*Automatic Recognition of Basic Terrain Types from Aerial Photographs**

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ABSTRACT: *The ability of the photo interpreter to identify basic terrain types at a glance seems to result at least in part from the fact that these types have characteristic "visual textures." The spatial frequencies with which contrasts of various degrees occur appear to be useful measures of visual texture. Experimental computation of such frequencies for assorted "uniformly textured" photographic terrain samples suggest that many basic terrain types can indeed be distinguished by automatic visual texture measurement.*

THIS paper describes a study of the feasibility of automatically identifying various types of terrain on the basis of aerial reconnaissance data. The specific terrain types investigated include hydrographic features, cultivated and uncultivated land, and various types of urban areas.

The scope of the study program described in this paper was restricted, for the sake of simplicity, as follows:

1. Only conventional aerial photography was used as an input; other reconnaissance sensors, such as radar, infrared, etc., were not considered.
2. Experimental work was limited to black-and-white, nominally vertical photographs taken at the single, relatively large scale of 1:5500. This scale was chosen because of ready availability of photographic material, and convenience for use in conjunction with available scanning equipment.
3. Only clear, contrasty photographs, not obscured by cloud cover, were used. (It is believed, incidentally, that techniques analogous to those investigated in the subject research program could be used to automatically identify *cloud types* as observed by satellite-borne meteorological sensors.)

The theory underlying the method of automatic terrain type recognition which was investigated may be summarized as follows: Typical specimens of terrain types such as those listed above can be recognized virtually at a glance by an observer having a minimum of photo interpretational training. This instant recognition seems to be based on a combination of factors, two of the most important of which being

a) The fact that each of these terrain types has a characteristic "visual texture"; and
b) The fact that certain "terrain" types associated with cultural features are characterized by the presence of certain simple geometrical figures such as straight lines, basic straight line combinations (parallels, perpendiculars etc.), and circles.

Basic terrain types should thus be identifiable automatically if automatic visual texture measurement and automatic recognition of straight lines, etc. are possible.

The problem of automatically recognizing the presence of simple geometrical figures on an aerial photograph has been considered in detail elsewhere; it will not be discussed in this paper. In the subject study program, consideration was restricted to the problem of defining and measuring the visual texture of portions of a photograph and using this measurement as an objective basis for terrain type classification.

The visual texture of a portion of an aerial photograph seems intuitively to be determined by (a) the overall average density of the portion and (b) the mean frequency with which contrasts (i.e. local departures of the density from this average) of varying degrees occur in the portion. To measure this contrast

(*Text continued on page 129*)

* An abridged version of this paper was presented at the 1961 East Coast Conference on Aerospace and Navigational Electronics.

TABLE 1A

CONTRAST FREQUENCIES FOR FIGURE 1A

Scan	*Number of Peak Heights* $\geq x/32''$ *for* $x=$													
	15	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	1	1	1	2	2	3	3	5	5	6	8	11	12	15
2	3	3	3	4	5	6	6	7	8	9	9	12	13	14
3	2	2	2	2	2	3	3	6	7	9	9	9	11	14
4	3	4	4	4	5	7	8	9	10	12	12	13	15	15
5	1	2	2	3	3	3	6	7	11	14	15	16	16	19
6	2	2	3	3	5	5	6	7	8	9	10	12	13	13
7	0	1	1	1	2	3	5	9	9	9	10	12	12	13
8	0	1	3	4	4	5	5	5	6	7	8	10	12	14
9	1	1	2	2	2	2	2	3	4	6	6	6	9	17
10	0	0	1	2	3	4	5	5	5	5	6	7	7	7
11	0	0	0	0	1	1	2	4	4	5	8	10	10	12
12	0	0	0	0	2	4	4	5	7	8	9	11	12	15
13	0	0	0	0	2	3	5	5	7	11	12	15	17	20
14	0	0	1	3	5	7	9	14	16	18	19	19	19	20
15	0	0	0	0	1	1	4	5	6	7	9	11	13	15
16	1	1	1	2	3	5	7	8	10	12	13	14	14	15
17	0	0	1	1	1	3	4	5	5	8	11	12	15	15
18	0	0	1	3	3	3	4	4	4	5	5	7	10	16
Total	*14*	*18*	*26*	*36*	*51*	*68*	*88*	*113*	*132*	*160*	*179*	*207*	*230*	*269*
Average	*.8*	*1.0*	*1.4*	*2.0*	*2.8*	*3.8*	*4.9*	*6.3*	*7.3*	*8.9*	*9.9*	*11.5*	*12.8*	*14.9*

TABLE 1B

CONTRAST FREQUENCIES FOR FIGURE 1B

Scan	*Number of Peak Heights* $\geq x/32''$ *for* $x=$													
	15	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	1	2	2	2	2	5	6	7	8	9	9	10	13	17
2	1	1	1	2	2	2	3	4	4	5	9	10	12	15
3	0	0	0	1	1	1	3	5	5	7	8	10	11	14
4	2	4	4	4	4	4	4	4	4	4	5	5	8	8
5	2	2	2	3	3	3	6	6	6	7	8	8	11	13
6	1	1	1	1	1	3	3	5	7	7	8	11	13	16
7	0	1	1	1	1	3	3	3	3	5	6	7	9	12
8	2	2	2	2	2	2	4	6	8	8	8	8	11	13
9	2	2	2	3	3	4	5	6	6	8	8	10	12	13
10	0	0	0	2	3	3	4	6	7	8	9	11	13	15
11	1	1	1	2	2	6	7	7	7	8	8	8	11	14
12	0	0	0	1	1	2	4	5	5	7	8	12	13	14
13	0	0	0	0	1	3	3	3	4	5	7	10	10	12
14	0	0	0	2	2	2	4	4	7	8	9	10	12	17
15	1	1	2	3	4	4	6	6	6	6	6	7	7	8
16	0	0	0	0	1	1	1	3	5	6	7	8	10	16
17	1	1	2	4	4	6	6	6	7	7	9	11	14	17
18	0	0	1	3	3	5	7	8	8	8	11	11	12	15
Total	*14*	*18*	*21*	*36*	*40*	*59*	*79*	*94*	*117*	*123*	*143*	*167*	*202*	*249*
Average	*.8*	*1.0*	*1.2*	*2.0*	*2.2*	*3.3*	*4.4*	*5.2*	*6.5*	*6.8*	*7.9*	*9.3*	*11.2*	*13.8*

