TERRA ASSOCIATES, Inc.
Consultants in Geotechnical Engineering, Geology
and
Environmental Earth Sciences

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August 30, 2001
Project No. T-4515

Ms. Lisa Pascualy
Firwood Lane, PS.
4318 – 55th Avenue NE
Seattle, Washington 98105

Subject: Geotechnical Engineering Study
Streambank Stabilization
Firwood Mobile Home Park
Kirkland, Washington

Dear Ms. Pascualy:

As requested, we have completed a geotechnical engineering study for the above subject project. The purpose of our work was to evaluate the stability of the existing rockery construction along the east flank of an existing stream corridor adjacent to the west side of the mobile home units. Based on the results of our analysis, we were to develop recommendations for supplementing the stability of these rockeries, if required. In addition, our evaluation was to include review of historical information to determine if current conditions had substantially modified those that existed prior to rockery construction.

Site Conditions

Surface

The site is located south of 124th Street NE, west of 93rd Lane NE, in Kirkland, Washington. The stream corridor, adjacent to which rockery construction has occurred, lies west of the mobile home units. Along the initial approximately 160-foot northern reach of the stream, both the west and east banks have been lined with a rock revetment to mitigate stream flow erosion. South of this rock-lined channel, a single- tier rockery, having an overall height ranging from two to five feet, has been constructed along the east stream bank for a length of approximately 70 feet. South of single-tier rockery, a two-tiered or terraced rockery has been constructed along the east stream bank for an additional distance of approximately 160 feet. This two-tiered rockery has a maximum overall relief from the upper rockery to the base of the lower rockery of approximately eight feet.

ENCLOSURE 4

12525 Willows Road, Suite 101, Kirkland, Washington 98034
Phone (425) 821-7777 • Fax (425) 821-4334 • terra@terra-associates.com

We observed that the stream flow was contained within the rock-lined stream banks for the northern reach of the stream and flowed relatively close to the base of the single-tier rockery, immediately to the south. This stream flow continues to occur relatively close to the base of the rockery in the two-tiered section, for an additional distance of approximately 80 feet. At this point, the stream flow shifts to the southwest away from the rockery base. We observed that the stream corridor was well vegetated, and that there was no evidence of significant uncontrolled erosion.

Soils and Groundwater

To obtain soil information necessary for us to complete our evaluation, in addition to site reconnaissance, we completed an exploration program consisting of drilling two soil test borings and excavating one test pit by hand behind the rockery construction. The test borings were drilled to a depth of about 20 feet, and the test pit was excavated to a depth of approximately 2 feet. The approximate location of the test pit and test borings is shown on Figure 2.

Soil conditions we observed at the test boring locations consisted of fill material overlying alluvial sand and gravel deposits. The fill material was observed to a depth of approximately 7 feet at Boring B-1 and 12 feet at Boring B-2. The fill was noted to consist predominately of a fine-grained silty sand to organic sandy silt. The fill was noted to be in a loose field condition. Underlying the fill at Boring B-1, we observed an organic silt layer that extended to a depth of approximately ten feet. Below this organic silt and below the fill material at Boring B-2, layers of relatively clean sand and gravel were observed to the boring termination depths. When initially encountered, these alluvial soils were noted to be in a very loose to loose field condition, with relative density increasing to medium dense to very dense with increasing depth.

Groundwater was observed at a depth of 9.5 feet and 12.0 feet during drilling at each Test Boring, respectively. These depths correspond roughly to the elevation of the adjacent stream flow on the west side of the rockeries.

The preceding discussion is intended as a general review of the soil conditions we observed at the site. For a more complete description, please refer to the Exploration Logs attached as Figures 4 through 6.

Stability Evaluation

During our reconnaissance of the site, we did not observe any indications that the rockery construction was completed in an unstable manner. The rocks used appear to be sound and durable, and their positioning in the rock face appeared consistent with the local standard of practice used in rockery construction. However, the fill material behind the rockery construction, along with native materials which form the rockery foundation, are noted to be in a loose and non-compact state. We analyzed the stability of these conditions in conjunction with the rockery facing and found that the safety factors against failure or instability were below accepted engineering standards. Safety factors indicated by our analysis for the rockery construction, as currently exists, were only slightly greater than one. Local design standards would require safety factors against instability of 1.5 or greater.

