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WHAT THE PLANNER NEEDS TO KNOW. VOLUME I. ABOUT THE DEBRIS ENVIRONMENT. VOLUME II. ABOUT DEBRIS CLEARING OPERATIONS

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Jacobs Associates

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WHAT THE PLANNER NEEDS TO KNOW
VOL. I - ABOUT THE DEBRIS ENVIRONMENT
VOL. II - ABOUT DEBRIS CLEARING OPERATIONS

Technical Report
No. 135

Final Report
June, 1975

DCPA Work Unit 3325G
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WHAT THE PLANNER NEEDS TO KNOW

VOLUME I - ABOUT THE DEBRIS ENVIRONMENT

VOLUME II - ABOUT DEBRIS CLEARING OPERATIONS

FINAL REPORT

JUNE 1975

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Volume I describes the types, quantities and distribution of debris likely to be generated by a nuclear attack in a city. It illustrates with tables, charts and examples, the methods employed to predict the debris environment, to enable the planner to adapt such a system to any community. Volume II describes various types of equipment capable of performing debris clearing operations and methods of estimating construction equipment performance characteristics for individual units and groups in the urban debris environment.

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CONTENTS OF REPORT

DETACHABLE SUMMARY

WHAT THE PLANNER NEEDS TO KNOW

VOLUME I: ABOUT THE DEBRIS ENVIRONMENT

VOLUME II: ABOUT DEBRIS CLEARING OPERATIONS

General

To make realistic plans for clearing debris from streets after a nuclear attack, the Planner must be able to appraise the potential magnitude of the problem - type, quantity and distribution of debris - that may be anticipated or actually experienced within his community. Volume I of the report sets forth general guidelines, charts and tables by which these appraisals of the debris environment can be made. Knowing the problem, the Planner must then be able to effectively implement those debris clearing tasks crucial to emergency operations of the early post-attack period. Evaluating the requirements and capabilities of available resources and how these resources can be used to accomplish various clearing tasks is discussed in Volume II. Both volumes are presented as a series of panels which discuss and illustrate the various steps and procedures to be followed in developing and evaluating their subject matter.

Volume I:

The debris environment in an urban area following a nuclear attack will consist primarily of a random mix of construction materials, furnishings and other content from damaged or destroyed buildings within the area. Using given tables and charts, it is possible to estimate the potential type, quantity and distribution of this debris on the basis of different assumed or actual attacks. Building debris is numerically categorized; (1 through 6) with respect to its anticipated material content and difficulty of handling during clearing operations, Type '1' being the least difficult, Type '6' the most difficult.

It is likely that other objects such as downed trees, light poles, signs, overpasses and damaged vehicles will be intermixed with the building debris. Relative evaluations as to how these inclusions could increase the difficulty of completing a clearing task are made by adjusting the building debris Type to a higher number.

The urban study area is divided into districts to facilitate planning and operational procedures. These districts and the organization of debris related activities should be incorporated in the community's overall emergency plan. In order to make reasonable estimates or predictions of debris environments, the districts are divided into various 'zones' within which the building types, street configurations and other physical features are sufficiently similar so that average debris generation parameters can be used to determine potential environment throughout the zone. Large scale maps of the study area should show all districts, zones, and the location of critical facilities for which access may be required in the emergency period.

Information and data needed to estimate potential debris environments within each zone is obtained by making a Debris Prediction Survey (DPS). This survey is essentially the recordation of pertinent physical features of the zone which would contribute to or affect the generation of debris in the event of a nuclear attack. DPS input could be obtained either from actual field surveys or from Sanborn or similar maps and records pertaining to the zone.

Using the DPS information in conjunction with predetermined debris generation factors it is possible to make a reasonable appraisal of the type and average depth of debris to be expected within the streets (off-site debris) of the zone due to various attack conditions. This procedure and the use of the various charts and tables is illustrated by examples. Considering variations of debris environments within all zones as occasioned by different assumed attack conditions will enable the Planner to better understand the potential magnitude of debris problems. Although the report deals primarily with debris in streets and thoroughfares, the methodology and calculations could be expanded so as to approximate on-site debris conditions. The study considers blast and fire damage but does not include the effects of radiation or fallout which would have to be considered in overall evaluations.

A general correlation between predicted and actual debris environments can be made by use of 'Zone Situations' which are based on the degree of damage as determined from visual inspection after an attack. This degree of damage is in turn related to the various predetermined debris generation factors used in pre-attack planning.

Volume II:

Rescue and evacuation of survivors from the devastated area will be a primary aim of emergency actions following a nuclear attack. To accomplish this, it is necessary that routes be cleared through the debris to provide access to critical locations and passage through the area. The Planner must be familiar with potential types and quantities of debris which may be encountered (Vol I) and the most likely location of routes to be cleared for the needed access. With this background he is prepared to define various clearing tasks to be accomplished, determine approximate quantities of debris to be handled and assess the relative degree of difficulty in completing the tasks.

The principal types of construction equipment to be used for debris clearing are bulldozers, front-end loaders, motor-graders, shovels and dump trucks. Anticipated production rates when handling different types of debris are tabulated for various sizes and models of construction equipment. Resource requirements such as gallons of fuel per hour and operating personnel are also indicated. Hand tools, protective clothing, light plants, chain saws, cutting torches and other supplies as well as additional manual labor will probably be required for most tasks. Typical requirements for these resources are noted.

Three methods or types of debris clearing operations are considered, 1) pushing the debris aside, 2) load-and-haul, and 3) a combination of the two, each with respect to three different widths of path to be cleared. In some instances a single unit of equipment could accomplish a task, in others, as in a narrow street where debris cannot be pushed aside, it would probably be necessary to use an 'equipment group' - front-end loader and dump trucks - to effectively load and haul the debris to a disposal site. Typical groups of equipment likely to be available in a study area are identified. Their production rates and respective hourly resource requirements are given.

Inventorying procedures - personnel, equipment and supplies - are provided by which the Planner can evaluate the potential or actual availability of needed resources within his community.

Debris clearing, which is an integral part of the area's overall emergency operation plan, should be under the direction of a manager fully acquainted with the debris problems and experienced in equipment capabilities and operation.

Organization, mobilization and direction of clearing operations will be conducted through a centrally located 'Multiple Staging Area' (MSA). Mobilization should start at the first warning of an impending attack and proceed in an orderly fashion from initial contacting of personnel and suppliers to the actual gathering of needed resources at the MSA. General guidelines and procedures are given. After clearing tasks are defined, the manager can deploy the most suitable equipment and resources on a priority basis. Revisions of inventories and the supply and maintenance of actual clearing operations will then proceed.

VOLUME I

WHAT THE PLANNER NEEDS TO KNOW

ABOUT THE DEBRIS ENVIRONMENT

PREFACE TO VOLUME I

This discussion of the debris environments occasioned by a nuclear attack is intended to provide the operational planner with basic information needed to make realistic appraisals of the potential magnitude of debris problems to be anticipated within his community. It does not assume knowledge of the material presented in chapters of the DCPA Attack Environment Manual but does presume a general familiarity with blast and shock effects and fire ignition and spread. As used in this chapter, debris environment reflects the physical composition, depth and overall distribution of debris within a study area. Other environmental aspects such as fallout or fire which must be considered in overall evaluations are treated in the DCPA Attack Environment Manual.

Information is presented in the form of 'panels' each consisting of a page and an associated sketch, photograph, chart or other visual image. Each panel covers a topic. This preface is like a panel with the list of topics in Volume I shown opposite. If the graphic portion is converted to slides or vugraphs, the panels can be used in an illustrated lecture or briefing, should that be desired.

The ordering of topics begins with two introductory panels followed by eight panels which discuss potential volume, type and distribution of debris resulting from partial or complete destruction of various types of buildings. The next two panels consider other inclusions in the debris, such as trees, poles or damaged vehicles. Six panels describe procedures and input data needed to make a 'Debris Prediction Survey' (DPS) during the pre-attack planning period. How data from the DPS can be used to make estimates of the magnitude of debris problems for various assumed attack conditions is given in the subsequent panel. The next panel gives another method of determining debris environment especially in the post-attack period and the one following outlines the steps needed to estimate the problem and discusses the possibility of successfully accomplishing clearing operations. The last panel is a list of suggested additional reading.

CONTENTS OF VOLUME I

WHAT THE PLANNER NEEDS TO KNOW ABOUT THE DEBRIS ENVIRONMENT

DEBRIS CAUSED BY NUCLEAR EXPLOSIONS

Although the word 'debris' is commonly used to describe the aftermath of various catastrophic events such as fires, floods, tornados and hurricanes, it is seldom that definitive descriptions can be devised that are equally meaningful with respect to any two specific occurrences. Debris situations resulting from various degrees of damage, from partial up to and including total destruction, could be experienced, depending on the phenomenon involved and the physical configuration and composition of the devastated area. A nuclear attack could combine the worst effects of a tremendously high energy release in the form of air blast and fire ball and an urbanized target area having a high potential of debris generation. Debris caused by the initial air blast may be partially consumed or augmented as a result of subsequent fire spread through the area, consequently a distinction is made between debris due to 'blast only' and that resulting from both 'blast and fire'.

A general appraisal of the anticipated debris environment can be made on the basis of observations of previous debris generating events such as the blasts at Nagasaki and Hiroshima and results of tests conducted at the Nevada test site. Also, various theoretical analyses of the failure mode of buildings and structures under assumed attack conditions and results of shock-tunnel experiments provide information helpful in approximating both debris generation and debris environments.

Due to unlimited possibilities and combinations of different attack conditions and potential target areas it is apparent that debris environments caused by a nuclear attack would be as varied and complex as the imagination could conceive. It is also apparent that any attempt to precisely define or analyze the effect of the many factors involved would probably be an exercise in futility.

It is essential, however, that some means be provided by which the order of magnitude of potential debris problems can be estimated. Effective planning or implementation of emergency operations depends on the ability to make timely and realistic assessments of the debris problem. The following panels discuss and illustrate how these estimates and appraisals can be made. The overall intent is to provide a procedure which can be used readily, flexible enough to accommodate the many variables involved and capable of providing realistic answers. To accomplish this, it is obvious that certain compromises and generalizations must be made. This should be kept in mind when considering the various topics. These topics are directed toward considerations pertinent to debris clearing operations.


YOU CAN SAY THAT AGAIN! WHAT THE HECK CAN WE DO ABOUT IT?!
GAD! WHAT A MESS!?

PANEL 1

CONTENT OF DEBRIS

In considering problems associated with debris it is necessary to have at least a reasonable approximation of its content. Since most debris will be derived from damaged or destroyed buildings, it follows that the major elements would be various pieces, fragments, hunks or shapes of structural or other material used in the building construction plus remains of the buildings' content. It could include among other things, bricks, timber, masonry, concrete, reinforcing steel, structural steel, siding, panels, piping, appliances, fixtures and furniture. The actual size, type and mix of such material would depend on the particular buildings involved and the extent of damage incurred. Although a great variety of buildings would be affected, it is usually found that most buildings within a specific block or area can be similarly classed or grouped so that general appraisals can be made by averaging their respective physical features and usage. Debris from wood-frame residential buildings will be primarily lumber intermixed with plumbing, appliances and other household furnishings. That from reinforced concrete multistory office buildings would likely consist of large hunks of reinforced concrete , interior wall panels and office fixtures. In addition to building materials there will be other inclusions or obstacles in the debris. Overpasses or other elevated structures might collapse. Utility poles, light standards, large overhead signs, trees and other objects will probably be dispersed throughout. The above 'fixed' sources of debris can be considered and evaluated during the pre-attack planning period with respect to their potential contribution to the debris environment.

Another inclusion, which could cause serious problems consists of damaged vehicles. This more or less variable content would be dependent on actual traffic conditions at the time of the attack. During peak commuter hours, main thoroughfares are likely to be filled with cars, buses, and trucks. At midnight these same streets may be virtually empty.

The pictures show some of the different types and mix of materials which would be encountered in debris clearing operations. It is apparent that the difficulty, or time and effort, required to handle debris is to a large extent directly related to the material content of the debris. This handling difficulty, which is fundamental in defining the magnitudes of debris problems, is considered in subsequent panels which describe and identify various debris environments.

Debris from building demolition showing brick rubble intermixed with light wood.

Debris from building demolition with large hunks of masonry, a concrete column, medium wood inclusions and some steel.

7<

BUILDING TYPES AND USES

Using available records and data of the damage experienced at Hiroshima and Nagasaki along with results and findings of field tests and research, it is possible to identify seven building types with respect to their response to a nuclear blast in terms of both structural damage and potential debris generation.

Even though there have been major changes in building construction during recent years, a vast majority of the existing buildings which will most likely contribute to the debris environment could be grouped or classified within the seven structural types listed in the table opposite.

Since the content of a building also contributes to the debris environment, it is necessary to make some determination as to what that content might be. In general, a building's content can be categorized as to both type and quantity by considering the predominant usage of the building as either Residential (R), Commercial (C), or Industrial (I). The right hand columns of the table indicate common usage of the respective building types. Subsequent reference to buildings is noted by the type number and a use symbol for example Type 5-R, which would identify a multistory reinforced concrete shearwall apartment building.

The first step in estimating the potential magnitude of debris problems is to identify by type and usage the buildings within the study area. This can be accomplished in one of two ways. First, by individuals who have the knowledge or capability of identifying building types and use by visual inspection or secondly, by referring to Sanborn Maps, construction plans or other records. By comparative and simultaneous use of both, it is likely that the planner would soon be able to make fairly realistic appraisals by visual inspection. In many instances it may be found that all or most buildings in a block or area are fairly typical so that a single type and use designation could be assigned. Where a mix of buildings is involved, the planner can use his judgement in assigning an appropriate average classification.

BUILDING TYPES AND USES

Building Type	Description	Use		
		R	C	I
1	Wood Frame	X	X	
2	Load Bearing Masonry	X	X	X
3	Steel Frame - Metal or Asbestos Sheathing		X	X
4	Light Reinforced Concrete Shearwall	X	X	X
5	Multistory Reinforced Concrete Shearwall	X	X	X
6	Multistory Steel or Conc. Frame - Nonearthquake Design	X	X	X
7	Multistory Steel or Conc. Frame - Earthquake Design	X	X	X

Abbreviations

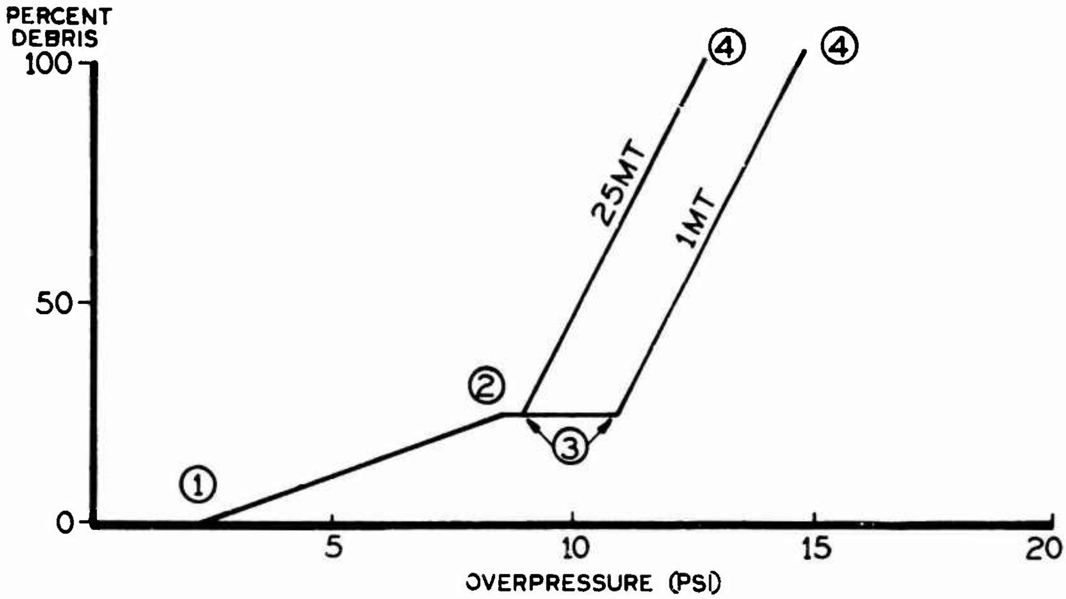
R - Residential
C - Commercial
I - Industrial

BUILDING DAMAGE - DEBRIS GENERATION

For every damaged or destroyed building there will be some debris. How much and what kind depends on the type, size and use of the building and the degree of damage sustained. Damage, which is primarily due to incident overpressure associated with the initial blast wave, can be categorized as 'light', 'moderate', or 'severe'. An overpressure which causes only moderate damage to one structure may completely destroy a less substantial one. 'Damage', used within the context of debris considerations, refers to that produced by those forces which generate debris rather than those which cause structural failure. Unless a building is completely destroyed, only those parts of the structure that fail under blast loading plus the contents of the failed portion of the building can become debris. Except for wood-frame and load-bearing masonry structures, many buildings have relatively light walls and partitions that will fail and generate debris at a much lower overpressure than the frame itself.

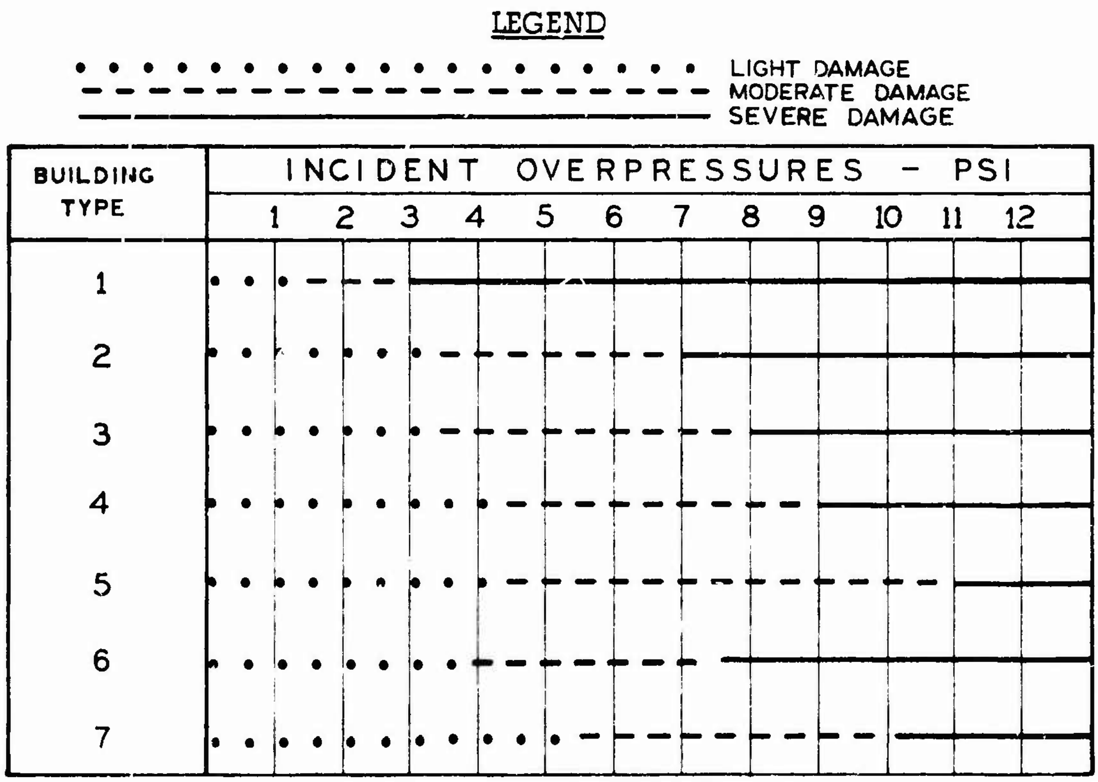
The upper sketch shows a debris chart illustrating the relationship between debris generation and overpressures. Two sizes of weapons, 1-MT and 25-MT, are used to illustrate this relationship. The lower leg, from point 1 to 2, shows a gradual increase in debris created as overpressure rises. This represents the frangible portions of the building such as wall panels and partitions. The horizontal line 2 to 3 shows a range of pressure where all 'frangible' elements have failed but the main structural frame has not. Lines 3 to 4 show the increase in debris due to the failure of the main structural system. Similar charts have been developed for other building types. They are based on a rather complicated analysis of both diffraction-sensitive and drag-sensitive structures subjected to different overpressures and are mentioned here merely to give the planner a general idea of debris generation.

The lower chart shows a general assessment of damage and debris generation. Although the distinction between light, moderate or severe damage cannot be sharply defined, the chart does provide a guide to what the debris environment might be. If the overpressure was known to be less than 2 psi it could be assumed that most buildings would have suffered only light damage and the debris problem would probably be of little consequence. It would be an entirely different situation at 8 or 10 psi. While post-attack reconnaissance would be used to determine the actual debris problem, the panel will aid the planner in understanding what difficulties he may expect to encounter and what the magnitude of the problem may be. They will also prepare him to recognize what he must deal with when he sees the actual debris or receives descriptions of it.



DEBRIS CHART FOR MULTISTORY STEEL OR
R.C. FRAMED BUILDING WITH LIGHT EXTERIOR PANELS

DEGREE OF DEBRIS - GENERATING DAMAGE



POTENTIAL QUANTITY OF DEBRIS FROM BUILDINGS

The quantity of debris which would be generated by the partial or complete destruction of a building is directly proportional to the actual volume (solid measure) of material used in the building construction plus the material content of all furnishings, equipment, appliances, inventory, stock, etc., which may be in the building at the time of disaster. Approximations of this quantity can be made by considering various empirical relationships based on type of construction, and size and use of the building. These relationships are expressed as 'material factors' and, in essence, show a comparison between total material quantity and the contained volume of the respective buildings. The following example briefly describes how these factors were developed. A six-story, reinforced concrete apartment building, Type 5-R, having a contained volume of 330,000 cubic feet, would require approximately 32,000 cubic feet of building material for construction. The material contained in the furnishings and other household effects, might amount to an additional 22,500 cubic feet, making a total of 54,500 cubic feet. If the building was completely destroyed by the air blast, the anticipated quantity of debris would be 54,500 cubic feet. Since this material would be scattered in a random manner, it will contain voids and therefore occupy a greater space than its original solid volume. For purposes of debris calculations a void ratio of 1:1 is used which makes the total quantity of debris equal to about 109,000 cubic feet. By dividing this quantity, 109,000 cubic feet, by the contained volume of the building, 330,000 cubic feet, a material factor of 0.33 is obtained. If subjected to fire, the quantity of debris would be less as indicated by the respective 'blast and fire' material factor shown in the table opposite. Similar evaluations and factors have been determined for the various building types and uses.

The listed factors reflect the total potential amount of material which could become debris. If the building incurs only partial damage then the amount of generated debris would be less than indicated by the material factor. This variation is considered along with the distribution of the debris in Panel 8 and is expressed as a factor of the total potential quantity dependent upon the incident overpressure.

