GRI
9750 SW Nimbus Avenue
Beaverton, OR 97008-7172
p | 503-641-3478 f | 503-644-8034

September 18, 2017 4450-B PRELIMINARY GEOTECHNICAL MEMORANDUM

City of Oregon City
625 Center Street
Oregon City, OR 97045

Attention: Aleta Froman-Goodrich, PE

SUBJECT: Preliminary Geotechnical Memorandum
Trillium Park Drive Landslide
Oregon City, Oregon

As requested, GRI conducted a preliminary geotechnical evaluation for the above-referenced project. We understand movement of the landslide occurred on an east-facing slope along Trillium Park Drive between Canyon Court and Swordfern Court in Oregon City, Oregon, following a period of heavy precipitation in February 2017. The general location of the project is shown on the Vicinity Map, Figure 1. The landslide extends into the paved area, and the roadway is closed to all traffic. The purpose of our services is to assist the City of Oregon City (City) with evaluating slope conditions in the project area, conduct preliminary engineering analyses, and provide conceptual options for landslide mitigation alternatives. Our work was completed in accordance with our City Personal Services Agreement dated March 13, 2017.

BACKGROUND

The City provided GRI several reports regarding the project area. The Trillium Park Estates development, developed in 1993, included a 25-acre development of 75 residential lots and access roadways. As part of development activities, geotechnical investigations of the area were conducted to evaluate the suitability of the project in regard to geologic hazards and, in particular, slope stability/landslide concerns.

An April 1993 geologic reconnaissance report identifies several areas of potential landslide deposits based on surface geomorphology (NGS, 1993). The reconnaissance noted irregular topography that included small hummocks created by tree blowdowns, local irregularities formed by slow creep of surficial soils on sloping bedrock, old road constructions from logging activities, and deposits that appear to be the debris of previous, shallow landslides. In 1994, a subsurface investigation was completed to evaluate the irregular topography observed during the geologic reconnaissance (NGS, 1994). Test pits were completed at 11 locations in the development area to assess the engineering characteristics of the shallow subsurface materials. All the explorations were excavated in silt material that included fragments of volcanic rock. Geologic mapping completed for the development project indicates material identified as "Sandy River Mudstone" was exposed at the ground surface at the bottom of a ravine where embankment fill for construction of Trillium Park Drive was proposed (NGS, 1994). Based on test pit explorations and geologic mapping, the topographic irregularities identified during the geologic reconnaissance were interpreted by NGS to be the result of erosion rather than slope failures (NGS, 1994). The observation of undisturbed silt in the test pits was used as evidence for the lack of past slope failures. Consequently, their geologic assessment concluded no site conditions were observed that would pose significant problems to development (NGS, 1994).

The geotechnical report for the project indicated fills up 9 ft would be required to develop the westerly access roadway (Trillium Park Drive) over two ravines (AW Geotechnical Services, 1994). At the time of the report, the ravine side slopes were generally about 17° (30% grade) over the southerly and westerly portions of the site and steepened to about 27° (51% grade) over the easterly ravine (AW Geotechnical Services, 1993). The location of one of these ravine fills coincides with the location of the current Trillium Park Drive landslide. The report recommended subsurface drains be placed at the base of the ravines and consist of free-draining, well-graded granular material encapsulated in geotextile fabric (AW Geotechnical Services, 1994).

In early 1999, a ground crack was observed crossing Trillium Park Drive following a period of heavy rain. At the request of the Trillium Park Estates developer, Columbia Geotechnical and Carlson Testing, Inc., installed three inclinometers, designated B-1 through B-3, on private property east of Trillium Park Drive. Rotational movement was recorded at a depth of 20 ft in boring B-1. Translational movement was recorded at a depth of about 15 ft in boring B-2. Boring B-3 appeared to have rotational movement at approximately 14 ft of depth (Columbia Geotechnical, 1999). In addition to the installation of inclinometers, a professional land surveyor placed surface-monitoring points to measure surface displacements of the landslide to evaluate the rate and magnitude of the downslope movement of the landslide. Very little lateral displacement was measured by the survey points in subsequent monitoring conducted from March through April 1999.

Following a period of prolonged, intense precipitation in January 2006, additional movement was observed along Trillium Park Drive. Maximum vertical and horizontal offsets on the order of 3 in. were observed along the headscarp. The headscarp ground crack could be traced southward beyond the City right-of-way onto private property and northward into a drainage swale on the west side of the roadway, see the Site Map, Figure 2. A map of the area geology is shown on Figure 3. A culvert extends eastward from a drainage swale located west of the roadway and outfalls through the face of a gabion-basket retaining wall into an unnamed drainage near the bottom of the embankment fill east of the roadway. GRI drilled and installed one inclinometer to a depth of 91.3 ft, designated B-1, for the City in Trillium Park Drive in September 2006. Additional details regarding GRI's 2006 consultation are presented in Appendix A. Inclinometer measurements collected in December 2006 indicated a small but noticeable movement at a depth of 65 ft in boring B-1, see Figure 4. Subsequent measurements in 2008, 2009, and 2010 indicated approximately 0.5 in. of additional horizontal displacement occurred at a depth of 65 ft below the roadway, see Figure 4. The zone of movement corresponds to the geologic contact where the Boring Lava landslide debris overlies the Sandy River Mudstone.

The stormwater pipe that crosses Trillium Park Drive was inspected by a camera following observations of slope movement in 2006. The camera inspection indicated the pipe had been deformed, but no cracking or separation was observed. To maintain the function of the pipe, a smaller-diameter insert sleeve was pulled through the pipe to transmit stormwater from the uphill side of Trillium Park Drive to the outfall on the east side of the embankment.

GEOLOGIC CONDITIONS

Surface Conditions and Topography

The ground surface in the area of the landslide slopes down to the east at 20° to 68° from an elevation of about 242 ft at Trillium Park Drive to an elevation of 180 ft (North American Vertical Datum of 1988

[NAVD88]) at the bottom of the slope, as shown on the Site Map, Figure 2. The ground continues to gradually slope downward to the east until reaching Newell Creek approximately 1,300 ft east of Trillium Park Drive. West of Trillium Park Drive, the ground surface slopes upward to gain about 20 ft in elevation before flattening out at the top of the slope, where the Providence Willamette Falls Hospital is located at about elevation 270 ft (NAVD 88). The landslide generally sits in a saddle of Trillium Park Drive between higher ground toward Canyon Court to the north and Swordfern Court to the south.

Local and Regional Geology

The site is located in the northern Willamette Valley, within the Portland Basin. The Portland Basin is a north-west trending structural basin that encompasses approximately 1,310 sq miles. The Portland Basin is characterized by relatively low topographic relief with areas of buttes and valleys containing steep slopes (McFarland and Morgan, 1996). Sedimentary deposits generally consisting of conglomerate, gravel, sand, silt, and some clay from volcanic, fluvial, and lacustrine material have filled the Portland Basin.

Some of the oldest rocks identified in the Portland Basin include the Miocene-age Columbia River Basalt Group. The Columbia River Basalt is a series of basalt flows about 1,000 ft thick (Schlicker and Finlayson, 1979). Miocene/Pliocene-age Sandy River Mudstone overlies the Columbia River Basalt and consists of thin-bedded micaceous and tuffaceous sandstone and siltstone, carbonaceous claystone, and local gravel lenses (Trimble, 1963; Swanson et al., 1993; Evarts et al., 2009). The Sandy River Mudstone is interbedded with the Troutdale Formation, and for the purpose of this report, they are considered equivalent (Evarts et al., 2009). The Pliocene/Pleistocene-age Troutdale Formation consists of gravel, sand, and silt. The generally weak to moderately strong Troutdale Formation is very prone to landsliding when overlain by Boring Lava flows (Madin, 2009). The Boring Lavas are Pliocene/Pleistocene-age basalts that are light gray and vary in thickness. They occur as blocky intracanyon flows, volcanic cones, and shield volcanoes, which are composed of thick basalt flows. The flows can be weathered to a red clay with scattered residual boulders (Schlicker and Finlayson, 1979). The Willamette Silt consists of silt and fine sand deposited by late-Pleistocene glacial-outburst floods (Gannet and Caldwell, 1998) and can locally overlie the Troutdale Formation or the Boring Lava.

The contact between the Troutdale Formation and the Boring Lava is an erosional surface where the top of the Troutdale Formation has been eroded and infilled by the Boring Lava. This erosional surface produces an undulating contact in the top of the Troutdale Formation that varies in elevation where it is exposed at the ground surface. The most recent geologic mapping of the area indicates the contact of the Troutdale Formation varies in elevation from about 140 ft along the slope above OR-213 to 225 ft near the residence at 13776 Canyon Court. The Boring Lava is mapped along the slope just below Trillium Park Drive. The Willamette Silt is mapped at the surface of the landslide and along higher elevations near the site (Madin, 2009), as presented on the Geologic Map, Figure 3.

The Newell Canyon area is prone to landslides that occur from erosion by Newell Creek, which have exposed the contact of the Troutdale Formation and Boring Lava. The failure plane of the Trillium Park Drive landslide appears to coincide with the exposed contact of weak, relatively impermeable sedimentary rock and the underling hard basalt rock, similar to other landslides in the Newell Creek drainage.

Landslide Mapping

The Oregon Department of Geology and Mineral Industries (DOGAMI) has produced maps showing areas of known landslides or areas with ground features indicative of landslide processes, termed "landslide topography." At the time of this report, the project site has not been mapped within the boundary of landslide topography (Burns and Watzig, 2014). However, a landslide was identified by DOGAMI near the Trillium Park Drive landslide and is shown on Figure 3 ("Qls" deposits shown as Oregon City 87 on Figure 3).

GRI evaluated the type and occurrence of landslides using information gathered through review of the Oregon Geologic Database Compilation (OGDC) Version 6 (Smith and Roe, 2015), Statewide Landslide Database for Oregon (SLIDO) Version 3.2 (Burns and Watzig, 2014), and remotely sensed data such as aerial photographs and lidar elevation data. The lidar data are used to generate a Digital Elevation Model (DEM). The lidar-derived DEM was evaluated by GRI using methods described in DOGAMI Special Paper 42 (Burns and Madin, 2009) to visually screen for landslides not identified in the existing literature. The lidar mapping evaluation revealed no apparent indications of scarps or landslide topography on the slopes at the site of the Trillium Park Drive landslide. However, indications of landslide topography may have been altered or covered by grading performed during previous development. The lidar data do show an area about 250 ft southeast of the site that has ground-surface features commonly associated with landslide topography, such as curved, scarp-like upland areas and linear flow features. The approximate limits of the landslide located 250 ft southeast of the site (designated Oregon City 87 in SLIDO) are shown on Figure 3 (Oregon City 87 on Figure 3). One of the areas identified as "irregular topography" and suspected landslide during the geologic reconnaissance in 1993 is located in the same general area as Oregon City 87.

2017 SITE RECONNAISSANCE

The City was notified of water-line damage in the roadway of Trillium Park Drive on February 16, 2017. Significant rainfall had occurred during late 2016 and early 2017. Based on field data gathered, movement of the downhill slope appeared to have pulled apart a water supply line at a slip joint, resulting in an outflow of water that damaged the asphalt pavement. The water pressure lifted the pavement upward and the water flow eroded material beneath the pavement, including the crushed-rock base course and some underlying soil. The water line was shut off by valves located north and south of the break area, and the road was closed to all traffic.

On February 21, 2017, City crews noticed additional pavement cracking in the roadway and a downed tree downslope of the roadway, and they contacted GRI. GRI observed several sets of pavement and ground cracks along Trillium Park Drive, and foundation cracks were visible in the residence at 13776 Canyon Court.

GRI subsequently visited the site on multiple occasions in February and March 2017 to conduct ground-level reconnaissance and visually observe landslide damage. The following paragraphs summarize our observations at the site.

The site has two sets of concentric, curvilinear ground cracks that cross the road in roughly semi-circular shapes with the open side of the circle pointing downslope (east). One set forms an inner half-circle arc with an apex about 14 ft from the eastern sidewalk. The limits of the inner set of ground cracks begin about 18 ft south of a catch basin located on the east side of the road near the intersection with Canyon Court and end about 20 ft north of boring B-1. The second half-circle set forms the outer ring of ground cracks, with an apex about 50 ft from the east sidewalk curb. The southern portion of this set of ground cracks was also observed by GRI in 2006, see Figure 2. Ground cracks in this area are visible on Google Street View photography collected in approximately August 2012.

In 2017, the southern limits of the ground cracks could be observed approximately 50 ft onto the undeveloped lot to the southeast of Trillium Park Drive. The outer ring of ground cracks could be followed from the east sidewalk to just east of a stormwater catch basin (west of Trillium Park Drive) but were obscured by vegetation north of this catch basin. Ground cracks were again visible about 15 ft west of a short concrete-block wall and continued to arc eastward toward the road to just west of a catch basin on the west side of the road near the intersection with Canyon Court.

2006 INCLINOMETER INSTALLATION AND SUBSURFACE CONDITIONS

Subsurface materials and conditions were evaluated by GRI on September 20 and 21, 2006, with one drilled boring, designated B-1. The location of the boring is shown on Figure 2. The boring was advanced to a depth of 91.3 ft with mud-rotary techniques using a truck-mounted drill rig provided and operated by Western States Soil Conservation, Inc., of Hubbard, Oregon. The log of the boring is provided on Figure 1A of Appendix A. The terms used to describe the soil and rock encountered in the boring are defined in Tables 1A and 2A.

In general, the boring completed in 2006 indicates the roadway consists of 2 in. of asphalt over 18 in. of crushed-rock base course over the embankment fill. An 11-ft-thick layer of fill is underlain by the Willamette Silt, which is in turn underlain by basalt rock of the Boring Lava formation and mudstone of the Troutdale Formation at depths of 40 and 62 ft in the boring, respectively. The units between the Willamette Silt and basalt layers are considered landslide debris.

For the purpose of this discussion, the materials disclosed by the boring have been grouped into the following units based on their physical characteristics and engineering properties. Listed as they were encountered from the ground surface to the bottom of the boring, the geologic units observed in the boring include the following:

1. **FILL**
2. **SILT and SAND (Missoula Flood Deposit/Landslide Debris)**
3. **CLAY (Residual Soil/Landslide Debris)**
4. **BASALT (Boring Lava/Landslide Debris)**
5. **MUDSTONE (Troutdale Formation)**

The following paragraphs provide a description of the materials encountered in the boring completed by GRI and include the results of inclinometer monitoring and groundwater-level measurements at the site.

1. FILL. Gravel fill was encountered below the base course in the boring and extends to a depth of about 5 ft. Silt fill that is generally brown with trace to some gravel and a sand content ranging from some fine-grained sand to sandy was encountered below the gravel fill to a depth of 13 ft. The relative consistency of the silt fill is very stiff to hard based on N-values of 16 blows/ft to 50 blows for 5 in. of penetration. The natural moisture content of the silt fill ranges from 23.5 to 27.5%. Scattered wood debris is noted in the boring between 10 and 13ft.

2. SILT and SAND (Missoula Flood Deposit/Landslide Debris). The fill in the boring is underlain by silt interpreted to be landslide debris that includes material from Missoula flood deposits and extends to a depth of about 30 ft. The silt is generally brown to gray mottled rust, has a variable clay content ranging from trace to some clay, and contains trace to some fine-grained sand. Boulders and cobbles are noted between 26 and 28 ft deep. The relative consistency of the silt is medium stiff based on an N-value of 5 blows/ft. The natural moisture content of the silt is between 30 and 33%. Thin layers of fine- to medium-grained sand are present above and below the silt. The sand above the silt is gray mottled rust, silty, and fine grained. The sand below the silt is brown, medium dense, and contains some silt.

3. CLAY (Residual Soil/Landslide Debris). Residual soil consisting of clay was encountered beneath the silt at a depth of about 30 ft. The residual soil, derived from the weathering of the underlying Boring Lava basalt, extends to a depth of about 40 ft. The residual soil is generally red-brown mottled black, yellow, and rust with a sand content ranging from some fine-grained sand to sandy. Trace gravel is present below 35 ft. The residual soil is medium stiff to stiff based on N-values of 4 to 12 blows/ft. The natural moisture content of the residual soil is 35 to 50%.

4. BASALT (Boring Lava/Landslide Debris). Very soft (R1) basalt that is gray, red, and rust in color was encountered beneath the clay (residual soil) in the boring at a depth of 40 ft and extends to 62 ft. The basalt is severely weathered to decomposed. N-values of 34 blows/ft to 50 blows for less than 4 to 7 in. of sampler penetration were recorded in the basalt. The degree of hardness and weathering of the basalt varies with depth.

