Final Report

December 1971

THE MAGNITUDE OF INITIAL POSTATTACK RECOVERY ACTIVITIES

Prepared for:

OFFICE OF CIVIL DEFENSE
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13. ABSTRACT

This study analyzes the life support tasks of the initial postattack recovery period from the time the survivors emerge from shelters until they have been provided with adequate accommodations. The objective is to provide a basis for the subsequent development of operational contingency plans for the initial postattack recovery period. The study develops quantitative descriptions of typical damage situations in metropolitan areas. The tasks necessary for survival are defined and estimates are made of the effort, equipment, and number of men required for the tasks. The major tasks analyzed are (1) debris clearance, (2) delivery of food and water, (3) decontamination, (4) relocation of the homeless survivors, and (5) boarding windows.

THE MAGNITUDE OF INITIAL POSTATTACK RECOVERY ACTIVITIES

By: RICHARD L. GOEN

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DETACHABLE SUMMARY

1. **Title:** The Magnitude of Initial Postattack Recovery Activities

   Author: Richard L. Goen

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2. **Type of Study:** The study is an analysis of the amount of effort required for essential survival tasks.

3. **Key Descriptors**

   * Nuclear attack

   * Postattack survival and recovery

   * Operational contingency plans

   * Relocation of survivors

   * Debris clearance

   * Decontamination

4. **Objectives**

   The objective is to determine the amount of effort required for postattack survival tasks as a basis for subsequent development of operational contingency plans.

5. Assumptions, Analytical Techniques, and Models

The study made use of data from past damage assessment studies to develop quantitative descriptions of the postattack situations in typical damaged metropolitan areas. Data from various studies of postattack tasks were used to determine the effort required for the tasks in the typical situations.

6. Scenarios

Information was used from attack results from the OCD DAL-67, DAL-69, and Five-City studies. One scenario was for a severely damaged SMSA, and another for a lightly damaged SMSA.

7. Measures of Effectiveness

Task requirements were measured in terms of the man-hours of effort, the number of men, and the amount of equipment required.

8. Problems Encountered--None.

9. Findings

The findings consist of definition of the size of postattack tasks and estimates of the effort, men, and equipment required for the tasks. The total effort is well within the capabilities of the potentially available work force, except that there may be a shortage of experienced operators for earth moving equipment for debris clearance and decontamination.

10. Recommendations

The next step is to make use of the findings of this study to develop operational contingency plans for the initial postattack period.

11. Contribution

This study provides the quantitative description cf the initial postattack recovery operations necessary for the development of operational contingency plans.

12. Key References

- Goen, R. L., et al., "Analysis of National Entity Survival," Stanford Research Institute, November 1967

- Wickham, G. E., "Debris Removal Civil Defense Operations, San Jose-Detroit Case Study, Volume II," Jacobs Associates, March 1969

- Lee, H., W. L. Owen, and C. F. Miller, "General Analysis of Radiological Recovery Capabilities," Stanford Research Institute, June 1968

13. Costs Associated with Recommendations--None.

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This study analyzes the life support tasks of the initial postattack recovery period from the time the survivors emerge from shelters until they have been provided with adequate accommodations. The objective is to provide a basis for the subsequent development of operational contingency plans for the initial postattack recovery period. The study develops quantitative descriptions of typical damage situations in metropolitan areas. The tasks necessary for survival are defined and estimates are made of the effort, equipment, and number of men required for the tasks. The major tasks analyzed are (1) debris clearance, (2) delivery of food and water, (3) decontamination, (4) relocation of the homeless survivors, and (5) boarding windows.

PREFACE

This study is a continuation of work under contract DAHC20-69-C-0186. The following three reports were previously prepared on this contract:

Richard L. Goen, Richard B. Bothun, and Frank E. Walker, "Potential Vulnerabilities Affecting National Survival," September 1970

Steven L. Brown and Pamela G. Kruzic, "Agricultural Vulnerability in the National Entity Survival Context," July 1970

Richard K. Laurino and Francis W. Dresch, "National Entity Survival: Measure and Countermeasure," June 1971.

The present study was under the supervision of Richard B. Bothun, Manager, Resources Analysis Group, and George D. Hopkins, Director, Operations Evaluation Department. Advice was provided by Hong Lee on several parts of the study, particularly on decontamination. John W. Ryan was also a contributor to the study.

Project guidance was provided by Dr. David W. Bensen, the Contracting Officer's technical representative, of the Office of Civil Defense.

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I INTRODUCTION AND SUMMARY

Objectives

The general objectives of this study were (1) to prepare a basis for development of contingency plans for life support activities in the postattack initial recovery period and (2) to establish the feasibility of meeting survival needs through that period.

Analysis is made of life support activities after emergence from shelter. The objectives are to (1) structure and describe postattack contingency situations, (2) identify major operational alternatives under various contingencies, (3) establish the magnitude of major tasks in terms of manpower, time, and resources, (4) determine the feasibility of accomplishing the tasks with the resources available, and (5) determine preferable courses and sequences of actions.

In addition to the application to contingency planning, the quantitative description of situations and the magnitude of postattack tasks should also be useful in providing insights that would be useful in carrying out postattack management responsibilities.

Scope

The initial postattack recovery period starts when survivors emerge from shelters and ends when survivors are situated in areas of significant stay times. At the time of emergence from shelters, the immediate post-attack task is to provide the survivors with essential goods and services, including housing, food, and water. (Medical care and public health measures were excluded from this study.) Necessary supporting tasks include debris clearance and decontamination.

This study analyzes the life support tasks of the initial postattack recovery period. A complete coverage of all activities is not attempted; rather, attention is limited to the most significant tasks. The study is principally an integrative effort, drawing on the results of past studies of specific and general postattack recovery problems, to provide an overview of the essential activities.

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The study focuses on a large SMSA (Standard Metropolitan Statistical Area), with the principal case being a severe damage situation, and another case being one of relatively light damage from a peripheral burst. A shelter posture based on extension of the present shelter program, and without preattack evacuation, is assumed.

Background

The OCD postattack research program has established that recovery after nuclear attack appears to be feasible, and has developed a good understanding of the problems and requirements of the postattack period. A major thrust of the OCD research program is now directed toward utilization of the knowledge from the extensive civil defense research for the development of operational plans. A major development in planning has been the Nuclear Emergency Operations Plan. The NEOP has been published by OCD as a "Local Emergency Action Checklist" (June 1971). This report contains five contingency plans that describe the series of emergency actions that should be taken during a crisis and under each of four attack contingencies. In addition to providing a checklist for planning and conduct of emergency actions, the NEOP is intended to serve as a tool for training in emergency operations. Currently work is underway to develop a comparable NEOP for the AREA level, the organizational level above the operating zone.

The NEOP covers primarily the emergency period. The extension of contingency plans to the initial recovery period is now needed, and OCD is planning to begin this activity.

This study is intended to lay a basis for the subsequent development of operational contingency plans for the initial postattack recovery period. The study develops quantitative descriptions of contingency situations, survival needs, and resource availability; this provides useful insight for development of plans by reducing the level of abstraction. If a desired action requires greater resources than are likely to be available, then the need is identified for alternative actions within the resource constraints. In addition, some idea of the magnitude of tasks is necessary for planning the level of effort to be assigned to the tasks.

In a typical heavy attack on a large metropolitan area a large proportion of the survivors would be left homeless. In many cases there would not be sufficient housing remaining for the survivors, and it might be necessary to relocate the survivors outside the metropolitan area. The amount of building space throughout the country would be

ample for housing; but, the provision of housing for the homeless would be a major activity. Furthermore, the housing requirement would often determine the requirements for other activities. Thus the provision of housing is a central theme of this study.

Postattack Situations

The spectrum of situations at the beginning of the initial postattack recovery period derives, of course, from the attack results that can be characterized by the damage level and the fallout level. The damage level is related to both the blast damage and the extent of fire. The following matrix illustrates the range of attack results for a damaged SMSA:

	Fallout Level	
	Heavy	Light or None
Severe blast		
Little fire	x	
Extensive fire		
Light blast		
Little fire	x	
Extensive fire		

All combinations are possible, but only the severe blast/little fire/heavy fallout, and light blast/little fire/heavy fallout cases are examined in this report.

The definition of terms is related to the factors in the postattack situation, which include the number of survivors, the condition of the survivors, the amount of building space relative to the number of survivors, debris levels, and the fallout constraints. Severe blast damage refers to destruction of the major portion of the buildings in the SMSA (e.g., two-thirds or more) and accompanying large blast fatalities. The light blast damage refers typically to a burst near the periphery of the SMSA, often aimed at an adjacent target, with the major portion of the buildings surviving, and only a few percent direct fatalities.

The extent of fire would vary with conditions. The possibilities range from almost complete burnout of the contiguous built-up area to fire loss of only a moderate fraction of the buildings.

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The fallout level of course would vary within the city. The heavy fallout level refers to a level over much of the city that would (1) result in heavy fatalities to people forced to leave shelter because of fire and (2) prevent general emergence from shelter for at least several days. The extensive fire case combined with heavy fallout has the effect of reducing both building space and survivors.

One of the major operational differences between the cases is related to the ratio of surviving building space to survivors. In the severe blast damage cases there would generally be insufficient building space to house the survivors, and extensive relocation to other communities would be required. With light blast damage and little fire there would be ample resources of building space and the survivors could remain within the local area.

This study has concentrated on the two cases of severe blast damage and light blast damage, both with little fire and heavy fallout. As previously noted, the effect of extensive fire combined with heavy fallout is to reduce both the amount of building space and the number of survivors. In the light or no fallout cases the effort required for decontamination is, of course, greatly reduced or eliminated. In addition, the number of men required for the other tasks is also reduced, from that for the heavy fallout cases, by relaxation of the fallout constraint on allowable work time.

Summary

A typical SMSA of one million population was defined for the study. Attention was confined to the urbanized part of the SMSA with a population of 870,000. Typical damage situations were defined and described quantitatively as a basis for the definition of the tasks in the initial postattack period and for the calculation of the effort required for the tasks. Many assumptions have to be made to derive the estimates. Although specific figures are given, the numbers are only intended to provide an indication of the dimensions of the effort.

Severe Damage Case

Damage Description--A typical description for severely damaged SMSAs was developed from past damage assessment results. Typical distributions of overpressure and survivors within annuluses about the SMSA center were derived. In the typical heavy damage case, most of the structures in the downtown area are destroyed, and the survival rate is

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very low. Most of the structures within the rest of the central city
are also severely damaged, yet many substantial buildings are not
demolished and the survival rate is about 30 percent. Within the adjacent
suburban areas surrounding the central city, four to eight miles from
the city center, most of the housing is destroyed, but the survival rate
is about 50 percent. The remainder of the urbanized area contains most
of the surviving housing, and fatalities are mainly from fallout.

The following tabulation gives the total number and the condition
of the survivors in all zones three days after the attack. (The "sick"
here refers to the survivors receiving over 200 r ERD (equivalent residual
dose), though they may not be sick at the time).

Uninjured and not sick	152,700
Injured or sick	201,800
Dying after three days	125,600
Total alive at three days	480,100
Dead by three days	389,900
Preattack population	870,000

The number surviving declines to 440,000 one week after the attack.

About 38,000 housing units (which had contained 125,000 preattack
residents) survive, based on a 2-psi damage criterion. However, fallout
levels and loss of utilities make some of the units unsuitable for early
occupancy. Also, virtually all the windows will be broken throughout
the area.

Required Tasks--The immediate survival needs at the time of shelter
emergence are water, food, and accommodations. As radiation levels
decline to levels permitting outside operations, the first step is to
establish the operational capability of the multipurpose staging areas,[*]
which might require decontamination and clearing of access routes. Vital
facilities such as electric power stations and water plants would be
restored to operation if any were sufficiently undamaged to permit early

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* The multipurpose staging area is a facility or group of facilities
  that would serve as a base of operations for emergency forces.

return to operation. Routes will be cleared through the debris to permit vehicular access to the survivors. Water and food may be distributed to some of the sheltered population, if necessary, before they can be relocated. Buses will move the homeless to housing both within and outside the urbanized area. Much of this housing will have to be decontaminated before use, and some will require restoration of utility service. Broken windows will have to be boarded up.

Debris Clearance--Most of the survivors within the urbanized area will be in areas where the streets are blocked with debris. Not much, if any, debris will be cleared before the arrival of fallout. A principal purpose of the debris clearance will be to provide vehicular access to the sheltered survivors for delivery of water and food, and for their removal.

A typical distribution of streets by overpressure would include about 1,600 miles within the 2- to 15-psi level, the range of potential concern for debris clearance. Above 15 psi the number of survivors will be too few to warrant debris clearance, except, perhaps, for some key routes. Most of the 1,600 miles of streets will be in suburban residential areas where debris depths will be much lower than in the downtown area. Clearing two lanes on the principal arterials would require removal of 283,000 cu yds of debris. Most of the survivors will be within half a mile of principal arterials. With the clearance of one lane on the remainder of the 1,600 miles of streets, the total debris volume to be removed would be 1.7 million cu yds.

A typical production rate for the equipment, such as loaders and bulldozers, that will be used for debris clearance is about 200 cu yds per hour. Clearance of the 1.7 million cu yds of debris would thus take 850 equipment days, based on ten hours per day. However most of the debris clearance effort will be in areas with debris depths of no more than a few inches. For that situation, a production rate in terms of cu yds per hour may not be appropriate. It has been estimated that in light debris a bulldozer, making a continuous run through the streets and spilling the debris to the sides, could clear 20 miles in a day. On that basis, 88 equipment days would be required. For calculating manpower and equipment requirements, a figure of 200 equipment days-- intermediate between 850 and 88--for debris clearance was assumed.

Considering the limits on food and water in the shelters, it will be desirable to provide supplies to the people in them or to evacuate them, within approximately one week if feasible. High dose rates would delay the debris clearance and increase the manpower requirements. Allowing

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a 5-day effort starting on the fifth day, and with standard intensities of about 4000 r/hr, and a 30 r per day dose limit, 74 bulldozers (or other equipment) and 148 men would be required.

Ample equipment will be available, but the expected availability of experienced equipment operators within the SMSA might be only 150 to 200. Thus the estimated manpower availability, though enough, is of the same order of magnitude as the requirements. This example illustrates the importance of having some idea of the magnitude of the operations and the available resources when making plans. If the manpower requirements had been an order to magnitude greater, the operational concept would have been substantially altered, since only very limited vehicular access could have been provided within the debris area.

Water and Food--The delivery of food and water to people in shelters might be important since many of the shelters may not have enough food and water to last until shelter emergence. This activity belongs in the shelter period. However, since the delivery of supplies could permit a delay in the time of shelter emergence (which defines the start of the initial postattack recovery period) it is appropriate to include that activity in the analysis of the initial recovery period.

Water can be delivered to shelters and to residential areas by tank trucks. If sufficient containers--such as 55-gallon drums or trash cans with plastic liners--can be found, the containers can be placed at the shelters and at various points in the residential areas, and filled periodically by the tank trucks. The effort required for water delivery is based on supplying water to 120,000 survivors in public shelters and to 120,000 at home, which will be about half the survivors on the fifth day. The number of tank trucks required is 16. If water delivery continues over an 8-day period beginning on the fifth day after attack, and if a 4000 r/hr standard intensity and a 100-r dose limit are assumed, 172 men will be required. This figure includes the men required for finding and delivering the containers.

Retail food stocks (mostly from damaged stores) within the area can provide sufficient supplemental food for several days. In about three hours a 5-man crew with a truck can pick up enough canned goods for one day for a shelter with 600 people in it. Assuming half of the shelters need additional food (120,000 people) the required work force would total 1,000 men each day. In most cases a shelter could provide its own work force.

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Relocation of Homeless--A large majority of the survivors will likely be homeless. As previously mentioned, the surviving housing in the example situation had only 125,000 preattack residents, while the number of people surviving after seven days was 440,000. Many of the survivors will be in a public shelter, but possibly half might be at home, in the ruins. Housing can be found for some within the urbanized area, but many will have to be sent to outside communities. Some can be housed in congregate facilities, such as schools, but most will have to be assigned to private homes.

A typical housing allocation is given in the following tabulation:

	Number of People
Within urbanized area	
Own home	87,000
Other residences	100,000
Congregate facilities	50,000
Outside urbanized area	
Congregate facilities	68,000
Residences	135,000
Total	440,000

Buses operating out of staging areas on the fringes of the damaged area can pick up the homeless and take them to the staging areas or to relocation centers in the outside communities for assignment and transportation to their assigned housing. Some people whose automobiles are operable can drive out themselves. The seriously injured or sick might be assigned to congregate facilities to the extent possible, to facilitate the provision of physical and medical care. Stretcher crews will be required in some areas to carry the seriously injured and sick to the buses. Housing assignment directors will also be needed.

The buses could make between five and ten roundtrips per day, depending on the situation and distance. The relocation is assumed to be carried out over a five-day period beginning on the seventh day after the attack. (Occupancy of houses would be delayed until later if dose

rates are high.) At a standard intensity of 4000 r/hr, and with a PF
(protection factor) of two, the work time would be limited to 35 hours
to keep the dose under 100 r. Hence two shifts per day would be required.
The number of buses and men required are:

Buses	459
Drivers	1,149
Stretcher crews and housing assignment directors	1,505
Total men	2,654

The required number of buses is well under the number expected to be
available within the SMSA.

Decontamination--Decontamination might be required for the multi-
purpose staging areas, vital facilities such as power plants and water
stations, and housing. The following lists the items considered for
decontamination:

	Number of Facilities
Electric generating station	1
Water treatment plant	1
Electric substation	3
Staging area	4
Congregate housing	-

The number of staging areas is the estimated number still suitable for
use after the attack. The staging areas accommodate 18,000 people for
congregate housing, leaving accommodations for an additional 32,000 to
be provided by other congregate facilities. Decontamination of residen-
tial areas is discussed later.

The effort and men required for decontamination of these facilities is given in Table 1. The vital facilities and staging areas are assumed to be decontaminated on the fifth day after the attack. The congregate housing is decontaminated in two days beginning on the seventh day. A 4000 r/hr standard intensity and a dose limit of 30 r in one day are assumed.

Table 1

EFFORT FOR DECONTAMINATION OF FACILITIES

	Vital Facilities and Staging Areas	Congregate Housing	Total
Effort (man-hours)			
Roofs and paved areas	1,052	1,152	2,204
Earth and lawn areas	391	1,600	1,991
Total	1,443	2,752	4,195
Number of men			
Roofs and paved areas	352	72	352 *
Earth and lawn areas	78	100	100 *
Total	430	172	451 *

* Crews for vital facilities and staging areas used again for the congregate facilities.

The amount of earth moving equipment available should be adequate for decontamination of earth and lawn areas. However, the debris clearance effort will use up the allowable dose of most of the experienced equipment operators. Hence a small number of additional equipment operators from outside the area might be needed.

The decontamination of residential areas requires much greater effort for the number of accommodations obtained than is required for decontamination of congregate facilities. However, often there would not be enough large buildings to supply congregate facilities for all the survivors, so residential housing might have to be used. Although it should be possible to avoid use of housing in the early postattack period, in areas with standard intensities over 4000 r/hr, the use of housing in the 2000-4000 r/hr standard intensity range would often be necessary. Nevertheless, housing in this dose range could not be occupied for several weeks, without excessive doses to the occupants, unless decontaminated.

The largest part of the effort for decontaminating residential areas is for the yards. Partial decontamination limited to the streets, other paved areas, roofs, and yard areas immediately adjacent to the houses can be performed with a feasible level of effort. The partial decontamination will reduce the dose rate by a factor of three, which will be sufficient to permit substantially earlier occupancy and to reduce post-shelter doses.

The streets are first cleaned with street sweepers or flushers. The roofs (sloped, shingle) are decontaminated by fire hose teams lobbing water onto them from the ground. Paved areas such as sidewalks and driveways for each house are swept manually. The lawn and earth areas within ten feet of each house are decontaminated by hand spading a two to three inch layer into a wheelbarrow and dumping the spoil away from the house. The manual decontamination around each house can be done by the occupants at the time they move in.

The work is assumed to be performed over a seven-day period. Occupancy, and hence the decontamination, will be delayed until the dose rate before decontamination is below 2 r/hr. The effort for decontamination of the 38,000 surviving houses within the urbanized area and the dose reduction are as follows:

	Man-hours	Men	Dose Reduction (percent)
Streets	966	22	15%
Roofs	26,000	476	27
Around a typical house	12		25
Total			67%

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There should be enough firehose equipment to decontaminate the roofs at that rate, if water is available from the fire hydrants.

Boarding Windows--Virtually all windows within the urbanized area will be broken. Material for covering the windows can be salvaged from buildings damaged beyond repair. The estimated window area to be covered is:

	Square Feet
Vital facilities, staging areas, and congregate housing	220,000
Houses	12,000,000

The windows in the vital facilities, staging areas, and congregate facilities are considered to be boarded over a four-day period beginning six days after the attack. The work on the houses will be delayed until near the time of occupancy. Possibly the occupants will cover the windows themselves. The effort is as follows:

	Man-hours	Men
Vital facilities, staging areas, and congregate housing	7,000	195
Houses	365,800	3,780

Total Effort--A summary of the total effort for the major tasks is given in Table 2. Excluding decontamination and boarding windows in residential areas, the largest task is the relocation of the homeless survivors. The number of men required, 4,563 (excluding the residential tasks), compares with approximately 70,000 able bodied people with shelter doses under 100 r ERD, or 35,000 able-bodied men. Some of the potential work force will be at home, and it would be more difficult to make contact with them to obtain their services than to contact those in public shelters. Thus the total effort will be well within the limits of the potential work force, but will require recruiting of a sizable fraction of the potential workers. The major limitation might be on the number of experienced earth moving equipment operators for debris clearance and decontamination.

Table 2

TOTAL EFFORT FOR THE SEVERELY DAMAGED SMSA

Task	Man-hours	Men
Debris clearance	2,000	148
Water delivery	2,012	136
Food delivery	25,000	1,000
Relocation	93,000	2,654
Decontamination (except residential)	4,195	432
Boarding windows (except residential)	7,000	193
Subtotal	133,207	4,563
Residential Decontamination (streets and roofs)	27,566	498
Boarding windows	365,800	3,780
Subtotal	393,366	4,278
Total	526,573	8,841

The number of men required is dependent on the radiation levels, the starting time for the tasks, and the length of time for completion of the tasks. The assumed uniform 4000 r/hr standard intensity is higher than occurs in most cities in damage assessment results for heavy attacks, although a few large cities receive even higher fallout levels over much of their area. Hence the typical situation will require fewer men than indicated in Table 2. The starting time for debris clearance and food and water distribution (assumed here to begin five day: after the attack) is dependent on the urgency of providing food and water. However, the time to begin leaving the shelters is more arbitrary.

Longer shelter stay times would decrease the number of men required for the relocation task, and also for the debris clearance and decontamination effort, parts of which could then be postponed.

The tasks related to the residential areas will be performed later than most of the other work, since high dose rate levels will delay occupancy. Dose limits for the work will not be much of a constraint, since performance of the tasks will not be necessary until dose rates have declined sufficiently to permit occupancy of the housing. The number of men required then is not really additive to the number required for the other tasks, since many of the same men can be used again for the residential tasks. The tasks in Table 2 do not include the manual decontamination of the yard areas immediately adjacent to the houses, which takes 456,000 man-hours of effort, but might be performed by the occupants.

Additional tasks covered in this report but not included in Table 2 are restoration of utility service, rescue, burial of the dead, and salvage of supplies.

Light Damage Case

The same typical SMSA used for the severe damage case is assumed for the light damage case, with a population of one million; attention is confined to the 870,000 people in the urbanized area. The light damage case is typified by a burst near the periphery of the urbanized area, such as the 5-MT weapon on Moffet Field near San Jose in the Five-City study. Damage levels for the light damage case are based on the San Jose results, but with heavy fallout.

Although direct effects fatalities are only five percent, fallout fatalities are large, and injuries and fallout sickness are extensive among the survivors. The casualty situation seven days after the attack is as follows:

Uninjured and not sick	331,000
Injured, sick, or dying	440,000
Total	731,000

The major operational difference in the postattack situation for the peripheral burst case compared to that for the severe damage case is the large number of surviving buildings, which permits housing the survivors within the urbanized area, rather than evacuating them to other communities, and also provides enough space for congregate housing in large buildings.

The total effort required for the initial postattack tasks in the light damage case is given in Table 3. The figures are based on the same assumptions about standard intensity (4000 r/hr) and dose limits as those used for the severe damage case, and the task schedule is similar.

Table 3

TOTAL EFFORT FOR THE LIGHTLY DAMAGED SMSA

Task	Man-hours	Men
Debris clearance	1,000	74
Water delivery	2,270	160
Food delivery	44,250	1,770
Relocation	35,000	1,660
Decontamination (except residential)	30,787	1,892
Boarding windows (except residential)	71,370	1,937
Subtotal	184,677	7,493
Decontamination of residential streets and roofs	106,785	1,192
Total	291,462	8,685

Debris clearance is performed in three days beginning on the fifth day after the attack. The total area requiring debris clearance is not much less than that in the severe damage case, but the debris volume is much less.

