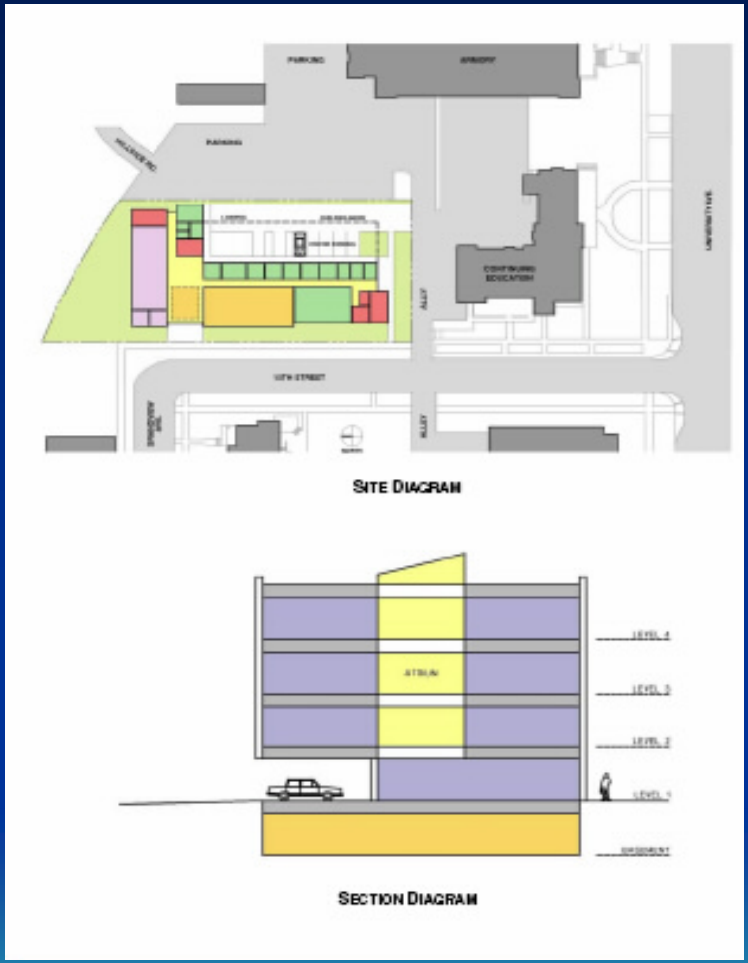
IBS Building
Geotechnical Investigation Considerations



Bob Scavuzzo, P.E.
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Geotechnical Consultant

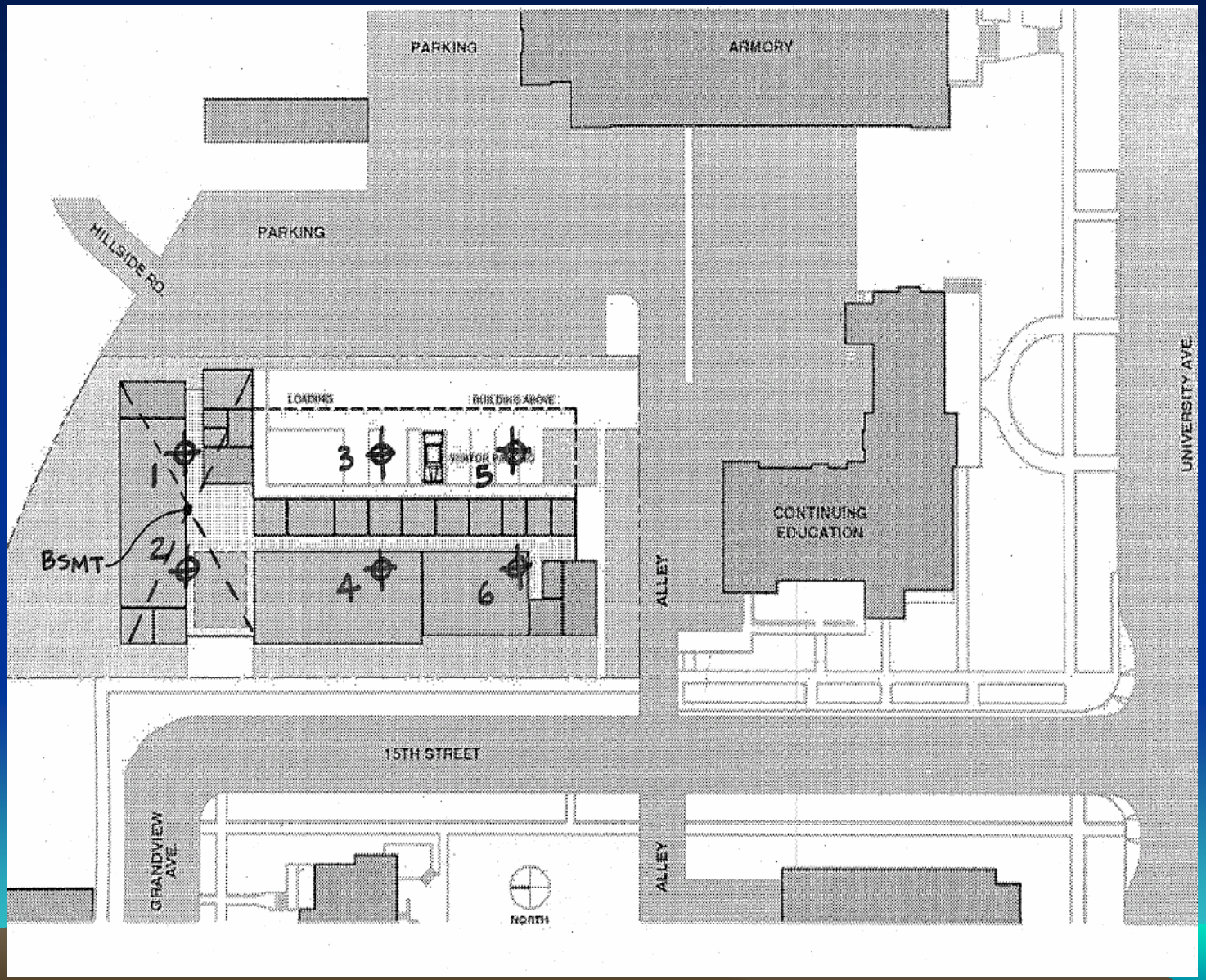
Audience/Role:

- Owner/Developer
- Structural Engineer
- Civil Engineer
- Architect
- Contractor
- Peers
- Lawyers

Considerations

- How Many Holes to Drill?
  - Building Size
  - Location
- Rule of Thumb/Standard of Care:
  - 100 foot spacing of borings

IBS Building Site Plan

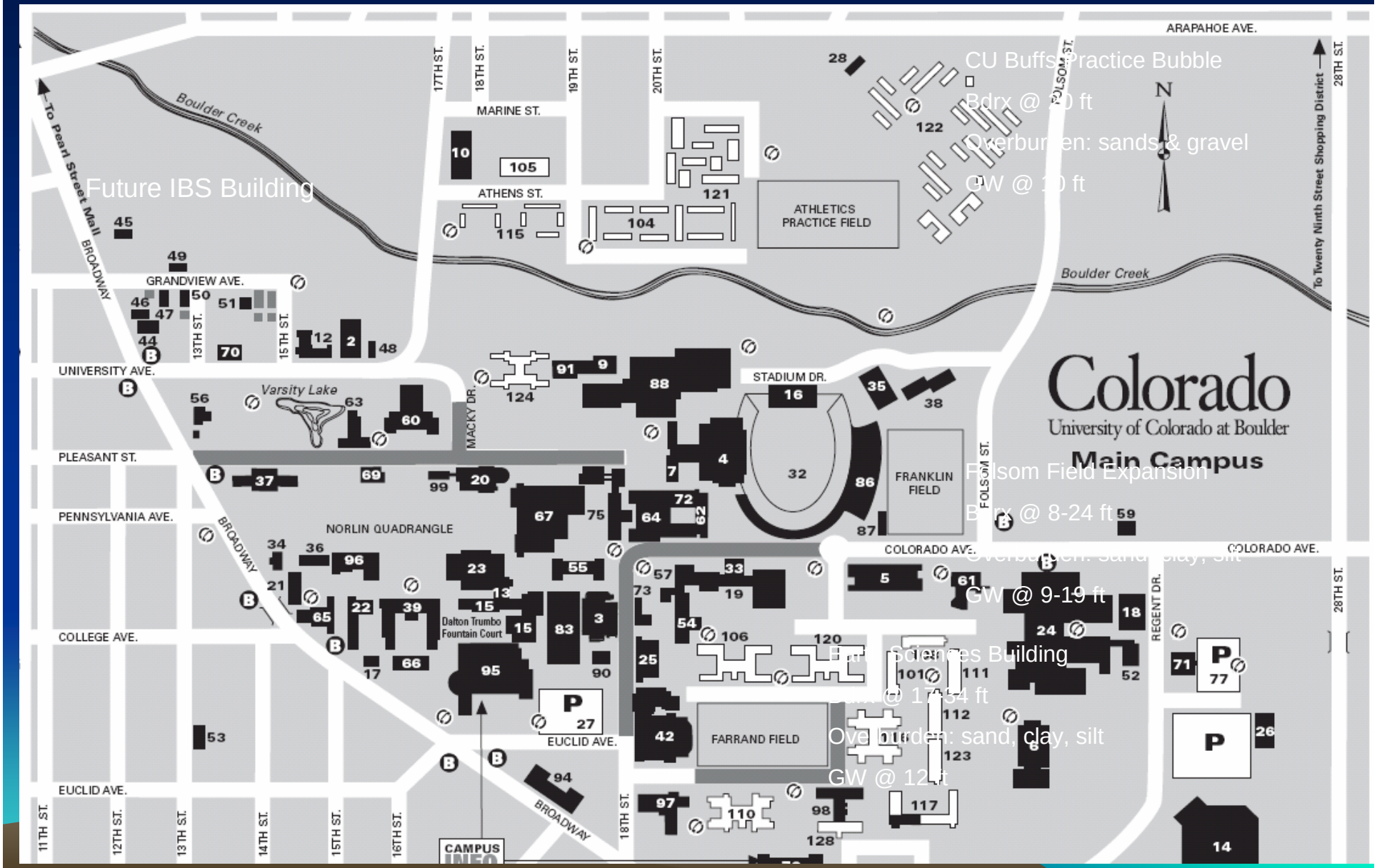


- 4 Story Building
- Partial Basement
- Footprint: 160 ft x 65 ft

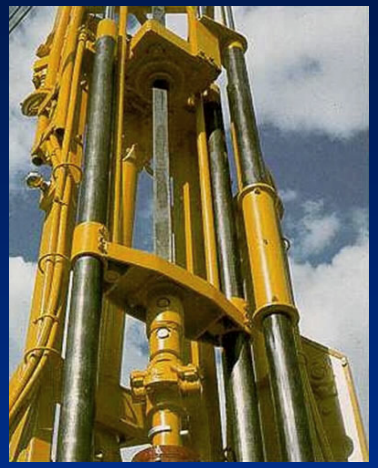
How Deep?

- Anticipated Foundation System
  - Piers, Footings, P-T Slab
- Depth to Bedrock
- Column Loads:
  - DL: 450 kips Max: 900 kips

