

**LIQUEFACTION SUSCEPTIBILITY MAPPING FOR SELECTED URBAN AREAS IN
THE CENTRAL PUGET SOUND REGION, WASHINGTON**

Final Technical Report

Award Number 99HQGR0073

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ABSTRACT

We have developed and published a liquefaction susceptibility map for the greater Tacoma urban area of Pierce and King Counties, Washington. The study area consists of the Tacoma South and Puyallup 7.5-minute quadrangles and those portions of the Tacoma North, Gig Harbor, Steilacoom, and Poverty Bay quadrangles east of the Puget Sound. The map is intended to provide building officials, land-use planners, emergency-response personnel, engineering consultants, building owners and developers, insurance providers, and private citizens with an estimate of the likelihood the soil will liquefy as a result of strong earthquake shaking. Both printed and on-line versions of this map can be obtained through the Washington Division of Geology and Earth Resources web page (<http://www.dnr.wa.gov/geology/>).

In this report we have included digital databases of geotechnical boring data from both the Tacoma and Everett urban areas. The Tacoma geotechnical database was used in developing the liquefaction susceptibility map, as documented in the report that accompanies this map. We have also included the logs and laboratory test data for four geotechnical borings drilled into sandy Fraser age recessional outwash and lake deposits in the Tacoma area. Also included in this report is the results from a shallow shear wave refraction survey performed at one of the drill sites.

The liquefaction susceptibility map has been used by various local agencies with the cities of Tacoma, Puyallup, and Lakewood, and Pierce County, to assist in building permitting, land-use planning, and emergency management activities. This map has also been used in earthquake loss evaluations including the King/Pierce County Project Impact transportation vulnerability study and the Earthquake Engineering Research Institute (EERI) Seattle Fault scenario. The Tacoma area database was also used by other researchers for evaluation of lateral spread hazards for the EERI Seattle Fault scenario.

INTRODUCTION

This project was originally accepted for a two year continuation. The deliverables for the first year of the project were the completed and published liquefaction susceptibility map for the Tacoma urban area, completion of the geotechnical boring databases for the Tacoma and Everett areas, and geotechnical investigations of sandy glacial lake deposits in the Tacoma study area. The major deliverables for the second year were the publication of the Everett urban area liquefaction susceptibility map, and dissemination of the mapping products and databases developed during the project.

The schedule for the production of the Tacoma liquefaction susceptibility map was predicated on the completion and release of 1:24,000-scale geologic mapping that was underway at the time of the grant proposal submission. After receiving approval of the grant, we found that the completion date for this geologic mapping was substantially delayed for reasons beyond our control. We obtained extensions to this first year of the project, and were finally able to complete the required tasks and deliverables. However, by the time that this work was completed, two of the co-principal investigators were not available to continue the second year of the project. Consequently, this report only documents the work completed on the first year of the project.

TACOMA LIQUEFACTION SUSCEPTIBILITY MAP

The liquefaction susceptibility map presented as an attachment to this report was based on available 1:24,000-scale geologic mapping and the analysis of 502 geotechnical borings obtained from local government agencies, the Washington State Department of Transportation, and a database used in a previous liquefaction hazard mapping project in the Tacoma area. Six categories of geologic deposits found in the Tacoma urban area were assigned a relative liquefaction hazard rating determined through analysis of the geotechnical data and geological characterization. A sixth category composed of areas underlain by Holocene peat is also shown on the liquefaction susceptibility map.

A high liquefaction susceptibility was assigned to the fill area covering the former tide flats of Commencement Bay and recent (mid- to late Holocene) alluvial deposits of the Puyallup Valley and Chambers Creek drainage. Areas underlain by Holocene landslide debris and beach deposits were considered to have a low to moderate susceptibility based on results from previous

liquefaction hazard mapping in the Puget Sound region. Sandy glacial outwash and ice-contact deposits from the recession of the latest Pleistocene continental glaciation (~13,000 years ago) were also regarded as having a low to moderate liquefaction susceptibility. Quantitative evaluation of geotechnical data obtained from all other Pleistocene deposits indicated a very low susceptibility to liquefaction. Peat deposits cannot liquefy, but may be subject to significant strength loss and both transient and permanent vertical and lateral displacement caused by ground shaking. Also, sand layers interbedded with the peat deposits may be liquefiable.

The technical evaluation used in generating the liquefaction susceptibility map of the Greater Tacoma urban area is documented in an accompanying report. Both printed and on-line versions of this map and its technical report can be obtained through the Washington Division of Geology and Earth Resources web page (<http://www.dnr.wa.gov/geology/>). A digital copy of the liquefaction susceptibility map and report are included in Adobe Acrobat format (pdf file) in the compact disk included with this report.

TACOMA AND EVERETT GEOTECHNICAL BORING DATABASES

A database of 504 geotechnical boring data was developed for the technical evaluation used in producing the Tacoma area liquefaction susceptibility map (Palmer and others, 2003). The boring logs and test data were obtained from geotechnical reports collected from a variety of public agencies, including the Port of Tacoma, the Tacoma and Puyallup building departments, the Pierce County public works department, and the Washington State Department of Transportation. A similar geotechnical database of 358 borings was developed for the Everett urban area from reports collected from the Port of Everett, city of Everett and Snohomish County public works departments, and the Washington State Department of Transportation.