Water and food delivery also begins on the fifth day. The effort is based on supplying water and food to half of the shelters over an eight-day period, and water to people at home whose homes are severely damaged. Since there are more survivors than in the severe damage case the effort is correspondingly larger.

The relocation task assumes that all the survivors remain within the urbanized area, but that no additional refugees are brought in for housing. Also, most of the people (even those with homes) when they emerge from shelter are assigned initially to congregate housing; this avoids the need for early decontamination of residential areas, and permits earlier shelter emergence. The relocation is assumed to take three days beginning on the seventh day after the attack. (The food and water delivery effort was calculated for a longer shelter stay time.)

The vital facilities and staging areas are assumed to be decontaminated on the fifth day after the attack. More staging areas survive than in the severe damage case, so the decontamination effort is larger. The congregate housing facilities are decontaminated in three days beginning on the seventh day after the attack. The length of time required is determined by the availability of street sweepers and flushers.

Even in the peripheral burst case, most of the windows will be broken throughout the urbanized area. The buildings in which the windows will be boarded include the vital facilities, staging areas, and congregate housing facilities.

The decontamination of residential areas will be less urgent than in the severe damage case, since there will be adequate accommodations in large buildings. The number of men required to decontaminate the streets and roofs in the surviving housing areas is based on a dose rate of 2 r/hr, the maximum that will permit occupancy after partial decontamination. Manual decontamination of yard areas adjacent to the houses will take 1.9 million man-hours.

Total manpower required for these tasks is small relative to the size of the potential workforce. However, the number of earth moving equipment operators required for debris clearance and decontamination exceeds the number of skilled operators expected to be in the area. The

largest number of operators is required for decontamination of the congregate housing. Selection of buildings that minimize the amount of unpaved areas to be decontaminated, or limiting decontamination to a smaller area around the buildings, might reduce the number of operators required. Alternatively, it might be possible to obtain additional operators from outside the area, or to delay occupancy of the congregate housing.

II DESCRIPTION OF A SEVERELY DAMAGED SMSA

Damage Levels

Quantitative descriptions of typical situations are necessary for
determining what needs to be done and for estimating the magnitude of
the required initial postattack recovery activities. The requirements
for the initial postattack activities, and the amount of effort for
those activities, will obviously vary greatly with the level of damage--
and a wide range of levels of damage is possible.

The total national fatalities calculated for postulated attacks in
a variety of studies have ranged up to about 50 percent. The national
fatalities in the mixed counterforce and city attack of the OCD DAL-67
study were 38 percent, with a 50 percent fatality level within all SMSAs,
and 57 percent fatalities in the damaged SMSAs.[1]* Fatality rates in some
SMSAs were as high as 80 percent. Generally an SMSA was hit with several
weapons.

The national fatalities in the mixed attack C of the DAL-69 study[2]
[with 1969 warning system, NFSS (National Fallout Shelter Survey) ex-
tended to 1975, and shelters stocked] were 40.5 percent, with an addi-
tional 3.6 percent at risk from fire. Blast fatalities were 24.8 per-
cent. Since the blast fatalities were predominantly in the SMSAs and
the SMSAs in 1975 are expected to contain about two-thirds of the popu-
lation, the blast fatality rate in the SMSAs would have been about 37
percent. Total national fallout fatalities were 15.7 percent. In the
DAL-67 study the fallout fatalities as a percentage of the preattack
population were about the same within and outside the SMSAs. Thus for
the DAL-69 C attack, the SMSA fatality rate would have been about 53
percent.

The attacks also generally concentrate on the larger SMSAs and omit
many of the smaller SMSAs. Furthermore the SMSAs, which are defined in
terms of complete counties, include a substantial number of people out-
side and often remote from the urbanized area (the contiguous built-up
area). In 1960, 16 percent of the SMSA population was outside the ur-
banized areas. Thus the fatality rate in the large urbanized areas will

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* References are listed at the end of this report.

be higher than the SMSA fatality rate. With national fatalities at about the 40 percent level, the typical fatality levels in the large urbanized areas might be on the order of 60 to 70 percent.

The situation in the large, severely damaged SMSAs is of the utmost importance for the initial postattack recovery planning. Even though the fatality rate will be high, the number of survivors will also be large. The SMSAs with over 500,000 population in 1975 will include about 110 million of the 150 million SMSA population. Even with a two-thirds fatality rate there will be 37 million survivors. Since most of those survivors will be injured and homeless, the potential additional losses from hunger, exposure, or fallout, which might be averted with proper postattack action, will be of major significance.

Consequently the situation of the large, severely damaged SMSA has received the major attention. Of course planning is desirable for less important situations also, though the criticality may be much less. The relatively light damage situation is covered in Chapter IV.

Examples of Severely Damaged SMSAs

An indication of typical distributions of blast damage, survivors, and injuries was obtained by calculating overpressure, survivors, and injuries within annuluses about the SMSA center for a selected group of 18 heavily damaged SMSAs from the mixed counterforce and city attack of the DAL-67 study. The radii of the annuluses were 0.25, 0.50, 1.0, and 1.5 times the radius of a circle with an area equal to the 1960 area of the urbanized area. The center of the annulus was the geographic center of the central business district.

An IITRI report[3] describes a typical metropolitan area in terms of the following six regions:

(1) The principal business and merchandising district, with multi-story buildings and large masonry wall, wood joist structures.

(2) A surrounding congested area of older manufacturing, warehousing, and merchandising buildings, primarily masonry wall, wood joist structures and a few multistory buildings.

(3) Transitional areas representing the encroachment of industry on previously residential areas, with industrial buildings and brick or wood frame apartment buildings.

(4) Residential areas.

(5.) Business strips.

(6) Industrial areas or parks.

Using this terminology, the inner 0.25 radius circle contains the princi-pal business district and the surrounding congested area (and also the major portion of the NFSS spaces). The second annulus between 0.25 and 0.5 of the urbanized area radius approximately represents the remainder of the central city, with transitional areas and residential areas inter-spersed with business strips. The residential areas are primarily brick or wood frame apartments, with an increasing proportion of one and two family homes toward the outer edge of the annulus. The next two annuluses out to 1.5 of the urbanized area radius represent the urban fringe of the SMSA, predominantly single family residential, interspersed with apartment areas, business strips, industrial areas, and shopping centers. The remainder of the SMSA outside the 1.5 circle represents approximately the part outside the urbanized area.

The MLOP (median lethal overpressure) used for each annulus was based on the number of shelter spaces and basement spaces, and on the following MLOPs for MT weapons used in the OCD DAL-69 study:[2]

	Overpressure (psi)	
	Upper Stories	Basements
NFSS buildings	7	12
One and two story residences	5	10

The MLOP was defined for 1-MT weapons, and range scaling was taken to be by the 0.35 power of the yield. The MLOPs for blast casualties (fatali-ties and injuries) ranged from 3 to 6 psi, depending on the amount of shelter spaces and basement spaces. The MLOPs for casualties in the DAL-67 study for 1-MT weapons were approximately 5 psi for shelter spaces and central city residences, and 4 psi for residences outside the central city, without distinguishing between basements and upper stories. Fallout fatalities were taken from the DAL-67 study damage assessment calcula-tions.

The resulting survival and injury rates by annulus for each of the 18 SMSAs are shown in Figure 1. The typical situation is one with very low survival rates in the downtown section and successively higher rates in the outer annuluses. However, as indicated on page 25, there are a few cases where the situation is reversed. The injury rate is also very high where the fatality rate is high--generally 80 to 90 percent of the survivors within the 0.5 circle.

The distribution of survivors by overpressure is relevant to evacuation and debris clearance problems. Figure 2 gives the percentage of survivors receiving more than a given overpressure, in each annulus. As would be expected, usually a larger percentage of the survivors in the inner annuluses are in areas with higher overpressures.

A Typical Severely Damaged SMSA

A typical situation for the heavy damage case will be described by generalization from the 18 SMSAs shown in Figures 1 and 2. The purpose of the generalization is for convenience in exposition of (1) a quantitative description of a typical situation and (2) the significance for the initial postattack recovery activities. The case will be presented in terms of an SMSA of one million population. Results for other SMSA sizes can be scaled from this case in proportion to population. The typical urbanized area of an SMSA of one million has an area equivalent to a circle of 8 miles radius. The urbanized area radius scales approximately with the square root of the population (e.g., for an SMSA with a population of two million, the radius in miles, would be approximately $8\sqrt{2}$, which equals 11.3). Attention is restricted to the urbanized area (the contiguous built-up area), which corresponds to the part of the SMSA within 12 miles of the center, and contains 870,000 of the one million population.

Figure 3 gives the cumulative preattack population, survivors, and uninjured by distance from center for the typical SMSA. Although the preattack population in the downtown section (within two miles of the center) is about 120,000, there are only about 12,000 survivors. (These figures are based on the resident population. The peak daytime population in the downtown area would be larger. Also movement into the downtown area to utilize the shelters might increase the numbers.) Thus the number of people to be removed from the most densely built-up area, with the greatest potential debris problem, is relatively small. However, most of them are injured. Only about 20 percent of the survivors within a 12-mile radius are within the central 4-mile radius area.
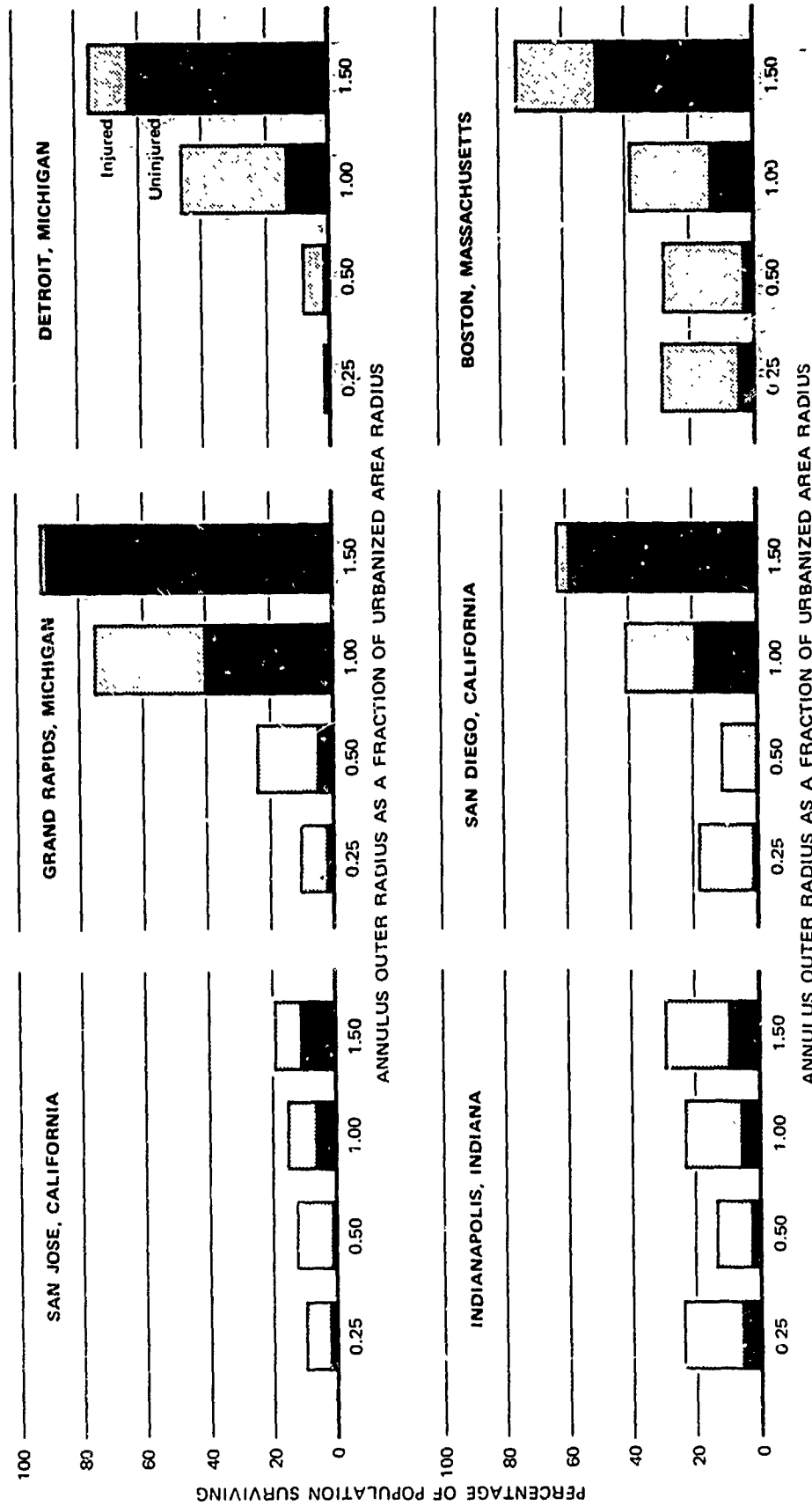
22

FIGURE 1   SURVIVAL RATE BY ANNULUS FOR SELECTED SMSAs

23

FIGURE 1 SURVIVAL RATE BY ANNULUS FOR SELECTED SMSAs (Continued)

24

SACRAMENTO, CALIFORNIA

BIRMINGHAM, ALABAMA

Injured

Uninjured

TACOMA, WASHINGTON

ALBUQUERQUE, NEW MEXICO

NEW ORLEANS, LOUISIANA

SAN ANTONIO, TEXAS

ANNULUS OUTER RADIUS AS A FRACTION OF URBANIZED AREA RADIUS

ANNULUS OUTER RADIUS AS A FRACTION OF URBANIZED AREA RADIUS

PERCENTAGE OF POPULATION SURVIVING

FIGURE 1 SURVIVAL RATE BY ANNULUS FOR SELECTED SMSAs   (Concluded)

FIGURE 2   DISTRIBUTION OF SURVIVORS BY OVERPRESSURE FOR SELECTED SMSAs

FIGURE 2   DISTRIBUTION OF SURVIVORS BY OVERPRESSURE FOR SELECTED SMSAs   (Continued)

27

FIGURE 2   DISTRIBUTION OF SURVIVORS BY OVERPRESSURE FOR SELECTED SMSAs   (Concluded)

28
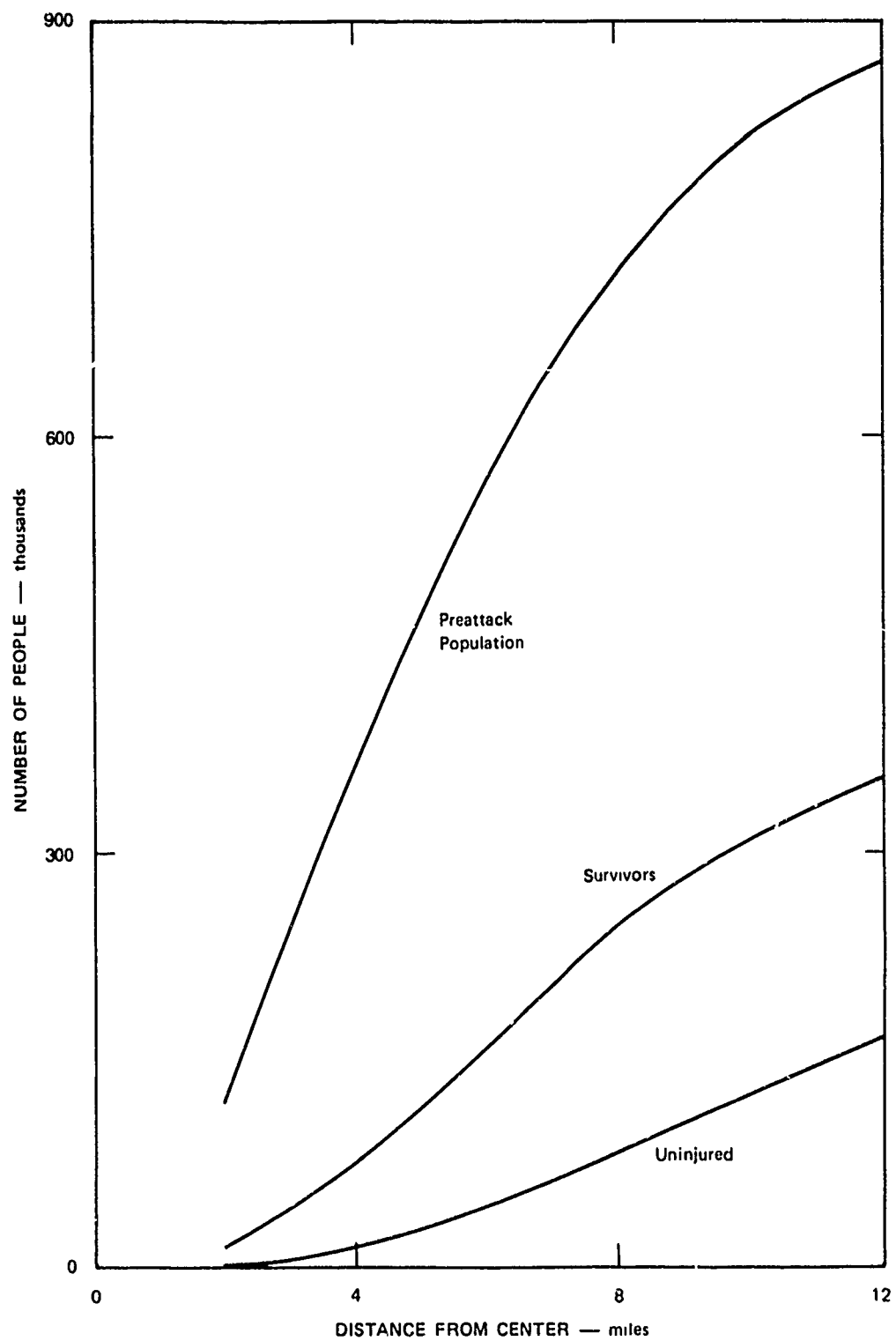
FIGURE 3   DISTRIBUTION OF SURVIVORS BY DISTANCE FROM CENTER FOR TYPICAL
SMSA

Figure 4 shows the percentage of the preattack population in each annulus that receives more than a given overpressure. (The center of the annuluses is the SMSA center. The burst point or points would not generally be at the center.) The relationship to building destruction can be inferred from the following table of overpressures required to cause building collapse:[4]

Building Type	Overpressure (psi)
Brick or wood frame, 1 or 2 story	3.5
Load-bearing walls, multistory	7
Steel-framed, 12 story	14

Generally, most of the structures in the downtown area will be demolished, although some of the steel or reinforced concrete frame buildings will still be standing. Thus there will be heavy debris throughout most of the downtown section. In the next annulus (representing the remainder of the central city) a larger proportion of the steel and reinforced concrete frame buildings will remain standing, but most of the more vulnerable buildings will collapse. In the third annulus (from four to eight miles, with predominantly single family residences) most of the housing will be demolished, since the overpressures required for collapse are lower. Since the density of multistory buildings is much lower than in the downtown section, and since many will remain standing, the structural debris is much less. Outside the eight-mile radius there will be little building collapse. However, overpressure lev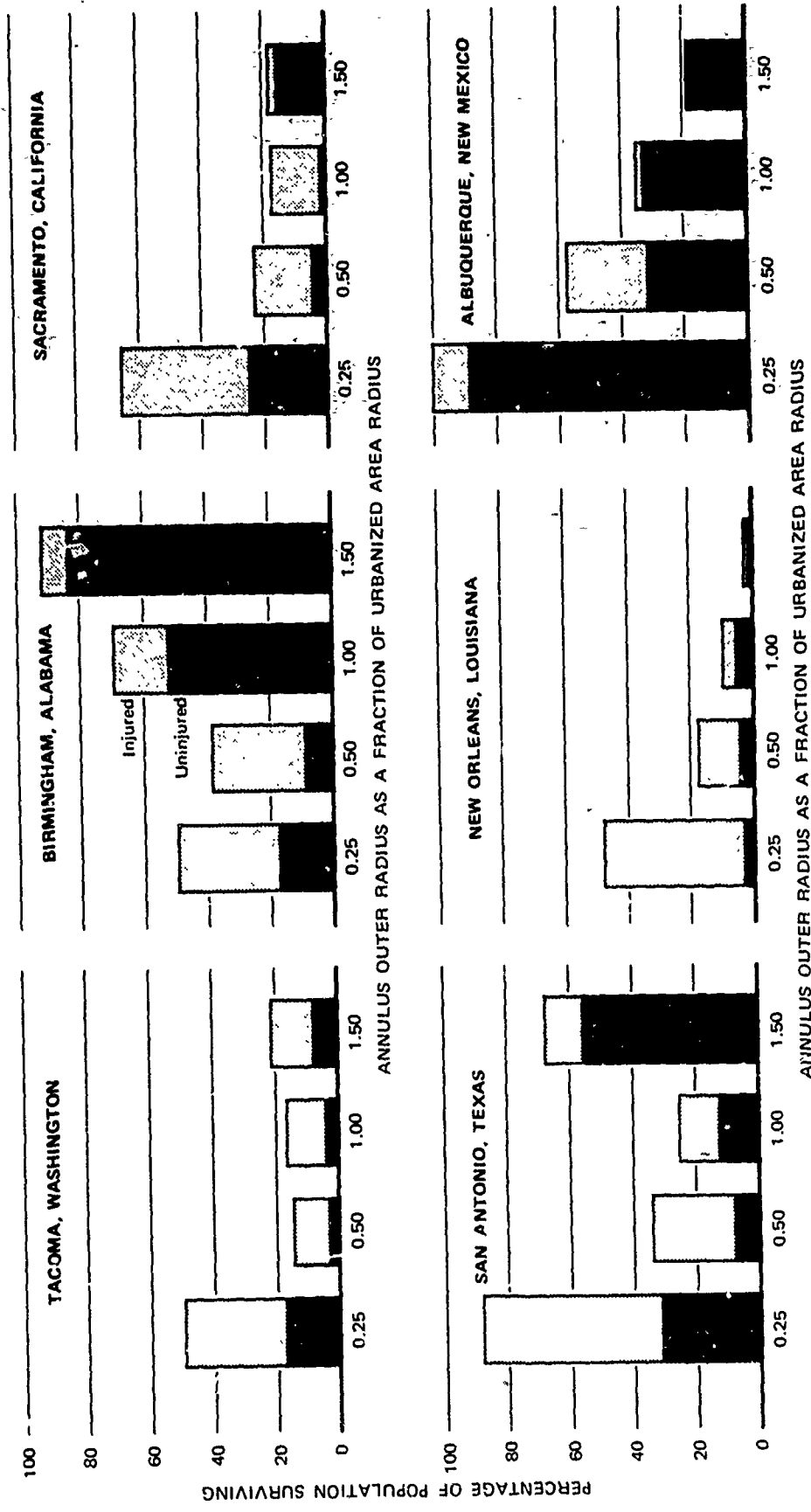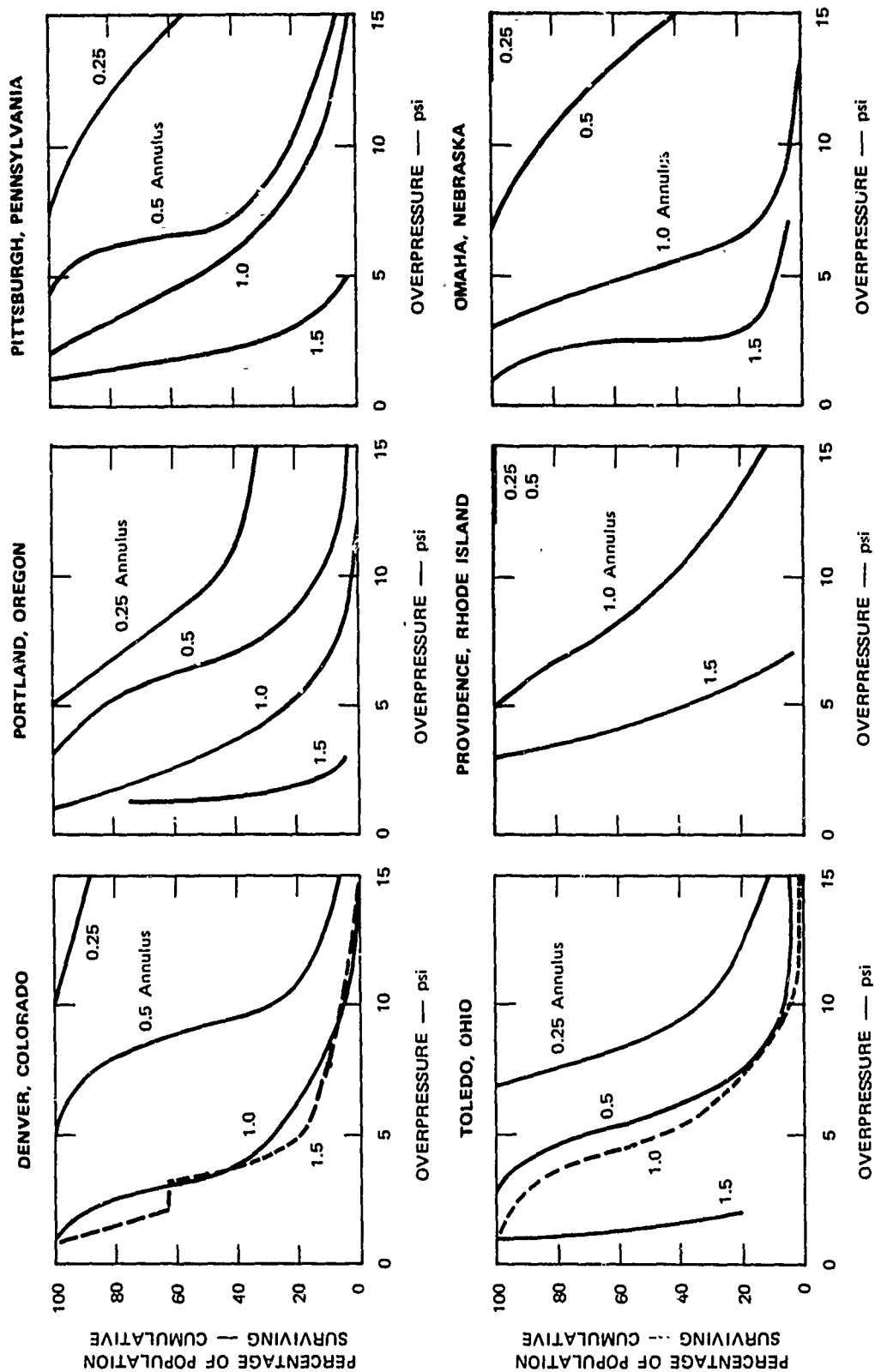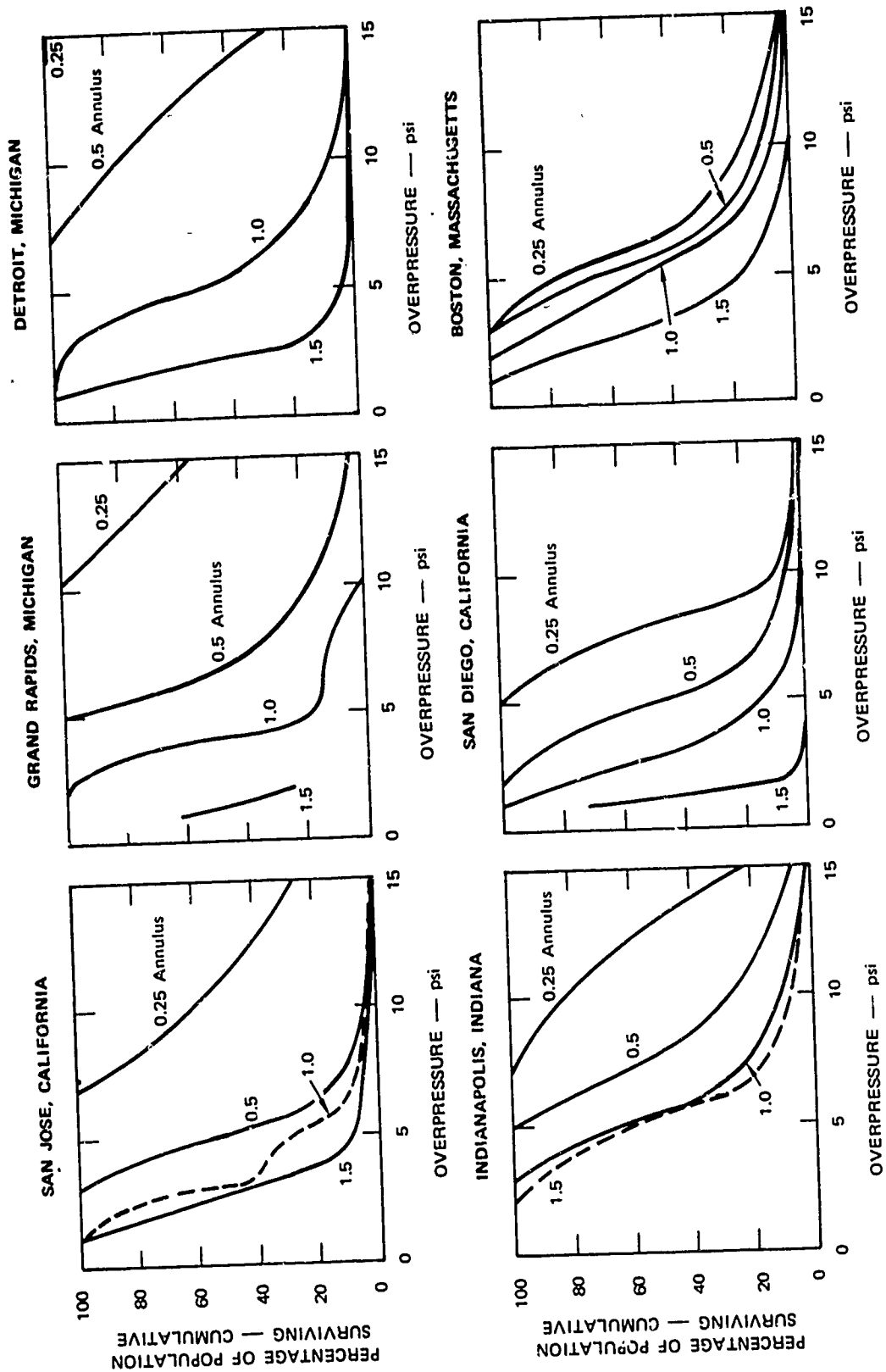els will be sufficient for moderate damage to some of the housing, window breakage almost everywhere, and some debris from trees and power and telephone lines.

