In response to a request from Bret Davidson, the Geotechnical Section has conducted an investigation to determine the cause of and corrective measures for two slides that have occurred on the north and south sides of Highway 59 in Holt County. These slides are located approximately ½ mile east of Oregon, MO. The slide along the northern slope extends from Sta 1526+50 to 1531+50, for an approximate length of 500 feet. The slide along the southern slope extends from Sta 1526+75 to Sta 1533+50, for a length of 675 feet.

Coordinates and elevations were provided by Northwest District survey. Cross-sections were not provided for our analysis. The top of slope and bottom of slope elevations, along with project plans along the route, were utilized to create a general profile to perform an analysis. Attached are typicals for repair options, an aerial photo of boring locations, logs of borings, photos of the northern and southern slope and aerial photos from 2008 to 2014.

History
These slides have been a problem for many years. Maintenance has tried to remove the material from the toe and push it back up slope several times over the years. According to maintenance, the ditch lines along this section are perpetually wet.

Aerial maps from Google Earth Pro are attached showing a history of movement. The earliest map that could be obtained was dated April 2008. In this aerial, you can see movement along the south slope, but not as much along the northern slope. The August 2010 aerial shows additional movement along the southern slope and vegetation loss across the northern slope, which is most likely signs of movement. The September 2012 and October 2014 aerials show little or no change on either slope.

There have been a few significant precipitation events since our exploration and little or no movement has occurred following these events.

Existing Conditions
Five borings were performed across the site. Two were completed along the southern slope and three along the northern slope. See attached aerial for boring locations.

Along the northern slope, the back fill height is about 42.5 feet at the highest point, with the back fill cut on a slope of about 2.5H to 3H:1V. The northern slope consists of silt, overlying lean clay on top
of sand and shale, which is visible in the ditch. The silt and lean clay classify as ML, ML-CL, and CL material by ASTM classification methods. Along the southern slope, the backfill height is about 47 feet at the highest point, with the backfill cut on a slope of about 2H to 2.5H:1V. The southern slope consists of silt, overlying lean clay on top of shale which is visible in the ditch. The silt and lean clay classify as ML, ML-CL, and CL material by ASTM classification methods. The ditches along both sides of the roadway are filled with cattails, a wetland plant that thrives in a wet environment.

Present guidelines in the EPG 321.1 would require slopes no steeper than 2.5H:1V for this material and old plan sheets show a 3H:1V slope was designed for this location. Both of these slides appear to be caused by water seepage into the silt material, most likely caused by sparse vegetation along the slope in addition to a water table that appears to be either perched in the silt or slowly draining at the toe of the slope. This drainage is creating a permanently saturated condition at the toe of the slope.

**Rock Blanket Repair Recommendations for the Northern Slope (Sta 1526+50 to 1531+50)**
Beginning at least 195 feet left of C/L (at the center of the area showing movement), excavate and bench the existing slope on a 1.5H:1V to 3 feet below the toe of the slope to remove the disturbed material. Any additional disturbed material remaining below the 1.5:1 slope should be removed. The excavation should be backfilled with rock fill meeting Specification 214 to reconstruct a slope no steeper than 2H:1V or flatter. The minimum thickness or the rock blanket shall be 6 feet. Geotextile shall be placed against the excavation slope to keep fines from infiltrating the rock fill. See Figure 1. The repair should extend a minimum of 10 feet outside of the sliding area.

Attention should be brought to the continued drainage of this excavation which may require additional excavation to allow for gravity drainage at the toe of this repair. If gravity drainage is not possible, it may be necessary to install a geotextile wrapped perforated drainage pipe placed at the back edge of the rock fill key. The perforated pipe should be connected to a non-perforated drainage pipe placed every 50 feet along the excavation area to outlet the water. It is also recommended to line the ditch along the slide location and beyond to promote gravity drainage away from the slide location.

