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Studies of Decontamination Effectiveness

by

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ABSTRACT

This report examines, by theory and by analysis of real structures, the reductions in intensity inside and outside NFSS buildings that can be brought about by decontaminating the accessible surfaces on and around the buildings. Specifically the report presents the theory and applies the theory to nine different NFSS buildings in order to:

1. Determine the intensity reductions that can be achieved by decontamination methods applied to practical situations involving real physical structures.
2. Determine the intensity reductions that can be achieved when the detector is located inside a structure and when the detector is located outside the structure.
3. Determine the decontamination costs (equipment, water expended, radiation dose received by the decontamination crews) in achieving the intensity reductions.
4. Determine the sensitivity of the achieved intensity reduction to the cleaning efficiency of the decontamination operation (and, therefore, to the type of decontamination method).
5. Determine the relative importance of the various surfaces (roofs, paved roads, parking lots, etc.) that can be decontaminated to the intensity reduction that can be achieved.

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I. INTRODUCTION

A. Objectives

As a radiological countermeasure, decontamination can be employed to achieve one or more different operational objectives. For example, it may be used to accelerate the re-entry and recovery of a contaminated building or building complex. It may be used to reduce the radiation hazard associated with a continuing operation such as a power station or communication link. It may be used to reduce the radiation dose associated with a change in operations, such as H+2 week shelter emergence. In each of these applications and others that may arise, decontamination achieves the objective by removing fallout material and thus reducing the radiation intensity in the neighboring space. The degree to which a particular operational objective is achieved, depends on the effectiveness with which decontamination reduces the intensity. This in turn depends on the amount of fallout material removed from specific contaminated planes as a result of decontaminating those planes, and on the importance of each plane as a contributor to the intensity at the point where the intensity reduction is measured or desired.

This report examines the reduction in intensity that is achieved in a variety of circumstances as a function of the manner in which planes are decontaminated and of the importance of each plane to the intensity at the detector location. In particular, the analyses are formulated to accomplish the following primary objectives:

1. Determine the intensity reductions that can be achieved by decontamination methods applied to practical situations involving

real physical structures.

2. Determine the intensity reductions that can be achieved when the detector is located inside a structure and when the detector is located outside the structure.

3. Determine the decontamination costs (equipment, water expended, radiation dose received by the decontamination crews) in achieving the intensity reductions.

4. Determine the sensitivity of the achieved intensity reduction to the cleaning efficiency of the decontamination operation (and, therefore, to the type of decontamination method).

5. Determine the relative importance of the various surfaces (roofs, paved roads, parking lots, etc.) that can be decontaminated to the intensity reduction that can be achieved.

To accomplish the above objectives, ten situations were analyzed. Each analysis forms the basis of one of the ten subsequent chapters. Nine analyses, Chapters II through X, investigate the effect on the intensity reduction inside and outside existing NFSS shelters of decontaminating the various accessible contaminated areas in, on, and around the shelter structure. The tenth analysis, Chapter XI, is a parametric study that investigates the height, width, and length effects on the intensity reduction of decontaminating a variety of contiguous contaminated planes.

All analyses are formulated so that the effect of decontaminating any subset of the accessible areas (roofs, street segments, parking lots, etc.) with any level of decontamination effort may be determined quickly and easily. Although the analyses assume a uniform distribution of fallout material, a method by which the results can be modified (or interpreted) for the situation involving non-uniform distribution, is also presented (Chapter I, Section F).

B. Decontamination Data

Decontamination efforts are applied to relevant contaminated surfaces and the fallout material removed is estimated using the information developed at USNRDL (References 1, 2, 4, and 5) and Curtiss-Wright (Reference 6). The decontamination effort is measured in terms of the resources required to decontaminate, to a given level, a specified area (square feet) of a specified material (asphalt, concrete, tar paper, ground, etc.). The resources employed are specified by describing:

(1) The type of equipment used (street flushers, firehoses, etc.);

(2) The number and capabilities of working personnel required;

(3) The quantity of resources expended (gallons of water);

(4) The time required for the decontamination activity; and,

(5) The radiation dose received by the decontamination crew members

This specification is restricted to the actual decontaminating activity and hence does not include such items as:

(1) The time required to transport people and equipment to and from the site;

(2) Resources required for the above transportation;

(3) Requisite coordinating command and control activities such as radiological monitoring; and,

(4) When appropriate, additional resources required to transport the collected fallout material away from the decontaminated site.

In general, when decontaminating a specified structure, three types of surfaces are investigated. First, the roof of the structure itself is decontaminated using firehose teams. This effort normally requires a seven man team working .1 to .4 hours per thousand square feet to remove 90 to 98 per cent of the fallout material deposited on the roof (Reference 6). Second, the paved ground surfaces (roads, parking lots, and playgrounds) adjacent to the structure are decontaminated. In this case various methods including firehose teams, street flushers, mechanical sweepers and vacuum sweepers are employed. When equipment other than firehoses is used, it normally requires a one man team working .01 to .04 hours per thousand square feet to remove 90 to 98 per cent of the fallout material deposited on the surface (Reference 6). Third, when appropriate, the roofs of adjacent buildings are decontaminated using firehose teams. For each surface, the actual methods employed, times required, and material removed are specified in each study.

C. <u>Structures Analyzed</u>

As stated earlier, one purpose of this report is to apply decontamination efforts and efficiencies to real physical structures and estimate the intensity reductions that can be accomplished in practical situations. To accomplish this, nine structures were selected from a study of NFSS buildings where methods and accuracies of computing the building protection factors (PF) are analyzed and compared (Reference 3). The structures[1/] selected are:

Chapter II	Six Story Apartment Building 81 West 182nd Street Bronx, N.Y.C.

[1/] The majority of structures considered have protection factors (PF) greater than 40. Because the intensity reduction depends on the shape of the structures and the mass thickness (psf) of walls and roofs, relative to one another, the structure PF can be decreased by appropriately decreasing the psf's of the walls and roofs without changing the intensity reduction factors. This is solely a paper exercise and is pointed out to indicate that the PF's of the structures analyzed are of minor interest and do not restrict the range of application of the analysis data.

Chapter III	Six Story Apartment Building 362 West 52nd Street Manhattan, N.Y.C.
Chapter IV	Twenty-one Story Office Building 310 Park Avenue Manhattan, N.Y.C.
Chapter V	General Dyestuff Corporation Building 435 Hudson Street Manhattan, N.Y.C.
Chapter VI	High School Gymnasium Bennett Street Boston, Massachusetts
Chapter VII	Simonds Press Building 37-49 South Avenue Rochester, New York
Chapter VIII	Department of Interior Building 18th and C Streets, N. W. Washington, D. C.
Chapter IX	Three Story Department Store Building 619 Main Street Houston, Texas
Chapter X	Bell Telephone Building 1010 Pine Street St. Louis, Missouri

In addition to the above structures, a tenth structure,

Chapter XI	Five Story Parametric Study Building Fictitious Location,

is included to examine, in a controlled parametric manner, the effect on the intensity reduction of certain factors such as:

(1) The mass thickness (psf) of interior partitions;

(2) The roof heights of adjacent buildings:

(3) The floor on which the detector is located;

(4) The width of all adjacent streets;

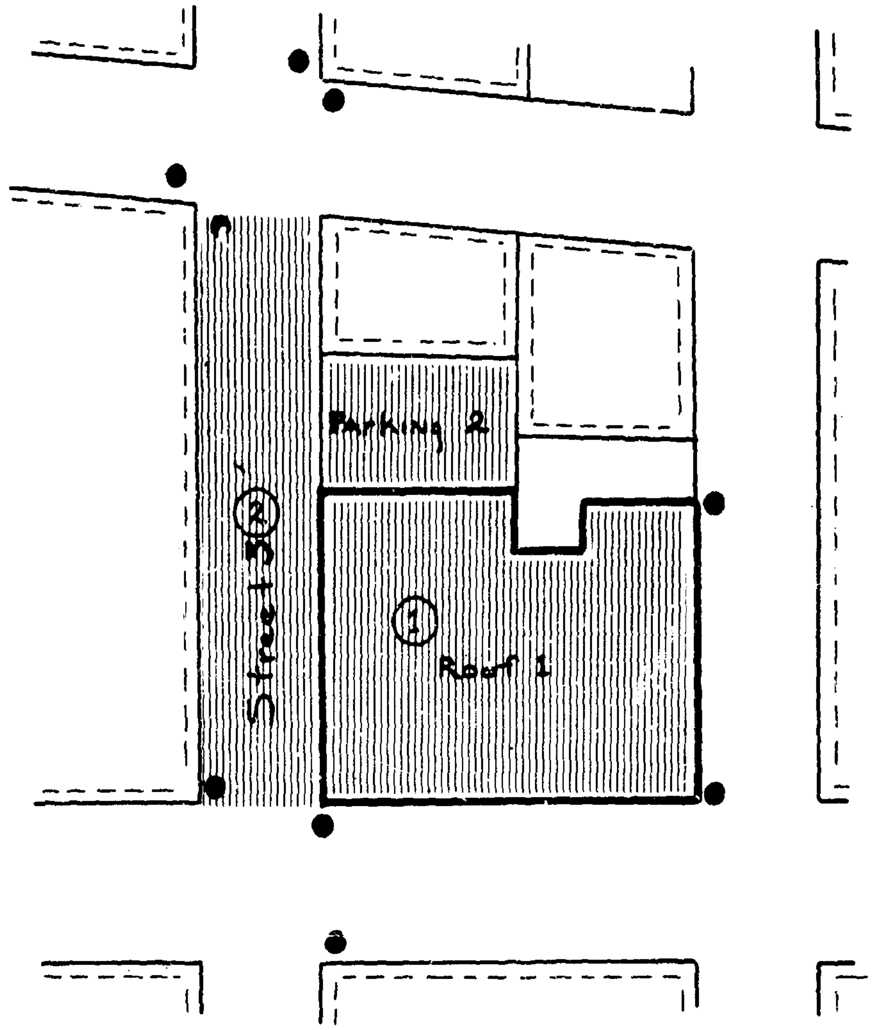
(5) The solid angle subtended by the apertures; and,

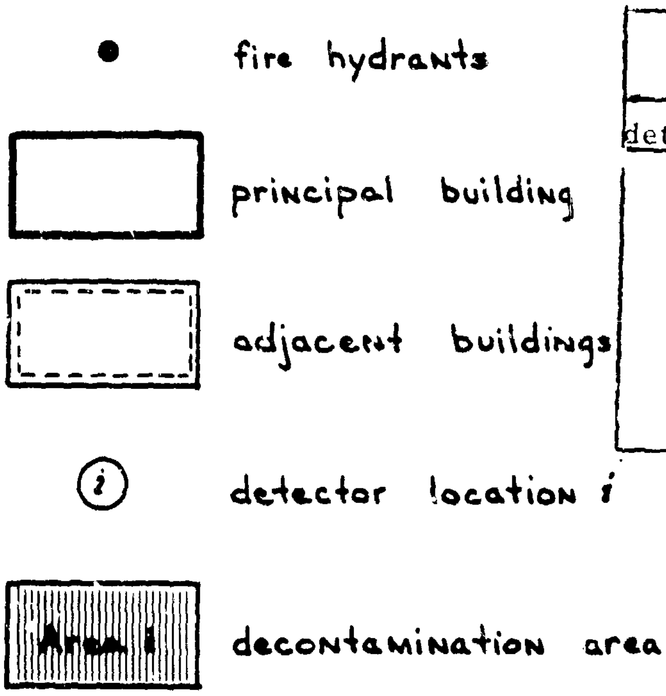
(6) The mass thickness (psf) of the exterior walls.

In this parametric study, and also in Chapters II, VII, and VIII, the intensity reduction is studied first with the detector located inside the structure and second with the detector located at various positions outside the structure. When the detector is located at ground level outside the structure it is interesting to note that no intensity contribution is received from contaminated roofs of the surrounding structures. This characteristic (from Reference 7) is not expected to be valid when the surrounding structures have low PF's (such as might be encountered in analyzing a shopping center).

D. Intensity Reduction Calculation

The determination of intensity reduction brought about by decontamination efforts involves the use of several terms (or definitions) whose meaning should be clarified before entering into the individual analyses. These terms will be developed and explained using a hypothetical example whose layout is presented in Figure 1-1. The structure of interest occupies one half of a city block and has paved surfaces (roads and parking lots) on all four sides. Two detector locations will be considered: number 1 location is inside the structure and number 2 location is outside the structure in the center of an adjacent street. The effect of decontaminating three surfaces -- a roof, a parking lot, and a street segment (numbers 1, 2 and 3 respectively) -- on the intensity at the two detector locations will be determined. To determine the intensity reductions, it is necessary to obtain certain numerical factors. In Chapters II through XI, the necessary factors are calculated using the analytical methods presented in the OCD engineering manual, (Reference 7). In the following discussion, the intent is to explain the necessary terms and methodology. Therefore elaborate calculations will be avoided and, where necessary, the appropriate numerical factors will be assigned values rather than calculated.





Ideal Intensity Reduction Factors	
detector location 2	detector location 1
$f^*_{1,2} = 1.0$	$f^*_{1,1} = .70$
$f^*_{2,2} = .92$	$f^*_{2,1} = .88$
$f^*_{3,2} = .13$	$f^*_{3,1} = .75$
$F^*_2 = .05$	$F^*_1 = .33$

FIGURE 1-1. Location Map of Decontamination Areas

EXAMPLE

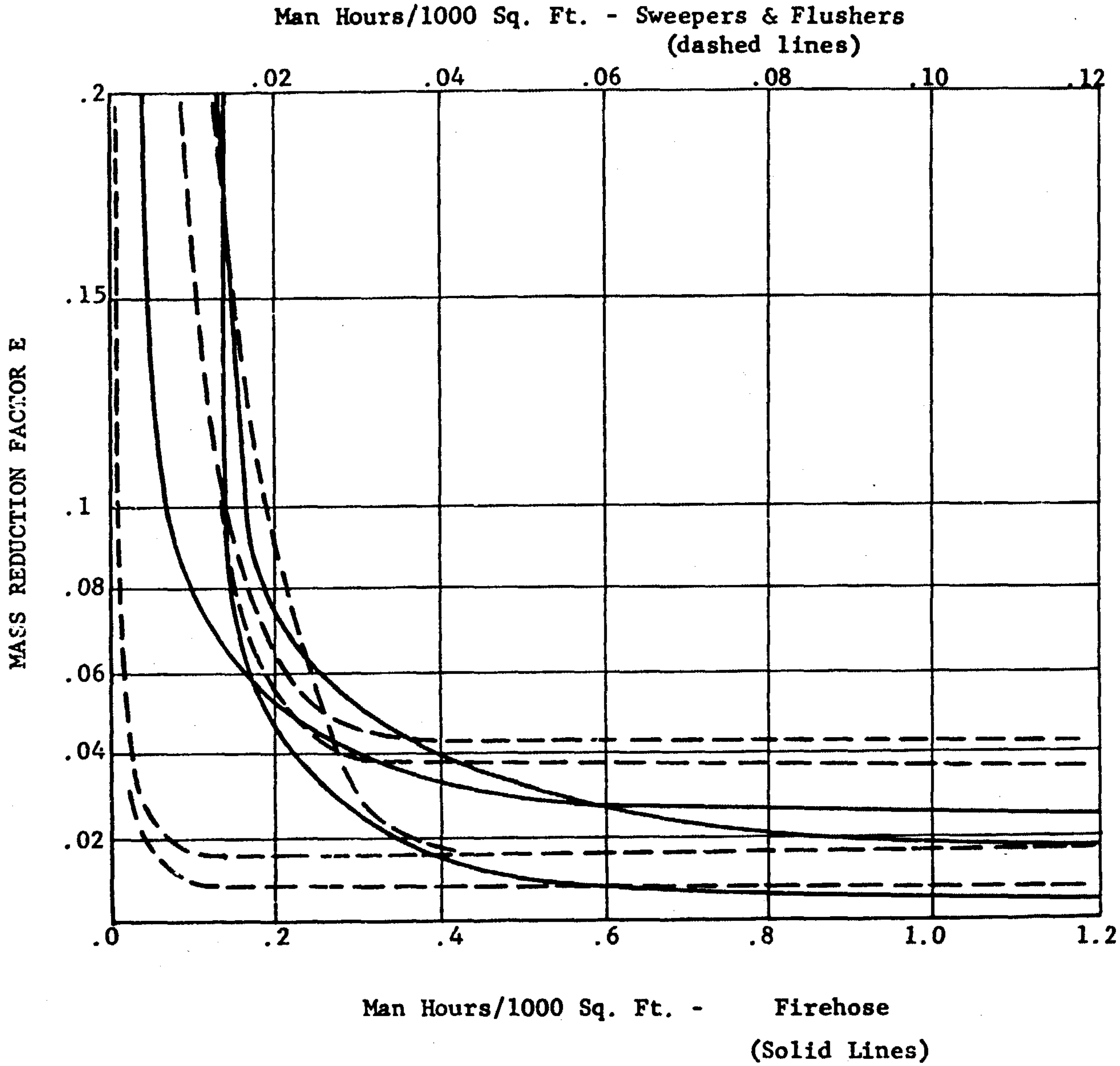
The first factor to consider in an analysis is the extent to which a contaminated surface is cleaned. When decontamination resources are applied to a specified area, the effect of the effort is measured by the achieved reduction in residual mass level of fallout material. This effect is specified by the fraction of the fallout material deposited on the area that remains on the area after the decontamination operation is completed. Each surface decontaminated will have an associated fraction. The i^{th} fraction, associated with the i^{th} area, is called the <u>mass reduction factor, E_i</u>, of the i^{th} area. It is defined as follows:

$$E_i = \frac{m_i^a}{m_i} , \qquad (1)$$

where m_i = residual mass deposited on the i^{th} area, and m_i^a = residual mass remaining on the i^{th} area after the area has been decontaminated. Both m_i and m_i^a are assumed to be uniformly distributed over the surface of interest.

