March 3, 2020

Mr. Todd Vacura
Ferguson Construction
13810 Southeast Eastgate Way, Suite 110
Bellevue, Washington 98005

RE: Bulkhead Recommendations (Revised)
87th Street Bulkhead
8439 Southeast 87th Street
Mercer Island, Washington
RGI Project number 2019-328

References: Lake Washington Wave Climate Classification Report, prepared by Mott McDonad dated September 30, 2015
Review Comments from City of Mercer Island dated February 27, 2020

Dear Mr. Vacura:

The Riley Group, Inc. (RGI) is pleased to present our recommendations for repairing a bulkhead at the above-referenced site. On November 6, 2019, RGI observed the site condition and performed subsurface exploration by advancing three shallow borings using a hand auger in the proposed bulkhead repair areas. The boring locations are shown on Figure 2. On February 27, 2020, we received Lake Washington Wave Climate Report (Reference 1) and review comments from The City of Mercer Island (Reference 2). The following presents our findings of the soil conditions and recommendations for the proposed project based on referenced report and document.

PROJECT DESCRIPTION

RGI understands that the owner plans to rebuild an existing approximately 4- to 6-foot tall rock bulkhead extending about 65 feet along the shoreline of Lake Washington. Geotechnical recommendations will be needed for bulkhead design and construction. Our understanding of the project is based on our email communications with Mr. Evan Wehr of Ecco Architecture and Design dated October 18, 2019.

An RGI geologist visited the site on November 6, 2019 and observed the existing shoreline condition. Based on our observation, the existing rock bulkhead has a significant amount of movement and deterioration.

Currently, the bulkhead is the only structure to protect the site from being damaged by wave action. Per City of Mercer Island Municipal Codes 19.07110 (E)(2)(h), we recommend that the bulkhead be repaired or replaced with a similar structure.

SOIL AND GROUNDWATER CONDITION

The soils encountered during field exploration include stiff silt and medium dense silty sand with trace to some gravel and sand with some silt. More detailed descriptions of the subsurface conditions encountered are presented in the attached logs. Sieve analysis was performed on one selected soil sample. The grain size distribution curve is included.

At the time of the field exploration was performed, the lake level is 2 feet above the bottom of the bulkhead. RGI understands that the lake level variates about 2 feet and will be higher in the summer.

GEOTECHNICAL RECOMMENDATIONS

Analysis

The existing bulkhead is supporting the slope above the shoreline. It has a significant amount of movement and deterioration and is gradually losing support of the property above it. As soon as the bulkhead completely loses its support of the soil above it, the slope will be affected by erosion caused by wave action.

Based on the referenced report, the largest significant waves occur at the shoreline facing south and southwest in Lake Washington. The project area is facing south and therefore is vulnerable to significant wave action. The wave height at the bulkhead area is 3 to 4 feet with a peak period of 3 to 4 seconds and wave energy of 100 to 150 labs-foot per square foot. With the expected wave height, peak period, and energy, we expect that the shoreline, without protection from a bulkhead, will have an erosion rate from several inches to a foot per year. The toe of slope will be completely eroded within the next three years. The slope stability will be affected and a landslide will likely occur in the affected area.

Currently, the bulkhead is the only structure that protects the slope from being damaged by wave action. Based on our evaluation, the bulkhead has a significant amount of movement and deterioration and is not providing the needed protection for the property. Per City of Mercer Island Municipal Codes 19.07110 (E)(2)(h), we recommend that the bulkhead be repaired or replaced with a similar structure.

Based on the current scope of work, the existing rock bulkhead will be removed and a new rock bulk head will be constructed at the same location. Some of the rock blocks will be reused. We recommend that the height of the bulkhead be at least 2 feet higher than the maximum wave height which is 3 to 4 feet. The new bulkhead will be at least 5 to 7 feet above the existing water level. Our geotechnical comments and recommendations concerning the design and construction of the replacement bulkhead are provided below.

Rock Bulkhead

Rock bulkhead is a rockery used to protect waterfront property and it is not intended to function as an engineered structures to resist lateral earth pressures as a retaining wall. The primary function of a rock bulkhead is to provide stability and erosion control due to wave action. The amount of support obtained will depend on a large extent on the quality of the workmanship, size, shape of the rocks used, and drainage behind it. A critical factor in rockery construction is the quality of the rock material used. Rock for use in rockery should be cubical, rectangular, or tubular in shape with the longest dimension not exceeding three times the width. The rocks recycled from existing bulkhead may not be used if not meeting the requirement. Additional rocks may need to be imported. The rock bulkhead should be constructed by an experienced rockery contractor in accordance with Associated Rockery Contractors (ARC) guidelines.

We recommended that limiting the rockery height to eight feet placed along the native dense soil. A general rock bulkhead section detail is included on Figure 3.

The following sections of the report provide general recommendations related to erosion and sediment control, excavations, structural fill, and backfill compaction.

Erosion and Sediment Control

Potential sources or causes of erosion and sedimentation depend on construction methods, slope length and gradient, amount of soil exposed and/or disturbed, soil type, construction sequencing and weather. The impacts on erosion-prone areas can be reduced by implementing an erosion and sedimentation control plan. The plan should be designed in accordance with applicable city and/or county standards.

RGI recommends the following erosion control Best Management Practices (BMPs):

- Scheduling site preparation and grading for the drier summer and early fall months and undertaking activities that expose soil during periods of little or no rainfall
- Establishing a quarry spall construction entrance
- Installing siltation control fencing or anchored straw or coir wattles on the downhill side of work areas
- Covering soil stockpiles with anchored plastic sheeting
- Revegetating or mulching exposed soils with a minimum 3-inch thickness of straw if surfaces will be left undisturbed for more than one day during wet weather or one week in dry weather
- Directing runoff away from exposed soils and slopes
- Minimizing the length and steepness of slopes with exposed soils and cover excavation surfaces with anchored plastic sheeting (Graded and disturbed slopes should be tracked in place with the equipment running perpendicular to the slope contours so that the track marks provide a texture to help resist erosion and channeling. Some sloughing and raveling of slopes with exposed or disturbed soil should be expected.)
- Decreasing runoff velocities with check dams, straw bales or coir wattles
- Confining sediment to the project site
- Inspecting and maintaining erosion and sediment control measures frequently (The contractor should be aware that inspection and maintenance of erosion control BMPs is critical toward their satisfactory performance. Repair and/or replacement of dysfunctional erosion control elements should be anticipated.)

Permanent erosion protection should be provided by reestablishing vegetation using hydroseeding and/or landscape planting. Until the permanent erosion protection is established, site monitoring should be performed by qualified personnel to evaluate the effectiveness of the erosion control measures. Provisions for modifications to the erosion control system based on monitoring observations should be included in the erosion and sedimentation control plan.

Excavations

All temporary cut slopes associated with the site and utility excavations should be adequately inclined to prevent sloughing and collapse. Based on OSHA regulations, the native soil classifies as a Group B soil. Accordingly, for excavations more than 4 feet but less than 20 feet in depth, the temporary side slopes should be laid back with a minimum slope inclination of 1H:1V (Horizontal:Vertical).

In all cases, however, appropriate inclinations will depend on the actual soil and groundwater conditions encountered during earthwork. Ultimately, the site contractor must be responsible for maintaining safe excavation slopes that comply with applicable OSHA or WISHA guidelines.

Structural Fill

The native soil encountered is suitable for re-use as structural fill if the moisture can be property controlled. If the construction occurs in wet weather, RGI recommends import structural fill be used for all grading and backfill. The import material must meet the grading requirements listed in Table 1 in order to be used as structural fill.

Table 1 Structural Fill Gradation

U.S. Sieve Size	Percent Passing
3 inches	100
No. 4 sieve	75 percent
No. 200 sieve	5 percent *

*Based on minus 3/4 inch fraction.

Prior to use, an RGI representative should observe and test all materials imported to the site for use as structural fill. Structural fill materials should be placed in uniform loose layers not exceeding 12 inches and compacted as specified in Table 2. The soil's maximum density and optimum moisture should be determined by American Society of Testing and Materials D1557-09 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (ASTM D1557).

Table 2 Structural Fill Compaction ASTM D1557

Location	Material Type	Minimum Compaction Percentage	Moisture Content Range	
Foundations	On-site granular or approved imported fill soils:	95	+2	-2
Retaining Wall Backfill	On-site granular or approved imported fill soils:	92	+2	-2

Placement and compaction of structural fill should be observed by RGI. A representative number of in-place density tests should be performed as the fill is being placed to confirm that the recommended level of compaction is achieved.

ADDITIONAL SERVICES

RGI is available to provide further geotechnical consultation throughout the design phase of the project. RGI should review the final design and specifications in order to verify that earthwork and foundation recommendations have been properly interpreted and incorporated into project design and construction.

RGI is also available to provide geotechnical engineering and construction monitoring services during construction. The integrity of the earthwork and construction depends on proper site preparation and procedures. In addition, engineering decisions may arise in the field in the event that variations in subsurface conditions become apparent. Construction monitoring services are not part of this scope of work. If these services are desired, please let us know and we will prepare a cost proposal.

LIMITATIONS

This letter is the property of RGI, Ferguson Construction, and its designated agents. Within the limits of the scope and budget, this letter was prepared in accordance with generally accepted geotechnical engineering practices in the area at the time this letter was issued. This letter is intended for specific application to the 87th Street Bulkhead project in Mercer Island, Washington, and for the exclusive use of Ferguson Construction and its authorized representatives. No other warranty, expressed or implied, is made. Site safety, excavation support, and dewatering requirements are the responsibility of others.

The scope of services for this project does not include either specifically or by implication any environmental or biological (for example, mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, we can provide a proposal for these services.

