July 8, 2014
Job No. 1661-02N-14

Mr. Eric Householder
Lewis Homes
5577 Elkhorn Drive
Eden, UT 84092

Mr. Householder:

Re: Proposed Rock Retaining Walls
The Ridge Development
Moose Hollow Drive
Eden, Utah

This letter presents our evaluation and analyses results for the proposed rock retaining wall at the subject site. Based on the information provided by Lewis Homes and our observations of the site, it appears that one to two rock wall tiers will be constructed within the cut slope for the extension of Moose Hollow Drive to a maximum exposed height of 17 feet (up to 8.5 feet per tier) and will retain relatively level to moderately sloping backfill. Due to site grading requirements, one rock wall tier up to a maximum exposed height of 8.5 feet may be utilized in some areas. Mr. Andrew M. Harris, P.E., of GSH Geotechnical, Inc. (GSH) visited the site on the morning of June 27, 2014 and observed the existing geometry and natural soils exposed in the cut slope for Moose Hollow Drive at the site, which consisted of stiff to very stiff, slightly moist to moist, light gray to light brown, fat clay.

Stability Analyses

The properties of the fat clay soils observed in the exposed cut slope at the proposed wall locations were estimated using published correlations and our experience with similar soils. Based on tests performed by the Bureau of Reclamation[1], higher plasticity clay soils have an internal friction angle ranging from 14 to 24 degrees and an apparent cohesion of 120 to 360 psf. Accordingly, we estimated the following parameters for use in the stability analyses:

1 U.S. Bureau of Reclamation, 1987, "Design Standards No. 13, Embankment Dams," Denver, Colorado.

Material	Internal Friction Angle (degrees)	Apparent Cohesion (psf)	Saturated Unit Weight (pcf)
On-Site Fat Clay	24	200	115
Rock Boulders	0 (or 45)	9000 (or 0)	145

For the seismic (pseudostatic) analysis, a peak horizontal ground acceleration of 0.4309*g* for the 2 percent probability of exceedance in 50 years was obtained for site (grid) locations of 41.3222 degrees latitude (north) and 111.8250 degrees longitude (west). To model sustained accelerations at the site, one-third to one-half of this value is typically employed. Accordingly, a value of 0.20 was used as the pseudostatic coefficient for the stability analysis.

Using these input parameters, the internal (rock-to-rock) stability of the wall was evaluated considering sliding, overturning, and bearing capacity to achieve respective minimum factors of safety of 1.5, 2.0, and 3.0 for static conditions and 1.1, 1.5, and 1.5 for seismic conditions. The results of this analysis (see attached Figure 1) indicate that a maximum rock wall height of about 8.5 feet can be achieved in 1 tier using boulder sizes ranging from 36 inches (top row) to 48 inches (bottom row), with these dimensions oriented into the hillside.

We also evaluated the global stability of the wall using the computer program *SLIDE*. This program uses a limit equilibrium (Simplified Bishop) method for calculating factors of safety against sliding on an assumed failure surface and evaluates numerous potential failure surfaces, with the most critical failure surface identified as the one yielding the lowest factor of safety of those evaluated. The configuration we analyzed consisted of two 8.5-foot high rock boulder walls separated by about 8 feet from wall face to wall face, with the upper tier retaining a 3H:1V (Horizontal:Vertical) slope about 5 feet tall. The rock wall tiers were composed of 48 inch size boulders for the lowest row of boulders grading to 36 inch size boulders for the upper row of boulders. The lowest row of boulders for both tiers was embedded about 1 foot. The faces of both rock wall tiers were inclined at about 1H:2V. Typically, the required minimum factors of safety are 1.5 for static conditions and 1.1 for seismic (pseudostatic) conditions. The results of our analyses indicate that the proposed rock wall will meet both these requirements provided our recommendations are followed. The slope stability data are included as Figures 2 and 3, attached.

