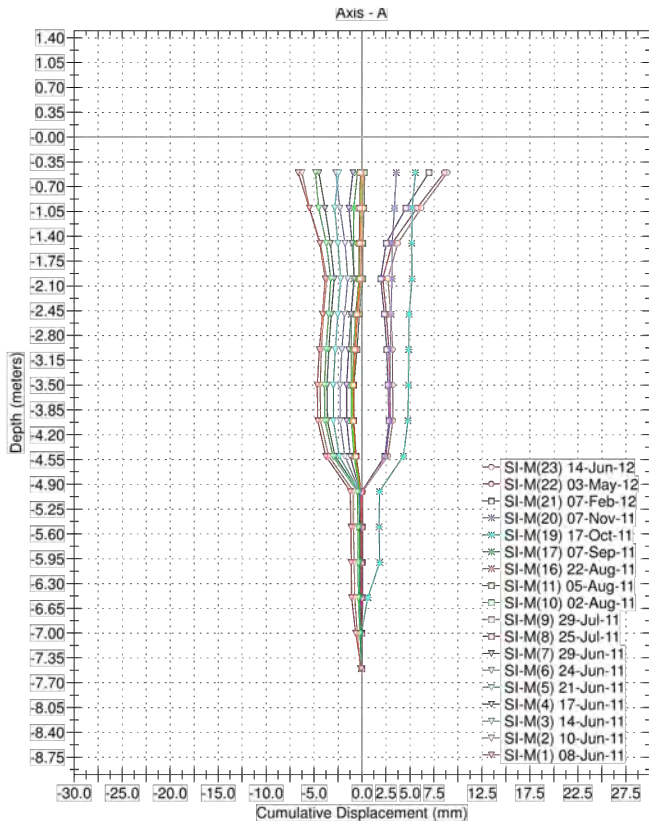
CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-9C	

ABSOLUTE POSITION



CUMULATIVE DISPLACEMENT











CLIENT:



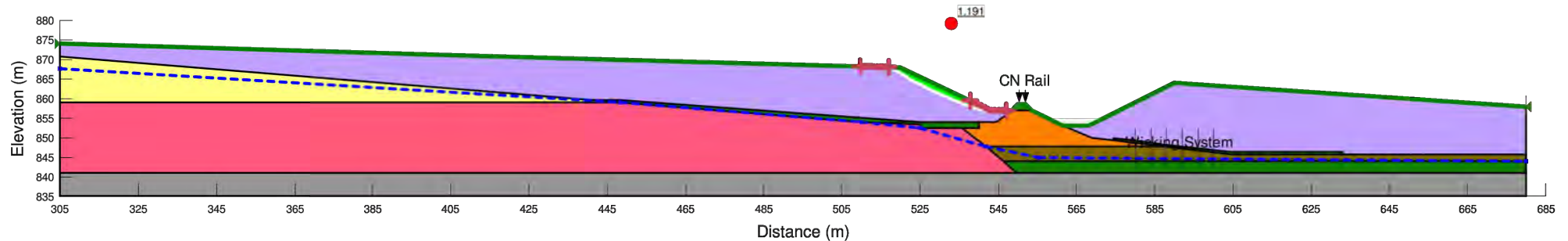
SLOPE INDICATOR MEASUREMENTS

CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN:	CHK'D:	REV #:	DATE:
PS	MDB	2	APRIL 2019
SCALE:	JOB NO.	DRAWING NO.	
AS SHOWN	RD6500-26	FIGURE 26-9D	

Color	Name	Unit Weight (kN/m ³)	Cohesion' (kPa)	Phi' (°)
	Alluvial Deposits	18	2	25
	Bedrock	20	10	40
	Clay	19.5	2	25
	Clay Fill	19.5	0	28
	Colluvium	18	0	21
	Gravel	21	0	35
	Gravel Fill	21	0	35
	Till	21	5	28

26-9: Head Slope Slope - Normal GWT
(Cross Section A-A')



PROFILE BASED ON ASBUILT PROVIDED BY ISL.



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
NORTH HIGHWAY CONNECTOR - WEST SLOPE

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-26	DRAWING NO. FIGURE 26-10	

SITE #26 - NORTH HIGHWAY CONNECTOR - WEST SLOPE

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 26-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018			NORTHING	EASTING	ELEVATION	COMMENT
		NORTHING	EASTING	ELEVATION				
#SM26-001	Pole	5800081.95	308613.37	878.94				
#SM26-002	Pole	5800059.73	308663.72	871.30				
#SM26-003	Valve	5800050.67	308680.34	870.66				
#SM26-004	Valve	5800052.93	308680.29	870.70				
#SM26-005	Pole	5800024.68	308700.64	867.14				
#SM26-006	Pole	5800056.82	308720.12	865.79				
#SM26-007	Pole	5800055.77	308751.62	861.50				
#SM26-008	SI-M	5800043.74	308745.98	862.24				
#SM26-009	Culvert	5800024.26	308765.91	857.67				
#SM26-010	Culvert vert	5800133.79	308793.02	860.03				
#SM26-011	Culvert vert	5800166.90	308803.31	860.71				
#SM26-012	SI-E	5799970.87	308727.40	858.31				
#SM26-013	Post	5799882.55	308645.23	871.72				
#SM26-014	Fence	5799936.74	308663.75	868.68				
#SM26-015	Top drain erosion	5799946.79	308697.43	864.88				
#SM26-016	Fence	5799953.23	308695.99	867.25				
#SM26-017	SI-C	5799987.86	308700.79	868.57				
#SM26-018	CB	5800005.32	308673.27	870.37				
#SM26-019	Pole	5799973.61	308669.57	869.74				
#SM26-020	Pole	5799943.62	308652.25	871.31				
#SM26-021	SI-A	5799958.78	308649.69	871.14				
#SM26-022	Pole	5799969.82	308607.51	876.76				
#SM26-023	Pole	5799993.56	308567.80	878.16				
#SM26-024	ASCM20487	5799477.43	308228.63	876.49				

TABLE 26-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD		COMMENT
		NORTHING	EASTING		2011	2018	
#P26-009	Power line alignment along crest	5799991	308569	SE		Y*	
#P26-018	Power line alignment	5799978	308670	NE	Y*	Y*	
#P26-021	South slope face	5799978	308670	W		Y*	
#P26-049	South Slope face	5799968	308740	SW	Y*	Y*	
#P26-050	North slope and toe of slope along RR	5799968	308740	N		Y*	
#P26-060	North slope face and toe of slope	5800084	308779	SW		Y*	
#P26-069	North slope face beside RR	5800044	308744	W		Y*	
#P26-077	North slope	5800031	308701	NE		Y*	
#P26-085	NHC, slope embankment (post const.)			W	Y*		Taken from airplane

Notes:

2011 Photographs from Reference #91

* Provided in the report

All measurements in metres

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	26	
Site Name	North Highway Connector	
Legal Land Description	NW 33-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	308750 E, 5799960 N	
Operational Site Instrumentation	Slope Indicator	3
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	2013	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 29, 2018	7	2	14
Inspected By:	Bryden Lutz – PGEO			
Report Attachments:	84 Site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded (constructed)	N/A	
Slope Movement	None observed	N/A	
Erosion	Down cutting in riprap drain ditch south of head slope	N/A	
Seepage	Water can be heard in drainage system on CN track just north of site.	N/A	
Distress	None observed	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments:	<ul style="list-style-type: none"> Creek rerouted in 1980s to stabilize slope and straightened through culvert when Taylor Drive built. 		

