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Survival of the Relocated Population of the U.S. After a Nuclear Attack

FINAL REPORT • JUNE 1976

Interagency Agreement AEC 40-31-64
and DCPA 01-74-C-0227, Work Unit 3539A

ORNL-ERDA SURVIVAL OF THE RELOCATED POPULATION OF THE U.S. AFTER A NUCLEAR ATTACK FINAL REPORT • JUNE 1976 DCPA Work Unit 3539A

OAK RIDGE NATIONAL LABORATORY
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HEALTH PHYSICS DIVISION
Emergency Technology Section

SUMMARY

SURVIVAL OF THE RELOCATED POPULATION OF THE U.S. AFTER A NUCLEAR ATTACK

Final Report

by

Carsten M. Haaland
Conrad V. Chester
Eugene P. Wigner

for

Defense Civil Preparedness Agency
Washington, D. C. 20301

Interagency Agreement AEC 40-31-64
and DCPA 01-74-C-0227, Work Unit 3539A

DCPA Review Notice

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

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Oak Ridge, Tennessee 37830
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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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C. M. Haaland, C. V. Chester, and E. P. Wigner

SUMMARY

The feasibility of continued survival after a hypothetical nuclear attack is evaluated for people relocated from high-risk areas during the crisis period before the attack. The attack consists of 6559 MT, of which 5951 MT are ground bursts, on military, industrial, and urban targets. Relocated people are assumed to be adequately protected from fallout radiation by shelters of various kinds. The major problems in the postattack situation will be the control of exposure to fallout radiation, and prevention of severe food shortages to several tens of millions of people. A reserve of several million additional dosimeters is recommended to provide control of radiation exposure. Written instructions should be provided with each on their use and the evaluation of the hazard. Adequate food reserve exists in the U.S. in the form of grain stocks, but a vigorous shipping program would have to be initiated within two or three weeks after the attack to avoid large scale starvation in some areas. If the attack occurred in June when crops on the average are the most vulnerable to fallout radiation, the crop yield could be reduced by about one-third to one-half, and the effects on crops of possible increased ultraviolet radiation resulting from ozone layer depletion by nuclear detonations may further increase the loss. About 80% of the U.S. crude refining capacity and nearly all oil pipelines would be either destroyed or inoperative during the first several weeks after an attack. However, a few billion gallons of diesel fuel and gasoline would survive in tank storage throughout the country, more than enough for trains and trucks to accomplish the grain shipments required for survival. Results of a computer program to minimize the ton-miles of shipments of grain between Business Economic Areas (BEAs) indicate that less than 2% of the 1970 rail shipping capacity, or less than 6% of the 1970 truck shipping capacity would be adequate to carry out the necessary grain shipments. The continuity of a strong federal government throughout the attack and postattack period is essential to coordinate the wide-scale interstate survival activities.

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[*] A Glossary of Acronyms for this report is given on page xi.

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GLOSSARY OF ACRONYMS

BEA	-	Business Economic Area
CAP	-	Civil Air Patrol
CB	-	Citizens Band
CEP	-	Circular Error Probable
COTR	-	Contracting Officer's Technical Representative
CRAF	-	Civil Reserve Air Fleet
CRP	-	Crisis Relocation Planning
CSLWEMND	-	Committee to Study the Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations
DCPA	-	Defense Civil Preparedness Agency
EBS	-	Emergency Broadcast System
EMP	-	Electromagnetic Pulse (from nuclear detonations)
EOC	-	Emergency Operating Center
ERD	-	Equivalent Residual Dose
FAA	-	Federal Aviation Administration
FCC	-	Federal Communications Commission
FPA	-	Federal Preparedness Agency
GSA	-	General Services Administration
HOB	-	Height of Burst
ICBM	-	Intercontinental Ballistic Missile
LAS	-	Leo A. Schmidt
LET	-	Linear Energy Transfer
NAS	-	National Academy of Science
NASA	-	National Aeronautics and Space Administration
NCRP	-	National Council on Radiation Protection
OHVM	-	Other High Value Military
ORNL	-	Oak Ridge National Laboratory
PF	-	Protection Factor
RADEF	-	Radiological Defense
RAM	-	Ralph A. Mason
RBE	-	Relative Biological Effectiveness
RDO	-	Radiological Defense Officer
RDPOG	-	Radiological Defense Planning & Operations Guide

RES - Reference Equivalent Space Exposure
RFMSF - Radiological Factors in Manned Space Flight
SAC - Strategic Air Command
SLBM - Submarine Launched Ballistic Missile
SSBN - Ballistic Missile Submarine (nuclear)
UI - Urban-Industrial
USDA - United States Department of Agriculture
WASP - War Air Services Program
WSEG - Weapons Systems Evaluation Group

SURVIVAL OF THE RELOCATED POPULATION OF THE U.S. AFTER A NUCLEAR ATTACK

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ABSTRACT

The feasibility of continued survival after a hypothetical nuclear attack is evaluated for people relocated from high-risk areas during the crisis period before the attack. The attack consists of 6559 MT, of which 5951 MT are ground bursts, on military, industrial, and urban targets. Relocated people are assumed to be adequately protected from fallout radiation by shelters of various kinds. The major problems in the postattack situation will be the control of exposure to fallout radiation, and prevention of severe food shortages to several tens of millions of people. A reserve of several million additional dosimeters is recommended to provide control of radiation exposure. Written instructions should be provided with each on their use and the evaluation of the hazard. Adequate food reserve exists in the U.S. in the form of grain stocks, but a vigorous shipping program would have to be initiated within two or three weeks after the attack to avoid large scale starvation in some areas. If the attack occurred in June when crops on the average are the most vulnerable to fallout radiation, the crop yield could be reduced by about one-third to one-half, and the effects on crops of possible increased ultraviolet radiation resulting from ozone layer depletion by nuclear detonations may further increase the loss. About 80% of the U.S. crude refining capacity and nearly all oil pipelines would be either destroyed or inoperative during the first several weeks after an attack. However, a few billion gallons of diesel fuel and gasoline would survive in tank storage throughout the country, more than enough for trains and trucks to accomplish the grain shipments required for survival. Results of a computer program to minimize the ton-miles of shipments of grain between Business Economic Areas (BEAs) indicate that less than 2% of the 1970 rail shipping capacity, or less than 6% of the 1970 truck shipping capacity would be adequate to carry out the necessary grain shipments. The continuity of a strong federal government throughout the attack and postattack period is essential to coordinate the wide-scale interstate survival activities.

1. INTRODUCTION

This report describes research performed at ORNL[*] for DCPA Work Unit 3539A titled Postattack Survival Planning. The objective and scope of work for the study are quoted from the Task Order as follows:

> "SCOPE: Given the assumptions that:
>
> (1) At a time in the not too distant future an international nuclear crisis has occurred;
>
> (2) That U.S. Crisis Relocation Plans in accordance with currently conceived elements have been implemented;
>
> (3) That radiological protection has been provided and used, again according to currently conceived ideas; and
>
> (4) That a nuclear attack on the U.S. of a magnitude within that considered consistent with current SALT weapons limitations has occurred.
>
> "Define the nature and scope of plans for caring for the survivors of the attack, concentrating on those personnel who have been relocated into the host areas.
>
> "The time of consideration for this research effort will be from about one day following initiation of the nuclear attack until the end of the so-called survival period--a few weeks to a few months later.
>
> "This survival plan shall consider two possibilities:
>
> (1) The attack occurs in the quite near future, therefore only today's resources (i.e., radiological instruments, current state of trained personnel, warning capabilities, and the like) exist; and
>
> (2) The attack occurs after a few years of modest civil preparedness effort, and therefore today's resources could have been augmented accordingly.
>
> "The cost/benefits of such augmentation shall be examined.
>
> "The constituents of these postattack survival plans shall include, but not be limited to, the following:
>
> (1) Radiological exposure control;

---

[*] A Glossary of Acronyms for this report begins on page xi.

(2) Housing, feeding, medical, and public health services;

(3) Organization and constitution of an emergency labor force;

(4) Expedient (and perhaps temporary) social and political reorganization.

"In addition to an overall report, an explicit output of the study shall be a definition of areas where additional research is required (including suggested Scopes of Work)."

This report consists of ten chapters, briefly outlined as follows: Chapter 2 summarizes important results, conclusions and recommendations. Chapter 3 describes the attack scenario as specified by DCPA, including the details of the nuclear attack and the location of people under relocation planning. Chapter 4 discusses an idealized fallout pattern from the attack, briefly reviews the current U.S. RADEF program, and surveys radiological monitoring and control, including that of the Soviet Union. Chapter 5 presents a brief survey of current communications capabilities in the U.S. followed by a rough estimate of what might survive a nuclear attack, the effect of EMP, and what communications will be essential for postattack survival. In Chapter 6 the status of food and water in the U.S. is reviewed as it might exist before and after the attack, with emphasis on the location and quantities of surviving grain stocks in relation to the distribution of the surviving relocated people. Transportation capabilities before and after the attack are discussed in Chapter 7 with emphasis on the capability of the trucking industry to transport grain in order to avert starvation. Petroleum reserves, refining and shipping capabilities, before and after an attack, are discussed in Chapter 8 primarily in regard to needs for survival, principally food transport and fuel for heating. Estimates of the additional medical load brought about by relocation of people followed by an attack are given in Chapter 9 in addition to a review of status of drug supplies. Requirements for governmental functions and social structure are discussed in Chapter 10 especially in relation to survival capability. The last chapter is followed by an annotated bibliography of about 150 reports relating to postattack survival and three appendices which contain material too detailed and/or technical to include in the main body of the report.

2. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

2.1 Summary

A hypothetical nuclear attack of 6559 MT, of which 5951 MT are ground bursts, is assumed to strike industrial and population targets in the U.S. in the not-too-distant future. If the people in high-risk areas are relocated during the crisis period preceding the attack to rural shelters where they are remote from the direct effects of nuclear weapons and protected against fallout, can they survive through the first few weeks after the attack, until recovery operations are well under way?

The two major threats to individual survival in the early post-attack situation under these circumstances are: (1) excessive exposure to fallout radiation through improper monitoring and control of dose; and, (2) shortages of food.

In regard to the first threat, this report reviews established exposure control guidelines for fallout radiation, including the "penalty" table recently published by the National Council on Radiation Protection, and assesses the capability for following them.

In regard to the second threat, the location of people as planned with the current program and the location of grain stocks indicates a possibility that millions may perish from food shortages unless food shipments are begun within two or three weeks after the attack. Sufficient grain to feed the entire population of the U.S. for several months to more than a year, depending on the season, exists in storage in the local areas where it is produced. When the quantity of grain in storage is less than a year's supply, there is adequate grain growing in the fields, much of which can be harvested with little radiation hazard to agricultural workers if appropriate precautions are taken. If the attack occurs in June, when crops are on the average most vulnerable to fallout radiation, about one-third to one-half of the annual crop yield could be destroyed. Additional crop failure could occur due to increased ultraviolet radiation resulting from depletion of the ozone layer.

The shipment of grain to deficit areas will require not more than 2% of the 1970 rail shipping capability nor more than 6% of the trucking capability, and sufficient reserve petroleum will survive to accomplish this shipment.

The survival of communications, transportation, petroleum, electrical power, and the requirements for medical aid are surveyed and assessed only as far as they are necessary to assure survival of the relocated population through the first few weeks after the nuclear attack. The results at this assessment are summarized in Table 2.1.

Citizens' Band radios will probably survive in numbers adequate for critical civilian communications. In 1973, there were approximately 4 million CB transmitters in the U.S., and this number may double by 1977. Shipment of food and other crucial supplies will use primarily trucks and trains, of which at least 60% may be expected to survive because of relocation measures taken during the crisis period. Ships and barges may not be very useful in the first few weeks after the attack because of fallen bridges and destroyed locks and docks, although the vessels themselves may survive because of crisis period action. Oil pipeline terminals will be damaged or destroyed in crucial locations, and most of the refineries will be destroyed. However, about two billion gallons of diesel and about three billion gallons of gasoline would survive in tank storage outside of the major risk areas, which would be more than adequate for the trains and trucks to carry out survival missions during the first few weeks after the attack.

At least 20 million gallons of aircraft fuel will survive in tanks at lesser airports, which may be available to light aircraft of the Civil Air Patrol. First priorities should be given for reconnaissance of transportation routes, surveying blockages by debris and fallen bridges, and monitoring radiological hazard with aerial survey meters.

Very few large interconnected power plants are expected to be operating in the first few weeks after an attack because of disruption of the transmission grid by blast and fire. It is anticipated that electrical power will not be essential for basic survival in the first few weeks after the attack and will gradually be restored during the recovery period.