Conclusions and Recommendations

Based on the results of our analyses, the rock retaining walls at this site will be stable if constructed as follows (also see Figures 4 and 5, attached):

- The single-tier rock wall may be constructed up to a maximum exposed total height of 8.5 feet. The two-tier rock wall may be constructed to a maximum exposed height 8.5 feet per tier, with each tier separated by a minimum of 8 feet (face to face). The bottom row of rock boulders for each tier should be embedded a minimum 1 foot below the ground surface.

- The rock wall facing should slope at 1H:2V or flatter.

- The rock wall should be composed of boulders with a minimum nominal size (diameter) of 48 inches for the lowest row of rocks, grading in size to 36 inches for the top row.

- Boulders used in the rock walls should be durable (i.e. not limestone, soft sandstone, or other rocks which have weakened planes that could cause rocks to split) and placed in a manner that will not significantly weaken their internal integrity. There should be maximum rock-to-rock contact when placing the rock boulders and no rocks should bear on a downward-sloping face of any supporting rocks. Larger gaps may be filled with smaller rocks or sealed with a cement grout.

- Drainage behind the wall is recommended, as shown on Figures 4 and 5. The drain should consist of a perforated 4-inch minimum diameter pipe wrapped in fabric and placed at the bottom and behind the lowest row of boulders. The pipe should daylight at one or both ends of the wall and discharge to an appropriate drainage device or area. Clean gravel up to 2 inches in maximum size, with less than 10 percent passing the No. 4 sieve and less than 5 percent passing the No. 200 sieve, should be placed around the drain pipe. A fabric, such as Mirafi 140N or equivalent, should be placed between the clean gravel and the adjacent soils. A zone of clean gravel and fabric at least 12 inches wide should also extend above the drain, upward and behind the boulders to about 2 feet below the top of the wall, as shown on Figures 4 and 5.

- Note that wall movements or even failure can occur if the walls are undermined or the backfill soils become saturated. Therefore, we recommend that irrigation lines not be placed within the backfill or directly on top of the wall. Surface drainage at the bottom and top of the walls should also be directed away from the wall. The property owner and the owner's representatives should be made aware of the risks should these or other conditions occur that could saturate or erode/undermine the soil behind the wall

Closure

Our professional services have been performed, our findings developed, and our recommendations prepared in accordance with generally accepted engineering principles and practices in this area at this time.

If you have any questions or would like to discuss these items further, please feel free to contact us at (801) 393-2012.

Respectfully submitted,

GSH Geotechnical, Inc.

Andrew M. Harris, P.E.
State of Utah No. 7420456
Senior Geotechnical Engineer

Reviewed by:

William G. Turner, P.E.
State of Utah No. 171715
Senior Geotechnical Engineer

AMH/WGT:mmh

Encl. Figure 1, Rock Wall Stability Evaluation
Figures 2 and 3, Stability Results
Figures 4 and 5, Rock Wall Detail

Addressee (email)

ROCK WALL STABILITY EVALUATION

Project:	**The Ridge Development**			Date:	**7/8/2014**
Location:	**Eden, Utah**			By:	**WGT**
Backfill slope angle, β:	**0**	degrees (β)	Foundation soil γ :	**115**	pcf
Batter angle (from vertical):	**26.6**	degrees (α)	Foundation soil ϕ :	**24**	degrees
Soil/wall interface friction:	**0**	degrees (δ)	Found. soil cohesion:	**200**	psf
Surcharge pressure:	**0**	psf	Retained soil γ :	**115**	pcf
	static	**seismic**	Retained soil ϕ :	**24**	degrees
FS against sliding (Stat/Seis):	**1.5**	**1.1**	Retain. soil cohesion:	**200**	psf
FS against overturning (St/Se):	**2.0**	**1.5**	Rock boulder γ :	**145**	psf
FS for bearing (Static/Seismic):	**2.5**	**1.5**	Rock boulder ϕ :	**45**	degrees
Horizontal seismic coeff., k_h:	**0.2**	(typically ½ of PGA)	Embedment depth:	**1**	feet
Vertical seismic coeff., k_v:	**0**	(typically 0)	Average rock wall γ :	**145**	pcf
Rock to Rock interface factor:	**0.67**	(typically 2/3)	Min. top rock size:	**36**	inches
Bearing Capacity	**9244**	psf (Meyerhoff)	Min.bottom rock size:	**48**	inches