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Side slopes where moving during construction.- No evidence of any movement since completion of construction.
Assessment	<ul style="list-style-type: none">- Slope appears stable.
Recommendations	<ul style="list-style-type: none">- Consider site inspections every 1 to 2 years.

SITE #27

Gaetz Lakes Landslides



SITE #27 - GAETZ LAKES LANDSLIDES

27.1 SITE DESCRIPTION

The Site #27 - Gaetz Lakes Landslides are located south of 67th Street, west of Clearview subdivision in NW 22-38-27-W4M, as shown on Figure 1 of the main report. The two landslide sites are within the Gaetz Lakes Sanctuary in the northeast corner of downtown Red Deer. The Site Plan is shown on Figure 27-1. A Contour Plan is provided on Figure 27-2. Cross-sections of the slope through the large landslide and the unfailed area immediately to the north are provided on Figure 27-3.

The sites are located on the east river valley slope overlooking the eastern-most of the two Gaetz Lakes. The river valley slope is about 35 m high with a upland elevation of 885 to 887 m and toe elevation of 851 m at the edge of the lake during normal groundwater periods. Gaetz Lakes are oxbow lakes on the edge of the flood plain. The lake basins are within the gravel layer which blankets the downtown area and is hydraulically connected to the Red Deer River which is located about 450 to 600 m to the west. Therefore, the lake surfaces are groundwater features which are subject to the surface fluctuations in the river. The upland area to the east of the slope is bordered by Clearview Ridge subdivision to the east and the Michener Centre campus to the southeast. The upland area was originally relatively level prairie prior to residential development which started in 2005. A buffer strip at least 45 m wide was provided between the crest and the new development.

There is one large landslide about 400 m south of the north tip of the east lake which spilled colluvium out into the lake almost half way to the far shoreline. This larger failure was a bowl shaped slide which is about 50 m wide and 15 m deep to the back scarp. The upper part of this slide area appears to have been modified with fill for the trail and several smaller slides are apparent in the steepened area of the slide mass around this path. There are two smaller landslides: one about 100 m south of the large slide and another older slide about 200 m north of the south tip of the lake. The smaller slides appear to be a combination of erosion from local run-off and associated sliding.

The river valley slope above the lake is rugged terrain that is densely vegetated with deciduous and coniferous trees and brush. The slope has several walking paths which traverses the slope, including a path along the upper slope which is considered to be the remnant of an old access road. The slope angles in the undisturbed areas outside of the landslide sites were about 2.5H:1V; steepening towards the bottom of the slope. The largest landslide has a slope angle of about 2 to 3H:1V and the old crest areas below the back scarp has created a narrow terrace at an elevation of about 873 m. Aerial photographs showing the site in 1980, 1985, 2001 and 2016 are provided on Figures 27-4A and 27-4B. Eight selected representative photographs from the site are provided on Figures 27A to 27-5B.

27.2 REFERENCES

The references from Appendix B which apply to Site #27 - Gaetz Lake Slides include References #92 to #95. The initial landslide assessment was performed in 1982, but only anecdotal information is available from that study in the 1998 assessment (Reference #93). That study included additional boreholes that were drilled in 1997 and provided set back recommendation for planning purposes. More recently boreholes have been drilled in the area for subdivision development.

27.3 GEOTECHNICAL INVESTIGATION AND INSTRUMENTATION

In 1997 and 1998; six boreholes were drilled at the site. Three of the boreholes were drilled to depths of approximately 30 m along the crest. The other three were drilled in the flood plain near the north end of East Gaetz Lake. The borehole locations are shown on Figure 27-1. No slope inclinometers or other instrumentation has been installed in this area.

27.4 2018 REVIEW

Aerial photography is provided on Figures 27-4A and 27-4B, for the years listed in the following table. The aerials show concur with the anecdotal information suggesting the major landslide occurred in 1981. The small slide site in the south part of the lake was present going back to the at least the 1960s.

TABLE 27-1: AERIAL PHOTOGRAPHS

Year	Description
1980	Shows the original site condition prior to 1981 landslides
1985	Shows the condition shortly after the 1981 landslides.
2001	Shows the condition of the site about 15 years ago.
2016	Shows the present Site condition.

This site was visited on October 31 and November 27, 2018. A copy of the field inspection record is attached at the end of this appendix.

The reviewed topographic information includes survey profiles from the 1998 report (Reference #93) and the ortho-contours based on 2016 City aerials. A record of survey control points and data for this site is appended in Table 27-4. A reference drawing of survey reference points is provided on Figure 27-6.

Photographs were taken during the 2018 site visit. A list of available photos at this site is appended in Table 27-5. Selected site photographs are provided on Figures 27-5A and 27-5B; along with a reference drawing of all photograph locations which is provided on Figure 27-7.

27.5 SLOPE BACKGROUND

The east slope overlooking Gaetz Lakes is the scarp of ancient high bank slope that was present before the Red Deer River channel shifted to the west creating the two oxbow lakes at the toe of the slope. The most significant slope failures in this area were the two slides which occurred in 1981. The locations of these slope failures are shown on Figures 27-1 and 27-2. From Reference #93, these old slides did not appear active in 1998 and the profile of those slide areas has not changed significantly in the past 21 years. The failures were thought to be the result of over-steepening of the crest area with fill material in combination with a seasonal high groundwater condition and/or run-off caused by concentrated drainage or activity in the upland areas. A tree nursery was operated in the area above the landslide sites at the time of failure, but records suggest the facility was not irrigated. In 1998, it was theorized that the cultivation of the nursery and up-slope land east of the nursery may have experienced higher groundwater levels due to increased infiltration.

Upland development set-backs of 45 m from the crest were first recommended to the City of Red Deer for this area in the 1998 geotechnical report (Reference #93). It is understood the City of Red Deer adopted a 50 m set back as a wild life buffer between the crest and the closest property lines for proposed residential lots at the time of subdivision development.

27.6 SUBSURFACE PROFILE

The general soil profile at the crest encountered topsoil followed by silty glacio-lacustrine clay and sand overlying till. This soil profile is considered to be typical for the east hill area of Red Deer. In the flood plain the boreholes encountered topsoil followed by alluvial clay, silt, sand and gravel. The following is a brief description of the soil types encountered.

1. **Topsoil.** Topsoil was present at ground surface in each borehole. It was generally 0.1 to 0.3 m thick.
2. **Silt, Sand and Clay.** Glacio-lacustrine silty clay and sand was present to 16.5 to 20.7 m below ground surface. The clay layers were generally silty, firm to very stiff low to medium plastic, and moist to wet. The sand layers were generally compact to dense and moist to saturated. The moisture contents were 20 to 40 percent in the clay; 5 to 10 percent in the sand above the groundwater table and 15 to 20 percent below.
3. **Till.** Both clay and sand till was encountered below the lacustrine deposits of silty clay or silty sand. The till was hard/dense, low to medium plastic and damp to moist. Occasional saturated sand layers or lenses were encountered.
4. **Bedrock.** Bedrock was not encountered in the boreholes to depths of over 29.7 m which is below the toe of the slope.