If decontamination is not performed, or if no material is removed during the decontamination operation, then $E_i = 1$. If all of the fallout material is removed in the process, then $E_i = 0$. In general, E_i a function of the level of decontamination effort applied to the i^{th} area, will be less than one and greater than zero. In Figure 1-1, there are three areas to be decontaminated and, therefore there are three mass reduction factors to be considered. If 85 per cent of the fallout material is removed from the roof, surface 1, then $E_1 = .15$. If 95 per cent of the fallout material is removed from the street segment, then $E_3 = .05$. If 90 per cent of the fallout material is removed from the parking lot, then $E_2 = .10$. These factors are taken from curves that relate the mass removed to the effort expended. Examples of such curves, taken from Reference 6, are presented in Figure 1-2.

FIGURE 1-2: <u>Efficiencies of Decontamination Methods</u>
(curves from Reference 6)
H+1 reference intensity applicable to all curves is 1000 r/hr.



Removing a portion of the fallout material deposited on the i^{th} area will decrease the radiation intensity in and around the structure. The magnitude of the resultant decrease will depend on both the location of the point where the intensity is measured relative to the location of the decontaminated i^{th} area, and on the type and location of structures in the locality. Therefore, in Figure 1-1, the effect of $E_2 = .1$ on the intensity at detector location one will be different from the effect of $E_2 = .1$ on the intensity at detector location two.

In addition to depending on the locations, the fraction by which the intensity[2/] decreases will depend on the fallout material deposited (or remaining) on the other contaminated areas. To determine the composite effect of E_i on the intensity at detector location j, it is necessary to calculate or measure the point intensity at location j, I_j, and the portion of the point intensity that is due to the contamination on the i^{th} area, $I_{i,j}$. When the distribution of fallout material in neighboring space is specified, these intensities I_i and $I_{i,j}$ can be calculated using the methods presented in the OCD engineering manual (Reference 6). Because:

(1) all contaminated areas contribute independently to the intensity at location j (That is, $I_j = \sum_{i=i}^{n} I_{i,j}$ where n = number of contributing contaminated areas), and

(2) the intensity due to the i^{th} area is directly proportional to the fallout material on the i^{th} area,

the intensity at location j after only the k^{th} area is decontaminated, I_j^k, is

$$I_j^k = I_j - (1-E_k)\, I_{k,j} \quad . \tag{2}$$

2/ All intensities are assumed corrected to eliminate the effect of decay.

Obviously, if all fallout material is removed from the k^{th} area (the ideal case where $E_k = 0$ then

$$I_j^k = I_j - I_{k,j} \quad . \tag{3}$$

In this ideal situation, the fractional reduction that has occurred is called $f^*_{k,j}$, the <u>ideal intensity reduction factor</u> of the k^{th} contaminated area relative to the j^{th} detector location, and is defined as follows:

$$f^*_{k,j} = \frac{I_j - I_{k,j}}{I_j} = 1 - \frac{I_{k,j}}{I_j} \quad . \tag{4}$$

For each contaminated area and detector location, this factor $f^*_{k,j}$ is calculated using the methods outlined in the OCD engineering manual (Reference 6). The factor represents the fractional reduction in intensity that can be achieved at detector location j by perfectly decontaminating only the k^{th} contaminated surface ($E_k = 0$). In Figure 1-1 these factors have been assigned the following representative values:

at detector location 1

surface 1 $f^*_{1,1} = .70$

surface 2 $f^*_{2,1} = .88$

surface 3 $f^*_{3,1} = .75$

at detector location 2

surface 1 $f^*_{1,2} = 1.0$

surface 2 $f^*_{2,2} = .92$

surface 3 $f^*_{3,2} = .13$

Let the intensity at detector location one be I_1 and the intensity at detector location two be I_2. Thus, if surface 3, the street segment, is perfectly decontaminated ($E_3 = 0$), then the new intensity at detector one,

I_1^*, is

$$I_1^3 = f_{3,1}^* I_1 = .75 I_1 \quad , \tag{5}$$

and the new intensity at detector location two, I_2^3 , is

$$I_2^3 = f_{3,2}^* I_2 = .13 I_2 \quad . \tag{6}$$

That is, by removing all fallout material from surface 3 (<u>and only surface 3</u>), the intensity at detector location one (two) is reduced to 75 (13) per cent of its former value. In contrast, if all fallout material is removed from surface 1 (and only from surface 1) then the intensity at detector location one is reduced to 70% of its former value while the intensity at detector location two is not affected ($f_{1,2}^* = 1.0$).

The ideal intensity reduction factors, $f_{i,j}^*$, form the core of the intensity reduction analyses. At the beginning of each analysis, they are determined for each surface of interest relative to each detector point of interest. In terms of these (the $f_{i,j}^*$'s) and the mass reduction factors, E_i, the intensity reduction at any detector location can be determined for any combination of decontaminated surfaces. To develop the appropriate expression for this, first consider the intensity reduction achieved at detector location j when surface k (and only surface k) is decontaminated with $E_k \neq 0$. In this realistic situation, the fraction reduction that has occurred is called $f_{k,j}$, the <u>intensity reduction factor</u> of the k^{th} contaminated area relative to the j^{th} detector location, and is defined, using Equation 2, as follows:

$$f_{k,j} = \frac{I_j - (1-E_k)\, I_{k,j}}{I_j} \quad . \tag{7}$$

This factor is more conveniently expressed in terms of E_k and $f^*_{k,j}$ as follows:

$$f_{k,j} = f^*_{k,j} + (1-f^*_{k,j})\, E_k \quad . \tag{8}$$

In Figure 1-1, as before, let the intensity at detector location one be I_1 and the intensity at detector location two be I_2. In addition assume that 95% of the fallout material deposited on surface 3 is removed. That is, let $E_3 = .05$. As a result of this operation, the new intensity at detector one, I_1^3, is

$$\begin{aligned} I_1^3 &= (.75 + .25 \times .05)\ I_1 \\ &= .7625\ I_1 \quad , \end{aligned} \tag{9}$$

and the new intensity at detector two, I_2^3, is

$$\begin{aligned} I_2^3 &= (.13 + .87 \times .05)\ I_2 \\ &= .1735\ I_2 \quad . \end{aligned} \tag{10}$$

Up until now only one surface at a time has been decontaminated. To decontaminate several surfaces simultaneously, it is necessary to introduce one more relationship involving the $f^*_{k,j}$'s. From Equation 4, it is easily seen that the actual fractional intensity contribution of the i^{th} surface to the intensity at detector j can be expressed as follows:

$$\frac{I_{i,j}}{I_j} = 1 - f^*_{i,j} \quad . \tag{11}$$

Because the sum of all fractional contributions must equal unity, the following relationship is evident.

$$\sum_i (1 - f^*_{i,j}) = 1.0 \quad . \tag{12}$$

If there are n such surfaces ($i = 1, 2, \ldots, n$), this becomes:

$$\sum_{i=i}^{n} f^*_{i,j} = n - 1 \quad . \tag{13}$$

Notice, that in Figure 1-1, there are actually four surfaces to be considered: 1, the roof; 2, the parking lot; 3, the street segment; and 4, all others. If the fourth surface ideal intensity reduction factor is $f^*_{4,j}$, then the best possible intensity reduction that can be achieved by decontaminating surfaces 1, 2, and 3 with $E_1 = E_2 = E_3 = 0$ is simply $1 - f^*_{4,j}$. That is, the <u>ideal combined intensity reduction factor</u>, F^*_j, is

$$F^*_j = 1 - f_{n,j} = 1 - (n-1- \sum_{i=1}^{n-1} f^*_{i,j})$$

$$= 1 - m + \sum_{i=1}^{m} f^*_{i,j} \quad , \tag{14}$$

where $f_{n,j}$ represents the contribution from the surfaces not decontaminated.

Returning to the example in Figure 1-1, consider the best intensity reductions that can be achieved at each detector location when the three surfaces are perfectly decontaminated.

At detector location 1,

$$F^*_1 = \sum_{i=1}^{3} f^*_{i,1} + 1 - 3$$

$$= .70 + .88 + .75 - 2$$

$$= .33 \quad . \tag{15}$$

At detector location 2,

$$F^*_2 = \sum_{i=1}^{3} f^*_{i,2} + 1 - 3$$

$$= 1 + .92 + .13 - 2$$

$$= 05 \quad . \tag{16}$$

That is, if the intensities before any decontamination is performed are I_1 and I_2, and if surfaces 1, 2, and 3 are perfectly decontaminated, then the intensities after the decontamination is performed are .33 I_1 and .05 I_2 respectively.

In the realistic situation, where the mass reduction factors are not equal to zero, it is a simple process to show that the <u>combined intensity reduction factor</u>, F_j, may be obtained from Equation 14 by merely substituting $f_{i,j}$ in place of $f^*_{i,j}$. That is,

$$F_j = \sum_{i=1}^{m} f_{i,j} + 1-m \quad , \qquad (17)$$

where, as previously stated, $f_{i,j}$ is equal to $f^*_{i,j} + (1-f^*_{i,j})\, E_i$. Equation 17 is the expression that gives the fractional reduction in intensity that results when several surfaces are decontaminated.

To see how closely the ideal situation is approached when practical decontamination methods are employed in Figure 1-1, let E_1 = .15, E_2 = .10, and E_3 = .05. Using Equation 8, the intensity reduction factors are:

At detector location one,

$$f_{1,1} = .70 + .30 \times .15 = .75$$

$$f_{2,1} = .88 + .12 \times .10 = .892$$

$$f_{3,1} = .75 + .25 \times .05 = .7625 \qquad (18)$$

therefore

$$F_1 = .75 + .892 + .7625 - 2$$

$$= .4045 \quad , \qquad (19)$$

out of a possible F^*_1 = .33 as determined in Equation 15.

At detector location two,

$$f_{1,2} = 1.0$$

$$f_{2,2} = .92 + .08 \times .1 = .928$$

$$f_{3,2} = .13 + .87 \times .05 = .1735 \qquad (20)$$

therefore

$$F_2 = .1735 + .928 - 1$$

$$= .1015 \quad , \qquad (21)$$

out of a possible $F_2^* = .05$ as determined in Equation 16.

On the other hand, if only the ground level surfaces (2 and 3) were decontaminated with $E_2 = .10$ and $E_3 = .05$, the following results would be obtained:

At detector location one,

$$f_{2,1} = .88 + .12 \times .10 = .892$$

$$f_{3,1} = .75 + .25 \times .05 = .7625 \qquad (22)$$

therefore

$$F_1 = .7625 + .892 - 1$$

$$= .6545 \quad . \qquad (23)$$

At detector location two,

$$f_{2,2} = .92 + .08 \times .1 = .928$$

$$f_{3,2} = .13 + .87 \times .05 = .1735 \qquad (24)$$

therefore

$$F_2 = .1735 + .928 - 1$$

$$= .1015 \quad . \qquad (25)$$

In the above calculations, the factors that are necessary are the $f_{i,j}^*$'s and the E_i's. The E_i's are obtained from curves and the $f_{i,j}^*$'s are calculated with the techniques used to calculate the protection factor of the structure itself (Reference 7). The combining of these two sets of factors is the primary portion of the analyses presented in Chapters II through XI.

E. Presentation of Analysis Data

The results of the analysis of each of the ten structures are presented in summary form in Chapters II through XI. For each analysis, the following material is presented:

(1) Basic analysis data giving the building address, height of detector. NFSS protection factor, decontamination areas (location type, and size), ideal intensity reduction factors ($f^*_{i,j}$) for each decontamination area, practical mass reduction factors (E_i) for each decontamination area; and practical intensity reduction factors ($f_{i,j}$ and F_j);

(2) A map showing the location of the building, the location of surfaces to be decontaminated, and the detector locations;

(3) Photographs, when available, showing the building, its surroundings, and the areas to be decontaminated;

(4) When appropriate, a general discussion of unusual factors or items encountered in the analysis; and,

(5) Descriptions of the strategy for each decontamination area including, for various methods of decontamination, the applicable reference H+1 intensity, the man hours of effort, the respective mass and intensity reduction factors ($f_{i,j}$ and E_i), the radiation dose received by the crew members, and the water required for the operation.

F. Practical Considerations

In this final section, three topics are discussed: (1) on site postattack measurement of $f^*_{i,j}$, (2) sensitivity of $f_{i,j}$ and F_i to the value of the mass reduction factor E_i and appropriate simplified expressions for F_j, and (3) analysis adjustments to account for weathering in calculations of F_j. Each topic will be discussed using the example presented in Figure 1-1 and the definitions presented in Section D of this chapter.

Using the methods presented in Reference 7, the OCD engineering manual, the pertinent ideal intensity reduction factors, $f^*_{i,j}$ and F^*_j, can be determined for a specific building as easily as the protection factor itself can be calculated. In the postattack environment, however, it may be very desirable to conduct an on-site measurement of the factors $f^*_{i,j}$ before commencing decontamination operations. The reason for this is that expected weathering will cause a redistribution of fallout material. As a result of this redistribution, the values of the $f^*_{i,j}$ factors (and, incidentally, the protection factor itself) will change and therefore the effect of decontaminating specified areas with respect to specified detector locations will change. What previously were important areas to decontaminate may become unimportant (and, also, the reverse). Therefore, it would be desirable to check values of the $f^*_{i,j}$'s by measurement prior to commencing decontamination operations.

An on-site estimate of important $f^*_{i,j}$ factors can be made with appropriate directional detectors. This can be seen from the equation for $f^*_{i,j}$,

$$f^*_{i,j} = 1 - \frac{I_{i,j}}{I_j} \quad . \tag{4}$$

Using an omni-directional detector, I_j can be measured directly. Using an appropriate directional detector, $I_{i,j}$ can also be measured, although not as accurately as I_j due to scattering. If such detectors are available, the measurements can be made quickly and easily at the location of interest and the values of $f^*_{i,j}$ can be adjusted if they were previously calculated, or estimated if they were not previously calculated.

Once the $f^*_{i,j}$ values are established, the resultant intensity reduction factor for detector location j can be determined from the equation

$$F_j = \sum_{i=1}^{n} (f^*_{i,j} + (1 - f^*_{i,j}) E_i) + 1 - n \qquad (26)$$

for any desired set of mass reduction factors E_i. As previously mentioned these factors E_i are taken from experimental curves such as those presented in Figure 1-2. To examine the sensitivity of F_j to the values of E_i that are selected, it is convenient to begin by examining Equation 26 when all E_i are equal. This situation is illustrated by Figure 1-3 where F_j is presented as a function of F^*_j for E_i = .1, .06, and .01. The values for E_i were selected from Figure 1-2 to represent high, average, and low values of E_i. From Figure 1-3, it is obvious that F_j is sensitive to E_i when F^*_j is less than .2. Based on this observation, it is interesting to determine the maximum error that could result if all E_i's were assumed equal to .06. In this case, the maximum errors would occur if all E_i's were actually equal to .1 or .01 (assuming, from Figure 1-2, $.1 > E_i > .01$). These two errors -- using E = .06 rather than E = .1 -- are displayed as a function of F^*_j in Figure 1-4. Based on Figures 1-3 and 1-4, it is evident that the actual values of E_i are not very significant in determining F_j when F^*_j is greater than .2. Therefore when F^*_j is greater than .2 the approximation

$$F_j \simeq F^*_j + (1 - F^*_j)\ .06$$

$$= .94\ F^*_j + .06 \qquad (27)$$

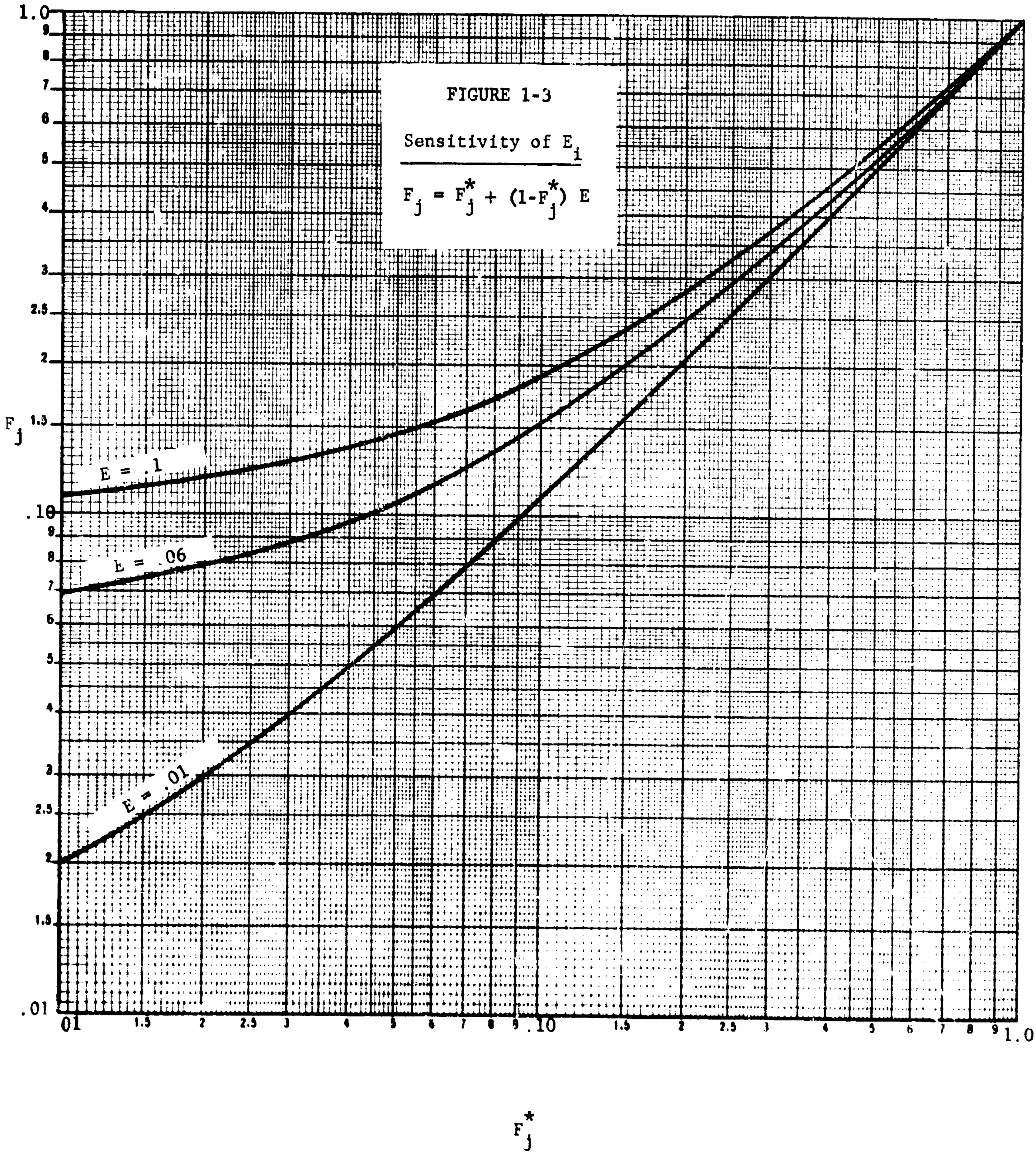


FIGURE 1-3
Sensitivity of E
F j = F*j + (1-F*j) E
E = .1
E = .06
E = .01
1.0
.10
.01
Fj
F*j

