DC-FR-1039

VULNERABILITY REDUCTION USING MOVEMENT AND SHELTER

VOL. II - - FINAL REPORT

by

R. J. Flanagan

D. E. Brannon — A. R. Durand

S. H. Dike — A. R. Bliss

K. D. Granzow — D. L. Summers

OCD Subtask 2311D

Contract No. OCD-OS-63-109

Prepared for

Department of Defense
Office of Civil Defense
Washington, D. C. 20310

June 1965

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The Dikewood Corporation

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OCD REVIEW NOTICE

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

THE DIKEWOOD CORPORATION

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(continued)

LIST OF TABLES

LIST OF TABLES
(continued)

VULNERABILITY REDUCTION USING MOVEMENT AND SHELTER

CHAPTER I

INTRODUCTION

The purpose of this study is indicated by the following quotation from the Scope of Work statement in the Contract:

"Specific work and services to be performed shall include, but are not limited to, the following:

1. Investigate the relationships among vulnerability, warning times, shelter costs and other factors involved in strategic movement using basic data developed under Contract OCD-OS-62-248.

2. Postulate various combinations and mixes of strategic evacuation and shelter and analyze and compare them.

3. Devise methods of evaluating overall, alternative plans for reducing vulnerability on the basis of survival rates, warning times, costs, time required for activation and other factors.

4. Examine the evolutionary development, characteristics, and desired order of development of survival capabilities related to vulnerability reduction."

As indicated in Par. 1 of the above quotation, the present study is a continuation of earlier Dikewood strategic movement studies.[1,2] The overall effort may be placed in perspective with the aid of Fig. 1 and some intuitive arguments.

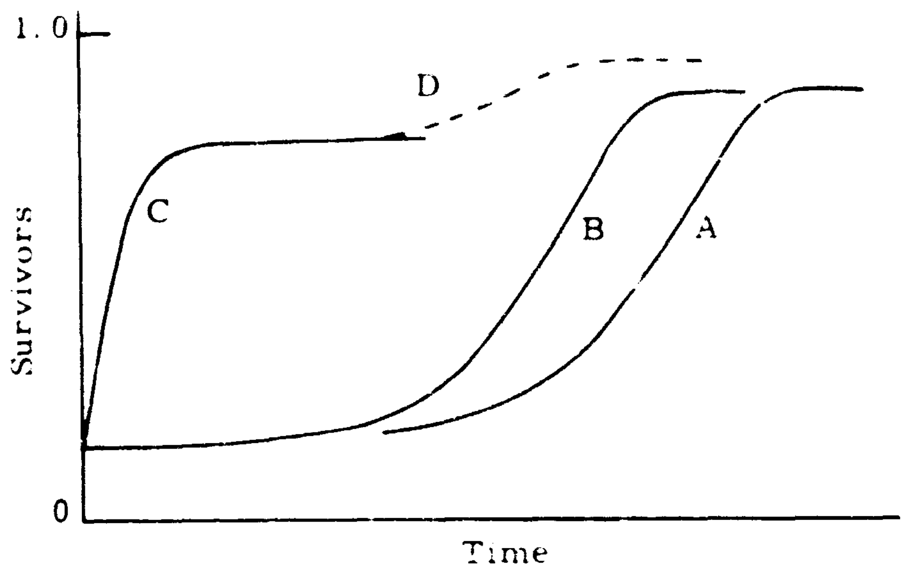

Fig. 1

Survivors Versus Time for
Various Movement and Shelter Policies

With very long action times (time between decision to act and arrival of lethal effects) complete evacuation of a city could be carried out, and the

[1] R. J. Flanagan, et al., Specific Strategic Movement Studies, Dikewood Corporation Final Report on Contract OCD-OS-62-248, DC-FR-1030; May 1963. (Confidential)

[2] S. D. Stearns, "A Mathematical Model for Strategic Movement," Operations Research, Vol. 12, No. 2; March-April 1964.

immediate survival rate would be essentially 100%, if the evacuated city were bombed This survival rate must be reduced by fallout casualties in the reception area, but given sufficient time, improvised fallout protection can be provided, and a very high attack survivor rate can be achieved (Curve A in Fig 1). If fallout protection were already available in the reception area, the action time required to achieve this survival rate would be reduced (Curve B). If shelters (from initial effects as well as fallout) were provided in the target area and the population vulnerability decreased for short action times, there would still be enough people killed either directly or indirectly that the total survival rate would probably be smaller than that possible with evacuation and a long action time (Curve C) Combinations that evacuate those in the most vulnerable locations while providing shelter for those in somewhat safer positions might lead to survival curves like the dashed curves in the figure (Curve D)

The development of realistic curves of the types shown in Fig 1 may be done in three major steps

1 Postulation of alternative movement and shelter policies.
2 Development f movement and shelter plans based on the policies in (1), and
3 Evaluation of plans developed in (2) against the range of attack conditions considered reasonable

In carrying out the first step one would hope to postulate as many policies as imagination allows, this is largely an intuitive step

Once a policy is postulated, a technique for developing plans to carry out the policy can be constructed. In this report, Chapter II describes a basis for development of strategic movement plans previously described in more detail in Refs. 3 and 4. Chapter III describes tools developed to fulfill Step 3 for strategic movement plans.

Chapter IV describes some possible shelter policies (Step 1) and computer programs that can be used as a basis for development of shelter plans (Step 2). The evaluation of shelter plans (Step 3) against various attacks is a fairly straightforward step, but the procedure for doing so has not been automated.

Chapters II-IV then are aimed at the final goal of developing preferred mixtures of movement and shelter typified by an evaluation curve of Type D in Fig. 1. Another independent approach to the development of such preferred mixtures was also followed and is described in Chapter V and in Ref. 5.

All four items in the Scope of Work statement of this contract describe problems that will require continuing treatment by the Office of Civil Defense. The effort summarized in this report provides some help

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[3] R. J. Flanagan, et al., Large-Scale Strategic Movement Planning, Dikewood Corporation Technical Note DC-TN-1039-1; January 15, 1964.

[4] S. H. Dike, et al., A Computer Program for Planning a Strategic Movement, Dikewood Corporation Technical Note DC-TN-1039-9; May 24, 1965.

[5] K. D. Granzow, A Model for Development of Preferred Mixtures of Evacuation and Shelter, Dikewood Corporation Technical Note DC-TN-1039-2; July 6, 1964.

in understanding Pars. 1, 2, and 3, but very little toward Par. 4. Some ideas for treatment of problems associated with Par. 4 are being developed and will be reported later under Contract OCD-PS-65-53, where further work in these areas is being supported.

CHAPTER II

LARGE-SCALE STRATEGIC MOVEMENT PLANNING

1.0 Introduction

Capability for movement has probably always been understood to be a proper element of a defense system. Its potential value in many kinds of thermonuclear conflicts has been pointed out by a few workers, notably Herman Kahn and some of his former co-workers at RAND.

The Hudson Institute staff examined some of the variables involved in strategic movement problems as a part of an OCD-sponsored study.[6] In that study, a set of three illustrative plans was prepared for the north-eastern section of the U. S. These plans were associated with various levels of crises, the primary effort being devoted to an evacuation that would take a week to complete. Modifications to the basic one-week plan to illustrate some effects of other warning times were also examined. These included a two-day plan and a plan that might be associated with a crisis that escalates over a one-month period. This set of plans provided insight into a number of problems and has proved very valuable in Dike-wood studies.

The Dikewood Corporation was asked to perform a study of strategic movement from two cities: one city that is relatively isolated and one city

[6] William M. Brown, Editor, Strategic and Tactical Aspects of Civil Defense with Special Emphasis on Crisis Situations, Hudson Institute Report No. HI-160-RR, January 7, 1963.

surrounded by other population centers so that evacuees from it would have to compete with other evacuees for reception area space The two cities chosen were Albuquerque and New York The development of plans for these two particular cities included an examination of some questions concerning the feasibility of strategic movement. Some of the factors considered in Ref 1 were re-examined and are discussed in this chapter.

In the course of the study, a computer program was developed that can be used to calculate the evacuee distribution for which expected casualties are a minimum within an attack area that includes a number of evacuation and reception sectors. This program is referred to as the Distribution program and is described briefly in this chapter and, in more detail, in Refs 1, 2, and 3

Two alternative techniques for planning movements to achieve any desired distribution have been developed and are also described in this chapter The planning techniques make use of either of two computer programs referred to as the Movement and Min Man-Mile programs The Distribution program can be used to decide how many evacuees should be housed in each reception place and the Movement and Min Man-Mile programs can be used to decide where they come from, when they should leave, and what routes are to be followed

The techniques discussed in this chapter are not suggested as being unique, optimum, or in any sense the only right way to plan strategic movement However, they do represent one method that has received much careful consideration and is as nearly automated as seems reasonable. Again, computers are not expected to add any magic to the results, but they do provide an accurate, convenient, and inexpensive means of handling the large amount of bookkeeping required in planning such an operation.

If the planning techniques described in this chapter were applied, the bare minimum of planning needed for an emergency capability to perform a strategic movement would be established. However, much of the detailed planning required to make one confident that the operation would be successful and that it would proceed smoothly would require further consideration. These details should be treated later by planning groups working, for example, at the state or local level. These more detailed plans might be prepared in the same way that the State Survival Plans were prepared, in the way the National Fallout Shelter Survey was performed, or in some similar manner.

2.0 Prediction of Expected Casualties and Their Relation to the Evacuee Housing Problem

One reasonable criterion for use in planning a strategic movement is the minimization of the expected number of casualties, and a previous Dikewood effort emphasized the development of a technique for calculating such minimum-casualty distributions.[1,2] To find a minimum-casualty distribution for any given area such as a state or group of states, the area was divided into constant-vulnerability sectors in which the initial population and shelter protection factors and capacities were known. The number of people that can move from one sector to all others in the time period of interest was then specified. With these data items it is possible to calculate the minimum-casualty distribution. A computer program was developed to facilitate the calculation; the program is described briefly in the final report on Contract OCD-OS-62-248[1] and in more detail in an earlier report[2] written under the same contract. The technique was applied to Albuquerque and New York City to develop specific distribution plans and to see how the choice of plans affects the numbers of casualties. Albuquerque was treated as an isolated city, i.e., a particular reception area was chosen arbitrarily and various plans for moving people within this one area were studied. For New York City, the problems associated with competition for space were emphasized by examining plans for various groups of states in the Northeast.

In the studies of both of these areas, fatalities were related to housing load factor. Housing load factor is a measure of billeting burden and is defined as the ratio of population after movement to the population prior to movement in any particular area of interest. For example, if some town experiences a load factor (LF) of two, it simply means that people are "doubling up."

Calculations of fatalities verified the intuitive expectation of a large decrease in fatalities associated with emptying places that receive initial effects. For example, the relation between load factor and fatalities associated with the NAHICUS '63 attack[7] is shown in Table I for Albuquerque and its reception area.

Table I

Fatalities versus Maximum Housing Load Factor for Residents of Albuquerque and Its Reception Area

Maximum housing load factor	Expected fatalities (%)	First differences[a]
1 (no evacuation)	61	
2.73 (uniform)	12	28
3	10	7.4
5	8	1
7	7	0.5
9	7	0

[a] For a unit change in maximum housing load factor.

There are several reasons for preferring a load factor near uniform. First, the results in Table I indicate that there is still a sizeable gain for increasing the load factor to a level somewhat greater than uniform, but

[7] Nuclear Attack Hazard in Continental U.S., 1963, Office of Emergency Planning and Department of Defense.
a. Vol. I, Problem and Approach (Confidential).
b. Vol. II, Methodology and Input (TSRD).
c. Vol. III, Summary of Attack-Effects Probabilities (Secret).

that the rate of return then decreases rapidly (See first differences in Table I) This is not unexpected because increasing the load factor above the uniform level simply means that the areas expected to experience heaviest fallout will be avoided Also, strain upon both hosts and evacuees decreases with decreasing load factor Finally, three important sources of uncertainty in the calculations upon which Table I is based also lead one to favor load factors near uniform. These uncertainties are

a Fallout prediction techniques,

b Winds, and

c. Enemy intentions.

It is fairly well-known that various techniques for calculation of fallout patterns even for a single wind structure may lead to some rather large differences in predicted dose patterns. This is at least partly because there has never been conducted a well-instrumented large-yield burst over a land surface with strong winds aloft For obvious reasons, such a test may never be carried out even though it would do much to clarify the fallout prediction problem.

Uncertainties in wind structure are another source of difficulty One example that illustrates this point is given in Fig 2 where the 1000-r dose contours for winds observed on four particular days are shown on the same map[8] Figure 2 indicates that, while it may be reasonable to plan on

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[8] D A Young. Fallout Contours at Albuquerque. New Mexico Sandia Corporation Technical Memorandum SCTM-195-59(51). January, 1960

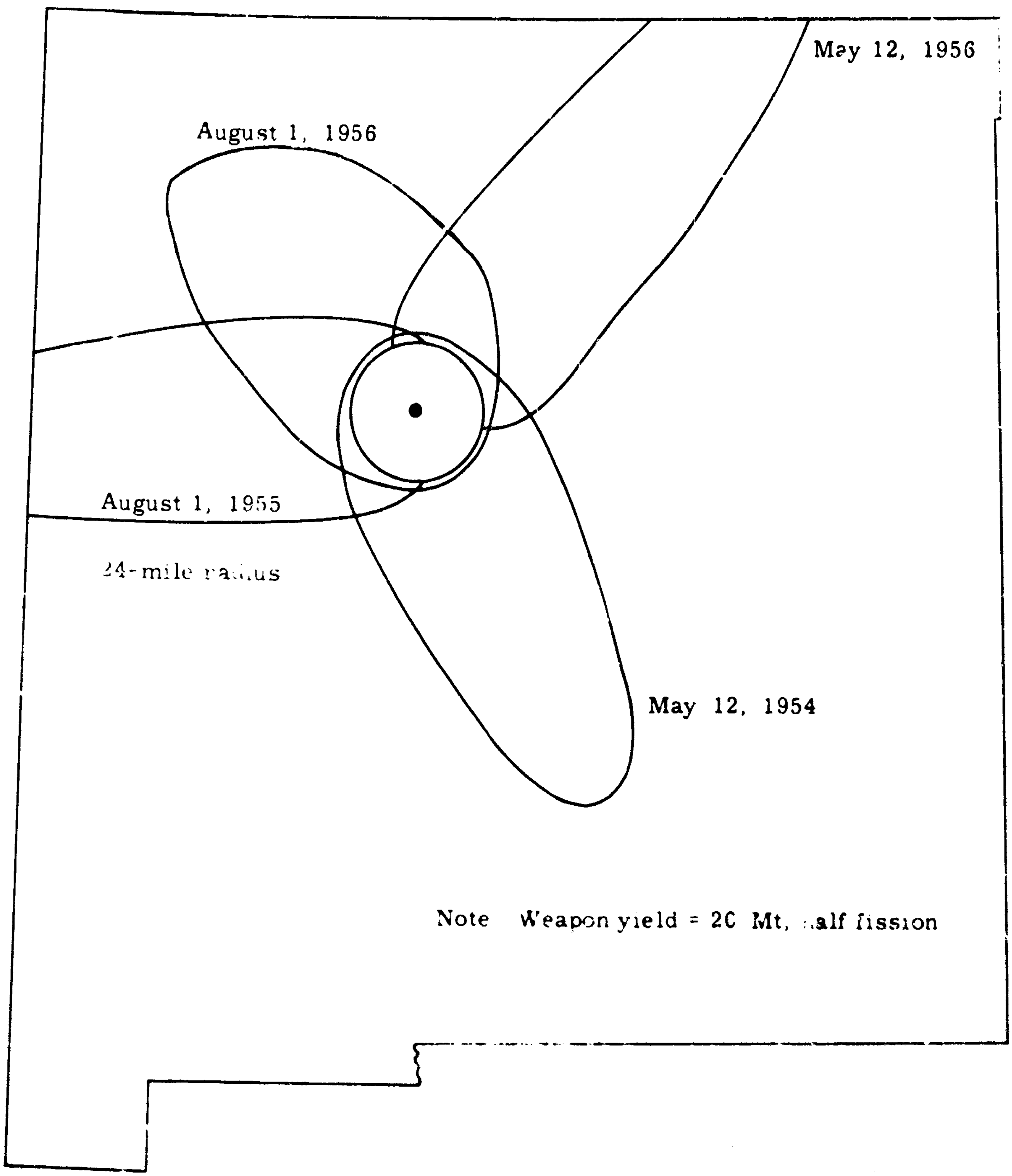

Fig 2

San ia Fallout Model Predictions of the 1000-R Dose Contours for Bursts at Albuquerque on Four Particular Days expected value basis, one should be aware that almost any wind pattern is at least possible. An investigation of fallout wind statistics may be found in Refs. 9 and 10.

The third source of uncertainty mentioned above, the enemy's intentions, has been discussed at length in a number of publications (e.g., see Ref. 11). As a hedge against the particular uncertainty of whether an enemy would consider population a principal target, a bonus target or a target to be spared, one might employ a plan that distributes the population in a nearly uniform manner.* For a fixed hardness posture such a distribution would tend to impose the greatest cost upon an enemy that has as a goal the destruction of some large fraction of the U. S. population. A uniform distribution can be approached if some upper limit is placed on the size of post-movement population groups.

Next, it is appropriate to consider the numerical values of uniform load factor for a large-scale evacuation and to consider whether they are prohibitively large. One approximation can be made by examining the fraction of the U. S. population contained in cities versus city size. Then, if

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[9] E. D. Callahan, et al., The Probable Fallout Threat Over the Continental United States, Technical Operations, Inc. Report No. TO-B-60-13, December 1, 1960.

[10] B. N. Charles, Mean Layer Winds by Seasons, Sandia Corporation and U. S. Weather Bureau Cooperative Project in Climatology Phase Two, March 1960, (unpublished)

[11] Herman Kahn, Thinking about the Unthinkable, Horizon Press, N. Y., 1962

* Strategic evacuation allows the offense to plan a countervalue attack that is aimed at the destruction of facilities without requiring an attack that would also kill a large fraction of the population.

one can decide on the minimum size of a city to be evacuated, an estimate of the uniform load factor can be made on a national basis. For this estimate the Census Bureau's "urbanized areas" have been used because they are believed to provide the best separation of urban and rural population in the vicinity of large cities. The results are shown in Table II. Note that even if all urbanized areas with populations greater than 50,000 were evacuated, the uniform load factor is not much more than 2.

Table II

Estimate of National Uniform Load Factor for Evacuation of U. S. Urbanized Areas[a]

Minimum population (thousands)	Fraction of U. S. population	Uniform load factor
1000	.29	1.4
750	.33	1.5
500	.37	1.6
250	.43	1.8
200	.46	1.9
100	.51	2.0
75	.52	2.1
50	.54	2.2

[a] Data from 1960 U. S. Census.

Of course, this is a very rough approximation, but it serves to indicate that the problem is soluble. A more detailed examination of the problem has been made and it tends to bear out the same conclusion. In this second look, the load factor was calculated for each state, since it is believed that the smaller the number of governments involved, the more manageable the plan. Thus, it seems preferable to have each state stand alone or, where this is impossible, to have the smallest reasonable group of states involved in supporting each other. While this policy of minimizing the number of interstate agreements required may cause some hardship, it is expected that it would lead to a workable plan in the shortest time.

As a further improvement on the first load-factor estimates, a specific heavy attack was chosen and the load factors were calculated assuming that everyone living within 24 miles of each target would be evacuated.* This radius was originally chosen somewhat arbitrarily on the basis that it is the distance to an overpressure of 1 psi plus 3 times an estimated CEP of 1.5 miles for a surface burst of a 20-Mt weapon. These choices were expected to lead to a conservative estimate of the number of evacuees since they are associated with a 0.002 probability of exceeding 1 psi on the circumference. The results of the analysis of uniform load factors by states for the Tech Ops attack are shown in Fig. 3. Note that some of the states will have to be grouped, particularly in the Northeast.

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*The chosen attack is often referred to as the "Tech Ops Attack" and includes delivery of 816 weapons on U. S. military, industrial, and dam targets (Ref. 9)

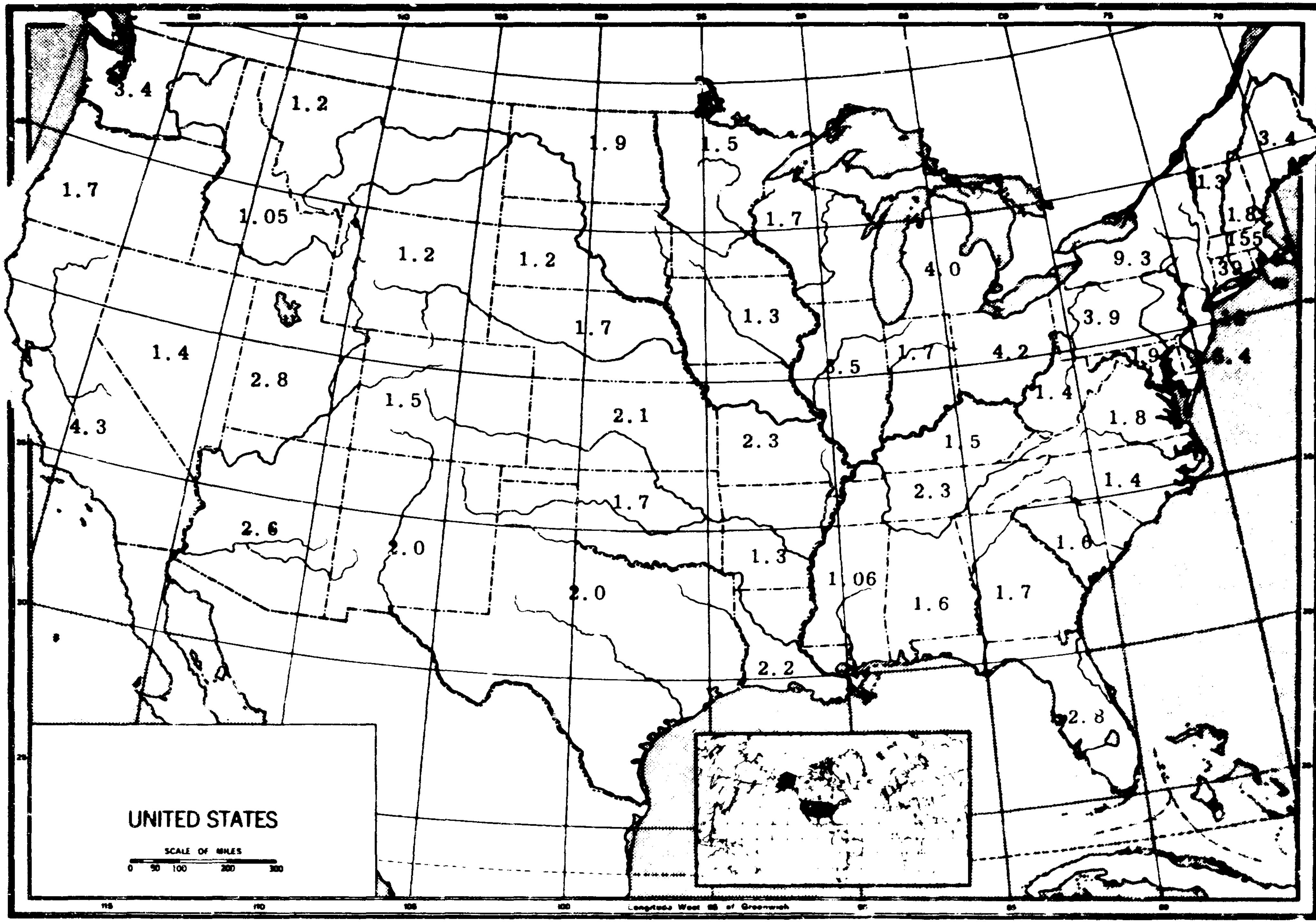

Fig. 3
Uniform Load Factor for Each State

Because the results of the analysis depicted in Fig. 3 seemed favorable, a post-movement limit of 100,000 people was imposed on reception city size and the uniform load factors for the remaining areas were recalculated. This calculation was performed for each state and for several groups of states in the Northeast. The results are given in Tables III and IV. It should be pointed out that no check was made to be sure that there were no more than 100,000 people in groups located within 24 miles of each other.

Some indication of the size of load factors that might become acceptable under the desperate conditions associated with a "total" evacuation can be obtained by comparing present U. S. housing levels to those of other countries. Such a comparison is made in Table V where it may be noted that current load factors of 3 are common and that they are as high as 5.2 relative to U. S. standards.[12] One might guess that load factors larger than twice the maximum current world value would be tolerable for only a short time or under very desperate conditions. The data in Tables III and IV indicate that a maximum load factor of less than ten is easily achieved by grouping states and that even a maximum load factor of less than five may be achievable everywhere in the U. S.

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[12] United Nations Statistical Yearbook for 1961, Statistical Office of the United Nations, Department of Economic and Social Affairs, 1961.

Table III

Population and Load Factor Data for Conterminous U. S.[a]

	Total population[b]	Target area population[b]	Reception area population[c]	Uniform load factor[c] No limit[d]	Uniform load factor[c] 10^5 limit[d]
Alabama	3,267	1,218	2,049	1.6	1.6
Arizona	1,302	794	508	2.6	2.6
Arkansas	1,786	451	1,335	1.3	1.3
California	15,717	12,088	3,629	4.3	4.6
Colorado	1,754	551	1,203	1.5	1.5
Connecticut	2,535	2,470	65	39	39
Delaware	446	377	69	6.4	6.4
District of Columbia	764	764	0	-	-
Florida	4,952	3,180	1,772	2.8	2.9
Georgia	3,943	1,644	2,299	1.7	1.7
Idaho	233	12	221	1.1	1.1
Illinois	10,081	7,136	2,945	3.5	3.6
Indiana	4,662	1,978	2,684	1.7	1.8
Iowa	2,758	578	2,171	1.3	1.3
Kansas	2,179	1,136	1,043	2.1	2.1
Kentucky	3,038	1,074	1,964	1.5	1.5
Louisiana	3,257	1,767	1,490	2.2	2.2
Maine	969	680	289	3.4	3.4
Maryland	3,100	1,504	1,596	1.9	1.9
Massachusetts	5,148	5,115	33	155	-
Michigan	7,823	5,853	1,970	4.0	4.2
Minnesota	3,414	1,161	2,253	1.5	1.5
Mississippi	2,178	123	2,055	1.1	1.1

Table III (Continued)

Population and Load Factor Data for Conterminous U. S.[a]

	Total population[b]	Target area population[b]	Reception area population[c]	Uniform load factor[c] No limit[d]	Uniform load factor[c] 10^5 limit[d]
Missouri	4,320	2,467	1,853	2.3	2.5
Montana	675	112	563	1.2	1.2
Nebraska	1,411	597	814	1.7	1.7
Nevada	285	79	206	1.4	1.4
New Hampshire	607	272	335	1.8	1.8
New Jersey	6,067	5,684	383	16	19.3
New Mexico	951	468	483	2.0	2.0
New York	16,782	14,977	1,805	9.3	10.6
North Carolina	4,556	1,252	3,304	1.4	1.4
North Dakota	214	103	111	1.9	1.9
Ohio	9,706	7,393	2,313	4.2	4.5
Oklahoma	2,328	966	1,362	1.7	1.7
Oregon	1,769	754	1,015	1.7	1.7
Pennsylvania	11,319	8,440	2,879	3.9	4.1
Rhode Island	859	859	0	-	-
South Carolina	2,383	930	1,453	1.6	1.7
South Dakota	681	107	574	1.2	1.2
Tennessee	3,567	1,998	1,569	2.3	2.3
Texas	9,580	4,868	4,712	2.0	2.1
Utah	891	576	315	2.8	2.8
Vermont	390	95	295	1.3	1.3
Virginia	3,967	1,822	2,145	1.8	1.9

Table III (Continued)

Population and Load Factor Data for Conterminous U. S.[a]

	Total population[b]	Target area population[b]	Reception area population[c]	Uniform load factor[c] No limit[d]	Uniform load factor[c] 10^5 limit[d]
Washington	2,853	2,016	837	3.4	3.5
West Virginia	1,860	510	1,350	1.4	1.4
Wisconsin	3,952	1,671	2,281	1.7	1.7
Wyoming	330	54	276	1.2	1.2
Totals	177,609	110,733	66,876	2.7	

[a] Assumes evacuation of all people within a 24-mile radius of the targets in the Tech Ops list of military, industrial, and dam targets (Ref. 9).

[b] All populations are expressed in thousands.

[c] Uniform load factor equals "Total population" divided by "Reception area population."

[d] Refers to post-movement limit on size of places in reception areas.

Table IV

Housing Load Factors for Northeastern States

Group		Uniform load factor	
		No limit[a]	10^5 limit[a]
I.	New York, New Jersey, Pennsylvania	6.7	7.2
II.	Group I plus West Virginia and Ohio	5.2	5.5
III.	New York, New Jersey, Pennsylvania, West Virginia, Virginia, Maryland, Delaware, and District of Columbia	4.3	4.5
IV.	Maine, Vermont, New Hampshire, Connecticut, Massachusetts, and Rhode Island	10.3	11.1
V.	Group III plus group IV	4.9	5.1
VI.	Group V plus Indiana, Michigan, Ohio, Kentucky, Tennessee, and North Carolina	3.5	3.6

[a] Refers to post-movement limit on population of places in reception areas.