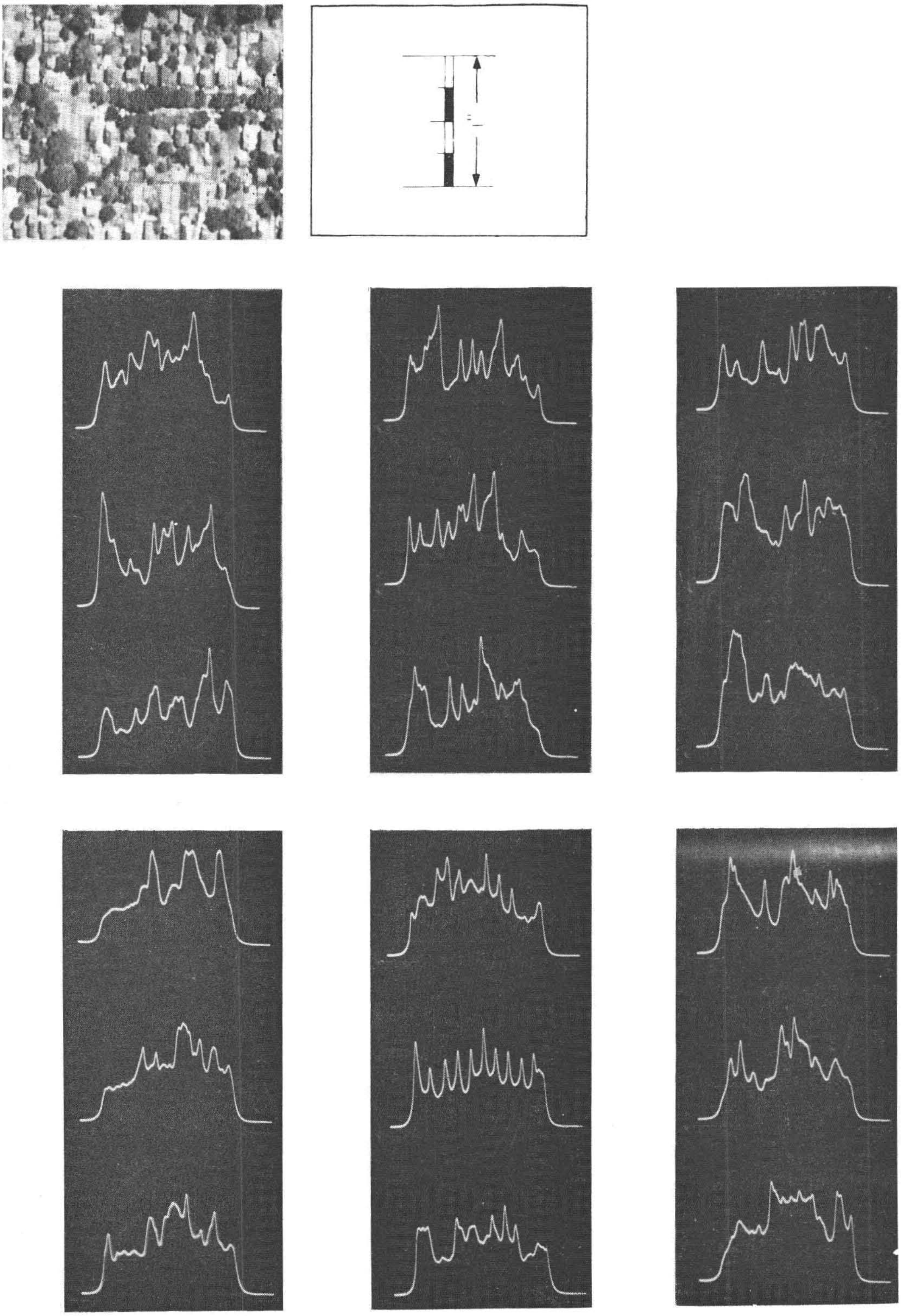

FIG. 1A. Urban residential area.

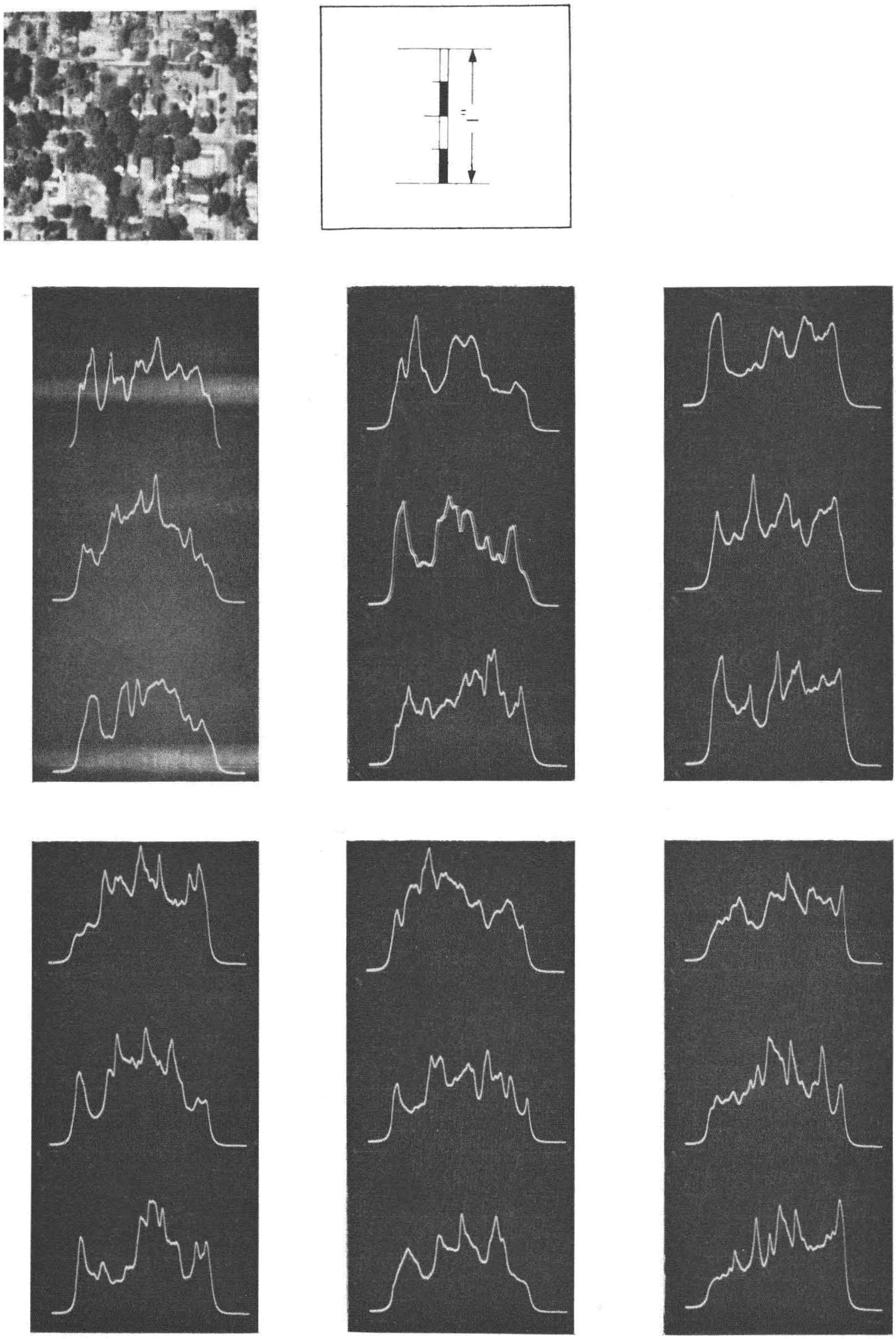

FIG. 1B. Urban residential area.

TABLE 2A

CONTRAST FREQUENCIES FOR FIGURE 2A

Scan	*Number of Peak Heights ≥ x/32″ for x =*													
	15	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	0	0	0	0	0	0	0	0	2	2	4	7	9	11
2	0	0	0	0	0	0	1	1	2	4	6	9	12	17
3	0	0	0	0	0	0	0	0	0	3	4	5	8	16
4	0	0	0	0	0	0	0	0	0	1	2	5	8	12
5	0	0	0	0	0	1	1	1	1	1	3	4	7	10
6	0	0	0	0	0	0	0	0	0	0	0	6	8	12
7	0	0	0	0	0	1	1	1	1	2	2	7	12	15
8	1	2	2	2	2	2	2	2	2	2	3	5	7	11
9	0	0	0	0	0	0	0	0	1	1	2	4	8	10
10	0	0	0	0	0	0	0	0	1	3	3	6	9	14
11	0	0	0	0	0	0	0	0	1	4	5	5	8	13
12	0	0	0	0	0	0	0	1	1	2	3	5	10	15
13	0	0	0	0	0	0	0	0	0	1	1	3	7	11
14	0	0	0	0	0	0	0	0	0	0	0	0	0	2
15	0	0	0	0	1	2	2	2	2	2	2	4	7	14
16	0	0	0	0	0	0	0	0	1	1	2	6	9	16
17	0	0	0	0	0	0	2	2	2	2	2	4	8	13
18	0	0	0	0	0	0	0	0	0	2	3	4	7	10
Total	*1*	*2*	*2*	*2*	*3*	*6*	*9*	*10*	*17*	*33*	*47*	*89*	*144*	*222*
Average	*.1*	*.1*	*.1*	*.1*	*.2*	*.3*	*.5*	*.6*	*.9*	*1.8*	*2.6*	*4.9*	*8.0*	*12.3*