Figure 5 gives the number of survivors in areas with more than a given overpressure, for each annulus of the SMSA. The figure indicates the number of people to be supplied with food and water, or extricated from the area, in the different sections of the SMSA--which would have varying debris conditions.

As was indicated in Figure 3, only a small proportion of the survivors are within the downtown two-mile radius circle. Most of the survivors in this section are in areas with sufficient overpressure for significant building damage or collapse; thus access must be provided to those people in areas of heavy structural debris. However, the large portion of the downtown section with overpressures over 15 psi (about 84 percent, from Figure 8) will have few survivors. Hence access will be needed for only a small fraction of the downtown area; for the few

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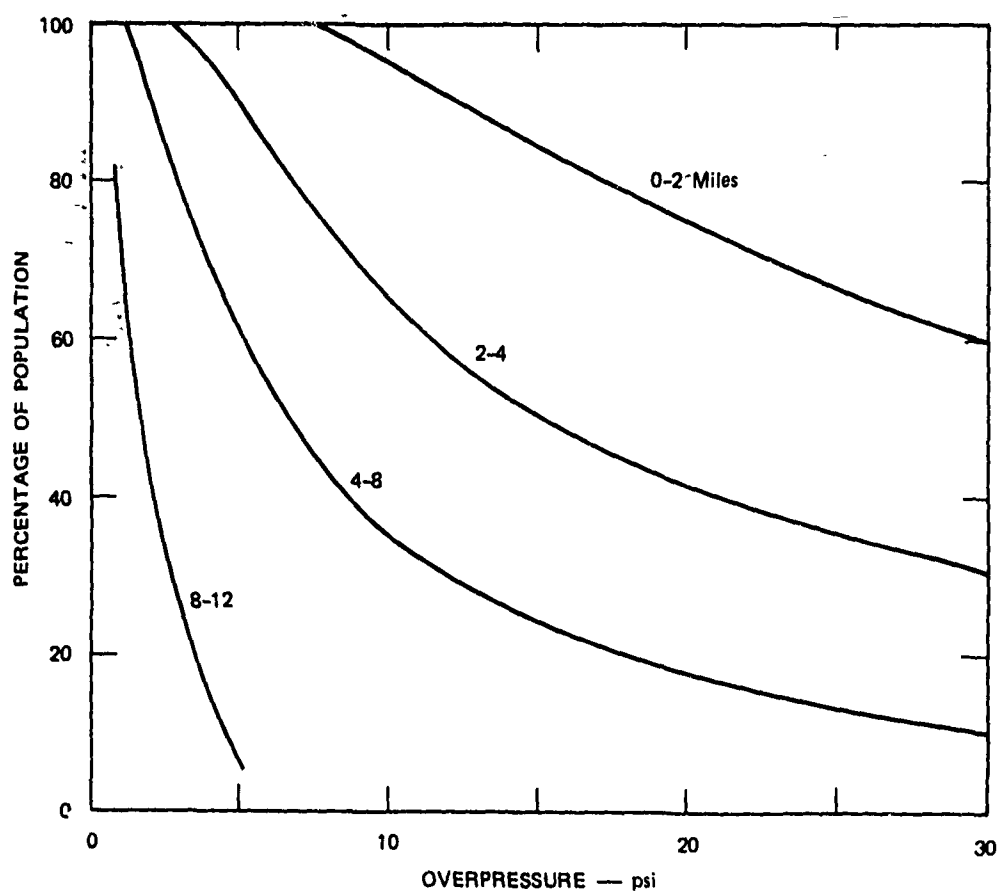
FIGURE 4   DISTRIBUTION OF PREATTACK POPULATION BY OVERPRESSURE AND
DISTANCE FROM CENTER FOR TYPICAL SMSA
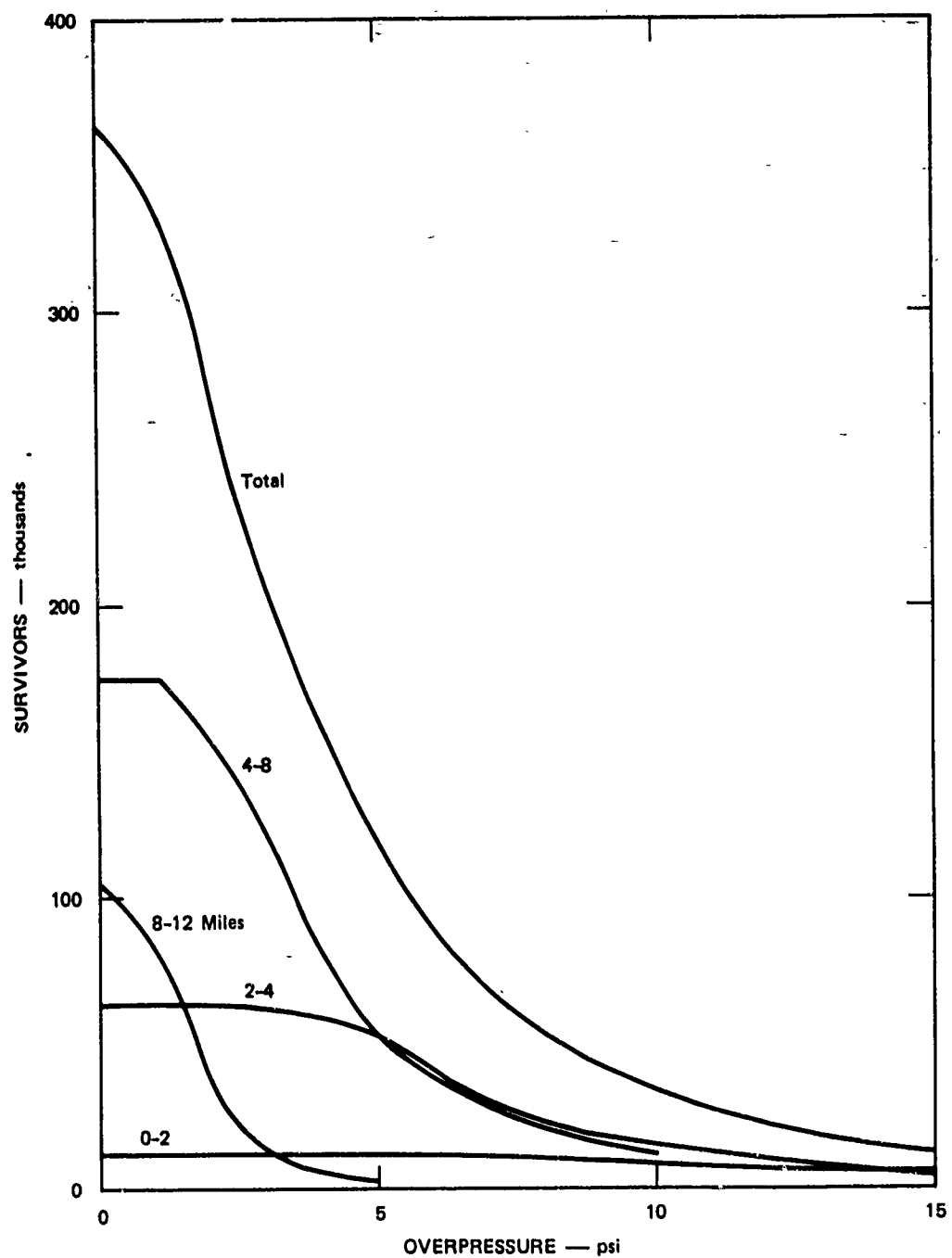
FIGURE 5   DISTRIBUTION OF SURVIVORS BY OVERPRESSURE AND DISTANCE FROM
CENTER FOR TYPICAL SMSA

survivors in the remaining area it might be more efficient to have them walk out or be carried out manually over the debris, rather than clearing the debris.

The number of survivors is much larger in the annulus from two to four miles; an increasing proportion of them are in areas with lower over-pressures. Nearly half of the survivors within the 12-mile radius are within the four to eight mile annulus, which represents the immediate urban fringe surrounding the central city. Although approximately 70 percent of the survivors in this annulus receive less than 5 psi, the absolute number of survivors receiving higher overpressures is much greater than in the downtown section.

The distribution of the total survivors within 12 miles of the SMSA center, by overpressure, is also given in Figure 5.

Fire Effects

The time period of interest for this study is after the emergency period when fires will no longer pose a threat. However, the results of the fires will have an effect on the requirements for postattack activities. The need for access to areas affected by fire will be reduced or eliminated, since the blast survivors will have moved from some areas and the fire will have eliminated others.

The extent of fires is uncertain both because of variations in conditions (e.g., visibility, humidity, wind) and uncertainty in estimating the extent of fires under given conditions. Models have been developed for the development of fire in urban areas. Two fire models were developed by IITRI (IIT Research Institute) and URS Systems Corporation for the Five-City Study. Another model was developed by SSI (Systems Sciences, Inc.) and a modification of the originally developed model was used in the OCD DAL-69 study.[2] IITRI[5] and URS[6] have applied their models to some of the cities with the Five-City Study attacks, and SSI[4] has made a comparison of the three models for the Five-City attack on San Jose, California.

The San Jose attack was a 5-MT weapon with a 14,500-foot height of burst at Moffet Field, on the north edge of the city. Clear visibility and a negligible wind of less than 10 mph were assumed. The URS and IITRI models differed in their predictions of the percentage of buildings burned out by initial fires, but both indicated destruction by fire of a major portion of the buildings in the area. The SSI model predicted lower fire damage.

The variations among the models have been analyzed and evaluated in a Dikewood study[7] of the ignition and early fire portion of the models, and an SRI study[8] of the fire spread portion. The differences have been accounted for in these comparative analyses, and are due to differences in the initial assumptions and approach. A unified fire model is now under development.

A possible serious omission is that none of the models takes into account the fire-blast interaction. One of the effects of the blast wave is to extinguish the flames. Thus the number of initial fires may be greatly reduced.

For the heavy damage case the percentage of buildings (outside the severe blast damage area) burned out would be much greater than in the San Jose peripheral burst case. Thus, even allowing for the reduced ignition radius if surface bursts are used, the IITRI and URS models would indicate only limited small areas and isolated buildings surviving the fire throughout the contiguous urbanized area. This situation represents one extreme of the range of possibilities for fire damage.

The fire model used in the OCD DAL-69 study predicts much lower fire damage. In the DAL-69 study the probability of destruction by fire was calculated by applying the following multipliers to the probability of room ignition:

Type of Building	Multiplier
Urban residence	0.50
Suburban residence	0.28
Shelter building	0.35

Assuming 12-mile visibility and surface bursts, and using the distribution of survivors by overpressure from Figure 5, we get this percentage of blast survivors in buildings burned out by fire in each annulus:

Annulus (miles)	Percentage Surviving
0 - 2	34%
2 - 4	36
4 - 8	15
8 - 12	3

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Thus in the central city (four-mile radius circle) only a little over one-third of the blast survivors are in buildings burned out by fire; in the suburbs a much smaller fraction are in buildings burned out by fire.

Lower visibilities would reduce the fire damage, as would fire suppression and fire fighting. On the other hand, the DAL-69 fire model does not include mass fire effects or fire spread by firebrands. Thus the fire possibilities range from almost total burnout, to only a small fraction of the buildings burned out. Three cases that bound the range of situations with respect to postattack activities can be distinguished:

(1) Low fire

(2) High fire, little fallout

(3) High fire, heavy fallout.

In the "low fire" case, the fire will have relatively little effect on the situation with respect to postattack requirements. Some casualties will result from fire, especially in the central, high density areas. If fallout is heavy, additional fallout casualties will occur among those forced to move because of fire. However, with at most 36 percent of the blast survivors in any annulus forced to move because of fire, most will be able to find other shelter within their area.

In the "high fire, little fallout" case, some casualties will be caused by the fire. In addition to those trapped in burning buildings, the extensive fires, and possibly mass fires or conflagrations, will often prevent escape through the streets in the densely built up areas. However, as previously discussed, the number of survivors in the densely built up central section will be relatively small, and in the suburbs with lower building densities there will generally be adequate open space to escape the fires. Thus, for planning purposes, the total number of survivors should not be significantly reduced. For postattack considerations the major effect of fire will be that the post-shelter phase begins within hours, instead of days or weeks. The number of survivors to be relocated will also be larger because of the loss of housing from fire. The survivors generally will be out in the open with debris blocking vehicular exit. Most of the survivors, although ambulatory, will be injured, making it difficult to walk out the several miles to get beyond the debris area. If the weather is moderate a few days delay in evacuation should not be serious, although lack of water could soon become critical. In severe cold weather, however, deaths from exposure would soon begin, and a quick evacuation capability could save many lives.

In the "high fire, heavy fallout" case most of the blast survivors, forced out of shelter by fire and with no other shelter to go to, would

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receive a lethal radiation dose from fallout. Thus the life-saving potential of postattack activities is greatly diminished. However, requirements would still exist for relocating the small number of survivors. Also, there might be significant numbers still alive who had received lethal doses.

Fallout Levels

The possibilities for fallout levels in an SMSA obviously range from none up to high levels throughout most of the SMSA. The requirements and timing of the postattack activities will vary with the fallout levels both within the damaged metropolitan area and in the surrounding areas that provide support and housing for the homeless. With little or no fallout, the postshelter phase will begin as soon as the threat of further attack is over. With increasing fallout levels, shelter stay times and decontamination requirements increase. Possibly distribution of food and water to survivors within the damaged areas will be required, if supplies run out before it is feasible to leave shelter.

An idea of typical fallout levels can be derived from past damage assessment results. Figures 6 and 7 are based on the population attack from the OCD DAL-69 study. The damage assessment calculations were provided by Systems Sciences, Inc.,[9] for the previous year's study. This material gave the blast survivors and surviving housing by standard intensity within circles of various sizes about 73 of the largest SMSAs. Figure 6 gives the number of SMSAs in which more than 20 percent--and also the number in which more than 80 percent--of the blast survivors within a 20-mile radius circle are in areas with more than a given standard intensity (H + 1 hour dose rate). Most of the SMSAs have at least a small proportion of the blast survivors in areas with standard intensities of 500 r/hr or more. However only a few have a large proportion of the blast survivors in areas with standard intensities over 3000 r/hr. The NEOP (Nuclear Emergency Operations Plan) plan[10] suspends all nonessential operations outside of shelter if dose rates of 50 r/hr or more are present or are anticipated.

The implication of these fallout levels is that typically the fallout will preclude operations outside shelter, except for fire emergency, for at least several hours after fallout arrival, and up to a day or two. (After two days the intensities are reduced by a factor of 100. Thus a 5000 r/hr standard intensity would be reduced to about 50 r/hr.) However, even after this time, outside exposure would generally be limited to no more than a few hours.

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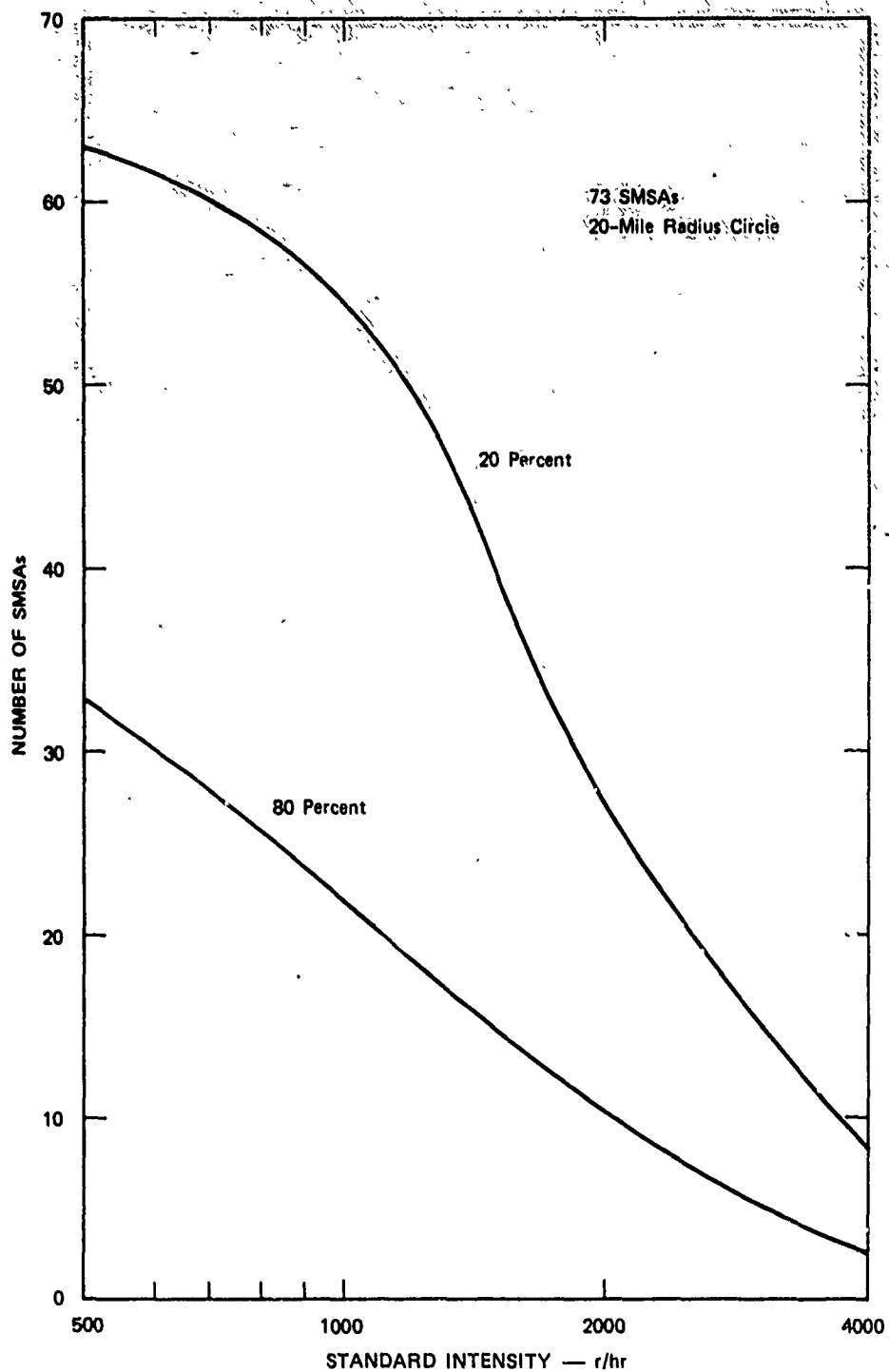
FIGURE 6 NUMBER OF SMSAs IN WHICH MORE THAN 20 PERCENT (Or 80 percent)
OF THE BLAST SURVIVORS ARE IN AREAS WITH MORE THAN THE
INDICATED STANDARD INTENSITY
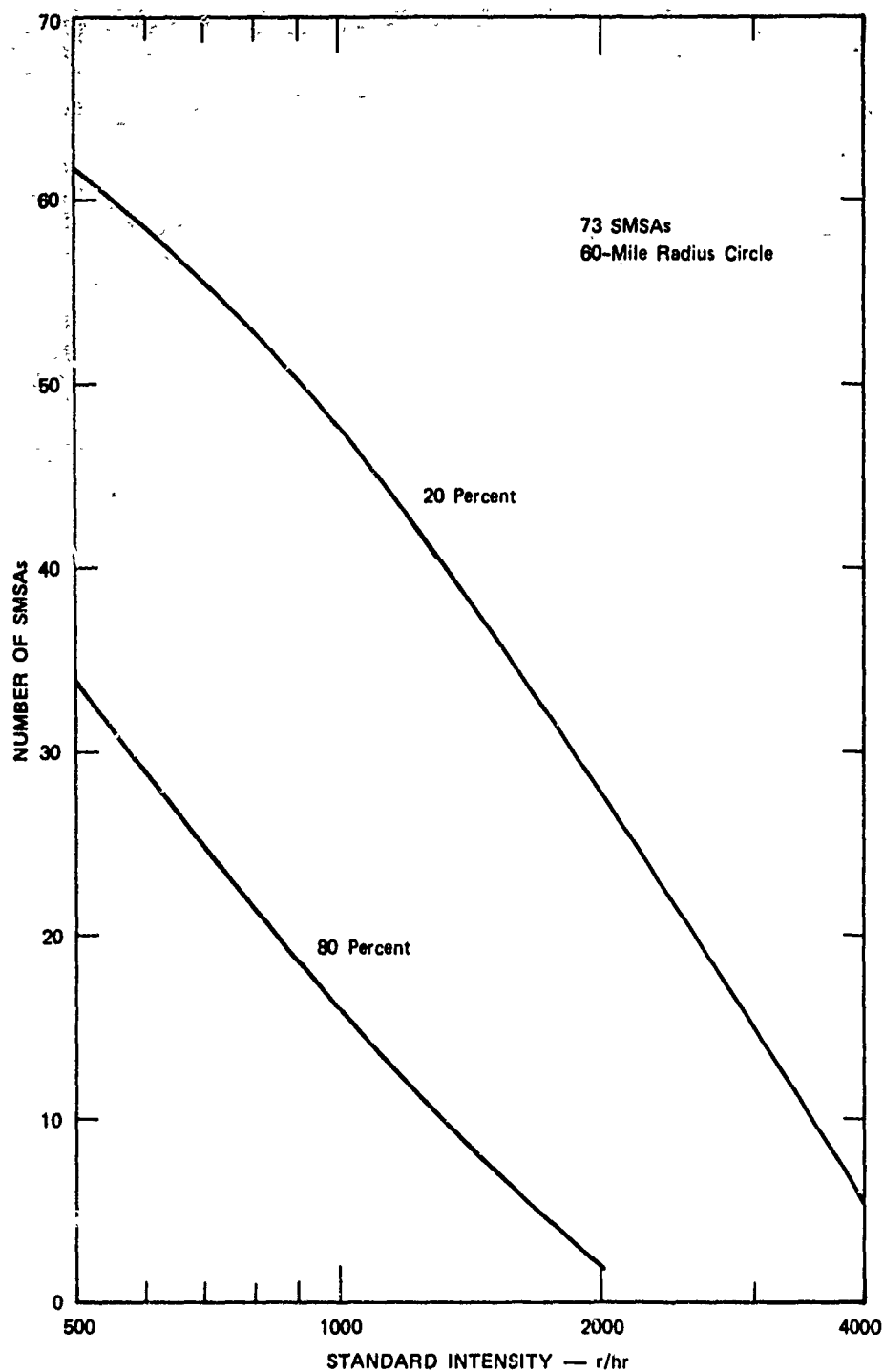
FIGURE 7   NUMBER OF SMSAs IN WHICH MORE THAN 20 PERCENT (or 80 percent) OF THE SURVIVING URBAN HOUSING IS IN AREAS WITH MORE THAN THE INDICATED STANDARD INTENSITY

