MEMORANDUM

Missouri Department of Transportation
Construction & Materials
Central Laboratory

TO: Bret Davidson-ne/cm

CC/ATT: Jeffrey Niemeyer-ne/do
Jennifer Hinson-ne/mt

FROM: Duncan Noack, G.R.I.T.
Intermediate Geotechnical Specialist

Zachary Troesser, P.E.
Geotechnical Engineer

DATE: September 20, 2022

SUBJECT: Geotechnical Section
Slide Investigation
Slide No. S2967
Job No. R35G
Route U, Warren County

In response to a request from Bret Davidson, the Geotechnical Section has conducted an investigation to determine the cause and corrective measures for two slides that have occurred on Route U in Warren County.

Location and History

The two slides are located just south of Rodgers Drive on Route U in Warren County. Slide 1 is located near Sta 109+48.0, approximately 300 feet south of Rodgers Road. Slide 1 is approximately 90 feet in width and 22 feet in height. Slide 2 is located near Sta 105+00, approximately 700 feet south of Rodgers Drive, and is approximately 110 feet in width and 15 feet in height.

The slides were discovered by the district on May 24, 2022. It is unknown when the slides began moving. Slide 1 does not show signs of movement at the toe of the slope but settled along the center line and within the northbound lane leading to cracks roughly 1 to 2 inches deep developing. Slide 2 shows signs of previous movement with an older slide being visible just off the side of the road. In addition, there is evidence that the pavement has been repaired before by repaving over where the road has settled with the pavement being 2.5 feet thick in places under the roadway. This likely only induces additional movement of the slide as more asphalt is placed on top. The current slide appears to have developed cracks from the center line to the edge of the northbound lane.

Existing Conditions

Our investigation for each slide was completed from the roadway limits due to site constraints. We have extrapolated conditions at the toe of each slide based on materials encountered from our borings in the roadway. Conditions are likely to vary from the assumed stratigraphy and should be verified during the repair of each failed embankment.

The slope height of Slide 1 is approximately 22 feet with the subsurface consisting of roughly 1.5 feet of asphalt and road base underlain by 10 to 15 feet of gravelly lean clay. The gravelly lean clay is divided into a soft to medium stiff saturated layer in the upper 6 to10 feet. The lower layer is moist and stiff. Beneath the clay layer is a layer of highly weathered dolomite roughly 2.5 to 4 feet thick underlain by a very dry, red, thinly laminated shale.

The slope height of Slide 2 is approximately 15 feet with the subsurface consisting of 1.0 to 2.5 feet of asphalt underlain by 0.8 to 3.7 feet of road base. Beneath the subgrade is 5.5 to 7.5 feet of soft to medium stiff lean and gravely lean clay followed by 1.0 to 5.0 feet of stiff, reddish brown fat clay believed to be completely weathered shale. Underlying the fat clay is a tannish grey dolomite with thin clay seams.

Though there could be additional reasons not discovered by the field investigation, it is believed that Slide 1 likely occurred due to the over saturation of the upper layer of gravelly lean clay resulting in a loss of shear strength. This combined with the very steep nature of the embankment allowed the layer to begin sliding along the surface of the lower clay layer resulting in the settling and cracking in the pavement. Slide 2 is a result of poorly placed fill that became saturated resulting a loss of shear strength.

Site Drainage

On the west side of the roadway, it appears rock is near the surface at both slides. The ditch line appears to be choked in some places with debris consisting of sand, gravel, cobbles, leaves, and tree limbs.

A drainpipe was discovered on the downhill slope between Slide 1 and 2 at roughly Sta. 107+50. The uphill side of the drain could not be found but is believed to daylight somewhere between the slides, in the ditch on the west side of the roadway. Without this drain, drainage is facilitated by the ditch on the west side of the roadway. As stated above the ditch seems to be cluttered with debris and is likely affected by this. We recommend that the drainpipe's uphill side should be found and cleaned out if it is not damaged. In addition, we recommend that the ditch be cleaned and have a ditch liner placed according to Specification Section 609.6 between stations 104+50 and 110+00. It is also encouraged that regular inspection and cleaning of the ditch be conducted for the length of Route U between Rodgers Drive and Lake Ridge Lane after the project's completion.

Recommendations for Slide 1 (Sta 108+50 to 110+00) Reinforced L-Basket Slope Repair (Figure 1)

Global stability modeling was completed for a slope reconstructed to follow a similar geometry to the existing slope prior to failure. Our initial repair model consisted of a rock wedge with an embankment slope of 1.5:1. However, this system has a very low factor of safety (FOS~1.1) and is not recommended. We then modeled a repair consisting of a reinforced rock wedge fill. This system has a suitable factor of safety for global stability and incorporates a slope facing product and horizontal geogrid reinforcement as outlined below.

Beginning at the edge of the western shoulder, make a temporary benched excavation no steeper than 1.5H:1V. The excavation should be embedded a minimum of 4 feet into shale at the toe of the slope or excavator refusal if shallower. We recommend the shale surface at the base of the repair be excavated such that it's slope is no steeper than 10 percent in any direction. We also recommend a representative from the geotechnical section be on site during excavation of the toe of the slope to verify these recommendations are valid based upon actual subsurface conditions.

We recommend an 8oz non-woven geotextile (such as US Fabrics US 205NW or Mirafi 180N) be laid down to separate existing soil from the new rock fill. The fabric should be lapped at the edges a minimum of 18-inches. The embankment should be reconstructed with Select Granular Backfill (SGB) in accordance with Specification Section 1010 with a final embankment slope no steeper than 1.5:1. The SGB should be faced with L-Shaped

Welded Wire Frame such as US Fabric's Welded Wire Facing Unit, or equivalent, see Image 1 below. The final slope will have a stepped finish.

