RH2 ENGINEERING
PORTLAND
5335 Meadows Road, Suite 420
Lake Oswego, OR 97035
1.800.720.8052 / rh2.com

May 31, 2019

Mr. John Burrell
Project Manager
City of Oregon City – Public Works
625 Center Street
Oregon City, OR 97045

Sent via: Email

Subject: Trillium Park Drive Landslide Mitigation Alternatives Analysis

Dear Mr. Burrell:

This letter summarizes the results of the alternatives analysis for mitigation of the slow-moving landslide occurring on Trillium Park Drive and for addressing utilities affected by the slide.

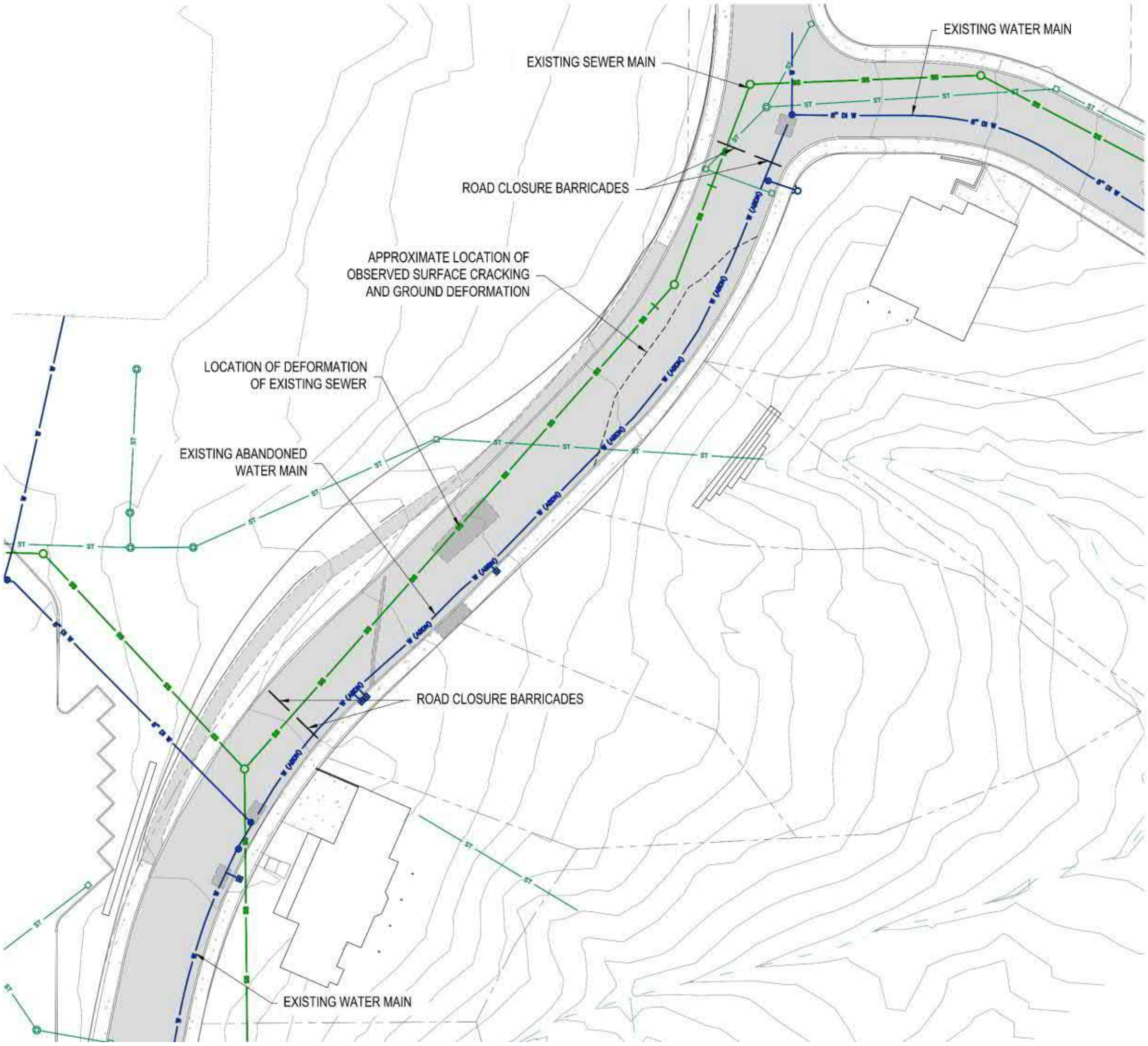
BACKGROUND

Trillium Park Drive, a two-lane local street, has been experiencing a slow-moving landslide since its construction in 1998. In 2006, the City of Oregon City (City) contracted with Geotechnical Resources, Inc., (GRI) and Compass Land Surveyors (Compass) to monitor the slide and measure its movement. GRI installed monitoring wells with inclinometers at multiple locations, and Compass surveyed the movement of Trillium Park Drive relative to fixed monuments. In February 2017, following a period of heavy rainfall, Trillium Park Drive experienced significant earth movement that led to a waterline separation, and movement and deformation of a sewer line. The waterline within the slide zone was abandoned, but the sewer remains in service. Other utilities within the slide zone, including power and gas, have been rerouted, and the street has been closed to vehicular traffic (**Figure 1**). The City requested that RH2 Engineering, Inc., (RH2), with assistance from GRI, develop and evaluate alternatives and conceptual designs for stabilizing the landslide and restoring or permanently abandoning the road and utilities in Trillium Park Drive.

WASHINGTON LOCATIONS
Bellingham
Bothell (Corporate)
East Wenatchee
Issaquah
Richland
Tacoma

OREGON LOCATIONS
Medford
Portland

Figure 1 – Existing Site Conditions



ALTERNATIVES DEVELOPMENT

The issues and questions surrounding the Trillium Park Drive landslide mitigation are multi-faceted and complex. As discussed in GRI's Geotechnical Services Report, included as **Attachment 1**, it appears that construction of Trillium Park Drive resulted in the placement of a significant amount of fill material over the deposits of an ancient landslide. In 1999, shortly after the road was constructed, a landslide occurred on the east-facing slope along Trillium Park Drive between Canyon Court and Swordfern Court. In February 2017, this landslide was reactivated following a period of heavy precipitation, resulting in damage to the City's waterline and the closure of the roadway section within the slide area. Since that time, additional ground movement has occurred that has resulted in damage to the City's gravity sewer line.

As discussed in RH2's scope of work, the intent of the Trillium Park Drive Landslide Mitigation Alternatives Analysis was to develop and evaluate conceptual level design alternatives for restoring or abandoning the road and utilities based on the landslide mitigation options developed by GRI. The following landslide mitigation options were identified in GRI's earlier work with the City: 1) abandon the road and monitor the landslide (do nothing option); 2) construct a tied-back soldier-pile retaining wall; 3) regrade the slope; and 4) improve drainage. Based on these options, the following conceptual design alternatives were initially identified for evaluation: 1) construct a tie-back wall to stabilize the road and restore road and utility service; 2) abandon the road in place and reroute utilities; 3) abandon the road by regrading and removing soil overburden, and reroute utilities and pedestrian access; 4) install drainage improvements to stabilize the slope and restore and/or abandon the road; or 5) combinations thereof. In addition, during the alternatives analysis, the City also requested that additional alternatives be considered that utilize lightweight fill material within the slide zone area in lieu of the existing soil fill material.

At the core of the alternatives development and evaluation are the following goals:

1) Identify and evaluate alternatives for stabilizing the landslide and/or mitigating the risk of future slides.
2) Identify and evaluate alternatives that will remedy the ongoing maintenance and repair costs associated with the failing gravity sewer caused by the landslide, and if possible, restore water service through the slide zone.
3) Identify and evaluate alternatives for restoring vehicular traffic and/or maintaining pedestrian access through the slide zone.
4) Considering the above, determine the combination of geotechnical and utility alternatives that will result in a total solution that will strike an acceptable balance between project cost, risk mitigation, road and utility level of service, and public acceptance for the City.

Five distinct geotechnical solutions have been developed to address goals 1 and 3, and five distinct utility solutions have been developed to address goal 2. These geotechnical and utility solutions have then been combined to develop seven distinct project alternatives that can be evaluated against goal 4.

Each of the geotechnical alternatives can be separated into two basic categories depending on whether the alternative ultimately results in the restoration or abandonment of Trillium Park Drive to vehicular traffic. In both cases, it should be presumed that a pathway for pedestrian traffic would be maintained. Whether vehicular traffic can be restored to Trillium Park Drive and the manner in which it is restored will affect its effective level of service. An evaluation of each of the alternative's effective level of service as a roadway, as well as its level of landslide risk mitigation, is provided in the **Evaluation Criteria and Scoring** section.

Likewise, the geotechnical approach used to stabilize the slide area also affects the options available for restoring utility services through the area, which in turn directly effects the level of service of the City's utilities. An evaluation of each of the utility alternative's effective level of service is provided in the **Evaluation Criteria and Scoring** section.

For organizational purposes, the following schema was used in numbering the alternatives. In general, alternatives are numbered using an X.Y.Z format, where:

- X = Base Alternative for Roadway Restoration
    - 1 = Roadway will be Abandoned to Vehicular Traffic
    - 2 = Roadway will be Restored to Vehicular Traffic
- Y = Geotechnical Alternative to Mitigate Landslide
    - 0 = Do Nothing (De-Pave Road and Monitor Landslide)
    - 1 = Excavate Overburden and Install Drainage Improvements
    - 2 = Construct Tie-back Wall to Support Road and Utilities
    - 3 = Reconstruct Road using Geofoam
    - 4 = Reconstruct Road using Cellular Concrete
- Z = Utility Alternative to Mitigate Sewer and Water Service
    - 0 = Do Nothing
    - 1 = Reconstruct Sewer in Place
    - 2 = Re-Route Sewer via Open-Cut
    - 3 = Re-Route Sewer via Horizontal Directional Drill
    - 4 = Re-Route Sewer via Lift Station and Force Main
    - 5 = Reconstruct Sewer and Water in Place

While multiple combinations of geotechnical and utility alternatives were considered, many alternatives were eliminated quickly from further development and evaluation due to the apparent high cost of construction, concerns regarding constructability, or inability to meet stated project goals. The following are the notable alternatives that were eliminated:

- Alternative 1.0.0 – Abandon road, do nothing to mitigate landslide, do nothing to mitigate sewer or water service. This alternative was not considered for further development as it would not achieve any of the project goals.
- Alternative 1.1.2 – Abandon road, excavate overburden, install drainage improvements and re-route sewer via open-cut. This alternative was developed to a conceptual level, but ultimately was eliminated from further analysis due to significant concerns regarding constructability and risk associated with the depth of excavation required for the open-cut sewer installation adjacent to an active slide zone.

The following are the seven alternatives that were developed for evaluation and are presented herein.

- Alternative 1.0.3 – Abandon and de-pave road, monitor slide, and re-route sewer via horizontal directional drilling.
- Alternative 1.1.1 – Abandon road, excavate overburden, install drainage improvements, and reconstruct sewer in place.
- Alternative 1.1.3 – Abandon road, excavate overburden, install drainage improvements, and re-route sewer via horizontal directional drill.
- Alternative 1.1.4 – Abandon road, excavate overburden, install drainage improvements, and re-route sewer via lift station and force main.

- Alternative 2.2.5 – Construct tie-back wall, restore road, and reconstruct sewer and water utilities in place.
- Alternative 2.3.3 – Reconstruct road as one-way multimodal road using geofoam and re-route sewer via horizontal directional drilling.
- Alternative 2.4.5 – Reconstruct road with lightweight cellular concrete and reconstruct sewer and water utilities in place.

Descriptions and conceptual level design figures, and planning-level opinions of probable construction costs for each of the alternatives are provided in **Attachment 2** and **Attachment 3**, respectively.

EVALUATION CRITERIA AND SCORING

The alternatives were evaluated and scored based on the following criteria:

- Landslide risk mitigation;
- Utility level of service;
- Roadway level of service; and
- Capital improvement cost.

As previously stated, the seven alternatives developed for evaluation are combinations of various roadway, geotechnical, and utility approaches, each with their own advantages and disadvantages. To help facilitate evaluation and comparison of each alternative, points have been assigned for how well the various approaches address the stated project goals, where the highest number of points represents the most desirable or advantageous approach.

Landslide Risk Mitigation

The five geotechnical alternatives previously described were modeled using slope stability analysis software to determine the risk of further landslide events. This risk is based on the alternative's Factor of Safety (FS), which is calculated as a ratio of forces resisting slope movement to forces driving slope movement. As such, a factor of safety of 1.0 indicates approximate force equilibrium and marginal stability of the slope. Further, a factor of safety larger than 1.0 indicates that resisting forces exceed driving forces, while a slope with a factor of safety less than 1.0 indicates that driving forces exceed resisting forces. Further information regarding the slope stability modeling and analysis can be found in GRI's Geotechnical Services report provided as **Attachment 1**.

Table 1 summarizes the results of the slope stability modeling results and provides scoring for each of the geotechnical approaches for mitigating the landslide risk. Alternatives were scored based on the FS yielded for the alternative by the limit equilibrium stability analysis. Alternatives that resulted in a FS less than or equal to 1.0, indicating no or only marginal improvement over the base condition, were assigned 0 points; alternatives that resulted in a FS between 1.0 and 1.2 were assigned 1 point indicating a 20-percent improvement in slope stability; and alternatives with a FS greater than 1.2 were assigned a score of 2.

Table 1
Landslide Mitigation Factors of Safety

Geotechnical Alternative Description	Factor of Safety (FS)	Evaluation Score
De-pave roadway (do not mitigate landslide)	1.0	0
Excavate overburden and install drainage improvements	1.2	1
Restore roadway with geofoam blocks	1.2	1
Restore roadway with lightweight concrete fill	1.2	1
Restore roadway with tie-back wall	1.4	2

As shown in **Table 1**, stabilizing the slope with a tie-back wall is the most conservative geotechnical approach and has the highest FS of 1.4; therefore, it has been given the highest score of 2 points. On the other hand, abandoning and depaving the road, which has a FS of 1.0, has been given 0 points, as it has little effect on improving slope stability. Each of the other geotechnical alternatives yielded a FS of 1.2 and were assigned a score of 1 point.

Utility Level of Service

Table 2 summarizes the various utility mitigation approaches and provides scoring for each. Alternatives were scored based on the following factors: 1) gravity versus pressure sewer, where gravity was preferred; 2) easement versus right-of-way (ROW) construction, where ROW was preferred; and 3) the ability to restore both sewer and water utility service, where restoring both was preferred.

Table 2
Utility Restoration Level of Service

Utility Alternative Description	Evaluation Score
Lift Station and Force Main	1
Gravity Sewer, Easement Required	2
Gravity Sewer, No Easement Required	3
Gravity Sewer and Water Main, No Easement Required	4

As shown in **Table 2**, alternatives that involve reconstructing both the gravity sewer and water utilities in their original ROW alignments have been given the highest score of 4 points. Alternatives that allow the gravity sewer to be reconstructed in its original alignment have been assigned a score of 3 points, as this approach keeps the sewer in the ROW, providing easier access for maintenance and not requiring easement acquisition. Rerouting the sewer to the west of Trillium Park Drive and outside of the landslide zone using horizontal directional drilling has been assigned a score of 2 points, as this approach would require an easement acquisition and creates moderate maintenance issues. Finally, alternatives that required rerouting the sewer via a lift station and force main have been assigned the lowest score of 1 point, as this approach introduces significant ongoing operations and maintenance costs that are indicative of pressure sewer applications and not applicable to gravity sewer.

Roadway Level of Service

As previously discussed, there are two base alternatives for dealing with the roadway. The first is to abandon the roadway, by either removing it as part of the excavation of the overburden to address the landslide mitigation issue or by de-paving the roadway (which results in no landslide mitigation). The second is to restore the roadway by either constructing a tie-back wall or reconstructing the roadway with either geofoam blocks or lightweight cellular concrete. Depending on the alternative selected, the City also may wish to consider whether the road should be restored to allow for full, two-way access or limited, one-way access. **Table 3** summarizes the various approaches for roadway abandonment or restoration and provides their scoring.

Table 3
Roadway Level of Service

Roadway Alternative Description	Evaluation Score
Abandon Road and Remove Overburden	1
Abandon Roadway and De-Pave	2
Restore as One-Way Multimodal Road	3
Restore as Two-Way Road	4

As can be seen in **Table 3**, alternatives that allow the City to fully restore the road and support two-way vehicular travel were assigned the highest score of 4 points. Alternatives that allow the road to be restored as a one-way, multimodal road received a score of 3 points, as these alternative would still provide the basic level of service required of a low-volume residential road. Abandoning the road by removing the asphalt pavement received a score of 2 points, as it would still allow an easy pathway for pedestrian traffic. The lowest score of 1 point was assigned to alternatives that require the complete abandonment of the roadway and removal of the overburden fill material, which would result in steep slopes at pedestrian paths that could limit the accessibility of the pathway.

Capital Improvement Cost

A planning-level opinion of probable construction cost estimate has been developed for each geotechnical and utility alternative and are provided as **Attachment 3** of this letter report. These estimates are based on the conceptual level designs for the combined alternatives provided as **Attachment 2**. As these designs are conceptual in nature and subject to change as design progresses, the estimated costs were increased by a contingency amount. A 50-percent contingency was applied to the geotechnical cost estimates due to the higher level of risk and complexity associated with the landslide mitigation, whereas a more traditional 30-precent contingency was applied to the utility cost estimates. Alternatives were scored based on the combined construction cost (presented in **Table 4** as Total Estimated Direct Cost) and a 30-percent markup was added to account for indirect project costs including administration, engineering, permitting, bidding, and construction inspection (presented in **Table 5** as Total Estimated Indirect Cost). Alternatives with construction costs less than $1,000,000 were assigned the highest score of 3 points; alternatives that are over $1,000,000, but less than $1,500,000, were assigned a score of 2 points; and alternatives that are over $1,500,000 were assigned a score of 1 point. A summary of the estimated geotechnical and utility, and the scoring for each of the alternatives is shown in **Table 4**.

Table 4
Estimated Construction Cost Summary and Scoring

Alternative	Description	Geotechnical Construction Cost	Utility Construction Cost	Total Estimated Direct Cost	Evaluation Score
Alternative 1.0.3	Abandon and de-pave road. Re-route sewer via HDD.	$230,000	$270,000	$500,000	3
Alternative 1.1.1	Abandon road, excavate overburden, install drainage and reconstruct sewer in place.	$760,000	$150,000	$910,000	3
Alternative 1.1.3	Abandon road, excavate overburden, install drainage and re- route sewer via HDD.	$760,000	$270,000	$1,030,000	2
Alternative 1.1.4	Abandon road, excavate overburden, install drainage and re- route sewer via lift station.	$760,000	$1,010,000	$1,770,000	1
Alternative 2.2.5	Construct tie-back wall, restore road, and reconstruct sewer and water in place.	$2,130,000	$190,000	$2,320,000	1
Alternative 2.3.3	Reconstruct road as one-way multimodal road with Geofoam and re-route sewer via HDD.	$680,000	$270,000	$950,000	3
Alternative 2.4.5	Reconstruct road with cellular concrete and reconstruct sewer and water in place.	$1,540,000	$190,000	$1,730,000	1

Table 5
Estimated Capital Improvement Cost

Alternative	Total Estimated Direct Cost	Total Estimated Indirect Cost*	Total Estimated Project Cost
Alternative 1.0.3	$500,000	$150,000	$650,000
Alternative 1.1.1	$910,000	$273,000	$1,183,000
Alternative 1.1.3	$1,030,000	$309,000	$1,339,000
Alternative 1.1.4	$1,770,000	$531,000	$2,301,000
Alternative 2.2.5	$2,320,000	$696,000	$3,016,000
Alternative 2.3.3	$950,000	$285,000	$1,235,000
Alternative 2.4.5	$1,730,000	$519,000	$2,249,000

*Total indirect cost is estimated to be 30% of total direct cost.

ALTERNATIVES ANALYSIS

An evaluation matrix was developed to present and summarize the score and ranking of each alternative and is shown in **Table 6**. A sensitivity analysis also was performed to evaluate the effect that weighting of certain criteria based on City values could have on the ranking of the alternatives. Results from the alternatives and sensitivity analyses are included in **Attachment 4** for reference.

The evaluation matrix includes individual weighting for different criteria and allows the City to conduct a sensitivity analysis by adjusting the weighting factor of criteria depending on the goals and values of the City. For example, while the City may desire a solution that addresses each of the three primary goals listed in this letter report, it may place a higher value on solutions that achieve this at a lower capital cost and with a greater factor of safety for landslide risk mitigation, in which case the weighting factor would be increased for those criteria. By varying the weighting factors applied to different evaluation criteria, it also reveals that certain alternatives are much more advantageous across all the criteria, whereas others are not.

When no weighting factors are applied to the evaluation criteria (i.e., all criteria are equally weighted), the following are the top ranked alternatives:

1. Alternative 2.2.5.
2. Alternative 2.3.3 and Alternative 2.4.5 (tied).

When a weighting factor of 2 is applied to the capital improvement cost evaluation criteria, the top ranked alternatives are:

1. Alternative 2.3.3;
2. Alternative 2.2.5; and
3. Alternative 2.4.5 and Alternative 1.1.1 (tied).

When a weighting factor of 2 is applied to the landslide risk mitigation evaluation criteria, the top ranked alternatives are:

1. Alternative 2.2.5;
2. Alternative 2.3.3 and Alternative 2.4.5 (tied);

When a weighting factor of 2 is applied to the utility level of service evaluation criteria, the top ranked alternatives are:

1. Alternative 2.2.5;
2. Alternative 2.4.5; and
3. Alternative 2.3.3.

When a weighting factor of 2 is applied to the roadway level of service evaluation criteria, the top ranked alternatives are:

1. Alternative 2.2.5;
2. Alternative 2.4.5; and
3. Alternative 2.3.3.

Table 6
Evaluation Matrix

CRITERIA	POINTS	Alternative 1.0.3	Alternative 1.1.1	Alternative 1.1.3	Alternative 1.1.4	Alternative 2.2.5	Alternative 2.3.3	Alternative 2.4.5
Capital Improvement Cost								
Weighting Factor	2							
Over $1,500,0000	1				1	1		1
Over $1,000,0000	2							
Less than $1,000,0000	3	3	3	3			3	
Landslide Risk Mitigation								
Weighting Factor	2							
FS <= 1.0	0	0						
FS <= 1.2	1		1	1	1		1	1
FS > 1.2	2					2		
Utility Level of Service								
Weighting Factor	1							
Sewer Lift Station and Force Main	1				1			
Gravity Sewer, Easement Required	2	2		2				
Gravity Sewer, No Easement	3		3				3	
Gravity Sewer and Water Main, No Easement	4					4		4
Roadway Level of Service								
Weighting Factor	1							
Abandon Roadway and Remove Overburden	1		1	1	1			
Abandon Roadway and Depave	2	2						
Restore as One-Way Multi-modal Road	3						3	
Restore as Two-Way Road	4					4		4
TOTAL UNWEIGHTED SCORE	13	7	8	7	4	11	10	10
TOTAL WEIGHTED SCORE	18	10	12	11	6	14	14	12
PRIORITY RANKING		**6**	**3**	**5**	**7**	**1**	**1**	**3**

From evaluating the results of the sensitivity analysis, it becomes clear that Alternatives 2.2.5, 2.3.3, and 2.4.5 are consistently among the top ranked alternatives. This is a result of the fact that these alternatives provide a geotechnical mitigation approach that would allow for higher utility and roadway levels of service than the other alternatives. Alternative 2.2.5 (tieback wall alternative) provides the most traditional approach and highest degree of landslide risk mitigation, but it is also the highest cost alternative. Alternatives 2.3.3 and 2.4.5 (lightweight fill alternatives) are equal in landslide risk mitigation but scored slightly different in the other criteria. This is primarily the result of the way that these two alternatives were defined. While only one road restoration option is presented above for each of the two lightweight fill alternatives (i.e. two-lane road with geofoam or one-lane multimodal road with cellular concrete), both road configurations could be achieved with either of the lightweight fill options. Therefore, for the purposes of this analysis, Alternatives 2.3.3 and 2.4.5 are generally considered equal, and the decision of which lightweight fill is used should be determined in the design and based on the City's road and utility service goals. For example, while geofoam is a good geotechnical option, it does complicate the construction and maintenance of utilities in the roadway.

The least desirable alternative analyzed was Alternative 1.1.4, which involved mitigating for landslide risk by excavating the overburden materials, abandoning the road, and rerouting the sewer via a lift station. This was the second most costly alternative and offered little advantages in comparison to the other alternatives.

Of the alternatives analyzed where the road would be abandoned, Alternative 1.1.1 fared the best. It provided a higher level of service at a significantly lower cost than the other road abandonment alternatives.

Although Alternative 1.0.3 was the least costly alternative, it provided few benefits. While it would have the sewer relocated and service restored, it would not have addressed the landslide risk and would have resulted in an abandoned road.

CONCLUSION

In selecting the preferred alternative to move forward into design, the City will need to consider what (if any) criteria is of higher value. Of the four criteria, risk mitigation and capital cost are objective criteria where the value is fairly easy to quantify and assess. On the other hand, utility and roadway level of service are more subjective criteria where the value can be more heavily influenced based on the viewpoint or goals of a particular stakeholder group. That said, if it is assumed that both capital cost and risk mitigation are of equal weight and are ranked higher than the other criteria, Alternative 2.3.3, which includes utilizing lightweight fill to restore a one-way multimodal road, appears to provide the best balance of the overall criteria.

It has been a pleasure assisting the City with this evaluation. If you have any questions regarding the analysis or conclusions presented herein, please contact myself at (503) 446-2816 or via email at kpettibone@rh2.com, or Justin Barrow at (503) 446-2911 or via email at jbarrow@rh2.com. Thank you for the opportunity to assist you with this project.

Sincerely,

Justin Burrow, PE

Project Engineer

Kyle Pettibone

Kyle Pettibone, PE

Principal

KMP/JRB/sp/ms/ge

Attachments:

Attachment 1 – Geotechnical Services Report
Attachment 2 – Alternatives Descriptions and Figures
Attachment 3 – Opinions of Probable Construction Cost
Attachment 4 – Alternatives Evaluation and Sensitivity Analysis

Attachment 1
Geotechnical Services Report

THIS PAGE INTENTIONALLY LEFT BLANK

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

May 31, 2019 6082 GEOTECHNICAL RPT

RH2 Engineering
6500 SW Macadam Avenue
Portland, OR 97239

Attention: Kyle Pettibone

SUBJECT: Geotechnical Services Report
Trillium Park Drive Landslide Mitigation Alternatives Analysis
Oregon City, Oregon

As requested, GRI prepared this report summarizing engineering related to 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 Vicinity Map, Figure 1, and Site Plan, Figure 2. The landslide extends into the paved area, and the roadway is closed to vehicle traffic.

