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ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

TECHNICAL MEMORANDUM

TO: Ms. Peg Staheli and Ms. Kathy Gwilyn

FROM: Brian A. Bennetts, P.E. and Toby Meierbachtol

DATE: January 7, 2009

RE: **STORMWATER RETROFIT EVALUATION**
WASHINGTON STATE UNIVERSITY
RESEARCH AND EXTENSION CENTER
PUYALLUP, WASHINGTON

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1/7/09

INTRODUCTION

This technical memorandum summarizes the results of the field exploration program and provides the recommended design infiltration rate and porous pavement design for the proposed porous pavement and bio-retention facilities located at the Washington State University – Research and Extension Center located (WSU Extension Center) at 7612 Pioneer Way East in Puyallup, Washington. The project location is shown on the Vicinity Map, Figure 1. The Site and Exploration Plan, Figure 2, shows the project area and the approximate location of the explorations completed for this study.

PROJECT BACKGROUND

We understand that Washington State University plans to retrofit the existing stormwater facilities at the Puyallup Research and Extension Center. Stormwater from impermeable areas currently flows into the existing storm sewer system from which it is directly discharged into Woodland Creek. Flow from Woodland Creek eventually enters into Clark's Creek and the Puyallup River. No stormwater flow control or treatment exists in the existing stormwater system.

The new stormwater system at the site is anticipated to include Low Impact Development (LID) techniques such as pervious pavement and bioretention. The pervious pavement and bioretention facilities planned at the site will be utilized to demonstrate the technologies and to educate the public about LID approaches.

SCOPE OF SERVICES

The purpose of our services was to excavate a series of test pits to characterize soil and groundwater conditions, determine the in situ infiltration rate of the near-surface soils by completing pilot infiltration tests (PIT), and preparing this technical memorandum summarizing the results of this

investigation and recommendations for design infiltration rates and design of porous pavement. This technical memorandum includes:

- A site plan showing the locations of the explorations completed for this study.
- Descriptive summary logs of the soil and groundwater conditions observed at each of the exploration locations.
- A discussion of the observed near-surface soil and groundwater conditions within the footprint of the vault.
- An assessment of the feasibility of stormwater infiltration at the proposed site and the recommended design infiltration rates per the Washington State Department of Ecology (WDOE) 2005 *Stormwater Management Manual for Western Washington* (SMMWW).
- Recommendations for structural design of porous pavement.

In addition to the services provided above, the test pits were monitored for archaeological artifacts. The results of the archaeological monitoring were summarized in a cultural resources technical memorandum, which is provided under separate cover.

Our services were provided in accordance with our July 17, 2008 Revised Proposal for Geotechnical Engineering and Archaeological Monitoring Services. Written notice to proceed was received on July 30, 2008.

EXISTING CONDITIONS

This section provides a discussion of the general surface and subsurface conditions observed at the project site at the time of our investigations. Interpretations of the site conditions are based on our review of available information and the results of our subsurface explorations.

SURFACE CONDITIONS

The Washington State University Research and Extension Center is located on 160 acres of land on the southwestern boundary of the Puyallup River Valley. There are over 50 buildings located on the main campus including administrative and office buildings, laboratory buildings, storage buildings, maintenance shops, and covered garages. The buildings are connected by a series of paved or unpaved roadways. Several large parking lots are situated within the project site.

GEOLOGIC SETTING

Geologic information for the project area was obtained from the *Geologic Map of the Puyallup 7.5-Minute Quadrangle, Washington* (Troost in review). According to Troost, subsurface deposits in the vicinity of the proposed improvements consist of recessional lacustrine deposits. Soil defined as recessional lacustrine deposits typically consists of interbedded fine sand, silt, and clay. Recessional lacustrine deposits were transported by meltwater streams and deposited in streams and pools emanating from the face of an ablating glacier. Recessional lacustrine deposits have not been glacially overridden. The unit is generally loose to medium dense/soft to medium stiff in density/consistency, exhibits low to moderate shear strength, and has a low permeability.

Although not shown on the above-referenced map, subsurface deposits classified as alluvium and fill were encountered in the test pits completed for this project. Fill encountered at the site is associated with previous site development. Deposits defined as alluvium typically consist of younger, unconsolidated, stratified units of silt, sand, and gravel. In areas alluvium may contain interbeds of peat and organic silt. The alluvium was transported and deposited by moving water. This unit has not been glacially overridden, is typically very soft/loose to stiff/medium dense, and depending on its composition, can be moderately compressible.

FIELD EXPLORATION PROGRAM

Subsurface conditions at the location of the proposed infiltration facilities were explored between September 15 and September 19, 2008. Field explorations for this investigation consisted of advancing a series of five geotechnical test pits to characterize subsurface soil and groundwater conditions at the site. The approximate exploration locations of the test pits are shown on Figure 2. Pilot infiltration test (PIT) were completed in three of the five test pits (TP-1, TP-2, and TP-4). The field exploration program was also to include completion of PIT investigations in test pits TP-3 and TP-5. Per the request of WSU personal, these test pits were extended into the native alluvial deposits such that the infiltration rate of the alluvium could be determined. Upon reaching the alluvium, groundwater seepage was encountered in the test pits just above the alluvial deposits. The presence of groundwater precluded the completion of PIT investigation in these test pits.

The test pits were excavated utilizing a rubber-tired backhoe supplied and operated by Washington State University. The dimensions of the test pits varied between 4.6 ft and 6.3 ft wide and between 5.3 ft and 7.3 ft long. Test pits TP-1, TP-2, and TP-4 were initially excavated to depths of 2.7, 2.3 and 2.0 ft respectively. Test pits TP-3 and TP-5 were initially excavated to depths of 5.3 and 7.0 ft respectively. Following completion of infiltration testing, test pits TP-1 and TP-4 were excavated to a

final depth of about 4.5 ft. Due to time constraints, test pit TP-2 was not extended further after the completion of the infiltration testing.

The field exploration program was coordinated and monitored by representatives from our firm whom also obtained representative soil samples, maintained a detailed record of observed subsurface soil and groundwater conditions, and described the soil encountered by visual and textural examination. Disturbed bag samples of the soil encountered in the test pits were obtained at selected intervals and taken to our laboratory for further visual examination.

Each representative soil type observed was described using the soil classification system shown on Figure 3, in general accordance with ASTM D 2488, *Standard Recommended Practice for Description of Soils (Visual-Manual Procedure)*. Logs of the test pit explorations are presented on Figures 4 through 6. These logs represent our interpretation of subsurface conditions identified during the field explorations. The stratigraphic contacts shown on the individual logs represent the approximate boundaries between soil types; actual transitions may be more gradual. Also, the soil and groundwater conditions depicted are only for the specific date and locations reported, and therefore, are not necessarily representative of other locations and times.

SUBSURFACE SOIL CONDITIONS

Test pit TP-1 was advanced near the Administration Building. At that location, topsoil overlying soil interpreted to be recessional lacustrine deposits was encountered throughout the depth explored (4½ ft BGS). The recessional lacustrine deposits encountered at this location consist of stiff, wet, clayey silt.

Test pits TP-2 and TP-3 were advanced in the existing parking lot located west of Kalkus Hall. The existing asphalt pavement section was measured to be between 2½ and 2¾ inches thick. Fill, associated with previous site development was encountered below the pavement throughout the depths explored (2¼ ft BGS) at test pit location TP-2 and to a depth of about 4 ft BGS in test pit TP-3. Fill encountered in test pit TP-2 consists of a sequence of medium dense, sandy gravel; medium dense, sandy gravel with silt; and stiff, gravelly, sandy silt. Fill encountered in test pit TP-3 consists of medium dense, fine to coarse sand with silt and variable gravel content. Soil interpreted to be alluvium was encountered in test pit TP-3 below the fill to the maximum depth explored. Alluvium was observed to consist of a sequence of soft to medium stiff, silt with sand and gravel and soft to medium stiff, silt with organics.

Test pits TP-4 and TP-5 were advanced in the gravel covered area west of the D.F. Allmendinger Center. Fill was encountered throughout the depth explored (4½ ft BGS) in test pit TP-4. Fill was observed to consist of about 2½ ft of medium dense, silty, sandy gravel; about 1 ft of medium dense, very silty, fine to coarse sand with organics; about ½ ft of very stiff, wet, sandy gravel silt with gravel and

trace organics; and medium dense, fine to medium sand with silt throughout the remaining depths explored.

About 6⅓ ft of fill was encountered at the location of test pit TP-5. Fill encountered at this location consists of a sequence of medium dense, silty, gravelly fine to coarse sand (0 to 2½ ft); medium dense, sandy, very silty, gravel (2½ to 4¾ ft BGS); and medium dense, sandy gravel with silt (4¾ to 6⅓ ft BGS). Fill was underlain by alluvium composed of soft, silt with abundant organics. The test pit did not penetrate through the alluvium deposits throughout the remaining depths explored, about 7 ft BGS.

GROUNDWATER CONDITIONS

Groundwater was not encountered within the depths explored in test pits TP-1, TP-2 and TP-4. Groundwater was encountered in test pits TP-3 and TP-5 at depths of about 3½ and 5¾ ft BGS, respectively. The groundwater observed in these test pits is interpreted to be perched groundwater located above the relatively low permeable alluvial deposits. These test pits were advanced in the area to the west of Kalkus Hall and D.F. Allmendinger Hall. Test pits TP-2 and TP-4 were also advanced in this area, and it is anticipated that groundwater in these areas will also be perched above the relatively impermeable alluvium. Groundwater conditions will vary depending on local subsurface conditions, the weather, and other factors. It is likely that maximum groundwater levels would occur in the winter/spring months.

PILOT INFILTRATION TESTS

In-situ infiltration testing was completed on September 16, 17, and 18, 2008, in test pits TP-1, TP-2, and TP-4 respectively. The test pit locations were field-located by Washington State University personnel. Washington State University provided equipment and personnel for excavation and water supply.

Infiltration testing was completed in general accordance with the procedure listed in Appendix III-D of the of the Washington State Department of Ecology (WSDOE) *2005 Stormwater Management Manual for Western Washington* (2005 SMMWW). Some modifications were made to the above-referenced procedure to account for the site conditions and the near-surface nature of the proposed facilities (i.e. the head in porous pavement and bioretention facilities will be much lower than typical heads anticipated in stormwater ponds). The test procedure utilized in the PIT investigation is summarized below.