In our opinion, it will not be necessary to dismantle and reconstruct the rockeries using suitable compacted structural fill in order to achieve an acceptable stable configuration. Increasing the stability of the current rockery configuration can be achieved by installation of reinforcing anchors through the rockery face. A design detail for installation of the anchors through the rockery face is shown on attached Figure 8. Stability analysis of the rockery construction, with the reinforcing anchors installed as detailed, indicates safety factors against instability of 1.5 or greater will be achieved.

The reinforcing anchors will be installed by hand labor using either an electric or hydraulic 90-pound jackhammer. This stabilization technique would be applied to the terraced rockery construction, as well as the single-tiered rockery that extends an additional 75 feet north of the terraced section (See Figure 2). We estimate that a total of 150 anchors will be required to complete the stabilization project. Stabilization of the rockery construction in this manner will, in our opinion, be the least disruptive procedure that could be considered along the stream corridor.

Historical Review and City of Kirkland Code Compliance Issues

To evaluate whether or not the current conditions at the site have been significantly altered by the rockery construction, we reviewed historical photographs and topographic information of the site. Photograph review included stereo pairs of 1970 and 1990 aerial photographs of the site, with topographic review including a 1984 site plan for the adjacent Creek Side project, and a current topographic site plan, prepared in 1999 by Triad Associates. Review of the aerial photographs indicates that in 1970 the mobile home park was not present, and the site was occupied by a single residence and a driveway. The photographs show a west-facing slope leading from the west side of the residence down towards the stream. The slope is in the location of the southern mobile homes on the project site. Review of the 1990 photograph and site reconnaissance indicate that fill was placed on the slope for current driveway and mobile home pad construction. However, the stream course alignment appears similar to that which exists today.

Review of the topographic site plans shows that prior to construction of the rockeries, the east bank of the stream was a relatively steep fill slope. The 1984 topographic map shows this eastern stream bank inclined at a gradient of 40 to 60 percent, with local elevation relief of 8 to 10 feet. Results of our site reconnaissance and stability analysis indicates that this slope condition was unstable, and that sloughing or shallow failures of the slope likely occurred regressing back towards the mobile home units. These unstable conditions were observed and documented by several of the mobile home tenants. In our opinion, stabilization of the slope adjacent to mobile home units would have required a retaining element or bulkhead, and planting of vegetation alone would not have mitigated the slope instability that was impacting the mobile home units.

Review of the aerial photographs and the past and recent surveys of the stream show that the current rockery construction has not affected or altered the creek alignment. As noted above, the current alignment appears similar to that which existed in 1970. The current modifications occurred only on the slope adjacent to the stream in an attempt to stabilize it. The surveys show that only a relatively minor volume of additional fill was placed behind the rockery construction to achieve the current grade. In our opinion, this effort has provided some level of improved stability. However, as discussed in the preceding section, our analysis indicates that additional stabilization measures will be required to provide for long-term stability.

As discussed earlier, rock revetment has been placed on both the west and east sides of the streams along this northern reach. In our opinion, this revetment construction would not fall under the definition of bulkhead construction similar to the single-tier and terraced walls along the east side of the stream to the south. This channel lining was done only to prevent excessive erosion of the stream banks, and the revetment does not provide any significant lateral support of the adjacent soils as a bulkhead would do. Our observations of the revetment noted that it was performing satisfactorily and in our opinion, no supplemental stabilization would be required.

Limitations

This report is the copyrighted property of Terra Associates, Inc. and was prepared in accordance with generally accepted geotechnical engineering practices. This report is intended for specific application to the Firwood Mobile Home Park project and for the exclusive use of Firwood Lane, PS and their authorized representatives. No other warranty, expressed or implied, is made.

We trust the information presented is sufficient to meet your current needs. Should you have any questions or require additional information, please call.

Sincerely yours,
TERRA ASSOCIATES, INC.

