AMERICAN ENGINEERING TESTING, Inc.

REPORT OF GEOTECHNICAL EXPLORATION AND REVIEW

CUSTER WEST DAM
CUSTER, SOUTH DAKOTA

AET No. 17-02228

CONSULTANTS
- GEOTECHNICAL
- MATERIALS
- ENVIRONMENTAL
- FORENSICS

Date:

June 2, 2015

Prepared for:

Banner & Associates Inc.
730 South Street, Suite 201
Rapid City, South Dakota 57701

www.amengtest.com

June 2, 2015

Banner & Associates Inc.
730 South Street, Suite 201
Rapid City, South Dakota 57701

Attn: Mr. Dave LaFrance

RE: Geotechnical Exploration and Review
Custer West Dam
Custer, South Dakota
Report No.17-02228

Dear Dave,

American Engineering Testing, Inc. (AET) is pleased to present the results of our subsurface exploration program and geotechnical engineering review for the Custer West Dam embankment in Custer, South Dakota. These services were performed in general accordance with our proposal dated April 30, 2015. We are submitting one electronic copy of the report to your office.

Within the limitations of scope, budget, and schedule, our services have been conducted according to generally accepted geotechnical engineering practices at this time and location. Other than this, no warranty, either expressed or implied, is intended. Important information regarding risk management and proper use of this report is given in the Appendix entitled "Geotechnical Report Limitations and Guidelines for Use".

Please contact me if you have any questions about the report. I can also be contacted for arranging construction observation and testing services during the construction phase of the project.

Sincerely,
American Engineering Testing, Inc.

Robert Temme, P.E.
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SIGNATURE PAGE

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TABLE OF CONTENTS

Transmittal Letter i
Signature Page ii
TABLE OF CONTENTS iii
1.0 INTRODUCTION 1
2.0 SCOPE OF SERVICES 1
3.0 PROJECT INFORMATION 1
4.0 SUBSURFACE EXPLORATION AND TESTING 2
4.1 Field Exploration Program 2
4.2 Laboratory Testing 2
5.0 SITE CONDITIONS 3
5.1 Surface Observations 3
5.2 Subsurface Soils/Geology 3
5.3 Groundwater 3
6.0 EMBANKMENT RECONSTRUCTION 4
6.1 Discussion 4
6.2 Grading/Excavation 4
7.0 CONSTRUCTION CONSIDERATIONS 5
8.0 LIMITATIONS 5

STANDARD SHEETS – Excavation and Refilling for Structural Support

APPENDIX A – Geotechnical Field Exploration and Testing

Boring Log Notes
Unified Soil Classification System
Boring Log Notes
Rock Description Terminology
Site Location Map
Boring Location Map
Site Plan Boring Location Map
Subsurface Boring Logs

APPENDIX B – Geotechnical Report Limitations and Guidelines for Use

1.0 INTRODUCTION

We understand the City of Custer is proposing to reconstruct the Custer West Dam in Custer, South Dakota. Please refer to the Site Location Map within Appendix A. To assist with the planning and design, you have authorized American Engineering Testing, Inc. (AET) to conduct a subsurface exploration program at the site, conduct soil laboratory testing, and perform a geotechnical engineering review for the project. This report presents the results of the above services, and provides our engineering recommendations based on this data.

2.0 SCOPE OF SERVICES

AET's services were performed in general accordance with our proposal dated April 30, 2015. The authorized scope consists of the following:

- Drill three (3) Standard Penetration Test (SPT) borings to depths of 30 feet below the existing ground surface.
- Soil laboratory testing.
- Geotechnical engineering analysis based on the gained data and preparation of this report.

These services are intended for geotechnical purposes only. The scope is not intended to explore for the presence or extent of environmental contamination.

3.0 PROJECT INFORMATION

Based on the information provided, we understand the outlet works of the dam is no longer working and the dam has been drained. The existing dam is approximately 400 feet long with a maximum height on the order of 20 feet. We understand the dam embankment is to be lowered and both the upstream and downstream faces are to be armored to allow the structure to act as a large spillway in the event of a 100 year storm event. We understand the exact type of armoring, rip rap, rock gabbions, etc. is yet to be decided.

We understand that the current plan is to lower the crest of the dam by approximately 5 feet placing it close to elevation 5349.0. The crest of the reconstructed dam will be approximately 18 feet wide. The upstream face of the dam will be constructed with a 2.5H:1V slope for a horizontal distance of approximately 10 feet and then the upstream slope will be flatted to closer to a 5:1H slope to the base of the dam of 5335. The downstream face of the dam will be reconstructed to a slope of 3H:1V or flatter and tied into the existing ground surface.

The previously stated information represents our understanding of the proposed construction. This information is an integral part of our engineering review. It is important that you contact us if there are changes from that described so that we can evaluate whether modifications to our recommendations are appropriate.