Previous CU Campus Investigations



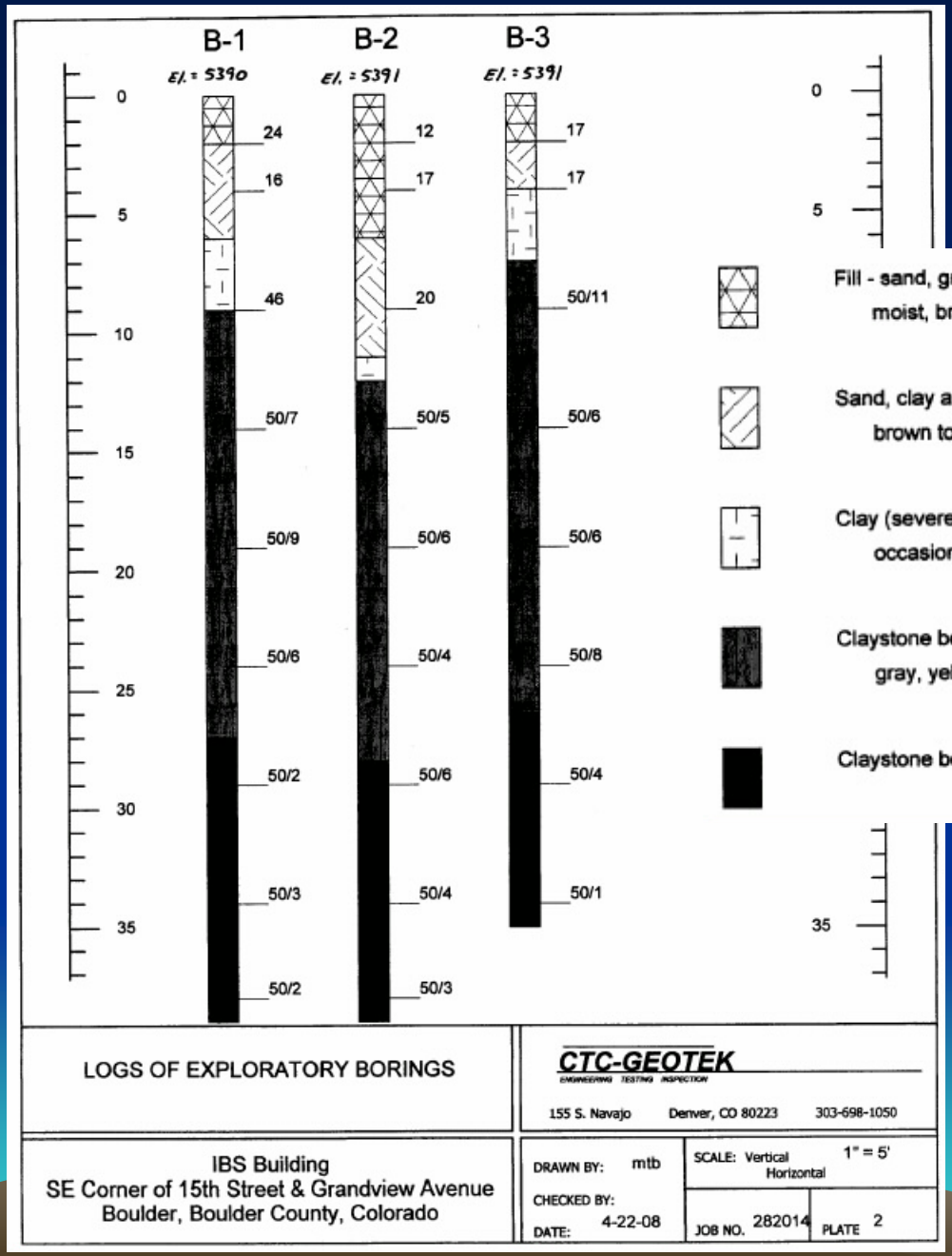
Drilling and Sampling



Drilling and Sampling

- Sampling Frequency:
  - 2, 4, 9, (3 samples in top 10 feet)
  - 5 feet intervals thereafter
- 140 lb hammer falling 30 inches (ASTM D1586)
- Number of hammer blows to drive sampler 1 foot or fraction

Boring Logs


B-1
El. = 5390
B-2
El. = 5391
B-3
El. = 5391
0
5
10
15
20
25
30
35
24
16
46
50/7
50/9
50/6
50/2
50/3
50/2
12
17
20
50/5
50/6
50/4
50/6
50/4
50/3
17
17
50/11
50/6
50/6
50/8
50/4
50/1
Fill - sand, gravel, clay and silt, various mixtures, moderately compact to compact, medium moist to moist, brown, red-brown
Sand, clay and silt, various mxtures and layers, occasionally gravelly, medium moist to moist, brown to brownish red
Clay (severely weathered claystone), silty, very stiff, medium moist to moist, brown to dark brown, occasionally calcareous
Claystone bedrock, weathered, silty, medium hard to very hard, medium moist, gray, yellow-brown, brown
Claystone bedrock (shale), silty, occasionally sandy, very hard, medium moist, gray, gray-blue, black
LOGS OF EXPLORATORY BORINGS
CTC-GEOTEK
ENGINEERING TESTING INSPECTION
155 S. Navajo Denver, CO 80223 303-698-1050
IBS Building
SE Corner of 15th Street & Grandview Avenue
Boulder, Boulder County, Colorado
DRAWN BY: mtb
CHECKED BY:
DATE: 4-22-08
SCALE: Vertical 1" = 5'
Horizontal
JOB NO. 282014
PLATE 2

