SUBSURFACE EXPLORATION

PROPOSED ELM PLACE EXTENSION
BROKEN ARROW, OKLAHOMA

Project No. 1085067
August 12, 2008

Prepared for:

HRAOK, INC.
Broken Arrow, Oklahoma

Prepared by:

BELONGIA CONSULTANTS INC.
Broken Arrow, Oklahoma

BELONGIA CONSULTANTS, INC.

2145 W. Concord Circle
Broken Arrow, OK 74012
(918) 251-5500 Fax: (918) 251-5708

August 12, 2008

HRAOK, Inc.
1913 West Tacoma, Suite A
Broken Arrow, Oklahoma 74012

Attention: Mr. Barrick Rosenbaum, P.E

Re: Subsurface Exploration
Proposed Elm Place Extension
Broken Arrow, Oklahoma
Project No. 1085067

Dear Mr. Rosenbaum:

We are submitting, herewith, the results of the supplemental subsurface exploration performed for the proposed Elm Place Extension in Broken Arrow, Oklahoma. General comments regarding pavement sections, support of pavements and general earthwork procedures, relative to the subsurface conditions encountered in the borings, are presented in the following report.

If you have any questions regarding the contents of this report or if we can be of further service, please do not hesitate to contact us.

Sincerely,

David L. Belongia, P.E.
Oklahoma No. 12908

REGISTERED PROFESSIONAL ENGINEER
DAVID LEE BELONGIA
12908
OKLAHOMA
8/12/08

DLB:PS
Enclosure
Copies To: Addressee (3)

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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., unless otherwise noted	PA:	Power Auger
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
WCI:	Wet Cave in	WD:	While Drilling
DCI:	Dry Cave in	BCR:	Before Casing Removal
AB:	After Boring	ACR:	After Casing Removal

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 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	<2	Very Soft
500 – 1,000	2-3	Soft
1,001 – 2,000	4-6	Medium Stiff
2,001 – 4,000	7-12	Stiff
4,001 – 8,000	13-26	Very Stiff
8,000+	26+	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 – 49	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 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm 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
Modifiers	> 12

PLASTICITY DESCRIPTION

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

GENERAL NOTES

Sedimentary Rock Classification

DESCRIPTIVE ROCK CLASSIFICATION:

Sedimentary rocks are composed of cemented clay, silt and sand sized particles. The most common minerals are clay, quartz and calcite. Rock composed primarily of calcite is called limestone; rock of sand size grains is called sandstone, and rock of clay and silt size grains is called mudstone or claystone, siltstone, or shale. Modifiers such as shaly, sandy, dolomitic, calcareous, carbonaceous, etc. are used to describe various constituents. Examples: sandy shale; calcareous sandstone.

LIMESTONE	Light to dark colored, crystalline to fine-grained texture, composed of $CaCo_3$, reacts readily with HCl.
DOLOMITE	Light to dark colored, crystalline to fine-grained texture, composed of $CaMg(CO_3)_2$, harder than limestone, reacts with HCl when powdered.
CHERT	Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz ($Si0_2$), brittle, breaks into angular fragments, will scratch glass.
SHALE	Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The unlaminated equivalent is frequently referred to as siltstone, claystone or mudstone.
SANDSTONE	Usually light colored, coarse to fine texture, composed of cemented sand size grains of quartz, feldspar, etc. Cement usually is silica but may be such minerals as calcite, iron-oxide, or some other carbonate.
CONGLOMERATE	Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (½ inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.

DEGREE OF WEATHERING:

SLIGHT	Slight decomposition of parent material on joints. May be color change.
MODERATE	Some decomposition and color change throughout.
HIGH	Rock highly decomposed, may be extremely broken.

Classification of rock materials has been estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

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 / Liquid limit - not dried	< 0.75	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 lots below "A" line		MH	Elastic Silt[K,L,M]
		organic	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OH	Organic clay[K,L,M,P] / 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.