TABLE 2B

CONTRAST FREQUENCIES FOR FIGURE 2B

Scan	*Number of peak heights ≥ x/32″ for x =*													
	15	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	0	0	0	0	0	2	2	3	3	4	5	8	9	20
2	0	0	0	1	1	1	4	4	7	7	7	8	11	12
3	0	0	0	0	0	1	1	3	4	6	9	11	13	17
4	0	0	1	1	1	1	2	2	2	4	6	9	11	14
5	0	0	0	0	0	0	0	0	0	2	2	3	3	9
6	0	0	0	0	0	0	0	0	2	2	2	4	9	15
7	1	1	1	1	1	1	2	2	4	4	7	10	12	20
8	0	0	0	0	1	1	1	2	3	3	4	7	9	13
9	0	0	0	1	1	2	3	4	6	8	10	10	10	11
10	0	1	1	2	3	3	3	5	5	5	6	8	12	14
11	0	0	0	0	1	1	4	4	4	4	6	10	13	17
12	0	0	0	0	0	0	0	0	0	0	3	5	9	10
13	0	0	0	0	0	0	0	0	1	1	2	6	8	12
14	0	0	1	1	1	1	1	1	3	6	8	9	13	17
15	0	0	0	0	0	0	0	0	1	1	2	2	5	11
16	0	0	0	0	0	0	0	0	1	2	2	7	11	16
17	0	0	0	0	0	0	0	1	1	3	5	6	6	9
18	0	0	0	1	1	1	1	2	2	4	6	7	8	14
Total	*1*	*2*	*4*	*8*	*11*	*15*	*24*	*33*	*49*	*66*	*92*	*130*	*172*	*251*
Average	*.1*	*.1*	*.2*	*.4*	*.6*	*.8*	*1.3*	*1.8*	*2.7*	*3.7*	*5.1*	*7.2*	*9.6*	*13.9*

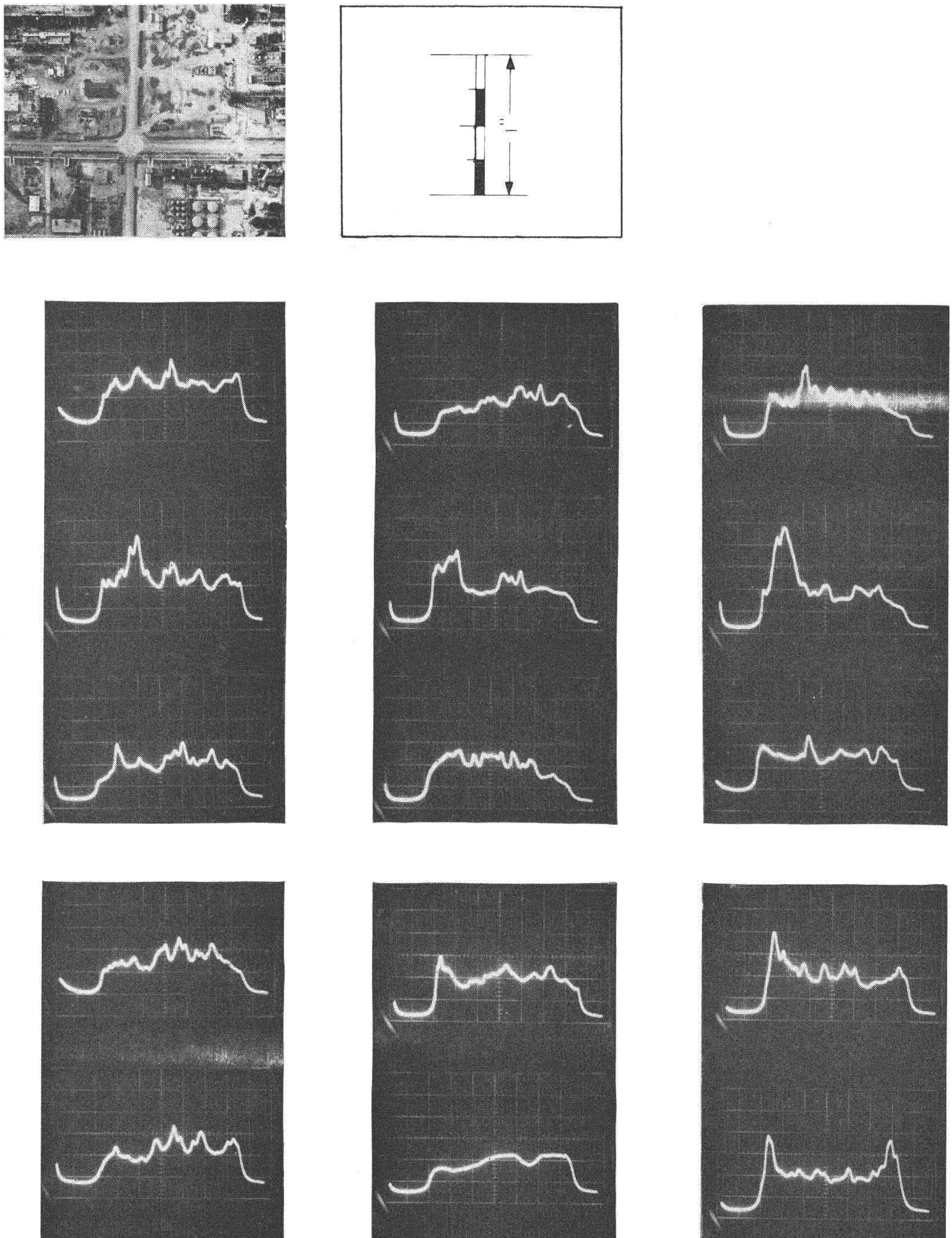

FIG. 2A. Industrial area.

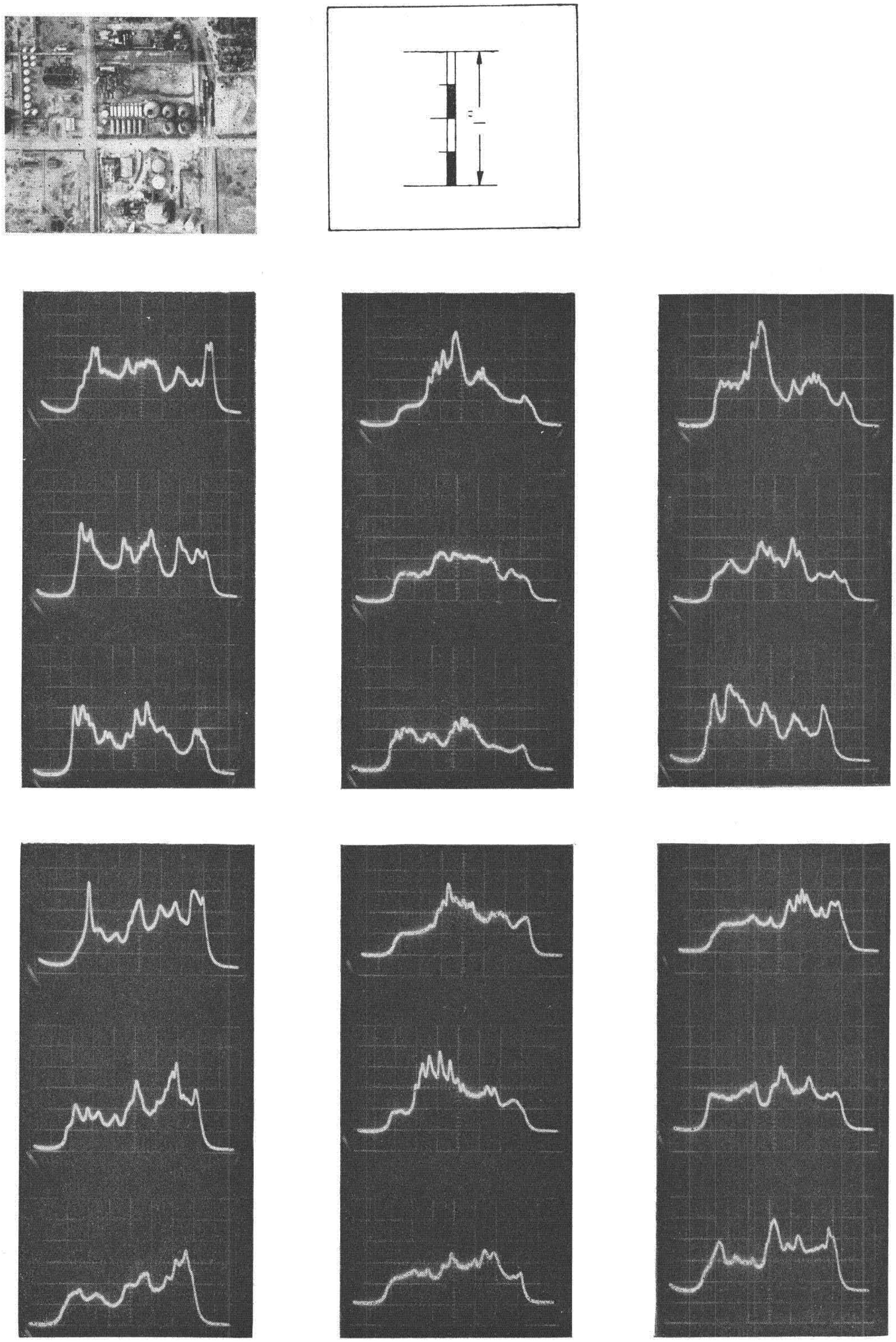

FIG. 2B. Industrial area.

