GEOTECHNICAL EVALUATION

Centralia Alpha Road Alignment Project

Centralia Alpha Road between
Senn Road and Oppelt Road
Lewis County, Washington

Prepared for: Lewis County Public Works

Project No. 180370 • September 14, 2018

Aspect
CONSULTING

earth + water

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Aspect Consulting, LLC

State of Washington
9/14/18
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1 Introduction

1.1 General

This report summarizes Aspect Consulting, LLC's (Aspect) geotechnical engineering evaluation for the Centralia Alpha Road Alignment project (Project) for Lewis County Public Works. The overall Project is located along Centralia Alpha Road, with the focus of this report being specific to the section between Senn Road and Oppelt Road at approximately Stations 40+00 to 65+00 (Site), in Lewis County, Washington. The Project and Site locations are shown on Figure 1, Site Location Map. We performed our services in accordance with our agreed-upon scope of work and signed contract.

1.2 Scope of Services

Our scope of services included a literature review of the readily available information and previous subsurface explorations, a Site reconnaissance, monitoring of existing instruments, and geotechnical engineering evaluations. This report includes:

- A Site Plan showing the existing instrument and previous exploration locations
- A description of the existing monitoring installations and equipment used.
- A graphical display of the cumulative displacement of the inclinometer casings from its initial installation to present.
- The groundwater results and graphs from data recorded in the vibrating-wire piezometer data loggers.
- The results of the rate of movement and inclinometer casing conditions.
- A review and assessment of the Project plans based on the newly acquired monitoring data and our opinions regarding the current approach of lowering the Centralia Alpha Road profile by 19 feet to match the Senn Road grade and cutting (steepening) the slopes along the sides of the road.
- Our recommendations for additional design/construction considerations for the Project related to slope movement or stabilization, based on the data collected to date.
- Our recommendations for the need for additional monitoring events and equipment maintenance, as appropriate.

1.3 Project Description

Lewis County Public Works (County) has been planning on reconstructing approximately 9,000 linear feet of the Centralia Alpha Road between North Fork Road (west end) and Oppelt Road (east end, east connection). The majority of the roadway within the Project area is relatively straight and flat, with the exception of an approximately 2,500 linear foot winding section.

In this 2,500-foot section (approximately Stations 40+00 to 65+00), past plans indicated lowering the existing road profile by as much as 19 vertical feet in order to connect Centralia Alpha Road with Senn Road. To accommodate this change in the existing road profile, the County is proposing cutting into the adjacent slopes along the road at a grade of 1.5H:1V (horizontal to vertical).

Previous work at the Site by PBS Engineering and Environmental (PBS) included drilling borings and installing instrumentation to monitor groundwater levels and potential slope movements (PBS, 2014, 2015a, and 2015b). The County has requested that Aspect assess the conditions, compare our findings with the past work and monitoring results, and provide our recommendations for the currently proposed plans.

2 Site Description

The majority of Centralia Alpha Road within the Project area is relatively straight and flat, with the exception of an approximately 2,500-foot-long winding portion east of Senn Road. In this area, the road is adjacent to an unnamed tributary of the North Fork River (river). The area is hilly, and the road alignment generally slopes up towards the east. The surrounding area is heavily vegetated with large deciduous and coniferous trees and underbrush.

PBS previously performed a Site reconnaissance in October 2014 to observe the roadway's condition and identify potential landslides within its proximity. Significant pavement deterioration and several landslides were identified, which appeared to be shallow slump failures along the north edge of the embankments that are undermining the road. Several pavement overlays have been placed during the life of the road in this area, including as recently as August 2018. In addition to the three County identified landslides affecting Centralia Alpha Road, three other landslides along the road embankment were observed during PBS's Site reconnaissance.

2.1 LiDAR Review

Previous interpretation from the 2006 LiDAR imagery identified several potential and likely slope failures, mainly located within the river channel. A large landslide located on the north side of the river likely caused the river to shift, undercutting and over-steepening the Centralia Alpha Road embankment. The most significant feature along the alignment noted on the LiDAR imagery at that time was a potential landslide that could underlie the roadway within the Site.

More recent 2017 LiDAR imagery with a higher resolution is now available and was reviewed by Aspect. The inferred landslides discussed above are more distinct and several others are identifiable, including an apparent flow-type failure underlying the locations of borings B-1, B-2, B-3, and B-9, between Stations 40+00 and 54+00 (Figure 2, Site Plan and Exploration Map). This landslide was also identified in more recently released data through the Washington State Department of Natural Resources (DNR) as being deep-seated with probable with moderate to high confidence and deep-seated (Goetz et al., 2006).

2.2 Site Geology

Locally, the area is mapped by Logan (1987) as Upper Miocene Wilkes Formation (Twk) on the western half and Pleistocene Logan Hill Formation (Qlh) on the eastern half of the overall Project alignment. The Qlh Formation consists of alpine outwash sand and gravel with minor interbedded silt and clay that is stained reddish brown and completely weathers to clay near the surface. The Twk Formation consists of continental sedimentary rocks, semi-consolidated sandstone, siltstone, and conglomerate, commonly tuffaceous, blue gray and olive green that weathers to a mottled yellowish and orange color. This formation also includes tuff breccias, lahars, and volcanic arenites. Based on the data from the previous borings, the Qlh overlies the Twk along the alignment. The Qlh is generally a soft to medium stiff clay and the Twk is a hard clay/extremely weak (R0) claystone bedrock.

2.3 Previous Subsurface Explorations

Previous work by PBS included drilling several borings along the Project alignment. The borings within the Site are B-1, B-2, B-3, B-4, and B-9.

Between October 8 and 10, 2014, PBS completed four borings, designated B-1 through B-4, to depths between approximately 26.5 and 41.5 feet below ground surface (bgs) and on March 23, 2015, one additional boring, designated B-9, was drilled to 41.5 feet bgs. The logs for B-1 through B-4 and B-9 show the various types of materials that were encountered in the borings and the depths where the materials and/or characteristics of these materials changed (Appendix A).

Initially, inclinometer casing was installed in borings B-1 and B-3. Boring B-3 was also equipped with a VW piezometer. The casings and VW piezometers were first monitored upon installation in October 2014. Based on apparent offset observed by inclinometer casing deflection in boring B-1, the boring B-9 was drilled adjacent to the road and in-parallel to the sense of slope movement. Inclinometer casing and a VW piezometer were installed to monitor slope movement and groundwater levels.

2.3.1 Soil and Bedrock

PBS summarized the subsurface units below the existing ground surface as follows (with Aspect annotations to include current data):

PAVEMENT SECTION:	Asphalt Concrete – 6 to 12 inches thick Base Course – 6 to 12 inches thick
FILL:	Fill generally consisted of coarse-grained sand and gravel material that was encountered from 1.5 to 8.5 feet bgs in B-1. Hard, brown with orange mottling, CLAY that is being interpreted as fill, was observed below a sand layer in B-4 from 3 to 11 feet bgs. Fill was not observed in borings B-2, B-3, and B-9.
LOGAN HILL FORMATION:	Logan Hill Formation was encountered beneath the fill and generally consisted of soft to medium stiff, light brown Fat CLAY (CH). Logan Hill Formation was between 11.5 and 18.5 feet thick in B-1 through B-4 and B-9.
WILKES FORMATION:	Wilkes Formation was encountered in the borings and, where drilled into in B-1 to B-4 and B-9, extended to a depth of at least 41.5 feet bgs. The unit generally consists of interbedded very stiff to hard CLAY and medium dense to dense clayey SAND.

2.4 Groundwater

The VW piezometer installed in boring B-3 recorded groundwater depths between 19 and 23 feet bgs (Elevation [EL] 438 feet and EL 434 feet[1]) from October 2014 to April 2015. No additional readings were acquired after April 2015, and the VW piezometer is no longer accessible.

The depth to groundwater in boring B-9 was initially measured on March 24, 2015, at approximately 1.5 feet bgs and on April 23, 2015, at approximately 5 feet bgs. During our Site visit on August 7, 2018, the VW piezometer data was downloaded. In addition, PBS provided readings acquired between April 2015 and May 2016. A gap in the data occurred between June 2016 and August 2017, though readings were recorded in April 2017. From April 2015 to August 2018, groundwater levels have fluctuated between approximately 4.5 and 14.5 feet bgs (EL 453.5 feet and EL 440 feet). These data show a seasonal trend, with groundwater levels deeper in the summer and fall and shallower in the winter and spring (Appendix B).

2.5 Inclinometers

2.5.1 Inclinometer Installations

Slope inclinometer casings were installed by PBS in borings B-1, B-3, and B-9 along Centralia Alpha Road. The casings in B-1 and B-9 were installed to 35 and 40 feet bgs, respectively. The B-3 inclinometer casing is no longer accessible due to the road paving.

The inclinometers consist of 2.75-inch-diameter polyvinyl chloride (PVC) casing with interior tracks to insert a monitoring probe down the casing. The inclinometer probe attaches to a datalogger and measures and records inclinometer casing deflection, presumably related to ground movement. Slope Indicator™ manufactures this probe and datalogger system and publishes an error calculation formula that reports the instrument accuracy based on the number of data points involved in calculating observed cumulative deflection. If there is no new discernible deflection in the inclinometer plots, or the deflection measured is less than the calculated error, the results are reported as a value less than the calculated error.

2.5.2 Inclinometer Readings

The profile change (aka cumulative deflections) of the casings on the A- (downslope) and B-axes (perpendicular to A-axis) are presented in Appendix B. The A- and B-axes are based on grooves in the inclinometer casing that are assumed to be approximately parallel and perpendicular to the direction of landslide movement, respectively. Since these axes are not exactly parallel or perpendicular to landslide movement, the results are reported by the estimated vector magnitudes of the casing deflections between (1) the most recent readings from June 2017 and August 2018, and (2) the total vector magnitude of deflection from installation. The following is a summary of the inclinometer readings.

Inclinometer B-1: Inclinometer B-1 has recorded yearly episodes of measurable deflection since October 2015 (Appendix B, B-1 Profile Change) with a zone of

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[1] North American Vertical Datum 1988 (NAVD88)

deflection between 16 and 24 feet bgs. A discrete date and rate of deflection during ground movement cannot be ascertained from the periodic readings. The vector deflection between June 2017 and August 2018 was approximately 0.12 inches, and the total vector casing deflection from October 2014 to August 2018 has been 0.64 inches.

Inclinometer B-3: Inclinometer B-3 recorded deflections of less than the instrument accuracy of 0.002 inches from initial installation in October 2015 through June 2017.

Inclinometer B-9: Inclinometer B-9, located approximately 60 feet south of B-1 and off the road, recorded no deflection between its initial installation in March 2015 and June 2017. Recent measurements indicate likely movement has occurred between June 2017 and our August 2018 readings. Some of the perceived deflection may be due to a rotational error caused by using two different inclinometer instruments. However, the shape of the graph does indicate measurable deflection.

The plot of the data is more curved and less discrete than in B-1, with an estimated zone of deflection between 22 and 32 feet bgs. A discrete date and rate of deflection during ground movement cannot be ascertained from the periodic readings. The vector deflection between June 2017 and August 2018 was approximately 0.24 inches, and the total vector casing deflection from October 2014 to August 2018 has been 0.25 inches.