- Pits were excavated to the target depth, about 2 ft BGS, using a rubber-tired excavator. The bottom of the test pits was between 4.6 ft and 6.3 ft wide by about 5.3 and 7.3 ft long.
- Loose soil was cleaned from the bottom of the pit and the dimensions of the pit were measured and recorded.

- A six-inch diameter PVC pipe with a tee and 90 degree elbows at the base was placed in the pit to control water inflow to the pit excavation and to reduce bottom scour and excess suspension of sediment in the water pit (see Figure 7). The PVC pipe extended from roughly the pit center at a 45 degree angle to the top of the pit.

- The pit was filled with water to a depth of about 7 inches above the pit bottom. Water was supplied by a hydrant. Initial filling of the infiltration pits took approximately 5 to 9 minutes. An initial pit water level of 7 inches is lower than that suggested by SMMWW, but is a reasonable modification due to the anticipated heads and near-surface nature of the proposed facilities.

- Water levels in the pit were monitored by two methods: a 5 psi Aquistar PT2X data logging electronic pressure transducer was used for electronic water level measurements (0.028 inches increments) and a stadia gage rod (0.01 foot increments) for direct water level measurements. Both were installed on a 2 x 4 post securely anchored in the middle of the pit. Water levels were initially monitored with the pressure transducer at 1 minute increments for the first two to three hours of the test. The sampling interval was then changed to 5 minutes, and the pressure transducer was allowed to record over night.

- The procedure outlined in the 2005 *SMMWW* calls for adding water to the test pit until a given depth of water is achieved (about 7 inches for this project). The flow of water is than regulated such that a constant water level is maintained in the pit. The flow rate is then divided by the pit bottom area to determine the infiltration rate. In each of the three test pits where the pilot infiltration tests were performed, the inflow of water needed to maintain a constant water level was lower than the measurement capabilities of the low flow flowmeter (lower limit of 0.3 gpm). As a result, the flow rate necessary to maintain a stable pit water level could not be accurately measured. The test procedure was modified by filling the test pit to an appropriate depth with water and allowing infiltration without additional water input.

- Upon completion of the test, the bottom of test pits TP-1 and TP-4 was excavated to a depth of about 4.5 ft below the existing ground surface to check for the presence of low permeable layers and to obtain a soil sample from the pit bottom.

- After completion of testing, the pit was backfilled with excavated soil.

The infiltration testing was coordinated and monitored by representatives from our firm who also obtained representative soil samples, maintained a detailed record of observed subsurface soil and groundwater conditions, and described the soil encountered by visual examination and laboratory testing. Representative bulk soil samples were obtained from the test pits, placed in air-tight plastic bags, and returned to our laboratory for further classification and laboratory testing.

DESIGN INFILTRATION RATE

Infiltration curves (height of water in pit versus time) for the PIT investigations, PIT 1, PIT 2, and TP 3, completed in test pits TP-1, TP-2, and TP-4, respectively, are shown on Figures 7 through 9. Early "noisy" data in water level drawdown is likely due to initial saturation of the pit bottom and surrounding pit walls, as well as side slump from the pit walls. Two artificial perturbations in the curves for PIT 1 (TP-1) and PIT 2 (TP-2) are evident and merit acknowledgement. In PIT 1 (see Figure 7), there is an approximately 0.3 inch increase in pit water level 17 minutes after initiation of the test. This is due to the manual dumping of a 5-gallon bucket of water into the test pit by a Landau Associates representative. In PIT 2 (see Figure 8), an approximately 1 inch rise in pit water level 175 minutes after test initiation is due to the refilling of the test pit prior to abandonment of the site for the evening.

The linearly regressed portions of each curve were manually chosen based on the linearity of the drawdown. The in-situ infiltration rate was calculated by applying a linear regression to the latter part of the data once the infiltration rate had stabilized. This is analogous to the analysis procedure outlined in the 2005 *SMMWW*, in which the infiltration rate is calculated from the water flow rate after the flow rate has stabilized. The slope of the linear regressions represents the infiltration rate in inches per minute. This was then converted to inches per hour. Based on the linear regression, the infiltration rates for test pits TP-1, TP-2 and TP-4 were calculated as 0.036, 0.144, and 0.024 inches per hour respectively.

Table 3.9 of the 2005 *SMMWW* provides recommended correction factors to be used with insitu infiltration rates to determine the long-term infiltration rate. The correction factors are used to account for soil variability and future maintenance and influent control measures. For soil variability, the Ecology 2005 *SMMWW* recommends using a correction factor between 1.5 and 6.0. Soil conditions encountered in all test pits were similar. Furthermore, an infiltration-controlling silt layer was encountered in each of the excavated test pits. Because of the pervasive silt layer encountered across the site, we recommend utilizing a correction factor of 2.0. To account for potential siltation and biofouling, the Ecology 2005 SWMMWW recommends using a correction factor between 2.0 to 6.0. We assume that the facilities will be properly maintained and thus suggest using a correction factor of 2.0. To account for the degree of influent control to prevent siltation and biofouling, the Ecology 2005 *SMMWW* recommends using a correction factor between 2.0 to 6.0. Our understanding is that the porous pavement will treat only direct rainfall, and thus additional sediment introduced from routing water from other sources (ie. rooftops) will be minimal. We therefore recommend an influent control correction factor of 2.0. The total correction factor is the sum of the above factors, and would be 6.0 (2.0 + 2.0 + 2.0 = 6.0). The correction factors for influent control and siltation and biofouling were selected after consultation with the design team. SvR Design and Washington State University representatives should review the assumptions regarding the expected level of maintenance and influent control and confirm the appropriateness of the suggested

correction factors. Using the correction factor of 6.0, the recommended long-term infiltration rates would be about 0.006, 0.025, and 0.004 inches per hour for test pits TP-1, TP-2, and TP-4, respectively.

Based on the conditions observed in the explorations, the results of the PIT investigations, and application of the correction factor of 6, we recommend assuming a long-term infiltration rate of 0.006 inches per hour. It should be noted that actual infiltration rates may vary from those determined by the PIT investigation due to many factors, such as the degree of soil saturation, disturbance of the soil during construction, and the level of soil compaction.

POROUS PAVEMENT DESIGN

We understand that the porous asphalt pavement that will be installed on the WSU Research and Extension Center will be utilized as a research tool. An impermeable membrane will be installed under a portion of the porous pavement. In these areas, horizontal drains will be installed to route the stormwater out of the porous pavement drainage course.[1] The drains will be installed at the approximate depth of frost penetration. The horizontal drains will prevent water from wicking up through the porous pavement section. Ports will be installed at various locations within the pavement section to allow for the collection of stormwater samples for analytical testing.

FROST DEPTH

We understand that the horizontal drains will be installed at or below the maximum depth of frost penetration. The frost depth is dependent on the composition of the soil closest to the proposed final grade. For this project, the near-surface soil is anticipated to consist primarily of the porous pavement and reservoir base course. According to the Washington State Department of Transportation (WSDOT) *Pavement Guide* (WSDOT 2008a), the maximum depth of frost penetration (coarse-grained soils) in the project area is on the order of 20 to 25 inches. During the winters of 1949 and 1950, the frost depth measured by WSDOT in the Puyallup area varied from between 15 and 20 inches. We recommend assuming a maximum frost depth of 20 inches for this project. The frost depth should be measured from the top of the porous pavement.

SUBGRADE STRENGTH

Assuming the porous pavement section does not exceed 4 ft, the worst case subgrade soil at the site is anticipated to be the recessional lacustrine deposits which were encountered in test pit TP-1

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[1] Due to the low design infiltration rate, we recommend that horizontal drains also be installed in areas where impermeable membrane is not installed.

advanced near the administration building. A representative sample of the recessional lacustrine deposits encountered in test pit TP-1 was submitted to Analytical Resources, Inc. (ARI) for modified Proctor (ASTM D1557) and CBR testing (ASTM D1883). The results of the modified Proctor testing and CBR testing is summarized in the following table. The modified Proctor and CBR test results are included as an attachment to this technical memorandum.

MODIFIED PROCTOR TEST RESULTS SUMMARY

Test Pit Designation	Sample Depth (ft)	Sample Composition	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	CBR Value[1] (%)
TP-1	2½ to 3	Clayey SILT (Recessional Lacustrine)	106.5	19.8	0.75

Notes:

(1) CBR value for subgrade compacted to 90 percent of the maximum dry density as determined by ASTM D1557.

For pervious pavement to function properly, the subgrade soil is generally not moisture conditioned and compacted to 95 percent of the maximum dry density, as typically required with standard pavement sections. Consequently, we utilized a reduced CBR value of 0.75 percent in the design of the porous concrete pavement section. This CBR value corresponds to the subgrade soil having a density equal to 90 percent of the maximum dry density determined by ASTM D1557. Using the relationship provided in WSDOT *Pavement Guide*, $M_r = 2{,}555*CBR^{0.64}$, a CBR of 0.75 percent is approximately equivalent to a M_r value (resilient modulus) of 2,000 psi.

The alluvial deposits encountered in test pits TP-3 and TP-5 are likely to be present below the fill at the location of test pits TP-2 and TP-4 and anticipated to have similar subgrade support characteristics as the recessional lacustrine deposits. We utilized a resilient modulus value of 2,000 psi when designing the pavement sections in the area located to the west of Kalkus Hall and the D.F. Allmendinger Center.

HEAVING GROUND

As part of the CBR testing, ARI soaked the soil (recessional lacustrine deposits) excavated from test pit TP-1 in a water bath for 72 hours. When exposed to water over the duration of the soaking period, the tested specimen swelled by as much as 4 percent. Based on these observations, it is likely that the recessional lacustrine deposits encountered near the Administration Building will swell when exposed to a constant supply of water. In the Pacific Northwest, swelling soils are typically mitigated by removing them to a depth of at least 24 inches below the proposed improvements and then replacing the excavated

soil with import structural fill. Placement of the reservoir base course should provide the adequate overburden to prevent swelling of the subgrade soil encountered near the Administration Building.