4.0 SUBSURFACE EXPLORATION AND TESTING

4.1 Field Exploration Program

The subsurface exploration program conducted for the project consisted of three (3) SPT borings drilled on May 15, 2015. Each boring was drilled to a depth of 30 feet below existing grade. The approximate boring locations are shown on the Boring Location Map included within Appendix A of this report.

Borings were staked in the field by American Engineering Testing (AET) personnel. An elevation of 100 feet was used for the TBM of the top of the PVC sewer cleanout for the adjacent golf course for referencing borehole elevations. The TBM location is also shown on the Boring Location Map within Appendix A. Please note that a second Site Plan Boring Location Map has been included showing the approximate locations of our test borings and the reconstructed embankment. Surface elevations of the test borings were interpolated off the profile provided by Banner.

The log of the boring and details of the methods used appear in Appendix A. The log contains information concerning soil layering, soil classification, geologic description, and moisture condition. Relative density or consistency is also noted for the natural soils, which is based on the standard penetration resistance (N-value).

4.2 Laboratory Testing

The laboratory test program included water content, dry density and #200 sieve. The water content, dry density, and percent passing #200 sieve test results appear in Appendix A on the individual boring logs adjacent to the samples upon which they were performed.

5.0 SITE CONDITIONS

5.1 Surface Observations

At the time of our field work, the overall site consisted of the existing dam embankment spanning approximately 20-feet in elevation over the existing creek. The impounded water had been drained prior to our arrival on site. The area across the dam embankment consisted of asphalt, base course, planted grasses and large boulders along the edge of the dam. In general, the site slopes downward to the east-northeast.

5.2 Subsurface Soils/Geology

In general, the subsurface conditions consisted of 16 to 20-feet of silty and sandy lean clay fill beneath approximately 3-inches of asphalt and 6 inches of base course. Approximately 3 to 7-feet of stiffer, native alluvium as silty sand and gravel was then encountered to approximate depths of 23 to 27-feet. Below the alluvium, a very dense weathered schist bedrock (gravel), extended to the final sampled depths of 31.5-feet, with the exception of borehole B-1 where auger refusal occurred at 27-feet.

The Subsurface Boring Logs included in Appendix A give a more detailed description of the soils and soil layers encountered within the borings.

5.3 Groundwater

At the time of our field work, groundwater was encountered in all three borings at depths of 19.0 to 20.5 feet below the existing ground surface. The depth of groundwater should not be taken as an accurate representation of the actual groundwater levels. The time of year that the boring was drilled and the history of precipitation prior to drilling should be known when using the water level information on the soil boring log to extrapolate water levels at other points in time. Groundwater can be expected to fluctuate with varying seasonal events and water level fluctuations behind the embankment.

6.0 EMBANKMENT RECONSTRUCTION

6.1 Discussion

We understand that ideally the lowering and the reshaping of the existing dam without full removal of the exiting embankment is the preferred option. However, based on our test borings it appears the existing embankment soils become softer with depth. Therefore, it is our opinion the full removal of the embankment fill is the best option for the reconstruction of this embankment.

Based on subsurface soils encountered within our test borings, the site soils are suitable for reuse in the reconstruction of the new embankment. Note that the moisture content of the existing embankment soils will vary and moisture conditioning of the soils should be anticipated prior to their reuse and placement as new embankment fill.

Please note that opinions regarding the current embankment or the future stability of the reconstructed dam embankment was not requested in this study.

6.2 Grading/Excavation

Based on our boring data, it is our opinion the existing embankment should be excavated and removed in its entirety. This would require excavation depths on the order of 17 to 20 feet in depth. The existing road materials, asphalt and base course, should be removed and wasted off site. The excavated soils can be stockpiled on-site for reuse as new embankment fill. While not encountered, any rock fragments greater than 6-inches in maximum side should be removed from the stockpile and may be placed on the downstream surface

Please note that groundwater should be anticipated near the contact between the base of the old fill and the underlying alluvial soils. When encountered we recommend conventional dewatering methods be used to lower the existing groundwater levels and temporarily route the water beyond the limits of the new embankment fill.

The exposed subgrade should be proof rolled prior to the placement of new fill to obtain a firm and unyielding subgrade. The proof rolling of the base of the new embankment should be observed by the geotechnical engineer to determine that a suitable subgrade has been obtained and if any additional excavation should be done to establish a firm and unyielding subgrade.

The moisture content of the stockpiled fill soils should be adjusted to within 2% of optimum and the soils compacted to at least 95% of maximum modified Proctor dry density. The embankment fill should be placed in level lifts and should be placed in 8-inch thick maximum loose lifts. The upstream and downstream faces of the reconstructed embankment should be shaped to the final contours.

New outlet works structures placed within the embankment should be incorporated into the backfill process and hand compaction equipment should be used around this structure to ensure that all new fill is properly placed and compacted.