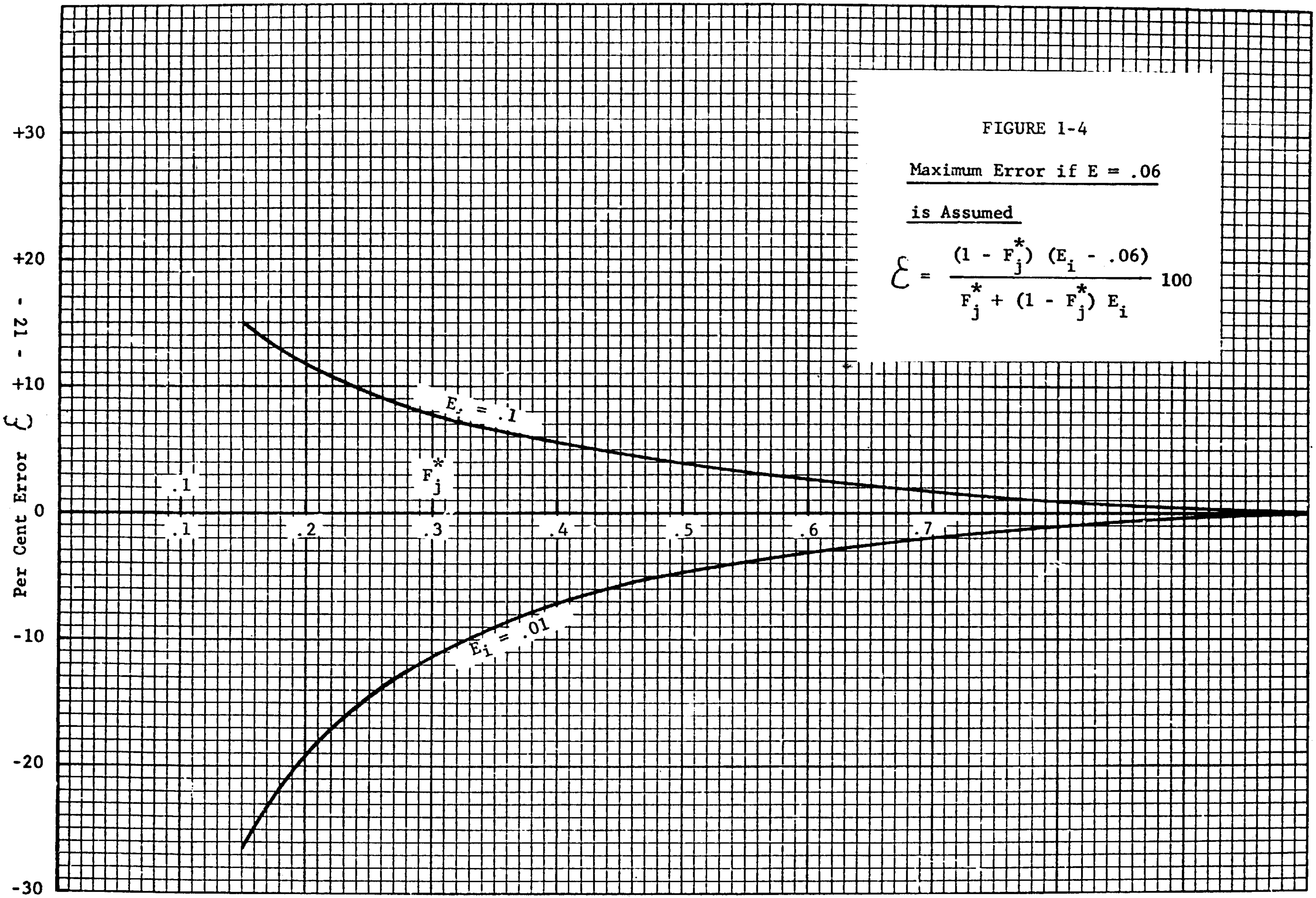


FIGURE 1-4

Maximum Error if E = .06 is Assumed

$$\mathcal{E} = \frac{(1 - F_j^*)\ (E_i - .06)}{F_j^* + (1 - F_j^*)\ E_i}\ 100$$

is useful for quickly estimating F_j. This approximation is appropriate in situations where the detector is located inside the building. In that situation, there are several contributing planes -- ground and roof -- of contamination. Each plane will have an appropriate mass reduction factor, E_i, that is less than .1 and, for most cases (from Figure 1-2) greater than .01. If E_i was assumed equal to .06 for all planes, then the maximum error in the calculated F_j would arise in the equally unlikely situation where all E_i's were actually .1 (or, .01). In actual situations where all E_i's were assumed equal to .06 the actual value of E_i would lie between .01 and .1, on both sides of .07, and the errors that result from setting $E_i = .06$ would tend to cancel out, resulting in an error much less than the maximum errors shown in Figure 1-4.

In contrast to the above situation, when the detector is located externally, there are very few contributing planes -- ground-level surfaces only (Reference 7) -- of contamination. In particular, the plane above which the detector is located is so significant a contributor that F_j^* can often be assumed equal to the $f_{i,j}^*$ of that plane. In addition, this $f_{i,j}^*$ tends to be less than .2, and, in many cases, less than .03. For such circumstances it is convenient to set $f_{i,j}$ equal to $f_{i,j}^* + E_i$ rather than $f_{i,j}^* + (1-f_{i,j}^*)\ E_i$. When $f_{i,j}^*$ is less than .1, and E_i is less than .1, the error that results from using this approximation, $f_{i,j} = f_{i,j}^* + E_i$ is always less than 5.3% as shown in Figure 1-5.

When it is desired to predict the effects of weathering or redistribution of fallout material, the preceding discussions are applicable if the value of $f_{i,j}^*$ is properly modified. The adjustment of $f_{i,j}^*$ is developed from the basic equation for the intensity at detector location j ,

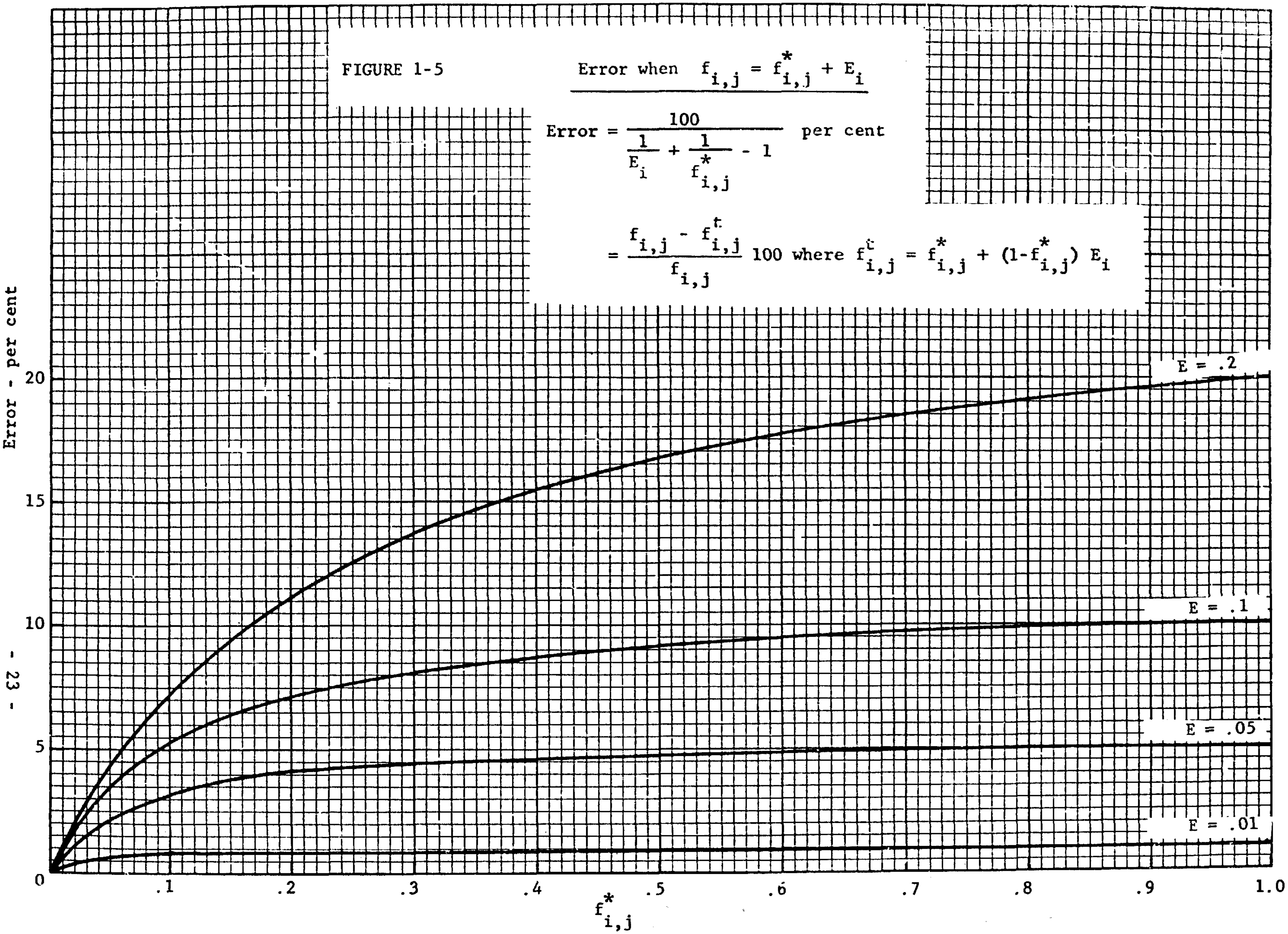


FIGURE 1-5

Error when $f_{i,j} = f^*_{i,j} + E_i$

$$\text{Error} = \frac{100}{\frac{1}{E_i} + \frac{1}{f^*_{i,j}} - 1} \text{ per cent}$$

$$= \frac{f_{i,j} - f^t_{i,j}}{f_{i,j}} 100 \text{ where } f^t_{i,j} = f^*_{i,j} + (1 - f^*_{i,j}) E_i$$

$f^*_{i,j}$

$$I_j = \sum_i I_{i,j} \quad . \tag{28}$$

If the fallout material is shifted about, the intensity at j becomes,

$$I_j^o = \sum_i k_i \, I_{i,j} \quad , \tag{29}$$

where k_i is the fractional increase or decrease in material deposited on the i^{th} plane. This expression can also be written as

$$I_j^o = k_j \sum_i I_{i,j} \quad , \tag{30}$$

where k_j is the fractional increase or decrease in intensity at location j due to the redistribution. From Equation 4

$$f_{i,j}^* = 1 - \frac{I_{i,j}}{I_j} \quad , \tag{4}$$

the appropriate $f_{i,j}^*$ after weathering has occurred, $f_{i,j}^{**}$, becomes,

$$f_{i,j}^{**} = 1 - \frac{k_i \, I_{i,j}}{k_j \sum_i I_{i,j}} \quad , \tag{31}$$

or

$$f_{i,j}^{**} = 1 - \frac{k_i}{k_j} \left(1 - f_{i,j}^*\right) \quad . \tag{32}$$

Naturally if the weathering does not change the intensity at location j ($k_j = 1$) then the ideal intensity reduction factors become,

$$f_{i,j}^{**} = 1 - k_i + k_i \, f_{i,j}^* \quad . \tag{33}$$

II. SIX-FLOOR APARTMENT BUILDING

A. Analysis Data

Address: 81 West 182nd Street
Bronx, N.Y.C.

Detector: 1st Floor

Normal Protection Factor: PF = 45

Decontamination Areas:

1. Roof: 9918 sq.ft. tar and gravel
2. Ground Level: 15,000 sq.ft. asphaltic concrete on West 182nd Street
   16,000 sq.ft. asphaltic concrete on Aqueduct Avenue
   13,000 sq.ft. asphalt on P.S. 91 playground

Ideal Intensity Reduction Factors:

1. Roof: $f^*_{1,1} = .641$
2. Ground Level: $f^*_{2,1} = .494$
3. Roof and Ground combined: $F^*_1 = f^*_{1,1} + f^*_{2,1} - 1 = .135$

Practical Mass Reduction Factors:

1. Roof: $E_1 = .1$
2. Ground Level: $E_2 = .02$

Practical Intensity Reduction Factors Decontaminating:

1. Roof only: $F_1 = .677$
2. Ground Level only: $F_1 = .504$
3. Roof and Ground Level: $F_1 = .181$.

B. Map

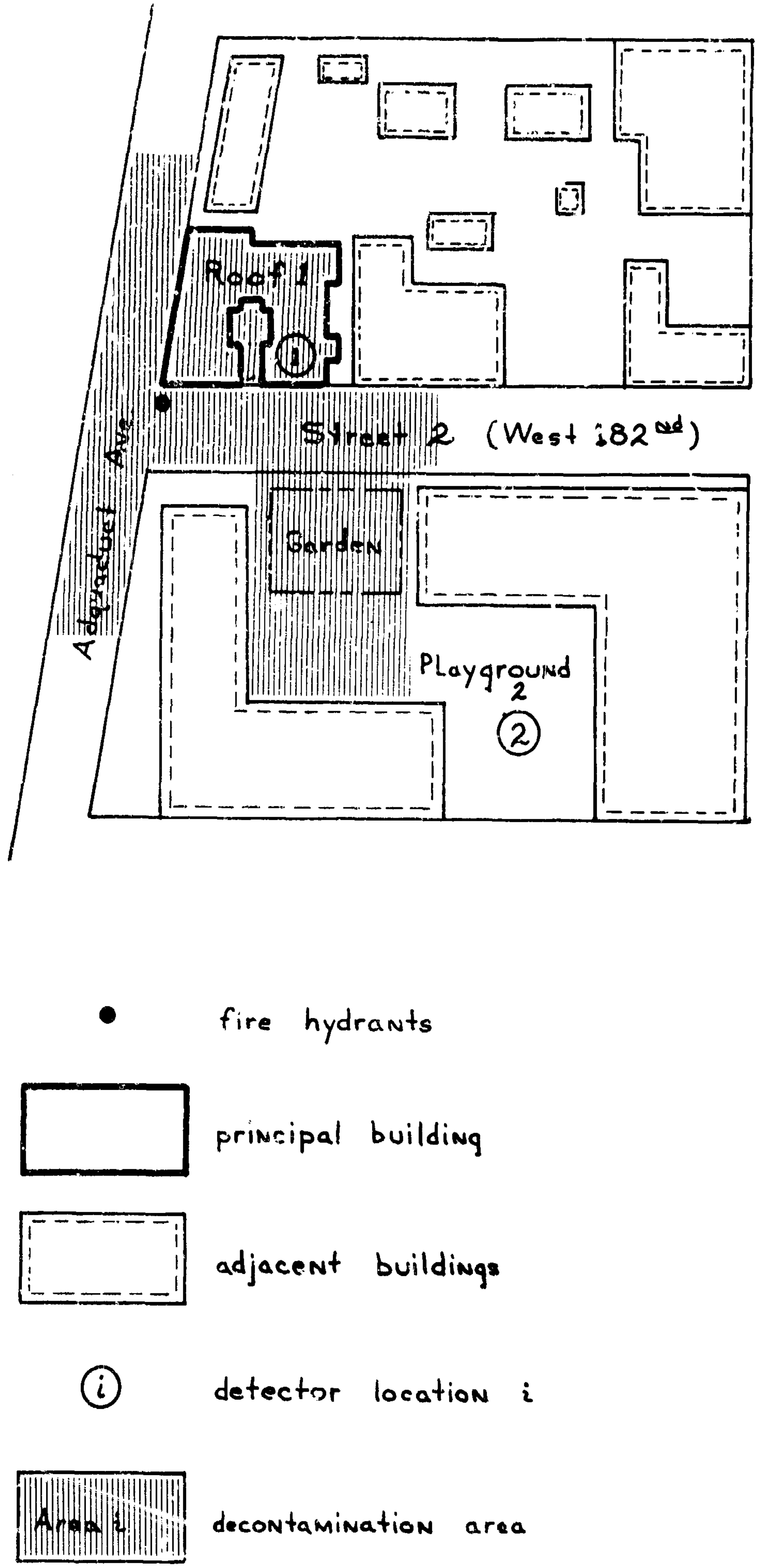
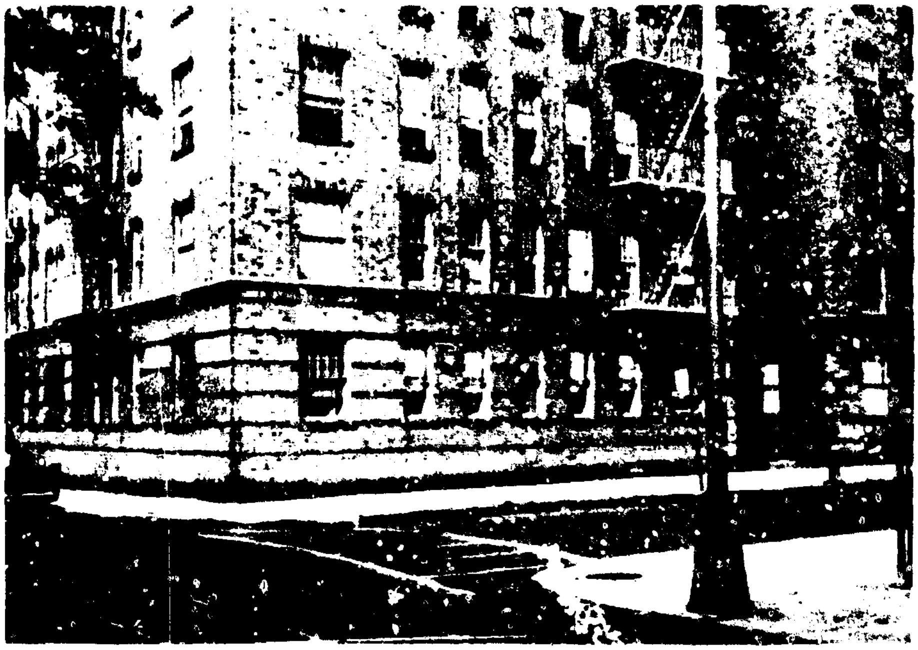