The analyses and recommendations presented in this letter are based upon data obtained from reviewing the explorations completed by others on the site. Variations in soil conditions can occur, the nature and extent of which may not become evident until construction. If variations appear evident, RGI should be requested to reevaluate the recommendations in this letter prior to proceeding with construction.

We trust the information presented is sufficient for your current needs. If you have any questions regarding this letter report or require additional information, please call us at (425) 415-0551.

Sincerely yours,

THE RILEY GROUP, INC.

State of Washington Licensed Geologist 2698 — ERIC L. WOODS — 3/3/2020

Ricky Runqi Wang, State of Washington, 35013, Registered Professional Engineer — 3/3/2020

Eric L. Woods, LG

Ricky R. Wang, PhD, PE

Project Geologist Principal Engineer

Attachments:
Figure 1 Vicinity Map
Figure 2 Geotechnical Exploration Plan
Figure 3 Typical Rock Bulkhead Section
Hand Auger Boring Logs and Grainsize Analysis
Associated Rockery Contractors (ARC) Guidelines

USGS, 2014, Mercer Island, Washington
7.5-Minute Quadrangle

Approximate Scale: 1"=1000'

0 500 1000 2000

N

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Bothell, Washington 98011
Phone: 425.415.0551
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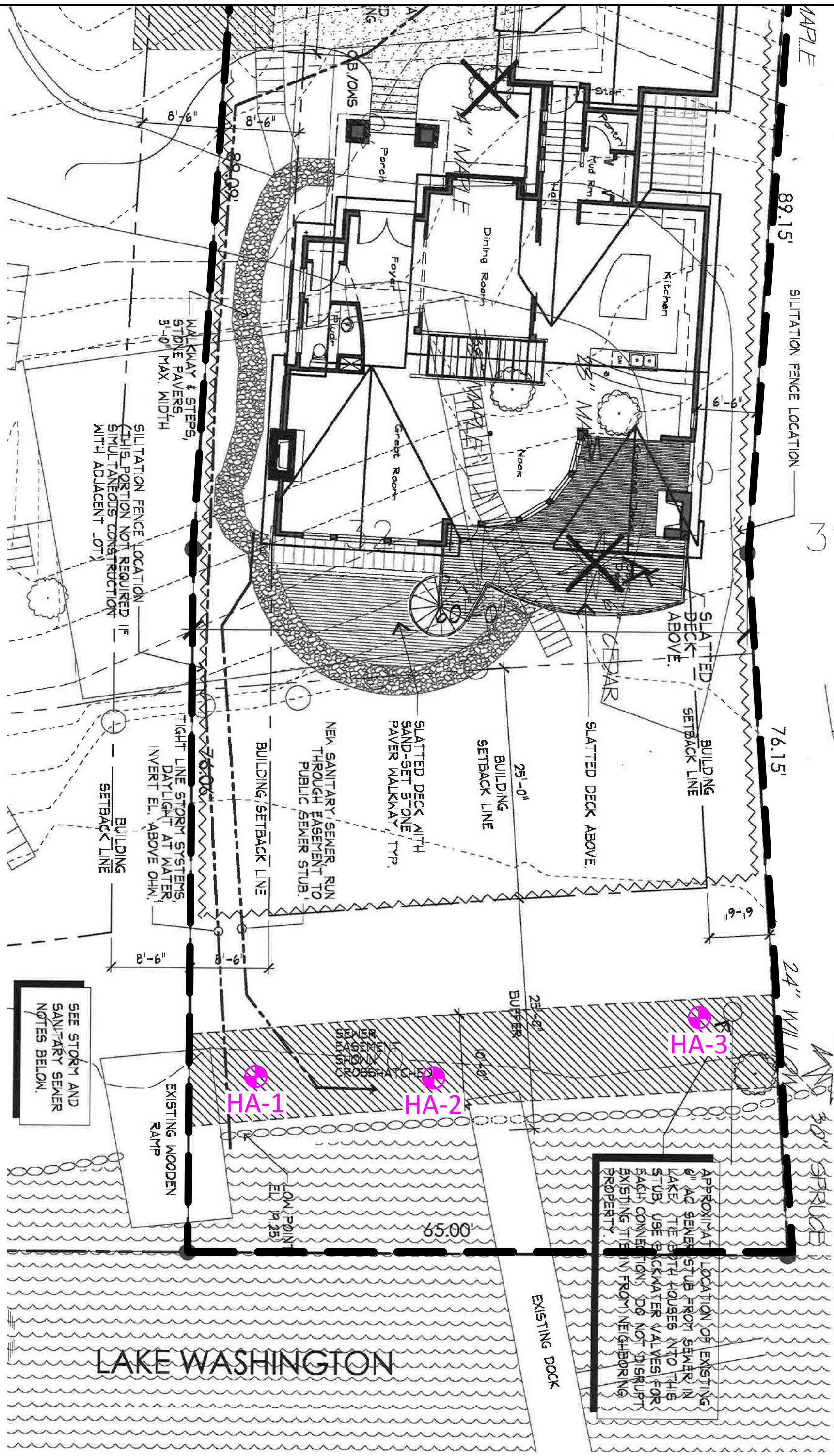
87th Street Bulkhead		Figure 1
RGI Project Number: 2019-328	Site Vicinity Map	Date Drawn: 11/2019
Address: 8439 Southeast 87th Street, Mercer Island, Washington 98040		



● = Hand auger boring by RGI, 11/06/19

— — — = Site boundary

Approximate Scale: 1"=20'

0 10 20 40

N

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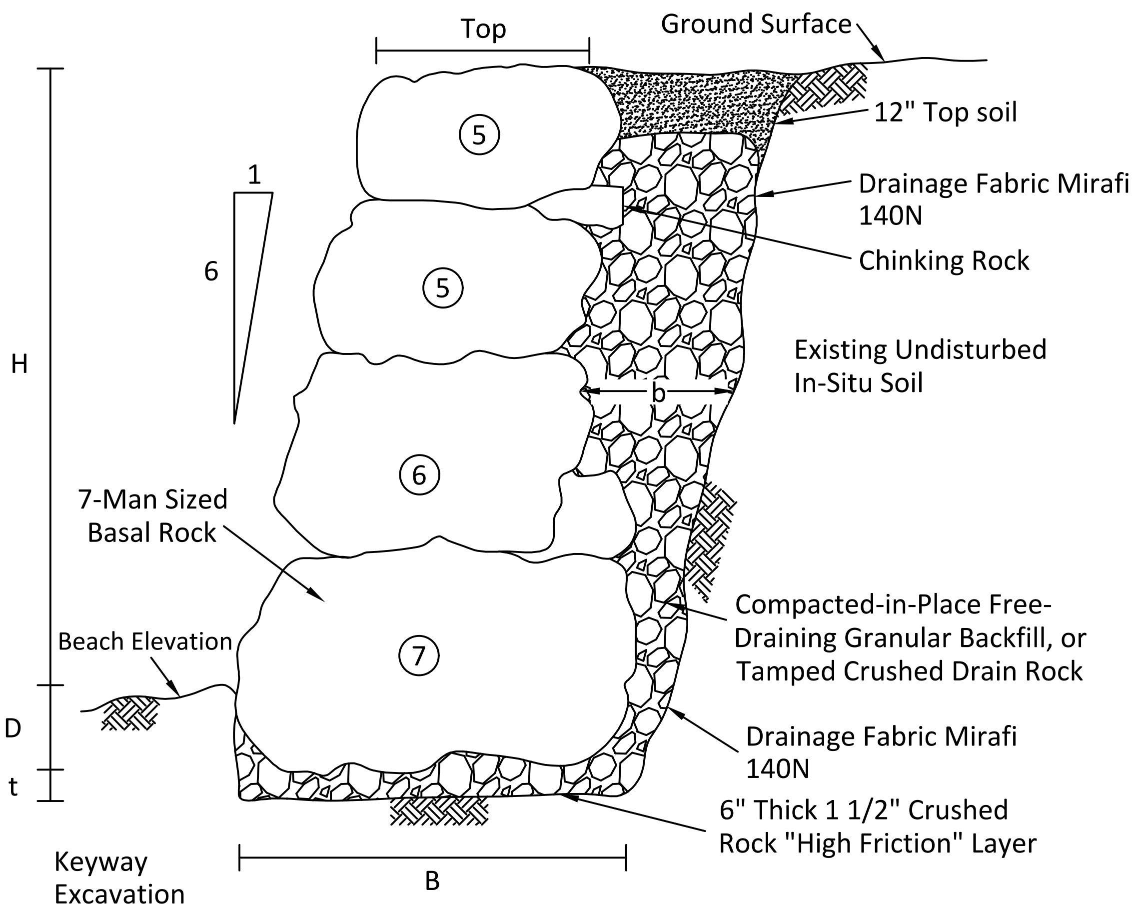
87th Street Bulkhead		Figure 2
RGI Project Number: 2019-328	Geotechnical Exploration Plan	Date Drawn: 11/2019
Address: 8439 Southeast 87th Street, Mercer Island, Washington 98040		



LEGEND

- Maximum estimated free-standing rock wall height, H = 12 feet
- Minimum estimated keyway excavation depth, D = 2-1/2 feet
- Minimum recommended thickness of 1-1/2" crushed rock "high friction" - layer t = 6 inches
- Minimum estimated total rock wall length, H+D-I = 13-1/2 feet
- Minimum recommended width of keyway excavation, B = See Table
- Minimum recommended thickness of drain rock layer, b = 1 foot
- Allowable soil bearing capacity of base of rock wall = 2,100 psf
- Minimum recommended basal rock size = 7-man
- Minimum recommended size of chinking rock = 2-man
- Neglect upper 1 foot of passive resistance in design
- Rock bulkhead wall construction to be in general accordance with the geotechnical engineering report and the ARC Rockery Construction Guidelines