5. MUDSTONE (Troutdale Formation). Extremely soft (R0), gray to red-gray mudstone was encountered beneath the Boring Lava in the boring at a depth of 62 ft and extends to the maximum depth explored of 91.3 ft. The mudstone is decomposed; however, weathering decreases with depth. N-values of 20 blows/ft to 50 blows for less than 4 to 6 in. of sampler penetration were recorded in the mudstone.

Inclinometer Monitoring

The slope inclinometer monitoring performed by GRI in boring B-1 between the initialization date of October 4, 2006, and June 11, 2010, indicates a maximum lateral movement of about 0.5 in. occurred at a depth of approximately 65 ft below the ground surface. Inclinometer monitoring results are provided in Figure 4. In March 2017, the City evaluated the inclinometer with a video camera and found the inclinometer casing sheared at a depth of about 61.8 ft. The amount of lateral movement that sheared the casing could not be determined from the video.

Groundwater

The boring was completed with mud-rotary drilling techniques, which do not allow the direct observation of groundwater levels at the time of drilling. A vibrating-wire piezometer was installed at a depth of 35 ft in boring B-1. The groundwater levels in the piezometer were measured from September 2006 to June 2010. The data logger battery failed in 2010. Groundwater elevation data from B-1 and precipitation data from the Collins View Rain Gage located at Riverdale High School, 9806 SW Boones Ferry Road, approximately

8 miles northwest of Trillium Park Drive are plotted on Figure 5 from 2006 to 2010. Groundwater occurs between about elevation 232 and 240 ft, or about 10 to 20 ft below the street grade, in the 2017 landslide area.

PRECIPITATION

A graph of daily precipitation between1998 and 2017 for the Portland area is shown on Figure 6. Figure 6 also shows the landslide events in March 1999 and February 2006, the sewer repair in August 2016, and the February 2017 landslide.

Daily precipitation data obtained from the Collins View Rain Gage indicate that on February 5, 2017, approximately 2.8 in. of rain occurred following two previous days of about 1 in. of rain each. On February 8, 2017, 1.37 in. of rain fell. Heavy precipitation was again recorded on February 15 and 16, 2017, with approximately 1.11 and 1.43 in. of rain, respectively. In total, approximately 10 in. of rain occurred over a 2-week period in early February prior to GRI's visit to the site on February 21, 2017.

The climatic normal precipitation at the Portland airport is 36.03 in. (October to September water year). As of March 1, 2017, over 44 in. of rain was recorded at the Collins View station, which is *above-normal*. Precipitation data from the Collins View station are plotted in Figure 7 from October 2016 to May 2017.

2016 SEWER PIPE REPAIR

In August 2016, City forces observed a deformation in the 8-in. diameter PVC pipe in Trillium Park Drive. The area was excavated and the deformed section of pipe repaired. Details regarding the pipe repair are provided in Appendix B.

2017 ADDITIONAL INCLINOMETERS

A replacement inclinometer, designated B-2, was installed in Trillium Park Drive in June 2017. Three other inclinometers were installed in the project area to allow for future monitoring of area slope instability that may affect public improvements. Details regarding these new inclinometer installations are provided in Appendix C. It should be noted that landslide debris was only encountered in the replacement inclinometer but not the three other borings installed in the neighborhood.

CONCLUSIONS AND RECOMMENDATIONS

Our review of available information indicates the Trillium Park Drive ancient landslide became reactivated in 1999 following construction activities. The Trillium Park Estates development project involved fills placed in a ravine over an existing ancient landslide. The site has experienced frequent roadway damage at varying rates and severity since construction was completed in 1999. The rate of land movement at the site increases following major storm events, such as in February 2017 when above-average precipitation resulted in several inches of movement and closure of Trillium Park Drive. The February 2017 slope movement occurred after the area received approximately 10 inches of rain over the preceding 2 weeks.

In our opinion, the February 2017 landslide movement was the cause of the damage to the City water line. The landslide reactivated following a period of prolonged, intense, above-normal precipitation that caused elevated groundwater levels

The 1999 and 2006 movements and current 2017 landslide movement most likely are the result of a combination of several factors. These factors include the placement of fill in a drainage ravine, geologic site conditions conducive to landslides, steep slopes, erosion by creeks at the toe of the slope, and periods of heavy precipitation that elevated groundwater levels. The combination of site grading, geologic conditions, and elevated groundwater levels from heavy precipitation created site conditions conducive to landslides. In our opinion, the deep-seated landslide at Trillium Park Drive was likely present before development of the site and was reactivated by heavy rainfall that occurred after severe storms in 1999, 2006, and 2017. Based on the recurrence of movement, there is a risk additional deep-seated slope movements will occur in the future.

To reduce the potential for future slope movements, some form of landslide mitigation should be considered. For this report, we consider "mitigation" a sustained, deliberate measure (or measures) implemented to reduce the severity of landslide movement and damage to the roadway. The mitigation alternatives considered below are based on various project goals, including constructability, costs, and minimizing adverse effects to adjacent properties.

Potential Mitigation Concepts

The following provides a brief description of potential concepts that can be considered for mitigation of the landslide. A rock buttress, conventional gravity retaining wall, or mechanically stabilized earth (MSE) retaining wall were not evaluated due to the significant depth of movement (65 ft) and very large excavation that would be required.

Potential mitigation concepts include the following:

1) **Abandon the Road and Monitor.** As implied, this alternative consists of leaving the slope as-is without any mitigation measures. Based on our evaluation, we anticipate downslope movement of the landslide will continue following periods of prolonged precipitation and intense rainfall. Continued monitoring of inclinometers and surface monitoring should be included with this option. Impermeable check dams with drainage outlets downslope of the roadway should be installed in subsurface City utility lines outside the landslide area. Conceptual costs for this alternative are likely in the range of $20,000 to $50,000.

2) **Tied-Back Soldier-Pile Retaining Wall.** This type of wall is constructed of steel soldier-pile beams placed in vertical drilled shafts spaced about 6 to 8 ft apart with lagging between the soldier piles. The drilled shafts are backfilled with concrete to hold the soldier-pile beams in place. The pile tips would be installed below the landslide surface, which is 65 ft deep. Conceptual costs for this alternative are likely in the range of $1 million to $1.5 million.

3) **Slope Regrading.** This mitigation alternative includes excavation of Trillium Park Drive to unload the head, or upslope portion, of the landslide. The elevation of the road would be brought back to current grades by using lightweight fill materials, such as foam blocks. Conceptual costs for this alternative are likely in the range of $100,000 to $300,000.

4) **Drainage Improvements.** Elevated groundwater levels from heavy precipitation could be lowered to increase slope stability by constructing subsurface drains. Subsurface drains, such as trench drains or directionally drilled horizontal drains, could be used to lower the groundwater level in the embankment fill. Stormwater could be transmitted farther downslope by pipes to reduce the volume of water passing by the toe of the landslide. Conceptual costs for this alternative are likely in the range of $100,000 to $300,000.

GRI can assist the City with further evaluation of these potential concepts upon request.

LIMITATIONS

The information contained in this report is presented to allow for the reduction, but not elimination, of the risk of potential injury or property damage resulting from ground movements at the subject site. It must be acknowledged that the risk of injury or future damage to improvements is difficult to quantify. It must be understood that the processes cannot be accurately predicted. The analysis and recommendations presented herein are based on the data obtained from our ground-level reconnaissance, subsurface explorations, field instrumentation, and the referenced data sources. In the performance of work such as this, specific information is obtained at specific locations at specific times. However, it must be acknowledged that variations in soil or rock conditions may exist between boring locations. The nature and extent of variation may not become evident until a significant change in the existing conditions occurs, such as the appearance of new ground cracks. If conditions different from those encountered during our reconnaissance and ground monitoring are observed or encountered, we should be advised at once so that we can observe and review these conditions and reconsider our opinions where necessary.

Submitted for GRI,

Renews 02/2018

George A. Freitag, CEG	Michael J. Zimmerman, PE, GE, CEG	Michael S. Marshall, CEG
Principal	Senior Engineer/Geologist	Project Geologist

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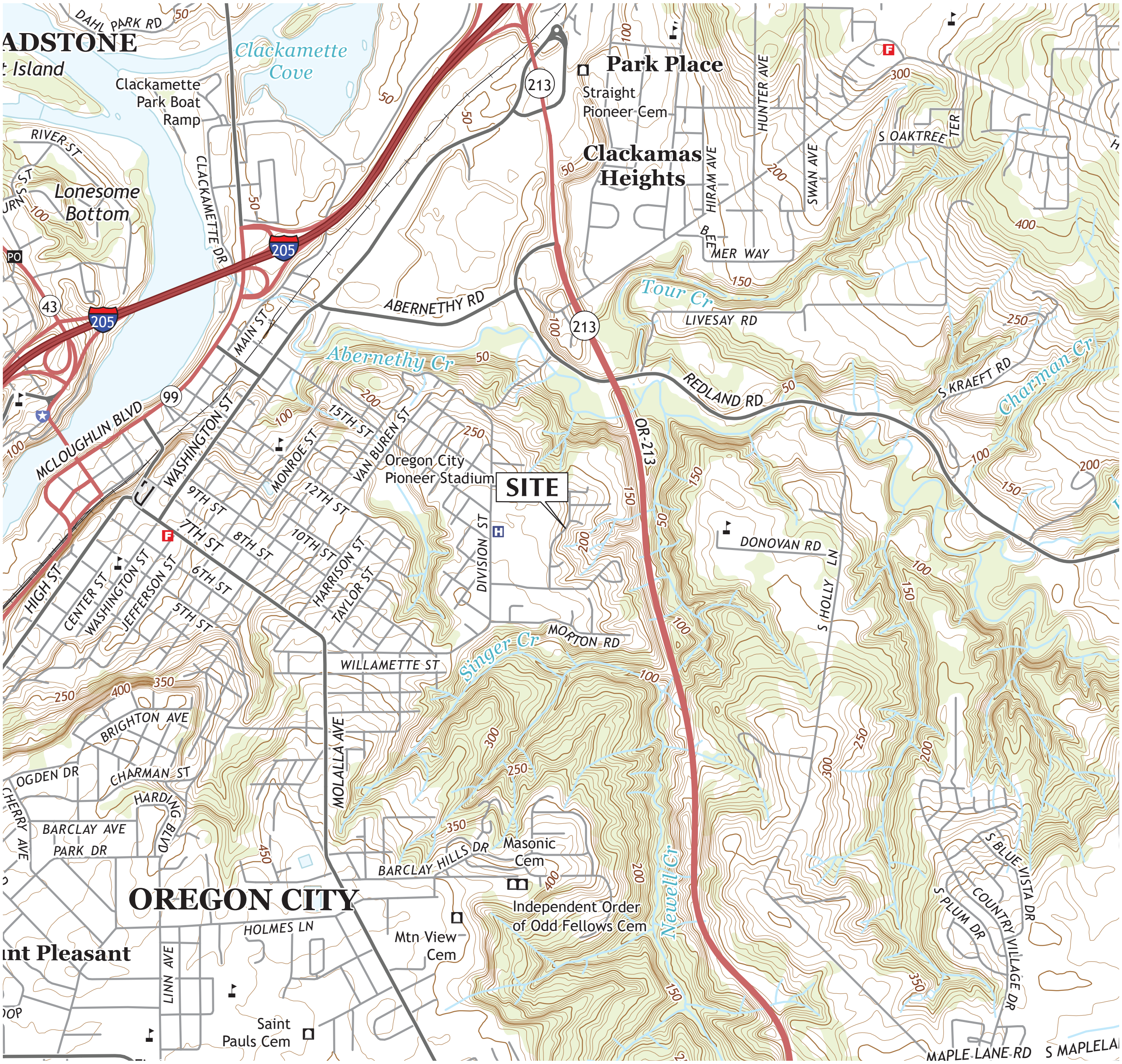


USGS TOPOGRAPHIC MAP
OREGON CITY, OREG. (2014)

North

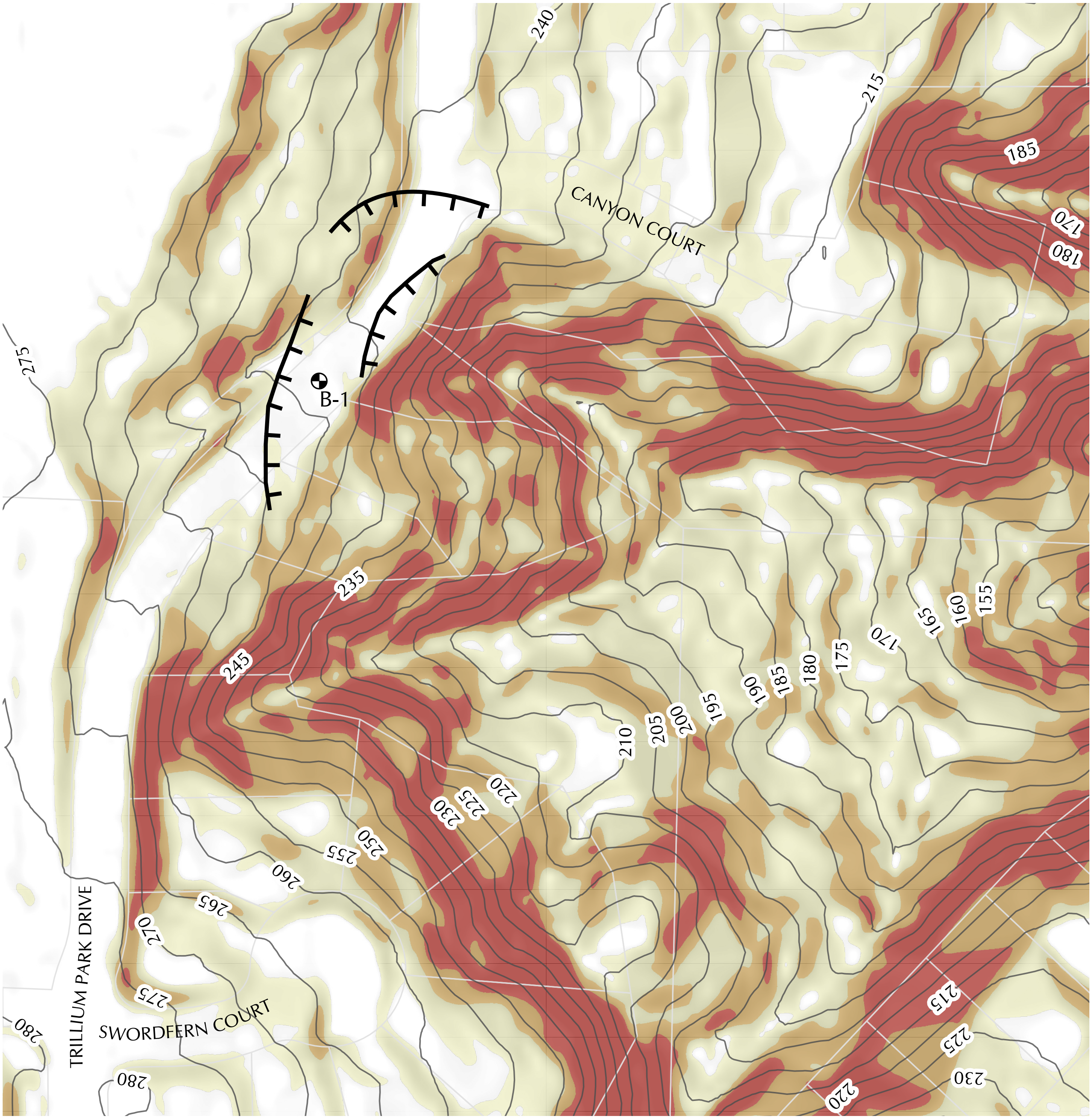
0 1/2 1 MILE

GRI

CITY OF OREGON CITY
TRILLIUM PARK DRIVE

VICINITY MAP

SEP. 2017 JOB NO. 4450-B FIG. 1



TOPOGRAPHY FROM: 2004 PSLC LIDAR: PORTLAND (OR)

APPROXIMATE LOCATION OF GROUNDCRACKS

B-1 BORING COMPLETED BY GRI SEPT. 2006

SLOPE (DEGREES)