Laboratory Testing

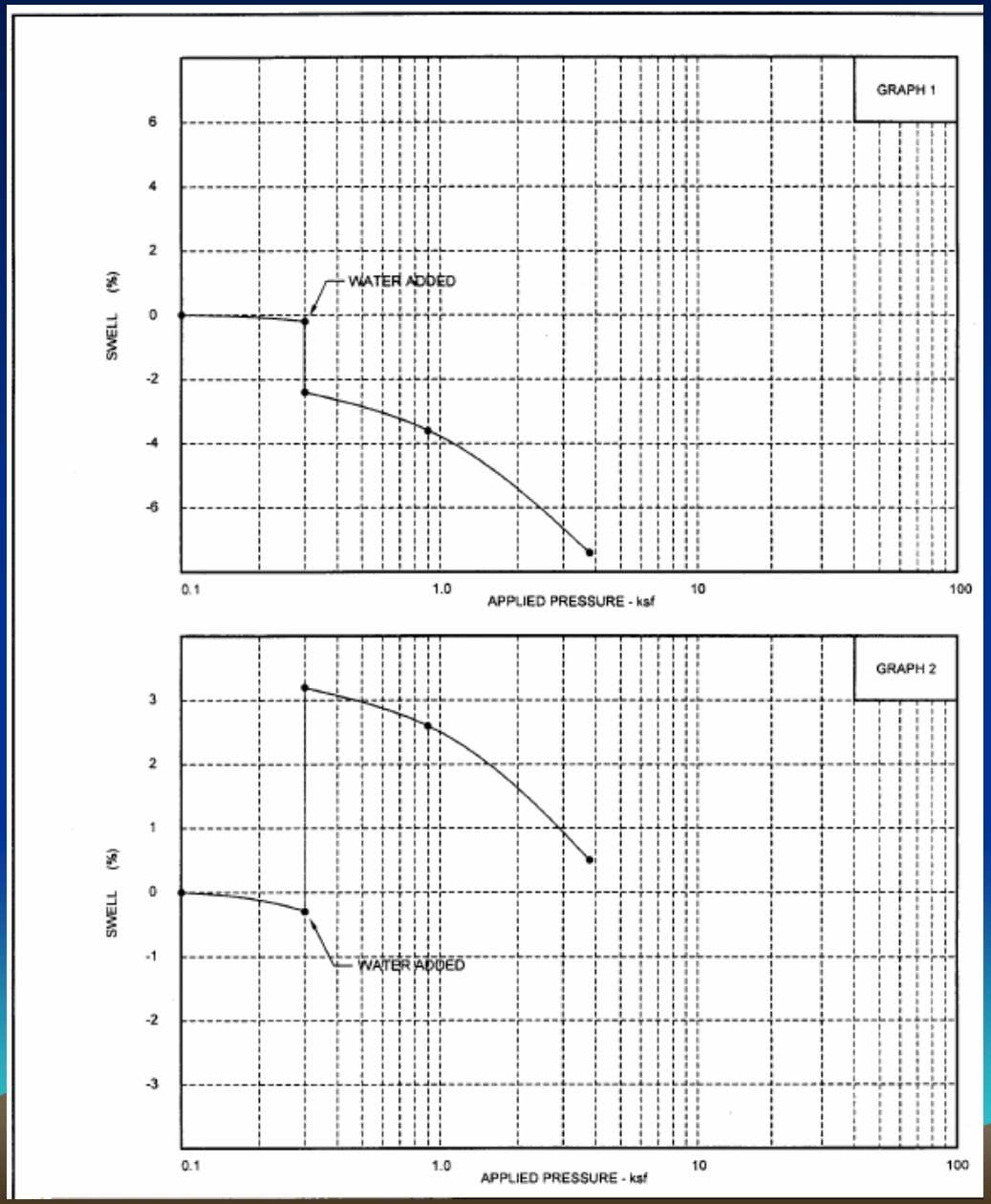
CTC-GEOTEK
ENGINEERING TESTING INSPECTION

SUMMARY OF LABORATORY TEST RESULTS

Project No. 282014

BORING NO.	SAMPLE NO.	DEPTH IN FEET	SAMPLE TYPE (NOTE 1)	DRY DENSITY (PCF)	MOISTURE (%)	ATTERBERG LIMITS			% FINES	WATER SOLUBLE SULFATES (%)	SHEAR STRENGTH (PSF) (NOTE 2)	ADDITIONAL TEST RESULTS ATTACHED (NOTE 3)		SOIL DESCRIPTION
						LL	PI	PL						
B1		4	CA	77.8	11.6							SW		Silty Clay, and sand, trace gravel
B1		9	CA	114.5	13.3							SW		Claystone
B2		2	CA	88.9	14.8	45	22	23	37.2					Sand, and silty clay, trace gravel A-7-6(3) SC
B2		14	CA	96.5	11.4							SW		Claystone
B3		4	CA	102.1	19.0					.004		SW		Claystone
B4		9	CA	120.6	14.1					.005		SW		Claystone
B6		2	CA	106.3	16.7							SW		Silty Clay, and sand, trace gravel
B6		9	CA	112.6	17.9	49	33	16	97.2					Claystone A-7-6(34) CL

Laboratory Testing



Swell/Consolidation Results

Laboratory Testing

Water Soluble Sulfates
ACI Specifications

Table 2.3—Requirements to protect against damage to concrete by sulfate attack from external sources of sulfate

Severity of potential exposure	Water-soluble soluble sulfate (SO_4)*	Sulfate (SO_4)* in water, ppm	w/cm by mass, max.†‡	Cementitious material requirements
Class 0 exposure	0.00 to 0.10	0 to 150	No special requirements for sulfate resistance	No special requirements for sulfate resistance
Class 1 exposure	> 0.10 and < 0.20	> 150 and < 1500	0.50‡	C 150 Type II or equivalent§
Class 2 exposure	0.20 to < 2.0	1500 to < 10,000	0.45‡	C 150 Type V or equivalent§
Class 3 exposure	2.0 or greater	10,000 or greater	0.40‡	C 150 Type V plus pozzolan or slag§
Seawater exposure	—	—	See Section 2.4	See Section 2.4

*Sulfate expressed as SO_4 is related to sulfate expressed as SO_3, as given in reports of chemical analysis of portland cements as follows: $SO_3\% \times 1.2 = SO_4\%$.

†ACI 318, Chapter 4, includes requirements for special exposure conditions such as steel-reinforced concrete that may be exposed to chlorides. For concrete likely to be subjected to these exposure conditions, the maximum w/cm should be that specified in ACI 318, Chapter 4, if it is lower than that stated in Table 2.3.