Although the relationship between contained volumes and solid volume of material would vary for each and every building, the listed factors give a reasonable approximation of total quantity of debris to be expected. In instances where several different building types are involved, an average factor should be determined by considering the relative mix of buildings.

MATERIAL FACTORS

Contained Volume of Building x Factor Gives
Potential Debris Quantity

Building Type	Blast Only			Blast & Fire		
	R	C	I	R	C	I
1	.22	.35	-	.03	.08	-
2	.38	.49	.39	.19	.23	.22
3	-	.16	.19	-	.04	.05
4	.28	.32	.30	.14	.15	.15
5	.33	.44	.42	.18	.24	.25
6	.29	.43	.30	.15	.20	.18
7	.31	.45	.33	.17	.22	.20

DEVELOPMENT OF MATERIAL FACTORS

Six-story, reinforced concrete apartment building, Type 5-R, having a contained volume of 330,000 cubic feet.

Solid Volume of Building Materials	32,000 cubic feet
Solid Volume of Furnishings	22,500 cubic feet
Total Solid Volume of Material	54,500 cubic feet

Void Ratio of Debris is 1:1

Total Quantity of Debris including Voids (at Total Destruction)	109,000 cubic feet

Material Factor

$$\frac{\text{Total Quantity of Debris}}{\text{Contained Volume}} = \frac{109,000}{330,000} = 0.33$$

CONTAINED VOLUMES OF BUILDINGS

EQUIVALENT BUILDING DEPTH

Approximations of the total potential quantity of debris can be made by using the material factors just discussed if some prior evaluation has been made of the contained volume of the buildings in question. Short of a building by building survey, this can be accomplished by considering a hypothetical building which reflects the total contained volume of all buildings within a block. The plan dimensions of this hypothetical building — length, and width or depth — are determined in the following manner. The frontage (length) of the building is taken as the peripheral distance around the block. The width or Equivalent Building Depth (EBD) is determined by considering the actual building coverage with respect to the configuration of the hypothetical building. The plan of a typical block is shown opposite with the necessary calculations for determining the EBD which, for the example, is 35 feet±. Calculation of EBD's have been made in this way for typical block sizes with respect to different building coverage and are shown in the table. The building coverage for the example is 50%. If 70% of the area of the 200-foot x 300-foot block had been occupied by buildings the table shows that the EBD would have been 54. The height of the hypothetical building is taken as the average height of the actual buildings. For the example this is assumed to be 66 feet. The contained volume is determined by considering these dimensions of length, depth and height, 860 x 35 x 66, which in this case equals 1,986,600 cubic feet. This compares reasonably well with the total contained volumes of the actual buildings of 1,980,000 cubic feet (6 x 330,000). Most debris problems are concerned with the amount of debris per lineal foot of route which must be cleared in the immediate post-attack period. Since a continuous frontage equal to the block dimensions has been assumed for the hypothetical building, it follows that the contained volume of one lineal foot of the building (depth times height) could be used as an indication of the potential amount of debris per lineal foot that must be considered in estimating the magnitude of debris problems.

In the example, this volume would equal 2,310 cubic feet (35 x 66). Debris factors for Type 5-R buildings are 0.33 for blast only and 0.18 for blast and fire from Panel 5. Anticipated quantities of debris per lineal foot would be 762 and 416 cubic feet respectively.

The topics so far have dealt with estimating the maximum quantity of debris (total destruction) that might be anticipated in various urban areas. The physical data — sizes and types of buildings, building density or block coverage, sizes of blocks, etc. — necessary to make the determinations can be obtained by visual inspection of the study areas or use of maps and records. How these debris quantities are adjusted to reflect lesser degrees of damage and how the debris is distributed throughout an area are discussed in the following panels.

DEVELOPMENT OF EQUIVALENT BUILDING DEPTH

Block size	200' by 300'
Building type	5-R
Number of buildings	6
Average plan area, each	5000 sq ft
Average height	66 ft
Contained volume, each	330,000 cu ft

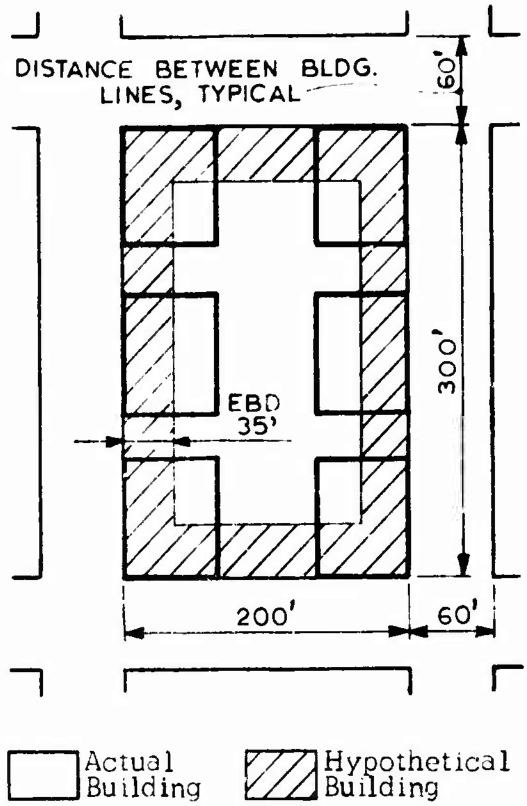
To calculate EBD:

$$6(5000) = [600 + (400-4y)]y$$

$$y = 35 \text{ ft} \pm = \text{EBD}$$

% of Building Coverage:

$$\frac{6 \times 5000}{200 \times 300} \times 100\% = 50\%$$



EQUIVALENT BUILDING DEPTH (EBD)

% of Building Coverage	SIZE OF BLOCK IN FEET					
	100 by 300	200 by 200	200 by 300	300 by 300	300 by 400	400 by 400
10	4	5	6	8	9	11
20	8	11	13	16	18	21
30	12	16	20	25	28	33
40	16	23	27	34	39	45
50	21	30	35	44	50	59
60	26	37	44	55	63	73
70	30	46	54	68	77	90
80	37	56	65	84	94	110
90	43	68	79	103	115	136
100	50	100	100	150	150	200

DISTRIBUTION OF DEBRIS

Probably the most difficult determination in considering debris problems is in making some assessment of how generated debris will be distributed throughout an urbanized area after an attack. Each block or study area could present different physical characteristics — size and density of buildings, width of adjacent streets and amount of open space — all of which would have varying effects on the distribution depending on the direction and magnitude of the air blast.

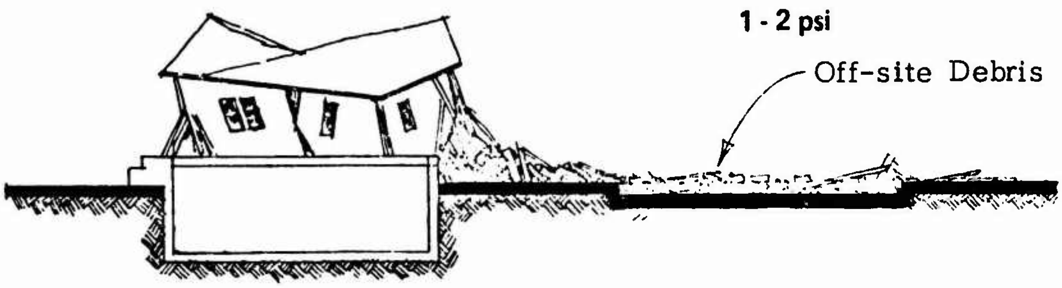
Debris from destroyed wood frame structure situated in the center of an otherwise vacant block, would probably be scattered throughout the area in general alignment with the direction of the blast wave. The distance traveled by the airborne debris would depend on the weight and size of the debris particles and the force of the blast wave. The travel could be abruptly stopped if the particles struck an obstacle such as a remaining concrete wall. This interaction of debris particles with both remaining structures and other debris can not presently be evaluated further than to acknowledge that it does affect final distribution.

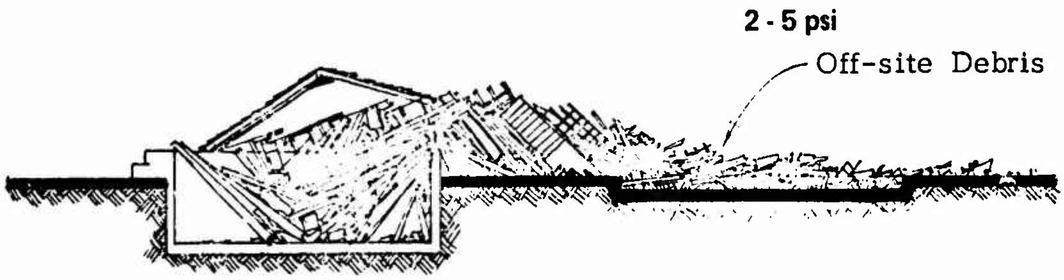
The sketches merely indicate different possibilities. A general conclusion that can be reached is that in the event of total destruction the debris would probably be distributed uniformly throughout. At the other extreme, where only minor damage was sustained, the debris would probably remain close to the respective damaged structures. Debris related problems are usually concerned with situations which fall between these two, that is, in areas where overpressures would be in the general order of two to ten psi. Both the quantity and distribution of debris are directly related to the intensity of the initial blast wave and consequently referred to as 'blast only' debris. If subsequently subjected to fire the resulting debris environment would be identified as 'blast and fire'.

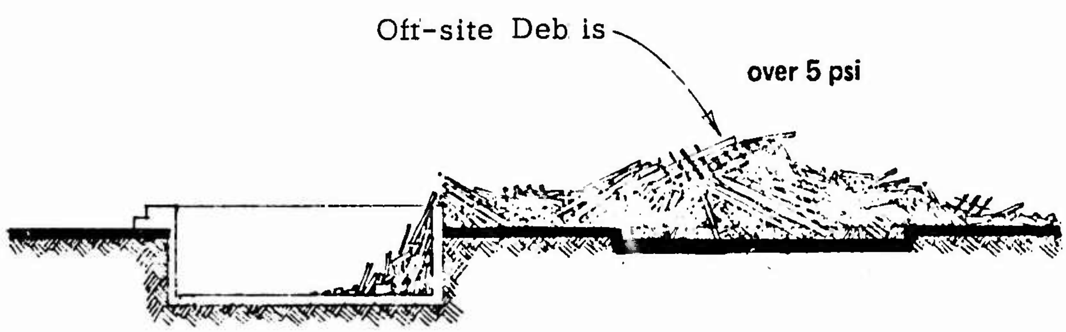
A distinction is made between that debris which will remain essentially within the confines of the building itself and that debris which is trajected away from the building. In the first instance the resulting debris — termed 'on-site' debris — would resemble that which might be expected from a collapsed, fire-gutted building; in the other instance the debris — 'off-site' debris — would generally resemble that left in the wake of a tornado. The quantity of each is dependent on the overpressure experienced. Both 'on-site' and 'off-site' debris must eventually be considered in overall post-attack recovery efforts but the initial and primary concerns of early emergency operations involve essentially the clearing or removal of debris from streets or thoroughfares — or that which is considered 'off-site' debris.

DISTRIBUTION OF DEBRIS

These sketches illustrate the distribution of the debris from the destruction of one wood-frame house. Debris from nearby structures could be scattered over the open area to the left with some of this debris falling into the exposed basement.







OFF-SITE DEBRIS

The distribution of debris is affected by many variables, features or conditions of both the attack and the physical configuration of the target area. Except in instances of total destruction where uniform distribution is assumed, it is apparent that any quantitative distinction between on-site and off-site debris would be very difficult to make. General assumptions can be made by considering the percentage increase in debris generation with respect to increase in overpressures (Panel 4) and then making a relative evaluation as to what percentage of this debris would be trajected from the site. These relative relationships are in turn dependent on and vary with respect to building types, overpressures and direction of blast wave. Following this rationale a table of off-site factors has been developed as shown opposite. The factors are listed by building types and overpressures and are applicable to both 'blast only' and 'blast and fire' conditions. Basically they indicate that portion of total generated debris which would probably be trajected off-site.

If the Type 5-R building considered in the example were subjected to an overpressure of 8 psi an estimate of the amount of off-site debris could be made by multiplying the total potential debris quantities by the off-site factor of 0.10. For the blast only condition this gives 76 cubic feet (762 x 0.10); for blast and fire, 42 cubic feet (416 x 0.10). Again, these quantities reflect totals per lineal foot of street or frontage. If the overpressure had been 15 psi the off-site volumes would have been 267 cubic feet and 146 cubic feet respectively.

OFF-SITE DEBRIS FACTOR

Building Type	Incident Overpressure, psi													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	.03	.27	.50	.60									
2	0	0	0	.01	.05	.18	.54	.60						
3	.09	.27	.37											
4	0	.01	.06	.17	.27	.33	.42	.55	.60	.61				
5	0	0	.01	.02	.04	.06	.10	.14	.18	.23	.27	.30	.33	.35
6	0	0	.02	.06	.09	.14	.30	.38	.41	.42	.45			
7	0	0	.01	.03	.07	.12	.20	.27	.38	.42	.45			

DEPTH OF DEBRIS

An estimate of the average debris depth in feet can be obtained by dividing the total estimated quantity (cubic feet) by the gross area (square feet) over which the debris is distributed. The area of distribution would include frontage streets, adjacent intersections, etc. For various combinations of street and block configurations, factors have been developed which reflect a general relationship between the distance between building lines and possible area of distribution. These factors, called 'Average Depth Factors', are used as follows:

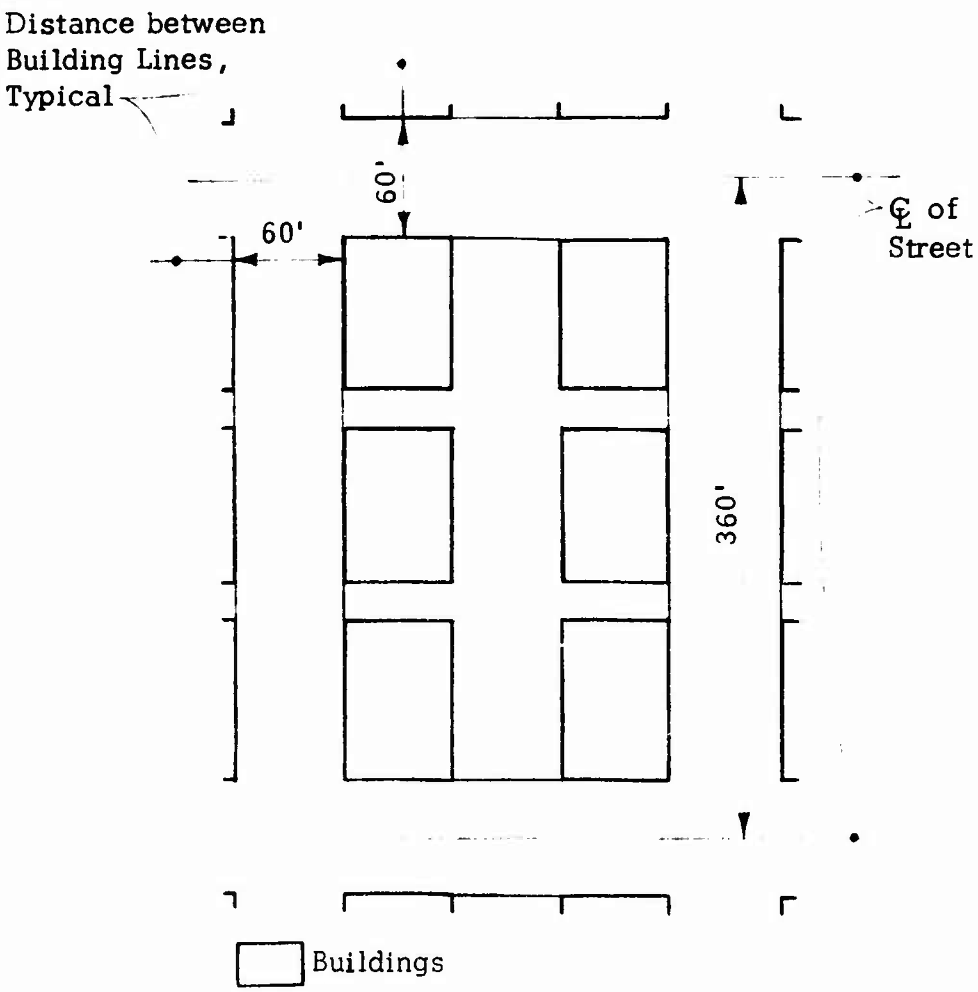
Using the example of Panel 8 the estimated quantity of off-site debris for 8 psi incident overpressure was 76 and 42 cubic feet per linear foot of street for 'blast only' and 'blast and fire' conditions. The area configuration is as shown on the opposite page with the distance between building lines of 60 feet. Multiplying these off-site debris quantities by the appropriate factor (.011) from the Average Depth Factor table, the estimated average depth along the streets would be 0.84 feet for 'blast only' condition and 0.46 feet for 'blast and fire' situation.

If a 20-foot path was to be cleared through this area the quantities are debris per linear foot would be 17 and 9 cubic feet per linear foot respectively. The total quantity of debris to be handled in clearing a path along the length of the block (360 feet center to center of intersections) would be 6,120 cubic feet for 'blast only' or 3,240 cubic feet for 'blast and fire'. The unit of measure usually used for this type of material handling is the cubic yard. Therefore, dividing by 27 cubic feet per cubic yard, we would have about 227 or 120 cubic yards of material to move for each block of 20-foot path cleared.

The above appraisal of average debris depths would only be applicable in areas of severe damage or total destruction wherein uniform distribution is assumed. In most instances, off-site debris would probably be randomly scattered in piles of greater than average depths with intervening areas of less than average depth. It is likely that any emergency access through the area would be made by clearing a meandering path between the piles, following a path of least resistance or minumum depth. This procedure would result in a lesser quantity of debris being handled than that determined by assuming average depth throughout. Allowance for this meandering path possibility can be made by use of the shown factors. In the example using Type 5-R building and incident overpressure of 8 psi the degree of damage would be moderate according to the chart in Panel 4. Therefore the volume of material to be moved following a meandering path 20 feet wide along the block would be 170 (.75 x 227) or 90 (.75 x 120) cubic yards for 'blast only' or 'blast and fire'.

AVERAGE DEPTH FACTOR

	Distance between Building Lines in Feet								
	30	40	50	60	70	80	90	100	110
Factor	.022	.017	.013	.011	.009	.008	.007	.006	.005



MEANDERING PATH FACTOR

	Degree of Damage		
	Light	Moderate	Severe
Factor	0.50	0.75	1.00

TYPE OF BUILDING DEBRIS

In order to evaluate debris problems or environments, it is necessary to make some appraisal of the type of debris that will be encountered along the streets or thoroughfares. Will it be basically large hunks of reinforced concrete, twisted steel or broken glass? It is obvious that debris could contain any one or all of these materials in various sizes, quantities and mixes. Although it would be impossible to define or describe the exact composition, it is possible to indicate the major elements of debris by considering different buildings and various degrees of damage. Wood is the major debris element of a destroyed house; steel, that from a steel frame industrial building or apartment house.

The various structural elements or materials comprising all buildings and their contents can be generally considered as either 'wood' or 'steel'; wood implying large timbers, lumber, wood trusses, panels and furniture; and the term 'steel' including reinforced concrete, steel beams, piping, shop equipment, safes, and other heavy steel equipment. The comparative quantities or mix of these elements within the total volume of debris can be expressed in relative terms such as none, light, medium or heavy. On this basis, structural elements can be used as a general description of debris types as shown in the upper table. This numberical classification of debris types also gives an indication of the degree of difficulty in handling, that is, the types have been listed in the order of increasing difficulty. Type 1 is less difficult to clear away than Type 2 and so on up to Type 6 which is the most difficult debris to handle. An increase in the difficulty of the task due to debris inclusions which were not generated by destruction of buildiings can be made by increasing the Debris Type number. These other inclusions are discussed in subsequent panels. In making such adjustments, careful judgement must be used in determining how much to increase the Debris Type number to account for increased difficulty of handling, taking into account the types of elements present in the original debris and in the additional inclusions.

The lower table shows the type of debris which may be anticipated for various degrees of damage for each building type. Type of debris may change as degree of damage increases. This is due to different type and mix of material becoming debris at higher overpressures.

DEFINITION OF DEBRIS TYPES

Structural Element	Debris Type
None	1
Light Wood	2
Heavy Wood	3
Light Steel	4
Medium Steel	5
Heavy Steel	6

DESIGNATIONS FOR TYPES OF BUILDING DEBRIS

Building Type	Light Damage			Moderate Damage			Severe Damage		
	R	C	I	R	C	I	R	C	I
1	1	1	-	2	3	-	2	3	-
2	1	1	3	1	3	3	1	3	4
3	-	3	3	-	4	5	-	6	6
4	3	3	3	4	4	5	5	6	6
5	3	3	3	4	5	6	6	6	6
6	3	4	4	4	5	5	5	6	6
7	1	3	3	3	4	4	5	5	5

Abbreviations

R - Residential
C - Commercial
I - Industrial

PANEL 10

EFFECT OF OTHER DAMAGED STRUCTURES AND TREES

The debris discussed so far has come from the damaging of buildings. It is likely that other obstacles such as fallen trees, poles, signs or overpasses will be intermixed with this building debris. Although the quantity of the debris from these sources would probably be considerably less than that generated from the buildings, the nature of these inclusions could cause additional problems during clearing operations.

Relative evaluations of the possible effect on clearing operations can be made from visual inspection of the area. A few scattered trees or poles, in an area of high-density large apartment buildings, would have little effect on potential clearing problems. On the other hand, numerous standing signs and metal utility poles in a sparsely built-up area could constitute the major problem. Since these inclusions are essentially structural elements they can be considered in the same manner as the 'structural elements' in building debris. A light amount of wood from trees or telephone poles would be given a Designation of 2; heavier quantities of wood, 3; steel (and concrete) 4, 5 or 6, depending on quantity. If large structural elements from damaged buildings are already being considered in the debris the Designation Number should be increased to allow for the additional 'structural elements'.

In the case of the collapse of a large overpass the degree of difficulty might well be too great to be handled in the early clearing operations, and routes by-passing such structures should be considered in the early planning.

UTILITY POLE
DAMAGE AT 5 PSI
AT NEVADA
PROVING GROUNDS

FREEWAY
OVERPASS
COLLAPSE
1971 CALIFORNIA
EARTHQUAKE

EFFECT OF DAMAGED VEHICLES

The possibility of encountering damaged vehicles intermixed with building debris must be taken into account in estimating the magnitude of debris problems. In areas where only small quantities of debris are involved, damaged vehicles could probably be pushed aside with little additional effort. In other areas, their presence could materially affect the time and difficulty of clearing. Their overall effect on clearing operations is related both to the number of vehicles involved and to the type of debris being handled.