- 0 - 6
- 7 - 14
- 14 - 20
- >20

North

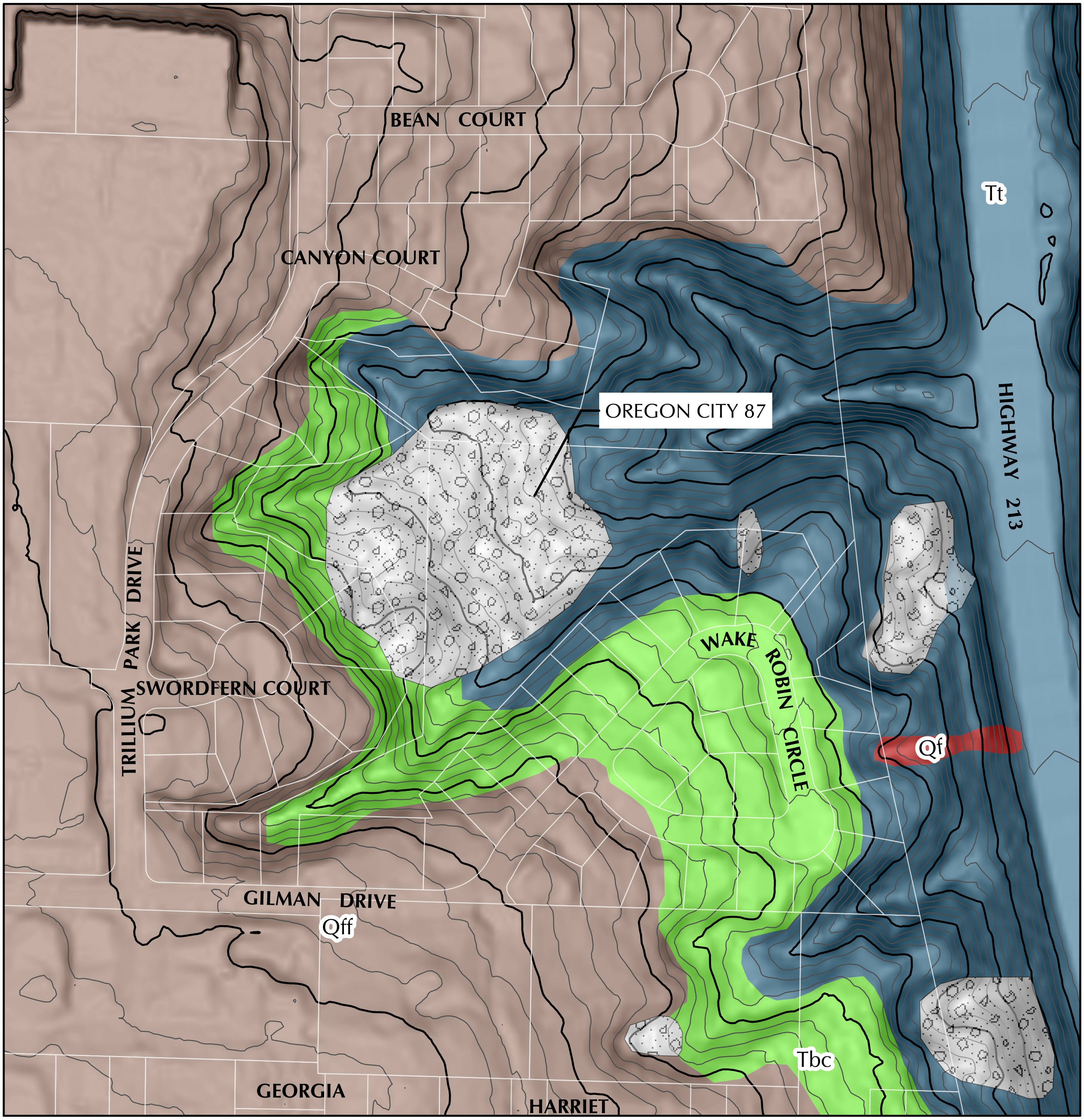
0 100 200 FT

GRI

CITY OF OREGON CITY
TRILLIUM PARK DRIVE LANDSLIDE

SITE MAP

SEP. 2017 JOB NO. 4450-B FIG. 2



TOPOGRAPHY FROM: 2004 PSLC LIDAR: PORTLAND (OR)
GEOLOGY FROM: 2014 OREGON GEOLOGIC DATABASE COMPILATION

North

0 200 400 FT

GEOLOGIC UNITS

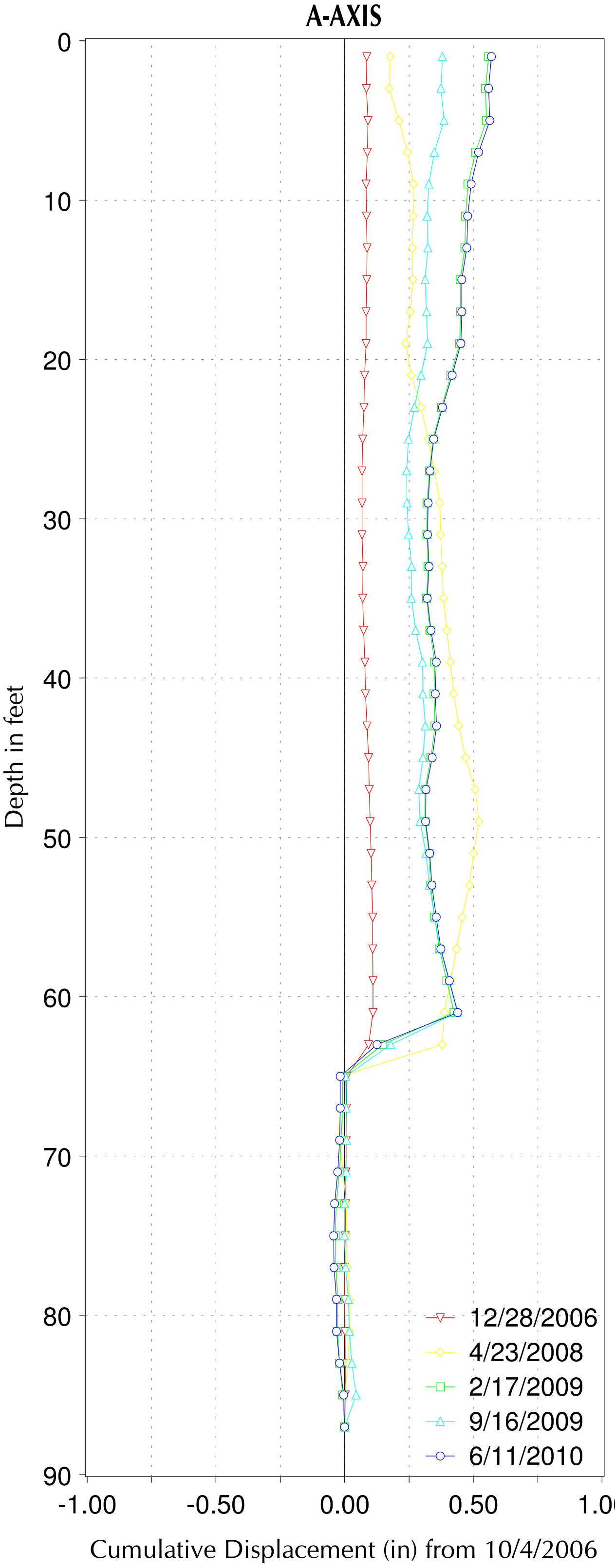
- Qls - LANDSLIDE DEPOSIT
- Qf - DEBRIS FLOW FAN
- Qff - WILLAMETTE SILT
- Tbc - BORING LAVA
- Tt - TROUTDALE FORMATION

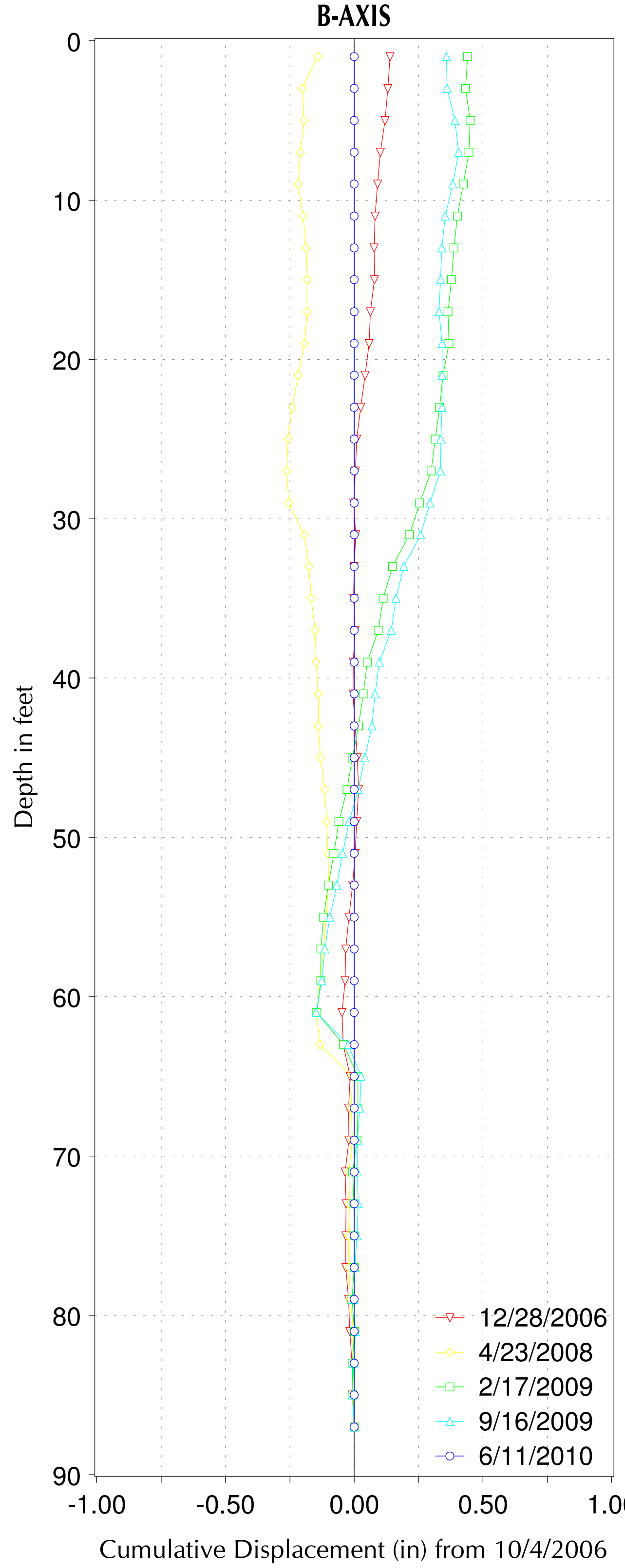
GRI

CITY OF OREGON CITY
TRILLIUM PARK DRIVE LANDSLIDE

GEOLOGIC MAP

SEP. 2017 JOB NO. 4450-B FIG. 3





NOTES:

1) A-Axis bias shift correction applied to 4/23/08, 2/17/09, 9/16/09, and 6/11/10

2) Ground surface elevation +248 ft

3) Piezometer elevation +225 ft

4) B-axis plot for 6/11/10 un-validated and therefore not shown

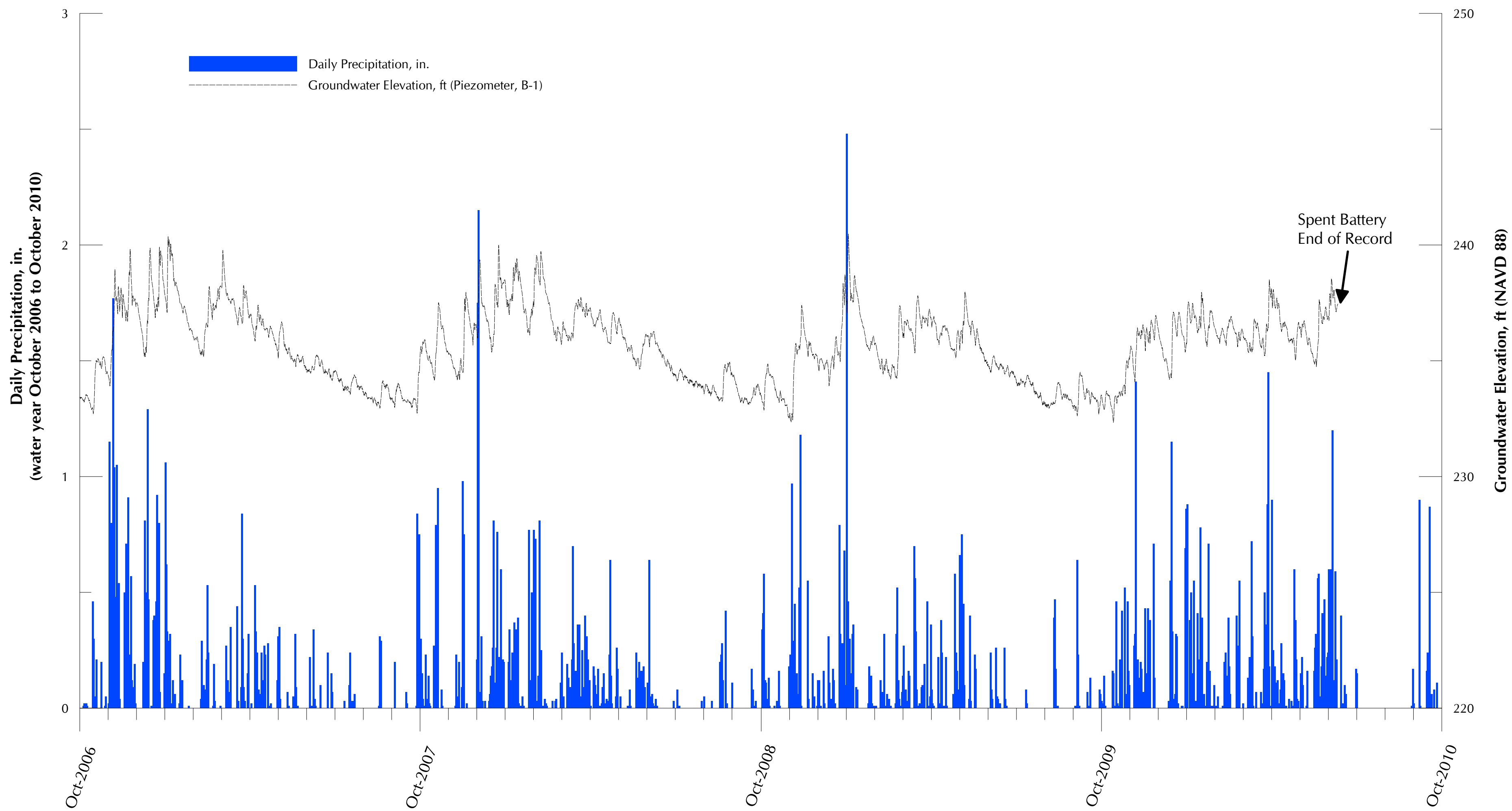
GRI

CITY OF OREGON CITY
TRILLIUM PARK DRIVE LANDSLIDE

INCLINOMETER SUMMARY

(BORING B-1)

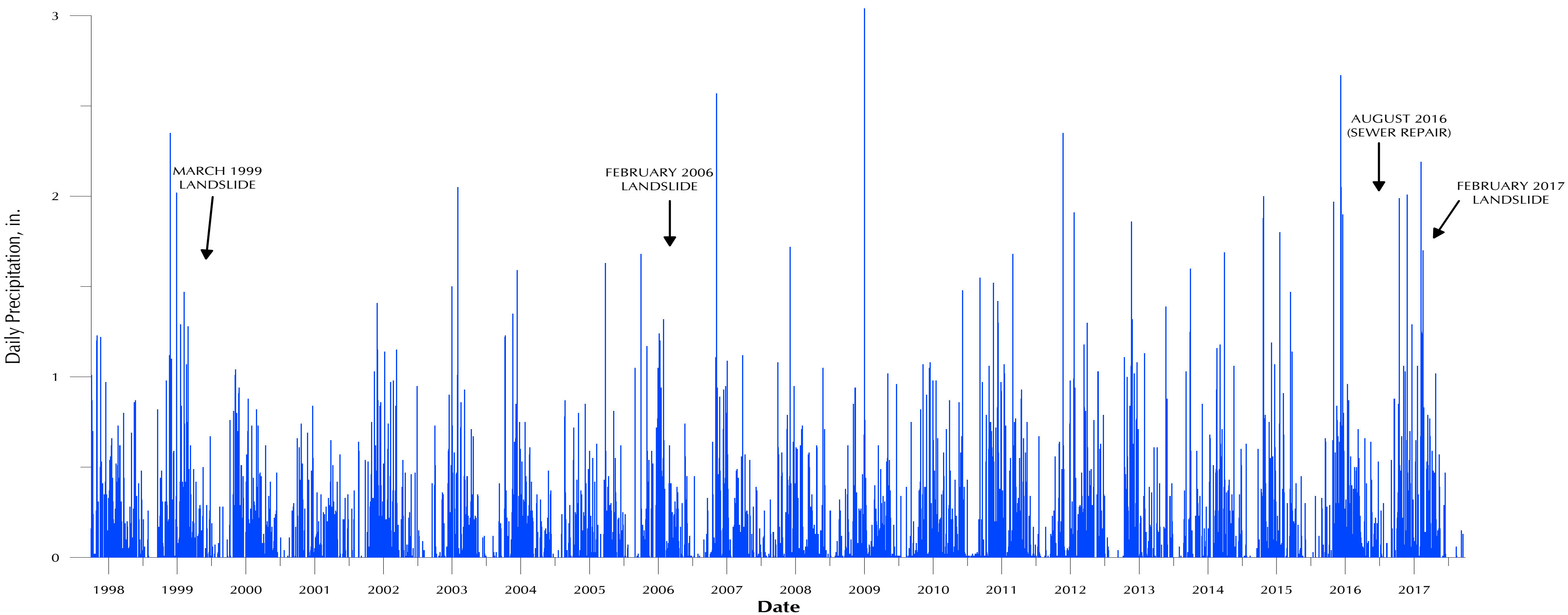
SEP. 2017 JOB NO. 4450-B FIG. 4



GRI

TOTAL DAILY PRECIPITATION & GROUNDWATER ELEVATION (PIEZOMETER B-1)