Table V

Average Housing Load for Various Places[a]

Place[a]	Data for year	No. of persons per room	Load factor[b]
Argentina	1947	2.2	3.7
Bulgaria	1956	1.8	3.0
Canada	1951	0.7	1.2
Czechoslovakia	1950	1.5	2.5
Denmark	1955	0.7	1.2
Dominican Republic	1955	1.7	2.8
Finland	1950	1.5	2.5
France	1954	1.0	1.7
Germany, Federal Republic	1956	1.0	1.7
Greece	1951	1.8	3.0
Guatemala	1949	3.1	5.2
Italy	1951	1.3	2.2
Poland	1950	1.4	2.3
Spain	1950	1.1	1.8
USSR	1956	1.5	2.5
UK	1951	0.8	1.3
Yugoslavia	1954	2.3	3.8
US	1960	0.6	1.0

[a] Source is United Nations Statistical Yearbook, 1961 (Ref. 12)

[b] Load factor is measured relative to the U. S. for 1960.

To summarize the remarks on choice of load factor:

a. The facts that expected casualties decrease slowly with load factor above the uniform level, that the strain among hosts and evacuees decreases with decreasing load factor, and that load factors close to the uniform level are a hedge against uncertainties, make a load factor slightly greater than uniform the preferred choice.

b. Load factors smaller than those commonly accepted for everyday living by other people in the world are achievable within most states or at worst by grouping several states.

3.0 Effects of Providing Simple Fallout Shelter

The numbers of fatalities shown in Table I for the Albuquerque area were obtained under the assumption that anyone who lacked space in a National Fallout Shelter Survey (NFSS) Phase 1 shelter or a Phase 2 mine shelter was protected only by a house (assumed PF=2).* Since there are not many shelters in the reception area, this meant that most people were protected with a PF of only two. There are at least two simple types of temporary shelters that can be constructed rapidly to obtain a PF of at least 20 and, for a small additional cost, a PF of 100. The Tech Ops improved basement shelter[13] is one type that can be used in many parts

* There are practically no basements in New Mexico.

[13] E. D. Callahan, L. Rosenblum, J. R. Coombe, Shelter from Fallout, Tech Operations, Inc., Report No. TO-B60-30, April 1961.

of the U. S.; the other is the simple trench. A few rudimentary experiments with the construction of trench shelters were performed by two of the authors and details which indicate their feasibility are reported in Ref. 1; the Hudson Institute and Research Triangle Institute have also considered use of trench shelters and believe it to be feasible.[6, 14]

Table VI shows the results of calculations of the numbers of fatalities if a PF=20 or a PF=100 shelter is provided for all Albuquerque evacuees and their hosts. Note that if shelters having a PF=100 were provided, no fatalities would be expected. Typical results for some northeastern states are given in Table VII.

4.0 Transportation Problems

A feeling for the mobility of the U. S. population can be obtained by examining the data in Table VIII, where it is shown that the states all have an average of four or less people per automobile.[15] Of course, the average will be larger in cities that have extensive public transportation systems. The five boroughs of New York City have the largest average with 5.9 persons per automobile. Boston is next with 4.5, Philadelphia has 4.1, and all others are 4.0 or less.[6] In addition, there were about 12 million trucks, buses, and publicly-owned vehicles in 1960, probably enough capacity to

---

[14] K. E. Willis, E. R. Brooks, L. J. Dow, Final Report: Crash Civil Defense Program Study, Research Triangle Institute, Operations Research Division, April 30, 1963.

[15] Highway Statistics, 1961, U. S. Dept. of Commerce, Bureau of Public Roads, U. S. Government Printing Office, 1963. ($1.00)

Table VI

Fatalities for Albuquerque Reception Area
When Simple Fallout Shelters are Provided

Maximum housing load factor	Fatalities(%)		
	Existing shelter	Min. PF=20	Min PF=100
2.7 (uniform)	12	---[a]	---[a]
3	10	1.5	0
5	8	0.7	0
7	7	0.5	0
9	7	0.5	0

[a] Not calculated

Table VII

Fatalities in Northeastern States[a]

Load Factor	Fatalities (%)	
	Min. PF=20	Min. PF=100
5.2 (uniform)	---[b]	---[b]
6	10	3
8	8	2
10	8	1.5

[a] Group for these calculations consists of New York, New Jersey, Pennsylvania, West Virginia, and Ohio

[b] Not calculated

Table VIII

Number of Registered Automobiles by State

State	Total population (thousands)	Registered autos (thousands)	Registered trucks (thousands)	People per auto[a]	People per truck
Alabama	3,267	1,065	239	3.1	13.7
Arizona	1,302	520	142	2.5	9.2
Arkansas	1,786	516	211	3.5	8.5
California	15,717	6,892	1,187	2.3	13.2
Colorado	1,754	751	217	2.3	8.1
Connecticut	2,535	1,011	128	2.5	19.8
Delaware	446	147	51	3.0	8.7
District of Columbia	764	486	20	4.1	38.2
Florida	4,952	2,125	317	2.3	15.6
Georgia	3,943	1,261	291	3.1	13.5
Idaho	233	264	121	0.9	1.9
Illinois	10,081	3,389	456	3.0	22.1
Indiana	4,662	1,719	363	2.7	12.8
Iowa	2,758	1,089	258	[illegible]	10.7
Kansas	2,179	897	291	2.4	7.5
Kentucky	3,038	977	253	3.1	12.0
Louisiana	3,257	952	231	3.4	14.1
Maine	969	310	73	3.1	13.3
Maryland	3,100	1,034	144	3.0	21.5
Massachusetts	5,148	1,660	194	3.1	26.5
Michigan	7,823	2,938	406	2.7	19.3
Minnesota	3,414	1.321	282	2.6	12.1
Mississippi	2,178	548	192	4.0	11.3
Missouri	4,320	1,291	344	3.3	12.6
Montana	675	266	121	2.5	5.6
Nebraska	1,411	571	184	2.5	7.7

Table VIII (Continued)

Number of Registered Automobiles by State

State	Total population (thousands)	Registered autos (thousands)	Registered trucks (thousands)	People per auto[a]	People per truck
Nevada	285	141	45	2.0	6.3
New Hampshire	607	229	46	2.7	13.2
New Jersey	6,067	2,248	278	2.7	21.8
New Mexico	951	327	115	2.9	8.3
New York	16,782	4,630	549	3.6	30.6
North Carolina	4,556	1,435	339	3.2	13.4
North Dakota	214	234	114	0.9	1.9
Ohio	9,706	3,707	444	2.6	21.9
Oklahoma	2,328	904	312	2.6	7.5
Oregon	1,769	763	176	2.3	10.1
Pennsylvania	11,319	3,805	552	3.0	20.5
Rhode Island	859	309	38	2.8	22.6
South Carolina	2,383	737	155	3.2	15.4
South Dakota	681	262	102	2.6	6.7
Tennessee	3,567	1,119	238	3.2	15.0
Texas	9,580	3,611	938	2.7	10.2
Utan	891	345	90	2.6	9.9
Vermont	390	124	30	3.1	13.0
Virginia	3,967	1,247	228	3.2	17.4
Washington	2,853	1,135	265	2.5	10.8
West Virginia	1,860	490	125	3.8	14.9
Wisconsin	3,952	1,355	275	2.9	14.4
Wyoming	330	142	67	2.3	4.9

[a] The numbers of automobiles are for the year 1961, the population for 1960. Because of this time difference between the two sources of data the tabulated values are slightly optimistic. The source of motor vehicle data is Ref. [illegible]

carry out an evacuation solely by this means since it would imply an average load of less than 10 people per truck.

In addition to the U. S. capacity for movement of people by motor vehicle, there is a large railroad capacity. In the Hudson Institute plans for evacuation of the northeastern states, about 20 percent of the evacuees moved by rail. This movement would be primarily by freight car, with each car holding 65 people and each train including 100 cars. Movement by rail has a number of advantages, a principal one being that it is less weather-dependent than movement by automobile.

5.0 Recent Examples of Large-Scale Movements

Both experiment and history indicate that strategic movement is feasible. Some of the major attempts to test evacuation techniques are described in Refs. 16 and 17. In Operation Rideout, a test evacuation of Bremerton, Washington, about 2000 vehicles evacuated the downtown area and passed the city limits in a half hour. The average speed of the traffic columns was 30 mph.

Operation Green Light was a test evacuation of a 1000-block area of downtown Portland, Oregon. In 34 minutes about 29,000 vehicles and 101,000 people had left the area; this included 11,000 people who walked.

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[16] Operations Walkout, Rideout, and Scat, National Academy of Sciences, National Research Council, 1955 (unpublished).

[17] Operation Green Light, Disaster Relief and Civil Defense Office, Portland, Oregon, September 1955.

Hurricane Carla provided an example of the feasibility and possible value of employing strategic evacuation. In the evacuation of the Texas and Louisiana coastal areas, about 500,000 people moved distances of as much as 350 miles in less than two days. Decisions to evacuate were not made simultaneously over the rather large area evacuated and a check of individual city or county movement times indicates that the movement rates for Operations Rideout and Green Light were not atypical. For example, it took about 6 hours to evacuate 108,000 people from Jefferson County, Texas. The Carla evacuations were performed using normal traffic procedures or, in some places, by using all but one lane which was left open for emergency traffic. Perhaps the best endorsement for strategic evacuation comes from the people and officials involved. The following two paragraphs are typical expressions of the people directly involved in the evacuation:[18]

> "The success of the Carla operation left coastal officials without exception sold on evacuation as a practical, cheap, and life-saving device. Agreement was unanimous among state and local officials that, if they had listened to defeatists and critics of evacuation, thousands of lives would have been lost. The Port Arthur CD director said, 'Anyone who says now that total evacuation is impossible is crazy. It was proven, we did it.'
>
> "The extent of the success startled even those traffic experts who had engineered the operation. The State Director of the Texas Department of Public Safety said, 'If someone had told me that we could have evacuated between

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[18] Mattie E. Treadwell, Hurricane Carla, Department of Defense, Office of Civil Defense, Region 5, U. S. Government Printing Office, December 1961. ($0.55).

half a million and 750,000 people, under the stress we had, and not have one fatality or injury, I wouldn't have believed him. If someone had told me there'd be no panic, I wouldn't have believed him.'"

6.0 Elements of a Strategic Movement Plan

The following are believed to be the basic elements that require consideration in a strategic movement plan:

a. Decision as to who moves and when.

b. Delineation of evacuation and reception places.

c. Transportation, including method, traffic control, refueling, treatment of breakdown, and similar details.

d. Billeting, feeding, and medical care.

e. Fallout shelter and radiological monitoring in reception areas.

f. Supply.

g. Command and control.

h. Communications.

The choice of what groups of people should move and when should be made at a high level, and the announcement should probably come from the President. Some local officials may anticipate such an announcement, but a national decision would still seem appropriate. One interesting scenario in which a sequence of events leads to a strategic evacuation may be found in Ref 6 (p. V-B-1 ff.). Another fictional, but plausible, sequence in which there was time to employ strategic evacuation but no capability for it, is provided in Pat Frank's novel Alas, Babylon.

The choice of evacuation and reception places and their association is the main subject of the planning study suggested in Ref. 3. It is believed that making this set of choices is a basic step in the development of a capability for strategic evacuation. Improvisation might take care of most problems associated with strategic evacuation, but the relative simplicity of assigning reception areas for each evacuation area makes it seem extremely unwise to risk the possible mass confusion associated with improvisation in the assignment of reception areas to evacuees.

A gross treatment of transportation problems is described in Ref. 3. That is, it is suggested that major transportation routes between evacuation and reception areas be catalogued and assigned in an efficient manner, but that details of keeping these routes full and the traffic controlled, be planned with local participants.

Billeting, feeding, and medical care are believed to be matters that should be handled locally. Actually, these functions were delegated by the President to the Department of Health, Education, and Welfare except for some aspects of food management that were assigned to the Department of Agriculture.[19] However, it would seem that OCD at least has a responsibility to see that these departments are apprised of strategic movement plans and that they then make suitable arrangements to fulfill their assigned roles.

[19] Executive Order 10958, As Amended; August 14, 1961 and Executive Order 11001; February 16, 1962.

Fallout shelter in reception areas can be provided for everyone at a very modest cost by using improved basement or trench shelters. This would require a certain amount of preplanning to determine how many shelter spaces are needed in each reception area, how many could be constructed with available equipment and materials, and how much additional stockpiling is required. The study outlined in Ref. 3 would make a start in this direction by indicating how many NFSS spaces would be used, how many basements, and how many trenches are required for the remainder.

Supply problems and command and control problems can be considered in the following phases:

a. Pre-movement,
b. Movement,
c. Post-movement, pre-attack,
d. Post-attack, in-shelter, or
e. Return.

Both supply and command and control problems will require local-level planning. However, specification of the distribution of people requiring supplies during the post-movement, pre-attack and the post-attack, in-shelter phases would be a necessary input. This distribution would provide a basis for planning the rerouting of normal supply lines and the stockpile locations for supplies for these two phases.

Communications and radiological monitoring needs are expected to be fulfilled by meeting the requirements associated with other parts of the national CD capability. Of course this is only a judgment and eventually a study would be required to define these particular needs and to determine the feasibility of adapting available systems to this application. At the very least, some paper planning will be required to make use of the existing and planned facilities.

The 1959 State Survival Plans represent an approximation to the type of local planning that is needed. It is believed that such local plans can be made as they were before, but that procedures should be formalized to keep the plans exercised and up-dated. It is expected that in a strategic evacuation, the local civil defense directors will act as advisers to the normal government officials, rather than as commanders. Again, Hurricane Carla indicated that this method of operating is adequate for a strategic evacuation. There were no great command and control problems--even the fact that there was no racial segregation caused no special problems. There is a much greater need for planning to use available resources of trained men, working organizations, and materials than for the establishment of any radically new and different organization just to handle a strategic evacuation.

7.0 An Approach to Planning Assignments of Evacuees to Reception Areas

Since Ref. 3 contains a detailed description of a technique for planning the assignment of evacuees to reception areas, the technique will be described only briefly here. The process leads first to the development of a suggested Distribution Plan which is a listing of the number of evacuees to be assigned to each reception area. Next, a Movement Plan is developed that tells which evacuees are assigned to each reception area, which route they are to use, and at what time they should depart.

7.1 Distribution Plan. The distribution plan is based on the minimum-casualty distribution program described in Ref. 2. The following are required items of input data:

a. Definition of evacuation and reception sectors;

b. Initial population, shelter capacity in each of a number of protection factor categories, and vulnerability of people in each shelter; and

c. An Allowed Movement Table.

The definition of evacuation areas may be made in any of a number of ways. However, what is basically required is a list of possible targets and a choice of area to be evacuated around each target. The suggested technique makes use of the NAHICUS '63 attack study[7], and the area evacuated is that area bounded by the curve on which there is a 0.1 probability of exceeding 1 psi. This is the most conservative choice available if the NAHICUS results are used. The area evacuated would, of course, be approximated by commonly recognized geographic features. In view of the rather large number of recent changes in U. S. military bases, it would be appropriate to make use of a more up-to-date attack, but the basic idea of choosing a conservatively large area to be evacuated can be associated with any attack picture.

Reception areas may be chosen in a similar way. The suggested approach is to select areas that are about the size of a county or a small number of counties and that have about the same vulnerability. Vulnerability is defined to be the probability of exceeding some preselected casualty-producing radiation dose. Two hundred roentgens, the threshold for lethality, is suggested as a reasonable choice for this problem.

The initial population is simply taken from census data. The shelter capacity is that found in the NFS Phase 2 survey. However, since the number of spaces in reception areas is somewhat limited, two shelter classes are used to represent the protection afforded by houses. A house with no basement is assigned a PF of 2; one with a basement is assigned a PF of 20. The number of basements in the reception area is estimated from the Housing Census.[20] Once the PF of a shelter class is chosen, the vulnerability of people in that shelter class is taken to be the probability of exceeding a free-field dose of 200 times the PF.

The final step in preparation of input data involves the construction of an "Allowed Movement Table." This table consists of an array that indicates whether movement between particular evacuation and reception areas is to be allowed or not. It is intended to help limit the problem and yet to allow reasonably complete use of transportation facilities. Thus, for example, an arbitrary distance limit might be imposed, or travel across a large river or other major barrier may be limited.

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[20] United States Census of Housing, 1960, Series HC(1), U. S. Department of Commerce, Bureau of the Census, U. S. Government Printing Office January 1962.

Table IX summarizes the input data requirements for the minimum-casualty distribution program used to obtain the distribution plan.

Table X summarizes the output obtained from the program. Note that, in addition to the distribution plan, the expected number of casualties for each reception sector is printed for the assumed shelter distribution and for the cases where the shelter system is upgraded to provide everyone a PF of at least 20 or 100. The number of survivors added by raising the minimum PF to each of these levels is also printed along with the number of spaces required to so upgrade the shelter system. Any other pair of PF's may be chosen; these were chosen to represent the value of preparing trenches with only weather cover (PF=20) and with about 100 psf of roof cover for shielding (PF=100).[1]

7.2 Movement Plan. Appendix C of Ref. 3 provides a description of a computer program that may be used to design a movement plan. The program has since undergone considerable development, the results of which are reported in Ref. 4. In addition, a second technique has been developed which allows planning of minimum-cost movements.[21] This choice might be employed at a lower rung on the escalation ladder if the "rate of climb" is sufficiently low.* It would be appropriate, for example, to employ minimum-cost movements for partial evacuations of non-essential

[21] D. E. Brannon, A Computer Program for Calculating Minimum Cost Movements, Dikewood Corporation Technical Note No. DC-TN-1039-6, December 17, 1964.

* For a discussion of such considerations, see Ref. 22.

Table IX

Input Data for Distribution Program

A. Sector Characteristics

Sector	Initial population	Shelter class 1 . . . n	
		Capacity	Vulnerability
1			
2			
3			
.			
.			
.			

B. Allowed Movement Table[a]

From	To reception sectors						
	1	2	3	4	.	.	.
1							
2							
3							
.							
.							
.							
evacuation sectors							

[a] Table entries indicate whether movement is allowed, an entry of 0 means movement is not allowed, 1 means it is allowed

Table X

Output Data from Distribution Program

A. Results using available shelter

Reception sector	Shelter class 1 . . . n	Totals
1	Final population Expected casualties	Final population Expected casualties
2		
.		
.		
.		
		Total population Total expected casualties

B. Results assuming minimum PF=20 or 100[a]

	Min PF=20[a]			Min PF=100[a]		
Reception sector	Expected casualties	Added survivors	Added spaces required	Expected casualties	Added survivors	Added spaces required
1						
2						
.						
.						
.						

Table X (Continued)

Output Data from Distribution Program

C. Distribution table[b]

Evacuation sector	Reception sector					
	1	2	3	.	.	.
1						
2						
.						
.						

---

[a] Any pair of PF's may be used.

[b] Table entries are numbers of people moved from an evacuation sector to a reception sector.

workers and their dependents, particularly if the crisis were still at levels at which decision-makers would not want to disrupt the transportation system. The input and output associated with each of these programs is described below.

7.2.1 A Computer Program for Planning Rapid Strategic Movement. The computer program described in Ref. 4 operates on an initial population distribution, a desired final distribution, movement rates and a segment-node description of the route network over which the movement is to be accomplished. From this data, the number of people to be moved from each evacuation site to each reception site, the routes involved, and the associated time schedules are calculated. The logic in the program is basically heuristic and consists of a series of algorithms, originated during the development of the program, that tend to minimize the time required to attain the desired distribution.

A mathematical proof that the technique used leads to a minimum-time movement has not been found. Attempts to develop a technique that has a more rigorous basis have been unsuccessful to date.

The initial population is taken from census data and should correspond to that used in the preparation of input for the Distribution Program (see Table IX). The desired final distribution is taken from the output of the Distribution Program (Part C of Table X). Note that the Distribution Program output associates a number of evacuees with each evacuation-reception sector pair. However, it is the desired final distribution that is of greatest interest, since any other association of evacuees with evacuation-reception sector pairs that gives the same final distribution will also be a minimum-casualty movement. The Movement Program is therefore employed to provide a set of such associations that will make efficient use of the transportation system. The present version of this Movement Program will accept as many as 10 evacuation sectors and 50 reception sectors. The Distribution Program will treat many more, but if the Movement Program limits are exceeded, the Distribution Program output will have to be broken into parts for input to the Movement Program.

The evacuation rate is defined in terms of the number of people per hour that can move past a point on a "unit-capacity" segment of a transportation route. A unit-capacity segment may, for example, be defined as one lane of a highway. Then, if one assumes an evacuation rate of 1000 automobiles per lane per hour, with each auto containing 4 persons, the evacuation rate is 4000 people per hour. Any other physically reasonable choice can be used.

A general speed in miles per hour is specified that is consistent with the probable travel rate over the evacuation routes (e.g., 30 mph). If there is a segment over which a speed can be maintained that is significantly different from the general speed, the mileage of this segment must be appropriately adjusted. Thus, if 45 mph can be maintained on a given segment while the general route speed is 30 mph, the true segment mileage is multiplied by 30/45 or 0.67 to adjust its length. This kind of adjustment is also used to treat other types of transportation, such as railroads. Here the adjustment can be made to reflect necessary changes in both evacuation rate and route speed, the first by varying the number of unit-capacity segments, and the second by adjustment of segment length.

Memory of the Dikewood 7044 computer limits the present version of the program to treatment of less than 500 segments. A few remarks to explain the node-numbering conventions used in the program will help the reader understand the sample problem discussed later in this section. However, these remarks are not essential to understanding the program and its limitations and the reader not interested in these details should skip to the text that follows Fig. 6. The node numbers assigned to evacuation areas must be less than 100, and the numbers assigned serially to reception areas must start at 2000. Non-terminal nodes are numbered serially beginning with 100 and numbers from 1300 to 1399 are used for dummy nodes to represent multiple-capacity route segments. Some reception places will also be junctions in the network for travel to other reception sectors. Such places are assigned a non-terminal node number for the travel network and a zero-length segment with a terminal node number to indicate that it is a reception site.

Figure 4 shows a single 10-mile segment of a route between nodes 220 and 221.

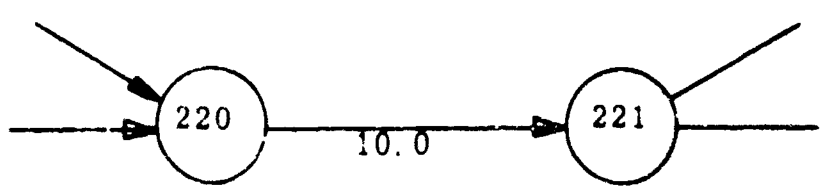

Fig. 4

Map of a Unit-Capacity Route Segment

If a portion of a route has a capacity of two (two lanes of a highway to be used) it is mapped with a dummy node into two unit-capacity segments. Figure 5 shows a 12-mile, 2-lane segment available between nodes 221 and 222.

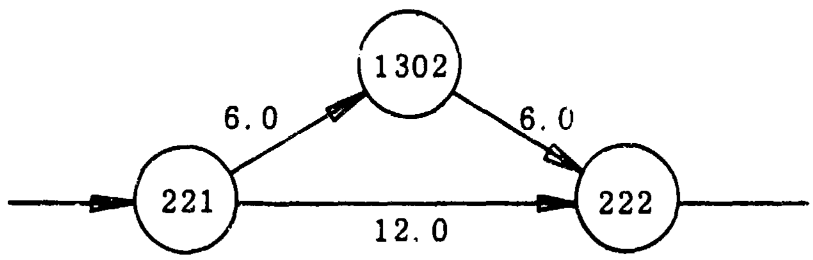

Fig. 5

Map of a Double-Capacity Segment

When a route to a given reception area passes through another reception area, a dummy node and a zero-length segment are used so that the bypassed reception area remains a terminal node. Figure 6 illustrates this situation.

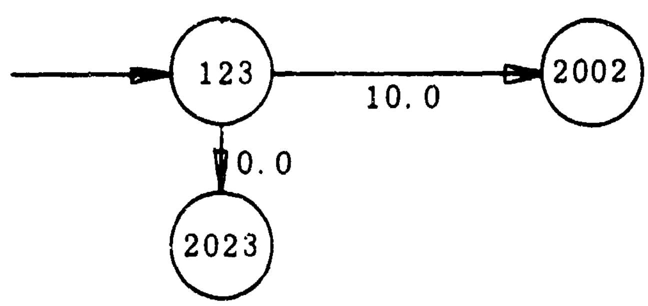

Fig. 6

Map of Route to Reception Area 2002 that Passes Through Reception Area 2023

The direction of traffic flow must also be indicated in the input data. In Figs. 4, 5, and 6, this direction is indicated by the placement of an arrowhead. This choice requires considerable judgment on the part of the planner. He should first make some gross estimates of the desired overall direction of flow. In making the final choices, he will find that a large problem area may be divided into several subareas simply by proper choice of flow directions on individual segments.

Two additional input data items must be specified, namely, a time unit and a precision variable. The time unit is specified for the problem such that the physical length of the line of people passing a point in unit time is small compared to the number of people using the route. For example, a time unit of 0.01 hours and an evacuation rate of 4000 people per hour would establish the program's concern with the movement of units containing 40 people. The precision variable establishes the degree of precision desired in the calculations and is equal to the desired precision divided by the time unit. For example, if the desired precision is a half-hour (that is, no readjustments are to be made in the schedule if it cannot be improved by more than a half-hour) and the time unit is 0.01, the precision variable is 0.5/0.01 or 50.

The output of the program is simply a list of the numbers of people to be moved from each evacuation site to each reception site, the route to be taken by each group, the time of departure after movement begins, and the time when each reception sector is full.

Several sample problems were run in the development of the program. Among these was one used to produce a sample strategic movement plan for the State of New Mexico. Target cities within the state and in neighboring states were taken from the Tech-Ops Target List.[9] It was assumed that half of the population of El Paso, Texas, would also take part in the New Mexico movement. This was done because of the scarcity of reception areas, external to New Mexico, for the El Paso population. All other places within the state with a population greater than 200 people were divided into groups to form reception areas. Each reception area was given the name of the largest place within it.

Figure 7 is an arrow diagram map of allowed traffic flow superimposed on a segment-node map of the highway network.

The number of people to be sent to each reception area was based on a uniform load factor for the state. (The load factor was 2.28 for the problem.) Table XI lists the initial population of each reception area and the number of evacuees assigned to it.

Figure 8 depicts the evacuation routes that were calculated by the program. Evacuation areas are enclosed by 24-mile radius circles. Principal cities in reception areas are designated by crosses. The computer printout of the schedule is shown in Table XII. Note that there are 6 evacuation areas and 38 reception areas. There are 42 different routes used in the schedule and 27 hours are required to complete the movement of the 637,616 people by auto. No rail movements were used in this problem.

