Geotechnical Engineering Report

XENON WATER STORAGE PITS
PRELIMINARY SLOPE STABILITY ANALYSIS
North ½ Section 12, Township 7 North, Range 93 West,
6th Principal Meridian
West of Craig, Moffat County, Colorado

June 28, 2012
Terracon Project No. AD125020

Prepared for:
Fox Engineering Solutions, Inc.
670 Canyon Creek Drive
Grand Junction, Colorado 81507-9594

Prepared by:
Terracon Consultants, Inc.
Grand Junction, Colorado

June 28, 2012

Fox Engineering Solutions, Inc.
670 Canyon Creek Drive
Grand Junction, Colorado 81507-9594

Attn: Mr. Dave Fox, P.E.
C: (970) 260-78106822
E: coloradofox@bresnan.net

Re: Geotechnical Engineering Report
Xenon Water Storage Pits
Preliminary Slope Stability Analysis
West of Craig, Moffat County, Colorado
Terracon Project Number: AD125020

Dear Mr. Fox:

Terracon Consultants, Inc. (Terracon) has completed geotechnical engineering services for the above referenced project. This study was performed in general accordance with the Geotechnical Engineering Agreement between Fox Engineering Solutions, Inc. and Terracon. This report presents Terracon observation of existing embankments, preliminary calculations of slope stability and discussion of remediation concepts. Design and construction recommendations for foundations or repair are not included in the scope of this study. Slope stabilization recommendations are not included in the scope of this study.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

Norman W. Johnston, P.E.
Senior Engineer

John P. Withers, P.E.
Senior Engineer

Enclosures
cc: 1 – Client (bound)
1 –Dave Fox: coloradofox@gresnan.net (electronic-PDF)
1 – File

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EXECUTIVE SUMMARY

A geotechnical investigation has been performed for the existing main, upper, middle and lower Xenon pits preliminary slope stability located about 12 miles west of Craig in the North ½ of Section 12, Township 7 North, Range 93 West, 6th Principal Meridian in Moffat County, Colorado. Four existing Water storage pits were observed and the soils exposed were sampled. The existing pits were 19 and 22 feet deep and were lined with a synthetic liner. The site observations did not include subsurface exploration or soil strength testing and do not meet our understanding of standard of practice for final level slope investigation.

Existing pit slope stability was evaluated using the information obtained from our site visit. The following geotechnical considerations were identified:

- Soil strength parameters were assumed based on soil classification. Soil strength parameters were also calculated by slope stability analysis for a slope failure condition.
- Existing pit liners are in relatively poor condition with multiple holes, tears and improperly oriented seams.
- Multiple rodent holes were observed in the embankments for each pit.
- Shallow Slope failure indicated by surface slumps and tension cracks was observed in the exterior embankment slopes.
- We believe the pits may have been constructed without adequate slope compaction.
- We performed a slope stability analysis for a slope inclination of 2.37H to 1 V for the main pit and 1.55H to 1V exterior and 2.48H to 1 V interior for the smaller pits. Our slope stability analysis indicates a factor of safety ranging from 1.3 to 2.46 for the main pit and ranging from 1.0 to 1.82 for the smaller pits using assume soil properties.
- We consider a minimum factor of safety against slope movement of no less than 1.5 warranted for conditions such as those at the subject site. (Reference "Soil Mechanics Design Manual 7.1", page 7.1-329, Department of the Navy, Naval Facilities Engineering Command dated May 1982).
- Pit maintenance should include re-compaction of the slope surface soils to a depth of at least 3 feet. A excavation and re-compaction bench concept is shown on Fig. A-2.
- Rodents should be removed from the site and the rodent holes repaired.
- The pit liners should be removed with new liners which are properly bedded, placed and seams oriented properly.

This summary should be used in conjunction with the entire report for design and construction purposes. It should be recognized that details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein. The section titled **GENERAL COMMENTS** should be read for an understanding of the report limitations.

GEOTECHNICAL ENGINEERING REPORT
XENON WATER STORAGE PITS
SLOPE STABILITY
Craig , Moffat County, Colorado

Terracon Project No. AD125020

June 28, 2012

1.0 INTRODUCTION

A geotechnical engineering report has been completed for the existing Xenon pits located about 12 miles west of Craig, Colorado in the North ½ of Section 12, Township 7 North, Range 93 West, 6th Principal Meridian in Moffat County Colorado. The existing water storage pits were observed and the soils exposed near the slope surface were sampled.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- existing pit conditions
- maintenance and repair
- pit slope stability

2.0 PROJECT INFORMATION

2.1 Project Description

ITEM	DESCRIPTION
Structure	The existing site development includes four water storage pits. The main pit is about 19 feet deep with slope inclination of about 2.37 Horizontal to 1 Vertical for both interior and exterior slopes. The smaller pits are about 22 feet deep with interior slope inclination of about 2.48H to 1V and exterior slope inclinations of about 1.55 H to 1V
Existing conditions	Observation of the existing water storage pits identified poor liner conditions. About 300 holes were observed in the liner for the main pit with 2/3 to ¾ of the holes below maximum water level. There were locations in each liner where the seams are oriented in the wrong (parallel to the slope) direction. Multiple locations of shallow soil sloughing, especially around the main pit, and cracking and scarps in the upper and lower pit top of exterior slope areas were observed. Multiple rodent holes were observed on the pit slopes.

2.2 Site Location and Description

ITEM	DESCRIPTION
Location	This project is located about 12 miles west of Craig, Colorado. The site is located in the North ½ of Section 12, Township 7 North, Range 93 West, 6th Principal Meridian in Moffat County, Colorado.
Current ground cover	Open, vacant land with low ground cover type vegetation surrounding the existing ponds
Existing topography	The site is an existing water storage pits development with 4 pits. The general slope in the area is down to the east.

3.0 SUBSURFACE CONDITIONS

3.1 Geology

Based on the 1979 Geologic Map of Colorado, United States Geological Survey, the shallow soils of the site consist generally of modern alluvium. The modern alluvium is generally sandy clay that exhibit volume change potential when loaded and/or wetted. Soil strengths of this strata can be low to moderate.

Formational material in this area is Tertiary Browns Park formation. Browns Park formation generally consists of sandstone and siltstone.