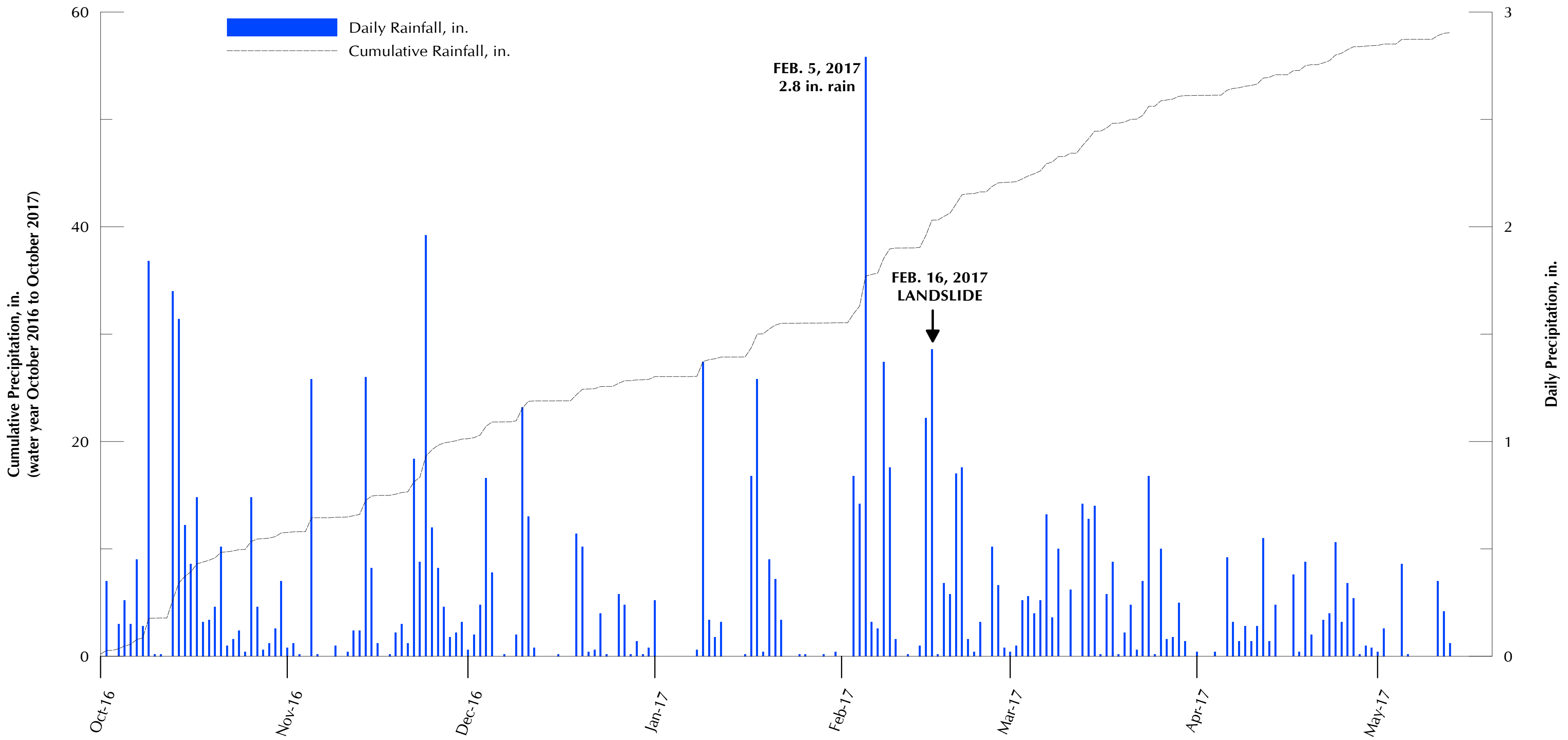
SEP. 2017 JOB NO. 4450-B FIG. 5



GRI

TOTAL DAILY PRECIPITATION
OCT. 1997 TO OCT. 2017
(PDX)

SEP. 2017 | JOB NO. 4450-B | FIG. 6



GRI

TOTAL DAILY PRECIPITATION & CUMULATIVE RAINFALL (COLLINS VIEW GAGE)

SEP. 2017 | JOB NO. 4450-B | FIG. 7

APPENDIX A

2006 Field Explorations and Laboratory Testing

APPENDIX A

FIELD EXPLORATIONS AND LABORATORY TESTING

2006 SUBSURFACE EXPLORATIONS

Subsurface materials and conditions at the site were investigated on September 20 and 21, 2006, with one boring, designated B-1. The approximate location of the boring is shown on Figure 2 of the main report. The field exploration work was directed by an experienced member of GRI's geotechnical engineering staff or an engineering geologist from GRI, who maintained a detailed log of the materials disclosed during the course of the work and obtained samples at intervals noted on the boring log.

Disturbed soil samples were recovered from boring B-1 at 2.5-ft intervals of depth using a standard split-spoon sampler. The sampling interval was increased to 5 ft below a depth of 10 ft and 10 ft below a depth of 50 ft. The Standard Penetration Test was conducted at the time of sampling. This test consists of driving a standard split-spoon sampler into the soil a distance of 18 in. using a 140-lb hammer dropped 30 in. The number of blows required to drive the sampler the last 12 in. is known as the Standard Penetration Resistance, or N-value. N-values provide a measure of the degree of compactness of granular soils, such as sand, and the degree of softness or stiffness of cohesive soils, such as clayey silt. All of the split-spoon samples were saved in airtight jars and returned to our laboratory for further examination and testing. The natural moisture contents of soil samples were determined in conformance with ASTM D2216.

A log of the boring is provided on Appendix A, Figure 1A. The log presents a descriptive summary of the various types of materials encountered in the boring and notes the depths at which the materials and/or characteristics of the materials change. To the right of the descriptive summary, the numbers and types of samples that were taken during the drilling operation are indicated. Farther to the right, N-values are shown graphically. The far right column provides any field comments. The terms and symbols used to describe the materials encountered in the boring are defined in Appendix A, Tables 1A and 2A, and on the attached legend.

LABORATORY TESTING

General

All samples obtained from the field were returned to our laboratory for examination and testing. The physical characteristics were noted, and the field classifications were modified where necessary. The laboratory program included laboratory soil classifications, determinations of natural moisture contents, and washed-sieve analyses.

Natural Moisture Content

Natural moisture content determinations were made in conformance with ASTM D2216. The results are shown on Appendix A, Figure 1A.

Washed-Sieve Analysis

Washed-sieve analyses were performed using selected soil samples to assist in classification of the soils. The test is performed by taking a sample of known dry weight and washing it over a No. 200 sieve. The material retained on the sieve is oven-dried and weighed. The percentage of material passing the No. 200 sieve is then calculated. The results are provided on Appendix A, Figure 1A.

Table 1A

ODOT GUIDELINES FOR CLASSIFICATION OF SOIL

Description of Relative Density for Granular Soil

Relative Density	Standard Penetration Resistance (N-values), blows per ft
very loose	0 - 4
loose	4 - 10
medium dense	10 - 30
dense	30 - 50
very dense	over 50

Description of Consistency for Fine-Grained (Cohesive) Soils

Consistency	Standard Penetration Resistance (N-values), blows per ft	Torvane or Undrained Shear Strength, tsf
very soft	0 - 2	less than 0.125
soft	2 - 4	0.125 - 0.25
medium stiff	4 - 8	0.25 - 0.50
stiff	8 - 15	0.50 - 1.0
very stiff	15 - 30	1.0 - 2.0
hard	over 30	over 2.0

Sandy silt materials that exhibit general properties of granular soils are given relative density descriptions.

Grain-Size Classification

Boulders:
12 - 36 in.

Cobbles:
3 - 12 in.

Gravel:
1/4 - 3/4 in. (fine)
3/4 - 3 in. (coarse)

Sand:
No. 200 - No. 40 sieve (fine)
No. 40 - No. 10 sieve (medium)
No. 10 - No. 4 sieve (coarse)

Silt/Clay:
pass No. 200 sieve

Modifier for Subclassification

Adjective	Primary Constituent SAND or GRAVEL	Primary Constituent SILT or CLAY
	Percentage of Other Material (by weight)	
trace:	5 - 15 (sand, gravel)	5 - 15 (sand, gravel)
some:	15 - 30 (sand, gravel)	15 - 30 (sand, gravel)
sandy, gravelly:	30 - 50 (sand, gravel)	30 - 50 (sand, gravel)
trace:	< 5 (silt, clay)	*Relationship of clay and silt determined by plasticity index test*
some:	5 - 12 (silt, clay)	
silty, clayey:	12 - 50 (silt, clay)	

Table 2A

GUIDELINES FOR CLASSIFICATION OF ROCK

RELATIVE ROCK WEATHERING SCALE:

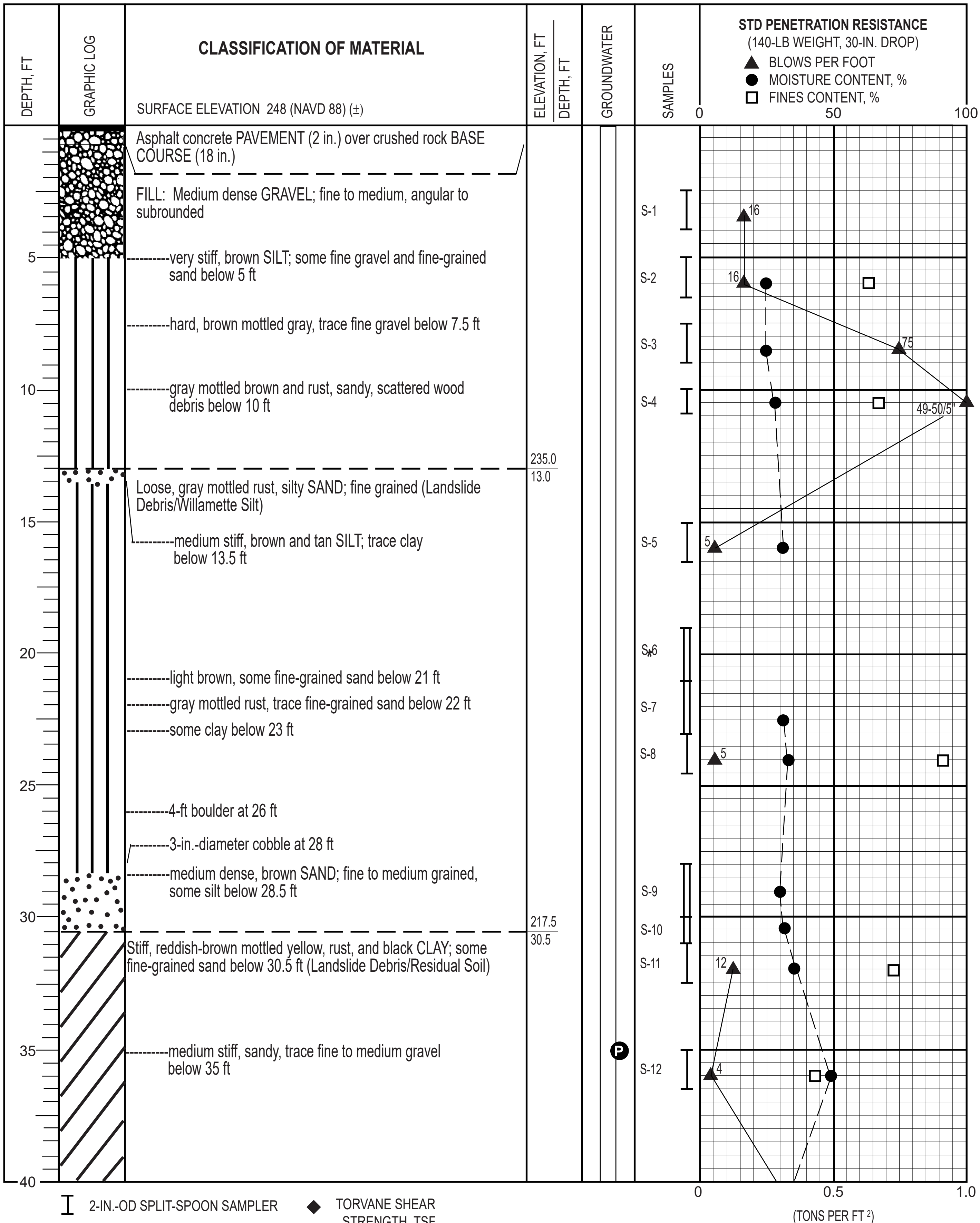
Term	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 in. into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

RELATIVE ROCK HARDNESS SCALE:

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife and scratched with fingernail.	100 - 1,000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1,000 - 4,000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4,000 - 8,000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8,000 - 16,000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16,000 psi

RQD AND ROCK QUALITY:

Relation of RQD and Rock Quality		Terminology for Planar Surface		
RQD (Rock Quality Designation), %	Description of Rock Quality	Bedding	Joints and Fractures	Spacing
0 - 25	Very Poor	Laminated	Very Close	< 2 in.
25 - 50	Poor	Thin	Close	2 in. – 12 in.
50 - 75	Fair	Medium	Moderately Close	12 in. – 36 in.
75 - 90	Good	Thick	Wide	36 in. – 10 ft
90 - 100	Excellent	Massive	Very Wide	> 10 ft



2-IN.-OD SPLIT-SPOON SAMPLER

3-IN.-OD THIN-WALLED SAMPLER

G GRAB SAMPLE OF DRILL CUTTINGS

NX CORE RUN

SLOTTED PVC PIPE

Water Level (date)

◆ TORVANE SHEAR STRENGTH, TSF

■ UNDRAINED SHEAR STRENGTH, TSF

* NO RECOVERY

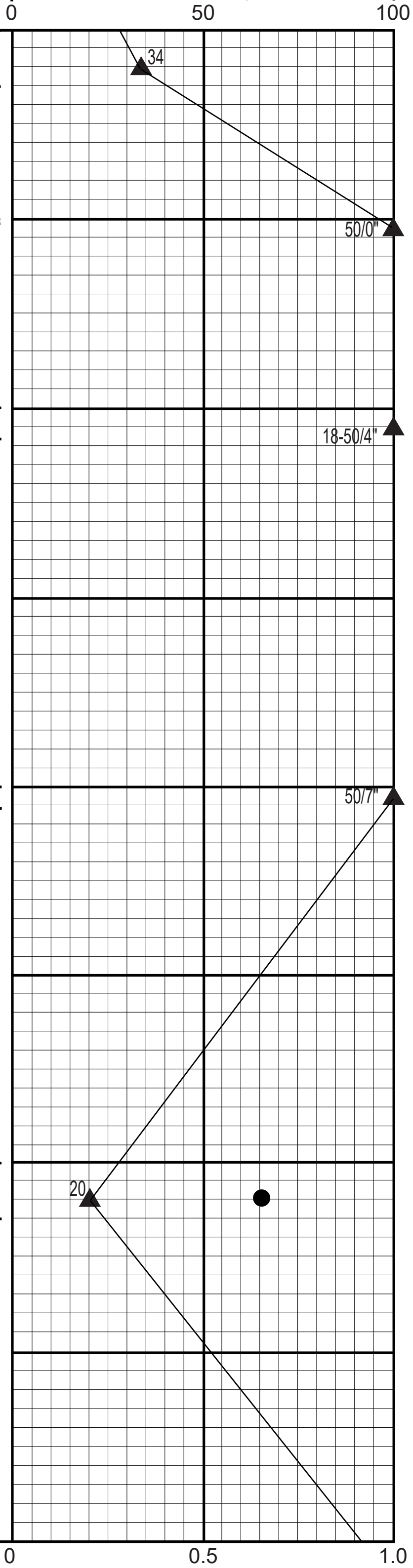
Liquid Limit / Moisture Content / Plastic Limit

