GeoEngineers

Memorandum

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To:	James Yap, Snohomish County Parks and Recreation
From:	Debra Overbay, PE and Jon Ambrose, GeoEngineers
Date:	December 29, 2010
File:	3734-008-03
Subject:	Technical Memorandum Centennial Trail Phase 2B, Pilchuck Creek Embankment Repair and Haller Trestle Pier 4

This memorandum presents a summary of our additional explorations and analyses completed in support of the Pilchuck Embankment Repair and protection of Haller Trestle Pier 4 as part of the Centennial Trail Phase 2B project. Geotechnical engineering recommendations for repair to the Pilchuck Creek Bridge Pier 2 repairs were provided in our previous report dated February 4, 2010, "Pilchuck Creek Bridge Crossing, Centennial Trail, Phase 2, Snohomish County, Washington".

SITE CONDITIONS

Pilchuck Creek Embankment Failure

Recent changes to the flow in Pilchuck Creek resulted in a moderate bank failure between approximate Stations 254+75 and 256+75. The proposed trail through this area consists of an approximate 35-foot-high embankment that was constructed at an approximate 1.5H:1V (horizontal to vertical) to 2H:1V inclination. During the winter of 2009/2010, scour at the toe of the embankment washed out an approximate 20- to 30-foot wide width of the embankment toe, resulting in an oversteepened side slope and loss of a portion of the embankment crest where the future trail is planned. To reduce earthwork quantities and therefore construction costs, the trail grade will be lowered in this area as part of the embankment repair, and a cribwall structure is planned at the toe. The existing trail elevation above the failure area is generally near Elevation 149 feet, and the proposed trail grade within this area will slope gently down from approximate Elevation 143 feet in the south to Elevation 136 feet in the north.

Haller Trestle Pier 4

The project area for additional work on Haller Trestle Pier 4 includes the area around pier 4 located at approximate Sta. 10+50, and the access route from the north abutment. On-going scour and damage from log jams have resulted in a notable increase in undercutting of the foundation at the Haller Trestle Pier 4, which is located at the confluence of the North Fork and Main Fork of the Stillaguamish River. This is one of eight piers (six freestanding piers and two abutments) supporting the Haller Trestle, which is the superstructure for the new decking proposed for the extension of the Centennial Trail.

Protection of Pier 4 will include inspection of the existing piles during construction, removing the upper decayed portion of the timber (if encountered), deepening and re-constructing the pile cap, and placement of a revetment to protect the pier from scour.

SUBSURFACE CONDITIONS

Subsurface Exploration and Laboratory Testing

Subsurface soil and groundwater conditions were evaluated by drilling one hollow-stem auger boring at the north end of the Pilchuck Creek Embankment Failure, and two borings approximately 30 to 35 feet west of

Pier 4 of the Haller Trestle. The borings were drilled with a portable tracked rig owned and operated by Geologic Drill. Each boring was continuously monitored by a geotechnical engineer or engineering geologist from our firm who examined and classified the soils encountered, obtained representative soil samples, and observed groundwater conditions. Soils were classified in general accordance with the classification system described in Figure A-1. A key to the exploration log symbols is also presented in Figure A-1. The logs of the explorations are included in the attachment as Figures A-2 through A-4. All samples were brought back to our laboratory for additional classification, moisture content testing, and grain size analyses. The results of our moisture and percent fines content are shown on the logs, and the results of our grain size analyses is provided in Figure A-5.

Pilchuck Creek Embankment Failure

Boring B-1 was drilled to a depth of 41½ feet below the existing ground surface (bgs) at the north end of the embankment failure, at approximately Elevation 148.5 feet. Loose to medium dense embankment fill was encountered to a depth of approximately 32 feet, or to roughly Elevation 116.5 feet. The upper two to three feet of the fill consists of sand with silt and gravel. The remaining fill contains considerable fines, consisting primarily of silty sand with occasional gravel. Fine to coarse gravel with sand and silt was encountered beneath the fill (interpreted to be older alluvium). Very dense fine sand (likely weathered sandstone), was encountered below the alluvium at a depth of about 38 feet, or approximate Elevation 111.