Rock Man-Size	Rock Dimensions (Inches)	Rock Weight (Pounds)
3-man	28-36	700-2,000
4-man	36-48	2,000-4,000
5-man	48-54	4,000-6,000
6-man	54-60	6,000-8,000
7-man	>60	>8,000

H (Feet)	B (Feet)	Top (Feet)
4	4	3
6	5.5	4
8	7	5.5
10	8.5	6
12	9.5	7

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87th Street Bulkhead

Figure 3

RGI Project Number: 2019-328

Typical Rock Bulkhead Section

Date Drawn: 11/2019

Address: 8439 Southeast 87th Street, Mercer Island, Washington 98040

Project Name: **87th Street Bulkhead** Project Number: **2019-328** Client: **Ferguson Construction**	RILEYGROUP Hand Auger No.: **HA-1** **Sheet 1 of 1**

Date(s) Drilled: **11/6/2019**	Logged By: **ELW**	Surface Conditions: **Sod**
Drilling Method(s): **Hand Auger**	Drill Bit Size/Type: **N/A**	Total Depth of Borehole: **1 feet bgs**
Drill Rig Type: **N/A**	Drilling Contractor: **N/A**	Approximate Surface Elevation: **20**
Groundwater Level: **Not Encountered**	Sampling Method(s):	Hammer Data : **N/A**
Borehole Backfill: **Cuttings**	Location: **8439 Southeast 87th Street, Mercer Island, Washington**	

Elevation (feet)	Depth (feet)	Sample Type	Sample ID	Sampling Resistance, blows/ft	Recovery (%)	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Moisture (%)
20	0					TPSL		5" topsoil	
						Fill		Gray mottled SILT, stiff, moist (Fill)	
								Hand Auger terminated at sprinkler line	
15	5								

Project Name: **87th Street Bulkhead**
Project Number: **2019-328**
Client: **Ferguson Construction**

RILEYGROUP

Hand Auger No.: **HA-2**
Sheet 1 of 1

Date(s) Drilled: **11/6/2019**	Logged By: **ELW**	Surface Conditions: **Sod**
Drilling Method(s): **Hand Auger**	Drill Bit Size/Type: **N/A**	Total Depth of Borehole: **3.5 feet bgs**
Drill Rig Type: **N/A**	Drilling Contractor: **N/A**	Approximate Surface Elevation: **20**
Groundwater Level: **Not Encountered**	Sampling Method(s):	Hammer Data : **N/A**
Borehole Backfill: **Cuttings**	Location: **8439 Southeast 87th Street, Mercer Island, Washington**	

Elevation (feet)	Depth (feet)	Sample Type	Sample ID	Sampling Resistance, blows/ft	Recovery (%)	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Moisture (%)
20	0					TPSL		6" topsoil	
						Fill		Gray SILT with trace fine gravel, stiff, moist (Fill)	
						Fill		Gray silty SAND with trace gravel, medium dense, moist to wet (Fill)	
						Fill		Quarry spalls in a black gravelly sand matrix, medium dense, moist (Fill)	
								Hand Auger terminated at 3.5' due to rock obstruction	
15	5								

Project Name: **87th Street Bulkhead**

Project Number: **2019-328**

Client: **Ferguson Construction**

RILEYGROUP

Hand Auger No.: **HA-3**

Sheet 1 of 1

Date(s) Drilled: **11/6/2019**	Logged By: **ELW**	Surface Conditions: **Sod**
Drilling Method(s): **Hand Auger**	Drill Bit Size/Type: **N/A**	Total Depth of Borehole: **4 feet bgs**
Drill Rig Type: **N/A**	Drilling Contractor: **N/A**	Approximate Surface Elevation: **20**
Groundwater Level: **Not Encountered**	Sampling Method(s):	Hammer Data : **N/A**
Borehole Backfill: **Cuttings**	Location: **8439 Southeast 87th Street, Mercer Island, Washington**	

Elevation (feet)	Depth (feet)	Sample Type	Sample ID	Sampling Resistance, blows/ft	Recovery (%)	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Moisture (%)
20	0					TPSL		2" topsoil	
						Fill		Gray silty SAND with trace gravel, loose to medium dense, moist (Fill)	
						ML		Tan SILT, stiff, moist	
						SP-SM		Gray SAND with some silt, medium dense, moist	
						SM		Gray silty SAND with some gravel, medium dense, moist to wet	
								Hand auger terminated at 4' due to rock obstruction	
15	5								

Project Name: **87th Street Bulkhead**
Project Number: **2019-328**
Client: **Ferguson Construction**

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Key to Log of Boring
Sheet 1 of 1

Elevation (feet)	Depth (feet)	Sample Type	Sample ID	Sampling Resistance, blows/ft	Recovery (%)	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	Moisture (%)
1	2	3	4	5	6	7	8	9	10

COLUMN DESCRIPTIONS

1 Elevation (feet): Elevation (MSL, feet).
2 Depth (feet): Depth in feet below the ground surface.
3 Sample Type: Type of soil sample collected at the depth interval shown.
4 Sample ID: Sample identification number.
5 Sampling Resistance, blows/ft: Number of blows to advance driven sampler one foot (or distance shown) beyond seating interval using the hammer identified on the boring log.
6 Recovery (%): Core Recovery Percentage is determined based on a ratio of the length of core sample recovered compared to the cored interval length.
7 USCS Symbol: USCS symbol of the subsurface material.
8 Graphic Log: Graphic depiction of the subsurface material encountered.
9 MATERIAL DESCRIPTION: Description of material encountered. May include consistency, moisture, color, and other descriptive text.
10 Moisture (%): Moisture, expressed as a water content.

FIELD AND LABORATORY TEST ABBREVIATIONS

CHEM: Chemical tests to assess corrosivity
COMP: Compaction test
CONS: One-dimensional consolidation test
LL: Liquid Limit, percent
PI: Plasticity Index, percent
SA: Sieve analysis (percent passing No. 200 Sieve)
UC: Unconfined compressive strength test, Qu, in ksf
WA: Wash sieve (percent passing No. 200 Sieve)

MATERIAL GRAPHIC SYMBOLS

AF
SILT, SILT w/SAND, SANDY SILT (ML)
Silty SAND (SM)
Poorly graded SAND with Silt (SP-SM)
Topsoil

TYPICAL SAMPLER GRAPHIC SYMBOLS

Auger sampler
Bulk Sample
3-inch-OD California w/ brass rings
CME Sampler
Grab Sample
2.5-inch-OD Modified California w/ brass liners
Pitcher Sample
2-inch-OD unlined split spoon (SPT)
Shelby Tube (Thin-walled, fixed head)

OTHER GRAPHIC SYMBOLS

Water level (at time of drilling, ATD)
Water level (after waiting)
Minor change in material properties within a stratum
Inferred/gradational contact between strata
? Queried contact between strata

GENERAL NOTES

1: Soil classifications are based on the Unified Soil Classification System. Descriptions and stratum lines are interpretive, and actual lithologic changes may be gradual. Field descriptions may have been modified to reflect results of lab tests.
2: Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced. They are not warranted to be representative of subsurface conditions at other locations or times.

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GRAIN SIZE ANALYSIS
ASTM D421, D422, D1140, D2487, D6913

PROJECT TITLE	87th Bulkhead	SAMPLE ID/TYPE	HA-3
PROJECT NO.	2019-328	SAMPLE DEPTH	1.5'
TECH/TEST DATE	JDH 11/18/2019	DATE RECEIVED	11/17/2019

WATER CONTENT (Delivered Moisture)

Wt Wet Soil & Tare (gm)	(w1)	148.9
Wt Dry Soil & Tare (gm)	(w2)	118.8
Weight of Tare (gm)	(w3)	16.1
Weight of Water (gm)	(w4=w1-w2)	30.1
Weight of Dry Soil (gm)	(w5=w2-w3)	102.7
Moisture Content (%)	(w4/w5)*100	29

Total Weight Of Sample Used For Sieve Corrected For Hygroscopic Moisture

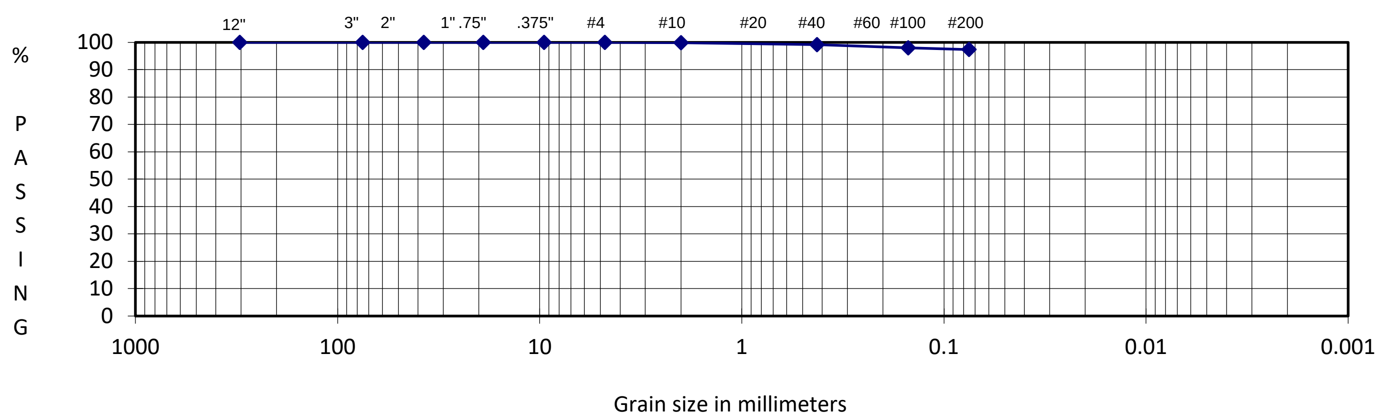
	Weight Of Sample (gm)	118.8
	Tare Weight (gm)	16.1
(W6)	Total Dry Weight (gm)	102.7