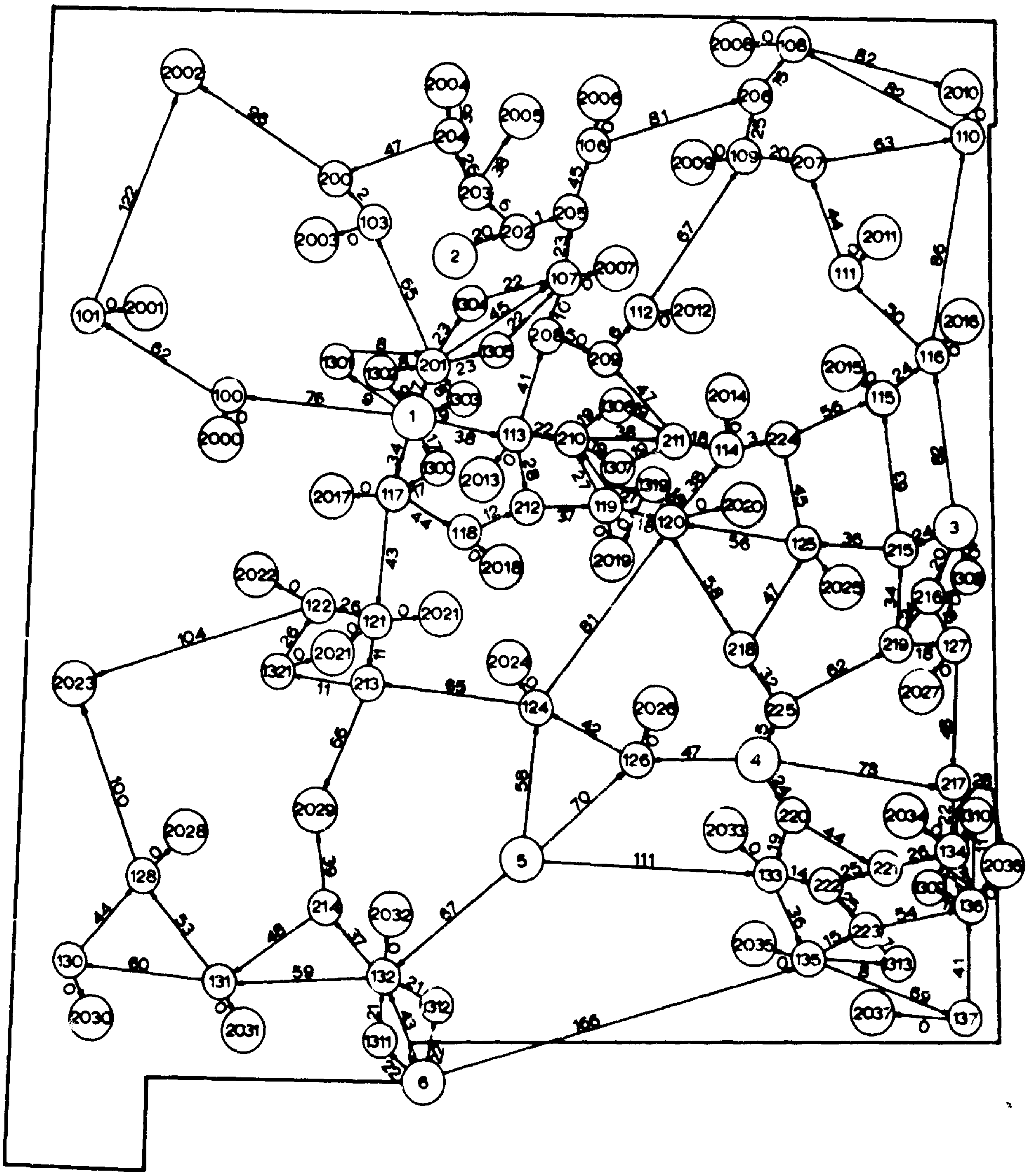

Fig. 7

Segment-Node Diagram for New Mexico Strategic Movement

Table XI

Evacuee Assignment for a New Mexico Strategic Movement Plan

Reception area	Initial population[a]	Number of evacuees assigned[b]
Farmington	53,306	68,348
Gallup	37,209	47,709
Grants	22,939	29,412
Cuba	5,469	7,012
Tierra Amarilla	7,443	9,543
Vallecitos	958	1,228
Taos	24,653	31,610
Raton	10,408	13,345
Clayton	6,068	7,780
Springer	3,398	4,357
Mosquero	1,875	2,404
Logan	674	864
Tucumcari	11,605	14,880
Las Vegas	23,468	30,090
Santa Fe	38,388	49,220
Santa Rosa	4,308	5,524
Moriarty	3,073	3,940
Belen	9,101	11,669
Mountainair	2,366	3,034
Encino	1,058	1,356
Vaughn	1,302	1,669
Jal	8 927	11,446
Reserve	2,773	3,555
Magdalena	1,825	2,340
Socorro	8,343	10,697
Ft. Sumner	2,991	3,835
Carrizozo	2,571	3,296
Hondo	5,173	6,633
Truth or Consequences	6,409	8,217
Silver City	21,059	27,001
Dora	2,781	3,566
Artesia	17,686	22,677
Lovington	15,034	19,276
Carlsbad	33,397	42,821
Hobbs	29,468	37,783
Lordsburg	5,215	6,687
Deming	9,839	12,615
Las Cruces	54,728	70 177
Totals	497,288	637,616

[a] Population based on 1960 census.

[b] Includes 205,350 evacuees from El Paso.

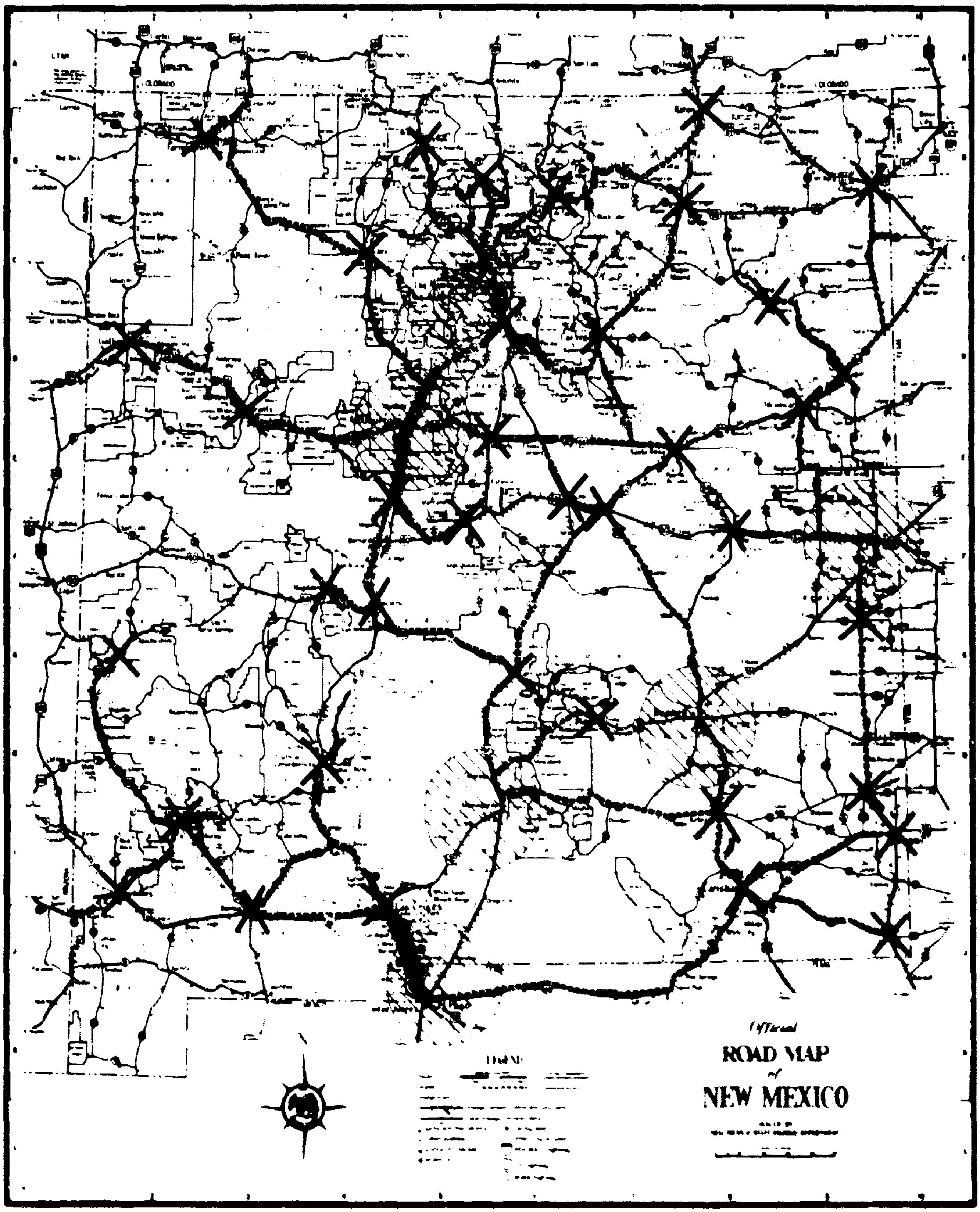

Fig. 8

Route Map of a Strategic Movement Plan for New Mexico

Table XII

Computer Output for a New Mexico Strategic Movement Plan

EVAC RATE= 4000., ROUTE VEL= 30., TIME UNIT=.01, POP UNIT= 40.00, IMPROVEMENT INCREMENT=0.50 HOURS.

EVAC POINT	UNITS
1	6865
2	375
3	1292
4	1429
5	845
6	5134

RECEP POINT	UNITS
2000	735
2001	1193
2002	1709
2003	175
2004	239
2005	31
2006	790
2007	1230
2008	334
2009	109
2010	194
2011	60
2012	752
2013	99
2014	138
2015	372
2016	22
2017	292
2018	76
2019	34
2020	42
2021	267
2022	58
2023	89
2024	82
2025	96
2026	166
2027	89
2028	675
2029	205
2030	167
2031	315
2032	1754
2033	567
2034	482
2035	1071
2036	945
2037	286

RECEPTION AREA	TIME WHEN FULL
2000	21.813
2001	16.530
2C02	23.090
2003	21.573
2004	6.340
2005	5.883
2006	14.523
2007	18.417
2008	9.823
2009	7.590
2010	7.540
2011	6.940
2012	15.220
2013	3.637
2014	5.247
2015	6.620
2016	5.493
2017	3.263
2018	3.360
2019	11.627
2020	7.403
2021	7.137
2022	4.013
2023	9.390
2024	5.523
2025	6.480
2026	3.993
2027	6.747
2028	14.477
2029	8.577
2030	7.960
2031	12.021
2032	13.553
2033	7.863
2034	8.797
2035	15.373
2036	27.123
2037	7.793

Table VII

ROUTE NUMBER 69 ALBUQUERQUE TO SANTA ROSA - MOVE 5382 PEOPLE WITH START TIME OF 0. HOURS.
ALBUQUERQUE TO MORIARTY TO CLINES CNRS TO JCT. 84-66W TO SANTA ROSA

ROUTE NUMBER 3 ALBUQUERQUE TO MORIARTY - MOVE 3861 PEOPLE WITH START TIME OF 1.38 HOURS.
ALBUQUERQUE TO MORIARTY

ROUTE NUMBER 156 LOS ALAMOS TO RATON - MOVE 4095 PEOPLE WIT TART TIME OF 0. HOURS.
LOS ALAMOS TO ESPANOLA TC RIVERSIDE TO TAOS TO JCT. 64-85 T. RATON

ROUTE NUMBER 44 LOS ALAMOS TO T.A. - MOVE 9321 PEOPLE WITH START TIME OF 1.05 HOURS.
LOS ALAMOS TO ESPANOLA TO HERNANDEZ TO JCT. 84-96 TO T.A.

ROUTE NUMBER 27 LOS ALAMOS TO VALLECITOS - MOVE 1209 PEOPLE WITH START TIME OF 3.44 HOURS.
LOS ALAMOS TO ESPANOLA TO HERNANDEZ TO VALLECITOS

ROUTE NUMBER 121 ALBUQUERQUE TO GALLUP - MOVE 46527 PEOPLE WITH START TIME OF 0. HOURS.
ALBUQUERQUE TO GRANTS TO GALLUP

ROUTE NUMBER 31 ALBUQUERQUE TO GRANTS - MOVE 28665 PEOPLE WITH START TIME OF 11.93 HOURS.
ALBUQUERQUE TO GRANTS

ROUTE NUMBER 292 ALBUQUERQUE TO RATON - MOVE 8931 PEOPLE WITH START TIME OF 0. HOURS.
ALBUQUERQUE TO BERNALILLO TO SANTA FE TO RIVERSIDE TO TAOS TO JCT. 64-85 TO RATON

ROUTE NUMBER 218 ALBUQUERQUE TO SPRINGER - MOVE 4251 PEOPLE WITH START TIME OF 0. HOURS.
ALBUQUERQUE TO BERNALILLO TO SANTA FE TO JCT. 85-285 TO ROMEROVILLE TO LAS VEGAS TO SPRINGER

ROUTE NUMBER 184 ALBUQUERQUE TO FARMINGTON - MOVE 66651 PEOPLE WITH START TIME OF 0. HOURS.
ALBUQUERQUE TO BERNALILLO TO CUBA TO JCT. 96-44 TO FARMINGTON

ROUTE NUMBER 98 ALBUQUERQUE TO TAOS - MOVE 30810 PEOPLE WITH START TIME OF 2.29 HOURS.
ALBUQUERQUE TO BERNALILLO TO SANTA FE TO RIVERSIDE TO TAOS

ROUTE NUMBER 310 ROSWELL TO LAS VEGAS - MOVE 29328 PEOPLE WITH START TIME OF 0. HOURS.
ROSWELL TO JCT. 285-70 TO JCT. 285-20 TO VAUGHN TO ENCINO TO CLINES CNRS TO JCT. 84-66W
TO ROMEROVILLE TO LAS VEGAS

ROUTE NUMBER 64 ROSWELL TO ENCINO - MOVE 1326 PEOPLE WITH START TIME OF 7.52 HOURS.
ROSWELL TO JCT. 285-70 TO JCT. 285-20 TO VAUGHN TO ENCINO

ROUTE NUMBER 55 ALBUQUERQUE TO MAGDALENA - MOVE 2262 PEOPLE WITH START TIME OF 0. HOURS.
ALBUQUERQUE TO BELEN TO SOCORRO TO MAGDALENA

ROUTE NUMBER 37 ALBUQUERQUE TO CUBA - MOVE 6825 PEOPLE WITH START TIME OF 17.09 HOURS.
ALBUQUERQUE TO BERNALILLO TO CUBA

ROUTE NUMBER 34 ALBUQUERQUE TO MTNAIR - MOVE 2964 PEOPLE WITH START TIME OF 0. HOURS.
ALBUQUERQUE TO BELEN TO MTNAIR

ROUTE NUMBER 113 ALAMOGORDO TO SOCORRO - MOVE 10413 PEOPLE WITH START TIME OF 0. HOURS.
ALAMOGORDO TO CARRIZOZO TO SAN ANTONIO TO SOCORRO

ROUTE NUMBER 13 ALBUQUERQUE TO SANTA FE - MOVE 24024 PEOPLE WITH START TIME OF 10.19 HOURS.
ALBUQUERQUE TO BERNALILLO TO SANTA FE

ROUTE NUMBER 2 ALBUQUERQUE TO BELEN - MOVE 6045 PEOPLE WITH START TIME OF 0.58 HOURS.
ALBUQUERQUE TO BELEN

ROUTE NUMBER 133 ROSWELL TO JAL - MOVE 11154 PEOPLE WITH START TIME OF 0. HOURS.
ROSWELL TO HAGERMAN TO ARTESIA TO CARLSBAD TO JAL

ROUTE NUMBER 58 CLOVIS TO LOVINGTON - MOVE 17901 PEOPLE WITH START TIME OF 0. HOURS.
CLOVIS TO PORTALES TO DORA TO TATUM TO LOVINGTON

ROUTE NUMBER 4 CLOVIS TO DORA - MOVE 3471 PEOPLE WITH START TIME OF 4.59 HOURS.
CLOVIS TO PORTALES TO DORA

ROUTE NUMBER 6 ROSWELL TO ARTESIA - MOVE 13923 PEOPLE WITH START TIME OF 2.86 HOURS.
ROSWELL TO HAGERMAN TO ARTESIA

ROUTE NUMBER 7 EL PASO TO LAS CRUCES - MOVE 43875 PEOPLE WITH START TIME OF 0. HOURS.
EL PASO TO LAS CRUCES

ROUTE NUMBER 123 ALAMOGORDO TO VAUGHN - MOVE 390 PEOPLE WITH START TIME OF 2.67 HOURS.
ALAMOGORDO TO CARRIZOZO TO VAUGHN

ROUTE NUMBER 11 ALAMOGORDO TO CARRIZOZO - MOVE 3198 PEOPLE WITH START TIME OF 2.77 HOURS.
ALAMOGORDO TO CARRIZOZO

ROUTE NUMBER 45 CLOVIS TO TUCUMCARI - MOVE 14508 PEOPLE WITH START TIME OF 0. HOURS.
CLOVIS TO MELROSE TO TUCUMCARI

ROUTE NUMBER 394 EL PASO TO RESERVE - MOVE 3471 PEOPLE WITH START TIME OF 0. HOURS.
EL PASO TO LAS CRUCES TO DEMING TO SILVER CITY TO RESERVE

ROUTE NUMBER 157 EL PASO TO LORDSBURG - MOVE 6513 PEOPLE WITH START TIME OF 0.89 HOURS.
EL PASO TO LAS CRUCES TO DEMING TO LORDSBURG

ROUTE NUMBER 167 CLOVIS TO CLAYTON - MOVE 7566 PEOPLE WITH START TIME OF 0. HOURS.
CLOVIS TO LOGAN TO CLAYTON

ROUTE NUMBER 142 EL PASO TO SILVER CITY - MOVE 26325 PEOPLE WITH START TIME OF 2.56 HOURS.
EL PASO TO LAS CRUCES TO DEMING TO SILVER CITY

ROUTE NUMBER 111 CLOVIS TO MOSQUERO - MOVE 2340 PEOPLE WITH START TIME OF 1.94 HOURS.
CLOVIS TO LOGAN TO MOSQUERO

ROUTE NUMBER 71 EL PASO TO T. OR C. - MOVE 7995 PEOPLE WITH START TIME OF 2.56 HOURS.
EL PASO TO LAS CRUCES TO HATCH TO T. OR C.

ROUTE NUMBER 41 CLOVIS TO LOGAN - MOVE 858 PEOPLE WITH START TIME OF 2.54 HOURS.
CLOVIS TO LOGAN

ROUTE NUMBER 12 CLOVIS TO FT. SUMNER - MOVE 3744 PEOPLE WITH START TIME OF 3.72 HOURS.
CLOVIS TO MELROSE TO FT. SUMNER

```
ROUTE NUMBER  30        ALAMOGORDO  TO HONDO        - MOVE   6474 PEOPLE WITH START TIME OF  0.    HOURS.
 ALAMOGORDO  TO HONDO

ROUTE NUMBER 130        ALAMOGORDO  TO CARLSBAD     - MOVE   4290 PEOPLE WITH START TIME OF  0.60 HOURS.
 ALAMOGORDO  TO ARTESIA     TO CARLSBAD

ROUTE NUMBER  62        ALAMOGORDO  TO ARTESIA      - MOVE   8190 PEOPLE WITH START TIME OF  1.70 HOURS.
 ALAMOGORDO  TO ARTESIA

ROUTE NUMBER  74        ALBUQUERQUE TO VAUGHN       - MOVE   1248 PEOPLE WITH START TIME OF  2.37 HOURS.
 ALBUQUERQUE TO MORIARTY    TO JCT. 41-60  TO ENCINO       TO VAUGHN

ROUTE NUMBER 401        EL PASO     TO LOVINGTON    - MOVE    897 PEOPLE WITH START TIME OF  0.    HOURS.
 EL PASO     TO CARLSBAD    TO JCT. 360-62 TO HOBBS        TO LOVINGTON

ROUTE NUMBER 166        EL PASO     TO CARLSBAD     - MOVE  37479 PEOPLE WITH START TIME OF  0.23 HOURS.
 EL PASO     TO CARLSBAD

ROUTE NUMBER 319        EL PASO     TO HOBBS        - MOVE  36855 PEOPLE WITH START TIME OF  9.84 HOURS.
 EL PASO     TO CARLSBAD    TO JCT. 360-62 TO HOBBS

ROUTE NUMBER  18        ALBUQUERQUE TO SANTA FE     - MOVE  23946 PEOPLE WITH START TIME OF 10.19 HOURS.
 ALBUQUERQUE TO BERNALILLO  TO SANTA FE

ROUTE NUMBER  91        EL PASO     TO DEMING       - MOVE  12285 PEOPLE WITH START TIME OF  4.61 HOURS.
 EL PASO     TO LAS CRUCES  TO HATCH       TO DEMING

ROUTE NUMBER   8        EL PASO     TO LAS CRUCES   - MOVE   7488 PEOPLE WITH START TIME OF  9.31 HOURS.
 EL PASO     TO LAS CRUCES

ROUTE NUMBER   9        EL PASO     TO LAS CRUCES   - MOVE  17004 PEOPLE WITH START TIME OF  7.76 HOURS.
 EL PASO     TO LAS CRUCES

ROUTE NUMBER   1        ALBUQUERQUE TO BELEN        - MOVE   5343 PEOPLE WITH START TIME OF  0.76 HOURS.
 ALBUQUERQUE TO BELEN




THE FOLLOWING ROUTES ARE IDENTICAL

   ROUTE NUMBERS    13,   15,   18

   ROUTE NUMBERS     2,    1

   ROUTE NUMBERS     7,    8,    9

                    NO ALTERNATE SCHEDULE
```

Another problem for which this program was used is described in Par. 2.2 of Chapter III.

7.2.2 A Computer Program for Planning Minimum-Cost Movements. A second movement planning technique has been prepared for possible use following strategic warning. Emphasis is placed on the word strategic; it is assumed that the decision-maker has high confidence that the warning is strategic and that he would therefore prefer to carry out a minimum-cost movement. Cost is expressed in terms of man-miles and the program determines that movement which minimizes total man-miles traveled. It is further assumed that only one lane of each route would be made available for evacuees. This is considered appropriate for the assumed level of crisis; a level at which one may, for example, wish to evacuate dependents, but not preclude use of the transportation system for other essential purposes. Keeping other lanes open would also simplify logistics and control requirements.

The input data required for this program is very similar to that for the program described in Par. 7.2.1. A principal difference is that this program does not require prior choice of direction of flow and the preparation of the node-segment network is therefore much simpler. Otherwise, the program requires initial and final population distributions, evacuation rate, and the general speed of travel over the transportation network to be specified.

The calculations are also more straightforward. First an algorithm by Moore[23] is applied to calculate the shortest route from each evacuation site to each reception site. These shortest routes are stored in the form of a sequence of node numbers and total route length. The array of shortest-route lengths between each evacuation site and each reception site may be thought of as a "cost" matrix.

The next step in the calculations makes use of another algorithm[24] and the initial and final population distributions and the cost matrix. This algorithm allows calculation of the number of people to be moved from each evacuation site to each reception site such that the total number of man-miles traveled is a minimum.

In the next section of the program, competition is resolved on those routes selected for use. Evacuees moving the greatest distance are given first priority. If two groups of evacuees both use a particular segment of highway, the group traveling the shorter distance is delayed at their origin long enough so that the segment in common use is available to them just as they reach it.

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[23] Pollack, Maurice and Wiehenson, Walter, "Solutions of the Shortest-Route Problem--A Review," Operations Research, Vol. 12, No. 4, pp. 519-653.

[24] Ford, L. R., and Fulkerson, D. R., Flows in Networks, Princeton University Press, 1962, p. 93.

The other choice that would use the highway efficiently would require the group traveling the shorter distance to wait in a "holding area" near the entrance to the segment in common use. Such a procedure may be worthwhile in movements carried out at a higher level of crisis to get people out of potential initial effects areas as soon as possible. However, for lower-level crises appropriate to choice of a minimum-cost movement, asking evacuees to wait in holding areas for times as long as a day seems undesirable.

Finally, the program prints a listing of the route description, departure schedule, and total time required to complete movement to each reception site.

This program has also been applied to a number of problems, one of which is described here to illustrate use of the program. The place to be evacuated is Albuquerque, New Mexico; the reception places are arbitrarily chosen to include all places with populations over 200 in about the northern half of the state. The input data assumptions are listed below.

The initial distribution of population was taken from the 1960 Census. The desired final distribution of evacuees was found using the minimum-casualty movement technique developed by Dikewood under Contract OCD-OS-62-248.[1,2] As indicated previously, this technique requires assumptions concerning the attack, shelter distribution, and a casualty criterion. The NAHICUS '63 results were used to describe the fallout threat in reception areas the the area evacuated was a 24-mile radius circle around the aiming points. It was assumed that NFSS Phase I shelters and mines from the Phase II survey were used for fallout protection. A PF of two, associated with houses, was assigned to those for whom there is no space in the NFSS shelters. Mortality was selected as the casualty level to be minimized; a simple straight-line mortality-versus-dose relation was assumed, with the threshold at 200 roentgens and 100 percent mortality at 750 roentgens. A maximum housing load factor of three was chosen and a calculation made of the desired distribution of evacuees. The results are shown in Table XIII.

The desired distribution shown in Table XIII was then used as part of the input data to the transportation assignment program described here. The other input required for this calculation is a node-link diagram of the transportation system. This diagram was prepared for the Albuquerque area assuming that one lane of each available highway would be used; the results of the transportation assignment program are given in Table XIV. Figure 9 consists of a map of the highway network used as input to the program; Fig. 10 illustrates the solution obtained.

Table XV consists of a printout of the computer output for the sample problem.

Table XIII

Desired Population Distribution
for Minimum-Fatality Movement from Albuquerque
(Maximum load factor = 3)

		Population[a] (thousands)	
Sector No.	Principal city	Initial	Final
1-6	Albuquerque	274.6	0
7	Farmington	31.1	93.0
8	Santa Fe	37.6	108.7
9	Gallup	14.9	14.9
10	Grants	14.7	44.1
11	Belen	5.6	16.8
12	Clayton	4.5	13.5
13	Las Vegas	15.1	45.3
14	Raton	8.4	25.1
15	Socorro	6.2	18.6
16	Magdalena	1.4	4.2
17	Mountainair	2.[illegible]	8.1
18	Taos	6.7	20.1
19	Vaughn	1.5	1.5
20	Santa Rosa	2.5	2.5
21	Springer	4.0	12.0
22	Cuba	1.5	4.6

[a] 1960 Census.

Table XIV

Route Assignments for Albuquerque Strategic Movement

Sector	Route Description	Number of evacuees (thousands)	Starting delay (hours)	Time when full (hours)
7	US 85 N to Bernalillo; NM 44 NW to Bloomfield; NM 17 W to Farmington	61.9	0.0	[illegible]
8	NM 422 N to Santa Fe	71.1	19.3	39.1
10	US 66 W to Grants	29.4	0.0	9.9
11	US 85 S to Belen	11.2	3.8	7.6
12	NM 422 N to Santa Fe; US 84-85 NE to Springer; US 64-87 E to Clayton	9.0	0.0	11.5
13	NM 422 N to Santa Fe; US 84-85 NE to Las Vegas	30.2	11.8	23.5
14	NM 422 N to Santa Fe; US 84-85 NE to Springer; US 85 N to Raton	16.7	2.3	14.2
15	US 85 S to Socorro	12.4	0.7	6.3
16	US 85 S to Socorro; US 60 W to Magdalena	2.8	0.0	4.1
17	NM 47 S to Belen; NM 6 SE to US 60; US 60 E to Mountainair	5.4	0.0	3.8
18	NM 422 N to Santa Fe; US 64 NE to Taos	13.4	8.4	16.9
21	NM 422 N to Santa Fe; US 84-85 NE to Springer	8.0	6.4	14.9
22	US 85 N to Bernalillo; NM 44 NW to Cuba	3.1	15.5	19.0