5. **Groundwater.** The groundwater table in the upland east hill area of Red Deer is 3 to 5 m below grade. The groundwater table at the crest of the slope in 1997 was about 16 m below grade which is considered typical due to proximity of the crest to the nearby river valley slope. The groundwater table begins to drop in the crest area to provide a hydraulic connection with the groundwater levels in the river valley which were within 1 m of grade at the toe of the slope at the time of investigation.
6. **Lake Levels.** The normal water surface elevation of the Gaetz Lakes below this site is about 849 to 850 m. The lakes are oxbow channels in the river valley and the lake levels are considered to be indicative of groundwater levels which are influenced by the levels of the nearby Red Deer River through a hydraulic connection in the highly permeable flood plain gravel deposits.

The inferred soil profile for the slope is shown on Figure 27-3. The following effective strength parameters were assumed for this site.

TABLE 27-2: SOIL PARAMETERS FOR STABILITY ANALYSIS

Soil	Unit Weight (kN/m ³)	Cohesion, c' (kPa)	Phi' (Degrees)
Colluvium	18	0	25
Sand	20	0	30 - 32
Clay	20	0 - 2	25 - 28
Clay Till	21	2 - 5	28 - 30

For review of the detailed soil conditions encountered at the borehole locations in this area, please refer to available site specific reports referenced in Appendix A.

27.7 REVIEW OF STABILITY ASSESSMENT

Limited historical stability analysis was available for this site. A preliminary estimate of stability along the crest has been undertaken for Site #27 using the *SLOPE/W* computer program as part of this review. The following table summarizes the results of the slope stability analysis.

TABLE 27-3: 2018 SLOPE STABILITY ESTIMATE

Case	FS	Figure
Shallow Slope Face Failure	1.0 - 1.2	-
28 m From Crest	1.5	Figure 27-8
At Existing Building (55 m from crest)	~ 1.7	-

A representative stability analysis run for the governing slope model at this site is provided in this appendix as noted above.

This river valley slope above the Gaetz Lakes is considered to be an ancient high bank slope which have undergone some slope flattening over the centuries since the river moved away from the toe of the slope. The current slopes are considered to be marginally stable in the long-term. The relatively recent failures in 1981 are considered to be unusual and possibly indicative of some change in conditions which were probably related to crest area disturbance such as improper fills or changes in groundwater or surface water conditions.

The long-term assessment at this site is that the potential for a major slope movement is low to moderate under present normal conditions with reasonable variation and the risk of ongoing face regression has been reduced. The FS against a small shallow “slump-type” failure on the slope face is estimated to be moderate to high, but with the present vegetation cover it would take unusually wet conditions to cause a shallow slump in the slope face. For the representative slope profile under reasonably adverse soil moisture and groundwater conditions, a point about 28 m back from the current location of the crest is considered to be stable in the long-term.

If a large movement in the upper slope were to occur, the failure of the slope is expected to be slow moving and would provide some warning in the form of tipping trees and tension cracks at the crest or on the slope face prior to failure. The size of any future slope failure would be similar to the 1981 landslides. The north 1981 landslide was considered to be relatively large for Red Deer area. In review, this basic set-back was considered to be reasonable, if not conservative. As a result, the risk to the private property is considered to be negligible.

27.8 DETAILED RISK RANKING

The risk level for this site, has been assessed as follows:

$$PF(7) * CF(1) = 7$$

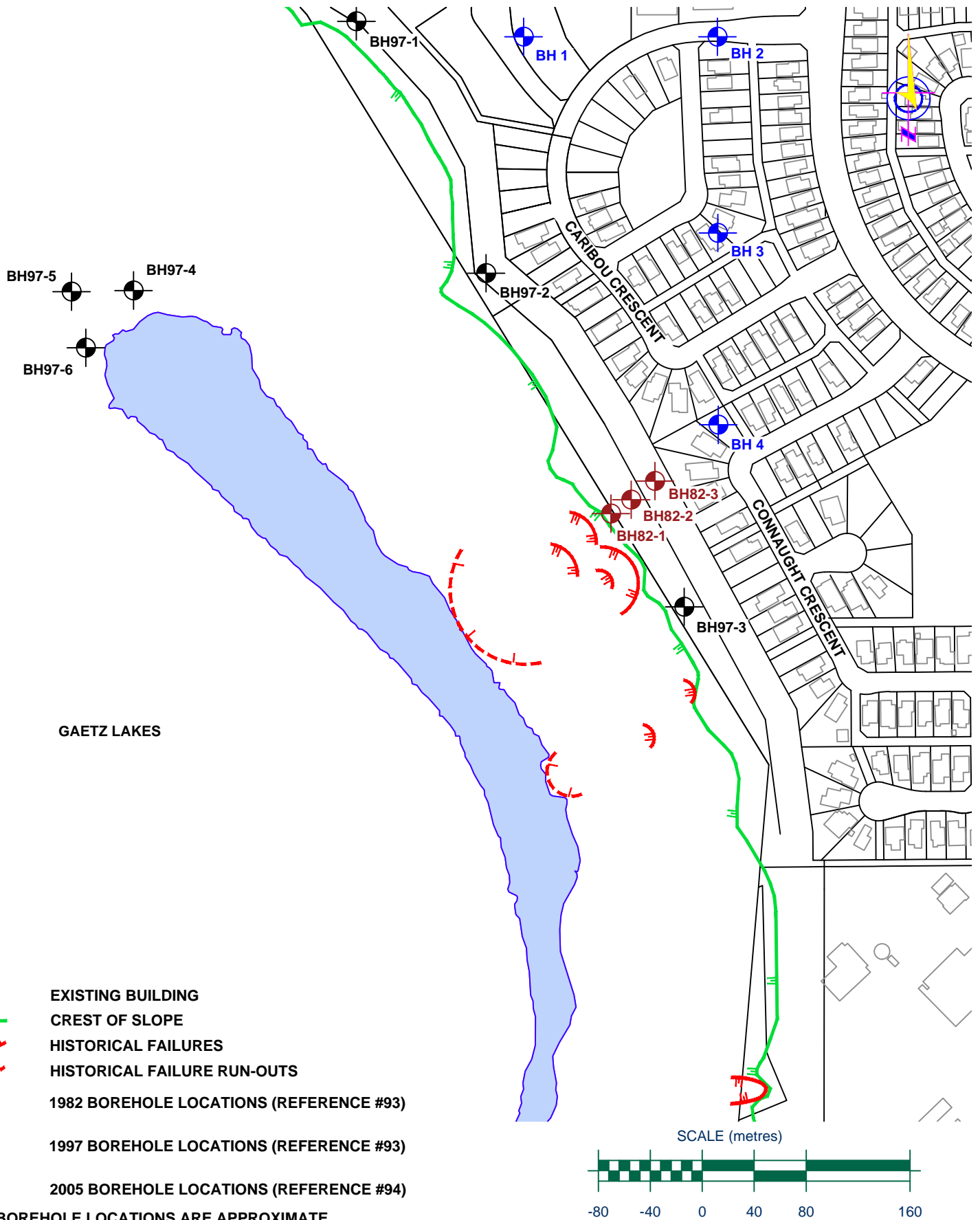
A Probability Factor of 7 is considered to be appropriate since there no active landsliding in the upper slope along the entire top-of-slope area. However, the geologic conditions which caused the two slides in 1981 are likely still applicable along the steeper undisturbed crest areas. Therefore, a moderate to high probability of failure exists even though it could be a long time before a new landslide occurs. A Consequence Factor of 1 is considered appropriate since the expected size of landslide in the upper slope at this site would only impact park areas. A major landslide would have negligible consequences to private property in the area due to the set backs provided by development plans for the subdivision.