A fairly reliable estimate of the number of vehicles can be made by considering various traffic patterns or studies applicable to different areas. Traffic conditions will probably vary in accordance with time of day, day of week, or specific occasion. The table opposite is a suggested method of evaluating the number of vehicles which may be in an area at time of attack. If all areas were subjected to 'severe' damage (usually over 6 psi overpressure with respect to vehicles) it is likely that most vehicles would be damaged and therefore contribute to the debris problem. In this case of severe damage the traffic designations — light (L), medium (M), and heavy (H) — would reflect the relative number of disabled vehicles. However if an area noted as having heavy traffic conditions at the time of the blast were subjected to only light damage, it would be reasonable to assume that most vehicles could leave the area under their own power, consequently a lesser traffic designation (M or L) would be used in considering debris problems.

The additional effort required for the clearing operation because of the inclusion of disabled vehicles can be evaluated approximately and can be expressed as a reduction in the amount of debris that a given piece of equipment can remove in a specified length of time.

VARIABLE INCLUSIONS

Traffic Conditions

Area \ Day of Week \ Time	6 PM - 6 AM		6 AM - 9 AM 4 PM - 6 PM		9 AM - 4 PM		Warning Activities
	Week-days	Week-end	Week-days	Week-end	Week-days	Week-end	All Days
Residential - Single Units	L	L	M	L	L	L	L
Residential - Multiple Units	M	M	M	M	L	M	M
Commercial - Office Buildings	L	L	H	L	M	L	H
Commercial - Wholesale District	L	L	H	L	H	L	M
Commercial - Retail Stores	L	L	M	L	M	M	L
Industrial - Light	L	L	H	L	M	L	H
Industrial - Heavy	L	L	H	L	H	L	H

Holidays same as weekend.

Abbreviations

L - Light
M - Medium
H - Heavy

DEBRIS PREDICTION SURVEY

Estimates of the magnitude of debris problems must be made in both the pre-attack and post-attack periods. In the first instance, estimates must cover all possibilities regardless of weapon size or detonation point so that potential recovery efforts may be planned and organized realistically. In the post-attack period the estimate must reflect as nearly as possible the actual situation so that recovery operations can be effectively implemented. In both cases, the basic information needed to make the estimates can be obtained and evaluated in the pre-attack period. The process involved which has basically been described in previous panels is referred to as a Debris Prediction Survey (DPS). A summarization of the pertinent information gathered in the survey could be arranged in a convenient format such as the one shown, so that it can be used to readily identify potential debris environments in pre-attack planning or actual debris environments when degree of damage is known.

The input data and applicable factors are noted by letters or numbers on the DPS sheet. Items (A) through (G) identify the physical features of the study area which would contribute to or affect the debris environment. Items (H) through (L) show applicable factors and calculations pertaining to debris generation as determined for the specific area configuration. Incident overpressures to which the area may be or has been subjected are listed in Column (1). The range of overpressures would be limited to a certain extent by the particular building type noted for (E). For instance it would be meaningless to consider overpressures of 10-15 psi for a wood-frame building since total destruction occurs at about 4 psi. Similar overpressures will be listed for both blast only and blast and fire conditions. Visual degree of damage with respect to overpressures is indicated in Column (2). The remaining columns are for factors and calculations used in deriving the predicted debris type.

A seperate DPS form would be prepared for each study block, zone or area as may be required. The required data would be assembled and necessary calculations made to complete the numbered columns with respect to the various overpressures and degrees of damage listed in Columns (1) and (2). Using the completed sheet, it is possible to make an estimate of potential debris environments resulting from any attack condition (pre-attack) or define the environment due to known attack conditions of the post-attack period.

In conjunction with the DPS it will also be necessary to make some evaluation of the potential effect of damaged vehicles in the respective blocks or zones being studied. This can be done by preparing Traffic Conditions tables as discussed in Panel 12.

DPS SHEET

DEBRIS PREDICTION Date ________ City ________ District ______ Zone ______

(A) Block Size ________ (B) Street Width: to Curbs ____; to Bldg Lines ________ (C) % Bldg Coverage ______

(D) Avg Bldg Height ________ (E) Building Type-Use ________ (F) Trees, Poles, etc. ________

(G) Comments ________

(H) EBD ______ (I) Contained Volume ________ (J) Material Factor: Blast ________; Blast and Fire ______

(K) Potential Debris Material: Blast ________; Blast and Fire ________ (L) Avg Depth Factor ______

PREDICTED ENVIRONMENTS

ATTACK CONDITION	(1) Incident Over-pressure psi	(2) Damage Light-L Moderate-M Severe-S	(3) Off-Site Factor	(4) Volume Off-Site Debris cu ft/ft	(5) Average Depth Feet	(6) Predicted Debris Type
BLAST ONLY						
BLAST AND FIRE						

PANEL 13

AREA ZONE MAP

Emergency planning procedures are usually developed on the basis of individual areas, districts or zones within the community, each reflecting specific conditions, requirements or potential problems that might result from some catastrophic event. A common example would be fire districts, where type and quantity of fire fighting equipment are assigned on the basis of potential fire hazards of the particular district. Evaluating or estimating debris problems can be similarly considered, i.e. by dividing a community into districts which in general could be categorized on the basis of similar debris generating potentials.

For purposes of administration the districts should not be too small, approximately ten to twenty-five square miles in extent, but where the construction and street configuration vary widely districts should be divided into smaller zones each of which would then be similar in debris-producing potential within itself. A large residential area in which building types, lot and block sizes, and street widths and patterns are typical throughout, or a single block of high density office buildings, could be considered as zones. In both cases the similarity of buildings and area configuration is such that typical or average debris generation factors could be considered as applying to the block or zone. Number and size of zones would be dependant on the variety and mix of buildings involved and the amount of detail considered necessary in the particular community. They would probably be established in consultation with members of various emergency planning departments or agencies.

An area zone map for the City of San Francisco is shown. It basically reflects the ten established fire districts within the area. For purposes of debris studies the fire districts have been subdivided into smaller zones on the basis of types of buildings, street patterns, etc. Zones are identified by number, the whole number indicating the respective district, the decimal identifying the zone within the district. Any [illegible]enient method of identification could be used. For the study area, boundaries of defined zones should be plotted on large scale maps which show street patterns, main thoroughfares, public buildings, parks, major utilities and other areas or facilities which may be relevant to post-attack emergency operations.

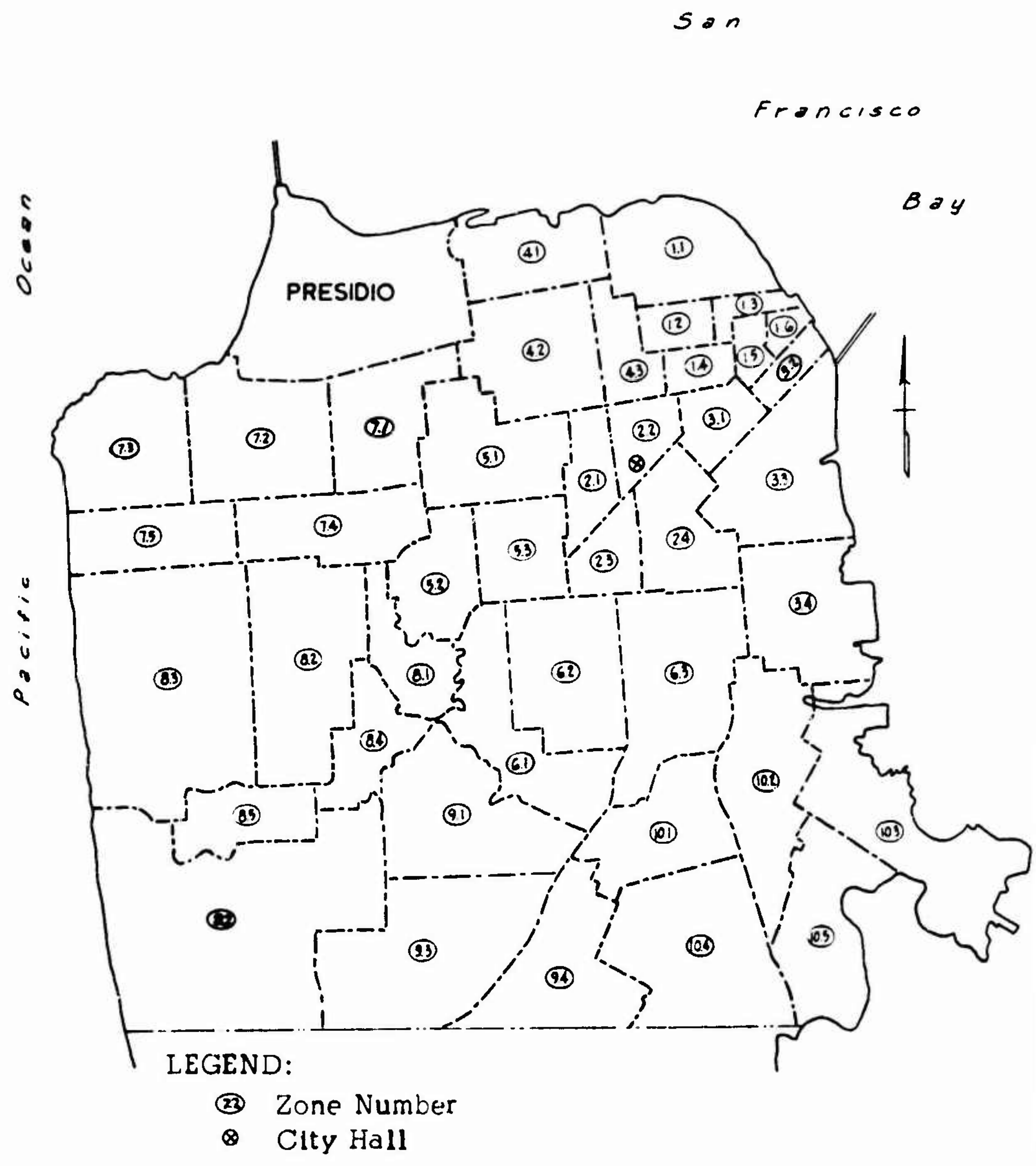
A DPS sheet would be provided for each zone.

Access or evacuation routes which would most likely be required in the early post-attack period should also be shown on the area zone map. These routes will probably pass through several zones and should be identified to indicate this.

The area zone map is a primary tool to be used in evaluating and estimating debris problems in both the pre-attack and post-attack periods. Its use, in conjunction with various overlays, is discussed later.

AREA ZONE MAP

CITY OF SAN FRANCISCO



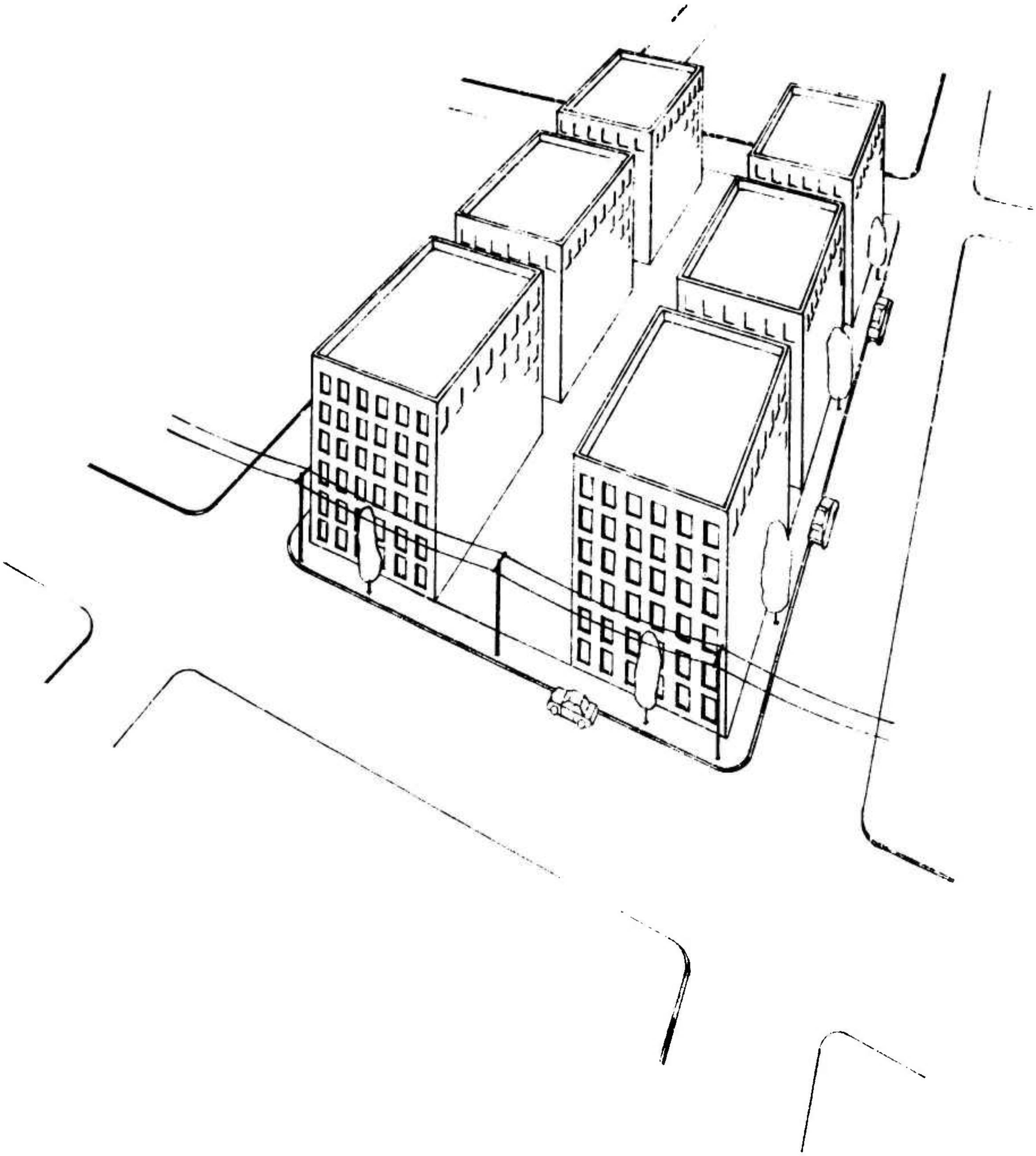
THE STUDY BLOCK

Planners in each urban community will determine the size, shape and number of districts and zones to be considered in evaluating or estimating debris problems. Their choice would be based on the physical configuration of the community and the amount of detail or data which they feel is required.

Regardless of the zones defined, whether fairly large areas or individual blocks, the overall procedure and input necessary to make a DPS would be the same.

For purposes of illustration, a single block is used as per the sketch opposite. It represents a residential area such as may be found in most communities. It is also assumed that this particular block is located within Zone 8.2 as shown on Panel 14 and is typical of the entire zone.

THE STUDY BLOCK



PANEL 15

MAKING THE SURVEY

The first step in making a DPS is to determine and record pertinent physical features [inputs (A) through (G)] of the particular study area. This can be accomplished in one of two ways: 1) by an actual field survey, or 2) by studying Sanborn or similar type maps and records. In initiating the survey, it may be desirable to use both methods so that field data can be verified or compared with corresponding map and record data. This checking process should also increase the capability and confidence of making field surveys in areas for which recorded data is not available. The remaining input and calculations would be completed in the office following the general procedure outlined in the accompanying table.

The effort and time spent in making the survey would depend on the extent of emergency planning requirements considered necessary in a particular community.

In areas where pre-attack planning has specified certain emergency routes to be used, it may be sufficient to survey only those streets or thoroughfares designated. This procedure, called a 'route survey' would be adequate to define the debris environments along the routes but may or may not be applicable to adjacent areas. This is due to so-called 'strip-zoning' commonly found along major thoroughfares wherein the types and use of buildings fronting the street are different from the typical neighborhood configurations. An example would be a strip of commercial buildings within a residential district.

The DPS sheets completed before the attack should be indexed and filed for quick reference in the emergency period.

DPS INPUT

Item	How Obtained	Comments
(A)	Survey	Curb line to curb line
(B)	Survey	Both curb line to curb line and building line to building line
(C)	Survey	Base area of buildings ÷ area of block
(D)	Survey	Average height of buildings
(E)	Survey	As per Panel 3
(F)	Survey	Relative appraisal
(G)	Survey	Exceptional features
(H)	Panel 6	
(I)	Calculation	(H) x (D) in cu ft/ft
(J)	Panel 5	Both B and BF
(K)	Calculation	(I) x (J) for both B and BF, in cu ft/ft
(L)	Panel 9	
(1)	Panel 4	Potential overpressures both B and BF
(2)	Panel 4	With respect to overpressures
(3)	Panel 8	For listed overpressures both B and BF
(4)	Calculation	(K) x (3) for B or BF
(5)	Calculation	(L) x (4) for B or BF
(6)	Panel 10, adjusted if necessary according to Panel 11	Most difficult designation

Abbreviations

B - Blast only
BF - Blast and fire

All symbols in parentheses as (I) refer to the DPS sheet

COMPLETED DPS SHEET

Following the procedure outlined in Panel 16 the DPS sheet would be completed as shown opposite. The completed calculations, Columns (1) through (6) for both 'blast only' and 'blast and fire' define potential debris environments which may be expected due to various attack conditions. For instance, if the block were subjected to an incident overpressure of 10 psi without fire the debris in the streets could be identified as Type 4, with average depth of 1.51 feet. With fire the remaining debris would be Type 4, average depth of 0.83 foot. If input (A) through (G) were considered typical for a large area, say Zone 8.2 as shown on the area zone map, then the DPS sheet would provide the means of making a reasonable evaluation as to the debris environment that may be anticipated in that zone. The number of DPS sheets required to complete a survey for any particular community could vary from 40 or 50 to several hundred. Once completed, however, the planner would have a statistical picture or record of potential debris environments which may be anticipated within his community due to various attack situations.

The Predicted Debris Type, Column (6), would be adjusted to reflect the effect of damaged vehicles in final determinations of debris environments.

DPS SHEET

DEBRIS PREDICTION Date 12 Jan 1975 City San Francisco District 8 Zone 2

(A) Block Size 200' x 300' (B) Street Width: to Curbs 40' ; to Bldg Lines 60' (C) % Bldg Coverage 50

(D) Avg Bldg Height 66' (E) Building Type -Use 5-R (F) Trees, Poles, etc. Few

(G) Comments Typical block - light traffic all hours

(H) EBD 35' (I) Contained Volume 2310 cu ft/ft (J) Material Factor: Blast 0.33 ; Blast and Fire 0.18

(K) Potential Debris Material: Blast 762 cu ft/ft ; Blast and Fire 416 cu ft/ft (L) Avg Depth Factor 0.011

PREDICTED ENVIRONMENTS

ATTACK CONDITION	(1) Incident Over-pressure psi	(2) Damage Light-L Moderate-M Severe-S	(3) Off-Site Factor	(4) Volume Off-Site Debris cu ft/ft	(5) Average Depth Feet	(6) Predicted Debris Type
BLAST ONLY	2	L	0	0	-	-
	4	L	.01	8	.09	3
	6	M	.04	30	.33	4
	8	M	.10	76	.84	4
	10	M	.18	137	1.51	4
	12	S	.27	206	2.27	6
BLAST AND FIRE	2	L	0	0	-	-
	4	L	.01	4	.04	3
	6	M	.04	16	.18	4
	8	M	.10	42	.46	4
	10	M	.18	75	.83	4
	12	S	.27	112	1.23	6

ASSUMED DEBRIS CONDITIONS

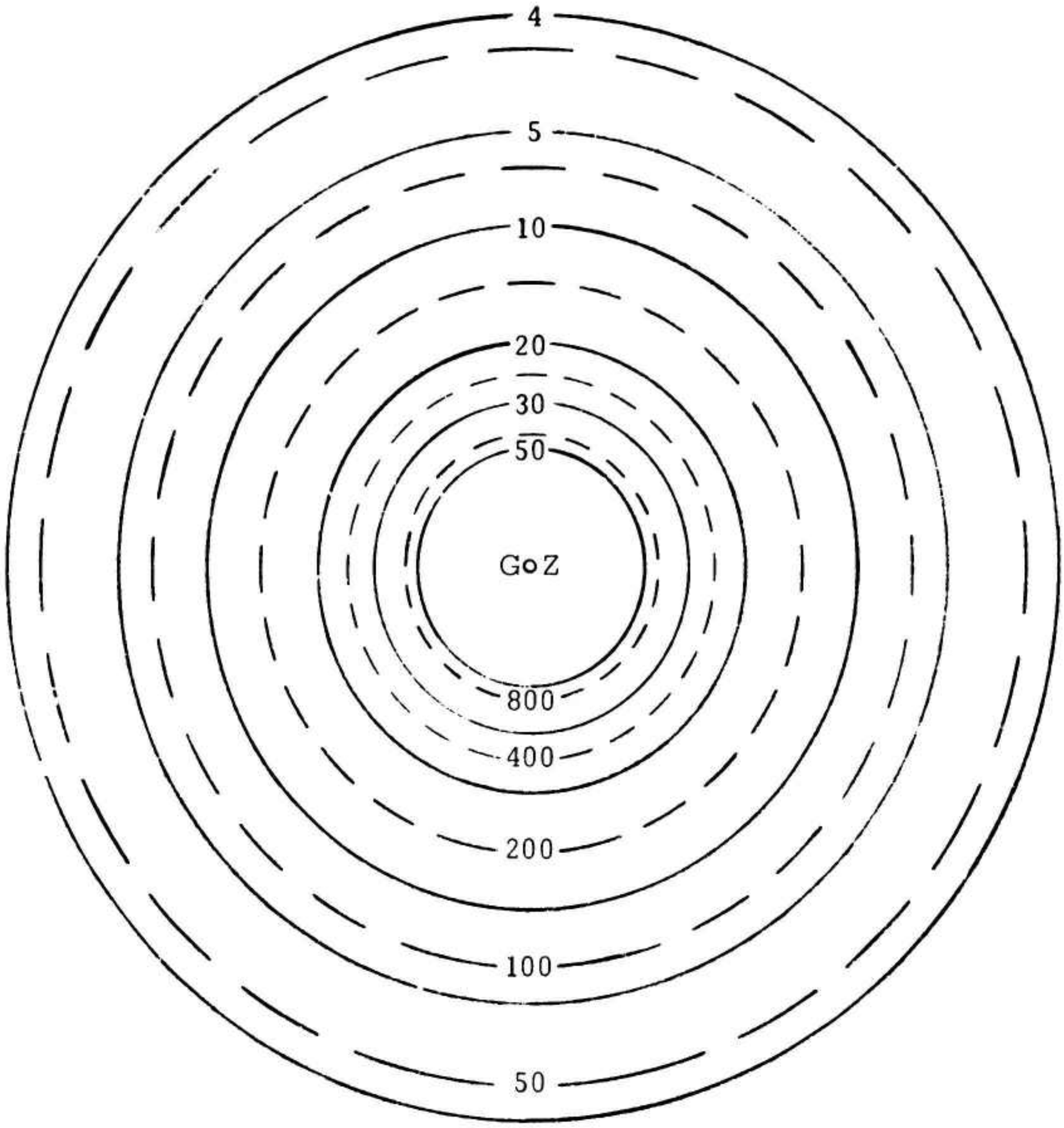
Pre-event planning of emergency operations for any catastrophic happening is usually based on some assumption of what destructive parameters must be considered. With respect to a nuclear attack these parameters are: 1) size of weapon, 2) geographic location, and 3) type of burst — surface or air.