DESIGN PAVEMENT SECTION

Porous pavement should consist of 2½ inches of asphalt concrete pavement over a minimum of 18 inches of reservoir base. Alternatively, permeable pavers could be utilized instead of porous pavement.[2] The minimum requirement of reservoir base course is the minimum thickness required for structural support of the asphalt. If existing granular fill is present below the porous pavement section (i.e. to the west of the Kalkus Hall and the D.F. Allmendinger Center), the thickness of the reservoir base course could be decreased, so long as the combined thickness of the existing granular fill and reservoir base course is 18 inches. The thickness of the reservoir base course may need to be increased to accommodate the storage of groundwater until it has infiltrated or other factors. The pavement section provided above assumes a 20-year pavement design life and a maximum of 10 heavy vehicles per week (design Equivalent Single Axel Load of 10,400).

Aggregate for porous pavement should be relatively uniform and have a low percentage of fines (percentage of particles by weight passing the U.S. No 200 sieve). Various different aggregate gradations have been utilized for porous pavement. The National Asphalt Pavement Association (2008) recommends the following gradation for porous pavements utilized in parking areas.

TYPICAL POROUS PAVEMENT AGGREGATE GRADATION

Sieve Size	Percent Finer (By Weight)
½"	99 – 100
3/8"	90 – 100
U.S. No. 4	22 - 40
U.S. No. 8	5 – 15
U.S. No. 200	1 - 5

A stiff asphalt binder, such as PG70-22, is usually utilized for porous pavement. The binder should be between 5½ and 6 percent of the pavement section, by weight.

The reservoir base course material should consist of a clean, uniformly graded aggregate such as AASHTO Grading No. 57, as specified in Section 9-03.1(4)C of the *WSDOT Standard Specifications for Road, Bridge, and Municipal Construction* (WSDOT 2008b). AASHTO Grading No. 1, AASHTO Grading No. 2, or AASHTO Grading No. 3 could also be utilized as the reservoir base course, however,

[2] Permeable pavers should be installed in accordance with the manufacturers recommendations.

these materials are not specified in the 2008 WSDOT *Standard Specifications,* and are anticipated to be more difficult to obtain. The gradation of AASHTO Grading No. 57 aggregate is provided in the table below.

RESERVOIR BASE COURSE – AASHTO GRADING NO. 57 GRADATION

Sieve Size	Percent Finer (By Weight)
1½"	100
1"	95 – 100
½"	25 – 60
U.S. No. 4	0 – 10
U.S. No. 8	0 – 5

The reservoir base course material should be locked into its most compact condition with several passes of a large smooth drummed vibratory roller without the use of vibration.

AASHTO Grading No. 57 aggregate has been utilized as the "choker" course in several porous pavement projects in Oregon and could be used if a more coarse-grained reservoir base course is utilized (i.e. AASHTO Grading No. 1, AASHTO Grading No. 2, or AASHTO Grading No. 3) . The choker course should be a maximum of 2 inches thick. If AASHTO Grading No. 57 is utilized as the reservoir base course, a choker course will not be required.

To provide separation of the native subgrade and the reservoir base course material, a non-woven geotextile should be placed between the non-compacted subgrade and the reservoir base course. If the non-woven geotextile is utilized in areas underlain by silt (i.e. recessional lacustrine deposits and or alluvium), the non-woven geotextile should be Mirafi 1100N, or equivalent[3]. In areas where the non-woven geotextile will be underlain by existing granular fill (i.e. in the existing parking lot area to the west of Kalkus Hall and D.F. Allmendinger Hall), the non-woven geotextile should be Mirafi 180N, or equivalent. The non-woven geotextile should either be overlapped a minimum of 2 ft along all of the transverse and longitudinal joints or the seams should be sown together. In order to minimize the potential for damaging the subgrade, we recommend that a minimum 12-inch thick layer of the reservoir base course material be placed over the geotextile prior to compaction. Turning of construction vehicles over the first lift of prepared fill should be avoided.

[3] The geotextile underneath the porous pavement will likely not be in intimate contact with the soil and dynamic or pulsating loading conditions may create large hydraulic gradients. This may prohibit the bridging of soil particles behind the geotextile and the geotextile will be required to retain even finer particles. Consequently, we recommend the use of the Mirafi 1100N geotextile in areas underlain by silt. The Mirafi 1100N geotextile has a smaller apparent opening size, when compared to the Mirafi 180N.

USE OF THIS TECHNICAL MEMORANDUM

This technical memorandum was prepared for the exclusive use of SvR Design Co. and Washington State University for specific application to the determination of the design infiltration rate for the porous pavement and bioretention facilities at the Washington State University – Research and Extension Center located at 7612 Pioneer Way East in Puyallup, Washington. The use by others, or for purposes other than intended, is at the user's sole risk. The findings, recommendations, and opinions presented herein are based on conditions observed in test pits completed for the project. Within the limitations of scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this technical memorandum were prepared in accordance with generally accepted professional geotechnical engineering principles and practices in this area at the time this report was prepared. We make no other warranty, either express or implied.

Given the geologic setting, there may be some variation in subsurface soil and groundwater conditions at the site, and the nature and extent of the variations may not become evident until construction. Accordingly, a contingency for unanticipated conditions should be included in the construction budget and schedule.

We appreciate the opportunity to provide geotechnical services on this project and look forward to continued involvement on the project. If you have any questions or comments, or if we may be of further service, please call us at 253-926-2493.

REFERENCES

National Asphalt Pavement Associations (NAPA). 2008. *Porous Asphalt Pavements for Stormwater Management – Design, Construction and Maintenance Guide.* Information Series 131.

Troost, K.G. in review. *Draft Geologic Map of the Puyallup 7.5-Minute Quadrangle, Washington.* U.S. Geological Survey Miscellaneous Field Investigation, scale 1:24,000.

WSDOE. 2005. *Stormwater Management Manual for Western Washington.* Volume III. Publication Number 05-10-31. Washington State Department of Ecology. September.

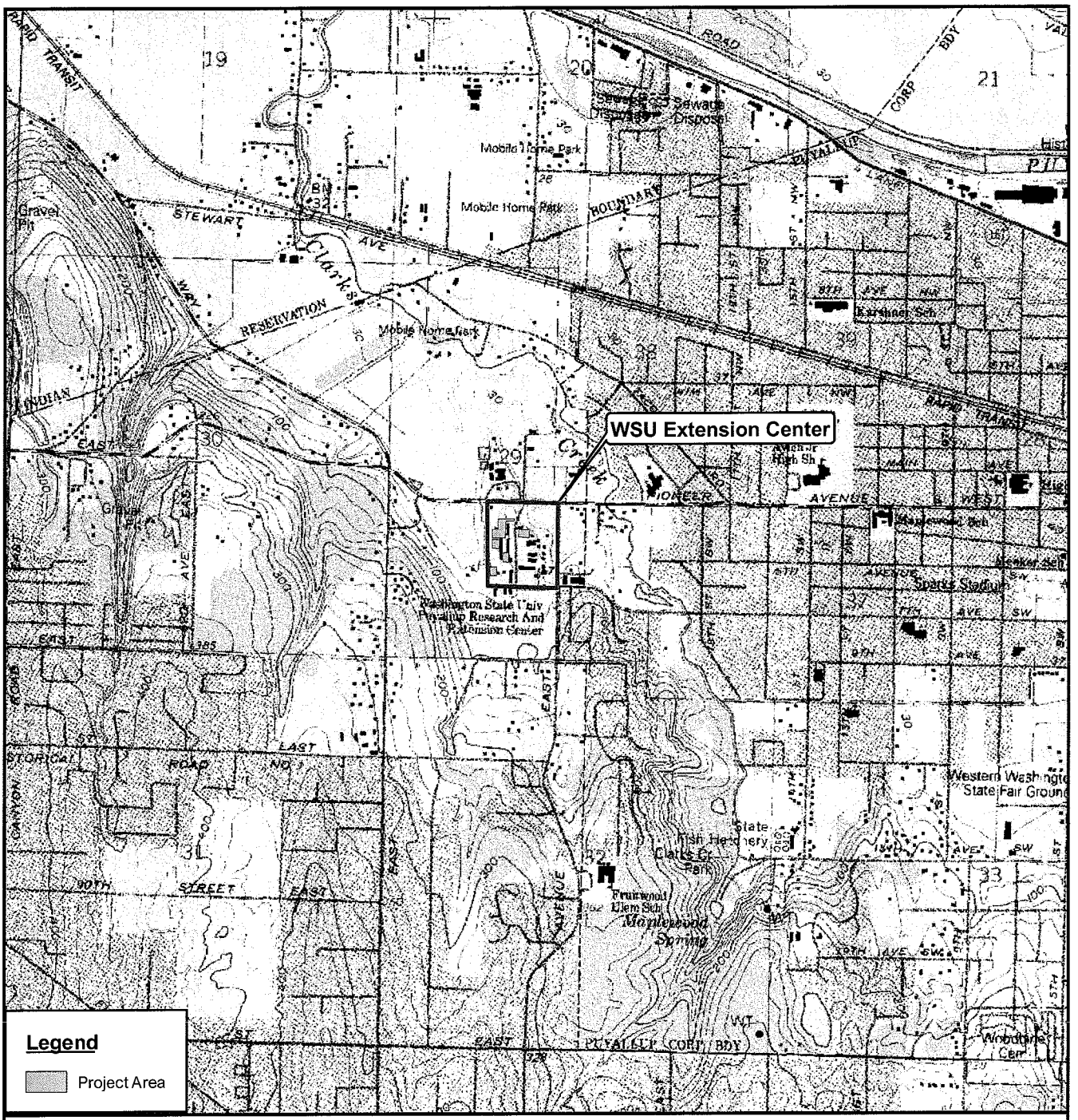
WSDOT. 2008a. *WSDOT Pavement Guide.* URL http://training.ce.washington.edu/WSDOT/. Accessed October 23.

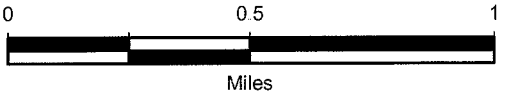
WSDOT. 2008b. *Standard Specifications for Road, Bridge, and Municipal Construction.* Washington State Department of Transportation.