27.9 RECOMMENDATIONS

The recommended course of action at this site is to undertake periodic visual site inspections of the slope on an “as required” basis to identify any significant changes, if present.

27.10 ATTACHMENTS

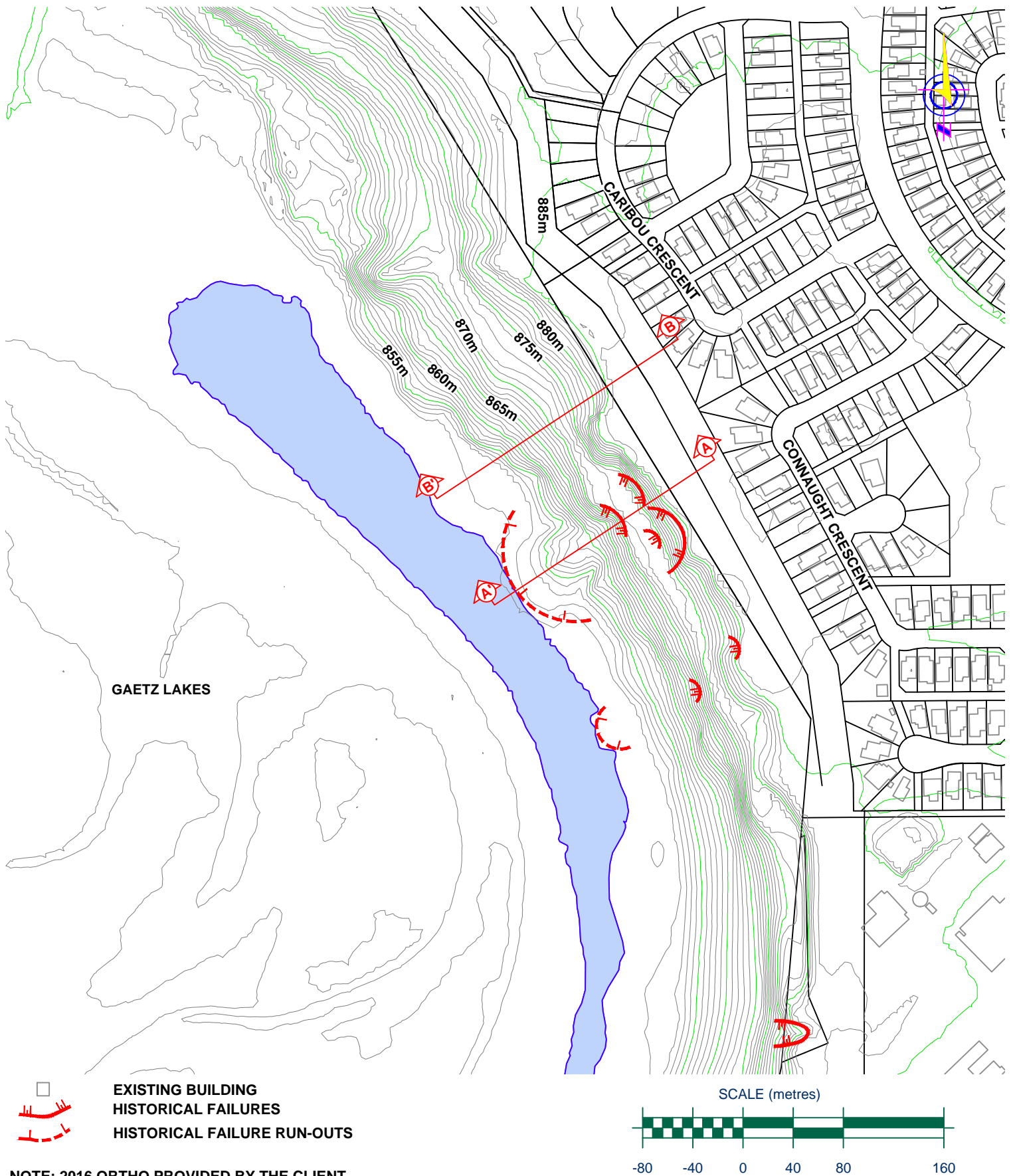
Figure 27-1 - Site Plan
Figure 27-2 - 2016 Contour Plan
Figure 27-3 - Cross Section Profile
Figure 27-4 - Aerial Photographs
Figure 27-5 - Site Photographs
Figure 27-6- Survey Marker Plan
Figure 27-7 - Photograph Plan
Figure 27-8 - Stability Analysis Run
Table 27-4 - List of Survey Markers
Table 27-5 - List of Photographs
Site Inspection Record (October 31, 2018)



SITE PLAN

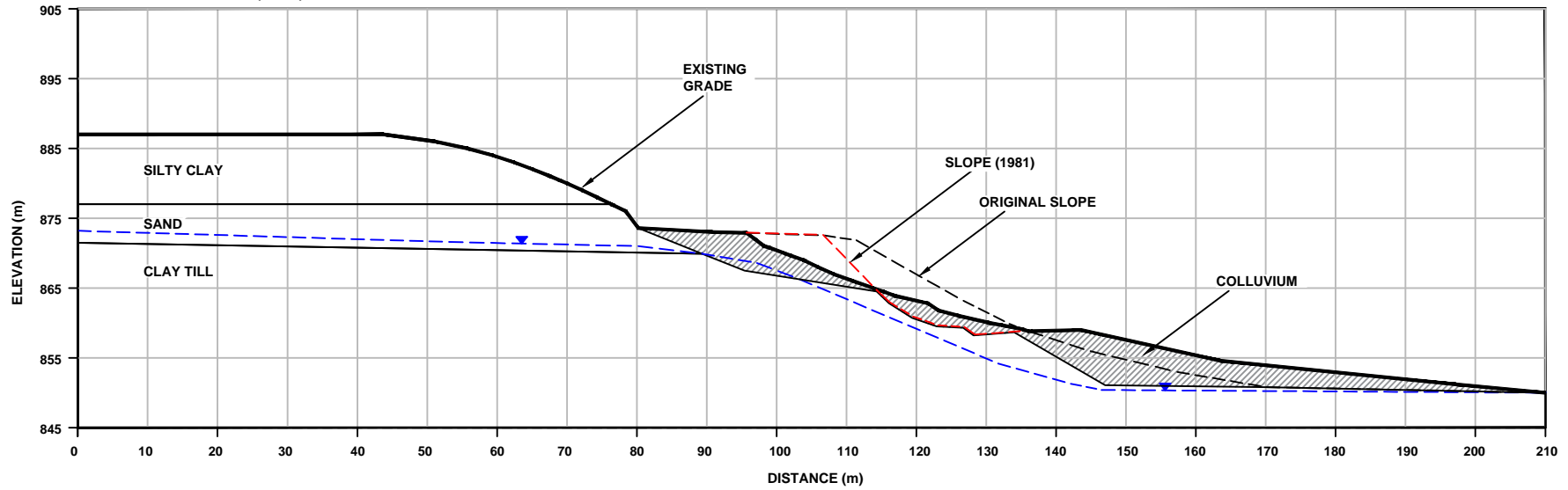
CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ LAKES LANDSLIDES