% COBBLES	0.0
% C GRAVEL	0.0
% F GRAVEL	0.0
% C SAND	0.1
% M SAND	0.8
% F SAND	1.8
% FINES	97.4
% TOTAL	100.0

D10 (mm)	
D30 (mm)	
D60 (mm)	
Cu	
Cc	

SIEVE ANALYSIS

Sieve	Wt Ret +Tare	(Wt-Tare)	Cumulative (%Retained) {(wt ret/w6)*100}	% PASS (100-%ret)	
12.0"	16.1	0.00	0.00	100.00	cobbles
3.0"	16.1	0.00	0.00	100.00	coarse gravel
2.5"					coarse gravel
2.0"					coarse gravel
1.5"	16.1	0.00	0.00	100.00	coarse gravel
1.0"					coarse gravel
0.75"	16.1	0.00	0.00	100.00	fine gravel
0.50"					fine gravel
0.375"	16.1	0.00	0.00	100.00	fine gravel
#4	16.1	0.00	0.00	100.00	coarse sand
#10	16.2	0.10	0.10	99.90	medium sand
#20					medium sand
#40	17.0	0.90	0.88	99.12	fine sand
#60					fine sand
#100	18.2	2.10	2.04	97.96	fine sand
#200	18.8	2.70	2.63	97.37	fines
PAN	118.8	102.70	100.00	0.00	silt/clay



DESCRIPTION	SILT
USCS	ML

Prepared For:

Reviewed By:

RILEYGROUP

ARC

Associated Rockery Contractors

Rock Wall Construction Guidelines

P.O. Box 1794 • Woodinville, Washington 98072

Association Representative
(425) 481-3456 or
(253) 838-4836

ARC ROCKERY CONSTRUCTION GUIDELINES

Contents

ARC ROCKERY CONSTRUCTION GUIDELINES

Section 1
Introduction

1.01.1 Historical Background

These rock wall construction guidelines have been developed in an effort to provide a more stringent degree of control on materials and construction methodology in the Pacific Northwest, and elsewhere. They have been assembled from numerous other data presently in use in the area, from expertise provided by local geotechnical engineers, and from the wide experience of the members of the Associated Rockery Contractors (ARC).

1.101.2 Goal

The primary goals of this document are to develop appropriate methods of construction for rock walls, including those of less than over four feet in height, and to provide a means of verifying the quality of materials used in construction and the workmanship employed in construction. These guidelines have also been developed in a manner that makes them, to the best of ARC's knowledge, more stringent than the others construction methods or requirements presently in use by local municipalities.

Section 2
Materials

2.01.1 Rock Quality

All rock shall be sound, angular ledge rock that is resistant to weathering. The longest dimension of any individual rock should not exceed three times its shortest dimension. Acceptability of rock will be determined by laboratory tests as hereinafter specified, geologic examination and historical usage records.

All rock delivered to and incorporated in the project shall meet the following **Minimum** specifications:

a.	Absorption ASTM C-127 AASHTO T-85	*Not more than 2.0% for igneous and metamorphic rock types and 3.0% for sedimentary rock types.*
b.	Accelerated Expansion *(15 days) CRD-C-148 *1, *2*	*Not more than 15% breakdown.*
c.	*Soundness (MsSO4 at 5 cycles)* ASTM C-88 or CRD-C-137	*Not greater than 5% loss.*

d. Unconfined Compressive Strength *ASTM D-2938* — *Intact strength of 6,000 psi,* or greater

e. Bulk Specific Gravity (155pcf) *ASTM C-127* *AASHTO T-85* — *Greater than 2.48*

*1. The test sample will be prepared and tested in accordance with Corps of Engineers Testing procedure CRD-C-148, "Method of Testing Stone for Expansive Breakdown on Soaking in Ethylene Glycol."

*2. Accelerated expansion tests should also include analysis of the fractures and veins found in the rock.

2.01.2 Frequency of Testing

Quarry sources shall begin testing program when either becominga supplier or when a new area of the source pit is opened. The tests described in Section 2.01.1 shall be performed for every four thousand (4000) tons, for the first twelve thousand (12,000) tons of wall rock supplied to establish that specific rock source. The tests shall then be performed once a year, every forty thousand (40,000) tons (whichever occurs first), or at an apparent change in material. If problems with a specific area in a pit, or with a particular material, are encountered the initial testing cycle shall be restarted.

2.01.3 Rock Density

Recognizing that numerous sources of rock exist, and that the nature of rock will vary not only between sources but also within each source, the density ofthe rock shall be equal to, or greater than, one hundred fifty-five (155) pcf. Typically, rocks used for rock wall construction shall be sized approximately as follows:

Rock Size	Rock Weight	Average Dimension
One Man	50-200 pounds	12 to 18 inches
Two Man	200-700 pounds	18 to 28 inches
Three Man	700-2000 pounds	28 to 36 inches
Four Man	2000-4000 pounds	36 to 48 inches
Five Man	4000-6000 pounds	48 to 54 inches
Six Man	6000-8000 pounds	54 to 60 inches

ARC ROCKERY CONSTRUCTION GUIDELINES

In rock walls of greater than eight feet in free-standing height it should not be possible to move the large sized rocks (four to six-man size) with a pry bar. If these rocks can be moved, the rock wall should not be considered capable of restraining any significant lateral load. However, it is both practical and even desirable that smaller rocks, particularly those used for "chinking" purposes, can be moved with a pry bar to achieve the "best fit".

2.01.4 Submittals

The rock source shall present current geologic and test data for the minimum guidelines described in Section 2.01.1 on request by either the rock wall contractor, the owner, or the applicable public agency.

Section 3
Rock Wall Construction

3.01.1 General

Rock wall construction is a craft and depends largely on the skill and experience of the builder. A rock wall is a protective system which helps to retard the weathering and erosion process acting on an exposed cut or fill soil face. While by its nature (the mass, size and shape of the rocks) it will provide some undetermined degree of "mass" or "gravity" retention, it is not typically a designed or engineered system in the sense a reinforced concrete retaining wall would be considered designed or engineered. The degree of retention achieved is dependent on the size of rock used; that is, the "mass" or weight, and the height of the rock wall being constructed. The larger the rock, the more competent the rock wall. To develop an appropriate degree of competency, all rock walls in excess of four feet in height should be built on a "mass" basis, i.e. by the ton, NOT on a square foot of exposed face basis.

To provide a competent and adequate rock wall structure, all rock walls constructed in front of either cuts or fills eight feet and over in height should be bid and constructed in accordance with these guidelines and the geotechnical engineer's supplemental geotechnical recommendations. Both the ARC guidelines and the supplemental geotechnical recommendations should be provided to prospective bidders **before** bidding and the start of construction.

3.01.2 Geotechnical Engineer

The geotechnical engineer retained to provide necessary supplemental rock wall construction guidelines shall be a practicing geotechnical/civil engineer licensed as a professional civil engineer in the State of Washington. He or she should have at least four years of professional employment as a geotechnical engineer in responsible charge, including experience with fill construction and stability and rock wall construction. The geotechnical engineer should be hired either by the rock wall contractor or the owner.

It is **CRITICAL** that the geotechnical engineer visit the site of a proposed rockery before providing any geotechnical recommendations whatsoever. This visit provides the opportunity for the geotechnical engineer to evaluate the proposed wall location and alignment, and to determine if there are any potential site related concerns that might detrimentally impact the rockery's "design" or construction. Failure to conduct this site visit could result in damage to the constructed wall or even to a wall failure.

3.01.3 Responsibility

The ultimate responsibility for rock wall construction should remain with the rock wall builder. However, rock walls protecting moderate to thick fills, with steep sloping surfaces above or below them, with multiple steps or stages, with foundation or other surcharge loads affecting them, protecting sandy or gravelly soils subject to raveling, with seepage or wet conditions, or that are greater than eight feet in free-standing height, all represent special "design" conditions and require consultation and/or advice from a suitably qualified geotechnical engineer.

3.01.4 Workmanship

All workmanship is guaranteed by the rock wall contractor and all materials are guaranteed by the supplying quarry for a period of six years from the date of completion of erection, providing no modification or changes to the conditions existing at the time of completion are made.

3.01.5 Changes to Finished Product

Such changes include, but are not necessarily limited to, temporary excavation of ditches or trenches for any utility within a distance of less than five feet from the back of the top of the rock wall; excavation made either within a distance equal to at least two thirds of the free-standing wall height in front of the toe of a rock wall, or that will penetrate an imaginary line extended at a 1H:1V (Horizontal:Vertical) slope from the front edge of the rock wall toe (see figure D); removal of any material from the subgrade in front of the wall, excavation of material from any location behind the rock wall within a distance at least equal to the rock wall's height, the addition of any surcharge or other loads within a similar distance of the top of the wall, or surface or subsurface water forced, directed, or otherwise caused to flow behind the rock wall in any quantity.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.6 Slopes

Slopes above rock walls should be kept as flat as possible, but should not exceed 2H:1V unless the rock wall is "engineered" specifically to provide some restraint to the surcharge load imposed by the slope. Any slope existing above a completed rock wall should be immediately covered with vegetation by the owner to help reduce the potential for surface water flow induced erosion. It should consist of a deep rooted, rapid growth vegetative mat, and will typically be placed by hydroseeding and covered with a mulch. It is often useful to overlay the seed and mulch with either pegged in-place jute matting, or some other form of approved geotextile or erosion control blanket, to help maintain the seed in-place until the root mat has an opportunity to germinate and take hold,

3.01.7 Monitoring

All rock walls constructed against cuts or fills of greater than four feet in height shall be periodically monitored during construction by the geotechnical engineer to verify that the nature and quality of the materials being used are appropriate, that the construction procedures are appropriate, and that the rock wall is being constructed in a generally professional manner and in accordance with this ARC guideline and any supplemental geotechnical recommendations. Past experience indicates that a **minimum** of two visits of limited duration is typically acceptable for monitoring purposes of single-stage walls of less than fifty (50) feet in length. For walls of greater than fifty (50) feet but less than one hundred (100) feet in length three monitoring visits are considered the **minimum** acceptable. For walls of greater than one hundred (100) feet in length an appropriate monitoring program shall be developed by the geotechnical engineer. For a multi-stage rock wall the **minimum** acceptable number of monitoring visits shall be considered at two visits for each stage of the wall.