TABLE 3A

CONTRAST FREQUENCIES FOR FIGURE 3A

Scan	Number of peak heights ≥x/32″ for x=													
	15	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	0	0	0	0	0	0	0	0	0	1	3	6	9	15
2	0	0	0	0	0	0	0	1	3	5	5	6	9	16
3	0	0	0	0	0	0	0	3	4	5	8	8	12	17
4	0	0	0	0	2	3	4	4	4	4	4	5	7	12
5	0	0	0	0	2	2	2	3	3	4	7	8	10	16
6	0	0	0	0	0	1	2	3	3	3	3	5	8	15
7	0	0	0	0	1	1	1	1	2	4	4	6	10	19
8	0	0	0	0	0	1	1	2	2	3	4	6	7	13
9	0	0	0	0	0	0	0	0	0	4	6	9	11	19
10	0	0	0	0	0	0	0	0	1	2	2	4	6	14
11	0	0	0	0	0	0	0	1	1	2	5	6	8	14
12	0	0	0	0	0	1	1	2	3	5	6	6	9	12
13	0	0	0	0	0	0	0	0	2	2	2	4	8	16
14	0	0	0	0	0	0	0	1	2	4	5	8	9	15
15	0	0	0	0	0	0	0	2	2	2	3	5	9	16
16	0	0	0	0	2	2	2	2	2	3	5	6	11	20
17	0	0	0	0	0	1	1	3	3	4	4	5	7	14
18	0	0	0	0	0	0	0	0	0	0	1	3	5	13
Total	*0*	*0*	*0*	*0*	*7*	*12*	*14*	*28*	*37*	*57*	*77*	*106*	*155*	*276*
Average	*0*	*0*	*0*	*0*	*.4*	*.7*	*.8*	*1.6*	*2.1*	*3.2*	*4.3*	*5.9*	*8.6*	*15.3*

TABLE 3B

CONTRAST FREQUENCIES FOR FIGURE 3B

Scan	Number of peak heights ≥x/32″ for x=													
	15	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	0	0	0	0	0	0	0	0	2	2	5	7	9	19
2	0	0	0	0	0	0	0	0	0	1	4	5	8	16
3	0	0	0	0	0	0	0	0	0	0	1	2	3	10
4	0	0	0	0	0	0	0	0	0	0	3	6	8	18
5	0	0	0	0	0	0	2	2	2	2	4	8	9	14
6	0	0	0	0	0	0	0	0	0	2	3	4	8	12
7	0	0	0	0	0	0	0	0	0	2	4	7	9	17
8	0	0	0	0	0	0	0	0	1	1	3	7	13	20
9	0	0	0	0	0	0	0	0	1	1	4	6	7	15
10	0	0	0	0	0	0	0	1	1	2	4	5	7	17
11	0	0	0	0	0	0	0	1	2	4	5	7	9	14
12	0	0	0	0	0	0	0	0	0	1	1	3	6	15
13	0	0	0	0	0	0	0	0	0	0	0	0	4	14
14	0	0	0	0	0	0	0	0	0	0	1	1	7	14
15	0	0	0	0	0	0	0	0	0	1	3	4	8	17
16	0	0	0	2	2	2	2	2	2	4	6	7	11	19
17	0	0	0	0	0	0	0	0	0	0	3	7	12	19
18	0	0	0	0	0	0	0	0	0	0	1	3	9	17
Total	*0*	*0*	*0*	*2*	*2*	*2*	*4*	*6*	*11*	*23*	*55*	*89*	*147*	*287*
Average	*0*	*0*	*0*	*.1*	*.1*	*.1*	*.2*	*.3*	*.6*	*1.3*	*3.1*	*4.9*	*8.2*	*15.9*

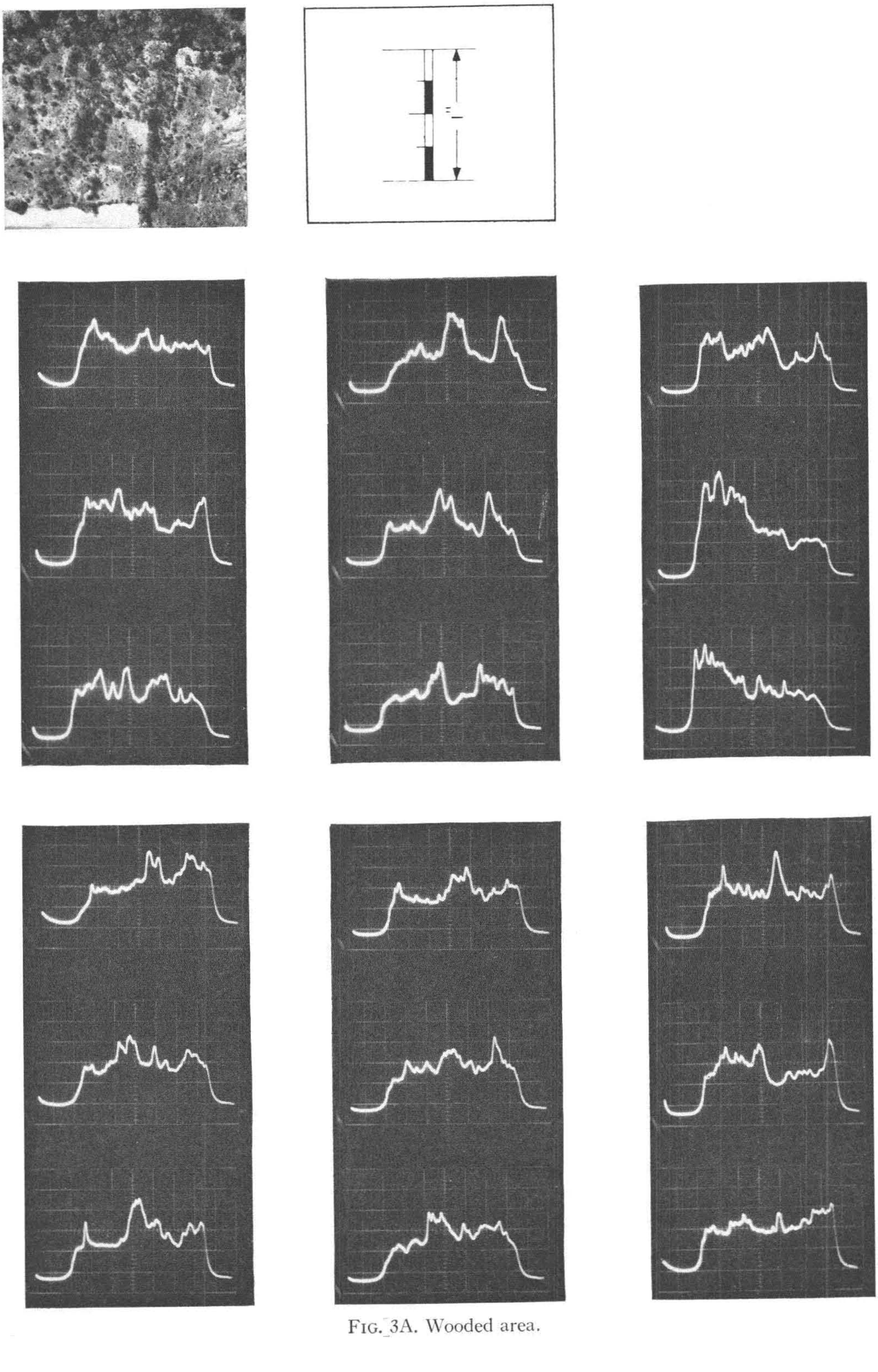

FIG. 3A. Wooded area.