The purpose of our services is to assist RH2 Engineering (RH2) and the City of Oregon City (City) with evaluating long-term stability considerations and landslide-mitigation options to maintain an operational sanitary-sewer utility located in the roadway. The overall project goal is to develop a landslide-mitigation alternative that will reduce the risk of future landslide movement and therefore reduce the risk of future damage to the sanitary sewer. This report summarizes the results of our engineering studies and alternatives analysis.

PROJECT AND SITE DESCRIPTION

Background

The site is located within the Newell Creek drainage area of Oregon City. 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 utility damage within Trillium Park Drive. At present, the City has closed Trillium Park Drive between Swordfern Court and Canyon Court. GRI installed monitoring equipment within the landslide in June 2017, and no measurable slope movement occurred between installation and May 2018.

The sanitary sewer generally is located near the centerline of Trillium Park Drive. Based on topographic information provided by RH2, the invert depth near the landslide ranges from about 15 ft below grade on the south near the residence at the 17346 address to about 12 ft below grade near Canyon Court on the north. As shown on the Site Plan, Figure 2, an approximate 150-ft reach of sewer is located within the landslide area.

Surface Conditions and Topography

The ground surface in the area of the landslide slopes down to the east 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 Vicinity Map, Figure 1, and Site Plan, 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 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. Near 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 (Evarts et al., 2009). The generally weak to moderately strong Troutdale Formation is very prone to landslides 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 Highway OR213 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.

A review of existing subsurface information indicates the subsurface conditions at the site generally consist of asphalt concrete (AC) pavement, fill materials, landslide debris, gravel, decomposed to fresh sedimentary rock (mudstone, siltstone, sandstone), and basalt. A summary of soil and groundwater conditions encountered at the site are discussed in the subsequent sections of this report.

SUBSURFACE CONDITIONS

General

Subsurface materials and conditions at the inclinometer locations were investigated by GRI during two separate mobilizations: the first on September 20 and 21, 2006, with one drilled boring, designated B-1, and the second 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 Vicinity Map, Figure 1. The field work was coordinated and documented by a member of GRI's geotechnical staff, who maintained a log of the materials and conditions disclosed during the work. For the purposes of this alternatives analysis, GRI focused on the conditions disclosed by borings B-1 and B-2 for the evaluation of the landslide-mitigation alternatives since they are located within the documented landslide area.

Soil, Rock, and Landslide Debris

The soil and rock units disclosed in B-1 during our September 2006 investigation and in B-2 during our June 2017 investigation are generally consistent with previous work completed by GRI in the area and our understanding of the local geology. At these locations, landslide debris consisting of fill, Willamette Silt, and residual Boring Lava basalt extends to depths of about 61 to 62 ft. The landslide debris is underlain by extremely soft, decomposed mudstone and siltstone of the Troutdale Formation. The siltstone and mudstone extend to the maximum depth explored of 101.5 ft. Logs of borings B-1 and B-2 are included on Figures 3 and 4. The terms used to describe the soil and rock units are provided in Tables 1 and 2.

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 or residual soils that mantle the site, particularly during the wet winter and spring months or 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 35 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 a vibrating-wire piezometer installed in boring B-2 measured perched groundwater at depths ranging from approximately 12 to 16 ft below the existing ground surface between July 2017 and September 2017.

Sewer Line Relocation

As part of our geotechnical evaluation, GRI reviewed the proposed sewer realignments for the existing sanitary-sewer line. Based on our review of the available preliminary documents provided by RH2 on October 17, 2018, we understand three alternatives are being considered for the relocation of the existing sewer line, numbered 1.1.1 through 1.1.3. The alternatives include abandoning the existing road and relocating the sewer line utilizing open-cut or horizontal-directional drill (HDD) methods or rerouting the sewer line and constructing a lift station. We understand these alternatives would apply to either a road removal and regrading alternative (with drainage improvements) or an alternative that would include abandoning the roadway. With a soldier-pile-wall alternative, we understand the sewer and other utilities would likely be restored in their original alignments.

CONCLUSIONS AND RECOMMENDATIONS

General

The project goal is to develop a landslide-mitigation alternative that will reduce the risk of future landslide movement and therefore reduce the risk of future damage to the sanitary sewer. As part of the modeling effort, GRI evaluated the existing condition of the slope based on available topographic information. A stability analysis of the existing condition was completed for static conditions using the limit-equilibrium program SLIDE v. 8.0 developed by Rocscience, Inc., of Toronto, Canada. Limit-equilibrium stability modeling consists of evaluation of estimated driving and resisting forces affecting a given landslide. The estimated forces are influenced by factors such as slope geometry, groundwater, soil type, and soil strength, among other global conditions. The output of a limit-equilibrium stability analysis yields a factor of safety for a given slope. The factor of safety is calculated as a ratio of forces resisting slope movement to forces driving slope movement. As such, a factor of safety of 1.0 indicates approximate force equilibrium and marginal stability of the slope. Further, a factor of safety larger than 1.0 indicates resisting forces exceed driving forces, while a slope with a factor of safety less than 1.0 indicates driving forces exceed resisting forces. The analysis indicates the existing slope has a global static factor of safety of about 1.0, suggesting the landslide is currently marginally stable. This factor of safety is consistent with the intermittent movement of the landslide based on changes in the global conditions, such as an increase in water-table elevation. The properties used for analysis and slope-stability output are shown on Figure 5.

Sewer Line Relocation

We understand Alternative 1.1.1 includes open-cut trenching on the order of 15 to 23 ft deep to facilitate relocation of the existing sewer line. Based on the depths of these proposed cuts and conditions disclosed by the borings, we anticipate the open cuts would occur within the documented landslide mass. In our opinion, the landslide-debris soils that mantle the site are not suitable for open-cut construction in this range of depths. As such, we recommend HDD installation methods be considered if the project team elects to reroute the sewer line. In our opinion, from a geotechnical standpoint, Alternatives 1.1.2 and 1.1.3 are feasible options for relocation or rerouting of the sewer line. It should be noted, however, elevations of the final sewer alignment should be compared with grading plans for the selected landslide-mitigation alternative prior to final design and construction. Additional discussion of the landslide-mitigation alternatives is included below.

Mitigation Alternatives Evaluated (1.0 Alternatives)

Two repair alternatives have been considered based on various project goals, including stability of the repair, constructability, costs, and minimizing impacts to utilities crossing Trillium Park Drive. The alternatives evaluated include construction of a tied-back retaining wall and unloading of the landslide, which involves excavating a portion of the landslide mass in conjunction with installation of trench drains.

Global-stability analyses of the existing slope condition, excavation with drains, and retaining wall were evaluated for static conditions using the limit-equilibrium program SLIDE v. 8.0. The slope-stability analyses targeted the maximum factor of safety for global stability for practical, constructible conditions. Figures illustrating our slope-stability models and profiles of the ground surface, stratigraphy, and landslide characteristics for the 1.0 alternatives are provided on Figures 5 through 7.

The following paragraphs discuss the results of our geotechnical analysis of the mitigation alternatives evaluated. It should be noted the slope-stability evaluation targeted a factor of safety of 1.2 for static loading conditions. This factor of safety is typically required to reduce the risk associated with deformations of the slope over the design life of the project.

Excavation and Drainage System. To provide a practical solution that reduces constructability concerns and distress to the existing utilities, we evaluated and modeled excavation of Trillium Park Drive completed in conjunction with the installation of trench drains. The primary goal of this method is to reduce the driving force by removing material from the landslide mass and lowering the groundwater surface.

The proposed excavation and drainage were modeled in SLIDE v. 8.0 with an excavation and trench drains that extend to depths of about 15.5 and 30.5 ft below the existing grade of Trillium Park Drive, respectively. It should be noted an excavation to this depth would require relocation of the existing sewer line within Trillium Park Drive. For modeling purposes, the analysis assumed the north side of Trillium Park Drive will be cut at a 2H:1V (Horizontal to Vertical) slope to accommodate the excavation depth. The slopes on the north side of Trillium Park Drive should be considered when selecting the relocation method and alignment of the sewer line. In our opinion, the maximum excavation depth should extend laterally to the approximate eastern and western extents of the observed landslide movement. The approximate recommended extents of excavation are shown on the attached Site Plan, Figure 2. The recommended extents should mark the crests of the temporary construction slopes, which should slope down at 1H:1V to the maximum excavation depth. For the purposes of the preliminary slope modeling, GRI assumed the proposed drainage system will consist of 3-ft-wide by 60-ft-long trench drains spaced laterally every 15 to 20 ft. The drains should be configured such that a minimum of six total drains are installed. It should be noted installation of 15-ft-deep trench drains may require temporary shoring or construction of temporary construction slopes, including possible removal of the existing gabion wall. Both the trench drains and excavation should also daylight to the face of the slope. The excavation and drainage alternative with the assumptions outlined above yields a global static factor of safety of about 1.2. The properties used for analysis and slope-stability output for the excavation and drainage option are shown on Figure 6.

Tied-Back Wall System. As part of our analysis, GRI also evaluated and modeled a permanent tied-back wall system. It should be noted large-diameter boulders were encountered during drilling on Trillium Park Drive and may present constructability concerns for installation of vertical elements of a tied-back wall system. In our opinion, conventional wall construction using augured drilling methods and H-piles for vertical elements may not be feasible in these conditions. Alternative vertical elements, such as micropiles, may be required to construct the wall. Micropiles have the benefit of installation using a smaller-diameter downhole air-rotary hammer that can penetrate boulders and rock. GRI should be given the opportunity to review plans for a tied-back wall system, if selected, prior to construction.

The proposed wall was modeled in SLIDE v. 8.0 with an alignment on the southern edge of the existing sidewalk on Trillium Park Drive. The wall was modeled as an equivalent horizontal pressure of 2,500 psf, based on typical tie-back loads and spacing between anchors, acting over the entire wall to a depth of about 40 ft below the existing sidewalk grade. The analysis also assumed final grade at the base of the wall will be approximately 10 ft above the base of the wall. For modeling purposes, we assumed local excavation may be required at the wall face to facilitate tie-back installation. As such, backfilling at the face of the wall may be required following construction to meet final grading recommendations. The tied-back wall alternative with the assumptions outlined above yields a global static factor of safety of about 1.4. The properties used for analysis and slope-stability output for the tied-back wall are shown on Figure 7.

Mitigation Alternatives Evaluated (2.0 Alternatives)

Upon review of the 1.0 alternatives discussed above, the City requested additional analysis of a "do nothing" alternative, lightweight-fill alternatives, and a modified excavation alternative without the use of trench drains. Based on our ongoing discussions with the City, we understand alternatives maintaining vehicle access to Trillium Park Drive are being considered.

Global-stability analyses of a "do nothing" alternative, the utilization of lightweight fills, and the modified excavation alternative were completed for static conditions using the limit-equilibrium program SLIDE v. 8.0. The slope-stability analyses targeted the maximum factor of safety for global stability for practical, constructible conditions. Figures illustrating our slope-stability models and profiles of the ground surface, stratigraphy, and landslide characteristics for the 2.0 alternatives are provided on Figures 8 through 13.

The following paragraphs discuss the results of our geotechnical analysis of the mitigation alternatives evaluated. It should be noted the slope-stability evaluation targeted a factor of safety of 1.2 for static loading conditions. This factor of safety is typically required to reduce the risk associated with deformations of the slope over the design life of the project.

"Do Nothing." At the request of the City, GRI evaluated and modeled an alternative that included minimal regrading of Trillium Park Drive. To complete this analysis GRI modified the model of the existing slope to include excavation and removal of the existing roadway. This alternative includes limited excavation but requires abandoning Trillium Park Drive and does not allow for future vehicle access.

The proposed alternative was modeled in SLIDE v. 8.0 with an approximately 3-ft-deep excavation from existing grades along the existing alignment of Trillium Park Drive. The approximate alignment of the existing roadway is shown on the attached Site Plan, Figure 2. For modeling purposes, the analysis assumed temporary excavation slopes of 1H:1V to accommodate the excavation depth. We anticipate this alternative will include removal of all roadway asphalt along the alignment of Trillium Park Drive within the project area; however, at a minimum, we recommend excavation take place within the extents shown on Figure 2. The "do nothing" alternative with the assumptions outlined above yields a global static factor of safety of about 1.0, showing no measurable improvement from the marginally stable existing condition. The properties used for analysis and slope-stability output for the "do nothing" option are shown on Figure 8.

Lightweight Fill. As part of our analysis, GRI also evaluated and modeled lightweight-fill options consisting of geofoam and lightweight cellular concrete. As noted above, we understand the City is considering mitigation alternatives that also allow for future vehicle access to Trillium Park Drive. As such, GRI evaluated one-lane- and two-lane-wide alternatives for each lightweight fill material. GRI should be given the opportunity to review plans for a lightweight-fill section, if selected, prior to construction.

The proposed lightweight fills were modeled in SLIDE v. 8.0. The analysis assumed drainage improvements, such as a drainage blanket, will be installed at the base of the excavated depth to manage water runoff from the existing slope west of Trillium Park Drive and reduce the risk of elevated groundwater levels. The drainage blanket should daylight to the face of the slope. Both lightweight-fill options exhibited similar performance for landslide-hazard mitigation. It should be noted, however, the relatively light weight of geofoam in comparison to cellular concrete allowed a reduced excavation depth for geofoam alternatives. In addition, when comparing geofoam and cellular concrete, it is important to consider constructability constraints with each material. For example, the geofoam alternative will require a retaining-wall structure to create a vertical face on the downslope side of the fill section and a "topping slab" for roadway support. For modeling purposes, we assumed minor, local excavation may be required to construct the fills. The lightweight-fill alternatives with the assumptions outlined above yield a global static factor of safety of about 1.2. The properties used for analysis and slope-stability output for the lightweight-fill options are shown on Figures 9 through 12.

Excavation without Trench Drainage. During the course of our analysis of the 2.0 mitigation alternatives, the City requested evaluation of an alternative that includes excavation of a portion of the landslide mass without the use of trench drainage. The goal of evaluating this alternative was to evaluate the sensitivity of the factor of safety to the proposed changes to the groundwater-table elevation.

The proposed excavation was modeled in SLIDE v. 8.0 and extended to a depth of about 15.5 ft below the existing grade of Trillium Park Drive. As discussed above, it should be noted an excavation to this depth would require relocation of the existing sewer line within Trillium Park Drive. For modeling purposes, the analysis assumed the north side of Trillium Park Drive will be cut at a 2H:1V slope to accommodate the excavation depth. The slopes on the north side of Trillium Park Drive should be considered when selecting the relocation method and alignment of the sewer line. As in the 1.0 alternative, in our opinion, the maximum excavation depth should extend laterally to the approximate eastern and western extents of the observed landslide movement. The approximate recommended extents of excavation are shown on the attached Site Plan, Figure 2. The recommended extents should mark the crests of the temporary construction slopes, which should slope down at 1H:1V to the maximum excavation depth. While this alternative does not consider trench drains, improvements such as a drainage blanket should be installed at the base of the excavated depth to manage water runoff from the existing slope west of Trillium Park Drive and reduce the risk of elevated groundwater levels. The drainage blanket should daylight to the face of the slope. The excavation alternative with the assumptions outlined above yields a global static factor of safety of about 1.2. The properties used for analysis and slope-stability output for the excavation without trench drains option are shown on Figure 13.

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 the risk of injury or future damage to improvements is difficult to quantify. It must be understood future landslide movements 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 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 than those encountered during our reconnaissance and ground monitoring are observed or encountered, we should be advised at once, so we can observe and review these conditions and reconsider our opinions where necessary.

We appreciate the opportunity to be of service to RH2 and the City. Please contact the undersigned with any questions.

Submitted for GRI,

CERTIFIED
OREGON
GEORGE A. FREITAG
E1380
ENGINEERING GEOLOGIST

George A. Freitag

Renews 2/2020

Thomas O'Dell

George A Freitag, CEG
Principal

Thomas O'Dell, PE
Project Engineer

This document has been submitted electronically.

References

Burns, W.J., and Watzig, R.J., 2014, Statewide landslide information database for Oregon, release 3 (SLIDO-3), Oregon Department of Geology and Mineral Industries.

Evarts, R.C., O'Connor, J.E., Wells, R.E., and Madin, I.P., 2009, The Portland Basin: a (big) river runs through it: GSA Today v. 19, no. 9.

Madin, I.P., 2009, Geologic map of the Oregon City 7.5' quadrangle, Clackamas County, Oregon, Oregon Department of Geology and Mineral Industries, Geologic Map Series GMS-119.

McFarland, W.D., and Morgan, D.S., 1996, Description of the ground-water flow system in the Portland Basin, Oregon and Washington, U.S. Geological Survey, Water-Supply Paper 2470-A.

Table 1: 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 2: 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

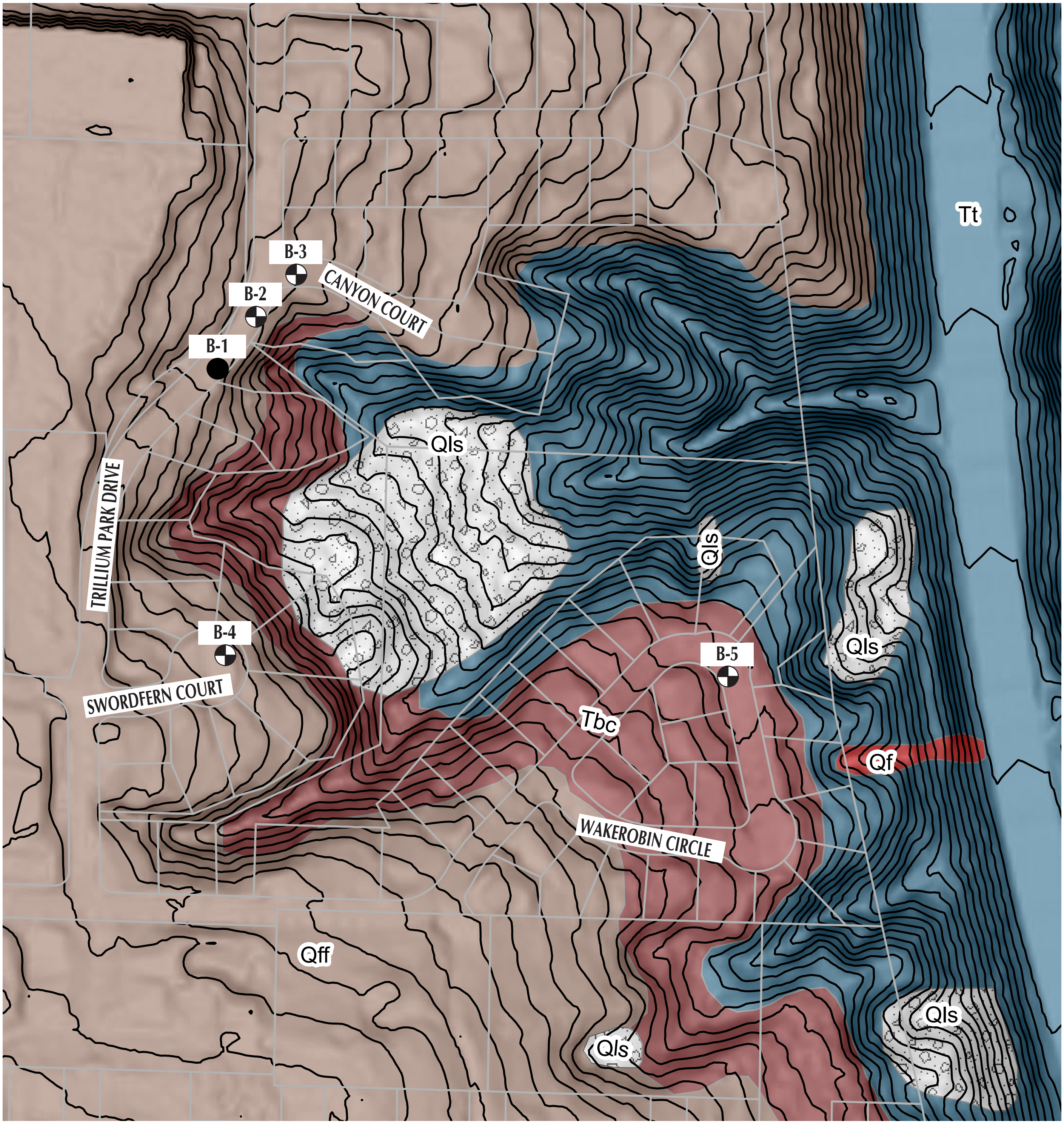
RQD AND ROCK QUALITY

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



GEOLOGIC UNITS

- 🟥 Qf - Debris flow fan
- 🟫 Qff - Willamette Silt
- ▨ Qls - Landslide Deposit
- 🟫 Tbc - Boring Lava
- 🟦 Tt - Troutdale Formation

⊕ BORING COMPLETED BY GRI
(JUNE 12-19, 2017)

● BORING COMPLETED BY GRI
(SEPTEMBER 20-21, 2006)

North

0 200 400 FT

REFERENCE:
SMITH, R.L., AND ROE, W.P., 2015
OREGON GEOLOGIC DATA COMPILATION, RELEASE 6
OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

GRI

RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

VICINITY MAP

MAY 2019 JOB NO. 6082 FIG. 1

◍ BORING COMPLETED BY GRI
(JUNE 12-19, 2017)

● BORING COMPLETED BY GRI
(SEPTEMBER 20-21, 2006)

SITE PLAN FROM FILE BY RH2 ENGINEERING, INC.

North

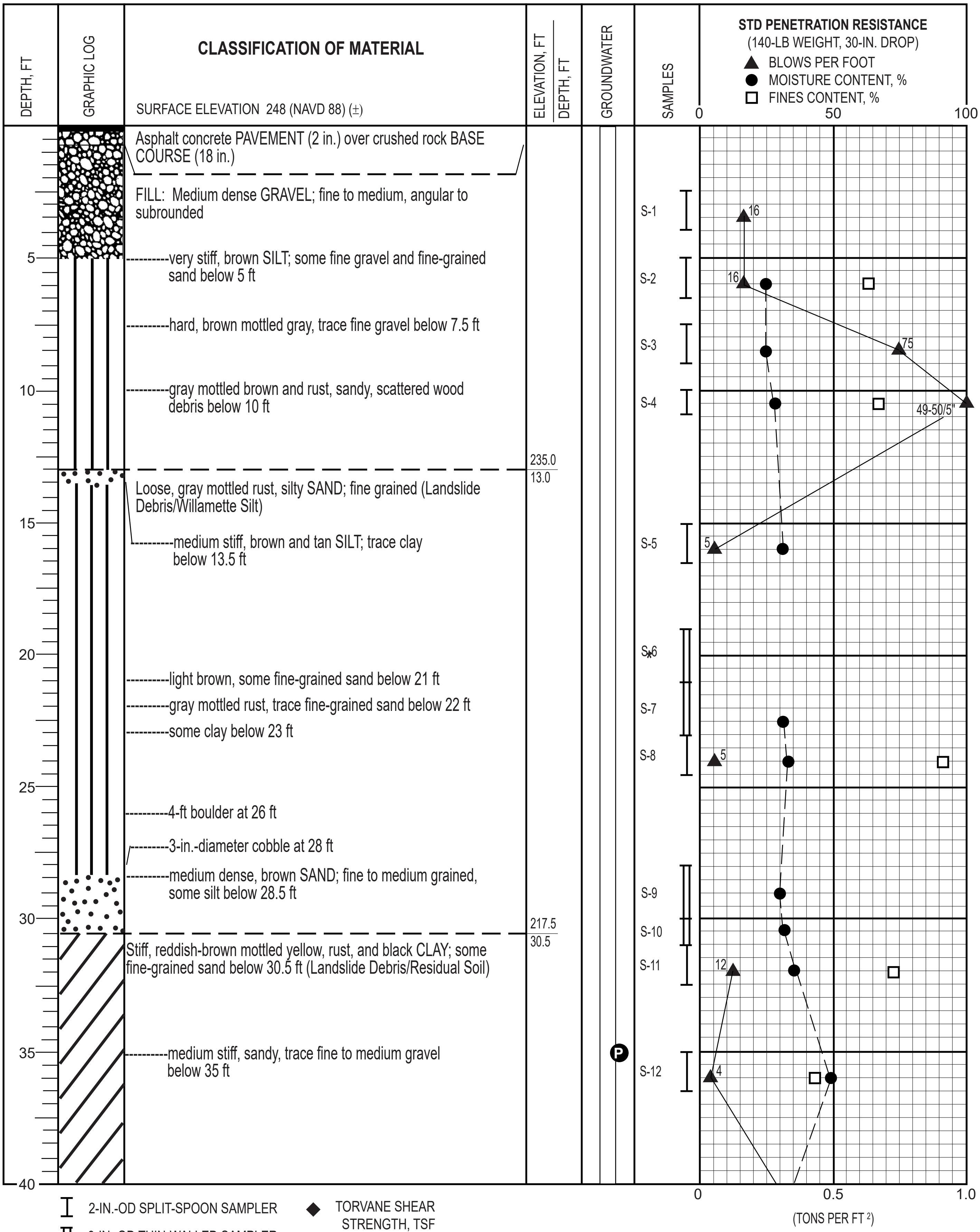
0 50 100 FT

GRI

RH2 ENGINEERING, INC.
TRILLIUM PARK DRIVE LANDSLIDE

SITE PLAN

MAY 2019 JOB NO. 6082 FIG. 2



CLASSIFICATION OF MATERIAL

SURFACE ELEVATION 248 (NAVD 88) (±)

Asphalt concrete PAVEMENT (2 in.) over crushed rock BASE COURSE (18 in.)