FIGURE 2-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces

FIGURE 2-2



View of Building from W. 182nd Street

(Note: fireplug)

FIGURE 2-3

W. 182nd Street (Note: large drain on corner)

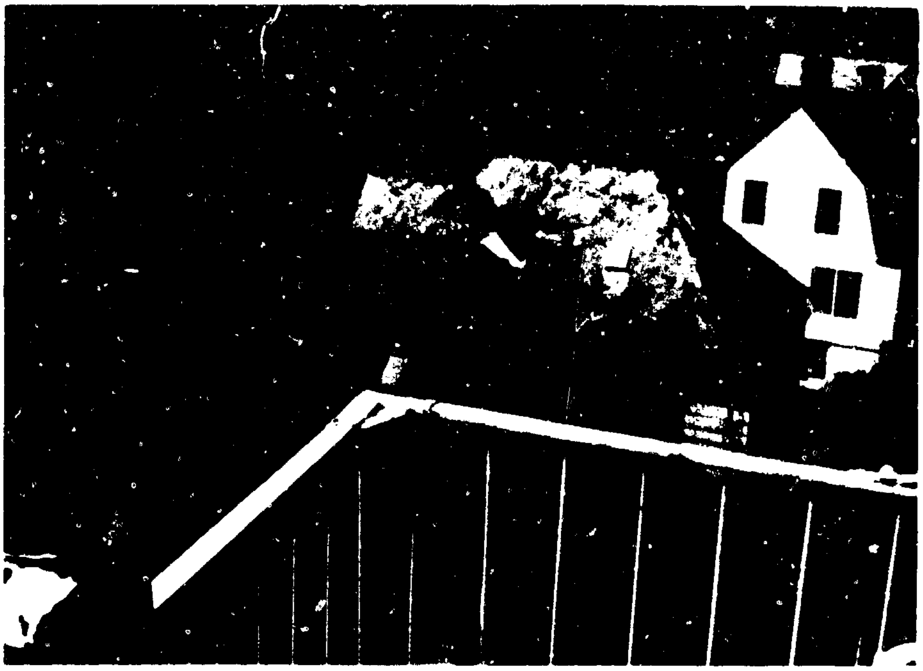
FIGURE 2-4

View of Roof

FIGURE 2-5

View of Side Alley

FIGURE 2-6



View of Adjacent Roofs

FIGURE 2-7

View of Playground and Garden Area

(Note: iron fence around garden)

D. Applied Strategies

1. Roof Decontamination

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To Which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1a	Firehose	300	1.41	7	14.1	1.41	42,300	.01	.65
1b		3000	1.41		14.1	1.41	42,300	.0025	.64
1c		300	.71		7.1	.71	21,300	.03	.65
1d		3000	.71		7.1	.71	21,300	.0025	.64
1e		300	.28		2.8	.28	8,400	.12	.69
1f		3000	.28		2.8	.28	8,400	.025	.65
			2. Ground Level Decontamination*						
2a	Street Flusher	300	.44	1	4.4	.44	13,200	.02	.50
2b		3000	.44		4.4	.44	13,200	.0125	.50
2c		300	.044		.44	.044	1,320	.08	.54
2d		3000	.044		.44	.044	1,320	.07	.53
2e	Firehose	3000	7.33	6	73.3	7.33	219,900	.02	.50

3. Ground Level and Roof Decontamination

Combined Strategies	F_1	Men	Total Man Hours of Effort
1b + 2b	.14	8	10.50
1d + 2d	.17	8	5.05
1f + 2d	.18	8	2.05

*Includes road area and playground.

E. Outside Detector

1. Location of Detector: In center of playground across the street from original building studied.

2. Original PF at site of detector ---------------------------------- 1.39

3. f*'s for individual planes

   $f^*_{1,2}$:(playground, i.e., plane above which detector is located) -- .056

   $f^*_{2,2}$: Street in front of building ------------------------------ .963

   $F^*_2 = f^*_{1,2} + f^*_{2,2} - 1 = .019$

III. SIX-FLOOR APARTMENT BUILDING

A. Analysis Data

Address: 362 West 52nd St.
Manhattan, N.Y.C.

Detector: 2nd Floor

Normal Protection Factor: PF = 73

Decontamination Areas:

1. Roof (Primary): 2,400 sq.ft. composition shingle of main building
2. Alleys: 1,400 sq.ft. asphaltic concrete behind building and garage
3. Road Area #1: 6,000 sq.ft. asphaltic concrete in front of building on West 52nd St.
4. Parking Lot, Garage Roof, Roof Area #2:
   9,200 sq.ft. parking lot of asphaltic concrete adjacent to building
   2,100 sq.ft. garage roof of composition shingle
   7,500 sq.ft. asphaltic concrete on West 52nd St. in front of parking lot

Ideal Intensity Reduction Factors:

1. Roof (Primary): $f^*_{1,1} = .583$
2. Alleys: $f^*_{2,1} = .774$
3. Road Area #1: $f^*_{3,1} = .836$
4. Parking Lot, Garage Roof, Road Area #2: .950
5. All Decontaminated Areas combined:

$$F^*_1 = f^*_{1,1} + f^*_{2,1} + f^*_{3,1} + f^*_{4,1} - 3 = .143$$

Practical Mass Reduction Factors:

1. Roof (Primary): $E_1 = .028$
2. Alleys: $E_2 = .100$
3. Road Area #1: $E_3 = .07$
4. Parking Lot, Garage Roof, Road Area #2: E_4 = Parking Lot = .0125
   Garage Roof = .028

Practical Intensity Reduction Factors Decontaminating:

1. Roof (Primary) only: $f_{1,1}$ (roof) = .589
2. Alleys only: $f_{2,1}$ (alleys) = .797
3. Road Area #1 only: $f_{3,1}$ (roads) = .848
4. Parking Lot, Garage Roof, Road Area #2 only: $f_{4,1}$ (parking lot, etc.) = .953
5. All Decontaminated Areas combined:

$$F_1 = \sum_{i=1}^{4} f_{i1} - 3 = .186$$

B. Map

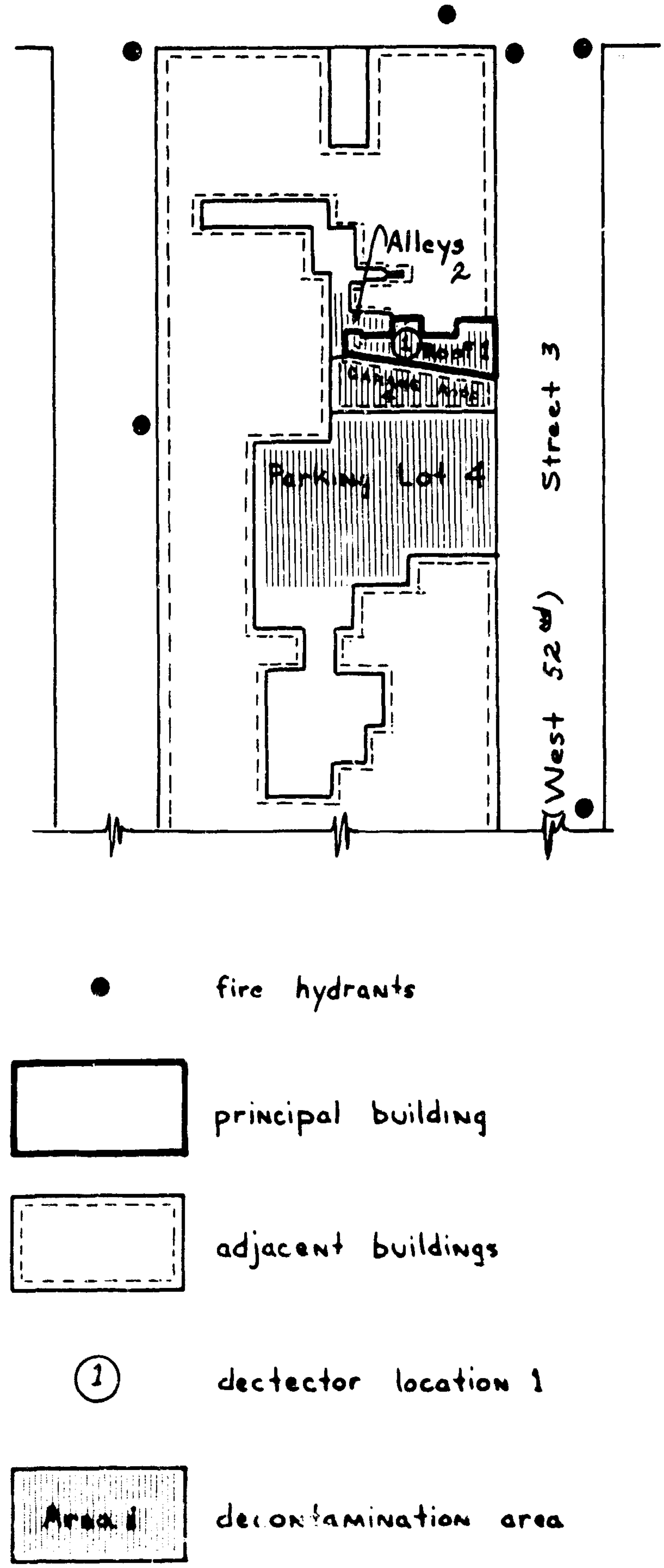


FIGURE 3-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces

FIGURE 3-2

A View of West 52nd Street

FIGURE 3-3

A View of the Narrow Alley Behind Building

FIGURE 3-4

View of Garage Roof and Parking Lot

FIGURE 3-5

View of Tunnel to Rear Alley

FIGURE 3-6

View of Building from West 52 Street

FIGURE 3-7

View of Roof (Note: 3 foot lip at edge)

D. Applied Strategies

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1. Roof (Primary) Decontamination									
1a	Firehose	300	.34	7	3.4	.34	10,000	.025	.59
1b		3000	.34		3.4	.34	10,000	.023	.59
1c		300	.17		1.7	.17	5,000	.030	.59
1d		3000	.17		1.7	.17	5,000	.028	.59
2. Alleys Decontamination									
2a	Firehose	300	.23	6	2.3	.23	6,900	.02	.78
2b		3000	.23		2.3	.23	6,900	.014	.78
2c		300	.04		0.4	.04	1,200	.10	.80
2d		3000	.04		0.4	.04	1,200	.10	.80
3. Road Area No. 1 Decontamination									
3a	Street Flusher	300	.06	1	.6	.06	1,800	.02	.84
3b		3000	.06		.6	.06	1,800	.0125	.84
3c		300	.01		.1	.01	300	.08	.85
3d		3000	.01		.1	.01	300	.07	.85
3e	Mech. Sweeper	300	.09	1	.9	.09		.10	.85
3f		3000	.09		.9	.09		.07	.85
3g	Vacuum Sweeper	300	.12	1	1.2	.12		.092	.85
3h		3000	.12		1.2	.12		.092	.85
3i	Firehose	300	.90	6	9.0	.90	27,000	.10	.85
3j		3000	.90		9.0	.90	27,000	.10	.85

D. Applied Strategies (Cont'd).

*4. Parking Lot, Garage Roof, Road Area #2 Decontamination

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
4a	Firehose on Roof	300	.18	7	1.8	.18	5,400	.03	.95
	Street Flusher on Road & Parking Lot		.19	1	1.9	.19	5,700	.02	
4b	Firehose on Roof	3000	.18	7	1.8	.18	5,400	.028	.95
	Street Flusher on Road & Parking Lot		.19	1	1.9	.19	5,700	.0125	
4c	Firehose on Roof	300	.18	7	1.8	.18	5,400	.03	.95
	Mech. Sweeper on Road & Parking Lot		.75	1	7.5	.75		.04	
4d	Firehose on Roof	3000	.18	7	1.8	.18	5,400	.028	.95
	Mech. Sweeper on Road & Parking Lot		.75	1	7.5	.75		.02	
4e	Firehose on Roof	300	.18	7	1.8	.18	5,400	.03	.95
	Vacuum Sweeper		.75	1	7.5	.75		.02	
4f	Firehose on Roof	3000	.18	7	1.8	.18	5,400	.028	.95
	Vacuum Sweeper		.75	1	7.5	.75		.011	

5. Combined Decontamination

Combined Strategies	F_1	Men	Total Man Hours
1d + 2b + 3d	.212	9	1.22

*These surfaces are considered to be decontaminated simultaneously because the individual intensity contribution for each surface was not separated in available data.

