EDWARD S. BARBER
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December 31, 1962

Department of the Interior
National Park Service
National Capital Parks
Washington 25, D. C.

Re: Order No. 28-987
Subsoil Study at the
Washington Monument
Grounds

Gentlemen:

In accordance with the above order, dated December 19, 1961, attached is my report on loading limitations at the Washington Monument Grounds. Also included are test results on undisturbed soil samples.

Very truly yours,

Edward S Barber

Edward S. Barber

ESB:j

LOADING LIMITATIONS
WASHINGTON MONUMENT GROUNDS
WASHINGTON, D. C.
SUBSOIL STUDY

FOR: NATIONAL PARK SERVICE
BY : EDWARD S. BARBER, C.E. December 31, 1962

In 1962 a subsurface soil study was undertaken on the Washington Monument Grounds to determine safe limitations on grading or new construction.

PREVIOUS DATA

A thorough study was made of library and National Archives records to supplement the almost complete record in "Improvement of the Washington Monument Grounds" (1).

Seven borings made in 1930 (2) and eight made in 1931 (3) showed stratification with no direct measure of soil strength or compressibility.

NEW BORINGS

For this study, nine borings were made with standard penetration. Undisturbed samples were taken of silts or clays, but undisturbed samples of sand could not be recovered.

Four of the new borings were taken at each corner of the Monument foundation; the five others extend the total area previously covered by borings. The boring locations are shown in Figure 1 and the logs are shown in Figure 2. The stratification agrees with that shown for the 1930-31 borings (4). In order to get a three-dimensional picture of the stratification, I made a model with painted pegs showing the logs to scale.

The Monument rests on about 35 feet of generally dense sand-gravel which is underlain by 30 feet of stiff clay over rock except that the clay is partly replaced by medium-dense fine sand at the Southeast corner and almost completely replaced at the Southwest corner.

LABORATORY TESTS

Test results on 36 undisturbed soil samples, taken in 3-inch outside-diameter shelby tubes, are shown in Tables 1 through 8.

The stiff clay has an unconfined compressive strength of 3 to 7 kips per square foot with a sensitivity of 3. Samples show a preconsolidation pressure of 8 to 10 kips per square foot both near the Monument and at considerable distance. The preconsolidation is probably due to drainage when sea level was much lower.

Most consolidation test samples were trimmed to 1.75-inch diameter by 0.5-inch height. Ten duplicate samples were also trimmed to 2.5-inch diameter and 1.0-inch height. Some of these samples indicated somewhat higher preconsolidation pressure than the smaller samples.

SETTLEMENT CALCULATIONS

Settlement, before underpinning was started in 1879, is uncertain; a tilt of 1.75 inches to the North was corrected during underpinning and settlement has been almost vertical since then. Loads and settlement are shown in reference (5)--

4.6 inches settlement during underpinning and completion of the Monument and 1.4 inch settlement since. Some variations can be attributed to a gradual 5-inch rise in sea level, several inches settlement of the obelisk bench mark used for reference, and uncertainties of 0.1 inch or more in check-leveling of the bench mark.

Before 1879, the ground surface (6) was at Elevation 26. (It is now 41) The water table has apparently been nearly constant at about Elevation 4. Using soil densities of 120 pounds per cubic foot from El. 26 to El. 4, 60 pounds per cubic foot from El. 4 to El. -30, and 50 pounds per cubic foot from El.-30 to El.-45, gives a soil pressure of 5.4 kips per square foot at the center of the clay layer. The 63,000 kip Monument, on an 80×80 foot footing, gives 9.85 kips per square foot gross or 8.9 kips per square foot net pressure at its base at El. 18. At El.-45 this gives an average increase of $8.9(80/143)^2 = 2.8$ kips per square foot or a total of 8.2 kips per square foot.

Since completion of the Monument, the soil pressure is 7.2 kips per square foot; the gross Monument pressure on its 126.5×126.5-foot footing is $162{,}000 \div 126.5^2 = 10.1$ kips per square foot; the net average pressure at El. 5 at the base of the new foundation becomes 5.8 kips per square foot; and the stress from the Monument at El.-45 is $5.8(126.5/176.5)^2 = 3.0$ kips per square foot; giving a total pressure in the clay of 10.2 kips per square foot.

The virgin compressibility of the clay is 8% for doubling the load or 1.44% per kip per square foot at 8 kips per square foot. For a load increase from 8.2 to 10.2 kips per square foot this gives 2.88%; for a 30-foot layer this gives a settlement of 0.0288(360) = 10.4 inches. The actual settlement is much less because the clay is preconsolidated, possibly beyond 10.2 kips per square foot. The total stress in the clay at the borings by the Monument is only 8 kips per square foot, so that the observed prestress of 10 kips per square foot is not due to the Monument load. Virgin consolidation may apply to any load added now.

For reloading, the compression is 1% for doubling the load (4-8 kips per square foot) or 0.18% per kip per square foot at 8 kips per square foot. This gives a settlement of 0.0036(360) = 1.3 inches. Using a coefficient of consolidation of 0.3 feet squared per day and a thickness of 30 feet with two drainage faces, the time for 90% consolidation is calculated as 630 days which is consistent with the time settlement record. Since the thickness of the clay is not uniform, this would cause some tilting unless the sand has a compressibility similar to the clay. The sand, with a penetration of 20-25 blows, has a relative density of about 50 for which Hough (7) gives a compressibility similar to that for the reloaded clay.

Some of the settlement is due to temporary increase in footing pressures during underpinning. The rest of the 4.6-inch settlement at the time of completing the Monument is probably due to compression of the sand-gravel.

PROGRESSIVE SETTLEMENT

The progressive settlement of 1.4 inch since 1886 has occurred at an almost uniform rate.

Secondary consolidation was measured under a load of 8 kips per square foot as 0.3% per log cycle (1-10 days). For a 360-inch thickness and 1.6 log cycles (2-80 years) this gives 0.0048(360) = 1.7 inches, which is the right order of magnitude but would not be linear and would involve tilting. The laboratory consolidation may be much less after one year.

The load differential of 3 kips per square foot from the Monument produces a shear stress in the clay of about 3÷5 = 0.6 kips per square foot. Housel (8) has measured creep in clays under buildings when the stresses exceed one-fourth the quick shear strength. For an average compressive strength of 5 kips per square foot, this yield strength is 5÷8 = 0.62 kips per square foot. Lack of tilting indicates that creep has not been significant; however, extensive unloading close to the Monument could permit creep of the clay and accelerate settlement of the structure.

The progressive settlement is probably due to further compression of the sand and gravel. This could be caused by repetitive loading such as results from vibrations or moment

from wind loading (9, 10). A wind load of 50 pounds per square foot causes an increase in pressure of 1 kip per square foot at the edge of the footing. The wind rose is fairly well balanced. Granular materials with a relative density less than 70 are considered compactable by vibration. The relative density of the sand is 50 and that of the gravel is uncertain--penetration resistance was generally high, but some loose areas are indicated.

LOADING LIMITATIONS

Added Load

Consider a displacement of 0.1 inch at the top of the Monument as permissible. This is equivalent to a settlement of one edge of the foundation of 0.023 inch. For virgin consolidation of the clay, this corresponds to a pressure increase of 5.6 pounds per square foot in a 30-foot thickness. Using Boussinesq's formula for stress distribution from a surface at El. 30 to a depth of El.-45, the allowable load is a function of the radial distance. The allowable loads in terms of fill weighing 120 pounds per cubic foot are:

Radial distance, feet	150	250	350	450	550
Length of fill 10 feet high by 100 feet wide, feet	5	80	600	2000	5000

Reduced Load

It is important that lateral support of the foundation material should not be appreciably reduced. Consider a passive resistance wedge starting at the rock below the edge of the foundation: at a slope of 2:1 it would intersect the surface at about 250 feet from the center of the Monument. This area should not be unloaded.

Using a safe angle of repose (with seepage) of 3:1 beyond this area, the minimum cut elevation reduces to El. 5 at a radial distance of 350 feet or less. The corresponding shear stress for horizontal creep in the clay is 0.54 kips per square foot which is a little less than the shear stress close to the Monument.

Pile Driving

The effect of pile driving is uncertain. Vibration tests (11) 5 feet from a pile being driven at the new Museum at 14th Street and Constitution Avenue showed no effect damaging to an ordinary structure. However, there are other records of settlement several hundred feet from pile driving which caused compaction of sand.

Pile driving would probably be harmless 250 feet from the Monument, but should be used only if necessary. Non-displacement piles are preferable. If piles are driven on the Monument Grounds, I recommend making careful concurrent observations of settlement and vibration of the Monument. Provision should be made for preboring, if found necessary.

SIMPLIFIED LIMITATIONS

Assuming there is no need for filling above El. 25, except locally, or cutting below El. 5, the above criteria of loading limitation can be simplified as shown in Figure 3 and the following table.

Radial Distance, feet	Loading Limitation
0 to 250	No change
Beyond 250	Fill to El. 25
250 to 350	Cut 3:1 slope
Beyond 350	Cut to El. 5

For pile driving -- observe movements

REFERENCES

(1) "Improvement of the Washington Monument Grounds", 72nd Congress, 2nd Session, House Document No. 528, GPO 1934.

(2) "Log of Borings, 1930", NPS Drawing No. 44-71.

(3) "Log of Borings, 1931", NPS Drawing No. 44-72.

(4) "Sections, 1931", NPS Drawing No. 44-112.

(5) "Loads and Settlement", NPS Drawing No. 44-115.

(6) "Plans and Section, 1881", NPS Drawing No. 74.8-2.

(7) "Basic Soils Engineering", by B. K. Hough, Ronald Press, 1957

(8) "Dynamic and Static Resistance of Cohesive Soil--1846 to 1958", by W. S. Housel, ASTM Special Technical Publication No. 254, 1959.

(9) "Vibration Observations in the Washington Monument", by Frank Neuman, Journal Washington Academy of Sciences, 23(3)158, 1933.

(10) "The Washingtoh Monument", by J. J. Creskoff, Journal Franklin Institute, Nov. 1934, page 533.

(11) "Transmission Coefficients for Ground Vibration Due to Blasting", by F. J. Crandell, Journal Boston Society of Civil Engineers, April 1960, page 152.