GRI

BORING B-1

SEP. 2017 JOB NO. 4450-B FIG. 1A

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL SURFACE ELEVATION 248 (NAVD 88) (±)	ELEVATION, FT / DEPTH, FT	GROUNDWATER	SAMPLES	STD PENETRATION RESISTANCE (140-LB WEIGHT, 30-IN. DROP) ▲ BLOWS PER FOOT ● MOISTURE CONTENT, % □ FINES CONTENT, %
40		Very soft (R1), gray, red, and rust BASALT; severely weathered, to medium stiff, reddish-brown CLAY; some fine-grained sand (Boring Lava Landslide Debris)	208.0 / 13.0		S-13	34
45		----------decomposed below 45 ft			S-14 *	50/0"
50					S-15	18-50/4"
55						
60					S-16	50/7"
62		Extremely soft (R0) gray MUDSTONE; decomposed, degree of weathering decreases with increasing depth (Troutdale Formation)	186.0 / 62.0			
65		----------zone of movement observed at 65 ft (12/28/06), see Inclinometer Graph, Figure ___				
70					S-17	20
75						
80						



I 2-IN.-OD SPLIT-SPOON SAMPLER

II 3-IN.-OD THIN-WALLED SAMPLER

G GRAB SAMPLE OF DRILL CUTTINGS

▌ NX CORE RUN

|— SLOTTED PVC PIPE

▼ Water Level (date)

◆ TORVANE SHEAR STRENGTH, TSF

■ UNDRAINED SHEAR STRENGTH, TSF

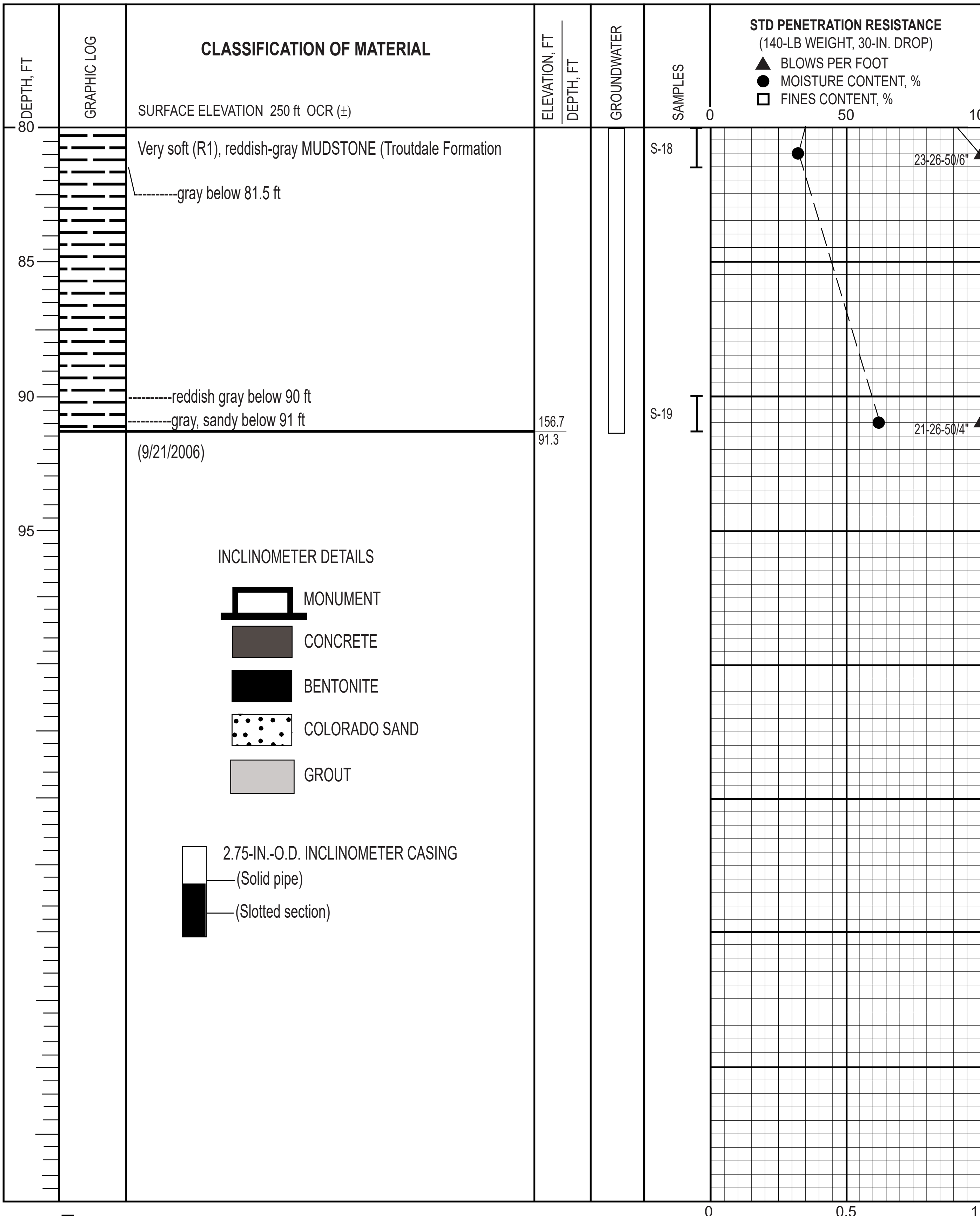
* NO RECOVERY

Plastic Limit — Moisture Content — Liquid Limit

GRI

BORING B-1 (cont.)

SEP. 2017 JOB NO. 4450-B FIG. 1A



2-IN.-OD SPLIT-SPOON SAMPLER
3-IN.-OD THIN-WALLED SAMPLER
G GRAB SAMPLE OF DRILL CUTTINGS
NX CORE RUN
SLOTTED PVC PIPE
Water Level (date)

TORVANE SHEAR STRENGTH, TSF
UNDRAINED SHEAR STRENGTH, TSF
* NO RECOVERY

Liquid Limit
Moisture Content
Plastic Limit

GRI

BORING B-1 (cont.)

SEP. 2017 JOB NO. 4450-B FIG. 1A

APPENDIX B

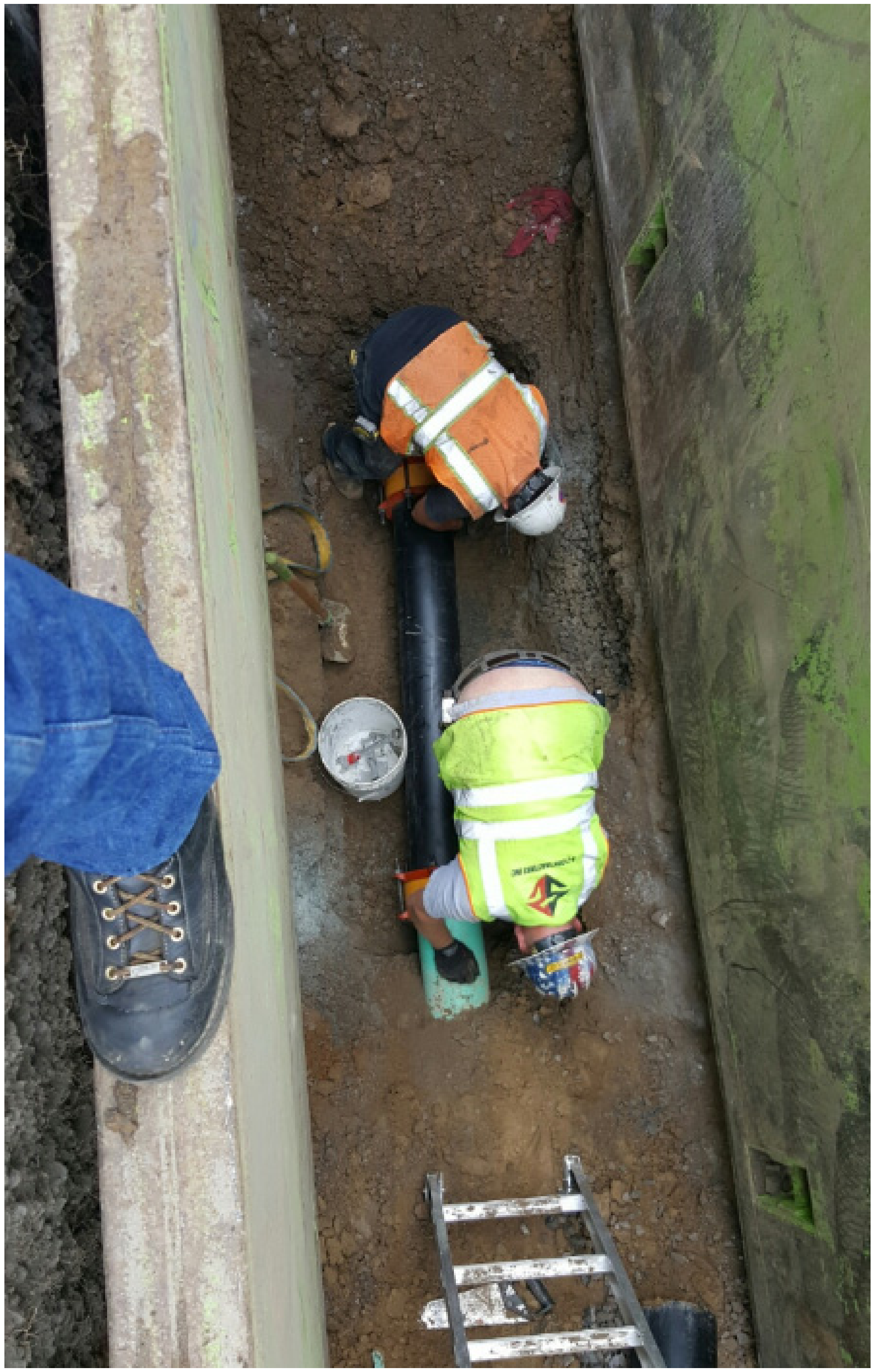
Email from City regarding August 2016 Sewer Repair

APPENDIX B

Email from City regarding August 2016 Sewer Repair

- August 2016:
  - Video survey just prior to City's August 2016 pavement maintenance project on Trillium Park Drive, a small section of City's underground 8-inch PVC sanitary sewer pipe was found to be deformed from a circular pipe to an oblong pipe.
  - This PVC pipe piece was removed and replaced with a length of HDPE pipe and two Romac couplings prior to the pavement maintenance work.
- August 2017:
  - Video survey performed of City's underground 8-inch sanitary sewer pipe in Trillium Park Drive and was found to be deformed from a circular pipe to an oblong pipe in the same location that found in 2016 a similar deformed pipe section that had been replaced in 2016.
- Below shows the 2016 deformed PVC section.

- Below shows the 2016 HDPE Replacement pipe section with the Romac couplings.




Location of 8" pipe section that deformed
Trillium Park Dr
13776
13829
13826
17346
13763
13759
0 30 60ft

APPENDIX C

2017 GRI Inclinometer Installations Memo

GRI
9750 SW Nimbus Avenue
Beaverton, OR 97008-7172
p | 503-641-3478 f | 503-644-8034

MEMORANDUM

To: Aleta Froman-Goodrich, PE / City of Oregon City

Date: July 28, 2017

GRI Project No.: 4450-B

From: George Freitag, CEG; Mike Marshall, CEG; Thomas O'Dell, EIT

Re: 2017 Inclinometer Installations
Trillium Park Drive Landslide and Surrounding Area
Oregon City, Oregon

This memorandum summarizes the installation of four new inclinometers in the area of a landslide that occurred along Trillium Park Drive in Oregon City, Oregon. The landslide originally occurred in 1999 on an east-facing slope along Trillium Park Drive between Canyon Court and Swordfern Court. Following a period of heavy precipitation in February 2017, the landslide reactivated. The general location of the project is shown on the Site Plan / Geologic Map, Figure 1. The landslide extends into the paved area, and the roadway is closed to vehicle traffic. The purpose of our services is to assist the City of Oregon City (City) with evaluating slope conditions in the project area and long-term monitoring of the public infrastructure. Our work was completed in accordance with our City Personal Services Agreement, dated March 13, 2017, and the two associated amendments: Amendment 1 and Amendment 2, dated April 24, 2017, and May 26, 2017, respectively. This memorandum summarizes the subsurface conditions encountered and inclinometer installations performed.

PROJECT AND SITE DESCRIPTION

Background

Since the development of Trillium Park Estates in 1993, there have been two prior instances of observed movement along the Trillium Park Drive landslide. Evidence of landslide movement was documented in both early 1999 and January 2006 following periods of intense precipitation. In February 2017, additional movement of the landslide was observed in Trillium Park Drive following an unusually wet and prolonged winter. The landslide resulted in localized pavement and ground cracks as well as a water-line being pulled apart at a slip joint in Trillium Park Drive. At present, the City has closed Trillium Park Drive between Swordfern Court and Canyon Court and posted the structure located at 13776 Canyon Court, which appears to be within the landslide mass, as a Dangerous Building.

Surface Conditions and Topography

The ground surface in the area of the landslide slopes down to the east at 20 to 68° from an elevation of about 242 ft at Trillium Park Drive to an elevation of 180 ft (North American Vertical Datum of 1988 [NAVD88]) at the bottom of the slope, as shown on the Site Plan / Geologic Map, Figure 1. The ground continues to gradually slope downward to the east until reaching Newell Creek approximately 1,300 ft east of Trillium Park Drive. West of Trillium Park Drive, the ground surface slopes upward to gain about 20 ft in elevation before flattening out at the top of the slope, where the Providence Willamette Falls Hospital is located at about elevation 270 ft (NAVD 88). The landslide generally sits in a saddle of Trillium Park Drive between higher ground toward Canyon Court to the north and Swordfern Court to the south.

Local and Regional Geology

The site is located in the northern Willamette Valley, within the Portland Basin. The Portland Basin is a northwest-trending structural basin that encompasses approximately 1,310 sq mi. The Portland Basin is characterized by relatively low topographic relief with areas of buttes and valleys containing steep slopes (McFarland and Morgan, 1996). Sedimentary deposits generally consisting of conglomerate, gravel, sand, silt, and some clay from volcanic, fluvial, and lacustrine material have filled the Portland Basin.

Some of the oldest rocks identified in the Portland Basin include the Miocene-age Columbia River Basalt Group. In the vicinity of the project site, Miocene/Pliocene-age Troutdale Formation overlies the Columbia River Basalt and consists of thin-bedded micaceous and tuffaceous sandstone and siltstone, carbonaceous claystone, and local gravel lenses (Trimble, 1963; Swanson et al., 1993; Evarts et al., 2009). The generally weak to moderately strong Troutdale Formation is very prone to landsliding when overlain by Boring Lava flows (Madin, 2009). The Boring Lavas are Pliocene/Pleistocene-age basalts that are light gray and vary in thickness. The most recent geologic mapping of the area indicates the contact of the Troutdale Formation varies in elevation from about 140 ft along the slope above OR-213 to 225 ft (NAVD88) near the residence at 13776 Canyon Court. The Boring Lava is mapped along the slope just below Trillium Park Drive. The failure plane of the Trillium Park Drive landslide appears to coincide with the exposed contact of weak, relatively impermeable sedimentary rock and the underling hard basalt rock, similar to other landslides in the Newell Creek drainage.

FIELD EXPLORATIONS AND INSTRUMENTATION

General

Subsurface materials and conditions at the inclinometer locations were investigated by GRI during two separate mobilizations, the first occurring on September 20 and 21, 2006, with one drilled boring, designated B-1 and the second mobilization occurring between June 12 and June 19, 2017, with four additional borings, designated B-2 through B-5. The location of each boring is shown on the Site Plan / Geologic Map, Figure 1. The field work was coordinated and documented by a member of GRI's geotechnical engineering staff, who maintained a log of the materials and conditions disclosed during the course of the work. Following completion of each boring, an inclinometer casing was installed in the borehole to monitor lateral movement of the adjacent slope. It should be noted that the City evaluated the inclinometer installed in boring B-1 in March 2017 and determined the inclinometer sheared at a depth of about 61.8 ft. The amount of lateral displacement across the inclinometer casing could not be determined. A description of the field exploration completed and instrumentation installed for this project, borings B-2 through B-5, is provided below.

