ND 18 LANDSLIDE SLOPE STABILITY RECOMMENDATION

TO:	**File**
FROM:	**Geotechnical Section**
DATE:	**12/20/2022**
HIGHWAY:	**ND 18**
PROJECT NUMBER:	**8-018(106)064**
PCN:	**23279**
LOCATION:	**8 North of Leonard, Maple River**
SUBJECT:	**ND 18 Landslide Slope Stability Recommendation**

The geotechnical section was tasked to remediate an existing landslide that is occurring on ND 18 at approximately RP 64. The landslide is occurring on the northern bank of the maple river and is affecting the bridge structure (Bridge No. 0018-064.955) that crosses the Maple River. This landslide has been affecting the current structure since the early 2000's and is causing the north pier to lean. Soil borings were completed at this location and instrumentation was installed to identify the depth of the landslide movement and the water table characteristics. Figure 1 below shows an aerial picture of the project location and the soil borings completed:

Figure 1 – Project Location and Soil Boring Locations

Figure 2 below shows the damage to the existing pier located on the north side of the Maple River:

Figure 2 – North Pier Leaning from Landslide

Soil samples were taken from the completed borings, and tests were run to identify the stratigraphy of the site and the engineering parameters. From the instrumentation installed, two different slip planes were identified and accounted for in the final design. See Appendix A for the soil boring logs.

Two projects have occurred at this landslide location on ND 18 at the Maple River bridge, project no's 8-018(088)064, PCN 21746 and 8-018(106)064, PCN 23279.

For the first project, 8-018(088)064, PCN 21746, the landslide fix was limited by the existing bridge and R/W. Due to these constraints and the weak soils at the project site that were unable to support a structural fix, it was decided to move forward with a dirt work project. Because of the location of the existing bridge, not as much excavation was able to be completed as desired. The area outside of the abutment could have more material removed and the factor of safety of this area was 1.26. The material behind the abutment and below the approach slab was removed as much as possible and this produced a factor of safety of 1.12. It was discussed with management and the project team that this proposed fix would improve the factor of safety, but it was unknown whether it would be enough to stop the landslide. The decision was made to move forward with this fix, and it was completed in the summer of 2018. Figure 3 below shows the excavation that occurred behind the existing abutment.

Figure 3 – Excavation Behind Existing Abutment

After the project was completed, the deeper landslide movement stopped and the shallower landslide movement slowed significantly, and recent surveys of the pier have shown that the pier is no longer moving. However, bridge division was concerned about the existing condition of the north pier, abutment, and approach slab permanently acting as a span. In addition, the shallower landslide was still moving and could potentially affect the structure. These concerns drove the need for another project to be completed.

The second project, 8-018(106)064, PCN 23279 is intended to fix the landslide and obtain the best factor of safety possible. This proposed project would involve replacing the damaged pier, replacing the current north abutment with a pier, and extending the bridge enough to complete the necessary excavation to remediate the landslide. Survey was completed to obtain the new existing ground (this survey confirmed the previous grading that was completed as part of the previous project). Design division also provided cross sections at three different locations that were skewed to the landslide movement and incorporated the new survey data. This new data was incorporated into the existing Slope/W model and served as the existing conditions model for the project. The cross section that was deemed critical was at Sta 0+48.92, which is on the west side of the landside and goes through the existing abutment. This was also the location where limited excavation was completed as part of the previous project due to the existing abutment piling. Figure 4 below shows where this cross section is located:

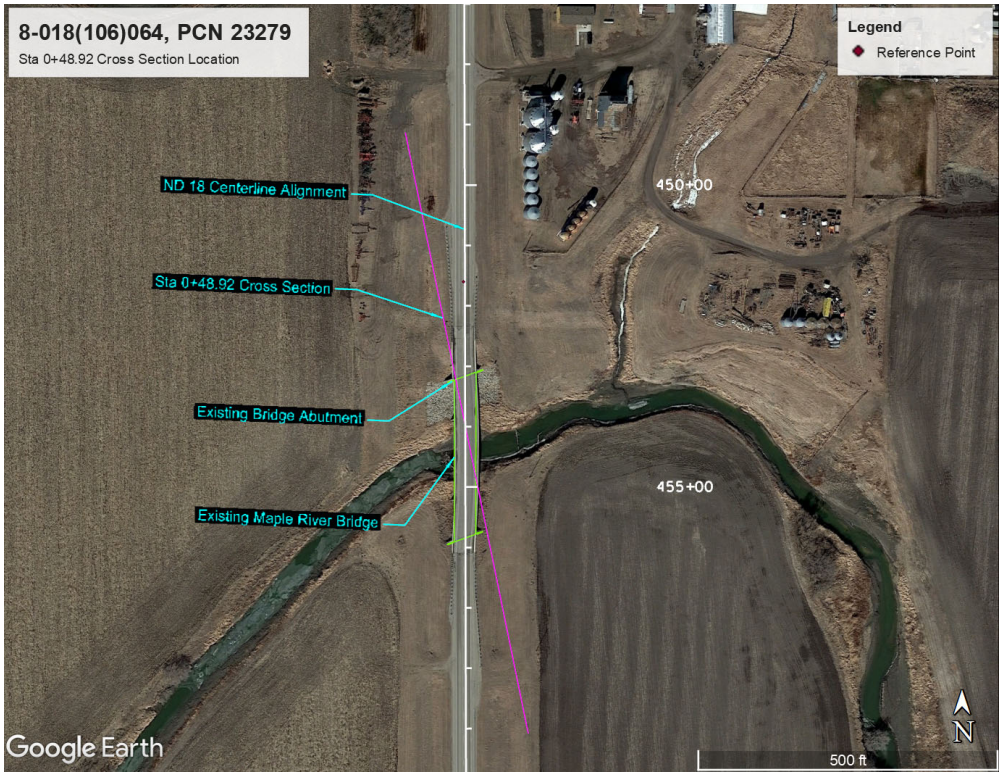

Figure 4 – Sta 0+48.92 Cross Section Location

The mitigation alternative evaluated for this project was an extension of the ideal excavation previously performed east of the bridge (which resulted in a factor of safety east of the bridge of 1.26), and the removal of the structural limitations from the excavation limits allowed for the excavation under the bridge to match the excavation elevation to the east. This proposed excavation results in a factor of safety of 1.21, which closely matches the previous factor of safety of 1.26 to the east. The shallower slip plane was also analyzed, and the proposed excavation results in a factor of safety of 1.44. See appendix B for the slope stability outputs.

The proposed excavation is based on the cross section at Sta 0+48.92 that was provided by design division and is shown in Figure 5 below:

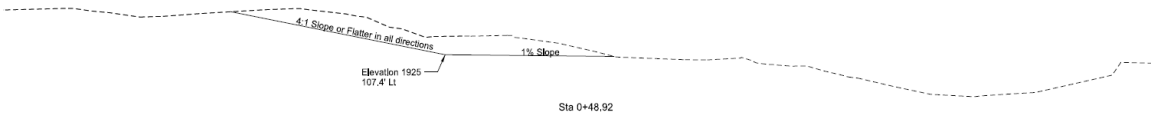

Figure 5 – Proposed Excavation @ Sta 0+48.92

This excavation is proposed to match into the east side where the previous grading was completed and extend to the west as far as possible within the current NDDOT R/W to encompass the entire landslide. As part of the proposed grading on the project, it is recommended to ensure positive drainage throughout the project limits to avoid any water ponding.

If there are any questions or concerns, please contact Jared Loegering jjloegering@nd.gov or Colter Schwagler cschwagler@nd.gov of the NDDOT Geotechnical Section.

Appendix A
Soil Boring Logs

LOG OF BORING SB - 1

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER 8-018(106)064 **DATE STARTED** 8/31/16 **COMPLETED** 8/31/16

PCN 23279 **ELEVATION** 924 ft

LOCATION Cass County **RP+Feet** 64+5062 ft **Offset** 40 Rt

DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD**

ENGINEER

NOTES

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
920	0	Soft to Medium Stiff Moist Grey to Dark Grey Fat Clay	A-7-6	CL	992	20	7	24 49	
			A-7-6	CL	993	10	9	22 49	
			A-7-6	CH	994	55		27 51	
			A-7-6	CH	995	85	4	24 59	
			A-7-5	CH	996	65		30 87	
910	10		A-7-6	CH	997	90	5	23 68	
			A-7-5	CH	998	85		31 88	
			A-7-6	CH	999	100	3	26 75	
			A-7-6	CH	1000	100		29 75	
			A-7-6	CH	1001	100	3	29 72	
900	20		A-7-5	CH	1002	100		30 77	
			A-7-6	CH	1003	100	3	28 107	
			A-7-6	CH	1004	100		29 86	
			A-7-6	CH	1005	100	2	28 76	
			A-7-5	CH	1006	100		31 71	
890	30		A-7-6	CH	1007	100	2	26 63	
			A-7-6	CH	1008	100		25 51	
			A-7-6	CL	1009	85	3	24 47	
		886.0 ft 38.0 ft	A-6	CL	1010	100		20 38	
	40	Medium Stiff Wet Grey Silt	A-4	ML	1011	60	7	0	
		882.0 ft 42.0 ft	A-4	ML	1012	75		35	
880		Very Stiff to Hard Glacial Till with Clayey Sand, Gravelly Clay, Lean Clay, Silty Sand, and Silt	A-6	SC	1013	75	27	32	
			A-7-6	GC	1014	100		41	
			A-6	CL	1015	75	44	35	
			A-6	CL	1016	75	47	29	
870	50		A-4	SM	1017	100	81	0	
			A-4	ML	1018	100	76	0	
			A-2-4	SM	1019	100		0	
			A-6	CL	1020	75	81	28	
		865.0 ft 59.0 ft	A-6	CL	1021	25	91	31	