IV. TWENTY-ONE STORY OFFICE BUILDING

A. Analysis Data

Address: 310 Park Avenue
New York City

Detector: 4th Floor

Normal Protection Factor: PF = 276

Decontamination Areas:

1. Park Ave: 110,000 sq.ft. asphaltic concrete
   12,000 sq.ft. grass island

2. Other Roads: 42,000 sq.ft. asphaltic concrete

Ideal Intensity Reduction Factors:

1. Park Ave.: $f^*_{1,1} = .433$

2. Other Roads: $f^*_{2,1} = .611$

3. All Road Areas: $F^*_1 = .044$

Practical Mass Reduction Factors:

1. Park Ave. (road surface only E = .01): $E_1 = .17$

2. Other Roads: $E_2 = .02$

Practical Intensity Reduction Factors Decontaminating:

1. Park Ave. - Road Surface only: $f_{1,1} = .56$

2. Other Roads: $f_{2,1} = .62$

3. All Road Surfaces: $F_1 = .18$.

B. Map

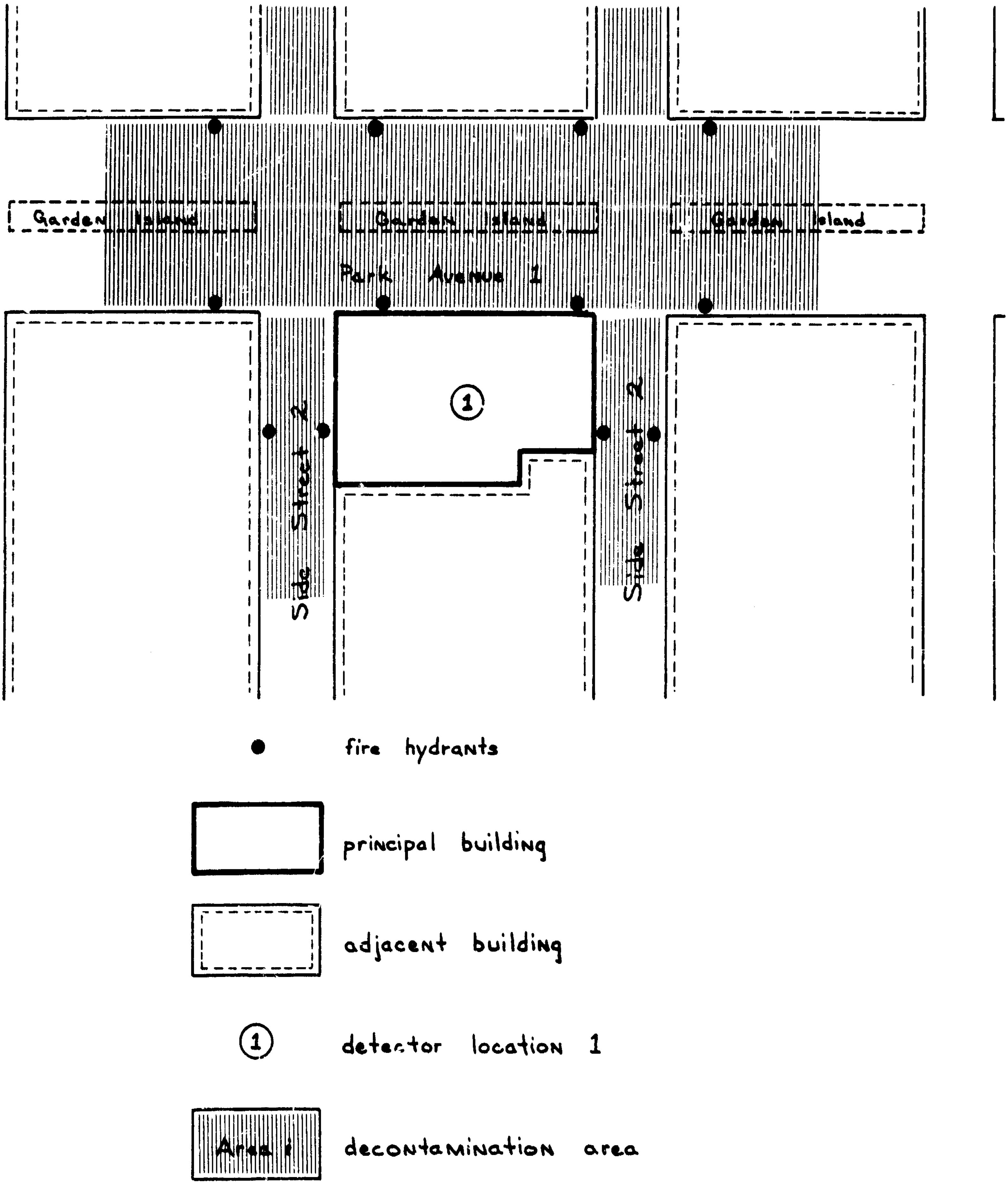
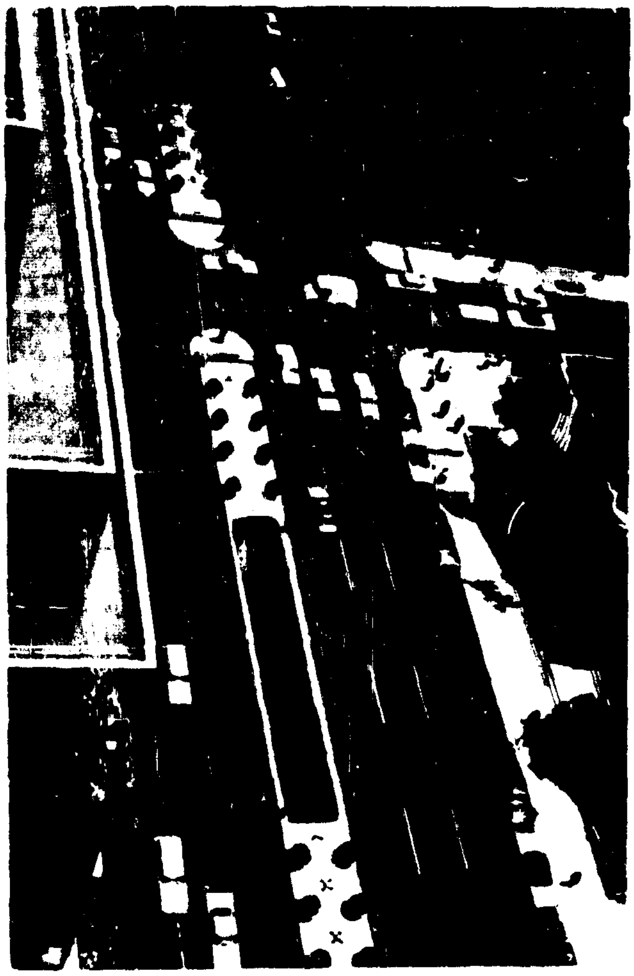


FIGURE 4-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces

FIGURE 4-2

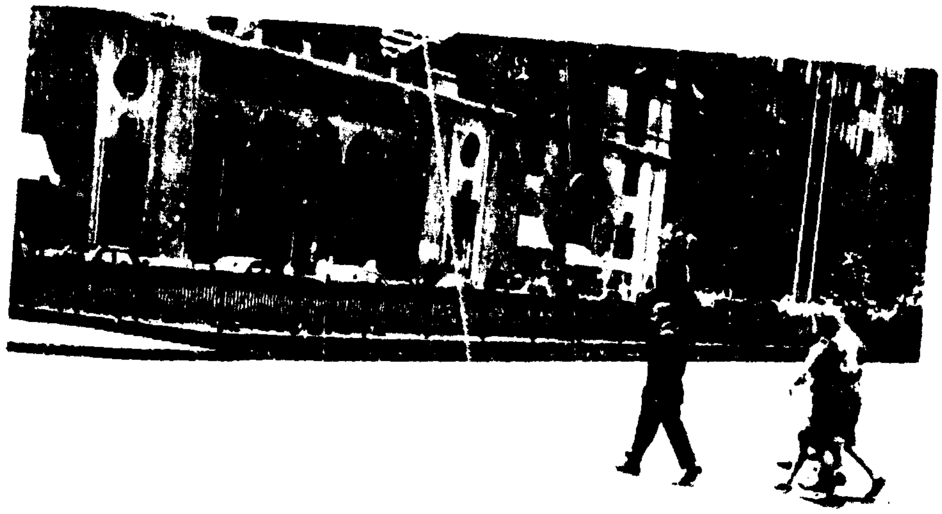


View of Park Avenue (Note: Island with Garden in Center of Road)

FIGURE 4-3

View of East 49th Street

FIGURE 4-4



View of Park Avenue Showing Iron Gate Around Center Island

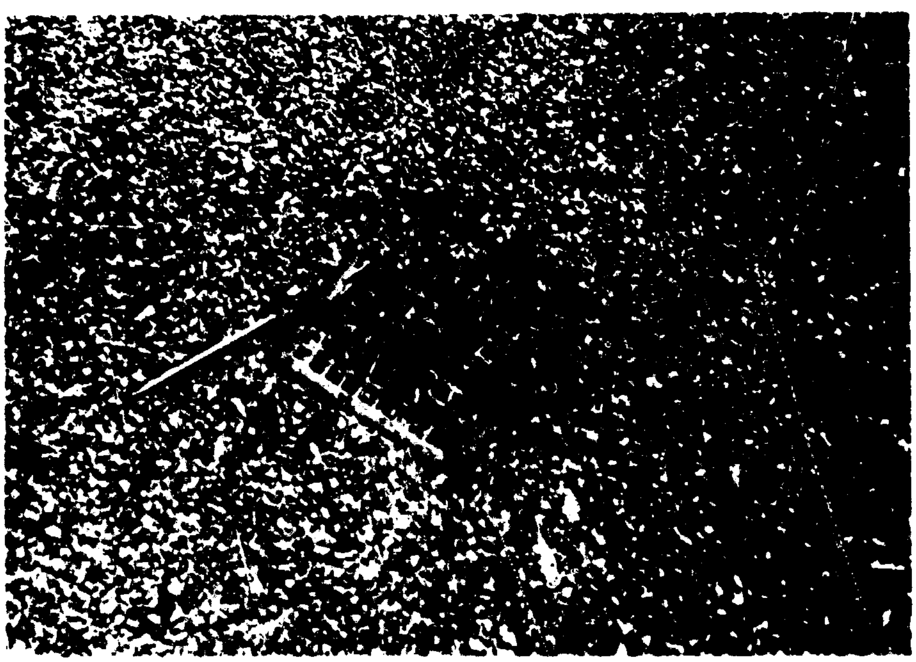
FIGURE 4-5

View of Sidewalk and Fireplug on East 49th Street

FIGURE 4-6

View of Roof (Non-contributing surface)

FIGURE 4-7



A Drain on the Roof

D. Applied Strategies

1. Park Avenue (excluding island) Decontamination

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 ' 1000) if Decont. at 2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1a	Firehose	3000	18.3	6	183	18.3	549,000	.12	.50
1b	Mech Sweeper	3000	4.4	1	44	4.4		.14	.51
1c	Mech. Sweeper	3000	1.65	1	16.5	1.65		.17	.56
1d	Street Flusher	3000	1.10	1	11.0	1.1	330,000	.11	.50
	2. Other Road Decontamination								
2a	Firehose	3000	.7	6	7.0	.7	210,000	.02	.62
2b	Street Flusher	3000	.42	1	4.2	.42	12,600	.01	.62

3. All Road Surface Decontamination

Combined Strategies	F_1	Men	Total Man Hours
1a + 2a	.12	12	114
1d + 2b	.12	2	1.52

V. GENERAL DYESTUFF CORPORATION

A. Analysis Data

Address: 435 Hudson St.
Manhattan, N.Y.C.

Detector: 4th Floor

Normal Protection Factor: PF = 126

Decontamination Areas:

1. Roads: 110,000 sq.ft.
2. Parking Lots: 6,000 sq.ft.
3. Roofs of Adjacent Buildings: 110,000 sq. ft.

Ideal Intensity Reduction Factors:

1. Roads: $f^*_{1,1} = .123$
2. Parking Lots and Playground: $f^*_{2,1} = .991$
3. Roofs of Adjacent Buildings: $f^*_{3,1} = .887$
4. Above Combined: $F_1 = .001$

Practical Mass Reduction Factors:

1. Roads: $E_1 = .02$
2. Parking Lots and Playground: $E_2 = .04$
3. Roofs of Adjacent Buildings: $E_3 = .03$

Practical Intensity Reduction Factors Decontaminating:

1. Roads: $f_{1,1} = .14$
2. Parking Lots and Playground: $f_{2,1} = .99$
3. Roofs of Adjacent Buildings: $f_{3,1} = .89$
4. Above Combined: $F_1 = .02$
5. Roads and Roofs: $F_1 = .03$

B. Map

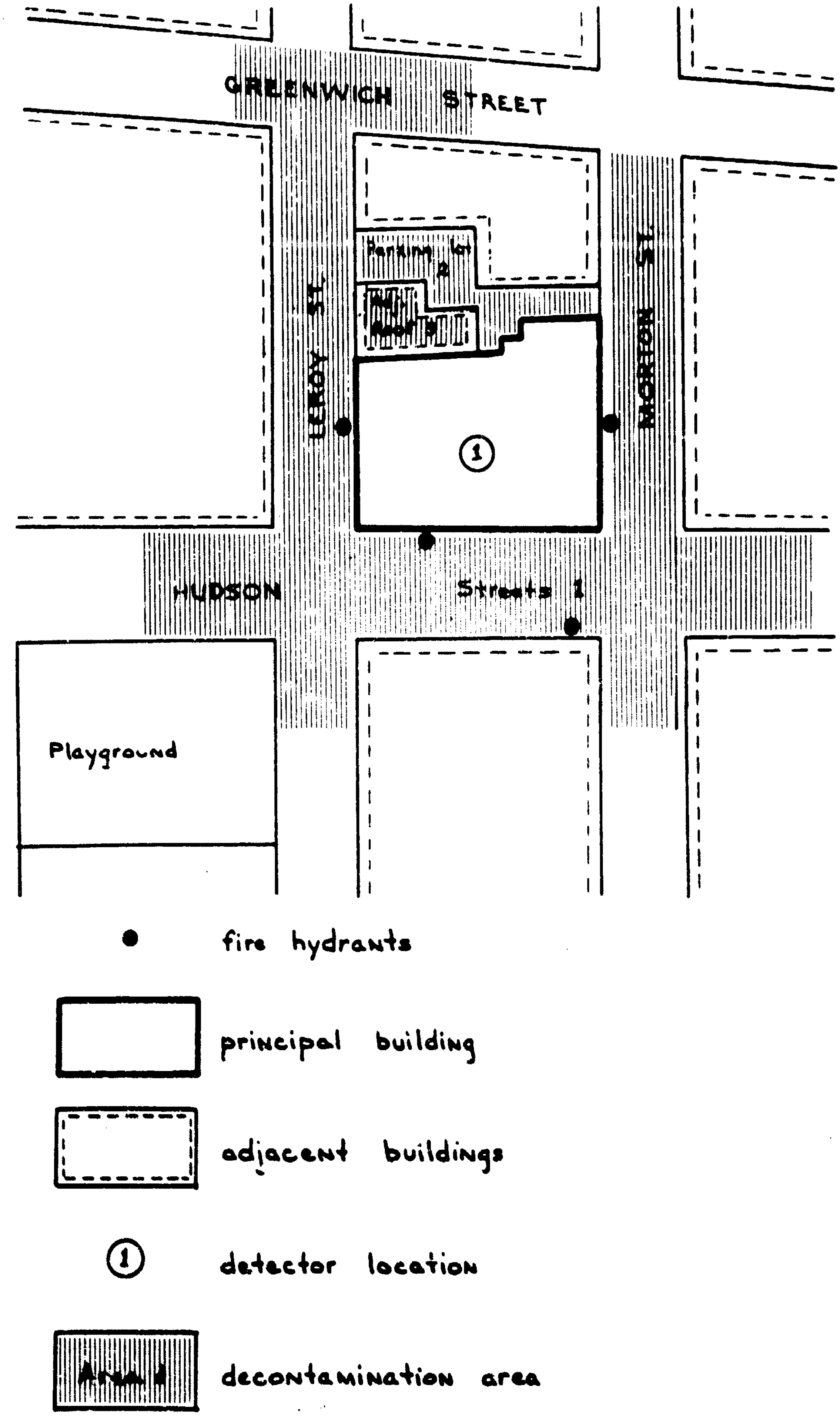


FIGURE 5-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces

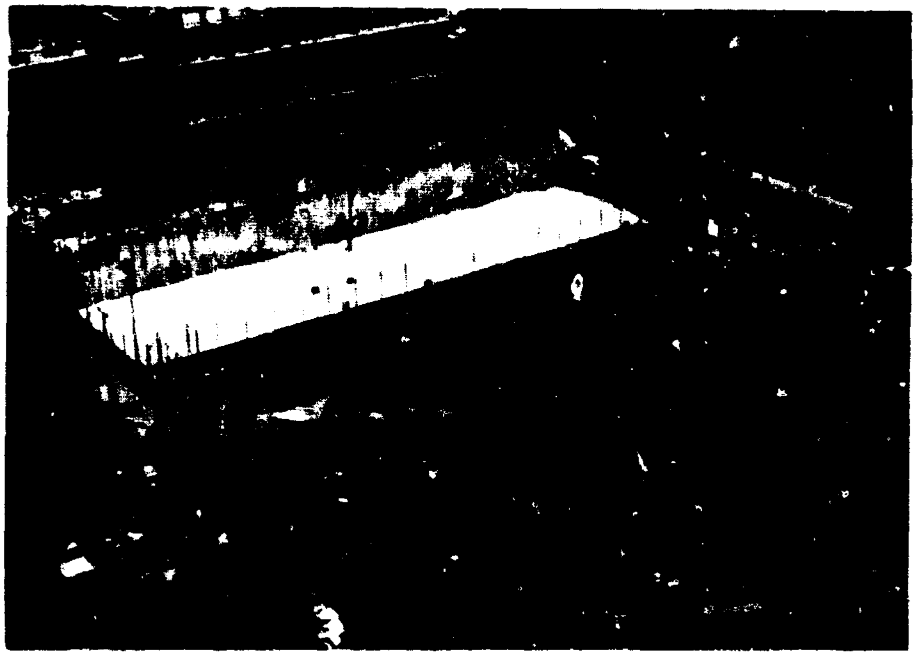
FIGURE 5-2

View of Building from Hudson Street. (Note: Sewer drain)

FIGURE 5-3

View of Intersection of Hudson Street and Morton Street. (Note: brick pavement, fire-plug and sewer)

FIGURE 5-4



View of Building Roofs Across Leroy Street

FIGURE 5-5

Playground (Note: two drains in center)

FIGURE 5-6

View of Hudson Street and Sidewalk Areas from Roof

FIGURE 5-7

View of Parking Lot and Adjacent Garage Roof. (Note: depression area on garage roof)

D. Applied Strategies

1. Road Area Decontamination

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont at 2 days (R)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont at 2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1a	Vacuum Sweeper	300	4.4	1	44	4.4		.02	.14
1b		3000	4.4		44	4.4		.011	.13
1c	Street Flusher	300	1.1	1	11	1.1	33,000	.02	.14
1d		3000	1.1		11	1.1	33,000	.0125	.13
2. Parking Lot and Playground Decontamination									
2a	Firehose	Any	1	6	10	.1	30,000	.02	.99
2b	Mech. Sweeper	Any	.24	1	2.4	.24		.04	.99
3. Roof of Adjacent Buildings Decontamination									
3a	Firehose	300	15.7	7	157	15.7	471,000	.01	.89
3b		3000	15.7		157	15.7	471,000	.0025	.89
3c		300	7.9		79	7.9	237,000	.03	.89
3d		3000	7.9		79	7.9	237,000	.0025	.89

4. Combined Road, Roof, Playground, and Parking Lot Decontamination

Combined Strategies	E_1	Men	Total Man Hours
1a + 2a + 3a	.02	14	121
1c + 2b	.12	2	1.34
1c + 2b + 3c	.01	9	57

VI. HIGH SCHOOL GYMNASIUM

A. Analysis Data

Address: Bennett Street
Boston, Mass.

