WSDOT Foundation and Fill Settlement Case Histories

WA-RD 884.1

Tony M. Allen

August 2018

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WSDOT Foundation and Fill Settlement Case Histories

by
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16. ABSTRACT:

Estimation of settlement below foundations and embankment fills is a routine geotechnical design requirement. A couple of settlement estimation methods are typically used for this purpose nationally and at WSDOT. These include the Hough and Schmertmann methods. This report provides a summary of these methods, and an assessment of their accuracy through comparison of predicted and measured settlement values. Based on long-term experience, it is usually assumed that settlement estimates are not reliable enough to predict settlements of less than 0.5 inch. The available data appear to support this in that the scatter in the measured settlement is greater than the settlement prediction for settlements of less than 0.5 inch.

The scope of this research is limited to sandy WSDOT sites where settlement was measured (i.e., settlement in clay is not included). Measured settlements ranged from 0.5 inch to 40 inches.

Overall, the Hough Method provided a more accurate prediction than did the Schmertmann Method.

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EXECUTIVE SUMMARY

Summarized in this report are comparisons between measured and predicted settlements obtained from three project sites in the State of Washington (13 individual measurements and predictions), two sites in western Washington and one site in eastern Washington. The eastern Washington case is a cut-and-cover tunnel in which the tunnel footing settlement was measured; however, the surrounding fill was the driver regarding the settlement measured there. The two western Washington cases represent bridge abutment fill settlement, though two of the measurement locations included an MSE wall. These measurements and predictions are used to determine the accuracy of two settlement estimation methods, the Hough Method and the Schmertmann Method, in Washington soils. The database of measurements reported here are not comprehensive, but do represent some typical cases.

Based on these data, both methods appear to be reliable, though in general, settlement estimates were conservative. The Hough Method was more consistent than the Schmertmann Method when SPT data are used, but on average was conservative by an approximate factor of 1.5 for the sites investigated. The Schmertmann Method predictions using CPT data were the most accurate, but that data set is extremely limited, so all that can be said at this point is that the Schmertmann Method has the potential to provide the most accurate results when CPT data are available.

THE PROBLEM

Estimation of settlement due to structure loads and beneath embankments is a common geotechnical design requirement. For structures, this settlement has a direct impact on the loads induced in a structure, affecting the structural design of the structure. For embankments, settlement can affect pavement design, impacts to adjacent structures, differential settlement between the bridge abutment and the approach fill, down drag loads on structure foundations, and the need to add fill to reestablish the embankment grade.

Settlement estimation methods typically used (e.g., Hough 1959) were developed decades ago, were based on limited data, and were not specifically developed for Washington soils. Settlement data collected for WSDOT projects can be used to assess the accuracy of these existing methods for soils commonly encountered in the state of Washington.

BACKGROUND FOR AND SUMMARY OF MOST COMMONLY USED SETTLEMENT PREDICTION METHODS

Two empirical settlement prediction methods have been commonly used for WSDOT projects to estimate “elastic” (i.e., not time dependent, but immediate) settlement in cohesionless soils: the Hough Method, and the Schmertmann Method, though the Schmertmann Method does have an empirical coefficient that can be used to simulate potential time dependency. Of these two methods, the Hough Method has been the most often used for WSDOT projects. Settlement of cohesionless soils usually occurs rapidly, essentially as soon as the foundation is loaded. Hence, this type of settlement is often characterized as elastic.

Note that it may be necessary to use more than one settlement estimation approach for layered profiles consisting of a combination of cohesive soil, cohesionless soil and/or rock. For example, for a cohesive soil layer, the settlement should be estimated using consolidation theory in combination with undisturbed soil samples tested using a laboratory consolidation test. For the cohesionless soil layers, the settlement estimation methods described in this report should be used. An appropriate settlement estimation procedure for each layer within the zone of influence of induced stress beneath the footing or embankment should be used.

Settlement prediction requires knowledge of:

- The applied stress increase due to the structure footing or embankment,
- The rate at which the stress increase dissipates with depth below the structure footing or embankment, and
- The compression characteristics of the soil layers (e.g., as estimated using the Hough or Schmertmann methods).

Prediction of Stress Increase as a Function of Depth

To estimate settlement, the stress increase at various depths below the applied load (i.e., due to the foundation or embankment load) must be estimated. Typically the estimation of stress increase as a function of depth is accomplished with linear elastic half-space methods such as by Boussinesq (1885) or Westegaard (1938). While most soils are not elastic materials, the theory of elasticity is the most widely used methodology to estimate the stress distribution in a soil deposit from a surface load.

The equations for the theory of elasticity have been incorporated into design charts and tables for typical loading scenarios, such as below a foundation or an embankment. Almost all foundation engineering textbooks include these charts. For convenience, charts to evaluate embankment loading are included as figures 1 and 2.

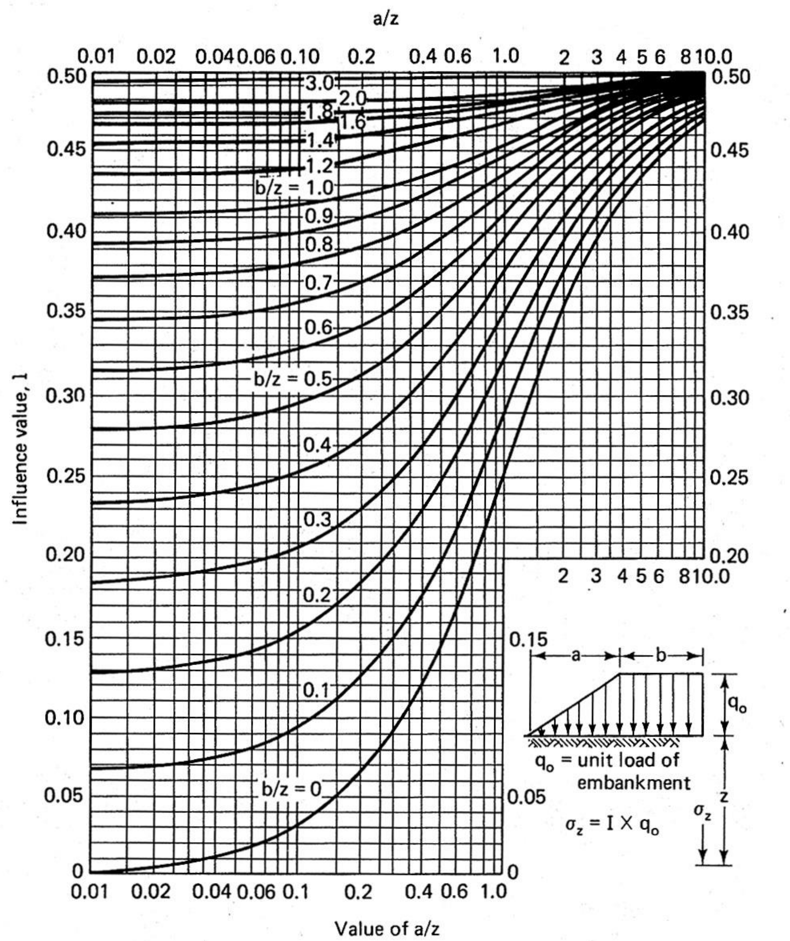


Figure 1. Influence factors for vertical stress under a very long embankment (after Osterberg 1957 as reported in Holtz and Kovacs, 1981).

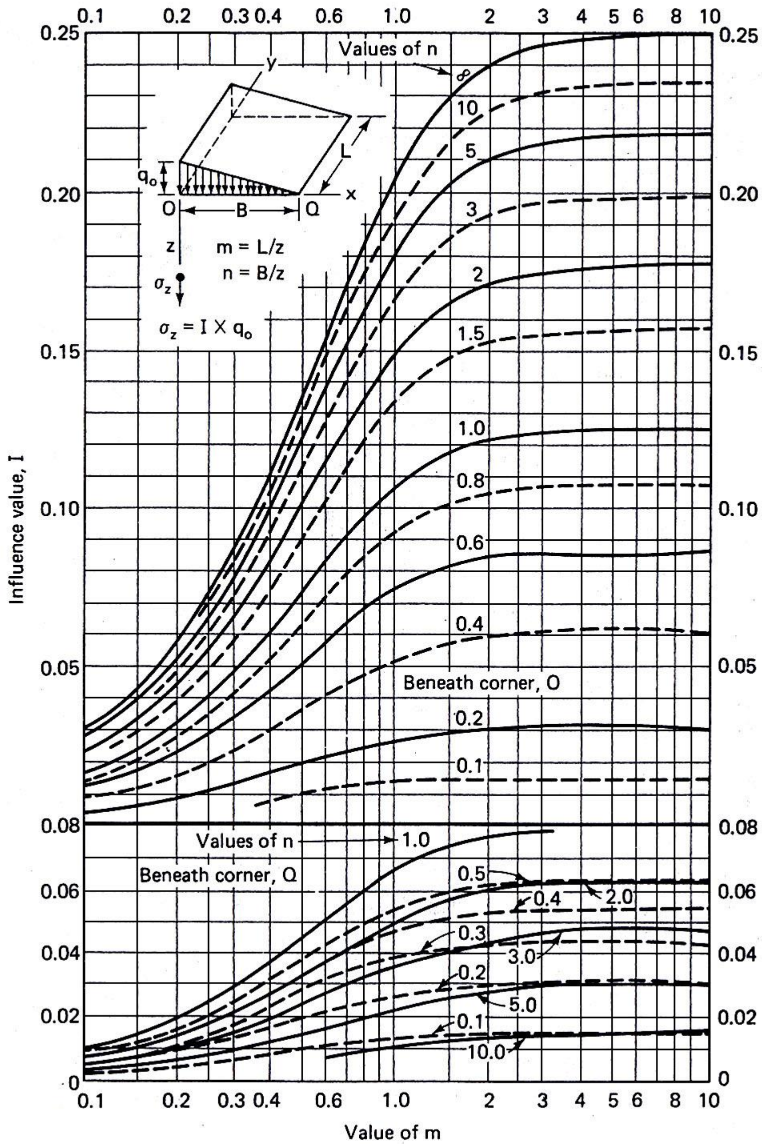


Figure 2. Influence values for vertical stress under the corners of a triangular load of limited length (after NAVFAC, 1971 as reported in Holtz and Kovacs, 1981).

The distribution of vertical stress increase below circular or square foundations, and long rectangular footings (i.e., where L > 5B), may be estimated using Figure 3.

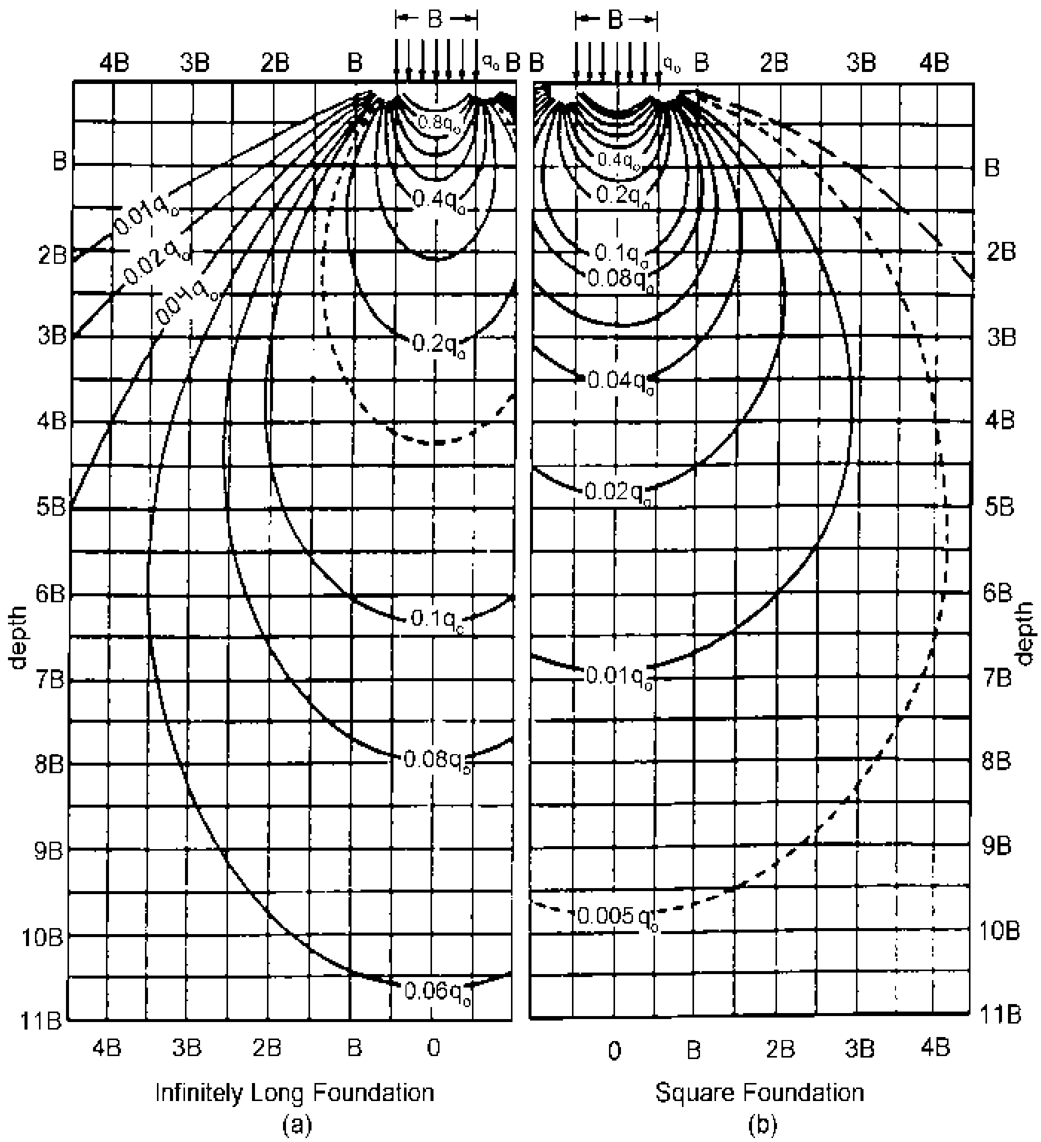


Figure 3. Boussinesq Vertical Stress Contours for Continuous and Square Footings Modified after Sowers (1979).

A more simplified approach that is sometimes used to estimate stress distribution at depth is the 2V:1H (vertical to horizontal) method. This empirical approach is based on the assumption that the area the load acts over increases geometrically with depth as depicted in Figure 4. Since the same vertical load is spread over a much larger area at depth, the unit stress decreases.

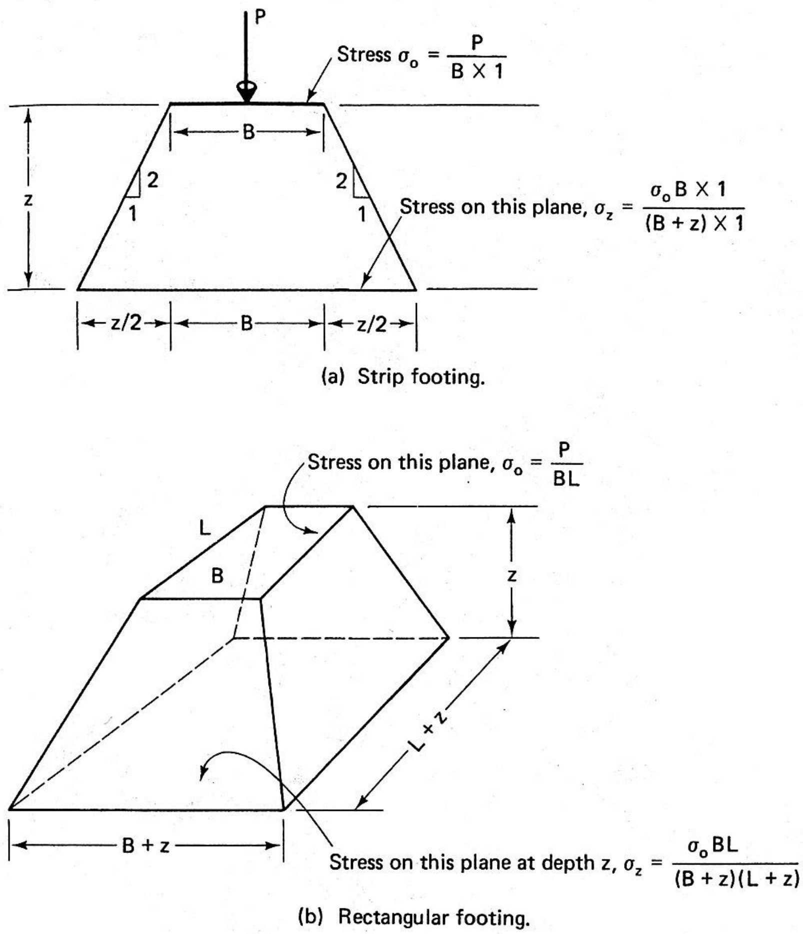


Figure 4. 2V:1H method to estimate vertical stress increase as a function of depth below ground (after Holtz and Kovacs, 1981).

The Hough Method uses the methods described above to estimate the stress increase at various depths below the applied load. The Schmertmann Method, however, uses its own approach developed from finite element modeling and greatly reduced scale laboratory experiments to estimate the stress and strain increase at various depths below the applied load (Schmertmann et al., 1978). Since the Schmertmann Method stress increase as a function of depth was originally developed for rigid footings, it may not be as applicable to embankment settlement.

The Hough Method

Estimation of settlement on cohesionless soils using the Hough Method is determined using Eqs. 1 and 2. Standard Penetration Test (SPT) blow counts are corrected as specified in the AASHTO LRFD Bridge Design Specifications (AASHTO 2017), Article 10.4.6.2.4, for depth, i.e. overburden stress, and hammer efficiency, before correlating the SPT blow counts to the bearing capacity index, *C′*.

$$S_e = \sum_{i=1}^{n} \Delta H_i \quad (1)$$

in which:

$$\Delta H_i = H_c \frac{1}{C'} \log\left(\frac{\sigma'_o + \Delta\sigma_v}{\sigma'_o}\right) \quad (2)$$

where:

n = number of soil layers within zone of stress influence of the footing

ΔH_i = elastic settlement of layer *i* (ft)

H_C = initial height of layer *i* (ft)

C' = bearing capacity index from Figure 5 (dim)

σ'_o = initial vertical effective stress at the midpoint of layer *i* (ksf)

$\Delta\sigma_v$ = increase in vertical stress at the midpoint of layer *i* (ksf)

Figure 5 provides the empirical correlation between the Hough bearing capacity index C’ and the corrected SPT blow counts, $N1_{60}$.

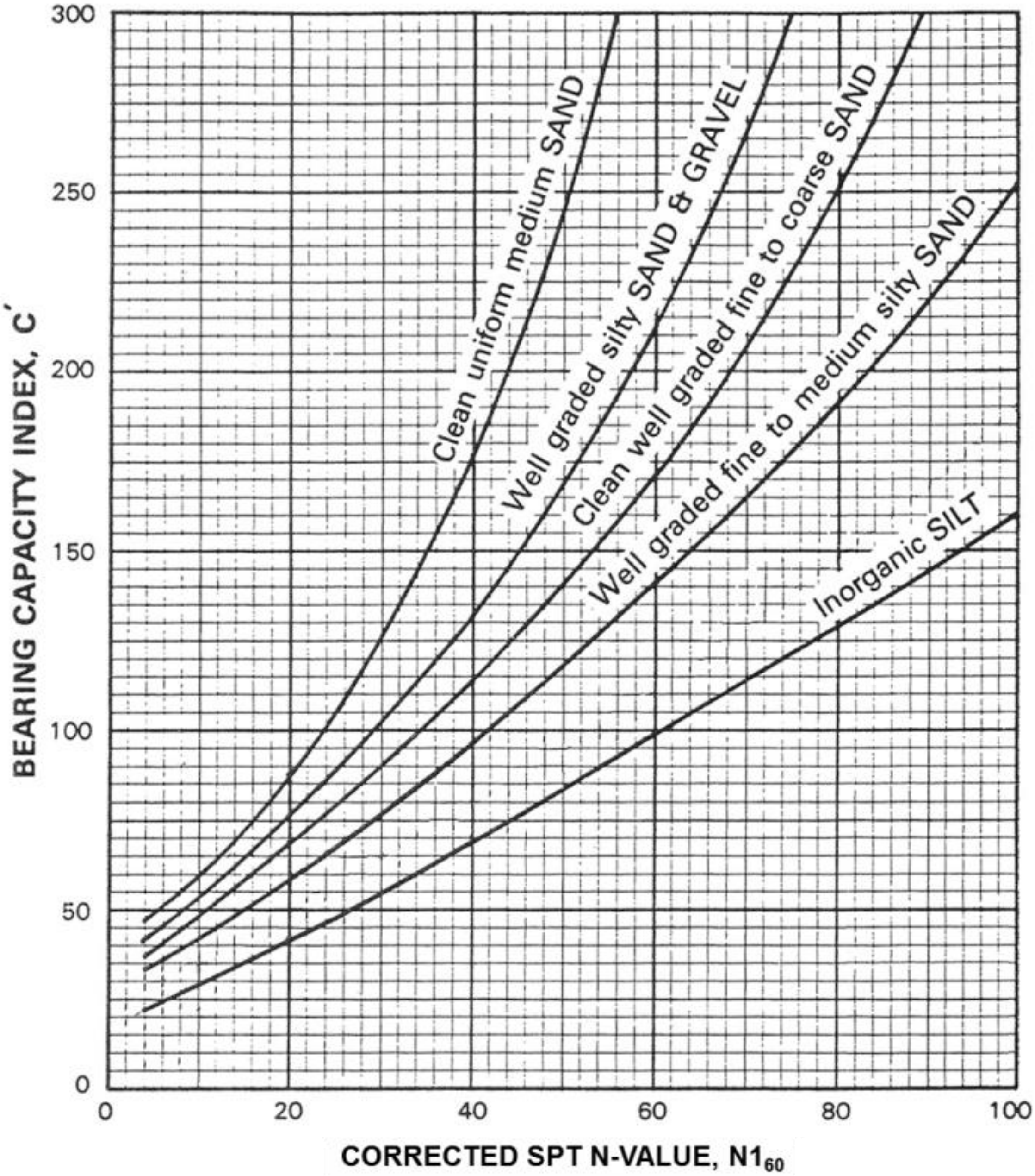


Figure 5. Bearing Capacity Index versus Corrected SPT (Hough, 1959, as modified in Samtani and Nowatzki, 2006)

The Hough Method was developed for normally consolidated cohesionless soils. The "Inorganic Silt" curve should generally not be applied to soils that exhibit plasticity. The settlement characteristics of cohesive soils that exhibit plasticity should be investigated using undisturbed samples and laboratory consolidation tests.

The Hough Method has several advantages over other methods used to estimate settlement in cohesionless soil deposits, including express consideration of soil layering and the zone of stress influence beneath a footing of finite size.

The subsurface soil profile should be subdivided into layers based on stratigraphy to a depth of about three times the footing width. The maximum layer thickness should be about 10 ft.

While Hough (1959) did not specifically state that the SPT N values should be corrected for hammer energy in addition to overburden pressure, due to the vintage of the original work, hammers that typically have an efficiency of approximately 60 percent were in general used to develop the empirical correlations contained in the method. If using SPT hammers with efficiencies that differ significantly from this 60 percent value, the *N* values should also be corrected for hammer energy, in effect requiring that $N1_{60}$ be used (Samtani and Nowatzki, 2006).

Studies conducted by Gifford et al. (1987) and Samtani and Nowatzki (2006) indicate that Hough's procedure is more conservative, but has less prediction variability, than the Schmertmann Method. However, this difference is mostly taken into account through the load factor, γ_{SE}, since it has been calibrated using reliability theory (Kulicki, et al., 2015; Samtani and Kulicki, 2018; and Samtani and Allen, 2018).

The Schmertmann Method

The Schmertmann Method was originally developed for rigid footings in sand using CPT data (Schmertmann 1970; Schmertmann et al. 1978), and has also been adapted for use with SPT data in Samtani and Nowatzki (2006). This method was originally developed for use with the static cone bearing resistance q_c, in which q_c was correlated to the soil modulus, E, and E is used directly in this method. The original formulation by Schmertmann (1970) for this correlation assumed E was in units of tsf (i.e., E (in tsf) = $2q_c$ (in tsf or kg/cm^2). The correlation in Table 1 predicts E in ksi. Correlations between E and the SPT N value are also available and provided in Table 1.

Equations 3 through 6 are used to estimate spread footing immediate, or elastic, settlement, S_i, on cohesionless soils by this method (Samtani and Nowatzki 2006).

$$S_i = C_1 C_2 \Delta p \sum_{i=1}^{n} \Delta J_i \quad (3)$$

in which:

$$\Delta J_i = H_c \left(\frac{I_z}{144 XE} \right) \quad (4)$$

$$C_1 = 1 - 0.5 \left(\frac{p_o}{\Delta p} \right) \geq 0.5 \quad (5)$$

$$C_2 = 1 + 0.2 \log_{10} \left(\frac{t}{0.1} \right) \quad (6)$$

where:

ΔJ_i = elastic spring stiffness of layer *i* (ft/ksf)

H_C = height of compressible soil layer *i* (ft)

I_z = strain influence factor from Figure 6. The dimension B_f represents the least lateral dimension of the footing after correction for eccentricities, i.e. use least lateral effective footing dimension. The strain influence factor is a function of depth and is obtained from the strain influence diagram. The strain influence diagram is constructed for the axisymmetric case ($L_f/B_f = 1$) and the plane strain case ($L_f/B_f \geq 10$) as shown in Figure 6a. The strain influence diagram for intermediate conditions should be determined by simple linear interpolation.

n = number of soil layers within the zone of strain influence (strain influence diagram).

Δp = net uniform applied stress (load intensity) at the foundation depth (see Figure 6b) (ksf).

E = elastic modulus of layer i based on guidance provided in Table 1 (ksi).

X = a factor used to determine the value of elastic modulus. If the value of elastic modulus is based on correlations with $N1_{60}$-values or q_c from Table 1, then values of X are as follows:

$X = 1.25$ for axisymmetric case ($L_f/B_f = 1$)

$X = 1.75$ for plane strain case ($L_f/B_f \geq 10$)

Use interpolation for footings with values of L_f/B_f between 1 and 10.

If the value of elastic modulus is based on other sources, such as in-situ testing (e.g., pressuremeter), use $X = 1.0$.

C_1 = correction factor to incorporate the effect of strain relief due to embedment

p_o = effective in-situ overburden stress at the foundation depth - pressure as shown in Figure 6b (ksf)

Δp = net uniform applied stress (load intensity) at the foundation depth as shown in Figure 6b (ksf).

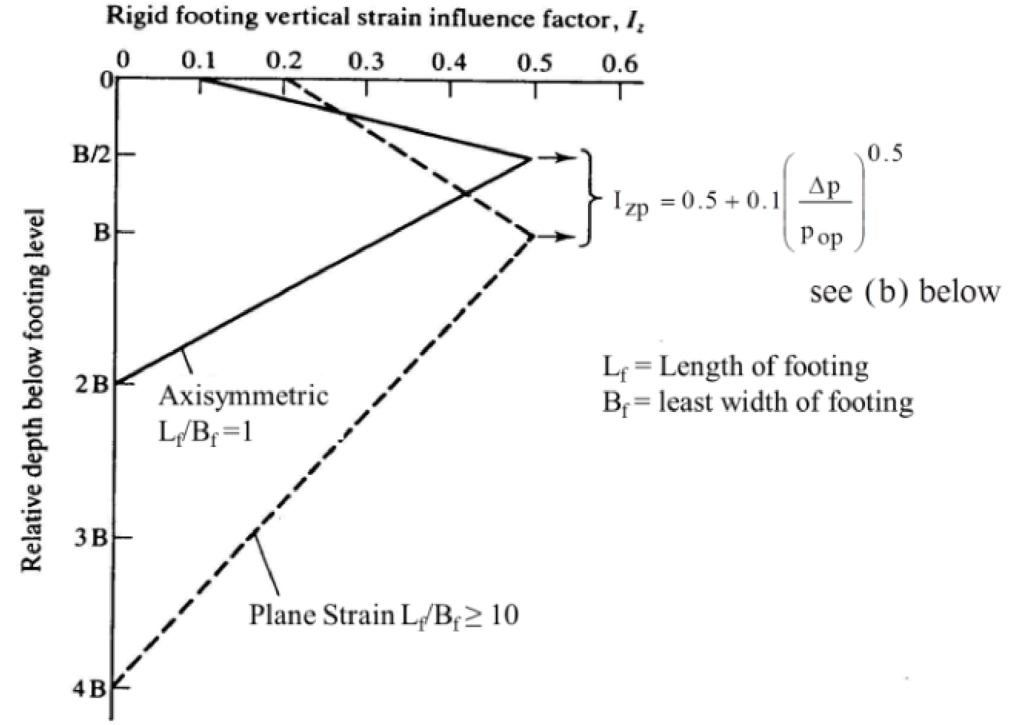
C_2 = correction factor to incorporate time-dependent (creep) increase in settlement for time t after construction

t = time t from completion of construction to date under consideration for evaluation of C_2 (yrs)

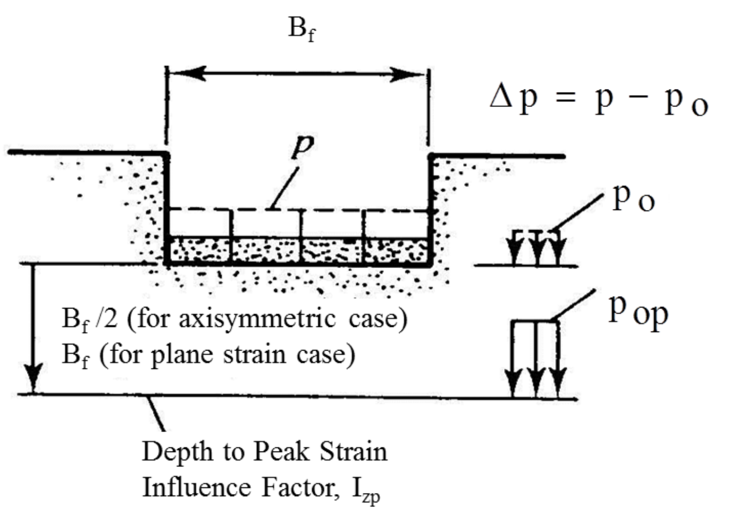
The C_2 parameter is not used to estimate time-dependent consolidation settlements. Where consolidation settlement can occur within the depth of the strain distribution diagram, the magnitude of the consolidation settlement should be estimated from consolidation tests conducted on undisturbed samples (see AASHTO LRFD Bridge Design Specifications Article 10.6.2.4.3) and added to the immediate settlement of other layers within the strain distribution diagram where consolidation settlement may not occur.

The variables in the equation for ΔJ_i (Equation 4) require specific units for H_c (ft) and E (provided in Table 1) is in ksi. This results in the units for ΔJ_i being ft/ksf. Furthermore, in Equation 3 and 5, units of p_o and Δp must be ksf.

For C_2 correction factor the time duration, t, in Eq. 6 is set to 0.1 years to evaluate the settlement immediately after construction, i.e., $C_2 = 1$. If long-term creep deformation of the soil is suspected then an appropriate time duration, t, should be used in the computation of C_2. Creep deformation is not the same as consolidation settlement. This factor can have an important influence on the reported settlement since it is included in Eq. 3 as a multiplier. For example, the C_2 factor for time durations of 0.1 yrs, 1 yr, 10 yrs and 50 yrs are 1.0, 1.2, 1.4 and 1.54, respectively. In cohesionless soils and unsaturated fine-grained silts with low plasticity, time durations of 0.1 yr and 1 yr, respectively, are generally appropriate and sufficient for cases of static loads.



(a)



(b)

Figure 6—(a) Simplified vertical strain influence factor distributions, (b) Explanation of pressure terms in equation for Izp (Samtani and Notatzki, 2006, after Schmertmann, et al., 1978).

Table 1: Correlations between Elastic Soil Modulus and SPT $N1_{60}$ or static Cone q_c values for the Schmertmann Method (Schmertmann 1970, and Samtani and Nowatzki 2006).

Correlation between *E* and SPT $N1_{60}$ Value	
Soil Type	**E (ksi)**
Silts, sandy silts, slightly cohesive mixtures	0.056 $N1_{60}$
Clean fine to medium sands and slightly silty sands	0.097 $N1_{60}$
Coarse sands and sands with little gravel	0.139 $N1_{60}$
Sandy gravel and gravels	0.167 $N1_{60}$
Correlation between E and q_c (static cone resistance, in tsf or kg/cm^2)	
Soil Type	**E (ksi)**
Sandy soils	$0.028q_c$

OBJECTIVE AND SCOPE OF THIS REPORT

The objective of this report is to summarize several WSDOT case histories in which settlement was measured and compare those measured settlements to the predicted settlement using both the Hough and Schmertmann methods. The data from these case histories can then be used to begin developing a database of predicted and estimated settlements to refine WSDOT design practice. The scope of this report is limited to cases in which the native soils are generally cohesionless in nature (i.e., silts, sands, and gravels). While some of the case histories have included foundation elements, in those cases, new fill was adjacent to or even surrounding the foundation elements such that the total load applied to the foundation soil is strongly influenced by the fill load.

CASE HISTORY DESCRIPTIONS

Case histories addressed in this report are as follows:

- SR395, Francis Avenue to US2 Structures, BNSF Railroad Overcrossing Tunnel
- SR522, University of Washington – Bothell/Cascadia Community College South Campus Access Walls
- I-5, I-5/SR432 Talley Way Interchange

SR395, BNSF Railroad Tunnel

This project involved construction of a spread footing supported (arch) tunnel to allow the proposed State Route (SR) 395 alignment/fill to pass over the existing Burlington Northern Santa Fe (BNSF) Railroad at the north end of Spokane, Washington. The project location is shown in Figure 7. The arch had a clear span (i.e., interior width) of approximately 51 feet at the base, and the footings were designed for a service limit state bearing stress of approximately 7 kips per square foot to keep the footing stress approximately the same as the added overburden stress due to the fill located beside the tunnel. A cross-section of the tunnel is provided in Figure 8, and a tunnel footing detail is provided in Figure 9. The proposed embankment over the existing BNSF tracks varied from 50 to 58 feet in total height. Figure 10 shows the tunnel and fill under construction. Due to the large amount of fill over and around the tunnel, the fill footprint is what controlled the stress increase with depth below the tunnel.

The subsurface conditions consisted of loose to dense sands above granitic bedrock at depths of 45 to 110 feet. The layout of the tunnel and the soil boring locations are shown in Figure 11. A longitudinal soil profile along the tunnel is provided in Figure 12.

Settlement predictions and measurements for this case history were conducted at eight locations along the tunnel alignment. The settlement estimates and measurements near the ends of the tunnel were treated as outliers for this study due to the extreme changes in fill/tunnel geometry that happen there. Therefore, only data at test holes RR-2-04 through RR-7-04 are used, corresponding to Site No's 1 through 6, respectively.

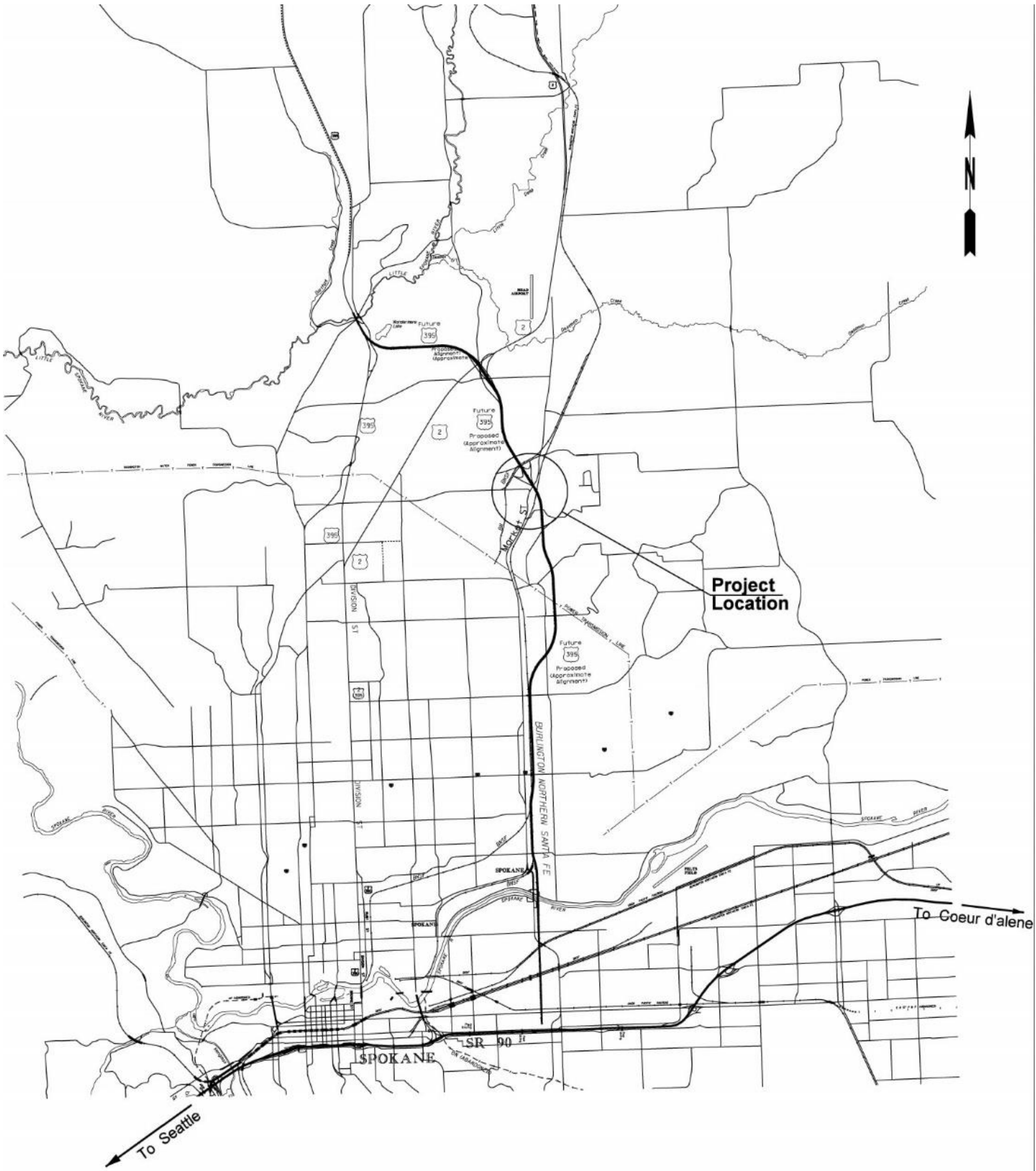


Figure 7. SR395 BNSF Railroad tunnel vicinity map.

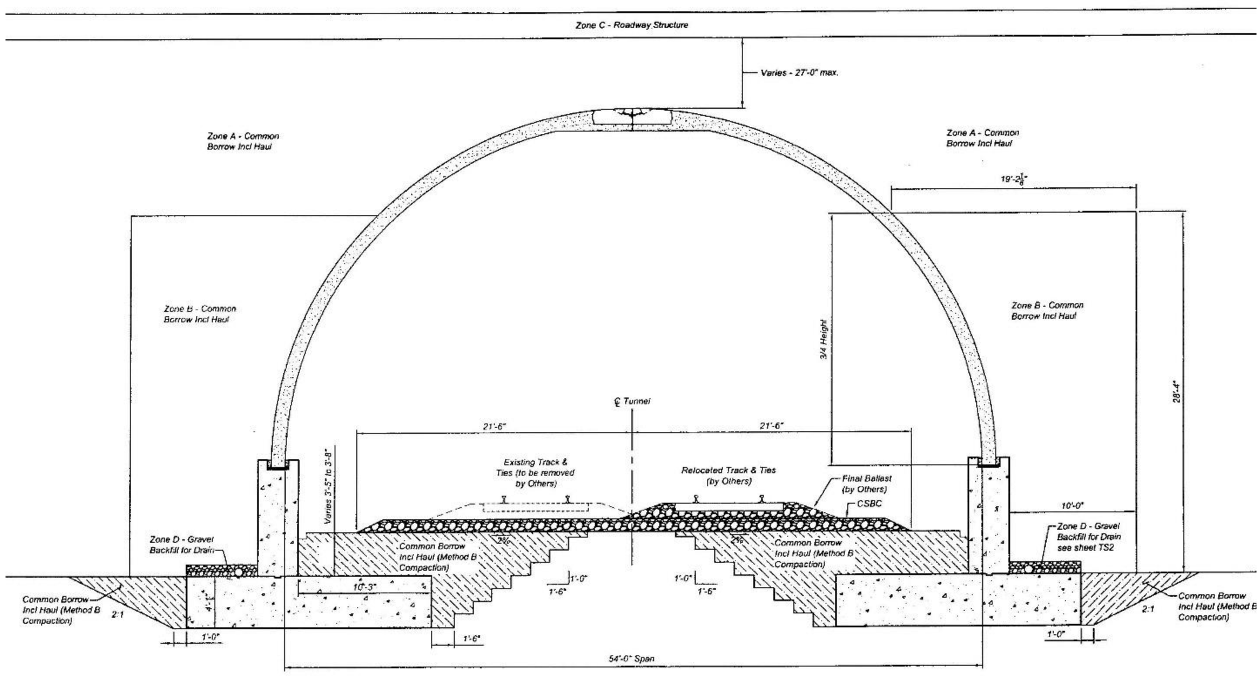


Figure 8. Cross-section of spread footing supported arch tunnel.