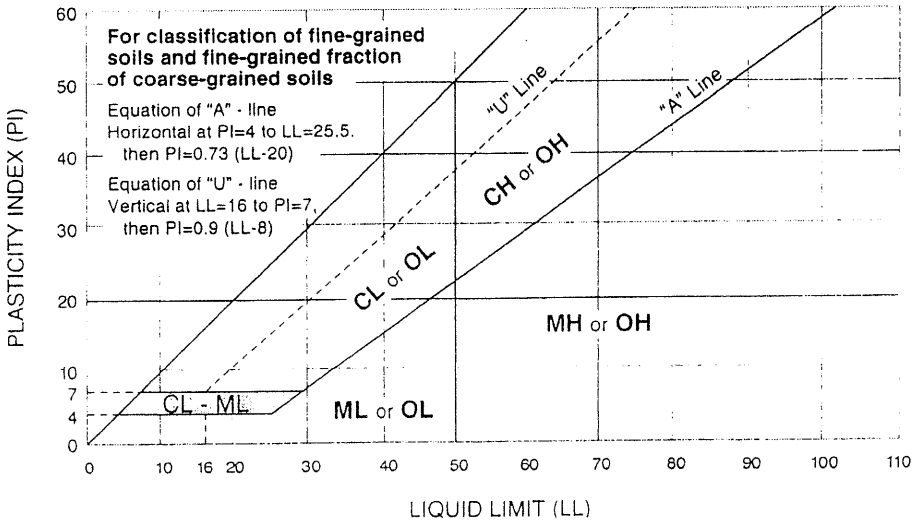
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[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.



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SUBSURFACE EXPLORATION

PROPOSED ELM PLACE EXTENSION
BROKEN ARROW, OKLAHOMA

Project No. 1085067
August 12, 2008

INTRODUCTION

This report presents the results of the supplemental subsurface exploration performed for the proposed Elm Place Extension in Broken Arrow, Oklahoma. This exploration supplements an exploration performed for the project by Kleinfelder in December 2005. Plans for the project have already been prepared based on the subsurface information presented in the Kleinfelder report. Since the submittal of those plans, a portion of the project has been realigned. The supplemental exploration was performed in the area where the realignment will occur. Four soil borings were drilled to depths of approximately 10 feet as part of our exploration. These results of the borings are attached.

The project involves extending Elm Place north to East 51st Street in Broken Arrow, Oklahoma. Cuts and fills in the area where the realignment will occur are expected to be less than 5 feet.

The purpose of this report is to describe the subsurface conditions encountered in the borings; analyze the data obtained and provide general comments regarding pavement sections, pavement support and earthwork procedures, relative to the subsurface conditions encountered in the borings.

SUBSURFACE EXPLORATION PROCEDURES

Four soil borings were drilled for the project. The boring locations were staked in the field by HRAOK, Inc. personnel. Ground surface elevations at the boring locations were also determined by HRAOK and are shown on the attached boring logs.

The borings were drilled with a truck-mounted drill rig using continuous flight augers to advance the borings. Representative soil samples were obtained using the split-barrel sampling procedure in general accordance with the appropriate ASTM standard.

Disturbed samples were obtained in the split-barrel sampling procedure by driving a 2-inch O.D. split-barrel sampling spoon into the ground using a 140-pound, automatic hammer falling 30 inches. The number of blows required to advance the sampler were recorded in the field and are shown on the boring logs as the standard penetration resistance (N) value. The number of blows required to advance the sampling spoon the final 12 inches or less of a standard 18-inch sampling interval indicate the in-place relative density of granular soils and, to a lesser degree of accuracy, the consistency of cohesive soils and the hardness of weathered bedrock.

A greater mechanical efficiency is achieved with the automatic hammer, compared to the conventional safety hammer operated with a cathead and rope. The effect of this increased efficiency has been considered in interpreting the standard resistance values.

Soil samples obtained in the field were sealed and returned to the laboratory for further examination, testing, and classification.