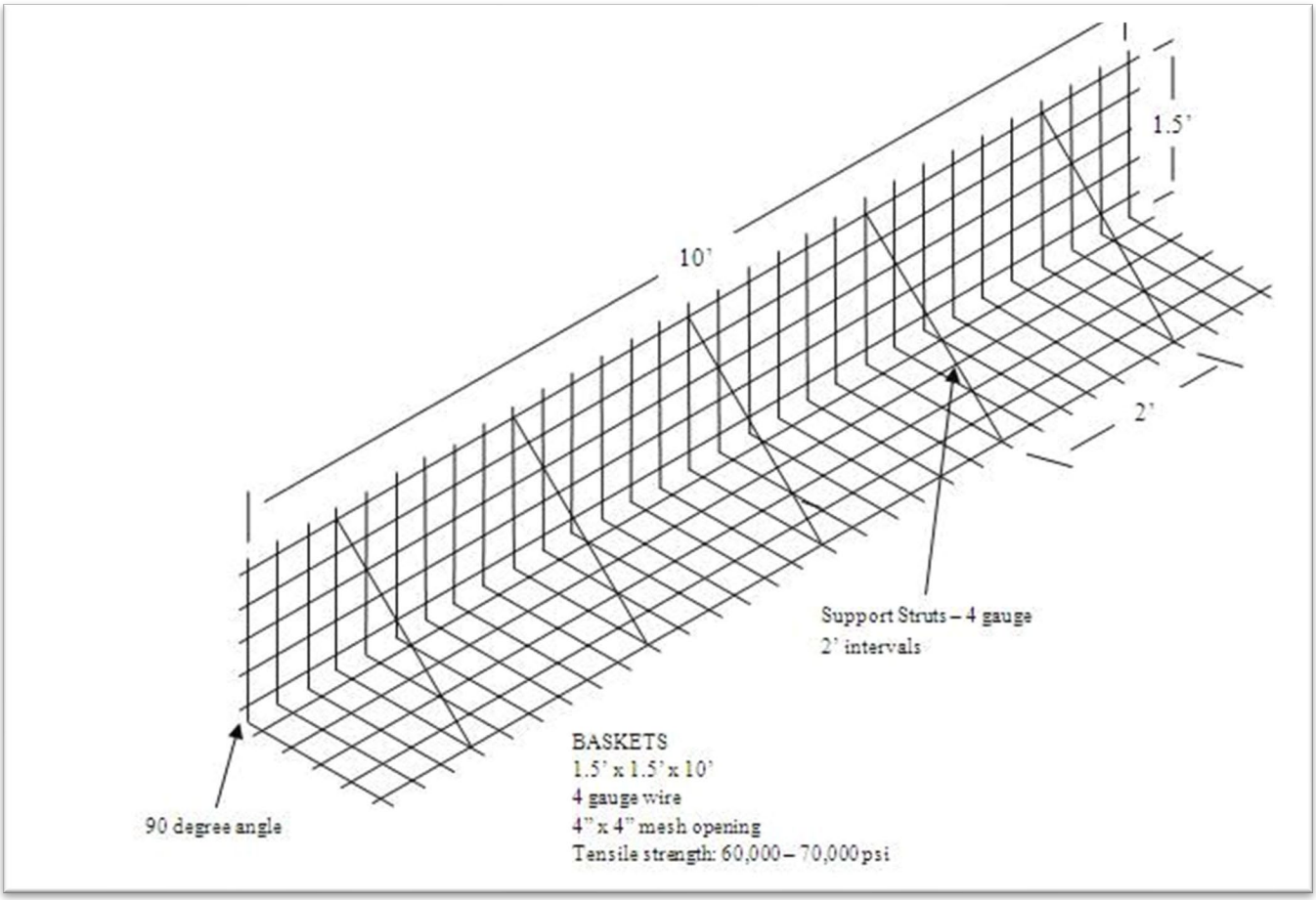

Image 1 - Welded Wire Facing Units, Taken From US Fabrics, www.usfabricsinc.com

This system should incorporate geogrid reinforcement placed horizontally from the back of the new fill to the face of each L-shaped Welded Wire Form. The L-shaped forms should be placed horizontally and be faced with a non-degradable/UV resistant mesh to retain fine materials. For a concept of the design, we anticipate the design will incorporate a polymer mesh facing similar to US Fabric's Startamesh and geogrid reinforcement similar to US Fabrics SGU 80 or SGU 100.

We recommend using an 8oz non-woven geotextile to separate the existing soil from the new rock fill. The fabric also needs to be lapped at the edges a minimum of 18 inches. We also recommend installing a 4-inch perforated pipe bedded in 1-inch clean rock and wrapped with an 8 oz non-woven geotextile, such as US Fabrics US 205NW or equivalent, at the back of the base of the repair. If the base of the repair dips toward the toe, a perforated pipe bedded in in 1-inch clean rock and wrapped with an 8-oz non-woven geotextile should also be placed along the toe of the repair. The perforated drainage pipe(s) should be connected to solid 4-inch drainage pipes spaced every 50 feet along the repair. The solid pipes should be routed to daylight and drain on a rock flume pad.

Recommendations for Slide 2 (Sta 104+50 to 105+80) Rock Wedge Repair (Figure 2)

Global stability modeling was completed for a slope reconstructed to follow a similar geometry to the existing slope prior to failure. Our repair model consisted of a rock wedge with an embankment slope of 2:1. A suitable factor of safety was achieved and recommendations for constructing the slope are provided below.

Beginning at the edge of the western shoulder, make a temporary benched excavation no steeper than 2H:1V. The excavation should be embedded a minimum of 4 ft into weathered dolomite or excavator refusal, whichever comes first. We recommend the dolomite surface at the base of the repair be excavated such that it is no steeper than 10 percent in any direction. We also recommend a representative from the geotechnical section be on site during excavation of the toe of the slope to verify these recommendations are valid based upon actual subsurface conditions.

It is recommended that a slope no steeper than 2H:1V be constructed utilizing large rock fill meeting the following:

- Predominant top size of 12 inches
- Particle top size should be restricted to 24”. If boulders larger than 24” are delivered to the site, they can be removed from the fill and placed near the toe of the slope.
- Up to about 20% passing 6 inches is permissible.
- Fines should not exceed 10%.

We recommend using an 8oz non-woven geotextile to separate the existing soil from the new rock fill. The fabric also needs to be lapped at the edges a minimum of 18 inches. We also recommend installing a 4-inch perforated pipe bedded in 1-inch clean rock and wrapped with an 8 oz non-woven geotextile, such as US Fabrics US 205NW or equivalent, at the back of the base of the repair. If the base of the repair dips toward the toe, a perforated pipe bedded in in 1-inch clean rock and wrapped with an 8-oz non-woven geotextile should also be placed along the toe of the repair. The perforated drainage pipe(s) should be connected to solid 4-inch drainage pipes spaced every 50 feet along the repair. The solid pipes should be routed to daylight and drain on a rock flume pad.

DN/zt

Missouri Department of Transportation
Construction and Materials

BORING NO. A1

Job No.: S2967 **County:** Warren **Route:** U
Design: N Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Kenneth Tuttle
Station: 109+61.3 **Northing:** 1047561.7 **Date of Work:** 07/13/22-07/13/22
Offset: 6.0 L **Easting:** 612708.4 **Depth to Water:**
Elevation: 876.4 **Requested Northing:** 1047559.7 **Depth Hole Open:**
Requested Station: 109+59.3 **Requested Easting:** 612712.4 **Time Change:**
Requested Offset: 4.0 L **Equipment:** Mobile B-31 ,
Requested Elevation: 876.4 **Location Note:**
Drill No.: G-9402 **Hammer Efficiency:** **Drilling Method:** Continuous Flight Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-1.4' ASPHALT	875						
		1.4-2.2' CRUSHED AGGREGATE BASE							
		2.2-4.3' Brown, GRAVELLY FAT CLAY, soft, moist							
5		4.3-7.2' Tan, GRAVELLY COBBLES	870						
		7.2-8.9' Brown, GRAVELLY LEAN CLAY trace cobbles, stiff, moist							
10		8.9-10.6' BOULDERS and cobbles	865						
		10.6-15.7' Tan, GRAVELLY LEAN CLAY trace cobbles, medium stiff, moist							
15		15.7-17.7' Bedrock, tan, highly weathered, likely Dolomite	860						
		17.7-18.3' Bedrock, tan, likely Dolomite							
		Bottom of borehole at 18.3 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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BORING NO. O-22-27 (B1)