The database is presented in Access 2000 format and as a series of three comma-delimited ASCII text files on the compact disk included with this report. The database is composed of three tables: BoringInformation, BoringData, and BoringLocation. In general, each of the compiled reports contains a number of geotechnical borings drilled to investigate a particular site location. The geologic descriptions presented in the boring logs have been summarized and basic data (for example, SPT blow counts, groundwater depth, etc.) have been entered into the database. Additionally gradation and Atterberg limits test data, when available, have been entered into the database.

The table BoringInformation contains basic information regarding the geotechnical report and a particular boring documented in that report. Each geotechnical boring in this database is assigned a unique identifier within the field BoringID, which relates data in tables BoringInformation, BoringData and BoringLocation. A unique identifier within the field ReportID, which relates data in tables BoringInformation and BoringLocation, identifies each geotechnical report in this database. Latitude and longitude locations presented in table BoringLocation refer to the location of the individual borings and are based on the GRS80 ellipsoid. Appendix A provides an overview of the database structure, summarizing the names, data types, field size, and description of each field in the three tables. The number of records in each of the three tables is also provided in this appendix.

DRILLING INVESTIGATION OF SANDY FRASER AGE GLACIAL DEPOSITS

Four borings were drilled in sandy Fraser age glacial outwash deposits in the northern portion of the study area to characterize their geology and geotechnical properties. The following table presents the boring identification numbers and locations (both latitude/longitude and street address). The logs of these borings and gradations performed on selected samples are presented in Appendix B.

Boring Identification	Latitude (WGS84)	Longitude (WGS84)	Street Address
H-1-01	47.31687	-122.38772	Twin Lakes Elementary School 4400 SW 320th St Federal Way, WA
H-2-01	47.31658	-122.38940	Twin Lakes Elementary School 4400 SW 320th St Federal Way, WA
H-3-01	47.30117	-122.40053	North shoulder of Northshore Parkway, east of intersection with Nassau Road
H-4-01	47.30513	-122.40806	Dash Point well field, east of Northpoint Way NE at its intersection with Chinook Drive NE

The borings drilled at Twin Lakes Elementary School (H-1-01 and H-2-01) encountered approximately 15 to 20 feet (4.5 to 6 m) of medium dense silty sand overlying at least 30 to 35 feet (9 to 12.5 m) of dense to very dense, clean sandy gravel or gravelly sand. Scattered thin laminated plastic silt beds within this lower section indicated that it was deposited in a proglacial lake environment. The sands in the lower unit had a particular salt and pepper coloration, which in the Seattle area is common in the Esperance Sand, an Fraser age advance outwash that filled a large proglacial lake proximal to the advancing ice front. Only this lower dense sand and gravel unit was encountered in H-3-01, again exhibiting the salt and pepper coloration in the sand fraction. We interpret that this lower dense sand and gravel unit is a Fraser age advance outwash correlative with the Esperance Sand.

Boring H-4-01, drilled in the Dash Point well field, consisted of more than 35 (11 m) feet of clean sandy gravel, based on the results of our drilling and the logs of the water wells in this well field. This deposit sits in a topographically low canyon incised into the predominantly sand deposits observed in borings H-1-01, H-2-01, and H-3-01. We interpret this gravel to be Fraser age recessional outwash deposited in a topographic depression carved into the older Esperance Sand equivalents by glacial excavation or sub-glacial meltwater erosion. The upper silty sand unit encountered in the Twin Lakes Elementary School boring is interpreted as having been

deposited during the highstand of a proglacial lake during the recessional phase of the Fraser glaciation.

A shear wave refraction survey was performed adjacent to the location of boring H-2-01 at Twin Lakes Elementary School to further characterize the properties of the sandy glacial outwash at this site. The results of this survey are presented in Appendix C. This profile shows that the upper 5 to 6 m (16 to 20 ft) is comprised of material with a shear wave velocity of about 280 m/sec (920 ft/sec). Beneath this layer the material has a shear wave velocity of approximately 615 m/sec (2020 ft/sec). The upper layer velocity is typical of Fraser age recessional outwash sand and silt deposits, whereas the higher velocity of the underlying unit is more representative of sand that has been compacted by glacial ice loading. The results from this survey support our interpretation of the near surface geology at Twin Lakes Elementary School.

INFORMATION DISSEMINATION

The liquefaction susceptibility map for the greater Tacoma urban area of Pierce and King Counties, Washington has been published and is available in both printed and on-line versions through the Washington Division of Geology and Earth Resources web page (<http://www.dnr.wa.gov/geology/>). This map had been provided to a number of local government organizations to assist in earthquake hazard mitigation, disaster planning, and enforcement of building ordinances. These organizations include the Pierce and King County emergency management agencies, the Pierce County and city of Lakewood planning agencies, and the building departments of Pierce County and the cities of Tacoma, Lakewood, and Puyallup. This map has also been used in the transportation vulnerability study performed as part of the King/Pierce County Project Impact program, and in evaluation of earthquake effects for the Engineering Earthquake Research Institute (EERI) Seattle Fault scenario. The Tacoma urban area database was also used by other researchers for evaluation of lateral spread hazards for the EERI Seattle Fault scenario. Printed versions of this map has also been distributed to a number of members of the public through request, and will continue to be available for the foreseeable future.

BIBLIOGRAPHY OF PUBLICATIONS RESULTING FROM THIS GRANT

Palmer, Stephen P.; Perkins, William J.; Grant, W. Paul, 2003, Liquefaction susceptibility of the greater Tacoma urban area, Pierce and King Counties, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-51, 1 sheet, scale 1:30,000 with 11 p. text.