Bottom of borehole at 59.0 ft

NDDOT
North Dakota Department of Transportation

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

LOG OF BORING SB - 2

PROJECT NUMBER 8-018(106)064 **DATE STARTED** 8/31/16 **COMPLETED** 8/31/16

PCN 23279 **ELEVATION** 930 ft

LOCATION Cass County **RP+Feet** 64+5140 ft **Offset** 50 Rt

DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD**

ENGINEER

NOTES

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	GRAPHIC LOG	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
930	0	Soft to Medium Stiff Moist Brown to Dark Grey Fat Clay		A-7-6	CH	1022	25	8	27 50	
				A-7-6	CH	1023	15	7	26 53	
				A-7-6	CH	1024	50		26 50	
				A-7-6	CH	1025	75	7	24 78	
				A-7-6	CH	1026	50		25 73	
920	10			A-7-5	CH	1027	75	6	31 64	
				A-7-5	CH	1028	85		31 96	
				A-7-6	CH	1029	85	5	29 78	
				A-7-6	CH	1030	95		25 57	
				A-7-6	CH	1031	90	4	23 52	
910	20			A-7-6	CH	1032	90		29 67	
				A-7-6	CH	1033	95	4	26 61	
				A-7-6	CH	1034	100		27 64	
				A-7-6	CH	1035	100	3	29 85	
				A-7-5	MH	1036	100		39 82	
900	30			A-7-5	MH	1037	100	3	38 81	
				A-7-6	CH	1038	100		29 69	
				A-7-5	CH	1039	100	2	30 69	
		892.0 ft 38.0 ft		A-7-6	CH	1040	100		26 60	
		Soft to Stiff Wet Dark Grey Silt		A-7-6	ML	1041	100	3	28 46	
890	40			A-4	ML	1042	100		0	
				A-4	ML	1043	100	4	0	
				A-4	ML	1044	100		0	
		882.0 ft 48.0 ft		A-4	ML	1045	100	11	0	
		Very Stiff to Hard Glacial Till including Lean Clay, Silty Lean Clay, and Silty Sand		A-6	CL	1046	85		17 29	
880	50			A-6	CL	1047	90	30	21 37	
				A-6	CL	1048	75	28	17 33	
				A-4	CL-ML	1049	100	62	118	
				A-4	CL-ML	1050	100		100 122	
		870.0 ft 60.0 ft		A-4	SM	1051	100	67	0	
870	60	Bottom of borehole at 60.0 ft								

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NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

LOG OF BORING SB - 3

PROJECT NUMBER 8-018(106)064 **DATE STARTED** 8/31/16 **COMPLETED** 8/31/16

PCN 23279 **ELEVATION** 933 ft

LOCATION Cass County **RP+Feet** 64+5200 ft **Offset** 56 Rt

DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD**

ENGINEER

NOTES

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	GRAPHIC LOG	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
930	0	Soft to Stiff Moist Brown to Dark Grey Fat Clay		A-4	ML	1052	15	8	0 / 26 83	
				A-7-6	CH	1053	70	10	26 89	
				A-7-6	CH	1054	75		23 65	
				A-7-6	CH	1055	85	5	25 73	
920	10			A-7-6	CH	1056	85		24 76	
				A-7-6	CH	1057	100	5	23 52	
				A-7-6	CH	1058	100		24 47	
				A-7-6	CL	1059	100	5	25 76	
910	20			A-7-6	CH	1060	100		23 64	
				A-7-6	CH	1061	100	6	25 75	
				A-7-6	CH	1062	100		25 74	
				A-7-6	CH	1063	100	6	31 96	
900	30			A-7-5	CH	1064	100		31 90	
				A-7-5	CH	1065	100	5	31 82	
				A-7-5	CH	1066	90		26 72	
				A-7-6	CH	1067	100	3	28 50	
	40	892.0 ft	41.0 ft	A-7-6	CH	1068	85		30 42	
890		Soft Wet Dark Grey Silt		A-7-5	ML	1069	100	3	0	
				A-4	ML	1070	90		0	
				A-4	ML	1071	100	4	0	
	50	882.0 ft	51.0 ft	A-4	ML	1072	100		19 37	
880		Very Stiff to Hard Glacial Till including Lean Clay and Silty Sand		A-6	CL	1073	100	19	16 29	
						1074	100			
				A-6	CL	1075	100	71	0	
		874.0 ft	59.0 ft	A-2-4	SM	1076	100	86		