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:4000	JOB NO. RD6500-27	DRAWING NO. FIGURE 27-1	

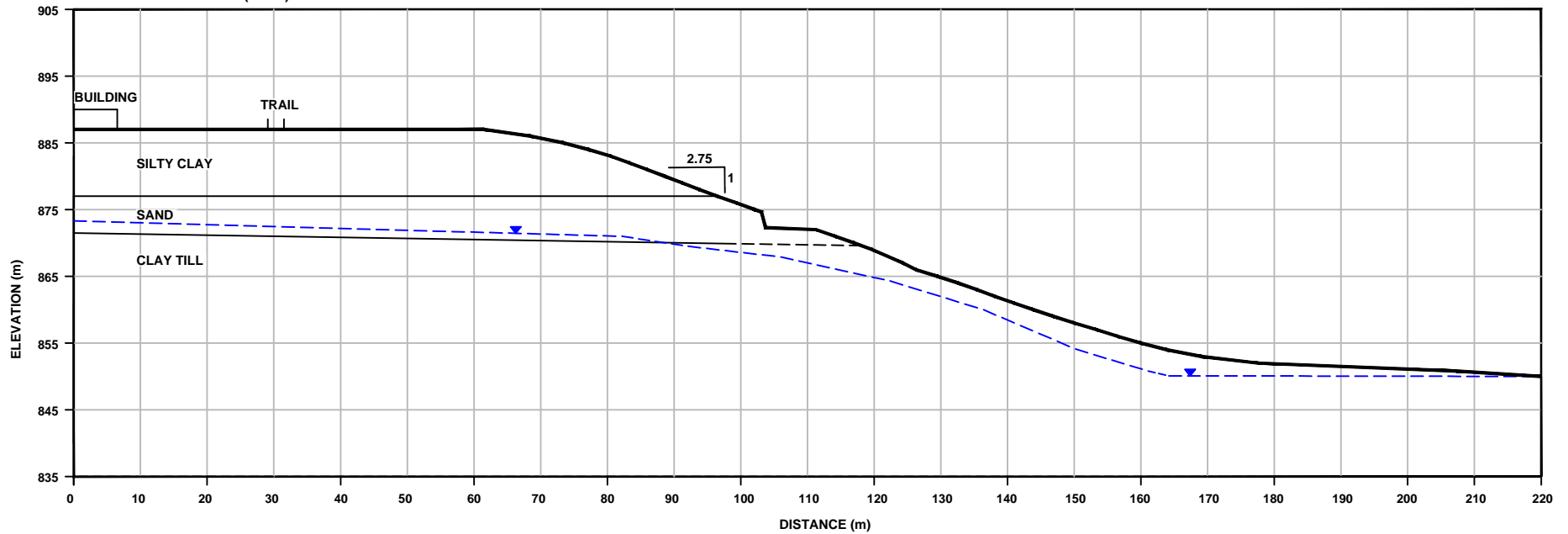


	CLIENT:		CONTOUR PLAN			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ LAKES LANDSLIDES			
			DRAWN:	CHK'D:	REV #:	DATE:
			PS	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
1:4000		RD6500-27		FIGURE 27-2		

27-3A: CROSS SECTION (A - A') - MAJOR SLIDE



27-3B: CROSS SECTION (B - B')



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



CLIENT:



CROSS SECTION PROFILE

CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ LAKES LANDSLIDES

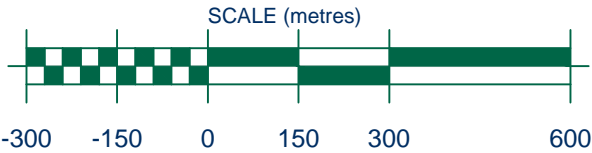
DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-27	DRAWING NO. FIGURE 27-3	



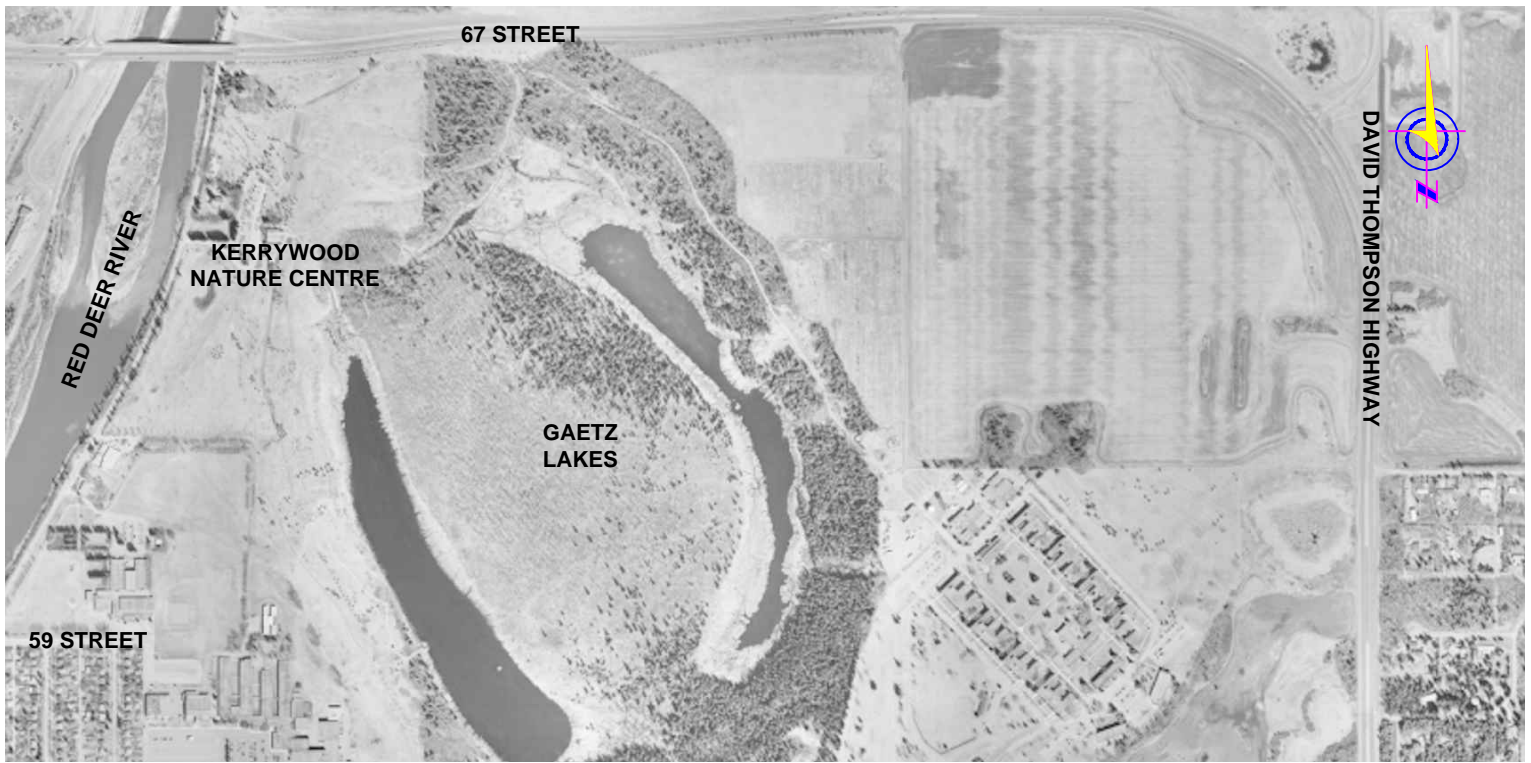
NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED MAY 2, 1980.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM ALBERTA ENVIRONMENT AND PARKS, DATED 1985.