Inclinometer Instrumentation

A 100-ft-long inclinometer casing was installed in the completed boreholes of borings B-2 through B-5. An inclinometer is a device that allows measurements to be made of below-ground lateral movements. The inclinometer casing consists of a 2.75-in.-outside-diameter (O.D.) ABS plastic casing with orthogonal grooves or slots that permit a calibrated instrument to be lowered to the bottom of the casing in a fixed orientation. When the ground surrounding the casing moves, the casing distorts above the zone of movement, and the orientation of the casing changes. The inclination, or vertical orientation, of the casing is monitored by lowering an electronic measuring device to the bottom of the grooved casing and obtaining readings at 2-ft intervals as the instrument is withdrawn. An initial set of readings serves as a "benchmark" and is commonly portrayed as the vertical axis on a plot of casing deflection versus depth. All subsequent readings are then referenced to the initial readings. By comparing relative movements at fixed depths over the length of the casing, zones of horizontal movement can be identified. The total, or cumulative, displacement with respect to the base of the casing is obtained by summing the relative displacements from the bottom to top.

The inclinometers were installed for future monitoring of the landslide area and its surrounding area. The inclinometer in boring B-2 will monitor landslide movement on Trillium Park Drive and function as a replacement for the sheared inclinometer in boring B-1. Inclinometers installed in borings B-3, B-4, and B-5 will monitor potential landslide movement in Canyon Court, Swordfern Court, and Wake Robin Circle, respectively. The inclinometers were installed by lowering the casing to the base of the borehole and filling the annular space surrounding the casing with a cement-bentonite slurry. The slurry was placed using tremie methods starting at the bottom of the borehole. The completed installation was protected at the ground surface with a steel monument set in concrete. At the time of each inclinometer installation, a Geokon Model 4500 ALV low-pressure, vented vibrating-wire piezometer was taped to the inclinometer casing and installed near the depth of the anticipated slide plane. Following installation, a benchmark reading was taken on June 30, 2017. Monitoring of the inclinometers and piezometers is scheduled to begin in winter 2017 and will extend into spring 2018.

SOILS AND GROUNDWATER

Subsurface materials and conditions were evaluated by GRI on September 20 and 21, 2006, with drilled boring B-1, as well as between June 12 and June 19, 2017, with drilled borings B-2 through B-5. The borings completed as part of the June 2017 investigation were advanced to a depth of 101.5 ft with mud-rotary techniques using a truck-mounted drill rig provided and operated by Western States Soil Conservation, Inc., of Hubbard, Oregon. The logs of borings B-2 through B-5 are provided on Figures 2 through 5 through . The terms used to describe the soil and rock encountered in the boring are defined in Tables 1C and 2C.

The soil and rock units disclosed by the borings completed as a part of the June 2017 investigation are generally consistent with previous work completed by GRI in the area and our understanding of the local geology. For the purpose of this discussion, the materials disclosed by the borings have been grouped into the following units based on their physical characteristics and engineering properties. Listed as they were encountered from the ground surface to the bottom of the boring, the geologic units observed in the borings include the following:

1. **PAVEMENT**
2. **FILL**
3. **SAND and SILT (Missoula Flood Deposit)**
4. **SAND, SILT, and CLAY (Landslide Debris)**
5. **BASALT (Landslide Debris)**
6. **BASALT (Boring Lava)**
7. **SILTSTONE and MUDSTONE (Troutdale Formation)**

1. PAVEMENT. Borings B-2 through B-5 were advanced through pavement sections and encountered between 3 and 4 in. of asphalt concrete (AC) pavement underlain by between 8 and 10 in. of crushed rock base (CRB) course.

2. FILL. Gravel fill was encountered below the base course in boring B-4 and extends to a depth of 6.5 ft. The gravel fill in boring B-4 also contains cobbles. Silt fill was encountered below the base course in borings B-2 and B-3 and extends to a depth of 20 ft in both borings. The silt fill is generally brown to gray, contains trace gravel and has sand and clay contents ranging from trace fine-grained sand to sandy and trace to some clay. The relative consistency of the silt fill ranges from very soft to medium stiff based on SPT N-values ranging from 2 to 4 blows/ft.

3. SAND and SILT (Missoula Flood Deposit). The fill in borings B-3 and B-4 and the base course in boring B-5 are underlain by silts and sands interpreted to be material from Missoula flood deposits that extend to depths of 20 to 45 ft. The silt flood deposits are generally brown to brown mottled rust, have a variable clay content ranging from trace clay to clayey, and range in sand content from trace fine-grained sand to sandy. The silt unit encountered in boring B-3 was interbedded with 2- to 3-in.-thick layers of silty sand below 20 ft. The relative consistency of the silt is very soft to medium stiff based on SPT N-values of 1 to 6 blows/ft.

The sand flood deposits are generally brown, are fine to coarse grained, have a variable silt content that ranges from some silt to silty, and contains a trace to some clay. The relative density of the sand is very loose to loose based on an SPT N-values of 1 to 8 blows/ft.

4. SAND, SILT, and CLAY (Landslide Debris). The fill in boring B-2 is underlain by silt, sandy silt, and clay landslide debris. The silt is generally brown mottled rust and contains trace clay and some fine-grained sand. The relative consistency of the silt is very soft to soft based on an SPT N-value of 2 blows/ft.

Sandy silt and clay landslide debris interpreted to be residual soil was encountered below the silt landslide debris in boring B-2 at a depth of 31 ft depth and extends to a depth of 40 ft. The residual soil is derived from the weathering of the underlying Boring Lava basalt. The residual soil is generally red-brown and sandy. The residual soil is stiff based on an SPT N-value of 10 blows/ft. Landslide debris was only encountered in boring B-2, which was drilled in Trillium Park Drive.

5. BASALT (Landslide Debris). Extremely soft (R0) basalt landslide debris interpreted to be of the Boring Lava formation was encountered beneath the silt and clay residual soil in boring B-2 at a depth of 40 ft. The basalt landslide debris extends to a depth of 61.5 ft. The basalt is generally gray mottled rust in color and decomposed. The basalt landslide debris contains gravel-sized fragments of soft to medium hard (R2 to R3) basalt below a depth of 50 ft. SPT N-values of 14 blows/ft to 50 blows for less than 6 in. of sampler penetration were recorded in the basalt. The degree of hardness and weathering of the basalt varies with depth. Landslide debris was only encountered in boring B-2, which was drilled in Trillium Park Drive.

6. BASALT (Boring Lava). Extremely soft to very soft (R0 to R1) basalt interpreted to be of the Boring Lava formation was encountered beneath the flood deposits in boring B-4 at a depth of 20 ft. The basalt extends to a depth of 35 ft. The basalt is generally gray to red-brown in color and predominantly decomposed to decomposed. Cobbles and boulders are present throughout the decomposed basalt unit. A 6-in.-thick layer of red-brown clay was encountered within the basalt at a depth of 28.5 ft. SPT N-values of 20 blows/ft to 50 blows for less than 1 in. of sampler penetration were recorded in the basalt.

7. SILTSTONE and MUDSTONE (Troutdale Formation). Siltstone interpreted to be of the Troutdale Formation was encountered below the basalt in borings B-2 and B-4 and below the sand and silt flood deposits in boring B-3. The siltstone extends to depths of 100, 38, and 35 ft in borings B-2, B-3, and B-4, respectively. The siltstone is generally gray, red-brown, and brown mottled rust and black; extremely soft (R0); and decomposed.

Mudstone interpreted to be of the Troutdale Formation was encountered below the siltstone in borings B-2, B-3, and B-4 and below the sand and silt flood deposits in boring B-5. The mudstone extends to the maximum depth explored of 101.5 ft. The mudstone is generally gray to red-gray or light brown, extremely soft (R0), and decomposed. SPT N-values of 0 to 53 blows/ft were recorded in the mudstone.

Groundwater

The borings were completed with mud-rotary drilling techniques, which do not allow the measurement of groundwater levels. The regional groundwater level typically occurs at depth in the highly fractured, hard basalt that underlies the site. However, our work in the area indicates perched groundwater conditions can occur in the silt fill, Missoula flood deposit, or residual soil that mantle the site, particularly during the wet winter and spring months or during periods of heavy or prolonged precipitation. To allow measurement and periodic monitoring of perched groundwater levels at the site, vibrating-wire piezometers were installed at depths ranging from 38 to 72 ft. On May 3, 2017, the local perched groundwater in the piezometer at boring B-1 was measured at a depth of 29 ft below the existing ground surface and on June 30, 2017, piezometers installed in borings B-2 through B-4 measured perched groundwater at approximately 12.5 to 17.5 ft below the existing ground surface.

LIMITATIONS

The information contained in this memorandum is presented to allow for the reduction, but not elimination, of the risk of potential injury or property damage resulting from ground movements at the subject site. It must be acknowledged that the risk of injury or future damage to improvements is difficult to quantify. It must be understood that the processes cannot be accurately predicted. The interpretations of subsurface conditions presented herein are based on the data obtained from our ground-level reconnaissance, subsurface explorations, field instrumentation, and the referenced data sources. In the performance of work such as this, specific information is obtained at specific locations at specific times. However, it must be acknowledged that variations in soil or rock conditions may exist between boring locations. The nature and extent of variation may not become evident until a significant change in the existing conditions occurs, such as the appearance of new ground cracks. If conditions different from those encountered during our reconnaissance and ground monitoring are observed or encountered, we should be advised at once so that we can observe and review these conditions and reconsider our opinions where necessary.

Submitted for GRI,

Renews 02/2018

George A Freitag, CEG
Principal

Michael S Marshall, CEG
Project Geologist

Thomas O'Dell, EIT
Engineering Staff

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4450-B INCLINOMETER INSTALLATION

This document has been submitted electronically.

Table 1C: GUIDELINES FOR CLASSIFICATION OF SOIL

Description of Relative Density for Granular Soil

Relative Density	Standard Penetration Resistance (N-values), blows per ft
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	over 50

Description of Consistency for Fine-Grained (Cohesive) Soils

Consistency	Standard Penetration Resistance (N-values), blows per ft	Torvane or Undrained Shear Strength, tsf
Very Soft	0 - 2	less than 0.125
Soft	2 - 4	0.125 - 0.25
Medium Stiff	4 - 8	0.25 - 0.50
Stiff	8 - 15	0.50 - 1.0
Very Stiff	15 - 30	1.0 - 2.0
Hard	over 30	over 2.0

Grain-Size Classification

Boulders:
- >12 in.

Cobbles:
- 3 - 12 in.

Gravel:
- 1/4 - 3/4 in. (fine)
- 3/4 - 3 in. (coarse)

Sand:
- No. 200 - No. 40 sieve (fine)
- No. 40 - No. 10 sieve (medium)
- No. 10 - No. 4 sieve (coarse)

Silt/Clay:
- pass No. 200 sieve

Modifier for Subclassification

	Primary Constituent SAND or GRAVEL	Primary Constituent SILT or CLAY
Adjective	**Percentage of Other Material (by weight)**	
trace:	5 - 15 (sand, gravel)	5 - 15 (sand, gravel)
some:	15 - 30 (sand, gravel)	15 - 30 (sand, gravel)
sandy, gravelly:	30 - 50 (sand, gravel)	30 - 50 (sand, gravel)
trace:	<5 (silt, clay)	*Relationship of clay and silt determined by plasticity index test*
some:	5 - 12 (silt, clay)	
silty, clayey:	12 - 50 (silt, clay)	

Table 2C: GUIDELINES FOR CLASSIFICATION OF ROCK

RELATIVE ROCK WEATHERING SCALE

Term	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 in. into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

RELATIVE ROCK HARDNESS SCALE

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife and scratched with fingernail.	100 - 1,000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1,000 - 4,000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4,000 - 8,000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8,000 - 16,000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16,000 psi

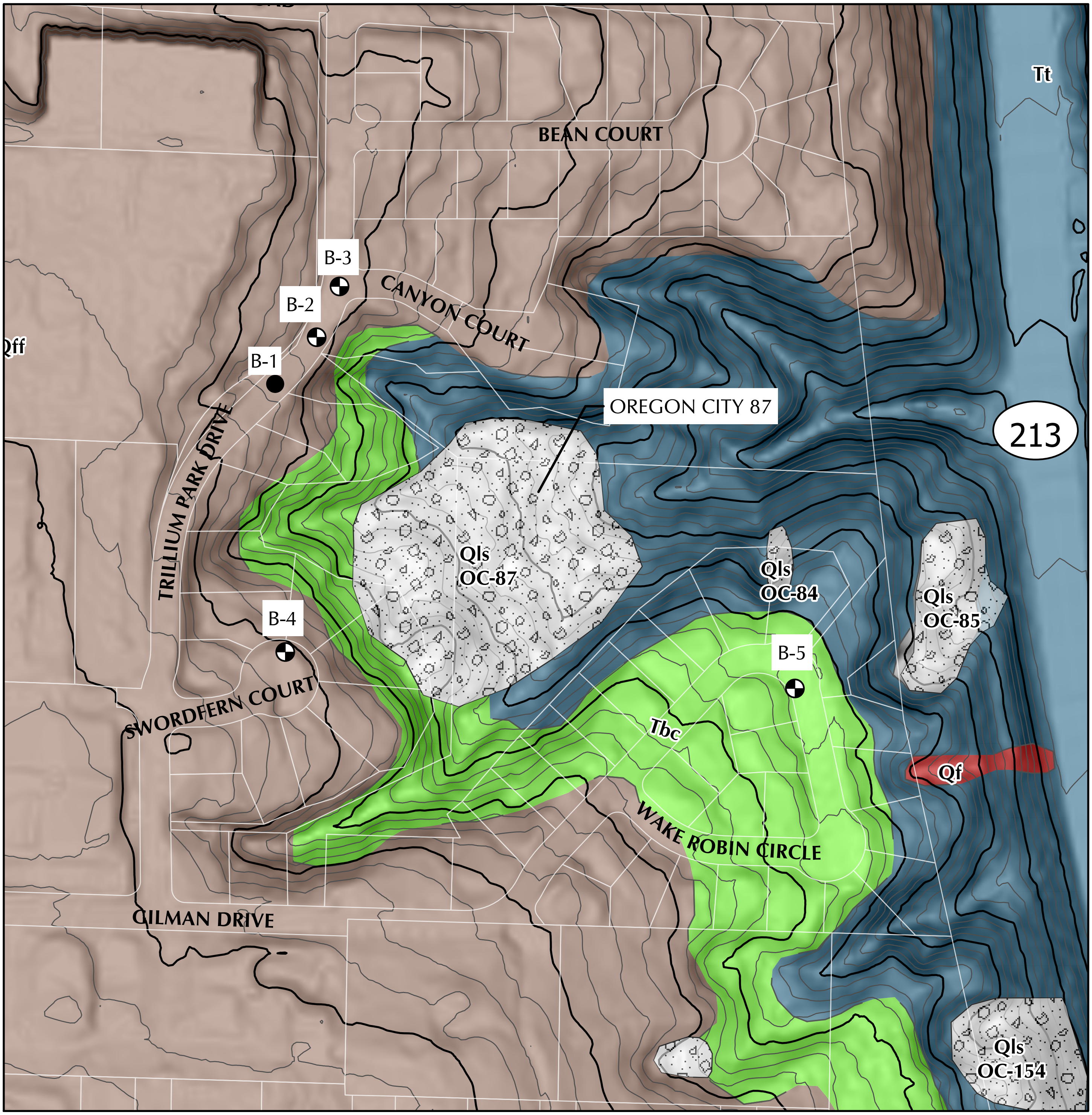
RQD AND ROCK QUALITY

Relation of RQD and Rock Quality

RQD (Rock Quality Designation), %	Description of Rock Quality
0 - 25	Very Poor
25 - 50	Poor
50 - 75	Fair
75 - 90	Good
90 - 100	Excellent

Terminology for Planar Surface

Bedding	Joints and Fractures	Spacing
Laminated	Very Close	< 2 in.
Thin	Close	2 in. – 12 in.
Medium	Moderately Close	12 in. – 36 in.
Thick	Wide	36 in. – 10 ft
Massive	Very Wide	> 10 ft



TOPOGRAPHY FROM: 2004 PSLC LIDAR: PORTLAND (OR)
GEOLOGY FROM: 2014 OREGON GEOLOGIC DATABASE COMPILATION

GEOLOGIC UNITS

- BORING COMPLETED BY GRI (SEPTEMBER 20 - 21, 2006)
- BORINGS COMPLETED BY GRI (JUNE 12 -19, 2017)
- Qls - LANDSLIDE DEPOSIT
- Qf - DEBRIS FLOW FAN
- Qff - WILLAMETTE SILT
- Tbc - BORING LAVA
- Tt - TROUTDALE FORMATION