Table 2.1

Summary of Assessment of Postattack Survival of Sectors for Support for the Relocated Population

Sector	Item	Estimated Survival
Communications	Telephones	Classified information
	AM Radio Broadcast	At least two operating stations receivable at any location in U.S., and at least 100 million portable AM receivers
	FM Radio Broadcast	Not estimated
	CB Radios	4-6 million mobile units (1977)
	Public Safety Transmitters	0.5 to 1.5 million mobile units, 80-100 thousand fixed units
	Industrial Services Transmitters	0.5 to 1.5 million mobile units, 90-110 thousand fixed units
	Land Transportation Transmitters	0.8 to 1.2 million mobile units
	Amateur and Disaster Radio Services	80 to 120 thousand fixed units
Transportation	Automobiles	At least 60 million (over 60%)
	Buses (includes school buses)	200-240 thousand (50-60%)
	Trucks	11-16 million (50-75%)
	Train Locomotives	15-22 thousand (50-75%)
	Freight Train Cars	0.9 to 1.3 million (50-75%)
	Aircraft (single engine)	59-88 thousand (50-75%) (at least 1000 airports with runways of 4000 feet or less will survive)

Table 2.1 (cont'd)

Sector	Item	Estimated Survival
Transportation (con'd)	Aircraft (twin engine or larger)	11-17 thousand (50-75%)
	Barges	11-17 thousand (50-75%) (usefulness limited because of destroyed locks and port facilities)
	Towboats	2-3 thousand (50-75%)
	Ships	3-4 hundred (50-75%)
	Pipelines	Most of the pipelines will survive but will not be able to function because of destroyed terminals and controls
Petroleum	Gasoline, automotive	3.0-4.4 billion gallons (40-60%)
	Distillate fuel oil and diesel	2.3-3.4 billion gallons (40-60%)
	Aviation gasoline	15-25 million gallons
	Refineries	80-100 refineries, having 20% pre-attack crude refining capacity
Electrical Power	Power generation stations	1.4-2.1 thousand (40-60%)
	Transmission networks	13-14 thousand miles (90-95%) Most of the power transmission net will survive but will not function for some time because of general damage by EMP and local blast and fire damage to substations.

2.2 Conclusions

Under the assumptions specified for this research program in the Scope of Work statement, we are to assume that people in high-risk areas are relocated "in accordance with currently conceived elements," one of which was the ADAGIO computer program which assigns 89.6 million people to host areas. According to this assignment, about 90% of the U.S. population would be located remote from the blast and fire effects of the nuclear weapons of the 6559 MT attack, and would therefore survive through the attack period.

Also, according to assumptions specified in the Scope of Work statement, we are to assume that "radiological protection has been provided and used during and after the attack," again according to currently conceived ideas. The fallout radiation from the specific 6559 MT CRP-2B attack is more severe than most attacks which have been considered in the past, and it may be necessary to increase the protection factor requirements of shelters to cope with the increased threat.

If we assume that the currently conceived ideas provide adequate fallout protection, then we conclude that most of those people in host areas who survive the attack will also survive through the early post-attack period, provided that: (1) guidelines for control of exposure to radiation are generally known, equipment is available to enable shelterees to adhere to these guidelines, and control measures are established to ensure that shelterees adhere to these guidelines in actuality; and (2) a vigorous shipping program of grain stocks is inaugurated in the first two or three weeks after the attack to prevent food shortages in those areas which do not have an adequate food reserve. Survival of adequate grain stocks and the emergence of a more-than-adequate transportation capability shortly after the attack is virtually certain.

Proper equipment in shelters includes adequate food and water for the anticipated period of confinement, adequate ventilation, two or more radiation survey meters and/or dosimeters for shelters of 50 or more occupants, two-way communications either by portable radio transmitter-receiver or telephone, and at least one portable AM radio receiver per shelter. At the present time there are not enough dosimeters or survey meters to provide two for every large shelter. However, there are more than enough portable AM radio receivers, and broadcasts from AM stations should provide adequate general information concerning fallout in their vicinity to prevent casualties due to people leaving shelters too soon after the attack.

Additional modest Civil Defense efforts carried on through several more years could result in a significant increase in the number of survivors over the number resulting from the current situation by developing the full potential of currently conceived Crisis Relocation Plans.

2.3 Recommendations

2.3.1 - The increased threat from fallout radiation posed by current force levels indicates that protection factors of shelters may have to be increased to reduce fatalities, and also to permit the control of dose accumulation so that it occurs primarily outside the shelters in the postattack situation. If the radiation protection of "currently conceived ideas" is adequate, as we are to assume for this study, then the additional requirement indicated by the increased threat is an increase of the number of dosimeters in reserve storage. During the shelter confinement period it may be necessary for one or more volunteers to perform an urgent mission or errand into the external environment, and at later times of the confinement, an increasing number of people may be required to leave the shelters for various tasks. If the shelter occupancy averages 100 people, there should be at least three dosimeters per shelter. Two dosimeters should be reserved for external use to provide a fairly good indication of accumulated dose among those who leave the shelters to work during the later periods of shelter confinement, that is, during the period of gradual emergence from shelters. An additional dosimeter should remain within the shelter to determine the accumulated exposure of the shelterees. If 180 million people are sheltered in the host areas, then, at 100 people per shelter on the average, and three dosimeters per shelter, 5.4 million dosimeters would be required for shelters. Actually a number of people may be located in small shelters, averaging perhaps 5 to 10 people per shelter. These shelters should have at least one dosimeter--an urgent requirement for the first emerging person and possible subsequent emergents, depending on the local situation. If dosimeters are not available in the shelters, some people may refuse to emerge, even though they are told by the local AM radio broadcasts that the radiation fields have decayed to safe levels.

Dosimeters should also be provided for workers in critical industry, who may be asked to volunteer to return to work in areas contaminated with fallout. Each person who must enter alone into a contaminated area should have a dosimeter, and every small group of two to five people who work together in a contaminated area should have at least two dosimeters. If a group working in a contaminated area has only one dosimeter and that dosimeter becomes damaged during the working time, then there is no record of the dose received, and it must then be assumed that the group was exposed to the maximum existing radiation in that area as determined by radiation survey meters. This procedure, which is similar to current practice with radiation survey crews, will usually result in the grounding of the work crew for a period, the length depending on their exposure history and the intensity of radiation in the hottest spots in the area in which they were working. If we assume that 20% of the workers in nonagricultural industry, of which there were 72 million in 1972, are involved in a critical industry, and that a dosimeter is required on the average for every other person, then 7.2 million dosimeters would be required for these workers. Perhaps as many as half of the dosimeters provided for shelters could be used for the critical labor force. These would reduce the number of dosimeters required for the critical labor force to 4.5 million, if 5.4 million are provided for shelters (although more dosimeters may be required for shelters when those with low occupancy are counted).

An additional number of dosimeters may be necessary for farmers, in the eventuality that their fields are contaminated with radioactive fallout during planting or harvest time. Because of the nature of farm labor, a dosimeter should be provided for each farm laborer. In 1970, there were 2.3 million people employed in agriculture, including self-employed, wage and salary, and unpaid family workers, indicating that about 2.3 million dosimeters should be made available for agricultural workers.

The total number of dosimeters required according to this very rough estimate is 12.2 million, compared with 2.7 million dosimeters on hand at the present time. A more detailed survey should be made to determine with greater certainty the number of additional dosimeters which may be required to cope with the greater threat of the current nuclear force levels. From our rough estimates, it seems certain that a large number of additional dosimeters would be required. If these additional dosimeters cannot be supplied, then information on the construction of improvised fallout meters should be widely disseminated.

2.3.2 - The Radiological Defense Planning and Operations Guide should be rewritten to adopt the guidelines of the "penalty" table, and the ERD concept should be dropped. The mathematical formulation of the ERD requires calculations in order to determine the ERD and these calculations are beyond the capabilities of the average layman, whereas the "penalty" table is very simple to understand and provides equally effective, if not better, guidelines.

2.3.3 - Alternate relocation plans should be considered which would minimize not only exposure to fallout, but also reduce the requirements for grain shipments after the attack. For example, heavy relocation from the cities of New York and Boston into the New England states results in a difficult food supply situation, whereas, if part of this population drove a greater distance during relocation into Ohio or Virginia, for example, the quantity of grain shipped could be greatly reduced.

2.3.4 - Further research on food crops is required to determine the effects of fallout radiation <u>combined</u> with additional ultraviolet radiation which may result from depletion of the ozone layer. It must be emphasized that the gamma and beta radiation to which the plants are exposed must simulate the decaying intensity of the fallout radiation at early times after the detonation. A gamma radiation field of unvarying intensity has been used in the past, and the extrapolation of these results to the case of a field of decaying intensity is doubtful because of the self-repair mechanisms which occur in plants.

2.3.5 - Additional maps of the U.S. should be prepared similar to Fig. 4.1, which would show contours of fallout radiation in terms of the unit-time reference dose rates, but for different wind conditions. These maps would have general usefulness for planning and for damage estimation. The computer program which generated Fig. 4.1 was designed to permit easy modification of entry parameters, and additional maps can be generated for different input conditions at relatively low costs.

2.3.6 - According to Bull and Sobin (1970) the animal feed industry has considerable potential for rapid conversion to the processing of grain for human consumption in a national emergency. A survey of feed mill location and capacity was made by USDA in 1971. This data base should be analyzed to determine the role these mills may have in connection with CRP, the CRP-2B attack, and postattack survival.

2.3.7 - A detailed estimate should be made on a county-by-county basis of the quantity and condition of non-grain food resources surviving the attack, including an assessment of the capability of postattack food-processing plants to supply the surviving population.

2.3.8 - A survey should be made of caves and mines which are suitable for human occupancy with special attention to the prevalence of histoplasmosis in the caves and mines.

3. THE ATTACK SCENARIO

3.1 Introduction

The general scenario to set the stage for research on this project was outlined for us in the first four statements of the Scope of Work specified by DCPA, as quoted in Chapter 1. Briefly, it consists of (1) an international crisis; (2) relocation of people in the U.S.; (3) protection against fallout; and (4) a nuclear attack. In this chapter, further details will be presented and examined on the location and distribution of the relocated people, and on the magnitude of the nuclear attack. Before getting into those details, it may be useful for the general reader to review the evolution of policy which prescribes this scenario.

From studies throughout the 1960's on how to protect people from the blast and fire effects of nuclear weapons, DCPA (then OCD) reached the following basic conclusions in the early 1970's, as quoted from a fact sheet on crisis relocation planning released by Information Services of DCPA on May 20, 1974:

> "(1) If an attack should occur, the primary enemy targets probably would be U.S. missile sites. military installations, and centers of industry and population (i.e., metropolitan areas).
>
> "(2) An attack very likely would be preceded by a period of international tension or crisis. This could constitute 'strategic warning,' and provide time for protective actions to be taken.
>
> "(3) A great deal of protection against radioactive fallout (i.e., fallout shelter) already exists in the United States, and more is being identified (mostly in new buildings) as time goes on. Attention should not be given to protection against nuclear blast and fire.
>
> "(4) Blast and fire would endanger mainly people living or working near military targets and in large metropolitan areas. These two types of location may therefore be called 'high-risk' areas.
>
> "(5) It is not financially feasible to build special underground blast-and-fire shelters in these high-risk areas.

> "(6) It may be feasible, however, when an international crisis threatens to result in a nuclear attack, for residents of high-risk areas to be temporarily relocated in small-town and rural areas, where nuclear weapons probably would not be targeted, provided these people could be protected against radioactive fallout."

The conclusion underlined in the sixth statement above has led to a comprehensive investigation by DCPA into the practicality of evacuating high-risk areas when nuclear attack threatens. This program of crisis relocation has been adopted as a civil defense option by the Department of Defense, as described in the following words by former Secretary of Defense James R. Schlesinger in a budget report to Congress on February 5, 1975:

> "The Soviet Union for many years has given a great deal of attention to civil defense, including not only the construction of shelters and the training of civilians but also the preparation of plans for evacuation of the bulk of the population from its major cities in the event of a crisis. Thus, the Soviet leaders have the option to evacuate the cities or to shelter the population in place, depending upon their assessment of the situation at the time.
>
> "We believe that the United States should have a similar option for two reasons: (1) to be able to respond in kind if the Soviet Union attempts to intimidate us in a time of crisis by evacuating the population from its cities; and (2) to reduce fatalities if an attack on our cities appears imminent.
>
> "Similarly, this nation should have the option in the event of an intense crisis to evacuate the civilian population from high risk areas near such military installations as SAC bases, ICBM fields, SLBM support facilities, etc., to less hazardous areas while protecting the rest of the population against fallout. As noted last year, a Soviet counterforce attack which deliberately avoids our cities would still produce a large amount of nuclear fallout which could drift over areas that are downwind from strategic military installations. This civil defense option would complement the military response options that we are now introducing into our planning to strengthen deterrence against a Soviet counter-force attack.
>
> "Accordingly, we propose to continue our efforts, within the limits of the resources available, to improve

our ability to protect the population in place against fallout and to develop in an orderly way two major options for the relocation of the population in a crisis. The first option, which would be designed against the threat of a Soviet counterforce attack, would involve the relocation of the population from high-risk areas near key military installations and the protection of the rest of the population against fallout. This option could reduce nationwide fatalities due to fallout from a limited Soviet counterforce attack to relatively low levels -- well under one million -- provided that the people in the communities that would be most exposed to fallout from such an attack make effective use of the shelters available.