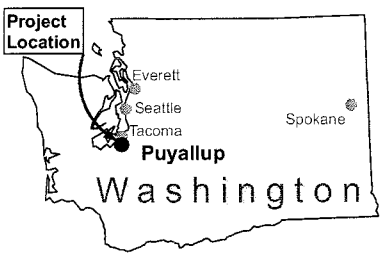
Attachments: Figure 1 – Vicinity Map
Figure 2 – Site and Exploration Plan
Figure 3 – Soil Classification System and Key
Figures 4 through 6 – Log of Test Pits

Figure 7 – Pilot Infiltration Test Configuration
Figure 8 – TP-1 Pilot Infiltration Test Results
Figure 9 – TP-2 Pilot Infiltration Test Results
Figure 10 – TP-4 Pilot Infiltration Test Results

Analytical Resources, Inc. Modified Proctor and CBR Test Results







Data Source: ESRI 2006

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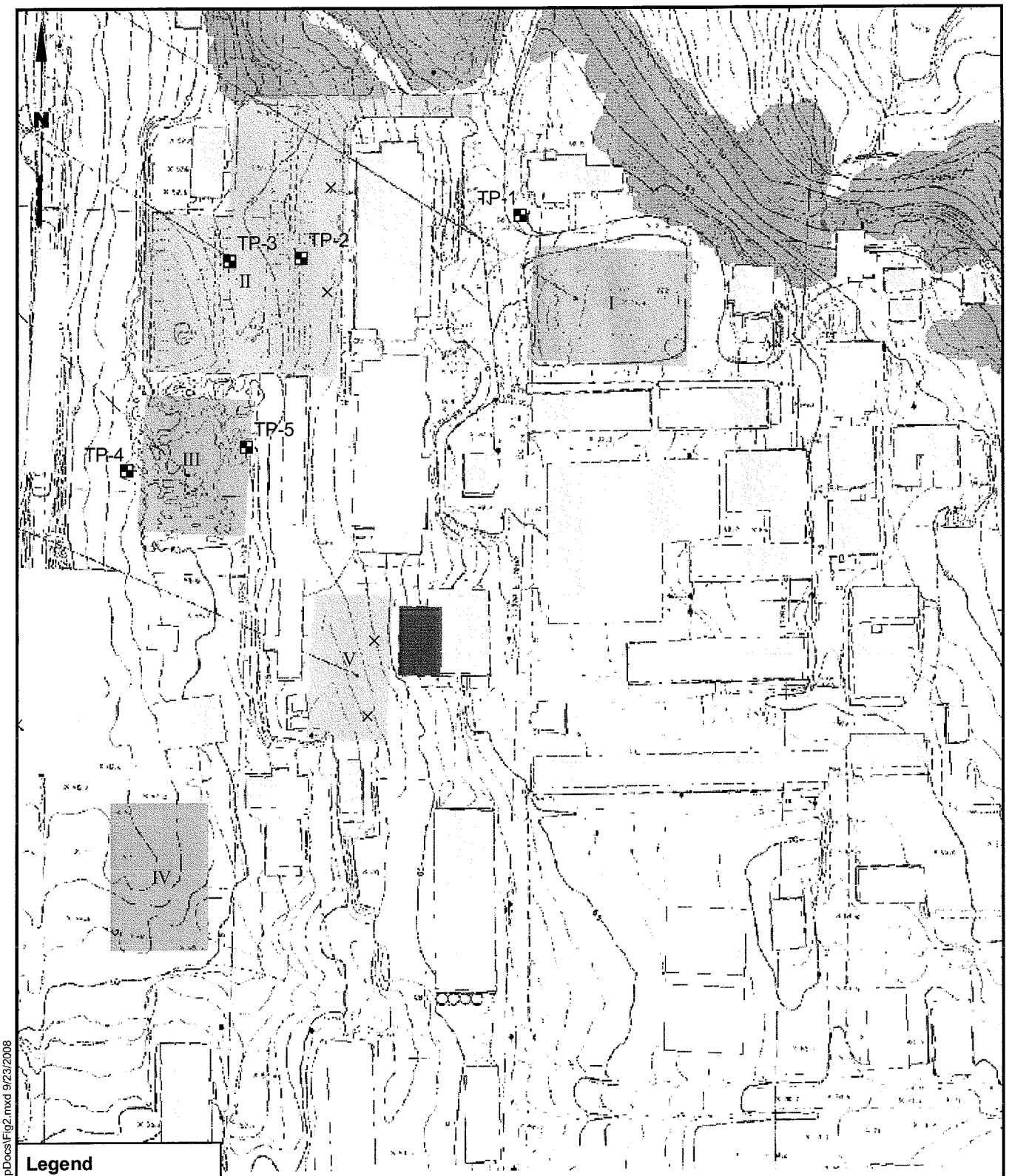
WSU-Puyallup Stormwater Retrofit Monitoring Project Puyallup, Washington	**Vicinity Map**	Figure **1**



Legend

Test Pit Locations

0 125 250

Scale in Feet

Data Source: WSU LID Conceptual Drawing

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WSU-Puyallup
Stormwater Retrofit
Monitoring Project
Puyallup, Washington

Test Pit Monitoring Location Map

Figure
2

Soil Classification System

MAJOR DIVISIONS			GRAPHIC SYMBOL	USCS LETTER SYMBOL[1]	TYPICAL DESCRIPTIONS [2][3]
COARSE-GRAINED SOIL (More than 50% of material is larger than No. 200 sieve size)	GRAVEL AND GRAVELLY SOIL (More than 50% of coarse fraction retained on No. 4 sieve)	CLEAN GRAVEL (Little or no fines)		GW	Well-graded gravel; gravel/sand mixture(s); little or no fines
				GP	Poorly graded gravel; gravel/sand mixture(s); little or no fines
		GRAVEL WITH FINES (Appreciable amount of fines)		GM	Silty gravel; gravel/sand/silt mixture(s)
				GC	Clayey gravel; gravel/sand/clay mixture(s)
	SAND AND SANDY SOIL (More than 50% of coarse fraction passed through No. 4 sieve)	CLEAN SAND (Little or no fines)		SW	Well-graded sand; gravelly sand; little or no fines
				SP	Poorly graded sand; gravelly sand; little or no fines
		SAND WITH FINES (Appreciable amount of fines)		SM	Silty sand; sand/silt mixture(s)
				SC	Clayey sand; sand/clay mixture(s)
FINE-GRAINED SOIL (More than 50% of material is smaller than No. 200 sieve size)	SILT AND CLAY (Liquid limit less than 50)			ML	Inorganic silt and very fine sand; rock flour; silty or clayey fine sand or clayey silt with slight plasticity
				CL	Inorganic clay of low to medium plasticity; gravelly clay; sandy clay; silty clay; lean clay
				OL	Organic silt; organic, silty clay of low plasticity
	SILT AND CLAY (Liquid limit greater than 50)			MH	Inorganic silt; micaceous or diatomaceous fine sand
				CH	Inorganic clay of high plasticity; fat clay
				OH	Organic clay of medium to high plasticity; organic silt
	HIGHLY ORGANIC SOIL			PT	Peat; humus; swamp soil with high organic content

OTHER MATERIALS	GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
PAVEMENT		AC or PC	Asphalt concrete pavement or Portland cement pavement
ROCK		RK	Rock (See Rock Classification)
WOOD		WD	Wood, lumber, wood chips
DEBRIS		DB	Construction debris, garbage

NOTES:

1. USCS letter symbols correspond to symbols used by the Unified Soil Classification System and ASTM classification methods. Dual letter symbols (e.g., SP-SM for sand or gravel) indicate soil with an estimated 5-15% fines. Multiple letter symbols (e.g., ML/CL) indicate borderline or multiple soil classifications.
2. Soil descriptions are based on the general approach presented in the *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*, outlined in ASTM D 2488. Where laboratory index testing has been conducted, soil classifications are based on the *Standard Test Method for Classification of Soils for Engineering Purposes*, as outlined in ASTM D 2487.
3. Soil description terminology is based on visual estimates (in the absence of laboratory test data) of the percentages of each soil type and is defined as follows:

Primary Constituent:	> 50% - "GRAVEL," "SAND," "SILT," "CLAY," etc.
Secondary Constituents:	> 30% and ≤ 50% - "very gravelly," "very sandy," "very silty," etc.
	> 15% and ≤ 30% - "gravelly," "sandy," "silty," etc.
Additional Constituents:	> 5% and ≤ 15% - "with gravel," "with sand," "with silt," etc.
	≤ 5% - "trace gravel," "trace sand," "trace silt," etc., or not noted

10/29/08 Y:\1130\R\REPORT\1130001.GPJ SCS WSDOT 1OF2

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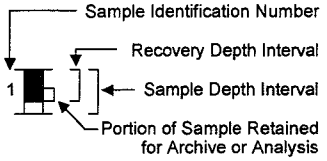
WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	Soil Classification System and Key	Figure 3 (1 of 2)

Drilling and Sampling Key

SAMPLER TYPE

Code	Description
a	3 25-inch O.D., 2.42-inch I.D Split Spoon
b	2 00-inch O.D., 1 50-inch I.D Split Spoon
c	Shelby Tube
d	Grab Sample
e	Single-Tube Core Barrel
f	Double-Tube Core Barrel
g	Other - See text if applicable
1	300-lb Hammer, 30-inch Drop
2	140-lb Hammer, 30-inch Drop
3	Pushed
4	Rotosonic
5	Air Rotary (Rock)
6	Wash Rotary (Rock)
7	Other - See text if applicable

SAMPLE NUMBER & INTERVAL



Field and Lab Test Data

Code	Description
PP = 1.0	Pocket Penetrometer, tsf
TV = 0.5	Torvane, tsf
PID = 100	Photoionization Detector VOC screening, ppm
W = 10	Moisture Content, %
D = 120	Dry Density, pcf
-200 = 60	Material smaller than No. 200 sieve, %
GS	Grain Size - See separate figure for data
AL	Atterberg Limits - See separate figure for data
VST	Vane Shear Test
GT	Other Geotechnical Testing
CA	Chemical Analysis

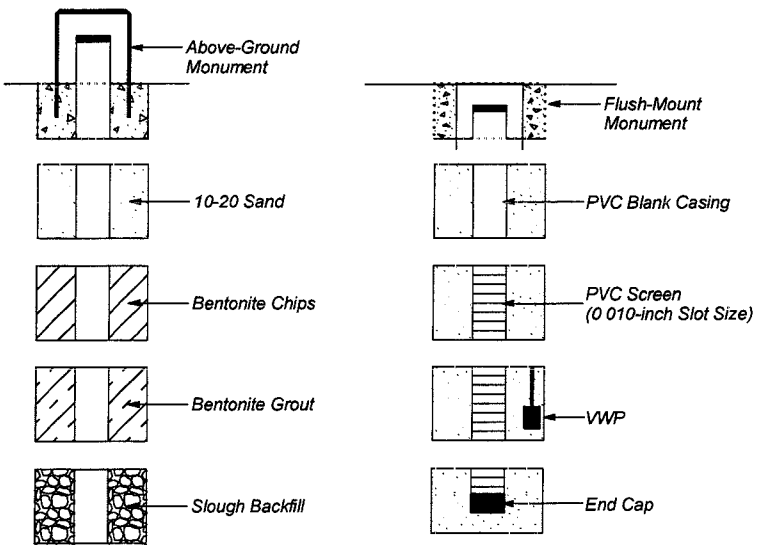
Groundwater

▽ Approximate water elevation at time of drilling (ATD)

▼ Approximate water elevation at other time(s). When multiple water levels are obtained other than ATD, only a representative range is shown. See text for additional information.