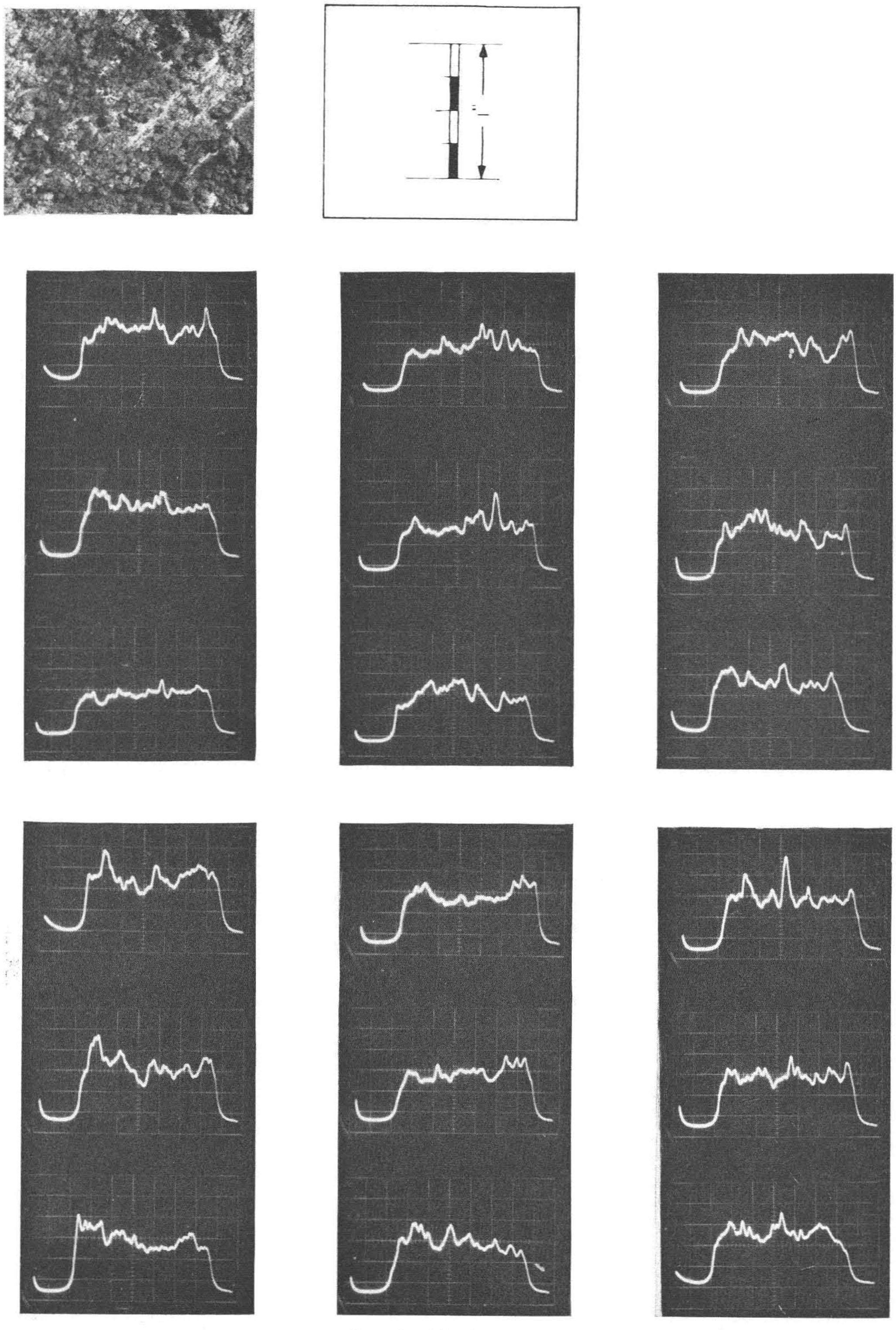

FIG. 3B. Wooded area.

TABLE 4A

CONTRAST FREQUENCIES FOR FIGURE 4A

	Number of peak heights ≥ x/32″ for x =													
Scan	*15*	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	0	0	0	0	0	0	0	0	0	2	2	2	3	7
2	0	0	0	0	0	0	0	1	3	3	5	7	7	10
3	0	0	0	0	0	0	0	0	1	2	3	5	7	9
4	0	0	0	0	0	0	0	0	0	0	2	2	5	7
5	0	0	0	0	0	0	0	0	0	0	0	1	4	6
6	0	0	1	1	1	2	2	2	3	3	3	3	5	10
7	0	0	0	0	0	0	1	1	2	3	3	4	6	10
8	0	0	0	0	0	0	1	2	3	3	5	5	6	12
9	0	0	0	0	0	0	2	2	2	3	4	4	4	10
10	0	0	0	0	0	0	0	0	2	2	3	4	5	12
11	0	0	0	0	0	0	0	0	1	3	3	4	6	10
12	0	0	0	0	0	0	0	3	3	4	4	5	8	11
13	0	0	0	0	0	0	1	1	1	2	2	5	6	9
14	0	0	0	0	0	0	0	0	1	1	1	2	7	10
15	0	0	0	0	0	0	0	3	3	3	3	4	6	7
16	0	0	0	0	0	0	1	1	2	5	5	6	6	8
17	0	0	0	0	1	1	1	1	2	4	6	8	9	16
18	0	0	0	0	0	1	1	1	3	6	6	6	8	9
Total	*0*	*0*	*1*	*1*	*2*	*4*	*10*	*18*	*32*	*49*	*60*	*77*	*108*	*173*
Average	*0*	*0*	*.1*	*.1*	*.1*	*.2*	*.6*	*1.0*	*1.8*	*2.7*	*3.3*	*4.3*	*6.0*	*9.6*

TABLE 4B

CONTRAST FREQUENCIES FOR FIGURE 4B

Scan	*Number of peak heights ≥ x/32″ for x =*													
	15	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*
1	0	0	0	0	0	1	1	1	1	1	1	1	2	10
2	0	0	0	1	1	1	1	1	1	1	1	1	1	9
3	0	0	0	1	1	2	2	2	2	2	4	6	7	11
4	0	1	1	1	1	1	1	2	2	2	2	3	4	6
5	1	1	1	1	1	1	1	1	1	2	2	2	5	7
6	1	1	1	1	1	1	1	1	2	2	2	3	5	8
7	0	0	0	0	0	1	1	1	1	1	1	2	3	6
8	0	0	0	1	1	1	1	1	1	2	3	5	6	10
9	0	0	0	0	0	1	1	1	1	1	2	2	2	7
10	0	1	1	1	1	1	1	1	1	2	2	3	3	8
11	0	1	1	1	2	2	2	2	2	2	2	2	5	8
12	1	1	1	1	1	1	2	2	2	4	4	4	6	7
13	0	1	1	1	1	1	1	1	2	2	3	4	7	10
14	0	0	0	0	0	1	1	2	2	3	4	4	4	6
15	0	0	0	0	1	1	1	1	2	2	2	3	4	9
16	0	0	0	0	0	0	0	1	1	1	1	1	3	9
17	0	0	1	2	2	2	2	3	3	3	5	5	8	10
18	0	0	0	1	1	1	1	1	1	1	1	1	3	7
Total	*3*	*7*	*8*	*13*	*15*	*20*	*21*	*25*	*28*	*34*	*42*	*52*	*78*	*148*
Average	*.2*	*.4*	*.4*	*.7*	*.8*	*1.1*	*1.2*	*1.4*	*1.6*	*1.9*	*2.3*	*2.9*	*4.3*	*8.2*