For nuclear weapons of various sizes assumed 'damage patterns', similar to the one shown here, have been prepared for both surface and air bursts. Here are shown isobars of incident overpressures and isotherms of radiant exposure with respect to ground zero of a 1-MT air burst.

Transparent overlays of damage patterns for several weapon sizes can be prepared to the same scale as the area zone maps. By positioning ground zero of each overlay at various locations in and around the community, it is possible to study the variations in overpressure and fire hazard that might reasonably be anticipated. While using these overlays the Planner can assess the relative variations in debris environments to be expected in any one attack situation. He can see the range of probable overpresures and be able to estimate the debris problems to be encountered.

If the 1-MT air burst pattern was centered over the City Hall of San Francisco (see Panel 14) anticipated overpressure for the study block in Zone 8.2 would be approximately 4 psi with a high likelihood of fire. Potential debris environment for the block would be identified by the 4 psi calculations for blast and fire conditions as shown on the respective DPS sheet. Zone 8.1 would have an incident overpressure of from 5 to 10 psi, Zone 5.2 from 5 to 18 psi, and Zone 5.3 from 13 to 50 psi. Having studied the types of debris to be expected in each zone as a result of various incident overpressures, the planner can judge what the problems might be and what might be accomplished in each zone under any particular attack situation.

DAMAGE PATTERN FOR 1-MT AIR BURST



LEGEND:

——— 10 ———	Incident Overpressure, pounds per square inch
— — 50 — —	Radiant Exposure, calories per sq cm
GoZ	Ground Zero

SCALE:

MAGNITUDE OF DEBRIS PROBLEMS

The magnitude of a debris problem is dependant on the type of attack, the area affected, and the emergency operation being considered. Clearing debris from all streets is obviously a greater undertaking than clearing a single 20-foot access route through the community. Since emergency operations in the early post-attack period, such as evacuation, fire fighting, rescue, and restoration of critical utilities, all require some form of vehicular access, it is apparent that one measure of the debris problem would be to determine the type and quantity of debris which must be cleared to provide the needed access. This can be estimated using the average depth and type of debris and the width and length of path to be cleared.

The table shown is a typical summary indicating the magnitude of the debris problem in clearing a specified group of emergency routes in the City of San Francisco after an assumed 1-MT blast. It represents only a fraction of the total debris quantity since it reflects only a few of the streets within the city.

Previcus panels have shown how the type and average depth of debris can be determined in any study block under different assumed or experienced attack conditions. The width of emergency routes would probably vary between 20 and 50 feet.

A path 20 feet or less in width would be for simple, quick access to a location; one of about 30 feet would provide for two-way travel of heavy vehicles; and the wider routes would be needed for major evacuation out of the devastated area.

Each of these routes would then be divided to reflect any significant changes in debris environment (depth and types of debris). These divisions of routes would be called 'tasks' and given a designation. Along Route 1, shown in the table, for Debris Types 2 through 6, the tasks would be numbered 1a through 1e, along Route 2 they would be designated 2a through 2c, and so on through all the routes. It will be noted that Routes 4, 7, 11 and 12 did not have to be so divided since each passed through only one type of debris. The lengths of these 'tasks' are used in the determination of debris quantities. The quantity of debris to be removed for each particular task would be determined by multiplying the task length by the width required to fulfill the purpose of the clearing and multiplying that product by the average depth as shown on the DPS sheet for the zone through which the route is passing.

For those routes which pass through different debris environments, the total requirements would be the sum of the quantities for all the different debris types encountered along the route. In the summary here the total quantity of debris to be removed in the early operation is 548,525 cubic yards.

SUMMARY - DEBRIS QUANTITIES
CITY OF SAN FRANCISCO
SIMULATED ATTACK

Route No.	DEBRIS TYPE					Total per Task (cu yd)
	2	3	4	5	6	
	QUANTITY OF DEBRIS, CU YD					
1	1,090	14,025	7,105	7,985	59,390	89,595
2	-	-	29,060	85,710	125,285	240,055
3	1,925	20,635	-	-	-	22,560
4	5,125	-	-	-	-	5,125
5	-	-	-	22,500	18,355	40,855
6	-	17,060	-	-	3,350	20,410
7	-	31,995	-	-	-	31,995
8	7,370	11,920	4,095	22,160	19,995	65,540
9	11,375	5,900	-	-	-	17,275
10	-	-	1,610	2,655	-	4,265
11	-	8,630	-	-	-	8,630
12	2,220	-	-	-	-	2,220
Totals	29,105	110,165	41,870	141,010	226,375	548,525

ZONE SITUATIONS

Another method of describing potential debris environments is by defining the damage situation which exists or could exist in any zone. With respect to debris problems, damage resulting from a nuclear attack is dependent on the intensity of two effects of the detonation — incident overpressure and fire. Following a concept which has been used in other attack analyses, these damage criteria can be related as shown by the table. Blast damage is dependent on type of building being considered and is rated 'light', 'medium', or 'severe' in accordance with Panel 4. Anticipated overpressures, corresponding to the blast damage, can also be approximated from that panel. Degrees of fire damage are noted as 'negligible', 'moderate', or 'severe'. A zone situation is designated by the appropriate number from the table which relates either anticipated or actual blast and fire damage. For instance, a Zone Situation of 7 (light blast and severe fire damage) would be used to identify the damage in the study block due to the assumed attack condition of Panel 18. Situation numbers 1, 2, and 3 would reflect 'blast only' condition as used on the DPS sheet. 'Blast and fire' condition would relate to Situations 7, 8, and 9. Situations 4, 5, and 6 represent a degree of damage between the two such as a partially burned area or a controlled fire situation.

During the early post-attack period, damage assessments will likely be reported in terms of degree of damage as determined from visual inspection of the devastated area. Zone Situation numbers provide a convenient and uniform method of making these assessments. They also provide a means of correlating pre-attack and post-attack determinations.

ZONE SITUATIONS

DEBRIS ENVIRONMENTS

	Negligible Fire Damage	Moderate Fire Damage	Severe Fire Damage
Light Blast Damage	1	4	7
Moderate Blast Damage	2	5	8
Severe Blast Damage	3	6	9

GENERAL EVALUATIONS

The debris problem has been considered primarily on the basis of quantity and type of debris. In the early post-attack period, it will also be necessary to consider other attack parameters which would affect the overall evaluation. For instance, it would be impossible to initiate a clearing operation in an area with an uncontrollable fire situation regardless of the amount of debris involved. An early appraisal of this condition with respect to the debris problem can be made by considering the zone situations discussed in Panel 20 and using reported damage assessments in general accordance with the following:

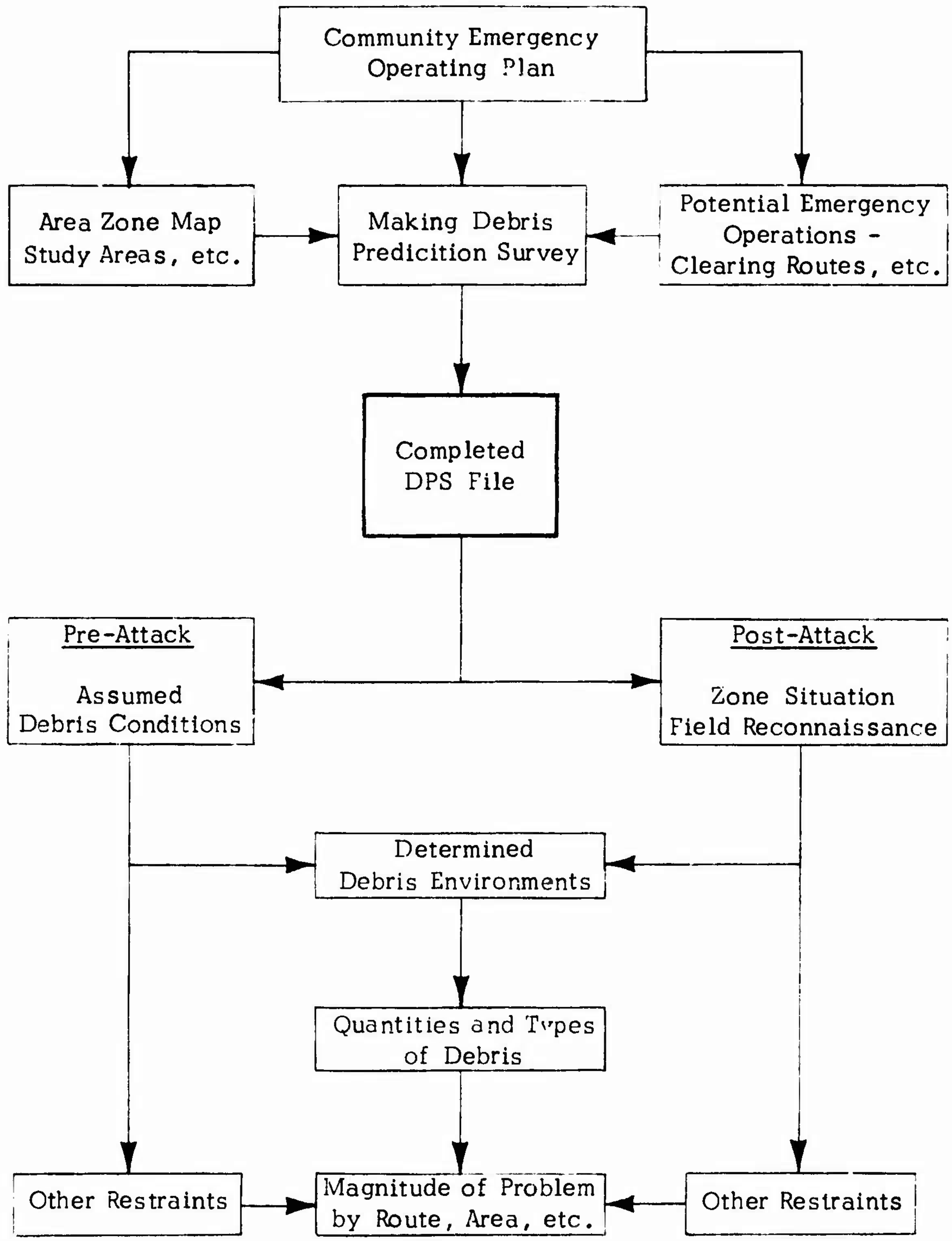
Zone Situation	Possibility of Accomplishment
7, 8, or 9	Unlikely
3, 5, or 6	Moderate
1, 2, or 4	High

This relationship between fire conditions and the debris problem varies with respect to time. An early uncontrollable fire situation (7, 8, or 9) could change to a negligible fire situation (1, 2, or 3) within a matter of hours. Although this changes the possibility of performing a clearing task, the debris environment (type and quantity) determined for the area would still reflect severe fire damage or blast and fire conditions shown on the DPS.

A similar evaluation could be made with respect to radiation, that is, whether or not it would be possible to initiate a clearing operation. In this case, however, the type and quantity of debris would not be affected.

The overall process of evaluating the debris problem is shown opposite.

ESTIMATING THE DEBRIS PROBLEM



SUGGESTED ADDITIONAL READING

The following sources provide additional background on the material in this chapter:

1. Edmunds, J. E., P.M. Sears - Debris Model Research and Five-City Study Applications - URS 686-4 Contract No.OCD 12471 (6300A-310) June, 1968.

2. Edmunds, J.E., - Structural Debris and Building Damage Prediction Methods - URS 686-5 Contract No.OCD 12471 (6300A-310) June, 1968.

3. Edmunds, J.E. - Debris Prediction Model - URS 686-10 Contract No.OCD 12471 (6300A-310) June, 1969.

4. Concept of Operations Under Nuclear Attack - (Federal Civil Defense Guide), Part G, Chapter 1, Appendix 1, Review Draft - November, 1967 - Department of Defense -- Office of Civil Defense.

5. Rotz, J.,J.E.Edmunds and K.Kaplan - Effects of Fire on Structural Debris Produced by Nuclear Blast - URS 639-1 Contract No.OCD PS-64-19 January, 1965.

6. Rotz, J., J.E.Edmunds and K.Kaplan - Formation of Debris from Buildings and Their Contents by Blast and Fire Effects of Nuclear Weapons - URS 651-4 Contract No.OCD-PS-64-201, April, 1966.

7. Wickham, G.E. - Debris Removel - Civil Defense Operations - Vol I - Jacobs Associates, TR 101 Contract No.OCD-DAHC 20-67-C-0136 Sub-Contract 12652 (6300A-340) for SRI March, 1969.

8. Wickham, G.E., T.N.Williamson - Operational Planning Debris Removal - Jacobs Associates, TR 110 Contract No.OCD-DAHC 20-70-C-0305 July 1971.


WHAT DO YOU CALL THIS MESS?
FROM THE LOOKS OF IT, I'D SAY IT'S ABOUT 50,000 CU YD OF TYPE 5 DEBRIS

PANEL 22

VOLUME II

WHAT THE PLANNER NEEDS TO KNOW

ABOUT DEBRIS REMOVAL OPERATIONS

PREFACE TO VOLUME II

This discussion of debris clearing operations is intended to provide the operational planner with basic information needed to effectively assess, implement and complete various debris clearing tasks which are crucial to the successful completion of emergency operations following a nuclear attack. It considers the following aspects: determining the type and amount of debris to be handled, defining the clearing task, assessing the capability and deployment of available resources, and time required for completion of various tasks. Although not included in the considerations, it comments on possible restraints due to fallout and fire situations. It presumes that the reader is familiar with material in Volume I and generally acquainted with emergency operational procedures of the early post-attack period.

Information is presented in the form of 'panels', each consisting of a page of text and an associated sketch, photograph, chart or other visual image. Each panel covers a specific topic. This preface is like a panel, with the list of topics in Volume II shown opposite. If the graphic portion is converted to slides or vugraphs, the panels can be used in an illustrated lecture or briefing, should that be desired.

The ordering of topics begins with two introductory panels, followed by five panels reviewing the debris characteristics needed to define the task to be done. There are next five panels discussing equipment to be used in the clearing operation, and then a panel describing other resources that will be required. The following three panels deal with equipment working in integrated groups. Three panels discuss resource inventories and the use of map overlays for visualizing these inventories. The subsequent eight panels take the planner from pre-attack planning, through mobilization, assignment of resources in the post-attack period and an examination of the total effort required during the early days of the clearing operation. Finally a list of suggested additional reading is included for those who are interested in further information on the general subject.

CONTENTS OF VOLUME II

WHAT THE PLANNER NEEDS TO KNOW ABOUT DEBRIS CLEARING OPERATIONS

OBJECTIVES OF CLEARING OPERATIONS

Emergency actions to be undertaken immediately following a nuclear attack will be directed primarily toward the rescue and evacuation of survivors within the devastated area. Thus an initial objective of debris clearing operations is to provide necessary access routes so that rescue functions can be undertaken. Access routes will also be needed to obtain emergency equipment such as fire trucks and ambulances; to reach facilities such as hospitals, large buildings still safe for sheltering survivors, factories and storage areas containing vital supplies; and to repair and maintain essential utilities. Debris clearing can also serve as a fire fighting tool by making firebreaks around burning areas. This would be especially valuable if the water supply to the area had been cut off or if no usable fire fighting equipment was available.

PANEL 1

PANEL 1

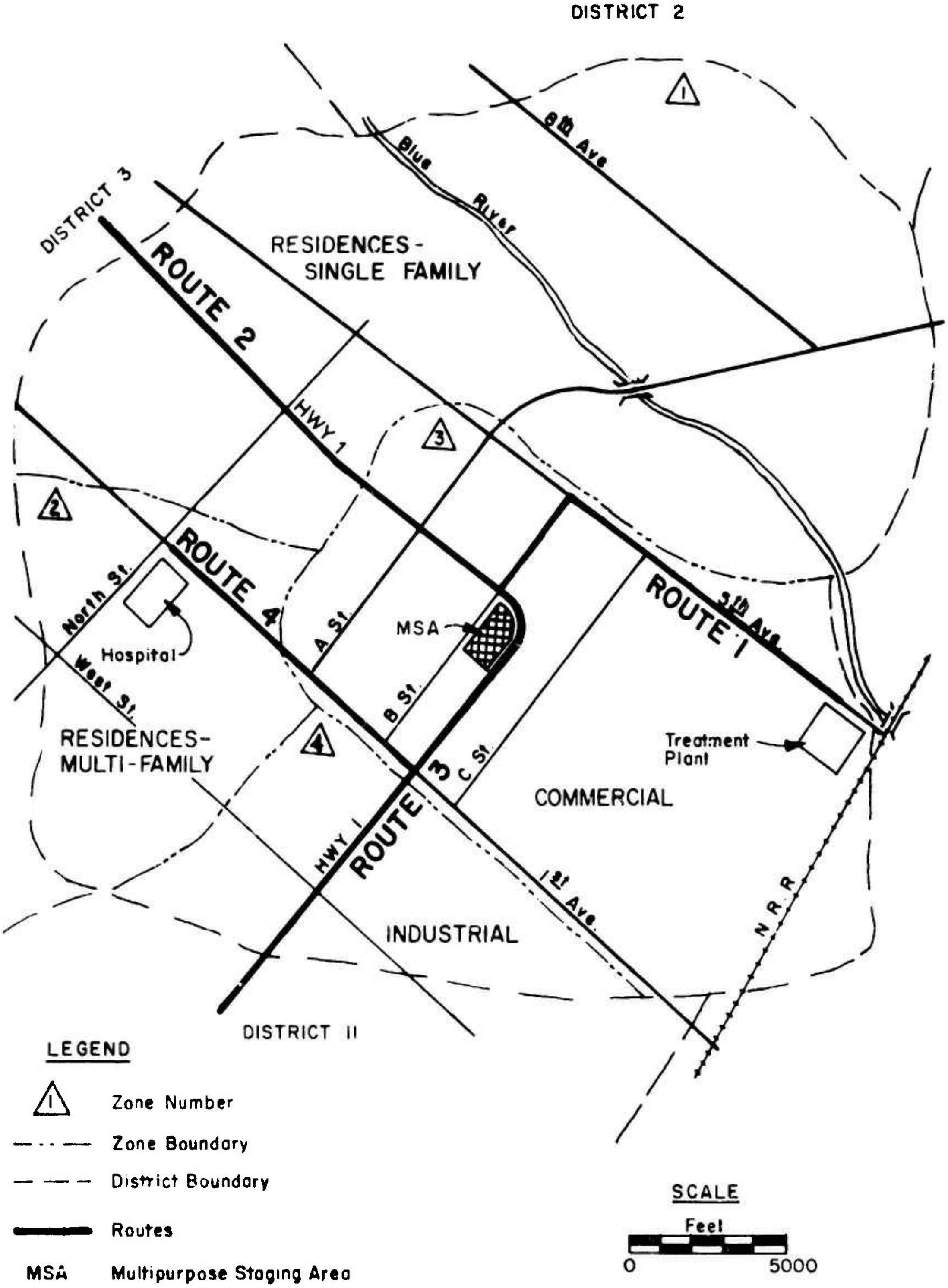
AREA ZONE MAP

As envisioned by present planning, urban areas will be divided into districts ranging in size from 10 to 25 square miles. Each district would be subdivided into several zones within each of which, for a given attack condition, a uniform debris environment (type and quantity) could be expected due to similarity of building types, densities and street patterns. Number, size and shape of districts and zones would depend on the particular area being considered, taking into account its physical configuration and other features pertinent to survival. Each district would have an operational headquarters or Multipurpose Staging Area (MSA), possibly a large shopping center, as near the middle of the District as possible. Debris clearing and other emergency operations within and between districts will be directed and coordinated from this headquarters. An MSA could be set up to house the Direction and Control (D&C) organization which will coordinate all emergency activities for the entire urban area.

The boundaries of these predetermined districts and zones would be shown on a large scale map of the urban area being considered. This map, called an Area Zone Map (see Volume I) would also show the locations of all critical facilities and pertinent physical features within the area as well as the various access routes which would most likely be used in the performance of emergency operations. These routes would probably pass through several districts and their respective zones.

A hypothetical district with four zones and a central MSA is shown opposite. The scaled lengths of the preplanned evacuation and access routes indicated on the map by heavy lines, provide the planner with an approximation of the extent of clearing operations which may be required within the District. The time and resources needed to accomplish the operations would depend on type and quantity of debris to be handled which in turn is dependent on degree of damage experienced within the individual zones through which the route passes. Pre-attack planning would familiarize personnel with potential problems or emergency requirements of the district and would provide a general appraisal of debris environments which may be anticipated due to various attack conditions. During any pre-attack warning period, the supplies, equipment, personnel and other resources which had been determined to be necessary would be assembled at the MSA. Similar procedures would be followed in each district, thereby providing an overall evaluation of the potential mobilization requirement for the area.

DISTRICT 7



PANEL 2

DEPTH AND TYPE OF BUILDING DEBRIS

Primary source of debris will be from buildings that are damaged or destroyed by the initial blast wave of the detonation. This debris could include every sort of construction material and remains of the content of buildings, whether homes, businesses, factories or warehouses. Subsequent fire spread through the area could consume some of the debris, reducing its quantity, but it might also weaken structures such as steel frames causing them to collapse, adding to the debris. Thus in any area there can be two different debris environments to consider for any given attack, one for 'blast only' and one for 'blast and fire'. The debris which concerns the planner in the emergency clearing operation is 'off-site debris' — the debris that is trajected from the building and remains in the streets or thoroughfares.

An approximation of the average depth and type of this debris can be made by following the procedure discussed in Volume I. This procedure, referred to as a Debris Prediction Survey (DPS), considers the physical characteristics and configuration of individual zones and respective predetermined factors pertaining to debris generation and distribution. A survey would be made for each zone with results summarized in a DPS sheet. The one shown here is for Zone 3 of the District shown in Panel 1. In essence the DPS sheet provides guidelines for predicting off-site debris due to various assumed or actual attack conditions, Column (5) supplying the average depth and Column (6) the type.

In the planning stage, depth and type of debris would be determined on the basis of predicted overpressures, Column (1), with respect to either 'blast only' or 'blast and fire' conditions. In the post-attack period, observed degree of damage such as light, moderate, or severe, Column (2), would be used considering the highest overpressure indicated for the damage category.

The numerical coding noted for type of debris in Column (6) is based on previous determinations of potential size and relative mix of various structural elements contained within debris resulting from partial or complete destruction of different types of buildings. These debris types, which are also discussed in Volume I, are listed in order of relative difficulty of handling during clearing operations: Type '1' debris being the easiest to remove and '6' indicating the type of debris most difficult to handle. This is a relative evaluation of debris content.