STATIC								
Wall Ht, H (ft)	**5.0**	**6.0**	**7.0**	**8.0**	**8.5**	**9.5**	**10.5**	**11.5**
Back of wall, ψ (°)	16.7	18.4	19.7	20.6	20.92450	21.5	22.0	22.4
Wall Wt, W (lbs/ft)	2538	3045	3553	4060	4314	4821	5329	5836
Wall $x_{centroid}$ (ft)	2.95	3.19	3.43	3.67	3.79	4.02	4.26	4.50
Wall $y_{centroid}$ (ft)	2.381	2.857	3.333	3.810	4.050	4.543	5.043	5.548
Coulomb K_a	0.3223	0.3125	0.3057	0.3006	0.2986	0.2951	0.2923	0.2900
F_a (lbs/ft)	1	2	87	229	311	499	718	967
$F_{sliding}$ (lbs/ft)	1	1	82	214	291	464	665	893
$F_{resisting}$ (lbs/ft)	1130	1356	1569	1772	1871	2065	2253	2434
$FS_{base\ sliding}$	**> 100**	**> 100**	**19.1**	**8.3**	**6.4**	**4.4**	**3.4**	**2.7**
$FS_{interface\ shear}$	**> 100**	**> 100**	**29.0**	**12.7**	**9.9**	**7.0**	**5.4**	**4.4**
$M_{overturn}$ (ft-lbs/ft)	2	3	192	572	824	1470	2328	3425
$M_{resisting}$ (ft-lbs/ft)	7490	9713	12038	14485	15765	18440	21263	24230
$FS_{overturn}$	**> 100**	**> 100**	**62.8**	**25.3**	**19.1**	**12.5**	**9.1**	**7.1**
Eccentricity, e (ft)	-0.95	-1.19	-1.36	-1.50	-1.56	-1.66	-1.74	-1.81
Bearing Pressure	1539	2119	2681	3227	3502	4045	4571	5068
$FS_{bearing}$	**6.0**	**4.4**	**3.4**	**2.9**	**2.6**	**2.3**	**2.0**	**1.8**
SEISMIC								
Mononobe-Okabe K_{ae} =	0.4969	0.4891	0.4836	0.4796	0.4780	0.4753	0.4732	0.4714
F_{ae} (lbs/ft)	9	173	389	657	811	1157	1555	2005
$F_{sliding}$ (lbs/ft)	516	773	1077	1427	1620	2040	2507	3021
$F_{resisting}$ (lbs/ft)	1129	1331	1523	1705	1792	1957	2113	2258
$FS_{base\ sliding}$	**2.2**	**1.7**	**1.4**	**1.2**	**1.1**	**1.0**	**0.8**	**0.7**
$FS_{interface\ shear}$	**3.3**	**2.6**	**2.2**	**1.9**	**1.8**	**1.6**	**1.4**	**1.3**
$M_{overturn}$ (ft-lbs/ft)	1234	2329	3754	5589	6696	9337	12593	16525
$M_{resisting}$ (ft-lbs/ft)	7479	9431	11480	13613	14705	16931	19205	21513
$FS_{overturn}$	**6.1**	**4.0**	**3.1**	**2.4**	**2.2**	**1.8**	**1.5**	**1.3**
Eccentricity (ft)	-0.46	-0.37	-0.26	-0.10	0.01	0.27	0.61	1.02
Bearing Pressure	193	327	524	820	1021	1549	2266	3200
$FS_{bearing}$	**47.9**	**28.3**	**17.6**	**11.3**	**9.1**	**6.0**	**4.1**	**2.9**

Max. Recommended Wall Height: 8.5 feet for 36-inch (top row) to 48-inch (bottom row) size boulders

Notes:

1. Equations from "Recommended Rockery Design & Construction Guidelines" Publication FHWA-CLF/TD-06-006, Nov. 2006.
2. Cohesion included in active pressure force by subtracting (2 * c * $\sqrt{K_a}$), but force is not allowed to be less than 0.
3. Other equations: W=[π*(average rock radius) ² *H]* γ_{rock} ; $FS_{interface\ shear}$=(Rock to Rock interface factor)*[W*tan(ϕ_{rock})/$P_{sliding}$]

PROJECT NO.: 1661-02N-14	GSH	**FIGURE NO.:** 1

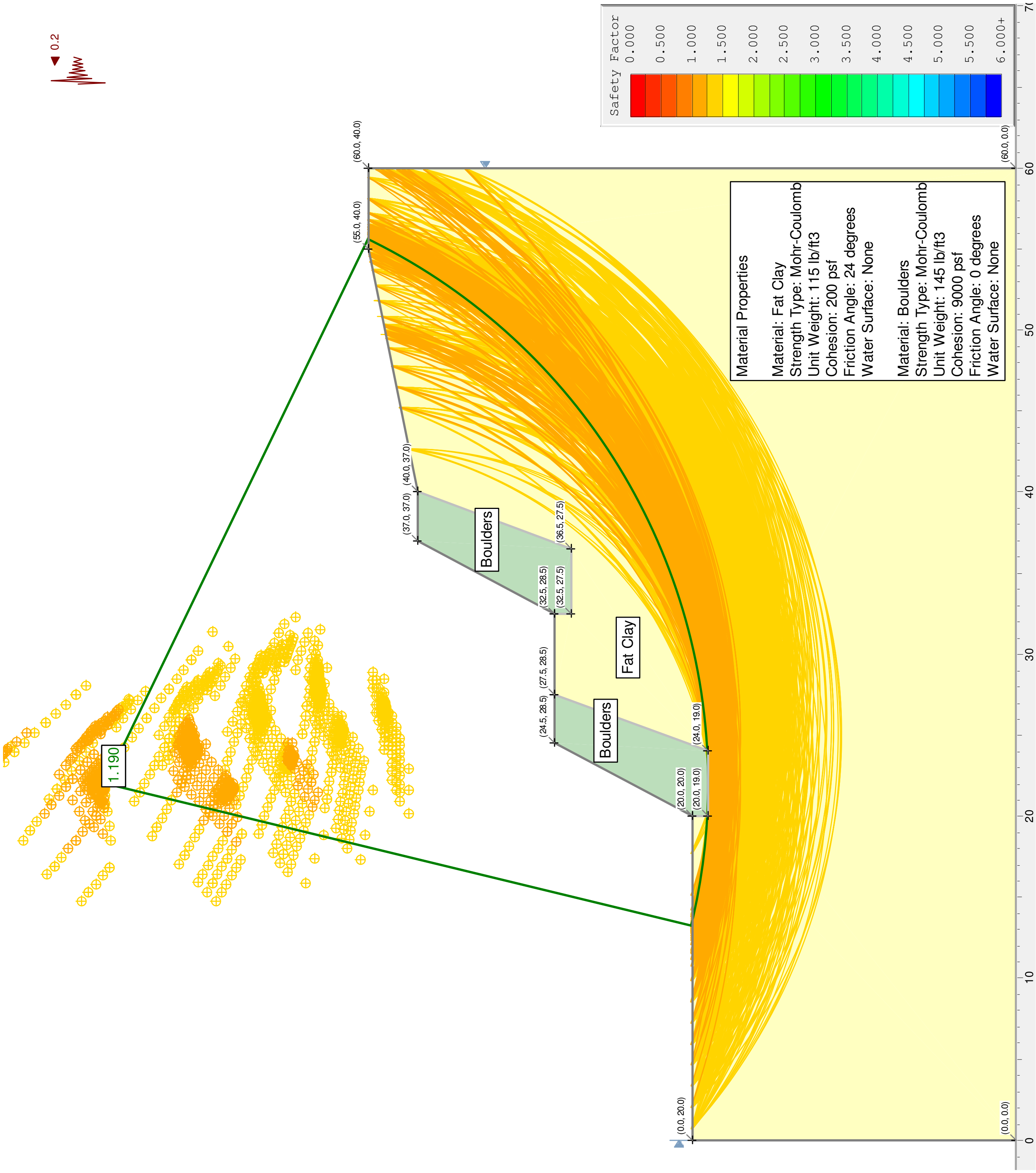
STABILITY RESULTS