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SOIL MECHANICS AND FOUNDATIONS

SOIL TEST RESULTS

Table 1

Date Nov. 30, 1962

National Park Service
Samples from Washington Monument Grounds

Boring No.	22	22	22	22	22	23
Sample No.	18	19	21	23	27	17
Depth, feet	74	78	84	89	101	68
Liquid Limit			59			
Plastic Limit			37			
Plasticity Index			22			
Initial Density, lb/cu.ft.	122	120	107	108	108	126
Initial Moisture, % dry wt.	29	33	46	47	44	25
Weight loss, 110C to 300C, %			5.6			
COMPRESSION TEST						
Lateral pressure, kips/sq.ft.	0	0	0	0	0	0
Reduction in height at failure, %	5	6	5	8	5	12
Max. stress difference, kips/sq.ft.	4.00	3.61	3.48	6.52	7.20	2.86
DIRECT SHEAR TEST, CONSOLIDATED						
Normal stress, kips/sq.ft.			32			
Thickness reduction before shear, %			20.2			
Maximum shear stress, kips/sq.ft.			10.6			
CONSOLIDATION TEST						
Coeff. of permeability, ft. per day						
Corresponding pressure, kips/sq.ft.	16, 32	16	16, 32	8, 16	8, 16	8, 1
Coeff. of consolidation, ft. sq/day	0.1, 0.1	0.3	0.2, 0.1	2, .3	2, .1	1, .
Cumulative % reduction in thickness for following loads:						
0.04 kips per sq. ft.	0	0	0	0	0	0
0.5	0.30	0.36	0.44	0.52	0.30	0.28
1	0.46	0.74	0.84	0.56	0.48	0.56
2	0.88	1.64	1.84	1.00	0.78	1.14
4	1.88	3.50	3.50	1.84	1.42	2.06
8 Inundated	3.60	6.66	6.26	3.20	2.48	3.78
4	3.38	6.42	5.68		2.06	3.50
2	2.94	5.98	4.74		1.54	3.10
1	2.40	5.42	3.80		1.10	2.72
.5	1.88	4.86	2.72		0.44	2.12
1	2.04	4.94	3.00		0.64	2.24
2	2.44	5.34	3.78		1.02	2.60
4	3.04	6.04	5.04		1.62	3.16
8	4.04	7.08	6.78		2.72	4.18
16	7.88	11.52	10.84	6.94	5.56	8.20
32	14.38		20.20	16.16	15.58	16.10
SIEVE ANALYSIS						
% Passing Sieve						
No. 10			100			
20			99.8			
40			99.5			
100			94			
200			78			
.05			70			
.02			48			
.005			24			
.002			14			
.001			9			

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Date December 1, 196

For National Park Service
Samples from Washington Monument Grounds

Boring No.	23	23	23	23	23	23
Sample No.	18	20	22	24	26	28
Depth, feet	73	78	82	88	92	97
Liquid Limit		47				73
Plastic Limit		22				35
Plasticity Index		25				38
Initial Density, lb/cu.ft.	123	120	108	108	107	107
Initial Moisture, % dry wt.	26	32	44	48	44	49
Weight Loss, 110 C to 300 C,%		1.4			17.4*	5.5
COMPRESSION TEST						
Lateral pressure, kips/sq.ft.	0	0	0	0	0	0
Reduction in height at failure, %	10	6	6	7	8	6
Max. stress difference, kips/sq.ft.	2.94	4.70	5.92	5.80	4.57	4.5
DIRECT SHEAR TEST, CONSOLIDATED						
Normal stress, kips/sq.ft.		32				
Thickness reduction before shear, %		19.4				
Maximum shear stress, kips/sq.ft.		9.37				
CONSOLIDATION TEST						
Coeff. of permeability, ft. per day						
Corresponding pressure, kips/sq.ft.	8, 16	8, 16	8, 16	8, 16	8, 16	8,
Coeff. of consolidation, ft. sq/day	1, .2	1, .2	1.5, .3	2, .5	1, .3	1.2
Cumulative % reduction in thickness for following loads:						
0.04 kips per sq. ft.	0	0	0	0	0	0
0.5	0.30	0.74	0.30	0.54	0.44	0.4
1	0.58	1.04	0.68	0.74	0.58	0.5
2	1.14	1.54	1.16	1.06	1.00	1.1
4	2.30	3.06	2.10	1.88	1.98	2.1
8 Inundated	3.70	6.46	3.68	3.30	3.36	3.4
4		5.96	3.18			2.9
2		5.22	2.62			2.4
1		4.46	2.00			1.8
.5		3.54	1.38			1.1
1		3.70	1.50			2.1
2		4:36	2.04			2.4
4		5.34	2.78			3.1
8		6.96	3.74			4.4
16	6.70	11.28	7.00	6.34	6.18	8.6
32	13.18	19.44	15.46			17.8
Secondary consol. 1-10 days,%		0.3				
SIEVE ANALYSIS						
% Passing Sieve						
No. 10		--				100
20		100				99
40		99.8				99
100		99.3				95
200		95				90
.05		91				85
.02		69				69
.005		41				31
.002		25				14
.001		17				9

*More organic part of sample TESTED tested

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SOIL MECHANICS AND FOUNDATIONS

SOIL TEST RESULTS

Table 3

Date Dec. 1, [illegible]2

For: National Park Service
Samples from Washington Monument Grounds

Boring No.	24	24	24	24	25	25
Sample No.	16	18	20	22	5	25
Depth, feet	83	88	95	99	15	104
Liquid Limit			65			83
Plastic Limit			32			36
Plasticity Index			33			47
Initial Density, lb/cu.ft.	102	90	108	108	123	105
Initial Moisture, % dry wt.	55	75	42	43	18	Re-50
Weight loss, 100 C to 300 C, %		19.4*	4.9		0.6	mo-5.9
COMPRESSION TEST						Oeo
Lateral pressure, kips/sq.ft.	0		0	0	0	0 0
Reduction in height at failure, %	5		6	6	8	15 9
Max. stress difference, kips/sq.ft.	3.57		4.07	5.66	1.07	125 3.27
DIRECT SHEAR TEST, CONSOLIDATED						
Normal stress, kips/sq.ft.		32	32			32
Thickness reduction before shear, %		18.7	13.6			24.1
Maximum shear stress, kips/sq.ft.		13.9	12.1			10.4
CONSOLIDATION TEST						
Coeff. of permeability, ft. per day						
Corresponding pressure, kips/sq.ft.	8, 16	8,16	8, 16	16	8	8, 1
Coeff. of consolidation, ft. sq/day	.3, .15	2, .5	1.5, .4	0.5	2+	1,
Cumulative % reduction in thickness for following loads:						
0.04 kips per sq. ft.	0	0	0	0	0	0
0.5	0.84	0.74	0.26	0.58	0.80	0.6
1	1.26	1.12	0.36	0.88	1.00	1.06
2	1.80	1.86	0.70	1.52	I 1.58	1.90
4	2.76	2.88	1.60	3.04		3.26
8 I = inundated	I 5.54	I 4.70	I 3.46	I 6.04		5.82
16 4	4.52	4.14	3.04	5.70		6.22
2	3.72	3.54	2.60	5.24		5.20
1	2.88	2.96	2.20	4.74	1.22	4.30
.5	1.92	2.46	1.70	4.20	1.14	3.38
1	--	2.74	1.94	4.36	1.24	3.60
2	2.80	3.14	2.32	4.74		4.24
4	3.96	3.86	2.78	5.38	2.66	5.38
8	5.72	4.98	3.70	6.46	3.22	7.26
16	12.16	9.10	7.22	10.44	5.60	12.92
32	21.48	18.74	13.62	16.60		24.14
SIEVE ANALYSIS						
% Passing Sieve No. 10					99.4	100
20			100		98	99.8
40			99.8		95	9.7
100			96		73	.1
200			91		63	/
.05			86		53	6
.02			73		46	3
.005			40		27	4
.002			22		21	2
.001			16		19	15

*More organic part of sample tested

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SOIL TEST RESULTS

Table 4

Date Dec. 1, 1962

For: National Park Service
Samples from Washington Monument Grounds

Boring No.	26	26	27	27	27	27
Sample No.	6	14	7	8	13	15
Depth, feet	17	44	20	25	41	47
Liquid Limit		65	46			41
Plastic Limit		33	27			21
Plasticity Index		32	19			20
Initial Density, lb/cu.ft.	116	105	108	97	126	121
Initial Moisture, % dry wt.	31	49	44	63	25	32
Weight loss, 100 C to 300 C, %		4.3	3.1			1.3
COMPRESSION TEST						
Lateral pressure, kips/sq.ft.	0	0	0	0	0	0
Reduction in height at failure, %	6	15	10	10	8	6
Max. stress difference, kips/sq.ft.	1.60	1.00	0.66	0.92	3.30	3.2
DIRECT SHEAR TEST, CONSOLIDATED						
Normal stress, kips/sq.ft.		8				8
Thickness reduction before shear, %		12.4				5.2
Maximum shear stress, kips/sq.ft.		4.18				2.6
CONSOLIDATION TEST						
Coeff. of permeability, ft. per day						
Corresponding pressure, kips/sq.ft.	4, 8	4, 8	4, 8	4, 8	4, 8	4,
Coeff. of consolidation, ft. sq/day	0.2,0.1	0.1,0.1	0.1, 0.1	0.5,0.5	1.8,0.5	2.0
Cumulative % reduction in thickness for following loads:						
0.04 kips per sq. ft.	0	0	0	0	0	0
0.5	0.72	0.84	0.92	1.76	0.40	0.4
1	1.24	1.96	2.44	3.04	0.68	0.6
2	2.64	4.22	I 4.80	I6.18	1.18	I 1.0
4	I 5.64	I 7.64	9.16	--	I 2.70	2.1
8	--	--	14.24	--	6.06	5.6
4	--	--	--	--	--	--
2	5.28	7.24	13.48	--	5.20	4.6
1	4.88	6.66	--	5.90	--	--
.5	4.30	5.98	12.20	5.44	4.16	3.4
1	4.52	6.14		5.68		
2	5.04	6.76		6.34		
4	5.98	8.04		10.78		
8	10.50	12.26		15.98		
SIEVE ANALYSIS						
% Passing Sieve No.						
10		100	--			--
20		99	--			100
40		98	100			99
100		95	99.8			99
200		92	99.7			97
.05		90	99			94
.02		77	97			80
.005		42	54			50
.002		24	32			32
.001		14	20			20

I = inundated

EDWARD S. BARBER, C. E. SOIL TEST RESULTS Table 5

SOIL MECHANICS AND FOUNDATIONS

Date Dec. 1, 1962

For: National Park Service

from Washington Monument Grounds

Boring No.	27	27	27	27	27	27
Sample No.	17	18	21	23	25	27
Depth, feet	52	56	62	67	71	76
Liquid Limit				67		
Plastic Limit				33		
Plasticity Index				34		
Initial Density, lb/cu.ft.	115	114	106	106	104	10
Initial Moisture, % dry wt.	36	35	48	46	51	47
Weight loss, 100 C to 300 C,%				4.5		4.
COMPRESSION TEST						
Lateral pressure, kips/sq.ft.	0	0	0	0	0	0
Reduction in height at failure, %	12	8	5	6	6	8
Max. stress difference, kips/sq.ft.	1.67	3.10	4.30	3.94	4.38	6.
DIRECT SHEAR TEST, CONSOLIDATED						
Normal stress, kips/sq.ft.				8		8
Thickness reduction before shear, %				6.4		5.
Maximum shear stress, kips/sq.ft.				3.12		4.
CONSOLIDATION TEST						
Coeff. of permeability, ft. per day						
Corresponding pressure, kips/sq.ft.	4, 8	4, 8	4, 8	4, 8	4, 8	4,
Coeff. of consolidation, ft. sq/day	1.4, .3	1.2, .4	2, .6	.8, .5	2.0, .4	1.
Cumulative % reduction in thickness for following loads:						
0.04 kips per sq. ft.	0	0	0	0	0	0
0.5	0.40	0.14	0.36	0.78	1.34	0.
1	0.90	0.48	0.84	1.18	1.82	1.
2 I = inundated	I 1.60	1.54	I 1.80	2.00	I 2.80	I 1.
4	--	I 3.52	3.32	I 3.26	4.68	--
8	--	7.00	6.16	5.68	8.18	--
~~4~~	--	--	--	--	--	--
2	--	5.90		4.60	6.74	--
1	1.40	--		--	--	1.
.5	1.04	4.24		3.24	5.08	0.
1	1.20					1.
2	1.70					1.
4	3.26					3.
8	6.14					5.
SIEVE ANALYSIS % Passing Sieve						
No. 10				--		--
20				100		100
40				99.7		99
100				96		98
200				88		95
.05				83		90
.02				66		73
.005				27		22
.002				13		11
.001				6		7