Job No.: S2967 **County:** Warren **Route:** U
Design: N Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 109+35.6 **Northing:** 1047535 **Date of Work:** 07/05/22-07/05/22
Offset: 9.5 R **Easting:** 612724 **Depth to Water:**
Elevation: 873.1 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler, Shelby Tube
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0	0.0-0.4' ASPHALT							
	0.4-1.4' CRUSHED AGGREGATE BASE							
	1.4-4.0' Gray, GRAVELLY LEAN CLAY, medium stiff, moist	870		27	3-3-2 (7)			
5	4.0-10.0' Brown mottled tan, LEAN CLAY trace gravel, soft, moist			45			PP = 0.25 tsf Torvane = 0.20 tsf	MC = 21.9% γ_{sat} = 128 pcf(1) LL = 30 PL = 16
		865		67	1-1-1 (3)		PP = 0.25 tsf	MC = 20.2% γ_{sat} = 130 pcf(1)
10	10.0-15.3' Brown, GRAVELLY LEAN CLAY trace cobbles, stiff to very hard, moist to wet 10.0-12.0' shelby tube crumpled due to gravel			25				
		860		27	5-3-7 (14)			MC = 20.7% γ_{sat} = 130 pcf(1)
15	15.3-17.9' Cherty Dolomite, light gray and white, highly weathered			67	14-29-32 (82)			MC = 25.7% γ_{sat} = 124 pcf(1)
	17.9-21.5' Shale, red, thinly laminated, moderately weathered to slightly weathered	855		69	13-31-37/0.5', 10/0'		PP = 7.50 tsf	
20				100	9-23-34 (77)			LL = 34 PL = 18
	Bottom of borehole at 21.5 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

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Missouri Department of Transportation
Construction and Materials

BORING NO. O-22-28 (B2)

Job No.: S2967 **County:** Warren **Route:** U
Design: N Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 109+58.1 **Northing:** 1047557.5 **Date of Work:** 07/05/22-07/05/22
Offset: 8.6 R **Easting:** 612724.9 **Depth to Water:**
Elevation: 876.1 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler, Shelby Tube
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-0.4' ASPHALT	875						
		0.4-1.4' CRUSHED AGGREGATE BASE							
		1.4-9.8' Brown mottled gray, GRAVELLY LEAN CLAY trace cobbles, soft to stiff, moist to wet			13	4-1-1 (3)			MC = 18.1% γ_{sat} = 133 pcf(1)
5			870		50			PP = 0.75 tsf Torvane = 0.50 tsf	MC = 19.0% γ_{sat} = 132 pcf(1) LL = 32 PL = 17
					20	5-3-5 (11)			
10		9.8-14.4' Dolomite, light gray and white, highly weathered	865		100	17-37-37/0.2', 10/0'			
					100	27/0.2', 10/0'			
		Bottom of borehole at 14.4 feet.			100	17/0.3', 10/0'			

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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BORING NO. A3

Job No.: S2967 **County:** Warren **Route:** U
Design: N Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Kenneth Tuttle
Station: 108+97.4 **Northing:** 1047498 **Date of Work:** 07/13/22-07/13/22
Offset: 5.4 L **Easting:** 612705.9 **Depth to Water:**
Elevation: 868.9 **Requested Northing:** 1047498 **Depth Hole Open:**
Requested Station: 108+97.4 **Requested Easting:** 612707.4 **Time Change:**
Requested Offset: 3.9 L **Equipment:** Mobile B-31 ,
Requested Elevation: 868.9 **Location Note:**
Drill No.: G-9402 **Hammer Efficiency:** **Drilling Method:** Continuous Flight Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-1.3' ASPHALT							
		1.3-2.2' CRUSHED AGGREGATE BASE							
		2.2-4.0' Brown, GRAVELLY LEAN CLAY, soft, moist	865						
5		4.0-6.5' BOULDERS and cobbles							
		6.5-9.0' Tan, GRAVELLY LEAN CLAY scattered cobbles, medium stiff, moist	860						
10		9.0-12.0' BOULDERS and cobbles							
		12.0-14.2' Tan, GRAVELLY LEAN CLAY scattered cobbles, medium stiff, moist	855						
15		14.2-18.0' Red, LEAN CLAY, stiff, moist							
		18.0-20.2' Bedrock, red, likely Shale	850						
20		Bottom of borehole at 20.2 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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BORING NO. O-22-29 (B3)

Job No.: S2967 **County:** Warren **Route:** U
Design: N Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 109+5.7 **Northing:** 1047505.3 **Date of Work:** 07/06/22-07/06/22
Offset: 9.1 R **Easting:** 612721.1 **Depth to Water:**
Elevation: 869.4 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler, Shelby Tube
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-0.4' ASPHALT							
		0.4-1.4' CRUSHED AGGREGATE BASE							
		1.4-11.1' Reddish brown, GRAVELLY LEAN CLAY, medium stiff, moist		X	27	3-3-1 (5)			MC = 9.0% γ_{sat} = 147 pcf(1)
			865						
5					100			PP = 0.50 tsf Torvane = 0.30 tsf	MC = 17.8% γ_{sat} = 133 pcf(1) LL = 47 PL = 21
		6.1' shelby tube refusal		X	40	4-3-2 (7)		PP = 0.00 tsf	
			860						MC = 20.9% γ_{sat} = 129 pcf(1)
10					100			PP = 0.25 tsf Torvane = 0.35 tsf	MC = 18.0% γ_{sat} = 133 pcf(1)
		11.1-14.7' Brown, GRAVELLY LEAN CLAY, very stiff, moist to wet 11.1' shelby tube refusal		X	7	12-10-5 (20)			MC = 17.4% γ_{sat} = 134 pcf(1)
			855						
15		14.7-21.2' Shale, red, thinly laminated, wiith layers of tan, highly weathered sandstone		X	100	9-13-18 (42)		PP = 8.00 tsf	LL = 24 PL = 15
				X	100	9-12-15 (36)		PP = 8.00 tsf	LL = 27 PL = 15
			850						
20				X	100	9-23-37/0.2', 10/0'		PP = 7.50 tsf	
		Bottom of borehole at 21.2 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

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Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Kenneth Tuttle
Station: 105+51.0 **Northing:** 1047150.8 **Date of Work:** 07/13/22-07/13/22
Offset: 15.8 L **Easting:** 612667.8 **Depth to Water:**
Elevation: 826.7 **Requested Northing:** 1047152.2 **Depth Hole Open:**
Requested Station: 105+50.0 **Requested Easting:** 612674.1 **Time Change:**
Requested Offset: 8.8 L **Equipment:** Mobile B-31 ,
Requested Elevation: 826.7 **Location Note:**
Drill No.: G-9402 **Hammer Efficiency:** **Drilling Method:** Continuous Flight Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-4.2' Brown, LEAN CLAY, soft, moist	825						
5		4.2-5.4' BOULDERS Bottom of borehole at 5.4 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
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BORING NO. A4B

Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Kenneth Tuttle
Station: 105+46.0 **Northing:** 1047145.8 **Date of Work:** 07/13/22-07/13/22
Offset: 14.8 L **Easting:** 612668.8 **Depth to Water:**
Elevation: 826.7 **Requested Northing:** 1047152.2 **Depth Hole Open:**
Requested Station: 105+50.0 **Requested Easting:** 612674.1 **Time Change:**
Requested Offset: 8.8 L **Equipment:** Mobile B-31 ,
Requested Elevation: 826.7 **Location Note:**
Drill No.: G-9402 **Hammer Efficiency:** **Drilling Method:** Continuous Flight Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-5.1' Brown, LEAN CLAY, soft, moist	825						
5		5.1-5.3' COBBLES 5.3-6.8' Brown, LEAN CLAY scattered gravel, soft, moist	820						
		6.8-6.9' COBBLES 6.9-13.6' Brown, GRAVELLY LEAN CLAY trace cobbles, soft, moist							
10			815						
		13.6-14.3' Bedrock, highly weathered, likely Dolomite 14.3-14.7' Bedrock, likely Dolomite Bottom of borehole at 14.7 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

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BORING NO. O-22-30 (B4)

Job No.: S2967 **County:** Warren **Route:** U
Design: N Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 109+21.6 **Northing:** 1047521.8 **Date of Work:** 07/06/22-07/06/22
Offset: 0.2 L **Easting:** 612713.2 **Depth to Water:**
Elevation: 871.5 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler, Shelby Tube
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-0.3' ASPHALT 0.3-1.7' CRUSHED AGGREGATE BASE	870						
		1.7-2.4' BOULDERS							
		2.4-8.4' Reddish brown, GRAVELLY LEAN CLAY trace cobbles, medium stiff to stiff, moist			33	2-5-4 (12)		PP = 0.50 tsf	MC = 22.1% γ_{sat} = 128 pcf(1)
5									
			865		33	1-2-2 (5)		PP = 0.50 tsf	MC = 22.1% γ_{sat} = 128 pcf(1)
					44			PP = 0.50 tsf Torvane = 0.30 tsf	MC = 12.2% γ_{sat} = 141 pcf(1) LL = 34 PL = 18
		8.4-12.6' Dolomite, light gray and white, highly weathered, with clay			33	8-8-5 (18)			
10		8.4' shelby tube refusal	860		67	3-11-19 (41)			
		12.6-13.9' Shale, red, thinly laminated, wiith layers of tan, highly weathered sandstone			93	18-32-37/0.4', 10/0'		PP = 3.00 tsf	MC = 6.9% γ_{sat} = 151 pcf(1)
		Bottom of borehole at 13.9 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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Missouri Department of Transportation
Construction and Materials

BORING NO. A5

Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Kenneth Tuttle
Station: 105+16.6 **Northing:** 1047119 **Date of Work:** 07/13/22-07/13/22
Offset: 14.9 L **Easting:** 612665.3 **Depth to Water:**
Elevation: 822.7 **Requested Northing:** 1047119 **Depth Hole Open:**
Requested Station: 105+16.6 **Requested Easting:** 612669.8 **Time Change:**
Requested Offset: 10.4 L **Equipment:** Mobile B-31 ,
Requested Elevation: 822.7 **Location Note:**
Drill No.: G-9402 **Hammer Efficiency:** **Drilling Method:** Continuous Flight Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-1.3' ASPHALT							
		1.3-2.6' CRUSHED AGGREGATE BASE	820						
		2.6-6.8' Brown, LEAN CLAY, soft, moist							
5									
		6.8-10.0' Brown, GRAVELLY LEAN CLAY trace cobbles, moist	815						
10		10.0-10.6' COBBLES							
		10.6-14.5' Light brown, FAT CLAY, moist	810						
		14.5-14.9' Bedrock, likely Dolomite							
		Bottom of borehole at 14.9 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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Missouri Department of Transportation
Construction and Materials

BORING NO. O-22-31 (B5)

Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 105+22.5 **Northing:** 1047123.8 **Date of Work:** 07/06/22-07/06/22
Offset: 2.9 R **Easting:** 612683.5 **Depth to Water:**
Elevation: 823.2 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler, Shelby Tube
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-2.5' ASPHALT							
		2.5-4.0' CRUSHED AGGREGATE BASE	820						
5		4.0-5.5' Brown, GRAVELLY LEAN CLAY trace cobbles, moist							
		5.5-9.7' Reddish gray mottled, FAT CLAY, moist, trace organics (roots)	815		50			PP = 0.50 tsf Torvane = 0.40 tsf	MC = 20.4% γ_{sat} = 130 pcf(1) LL = 44 PL = 22
10		9.7-13.2' Brownish gray, LEAN CLAY trace gravel, very stiff, moist			80		Qu Test Results UCS = 3.74 ksf MC = 25% γ_{moist} = 123.8 pcf Direct Shear Results	PP = 1.50 tsf Torvane = 0.70 tsf	MC = 29.4% γ_{sat} = 121 pcf(1) LL = 51 PL = 23
		11.5' shelby tube refusal	810		100	8-7-8 (20)		PP = 1.75 tsf	MC = 22.3% γ_{sat} = 128 pcf(1) LL = 56 PL = 24
15		13.2-17.4' Dolomite, and, highly weathered to moderately weathered 13.2-17.4' rock bitted							
		Bottom of borehole at 17.4 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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Missouri Department of Transportation
Construction and Materials

BORING NO. A6

Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Kenneth Tuttle
Station: 104+78.2 **Northing:** 1047080.8 **Date of Work:** 07/13/22-07/13/22
Offset: 14.4 W **Easting:** 612662.6 **Depth to Water:**
Elevation: 818.2 **Requested Northing:** 1047080.8 **Depth Hole Open:**
Requested Station: 104+78.2 **Requested Easting:** 612666.6 **Time Change:**
Requested Offset: 10.4 L **Equipment:** Mobile B-31 ,
Requested Elevation: 818.2 **Location Note:**
Drill No.: G-9402 **Hammer Efficiency:** **Drilling Method:** Continuous Flight Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-1.2' ASPHALT							
		1.2-3.7' CRUSHED AGGREGATE BASE	815						
5		3.7-6.2' Tan, GRAVELLY LEAN CLAY, soft, moist							
		6.2-12.4' Reddish brown, FAT CLAY, soft, moist	810						
10									
		12.4-12.7' Bedrock, highly weathered, likely Dolomite							
		12.7-12.8' Bedrock, likely Dolomite							
		Bottom of borehole at 12.8 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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Missouri Department of Transportation
Construction and Materials

BORING NO. O-22-32 (B6)

Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 104+82.5 **Northing:** 1047084.1 **Date of Work:** 07/06/22-07/06/22
Offset: 1.5 R **Easting:** 612678.9 **Depth to Water:**
Elevation: 818.4 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler, Shelby Tube
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-2.5' ASPHALT							
		2.5-3.5' CRUSHED AGGREGATE BASE	815						
5		3.5-9.8' Reddish brown mottled gray, GRAVELLY LEAN CLAY trace cobbles, medium stiff, moist 4.7-5.5' boulder							
			810		40	1-3-2 (7)		PP = 0.50 tsf	MC = 24.8% γ_{sat} = 125 pcf(1)
10		9.8-13.2' Reddish brown mottled gray, FAT CLAY trace fine gravel, hard, moist, trace organics (roots)			50		Qu Test Results UCS = 2.56 ksf MC = 28.4% γ_{moist} = 118.9 pcf Direct Shear Results	PP = 1.25 tsf Torvane = 0.70 tsf	MC = 27.6% γ_{sat} = 122 pcf(1) LL = 51 PL = 25
			805		46	3-9-20/0.3', 10/0'		PP = 1.50 tsf	MC = 24.7% γ_{sat} = 125 pcf(1)
15		13.2-16.2' Dolomite, tannish gray and, highly weathered to moderately weathered, with thin clay seams 13.2-16.2' rock bitted							
		Bottom of borehole at 16.2 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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Missouri Department of Transportation
Construction and Materials

BORING NO. O-22-33 (B7)

Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 105+50.5 **Northing:** 1047151.7 **Date of Work:** 07/06/22-07/06/22
Offset: 3.4 R **Easting:** 612686.9 **Depth to Water:**
Elevation: 826.4 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler, Shelby Tube
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-1.7' ASPHALT	825						
		1.7-2.5' CRUSHED AGGREGATE BASE							
		2.5-10.8' Reddish brown mottled gray, LEAN CLAY scattered fine gravel, trace cobbles, soft to stiff, moist							
5		4.7-5.0' cobbles	820		40	0-1-1 (3)		PP = 1.00 tsf	MC = 24.0% γ_{sat} = 126 pcf(1)
					33	2-5-6 (15)		PP = 3.00 tsf	MC = 20.2% γ_{sat} = 130 pcf(1)
10		10.8-11.9' Gray and reddish brown, FAT CLAY trace gravel, hard, moist, trace organics (roots)	815		80		Qu Test Results UCS = 4.66 ksf MC = 23% γ_{moist} = 126.9 pcf	PP = 1.50 tsf Torvane = 0.90 tsf	MC = 31.4% γ_{sat} = 119 pcf(1) LL = 74 PL = 36
		11.5' shelby tube refusal			100	20/0.4', 10/0'		PP = 2.50 tsf	LL = 53 PL = 25
		11.9-13.9' Dolomite, tannish gray and, highly weathered to moderately weathered, with thin clay seams							
		11.9-13.9' rock bitted							
		Bottom of borehole at 13.9 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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Missouri Department of Transportation
Construction and Materials

BORING NO. O-22-34 (B8)

Job No.: S2967 **County:** Warren **Route:** U
Design: S Slide **Skew:** **Location:**
Bent: **Logged By:** Duncan Noack **Operator:** Gary Degraffenreid
Station: 105+3.1 **Northing:** 1047105.5 **Date of Work:** 07/06/22-07/06/22
Offset: 9.4 L **Easting:** 612669.7 **Depth to Water:**
Elevation: 821.2 **Requested Northing:** **Depth Hole Open:**
Requested Station: **Requested Easting:** **Time Change:**
Requested Offset: **Equipment:** Acker Soil XLS ,Split-Spoon Sampler
Requested Elevation: **Location Note:**
Drill No.: G-9462 **Hammer Efficiency:** 81% **Drilling Method:** Hollow Stem Auger

Depth (ft)	Graphic	Description	Elevation (ft)	Sample Type	REC % (RQD %)	Blow Counts (N_{60})	Shear Data	Field Tests	Index Tests
0		0.0-1.0' ASPHALT	820						
		1.0-4.7' CRUSHED AGGREGATE BASE, very dry and dusty							
5		4.7-5.0' COBBLES							
		5.0-8.0' Reddish gray, LEAN CLAY with fine gravel, medium stiff to stiff, moist	815		67	6-2-4 (8)		PP = 1.50 tsf	MC = 32.0% γ_{sat} = 119 pcf(1) LL = 44 PL = 22
					87	6-4-5 (12)		PP = 1.50 tsf	MC = 16.4% γ_{sat} = 135 pcf(1)
		8.0' boring terminated due to mechanical issues Bottom of borehole at 8.0 feet.							

N_{60} = (Em/60)Nm N_{60} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual

Coordinate System: U.S. State Plane 1983 **Coordinate Zone:** Missouri Central **Coordinate Proj. Factor:**
Coordinate Datum: NAD 83 (CONUS) **Coordinate Units:** U.S. Survey Feet

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KEY TO SYMBOLS

Missouri Dept of Transportation

CLIENT _____ **PROJECT NAME** Slide Analysis

PROJECT NUMBER S2967 **PROJECT LOCATION** _____

LITHOLOGIC SYMBOLS
(Unified Soil Classification System)

- Asphalt
- Boulders and cobbles
- USCS High Plasticity Clay
- USCS High Plasticity Gravelly Clay
- USCS Low Plasticity Clay
- USCS Low Plasticity Gravelly Clay
- Dolomite
- USCS Poorly-graded Gravel
- Highly Weathered Dolomite
- Shale

SAMPLER SYMBOLS

- Split-Spoon Sampler
- Shelby Tube

WELL CONSTRUCTION SYMBOLS

ABBREVIATIONS

LL - LIQUID LIMIT (%)
PI - PLASTIC INDEX (%)
W - MOISTURE CONTENT (%)
DD - DRY DENSITY (PCF)
NP - NON PLASTIC
-200 - PERCENT PASSING NO. 200 SIEVE
PP - POCKET PENETROMETER (TSF)
Qu - UNCONFINED COMPRESSIVE STRENGTH (PSF)