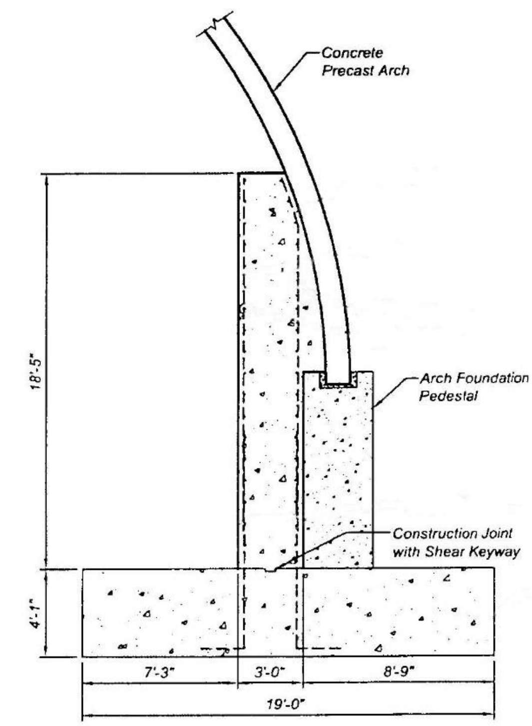


Figure 9. Close-up of spread footing that supports arch tunnel.

Figure 10. Overview showing arch and fill under construction.

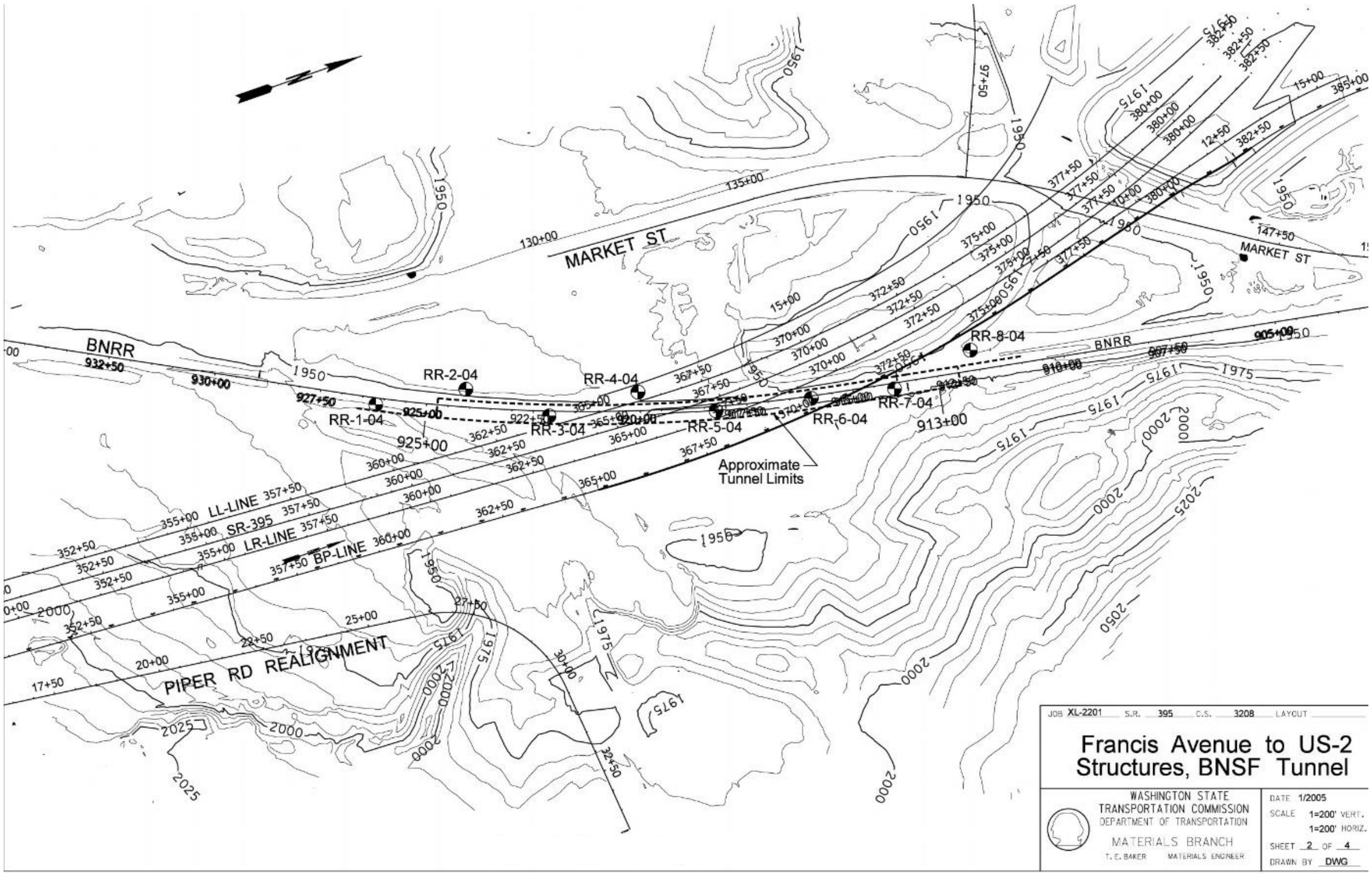


Figure 11. Plan view of tunnel showing boring locations.

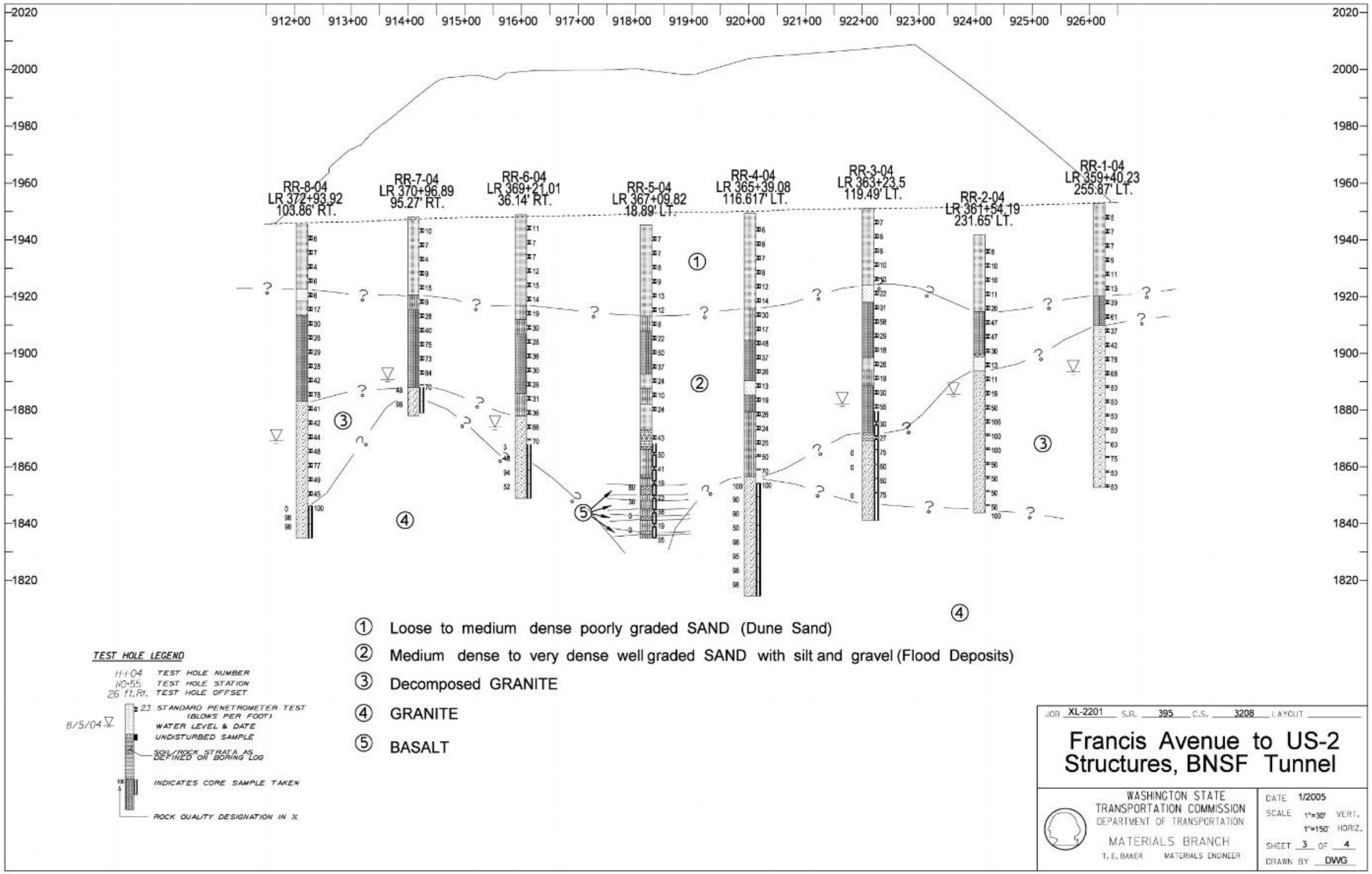


Figure 12. Geologic profile along tunnel showing subsurface conditions.

SR522, University of Washington – Bothell/Cascadia Community College South Campus Access Walls

This project involved construction of a number of transportation and associated infrastructure improvements intended to provide improved access to the University of Washington Bothell/Cascadia Community College campus from SR522 in Bothell, Washington. The project location is shown in Figure 13.

One of the project infrastructure improvements consisted of widening the SR522/28N Bridge and constructing geosynthetic approach walls (Walls 9 and 10) to accommodate this widening. The walls are located on the north side of the proposed widening, and they both were designed to match to the curtain walls of the bridge widening. Wall 9 is on the west abutment, and Wall 10 is on the east abutment. The general plan locations of the walls along with a subsurface profile are provided in figures 14 and 15, respectively. The walls were generally 7 to 8 feet tall in the areas monitored, and approximately 175 ft long. At the settlement plate locations, the soil was characterized as very loose to medium dense interbedded silt, organic silt, clayey sand, silty sand, and poorly-graded sand for the upper 10 ft to 20 ft (recent alluvium). Below that, it transitioned to a very dense silty sand and gravel (glacial till). Groundwater at this site was generally encountered within the upper 10 feet to 20 feet of the deposit. Due to near surface organic soils, the top 3 ft of soils at Wall 9 were over-excavated and replaced with compacted gravel borrow. Both walls were surcharged by over-building the wall by 5 feet in height, which was removed after the majority of the settlement occurred.

Settlements were predicted and measured at one location for each wall. These two locations are designated as Site No's 7 (i.e., Wall 9) and 8 (i.e., Wall 10).

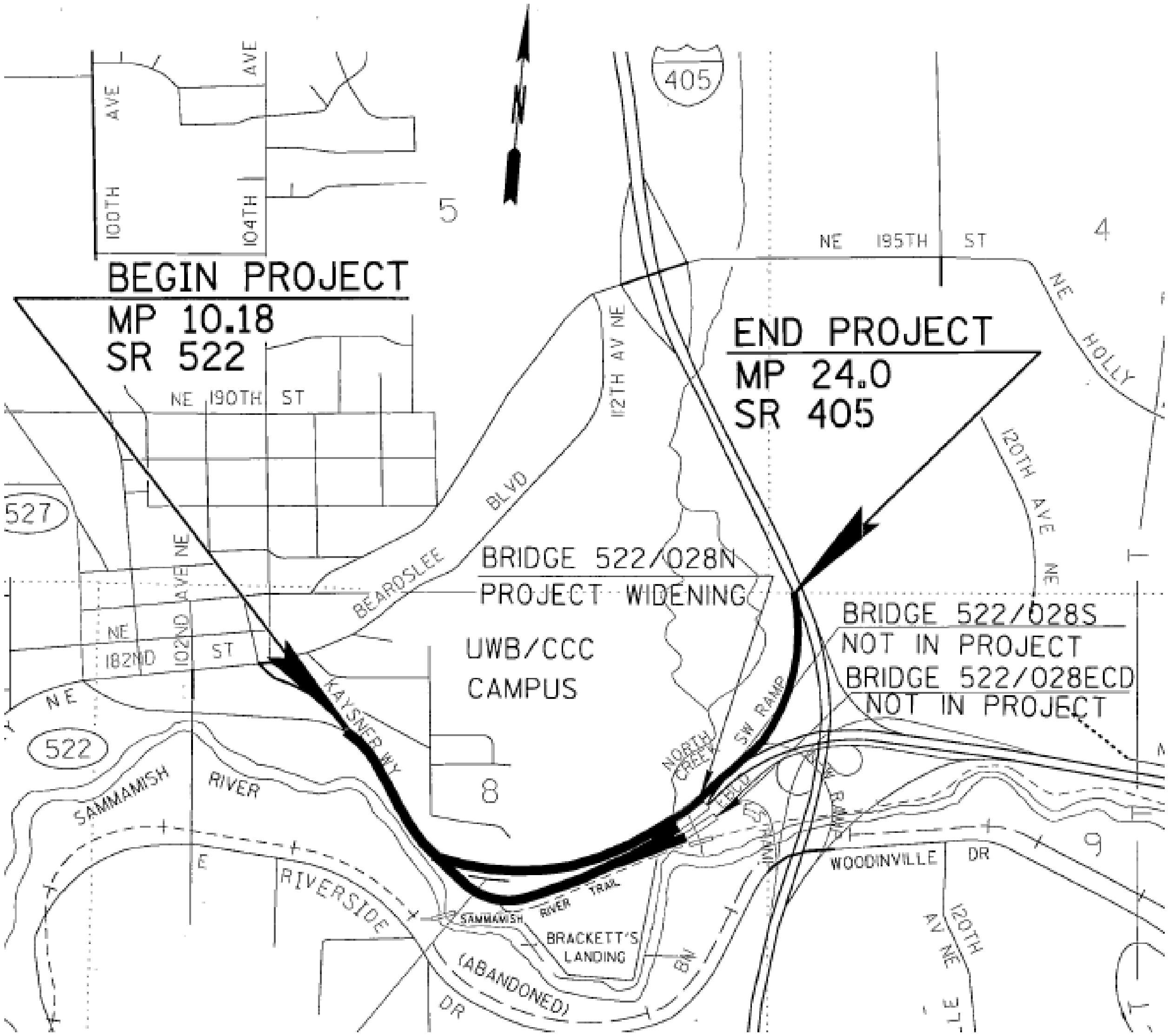


Figure 13. SR522, University of Washington – Bothell/Cascadia Community College South Campus Access Walls vicinity map.

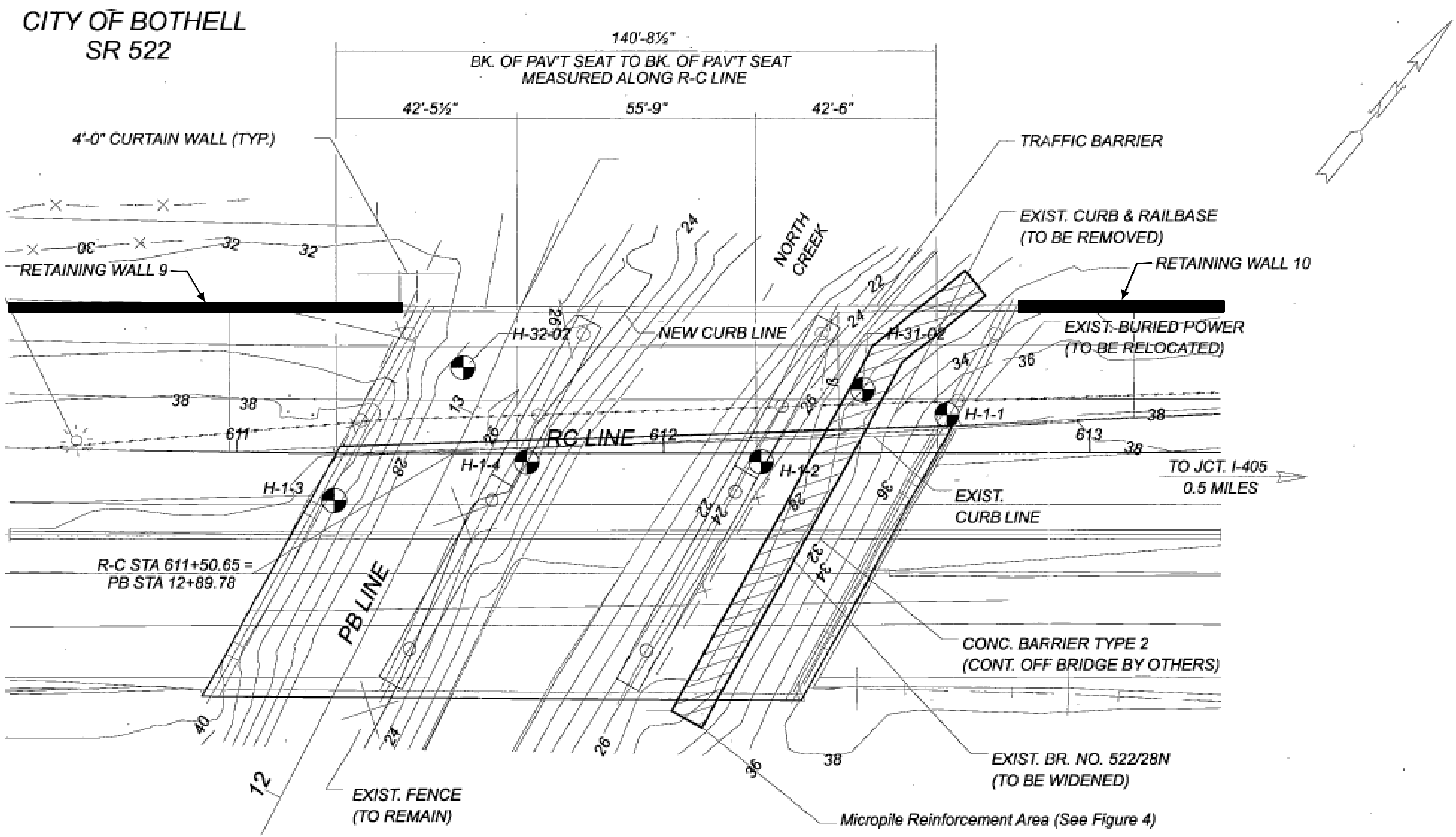


Figure 14. Plan View of Sites No. 7 and No. 8.

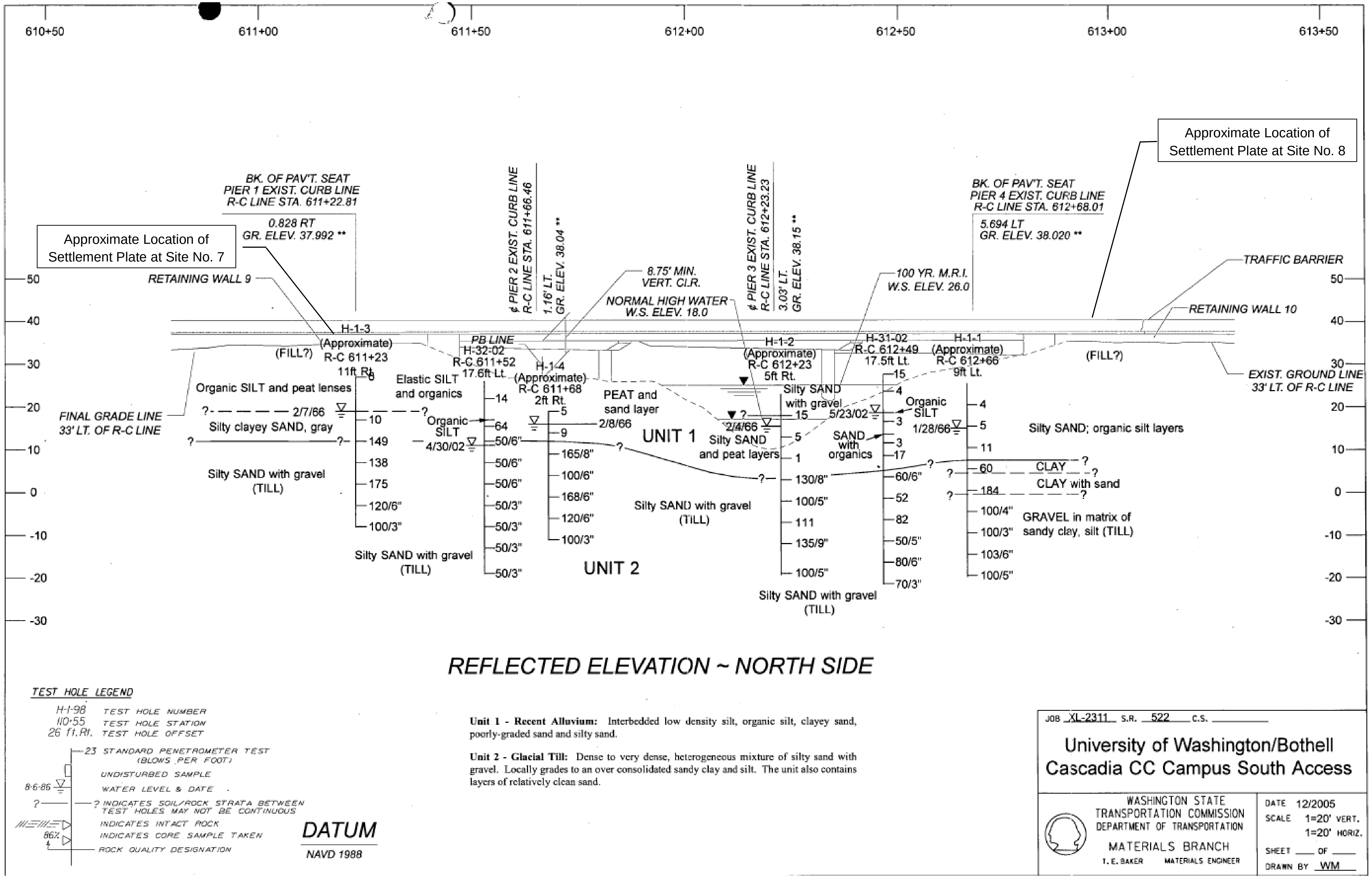


Figure 15. Subsurface Profile for Sites No.7 and No.8.

I-5/SR432 Talley Way Interchange

This project involved construction of a number of transportation and associated infrastructure improvements intended to provide improved access from I-5 to SR432 and Longview, Washington. The project location is shown in Figure 16. Deep soft soils at the project location created geotechnical design complications due to settlement and liquefaction effects such as lateral spreading and liquefaction induced settlement that had to be addressed during design and monitored during construction. Liquefaction problems were addressed in the vicinity of the structures through the use of stone columns.

Settlements were predicted and monitored at 16 sites across the project area, including both areas where stone columns were installed to mitigate liquefaction problems and areas where fill and wall settlement due to the static loads was expected. These sites were located along fill walls, embankments and bridge approaches. There were only five of the 16 settlement plates that were not installed in stone column improved areas, and these five settlement plates were used in this study. The locations of these five settlement plates were used to monitor settlement under fill embankments, a geosynthetic wall, and under a pre-load embankment between bridge abutments during the construction of the I-5/SR 432 Talley Way Interchange. These five individual sites are designated as Site No's 9 to 13.

The new embankments typically ranged from 20 ft to 30 ft in height. The geosynthetic wall was approximately 17 feet tall at the settlement plate location, and the pre-load embankment was typically 20 feet tall. A photograph of the pre-load embankment during construction is presented in Figure 17, and its cross-section is presented in Figure 18. The subsurface conditions consisted of up to 100 feet of very loose to medium dense sandy silt (alluvium), underlain by very dense sand, silt, or bedrock. Plan views of the approximate settlement plate locations including boring locations are provided in figures 19 through 21. Typical sections with soil profile data are provided in figures 22 through 24.

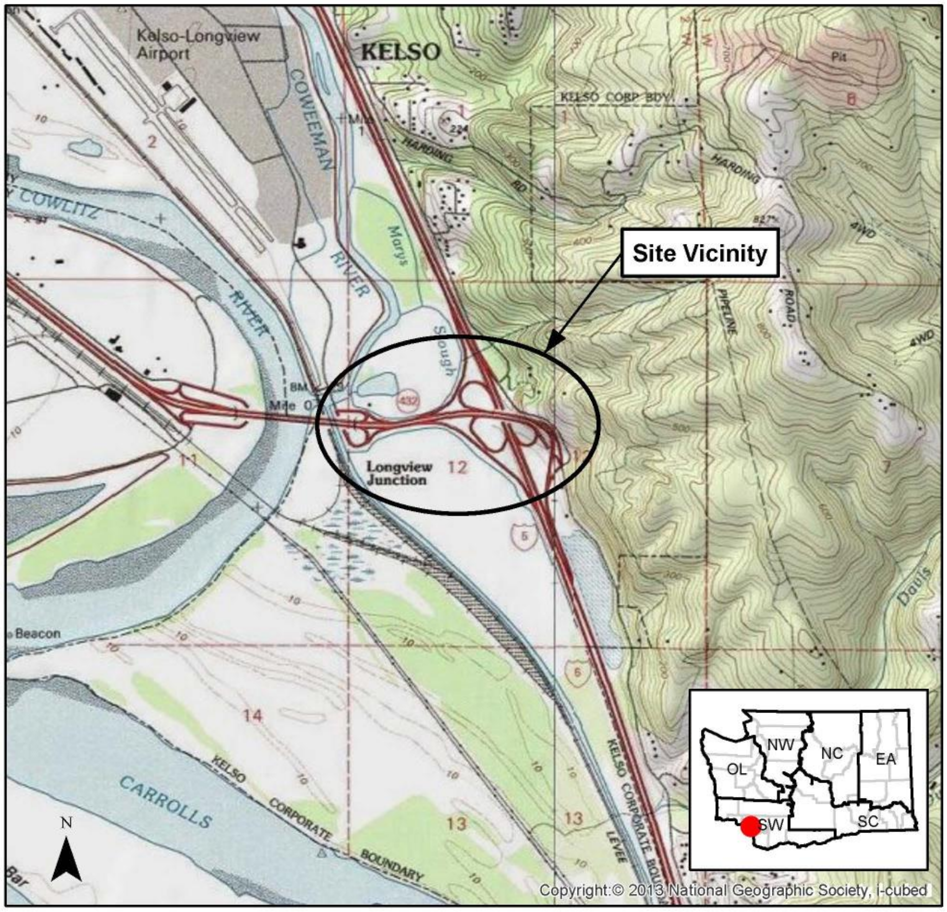


Figure 16. I-5/SR432 Talley Way Interchange vicinity map.

Figure 17. P-line Bridge Pre-load between Abutments (Sites No.10 and No.11).

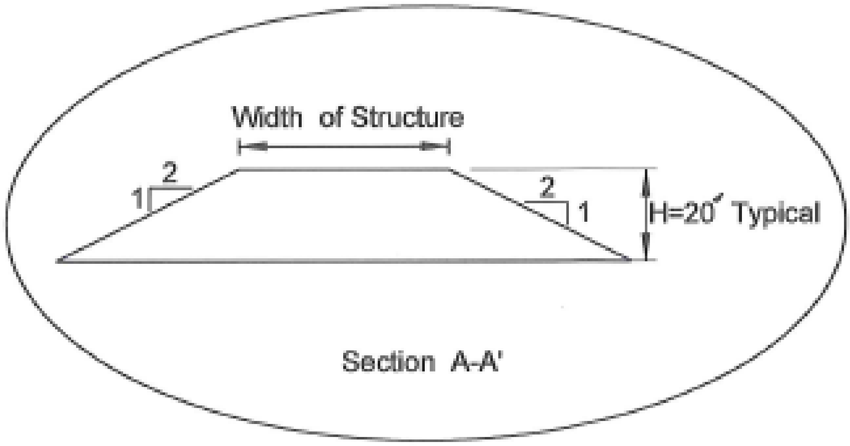


Figure 18. Typical Section of Pre-load for the P-Line Bridge at Sites No.10 and No.11 (width of structure was assumed to be 40 ft).

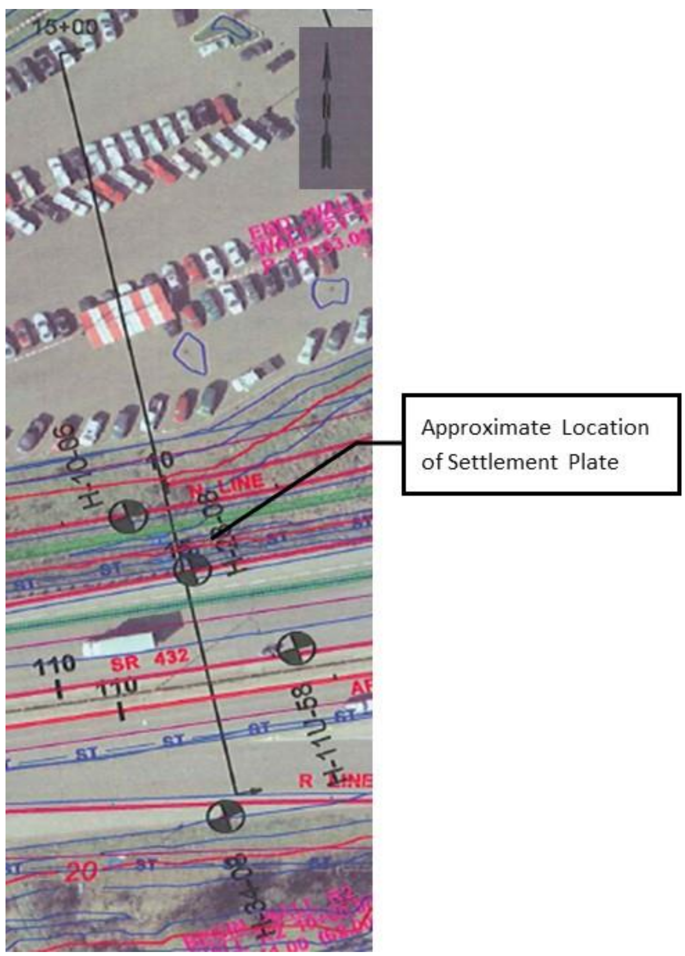


Figure 19. Plan View of Site No. 9, Section 15+00, on the P-Line with Boring Locations.

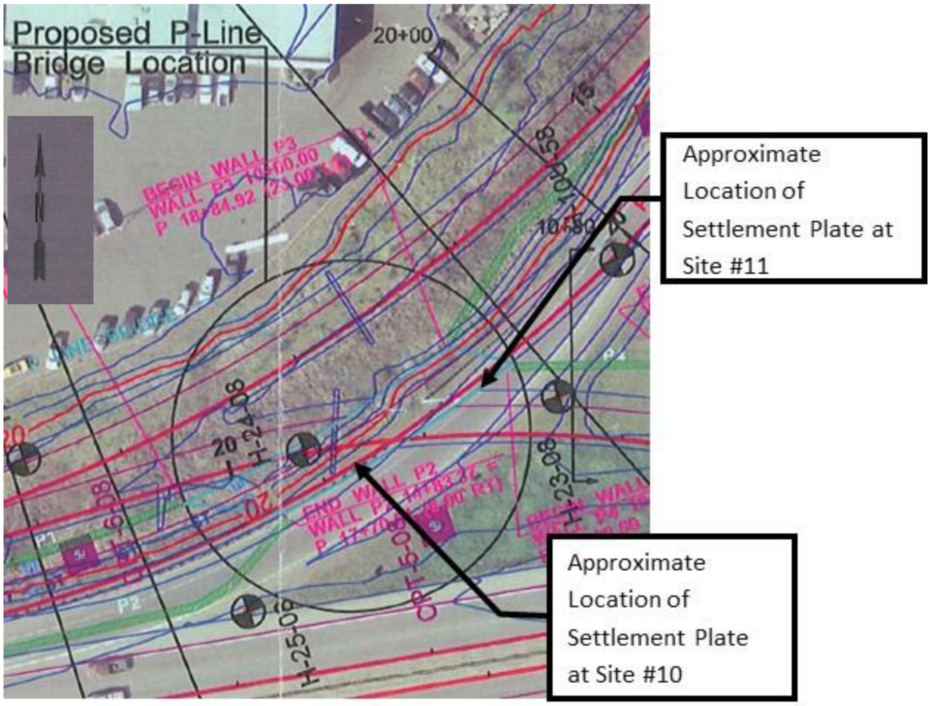


Figure 20. Plan View of Sites No.10 and No.11, the P-Line Bridge Pre-Load Area with Boring Locations.

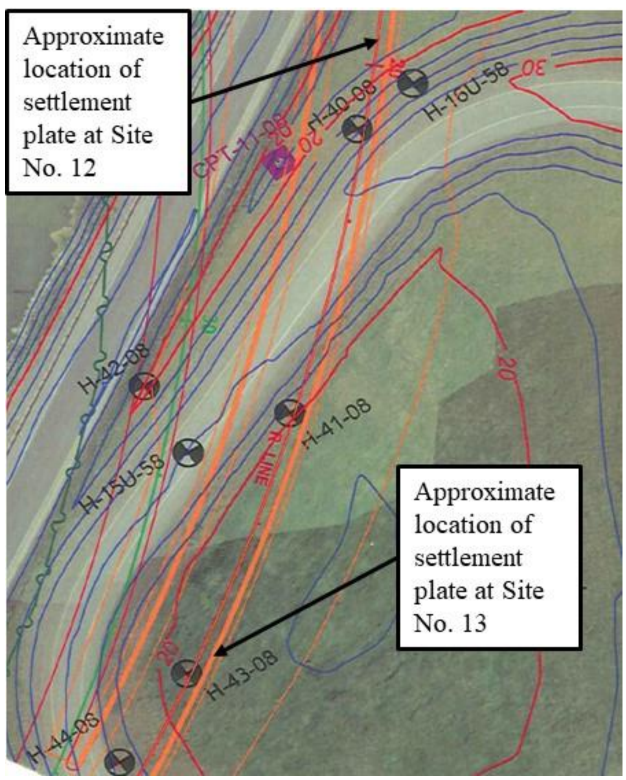


Figure 21. Plan View of Sites No.12 and No.13, Embankment between Stations 19+87 and 23+83 on the R-Line with Boring Locations.

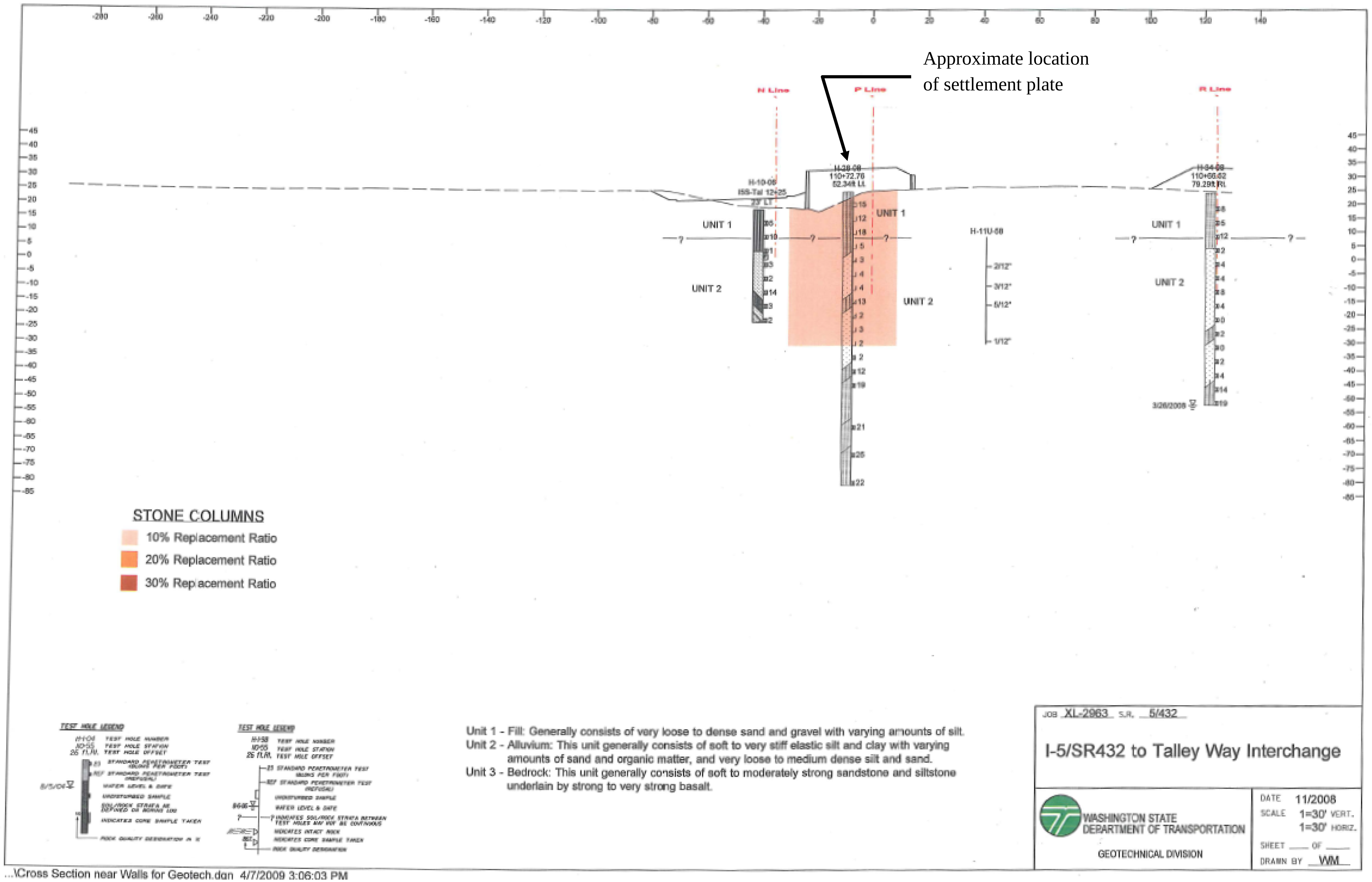


Figure 22. Site No.9, P-Line Cross-Section at Station 15+00 (The location of site/settlement plate No.9 was not underlain by stone columns).

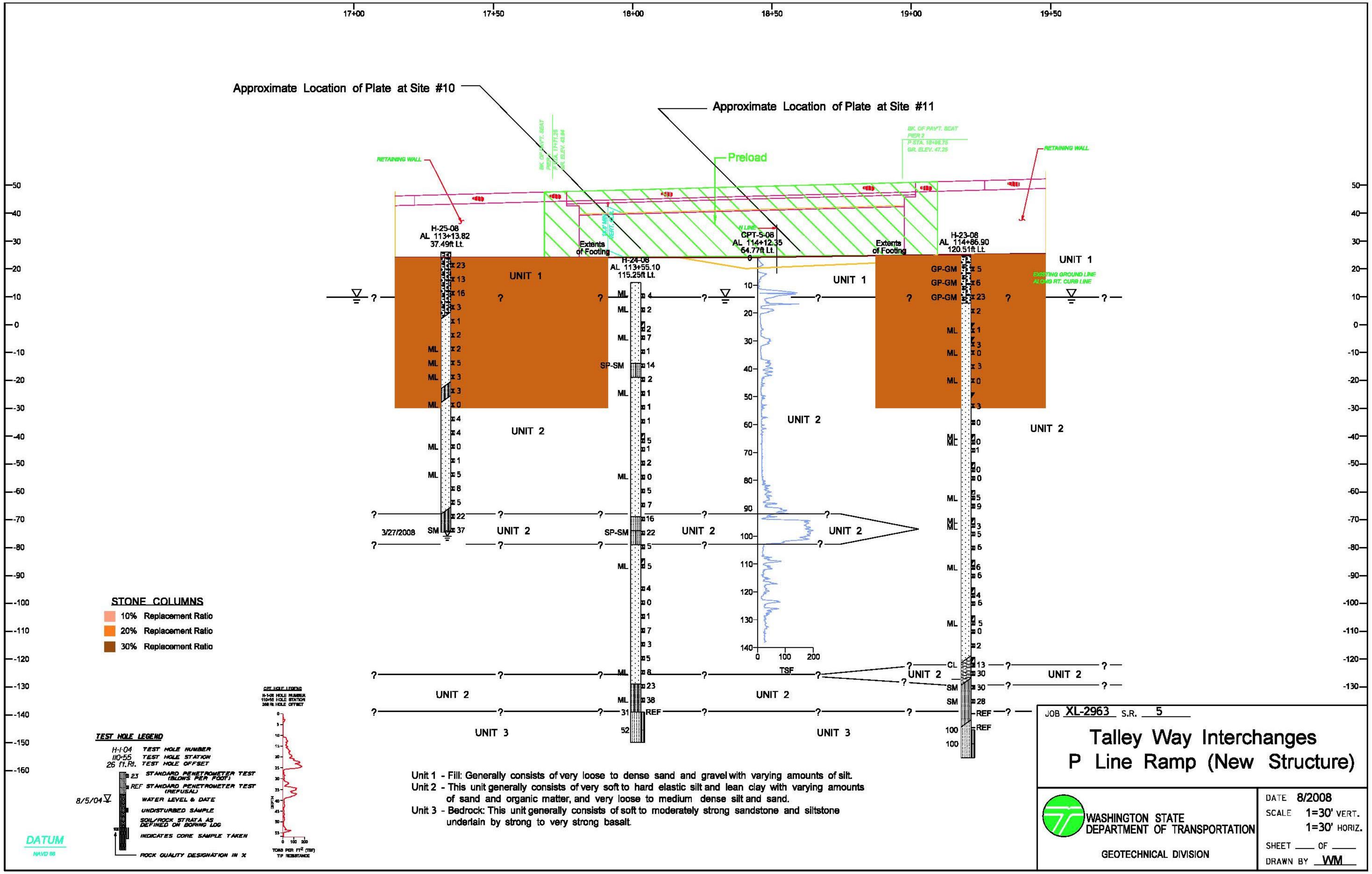


Figure 23. Profile of P-Line Bridge for Sites/Settlement Plates No.10 and No.11.