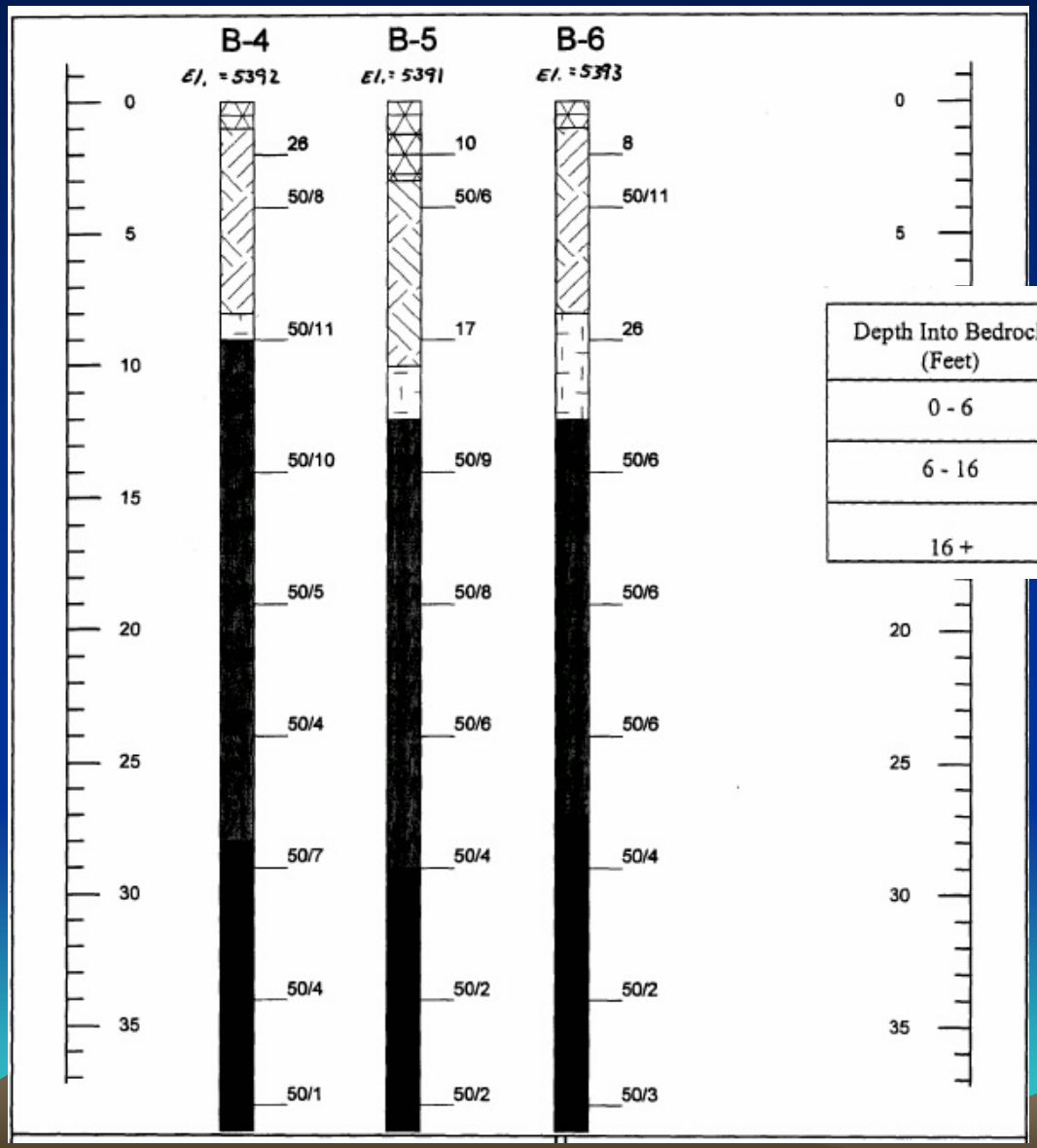
‡These values are applicable to normalweight concrete. They are also applicable to structural lightweight concrete except that the maximum w/cm ratios 0.50, 0.45, and 0.40 should be replaced by specified 28 day compressive strengths of 26, 29, and 33 MPa (3750, 4250, and 4750 psi) respectively.

§For Class 1 exposure, equivalents are described in Sections 2.2.5, 2.2.6, and 2.2.9. For Class 2 exposure, equivalents are described in Sections 2.2.5, 2.2.7, and 2.2.9. For Class 3 exposure, pozzolan and slag recommendations are described in Sections 2.2.5, 2.2.8, and 2.2.9.

Foundation Recommendations

- Drilled Piers
  - 18 foot minimum length
  - 6 foot minimum bedrock penetration
- Ensure pier bottom is in zone of stable moisture content