We completed a site reconnaissance of the lower slope and edge of the creek and observed weathered sandstone at approximately Elevation 112 to 114 feet (based on the survey contours provided by Pacific Survey & Engineering, Inc.). A coarser grained layer of bedrock was observed below the sandstone along the edge of the creek, roughly below Elevation 111 feet. We interpret this as a lense of conglomerate, consistent with the geologic mapping description of the McMurray Quadrangle. This material was also noted within the outcrop located at the north end of the failure zone at the edge of the creek.


North Edge of Pilchuck Creek Embankment Failure

Haller Trestle Pier 4

Borings B-2 and B-3 were drilled adjacent to Pier 4 of the Haller Trestle during low water conditions. We encountered medium dense gravel and sand fluvial deposits within the upper 21 to 22 feet of both borings. Boring B-2 was advanced 1 inch into very dense silty sand (interpreted as glacial till), at which point the auger encountered refusal due to the upper gravels weighing down the auger (the bored hole had become large) and inadequate power of the portable track rig. A second boring, boring B-3, was drilled 5 feet away and encountered a more silty deposit at the same depth, also interpreted as glacial till.


North Side of Pier 4, April 7, 2010


North Side of Pier 4, August 30, 2010


Drilling at Haller Trestle, Pier 4

CONCLUSIONS AND RECOMMENDATIONS

Pilchuck Creek Embankment

Crib Wall and Slope Reconstruction

We recommend a timber crib wall and engineered fill be constructed to restore the embankment failure between approximate stations 254+75 and 256+75. Design plans of the crib wall and rip-rap armor for the end treatment are shown in the drawings, Sheets CW1.1 through CW1.4 transmitted with the permit package. The anchored crib wall structure provides a stable toe along the embankment, as well as the recommended bioengineering features for the project. A summary of our analyses of the structure and upper slope, and construction considerations are presented below.

Slope Stability Analyses

We performed stability analyses for the crib wall structure and upper slope assuming both a low and high water condition. The low water condition was based on the survey data during the dry season, and the high water condition was based on the 500-year flood obtained from the hydraulic modeling. Soil strength parameters were based on laboratory testing and our experience with the recommended construction materials.

Slope stability analyses were completed using the Spencer method and the computer program SlopeW Version 7.14, developed by Geo-Slope International. Soil parameters used in our analyses are presented below.

Soil	γ (pcf)	ϕ (degrees)	C (psf)
Existing Embankment Fill (primarily silty sand)	115	32	0
Older Alluvium	120	32	0
Weathered Sandstone	132	40	0
Conglomerate Bedrock	145	45	0
Rock/Soil Mix Above Crib Wall	125	34	0

Results of Stability Analyses

Failure mechanisms that were considered included failures through the crib wall assuming the life of the wall was expired, and a deeper failure surface below the wall passing through the foundation soils. The phreatic surface was evaluated based on the low water condition (at the base of the crib wall), and the 500-year flood condition above the top of the crib wall. Tie down anchors were also utilized in design, consisting of two 12-kip drilled anchors spaced at 8 feet center-to-center along the wall alignment. The results of the slope stability analyses for these multiple cases are summarized below.

Analyses	Factor of Safety	
	Through Crib Wall[1]	Below Crib Wall[2]
High Water, No Anchors	1.2 to 1.3[3]	1.5
High Water, Two 12-kip Anchors at 8-ft center to center	--	1.8
Low Water, No Anchors	1.4	1.7
Low Water, Two 12-kip Anchors at 8-ft center to center	--	1.9

[1] Cases analyzed assuming life of the crib wall expired (assuming a low strength of the crib wall mass). Failures extend past the slope crest except as noted.

[2] Cases analyzed assuming crib wall still in service (higher strength of the crib wall mass). Failures extend past the slope crest.

[3] Factor of Safety of 1.2 does not extend beyond the crest, but is a 4- to 5-foot failure thickness down the slope. Factor of safety of 1.3 extends beyond the crest.

Scour and Buoyancy

Traditional scour analysis accounts for the resistance of the material beneath the structure in the stream or floodplain. A smooth shelf of conglomerate bedrock is present along the base of the proposed log crib wall that will limit the potential for scour. Rather than excavate into the bedrock shelf, the crib wall will be placed on the shelf after all unconsolidated alluvial or colluvial material has been brushed and removed from the shelf surface. Due to the hardness of the bedrock shelf, we do not expect scouring beneath the structure.