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SOIL MECHANICS AND FOUNDATIONS

SOIL TEST RESULTS

Table 6

Date Dec. 1, 1962

For National Capitol Parks
From Washington Monument Grounds

Boring No.	28	28	29	29	30	30
Sample No.	16	18	16	19	19	21
Depth, feet	61	67	66	77	77	82
Liquid Limit		88	62			
Plastic Limit		31	22			
Plasticity Index		57	40			
Initial Density, lb/cu.ft.	106	106	119	108	110	10
Initial Moisture, % dry wt.	51	51	33	44	47	46
Weight loss, 100 C to 300 C, %		4.3	1.3		Re-molded	
COMPRESSION TEST						
Lateral pressure, kips/sq.ft.	0	0	0	0	0	0
Reduction in height at failure, %	4	8	5	8	6	10
Max. stress difference, kips/sq.ft.	5.48	4.33	5.22	6.53	5.80	1.56
DIRECT SHEAR TEST, CONSOLIDATED						
Normal stress, kips/sq.ft.		8	8			
Thickness reduction before shear, %		4.1	2.2			
Maximum shear stress, kips/sq.ft.		3.35	4.18			
CONSOLIDATION TEST						
Coeff. of permeability, ft. per day						
Corresponding pressure, kips/sq.ft.	4, 8	4, 8	4, 8	4, 8	8, 16	8,
Coeff. of consolidation, ft. sq/day	1.6, .5	2, .5	1.2, .5	2, .4	2, .2	.2
Cumulative % reduction in thickness for following loads:						
0.04 kips per sq. ft.	0	0	0	0	0	0
0.5	0.30	0.46	0.38	0.34	0.56	0.
1	0.50	0.90	0.56	0.50	0.86	1.
2	0.78	1.62	0.90	0.70	1.16	3.
4	I 1.26	I 2.30	I 1.28	I 1.12	1.76	1.
8	--	--	--	--	I 2.76	I 9.
4	--	--	--	--	2.16	
2	0.86	1.94	1.04	0.82	1.72	
1	0.56	1.46	0.72	0.50	1.16	
.5	0.22	1.02	0.46	0.22	0.68	
1	0.36	1.16	0.58	0.30	0.78	
2	0.68	1.44	0.78	0.56	1.16	
4	1.18	2.20	1.20	1.12	1.36	
8	2.20	4.12	2.20	2.10	2.96	
16	6.44			5.20	5.84	15.
32					16.04	21.
SIEVE ANALYSIS % Passing Sieve No. 10		--	--			
20		100	--			
40		99.8	100			
100		99.6	99.8			
200		99	99.3			
.05		95	97			
.02		80	80			
.005		39	52			
.002		20	34			
.001		10	20			

I = inundated

EDWARD S. BARBER, C. E.
SOIL MECHANICS AND FOUNDATIONS

SOIL TEST RESULTS

Table 7

Date Dec. 1, 1952

For National Park Service
Samples from Washington Monument Grounds

Boring No.	22	23	23	24	25
Sample No.	21	20	28	20	25
Depth, feet	84	78	97	95	104
Initial Density, lb/cu.ft.					
Initial Moisture, % dry wt.					
COMPRESSION TEST					
Lateral pressure, kips/sq.ft.					
Reduction in height at failure, %					
Max. stress difference, kips/sq.ft.					
DIRECT SHEAR TEST, CONSOLIDATED					
Normal stress, kips/sq.ft.					
Thickness reduction before shear, %					
Maximum shear stress, kips/sq.ft.					
CONSOLIDATION TEST 2.5" dia.					
Coeff. of permeability, ft. per day					
Corresponding pressure, kips/sq.ft.					
Coeff. of consolidation, ft. sq/day					
Cumulative % reduction in thickness for following loads:					
0.04 kips per sq. ft.	0	0	0	0	0
0.5	0.32	0.27	0.26	0.30	0.32
1	0.50	0.45	0.48	0.45	0.57
2	0.95	0.67	0.69	0.74	0.96
4	1.77	1.49	1.10	1.14	1.43
8	2.92	2.94	2.60	2.03	2.61
16					

EDWARD S. BARBER, C. E.
SOIL MECHANICS AND FOUNDATIONS

SOIL TEST RESULTS

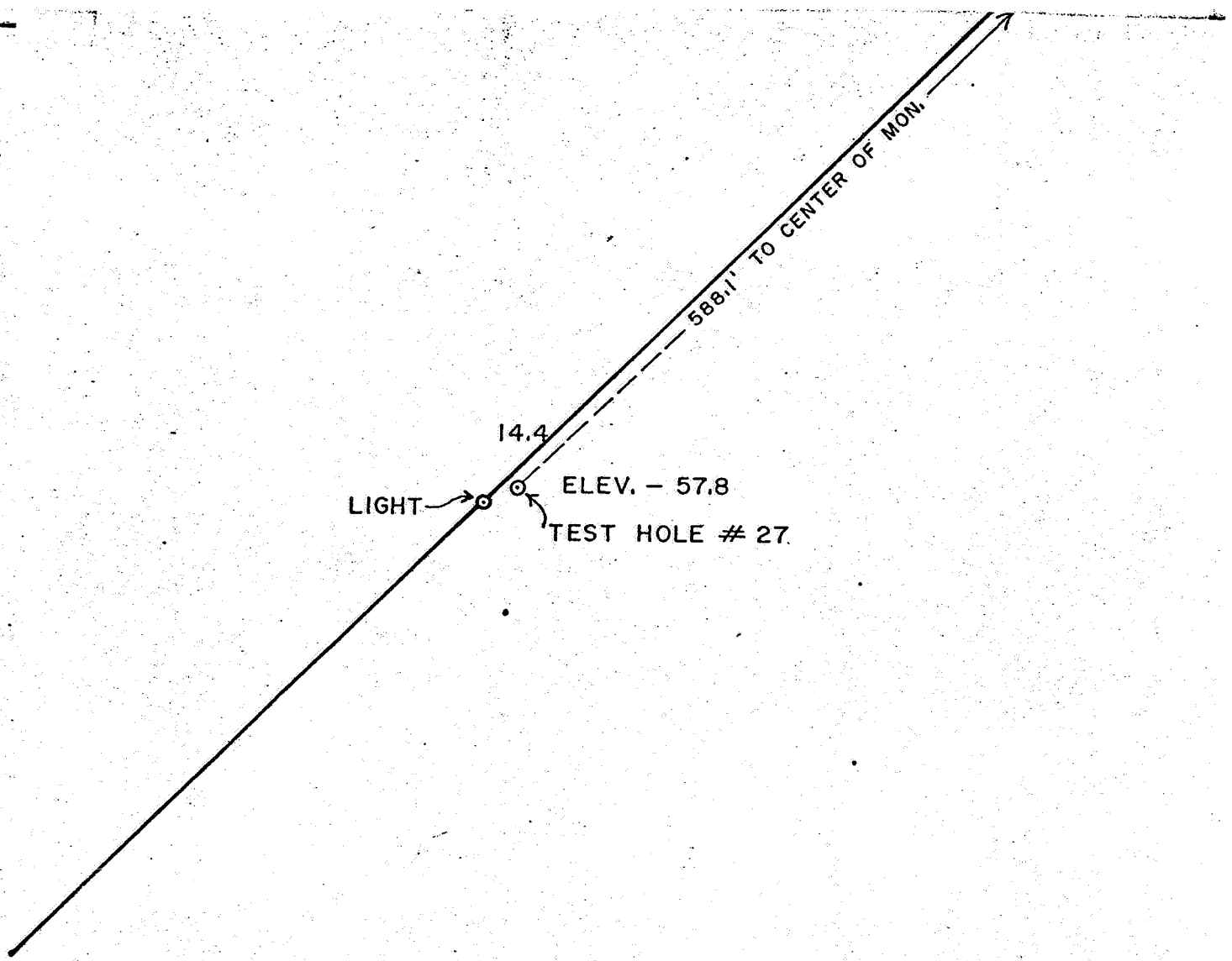
Table 8

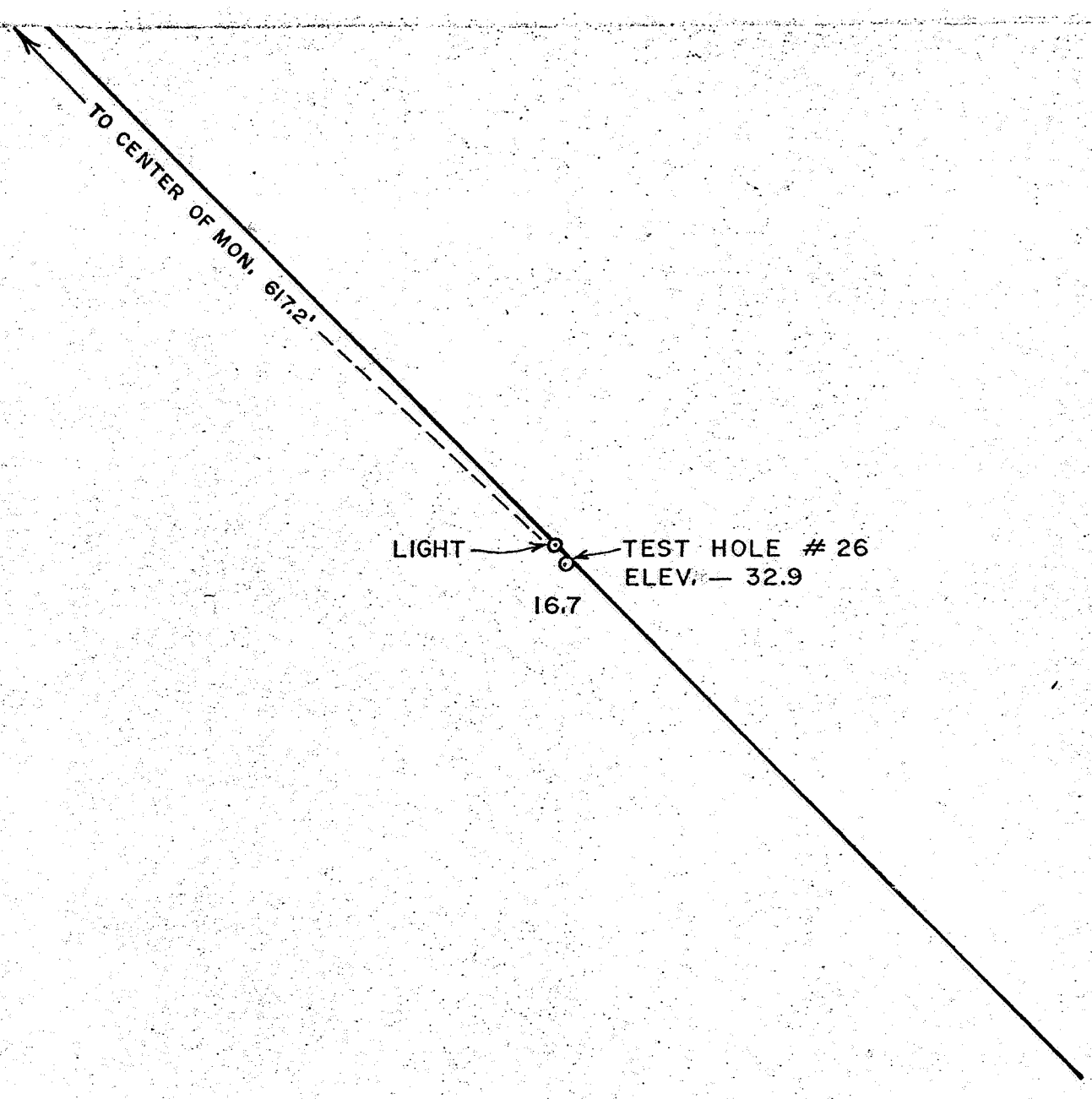
Date Dec. 1, 1

: National Park Service

Samples from Washington Monument Grounds

Boring No.	27	27	28	29
Sample No.	23	27	18	16
Depth, feet	67	76	67	66
Initial Density, lb/cu.ft.				
Initial Moisture, % dry wt.				
COMPRESSION TEST				
Lateral pressure, kips/sq.ft.				
Reduction in height at failure, %				
Max. stress difference, kips/sq.ft.				
DIRECT SHEAR TEST, CONSOLIDATED				
Normal stress, kips/sq.ft.				
Thickness reduction before shear, %				
Maximum shear stress, kips/sq.ft.				
CONSOLIDATION TEST 2,5" dia.				
Coeff. of permeability, ft. per day				
Corresponding pressure, kips/sq.ft.				
Coeff. of consolidation, ft. sq/day				
Cumulative % reduction in thickness for following loads:				
0.04 kips per sq. ft.	0	0	0	0
0.5	0.22	0.30	0.01	0.26
1	0.61	0.44	0.20	0.39
2	1.41	0.70	0.65	0.63
4	2.76	1.47	1.54	1.22
8	5.15	2.90	3.13	2.22
16				