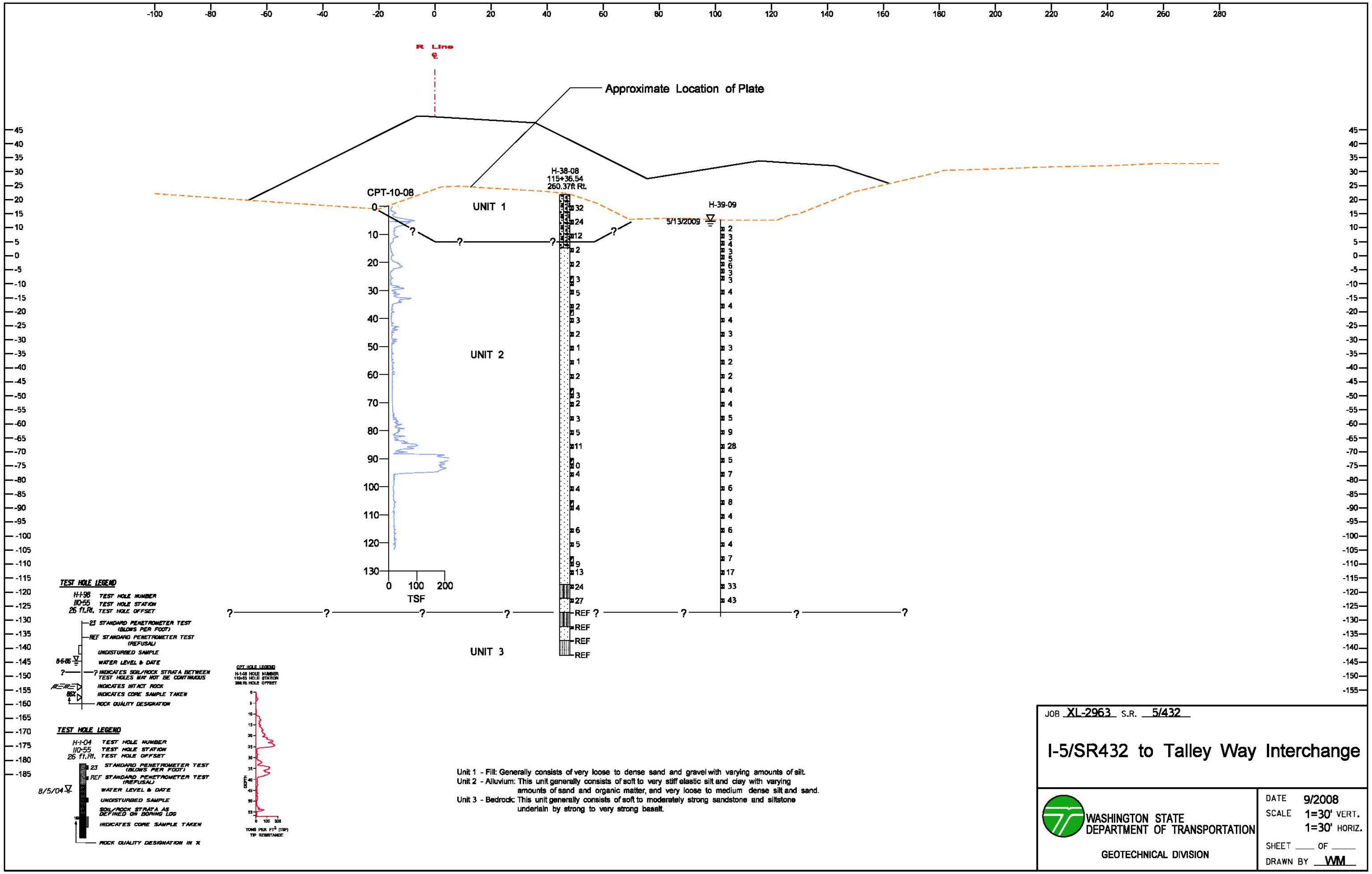


Figure 24. Typical Embankment Cross-Section for Sites/Settlement Plates No.12 and No.13 (R-Line Stations 19+87 and 23+83).

CASE HISTORY SETTLEMENT PREDICTIONS

SR395, BNSF Railroad Tunnel

Settlements were predicted and monitored at six sites along the locations of the spread footings for the tunnel structure. For design of the structure, settlements were estimated using the Hough Method. The combined footing/fill applied stress ranged from 650 psf near the ends of the tunnel to 9,000 psf near the mid-point of the tunnel length where the fill depth was deepest. The footing was essentially considered to be infinitely long to determine the distribution of stress with depth below the footing/fill. The soil was characterized as a clean uniform sand for much of the deposit, with layers of well graded silty sand and gravel and well graded fine to medium sand. The sand was loose to medium dense in the upper 35 to 40 ft of the deposit, and was medium dense to dense below that. Ground water at this site was deep and was not a factor in the design. Settlement at a given point along the tunnel was estimated using the depth of fill and footing stress at that location to calculate the stress increase, as the depth of fill over the tunnel was variable due to the fill side slopes and due to the extreme skew of the tunnel relative to the fill centerline – Figure 10 provides an illustration of the fill depth that was to be placed over the tunnel.

Table 2 provides a summary of one of the Hough Method settlement calculations. This example calculation was conducted near the halfway point along the tunnel's length. The input parameters used for the Hough analysis as well as the calculated values are summarized in this table and are based on Test Hole RR-5-04 (i.e., Site No. 4). All of the predicted settlements along the tunnel profile, using the Hough Method, are provided in Figure 25.

Settlement of this tunnel was also estimated by others using the Schmertmann Method (Naresh Samtani, personal communication, 1-27-2018). Table 3 provides a summary of Schmertmann Method settlement calculations at the same location (Test Hole RR-5-04) where the Hough Method calculations were performed in Table 2. The input parameters used for the Schmertmann analysis as well as the calculated values are summarized in this table. The soil modulus E was obtained through correlation to SPT N values (see Table 1). All of the predicted settlements along the tunnel profile, using the Schmertmann Method, are provided in Table 4.

Table 2. Summary of example Hough analysis (analyzed near mid-point of tunnel length) for BNSF Railroad tunnel, based on Test Hole RR-5-04 (Site No. 4).

Depth Below Footing (ft)	SPT N Field (bpf)	Soil γ_{sat} (pcf)	N'/N	SPT N' Corrected	Material Type	Hough C'	Effective Stress (psf)	I	Stress Change (psf)	Cumm. Settle. (in)
0 (N/A)		**125**	2.00	14	**1**	70	125	0.000	0.00	0.00
4	**7**		1.76	12	**1**	66	625	0.993	6580	0.85
9	**7**		1.12	8	**1**	55	1250	0.992	6576	1.77
14	**8**		0.96	8	**1**	54	1875	0.991	65690	2.55
19	**9**		0.88	8	**1**	55	2500	0.990	6562	3.20
24	**13**		0.82	11	**1**	61	3125	0.988	6554	3.73
29	**12**		0.77	9	**1**	58	3750	0.987	6544	4.19
34	**8**		0.73	6	**4**	36	4375	0.986	6534	4.69
39	**22**		0.66	15	**2**	64	5000	0.984	6523	5.19
44	**50**		0.60	30	**2**	102	5625	0.982	6512	5.43
49	**37**		0.60	22	**2**	82	6250	0.980	6500	5.64
54	**24**		0.60	14	**2**	64	6875	0.978	6487	5.90
59	**10**		0.60	6	**4**	36	7500	0.976	6474	6.23
64	**24**		0.60	14	**2**	64	8125	0.974	6460	6.58
74	**43**		0.60	26	**2**	91	9375	0.970	6432	6.95
80	**50**		0.60	30	**2**	102	10130	0.967	6414	7.12
85	**41**		0.60	25	**2**	88	10750	0.965	6398	7.25
90	**19**		0.60	11	**2**	57	11380	0.963	6382	7.42
95	**23**		0.60	14	**2**	62	12000	0.960	6366	7.61
100	**38**		0.60	23	**2**	83	12500	0.958	6350	7.76
105	**19**		0.60	11	**2**	57	12810	0.955	6333	7.92
107							12880	0.955	6330	7.95

Table 3. Summary of example Schmertmann analysis (analyzed near mid-point of tunnel length) for BNSF Railroad tunnel, based on Test Hole RR-5-04 (Site No. 4).

Layer No.	ΔZ (ft)	Layer Mid-Depth	Layer Midpoint Depth Below D_f	USCS	Raw N-Value	Corrected N-Val. $N1_{60}$	I_z	E (ksf)	$\Delta Z(I_z/E)$ (ft/ksf)	Settle. S (ft)
1	4.6	2.3	2.3	--	11.0	11.0	0.201	269	0.00343	0.0227
2	5	7.1	7.1	SP	7.0	13.0	0.202	318	0.00318	0.0211
3	5	12.1	12.1	SP	7.0	10.8	0.204	265	0.00385	0.0255
4	5	17.1	17.1	SP	8.0	10.9	0.206	267	0.00384	0.0255
5	5	22.1	22.1	SP	9.0	11.1	0.207	273	0.00380	0.0252
6	5	27.1	27.1	SP	13.0	14.8	0.209	362	0.00288	0.0191
7	5	32.1	32.1	SP	12.0	12.7	0.210	310	0.00339	0.0226
8	5	37.1	37.1	SM	8.0	7.9	0.212	138	0.00767	0.0509
9	5	42.1	42.1	SW	22.0	20.4	0.214	714	0.00150	0.0099
10	5	47.1	47.1	SW	50.0	43.7	0.215	1530	0.00070	0.0047
11	5	52.1	52.1	SW-SM	37.0	30.6	0.217	750	0.00145	0.0096
12	5	57.1	57.1	SP	24.0	18.8	0.218	462	0.00237	0.0157
13	5	62.1	62.1	SM	10.0	7.5	0.220	131	0.00843	0.0559
14	10	69.6	69.6	SP	24.0	17.1	0.222	418	0.00533	0.0353
15	5	77.1	77.1	GW	43.0	27.8	0.225	1168	0.00096	0.0064
16	5	82.1	82.1	SP	50.0	30.9	0.226	757	0.00150	0.0099
17	5	87.1	87.1	SP	41.0	24.2	0.228	594	0.00192	0.0127
18	5	92.1	92.1	SM	19.0	10.7	0.230	188	0.00611	0.0405
19	5	97.1	97.0	GW	23.0	12.5	0.231	523	0.00221	0.0147
20	5	102.1	102.1	GW	38.0	19.7	0.233	827	0.00141	0.0093
21	5	107.1	107.1	GW	19.0	9.6	0.235	1000000	0.00000	0.00001
22	100	159.6	159.6	GW	55.0	27.3	0.252	1000000	0.00003	0.00017
23	100	259.6	259.6	GW	100.0	100	0.284	1000000	0.00003	0.00019
24	100	359.6	359.6	GW	100.0	100	0.316	1000000	0.00003	0.00021
25	100	459.6	459.6	GW	100.0	100	0.348	1000000	0.00003	0.00023
26	100	559.6	559.6	GW	100.0	100	0.381	1000000	0.00004	0.00025
27	100	659.6	659.6	GW	100.0	100	0.413	1000000	0.00004	0.00027
28	100	759.6	759.6	GW	100.0	100	0.445	1000000	0.00004	0.00030
29	100	859.6	859.6	GW	100.0	100	0.477	1000000	0.00005	0.00032
30	100	959.6	959.6	GW	100.0	100	0.510	1000000	0.00005	0.00034
31	100	1059.6	1059.6	GW	100.0	100	0.513	1000000	0.00005	0.00034
32	100	1159.6	1159.6	GW	100.0	100	0.495	1000000	0.00005	0.00033
33	100	1259.6	1259.6	GW	100.0	100	0.478	1000000	0.00005	0.00032
34	100	1359.6	1359.6	GW	100.0	100	0.461	1000000	0.00005	0.00031
35	100	1459.6	1459.6	GW	100.0	100	0.443	1000000	0.00004	0.00029
36	100	1559.6	1559.6	GW	100.0	100	0.426	1000000	0.00004	0.00028
37	100	1659.6	1659.6	GW	100.0	100	0.408	1000000	0.00004	0.00027
38	100	1759.6	1759.6	GW	100.0	100	0.391	1000000	0.00004	0.00026
39	100	1859.6	1859.6	GW	100.0	100	0.373	1000000	0.00004	0.00025
40	100	1959.6	1959.6	GW	100.0	100	0.356	1000000	0.00004	0.00024
									Σ =	0.442

Calculate C1		1.000	
Calculate C2		1.000	
Immediate Settlement (Start to end of construction)	**0.442 ft**	**5.31**	**inches**
Creep (Long-Term) Settlement (During Design Life)	**0.000 ft**	**0.00**	**inches**
Total Settlement (Start of Const. to end of design life)	**0.442 ft**	***5.31***	***inches***

Table 4. Summary of Estimated Settlements using Schmertmann Method for the BNSF Railroad tunnel.

Test Hole Number	Settlement (inches)
RR-2-04 (Site No. 1)	1.26
RR-3-04 (Site No. 2)	3.50
RR-4-04 (Site No. 3)	5.04
RR-5-04 (Site No. 4)	5.31
RR-6-04 (Site No. 5)	2.98
RR-7-04 (Site No. 6)	2.28

SR522, University of Washington – Bothell/Cascadia Community College South Campus Access Walls

Settlements were predicted and monitored at each of the two geosynthetic approach walls (Walls 9 and 10, corresponding to Site No's 7 and 8). For design of the walls, settlements were estimated using the Hough Method. The applied design stress was approximately 1,625 psf at the settlement plates. The wall footings were essentially considered to be infinitely long, and Figure 1 was used to determine the distribution of stress with depth below the footing/fill.

Table 5 provides a summary of one of the Hough Method settlement calculations, and Table 6 summarizes the predicted settlements for both wall locations. The example calculation was conducted for the Wall 9 settlement plate at Site #7. The input parameters used for the Hough analysis as well as the calculated values summarized in Table 5 are based on Test Hole H-32-02. A detailed summary of the Schmertmann Method settlement estimate for Site No. 7 provided by others (Naresh Samtani, personal communication, 1-27-2018) is shown in Table 7, and Table 8 summarizes the predicted settlements for both wall locations.

Table 5. Summary of Hough analysis at Site #7, based on Test Hole H-32-02.

Depth Below Wall (ft)	SPT N Field (bpf)	γ_{sat} (pcf)	N'/N	SPT N' Corrected	Material Type	Hough C'	Effective Stress (psf)	I	Stress Change (psf)	Cumm. Settlement (in.)
1.5	35	130	1.78	83	2	300	195	1	1625	0.12
6.4	14	90	1.36	25	6	49	694	0.83	1349	0.90
13.1	64	90	1.15	98	6	158	1301	0.56	910	1.01
18.3	64	130	1.03	88	4	140	1833	0.43	699	1.05
22.5	50	67.6	0.97	64	4	235	2229	0.36	585	1.08
27.5	50	130	0.90	59	4	97	2723	0.3	488	1.13

Table 6. Hough settlement predictions at settlement plate at Site No's 7 and 8.

Site #	Settlement Prediction (in)
H-32-02 (Site 7)	1.1
H-31-02 (Site 8)	0.8

Table 7. Schmertmann analysis at Site No. 7, based on Test Hole H-32-02.

Layer No.	ΔZ (ft)	Layer Mid-Depth	Layer Midpoint Depth Below D_f	USCS	Raw N-Value	Corrected N-Val. $N1_{60}$	I_z	E (ksf)	$\Delta Z(I_z/E)$ (ft/ksf)	Settle S (ft)
1	3	1.5	1.5	--	35	35.0	0.288	858	0.00101	0.00166
2	7	6.5	6.5	CL	14	28.0	0.580	392	0.01036	0.01709
3	5	12.5	12.5	ML	64	100	0.450	1400	0.00161	0.00265
4	5	17.5	17.5	SM	50	75.5	0.305	1322	0.00115	0.00190
5	5	22.5	22.5	ML	50	69.1	0.160	968	0.00082	0.00136
6	5	27.5	27.5	ML	50	62.3	0.015	872	0.00008	0.00014
7	5	32.5	32.5	SM	50	59.4	0.000	1039	0.00000	0.00000
8	5	37.5	37.5	ML	50	54.7	0.000	766	0.00000	0.00000
9	5	42.5	42.5	SM	50	50.8	0.000	890	0.00000	0.00000
									Σ=	0.025

Calculate C1		1.000	
Calculate C2		1.000	
Immediate Settlement (Start to end of construction)	**0.025 ft**	**0.31**	**inches**
Creep (Long-Term) Settlement (During Design Life)	**0.000 ft**	**0.00**	**inches**
Calculate Total Settlement (Start of Const. to end of design life)	**0.025 ft**	***0.31***	***inches***

Table 8. Summary of Estimated Settlements using Schmertmann Method for SR 522 UWB CCC Campus S. Access.

Test Hole Location	Settlement, inches
H-32-02 (Site 7)	0.31
H-31-02 (Site 8)	0.30

I-5/SR432 Talley Way Interchange

Settlements were predicted and monitored at sixteen sites across the project area. These sites were along fill walls, embankments and bridge approaches. There were only six of the settlement plates that were not installed in stone column improved areas, and these six settlement plates were used in this study. For design of the wall and embankments, settlements were estimated using the Hough Method. The applied stress was approximately1,620 psf for site No.9, 2,700 psf for site No's 10 and 11 and 4,400 psf for site No's 12 and 13. The wall footing at site No. 9 was essentially considered to be infinitely long, and Figure 3 was used to determine the distribution of stress with depth below the footing/fill. The embankments at site No's 10 through 13 were essentially considered to be infinitely long, and Figure 1 was used to determine the distribution of stress with depth below the fill. The soil at the sites was generally characterized as loose to very dense sand and gravel with varying amounts of silt (fill) for the upper 10 ft to 15ft. It transitioned to a very loose to medium dense sandy silt (alluvium) to depths of 100 ft to 150 ft, underlain by very dense sand, silt, or bedrock. Groundwater at this site was generally encountered within the upper 10 feet of the deposit.

Table 9 provides a summary of one of the Hough Method settlement calculations. This example calculation was conducted for the preload embankment on the P-Line for settlement plates No.10 and No.11. The input parameters used for the Hough analysis as well as the calculated values are summarized in this table and are based on Test Hole H-23-08. Predicted settlements at each of the settlement plates, using the Hough Method, are provided in Table 10.

Settlements for the Talley Way Interchange were also estimated by others using the Schmertmann Method (Naresh Samtani, personal communication, 1-27-2018). Table 11 provides a summary of Schmertmann Method settlement calculations for Site No's 10 and 11 as an example. The input parameters used for the Schmertmann analysis as well as the calculated values are summarized in this table. All of the predicted settlements using the Schmertmann Method for this case history are provided in Table 12. Settlement analyses for Site No's 10 through 13 were performed using CPT results since the logs for test holes at these locations showed a SPT N-value of zero at some depths. For such cases, it is not possible to obtain a reliable value of elastic modulus, since the elastic modulus is a direct function of the N-value. In these cases, results from CPTs in the vicinity of the test holes were utilized. When CPTs were used, the elastic modulus, E_s, was calculated using E_s (tsf) = $3.5q_c$, where q_c is the cone tip resistance. This is based on the equation in Table 1 where E (ksi) = $0.028q_c$ which q_c is in tsf. For E in tsf, E = $2.0q_c$. Since the wall geometry can be considered to be plane-strain (i.e., its length is much greater than its width), the elastic modulus is multiplied by X=1.75. Thus, E (tsf) = $(1.75)(2.0)q_c = 3.5q_c$.

Table 9. Summary of example Hough analysis (site No's 10 and 11), based on Test Hole H-23-08.

Depth Below Embank. (ft)	SPT N Field (bpf)	Soil γ_{sat} (pcf)	N'/N	SPT N' Cor-rected	Mater-ial No.	Hough C'	Effective Stress (psf)	I	Stress Change (psf)	Cumm. Settlement (in)
2	5	120	2.00	10	2	54	115	1	2700	0.31
7	6	120	2.00	12	2	58	403	1.00	2691	1.41
12	23	120	1.64	38	2	125	691	0.98	2655	1.77
14	15*	120	1.48	22	2	80	806	0.97	2631	1.92
15	10*	100	1.43	15	5	43	844	0.97	2617	2.09
17	2	100	1.35	3	5	27	919	0.96	2586	2.56
24	1	100	1.16	1	5	25	1182	0.91	2452	4.28
29	3	100	1.07	3	5	27	1370	0.87	2341	5.32
32	0	100	1.04	0	5	23	1483	0.84	2273	5.92
37	3	100	1.00	3	5	27	1671	0.80	2159	6.80
42	0	100	0.97	0	5	23	1859	0.76	2047	7.62
51	3	100	0.92	3	5	27	2198	0.69	1860	8.86
57	0	100	0.89	0	5	23	2423	0.65	1746	9.58
64	0	100	0.86	0	5	23	2686	0.60	1624	10.36
67	1	100	0.85	1	5	24	2799	0.58	1576	10.65
74	0	100	0.82	0	5	23	3062	0.55	1472	11.29
77	0	100	0.81	0	5	23	3175	0.53	1430	11.54
84	5	100	0.79	4	5	28	3438	0.50	1341	12.03
87	9	100	0.79	7	5	32	3551	0.48	1305	12.19
94	3	100	0.77	2	5	26	3814	0.45	1228	12.56
97	5	100	0.76	4	5	28	3927	0.44	1198	12.71
102	6	100	0.75	5	5	29	4115	0.43	1150	12.94
109	6	100	0.73	4	5	29	4378	0.40	1088	13.24
112	6	100	0.72	4	5	29	4491	0.39	1063	13.35
119	4	100	0.69	3	5	27	4754	0.37	1010	13.62
122	6	100	0.68	4	5	28	4867	0.37	988	13.72
129	5	100	0.65	3	5	27	5130	0.35	941	13.95
132	0	100	0.65	0	5	23	5243	0.34	922	14.06
137	2	100	0.65	1	5	25	5431	0.33	892	14.22
141	8*	100	0.60	5	5	30	5582	0.32	869	14.33
142	10*	110	0.60	6	6	23	5629	0.32	864	14.37
144	13	110	0.60	8	6	26	5724	0.32	853	14.42
147	30	110	0.60	18	6	39	5867	0.31	837	14.49
152	30	140	0.60	18	1	81	6135	0.30	812	14.56
157	28	140	0.60	17	1	78	6523	0.29	789	14.60
162	101	140	0.60	61	1	337	6911	0.28	766	14.61

The asterisk in **Table 9** indicates that the value was interpolated.

Table 10. Hough Method Settlement predictions at site No's 9 through No.13.

Site/Settlement Plate No.	Settlement Prediction (in)
9 (H-28-08)	3.1
10 (H-23-08)	14.6
11 (H-23-08)	14.6
12 (H-38-08)	30.0
13 (H-38-08)	24.1

Table 11. Summary of example Schmertmann analysis for I-5/SR432 Talley Way Interchange R-Line Station 20+00 based on CPT 10-08 (Site No.12).

Layer No.	ΔZ (ft)	Layer Mid-Depth	Layer Midpoint Depth Below D_f	USCS	Raw N-Value	Corrected N-Val. $N1_{60}$	I_z	E (ksf)	$\Delta Z(I_z/E_s)$ (ft/ksf)	Settle. S (ft)
1	4.7	2.35	2.35	--	35.0	35.0	0.209	140	0.00702	0.0310
2	5	7.2	7.20	GM	32.0	59.9	0.228	140	0.00813	0.0359
3	5	12.2	12.20	GM	24.0	37.5	0.247	140	0.00882	0.0390
4	5	17.2	17.20	GM	12.0	17.6	0.266	140	0.00950	0.0420
5	5	22.2	22.20	ML	2.0	2.8	0.285	245	0.00582	0.0257
6	5	27.2	27.20	ML	2.0	2.7	0.304	245	0.00621	0.0275
7	5	32.2	32.20	ML	3.0	3.9	0.324	245	0.00661	0.0292
8	5	37.2	37.20	ML	5.0	6.3	0.343	70	0.02449	0.1083
9	5	42.2	42.20	ML	2.0	2.4	0.362	70	0.02586	0.1143
10	5	47.2	47.20	ML	3.0	3.5	0.381	70	0.02723	0.1204
11	5	52.2	52.20	ML	2.0	2.3	0.400	70	0.02860	0.1264
12	5	57.2	57.20	ML	1.0	1.1	0.420	70	0.02998	0.1325
13	5	62.2	62.20	ML	1.0	1.1	0.439	70	0.03135	0.1386
14	5	67.2	67.20	ML	2.0	2.1	0.458	70	0.03272	0.1446
15	5	72.2	72.20	ML	3.0	3.1	0.477	70	0.03409	0.1507
16	5	77.2	77.20	ML	2.0	2.0	0.496	280	0.00887	0.0392
17	5	82.2	82.20	ML	3.0	3.0	0.516	280	0.00921	0.0407
18	5	87.2	87.20	ML	5.0	4.8	0.535	280	0.00955	0.0422
19	5	92.2	92.20	ML	11.0	10.4	0.554	280	0.00989	0.0437
20	5	97.2	97.20	ML	0.0	0.0	0.573	105	0.02730	0.1207
21	5	102.2	102.20	ML	4.0	3.6	0.580	105	0.02761	0.1220
22	5	107.2	107.20	ML	4.0	3.6	0.570	105	0.02714	0.1200
23	10	114.7	114.70	ML	4.0	3.5	0.555	105	0.05290	0.2338
24	5	122.2	122.20	ML	6.0	5.1	0.541	71	0.03818	0.1687
25	6	127.7	127.70	ML	5.0	4.1	0.530	58	0.05489	0.2426
26	4	132.7	132.70	ML	9.0	7.3	0.520	102	0.02040	0.0902
27	5	137.2	137.20	ML	13.0	10.4	0.512	145	0.01761	0.0778
28	5	142.2	142.20	ML	24.0	18.8	0.502	264	0.00952	0.0421
29	5	147.2	147.20	ML	27.0	20.8	0.492	291	0.00845	0.0373
30	5	152.2	152.20	ML	50.0	37.9	0.482	530	0.00455	0.0201
31	5	157.2	157.20	ML	50.0	37.2	0.473	521	0.00453	0.0200
32	5	162.2	162.20	SP	50.0	36.6	0.463	897	0.00258	0.0114
33	5	167.2	167.20	SP	50.0	36.0	0.453	882	0.00257	0.0114
34	5	172.2	172.20	SP	100.0	100.0	0.443	2450	0.00091	0.0040
35	5	177.2	177.20	SP	100.0	100.0	0.434	2450	0.00089	0.0039

36	5	182.2	182.20	SP	100.0	100.0	0.424	2450	0.00087	0.0038
37	5	187.2	187.20	SP	100.0	100.0	0.414	2450	0.00085	0.0037
38	5	192.2	192.20	SP	100.0	100.0	0.405	2450	0.00083	0.0037
39	5	197.2	197.20	SP	100.0	100.0	0.395	2450	0.00081	0.0036
40	5	202.2	202.20	SP	100.0	100.0	0.385	2450	0.00079	0.0035
									Σ =	2.78

Calculate C1		1.000	
Calculate C2		1.000	
Immediate Settlement (Start to end of construction)	**2.78 ft**	**33.3**	**inches**
Creep (Long-Term) Settlement (During Design Life)	**0.000 ft**	**0.00**	**inches**
Calculate Total Settlement (Start of Const to end of design life)	**2.78 ft**	***33.3***	***inches***

Table 12. Summary of Estimated Settlements using Schmertmann Method for I-5/SR432 Talley Way Interchange.

Test Hole Location	Settlement, inches
H-28-08 [Site No.9]	4.3
H-23-08 (CPT-5-08) [Site No.10]	11.3
H-23-08 (CPT-5-08) [Site No.11]	11.3
H-38-08 (CPT-10-08) [Site No.12]	33.3
H-38-08 (CPT-10-08) [Site No.13)]	22.3

CASE HISTORY SETTLEMENT MEASUREMENTS

SR395, BNSF Railroad Tunnel

Settlement was monitored using a survey method, using targets established on the stem wall inside the tunnel. Settlement was monitored beginning with the placement of the targets on the stem walls after it was constructed. Settlement of the ground due to placement of the stem wall structure was assumed to be less than 0.5 inch. Settlement monitoring targets were established on both sides of the tunnel. Final settlement measurement results are provided in Table 13. Once the structure and fill were completed, settlement was also completed (no long-term settlement). For comparison to the predicted settlements along the length of the tunnel, the measured settlements were the average of the two settlement monitoring points (i.e., east and west stem walls) at each section of the tunnel, as shown in Table 13.

Table 13. Final settlement measurements and corresponding predictions for SR395 BNSF Railroad Tunnel.

[1]Station	Corresponding Site No. (Boring No.)	Measured Settlement (in.)		Average Measured Settlement (in.)	Hough Method Predicted Settlement (in.)	Schmertmann Method Predicted Settlement (in.)
		West Wall	East Wall			
18+00		3.36	2.52	2.94		
17+00	Site No. 1 (RR-2-04)	4.20	5.04	4.62	3.8	1.3
16+00		4.20	5.88	5.04		
15+00	Site No. 2 (RR-3-04)	5.64	5.76	5.70	7.2	3.5
14+00		4.92	4.32	4.62		
13+00	Site No. 3 (RR-4-04)	4.68	4.56	4.62	7.9	5.0
12+00		4.32	4.08	4.20		
11+00		4.44	3.96			
10+50*	Site No. 4 (RR-5-04)			3.87	8.0	5.3
10+00		4.32	2.76			
9+00	Site No. 5 (RR-6-04)	3.24	2.28	2.76	6.3	3.0
8+00		3.24	1.92	2.58		
7+00		2.52	1.32	1.92		
6+00	Site No. 6 (RR-7-04)	3.00	2.04	2.52	5.0	2.3

*Since there were no settlement monitoring points at this station, the settlement measurements at both station 10+00 and station 11+00 were averaged together.

[1]Tunnel begins at tunnel station 5+00 and ends at tunnel station 18+24. The roadway alignment stationing increases in the opposite direction, however.

SR522, University of Washington – Bothell/Cascadia Community College South Campus Access Walls

Settlement was monitored using a survey method. The method consisted of survey of settlement plates. See Figure 25 for the contract settlement plate detail. The settlement plates were placed a foot below the ground surface after clearing and grubbing operations were completed. A steel pipe was welded to the base of the steel plate, and steel riser pipe was used as the fill was placed. The pipe was wide enough for a survey rod to be inserted down to the plate. The plates were surveyed at the beginning and ending of each shift until the engineer allowed survey at longer intervals. Settlement was monitored until the survey readings approached zero vertical displacement. Final settlement measurement results, with their corresponding settlement predictions, are provided in Table 14.

Table 14. Settlement measurements of settlement and corresponding predictions at settlement plates at sites No's 7 and 8.

Site No.	Settlement Measurement (in)	Hough Method Predicted Settlement (in.)	Schmertmann Method Predicted Settlement (in.)
7	0.37	1.1	0.31
8	0.2	0.8	0.30

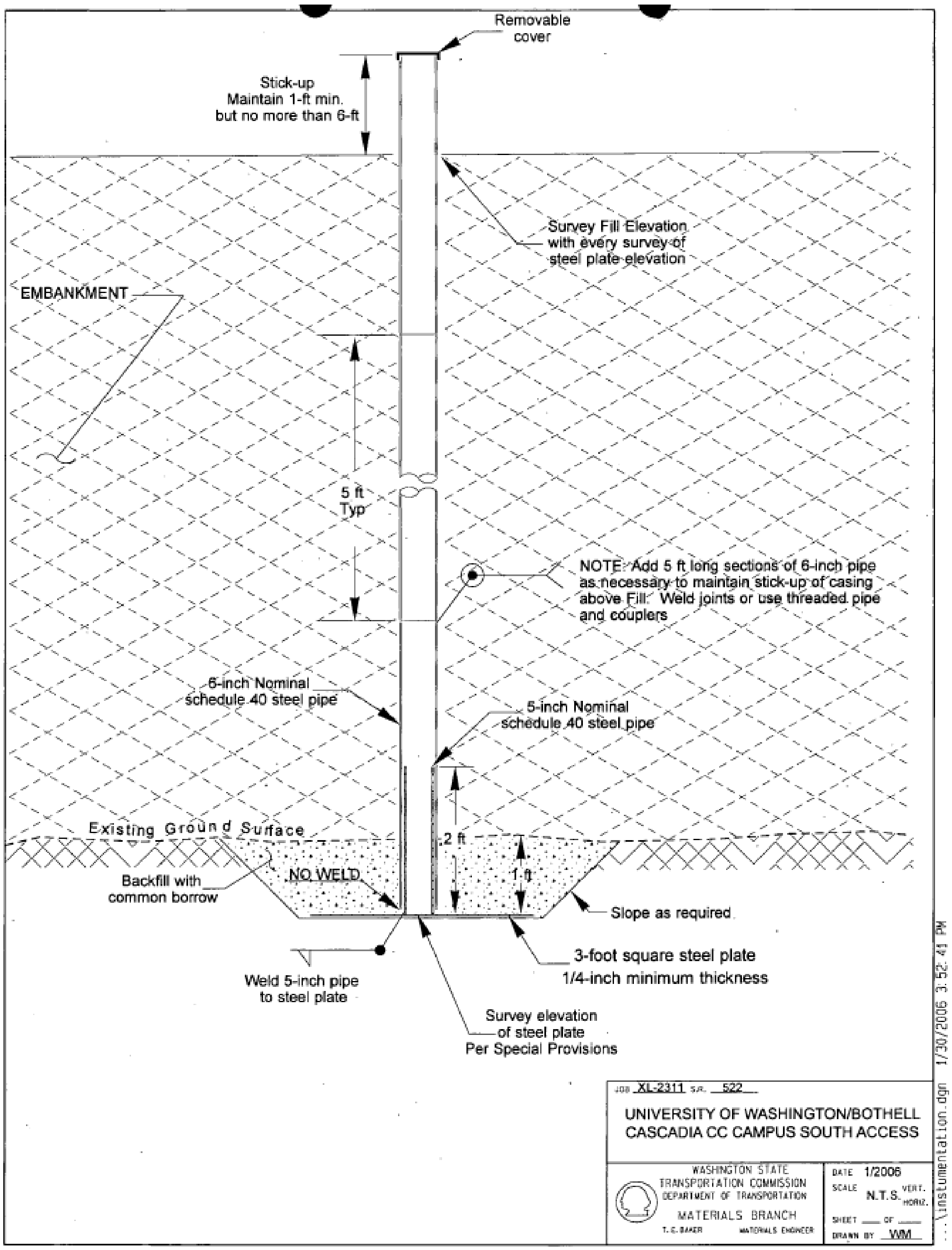
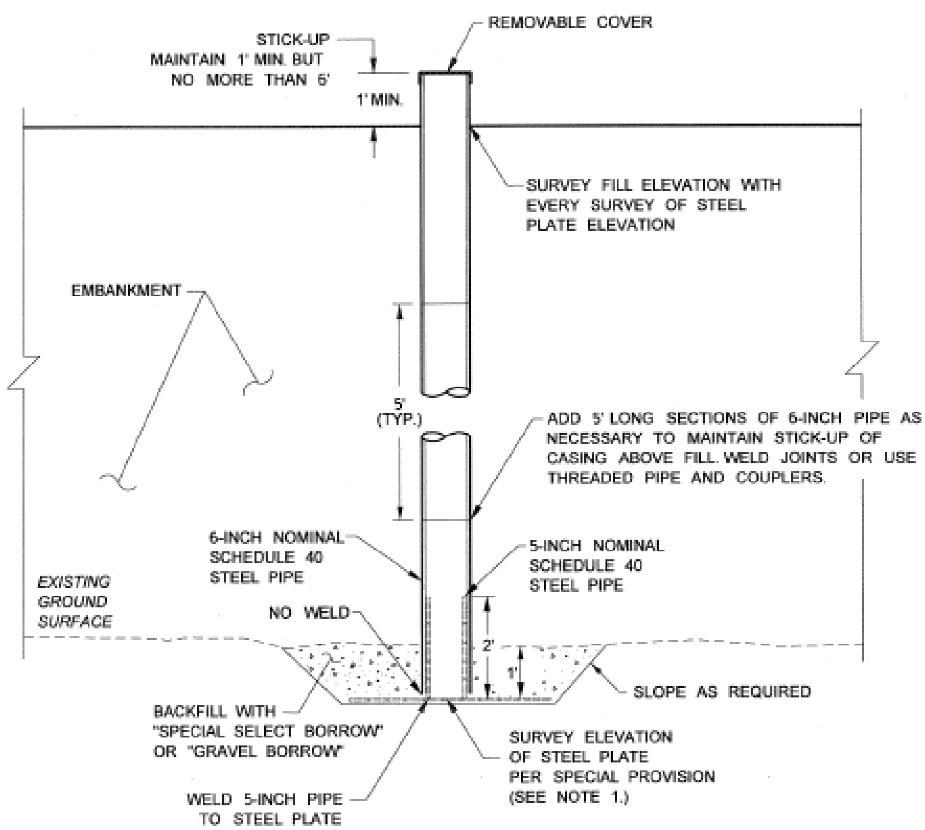


Figure 25. Installation Details for Settlement Plates at Site No's 7 and 8.

I-5/SR432 Talley Way Interchange

Settlement was monitored using a survey method. The method consisted of survey of settlement plates. See Figure 26 for the contract settlement plate detail. The settlement plates were placed a foot below the ground surface after clearing and grubbing operations were completed. A steel pipe was welded to the base of the steel plate, and steel riser pipe was used as the fill was placed. The pipe was wide enough for a survey rod to be inserted down to the plate. The plates were surveyed at the beginning and ending of each shift until the engineer allowed survey at longer intervals. Final settlement measurement results, with their corresponding settlement predictions, are provided in Table 15. Settlement was monitored until the survey readings approached zero vertical displacement.



TYPICAL SETTLEMENT PLATE

NOT TO SCALE

Figure 26. Settlement Plate Detail.

Table 15. Settlement measurements and corresponding predictions at settlement plates No's 9 through 13.

Site No.	Settlement Measurement (in.)	Hough Method Predicted Settlement (in.)	Schmertmann Method Predicted Settlement (in.)*
9	1.3	3.1	4.3
10	12.2	14.6	11.3
11	11.4	14.6	11.3
12	41.0	29.8	33.3
13	24.7	24.1	22.3

*Sites 10 through 13 are based on nearest CPT data.

CASE HISTORY DATA ANALYSES

Analyses were carried out to assess the ability of each settlement prediction method to accurately predict the settlement that was measured in the case histories presented in this report. This assessment of prediction accuracy is carried out using the bias, which is defined as the measured/predicted value. Predicted values have been generated using the Hough and Schmertmann methods.

Figure 27 shows measured and predicted values for settlement using the Hough Method. Dark symbols represent the WSDOT case history data, whereas the white symbols represent the data presented in Samtani and Allen (2018) except for the WSDOT case histories. This figure shows that the WSDOT cases settlement estimates tend to be conservative relative to the rest of the data presented in Samtani and Allen (2018) and relative to the one-to-one correspondence line shown.

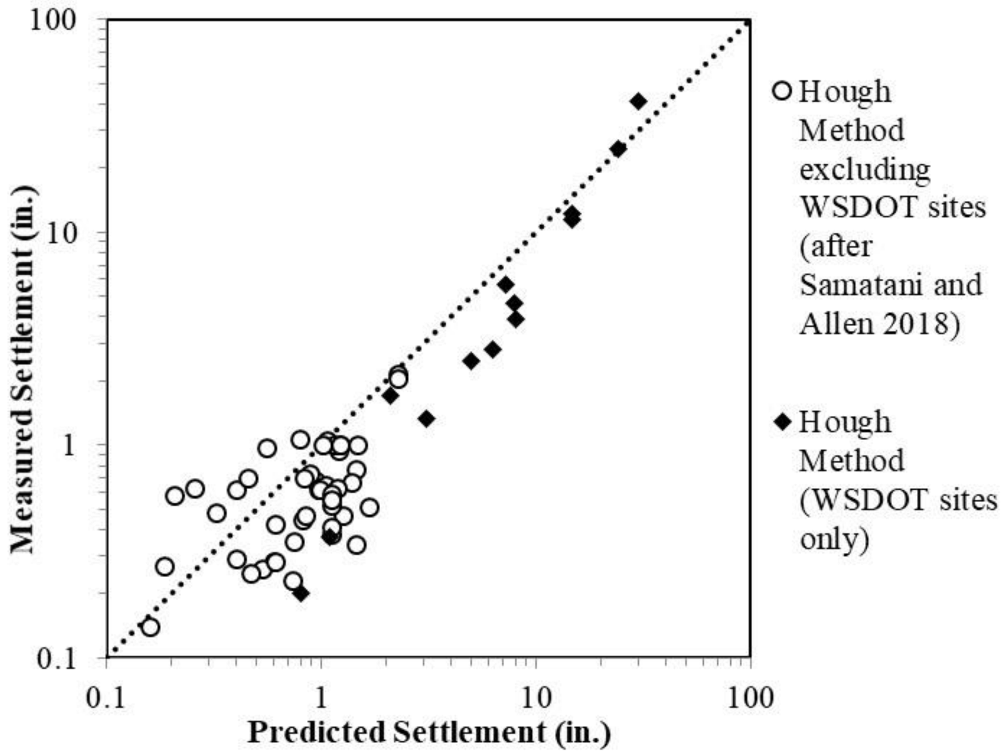


Figure 27. Predicted and measured settlement values for the Hough Method, comparing the WSDOT case history data to the rest of the data presented in Samtani and Allen (2018).

Similar to Figure 27, Figure 28 shows measured and predicted values for settlement using the Schmertmann Method. While data scatter for the Schmertmann Method appears to be greater than for the Hough Method predictions, the Schmertmann Method appears to be a little less conservative than the Hough Method.