Buoyancy was analyzed to estimate the effects of structural inundation up to the 100-year flood elevation. Structural buoyancy is offset by the mass of the crib wall structure. Unit weights of the crib wall were calculated according to the volume of wood, rock, and native backfill identified in the design. As an additional precaution against buoyancy, and as utilized in the stability analyses previously discussed, drilled anchors will be set into the native conglomerate with steel cable attached and looped through the crib wall.

Construction Considerations

The crib wall consists of stacked wood members with root wads extending towards the channel edge that will be activated during bankfull flows to increase channel roughness and provide refuge for salmonids from high velocity flows. Stacked members consist of 24 inch DBH fir trees with 4 foot diameter root wads. Cribbing for the structure consists of 24 inch DBH fir trees with no root wads. The lower lift of the structure will be placed on the conglomerate bedrock shelf, cribbing trees will be notched and pinned with steel between the first and second layers of stacked logs. The entire structure will be held together by 5/8-inch steel cable, passed through drilled holes in both stacked layers, and fastened to drilled rock anchors. The cable will be tension tested and tightened sequentially moving upwards through the structure during construction, and fastened with 2 cable clips. Backfill for the structure will consist of a 60-40 mix of light, loose riprap and native material.

Haller Trestle Pier 4

Timber Piles

We expect the timber piles supporting Pier 4 are likely founded within the glacial till encountered below a depth of about 22 feet. We were unable to confirm this by completing P.I.T. (Pile Integrity Testing), because the existing pile cap had broken off around the pier leaving no surface for impacting the hammer. We recommend P.I.T. be completed during construction after the new cap is formed to evaluate pile lengths and estimate individual pile capacities. Based on discussions with the structural engineer and as anticipated, static pile loads will be less for the proposed bridge use than the original design railroad loading.

We recommend a thorough inspection of all the piles be accomplished during construction after diversion of the river and excavation below the cap. We were able to evaluate two of the exterior piles using a small diameter increment borer. Based on our visual observations and the extracted bore, the exterior piles supporting Pier 4 were evaluated as sound. However, these piles were previously embedded into the top of the concrete cap, and therefore may have been protected for much of their life. Additional evaluations will be completed during construction.

Construction Considerations

A sheet pile cutoff wall will be required to reconstruct the pile cap and install the revetment and underlying geotextile (revetment for scour protection is designed by West Consultants and shown in the drawings).

Heavy sheets will be required for the wall to penetrate through the fluvial deposits and to retain the soil and hydrostatic head while excavating for revetment construction. A thorough inspection of the piles should be accomplished during construction when excavation is possible. Decayed piles can be utilized for support provided the upper portion is sawcut, and the pile cap is deepened for support on sound wood. Removal of pile decay should be accomplished per the direction of the field engineer and reconfiguration of the pile cap should be evaluated by the structural engineer.

We trust this technical memorandum meets your immediate needs. Please call if you have any questions or if you need additional information.

Attachment: Figure A-1, Key to Boring Logs
Figures A-2 to A-4, Logs of Borings
Figure A-5, Sieve Analyses

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% RETAINED ON NO. 200 SIEVE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	CC	Cement Concrete
	AC	Asphalt Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Measured groundwater level in exploration, well, or piezometer

Groundwater observed at time of exploration

Perched water observed at time of exploration

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PP	Pocket penetrometer
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

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FIGURE A-1

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	7/9/2010	7/9/2010	41.5	RBM	DCO	Geologic Drill	Hollow-stem Auger/SPT

Surface Elevation (ft) Vertical Datum	Hammer Data	Drilling Equipment
148.5	Rope and Cathead 140 (lbs) / 30 (in) Drop	Bobcat MT52 Track Drill Rig

Latitude Longitude	System Datum	Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
	N/A	7/9/2010	32.0	116.5

Notes: Auger Data: 2¼ inches I.D.; 5 inches O.D.