588.1' TO CENTER OF MON.
14.4
ELEV. – 57.8
LIGHT
TEST HOLE # 27

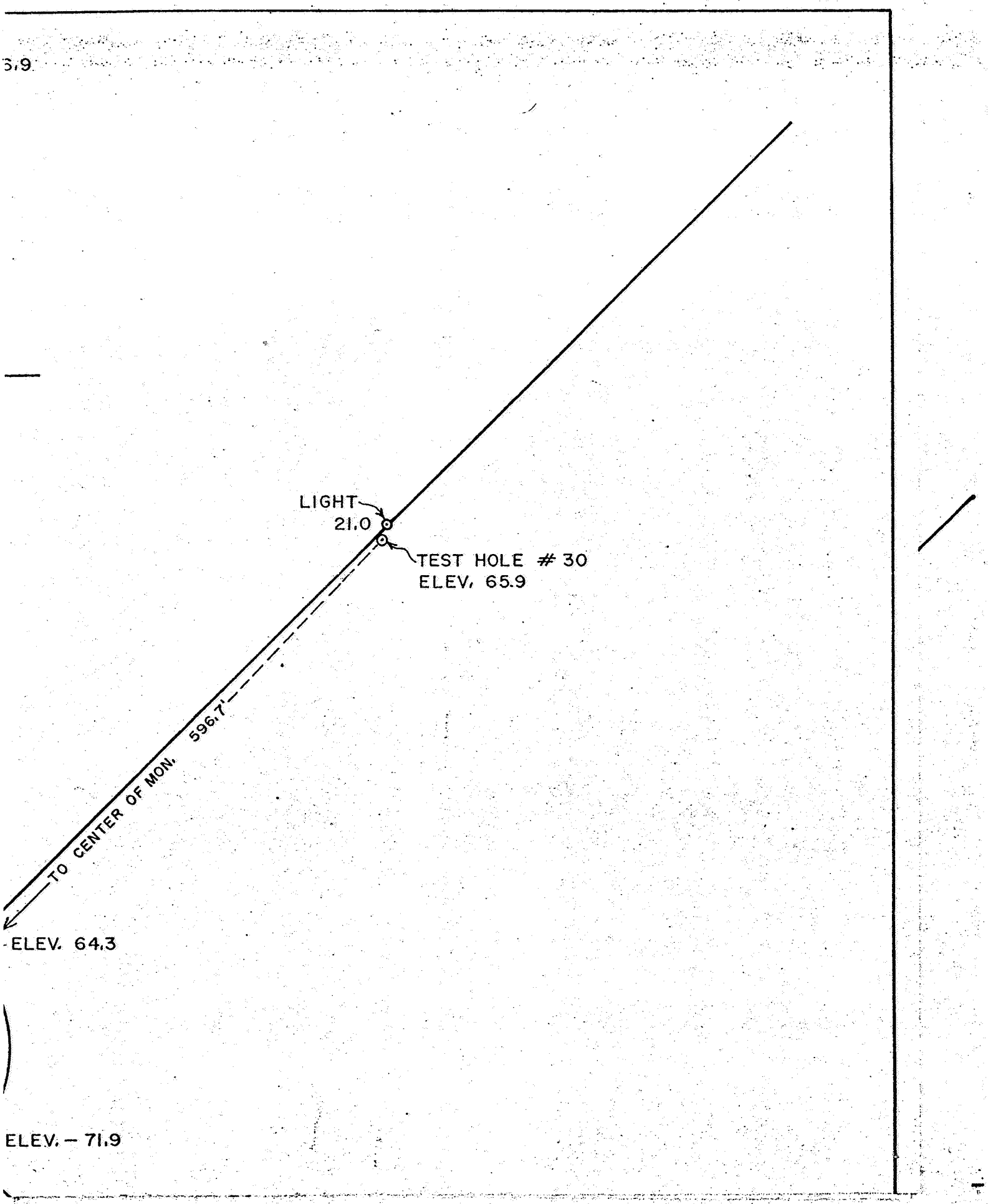


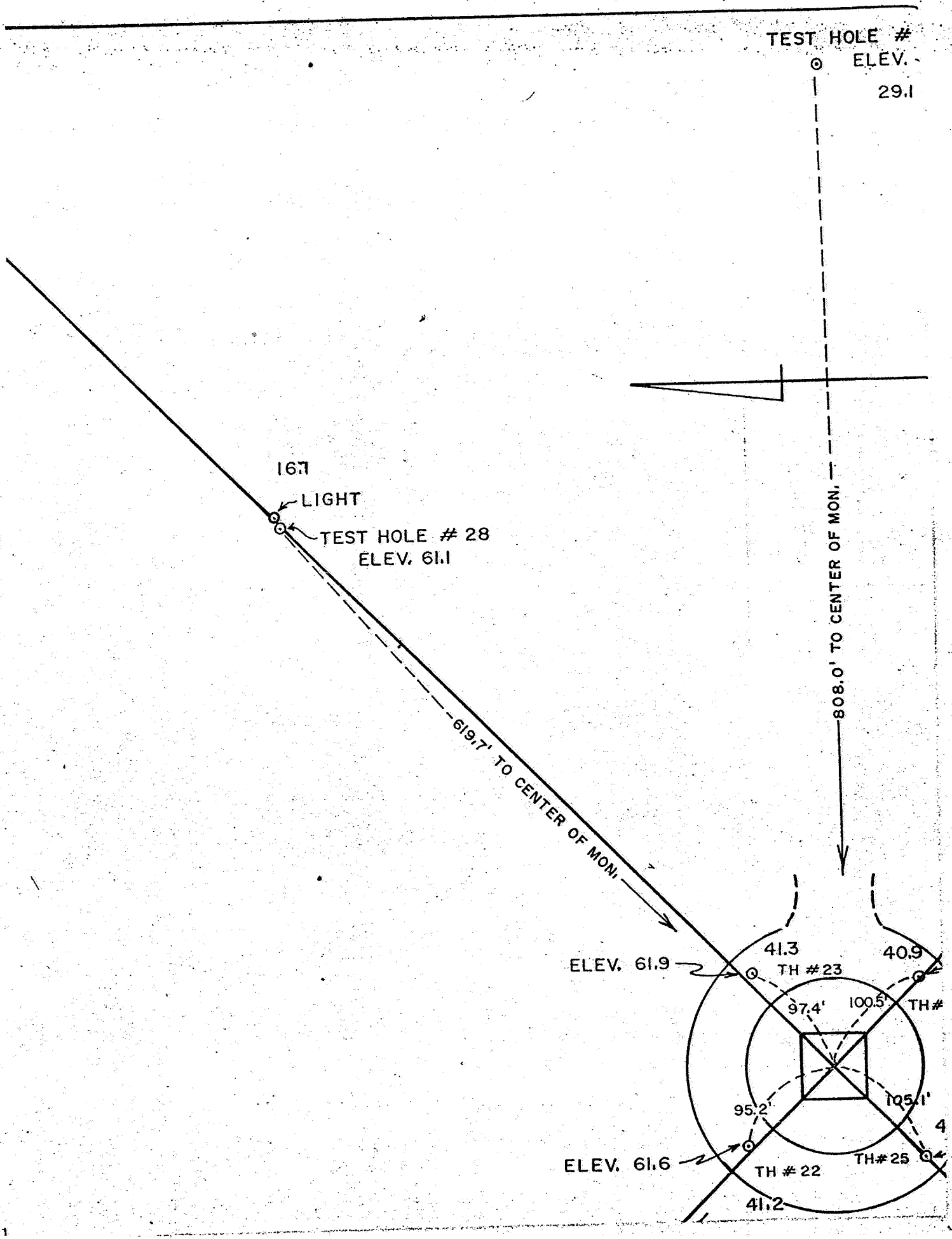
SCALE 1" = 100'
DATUM USED

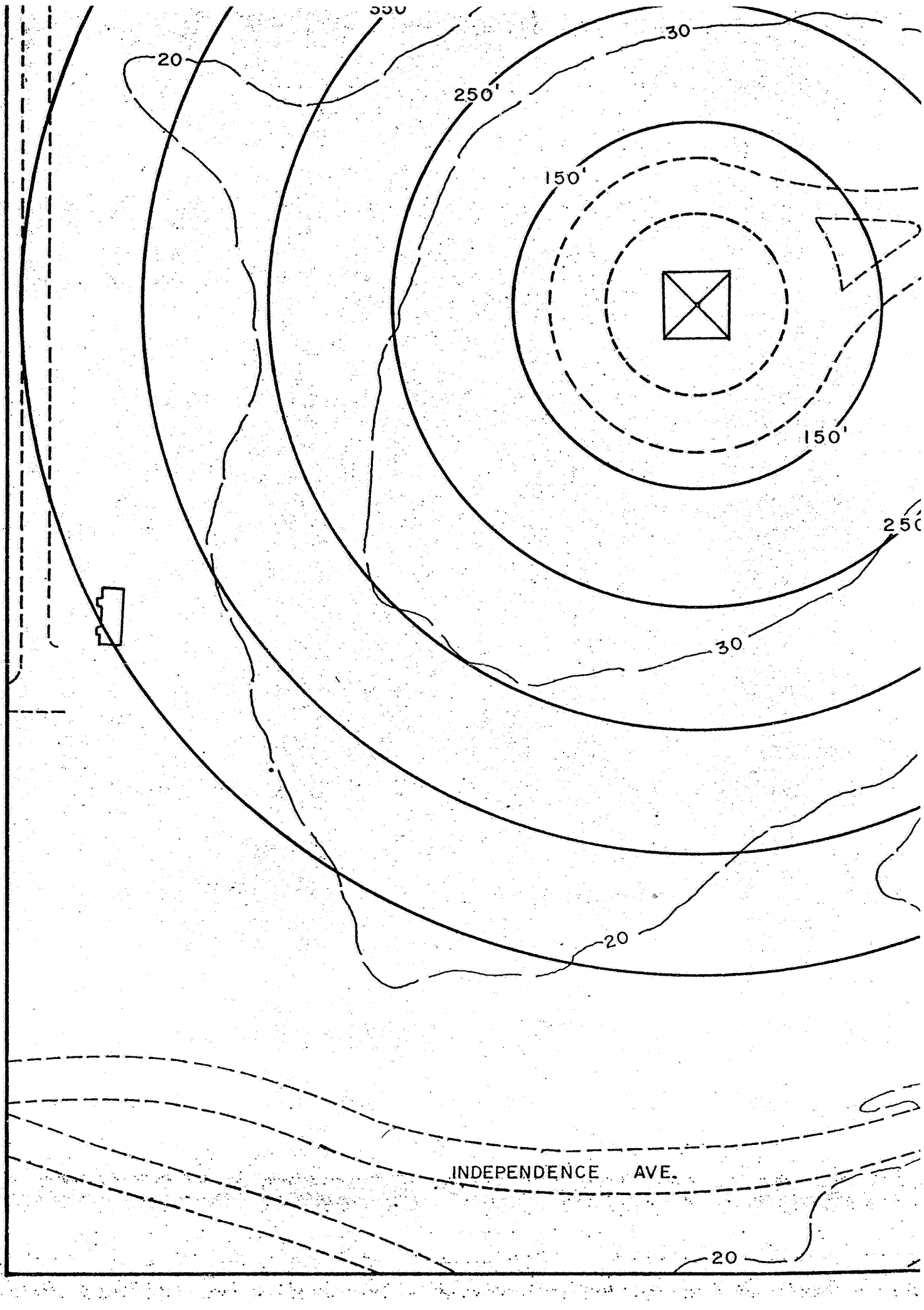
LOCATION OF TEST BORINGS
WASHINGTON MONUMENT GROUNDS
DRAWN 10-25-62 BY SCOTT DAVIS
FB 70-D-1

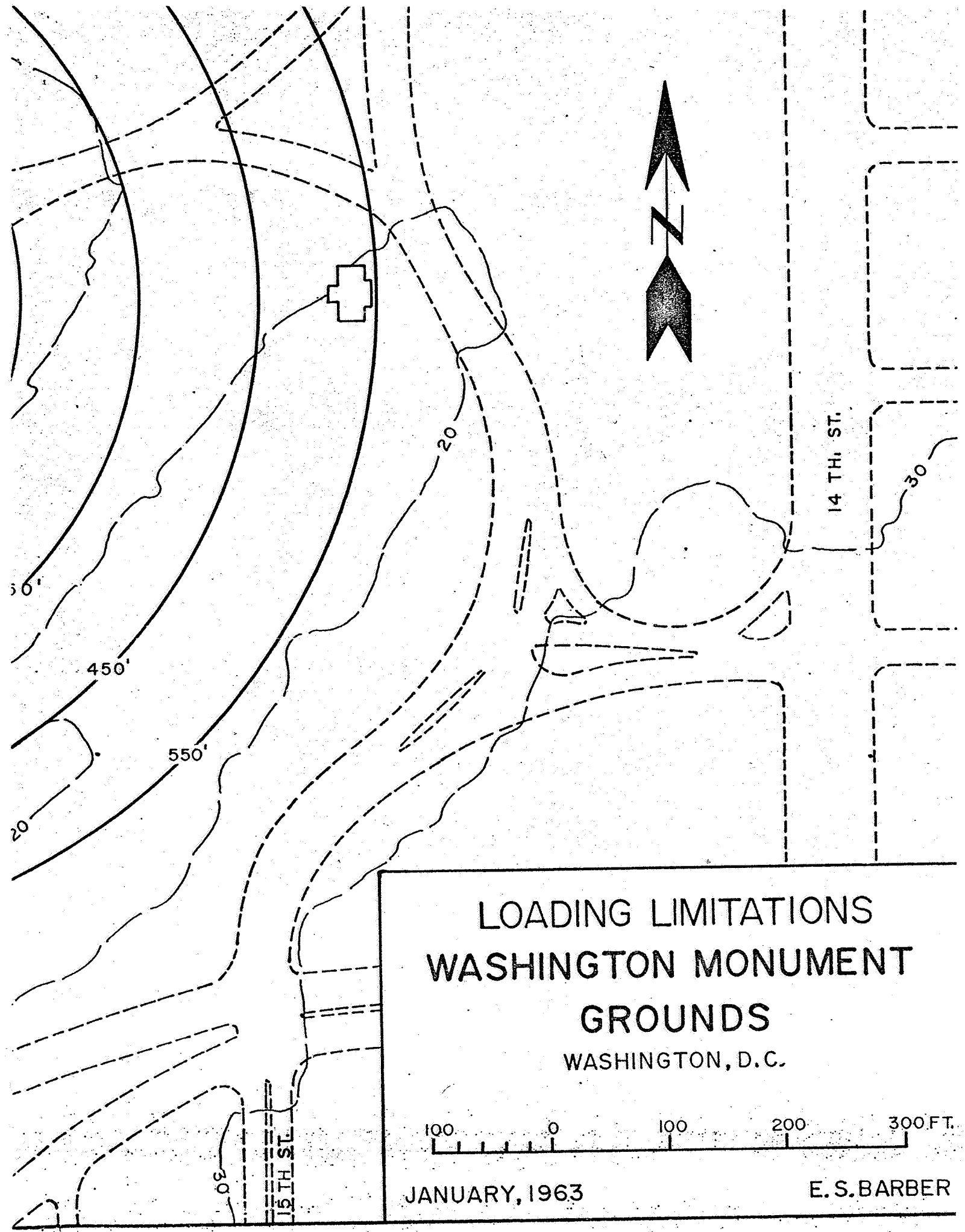
N.C.P. 44-344

FIGURE 1


LIGHT
21.0
TEST HOLE # 30
ELEV. 65.9