7.0 CONSTRUCTION CONSIDERATIONS

The recommendations in this report are based on the subsurface conditions found at our test boring locations. Since the soil conditions can be expected to vary away from the soil boring locations, we recommend on-site observation by a geotechnical engineer/technician during construction to evaluate these potential changes. Soil density testing should also be performed on fill placed in order to document that project specifications for compaction have been satisfied.

8.0 LIMITATIONS

Within the limitations of scope, budget, and schedule, our services have been conducted according to generally accepted geotechnical engineering practices at this time and location. Other than this, no warranty, either expressed or implied, is intended. Important information regarding risk management and proper use of this report is given in Appendix B entitled "Geotechnical Report Limitations and Guidelines for Use".

STANDARD SHEETS

EXCAVATION AND REFILLING FOR STRUCTURAL SUPPORT

EXCAVATION

Excavations for structural support at soil boring locations should be taken to depths recommended in the geotechnical report. Since conditions can vary, recommended excavation depths between and beyond the boring location should be evaluated by geotechnical field personnel. If groundwater is present, the excavation should be dewatered to avoid the risk of unobservable poor soils being left in-place. Excavation base soils may become disturbed due to construction traffic, groundwater or other reasons. Such soils should be subcut to underlying undisturbed soils. Where the excavation base slopes steeper than 4:1, the excavation bottom should be benched across the slope parallel to the excavation contour.

Soil stresses under footings spread out with depth. Therefore, the excavation bottom and subsequent fill system should be laterally oversized beyond footing edges to support the footing stresses. A lateral oversize equal to the depth of fill below the footing (i.e., 1:1 oversize) is usually recommended. The lateral oversize is usually increased to 1.5:1 where compressible organic soils are exposed on the excavation sides. Variations in oversize requirements may be recommended in the geotechnical report or can be evaluated by the geotechnical field personnel.

Unless the excavation is retained, the backslopes should be maintained in accordance with OSHA Regulations (Standards-29 CFR), Part 1926, Subpart P, "Excavations" (found on www.osha.gov). Even with the required OSHA sloping, groundwater can induce sideslope raveling or running which could require that flatter slopes or other approaches be used.

FILLING

Filling should proceed only after the excavation bottom has been approved by the geotechnical engineer/technician. Approved fill material should be uniformly compacted in thin lifts to the compaction levels specified in the geotechnical report. The lift thickness should be thin enough to achieve specified compaction through the full lift thickness with the compaction equipment utilized. Typical thicknesses are 6" to 9" for clays and 12" to 18" for sands. Fine grained soils are moisture sensitive and are often wet (water content exceeds the "optimum moisture content" defined by a Proctor test). In this case, the soils should be scarified and dried to achieve a water content suitable for compaction. This drying process can be time consuming, labor intensive, and requires favorable weather.

Select fill material may be needed where the excavation bottom is sensitive to disturbance or where standing water is present. Sands (SP) which are medium to coarse grained are preferred, and can be compacted in thicker lift thicknesses than finer grained soils.

Filling operations for structural support should be closely monitored for fill type and compaction by a geotechnical technician. Monitoring should be on a full-time basis in cases where vertical fill placement is rapid; during freezing weather conditions; where groundwater is present; or where sensitive bottom conditions are present.

EXCAVATION/REFILLING DURING FREEZING TEMPERATURES

Soils that freeze will heave and lose density. Upon thawing, these soils will not regain their original strength and density. The extent of heave and density loss depends on the soil type and moisture condition; and is most pronounced in clays and silts. Foundations, slabs, and other improvements should be protected from frost intrusion during freezing weather. For earthwork during freezing weather, the areas to be filled should be stripped of frozen soil, snow and ice prior to new fill placement. In addition, new fill should not be allowed to freeze during or after placement. For this reason, it may be preferable to do earthwork operations in small plan areas so grade can be quickly attained instead of large areas where much frost stripping may be needed.

Appendix A

AET Project No. 17-02228

Geotechnical Field Exploration and Testing
Unified Soil Classification System
Boring Log Notes
Rock Description Terminology
Site Location Map
Boring Location Map
Subsurface Boring Logs

A.1 FIELD EXPLORATION

The subsurface conditions at the site were explored by drilling and sampling standard penetration test borings. The locations of the borings appear on Figure 1, preceding the Subsurface Boring Logs in this appendix.

A.2 SAMPLING METHODS

A.2.1 Ring-lined barrel Samples - Calibrated to N_{60} Values

Standard penetration (ring-lined barrel) samples were collected in general accordance with ASTM: D3550. The ASTM test method consists of driving a 2.5-inch O.D. thick-walled, split-barrel sampler lined with brass rings into the in-situ soil with a 140-pound hammer dropped from a height of 30 inches. The sampler is driven a total of 18 inches into the soil. After an initial set of 6 inches, the number of hammer blows to drive the sampler the final 12 inches is known as the standard penetration resistance or N-value.