APPENDIX A

Geotechnical Database for the Greater Tacoma Urban Area, Pierce and King Counties, Washington

Table: BoringInformation

RecordCount: 504

Fields

Name	Type	Size	Description
BoringID	Text	20	Boring identification string -- tied to GIS map location
ReportNumber	Text	20	Hardcopy report number
ReportBoring	Text	10	Boring number from hardcopy report referenced above
ReportReference	Text	250	Citation reference of report
DrillDate	Date/Time	----	Date of drilling
DrillMethod	Text	30	Drilling method (if known)
SPTMethod	Text	30	Type of SPT method used
Elevation	Single	xxx.x	Elevation of boring from reference report, in feet
TotalDepth	Single	xxx.x	Total drilled depth, in feet
GroundwaterDepth	Single	xxx.x	Reported groundwater depth, in feet (estimated if not stated in report)

Table: BoringData

RecordCount: 7432

Fields

Name	Type	Size	Description
BoringID	Text	20	Boring identification string
SampleDepth	Single	xxx.x	Depth of sample (in ft)
SampleType	Yes/No	-	Undisturbed (Yes) or disturbed (No) sample
SPTValue	Integer	-	Reported SPT N-value (value = 100 if refusal, =0 for push, = 999 if undisturbed sample)
USCSClass	Text	10	USCS soil classification
SampleDescription	Text	250	Sample description summarized from boring log
Gravel	Single	xxx.x	Percent gravel from gradation data
Sand	Single	xxx.x	Percent sand from gradation data
Fines	Single	xxx.x	Percent fines from gradation data
D50	Single	xx.xxx	D(50) value (in mm) from gradation data
EstimatedFines	Single	xxx.x	Estimated percent fines if no gradation data
MoistureContent	Single	xxx.x	Moisture content
LiquidLimit	Single	xxx.x	Liquid limit from Atterberg test
PlasticLimit	Single	xxx.x	Plastic limit from Atterberg test
PlasticityIndex	Single	xxx.x	Plasticity index from Atterberg test

Table: BoringLocation

RecordCount: 504

Fields

Name	Type	Size	Description
BoringID	Text	255	Boring identification string
Longitude	Double	xxx.xxxxx	Decimal longitude of report site location in WGS84
Latitude	Double	xx.xxxxx	Decimal latitude of report site location in WGS84

Geotechnical Database for the Everett Urban Area, Snohomish County, Washington

Table: BoringInformation

RecordCount: 358

Fields

Name	Type	Size	Description
BoringID	Text	20	Boring identification string
ReportNumber	Text	20	Hardcopy report number
ReportBoring	Text	10	Boring number from hardcopy report referenced above
ReportReference	Text	250	Citation reference of report
DrillDate	Date/Time	----	Date of drilling
DrillMethod	Text	30	Drilling method (if known)
SPTMethod	Text	30	Type of SPT method used
Elevation	Single	xxx.x	Elevation of boring from reference report, in feet
TotalDepth	Single	xxx.x	Total drilled depth, in feet
GroundwaterDepth	Single	xxx.x	Reported groundwater depth, in feet (estimated if not stated in report)

Table: BoringData

RecordCount: 4188

Fields

Name	Type	Size	Description
BoringID	Text	20	Boring identification string
SampleDepth	Single	xxx.x	Depth of sample (in ft)
SampleType	Yes/No	-	Undisturbed (Yes) or disturbed (No) sample
SPTValue	Text	20	Reported SPT N-value (value =r[blows/x-inches] if refusal, =0 for push, =999 if undisturbed sample)
USCSClass	Text	10	USCS soil classification
SampleDescription	Text	250	Sample description summarized from boring log
Gravel	Single	xxx.x	Percent gravel from gradation data
Sand	Single	xxx.x	Percent sand from gradation data
Fines	Single	xxx.x	Percent fines from gradation data
D50	Single	xx.xxx	D(50) value (in mm) from gradation data
EstimatedFines	Single	xxx.x	Estimated percent fines if no gradation data
MoistureContent	Single	xxx.x	Moisture content
LiquidLimit	Single	xxx.x	Liquid limit from Atterberg test
PlasticLimit	Single	xxx.x	Plastic limit from Atterberg test
PlasticityIndex	Single	xxx.x	Plasticity index from Atterberg test

Table: BoringLocation

RecordCount: 358

Fields

Name	Type	Size	Description
BoringID	Text	255	Boring identification string
Longitude	Double	xxx.xxxxx	Decimal longitude of report site location in WGS84
Latitude	Double	xx.xxxxx	Decimal latitude of report site location in WGS84

APPENDIX B



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-1-01

Hole Location: Twin Lakes Elementary School, Federal Way

Drilling Equipment: CME

Drilling Method: Hollow Stem Auger

SPT Method: Automatic trip hammer

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 2/19/2001

Completion Date: 2/19/2001

Observer: Steve Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description	
1						
2						
3						
4						
5				4		4.5 - 6.0'; retained 1.2'
6			D-1	8	15	4.5 - 5.5': Brown, dry, silty SAND with scattered gravel (approx. 15% gravel). (note: sample should be wet sieved). 5.5 - 5.7': Gray silty SAND (note: not enough volume for grain size analysis).
7						
8						
9						
10				5		9.5 - 11'; retained 1.1'
11			D-2	9	26	9.5 - 9.8': Brown, mottled, very silty SAND. 9.8 - 10.6': Brown-gray, slightly silty, medium SAND with gravel.
12						
13						
14						
15			12		14.5 - 16.0'; retained 1.5'	
16		D-3	30	69	Gray (salt and pepper), dry, clean, fine to medium SAND.	
17						
18						
19						
20			D-4	13		19.5 - 21.0'; retained 1.0'