"The second option, which would be designed against an all-out Soviet nuclear attack, would involve the evacuation of the population from cities, as well as from areas near key military installations. Repeated studies have shown that the evacuation of the bulk of the population from our major metropolitan areas could save some 70 million lives in an all-out Soviet attack on the United States, over and above those saved by in-place protection options.

"Pilot-project work undertaken in areas near some of our important military installations during fiscal years 1974-75, has established the feasibility of developing plans to allocate risk area populations to surrounding host areas, including the development of standby public information (for publication during a crisis) on 'where to go and what to do' should relocation be implemented. Public officials at state and local levels in the pilot areas accepted the need for this type of contingency planning but pointed out that federally-supported planning assistance would be needed.

"Other studies indicate that it would be feasible to relocate population from cities over a period of several days, and to provide for their reception and care in host counties for a period of up to two weeks. Specially-tailored solutions, however, would have to be developed for the most densely-urbanized parts of the U.S., such as the Northeast. It would also be feasible to redirect the distribution of food and other essentials to support evacuees in host areas, provided adequate state-level planning is done with industries concerned. Pilot-project experience with a 'host area survey' indicates that local plans in host areas can provide for protecting evacuees from fallout radiation by use of best available existing protection, plus crisis action to improve fallout protection in existing buildings and to construct expedient shelters."

Given the assumptions concerning relocation as stated above, and that 90% of the U.S. population survives the attack, it is our task to assess their continuing survivability throughout the postattack period.

3.2 The Attack

If there were an all-out nuclear war between the U.S. and the Soviet Union, how would the Soviet Union distribute weapons on the United States? It is generally believed among defense planners in the U.S. that the principal targets, in order of priority, would be:

(1) U.S. military installations
(2) Military-supporting industrial, transportation and logistics facilities
(3) Other basic industries and facilities which contribute to the maintenance of the U.S. economy
(4) Population concentrations of 50,000 or greater.

These target priorities, combined with public projections of Soviet capabilities (circa 1980) under existing strategic arms limitations, can be used to generate possible Soviet weapon assignments which are useful for planning purposes. A specific hypothetical attack, prepared by DCPA and other defense planners, was given to us for our study. This attack, titled CRP-2B Attack, is summarized in Table 3.1, and consists of 1444 detonated weapons, for a total of 6559 megatons, of which 5051 megatons are ground bursts. The map of the U.S. in Fig. 3.1 shows circles within which the overpressure from blast exceeds 2 psi. Target points on ICBM fields do not designate actual locations of silos in order to retain an unclassified status for this attack, but they are sufficiently accurate to indicate possible fallout patterns for CRP. Other military targets were located partly with the aid of the February 1973 map titled "Major Army, Navy, and Air Force Installations in the United States," prepared by the Defense Mapping Agency.

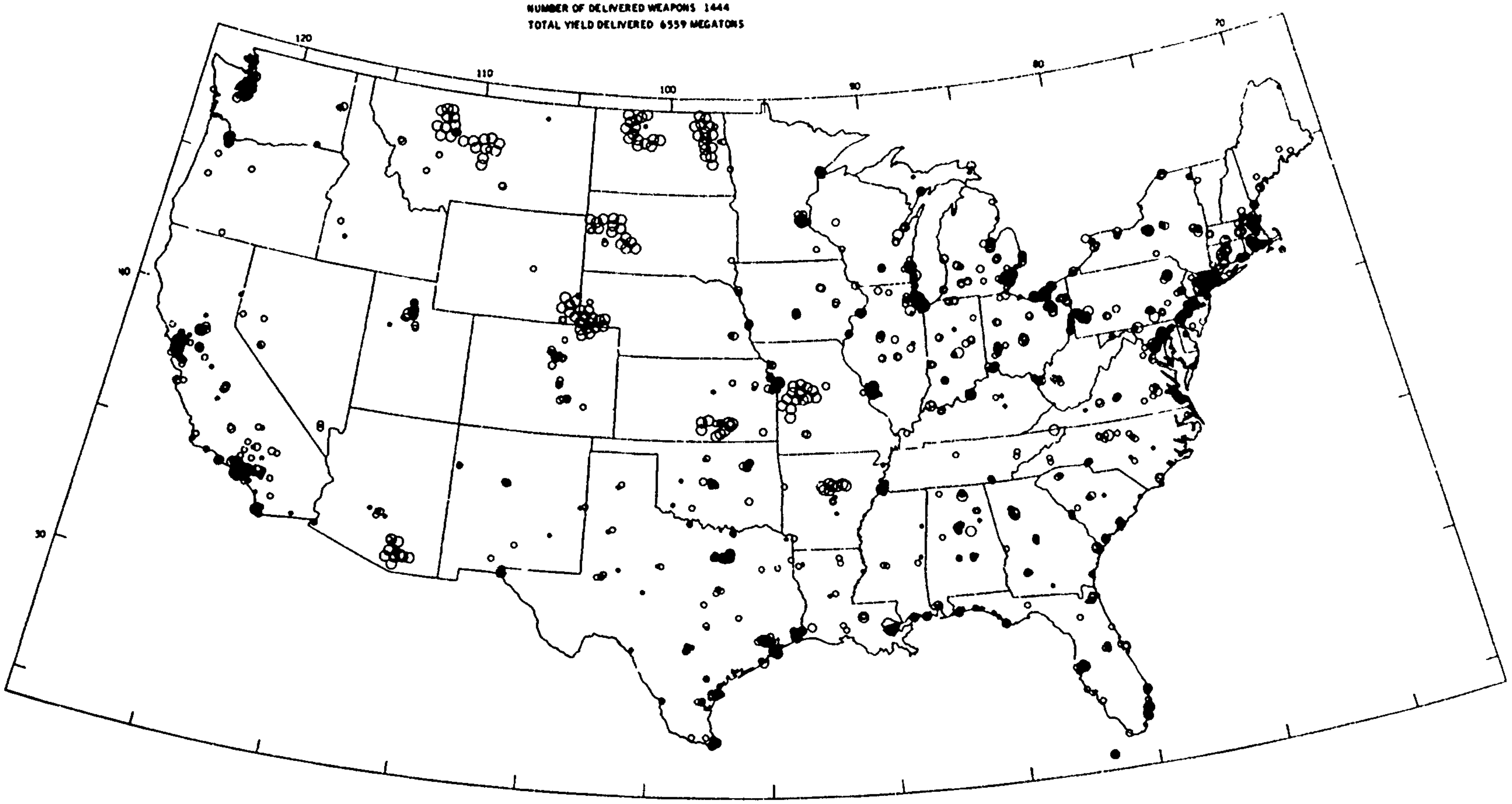
If people remained in place throughout the attack, about 125 million (1970 Census) would be located within the 2 psi circles, and about 58 million would be inside the 15 psi region, as shown in Fig. 3.2. The coverage on Northeastern U.S.A. for these two overpressures, chosen for

Table 3.1

Summary of CRP-2B Attack

Target Type	Numbers of Weapons				Type of Burst	Total Megatons
	Megatons					
	1	2	3	20		
ICBM Fields	0	0	0	127	Ground	2540
SAC AFB or SSBN Support	46	1	0	0	Ground	48
CRP/OHVM	183	0	0	1	Ground	203
CRP/UI	0	0	0	113	Ground	2260
CRP/UI	614	0	0	0	Air*	614
CRP/UI	0	183	1	0	Air*	369
CRP/UI	0	0	175	0	Air*	525
TOTALS	843	184	176	241		6559

*Height of burst chosen to maximize extent of 10 psi overpressure.



ORNL DWG 79 10959

HYPOTHETICAL NUCLEAR ATTACK FOR CRISIS RELOCATION PLANNING
CIRCLES SHOW AREAS COVERED WITH 2 psi OR GREATER OVER PRESSURE FROM BLAST
NUMBER OF DELIVERED WEAPONS 1444
TOTAL YIELD DELIVERED 6559 MEGATONS

Fig. 3.1 CRP-2B Attack Pattern on the U.S.

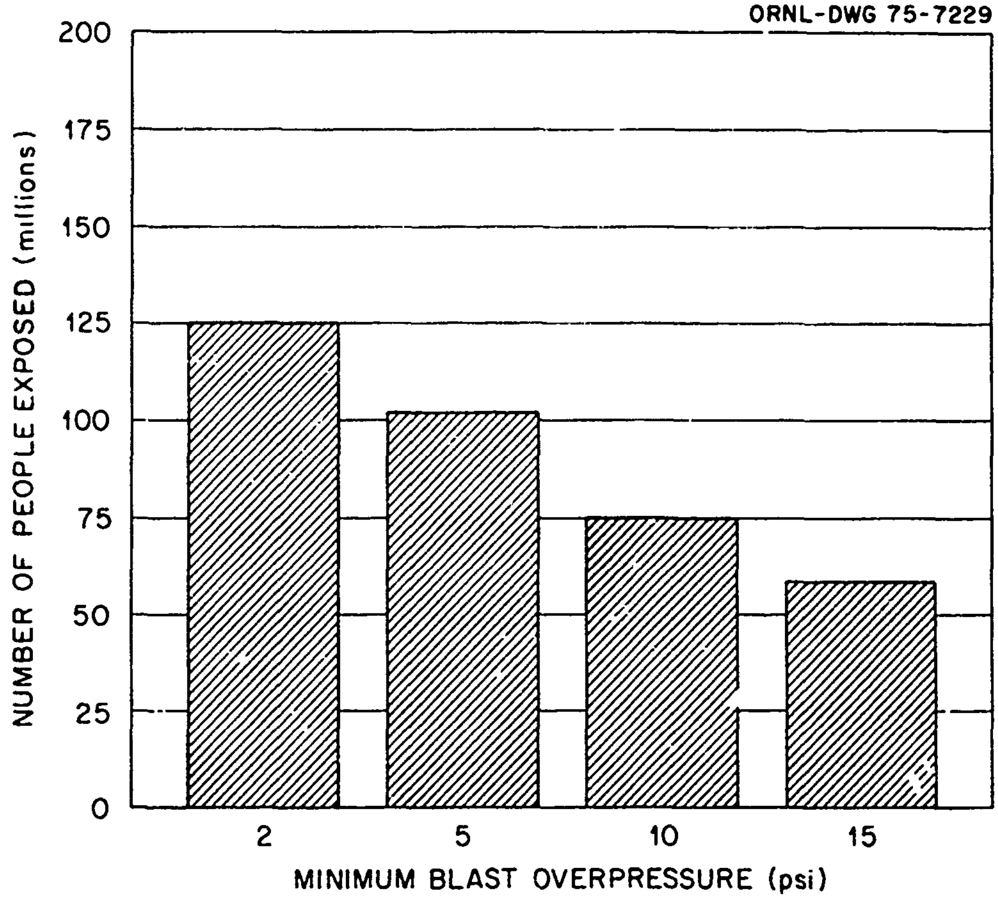


Fig. 3.2 Number of People in the 1970 U.S. Population (Without Relocation) Estimated to be Exposed to a Minimum Blast Overpressure from the CRP-2B Attack.

illustrative purposes only, are shown in Figs. 3.3 and 3.4. It is seen that bursts overlap on some targets. Due to unreliability of missile systems, the attacker cannot be certain that all of his weapons will reach their targets and explode. Hence, it is assumed that additional weapons would be assigned to some targets which the attacker especially wishes to destroy. The population numbers given above indicate that millions of people could survive the attack without relocation if they were provided with blast and fallout shelters of modest hardness. However, if relocation is an available option, then the act of remaining in shelters in high-risk areas would seem to many people to be playing Russian roulette, in view of the uncertainties as to the actual assignment of weapons by the Soviets and the inaccuracies in placing the weapons. It may be necessary for some people to take such risks if they are involved in critical industry, or are maintaining a manufacturing operation for which shutdown may be either disastrous or require many days.

The fallout resulting from this attack will be discussed in Chapter 4, Radiological Hazards and Defenses. Another aspect of this attack, concerning the survival of petroleum refineries (30% survive), will be discussed in Chapter 8 on petroleum. Other unclassified weapon assignment programs of similar yield have been developed by the Federal Preparedness Agency, GSA, and are designated as UNCLEX 73-Charlie and UNCLEX 73-Mike, according to whether the attack concentrates on civilian (Charlie) or military (Mike) targets.