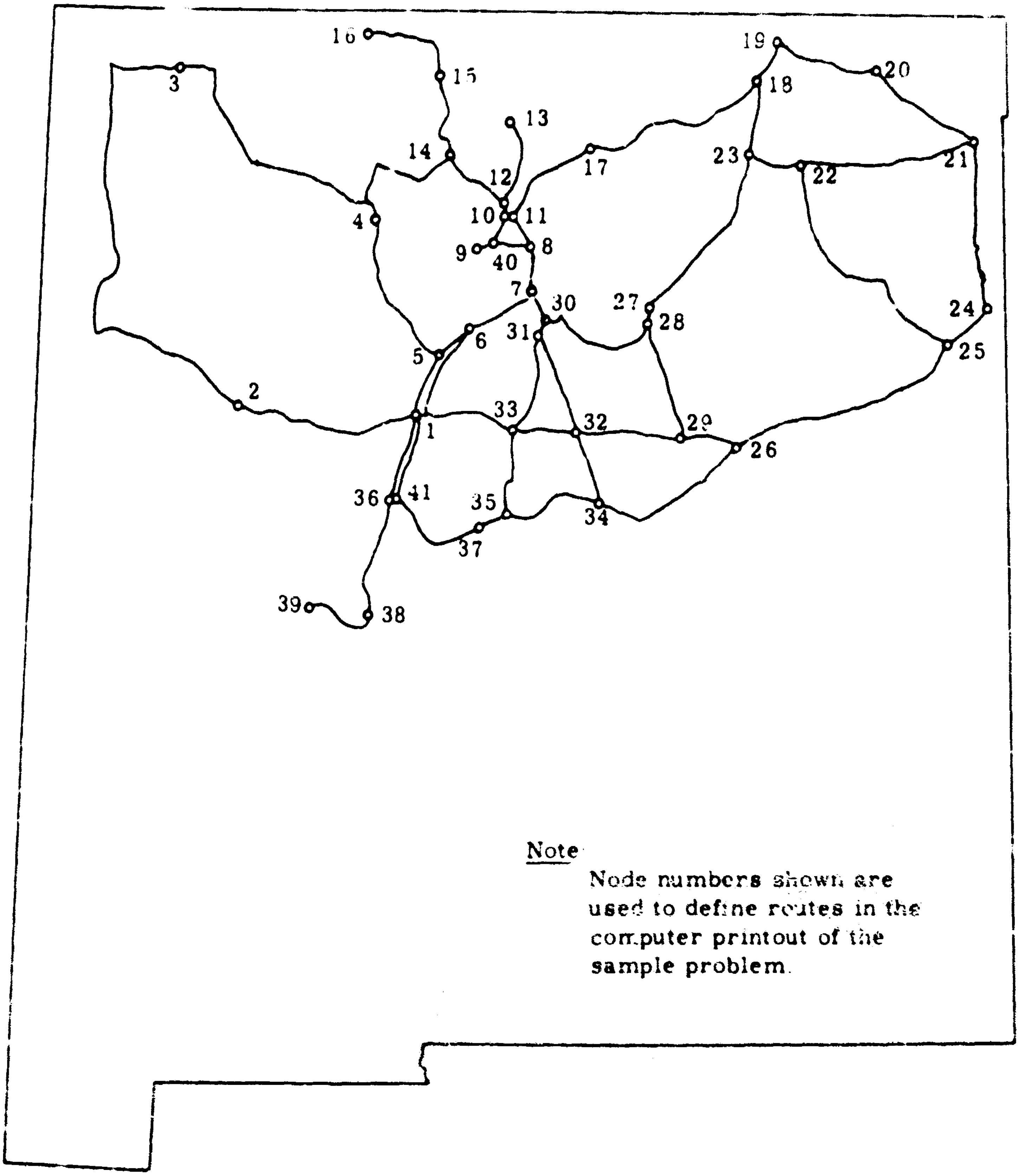

Fig. 9

Node-Link Map of Highway System for Albuquerque Evacuation

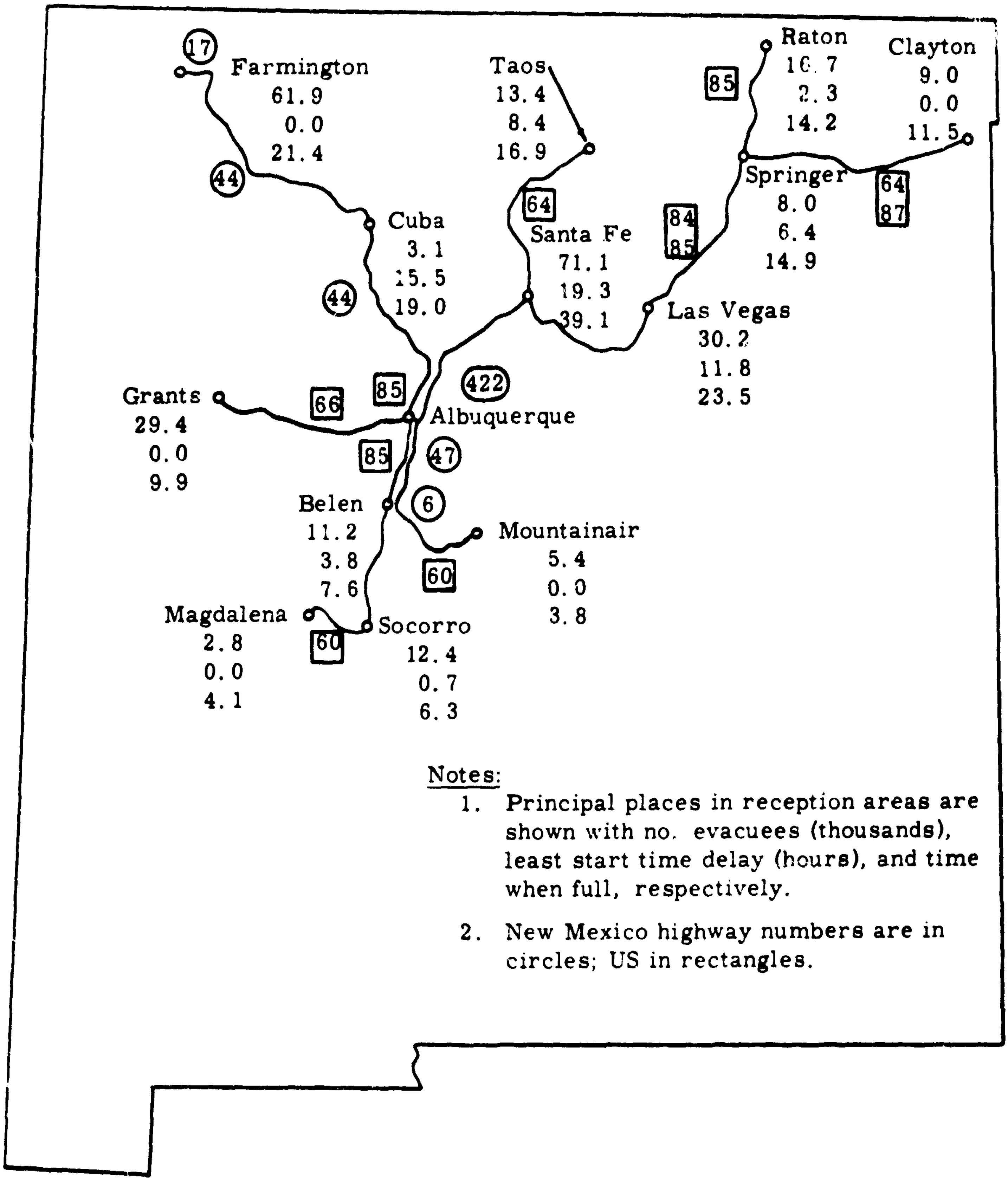

Fig. 10

Minimum Man-Miles Solution for Albuquerque Evacuation

Table XV

Minimum Man-Mile Computer Program Output
for an Albuquerque Strategic Movement

```
TO-    GRANTS     DISTANCE-   76.00 MILES    START TIME-    0.   HOURS
FROM-  ALBUQ      PEOPLE-     29.42 THOUS.   FINISH TIME-   9.89 HOURS

ROUTE SEQUENCE
 1   2

TO-    FRMGTN     DISTANCE-  179.00 MILES    START TIME-    0.   HOURS
FROM-  ALBUQ      PEOPLE-     61.92 THOUS.   FINISH TIME-  21.45 HOURS

ROUTE SEQUENCE
 1   5   4   3

TO-    CUBA       DISTANCE-   83.00 MILES    START TIME-   15.48 HOURS
FROM-  ALBUQ      PEOPLE-      3.08 THOUS.   FINISH TIME-  19.02 HOURS

ROUTE SEQUENCE
 1   5   4

TO-    S FE       DISTANCE-   60.00 MILES    START TIME-   19.33 HOURS
FROM-  ALBUQ      PEOPLE-     71.13 THOUS.   FINISH TIME-  39.11 HOURS

ROUTE SEQUENCE
 1   6   7

TO-    TAOS       DISTANCE-  153.00 MILES    START TIME-    8.43 HOURS
FROM-  ALBUQ      PEOPLE-     13.35 THOUS.   FINISH TIME-  16.87 HOURS

ROUTE SEQUENCE
 1   6   7   3  11  17

TO-    RATON      DISTANCE   233.00 MILES    START TIME-    2.26 HOURS
FROM-  ALBUQ      PEOPLE-     16.73 THOUS.   FINISH TIME-  14.21 HOURS

ROUTE SEQUENCE
 1   6   7  30  28  27  23  18  19

TO-    CLATON     DISTANCE-  276.00 MILES    START TIME-    0.   HOURS
FROM-  ALBUQ      PEOPLE-      9.03 THOUS.   FINISH TIME-  11.46 HOURS

ROUTE SEQUENCE
 1   6   7  30  28  27  23  22  21

TO-    SPRNGR     DISTANCE-  193.00 MILES    START TIME-    6.44 HOURS
FROM-  ALBUQ      PEOPLE-      7.98 THOUS.   FINISH TIME-  14.87 HOURS

ROUTE SEQUENCE
 1   6   7  30  28  27  23
```

```
TO-    LVEGAS       DISTANCE-  126.00 MILES     START TIME-    11.[illegible]7 HOURS
FROM- ALBUQ         PEOPLE-     30.22 THOUS.    FINISH TIME-   23.53 HOURS

ROUTE SEQUENCE
 1   6   7  30   28   27


TO-    BELEN        DISTANCE-   32.00 MILES     START TIME-     3.7[illegible] HOURS
FROM- ALBUQ         PEOPLE-     11.19 THOUS.    FINISH TIME-    7.65 HOURS

ROUTE SEQUENCE
 1  36


TO-    MTNAIR       DISTANCE-   74.00 MILES     START TIME-     0.   HOURS
FROM- ALBUQ         PEOPLE-      5.40 THOUS.    FINISH TIME-    3.32 HOURS

ROUTE SEQUENCE
 1  41   37


TO-    SOCORO       DISTANCE-   75.00 MILES     START TIME-     0.69 HOURS
FROM- ALBUQ         PEOPLE-     12.38 THOUS.    FINISH TIME-    6.29 HOURS

ROUTE SEQUENCE
 1  36   38


TO-    MAGDEL       DISTANCE-  101.00 MILES     START TIME-     0.   HOURS
FROM- ALBUQ         PEOPLE-      2.77 THOUS.    FINISH TIME-    4.06 HOURS

ROUTE SEQUENCE
 1  36   38   39
```

RECEPTION AREA	FILL TIME (HOURS)
2	9.89
3	21.45
4	19.02
7	39.11
17	16.87
19	14.21
21	11.46
23	14.87
27	23.53
36	7.65
37	3.82
38	6.29
39	4.06

CHAPTER III

EVALUATION OF STRATEGIC MOVEMENT PLANS

1.0 Introduction

Some techniques for planning strategic movements were discussed in Chapter II. These techniques would produce plans based on movements that minimize expected casualties in the face of a heavy attack. This chapter is concerned with the evaluation* of such planned movements under various particular situations. For example, one may wish to evaluate the effects of some particular wind structures, of various attacks, or of various alternative responses when an attack arrives before a movement is completed. Standard target-analysis techniques can be applied to the first two of these questions, but the third required development of a new technique. Again, the computer was found helpful because the bookkeeping problem gets quite involved. The computer program developed for this purpose[25] requires as input, the number of survivors among those left in the target area at the time of attack. This calculation of survivors is easy to do by hand, but the volume of work foreseen seemed to indicate

---

*The evaluation is expressed in terms of survivors versus time to attack, as in curves A and B in Fig. 1.

[25] D. E. Brannon, A Computer Program for Calculating Fatalities Among Evacuees Enroute When an Attack Begins, Dikewood Technical Note No. DC-TN-1039-5; December 3, 1964.

that it would be useful to program this problem also.[26] This chapter consists primarily of a description of these two programs. A few applications of the programs are also described.

2.0 Casualty Calculations for Evacuees Enroute When an Attack Begins

2.1 Description of the Computer Program. As indicated in the introduction to this chapter, a computer program has been developed that allows calculation of casualties among those enroute as well as among those in either a target or reception area at the time of attack. The program accounts for changes in location and protection factor after the attack as well as before.

The following input data items are required for this program:

1. Initial and desired final distribution of evacuees.
2. Number of evacuees assigned to each route.
3. Schedule of evacuee departures, rates of movement, and protection factors. One intermediate stopping point is allowed.
4. Latitudes and longitudes of enough points to describe each route.
5. Weapon yields, fission fractions, burst locations (latitude, longitude, and surface or airburst), and detonation times after movement begins.

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[26] D. E. Brannon, A Computer Program for Calculating Casualties From the Initial Effects of Nuclear Weapons, Dikewood Technical Note No. DC-TN-1039-8, February 4, 1965.

6. Effective wind velocity and shear components.[27]

7. Fraction of those in the target area who become casualties from initial effects.

Census data is usually a satisfactory source for the initial population distribution. The desired final distribution, route assignments, and movement schedules may be obtained using the procedures outlined in Chapter II. The protection factor and time unsheltered after arrival in the reception area must be specified; only one value of each of these two variables is used to represent all reception areas. One intermediate stopping point is allowed on each route. This feature was incorporated to permit analysis of the value of "holding areas." Holding areas can be large parking lots located, for example, on the city side of the point where the road leaving a target city narrows down from four to two lanes. Latitudes and longitudes of points along a route (Item 4) may be obtained from a number of types of maps; the distance between points need not be kept constant. The attack assumptions required (Item 5) need no further explanation. Determination of the effective wind speed and shear components (Item 6) is fairly complicated, but is described in Ref. 27 which also contains a description of the fallout model used as a subroutine in this program. A computer program has been prepared to convert observed wind structures to the desired form. Anyone

[27] Wood, W. D., et al., Emergency Operations Doctrine and Organization, Dikewood Corporation Report No. QR-1040-2, Addendum No. 1; February 14, 1964. (Secret)

who has many problems to solve may find it useful; copies may be obtained by writing to one of the authors of this report. As indicated in Par. 1.0, the fraction of those in the target area who become casualties from initial effects (Item 7) may be calculated using standard target-analysis techniques or the computer program described in Par. 3.0 of this chapter.

To calculate casualties, the computer is used to simulate the movement of people along each route. The events that take place and their associated time periods are illustrated in Fig. 11 and listed below.

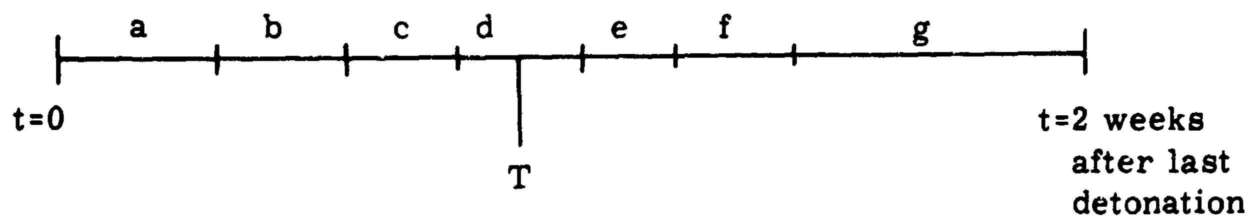

Fig. 11

History of Events for Enroute Casualty Calculations

a. The delay time before using the route (experienced by all units using the route).

b. Further delay experienced by a unit while all of the preceding units start out over the route.

c. The time period required for any unit to travel to a point of intermediate delay or "holding" area.

d. The delay experienced in the holding area.

e. Travel time from holding area to reception area.

f. The time period for which units are unsheltered after arriving in the reception area.

g. The time period for which each unit is sheltered.

T. Time of onset of attack (may occur at any assumed time).

During time periods (a) and (b) the users of a route may accumulate dose from fallout and may become fatalities from initial effects, if any are experienced at the coordinate position denoting the starting point for the route.

Figure 12 indicates the layout of a route, and shows the method of dose calculation for a unit of people.

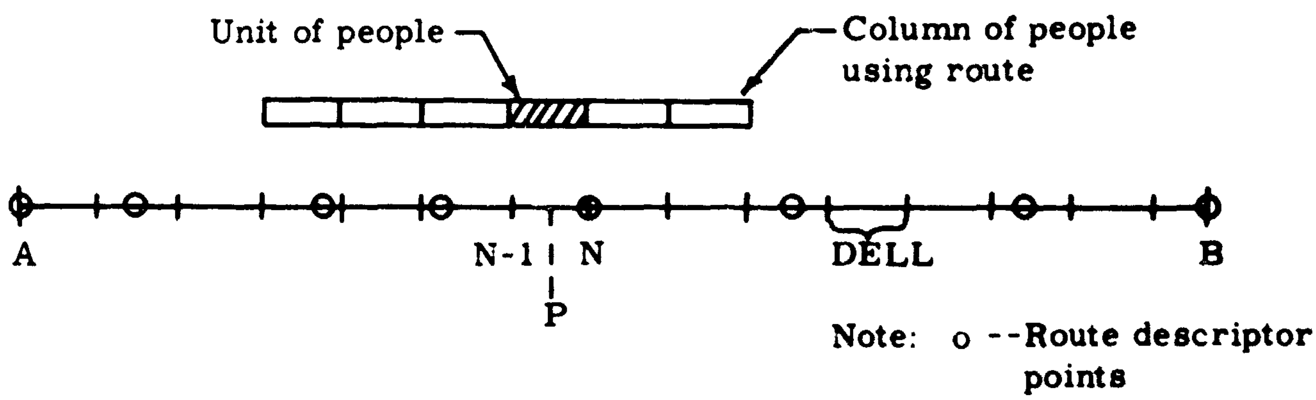

Fig. 12

Illustration of Technique Used for Dose Calculations

For example, consider the calculation of the dose added when the leading member of a unit advances from the point (N-1) to N, where N is an integral number of distance increments (DELL) from the origin. The dose rate at the coordinates midway between N-1 and N (point P) and the time t is calculated. The additional dose received by the unit at P is then given by:

$$\Delta \text{ dose} = \text{dose rate } (P, t) \Delta t,$$

where Δt is the time unit (DELL/ movement speed).

If the movement plan includes a stop at a holding area, the dose is accumulated at the point chosen to represent the holding area for the delay period represented by (d) in Fig. 11.

For times after arrival in the reception area, the dose received by a unit is calculated for the fixed coordinates of the reception center. After period (f) has passed for a unit, the people are assumed to be sheltered with the specified protection factor out to a time of two weeks after the last weapon detonation. The two-week dose is considered a reasonable maximum, because movement, decontamination measures, and radioactive decay will help reduce the exposure to relatively low levels after two weeks have passed. However, if desired, it is a simple matter to change the program to make use of any other upper limit of integration.

Direct numerical integration of the dose rate to find total dose is performed for a period of 24 hours after the last burst, to properly account for the dose accumulated during fallout arrival. From then on, the fallout is assumed to be on the ground and decaying according to the $t^{-1.2}$ law. The effect of biological recovery is ignored in the present program.

The number of fatalities from fallout experienced within a unit of people is calculated from a straight-line approximation of deaths versus dose between the limits of 200 r (0% fatalities) and 750 r (100% fatalities). Further, if th[illegible] happens to be within a 24-mile radius of a target point when the target is attacked, the fatalities in the unit from primary effects are also calculated as a fraction of the number of people in the unit.

The fatalities for all units are added together to find total fatalities for those using a given route.

The printed output from the program includes the items indicated in Table XVI.

Table XVI

Output Information for Enroute Casualty Calculation Program

1. Attack and shelter variables.

2. For each route:
   a. Origin and destination,
   b. Route number,
   c. Planned number of people to be moved over the route,
   d. Number of casualties,
   e. Percent casualties, and
   f. Dose received by each unit of people using the route.

3. For each problem:
   a. Planned total number of people to be moved over all routes,
   b. Total casualties,
   c. Total percent casualties,
   d. People per unit, and
   e. Time from beginning of movement to first detonation.

2.2 A Sample Problem. As indicated in Par. 2.1, this program requires as input, a schedule of evacuee departures and rates of movement. To obtain this schedule, the problem used in Par. 7.2.2 of Chapter II to illustrate the minimum man-mile movement program was run using the other movement program described in Chapter II, Par. 7.2.1. The initial and desired final population distributions are given in Table XIII in Chapter II. The movement schedule obtained is listed in Table XVII and is depicted in Fig. 13. The PF was assumed to be unity until one hour after arrival in the reception area at which time PF=2. This is equivalent to assigning evacuees the protection factor afforded by a house.

The following attack conditions were assumed:

Yield	= 10 Megatons
Fission fraction	= 0.5
Burst height	= surface
Burst location	= intersection of major runways at Kirtland Air Force Base
Burst time	= 8 hours after movement begins.

A wind structure observed at Albuquerque on 12 May 1956 was used; the values used in the computation were:

Effective windspeed	= 60 knots
Effective wind angle	= 45 degrees
Downwind (x) shear component	= +0.15 knots/kft
Crosswind (y) shear component	= -0.027 knots/kft

A hand calculation was made which indicated that about 60 percent of the population remaining in Albuquerque at the time of attack would be killed from initial effects if they were distributed as in the 1960 Census.

Table XVII

Route Assignments for Desired Population Distribution

Sector	Route description		Number evacuees (thousands)	Starting delay (hours)	Time when full (hours)
7	US 66 W to Gallup; US 666 to Shiprock; US 550 to Farmington		23.8	0.0	15.8
7	US 85 N to Bernalillo; NM 44 to Bloomfield; NM 17 W to Farmington		38.2	0.0	15.8
8	NM 422 N to Santa Fe	lane 2	49.1	0.0	14.3
		lane 3	11.0	9.5	14.3
		lane 4	7.9	10.3	14.3
8	US 66 E to Moriarty; NM 41 to US 285; US 285 to US 84-85; US 84-85 to Santa Fe		3.3	9.8	14.3
10	US 66 W to Grants		29.4	5.9	15.8
11	US 85 S to Belen		10.5	1.4	5.0
11	US 47 S to Belen		0.7	3.8	5.0
12	US 66 E to Santa Rosa; US 54 NE to Nara Visa; NM 18 N to Clayton		9.0	0.0	12.4
13	US 66 E to Moriarity; NM 41 N to US 84-85; US 84-85 E to Las Vegas		30.2	2.3	15.0
14	NM 422 N to Santa Fe; US 64 NE to Raton		16.7	0.0	11.8
15	US 85 S to Socorro		12.4	0.7	6.3
16	US 85 S to Socorro; US 60 W to Magdalena		2.8	0.0	4.0
17	US 47 S to NM6; NM 6 SE to US 60; US 60 E to Mountainair		5.4	0.0	3.8
18	NM 422 N to Santa Fe; US 64 NE to Taos		13.4	6.2	13.9
21	US 66 E to Moriarty; NM 41 N to US 84-85; US 84-85 NE to Springer		8.0	4.2	13.3
22	US 85 N to Bernalillo; NM 44 NW to Cuba		3.1	9.5	13.0

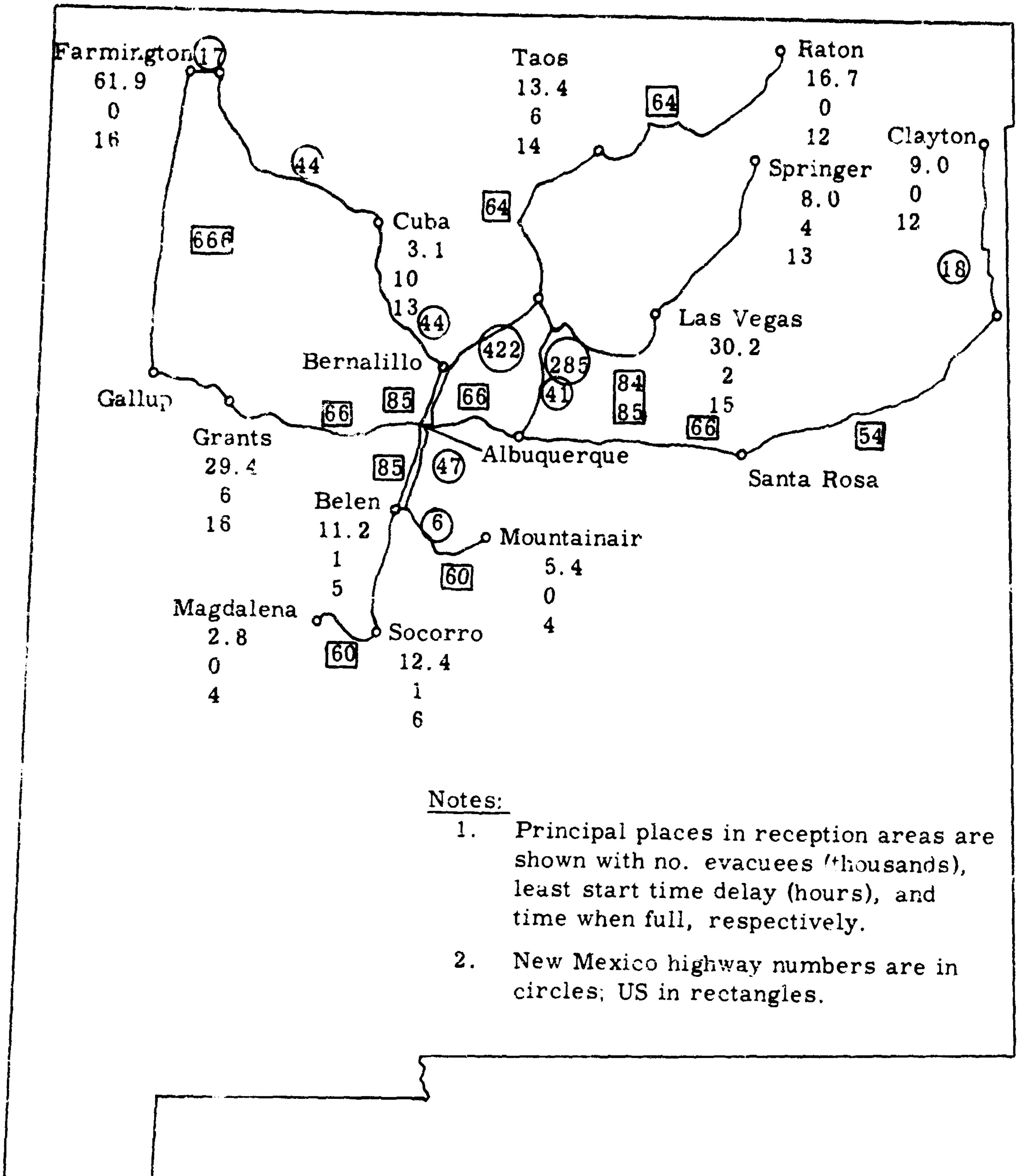

Fig. 13

Transportation Assignment for Albuquerque Evacuees

For illustrative purposes, the surviving evacuees were assumed to move according to the preplanned schedule after the attack takes place.

The detailed results are shown in Table XVIII.

Among other things, the results in Table XVIII indicate that the assumed conditions lead to a total of 37 percent fatalities among the Albuquerque population if the attack occurs eight hours after movement begins. As indicated in Table XVI, the list of numbers following the results for each route show the two-week dose received by each unit of evacuees. For example, if those going to Santa Fe are to survive, protective measures that would reduce their doses by an additional factor of about six are required.

3.0 Calculation of Casualties from Initial Effects

3.1 Description of the Initial Effects Casualty Calculation Program.

This program is used to calculate casualties within a target city for various attack and shielding assumptions. The calculations are made under the assumption that the vulnerability of the target city population can be represented by the following shielding categories, the first seven of which are defined in Ref. 28:

1. Outside unshielded
2. Outside shielded
3. Wood frame structure

[28] Davis, L. W., et al., Prediction of Urban Casualties From the Immediate Effects of a Nuclear Attack, Contract OCD-OS-62-203, Dikewood Report No. DC-FR-1028; April, 1963. (Confidential)

FROM TO
ALBUQ RATON

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
194	16720.00	0.	0.

12.42	12.42	12.42	12.42	12.42
12.42	12.42	12.42	12.42	12.42
12.42	12.42	12.42		

FROM TO
ALBUQ CLAYTON

ROUTE NUMBER	PEOPLF MOVED	EXPECTED CASUALTIES	PERCFNT CASUALTIES
18	9040.00	0.	0.

0.	0.	0.	0.	0.
0.	0.			

FROM TO
ALBUQ SPRINGER

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
197	8000.00	0.	0.

115.73	115.73	115.73	115.73	115.73
115.73	115.73			

FROM TO
ALBUQ LAS VEGAS

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
74	30240.00	4368.00	14.44

0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00
0.86	15.09	64.98	45.98	35.08
30.17	71.57	120.89	58.75	119.12
139.27	150.80	158.80		

FROM TO
ALBUQ TAOS

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
209	13360.00	7750.65	58.01

0.75	81.58	300.75	507.89	526.40
583.39	646.85	596.32	518.48	468.48
433.97				

FROM TO
ALBUQ CUBA

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
232	3080.00	1848.00	60.00

101.71	93.79	88.64

FROM TO
ALBUQ SOCORRO

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
142	12360.00	0.	0.

0.	0.	0.	0.	0.
0.	0.	0.	0.	0.

Table XVIII

Enroute Casualty Calculation Program Output for an Albuquerque Strategic Movement

```
PERCENT FATALITIES FROM PRIMARY EFFECTS    UNSHELTERED TIME (HRS) AT RECEPTION AREA    PROTECTION FACTOR IN RECEPTION AREA
 IF STILL IN TARGET AREA DURING ATTACK
             60.00                                        1.00                                       2.00

                                            ATTACK VARIABLES

YIELD(MT)  FISSION FRAC  X AND Y SHEAR(KNOTS/KFT)  EFF.WIND(KNOTS)  WIND ANGLE(DEGS)  DELAY(HRS)   TARGET COORDS(LONG AND LAT)
 10.000        0.50      0.14980      -0.02670        60.15             44.88           8.00    106. DEG 37. MIN 35.DEG  3. MIN

FROM        TO
ALBUQ       MOUNTINAIR

   ROUTE NUMBER    PEOPLE MOVED    EXPECTED CASUALTIES    PERCENT CASUALTIES
       367           5400.00              0.                      0.

       0.              0.              0.            0.           0.


FROM        TO
ALBUQ       FARMINGTON

   ROUTE NUMBER    PEOPLE MOVED    EXPECTED CASUALTIES    PERCENT CASUALTIES
       172          23760.00              0.                      0.

       0.              0.              0.            0.           0.
       0.              0.              0.            0.           0.
       0.              0.              0.            0.           0.
       0.              0.              0.

FROM        TO
ALBUQ       GRANTS

   ROUTE NUMBER    PEOPLE MOVED    EXPECTED CASUALTIES    PERCENT CASUALTIES
       174          29400.00          12696.00                  43.18

       0.              0.              0.            0.           0.
       0.00            7.35            2.82         75.81       103.79
     120.35          131.87          140.60        147.57       153.34
     158.24          162.49          166.22        169.55       172.54
     175.26          177.74          180.03

FROM        TO
ALBUQ       MAGDALENA

   ROUTE NUMBER    PEOPLE MOVED    EXPECTED CASUALTIES    PERCENT CASUALTIES
       101           2760.00              0.                      0.

       0.              0.              0.

FROM        TO
ALBUQ       FARMINGTON

   ROUTE NUMBER    PEOPLE MOVED    EXPECTED CASUALTIES    PERCENT CASUALTIES
       289          38160.00           3938.61                  10.32

       0.              0.              0.            0.           0.
       0.              0.              0.            0.           0.
       0.              0.              0.            0.           0.
       0.              0.              0.            0.           0.
       0.              0.00            0.00         78.84       211.15
     318.35          262.77          232.12        214.65
```

FROM	TO
ALBUQ	SANTA FE

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES		PERCENT CASUALTIES
250	49080.00	49080.00		100.00
1124.37	1124.37	11[illegible].37	1124.37	1124.37
1124.37	1124.37	112[illegible].37	1124.37	1124.37
1124.37	1124.37	112[illegible].37	1124.37	1124.37
1124.37	1124.37	1124.51	1217.15	1291.00
1373.82	1515.91	1562.15	1471.14	1439.81
1437.47	1300.87	1206.74	1137.58	1083.66
1039.86	1003.22	971.90	944.65	920.63
899.21	879.93			

FROM	TO
ALBUQ	BELEN

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES		PERCENT CASUALTIES
361	10480.00	0.		0.
0.	0.	0.	0.	0.
0.	0.	0.		