3.2 Soil Classification

Based on the results of the site observations, shallow soil sampling and the laboratory testing the soil samples generally consisted of clayey sand which was of low to moderate plasticity, and had the following measured strength characteristic:

Sample Location	Depth (feet)	Natural Moisture Content (%)	Liquid Limit	Plasticity Index)	Percent passing #200 sieve
Overflow channel, main pit	0	3.2	24	6	47

4.0 PRELIMINARY DISCUSSION OF SLOPE STABILITY

4.1 Slope stability analysis

This stability analysis is based on the observed site conditions and existing slopes and depth of the pit. The main pit slope inclination is about 2.37 Horizontal to 1 Vertical for both interior and exterior slopes. The depth of the main pit is about 19 feet. The smaller pits slope inclinations are about 2.48H to 1 V interior and1.55H to 1 V exterior. The depths of the smaller pits are about 22 feet. The maximum water depth in all pits is about 10 feet. We obtained shallow samples from the pit slopes for laboratory classification testing. We performed sieve analysis and Atterberg limits tests of one sample obtained from the pit slopes. Based on the laboratory soil classification test results we estimated soil strength properties of cohesion value of 250 psf and internal angle of friction of 26 degrees. We also performed a sensitivity analysis where soil strength parameters were back calculated for a slope stability factor of safety equal to 1, assumed slope failure condition. The low soil strength properties calculated included a cohesion of 140 psf and an internal angle of friction of 15 degrees. We used the graphical computer program Slide Version 6.0, manufactured by Rocscience Inc. and the Bishop simplified method of slices for our analysis. The stability analysis was performed for a cross section at the maximum depth of each pit slope and inclinations determined by site observation and as-built plan review. The stability analysis was performed using both the estimated soil strength properties based on laboratory classification tests and the low soil strength properties as back calculated from an assumed slope failure condition. strength properties for dry and wet conditions. We performed over 3500 separate theoretical failure plane analysis. This report presents the slope stability analysis with the lowest calculated factor of safety. The results of the slope stability analysis are presented on Figs. C-1 through C-8.

We consider a minimum factor of safety against slope movement of no less than 1.5 warranted for conditions such as those at the subject site (Reference "Soil Mechanics Design Manual 7.1", page 7.1-329, Department of the Navy, Naval Facilities Engineering Command dated May 1982). The slope stability analysis indicated a calculated factor of safety for the slopes ranging from 1.3 to 2.46 for the main pit for the estimated soil strength properties. The slope stability analysis indicated a calculated factor of safety for smaller pit slopes ranging from 1.o to 1.87 using estimated soil strength properties.

4.2 Preliminary Conclusions and Recommendations

Based on the results of our site observations, laboratory tests and the slope stability analysis we believe the pit berms may have been constructed with poor compactive effort at the exterior slopes resulting in low strength and settlement of the exterior slope soils. It is our opinion the

tension cracks and surface slumps observed were a result of combined shallow slope failure and settlement. The stability analysis indicates if the soils are well compacted the pit slopes are stable, however if the pit slopes are low density the stability of the pit slopes is marginally stable and likely have an accelerated slope creep to some degree of failure on an ongoing basis. In our opinion, design level geotechnical services are warranted to further investigate the four pits. Additional investigation would consist of a drilling and sampling program, laboratory strength testing and further stability analysis. Based on the results of this preliminary investigation, we believe remediation could consist of some degree of soils removal, moisture conditioning and replacement of a well compacted moisture conditioned fill. In one case, several feet of soils may be warranted. For discussion and preliminary consideration, we present the following: The exterior slope soils may be removed to a vertical depth of 3 feet, moisture conditioned and replaced in a well compacted manor. The exposed surface of the slope after slope soil removal should be benched horizontally at least 3 feet prior to replacing the slope soils. The bench concept is shown on Figure A-2. The slope soils should be moisture conditioned to within 2 percent of the optimum moisture content, placed in thin lifts (not exceeding 8 inches loos thickness) and compacted to at least 95 percent of the maximum standard Proctor (ASTM D-698) dry density.

Observation of the pit linings indicated multiple holes, tears and poorly oriented seams. The observed amount of holes in the pit linings is such that patching the existing lining is not practical. The pit linings should be removed and replaced with properly constructed linings. The new linings should be installed in accordance with the manufactures specifications with proper bedding and seam orientation.

Observation of the pit slopes indicated multiple rodent holes. Rodents should be removed from the pit areas and the rodent holes excavated and replaced in a well compacted manor. The rodent hole backfill should be moisture conditioned to within 2 percent of the optimum moisture content, placed in thin lifts and compacted to at least 95 percent of the maximum standard Proctor dry density.

The site should be observed at least annually for additional distress and rodents. If additional distress is observed measures should be taken to repair the distress. If rodents or rodent holes are observed the rodents should be removed and the holes repaired.

5.0 GENERAL COMMENTS

Terracon should be retained to review the mitigation plans so comments can be made regarding interpretation and implementation of our geotechnical recommendations here in.

The analysis and recommendations presented in this report are based upon the data obtained from the existing pits at the location sampled. This report does not reflect variations that may occur beyond the observed conditions, across the site, or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental or biological (e.g., 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, other studies should be undertaken.