3.3 Crisis Relocation

The hypothetical attack described above can be used to define high-risk areas from which relocation of population should be planned. In order to define these areas, the attack was modified in two ways, first, to maximize direct effects (blast) and second, to maximize fallout. For the first modification, all weapons were assumed to be airburst, systems reliability was 90% and the CEP of weapons was 0.5 nautical miles. Counties in which the geographical centroid was subject to a 50% or greater probability of receiving blast pressure of 2 psi or more were

ORNL-DWG 76-7134

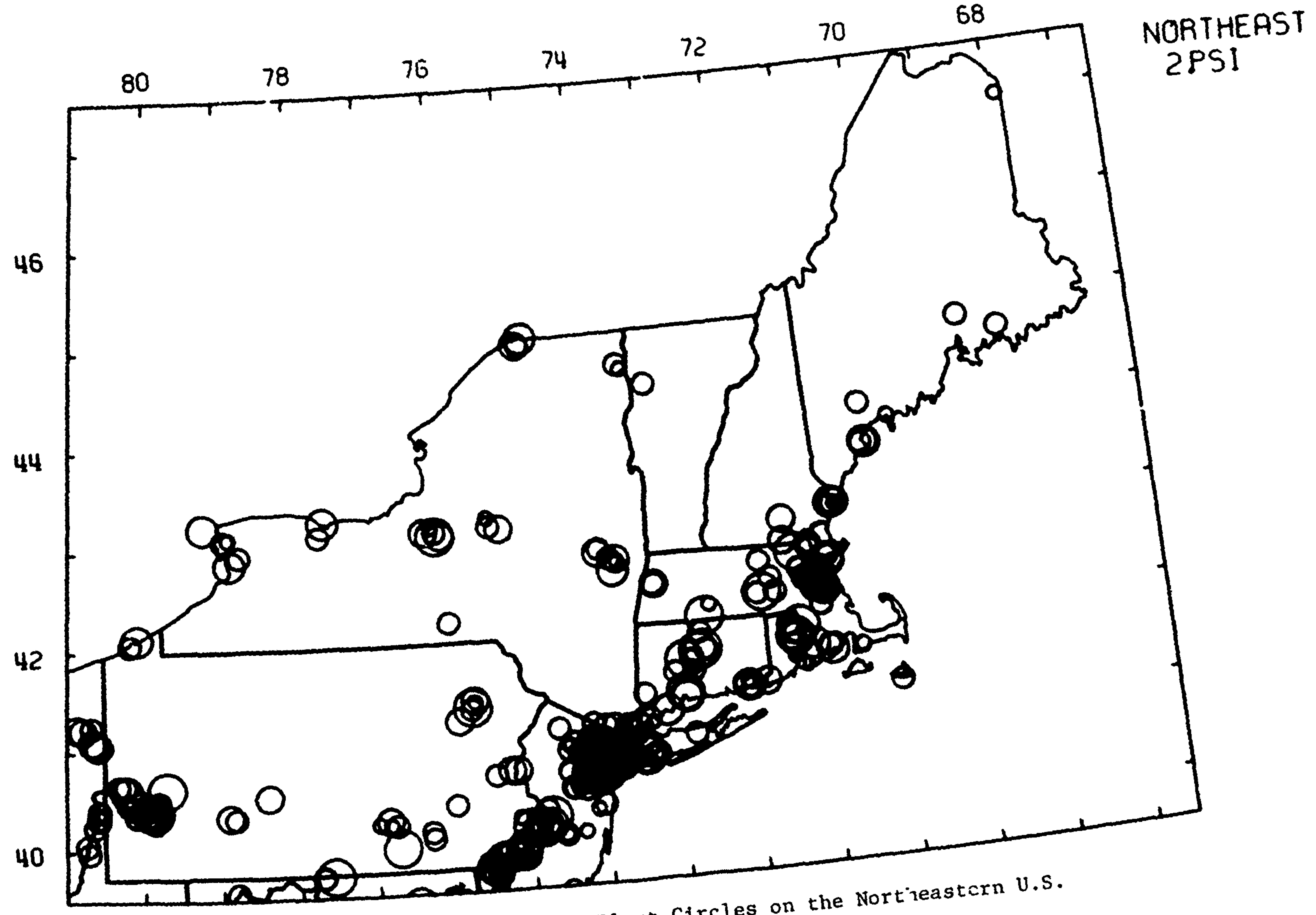


Fig. 3.3 Two-psi Blast Circles on the Northeastern U.S.

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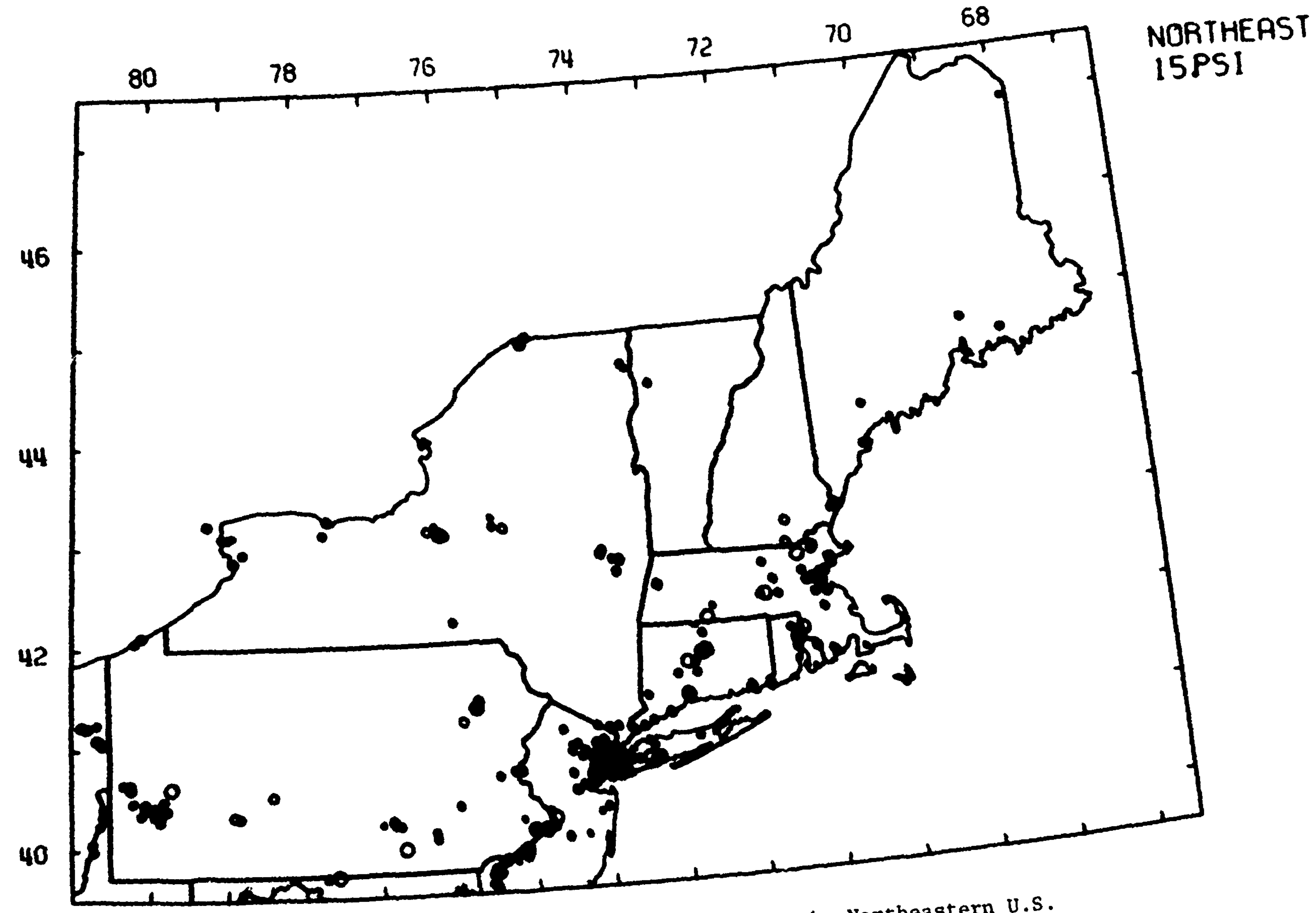

Fig. 3.4 Fifteen-psi Blast Circles on the Northeastern U.S.

considered to be high risk areas due to direct effects. For the second modification, all weapons were assumed to detonate at ground level, and all counties with a 50% or greater probability of 10,000-roentgen, 4-day cumulative dose or more at the centroid were assumed to be at high risk, under certain fallout arrival assumptions.

With these definitions of high risk areas combined with the ADAGIO-S computer program (Schmidt, 1974), the DCPA computer facility at Olney, Maryland, was used to develop a preliminary nationwide allocation of population. It was assumed that 80% of the population in all high-risk areas would be relocated, involving a total of 89.6 million people. Travel distance was limited to 200 miles on a straight line basis, except for California and the New England states. A hosting factor of 3 (ratio of evacuees to residential population) was used for all states except as indicated in Table 3.2. A hosting factor of 9 was used in California because the non-target areas have such a low population compared with the population in target areas, due to desert and mountain terrain. This hosting factor could be reduced by requiring that California sea coast residents drive even further inland.

A copy of the computer tape generated by this program was sent to us by DCPA, which made available, among other data, the total population per county after relocation. These data are displayed graphically in Figs. 3.5-3.11, in which the U.S. is broken into seven regions, and the number of people per county is indicated by the grid of lines drawn within the county boundary. A fairly complete evacuation is indicated for those counties for which all or nearly all of the area of the county is designated as a high-risk area, such as Nassau and Suffolk counties in New York (Fig. 3.5); De Kalb county in Georgia (Fig. 3.7); Hennepin and Ramsey counties in Minnesota, containing Minneapolis and St. Paul (Fig. 3.8); Chambers and Galveston counties in Texas (Fig. 3.9); and San Francisco and San Mateo counties in California (Fig. 3.11). In some areas these maps indicate the presence of people in high-risk areas, or in areas which are impossible to live in, such as desert areas. Usually these areas are large counties in which the people are actually located only in a part of the county, such as Cook county in Illinois, San Bernadino county in California, and Coconino county in Arizona.

Table 3.2

States with Relocation Hosting Factors Greater than Three

Arizona	5	Maine	6	Ohio	4
California	9	Maryland	4	Pennsylvania	6
Colorado	3.5	Massachusetts	6	Rhode Island	6
Connecticut	6	Michigan	4	Vermont	6
Delaware	4	New Hampshire	6	Virginia	4
Florida	5	New Jersey	6	Washington	4
Illinois	4	New York	6	West Virginia	4
Indiana	4				

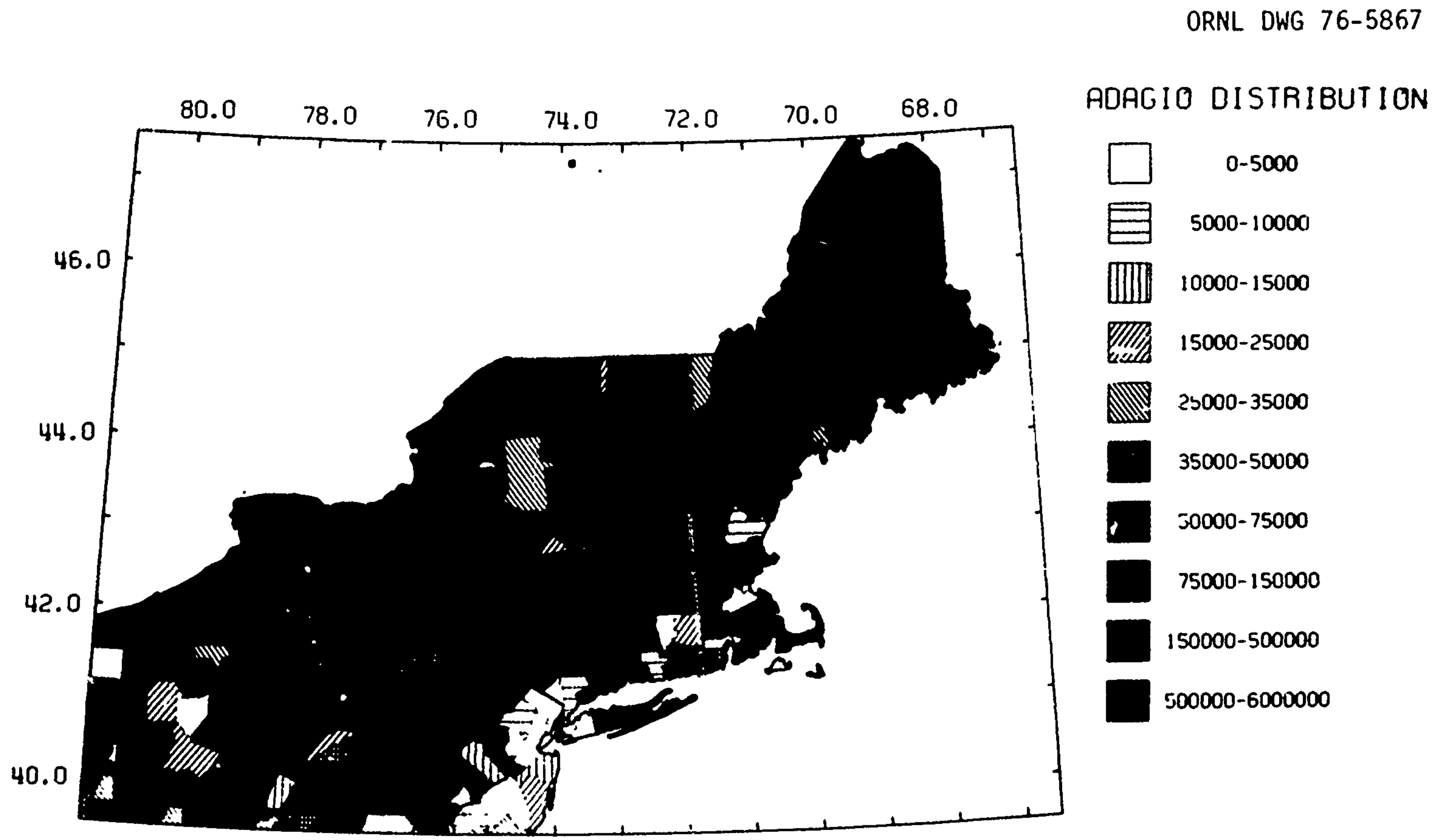

Fig. 3.5 Relocated Population, Northeast. The legend to the right indicates the number of people per county.