Another view of typical fallout levels is given in Figure 8. This figure is based on the mixed military and city attack of the DAL-67 attack with surface bursts. The figure gives the percentage of the blast survivors in the SMSAs who are within areas with more than a given standard intensity. Although a large number of blast survivors are in areas with standard intensities of 1000 r/hr or more, only a small percentage experience extreme intensities over 4000 r/hr. Also the fallout fatality rate will be higher at the higher dose rates; hence the percentage of ultimate survivors at the higher intensities will be lower than indicated. However, as discussed later, many of the fallout fatalities will still be alive at the time of shelter emergence and will affect the workload.

Figure 7 gives the number of SMSAs in which more than 20 percent--and the number in which more than 80 percent--of the surviving urban housing within a 60-mile radius is in an area with more than a given standard intensity, for the DAL-69 attack. The radiation level in an area surrounding a damaged SMSA is relevant to the support capabilities. Typically, much of the support area will receive fallout that would delay the initiation of support activities. However, extreme fallout levels will be rare. As discussed later, much of the housing may require decontamination to permit early occupancy.

Condition of Survivors

The physical condition of the survivors affects the postattack workload in two ways. First, many of the sick and injured will have to be carried. Second, the potential work force for the postattack activities will be limited to those whose condition permits them to work. The critical period for medical treatment of the injured is in the early hours after the injuries are received, and this study is concerned with a later time period. Of course, the requirements for medical care will extend beyond the emergency period, but this study is limited to the provision of life support requirements such as food and shelter, rather than medical care.

The typical numbers of injured in each annulus of the SMSA were indicated previously. In addition to the injured, many of the survivors will be sick from fallout radiation. Also, many of the mortally injured and those who will eventually die from fallout will still be alive at the time of interest for postattack activities. Abandonment of the injured and sick would be undesirable, since often it would not be known which would live and which would not. Families would also be reluctant to abandon a member who was dying.
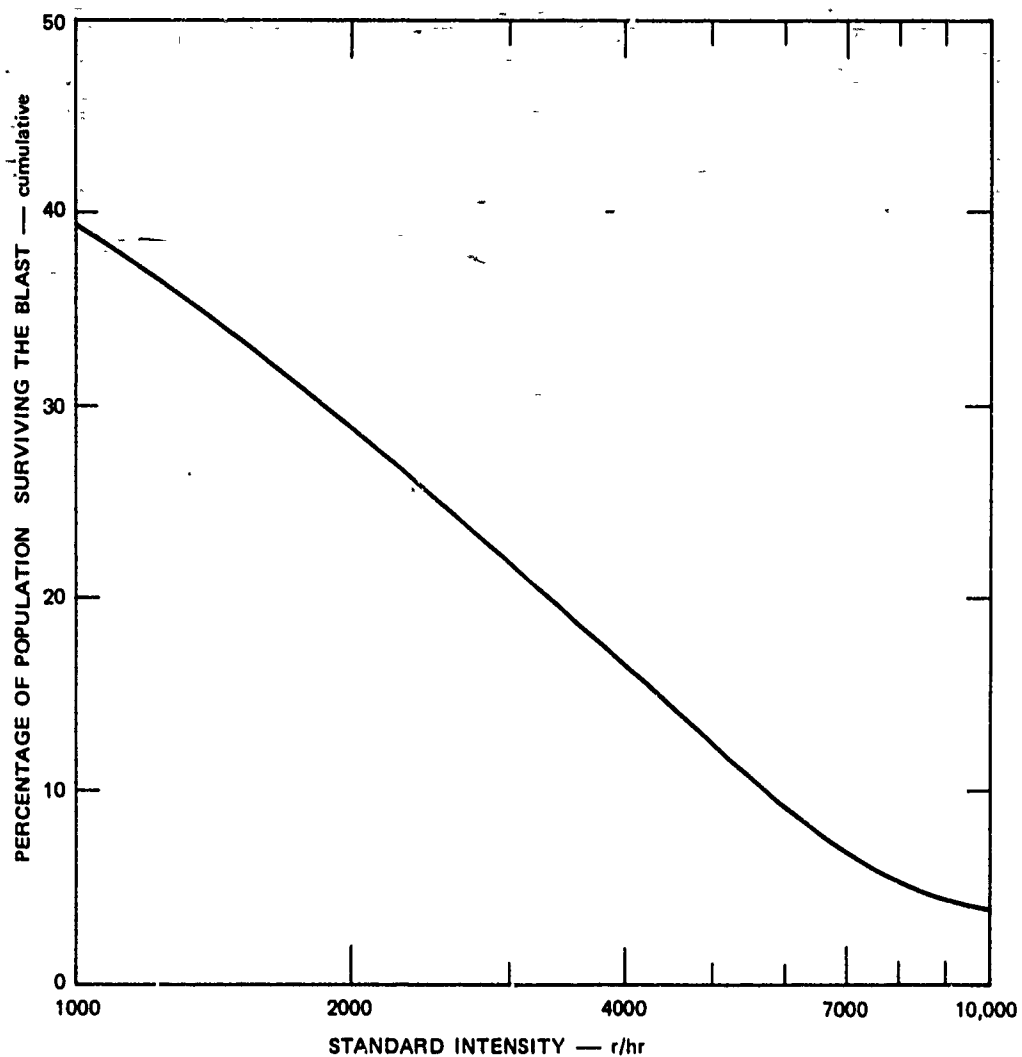
FIGURE 8   SMSA BLAST SURVIVORS IN AREAS WITH MORE THAN THE INDICATED
STANDARD INTENSITY—DAL-67 ATTACK

The categorization of the conditions of the survivors in past studies has been made with the objectives of (1) determining the medical load[11,12] and (2) determining the rescue requirements in the transattack period.[13] This study is concerned with the condition of the survivors after the emergency period (perhaps a few days later) with respect to their ability to care for themselves, to be able to walk for evacuation, or to be able to work (e.g., carry stretchers, clear debris). The following categories are at least related to those concerns, and estimation of typical distribution among the categories is derivable from the literature:

Categories of Survivor Conditions

Uninjured
Moderately injured
Severely injured but will survive
Mortally injured but still alive
Fallout sick who will survive
Lethally irradiated

As used here the lethally irradiated catego y excludes those mortally injured by immediate effects. The fallout sick category, in this study, refers to those who receive an ERD of 200 r or more, and yet ultimately survive.

Table 4 gives a breakdown of the condition of the survivors by annulus for the typical heavy damage case for an SMSA of one million population. In addition to the ultimate survivors, the table gives the number of mortally injured and the lethally irradiated still surviving at 1, 3, and 12 days after attack. Figure 9 shows the condition of all the survivors within a 12-mile radius as a function of time after attack, with some of the categories from Table 4 combined. The categories are (1) uninjured and not sick from fallout radiation, (2) moderately injured or sick from fallout radiation, (3) severely injured but ultimately surviving, and (4) mortally injured or lethally irradiated who are still alive. Figure 10 shows the same results for each of the four annuluses. In these figures the number of injured at any time is the number that received an injury, without regard to recovery. Similarly the number of fallout sick is the number of ultimate survivors that received an ERD of 200 r or more, even though they may not be experiencing illness at the time.

In the early days after attack only a small proportion of the people still alive will be uninjured and not sick (i.e., receiving less than 200 r ERD) from fallout radiation. Furthermore, many of them will have received enough of a radiation dose so that outside exposure will have

Table 4

CONDITION OF SURVIVORS
(Thousands of Survivors)

| | Miles from SMSA Center | | | | |
	0-2	2-4	4-8	8-12	0-12
End of first day					
Uninjured and not sick	1.1	11.4	63.7	76.5	152.7
Moderately injured or sick	8.7	41.1	95.5	26.4	171.7
Severely injured	2.2	10.0	15.8	2.1	30.1
Total ultimate survivors	12.0	62.5	175.0	105.0	354.5
Mortally injured	5.2	17.0	21.7	4.5	48.4
Lethally irradiated	4.4	22.5	64.0	38.0	128.9
Subtotal	9.6	39.5	85.7	42.5	177.3
Total	21.6	102.0	260.7	147.5	531.8
End of third day					
Mortally injured (73%)*	3.8	12.4	15.8	3.3	35.3
Lethally irradiated (70%)*	3.1	15.8	44.8	26.6	90.3
Subtotal	6.9	28.2	60.6	29.9	125.6
Total	18.9	90.7	235.6	134.9	480.1
End of twelfth day					
Mortally injured (38%)*	2.0	6.5	8.3	1.7	18.5
Lethally irradiated (30%)*	1.3	6.7	19.2	11.4	38.6
Subtotal	3.3	13.2	27.5	13.1	57.1
Total	15.3	75.7	202.5	118.1	411.6

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* Percentage of mortally injured or percentage of lethally
irradiated alive at end of first day.
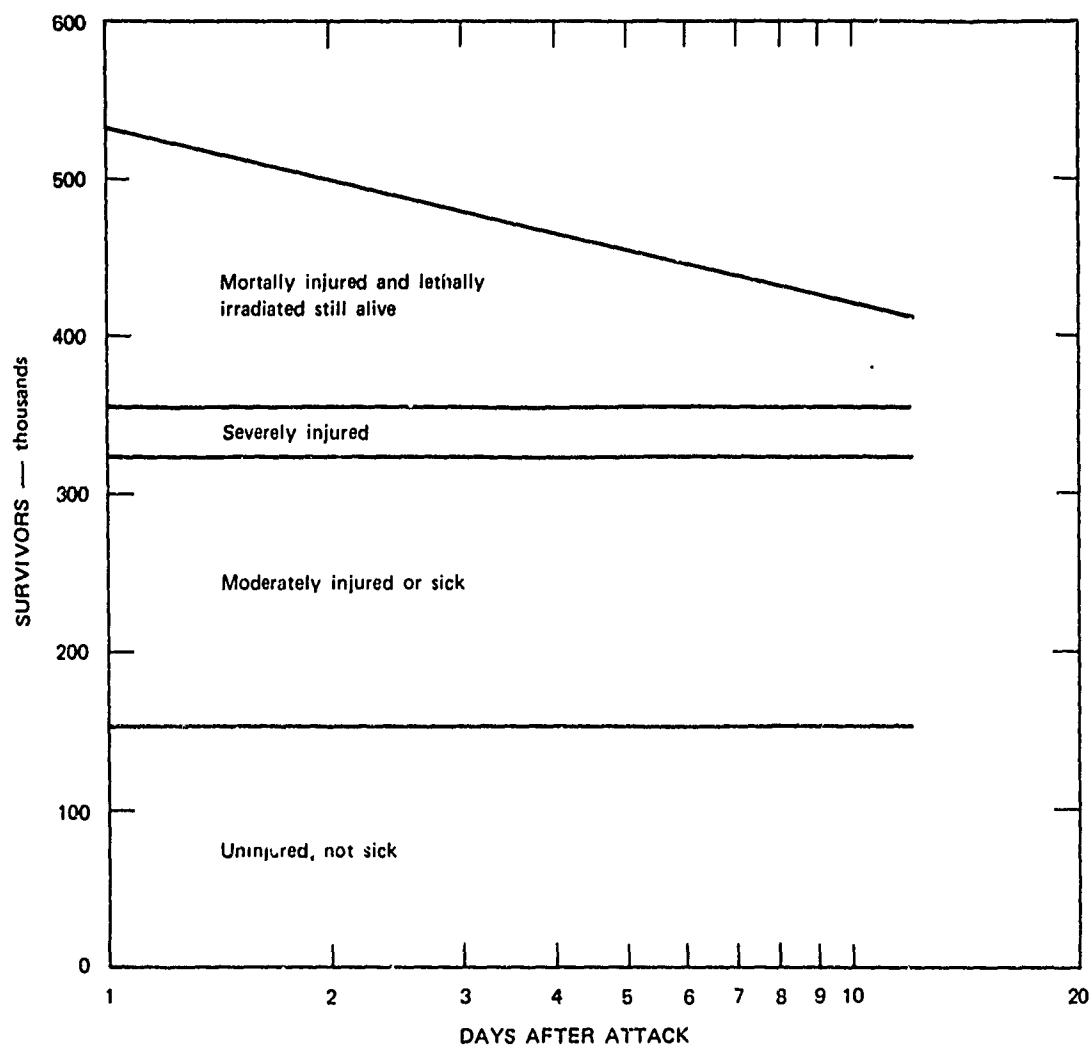
FIGURE 9   CONDITION OF SURVIVORS
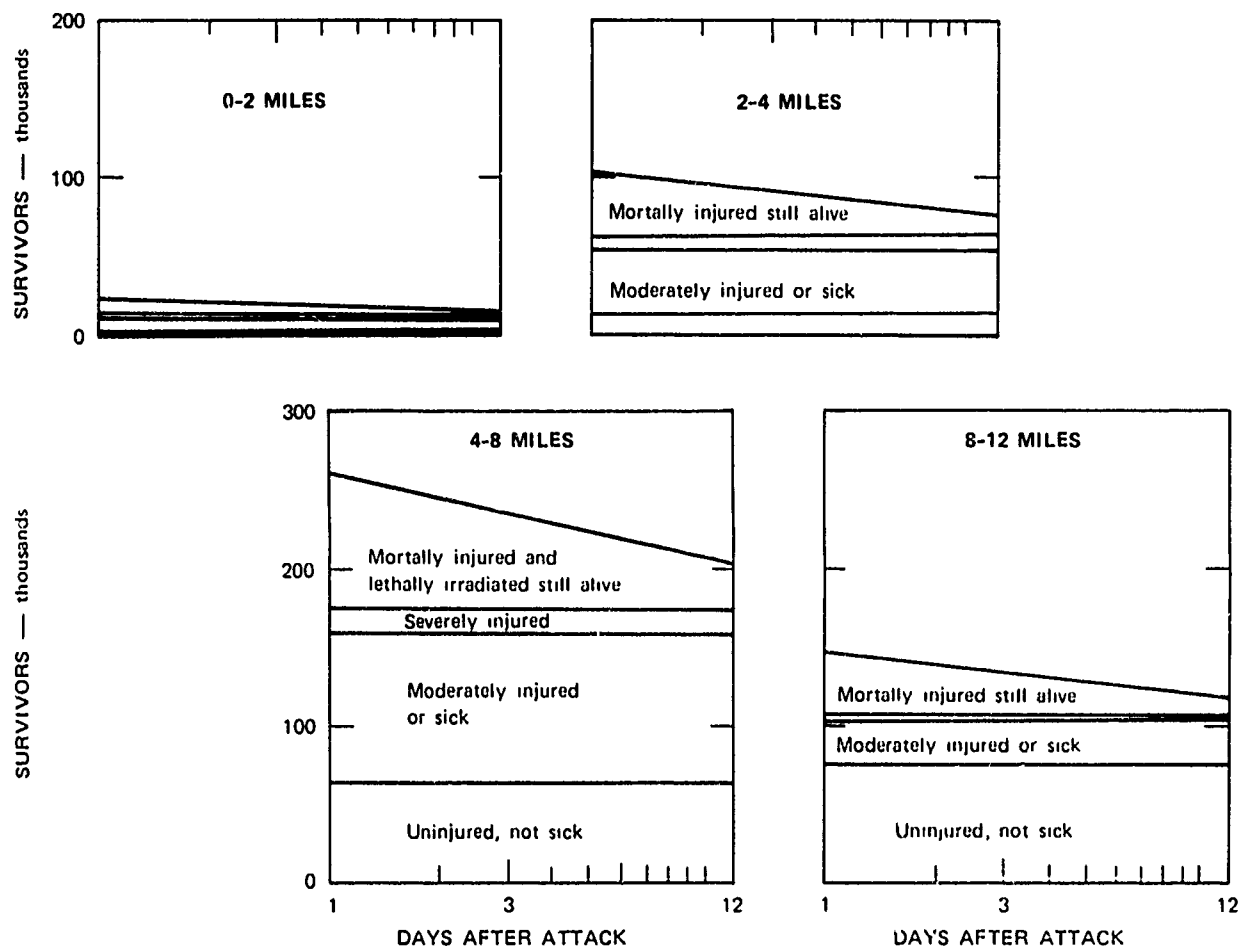
FIGURE 10   CONDITION OF SURVIVORS BY ANNULUS

to be very limited to avoid sickness. Three days after the attack 32 percent of the people still surviving will be without injury or fallout sickness (Figure 9). Within the central city (4-mile radius) the proportion well will be much smaller--only about 12 percent (Figure 10). Only in the 8 to 12 mile ring will more than half the survivors be well.

A large proportion of the people still alive will be dying. Unless they are abandoned a substantial workload will be required merely to provide self care. When relocation is begun, many will be nonambulatory and will have to be carried to and from the vehicles used for transporting them. However, for the fallout casualties in the lower dose range of 200 to 1000 r there is a latent period, after the symptoms of the first day or two, of five days to four weeks during which the victim feels relatively well.[14] During this latent period many will be able to walk to evacuation points without assistance.

Many of the severely injured will also require physical care and assistance in moving. The numbers of severely injured were calculated from the Dikewood work.[15] The criteria for severe mechanical injury were:

(1) Multiple lacerations, cuts, abrasions, contusions

(2) Fracture of one or more long bones, compound fracture of other bones, fracture of skull, fracture of spine.

According to the Dikewood work only about 30 percent of the severely injured would have fractures. Hence many might be sufficiently ambulatory to assist in their own evacuation.

Most of the moderately injured and those sick from fallout radiation will be able to care for themselves, and, considering the latent period for radiation effects, will be able to walk to evacuation points. Their use in the workforce however is doubtful, particularly the fallout sick who should avoid further fallout exposure.

The potential workforce will come mostly from the uninjured and not sick group. With allowance for exposure limitations on those with over, say, 100 r ERD, this category might have about 140,000 people. Excluding children under 16 and their mothers, the over 65, and the chronically ill reduces this number by half, to about 70,000.

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Derivation of Condition of Survivors

The derivation of the numbers of severely injured and mortally injured, and the times to death of the mortally injured, were based on the Dikewood studies, starting with the previously discussed typical survival and injury figures. Fallout casualties were based on results from the DAL-67 and DAL-69 studies, and times to death for fallout fatalities were based on information from Dolan[14] and Lushbaugh.[16] Casualties from fire were not included on the grounds that they might be minor, and if not, the fire would tend to reduce the workload by eliminating many of the survivors, particularly reducing the proportion of seriously injured.

Severely Injured

The Dikewood work gives the severely injured by blast as a percentage of the total ultimately surviving blast injured and as a function of overpressure and type of building. The percentage of survivors with blast injuries, as a function of overpressure was derived from the Dikewood figures on blast injuries or fatalities as a function of overpressure. This result was combined with the distribution of survivors by overpressure (Figure 9) to give the distribution of injured by overpressure. Combining this latter result with the severely injured as a percentage of total blast injuries, gives the total severely injured as a percentage of total blast injuries for each annulus. The results are:

Annulus (miles)	Severely Injured as a Percentage of Total Injured
0-2	20%
2-4	20
4-8	15
8-12	10

Mortally Injured

The mortally injured as a percentage of total mortalities, averaged over building types, was derived from the Dikewood studies. That result was then related to overpressure for the mortality functions used in this study and combined with the distribution of preattack population by overpressure from Figure 8. The mortally injured as used in the Dikewood studies refers to those alive at the end of the first day after attack

who subsequiently die, since the original Japanese data have that limitation. The curve of time to death for the mortally injured for buildings of heavy construction (which is intermediate among building types) gives the following:

Days After Attack	Percentage of Mortally Injured Still Alive
3	73%
12	38

Fallout Casualties

Fallout fatalities in the SMSAs in the DAL-67 and DAL-69 attacks were about 25 percent of the SMSA fatalities. This figure was used to represent the fallout fatalities for the typical heavy damage case. In the DAL-67 study the SMSA survivors with over 200 r ERD were approximately half as many as the fallout fatalities. Thus the number of surviving fallout sick in the present study was taken to be half the number of fallout fatalities. The number of survivors in the 100 to 200 r ERD bracket was also about half the number of fallout fatalities.

The estimated times to death for radiation fatalities from two sources are as follows:

Dose (roentgens)	Dolan[14] (days)	Lushbaugh[16] (days)
450		30-45
400-600	14-70	
600-1,000	7-42	10-14
1,000-2,500	4-14	
4,000		less than 2

Of course at the lower doses, not everyone dies; the times to death refer only to those who do die. The survival rate declines from about 50 percent at 450 r, to 0 at 600 r.

A simplified representation of the time to death of the fallout fatalities was made as follows:

Dose (roentgens)	Cumulative Percentage of Fallout Fatalities	Time to Death
1,000	70%	12 days
4,000	30	3 days

III   POSTATTACK TASKS IN A SEVERELY DAMAGED SMSA

The immediate survival needs at the time of shelter emergence will
be water, food, and accommodations. As radiation levels decline to levels
permitting outside operations, the first step will be to establish the
operational capability of the multipurpose staging areas, which might re-
quire decontamination and clearing of access routes. Vital facilities
such as electric power stations and water plants would be restored to
operation if any were sufficiently undamaged to permit early return to
operation. Routes will be cleared through the debris to permit vehicular
access to the survivors. Water and food might be distributed to some of
the sheltered population if necessary before they can be relocated. Buses
will move the homeless to housing both within and outside the urbanized
area. Much of this housing will have to be decontaminated before use,
and some will require restoration of utility services. In cold weather,
broken windows would have to be boarded up.

In this report, the above tasks are defined and quantitative estimates
are made of the magnitude of the tasks. The required effort is given in
terms of man-hours of work and the amount of equipment. The number of men
required for each task is based on considerations of dose rates, dose
limits, how soon the tasks are begun, and the length of time for complet-
ing the tasks. The amount of resources, such as men and equipment poten-
tially available, is estimated and related to the effort requirements, so
as to determine the feasibility of accomplishing the tasks.

Many assumptions have to be made to derive specific, quantitative
estimates for the tasks. Some of the assumptions are necessarily quite
arbitrary. Many simplifying assumptions have to be made for convenience
in calculation and clarity in exposition.