TV - TORVANE
PID - PHOTOIONIZATION DETECTOR
UC - UNCONFINED COMPRESSION
ppm - PARTS PER MILLION

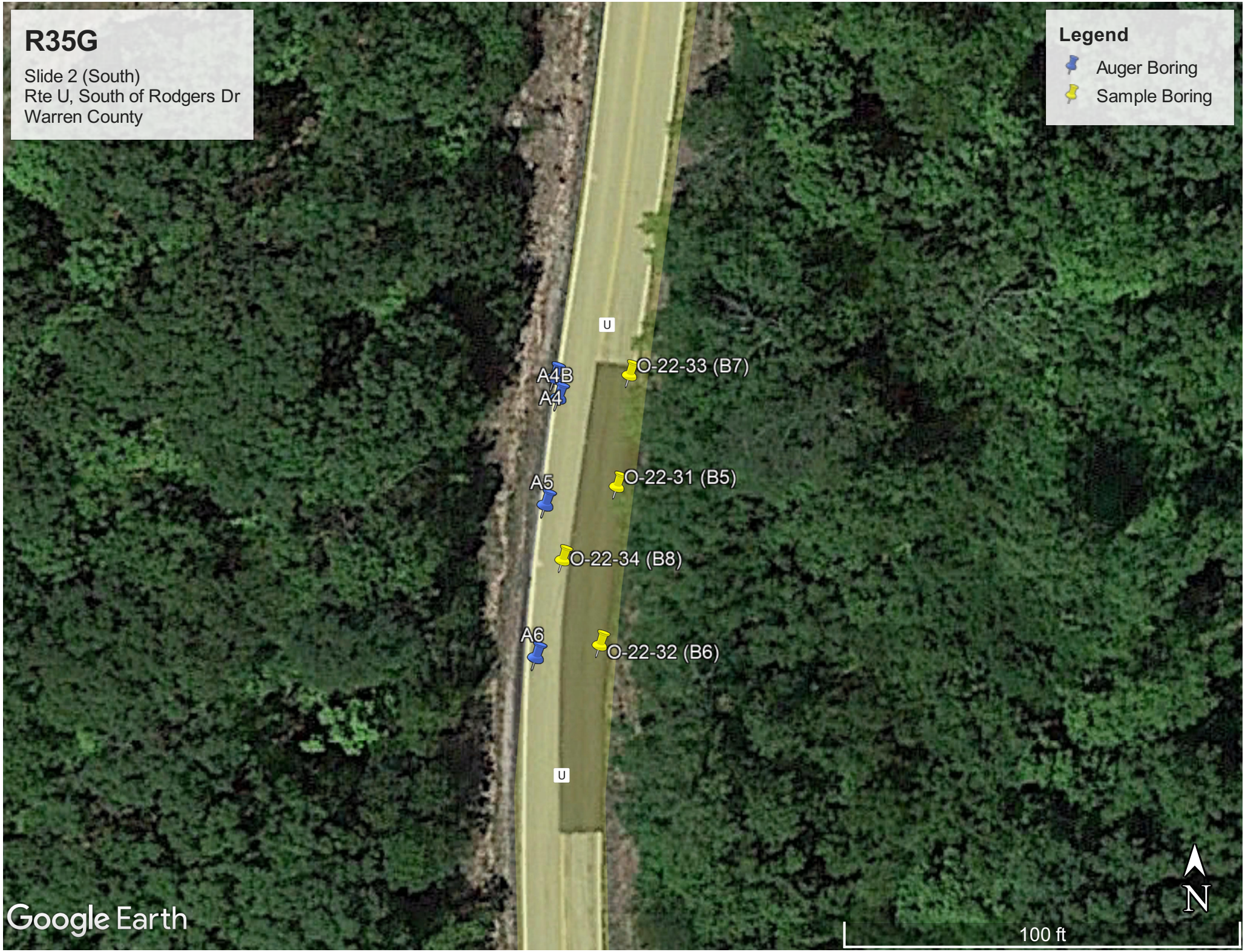
▽ Water Level at Time of Drilling

▼ Water Level at End of Drilling

▼ Water Level after Drilling


R35G
Rte U, South of Rodgers Dr
Warren County
Legend
Auger Boring
Sample Boring
A1
O-22-28 (B2)
O-22-27 (B1)
O-22-30 (B4)
O-22-29 (B3)
A3
A4B
A4
O-22-33 (B7)
A5
O-22-31 (B5)
O-22-34 (B8)
A6
O-22-32 (B6)
N
200 ft
Google Earth


R35G
Slide 1 (North)
Rte U, South of Rodgers Dr
Warren County
Legend
Auger Boring
Sample Boring
U
A1
O-22-28 (B2)
O-22-27 (B1)
O-22-30 (B4)
U
O-22-29 (B3)
A3
N
100 ft
Google Earth


R35G
Slide 2 (South)
Rte U, South of Rodgers Dr
Warren County
Legend
Auger Boring
Sample Boring
U
A4B
A4
O-22-33 (B7)
A5
O-22-31 (B5)
O-22-34 (B8)
A6
O-22-32 (B6)
U
N
100 ft
Google Earth