**Rock Blanket Repair Recommendations for the Southern Slope (Sta 1526+75 to 1533+50)**
Beginning at least 205 feet right of C/L (at the center of the area showing movement), excavate and bench the existing slope on a 1.5H:1V to 3 feet below the toe of the slope to remove the disturbed material. Any additional disturbed material remaining below the 1.5:1 slope should be removed. The excavation should be backfilled with rock fill meeting Specification 214 to reconstruct a slope no steeper than 2H:1V or flatter. The minimum thickness or the rock blanket shall be 6 feet. Geotextile shall be placed against the excavation slope to keep fines from infiltrating the rock fill. See Figure 1. The repair should extend a minimum of 10 feet outside of the sliding area.

Attention should be brought to the continued drainage of this excavation which may require additional excavation to allow for gravity drainage at the toe of this repair. If gravity drainage is not possible, it may be necessary to install a geotextile wrapped perforated drainage pipe placed at the back edge of the rock fill key. The perforated pipe should be connected to a non-perforated drainage pipe placed every 50 feet along the excavation area to outlet the water. It is also recommended to line the ditch along the slide location and beyond to promote gravity drainage away from the slide location.
General Requirements
The Geotechnical Engineering Section recommends that the removal of the existing disturbed material be done in the shortest practical increments with rapid reconstruction to reduce the possibility of additional sliding beyond the temporary excavation. It is recommended to have rock on site during excavation to expedite placement. During the repair, any temporary construction surfaces shall be sloped and sealed as appropriate to prevent ponding and minimize infiltration of precipitation and runoff.

Drainage Repair Only
Both of these slides are very large, both horizontally and vertically, which makes a rock blanket repair very costly. After reviewing the aerial photos from April 2008 to October 2014, the additional movement within this slope has been minimal, but the ditch line has been a problem for maintenance and is wet year round. Another option would be to simply address drainage within the slope by installing aggregate drains. This repair may not be a permanent fix, but will reduce the water within the slope which can increase the strength of the soil. This may reduce or even prevent additional movement within the slope.

Aggregate Drains (See page 14-17 of Slide Repair Guidebook)
The top of the drain should extend a minimum of 5 feet past the slide scarp, although 10 feet past is preferable (at least 195 feet left of C/L for the northern slope and 205 feet right of C/L for the southern slope). The drains should extend a minimum of 10 feet below existing grade and slope towards the bottom of the slope, regardless of where the slide ends. The drains should be constructed approximately 30-inches wide and be installed on 20 to 40-foot centers within the slide area. See Figure 2.

Drain material should consist of MoDOT Aggregate for Drainage in accordance with 1009.3.5 Grade 5. Pipes and separation fabric are not required in the drains. Once the drains are installed, the slope should be re-graded and any cracks in the ground surface, above the slide, should be sealed to prevent surface water from entering the slide. This can be accomplished by blading and tracking over cracks with a small dozer. Vegetation should be established as quickly as possible. The use of coconut fabric is recommended to promote vegetation growth.

Attention should be brought to the continued drainage of this excavation which may require additional excavation to allow for gravity drainage at the toe of this repair. It is also recommended to line the ditch along the slide location and beyond to promote gravity drainage away from the slide location.
Minimum 5-10 Feet Beyond Slide Scarp

Minimum 10 Feet Beneath Ground Surface

Each Drain Should Be 30-inches Wide

Drains Installed on 20-40 Foot Centers Within Slide Location

Regrade existing slope and seal cracks

Drainage Aggregate Specification 1009.3.5 Grade 5
Temporary 1.5H:1V Benched Excavation with Separation Geotextile (Section 1011)

Rock Fill: 2H:1V or Flatter

Rock Fill
Specification Section 214

Perforated Drainage Pipe
(if gravity drainage is not possible)

Minimum 3' excavation into the toe of the slope
### Missouri Department of Transportation
### Construction and Materials