Note: Groundwater levels can fluctuate due to precipitation, seasonal conditions, and other factors.

Well Log Graphics



10/29/08 Y:\1130\R\REPORT\1130001.GPJ SCS WSDOT 2OF2

LANDAU ASSOCIATES

WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	Soil Classification System and Key	Figure 3 (2 of 2)

TP-1

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Measured	
0					ML	(TOPSOIL) 0.25	Groundwater not encountered
					ML	Brown-gray with iron-oxide staining, clayey SILT (stiff, wet) (RECESSIONAL LACUSTRINE)	
2	S-1	d					
	S-2	d	CBR				
4	S-3	d				4.5	
6							
8							

Test Pit Completed 09/15/08
Total Depth of Test Pit = 4.5 ft

TP-2

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Measured	
0					AC	Asphalt Concrete Pavement (2 3/4" thick) 0.25	Groundwater not encountered
	S-1	d			GP	Brown, sandy GRAVEL (medium dense, moist) 1	
	S-2	d			GP-GM	(FILL) 2	
2	S-3	d			ML	Gray, sandy GRAVEL with silt (medium dense, moist) 2.25	
						Dark-brown, gravelly, sandy SILT (stiff, wet)	
4							
6							
8							

Test Pit Completed 09/17/08
Total Depth of Test Pit = 2.3 ft

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

1130001.01 10/29/08 Y:\1130\R\REPORT\1130001.GPJ TEST PIT LOG

LANDAU ASSOCIATES

WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	Log of Test Pits	Figure 4

TP-3

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Measured
0					AC	Asphalt Concrete Pavement (2 1/2" thick) 0.2
	S-1	d			SP-SM	Brown, gravelly, fine to coarse SAND with silt (medium dense, moist to wet) **(FILL)**
2						3
	S-2	d			SP-SM	Brown, fine to coarse SAND with gravel and silt (medium dense, moist to wet) 4
4	S-3	d			ML	Dark-brown SILT with sand and gravel (soft to medium stiff, wet) **(ALLUVIUM)** 5
	S-4	d			ML	Blue-gray with iron-oxide staining SILT with organics (soft to medium stiff, wet) 5.25
6						
8						

Test Pit Completed 09/15/08
Total Depth of Test Pit = 5.3 ft.

Slight Seepage

TP-4

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Measured
0					GM	Brown, silty, sandy GRAVEL (medium dense, moist) **(FILL)**
	S-1	d				
2	S-2	d				2.5
					SM	Brown, very silty, fine to coarse SAND with organics (medium dense, wet) 3.5
	S-3	d				
4	S-4	d			ML	Blue-gray, sandy SILT with gravel and trace organics (very stiff, wet) 4
	S-5	d			SP-SM	Brown, fine to medium SAND with silt (medium dense, moist) 4.5
6						
8						

Test Pit Completed 09/17/08
Total Depth of Test Pit = 4.5 ft.

Groundwater not encountered.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

1130001.01 10/29/08 Y:\1130\R\REPORT\1130001.GPJ TEST PIT LOG

LANDAU ASSOCIATES

WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	Log of Test Pits	Figure 5

TP-5

SAMPLE DATA			SOIL PROFILE			GROUNDWATER
Depth (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Rubber-tired Backhoe Ground Elevation (ft): Not Measured
0					SM	Brown, silty, gravelly, fine to coarse SAND (medium dense, moist) **(FILL)**
2	S-1	d				2.5
					GM	Brown and gray mixed, sandy, very silty GRAVEL (medium dense, wet)
4	S-2	d				4.75
	S-3	d			SP-SM	Brown-gray, sandy GRAVEL with silt (medium dense, wet)
6						6.33
	S-4	d			ML	Dark brown SILT with abundant organics (soft, wet) **(ALLUVIUM)**
						7
8						

Slight Seepage

Test Pit Completed 09/15/08
Total Depth of Test Pit = 7.0 ft.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

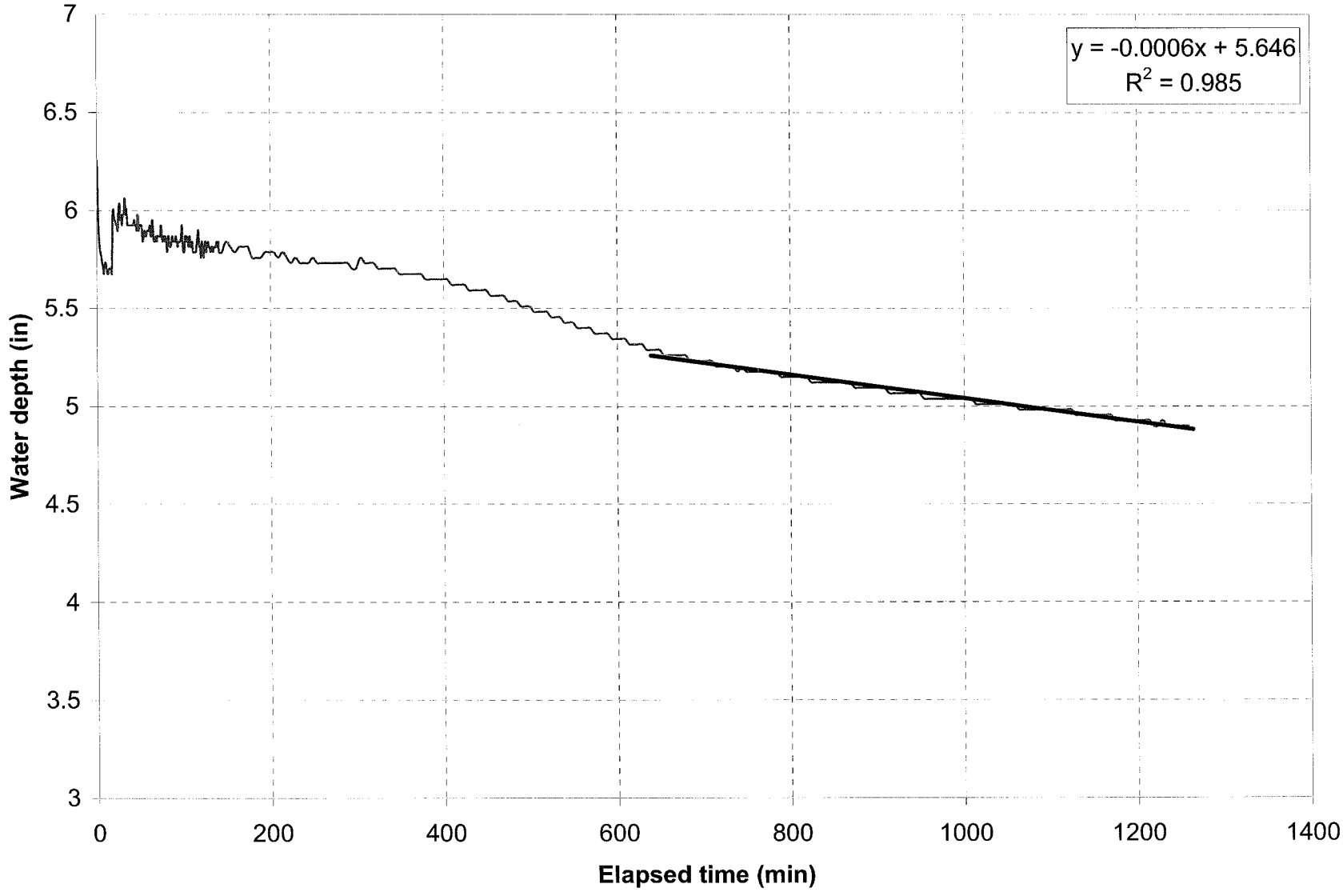
1130001.01 10/29/08 Y:\1130\R\REPORT\1130001.GPJ TEST PIT LOG