TO CENTER OF MON. 596.7'
ELEV. 64.3
ELEV. — 71.9


TEST HOLE #
ELEV. 29.1
808.0' TO CENTER OF MON.
167
LIGHT
TEST HOLE # 28
ELEV. 61.1
619.7' TO CENTER OF MON.
ELEV. 61.9
41.3
TH #23
40.9
97.4'
100.5'
TH#
105.1'
95.2'
4
ELEV. 61.6
TH #22
TH#25
41.2


20
250'
30
150'
150'
250
30
20
INDEPENDENCE AVE.
20



LOADING LIMITATIONS
WASHINGTON MONUMENT GROUNDS

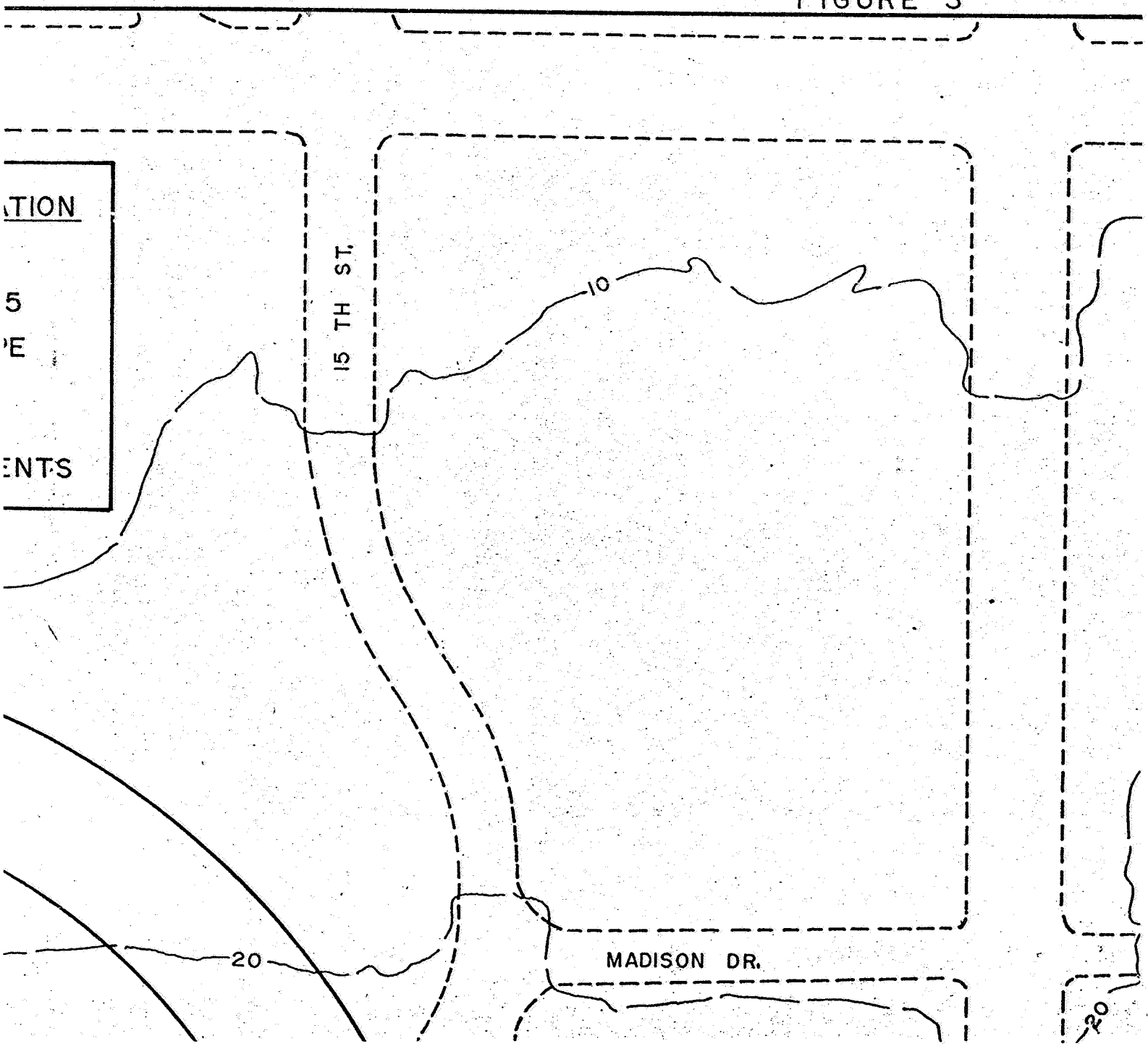
WASHINGTON, D.C.