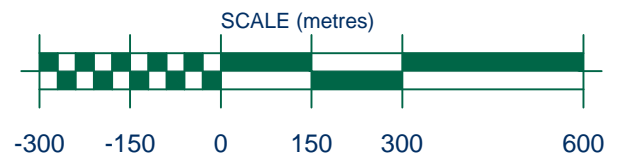
	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ LAKES LANDSLIDES			
			DRAWN:	CHK'D.:	REV #:	DATE:
			NC	MDB	2	APRIL 2019
SCALE:		JOB NO.		DRAWING NO.		
1:12500		RD6500-27		FIGURE 27-4A		



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM CITY OF RED DEER WEB MAP, DATED 2010.



NOTE: AERIAL PHOTOGRAPH OBTAINED FROM GOOGLE EARTH, DATED AUGUST 28, 2016.



	CLIENT:		AERIAL PHOTOGRAPHS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ LAKES LANDSLIDES			
			DRAWN: NC	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
			SCALE: 1:12500	JOB NO. RD6500-27	DRAWING NO. FIGURE 27-4B	



PHOTOGRAPH 6 (2018): SLOPE ABOVE THE MINOR SLIDE , TAKEN FROM CREST OF FAILURE, FACING NORTH



PHOTOGRAPH 15 (2018): TRAIL ALONG THE CREST, FACING SOUTH



PHOTOGRAPH 28 (2018): FALLEN TREES DUE TO 2017 WINDSTORM, TAKEN FROM CREST OF FAILURE, FACING SOUTHEAST



PHOTOGRAPH 55 (2018): SLOPE AT THE MINOR SLIDE, FACING SOUTH



PHOTOGRAPH 58 (2018): CREST OF SLOPE AT THE MINOR SLIDE, FACING EAST



PHOTOGRAPH 62 (2018): MAJOR SLIDE, TAKEN FROM SOUTH OF CREST, FACING WEST

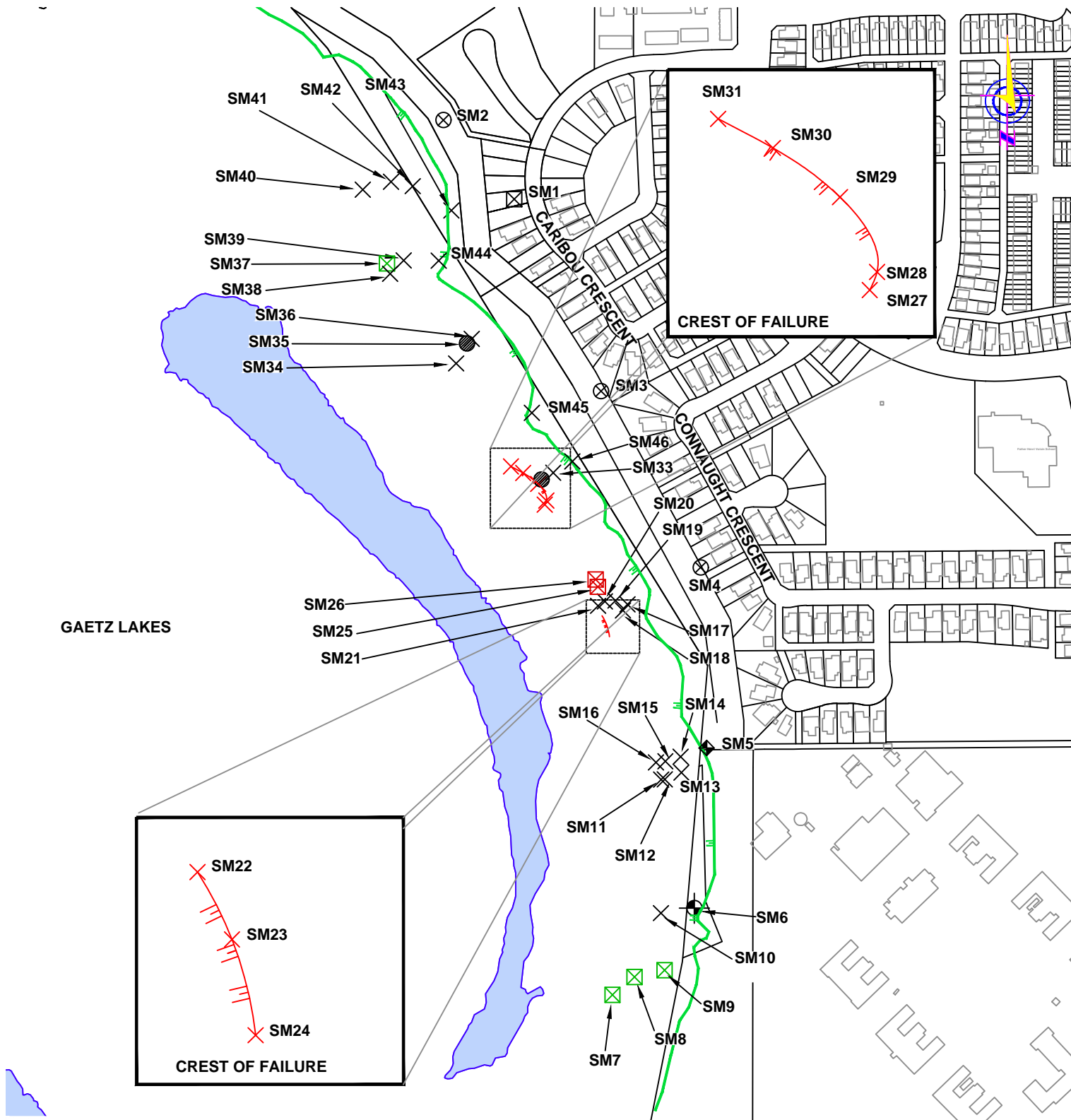


PHOTOGRAPH 70 (2018): MAJOR SLIDE, LOOKING UP THE SLOPE, FACING NORTHEAST



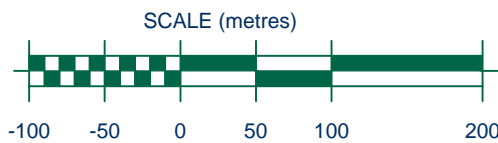
PHOTOGRAPH 115 (2018): CREST OF SLOPE, FACING NORTHWEST

	CLIENT:		SITE 27 PHOTOGRAPHS					
			CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ LAKES LANDSLIDES					
	DRAWN:	PS	CHK'D.:	MDB	REV #:	2	DATE:	APRIL 2019
	SCALE:	NTS	JOB NO.			RD6500-27	DRAWING NO. FIGURE 27-5B	