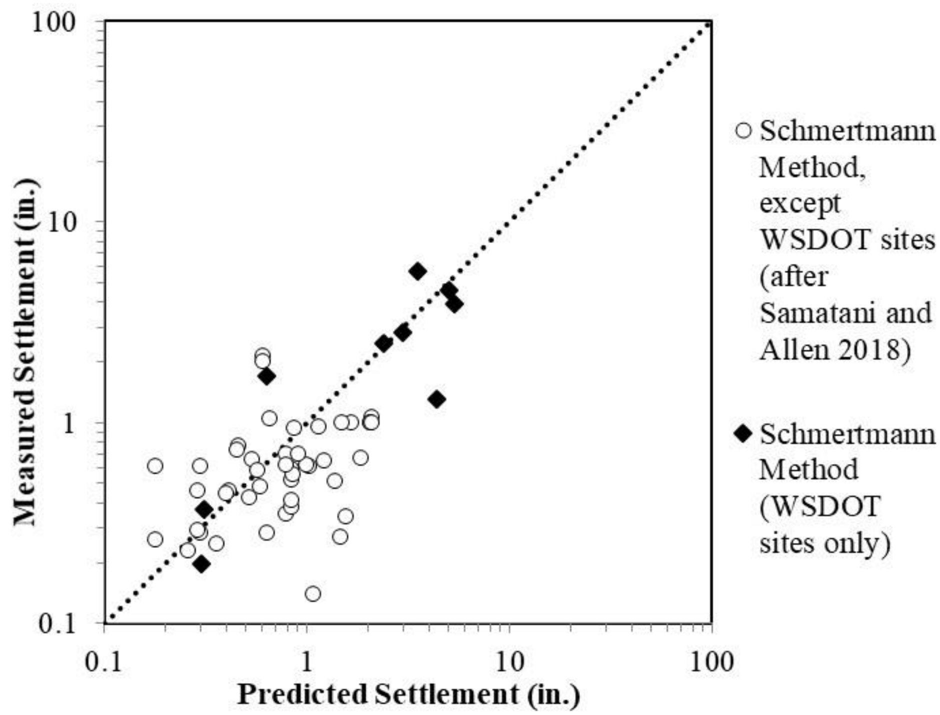


Figure 28. Predicted and measured settlement values for the Schmertmann Method, comparing the WSDOT case history data to the rest of the data presented in Samtani and Allen (2018).

Figures 29 and 30 show the same data, but instead prediction bias is shown on the vertical axis. When the bias is less than 1.0, the prediction is conservative (i.e., less settlement occurred than was predicted), and when the bias is greater than 1.0, the prediction is unconservative. Based on these figures, both prediction methods are conservative for settlements of approximately three-fourths inch or more. However, at a settlement of approximately 0.5 inch or less (vertical dotted line in figures), data scatter increases significantly. The increase in data scatter at 0.5 inch or less could not be verified for the WSDOT data, due to lack of WSDOT settlement data less than 0.5 inch.

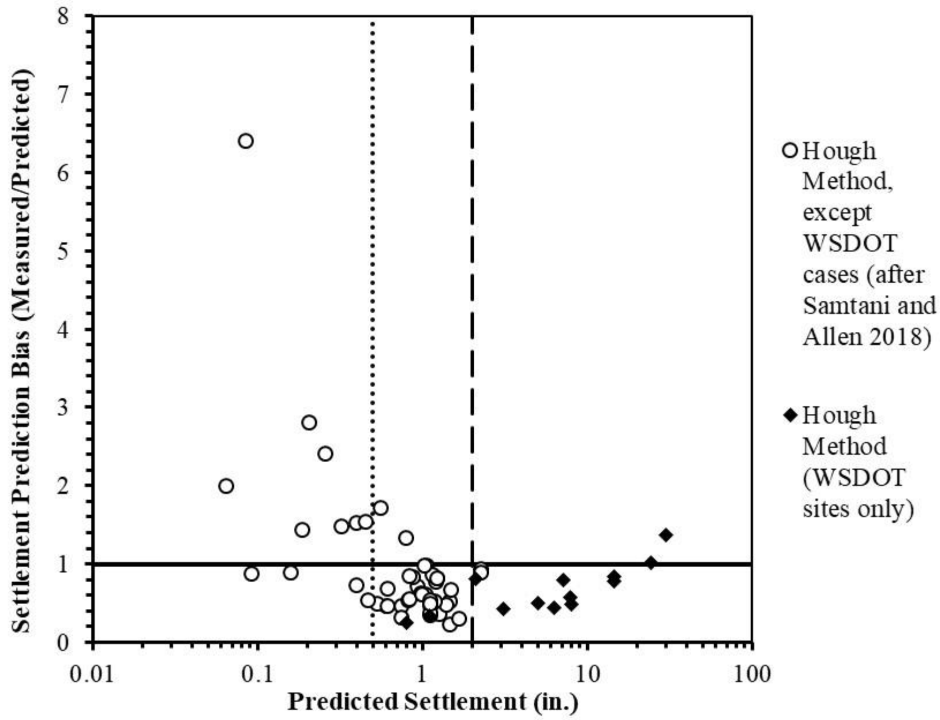


Figure 29. Bias versus predicted settlement for the Hough Method.

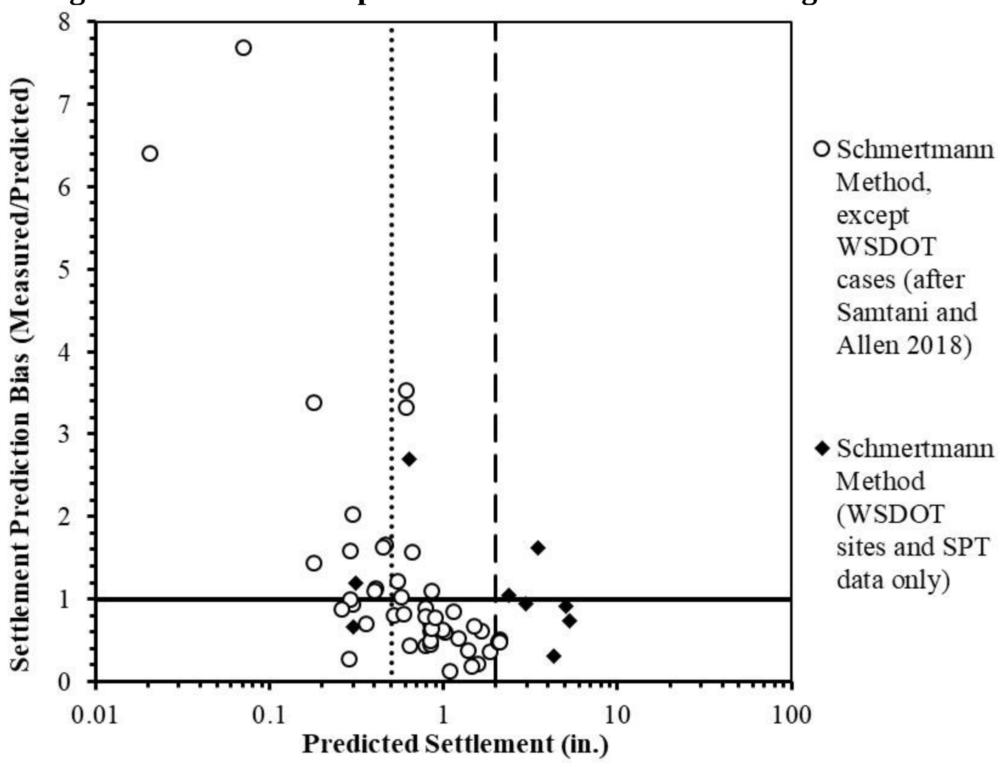


Figure 30. Bias versus predicted settlement for the Schmertmann Method.

Figure 31 shows the Schmertmann Method predictions for the WSDOT case histories site using CPT and SPT data. While a direct comparison between the SPT and CPT based settlement estimates was not possible, this figure shows that estimates using both types of data track reasonably well on the one-to-one correspondence line.

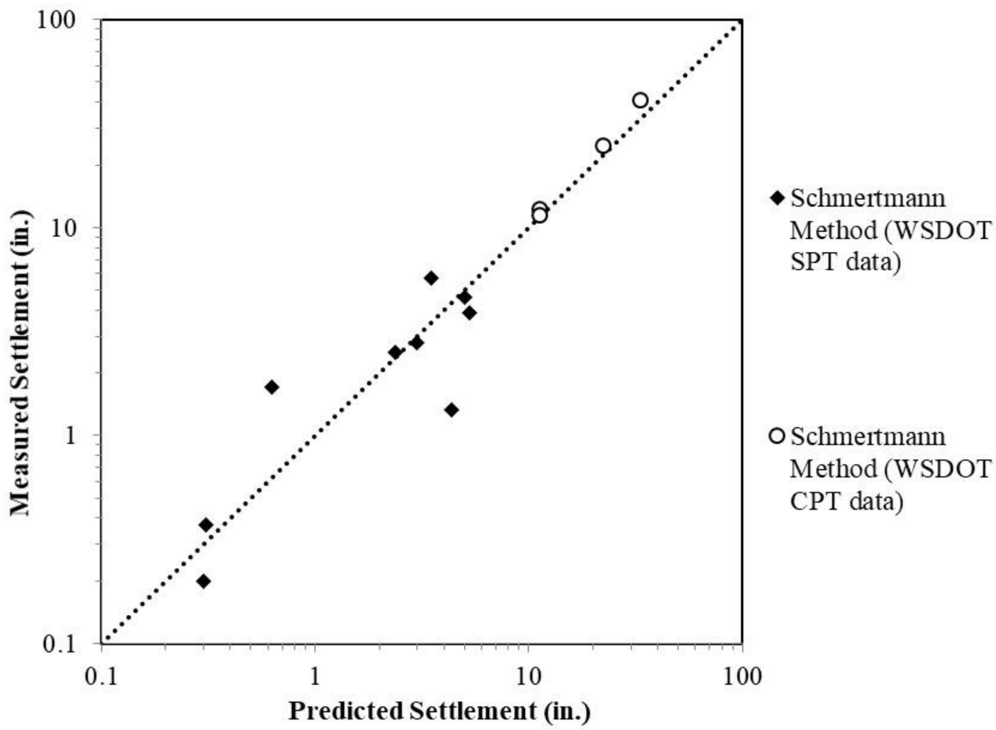


Figure 31. Measured settlement and Schmertmann Method settlement predictions using both CPT and SPT data for the WSDOT case histories.

Table 16 summarizes the mean and coefficient of variation (i.e., COV) for each case history for both settlement prediction methods. Table 17 summarizes the mean and COV for the case where CPT data are available for estimating settlement using the Schmertmann Method. Based on these results, the Hough Method has less data scatter than the Schmertmann Method when basing the settlement estimates based on SPT data. There were not adequate data available to assess the potential accuracy of CPT based Schmertmann Method estimates, though for the data that were available, the CPT based estimates followed the one-to-one correspondence line fairly closely, indicating that if CPT data are available, the Schmertmann Method has the potential to be the most accurate prediction method. Considering that the Schmertmann Method was developed with CPT data in mind, the potential for the Schmertmann Method to be the most accurate alternative when CPT data are available was not unexpected.

Table 16. Summary statistics for each settlement case history, for both the Hough and Schmertmann methods, based on SPT blow counts.

Case History	N	Hough Method		N	*Schmertmann Method	
		Mean Bias	COV		Mean Bias	COV
SR395, BNSF Railroad Tunnel	6	0.60	26.5%	6	1.33	55.6%
SR522, U of W Bothell Campus	2	0.29	20.8%	2	0.93	40.1%
I-5/SR432 Talley Way Interchange	5	0.89	39.1%	1	0.30	--
All WSDOT Case Histories	**13**	**0.67**	**46.9%**	**9**	**1.13**	**61.7%**

*Based on SPT data only.

Table 17. Summary statistics for the case where CPT data are available as the basis for estimating settlement using the Schmertmann Method.

Case History	N	*Schmertmann Method	
		Mean Bias	COV
I-5/SR432 Talley Way Interchange	4	1.11	8.2%

*Based on CPT data only.

Figures 32 and 33 show the Cumulative Distribution Functions (CDFs) for both the Hough and Schmertmann method predictions, respectively. Both bias and ln(bias) plots are shown. These figures indicate that the data are generally lognormally distributed. This is consistent with the larger data set gathered and analyzed by Samtani and Allen (2018).

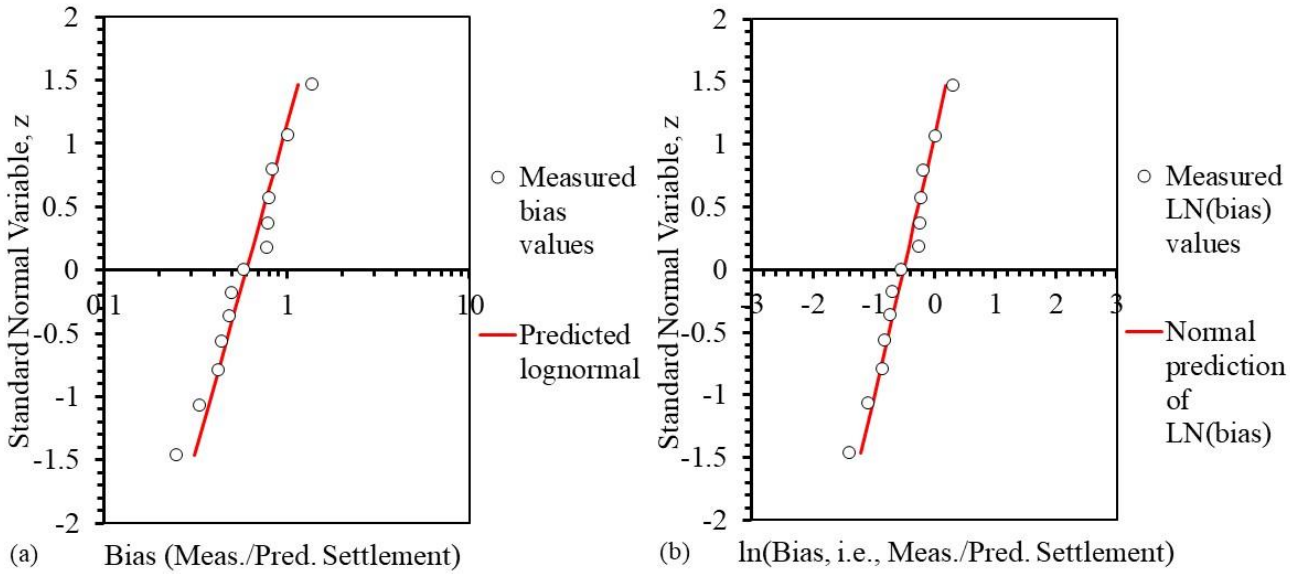


Figure 32. Cumulative Distribution Functions (CDFs) of Hough Method prediction bias values for the WSDOT case histories, using (a) bias plotted on a lognormal axis, and (b) ln(bias) plotted on a normal axis.

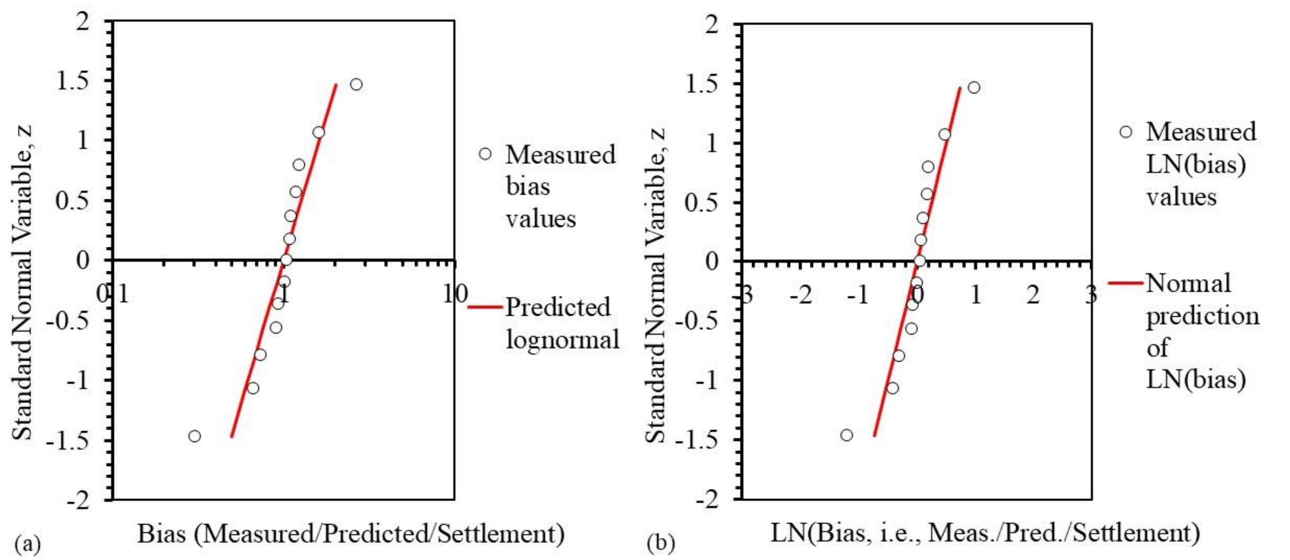


Figure 33. Cumulative Distribution Functions (CDFs) of Schmertmann Method prediction bias values for the WSDOT case histories, using (a) bias plotted on a lognormal axis, and (b) ln(bias) plotted on a normal axis.

SUMMARY AND CONCLUSIONS

Summarized in this report are comparisons between measured and predicted settlements obtained from three project sites in the State of Washington (13 individual measurements and predictions), two sites in western Washington and one site in eastern Washington. The eastern Washington case is a cut-and-cover tunnel in which the tunnel footing settlement was measured; however, the surrounding fill was the driver regarding the settlement measured there. The two western Washington cases represent bridge abutment fill settlement, though two of the measurement locations included an MSE wall. These measurements and predictions are used to determine the accuracy of two settlement estimation methods, the Hough Method and the Schmertmann Method, in Washington soils. The database of measurements reported here are not comprehensive, but do represent some typical cases.

Based on these data, both methods appear to be reliable, though in general, settlement estimates were conservative. The Hough Method was more consistent than the Schmertmann Method when SPT data are used, but on average was conservative by an approximate factor of 1.5 for the sites investigated. The Schmertmann Method predictions using CPT data were the most accurate, but that data set is extremely limited, so all that can be said at this point is that the Schmertmann Method has the potential to provide the most accurate results when CPT data are available.

ACKNOWLEDGMENTS

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APPENDIX A

SUBSURFACE DATA FOR SR395 BNSF TUNNEL PROJECT

Washington State
Department of Transportation

Test Boring Legend

Sampler Symbols

	Standard Penetration Test
	Oversized Penetration Test (Dames & Moore, California)
	Shelby Tube
P	Piston Sample
	Washington Undisturbed
	Vane Shear Test
	Core
	Becker Hammer
B	Bag Sample

Well Symbols

	Cement Surface Seal
	Piezometer Pipe in Granular Bentonite Seal
	Piezometer Pipe in Sand
	Well Screen in Sand
	Granular Bentonite Bottom Seal
	Inclinometer Casing in Concrete Bentonite Grout

Laboratory Testing Codes

UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
UC	Unconfined Compression Test
DS	Direct Shear Test
CN	Consolidation Test
GS	Grain Size Distribution
MC	Moisture Content
SG	Specific Gravity
OR	Organic Content
DN	Density
AL	Atterberg Limits
PT	Point Load Compressive Test
SL	Slake Test
DG	Degradation
LA	LA Abrasion

Soil Density Modifiers

Gravel, Sand & Non-plastic Silt		Elastic Silts and Clay	
SPT Blows/ft	Density	SPT Blows/ft	Consistency
0-4	Very Loose	0-1	Very Soft
5-10	Loose	2-4	Soft
11-24	Medium Dense	5-8	Medium Stiff
25-50	Dense	9-15	Stiff
>50	Very Dense	16-30	Very Stiff
		31-60	Hard
		>60	Very Hard

Angularity of Gravel & Cobbles

Angular	Coarse particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Coarse grained particles are similar to angular but have rounded edges.
Subrounded	Coarse grained particles have nearly plane sides but have well rounded corners and edges.
Rounded	Coarse grained particles have smoothly curved sides and no edges.

Soil Moisture Modifiers

Dry	Absence of moisture; dusty, dry to touch
Moist	Damp but no visible water
Wet	Visible free water

Soil Structure

Stratified	Alternating layers of varying material or color at least 6mm thick; note thickness and inclination.
Laminated	Alternating layers of varying material or color less than 6mm thick; note thickness and inclination.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, somtimes striated.
Blocky	Cohesive soil that can be broken down into smaller angular lumps which resist further breakdown.
Disrupted	Soil structure is broken and mixed. Infers that material has moved substantially - landslide debris.
Homogeneous	Same color and appearance throughout.

HCL Reaction

No HCL Reaction	No visible reaction.
Weak HCL Reaction	Some reaction with bubbles forming slowly.
Strong HCL Reaction	Violent reaction with bubbles forming imediately.

Degree of Vesicularity of Pyroclastic Rocks

Slightly Vesicular	5 to 10 percent of total
Moderately Vesicular	10 to 25 percent of total
Highly Vesicular	25 to 50 percent of total
Scoriaceous	Greater than 50 percent of total

Test Boring Legend

Grain Size

Fine Grained	< 1mm	Few crystal boundaries/grains are distinguishable in the field or with hand lens.
Medium Grained	1mm to 5mm	Most crystal boundaries/grains are distinguishable with the aid of a hand lens.
Coarse Grained	> 5mm	Most crystal boundaries/grains are distinguishable with the naked eye.

Weathered State

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discoloration in major discontinuity surfaces.	I
Slightly Weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than its fresh condition.	II
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as core stones.	III
Highly Weathered	More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as discontinuous framework or as core stone.	IV
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual Soil	All rock material is converted to soil. The mass structure and material fabric is destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Relative Rock Strength

Grade	Description	Field Identification	Uniaxial Compressive Strength approx
R1	Very Weak	Specimen crumbles under sharp blow from point of geological hammer, and can be cut with a pocket knife.	1 to 25 MPa
R2	Moderately Weak	Shallow cuts or scrapes can be made in a specimen with a pocket knife. Geological hammer point indents deeply with firm blow.	25 to 50 MPa
R3	Moderately Strong	Specimen cannot be scraped or cut with a pocket knife, shallow indentation can be made under firm blows from a hammer.	50 to 100 MPa
R4	Strong	Specimen breaks with one firm blow from the hammer end of a geological hammer.	100 to 200 MPa
R5	Very Strong	Specimen requires many blows of a geological hammer to break intact sample.	Greater than 200 MPa

Discontinuities

Spacing	
Very Widely	Greater than 3 m
Widely	1 m to 3 m
Moderately	0.3 m to 1 m
Closely	50 mm to 300 mm
Very Closely	Less than 50 mm

RQD (%)

$$\frac{100(\text{length of core in pieces} > 100\text{mm})}{\text{Length of core run}}$$

Condition	
Excellent	Very rough surfaces, no separation, hard discontinuity wall
Good	Slightly rough surfaces, separation less than 1 mm, hard discontinuity wall.
Fair	Slightly rough surfaces, separation greater than 1 mm, soft discontinuity wall.
Poor	Slickensided surfaces, or soft gouge less than 5 mm thick, or open discontinuities 1 to 5 mm.
Very Poor	Soft gouge greater than 5 mm thick, or open discontinuities greater than 5 mm.

Fracture Frequency (FF) is the average number of fractures per 300 mm of core.
Does not include mechanical breaks caused by drilling or handling.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984
HOLE No. RR-1-04
Sheet 1 of 5

Job No. XL-2201 | SR 395 | Elevation 1953.4 ft (595.4 m)

Project NSLAC-BNSF RR Over Crossing Tunnel | Driller Kerry Cooper | Lic# 2552

Site Address Vicinity of Market Street and Piper Road | Inspector Cleo Andrews

Start July 13, 2004 | Completion July 14, 2004 | Well ID# | Equipment CME 45 w/ autohammer

Station LR 359+40.23 | Offset 255.87' LT. | Casing HQ 3" x 105.0' | Method Wet Rotary

Northing 620162 | Easting 2822883 | Latitude | Longitude

County Spokane | Subsection NE 1/4 of the SW 1/4 | Section 15 | Range 43 EWM | Township 26

SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
			0.0' to 4.0' Poorly graded Sand with gravel as indicated by drilling and wash return. 100% drilling fluid return.
3 2 3 (5)	D-1		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Top surface gravel from RR access road. Length Recovered 1.5 ft, Length Retained 1.0 ft
3 3 4 (7)	D-2	GS MC	SP, M.C. = 20% Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
4 3 4 (7)	D-3		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
4 5	D-4		Poorly graded SAND, loose, olive gray, moist, Stratified, HCl reaction not tested. 0.4' of volcanic ash pinkish gray

Washington State Department of Transportation

LOG OF TEST BORING

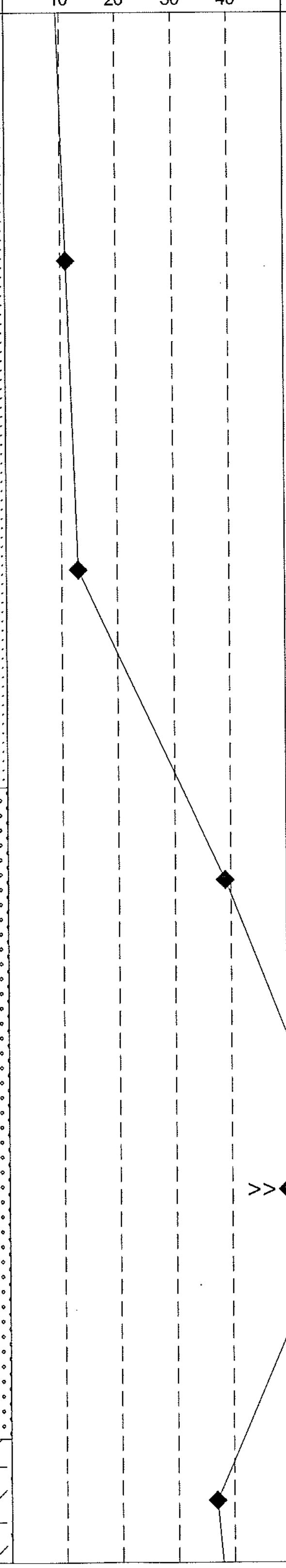
Start Card S-23984
HOLE No. RR-1-04
Sheet 2 of 5

Job No. XL-2201 SR 395 Elevation 1953.4 ft (595.4 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Standard Penetration Blows/ft (10, 20, 30, 40)



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		5 (9)			in color from 20.1' to 20.5'. Length Recovered 1.5 ft, Length Retained 1.0 ft
	7				
25		5 6 5 (11)	D-5		Poorly graded SAND, medium dense, brown, moist, Stratified, HCl reaction not tested. 1" layer of silt, olive gray in color. Length Recovered 1.5 ft, Length Retained 1.0 ft
	8				
30	9	6 7 6 (13)	D-6		Poorly graded SAND, medium dense, brown, moist, Stratified, HCl reaction not tested, very little drilling fluid loss. 1" layer of sandy silt. Length Recovered 1.5 ft, Length Retained 1.0 ft
	10				
35		13 17 22 (39)	D-7		Well graded SAND with gravel, with silty sand lens, dense, dark brown, moist, Laminated, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
	11				
40	12	34 29 32 (61)	D-8	GS MC	SW-SM, M.C. = 9% Well graded SAND with silt and gravel, subrounded, very dense, dark yellowish brown, moist, Homogeneous, HCl reaction not tested, traces of oxidized stains and silt. Length Recovered 1.0 ft, Length Retained 1.0 ft
	13				
45		8 17	D-9		GRANITE, olive gray, coarse grained, completely weathered, very weak rock.

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card	S-23984
HOLE No.	RR-1-04
Sheet	3 of 5
Job No.	XL-2201
SR	395
Elevation	1953.4 ft (595.4 m)
Project	NSLAC-BNSF RR Over Crossing Tunnel
Driller	Kerry Cooper
Lic#	2552

Depth (ft): 45–70; Meters (m): 14–21

Depth (ft)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
~45	20 (37)				Length Recovered 1.5 ft, Length Retained 1.3 ft	
~49	10 18 24 (42)		D-10		GRANITE, olive gray, coarse grained, completely weathered, very weak rock. Length Recovered 1.5 ft, Length Retained 1.0 ft	
~54	14 38 40 (78)		D-11		GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock. Length Recovered 1.5 ft, Length Retained 1.3 ft	
~59	16 28 45 (68)		D-12		GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock. Length Recovered 1.5 ft, Length Retained 1.0 ft	∇ 07/15/2004
~64	14 50/6 (50)		D-13		GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft, Length Retained 1.0 ft	
~69	36 35		D-14		GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock.	

Job No. XL-2201 SR 395 Elevation 1953.4 ft (595.4 m)

Project NSLAC-BNSF RR Over Crossing Tunnel Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Description of Material
		50/4 (50)		Length Recovered 1.3 ft, Length Retained 1.3 ft
	22			
75	23	27 50/6 (50)	D-15	GRANITE, brownish orange, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft, Length Retained 1.0 ft
80	24	28 50/4 (50)	D-16	GRANITE, reddish brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.8 ft, Length Retained 0.8 ft
	25			
85	26	>> 60/5 (60)	D-17	GRANITE, dark brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.4 ft, Length Retained 0.4 ft
90	27	>> 75/6 (75)	D-18	GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock. Length Recovered 0.5 ft, Length Retained 0.5 ft
	28			
95		22 50/4	D-19	GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock.

Standard Penetration Blows/ft: 10 20 30 40

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-1-04

Job No. XL-2201 SR 395 Elevation 1953.4 ft (595.4 m)

Sheet 5 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29			(50)				Length Recovered 0.8 ft, Length Retained 0.8 ft		
	30			28 50/6 (50)		D-20		GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft, Length Retained 1.0 ft		
100										
	31							End of test hole boring at 100 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. (Water table in hole before bailing is 7.0', bailed hole to 78.0' after 15 minute delay water table stayed at 78.0', pulled 5.0' of casing after 30 minutes stabilized at 59.4', hole left open over night water table remained the same. Ended and abandoned test boring at 100.0' below ground elevation.		
105	32									
	33									
110	34									
115	35									
	36									
120										

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-2-04

Sheet 1 of 5

Job No. XL-2201 SR 395 Elevation 1942.3 ft (592.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Site Address Market St. & Piper Rd.

Inspector Dave Nelson

Start July 14, 2004 Completion July 15, 2004 Well ID# AHN-668

Equipment CME 850 w/ auto hammer

Station LR 361+54.19 Offset 231.65' LT. Casing 6" x 40' & 4" x 98'

Method Wet Rotary

Northing 620374 Easting 2822920 Latitude Longitude

County Spokane Subsection NE 1/4 of SW 1/4 Section 15 Range 43 EWM Township 26

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	1									
5			8	2 4 4 (8)		D-1		Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
	2									
10	3		10	2 4 6 (10)		D-2	GS MC	SP-SM, M.C. = 16% Poorly graded SAND with silt, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
	4									
15			10	3 5 5 (10)		D-3		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
	5									
20	6									

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-65902

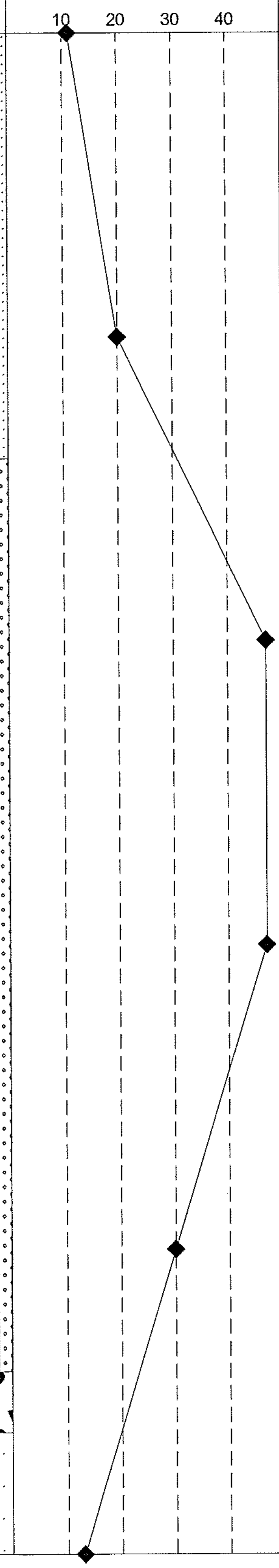
HOLE No. RR-2-04

Sheet 2 of 5

Job No. XL-2201 SR 395 Elevation 1942.3 ft (592.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
20		4 5 6 (11)	D-4		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	7				
25	8	4 9 11 (20)	D-5		Poorly graded SAND, with silt, medium dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	9				
30		17 22 25 (47)	D-6	GS MC	SW-SM, M.C. = 13% Well graded SAND with silt and gravel, dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	10				
35	11	18 20 27 (47)	D-7		Well graded SAND with silt, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	12				
40		13 15 15 (30)	D-8		Well graded SAND with gravel, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	13				
45					

Columns also shown: Profile, Sample Type, Groundwater, Instrument

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-65902

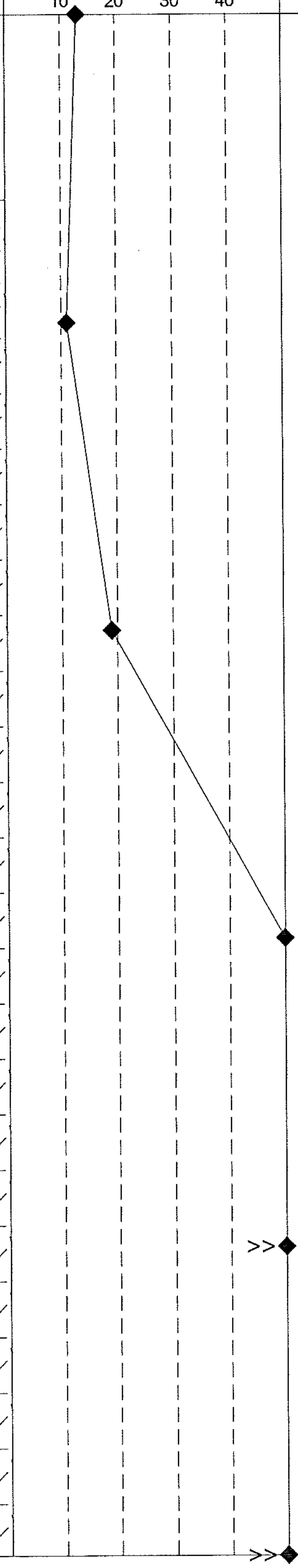
HOLE No. RR-2-04

Sheet 3 of 5

Job No. XL-2201 SR 395 Elevation 1942.3 ft (592.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel Driller Joe Judd Lic# 2454

Standard Penetration Blows/ft (10, 20, 30, 40)



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
	14	3 5 8 (13)	D-9	GS MC AL	ML, M.C. = 23%, PI = 21 Sandy SILT, medium dense, brown, moist, Homogeneous, HCl reaction not tested. Layer of gravel from 42' to 43'. Length Recovered 1.5 ft
50	15	2 4 7 (11)	D-10		GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.5 ft
55	16, 17	2 6 13 (19)	D-11		GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.5 ft 07/15/2004 (groundwater ∇)
60	18	9 20 30 (50)	D-12		GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.5 ft
65	19, 20	15 36 70 (106)	D-13		GRANITE, reddish brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft
70	21				

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-2-04

Job No. XL-2201 SR 395 Elevation 1942.3 ft (592.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Description of Material
		13 100 (100)	D-14	GRANITE, reddish brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.8 ft
	22			
75	23	30 100 (100)	D-15	GRANITE, reddish brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.7 ft
	24			
80		33 50 (50)	D-16	GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.8 ft
	25			
85	26	30 50 (50)	D-17	GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.8 ft
	27			
90		50 (50)	D-18	GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.4 ft
	28			
95				

Standard Penetration Blows/ft: 10 20 30 40

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-2-04

Job No. XL-2201 SR 395 Elevation 1942.3 ft (592.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29			50 (50)		D-19		GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 0.4 ft		
	30		>>	100 (100)		D-20		No Recovery End of test hole boring at 98 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Bailed Hole to 60.3 with recharge to 56.2 WATER LEVEL READINGS DATE: 8/17/04 — DEPTH: 56.1		
100										
	31									
105	32									
	33									
110										
	34									
115	35									
	36									
120										

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-3-04

Job No. XL-2201 SR 395 Elevation 1951.1 ft (594.7 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Site Address Vicinity of Market Street and Piper Road

Inspector Cleo Andrews

Start July 14, 2004 Completion July 15, 2004 Well ID#

Equipment CME 45 w/ autohammer

Station LR 363+23.5 Offset 119.49' LT. Casing HQ 3" ID x 115.0'

Method Wet Rotary

Northing 620536 Easting 2823042 Latitude

Longitude

County Spokane Subsection NE 1/4 of the SW 1/4 Section 15 Range 43 EWM Township 26

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	1									
5				2 3 4 (7)		D-1		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Top surface crushed rock from from RR access road. 0.0' to 4.0' Poorly graded Sand with some gravel as indicated by drilling and wash return. 100% drilling fluid return. Length Recovered 1.5 ft, Length Retained 1.0 ft		
	2									
10	3			3 4 4 (8)		D-2		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft		
	4									
15				4 4 4 (8)		D-3	GS MC	SP, M.C. = 20% Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested, very little drilling fluid loss. Length Recovered 1.5 ft, Length Retained 1.0 ft		
	5									
20	6			3 5		D-4		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested.		