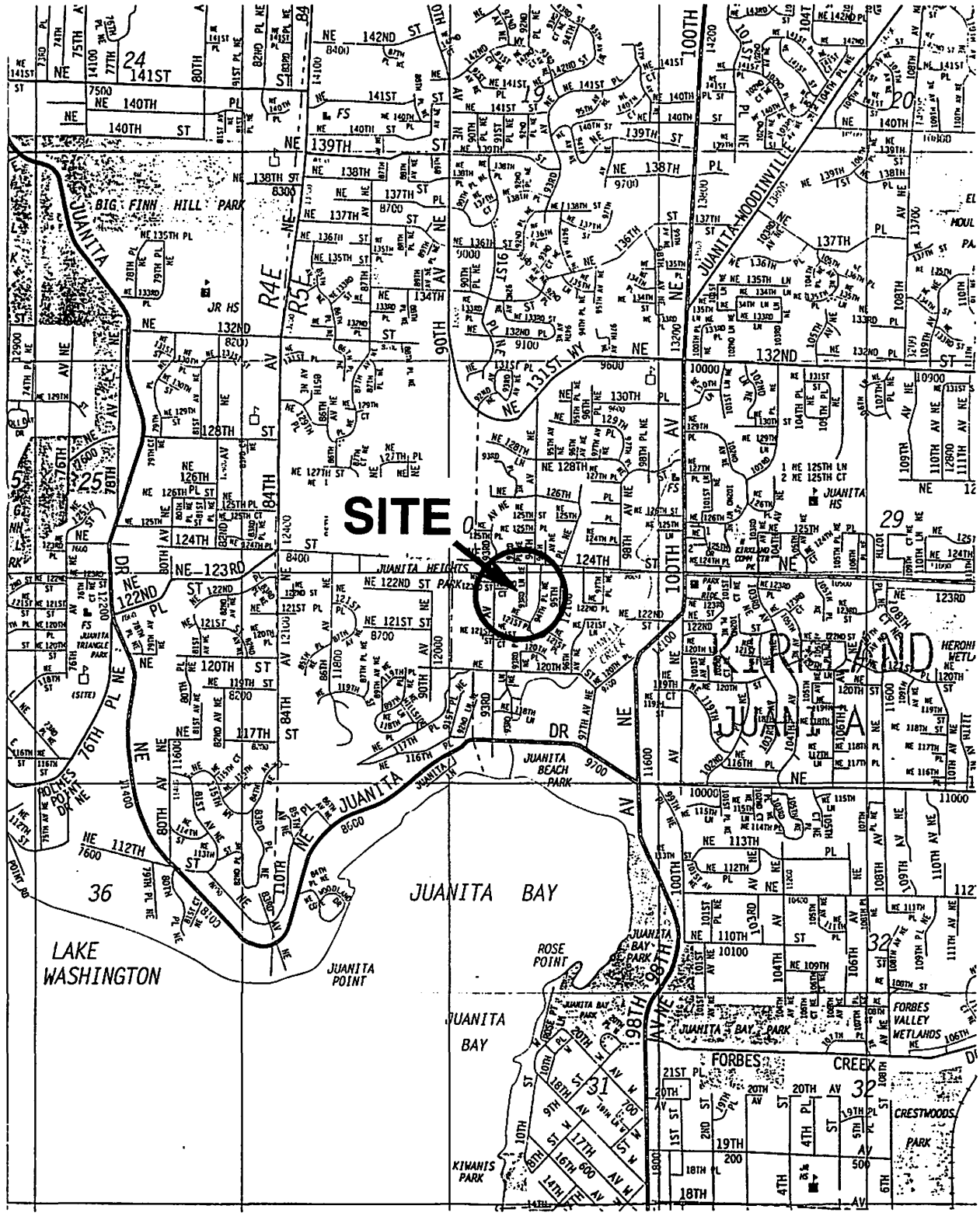
8-30-01

Theodore J. Schepper, P.E.
Principal Engineer

TJS:ae

Encl: Figure 1 – Vicinity Map
Figure 2 – Exploration Location Plan
Figure 3 – Unified Soil Classification System
Figure 4 through 5 – Borings Logs
Figure 6 – Test Pit
Figure 7 – Grain Size Analysis
Figure 8 – Reinforcing Anchor Installation

cc: Mr. Bill Shiels, Talasaea Consultants



REFERENCE: Thomas Guide, Metropolitan Edition, 2000. Pages 506 and 536.