The monitoring agent, typically the geotechnical engineer of record, shall maintain a written record of the nature and condition of the segment of the rock wall being monitored during that visit. An example of a Rockery Examination Record suitable for this form of documentation is attached to this ARC Guideline for informational purposes.

Where there is a slope above or below the rockery wall it is important that the monitoring agent make a visual assessment of the slopes' stability, and record the results. Additionally, the inclination of the slope either in degrees or as a H:V slope, shall be approximately determined and recorded.

When the monitoring agent is checking a rocks soundness as it is struck with a hammer (see attached Rockery Examination Record) one of several "sounds" will be generated. A "clink" or "ringing ping" typically results from a fresh and competent rock with little or no defects. A duller "thud" or "clonk" sound is more indicative of a poor quality rock, often with many seams or defects. The duller "thudding" sound is often exhibited by a rock that has a high tendency to rapidly deteriorate back into a highly weathered and "soft" rock or even to a "soil." Where such rocks are encountered the contractor should be requested to move the rock to the upper row or to a lower segment of the wall where it can more easily be reached and removed when it degrades without causing any significant disruption to the completed wall.

On completion of the rock wall, the geotechnical engineer should submit to the client, the rock wall contractor, and to the appropriate municipality, copies of his rock wall examination reports along with a final report summarizing rock wall construction.

3.01.8 Fill Compaction

Where rock walls are constructed in front of a fill, it is imperative that the owner ensure the fill be placed and compacted in a manner that will provide a competent fill mass. To achieve this goal, all fills should consist of relatively clean, organic and debris free, granular material with a maximum size of four inches. Ideally, but particularly if placement and compaction is to take place during the wet season, they should contain no more than five percent fines (silt and clay sized particles) passing the number 200 mesh sieve).

All fills should be placed in thin lifts not exceeding ten (10) inches in loose thickness. Each lift should be compacted to at least 95 percent of the maximum dry density, as determined by Modified Proctor, before any additional fill is placed and compacted. In-place density tests should be performed by an independent testing agency at random locations within each lift of the fill using either a nuclear density testing gauge or a more traditional sand cone device to verify that this degree of compaction is being achieved. Failure to achieve this degree of compaction could result in the imposition of a greater lateral load on the rock wall that could, over time, cause lateral movement or even "failure" of the rock wall. This situation is to be avoided!

3.01.9 Fill Construction Reinforcement

There are two methods of constructing a fill. The first, which typically applies to rock walls of less than eight feet in free-standing height, is to overbuild and then cut back the fill. The second, which applies to all rock walls of greater than eight feet in height, is to construct the fill using a geogrid or geotextile reinforcement.

Overbuilding the fill allows for satisfactory compaction of the fill mass out beyond the location of the fill face to be protected. Overbuilding also allows the earthwork contractor to use larger and more effective compaction equipment in his compactive efforts, thereby typically achieving a more competent fill mass. Cutting back into the well compacted fill also typically results in construction ofa competent near vertical fill face against which to build the rock wall. This option is pictorially depicted on Plate B, attached.

For higher rock walls the use of a geogrid or geotextile fabric to help reinforce the fill results in construction of a more stable fill face against which to construct the rock wall. This form of construction leads to a longer lasting more stable rock wall and helps reduce the risk of significant long term maintenance.

This latter form of construction requires a design by the geotechnical engineer for each specific case. The vertical spacing of the reinforcement, the specific type of reinforcement, the distance it must extend back into the fill, the amount of lapping and the construction sequence must be determined on a case by case basis. This option is pictorially depicted on Plate C, attached.

3.01.10 Rock Wall Keyway

The first step in rock wall construction, after general excavation, is to construct a keyway in which to install or "set" the basal row of rock forming the rock wall. The keyway shall comprise a shallow trench of not less than twelve (12) inches in depth, extending for the full length of the rock wall. If the rock wall is a waterfront bulkhead wall the **Minimum** keyway depth shall be two feet, measured from the natural beach elevation in front of the wall that existed before wall construction began. The keyway subgradeshould be slightly inclined back towards the face being protected. It is typically dug as wide as the rock wall (including the width of the drain rock layer). If thecondition of the cut face is of concern, the keyway should be constructed in sections of manageable length, that is, of a length that can be constructed in one shift or one day's work, or if a waterfront wall between high tides.

The competency of the keyway subgrade to support the rock wall shall be verified by the geotechnical engineers' probing with a small diameter steel rod. The rod shall have a diameter of between three-eighths and one-half inch, and shall be pushed into the subgrade in a smooth unaided manner under the body weight of the prober only. Penetration of up to six inches, with some difficulty, shall indicate a "competent" keyway subgrade unless other factors in the geotechnical engineer's opinion shall be considered to indicate otherwise.

Penetration in excess of six inches, with ease, shall indicate a "soft" subgrade and one that could require treatment. Shallow soft areas of the subgrade can be "firmed up" by tamping a layer of coarse quarry spalls into the subgrade.

Where a rock wall is being "analyzed" or "engineered" as a wall capable of at least partially restraining a lateral load it is often appropriate to install a layer of coarse, angular crushed rock over the prepared keyway subgrade to enhance the frictional resistance between the subgrade and basal rock and, thus, the walls ability to resist sliding. This crushed rock layer should be not less than six inches in thickness, after being firmly tamped into the subgrade, and should typically comprise "fines free" two to four inch sized crushed rock "quarry spalls" or crushed recycled concrete.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.11 Keyway Drainage

Upon completion of keyway excavation, a four-inch minimum diameter perforated or slotted, smooth-walled rigid plastic drain pipe, or equivalent approved in writing by a geotechnical engineer, should be installed at the rear of the keyway, behind the basal rock. It should be bedded on and surrounded by a free-draining crushed rock. It is **critical** to exercise due care when setting rocks to prevent the pipe from being inadvertently crushed by pieces of the rock wall rock. This drain pipe should be installed with sufficient gradient to initiate flow either to one end or the other, or to a low point, and the outfall should be connected by unperforated tightline to a positive and permanent discharge.

Positive and permanent drainage should be considered to mean an existing, or to be installed, storm drain system, a detention or retention pond, drain swale, or other stable native site feature or previously installed collection system.

Where a rock wall is being installed as a waterfront bulkhead wall subject to tidal and current activity the above-described drain pipe becomes redundant and may be omitted. With hydraulic/tidal fluctuations the water penetrating through the rock wall will drain back out through the void spaces far more rapidly than can be achieved by the basal drain.

In arid regions, such as Eastern Washington and Nevada, where there is little risk of seepage occurring the basal drain pipe may be omitted. However, the minimum thickness of drain rock should be installed to help protect the soil face behind the constructed wall, and to assist in "blocking" or "chinking" the voids between the individual rockery rocks.

3.01.12 Rock Wall Thickness

The individual rock wall thickness should be equal to the thickness of the recommended size of rock plus the thickness of the drain rock layer. This thickness, which will be determined on a case by case basis, will be dependant on the specific rock sizes recommended for each individual rock wall. For example, if four-man rock is used the rock wall thickness will be approximately five feet (rock width plus twelve [12] inches of drain rock).

If the rock wall is to act, even in part, as a "retaining" structure it is **critical** that the size and mass of the in-place rock is adequate to resist the applied load. In some instances it may be necessary to install more than one row of rock. In this case it is **imperative** that the owner and rock wall contractor seek the advice of a professional geotechnical engineer before proceeding with construction.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.13 Rock Selection

The contractor should have sufficient space available so that he can select from among a number of stockpiled rocks for each space in the rock wall to be filled. Rockswhich have shapes which do not match the spaces offered by the previous course of rock should be placed elsewhere to obtain a better fit. Rock should be of a generally cubical, tabular or rectangular shape and selected in accordance with Section 2.01.3 of this Guideline. Any rocks of basically rounded or tetrahedral form should be rejected or used for filling large void spaces.

It is also important to select rocks that do not exhibit any significant cracks, seams or foliation joints so that, once in-place, the individual rocks do not break, split or crumble and thereby create a weak zone within the constructed wall. It is acceptable to install individual rocks with cracks, seams, or foliation joints in a wall providing that theycan be firmly and adequately confined by the surrounding rocks. It is critical that the cracks, seams or foliation joints do NOT allow for portions of the rock to spall off and fall out of the wall. Similarly, considerable care should be exercised by the rock wall contractor to avoid installing any rock with a weakened or "scabbing" face that might spall off and fall out of the wall, or off the wall face.

3.01.14 Rock Placement

The first course of rock should be placed on firm unyielding soil, or onto the previously installed layer of crushed rock. There should be full contact between the rock and soil or crushed rock surface, which may require shaping of the ground surface or slamming or dropping the rocks into place so that the soil or angular crushed rock covered subgrade better conforms to the rock face bearing on it. The bottom of the first course of rock should be a **minimum** of twelve (12) inches below the lowest adjacent site grade, or not less than two feet for a waterfront bulkhead wall per Section 3.01.10 of this Guideline.