FILL: Medium dense GRAVEL; fine to medium, angular to subrounded

----------very stiff, brown SILT; some fine gravel and fine-grained sand below 5 ft

----------hard, brown mottled gray, trace fine gravel below 7.5 ft

----------gray mottled brown and rust, sandy, scattered wood debris below 10 ft

Loose, gray mottled rust, silty SAND; fine grained (Landslide Debris/Willamette Silt)

----------medium stiff, brown and tan SILT; trace clay below 13.5 ft

----------light brown, some fine-grained sand below 21 ft

----------gray mottled rust, trace fine-grained sand below 22 ft

----------some clay below 23 ft

----------4-ft boulder at 26 ft

----------3-in.-diameter cobble at 28 ft

----------medium dense, brown SAND; fine to medium grained, some silt below 28.5 ft

Stiff, reddish-brown mottled yellow, rust, and black CLAY; some fine-grained sand below 30.5 ft (Landslide Debris/Residual Soil)

----------medium stiff, sandy, trace fine to medium gravel below 35 ft

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)

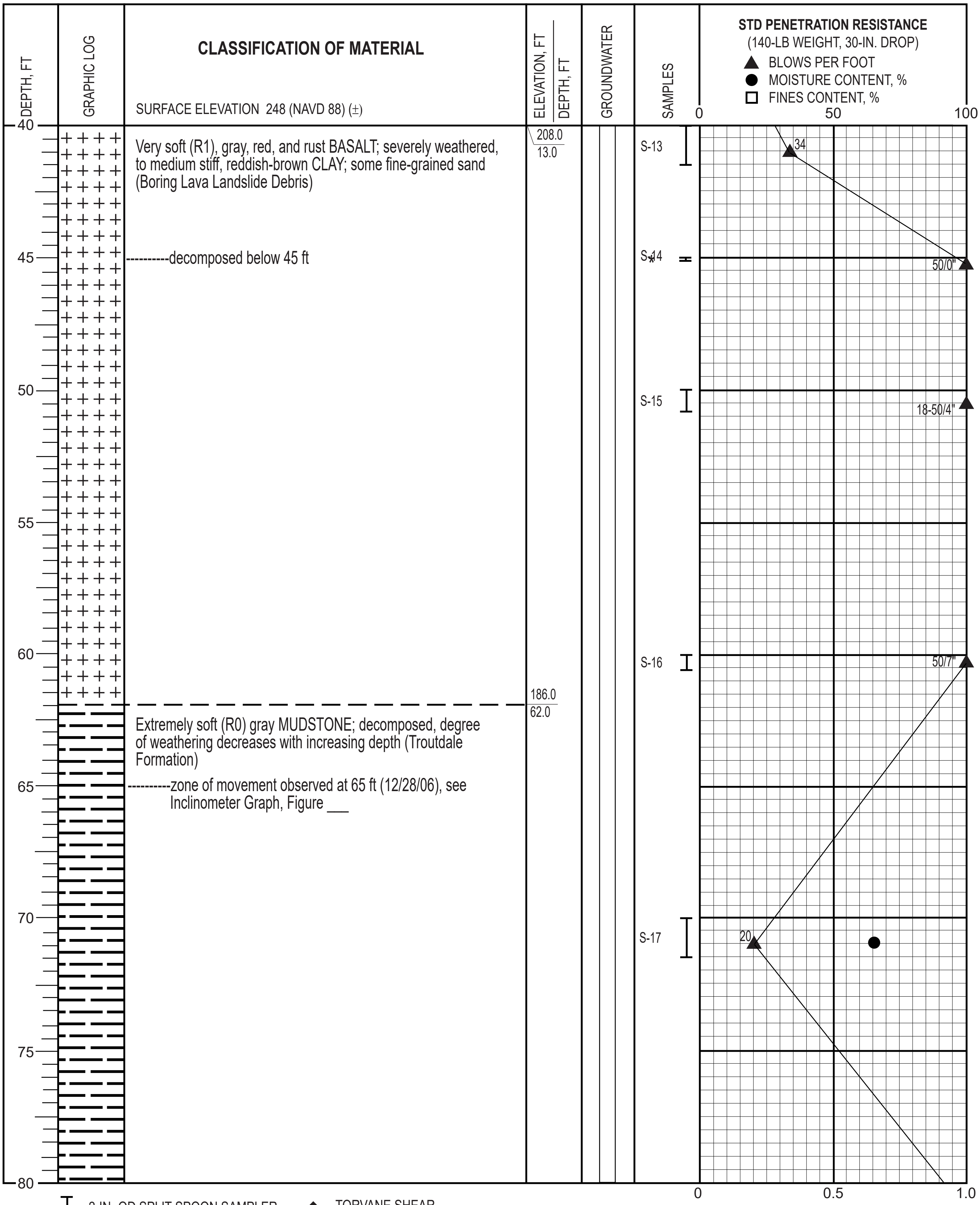
◆ TORVANE SHEAR STRENGTH, TSF
■ UNDRAINED SHEAR STRENGTH, TSF
* NO RECOVERY

Liquid Limit
Moisture Content
Plastic Limit

GRI

BORING B-1

MAY 2019 JOB NO. 6082 FIG. 3



CLASSIFICATION OF MATERIAL

SURFACE ELEVATION 248 (NAVD 88) (±)

Very soft (R1), gray, red, and rust BASALT; severely weathered, to medium stiff, reddish-brown CLAY; some fine-grained sand (Boring Lava Landslide Debris)

----------decomposed below 45 ft

Extremely soft (R0) gray MUDSTONE; decomposed, degree of weathering decreases with increasing depth (Troutdale Formation)

----------zone of movement observed at 65 ft (12/28/06), see Inclinometer Graph, Figure ___

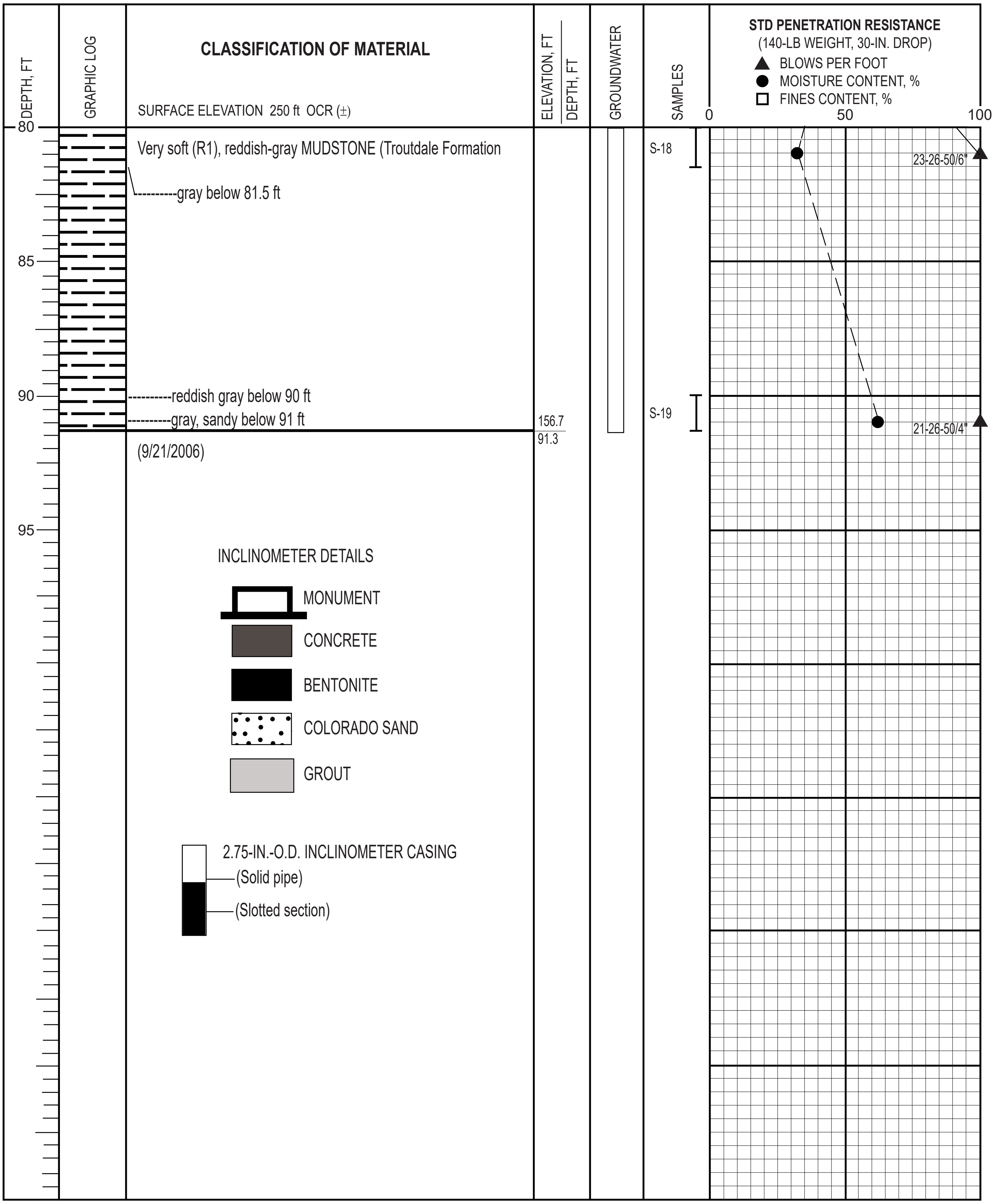
I 2-IN.-OD SPLIT-SPOON SAMPLER	◆ TORVANE SHEAR STRENGTH, TSF
Ⅱ 3-IN.-OD THIN-WALLED SAMPLER	■ UNDRAINED SHEAR STRENGTH, TSF
G GRAB SAMPLE OF DRILL CUTTINGS	* NO RECOVERY
▌ NX CORE RUN	
├── SLOTTED PVC PIPE	
▼ Water Level (date)	

Liquid Limit
Moisture Content
Plastic Limit

GRI

BORING B-1 (cont.)

MAY 2019 JOB NO. 6082 FIG. 3



CLASSIFICATION OF MATERIAL

SURFACE ELEVATION 250 ft OCR (±)

Very soft (R1), reddish-gray MUDSTONE (Troutdale Formation

----------gray below 81.5 ft

----------reddish gray below 90 ft

----------gray, sandy below 91 ft

(9/21/2006)

INCLINOMETER DETAILS

MONUMENT

CONCRETE

BENTONITE

COLORADO SAND

GROUT

2.75-IN.-O.D. INCLINOMETER CASING

—(Solid pipe)

—(Slotted section)

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

Liquid Limit

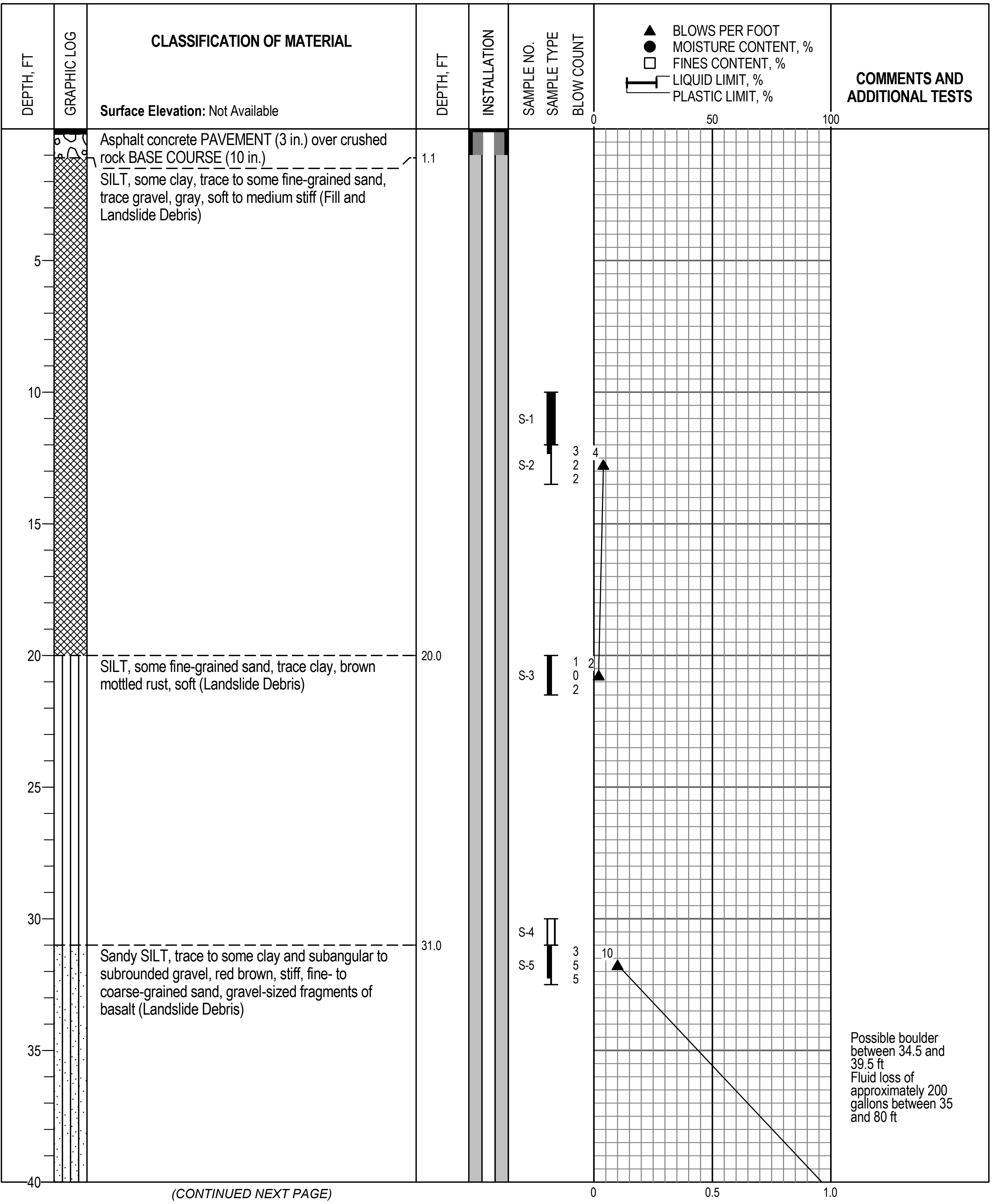
Moisture Content

Plastic Limit

GRI

BORING B-1 (cont.)

MAY 2019 JOB NO. 6082 FIG. 3



CLASSIFICATION OF MATERIAL

Surface Elevation: Not Available

DEPTH, FT	CLASSIFICATION OF MATERIAL
	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)
20.0	SILT, some fine-grained sand, trace clay, brown mottled rust, soft (Landslide Debris)
31.0	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)

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

COMMENTS AND ADDITIONAL TESTS

Possible boulder between 34.5 and 39.5 ft
Fluid loss of approximately 200 gallons between 35 and 80 ft

(CONTINUED NEXT PAGE)

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

GRI BORING LOG (LAT/LONG) - NO ELEV GRI DATA TEMPLATE.GDT 7/26/17

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

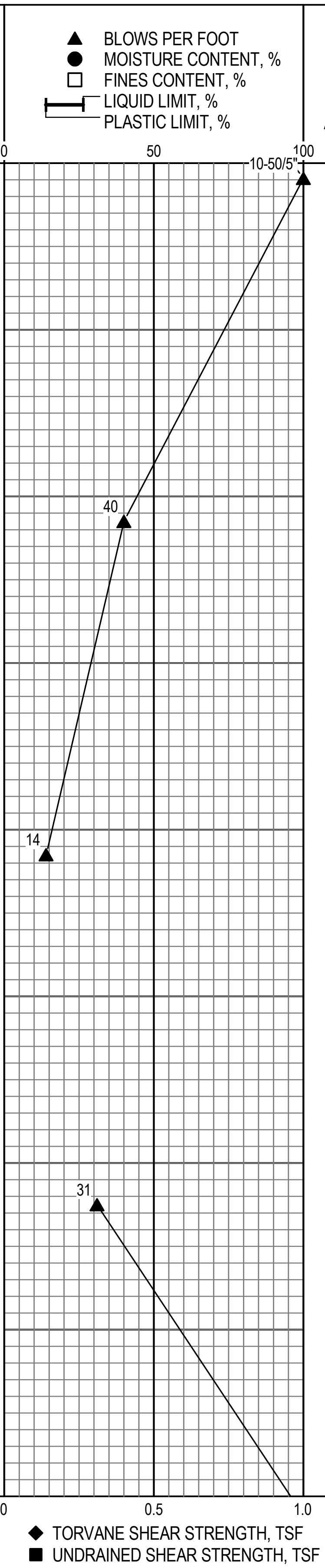
GRI

BORING B-2

MAY 2019 JOB NO. 6082 FIG. 4

Surface Elevation: Not Available

DEPTH, FT	CLASSIFICATION OF MATERIAL	DEPTH, FT	SAMPLE NO.	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		
			S-12	10 12 19	
75					
80					



(CONTINUED NEXT PAGE)

GRI BORING LOG (LAT/LONG) - NO ELEV GRI DATA TEMPLATE.GDT 7/26/17

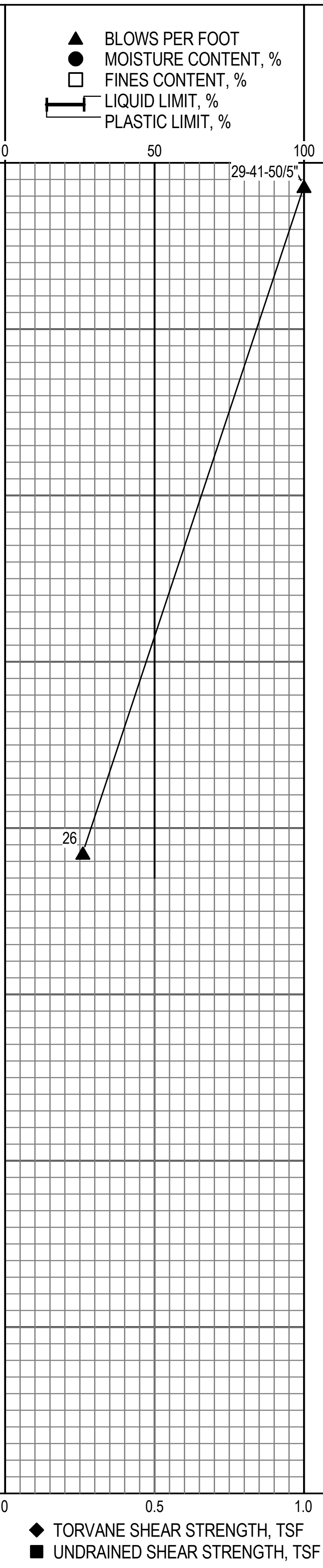
GRI

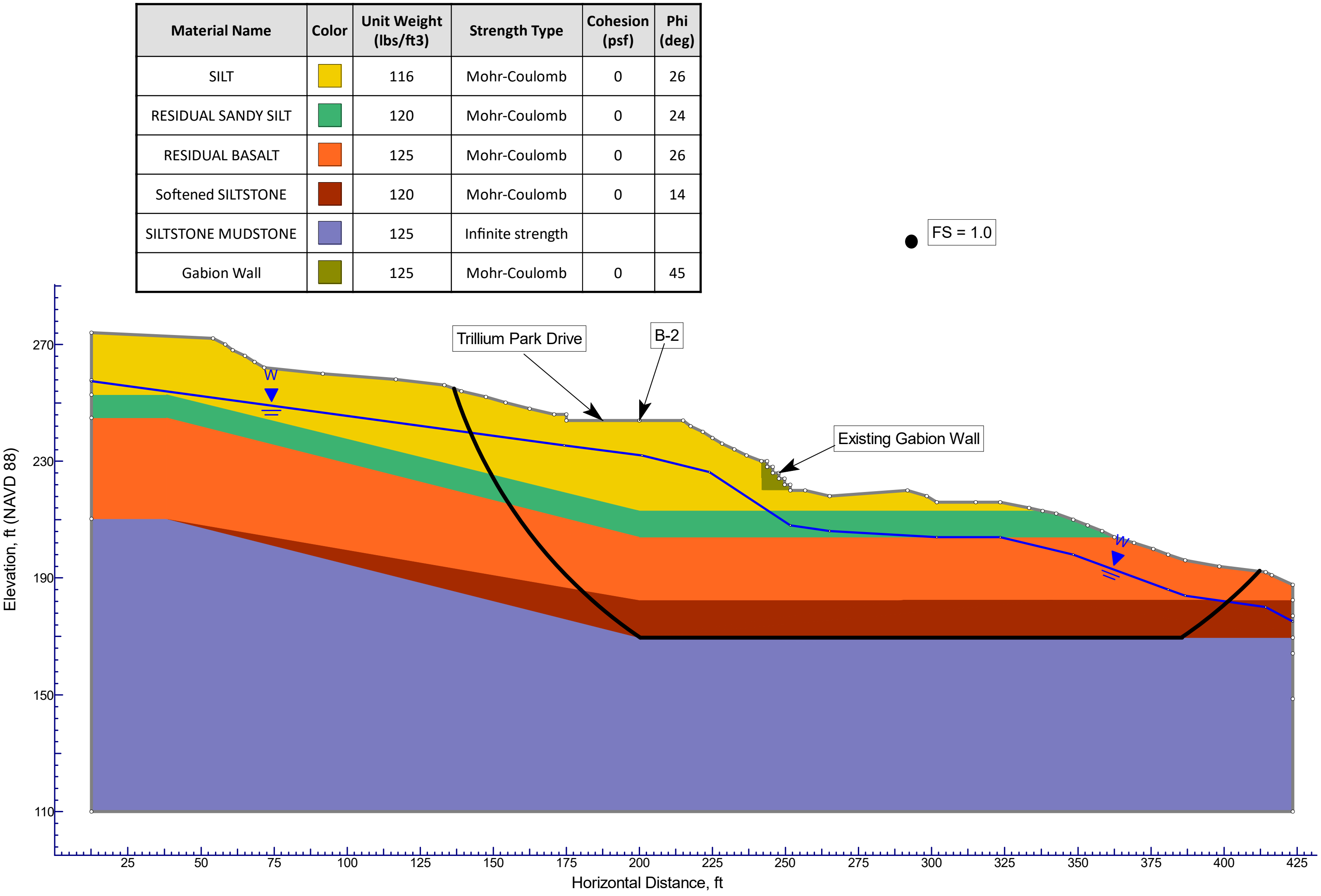
BORING B-2

MAY 2019 JOB NO. 6082 FIG. 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						
		SILTSTONE, gray, predominantly decomposed to decomposed, extremely soft (R0) (Troutdale Formation)			S-13	I	29 41 50/5"	
100		MUDSTONE, gray mottled rust, decomposed, extremely soft (R0) (Troutdale Formation)	100.0		S-14	I	9 11 15	
		(6/13/2017)	101.5					

Depth scale: 85, 90, 95, 100, 105, 110, 115, 120





Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45

GRI

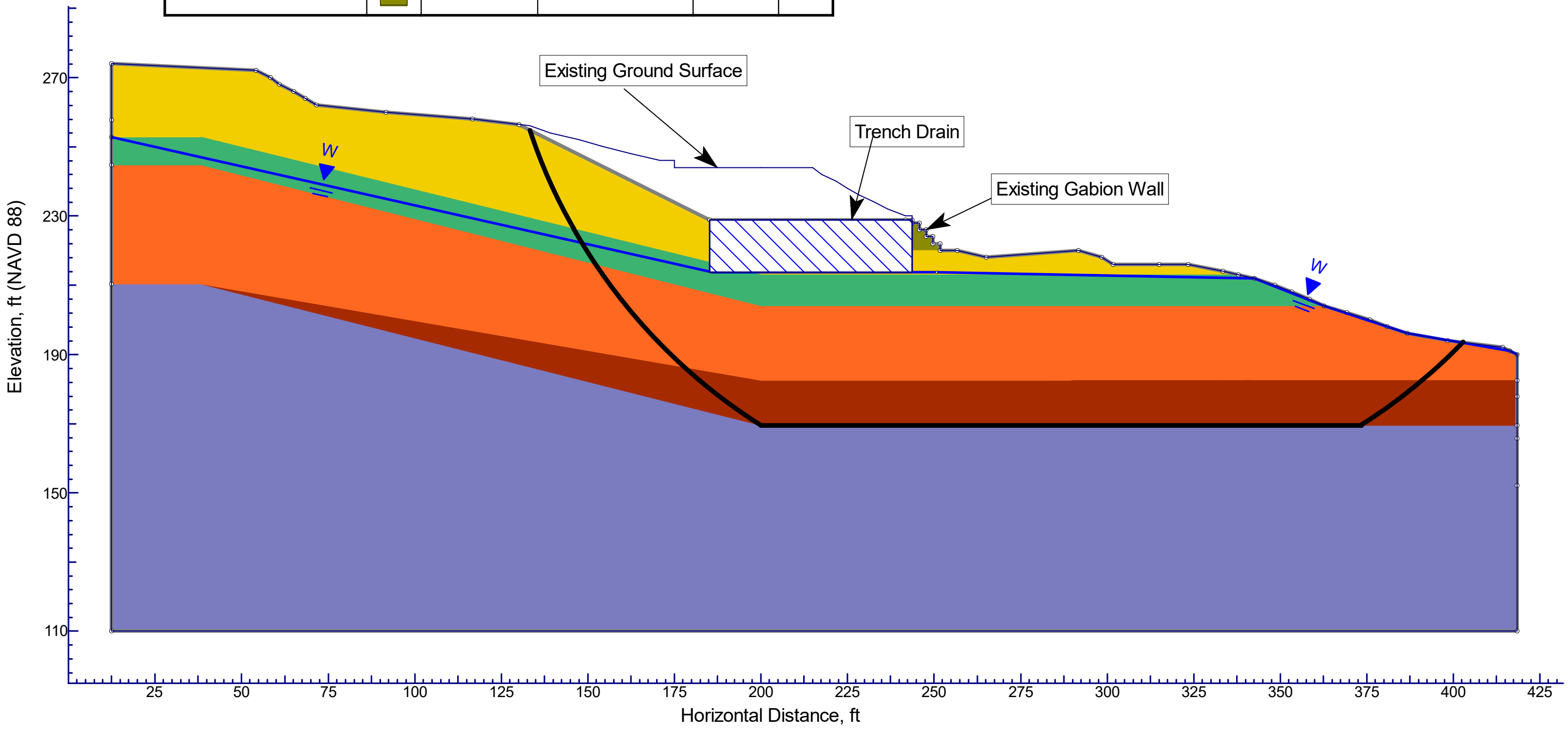
RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL
(EXISTING CONDITIONS)