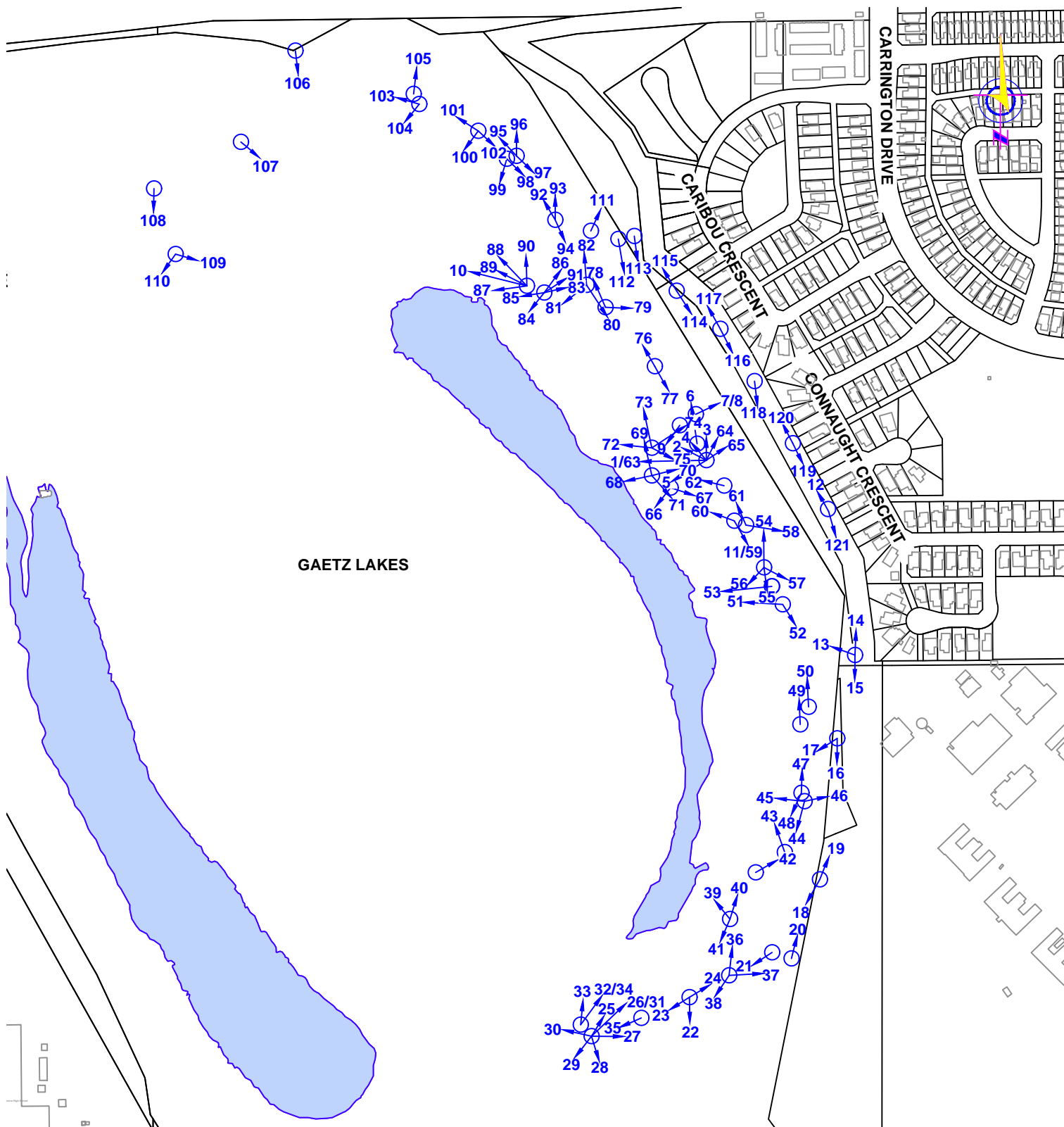


- CREST OF SLOPE
- X BUILDING CORNER
- MANHOLE
- X LAND POINT
- X SLUMP
- CREST OF FAILURE

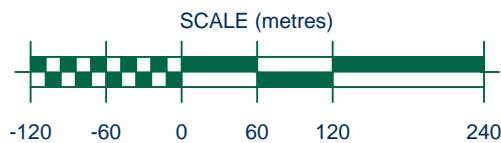
- ◆ FIRE HYDRANT
- MONITORING WELL
- X STAIRS
- SURVEY MARKER
- X EROSION WALL



	CLIENT:		SURVEY MARKERS			
			CITY OF RED DEER SLOPE STABILITY EVALUATION GAETZ LAKES LANDSLIDES			
			DRAWN: RS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
	SCALE: 1:5000		JOB NO. RD6500-27		DRAWING NO. FIGURE 27-6	



ALL PHOTOGRAPH LOCATIONS ARE APPROXIMATE



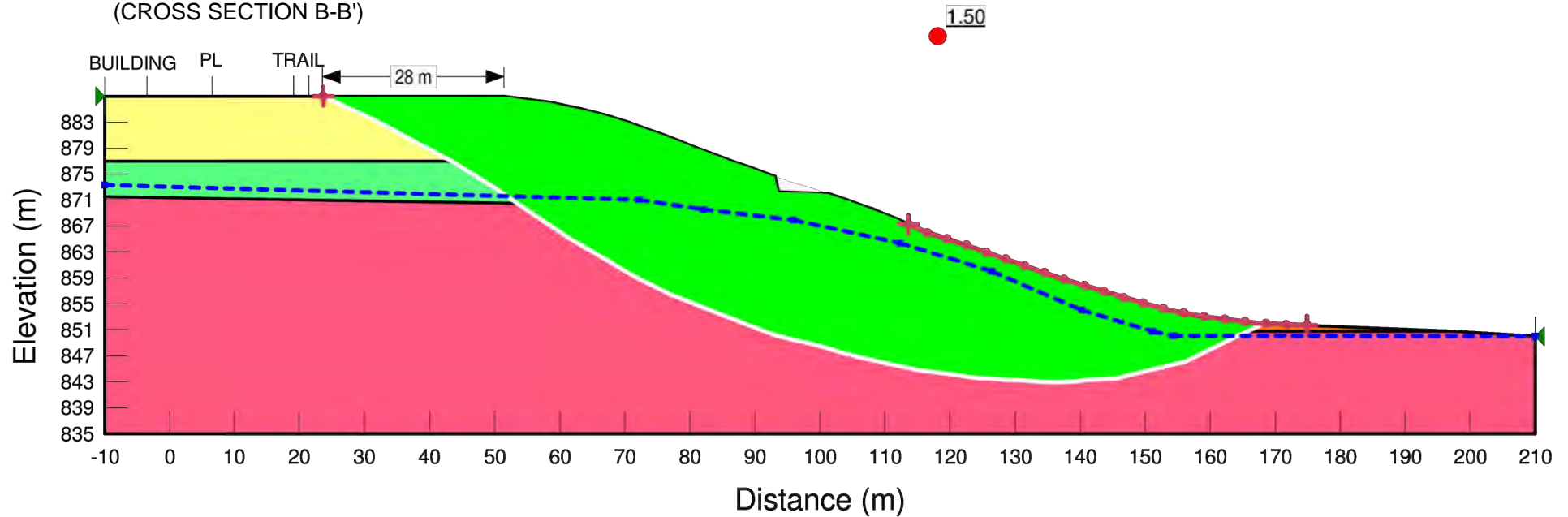
PHOTOGRAPH PLAN

CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ LAKES LANDSLIDES

DRAWN: PS	CHK'D: MDB	REV #: 2	DATE: APRIL 2019
SCALE: 1:6000	JOB NO. RD6500-27	DRAWING NO. FIGURE 27-7	

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
■	Clay Till	21	3	29
■	Colluvium	18	0	25
■	Sand	20	0	30
■	Silty Clay	20	0	24

27-8: SETBACK FOR GLOBAL STABILITY OF FS 1.5
(CROSS SECTION B-B')



PROFILE BASED ON 2016 CONTOURS PROVIDED BY CLIENT.