Pier Design Values

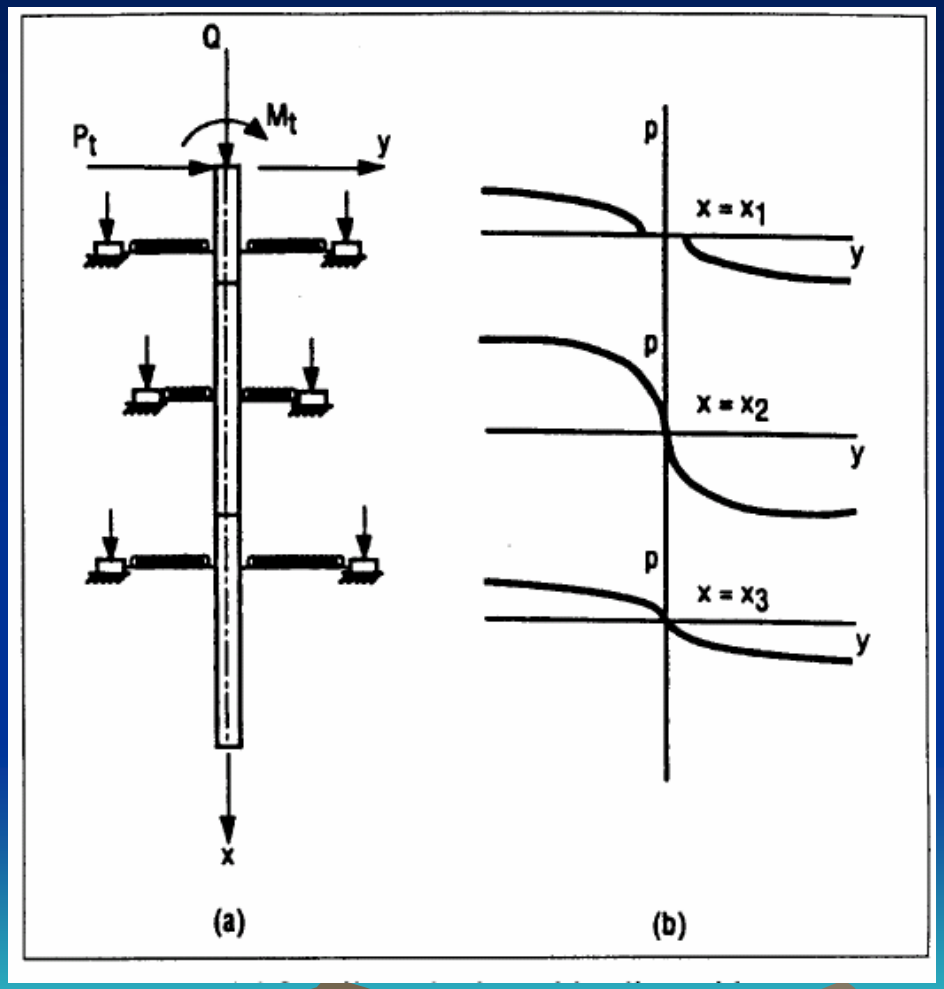


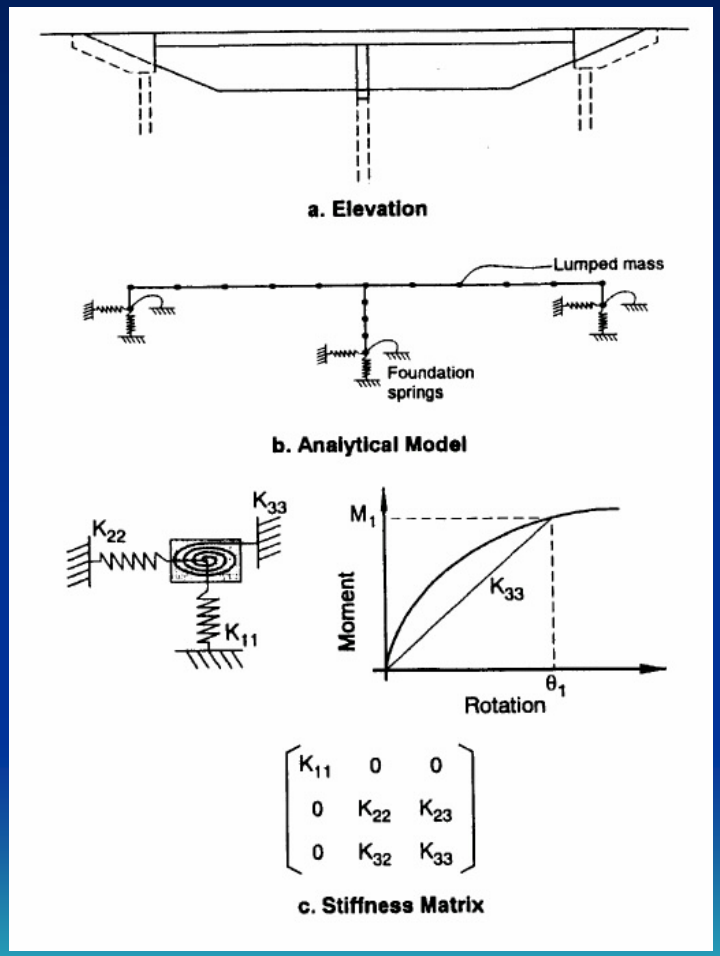
Depth Into Bedrock (Feet)	End Bearing Pressure (PSF)	Compressive Side Shear (PSF)
0 - 6	35,000	2,500
6 - 16	35,000	4,000
16 +	50,000	5,000

Pier Design Values

- Minimum Pier Diameter
- L/D Ratio
- Design Pressure Reductions (Group Action)

L-Pile Parameters





Seismic Survey

2006 IBC

(2004 Denver Amendment)