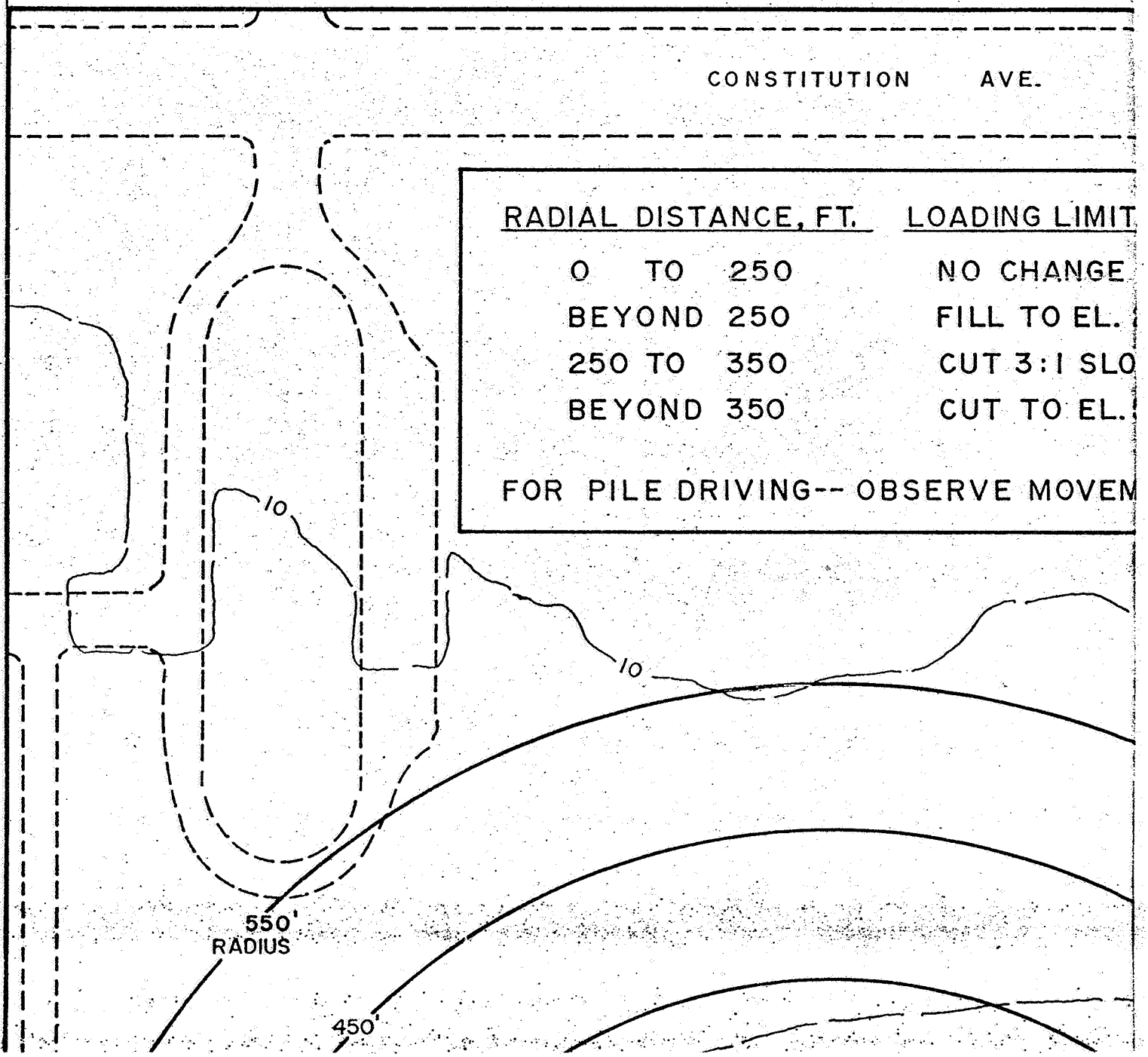
100 0 100 200 300 FT.

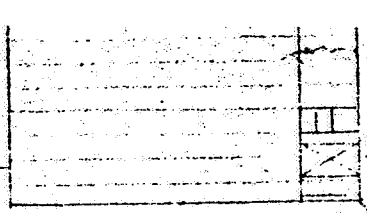
JANUARY, 1963

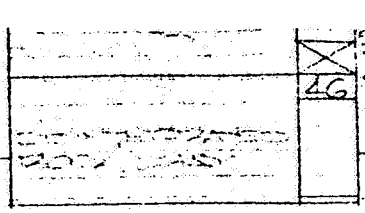
E. S. BARBER

FIGURE 3




CONSTITUTION AVE.
RADIAL DISTANCE, FT.
LOADING LIMIT
0 TO 250
NO CHANGE
BEYOND 250
FILL TO EL.
250 TO 350
CUT 3:1 SLO
BEYOND 350
CUT TO EL.
FOR PILE DRIVING-- OBSERVE MOVEM
10
10
550'
RADIUS
450'





-60

NOTE A:
3" THINWALL SAMPLE
PUSHED 12" FROM
73'-0" TO 74'-0",
11" RECOVERY

NOTE B:
3" THINWALL SAMPLE
PUSHED 0" FROM
78'-0" TO 78'-0",
0" RECOVERY

-70

NOTE C:
3" THINWALL SAMPLE
PUSHED 12" FROM
83'-0" TO 84'-0",
10" RECOVERY

NOTE D:
3" THINWALL SAMPLE
PUSHED 2" FROM
88'-0" TO 89'-0",
12" RECOVERY

NOTE E:
3" THINWALL SAMPLE
PUSHED 5" FROM
93'-0" TO 93'-5",
NO RECOVERY

NOTE F:
3" THINWALL SAMPLE
PUSHED 6" FROM
100'-6" TO 101'-0",
6" RECOVERY

NOTE G:
DISINTEGRATED
ROCK (CLAY) 102'-7"
TO 102'-9"

NOTE H:
REFUSAL, ROCK
OR BOULDER @ 102'-9"

WATER LEVELS

Upon Completion at 30'-6"

Hole bailed to 33'-11"

After Casing pulled NONE TO 41'-9" (A)

Water at 33'-8" after 24 HRS. (B)

(A) CAVED & WET

(B) CAVED @ 41'-6"

NOTE A:
REFUSAL ENCOUNTERED AT 61'-0",
PROBABLE BOULDER.
OFFSET HOLE 2'-0"
EAST & DRILLED
ALTERNATE HOLE

NOTE B:
3" THINWALL SAMPLE
PUSHED 24" FROM
66'-6" TO 69'-6",
23" RECOVERY

NOTE C:
3" THINWALL SAMPLE
PUSHED 21" FROM
71'-6" TO 73'-3",
8" RECOVERY

NOTE D:
3" THINWALL SAMPLE
PUSHED 20" FROM
76'-6 TO 78'-2",
20 RECOVERY

NOTE E:
3" THINWALL SAMPLE
PUSHED 12" FROM
81'-3" TO 82'-6",
12" RECOVERY

NOTE F:
3" THINWALL SAMPLE
PUSHED 21" FROM
86'-6" TO 88'-3",
19" RECOVERY

NOTE G:
3" THINWALL SAMPLE
PUSHED 15" FROM
91'-6 TO 92'-7",
11" RECOVERY

NOTE H:
3" THINWALL SAMPLE
PUSHED 17" FROM
96'-6 TO 97'-11",
6" RECOVERY

NOTE I:
REFUSAL, ROCK
OR BOULDER @ 98'-2

WATER LEVELS

Upon Completion at 33'-4"

Hole bailed to NONE TO 40'-6" (A)

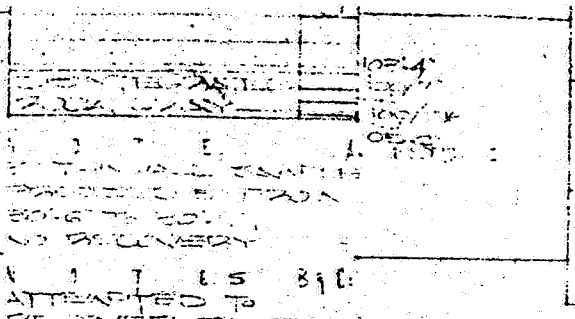
After Casing pulled NONE TO 40'-6" (A)

Water at 40'-6" after 24 HRS (A)

(A) CAVED AND WET FROM BOTTOM

GENERAL

1. POWER IN RIGHT HAND COLUMN OF BORING LOG INDICATES BLOWS REQUIRED TO DRIVE 2 INCH O.D., 3/8 INCH I.D. SAMPLING SPOON ONE FOOT, USING 140 POUND HAMMER FALLING 30 INCHES.
2. CLASSIFICATION OF SOILS IS BY VISUAL INSPECTION & IS IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.
3. ESTIMATED GROUND-WATER LEVELS INDICATED BY ▼. THESE LEVELS ARE ONLY ESTIMATES FROM



NOTE A:
3" THINWALL SAMPLE
ATTEMPTED TO
RECOVER SAMPLE
WITH OPEN END
ROD.

NOTE B:
3" THINWALL SAMPLE
ADVANCED 24" FROM
21'-6" TO 93'-6",
2" RECOVERY

NOTE C:
3" THINWALL SAMPLE
ADVANCED 11" FROM
68'-6" TO 38'-5",
10" RECOVERY

NOTE D:
3" THINWALL SAMPLE
ADVANCED 8" FROM
94'-0" TO 96'-1",
2" RECOVERY

NOTE E:
3" THINWALL SAMPLE
ADVANCED 11" FROM
99'-0" TO 99'-11",
11" RECOVERY

NOTE F:
ENCOUNTERED
BOULDER 31'-2" TO 31'-6"

NOTE G:
REFUSAL, ROCK
OR BOULDER @ 105'-2"

WATER LEVELS

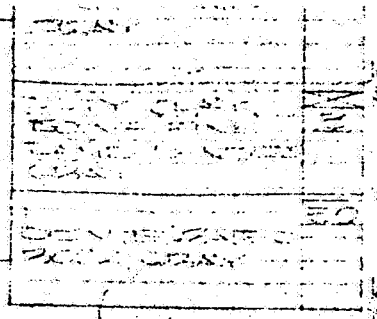
Upon Completion at 21'-9"

Hole balled to 34'-10"

After Casing pulled NONE TO 38'-2" (A)

Water at 20'-8" after 24'-0"

(A) CAVED @ 38'-0", WET



NOTE A:
3" THINWALL SAMPLE
ADVANCED 12" FROM
14'-0" TO 15'-0",
12" RECOVERY

NOTE B:
3" THINWALL SAMPLE
ADVANCED 2" FROM
71'-6" TO 71'-8",
NO RECOVERY

NOTE C:
3" THINWALL SAMPLE
ADVANCED 8" FROM
104'-0" TO 104'-8",
7" RECOVERY

NOTE D:
ENCOUNTERED
BOULDER 42'-11" TO 43'-4"

NOTE E:
FINE TO COARSE
SAND, SOME
GRAVEL, TRACE
SILT, GRAY

NOTE F:
REFUSAL, ROCK
OR BOULDER @ 112'-0"

WATER LEVELS

Upon Completion at 8'-3"

Hole balled to 31'-10"

After Casing pulled NONE TO 42'-8" (A)

Water at NONE TO 42'-8" after 48 HRS (B)

(A) CAVED & WET @ 42'-8"

(B) CAVED & DRY @ 42'-8"

WATER LEVELS

Upon Completion at 2

Hole balled to 33'-2

After Casing pulled

Water at 15'-6" after

(A) 20'-0" OF 1 1/4" F
INDENTED

NOTES:

3. AVAILABLE DATA MAY VARY WITH PRECIPITATION, PORCITY OF THE SOIL, SITE TOPOGRAPHY ETC.
4. BORING LOCATIONS & GROUND SURFACE ELEV. FURNISHED BY
5. ALL THINWALL TUBES WERE TAKEN WITH 3" & 2" SHELBY TUBES, EXCEPT THE FOLLOWING WERE BY A PISTON SAMPLER: BORING Nº 26 @ 15'-0" & 43'-0", BORING Nº 27 @ 23'-0 BORING Nº 30 @ 76'-1" & 81'-0".
6. KEY TO ABBREVIATIONS & SYMBOLS: G.S. GROUND SUR
* NO SAMPLE RECOVERY; [X] UNDISTURBED SAMPLE.