High, but not extreme dose rates are generally assumed. It is con-
sidered desirable to begin operations early, but not necessarily at the
earliest possible for the dose rate levels. Fairly extreme conditions
are chosen for each task independently. In most cases the schedules are
consistent among the tasks, but in some cases the assumptions are not
comparable. For example, the effort for delivery of food and water to
the shelters assumes an extended shelter stay time, while the relocation
effort is based on earlier shelter emergence.

Debris Clearance

When activities outside the shelters become feasible, the initial
requirements will be the distribution of food and water to the survivors,
or their evacuation. Most of the survivors will be in areas that had
more than 2 psi overpressure, and debris in the streets will generally
block vehicular access. Walking miles through the debris carrying sup-
plies would subject large numbers of people to excessive radiation doses.
Evacuation on foot to the perimeter of the debris area might be possible,
but large numbers of sick and injured would have to be carried on stretch-
ers, and a large additional dose burden would be imposed on most of the
people. Hence, some degree of vehicular access requiring debris clearance
will be desirable.

A substantial amount of research has been conducted for OCD on debris
production and debris clearance by URS, ITTRI, ORI (Operations Research,
Inc.), and Jacobs Associates. The following analysis of debris clearance
for the typical heavily damaged SMSA makes use of that background of in-
formation.

Debris Depths

Debris depth contours have been calculated for particular cases in
connection with the Five-City studies. The debris problem requires esti-
mates of debris depths by street mileage and overpressure in different
parts of the SMSA. For this study, the street miles versus overpressure
were developed for the typical heavily damaged SMSA of one million popula-
tion. Debris by overpressure and distance from SMSA center were based on
the IITRI debris clearance study,[17] and were also consistent with the
later debris contour estimates in the Five-City studies.

Table 5 gives the SMSA street and potential debris depth model used
for the debris estimates. The area figures represent the built-up area
within the annuluses. The street miles represent typical street densities
within the built-up area which decrease with distance from the SMSA center.
The cumulative distribution of street miles by overpressure, for over-
pressures between 2 and 15 psi (the range of interest for debris clearance)
is shown in Figure 11. This distribution is based on the distribution of
preattack population by overpressure from Figure 4.

The potential debris depth of Table 5 represents the debris depth if
100 percent of the structures and contents becomes debris and is uniformly
distributed over the block. The buildings are divided into two categories--
(1) one and two family houses and (2) large structures, including commercial

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Table 5

SMSA MODEL FOR DEBRIS ESTIMATE

Annulus (miles)	Urbanized Area (sq mi)	Street Miles	Potential Debris Depth from Destruction of: (inches)		Percentage of Street Miles with:	
			Houses	Large Structures	Houses	Large Structures
0-2	12	300	12	30	25%	75%
2-4	38	700	8	24	50	50
4-8	100	1,500	6	18	60	40
8-12	50	500	4	12	70	30

and public buildings, apartments, and buildings used for manufacturing. Some typical figures on debris depths for various types of neighborhoods from the IITRI report[17] are listed below:

Type of Neighborhood	Debris Depth (inches)
One- and two-story residences, and garages (25 ft lot width)	8
Three-story flat-buildings with garages	28
High rise apartments	25
Neighborhood business district	19-54

The debris figures do not include the effects of fire, which might burn up some of the debris. As previously discussed, the extent of fire is uncertain, so the no-fire case is considered here since it represents a larger debris clearance requirement.

The division of streets between the two categories of structures is based on the proportion of the area in (1) houses and (2) large apartments and nonresidential use. Another IITRI report[18] gives the percentage of land in residential use, commercial use, and so on, by distance from downtown Chicago.

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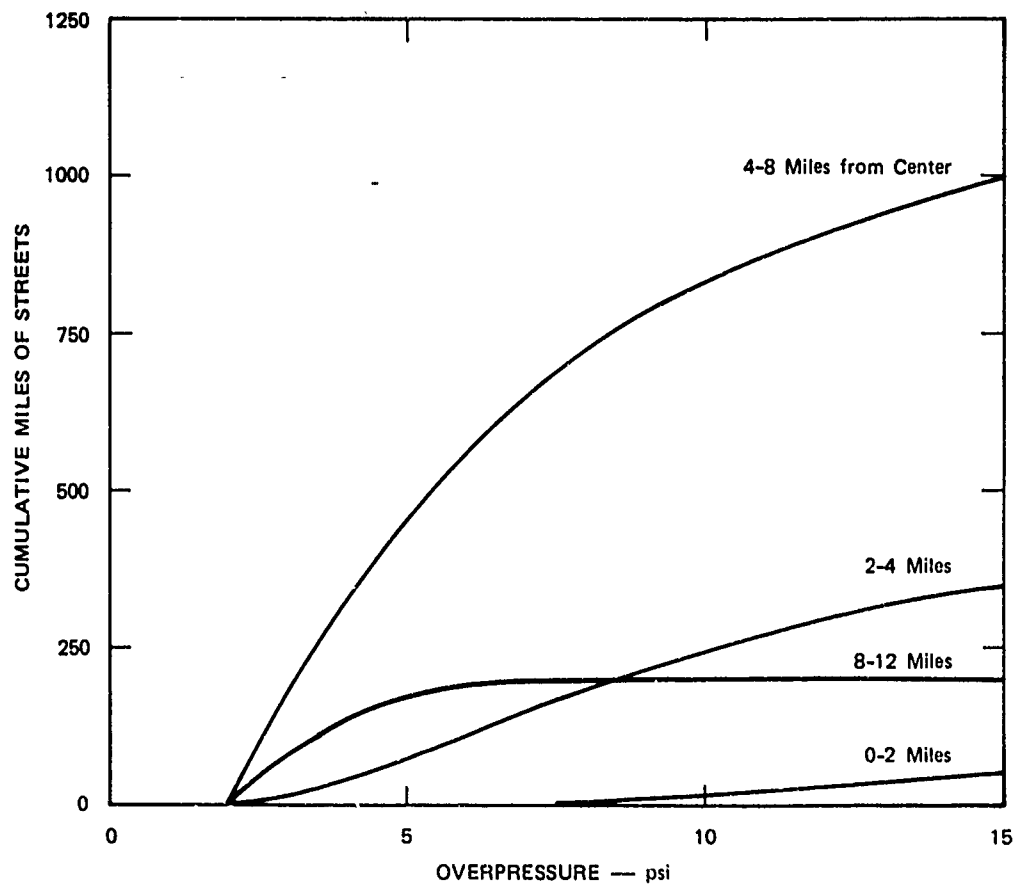
FIGURE 11   STREET MILES FOR DEBRIS CLEARANCE

Next, the percentage of building materials that becomes debris as a function of overpressure was taken from a URS study.[19] A curve for wood frame buildings from the URS study was used to represent the houses category, and a curve for masonry load-bearing wall buildings was used to represent the large structure category. For wood frame buildings, the percentage of material that becomes debris ranges from 0 percent at 2 psi to 100 percent at 5 psi. The corresponding figures for masonry load bearing wall buildings are 0 at 4 psi and 100 percent at 10 psi. Multistory steel or reinforced concrete buildings will represent only a small fraction of the structures outside the area of total devastation. Also it is presumed that streets where such buildings have collapsed could generally be by-passed in the initial debris clearance.

Combining the percent debris versus overpressure figures with the potential debris figures of Table 5 gives the average debris depth as a function of overpressure in each of the outer three annuluses. This is shown in Figure 12. Since most of the central 2-mile radius circle will receive overpressures resulting in 100 percent debris, only a single figure of 24-inch average depth is used for that area.

Two limitations of the debris production models should be noted. First, the models assume the debris is uniformly scattered over the area. However, the debris will be deeper nearer a building site. Photographs of houses subjected to 5-psi overpressure in weapons tests show most of the debris remaining on the building site, and most of the scattered debris within a few yards of the site.[20] Thus the models may overestimate substantially the amount of debris in the streets, particularly on residential streets where the houses are set back from the street. A later URS report[21] provides some discussion of the off-site factor.

A second limitation is that the models have concentrated on building debris. At the lower overpressures much of the street blockage may be from fallen trees, telephone poles, and cars. Expressing this condition in terms of inches of debris is not very meaningful. Likewise, the debris clearance models are for rubble conditions and express production rates in terms of cubic yards per hour.

Debris Clearance Effort

The first question in determining the debris clearance effort is what streets should be cleared. As previously discussed, the immediate purpose of debris clearance is to provide vehicular access for supplies to the people in shelter, and for evacuation.
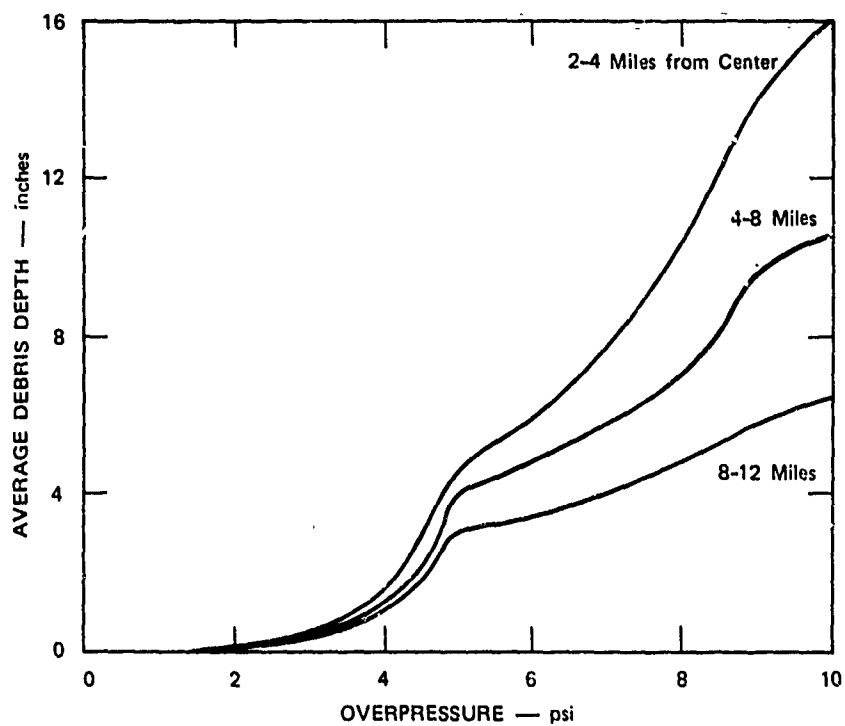
FIGURE 12   AVERAGE DEBRIS DEPTH

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The total street mileage within the 2 to 15-psi overpressure range of interest is 1,600 miles (Figure 11). Access lanes through all of those streets would be desirable if the effort required would not be excessive. However, considerably less miles of street clearance could still provide vehicular access within a short walking distance of all the survivors. The following tabulation gives the street miles in each annulus to be cleared of debris for various spacings of cleared streets.

Annulus (miles)	Area Within 2-15 psi (sq mi)	Street Miles			
		1 X 2 mi Spacing	1/2 x 1 mi Spacing	1/4 X 1/2 mi Spacing	All Streets
0-2	2	3	6	12	45
2-4	19	29	57	114	350
4-8	68	102	204	408	1,005
8-12	20	30	60	120	200
Total	109	164	327	65-	1,600

The federal guidelines for classification of urban roads and streets[22] gives the following percentages of miles for each category:

Principal arterials	5-10%
Principal plus minor arterials	15-25
Collector streets	5-10
Local streets	65-80

On this basis the spacing of cleared streets would be approximately equivalent to clearing the street system categories listed in the following tabulation (which also gives the maximum walking distance to a cleared street for each spacing):

Street Spacing (miles)	Equivalent to:	Maximum Walking Distance (miles)
1 X 2	Principal arterials	1/2
1/2 X 1	Principal plus minor arterials	1/4
1/4 X 1/2	Arterials plus collector streets	1/8

These equivalences are only approximate, of course, since the streets are closer spaced toward the center of town.

We presume that, as a minimum, the equivalent of the principal arterials would be cleared to a width of two lanes (one lane in each direction, or approximately 20 feet). Since traffic requirements will be light, a single lane (10 feet) on any additional streets cleared should be adequate. Combining the distribution of street miles by overpressure (Figure 11) with the debris depths versus overpressure (Figure 12), the debris volume to be cleared would be as shown in Table 6.

Table 6

DEBRIS VOLUME TO BE CLEARED
(Thousands of Cubic Yards)

Annulus (miles)	Principal Arterials	Principal plus Minor Arterials	Arterials plus Collector Streets	All Streets
0-2	23	35	58	188
2-4	90	135	225	590
4-8	159	239	398	865
8-12	11	17	28	44
Total	283	426	709	1,686

Note: Two lanes cleared on principal arterials, one lane on other streets.

As previously noted, the volume of debris in the streets may be overestimated because of the off-site factor.

The debris depth on the principal arterials (1 x 2 mi spacing) was assumed to be the same as that on all the streets. However, the arterials tend to have more commercial buildings; this will result in greater debris depths in the streets. Offsetting that to some extent is the fact that the arterials sometimes consist of expressways, which will usually have less debris. Also, in clearing routes equivalent to the principal arterials

it would be possible to bypass arterials with heavy debris, for example by taking a parallel, adjacent residential street with lower building density.

The debris clearance studies express debris clearance rates in terms of cubic yards per hour. The production rates vary with various factors such as type and size of equipment, type and depth of debris, and haul distance. In this study it is seen that most of the streets to be cleared will have only a few inches of debris. Bulldozers will be most appropriate for clearing access lanes through the light debris, though other equipment, particularly front-end loaders, will have applicability in some spots with deeper debris. The standard production rates for various types of bulldozers, given by Jacobs Associates,[23] range from 140 to 530 cubic yards per hour. Adjustment factors reduce those figures depending on conditions. For this study a nominal rate of 200 cubic yards per hour is used. This figure is consistent with the effort calculated by Jacobs Associates[23] for clearing specific streets in Detroit by bulldozer.

Figure 13 gives the equipment-days required to clear streets in areas that had less than 15 psi overpressure (based on a ten hour working day) for various maximum walking distances to the nearest cleared street. The three points shown on the curve indicate:

- All streets can be cleared in 843 equipment-days (two lanes on principal arterials and one lane on other streets).

- Two lanes on principal arterials and one lane on minor arterials can be cleared in approximately 200 equipment-days.

- Two lanes on principal arterials only can be cleared in about 140 equipment-days.

Another way of considering the debris clearance effort is in terms of how far a bulldozer can travel in a day making a continuous run through the debris in the streets, spilling it to the sides. Lee[24] estimated that by skirting the zone of total destruction a bulldozer could clear a swath in one day through the 20-mile diameter of the debris zone for a 10 MT surface burst. On this basis the 1,600 miles of streets (1,764 lane miles) could be cleared in 88 equipment-days. This point is also indicated in Figure 13.

Thus complete access would require between 88 and 843 equipment-days of debris clearance effort. An intermediate figure of, say, 200 equipment-days (2,000 equipment-hours) would at least provide access equivalent to the arterial system, with maximum walking distances to clear access routes
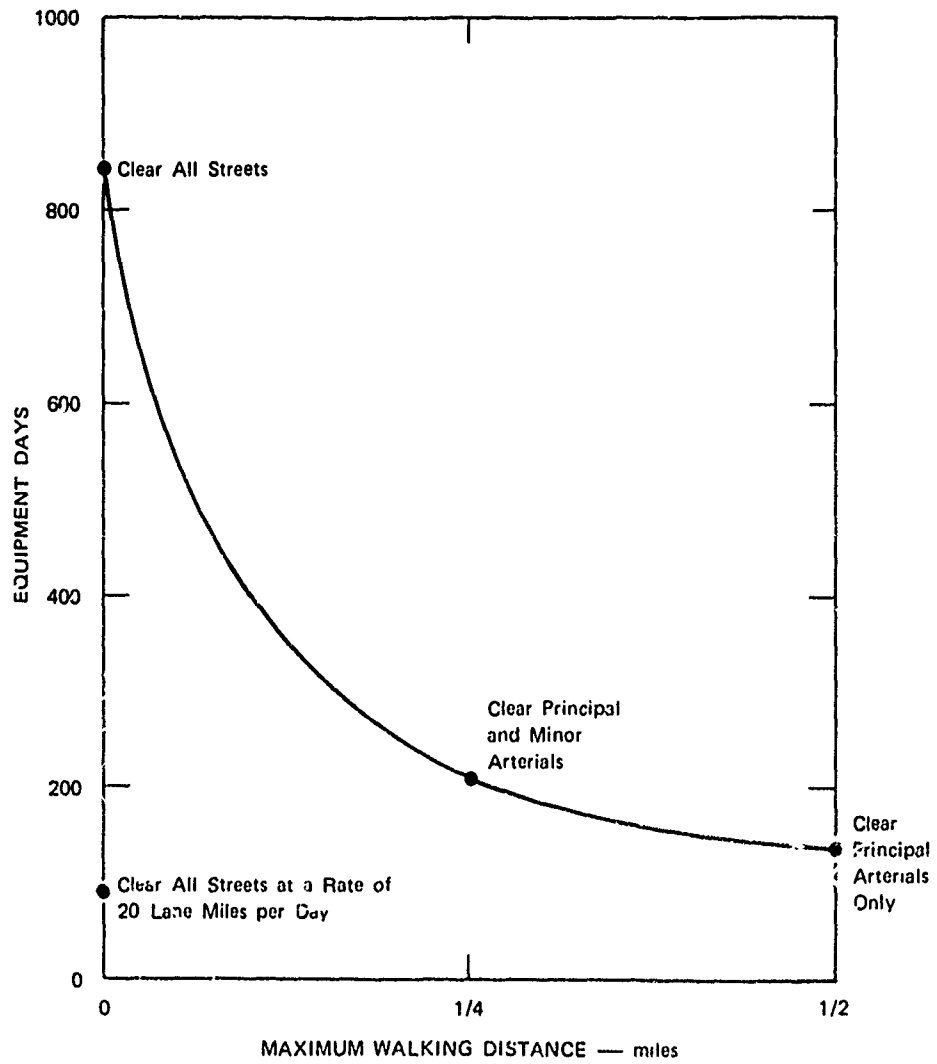
FIGURE 13   DEBRIS CLEARANCE EFFORT

of about 1/4 mile. By bypassing the few areas with heavy debris it is likely that access lanes could be provided on nearly all streets with . that level of effort. Of course, some additional support effort and minor equipment would be required.

Availability of Men and Equipment

The number of people in the United States in 1970 with skills in excavating, grading, and road machinery operation is indicated in the following tabulation:

Experienced civilian labor force	275,000
Total employed	245,000

The figures are derived from data from the 1960 census[25] on the basis of the increase in construction workers in heavy construction between 1960 and 1970.[26] Of the employed manpower, approximately 53 percent were in rural areas. Thus, people with these skills should have a higher survival rate than the population as a whole.

A typical (and slightly conservative) figure for the number of employed workers in this category for an SMSA of one million population is 600.[26] These workers also tend to be less concentrated in the central city than is the general population, and hence will have a higher survival rate. A SMSA's share of the workers in this category outside the SMSA will be approximately twice this number, or 1,200. However, the number sufficiently close to be of use will vary among SMSAs. If, because of the higher survival rate, one-fourth to one-third of the SMSA workers in the category are able to work, the number available would be about 150 to 200, plus some more uncertain number from outside the SMSA.

The estimated equipment in use in construction in the United States in 1960 was given in Ref. 17. Bulldozers (including angle dozers) numbered 165,000, and the total number of shovels, front-end loaders, scrapers, and graders was more than twice that. If we assume that the equipment is distributed in proportion to the workers in the excavating, grading, and road machinery operations category, there would be about 500 bulldozers in the SMSA and more than 1,000 pieces of the other kinds of equipment. Survival rates of the equipment will be much higher than that of the population, since the equipment is less vulnerable and also is generally outside the central part of the SMSA. With a conservative 50 percent survival rate there would be 250 bulldozers available. The previously

discussed nominal figure for debris clearance effort was 200 equipment-days. Thus there should be ample equipment, even for clearing all the access routes in a single day.

Men Required

The number of men required for the debris clearance depends on the dose rates, starting time, and time allowed for clearing debris. Considering the limits on food and water in the shelters, it will be desirable to provide supplies to the people therein (or to evacuate them) within approximately a week, if feasible.

Although the amount of equipment for debris clearance should be ample, the number of skilled equipment operators may be a constraining factor if fallout levels are high. As previously discussed, fallout levels will be typically in the 500 to 4000 r/hr standard intensity range. At the lower 500 r/hr figure fallout would not be constraining after the first two days; in two days the intensity would decline to 5 r/hr, or even less considering weathering effects. Vehicle shielding will provide a reduction factor of about 0.5, giving a dose rate of 2.5 r/hr. Starting at two days, the dose for a ten-hour work day (plus, say, two hours to get into position and return to shelter) would be an acceptable 30 r, and about 60 r for three days' work. Thus, the nominal 200 work days would require only 67 men for completion in three days, or 200 men for completion in one day, starting two days after the attack.

At a standard intensity of 4000 r/hr the manpower requirement increases, or the time when debris clearance begins increases, in order to limit the radiation dose. One dose limit sometimes considered is 30 r in one day. With that dose limit the exposure time allowed (with a vehicle shielding factor of 2) on the fifth to seventh days after attack is:

Day	Exposure Time (hours)
5	4.5
6	5.5
7	7.5

Assuming two hours getting into position and returning to shelter on the first day and one hour on each of the next two days, the allowable working time would be 13.5 hours. The nominal 2,000 working hours would then require 148 men.

If the 30 r per day limit is disregarded, and the work is all per-
formed in one day, starting five days after attack, with 200 men, the
dose for ten working hours plus two travel hours would be 80 r.

Although the indicated manpower requirement is comparable to the
previously mentioned 150 to 200 skilled equipment operators available,
at the higher intensity a larger proportion would be limited by the dose
received in shelter. Thus there is potentially a shortage of equipment
operators that might delay the debris clearance or require excessive doses
to the operators. However, not many SMSAs will experience the higher dose
rate levels over much of their area. Generally a force of 150 equipment
operators should be available and adequate for access route clearing within
two to seven days.

Some additional support personnel and equipment will be required.
Trucks might be required for hauling the debris away from a few places
that could not be bypassed, where the debris is too deep to be pushed
aside. However, the availability of trucks and truck drivers is so great
that there will be little difficulty in meeting the need. Vehicles and
drivers for transporting the equipment to the use point will also be
required. Decontamination of staging areas (outside the debris area)
for the debris clearance operations will also be necessary in some cases.
The workload for this task is discussed in the decontamination section.

Water Delivery

Potential Need for Water

The importance of water is much greater even than that of food, since
survival is possible for a longer time without food than without water.
There may be a critical water shortage for some of the sheltered popula-
tion in a damaged area. The water distribution system is likely to be
inoperative due to loss of power and line breaks. Even light structural
damage can cause breaks in water pipes. In the damaged areas breaks in
the lines entering damaged buildings may require shutting off the lines
to those areas even after other parts of the system are restored. Heavy
fallout levels in the damaged areas or in the evacuation area may delay
evacuation until after water supplies have been exhausted. Without water,
people would be forced to leave shelter to seek water. Some might not
find any, others might be forced to use polluted water, and many would
be exposed to high radiation levels.

Survival supplies with water containers are stocked in many of the
shelters. However, in many of the shelters there may not be enough water.

Only about half the shelters are expected to be occupied[2] and, since most of the stocking has taken place without the benefit of community shelter plans, the supplies may not be distributed where they are needed. Also, in many cases the owner of the shelter has not given permission to have the shelter stocked. Hence many of the occupied shelters will be without shelter supplies, unless shelter stocking is resumed. Although substantial supplies of trapped water are in many shelter facilities, the amounts are widely variable among shelters. Also, many of the shelters will be badly damaged, even though permitting survival, and some of the trapped water may be lost. Furthermore, the consumption of water may increase if shelter temperatures are high.

With the present shelter system, or with minimum extensions to it, a large proportion of the survivors would be at home rather than in a shelter. With a continuation of the NFSS to 1975, only 39 to 50 percent of the population would be in a shelter, depending on the warning system.[2] Although the proportion of people sheltered would be higher in the large SMSAs, the higher fatality rate in the center of the city, where most of the people could be sheltered, would lower the proportion of survivors in shelters. Thus, about half of the survivors might be at home rather than in a public shelter.

It seems likely that survivors in their homes generally will have sufficient water for at least two weeks. In addition to liquids in cans and bottles, and the possible storage of water in a crisis, major potential sources of water are in toilet tanks and hot water heaters. A 30-gallon water heater, for example, would provide a family of six with a quart of water per day per person for 20 days.

However, there will be large numbers of survivors in damaged houses. The damage might cause loss of the trapped water; hence a capability for supplying water to survivors in houses might be desirable.

Supplying Water to Public Shelters

To determine a representative figure for the effort to supply water to the public shelters it is assumed that half of the survivors (455,000 at five days, Figure 9) are in public shelters, and that slightly over half of them have insufficient water. The requirement then is to supply approximately 120,000 people with water. For the purposes of this study, the delivery of one quart of water per day per person is assumed, or 30,000 gallons per day.