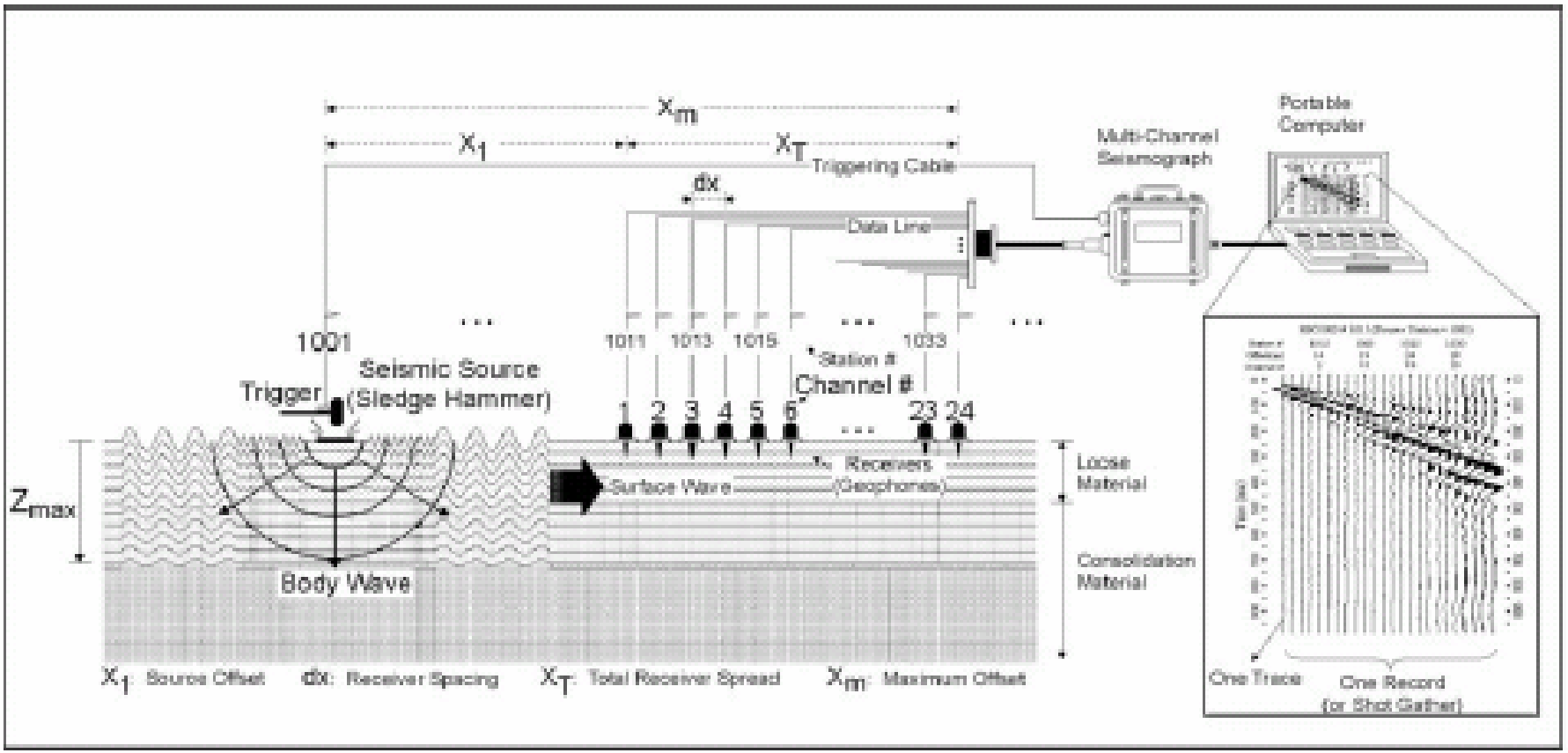
TABLE 1613.5.2
SITE CLASS DEFINITIONS

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, SEE SECTION 1613.5.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_s \leq 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \leq 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \geq 2{,}000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1{,}200$	$15 \leq \bar{N} \leq 50$	$1{,}000 \leq \bar{s}_u \leq 2{,}000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays (H > 10 feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays (H >25 feet with plasticity index PI >75) 4. Very thick soft/medium stiff clays (H >120 feet)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2, 1 pound per square foot = 0.0479 kPa. N/A = Not applicable

Seismic Survey

Test Schematic

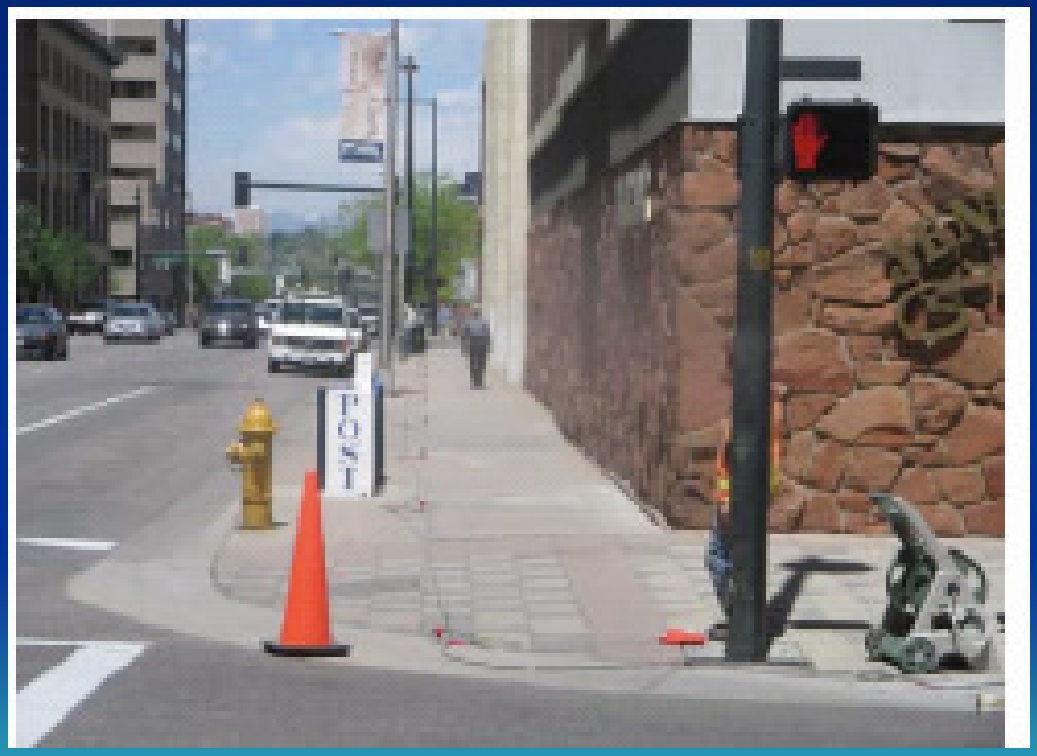


Seismic Survey

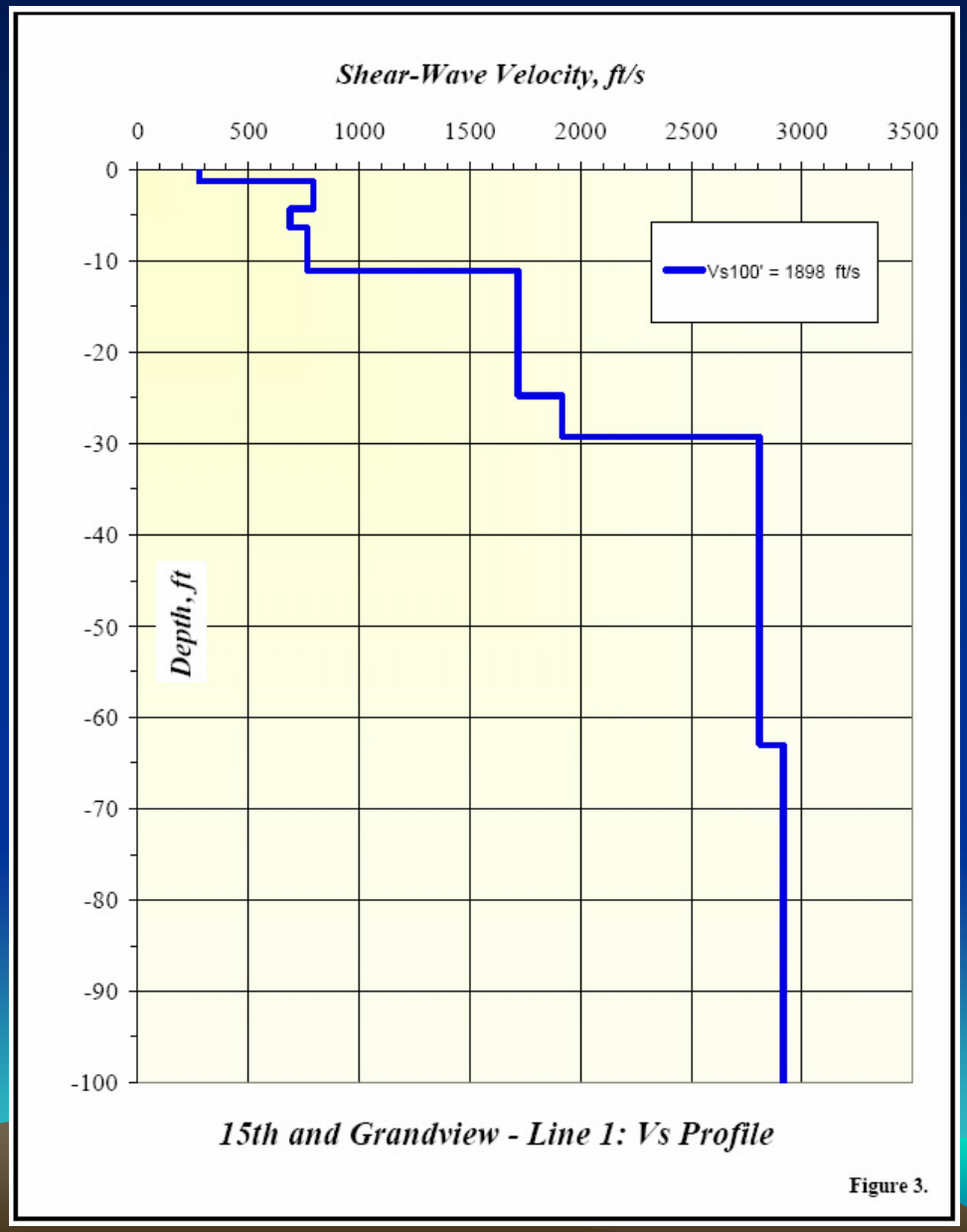
100 foot long lines, 100 foot deep analysis