Structural Element	Debris Type
None	1
Light wood	2
Heavy wood	3
Light steel	4
Medium steel	5
Heavy steel	6

Completed Debris Prediction Surveys, reflecting average conditions for a typical block for each zone throughout the District, provide an indication of potential debris environments that may be encountered during clearing operations.

DPS SHEET

DEBRIS PREDICTION Date 12 Jan 1975 City ____ District 7 Zone 3

(A) Block Size 300' x 400' (B) Street Width: to Curbs 60'; to Bldg Lines 80' (C) % Bldg Coverage 70

(D) Avg Bldg Height 40' (E) Building Type-Use 5-C (F) Trees, Poles, etc. Few

(G) Comments Commercial - wholesale

(H) EBD 77' (I) Contained Volume 3080 cu ft/ft (J) Material Factor: Blast 0.44; Blast and Fire 0.24

(K) Potential Debris Material: Blast 1355 cu ft/ft; Blast and Fire 739 cu ft/ft (L) Avg Depth Factor 0.008

PREDICTED ENVIRONMENTS

ATTACK CONDITION	(1) Incident Over-pressure psi	(2) Damage Light-L Moderate-M Severe-S	(3) Off-Site Factor	(4) Volume Off-Site Debris cu ft/ft	(5) Average Depth Feet	(6) Predicted Debris Type
BLAST ONLY	2	L	-	-	-	3
	4		.01	14	0.11	3
	6	M	.04	54	0.43	5
	8		.10	136	1.09	5
	10		.18	244	1.95	5
	12	S	.27	366	2.93	6
BLAST AND FIRE	2	L	-	-	-	3
	4		.01	7	0.06	3
	6	M	.04	30	0.24	5
	8		.10	74	0.59	5
	10		.18	133	1.06	5
	12	S	.27	200	1.60	6

PANEL 3

OTHER DEBRIS INCLUSIONS

Intermixed with the building debris will be downed trees, utility poles, light and sign standards, damaged vehicles and possibly collapsed overhead structures. These inclusions could add appreciatively to the difficulty of clearing and in some instances make it virtually impossible to complete a task within a reasonable period of time. With the exception of vehicles, the potential quantity or magnitude of these inclusions can be appraised when making the debris prediction survey. A quantitative evaluation of their effect on clearing operations cannot be made except to indicate additional effort or increased degree of difficulty in handling the debris. For instance, if a building Debris Type 3 had been determined for a zone which contained a large number of metal standards, a Debris Type 4 would be used for determining clearing requirements.

The presence of damaged vehicles, which would probably present the most serious restraint, would vary with respect to local traffic conditions at time of the attack. By means of traffic studies, it would be possible to predict the number of vehicles expected within an area based on time of day and day of week. The traffic or potential number of vehicles can be expressed in the relative terms: light, medium or heavy. Their presence within the debris has different effects on clearing operations. In areas where debris is light and space available, damaged vehicles can be pushed aside with little additional effort. In heavy debris, the overall task is such that their presence would not materially affect the total operation. Between these two extremes, damaged vehicles could have a marked influence on the type of equipment and time required for clearing. Their effect on the clearing requirement is considered with respect to the overall production of clearing equipment as discussed in Panel 12.

It is apparent that these evaluations of the effect of various inclusions are primarily a judgement factor and take into account incident overpressures experienced within the respective areas. Overpasses would probably not collapse when subjected to overpressures less than 8 psi; most vehicles would still be operable after exposure to overpressures less than 3 psi.

VEHICLE DAMAGE
AT 5 PSI, NEVADA
TEST SITE; BOTH
VEHICLES OPERABLE

FREEWAY
OVERPASS
COLLAPSE
1971 CALIFORNIA
EARTHQUAKE

PANEL 4

MEANDERING PATHS AND TYPE OF OPERATION

Although Panel 3 discusses average depth it is apparent that off-site debris will be randomly scattered along the streets. In some instances there could be fairly large isolated piles of debris with intermittent areas containing little or no debris. Since speed of opening access routes would be of prime importance in the emergency period, the clearing equipment may follow a meandering path of minimum depth. The distribution of off-site debris, which is dependent on height and densities of buildings, width of street and incident overpressure, can only be approximated. In instances of severe damage uniform distribution is assumed. As illustrated by the sketches, anticipated depth of debris along a meandering path would be somewhat less than the determined average depth. To allow for this variation in depth, the determined average depth is multiplied by a factor as shown below.

Meandering Path Factor

Degree of Damage		
Light	Moderate	Severe
0.50	0.75	1.00

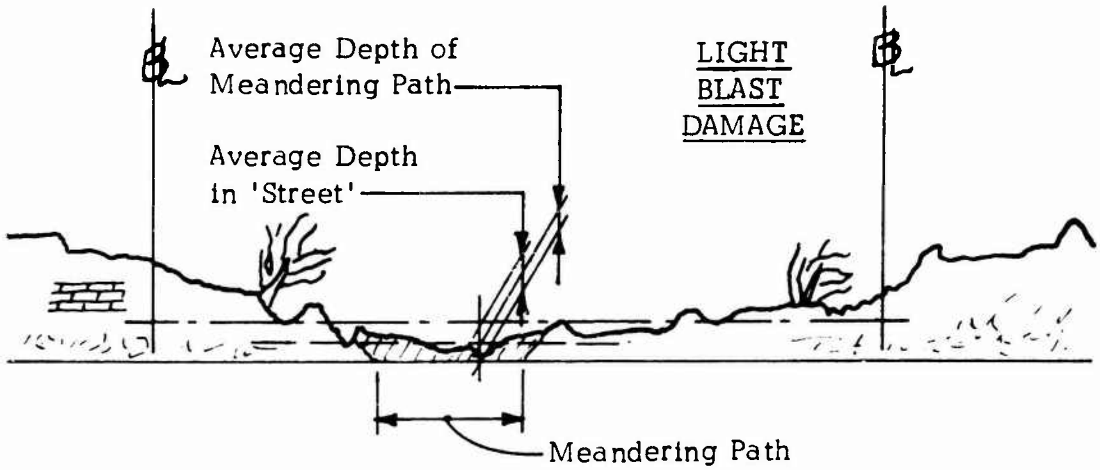
There are three types of operations which will be used for debris clearing: (1) dozing — pushing the debris aside, (2) load-and-haul — loading debris into trucks and hauling to a disposal area, and (3) a combination of the two. Determination of what type of operation to use requires a knowledge of the capabilities of available equipment, the physical features along the route such as street widths, etc., and the anticipated depth and type of debris to be handled.

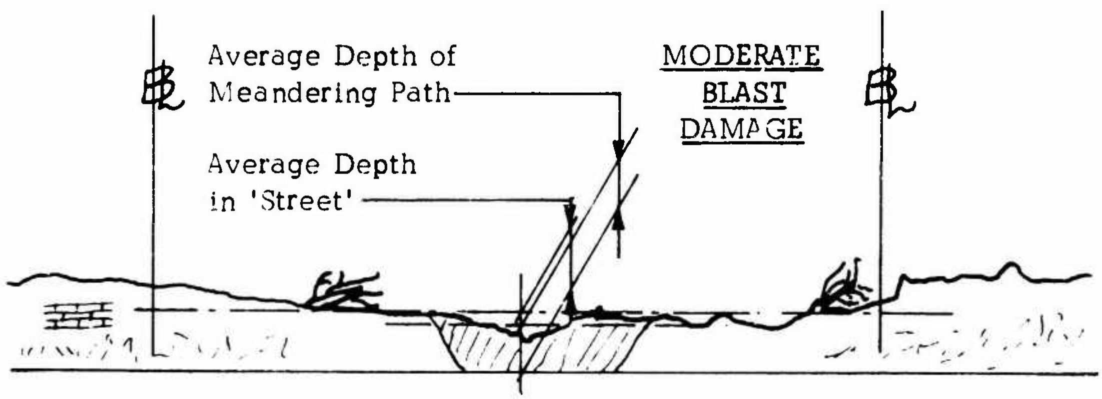
Dozing would probably be used in areas with depths of debris less than 3 or 4 feet, with fairly wide streets or adjacent vacant areas into which the debris could be pushed. Debris in a narrow downtown street, flanked by remains of high rise office buildings would have to be loaded into trucks and hauled to a disposal site.

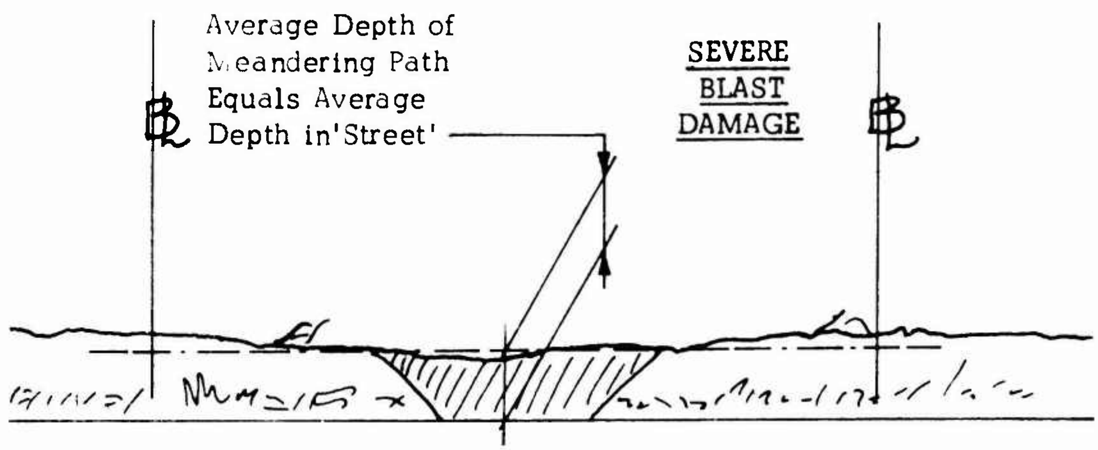
Most emergency clearing would consist of dozing where possible, but eventually all debris must be loaded and removed.

The choice of operation type for use in any particular clearing task would be made by the local Debris Manager. In subsequent discussions the types of operations are noted as (1), (2), or (3).

MEANDERING PATHS







PANEL 5

ZONE SITUATIONS

During the early post-attack period the debris environment will probably not be defined as due to specific overpressures. Instead, damage assessments will be reported in terms of degree of blast and fire damage determined by visual inspection of the devastated area. Following a concept which has been used in other attack analyses, these damage criteria can be described by using the number designations shown in the table. Blast damage varies with respect to type of building being considered and is rated 'light', 'moderate', or 'severe'. Degrees of fire damage are noted as 'negligible', 'moderate', or 'severe'. Zone situations are determined by appropriate numbers from the table which relate observed blast damage and fire damage. Numbers 1, 2, and 3 would reflect 'blast only' condition as used on the DPS sheet. Blast and fire condition would relate to Situations 7, 8 and 9. Situations 4, 5 and 6 represent a degree of damage between the two such as a partially burned area or a controlled fire situation. Blast damage — light, moderate or severe — is used to correlate zone situations with various attack conditions assumed for the DPS sheet by considering the highest incident overpressure (Column 1) shown within the range of damage (Column 2). Zone situation numbers provide a convenient, uniform method of making damage assessments and a means of correlating pre-attack and post-attack determinations. For instance, if a Zone Situation of 3 was reported for Zone 3 of District 7, the anticipated debris would be identified as Type 6 with an average depth of 2.93 feet (See DPS sheet for 'blast only' condition and severe damage.) If the area was subsequently subjected to severe fire (Situation 9) the debris indicated by the 'blast and fire' condition would be Type 6 with an average depth of 1.6 feet.

It is apparent that the existing or potential fire situation in a zone would have to be evaluated before initiating clearing operations. In addition, it will also be necessary to consider potential exposure of the clearing crews to radiation and fallout. This hazard, which is discussed in chapters of the DCPA Attack Environmental Manual, does not affect the physical properties or requirements of the clearing operation but obviously could be a governing factor as to whether or not clearing operations should be initiated or conducted in any particular area.

ZONE SITUATIONS

DEBRIS ENVIRONMENTS

	Negligible Fire Damage	Moderate Fire Damage	Severe Fire Damage
Light Blast Damage	1	4	7
Moderate Blast Damage	2	5	8
Severe Blast Damage	3	6	9

PANEL 6

DEFINING THE CLEARING TASK

To determine requirements for any materials handling task, the task itself must first be defined. For a debris clearing task the definition would include the length and width of the route to be cleared and the type and quantity of debris to be removed.

In the pre-event planning a network of routes connecting all districts of the metropolitan area should be laid out for consideration in early clearing operations. This layout should include any additional paths needed to reach essential facilities and places in which large groups of people are likely to survive. These routes should be selected with regard to the types and quantities of debris that may be expected along them to insure a high probability of rapid opening of the routes. In general, wide streets lined with low buildings set back from the curb will be the preferred routes. Panel 3 discusses a method (DPS) by which approximations can be made of type and average depth of debris to be expected along the respective routes. By comparison of these debris predictions for several alternative routes to a given objective a selection of the most desirable route can be made. This route should also be examined for possible heavy traffic or other restrictions.

In the actual post-attack situation, it may be found that different or additional routes may become essential. The planner will make adjustments in his layout for these deviations from plan and then set up a list of tasks he must accomplish with a description of each. Typical routes are shown on the map of District 7, Panel 2. Highway 1 has been 'strip-zoned' for Commercial Retail through Zone 3. The remainder of Zone 3 is Commercial, Office Buildings.

This list, similar to the Route Descriptions shown, will designate the routes by number with a brief description of where each is to start and end, the objective and the length and width of the path. If a route passes through several zones or different debris environments (depth and type) then the route will be divided into respective sections or tasks as indicated by the addition of a letter to the route number.

A Task Definition form similar to the one shown can then be completed by using the information from respective DPS sheets or as may be reported by observers after the attack.

During pre-attack planning the various tasks can be defined on the basis of assumed overpressures and fire conditions. This will provide the planner with a general range of magnitude for debris clearing requirements anticipated within the respective zones. In the post-attack period the task definitions would probably be made on the basis of reported damage of Zone Situations. If moderate damage was assumed or observed for Zone 3 then Task 1a would be defined as shown. The other tasks are defined merely to illustrate the procedure. The quantity and type of debris and anticipated inclusion of damaged vehicles (Traffic Content) are used to determine equipment requirements and productivity as discussed later. The type of operation noted is the Debris Manager's appraisal of the most efficient method to use (see Panel 5) and may be adjusted when considering available equipment.

ROUTE DESCRIPTIONS — DISTRICT 7

Route 1 from MSA to Treatment Plant, length 15,100 feet, width 20 feet for repair crew.
Route 2 from MSA to District 3, length 17,900 feet, width 50 feet for evacuation along Hwy 1.
Route 3 from MSA to District 11, length 12,400 feet, width 50 feet for evacuation along Hwy 1.
Route 4 from Hwy 1 and 1st Ave along 1st Ave to Hospital, length 10,500 feet, width 30 feet for two-way traffic.

TASK DEFINITION

Route No.	Zone No.	Task No.	Type of Oper	Degree of Damage	Length feet	Width feet	Average Depth feet	Meander Factor	Quantity of Debris cu yd	Type of Debris	Traffic Content
1	3	1a	1	M	15,100	20	1.95	0.75	16,360	5	H
2	3	2a	1	M	7,600	50	1.70	N.A.	23,900	4	M
	1	2b	1	M	10,300	50	0.03	N.A.	570	1	M
3	3	3a	1	M	5,400	50	0.38	N.A.	3,800	3	M
	4	3b	1	M	7,000	50	0.06	N.A.	780	3	M
4	3	4a	1	M	5,800	30	0.18	0.75	870	3	M
	2	4b	1	L	4,700	30	0.09	0.50	235	3	L

N.A. - For widths greater than 30' the use of a Meandering Factor is not applicable.

Quantity of Debris = Length x Width x Average Depth x Meandering Factor $\div$ 27.

PANEL 7

EQUIPMENT FOR CLEARING OPERATIONS

The most useful equipment used in clearing operations includes bulldozers, front-end loaders, motor graders and shovels. These may be track-mounted (crawler) or rubber-tired (wheeled). In general, crawler mounted equipment is more suited to climb over debris. Other equipment which could be used include clamshells, backhoes, scrapers, cranes, trucks and other miscellaneous equipment. These also may be track-mounted or rubber-tired except graders, scrapers and trucks which are all rubber-tired.

All of these items are standard construction equipment. The main source will be contractors, public utilities, government agencies, (municipal, county, state and federal) and equipment dealers including rental companies.

The familiar bulldozer pictured here is the work horse of the dozing operation (Type 1). However the front-end loader and motor grader can be used, though less effectively, for the same operation.

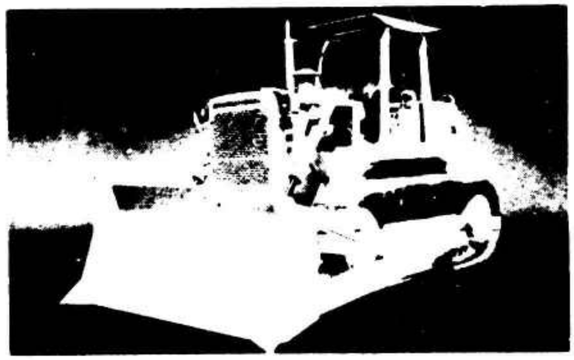
For load-and-haul operations (Type 2) the front-end loader can be used by itself, though inefficiently, since it can pick up a bucketful of debris and carry it to a dump site. In general, however, the load-and-haul operation would imply a front-end loader with two or more dump trucks, the loader loading the debris into the trucks for hauling to the dump site. Various kinds of shovels and clamshells can be used in the same fashion.

The combination operation (Type 3) would normally be carried on by using a bulldozer with a front-end loader or shovel supported by two or more dump trucks. Here the bulldozer could fill two functions, that of actually clearing the path by dozing and that of gathering the debris for more efficient pickup by the loading equipment.

If a crane is available its use would be to pick up large elements in the debris that cannot be dozed out of the way or lifted by the other equipment available.

PRIMARY EQUIPMENT

BULLDOZER
Wheeled



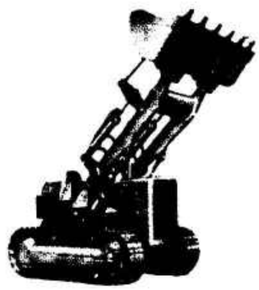
BULLDOZER, Crawler

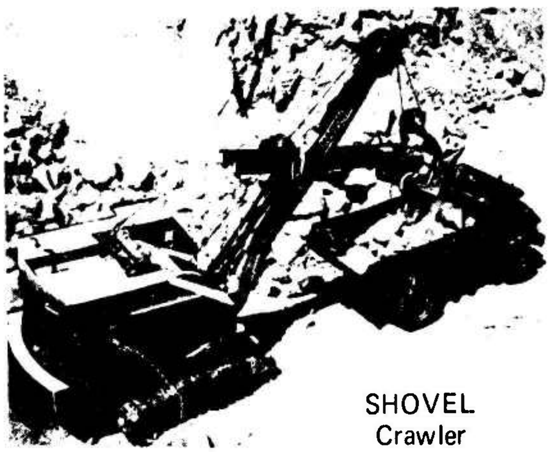
MOTOR GRADER

Wheeled

FRONT-END LOADERS

Crawler





SHOVEL
Crawler

SHOVEL
Wheeled

DUMP TRUCK

CLASSIFICATION OF EQUIPMENT

The equipment used for debris clearing would include a great many different makes and models of basically the same type of equipment having similar operating characteristics and production capabilities. Since it is unlikely that each and every make or model could be effectively considered in the post-attack period, typical debris clearing equipment has been grouped into several general classifications such as 'bulldozers' or 'front-end loaders'. Each classification, as noted by the numerical code shown on the table, is subdivided with respect to major characteristics such as horsepower rating, production capacity, or whether the equipment is track-mounted or rubber-tired. For example, the Code '282' refers to all makes and models of crawler type bulldozers of from 150 to 200 horsepower rating. This classification of equipment by numerical code will facilitate various inventorying and assignment requirements which are discussed later. Subsequent reference to equipment will be by code number.

CLASSIFICATION OF EQUIPMENT — CODE NUMBERS

Horsepower Rating or Capacity	Bulldozers		Front-End Loaders				Motor Graders	Shovels		Clamshells		Backhoes		Scrapers		Cranes		Trucks
			End-Dump		Side-Dump													
	Crawl	Wheel	Crawl	Wheel	Crawl	Wheel	Wheel	Crawl	Wheel	Crawl	Wheel	Crawl	Wheel	Self-Propel	Self-Load	Crawl	Wheel	Wheel
Up to 150 HP	280		160	161	170	171	141											
150 to 200 HP	282	283	162	163	172	173	143											
200 to 250 HP	284	285	164	165	174	175	145											
250 to 300 HP	286	287	166	167	176	177												
Over 300 HP	288	289		169		179												
Up to 1 cu yd								260	261	080	081	020	021					
1 to $1\frac{1}{2}$ cu yd								262		082	083							
$1\frac{1}{2}$ to 2 cu yd								264		084	085							
2 to 3 cu yd								266		086	087							
1 to 2 cu yd												022	023					
2 to 3 cu yd												024	025					
3 to 10 cu yd								268		088	089			251	255			311
10 to 15 cu yd														253	257			313
15 to 20 cu yd																		315
Up to 11 tons																070	071	
11 to 20 tons																072	073	
Over 20 tons																074	075	
Low Bed Truck																		317
Service Truck																		751
Tire Truck																		753
P.O.L. Truck																	—	755

EQUIPMENT OPERATING REQUIREMENTS

In planning for or using equipment it is necessary to know what personnel and supplies — petroleum (fuel), oil and lube (P.O.L.), etc., will be needed for its operation.

Debris clearing equipment, as shown in Panel 9, has been grouped into general classifications each of which encompasses several different makes and models with essentially the same operating requirements or characteristics. Average requirements for each hour of equipment operation are shown for each classification. Labor is considered in four grades of skill and noted as 1 = Operators, 2 = Mechanics, 3 = Semi-skilled including drivers and 4 = Unskilled. Manhours required of each skill for each hour of equipment operation is shown in the respective columns. P.O.L. requirements per hour of operation are shown as gallons or pounds as noted.

No allowance is made for hourly requirements of repair parts or tires as it is assumed that all equipment will be in good working condition at the start of clearing operations. Any equipment requiring major repair would probably be abandoned during the clearing operation and other equipment used in its place.

In considering debris clearing operations, an approximation of total requirements can be made by multiplying the shown hourly requirements by the total hours of equipment operation. Assume a bulldozer, Code 286, requires 200 hours to complete a task. Labor and P.O.L. requirements would be as follows:

Operator (Grade 1)	200 hours
Mechanics (Grade 2)	66 hours
Diesel Fuel	2,820 gallons
Lubrication	140 pounds
Oil	54 gallons

The equipment operating hours used to determine requirements should include actual time of clearing plus allowance for mobilization, moving between tasks or other non-productive time as may be applicable. These non-productive hours would probably amount to 15-25% of actual time of clearing.