A source of water on the periphery of the urbanized area is assumed. Water is delivered to the shelters by tank truck. Containers are placed at the shelters and filled by the tank trucks. At 2,000 gallons per truck, 15 tank truck loads would be required. Round trip distances will average about 30 miles. The number of facilities to be served will be about 200, with an average of 600 survivors in each facility. As discussed later, a shortage of containers might limit the amount of water that could be left at a facility, possibly requiring delivery of water every day. Thus each trip would supply an average of 13 shelter facilities, and 15 trips per day would be required.

About two hours should be sufficient for travel time, although finding the shelters might be complicated by the damage. The time to off-load the water would be nominal, since flow rates for gasoline tank trucks are generally well over 100 gallons per minute. Allowing about ten minutes at each facility, total trip times would be about five or six hours. Thus two trips per day would be possible, and eight tank trucks would be sufficient.

Sufficient tank trucks should be available. The total number of tank trucks for liquid use in the United States in 1967 was 294,000.[27] If distributed in proportion to population there would be approximately 1,500 in an SMSA of one million population. Of course, a large proportion of them are in use for petroleum products or chemicals and might be unsuitable for water service, or might require cleaning. More suitable are water trucks used in construction, street flushers, and milk trucks. Damage will also reduce the number of tank trucks available, but the potential numbers are very large in proportion to the needs.

Greater efficiency in water delivery could be achieved if enough containers could be found for several days supply of water at each of the shelters. The production of steel shipping barrels and drums of 55- to 57-gallon capacity runs about 1.5 million per month,[28] which is about 7,500 drums per million population. However, the availability is uncertain; finding them might be difficult unless it were known ahead of time where to look. Trash cans with plastic liners could also be used. The equivalent of approximately 600 50-gallon drums (a nominal 50-gallon capacity is assumed for convenience in calculation) will be required with daily water delivery. About 12 truck-loads will be required for picking up and delivering the containers. With three men per truck, 36 men would be required.

Decontamination might be necessary at the place where the water is picked up. Also, a decontaminated staging area for the water delivery operations would be useful. Decontamination effort requirements are estimated in the decontamination section.

Supplying Water to People not in Public Shelters

Supplying water to the people not in public shelters will be more difficult because of the greater dispersal. As previously mentioned, the trapped water in residences might be lost if the buildings were severely damaged. Taking 4 psi as the level at which the trapped water will be lost, approximately half of the survivors will be in areas with at least that overpressure (Figure 5); this will be approximately 120,000 of the survivors not in public shelters. They will be distributed over approximately 2,400 city blocks. If the trapped water is lost in all houses at 1 to 2 psi, the number of people to be supplied with water would be increased by 50 to 75 percent.

Water could be distributed by delivering it by tank truck to containers (nominally, 50-gallon drums) at many points throughout the area, from which people in the neighborhood could fetch water to their homes. Alternatively, the water could be provided directly from the tank trucks, which could stop frequently while driving through the neighborhoods. People could come out to the trucks with their own containers. If enough large containers could be found, the first method would require fewer tank trucks and drivers.

If water containers were placed at every second intersection, the maximum round trip walking distance to get water would be two blocks. Each container location would service the equivalent of two blocks, with an average of 50 survivors per block. One 50-gallon container at each location would supply water for two days at one quart per person per day. Such minimum usage would require rationing, with someone in the neighborhood doling out the water. About 1,200 50-gallon drums or the equivalent would be required if the containers were left in place. With a tank truck capacity of 2,000 gallons, each trip could supply 40 locations. Allowing five minutes per location and two hours travel time, trip time would be about five or six hours, and two trips could be made per day. Hence, eight tank trucks would be sufficient for a two-day resupply cycle. Since the delivery is spaced over two days, instead of the one day for delivery of containers to the public shelters, and twice as many containers are required, the men and trucks required for collecting and delivering the containers would be the same as that for the public shelters (12 trucks and 36 men).

If enough containers cannot be found, the few containers available could be moved from place to place as they are emptied. This procedure would require each family group to provide its own containers, with sufficient total capacity for the resupply interval. A family of six would require container capacity of approximately three gallons to last two

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days. Kettles, pails, plastic wastebaskets, and so on, should be suffici-
ent in most homes if they can be found amid the debris. One truck for
moving 50-gallon containers should be able to keep up with each tank-truck.

If people obtain the water in small containers directly from the
tank trucks, the filling time of the small containers (caused by turning
the water on and off and by the slower flow rate necessary to avoid splash-
ing water out of the containers) would reduce the rate of progress of the
trucks. With one-stop in each block there would be 2,400 stops, with an
average of 50 people per stop. For a 2-day supply 25 gallons would be
required. Allowing about one minute per gallon, the time per stop would
be about 1/2 hour. Thus 60 tank trucks would be required.

Manpower Required for Water Delivery

- The number of men required for water delivery depends on the radia-
tion intensity. The importance of water might be so great in some cases
as to justify casualty producing doses. However, in contrast to the debris
clearance effort, truck driving skill is widespread, and the required dose
for water delivery can be spread over enough men to avoid excessive doses.

An indication of the manpower required for water delivery will be
given for a uniform standard intensity of 4000 r/hr. With delivery be-
ginning on the fifth day after the attack, a vehicle protection factor of
two, and a 100 r dose limit, the allowable working time over, say, an
eight-day period would be 30 hours. At 12 hours per day each tank truck
would be in use 96 hours during the eight-day period. Hence, four men
would be required for each tank truck, or a total of 64 men for the 16 tank
trucks.

The total effort and number of men required for water delivery are
then summarized as follows:

Task	Man-hours	Men
Public shelter		
Collecting and delivering containers	162	36
Delivering water	763	32
Homes		
Collecting and delivering containers	324	36
Delivering water	763	32
Total	2,012	136

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Earlier starting times for water delivery would increase the manpower requirement because of the higher dose rates. Reducing the dose limit would also increase the manpower requirement. A shortage of containers would increase substantially the number of tank trucks and tank truck drivers required.

Relationships to Other Tasks

Debris clearance is a prerequisite for water delivery in most of the area. Debris clearance schedules beginning on the fifth day after attack were discussed in the debris clearance section. By concentrating first on clearance of routes to the shelters needing water, the water delivery to many of the shelters could be accomplished on the same day that debris clearance begins. Debris clearance could be conducted a day earlier, on the fourth day after attack, with a dose of approximately 100 r per man. The possible shortage of equipment operators for debris clearance might require excessive doses to the operators in some areas if earlier water delivery is required.

For simplicity, the water delivery and food delivery effort is calculated on the basis of supplying a fixed fraction of the survivors over an 8-day period beginning on the fifth day after the attack, assuming that the people remain in shelter throughout the 8-day period, which is a possible option. The subsequent calculation of relocation effort is based on earlier emergence from shelter beginning on the seventh day after the attack and extending over a 5-day period. Although the situations for the different tasks are not strictly comparable, the effort for the water and food delivery would be reasonably applicable also to the earlier relocation situation. Although some of the people being supplied would be leaving the area, other shelters, and people at home, would be running out of provisions, and the people relocated within the area would still need to be supplied.

Food Delivery

As previously mentioned many of the public shelters are not stocked with survival supplies. Some of these buildings may have small amounts of food, and some people may bring food with them to the shelter, depending on warning circumstances. However, the possibility exists that large numbers of people will be in shelters with little or no food. People can survive a few days without food. However, if fallout levels require shelter stay times of a week or two, the delivery of food to the shelters would be necessary. The food for the shelters would have to be edible

without cooking, since the buildings would not usually have cooking facilities and, of course, in the damaged areas the utilities would not be functioning.

The food supplies of people not in public shelters should be greater than those of the stocked shelters. A Department of Agriculture study[29] showed ten days supply of food in homes in the large SMSAs. Housing damage and spoilage from lack of refrigeration would reduce the food supply. Offsetting this to some extent would be the reduction in the number of people, due to fatalities. Also, people could in some cases obtain food from neighboring houses whose occupants have gone to public shelters. Part of the home food supply would be in items such as flour and potatoes which require cooking. However, wood-fueled cooking fires could generally be improvised. Thus, the need for additional food supplies before shelter emergence should be less than that for the unstocked public shelters.

Food supplies from outside the area are unlikely to be received during the shelter period because of disruption of the food system and because of fallout constraints on activities outside shelter. However, substantial stocks will survive within the area in retail stores, wholesale warehouses, and food processor plants. These supplies were estimated to provide 86 days of food at 2,000 calories per day per person for the United States in 1963.[29] Food from these sources could be used to provide additional food during the shelter period where shelter supplies are inadequate, and for subsequent weeks in the evacuation areas until food distribution can be established.

The wholesale and food processor stocks vary widely among the SMSAs, and in some cases are far below the average per capita amounts. Also, the warehouses and plants may be concentrated in certain parts of the SMSA and hence vulnerable. Retail stocks are less variable and tend to be distributed the same as the population.

The retail food stocks in the large SMSAs were estimated to provide 12 to 16 days supply in 1963.[29] Slightly more than four-fifths can be stored for relatively long periods without special handling (though the amount of frozen food has increased since 1963). Canned and bottled foods provide about five days supply, and dried and packaged products such as cereals, flour, and sugar will last about seven days. The products requiring cooking will not be suitable for shelter use.

In the damaged area some of the fresh and frozen products will spoil in the first few days while fallout restricts activities. Many food stores will be demolished and most will at least have broken windows and

supplies knocked off shelves. Unpackaged things will sometimes be contaminated with glass or fallout, bottles will often be broken, and packages will sometimes be soaked through by rain or broken open. But in the absence of fire, most of the canned food and some of the other products should survive. Access will be hampered where the building has collapsed, though even then some food might be accessible if the roof has been blown to one side.

The number of supermarkets (over $500,000 annual sales) in 1967 in the United States was 34,770.[30] These stores accounted for 15.4 percent of grocery stores and 72.3 percent of sales. The food salvage operations could be limited initially to the smaller number of large grocery stores. If distributed in proportion to population, there would be approximately 150 supermarkets for the urbanized area of 870,000 population. Assuming salvage can be conducted where overpressures were less than 5 to 10 psi, about 1/3 to 1/2 of the stores, or 50 to 75, would be available. Also assuming that a third of the 9-day (the supermarket share of the 12 days for all grocery stores) stocks of canned, bottled, dried, or packaged products can be salvaged and is edible without cooking, these stores could supply 0.9 to 1.3 million ration days of food.

An indication of the effort required to salvage food to make up shortages in shelter supplies will be based on providing food for eight days for the 120,000 survivors in unstocked public shelters. The requirement of 960,000 ration days of food is then consistent with the amount available in the supermarkets.

As a simplification, the effort will be estimated for canned goods only. The common and intermediate size No. 2 can holds approximately 1 lb, 4 oz. For typical foods such as fruit in syrup pack, corn, and baked beans the No. 2 can provides roughly 500 calories.[31] (This is higher for meat contents and lower for most other vegetables.) Thus, for 2,000 calories per day, four cans would be required. The 960,000 ration days of food would then require the equivalent of 3.8 million cans.

The food will generally be knocked off the shelves, and debris will hamper access. Under these conditions, picking up the cans, putting them in a box (20 cans per box), carrying the box outside to a truck, emptying the box (because of insufficient boxes), and returning for another load is estimated to take five minutes. To the extent that dollies and carts can be used, and full cartons obtained from back storerooms, the time will be reduced. Unloading at the shelter might take about three minutes per box. Transportation time, assuming paths have been cleared through the debris in the streets, will be relatively negligible. Thus, approximately 25,000 man-hours of effort will be required.

An allocation scheme should be devised to assign the grocery stores to the shelters. Each supermarket could serve about three shelters, on the average. With 600 people per shelter, obtaining the food supplies for one day would require about 16 man-hours. With a five-man crew, each shelter could be supplied in a little over three hours, so one truck would be adequate for three shelters. Thus 67 trucks would be required. In the less severely damaged areas it should be possible to find operable trucks in the vicinity of the shelters. Trucks will have to be sent into the more heavily damaged areas.

The shelter occupants could generally provide the work force for obtaining food for their own shelter, except where there are not enough uninjured people. With the average five-man crew for each of the 200 shelters, the work force would total 1,000 men each day. If necessary to spread the dose burden, a different crew could unload the truck, and new crews could be assigned each day. However, with an average PF of two during the work, and a standard intensity of 4000 r/hr, the same men could work each day of an eight-day period, beginning on the fifth day after the attack, without exceeding a 100 r dose.

Food supplies remaining in the heavily damaged areas to be evacuated, or in severely damaged buildings, could also be salvaged for distribution to the parts of the city not being evacuated, or to the relocation areas. Supplies remaining in grocery stores that could resume operations might be left there. Considering the remaining food in retail stores and additional supplies at wholesalers and food processors, the completion of food salvage might require several times as much effort as for obtaining food just for the shelter period. However, this effort would be at a later time, say two to three weeks after attack, permitting longer work hours.

Rescue

The studies of rescue[13] have been directed to the early hours after the attack, before fires spread and fallout arrives. A very large and well-organized rescue effort would be required for effective results in the short time available, and the payoff is considered to be relatively small. Hence little rescue is likely to be accomplished in the emergency period.

Many trapped people might still be alive at the time of shelter emergence. However, it is doubtful that extensive plans or organization should be set up for this task of possibly marginal value. One possible argument in favor of some organized rescue effort in the shelter emergence

period is the effect on the relocation effort. When picking up people from shelters and ruined homes for relocation, the work will be slowed down if the relocation personnel stop to free people who are trapped. Therefore, it might be desirable for rescue teams to precede the relocation workers to (1) notify the people that they will soon be picked up (so they can gather up things they wish to take with them) and (2) free any trapped people who are easily discovered.

Reference 13 gives the percentage of people trapped in various types of buildings as a function of the fatality rate in those buildings. Relating fatality rate to overpressure, and using the distribution of population by overpressure (Figure 4), the estimated number of people trapped is approximately 20,000. Fire and deaths from other causes would reduce this figure. With the fire model used in the DAL-69 study, less than a third of the trapped would be in buildings that burn. For estimating rescue effort, half of the trapped are taken to be still alive, or 10,000 persons.

The ratio of rescuers to rescued, working within a time constraint of four hours, was estimated to be 2:1.[13] The four hours included time to reach the rescue site and evacuate. If we assume a three-hour working time limit in this period, the rescue capability in a nine hour day would be three times as great. With two days of work per rescuer, approximately 3,300 men would be required. If the rescue efforts are restricted to people who are known to be trapped (e.g., someone replies when the rescuers call out) rather than having a general search through the rubble, the total effort should be much lower.

Relocation of Homeless Survivors

The Problem

A nuclear attack such as the mixed attack of the DAL-57 study would leave some tens of millions of survivors homeless in the large metropolitan areas. The homeless might constitute the major proportion of the survivors in the heavily damaged metropolitan areas. Furthermore most of the homeless might be injured or sick from fallout.

Provision of housing and other care for the homeless will be important for two reasons. First, a substantial potential loss of life might be avoided. Second, little utilization of the homeless for post-attack recovery activities can be expected until they have adequate accommodations.

The previous studies in this series[32],[33] have indicated that in most areas sufficient housing can be found for the homeless within 40 to 60 miles, with a reasonable overcrowding factor of about three (i.e., three times as many people per housing unit as the normal occupancy). However, a large proportion of the housing will require decontamination to permit early occupancy. Although some congregate housing can be provided in large buildings, such as schools, the major proportion of the housing will have to be in homes.

Housing Situation

A typical housing situation in a heavily damaged SMSA is described herein as a basis for estimating the effort required to relocate the homeless. Table 7 gives the housing status and condition of the survivors. The number of survivors is taken as the number alive after seven days (Figure 9). The survivors are categorized in three ways: (1) by location—at home or in public shelter, (2) by housing status—homeless or those whose homes survived, and (3) by physical condition. Half of the survivors are taken to be at home and half in public shelter. The housing survival is based on 2 psi, considering losses from fire as well as blast, and is taken from the distribution of population by overpressure (Figure 4).

Table 7 illustrates the extent of the housing problem. It also points out that a large proportion of the survivors are likely to be at home (or in the ruins thereof) rather than in public shelters, with a consequent effect on operational plans. The large numbers of severely injured also affect the operational requirements of the situation. A larger proportion of the people at home are likely to be in serious condition because of less fallout protection than in the public shelters. The homeless are also likely to be in poorer condition than the survivors with homes, since the homeless will generally have experienced higher overpressures.

The occupancy status of the surviving housing units is indicated in Table 8. Typically, over half of the surviving housing units will be occupied, while less than half will be empty, with their residents having gone to public shelter. In some cases the residents remaining at home will have died from fallout radiation, or the residents going to public shelter will have been killed.

Housing Allocation

Many of the survivors may be accommodated within the urbanized area, but many will have to be sent outside the area for housing. In each case

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Table 7

HOUSING STATUS AND CONDITION OF SURVIVORS

	Thousands of Survivors[*]		
		In Public	
	At Home	Shelters	Total
Survivors with surviving housing			
Uninjured and not sick	29	36	65
Moderately injured or sick	16	10	26
Severely or mortally injured or lethally irradiated	15	4	19
Subtotal	60	50	110
Homeless			
Uninjured and not sick	40	48	88
Moderately injured or sick	12	104	116
Severely or mortally injured or lethally irradiated	78	18	96
Subtotal	160	170	330
Total	220	220	440

* Surviving after seven days.

Table 8

OCCUPANCY STATUS OF SURVIVING HOUSING UNITS

	Number of Housing Units
Residents in shelter	15,000
Residents at home	20,000
Residents dead	3,000
Total	38,000

accommodations will be divided between private residences and congregate facilities. The physical condition of the survivors might have an affect on the allocation of housing. Table 9 illustrates a possible housing allocation.

The rationale for the allocation is as follows. Those whose homes survived are likely to wish to stay in their homes, even with considerable damage and loss of utilities. Even with high radiation levels they could generally stay in the basement if they have one. However, it might be better not to assign additional people to homes in those conditions. In some cases it might be better to take people in serious physical condition elsewhere, where they could be cared for, rather than leave them at home. Thus the number of people assigned to homes within the urbanized area will be less than the theoretical capacity.

Window breakage and utility loss will reduce the desirability of both homes and other buildings within the urbanized area for billeting.

Table 9

HOUSING ALLOCATION

| | Thousands of Survivors* | | | |
	Uninjured, not Sick	Moderately Injured or Sick	Severely or Mortally Injured or Lethally Irradiated	Total
Within urbanized area				
Own homes	63	24		87
Congregate housing	14		36	50
Others residences	27	73		100
Subtotal	104	97	36	237
Outside urbanized area				
Congregate housing	17		51	68
Residences	32	75	28	135
Subtotal	49	75	79	203
Total	153	172	115	440

* Surviving after seven days.

In most cases adequate housing of better quality can be found outside
the area, though entailing greater travel distances. Thus, only partial
utilization of congregate housing within the area was assumed in this
study. Often there will be substantial latitude between use of lightly
damaged buildings within the area, or greater travel distance, with weather
conditions being a factor in the choice.

As previously mentioned, most of the homeless are likely to have to
be placed in homes, rather than in congregate facilities. The Montgomery
County study[34] estimated that only 10 to 30 percent of the total billeting
capacity would be in congregate facilities. This factor should be gen-
erally applicable to the suburban areas and smaller communities that might
supply most of the housing. However, if some large cities are not attacked
the potential for congregate housing will be larger. Also additional con-
gregate housing could often be obtained, if desired, by increasing travel
distances.

The physical condition of the homeless will be relevant to the choice
of assignment between homes or congregate housing. It might be easier to
provide physical and medical care for the seriously injured or sick if
they are grouped together in congregate facilities, rather than being
scattered among private homes. The housing allocation of Table 9 assumes
that the seriously injured or sick (including the dying) are placed in
congregate facilities to the extent possible. Enough able-bodied people,
plus their families, are assigned to the congregate facilities to care
for the sick and injured. The remaining seriously injured or sick are
assigned to homes outside the urbanized area, since the damage within the
urbanized area would make it more difficult to care for them there.

The housing allocation scheme of Table 9 is obviously quite arbitrary;
but, even so, an example with specific numbers should be useful in pro-
viding insight for planning. Also, some allocation scheme is necessary
as a basis for estimating the effort required for relocation of the home-
less.

Moving the Homeless to Housing

Once access routes have been cleared through the debris, vehicles
can be sent in to pick up the homeless from the shelters and damaged houses.
Buses operating out of staging areas on the fringes of the damaged area
will pick up the homeless and take them back to the staging areas or to
relocation centers in the outside communities for assignment and trans-
portation to their assigned housing. In some cases they might be taken
directly to the housing. Providing transportation, instead of requiring

the homeless to walk to staging areas, will be desirable to avoid adding
to their dose burden. Also, with the large proportion of disabled, move-
ment without vehicles would cause hardship and require extensive effort
in carrying the disabled.

An illustrative example giving the number of people moved from public
shelters or their homes to the intermediate staging areas and reception
areas and finally to assigned housing in residences or in congregate fa-
cilities within or outside the urbanized area is shown in Table 10. Most
of the people are moved by bus, but some are assumed to drive in their
own cars. Motor vehicles can remain operable at overpressures that de-
molish most houses.[20] Hence many of the homeless would be able to drive
in their own autos.

The effort requirements were estimated for each of the categories of
moves. The requirements are for buses, drivers, stretcher bearers in
some cases, and housing assignment directors. Bus loadings were taken
as about 40 persons, more or less depending on the proportion of seriously
injured and whether or not stretcher crews are carried. A few seats might
be removed to provide room for some of the injured to lie down. Alterna-
tively, trucks could be used for those who could not sit up.

With several staging areas (say four or more) the trip distances
within the urbanized area would be only a few miles. Likewise the dis-
tances from the reception centers in other communities to the assigned
housing in the same community would also be small. An average distance
of 30 miles from the damaged urbanized area to the reception centers was
assumed.

Loading and unloading times of the buses were each estimated to be
about 20 minutes, more or less depending on the situation. Longer times
might be required when many of the passengers are sick or injured, when
picking up people from single family residences rather than from public
shelter, and when delivering people to private residences where assign-
ment problems might cause delays.

On this basis the buses could make between five and ten round trips
per day, depending on the situation and the distance. The number of buses
required to complete the move over a period of five days is given in
Table 11.

The total of 459 buses is well within the number that should be
available within the area and surrounding support communities. The num-
ber of buses in the United States in 1969 was 364,282, including 273,973
school buses.[35] If distributed in proportion to population, an SMSA of

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Table 10

NUMBER OF PEOPLE MOVED

From	To	Thousands of People	
		Bus	Auto
Residences	Staging areas*	145	30
Shelters	Staging areas	44	45
Shelters	Reception centers*	89	
Staging areas	Residences within urbanized area	65	35
Staging areas	Congregate facilities within urbanized area	50	
Staging areas	Reception centers	74	40
Reception centers	Residences outside urbanized area	95	40
Reception centers	Congregate facilities outside urbanized area	68	

* Staging areas are within the urbanized area while reception centers are in other communities.

one million population would have about 1,800 buses. With a 50 percent survival rate there would be 900 buses within the SMSA alone. Since additional buses will generally be available from surrounding communities, the potential supply of buses will be ample. Trucks and passenger cars could also be used.

The number of drivers and auxiliary personnel required depends on the radiation levels. At a 4000 r/hr standard intensity, approximately 35 hours work between the 7th and 11th days after the attack, with a PF of 2, would keep the dose under 100 r. The manpower requirements of Table 11 are based on two work shifts per day for each bus. At 35 hours per man, the total effort would be approximately 93,000 man-hours. Lower radiation intensities would permit earlier starting times or fewer men.

As will be discussed in the decontamination section, the occupancy of the surviving housing within the area will not be possible that soon if the standard intensity is 4000 r/hr, and therefore the people going to the houses will actually be moved later. Thus, the manpower requirement for relocation to the houses will be less, since the dose rate at the later time will be lower. However, that portion of the relocation

Table 11

NUMBER OF BUSES, DRIVERS, AND HELPERS REQUIRED FOR RELOCATION

From	To	Buses	Drivers	Helpers
Residences	Staging areas	132	264	1,056[*]
Shelters	Staging areas	22	44	
Shelters	Reception centers	89	178	
Staging areas	Residences within urbanized area	26	52	52[†]
Staging areas	Congregate facilities within urbanized area	29	58	
Staging areas	Reception centers	74	148	
Reception centers	Residences outside urbanized area	48	96	96[†]
Reception centers	Congregate facilities outside urbanized area	39	78	
Total		459	918	1,204

* Stretcher crews.
† Housing assignment directors.

effort is minor, and for simplicity the manpower requirements for all the relocation efforts are based on the same standard intensity and the same time period.

A four-man stretcher crew is provided with each bus for picking up people from homes. At the public shelters or staging areas and reception centers there will usually be enough able-bodied men in the group to carry the sick and injured. A housing assignment director is provided on each bus delivering people to residences.