THE RIDGE DEVELOPMENT, MOOSE HOLLOW DRIVE, EDEN

PROJECT NO.: 1661-02N-14	GSH	FIGURE NO.: 2

STABILITY RESULTS

THE RIDGE DEVELOPMENT, MOOSE HOLLOW DRIVE, EDEN



PROJECT NO.: 1661-02N-14	GSH	FIGURE NO.: 3

ROCK WALL DETAIL

THE RIDGE DEVELOPMENT, EDEN

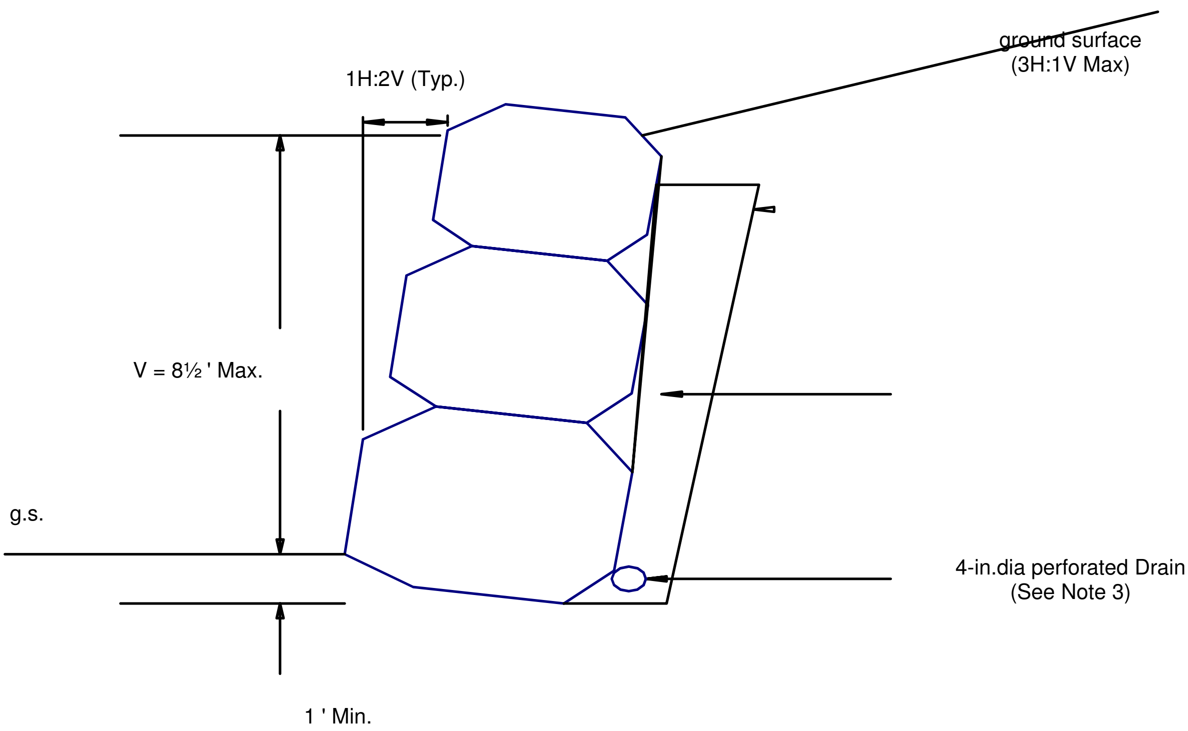
NOTES:

1. BACKFILL SOILS SHOULD BE PLACED IN LOOSE LIFTS NOT EXCEEDING A THICKNESS OF 12 INCHES, MOISTURE CONDITIONED TO WITHIN 2% OF OPTIMUM, AND COMPACTED TO A MINIMUM 95% OF THE MAXIMUM DRY DENSITY AS DETERMINED BY ASTM D1557.