North

0 200 400 FT

GRI

CITY OF OREGON CITY
TRILLIUM PARK DRIVE LANDSLIDE

SITE PLAN / GEOLOGIC MAP

JULY 2017 | JOB NO. 4450-B | FIG. 1

Table 1C: GUIDELINES FOR CLASSIFICATION OF SOIL

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trace:	< 5 (silt, clay)	*Relationship of clay and silt determined by plasticity index test*
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Thick	Wide	36 in. – 10 ft
Massive	Very Wide	> 10 ft

BORING AND TEST PIT LOG LEGEND

SOIL SYMBOLS

Symbol	Typical Description
	LANDSCAPE MATERIALS
	FILL
	GRAVEL; clean to some silt, clay, and sand
	Sandy GRAVEL; clean to some silt and clay
	Silty GRAVEL; up to some clay and sand
	Clayey GRAVEL; up to some silt and sand
	SAND; clean to some silt, clay, and gravel
	Gravelly SAND; clean to some silt and clay
	Silty SAND; up to some clay and gravel
	Clayey SAND; up to some silt and gravel
	SILT; up to some clay, sand, and gravel
	Gravelly SILT; up to some clay and sand
	Sandy SILT; up to some clay and gravel
	Clayey SILT; up to some sand and gravel
	CLAY; up to some silt, sand, and gravel
	Gravelly CLAY; up to some silt and sand
	Sandy CLAY; up to some silt and gravel
	Silty CLAY; up to some sand and gravel
	PEAT

BEDROCK SYMBOLS

Symbol	Typical Description
	BASALT
	MUDSTONE
	SILTSTONE
	SANDSTONE

SURFACE MATERIAL SYMBOLS

Symbol	Typical Description
	Asphalt concrete PAVEMENT
	Portland cement concrete PAVEMENT
	Crushed rock BASE COURSE

SAMPLER SYMBOLS

Symbol	Sampler Description
	2.0-in. O.D. split-spoon sampler and Standard Penetration Test with recovery (ASTM D1586)
	Shelby tube sampler with recovery (ASTM D1587)
	3.0-in. O.D. split-spoon sampler with recovery (ASTM D3550)
	Grab Sample
	Rock core sample interval
	Sonic core sample interval
	Geoprobe sample interval

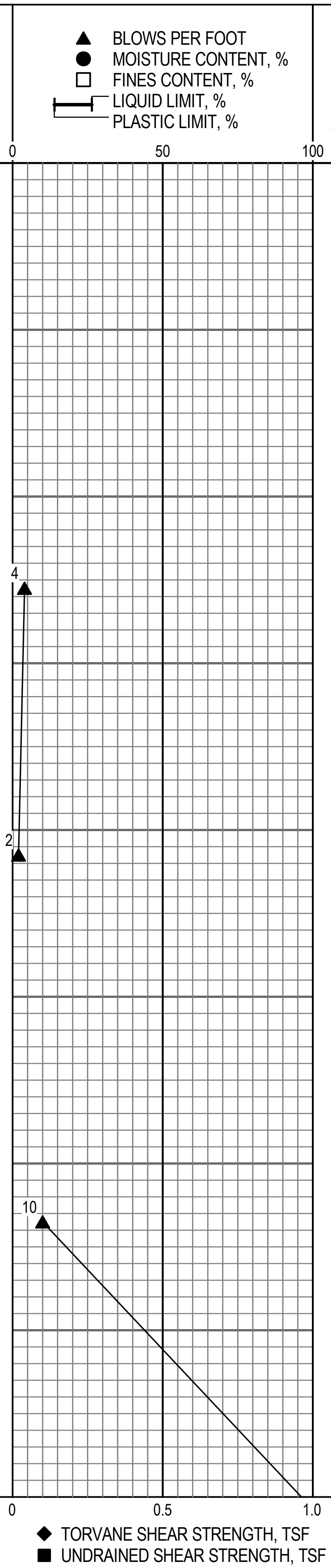
INSTALLATION SYMBOLS

Symbol	Symbol Description
	Flush-mount monument set in concrete
	Concrete, well casing shown where applicable
	Bentonite seal, well casing shown where applicable
	Filter pack, machine-slotted well casing shown where applicable
	Grout, vibrating-wire transducer cable shown where applicable
P	Vibrating-wire pressure transducer
	1-in.-diameter solid PVC
	1-in.-diameter hand-slotted PVC
	Grout, inclinometer casing shown where applicable

FIELD MEASUREMENTS

Symbol	Typical Description
▽	Groundwater level during drilling and date measured
▼	Groundwater level after drilling and date measured
	Rock core recovery (%)
	Rock quality designation (RQD, %)

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	COMMENTS AND ADDITIONAL TESTS
		Surface Elevation: Not Available						
		Asphalt concrete PAVEMENT (3 in.) over crushed rock BASE COURSE (10 in.)	1.1					
		SILT, some clay, trace to some fine-grained sand, trace gravel, gray, soft to medium stiff (Fill and Landslide Debris)						
10					S-1			
					S-2		3 2 2	
20		SILT, some fine-grained sand, trace clay, brown mottled rust, soft (Landslide Debris)	20.0		S-3		1 0 2	
30					S-4			
		Sandy SILT, trace to some clay and subangular to subrounded gravel, red brown, stiff, fine- to coarse-grained sand, gravel-sized fragments of basalt (Landslide Debris)	31.0		S-5		3 5 5	
35								Possible boulder between 34.5 and 39.5 ft Fluid loss of approximately 200 gallons between 35 and 80 ft
40								



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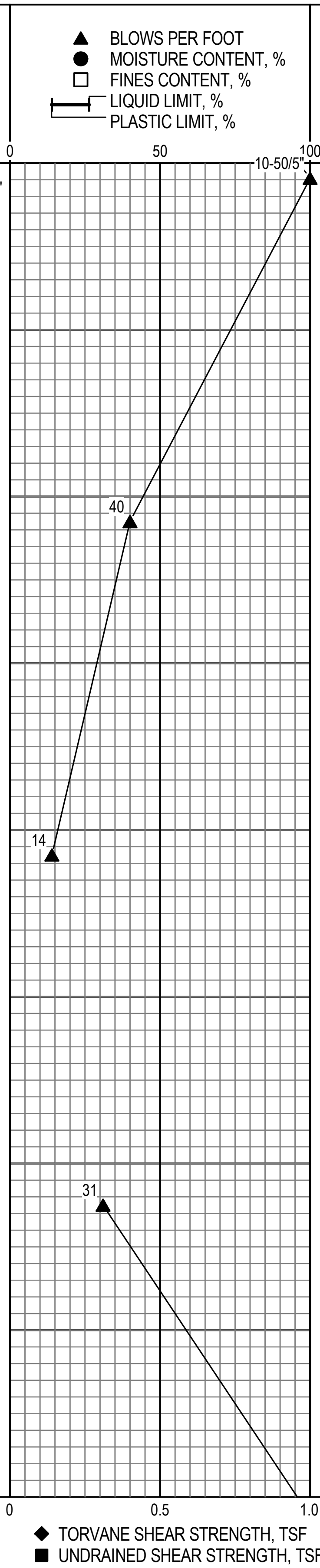
Logged By: T. O'Dell	**Drilled by:** Western States Soil Conservation, Inc.
Date Started: 6/12/17	**Coordinates:** Not Available
Drilling Method: Mud Rotary **Equipment:** CME 75 HT Truck-Mounted Drill Rig **Hole Diameter:** 5 in.	**Hammer Type:** Auto Hammer **Weight:** 140 lb **Drop:** 30 in. **Energy Ratio:** 0.8
Note: See Legend for Explanation of Symbols	

GRI

BORING B-2

JULY 2017 JOB NO. 4450-B FIG. 2

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL Surface Elevation: Not Available	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	COMMENTS AND ADDITIONAL TESTS
		BASALT, gray mottled rust, decomposed, extremely soft (R0) (Boring Lava / Landslide Debris)			S-6		10 50/5"	
45								
50		---contains gravel-sized fragments of soft to medium hard (R2 to R3) basalt below 50 ft			S-7		15 16 24	Caving observed at 52.5 ft
55								
60					S-8		19 10 4	
		SILTSTONE, brown mottled rust and black, decomposed, extremely soft (R0) (Troutdale Formation)	61.5		S-9			
65					S-10			
70		---gray, predominantly decomposed to decomposed below 70 ft			S-11			
				P	S-12		10 12 19	
75								
80								



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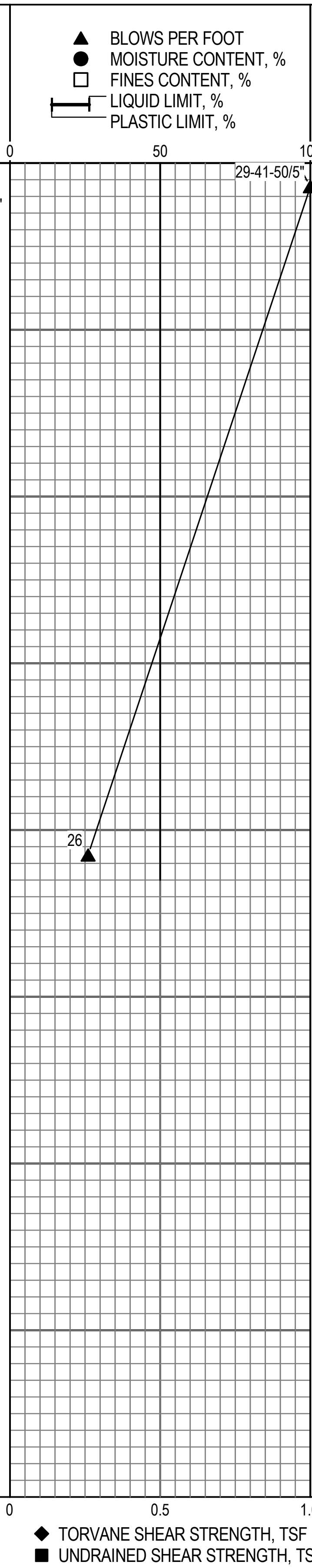
GRI BORING LOG (LAT/LONG) - NO ELEV GRI DATA TEMPLATE.GDT 10/6/17

GRI

BORING B-2

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL **Surface Elevation:** Not Available	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	COMMENTS AND ADDITIONAL TESTS
		SILTSTONE, gray, predominantly decomposed to decomposed, extremely soft (R0) (Troutdale Formation)			S-13		29 41 50/5"	
85								
90								
95								
100		MUDSTONE, gray mottled rust, decomposed, extremely soft (R0) (Troutdale Formation)	100.0		S-14		9 11 15	
		(6/13/2017)	101.5					
105								
110								
115								
120								



GRI BORING LOG (LAT/LONG) - NO ELEV GRI DATA TEMPLATE.GDT 10/6/17

GRI

BORING B-2

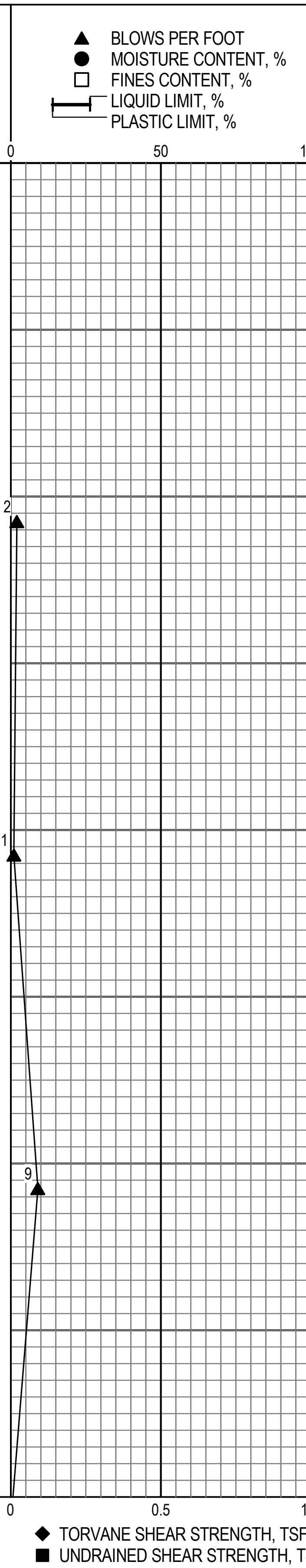
JULY 2017 JOB NO. 4450-B FIG. 2

BORING B-3

Surface Elevation: Not Available

Depth, ft	Classification of Material
0 – 1.1	Asphalt concrete PAVEMENT (3 in.) over crushed rock BASE COURSE (10 in.)
1.1 – 20.0	Sandy SILT, trace clay, brown, very soft to soft, fine- to medium-grained sand (Fill)
20.0 – 30.0	Sandy SILT, trace clay, brown mottled rust, very soft, contains 2- to 3-in.-thick layers of silty sand (Missoula Flood Deposits)
30.0 – 38.0	SILTSTONE, gray, decomposed, extremely soft (R0) (Troutdale Formation)
38.0 –	MUDSTONE, gray, decomposed, extremely soft (R0) (Troutdale Formation)

Sample No.	Blow Count	Blows per Foot
S-1	1, 1, 1	2
S-2	0, 0, 1	1
S-3	1, 4, 5	9



COMMENTS AND ADDITIONAL TESTS

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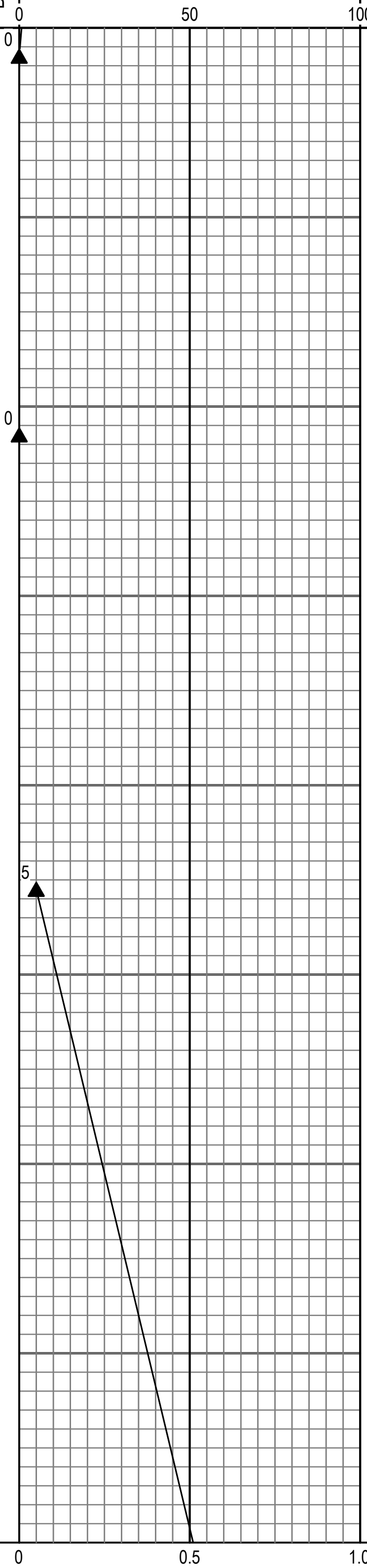
Logged By: T. O'Dell	**Drilled by:** Western States Soil Conservation, Inc.
Date Started: 6/16/17	**Coordinates:** Not Available
Drilling Method: Mud Rotary **Equipment:** CME 75 HT Truck-Mounted Drill Rig **Hole Diameter:** 5 in.	**Hammer Type:** Auto Hammer **Weight:** 140 lb **Drop:** 30 in. **Energy Ratio:** 0.8
Note: See Legend for Explanation of Symbols	

GRI

BORING B-3

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	COMMENTS AND ADDITIONAL TESTS
		Surface Elevation: Not Available						
		MUDSTONE, gray, decomposed, extremely soft (R0) (Troutdale Formation)			S-4		0 0 0	
45								
50		---light brown mottled rust below 50 ft		P	S-5		0 0 0	
55								
60		---blocky structure, contains wood debris at 61 ft			S-6			
					S-7		0 2 3	
65								
70								
75								
80								