FROM	TO
ALBUQ	SANTA FE

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES		PERCENT CASUALTIES
288	10960.00	10960.00		100.00
997.99	950.87	911.84	878.72	850.09
824.96	802.65	782.63	764.52	

FROM	TO
ALBUQ	SANTA FE

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES		PERCENT CASUALTIES
212	7880.00	7880.00		100.00
882.16	850.56	823.10	798.91	777.36
757.97				

FROM	TO
ALBUQ	SANTA FE

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
44	3260.00	3280.00	100.00
575.37	565.84	558.50	

FROM	TO
ALBUQ	BELEN

ROUTE NUMBER	PEOPLE MOVED	EXPECTED CASUALTIES	PERCENT CASUALTIES
171	720.00	0.	0.
0.			

TOTAL PEOPLE MOVED	TOTAL CASUALTIES	TOTAL PERCENT CASUALTIES	PEOPLE PER UNIT	TIME TO ATTACK
274680.00	101801.25	37.04	1333.33	8.00

4. Brick structure
5. Light steel frame structure
6. Heavy steel frame structure
7. Reinforced concrete structure
8. Undefined
9. Undefined
10. Undefined.

The last three categories were left open and undefined to allow for other shielding postures that one might make use of in a particular problem; e.g., for people in automobiles, basements, trenches, or blast shelters. The mortality curves associated with each shielding category have been converted to tabulated values of the fraction of people killed as a function of distance, burst height, and yield. Tables for two values of burst height are available for the first 7 categories, namely, zero and the Hiroshima scaled height of burst, $846W^{1/3}$. The Hiroshima height is optimum for about 8 psi.[29] Tables are available for yields of 0.4, 1, 4, 10, 25, and 50 Mt.

The following input data is also required:

1. Number of weapons, their yield, burst height (surface or air), and burst point latitude and longitude.

[29] Samuel Glasstone, Editor, The Effects of Nuclear Weapons, Supt. of Documents, U. S. Government Printing Office, Washington, D. C.; 1962, ($3.00)

2. Geographic unit number, e.g., Standard Location Area (SLA) number,[30] and a single latitude and longitude pair used to represent the location of the people in that unit.

3. Number of people in each shielding category in each geographic unit.

The program simply calculates the distance from the burst point to each geographic unit, looks up the fraction of survivors in each shielding category, and multiplies by the number in that category. For multiple weapon attacks it is assumed that the weapons act independently, i.e., the survivors of the first explosion are assumed to be in the same shielding category after the first explosion as before.

The program output includes:

1. City name

2. Weapon yield, burst height, and burst location

3. For each geographic unit:
   a. Latitude and longitude
   b. Peak overpressure
   c. Survivors in each of the ten shielding categories
   d. Percent survivors in the geographic unit

4. Total population, total number, and total percent survivors

---

[30] National Location Code, OCD-OEP Region 5, OCD-FG-IV-3.115, Bureau of the Census, 1962.

3.2 A Sample Initial Effects Casualty Calculation. The attack assumptions for this sample problem are the same as for the sample problem in Par. 2.2 of this chapter.

Standard Location Areas were taken as the basic geographic units. The population in each SLA was taken from Ref. 30. To obtain the distribution of the people in each SLA over the ten shielding categories, estimates were made of the type of building the people were housed in by examining the United States Census of Housing for 1960,[20] and Sanborn Maps of the area. These estimates indicated that only 3 of the 10 shielding categories were occupied assuming that the population was unwarned. These three categories were: wood-frame structures, brick structures, and reinforced concrete structures (apartment houses).

The results of the calculation are reproduced in Table XIX. Note that 56 percent of the people are killed, which is in reasonable agreement with the hand-calculated value of 60 percent used in Par. 2.2. The hand-calculated value is somewhat less accurate because it was based on a less detailed examination of the shielding posture of the population.

4.0 Some Implications of Various Trans-Attack Policies for Strategic Movements Interrupted by War

A number of runs of the program described in Par. 2.0 have been made to estimate casualties for a variety of input parameters and trans-attack policies for strategic movements interrupted by war.

44	35.	5.	106.	34.	13.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
45	35.	3.	106.	31.	5.8	0.	0.	0.	6.6	0.	0.	0.	0.	0.	0.	66.1
46	35.	3.	106.	34.	24.3	0.	0.	6.9	222.7	0.	0.	0.	0.	0.	0.	3.5
47	35.	3.	106.	35.	69.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
48	35.	3.	106.	36.	1000.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
49	35.	5.	106.	41.	6.8	0.	0.	1618.3	1623.1	0.	0.	0.	0.	0.	0.	48.6
50	35.	6.	106.	42.	4.2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51	35.	7.	106.	41.	4.0	0.	0.	243.0	222.9	0.	0.	0.	0.	0.	0.	80.3
52	35.	8.	106.	40.	3.6	0.	0.	32.8	27.1	0.	0.	0.	0.	0.	0.	85.5
53	35.	8.	106.	38.	4.2	0.	0.	213.4	267.8	7.9	0.	37.3	0.	0.	0.	79.8
54	35.	9.	106.	39.	3.0	0.	0.	3334.4	3265.4	0.	0.	0.	0.	0.	0.	93.9
55	35.	12.	106.	37.	1.7	0.	0.	1569.1	1701.9	0.	0.	0.	0.	0.	0.	97.9
56	35.	9.	106.	37.	3.2	0.	0.	0.	1327.2	0.	0.	0.	0.	0.	0.	92.8
57	35.	5.	106.	23.	1.2	0.	0.	1349.2	1580.5	0.	0.	0.	0.	0.	0.	100.0
58	35.	56.	106.	42.	0.	0.	0.	150.0	610.0	0.	0.	0.	0.	0.	0.	100.0
59	35.	0.	106.	39.	14.5	0.	0.	139.0	215.4	0.	0.	0.	0.	0.	0.	19.8
60	35.	3.	106.	39.	33.0	0.	0.	0.	9.6	0.	0.	0.	0.	0.	0.	3.6
61	35.	4.	106.	39.	22.2	0.	0.	18.1	47.1	0.	0.	0.	0.	0.	0.	3.5
62	35.	4.	106.	40.	16.2	0.	0.	328.3	523.0	0.	0.	0.	0.	0.	0.	15.7
63	33.	3.	106.	42.	6.5	0.	0.	897.4	1226.5	0.	0.	0.	0.	0.	0.	52.1
64	35.	3.	106.	41.	9.5	0.	0.	697.7	1035.1	0.	0.	0.	0.	0.	0.	28.5
65	35.	1.	106.	42.	5.9	0.	0.	1403.8	1834.4	0.	0.	0.	0.	0.	0.	59.1
66	35.	5.	106.	43.	3.9	0.	0.	384.1	458.4	0.	0.	0.	0.	0.	0.	81.9
67	35.	2.	106.	53.	0.9	0.	0.	360.0	380.0	0.	0.	0.	0.	0.	0.	100.0
1	35.	20.	106.	28.	0.6	0.	0.	1950.0	2100.0	0.	0.	0.	0.	0.	0.	100.0
2	35.	20.	106.	40.	0.6	0.	0.	610.0	660.0	0.	0.	0.	0.	0.	0.	100.0
7	34.	49.	106.	44.	0.8	0.	0.	3390.0	3660.0	0.	0.	0.	0.	0.	0.	100.0

TOTAL POPULATION	TOTAL SURVIVORS	PERCENT SURVIVORS
274600.0	121603.3	44.3

Table XIX

Initial Effects Casualty Calculation Program Output for an Albuquerque Attack

CITY-ALBUQUERQUE

WEAPON VARIABLES

YIELD(KT)	BURST TYPE	LATITUDE	LONGITUDE
10.00	1	35. DEG 2.60 MIN	105. DEG 36.70 MIN

CODE NUMBER	LATITUDE		LONGITUDE		PEAK OVERPRESSURE	0-U	0-S	SURVIVORS IN CATAGORIES ONE THROUGH TEN WF	BR	LSF	MSF	RC	8	9	10	PERCENT SURVIVORS
1	35.	7.	106.	31.	3.2	0.	0.	3937.6	3333.0	0.	0.	0.	0.	0.	0.	89.3
2	35.	7.	106.	33.	4.4	0.	0.	1284.8	1156.1	0.	0.	0.	0.	0.	0.	74.9
3	35.	6.	106.	33.	6.1	0.	0.	3134.0	3021.4	0.	0.	0.	0.	0.	0.	55.3
4	35.	6.	106.	33.	6.1	0.	0.	2317.7	1930.7	0.	0.	0.	0.	0.	0.	55.7
5	35.	6.	106.	31.	3.9	0.	0.	3541.1	3111.2	0.	0.	0.	0.	0.	0.	82.3
6	35.	7.	106.	35.	5.9	0.	0.	3912.3	3741.8	0.	0.	0.	0.	0.	0.	57.9
7	35.	6.	106.	35.	8.9	0.	0.	1348.7	1420.8	0.	0.	0.	0.	0.	0.	31.6
8	35.	6.	106.	37.	10.8	0.	0.	721.4	784.7	0.	0.	0.	0.	0.	0.	26.3
9	35.	6.	106.	35.	8.9	0.	0.	1365.0	1439.1	0.	0.	0.	0.	0.	0.	31.6
10	35.	5.	106.	35.	17.3	0.	0.	314.3	384.4	0.	0.	0.	0.	0.	0.	7.5
11	35.	5.	106.	34.	13.8	0.	0.	351.6	391.8	0.	0.	0.	0.	0.	0.	23.5
12	35.	5.	106.	34.	13.8	0.	0.	547.7	850.0	0.	0.	0.	0.	0.	0.	23.8
13	35.	5.	106.	31.	4.6	0.	0.	1494.4	1360.4	0.	0.	0.	0.	0.	0.	73.0
14	35.	4.	106.	34.	17.8	0.	0.	7.5	9.8	0.	0.	0.	0.	0.	0.	7.0
15	35.	4.	106.	34.	17.8	0.	0.	333.3	396.4	0.	0.	0.	0.	0.	0.	7.3
16	35.	3.	106.	36.	1000.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	35.	4.	106.	36.	61.2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	35.	4.	106.	38.	38.6	0.	0.	0.	5.7	0.	0.	0.	0.	0.	0.	0.1
19	35.	4.	106.	39.	22.2	0.	0.	58.3	134.4	0.	0.	0.	0.	0.	0.	3.6
20	35.	4.	106.	39.	22.2	0.	0.	49.8	131.0	2.2	0.	46.1	0.	0.	0.	5.1
21	35.	5.	106.	38.	17.8	0.	0.	123.5	187.9	0.	0.	0.	0.	0.	0.	7.2
22	35.	5.	106.	38.	17.8	0.	0.	93.2	121.2	0.	0.	0.	0.	0.	0.	7.1
23	35.	5.	106.	37.	20.9	0.	0.	94.5	142.8	0.	0.	0.	0.	0.	0.	6.1
24	35.	5.	106.	37.	20.9	0.	0.	23.2	32.5	0.	0.	0.	0.	0.	0.	5.1
25	35.	5.	106.	38.	17.8	0.	0.	38.6	50.1	0.	0.	0.	0.	0.	0.	7.1
26	35.	6.	106.	38.	9.4	0.	0.	413.4	563.3	0.	0.	0.	0.	0.	0.	20.9
27	35.	5.	106.	39.	16.1	0.	0.	96.8	496.8	0.	0.	161.6	0.	0.	0.	19.9
28	35.	5.	106.	40.	9.2	0.	0.	498.6	518.8	0.	0.	0.	0.	0.	0.	23.7
29	35.	5.	106.	42.	5.2	0.	0.	232.9	240.7	0.	0.	0.	0.	0.	0.	57.2
30	35.	3.	106.	42.	5.2	0.	0.	2434.4	2570.0	0.	0.	0.	0.	0.	0.	57.0
31	35.	6.	106.	41.	5.3	0.	0.	1414.2	1548.7	0.	0.	0.	0.	0.	0.	65.6
32	35.	6.	106.	40.	6.6	0.	0.	571.4	666.3	0.	0.	0.	0.	0.	0.	51.1
33	35.	6.	106.	39.	8.1	0.	0.	767.4	1059.4	0.	0.	0.	0.	0.	0.	38.2
34	35.	6.	106.	39.	8.1	0.	0.	190.2	260.5	3.9	0.	29.2	0.	0.	0.	39.3
35	35.	7.	106.	39.	5.5	0.	0.	1787.2	1977.4	0.	0.	0.	0.	0.	0.	62.7
36	35.	7.	106.	40.	4.7	0.	0.	617.0	588.5	0.	0.	0.	0.	0.	0.	71.3
37	35.	8.	106.	40.	3.6	0.	0.	1310.4	1130.8	0.	0.	0.	0.	0.	0.	85.7
38	35.	8.	106.	39.	3.9	0.	0.	2351.1	2442.8	0.	0.	0.	0.	0.	0.	81.9
39	35.	8.	106.	38.	4.2	0.	0.	2016.2	1724.1	0.	0.	0.	0.	0.	0.	77.9
40	35.	8.	106.	37.	4.3	0.	0.	35.8	41.0	0.	0.	0.	0.	0.	0.	75.9
41	35.	8.	106.	39.	3.9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
42	35.	3.	106.	38.	125.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
43	35.	4.	106.	39.	22.2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

At the time the calculations discussed in this paragraph were made, the Movement program (Chapter II, Par. 7.2.1) was nearing completion of its development. The available version of the program was applied to the problem described in Par. 2.2 of this chapter and the results obtained were not greatly different from those given in Table XVII and Fig. 13. Thus, while the results to be described at this point are based on a slightly different movement, the reader can get a sufficiently accurate picture of the movement schedule from Fig. 13.

The assumed attack consists of a 10-Mt, 50-percent fission weapon surface burst at a runway intersection at Kirtland Air Force Base in Albuquerque.

The wind velocity and shear components were determined from wind structures[8] used to develop Fig. 2. These structures are believed to represent, reasonably well, the range of structures to be expected in the Albuquerque area.

It was assumed that the evacuees would be unsheltered for one hour after arrival in their reception place, after which they would be given a PF of two. It was assumed that the movement would continue as planned after the attack took place.

Figure 14 illustrates the results for the four wind structures. It shows that more than half the evacuees can be expected to survive if the attack takes place as early as seven hours after the movement begins. If

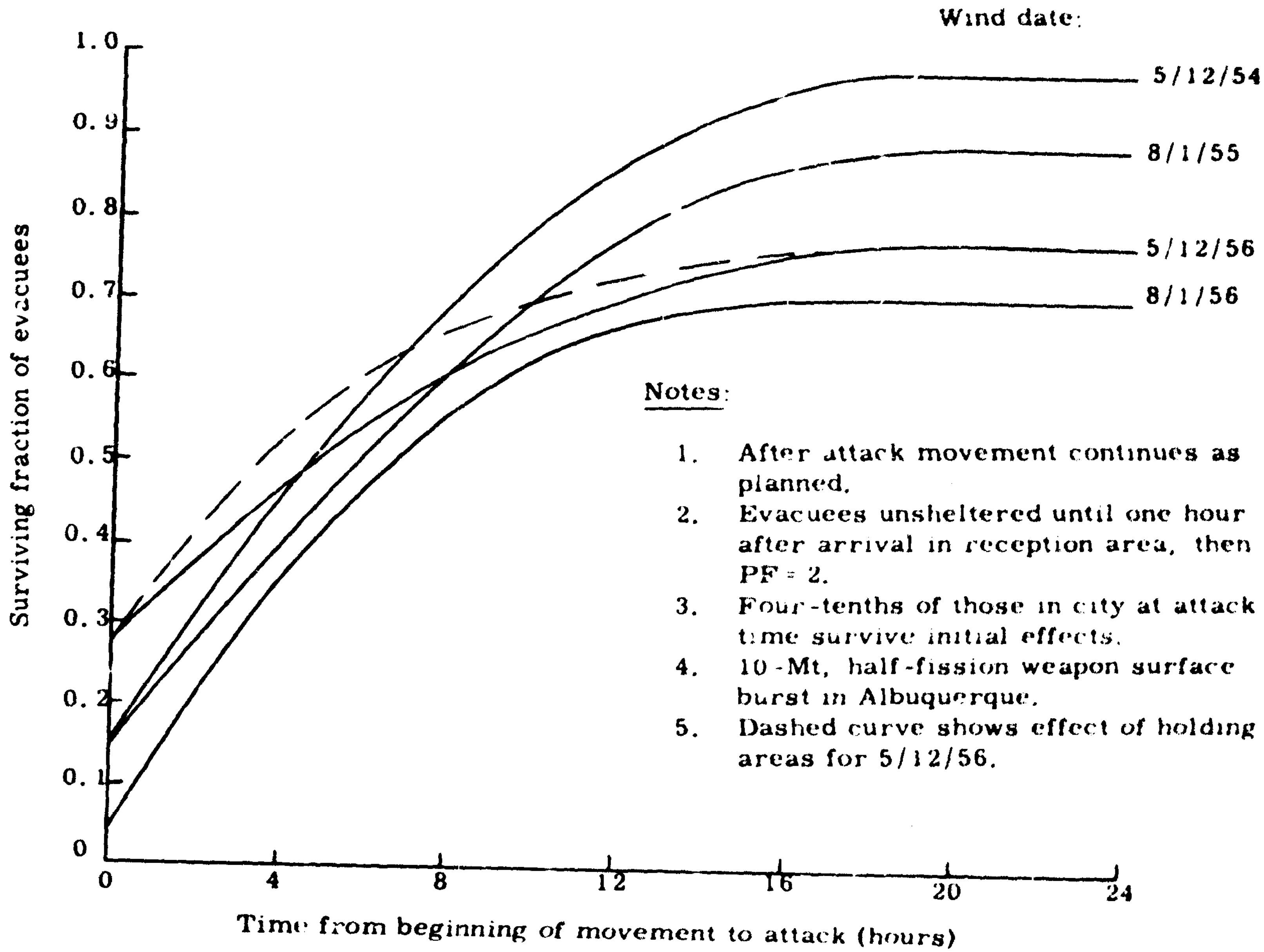

Fig. 14

Albuquerque Evacuees that Survive an Evacuation Interrupted by War the attack occurs just as the movement is completed, a minimum of 0.7 of the evacuees would survive compared to a maximum of 0.3 if the attack occurs just as the movement begins.

Figure 14 also illustrates the effect of using holding areas near the edge of the initial effects area. For this one set of calculations, an improvement of about 15 percent in the fraction surviving is realized for attacks that occur about 4 hours after the movement begins.

Figure 15 shows the effect of employing simple trench or basement shelters. Note that, if the movement is completed, all evacuees would survive and even if the attack occurs as the movement begins, there is about a 30 percent increase in the fraction surviving. Of course, this is optimistic because of the assumption that, after the attack, the survivors would continue the movement as planned.

Figure 16 shows the effect of a 24-hour delay in the construction of shelters; 24 hours is a conservatively large estimate of the time required to prepare a trench shelter. Since the gain is small if the evacuees are unsheltered 24 hours, it would be worth-while to begin shelter construction at a lower rung of the escalation ladder than the one used to begin the final stage of an evacuation.

Some more detailed calculations along these lines seem in order. Of special interest would be the calculation of casualties when the population location and vulnerability in town are improved by moving people out of the areas near the likely aiming points before moving others. This would require development of a detailed movement plan within the city, but it would appear to be worth the effort.

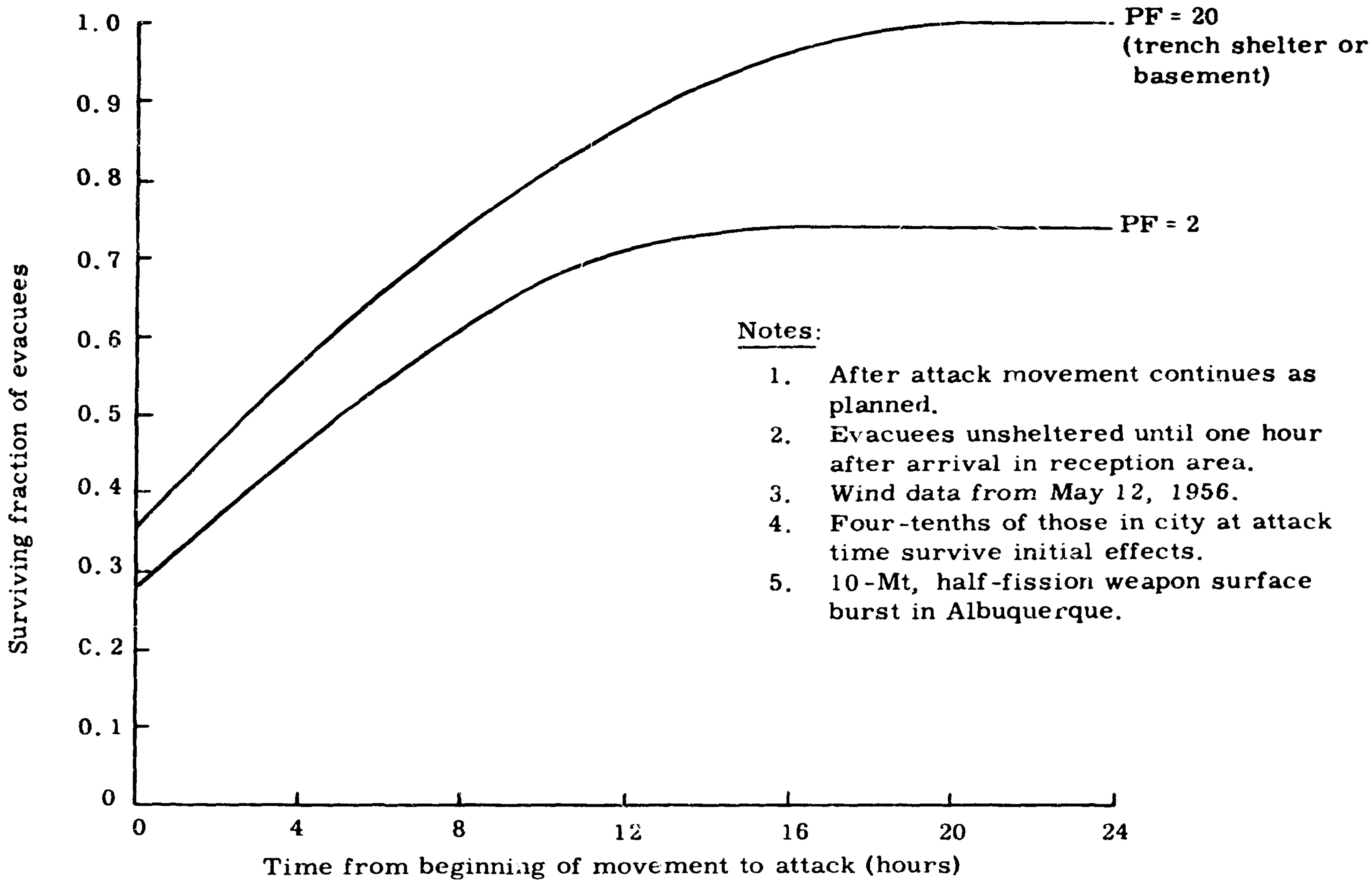

Fig 15

Survivors Added by Improving Protection Factor

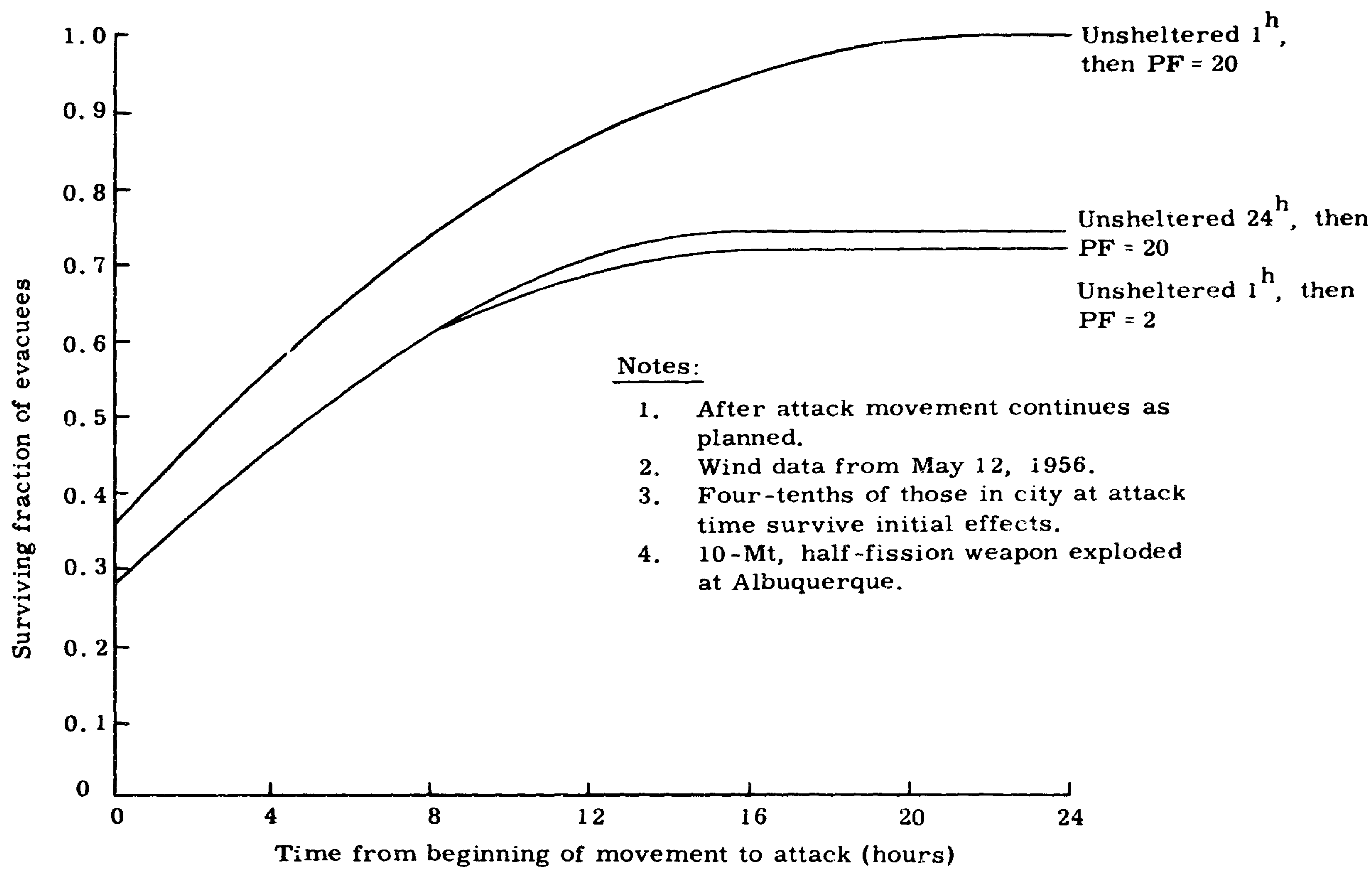

Fig. 16

Effect of Delayed Shelter Preparation on Surviving Fraction

CHAPTER IV

SOME SHELTER POLICIES AND PROGRAMS

1.0 Introduction

This chapter consists of a discussion of the development of curves of Type C in Fig. 1. Once again, as for movement strategies, one may wish to first plan a shelter system, then to evaluate it against a range of attacks. The evaluation against a particular attack to obtain curves of Type C is a relatively simple matter, but the shelter system design may not be. A number of shelter system design policies have been suggested by various authors. The following are among the policies considered of possible interest:

1. Uniform maximum fatalities per incoming weapon.*
2. Uniform probability of survival.
3. Uniform shelter design overpressure.
4. Maximum added survivors per dollar expended.
5. Maximum enemy cost per kill.

The first policy was originally suggested by Hudson Institute (Herman Kahn and William Brown).[31] Basically, the policy leads to a shelter system that gives up a constant maximum number, β, of fatalities for each incoming weapon. Shelter hardness is then related to population density, anticipated yields of the incoming weapons, budget, and β. Table XX shows how these

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* Note added in proof: A recent IDA report, S-186, describes a computer program for Policy (1).