Detector: 2nd Floor

Normal Protection Factor: PF = 116

Decontamination Areas:

1. Roads: 5,000 sq.ft. asphaltic concrete
2. Parking Lot: 10,000 sq.ft. dirt
3. Playground: 23,750 sq.ft. asphaltic concrete
4. Roof: 4,700 sq.ft.

Ideal Intensity Reduction Factors:

1. Roads: $f^*_{1,1} = .948$
2. Parking Lot: $f^*_{2,1} = .789$
3. Playground: $f^*_{3,1} = 767$
4. Roof: $f^*_{4,1} = .513$
5. Ground Areas (1,2,3): $F^*_1 = .504$
6. All Areas (1,2,3,4): $F^*_1 = .017$

Practical Mass Reduction Factors:

1. Roads: $E_1 = .02$
2. Parking Lots: $E_2 = .004$
3. Playground: $E_3 = .1$
4. Roof: $E_4 = .03$

Practical Intensity Reduction Factors Decontaminating:

1. Roads: $f_{1,1} = .95$
2. Parking Lots: $f_{2,1} = .80$
3. Playground: $f_{3,1} = .80$
4. Roof: $f_{4,1} = .53$
5. Ground Areas (1,2,3): $F_1 = .55$
6. All Areas (1,2,3,4): $F_1 = .08$.

B. Map

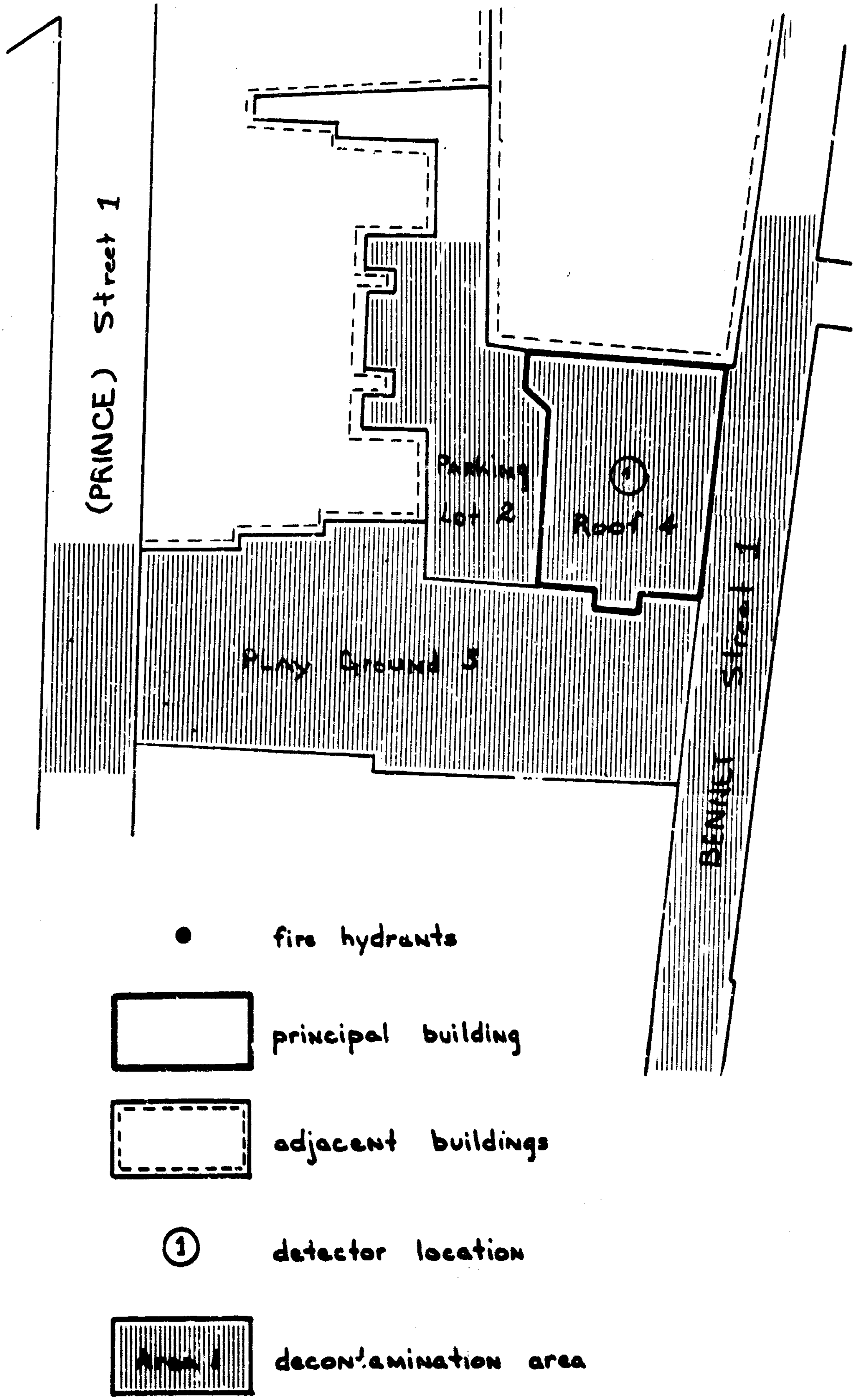
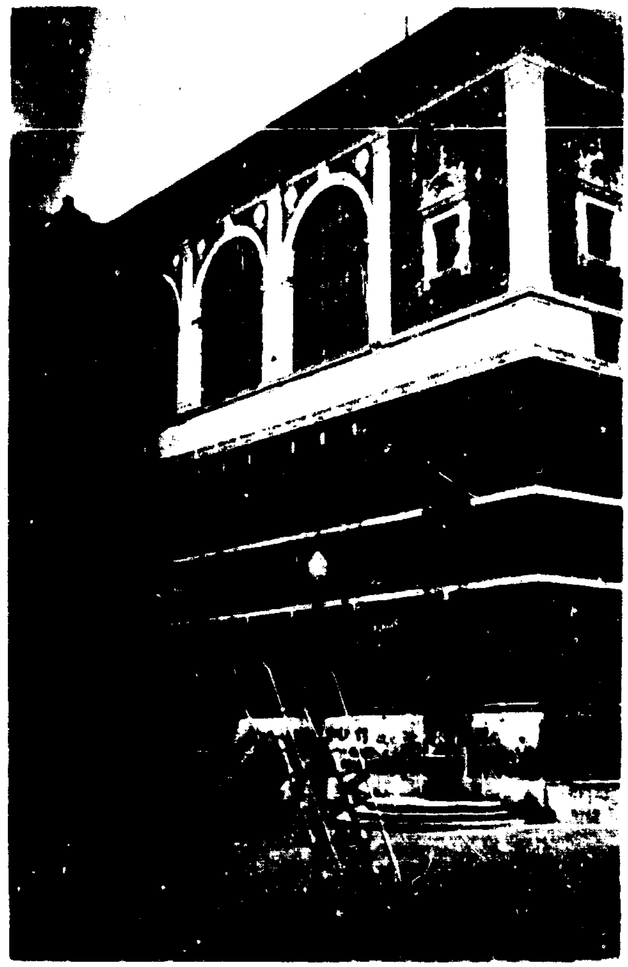


FIGURE 6-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces



View of Building from Bennett St.

Playground

D. Applied Strategies

1. Road Decontamination

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1a	Street Flusher	300	.05	1	.5	.05	1,500	.02	.95
1b		3000	.05		.5	.05	1,500	.0125	.95
			2. Parking Lot Decontamination						
2a	Scraper	Any	2.9	1	29	2.9		.004	.8
			3. Playground Decontamination						
3a	Firehose		1.7	6	17	1.7	51,000	.02	.77
3b			.22		2.2	.22	6,600	.1	.80
3c	Vacuum Sweeper		.4	1	4.0	.4		.02	.77
3d			.4		4.0	.4		.011	.77
			4. Roof Decontamination						
4a	Firehose	300	.336	7	3.36	.336	10,080	.03	.53
4b		3000	.336		3.36	.336	10,080	.0025	.51

5. Combined Decontamination

Combined Strategies	F_1	Men	Total Man Hours
1a + 2a + 3c	.52	3	3.4
1a + 2a + 3c + 4a	.05	10	5.7

VII. SIMONDS PRESS BUILDING

A. <u>Analysis Data</u>

Address: 37-49 South Avenue
Rochester, N. Y.

Detector: Basement

Normal Protection Factor: PF = 47

Decontamination Areas:

1. Roof: 10,000 sq.ft. composition shingle - 5° pitch
2. Ground Level: 25,000 sq.ft. asphaltic concrete - South Avenue
   8,930 sq.ft. brick - South Water Street
   1,980 sq.ft. brick - Ely Street
   2,800 sq.ft. asphaltic concrete - Parking
   880 sq.ft. asphaltic concrete - Ely extension

Ideal Intensity Reduction Factors:

1. Roof: $f^*_{1,1} = .111$
2. Ground Level: $f^*_{2,1} = .896$
3. Roof and Ground combined: $F^*_1 = .007$

Practical Mass Reduction Factors:

1. Roof: $E_1 = .03$
2. Ground Level: $E_2 = .02$

Practical Intensity Reduction Factors Decontaminating:

1. Roof only: $f_{1,1} = .137$
2. Ground Level only: $f_{2,1} = .898$
3. Roof and Ground Level: $F_1 = .035$

B. Map

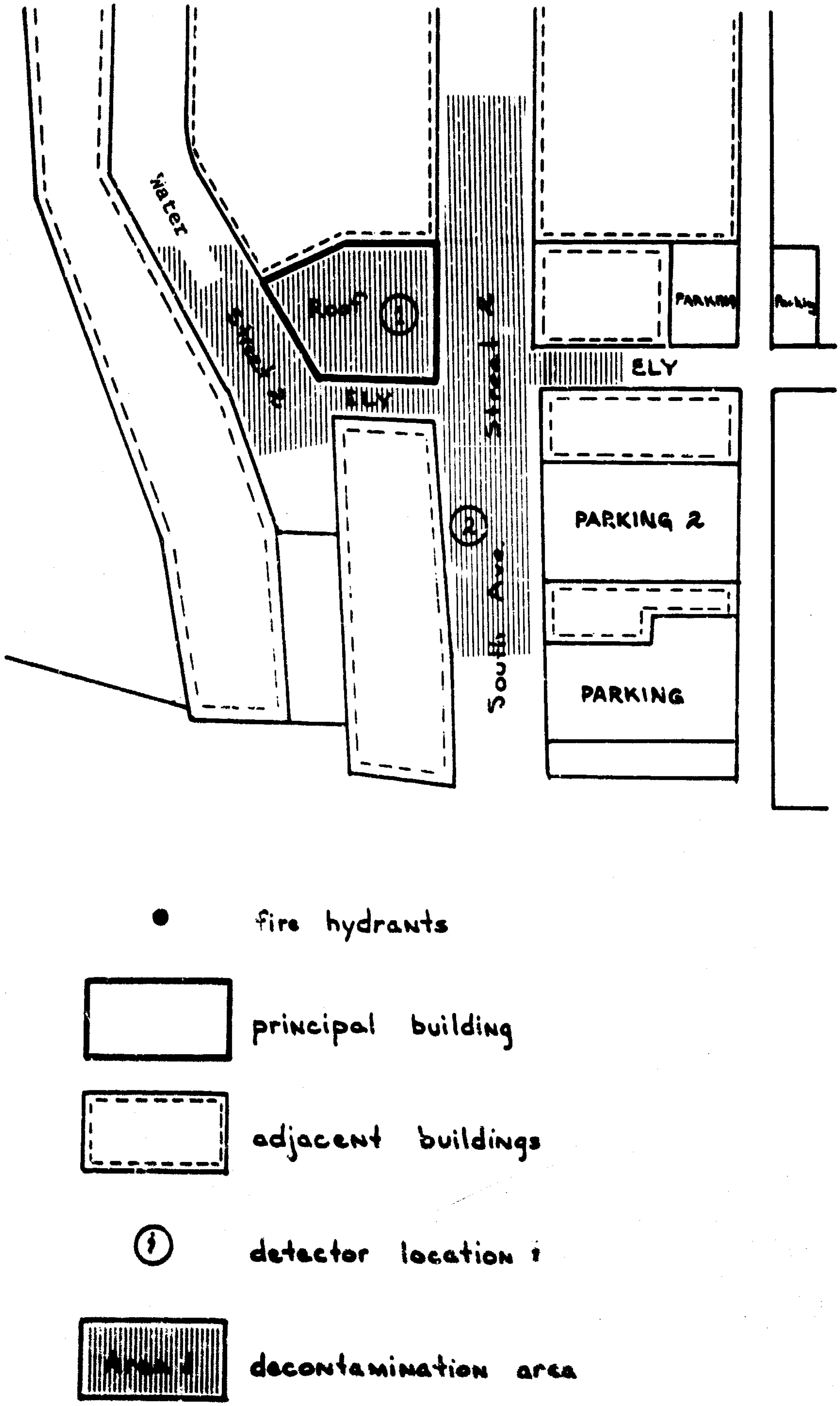


FIGURE 7-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces

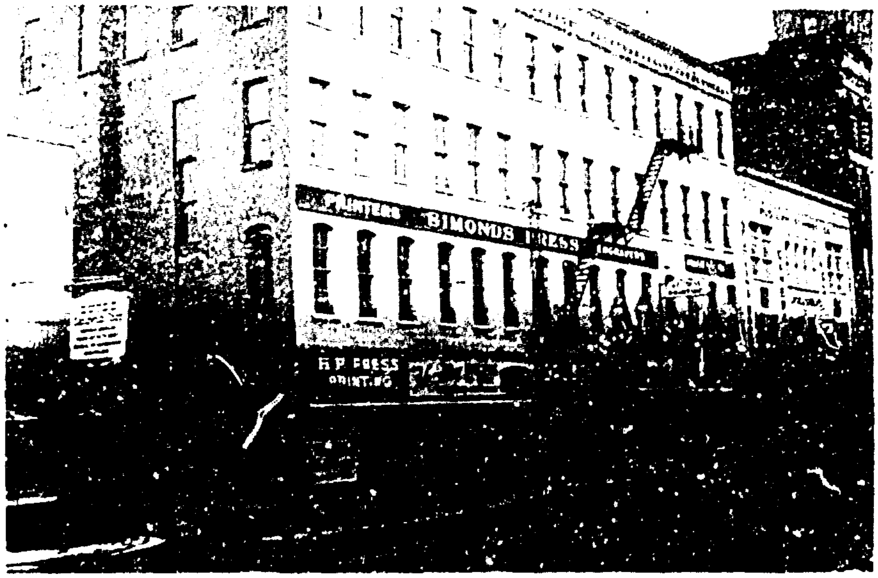
FIGURE 7-2

View of Building from S. Water Street

FIGURE 7-3

View of Building from Ely Street -
(Note: steep grade)

FIGURE 7-4



View of Building from South Avenue

FIGURE 7-5

View of Building from Intersection of
South Avenue and Ely Street

D. Applied Strategies

1. Roof Decontamination

STRATEGY			COST DATA		Multiplying Factor for Crew Dose (Assuming H+1 = 1000 if decont. at			EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1a	Firehose	300	1.67	7	16.7	1.67	50,100	.025	.13
1b		3000	1.67		16.7	1.67	50,100	.023	.13
1c		300	.83		8.3	.83	24,900	.03	.14
1d		3000	.83		8.3	.83	24,900	.028	.14
			2. Paved Area Decontamination						
2a	Street Flusher	300	.4	1	4.0	.4	12,000	.02	.90
2b		3000	.4		4.0	.4	12,000	.0125	.90
2c	Firehose	300	6.61	6	66.1	6.61	198,300	.02	.90
2d		3000	6.61		66.1	6.61	198,300	.02	.90

3. Roof and Paved Area Decontamination

Combined Strategies	F_1	Men	Total Man Hours
1b + 2b	.03	7	12.1
1c + 2a	.04	7	6.2

E. Outside Detector

1. Location of Detector: In center of South Avenue about 90 feet from Simonds Press Building.

2. Original PF at site of detector------------------------- 1.40

3. f*'s for individual planes:

$f^*_{1,2}$: (South Avenue, i.e., plane above which the detector is located)------------------------------ .029

$f^*_{2,2}$: (Parking Lot in middle of block)------------------ .972

$F^*_2 = f^*_{1,2} + f^*_{2,2} - 1 = .001$

VIII. DEPARTMENT OF INTERIOR*

A. Analysis Data

Address: 18th and C Streets, N.W.
Washington, D. C.

Detector: 3rd Floor

Normal Protection Factor: PF = 1090

Decontamination Areas:

1. Interior Court: 23,400 sq.ft. concrete
2. Ground Level Streets: 800 sq.ft. - 19th St. N.W.
   1200 sq.ft. - 18th St. N.W.

Ideal Intensity Reduction Factors:

1. Interior Court: $f^*_{1,1} = .392$
2. Ground Level Streets: $f^*_{2,1} = .818$
3. Court and Streets combined: $F^*_1 = .21$

Practical Mass Reduction Factors:

1. Interior Court: $E_1 = .01$
2. Ground Level Streets: $E_2 = .07$

Practical Intensity Reduction Factors Decontaminating:

1. Interior Court only: $f_{1,1} = .4$
2. Streets only: $f_{2,1} = .83$
3. Courts and Streets: $F_1 = .23$.

*Section B not included in this chapter inasmuch as no photographs were available.