Bottom of borehole at 59.0 ft

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

LOG OF BORING SB - 4

PROJECT NUMBER 8-018(106)064 **DATE STARTED** 8/2/17 **COMPLETED** 8/2/17

PCN 23279 **ELEVATION** 924 ft

LOCATION Cass County **RP+Feet** 64+5100 ft **Offset** 92 Rt

DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD**

ENGINEER

NOTES

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
924	0	Soft to Medium Stiff Moist Grey to Dark Grey Fat Clay			647	20	6		
					648	20	10		
920			A-7-5	MH	649	50		PL 30 LL 55	
			A-7-6	CH	650	85	6	PL 25 LL 57	
	10		A-7-6	CH	651	65	6	PL 25 LL 75	
			A-7-6	CH	652	75	6	PL 28 LL 75	
910			A-7-6	CL	653	75		PL 22 LL 49	
			A-7-6	CH	654	90	3	PL 28 LL 71	
	20		A-7-6	CH	655	100	4	PL 27 LL 69	
			A-7-6	CH	656	100	5	PL 24 LL 52	
900			A-7-6	CH	657	75		PL 21 LL 52	
			A-7-5	MH	658	100	3	PL 36 LL 75	
	30		A-7-5	CH	659	100	3	PL 31 LL 65	
			A-7-6	CH	660	100	3	PL 28 LL 52	
890		890.0 ft 34.0 ft							
		Medium Stiff Wet Grey Silt	A-7-6	ML	661	100		PL 29 LL 42	
			A-4	ML	662	100	4	PL 33 LL 36	
	40		A-4	ML	663	100	7	0 / 100	
			A-4	ML	664	100			
880		880.0 ft 44.0 ft							
		Very Stiff to Hard Glacial Till including Lean Clay, Silty Lean Clay, and Silty Sand	A-6	CL	665	85	24	PL 20 LL 37	
			A-6	CL	666	85	43	PL 14 LL 31	
	50		A-4	ML	667	100	57	0	
			A-4	SM	668	90	73	0	
870			A-4	SM	669	90		87 / 0	
			A-4	SC-SM	670	85		PL 100 LL 227	
	60	863.0 ft 61.0 ft	A-6	CL	671	85		PL 100 LL 2234	

Bottom of borehole at 61.0 ft

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LOG OF BORING SB - 5

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER 8-018(106)064 **DATE STARTED** 8/2/17 **COMPLETED** 8/2/17

PCN 23279 **ELEVATION** 925 ft

LOCATION Cass County **RP+Feet** 64+5049 ft **Offset** 63 Lt

DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD**

ENGINEER

NOTES

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
920	0	Soft to Medium Stiff Moist Grey to Dark Grey Fat Clay	A-7-6	CH	672	25	8	25 52	
			A-7-6	CH	673	25	10	24 54	
			A-7-6	CL	674	50		23 45	
			A-7-6	CH	675	75	4	25 76	
910	10		A-7-6	CH	676	90	4	23 69	
			A-7-6	CH	677	100	5	23 67	
			A-7-6	CH	678	90		25 63	
			A-7-6	CH	679	100	2	25 71	
900	20		A-7-6	CH	680	100	3	24 68	
			A-7-6	CH	681	100	4	24 65	
			A-7-6	CH	682	100		29 76	
			A-7-6	CH	683	100	3	29 78	
890	30		A-7-6	CH	684	100	3	27 63	
			A-7-6	CH	685	100	2	25 54	
		891.0 ft 34.0 ft							
		Medium Stiff Wet Grey Silt	A-7-6	ML	686	100		29 45	
			A-4	ML	687	100	3	0	
880	40		A-4	ML	688	100	5	0	
			A-4	ML	689	100	7	0	
		882.0 ft 43.0 ft							
		Hard Glacial Till including Lean Clay, Silty Lean Clay, and Silty Sand	A-6	CL	690	100		22 40	
			A-6	CL	691	90	48	17 31	
870	50		A-4	CL-ML	692	90		84 122	
			A-4	SM	693	100		100	
			A-4	SC-SM	694	100		100 1 21	
			A-4	CL-ML	695	100		100 1 21	
	60		A-4	SC	696	100		100 2 31	
		864.0 ft 61.0 ft							