MAY 2019 JOB NO. 6082 FIG. 5

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45

● FS = 1.2



GRI

RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

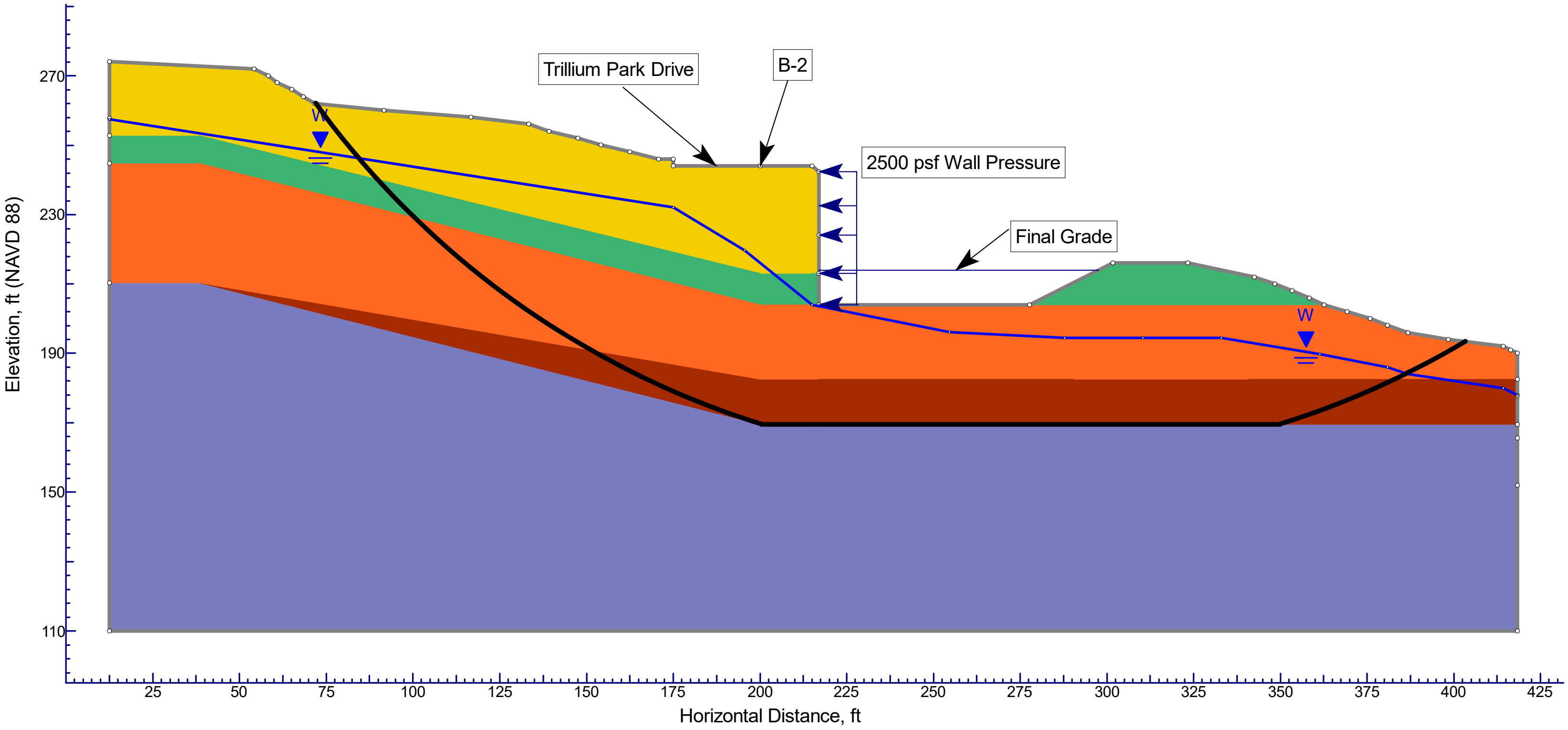
SLOPE STABILITY MODEL

(EXCAVATION AND DRAIN ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 6

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		

● FS = 1.4



GRI

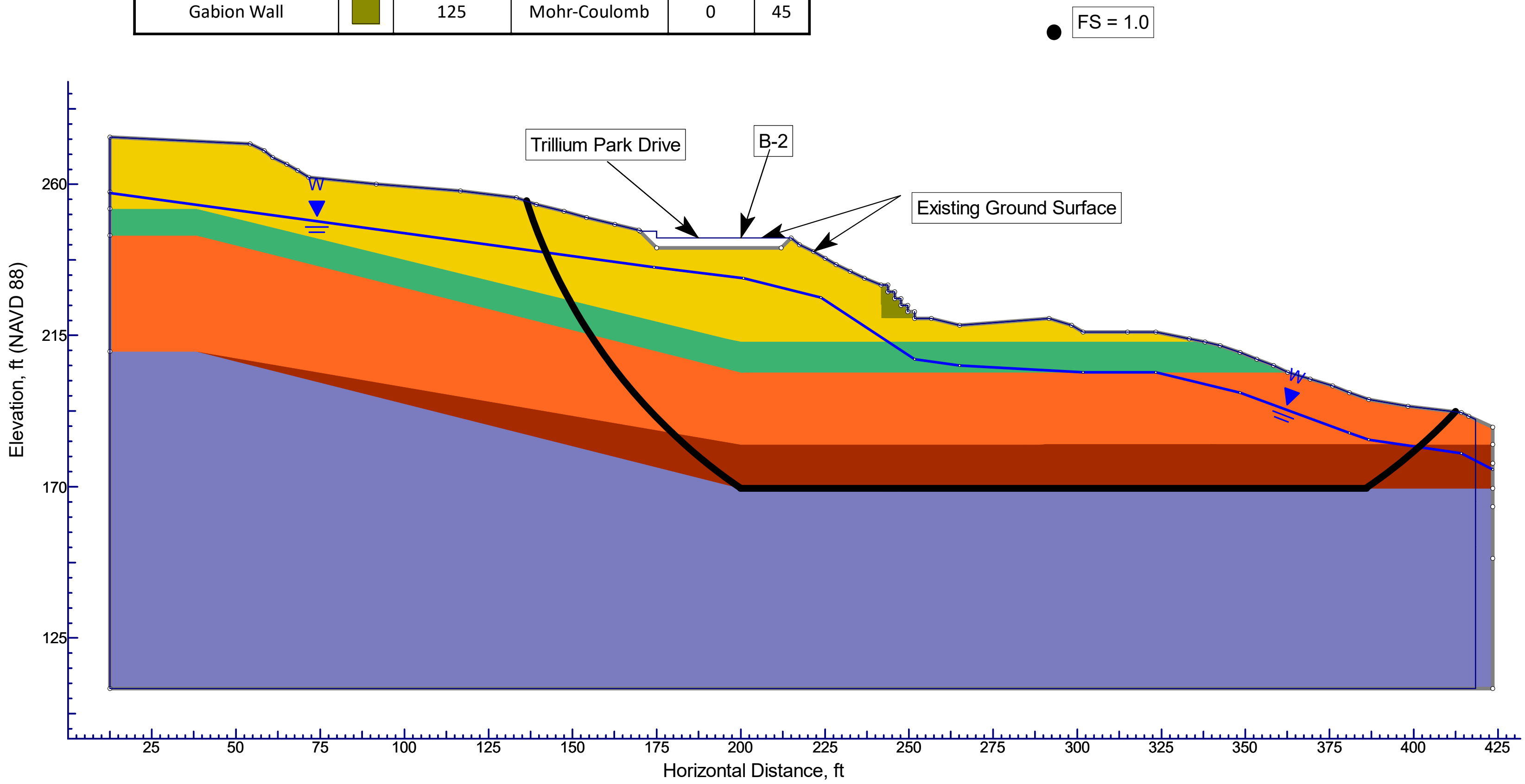
RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL

(RETAINING WALL ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 7

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45



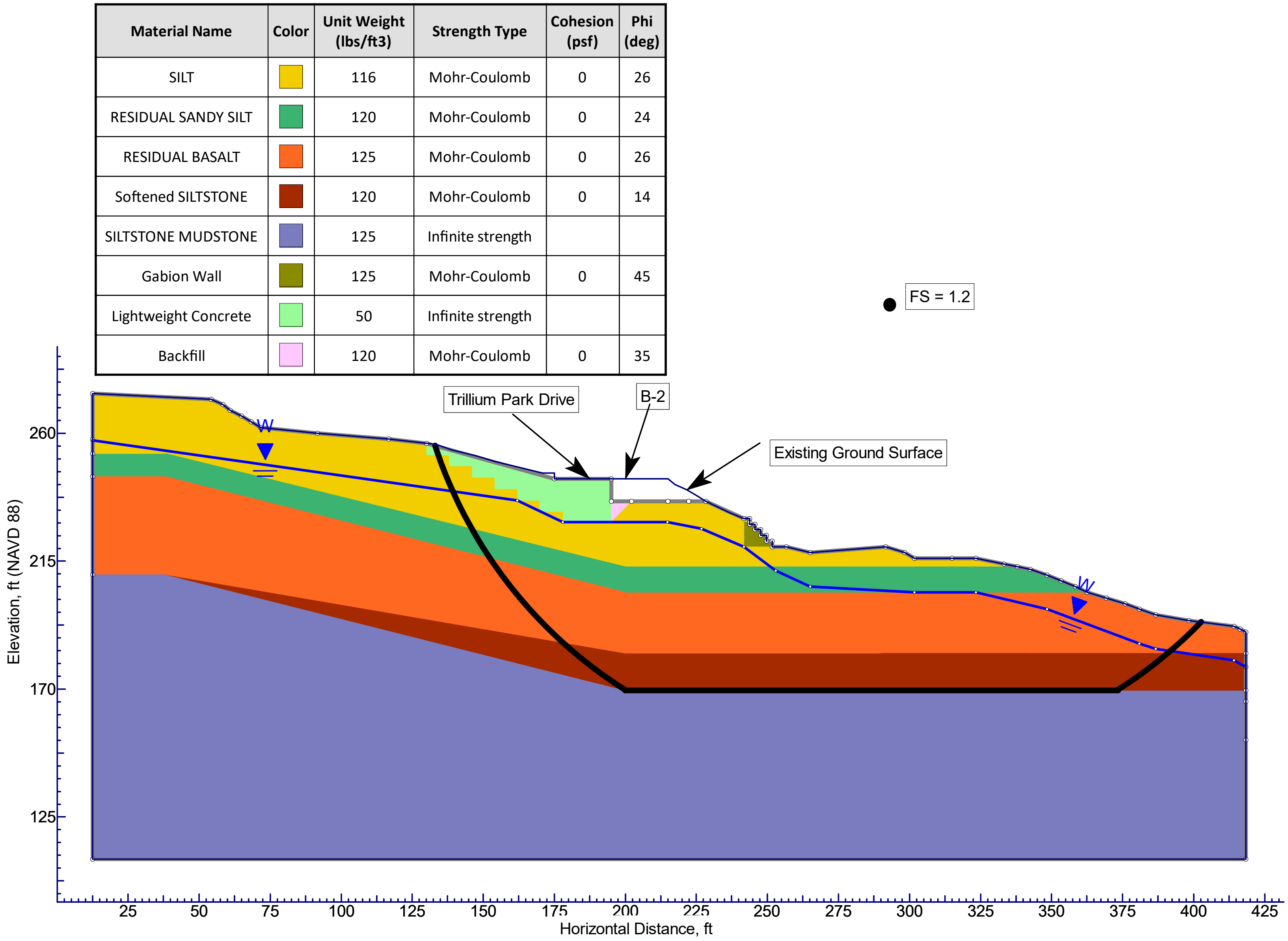
GRI

RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL

("DO NOTHING" ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 8



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45
Lightweight Concrete	🟩	50	Infinite strength		
Backfill	🟪	120	Mohr-Coulomb	0	35

GRI

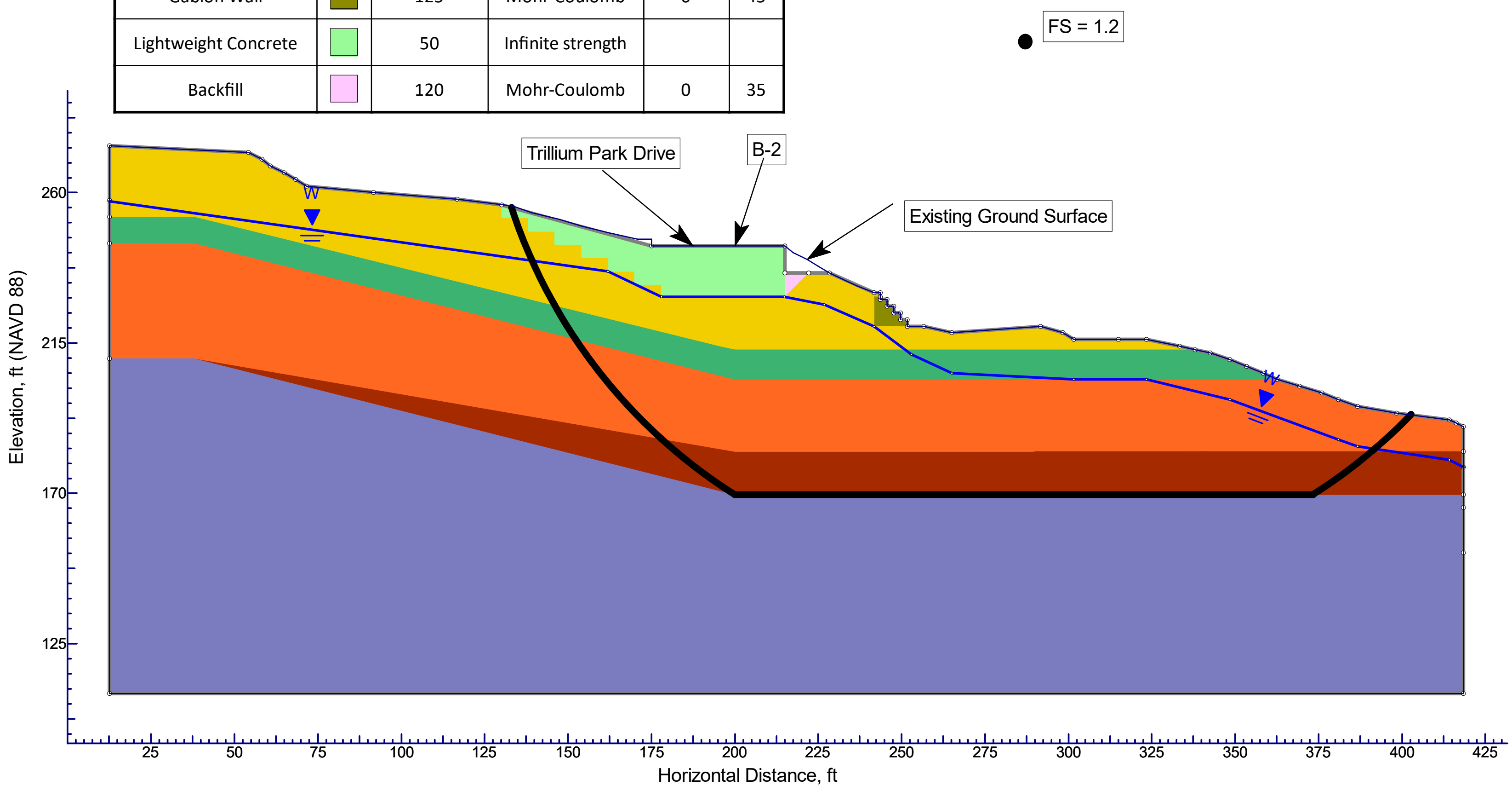
RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL

(CELLULAR CONCRETE ONE LANE ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 9

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45
Lightweight Concrete	🟩	50	Infinite strength		
Backfill	⬜	120	Mohr-Coulomb	0	35



GRI

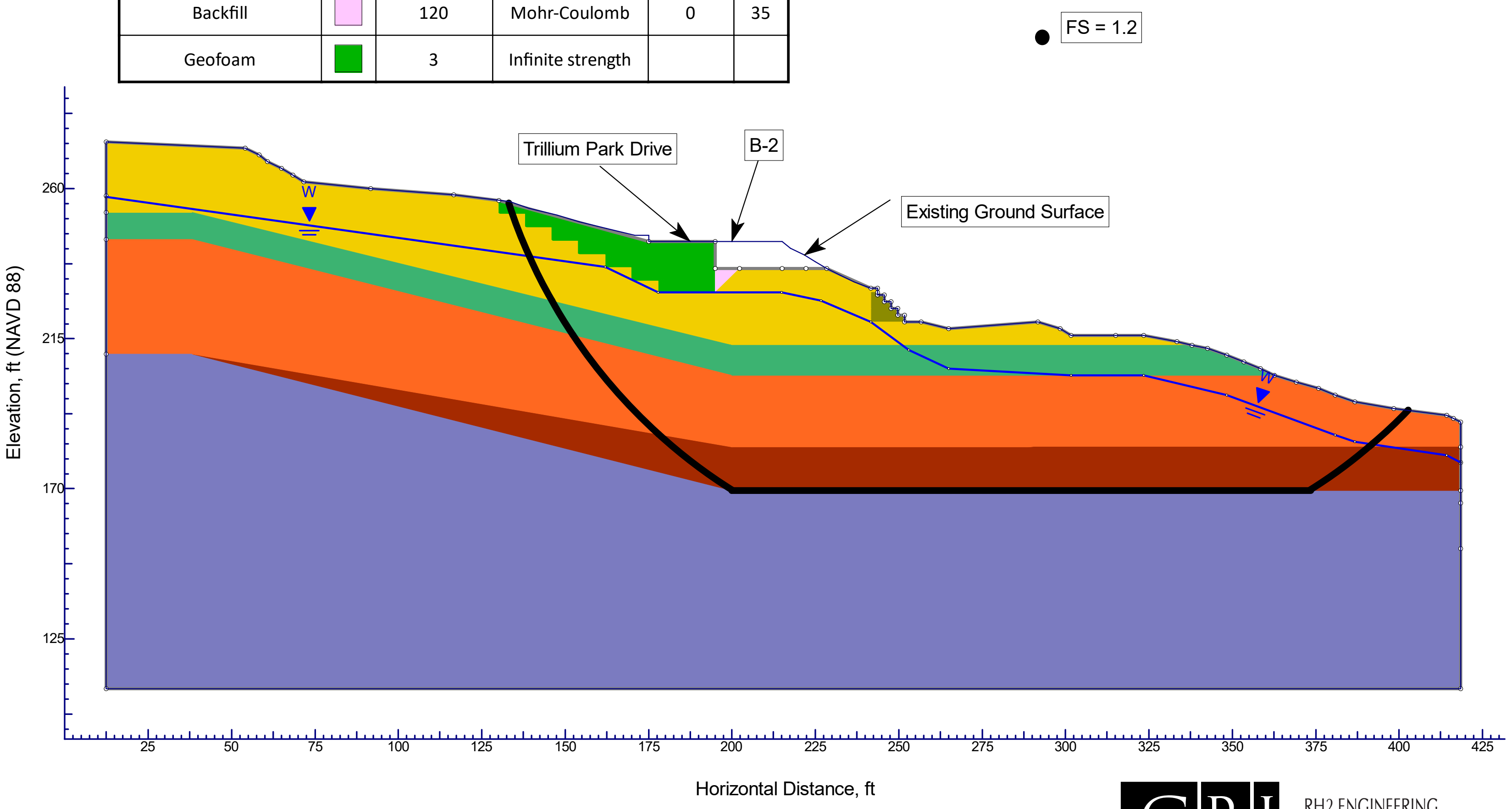
RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL

(CELLULAR CONCRETE TWO LANE ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 10

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45
Backfill	⬜	120	Mohr-Coulomb	0	35
Geofoam	🟩	3	Infinite strength		



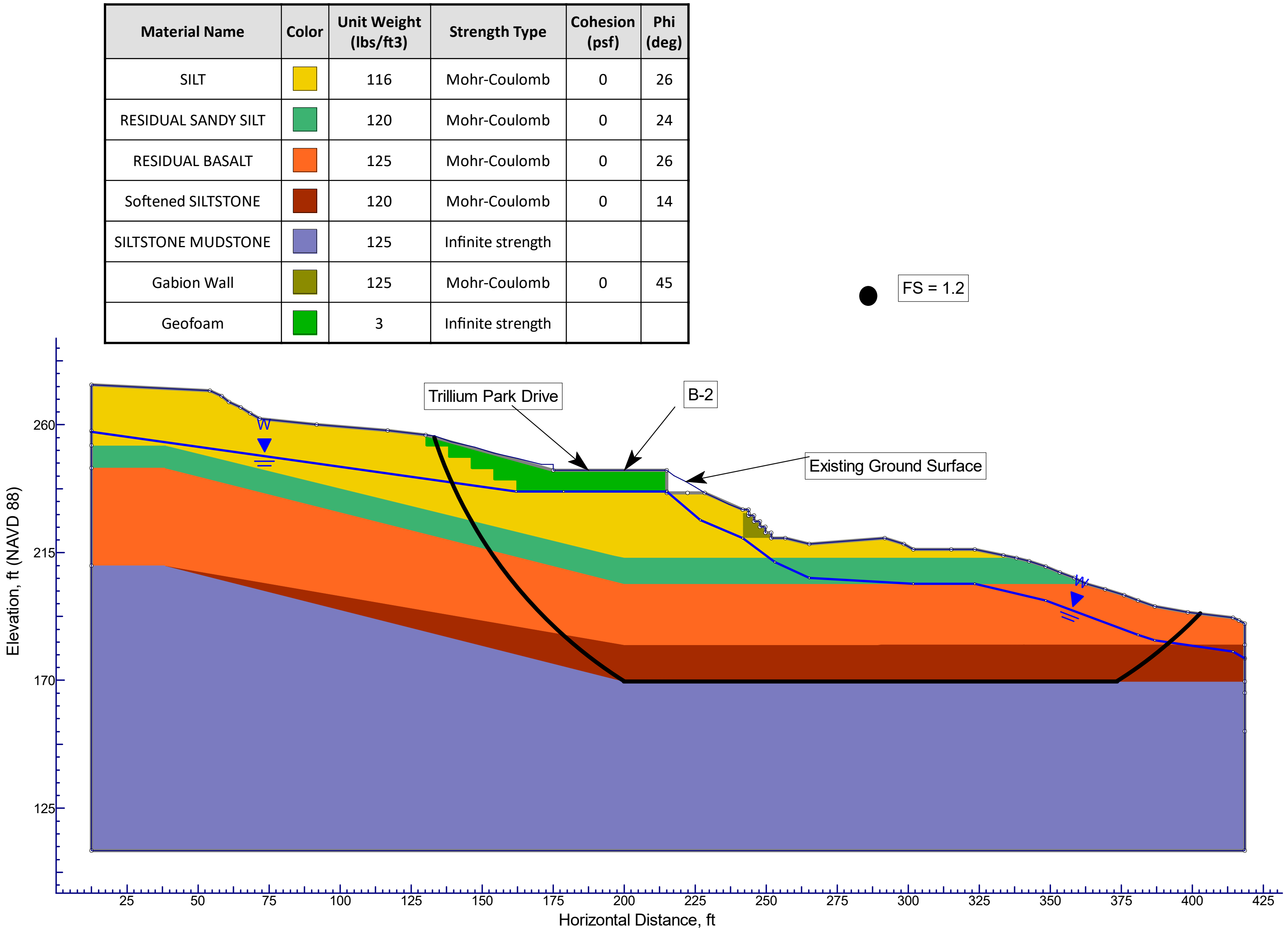
GRI

RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL

(GEOFOAM ONE LANE ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 11



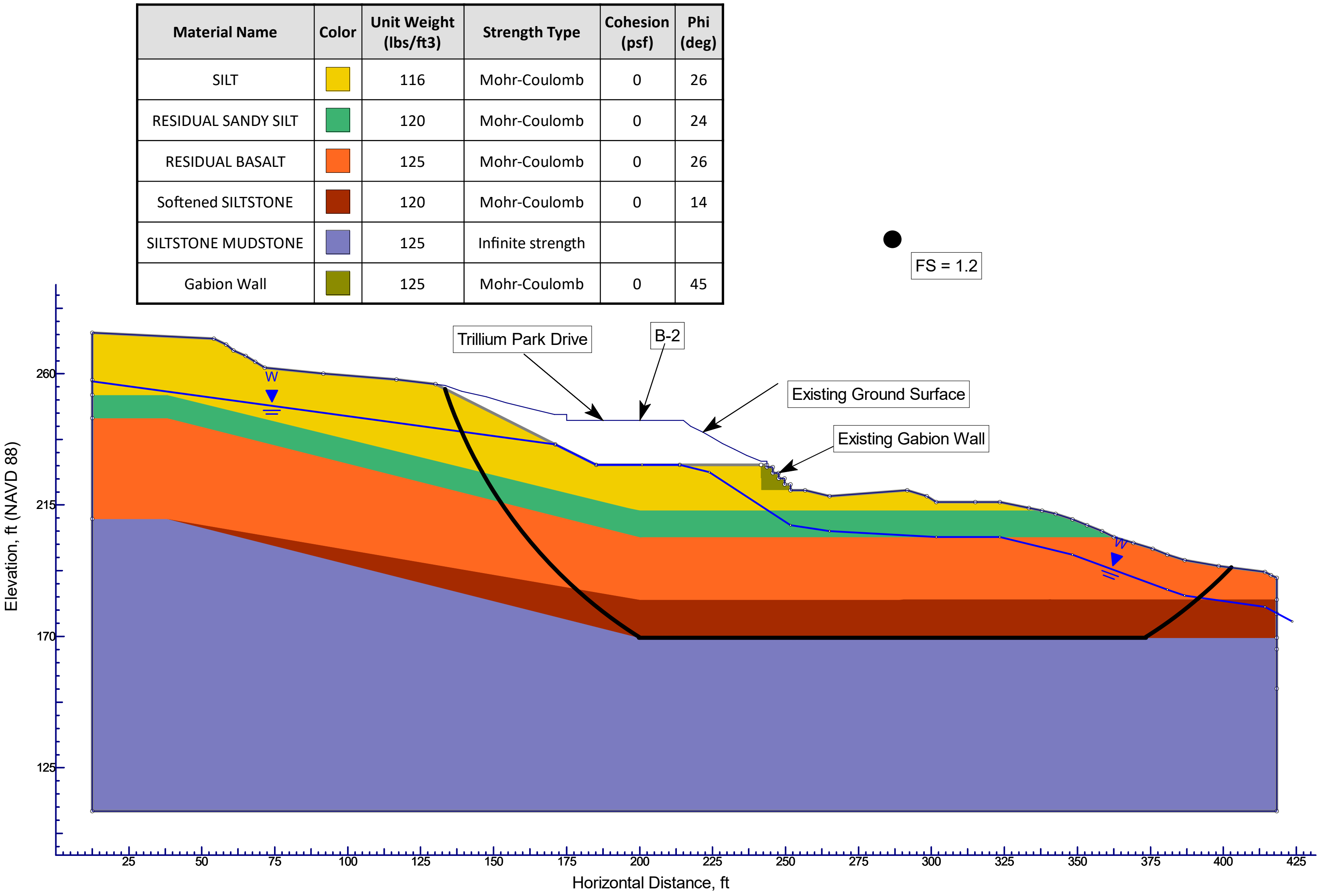
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45
Geofoam	🟩	3	Infinite strength		

RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL

(GEOFOAM TWO LANE ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 12



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
SILT	🟨	116	Mohr-Coulomb	0	26
RESIDUAL SANDY SILT	🟩	120	Mohr-Coulomb	0	24
RESIDUAL BASALT	🟧	125	Mohr-Coulomb	0	26
Softened SILTSTONE	🟥	120	Mohr-Coulomb	0	14
SILTSTONE MUDSTONE	🟪	125	Infinite strength		
Gabion Wall	🟫	125	Mohr-Coulomb	0	45

GRI

RH2 ENGINEERING
TRILLIUM PARK DRIVE LANDSLIDE

SLOPE STABILITY MODEL

(EXCAVATION NO DRAIN ALTERNATIVE)

MAY 2019 JOB NO. 6082 FIG. 13

Attachment 2

Alternatives Descriptions and Figures

THIS PAGE INTENTIONALLY LEFT BLANK

Descriptions of Developed Alternatives

Alternative Numbering Schema

For organizational purposes, the following schema was used in numbering the alternatives. In general, alternatives are numbered using a X.Y.Z format, where:

- X = Base Alternative for Roadway Restoration
    - 1 = Roadway will be Abandoned to Vehicular Traffic
    - 2 = Roadway will be Restored to Vehicular Traffic
- Y = Geotechnical Alternative to Mitigate Landslide
    - 0 = Do Nothing (De-Pave Road and Monitor Landslide)
    - 1 = Excavate Overburden and Install Trench Drains
    - 2 = Construct Tieback Wall to Support Road and Utilities
    - 3 = Reconstruct Road using Geofoam
    - 4 = Reconstruct Road using Cellular Concrete
- Z = Utility Alternative to Mitigate Sewer and Water Service
    - 0 = Do Nothing
    - 1 = Reconstruct Sewer in Place
    - 2 = Re-Route Sewer via Open-Cut
    - 3 = Re-Route Sewer via Horizontal Directional Drill
    - 4 = Re-route Sewer via Lift Station and Force Main
    - 5 = Reconstruct Sewer and Water in Place

Not all alternatives are equal and some alternatives may result in a higher level of service than others. Of the eight fully developed alternatives evaluated, three of the alternatives proposed to restore the gravity sewer by re-routing via HDD and two of the alternatives proposed to restore both gravity sewer and water lines within Trillium Park Drive.