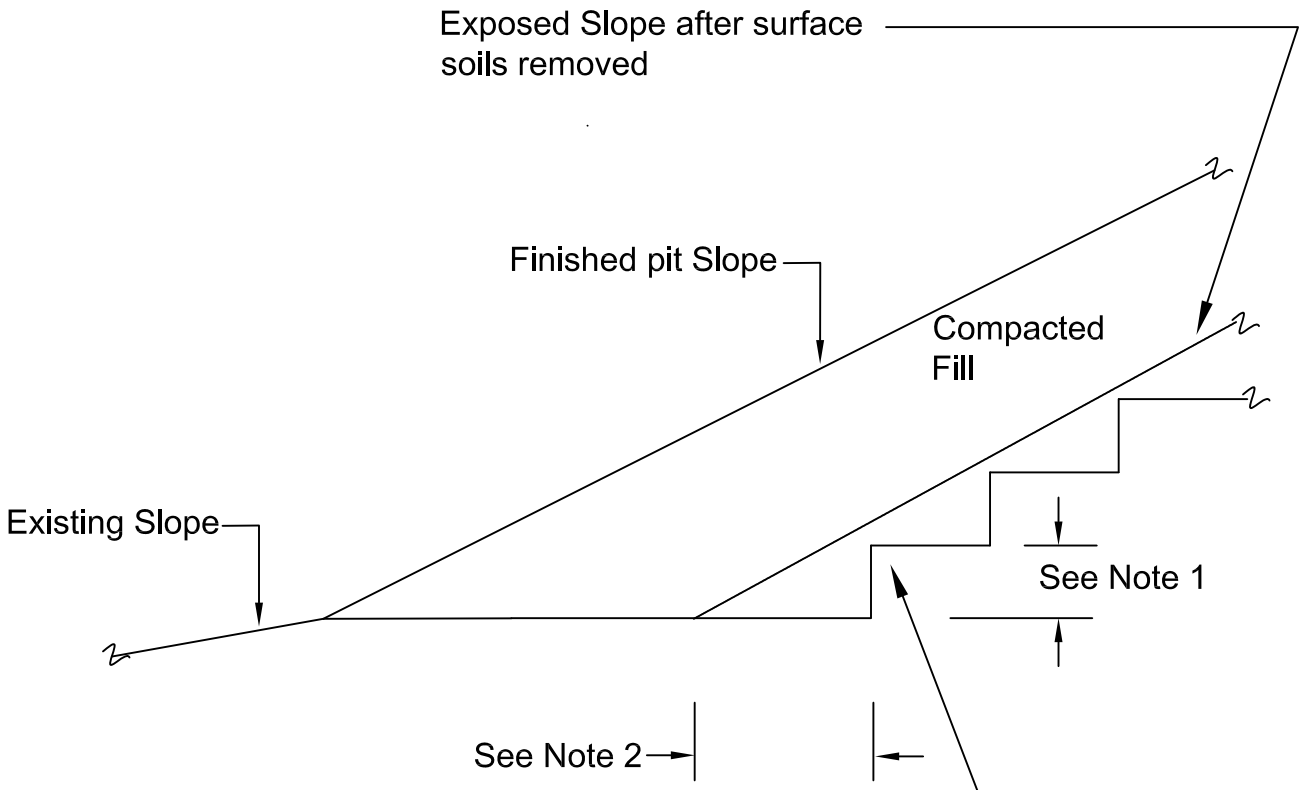
This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION

N

SUBJECT SITE

Terracon	SITE LOCATION MAP Xenon Water Storage Pits Moffat County, Colorado North 1/2, Section 12, T7N, R93W, 6thPM	DATE: 6/28/12
JOB NO. AD125020		Fig. A-1



Horizontal benches constructed into competent pit slope material. Benches to step up slope as slope soil is removed to top of embankment. Bench heights determined during construction by Terracon. Benches may be constructed by removing the material, moisture conditioning, replacing on lower bench and compacting as discussed in the report.

Note 1: Excavated into competent pit slope material (estimated 3 to 5 feet). To be verified by Terracon during construction

Note 2: Bench width varies to accommodate equipment and bench depth.

Terracon	*BENCH CONCEPT* *Xenon Water Storage Pits* *Moffat County, Colorado* *North 1/2, Section 12, T7N, R93W, 6thPM*	**DATE:** 6/28/12
JOB NO. AD125020		**Fig.** A-2

Field Exploration Description

The field exploration consisted of a walking surface observation made from the crest of each pit. One shallow soil sample was obtained from the overflow channel excavation of the main pit and returned to the laboratory for soil classification tests.

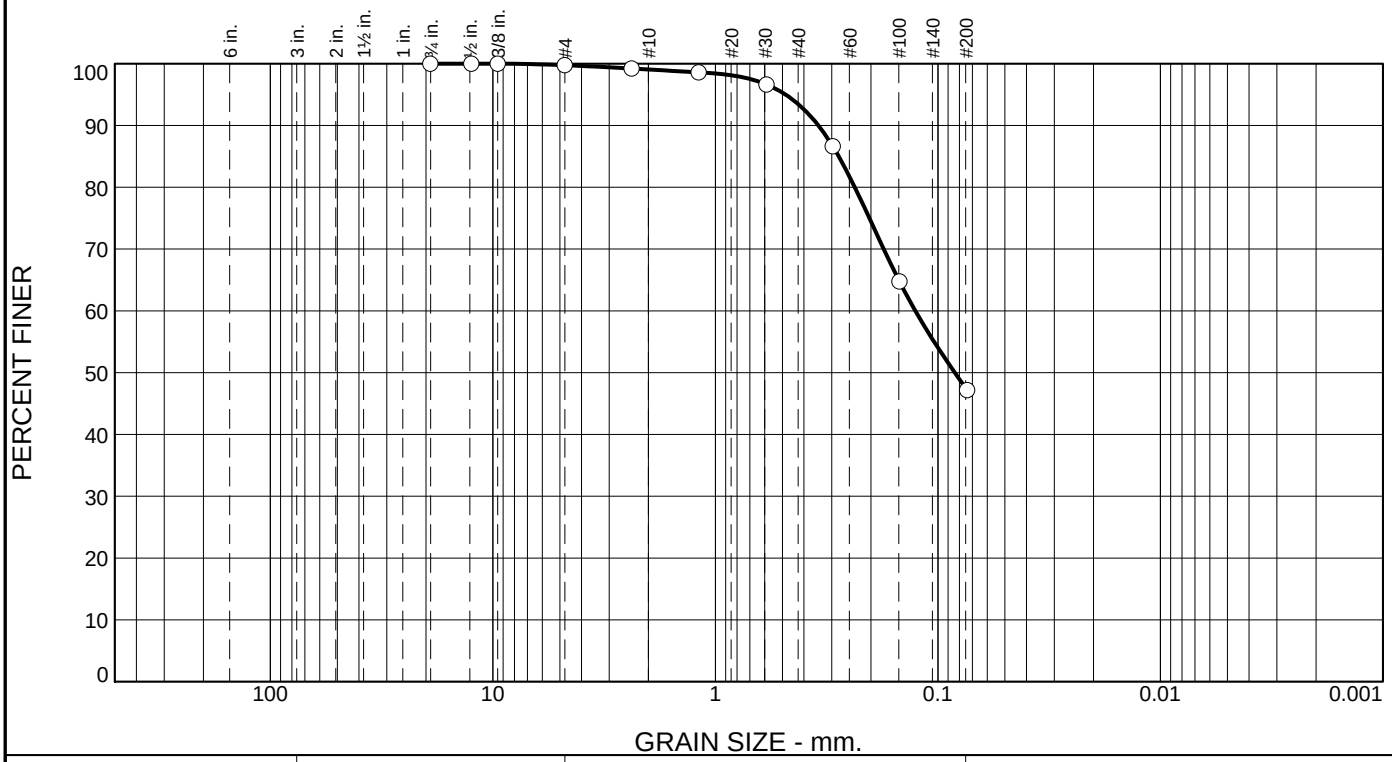
APPENDIX B
LABORATORY TESTING

Laboratory Testing

Soil samples were tested in the laboratory to measure their natural moisture content, gradation and Atterberg limits characteristics. The test results are included in Appendix B.