Seismic Survey

Field Investigation



Seismic Survey



Lateral Earth Pressure

- Foundation Walls
- Retaining Walls

Classification	Friction Angle ϕ (deg.)	Density or Consistency	Unit Soil Weight, γ (lb./cu. ft.)	Unit Wt. of Equivalent Fluid, γ'_w (lb./cu. ft.)	
				Active Case	Passive Case
Coarse sand or sand and gravel	45	Compact	140	24	820
	38	Firm	120	29	510
	32	Loose	90	28	290
Medium sand	40	Compact	130	28	600
	34	Firm	110	31	390
	30	Loose	90	30	270
Fine sand	34	Compact	130	37	460
	30	Firm	100	33	300
	28	Loose	85	31	280
Fine, silty sand or sandy silt	32	Compact	130	40	420
	30	Firm	100	33	300
	28	Loose	85	31	280
Fine, uniform silt	30	Compact	135	45	400
	28	Firm	110	38	300
	26	Loose	85	33	220
Clay-silt	20	Medium	120	59	245
		Soft	90	44	183
Silty clay	15	Medium	120	71	204
		Soft	90	53	153
Clay	10	Medium	120	84	170
		Soft	90	63	153
Clay	0	Medium	120	120	120
		Soft	90	90	90

Structural Plan Specifications

SECTION 2 - FOUNDATIONS

1. **DESIGN CRITERIA:**

1A. THE GEOTECHNICAL REPORT PREPARED BY CTC-GEOTEK, INC, NUMBER 282014, DATED MAY 12, 2008, PROVIDED CRITERIA FOR THE FOUNDATION DESIGN FOR THE PROJECT.

2. **DRILLED PIERS:**

2A. PIER CAPACITY CRITERIA:

- MAXIMUM END BEARING PRESSURE (0-16 FEET OF PEN) = 35,000 PSF
- MAXIMUM END BEARING PRESSURE (OVER 16 FEET OF PEN) = 50,000 PSF
- MAXIMUM SIDE SHEAR FOR LENGTH OF PENETRATION INTO BEDROCK FOR GRAVITY LOADS:
  - (0-6 FEET OF PEN) = 2,500 PSF
  - (6-16 FEET OF PEN) = 4,000 PSF
  - (OVER 16 FEET OF PEN) = 5,000 PSF
- MAXIMUM SIDE SHEAR FOR LENGTH OF PENETRATION INTO BEDROCK FOR UPLIFT LOADS:
  - (0-6 FEET OF PEN) = 1,500 PSF
  - (6-16 FEET OF PEN) = 2,400 PSF
  - (OVER 16 FEET OF PEN) = 3,000 PSF
- MINIMUM DEAD LOAD END BEARING PRESSURE MAINTAINED = 20,000 PSF
- WHERE MINIMUM DEAD LOAD PRESSURES WERE NOT OBTAINED, PIER LENGTHS WERE EXTENDED BEYOND THE MINIMUM PENETRATION USING 60 PERCENT OF THE SIDE SHEAR TO MAKE UP THE DEAD LOAD DEFICIT.
- SEE 'DRILLED PIERS TABLE'.

3. **FOUNDATION WALLS:**

3A. EQUIVALENT FLUID PRESSURES USED FOR WALL DESIGN:

- "AT REST" CONDITION = 60 PCF
- "PASSIVE" CONDITION = 280 PCF
- LATERAL PRESSURE DUE TO SURCHARGE = 100 PSF

3B. WALL DESIGN BASED ON ON-SITE BACKFILL ADJACENT TO FOUNDATION WALLS. SEE GEOTECHNICAL REPORT FOR REQUIREMENTS.

4. **RETAINING WALLS:**

4A. EQUIVALENT FLUID PRESSURES USED FOR WALL DESIGN:

- "ACTIVE" CONDITION = 45 PCF
- "PASSIVE" CONDITION = 280 PCF
- LATERAL PRESSURE DUE TO SURCHARGE = 100 PSF
- MAXIMUM FOOTING TOTAL LOAD SOIL BEARING PRESSURE = 2,500 PSF
- ULTIMATE COEFFICIENT OF FRICTION USED IN DESIGN TO RESIST LATERAL LOADS = 0.50.

4B. WALL DESIGN BASED ON ON-SITE BACKFILL ADJACENT TO FOUNDATION WALLS. SEE GEOTECHNICAL REPORT FOR REQUIREMENTS.

5. **VOID FORM:**

5A. ALL GRADE BEAMS, TIE BEAMS, PIER CAPS, SHALL BE CONSTRUCTED OVER A 4 INCH HIGH VOID.

Concluding Remarks

QUESTIONS?