**Job No.:** S2498  
**Design:** S2498  
**County:** Holt  
**Route:** 59  
**Location:** Holt County  
**Logged By:** Lydia Brownell  
**Operator:** Kenny Mathews  
**Date of Work:** 09/07/17-09/07/17  
**Easting:** 2614423.289  
**Depths:** 1014.5  
**Requested Northing:**  
**Requested Easting:**  
**Equipment:** Acker Renegade,  
**Location Note:**  
**Drill No.:** G-9667  
**Hammer Efficiency:** 76%  
**Drilling Method:** Continuous Flight Auger

#### Depth (ft)

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<th>Graphic</th>
<th>Description</th>
<th>Elevation (ft)</th>
<th>REC % (ROD %)</th>
<th>Blow Counts (N60)</th>
<th>Shear Data</th>
<th>Field Tests</th>
<th>Index Tests</th>
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<tbody>
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**NOTE:**

- **N60 = (Em/60)Nn:**  
- **N60** - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nn - Observed N-value  
  
  (1) = Assumed, (2) = Actual

**Coordinate System:** Modified U.S. State Plane 1983  
**Coordinate Zone:** Missouri West  
**Coordinate Proj. Factor:** 1.0000754

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

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**Missouri Department of Transportation**  
**Construction and Materials**

**BORING NO. A3**  
Page 1 of 1

<table>
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<th>Sample Type</th>
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**Note:**

- **N<sub>60</sub>** = (Em/80)N<sub>m</sub>  
- **N<sub>m</sub>** - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value

**Coordinate System:** Modified U.S. State Plane 1983  
**Coordinate Zone:** Missouri West  
**Coordinate Proj. Factor:** 1.0000754

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

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<th>Graphic</th>
<th>Description</th>
<th>Elevation (ft)</th>
<th>Sample Type</th>
<th>REC % (ROD %)</th>
<th>Blow Counts (N60)</th>
<th>Shear Data</th>
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<td>0.0-7.5' Light gray and orange, CLAYEY SILT, stiff, dry to moist</td>
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<td>PP = 8.00 tsf</td>
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<td>MC = 13.8%</td>
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<td>Depth (ft)</td>
<td>Description</td>
<td>Elevation (ft)</td>
<td>Sample Type</td>
<td>RCD (%)</td>
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<td>Shear Data</td>
<td>Field Tests</td>
<td>Index Tests</td>
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<tr>
<td>30</td>
<td>30.0-35.0' Tannish brown and gray, SILTY SAND, medium stiff, moist to wet, fine grained 31.7-31.7' Water encountered.</td>
<td>990</td>
<td>X</td>
<td>88</td>
<td>5-4-6</td>
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<td>PP = 1.50 tsf</td>
<td>PL = 19</td>
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<td>X</td>
<td>72</td>
<td>6-8-6</td>
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<td>MC = 23.2%</td>
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N60 = (Em/80)Nn  Nn = Corrected N value for standard 60% SPT efficiency; Em = Measured hammer efficiency in percent; Nm = Observed N-value

(1) = Assumed, (2) = Actual


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

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### Missouri Department of Transportation
**Construction and Materials**

**BORING NO. V-17-94**

**Page 1 of 2**

**Job No.:** S2498  
**Design:** S2498  
**Bent:**  
**Station:** 1529+88  
**Offset:** 240 R  
**Elevation:** 1027.6  
**Requested Station:**  
**Requested Offset:**  
**Drill No.:** G-9667  
**Hammer Efficiency:** 76%  
**Drilling Method:** Hollow Stem Auger

-----

**County:** Holt  
**Route:** 59  
**Location:** Holt County  
**Logged By:** Lydia Brownell  
**Operator:** Kenny Mathews  
**Northing:** 1389272.085  
**Easting:** 2614284.665  
**Date of Work:** 09/06/17-09/06/17  
**Depth to Water:**  
**Depth Hole Open:** 3.2  
**Time Change:** 8 hours  
**Equipment:** Acker Renegade, Split-Spoon Sampler, Shelby Tube  
**Location Note:**