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-1-01

Hole Location: Twin Lakes Elementary School, Federal Way

Drilling Equipment: CME

Drilling Method: Hollow Stem Auger

SPT Method: Automatic trip hammer

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 2/19/2001

Completion Date: 2/19/2001

Observer: Steve Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description	
21		D-4	20 28	48	Gray (salt and pepper), dry, clean, fine to medium SAND with scattered fine, subrounded to subangular gravel. 24.5 - 26.0'; retained 1.3 Dry, gray (salt and pepper), clean, fine to medium SAND with silt and increased scattered, fine, subangular to subrounded gravel. 29.5 - 31.0'; retained 0.9' Dry, gray (salt and pepper), clean, fine to medium SAND with silt and scattered fine, subangular to subrounded gravel. 34.5 - 36.0'; retained 1.1' Dry, gray (salt and pepper), clean, fine to medium SAND with silt and scattered fine, subangular to subrounded gravel. Sample fines toward bottom. 39.5 - 41.0'; retained 1.5'	
22						
23						
24						
25				13		
26		D-5	40 28/3	68/9"		
27						
28						
29						
30				28		
31		D-6	50/5	50/5"		
32						
33						
34						
35				13		
36		D-7	46 37	83		
37						
38						
39						
40				13		



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-1-01

Hole Location: Twin Lakes Elementary School, Federal Way

Drilling Equipment: CME

Drilling Method: Hollow Stem Auger

SPT Method: Automatic trip hammer

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 2/19/2001

Completion Date: 2/19/2001

Observer: Steve Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description		
41		D-8	18	40	39.5 - 39.7': Dry, gray (salt and pepper), clean, fine to medium SAND with silt and scattered fine, subangular to subrounded gravel. 39.7 - 41.0': Gray, non-plastic SILT with 1" thick sand lens containing FeO staining. 44.5 - 46.0'; retained 1.5'		
42			22				
43							
44							
45				25			
46		D-9	39	79	44.5 - 45.1': Gray (salt and pepper), fine to medium, clean, dry SAND (sample too small for analysis). 45.1 - 46.0': ML - Gray (salt and pepper), dry, sandy SILT (MC = 17.94%; 0.0% gravel, 25.9% sand, 74.1% fine; sample should be wet sieved for more accurate results). 49.5 - 51.0'; retained 1.5'		
47			40				
48							
49							
50				13			
51			D-10	26		63	
				37			
52							49.5 - 49.9': Gray (salt and pepper), moist, fine silty SAND. 49.9 - 51.0': Gray (salt and pepper), dry, fine to medium clean SAND. Total depth of hole: 51.0'
53							
54							
55							
56							
57							
58							
59							
60							