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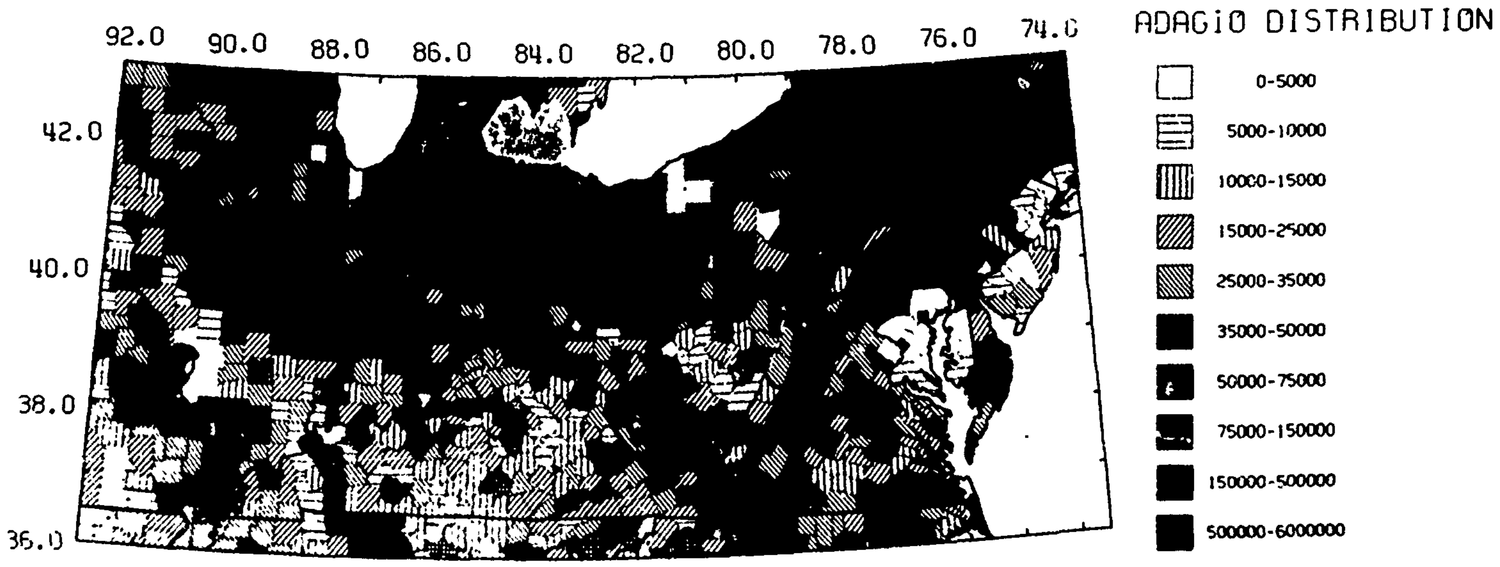

Fig. 3.6 Relocated Population, Central and East. The legend to the right indicates the number of people per county.

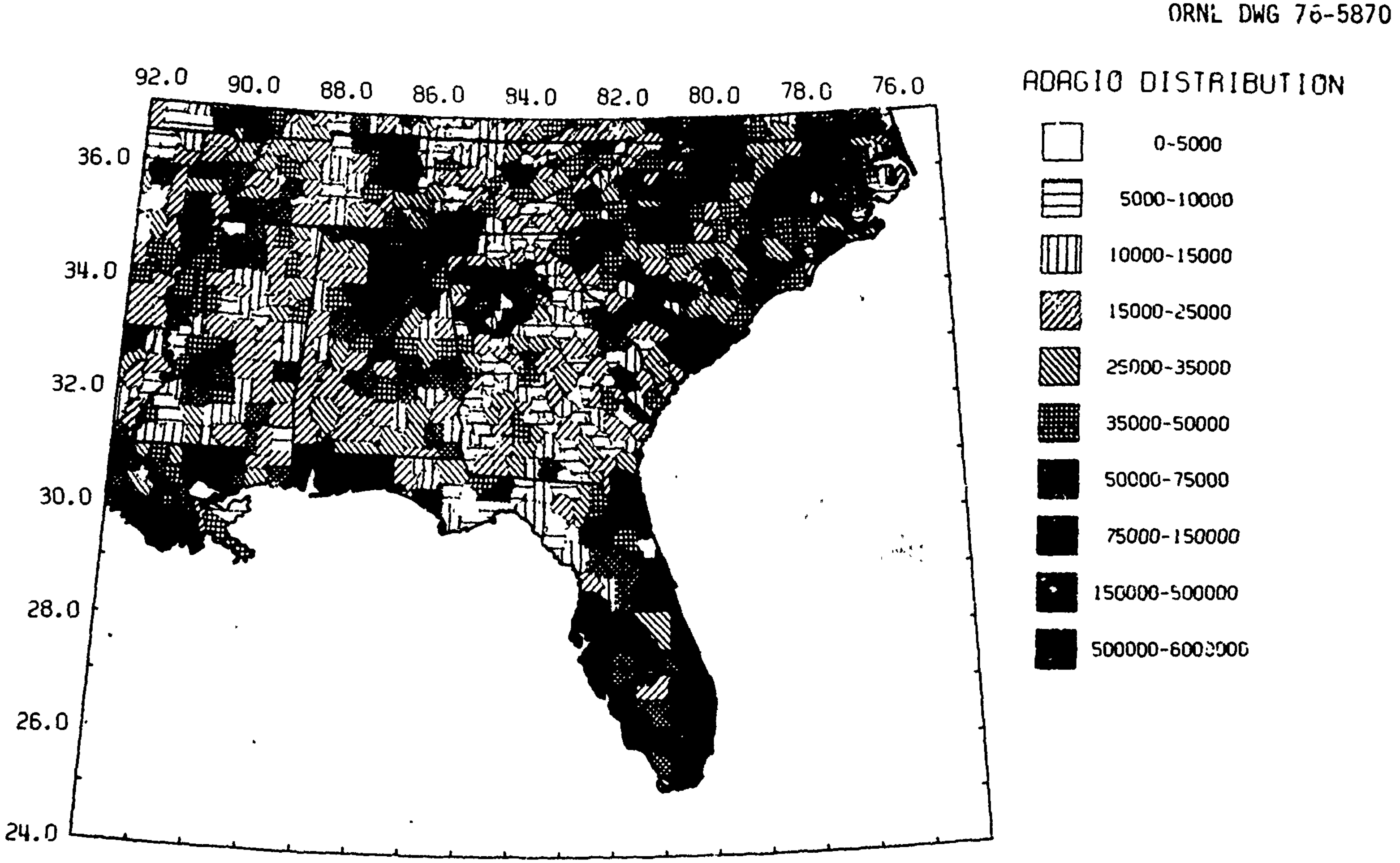

Fig. 3.7 Relocated Population, Southeast. The legend to the right indicates the number of people per county.

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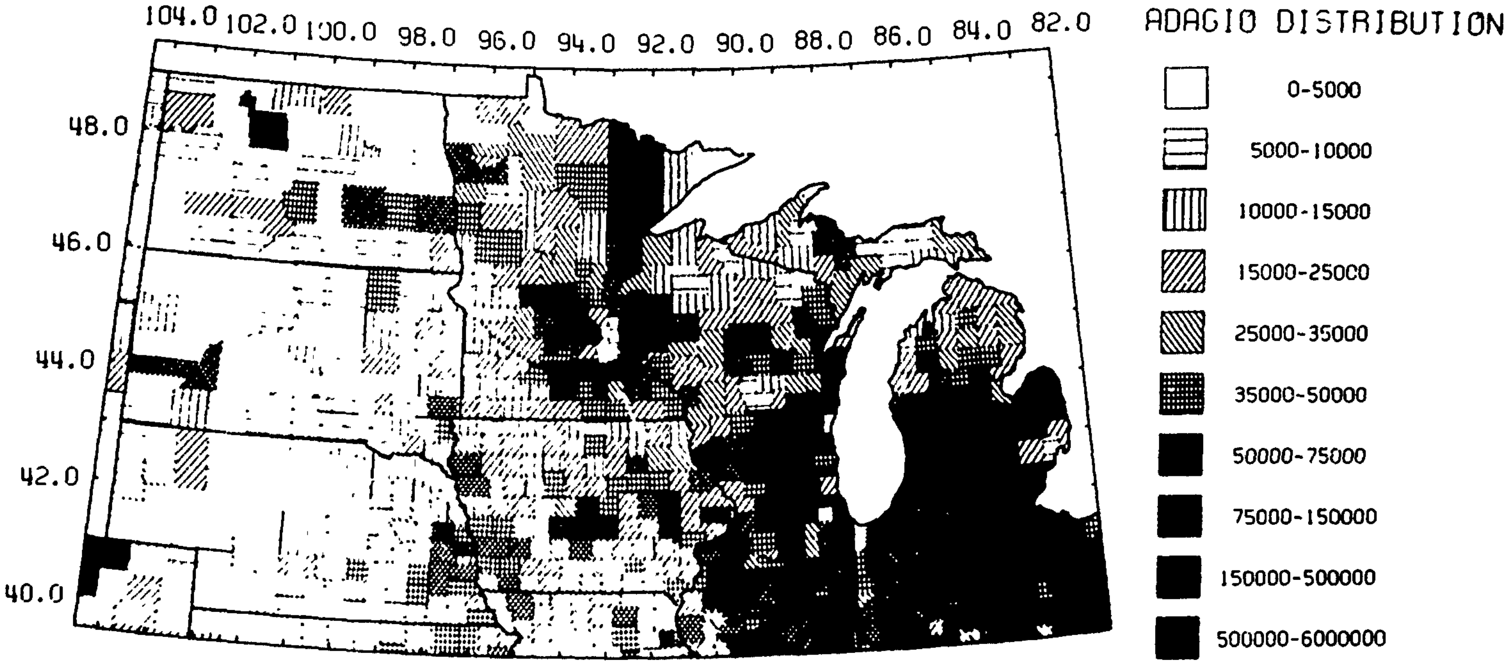

Fig. 3.8 Relocated Population, Midwest. The legend to the right indicates the number of people per county.