LANDAU ASSOCIATES

WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	Log of Test Pits	Figure 6

LANDAU ASSOCIATES

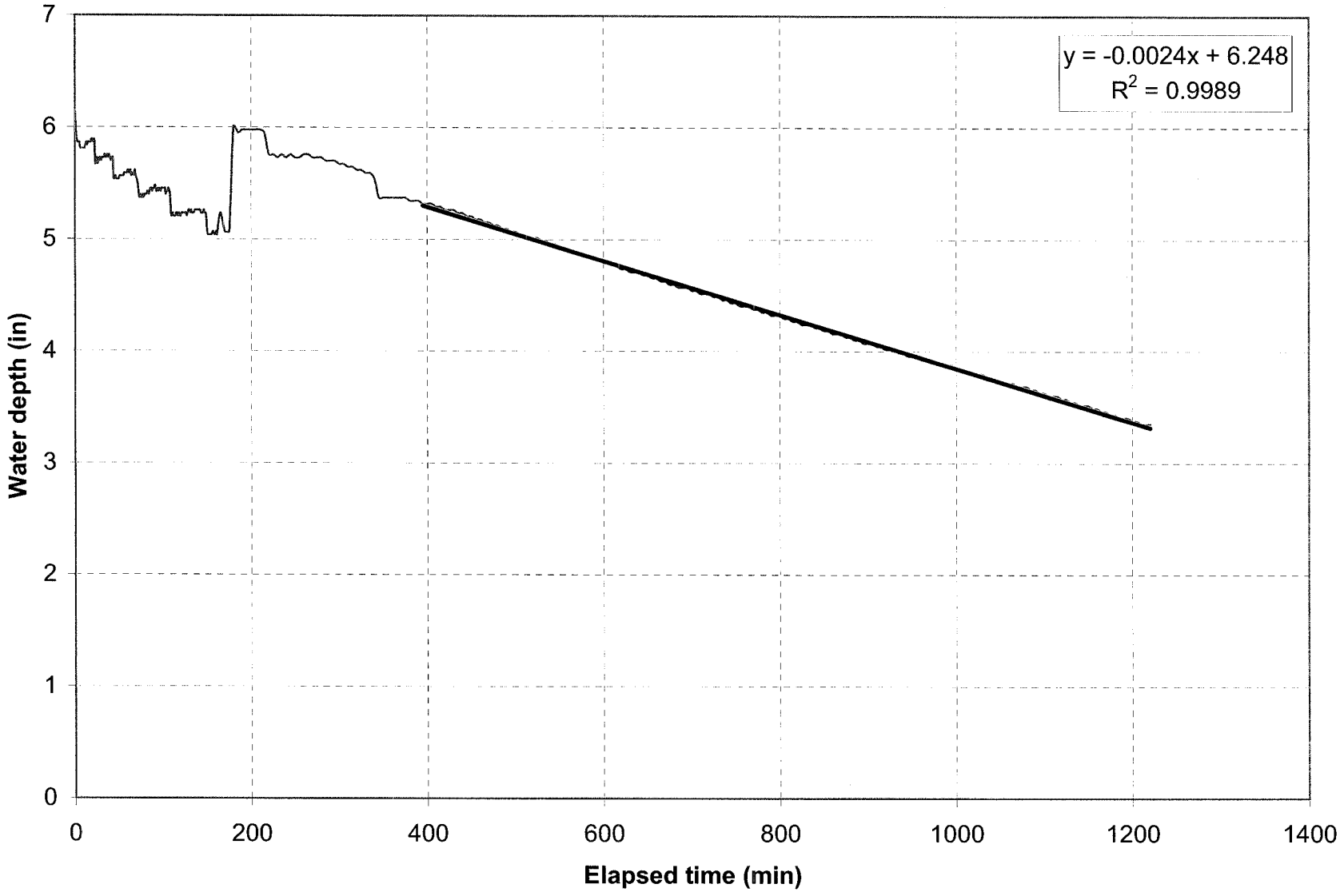
WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	**Pilot Infiltration Test Configuration**	Figure 7



LANDAU ASSOCIATES

WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	**TP-1 Pilot Infiltration Test Results**	Figure 8

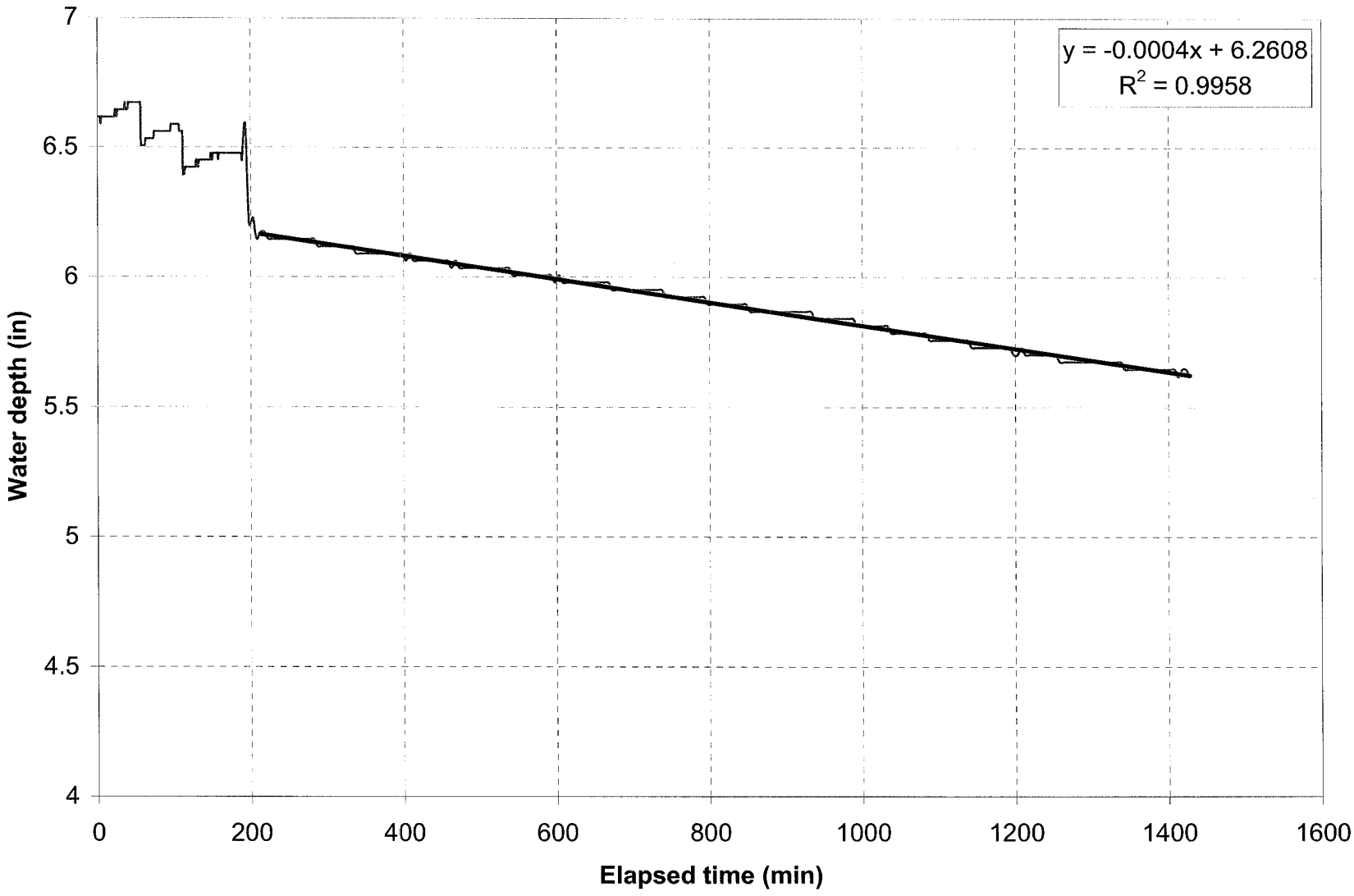
Source: S:\SHAREDOC\Example1.xls Sheet Title



LANDAU ASSOCIATES

WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	**TP-2 Pilot Infiltration Test Results**	Figure 9

Source: S:\SHAREDOC\Example1.xls Sheet Title



LANDAU ASSOCIATES

WSU Puyallup Research and Extension Center Stormwater Retrofit Evaluation Puyallup, Washington	**TP-4 Pilot Infiltration Test Results**	Figure 10

Analytical Resources, Incorporated
Analytical Chemists and Consultants

October 21, 2008

Mr. Brian Bennetts, PE
Landau Associates, Inc.
950 Pacific Avenue
Suite 515
Tacoma WA 98402

Subject: WSU Puyallup
ARI Project No. NR95

Dear Mr. Bennetts;

The following pages provide the information you requested. Please call me to discuss any questions, or comments you may have on the data or its presentation.

Best Regards,
Analytical Resources Incorporated

Harold Benny

Harold Benny
Geotechnical Division Manager
206-695-6246
haroldb@arilabs.com

Enclosures

cc: File NR95

Analytical Resources, Incorporated
Analytical Chemists and Consultants

Client: Landau Associates, Inc.	Project No.: NR95
Client Project: WSU Puyallup	

Case Narrative

1. One sample of soil was received for Modified Proctor and CBR testing on September 30, 2008.
2. The modified Proctor test was run according to ASTM D1557, method C. Rock corrections were not required; there was no oversize material in the sample.
3. The CBR test was run according to ASTM D1883. The soil was compacted at three compactive efforts; 45 blows per layer, 25 blows per layer and 10 blows per layer.
4. The specimens soaked for a full 72 hours, and they swelled a great deal.
5. The data is provided in summary tables and plots.
6. There were no other noted anomalies in this project.