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984

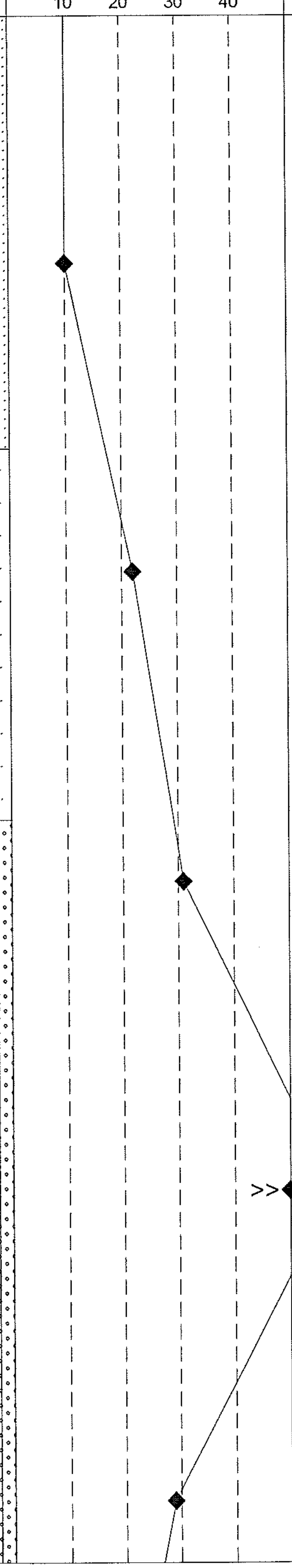
HOLE No. RR-3-04

Sheet 2 of 5

Job No. XL-2201 | SR 395 | Elevation 1951.1 ft (594.7 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper | Lic# 2552



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		5 (10)			Length Recovered 1.5 ft, Length Retained 1.0 ft
	7				
25		5 5 5 (10)	D-5		Poorly graded SAND, with 1" layer of sandy silt, loose, brown, moist, Stratified, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
	8				
30	9	10 12 10 (22)	D-6	GS MC	ML, M.C. = 50% SILT and sand, medium dense, olive gray, moist, Homogeneous, HCl reaction not tested, (material is Volcanic Ash very fine grained). Length Recovered 1.0 ft, Length Retained 1.0 ft
	10				
35	11	12 15 16 (31)	D-7		Well graded SAND with silt and gravel, with sandy silt lens, subrounded, dense, dark brown, moist, Laminated, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft
40	12	20 20 38 (58)	D-8		Well graded SAND with silt, with sandy silt lens, subrounded, very dense, grayish brown, moist, Laminated, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft
	13				
45		13 14	D-9	GS MC	SW-SM, M.C. = 14% Well graded SAND with silt, dense, grayish brown, moist,

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-3-04

Job No. XL-2201 SR 395 Elevation 1951.1 ft (594.7 m)

Sheet 3 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		15 (29)			Homogeneous, HCl reaction not tested. Length Recovered 1.2 ft, Length Retained 1.0 ft
	14				
	15	10 9 9 (18)	D-10		Well graded SAND with silt and gravel, medium dense, dark yellowish brown, moist, Stratified, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
50					
	16				
		7 13 13 (26)	D-11		Poorly graded SAND with gravel, with 0.3' of sandy Silt, dense, dark yellowish brown, moist, Stratified, HCl reaction not tested, traces of mica. Length Recovered 1.5 ft, Length Retained 1.0 ft
55	17				
	18	9 9 10 (19)	D-12		Silty SAND, with horizontal fine grained sand lenses, medium dense, olive gray, moist, Laminated, HCl reaction not tested, lenses are brown in color, traces of mica. Length Recovered 1.5 ft, Length Retained 1.0 ft
60					
	19				
		12 18 12 (30)	D-13		Well graded SAND with silt and gravel, with 0.3' of poorly graded sand with some coarser grains, dense, dark yellowish brown, moist, Stratified, HCl reaction not tested, very little drilling fluid loss. Length Recovered 1.5 ft, Length Retained 1.0 ft
65	20				
	21	27 25	D-14	GS MC	07/15/2004 SW-SM, M.C. = 11% Well graded SAND with silt and gravel, subrounded, very
70					

Standard Penetration Blows/ft: 10 20 30 40 (>> at D-14)

SOIL XL-2201, SR-395, NSLAC-BNSF RR OVER CROSSING TUNNEL.GPJ SOIL.GDT 12/20/04,12:06:53

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-3-04

Sheet 4 of 5

Job No. XL-2201 SR 395 Elevation 1951.1 ft (594.7 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		30 (55)			dense, dark yellowish brown, moist, Homogeneous, HCl reaction not tested, Note switched over to HQ core barrel at 71.5' refusal with HQ advancer. Changed to dark gray in color at 71.5', changed back to yellowish orange in color at 73.0' Length Recovered 1.5 ft, Length Retained 1.0 ft
	22		C-15		Well graded SAND with gravel, with (3) 1", 2" and 4" long pieces of basalt rock, dense, brown, moist, Stratified, HCl reaction not tested, traces of mica. Length Recovered 3.3 ft, Length Retained 3.3 ft
75	23	18 23 17 (30)	D-16		Well graded SAND with silt and gravel, with one thin lens of sandy silt, brownish orange in color, dense, grayish brown, moist, Laminated, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
			C-17		Well graded SAND with gravel, with 0.6' of elastic silt, dense, brown, moist, Stratified, HCl reaction not tested. Length Recovered 2.6 ft, Length Retained 2.6 ft
	24				
80		8 10 17 (27)	D-18	GS MC AL	CL, M.C. = 18%, PI = 15 Sandy lean CLAY, with gravel, very stiff, dark brown, moist, Stratified, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
			C-19		
	25				GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock, HCl Reaction not tested. Length Recovered 3.5 ft, Length Retained 3.5 ft
85	26	75/3 (75) RQD 0 FF 26	D-20 C-21		GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock, HCl reaction not tested. Discontinuities are very widely spaced and in very poor condition. Length Recovered 0.2 ft, Length Retained 0.2 ft
	27				GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock, HCl reaction not tested. Discontinuities are very widely spaced and in very poor condition. Percent Recovered 82.0%
90	28	60/4" (60) RQD 0 FF 26	D-22 C-23		GRANITE, grayish brown, coarse grained, completely weathered, very weak rock, HCl reaction not tested. Length Recovered 0.3 ft, Length Retained 0.3 ft GRANITE , yellowish brown, coarse grained, highly weathered, very weak rock, HCl reaction not tested. Discontinuities are very widely spaced and in very poor condition. Percent Recovered 82.0%
95					

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-3-04

Job No. XL-2201 SR 395 Elevation 1951.1 ft (594.7 m)

Sheet 5 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29		>>	60/4 (60)		D-24 C-25		GRANITE, grayish brown, coarse grained, completely weathered, very weak rock, HCl reaction not tested. Discontinuities are very widely spaced and in very poor condition. Length Recovered 0.3 ft, Length Retained 0.3 ft No Recovery		
	30									
100			>>	75/4 (75) RQD 0 FF 26		D-26 C-27		GRANITE, yellowish orange, coarse grained, completely weathered, very weak rock. Length Recovered 0.3 ft, Length Retained 0.3 ft		
	31							GRANITE, yellowish gray, coarse grained, highly weathered, very weak rock, HCl reaction not tested. Discontinuities are very widely spaced and in very poor condition. (Note water table in casing before bailing hole is 7.0', bailed hole to 88.0' bailer lost in hole. Over night reading is 68.9'., Percent Recovered 1.7%		
105	32									
	33									
110								End of test hole boring at 110 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data.		
	34									
115	35									
	36									
120										

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-4-04

Sheet 1 of 6

Job No. XL-2201 | SR 395 | Elevation 1949.5 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel | Driller Joe Judd | Lic# 2454

Site Address Market St. & Piper Rd. | Inspector Dave Nelson

Start July 13, 2004 | Completion July 14, 2004 | Well ID# AHN-669 | Equipment CME 850 w/ auto hammer

Station LR 365+39.08 | Offset 116.61' LT. | Casing 6" x 15.0 & 4" x 135 | Method Wet Rotary

Northing 620750 | Easting 2823058 | Latitude | Longitude

County Spokane | Subsection NE 1/4 of SW 1/4 | Section 15 | Range 43 EWM | Township 26

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
5			6	2 3 3 (6)		D-1		Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
10	3		6	2 3 3 (6)		D-2		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
15			7	2 3 4 (7)		D-3		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
20	6									

Washington State
Department of Transportation

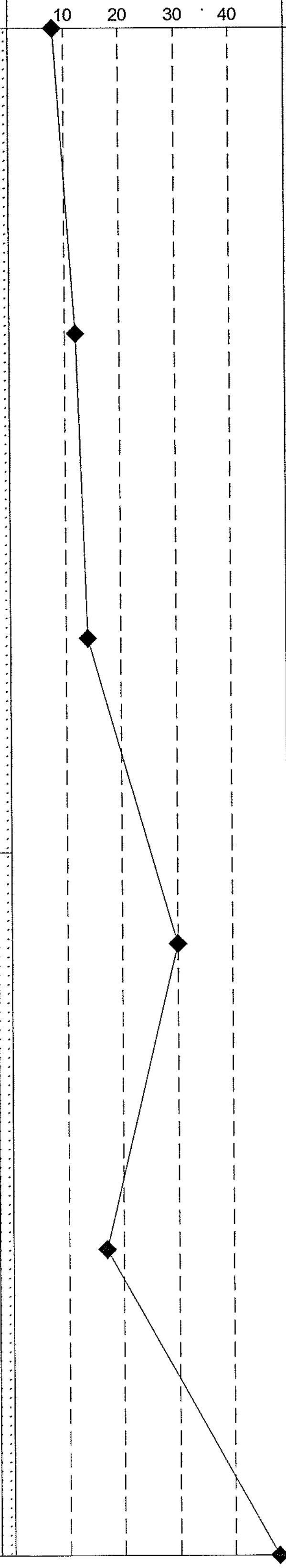
LOG OF TEST BORING

Start Card R-65902
HOLE No. RR-4-04
Sheet 2 of 6

Job No. XL-2201 SR 395 Elevation 1949.5 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel Driller Joe Judd Lic# 2454

Standard Penetration Blows/ft



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		3 4 4 (8)	D-4	GS MC	SP, M.C. = 19% Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	7				
25		3 6 6 (12)	D-5		Poorly graded SAND, medium dense, brown, moist, Stratified, HCl reaction not tested, silt stratified. Length Recovered 1.0 ft
	8				
	9				
30		5 7 7 (14)	D-6		Poorly graded SAND, medium dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	10				
35		5 13 17 (30)	D-7		Well graded SAND with silt and gravel, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	11				
	12				
40		7 9 10 (17)	D-8	GS MC	SP-SM, M.C. = 13% Poorly graded SAND with silt and gravel, medium dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
	13				
45					

Column headings: Depth (ft) | Meters (m) | Profile | Standard Penetration Blows/ft | SPT Blows/6" (N) | Sample Type | Sample No. (Tube No.) | Lab Tests | Description of Material | Groundwater | Instrument

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-4-04

Sheet 3 of 6

Job No. XL-2201 SR 395 Elevation 1949.5 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
	18 26 22 (48)	D-9		Well graded SAND with silt and gravel, dense, grey, wet, Homogeneous, HCl reaction not tested. Length Recovered 0.2 ft
50	12 16 21 (37)	D-10	GS MC	SW-SM, M.C. = 12% Well graded SAND with silt and gravel, dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
55	12 14 12 (26)	D-11		Well graded SAND with silt and gravel, dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
60	5 5 8 (13)	D-12	GS MC	ML, M.C. = 27% Sandy SILT, medium dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
65	7 9 10 (19)	D-13		Well graded SAND with silt, medium dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
70				

Meters (m): 14, 15, 16, 17, 18, 19, 20, 21

Standard Penetration Blows/ft: 10 20 30 40

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-4-04

Job No. XL-2201 SR 395 Elevation 1949.5 ft (594.2 m)

Sheet 4 of 6

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
70		5 11 15 (26)	D-14		Silty SAND, dense, brown, wet, Stratified, HCl reaction not tested, stratified with well graded sand, traces of mica. Length Recovered 1.0 ft
	22				
75	23	12 12 12 (24)	D-15	GS MC	SM, M.C. = 17% Silty SAND, medium dense, brown, wet, Homogeneous, HCl reaction not tested, traces of mica. Length Recovered 1.0 ft
	24				
80		12 12 13 (25)	D-16		Silty SAND with gravel, dense, brown, wet, Homogeneous, HCl reaction not tested, traces of mica. Length Recovered 1.0 ft
	25				
85	26	35 50 (50)	D-17		Silty SAND, very dense, yellowish brown, moist, Homogeneous, HCl reaction not tested, traces of mica. Length Recovered 0.5 ft
	27				
90		70 (70)	D-18		Silty SAND, very dense, yellowish brown, moist, Homogeneous, HCl reaction not tested, traces of mica. Length Recovered 0.4 ft
	28				
95					

Standard Penetration Blows/ft: 10 20 30 40

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-4-04

Job No. XL-2201 SR 395 Elevation 1949.5 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Description of Material
	29	100 (100) RQD 100 FF 0	D-19 C-20	GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock, HCl reaction not tested. Length Recovered 0.3 ft GRANITE, light olive grey, coarse grained, highly weathered, very weak rock, HCl reaction not tested. Discontinuities are closely spaced and in fair condition. Percent Recovered 100.0%
	30			
100		RQD 90 FF 0	C-21	GRANITE, light olive grey, coarse grained, highly weathered, very weak rock, HCl reaction not tested. Discontinuities are moderately spaced and in fair condition. Percent Recovered 100.0%
	31			
105	32	RQD 90 FF 1	C-22	GRANITE, bluish-grey, coarse grained, moderately weathered, moderately strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in fair condition. Percent Recovered 100.0%
	33			
110		RQD 50 FF 2	C-23	GRANITE, bluish-grey, coarse grained, slightly weathered, moderately strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in fair condition. Percent Recovered 100.0%
	34			
115	35	RQD 98 FF 1	C-24	GRANITE, bluish-grey, medium grained, slightly weathered, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in good condition. Percent Recovered 100.0%
	36			
120				

Standard Penetration Blows/ft: 10 20 30 40

Columns: Profile, Sample Type, Lab Tests, Groundwater, Instrument

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-4-04

Sheet 6 of 6

Job No. XL-2201 SR 395 Elevation 1949.5 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	37			RQD 95 FF 1		C-25		GRANITE, bluish-grey, medium grained, slightly weathered, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in good condition. Percent Recovered 100.0%		
125	38			RQD 98 FF 0		C-26		GRANITE, bluish-grey, medium grained, fresh, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in excellent condition. Percent Recovered 100.0%		
130	39, 40			RQD 98 FF 0		C-27		GRANITE, bluish-grey, medium grained, fresh, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in excellent condition. Percent Recovered 100.0%		
135	41							End of test hole boring at 135 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Bailed hole to 130 with no recharge WATER LEVEL READINGS DATE 8/17/04 — DEPTH dry		
140	42, 43									
145	44									

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-5-04

Sheet 1 of 5

Job No. XL-2201 SR 395 Elevation 1949.6 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Site Address Vicinity of Market Street and Piper Road

Inspector Cleo andrews

Start July 15, 2004 Completion July 16, 2004 Well ID#

Equipment CME 45 w/ autohammer

Station LR 367+04.82 Offset 18.89' LT. Casing HQ 3" ID x 115.0'

Method Wet Rotary

Northing 620910 Easting 2823160 Latitude Longitude

County Spokane Subsection NE 1/4 of the SW 1/4 Section 15 Range 43 EWM Township 26

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	1									
5				3 3 4 (7)		D-1		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Top surface gravel from access road. 0.0' to 4.0' Poorly graded sand with some gravel as indicated by drilling and wash return. 100% drilling fluid return. Length Recovered 1.5 ft, Length Retained 1.0 ft		
	2									
10	3			3 4 3 (7)		D-2		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested, very little drilling fluid loss. Length Recovered 1.5 ft, Length Retained 1.0 ft		
	4									
15				3 4 4 (8)		D-3		Poorly graded SAND, with silt lens, loose, brown, moist, Laminated, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft		
	5									
20	6			3 4		D-4	GS MC	SP, M.C. = 18% Poorly graded SAND, loose, brown, moist,		

SOIL XL-2201, SR-395, NSLAC-BNSF RR OVER CROSSING TUNNEL.GPJ SOIL.GDT 12/20/04,12:06:55

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-5-04

Job No. XL-2201 SR 395 Elevation 1949.6 ft (594.2 m)

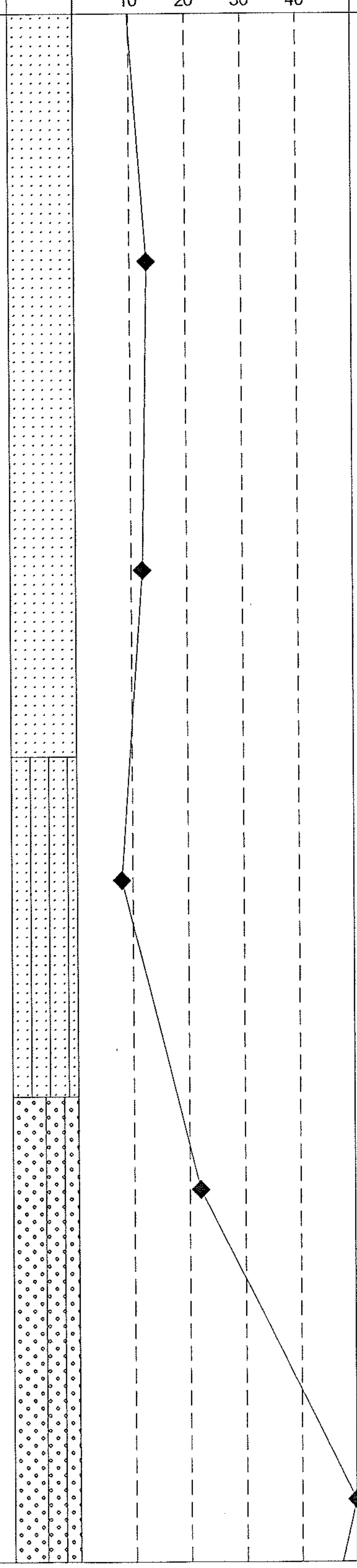
Sheet 2 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft): 25, 30, 35, 40, 45 — Meters (m): 7, 8, 9, 10, 11, 12, 13

Standard Penetration Blows/ft: 10, 20, 30, 40



SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
5 (9)			Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft
6 7 7 (13)	D-5		Poorly graded SAND, with silt lens, medium dense, brown, moist, Laminated, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
5 5 7 (12)	D-6		Poorly graded SAND, medium dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
3 4 4 (8)	D-7	GS MC	SM, M.C. = 19% Silty SAND, loose, brown, moist, Stratified, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
9 9 13 (22)	D-8		Well graded SAND with silt and gravel, medium dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft
28 50/4	D-9		Well graded SAND with silt and gravel, with silt lens, subrounded, very dense, dark yellowish brown, moist,

Groundwater | Instrument

SOIL XL-2201, SR-395, NSLAC-BNSF RR OVER CROSSING TUNNEL.GPJ SOIL.GDT 12/20/04,12:06:56

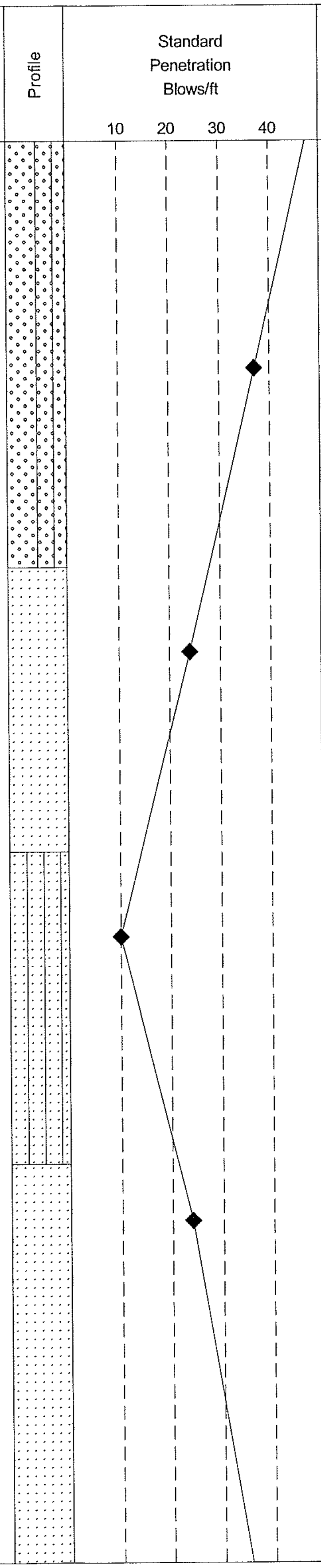
Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984
HOLE No. RR-5-04

Job No. XL-2201 | SR 395 | Elevation 1949.6 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel | Driller Kerry Cooper | Lic# 2552



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		(50)			Laminated, HCl reaction not tested. Length Recovered 0.5 ft, Length Retained 0.5 ft
	14				
50	15	19 20 17 (37)	D-10	GS MC	SW-SM, M.C. = 10% Well graded SAND with silt and gravel, subrounded, dense, grayish brown, moist, Laminated, HCl reaction not tested. Sand lens brownish orange in color. Length Recovered 1.0 ft, Length Retained 1.0 ft
55	16	22 14 10 (24)	D-11		Poorly graded SAND, with gravel, medium dense, grayish brown, moist, Stratified, HCl reaction not tested, laminated with silty sand lens, brownish orange in color. Length Recovered 1.5 ft, Length Retained 1.0 ft
60	17, 18	12 6 4 (10)	D-12		Silty SAND, with 0.3' of well graded sand with small gravel, loose, olive gray, moist, Stratified, HCl reaction not tested, change is from 64.0' to 64.3', traces of mica. Took moister can sample MC-12a from same depth, retained 0.3'. Length Recovered 1.0 ft, Length Retained 1.0 ft
65	19, 20	11 13 11 (24)	D-13		Poorly graded SAND, with 1" layer of silt, medium dense, dark brown, moist, Stratified, HCl reaction not tested, laminated with thin lenses of silty sand, traces of mica. Length Recovered 1.5 ft, Length Retained 1.0 ft
70	21				

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984
HOLE No. RR-5-04
Sheet 4 of 5

Job No. XL-2201   SR 395   Elevation 1949.6 ft (594.2 m)

Project NSLAC-BNSF RR Over Crossing Tunnel   Driller Kerry Cooper   Lic# 2552

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Description of Material
75	22–23	13 18 25 (43)	D-14	Well graded GRAVEL with sand, with 0.2' of sandy silt, subrounded, dense, grayish brown, moist, Stratified, HCl reaction not tested, traces of decomposed granite, light gray in color, mica sand and brownish orange stain. (Note refusal with HQ advancer at 76.5', switched over to HQ coring at 75.5'). Length Recovered 1.2 ft, Length Retained 1.0 ft
			C-15	Well graded SAND with gravel, yellowish orange in color, very dense, gray, moist, Stratified, HCl reaction not tested. 0.3' piece of Basalt. Length Recovered 1.0 ft, Length Retained 1.0 ft
80	24	43 32 50/2" (50)	D-16	Poorly graded SAND with silt, dense, yellowish orange, moist, Stratified, HCl reaction not tested, with pieces of basalt and granite gravel. Length Recovered 1.0 ft, Length Retained 1.0 ft
	25		C-17	Well graded SAND with gravel, very dense, yellowish orange, moist, Stratified, HCl reaction not tested. 0.3' of basalt rock, gray in color, Length Recovered 1.0 ft, Length Retained 1.0 ft
85	26	15 19 22 (41)	D-18 / C-19	Poorly graded SAND, dense, yellowish orange , moist, Stratified, HCl reaction not tested. Pieces of basalt, gray in color. Length Recovered 1.5 ft, Length Retained 1.0 ft
	27			Silty SAND, medium dense, light gray, moist, Homogeneous, HCl reaction not tested. Length Recovered 0.3 ft, Length Retained 0.3 ft
90		11 7 12 (19)	D-20	Silty SAND, with Volcanic Ash, medium dense, yellowish orange, moist, Stratified, HCl reaction not tested. Changed to Basalt Rock at 92.0'. Length Recovered 0.3 ft, Length Retained 0.3 ft
	28	RQD 60 FF 1	C-21	Basalt, gray, fine grained, slightly weathered, strong rock, HCl reaction not tested. Very little drilling fluid loss. Percent Recovered 71.0%
95				

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-5-04

Job No. XL-2201 SR 395 Elevation 1949.6 ft (594.2 m)

Sheet 5 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29		9 10 13 (23)	D-22		Silty SAND, with Volcanic Ash, medium dense, yellowish orange, wet, Stratified, HCl reaction not tested. Length Recovered 0.3 ft, Length Retained 0.3 ft		
	30		RQD 38 FF 3	C-23		Basalt, dark gray, fine grained, fresh, strong rock, HCl reaction not tested. Percent Recovered 71.0%		
100			9 10 28 (38)	D-24		Poorly graded SAND, with 1" layer of silty Sand, dense, grayish brown, moist, Stratified, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft		
	31		RQD 0 FF 26	C-25		Basalt, highly fractured, dark gray, fine grained, slightly weathered, strong rock, HCl reaction not tested. Percent Recovered 85.0%		
105	32		1 7 12 (19)	D-26		Silty SAND, with pieces of basalt rock, medium dense, yellowish orange, moist, Stratified, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft		
	33		RQD 0 FF 26	C-27		Basalt, highly fractured, gray, fine grained, slightly weathered, strong rock, HCl reaction not tested. Percent Recovered 85.0%		
110		>>	55/4 (55)	D-28		Silty SAND, very dense, orange, moist, Homogeneous, HCl reaction not tested. Length Recovered 0.4 ft, Length Retained 0.4 ft		
	34					End of test hole boring at 110.4 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Water table in casing before bailing is 12.8', pulled 5.0' of casing bailed hole to 106.0', water table after 15 minutes is 106.2'. (Dry hole) Ended and abandoned test boring at 110.4' below ground elevation. 7/17/04.		
115	35							
	36							
120								

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984
HOLE No. RR-6-04
Sheet 1 of 5

Job No. XL-2201 SR 395 Elevation 1948.9 ft (594.0 m)

Driller Joe Judd Lic# 2454

Project NSLAC-BNSF RR Over Crossing Tunnel

Site Address Market St. & Piper Rd.

Inspector Dave Nelson

Start July 17, 2004 Completion July 18, 2004 Well ID#

Equipment CME 850 w/ autohammer

Station LR 369+20.01 Offset 36.14' RT. Casing 4" x 100.0

Method Wet Rotary

Northing 621127 Easting 2823208 Latitude

Longitude

County Spokane Subsection NE 1/4 of SW 1/4 Section 15 Range 43 EWM Township 26

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
4	1		11	4 5 6 (11)		D-1		Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
9	2–3		7	2 3 4 (7)		D-2		Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
14	4		7	2 3 4 (7)		D-3	GS MC	SP, M.C. = 10% Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
19	5–6			3 5		D-4		Poorly graded SAND, medium dense, brown, dry, Homogeneous, HCl reaction not tested.		

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-6-04

Job No. XL-2201 SR 395 Elevation 1948.9 ft (594.0 m)

Sheet 2 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
7 (12)			Length Recovered 1.0 ft
5 8 7 (15)	D-5		Poorly graded SAND, medium dense, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
7 7 7 (14)	D-6		Poorly graded SAND, medium dense, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
8 8 11 (19)	D-7	GS MC	SP-SM, M.C. = 20% Poorly graded SAND with silt, medium dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
11 13 17 (30)	D-8	GS MC	SM, M.C. = 20% Silty SAND, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 0.2 ft
12 14	D-9		Well graded SAND with silt and gravel, dense, brown, wet, Homogeneous, HCl reaction not tested.

SOIL XL-2201, SR-395, NSLAC-BNSF RR OVER CROSSING TUNNEL.GPJ SOIL.GDT 12/20/04,12:06:57

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-6-04

Job No. XL-2201 SR 395 Elevation 1948.9 ft (594.0 m)

Sheet 3 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
				14 (28)				Length Recovered 0.8 ft		
	14									
	15			16 18 18 (36)		D-10	GS MC	SW-SM, M.C. = 12% Well graded SAND with silt, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
50										
	16									
				12 15 15 (30)		D-11		Well graded SAND with silt and gravel, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
55	17									
	18			10 12 16 (28)		D-12		Silty SAND with silt and gravel, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
60										
	19									
				10 13 18 (31)		D-13	GS MC	SM, M.C. = 16% Silty SAND, dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
65	20									
	21			7 17		D-14	GS MC	SM, M.C. = 16% Silty SAND, dense, brown, wet, Stratified, HCl reaction		
70										

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-6-04

Job No. XL-2201 SR 395 Elevation 1948.9 ft (594.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
		19 (36)			not tested, stratified w/ silt. Length Recovered 1.0 ft	
	22					
75	23	18 28 38 (66)	D-15		GRANITE, reddish brown, coarse grained, completely weathered, very weak rock, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft	∇
80	24	70 (70)	D-16		GRANITE, reddish brown, coarse grained, completely weathered, very weak rockHomogeneous, HCl reaction not tested. Length Recovered 0.5 ft	
	25	RQD 3 FF 4	C-17		GRANITE, bluish-grey, medium grained, slightly weathered, moderately strong rock, HCl reaction not tested. Discontinuities are widely spaced and in fair condition. Percent Recovered 100.0%	
85	26	RQD 48 FF 2	C-18		GRANITE, bluish-grey, medium grained, slightly weathered, moderately strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in fair condition. . Percent Recovered 100.0%	
90	27	RQD 94 FF 1	C-19		GRANITE, bluish-grey, medium grained, slightly weathered, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in good condition. Percent Recovered 100.0%	
95	28					

Standard Penetration Blows/ft: 10 20 30 40

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-6-04

Job No. XL-2201 SR 395 Elevation 1948.9 ft (594.0 m)

Sheet 5 of 5

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29			RQD 52 FF 2		C-20		GRANITE, bluish-grey, medium grained, slightly weathered, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in good condition. Percent Recovered 100.0%		
	30									
100								End of test hole boring at 100 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Bailed hole to 70.0 and after 24 hours WT @ 75.0		
	31									
105	32									
	33									
110										
	34									
115	35									
	36									
120										

SOIL XL-2201, SR-395, NSLAC-BNSF RR OVER CROSSING TUNNEL.GPJ SOIL.GDT 12/20/04,12:06:57

LOG OF TEST BORING

Washington State Department of Transportation

Job No. XL-2201	SR 395	Elevation 1948.8 ft (594.0 m)	HOLE No. RR-7-04
Start Card R-65902			Sheet 1 of 4
Project NSLAC-BNSF RR Over Crossing Tunnel		Driller Kerry Cooper	Lic# 2552
Site Address Vicinity of Market Street and Piper Road		Inspector Cleo Andrews	
Start July 17, 2004	Completion July 17, 2004	Well ID# AHN-670	Equipment CME 45 w/ autohammer
Station LR 370+96.89	Offset 95.27' RT.	Casing (HWT 4" ID x 12.0')(HQ 3" ID x 75.0')	Method Wet Rotary
Northing 621312	Easting 2823249	Latitude	Longitude
County Spokane	Subsection NE 1/4 of the SW 1/4	Section 15	Range 43 EWM, Township 26

Depth (ft)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
~4–5.5	4 5 5 (10)	D-1		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Top surface crushed rock from RR access road. 0.0' to 4.0' Poorly graded Sand with gravel as indicated by drilling and wash return. 100% drilling fluid return. Length Recovered 0.5 ft, Length Retained 0.5 ft
~9–10.5	3 3 4 (7)	D-2		Poorly graded SAND, loose, brown, moist, Homogeneous, HCl reaction not tested, very little drilling fluid loss. Length Recovered 1.0 ft, Length Retained 1.0 ft
~14–15.5	3 2 2 (4)	D-3	GS MC	SP, M.C. = 21% Poorly graded SAND, very loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft
~19–20	5 5	D-4		Poorly graded SAND, with silty sand lense of, loose, brown, moist, Laminated,Fissured, HCl reaction not

Standard Penetration Blows/ft: 10 20 30 40

Depth (ft): 5, 10, 15, 20; Meters (m): 1, 2, 3, 4, 5, 6

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-65902
HOLE No. RR-7-04
Sheet 2 of 4

Job No. XL-2201 SR 395 Elevation 1948.8 ft (594.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft): 25, 30, 35, 40, 45
Meters (m): 7, 8, 9, 10, 11, 12, 13

Standard Penetration Blows/ft: 10, 20, 30, 40

SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
4 (9)			tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
5 6 9 (15)	D-5		Poorly graded SAND, medium dense, brown, moist, Stratified, HCl reaction not tested, traces of root hairs, very little drilling fluid loss. With 0.3' layer of silt (volcanic ash), very fine grained, pinkish brown in color. Length Recovered 1.5 ft, Length Retained 1.0 ft
4 5 4 (9)	D-6	GS MC	SM, M.C. = 21% Silty SAND, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
7 13 15 (28)	D-7		Well graded SAND with silt and gravel, with 1" layer of silty sand, dense, grayish brown, moist, Stratified, HCl reaction not tested Length Recovered 1.5 ft, Length Retained 1.0 ft
14 20 20 (40)	D-8	GS MC	SW-SM, M.C. = 13% Well graded SAND with silt, dense, brownish gray, moist, Homogeneous, HCl reaction not tested Length Recovered 1.5 ft, Length Retained 1.0 ft
>> 32 37	D-9		Well graded SAND with silt and gravel, very dense, brownish gray, moist, Homogeneous, HCl reaction not

Washington State
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LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-7-04

Sheet 3 of 4

Job No. XL-2201 SR 395 Elevation 1948.8 ft (594.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
	14	38 (75)			tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
50	15	26 35 38 (73)	D-10	GS MC	SW-SM, M.C. = 12% Well graded SAND with silt, very dense, brownish gray, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.0 ft
55	16	38 44 40 (84)	D-11		Well graded SAND with silt and gravel, very dense, brownish gray, moist, Laminated, HCl reaction not tested, silty Sand lens, brownish orange in color. Length Recovered 1.5 ft, Length Retained 1.0 ft
	17				07/21/2004
60	18	70/4 (70)	D-12		Well graded SAND, very dense, yellowish orange, moist, Homogeneous, HCl reaction not tested, (Material consists of decomposed GRANITE). Note refusal at 60.3' with HQ advancer, switched over to HQ core Barrel. Length Recovered 0.3 ft, Length Retained 0.3 ft
	19	RQD 48 FF 5	C-13		GRANITE, pinkish gray, medium grained, slightly weathered, strong rock, HCl reaction not tested. Discontinuities are closely spaced and in good condition. Percent Recovered 100.0%
65	20	RQD 98 FF 1	C-14		GRANITE, light gray, coarse grained, fresh, strong rock, HCl reaction not tested. Discontinuities are closely spaced and in good condition. Percent Recovered 100.0%
70	21				

Standard Penetration Blows/ft: 10 20 30 40

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-65902

HOLE No. RR-7-04

Job No. XL-2201 SR 395 Elevation 1948.8 ft (594.0 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
								End of test hole boring at 70 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Water table in casing before bailing hole is 12.5', bailed hole to 62.4', after 15 minutes delay water table stabilized at 54.7. Installed and bailed piezo. Ended test boring at 69.0' below ground elevation. WATER LEVEL READINGS DATE DEPTH 8/17/2004 dry		
	22									
75	23									
	24									
80	25									
85	26									
	27									
90	28									
95										

LOG OF TEST BORING

Washington State Department of Transportation

Start Card	S-23984
HOLE No.	RR-8-04
Sheet	1 of 5
Job No.	XL-2201
SR	395
Elevation	1944.4 ft (592.7 m)
Project	NSLAC-BNSF RR Over Crossing Tunnel
Driller	Joe Judd
Lic#	2454
Site Address	Market St. & Piper Rd.
Inspector	Dave Nelson
Start	July 16, 2004
Completion	July 17, 2004
Well ID#	
Equipment	CME 850 w/ auto hammer
Station	LR 372+93.92
Offset	103.86' RT.
Casing	4" x 110.5
Method	Wet Rotary
Northing	621515
Easting	2823226
Latitude	
Longitude	
County	Spokane
Subsection	NE 1/4 of SW 1/4
Section	15
Range	43 EWM
Township	26

Depth (ft)	Meters (m)	Profile	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	1								
5			2 3 3 (6)		D-1		Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
	2								
10	3		3 3 4 (7)		D-2	GS MC	SP, M.C. = 16% Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
	4								
15			2 2 2 (4)		D-3		Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
	5								
20	6		3 3		D-4		Poorly graded SAND, loose, brown, dry, Homogeneous, HCl reaction not tested.		

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984
HOLE No. RR-8-04
Sheet 2 of 5

Job No. XL-2201 SR 395 Elevation 1944.4 ft (592.7 m)

Project NSLAC-BNSF RR Over Crossing Tunnel Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		3 (6)			Length Recovered 1.0 ft
25	7	3 3 3 (6)	D-5	GS MC	ML, M.C. = 45% Sandy SILT, loose, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
30	8, 9	4 6 11 (17)	D-6		Poorly graded SAND, medium dense, brown, moist, Homogeneous, HCl reaction not tested. Length Recovered 0.8 ft
35	10, 11	11 13 17 (30)	D-7		Well graded SAND with gravel, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
40	12	10 11 15 (26)	D-8	GS MC	SW-SM, M.C. = 18% Well graded SAND with silt, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft
45	13	9 12	D-9	GS MC	SW-SM, M.C. = 13% Well graded SAND with silt, dense, brown, wet,

Standard Penetration Blows/ft: 10 20 30 40

Washington State
Department of Transportation

LOG OF TEST BORING

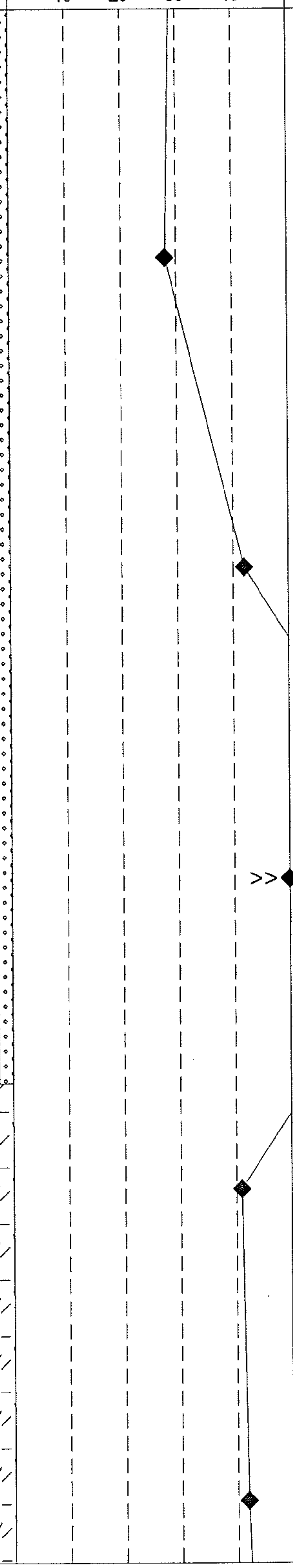
Start Card S-23984

HOLE No. RR-8-04

Job No. XL-2201 SR 395 Elevation 1944.4 ft (592.7 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454



Depth (ft)	Meters (m)	Profile	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
			17 (29)			Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
	14							
	15		12 14 14 (28)	D-10		Well graded SAND, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
50								
	16							
			14 20 22 (42)	D-11		Well graded SAND with gravel, dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
55	17							
	18		23 28 50 (78)	D-12		Well graded SAND with gravel, very dense, brown, wet, Homogeneous, HCl reaction not tested. Length Recovered 1.0 ft		
60								
	19							
			15 17 24 (41)	D-13		GRANITE, reddish brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft		
65	20							
	21		12 18	D-14		GRANITE, brown, coarse grained, completely weathered, very weak rock.		
70								

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-23984

HOLE No. RR-8-04

Sheet 4 of 5

Job No. XL-2201 SR 395 Elevation 1944.4 ft (592.7 m)

Project NSLAC-BNSF RR Over Crossing Tunnel

Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
				24 (42)				Length Recovered 1.0 ft		
	22									
				10 15 29 (44)		D-15		GRANITE, brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft		
75	23								∇	
	24			18 18 30 (48)		D-16		GRANITE, brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft		
80										
	25									
			>>	11 37 40 (77)		D-17		GRANITE, yellowish brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft		
85	26									
	27			12 19 30 (49)		D-18		GRANITE, reddish brown, coarse grained, completely weathered, very weak rock. Length Recovered 1.0 ft		
90										
	28									
				10 16		D-19		GRANITE, reddish brown, coarse grained, completely weathered, very weak rock.		
95										

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-23984
HOLE No. RR-8-04
Sheet 5 of 5

Job No. XL-2201 SR 395 Elevation 1944.4 ft (592.7 m)

Project NSLAC-BNSF RR Over Crossing Tunnel Driller Joe Judd Lic# 2454

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29			29 (45)				Length Recovered 1.0 ft		
	30		>>	100 (100) RQD 0 FF 3		D-20 C-21		No Recovery GRANITE, bluish-grey, coarse grained, slightly weathered, moderately strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in poor condition, Percent Recovered 100.0%		
100				RQD 98 FF 1		C-22		GRANITE, bluish-grey, medium grained, fresh, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in excellent condition. Percent Recovered 100.0%		
	31									
105	32			RQD 98 FF 1		C-23		GRANITE, bluish-grey, medium grained, fresh, strong rock, HCl reaction not tested. Discontinuities are moderately spaced and in excellent condition. Percent Recovered 100.0%		
	33									
110										
	34							End of test hole boring at 110.5 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data.		
115	35									
	36									
120										

Job No.	XL-2201	Date	July 29, 2004
Hole No.	RR-1-04	Sheet	1 of 1
Project	NSLAC-BNSF RR Over Crossing Tunnel		

Laboratory Summary

Washington State Department of Transportation

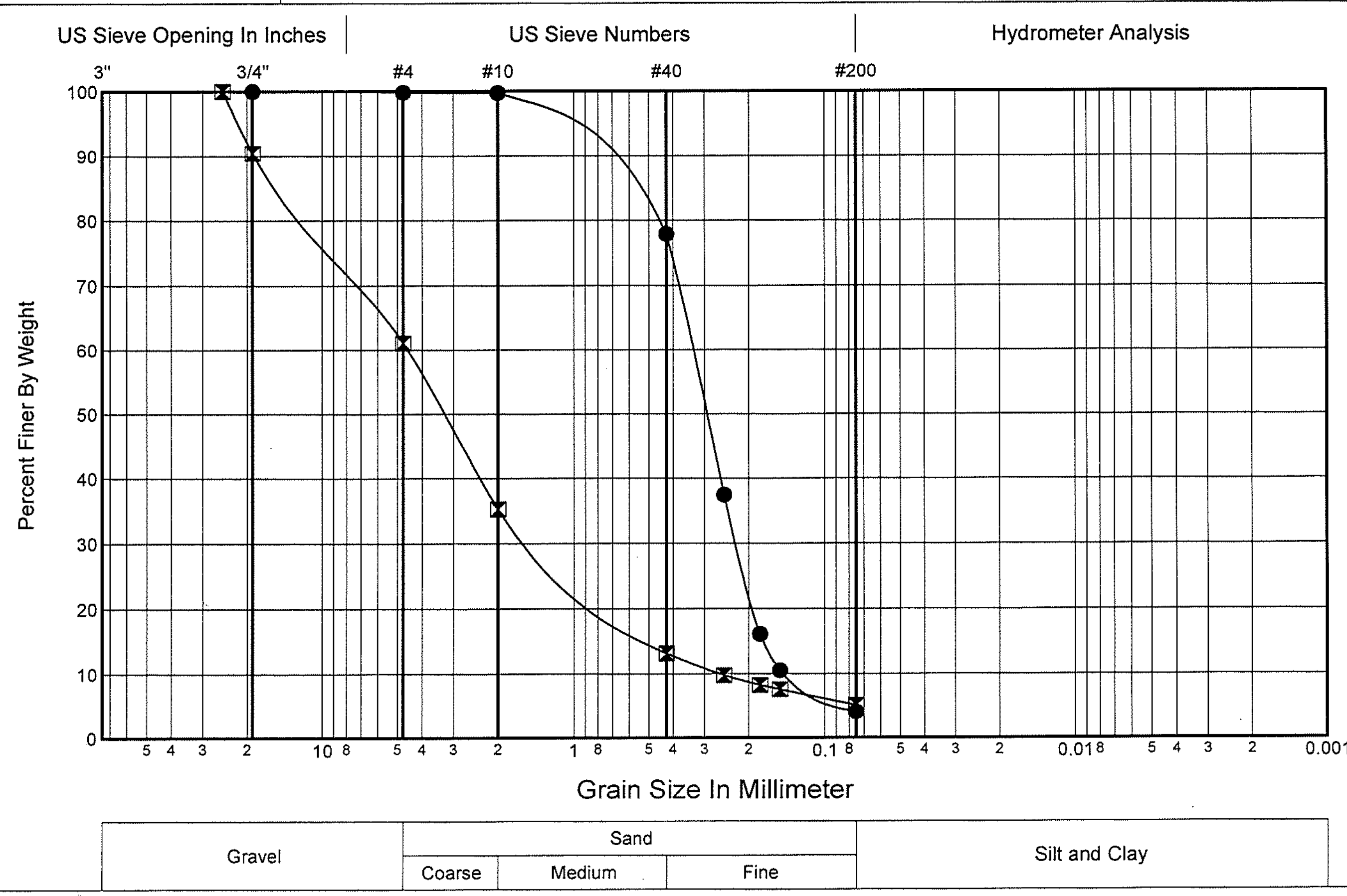
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	9.0	2.74	D-2	SP		POORLY GRADED SAND	20			
⊠	39.0	11.89	D-8	SW-SM		WELL-GRADED SAND with SILT and GRAVEL	9			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.2	95.8	4.0	1.0	2.4
⊠	38.9	56.0	5.1	1.6	17.7