Missouri Dept of Transportation

SUBSURFACE DIAGRAM

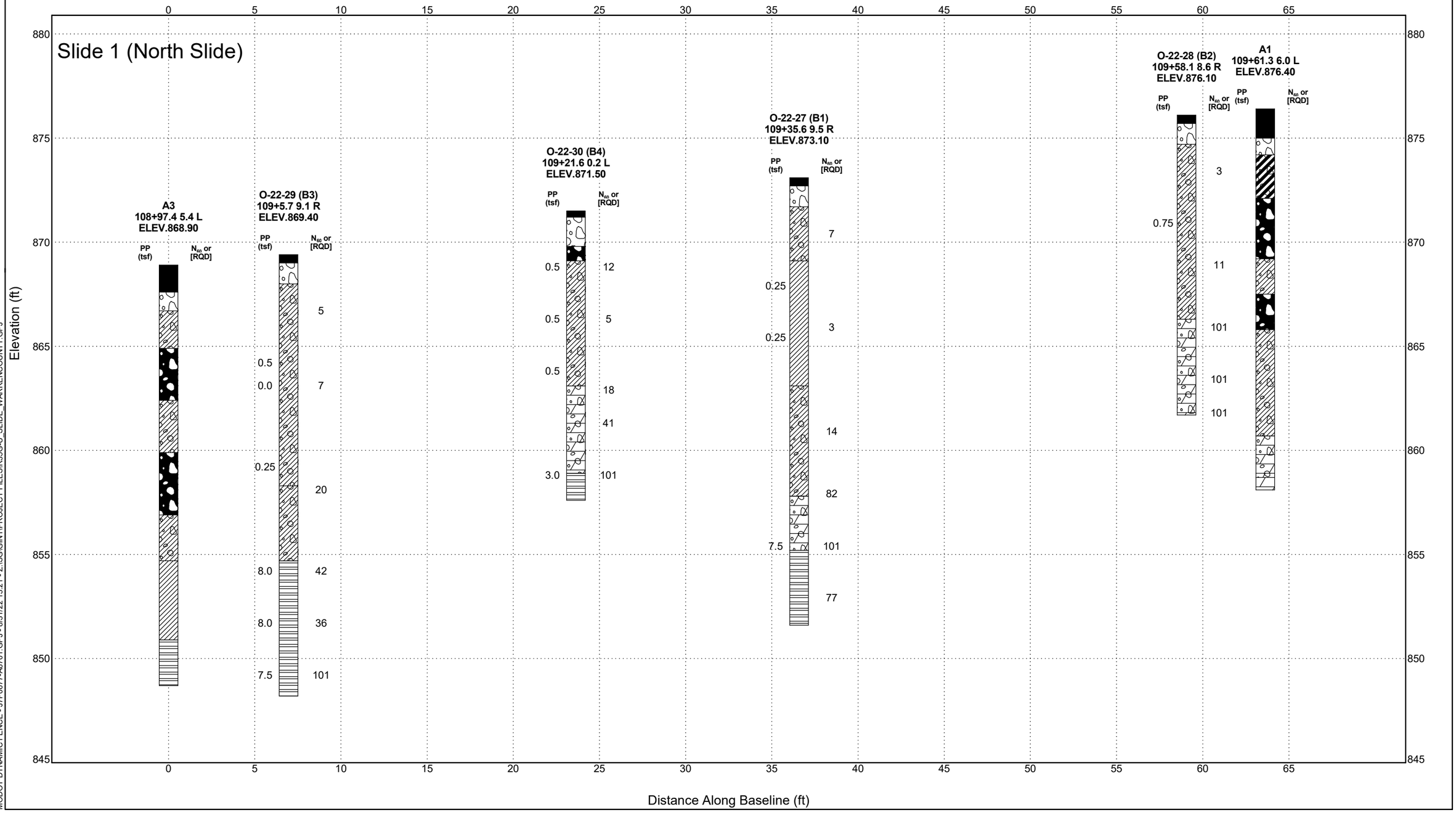
PROJECT NAME Slide Analysis

PROJECT LOCATION Slide 1

CLIENT

PROJECT NUMBER S2967

- Asphalt
- Boulders and cobbles
- Dolomite
- USCS Poorly-graded Gravel
- USCS Low Plasticity Gravelly Clay
- USCS Low Plasticity Clay
- USCS High Plasticity Gravelly Clay
- Highly Weathered Dolomite
- Shale



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Missouri Dept of Transportation

SUBSURFACE DIAGRAM

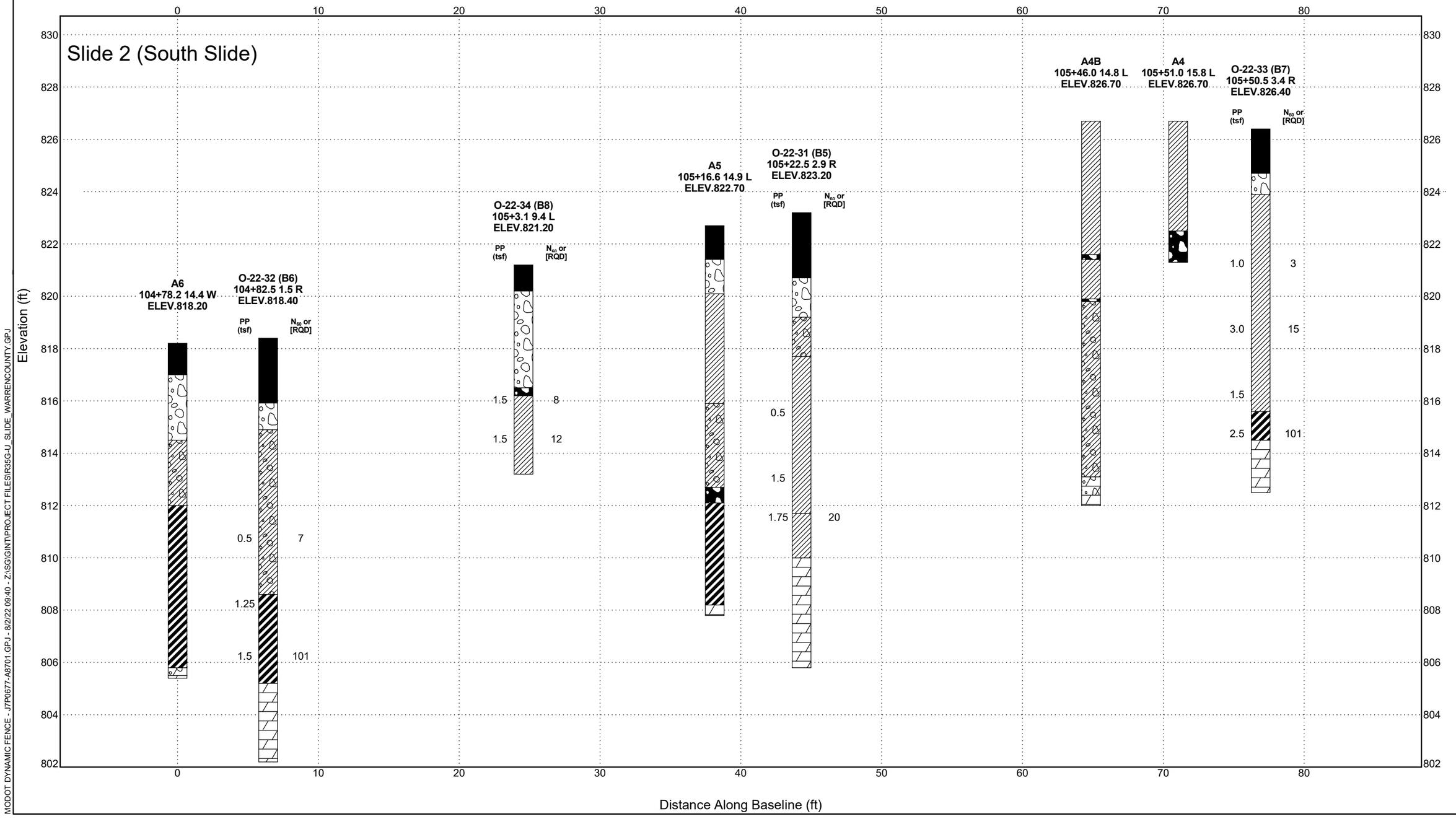
PROJECT NAME Slide Analysis

PROJECT LOCATION Slide 2

CLIENT

PROJECT NUMBER Warren County Slide

- USCS Low Plasticity Clay
- Highly Weathered Dolomite
- USCS Poorly-graded Gravel
- Boulders and cobbles
- Dolomite
- USCS High Plasticity Clay
- USCS Low Plasticity Gravelly Clay
- Asphalt