Grain Size Analyses Laboratory Summary



WASHINGTON STATE DEPARTMENT OF
Natural Resources

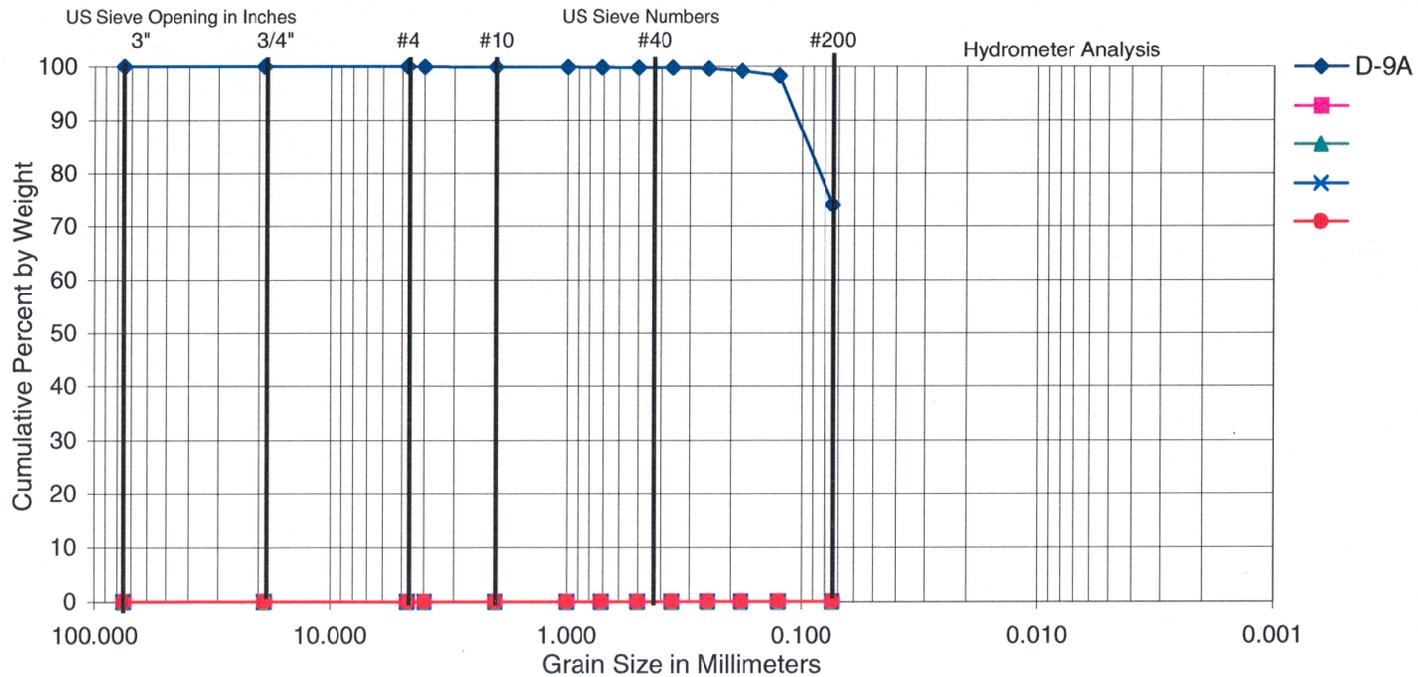
Boring Number: H-1-01

Date: 06/05/2001

Boring Location: Federal Way

Sheet 1 **of** 1

Sample number	Depth (ft)	%Gravel	%Sand	%Fines	D60	D50	D30	D10	MC%	Cu	Cc	USCS
D-9A	44.5	0.0	25.9	74.1					17.94			fine



Gravel	Sand			Silt and Clay
	Coarse	Medium	Fine	



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-2-01

Hole Location: Twin Lakes Elementary School, Federal Way

Drilling Equipment: CME

Drilling Method: Hollow Stem Auger

SPT Method: Automatic Trip Hammer

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 02/19/01

Completion Date: 02/19/01

Observer: Steve Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description	
1						
2						
3						
4						
5				6		4.5 - 6.0'; retained 1.4'
6		D-1		8	15	Gray (salt and pepper), mottled, moist to wet, fine to medium SAND with silt and scattered subrounded gravel.
				7		
7						
8						
9						
10				5		9.5 - 11.0'; retained 1.1'
		D-2		7	16	Gray (salt and pepper), fine to medium, wet, silty, gravelly SAND.
11				9		
12						
13						
14						
15				11		14.5 - 16.0'; retained 1.0'
		D-3		15	42	Gray (salt and pepper), moist, silty, subangular to subrounded gravelly, fine to coarse SAND.
16				27		
17						
18						
19						
20		D-4	15		19.5 - 21.0'; retained 1.5'	



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-2-01

Hole Location: Twin Lakes Elementary School, Federal Way

Drilling Equipment: CME

Drilling Method: Hollow Stem Auger

SPT Method: Automatic Trip Hammer

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 02/19/01

Completion Date: 02/19/01

Observer: Steve Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description	
21		D-4	30 30	60	SW - Gray (salt and pepper), dry to moist, clean, rounded to subangular gravelly, fine to medium SAND. 30.1% gravel, 67.1% sand, 2.9% fine 24.5 - 26.0'; retained 1.5' Gray (salt and pepper), dry to moist, clean, rounded to subangular gravelly, fine to medium SAND. Gravel is slightly larger (~1cm) than in D-4. 29.5 - 30.5'; retained 0.8' Gray (salt and pepper), dry to moist, clean, fine to coarse sandy, fine GRAVEL. 34.5 - 36.0'; retained 1.5' Gray (salt and pepper), dry to moist, clean, fine to coarse sandy, fine GRAVEL grading down to gray, moist, clean, fine gravelly, fine to medium SAND. 39.5 - 40.5'; retained 1.0'	
22						
23						
24						
25				18		
26			D-5	35 45		80
27						
28						
29						
30				22		
31			D-6	47/6		47/6"
32						
33						
34						
35				22		
36			D-7	27 50		77
37						
38						
39						
40			D-8	22		



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-2-01

Hole Location: Twin Lakes Elementary School, Federal Way

Drilling Equipment: CME

Drilling Method: Hollow Stem Auger

SPT Method: Automatic Trip Hammer

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 02/19/01

Completion Date: 02/19/01

Observer: Steve Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description	
41		D-8	50/6	50/6"	Gray (salt and pepper), moist, fine to medium SAND with very scattered gravel.	
42						
43						
44						
45				26		44.5 - 46.0'; retained 1.5'
46		D-9	35	40	75	44.5 - 45.0': Olive, wet, low plasticity SILT. 45.0 - 46.0': Gray, slightly silty, dry to moist fine SAND (no gravel).
47						
48						
49						
50				26		49.5 - 50.8'; retained 1.2'
51			D-10	36	64/9"	Gray, dry to moist, clean, fine to medium SAND grading down to dry, fine SAND with silt. No gravel.
52					Bottom of hole at 50.8'	
53						
54						
55						
56						
57						
58						
59						
60						