As the rock wall is constructed, the rocks should be placed so that there are no continuous joint planes in either the vertical or lateral direction. Wherever possible, each rock should bear on a least two rocks below it. Rocks should be placed so that there is some bearing between flat rock faces rather than in or on spaces between the underlying rocks. The upper plane of each rock between courses (the top surface of rock), should slope back towards the protected soil face and away from the face of the rock wall.

Because stacked rocks exhibit a tendency to "topple" outwards it is **crucial** that individual rocks NOT be stacked like shoe boxes in any wall regardless of the total height. Whilst an occasional rock will, simply because of its shape or size, be stacked atop another, stacking must not become a practice. If rocks are stacked like shoe boxes the rock wall contractor shall be instructed to "deconstruct" the affected portion of the wall and to rebuild it in strict accordance with these ARC Guidelines.

It is also **critical** that no rock be set into any wall with a top surface sloping downwards out of the wall face. This will create a potential plane of weakness, if not of failure, within the wall and should be avoided at all costs. If any rock is seen to be placed within a wall with this outwards sloping surface the rock wall contractor must be directed to remove it and replace it before proceeding with wall construction. No completed rock wall shall be accepted by the geotechnical engineer if any rock within the structure exhibits this outwards sloping geometry.

It is also important to place as much mass of rock in-place as possible to create a stable rock wall. In addition to the selection of appropriately sized rocks, it is also important, wherever possible, to install the rocks with the longest dimension set back towards the soil face being protected. This is of particular importance when construction a rock bulkhead wall that is likely to be subject to tidal and/or hydraulic action.

Smaller rocks (one or two-man size) are often used to create an aesthetically pleasing "top edge" to a rock wall. This is an acceptable practice provided none of the events described in Section 3.01.5 of this Guideline occur, and that people are prevented form climbing or walking on the finished wall. ***This is the owner's responsibility.***

Where a rock wall is constructed as a waterfront bulkhead it is **critical** that the ends of the wall either abut a neighboring bulkhead wall, or that a "return" back into the protected site be constructed. Where the wall abuts its neighbor the placement of the end rocks becomes a critical element of the walls construction since these end walls must make as close contact with the neighboring wall as is possible to avoid developing any significant void spaces. The wall contractor must make every reasonable effort to install rocks that can be set essentially "flush" against the neighboring wall.

Where a "return" is constructed the contractor must excavate an extension of the keyway approximately at a right angle (90 degrees) to the wall alignment back into the site. Where there is the potential for tidal activity above the toe of the wall it is important that this return extend for a distance sufficient to install a minimum of three rocks of equal size to those used in the construction of the wall face. For example, if five-man size rocks (average dimension of about fifty [50] inches) are used in the wall the return should be approximately thirteen (13) to fourteen (14) feet long. Wherever possible, any space between the return rocks and the excavated soil face should be carefully and thoroughly backfilled with two to four inch sized coarse, angular, crushed rock "quarry spalls" or recycled concrete.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.15 Face Inclination

The face of the rock wall should be inclined at gradient of about 1H:6V back towards the face being protected. The inclination of the wall face shouldnot be constructed flatter than 1H:4V.

3.01.16 Voids

Because of the nature of the product used to construct a rock wall, it is virtually impossible to avoid creating void spaces between individual rocks. However, it should be recognized that voids do not necessarily constitute a problem in rock wall construction. As the size of rock used to build a rock wall increases, i.e. to six-man size, the void spaces between individual rocks should be expected to be larger due simply to the rock dimensions and shape.

Where voids of greater than six inches in dimension exist in the face of a rock wall they should be visually examined to determine if contact between the rocks exists within the thickness of the rock wall. If contact does exist, no further action is required. However, if there is no rock contact within the rock wall thickness the void should be "chinked"with a smaller piece of rock.

Because the loss of drain rock or of the soil being protected by the rock wall must be avoided, "chinking" of these larger void spaces is a critical element in rock wall construction. To create a stable wall, and particularly if the wall is to be a waterfront bulkhead wall subject to tidal and hydraulic impacts, all chinking shall be carried out from the rear face of the wall. In this manner the chinking rocks can be firmly set into the voids and braced against the inboard sides of the wall rocks thereby enhancing their ability to resist being "flushed" or "picked" out of the wall. Whilst recognizing this form of chinking can slow down the speed with which a contractor can erect a rock wall, this methodology is considered to be of critical importance to the long term stability and structural integrity of a constructed rock wall and its attendant drainage system.

3.01.17 Drain Rock Layer

In order to provide some degree of drainage control behind the rock wall, and as a means of helping to prevent the potential loss of soil through the face of the rock wall, a rock drainage "filter" layer shall be installed between the rear face of the rock wall and the soil face being protected. This drain rock layer should be a minimum of twelve (12) inches in thickness. For rock walls of greater than eight feet in free-standing height should be at least eighteen (18) inches thick. It should be composed of two to four inch sized crushed rock quarry spalls, crushed recycled concrete, or other material approved in writing by the geotechnical engineer.

3.01.18 Surface Drainage

It is the owner's responsibility to intercept surface drainage from above the rock wall and direct it away from the rock wall to a positive and permanent discharge well below and beyond the top or toe of the rock wall. Use of other drainage control measures should be determined on a case-by-case basis by the geotechnical engineer prior to the contractor bidding on the project.

ARC ROCKERY CONSTRUCTION GUIDELINES

If a random wall rock extends back to the exposed soil face, it is not necessary that the filter rock layer extend between it and the soil face providing it does extend around the rock and behind those in contact with it.

Depending on soil type and the potential for water seepage, a geotextile fabric may or may not be required. This can be determined on a case-by-case basis by the geotechnical engineer during design and prior to bidding.

Where a wall is to act as a waterfront bulkhead wall it is of greater importance to reduce the risk of hydraulic activity degrading the protected soil face and removing soil from behind the wall and thereby potentially creating void spaces. In all bulkhead wall locations, with the possible exception of an exposed cemented glacial till soil, a layer of protective geotextile shall be installed against the exposed soil face. The geotextile should be anchored along the top of the excavation and draped down over the exposed soil face and then across the keyway subgrade. The toe edge of the geotextile shall be anchored-in-place by the basal row of wall rock. **It is critical** the any geotextile be installed in strict accordance with the manufacturers specifications since failure to do so can void any warranty or guarantee.

It is also important that the geotextile be installed in very close contact with the soil face or subgrade surface to avoid the risk of developing "pockets" of loose fabric in which soil fines can collect and "block" the geotextile, a situation that can lead to failure of the geotextile and development and imposition of large unforeseen lateral loads on the wall. Close contact between the geotextile and the soil can be achieved with the assistance of numerous hand installed steel pins or wooden stakes.

The following tabulation, though not all inclusive, provides the names of several geotextiles that are suitable for this purpose:

- AMOCO 4504 or AMOCO 4546
- Carthage Mills FX-60HS
- Mirafi 180N
- Synthetic Industries Geotex 311
- Webtec TerraTex N04 or TerraTex SD

In arid regions the geotextile layer may be omitted unless that area where the wall is built is subject to periodic "flash" flooding. Where "flash" flooding may be a riak the geotextile should be included as a precautionary measure.

Schematic Only - Not to Scale

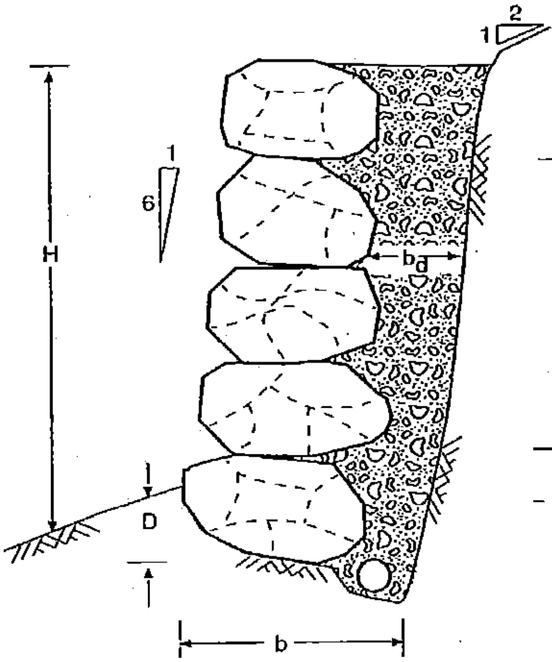


Fig. A. Rockery Section

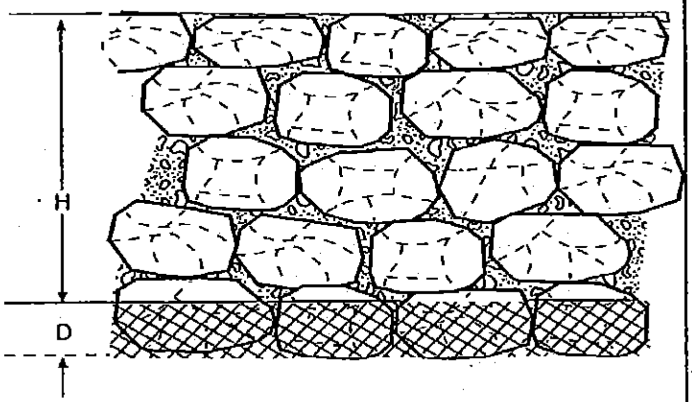


Fig. B. Rockery Elevation

NOTES

- Rockery construction is a craft and depends largely on the skill and experience of the builder.
- A rockery is a protective system which helps retard the weathering and erosion process on an exposed soil face.
- While by its nature (mass, size and shape of the rocks) it will provide some degree of retention, it is not a designed or engineered system in the sense a reinforced concrete retaining wall would be considered designed or engineered.
- The degree of retention achieved is dependent on the size of the rock used; that is, the mass or weight, and the height of the wall being constructed. The larger the rock, the more competent the rockery should be.
- Rockeries should be considered maintenance items that will require inspection and repair. They should be located so that hey can be reached by a contractor if repairs become necessary.
- Maximum inclination of the slopes above and behind rockeries should be 2:1 (Horizontal:Vertical).
- Minimum thickness of rock filter layer b = 12 inches.
- Minimum embedment D = 12 inches undisturbed native soil or compacted fill placed in accordance with report recommendations.
- Maximum rockery height H = ______ feet.
- Rockeries greater than 8 feet in height to be installed under periodic or full time observation of the geotechnical engineer.
- Rocks should be placed to gradually decrease in size with increasing wall height in accordance with geotechnical engineers recommendations.
- Minimum width of keyway excavation, b, should be equal to the thickness of the basal rock (as determined by the geotechincal engineer) plus b_d.
- The long dimension of the rocks should extend back towards the cut or fill face to provide maximum stability. Rocks should not be stacked like shoe boxes. They should be placed to avoid continuous joint planes in vertical or lateral directions wherever possible. Whenever possible each rock should bear on two or more rocks below it, with good flat-to-flat contact.
- All rockeries over 4 feet in height should be constructed on basis of wall mass, not square footage of face, and should be subject to engineering "design" by geotechnical engineer.