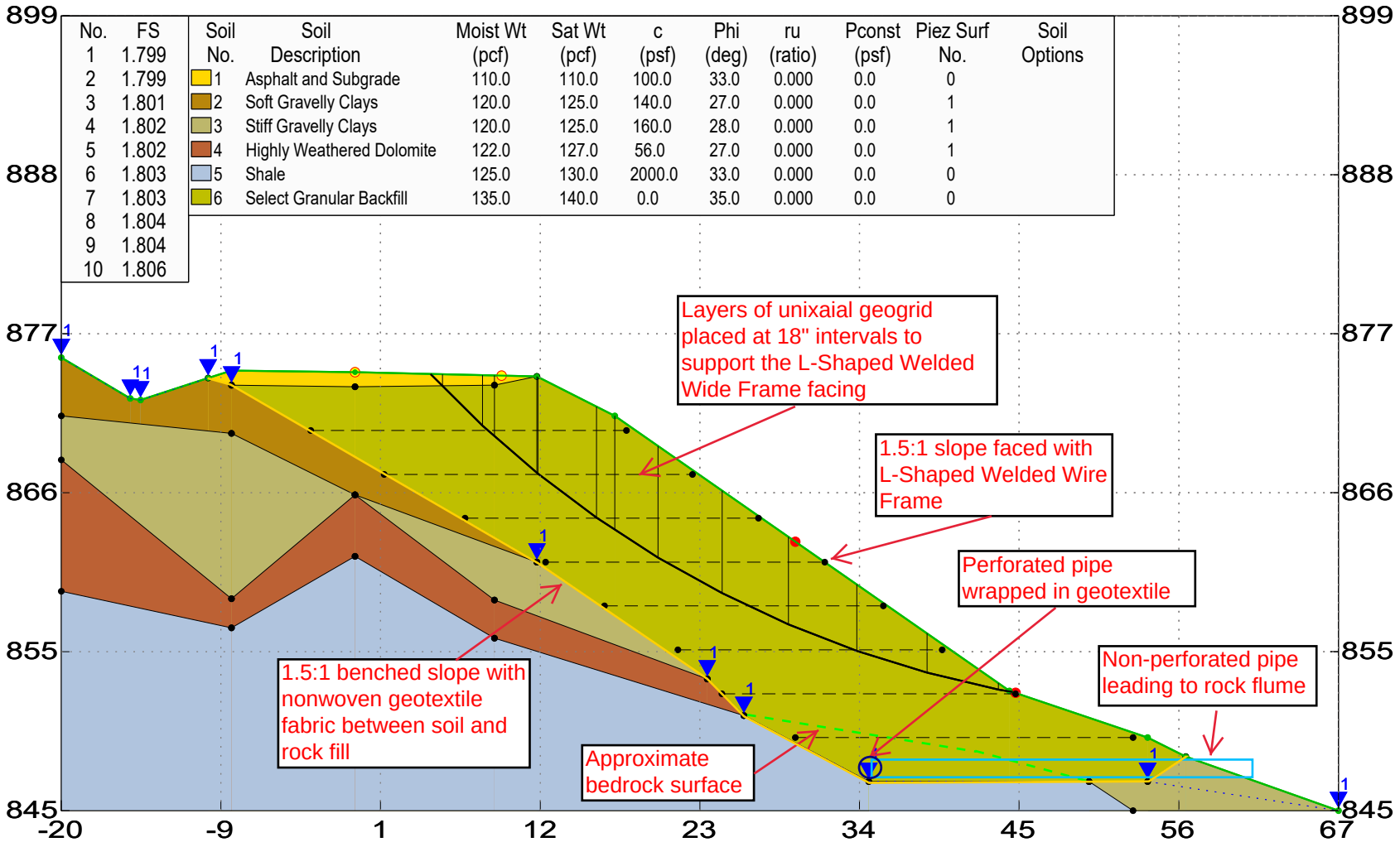


Warren County - Rte U
R35G - Station 109+48
Slide 1 (North Slide)

Figure 1

MODOT/den

Slide 1 - Reinforced L-Shaped Welded Wire Facing



GEOSTASE FS = 1.799

Simplified Bishop Method

Drawing Not to Scale

GEOSTASE Slope Stability Analysis

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

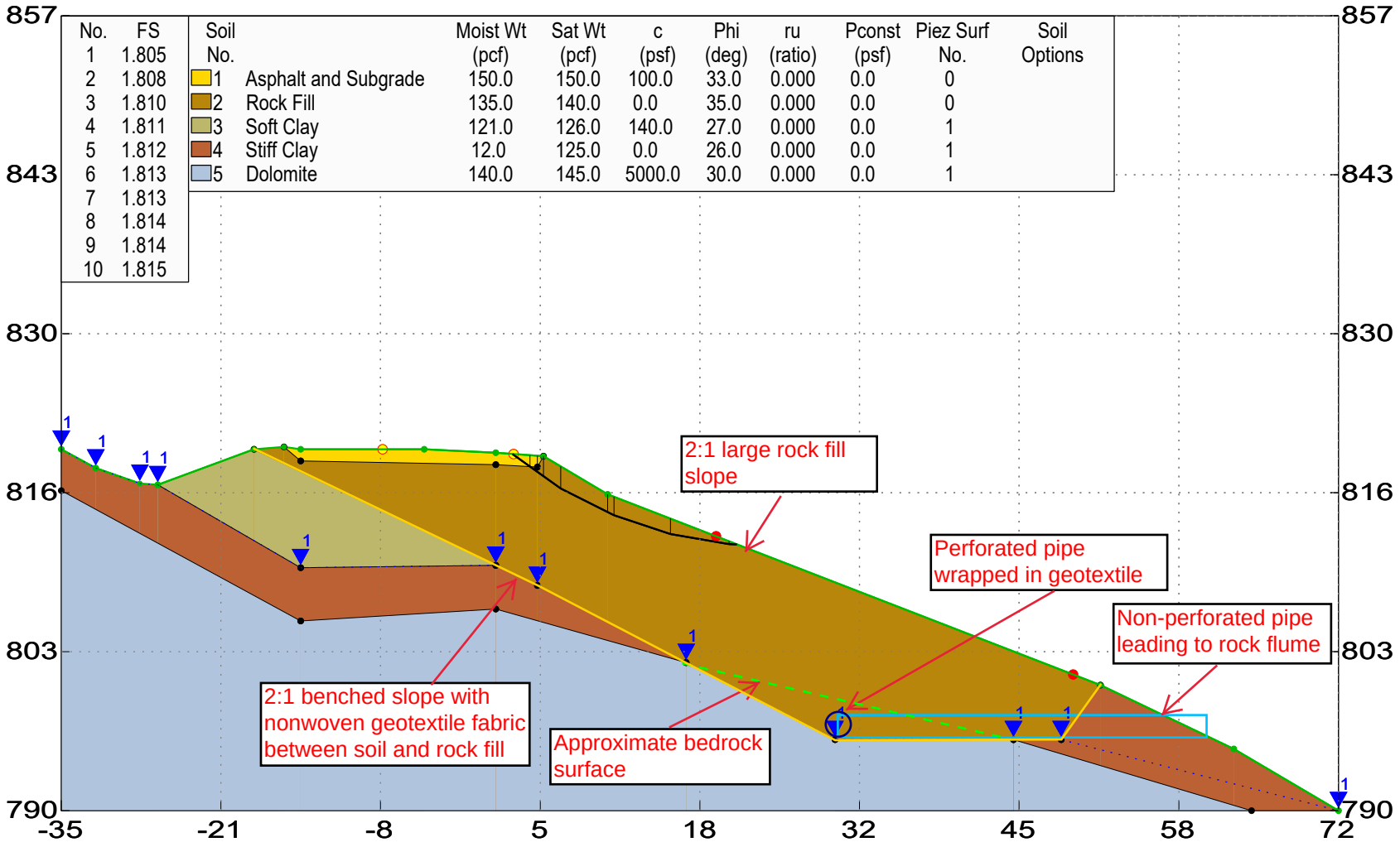
PLATE C.1

Figure 2

Warren County - Rte U
S2967 - Station 104+98
Slide 2 (South Slide)

MODOT/den

Slide 2 - Large rock Fill Slope



GEOSTASE FS = 1.805

Simplified Bishop Method

Drawing Not To Scale

GEOSTASE Slope Stability Analysis

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.1