Grain Size Analyses Laboratory Summary



WASHINGTON STATE DEPARTMENT OF
Natural Resources

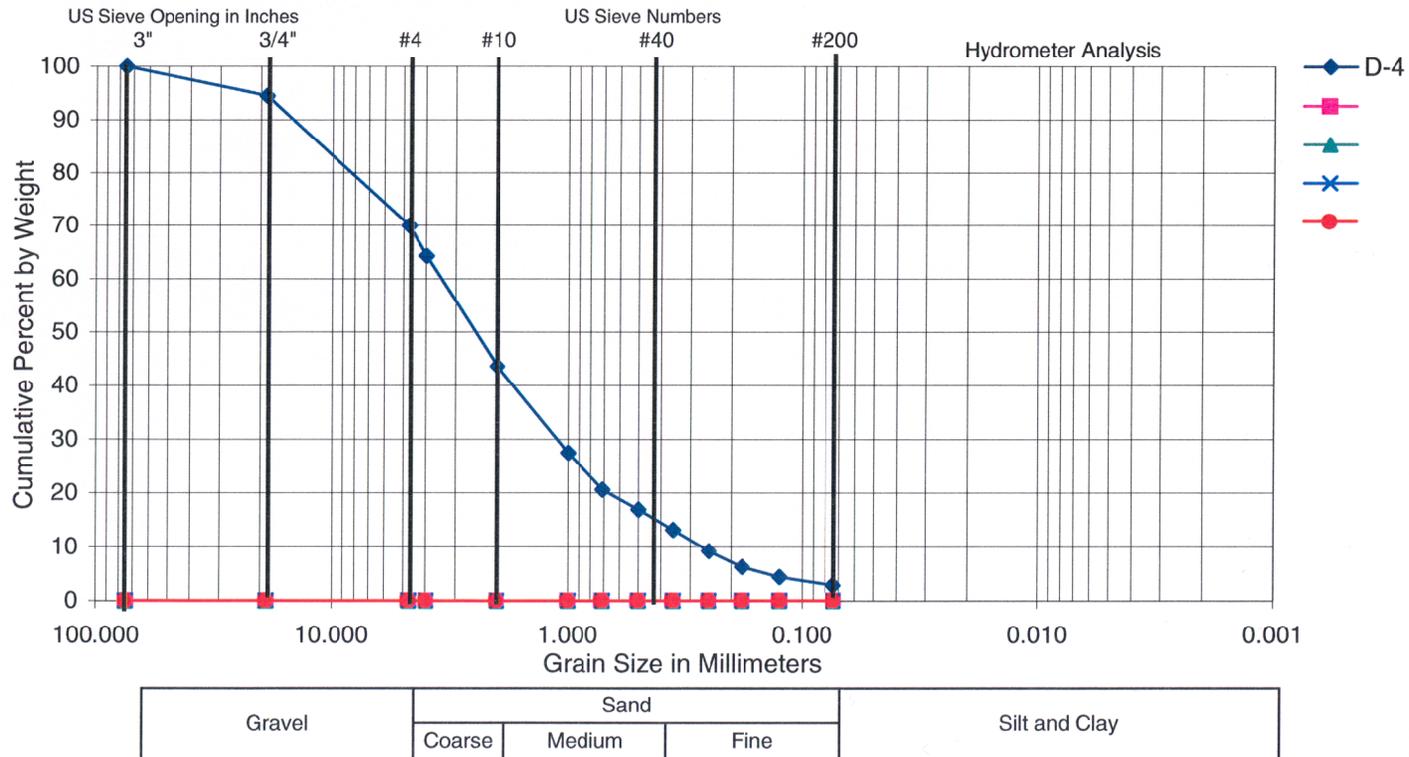
Boring Number: H-2-01

Date: 06/05/2001

Boring Location: Federal Way

Sheet 1 of 1

Sample number	Depth (ft)	%Gravel	%Sand	%Fines	D60	D50	D30	D10	MC%	Cu	Cc	USCS
D-6	19.5	30.1	67.1	2.9	3.59	2.62	1.16	0.27		13.2	1.4	SW





WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-3-01

Hole Location: N.side Northshore Pkwy, near Nassau Ave

Drilling Equipment:

Drilling Method:

SPT Method:

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 02/20/01

Completion Date: 02/20/01

Observer: S. Palmer/S. Magsino

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description
1					
2					
3					
4					
5			12		4.5 - 6.0'; retained 1.3'
6		D-1	21	47	Gray (salt and pepper), fine to medium, moist, clean SAND.
			26		
7					
8					
9					
10			14		9.5 - 11.0'; retained 1.2'
		D-2	25	60	SP-SM: Gray (salt and pepper), fine to medium, moist, clean SAND.
11			35		0.0% gravel, 94.2% sand, 5.8% fine
12					
13					
14					
15			14		14.5 - 16.0'; retained 1.4'
		D-3	35	75	Gray (salt and pepper), moist, medium SAND with gravel.
16			40		
17					
18					
19					
20		D-4	25		19.5 - 20.4'; retained 0.9'



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-3-01

Hole Location: N.side Northshore Pkwy, near Nassau Ave

Drilling Equipment:

Drilling Method:

SPT Method:

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 02/20/01

Completion Date: 02/20/01

Observer: S. Palmer/S. Magsino

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description
21		D-4	50/5	50/5"	19.5 - 20.1': Gray, moist, clean, fine to medium SAND with gravel. 20.1 - 20.4': Gray, dry clean, fine SAND. 24.5 - 25.9'; retained 1.5'. MC=4.19% SP: Gray, moist, clean, fine to medium SAND. 0.0% gravel, 97.5% sand, 2.5% fine 29.5 - 30.5'; retained 1.0' Gray, moist, clean, fine to medium SAND. 34.5 - 35.3'; retained 1' Gray, fine to medium, moist, very slightly silty SAND with gravel at bottom of sample. 39.5 - 40.4'; retained 0.9'
22					
23					
24					
25				14	
26		D-5	43	93/11"	
			50/5		
27					
28					
29					
30				25	
31		D-6	50/5.75	50/5.75"	
32					
33					
34					
35				30	
36		D-7	50/4	50.4"	
37					
38					
39					
40	D-8		25		