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<th>Graphic</th>
<th>Description</th>
<th>Elevation (ft)</th>
<th>Sample Type</th>
<th>REC % (R&amp;D %)</th>
<th>Blow Counts (Nl)</th>
<th>Shear Data</th>
<th>Field Tests</th>
<th>Index Tests</th>
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<tr>
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<td>76</td>
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<td>PP = 1.25 tsf</td>
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<tr>
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<td>14.0-16.5' Gray, SILT, stiff, moist</td>
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<td>4-4-4</td>
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<td>84</td>
<td>2-3-4</td>
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<td>64</td>
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<tr>
<td>25</td>
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<td>25.0-35.0' Tan and orange, SILTY LEAN CLAY, medium stiff to soft, moist to wet, Water @ 30'. Water poured out of top of Shelby tube @ 35'</td>
<td>1000</td>
<td>60</td>
<td>0-1-2</td>
<td>PP = 0.75 tsf</td>
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**Note:**

- **Nl:** (Em/80)Nm  
- **Nl:** 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. V-17-94
Page 2 of 2

Job No.: S2498

County: Holt

Route: 59

Design: S2498

Location: Holt County

Bent: ____________________

Skew: ____________________

Operator: Kenny Mathews

Station: 1529+88

Logged By: Lydia Brownell

Depth to Water: 6.2

Offset: 240 R

Date of Work: 09/06/17-09/06/17

Elevation: 1027.6

Depth Hole Open: 3.2

Requested Station: ____________________

Time Change: 8 hours

Requested Offset: ____________________

Equipment: Acker Renegade Split-Spoon Sampler, Shelby Tube

Requested Elevation: ____________________

Location Note: ____________________

Hammer Efficiency: 76%

Drill No.: G-9667

Drilling Method: Hollow Stem Auger

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<th>Graphic</th>
<th>Description</th>
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<th>Sample Type</th>
<th>REC % (ROD %)</th>
<th>Blow Counts (N60)</th>
<th>Shear Data</th>
<th>Field Tests</th>
<th>Index Tests</th>
</tr>
</thead>
</table>
| 30        |         | 25.0-35.0’ Tan and orange, SILTY LEAN CLAY, medium stiff to soft, moist to wet, Water @ 30’. Water poured out of top of Shelby tube @ 35’ (continued) 30.0’ Groundwater encountered. | 995 | 88 | 2-3-4 | PP = 0.50 taf Torvane = 3.25 taf | MC = 28.1% | Sieve # % Passing:
|           |         |             |               |             |               |                   |            | #40 100.0  |           |
|           |         |             |               |             |               |                   |            | #200 99.7  |           |
|           |         |             |               |             |               |                   |            | #122 pcf   |           |
| 35        |         | 35.0-40.0’ Tannish brown and orange, LEAN CLAY scattered fine gravel, trace sand, stiff, moist 35.0-37.5’ Water poured out of top of Shelby tube. | 990 | 64 | 2-3-5 | PP = 0.75 taf Torvane = 7.00 taf | MC = 25.5% | Sieve # % Passing:
|           |         |             |               |             |               |                   |            | #10 100.0  |           |
|           |         |             |               |             |               |                   |            | #200 97.7  |           |
|           |         |             |               |             |               |                   |            | #125 pcf   |           |
|           |         |             |               |             |               |                   |            | #20        |           |
|           |         |             |               |             |               |                   |            |              |           |
| 40        |         | 40.0-45.0’ Shale, tan and gray, soft | 985 | 84 | 6-8-12 | PP = 1.50 taf Torvane = 9.00 taf | MC = 21.7% | Sieve Analysis:
|           |         |             |               |             |               |                   |            | #4 100.0    |           |
|           |         |             |               |             |               |                   |            | #10 99.9    |           |
|           |         |             |               |             |               |                   |            | #40 98.9    |           |
|           |         |             |               |             |               |                   |            | #20 90.3    |           |
| 45        |         | 45.0-46.5’ Orangish tan and gray, SANDY LEAN CLAY scattered fine gravel, very stiff, moist Bottom of borehole at 46.5 feet. | 975 | 5-8-13 | PP = 4.00 tf Torvane = 12.00 tf | MC = 21.7% | Sieve Analysis:
|           |         |             |               |             |               |                   |            | #4 100.0    |           |
|           |         |             |               |             |               |                   |            | #10 99.9    |           |
|           |         |             |               |             |               |                   |            | #40 98.9    |           |
|           |         |             |               |             |               |                   |            | #20 90.3    |           |