Planning

A substantial planning effort will be required to implement the relocation of the homeless. Some of this planning could be done in peacetime, but a large effort will still be required during the shelter period. From damage assessment reports and reports from shelters, estimates should be made of the numbers, locations, and conditions of survivor

The housing situation should also be assessed in terms of which areas have habitable buildings and the number of people that could be accommodated. In the surrounding area the extent of housing availability in undamaged communities should be determined.

Coordination will be required to allocate the housing and other support in the undamaged communities among the damaged metropolitan areas. After reception centers are selected in the support communities, housing assignments can be drawn up and schedules prepared.

Decontamination

Decontamination has been a major study area of the OCD research program. Doctrine and procedures have been developed, and effort requirements and effectiveness have been determined. This section is intended to provide an indication of the effort required for decontamination in the typical severely damaged SMSA for the situation described in Chapter II, and as related to the other postattack activities previously discussed. Estimates of decontamination effort per unit of area are derived from the extensive literature on decontamination.

The priority needs for decontamination will be the multipurpose staging areas, and vital facilities such as water stations and power plants. A possible additional need will be for decontamination of housing to permit earlier emergence from shelter. Decontamination of some of the surviving industrial plants might be desirable to permit earlier resumption of production. However, industrial decontamination is not covered here since the focus is on immediate survival needs.

Vital Facilities

As an illustrative example, the following facilities are identified for decontamination: (1) electric generating station, (2) water treatment plant, and (3) three electric substations.

The effort required for decontamination of the electric generating station and the water plant is taken from an RTI study of decontamination in Detroit.[36] The electric generating station is the Mistersky Power Plant, a coal-burning, steam generating plant. Of three degrees of decontamination of the roofs given in the RTI study, the intermediate level of 0.07 reduction factor is used. The decontamination effort is given in Table 12. A division of effort between (1) roofs and paved areas and (2) earth and lawn areas is made in the table, since the skilled manpower for operation of earth-moving equipment may be limiting. The figures in Table 12 include support time, derived from Ref. 37, which was not included in the RTI figures.

The water plant is the Springwells Water Pumping Station which is also a treatment plant. The capacity of the plant is 37 percent of the capacity of the total treatment capacity of the Detroit Metropolitan Water Services, which served a 1967 population of 1.9 million.[38] Thus the plant size is roughly consistent with that required for a single treatment plant for the SMSA of one million population.

Table 12

EFFORT FOR DECONTAMINATION OF FACILITIES

Type of Facility	Man-hours			Accom-modations (people)
	Roofs and Paved Areas	Earth and Lawn Areas	Total	
Vital facilities				
Electric generating plant	75	125	200	--
Water treatment plant	142	--	142	--
Electric substations (3)	5	66	71	--
Subtotal	222	191	413	
Staging areas				
Shopping centers (2)	690	--	690	12,000
High schools (2)	140	200	340	6,000
Subtotal	830	200	1,030	18,000
Congregate facilities				
Schools or equivalent (32)	1,152	1,600	2,752	32,000
Total	2,204	1,991	4,195	50,000

Man-hours of decontamination effort for the water plant are given in Table 12. Most of the effort is for decontaminating the roofs. An additional 200 man-hours would be required for decontaminating the adjacent lawn areas, but this is not included in the table because the radiation contribution from the lawn areas to most locations within the plant is minor and decontamination of the lawns would probably not be necessary, or at most could be limited to small areas immediately adjacent to the most vulnerable locations.

In the areas within which the buildings and electric distribution network are largely intact, decontamination of some of the electric substations might be necessary or desirable to permit repairs or manual operation, provided radiation exposure for decontamination was less than that for the repairs or manual operation without decontamination. The surviving housing had a preattack occupancy of approximately 125,000. Twenty electric substations would be typical of the number serving the surviving areas. However, as discussed later, substations would generally remain operable in areas where housing survives, also, surviving substations

can serve distribution areas of adjacent damaged substations. A require-
ment for decontamination of three substations is assumed.

The area to be decontaminated for each substation is taken to be
200 feet in radius, with one-fourth of the area paved. The resulting
decontamination effort for the three substations is given in Table 12.
The decontamination effort is based on the use of street sweepers on the
paved areas and scraping of the unpaved areas with a light tractor, with
effort per unit of area taken from Ref. 39.

Staging Areas

The concept of operations under nuclear attack given in Ref. 40 is
based on operating zones. Each zone will have a multipurpose staging area.
The maximum suggested size of an operating zone is 100,000 people. Juris-
dictions with fewer people will also have their own operating zones.
Thus, a representative figure for the number of people within an operating
zone might be about 50,000. The urbanized area with 870,000 of the one
million population of the SMSA would then have about 17 operating zones
and 17 staging areas.

Most of the staging areas will be destroyed in the attack. If the
survival rate of the staging areas is the same as that of the housing
(the surviving housing had 125,000 preattack residents) two or three
staging areas will survive. But, since the staging areas will be in large
buildings, generally less vulnerable than the housing, the survival rate
of the staging areas might be somewhat higher. However debris problems
at the higher overpressures might be a limiting factor in utilizing the
staging areas. Somewhat arbitrarily, the number of staging areas to be
decontaminated is taken to be four.

Large shopping centers would be particularly suitable for staging
areas because of the amount of space and ease of decontamination. However,
there are not likely to be enough large shopping centers sufficiently un-
damaged for use as staging centers. Two of the four staging areas are
taken to be shopping centers and the other two high schools.

The decontamination effort for the shopping centers is taken from
Ref. 37 which analyzes decontamination of the Westgate Shopping Center,
San Jose, California. The Westgate Shopping Center contains about
480,000 sq ft of floor space, excluding basements. The decontamination
effort for the two shopping centers is given in Table 12. Most of the
effort is for decontaminating the roofs, since the use of street sweepers
and flushers on the paved parking lots is relatively very fast.

The number of people accommodated in the staging area, when used as congregate facilities, is also given in Table 12. This figure assumes 50 percent usable space, including allowance for operations areas, and 40 square feet per person.

The other two staging areas are taken to be high schools. A typical high school might have 100,000 sq ft of roof, 100,000 sq ft of paved area, and 400,000 sq ft of lawn and other unpaved area to be decontaminated, assuming decontamination extending 200 ft from the buildings. Decontamination of 100,000 sq ft of tar and gravel roof with fire hoses takes 18.5 nozzle-hours, with three men per nozzle, or 55.5 man-hours.[39] Adding 20 percent for setup time[37] gives 67 man-hours. Sweeping the paved areas with street sweepers takes about three hours.[37,39] It happens that the unpaved area is one-half the lawn area of the Springwells Water Pumping Station in Detroit, so the decontamination effort with a grader is taken as one-half that calculated by RTI for the Springwells Station lawn area.[36] The resulting effort for two high schools (200 man-hours) is given in Table 12.

The accommodations possible at high schools when used as congregate facilities are calculated on the basis of a typical floor space of 160,000 sq ft, a 75 percent usable floor space factor, and 40 sq ft per person. The number accommodated is then 3,000 survivors per school.

Congregate Facilities

If we want the total accommodations in congregate facilities to be 50,000, the accommodations in congregate facilities not counting the 18,000 in the staging areas must be 32,000, as shown in Table 12. Much of the congregate accommodations will be in schools. For simplicity, the decontamination effort is calculated in terms of schools. Elementary schools typically have about a fourth to a fifth as much floor space as high schools. With a mix of elementary and junior high schools, the average might be about one-third the floor space of the high schools. Thus, average accommodations will be about 1,000 per school, and 32 schools (or the equivalent) will provide additional accommodations for the 32,000 people. Decontamination effort per school will be about half that for the high schools. The resulting decontamination effort for the additional congregate facilities is also given in Table 12.

Manpower

For calculation of manpower requirements for decontaminating the vital facilities and staging areas, a 4000 r/hr standard intensity is assumed, the work is considered to take place five days after the attack, and to be completed in one day. The dose to the crew hosing down the roofs is reduced by half due to working in a partially cleaned area.[37] The dose to the equipment operators decontaminating the earth or lawn areas is reduced by two-thirds to include the attenuation afforded by the vehicle, as well as the effect of working in a partially decontaminated area. With a dose limit of 30 r in one day, the allowable exposure times are approximately 4.5 hours and 7 hours respectively, or with allowance for travel time, 3 hours and 5 hours. The number of men required is given in Table 13.

Table 13

MANPOWER FOR DECONTAMINATION OF FACILITIES
(Number of Men)

	Firehosing and Sweeper Operations	Earth Moving Equipment Operators	Total
Vital facilities and staging areas	352	78	430
Congregate facilities	72	80	172
Total*	352	80	432

* Figures do not add because crews for vital facilities and staging areas are used again for the congregate facilities.

Decontamination of the congregate facilities is considered to begin seven days after the attack and to be completed in two days. The manpower requirements with the firehose crews working two 8-hour days, and the earth-moving equipment operators two 10-hour days, are given in Table 13. The resulting dose to the crews would be within the 30 r per day dose limit. The total number of men required assumes that the crews that had

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worked on the vital facilities and staging areas are used also for the
congregate facilities. Since the debris clearance work may have used up
the allowable dose for most of the experienced equipment operators, addi-
tional equipment operators from outside the area may be required. Alter-
natively, debris clearance and decontamination work might have to be
delayed a few more days, or the amount of debris clearance and decontamina-
tion might be reduced.

Decontamination of Residential Areas

Occupancy Time--As discussed in Chapter II, it should generally be
possible to avoid the use of housing in areas with standard intensitites
over 4000 r/hr in the early postattack period. However, the use of housing
in the 2000 to 4000 r/hr standard intensity range will often be necessary.
Housing in this dose rate range could not be occupied for several weeks
without excessive doses, unless decontaminated. However decontamination
of residential areas, which consist mainly of single family homes, requires
a large effort. The effort required for decontamination of the streets,
other paved areas, and roofs is moderate; the main problem is the decon-
tamination of the yards. Partial decontamination limited to the streets,
other paved areas, roofs, and the yard areas immediately adjacent to the
houses can be performed with a feasible level of effort. The reduction
in dose rates would be sufficient to permit substantially earlier occu-
pancy and to reduce post-shelter doses.

With a standard intensity of 4000 r/hr and housing with a PF of two,
occupany would be delayed for five weeks to limit the dose to an ERD of
200 r in one month, even with no shelter dose. This delay would be ex-
tended to six or seven weeks with allowance for shelter doses of 100 to
200 r ERD. With a 100 r ERD shelter dose, occupancy of housing in four
weeks would be limited to areas with standard intensities under 2700 r/hr.
In addition to the shelter dose, allowance should be made for uncertain-
ties in the shelter dose, and for outside exposure at higher dose rates.

The alternative to decontamination of residential areas is to remain
longer in shelter. This alternative will require additional effort to
supply the sheltered population with food and water over a period of
several weeks. The degree of crowding in the shelters could be reduced
by utilizing congregate facilities to the extent available.

Earlier occupancy of houses with basements could be obtained by
spending most of the time in the basement, though that would limit the
number of people that could be accommodated. Occupancy of residential
areas before a reduction in dose rates to levels permitting normal

Manpower

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occupancy would also increase the logistical problems of supplying provisions.

Weathering may reduce the dose rates to some extent, thus permitting somewhat earlier occupancy than that discussed above.

Size of Area--The amount of surviving housing within the urbanized area was 38,000 housing units (Table 8). Some of the housing might not be used because of lack of utilities, excessive dose rates, or debris that would prevent decontamination. For this exposition it is assumed that all of the surviving housing is to be decontaminated.

Most of the housing in the United States is in single-unit structures. The surviving housing would be mostly in the suburbs where there are fewer large apartments than in the central cities. In 1960 only six percent of the housing units in the SMSAs outside the central cities were in structures with five or more units, and 85 percent were single-unit structures.[41] The proportion of housing in structures with two or more units has increased somewhat; for example, in the Detroit suburbs from 10 percent in 1960 to 17 percent in 1970, and in the Chicago suburbs from 20 percent in 1960 to 27 percent in 1970.[42] With the large predominance of single-unit housing, the 38,000 housing units are assumed, for simplicity, to be all single-unit houses.

Street widths are taken to be 50 feet; an average frontage of 60 feet per house is assumed, as shown in Table 14. Thus with houses on both sides of the street there would be 1,500 sq ft of street per house, or a total of 57 million sq ft of street area.

Decontamination of Streets--The length of time required for decontaminating the streets depends on the number of street sweepers and street flushers available. Detroit, with a population of 1.7 million, has 36 sweepers and 16 flushers.[38] On a comparable basis the urbanized area with a population of 870,000 would have about 18 sweepers and 8 flushers. As in the debris clearance section, 50 percent survival of the equipment is assumed, since the equipment is less vulnerable than the population. There would then be 9 sweepers and 4 flushers.

The rate of coverage is 167,000 sq ft/hr for the flushers and 66,000 sq ft/hr for the sweepers.[39] Allowing for support time,[37] the effective rate of coverage is reduced to 83,000 sq ft/hr and 48,800 sq ft/hr respectively. With the 9 sweepers and 4 flushers the 57 million sq ft of streets could be decontaminated in 7 days (6.2 days, to be precise), working 12 hours per day (Table 14).

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Table 14

PARTIAL* DECONTAMINATION OF RESIDENTIAL AREAS

Residential Area
  Number of houses: 38,000
  Width of streets: 50 ft
  Frontage per house: 60 ft

Decontamination of Streets
  Equipment
    Street flushers: 4
    Street sweepers: 9
  Length of time: 7 days
  Man-hours: 966
  Men: 22

Decontamination of Roofs
  Firehose team: 2 nozzles and 7 men
  Rate: 10 houses per hour
  Length of time: 7 days
  Men: 476

Vicinity of Houses
  Effort: 12 man-hours per house (by occupants)

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* Paved areas, roofs, and yard areas immediately
  adjacent to houses only.

The dose rate at the time of decontamination will not be high, since there will be no need to decontaminate the residential areas before the dose rate declines to levels that will permit occupancy with the limited degree of decontamination. As discussed later, the partial decontamination could reduce the dose rate by a factor of about three. With a PF of two for the houses, the total reduction factor would be about six. (It is recognized that the PF of the house may be somewhat altered after the decontamination, but this effect is not considered significant for purposes of this discussion.) Occupancy, and hence decontamination, should be delayed until the dose rate declines to about 2 r/hr so as to limit the dose to 35 r in the first week of occupancy. This assumes a standard intensity of 2000 r/hr, in which case occupancy could begin two

weeks after the attack. If we assume higher standard intensities, occupancy will be further delayed; furthermore, the dose rate will decline more slowly, and the allowable intensity will have to be somewhat less than 2 r/hr to limit the occupancy dose to the same 35 r as before.

The dose rate to the flusher operators will be decreased by about two-thirds, mainly because of attenuation by the vehicle, while the dose to the sweeper operators is increased by about 20 percent because of the accumulation of fallout particles in the hopper.[37] At the 2 r/hr rate the dose rate to the flusher operators would only be about 0.66 r/hr, while the dose rate to the sweeper operators would be 2.4 r/hr. Hence only one shift of flusher operators (four men) would be needed, while two shifts of sweeper operators (18 men) might be desirable, or a total of 22 men (Table 14).

If there is insufficient water available for the street flushers, the manpower and time required would be increased because of the slower rate of the sweepers and the higher operator dose. If water and more street flushers are available the manpower and time required would be reduced. In any case, the manpower required to decontaminate the streets is very low.

Decontamination of Roofs--Most houses have sloped, shingle roofs, and the calculations here are based on that roof type. Decontamination of flat tar and gravel roofs would require greater effort.

The procedure is to lob a stream of water onto the roof with a firehose from the ground. A typical team might consist of seven men with two nozzles. Possibly pumpers might be needed where water pressure is inadequate. The rate of coverage is 15,500 sq ft per nozzle per hour at mass loadings of 100 grams per sq ft,[39] or about 20 houses per hour for the team. Allowing one hour setup time for each block of 20 houses gives an effective rate of 10 houses per hour for the seven-man team. The total effort for the 38,000 houses is then 26,600 man-hours.

Since the streets would be cleaned first, and the firehose teams would be working in or near the street, the dose rate would be cut nearly in half. Thus with a 2 r/hr dose rate their dose for an eight-hour day would be only 8 r. Hence the same crews could work for an extended period. Completion in seven days would require 476 men (Table 14). The amount of surviving firehose equipment is likely to be marginally sufficient for that level of effort. However, water will have to be available from the fire hydrants, since otherwise there will not likely be enough pumpers.

Decontamination Around Houses--Although decontamination of the yards will involve a large effort, decontamination of the paved areas--walks and driveways--and the yard areas immediately adjacent to the houses will require only a moderate effort and can reduce dose rates appreciable. That work can be done by the occupants when they move in. The paved areas can be cleaned by vacuuming (if electricity is available and weather permits), sweeping, or hosing with a garden hose. A typical house might have about 1,000 sq ft of paved area; that area can be swept in about a half hour.[39]

The lawn and earth areas immediately adjacent to the house can be decontaminated by hand spading a two to three inch layer into a wheelbarrow and, perhaps, dumping the spoil in the back yard away from the house. The rate of coverage is six man-hours or less per 1,000 sq ft.[39] Assuming decontamination to a distance of ten feet surrounding the house, the area for a typical house might be about 1,900 sq ft. The work then requires about 11.5 man-hours. Including sweeping the paved areas, the total effort is then 12 man-hours.

Decontamination Effectiveness--The effectiveness of the partial decontamination of the residental areas depends primarily on the contributions to the dose rate within the houses from the remaining yard areas not decontaminated. The contribution from the residual fraction on the decontaminated surfaces is relatively minor. The streets, other paved areas, and roofs contribute about half of the total dose rate within the houses. Thus, decontamination of those surfaces would reduce the dose rate by about half.[43] Some of the roof contribution would be transferred to the ground because of the redeposition on the ground of fallout particles washed off the roof. However, the decontamination of the yard area immediately around the house would remove most of that, as well as removing a sizable fraction of the total contribution from the yard area. The combined effect is estimated to reduce the dose rate within the houses by a factor of three. The reduction at the center of the street would be comparable.

With this dose rate reduction, occupancy of housing with a PF of 2 becomes possible within two weeks for standard intensities up to 4000 r/hr and shelter doses up to 100 r ERD, based on a 200 r ERD limit.

Alternatives--In terms of the physical effort involved it would be feasible for the occupants of the housing to decontaminate the streets and roofs themselves. The street could be swept manually with less than one hour of effort per house. The use of street cleaning equipment would

be far more efficient than manual sweeping, and should generally be possible. Conditions permitting, the roof could be garden hosed in an hour, or swept with a broom with two man-hours of effort.[39] Firehosing the roofs would not be substantially more efficient in terms of effort than the other methods. However, there would be uncertainty about getting the occupants to clean the roofs themselves, although teams might be formed from the occupants to clean the roofs of a group of houses.

Decontamination of the yards by mechanical methods would be limited by the availability of skilled equipment operators. An intermediate rate of coverage for scraping yards in confined areas with light tractors is about 2,000 sq ft per hour.[39] At 5,000 sq ft of unpaved area per house the time per house would be 2.5 hours. One loader and two dump trucks for each five tractors are assumed for loading and removing the spoil, although part of the spoil might be directly deposited at the rear of the lots. Thus eight equipment operators could decontaminate the yards of 20 houses in a ten hour day. Then 2,178 men would be required to decontaminate the 38,000 yards in seven days. Additional manual work would be required for areas the equipment could not cover.

As previously discussed in connection with debris clearance, there are not likely to be enough skilled equipment operators for this level of effort. Some reduction in the number required could be obtained by extending the work over a longer period of time, but dose limits would become limiting. Equipment might also be limiting for decontamination within seven days.

Restoration of Utility Service

Most of the urbanized area in the heavy damage case could not be used for habitation. Restoration of utility service in the early post attack time period will be desired only for the areas with surviving housing, and for various vital facilities. Most of the surviving housing will be around the fringes of the urbanized area, though there might be some scattered neighborhoods and particular large buildings of harder construction closer in that could be used.

The utility distribution systems will generally survive in areas where housing survives. The survival of transmission systems, however, will be highly variable, depending on anomalies of the particular area and the location of hits. Restoration of utility service will have to be performed primarily by utility personnel, although assistance could be provided by unskilled labor in some tasks. Thus, the applicable labor force will be quite limited. The question is not how much labor is needed for utility repairs, but rather how soon the surviving utility personnel could restore service.

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Electricity

Studies of the vulnerability of electric power systems have indicated that losses among users of electricity will reduce power demands more than the reduction in electric generating capacity.[44] Nearly half of the nation's generating capacity is located outside SMSAs.[33] A high degree of interconnections among central stations will provide some means of rerouting power, at least to the vicinity of damaged SMSAs that have lost their primary sources of electric power.

The vulnerability of the electric distribution system is comparable to that of houses. Outages from damage to distribution systems will generally be limited to areas with 2.5 psi overpressure or above,[45] which is about the overpressure for severe damage to wood-frame buildings.[20] Of course, some large buildings of harder construction will survive at higher overpressures, but the electric distribution systems serving them might be disrupted.

Substations will also remain operable--if not subjected to flying debris--at overpressures up to 4 or 5 psi, though manual operation will generally be necessary, and poles and lines would be down at overpressures above 2.5 psi. Substations are generally capable of serving at least a portion of the distribution area served by adjoining substations. Hence, there should generally be some operable substations able to serve the surviving housing.

Although the transmission systems provide alternate routings, cuts in transmission lines, resulting in isolation of some neighborhoods from electric power, can be expected. The transmission system for an urbanized area often consists of a ring around the area, plus a partial network. The ring might be broken in several places if multiple hits occur. Transmission line repairs, using wooden poles, take about 60 man-days per mile, with qualified linemen and unskilled personnel.[46] Assuming a ring of ten miles radius, and the replacement of one-fourth of it (16 miles), the repair effort would be 960 man-days. There were 54 lineman in Albuquerque[45] for a 1970 population of 316,000. In proportion there would then be 138 linemen for the urbanized area with 870,000 population. However, only about 27 would be uninjured. If half the effort could be performed by other workers, the transmission line repairs would take 18 days, unless skilled personnel could be made available from outside the area. If dose rate levels were high, the repair would be delayed for some weeks. Hence, early restoration of electric service to surviving housing will only be possible if some transmission line to the area is largely intact, or if substantial help can be provided from outside the area. Short breaks can probably be repaired by cannibalizing redundant lines or lines leading to destroyed areas. Repairs to the distribution system in the early period

will likely be limited to areas where only a few lines, transformers, and house connections are damaged. A URS report[47] indicates a repair effort of about 100,000 man-days for a distribution system for a population of 400,000, all of which was uniformly covered by 3-psi overpressure. The preattack population of surviving housing in areas with about 3-psi overpressure might be 20,000. (The remaining surviving housing would be mostly in areas with lower overpressure with little damage to the distribution system). The repair effort then would be about 5,000 man-days. Clearly this effort is too large for the limited number of skilled personnel to be able to restore service in the shelter emergence period. However, restoration of distribution lines to particular vital facilities or large buildings suitable for housing might be feasible even where the distribution system is largely destroyed.

Gas

The gas transmission and distribution systems are less vulnerable than those for electricity because of the underground location. The connections at the houses are more vulnerable than the lines, but usually the houses will be severely damaged at overpressures that damage the house connections. The above ground facilities, such as border stations, river crossings, and regulating stations are also more vulnerable than the lines. However, the numerous district regulators are expected to be undamaged at overpressures up to 2.5 psi.[48] Thus the gas system will generally be intact in the areas where the housing survives. Service to some surviving large facilities may be interrupted because of the need to shut off the gas to the damaged area in which they are located to prevent escape of gas through breaks. The transmission system might be disrupted in some cases, depending on the location of hits, thus preventing service to surviving neighborhoods.

A URS report[47] estimates that the repair effort for the city gate stations, district regulators, peak shave plants, and the compressor station for a typical city of 400,000 population begins at 1 psi (uniformly over the city), reaches 100 man-days at 3 psi, and approaches a maximum of 200 man-days. Of course, in a realistic case only a small fraction of those facilities would require repair, since many would be destroyed, and others serving severely damaged areas would not be needed.

Water

The water distribution system within the areas with surviving housing will be generally intact. However, loss of pumping stations, electric power, and main pipelines will often disrupt service to surviving neighborhoods. The repair effort generally requires skills and system knowledge, so the availability of experienced personnel will be limiting. The uniqueness of water supply systems, and the variations in hit locations make it difficult to generalize on water system repair effort. Repairs for the early time period are likely to be limited to activities such as shutting off and turning on valves, restarting pumps, and restoring electric service to key elements, rather than. say, major reconstruction of treatment plants or replacement of main pipeline segments. Resumption of water service to some of the surviving neighborhoods in some of the heavily damaged cities should be possible for the shelter emergency period, but in other cases it may not be feasible for a long time. In such cases, it might be better to move people to other areas rather than to occupy the housing without water service.