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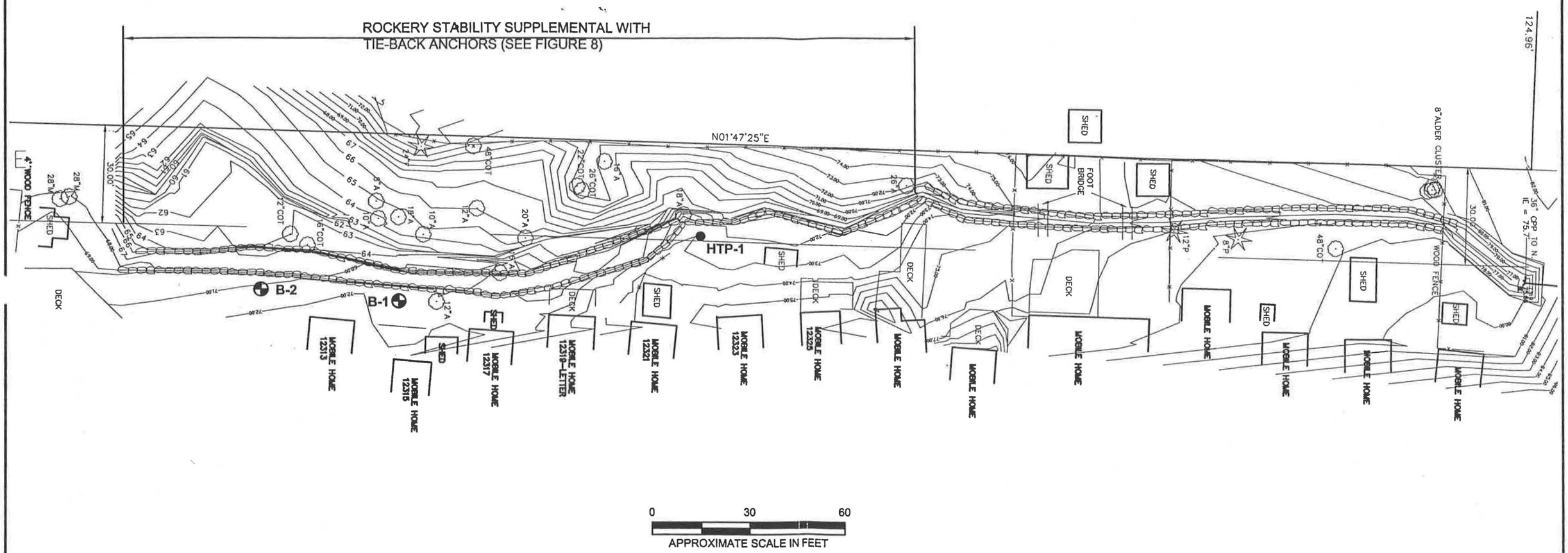
VICINITY MAP
ROCKERY STABILIZATION
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. 4515	Date AUG 2001	Figure 1



NOTE:

THIS SITE PLAN IS FOR REFERENCE PURPOSES ONLY AND IT SHOULD NOT BE USED FOR CONSTRUCTION OR DESIGN PURPOSES.

REFERENCE:

SITE PLAN PROVIDED BY TRIAD ASSOCIATES.

LEGEND:

- APPROXIMATE BORING LOCATION
- APPROXIMATE HAND-EXCAVATED TEST PIT LOCATION

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EXPLORATION LOCATION PLAN
ROCKERY STABILIZATION
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. 4515	Date AUG 2001	Figure 2

MAJOR DIVISIONS			LETTER SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS More than 50% material larger than No. 200 sieve size	GRAVELS More than 50% of coarse fraction is larger than No. 4 sieve	Clean Gravels (less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures, non-plastic fines.
			GC	Clayey gravels, gravel-sand-clay mixtures, plastic fines.
	SANDS More than 50% of coarse fraction is smaller than No. 4 sieve	Clean Sands (less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines.
			SP	Poorly-graded sands or gravelly sands, little or no fines.
		Sands with fines	SM	Silty sands, sand-silt mixtures, non-plastic fines.
			SC	Clayey sands, sand-clay mixtures, plastic fines.
FINE GRAINED SOILS More than 50% material smaller than No. 200 sieve size	SILTS AND CLAYS Liquid limit is less than 50%		ML	Inorganic silts, rock flour, clayey silts with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, (lean clay).
			OL	Organic silts and organic clays of low plasticity.
	SILTS AND CLAYS Liquid limit is greater than 50%		MH	Inorganic silts, elastic.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of high plasticity.
HIGHLY ORGANIC SOILS			PT	Peat.