N_{L_0} = (E/60)N_{L_0}; N_{L_0} - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nm - Observed N-value
(1) = Assumed, (2) = Actual


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

* Persons using this information are cautioned that the materials shown are determined by the equipment noted and accuracy of the "log of materials" is limited thereby and by judgement of the operator. THIS INFORMATION IS FOR DESIGN PURPOSES ONLY.
Missouri Department of Transportation
Construction and Materials

Job No.: S2498
Design: S2498
Bent: 
Station: 1530+00
Offset: 195 L
Elevation: 1027.9
Requested Station: 
Requested Offset: 
Requested Elevation: 
Drill No.: G-9667
County: Holt
Skew: 
Logged By: Lydia Brownell
Northing: 1389562.146
Easting: 2614585.539
Requested Northing: 
Requested Easting: 
Equipment: Acker Renegade
Hammer Efficiency: 76%
Drilling Method: Continuous Flight Auger
Location: Holt County
Operator: Kenny Mathews
Date of Work: 09/07/17-09/07/17
Depth to Water: 8.4
Depth Hole Open: 8.4
Time Change: 0 hours

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Graphic</th>
<th>Description</th>
<th>Elevation (ft)</th>
<th>Sample Type</th>
<th>REC % (ROD %)</th>
<th>Blow Counts (N_b)</th>
<th>Shear Data</th>
<th>Field Tests</th>
<th>Index Tests</th>
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<tbody>
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<td>0</td>
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<td>0.0-5.0' Tan and gray, CLAYEY SILT, stiff to medium stiff, dry</td>
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<td>30.0-36.5' Tan and gray, SANDY SILT, stiff, moist to wet</td>
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<td>36.5-43.0' Tan and gray, SANDY SILT, stiff to very stiff, moist to wet</td>
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</table>

Bottom of borehole at 43.0 feet.

N_b = (Em/80)Nn  N_b - Corrected N value for standard 60% SPT efficiency; Em - Measured hammer efficiency in percent; Nn - Observed N-value
(1) = Assumed, (2) = Actual

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

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Photos of Northern Slope

Northern slope looking north.

Northern slope looking northeast.
Sparse vegetation along northern slope.
Photos of Southern Slope (September 2017)

Southern Slope

Cattails in southern ditch line.
Southern Slope

Filled ditch beneath southern slope.
Cracks along upper surface of southern slope.
LITHOLOGIC SYMBOLS
(Unified Soil Classification System)

- Bedrock
- USCS High Plasticity Clay
- USCS Low Plasticity Clay
- USCS Low Plasticity Gravelly Clay
- USCS Low Plasticity Silty Clay
- USCS Low Plasticity Sandy Clay
- USCS Silt
- USCS Gravelly Silt
- USCS Sandy Silt
- Shale
- USCS Silty Sand

SAMPLER SYMBOLS

- Split-Spoon Sampler
- Shelby Tube

WELL CONSTRUCTION SYMBOLS

ABBREVIATIONS

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

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

Water Level at Time of Drilling
Water Level at End of Drilling
Water Level after Drilling