FIELD DATA

Depth (feet)	Recovered (in)	Blows/foot	Sample Name	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
0				SP-SM	Brown fine to medium sand with silt and gravel (medium dense, moist) (fill)			
	9	19	1	SM	Brown silty fine to medium sand with occasional gravel (medium dense, moist) (fill)	7 14		SA; %F = 6.2 %F = 20
5	6	11	2			13		%F = 19.6
	7	5	3	SP-SM	Grayish brown fine to medium sand with silt and gravel (loose, moist) (fill)	7		%F = 11.2
10	12	5	4	SM	Grayish brown silty fine to medium sand (moist, loose) (fill)	21		%F = 49.2
15	14	5	5					
				SM	Brown silty fine to medium sand with occasional gravel (loose, moist) (fill)			
20	14	4	6			31		%F = 25.5
25	14	6	7					
				SP-SM	Brown fine to coarse sand with silt and gravel (medium dense, moist) (fill)			
30	7	17	8			8		%F = 10.1
				GP-GM	Brown and gray silty fine to coarse gravel with sand and silt (medium dense, wet) (older alluvium)			
35	8	26	9					

Elevation (feet): 145, 140, 135, 130, 125, 120, 115

Note: See Figure A-1 for explanation of symbols.

Log of Boring B-1

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Project:	Snohomish County Parks/Centennial Trail 2
Project Location:	Everett, Washington
Project Number:	3734-008-03

Figure A-2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
110									SM	Gray silty fine sand (very dense, wet) (weathered sandstone?)			
	40		17	83		10							

Note: See Figure A-1 for explanation of symbols.

Log of Boring B-1 (continued)

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Project: Snohomish County Parks/Centennial Trail 2
Project Location: Everett, Washington
Project Number: 3734-008-03

Drilled	Start 8/6/2010	End 8/6/2010	Total Depth (ft) 22.5	Logged By AKL Checked By DCO	Driller Geologic Drill	Drilling Method Hollow-stem Auger/SPT

Surface Elevation (ft) Vertical Datum: Undetermined	Hammer Data: Rope and Cathead 140 (lbs) / 30 (in) Drop	Drilling Equipment: Bobcat MT52 Track Drill Rig	
Latitude Longitude	System Datum: N/A	Groundwater	
Notes: Auger Data: 2¼ inches I.D.; 5 inches O.D.			

Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
8/6/2010	3.5	Undetermined

Elevation (feet)	Depth (feet)	Interval / Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0							GP	Gray fine to coarse gravel with sand (medium dense, moist) (alluvium)			
								SP	Gray fine to medium sand with gravel (medium dense, wet)			
		6	10		1	▼						
	5	4	15		2							
									Becomes fine to coarse			
								GP	Gray fine to coarse gravel with sand (medium dense, wet)			
		6	44		3							Blowcount may not be representative due to gravel
	10	3	31		4							
	15	4	13		5							
	20	4	24		6							
								SM	Gray silty fine sand (very dense, moist) (glacial till)			Refusal at 22.5 due to gravels weighing down auger and not enough power to drill through the till.
		7	50/1"		7							

Note: See Figure A-1 for explanation of symbols.

Log of Boring B-2

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Project: Snohomish County Parks/Centennial Trail 2
Project Location: Everett, Washington
Project Number: 3734-008-03

Figure A-3
Sheet 1 of 1

Drilled	Start 8/6/2010	End 8/6/2010	Total Depth (ft)	23	Logged By AKL / Checked By DCO	Driller	Geologic Drill	Drilling Method	Hollow-stem Auger/SPT

Surface Elevation (ft) / Vertical Datum	Undetermined	Hammer Data	Rope and Cathead 140 (lbs) / 30 (in) Drop	Drilling Equipment	Bobcat MT52 Track Drill Rig
Latitude / Longitude		System / Datum	N/A	Groundwater	

Notes: Auger Data: 2¼ inches I.D.; 5 inches O.D.

Groundwater: Date Measured | Depth to Water (ft) | Elevation (ft): Undetermined

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name / Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0								SP	Gray fine to medium sand with gravel (medium dense, moist) (alluvium)			
									GP	Gray fine to coarse gravel with sand Driller bum to 22.5 feet to sample till, refer to B-2 for typical conditions			
	5												
	10												
	15												
	20												
			4.5	100/4.5"		1			ML	Gray silt with sand (hard, moist) (glacial till)			

Note: See Figure A-1 for explanation of symbols.