A.2.2 Disturbed Samples (DS)/Spin-up Samples (SU)

Sample types described as "DS" or "SU" on the boring logs are disturbed samples, which are taken from the flights of the auger. Because the auger disturbs the samples, possible soil layering and contact depths should be considered approximate.

A.2.3 Sampling Limitations

Unless actually observed in a sample, contacts between soil layers are estimated based on the spacing of samples and the action of drilling tools. Cobbles, boulders, and other large objects generally cannot be recovered from test borings, and they may be present in the ground even if they are not noted on the boring logs.

Determining the thickness of "topsoil" layers is usually limited, due to variations in topsoil definition, sample recovery, and other factors. Visual-manual description often relies on color for determination, and transitioning changes can account for significant variation in thickness judgment. Accordingly, the topsoil thickness presented on the logs should not be the sole basis for calculating topsoil stripping depths and volumes. If more accurate information is needed relating to thickness and topsoil quality definition, alternate methods of sample retrieval and testing should be employed.

A.3 CLASSIFICATION METHODS

Soil descriptions shown on the boring logs are based on the Unified Soil Classification (USC) system. The USC system is described in ASTM: D2487 and D2488. Where laboratory classification tests (sieve analysis or Atterberg Limits) have been performed, accurate classifications per ASTM: D2487 are possible. Otherwise, soil descriptions shown on the boring logs are visual-manual judgments. Charts are attached which provide information on the USC system, the descriptive terminology, and the symbols used on the boring logs.

Visual-manual judgment of the AASHTO Soil Group is also noted as a part of the soil description. A chart presenting details of the AASHTO Soil Classification System is also attached.

The boring logs include descriptions of apparent geology. The geologic depositional origin of each soil layer is interpreted primarily by observation of the soil samples, which can be limited. Observations of the surrounding topography, vegetation, and development can sometimes aid this judgment.

A.4 WATER LEVEL MEASUREMENTS

The ground water level measurements are shown at the bottom of the boring logs. The following information appears under "Water Level Measurements" on the logs:

- Date and Time of measurement
- Sampled Depth: lowest depth of soil sampling at the time of measurement
- Casing Depth: depth to bottom of casing or hollow-stem auger at time of measurement
- Cave-in Depth: depth at which measuring tape stops in the borehole
- Water Level: depth in the borehole where free water is encountered
- Drilling Fluid Level: same as Water Level, except that the liquid in the borehole is drilling fluid

The true location of the water table at the boring locations may be different than the water levels measured in the boreholes. This is possible because there are several factors that can affect the water level measurements in the borehole. Some of these factors include: permeability of each soil layer in profile, presence of perched water, amount of time between water level readings, presence of drilling fluid, weather conditions, and use of borehole casing.

A.5 LABORATORY TEST METHODS

A.5.1 Water Content Tests
Conducted per AET Procedure 01-LAB-010, which is performed in general accordance with ASTM: D2216 and AASHTO: T265.

A.5.2 Atterberg Limits Tests
Conducted per AET Procedure 01-LAB-030, which is performed in general accordance with ASTM: D4318 and AASHTO: T89, T90.

A.5.3 Sieve Analysis of Soils (thru #200 Sieve)
Conducted per AET Procedure 01-LAB-040, which is performed in general conformance with ASTM: D6913, Method A.

A.6 TEST STANDARD LIMITATIONS

Field and laboratory testing is done in general conformance with the described procedures. Compliance with any other standards referenced within the specified standard is neither inferred nor implied.

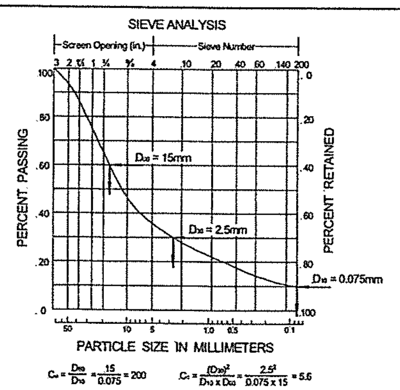
A.7 SAMPLE STORAGE

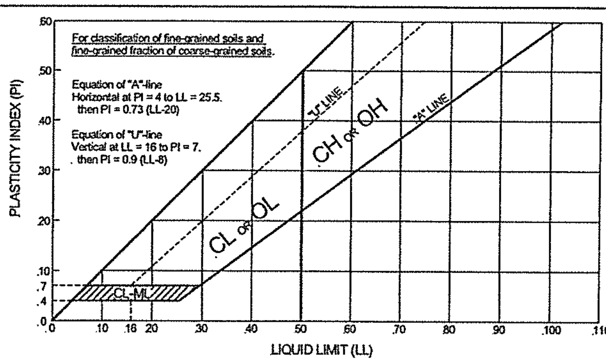
Unless notified to do otherwise, we routinely retain representative samples of the soils recovered from the borings for a period of 30 days.