ORNL DWG 76-5872

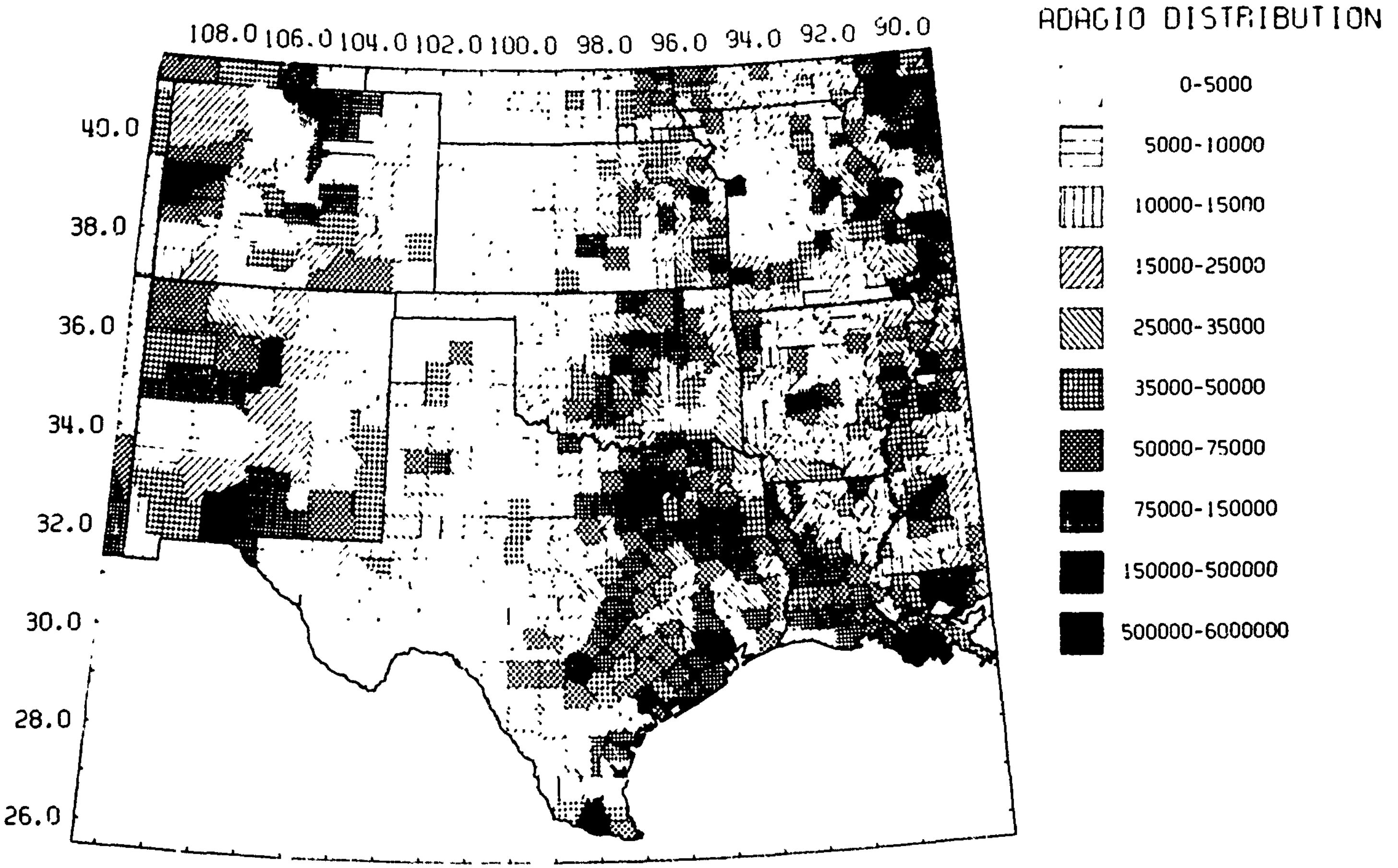

Fig. 3.9 Relocated Population, South Central. The legend to the right indicates the number of people per county.

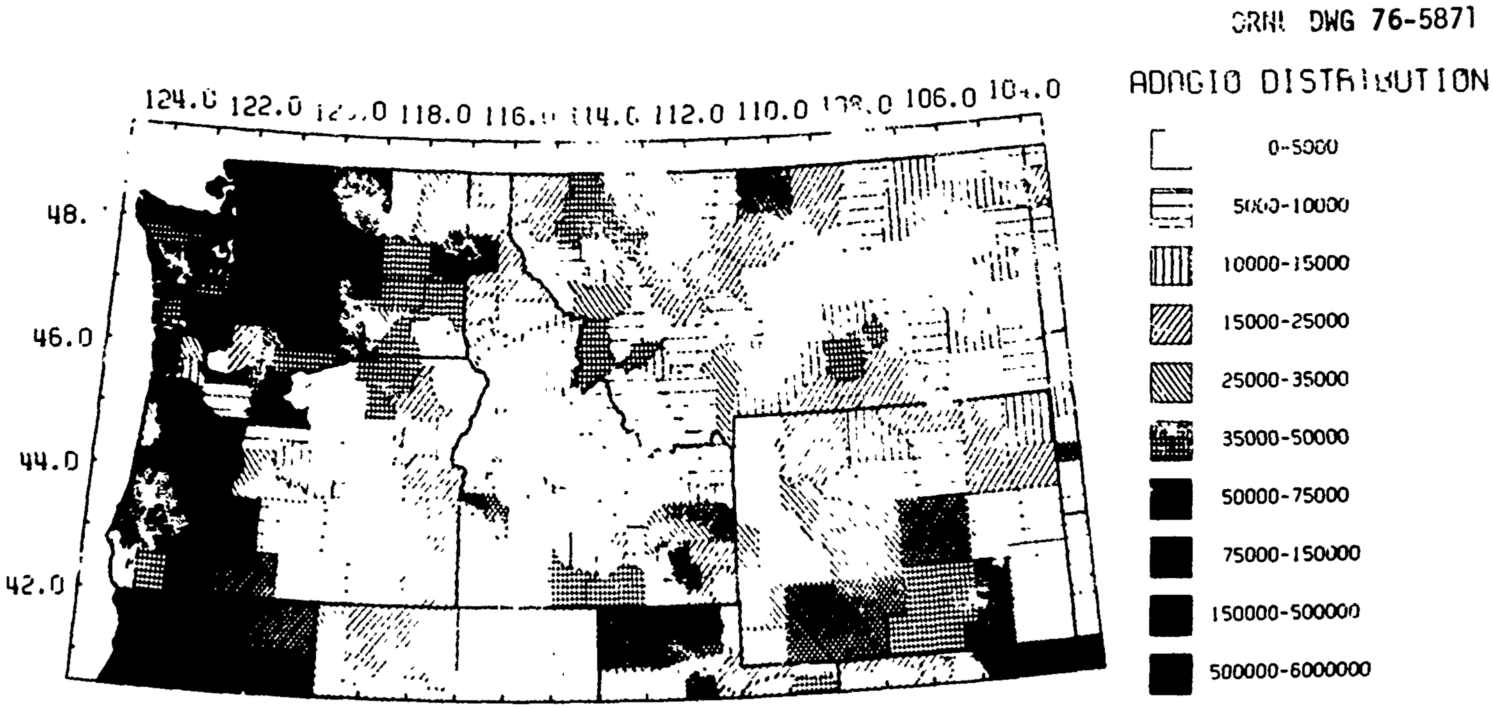

Fig. 3.10 Relocated Population, Northwest. The legend to the right indicates the number of people per county.

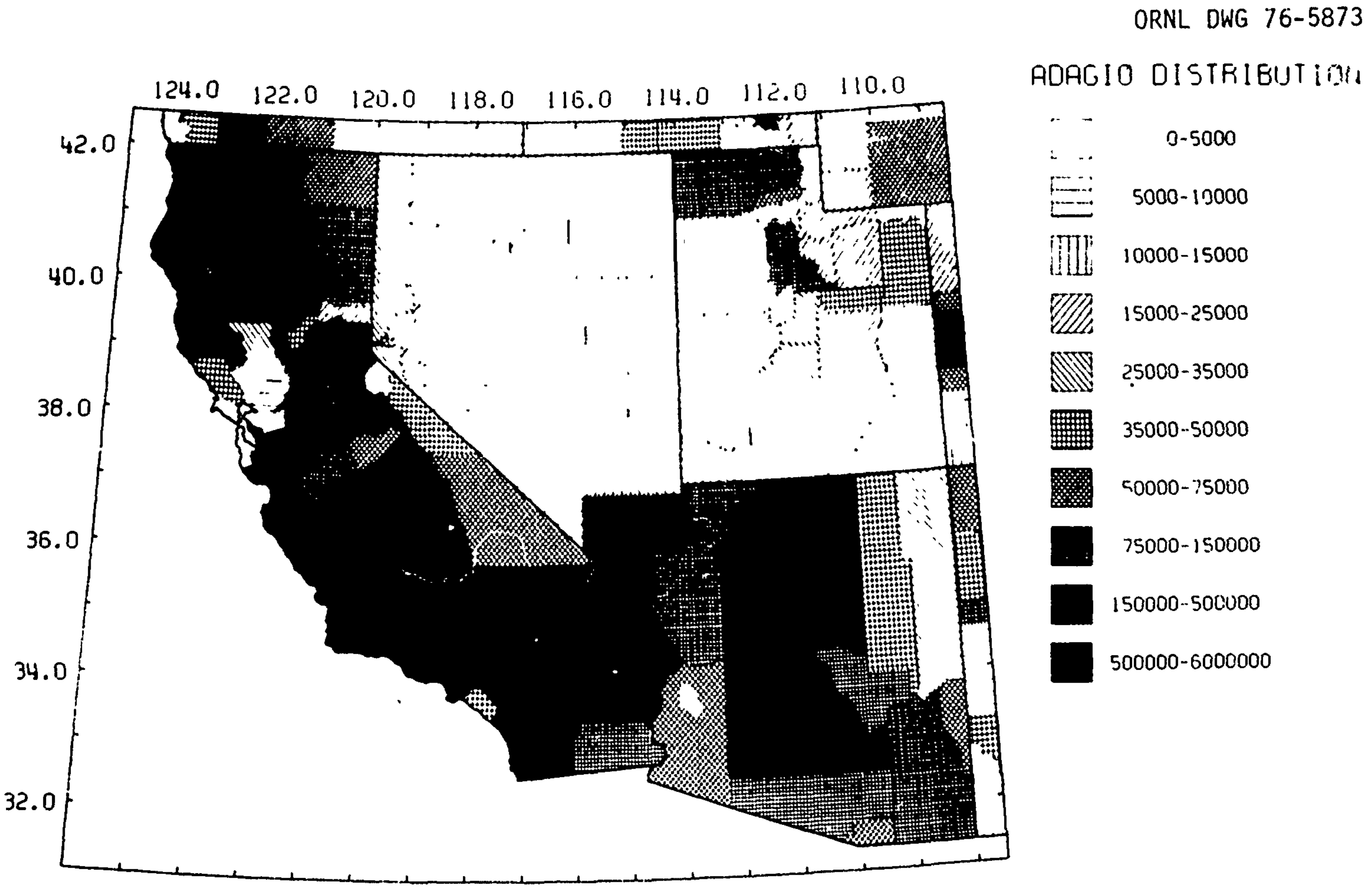

Fig. 3.11 Relocated Population, Southwest. The legend to the right indicates the number of people per county.

The movement and care of relocated populations are under continuing study. For the purposes of this investigation, the preliminary distribution reported herein will be used to study the effects of radiation from fallout and to assess the availability of food. As we shall see from a study of food distribution based on grain stocks, a different relocation plan could be considered which would reduce the requirements for grain shipments in the postattack situation.

4. RADIOLOGICAL HAZARDS AND DEFENSES

4.1 Introduction

Of all the disastrous effects of nuclear weapons, the hazards of radioactive fallout from ground-burst detonations cover the largest area. The Soviet arsenal of nuclear weapons has the capability of covering over half the area of the United States with radioactive fallout which would be lethal to unprotected humans. In this study, we assume that fallout protection has been provided, hence our concern with fallout will be with the manner in which it impedes survival activities after the attack. We will construct a hypothetical pattern of fallout from the attack described in Chapter 3 and use it to indicate the general magnitude of the problem. Radiological mapping capabilities as they currently exist in the United States will then be described, followed by a discussion of radiological control guidelines, including those of the Soviet Union.