EQUIPMENT SUPPLY REQUIREMENTS AND PERTINENT SPECIFICATIONS

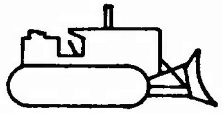
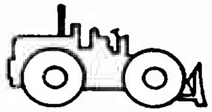
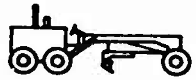
EQUIPMENT		P.O.L. REQ/HR				LABOR/HR		
		GAS	DIES.	LUBE	OIL	GRADE		
TYPE/ MOUNT	CODE	GAL	GAL	LB	GAL	1	2	3
DOZERS								
Crawler	280	-	5.0	.4	.14	1	.20	-
	282	-	8.0	.4	.17	1	.25	-
	284	-	11.3	.5	.24	1	.30	-
	286	-	14.1	.7	.27	1	.33	-
	288	-	16.6	.8	.40	1	.41	-
Wheel	283	-	7.5	.3	.17	1	.23	-
	285	-	10.0	4	.20	1	.25	-
	287	-	13.7	.7	.30	1	.35	-
	289	-	17.5	.7	.44	1	.47	-
FRONT END LOADERS								
End Dump								
Crawler	160	-	5.0	.5	.11	1	.22	-
	162	-	7.5	.6	.16	1	.31	-
	164	-	10.0	.7	.21	1	.35	-
	166	-	11.5	.9	.25	1	.37	-
Wheel	161	-	5.6	.3	.13	1	.24	-
	163	-	8.1	.6	.17	1	.40	-
	165	-	10.5	.7	.22	1	.37	-
	167	-	13.5	.8	.30	1	.42	-
	169	-	15.1	.8	.35	1	.46	-
Side Dump								
Crawler	170	-	5.0	.5	.11	1	.24	-
	172	-	7.5	.7	.17	1	.34	-
	174	-	10.0	.7	.21	1	.36	-
	176	-	11.5	.9	.25	1	.40	-
Wheel	171	-	5.2	.4	.11	1	.26	-
	173	-	8.0	.6	.17	1	.40	-
	175	-	10.7	.7	.22	1	.39	-
	177	-	13.7	.8	.31	1	.45	-
	179	-	14.5	.8	.33	1	.47	-
GRADERS								
Wheel	141	-	5.8	.3	.13	1	.23	-
	143	-	7.3	.3	.17	1	.25	-
	145	-	10.0	.4	.22	1	.28	-
SHOVEL								-
Crawler	260	-	3.7	.8	.08	1	.29	-
	262	-	7.0	1.0	.15	1	.32	-
	264	-	9.5	1.2	.20	1	.38	-
	266	-	10.3	1.5	.20	1	.45	-
	268	-	10.8	1.8	.23	1	.60	-
Wheel	261	3.0	4.0	.8	.20	1	.30	-
CRANES								
Crawler	070	-	4.0	.7	.09	1	.32	-
	072	-	6.0	.8	.10	1	.38	-
	074	-	9.0	1.1	.14	1	.52	-
Wheel	071	-	6.5	.5	.18	1	.33	-
	073	8.0	-	.3	.10	1	.35	1
	075	8.0	3.1	.9	.20	1	.50	1
TRUCKS								
Wheel	311	5.0	-	.10	.03	-	.15	1
	313	-	6.0	.12	.04	-	.18	1
	315	-	7.0	.14	.05	-	.20	1
	317	4.5	4.5	.35	.21	-	.16	1
Service Truck	751	2.0	-	.04	.02	-	.10	1
Tire Truck	753	2.0	-	.04	.02	-	.10	1
P.O.L. Truck	755	2.0	-	.06	.03	-	.10	1
Sweeper	757	2.0	2.0	.15	.08	-	.15	1
Air Compr. & Tools	600	-	3.0	.20	.07	-	-	-
Light Plant & Access.	602	0.8	-	.01	.01	-	-	-

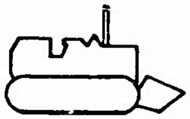
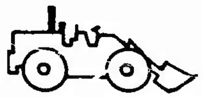
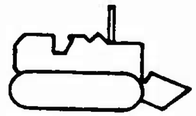
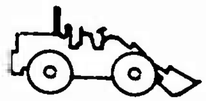
EQUIPMENT PRODUCTION - STANDARD

To determine or compare the time needed for different pieces of equipment to accomplish a given task some common measures of production must be established. Using a material such as 'well-blasted rock' it is possible to establish standard production rates for each type of equipment. In the table shown here, these standard production rates are given in cubic yards per hour for each type of equipment. The types of equipment are identified by the numerical code shown in Panel 9. These rates are based on handling well-blasted rock at such depths as to afford maximum production for the given piece of equipment and assume no restrictions imposed on the operation, such as limited working space. They are based on a 50-minute working hour and all volumes are loose measure.

The equipment shown in this Standard Production Rate table is designated 'Primary Equipment' since, in the emergency debris clearing activity, this equipment will control the production rate of the operation. It is the equipment most commonly used in debris removal operations.

STANDARD PRODUCTION RATE — PRIMARY EQUIPMENT

	BULLDOZERS				MOTOR GRADERS	
	CRAWLER 		WHEEL 		WHEEL 	
Horsepower Rating	Code Number	Std Prod Rate cu yd/hr	Code Number	Std Prod Rate cu yd/hr	Code Number	Std Prod Rate cu yd/hr
Up to 150	280	140	-	-	141	160
150 to 200	282	230	283	190	143	200
200 to 250	284	330	285	275	145	280
250 to 300	286	400	287	350	-	-
Over 300	288	520	289	530	-	-

	FRONT-END LOADERS							
	END-DUMP				SIDE-DUMP			
	CRAWLER 		WHEEL 		CRAWLER 		WHEEL 	
Horsepower Rating	Code Number	Std Prod Rate cu yd/hr	Code Number	Std Prod Rate cu yd/hr	Code Number	Std Prod Rate cu yd/hr	Code Number	Std Prod Rate cu yd/hr
Up to 150	160	100	161	130	170	125	171	155
150 to 200	162	140	163	185	172	190	173	220
200 to 250	164	185	165	250	174	215	175	300
250 to 300	166	245	167	330	176	290	177	400
Over 300	-	-	169	430	-	-	179	525

EQUIPMENT PRODUCTION - DEBRIS

Actual production rates when handling debris may fall well below the 'standard' rates which are established for a fairly uniform material. The actual rates are influenced by the maximum fragment size, the average and maximum depths and composition of the debris, and by the traffic content. The debris type designation in Column (6) of the DPS sheet, Panel 3, incorporates all these factors except the traffic content.

The accompanying table has been prepared to show the relationship between debris type and production rates for several types of primary equipment and includes the effect on production rate of various amounts of traffic inclusions. The rates are based on having adequate working space for the equipment. To illustrate the use of the table, assume an incident overpressure of 10 psi, no fire, and heavy traffic for Zone 3 of Panel 3. For these conditions the predicted debris type shown on the DPS sheet is 5. Subjected to an overpressure of 10 psi, many of the vehicles will be inoperable so the 'traffic inclusions' will be 'heavy'. Now assume the availability of a Code 165 front-end loader whose standard production rate is 250 cubic yards per hour (Panel 11). Enter the table here with Debris Type 5 and locate the required factor in the 'H' column of the front-end loader group. The factor is 0.25. Therefore the production rate expected of the available equipment is 250 x 0.25 = 63 cubic yards per hour. If this piece of equipment were used to complete Task 1a (Panel 7) it would require 260 hours of operation (16,360 ÷ 63).

EQUIPMENT PRODUCTION ADJUSTMENT FACTORS

FOR

DEBRIS TYPE AND TRAFFIC INCLUSIONS

EQUIP. / TRAFFIC INCLUSIONS / DEBRIS TYPE	BULLDOZER			FRONT-END LOADER			SHOVEL		
	L	M	H	L	M	H	L	M	H
1	.95	.93	.86	.93	.91	.86	.48	.47	.47
2	.73	.72	.67	.72	.70	.66	.43	.42	.41
3	.71	.58	.55	.70	.55	.52	.41	.40	.38
4	.52	.43	.40	.51	.47	.42	.37	.32	.26
5	.33	.33	.22	.36	.36	.25	.24	.24	.16
6	.18	.16	.16	.20	.18	.18	.13	.12	.12

Abbreviations

L - Light Traffic Content
M - Moderate Traffic Content
H - Heavy Traffic Content

PANEL 12

OTHER RESOURCES

Not all of the activities necessary in the emergency clearing operations can be performed by the heavy equipment discussed in the preceding panels. Large pieces of debris may have to be sawn, cut, jackhammered, blasted or fastened to a tractor and pulled out of the way rather than being pushed aside. Metal and wood cutting outfits, blasting equipment and materials, hand tools, ropes, chains, pulleys, two-way radios and other supplies will probably be needed.

The accompanying table lists the auxiliary equipment and supplies which may be available at the MSA for assignment with the equipment sent out. Such a list may serve a dual purpose: as a check list during assignment and as a record of what auxiliary items were dispatched. For illustration in this chapter, these items have been divided into three sets, and each set has been assigned a code number. In assigning the type and number of sets to any particular clearing task the Debris Manager must consider the original building debris type and other inclusions which may be encountered. Supply Set 620 would be required for all tasks. Sets 621 and 622 would be assigned on the basis of the appraised type and quantity of debris to be handled.

In addition, other auxiliary equipment will be needed. Air compressors and tools (Code 600) may be needed for demolition; light plants and accessories (Code 602) will be needed for night work; and fuel and supply trucks will be required to service the various task operations. The need for these items is dependent on specific task conditions and would be assigned individually as problems were encountered along the route.

Manpower required to operate this equipment as well as labor necessary for demolition work would be in addition to labor requirements indicated for the primary equipment operation.

SUPPLIES, HAND TOOLS AND MANUAL LABOR

Item Description	Equipment and General Supply Set Code 620	Steel Demolition Set Code 621	Wood Demolition Set Code 622
Two-way radios, set	1		
Hard hats	6		
Protective clothing, set	6		
Dosimeter	1		
Stretchers, Blankets, etc.	1 each		
First aid kits	2		
Drinking water, cups, etc., kit	1		
Rope, cable and pulleys, kit	1		
Crow bars, sledge hammers, axes	3 each		
Hand shovels	3		
Fire extinguishers	2		
Wrenches, firemain, etc., kit	1		
Spader points, mauls, etc., kit		1	
Cutting torches		2	
Oxygen and acetylene tanks, set		1	
Dynamite (with detonators, etc.)		25 lb	
Wire cutters		1	
Jacks, kit		1	1
Timber cants and hooks, kit			1
Power saws - hand			2
Labor - semiskilled (Grade 3)		2 men	
unskilled (Grade 4)	2 men	2 men	3 men

EQUIPMENT GROUPS - COMPOSITION

In most instances a group of equipment will be required to complete any particular task. An 'equipment group' can vary from one bulldozer and hand tools to a combination of shovels, front-end loaders, and/or bulldozers with trucks, cranes and miscellaneous tools. Part-time allocation of fuel trucks and other service vehicles will be required.

The planner or debris manager should consider the possible debris clearing tasks with which he may be faced and how the equipment tentatively assigned to his district could be used to complete these anticipated tasks.

In the pre-attack planning period, provisional equipment groups can be set up using the anticipated equipment and matching the most suitable equipment to the various tasks considered. This should be done for the various situations and for a sequence of tasks starting with the clearing of narrow paths for rescue, firefighting and access to facilities and concluding with the opening of major evacuation routes.

On the page opposite are listed six suggested equipment groups with the make-up of each, using the resource code numbers from previous panels. Although this predetermination is useful it is based on the assumption that all required resources will be available in the post-attack period. Since it is unlikely that this will be the case, the debris manager will probably have to modify the planned equipment groups using surviving resources.

The six groups shown can be used as a guideline of requirements for typical types of clearing operations and path widths. For emergency debris clearing operations the groups should be kept fairly small because of the limited working space (narrow width of paths) to be expected for most of the tasks to be accomplished. Extra equipment in a confined space reduces efficiency through mutual interference.

Each group, whether established in the pre-attack or post-attack period should be assigned a number and listed on a group card showing the number and type (code) of required resources.

Additional information such as the source or location of resources, P.O.L. requirements and production rates of the group should be added to the equipment group card to provide the planner with a statistical record of group requirements from initial mobilization through completion of the tasks. This is discussed in subsequent panels.

TYPICAL EQUIPMENT GROUPS
DEBRIS CLEARING OPERATIONS

Type of Operation		1		2		3	
Width of Route		20'	50'	20'	50'	30'	50'
Group No.		1	2	3	4	5	6
Resources Requirement — Code							
PRIMARY EQUIPMENT	284						1.00
	285	1.00					
	286		1.00			1.00	
	166						2.00
	174					1.00	
	176			1.00			
	179				3.00		
AUXILIARY EQUIPMENT	072	1.00	1.00	1.00			1.00
	073				1.00		
	751	0.10	0.15	0.15	0.20	0.15	0.25
	753				0.10		
	755	0.10	0.15	0.10	0.20	0.15	0.20
	313					2.00	
	315			2.00	7.00		4.00
	600				1.00		
	602	1.00	1.00	1.00	1.00	1.00	1.00
*SUPPORT LABOR	3	2.00	2.00		2.00	2.00	
	4	4.00	4.00	2.00	6.00	4.00	2.00
TOOLS AND SUPPLIES	620	1.00	1.00	1.00	2.00	1.00	1.00
	621	1.00	1.00		1.00	1.00	

*This labor is that shown in Panel 12.

EQUIPMENT GROUPS - CHARACTERISTICS

The hourly requirements of labor and P.O.L. supplies for an equipment group are essentially the sum of requirements for the individual resources used and can be determined from data provided in previous panels. Requirements for the six groups shown in Panel 14 are given in the upper table. Similar determinations, made for any equipment group, should be listed on the respective group cards (Panel 16). Total requirements needed to complete a task are found by multiplying the respective hourly requirements by the total hours of group operation plus an allowance for mobilization, etc. The labor and P.O.L. needed for all the equipment and tools shown in Panel 14 as a part of each equipment group have been included in the supply requirements shown.

Although group operation is dependent on performance of primary units of equipment, there are certain restrictions or characteristics that must be kept in mind. This relates, primarily to working space required for efficient operation. For instance, two bulldozers working together in clearing a narrow path can not operate as efficiently as working singly with no interference from the other. The effect of this space restriction when operating multiple units of equipment is primarily a judgement factor which the debris manager must appraise for each particular task. The lower table can be used as a guide in determining potential loss of efficiency when operating multiple units in different widths of path. If the two bulldozers mentioned above were clearing a 30' path the anticipated efficiency of each would be 70% of the production of one unit acting independently under unrestricted conditions. No factor is listed for those instances where it would not be practical to use multiple units for a particular path width.

It should be noted that although efficiency of individual units is reduced, the rate of production of the group is greater than that achieved by any one unit working alone. Group operations should be considered where time of completion is a governing factor.

EQUIPMENT GROUP SUPPLY REQUIREMENTS

Hourly Requirements for Group Operation								
	Man Hours per Labor Grade				P.O.L.			
Equipment Group Number	1 Oper-ator	2 Me-chanic	3 Semi-Skilled	4 Labor	Diesel gallons	Gas-oline gallons	Lubri-cation pounds	Oil gallons
1	2	0.7	2.2	4	16.0	1.2	1.2	0.3
2	3	1.1	2.3	4	34.2	1.4	2.2	0.7
3	2	1.2	2.3	2	31.5	1.3	2.0	0.5
4	4	3.2	10.5	6	95.5	9.8	3.9	1.5
5	2	1.1	4.3	4	36.1	1.4	1.7	0.6
6	4	2.3	4.5	2	68.3	1.7	3.7	1.1

MULTIPLE UNITS
Combination Factors

Width of Route	20 feet			30 feet			50 feet		
No. of Units	1	2	3	1	2	3	1	2	3
Equipment									
Bulldozer	1.0	0.6	-	1.0	0.7	0.5	1.0	0.9	0.7
F.E. Loader E.D.	0.7	-	-	1.0	0.6	-	1.0	0.7	0.4
F.E. Loader S.D.	0.9	0.4	-	1.0	0.7	-	1.0	0.9	0.7
Motor Grader	0.9	-	-	1.0	0.7	-	1.0	0.9	0.6

EQUIPMENT GROUPS - PRODUCTION

The production rates of equipment groups reflect the capabilities or production rates obtained by the primary equipment in the group. Where a single primary unit is used, such as a bulldozer Code 286, the standard production for the group will be 400 cubic yards per hour (Panel 11). If multiple units are used for a particular path width, the production rates of the individual units will be adjusted in general accordance with applicable factors shown in Panel 15. The upper table here lists the standard production rates determined for the six equipment groups listed in Panel 14. These rates will vary if a particular group is used in clearing a path width different from that shown. Standard production rates reflecting different path widths should be determined and then listed on the respective equipment group card.

It is assumed that the required auxillary equipment, such as trucks, is adequate to maintain determined production.

The standard production rate of a group is also adjusted with respect to type of debris and damaged vehicle inclusion in the same way as for individual units of equipment (Panel 12). For example if Group 2 (two bulldozers) is used to clear a 50-foot path through Type 4 debris with 'heavy' traffic inclusions, the anticipated rate of production is 288 cubic yards per hour (720 x 0.40).

A suggested format for an equipment group card is shown. When debris conditions are known (either assumed or actual) the anticipated actual production can be determined for a variety of tasks. This will enable the planner to appraise the effectiveness of a group with respect to several task assignments (usually on a basis of highest actual production) and also compare capabilities of different equipment groups in performing certain tasks. Since most routes to be cleared will pass through several zones (different debris conditions) the planner must keep in mind the overall requirement. His choice of group assignment should be that group which could most effectively complete all tasks along a route.

STANDARD PRODUCTION RATES — EQUIPMENT GROUPS

Cubic Yards/Hour

Group Number	Type of Operation	Width of Route		
		20 feet	30 feet	50 feet
1	1	275	275	275
2	1	480	560	720
3	2	260	290	290
4	2	-	-	1100
5	3	320	430	550
6	3	-	-	420

GROUP CARD:

Equipment Group Number ____________ Location ________

Resources

Primary Equipment	Auxiliary Equipment	Support Labor		Tools and Supplies
		Grade	Number	

Hourly Requirements for Group Operation

Man Hours per Labor Grade				P.O.L.			
1	2	3	4				
Oper-ator	Me-chanic	Semi-Skilled	Labor	Diesel gallons	Gas-oline gallons	Lubri-cation pounds	Oil gallons

Type of Operation ______________________________ Type Code ___

Production Rate, Cubic Yards/Hour

Width of Route	Standard Prod Rate *	Debris-Traffic Adj Factor	Actual Prod Rate

* Corrected for route width.

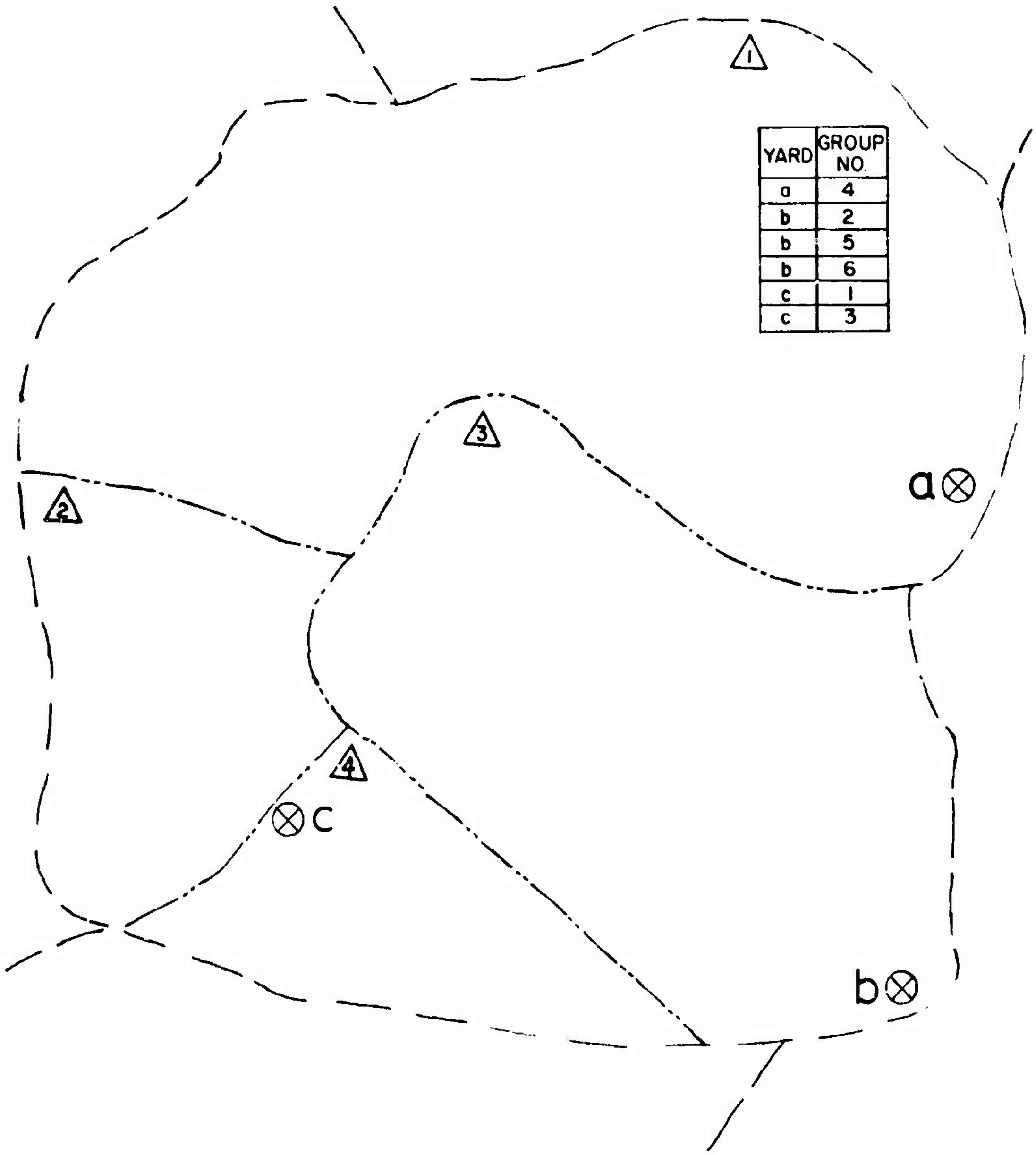
MAP OVERLAYS

Area zone maps were discussed in Panel 2. With these maps it is helpful to use transparent overlays showning outlines of the various districts and zones identified with their numbers. Upon these transparencies can be recorded such pertinent information as the predicted debris environments for every zone under different simulated attack conditions, the locations of equipment yards with quantity of each type of useful equipment normally available at that yard, and location and amounts of P.O.L. storage.