3 Conclusions and Recommendations

Based on our recent instrument monitoring and review of the previous geotechnical evaluation of the Site, which included a data review, Site reconnaissance, and subsurface explorations, the following key findings and conclusions should be considered in the Project planning:

- During their data review, PBS identified larger landslides and potentially unstable areas upslope of the roadway and on the adjacent hillside to the north of Centralia Alpha Road. Those areas could be activated if not properly considered in the design and during construction.
- Recent, higher-resolution 2017 LiDAR imagery indicates landslides along and underlying the Project alignment through the Site, which could potentially be destabilized without proper consideration during planning and construction.
- Inclinometer casing deflections toward the river channel were recorded in boring B-1 between October 2014 and August 2018 and in B-9 between June 2017 and August 2018, indicating this area is marginally stable to unstable.
- The zone of deflection in B-1 and B-9 generally align with the contact between the softer Logan Hill Formation and the underlying, more competent Wilkes Formation at approximately 20 feet bgs.
- Although the inclinometer casings are measured periodically, and a discrete timeframe of movement cannot be determined, movement is likely connected to higher groundwater levels during the winter and spring, which can fluctuate by up to 10 feet with the seasons.

We understand the County is proposing to generally widen the lanes and shoulders, shift the roadway from its current alignment in specific areas, and change the roadway grade by as much as 19 vertical feet. The County also currently proposes the cut slopes along the side of the road to be graded at 1½H:1V to reduce right-of-way (ROW) impacts.

The preliminary plans provided by the County show significant alignment shifts and grade changes will be between Stations 40+00 and 65+00. The deepest cuts will be from Station 40+00 to 54+00 and through the toe of two deep-seated landslides. We find the work through this section, as currently proposed, will further destabilize the existing landslide between Stations 40+00 and 51+00 and could reactivate the inferred landslide between Stations 52+00 and 54+00.

The improvements along the Project alignment between Stations 0+00 and 40+00 and 54+00 to 90+00 will likely not affect slope stability, including the addition of up to 5 feet of fill through the toe of the older landslide mapped between 27+00 and 32+00.

3.1 Slope Mitigation Considerations

3.1.1 General

Alternatives for addressing slope instabilities and mitigating landslides typically involve avoidance, reducing driving forces acting to move the landslide downslope, and/or increasing the resisting forces acting to the hold the landslide in-place that can be done by managing surface water and groundwater, earthwork solutions, or reinforcement and retainage systems. Many times, the mitigation will be a combination of these different alternatives.

For this Site between Stations 40+00 and 54+00, general mitigation alternatives include:

- Maintenance of post-construction conditions with no stabilization effort
- Dewatering and seepage barrier solutions to control surface water and groundwater, including horizontal drains, trench drains, extraction wells, cut-off walls, curtains, or liners
- Earthwork solutions, including regrading, unloading (by excavation), realigning, and rerouting
- Reinforcement and retaining solutions, including block, gabion basket, or gravity walls; reinforced earth and buttresses; nail or rock anchors; and soldier piles

Although numerous technical options are available within each of the mitigation alternatives above, not all are feasible due to the Site geometry and complexity, various constraints, and/or available resources. Marginal stabilization techniques can be implemented to slow landslide movement, to reduce the extent and frequency of road maintenance, generally improve roadway safety, and be a more cost-effective approach to managing the existing conditions.

3.1.2 Alternatives Feasibility Assessment

A matrix of preliminary alternatives and the feasibility of each for mitigating the slope hazards is provided in Table 1 below and outlined in the following sections. The feasibility is dependent on the subsurface conditions and may change during construction.

Table 1. Alternative Mitigation Feasibility Assessment Matrix

Mitigation Alternative	Pros and Cons	Feasibility
No Mitigation		
Routine Maintenance	Pros: Typically inexpensive approach if risk is low, movement is slow, and damage is minimal Cons: Does not provide any stability improvement and could worsen conditions	Low and time-sensitive. Impact of proposed improvements is unknown
Dewatering and Drainage		
Horizontal drains	Pros: Can lower groundwater at the landslide. Is sometimes a first alternative to observe effectiveness Cons: Can be expensive to install, designs are typically conservative/redundant, not effective in fine-grained deposits, and can be damaged by ground movement	Low as stand-alone alternative, but potentially feasible as adjunct to another alternative
Ditch, trench, and cut-off drains	Pros: Inexpensive alternative and part of most landslide mitigations Cons: Not typically used for stabilization on its own itself, sometimes used as a first approach to check effectiveness	High, controlling surface and groundwater likely be a component of mitigation
Earthwork		
Grading	Can completely remove a landslide or reduce driving forces	Low, a complete removal of the landslides is not feasible
Realigning	Pros: Can be an alternative if the landslide can be avoided within the existing County ROW Cons: Not a stabilization and is sometimes used as part of the mitigation. May not be an option due to Site constraints, property ownerships, or the landslide type and geometry	Low, the County has limited ROW.
Rerouting	Pros: Can be an alternative if the landslide cannot be mitigated and there are other routes Cons: May not be an option due to Site constraints, property ownerships, or the landslide type and geometry. Alternative routes will require investigation and design	Oppelt Road parallels Centralia Alpha around the unstable section
Reinforcement and Retainage		
Gravity and cantilever walls	Pros: Can be a good alternative if the landslide shear zone is shallow and with minimal Site constraints Cons: May not be an option due to Site constraints, property ownerships, or the landslide type and geometry	Moderate, will depend on the selected alignment and landslide geometry
Reinforced earth and buttresses	Pros: Can be a good alternative if the landslide is shallow and minimal Site constraints Cons: May not be an option due to Site constraints, property ownerships, or the landslide type and geometry	Moderate to high, will depend on the selected alignment and landslide geometry
Pile walls	Pros: Typically done with incorporating ground anchors Cons: Installation may require drilled shafts or extensively deep	High, though may require drilling to install

3.1.2.1 Maintenance with No Mitigation

If no mitigation were to be done at the Site, the slopes would continue to move episodically in conjunction with larger rainfall and snow-melt events. Depending on the degree of each failure, damage to the road may range from small displacements and cracking to larger displacements with significant vertical offsets that require closing the road and ongoing repair efforts by the County.

Through the no-mitigation approach, the failed road segment would be patched or repaired immediately following damage due to ground movements. The ground movement and subsequent maintenance should be seasonal, occurring primarily in the rainy season and/or following snow melt. The severity of the maintenance will be dependent on the amount, intensity, and duration of precipitation.

With the limited existing Site data and considering the relatively large amount of material that will be removed during construction, it is not possible to estimate the overall impacts from the Project on the stability of the cut slopes and the resulting rates these may move. Our current opinion is this option should not be considered due to the unknowns and potential safety concerns.

3.1.2.2 Dewatering

The excavation will intercept groundwater based on the VW piezometer data and is considered a significant factor in the slope stability. Controlling surface and groundwater at the Site should include ditches to convey runoff away from the road, along with cutoff trench drains, lateral drains, and toe drains. Horizontal drains may also be effective and would require further analyses. It is unlikely that lowering groundwater levels by installing a permanent dewatering drainage system would be effective, on its own, to stabilize the slopes in the context of the Project.

3.1.2.3 Gravity & Cantilever and MSE & Rock Buttress

Retaining walls work by intersecting the critical sliding surface, thus forcing the potential failure surface to a deeper, less critical depth. The structure must be able to withstand shearing, overturning, and sliding at the base. It must, therefore, be strongly built by burying to sufficient depth and extending beyond the critical failure plane. For all types of retaining walls, adequate drainage through the structure is essential because very high groundwater pressure can build up behind any retaining wall, leading to its failure.

A buttress provides resistance through bulk weight acting to support the landslide and counteract the driving forces, thereby increasing slope stability FOS and retaining soil that is upslope of it. The stability of the buttress is developed from self-weight, friction along its base, and embedment into the bearing layer (beneath the identified/preferential failure surface). The stability of these buttresses is not reliant on passive earth pressure resistance from downslope landslide debris. The concept of mechanically stabilized earth (MSE) or rock buttresses consists of excavation and removal of the landslide debris to below the basal landslide shear zone.

3.1.2.4 Soldier Pile Wall with Tieback Anchors

The general concept of a pile wall consists of drilling 2- to 3-foot-diameter concrete-filled shafts (piles) along a row to form a wall. Between the piles, timber or precast concrete lagging is installed to span between the steel beams to retain soil while still allowing some drainage out of the wall face.

Pile walls can typically be cantilevered up to about 12 feet in exposed wall height, beyond which it becomes more cost-effective to incorporate tieback anchors. Steel-tendon tieback anchors can be drilled at an angle from horizontal into stable bearing soils behind and below the wall and grouted into place. The tieback anchors are tensioned to apply a horizontal load component to the wall, which allows the allowable exposed height of the solider pile wall to be increased while maintaining stability and retaining the soils behind the wall.

Mass excavation down to the basal landslide shear zone is not required, but grading and removal of landslide debris upslope of the wall can be utilized to reduce the total exposed/retained height.

3.2 Future Work

Additional work is recommended to fully analyze and select the preferred stabilization alternative(s). These tasks include additional targeted subsurface explorations and monitoring installations, slope stability analyses, and design and construction considerations.

3.2.1 Geotechnical Explorations and Analysis

Depending on how the County chooses to proceed, two additional deep borings could be advanced between Stations 40+00 and 47+00 to characterize the lithologic contact depths along the alignment. This information would better inform on slip planes, profiles, slope stability analyses, and potential stabilization alternatives.

Stabilization alternatives using the data collected thus far will be used to:

- Complete two-dimensional, limit equilibrium slope stability analysis of existing conditions and up to three stabilization alternatives to evaluate feasibility
- Develop design and construction considerations for preferred alternatives
- Assist the County in identifying fatal flaws with respect to the grade, and horizontal and vertical alignments.

4 References

Goetz, Venice; Clark, Jeffrey, 2006, Landslide hazard zonation project--Mass wasting assessment--Upper North Fork Newaukum watershed, Washington: Washington Department of Natural Resources, Forest Practices, 38 p., 2 plates, scale 1:24,000.

Logan, R. L., compiler, 1987, Geologic map of the Chehalis River and Westport quadrangles, Washington: Washington Division of Geology and Earth Resources Open File Report 87-8, 16 p., 1 plate, scale 1:100,000.

PBS Engineering and Environmental, 2014, Geotechnical Engineering Report, Roadway Realignment Project, Centralia Alpha Road, Lewis County, Washington, PBS Project No. 73137.000, dated November 17, 2014.

PBS Engineering and Environmental, 2015a, Instrument Monitoring Report – February 2015, Centralia Alpha Road, Between North Fork Road and Oppelt Road (East), Lewis County, Washington, PBS Project No. 73137.000, dated February 17, 2015.

PBS Engineering and Environmental, 2015b, Geotechnical Engineering Services Report - Addendum No. 1, Roadway Realignment Project, Centralia Alpha Road, Lewis County, Washington, PBS Project No. 73137.000, dated June 2, 2015.

5 Limitations

Work for this project was performed for Lewis County Public Works (Client), and this report was prepared consistent with recognized standards of professionals in the same locality and involving similar conditions, at the time the work was performed. No other warranty, expressed or implied, is made by Aspect Consulting, LLC (Aspect).

Recommendations presented herein are based on our interpretation of site conditions, geotechnical engineering calculations, and judgment in accordance with our mutually agreed-upon scope of work. Our recommendations are unique and specific to the project, site, and Client. Application of this report for any purpose other than the project should be done only after consultation with Aspect.