4.2 Fallout from the CRP-2B Attack

A number of computer programs have been developed for the purpose of predicting fallout from ground-burst nuclear weapons (Polan, 1966). Our patterns for fallout from the CRP-2B attack, for which the unit-time reference dose rates are shown in Fig. 4.1, are based on the WSEG-10 NAS/RAM/LAS model, as transmitted to us by Leo A. Schmidt (1974). For simplicity we have assumed that all weapons are detonated simultaneously, and that the wind is uniformly from the west with an effective velocity of 25 mph. The wind shear is assumed to be 0.2 mph per kilofoot of vertical cloud thickness, the terrain factor and fission-fusion ratio are both unity, and the normalization factor, also called the K factor (Advisory Committee on Civil Defense, 1973), is 1930 roentgens per hour per kiloton per square mile. Although these conditions and assumptions are somewhat idealized, the results should be adequate for gaining an insight into the magnitude of the problem, and to provide a basis for generating plans to cope with the problem. In an actual situation, the

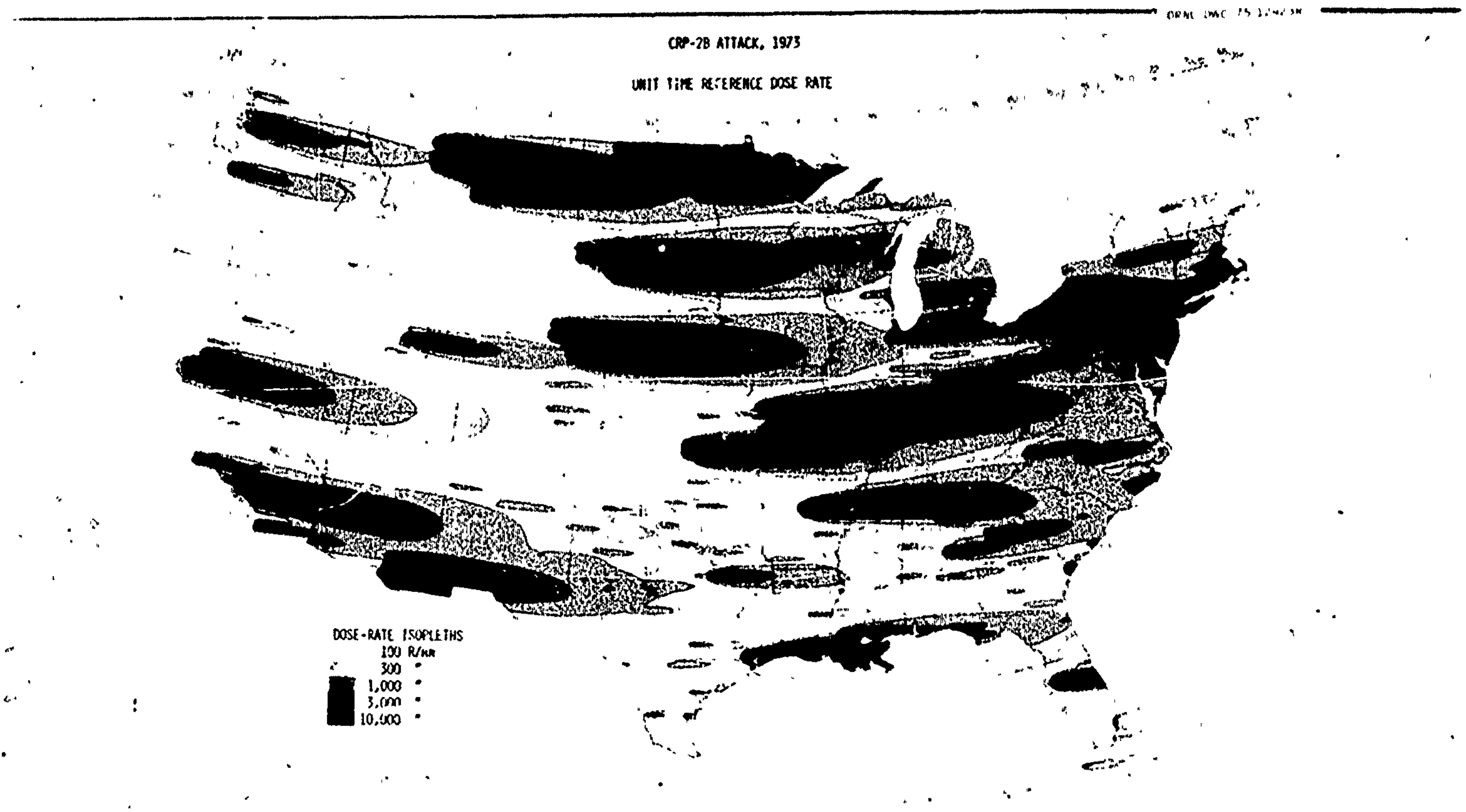

Fig. 4.1 Fallout from CRP-2B Attack.

winds and weather will be highly variable, resulting in extremely complex patterns of fallout such that the determination of the extent of fallout radiation must be determined by actual measurements by radiation survey instruments. The capability for such measurement will be discussed after discussion of this hypothetical model.

The darkest areas in Fig. 4.1 indicate areas in which the unit-time reference dose rate is 10,000 R/hr or greater, and the total area at this level is about 60,000 sq mi, as summarized in Table 4.1. The cumulative area covered by fallout as a function of unit-time reference dose rate is shown graphically in Fig. 4.2. If we assume that the radiation intensity decays uniformly throughout the country, and that the fallout remains fixed in place after being deposited on the ground, then the dose rate isopleths in Fig. 4.1 represent the relative levels of radiation intensity at various times after the attack. According to the standard radiation decay model for fallout from nuclear weapons, the intensity of radiation decreases with time according to $R = R_o t^{-1.2}$, where R is the intensity of radiation in roentgens/hour at time t in hours after the attack, and R_o is the unit-time reference dose rate. Factors by which the radiation intensity is reduced according to this law are listed in Table 4.2. These factors may be applied to the contours in Fig. 4.1 to indicate the radiation intensity levels at time t (in hours) after the attack. As an example, the contours in Fig. 4.1 for 10,000 R/h at unit time (H+1) become contours of 100 R/hr in two days after the attack, and the same contours indicate levels of 10 R/hr in thirteen days after the attack, and after 90 days, the same contours represent radiation levels of 1 R/hr.

Because the biological effects of radiation depend on accumulated dose, the contours in Fig. 4.1 are not immediately useful to a defense planner. In order to increase the usefulness of these contours, the graphs in Fig. 4.3 were developed, which show the four-day dose or peak ERD (Equivalent Residual Dose) as a function of the arrival time of the fallout. In an actual situation, the fallout will arrive at different times at different locations, due to varying wind conditions. In this case, the unit-time reference dose rate can be estimated by measuring

Table 4.1

Areas Covered by Fallout (Hypothetical Situation)

Unit-Time Reference Dose Rate (R/hr)	Area sq mi	Cumulative Area sq mi	Cumulative Percent of Area of Coterminous U.S.
≥10,000	60,000	60,000	2.0
3000 to 10,000	295,000	355,000	12.0
1000 to 3000	446,000	801,000	27.0
300 to 1000	648,000	1,449,000	48.9
100 to 300	493,000	1,942,000	65.5
30 to 100	437,000	2,379,000	80.3
10 to 30	170,000	2,549,000	86.0

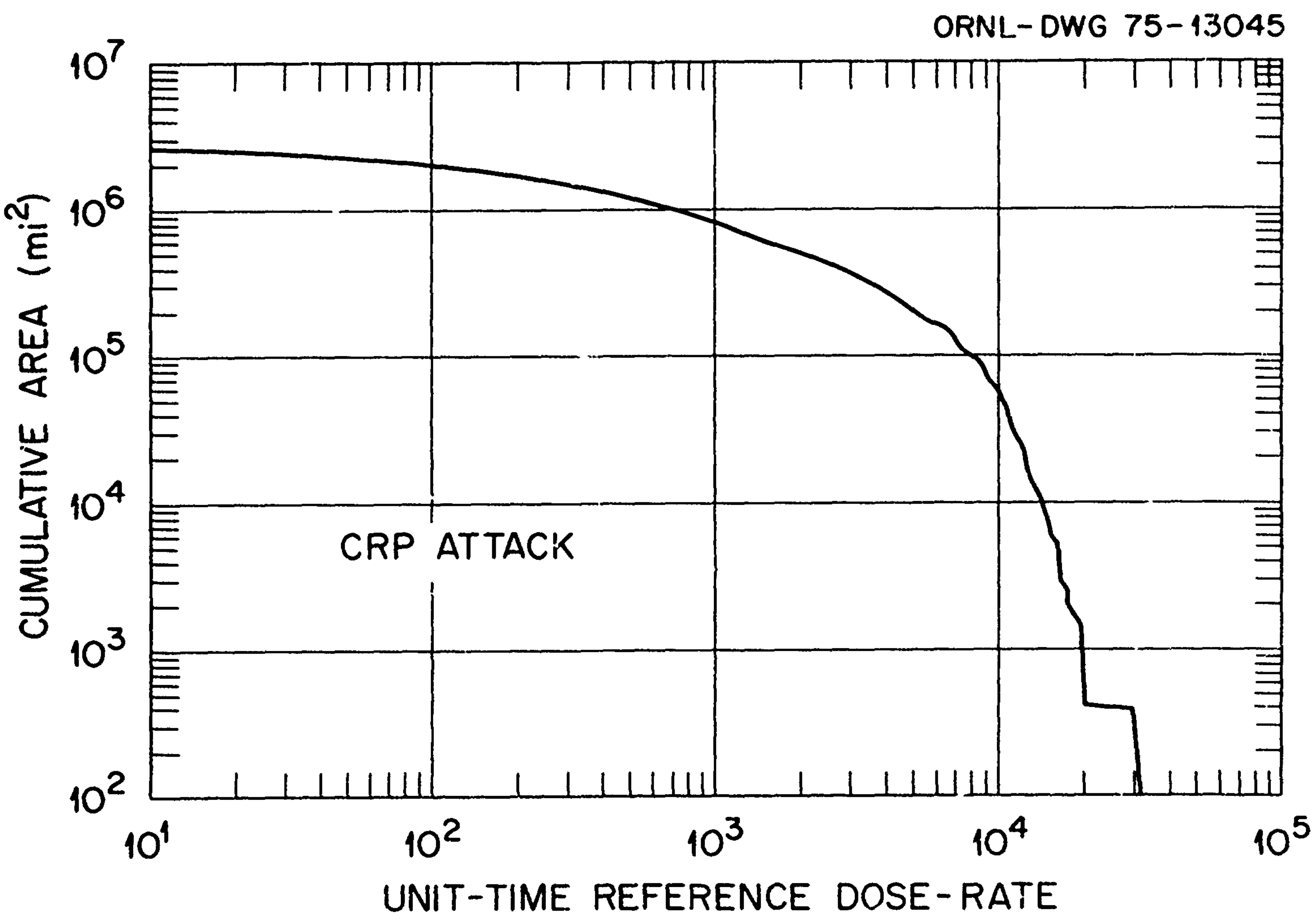

Fig. 4.2 Area of U.S. as a Function of Unit-Time Reference Dose Rate.

Table 4.2

Reduction Factors for Radiation Intensity Due to Decay

Time After Attack (Days)	Reduction Factor
1.9	0.01
13.2	0.001
89.8	0.0001

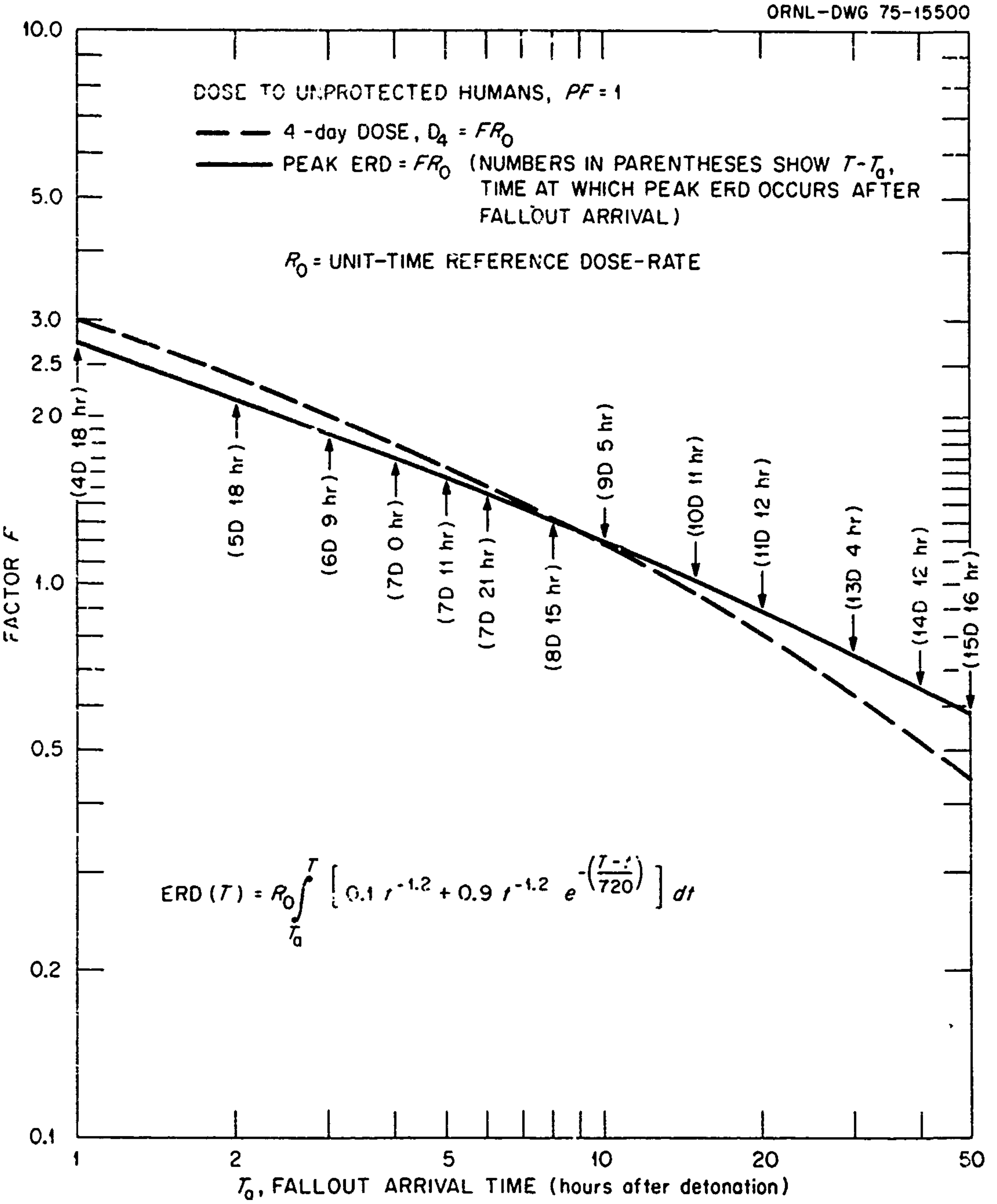

Fig. 4.3 Four-Day Dose and Peak ERD as a Function of Arrival Time of Fallout.

the radiation dose rates at various times, plotting these values on a graph, and extrapolating back to one hour after detonation.