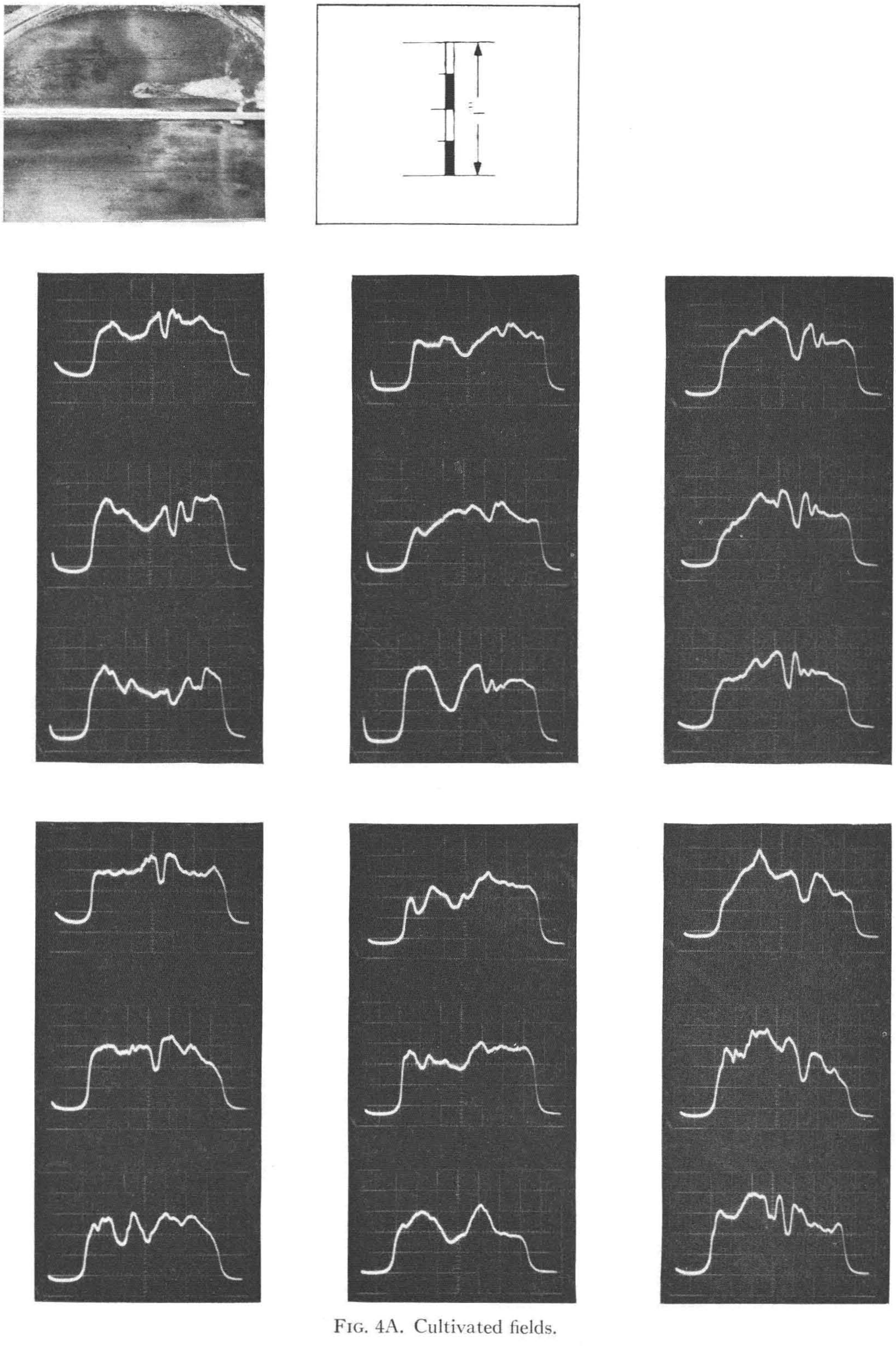

FIG. 4A. Cultivated fields.

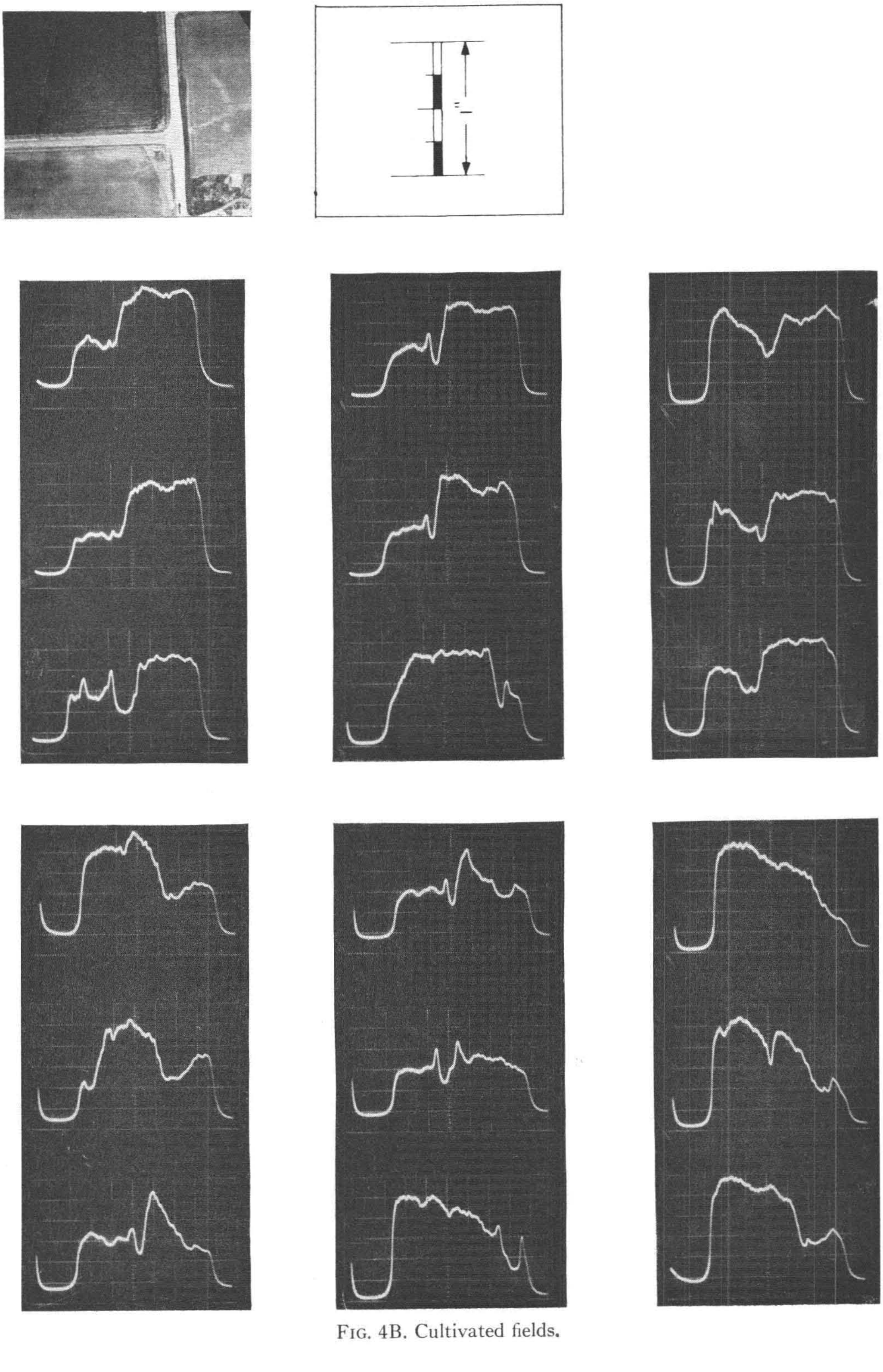

FIG. 4B. Cultivated fields.