Variations may exist between the soil and groundwater conditions reported and those actually underlying the site. The nature and extent of such soil variations may change over time and may not be evident before construction begins. If any soil conditions are encountered at the site that are different from those described in this report, Aspect should be notified immediately to review the applicability of our recommendations.

It is the Client's responsibility to see that all parties to this project, including the designer, contractor, subcontractors, and agents, are made aware of this report in its entirety. At the time of this report, design plans and construction methods have not been finalized, and the recommendations presented herein are based on preliminary project information. If project developments result in changes from the preliminary project information, Aspect should be contacted to determine if our recommendations contained in this report should be revised and/or expanded upon.

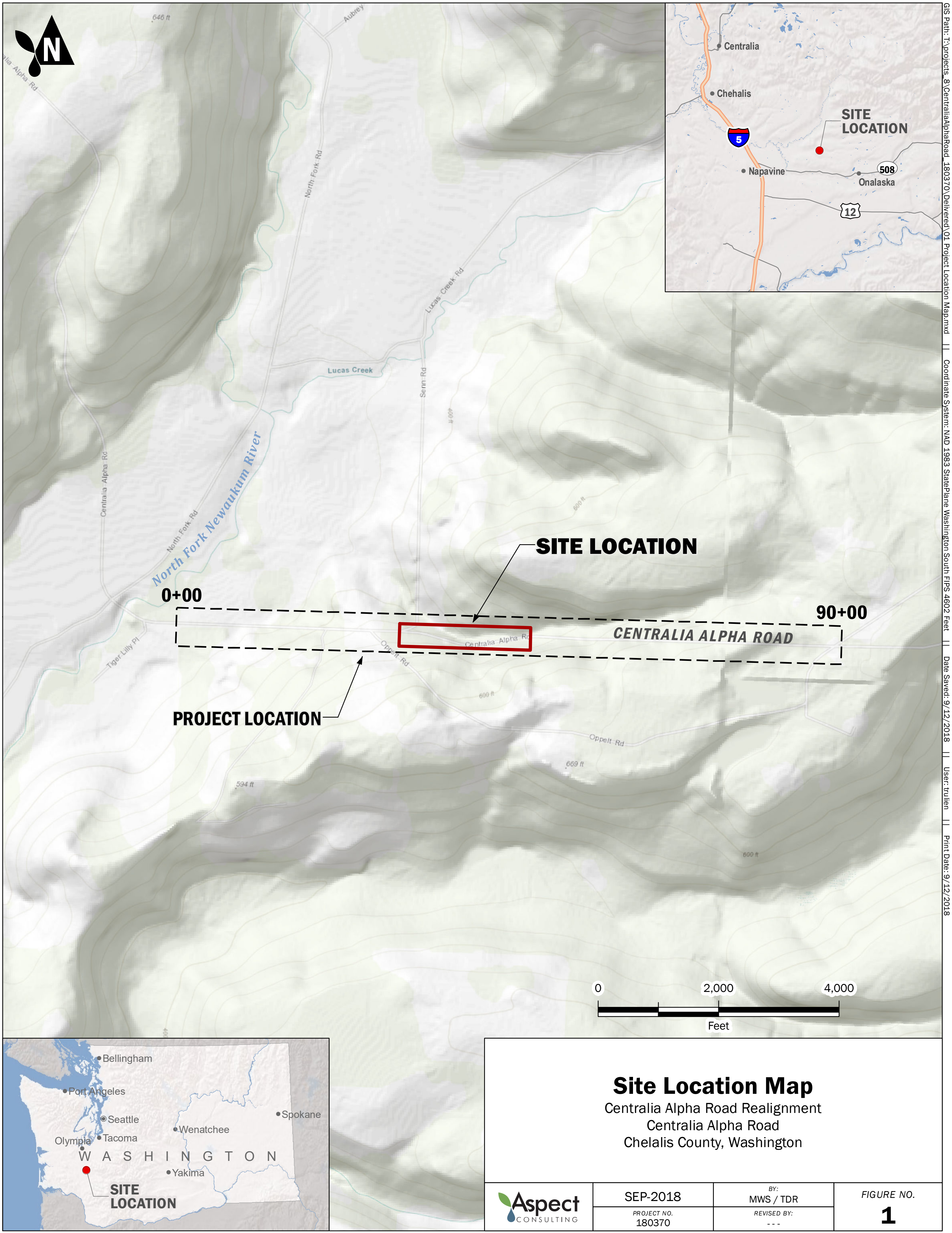
The scope of work does not include services related to construction safety precautions. Site safety is typically the responsibility of the contractor, and our recommendations are not intended to direct the contractor’s site safety methods, techniques, sequences, or procedures. The scope of our work also does not include the assessment of environmental characteristics, particularly those involving potentially hazardous substances in soil or groundwater.

All reports prepared by Aspect for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect. Aspect’s original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Please refer to Appendix C titled “Report Limitations and Guidelines for Use” for additional information governing the use of this report.

We appreciate the opportunity to perform these services. If you have any questions please call Mark Swank, LEG, Senior Engineering Geologist, 971.865.5893.

FIGURES



Site Location Map

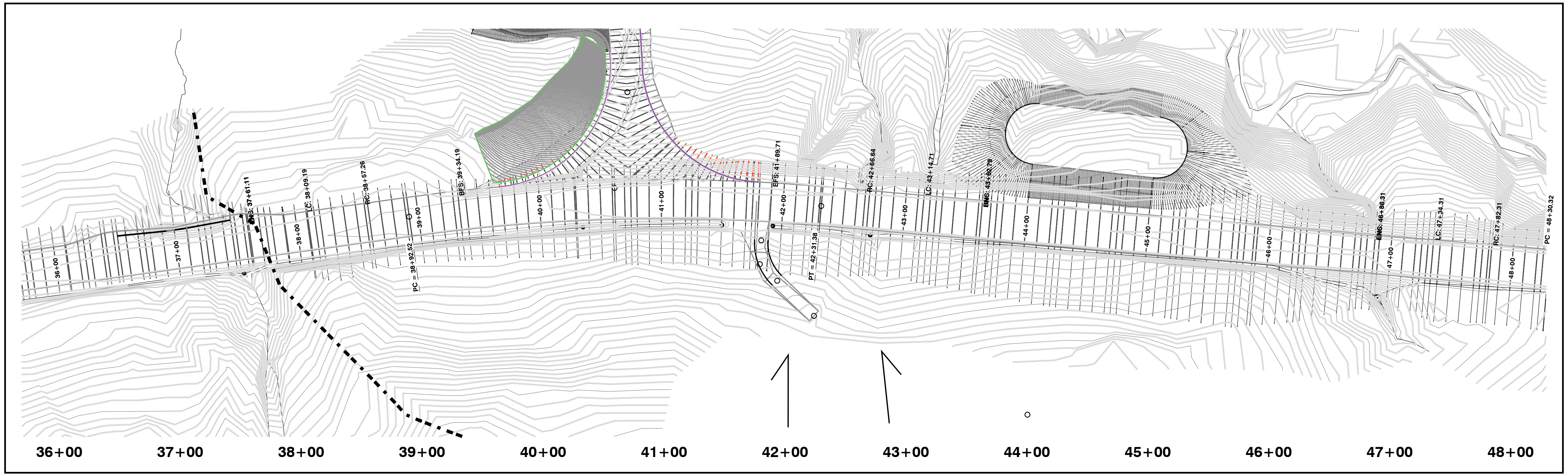
Centralia Alpha Road Realignment
Centralia Alpha Road
Chelalis County, Washington

Aspect CONSULTING

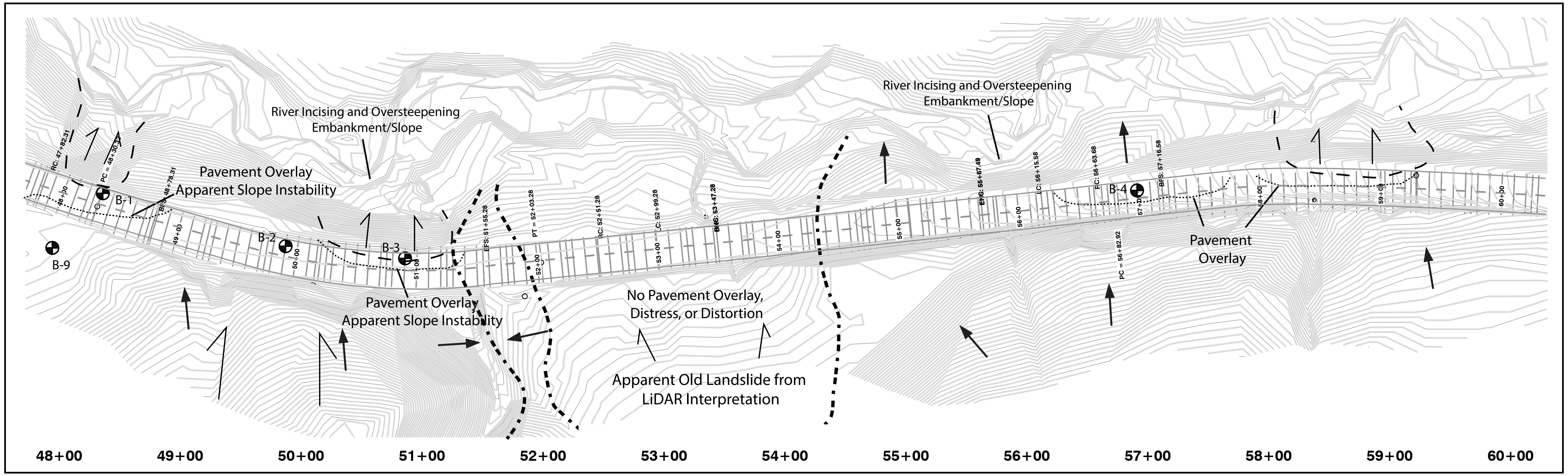
SEP-2018	BY: MWS / TDR	FIGURE NO.
PROJECT NO. 180370	REVISED BY: - - -	1

GIS Path: T:\projects_8\CentraliaAlphaRoad_180370\Delivered\01 Project Location Map.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 9/12/2018 || User: trullen || Print Date: 9/12/2018

Basemap Layer Credits || Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



STATIONS 36+00 to 48+00



Source: Modified from PBS Engineering and Environmental, Figure 5, Site Reconnaisance (PBS, 2014)

STATIONS 48+00 to 60+00

Legend:

⊕B-1	PBS BORING NUMBER AND LOCATION
↑	APPROXIMATE SLOPE TREND
....	APPROXIMATE BOUNDARY OF PAVEMENT OVERLAY
	APPARENT LANDSLIDE FROM LiDAR INTERPRETATION
	APPARENT LANDSLIDE FROM FIELD OBSERVATION AND/OR TOPO SURVEY

N

0 100 200

Feet

Site Plan and Exploration Map

Centralia Alpha Road Realignment
Centralia Alpha Road
Chehalis County, Washington

Aspect
CONSULTING

SEP-2018

PROJECT NO.
180370

BY:
MWS

REV BY:
- - -

FIGURE NO.
2

APPENDIX A

Previous Subsurface Exploration Logs

PBS
Engineering + Environmental
4412 SW Corbett Avenue
Portland, Oregon 97239
Phone: 503.248.1939
Fax: 866.727.0140

CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

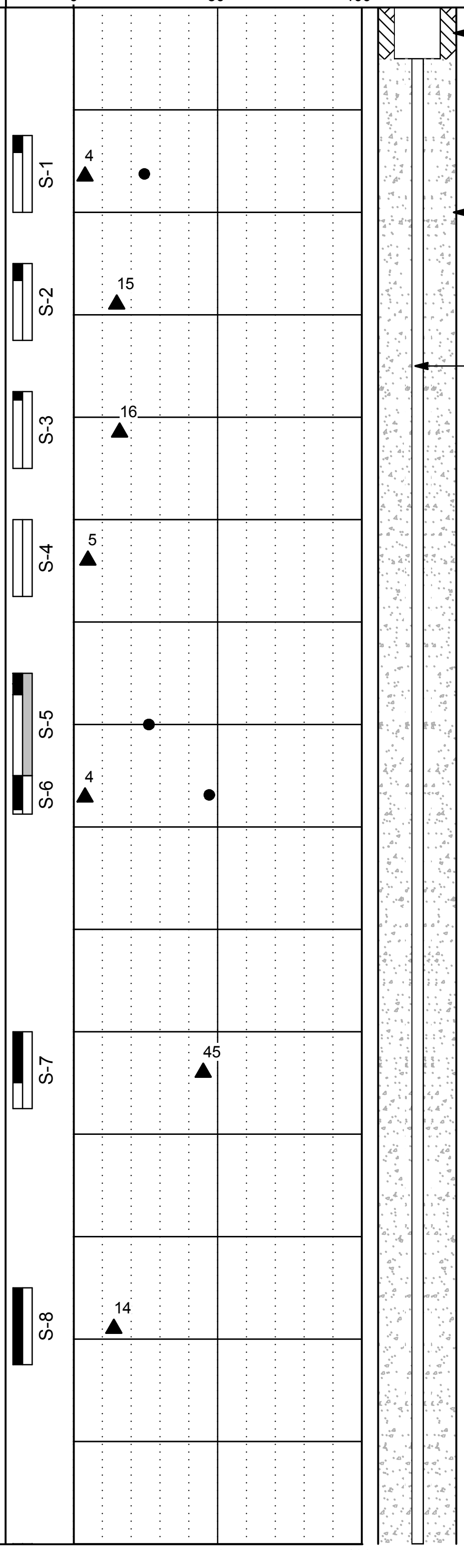
PBS PROJECT NUMBER:
73137.000

BORING B-1

APPROX. BORING B-1 LOCATION:
STATION 49+00
(See Site Plan)

NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

DEPTH	MATERIAL DESCRIPTION
1.0	Asphalt Concrete (12 Inches)
1.5	3/4"-0 Base Rock (6 Inches)
4.0	Loose brown poorly graded SAND (SP); fine sand; moist.
9.0	Medium dense poorly graded GRAVEL (GP); fine to coarse, subround to subangular gravel; moist. **FILL**
20.5	Soft to medium stiff light brown FAT CLAY (CH); high plasticity; moist. **LOGAN HILL FORMATION**
21.5	Hard brown with orange mottling FAT CLAY (CH); high plasticity; moist.
22.5	Dense gray clayey SAND (SC); medium plasticity; fine to medium sand; moist.
	Stiff to hard gray LEAN CLAY (CL); medium plasticity; moist. **WILKES FORMATION**



▲ BLOW COUNT
◆ DYNAMIC CONE PENETROMETER
● MOISTURE CONTENT %
▥ RQD% ▨ CORE REC%

SAMPLE TYPE SAMPLE ID	BLOW COUNT
S-1	4
S-2	15
S-3	16
S-4	5
S-5	
S-6	4
S-7	45
S-8	14

INSTALLATION AND COMMENTS
Surface Conditions: Asphalt Road

12-Inch Diameter Flush Mount Monument

Cement Grout Backfill

2.75-Inch Diameter Inclinometer Casing to 35 feet bgs

0.3tsf, Torvane used

DRILLING METHOD: Mud Rotary
DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: T. Rikli

BIT DIAMETER: 4 7/8-inch
HAMMER EFFICIENCY PERCENT: 82
LOGGING COMPLETED: 10/09/14

FIGURE A1

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Phone: 503.248.1939
Fax: 866.727.0140

CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

PBS PROJECT NUMBER:
73137.000

BORING B-1
(continued)

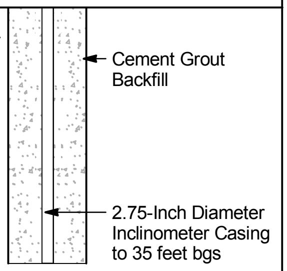
APPROX. BORING B-1 LOCATION:
STATION 49+00
(See Site Plan)

NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

▲ BLOW COUNT
✦ DYNAMIC CONE PENETROMETER
● MOISTURE CONTENT %
▥ RQD%
▨ CORE REC%

INSTALLATION AND COMMENTS
Surface Conditions: Asphalt Road

DEPTH FEET	MATERIAL DESCRIPTION	DEPTH	TESTING	SAMPLE TYPE SAMPLE ID	BLOW COUNT (0-50-100)
30.0	Stiff to hard gray FAT CLAY (CH); high plasticity; moist. **WILKES FORMATION**			S-9	44-50/5"
32.0					
34.0					
				S-10	44-50/3"
		35.8			
36.0	Final depth 35.8 feet below ground surface; Inclinometer Casing installed				
38.0					
40.0					
42.0					
44.0					
46.0					
48.0					
50.0					
52.0					
54.0					
56.0					
58.0					
60.0					



BORING LOG 73137 B1-8 110514 RD.GPJ PBS DATATMPL GEO.GDT PRINT DATE: 11/17/14:MS

DRILLING METHOD: Mud Rotary
DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: T. Rikli

BIT DIAMETER: 4 7/8-inch
HAMMER EFFICIENCY PERCENT: 82
LOGGING COMPLETED: 10/09/14

FIGURE A1

PBS Engineering + Environmental
4412 SW Corbett Avenue
Portland, Oregon 97239
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Fax: 866.727.0140

CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

BORING B-2

PBS PROJECT NUMBER:
73137.000

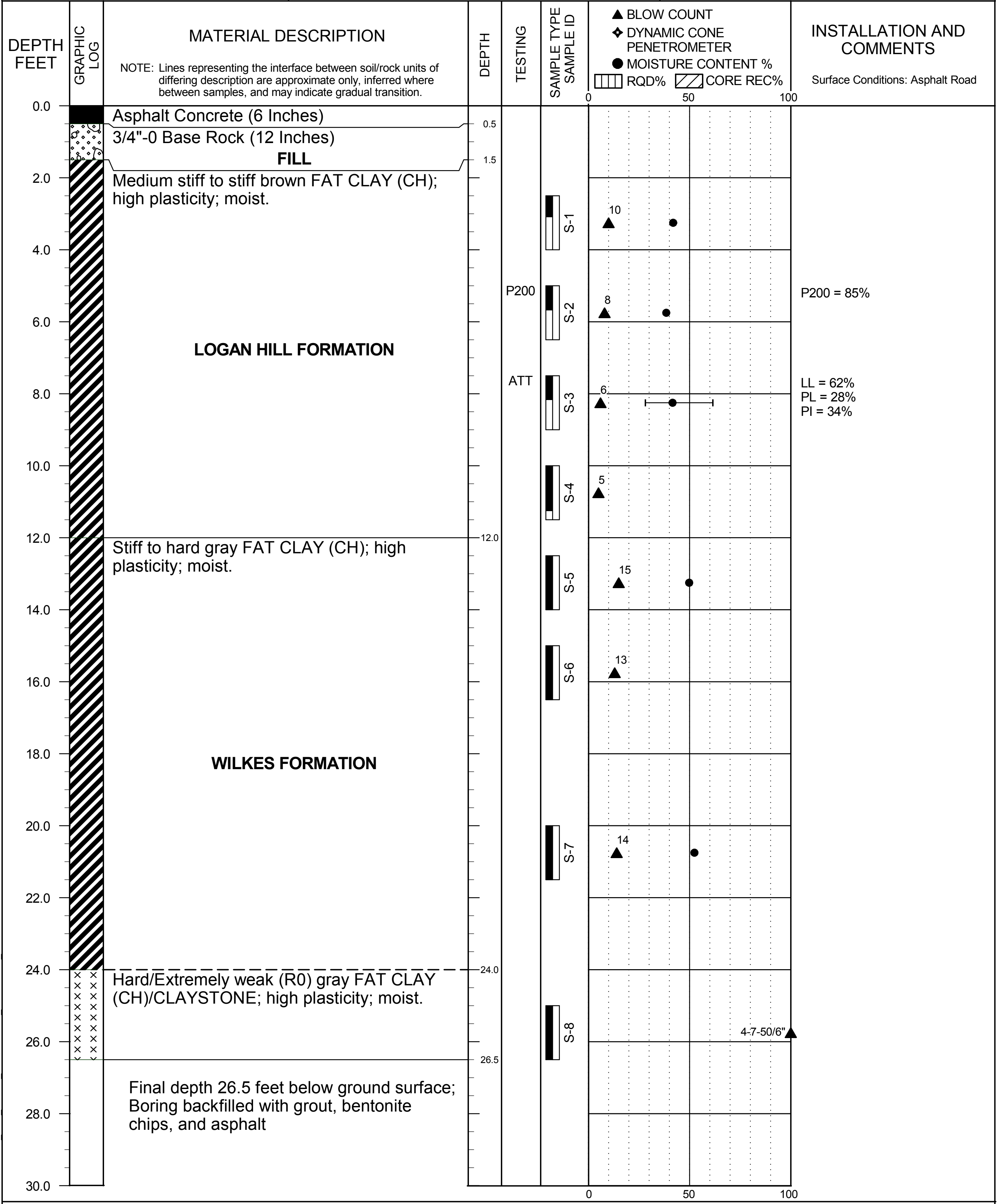
APPROX. BORING B-2 LOCATION:
STATION 50+00
(See Site Plan)

MATERIAL DESCRIPTION

NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

INSTALLATION AND COMMENTS

Surface Conditions: Asphalt Road



Asphalt Concrete (6 Inches)

3/4"-0 Base Rock (12 Inches)

FILL

Medium stiff to stiff brown FAT CLAY (CH); high plasticity; moist.

LOGAN HILL FORMATION

P200 = 85%

LL = 62%
PL = 28%
PI = 34%

Stiff to hard gray FAT CLAY (CH); high plasticity; moist.

WILKES FORMATION

Hard/Extremely weak (R0) gray FAT CLAY (CH)/CLAYSTONE; high plasticity; moist.