Option 1 – Abandon Road and Reroute Utilities

Under the Abandon Road alternative, the roadway would be abandoned to vehicular traffic and the gravity sewer would be restored to an acceptable level of service. The existing water line would also be permanently abandoned requiring the relocation of the existing hydrant at the corner of Canyon Court. Under this alternative, the City would have the option of either mitigating the landslide risk by excavating the overburden material causing the slide or simply depaving the road and leaving the slide as is (i.e. do nothing). For each of these geotechnical alternatives, one or multiple utility alternatives may exist as described below.

Geotechnical Alternative 0 – Do Nothing (De-Pave Road)

Under this alternative, Trillium Park Drive would be abandoned and the existing roadway within the area of the landslide would be removed (de-paved). The slide zone would then be left as is. Under this alternative, the existing sewer would be re-routed outside of the slide zone.

Alternative 1.0.3 – Abandon Road and De-pave Roadway. Build Vehicle Turnaround. Restore Utility Service by Re-Routing Sewer via HDD

Similar to Alternative 1.1.3, this alternative would reroute the sewer to the west of the slide area utilizing HDD for the installation of a 10-inch HDPE sewer main.

Geotechnical Alternative 1 – Excavate Overburden and Install Trench Drains

Under this alternative, Trillium Park Drive would be abandoned in the area of the slow-moving landslide and the overburden soil (fill placed in ravine during development of Trillium Park Estates) would be removed. Additional native material compromised by the landslide would also be removed and graded back at a slope of 2:1 to meet the existing grade. Drainage improvements would then be installed to collect and route surface and ground water to the existing natural drainage course in the ravine downstream. The drainage improvements would comprise of installing a manifold of perforated pipes approximately 3-feet deep in trenches backfilled with drain rock. The exposed slopes would then be matted and hydroseeded and the base of the excavation covered with rip-rap for permanent erosion control measures. The following four utility alternatives are based on this geotechnical alternative.

Alternative 1.1.1 – Abandon Road and Excavate Overburden. Install Trench Drains and Reconstruct Sewer in Place

Following excavation of overburden and installation of trench drains, approximately 320 lineal feet (LF) of existing 8-inch diameter sewer main and one manhole damaged by the landslide would be reconstructed in their existing location. Due to the depth of the excavation of overburden material, the reconstructed sewer would either be designed to remain exposed or would be covered by an embankment.

Alternative 1.1.2 – Abandon Road and Excavate Overburden. Install Trench Drains and Restore Utility Service by Re-Routing Sewer via Open Cut

Under this alternative, the sewer would be rerouted out of the Trillium Park Drive Right-of-Way (ROW) to the west of the slide area. Approximately 350 LF of 8-inch PVC sewer pipe and two manholes would be installed using open-cut construction. A perforated drain pipe would be installed within the sewer trench to mitigate groundwater. At the deepest point, the sewer would be approximately 23 feet deep. This alternative would also require clearing trees, tree mitigation, and easement acquisition.

Alternative 1.1.3 – Abandon Road and Excavate Overburden. Install Trench Drains and Restore Utility Service by Re-Routing Sewer via HDD

Similar to Alternative 1.1.1, this alternative would reroute the sewer to the west of the slide area but would utilize horizontal directional drilling (HDD) for the installation of a 10-inch HDPE sewer main. As a result, no deep excavation or tree clearing on the landscaped hillside would be necessary. Two manholes would be installed within the ROW at the HDD entry and receiving pits. Like Alternative 1.1.2, this alternative would require easement acquisition.

Alternative 1.1.4 – Abandon Road and Excavate Overburden. Install Lift Station and Restore Utility Service by Re-routing Sewer to South

Rather than rerouting the sewer to the west and utilizing gravity for conveyance, this alternative would reroute the sewer to the south by means of a duplex lift station. The wastewater would be pump through approximately 750 LF of 4-inch ductile iron force main installed within the Trillium Park Drive ROW and would discharge into an existing manhole on Gilman Drive, which is approximately 12’ higher in elevation. It is assumed that the lift station would be comprised of a 72” wet well, dual 150 gpm submersible pumps, and have an above-grade enclosure for the electrical panel.

Option 2 –Restore Travel Path and Utilities

Under the Restore Travel Path alternative, the roadway would be restored to support vehicular traffic and the gravity sewer would be restored to an acceptable level of service. Under two of the three alternatives, the existing water line would also be restored.

Geotechnical Alternative 2 –Tie-Back Wall

Under this alternative, an approximately 230-foot long, 40-foot high tie-back retaining wall would be constructed to stabilize the slide area. This would allow the roadway and utilities to be reconstructed to match original design conditions.

Alternative 2.2.5 – Restore Travel Path and Utilities. Construct Tie-back Wall and Replace Existing Sewer and Waterline as Required

This alternative proposes to reconstruct approximately 320 lineal feet (LF) of existing 8-inch diameter sewer main and one manhole damaged by the landslide in its original location. The 8-inch ductile iron water main that was damaged and abandoned would be reconstructed as well. Following reconstruction of the utilities, the roadway, curbs, gutters, and sidewalks would also be reconstructed in their existing location.

Geotechnical Alternative 3 –Geofoam Fill

Under this alternative the existing roadway would be reconstructed utilizing geofoam blocks in place of standard structural fill. To reduce project costs, this alternative proposes to reconfigure the road as a one-lane multi-modal roadway. This alternative would require excavation of the existing structural fill and replacement with geofoam to a minimum depth of 7’ as well as a concrete cap over the geofoam blocks to support the road base. All exposed ends of the geofoam blocks would need to be finished with a fascia or backfilled to protect the blocking. In general, it is assumed that all major utilities would need to be relocated outside of the geofoam fill.

Alternative 2.3.3 – Reconstruct Road with Geofoam as One-Way Multi-Modal Road. Restore Utility Service by Re-Routing Sewer via HDD

The sewer would be routed to the west of the slide area and utilize horizontal directional drilling (HDD) for the installation of a 10-inch HDPE sewer main. Two manholes would be installed within the ROW at the HDD entry and receiving pits. This alternative would also require easement acquisition.

Geotechnical Alternative 4 –Lightweight Concrete

Similar to the geofoam alternative, this alternative proposes to reconstruct the road using lightweight concrete in lieu of structural fill. However, due to the differences between how geofoam and lightweight concrete are installed, it is assumed that both the water and sewer lines would be restored. Due to the higher density of lightweight concrete, it is assumed that up to 15’ in depth of existing fill will need to be removed and replaced with lightweight concrete.

Alternative 2.4.5 – Reconstruct Road with Cellular Concrete Fill. Remove and Replace Existing Gravity Sewer and Waterline

Lightweight cellular concrete would serve support the road, which would be rebuilt to original design conditions. Utilities would then be restored, including the repair or replacement approximately 330 LF of existing 8-inch DI water main.

OREGON CITY

FIGURE 1

MAY 2019

JOB NO. 818-007

TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 1.0.3

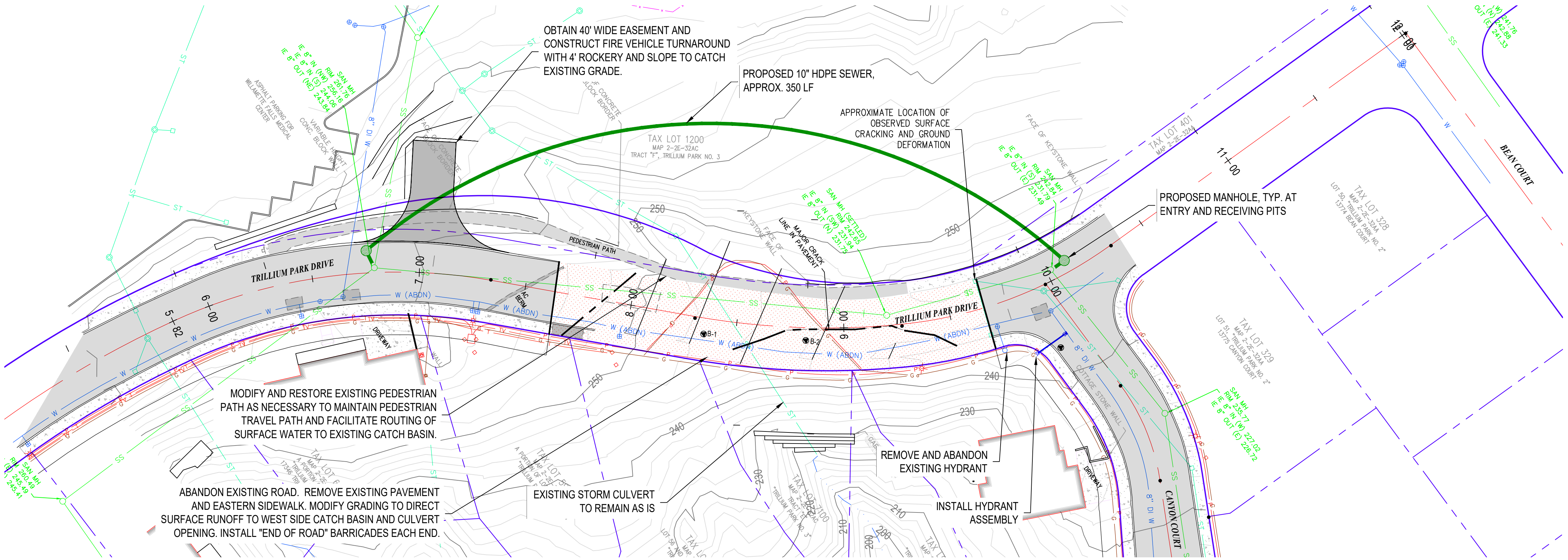
ABANDON ROAD AND DE-PAVE ROADWAY. BUILD VEHICLE TURNAROUND. RESTORE UTILITY SERVICE BY RE-ROUTING SEWER VIA HDD

SCALE: 1" = 30'

0" 1" 2"

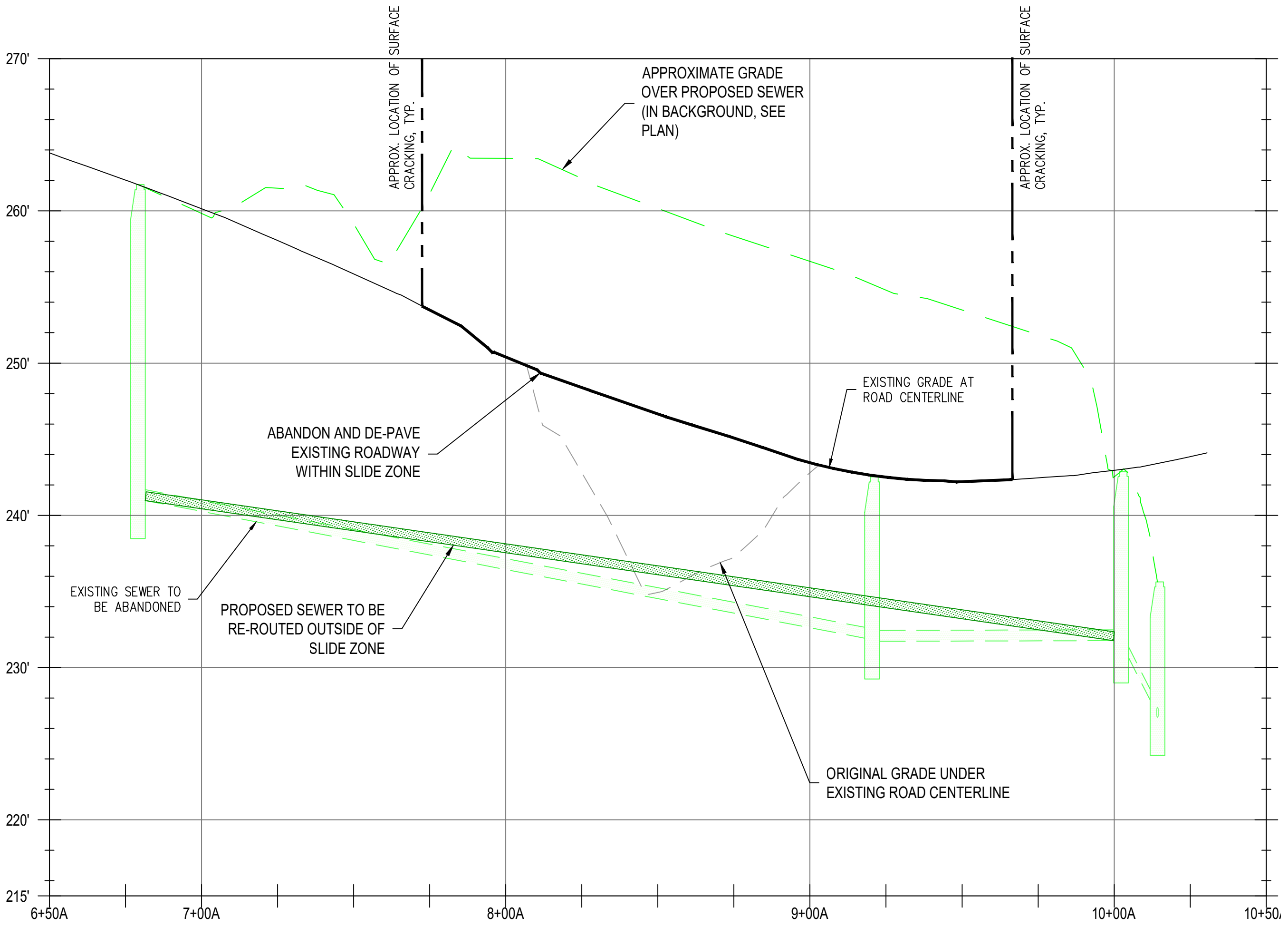
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2



PLAN VIEW

1" = 30'



PROFILE VIEW

H: 1" = 30', V: 1" = 6'

OREGON CITY

FIGURE 2
MAY 2019
JOB NO. 818-007

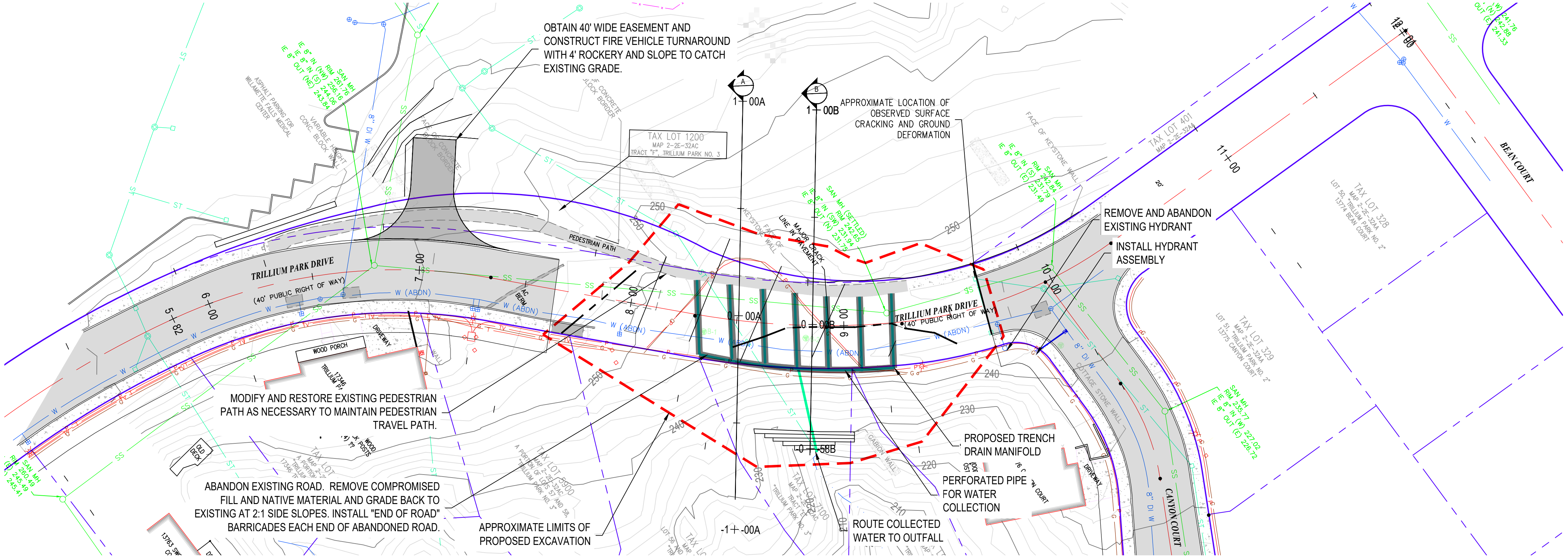
TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 1.1.1

ABANDON ROAD AND EXCAVATE OVERBURDEN. INSTALL DRAINAGE IMPROVEMENTS AND RECONSTRUCT EXISTING SEWER IN PLACE.

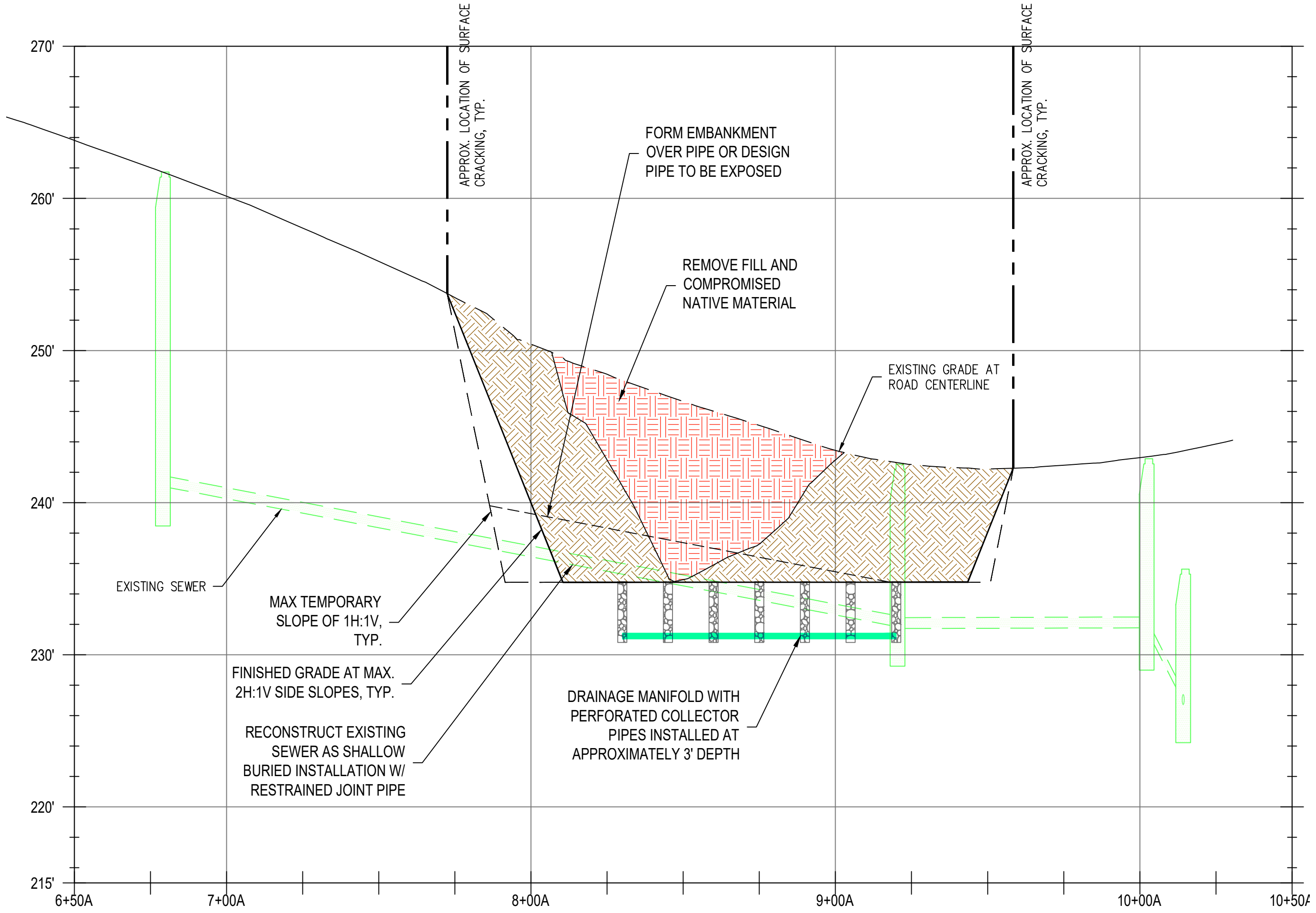
SCALE: 1" = 30'
0" 1" 2"
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2



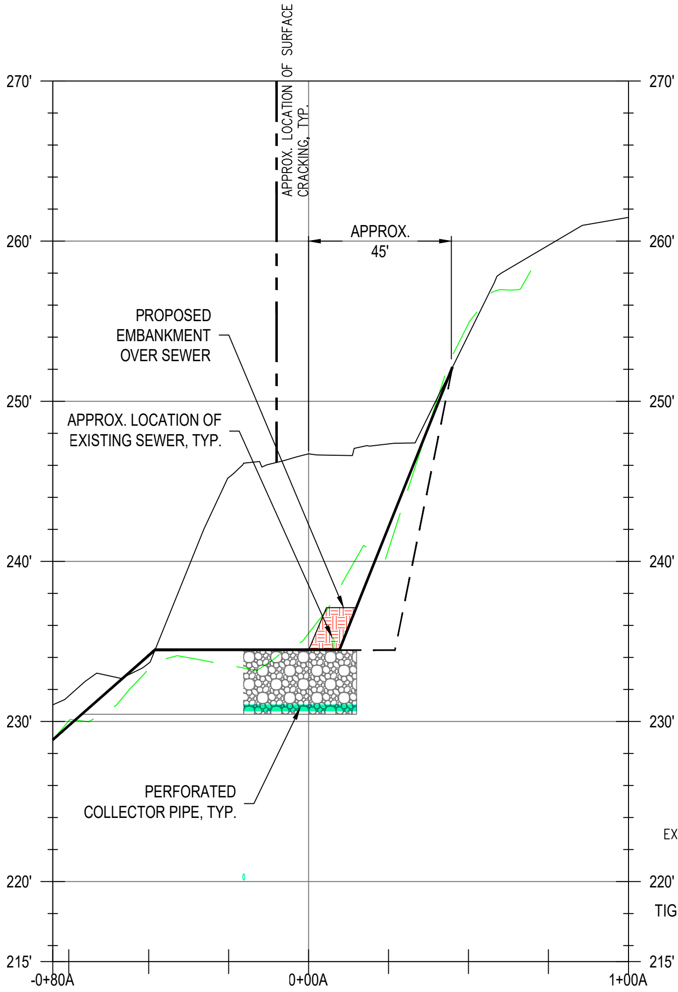
PLAN VIEW

1" = 30'



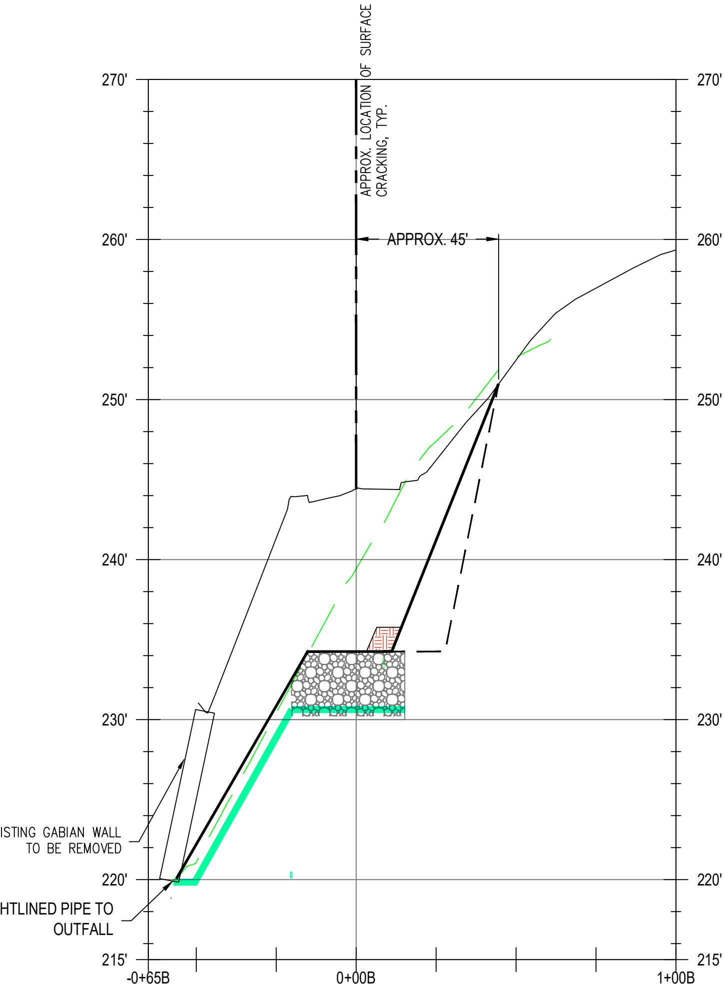
PROFILE VIEW

H: 1" = 30', V: 1" = 6'