B. Map

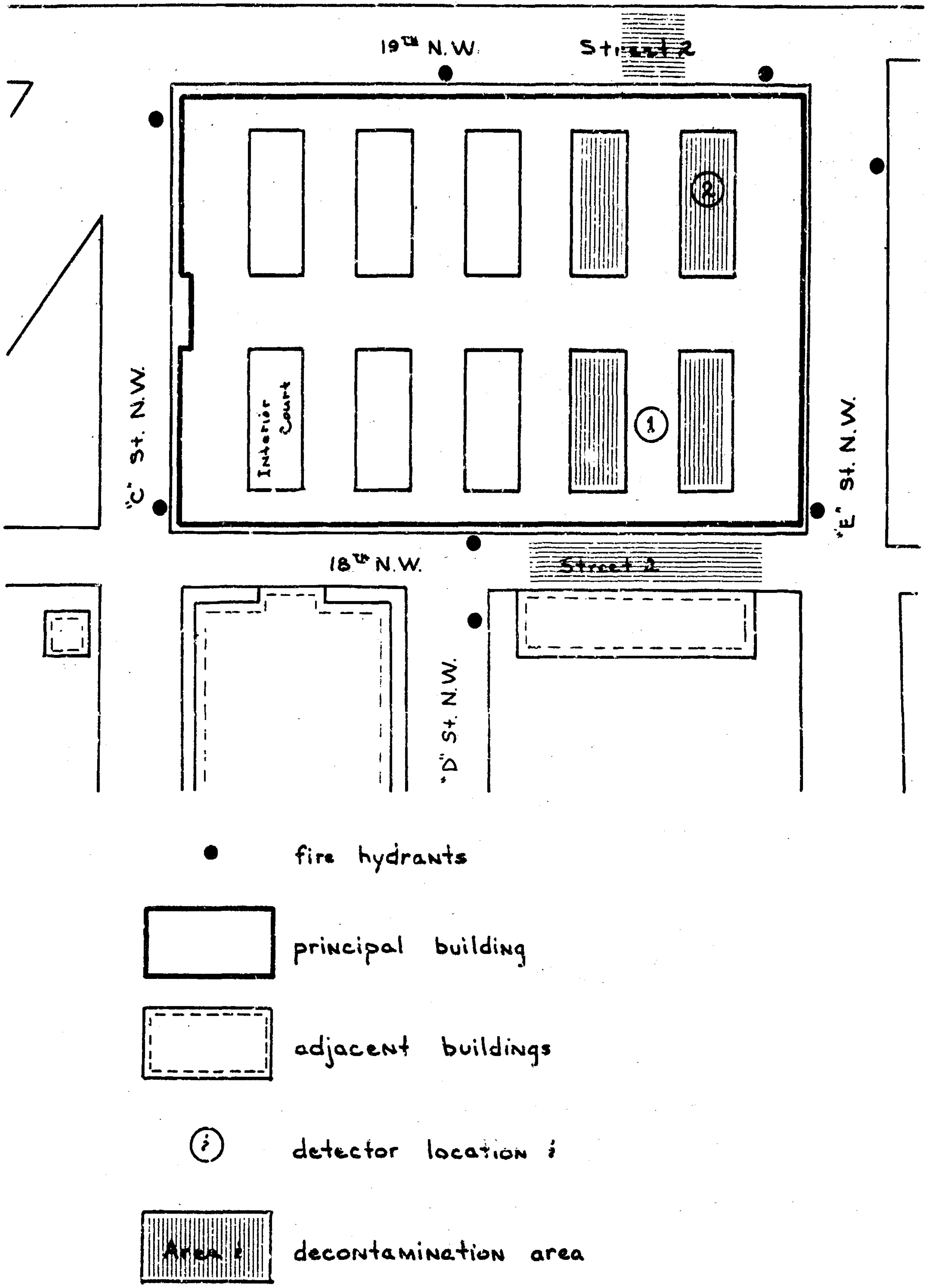


FIGURE 8-1. Location Map of Decontamination Areas

D. Applied Strategies

1. Interior Court Decontamination

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 days (R)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1a	Firehose	300	3.9	6	39.0	3.9	117,000	.01	.40
1b		3000	3.9		39.0	3.9	117,000	.0025	.39

2. Road Area Decontamination

No.	Description	Intensity	Team hrs. of effort	Team Size (Men)	2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
2a	Mech. Sweeper	300	.08	1	.80	.08		.04	.83
2b		3000	.08		.80	.08		.02	.82
2c		300	.03		.30	.03		.10	.84
2d		3000	.03		.30	.03		.07	.83
2e	Street Flusher	3000	.02	1	.20	.02	600	.02	.82
2f		3000	.002		.02	.002	60	.07	.83

3. Interior Court and Road Decontamination

Combined Strategies	F_1	Men	Total Man Hours
1b + 2b	.216	7	23.5
1b + 2d	.224	7	23.4

E. Outside Detector

1. Location of Detector: The center of any of the interior court sections.

2. Original PF at site of detector---------------------------- 1.61

3. F_2^* for court = 0

IX. A DEPARTMENT STORE BUILDING

A. Analysis Data

Address: 619 Main Street
Houston, Texas

Detector: 2nd Floor

Normal Protection Factor: PF = 26

Decontamination Areas:

1. Roof: 9,400 sq.ft. tar and gravel
2. Road Area: 68,300 sq.ft. asphaltic concrete on surrounding streets

Ideal Intensity Reduction Factors:

1. Roof: $f^*_{1,1} = .382$
2. Road Area: $f^*_{2,1} = .619$
3. Roof and Road Areas combined: $F^*_1 = f^*_{1,1} + f^*_{2,1} - 1 = .001$

Practical Mass Reduction Factors:

1. Roof: $E_1 = .025$
2. Road Area: $E_2 = .07$

Practical Intensity Reduction Factors Decontaminating:

1. Roof only: $f_{1,1} = .397$
2. Road Area only: $f_{2,1} = .645$
3. Roof and Road Area combined: $F_1 = f_{1,1} + f_{2,1} - 1 = .042$

B. Map

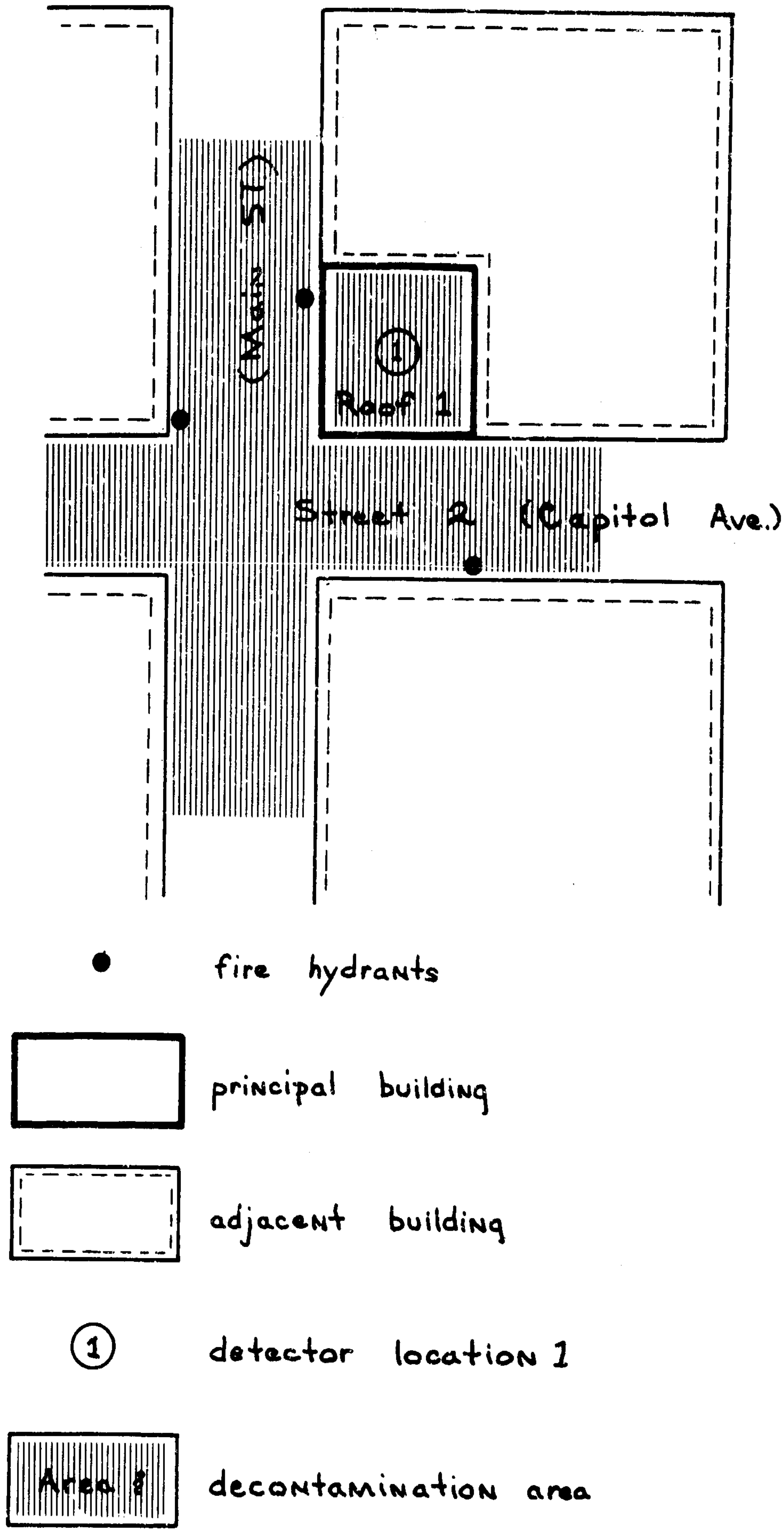


FIGURE 9-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces

FIGURE 9-2

View of Building From Main Street

FIGURE 9-3

View of Building from Capitol Avenue

D. Applied Strategies

1. Roof Decontamination

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 days (R)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
1a	Firehose	300	1.34	7	13.4	1.34	40,200	.01	.39
1b		3000	1.34		13.4	1.34	40,200	.0025	.38
1c		300	.67		6.7	.67	20,100	.03	.40
1d		3000	.67		6.7	.67	20,100	.0025	.38
1e		300	.27		2.7	.27	8,100	.12	.46
1f		3000	.27		2.7	.27	8,100	.025	.40

2. Road Area Decontamination

No.	Description	Intensity (H+1 in r/hr.)	Team hrs. of effort	Team Size (Men)	2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
2a	Street Flusher	300	.68	1	6.8	.68	20,400	.02	.63
2b		3000	.68		6.8	.68	20,400	.012	.62
2c		300	.07		0.7	.07	2,100	.07	.65
2d		3000	.07		0.7	.07	2,100	.07	.65
2e	Mech. Sweeper	300	2.73	1	27.3	2.73		.04	.63
2f		3000	2.73		27.3	2.73		.02	.63
2g		300	1.02		10.2	1.02		.10	.66
2h		3000	1.02		10.2	1.02		.07	.65
2i	Vacuum Sweeper	300	1.37	1	13.7	1.37		.092	.65
2j		3000	1.37		13.7	1.37		.09	.65
2k	Firehose	300	1.72	6	17.2	1.72	51,600	.10	.66
2l		3000	1.72		17.2	1.72	51,600	.10	.66

3. Roof and Road Decontamination

Combined Strategies	E_1	Men	Total Man Hours
1d + 2b	.007	7	5.4

X. BELL TELEPHONE BUILDING

A. Analysis Data

Address: 1010 Pine Street
St. Louis, Mo.

Detector: 13th Floor

Normal Protection Factor: PF = 127

Decontamination Areas:

1. 4th Floor Roof: 7,100 sq.ft. composition shingle and tile
2. 14th Floor Roof: 700 sq.ft. composition shingle and tile
3. Ground Level Roads: 56,400 sq.ft. Chestnut St.
   50,000 sq.ft. Market St.
   30,000 sq.ft. N. 11 St.
   24,000 sq.ft. Pine St.
   40,500 sq.ft. N. 10 St.
4. Ground Level Parking Lots: 73,000 sq.ft.
5. Ground Level Grass Lawns: 36,100 sq.ft.

Ideal Intensity Reduction Factors:

1. 4th Floor Roof: $f^*_{1,1} = .73$
2. 14th Floor Roof: $f^*_{2,1} = .88$
3. Roads: $f^*_{3,1} = .837$
4. Parking Lots: $f^*_{4,1} = .874$
5. Grass Lawns: $f^*_{5,1} = .9896$
6. All Above: $F^*_1 = .31$

Practical Mass Reduction Factors:

1. 4th Floor Roof: $E_1 = .02$
2. 14th Floor Roof: $E_2 = .02$
3. Roads: $E_3 = .1$
4. Parking Lots: $E_4 = .1$
5. Grass Lawns: $E_5 = .02$

Practical Intensity Reduction Factors Decontaminating:

1. 4th Floor Roof: $f_{1,1} = .74$
2. 14th Floor Roof: $f_{2,1} = .88$
3. 4 and 14th Floor Roofs: $F_1 = f_{1,1} + f_{2,1} - 1 = .62$
4. Roads: $f_{3,1} = .85$
5. Parking Lots: $f_{4,1} = .89$
6. Roads and Parking Lots: $F_1 = .74$
7. Roads, Parking Lots, 4 and 14th Floor Roofs: $F_1 = .36$.

B. Map

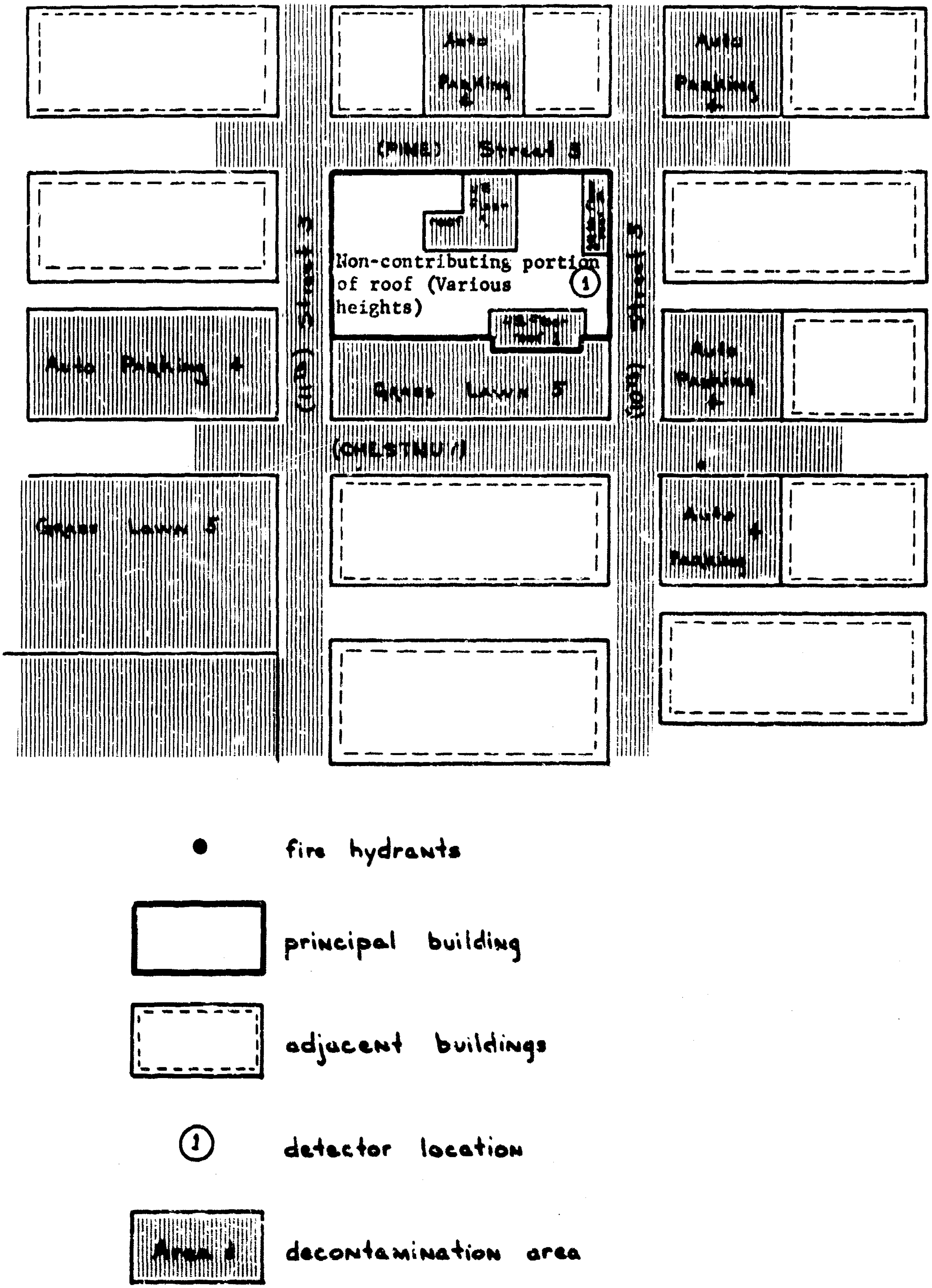


FIGURE 10-1. Location Map of Decontamination Areas

C. Some Photographs of the Associated Contaminated Surfaces

FIGURE 10-2

View of Building from Intersection of 11th St. and Chestnut Street

FIGURE 10-3

View of Building from Pine Street

FIGURE 10-4

View of Building from 10th St. and Chestnut Street

FIGURE 10-5

View of the Building from 11th Street

D. Applied Strategies

STRATEGY			COST DATA					EFFECTIVENESS DATA	
No.	Description	Intensity To Which Mass Reduction Factor Applies (H+1 in r/hr.)	Team hrs. of effort	Team* Size (Men)	Multiplying Factor for Crew Dose (Assuming H+1 = 1000) if decont. at 2 days (R)	2 weeks (R)	Water Used (gal.)	Mass Reduction Factor (E)	Intensity Reduction Factor ($f_{i,j}$)
			1. 4th Floor Roof Decontamination						
1a	Firehose	300	1.18	6	11.8	1.18	35,400	.02	.74
1b		3000	1.18		11.8	1.18	35,400	.02	.74
			2. 14th Floor Roof Decontamination						
2a	Firehose	300	.12	6	1.2	..12	360	.02	.88
2b		3000	.12		1.2	.12	360	.02	.88
			3. Road Decontamination						
3a	Firehose	3000	22.9	6	.229	22.9	687,000	.02	.84
3b		3000	11.45		114.5	11.45	343,500	.10	.85
3c	Street Flusher	3000	1.37	1	13.7	1.37	41,100	.02	.84
3d		3000	.137		1.37	.137	4,110	.01	.84
			4. Parking Lot Decontamination						
4a	Firehose	300	12.2	6	122	12.2	366,000	.02	.88
4b		3000	12.2		122	12.2	366,000	.02	.88
4c		300	1.83		18.3	1.83	[illegible]	.1	.89
4d		3000	1.83		18.3	1.83	54,900	.1	.89
4e	Street Flusher	300	.73	1	7.3	.73	21,900	.02	.88
4f		3000	.73		7.3	.73	21,900	.0125	.88
4g		3000	.073		0.73	.073	2,190	.08	.88
			5. Grass Lawn Decontamination						
5a	Scraper (1 pass)	3000	4.00	1	40.0	4.00		.019	.99
5b	Scraper (2 passes)	3000	10.47	1	104.7	10.47		.004	.99

*Only six men would be required to hose this roof inasmuch as firehose connectors are provided inside the building.