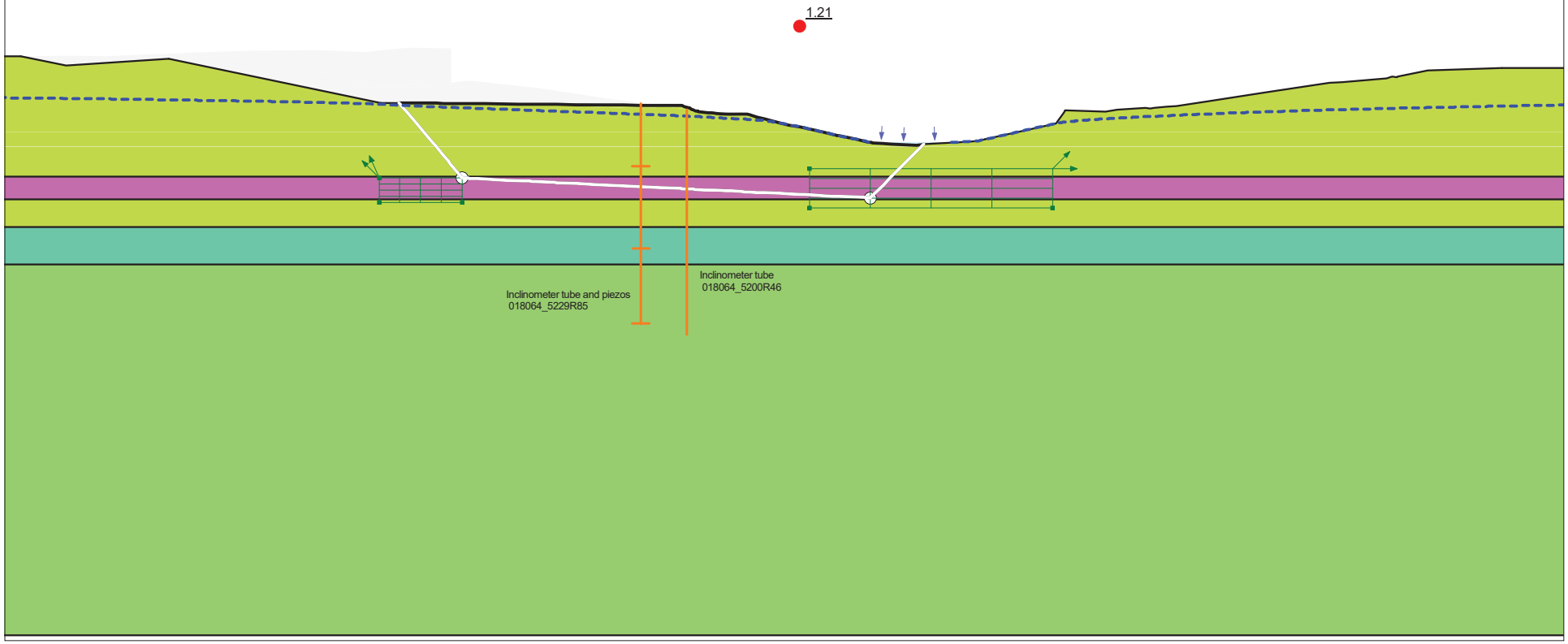
Bottom of borehole at 61.0 ft

Appendix B
Slope Stability Outputs

Effective Stress Analysis for Deeper Slip Plane

Factor of Safety
- 1.21 - 1.26
- 1.26 - 1.31
- 1.31 - 1.36
- 1.36 - 1.41
- ≥ 1.41

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Strength Function	Effective Cohesion (psf)	Effective Friction Angle (°)
	Fat Clay	Mohr-Coulomb	115		0	25
	Silt	Mohr-Coulomb	125		0	25
	Slip Plane	Shear/Normal Fn.	115	LL=80 CF=90		
	Till	Mohr-Coulomb	130		0	30



Effective Stress Analysis for Shallower Slip Plane

Factor of Safety
- 1.44 - 1.49
- 1.49 - 1.54
- 1.54 - 1.59
- 1.59 - 1.64
- ≥ 1.64

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Fat Clay	Mohr-Coulomb	115	0	25
	Silt	Mohr-Coulomb	125	0	25
	Slip Plane (Shallow Layer)	Mohr-Coulomb	115	0	8.5
	Till	Mohr-Coulomb	130	0	30