In the post-attack period, transparent overlays showing actual debris situations reported and planned debris removal routes would be used. These could be updated or replaced as emergency debris removal operations progressed.

Shown here is an overlay for District 7, showing the boundaries of the four zones, locations of equipment yards and the group numbers assigned to the equipment groups which might be drawn from each.

EQUIPMENT GROUP INVENTORY OVERLAY



YARD	GROUP NO.
a	4
b	2
b	5
b	6
c	1
c	3

Zone Number

— - - — Zone Boundary

— — — District Boundary

b⊗ Location Of Yard

EQUIPMENT INVENTORY

Pre-attack planning should include canvassing the city and surrounding suburbs for appropriate equipment and preparing an equipment inventory list for the area. This inventory should be limited to the types and size ranges of equipment essential to the debris removal operation. From this list preliminary allocations of the equipment can be made to the various districts based on minimum travel requirements to provide each district with a proportionate amount of equipment. The detailed plans for the districts can then be prepared based on the availability of that equipment and the assumption that the devastation in the area will not preclude the survival of the equipment.

A list of owners with the locations of the storage yards where their equipment is normally based, should be made and a serial number assigned to each location. An Equipment Inventory-Locator sheet may be made for each location, listing all the equipment the firm usually keeps at that yard. A suggested heading for such a sheet is shown opposite. In the first column are listed the types of equipment such as 'bulldozer', 'shovel', etc., followed by 'crawler' or 'wheeled' as applies. The column 'Code' is filled in using the designations shown in Panel 9. The approximate horsepower or capacity is placed in the next column. The manufacturer and model number are entered in the next two columns. Anything unusual about the condition of the equipment will be shown but if it is in good order and ready for normal duty, as expected, the 'Conditions' column will be blank. The last column 'Relocation of Unit' will show when a piece of equipment is moved from its normal storage area. If transferred to another yard in the same city, the new yard location serial number should be listed. If relocated to another city the name of the city should be listed. A summary of all the units available in the area should be listed by code number on a form similar to the second one shown.

The equipment inventory should be updated periodically.

An overlay map of the area showing the locations of the yards has been suggested in Panel 17 and will be helpful in planning the allocation of the equipment.

An equipment parts locator could be prepared in a similar fashion so that the necessary information is easily available. It might include the type of equipment, manufacturer's name, factory and branch locations, phone, radio, and contact people; the local distributor and nearest alternate distributor, with similar contact information; and a list of any other important parts sources.

EQUIPMENT INVENTORY LOCATOR

SOURCE OR FIRM ____________________ YARD LOCATION SERIAL NO. ________

STREET (OFFICE) ____________________ CITY ____________________

PHONE ____________________ RADIO FREQUENCY ____________________

STREET (STORAGE YARD) ____________________ CITY ____________________

PHONE ____________________ CONTACT(S) ____________________

Equipment	Code	Horsepower or Capacity	Manufacturer	Model	Condition	Relocation of Unit

KEY EQUIPMENT INVENTORY SUMMARY

CITY ____________________ DATE ____________________

QUANTITY

EQUIPMENT CODE

Zone Number									

86

PANEL 18

PERSONNEL AND P.O.L. INVENTORIES

In the pre-event planning it is assumed that a governmental management group would be available to take command of the post-attack recovery activities. Assignments of suitable personnel from this group should be made to D & C and the various MSA's. These assignments would include a manager of debris removal activities. Preparations should provide for an alternative list of key personnel. This reserve cadre should be knowledgeable in the field of heavy construction and public works and have had some pre-event training in what may be required of them. Such people would have knowledge of, and access to, the lists of available qualified personnel and would be able to recruit, train and direct the necessary subordinate personnel required to get the job done.

Sources of qualified personnel would be the Associated General Contractors of America (AGC), the American Society of Civil Engineers (ASCE), the Society of Mining Engineers (SME), or other comparable organizations. The individuals should be contacted, and those who are in a position to offer their assistance should be placed on a Key Personnel (Management) list. Suggested headings for such a list are shown opposite. It would be advisable to provide pre-event training in the problems peculiar to the removal of debris generated by a nuclear attack.

A similar list should be prepared of equipment operators using owners of equipment and union headquarters as sources for the volunteers. Equipment brought to the MSA may have an operator with it, since owners sometimes assign an operator more or less permanently to a particular piece of equipment. Operators (Grade 1) skilled in the use of all three types of primary equipment would be preferred. Mechanics (Grade 2) for maintenance and repair are slightly less critical than experienced operators since the operators can do routine maintenance on their equipment. Helpers and laborers (Grades 3 and 4)will be required, especially for the larger equipment. Field management personnel including task supervisors will also be needed. The number of operators and attendant personnel required for the operation will be dependent upon the equipment available for use, the number of hours per day it is to be used, and the number of hours per day each person will work, plus extra replacements to cover contingencies.

The equipment sent to the MSA will probably be completely fueled and lubricated before leaving the owners' yards. Subsequently P.O.L. supplies will probably have to be obtained elsewhere. The pre-event planning should include a list of the approximate quantitative requirements for the various phases of the early cleanup operations. The D & C could use this list in establishing needs and priorities for P.O.L. supplies. It would also be desirable to request distribution of any portable diesel fuel tanks to different zones where debris difficulty might be expected as indicated by debris prediction studies. These portable tanks should be filled. Drums of fuel oil should be assembled at each MSA or yard location. They will be useful to stock individual tasks and for hauling fuel over debris with a front-end loader.

A list of names and addresses of contacts at major P.O.L. distribution centers should be made by the debris removal manager. A form for tabulating storage sources and normal stocks of P.O.L. is shown opposite. These inventories should be kept current by periodic updating.

KEY PERSONNEL (Management)

Name and Affiliation	Business Address	Phone	Home Address	Phone

KEY PERSONNEL (Operators)

Name and Affiliation	Business Address	Phone	Home Address	Phone

P.O.L. SOURCES

City ______

Date ______

Supplier Name and Phone	Stock Location Address	District	P.O.L. Diesel gallons	Gas gallons	Lube pound	Oil gallons

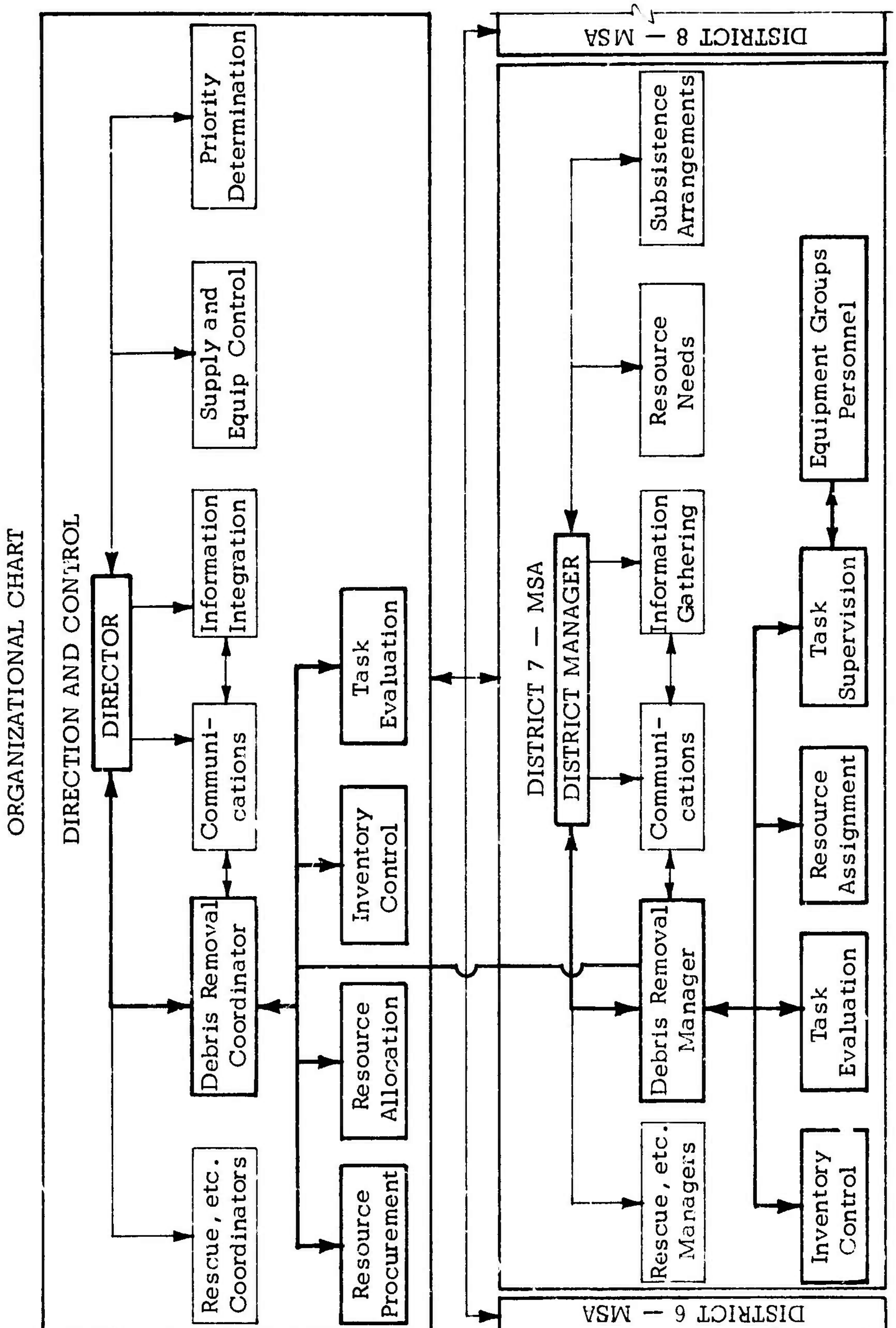
PRE-ATTACK PLANNING

The degree of success of the recovery operation is dependent on the practicality of the pre-attack planning. Since the removal of the debris will be prerequisite to most vital activities in the post-attack period, well organized planning of the debris removal operations can do much to contribute to that success. These operations must be integrated into the overall recovery activities. This can be done by placing its direction under the D & C organization established to direct the entire operation. In this organization there might be a number of coordinators each concerned with a separate essential activity such as firefighting, rescue, or debris removal. The D & C should have a support arm supplying administrative and clerical backup for all groups including central communication, information integration, priority determination, fiscal accounting, and record management.

In each MSA there should be a Debris Removal Manager working under the District Manager. The Debris Removal Manager for each district needs personnel to handle inventory control, task evaluation, resource assignment, and record management specifically oriented to debris removal, as well as men trained to supervise the equipment groups doing the removal work. These supervisors may be headquartered in the MSA or moving about the district. Once a task has been laid out and instructions given, most equipment operators are capable of completing the task on their own. In the event of unusual problems or breakdown of equipment they would be in radio contact with the supervisors. A competent supervisor can keep 3 or 4 groups of equipment going if they are located within reasonable distances of each other.

A suggested organizational chart is shown opposite. Number of personnel required for each function would be dependent on the magnitude of debris clearing operations anticipated for the district.

In the pre-attack planning period this skeleton organization should be set up and trained. This crew can organize the equipment, personnel and supply requirements for possible attack conditions. This exercise will help to familiarize them with the specific duties to be performed, and the scope of the resources that will be required in an actual attack situation. This group will form the nucleus of the mobilization effort when warning of attack is given.


ORGANIZATIONAL CHART
DIRECTION AND CONTROL
DIRECTOR
Priority Determination
Supply and Equip Control
Information Integration
Communi-cations
Debris Removal Coordinator
Rescue, etc. Coordinators
Task Evaluation
Inventory Control
Resource Allocation
Resource Procurement
DISTRICT 8 — MSA
DISTRICT 7 — MSA
DISTRICT MANAGER
Subsistence Arrangements
Resource Needs
Information Gathering
Communi-cations
Debris Removal Manager
Rescue, etc. Managers
Equipment Groups Personnel
Task Supervision
Resource Assignment
Task Evaluation
Inventory Control
DISTRICT 6 — MSA

MOBILIZATION

Proper, timely mobilization of trained personnel and adequate resources for debris clearing can mean the difference between saving a city and its surviving population, or losing, in confusion and flames, what is left after the attack.

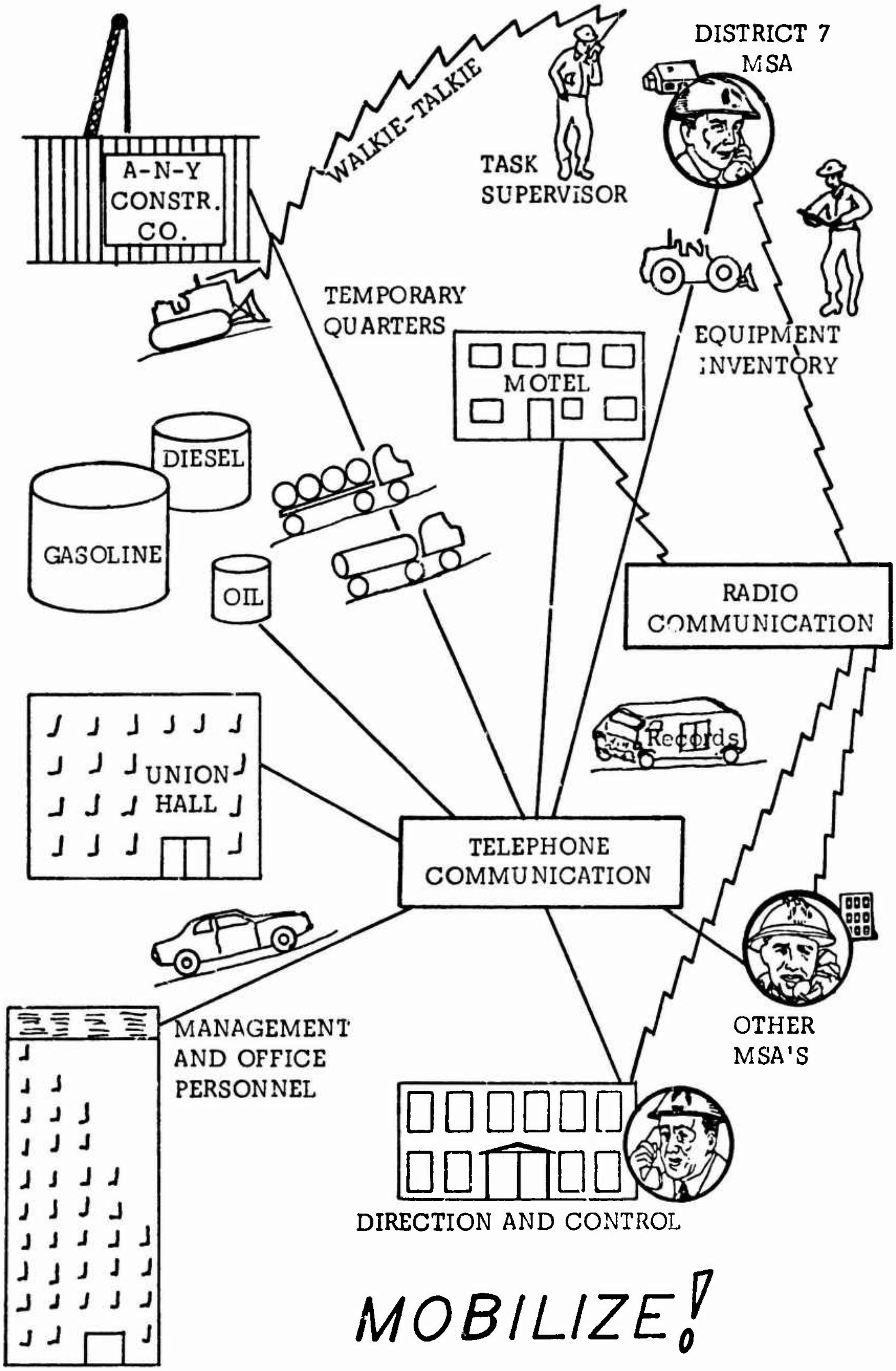
The nucleus of an organization setup trained in the use of orderly procedures for evaluating debris conditions and implementing clearing operations, and armed with lists of possible personnel, equipment and supplies, is a minimum requirement for initial mobilization. At first warning these key personnel will report to their assigned headquarters. The Debris Removal Manager will move into his quarters at the MSA and establish communication with the District Manager and the Debris Removal Coordinator at D & C. He will then form a small office force to maintain records, provide communication, and perform other office management tasks. The debris removal data developed in the planning period will be transferred to the headquarters.

Owners of equipment and supplies will be contacted in order to start the movement of these resources to the districts to which they have been allocated. Knowing what equipment will be within his jurisdiction the Debris Removal Manager can contact the union hall for the necessary personnel to operate and maintain it. Sufficient personnel will be needed for a 24-hour a day operation. Temporary quarters will have to be provided for the entire staff near the MSA and communications established between the command post and these quarters, preferably by radio as well as phone, if the MSA and quarters are physically separated. If the alert signals a real attack situation, the debris removal team is ready. After emerging from the shelter they need only check over equipment and supplies, determine the zone situations and priorities of tasks, and start the clearing operations.

If there has been no warning, the mobilization will not proceed smoothly and many gaps in personnel and other resources may be expected. These gaps will have to be bridged by reassignments. Furthermore, additional time will have to be allowed for the equipment still at the storage yard to reach the starting point of the task.

This starting point can be adjusted to coincide with the point along the route which the equipment could reach most readily.

The debris personnel will need much ingenuity and resourcefulness to handle their end of the survival activities.


A-N-Y
CONSTR.
CO.
WALKIE-TALKIE
TASK
SUPERVISOR
DISTRICT 7
MSA
TEMPORARY
QUARTERS
MOTEL
EQUIPMENT
INVENTORY
DIESEL
GASOLINE
OIL
RADIO
COMMUNICATION
Records
UNION
HALL
TELEPHONE
COMMUNICATION
OTHER
MSA'S
MANAGEMENT
AND OFFICE
PERSONNEL
DIRECTION AND CONTROL
MOBILIZE!

PANEL 21

After the attack, when it is known what the zone situations are and what tasks are actually required, assignment of resources must be undertaken. To make the selection in an orderly fashion, cards summarizing the requirements for each of the tasks to be done should be prepared. A format for such a card is shown here and Task 4a of Panel 6 has been utilized to illustrate its use.

'Priority' will probably be assigned by D & C but a system for determining provisional priorities of tasks will be discussed in the next panel. 'Date', 'District', 'Zone', and 'Task No.' are self-explanatory.

The 'Task Requirement Summary' describes the conditions existing along the path, the time limitation for completion of task required for success, the difficulties connected with the task, the appropriate type of operation, and the minimum production rate needed to complete the task in the alloted time. The 'Zone Situation' is as reported or estimated and is designated by the appropriate number code from Panel 6. 'Fallout' and 'Fire Conditions' are determined from reports received and may be recorded in color coding in accord with the Alpha Neop Plan or in the coding system selected for use in the area. Here the 'yellow' for Fallout and for Fire Condition indicates negligible fallout and fire.

'Finish-Day' and 'Hour', dependent upon the critical time for finishing the task, will probably be assigned by D & C. If not, an estimate must be made of how soon the task must be completed to accomplish its purpose. The 'Hours Allowed' will be somewhat less than the difference between the finish time and the time of assignment to allow for travel to the site. The remainder of the information is obtained from the 'Task Definition' sheet (Panel 7) and the DPS sheet (Panel 3).

The appropriate available groups are listed in the 'Resource Evaluation' table. Their distances from the location of the task are measured on the Equipment Group Inventory overlay (Panel 17). Tables in Panels 16 and 12 give the 'Standard' production rate and reduction factor needed to determine the 'Actual' production rate. Anticipated 'Travel' hours are estimated by considering how long it will take to man the assigned equipment and move it to the starting point of the task. Generally this could be expected to take from 1 to 8 hours depending on the route, the amount of debris and the type of equipment. However if equipment is to start a new task at the point of termination of its previous task the travel time would be zero and if the equipment had to be brought from another zone it might take considerably longer. 'Operating' hours, anticipated, are determined by dividing the 'Quantity' by the 'Actual' production rate. This added to the 'Travel' hours gives the 'Total Anticipated Hours'. A choice of equipment can be made from these figures. Panel 13 discusses the selection of 'Other Resources' that may be required.

After selection, the group number and starting day and hour are recorded under 'Resource Assignment'. Using the operating characteristics for the group selected (Panel 15) the total P.O.L. and labor required for the task can be computed. Upon completion, the 'Total Actual Equipment Hours' can be recorded.

TASK REQUIREMENT CARD

Priority: 1

Date: 12 Jan. 1975 District: 7 Zone: 3 Task No: 4a

Task Requirement Summary

Zone Situation: 2 Fallout: yellow Fire Condition: yellow

Finish — Day: 12 Jan. 1975 Hour: 16.00 Hours Allowed: 7

Debris Type: 3 Traffic Content: M Type of Operation: 1 or 2

Street Width: 60' Route Width: 30' Average Depth: 0.18' (0.75)

Length: 5,800' Quantity: 870 cu yd Req Prod Rate: 125 cu yd/hr

Resource Evaluation

Group Number	Production Rate, cubic yards/hour			Anticipated Hours		
	Standard	Debris-Traffic Adj Factor	Actual	Travel	Oper-ating	Total
1	275	0.58	160	2.0	5.5	7.5
3	290	0.55	160	1.0	5.5	6.5

Additional Resources Required:

Resource Assignment:

Group No. 3

Operating Hours:

Finish — Day: ______ Hour: ______

Start — Day: ______ Hour: ______

Total Actual Equipment Hours: ______

Labor Skills	Man Hours	
	Antici-pated	Actual
1- Operator	13	
2- Mechanic	8	
3- Semiskilled	15	
4- Laborer	13	
Total	49	

P.O.L. Requirements	Antici-pated	Actual
Diesel, gal	205	
Gasoline, gal	8	
Lube, lb	13	
Oil, gal	3	

PRIORITY OF TASKS

Almost all tasks will seem critical in the immediate post-attack period so it will be imperative to have some means of determining an order of priorities for the tasks to be done. This determination should be made with the broadest possible knowledge of the entire area situation. Generally D & C will be in the best position to have this knowledge since all districts report their information to D & C.

The debris removal group will supply D & C with information on how the task can be performed, what it will cost in resources, and the chance of successful completion.

It will, however, take time for D & C to accumulate and act on the information supplied from all districts so the personnel at the district level should be prepared to assign provisional priorities to the tasks that must be performed within the district.

Two criteria may be used to determine the priority, first the urgency and second the chance of successfully completing the task. If there appears to be no chance of success, it may be a useless waste of resources to start it even though the urgency is great. On the other hand, it may still be considered worth the effort. If there are sufficient debris removal resources, the task may be started even if its chance of success appears nonexistent.

The left hand chart assigns an 'Urgency' to the task dependent upon the number of people and the situation in which they are involved. With this 'Urgency' established and a knowledge of the probability of completing the task within the allotted time a provisional priority can be obtained from the right hand graph.