[31] W. M. Brown, The Design and Performance of "Optimum" Blast Shelter Programs, Hudson Institute Report No. HI-361-RR/2; June 11, 1964.

Table XX

Cost of Blast Shelters for 213 Urbanized Areas (1960)

Criterion, β (thousands of fatalities)	Shelter required (psi) at			Total cost (billions)
	ρ^* = 3,000	ρ = 10,000	ρ = 30,000	
5	90	300	900	31.6
10	45	150	450	23.8
15	30	100	300	20.3
25	18	60	180	16.8
40	11	37	112	14.3
60	7.5	25	75	12.5
80	5.6	19	56	11.5

* ρ = population density (number per square mile).

variables are related for some sample values.[32] The table was constructed associating one-megaton weapons with the mortality criterion, β.

This policy seems appropriate for a shelter system designed against a population attack. However, other policies may also prove interesting for various reasons. For example, if a counterforce target is located in the vicinity of a city, it may be appropriate to consider the influence of the target on the choice of shelter hardness for that city. Also, it seems appropriate to compare systems based on the various policies to determine whether some conclusions can be drawn that are insensitive to the choice of policy. Or, Policy 4 in the above list might be used to obtain a preferred order of spending money on whichever other policy is chosen as a design basis.*

Computer programs for designing systems associated with Policies 2, 3, and 4 have been prepared and are briefly discussed in this chapter. If the reader is interested in using the programs, a detailed description is provided in Refs. 33. 34, and 35.

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[32] Herman Kahn, Some Comments on Group A, B, and C's Work, A Project Harbor Briefing, Hudson Institute Report No. HI-305-BN, November 15, 1963.

* The computer program associated with Policy (4) can also be used to obtain a preferred order of spending for other protective programs, such as thermal countermeasures.

[33] K. D. Granzow and D. L. Summers, A Computer Program for Calculating Shelter Hardness and Cost for Uniform Survival Probability, Dikewood Corporation Technical Note No. DC-TN-1039-3; December 3, 1964.

[34] K. D. Granzow, et al., A Computer Program for Calculating the Expected Cost per Survivor for a Uniform Shelter Design Overpressure Policy, Dikewood Corporation Technical Note No. DC-TN-1039-7; January 29, 1965.

[35] D. L. Summers and A. R. Bliss, A Computer Program for Finding the Order of Expenditure on Blast Shelters that Maximizes Additional Survivors per Dollar, Dikewood Corporation Technical Note No. DC-TN-1039-10; June 1965.

The expected number of fatalities could be calculated for use in Policy 5 studies with a simple modification of a subroutine used in the three programs associated with Policies 2, 3, and 4. This has not been done, however, and the rest of this chapter is concerned only with an explanation of the computer programs for Policies 2, 3, and 4.

Policies 2 and 3 are fairly obvious possibilities and had been selected for study when it was learned that W. F. Roherty at Sandia Corporation had already developed computer programs to calculate the implications of Policy 4 in addition to 2 and 3. He discussed his work with Dikewood staff members and, while the programs have undergone several revisions, they still make considerable use of ideas and actual routines originally suggested by Mr. Roherty. The principal changes include a subroutine to calculate either the geometric or the population centroid of an area of interest and the development of a table look-up procedure for finding the probability of covering a point a known distance from an aiming point with at least a given initial effect. The table look-up procedure is faster than the calculation procedure used in the original program. Provisions have also been made to include cost functions other than the one in the original program. Other changes are principally in format and similar details.

One further acknowledgement is in order, namely, to Mr. Luke Vortman also of Sandia Corporation. Mr. Vortman had applied the original programs to perform an analysis of shelter systems for Albuquerque and he made his results available to Dikewood for use in checking out the new programs.

2.0 Uniform Probability of Survival

This program was written to facilitate calculation of the shelter design overpressures required to give a uniform survival probability to the population considered. The area of interest is divided into tracts small enough to permit the effects of assumed weapons to be considered uniform over the tract. Although SLA's do not always satisfy this condition, their use is believed appropriate since uncertainties about the enemy choice of aiming point and yield probably override the errors associated with using SLA's. The position (lat. and long.) and the population of each tract are input data to the program. A table of survival percentages (up to ten at a time) for which the calculation is to be done must also be supplied.

The program is arranged so that a specific aiming point can be given as input or the program will compute the geometric or population centroid of the tracts and use either one of these as the aiming point. A CEP and a table of radius of effect versus shelter design overpressure are also required.

Besides yielding a shelter design overpressure for each tract for each survival percentage, the program computes the total cost and the cost per survivor for the shelters associated with each survival percentage for the overall area of interest. These costs are computed in three different ways:

(1) by the formula* cost ($) per person = $30\sqrt{\text{design overpressure (psi)}}$

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*Originally suggested by Mr. Luke Vortman, Sandia Corporation, but obviously not intended for use at low overpressures.

(2) by the formula:[31] cost (\$) per person = $50+20\sqrt{\text{design overpressure (psi)}}$

(3) by using a table of cost versus design overpressure supplied as input to the computer.

A table of values is used to relate the probability of covering a point a given distance, δ, from the aiming point with a given overpressure (radius of effect). The table lists probability of coverage as a function of radius of effect divided by CEP and δ divided by CEP.

For a particular tract or SLA, the program finds the probability of coverage with each of the overpressures which are listed in order of increasing overpressure. A percent-saved figure is then chosen, converted to a decimal and subtracted from one to give the corresponding mortality fraction. This fraction is then compared to each of the probability of coverage figures to find the first overpressure at which the probability of coverage is less than or equal to the value of the fraction. This implies that at this overpressure at least the desired percent of the population is saved, i.e., the mortality fraction is not exceeded.

The program then checks to make sure that at this overpressure the percent saved does not also exceed the next higher desired percent saved. In other words if a table overpressure value yields a probability of coverage, hence mortality, which saves at least the desired percentage of population but does not save as many as the next higher desired percentage then that value of coverage probability is used to compute the number of survivors and the cost of shelters of the associated overpressure.

In case the overpressure found initially gives a value of probability of coverage outside the interval between the two mortality fractions, an interpolation is made on the radius of effect to reduce the overpressure so that the probability of coverage comes into this specified interval. It should be noted that in every case the overpressure finally found will be at least as great as that required to save the desired percent exactly. The total numbers of survivors in the printout for a desired percentage will therefore always be greater than the desired percentage of the total population of that SLA. The cost of providing shelters of the design overpressure calculated in the above manner is then found for the tract.* This procedure is repeated in the other tracts and the cost is summed over all tracts to find the total cost of providing the desired survival probability to the area being considered.

This cost is then divided by the expected total number of survivors to obtain a cost-per-survivor value for each desired survival probability.

A computer printout for a sample problem is reproduced in Table XXI. The printout provides an adequate description of the problem. The

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* In the present version of the program, it is assumed that shelters having a capacity equal to the tract population would be built. The program could be modified to accommodate some standard shelter capacities, or, two runs could be made. The first, with the real populations, could be used to estimate casualties; the second, with standard shelter capacities in place of tract population, could be used to estimate cost.

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 300235

	PERCENT SAVED							
SLA	20	40	60	70	80	85	90	95
44	8.0	15.0	20.0	25.0	40.0	50.0	100.0	200.0
45	3.5	4.0	5.0	6.0	6.5	7.0	8.0	15.0
46	6.0	8.0	12.5	15.0	17.5	20.0	30.0	50.0
47	8.0	10.0	15.0	20.0	30.0	40.0	50.0	100.0
48	8.0	15.0	20.0	25.0	40.0	50.0	75.0	200.0
49	8.0	15.0	20.0	25.0	40.0	50.0	75.0	150.0
50	6.0	8.0	12.5	15.0	20.0	25.0	40.0	75.0
51	7.0	8.0	15.0	20.0	25.0	30.0	40.0	75.0
52	6.0	8.0	10.0	12.5	15.0	20.0	25.0	40.0
53	8.0	15.0	20.0	25.0	40.0	50.0	75.0	200.0
54	6.0	8.0	12.5	15.0	20.0	25.0	30.0	50.0
55	3.0	3.5	4.0	5.0	5.5	6.0	7.0	8.0
56	6.0	8.0	0.0	12.5	15.0	20.0	30.0	50.0
57	1.2	1.5	1.6	1.7	1.7	1.8	1.9	2.0
58	1.6	1.7	1.9	1.9	2.0	2.2	2.5	3.0
59	4.0	5.0	6.5	7.0	8.0	10.0	15.0	20.0
60	10.0	15.0	30.0	[illegible]	75.0	100.0	150.0	500.0
61	15.0	20.0	30.0	50.0	75.0	100.0	200.0	500.0
62	8.0	15.0	20.0	25.0	40.0	50.0	75.0	150.0
63	6.0	8.0	10.0	12.5	15.0	20.0	25.0	40.0
64	6.0	8.0	12.5	15.0	20.0	25.0	30.0	50.0
65	3.5	4.0	5.5	6.0	7.0	8.0	10.0	15.0
66	5.0	6.0	7.5	8.0	11.0	12.5	15.0	25.0
67	0.	1.2	1.3	1.4	1.5	1.6	1.6	2.0
TOTAL NUMBER SAVED	84102	144482	196441	223037	247624	260697	274362	287331
TOTAL COST(1)	0.270E 08	0.333E 08	0.427E 08	0.498E 08	0.616E 08	0.708E 08	0.943E 08	0.143E 09
COST(1)/SURVIVOR	321	230	217	223	248	271	343	496
TOTAL COST(2)	0.330E 08	0.372E 08	0.435E 08	0.482E 08	0.561E 08	0.622E 08	0.779E 08	0.110E 09
COST(2)/SURVIVOR	392	257	221	216	226	238	283	383
TOTAL COST(3)	0.516E 08	0.549E 08	0.582E 08	0.606E 08	0.635E 08	0.653E 08	0.690E 08	0.761E 08
COST(3)/SURVIVOR	612	380	296	271	256	250	251	264

Table XXI

Uniform-Survival-Probability Program Output for an Attack on Albuquerque

UNIFORM SURVIVAL PROBABILITY RUN 2CK PAGE 1

AIMING POINT—GEOMETRIC CENTROID
LATITUDE— 35 DEG 5 MIN 8 SEC LONGITUDE— 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 300235

	PERCENT SAVED							
SLA	20	40	60	70	80	85	90	95
1	3.5	4.0	5.5	6.0	7.0	7.5	8.0	15.0
2	5.0	7.0	8.0	12.5	13.7	15.0	20.0	40.0
3	6.0	7.0	8.0	12.5	15.0	20.0	25.0	40.0
4	6.0	8.0	12.5	15.0	17.5	20.0	30.0	50.0
5	4.0	5.0	6.0	7.0	7.5	8.0	10.0	15.0
6	8.0	15.0	20.0	25.0	40.0	50.0	75.0	200.0
7	8.0	15.0	25.0	30.0	50.0	75.0	100.0	250.0
8	15.0	25.0	50.0	75.0	150.0	200.0	500.0	1000.0
9	15.0	20.0	30.0	50.0	75.0	100.0	200.0	500.0
10	15.0	20.0	40.0	50.0	87.5	100.0	200.0	500.0
11	8.0	10.0	15.0	20.0	30.0	40.0	75.0	150.0
12	7.0	8.0	15.0	20.0	25.0	30.0	50.0	100.0
13	4.0	5.0	6.0	7.0	7.5	8.0	12.5	15.0
14	7.0	8.0	12.5	15.0	20.0	30.0	40.0	75.0
15	8.0	15.0	20.0	25.0	40.0	50.0	75.0	150.0
16	10.0	15.0	30.0	40.0	75.0	100.0	150.0	300.0
17	15.0	20.0	40.0	50.0	100.0	150.0	200.0	1000.0
18	15.0	25.0	50.0	75.0	150.0	200.0	500.0	1000.0
19	15.0	25.0	40.0	75.0	100.0	150.0	250.0	1000.0
20	15.0	25.0	40.0	75.0	100.0	150.0	250.0	1000.0
21	20.0	30.0	75.0	100.0	150.0	200.0	500.0	5000.0
22	20.0	40.0	75.0	100.0	200.0	250.0	500.0	5000.0
23	20.0	30.0	75.0	100.0	150.0	200.0	500.0	5000.0
24	20.0	40.0	75.0	100.0	200.0	250.0	500.0	5000.0
25	20.0	40.0	75.0	100.0	200.0	250.0	500.0	5000.0
26	20.0	30.0	75.0	100.0	175.0	200.0	500.0	5000.0
27	15.0	25.0	50.0	75.0	100.0	200.0	500.0	1000.0
28	15.0	20.0	30.0	50.0	75.0	100.0	200.0	500.0
29	7.0	8.0	12.5	15.0	20.0	30.0	40.0	75.0
30	6.0	8.0	12.5	15.0	20.0	25.0	30.0	50.0
31	8.0	10.0	15.0	20.0	30.0	40.0	75.0	150.0
32	10.0	15.0	25.0	40.0	75.0	100.0	150.0	500.0
33	15.0	20.0	40.0	75.0	100.0	150.0	200.0	1000.0
34	15.0	25.0	50.0	75.0	150.0	200.0	500.0	1000.0
35	10.0	20.0	30.0	40.0	75.0	100.0	200.0	500.0
36	8.0	15.0	25.0	30.0	50.0	75.0	100.0	250.0
37	7.0	8.0	12.5	15.0	20.0	30.0	40.0	75.0
38	8.0	15.0	20.0	25.0	40.0	50.0	75.0	150.0
39	8.0	10.0	15.0	20.0	25.0	30.0	50.0	100.0
40	8.0	15.0	17.5	20.0	30.0	40.0	75.0	150.0
41	6.0	8.0	12.5	15.0	20.0	25.0	30.0	50.0
42	8.0	15.0	25.0	40.0	50.0	75.0	100.0	250.0
43	15.0	20.0	30.0	50.0	75.0	100.0	200.0	500.0

COST(1)=30*SQRT(OPS) COST(2)=50+20*SQRT(OPS) COST(3)=FOLLOWING TABLE OF VALUES

500 PERSONS PER SHELTER

SHELTER DESIGN OVERPRESSURE	SHELTER COST PER PERSON
1.0	140.00
2.5	140.00
5.0	140.00
10.0	195.00
25.0	198.00
50.0	210.00
100.0	250.00
250.0	260.00
500.0	280.00
1000.0	320.00

cost table, COST (3), is based on a Guy B. Panero study;[36] any other cost table of interest can be used in place of this one.

The cost-per-survivor rows indicate that a minimum exists at about 65 percent saved (60 percent desired) for COST (1), 74 percent for COST (2), and 87 percent for COST (3). This helps illustrate the importance of understanding costs. However, the reader is cautioned against drawing general conclusions from this one printout; its primary purpose is to illustrate use of the program.

3.0 Uniform Shelter Design Overpressure

This program permits calculation of some implications of a policy in which everyone is given space in shelters having the same design overpressure. The same alternative aiming points are allowed as in the uniform survival probability program. Then, for the given attack variables, the computer calculates the probability of covering a geographic subarea (e.g., SLA) with a particular overpressure. This probability is multiplied by the number of people present in the subarea, the process is repeated for all of the subareas, and the sum of the expected number of fatalities is calculated and printed for the chosen overpressure. The percent fatalities, the total cost of supplying everyone with space in shelter of this design overpressure and the cost per survivor are also calculated and printed. The process is then repeated for each of the other overpressures supplied as input data.

[36] Guy B. Panero, Inc., Shelter Configuration Factors, Prepared under Contract OCD-OS-62-108; April 15, 1963.

A sample problem is illustrated in Table XXII. The problem is explained in the table heading. The point made in Par. 2.0 about cost uncertainties can be made again with Table XXII. The overpressures associated with the minimum cost per survivor and total program costs are shown in Table XXIII.

Table XXIII

Effect of Cost Uncertainties in a Uniform Shelter Design Overpressure Sample Problem

Cost function	Overpressure (psi) for minimum cost per survivor	Min. cost ($) per survivor	Total cost ($ millions)	Expected % survivors
COST (1)	15	204	35	57
COST (2)	20	212	42	66
COST (3)	50	251	63	84

4.0 Maximum Added Survivors per Dollar

This program makes use of the same input data as in Pars. 2 and 3 of this chapter. The probability of coverage is computed for each geographic subarea (SLA) for each of a number of assumed shelter design overpressures. Next, it is assumed that everyone in the geographic area (e.g., city) is given at least the protection of a shelter having some low value of design overpressure, referred to as the BASE overpressure. The expected number of survivors added by raising the shelter design overpressure to

Table XXII

Uniform-Shelter-Design-Overpressure Program Output for an Attack on Albuquerque

UNIFORM SHELTER DESIGN OVERPRESSURE   RUN 2CK   PAGE 1

AIMING POINT-GEOMETRIC CENTROID
LATITUDE-   35 DEG   5 MIN   8 SEC   LONGITUDE- 106 DEG 37 MIN 32 SEC
YIELD(MT)= 10.000   HEIGHT OF BURST(FEET)=   0   CIRCULAR PROBABLE ERROR(MI)= 2.0000
COST=30*SQRT(OVERPRESSURE)

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M.   TOTAL POPULATION=   300235

OVERPRESSURE LEVEL(PSI)	EXPECTED TOTAL FATALITIES	EXPECTED PERCENT FATALITIES	EXPECTED TOTAL COST	EXPECTED COST/SURVIVOR
1.00000	299666.	99.81	0.90070500E 07	15818.54
1.50000	297038.	98.94	0.11031338E 08	3450.00
2.00000	293316.	97.70	0.12737892E 08	1840.98
2.50000	291903.	97.22	0.14241396E 08	1709.21
3.00000	290492.	96.75	0.15600668E 08	1601.24
4.00000	271231.	90.34	0.18014100E 08	621.09
5.00000	259303.	86.37	0.20140376E 08	492.04
6.00000	241129.	80.31	0.22062676E 08	373.28
8.00000	190915.	63.59	0.25475784E 08	233.04
10.00000	176095.	58.65	0.28482793E 08	229.44
15.00000	128877.	42.93	0.34884154E 08	203.57
20.00000	102916.	34.28	0.40280752E 08	204.14
25.00000	89786.	29.91	0.45035250E 08	214.00
30.00000	75371.	25.10	0.49333644E 08	219.39
40.00000	60819.	20.26	0.56965586E 08	237.94
50.00000	48948.	16.30	0.63689461E 08	253.45
75.00000	36973.	12.31	0.78003339E 08	296.30
100.00000	26312.	8.76	0.90070500E 08	328.82
150.00000	20956.	6.98	0.11031338E 09	394.99
200.00000	15236.	5.07	0.12737892E 09	446.94
250.00000	13655.	4.55	0.14241396E 09	496.94
500.00000	9029.	3.01	0.20140376E 09	691.62
1000.00000	5614.	1.87	0.28482792E 09	966.76

UNIFORM SHELTER DESIGN OVERPRESSURE RUN 2CK PAGE 3

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC
YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0000
COST=50+20*SQRT(OVERPRESSURE)

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 300235

OVERPRESSURE LEVEL(PSI)	EXPECTED TOTAL FATALITIES	EXPECTED PERCENT FATALITIES	EXPECTED TOTAL COST	EXPECTED COST/SURVIVOR
1.00000	299666.	99.81	0.21016450E 08	36909.92
1.50000	297038.	98.94	0.22365975E 08	6994.85
2.00000	293316.	97.70	0.23503678E 08	3396.94
2.5000C	291903.	97.22	0.24506014E 08	2941.15
3.00000	290492.	96.75	0.25412195E 08	2608.29
4.00000	271231.	90.34	0.27021150E 08	931.63
5.00000	259303.	86.37	0.28438667E 08	694.78
6.00000	241129.	80.31	0.29720201E 08	502.93
8.00000	190915.	63.59	0.31995606E 08	292.68
1C.00000	176095.	58.65	0.34000279E 08	273.89
15.00000	128877.	42.93	0.38267852E 08	223.32
20.00000	102916.	34.28	0.41865585E 08	212.17
25.00000	89786.	29.91	0.45035250E 08	214.00
30.00000	75371.	25.10	0.47900845E 08	213.02
40.00000	60819.	20.26	0.52988807E 08	221.33
50.00000	48948.	16.30	0.57471390E 08	228.71
75.00000	36973.	12.31	0.67013977E 08	254.55
100.00000	26312.	8.76	0.75058750E 08	274.01
150.00000	20956.	6.98	0.88554004E 08	317.08
200.00000	15236.	5.07	0.99931031E 08	350.64
250.00000	13655.	4.55	0.10995439E 09	383.68
500.00000	9029.	3.01	0.14928092E 09	512.63
1000.00000	5614.	1.87	0.20489703E 09	695.46

UNIFORM SHELTER DESIGN OVERPRESSURE RUN 2CK

COST(1)=30*SQRT(OPS) COST(2)=50+20*SQRT(OPS) COST(3)=FOLLOWING TABLE OF VALUES

500 PERSONS PER SHELTER

SHELTER DESIGN OVERPRESSURE	SHELTER COST PER PERSON
1.0	140.00
2.5	140.00
5.0	140.00
10.0	195.00
25.0	196.00
50.0	210.00
100.0	250.00
250.0	260.00
500.0	280.00
1000.0	320.00

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC
YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0000
COST=TABULAR VALUES

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 300235

OVERPRESSURE LEVEL(PSI)	EXPECTED TOTAL FATALITIES	EXPECTED PERCENT FATALITIES	EXPECTED TOTAL COST	EXPECTED COST/SURVIVOR
1.00000	299666.	99.81	0.42032900E 08	73819.84
1.50000	297038.	98.94	0.42032900E 08	13145.58
2.00000	293316.	97.70	0.42032900E 08	6074.97
2.50000	291903.	97.22	0.42032900E 08	5044.68
3.00000	290492.	96.75	0.42032900E 08	4314.23
4.00000	271231.	90.34	0.42032900E 08	1449.20
5.00000	259303.	86.37	0.42032900E 08	1026.89
6.00000	241129.	80.31	0.45335485E 08	767.03
8.00000	190915.	63.59	0.51940655E 08	475.12
10.00000	176095.	58.65	0.58545825E 08	471.61
15.00000	128877.	42.93	0.58846060E 08	343.41
20.00000	102916.	34.28	0.59146295E 08	299.75
25.00000	89786.	29.91	0.59446530E 08	282.48
30.00000	75371.	25.10	0.60167094E 08	267.57
40.00000	60819.	20.26	0.61608221E 08	257.33
50.00000	48948.	16.30	0.63049350E 08	250.91
75.00000	36973.	12.31	0.69054050E 08	262.30
100.00000	26312.	8.76	0.75058750E 08	274.01
150.00000	20956.	6.98	0.76059532E 08	272.34
200.00000	15236.	5.07	0.77060315E 08	270.39
250.00000	13655.	4.55	0.78061100E 08	272.39
500.00000	9029.	3.01	0.84065800E 08	288.68
1000.00000	5614.	1.87	0.96075200E 08	326.10

00644 END OF FILE EXIT

each of the other overpressures chosen is then calculated for each SLA and divided by the cost of upgrading the protection to these chosen levels. The maximum value is found for each SLA and these maximum values are then ordered in decreasing order of expected added survivors per dollar. The value at the top of the list is printed along with identifying information. This value will be associated with a particular SLA and increase in shelter design overpressure. For example, suppose that upgrading the shelter in SLA 58 from 1 to 3 psi yields the maximum expected added survivors per dollar. Then, SLA 58 must now be treated as if its BASE overpressure were 3 psi and the number of added survivors per dollar must be computed for raising SLA 58 shelters from 3 psi to each of the higher shelter design overpressures. The maximum of these values is found and replaces the old maximum value for SLA 58. The whole list is reordered, including this new value, its maximum value is printed, and the process is repeated until a complete printout is obtained of the order of spending that maximizes expected added survivors per dollar. The list may be used, for example, to decide on the shelter design overpressure for each SLA for a fixed budget. The printout contains an accumulated cost column. When the cost of supplying shelters of the original BASE overpressure is added to any particular value in this column, the total cost of the program is then obtained for the shelter system indicated to that point. Then, all that is needed is to enter this total cost list at the budget level of interest and proceed toward the beginning of the printout, selecting the maximum shelter design overpressure found for each SLA. The list will also provide an order for construction that leads to the greatest number of survivors per dollar spent up to any particular time.

A sample problem printout is shown in Table XXIV; the heading explains the problem. The probability of coverage table is printed because it is useful for checking purposes.

Table XXIV

Maximum-Added-Survivors-per-Dollar Program Output for an Albuquerque Attack

MAXIMUM ADDITIONAL SURVIVORS PER DOLLAR RUN 2CK PAGE 1

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 300235

PROBABILITY OF COVERAGE AS A FUNCTION OF MAXIMUM OVERPRESSURE(PSI)

SLA	1.0	3.0	10.0	30.0	100.0	250.0	500.0	1000.0
1	1.0000	0.9092	0.0678	0.0046	0.0005	0.0002	0.0001	0.0000
2	1.0000	0.9900	0.3011	0.0505	0.0096	0.0039	0.0023	0.0012
3	1.0000	0.9920	0.3343	0.0612	0.0122	0.0051	0.0030	0.0016
4	1.0000	0.9953	0.4026	0.0859	0.0187	0.0081	0.0048	0.0027
5	1.0000	0.9280	0.0865	0.0068	0.0008	0.0003	0.0001	0.0001
6	1.0000	0.9994	0.6487	0.2242	0.0649	0.0317	0.0205	0.0126
7	1.0000	0.9998	0.7289	0.2942	0.0934	0.0470	0.0307	0.0190
8	1.0000	1.0000	0.9016	0.5264	0.2089	0.1120	0.0750	0.0471
9	1.0000	0.9999	0.8179	0.3953	0.1399	0.0726	0.0480	0.0299
10	1.0000	0.9999	0.8240	0.4031	0.1436	0.0747	0.0495	0.0308
11	1.0000	0.9990	0.5931	0.1850	0.0504	0.0242	0.0155	0.0095
12	1.0000	0.9980	0.5137	0.1374	0.0342	0.0160	0.0101	0.0061
13	1.0000	0.9481	0.1128	0.0100	0.0013	0.0005	0.0002	0.0001
14	1.0000	0.9975	0.4800	0.1199	0.0286	0.0132	0.0083	0.0050
15	1.0000	0.9994	0.6415	0.2183	0.0625	0.0305	0.0197	0.0120
16	1.0000	0.9999	0.7795	0.3465	0.1164	0.0595	0.0391	0.0243
17	1.0000	1.0000	0.8414	0.4269	0.1555	0.0814	0.0540	0.0337
18	1.0000	1.0000	0.8945	0.5133	0.2016	0.1078	0.0721	0.0452
19	1.0000	1.0000	0.8660	[illegible]	0.1753	0.0927	0.0617	0.0386
20	1.0000	1.0000	0.8727	0.4753	0.1807	0.0957	0.0638	0.0400
21	1.0000	1.0000	0.9232	0.5691	0.2335	0.1263	0.0849	0.0535
22	1.0000	1.0000	0.9446	0.6169	0.2622	0.1432	0.0966	0.0610
23	1.0000	1.0000	0.9248	0.5726	0.2356	0.1275	0.0857	0.0540
24	1.0000	1.0000	0.9473	0.6233	0.2662	0.1456	0.0982	0.0620
25	1.0000	1.0000	0.9489	0.6272	0.2685	0.1470	0.0992	0.0627
26	1.0000	1.0000	0.9339	0.5918	0.2469	0.1342	0.0903	0.0569
27	1.0000	1.0000	0.8881	0.5016	0.1951	0.1040	0.0695	0.0436
28	1.0000	0.9999	0.8095	0.3846	0.1348	0.0697	0.0461	0.0287
29	1.0000	0.9973	0.4714	0.1154	0.0272	0.0125	0.0079	0.0047
30	1.0000	0.9960	0.4242	0.0947	0.0212	0.0093	0.0056	0.0031
31	1.0000	0.9990	0.5949	0.1862	0.0508	0.0244	0.0157	0.0096
32	1.0000	0.9998	0.7546	0.3206	0.1050	0.0533	0.0350	0.0216
33	1.0000	1.0000	0.8542	0.4467	0.1658	0.0873	0.0580	0.0363
34	1.0000	1.0000	0.8988	0.5211	0.2060	0.1103	0.0738	0.0464
35	1.0000	0.9999	0.7963	0.3678	0.1267	0.0652	0.0430	0.0267
36	1.0000	0.9998	0.7327	0.2980	0.0951	0.0479	0.0313	0.0193
37	1.0000	0.9975	0.4834	0.1217	0.0292	0.0135	0.0085	0.0051
38	1.0000	0.9994	0.6462	0.2222	0.0641	0.0313	0.0202	0.0124
39	1.0000	0.9984	0.5370	0.1496	0.0380	0.0179	0.0114	0.0069

MAXIMUM ADDITIONAL SURVIVORS PER DOLLAR RUN 2CK PAGE

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.[illegible]