Descriptive classifications of the soils are in accordance with the enclosed General Notes and the Unified Soil Classification System. A brief description of this classification system is attached to this report. All classification was by visual manual procedures.

Gradation Test Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	1	6	46	47	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
3/4	100		
1/2	100		
3/8	100		
#4	100		
#8	99		
#16	99		
#30	97		
#50	87		
#100	65		
#200	47		

* (no specification provided)

Material Description

Sand, Very Clayey

Atterberg Limits (ASTM D 4318)

PL= 18 **LL=** 24 **PI=** 6

Classification

USCS (D 2487)= SC-SM **AASHTO (M 145)=** A-4(0)

Coefficients

D_{90}= 0.3446 D_{85}= 0.2792 D_{60}= 0.1264
D_{50}= 0.0839 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 06/22/2012 **Date Tested:** 02/25/2012

Tested By: RWA

Checked By: NJ

Title:

Source of Sample: Overflow Channel Main Pit **Depth:** 0 **Date Sampled:** 06/21/2012

Sample Number: 1

Terracon, Inc.

Grand Jct., Colorado

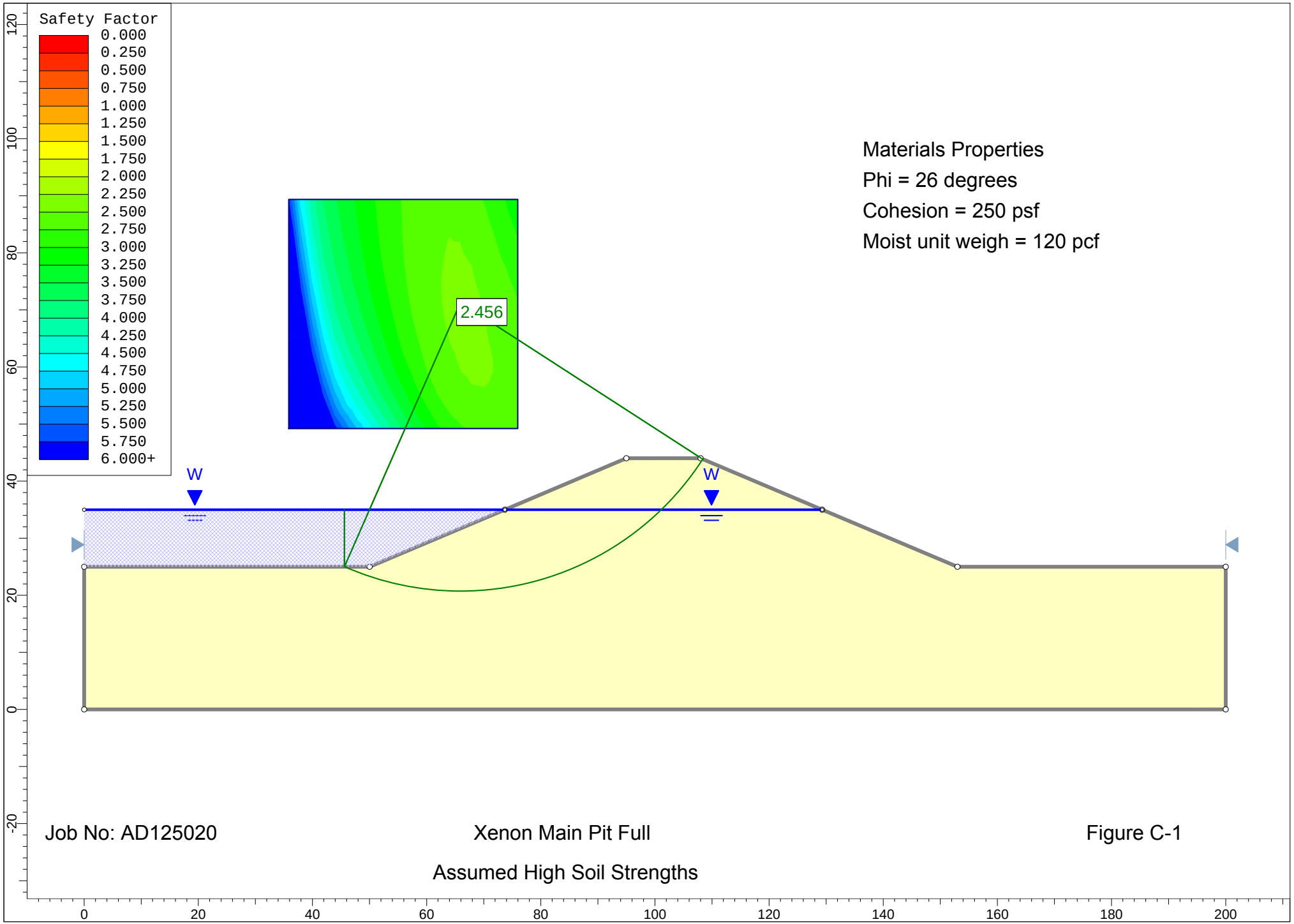
Client: Fox Engineering Solutions

Project: Xenon Water Storage Pits

Project No: AD125020 **Figure** B-2

APPENDIX C
SLOPE STABILITY ANALYIS