UNIFIED SOIL CLASSIFICATION SYSTEM
ASTM Designations: D 2487, D2488

AMERICAN ENGINEERING TESTING, INC.

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% 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 $1 > Cc > 3$[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 (see Plasticity Chart below)	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 / Liquid limit – not dried	OL	Organic clay[K,L,M,N] / 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 / Liquid limit – not dried	OH	Organic clay[K,L,M,P] / Organic silt[K,L,M,Q]
Highly organic soil			Primarily organic matter, dark in color, and organic in odor	PT	Peat[R]





Plasticity Chart

Notes

[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]$Cu = D_{60} / D_{10}$, $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[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 is hatched area, soils 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.

[R]Fiber Content description shown below.

ADDITIONAL TERMINOLOGY NOTES USED BY AET FOR SOIL IDENTIFICATION AND DESCRIPTION

Grain Size

Term	Particle Size
Boulders	Over 12"
Cobbles	3" to 12"
Gravel	#4 sieve to 3"
Sand	#200 to #4 sieve
Fines (silt & clay)	Pass #200 sieve

Gravel Percentages

Term	Percent
A Little Gravel	3% - 14%
With Gravel	15% - 29%
Gravelly	30% - 50%

Consistency of Plastic Soils

Term	N-Value, BPF
Very Soft	less than 2
Soft	2 - 4
Firm	5 - 8
Stiff	9 - 15
Very Stiff	16 - 30
Hard	Greater than 30

Relative Density of Non-Plastic Soils

Term	**N-Value, BPF**
Very Loose	**0 - 4**
Loose	**5 - 10**
Medium Dense	**11 - 30**
Dense	**31 - 50**
Very Dense	**Greater than 50**

Moisture/Frost Condition

(MC Column)

D (Dry):	Absense of moisture, dusty, dry to touch.
M (Moist):	Damp, although free water not visible. Soil may still have a high water content (over "optimum").
W (Wet/ Waterbearing):	Free water visible intended to describe non-plastic soils. Waterbearing usually relates to sands and sand with silt.
F (Frozen):	Soil frozen

Layering Notes

Laminations:	Layers less than ½" thick of differing material or color.
Lenses:	Pockets or layers greater than ½" thick of differing material or color.

Fiber Content of Peat

Term	Fiber Content (Visual Estimate)
Fibric Peat:	Greater than 67%
Hemic Peat:	33 – 67%
Sapric Peat:	Less than 33%

Organic/Roots Description (if no lab tests)

Soils are described as *organic*, if soil is not peat and is judged to have sufficient organic fines content to influence the soil properties. *Slightly organic* used for borderline cases.

With roots:	Judged to have sufficient quantity of roots to influence the soil properties.
Trace roots:	Small roots present, but not judged to be in sufficient quantity to significantly affect soil properties.

BORING LOG NOTES

DRILLING AND SAMPLING SYMBOLS

Symbol	Definition
AR:	Sample of material obtained from cuttings blown out the top of the borehole during air rotary procedure.
B, H, N:	Size of flush-joint casing
CAS:	Pipe casing, number indicates nominal diameter in inches
COT:	Clean-out tube
DC:	Drive casing; number indicates diameter in inches
DM:	Drilling mud or bentonite slurry
DR:	Driller (initials)
DS:	Disturbed sample from auger flights
DP:	Direct push drilling; a 2.125 inch OD outer casing with an inner 1½ inch ID plastic tube is driven continuously into the ground.
FA:	Flight auger; number indicates outside diameter in inches
HA:	Hand auger; number indicates outside diameter
HSA:	Hollow stem auger; number indicates inside diameter in inches
LG:	Field logger (initials)
MC:	Column used to describe moisture condition of samples and for the ground water level symbols
N (BPF):	Standard penetration resistance (N-value) in blows per foot (see notes)
NQ:	NQ wireline core barrel
PQ:	PQ wireline core barrel
RDA:	Rotary drilling with compressed air and roller or drag bit.
RDF:	Rotary drilling with drilling fluid and roller or drag bit
REC:	In split-spoon (see notes), direct push and thin-walled tube sampling, the recovered length (in inches) of sample. In rock coring, the length of core recovered (expressed as percent of the total core run). Zero indicates no sample recovered.
SS:	Standard split-spoon sampler (steel; 1.5" is inside diameter; 2" outside diameter); unless indicated otherwise
SU	Spin-up sample from hollow stem auger
TW:	Thin-walled tube; number indicates inside diameter in inches
WASH:	Sample of material obtained by screening returning rotary drilling fluid or by which has collected inside the borehole after "falling" through drilling fluid
WH:	Sampler advanced by static weight of drill rod and hammer
WR:	Sampler advanced by static weight of drill rod
94mm:	94 millimeter wireline core barrel
▼:	Water level directly measured in boring
⊥:	Estimated water level based solely on sample appearance