During the drilling operation, field logs were prepared by the drill crew. These logs report drilling and sampling methods, sampling intervals, soil and groundwater conditions, and the driller's visual evaluation of the conditions encountered between samples. The final boring logs, included in this report, have been prepared based on the driller's field logs and have been modified, where appropriate, based on the results of the laboratory observation and testing.

LABORATORY TESTING PROGRAM

Moisture content and, where applicable, calibrated hand penetrometer tests were performed on the split-barrel samples. Also, Atterberg limits tests were performed on representative samples of the near surface soils. The calibrated hand penetrometer test provides an approximation of the unconfined compressive strength of a cohesive soil. The Atterberg limits indicate the plasticity of a cohesive soil and are used to approximate the soil's potential for volume change with variation in moisture content. The laboratory test results are reported on the boring logs.

The soil samples were examined in the laboratory by an experienced geotechnical engineer and classified based on the soil's texture and plasticity in accordance with the attached General Notes and Unified Soil Classification System. The estimated Unified System group symbols are shown on the boring logs. A brief description of the Unified System is attached to

this report. Samples of the bedrock materials were classified in accordance with the attached General Notes and described using commonly accepted geotechnical terminology. Petrographic analysis may reveal other rock types.

SUBSURFACE CONDITIONS

The stratification lines shown on the boring logs represent the approximate boundary between soil and rock types; in-situ, the transition between materials may be gradual and indistinct.

About 6 inches of surface vegetation and topsoil was encountered at the boring locations. The topsoil was generally underlain by dark brown, silt with varying amounts of clay and gravel. The silt was underlain by brown and reddish brown, stiff to very stiff, lean clay with varying amounts of sand and gravel to depths of about 4.5 to 5.5 feet. At borings B-1 and B-3, the above described clay was underlain by brown and olive brown, shaley lean clay to depths of about 8.5 to 9 feet. The lean clay and shaley clay was underlain by soft, olive brown, highly weathered shale, trace sandstone to the bottom of the borings. At boring B-4, the lean clay was underlain by a layer of brown, reddish brown and gray, lean to fat clay which extended to about 7.5 feet. The lean to fat clay was underlain by very stiff, brown and olive brown, lean clay with silt, which extended to the bottom of the boring.

GROUNDWATER CONDITIONS

Groundwater level observations made while drilling and immediately after completion of the borings are shown in the lower left corner of the boring logs. As shown on the boring logs, no groundwater was encountered at these times.

The groundwater level observations made during our exploration provide an indication of the groundwater conditions at the time the borings were drilled. Longer monitoring in piezometers or cased holes would be required to evaluate long-term groundwater conditions. During some periods of the year, perched water could develop in the near surface soils. Fluctuations in the amount of perched water, if any, and long-term groundwater levels should be expected throughout the years depending upon variations in the amount of rainfall, runoff, evaporation, and other hydrological conditions not apparent at the time the borings were drilled.

ANALYSIS AND RECOMMENDATIONS

Geotechnical Considerations

Based on the borings, the subsurface materials encountered in the area of the proposed realignment generally consist of clay overburden soils underlain by weathered shale bedrock. The clay soils generally have plasticity indexes greater than 10 and will require modification to reduce their plasticity. It should be feasible to excavate the overburden soil and underlying shale with heavy duty, track mounted, excavation equipment.

Pavement Section

The proposed pavement section per the submitted plans is outlined below.

ARTERIAL STREET PAVING SECTION

2.0" ODOT Type "B" Asphaltic Concrete
3.0" ODOT Type "A" Asphaltic Concrete
4.0" ODOT Type "A" Asphaltic Concrete
4.0" ODOT Type "A" Aggregate Base
Geotextile Fabric
8.0" Compacted Subgrade (PI <10)

This section satisfies the City of Broken Arrow requirements for Arterial Streets provided the 8 inch compacted subgrade consists of properly modified site soils or an approved select fill.

GENERAL COMMENTS

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from any other information discussed in this report. This report does not reflect any variations which may occur across the site. The nature and extent of such variations may not become evident until construction. If variations appear, it will be necessary to reevaluate the recommendations of this report.