APPENDIX D
SUPPORTING DOCUMENTS

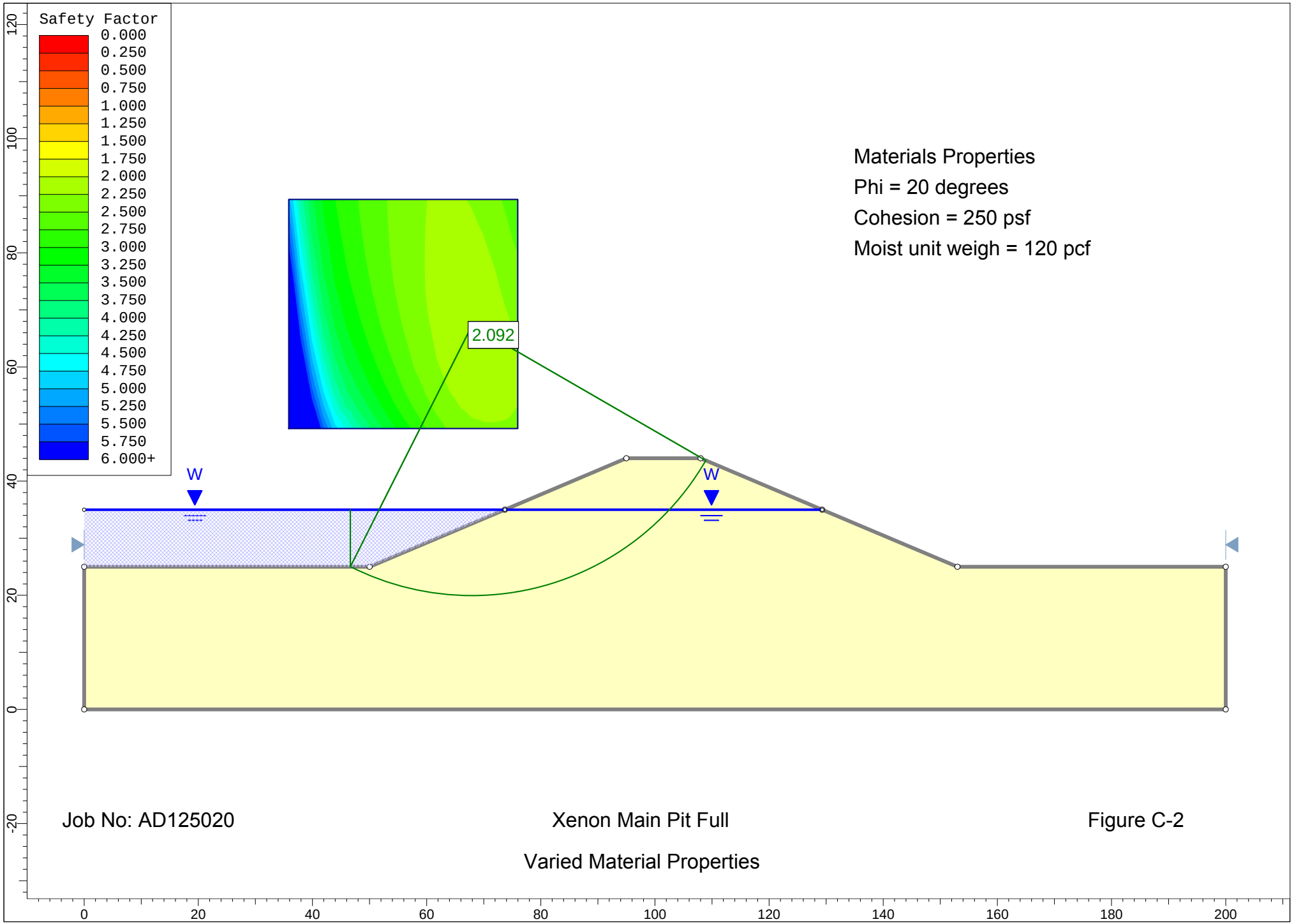


Job No: AD125020

Xenon Main Pit Full

Assumed High Soil Strengths

Figure C-1

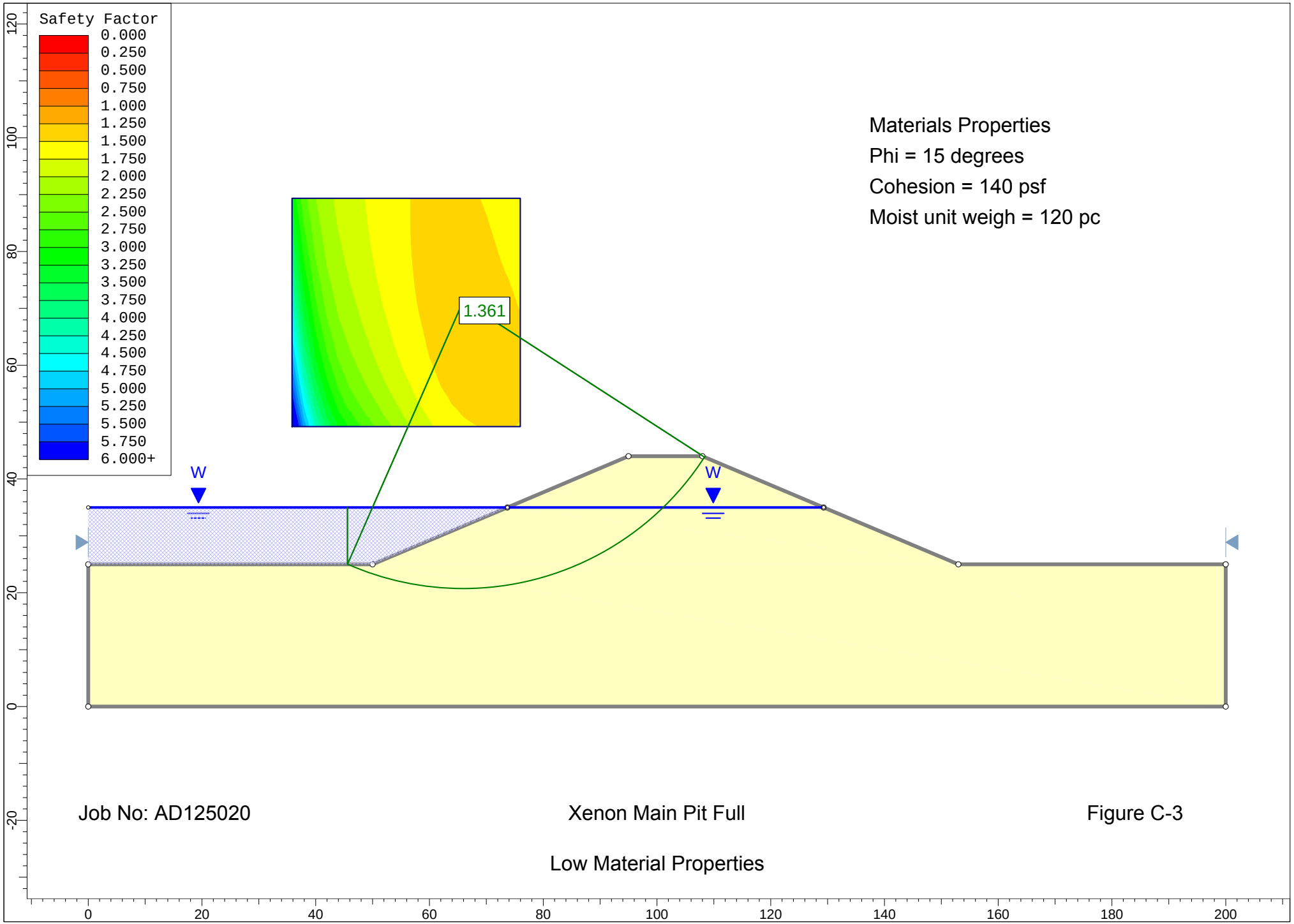


Job No: AD125020

Xenon Main Pit Full

Varied Material Properties

Figure C-2

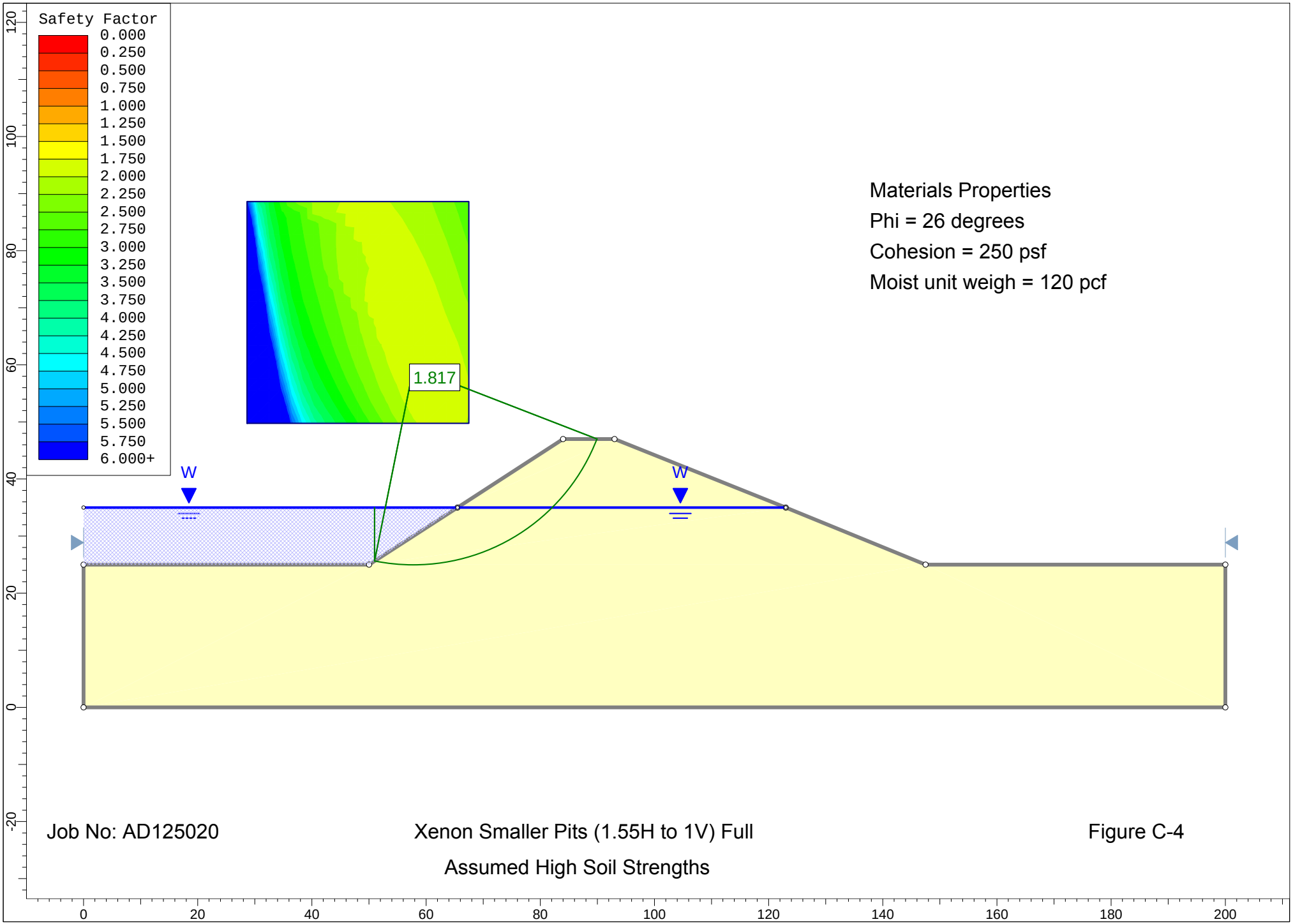


Job No: AD125020

Xenon Main Pit Full

Figure C-3

Low Material Properties

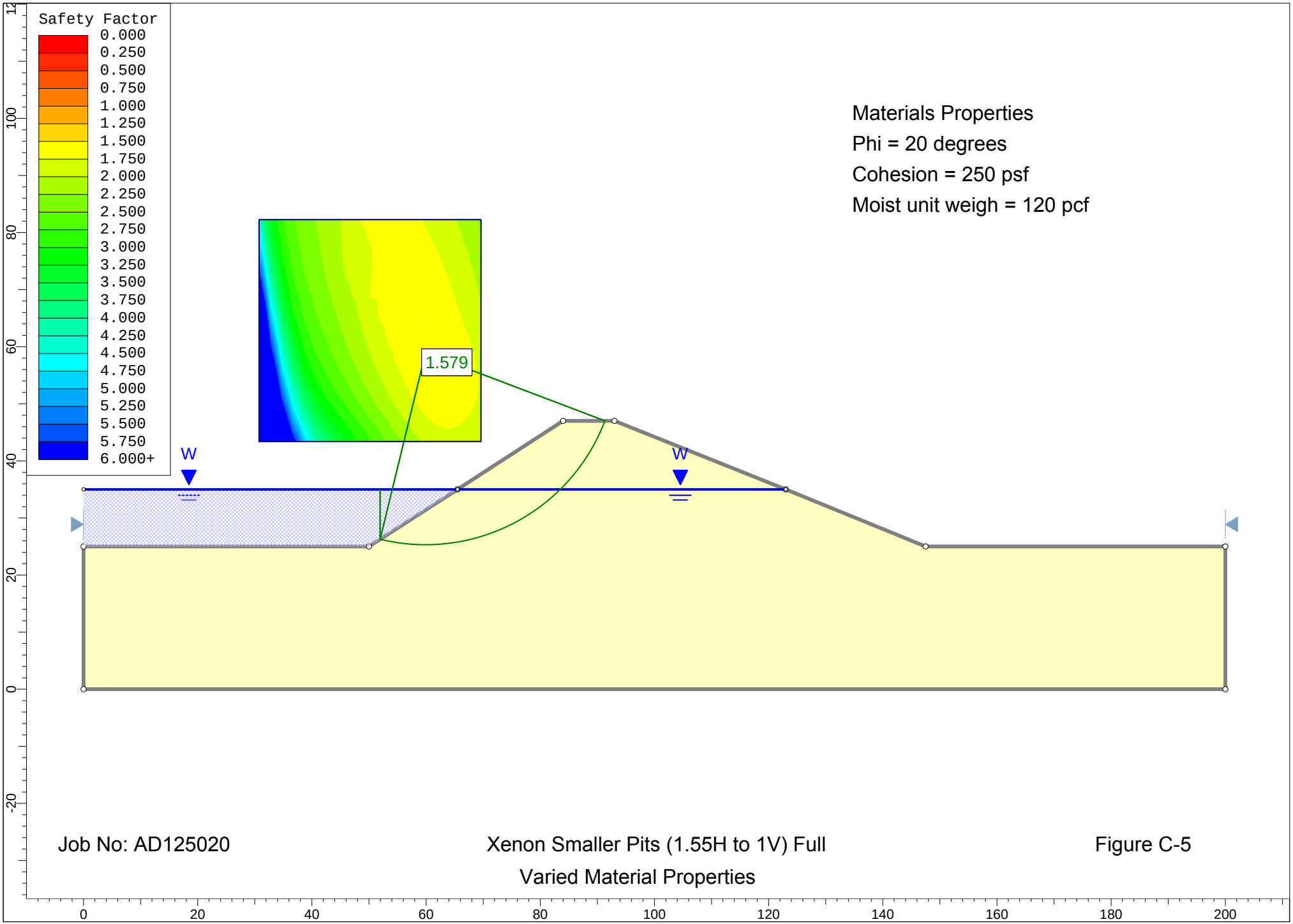


Job No: AD125020

Xenon Smaller Pits (1.55H to 1V) Full

Assumed High Soil Strengths

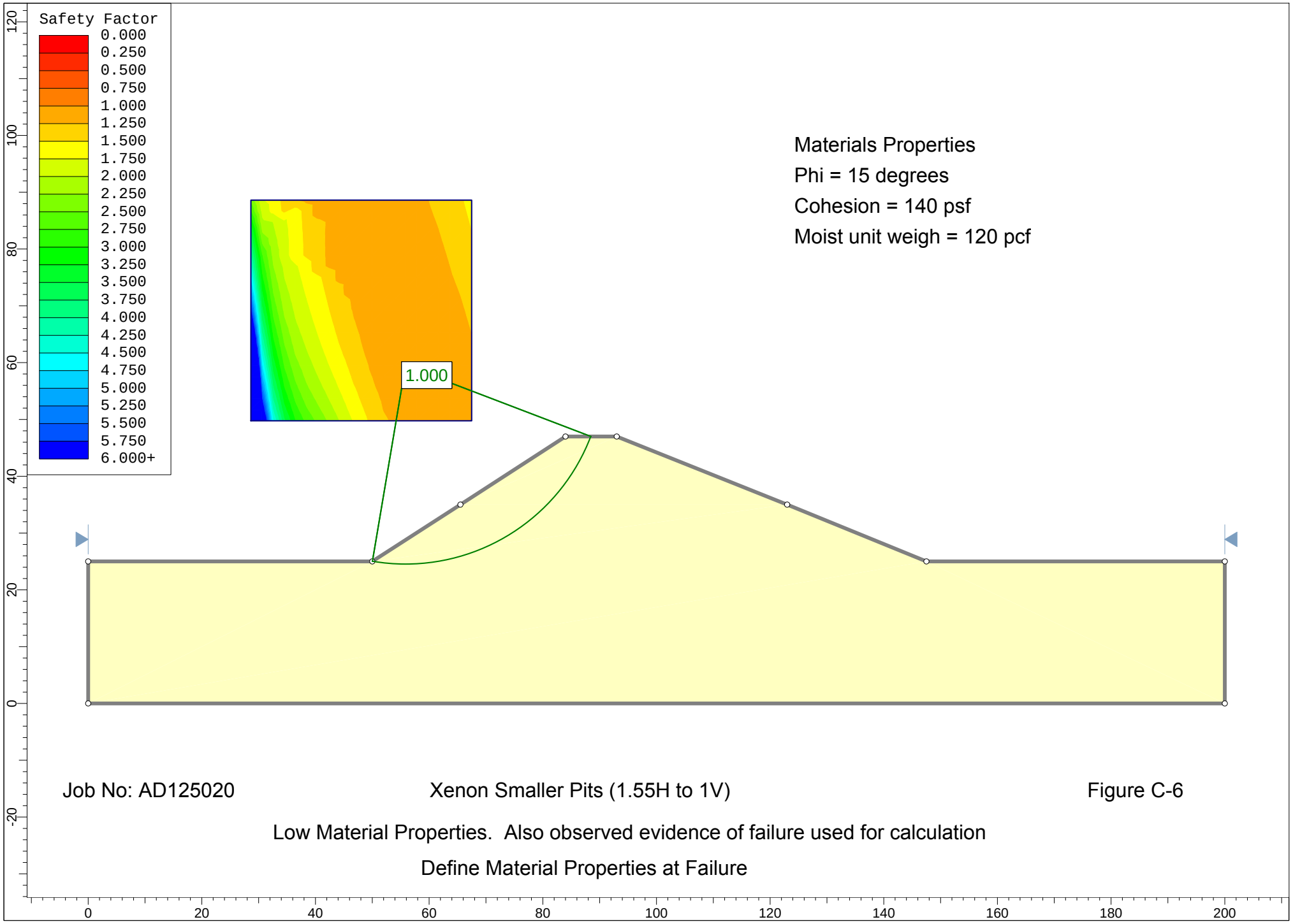
Figure C-4



Job No: AD125020

Xenon Smaller Pits (1.55H to 1V) Full
Varied Material Properties

Figure C-5



Job No: AD125020 Xenon Smaller Pits (1.55H to 1V) Figure C-6

Low Material Properties. Also observed evidence of failure used for calculation

Define Material Properties at Failure

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon - 1-$^3/_8$" I.D., 2" O.D., unless otherwise noted	HS:	Hollow Stem Auger
ST:	Thin-Walled Tube – 2" O.D., 3" O.D., unless otherwise noted	PA:	Power Auger (Solid Stem)
RS:	Ring Sampler - 2.42" I.D., 3" O.D., unless otherwise noted	HA:	Hand Auger
DB:	Diamond Bit Coring - 4", N, B	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	WB	Wash Boring or Mud Rotary