DEFINITION OF TERMS AND SYMBOLS

SAND or GRAVEL

Density	Standard Penetration Resistance in Blows/Foot
Very loose	0-4
Loose	4-10
Medium dense	10-30
Dense	30-50
Very dense	>50

SILT or CLAY

Consistency	Standard Penetration Resistance in Blows/Foot
Very soft	0-2
Soft	2-4
Medium stiff	4-8
Stiff	8-16
Very stiff	16-32
Hard	>32

I	2" OUTSIDE DIAMETER SPLIT SPOON SAMPLER
I	2.4" INSIDE DIAMETER RING SAMPLER OR SHELBY TUBE SAMPLER
▼	WATER LEVEL (DATE)
Tr	TORVANE READINGS, tsf
Pp	PENETROMETER READING, tsf
DD	DRY DENSITY, pounds per cubic foot
LL	LIQUID LIMIT, percent
PI	PLASTIC INDEX
N	STANDARD PENETRATION, blows per foot

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UNIFIED SOIL CLASSIFICATION SYSTEM
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. T-4515	Date AUG 2001	Figure 3

Boring No. B-1

Logged by: KPR

Date: 10/14/99

Approximate Elev. 71'

Soil Description	Consistency/ Relative Density	Depth (ft.)	Sample	(N) Blows/ ft.	Moisture Content (%)	Notes
FILL: Dark brown organic silty fine sand, with wood bits, few gravel inclusions, moist. (OL/SM)	Loose			5	13.1	No SPT recovery. Shovel sample.
FILL: Brown, organic silty fine sand with rounded gravel and wood chunks, moist. (SM/OL)	Medium Dense			12	10.8	
FILL: Brown gravelly silty fine sand, occasional wood and masonry bits, moist. (SM)	Loose	5		4	16.5	Rounded medium gravel cuttings.
Brown-gray organic SILT, with rootlets, occasional saturated sand seams, wood bits, wet, slight plasticity. (OL)	Very Soft			2	70.1	
Gray fine to medium SAND with silt, 4-inch silty fine sand layer at 10.5 feet, water-bearing. (SP-SM)	Very Loose	10		2	25.8	
Gray sandy small to medium GRAVEL with silt, water-bearing. (GP-GM)	Medium Dense			17	9.2	More difficult drilling.
Gray, mottled sandy small GRAVEL with silt, medium to coarse sand, wet. (GP-GM)	Very Dense	15		54	10.4	

Boring terminated at 16.5 feet.
Groundwater encountered at 9.5 feet.

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BORING LOG
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. T-4515	Date AUG 2001	Figure 4

Boring No. B-2

Logged by: KPR

Date: 10/14/99

Approximate Elev. 71'

Soil Description	Consistency/ Relative Density	Depth (ft.)	Sample	(N) Blows/ ft.	Moisture Content (%)	Notes
FILL: Brown silty very fine sand with bits of wood, moist. (SM)	Loose			8	13.5	
FILL: Brown organic sandy silt with wood chunks, fine sand, moist, non-plastic. (OL)	Soft			4	16.6	Rounded medium gravel cuttings.
FILL: Brown to gray silty medium sand, moist. (SM)	Loose	5		7	9.8	
				5	7.8	
FILL: Brown medium sand, damp. (SP)	Loose	10		6	6.6	
Brown-gray, mottled, fine SAND with silt, water-bearing. (SP-SM)	Loose			8	25.4	
Gray fine to medium SAND, water-bearing. (SP)	Loose	15		6	29.3	More difficult drilling.
Gray fine to coarse SAND with silt and few gravel inclusions, water-bearing. (SP-SM)	Medium Dense			20	16.6	Rock in sampler shoe.

Boring terminated at 19 feet.
Groundwater encountered at 12 feet.