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.336	0.29	0.22	0.19	0.142
⊠	4.579	3.28	1.38	0.69	0.259



Job No.	XL-2201
Hole No.	RR-2-04
Project	NSLAC-BNSF RR Over Crossing Tunnel

Date **August 6, 2004**

Sheet 1 of 1

Laboratory Summary

Washington State
Department of Transportation

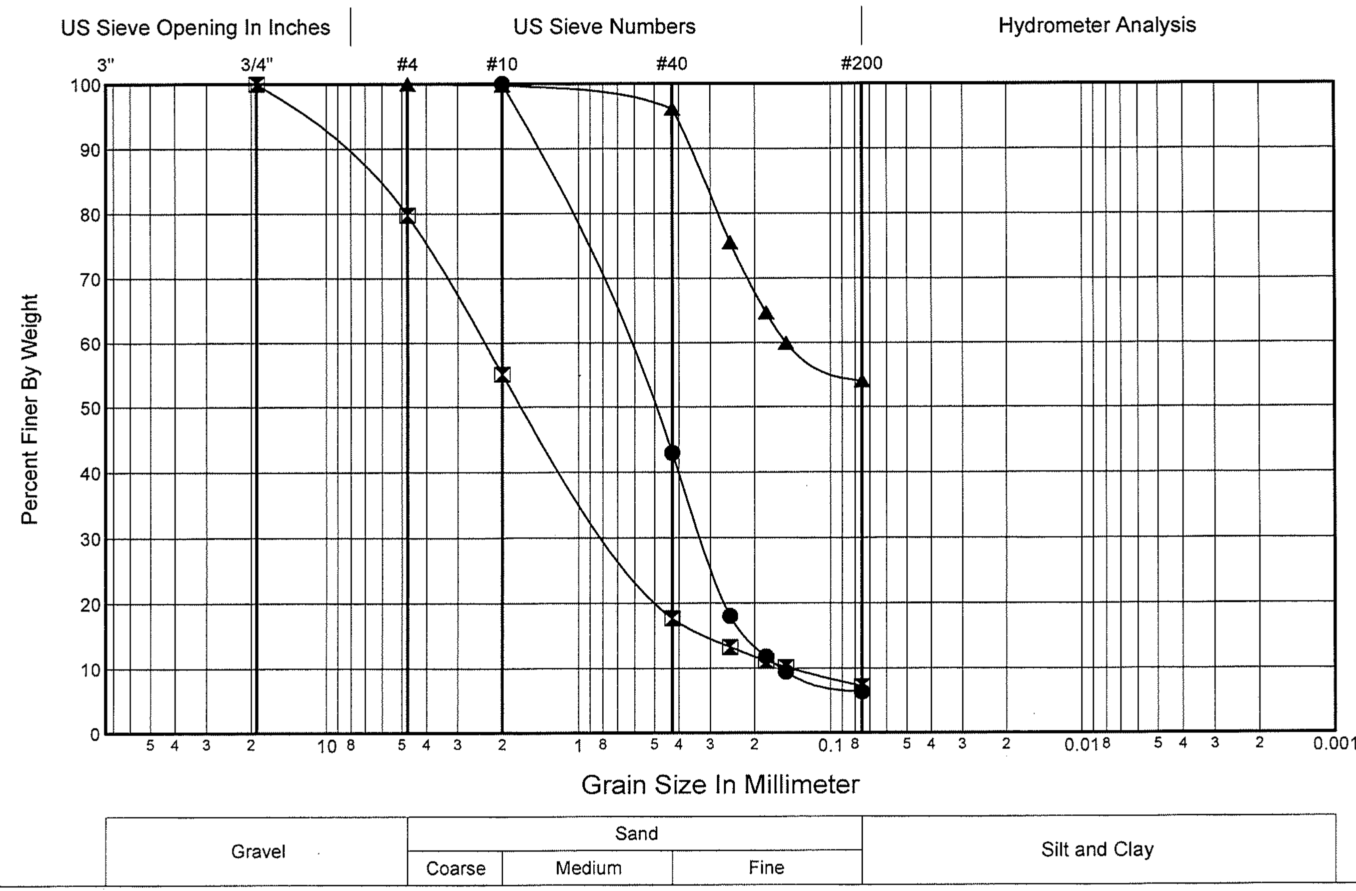
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	10.0	3.05	D-2	SP-SM		POORLY GRADED SAND with SILT	16			
⊠	30.0	9.14	D-6	SW-SM		WELL-GRADED SAND with SILT and GRAVEL	13			
▲	45.0	13.72	D-9	ML		SANDY SILT	23	49	28	21

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.0	93.7	6.3	1.0	4.3
⊠	20.2	72.6	7.1	1.5	16.5
▲	0.0	46.0	54.0		

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.675	0.51	0.32	0.26	0.157
⊠	2.376	1.62	0.71	0.47	0.144
▲	0.150				



Job No. **XL-2201** Date **August 6, 2004**

Hole No. **RR-3-04** Sheet **1** of **1**

Project **NSLAC-BNSF RR Over Crossing Tunnel**

Laboratory Summary

Washington State Department of Transportation

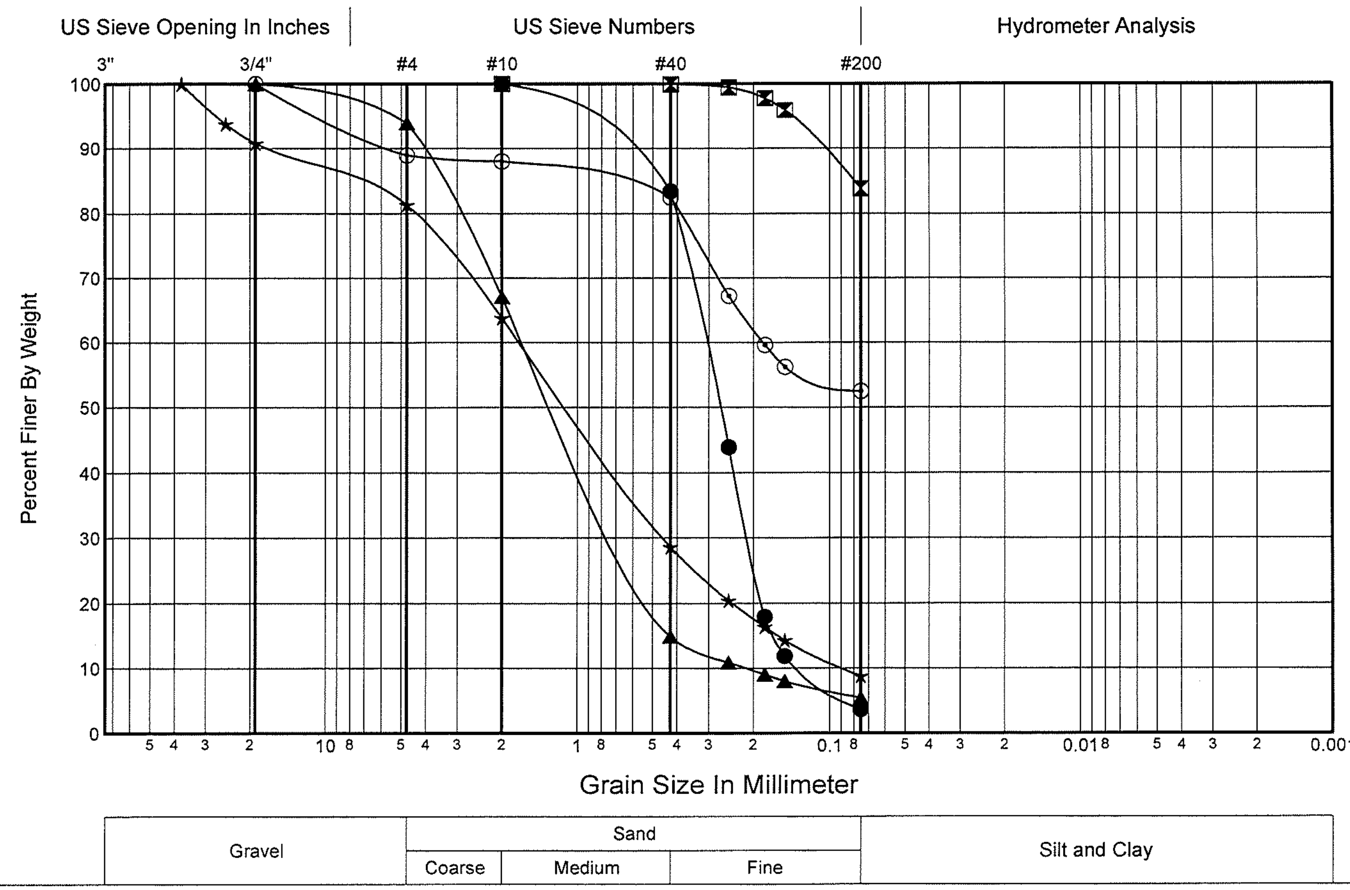
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	14.0	4.27	D-3	SP		POORLY GRADED SAND	20			
⧗	29.0	8.84	D-6	ML		SILT with SAND	50			
▲	44.0	13.41	D-9	SW-SM		WELL-GRADED SAND with SILT	14			
★	69.0	21.03	D-14	SW-SM		WELL-GRADED SAND with SILT and GRAVEL	11			
⊙	80.0	24.38	D-18	CL		SANDY LEAN CLAY	18	34	19	15

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.0	96.4	3.6	1.1	2.4
⧗	0.0	16.2	83.8		
▲	6.1	88.5	5.4	1.3	7.6
★	18.7	72.6	8.8	1.4	19.3
⊙	11.1	36.5	52.4		

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.311	0.27	0.21	0.18	0.129
⧗					
▲	1.625	1.21	0.67	0.50	0.215
★	1.696	1.09	0.45	0.24	0.088
⊙	0.183				



Job No.	XL-2201	Date	August 6, 2004
Hole No.	RR-4-04	Sheet	1 of 1
Project	NSLAC-BNSF RR Over Crossing Tunnel		

Laboratory Summary

Washington State Department of Transportation

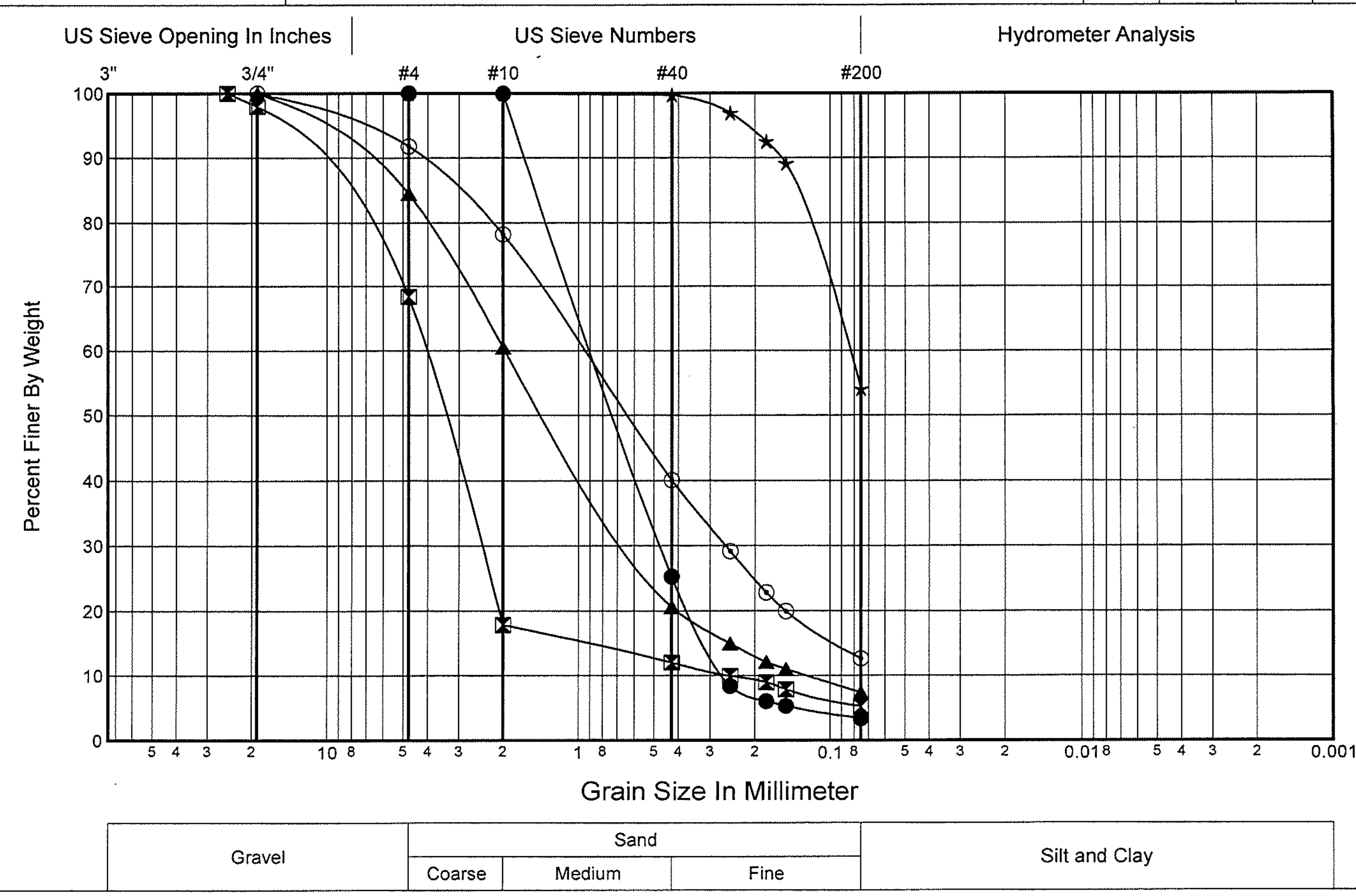
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	**20.0**	**6.10**	**D-4**	**SP**		**POORLY GRADED SAND**	**19**			
⧗	**40.0**	**12.19**	**D-8**	**SP-SM**		**POORLY GRADED SAND with SILT and GRAVEL**	**13**			
▲	**50.0**	**15.24**	**D-10**	**SW-SM**		**WELL-GRADED SAND with SILT and GRAVEL**	**12**			
★	**60.0**	**18.29**	**D-12**	**ML**		**SANDY SILT**	**27**			
⊙	**75.0**	**22.86**	**D-15**	**SM**		**SILTY SAND**	**17**			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	**0.0**	**96.6**	**3.4**	**1.0**	**3.3**
⧗	**31.7**	**63.1**	**5.2**	**5.7**	**16.1**
▲	**15.5**	**77.1**	**7.4**	**1.5**	**15.8**
★	**0.1**	**45.9**	**54.0**		
⊙	**8.2**	**79.1**	**12.6**		

GRADATION VALUES

	D60	D50	D30	D20	D10
●	**0.874**	**0.71**	**0.47**	**0.36**	**0.263**
⧗	**4.119**	**3.47**	**2.46**	**2.07**	**0.256**
▲	**1.965**	**1.33**	**0.61**	**0.40**	**0.124**
★	**0.084**				
⊙	**0.955**	**0.64**	**0.26**	**0.15**	



Job No.	XL-2201	Date	August 6, 2004
Hole No.	RR-5-04	Sheet	1 of 1
Project	NSLAC-BNSF RR Over Crossing Tunnel		

Laboratory Summary

Washington State Department of Transportation

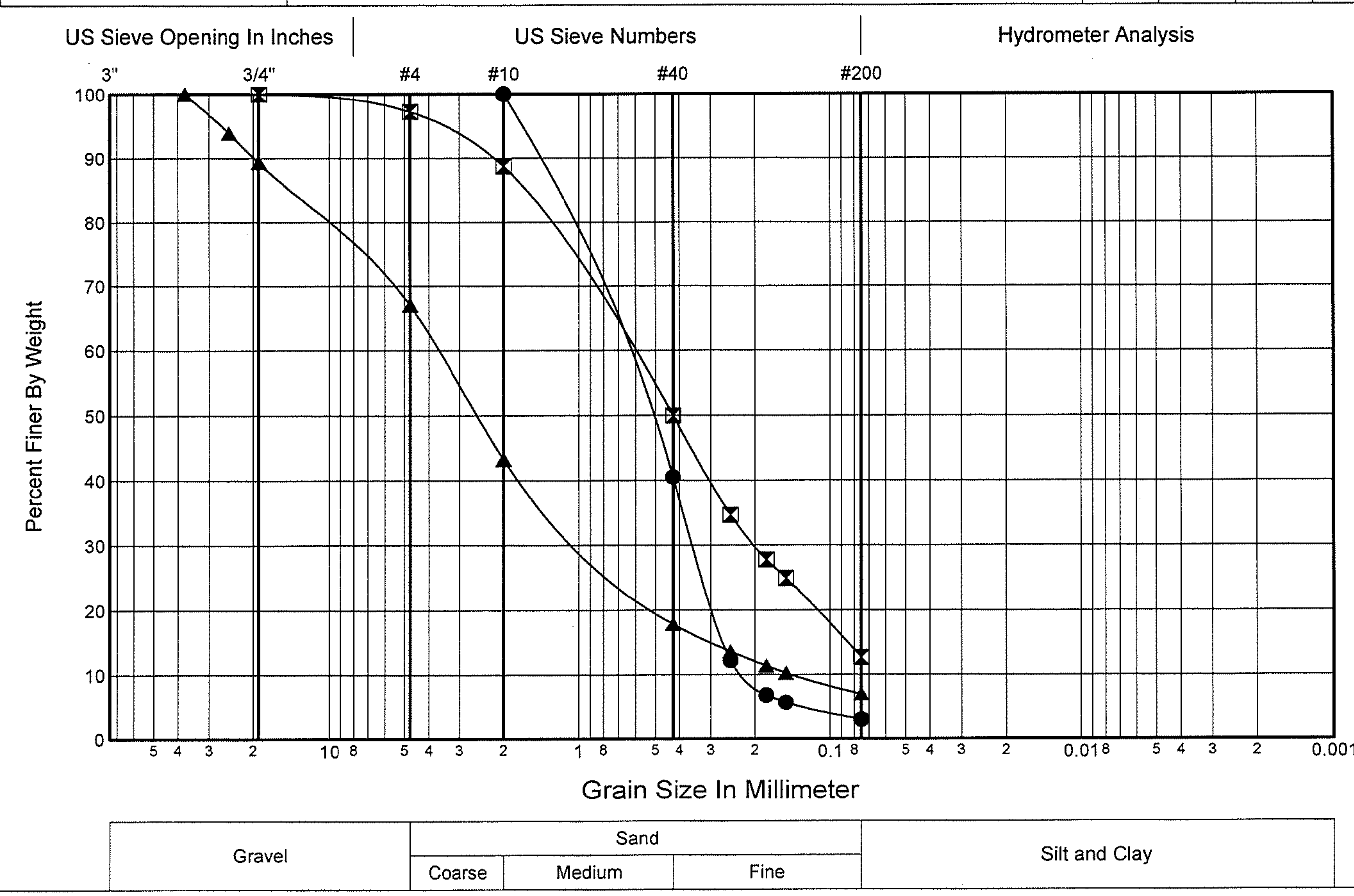
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	19.0	5.79	D-4	SP		POORLY GRADED SAND	18			
⊠	34.0	10.36	D-7	SM		SILTY SAND	19			
▲	49.0	14.94	D-10	SW-SM		WELL-GRADED SAND with SILT and GRAVEL	10			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.0	97.0	3.0	0.8	3.2
⊠	2.8	84.6	12.7		
▲	33.0	60.0	7.0	1.5	25.8

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.706	0.54	0.35	0.29	0.219
⊠	0.635	0.43	0.20	0.11	
▲	3.685	2.56	0.89	0.49	0.143



Job No.	XL-2201	Date	August 6, 2004
Hole No.	RR-6-04	Sheet	1 of 2
Project	NSLAC-BNSF RR Over Crossing Tunnel		

Laboratory Summary

Washington State Department of Transportation

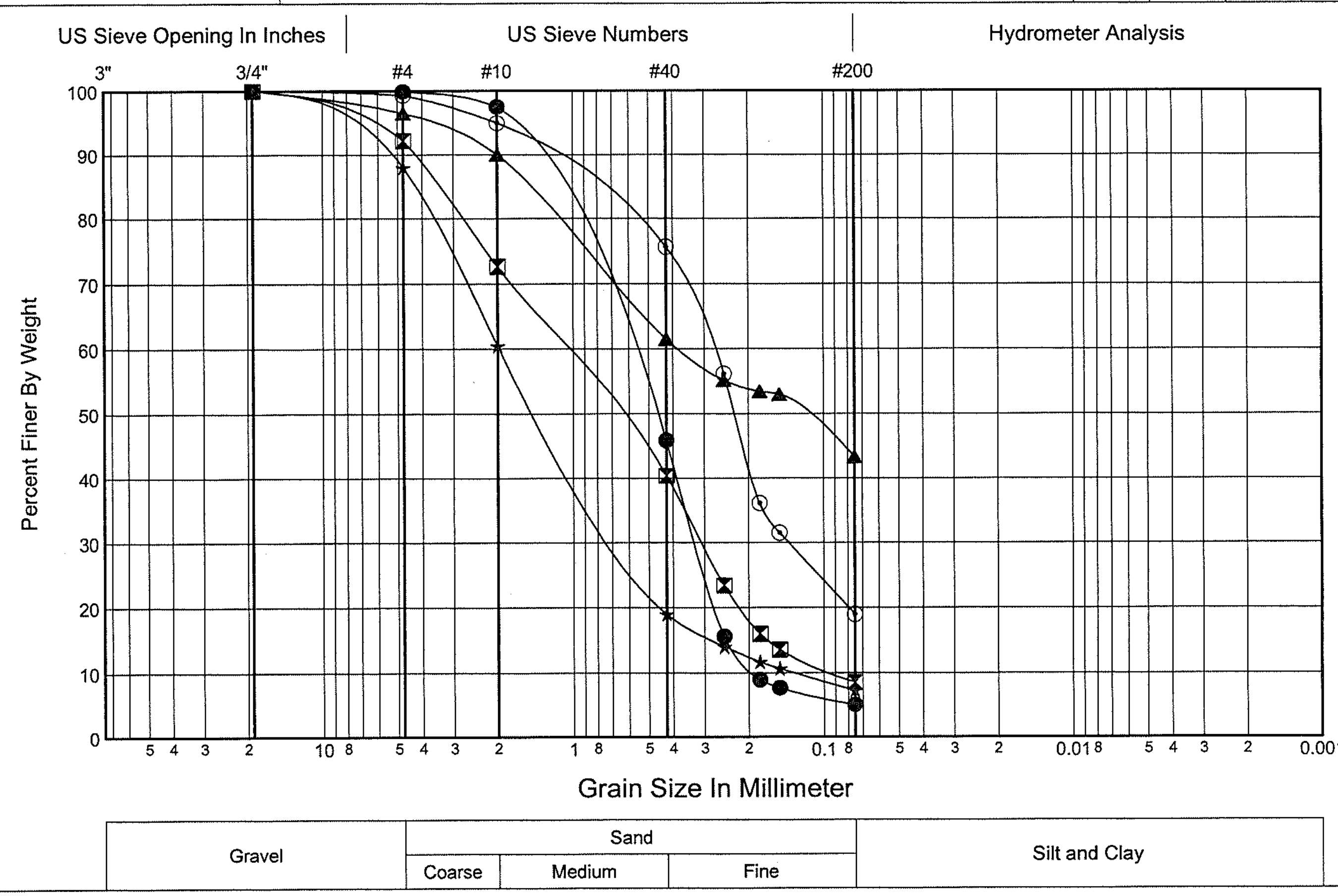
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	14.0	4.27	D-3	SP		POORLY GRADED SAND	10			
⧗	34.0	10.36	D-7	SP-SM		POORLY GRADED SAND with SILT	20			
▲	39.0	11.89	D-8	SM		SILTY SAND	20			
★	49.0	14.94	D-10	SW-SM		WELL-GRADED SAND with SILT	12			
⊙	64.0	19.51	D-13	SM		SILTY SAND	16			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.1	94.9	5.0	0.8	3.4
⧗	7.9	83.6	8.5	0.9	11.9
▲	3.5	53.2	43.3		
★	12.0	80.7	7.3	1.6	15.0
⊙	0.7	80.4	18.9		

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.650	0.48	0.32	0.27	0.190
⧗	1.092	0.68	0.31	0.22	0.092
▲	0.376	0.12			
★	1.970	1.36	0.64	0.44	0.131
⊙	0.278	0.23	0.14	0.08	



Job No. **XL-2201** Date **August 6, 2004**

Hole No. **RR-6-04** Sheet **2** of **2**

Project **NSLAC-BNSF RR Over Crossing Tunnel**

Laboratory Summary

Washington State Department of Transportation

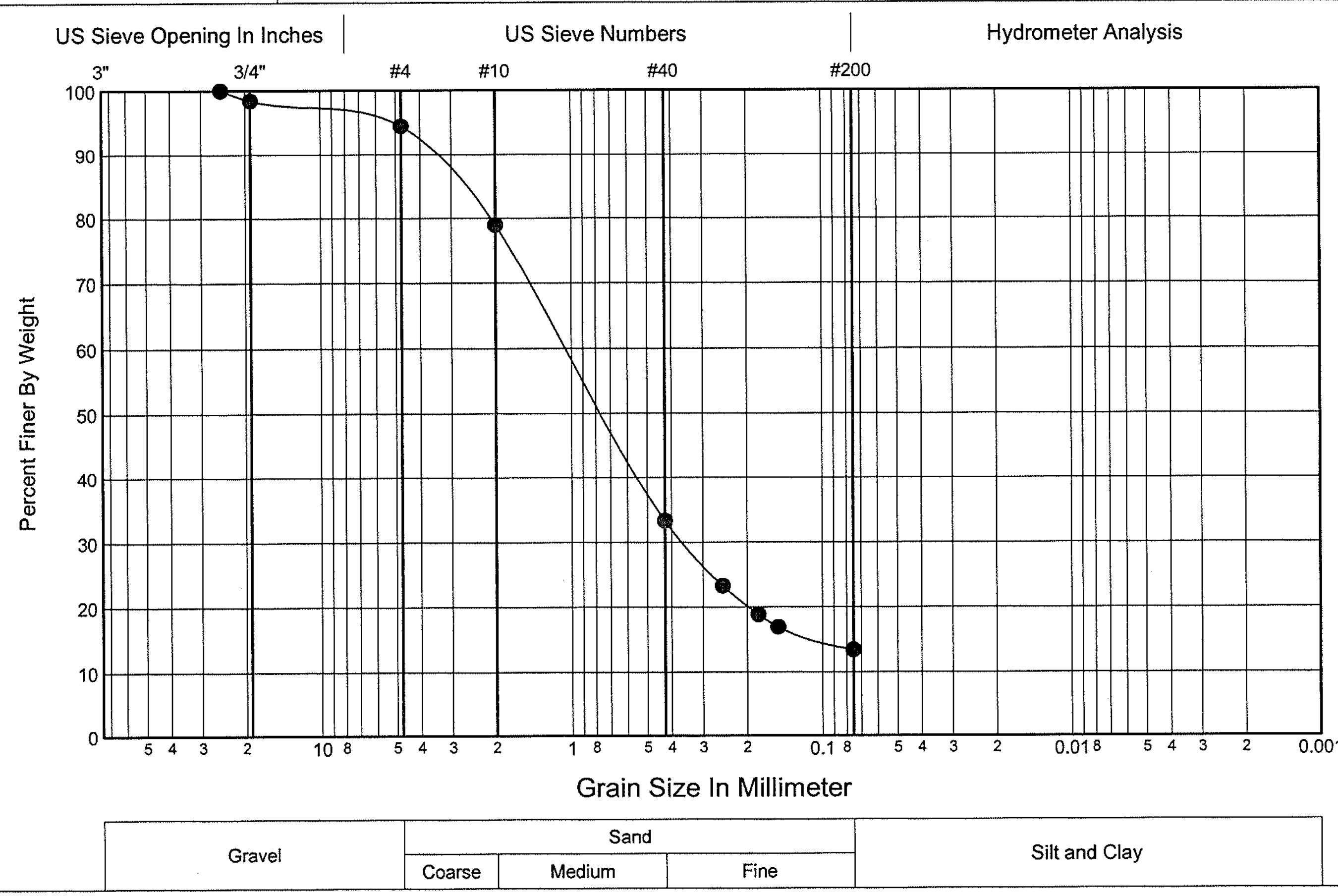
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	**69.0**	**21.03**	**D-14**	**SM**		**SILTY SAND**	**16**			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	**5.6**	**81.1**	**13.3**		

GRADATION VALUES

	D60	D50	D30	D20	D10
●	**1.053**	**0.75**	**0.36**	**0.20**	



Job No.	XL-2201	Date	August 6, 2004			
Hole No.	RR-7-04	Sheet	1	of	1	
Project	NSLAC-BNSF RR Over Crossing Tunnel					

Laboratory Summary

Washington State Department of Transportation

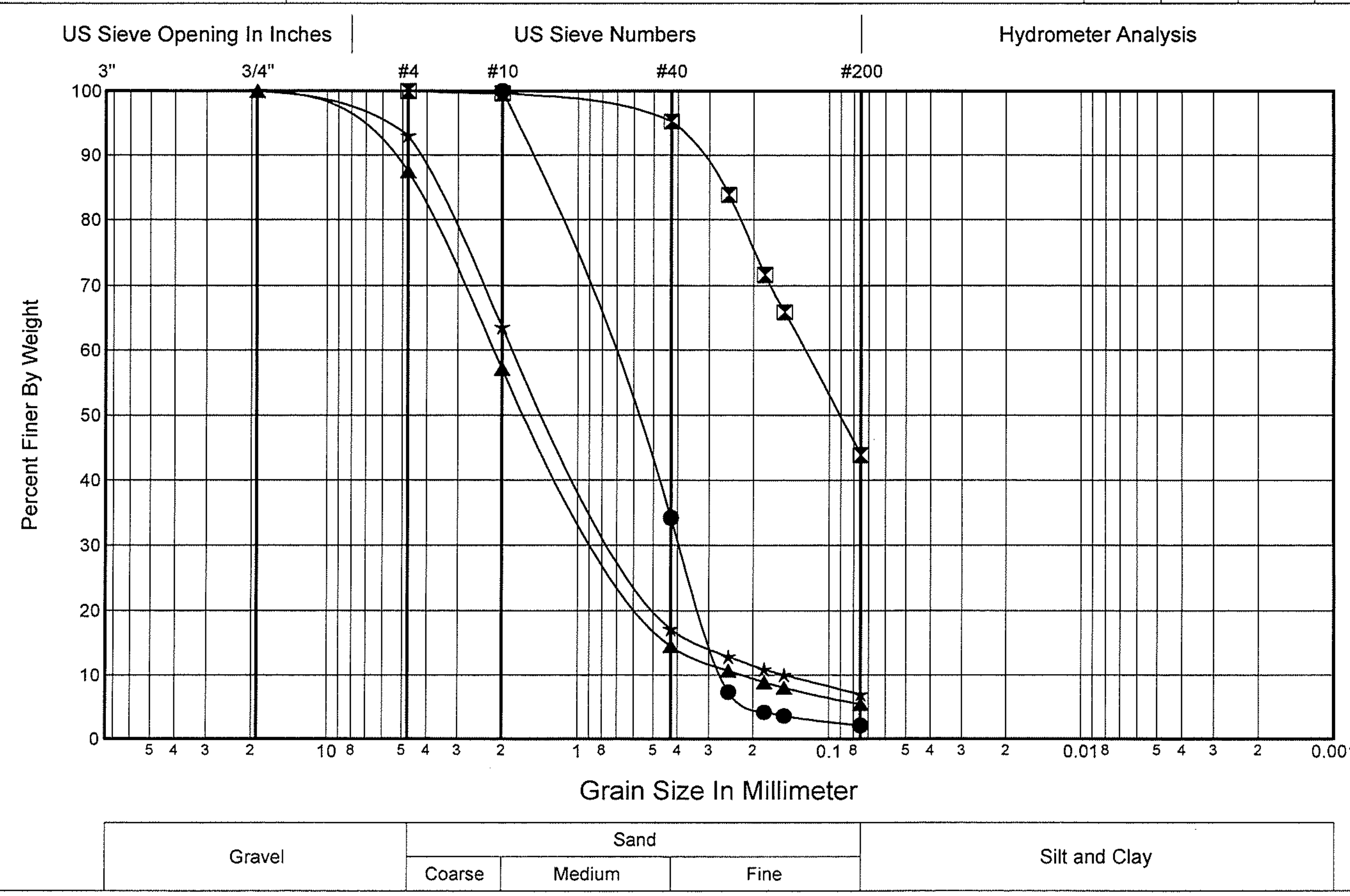
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	14.0	4.27	D-3	SP		POORLY GRADED SAND	21			
⊠	29.0	8.84	D-6	SM		SILTY SAND	21			
▲	39.0	11.89	D-8	SW-SM		WELL-GRADED SAND with SILT	13			
★	49.0	14.94	D-10	SW-SM		WELL-GRADED SAND with SILT	12			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.0	97.9	2.1	0.7	3.0
⊠	0.0	56.2	43.8		
▲	12.6	82.0	5.4	1.2	9.8
★	7.0	86.1	7.0	1.6	11.9

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.780	0.62	0.39	0.32	0.264
⊠	0.125	0.09			
▲	2.172	1.54	0.75	0.52	0.221
★	1.776	1.27	0.65	0.47	0.149



Job No.	XL-2201	Date	August 6, 2004
Hole No.	RR-8-04	Sheet	1 of 1
Project	NSLAC-BNSF RR Over Crossing Tunnel		

Laboratory Summary

Washington State Department of Transportation

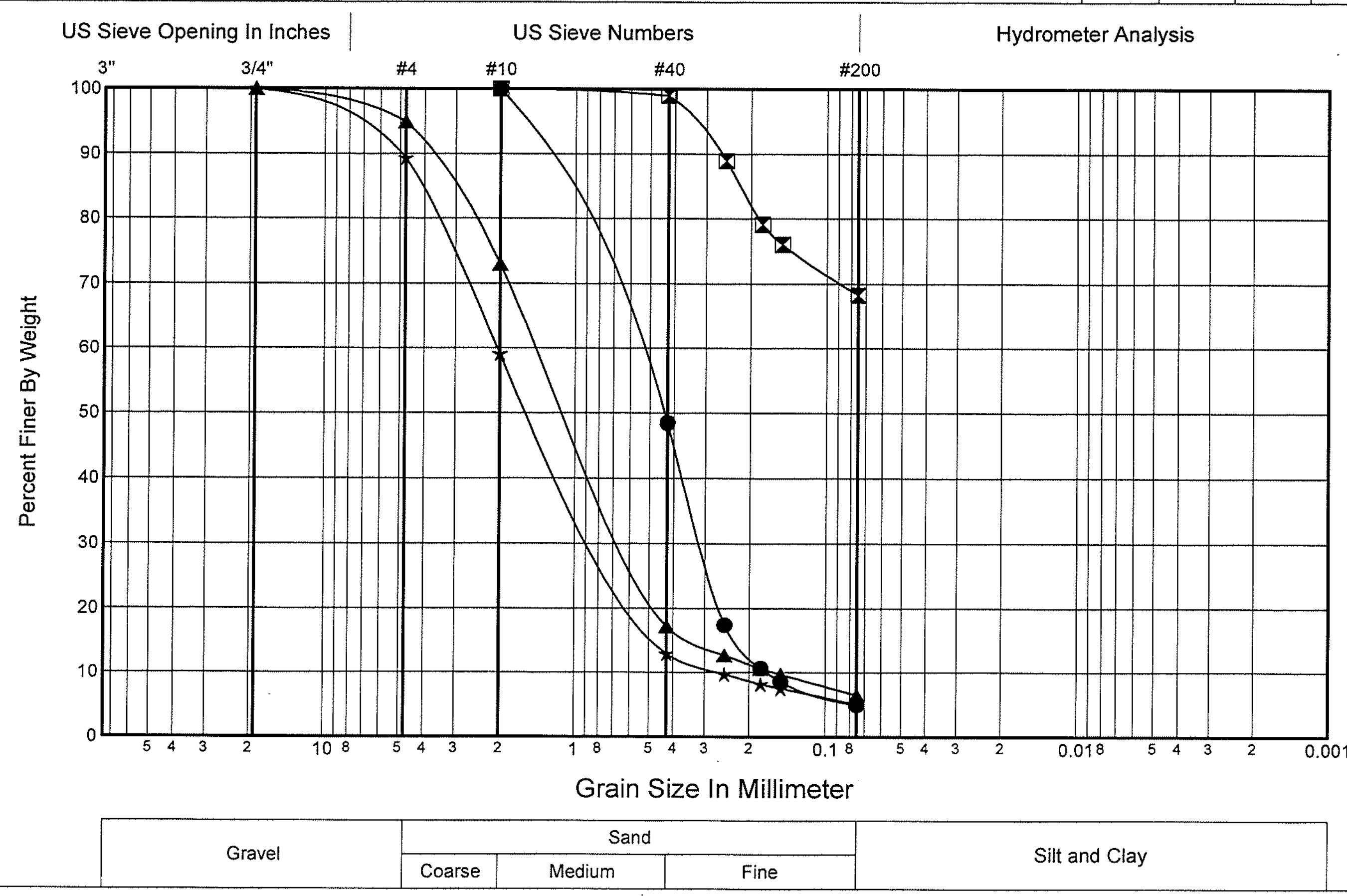
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	9.0	2.74	D-2	SP		POORLY GRADED SAND	16			
⊠	24.0	7.32	D-5	ML		SANDY SILT	45			
▲	39.0	11.89	D-8	SW-SM		WELL-GRADED SAND with SILT	18			
★	44.0	13.41	D-9	SW-SM		WELL-GRADED SAND with SILT	13			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.0	95.1	4.9	0.9	3.5
⊠	0.0	31.7	68.3		
▲	5.1	88.5	6.4	1.6	8.7
★	10.6	84.3	5.0	1.1	7.8

GRADATION VALUES

	D60	D50	D30	D20	D10
●	0.601	0.45	0.31	0.26	0.170
⊠					
▲	1.394	1.06	0.61	0.46	0.160
★	2.053	1.47	0.75	0.54	0.263



APPENDIX B

SUBSURFACE DATA FOR SR522 CAMPUS ACCESS PROJECT

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-15283
HOLE No. H-31-02
Sheet 1 of 3

Job No. XL-2311 | SR 522 | Elevation 27.6 ft

Project SR 522 UWB CCC Campus S. Access.

Driller Harvey | Lic# T2599

Site Address

Inspector Hanning

Start May 22, 2002 | Completion May 23, 2002 | Well ID#

Equipment CME 850 w/ autohammer

Station R-C 612+49 | Offset 17.5ft Lt. | Hole Dia (inches) HQ

Method Wet Rotary

Northing 607316.14 | Easting 1635190.93 | Collected by

Datum

County King | Subsection SE/NE | Section 8 | Range 5 EWM | Township 26 N

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched). Scale: 20, 40, 60, 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
0	27.6	4, 7, 8 (15)	D-1		Silty SAND with gravel and organics throughout, medium dense, olive brown, moist, homogeneous, no HCl reaction Length Recovered 0.5 ft, Length Retained 0.5 ft	
	25.0					
		1, 1, 3 (4)	D-2	GS MC	ML, MC=117% Sandy ORGANIC SILT, very soft, dark brown, moist, stratified, no HCl reaction Length Recovered 1.5 ft, Length Retained 1.5 ft	
5						
	20.0					
			S-3		05/23/2002	▽
10						
		1, 2, 1 (3)	D-4	GS MC	SP-SM, MC=39% Poorly graded SAND with silt and organics, very loose, dark gray, wet, stratified, no HCl reaction Length Recovered 1.5 ft, Length Retained 1.5 ft	
	15.0					
			S-5		Sandy ORGANIC SILT, very soft, dark gray brown, wet, stratified, no HCl reaction Length Recovered 1.5 ft, Length Retained 1.5 ft	
15						
		2, 1, 2 (3)	D-6	GS MC	SP-SM, MC=45% Poorly graded SAND with silt and wood chunks, very loose, dark gray brown, wet, stratified, no HCl reaction Length Recovered 1.5 ft, Length Retained 1.5 ft	
	10.0					
		0, 5	D-7	GS MC	ML, MC=57%, PI=11 SILT with sand, very soft, dark gray, wet, stratified, no	
20						

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-15283

Job No. XL-2311 SR 522 Elevation 27.6 ft

HOLE No. H-31-02

Sheet 2 of 3

Project SR 522 UWB CCC Campus S. Access.