SECTION VIEW (A)

H: 1" = 30', V: 1" = 6'



SECTION VIEW (B)

H: 1" = 30', V: 1" = 6'

OREGON CITY

FIGURE 3

MAY 2019

JOB NO. 818-007

TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 1.1.2

ABANDON ROAD AND EXCAVATE OVERBURDEN. INSTALL DRAINAGE IMPROVEMENTS AND RESTORE UTILITY SERVICE BY RE-ROUTING SEWER VIA OPEN CUT

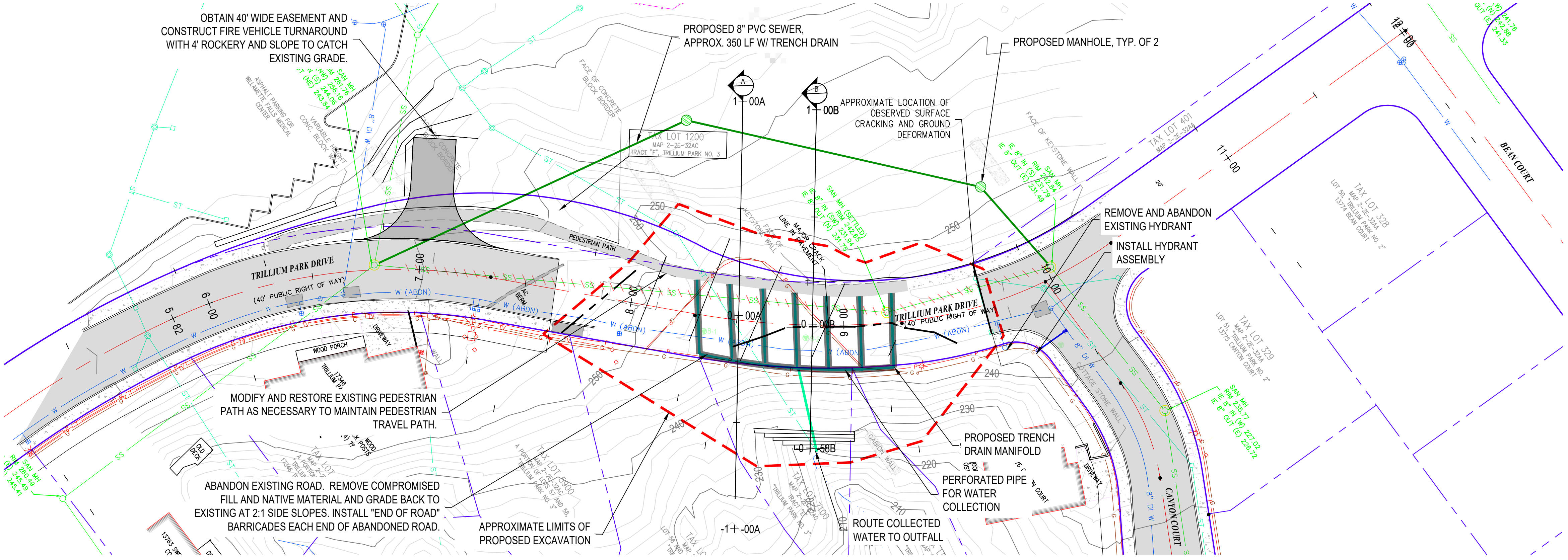
SCALE: 1" = 30'

0" 1" 2"

DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

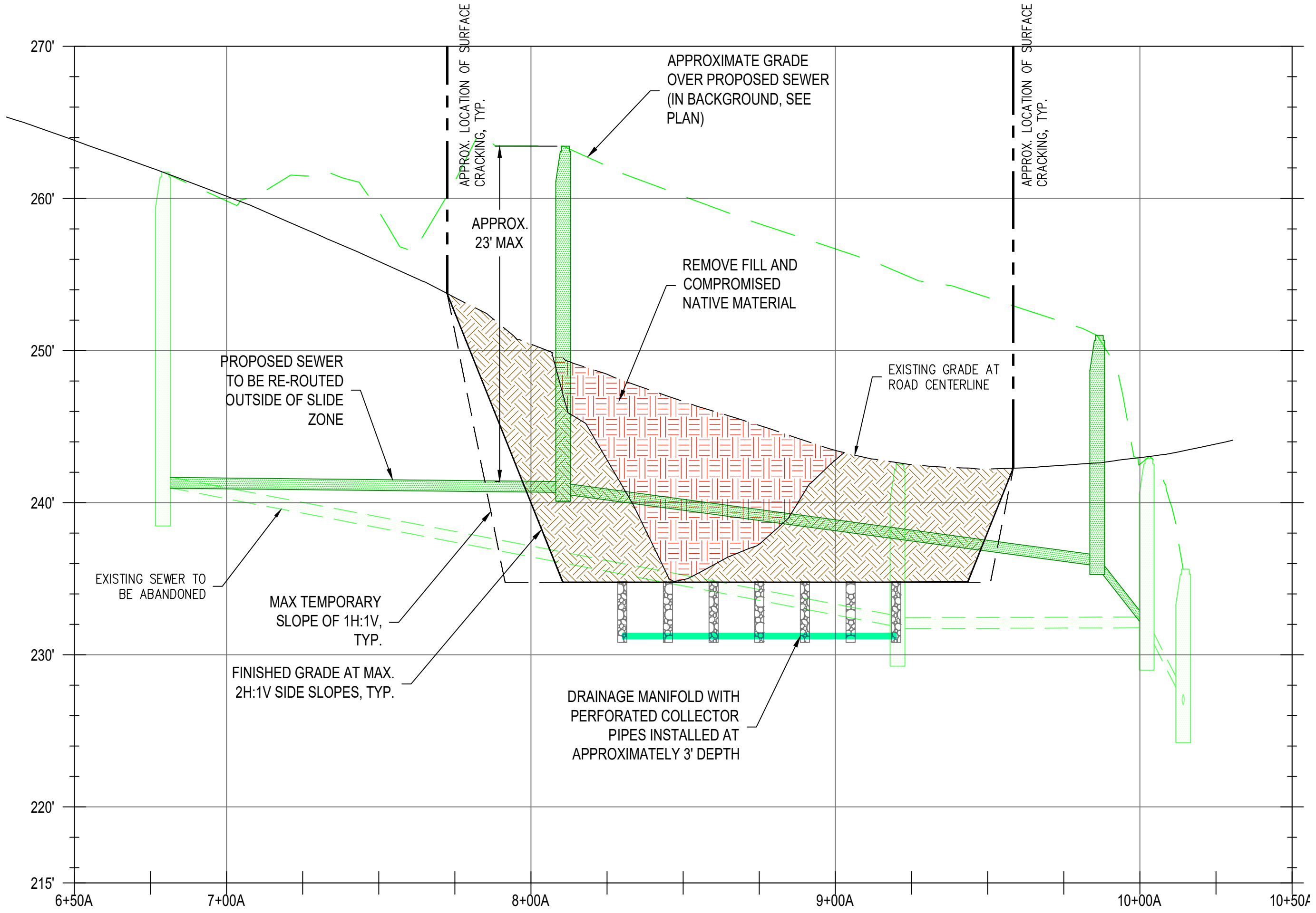
RH2

NOTE: NOT INCLUDED IN ALTERNATIVES EVALUATION DUE TO CONCERNS REGARDING RISK MITIGATION AND CONSTRUCTABILITY.



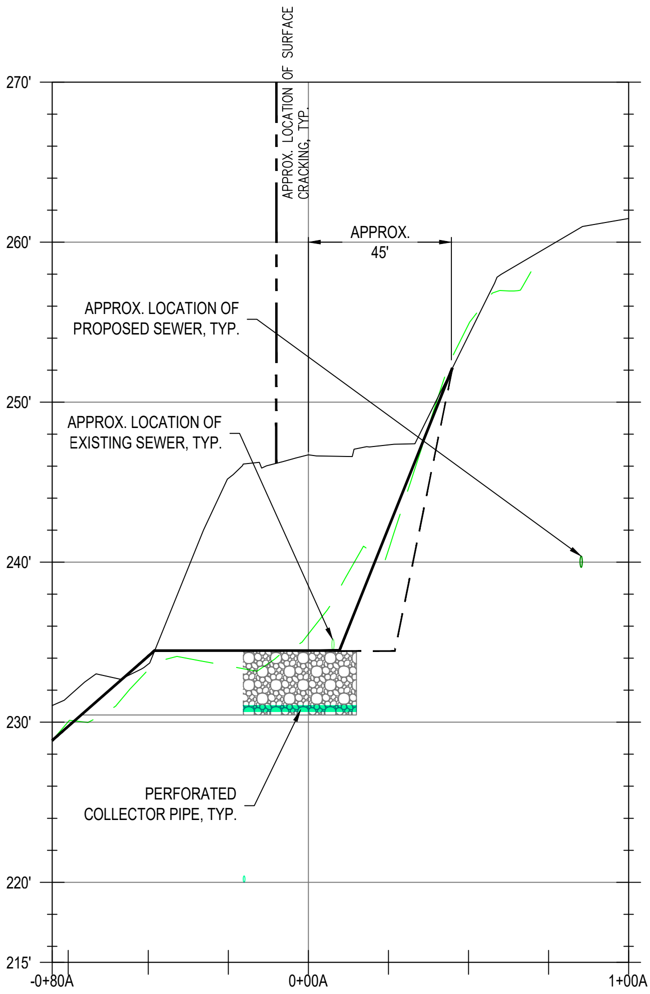
PLAN VIEW

1" = 30'



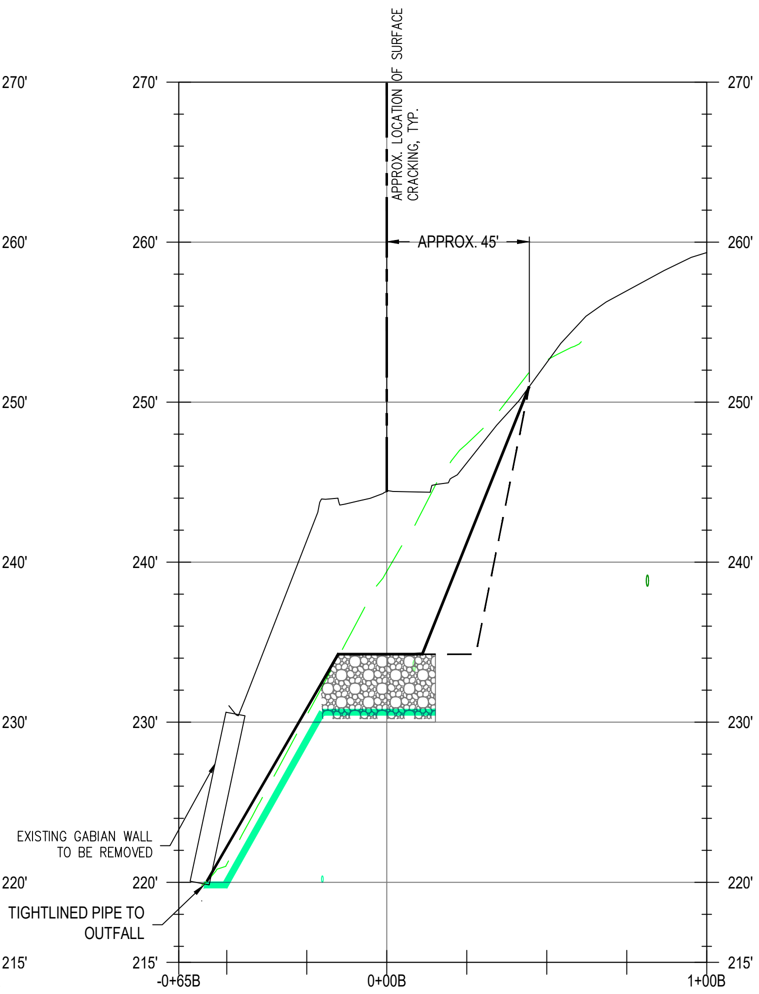
PROFILE VIEW

H: 1" = 30', V: 1" = 6'



SECTION VIEW (A)

H: 1" = 30', V: 1" = 6'



SECTION VIEW (B)

H: 1" = 30', V: 1" = 6'

OREGON CITY

FIGURE 4

MAY 2019

JOB NO. 818-007

TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 1.1.3

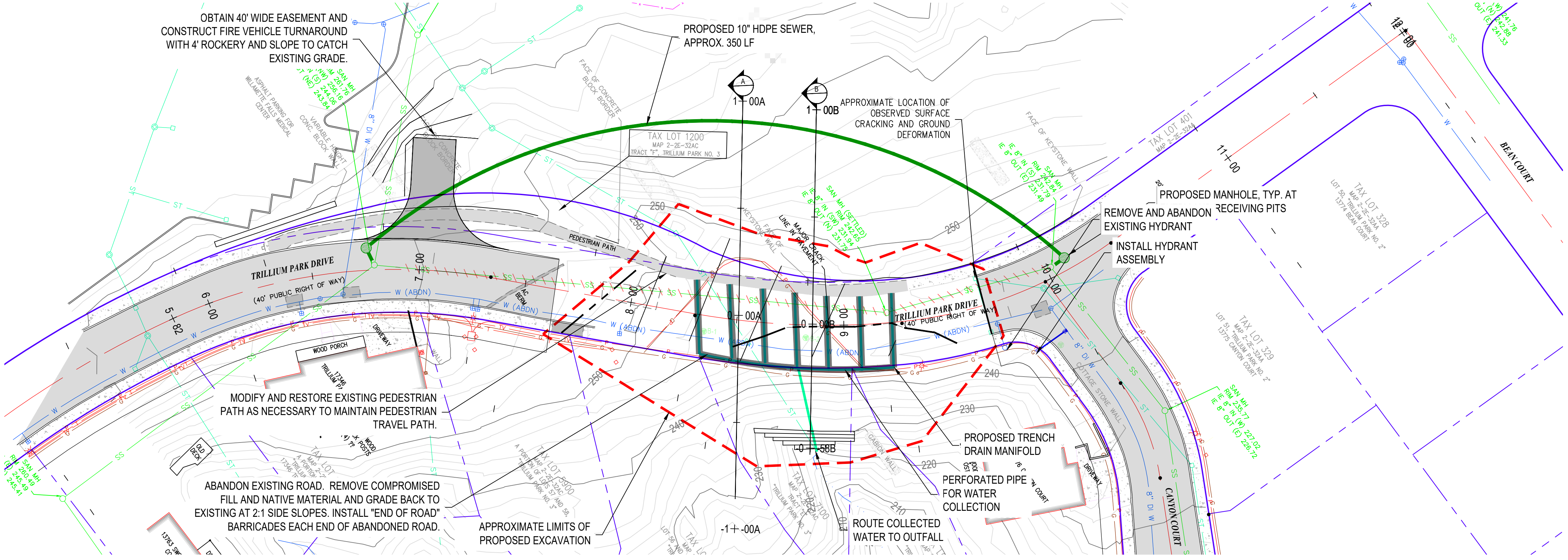
ABANDON ROAD AND EXCAVATE OVERBURDEN. INSTALL DRAINAGE IMPROVEMENTS AND RESTORE UTILITY SERVICE BY RE-ROUTING SEWER VIA HDD

SCALE: 1" = 30'

0" 1" 2"

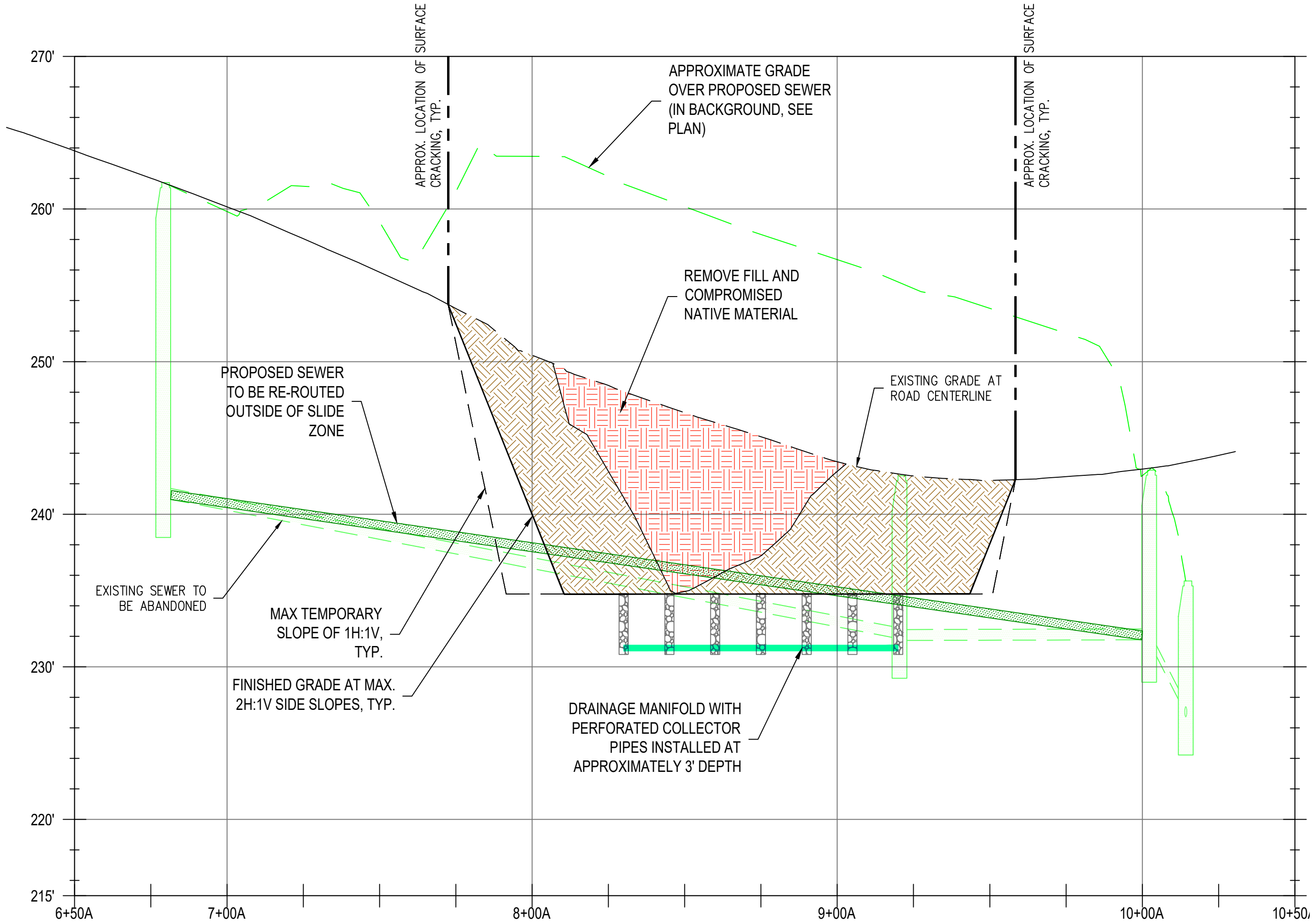
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2



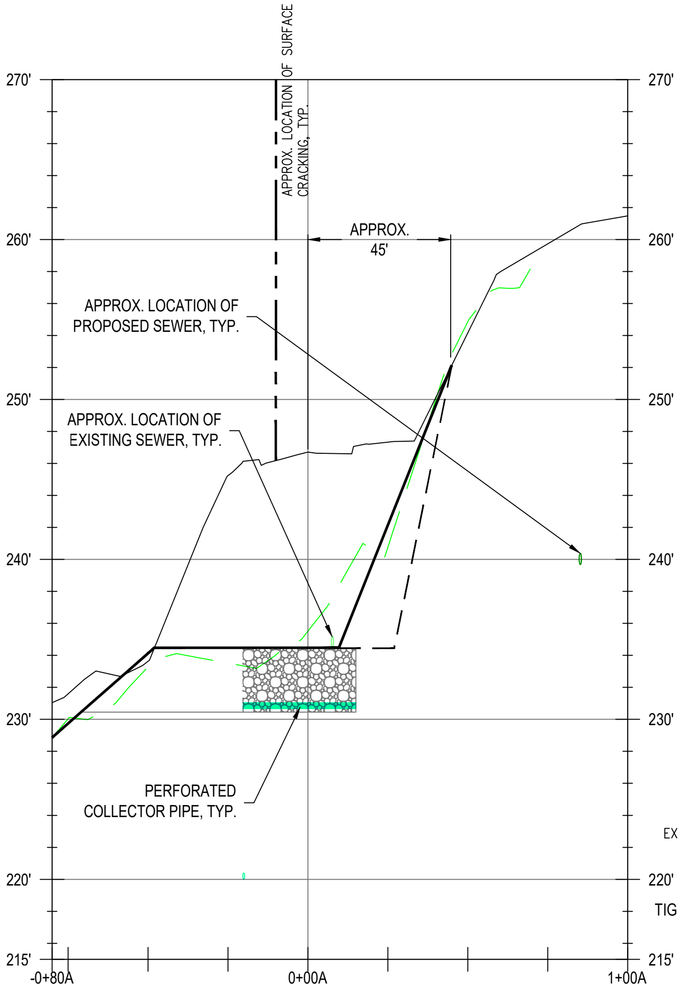
PLAN VIEW

1" = 30'



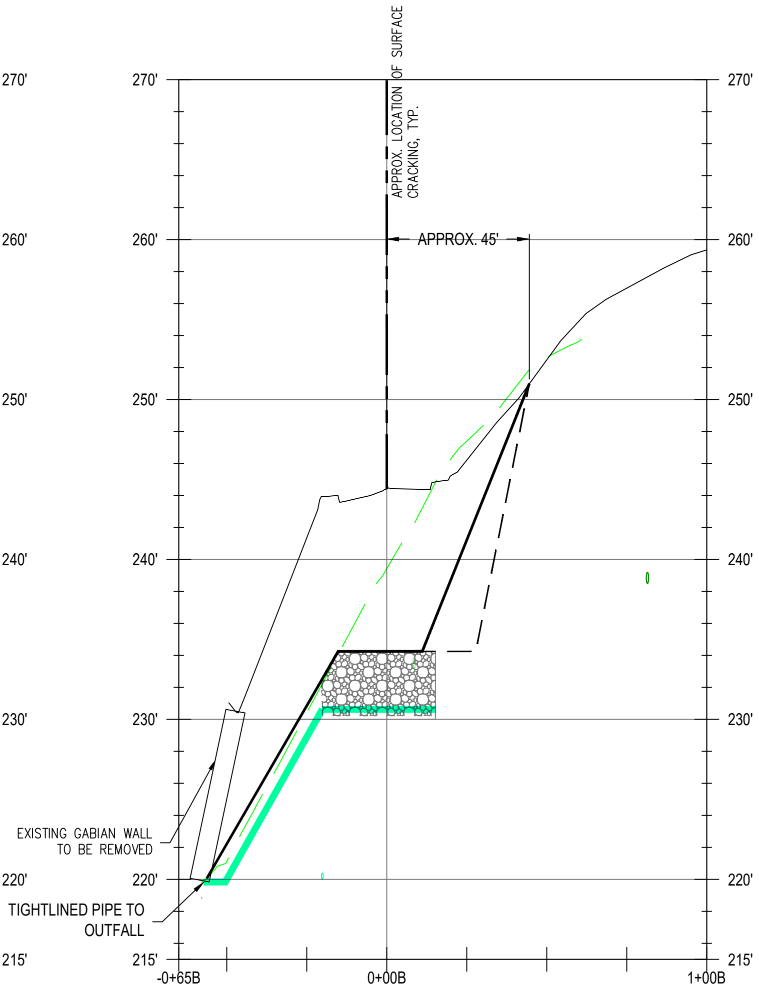
PROFILE VIEW

H: 1" = 30', V: 1" = 6'



SECTION VIEW A

H: 1" = 30', V: 1" = 6'



SECTION VIEW B

H: 1" = 30', V: 1" = 6'

OREGON CITY

FIGURE 5

MAY 2019

JOB NO. 818-007

TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 1.1.4

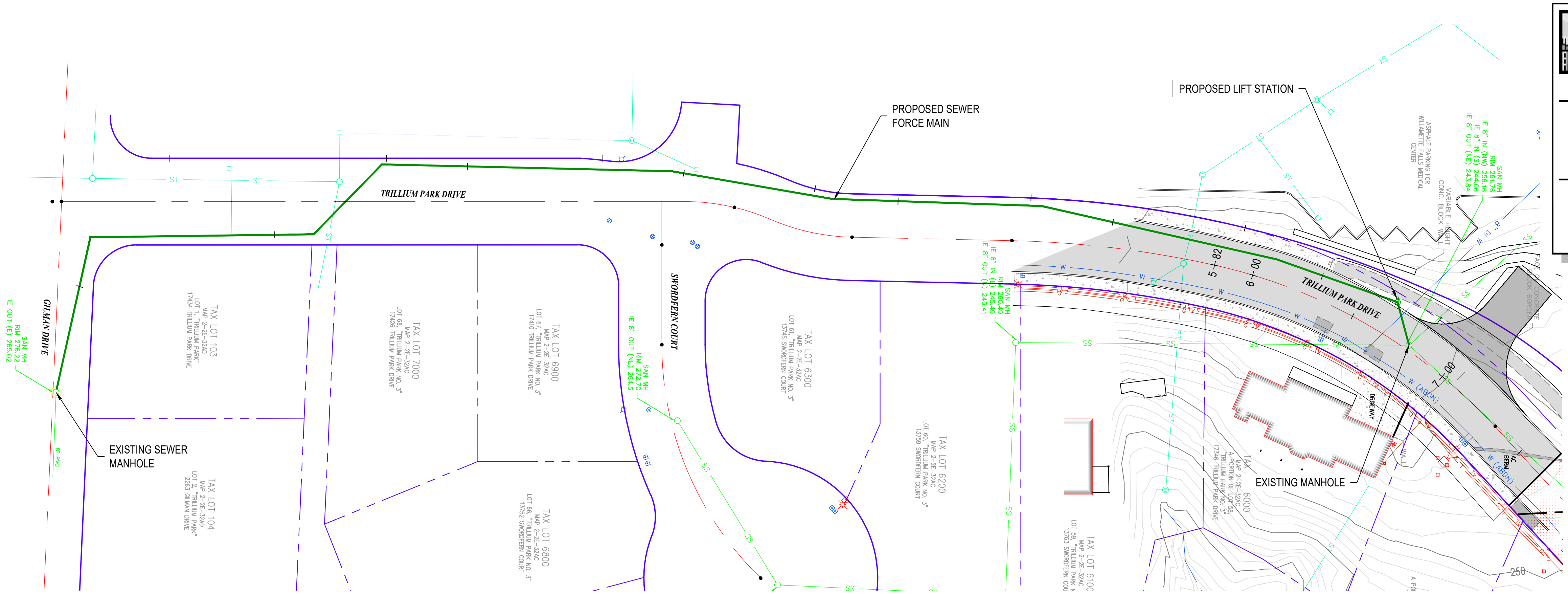
ABANDON ROAD AND EXCAVATE TO SUBGRADE. INSTALL VEHICLE TURNAROUND. INSTALL LIFT STATION AND RESTORE UTILITY SERVICE BY RE-ROUTING SEWER TO SOUTH