TEST SYMBOLS

Symbol	Definition
CONS:	One-dimensional consolidation test
DEN:	Dry density, pcf
DST:	Direct shear test
E:	Pressuremeter Modulus, tsf
HYD:	Hydrometer analysis
LL:	Liquid Limit, %
LP:	Pressuremeter Limit Pressure, tsf
OC:	Organic Content, %
PERM:	Coefficient of permeability (K) test; F - Field; L - Laboratory
PL:	Plastic Limit, %
q_p:	Pocket Penetrometer strength, tsf (approximate)
q_c:	Static cone bearing pressure, tsf
q_u:	Unconfined compressive strength, psf
R:	Electrical Resistivity, ohm-cms
RQD:	Rock Quality Designation of Rock Core, in percent (aggregate length of core pieces 4" or more in length as a percent of total core run)
SA:	Sieve analysis
TRX:	Triaxial compression test
VSR:	Vane shear strength, remolded (field), psf
VSU:	Vane shear strength, undisturbed (field), psf
WC:	Water content, as percent of dry weight
%-200:	Percent of material finer than #200 sieve

STANDARD PENETRATION TEST NOTES
(Calibrated Hammer Weight)

The standard penetration test consists of driving a split-spoon sampler with a drop hammer (calibrated weight varies to provide N_{60} values) and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), permitted in ASTM: D1586, the blows for each complete 6" increment and for each partial increment is on the boring log. For partial increments, the number of blows is shown to the nearest 0.1' below the slash.

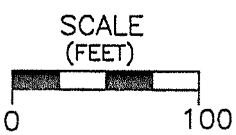
The length of sample recovered, as shown on the "REC" column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM: D1586 is encountered) whereas the length of sample recovered is for the entire sampler drive (which may even extend more than 18").

ROCK DESCRIPTION TERMINOLOGY

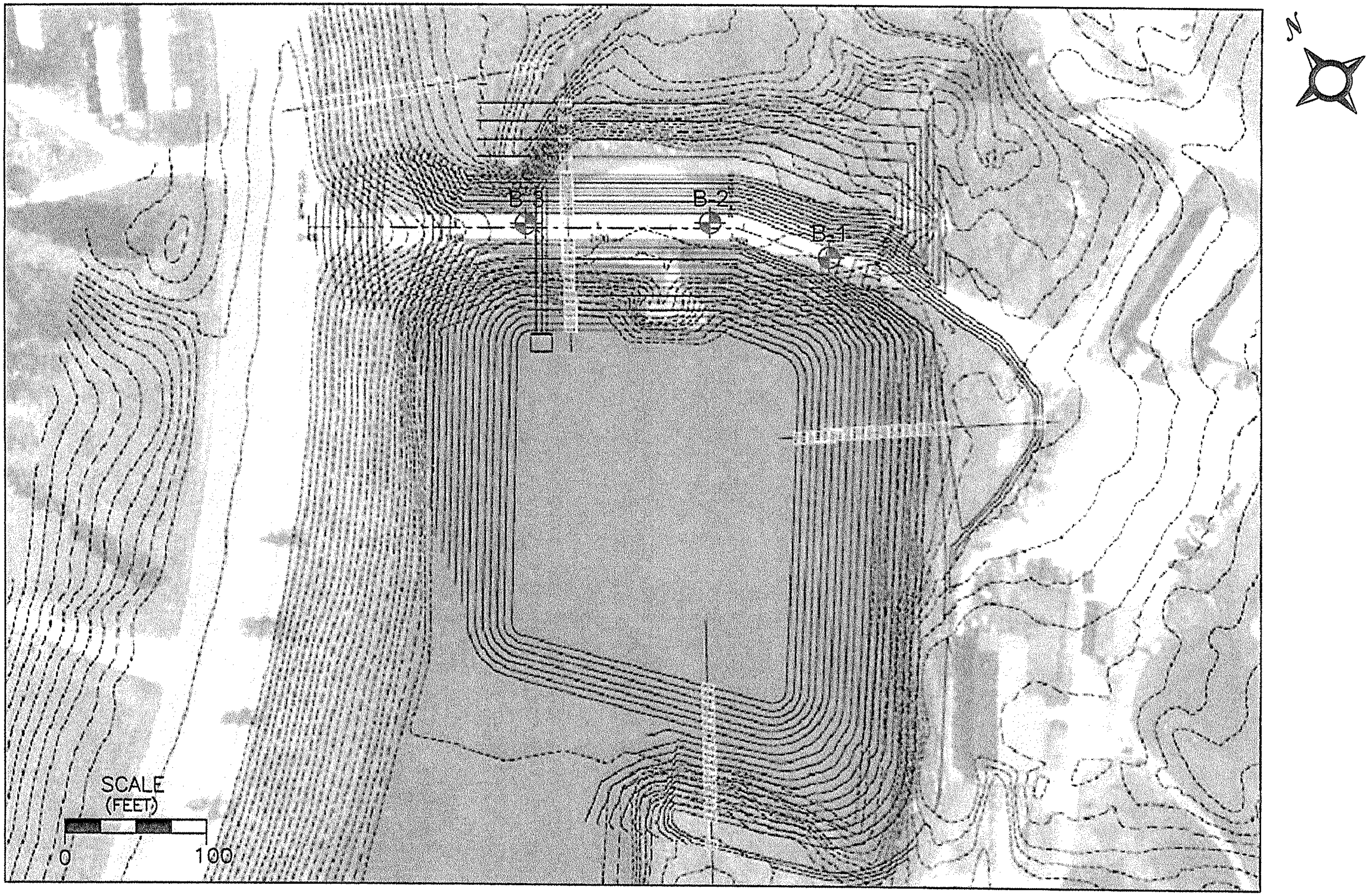
Rock Property	Descriptive Term	Visual or Physical Properties
Weathering	Highly Weathered	Almost complete rock disintegration and decomposition. Soil-like texture with some small inclusions of hard rock.
	Very Weathered	Abundant fractures coated with oxides, carbonates, sulfates, mud, etc., thorough discoloration, rock disintegration, and mineral decomposition.
	Moderately Weathered	Some fracture coating, moderate or localized discoloration, little to no effect on cementation, slight mineral decomposition
	Slightly Weathered	A few stained fractures, slight discoloration, little to no effect on cementation, no mineral decomposition.
	Fresh	Unaffected by weathering agents, no appreciable change with depth.
Fracturing	Intensely Fractured	Less than 1" spacing
	Very Fractured	1" to 6" spacing
	Moderately Fractured	6" to 12" spacing
	Slightly Fractured	12" to 36" spacing
	Solid	36" spacing or greater
Stratification	Thinly Laminated	Less than 1/10"
	Laminated	1/10" to 2"
	Very Thinly Bedded	2" to 2"
	Thinly Bedded	2" to 2'
	Thickly Bedded	More than 2'
Hardness	Soft	Can be dug by hand and crushed by fingers.
	Moderately Hard	Friable, can be gouged deeply with knife and will crumble readily under light hammer blows.
	Hard	Knife scratch leaves dust trace, will withstand a few hammer blows before breaking.
	Very Hard	Scratched with knife with difficulty, difficult to break with hammer blows.
RQD*	Very Poor	0 - 25 (%)
	Poor	25 - 50 (%)
	Fair	50 - 75 (%)
	Good	75 - 90 (%)
	Excellent	90 - 100 (%)