Size	Approximate Weight - lbs.	Approximate Diameter
1 Man	50 - 200	12 - 18"
2 Man	200 - 700	18 - 28"
3 Man	700 - 2000	28 - 36"
4 Man	2000 - 4000	36 - 48"
5 Man	4000 - 6000	48 - 54"
6 Man	6000 - 8000	54 - 60"

Reference: Local quarry weight study using average weights of no less than six rocks of each man size conducted in January, 1988.

LEGEND

Drainage materials to consist of clean angular 4 to 2 inch spalls, or other material approved by the geotechnical engineer.

Surface seal; may consist of impervious soil or a fine free-draining granular material.

Undisturbed firm Native soil.

Drain pipe: 4-inch minium diameter, perforated or slotted, rigid, smooth-walled, plastic ADS pipe laid with a positive gradient to discharge under control well away from the wall.

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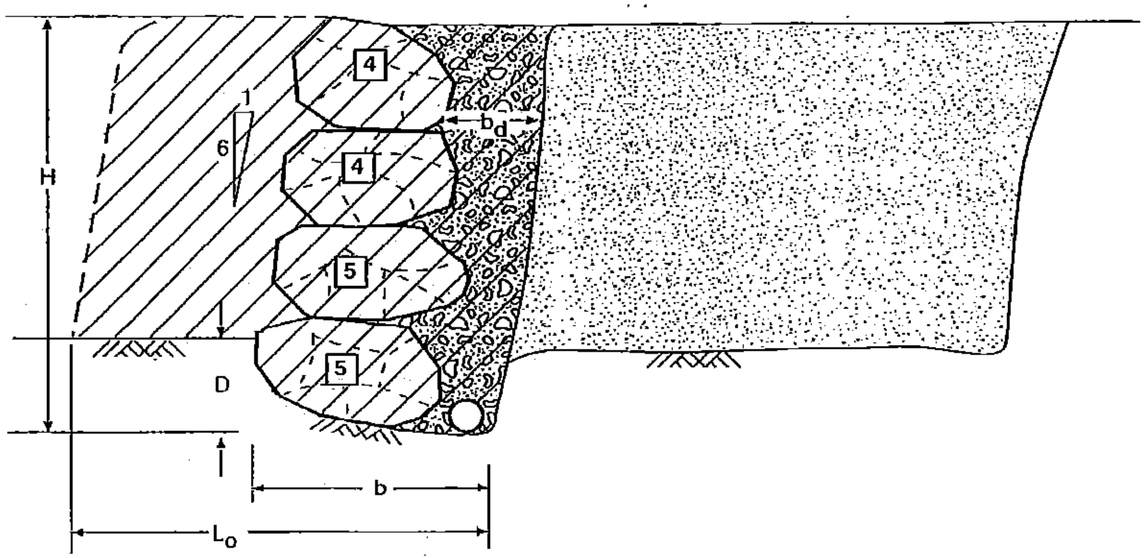
ARC Associated Rockery Contractors

TYPICAL ROCKERY DETAIL
NATIVE CUT, ANY HEIGHT OVER 4 FEET

Plate A

Schematic Only - Not to Scale



LEGEND

Crushed rock or crushed concrete drain rock material ranging between 4 and 2 inches in size and free of organics, with less than 5 percent fines (silt and clay size particles passing the No. 200 mesh sieve).

Structural fill overbuild, compacted to at least 95% of maximum dry density as determined by Modified Proctor.

Compacted structural fill consisting of free-draining organic-free material with a maximum size of 4 inches. Should contain no more than 7 percent fines (described above), compacted to at least 95 percent of Modified Proctor maximum dry density.

Perforated or slotted, smooth-walled, plastic drain pipe with 4 inch minimum diameter bedded on and surrounded by crushed rock filter material, described above.

5 Designates size or rock required, i.e. 5- man.

NOTES

- All fill should be placed in thin lifts not exceeding 10 inches in loose thickness. Each layer should be compacted to no less than 95 percent of maximum dry density, as determined by Modified Proctor.
- Thickness of crushed filter rock layer, b_d, should be no less than 12 inches.
- Depth of burial of basal layer of rock, D, should be no less than 12 inches.
- Free-standing height of rockery, H, should not exceed _____ feet.
- Lateral extent of fill overbuild, L_o, should be no less than H feet.
- Estimated width of keyway excavation, b, should be equal to the thickness of the basal rock (as determined by the geotechnical engineer) plus b_d.

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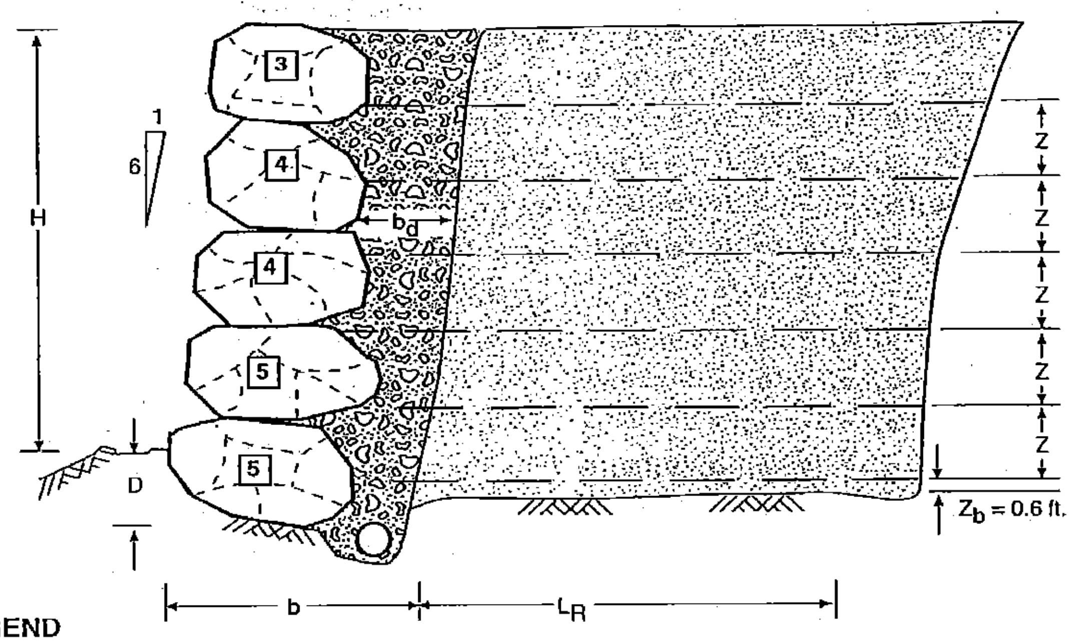
TYPICAL ROCKERY DETAIL
OVERBUILT FILL CONSTRUCTION ROCKERY
8 FEET OR LESS IN HEIGHT

Plate
B

91-1180 / 5.30.99

Schematic Only - Not to Scale



LEGEND

Crushed rock or crushed concrete drain rock material ranging between 4 and 2 inches in size and free of organics, with less than 5 percent fines (silt and clay size particles passing the No. 200 msh sieve).

Compacted structural fill consisting of free-draining material with a maximum size of 4 inches. Should contain no more than 7 percent fines (described above), compacted to at least 95 percent of Modified Proctor maximum dry density.

Undisturbed firm Native soil.

Geogrid reinforcement approved by geotechnical engineer.

Perforated or slotted, smooth-walled, plastic drain pipe with 4 inches minimum diameter bedded on and surrounded by crushed rock filter material, described above.

[5] Designates size or rock required, i.e. 5- man.

NOTES

- All fill should be placed in thin lifts not exceeding 10 inches in loose thickness. Each layer should be compacted to no less than 95 percent of maximum dry density, as determined by Modified Proctor.
- Length of reinforcing geogrid, L_R shall be _____ feet.
- Geogrid reinforcement layer spacing, Z, shall be _____ feet as determined by the geotechnical engineer.
- Height of rock wall, H, should not exceed _____ feet.
- Thickness of crushed drain rock layer, b_d, should be no less than 12 inches.
- Depth of burial of basal layer of rock, D, should be no less than 12 inches.
- Minimum width of keyway excavation, b, should be equal to the thickness of the basal rock (as determined by geotechnical engineer) plus b_d.