2. FREE-DRAINING BACKFILL SHALL CONSIST OF GRAVEL HAVING LESS THAN 5% PASSING No. 200 SIEVE, OR MAY USE MIRADRAIN (OR EQUIVALENT) INSTEAD OF GRAVEL & FABRIC.

3. PERFORATED DRAIN SHALL BE WRAPPED WITH FABRIC, SLOPED A MINIMUM 2% TO SIDE OF WALL, AND DISCHARGED TO APPROPRIATE DRAINAGE DEVICE.

4. BOULDER SIZES SHALL BE A MINIMUM 48 INCHES FOR THE BOTTOM ROW AND A MINIMUM 36 INCHES FOR THE UPPER ROW FOR EACH TIER.



NOT TO SCALE

PROJECT NO.: 1661-02N-14	GSH	**FIGURE NO.:** 4

ROCK WALL DETAIL

THE RIDGE DEVELOPMENT, EDEN

NOTES:

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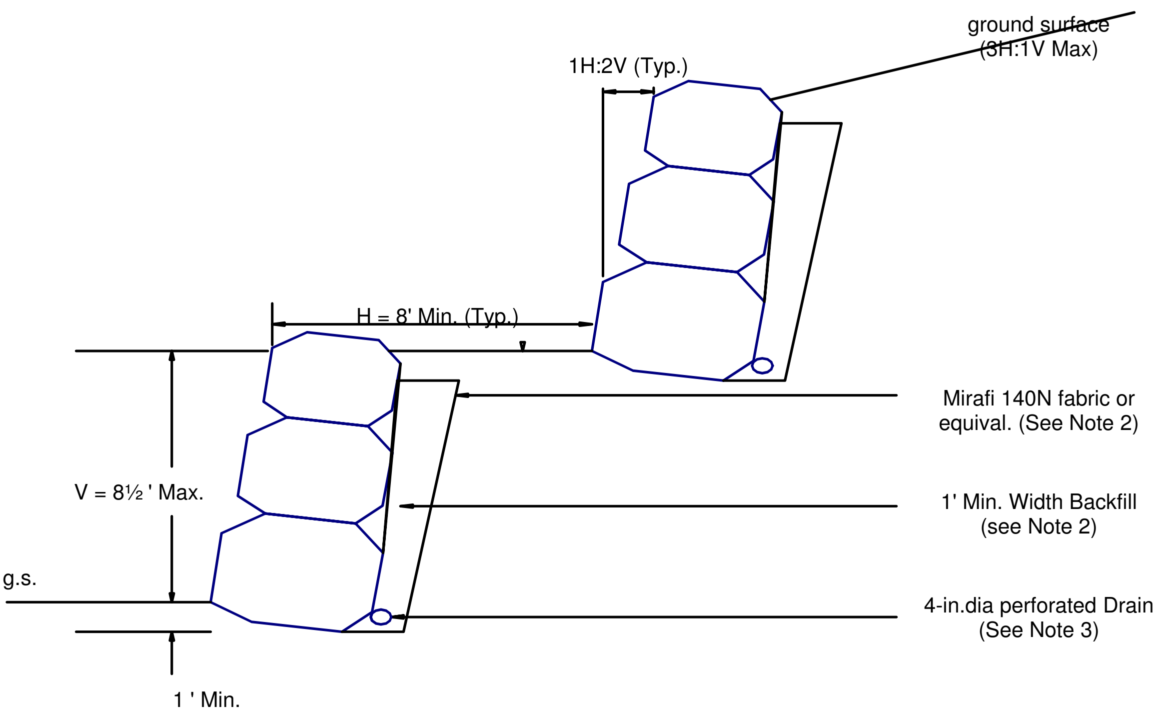

NOT TO SCALE

PROJECT NO.: 1661-02N-14	GSH	**FIGURE NO.:** 5