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Groundwater Depth: Unknown

Start Date: 02/20/01

Completion Date: 02/20/01

Observer: S. Palmer/S. Magsino

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description	
41		D-8	50/5		Gray, moist, clean, fine to medium SAND with single clast of gravel.	
42						
43						
44						
45				28		44.5 - 45.4'; retained 1.1'. MC = 3.22%
46		D-9	50/5	50/5"		SP: Gray, moist, clean, fine to coarse SAND with scattered, subrounded gravel. Sample is slightly coarser toward the top.
47						0.5% gravel, 95.9% sand, 3.6% fine.
48						
49						
50				49		49.5 - 50.4'; retained 0.8'. Gray, moist, clean, fine to coarse SAND. Coarser grained toward top of sample.
		D-10	50/5	50/5"		
51					Bottom of hole at 50.4".	
52						
53						
54						
55						
56						
57						
58						
59						
60						

Grain Size Analyses Laboratory Summary



WASHINGTON STATE DEPARTMENT OF
Natural Resources

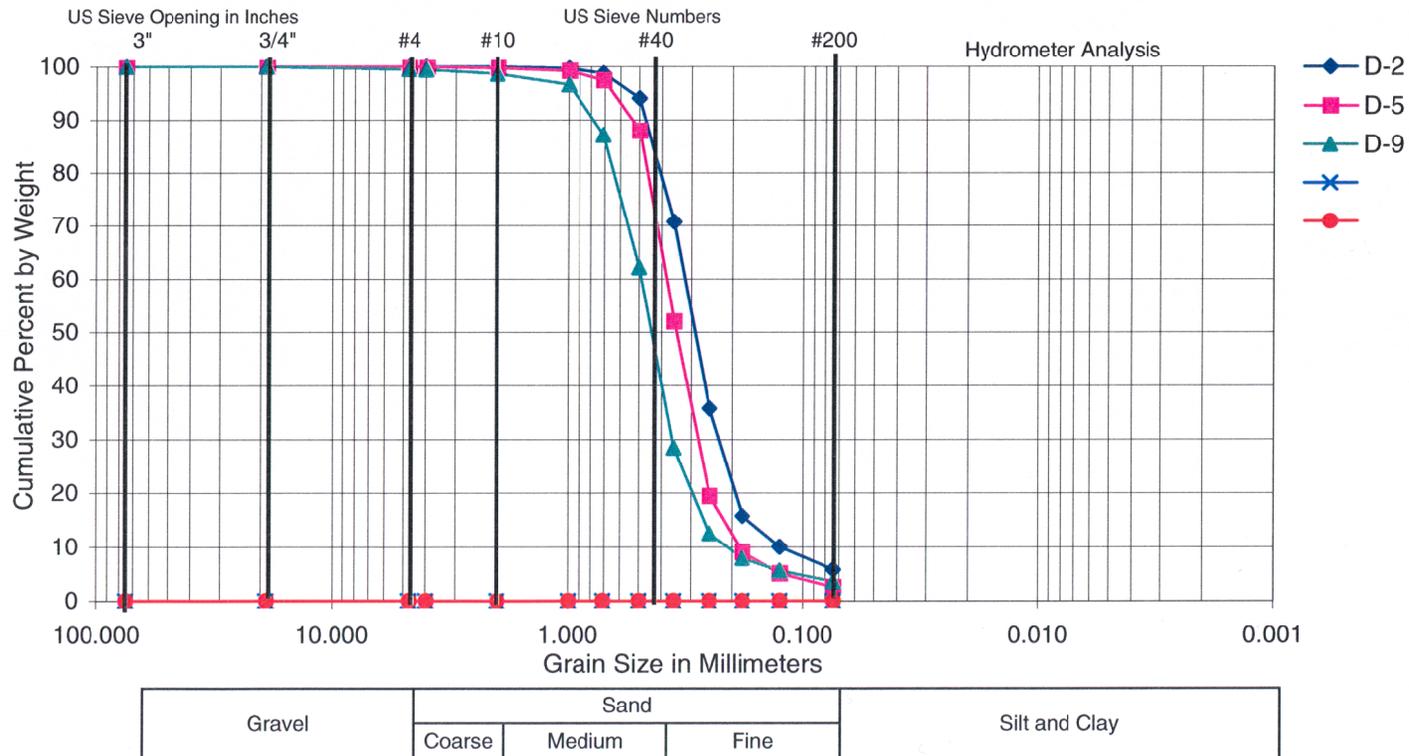
Boring Number: H-3-01

Date: 05/30/2001

Boring Location: Federal Way

Sheet 1 **of** 1

Sample number	Depth (ft)	%Gravel	%Sand	%Fines	D60	D50	D30	D10	MC%	Cu	Cc	USCS
D-2	9.5	0.0	94.2	5.8	0.32	0.29	0.23	0.12		2.6	1.3	SP-S*
D-5	24.5	0.0	97.5	2.5	0.39	0.35	0.28	0.19	4.19	2.1	1.1	SP
D-9	44.5	0.5	95.9	3.6	0.49	0.45	0.36	0.21	3.22	2.3	1.3	SP





WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-4-01

Hole Location: Dash Point well field, Federal Way

Drilling Equipment:

Drilling Method:

SPT Method:

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 02/20/01

Completion Date: 02/20/01

Observer: S. Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description	
1						
2						
3						
4						
5				10		4.5 - 6.0'; retained 1.3'
6		D-1		18	38	Brown-gray, wet, silty, sandy (fine to coarse), fine GRAVEL.
7				20		
8						
9						
10				20		9.5 - 11.0'; retained 1.5'
11		D-2		25	63	Brown-gray, wet, silty, sandy (fine to coarse), fine to medium GRAVEL with peat.
12				38		
13						
14						
15		D-3			refusal	14.5 - 16.0'; retained ?
16						Wet, fine to coarse SAND at top grading to silty, sandy (fine to coarse), fine to coarse GRAVEL.
17						
18						
19						
20		D-4		>40	>40	19.5 - 21.0'; retained 1.7'. MC = 55.67%