Final depth 26.5 feet below ground surface; Boring backfilled with grout, bentonite chips, and asphalt

DRILLING METHOD: Mud Rotary
DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: T. Rikli

BIT DIAMETER: 4 7/8-inch
HAMMER EFFICIENCY PERCENT: 82
LOGGING COMPLETED: 10/10/14

FIGURE A2

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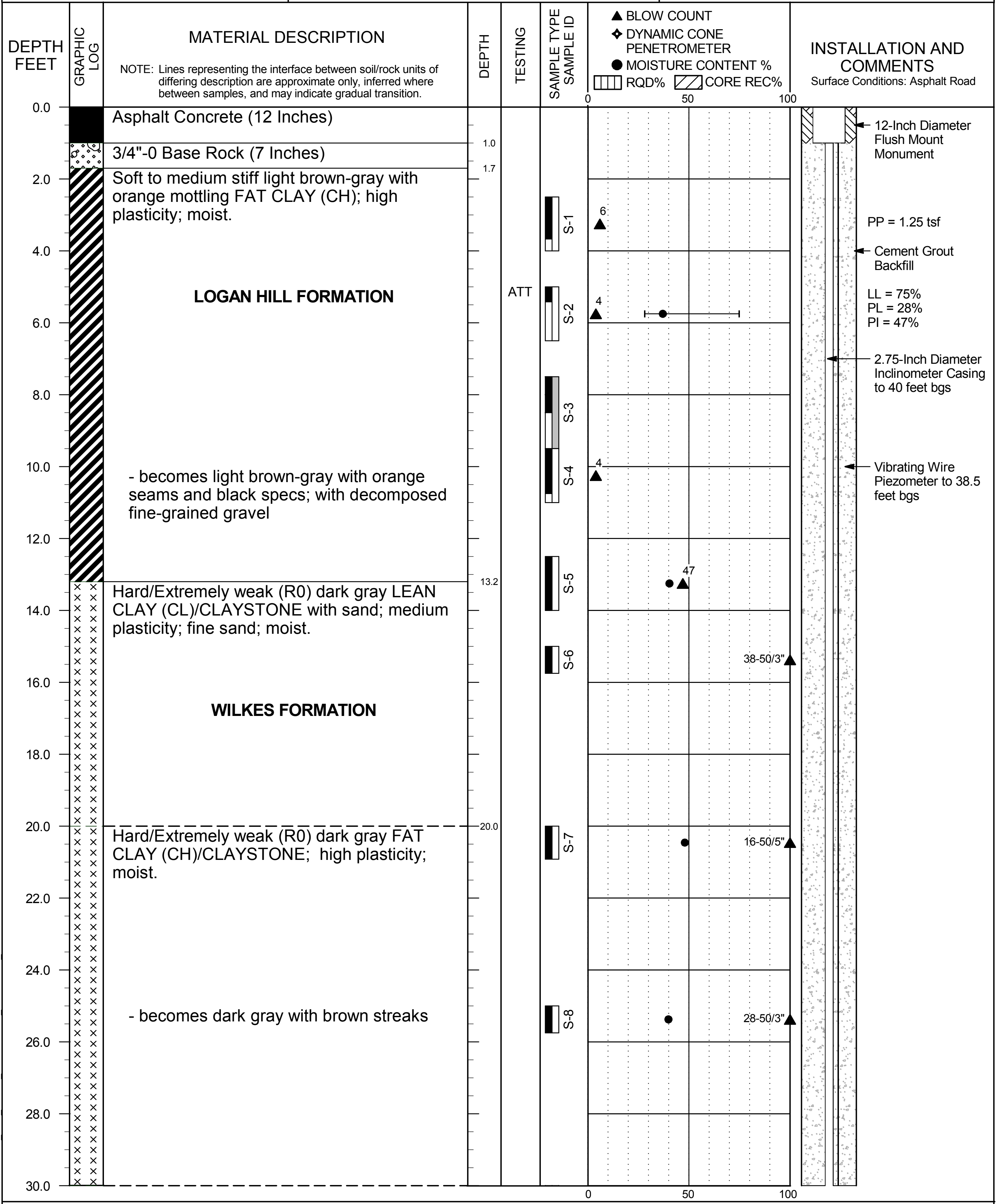
CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

BORING B-3

PBS PROJECT NUMBER:
73137.000

APPROX. BORING B-3 LOCATION:
STATION 51+00
(See Site Plan)



0.0	Asphalt Concrete (12 Inches)
1.0	3/4"-0 Base Rock (7 Inches)
1.7	Soft to medium stiff light brown-gray with orange mottling FAT CLAY (CH); high plasticity; moist. **LOGAN HILL FORMATION** - becomes light brown-gray with orange seams and black specs; with decomposed fine-grained gravel
13.2	Hard/Extremely weak (R0) dark gray LEAN CLAY (CL)/CLAYSTONE with sand; medium plasticity; fine sand; moist. **WILKES FORMATION**
20.0	Hard/Extremely weak (R0) dark gray FAT CLAY (CH)/CLAYSTONE; high plasticity; moist. - becomes dark gray with brown streaks

DRILLING METHOD: Mud Rotary
DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: M. Swank

BIT DIAMETER: 4 7/8-inch
HAMMER EFFICIENCY PERCENT: 82
LOGGING COMPLETED: 10/08/14

FIGURE A3

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CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

PBS PROJECT NUMBER:
73137.000

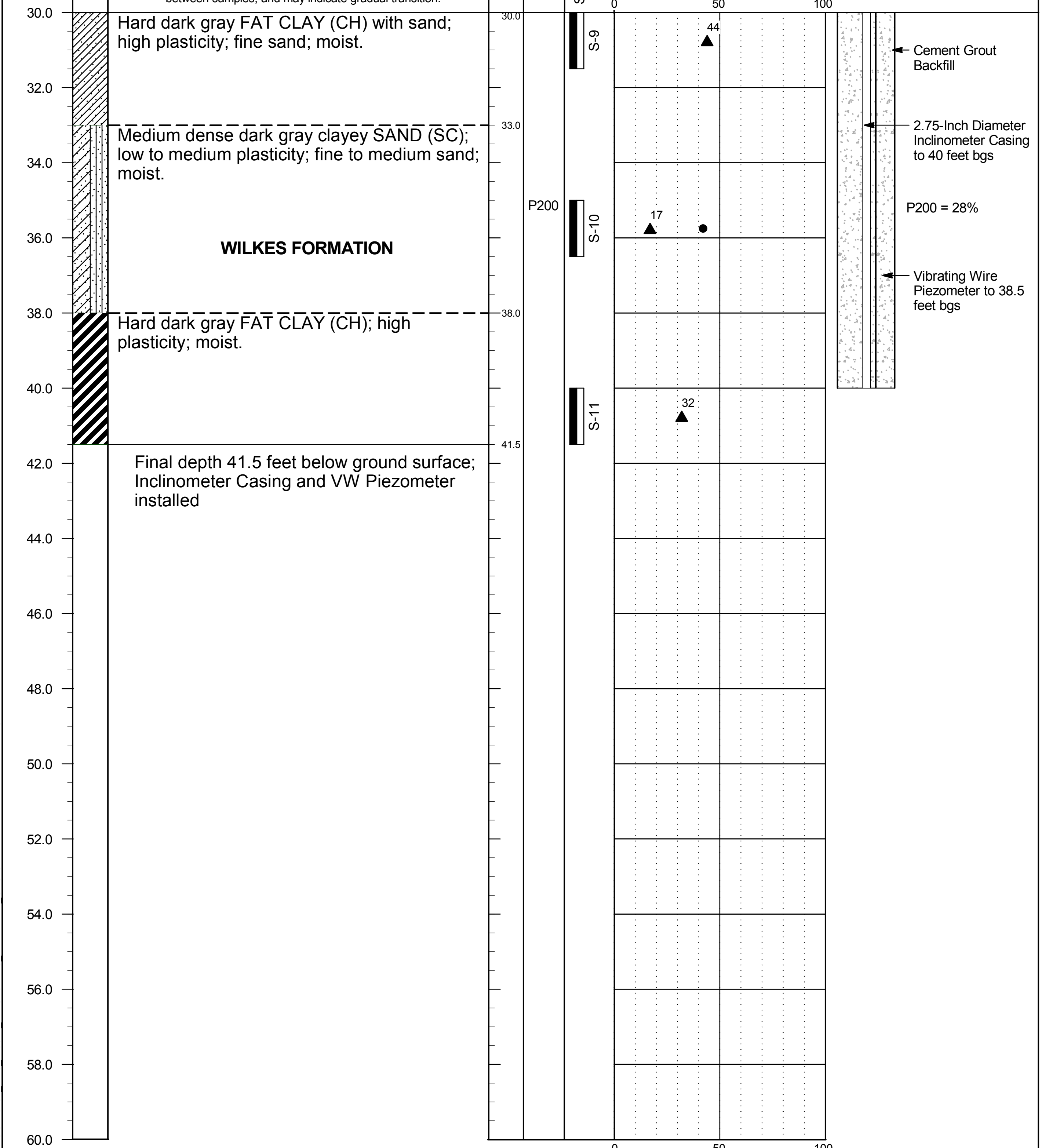
BORING B-3
(continued)

APPROX. BORING B-3 LOCATION:
STATION 51+00
(See Site Plan)

DEPTH FEET	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH	TESTING	SAMPLE TYPE SAMPLE ID	▲ BLOW COUNT ✧ DYNAMIC CONE PENETROMETER ● MOISTURE CONTENT % ▥ RQD% ▨ CORE REC%	INSTALLATION AND COMMENTS

NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

Surface Conditions: Asphalt Road



Hard dark gray FAT CLAY (CH) with sand; high plasticity; fine sand; moist.

Medium dense dark gray clayey SAND (SC); low to medium plasticity; fine to medium sand; moist.

WILKES FORMATION

Hard dark gray FAT CLAY (CH); high plasticity; moist.

Final depth 41.5 feet below ground surface; Inclinometer Casing and VW Piezometer installed

Cement Grout Backfill

2.75-Inch Diameter Inclinometer Casing to 40 feet bgs

P200 = 28%

Vibrating Wire Piezometer to 38.5 feet bgs

DRILLING METHOD: Mud Rotary
DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: M. Swank

BIT DIAMETER: 4 7/8-inch
HAMMER EFFICIENCY PERCENT: 82
LOGGING COMPLETED: 10/08/14

FIGURE A3

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Portland, Oregon 97239
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CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

PBS PROJECT NUMBER:
73137.000

BORING B-4

APPROX. BORING B-4 LOCATION:
STATION 57+00
(See Site Plan)

MATERIAL DESCRIPTION

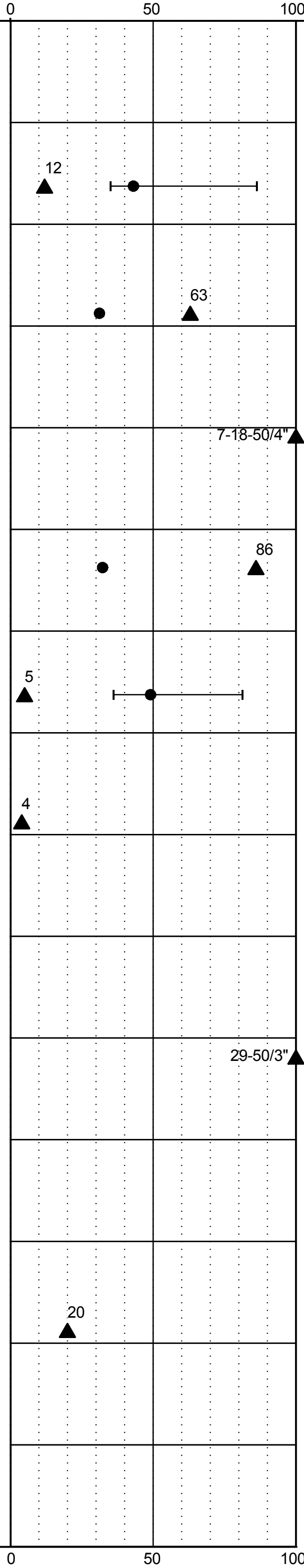
NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