Using Task 4a to illustrate the use of these charts, we find an urgency of "A" for opening a path to the hospital. If available resources are able to clear the route on time the 'Provisional Priority' will be "1".

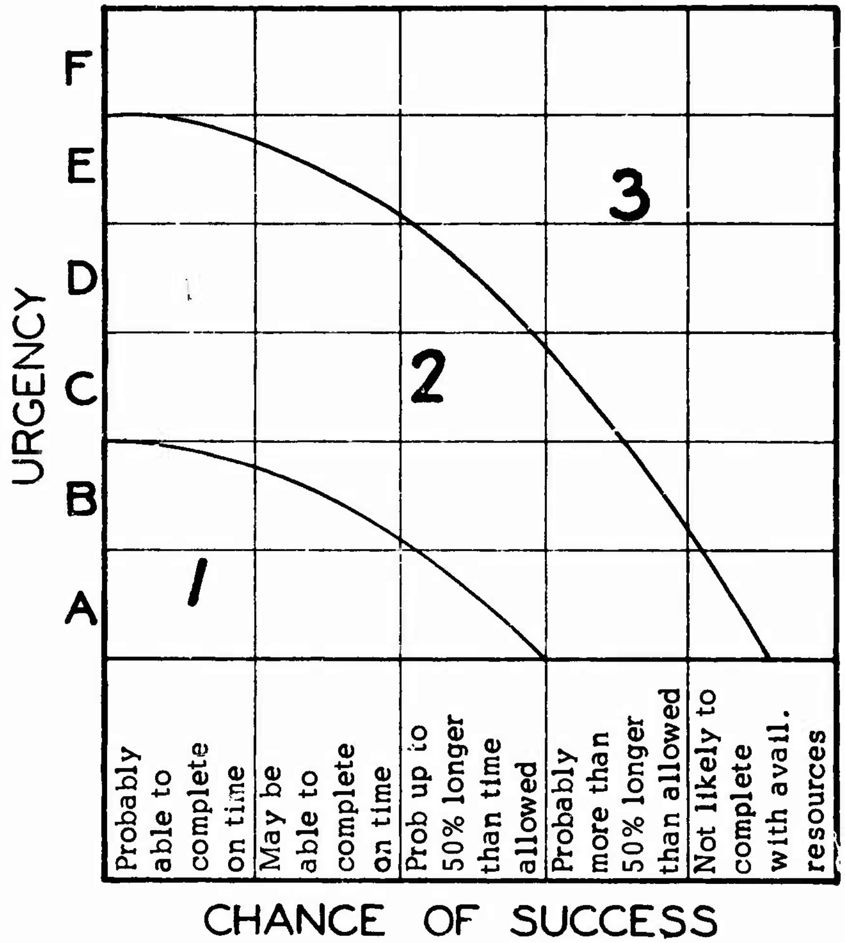
Local conditions may dictate a judgement granting a higher urgency which may not correspond with this general procedure.

All provisional priorities are subject to change. Changes can result from such things as orders from D & C, reconnaissance reports showing a change in debris environments or conditions of people, new developments such as fires or fallout, or changes in the values of the criteria used such as availability of equipment.

URGENCY

SITUATION					
Critical Materials	F	F	F	F	F
Utilities	E	E	E	E	E
Sheltered Groups	C	D	D	D	D
Unsheltered Groups	B	B	C	C	D
Schools, Nursing Homes, etc.	B	B	B	C	C
Hospitals	A	A	A	B	B
Fire or Danger of Collapse	A	A	A	A	B
NUMBER OF PEOPLE	Over 100	50 to 100	25 to 50	10 to 25	Less than 10

PROVISIONAL PRIORITY



ASSIGNMENT OF RESOURCES

There are eight actions to be taken in the assignment of resources for debris removal.

Decisions to be made prior to initiating a debris removal operation have been indicated in previous panels. They are repeated here to summarize the various steps to be taken.

1. Determination of zone situations and an overall evaluation of post-attack environment.

2. Determination of tasks to be performed and their priorities.

3. Determination of availability of equipment groups or resources.

4. Determination of mobilization requirements for available groups.

5. Determination of most effective group for each task in sequence.

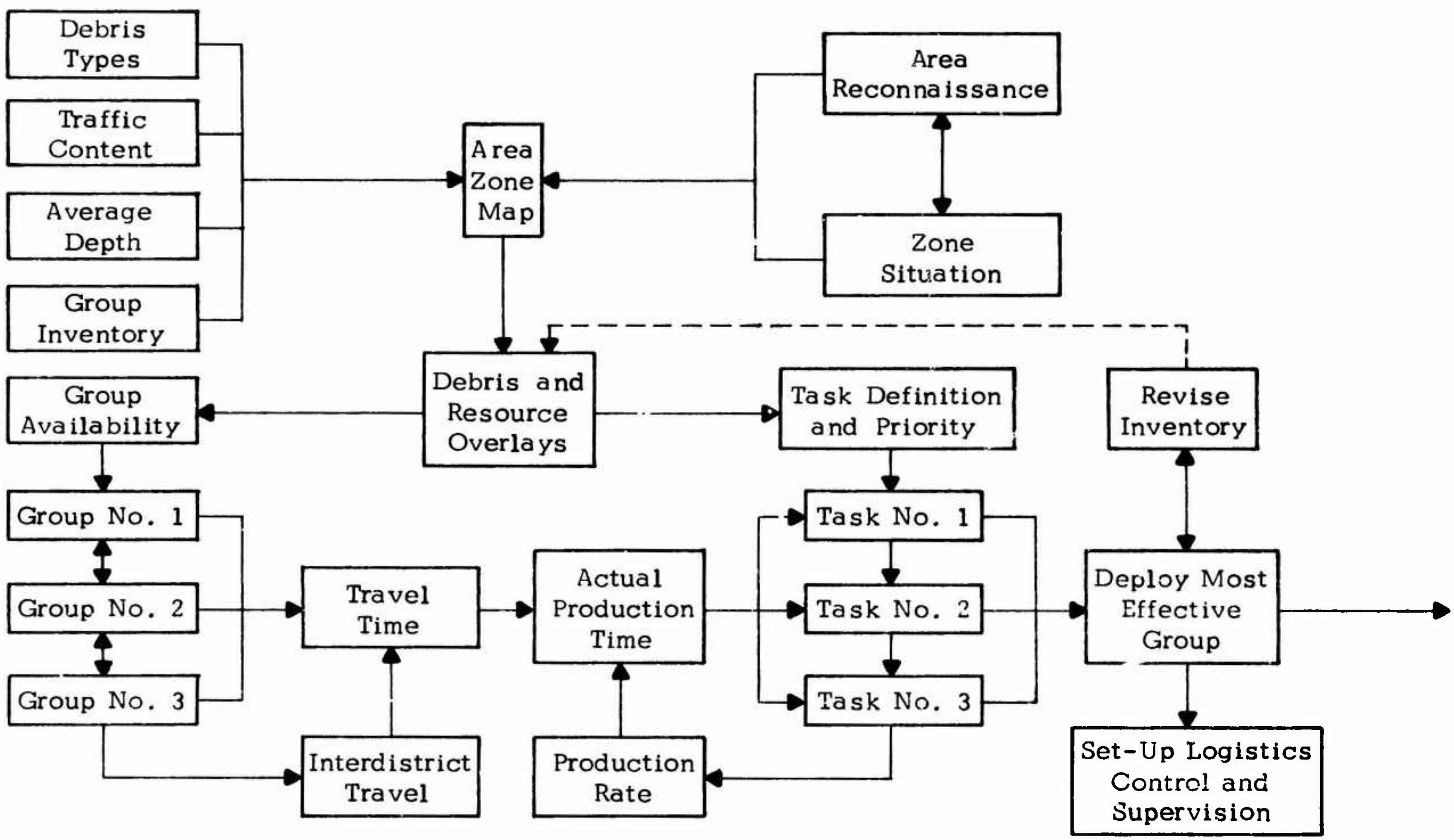
6. Deployment of groups.

7. Initiation of logistic control.

8. Revision of inventory.

The sequence and logic of the various steps are shown by the accompanying flow diagram. For simplicity, all resources have been combined into equipment groups, but they can be considered separately. By use of feedback techniques, the various groups can be considered for each task in order to determine the most effective group to deploy. The diagram indicates possible 'yes' - 'no' choices to be made during this period.

In the pre-attack planning, area zone maps will have been prepared with overlays, updated as necessary, displaying information such as anticipated debris environments and location of equipment. Post-attack zone situations, as they become known, can be placed on the area zone map along with the routes to be cleared. By comparison of the prepared overlays with the post-attack information, the location of the available equipment in relationship to the task can be seen, and the difficulty to be encountered in the clearing operation can be evaluated. The task can then be defined, a priority assigned, and a Task Requirement card completed. This technique allows the most effective group for each task to be selected and deployed. Then logistic control will be initiated and the inventory revised. The overlays must also be revised to show the change in availability of resources.



RESOURCE ASSIGNMENT FLOW DIAGRAM

DEBRIS CLEARING OPERATIONS

The mobilization of personnel and resources during a period of alert is described in Panel 21. At this point, the actual resources that will be available are gathered and inventoried. After the attack, reports of actual damage, objective goals, and debris environments will be analyzed to determine priority of tasks and possibility of success with the resources on hand. These assessments will be transmitted to the D & C for evaluation and interdistrict coordination. On the basis of reports from all districts, D & C may confirm the priority of tasks suggested or may request redeployment of resources between districts. This redeployment would probably be requested for a situation where a district of high priority tasks has insufficient resources, or where a particular objective in one district can be reached more readily from an adjacent district. As resource groups complete initial tasks, a continuous process of re-evaluation of remaining tasks and resources must take place on the district and D & C levels.

Orders to equipment operators may be oral, often by radio. A record will be kept by the administrative staff of work assignments, hours worked and supplies used. When possible, this record should contain: identity numbers of equipment, equipment code number, owner's serial number, operator's name, the task number, the route description, and the actual time sent out and returned. A form for this is shown opposite. The 'Identity' column is for a number to be designated by the Debris Removal Manager for each piece of equipment. A separate record should list the assigned identity number, the equipment model, make, manufacturer's serial number and the owner's name and serial number. If the equipment is sent out in 'groups' a similar form may be used based on the groups rather than the individual pieces of equipment.

The completed Equipment Assignment sheets for each day should be saved for a permanent record of the district operation. The task's beginning and completion points and the streets cleared will be written on a separate note for the equipment operator. This dated note will show time of start and completion and be signed by the operator.

EQUIPMENT ASSIGNMENT SHEET

City ______________ District ______________ Date ______________

Identity	Equipment Code	Owner's Serial No.	Task No.	Operator's Name	Task Starting Point	Streets to Be Cleared	Task Termination Point	Time	
								Out	In

PANEL 25

APPROXIMATION OF RESOURCE REQUIREMENTS

To effectively allocate the resources an approximation of the requirements of each district will be necessary. By calculating the resource requirements per thousand cubic yards for each equipment group being considered and for several debris environments it is a simple matter to determine the total resources required for a single task or a group of tasks (real or anticipated). The type and quantity of debris, traffic content, width of route, and suitable group are first determined. Then multiplying the quantity of debris in thousands of cubic yards by the resource requirements for removal of a thousand cubic yards for the group chosen and the debris environment being considered a reasonable approximation of the total resources needed for the task will be obtained.

The tables shown here use the six equipment groups from Panel 14 and show resource requirements for Debris Types 1 and 6 with moderate traffic content. The 'Operating Hours per 1000 cubic yards' shown do not include any mobilization or travel time. To present a complete picture of the needs this must be added to the total resource requirements obtained for the individual tasks.

By totaling the needs of all the high priority tasks in each district, the types and amounts of resources necessary are determined, and D & C can allocate what resources are available to the locations where they will be most effectively used.

REPRESENTATIVE RESOURCE REQUIREMENTS FOR REMOVAL OF 1000 CUBIC YARDS OF DEBRIS

Labor and P.O.L.

Equip Group Number	Type of Debris	Traffic Content	Route Width feet	Prod Rate cu yd/hr	Oper Hours/ 1000 cy	Man Hours per 1000 cu yd Grade				P.O.L. per 1000 cubic yards			
						1	2	3	4	Deisel gal	Gas gal	Lube lb	Oil gal
1	1	M	All	256	3.9	7.8	2.7	8.6	15.6	62.4	4.7	4.7	1.2
	6	M	All	44	22.7	45.4	15.9	50.0	90.8	363.2	27.3	27.3	6.8
2	1	M	30	521	1.9	5.7	2.1	4.4	7.6	65.0	2.7	4.2	1.3
	6	M	20	77	13.0	39.0	14.3	29.9	52.0	444.6	18.2	28.6	9.1
3	1	M	20	237	4.2	8.4	5.0	9.7	8.4	132.2	5.5	8.4	2.1
	6	M	20	47	21.4	42.8	25.7	49.2	42.8	674.1	27.8	42.8	10.7
4	1	M	50	1001	1.0	4.0	3.2	10.5	6.0	95.5	9.8	3.9	1.5
	6	M	50	198	5.1	20.4	16.3	53.6	30.6	487.1	50.0	20.0	7.7
5	1	M	30	396	2.5	5.0	2.8	10.8	10.0	90.3	3.5	4.3	1.5
	6	M	30	73	13.7	27.4	15.0	58.9	54.8	494.6	19.2	23.3	8.2
6	1	M	50	386	2.6	10.4	6.0	11.7	5.2	177.6	4.4	9.6	2.8
	6	M	50	71	14.0	56.0	32.2	63.0	28.0	956.2	23.8	51.8	15.4

Equipment and Supplies

Equip Group Number	Type of Debris	Traffic Content	Route Width feet	Prod Rate cu yd/hr	Oper Hours/ 1000 cy	Equipment Hours per 1000 cubic yards					Supplies and Hand Tools per 1000 cubic yards *			
						Bull-Dozer	F.E. Loader	Crane	Service Trucks	Dump Trucks	600	602	620	621
1	1	M	All	256	3.9	3.9	-	3.9	0.8	-	-	3.9	3.9	3.9
	6	M	All	44	22.7	22.7	-	22.7	4.6	-	-	22.7	22.7	22.7
2	1	M	30	521	1.9	3.8	-	1.9	0.6	-	-	1.9	1.9	1.9
	6	M	20	77	13.0	26.0	-	13.0	3.9	-	-	13.0	13.0	13.0
3	1	M	20	237	4.2	-	4.2	4.2	1.1	8.4	-	4.2	4.2	-
	6	M	20	47	21.4	-	21.4	21.4	5.3	42.8	-	21.4	21.4	-
4	1	M	50	1001	1.0	-	3.0	1.0	0.5	7.0	1.0	1.0	2.0	1.0
	6	M	50	198	5.1	-	15.3	5.1	2.5	35.7	5.1	5.1	10.2	5.1
5	1	M	30	396	2.5	2.5	2.5	-	0.8	5.0	-	2.5	2.5	2.5
	6	M	30	73	13.7	13.7	13.7	-	4.1	27.4	-	13.7	13.7	13.7
6	1	M	50	386	2.6	2.6	5.2	2.6	1.2	10.4	-	2.6	2.6	-
	6	M	50	71	14.0	14.0	28.0	14.0	6.3	56.0	-	14.0	14.0	-

* See Panels 9, 10, and 13 for identification of code numbers.

FROM PLANNING TO IMPLEMENTATION

The contribution of the debris removal team to the success of the recovery operation in the post-attack environment will be dependent on: constructive planning in the pre-event period, efficient organization during mobilization, and implementation of the planning by trained personnel after the attack. The various steps that have been discussed in Volumes I and II are summarized in the flow chart opposite. The discussion here covers planning, management, operating personnel, and equipment and related resources used to complete a maximum number of high priority tasks in the first critical days after the attack. Eventually, all debris, in all streets and on adjacent property, will have to be removed in an orderly fashion. In the period of fire, rescue and evacuation, it is the selective removal of debris from specific routes, to achieve particular goals, that requires careful planning and timely decisions.

In the pre-event planning there are six major items of preparation which are described and referenced below.

1) Event Description — see Volume I — especially note Panel 18.

2) Debris Prediction — Volume I, all; and Volume II, Panels 3 through 7.

3) Clearing Requirements — Volume I, Panel 14, and Volume II, Panels 2 and 7.

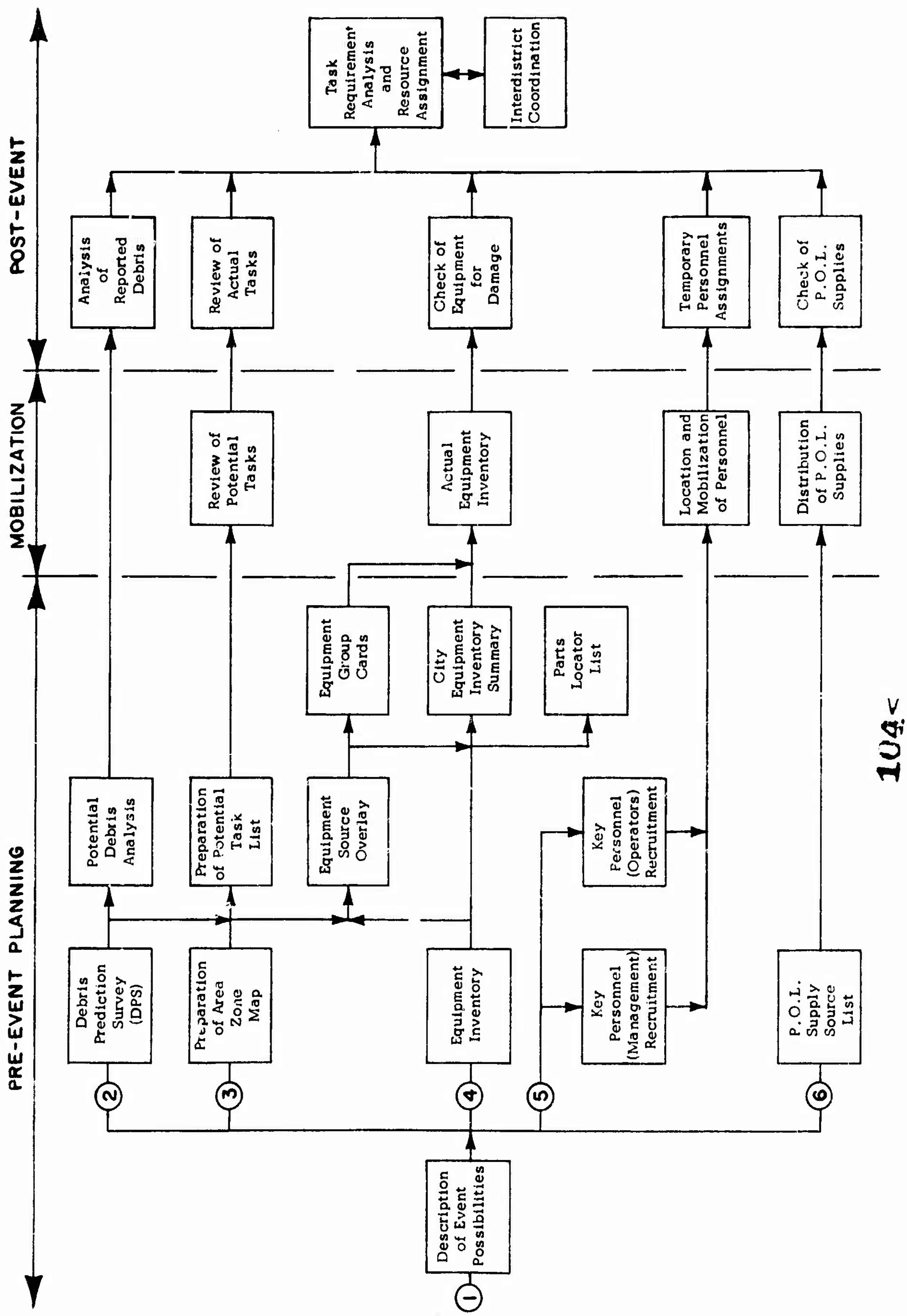
4) Equipment Analysis — Volume II, Panels 8 through 12 and 14 through 18.

5) Personnel Requirements — Volume II, Panel 19 and 20.

6) P.O.L. Supplies — Volume II, Panels 10, 15, and 19.

Mobilization will follow through on four of these items, namely, the review of the tasks considered in pre-event planning, updating of the equipment inventory, calling in the necessary personnel and distributing the P.O.L. supplies.

In the post-event period the actual debris types and inclusions are determined, the actual tasks are set up, equipment and P.O.L. supplies are checked, personnel are temporarily assigned and the job of clearing away the debris is begun, coordinated throughout the area by the D & C.



PRE-EVENT PLANNING
MOBILIZATION
POST-EVENT
1
Description of Event Possibilities
2
Debris Prediction Survey (DPS)
Potential Debris Analysis
Analysis of Reported Debris
3
Preparation of Area Zone Map
Preparation of Potential Task List
Review of Potential Tasks
Review of Actual Tasks
Equipment Source Overlay
Equipment Group Cards
4
Equipment Inventory
City Equipment Inventory Summary
Parts Locator List
Actual Equipment Inventory
Check of Equipment for Damage
5
Key Personnel (Management) Recruitment
Key Personnel (Operators) Recruitment
Location and Mobilization of Personnel
Temporary Personnel Assignments
6
P.O.L. Supply Source List
Distribution of P.O.L. Supplies
Check of P.O.L. Supplies
Task Requirement Analysis and Resource Assignment
Interdistrict Coordination
104

PANEL 27

SUGGESTED ADDITIONAL READING

The following sources provide additional background on the material in this chapter:

1. Rotz, J., J. E. Edmunds and K. Kaplan - Effects of Fire on Structural Debris Produced by Nuclear Blast - URS 639-1 Contract No.OCD PS-64-19, January, 1965.

2. Rotz, J., J. E. Edmunds and K. Kaplan - Formation of Debris from Buildings and their Contents by Blast and Fire Effects of Nuclear Weapons - URS 651-4 Contract No. OCD-PS-64-201, April, 1966.

3. Wickham, G. E. - Debris Removal - Civil Defense Operations - Vol. I - Jacobs Associates, TR 101 Contract No.OCD-DAHC 20-67-C-0136 Subcontract 12652 (6300A-340) for SRI, March, 1969.

4. Wickham, G. E., T. N. Williamson - Operational Planning Debris Removal - Jacobs Associates, TR 110 Contract No.OCD-DAHC 20-70-C-0305, July, 1971.

5. Williamson, T. N., G. E. Wickham, H. R. Tiedemann - Debris Clearing Times Affecting Critical Survival Actions - Jacobs Associates, TR 120 Contract No. DCPA - DAHC 20-72-C-0401, August, 1973.

6. Checklist Guide for Nuclear Emergency Operations Planning (ALPHA NEOP), Document CPG2-2A, Defense Civil Preparedness Agency, Washington, D.C., 1973.

7. Associated General Contractors of America, Constructor, Vol. XLIX,1967, A Program for Disaster Relief in Your Community: Plan Bulldozer.

PANEL 28