WASHINGTON STATE DEPARTMENT OF
Natural Resources

Hole Number: H-4-01

Hole Location: Dash Point well field, Federal Way

Drilling Equipment:

Drilling Method:

SPT Method:

Ground Elevation: Unknown

Groundwater Depth: Unknown

Start Date: 02/20/01

Completion Date: 02/20/01

Observer: S. Palmer

Depth (ft)	Profile	Sample Number	SPT Blows/6"	SPT N-value	Description
21	[Cross-hatched pattern]	D-4			SP: Wet, clean, fine to coarse SAND grading to sandy (fine to coarse), fine to coarse gravel with some silt.
22					24.9% gravel, 72.9% sand, 2.2% fine
23					
24					
25		D-5		refusal	24.5 - 26.0'; retained 0.5'. MC = 21.98%
26					SP: Wet, fine to coarse SAND with gravel, clay, and silt. 12.8% gravel, 83.3% sand, 3.9% fine
27					Bottom of hole at 26.0'.
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					

Grain Size Analyses Laboratory Summary



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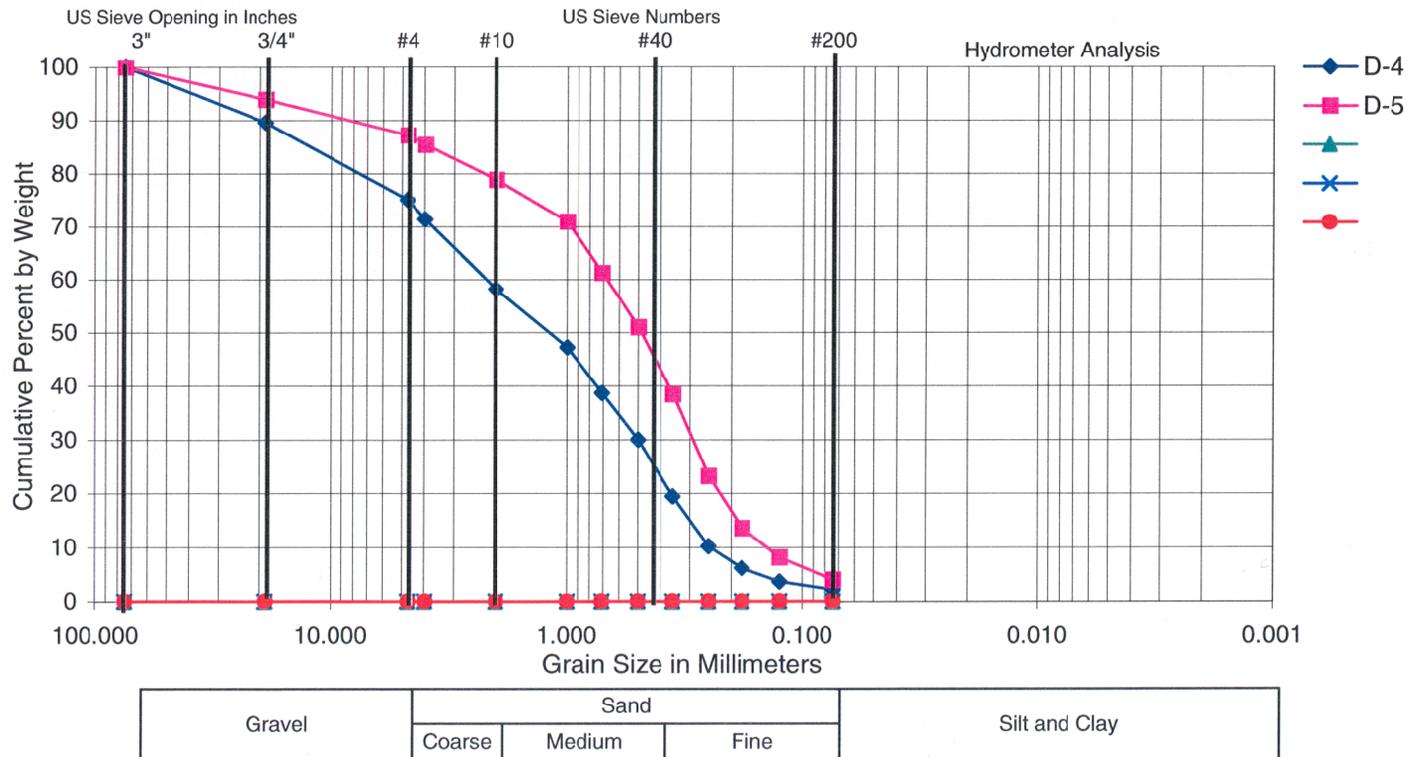
Boring Number: H-4-01

Date: 06/05/2001

Boring Location: Federal Way

Sheet 1 **of** 1

Sample number	Depth (ft)	%Gravel	%Sand	%Fines	D60	D50	D30	D10	MC%	Cu	Cc	USCS
D-4	19.5	24.9	72.9	2.2	2.27	1.25	0.50	0.25	55.67	9.2	0.4	SP
D-5	24.5	12.8	83.3	3.9	0.68	0.49	0.30	0.14	21.98	4.8	0.9	SP



APPENDIX C

Twin Lakes Elementary