SCALE: 1" = 30'

0" 1" 2"

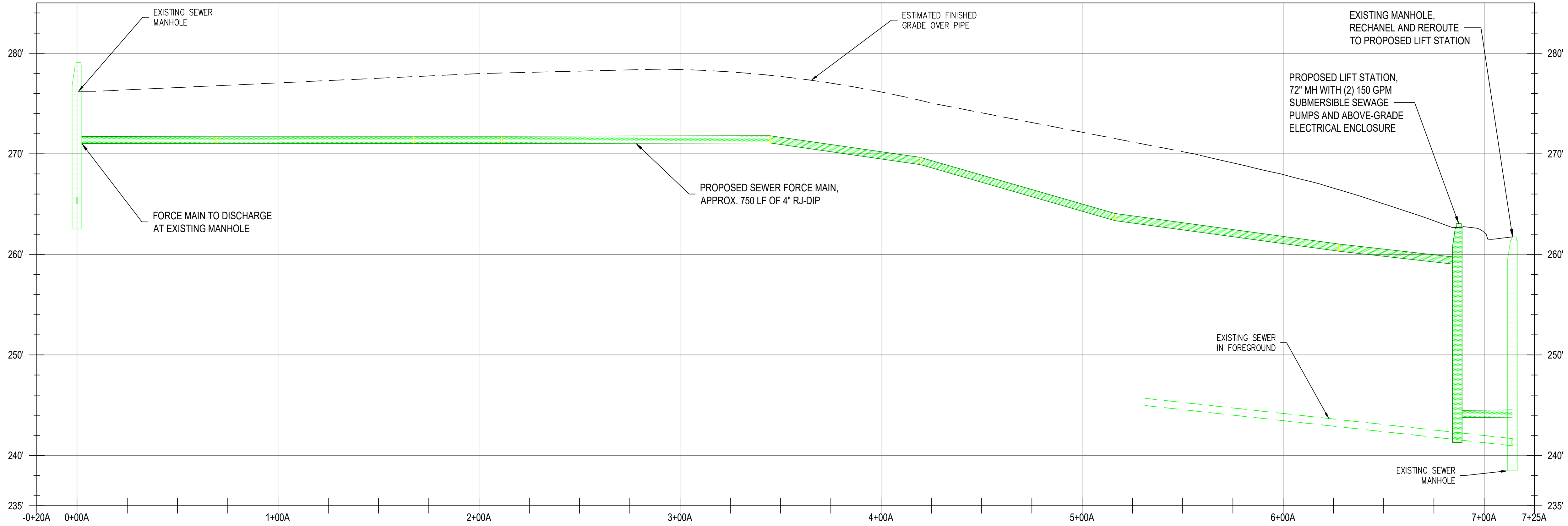
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2



PLAN VIEW

1" = 30'



PROFILE VIEW

H: 1" = 30', V: 1"= 6'

.LAYER

\DATA\ORC\818-007\CAD\TRILL-P-UTILP

OREGON CITY

FIGURE 6

MAY 2019

JOB NO. 818-007

TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 2.2.5

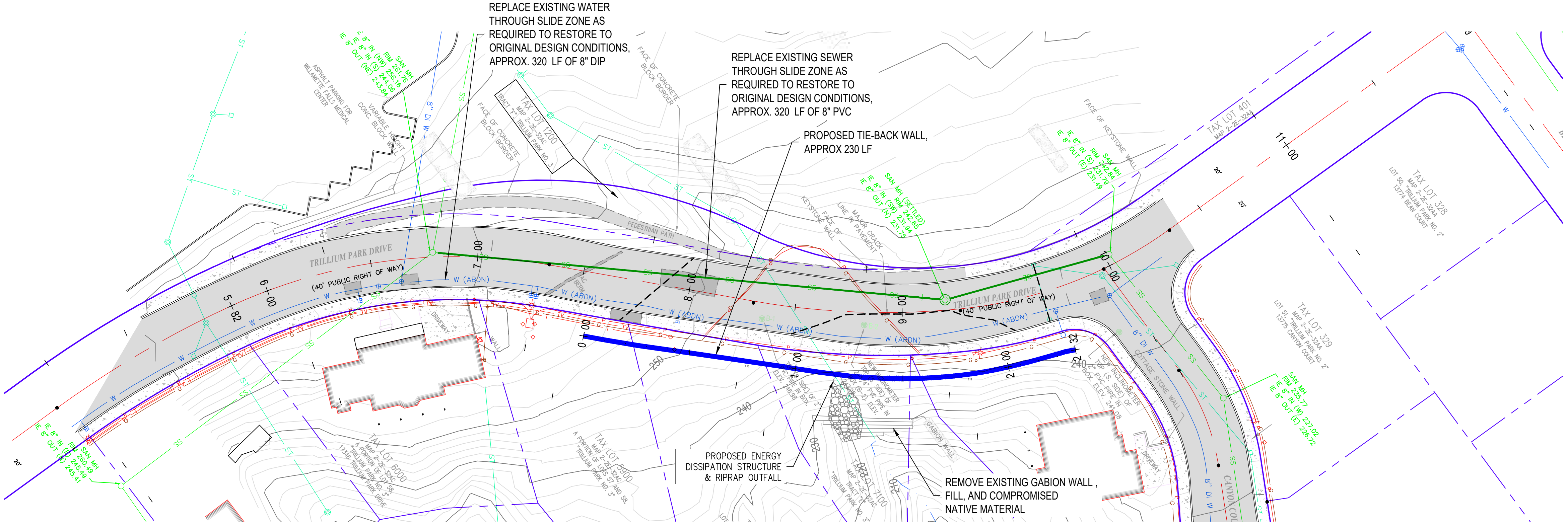
RESTORE TRAVEL PATH AND UTILITIES. CONSTRUCT TIE-BACK WALL AND REPLACE EXISTING SEWER AND WATERLINE AS REQUIRED.

SCALE: 1" = 30'

0" 1" 2"

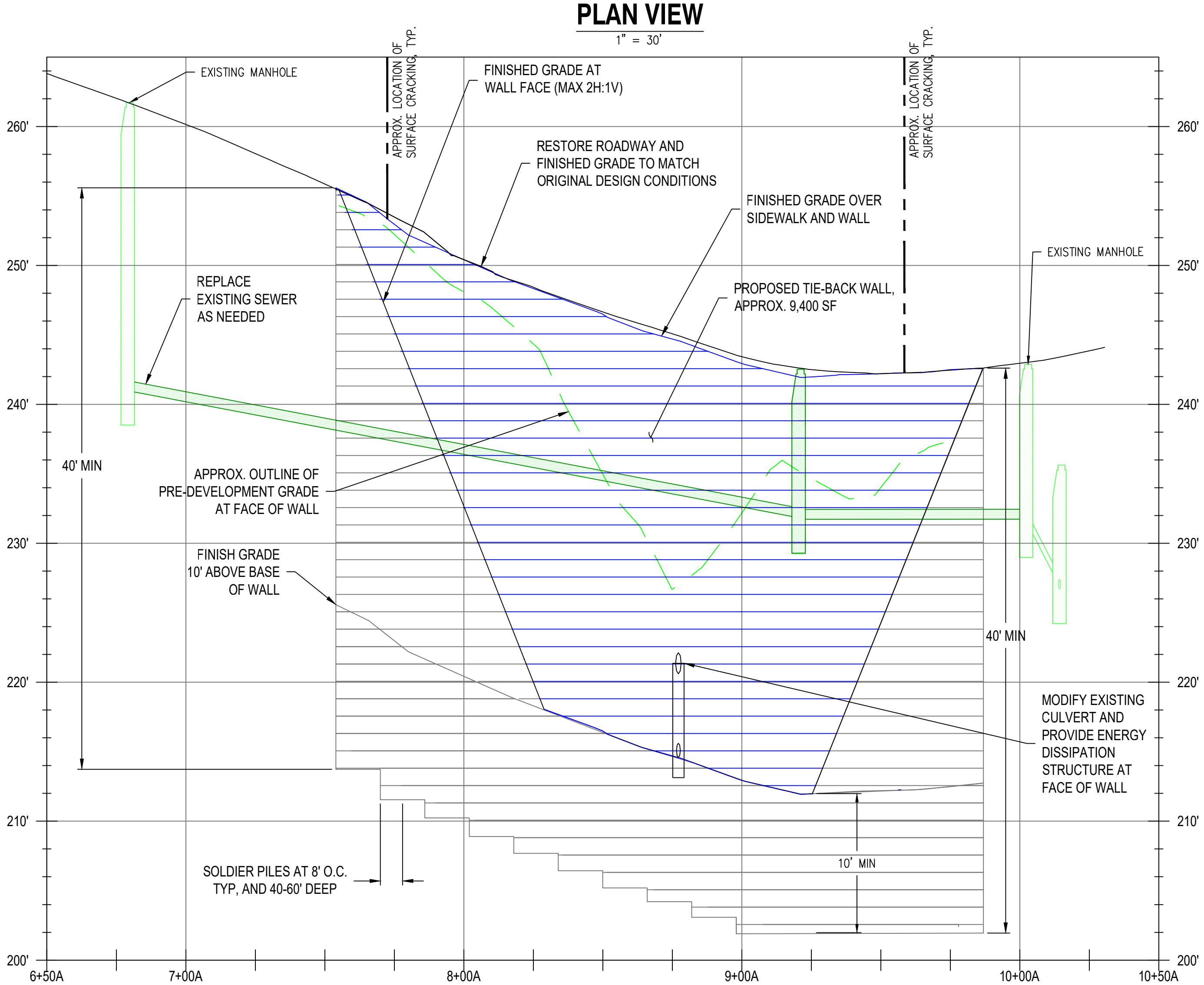
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2



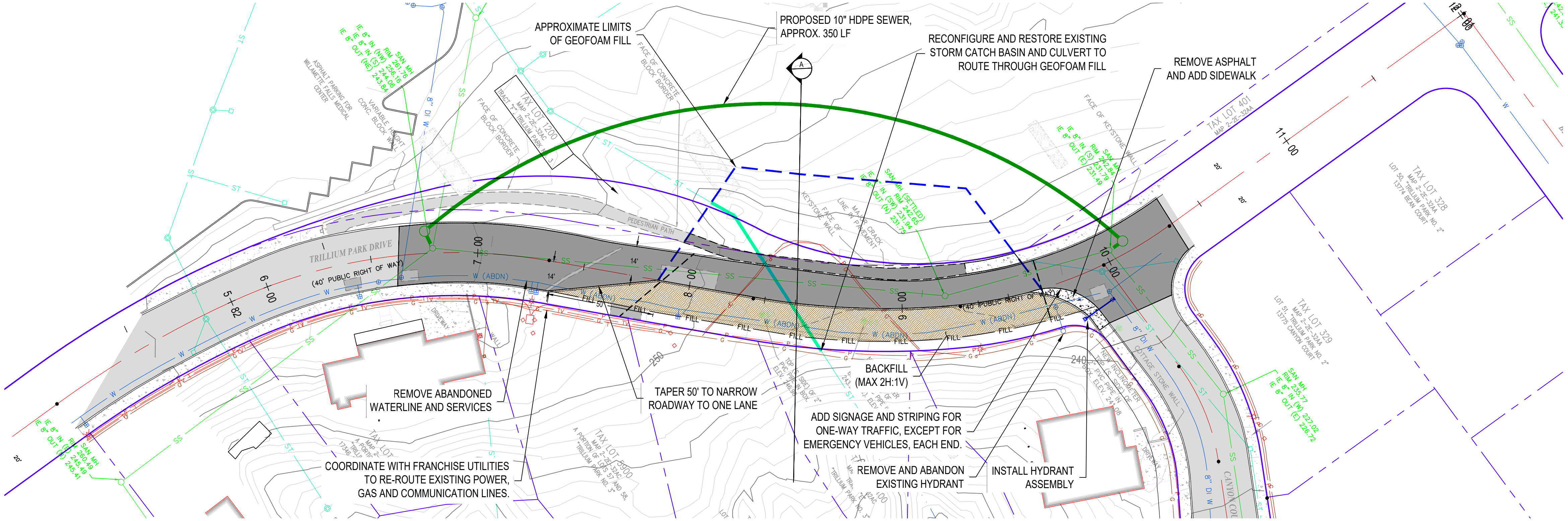
PLAN VIEW

1" = 30'

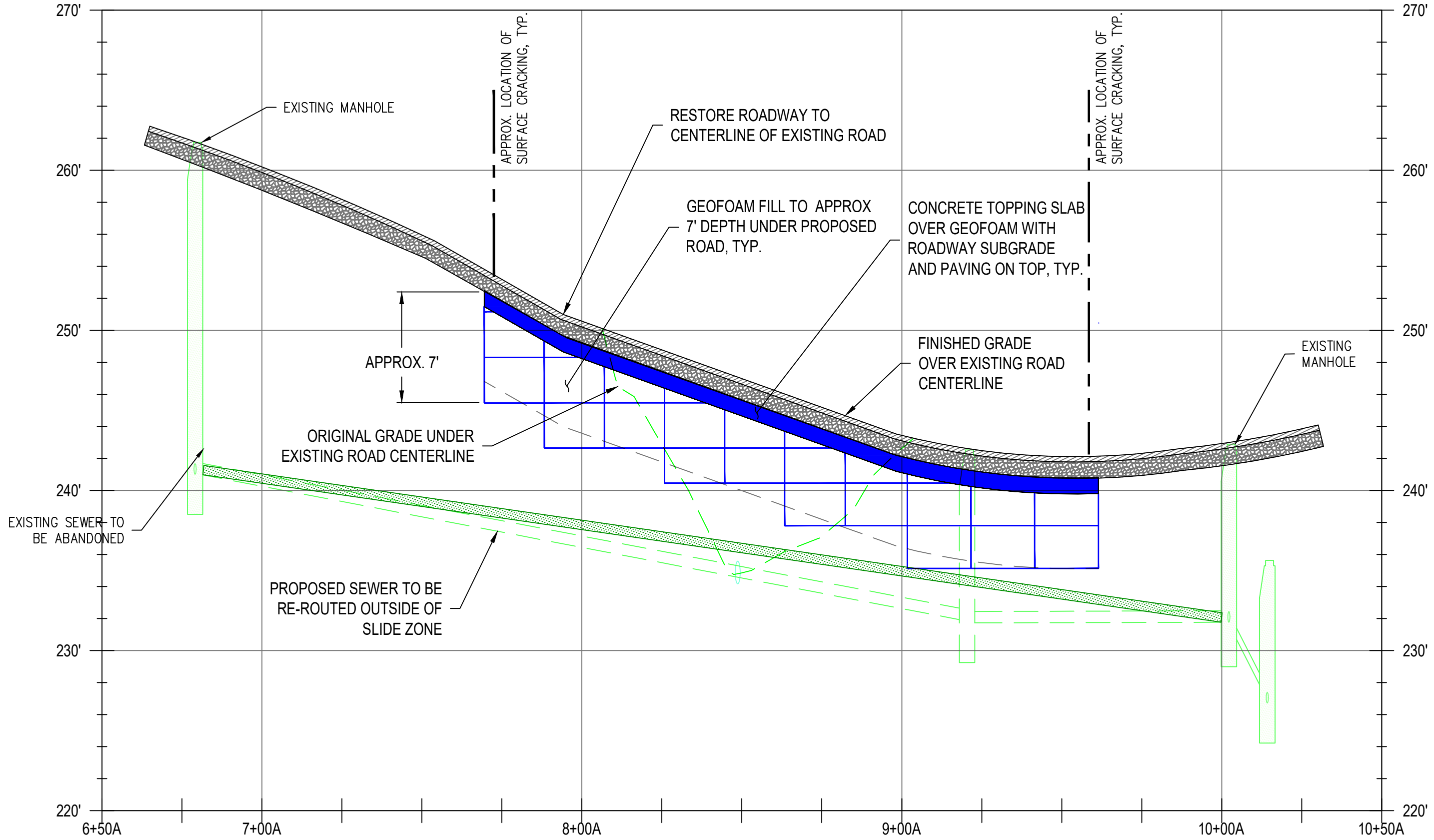


PROFILE VIEW

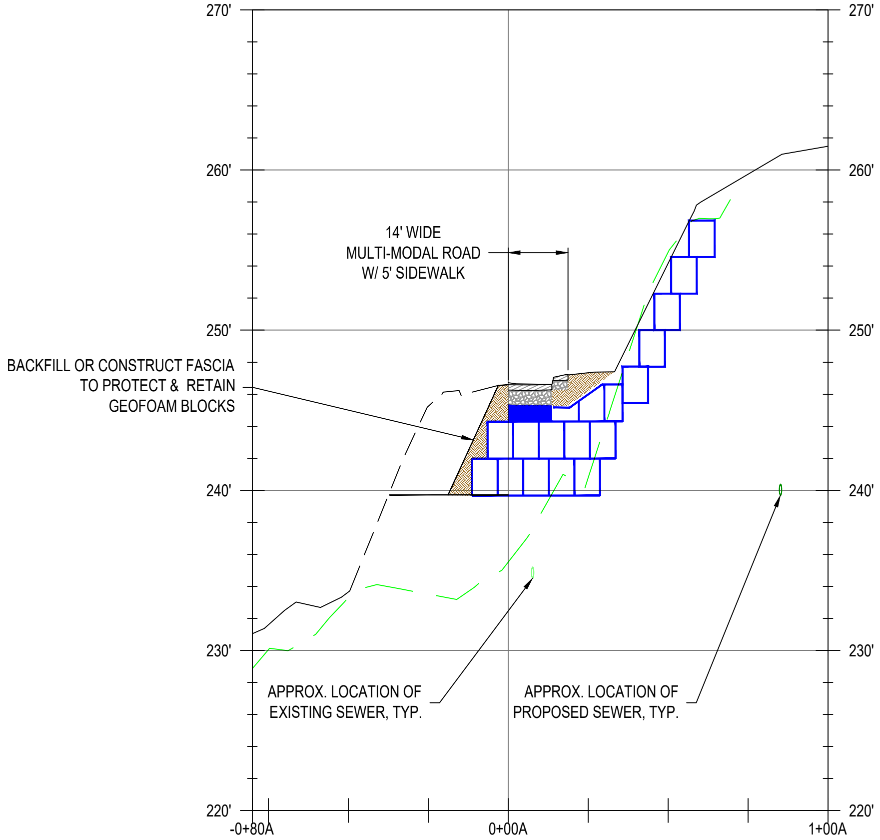
H: 1" = 30', V: 1" = 6'



PLAN VIEW
1" = 30'



PROFILE VIEW
H: 1" = 30', V: 1" = 6'



SECTION VIEW
A
H: 1" = 30', V: 1" = 6'

OREGON CITY

FIGURE 7
MAY 2019
JOB NO. 818-007

TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 2.3.3

RECONSTRUCT ROAD WITH GEOFOAM AS ONE-WAY / MULTI-MODAL ROAD.
RESTORE UTILITY SERVICE BY RE-ROUTING SEWER VIA HDD.

SCALE: 1" = 30'
0" 1" 2"
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2

OREGON CITY

FIGURE 8

MAY 2019

JOB NO. 818-007

TRILLIUM PARK DRIVE LANDSLIDE MITIGATION ALTERNATIVES ANALYSIS

ALTERNATIVE 2.4.5

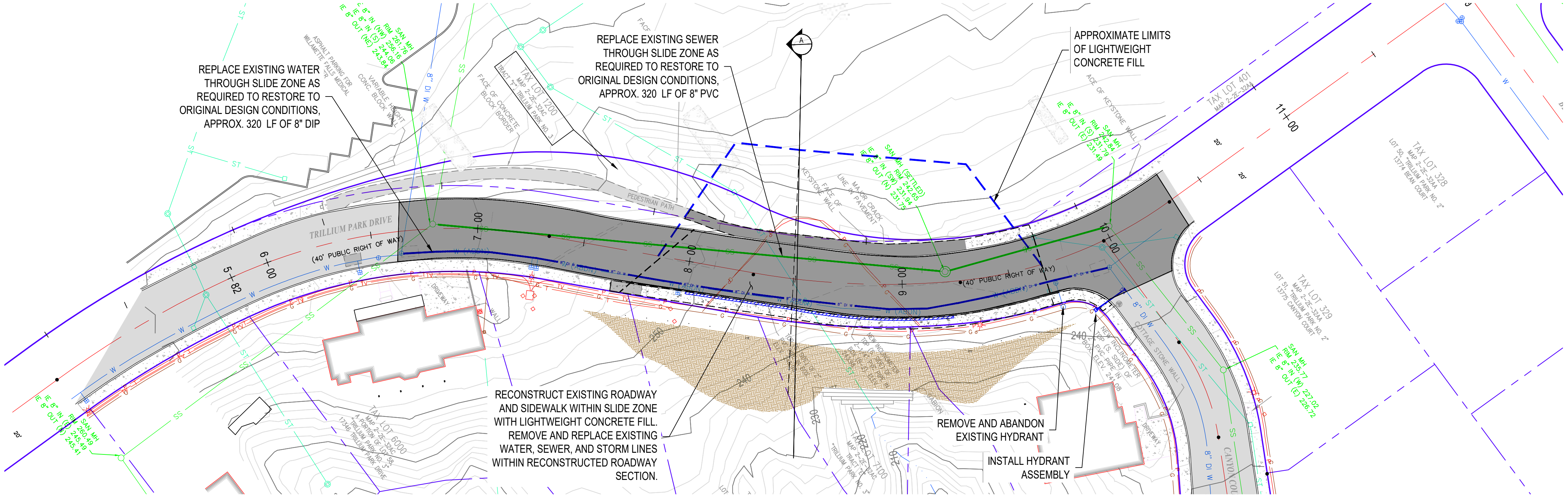
RECONSTRUCT ROAD WITH CELLULAR CONCRETE FILL. REMOVE AND REPLACE EXISTING GRAVITY SEWER AND WATERLINE

SCALE: 1" = 30'

0" 1" 2"

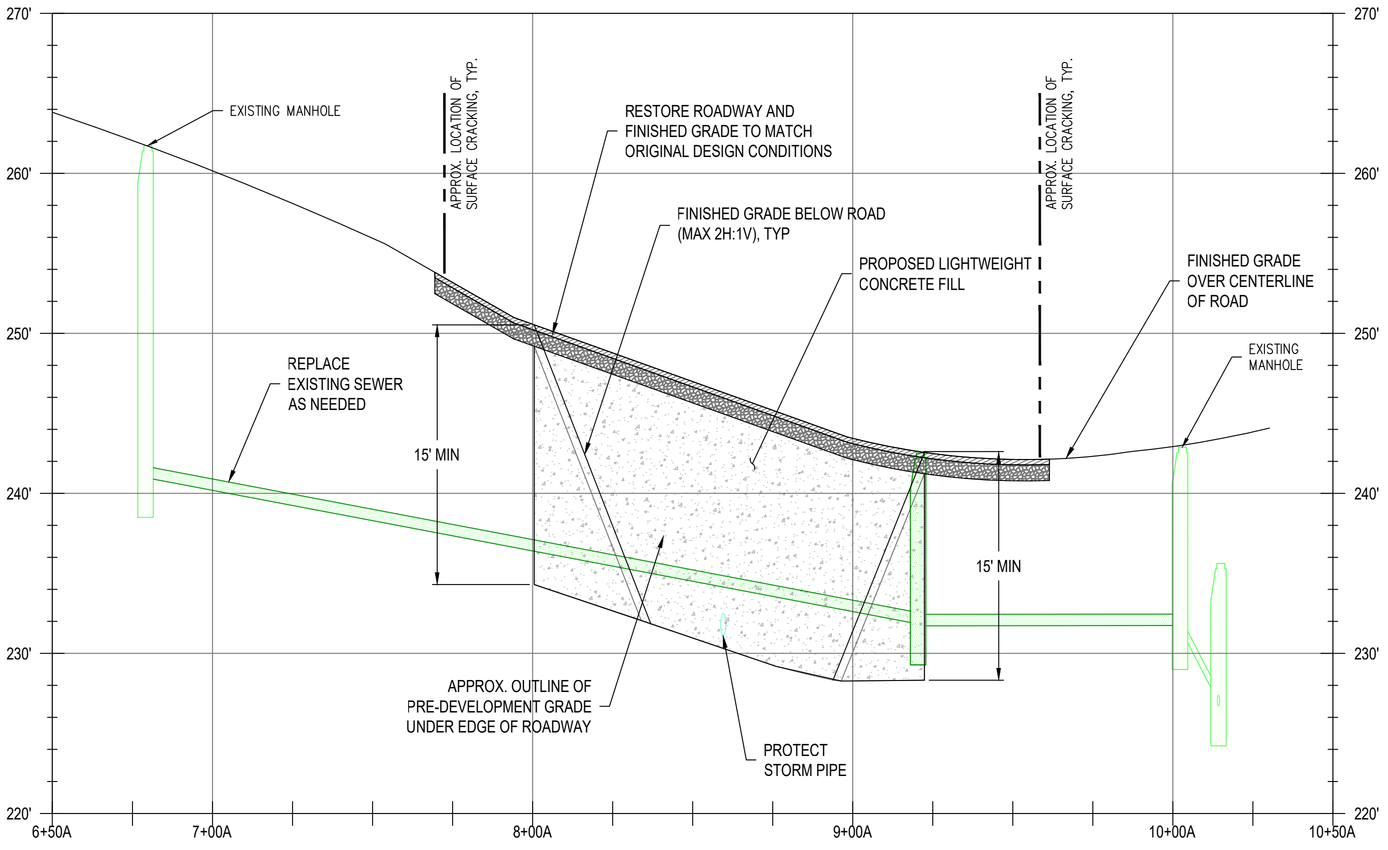
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2