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the "Standard Penetration" or "N-value".

WATER LEVEL MEASUREMENT SYMBOLS:

WL:	Water Level	WS:	While Sampling	BCR:	Before Casing Removal
WCI:	Wet Cave in	WD:	While Drilling	ACR:	After Casing Removal
DCI:	Dry Cave in	AB:	After Boring	N/E:	Not Encountered

Water levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels may not be possible with only short-term observations.

DESCRIPTIVE SOIL CLASSIFICATION: Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

CONSISTENCY OF FINE-GRAINED SOILS

Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-value (SS) Blows/Ft.	Consistency
< 500	0 - 1	Very Soft
500 – 1,000	2 - 4	Soft
1,000 – 2,000	4 - 8	Medium Stiff
2,000 – 4,000	8 - 15	Stiff
4,000 – 8,000	15 - 30	Very Stiff
8,000+	> 30	Hard

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Standard Penetration or N-value (SS) Blows/Ft.	Relative Density
0 – 3	Very Loose
4 – 9	Loose
10 – 29	Medium Dense
30 – 50	Dense
> 50	Very Dense

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 – 29
Modifier	≥ 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
Gravel	3 in. to #4 sieve (75mm to 4.75mm)
Sand	#4 to #200 sieve (4.75 to 0.075mm)
Silt or Clay	Passing #200 Sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 – 12
Modifier	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1-10
Medium	11-30
High	> 30

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification	
					Group Symbol	Group Name [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]		GW	Well-graded gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$ [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F,G,H]
			Fines classify as CL or CH		GC	Clayey gravel [F,G,H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [E]		SW	Well-graded sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$ [E]		SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH		SM	Silty sand [G,H,I]
			Fines Classify as CL or CH		SC	Clayey sand [G,H,I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above "A" line [J]		CL	Lean clay [K,L,M]
			PI < 4 or plots below "A" line [J]		ML	Silt [K,L,M]
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay [K,L,M,N]
			Liquid limit - not dried			Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line		CH	Fat clay [K,L,M]
			PI plots below "A" line		MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried	< 0.75	OH	Organic clay [K,L,M,P]