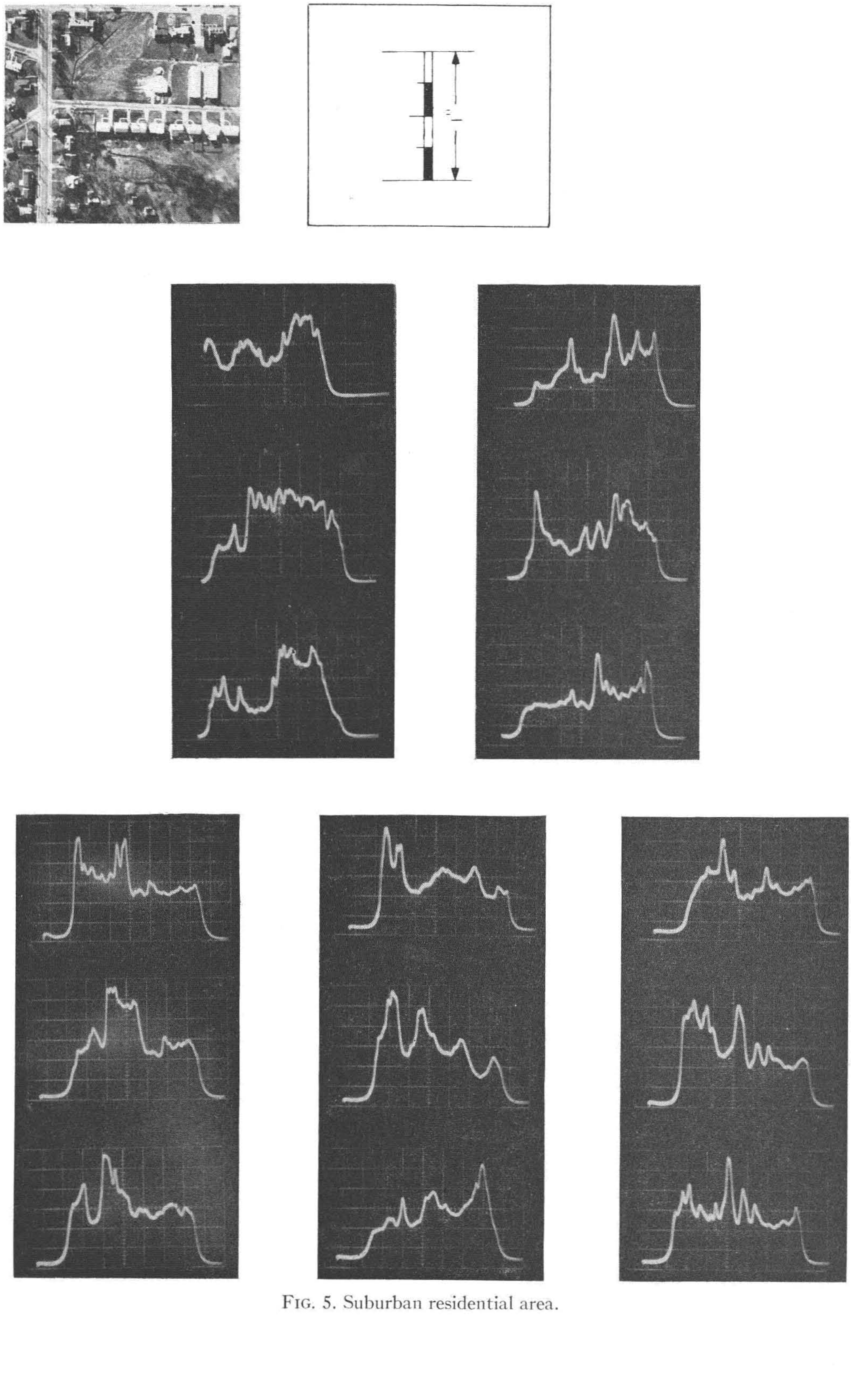

FIG. 5. Suburban residential area.

TABLE 5

CONTRAST FREQUENCIES FOR FIGURE 5

Scan	Number of peak heights $\geq x/32''$ for $x=$													
	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	0	0	0	0	0	0	0	3	3	5	5	8	11	15
2	1	1	1	1	1	1	2	2	4	6	8	14	18	20
3	1	1	1	1	1	1	3	4	5	5	10	11	14	18
4	1	1	2	2	2	2	3	4	5	6	7	9	11	14
5	1	2	2	2	3	3	3	3	6	9	10	12	13	18
6	0	1	1	1	1	1	2	3	3	3	5	9	11	18
7	1	1	1	1	1	1	1	3	4	5	5	5	8	17
8	1	1	1	2	2	2	2	2	2	2	6	9	10	17
9	1	1	1	1	1	2	2	2	3	4	5	8	11	15
10	0	0	0	1	1	2	2	2	2	3	5	6	10	16
11	0	1	1	3	3	5	5	5	5	5	6	7	9	11
12	0	0	0	0	0	0	1	1	3	4	6	5	9	12
13	0	0	0	0	1	2	3	3	4	5	6	6	9	15
14	1	1	2	2	2	3	3	4	4	6	9	10	11	14
15	2	2	2	2	2	2	4	5	5	7	11	12	16	20
Total	*10*	*13*	*15*	*19*	*21*	*27*	*36*	*46*	*58*	*75*	*104*	*132*	*171*	*240*
Average	*.7*	*.9*	*1.0*	*1.3*	*1.4*	*1.8*	*2.4*	*3.1*	*3.9*	*5.0*	*6.9*	*8.8*	*11.4*	*16.0*

frequency, it is convenient to scan the photograph and to convert the density information which it contains into a time varying video signal. The visual texture of the photograph can then be computed by performing operations of differentiation, level slicing, and averaging on the video data. Specifically, differentiation can be used to convert contrasts of varying degrees into peaks of varying heights. Level slicing and averaging can then be applied to determine the average number of peaks of approximately a given height per unit area of the photograph.

In the subject program, it was decided for simplicity to work with the raw video information, without further electronic processing, and to extract texture information manually by working with oscilloscope photographs of video traces. To implement this, portions of aerial photographs were scanned by a flying spot scanner and the video trace corresponding to each scan line was displayed and photographed. This was done for an assortment of line scans crossing the photographs at various locations and in various directions. For each of the resulting video traces, the slant heights of all peaks which were steeper than a preset value were measured, and the numbers of spacial peaks having heights in various ranges were recorded. It can be seen that this procedure yields a crude measure of the number of sharp contrasts (=steep peaks) of various

TABLE 6

CONTRAST FREQUENCIES FOR FIGURE 6

Scan	Number of peak heights $\geq x/32''$ for $x=$													
	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	0	0	0	0	0	0	0	0	0	0	0	0	0	6
2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
3	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Total	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*19*
Average	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*6.3*

degrees of density difference (=various height ranges) along the line scan. If these measurements are averaged for a sufficiently large number of scans covering a portion of a photograph, the result is a measure of the mean contrast frequency of the portion.

The process just described was carried out for assorted portions of aerial photographs showing essentially "uniformly textured" regions of terrain. Two specimens each of the following terrain types were used: urban residential, industrial, woods, and cultivated fields. Each sample was scanned along eighteen lines running in different directions. In addition, samples showing a suburban residential area and a body of water were tested. The samples used, and the corresponding video traces, are shown in Figures 1–6. To facilitate comparison, all of the samples used were selected from two aerial photographs having substantially equal exposures and approximately equal ground shadow effects.

The peaks on the video traces having upward or downward slopes steeper than 60° from the horizontal, and having slant heights greater than $\frac{1}{16}''$, were measured and tabulated manually. Tables 1–6 show the numbers of peak heights $\geq x$, for $x=\frac{2}{32}, \frac{3}{32}, \ldots, \frac{15}{32}''$, for each of the video traces of Figures 1–6. Composite averages for each of the terrain types are compared in the graph in Figure 7. Reference to this graph suggests that:

a) Urban residential areas have characteristically high-contrast frequencies at all contrast levels;
b) Cultivated fields have characteristically low frequencies of relatively low contrasts;
c) Industrial areas and woods have remarkably similar contrast frequency spectra, generally intermediate between those of residential areas and cultivated fields;
d) Suburban residential areas appear to be intermediate between woods/industrial areas and residential areas (this conclusion, however, is based on a small data sample and should not be regarded as definitive); and
e) Areas of water are characteristically free of significant contrast.

The numerical data shown in the Tables were also subjected to simple statistical analyses. Selected standard deviations, for the contrast frequencies corresponding to $x=\frac{9}{32}, \frac{7}{32}, \frac{5}{32}$, and $\frac{3}{32}''$, were computed for those cases in which two samples of a terrain type were tested. These standard deviations, together with the corresponding sample averages and