▲ BLOW COUNT
✥ DYNAMIC CONE PENETROMETER
● MOISTURE CONTENT %
▥ RQD%
▨ CORE REC%

INSTALLATION AND COMMENTS

Surface Conditions: Asphalt Road

DEPTH FEET	MATERIAL DESCRIPTION	DEPTH	TESTING	SAMPLE TYPE SAMPLE ID	INSTALLATION AND COMMENTS
0.0	Asphalt Concrete (6 Inches)	0.5			
	3/4"-0 Base Rock (6 Inches)	1.0			
	Medium dense gray poorly graded SAND (SP); coarse sand; moist.				
	Hard brown with orange mottling FAT CLAY (CH); high plasticity; moist. **FILL**	3.0	ATT	S-1	LL = 86% PL = 35% PI = 51%
				S-2	
				S-3	
				S-4	
	Medium stiff brown with orange mottling FAT CLAY (CH); high plasticity; moist. **LOGAN HILL FORMATION**	11.0	ATT	S-5	LL = 81% PL = 36% PI = 44%
				S-6	
20.0	Hard/Extremely weak (R0) gray FAT CLAY (CH)/CLAYSTONE; high plastiity; moist. **WILKES FORMATION**	20.0		S-7	
				S-8	
	Final depth 26.5 feet below ground surface; Boring backfilled with grout, bentonite chips, and asphalt	26.5			



DRILLING METHOD: Mud Rotary
DRILLED BY: Western States Soil Conservation, Inc.
LOGGED BY: T. Rikli

BIT DIAMETER: 4 7/8-inch
HAMMER EFFICIENCY PERCENT: 82
LOGGING COMPLETED: 10/10/14

FIGURE A4

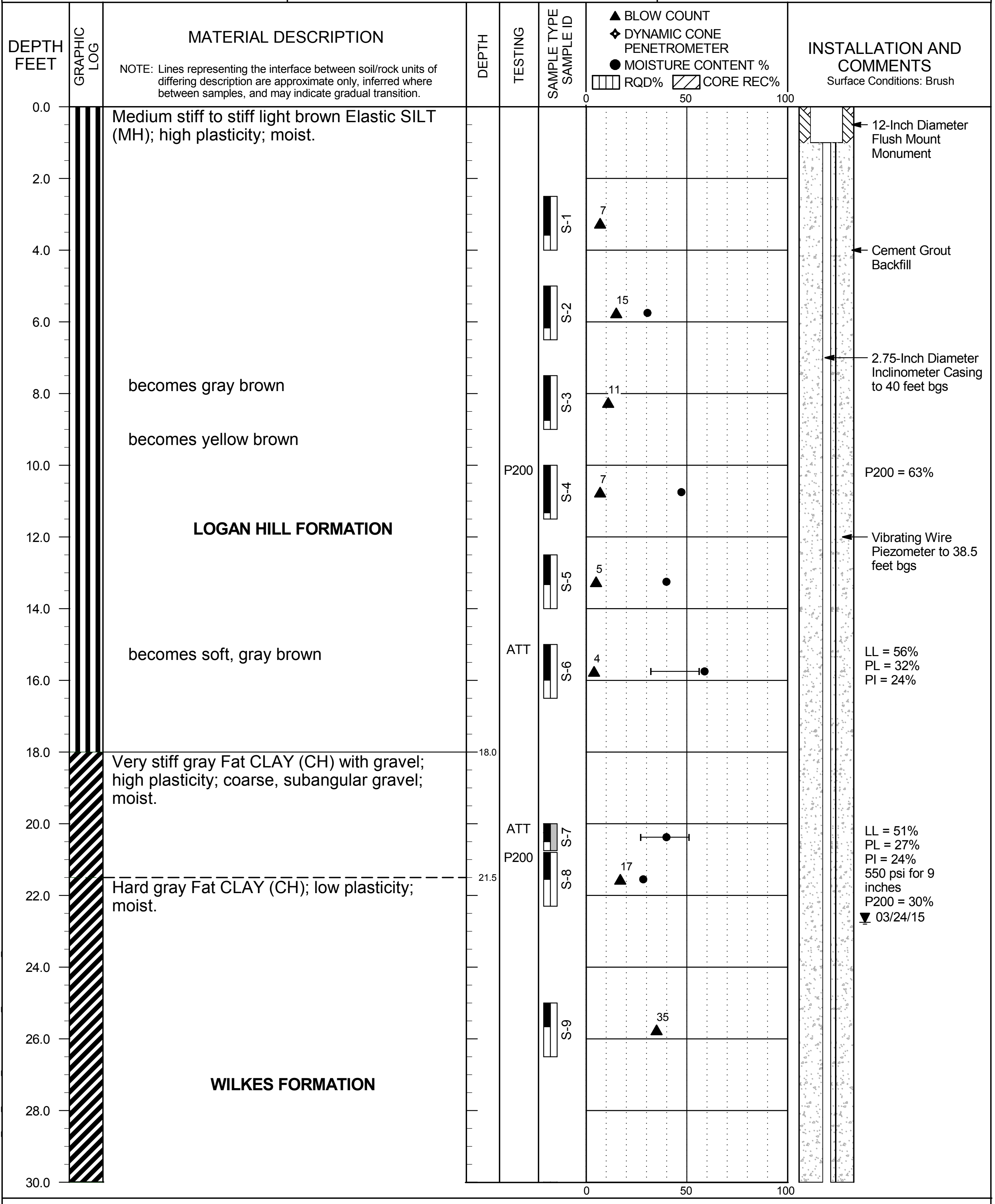
PBS Engineering + Environmental
4412 SW Corbett Avenue
Portland, Oregon 97239
Phone: 503.248.1939
Fax: 866.727.0140

CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

BORING B-9

PBS PROJECT NUMBER:
73137.000

APPROX. BORING B-9 LOCATION:
(See Site Plan)



NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.

Surface Conditions: Brush

Medium stiff to stiff light brown Elastic SILT (MH); high plasticity; moist.

becomes gray brown

becomes yellow brown

LOGAN HILL FORMATION

becomes soft, gray brown

Very stiff gray Fat CLAY (CH) with gravel; high plasticity; coarse, subangular gravel; moist.

Hard gray Fat CLAY (CH); low plasticity; moist.

WILKES FORMATION

12-Inch Diameter Flush Mount Monument

Cement Grout Backfill

2.75-Inch Diameter Inclinometer Casing to 40 feet bgs

P200 = 63%

Vibrating Wire Piezometer to 38.5 feet bgs

LL = 56%
PL = 32%
PI = 24%

LL = 51%
PL = 27%
PI = 24%
550 psi for 9 inches
P200 = 30%
▼ 03/24/15

DRILLING METHOD: Mud Rotary
DRILLED BY: Hardcore Drilling
LOGGED BY: T. Rikli

BIT DIAMETER: 4 7/8 inches
HAMMER EFFICIENCY PERCENT:
LOGGING COMPLETED: 3/23/15

FIGURE A3

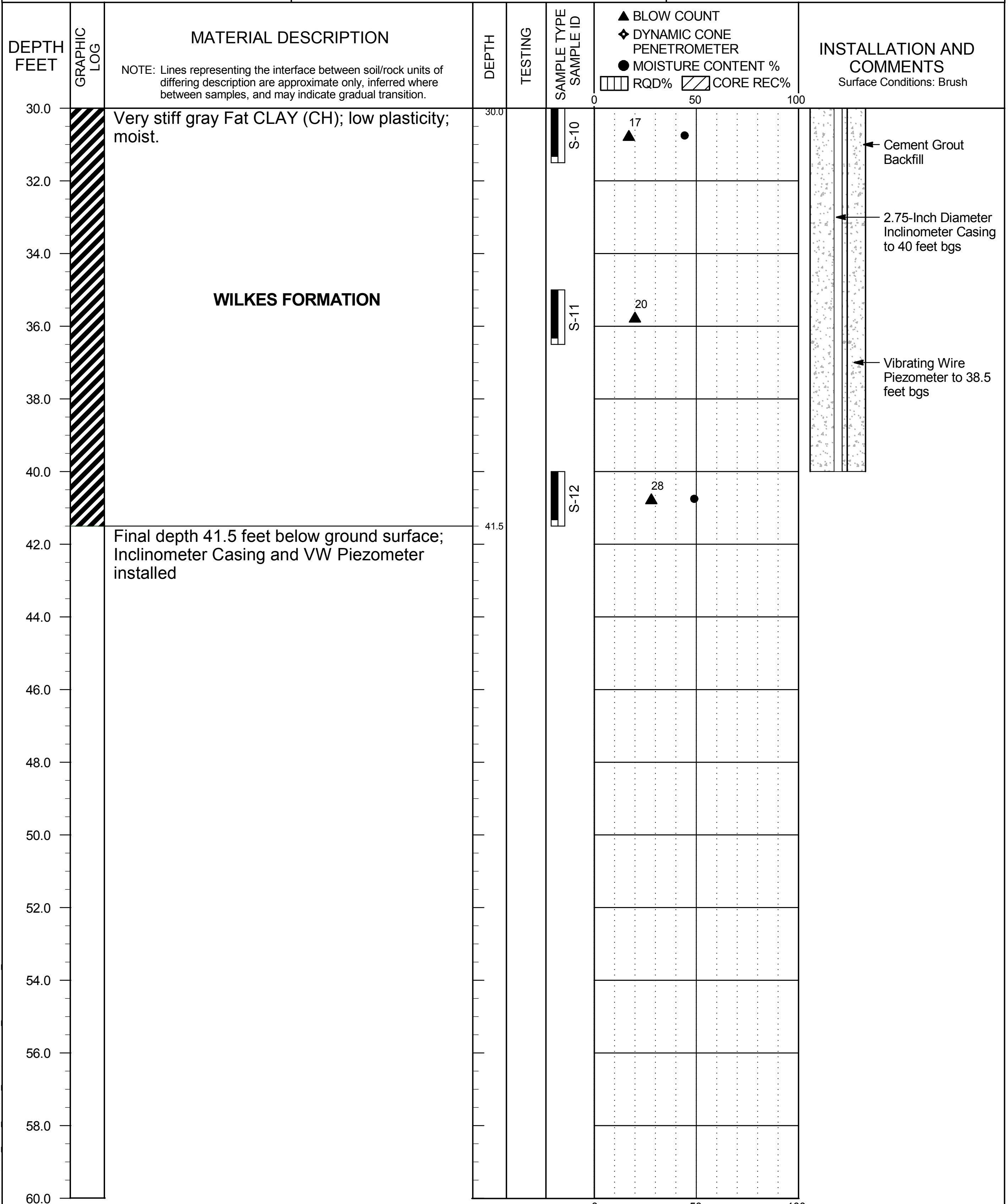
CENTRALIA ALPHA ROAD IMPROVEMENTS
LEWIS COUNTY, WA

PBS PROJECT NUMBER:
73137.000

BORING B-9
(continued)

APPROX. BORING B-9 LOCATION:
(See Site Plan)

NOTE: Lines representing the interface between soil/rock units of differing description are approximate only, inferred where between samples, and may indicate gradual transition.



Very stiff gray Fat CLAY (CH); low plasticity; moist.