			Liquid limit - not dried			Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.

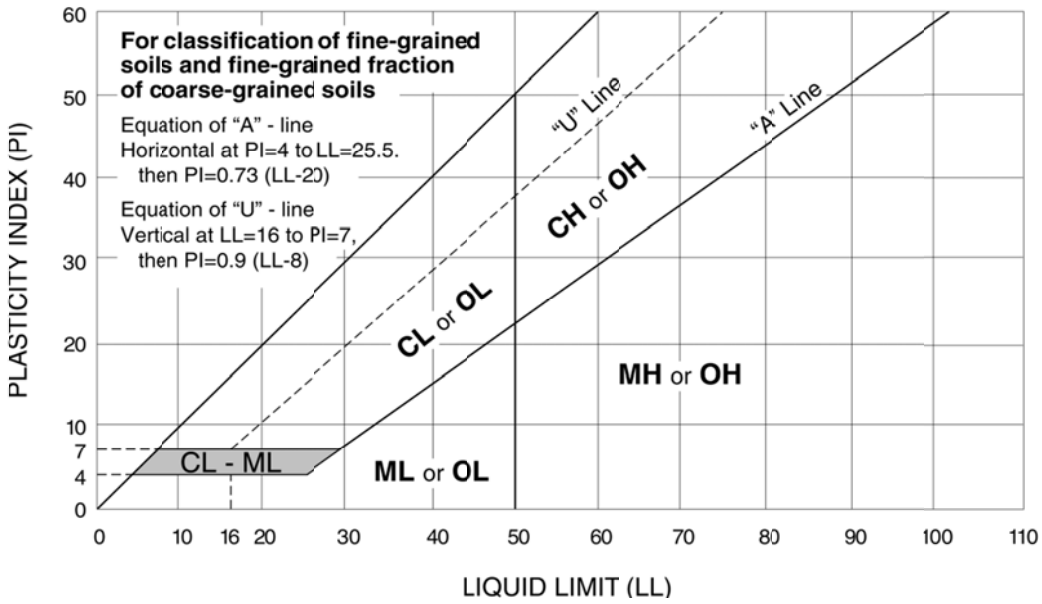


Exhibit D-2

GENERAL NOTES

Description of Rock Properties

WEATHERING

Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil". Rock "fabric" not discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)

Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Joint, Bedding and Foliation Spacing in Rock [a]		
Spacing	**Joints**	**Bedding/Foliation**
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

Rock Quality Designator (RQD) [b]		Joint Openness Descriptors	
RQD, as a percentage	**Diagnostic description**	**Openness**	**Descriptor**
Exceeding 90	Excellent	No Visible Separation	Tight
90 – 75	Good	Less than 1/32 in.	Slightly Open
75 – 50	Fair	1/32 to 1/8 in.	Moderately Open
50 – 25	Poor	1/8 to 3/8 in.	Open
Less than 25	Very poor	3/8 in. to 0.1 ft.	Moderately Wide
		Greater than 0.1 ft.	Wide

a. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.
b. RQD (given as a percentage) = length of core in pieces 4 in. and longer/length of run.

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976.
U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.