**Rock Quality Designation:* *Percent of core run consisting of the summation of hard, sound and unfractured rock core segments 4O or greater in length.*

AMERICAN ENGINEERING TESTING, INC.	PROJECT: CUSTER WEST DAM CUSTER, SOUTH DAKOTA		PROJECT NO. 17-02228
	SUBJECT: SITE LOCATION MAP		DATE: MAY 19, 2015
	SCALE: 1 INCH = 500 FEET	DRAWN BY: JR	REVIEWED BY: RT



AMERICAN ENGINEERING TESTING, INC.	PROJECT: CUSTER WEST DAM CUSTER, SOUTH DAKOTA		PROJECT NO. 17-02228
	SUBJECT: BORING LOCATION MAP		DATE: MAY 19, 2015
	SCALE: 1 INCH = 100 FEET	DRAWN BY: JR	REVIEWED BY: RT



AMERICAN ENGINEERING TESTING, INC.	PROJECT: CUSTER WEST DAM CUSTER, SOUTH DAKOTA	PROJECT NO. 17-02228
	SUBJECT: SITE PLAN BORING LOCATION MAP	DATE: JUNE 1, 2015
	SCALE: 1 INCH = 100 FEET | DRAWN BY: JR	REVIEWED BY: RT

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE BORING LOG

AET JOB NO: **17-02228** LOG OF BORING NO. **B-1 (p. 1 of 1)**

PROJECT: **Custer West Dam; Custer, South Dakota**

SURFACE ELEVATION: 5355.0

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DEN	LL	PL	%-#200
0	**ASPHALT**, 3 inches	PAVEMENT									
1	**BASE COURSE**, 6 inches	FILL									
2	**FILL**, Silty Sand with gravel, dark brown										
3–4			16	M	MC	18					
5–6			15	M	MC	18	23	98			64
8–9	**FILL**, Silty Lean Clay with sand, light brown-brown		12	M	MC	18					
10–11			12	M	MC	18	24	95			
13	sandy		9	M	MC	18					
15–16	with sand		9	M	MC	18	30	94			
18	**SILTY SAND**, dark brown, medium dense (SP)	ALLUVIUM									
19				▽							
21			14	W	MC	18					
23	**GRAVEL**, dark gray, very dense (GP)	WEATHERED SCHIST BEDROCK									
26			50/.2	M	MC	3	10				
27	Bottom of Boring (Auger Refusal at 27')										