ESI indicated a capability for restoring at least minimal water production capacities within several weeks after an attack with a 5-MT weapon on Detroit.[38]

Boarding Windows

Virtually all windows within the urbanized area will be broken. In cold weather the windows will have to be covered to permit occupany of the surviving housing. Some material (boards, cardboard, wooden fences) could be found around the houses to cover the windows. However, additional material will often be necessary. Wholesale and retail lumber stocks have averaged about 100 board feet per household.[49] The survival rate of the lumber stocks within the SMSAs will depend mostly on the extent of fire. However, because of generally outlying locations, and lesser vulnerability to blast, the lumber stock survival should be somewhat greater than that of housing. A typical house might require 300 sq ft of lumber to cover the windows. Thus, lumber stocks within the area can provide a sizable fraction of the material needed, However, there will be other important uses for the lumber stocks.

Lumber, nails, and other material from building debris will be another major resource for covering windows. The 38,000 surviving houses (Table 4) will require about 12 million sq ft of lumber for the windows, if all of the houses are to be utilized. Two men with a truck might be able to pick up, from building debris, and deliver to the surviving neighborhoods, three loads of lumber per day with 3,000 sq ft per load,

though the estimate may be optimistic. Then 4,000 truck loads would be required. As discussed in the decontamination section, dose rates (before decontamination) would have to be down to about 2 r/hr to permit occupancy of the housing. Assuming similar levels in the debris areas where the lumber is obtained, the average dose rate to the men will be about 1.3 r/hr, allowing for truck shielding in transit and decontamination of streets and roofs in the areas with surviving housing where the lumber is delivered. With a nine-hour day (three loads per day, three hours per load), the dose for eight days will be less than 100 r. Approximately 330 men and 165 trucks will then be required.

A rate of three man-hours per 100 sq ft of window is used for calculating the effort for boarding up the windows. This rate is based on the rough carpentry labor time for applying lumber siding or wall sheathing.[50] At this rate, each man can complete one house in a nine-hour day, and 38,000 man-days will be required. The dose rate after decontamination of streets and roofs will be about 1 r/hr. Each man can then work 11 days, with a 100 r dose limit. Then 3,450 men will be required for boarding up the windows of the houses.

Windows in vital facilities, staging areas, and congregate facilities will also have to be boarded up. The window area in the power plant, water station, four staging areas, and other congregate facilities is estimated to be 220,000 sq ft., compared with the 12 million sq ft of window area of the houses. Thus, 74 truckloads of lumber will be needed; boarding up the windows will take 6,600 man-hours.

The use of these buildings will be more urgent than the use of the houses. For consistency with the schedule in the decontamination section, the work on boarding up the windows is considered to be done in four days, beginning six days after the attack. With a 4000 r/hr standard intensity, the dose rate would be about 8 r/hr. The crews collecting lumber from the debris will spend 2/3 of their time loading lumber, with no shielding or decontamination, and the rest of time in the truck or a decontaminated area. Their dose rate will average 6 r/hr. Thus they will be limited to about five or six trips, to limit the dose to about 100 r. Hence, 14 crews, or 28 men, will be required, but only seven trucks.

The work on boarding up the windows will be performed after decontamination. Hence, dose rates will not be limiting. With a ten-hour day for four days, 165 men would be required. The effort and manpower requirements for boarding up windows are summarized in Table 15.

Employed carpenters in 1969 numbered 1.2 million,[51] or about 0.6 percent of the population. In proportion to the 168,000 uninjured survivors

Table 15

EFFORT FOR BOARDING WINDOWS

	Vital Facilities, Staging Areas, and Congregate Housing	Houses	Total
Man-hours			
Collecting lumber	400	23,800	24,200
Boarding windows	6,600	342,000	348,600
Total	7,000	365,800	372,800
Number of Men			
Collecting lumber	28	330	358
Boarding windows	165	3,450	3,615
Total	193	3,780	3,973

(Table 4) there would be approximately 1,000 carpenters. Hence additional unskilled help would be required. However, almost anyone could board windows.

Other Tasks

A wide variety of tasks can be conceived for the initial postattack period. However, rather than developing a comprehensive list of every conceivable task, this study has concentrated on what are believed to be the most fundamental and basic tasks for meeting the immediate survival needs. The following discusses in less detail some other tasks of perhaps lesser significance.

Burial of the Dead

Burial of the dead is commonly included in lists of postattack tasks. However, the importance of this task is doubtful, since the corpses are not expected to pose a serious threat to environmental health.[52] The dead in the heavily damaged urbanized area outnumber the living. There are 355,000 ultimate survivors (Table 4) out of a preattack population of 870,000 for the urbanized area. The uninjured with less than 200 r

ERD number only 152,700 (Table 4), compared with the 415,000 deaths. However, a large proportion of the dead will not require burial, since many of the bodies will be eliminated in the blast, cremated by fire, or buried in rubble. Of the 338,000 deaths the first day (Table 4), about 270,000 will be in areas that had over 15 psi overpressure. Only a small proportion of those deaths will result in recoverable corpses, and since this area will be abandoned as soon as the survivors can leave shelter, there will be little need to bury the corpses.

A potential problem might arise in areas with a smaller proportion of deaths, where families might be reluctant to abandon the corpse of a member without burial.

Fallout fatalities will create a corpse disposal problem in areas sufficiently undamaged to be usable. About 80,000 additional deaths after the first day will occur within the first week, and about 55,000 of them will be caused by fallout. Most of the fallout fatalities will be people at home rather than in public shelters. Where the houses are too damaged for use, removal of the corpses will not be necessary. However, some of the surviving housing will have corpses from fallout fatalities, which would have to be removed to permit occupancy. The surviving housing had a preattack population of 125,000. Assuming that about half of those people went to public shelter, the potential number of corpses, if fallout levels were high and the houses had no basements, could be as high as 62,000.

Salvage of Supplies

The salvage of food stocks to extend shelter rations has already been discussed. The homeless survivors moving into congregate housing or billeting in homes may be without some essential supplies. In cold weather, blankets, in particular, will be needed. In congregate housing facilities, eating and cooking utensils may also be needed. The resources of such supplies in surrounding undamaged communities may be needed for the influx of survivors from damaged areas. Thus, the homeless survivors remaining in the damaged urbanized area may be dependent on the resources within the area for such supplies.

The supply of blankets in retail stores is negligible--only three per 1,000 population.[53] A survey in western states indicated ten blankets (including quilts and comforters) as the median number stored in a household at any time of year, in addition to those in use.[54] The comparable number in southern states was 13 to 20.[55] Of course, in cold weather many of the stored blankets would be in use and the number of extra blankets would be much smaller.

The number of homeless survivors remaining in the urbanized area is 150,000, with 50,000 of them in congregate facilities and 100,000 in homes (Table 5). If those in congregate facilities need two blankets each, and those in homes one blanket (in addition to the extra blankets available in the homes), the number of blankets needed would be 200,000. If an average of ten blankets can be obtained from the wreckage of each house, then blankets from 20,000 houses would be needed. The number of houses in areas subjected to 2 to 5 psi overpressure is 28,000. Blankets and other supplies might be salvageable from many of those houses, depending on the extent of fire.

Allowing 1/2 man-hour per house for salvaging blankets, the total effort would be 10,000 man-hours. In the decontamination section, occupation of the congregate housing was considered to begin seven days after the attack, for a standard intensity of 4000 r/hr. The dose rate would then be about 8 r/hr. A 30 r dose limit for the salvage crews is assumed on the basis that a higher dose would not be warranted for that work. Then each man could work approximately 4 hours, and 1,250 men would be required to salvage 100,000 blankets for the congregate housing.

As discussed in the decontamination section, occupancy of the residential areas will be delayed until dose rates before decontamination are below 2 r/hr. Then each man could work 15 hours and 33 men would be required to salvage 100,000 blankets for the residential housing.

Effect of Weather

Weather conditions may affect the urgency of shelter emergence, what tasks need to be done, and the effort required for the tasks. Heavy snow would adversely affect the ability to clear access routes through the debris, as well as requiring snow removal beyond the debris area. As discussed in the debris clearance section, clearance of at least one lane through all the streets in the debris area (2-15 psi) appears feasible. However, at high dose rate levels the number of skilled equipment operators would be only marginally adequate. The addition of snow might limit the number of streets that could be cleared. However, it should still be possible to clear routes on the arterials and to major shelters. The survivors would then generally be within 1/4 mile walking distance of an access route.

Snow or cold would also increase the effort required for decontamination. Decontamination of vital facilities, staging areas, and large buildings for congregate housing should still be feasible. However, the

large-scale decontamination of residential areas of predominantly single-family houses might not then be feasible, and shelter stay times would have to be increased.

Cold weather would also prevent use of buildings without heat, or without windows until the windows could be boarded up. Most of the shelter space in the heavily damaged urbanized area would of course be without heat; the windows would be broken, and even the walls would often be demolished. However, in close-packed shelters, particularly in basements where there would be fewer openings, body-heat would generally provide sufficient warmth for survival. Thus crowded shelter conditions might have to be maintained just for the warmth, until windows could be boarded up and heating restored.

Hot weather would increase the urgency of shelter emergence, since the shelters would become overheated. However, the crowding that contributes so much to the overheating could be reduced by expanding to space with lower PFs, such as the upper floors of large buildings. In hot weather the broken windows wouldn't matter, and the task of boarding up windows could be deferred.

IV POSTATTACK TASKS IN A LIGHTLY DAMAGED SMSA

Damage Level

The preceding chapters have dealt with the situation of a large SMSA directly attacked and heavily damaged, with the heart of the city largely destroyed and surviving structures limited to the fringes of the urbanized area. Another possible situation of interest is the case of an attack on a target outside or on the fringe of the urbanized area.

The weapon on Moffett Field near San Jose for the Five-City study is a typical example of such an attack. The attack on Moffett Field was a 5-MT weapon with a 14 500-ft height of burst.[56] The detonation point was approximately 12 miles from the center of San Jose.

The same typical SMSA used for the severe damage case is assumed, with a population of one million; attention is confined to the 870,000 people in the urbanized area. The attack is a 5-MT airburst 12 miles from the center--the same as for the San Jose case. Although the population of the delimited San Jose study area was less than the 870,000 assumed here for the typical urbanized area, the areal extent is comparable because of the lower than average density of San Jose.

The case with heavy fallout is assumed. Heavy fallout is not inconsistent with an air burst, since, generally, much of the fallout in a local area is from weapons well beyond the direct effects radius.

A "low fire" situation is also assumed. As previously discussed, some fire models would estimate almost complete burnout of the contiguously built-up area. However, in that case the number of survivors would be greatly reduced because of the fallout fatalities to those forced to leave shelter.

Direct effects casualties are based on the San Jose results. The fatality rate for San Jose was about 5 percent, and the injury rate approximately 30 percent.[57] The fatality rate from fallout was assumed to be 25 percent, the same as was assumed for the severe damage case. Other assumptions regarding times to death are also the same as those used for the severe damage case. The resulting condition of the survivors and the number surviving seven days after the attack are given

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in Table 16. The 2-psi line passes near the center of the city, and about 38 percent of the urbanized area receives an overpressure of more than 2 psi.

Table 16

CONDITION OF SURVIVORS IN A LIGHTLY DAMAGED
URBANIZED AREA

	Thousands of People
Surviving after seven days	
Mortally injured	18
Lethally irradiated	93
Other injured-	186
Fallout sick	103
Uninjured and not sick	331
Subtotal	731
Dying in first week	
Direct fatalities	25
Fallout fatalities	114
Subtotal	139
Preattack population	870

The major operational difference in the postattack situation for the peripheral burst case, as compared to that for the severe damage case, is the large number of surviving buildings. They permit housing the survivors within the urbanized area, rather than evacuating them to other communities, and they also provide enough space for congregate housing.

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Debris Clearance

The rationale for debris clearance is the same as that for the severe damage case--namely, to provide vehicular access to the survivors in the damaged areas in order to supply them with food and water, or to move them to the surviving housing. The total area requiring debris clearance (82 sq mi that had over 2 psi overpressure) is only slightly less than the 109 sq mi for the severe damage case, since much of the area in the severe damage case received over 15 psi, and it was assumed that the debris would not be cleared in areas with over 15 psi. However, the volume of debris is much less, since the distribution of overpressures is much lower, and the highest overpressures occur on the fringes of the urbanized area where building densities are low.

Debris volume was estimated by taking debris depth as a function of the overpressure and the distance from the center of the city, in the same way as for the severe damage case. It was assumed that two lanes would be cleared on principal arterials, and one lane on all the remaining streets within the 2-psi contour. The following tabulation summarizes the debris clearance effort:

Street miles	1,240
Lane miles	1,364
Debris volume (cu yds)	576,400
Equipment-hours	1,000
Men	74

The indicated effort (1,000 equipment-hours) is intermediate between that calculated on the basis of 200 cu yds per hour (2,882 equipment-hours) and that calculated on the basis of 20 lane-miles per day (682 equipment-hours). The 1,000 equipment-hours is half that estimated for the severe damage case. The number of men required is then 74 (half the 148 men calculated for the severe damage case). The manpower requirement is based on a standard intensity of 4000 r/hr, the work performed in three days, beginning on the fifth day after the attack, and a 30 r daily dose limit, which with allowance for travel time permits 13.5 hours of work.

Water and Food

The effort for water delivery before shelter emergence is calculated on the assumptions that half of the shelters will need water, and people at home in areas that had over 4 psi overpressure will also need water. Trapped water is assumed to be available in the houses receiving less than 4 psi. The following tabulation summarizes the number of people for whom water is needed:

Survivors at five days	
Public shelter	425,000
Homes	335,000
Number needing water	
Public shelter	212,000
Homes	70,000

Half of the people were assumed to be at home and half in public shelters. However, the fallout fatalities would be almost entirely among the people at home, so the survivors at home are reduced disproportionately. If the trapped water is lost in all houses at 1 to 2 psi, the number of people to be supplied with water at home would be 2 to 4 times as great.

For the severe damage case, water was required for 120,000 people in public shelter, and for 120,000 in homes. In proportion, the effort and the number of men required for the peripheral burst case is:

	Man-hours	Number of Men	Number of Tank Trucks
Public shelter	1,635	120	14
Homes	635	40	5
Total	2,270	160	19

As previously discussed, the figures are for delivery of one quart of water per person per day for an eight-day period beginning on the fifth day after the attack.

The effort for salvaging food from grocery stores and delivering it to the shelters was estimated to require 1,000 men per day to supply 120,000 people in shelter, in the severe damage case. Then for the 212,000 (half the people in public shelter) in the peripheral burst

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case, 1,770 men would be required each day. At a total of 25 hours per man over an eight-day period, the total effort would be 44,250 man-hours.

Relocation of Homeless Survivors

In contrast to the severe damage case, a large amount of housing survives within the urbanized area. In addition, a major proportion of large buildings (office buildings, department stores, and the like) also survive. Thus, the survivors can be housed within the area. Also, the availability of large buildings provides ample accommodations for congregate housing, which requires much smaller decontamination effort than would be necessary for decontaminating residential neighborhoods.

About 62 percent of the housing survives, based on a 2-psi damage criterion. The following tabulation shows the housing status of the survivors seven days after the attack:

	Thousands of People		
		Not	
Location	Homeless	Homeless	Total
In public shelter	161	262	423
At home	118	191	309
Total	278	453	731

(The people at home who are homeless are those who have survived in the ruins of their homes or in shelters in their yards.)

Table 17 is a representative allocation of the people at home or in public shelter to their homes or to congregate housing within the area. The allocation assumes that all the survivors remain within the urbanized area and that no additional refugees are brought in for housing. Also, most of the people, even those with homes, are assigned to congregate housing to avoid the need for decontaminating residential areas. Only limited numbers of people go home, or stay home; they are the people whose basements afford adequate shielding. Many of the people at home whose homes survived will be dying from fallout radiation, or sick or injured; they will be assigned to congregate housing. It is assumed that just one-third of those whose homes survived go home or stay at home. Many of the shelter buildings would serve as congregate housing, so some of the people in public shelter will not have to move.

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Table 17

HOUSING ALLOCATION
(Thousands of People)

From	Congregate Housing within Shelter Bldg	Other Congregate Housing	Home	Total
Public shelter	112	224	87	423
Homes	--	242	67	309
Total	112	466	154	731

A major proportion of the cars in the area will remain operable, and hence many people could drive themselves to the congregate housing. The others can be moved by bus, and in some cases distances will be short enough for walking. Traffic congestion and the parking problem will have prevented many people from driving to the shelters, and hence their cars will not be nearby. One-third of the people from the shelters are assumed to go by car to the congregate housing, and the rest by bus. The people at home whose homes survived will have a higher availability of operable cars, though sickness will prevent driving in some cases. Two-thirds of those going to congregate housing are assumed to go by car. The people at home whose homes did not survive will have a lower availability of operable cars and a higher disability rate. One-third of them are assumed to go to congregate housing by car. The number of people going to congregate housing by car or by bus is:

From	Thousands of People	
	By Car	By Bus
Public shelter	75	149
Homes	122	120
Total	197	269

-The following tabulation summarizes the effort required for transporting the people to the congregate housing by bus.

	From Shelters	From Homes	Total
Bus trips per day	10	8	--
Passengers per bus	45	35	--
Bus-days	330	430	770
Number of buses	110	144	254
Number of men	220	1,440	1,660

Picking up people from homes will be slower than from the shelters because of more stops and a higher disability rate of the passengers, and fewer trips can be made per day. The number of passengers per trip will also be lower because of the higher disability rate, since some of the sick or injured might have to lie down. Also a four-man stretcher crew is assumed to be assigned to each bus picking up people from homes. The relocation is assumed to take three days, beginning on the seventh day after the attack. Two shifts of men per day are used to limit the dose. At seven hours per day for each man the total effort would be approximately 35,000 man-hours.

Decontamination

A much larger number of buildings survives the attack in the peripheral burst case than in the severe damage case, leaving a much larger potential area for decontamination. However, as previously mentioned, the availability of large buildings for congregate housing obviates the need to decontaminate residential areas that require too much effort for decontamination.

Vital Facilities and Staging Areas

The vital facilities identified for decontamination include an electric generating station, a water treatment plant, and ten electric substations. The effort required for decontamination is then the same as that shown in Table 12 for the severe damage case, except for the increase from three to ten electric substations. As before, the vital

facilities and staging area are assumed to be decontaminated five days after the attack, in a single day, and the standard intensity is 4000 r/hr.

As previously discussed, a typical number of staging areas for the urbanized area of 870,000 population is about 17. For the peripheral burst case about two-thirds of the area was outside the 2-psi contour. It is assumed here that damage and debris rule out decontamination of most of the staging areas within the 2-psi area, leaving about 12 staging areas to be decontaminated. The decontamination effort is then three times that required for the four staging areas in the severe damage case (Table 12). The resulting man-hours of effort and the number of men required are given in Table 18.

Table 18

DECONTAMINATION OF VITAL FACILITIES AND STAGING AREAS

	Roofs and Paved Areas	Earth and Lawn Areas	Total
Effort (man-hours)			
Vital facilities	232	345	577
Staging areas	2,490	600	3,090
Total	2,722	945	3,667
Number of men	606	135	741

Congregate Housing

As discussed in the housing section, the number of people to be accommodated in congregate housing is 578,000. The staging areas accommodate 54,000 (three times the 18,000 in the severe damage case, Table 12), leaving 524,000 additional accommodations required. Half of the additional accommodations are assumed to be in large buildings such as office buildings and department stores, generally in downtown or commercial areas, and often close together, where the surroundings are mostly paved. The other half of the congregate housing is assumed to be provided

by schools or similar isolated buildings where much of the surrounding area is lawn or earth.

The large office building and store category is assumed to have an average of 2-1/2 stories. The space per person is taken to be 40 sq ft, and 60 percent of the floor space is assumed to be usable. The surrounding paved area to be decontaminated is estimated to be twice the roof area. Total area to be decontaminated is then 7 million sq ft of roof and 14 million sq ft of paved area.

As previously discussed the typical school or other equivalent building was assumed to accommodate 1,000 persons, and hence 262 such buildings are required. Typical areas were 50,000 sq ft of roof, 50,000 sq ft of paved area, and 200,000 sq ft of lawn and earth areas to be decontaminated.

The time required for decontaminating the paved areas depends on the availability of street sweeping and flushing equipment. As previously discussed, typical numbers of sweepers and flushers for that size of area are 18 and 8 respectively. Assuming 80 percent survival, there would be about 14 sweepers and 6 flushers. Their combined rate of coverage would be 1,183,000 sq ft/hr, based on effective coverage rates of 48,000 sq ft/hr and 83,000 sq ft/hr for sweepers and flushers respectively. The 14 million sq ft of paved area for the large building and store category would then take 12 hours.

For the isolated schools, travel time between buildings takes up some time. Times for each school (50,000 sq ft) of 1.5 hours for sweepers, and one hour for flushers are estimated. The time required for the 262 schools or equivalent buildings is then 17 hours.

The total time required to decontaminate the congregate housing is summarized in Table 19. The effort for the roofs and earth and lawn areas is based on the previously discussed coverage rates. As before, the number of men required is based on a standard intensity of 4000 r/hr and a dose limit of 30 r per day, which limits sweeper operators to three hours per day. With the different reduction factors (previously discussed), eight hours per day is allowed for firehosing roofs, and ten hours per day for flusher and earth moving equipment operators.

Table 19

DECONTAMINATION OF CONGREGATE HOUSING

	Paved Areas	Roofs	Earth and Lawn Areas	Total
Effort (man-hours)				
Office buildings and large stores	240	4,690	--	4,930
Schools	340	8,750	13,100	22,190
Total	480	13,440	13,100	27,120
Number of men	53	661	437	1,151

The number of equipment operators required for the earth and lawn areas may exceed the number of skilled operators available. The number of earth moving equipment operators for the different operations were:

Debris clearance	74
Decontamination of vital facilities and staging areas	135
Decontamination of congregate housing	437
Total number of operators	646

This total exceeds the estimated 600 skilled operators in the area. In proportion to population casualties (Table 16), there would be only 230 equipment operators uninjured and not sick. Hence additional earth moving equipment operators from outside the area might be required. Alternatively it might be possible to select other buildings for congregate housing that have less lawn and earth areas requiring decontamination, limit decontamination to a smaller area around the buildings, or delay occupancy of the congregate housing.

Residential Areas

- Although enough large buildings for congregate housing will be available, the decontamination of residential areas might be desirable anyway, to shorten the time spent in congregate housing or even as a substitute for congregate housing, although in the latter case shelter stay times would be increased.

The amount of surviving housing is about four times as great as in the severe damage case. Allowing for the higher survival rate of street sweepers (14) and flushers (6) the time required for decontaminating the the streets is 16 days, with 12-hour days for the equipment.

As previously discussed, the dose rate would have to be under 2 r/hr to permit occupancy of houses. As before, a 100 r dose limit is assumed, and reduction factors of 1.2, 0.3, and 0.5 are assumed for the street sweepers, flushers, and firehosing roofs, respectively. Then five oper-ators are required for each sweeper and two for each flusher. The effort for firehosing roofs is four times the 26,600 man-hours required in the severe damage case, and work time is limited to 100 hours, say two six-hour shifts for 16 days. The effort and men required are summarized in the following tabulation:

	Man-hours	Men
Streets	385	82
Roofs	106,400	1,110

The effort for decontamination of the yard areas adjacent to the houses (within ten feet) was previously given as 12 man-hours per house. For the 158,000 surviving housing units the total effort is then approxi-mately 1.9 million man-hours.

Boarding Windows

Even in the peripheral burst case, most of the windows would be broken throughout the urbanized area. The buildings for which boarding the windows would be necessary include the vital facilities, staging areas, and congregate housing.

The window areas of the power plant, the water station, and 12 staging areas were estimated to be 270,000 sq ft. The window area for

the congregate housing was calculated on the basis of 7.5-percent of the floor area. Then, allowing 50 sq ft per person (before deduction of nonusable space) the window area is 3.75 sq ft per person. For the 524,000 persons to be accommodated in congregate housing (excluding the 54,000 already covered in the staging areas) the window area is 1.96 million sq ft. The total window area is then 2.23 million sq ft.

Again, it is presumed that much of the material for boarding the windows is salvaged from destroyed buildings. In the severe damage case it was estimated that 4,000 truckloads of material would be required for the 12 million sq ft of windows in the surviving housing. In proportion to those figures, 745 truckloads would then be required for the 2.23 million sq ft of windows.

Effort was calculated on the basis of three hours per truckload with a two-man crew. The work is considered to be done over a four-day period beginning six days after the attack. As before, average dose, with a 4000 r/hr standard intensity, was estimated to average 6 r/hr. Hence the crews would be limited to five or six trips, and 264 men would be required.

The effort for boarding windows was calculated on the basis of three man-hours per 100 sq ft of window. This work would be done in decontaminated areas so dose would not be limiting. A ten-hour work day for four days is assumed. The following tabulation summarizes the effort and men required for boarding windows:

	Man-hours	Number of Men
Collecting lumber	4,470	264
Boarding windows	66,900	1,673
Total	71,370	1,937

For this case, the people going to their homes instead of to congregate housing would be generally living in basements and without additional occupants. Thus only the windows for a small amount of living space would have to be covered. The residents are presumed to do this work themselves.

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