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BORING LOG
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. T-4515	Date AUG 2001	Figure 5

Test Pit No. HTP-1

Logged by: KPR

Approximate Elev. 72'

Date: 10/25/99

Depth (ft.)	Soil Description	Moisture Content (%)	
0	FILL: Dark gray-brown organic silty fine to medium sand with some gravel, wood chunks, loose, moist. (SM/OL)	18.0	
2	Test pit terminated at 2 feet due to refusal on obstruction. No groundwater encountered.		
3			

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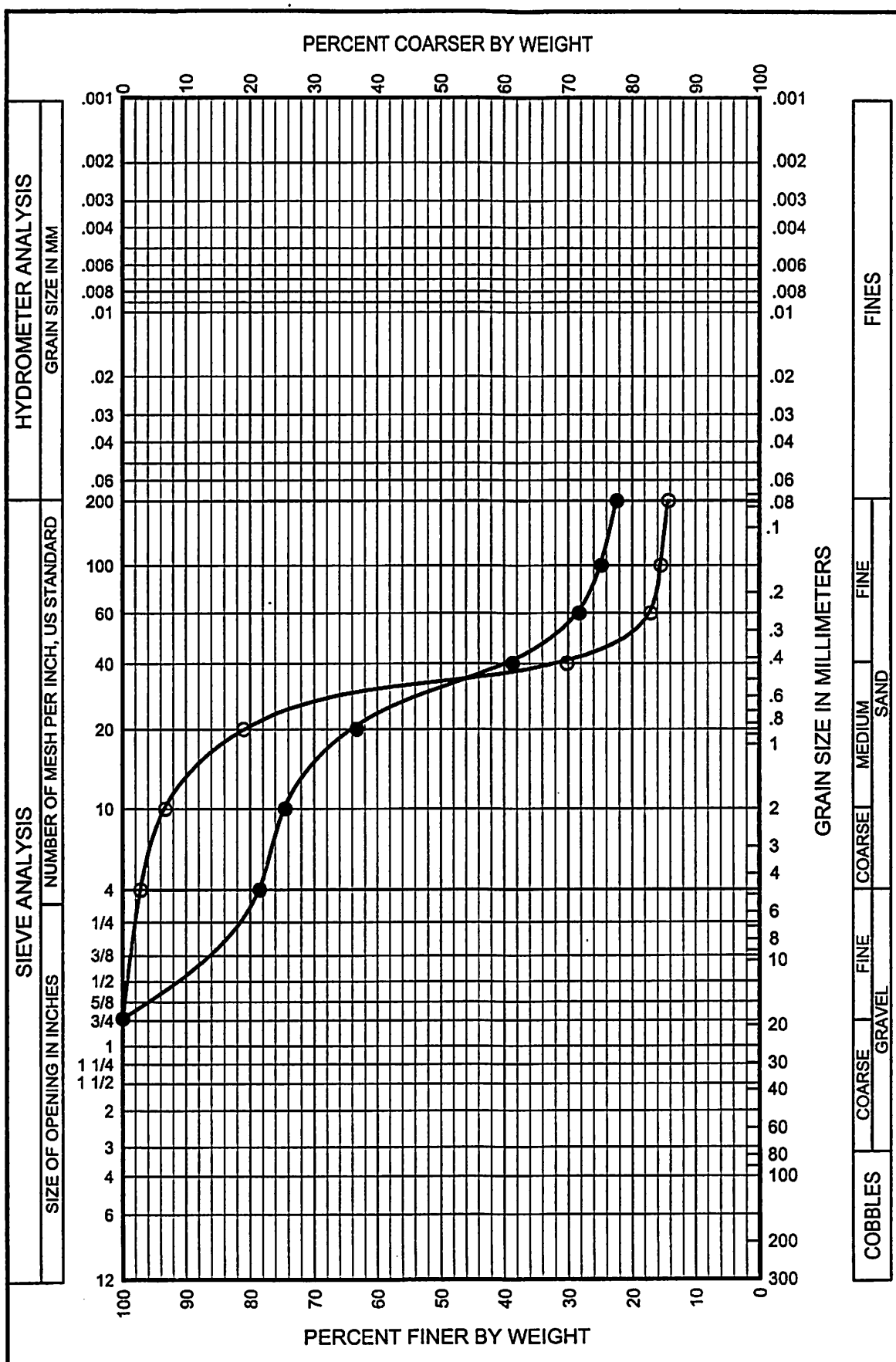
TEST PIT LOGS
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. T-4515	Date AUG 2001	Figure 6



Key	Exploration Number	Depth (ft.)	USCS	Description	Moisture Content (%)	LL	PL
●	B-1	5	SM	Gravelly Silty SAND			
○	B-3	5	SM	Silty SAND			