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 400235

COST=TABULAR VALUES

BASE OVERPRESSURE(PSI)= 1.0

SLA	POPULATION	OVERPRESSURE(PSI) LOWER	OVERPRESSURE(PSI) UPPER	SURVIVORS PER DOLLAR	CHANGE IN PROBABILITY	INCREASE IN COST	ACCUMULATED COST	ADDITIONAL SURVIVORS	ACCUMULATED SURVIVORS
58	750	1.0	3.0	0.9438E 00	0.94380	750	750	707	707
57	5000	1.0	3.0	0.9287E 00	0.92869	5000	5750	4643	[illegible]
67	739	1.0	3.0	0.6891E 00	0.68909	739	6489	509	[illegible]
55	3350	1.0	3.0	0.2112E-00	0.21122	3350	9839	707	6566
45	10	1.0	3.0	0.1067E-00	0.10668	10	9849	1	6567
1	8500	1.0	3.0	0.9079E-01	0.09079	8500	18349	771	7338
65	5500	1.0	3.0	0.8103E-01	0.08103	5500	23849	445	7783
5	8100	1.0	3.0	0.7197E-01	0.07197	8100	31949	582	8365
13	5000	1.0	3.0	0.5189E-01	0.05189	5000	36949	259	8624
59	1900	1.0	3.0	0.4064E-01	0.04064	1900	38849	77	8701
66	1300	1.0	3.0	0.2013E-01	0.02013	1300	40149	26	8727
66	1300	3.0	30.0	0.1613E-01	0.95170	76700	116849	1237	[illegible]
59	1900	3.0	30.0	0.1602E-01	0.94522	112100	228949	1795	[illegible]
13	5000	3.0	30.0	0.1590E-01	0.93807	295000	523949	4690	16449
2	3300	1.0	30.0	0.1582E-01	0.94946	198000	721949	3133	19582
3	11000	1.0	30.0	0.1565E-01	0.93876	660000	1381949	10326	29908
65	5500	3.0	10.0	0.1562E-01	0.84363	297000	1678949	4639	34547
5	8100	3.0	30.0	0.1561E-01	0.92128	477900	2156849	7462	[illegible]
52	90	1.0	30.0	0.1561E-01	0.93646	5400	2162249	84	[illegible]
1	8500	3.0	10.0	0.1558E-01	0.84143	459000	2621249	[illegible]	49245
63	4100	1.0	30.0	0.1556E-01	0.93330	246000	2867249	3026	53271
45	10	3.0	10.0	0.1548E-01	0.83581	540	2867789	8	53279
56	1600	1.0	30.0	0.1544E-01	0.92625	96000	2963789	1481	54760
4	14000	1.0	30.0	0.1524E-01	0.91411	840000	3803789	12797	67557
46	9500	1.0	30.0	0.1521E-01	0.91274	570000	4373789	8671	76028
41	3	1.0	30.0	0.1519E-01	0.91165	180	4373969	2	76030
54	7500	1.0	30.0	0.1519E-01	0.91165	450000	4823969	6837	82867
64	6100	1.0	30.0	0.1512E-01	0.90693	366000	5189969	5532	88399
30	7800	1.0	30.0	0.1509E-01	0.90526	468000	5657969	7060	95459
50	0	1.0	30.0	0.1494E-01	0.89655	0	5657969	0	95459
29	800	1.0	30.0	0.1474E-01	0.88459	48000	5705969	707	96166
14	246	1.0	30.0	0.1467E-01	0.88007	14760	5720729	216	96382
37	3000	1.0	30.0	0.1464E-01	0.87834	180000	5900729	2635	99017
51	600	1.0	30.0	0.1449E-01	0.86933	36000	5936729	521	99538
12	8400	1.0	30.0	0.1438E-01	0.86257	504000	6440729	7245	106783
55	3350	3.0	10.0	0.1420E-01	0.76676	180900	6621629	2568	109351
39	4900	1.0	30.0	0.1417E-01	0.85043	294000	6915629	4167	113518

MAXIMUM ADDITIONAL SURVIVORS PER DOLLAR   RUN ZCK   PAGE 7

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC   LONGITUDE- 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000   HEIGHT OF BURST(FEET)= 0   CIRCULAR PROBABLE ERROR(MI)= 2.0

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M.   TOTAL POPULATION= 330235

	PROBABILITY OF COVERAGE AS A FUNCTION OF MAXIMUM OVERPRESSURE(PSI)							
SLA	1.0	3.0	10.0	30.0	100.0	250.0	500.0	1000.0
40	1.0000	0.9991	0.6105	0.1964	0.0545	0.0263	0.0169	0.0103
41	1.0000	0.9955	0.4086	0.0884	0.0194	0.0084	0.0051	0.0028
42	1.0000	0.9998	0.7379	0.3034	0.0975	0.0492	0.0322	0.0199
43	1.0000	0.9999	0.8197	0.3976	0.1410	0.0732	0.0485	0.0302
44	1.0000	0.9995	0.6648	0.2376	0.0702	0.0346	0.0224	0.0137
45	1.0000	0.8933	0.0575	0.0037	0.0004	0.0001	0.0001	0.0000
46	1.0000	0.9954	0.4059	0.0873	0.0191	0.0083	0.0050	0.0028
47	1.0000	0.9987	0.5590	0.1626	0.0424	0.0201	0.0128	0.0078
48	1.0000	0.9994	0.6488	0.2243	0.0649	0.0318	0.0205	0.0126
49	1.0000	0.9993	0.6250	0.2059	0.0578	0.0 90	0.0181	0.0110
50	1.0000	0.9967	0.4454	0.1035	0.0236	0.0104	0.0063	0.0036
51	1.0000	0.9978	0.5007	0.1307	0.0320	0.0149	0.0094	0.0057
52	1.0000	0.9924	0.3414	0.0675	0.0128	0.0054	0.0031	0.0017
53	1.0300	0.9995	0.6584	0.2322	0.0680	0.0334	0.0216	0.0133
54	1.0000	0.9955	0.4086	0.0884	0.0194	0.0084	0.0051	0.0028
55	1.0000	0.7888	0.0220	0.0009	0.0001	0.0000	0.0000	0.0000
56	1.0000	0.9943	0.3730	0.0738	0.0153	0.0065	0.0038	0.0021
57	0.9332	0.0045	0.0000	0.	0.	0.	0.	0.
58	0.9927	0.0489	0.0000	0.	0.	0.	0.	0.
59	1.0000	0.9594	0.1393	0.0141	0.0020	0.0007	0.0004	0.0002
60	1.0000	0.9999	0.7815	0.3491	0.1177	0.0602	0.0396	0.0246
61	1.0000	0.9999	0.8197	0.3976	0.1410	0.0732	0.0485	0.0302
62	1.0000	0.9994	0.6366	0.2143	0.0609	0.0297	0.0191	0.0117
63	1.0000	0.9930	0.3512	0.0667	0.0136	0.0057	0.0034	0.0018
64	1.0000	0.9959	0.4201	0.0931	0.0207	0.0090	0.0054	0.0030
65	1.0000	0.9190	0.0753	0.0054	0.0006	0.0002	0.0001	0.0001
66	1.0000	0.9799	0.2143	0.0282	0.0046	0.0016	0.0010	0.0005
67	0.6892	0.0001	0.	0.	0.	0.	0.	0.

MAXIMUM ADDITIONAL SURVIVORS PER DOLLAR RUN 2CK

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 309235

COST=TABULAR VALUES

BASE OVERPRESSURE(PSI)= 1.0

SLA	POPULATION	OVERPRESSURE(PSI) LOWER	UPPER	SURVIVORS PER DOLLAR	CHANGE IN PROBABILITY	INCREASE IN COST	ACCUMULATED COST	ADDITIONAL SURVIVORS	ACCUMULATED SURVIVORS
26	3750	1.0	250.0	0.7215E-02	0.86583	450000	17751299	3246	226032
22	3700	1.0	250.0	0.7140E-02	0.85678	444000	18195299	3170	229202
24	7739	1.0	250.0	0.7120E-02	0.85444	928680	19123979	6612	235814
25	1251	1.0	250.0	0.7109E-02	0.85302	150120	19274099	1067	236881
8	7000	30.0	250.0	0.6906E-02	0.41438	420000	19694099	2900	239781
34	1500	30.0	250.0	0.6847E-02	0.41081	90000	19784099	616	240397
18	4500	30.0	250.0	0.6759E-02	0.40552	270000	20054099	1824	242[illegible]21
27	9000	30.0	250.0	0.6627E-02	0.39760	540000	20594099	3578	245799
20	5800	30.0	250.0	0.6325E-02	0.37952	348000	20942099	2201	248000
19	5700	30.0	250.0	0.6203E-02	0.37221	342000	21284099	2121	250[illegible]21
33	5000	30.0	250.0	0.5991E-02	0.35944	300000	21584099	1797	251918
17	3100	30.0	250.0	0.5759E-02	0.34555	186000	21770099	1071	252989
10	9000	30.0	250.0	0.5473E-02	0.32838	540000	22310099	2955	255944
43	0	30.0	250.0	0.5406E-02	0.32438	0	22310099	0	255944
61	1900	30.0	250.0	0.5406E-02	0.32438	114000	22424099	616	256560
9	9900	30.0	250.0	0.5378E-02	0.32267	594000	23018099	3194	259754
28	3800	30.0	250.0	0.5248E-02	0.31486	228000	23246099	1196	2609[illegible]0
35	6300	30.0	250.0	0.5043E-02	0.30259	378000	23524099	1906	262856
60	4100	30.0	250.0	0.4814E-02	0.28887	2460[illegible]	23870099	1184	264040
16	3399	30.0	250.0	0.4783E-02	0.28698	20[illegible]	24074039	975	265015
32	2600	30.0	250.0	0.4455E-02	0.26730	156000	24230039	694	265709
42	0	30.0	250.0	0.4237E-02	0.25424	0	24230039	0	265709
55	3350	10.0	30.0	0.4222E-02	0.02111	16750	24246789	70	265779
36	1800	30.0	250.0	0.4169E-02	0.25013	108000	24354789	450	266229
7	8900	30.0	250.0	0.4120E-02	0.24722	534000	24888789	2200	268429
44	0	30.0	250.0	0.3383E-02	0.20301	0	24888789	0	268429
53	300	30.0	250.0	0.3313E-02	0.19879	18000	24906789	59	26848[illegible]
48	3400	30.0	250.0	0.3209E-02	0.19255	[illegible]4000	25110789	654	269142
6	13300	30.0	250.0	0.3208E-02	0.19245	[illegible]8000	25908789	2559	2717[illegible]1
38	6000	30.0	250.0	0.3181E-02	0.19034	360000	26268789	1145	[illegible]
15	11900	30.0	250.0	0.3130E-02	0.18770	714000	26982789	2234	275080
62	5700	30.0	250.0	0.3077E-02	0.18461	342000	27324789	1052	276132
49	6800	30.0	250.0	0.2965E-02	0.17790	408000	27732789	1209	277341
40	300	30.0	100.0	0.2839E-02	0.14196	15000	27747789	42	277383
40	300	100.0	250.0	0.2815E-02	0.02815	3000	27750789	8	277391
31	4500	30.0	100.0	0.2707E-02	0.13537	225000	27975789	609	2780[illegible]
11	3700	30.0	100.0	0.2692E-02	0.13461	185000	28160789	498	278498

MAXIMUM ADDITIONAL SURVIVORS PER DOLLAR RUN 2CK PAGE 4

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 300235

COST=TABULAR VALUES

BASE OVERPRESSURE(PSI)= 1.0

SLA	POPULATION	OVERPRESSURE(PSI) LOWER	UPPER	SURVIVORS PER DOLLAR	CHANGE IN PROBABILITY	INCREASE IN COST	ACCUMULATED COST	ADDITIONAL SURVIVORS	ACCUMULATED SURVIVORS
65	5500	10.0	30.0	0.1399E-01	0.06993	27500	6943129	384	113902
47	288	1.0	30.0	0.1396E-01	0.83741	17280	6960409	241	114143
11	3700	1.0	30.0	0.1358E-01	0.81499	222000	7182409	3015	117158
31	4500	1.0	30.0	0.1356E-01	0.81381	270000	7452409	3662	120820
40	300	1.0	30.0	0.1339E-01	0.80358	18000	7470409	241	121061
49	6800	1.0	30.0	0.1323E-01	0.79406	408000	7878409	5399	126460
62	5700	1.0	30.0	0.1310E-01	0.78573	342000	8220409	4478	130938
15	11900	1.0	30.0	0.1303E-01	0.78173	714000	8934409	9302	140240
38	6000	1.0	30.0	0.1296E-01	0.77785	360000	9294409	4667	144907
6	13300	1.0	30.0	0.1293E-01	0.77580	798000	10092409	10318	155225
48	3400	1.0	30.0	0.1293E-01	0.77568	204000	10296409	2637	157862
53	300	1.0	30.0	0.1280E-01	0.76779	18000	10314409	230	158092
44	0	1.0	30.0	0.1271E-01	0.76244	0	10314409	0	158092
1	8500	10.0	30.0	0.1263E-01	0.06316	42500	10356909	536	158628
7	8900	1.0	30.0	0.1176E-01	0.70578	534000	10890909	6281	164909
36	1800	1.0	30.0	0.1170E-01	0.70196	108000	10998909	1263	166172
42	0	1.0	30.0	0.1161E-01	0.69656	0	10998909	0	166172
32	2600	1.0	30.0	0.1132E-01	0.67940	156000	11154909	1766	167938
16	3399	1.0	30.0	0.1089E-01	0.65350	203940	11358849	2221	170159
60	4100	1.0	30.0	0.1085E-01	0.65092	246000	11604849	2668	172827
45	10	10.0	30.0	0.1077E-01	0.05385	50	11604899	0	172827
35	6300	1.0	30.0	0.1054E-01	0.63217	378000	11982899	3982	176809
28	3800	1.0	30.0	0.1026E-01	0.61539	228000	12210899	2338	179147
9	9900	1.0	30.0	0.1008E-01	0.60472	594000	12804899	5986	185133
43	0	1.0	30.0	0.1004E-01	0.60238	0	12804899	0	185133
61	1900	1.0	30.0	0.1004E-01	0.60238	114000	12918899	1144	186277
10	9000	1.0	30.0	0.9949E-02	0.59692	540000	13458899	5372	191649
17	3100	1.0	30.0	0.9551E-02	0.57306	186000	13644899	1776	193425
33	5000	1.0	30.0	0.9222E-02	0.55330	300000	13944899	2766	196191
19	5700	1.0	30.0	0.8919E-02	0.53514	342000	14286899	3050	199241
20	5800	1.0	30.0	0.8746E-02	0.52474	348000	14634899	3043	202284
27	9000	1.0	30.0	0.8307E-02	0.49842	540000	15174899	4485	206769
18	4500	1.0	30.0	0.8112E-02	0.48671	270000	15444899	2190	208959
34	1500	1.0	30.0	0.7982E-02	0.47890	90000	15534899	718	209677
8	7000	1.0	30.0	0.7894E-02	0.47362	420000	15954899	3315	212992
21	4800	1.0	250.0	0.7281E-02	0.87367	576000	16530899	4193	217185
23	6420	1.0	250.0	0.7271E-02	0.87247	770400	17301299	5601	222786

COST(1)=30*SQRT(OPS) COST(2)=50+20*SQRT(OPS) COST(3)=FOLLOWING TABLE OF VALUES

500 PERSONS PER SHELTER

SHELTER DESIGN OVERPRESSURE	SHELTER COST PER PERSON
1.0	140.00
3.0	141.00
10.0	195.00
30.0	200.00
100.0	250.00
250.0	260.00
500.0	280.00
1000.0	329.00

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MAXIMUM ADDITIONAL SURVIVORS PER DOLLAR RUN 2CK PAGE 6

AIMING POINT-GEOMETRIC CENTROID
LATITUDE- 35 DEG 5 MIN 8 SEC LONGITUDE- 106 DEG 37 MIN 32 SEC

YIELD(MT)= 10.000 HEIGHT OF BURST(FEET)= 0 CIRCULAR PROBABLE ERROR(MI)= 2.0

5311 ALBUQUERQUE CITY AND BERNALILLO COUNTY(NIGHT POPULATION),N.M. TOTAL POPULATION= 300235

COST=TABULAR VALUES

BASE OVERPRESSURE(PSI)= 1.0

SLA	POPULATION	OVERPRESSURE(PSI) LOWER	UPPER	SURVIVORS PER DOLLAR	CHANGE IN PROBABILITY	INCREASE IN COST	ACCUMULATED COST	ADDITIONAL SURVIVORS	ACCUMULATED SURVIVORS
31	4500	100.0	250.0	0.2639E-02	0.02639	45000	28205789	118	278616
11	3700	100.0	250.0	0.2618E-02	0.02618	37000	28242789	96	278712
47	288	30.0	100.0	0.2403E-02	0.12015	14400	28257189	34	278746
25	1251	250.0	500.0	0.2388E-02	0.04777	25020	28282209	59	278805
24	7739	250.0	500.0	0.2367E-02	0.04734	154780	28436989	366	279171
22	3700	250.0	500.0	0.2331E-02	0.04662	74000	28510989	172	279343
47	288	100.0	250.0	0.2231E-02	0.02231	2880	28513869	6	279349
39	4900	30.0	100.0	0.2231E-02	0.11155	245000	28758869	546	279895
26	3750	250.0	500.0	0.2192E-02	0.04385	75000	28833869	164	280059
23	6420	250.0	500.0	0.2090E-02	0.04180	128400	28962269	268	280327
21	4800	250.0	500.0	0.2071E-02	0.04143	96000	29058269	198	280525
12	8400	30.0	100.0	0.2065E-02	0.10325	420000	29478269	867	281392
39	4900	100.0	250.0	0.2014E-02	0.02014	49000	29527269	98	281490
51	600	30.0	100.0	0.1972E-02	0.09862	30000	29557269	59	281549
8	7000	250.0	500.0	0.1849E-02	0.03699	140000	29697269	258	281807
37	3000	30.0	100.0	0.1849E-02	0.09247	150000	29847269	277	282084
14	246	30.0	100.0	0.1826E-02	0.09129	12300	29859569	22	282106
34	1500	250.0	500.0	0.1823E-02	0.03646	30000	29889569	54	282160
12	8400	100.0	250.0	0.1821E-02	0.01821	84000	29973569	152	282312
18	4500	250.0	500.0	0.1784E-02	0.03567	90000	30063569	160	282472
29	800	30.0	100.0	0.1764E-02	0.08820	40000	30103569	70	282542
27	9000	250.0	500.0	0.1725E-02	0.03449	180000	30283569	310	282852
51	600	100.0	250.0	0.1713E-02	0.01713	6000	30289569	10	282862
50	0	30.0	100.0	0.1596E-02	0.07982	0	30289569	0	282862
20	5800	250.0	500.0	0.1596E-02	0.03191	116000	30405569	185	283047
37	3000	100.0	250.0	0.1570E-02	0.01570	30000	30435569	47	283094
19	5700	250.0	500.0	0.1547E-02	0.03094	114000	30549569	176	283270
14	246	100.0	250.0	0.1543E-02	0.01543	2460	30552029	3	283273
30	7800	30.0	100.0	0.1471E-02	0.07355	390000	30942029	573	283846
29	800	100.0	250.0	0.1471E-02	0.01471	8000	30950029	11	283857
33	5000	250.0	500.0	0.1462E-02	0.02923	100000	31050029	146	284003
64	6100	30.0	100.0	0.1447E-02	0.07235	305000	31355029	441	284444
41	3	30.0	100.0	0.1379E-02	0.06895	150	31355179	0	284444
54	7500	30.0	100.0	0.1379E-02	0.06895	375000	31730179	517	284961

TOTAL SURVIVING POPULATION= 285529

CHAPTER V

A MODEL FOR DEVELOPMENT OF PREFERRED MIXTURES OF EVACUATION AND SHELTER

1.0 Introduction

This chapter is concerned with the development of a mathematical model for use in attempts to delineate preferred mixtures of shelter and evacuation. Warning time is considered more explicitly and in more detail than in past work.

Only one target area is considered in the model; the entire threat is considered to be that due to a nuclear attack on the area. It is assumed that the location of the aiming point is known and that one weapon is assigned to the aiming point. The weapon parameters (yield, burst height, and delivery accuracy) and the distribution of possible times of detonation are input parameters to the model.

It is assumed that shelters can be placed at any location. Shelter cost is assumed to increase with increasing hardness; hardness is assumed to be a measurable, reproducible quantity which indicates the vulnerability of those in the shelter. The evacuation rate and vulnerability of evacuees must be supplied as input parameters to the model.

2.0 The Mathematical Model

A path is defined over which it is planned to evacuate people from the target area. Along this path a distance coordinate s is defined. For each point along the path, there is a survival probability for an evacuating person who is at that point at the time of a detonation. This probability of surviving an attack while traveling is denoted $P_T(s)$. The function $P_T(s)$ depends upon delivery accuracy, weapon parameters, and the vulnerability of the evacuee.

Along the evacuation path a distribution of shelters is assumed such that at any point an evacuee can stop and quickly enter a shelter. If a weapon detonation occurs after he has entered a shelter at point s, then his survival probability is denoted $P_S(s)$. This continuous distribution of shelters is hypothetical; the desired distribution of shelters and their hardness are viewed as the unknowns in the problem. A continuous hypothetical distribution of shelters is, however, a useful conceptual tool.

Since a given amount of protection becomes cheaper to attain as the distance from an aiming point increases, it is assumed that some people in the target area begin evacuation as soon as an alert is given. A typical evacuee undergoes motion described by a function of time $s(t)$ along the evacuation route. Since he would be much safer in a shelter at the time of detonation than if he were traveling, he should stop and enter a nearby shelter at an appropriate time t_o. His survival probability for the attack is then

$$P_{sur} = \int_0^{t_o} P_T[s(t)]\, T(t)\,dt + P_S[s(t_o)] \int_{t_o}^{\infty} T(t)\,dt , \qquad (1)$$

where T(t) is defined by the following three properties:

(1) $\int_t^{t+\Delta t} T(t')\,dt'$ is the probability of a detonation occurring between times t and $t + \Delta t$,

(2) $\int_0^{\infty} T(t)\,dt = 1$, and

(3) $\lim_{t \to \infty} T(t) = 0$.

If $P_S(s)$, $P_T(s)$, and $T(t)$ are all considered to be known functions, the maxima and minima of the survival probability with respect to the take-shelter time can be found by setting dP_{sur}/dt_o equal to zero and simplifying:

$$P_S'(s_o)\, s'(t_o) \int_{t_o}^{\infty} T(t)\,dt - [P_S(s_o) - P_T(s_o)]\, T(t_o) = 0 , \qquad (2)$$

where the primes denote differentiation, and $s_o = s(t_o)$. Thus, solving Eq. (2) for t_o yields the time at which a person should stop traveling and enter a shelter to make his survival probability a maximum.

On the other hand, Eq. (2) can be viewed as a first-order linear ordinary differential equation in $P_S(s_o)$. Functions P_S satisfying Eq. (2) for all s_o have the property that they make P_{sur} constant, that is, independent of the take-shelter time t_o. Such a shelter distribution has increasing safety in the direction of motion such that the added risk of being exposed long enough to move an additional short distance is always exactly offset by the safety of the shelter entered after the movement. The general solution of Eq. (2) for the function P_S can be written:

$$P_S(s_o) = \frac{Q}{\int_{t_o}^{\infty} T(t)\, dt} , \tag{3a}$$

$$\text{where } Q = P_S(s_i) - \int_{s_i}^{s_o} \frac{T(t_o') P_T(s_o') ds_o'}{v(s_o')} \tag{3b}$$

and where t_o is the time of arrival at the point s_o, s_i is the initial value of s, and $v(s_o')$ is the travel velocity at the point s_o'.

The general solution of Eq. (2) given by Eqs. (3) can be divided into three cases depending on whether the value of $P_S(s_i)$ is less than, equal to, or greater than α,

$$\text{where} \qquad \alpha = \int_{s_i}^{\infty} \frac{T(t_o') P_T(s_o') ds_o'}{v(s_o')} .$$

Case 1, $P_S(s_i) < \alpha$. For some value of s_o, say s_o^*, the quantity Q vanishes and for $s_o > s_o^*$ it becomes negative. Thus, the only physically allowable values of $P_S(s_o)$ are for $s_o \leq s_o^*$ (see Fig. 17). Following the discussion of Case 2 it will be shown that stopping in any shelter in a distribution of shelters described in this case would result in lower survival probability than that associated with continuing the assumed motion given by $s(t)$.

Case 2, $P_S(s_i) = \alpha$. Let b be the least value of s_o such that $\int_{t_o}^{\infty} T(t)\,dt = 0$ (if b is not finite, the limit as $s_o \to \infty$ is to be substituted for $s_o \to b$ in the following). As s_o approaches b, the quantity Q approaches zero. Since the denominator of Eq. (3a), $\int_{t_o}^{\infty} T(t)\,dt$, approaches zero at the same point, an indeterminate form is obtained for $P_S(b)$. In evaluating the limit one finds that $\lim_{s_o \to b} P_S(s_o) = P_T(b)$. Thus the solution given in this case can be physically realized for all values of $s_o \leq b$. ($P_S(s_o)$ for $s_o > b$ is of no interest). Such a system of shelters has the property that stopping in any one of them gives the same survival probability as total evacuation by continuation of the assumed motion $s(t)$.

Note that P_S for Case 1 is always less than for Case 2 which provides the shelter distribution that has survival probability equal to that associated with evacuation. Thus, Case 1 shelters are less safe than evacuation.

Case 3, $P_S(s_i) > \alpha$. In this case, the quantity Q is positive for all values of s_o. Since the denominator of Eq. (3a) $\int_{t_o}^{\infty} T(t)\,dt$, approaches zero for some value (finite or infinite) of t_o and hence for some value of s_o, say $s_o = b$, the solutions have a pole at $s_o = b$. Thus for s_o greater than some value, say s_o^{**}, $P_S(s_o)$ is greater than unity and has no physical meaning. The portions of the solution for which $P_S \leq 1$ represent shelter distributions that offer greater safety than an attempt at total evacuation; however, notice that they exist physically for only limited distances from the target area.

Figure 17 is a sketch showing the features of the functions described under Cases 1, 2, and 3 above.

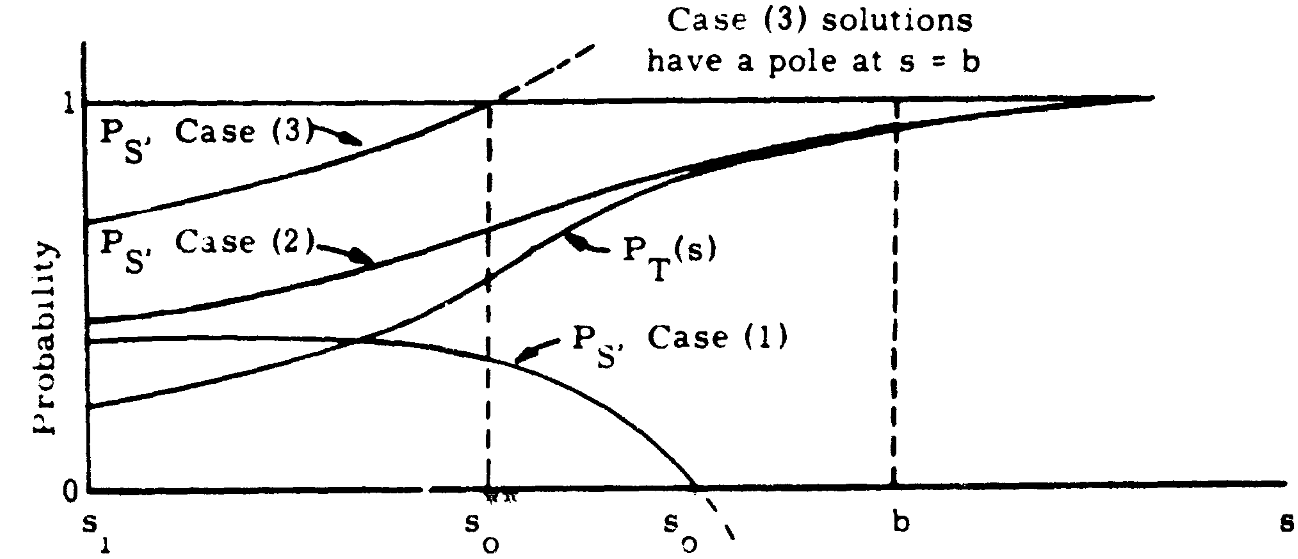


Fig. 17

Sketch of P_T and P_S for Various Constant Values of P_{sur}

3.0 Preferred Evacuation-Shelter Policies for Given Shelter Systems

The general solution of Eq. (2) for $P_S(s_o)$ has a usefulness aside from its direct application to the shelter system design problem. Suppose a function $P_S(s_o)$ is given as a result of some other considerations (possibly it corresponds to an existing shelter system or was theoretically derived on the basis of some other theory). It is then desired to find points s_o for which Eq. (2) is satisfied and thus find the optimum locations for evacuees to take shelter. At a point where Eq. (2) is satisfied, the given function $P_S(s_o)$ must be tangent to one of the curves belonging to the general solution. This is true because it must have a value and slope satisfying Eq. (2). Thus for a given T(t) and $P_T(s)$, if a grid is constructed of the general solution curves of Eq. (2) and then some other $P_S(s_o)$ is plotted on the same coordinates, the tangency points can be seen and thus (at least approximately) the points of solution of Eq. (2) can be read off the graph. Furthermore, in regions where the given function $P_S(s_o)$ crosses the general solution grid lines upwardly for increasing s_o, a traveler will increase his safety by proceeding farther. Similarly, in regions where $P_S(s_o)$ crosses the general solution grid lines downwardly for increasing s_o, a traveler would decrease his safety by continued travel.