Driller Harvey Lic# T2599

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft) scale: 25, 30, 35, 40, 45; Elevation (ft) scale: 5, 0, -5, -10, -15

Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
12 (17)		AL	HCl reaction. Length Recovered 1.5 ft, Length Retained 1.5 ft
			SM, MC=26% Silty SAND, medium dense, moist to wet, stratified, no HCL reaction. Legth Recovered 1.5 ft, Length Retained 1.5 ft
60/6" (60/6")	D-8	GS MC	SM, MC=11% Silty SAND, very dense, dark greenish gray, moist, stratified, strong HCl reaction Length Recovered 0.5 ft, Length Retained 0.5 ft
17 26 26 (52)	D-9		SILT with sand and some gravel, very dense, dark greenish gray, moist, stratified, no HCl reaction Length Recovered 1.5 ft, Length Retained 1.5 ft
16 32 50 (82)	D-10	GS MC AL	SM, MC=12% Silty SAND, trace gravel, very dense, dark greenish gray, moist, stratified, no HCl reaction Length Recovered 1.5 ft, Length Retained 1.5 ft
28 50/5" (50/5")	D-11		No Recovery Coarse GRAVEL indicated from drilling action.
80/6" (80/6")	D-12		Silty GRAVEL with sand, subrounded, very dense, dark greenish gray, moist, homogeneous, no HCl reaction

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-15283

Job No. XL-2311   SR 522   Elevation 27.6 ft

HOLE No. H-31-02

Sheet 3 of 3

Project SR 522 UWB CCC Campus S. Access.   Driller Harvey   Lic# T2599

Depth (ft)	Elevation (ft)	Profile	Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
								Length Recovered 0.5 ft, Length Retained 0.5 ft		
	-20									
				70/3" (70/3")		D-13		Silty GRAVEL with sand, subrounded, very dense, dark greenish gray, moist, homogeneous, no HCl reaction Length Recovered 0.2 ft, Length Retained 0.2 ft		
50								End of test hole boring at 49.2 ft below ground elevation. Bailed boring after drilling, water level stabilized at a depth of 9 ft. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data.		
	-25									
55										
	-30									
60										
	-35									
65										
	-40									
70										

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-15283

HOLE No. H-32-02

Job No. XL-2311	SR 522	Elevation 26.0 ft		Driller Joe Judd	Lic# 2454
Project SR 522 UWB CCC Campus S. Access.				Inspector Dave Nelson	
Site Address					
Start April 29, 2002	Completion April 30, 2002	Well ID#		Equipment CME 45 w/ auto hammer	
Station R-C 611+52	Offset 17.6ft Lt.	Hole Dia (inches) HQ x 45.0		Method Wet Rotary	
Northing 607254.24	Easting 1635116.91	Collected by		Datum	
County King	Subsection SE-NE	Section 8	Range 5 EWM	Township 26 N	

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
4.0	22.0	2 6 8 (14)	D-1	GS MC AL	MH, MC=46%, PI=23 Elastic SILT, orange mottling, stiff, blue gray, moist, homogeneous, no HCl reaction Length Recovered 1.0 ft	
9.0	17.0		S-2		ORGANIC SILT, dark brown, wet, stratified, no HCl reaction. Length Recovered 1.5 ft	
10.5	15.5	32 31 33 (64)	D-3	GS MC	ML, MC=14% Sandy SILT with gravel, very hard, gray, moist, homogeneous, no HCl reaction Length Recovered 1.0 ft	
14.0	12.0	50/6 (50/6")	D-4	GS MC	SM, MC=10% Silty SAND with gravel, very dense, gray, moist, homogeneous, no HCl reaction Length Recovered 0.5 ft	▽ 05/30/2002
19.0	7.0	50/6 (50/6")	D-5	GS MC	ML, MC=13% Sandy SILT, very dense, gray, moist, homogeneous, no	

Depth scale: 5, 10, 15, 20. Elevation scale: 25.0, 20.0, 15.0, 10.0.

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-15283

Job No. XL-2311 SR 522 Elevation 26.0 ft

HOLE No. H-32-02

Sheet 2 of 3

Project SR 522 UWB CCC Campus S. Access.

Driller Joe Judd Lic# 2454

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
	5				HCl reaction Length Recovered 0.5 ft
25	0	50/6 (50/6")	D-6		SILT with sand and gravel, very dense, gray, moist, homogeneous, no HCl reaction Length Recovered 0.5 ft
30	-5	50/3 (50/3")	D-7		Silty SAND with gravel, very dense, gray, moist, homogeneous, no HCl reaction Length Recovered 0.2 ft
35	-10	50/3 (50/3")	D-8		SILT, very dense, gray, moist, homogeneous, no HCl reaction Length Recovered 0.2 ft
40	-15	50/3 (50/3")	D-9		Silty SAND / Sandy SILT with gravel, very dense, gray, moist, homogeneous, no HCl reaction Length Recovered 0.2 ft
45					

SOILA XL-2311(XL-1542) SR-522 UWB CAMPUS S ACCESS.GPJ SOIL.GDT 6/22/16

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-15283

Job No. XL-2311 SR 522 Elevation 26.0 ft HOLE No. H-32-02

Sheet 3 of 3

Project SR 522 UWB CCC Campus S. Access. Driller Joe Judd Lic# 2454

Depth (ft)	Elevation (ft)	Profile	Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
				50/3 (50/3")		D-10		Silty SAND with gravel, very dense, gray, moist, homogeneous, no HCl reaction Length Recovered 0.2 ft		
	-20							End of test hole boring at 45.2 ft below ground elevation.		
								This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data.		
50	-25									
55	-30									
60	-35									
65	-40									
70										

APPENDIX C

SUBSURFACE DATA FOR SR5/SR432 TALLEY WAY I/C PROJECT

Washington State
Department of Transportation

Test Boring Legend

Sampler Symbols

- Standard Penetration Test
- Oversized Penetration Test (Dames & Moore, California)
- Shelby Tube
- Piston Sample
- Washington Undisturbed
- Vane Shear Test
- Core
- Becker Hammer
- Bag Sample

Well Symbols

- Cement Surface Seal
- Piezometer Pipe in Granular Bentonite Seal
- Piezometer Pipe in Sand
- Well Screen in Sand
- Granular Bentonite Bottom Seal
- Inclinometer Casing in Concrete Bentonite Grout

Laboratory Testing Codes

UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
UC	Unconfined Compression Test
DS	Direct Shear Test
CN	Consolidation Test
GS	Grain Size Distribution
MC	Moisture Content
SG	Specific Gravity
OR	Organic Content
DN	Density
AL	Atterberg Limits
PT	Point Load Compressive Test
SL	Slake Test
DG	Degradation
LA	LA Abrasion
HT	Hydrometer Test

Soil Density Modifiers

Gravel, Sand & Non-plastic Silt		Elastic Silts and Clay	
SPT Blows/ft	Density	SPT Blows/ft	Consistency
0-4	Very Loose	0-1	Very Soft
5-10	Loose	2-4	Soft
11-24	Medium Dense	5-8	Medium Stiff
25-50	Dense	9-15	Stiff
>50	Very Dense	16-30	Very Stiff
(REF)	Refusal	31-60	Hard
		>60	Very Hard

Angularity of Gravel & Cobbles

Angular	Coarse particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Coarse grained particles are similar to angular but have rounded edges.
Subrounded	Coarse grained particles have nearly plane sides but have well rounded corners and edges.
Rounded	Coarse grained particles have smoothly curved sides and no edges.

Soil Moisture Modifiers

Dry	Absence of moisture; dusty, dry to touch
Moist	Damp but no visible water
Wet	Visible free water

Soil Structure

Stratified	Alternating layers of varying material or color at least 6mm thick; note thickness and inclination.
Laminated	Alternating layers of varying material or color less than 6mm thick; note thickness and inclination.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, somtimes striated.
Blocky	Cohesive soil that can be broken down into smaller angular lumps which resist further breakdown.
Disrupted	Soil structure is broken and mixed. Infers that material has moved substantially - landslide debris.
Homogeneous	Same color and appearance throughout.

HCL Reaction

No HCL Reaction	No visible reaction.
Weak HCL Reaction	Some reaction with bubbles forming slowly.
Strong HCL Reaction	Violent reaction with bubbles forming immediately.

Degree of Vesicularity of Pyroclastic Rocks

Slightly Vesicular	5 to 10 percent of total
Moderately Vesicular	10 to 25 percent of total
Highly Vesicular	25 to 50 percent of total
Scoriaceous	Greater than 50 percent of total

Test Boring Legend

Grain Size

Fine Grained	< 1mm	Few crystal boundaries/grains are distinguishable in the field or with hand lens.
Medium Grained	1mm to 5mm	Most crystal boundaries/grains are distinguishable with the aid of a hand lens.
Coarse Grained	> 5mm	Most crystal boundaries/grains are distinguishable with the naked eye.

Weathered State

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discoloration in major discontinuity surfaces.	I
Slightly Weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than its fresh condition.	II
Moderately Weathered	Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as core stones.	III
Highly Weathered	More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as discontinuous framework or as core stone.	IV
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual Soil	All rock material is converted to soil. The mass structure and material fabric is destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Relative Rock Strength

Grade	Description	Field Identification	Uniaxial Compressive Strength approx
R1	Very Weak	Specimen crumbles under sharp blow from point of geological hammer, and can be cut with a pocket knife.	150-3500 psi
R2	Moderately Weak	Shallow cuts or scrapes can be made in a specimen with a pocket knife. Geological hammer point indents deeply with firm blow.	3500-7500 psi
R3	Moderately Strong	Specimen cannot be scraped or cut with a pocket knife, shallow indentation can be made under firm blows from a hammer.	7500-15000 psi
R4	Strong	Specimen breaks with one firm blow from the hammer end of a geological hammer.	15000-30000 psi
R5	Very Strong	Specimen requires many blows of a geological hammer to break intact sample.	Greater than 30000 psi

Discontinuities

Spacing	
Very Widely	Greater than 3 m
Widely	1 m to 3 m
Moderately	0.3 m to 1 m
Closely	50 mm to 300 mm
Very Closely	Less than 50 mm

RQD (%)

$$\frac{100(\text{length of core in pieces} > 100\text{mm})}{\text{Length of core run}}$$

Condition	
Excellent	Very rough surfaces, no separation, hard discontinuity wall
Good	Slightly rough surfaces, separation less than 1 mm, hard discontinuity wall.
Fair	Slightly rough surfaces, separation greater than 1 mm, soft discontinuity wall.
Poor	Slickensided surfaces, or soft gouge less than 5 mm thick, or open discontinuities 1 to 5 mm.
Very Poor	Soft gouge greater than 5 mm thick, or open discontinuities greater than 5 mm.

Fracture Frequency (FF) is the average number of fractures per 300 mm of core.
Does not include mechanical breaks caused by drilling or handling.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-26387

HOLE No. H-10-06

Sheet 1 of 2

Job No. XL-2963 SR 5 Elevation 18.0 ft

Project I-5 / SR-432 Talley Way Interchange

Driller Danny Henderson Lic# 2742 T

Site Address Vic. SR-432 and I-5

Inspector Brian Hilts

Start May 11, 2006 Completion May 11, 2006 Well ID#

Equipment CME 850 w/ autohammer

Station AL 110+46.77 Offset 84.85ft Lt. Hole Dia (inches) 4"ODx42'

Method Wet Rotary

Northing 291252.00 Easting 1035869.00 Collected by

Datum

County Cowlitz Subsection SW-NW Section 12 Range 2 WWM Township 7 N

Depth (ft)	Elevation (ft)	Profile	◆ Field SPT (N) ✚ Moisture Content ▨ RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
								5/11/2006	▽	
	15.0							5/11/2006	▼	
5				2 2 3 (5)		D-1	GS MC	SM, M.C. =29% Silty SAND with trace of brown organics, loose, very dark gray, wet, stratified, HCl reaction not tested. Length Recovered 0.8 ft, Length Retained 0.8 ft		
10	10.0			3 5 5 (10)		D-2		Silty SAND with gravel, loose, dark greenish gray, moist, stratified, HCl reaction not tested. Length Recovered 0.8 ft, Length Retained 0.8 ft *Note: The bottom .1 ft was brown in color, with some dark brown organics and hair roots throughout.*		
15	5.0			0 0 1 (1)		D-3	MC	M.C. = 68% SILT, very loose, dark greenish gray, moist, stratified, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.5 ft *Note: From 14.9' to 15' was silty sand, with trace wood debris. A moisture can was obtained at the sample depth.*		
						S-4		SILT, loose, dark greenish gray, moist, homogeneous, HCl reaction not tested. Length Recovered 2.0 ft, Length Retained 2.0 ft		
20	0.0			1 1		D-5	GS MC	ML, M.C. = 45%, PI = NA Sandy SILT with a trace of dark brown organics, very		

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-26387

HOLE No. H-10-06

Sheet 2 of 2

Job No. XL-2963 SR 5 Elevation 18.0 ft

Project I-5 / SR-432 Talley Way Interchange

Driller Danny Henderson Lic# 2742 T

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched) — scale 20, 40, 60, 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		2 (3)		AL	loose, very dark gray, moist, homogeneous, HCl reaction not tested. Length Recovered 1.2 ft, Length Retained 1.2 ft
25	-5	2 1 1 (2)	D-6	MC	M.C. = 43% SILT with sand, very loose, dark gray, wet, stratified, HCl reaction not tested. Length Recovered 1.2 ft, Length Retained 1.2 ft
30	-10	7 7 7 (14)	D-7	GS MC	SW-SM, M.C. = 27% Well graded SAND with silt and a trace of black and brown organics, medium dense, dark gray, wet, stratified, HCl reaction not tested. Length Recovered 1.1 ft, Length Retained 1.1 ft
35	-15	1 1 2 (3)	D-8	GS MC AL	ML, M.C. = 43%, PI = NA SILT with sand, very loose, dark gray, wet, homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.5 ft *Note: A moisture can was obtained at the sample depth.*
40	-20	0 1 1 (2)	D-9	MC	M.C. = 75% Elastic SILT with sand, soft, very dark gray, moist, homogeneous, HCl reaction not tested. Length Recovered 1.5 ft, Length Retained 1.5 ft *Note: A moisture can was obtained at the sample depth.*
45	-25				

End of test hole boring at 40.5 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data.

Note: The water table after drilling was measured at 1 ft. After removing the casing, the hole stayed open to 25 ft, and the water table was measured at 3 ft.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32519

HOLE No. H-23-08

Sheet 1 of 8

Job No. XL-2963 SR 5 Elevation 24.6 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Site Address Vic SR432 and I-5

Inspector Brian Hilts

Start April 7, 2008 Completion April 7, 2008 Well ID#

Equipment CME 850 with Autohammer

Station AL 114+86.90 Offset 120.51ft Lt. Hole Dia (inches) 6

Method Wet Rotary

Northing 291359.11 Easting 1036297.46 Collected by HQ Geotech Division

Datum State Plane South

County Cowlitz Subsection SE1/4 of NW1/4 Section 12 Range 2WWM Township 7

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched). Scale: 20, 40, 60, 80

Depth (ft)	Elevation (ft)	Profile	Field SPT (N)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
5	20.0			4 3 2 (5)		D-1	GS MC	GP-GM, MC=25% Poorly graded GRAVEL with silt and sand, angular, loose, brown, wet, homogenous, HCl not tested. Length Recovered:0.5 ft. Length Retained:0.5 ft.		
10	15.0			4 3 3 (6)		D-2		GP-GM, MC=25% Poorly graded GRAVEL with silt and sand, angular, loose, black, wet, homogenous, HCl not tested. Length Recovered:0.6 ft. Length Retained:0.6 ft. *Note: Fines washed out. At 9 ft we lost 100% water return during drilling.*		
15	10.0			14 9 14 (23)		D-3		GP-GM, MC=25% Poorly graded GRAVEL with silt and sand, angular, medium dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: At 17 ft the soil became less dense demonstrated by drilling.*		
20	5.0			0 1		D-4		SILT with sand, very loose, dark gray, wet, stratified, HCl not tested.		

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32519

Job No. XL-2963 SR 5 Elevation 24.6 ft

HOLE No. H-23-08

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N) ✚ Moisture Content ▨ RQD (scale 20, 40, 60, 80)

Depth (ft) scale: 25, 30, 35, 40, 45. Elevation (ft) scale: 0, -5, -10, -15, -20.

Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
1 (2)			Length Recovered:1.4 ft. Length Retained:1.4 ft. *Note: The top 0.6 ft consisted of silt with brown organics and hair roots, and the bottom 0.8 ft consisted of silt with sand.*
	S-5		SILT, dark gray, homogenous.
0 0 1 (1)	D-6	GS MC AL	ML, MC=69%, LL=42 SILT with a trace of organics and hair roots, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.2 ft. Length Retained:1.2 ft.
	S-7		No Recovery
1 2 1 (3)	D-8		Sandy SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.5 ft. Length Retained:0.5 ft.
0 0 0 (0)	D-9	GS MC AL	ML, MC=46%, LL=38 SILT with sandy silt lenses and some organics, very loose, dark gray, wet, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: At 34 ft we got our water return back.*
2 1 2 (3)	D-10		Sandy SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:0.5 ft. Length Retained:0.5 ft.
0 0	D-11	GS MC	ML, MC=52%, LL=35 SILT, very loose, dark gray, wet, homogenous, HCl not

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32519

Job No. XL-2963 SR 5 Elevation 24.6 ft

HOLE No. H-23-08

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		0 (0)		AL	tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
50	-25		S-12		No Recovery
			S-13		Sandy SILT, dark gray, stratified.
		0 1 2 (3)	D-14		SILT with sand, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.2 ft. Length Retained:1.2 ft.
55	-30				
60	-35	0 0 0 (0)	D-15		SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
65	-40		S-16	GS MC AL CN	ML, MC=45%, LL=37 SILT, dark gray, homogenous.
		0 0 0 (0)	D-17	GS MC AL	ML, MC=58%, LL=38 SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
70	-45	0 0	D-18		SILT with sand, very loose, dark gray, moist, homogenous, HCl not tested.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32519
HOLE No. H-23-08

Job No. XL-2963 SR 5 Elevation 24.6 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Field SPT (N) / Moisture Content / RQD — scale 20, 40, 60, 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		1 (1)			Length Recovered:0.5 ft. Length Retained:0.5 ft.
			S-19		SILT with sand, dark gray, homogenous.
75	-50				
		0 0 0 (0)	D-20		SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
		0 0 0 (0)	D-21		SILT with a 0.1 ft think lense of sandy silt, very loose, dark gray, moist, stratified, HCl not tested. Length Recovered:0.7 ft. Length Retained:0.7 ft.
80	-55				
			S-22		No Recovery
85	-60				
		1 2 3 (5)	D-23	GS MC AL	ML, MC=40%, PI=NA SILT, loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.2 ft. Length Retained:1.2 ft.
		2 4 5 (9)	D-24		SILT with sand, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.5 ft. Length Retained:0.5 ft.
90	-65				
			S-25		SILT with sand, dark gray, homogenous.
95	-70				

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32519

HOLE No. H-23-08

Job No. XL-2963 SR 5 Elevation 24.6 ft

Sheet 5 of 8

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft): 100, 105, 110, 115, 120
Elevation (ft): -75, -80, -85, -90, -95

Sample No. (Tube No.)	Blows/6" (N) and/or RQD FF	Lab Tests	Description of Material
D-26	2 2 1 (3)	GS MC AL	ML, MC=33%, PI=NA SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
D-27	0 3 2 (5)		SILT with sand and some wood debris, loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.2 ft. Length Retained:1.2 ft.
D-28	0 3 3 (6)		SILT with sand, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.4 ft. Length Retained:0.4 ft.
S-29			SILT with sand, dark gray, homogenous. *Note: The bottom of the shelby had wood debris.*
D-30	3 3 3 (6)	GS MC AL	ML, MC=33%, LL=31 SILT with sand, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: The bottom 0.4 ft had grayish brown chunks of siltstone.*
D-31	1 3 3 (6)		SILT with sand and a trace organics, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
S-32			SILT, dark gray, homogenous.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32519

HOLE No. H-23-08

Sheet 6 of 8

Job No. XL-2963 | SR 5 | Elevation 24.6 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert | Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft): 125, 130, 135, 140, 145
Elevation (ft): -100, -105, -110, -115, -120

Sample No. (Tube No.)	Blows/6" (N) and/or RQD FF	Lab Tests	Description of Material
D-33	0 2 2 (4)		SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
D-34	1 3 3 (6)		Sandy SILT, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
S-35			SILT with sand, dark gray, homogenous.
D-36	1 2 3 (5)	GS MC AL	ML, MC=50%, LL=38 SILT with sand and some organics, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
D-37	0 0 0 (0)		SILT with sand with organics, very loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: No blow count was obtained, the chain wrench broke and we dropped 120 ft of sample rods with 20 ft of free fall to obtain a sample.*
D-38	0 0 2 (2)		SILT with sand and some organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
S-39			SILT with sand, dark gray, homogenous.

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LOG OF TEST BORING

Start Card S-32519

HOLE No. H-23-08

Job No. XL-2963 SR 5 Elevation 24.6 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		6 7 6 (13)	D-40	GS MC AL	CL, MC=32%, PI=16 Lean CLAY with sand and some organics, medium dense, dark greenish gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-125	6 12 18 (30)	D-41		No Recovery
150					
	-130	5 10 20 (30)	D-42	GS MC AL	SM, MC=34%, PI=NA Silty SAND, dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.3 ft. Length Retained:1.3 ft.
155					
	-135	6 15 13 (28)	D-43	GS MC	SM, MC=28% Silty SAND, dense, dark gray, wet, stratified, HCl not tested. Length Recovered:0.9 ft. Length Retained:0.9 ft.
160					
	-140	>> 50/3" (REF)	D-44		Silty SAND, very dense, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.3 ft. Length Retained:0.3 ft. *Note: At 161 ft the soil became more dense demonstrated by drilling.*
165					
	-145	>> 50/3" (REF)	D-45		SANDSTONE, very dense, dark gray, moist, homogenous, HCl not tested.
170					

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Department of Transportation

LOG OF TEST BORING

Start Card S-32519

HOLE No. H-23-08

Job No. XL-2963 SR 5 Elevation 24.6 ft

Sheet 8 of 8

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Depth (ft)	Elevation (ft)	Profile	Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
						C-46		Length Recovered:0.3 ft. Length Retained:0.3 ft. SANDSTONE CONGLOMERATE with interbedded siltstone, medium grained, fresh, moderately weak rock, Discontinuities are very widely spaced and in good condition. Recovered:100% RQD:100 FF:0.		
175	-150					C-47		SANDSTONE CONGLOMERATE with interbedded siltstone, medium grained, fresh, moderately weak rock, Discontinuities are very widely spaced and in good condition. Recovered:100% RQD:100 FF:0.		
180	-155							The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Division and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew. End of test hole boring at 180 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Note: REF = SPT Refusal		
185	-160									
190	-165									
195	-170									

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LOG OF TEST BORING

Start Card S-32703
HOLE No. H-24-08
Sheet 1 of 7

Job No. XL-2963 SR 5 Elevation 15.0 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Site Address Vic SR432 and I-5

Inspector Brian Hilts

Start May 5, 2008 Completion May 7, 2008 Well ID#

Equipment CME 850 with Autohammer

Station AL 113+55.10 Offset 115.25ft Lt. Hole Dia (Inches) 6

Method Wet Rotary

Northing 291325.88 Easting 1036167.74 Collected by HQ Geotech Division

Datum State Plane South

County Cowlitz Subsection SE1/4 of NW1/4 Section 12 Range 2WWM Township 7

Depth (ft)	Elevation (ft)	Profile	◆ Field SPT (N) / ✚ Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
				4 2 2 (4)		D-1	GS MC	ML, MC=36% Sandy SILT, very loose, dark gray, wet, stratified, HCl not tested. Length Recovered:0.9 ft. Length Retained:0.9 ft. *Note: The bottom 0.4 ft of sample was sandy silt with some hair roots.*		
5	10.0									
				1 1 1 (2)		D-2	GS MC AL	ML, MC=74%, LL=48 SILT with sand, very loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: The top 0.4 ft of sample was silty sand, and the bottom 1.1 ft was silt with some wood debris and hair roots throughout.*		
10	5.0									
						S-3		SILT, dark gray, homogenous.		
15	0.0									
				1 1 1 (2)		D-4		SILT with some brown organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.2 ft. Length Retained:1.2 ft.		
				2 4		D-5	GS MC	ML, MC=41% Sandy SILT, loose, dark gray, moist, homogenous, HCl		
20										

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32703

HOLE No. H-24-08

Sheet 2 of 7

Job No. XL-2963 SR 5 Elevation 15.0 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched) — scale 20 40 60 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		3 (7)			not tested. Length Recovered:1.1 ft. Length Retained:1.1 ft.
25	-10	0 0 1 1 (1)	D-6		SILT with some brown and black organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
30	-15	3 7 7 (14)	D-7	GS MC	SP-SM, MC=27% Poorly graded SAND with silt, medium dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
35	-20	0 1 1 (2)	D-8		SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
40	-25	0 0 1 (1)	D-9	GS MC	ML, MC=46% SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
45		0 0	D-10		SILT, very loose, dark gray, moist, homogenous, HCl not tested.

SOILA XL-2963 I-5_SR432 TALLEY WAY I_C WITH CONE.GPJ SOIL.GDT 8/13/09

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32703

Job No. XL-2963 SR 5 Elevation 15.0 ft

HOLE No. H-24-08

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		1 (1)			Length Recovered:1.5 ft. Length Retained:1.5 ft.
50	-35	0 0 1 (1)	D-11		SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
			S-12		SILT, dark gray, homogenous.
55	-40	4 3 2 (5)	D-13		SILT, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.3 ft. Length Retained:1.3 ft.
60	-45	0 0 1 (1)	D-14		SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.6 ft. Length Retained:0.6 ft.
65	-50	0 1 1 (2)	D-15		SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
70		0 0	D-16	GS MC	ML, MC=47%, PI=7 SILT, very loose, dark gray, moist, homogenous, HCl not

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LOG OF TEST BORING

Start Card S-32703

HOLE No. H-24-08

Job No. XL-2963 SR 5 Elevation 15.0 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		0 (0)		AL	tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
75	-60	2 2 3 (5)	D-17		SILT, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
80	-65	0 4 3 (7)	D-18		SILT with sand, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.2 ft. Length Retained:1.2 ft.
85	-70	4 8 8 (16)	D-19		Poorly graded SAND, medium dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.
90	-75	8 10 12 (22)	D-20	GS MC	SP-SM MC=24% Poorly graded SAND with silt, medium dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:0.9 ft. Length Retained:0.9 ft.
95		0 3	D-21		SILT with some wood debris, loose, dark gray, moist, homogenous, HCl not tested.

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LOG OF TEST BORING

Start Card S-32703

HOLE No. H-24-08

Sheet 5 of 7

Job No. XL-2963 SR 5 Elevation 15.0 ft

Project I-5/SR 432 Talley Way Interchange Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		2 (5)			Length Recovered:1.3 ft. Length Retained:1.3 ft.
			S-22		SILT, dark gray, homogenous.
100	-85				
		0 3 2 (5)	D-23	GS MC AL	ML, MC=38%, LL=33 SILT with some brown organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
105	-90				
		1 2 2 (4)	D-24		SILT with some brown organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
110	-95				
		0 0 0 (0)	D-25		SILT with a trace of brown organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
115	-100				
		0 0	D-26		SILT with a trace of seashells and brown organics, very loose, dark gray, moist, homogenous, HCl not tested.
120					

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LOG OF TEST BORING

Start Card S-32703

HOLE No. H-24-08

Job No. XL-2963 SR 5 Elevation 15.0 ft

Sheet 6 of 7

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		1 (1)			Length Recovered:1.5 ft. Length Retained:1.5 ft.
125	-110	0, 3, 4 (7)	D-27		SILT with some brown organics, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
130	-115	0, 1, 2 (3)	D-28		SILT with some brown organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
135	-120	0, 2, 3 (5)	D-29		SILT with sand and some brown organics, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.
140	-125	1, 4, 4 (8)	D-30	GS MC AL	ML, MC=45%, LL=37 SILT with sand and some organics, loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. <I>Note: The bottom 0.3 ft ofthe sample was dark greenish gray silt with fine sand, at 140.2 ft a soil change was observed.
145		4, 8	D-31		Silty SAND, medium dense, dark greenish gray, wet, stratified, HCl not tested.

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LOG OF TEST BORING

Start Card S-32703

HOLE No. H-24-08

Job No. XL-2963 SR 5 Elevation 15.0 ft

Sheet 7 of 7

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N) ✚ Moisture Content ▨ RQD (scale 20 40 60 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		15 (23)			Length Recovered:1.1 ft. Length Retained:1.1 ft. *Note: A 0.1 ft piece of sandstone was observed.*
150	-135	8 18 20 (38)	D-32	GS MC	SM, MC=31% Silty SAND, dense, dark greenish gray, moist, stratified, HCl not tested,. Length Recovered:1.3 ft. Length Retained:1.3 ft. *Note: The top 0.2 ft of sample was sandy silt, the middle 0.7 ft of sample was silty sand stratified with (SP) sand, and the bottom 0.4 ft of sample was weathered sandstone with FeO stains throughout. At 153.5 ft the soil became denser demonstrated by drilling.*
155	-140	50/1" (REF)	D-33 C-34		SANDSTONE, very dense, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.1 ft. Length Retained:0.1 ft. SANDSTONE/SILTSTONE, fine grained, fresh, moderately weak rock, Discontinuities are very closely spaced and in fair condition. Recovered:97% RQD:31 FF:3
160	-145		C-35		SANDSTONE , medium grained, fresh, moderately weak rock, Discontinuities are closely spaced and in fair condition. Recovered:100% RQD:52 FF:3. *Note: The sample was stratified with some siltstone, the top 1 ft was fractured.*
165	-150				The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Division and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew. End of test hole boring at 165 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Note: REF = SPT Refusal
170					

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32519

HOLE No. H-28-08

Sheet 1 of 5

Job No. XL-2963 SR 5 Elevation 24.5 ft

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Site Address Vic SR432 and I-5

Inspector Cleo Andrews

Start March 31, 2008 Completion March 31, 2008 Well ID#

Equipment CME 55 with Autohammer

Station AL 110+72.76 Offset 52.34ft Lt. Hole Dia (inches) 4

Method Wet Rotary

Northing 291202.58 Easting 1035896.31 Collected by HQ Geotech Division

Datum State Plane South

County Cowlitz Subsection SE1/4 of NW1/4 Section 12 Range 2WWM Township 7

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
0	24.5					*Note: Silty SAND with gravel as indicated by drilling and wash returns, brown.*		
5	20.0	6 7 8 (15)		D-1		Silty SAND with gravel, medium dense, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.		
10	15.0	5 6 6 (12)		D-2	GS MC	SM, MC=27% Silty SAND with gravel, medium dense, brown, moist, homogenous, HCl not tested. Length Recovered:0.7 ft. Length Retained:0.7 ft. *Note: Bottom 0.25 ft of sample was light gray. Approximately 60-70% of drilling fluid was lost starting at 6.0 ft.*		
15	10.0	3 8 10 (18)		D-3		Silty SAND with gravel, medium dense, dark gray with FeO stains, moist, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft. *Note: The bottom 0.3 ft of sample was brown in color.*		
20	5.0	3 2		D-4	GS MC	SM, MC=26% Silty SAND with gravel, loose, dark gray, wet,		

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32519

HOLE No. H-28-08

Job No. XL-2963 SR 5 Elevation 24.5 ft

Sheet 2 of 5

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		3 (5)			homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.
25	0	2 2 1 (3)	D-5	GS MC AL	ML, MC=31%, PI=NA Sandy SILT with silt lenses and trace organics, very loose, dark gray, moist, laminated, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
30	-5	0 1 3 (4)	D-6	GS MC AL	ML, MC=60%, PI=7 SILT with organic lenses and root hairs, very loose, dark gray mottled with dark brown and green, moist, laminated, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
35	-10	0 1 3 (4)	D-7		Sandy SILT with organic lenses, very loose, dark brown, moist, laminated, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.
40	-15	4 6 7 (13)	D-8	GS MC	SM, MC=31% Silty SAND with wood debris and possible volcanic ash, medium dense, gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
45	-20	1 1	D-9		Sandy SILT with organics and wood debris, very loose, dark gray, moist, stratified, HCl not tested.

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LOG OF TEST BORING

Start Card S-32519

HOLE No. H-28-08

Sheet 3 of 5

Job No. XL-2963 SR 5 Elevation 24.5 ft

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		1 (2)			Length Recovered:1.5 ft. Length Retained:1.5 ft.
50	-25	1 2 1 (3)	D-10		Sandy SILT with traces of organic material, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
55	-30	0 1 1 (2)	D-11	GS MC AL	ML, MC=51%, LL=37 SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
60	-35	0 1 1 (2)	D-12		SILT with one organic lense (brown in color), very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
65	-40	5 8 4 (12)	D-13		Silty SAND, medium dense, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.6 ft. Length Retained:0.6 ft.
70	-45	7 9	D-14		Poorly graded SAND, medium dense, darh gray, wet, homogenous, HCl not tested.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32519

HOLE No. H-28-08

Job No. XL-2963 SR 5 Elevation 24.5 ft

Sheet 4 of 5

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material
		10 (19)				Length Recovered:1 ft. Length Retained:1 ft.
75	-50					
80	-55					
85	-60	7, 9, 12 (21)		D-15	GS, MC	SP-SM, MC=26% Poorly graded SAND with silt, medium dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.
90	-65					
95	-70	9, 11		D-16		Poorly graded SAND, dense, dark gray, wet, homogenous, HCl not tested.

Legend: Field SPT (N); Moisture Content; RQD (scale 20, 40, 60, 80)

Columns also include: Profile, Groundwater, Instrument

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32519

Job No. XL-2963 SR 5 Elevation 24.5 ft

HOLE No. H-28-08

Sheet 5 of 5

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Depth (ft)	Elevation (ft)	Profile	Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
				14 (25)				Length Recovered:1.5 ft. Length Retained:1.5 ft.		
100	-75									
	-80		◆ (22)	7 11 11 (22)		D-17		Poorly graded SAND, medium dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.		
105										
110	-85							The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Division and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew.)		
115	-90							End of test hole boring at 105.5 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Note: REF = SPT Refusal		
120	-95									

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-38-08

Sheet 1 of 7

Job No. XL-2963 SR 5 Elevation 21.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Site Address Vic SR432 and I-5

Inspector Brian Hilts

Start April 1, 2008 Completion April 3, 2008 Well ID#

Equipment CME 55 with Autohammer

Station AL 115+36.54 Offset 260.37ft Rt. Hole Dia (inches) 6

Method Wet Rotary

Northing 2921005.27 Easting 1036401.82 Collected by HQ Geotech Division

Datum State Plane South

County Cowlitz Subsection SE1/4 of NW1/4 Section 12 Range 2WWM Township 7

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Field SPT (N)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	20.0								
5		◆	7 14 18 (32)	⧗	D-1		Silty GRAVEL with sand, sub-angular, dense, grayish brown, moist, homogenous, HCl not tested. Length Recovered:0.4 ft. Length Retained:0.4 ft.		
	15.0								
10		◆	10 14 10 (24)	⧗	D-2		Silty GRAVEL with sand, sub-angular, medium dense, grayish brown, wet, homogenous, HCl not tested. Length Recovered:0.3 ft. Length Retained:0.3 ft.		
	10.0								
15		◆	4 6 6 (12)	⧗	D-3		Silty GRAVEL with sand, sub-angular, medium dense, grayish green, moist, homogenous, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.		
	5.0								
20		◆	0 0	⧗	D-4		SILT with gravel, organic soil and peat, very loose, dark gray, moist, homogenous, HCl not tested.		

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32521
HOLE No. H-38-08
Sheet 2 of 7

Job No. XL-2963 SR 5 Elevation 21.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		2 (2)			Length Recovered:0.8 ft. Length Retained:0.8 ft.
	0				
25		0 0 2 (2)	D-5	GS MC AL	SILT with some organic lenss, very loose, dark gray mottled with greenish gray, moist, laminated, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-5				
30			S-6		Sandy SILT with a trace of organics, dark gray, homogenous.
	-10	1 1 2 (3)	D-7		Sandy SILT with a trace of organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
35		4 2 3 (5)	D-8		Sandy SILT, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.1 ft. Length Retained:1.1 ft.
	-15				
40		2 1 1 (2)	D-9	GS MC AL	ML, MC=39%, PI=NA SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-20		S-10	GS MC AL CN	MC=37%(POST TEST MC:) ML, MC=42%, PI=NA SILT, dark gray, homogenous.
45		2 2	D-11	GS MC	ML, MC=44%, LL=34 Sandy SILT with organic lenss, very loose, dark gray,

LOG OF TEST BORING

Washington State Department of Transportation

Start Card S-32521

HOLE No. H-38-08

Job No. XL-2963 SR 5 Elevation 21.7 ft

Sheet 3 of 7

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched) — scale 20, 40, 60, 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		1 (3)		AL	wet, stratified, laminated, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-25				
		1 1 1 (2)	D-12		Sandy SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
50					
	-30				
		0 0 1 (1)	D-13		Sandy SILT with trace organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
55					
	-35				
		0 0 1 (1)	D-14		Sandy SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
60					
	-40				
		0 0 2 (2)	D-15	GS MC AL	ML, MC=56%, LL=40 SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
65					
	-45				
			S-16		Sandy SILT, dark gray, homogenous.
70					

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32521
HOLE No. H-38-08
Sheet 4 of 7

Job No. XL-2963 SR 5 Elevation 21.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched). Scale: 20, 40, 60, 80

Depth (ft) markers: 75, 80, 85, 90, 95
Elevation (ft) markers: -50, -55, -60, -65, -70

Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
0 1 2 (3)	D-17	GS MC AL	ML, MC=55%, LL=38 SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
0 0 2 (2)	D-18		SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
1 1 2 (3)	D-19	GS MC AL	ML, MC=59%, LL=37 SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.
2 3 2 (5)	D-20		SILT with sand, loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:0.9 ft. Length Retained:0.9 ft.
2 5 6 (11)	D-21		SILT with sand, medium dense, dark gray, wet, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.
	S-22		SILT with trace fine sand, dark gray, homogenous.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-38-08

Sheet 5 of 7

Job No. XL-2963 SR 5 Elevation 21.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft) scale: 100, 105, 110, 115, 120. Elevation (ft) scale: -75, -80, -85, -90, -95.

Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
0 0 0 (0)	D-23	GS MC AL	ML, MC=48%, LL=28 SILT with sand, very loose, dark gray, wet, stratified, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft. *Note: The bottom 0.3 feet of sample was silt with a trace of brown organics.*
0 2 2 (4)	D-24		SILT with sand, very loose, dark gray, moist, homogenous, HCl not tested, with a trace of brown organics. Length Recovered:1.5 ft. Length Retained:1.5 ft.
0 2 2 (4)	D-25		SILT with some brown organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	S-26		SILT, dark gray, homogenous.
0 2 2 (4)	D-27	GS MC AL	ML, MC=45%, LL=39 SILT with one gravel, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
0 3	D-28		SILT, loose, dark gray, moist, homogenous, HCl not tested, (moisture tin obtained).

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LOG OF TEST BORING

Start Card S-32521

HOLE No. H-38-08

Job No. XL-2963 SR 5 Elevation 21.7 ft

Sheet 6 of 7

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched). Scale: 20, 40, 60, 80

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		3 (6)			Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-100				
		0 2 3 (5)	D-29		SILT with trace brown organics, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
125					
	-105				
			S-30		SILT, dark gray, homogenous.
130					
		5 4 5 (9)	D-31		SILT with some brown organics, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-110				
		0 6 7 (13)	D-32	GS MC AL	ML, MC=36%, PI=NA SILT with sand, medium dense, dark greenish gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
135					
	-115				
		9 11 13 (24)	D-33		Sandy SILT with gravel, medium dense, dark greenish gray, wet, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.
140					
	-120				
		8 10	D-34	GS MC	ML, MC=34% Sandy SILT stratified with silty sand, dense, dark
145					

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32521
HOLE No. H-38-08
Sheet 7 of 7

Job No. XL-2963 SR 5 Elevation 21.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Shepherd, Robert Lic# 2710

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched). Scale: 20, 40, 60, 80

Depth (ft)	Elevation (ft)	Field SPT (N) / Moisture Content	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
			17 (27)			greenish gray, wet, stratified, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft. *Note: At 146 feet the soil became denser demonstrated by drilling.*
	-125					
		>>	50/3" (REF)	D-35		Sandy SILT, very dense, dark gray, dry, homogenous, HCl not tested. Length Recovered:0.3 ft. Length Retained:0.3 ft.
150						
	-130					
		>>; ✚ 20	28 50/4" (REF)	D-36	GS MC AL	ML, MC=20%, PI=9 Sandy SILT, very dense, dark grayish brown, dry, homogenous, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.
155						
	-135					
		>>	50/3" (REF)	D-37		Poorly graded SAND, very dense, dark gray, moist, homogenous, HCl not tested. Length Recovered:0.3 ft. Length Retained:0.3 ft.
160						
	-140					
		>>	50/3" (REF)	D-38		Poorly graded SAND, very dense, gray, moist. Length Recovered:0.3 ft. Length Retained:0.3 ft.
165						
	-145					
170						

The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Division and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew.

End of test hole boring at 164.3 ft below ground elevation.
This is a summary Log of Test Boring.
Soil/Rock descriptions are derived from visual field identifications and laboratory test data.
Note: REF = SPT Refusal

Washington State Department of Transportation

LOG OF TEST BORING

Start Card	S-32521
HOLE No.	H-40-08
Sheet	1 of 7
Job No.	XL-2963
SR	5
Elevation	23.7 ft
Project	I-5/SR 432 Talley Way Interchange
Driller	Haller, Robert
Lic#	2779
Site Address	Vic SR432 and I-5
Inspector	Cleo Andrews
Start	April 9, 2008
Completion	April 11, 2008
Well ID#	
Equipment	CME 45 with Autohammer
Station	AL 117+66.5
Offset	293.90ft Rt.
Hole Dia (inches)	4
Method	Wet Rotary
Northing	290965.60
Easting	1036583.61
Collected by	HQ Geotech Division
Datum	State Plane South
County	Cowlitz
Subsection	SE1/4 of NW1/4
Section	12
Range	2WWM
Township	7

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
5		14 8 5 (13)		D-1	GS MC	GP-GM, MC=18% Poorly graded GRAVEL with silt and sand, sub-angular, medium dense, dark gray, moist, HCl not tested. Length Recovered:0.5 ft. Length Retained:0.5 ft. *Note: Gravel is slightly weathered. from 0.0 ft to 5.0 ft Silty SAND with gravel was indicated by drilling and wash returns.*	
	15.0					4/9/2008	▼
10		13 13 8 (21)		D-2	GS MC	GP-GM, MC=18% Poorly graded GRAVEL with silt and sand, sub-angular, medium dense, dark gray, moist, HCl not tested. Length Recovered:0.5 ft. Length Retained:0.5 ft.	
	10.0						
15		5 8 8 (16)		D-3	GS MC	GP-GM, MC=18% Poorly graded GRAVEL with silt and sand, sub-angular, medium dense, dark green, moist, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.	
	5.0						
20							

Elevation 20.0 at approx. depth 3.7 ft.