DEPTH:	DRILLING METHOD
27.0	3.25" HSA

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
5/15/15	9:35	26.5	25.0	NA	NA	19.0

BORING COMPLETED: 5/15/15

DR: BT LG: JA Rig: RC-1

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AET_CORP 17-02228.GPJ AET+CPT+WELL.GDT 6/1/15

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE BORING LOG

AET JOB NO: **17-02228** LOG OF BORING NO. **B-2 (p. 1 of 1)**

PROJECT: **Custer West Dam; Custer, South Dakota**

SURFACE ELEVATION: **5354.6**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DEN	LL	PL	%-#200
	ASPHALT, 3 inches	PAVEMENT									
1	**BASE COURSE**, 6 inches	FILL									
2	**FILL**, Silty Lean Clay with sand, light brown-brown										
3			16	M	MC	18	18				
6			11	M	MC	18					
8			15	M	MC	18	22	100			
11			16	M	MC	18					
13			11	M	MC	18	24	96			
16			10	M	MC	18					
19				▽							
20	**SANDY GRAVEL** with silt, dark brown-gray, medium dense to dense (GP)	ALLUVIUM									
21			24	W	MC	18	30				
26			48	W	MC	18					
28	**GRAVEL**, dark gray, very dense (GP)	WEATHERED SCHIST BEDROCK									
31			50/.3	W	MC	4	17	115			
	Bottom of Boring										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
30.0	**3.25" HSA**	**5/15/15**	**10:40**	**31.5**	**30.0**	**NA**	**NA**	**19.5**

BORING COMPLETED: **5/15/15**

DR: **BT** LG: **JA** Rig: **RC-1**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AET_CORP 17-02228.GPJ AET+CPT+WELL.GDT 6/1/15

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE BORING LOG

AET JOB NO: **17-02228** LOG OF BORING NO. **B-3 (p. 1 of 1)**

PROJECT: **Custer West Dam; Custer, South Dakota**

DEPTH IN FEET	SURFACE ELEVATION: 5353.8 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	DEN	LL	PL	%-#200
	ASPHALT, 4 inches	PAVEMENT									
1	**BASE COURSE**, 7 inches	FILL									
2	**FILL**, Sandy Silt with clay, dark brown										
3			19	M	MC	18					
4											
5	**FILL**, Sandy Lean Clay with silt and trace gravel, dark brown										
6			20	M	MC	18	27	85			
7											
8			11	M	MC	18					
9											
10	with trace organics										
11			8	M	MC	18	28	87			
12											
13	silty, with sand		6	M	MC	18					
14											
15											
16	**FILL**, Lean Clay with sand, brown		7	M	MC	18	29	95			64
17											
18											
19											
20				▽							
21	**SANDY GRAVEL** with silt, dark brown, dense (GP)	ALLUVIUM	36	W	MC	18					
22											
23											
24	**GRAVEL**, dark gray, very dense (GP)	WEATHERED SCHIST BEDROCK									
25											
26			50/.5	W	MC	6	7				
27											
28											
29											
30											
31			50/.3	W	MC	4					
	Bottom of Boring										

DEPTH: DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
30.0 3.25" HSA	5/15/15	11:55	31.5	30.0	NA	NA	20.5

WATER LEVEL MEASUREMENTS

BORING COMPLETED: 5/15/15

DR: BT LG: JA Rig: RC-1

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AET_CORP 17-02228.GPJ AET+CPT+WELL.GDT 6/1/15

Appendix B

Geotechnical Report Limitations and Guidelines for Use

REFERENCE

This appendix provides information to help you manage your risks relating to subsurface problems which are caused by construction delays, cost overruns, claims, and disputes. This information was developed and provided by ASFE[1], of which, we are a member firm.

RISK MANAGEMENT INFORMATION

Geotechnical Services are Performed for Specific Purposes, Persons, and Projects
Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared solely for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. No one, not even you, should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report
Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report is Based on A Unique Set of Project-Specific Factors
Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typically factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, always inform your geotechnical engineer of project changes, even minor ones, and request an assessment of their impact. Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.

Subsurface Conditions Can Change
A geotechnical engineering report is based on conditions that existed at the time the study was performed. Do not rely on a geotechnical engineering report whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. Always contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

1 ASFE, 8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733 : www.asfe.org

Most Geotechnical Findings Are Professional Opinions
Site exploration identified subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are Not Final
Do not over rely on the construction recommendations included in your report. Those recommendations are not final, because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual subsurface conditions revealed during construction. The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.

A Geotechnical Engineering Report Is Subject to Misinterpretation
Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs
Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance
Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, but preface it with a clearly written letter of transmittal. In the letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need to prefer. A prebid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely
Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their report. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. Read these provisions closely. Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered
The equipment, techniques, and personnel used to perform a geoenvironmental study differ significantly from those used to perform a geotechnical study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Unanticipated environmental problems have led to numerous project failures. If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. Do not rely on an environmental report prepared for someone else.