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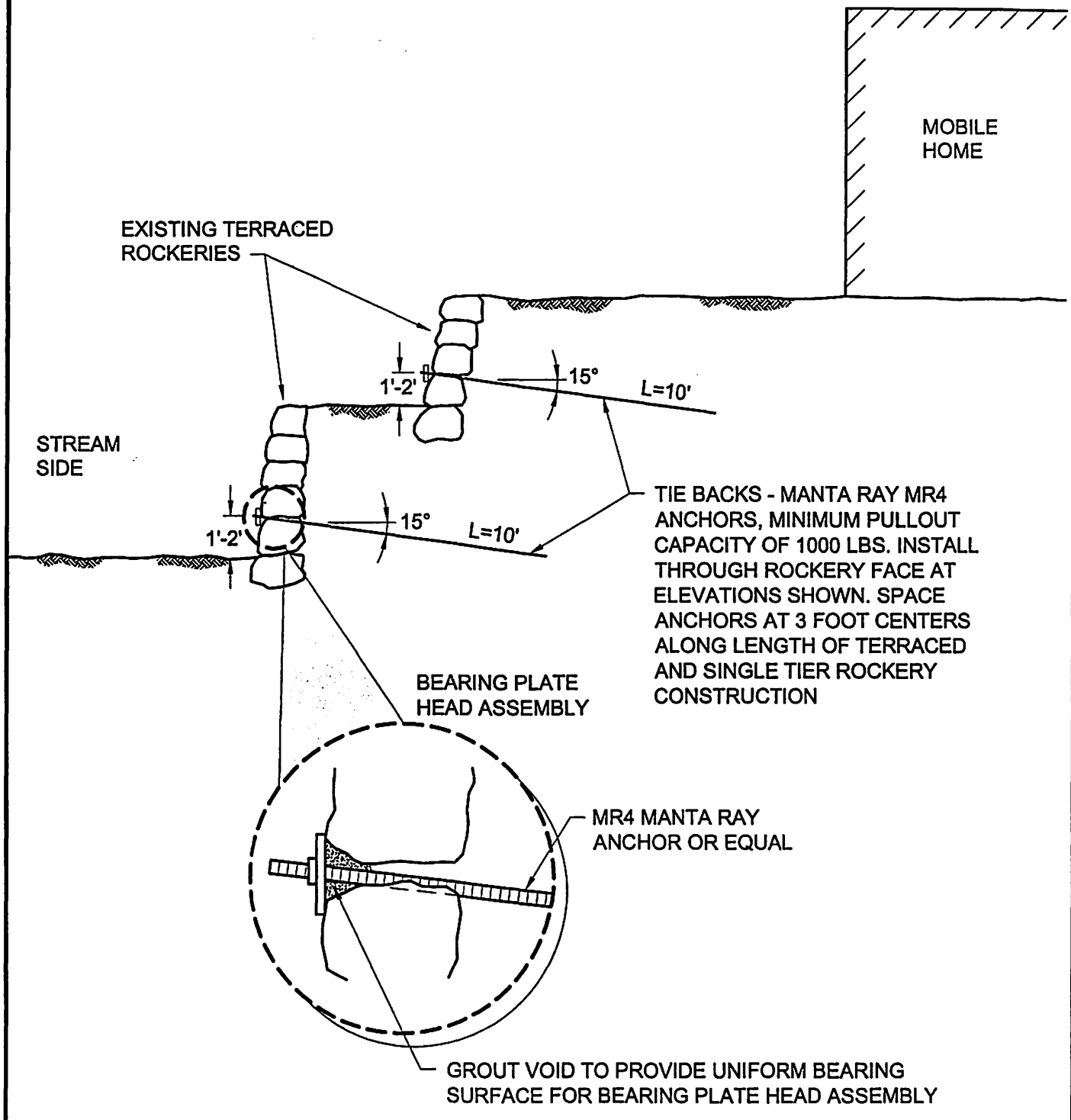
GRAIN SIZE ANALYSIS
ROCKERY STABILIZATION
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. 4515	Date AUG 2001	Figure 7



NOT TO SCALE

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REINFORCING ANCHOR INSTALLATION
ROCKERY STABILIZATION
FIRWOOD MOBILE HOME PARK
KIRKLAND, WASHINGTON

Proj. No. 4515	Date AUG 2001	Figure 8