CLIENT:



STABILITY ANALYSIS RUN

CITY OF RED DEER SLOPE STABILITY EVALUATION
GAETZ LAKES LANDSLIDES

DRAWN: PS	CHK'D.: MDB	REV #: 2	DATE: APRIL 2019
SCALE: AS SHOWN	JOB NO. RD6500-27	DRAWING NO. FIGURE 27-8	

SITE #27 - GAETZ LAKES LANDSLIDES

CITY OF RED DEER SLOPE EVALUATION STUDY

TABLE 27-4 - LIST OF SURVEY MARKERS

ID#	MARKER DESCRIPTION	2018						COMMENT
		NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	
#SM27-001	Building	5796463.76	310272.74	885.58				
#SM27-002	Survey marker	5796537.76	310206.33	883.56				
#SM27-003	Survey marker	5796284.07	310353.87	886.71				
#SM27-004	Survey marker	5796118.95	310447.14	886.35				
#SM27-005	FH	5795950.03	310452.82	884.62				
#SM27-006	MW1104	5795800.04	310441.34	884.15				
#SM27-007	Stairs post	5795719	310365	868.3				
#SM27-008	Stairs post	5795736	310385	875.4				
#SM27-009	Top Stairs	5795742.11	310413.47	883.72				
#SM27-010	Crest	5795795.45	310410.08	880.54				
#SM27-011	Ridge	5795920.49	310410.25	874.75				
#SM27-012	Toe	5795920.72	310413.63	874.89				
#SM27-013	Crest	5795927.09	310429.18	883.98				
#SM27-014	Crest	5795941.88	310428.47	884.24				
#SM27-015	Toe	5795937.54	310414.15	876.28				
#SM27-016	Ridge	5795936.57	310405.35	875.85				
#SM27-017	Crest	5796084.41	310378.65	886.18				
#SM27-018	Ridge Toe	5796078.79	310374.51	883.04				
#SM27-019	Ridge	5796087.96	310367.49	882.02				
#SM27-020	Toe	5796087.19	310357.61	875.52				
#SM27-021	Ridge	5796083.12	310351.14	875.31				
#SM27-022	Slump	5796073.67	310354.60	875.60				
#SM27-023	Slump	5796065.61	310358.73	876.35				
#SM27-024	Slump	5796054.13	310361.56	876.93				
#SM27-025	Wall	5796100.90	310351.02	874.63				
#SM27-026	Wall	5796107.83	310348.82	874.44				
#SM27-027	Slump	5796177.78	310301.26	872.31				
#SM27-028	Slump	5796181.56	310302.80	872.75				
#SM27-029	Slump	5796197.17	310295.07	872.75				
#SM27-030	Slump	5796207.45	310281.03	871.81				
#SM27-031	Slump	5796213.53	310269.61	870.85				
#SM27-032	MH	5796201.31	310298.09	873.30				
#SM27-033	Toe	5796207.64	310309.19	873.65				
#SM27-034	Mid	5796310.01	310218.27	870.67				
#SM27-035	MH	5796328.60	310228.32	874.83				
#SM27-036	Toe	5796333.02	310232.87	874.62				
#SM27-037	Stairs	5796403.54	310153.52	871.58				
#SM27-038	Crest	5796393.94	310156.49	871.39				
#SM27-039	Toe	5796406.35	310169.10	872.06				
#SM27-040	Ridge	5796472.59	310130.87	868.20				
#SM27-041	Toe	5796480.02	310157.26	871.14				
#SM27-042	Crest	5796475.93	310177.66	878.33				
#SM27-043	Crest	5796453.12	310213.89	884.62				
#SM27-044	Crest	5796406.25	310202.05	884.71				
#SM27-045	Crest	5796263.73	310289.22	885.91				
#SM27-046	Crest	5796218.26	310327.13	886.38				

TABLE 27-5 - LIST OF PHOTOGRAPHS

ID#	PHOTOGRAPH DESCRIPTION	APPROX. LOCATION		DIRECTION OF PHOTOGRAPH	YEARS OF RECORD	COMMENT
		NORTHING	EASTING		2018	
#P27-006	Slope above the minor slide	5796199	310287	N	Y*	
#P27-015	Trail along the crest	5795960	310465	S	Y*	
#P27-028	Fallen trees due to 20017 windstorm	5795531	310168	SE	Y*	
#P27-055	Slope at the minor slide	5796059	310363	S	Y*	
#P27-058	Crest of slope at the minor slide	5796107	310342	E	Y*	
#P27-062	Major slide	5796151	310318	W	Y*	
#P27-070	Major slide	5796163	310236	NE	Y*	
#P27-115	Crest of slope	5796371	310264	NW	Y*	

Notes:

2011 Photographs from Reference #86

* Provided in the report

All measurements in metres

Less accuracy due to tree cover

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Site Number	27	
Site Name	Gaetz Lakes Landslides	
Legal Land Description	NW/SW 22-38-27-W4M	
Address	N/A	
UTM Coordinates (approx. site center)	310300 E, 5796220 N	
Operational Site Instrumentation	Slope Indicator	N/A
	Pneumatic Piezometers	N/A
	Vibrating Wire Piezometers	N/A
	Standpipe Piezometers	N/A
Date of Last Instrumentation Readings	N/A	

Risk Assessment	Date	PF	CF	Risk Ranking
Previous Inspection:	N/A	-	-	-
Current Inspection:	October 31, 2018	7	1	7
Inspected By:	Bryden Lutz - PGEO			
Report Attachments:	169 site photos taken			

Observations	Description & Location	Noticeable Change	
		Yes	No
Crest Condition	Rounded	N/A	
Slope Movement	<ul style="list-style-type: none"> Evidence of historical movement at 2 slumps and continued crest regression of fill at large north slump. Surface drainage downcut and minor slope movement in SE corner near top of trail stairs across from Michener outbuilding. 	N/A	
Erosion	Possible surface drainage path between historical slumps.	N/A	
Seepage	None observed	N/A	
Distress	None observed	N/A	
Other		N/A	
Instrumentation:	N/A		
Other Comments: <ul style="list-style-type: none"> Wind storm in June 2017 knocked down many trees on slope face and leveled almost every tree on SE corner of Gaetz Lakes. 			

**CITY OF RED DEER
SLOPE MONITORING PROGRAM
2018 INSPECTION REPORT**



Discussion	<ul style="list-style-type: none">- Slope appears largely stable.- Continued crest regression of fill at north large slump.- Most of slope outside of noted slumps is well treed with estimated tree ages of > 60 years.
Assessment	<ul style="list-style-type: none">- With no toe erosion slope is considered stable from large slumps, possible to have slumps caused by old road cut.- South slopes outside of the study area could experience movement if significant rainfall event occur before new tree growth occurs, due to loss of mature tree coverage (2017 wind storm)
Recommendations	<ul style="list-style-type: none">- Consider site inspections every 5 years or in years with significant cumulative rainfall.