Approved by: Harold Berry Date: 10/21/08
Title: Geotechnical Division Manager

4611 South 134th Place, Suite 100 • Tukwila WA 98168 • **206-695-6200** • **206-695-6201** fax

LANDAU ASSOCIATES

Seattle (Redmond) (425) 778-0907
☑ Tacoma (253) 926-2493
☐ Spokane (509) 327-9737
☐ Portland (Tigard) (503) 443-6010
☐ _____

NR95

Date 9/30/08
Page 1 of 1

Chain-of-Custody Record

Project Name: WSU Puyallup Infiltration
Project No.: 1130001.010.011
Project Location/Event: WSU Puyallup
Sampler's Name: Brian Bennetts
Project Contact: Brian Bennetts
Send Results To: Brian Bennetts

Turnaround Time
☑ Standard
☐ Accelerated
☐ _____

Testing Parameters

Sample I.D.	Date	Time	Matrix	No. of Containers	Mod. Fied Proctor	CBR
Pit 1	9/19		Soil	2		

Observations/Comments

___ Allow water samples to settle, collect aliquot from clear portion

NWTPH-Dx:
___ run acid wash/silica gel cleanup
___ run samples standardized to _____ product

___ Analyze for EPH if no specific product identified

VOC/BTEX/VPH (soil):
___ non-preserved
___ preserved w/methanol
___ preserved w/sodium bisulfate
___ Freeze upon receipt

___ Dissolved metal water samples field filtered

Other _____

Special Shipment/Handling or Storage Requirements

Method of Shipment

Relinquished by	Received by	Relinquished by	Received by
Signature: B.A. Bennetts	Signature: Erik Rasarda	Signature	Signature
Printed Name: Brian A. Bennetts	Printed Name:	Printed Name	Printed Name
Company: Landau Associates	Company: DRF	Company	Company
Date: 9/30/08 Time: 9:15	Date: 09/30/08 Time: 9:14	Date ___ Time ___	Date ___ Time ___

WHITE COPY - Project File YELLOW COPY - Laboratory PINK COPY - Client Representative

Rev 4/01

08-25905

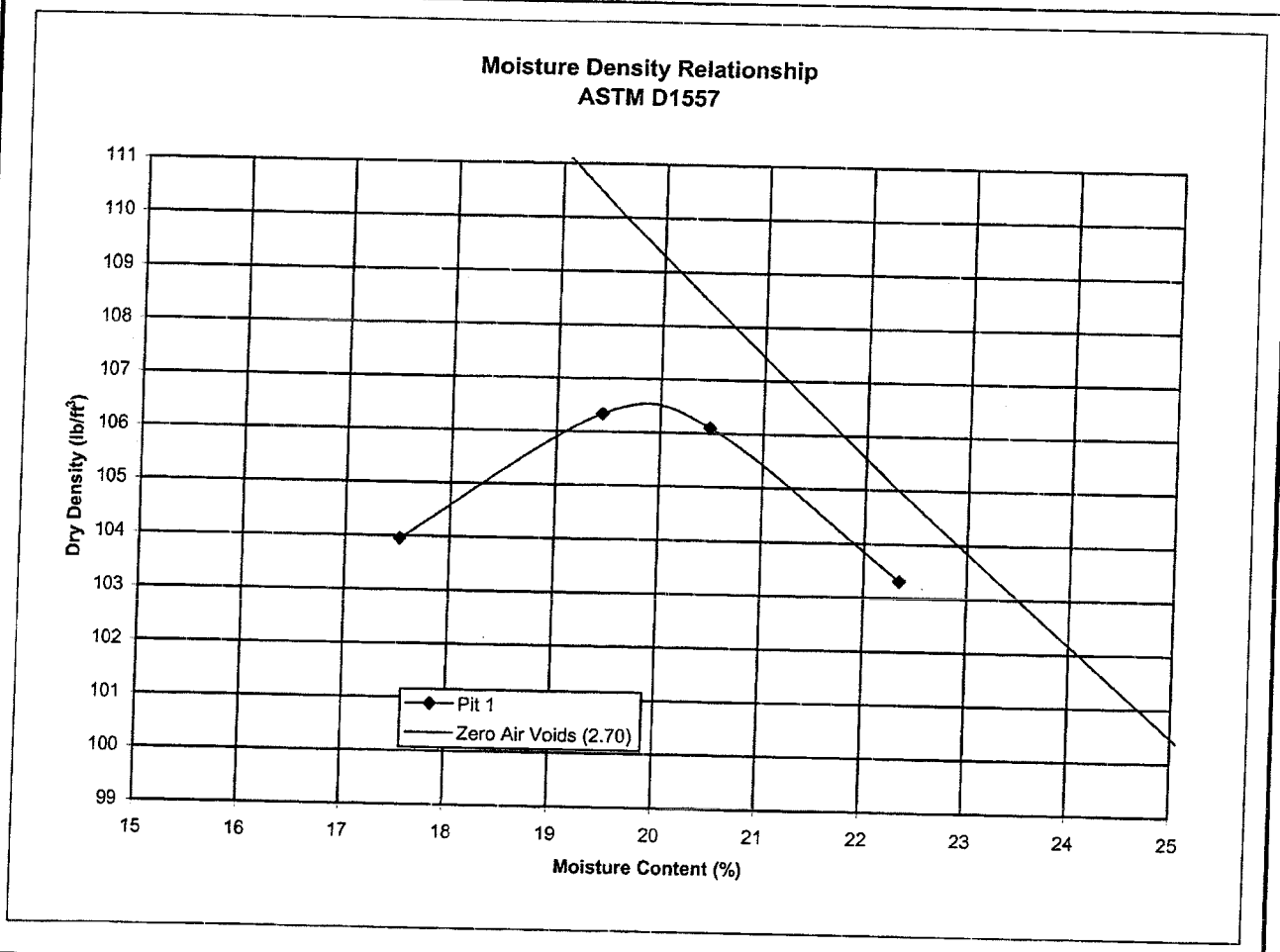
Moisture Density Relationship
ASTM D-1557, Method C

Client:	Landau Associates, Inc.	Date:	October 21, 2008
Project:	WSU Puyallup		
Project No.:	1130001.010.011		
Sample ID:	NR95		

	Standard	Corrected
Optimum Moisture Content	19.8 %	NA %
Maximum Density	106.5 lb/ft^3	NA lb/ft^3

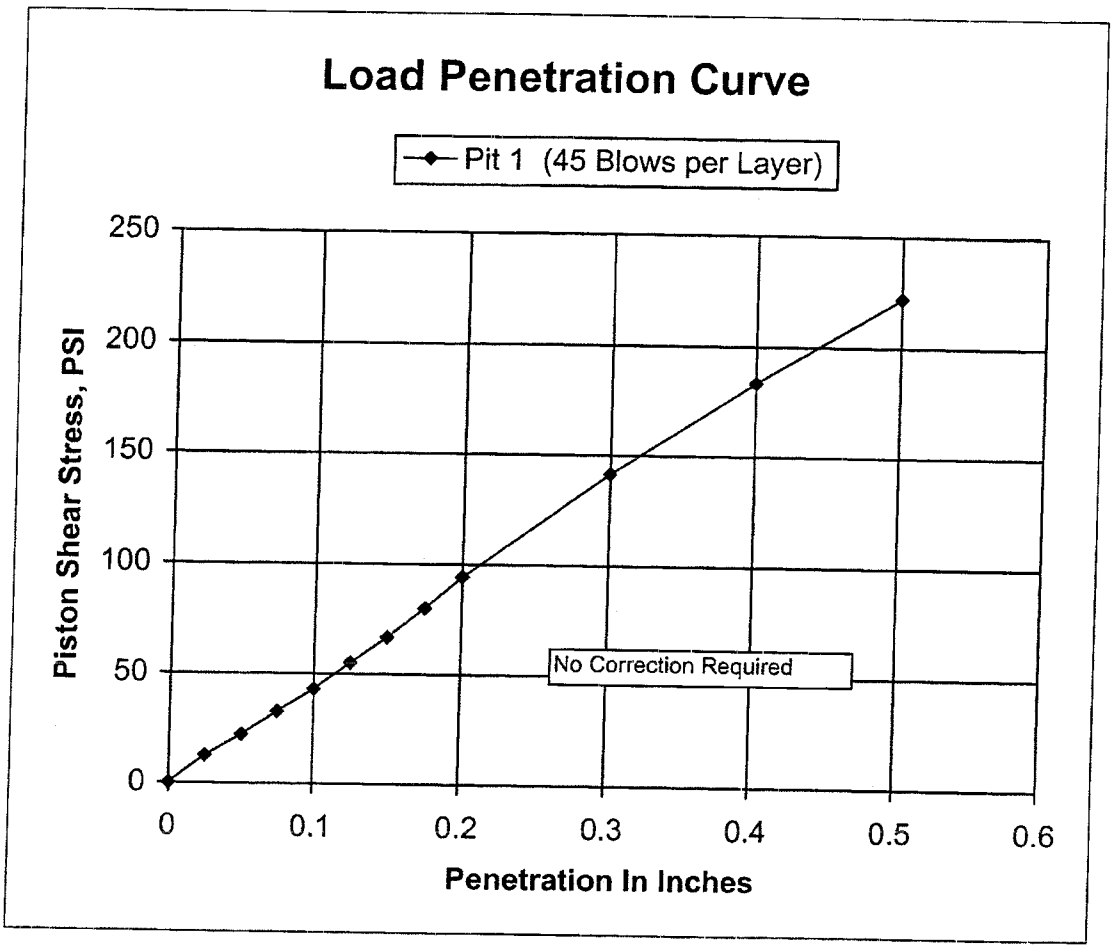
Percent retained on the 3/4 inch sieve	0.0	Rock correction required?	No

Note: The plot shows as-tested data (material greater than 3/4" removed).



If required, the Rock Correction is performed according to ASTM D4718

Landau Associates, Inc
WSU Puyallup



Bearing Ratio at 0.1 Inch Penetration	4.3
Bearing Ratio at 0.2 Inch Penetration	6.3

Initial Dry Density, pcf	106.3
Initial Moisture Content, %	20.5
Percent Swell	2.7
Dry Density After Soak, pcf	103.5
Moisture Content After Soak, %	22.9
Moisture Content, Top 1 Inch After Test, %	29.3