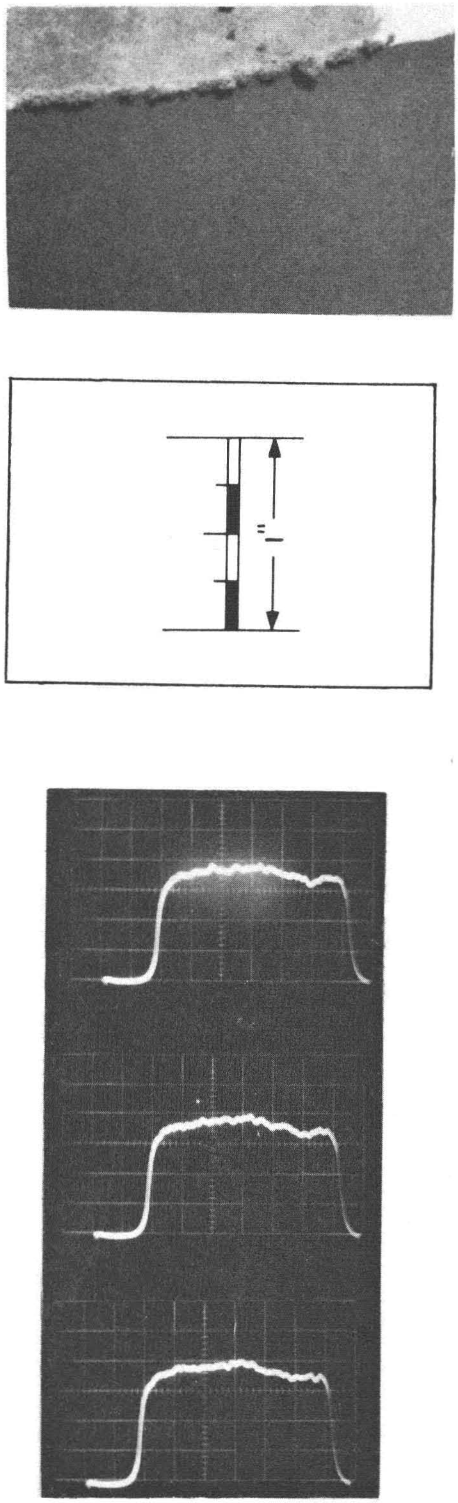

FIG. 6. Body of water (land at top of picture not scanned).

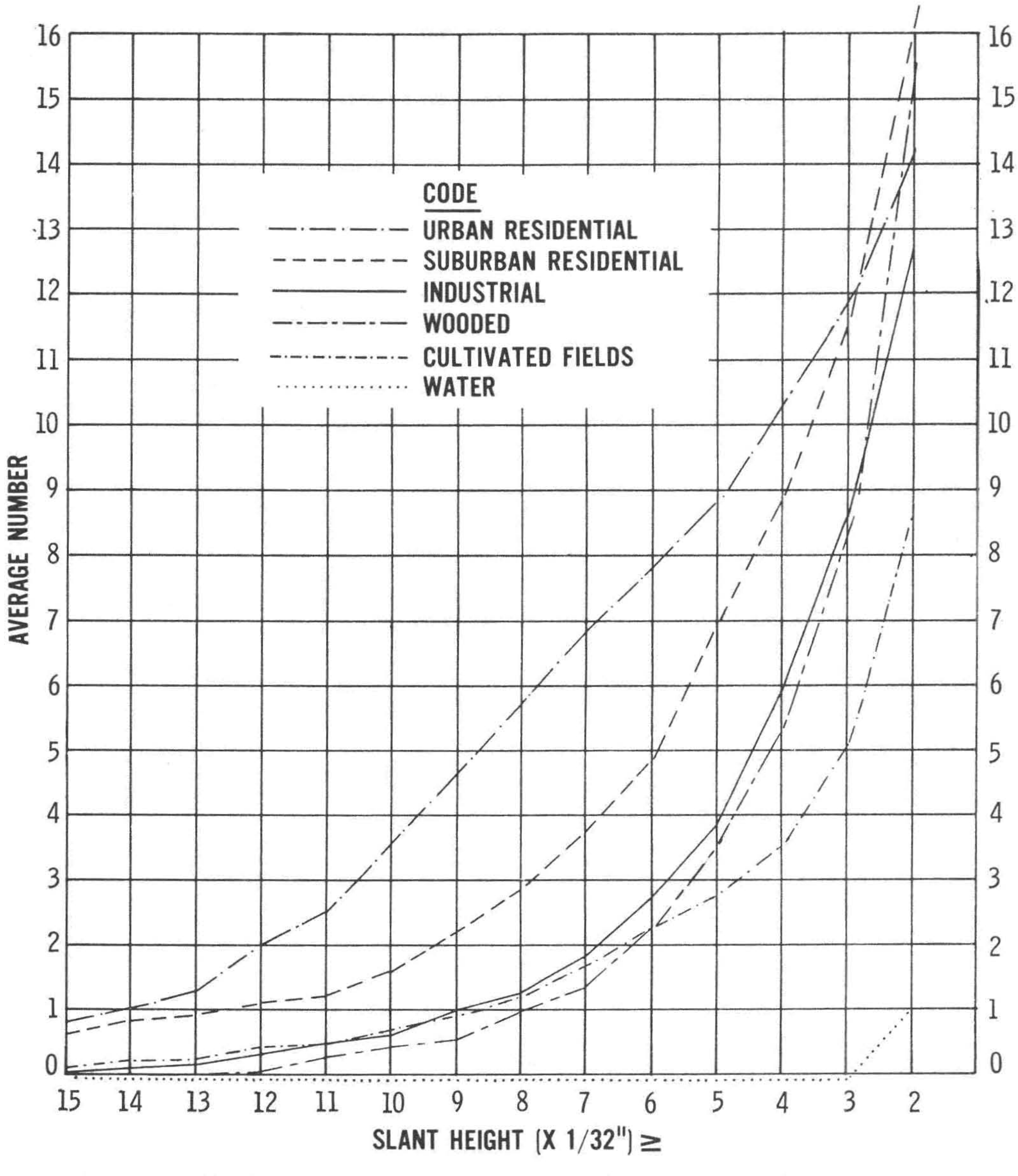

FIG. 7. Composite average curves for various types of terrain.

(*See page 132 for Table 7*)

composite averages, are shown in Table 7. It is seen that the sample averages lie consistently within one sigma of the composite average, and usually considerably closer. On the other hand, the composite averages are well over a sigma apart in portions of the contrast frequency curves described above as "characteristic."

The results just described suggest that it should be possible, by measurement of visual texture, to automatically identify certain basic terrain types, such as urban residential areas, cultivated fields, and hydrographic features, appearing on aerial photographs. Certain other types, on the other hand, do not seem to be automatically identifiable by texture measurement alone. For example, the identification of a portion of an aerial photograph as showing woods or an industrial area would have to involve something beyond

TABLE 7

SELECTED STANDARD DEVIATIONS

Figure	*Datum*	*Contrast magnitude*			
		≥9	≥7	≥5	≥3
1A–B	Composite average	4.7	6.9	8.9	12.0
1A–B	Standard deviation	1.7	2.4	2.5	2.4
1A	Average	4.9	7.3	9.9	12.8
1B	Average	4.4	6.5	7.9	11.2
2A–B	Composite average	.9	1.8	3.9	8.8
2A–B	Standard deviation	1.1	1.5	2.1	2.6
2A	Average	.5	.9	2.6	8.0
2B	Average	1.3	2.7	5.1	9.6
3A–B	Composite average	.5	1.4	3.7	8.4
3A–B	Standard deviation	.9	1.0	1.7	2.1
3A	Average	.8	2.0	4.3	8.6
3B	Average	.2	.6	3.1	8.2
4A–B	Composite average	.9	1.7	2.8	5.2
4A–B	Standard deviation	.6	.9	1.4	1.7
4A	Average	.6	1.8	3.3	6.0
4B	Average	1.2	1.6	2.3	4.3

simple texture determination, perhaps the automatic recognition of the presence or absence of straight lines. In addition, there will inevitably be "intermediate" terrain types (suburban residential areas, for instance) which yield an ambiguous range of measured textures; ambiguity will also be encountered at points where different terrain types adjoin. However, there is no doubt that considerable useful information about the content of an aerial photograph can be obtained by a process of visual texture measurement similar to that described in this paper. Such a process can thus constitute an important part of an automatic photointerpretation system.

Some subsidiary questions which should be investigated, now that the basic utility of automatic visual texture measurement has been confirmed, are:

a) The effects of such factors as gamma, scale, tilt, and resolution on texture measurements.
b) The effects of cloud cover, haze, shadows seasonal changes, etc., on characteristic terrain textures.

The possibility of applying texture measurement techniques to the automatic interpretation of, e.g., radar scope photographs also deserves serious consideration.

Many of the foregoing results are of a relatively "obvious" variety. (Perhaps the least expected of them was the negative result that woods and industrial areas have highly similar contrast frequency spectra.) The significance of the subject investigation lies not so much in its having yielded novel or unexpected results as in the fact that it confirms the possibility of objectively measuring the visual texture of aerial photographs in a very simple way. It is planned, now that the feasibility of this simple texture measurement technique has been confirmed, to undertake further studies in which the technique is applied to the simulation of more realistic tasks of automatic photo interpretation.