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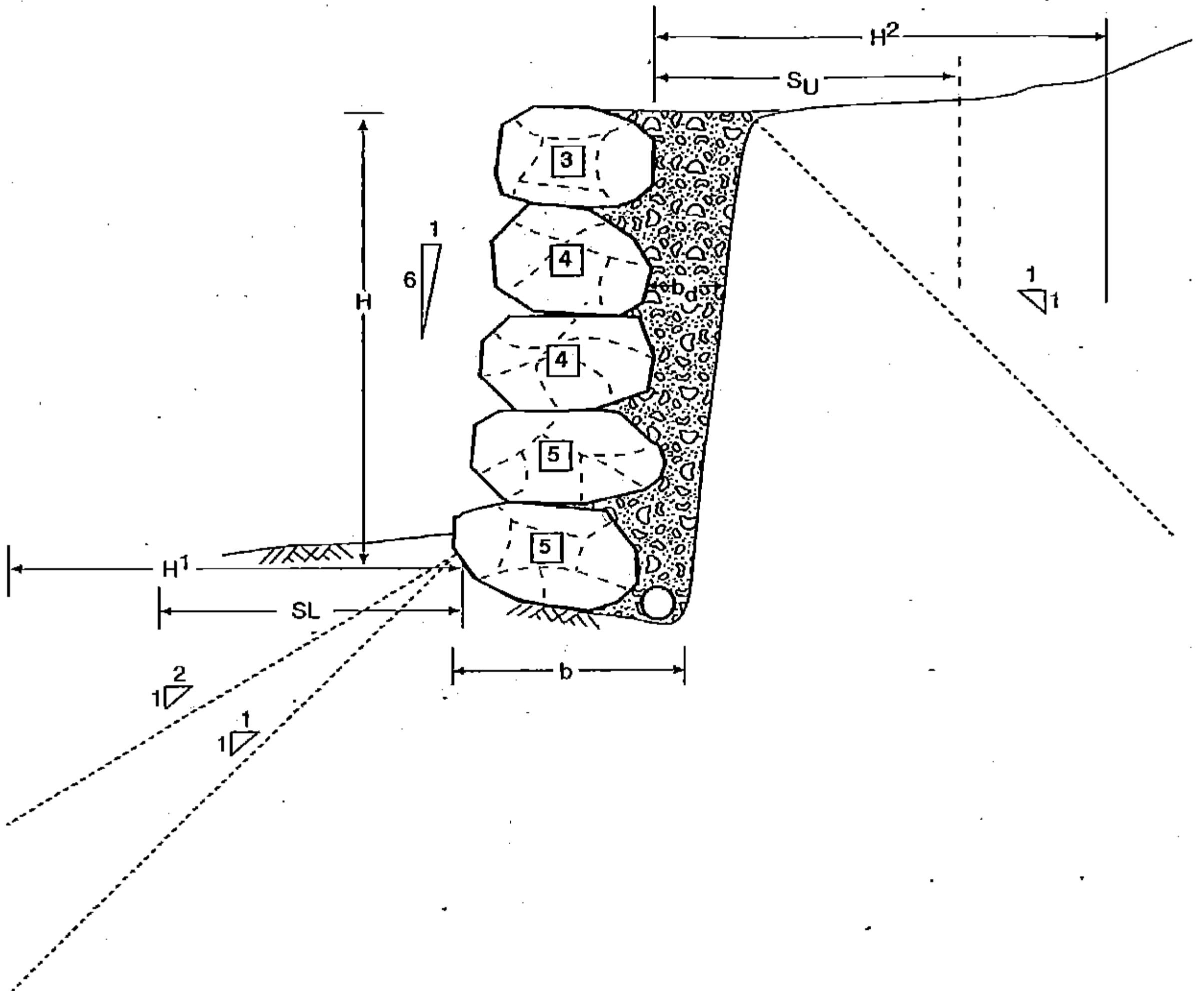
ARC Associated Rockery Contractors

TYPICAL ROCKERY DETAIL
GEOGRID REINFORCED FILL CONSTRUCTION
ROCK WALL 8 FEET OR MORE IN HEIGHT

Plate C

Schematic Only - Not to Scale



NOTES

- Free-standing height of rock wall, H = varies per design
- Minimum setback distance in which no temporary excavation or trenching may be performed, S_U = 5 feet
- Minimum setback distance in which no temporary excavation or trenching may be performed, S_L = 2/3H
- Minimum distance in which no permanent removal of subgrade is allowed, H^1 = 10 feet
- Minimum distance in which no excavation of material or any surcharge is allowed, H^2 = 10 feet
- Imaginary line below which no excavation is allowed above or below wall = 1H:1V
- Imaginary line depicting bounds for maximum finished grade or permanent excavation = 2H:1V
- All rockery walls of greater than 4 feet in maximum free-standing height should be required to undergo engineering "design" by geotechnical engineer.

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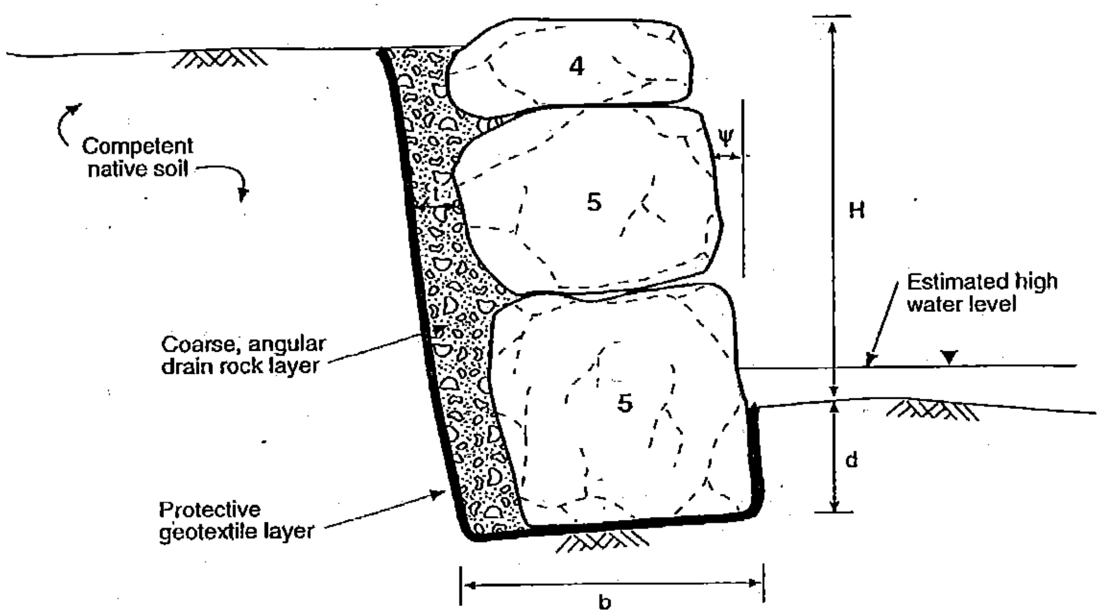
ARC Associated Rockery Contractors

TYPICAL ROCKERY DETAIL
POST CONSTRUCTION GUIDELINES

Plate D

Schematic Only - Not to Scale
(for informational purposes only)



NOTES

- Maximum estimated free-standing wall height, H = 6 feet
- Minimum depth of keyway excavation, d = 2 feet
- Minimum estimated width of wall excavation, b = 5 feet
- Minimum recommended thickness if drain rock layer, t = 1 foot
- Recommended protective geotextile layer to comprise a Mirafi 180N, or an equivalent approved in writing by the geotechnical engineer.
- Set all rocks in as close contact with each other as is feasible for specific rock shapes, and firmly set basal rock down into keyway subgrade.

91-1180 / 7.8.99

ARC Associated Rockery Contractors

TYPICAL BULKHEAD WALL SECTION

Plate

E

PROJECT NUMBER______________
DATE ______________
EXAMINED BY______________
CHECKED BY______________
SHEET__________ OF______

ROCKERY EXAMINATION RECORD

Project Site Location______________________________
Wall Location______________________________

Construction Status:
Rockery under construction YES / NO
Rockery completed YES / NO
Age of completed rockery______________
Staged rockery YES / NO
Stage of rockery being examined UPPER / LOWER

Soil Features:
Condition of soil face to be protected______________________________
Inclination of excavated slope __________ : __________ H:V
Depth of keyway cut __________feet Width of keyway cut __________feet
Condition and competency of keyway subgrade______________________________

Rockery Slope:
Is there a slope above wall YES / NO Gradient of slope _________ : _________H:V(measured/estimated)
Vegetative cover YES / NO Nature of cover______________________________
Is there a slope below rockery . YES / NO Gradient of slope _________ : ________H:V(measured/estimated)
Vegetative Cover YES / NO Nature of cover______________________________
Stability of slope(s) (visual evaluation)______________________________

Drainage Provisions:
Drainline is installed YES / NO With gradient YES / NO Drainline material______________
Drainline pipe diameter__________inches . Drainline type RIGID / FLEXIBLE
Width of drain filter rock behind wall__________feet Average rock size__________inches
Description of rock backfill______________________________

Rock Wall:
Length of wall examined this visit from__________feet to __________feet
Height of wall examined this visit from__________feet to __________feet
Total length of completed rock wall_________feet Max. height of completed rock wall________feet (to date)
Describe origin of wall measurement______________________________
____
Description of rock (type, hardness, etc.) ______________________________
Shape of rocks______________________________
Dimensions of largest and smallest rocks in section currently being examined
Largest - length __________feet, width__________feet, height__________feet } Excluding chinking rocks
Smallest - length __________feet, width__________feet, height__________feet }
Relationship of rock of rock contact______________________________
Angle of constructed wall face____: ____H:V Reaction of rocks to hammer (sound)______________

Additional Comments:______________________________
____
____
____
____
____
____