WILKES FORMATION

Final depth 41.5 feet below ground surface; Inclinometer Casing and VW Piezometer installed

Cement Grout Backfill

2.75-Inch Diameter Inclinometer Casing to 40 feet bgs

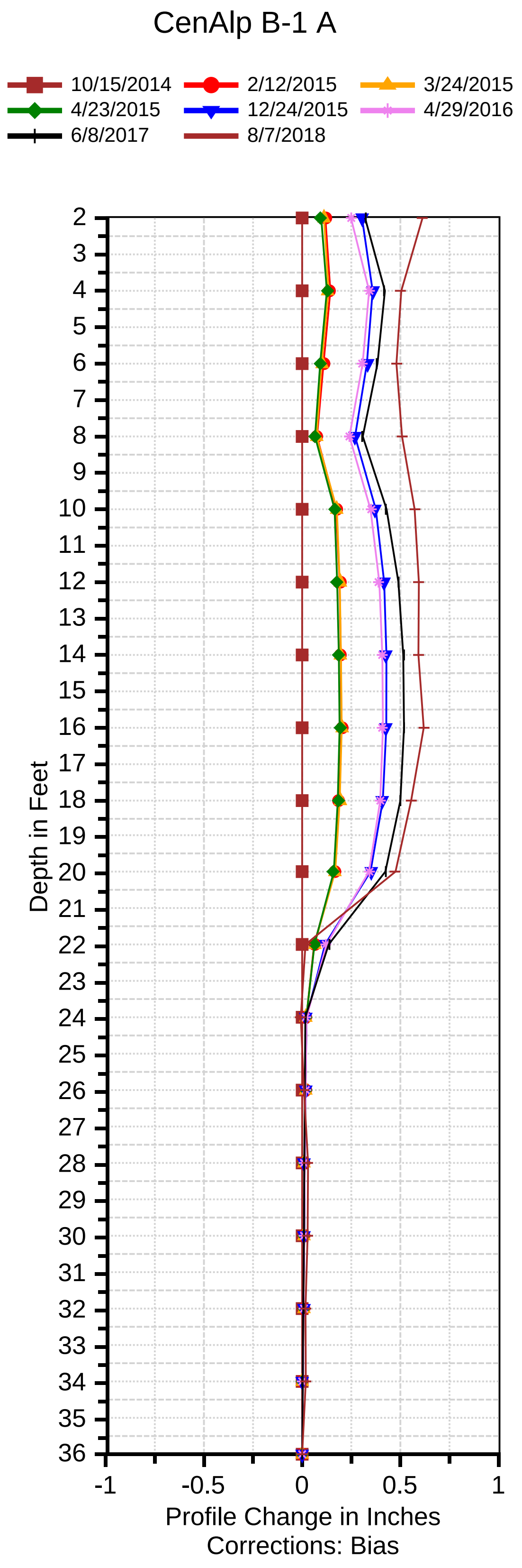
Vibrating Wire Piezometer to 38.5 feet bgs

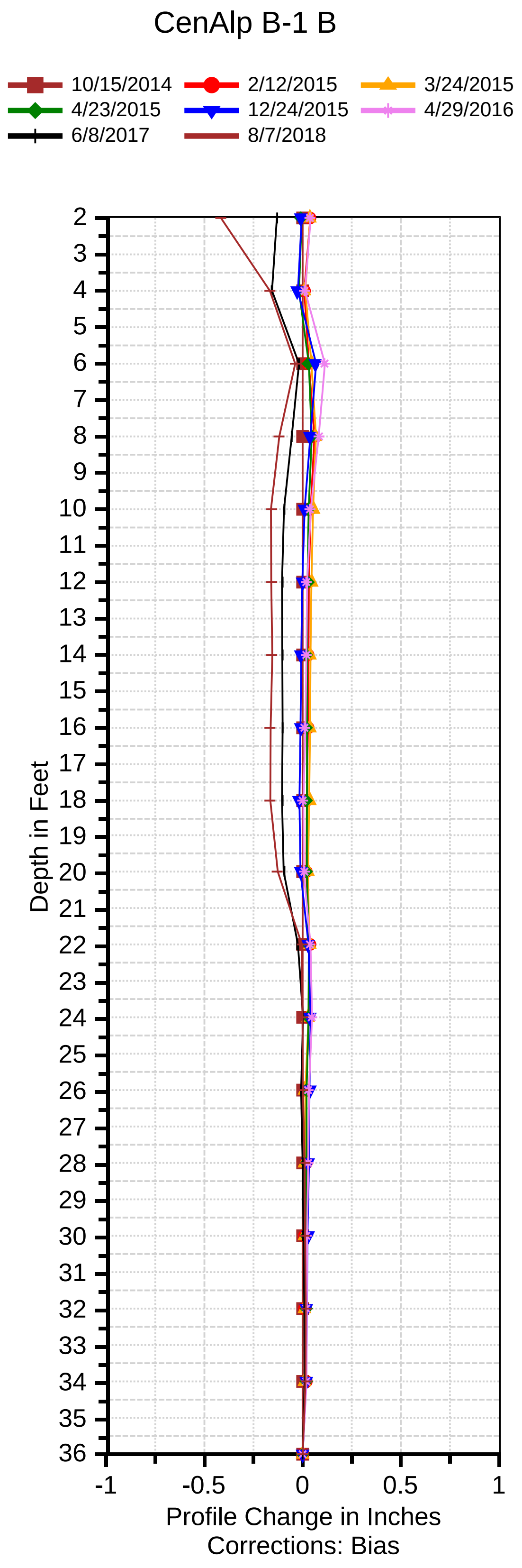
DRILLING METHOD: Mud Rotary
DRILLED BY: Hardcore Drilling
LOGGED BY: T. Rikli

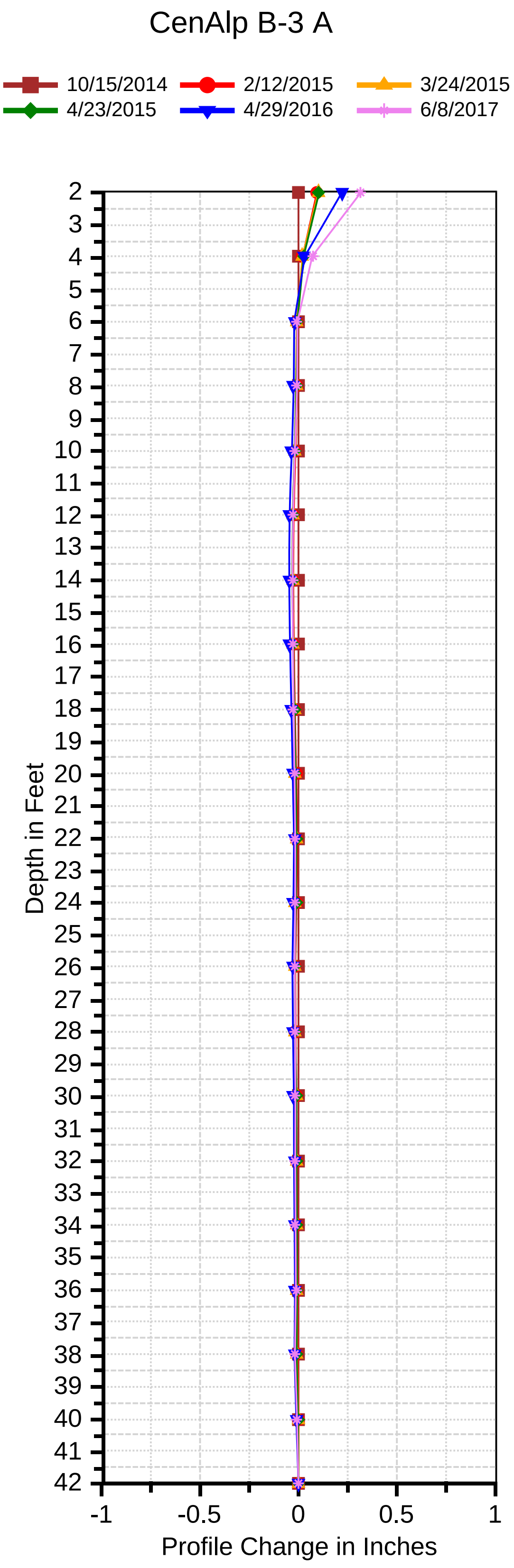
BIT DIAMETER: 4 7/8 inches
HAMMER EFFICIENCY PERCENT:
LOGGING COMPLETED: 3/23/15

APPENDIX B

Inclinometers and Vibrating-Wire Piezometers Data


CenAlp B-1 A
10/15/2014
2/12/2015
3/24/2015
4/23/2015
12/24/2015
4/29/2016
6/8/2017
8/7/2018
Depth in Feet
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
-1
-0.5
0
0.5
1
Profile Change in Inches
Corrections: Bias


CenAlp B-1 B
10/15/2014
2/12/2015
3/24/2015
4/23/2015
12/24/2015
4/29/2016
6/8/2017
8/7/2018
Depth in Feet
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
-1
-0.5
0
0.5
1
Profile Change in Inches
Corrections: Bias


CenAlp B-3 A
10/15/2014
2/12/2015
3/24/2015
4/23/2015
4/29/2016
6/8/2017
Depth in Feet
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
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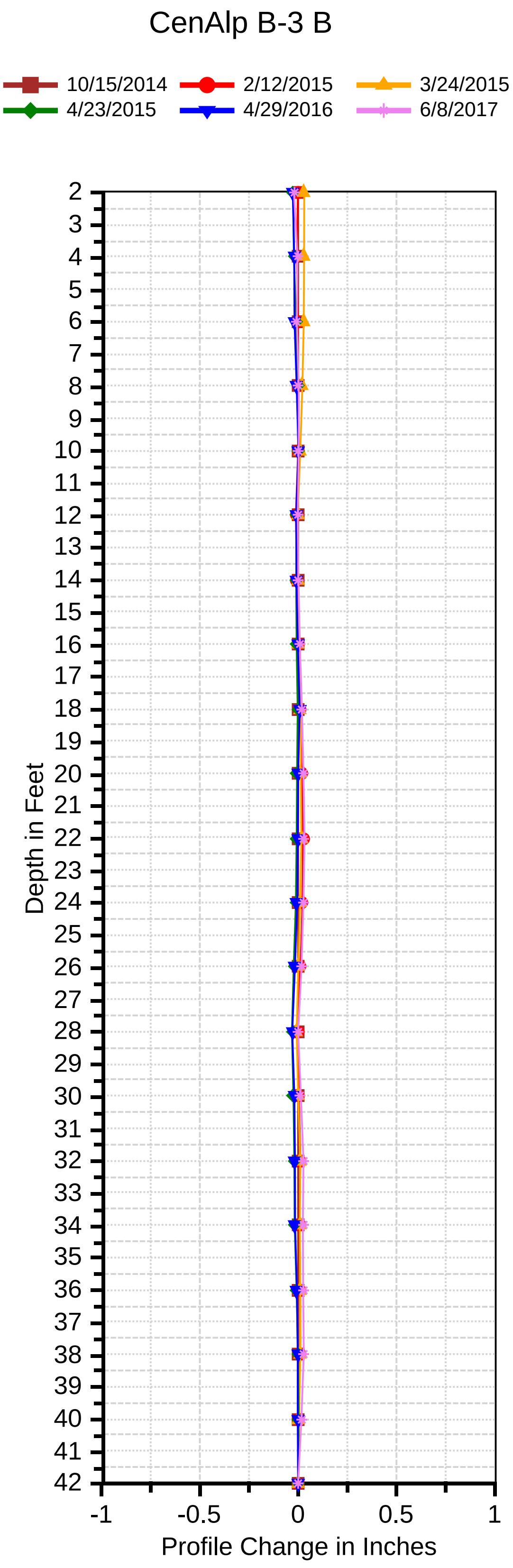
29
30
31
32
33
34
35
36
37
38
39
40
41
42
-1
-0.5
0
0.5
1
Profile Change in Inches