Log of Boring B-3

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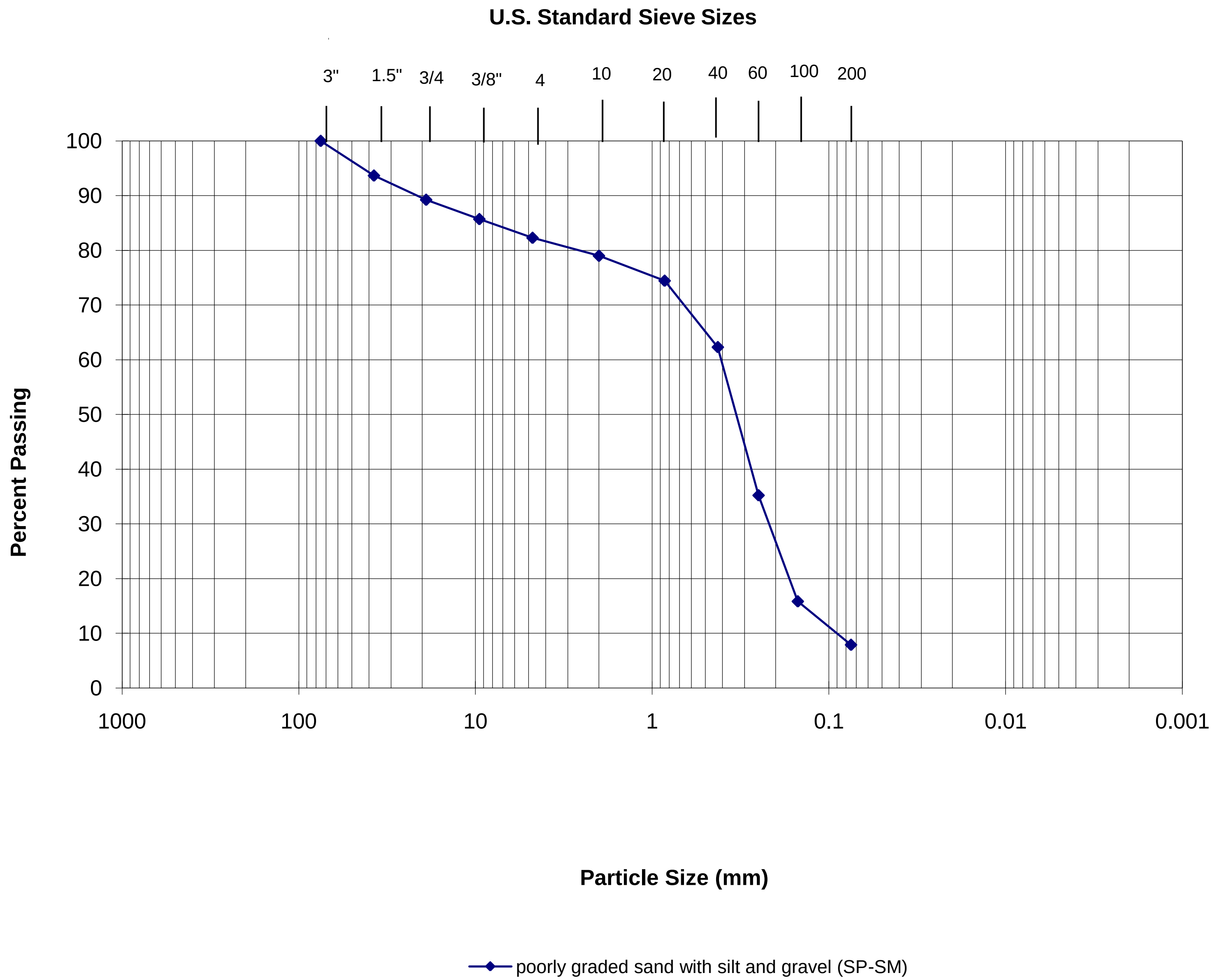
Project: Snohomish County Parks/Centennial Trail 2
Project Location: Everett, Washington
Project Number: 3734-008-03

Figure A-4
Sheet 1 of 1

3734-008-03 HBP : NDK : AMD 07-07-10 (Sieve.ppt)



SIEVE ANALYSIS RESULTS

FIGURE A-5