4.0 A Motivational Problem

When people in the same area have instructions to do different things to increase their safety they will probably question whether they or some other group are increasing their safety most effectively. The self-preservation instinct provides a strong motivation to do that which is thought to be safest. Thus, people instructed to stay in a shelter may be tempted to join with others who are traveling by just outside their door on their way to a shelter presumed to be safer because it is farther from the target area. On the other hand, those who are traveling may feel that they are much too vulnerable while traveling and therefore that they would be safer in one of the nearby shelters. Yet the civil defense plan may be designed to utilize the transportation facilities to the fullest leaving no transportation for those instructed to stay in shelters. Conversely, the shelters along the evacuation path may have no room for those instructed to travel, shelters for the travelers having been provided farther from the target area where a given shelter hardness provides a greater survival probability.

Though there would probably be some discontent in a situation such as the one described no matter what shelter plan had been followed, the cause for the discontent can be eliminated, in principle at least, by using a shelter distribution with safety given by Cases (2) or (3) of the general solution of Eq. (2) for $P_S(s_o)$. If the shelters correspond to Case (2), the travelers can evacuate completely and those in the shelters will have the same survival probability as those that have evacuated. If the shelters correspond to Case (3), the travelers will eventually have to stop and enter a shelter, but those who stop and enter a shelter first will have the same survival probability as those who go farther.

One difficulty soon becomes evident in realizing shelters that correspond to Cases (2) or (3); these theoretical shelter distributions are, in general, dependent on the initial position, s_i, of the traveler To circumvent this problem, a mean value of s_i for a traveling group can be used, or a special form of T(t) can be used which removes the dependence on s_i. Such a form for T(t) is presented in the section in which the function T(t) is discussed. In spite of this difficulty the theoretical distributions given by Cases (2) and (3) are of considerable conceptual significance.

5.0 Evacuation-Shelter Policy for a Fixed Budget

Shelter-building funds might be appropriated and distributed on the basis of population density. If so, a given population density would imply a particular shelter hardness, represented by shelter design overpressure. To locate shelters for small groups having a fixed budget, it is only necessary to construct the function $P_S(s_o)$ as a function of distance along the evacuation path. This function is inserted in Eq. (2) which is then solved for the maximum of total survival probability. Mechanically, this can be done by plotting $P_S(s_o)$ on the same graph with members of the set of functions that represent the general solution of Eq (2) and then looking for tangent points. If there is more than one tangent point representing a maximum, a shelter should be built where it offers the greatest survival probability. Figure 18 illustrates the technique.

6.0 Some Comments On and Examples Of The Function T(t)

An important property of the curves belonging to the general solution of Eq. (2), given by Eqs. (3), should be noticed. In regions where

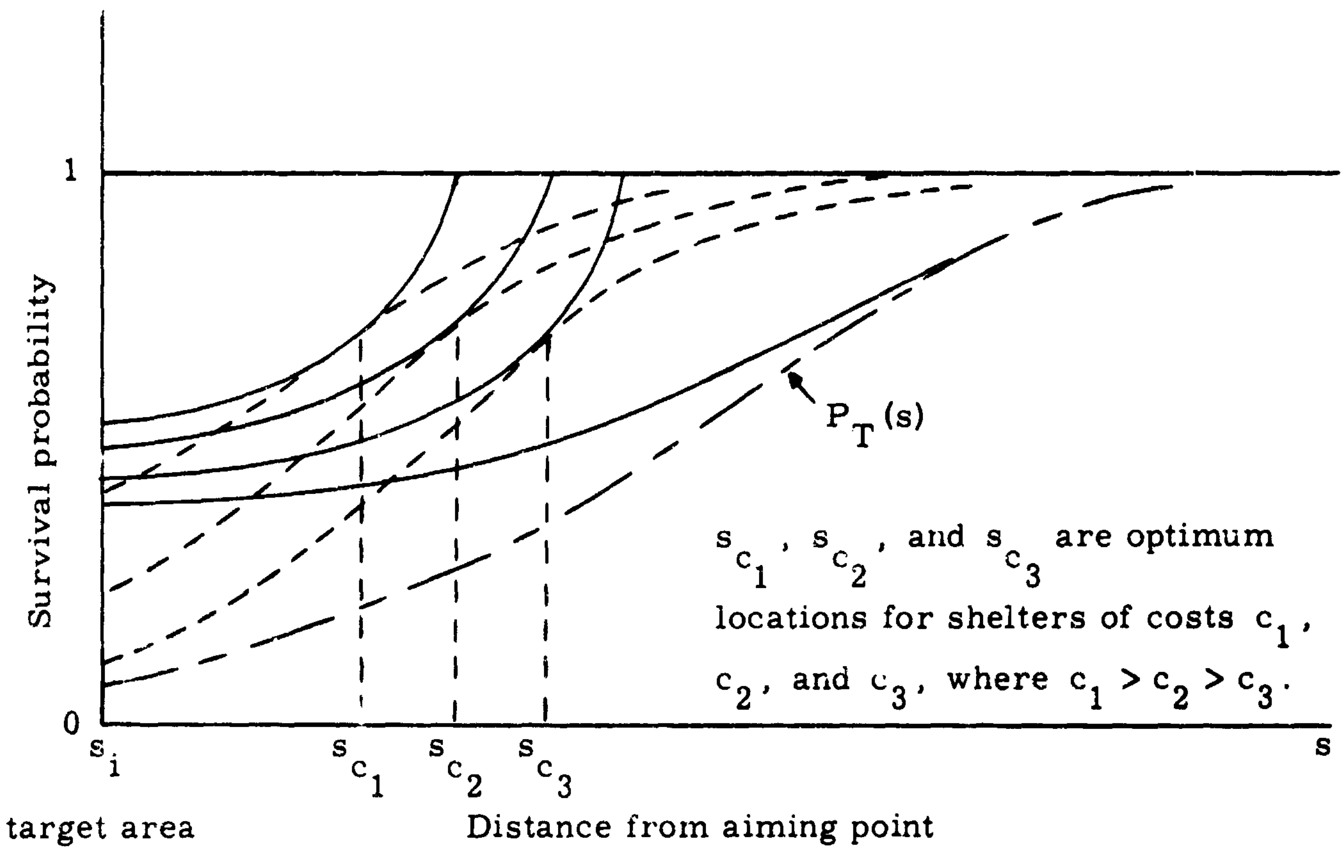


Fig. 18

Illustration of Technique for Finding the Optimum Location for a Shelter of a Given Cost

$T(t_o) = 0$, but $\int_{t_o}^{\infty} T(t)\,dt > 0$, the function $P_S(s_o)$ = a constant.

Thus, the initial portion of the curves given by Eq. (3) is constant and equal to $P_S(s_i)$ over the distance traveled by the person in question during any initial time in which $T(t) = 0$.

In the examples which follow it will be assumed that the motion of the traveler is given by $s(t) = s_i + vt$, where v is a constant. Specific forms of the function $T(t)$ will be chosen; they are not necessarily thought to be realistic, only instructive.

Example (1)

$$\begin{aligned} \text{Let } T(t) &= 0, \quad t < t_1 \\ &= (1/\tau)\exp\left\{-(t-t_1)/\tau\right\}, \quad t \geq t_1 \quad . \end{aligned}$$

For $t < t_1$, that is for $s_i \leq s_o < s_i + vt_1$, $P_S(s_o) = P_S(s_i)$.

For $t \geq t_1$,

$$P_S(s_o) = \exp(s_o / v\tau)\left\{P_S(s_i)\exp(-s_i/v\tau - t_1/\tau) - (1/v\tau)\int_{s_i}^{s_o} P_T(s_o')\exp(-s_o'/v\tau)\,ds_o'\right\} .$$

This can be rewritten

$$P_S(s_o) - \exp(s_o/v\tau)\left\{C \cdot (1/v\tau)\int_0^{s_o} P_T(s_o')\exp(-s_o'/v\tau)\,ds_o'\right\} , \quad (4)$$

$$\text{where } C = P_S(s_i)\exp(-s_i/v\tau - t_1/\tau) + (1/v\tau)\int_0^{s_i} P_T(s_o')\exp(-s_o'/v\tau)ds_o' .$$

The family of curves given by Eq. (4) is the general solution of Eq. (2) and is independent of s_i. The constant of integration is related to s_i as shown, but the same values of C are covered independent of s_i since $P_S(s_i)$ is an arbitrary constant. It should be remembered, however, that the solutions given by Eq. (4) hold only for $t \geq t_1$; this implies that $s_o \geq s_i + vt_1$.

This is simply a reminder that the first portion ($s_o \leq s_i + vt_1$) of each curve is a constant and then the curve should join one of those given by Eq. (4). Thus, if the family of curves given by Eq. (4) is plotted, an actual solution of Eq. (2) for a given s_i is formed by joining a horizontal straight line ($P_S = P_S(s_i)$) drawn from s_i to $s_i + vt_1$, to the proper curve given by Eq. (4). Figure 19 illustrates this construction.

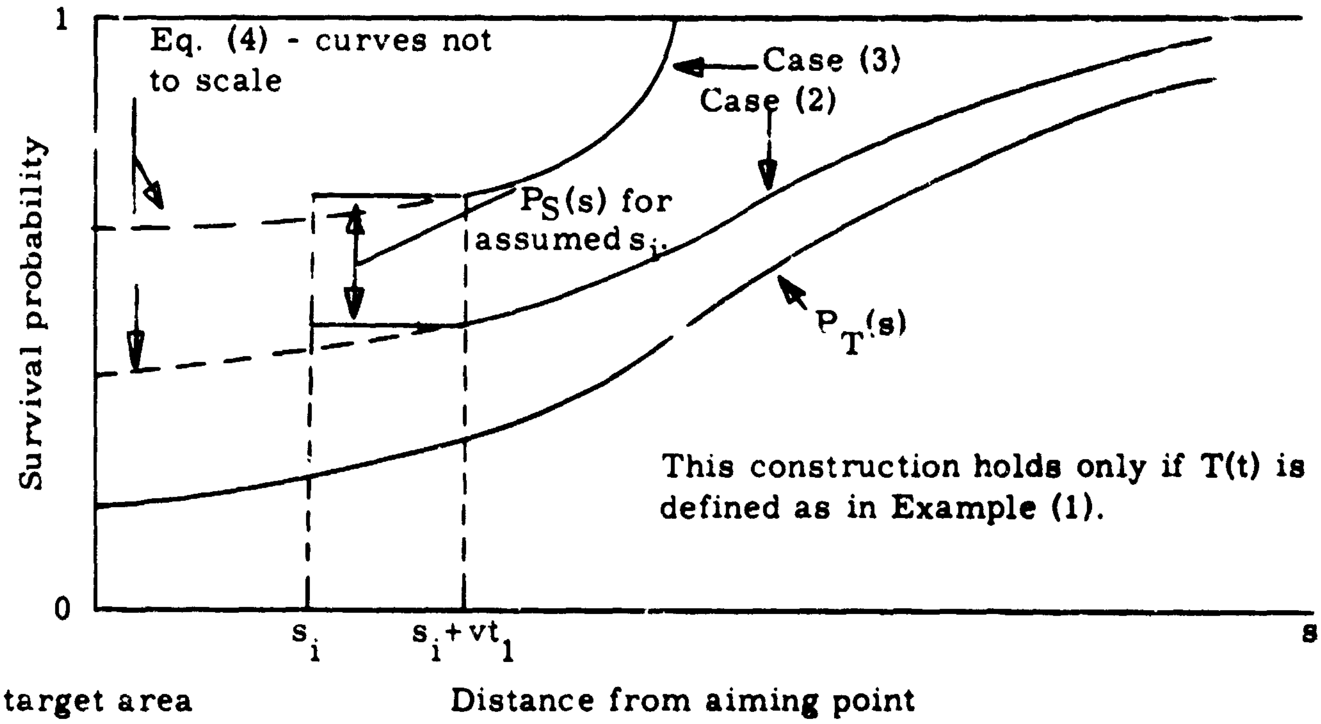


Fig. 19

Construction of Solutions of Eq. (2) from the Family of Curves Given by Eq. (4)

The particular form of T(t) discussed in this example has the interesting property that the general solution of Eq. (2) is independent of s_i

except for the (probably) small portion between s_i and $s_i + vt_1$. If $t_1 = 0$, the general solution is completely independent of s_i.

Example (2)

$$T(t) = 0, \quad t < t_1, \quad t > t_2$$
$$= 1/(t_2 - t_1), \quad t_1 \leq t \leq t_2 .$$

As in Example (1), $P_S(s_o) = P_S(s_i)$ for $t < t_1$ (or equivalently for $s_i \leq s_o < s_i + vt_1$). The general solution of Eq. (2) for $t_1 \leq t < t_2$ can be written (from Eq. (3)).

$$P_S(s_o) = \frac{t_2 - t_1}{t_2 - \frac{1}{v}(s_o - s_i)} \left\{ P_S(s_i) - \frac{1}{(t_2 - t_1)v} \int_{s_i + vt_1}^{s_o} P_T(s_o')\, ds_o' \right\}, \qquad (5)$$

where $s_i + vt_1 \leq s_o < s_i + vt_2$. The function $P_S(s_o)$ is physically meaningless for $t > t_2$ (or $s_o > s_i + vt_2$) since there is no longer any threat of attack, hence $P_S(s_o)$ will not be discussed further for that domain.

All solutions are constant for $s_i \leq s_o < s_i + vt_1$. Then the solution functions $P_S(s_o)$ begin to increase, taking on the values given by Eq. (5). Case (2) solutions intersect $P_T(s_o)$ at $s_o = s_i + vt_2$ and Case (3) solutions are singular at that point becoming greater than one for some $s_o < s_i + vt_2$ (see Fig. 20). Unlike the functions $P_S(s_o)$ of Example (1), the solutions $P_S(s_o)$ in this example are dependent on s_i.

A computer program to solve Eq. (2) has been developed and applied to some practical problems; a sample of the results obtained is provided in Table XXV and in Fig. 21.

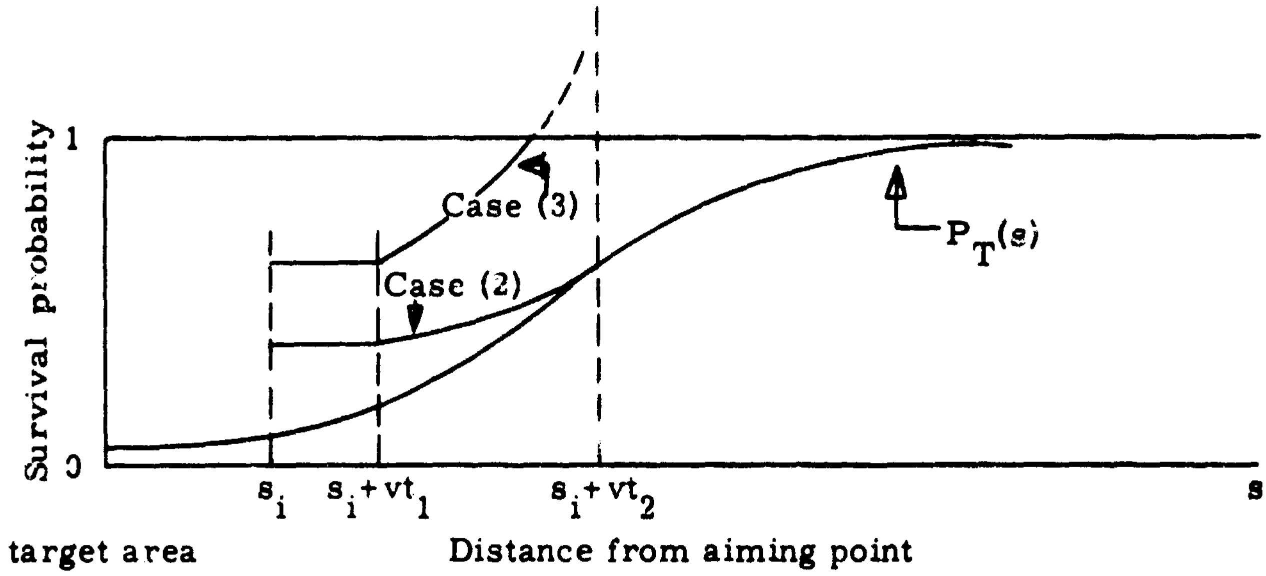


Fig. 20

Illustration of the General Solution of Eq. (2) for the Function T(t) as defined in Example (2)

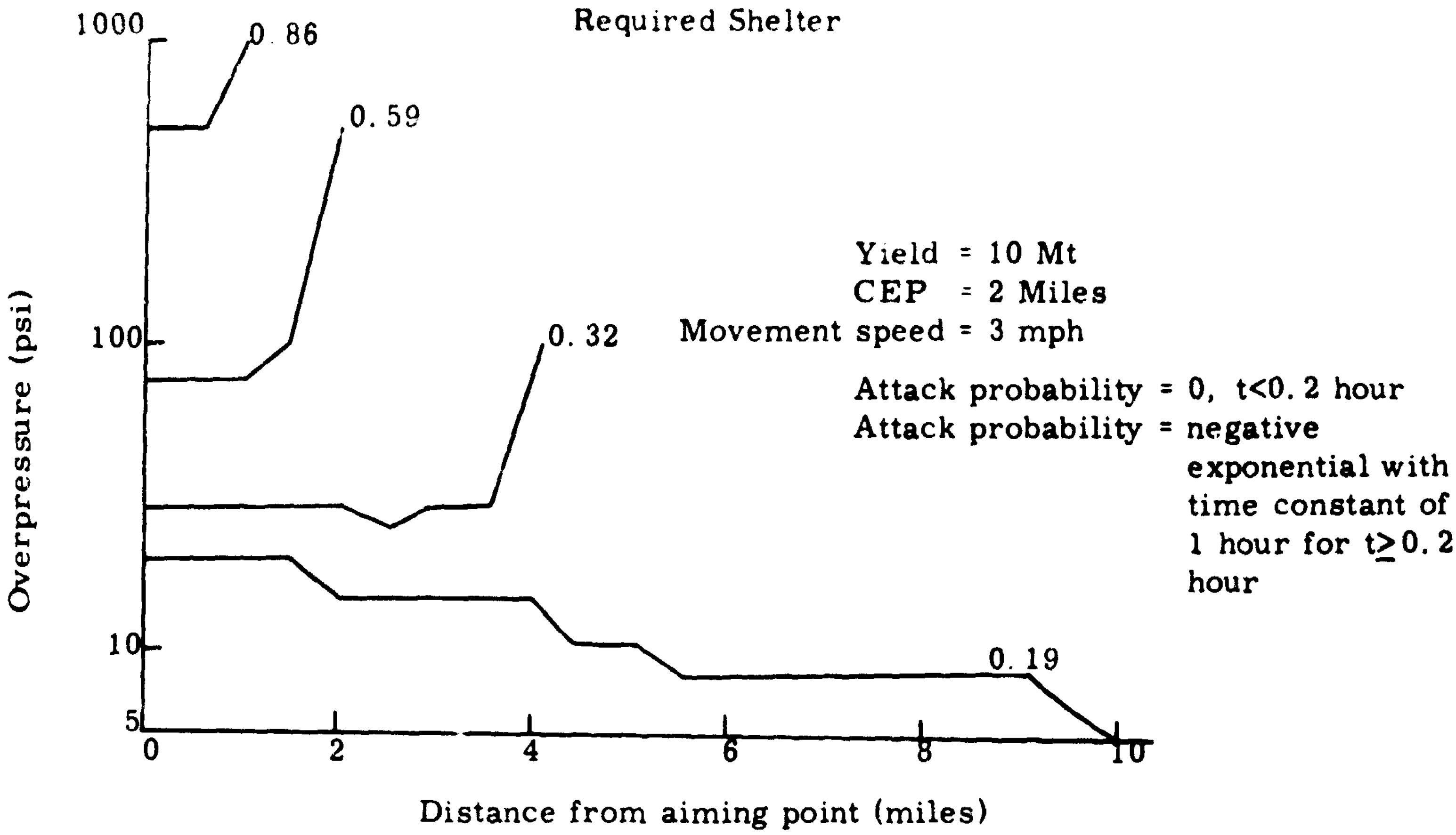
(5)

Table A-[illegible]

Typical Computer Output for Program to Find Movement-Shelter Mixtures for Constant Overall Survival Probability

PROGRAM GOSH
K. D. GRANZOW, DIKEWOOD CORP
MAY 15, 1964
DS = 0.500 MILES NOS = 20
CEP = 2.00 MILES YIELD = 10.00 MEGATON
VELOCITY = 3.00 MILES/HR
SI = 0. MILES
ATTACK PROBABILITY ZERO FOR T LESS THAN 0.2 HOURS
ATTACK PROBABILITY EXPONENTIAL WITH TIME CONSTANT 1.0 HOURS
HARDNESS LIST (PSI) - 1, 2, 5, 10, 20, 50, 100, 200, 500

	S	PT(S)	-----CONSTANT SURVIVAL PROBABILITY------ PS(S)(CASE 2)/ OVERPRESSURE	PS(S)/ OVERPRESSURE				
PS(SI) =			0.19	0.32	0.46	0.59	0.73	0.86
HARDNESS								
	0.	0.00	0.19	0.32	0.46	0.59	0.73	0.86
			20.0	30.0	40.0	75.0	150.0	500.0
	0.5	0.00	0.19	0.32	0.46	0.59	0.73	0.86
			20.0	30.0	40.0	75.0	100.0	500.0
	1.0	0.00	0.22	0.37	0.52	0.68	0.83	0.99
			20.0	30.0	50.0	75.0	200.0	5000.0
	1.5	0.00	0.25	0.44	0.62	0.80	0.98	1.17
			20.0	30.0	50.0	100.0	5000.0	6000.0
	2.0	0.01	0.30	0.51	0.73	0.95	1.16	1.38
			15.0	30.0	75.0	500.0	6000.0	6000.0
	2.5	0.02	0.35	0.61	0.86	1.11	1.37	1.62
			15.0	25.0	100.0	6000.0	6000.0	6000.0
	3.0	0.04	0.41	0.71	1.01	1.31	1.61	1.91
			15.0	30.0	6000.0	6000.0	6000.0	6000.0
	3.5	0.07	0.47	0.83	1.18	1.54	1.90	2.25
			15.0	30.0	6000.0	6000.0	6000.0	6000.0
	4.0	0.11	0.54	0.96	1.38	1.80	2.22	2.64
			15.0	100.0	6000.0	6000.0	6000.0	6000.0
	4.5	0.18	0.62	1.11	1.61	2.10	2.60	3.10
			10.0	6000.0	6000.0	6000.0	6000.0	6000.0
	5.0	0.26	0.69	1.27	1.86	2.45	3.03	3.62
			10.0	6000.0	6000.0	6000.0	6000.0	6000.0
	5.5	0.36	0.76	1.45	2.14	2.83	3.53	4.22
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	6.0	0.48	0.82	1.64	2.45	3.27	4.09	4.91
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	6.5	0.59	0.87	1.84	2.80	3.77	4.73	5.70
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	7.0	0.70	0.91	2.05	3.19	4.34	5.48	6.62
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	7.5	0.79	0.94	2.29	3.64	4.99	6.33	7.68
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	8.0	0.86	0.96	2.56	4.15	5.74	7.33	8.93
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	8.5	0.92	0.98	2.86	4.74	6.62	8.50	10.38
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	9.0	0.95	0.98	3.21	5.43	7.65	9.87	12.10
			8.0	6000.0	6000.0	6000.0	6000.0	6000.0
	9.5	0.98	0.99	3.61	6.24	8.86	11.49	14.12
			6.0	6000.0	6000.0	6000.0	6000.0	6000.0
	10.0	0.99	0.99	4.09	7.19	10.29	13.40	16.50
			5.0	6000.0	6000.0	6000.0	6000.0	6000.0



Note: Numbers on curves are overall survival probabilities.

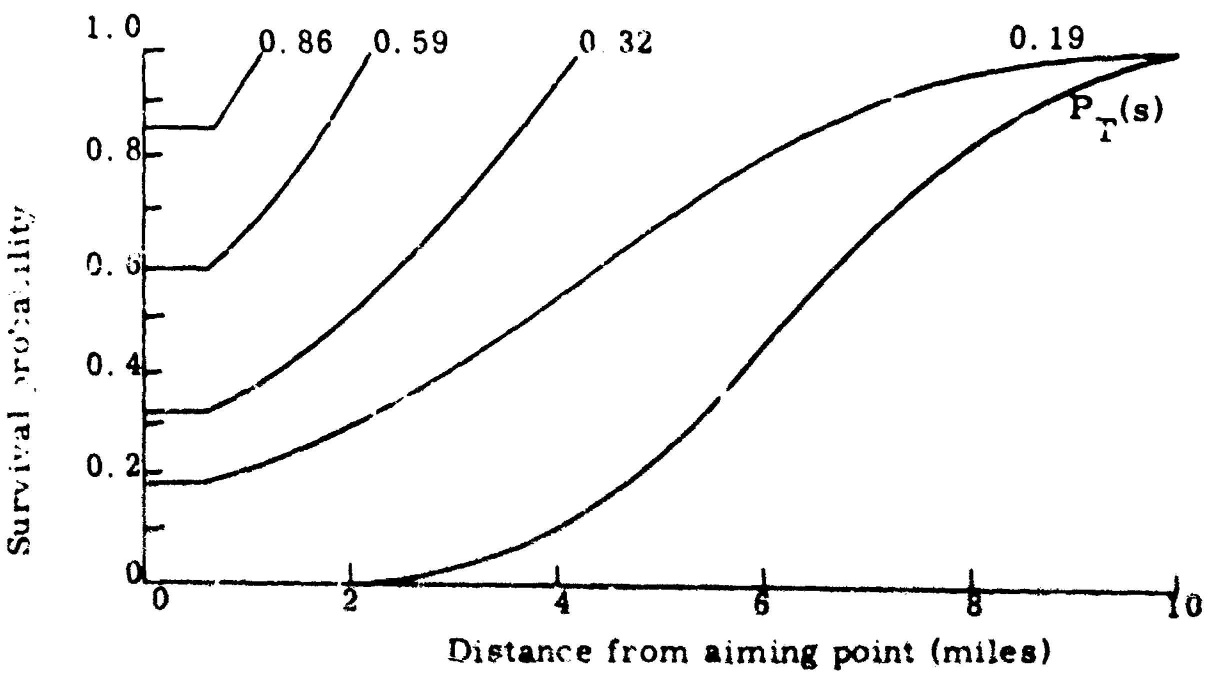


Fig. 21

Constant Survival Probability Curves for Mixtures of Movement and Shelter

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5,

ABSTRACT

This report describes an effort to find preferred mixtures of movement and shelter as Civil Defense responses to the threat of nuclear war. Two approaches were followed

1. Mixtures of movement and shelter were studied in three steps. These consisted of
   a. Postulation of alternative movement and shelter policies,
   b. Development of movement and shelter plans based on these policies,
   c. Evaluation of plans developed in (b) against the range of attack conditions considered reasonable.
2. A mathematical model was constructed to provide a vehicle for sensitivity analyses.

A technique for planning large-scale strategic movements was developed and applied to several particular places. The technique is believed to be developed sufficiently to provide a basis for planning a first-generation strategic movement capability for the U. S.

Two computer programs were developed as tools for evaluating strategic movement against particular attacks and for evaluating various trans-attack responses to large-scale movements interrupted by war.

Blast shelter planning programs are also reviewed and developed furthe Evaluation techniques are already available.

The mathematical model approach ended with the development of a computer program for finding the shelter location and hardness required to maximize overall survival probability for various warning time probability density functions and attack and movement assumptions.

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
The Dikewood Corporation 4805 Menaul Boulevard, NE Albuquerque, New Mexico	Unclassified 2b GROUP

3. REPORT TITLE

VULNERABILITY REDUCTION USING MOVEMENT AND SHELTER

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Vol. I - Summary, Vol. II - Final Report

5. AUTHOR(S) (Last name, first name, initial)

Flanagan, R. J.; Brannon, D. E.; Dike, S. H.; Granzow, K. D.; Durand, A. R.; Bliss, A. R.; Summers, D. L.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1965	Vol.I-8;Vol.II-128	36

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
Contract OCD-OS-63-109	DC-FR-1039
b. PROJECT NO. OCD Task 2311D	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. AVAILABILITY/LIMITATION NOTICES

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	Office of Civil Defense Office of the Secretary of the Army Washington, D.C.

13. ABSTRACT

See attached sheet.

DD FORM 1 JAN 64 1473

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Strategic Movement Planning Blast Shelter Planning Preferred Movement-Shelter Mixtures						

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