The scope of services for this project does not include either specifically or by implication any environmental assessment of the site or identification of contaminated or hazardous

materials or conditions. If the owner is concerned about the potential for such contamination, 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. In the event that any 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 Belongia Consultants Inc. reviews the changes, and either verifies or modifies the conclusions of this report in writing.

LOG OF BORING NO. B-1 (Sta 39+00)

CLIENT

ENGINEER **HRAOK, Inc.**

SITE **Broken Arrow, Oklahoma**

PROJECT **Elm Place Extension**

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, in.	SAMPLES SPT - N BLOWS / ft.	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 765.7 ft				PA					
	6" Topsoil SILT, TRACE CLAY dark brown, loose		ML	1	SS	18	5	15.1		
	763.5									
2	LEAN CLAY WITH GRAVEL brown and reddish-brown		CL GC	2	SS	12	9	17.9		
					PA					
		5	CL	3	SS	16	23	15.7		*8000
	759.5									
6	SHALEY LEAN CLAY brown and light brown, very stiff				PA					
				4	SS	12	35/6" 50/4"	10.8		
	756.5									
9										
9.3	HIGHLY WEATHERED SHALE olive-brown									
	756.5									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft	
WL	None WD
WL	
WL	

Belongia Consultants, Inc.

BORING STARTED			8-8-08
BORING COMPLETED			8-8-08
RIG	CME-55	FOREMAN	KW
APPROVED	DLB	JOB #	1085067

BOREHOLE 85067.GPJ BELONGIA 8/13/08

LOG OF BORING NO. B-2 (Sta 35+00)

CLIENT

ENGINEER
HRAOK, Inc.

SITE
Broken Arrow, Oklahoma

PROJECT
Elm Place Extension

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, in.	SAMPLES SPT - N BLOWS / ft.	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf	
	Approx. Surface Elev.: 774.4 ft										
	6" Topsoil				PA						
	SILT, TRACE CLAY AND GRAVEL dark brown		ML	1	SS	12	15	15.0			
	772.5	2									
	LEAN CLAY, TRACE SAND AND GRAVEL brown and reddish-brown, very stiff		CL	2	SS	12	14	18.4		*4000	S-2 LL=43 PL=21 PI=22
					PA						
	769.5	5									
	LEAN CLAY WITH GRAVEL, TRACE SAND brown and reddish-brown		CL GC	3	SS	14	16	18.4			
					PA						
	765	9.5		4	SS	18	22/6" 50/6"	13.7			
	HIGHLY WEATHERED SHALE, TRACE SANDSTONE olive-brown	10									
	764.5										

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft			
WL	▽ None WD	▼	
WL	▼	▼	
WL			

Belongia Consultants, Inc.

BORING STARTED	8-8-08		
BORING COMPLETED	8-8-08		
RIG	CME-55	FOREMAN	KW
APPROVED	DLB	JOB #	1085067

BOREHOLE 85067.GPJ BELONGIA 8/13/08

LOG OF BORING NO. B-3 (Sta 31+00)

CLIENT

ENGINEER
HRAOK, Inc.

SITE
Broken Arrow, Oklahoma

PROJECT
Elm Place Extension

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, in.	SAMPLES SPT - N BLOWS / ft.	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf	
	Approx. Surface Elev.: 767.3 ft										
	6" Topsoil				PA						
	SILT WITH CLAY, TRACE GRAVEL dark brown		ML	1	SS	18	9	16.7			
	2 765.5										
	SANDY LEAN CLAY brown and reddish-brown		CL SC	2	SS	18	14	17.5			
					PA						
	5.5 762	5	CL	3	SS	14	34	15.3			S-3 LL=34 PL=23 PI=11
	SHALEY LEAN CLAY olive-brown				PA						
	8.5 759										
	HIGHLY WEATHERED SHALE			4	SS	16	40/6" 50/3"	10.8			
	9.3 olive-brown, soft 758										

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	▽ None WD	▼
WL	▼	▼
WL		

Belongia Consultants, Inc.