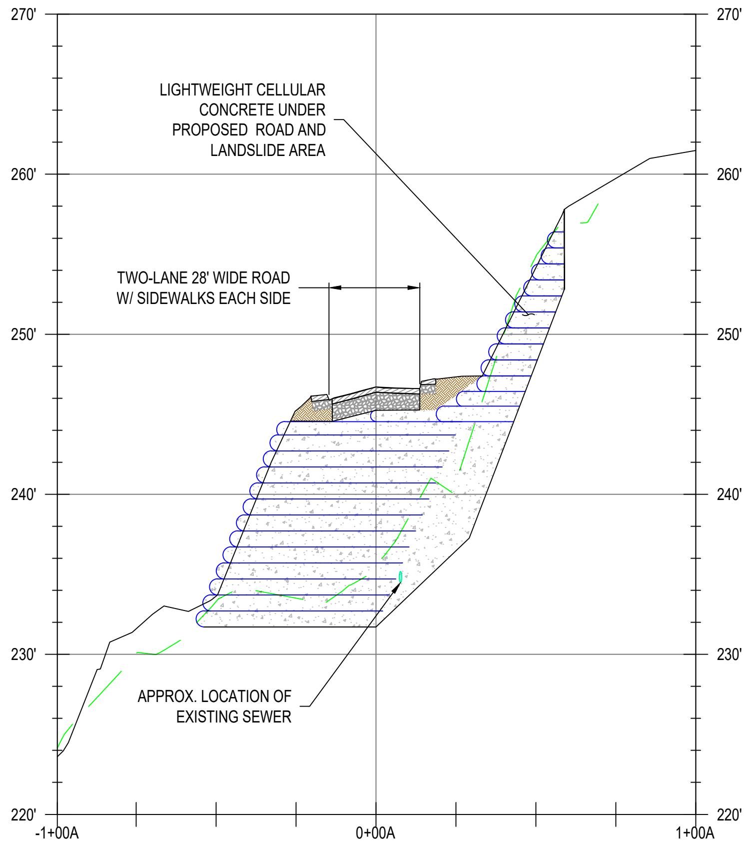
PLAN VIEW

1" = 30'



PROFILE VIEW

H: 1" = 30', V: 1" = 6'



SECTION VIEW

A

H: 1" = 30', V: 1" = 6'

Attachment 3

Opinions of Probable Construction Cost

THIS PAGE INTENTIONALLY LEFT BLANK

City of Oregon City 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Estimated Construction Cost

Option 1: Abandon Road and Reroute Utilities

Alternative	Description	Geotechnical Construction Cost	Utility Construction Cost	Total Estimated Direct Cost
1.0.3	Depave and Reroute using HDD	$230,000	$270,000	$500,000
1.1.1	Remove overburden, install drains, restore sewer in place	$760,000	$150,000	$910,000
1.1.2	Remove overburden, install drains, re-route using open-cut	$760,000	$320,000	$1,080,000
1.1.3	Remove overburden, install drains, re-route using HDD	$760,000	$270,000	$1,030,000
1.1.4	Remove overburden, install drains, re-route using lift station	$760,000	$1,010,000	$1,770,000

Option 2: Restore Travel Path and Utilities

Alternative	Description	Geotechnical Construction Cost	Utility Construction Cost	Total Estimated Direct Cost
2.2.5	Construct tie-back wall and restore roadway and utilities	$2,130,000	$190,000	$2,320,000
2.3.3*	Reconstruct roadway (one lane) with geofoam blocks and re-route sewer using HDD	$680,000	$270,000	$950,000
2.4.5**	Reconstruct roadway with lightweight cellular concrete and restore utilities	$1,540,000	$190,000	$1,730,000

* Estimate based on reconstructing roadway with one lane. It is estimated that reconstructing the roadway with two lanes using geofoam blocks would add approximately 30% more cost.

** Estimate based on reconstructing roadway with two lanes. It is estimated that reconstructing the roadway with one lane using cellular concrete would reduce costs by approximately 30%.

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Geotechnical Alternative 0: Abandon Road and Depave Roadway (Do Not Mitigate Landslide)					
Item	**Description**	**Quantity**	**Unit**	**Unit Price**	**Total**
1	Mobilization	1	LS	$12,500	$12,500
2	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
3	Erosion and Sediment Control	1	LS	$2,000	$2,000
4	Remove and Abandon Fire Hydrant	1	EA	$2,500	$2,500
5	Install Hydrant Assembly	1	EA	$6,000	$6,000
6	Remove Existing Roadway and Sidewalk	11,500	SF	$3	$34,500
7	Vehicle Turnaround Road Base (6" Depth)	133	SY	$55	$7,400
8	Vehicle Turnaround HMA (4" Depth)	133	SY	$28	$3,800
9	Site Grading	1	LS	$10,000	$10,000
10	Rockery, 4' Max Height	47	LF	$200	$9,400
11	Barricades	2	EA	$1,600	$3,200
12	Restore Curbs and Gutters	0	LF	$60	$0
13	Restore Asphalt Pathway, 5' Wide	30	LF	$45	$1,400
14	Easement Acquisition for Vehicle Turnaround	1	LS	$20,000	$20,000
15	Easement Acquisition for Utilities	1	LS	$50,000	$50,000
			Alternative Subtotal		$170,000
			Contingency (30%)		$51,000
	Geotechnical Alternative 0 Total Estimated Construction Cost				***$230,000***

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Geotechnical Alternative 1: Excavation of Overburden and Drainage Improvements

Item	Description	Quantity	Unit	Unit Price	Total
1	Mobilization	1	LS	$37,200	$37,200
2	Construction Survey Work	1	LS	$5,000	$5,000
3	Temporary Drainage Facilities	1	LS	$10,000	$10,000
4	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
5	Temporary Erosion and Sediment Control	1	LS	$10,000	$10,000
6	Removal of Structures & Obstructions	1	LS	$35,000	$35,000
7	Clearing and Grubbing	0.25	AC	$35,000	$8,800
8	Remove and Abandon Fire Hydrant	1.00	EA	$2,500	$2,500
9	Install Fire Hydrant	1.00	EA	$6,000	$6,000
10	Overburden Excavation and Grading	4600	CY	$40	$184,000
11	Vehicle Turnaround Road Base (6" Depth)	133	SY	$55	$7,400
12	Vehicle Turnaround HMA (4" Depth)	133	SY	$28	$3,800
13	Rockery, 4' Max Height	47	LF	$200	$9,400
14	Barricades	2	EA	$1,600	$3,200
15	Drainage Improvements (Excavation and Backfill w/ Drain Rock, Perf Pipe)	385	LF	$100	$38,500
16	Permanent Erosion Control (Matting & Hydroseed)	1400	SY	$17	$23,800
17	Permanent Erosion Control (Class 50 Rip-Rap)	500	SY	$15	$7,500
18	Easment Aquisistion for Vehicle Turnaround	1	LS	$20,000	$20,000
19	Easment Aquisistion for Vehicle Utilities	1	LS	$50,000	$50,000
			Alternative Subtotal		$502,100
			Contingency (50%)		$251,050
	Geotechnical Alternative 1 Total Estimated Construction Cost				***$760,000***

Assumptions:

1. Removal of Structures and Obstructions item includes removal of asphalt pavement, sidewalks, gabion wall, culvert pipe, abandoned water pipe and sanitary sewer pipe and manholes.

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Geotechnical Alternative 2: Tie-Back Wall

Item	Description	Quantity	Unit	Unit Price	Total
1	Mobilization	1	LS	$104,800	$104,800
2	Construction Survey Work	1	LS	$5,000	$5,000
3	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
4	Temporary Erosion and Sediment Control	1	LS	$20,000	$20,000
5	Removal of Structures & Obstructions	1	LS	$35,000	$35,000
6	Clearing and Grubbing	0.38	AC	$35,000	$13,300
7	Tie-Back Retaining Wall	9400	SF	$80	$752,000
8	Overburden Excavation and Grading	8000	CY	$40	$320,000
9	Restore Road Base (12" Depth)	756	SY	$55	$41,600
10	Restore HMA (4" Depth)	1,214	SY	$55	$66,800
11	Restore Curbs and Gutters	420	LF	$60	$25,200
12	Restore Sidewalks, Concrete	1,250	SF	$15	$18,800
13	Restore Asphalt Pathway, 5' Wide	135	LF	$45	$6,100
			Alternative Subtotal		$1,413,600
			Contingency (50%)		$706,800
	Geotechnical Alternative 2 Total Estimated Construction Cost				***$2,130,000***

Assumptions:

1. Removal of Structures and Obstructions item includes removal of asphalt pavement, sidewalks, gabion wall, culvert pipe, abandoned water pipe and sanitary sewer pipe and manholes.
2. Drainage improvements are incidental to tie-back wall construction.

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Geotechnical Alternative 3: Reconstruct Road with Geofoam as One-Way Multi-Modal

Item	Description	Quantity	Unit	Unit Price	Total
1	Mobilization	1	LS	$33,300	$33,300
2	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
3	Erosion and Sediment Control	1	LS	$2,000	$2,000
4	Remove and Abandon Fire Hydrant	1	EA	$2,500	$2,500
5	Install Hydrant Assembly	1	EA	$6,000	$6,000
6	Removal of Structures & Obstructions	1	LS	$35,000	$35,000
7	Excavate for Geofoam in Slide Zone and under Roadway	1,500	CY	$40	$60,000
8	Restore Road Base (12" Depth)	503	SY	$55	$27,700
9	Restore HMA (4" Depth)	820	SY	$55	$45,100
10	Restore Curbs and Gutters	165	LF	$60	$9,900
11	Restore Sidewalks, Concrete	340	SF	$15	$5,100
12	Restore Asphalt Pathway, 5' Wide	136	LF	$45	$6,200
13	Topping Slab (1' Thick Lightweight Concrete)	93	CY	$120	$11,200
14	Geofoam in Slide Zone and Under Roadway	1,250	CY	$120	$150,000
15	Easement Acquisition for Utilities	1	LS	$50,000	$50,000
			Alternative Subtotal		$449,000
			Contingency (50%)		$224,500
	Alternative 2.3.3 Total Estimated Construction Cost				***$680,000***

Assumptions:

1. Removal of Structures and Obstructions item includes removal of asphalt pavement, sidewalks, gabion wall, culvert pipe, abandoned water pipe and sanitary sewer pipe and manholes.
2. Drainage improvements are incidental to tie-back wall construction.

Item	Description	Quantity	Unit	Unit Price	Total
	Geotechnical Alternative 4: Reconstruct Road with Cellular Concrete Fill				
1	Mobilization	1	LS	$75,600	$75,600
2	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
3	Erosion and Sediment Control	1	LS	$2,000	$2,000
4	Remove and Abandon Fire Hydrant	1	EA	$2,500	$2,500
5	Install Hydrant Assembly	1	EA	$6,000	$6,000
6	Removal of Structures & Obstructions	1	LS	$35,000	$35,000
7	Excavate for Lightweight Cellular Concrete in Slide Zone and under Roadway	4,600	CY	$40	$184,000
8	Restore Road Base (12" Depth)	756	SY	$55	$41,600
9	Restore HMA (4" Depth)	1,214	SY	$55	$66,800
10	Restore Curbs and Gutters	420	LF	$60	$25,200
11	Restore Sidewalks, Concrete	1,250	SF	$15	$18,800
12	Restore Asphalt Pathway, 5' Wide	135	LF	$45	$6,100
13	Lightweight Cellular Concrete in Slide Zone and Under Roadway	4,600	CY	$120	$552,000
		Alternative Subtotal			$1,020,600
		Contingency (50%)			$510,300
	Geotechnical Alternative 4 Total Estimated Construction Cost				***$1,540,000***

Assumptions:

1. Removal of Structures and Obstructions item includes removal of asphalt pavement, sidewalks, gabion wall, culvert pipe, abandoned water pipe and sanitary sewer pipe and manholes.
2. Drainage improvements are incidental to tie-back wall construction.

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Utility Alternative 1: Abandon Road and Reconstruct Sewer In Place					
Item	**Description**	**Quantity**	**Unit**	**Unit Price**	**Total**
1	Mobilization	1	LS	$8,000	$8,000
2	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
3	Erosion and Sediment Control	1	LS	$2,000	$2,000
4	Construction Survey Work	1	LS	$5,000	$5,000
5	8-inch RJ DI Sanitary Sewer Pipe w/ Class B Backfill (Open-Cut)	320	LF	$190	$60,800
6	Replace Existing Manhole, 48" Dia.	1	EA	$7,000	$7,000
7	Bypass Pumping	1	LS	$20,000	$20,000
	Alternative Subtotal				$107,800
	Contingency (30%)				$32,340
	Utility Alternative 1 Total Estimated Construction Cost				***$150,000***

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Utility Alternative 2: Re-Route Gravity Sewer via Open Cut					
Item	**Description**	**Quantity**	**Unit**	**Unit Price**	**Total**
1	Mobilization	1	LS	$17,900	$17,900
2	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
3	Erosion and Sediment Control	1	LS	$2,000	$2,000
4	Construction Survey Work	1	LS	$5,000	$5,000
5	Removal of Structures & Obstructions	1	LS	$5,000	$5,000
6	Clearing and Grubbing	0.20	AC	$35,000	$7,000
7	8-inch PVC Sanitary Sewer Pipe w/ Class B Backfill and Trench Drain (Open-Cut)	350	LF	$250	$87,500
8	Concrete Sanitary Sewer Manhole, 48" Dia.	2	EA	$15,000	$30,000
9	Wall and Path Restoration	1	LS	$10,000	$10,000
10	Trench Resurfacing, HMAC, 4-inch Depth	20	SY	$55	$1,100
11	Tree Removal Mitigation	1	LS	$20,000	$20,000
12	Easement Acquisition	1	LS	$50,000	$50,000
			Alternative Subtotal		$240,500
			Contingency (30%)		$72,150
			Utility Alternative 2 Total Estimated Construction Cost		***$320,000***

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Item	Description	Quantity	Unit	Unit Price	Total
1	Mobilization	1	LS	$15,000	$15,000
2	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
3	Erosion and Sediment Control	1	LS	$2,000	$2,000
4	Construction Survey Work	1	LS	$5,000	$5,000
5	10-inch HDPE Sanitary Sewer Pipe (HDD)	350	LF	$300	$105,000
6	8-inch PVC Sanitary Sewer Pipe w/ Class B Backfill (Open Cut)	20	LF	$175	$3,500
7	Concrete Sanitary Sewer Manhole, 48" Dia.	2	EA	$7,000	$14,000
8	Trench Resurfacing, HMAC, 4-inch Depth	40	SY	$55	$2,200
8	Easement Acquisition	1	LS	$50,000	$50,000
			Alternative Subtotal		$201,700
			Contingency (30%)		$60,510
			Utility Alternative 3 Total Estimated Construction Cost		***$270,000***

Table title: ***Utility Alternative 3: Re-Route Gravity Sewer via HDD***

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Utility Alternative 4: Re-Route Gravity Sewer via Lift Station

Item	Description	Quantity	Unit	Unit Price	Total
1	Mobilization	1	LS	$57,600	$57,600
2	Work Zone Traffic Control, Complete	1	LS	$20,000	$20,000
3	Erosion and Sediment Control	1	LS	$8,000	$8,000
4	Construction Survey Work	1	LS	$10,000	$10,000
5	4-inch DI Sanitary Sewer Force Main	750	LF	$75	$56,300
6	Duplex Submersible Lift Station w/ Electrical Shelter	1	LS	$600,000	$600,000
7	Trench Resurfacing, HMAC, 4-inch Depth	450	SY	$55	$24,800
			Alternative Subtotal		$776,700
			Contingency (30%)		$233,010
			Utility Alternative 4 Total Estimated Construction Cost		***$1,010,000***

City of Oregon City Updated: 5/31/2019

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Utility Alternative 5: Restore Roadway and Replace Sewer and Waterline					
Item	**Description**	**Quantity**	**Unit**	**Unit Price**	**Total**
1	Mobilization	1	LS	$10,800	$10,800
2	Work Zone Traffic Control, Complete	1	LS	$5,000	$5,000
3	Erosion and Sediment Control	1	LS	$2,000	$2,000
4	Construction Survey Work	1	LS	$5,000	$5,000
5	8-inch PVC Sanitary Sewer Pipe w/ Class B Backfill (Open-Cut)	320	LF	$190	$60,800
6	Replace Existing Manhole, 48" Dia.	1	EA	$7,000	$7,000
7	Bypass Pumping	1	LS	$20,000	$20,000
8	8-inch DI Water Main	325	LF	$105	$34,200
			Alternative Subtotal		$144,800
			Contingency (30%)		$43,440
			Utility Alternative 5 Total Estimated Construction Cost		***$190,000***

THIS PAGE INTENTIONALLY LEFT BLANK

Attachment 4
Alternatives Evaluation and Sensitivity Analysis

THIS PAGE INTENTIONALLY LEFT BLANK

City of Oregon City
Trillium Park Drive Landslide Mitigation Alternatives Analysis
Evaluation Matrix
(highest score = most viable option)

Sensitivity Analysis Description
Equal weighting of all criteria.

CRITERIA	POINTS	Alternative 1.0.3	Alternative 1.1.1	Alternative 1.1.3	Alternative 1.1.4	Alternative 2.2.5	Alternative 2.3.3	Alternative 2.4.5
Capital Improvement Cost								
Weighting Factor	1							
Over $1,500,0000	1				1	1		1
Over $1,000,0000	2							
Less than $1,000,0000	3	3	3	3			3	
Landslide Risk Mitigation								
Weighting Factor	1							
FS <= 1.0	0	0						
FS <= 1.2	1		1	1	1		1	1
FS > 1.2	2					2		
Utility Level of Service								
Weighting Factor	1							
Sewer Lift Station and Force Main	1				1			
Gravity Sewer, Easement Required	2	2		2				
Gravity Sewer, No Easement	3		3				3	
Gravity Sewer and Water Main, No Easement	4					4		4
Roadway Level of Service								
Weighting Factor	1							
Abandon Roadway and Remove Overburden	1		1	1	1			
Abandon Roadway and Depave	2	2						
Restore as One-Way Multimodal Road	3						3	
Restore as Two-Way Road	4					4		4
TOTAL UNWEIGHTED SCORE	13	7	8	7	4	11	10	10
TOTAL WEIGHTED SCORE	13	7	8	7	4	11	10	10
PRIORITY RANKING		**5**	**4**	**5**	**7**	**1**	**2**	**2**

City of Oregon City

Trillium Park Drive Landslide Mitigation Alternatives Analysis

Evaluation Matrix

(highest score = most viable option)

Sensitivity Analysis Description

Equal weighting of all criteria.

CRITERIA	POINTS	Alternative 1.0.3	Alternative 1.1.1	Alternative 1.1.3	Alternative 1.1.4	Alternative 2.2.5	Alternative 2.3.3	Alternative 2.4.5
Capital Improvement Cost								
Weighting Factor	2							
Over $1,500,0000	1				1	1		1
Over $1,000,0000	2							
Less than $1,000,0000	3	3	3	3			3	
Landslide Risk Mitigation								
Weighting Factor	1							
FS <= 1.0	0	0						
FS <= 1.2	1		1	1	1		1	1
FS > 1.2	2					2		
Utility Level of Service								
Weighting Factor	1							
Sewer Lift Station and Force Main	1				1			
Gravity Sewer, Easement Required	2	2		2				
Gravity Sewer, No Easement	3		3				3	
Gravity Sewer and Water Main, No Easement	4					4		4
Roadway Level of Service								
Weighting Factor	1							
Abandon Roadway and Remove Overburden	1		1	1	1			
Abandon Roadway and Depave	2	2						
Restore as One-Way Multimodal Road	3						3	
Restore as Two-Way Road	4					4		4
TOTAL UNWEIGHTED SCORE	13	7	8	7	4	11	10	10
TOTAL WEIGHTED SCORE	16	10	11	10	5	12	13	11
PRIORITY RANKING		**5**	**3**	**5**	**7**	**2**	**1**	**3**

City of Oregon City
Trillium Park Drive Landslide Mitigation Alternatives Analysis
Evaluation Matrix
(highest score = most viable option)

Sensitivity Analysis Description
Equal weighting of all criteria.

CRITERIA	POINTS	Alternative 1.0.3	Alternative 1.1.1	Alternative 1.1.3	Alternative 1.1.4	Alternative 2.2.5	Alternative 2.3.3	Alternative 2.4.5
Capital Improvement Cost								
Weighting Factor	1							
Over $1,500,0000	1				1	1		1
Over $1,000,0000	2							
Less than $1,000,0000	3	3	3	3			3	
Landslide Risk Mitigation								
Weighting Factor	2							
FS <= 1.0	0	0						
FS <= 1.2	1		1	1	1		1	1
FS > 1.2	2					2		
Utility Level of Service								
Weighting Factor	1							
Sewer Lift Station and Force Main	1				1			
Gravity Sewer, Easement Required	2	2		2				
Gravity Sewer, No Easement	3		3				3	
Gravity Sewer and Water Main, No Easement	4					4		4
Roadway Level of Service								
Weighting Factor	1							
Abandon Roadway and Remove Overburden	1		1	1	1			
Abandon Roadway and Depave	2	2						
Restore as One-Way Multimodal Road	3						3	
Restore as Two-Way Road	4					4		4
TOTAL UNWEIGHTED SCORE	13	7	8	7	4	11	10	10
TOTAL WEIGHTED SCORE	15	7	9	8	5	13	11	11
PRIORITY RANKING		**6**	**4**	**5**	**7**	**1**	**2**	**2**

City of Oregon City
Trillium Park Drive Landslide Mitigation Alternatives Analysis
Evaluation Matrix
(highest score = most viable option)

Sensitivity Analysis Description
Equal weighting of all criteria.

CRITERIA	POINTS	Alternative 1.0.3	Alternative 1.1.1	Alternative 1.1.3	Alternative 1.1.4	Alternative 2.2.5	Alternative 2.3.3	Alternative 2.4.5
Capital Improvement Cost								
Weighting Factor	1							
Over $1,500,0000	1				1	1		1
Over $1,000,0000	2							
Less than $1,000,0000	3	3	3	3			3	
Landslide Risk Mitigation								
Weighting Factor	1							
FS <= 1.0	0	0						
FS <= 1.2	1		1	1	1		1	1
FS > 1.2	2					2		
Utility Level of Service								
Weighting Factor	2							
Sewer Lift Station and Force Main	1				1			
Gravity Sewer, Easement Required	2	2		2				
Gravity Sewer, No Easement	3		3				3	
Gravity Sewer and Water Main, No Easement	4					4		4
Roadway Level of Service								
Weighting Factor	1							
Abandon Roadway and Remove Overburden	1		1	1	1			
Abandon Roadway and Depave	2	2						
Restore as One-Way Multimodal Road	3						3	
Restore as Two-Way Road	4					4		4
TOTAL UNWEIGHTED SCORE	13	7	8	7	4	11	10	10
TOTAL WEIGHTED SCORE	17	9	11	9	5	15	13	14
PRIORITY RANKING		**5**	**4**	**5**	**7**	**1**	**3**	**2**

City of Oregon City
Trillium Park Drive Landslide Mitigation Alternatives Analysis
Evaluation Matrix
(highest score = most viable option)

Sensitivity Analysis Description
Equal weighting of all criteria.

CRITERIA	POINTS	Alternative 1.0.3	Alternative 1.1.1	Alternative 1.1.3	Alternative 1.1.4	Alternative 2.2.5	Alternative 2.3.3	Alternative 2.4.5
Capital Improvement Cost								
Weighting Factor	1							
Over $1,500,0000	1				1	1		1
Over $1,000,0000	2							
Less than $1,000,0000	3	3	3	3			3	
Landslide Risk Mitigation								
Weighting Factor	1							
FS <= 1.0	0	0						
FS <= 1.2	1		1	1	1		1	1
FS > 1.2	2					2		
Utility Level of Service								
Weighting Factor	1							
Sewer Lift Station and Force Main	1				1			
Gravity Sewer, Easement Required	2	2		2				
Gravity Sewer, No Easement	3		3				3	
Gravity Sewer and Water Main, No Easement	4					4		4
Roadway Level of Service								
Weighting Factor	2							
Abandon Roadway and Remove Overburden	1		1	1	1			
Abandon Roadway and Depave	2	2						
Restore as One-Way Multimodal Road	3						3	
Restore as Two-Way Road	4					4		4
TOTAL UNWEIGHTED SCORE	13	7	8	7	4	11	10	10
TOTAL WEIGHTED SCORE	17	9	9	8	5	15	13	14
PRIORITY RANKING		**4**	**4**	**6**	**7**	**1**	**3**	**2**

City of Oregon City
Trillium Park Drive Landslide Mitigation Alternatives Analysis
Evaluation Matrix
(highest score = most viable option)

Sensitivity Analysis Description
Equal weighting of all criteria.

CRITERIA	POINTS	Alternative 1.0.3	Alternative 1.1.1	Alternative 1.1.3	Alternative 1.1.4	Alternative 2.2.5	Alternative 2.3.3	Alternative 2.4.5
Capital Improvement Cost								
Weighting Factor	2							
Over $1,500,0000	1				1	1		1
Over $1,000,0000	2							
Less than $1,000,0000	3	3	3	3			3	
Landslide Risk Mitigation								
Weighting Factor	2							
FS <= 1.0	0	0						
FS <= 1.2	1		1	1	1		1	1
FS > 1.2	2					2		
Utility Level of Service								
Weighting Factor	1							
Sewer Lift Station and Force Main	1				1			
Gravity Sewer, Easement Required	2	2		2				
Gravity Sewer, No Easement	3		3				3	
Gravity Sewer and Water Main, No Easement	4					4		4
Roadway Level of Service								
Weighting Factor	1							
Abandon Roadway and Remove Overburden	1		1	1	1			
Abandon Roadway and Depave	2	2						
Restore as One-Way Multimodal Road	3						3	
Restore as Two-Way Road	4					4		4
TOTAL UNWEIGHTED SCORE	13	7	8	7	4	11	10	10
TOTAL WEIGHTED SCORE	18	10	12	11	6	14	14	12
PRIORITY RANKING		**6**	**3**	**5**	**7**	**1**	**1**	**3**