D. Applied Strategies (Cont'd)

6. Combined Strategies

Combined Strategies	F_1	Men	Total Man Hours
1b + 2b	.62	12	7.80
3d + 4g	.72	2	.21
1b + 2b + 3d + 4g	.34	14	8.01

XI. PARAMETRIC STUDY

Designation of Surfaces which can be Decontaminated

Surface Number (See Figure 11-1)	Description	
1	9 story building north of detector location	(120 ft. x 60 ft.)
2	3 story building east of detector location	(120 ft. x 60 ft.)
3	2 story building south of detector location	(120 ft. x 60 ft.)
4	6 story building west of detector location	(120 ft. x 60 ft.)
5	40 ft. wide road west of detector location	
6	40 ft. wide road east of detector location	
7	40 ft. wide road south of detector location	
8	20 ft. wide alley north of detector location	
9	Parking lot in NE corner	
10	The three unpaved fields	

All pavement in the intersections are considered part of the two north-south roadways.

c. Map.

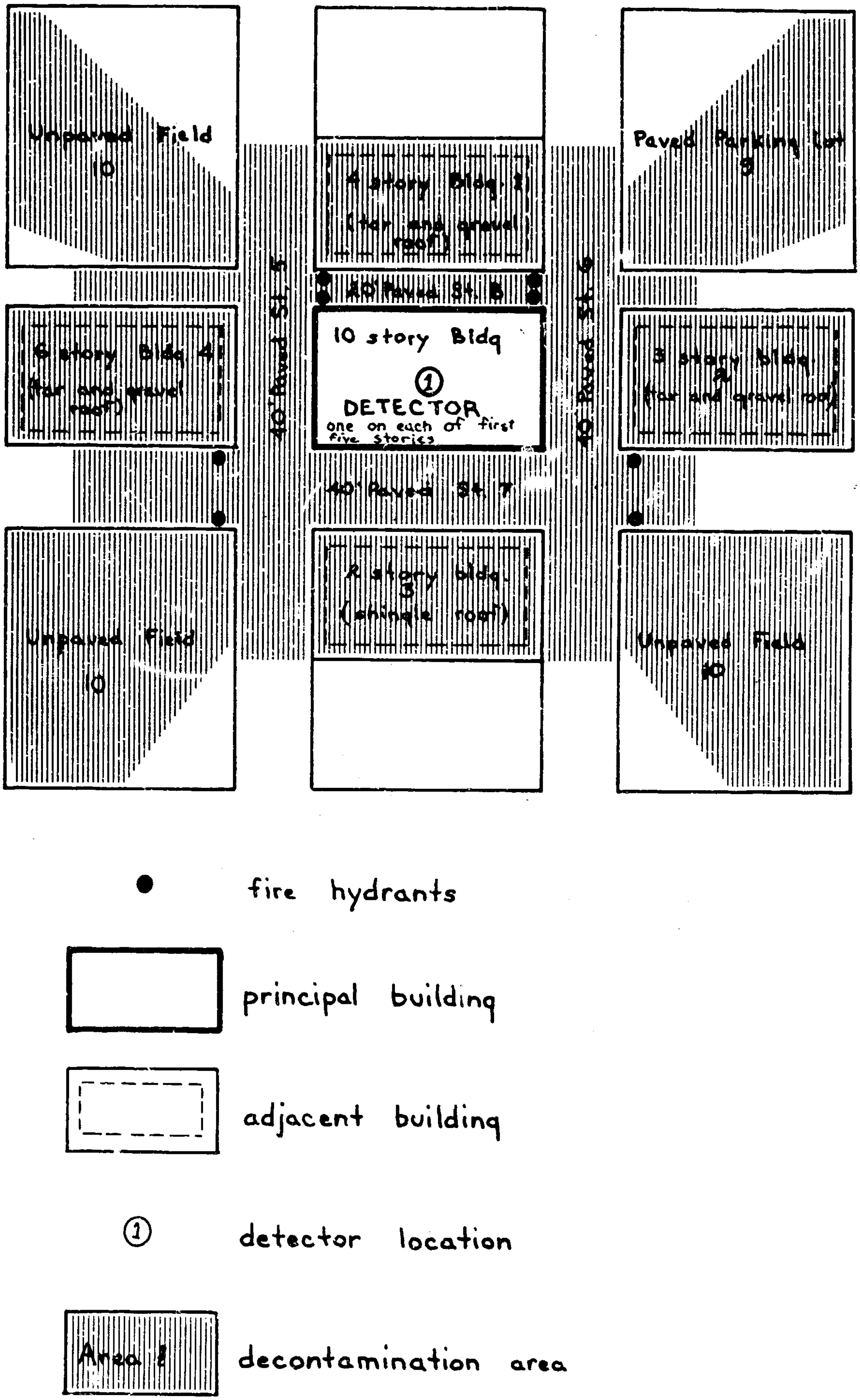


FIGURE 11-1. Location Map of Parametric Study

A. <u>Building Data For Parametric Charts I, II, and III</u>

1.	number of stories	10 (detector located on first five)
2.	number of asimuthal sectors	12
3.	total height of building	100'
4.	height of each story	10'
5.	roof weight	60 psf
6.	exterior wall weight	80 psf
7.	windows: sill height	3'
	top of window height	8'

(window widths total to about 50% of the exterior wall width)

8. Floor weights are shown on individual charts.

B. <u>Building Data For Parametric Chart IV</u>.

This building is like that for Charts I, II, and III except for the following:

1. North wall of building has no windows
2. West side of detector has additional protection from an interior partition (10 PSF).

Parametric Chart I: All Floor Weights = 37 psf

Values of $f^{*}_{i,j}$

Surface number i \ floor j	1	2	3	4	5
1	1	1	1	1	1
2	1	1	.999	.965	.955
3	1	.998	.930	.921	.918
4	1	1	1	1	1
5	.803	.849	.885	.913	.919
6	.787	.826	.860	.847	.874
7	.795	.797	.795	.984	.844
8	.843	.899	.951	.957	.972
9	.956	.930	.912	.958	.920
10	.815	.731	.684	.680	.699

floor (j)	original residual number	original PF
1	.0321899	31.07
2	.0265157	37.71
3	.0233717	42.79
4	.0225117	44.42
5	.0208844	47.88

Parametric Chart II: All Floor Weights = 17 psf

Values of $f^*_{i,j}$

Surface number i \ floor j	1	2	3	4	5
1	1	1	1	1	1
2	1	1	.998	.970	.946
3	1	.996	.941	.902	.901
4	1	1	1	1	1
5	.805	.859	.891	.924	.930
6	.788	.835	.869	.884	.894
7	.790	.797	.810	.857	.869
8	.848	.891	.951	.971	.976
9	.956	.928	.901	.905	.913
10	.814	.695	.655	.645	.676

floor (j)	original residual number	original PF
1	.0340460	29.37
2	.0352403	28.38
3	.0289268	34.57
4	.0281681	35.50
5	.0269712	37.08

Parametric Chart III: All Floor Weights = 57 psf

Values of $f^*_{i,j}$

Surface number i \ floor j	1	2	3	4	5
1	1	1	1	1	1
2	1	1	.999	.961	.961
3	1	.999	.923	.934	.931
4	1	1	1	1	1
5	.803	.843	.881	.906	.911
6	.786	.819	.855	.855	.860
7	.797	.797	.785	.821	.827
8	.842	.906	.950	.965	.969
9	.957	.931	.920	.924	.925
10	.816	.703	.703	.703	.715

floor (j)	original residual number	original PF
1	.0315151	31.73
2	.0226001	44.25
3	.0209305	47.78
4	.0200083	49.98
5	.0181717	55.03

Parametric Chart IV: All floor weights = 37 psf

Values of $f^*_{i,j}$

Surface number i \ floor j	1	2	3	4	5
1	1	1	1	1	1
2	1	1	1	1	.998
3	1	.999	.936	.910	.941
4	1	1	1	1	1
5	.879	.893	.914	.931	.932
6	.791	.818	.869	.891	.887
7	.737	.734	.737	.772	.793
8	.838	.917	.965	.979	.986
9	.951	.923	.908	.910	.957
10	.817	.694	.680	.658	.657

floor (j)	original residual number	original PF
1	.031735197	31.51
2	.025011274	39.98
3	.022059926	45.33
4	.020048274	49.88
5	.017455098	57.29

XII. UNSHIELDED DETECTOR ON STREETS

A. Straight Road

Table 12-I shows computed protection factors for persons standing in the middle of an asphalt street as shown in Figure 12-1 for various widths and lengths of contaminated roadway. All of the radiation intensity at the point is received from fallout on this single piece of road (i.e., within the area designated in Figure 12-1)

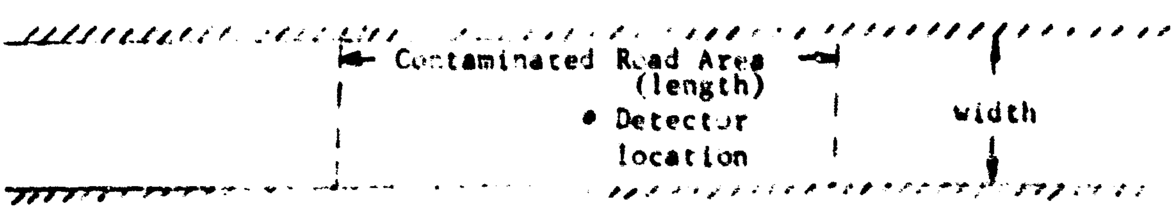
TABLE 12-I

Straight Road PF's

Length (feet)	Width (feet)	PF
1000	60	1.57
200	60	1.57
100	60	1.59
50	60	1.71
1000	40	1.67
200	40	1.67
100	40	1.68
50	40	1.79

FIGURE 12-1

Straight Road



B. T - Intersections

Table 12-II shows computed protection factors for persons standing in a T - shaped street intersection as shown in Figure 12-2 for various lengths and widths of the intersecting roads.

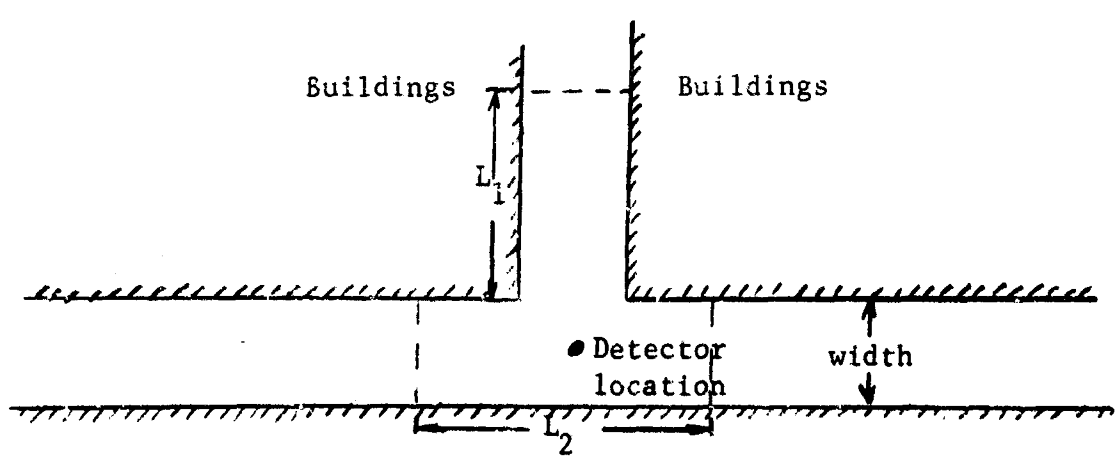
TABLE 12-II

T - Shaped Intersection PF's

Length L_1 (feet)	Length L_2 (feet)	Width (feet) Both Streets	PF
500	1000	60	1.54
100	1000	60	1.54
50	1000	60	1.55
0	1000	60	1.57
50	200	60	1.55
50	100	60	1.56
50	50	60	1.57
500	1000	40	1.63
100	1000	40	1.63
50	1000	40	1.64
0	1000	40	1.67

FIGURE 12-2

T - Shaped Street Intersection



C. Full Four-way Street Intersections

Table 12-III shows computed protection factors for persons standing in the center of a full four-way intersection for various road widths and lengths as designated in Figure 12-3.

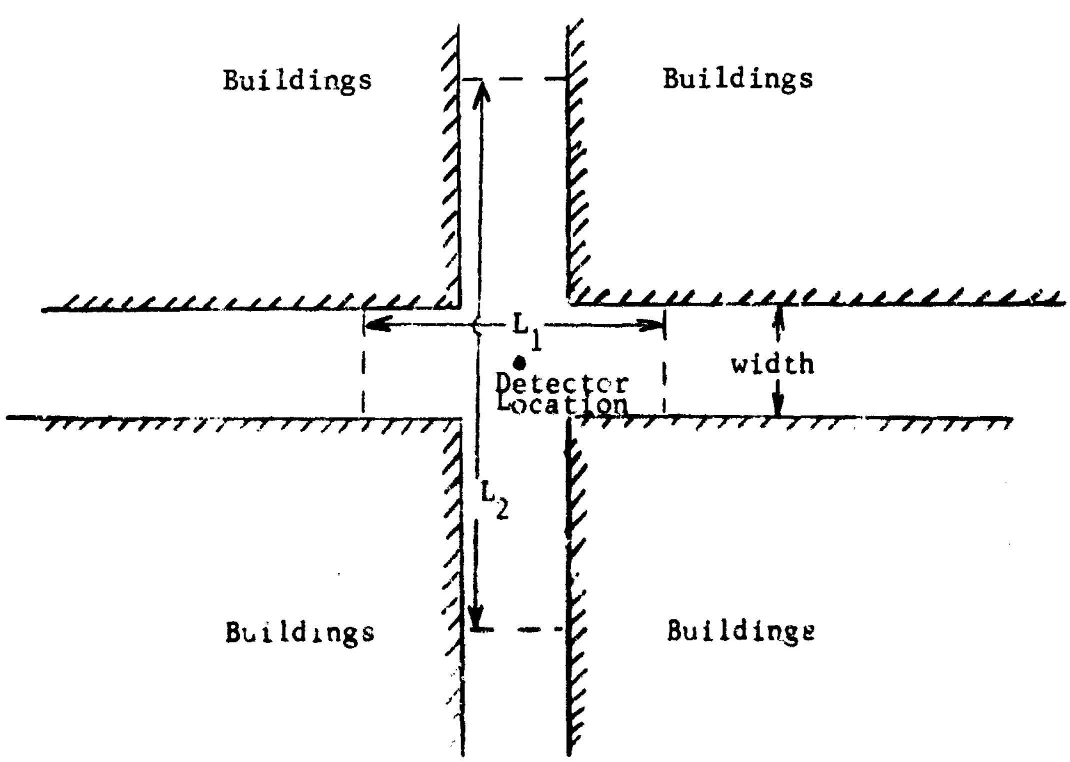
TABLE 12-III

Four-way Intersection PF's

Length L_1 (feet)	Length L_2 (feet)	Width (feet) Both Streets	PF
1000	1000	60	1.47
1000	200	60	1.47
1000	100	60	1.50
1000	60	60	1.57
1000	1000	40	1.50
1000	200	40	1.51
1000	100	40	1.54
1000	40	40	1.67

FIGURE 12-3

Full Four-way Intersection



D. Typical Protection Factors of Unshielded Detectors on Streets

Table 12-IV shows some typical protection factors afforded to unshielded individuals located in the center of various streets and intersections.

TABLE 12-IV

Typical Street PF's

Road Width (feet)	Detector Location	PF
60	Center of Straight Road	1.57
60	Center of T - Shaped Intersection	1.54
60	Center of Four-way Intersection	1.47
40	Center of Straight Road	1.67
40	Center of T - Shaped Intersection	1.63
40	Center of Four-way Intersection	1.50

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