40.6'

LS

etion at 7.2'

1 to 23.2'

; pulled 25.0' (A)

5.6' after 24 Hrs.

1/4 PIPE
TED

NOTE N

76.0'

77.6'

78.6'

NOTE P

N O T E A:
3" THINWALL SAMPLE
EJECTED 24" FROM
8'-6" TO 20'-6"
4" RECOVERY

N O T E B:
3" THINWALL SAMPLE
EJECTED 24" FROM
20'-6" TO 22'-6"
0" RECOVERY

N O T E C:
3" THINWALL SAMPLE
EJECTED 16" FROM
28'-0" TO 29'-4"
4" RECOVERY

N O T E D:
3" THINWALL SAMPLE
EJECTED 16" FROM
40'-6" TO 41'-6"
8" RECOVERY

N O T E E:
3" THINWALL SAMPLE
EJECTED 18" FROM
45'-6" TO 47'-0"
14" RECOVERY

N O T E F:
3" THINWALL SAMPLE
EJECTED 17" FROM
51'-6" TO 52'-11"
9" RECOVERY

N O T E G:
3" THINWALL SAMPLE
EJECTED 12" FROM
55'-0" TO 56'-0"
12" RECOVERY

N O T E H:
3" THINWALL SAMPLE
EJECTED 2" FROM
61'-0" TO 62'-0"
10" RECOVERY

N O T E I:
3" THINWALL SAMPLE
EJECTED 12" FROM
66'-6" TO 67'-6"
0" RECOVERY

N O T E J:
3" THINWALL SAMPLE
EJECTED 10" FROM
71'-0" TO 71'-10"
0" RECOVERY

N O T E K:
3" THINWALL SAMPLE
EJECTED 11" FROM
76'-0" TO 76'-11"
10" RECOVERY

WATER LEVELS

Upon Completion at 10.9'

Hole balled to 24.6'

After Casing pulled 11.1' (A)

Water at 10.10' after 24 Hrs.

(A) 20.0' OF 1/4" PIPE
INSERTED

77.9'

N O T E A:
3" THINWALL SAMPLE
EJECTED 20" FROM
5'-6" TO 23'-4"
NO RECOVERY

N O T E B:
3" THINWALL SAMPLE
EJECTED 2" FROM
53'-6" TO 53'-8"
NO RECOVERY

N O T E C:
3" THINWALL SAMPLE
EJECTED 2" FROM
53'-8" TO 53'-10"
NO RECOVERY

N O T E D:
3" THINWALL SAMPLE
EJECTED 12" FROM
60'-6" TO 61'-6"
12" RECOVERY

N O T E E:
3" THINWALL SAMPLE
EJECTED 8" FROM
65'-6" TO 67'-0"
18" RECOVERY

N O T E F:
REFUSAL, ROCK
OR BOULDER (A) 77'-9"

WATER LEVELS

Upon Completion at 18'-10"

Hole balled to 21'-10"

After Casing pulled 13.2'

Water at 15'-0" after 24 Hrs.

WAT

Upon

Hole

Afte

Wate

F

For:

Architec

Engineer

Date: 2

BY N.C.P.

BY TUBE

TON

23'-0",

SURFACE;

NOTE A:
3" THINWALL SAMPLE
PRESSED 24" FROM
30'-6" TO 32'-6"
NO RECOVERY

NOTE B:
3" THINWALL SAMPLE
PRESSED 24" FROM
32'-6" TO 34'-6"
NO RECOVERY

NOTE C:
3" THINWALL SAMPLE
PRESSED 15" FROM
35'-6" TO 37'-0"
NO RECOVERY

NOTE D:
RUNNING SAND
ENCOUNTERED
@ 6'-0" TO 7'-0"

NOTE E:
3" THINWALL SAMPLE
PRESSED 11" FROM
66'-0" TO 66'-11"
9" RECOVERY

NOTE F:
3" THINWALL SAMPLE
PRESSED 6" FROM
71'-0" TO 71'-6"
NO RECOVERY

WATER LEVELS

Upon Completion at 22'-10"

Hole bailed to 25'-2"

After Casing pulled 22'-0"

Water at 26'-10" after 24 Hrs.

NOTE H

87'-1"

NOTE I

ZONE ORGANIC MATTER & FINE SAND

SENSITIVE CLAY

31'-0"

NOTE G

10

1 1/2"

86'-1"

NOTE J

NOTE A:
ENCOUNTERED
RUNNING SAND

NOTE B:
3" THINWALL SAMPLE
PRESSED 3" FROM
75'-0" TO 75'-3"
NO RECOVERY

NOTE C:
3" THINWALL SAMPLE
PRESSED 10" FROM
76'-2" TO 76'-12"
NO RECOVERY

NOTE D:
3" THINWALL SAMPLE
PRESSED 13" FROM
76'-1" TO 77'-2"
12" RECOVERY

NOTE E:
3" THINWALL SAMPLE
PRESSED 13" FROM
81'-0" TO 82'-1"
13" RECOVERY

WATER LEVELS

Upon Completion at 15'-5"

Hole bailed to 12'-3"

After Casing pulled 15'-5"

Water at 12'-10" after 24 Hrs. (A)

(A) CAVED @ 24'-3"

FOUNDATION TEST SERVICE

Washington, D. C.

For:

Architect:

Engineer:

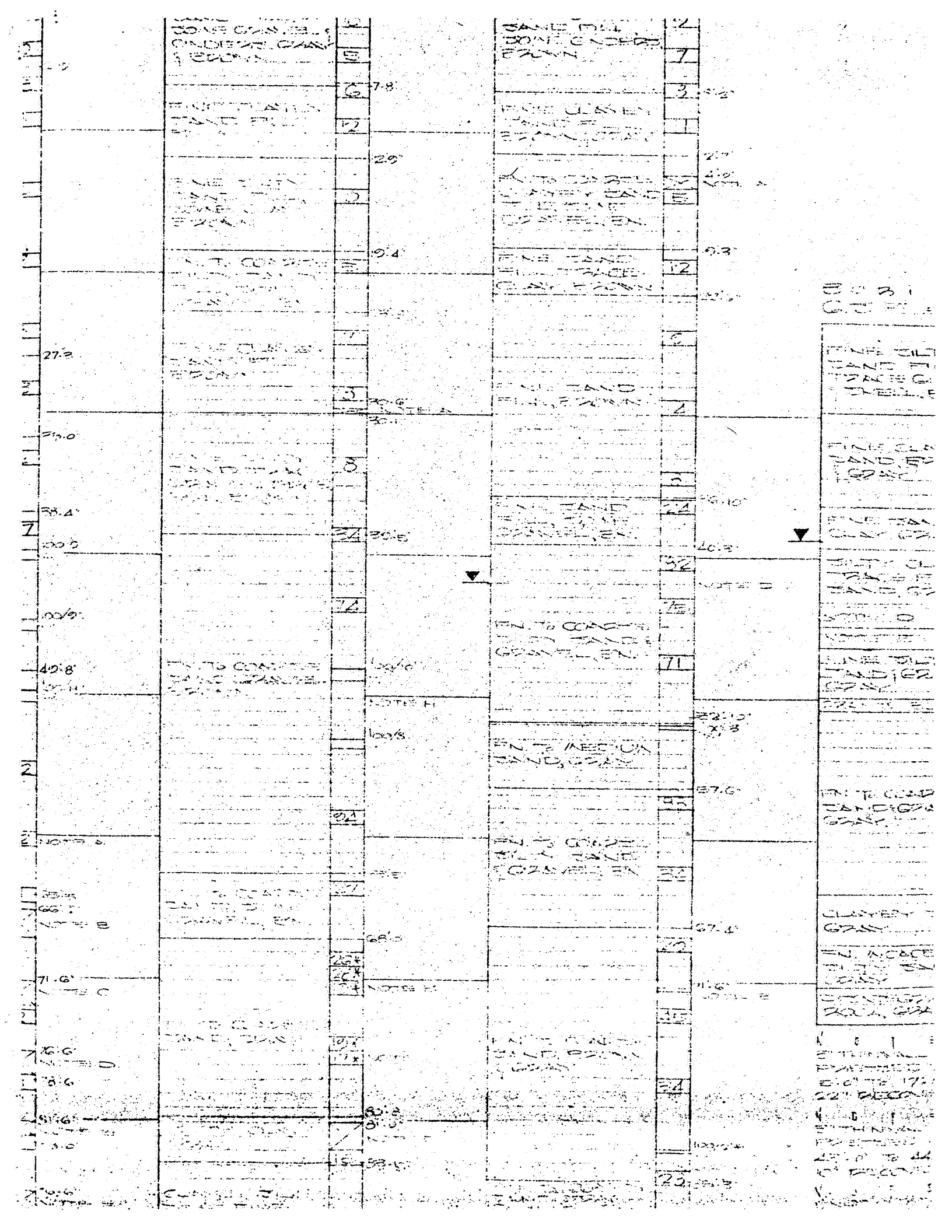
Date: 29

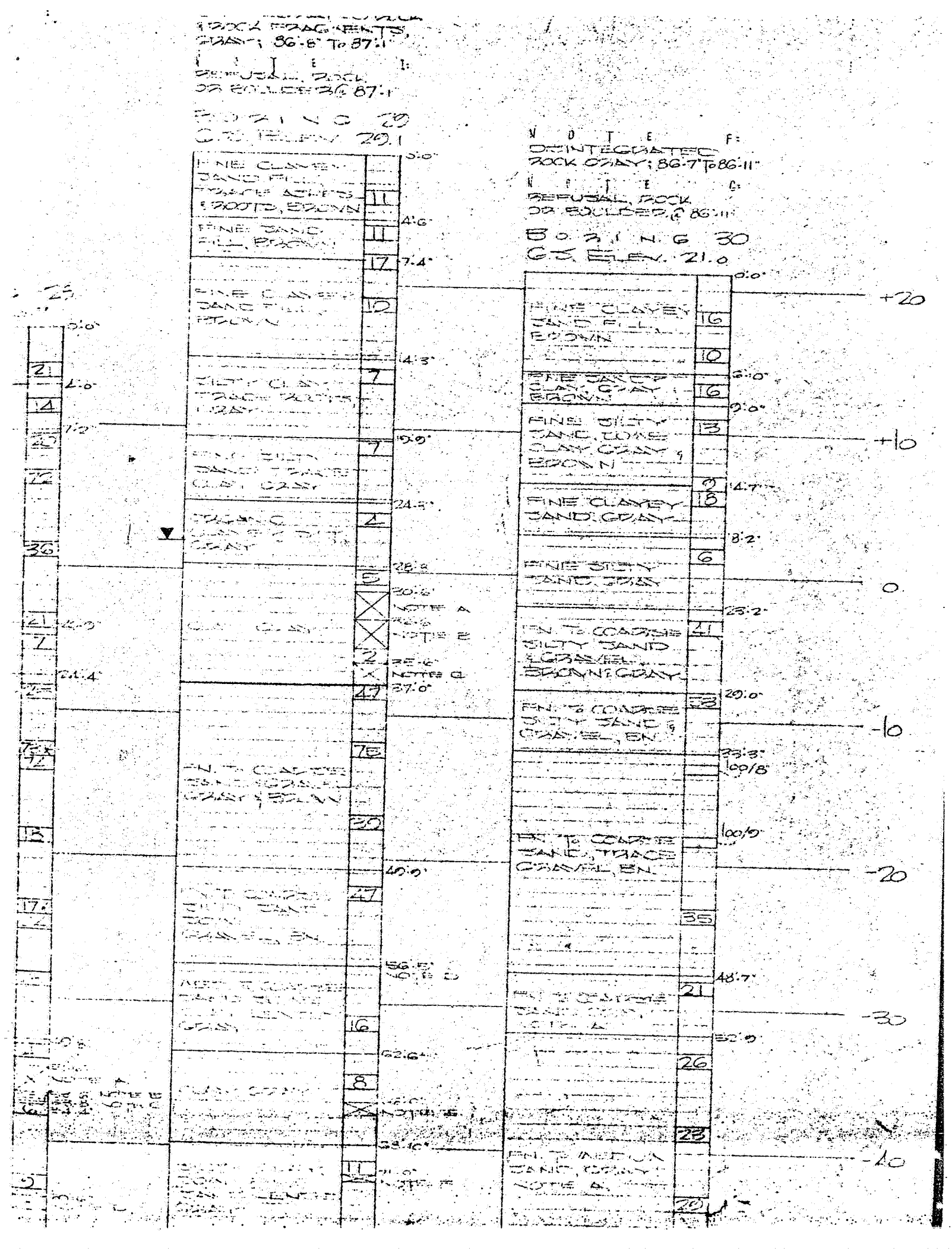
Drawn By:

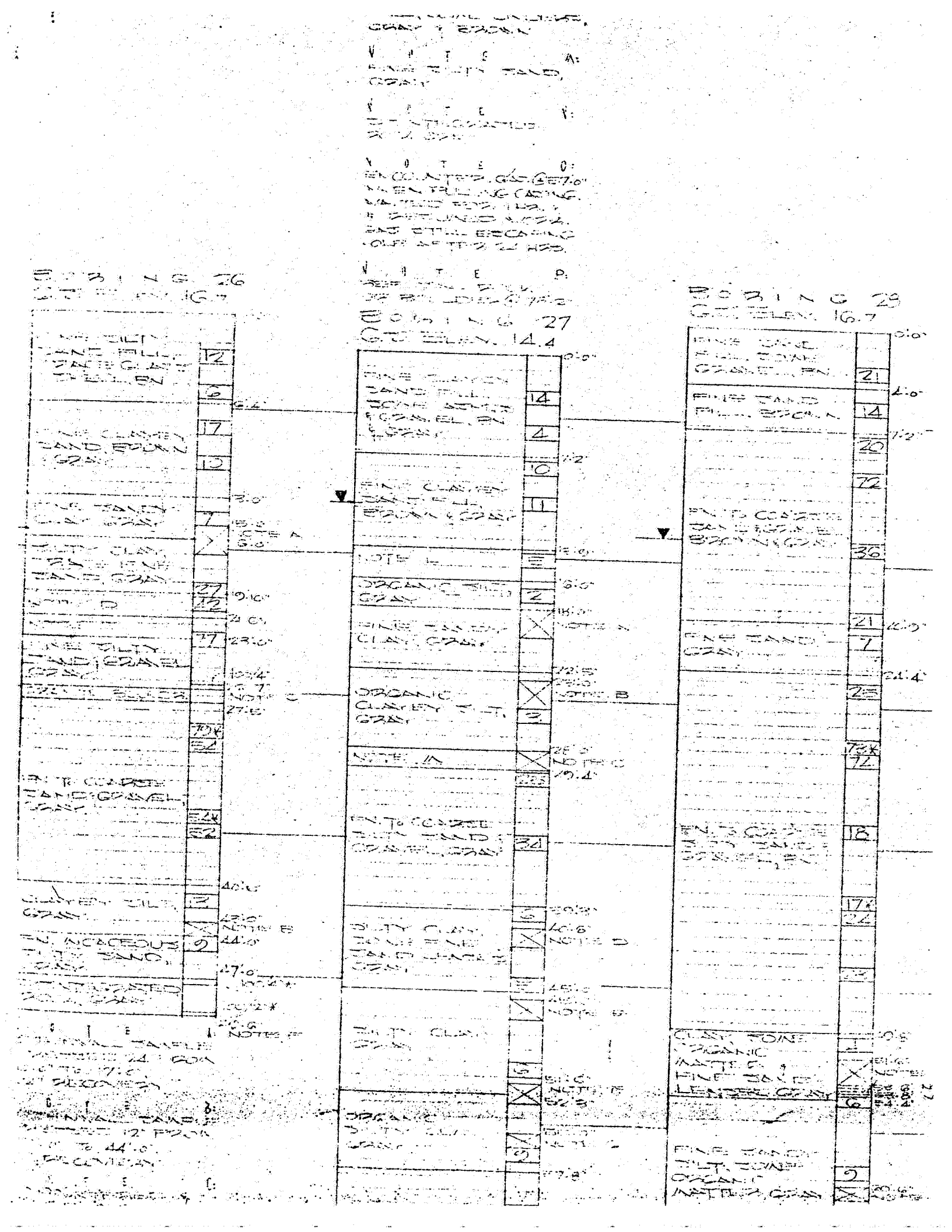
Checked:

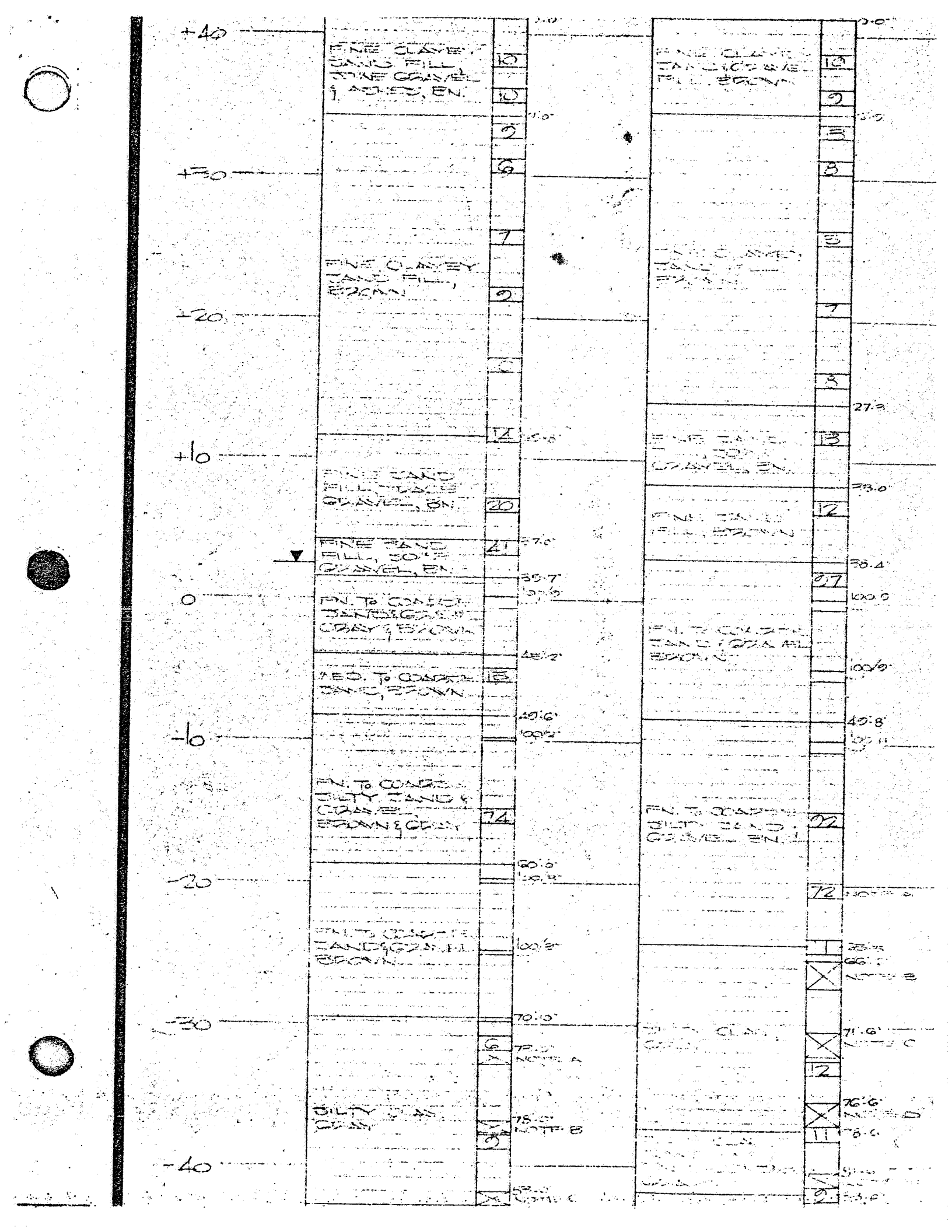
Vertical Scale:

Drawing No:




ROCK FRAGMENTS, GRAY; 86'-8" TO 87'-1"
REFUSAL, ROCK, DR BOULDER @ 87'-1
BORING 29
G.S. ELEV. 29.1
FINE CLAYEY SAND FILL, TRACE ASPHALT & ROOTS, BROWN
FINE SAND, FILL, BROWN
FINE CLAYEY SAND FILL, BLACK
SILTY CLAY, TRACE ROOTS, GRAY
FINE SILTY SAND TO SAND & CLAY, GRAY
FINE TO COARSE SAND & GRAVEL, GRAY
CLAY, GRAY
FINE TO COARSE SILTY SAND & GRAVEL, GRAY
FINE TO COARSE SILTY SAND, GRAY
FINE TO COARSE SAND, GRAY
NOTE A
NOTE B
NOTE C
NOTE D
NOTE E
NOTE F:
DISINTEGRATED ROCK GRAY; 86'-7" TO 86'-11"
NOTE G:
REFUSAL, ROCK, DR BOULDER @ 86'-11"
BORING 30
G.S. ELEV. 21.0
FINE CLAYEY SAND FILL, BROWN
FINE SAND & CLAY, GRAY & BROWN
FINE SILTY SAND, TRACE CLAY, GRAY & BROWN
FINE CLAYEY SAND, GRAY
FINE SILTY SAND, GRAY
FINE TO COARSE SILTY SAND & GRAVEL, BROWN & GRAY
FINE TO COARSE SILTY SAND & GRAVEL, GRAY
FINE TO COARSE SAND, TRACE GRAVEL, GRAY
FINE TO COARSE SAND, GRAY
NOTE A
+20
+10
0
-10
-20
-30
-40


BORING 26
G.S. ELEV. 16.7
BORING 27
G.S. ELEV. 14.4
BORING 29
G.S. ELEV. 16.7


+40
+30
+20
+10
0
-10
-20
-30
-40
FINE CLAYEY SAND FILL, SOME FINE GRAVEL & ASHES, BN.
FINE CLAYEY SAND FILL, BROWN
FINE SAND FILL, TRACE GRAVEL, BN.
FINE SAND FILL, 30% GRAVEL, BN.
FN. TO COARSE SAND & GRAVEL, GRAY & BROWN
MED. TO COARSE SAND, BROWN
FN. TO COARSE SILTY SAND & GRAVEL, BROWN & GRAY
FN. TO COARSE SAND & GRAVEL, BROWN
SILTY CLAY, GRAY
FINE CLAYEY SAND & GRAVEL FILL, BROWN
FINE SAND FILL, BROWN
FN. TO COARSE SILTY SAND & GRAVEL, BN.
FN. TO COARSE SAND & GRAVEL, BROWN
SILTY CLAY, GRAY
NOTE A
NOTE B
NOTE C
NOTE D
NOTE E