Instrument

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-40-08

Job No. XL-2963 SR 5 Elevation 23.7 ft

Sheet 2 of 7

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Depth (ft): 25, 30, 35, 40, 45 — Elevation (ft): 0, -5, -10, -15, -20

Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
0 1 1 (2)	D-4		Lean CLAY with gravel and root hairs, soft, dark olive gray with traces of green oxidized stains, moist, stratified, HCl not tested. Length Recovered:0.4 ft. Length Retained:0.4 ft.
0 1 2 (3)	D-5	GS MC	ML, MC=40% Sandy SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.
	SH-6		SILT with decayed wood particles and root hairs, dark gray. *Note: 0 PSI was required to push a 3-inch OD shelby tube 2.0 ft.*
1 1 1 (2)	D-7		SILT with decayed wood particles, root hairs and other organic material, very loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
1 3 3 (6)	D-8	MC	MC=35% Sandy SILT with traces of organic material, loose, dark gray, wet, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
	SH-9		Sandy SILT with traces of organic material, dark gray. *Note: 0 to 25 PSI was required to push a 3-inch shelby tube 2.0 ft.*
1 1 1 (2)	D-10		Sandy SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-40-08

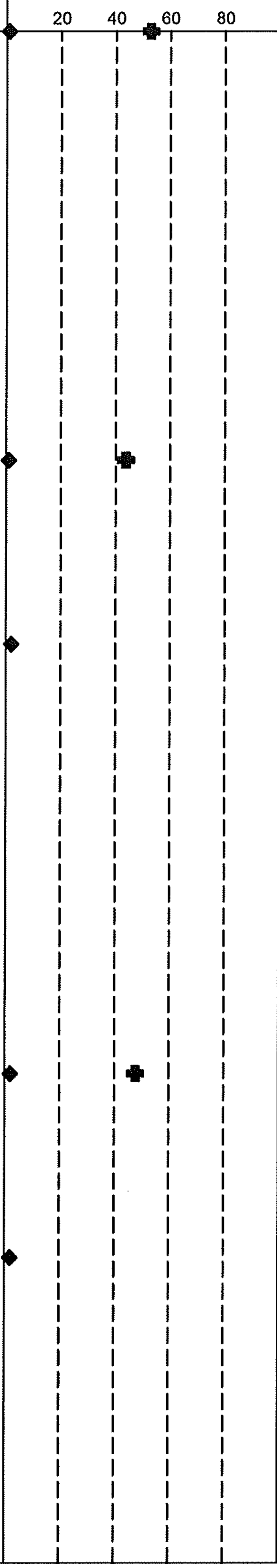
Sheet 3 of 7

Job No. XL-2963 SR 5 Elevation 23.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)



Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		0 0 1 (1)	D-11	GS MC AL	ML, MC=53%, PI=NA SILT with 6 inches of organic material in top of sample, very loose, dark gray, wet, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
	-25				
50			SH-12		Sandy SILT with organic material, dark gray. *Note: Sample becomes wet when shaken by hand. 0 to 25 PSI was required to push a 3-inch shelby tube 2.0 ft.*
		0 0 1 (1)	D-13	MC	MC=44% Sandy SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
	-30				
55		0 1 1 (2)	D-14		Sandy SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
	-35				
60			SH-15		Sandy SILT, , dark gray. *Note: Sample becomes wet when shaken by hand. 0 to 25 PSI was required to push a 3-inch Shelby tube 2.0 ft.*
		0 1 1 (2)	D-16	GS MC AL	ML, MC=48%, LL=32 SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
	-40				
65		0 1 1 (2)	D-17		Sandy SILT with trace organic material, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
	-45				
70					

Job No. XL-2963 SR 5 Elevation 23.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Depth (ft)	Elevation (ft)	Field SPT (N) / Moisture Content	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
				SH-18		SILT, dark gray. *Note: 0 to 25 PSI was required to push a 3-inch Shelby tube 2.0 ft.*
			0 1 1 (2)	D-19	MC	MC=58% SILT, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
75	-50		1 1 1 (2)	D-20		SILT, very loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: A pocket of light pink organic material was observed in the middle of the sample.*
80	-55			SH-21		Sandy SILT, medium dark gray. *Note: Sample becomes wet when shaken by hand. 0 to 350 PSI was required to push a 3-inch Shelby tube 2.0 ft.*
			2 2 2 (4)	D-22		Sandy SILT, very loose, medium dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
85	-60		2 2 2 (4)	D-23	MC	MC=41% Sandy SILT, very loose, medium dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
90	-65		1 3 4 (7)	D-24	MC	MC=40% Sandy SILT, fine grained silt layers, light gray in color, loose, medium dark gray, wet, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
95	-70					

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD. Scale: 20 40 60 80

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-40-08

Job No. XL-2963 SR 5 Elevation 23.7 ft

Sheet 5 of 7

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
			SH-25		SILT, gray. *Note: Sample becomes wet when shaken by hand. 25 to 250 PSI was required to push a 3-inch Shelby tube 2.0 ft.*
		1 2 5 (7)	D-26	GS MC AL	ML, MC=41%, PI=NA SILT, loose, gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Sample becomes wet when shaken by hand.*
100		3 6 6 (12)	D-27		Silty SAND with peat fibers, organic material (brown) and silt lenss (light gray), medium dense, dark gray, wet, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
105		4 4 4 (8)	D-28	MC	MC=43% SILT with organic material (brown) and tiny pieces of light pink shell light pink in color, loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
110			SH-29		SILT, dark gray. *Note: 0 to 25 PSI was required to push a 3-inch Shelby tube 2.0 ft.*
		2 3 4 (7)	D-30		SILT, traces of tiny pieces of shell, loose, dark gray, moist, homogenous, HCl not tested, traces of shell. Length Recovered:1.5 ft. Length Retained:1.5 ft.
115			SH-31		Sandy SILT, dark gray. *Note: 0 to 25 PSI was required to push a 2-inch Shelby tube 2.0 ft.*
		3 3 3 (6)	D-32	MC	MC=39% Sandy SILT with traces of organic material, loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
120					

Elevation scale: -75, -80, -85, -90, -95

Field SPT (N) / Moisture Content / RQD scale: 20 40 60 80

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-40-08

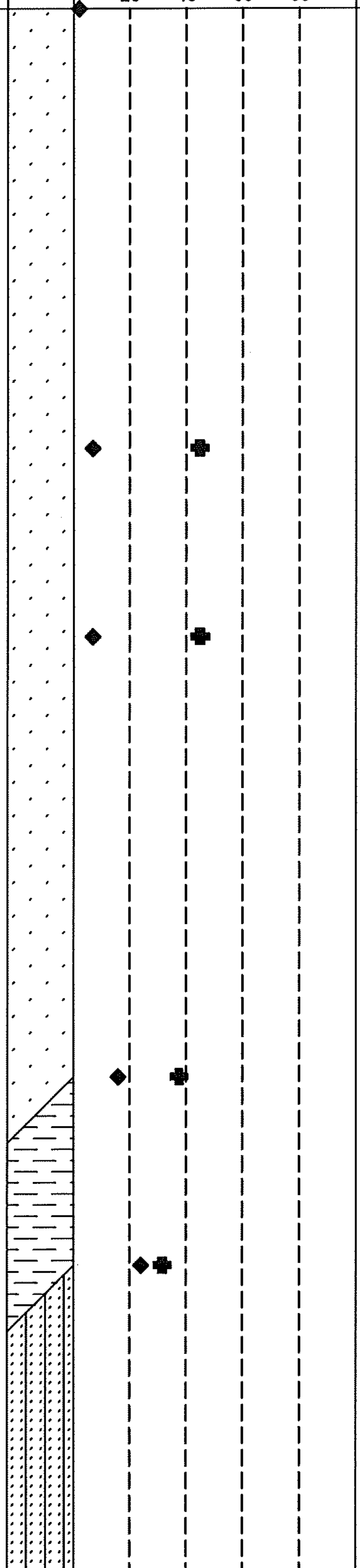
Job No. XL-2963 SR 5 Elevation 23.7 ft

Sheet 6 of 7

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)



Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		1 1 1 (2)	D-33		very loose, No recovery.
	-100				
125			SH-34		SILT with organic material (brown), dark gray. *Note: 0 to 25 PSI was required to push a 2-inch Shelby tube 2.0 ft.*
		2 2 5 (7)	D-35	GS MC AL	ML, MC=45%, LL=42 SILT with organic material (brown), loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-105				
130		2 4 3 (7)	D-36	MC	MC=45% SILT with decayed wood and other organic material (brown to black), loose, dark gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft. *Note: Silty sand with organic material (green) was observed at top of the sample.*
	-110				
135			SH-37		SILT with trace organic material, dark greenish gray , traces of organic. *Note: 0 to 50 PSI was required to push a 2-inch Shelby tube 2.0 ft.*
		6 8 8 (16)	D-38	GS MC AL	CH, MC=38%, PI=27 Fat CLAY with sand and organic material (brown), very stiff, dark greenish gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-115				
140		3 8 16 (24)	D-39	MC	MC=32% Silty SAND with sandy silt lenss, organic material (brown) and traces of small gravel, medium dense, dark greenish gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-120				
145					

SOILA XL-2963 I-5_SR432 TALLEY WAY I_C WITH CONE.GPJ SOIL.GDT 8/13/09

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-40-08

Sheet 7 of 7

Job No. XL-2963 SR 5 Elevation 23.7 ft

Project I-5/SR 432 Talley Way Interchange

Driller Haller, Robert Lic# 2779

Depth (ft)	Elevation (ft)	Profile	Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
			>>	50/5" (REF)		D-40		Silty SAND with gravel and traces of organic material, very dense, dark gray, moist, homogenous, HCl not tested, gravel is slightly weathered. Length Recovered:0.4 ft. Length Retained:0.4 ft. *Note: Started drilling harder at 144.0 ft.*		
	-125									
150				18 30 43 (73)		D-41	GS MC AL	SM, MC=24%, PI=NA Silty SAND with gravel/SANDSTONE, very dense, medium dark gray, moist, homogenous, HCl not tested, Sandstone is highly weathered. Length Recovered:1.5 ft. Length Retained:1.5 ft.		
	-130							The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Division and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew.") End of test hole boring at 151.5 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Note: REF = SPT Refusal		
155										
	-135									
160										
	-140									
165										
	-145									
170										

SOILA XL-2963 I-5_SR432 TALLEY WAY I_C WITH CONE.GPJ SOIL.GDT 8/13/09

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card S-32521
HOLE No. H-43-08
Sheet 1 of 6

Job No. XL-2963 SR 5 Elevation 18.4 ft

Project I-5/SR 432 Talley Way Interchange

Driller Henderson, Danny Lic# 2742

Site Address Vic SR432 and I-5

Inspector Vince Johnson

Start March 8, 2008 Completion March 8, 2008 Well ID#

Equipment CME 55 with Autohammer

Station AL 121+39.97 Offset 440.48ft Rt. Hole Dia (inches) 4

Method Wet Rotary

Northing 290775.23 Easting 1036888.08 Collected by HQ Geotech Division

Datum State Plane South

County Cowlitz Subsection SE1/4 of NW1/4 Section 12 Range 2WWM Township 7

Legend: ◆ Field SPT (N); ✚ Moisture Content; ▨ RQD (scale 20, 40, 60, 80)

Groundwater: ∇ 3/13/2008

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
	15.0				
		1 2 1 (3)	D-1		SILT with trace gravel and root hairs, very loose, brown to dark gray, moist, stratified, HCl not tested. Length Recovered:0.8 ft. Length Retained:0.8 ft.
5					
	10.0				
		0 1 1 (2)	D-2	GS MC AL	ML, M.C.=70%, LL-43, PL=NP SILT with trace organics, very loose, dark gray, moist, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
10					
	5.0				
			S-3		SILT, dark gray to brown, stratified.
15					
		2 2 1 (3)	D-4		Sandy SILT, very loose, gray, wet, stratified, HCl not tested. Length Recovered:1.1 ft. Length Retained:1.1 ft.
	0.0				
		1 2	D-5	GS MC	SM, M.C.=31% Silty SAND, loose, gray, wet, homogenous, HCl not
20					

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-43-08

Sheet 2 of 6

Job No. XL-2963 SR 5 Elevation 18.4 ft

Project I-5/SR 432 Talley Way Interchange

Driller Henderson, Danny Lic# 2742

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		4 (6)			tested. Length Recovered:1.2 ft. Length Retained:1.2 ft.
	-5				
25		0 2 1 (3)	D-6	GS MC AL	ML, M.C.=36% SILT with sand, very fine sand, very loose, gray, wet, homogenous, HCl not tested. Length Recovered:0.9 ft. Length Retained:0.9 ft.
	-10				
30		1 4 5 (9)	D-7	GS MC	SP-SM, M.C.=27% Poorly graded SAND with silt, loose, gray, wet, homogenous, HCl not tested. Length Recovered:1 ft. Length Retained:1 ft.
	-15				
35		2 2 1 (3)	D-8		SILT with sand, very loose, gray, wet, stratified, HCl not tested. Length Recovered:1.2 ft. Length Retained:1.2 ft. *Note: The upper 0.6 feet of sample was well graded sand, and the bottom 0.6 ft of the sample was silt.*
	-20		S-9		SILT, gray.
40		0 1 1 (2)	D-10	GS MC AL	ML, M.C.=47%, LL=35, PL=NP SILT with sand, very fine sand, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.4 ft. Length Retained:1.4 ft.
	-25	0 1	D-11		SILT, very loose, dark gray, wet, homogenous, HCl not tested.
45					

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD. Scale: 20, 40, 60, 80

Columns: Profile, Sample Type, Groundwater, Instrument

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-43-08

Sheet 3 of 6

Job No. XL-2963 SR 5 Elevation 18.4 ft

Project I-5/SR 432 Talley Way Interchange

Driller Henderson, Danny Lic# 2742

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		1 (2)			Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-30				
50		0 0 2 (2)	D-12		SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-35				
55		0 0 1 (1)	D-13		SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-40				
60		0 0 2 (2)	D-14	GS MC AL	ML, M.C.=49%, LL=30, PL=NP SILT with sand, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-45				
65		0 0 2 (2)	D-15		SILT, very loose, dark gray, wet, homogenous, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
	-50				
70		0 0	D-16		SILT, very loose, dark gray, wet, homogenous, HCl not tested.

Legend: Field SPT (N); Moisture Content; RQD (scale 20, 40, 60, 80)

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-43-08

Job No. XL-2963 SR 5 Elevation 18.4 ft

Sheet 4 of 6

Project I-5/SR 432 Talley Way Interchange

Driller Henderson, Danny Lic# 2742

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (hatched). Scale: 20, 40, 60, 80

Depth scale (ft): 75, 80, 85, 90, 95. Elevation scale (ft): -55, -60, -65, -70, -75.

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample No. (Tube No.)	Lab Tests	Description of Material
		2 (2)			Length Recovered:1.5 ft. Length Retained:1.5 ft.
		2 2 3 (5)	D-17		SILT, loose, dark gray, wet, laminated, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
		2 3 1 (4)	D-18		SILT, very loose, dark gray, wet, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
		1 2 3 (5)	D-19	GS MC AL	ML, M.C.=37%, LL=NA, PL=NP SILT, loose, gray, wet, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
		8 9 20 (29)	D-20		SILT, dense, gray to greenish gray, moist, stratified, HCl not tested. Length Recovered:1.5 ft. Length Retained:1.5 ft.
		50/6" (REF) >>	D-21		SILT, (SILTSTONE), very dense, dark greenish gray, moist, stratified, HCl not tested, Actual blow count 80/6".

Columns also include: Profile, Sample Type, Groundwater, Instrument.

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-43-08

Job No. XL-2963 SR 5 Elevation 18.4 ft

Sheet 5 of 6

Project I-5/SR 432 Talley Way Interchange

Driller Henderson, Danny Lic# 2742

Legend: ◆ Field SPT (N); ✚ Moisture Content; RQD (scale 20, 40, 60, 80)

Depth (ft)	Elevation (ft)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material
						Length Recovered:0.5 ft. Length Retained:0.5 ft.
	-80					
100		>> 50/6" (REF)	⧗	D-22		SILT, (SILTSTONE), very dense, dark greenish gray, moist, stratified, HCl not tested, Actual blow count 62/6". Length Recovered:0.5 ft. Length Retained:0.5 ft.
	-85					
105		>> 50/6" (REF)	⧗	D-23		SILTSTONE, CHLORITE, very dense, black, moist, homogenous, HCl not tested, Drlling fliud indicates soil change at approx. 101' from greenish gray to dark brown. Length Recovered:0.5 ft. Length Retained:0.5 ft.
	-90					
110		>> 50/6" (REF)	⧗	D-24		SILTSTONE, CHLORITE, very dense, black, moist, stratified, HCl not tested, Actual blow count 52/6". Length Recovered:0.5 ft. Length Retained:0.5 ft.
	-95					
115		>> 50/4" (REF)	⧗	D-25		SILTSTONE, very dense, dark gray, moist, stratified, HCl not tested, Actual blow count 60/5". Length Recovered:0.4 ft. Length Retained:0.4 ft.
	-100					
120		>> 50/4" (REF)	⧗	D-26		SILTSTONE, very dense, dark gray, moist, stratified, HCl not tested, Actual blow count 100/5".

Washington State Department of Transportation

LOG OF TEST BORING

Start Card S-32521

HOLE No. H-43-08

Job No. XL-2963 SR 5 Elevation 18.4 ft

Project I-5/SR 432 Talley Way Interchange

Driller Henderson, Danny Lic# 2742

Depth (ft)	Elevation (ft)	Profile	Field SPT (N) / Moisture Content / RQD (20 40 60 80)	Blows/6" (N) and/or RQD FF	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
								Length Recovered:0.4 ft. Length Retained:0.4 ft.		
	-105									
			>>	50/6" (REF)		D-27		SANDSTONE, very dense, dark gray, moist, stratified, HCl not tested, Actual blow count 87/6". Length Recovered:0.5 ft. Length Retained:0.5 ft.		
125										
	-110									
130										
	-115									
135										
	-120									
140										
	-125									
145										

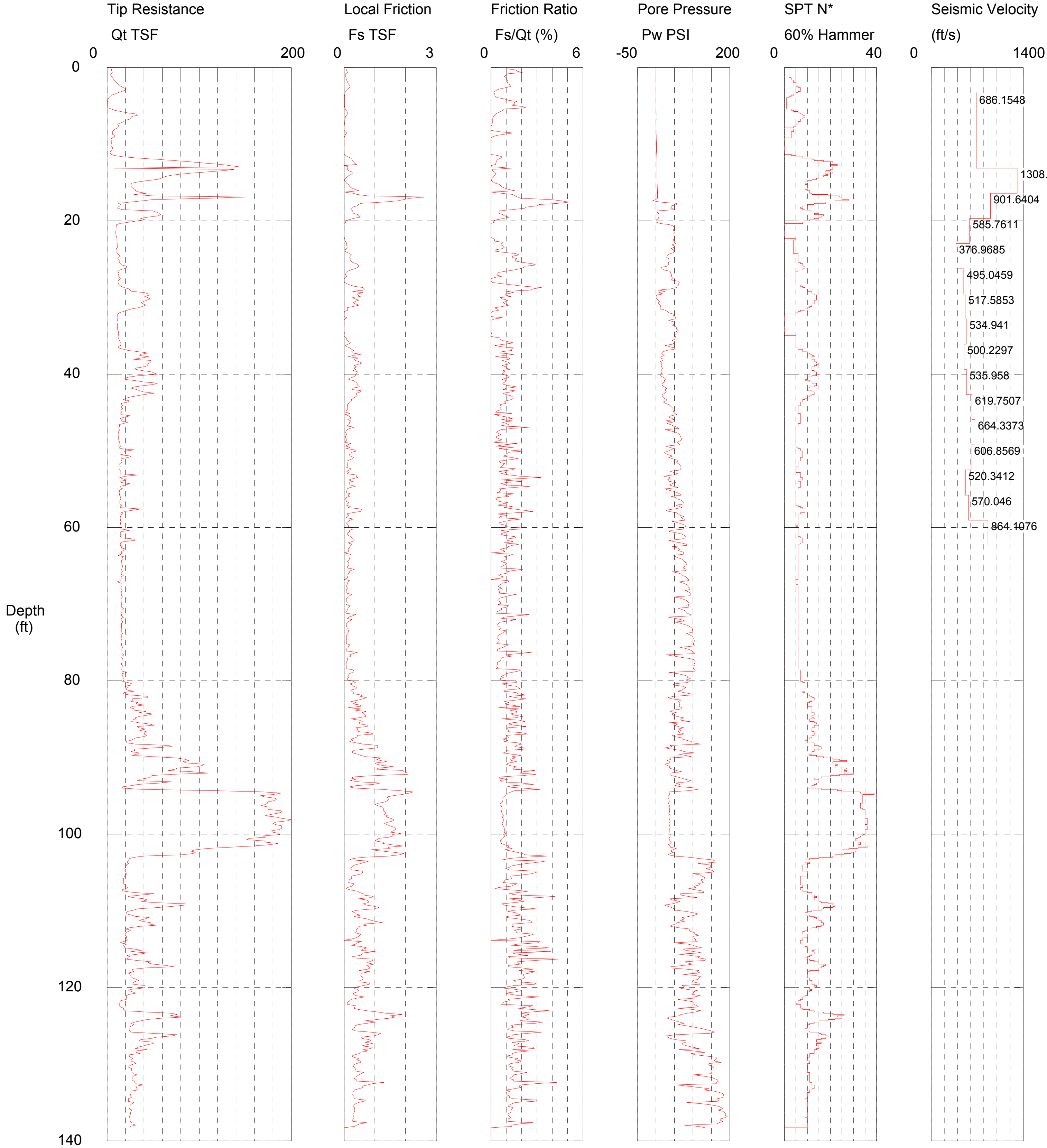
The implied accuracy of the borehole location information displayed on this boring log is typically sub-meter in (X,Y) when collected by the HQ Geotech Division and sub-centimeter in (X,Y,Z) when collected by the Region Survey Crew.

End of test hole boring at 124.5 ft below ground elevation.
This is a summary Log of Test Boring.
Soil/Rock descriptions are derived from visual field identifications and laboratory test data.
Note: REF = SPT Refusal

WSDOT Geotech.Division

Operator: Brian Hilts
Sounding: CPT-5-08
Elevation:

CPT Date/Time: 4/16/2008 8:15:01 AM
Location: N291319.5001 E1036246.802
Job Number: XL-2963



Maximum Depth = 138.29 feet

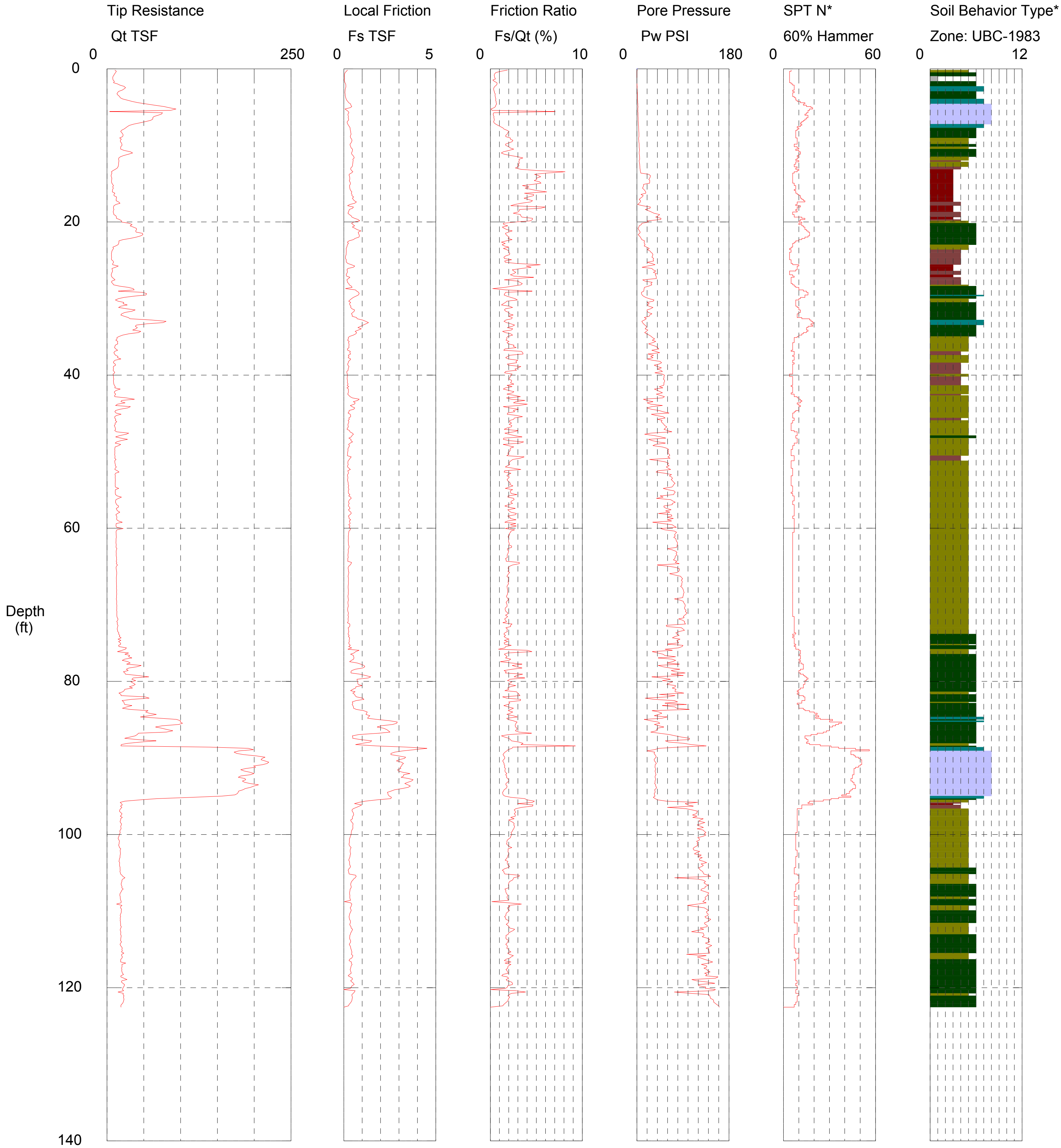
Depth Step = 0.164 feet

*Soil behavior type and SPT based on data from UBC-1983

WSDOT Geotech.Division

Operator: Brian Hilts
Sounding: CPT-10-08
Elevation:

CPT Date/Time: 5/1/2008 1:30:08 PM
Location: N291032.3104E1036434.908
Job Number: XL-2963



Maximum Depth = 122.54 feet

Depth Step = 0.164 feet

1 sensitive fine grained	4 silty clay to clay	7 silty sand to sandy silt	10 gravelly sand to sand
2 organic material	5 clayey silt to silty clay	8 sand to silty sand	11 very stiff fine grained (*)
3 clay	6 sandy silt to clayey silt	9 sand	12 sand to clayey sand (*)

I-5/SR-432 Talley Way I/C

A hub and stake marking hole location

*Soil behavior type and SPT based on data from UBC-1983

Washington State Department of Transportation

LOG OF CONE PENETROMETER TEST

Start Card S-32522

HOLE No. CPT-11-08

Sheet 1 of 3

Job No. XL-2963 SR 5 Elevation 40.0 ft

Project I-5/SR 432 Talley Way Interchange

Driller Brian Hilts Lic# 2249

Site Address Vic. Of I-5 and SR-432

Inspector Brian Hilts

Start May 1, 2008 Completion May 1, 2008 Well ID#

Equipment CPT with Autohammer

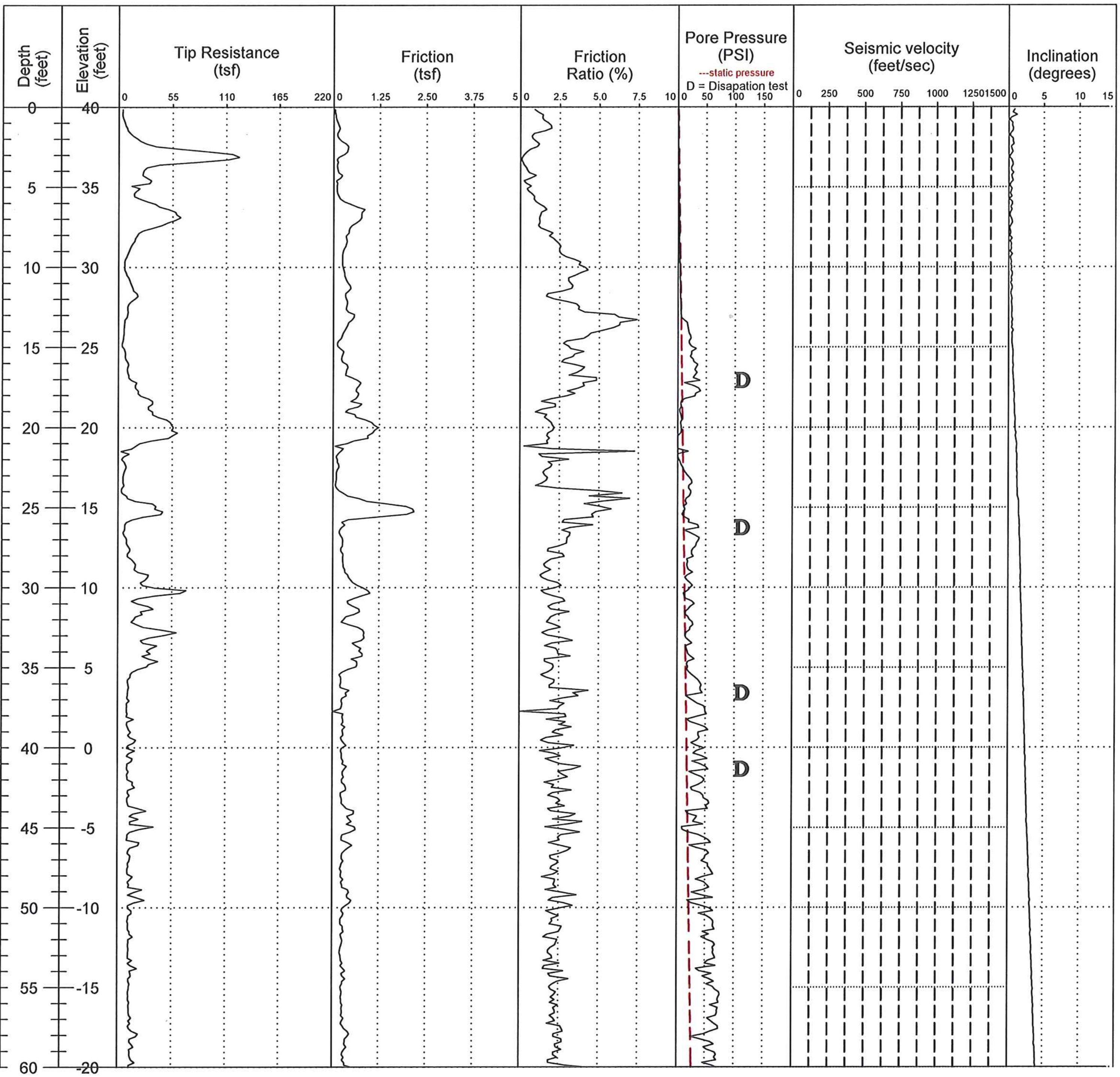
Station AL 117+63.15 Offset 338.98ft Rt. Hole Dia (inches) 1.5

Method Wet Rotary

Northing 290914.11 Easting 1036592.06 Collected by HQ Geotech Division

Datum State Plane South

County Cowlitz Subsection SE1/4 of NW1/4 Section 12 Range 2WWM Township 7



CPT XL-2963 I-5_SR432 TALLEY WAY I_C WITH CONE.GPJ SOILCPT.GDT 8/13/09

Washington State Department of Transportation

LOG OF CONE PENETROMETER TEST

Start Card S-32522

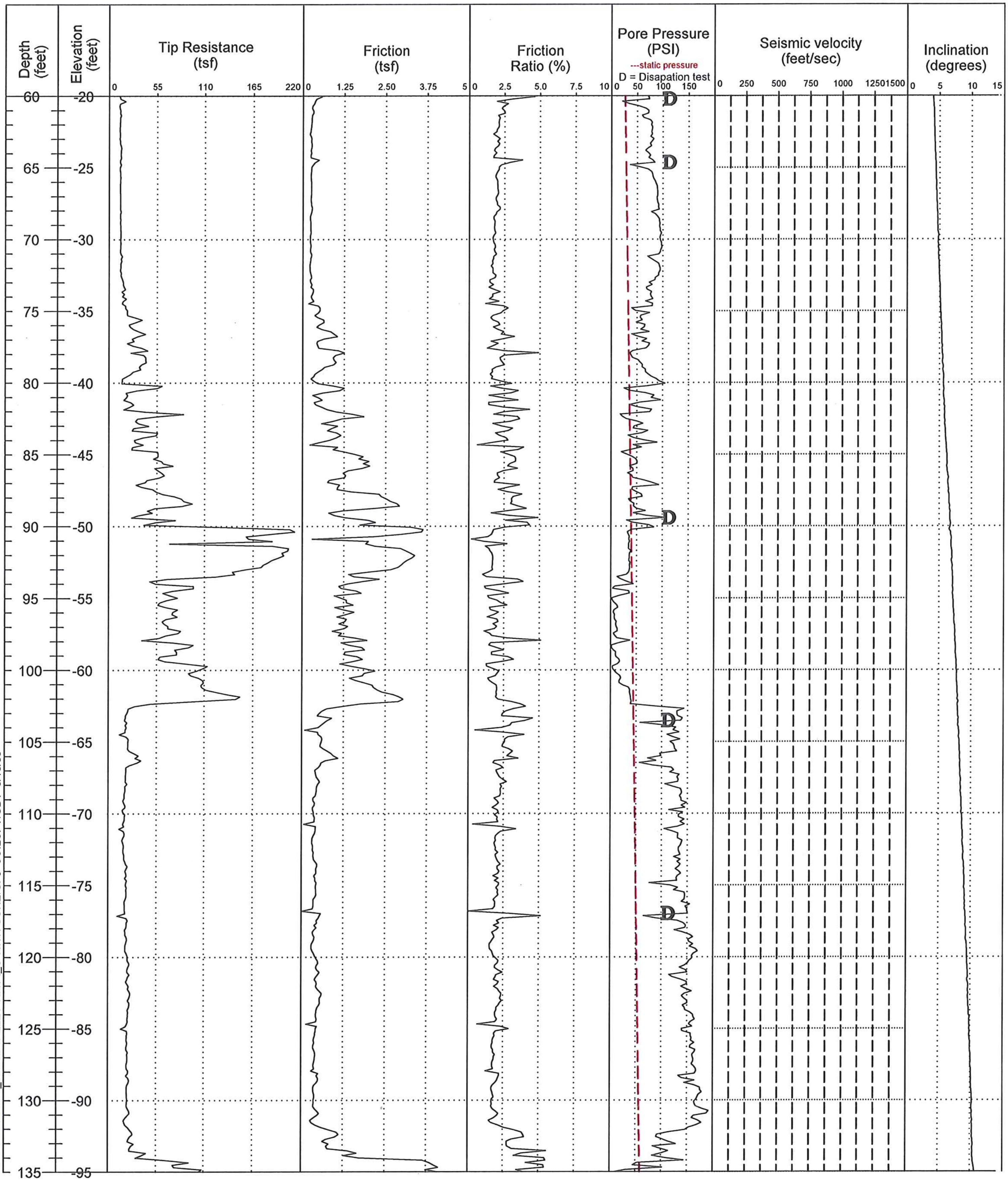
HOLE No. CPT-11-08

Job No. XL-2963 SR 5 Elevation 40.0 ft

Sheet 2 of 3

Project I-5/SR 432 Talley Way Interchange

Driller Brian Hilts Lic# 2249



Washington State
Department of Transportation

LOG OF CONE PENETROMETER TEST

Start Card S-32522

HOLE No. CPT-11-08

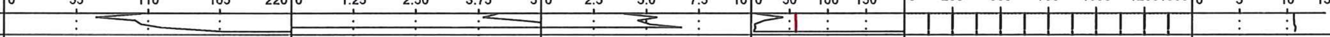
Job No. XL-2963 SR 5 Elevation 40.0 ft

Sheet 3 of 3

Project I-5/SR 432 Talley Way Interchange

Driller Brian Hilts Lic# 2249

Depth (feet)	Elevation (feet)	Tip Resistance (tsf) 0 55 110 165 220	Friction (tsf) 0 1.25 2.50 3.75 5	Friction Ratio (%) 0 2.5 5.0 7.5 10	Pore Pressure (PSI) ---static pressure D = Disapation test 0 50 100 150	Seismic velocity (feet/sec) 0 250 500 750 1000 1250 1500	Inclination (degrees) 0 5 10 15
135	-95						



APPENDIX D
EXAMPLE HAND CALCULATION FOR SCHMERTMANN METHOD

(Source: Naresh Samtani, personal Communication 1-27-18)

Test Hole Location : RR-5-04
Applied pressure = 6630 psf (6.63 ksf) from WSDOT
Depth of embedment, = 0 ft (i.e. fill bottom at existing ground level)
Net pressure, $\Delta p = 6.63$ ksf
Plane-strain case: Width = 1000 ft Length = 10,000 ft from WSDOT
$L/B = 10$

From Figure 6a choose the plane-strain influence diagram
↳ At depth = 0, $I_z = 0.20$

At depth = B = 1000 ft, $I_{zp} = 0.5 + 0.1 \left[\frac{\Delta p}{p_{op}}\right]^{0.5}$

p_{op} at depth = B = 1000 ft is calculated as follows
Unit weight (effective) = 125 pcf = 0.125 kcf from WSDOT
$p_{op} = (1000\ ft)(0.125\ kcf) = 125$ ksf

$I_{zp} = 0.5 + 0.1 \left[\frac{6.63\ ksf}{125\ ksf}\right]^{0.5} = 0.523$

Consider Layer 3 to demonstrate further calcs

Thickness of Layer, $\Delta z = 5$ ft at a depth $z = 10$ ft $p_o = 0.125\ kcf \times 10\ ft = 1.25\ ksf = 0.625\ tsf$
Depth to mid-layer ≐ 12.1 ft = D_f
USCS for soil at this depth = SP from WSDOT boring log (poorly graded sands)

SPT N-value, raw = 7 from WSDOT boring log

$N_{160} = 10.8$ based on following
overburden correction factor, $C_N = 0.77 \log\left[\frac{20}{p_o (tsf)}\right] = 0.77 \log\left[\frac{20}{0.625\ tsf}\right] = 1.16$
For auto-hammer, correction factor for $N_{60} = 1.33$
$N_{160} = (7)(1.16)(1.33) = 10.8$ [matches # in table]

Calculate I_z at mid-layer depth of 12.1ft

Interpolate between $I_z = 0.20$ at fill base
$I_{zp} = 0.523$ at $D = 1000$ft

$I_z = 0.20 + 12.10 \left[\frac{0.523 - 0.20}{1000}\right] = 0.204$ [matches # in table]

Calculate E_s

Soil is "SP". From Table 1, choose "clean fine to medium sands, and slightly silty sands"

$E_s = 0.097\ N_{160}$ in ksi

$= 14\ N_{160}$ in ksf

$N_{160} = 10.8$

For plane strain case, $X = 1.75$ (← 1.8 ≈ 10)

Thus, $E_s = (14)(1.75)(10.8) = 264.6$ ksf ≈ 265 ksf [matches # in table]

Calculate Elastic Spring Stiffness of Layer [Eq 10.6-2.4.2d-2]

$\Delta J_i = \Delta z \left(\frac{I_z}{E_s}\right)$

$= 5\text{ft} \left(\frac{0.204}{265\text{ ksf}}\right) = 0.00385 \frac{\text{ft}}{\text{ksf}}$

Correction Factor C_1 [Eq 10.6.2.4.2d-3]

$C_1 = 1 - 0.5\left[\frac{p_o}{\Delta p}\right] = 1 - 0.5\left[\frac{0\text{ ksf}}{6.63\text{ ksf}}\right] = 1.0$ (original pressure at ground before fill)

Correction Factor C_2 [Eq 10.6.2.4.2d-1]

Use end of construction $t = 0.1$ yrs (i.e. no long term creep settlement)

$C_2 = 1 + 0.2\log_{10}\left[\frac{0.1\text{ yrs}}{0.1}\right] = 1.0$

Calculate Layer Settlement, S_i [Eq 10.6.2.4.2d-1]

$$S_i = C_1 C_2 \Delta p (\Delta T_i)$$

$$= (1.0)(1.0)(6.63\ ksf)\left(0.00385\ \frac{ft}{ksf}\right)$$

$$= 0.0255\ ft$$ [matches # in Table]

Sum all layer settlements to obtain total settlement
$\Sigma = 0.442\ ft = 5.31$ inches

Comments

- Boring depth ≈ 110 ft
  Rock encountered ≈ 106 ft
  Assume all layers below @106 ft to have an arbitrarily high E_s value [100 0000 ksf] which makes settlement contribution from rock to be negligible.

- Thickness of top layer = 4.6 ft based on following:
  Top elevation: 1949.6 ft (based on top of boring RR-5-04)
  Depth of first sample = 5 ft
  Elevation of 1st sample = 1949.6 ft - 5 ft = 1944.6 ft
  Spreadsheet rounds off to nearest foot since that is more practical
  Thus, elevation of 1st sample (after rounding) = 1945 ft.
  Thus, thickness of 1st layer = 1949.6 ft - 1945 ft = 4.6 ft
  All samples below 1st sample are at appropriate intervals based on logs.