CenAlp B-3 B
10/15/2014
2/12/2015
3/24/2015
4/23/2015
4/29/2016
6/8/2017
Depth in Feet
2
3
4
5
6
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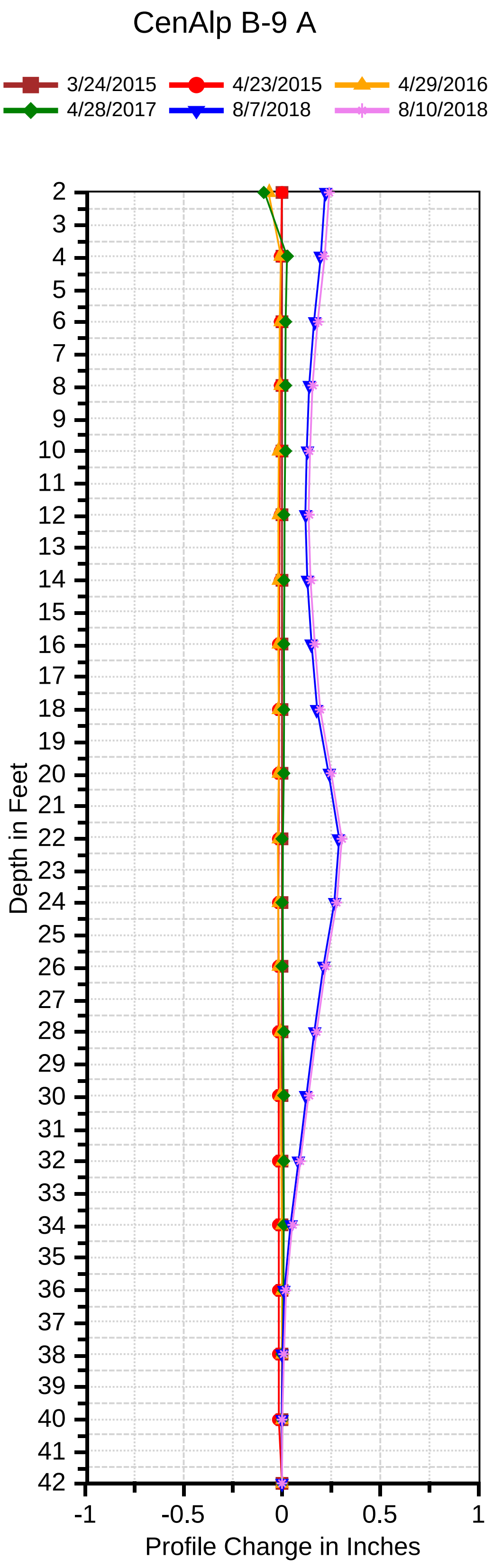
38
39
40
41
42
-1
-0.5
0
0.5
1
Profile Change in Inches


CenAlp B-9 A
3/24/2015
4/23/2015
4/29/2016
4/28/2017
8/7/2018
8/10/2018
Depth in Feet
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
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19
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21
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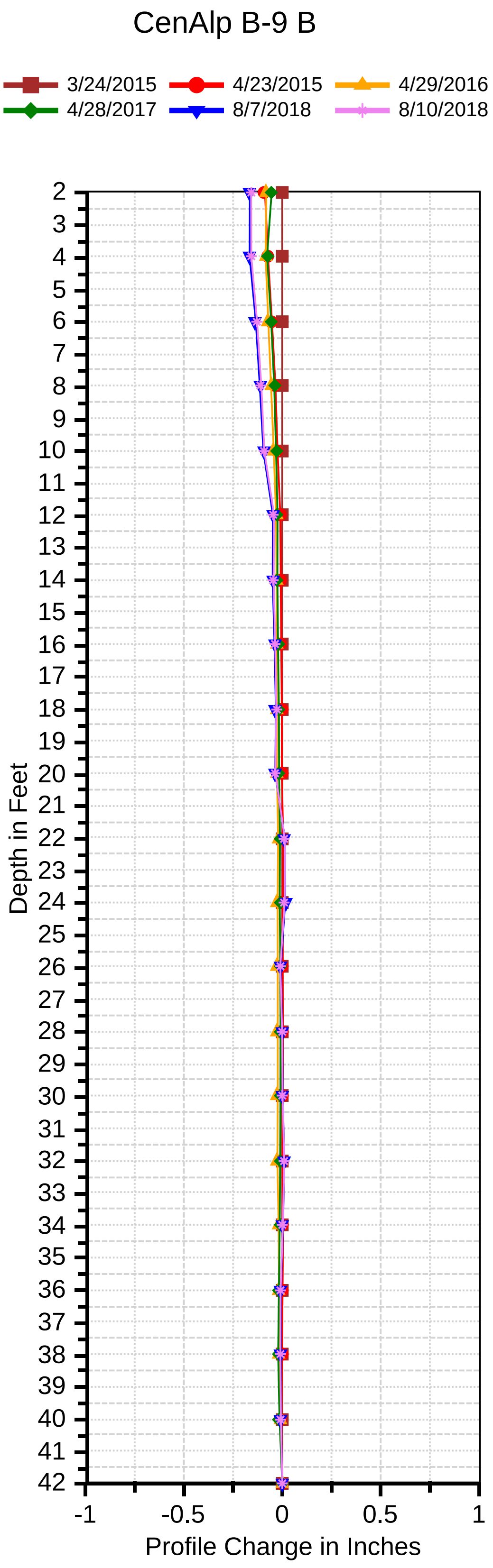
40
41
42
-1
-0.5
0
0.5
1
Profile Change in Inches


CenAlp B-9 B
3/24/2015
4/23/2015
4/29/2016
4/28/2017
8/7/2018
8/10/2018
Depth in Feet
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
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23
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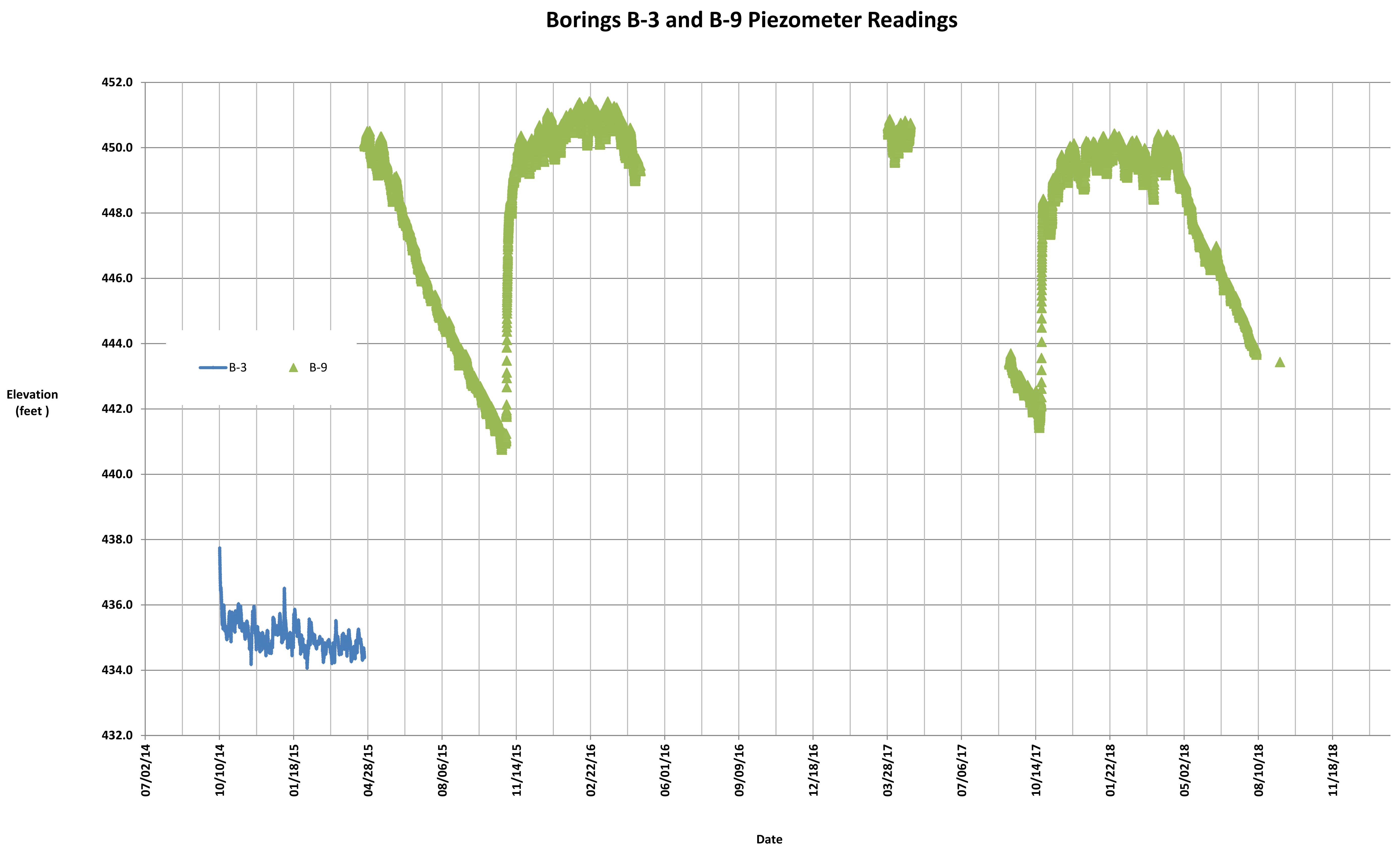
30
31
32
33
34
35
36
37
38
39
40
41
42
-1
-0.5
0
0.5
1
Profile Change in Inches



Borings B-3 and B-9 Piezometer Readings

APPENDIX C

Report Limitations and Guidelines for Use

REPORT LIMITATIONS AND GUIDELINES FOR USE

This Report and Project-Specific Factors

Aspect Consulting, LLC (Aspect) considered a number of unique, project-specific factors when establishing the Scope of Work for this project and report. You should not rely on this report if it was:

- Not prepared for you
- Not prepared for the specific purpose identified in the Agreement
- Not prepared for the specific real property assessed
- Completed before important changes occurred concerning the subject property, project or governmental regulatory actions

Geoscience Interpretations

The geoscience practices (geotechnical engineering, geology, and environmental science) require interpretation of spatial information that can make them less exact than other engineering and natural science disciplines. It is important to recognize this limitation in evaluating the content of the report. If you are unclear how these "Report Limitations and Use Guidelines" apply to your project or site, you should contact Aspect.

Reliance Conditions for Third Parties

This report was prepared for the exclusive use of the Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against liability claims by third parties with whom there would otherwise be no contractual limitations. Within the limitations of scope, schedule, and budget, our services have been executed in accordance with our Agreement with the Client and recognized geoscience practices in the same locality and involving similar conditions at the time this report was prepared

Property Conditions Change Over Time

This report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by events such as a change in property use or occupancy, or by natural events, such as floods, earthquakes, slope instability, or groundwater fluctuations. If any of the described events may have occurred following the issuance of the report, you should contact Aspect so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

Discipline-Specific Reports Are Not Interchangeable

The equipment, techniques, and personnel used to perform a geotechnical or geologic study differ significantly from those used to perform an environmental study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually address any environmental findings, conclusions, or recommendations (e.g., about the likelihood of encountering underground storage tanks or regulated contaminants). Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding the subject property.

We appreciate the opportunity to perform these services. If you have any questions please contact the Aspect Project Manager for this project.