BORING STARTED	8-8-08		
BORING COMPLETED	8-8-08		
RIG	CME-55	FOREMAN	KW
APPROVED	DLB	JOB #	1085067

BOREHOLE 85067.GPJ BELONGIA 8/13/08

LOG OF BORING NO. B-4 (Sta 27+00)

CLIENT

ENGINEER
HRAOK, Inc.

SITE
Broken Arrow, Oklahoma

PROJECT
Elm Place Extension

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, in.	SAMPLES SPT - N BLOWS / ft.	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf	
	Approx. Surface Elev.: 766.5 ft				PA						
	6" Topsoil SILT, TRACE CLAY dark brown		ML	1	SS	16	5	19.5			
	764.5	2									
	LEAN CLAY, TRACE SAND brown and reddish-brown, stiff		CL	2	SS	12	8	19.6		*3000	S-2 LL=43 PL=21 PI=22
					PA						
	762	4.5									
	LEAN TO FAT CLAY brown, reddish-brown, and gray, stiff	5	CL CH	3	SS	16	12	20.7		*3000	
					PA						
	759	7.5									
	LEAN CLAY WITH SILT brown and olive-brown, very stiff		CL	4	SS	10	16	17.6		*4000	
	756.5	10									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

WATER LEVEL OBSERVATIONS, ft		
WL	▽ None WD	▼
WL	▽	▼
WL		

Belongia Consultants, Inc.

BORING STARTED	8-8-08		
BORING COMPLETED	8-8-08		
RIG	CME-55	FOREMAN	KW
APPROVED	DLB	JOB #	1085067

BOREHOLE 85067.GPJ BELONGIA 8/13/08

GENERAL NOTES

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AB:	After Boring	ACR:	After Casing Removal

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 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	<2	Very Soft
500 – 1,000	2-3	Soft
1,001 – 2,000	4-6	Medium Stiff
2,001 – 4,000	7-12	Stiff
4,001 – 8,000	13-26	Very Stiff
8,000+	26+	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 – 49	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 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm 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
Modifiers	> 12

PLASTICITY DESCRIPTION

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

GENERAL NOTES

Sedimentary Rock Classification

DESCRIPTIVE ROCK CLASSIFICATION:

Sedimentary rocks are composed of cemented clay, silt and sand sized particles. The most common minerals are clay, quartz and calcite. Rock composed primarily of calcite is called limestone; rock of sand size grains is called sandstone, and rock of clay and silt size grains is called mudstone or claystone, siltstone, or shale. Modifiers such as shaly, sandy, dolomitic, calcareous, carbonaceous, etc. are used to describe various constituents. Examples: sandy shale; calcareous sandstone.

LIMESTONE	Light to dark colored, crystalline to fine-grained texture, composed of $CaCo_3$, reacts readily with HCl.
DOLOMITE	Light to dark colored, crystalline to fine-grained texture, composed of $CaMg(CO_3)_2$, harder than limestone, reacts with HCl when powdered.
CHERT	Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz ($Si0_2$), brittle, breaks into angular fragments, will scratch glass.
SHALE	Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The unlaminated equivalent is frequently referred to as siltstone, claystone or mudstone.
SANDSTONE	Usually light colored, coarse to fine texture, composed of cemented sand size grains of quartz, feldspar, etc. Cement usually is silica but may be such minerals as calcite, iron-oxide, or some other carbonate.
CONGLOMERATE	Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (½ inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.

DEGREE OF WEATHERING:

SLIGHT	Slight decomposition of parent material on joints. May be color change.
MODERATE	Some decomposition and color change throughout.
HIGH	Rock highly decomposed, may be extremely broken.

Classification of rock materials has been estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

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 / Liquid limit - not dried	< 0.75	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 lots below "A" line		MH	Elastic Silt[K,L,M]
		organic	Liquid limit - oven dried / Liquid limit - not dried	< 0.75	OH	Organic clay[K,L,M,P] / 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.