NR95

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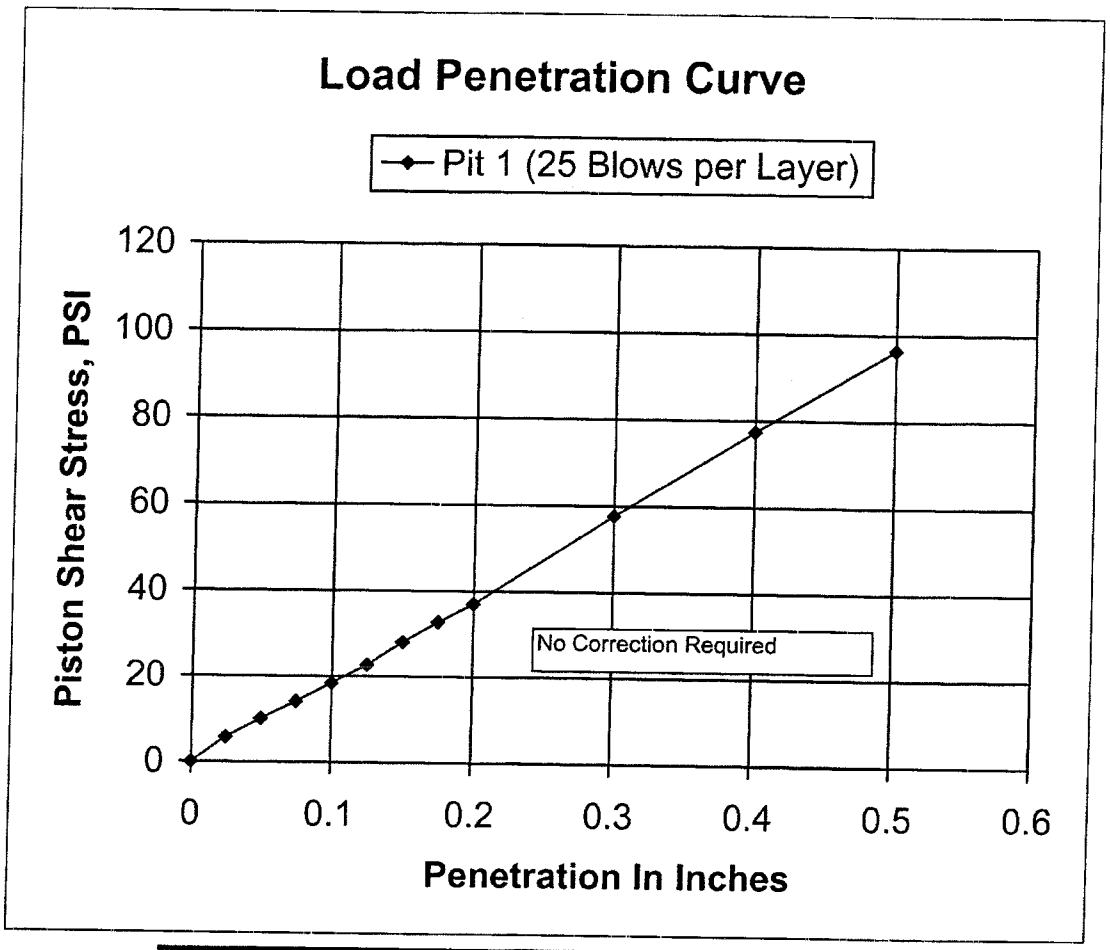
WSU Puyallup



Bearing Ratio at 0.1 Inch Penetration	1.8
Bearing Ratio at 0.2 Inch Penetration	2.5

Initial Dry Density, pcf	103.2
Initial Moisture Content, %	20.5
Percent Swell	3.9
Dry Density After Soak, pcf	99.3
Moisture Content After Soak, %	26.2
Moisture Content, Top 1 Inch After Test, %	31.5

NR95

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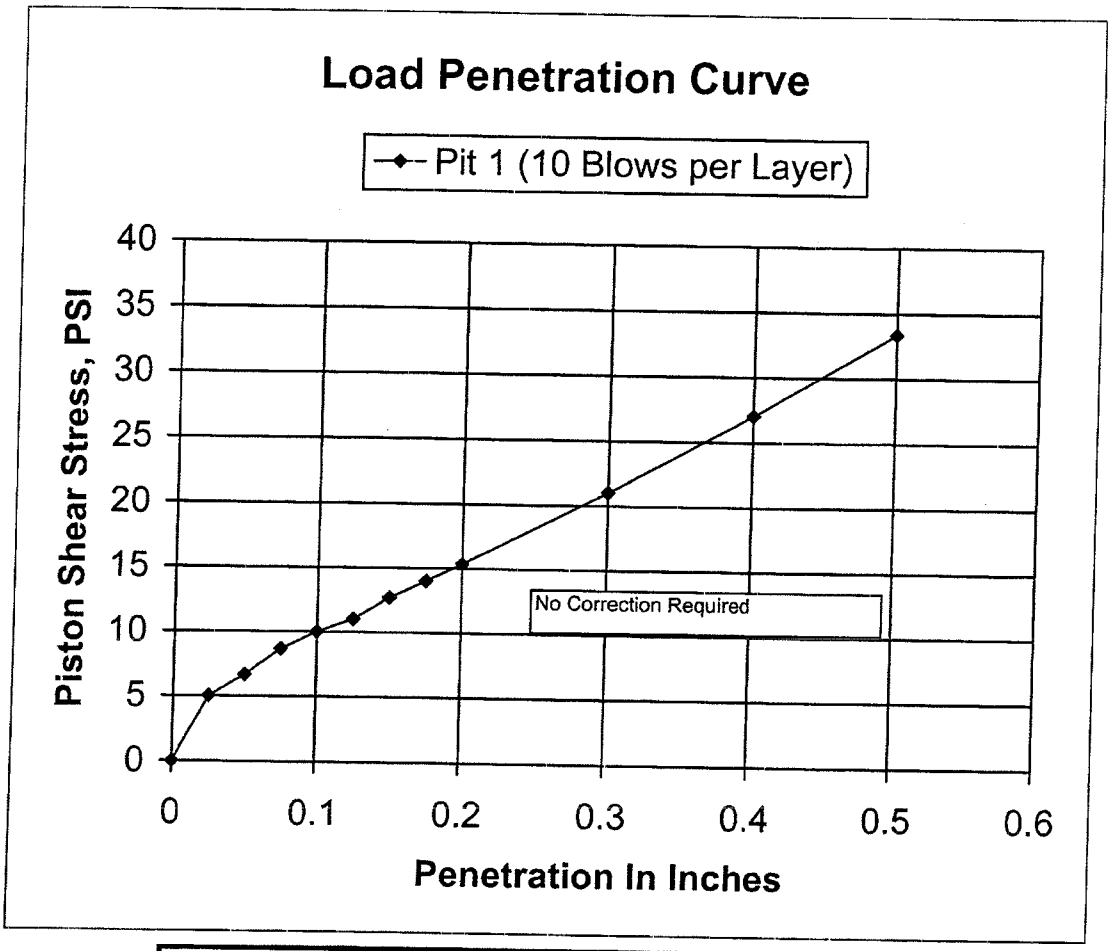
WSU Puyallup



Bearing Ratio at 0.1 Inch Penetration	1.0
Bearing Ratio at 0.2 Inch Penetration	1.0

Initial Dry Density, pcf	97.3
Initial Moisture Content, %	20.2
Percent Swell	0.3
Dry Density After Soak, pcf	97.0
Moisture Content After Soak, %	29.3
Moisture Content, Top 1 Inch After Test, %	34.3

NR95

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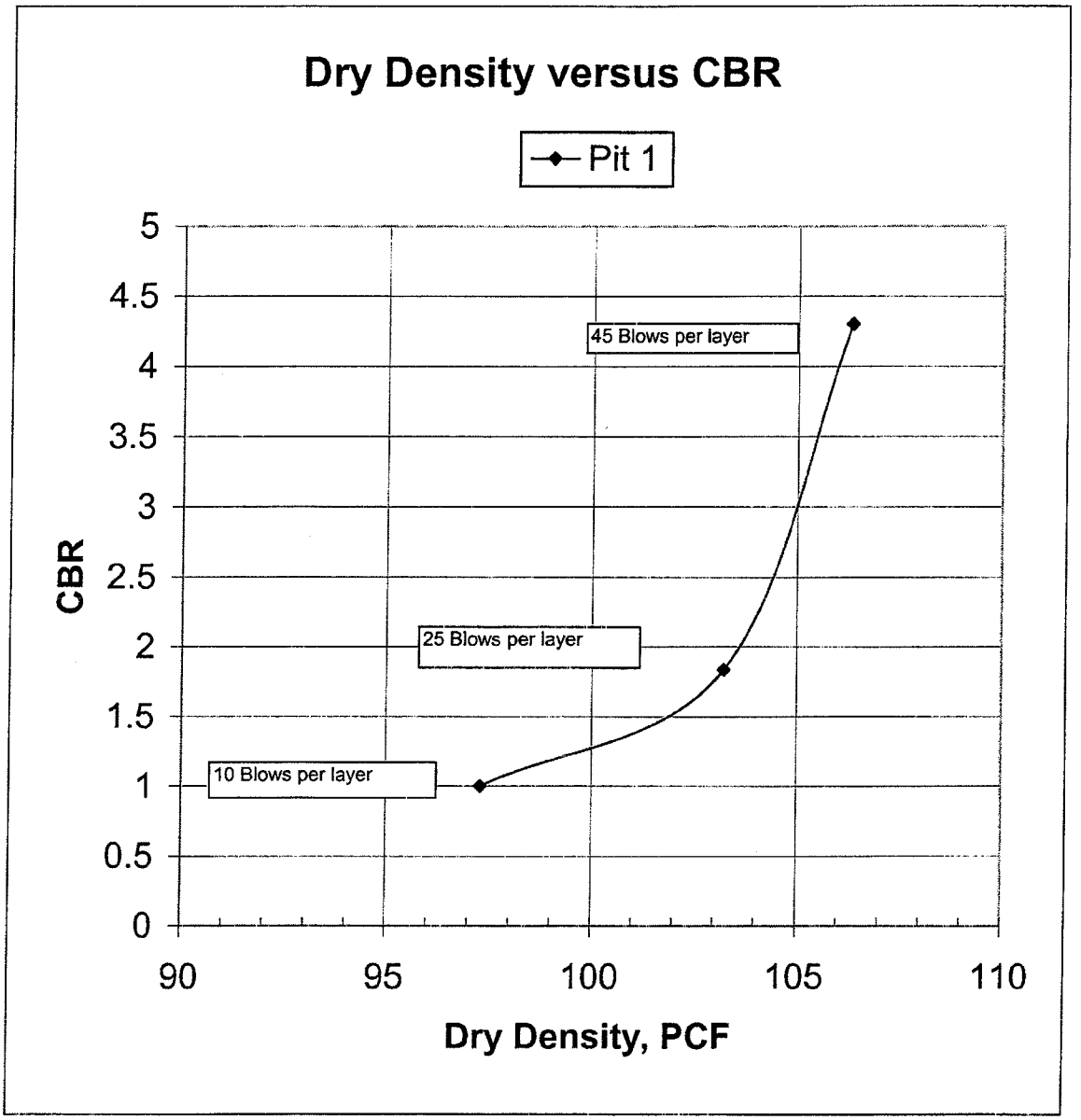
WSU Puyallup



NR95