▲ BLOWS PER FOOT
● MOISTURE CONTENT, %
□ FINES CONTENT, %
LIQUID LIMIT, %
PLASTIC LIMIT, %



◆ TORVANE SHEAR STRENGTH, TSF
■ UNDRAINED SHEAR STRENGTH, TSF

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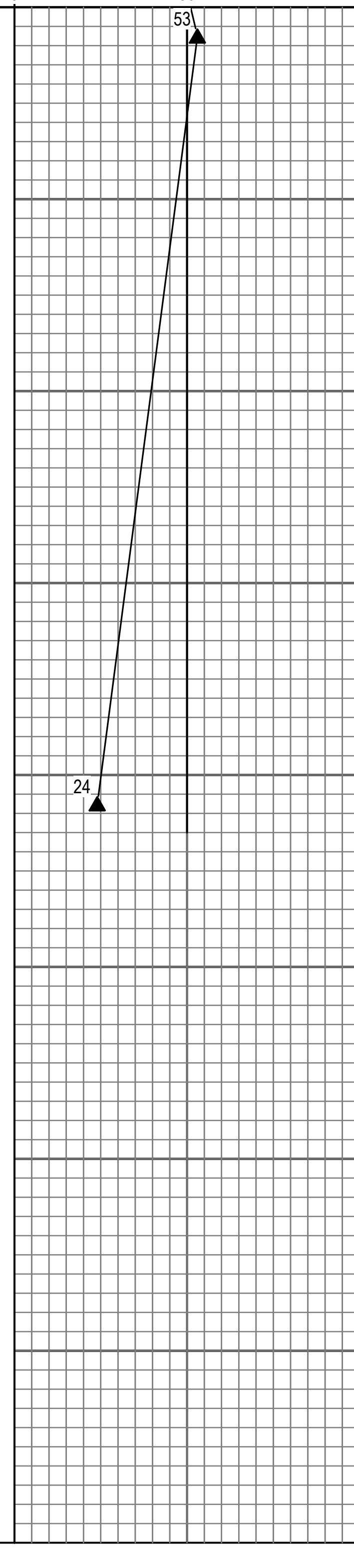
GRI

BORING B-3

JULY 2017 JOB NO. 4450-B FIG. 2A

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL **Surface Elevation:** Not Available	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	▲ BLOWS PER FOOT ● MOISTURE CONTENT, % □ FINES CONTENT, % LIQUID LIMIT, % PLASTIC LIMIT, % 0 50 100	COMMENTS AND ADDITIONAL TESTS
		MUDSTONE, blue-gray, predominantly decomposed to decomposed, extremely soft (R0), blocky structure (Troutdale Formation)			S-8		13 19 34	53	
85									
90									
95									
100		---light brown and rust below 100 ft			S-9		6 10 14	24	
		(6/19/2017)	101.5						
105									
110									
115									
120									



0 0.5 1.0

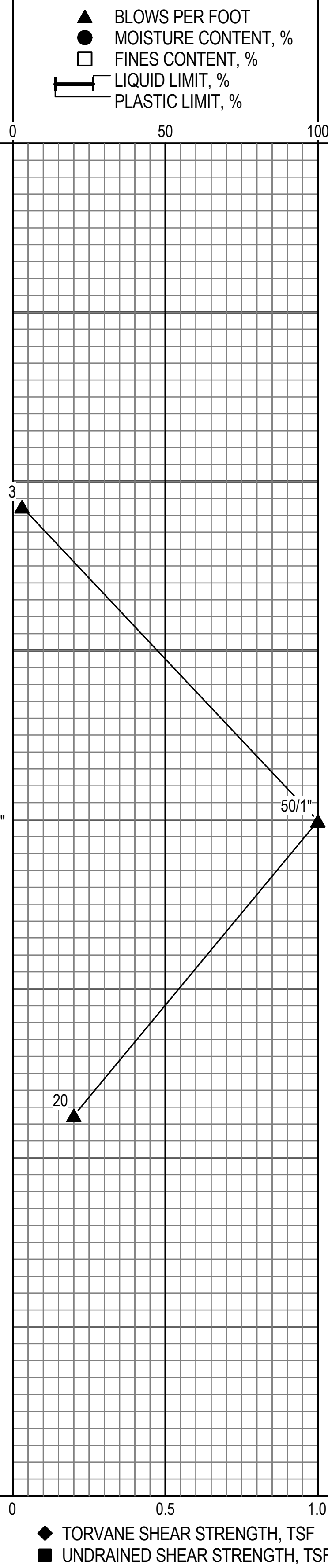
◆ TORVANE SHEAR STRENGTH, TSF
■ UNDRAINED SHEAR STRENGTH, TSF

GRI BORING LOG (LAT/LONG) - NO ELEV GRI DATA TEMPLATE.GDT 10/6/17

GRI

BORING B-3

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	COMMENTS AND ADDITIONAL TESTS
		Surface Elevation: Not Available						
		Asphalt concrete PAVEMENT (4 in.) over crushed rock BASE COURSE (8 in.)	1.0					Caving in upper 5 ft, cased to 6.5 ft
		GRAVEL and COBBLES (Crushed Rock Fill)	6.5					
		SILT, some clay, trace fine-grained sand, brown, soft (Missoula Flood Deposits)	20.0		S-1		0 1 2	
		BASALT, gray, predominantly decomposed, extremely soft to very soft (R0 to R1), contains cobbles and boulders (Boring Lava)			S-2		50/1"	
		---red-brown, decomposed, extremely soft below 26 ft						
		---6-in-thick layer of red-brown clay at 28.5 ft	35.0		S-3		5 6 14	
		SILTSTONE, red-brown, decomposed, extremely soft (R0) (Troutdale Formation)		P	S-4			



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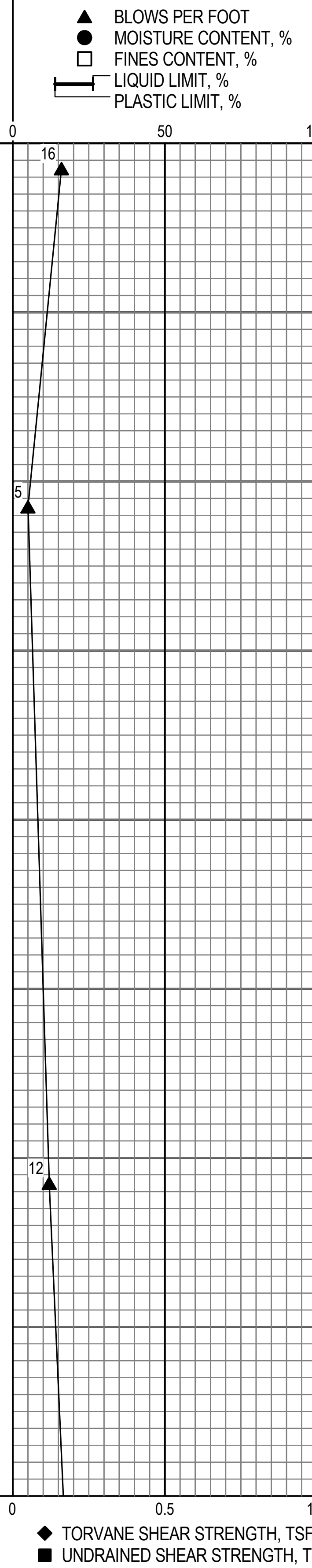
Note: See Legend for Explanation of Symbols	

GRI

BORING B-4

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	COMMENTS AND ADDITIONAL TESTS
		Surface Elevation: Not Available						
		MUDSTONE, light brown, predominantly decomposed to decomposed, extremely soft (R0) (Troutdale Formation)			S-5	I	4 9 7	
45								
50		---gray below 50 ft			S-6	I	0 2 3	
55								
60								
65								
70					S-7	I	3 5 7	
75								
80								



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GRI

BORING B-4

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	▲ BLOWS PER FOOT ● MOISTURE CONTENT, % □ FINES CONTENT, % LIQUID LIMIT, % PLASTIC LIMIT, % (0 – 50 – 100)	COMMENTS AND ADDITIONAL TESTS
		Surface Elevation: Not Available							
85–100		MUDSTONE, gray, predominantly decomposed to decomposed, extremely soft (R0) (Troutdale Formation)							
100		---blue-gray below 100 ft			S-8	I	9 11 16	27	
		(6/15/2017)	101.5						
105–120									

0 – 0.5 – 1.0

◆ TORVANE SHEAR STRENGTH, TSF

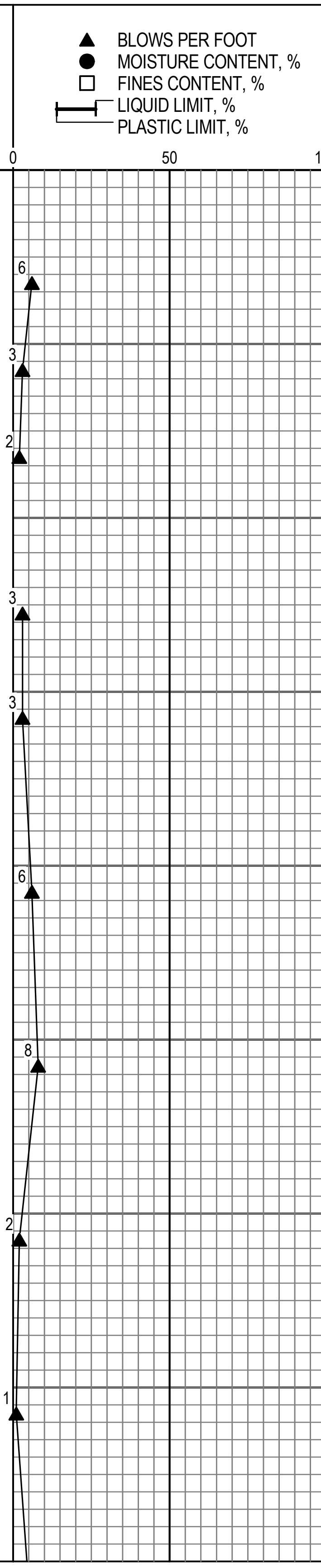
■ UNDRAINED SHEAR STRENGTH, TSF

BORING B-5

Surface Elevation: Not Available

DEPTH, FT	CLASSIFICATION OF MATERIAL	DEPTH, FT
0–1.0	Asphalt concrete PAVEMENT (4 in.) over crushed rock BASE COURSE (8 in.)	1.0
1.0–20.0	SILT, some clay to clayey, trace to some fine-grained sand, brown, medium stiff (Missoula Flood Deposits)	
5	---trace fine-grained sand, clay absent, soft below 5 ft	
12	---sandy, some clay, brown, fine-grained sand below 12 ft	20.0
20.0–40	Silty SAND, some clay, brown, loose, fine to coarse grained (Missoula Flood Deposits)	
25	---some silt to silty, trace clay, fine to medium grained below 25 ft	
30	---very loose below 30 ft	

SAMPLE NO.	BLOW COUNT	BLOWS PER FOOT
S-1	1 3 3	6
S-2	0 2 1	3
S-3	0 0 2	2
S-4		
S-5	0 1 2	3
S-6	1 1 2	3
S-7	2 3 3	6
S-8	3 3 5	8
S-9	0 1 1	2
S-10	0 0 1	1



COMMENTS AND ADDITIONAL TESTS

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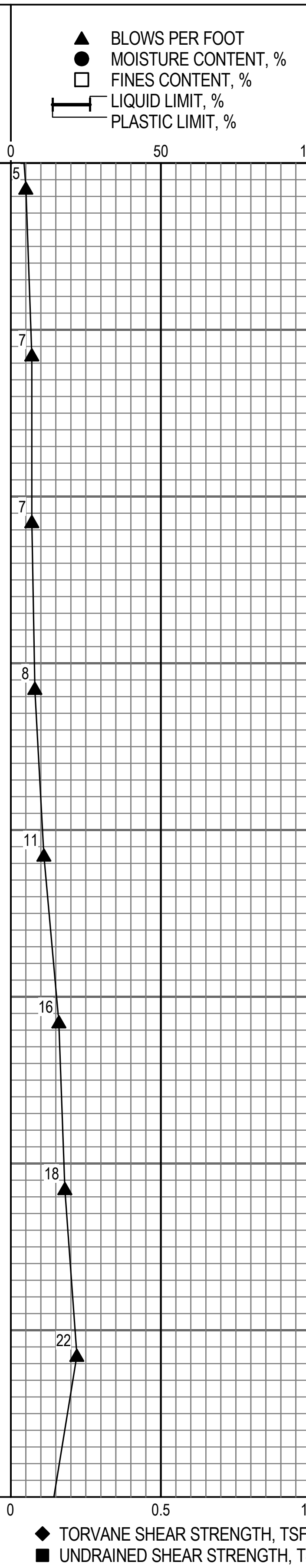
Logged By: T. O'Dell	**Drilled by:** Western States Soil Conservation, Inc.
Date Started: 6/13/17	**Coordinates:** Not Available
Drilling Method: Mud Rotary **Equipment:** CME 75 HT Truck-Mounted Drill Rig **Hole Diameter:** 5 in.	**Hammer Type:** Auto Hammer **Weight:** 140 lb **Drop:** 30 in. **Energy Ratio:** 0.8
Note: See Legend for Explanation of Symbols	

GRI

BORING B-5

DEPTH, FT	CLASSIFICATION OF MATERIAL	DEPTH, FT	SAMPLE NO.	BLOW COUNT	BLOWS PER FOOT	COMMENTS AND ADDITIONAL TESTS
	Surface Elevation: Not Available					
	Clayey SILT, some fine- to coarse-grained sand, brown, medium stiff		S-11	1 2 3	5	
45	MUDSTONE, gray, decomposed, extremely soft (R0) (Troutdale Formation)	45.0	S-12	1 3 4	7	
50			S-13	0 3 4	7	
55	---dark gray, blocky texture below 55 ft		S-14	2 4 4	8	
60			S-15	3 4 7	11	
65	---blue-gray below 65 ft		S-16	3 6 10	16	
70	---yellow-brown laminated rust below 70 ft		S-17	5 8 10	18	
75			S-18	8 10 12	22	
80						



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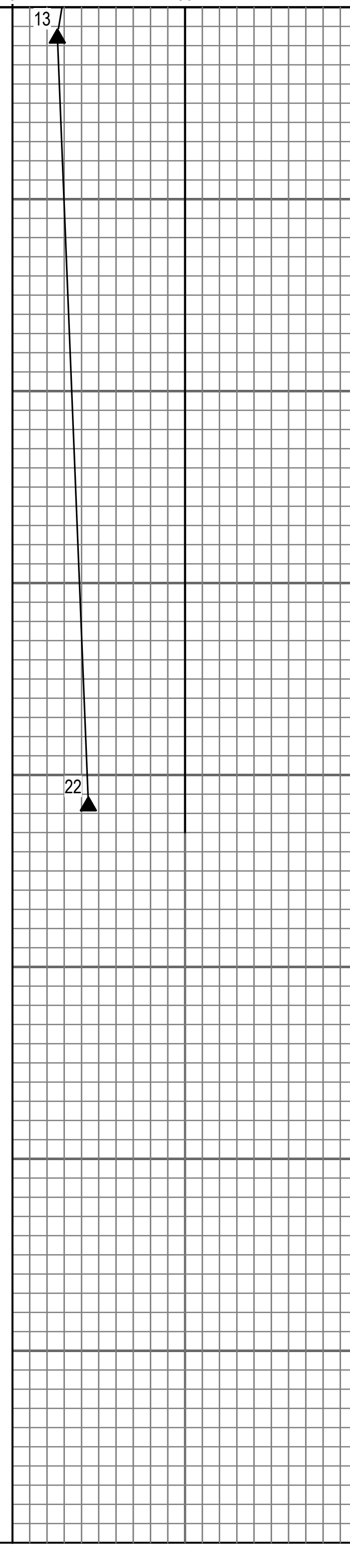
GRI

BORING B-5

DEPTH, FT	GRAPHIC LOG	CLASSIFICATION OF MATERIAL	DEPTH, FT	INSTALLATION	SAMPLE NO.	SAMPLE TYPE	BLOW COUNT	▲ BLOWS PER FOOT ● MOISTURE CONTENT, % □ FINES CONTENT, % LIQUID LIMIT, % PLASTIC LIMIT, %	COMMENTS AND ADDITIONAL TESTS
		Surface Elevation: Not Available						0 50 100	
		MUDSTONE, light brown mottled rust, decomposed, extremely soft (R0) (Troutdale Formation)			S-19		7 6 7	13	
85									
90									
95									
100		---gray below 100 ft			S-20		6 9 13	22	
		(6/14/2017)	101.5						
105									
110									
115									
120								0 0.5 1.0	



◆ TORVANE SHEAR STRENGTH, TSF
■ UNDRAINED SHEAR STRENGTH, TSF

GRI

BORING B-5