Because the radiation is decaying while it is enroute to the final deposition area, the dose at the area will be reduced considerably, depending on how far downwind the deposition area is located from the detonation. The dose to unprotected humans as a function of the fallout arrival time can then be estimated by the factors given in Fig. 4.3.

The fallout patterns in Fig. 4.1 were calculated with the assumption that the mean wind velocity for fallout transport is 25 mph from the west, as mentioned previously. Suppose, as an example, that we wish to estimate the four-day dose to unprotected humans at Marshall, Minnesota, under these wind conditions, and for the CRP-2B attack. Marshall is located at approximately 44.4° N latitude and 95.8° W longitude. The upwind nuclear bursts which will produce fallout on Marshall, under the wind and attack assumptions used here, are located in western South Dakota. The latitude scale on the left side of Fig. 4.1 can be used as a distance scale; one degree of latitude corresponds to 60 nautical miles or 69.1 statute miles. The distance from Marshall, Minnesota, to the nuclear burst sites in South Dakota varies between approximately 4.5° and 5.5° of latitude, or between 311 and 380 miles. With a mean effective wind for fallout transport of 25 mph, the time of arrival of fallout in Marshall will range between about 12 hours for the earliest arrival and 15 hours for the latest. From Fig. 4.3, the factor for estimating the four-day dose (the dashed line) is about 1.07 for 12 hours arrival time, and about 0.96 for 15 hours arrival time. We will use F = 1. From Fig. 4.1, the unit-time reference dose rate, R_o, is near the 3000 R/hr isopleth, so we estimate it to be about 2500 R/hr. The four-day dose at Marshall for these conditions for unprotected humans is then 2500 roentgens, obtained from the product of F, the factor obtained from Fig. 4.3 and R_o, the unit-time reference dose rate obtained from Fig. 4.1.

Exposure to 400-450 roentgens of whole-body radiation is considered to be fatal to 50% of the people exposed, as discussed in sections 4.4 and 4.5. It is evident that fallout shelters would be required in Marshall, Minnesota, under these conditions. Factors which enter the considerations in selecting the degree of protection are discussed on page 75.

If a person remained an entire lifetime in an area contaminated by radioactive fallout from a single attack by nuclear weapons, the total dose, if unprotected, would be approximately four times the unit-time reference dose rate. However, because of biological recovery from much of the radiation damage, the Equivalent Residual Dose (ERD), as defined by the equation in Fig. 4.3, will reach a peak at about five days after the attack in the case where the fallout reaches the area in one hour after the detonations, about 25 miles downwind for the hypothetical case we are considering, and the peak ERD will be about 2.8 times the unit-time reference dose rate.

The number of people in the areas of fallout are listed in Table 4.3 for two cases, the 1970 residential population and the population relocated according to the ADAGIO program. A more complete display of the data obtained is shown in Fig. 4.4, which plots the percent of people, plotted on the ordinate, which are located in areas having a unit-time reference dose rate equal to or greater than that shown along the abscissa. The names of forty counties which have the heaviest fallout from this attack are listed in Table 4.4.

It is often useful to have a single index by which the relative effectiveness of one situation can be compared with another. The effectiveness of the relocation in avoiding fallout can be roughly indicated by a single index, I_f, which we call the Fallout Avoidance Index. If the relocation is the best possible with regard to avoiding fallout, the index will have the value of unity. If the relocation makes no change, the index will be zero, and if conditions are worse, the index will be negative. We define $G_e = \sum_i P_{ie} R_i$, the sum over all U.S. counties of the product, in each county, of the population in the county after relocation, and R_i, the unit-time reference dose rate in the county. Similarly, we define $G_r = \sum_i P_{ir} R_i$, involving the residential in situ population. Finally, we define $G_o = 1.94 \times 10^{-5} P$, where P is the total population of the country, and the constant is the dose rate per hour based on the tolerable background radiation of 170 mr/yr, as

Table 4.3

Population in Areas Covered with Fallout (Hypothetical Situation)

Unit-Time Reference Dose Rate (R/hr)	Population (1970 Residential) (millions)	Population (1970 Residential) (percent)	Population (relocated) (millions)	Population (relocated) (percent)
10,000	18.55	9.17	8.74	4.32
3000 to 10,000	48.65	24.07	30.60	15.13
1000 to 3000	46.86	23.18	51.43	25.43
300 to 1000	45.06	22.29	50.62	25.03
100 to 300	18.24	9.02	25.50	12.61
30 to 100	10.95	5.42	15.50	7.67
10 to 30	3.17	1.57	3.81	1.88
0 to 10	10.66	5.28	15.94	7.92

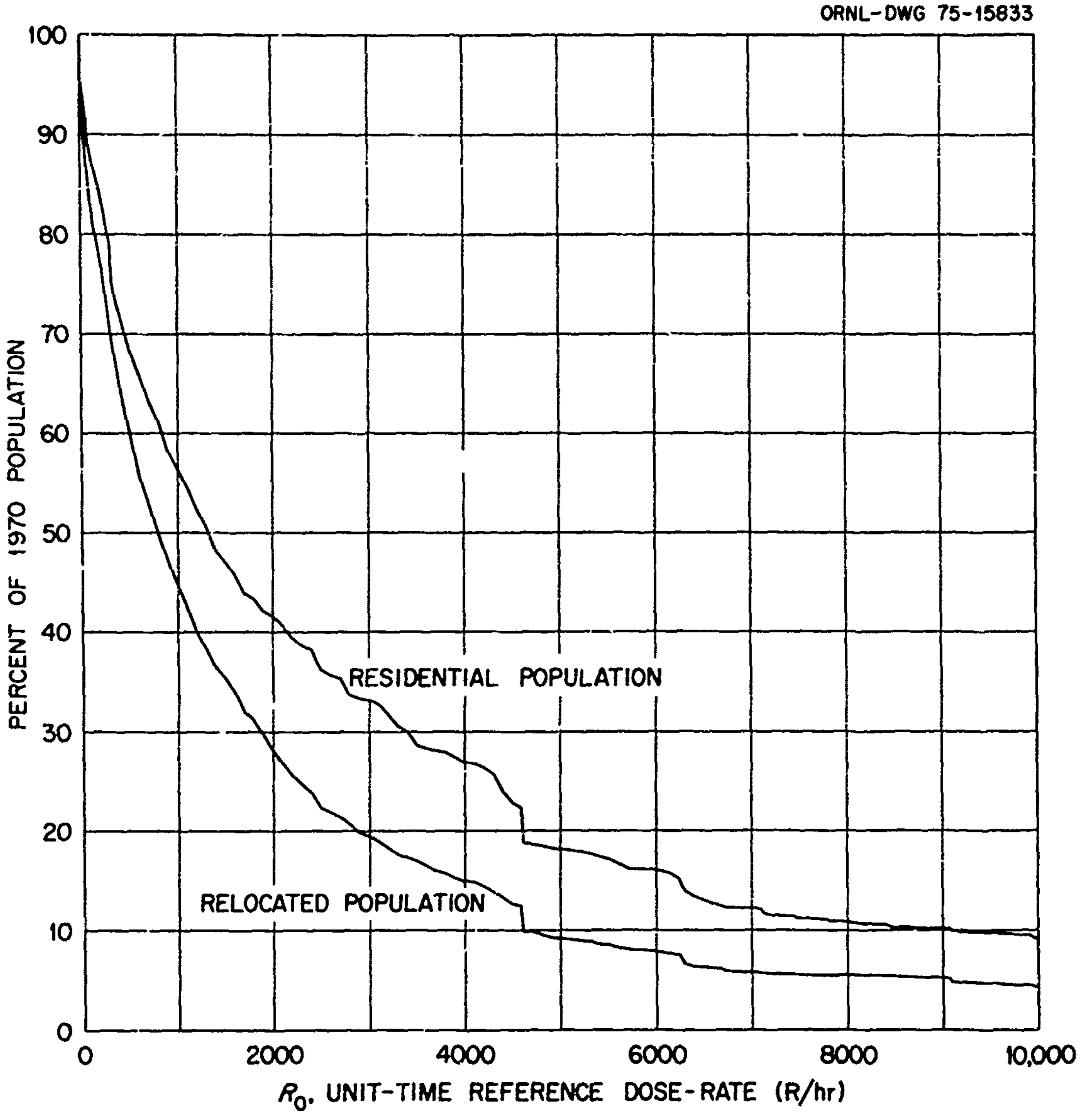

Fig. 4.4 Percent of Population vs Unit-Time Reference Dose Rate.

TABLE 4.4

Forty Counties with Severe Fallout Radiation from the CRP-2B Attack (Hypothetical Situation)

	County	State	Unit-Time Reference Dose Rate (R/hr)
1.	Queens	New York	32,000
2.	Nassau	New York	30,000
3.	New York	New York	20,600
4.	White	Arkansas	19,800
5.	Cooper	Missouri	17,800
6.	Moniteau	Missouri	17,800
7.	Deuel	Nebraska	17,000
8.	Cheyenne	Nebraska	16,600
9.	Bronx	New York	16,600
10.	Suffolk	New York	16,400
11.	Boone	Missouri	15,400
12.	Keith	Nebraska	15,300
13.	Kent	Maryland	15,300
14.	Cole	Missouri	15,100
15.	Clinton	Illinois	15,000
16.	Kings	New York	15,000
17.	Callaway	Missouri	14,900
18.	Woodruff	Arkansas	14,500
19.	Walsh	North Dakota	14,100
20.	Cross	Arkansas	14,100
21.	Pettis	Missouri	13,800
22.	Grand Forks	North Dakota	13,300
23.	Osage	Missouri	13,200
24.	Ramsey	Minnesota	13,100
25.	Petroleum	Montana	12,900
26.	Sedgwick	Colorado	12,900
27.	Shelby	Tennessee	12,800
28.	Bristol	Massachusetts	12,700
29.	Madison	Illinois	12,700
30.	Cochise	Arizona	12,400
31.	Warren	Missouri	12,300
32.	Washington	Minnesota	12,200
33.	Marion	Illinois	12,100
34.	Marshall	Minnesota	12,000
35.	Wilson	Kansas	11,900
36.	Montgomery	Missouri	11,900
37.	Fayette	Tennessee	11,700
38.	Pennington	Minnesota	11,600
39.	Contra Cosa	California	11,500
40.	Queen Annes	Maryland	11,500

set by the NCRP. The Fallout Avoidance Index, I_f, may then be defined as:

$$I_f = (G_r - G_e)/(G_r - G_o) \quad .$$

If the relocation results in placing people such that the radiation in their new locations is equal to the specified tolerable background radiation, then the value of the index is unity, indicating a good solution to the problem. If the relocation results in the same sum of products of population and radiation as the residential location, then the index will be zero, indicating a poor solution to the problem. For this attack, $G_e = 4.0 \times 10^{11}$ and $G_r = 6.8 \times 10^{11}$ for the 1970 residential population, and $G_o = 3922$. The value of I_f is 0.41. The ADAGIO relocation was based on a different fallout pattern, hence the index is not as high as it would have been if the relocation had been based on the fallout pattern used here, as shown in Fig. 4.1.

The fallout areas shown in Fig. 4.1 can be used as a rough indicator for requirements for fallout shelters under fairly general wind conditions. Transport of fallout from megaton-yield weapons takes place primarily in the stratosphere. In the winter, stratospheric winds blow predominantly from the west, but in the summer over much of the U.S., the stratospheric winds blow from the east (Crutcher, 1959). Because <u>any</u> wind direction is <u>possible</u> (the <u>probability</u> is not relevant if alternatives are available unless the shelterees wish to engage in Russian roulette), the areas of <u>possible</u> heavy fallout around high-risk areas is represented by a circle which can be generated by placing a compass point on the western edge of the dark area, and inscribing a circle with radius equal to the downwind distance to the isopleth value.

Alternately, the fallout protection factor (PF) for a shelter in a given area can be estimated as follows: First, locate the geographical position of the shelter on the map; second, place a compass point on the western edge of the nearest and darkest fallout pattern (the point of detonation); third, with radius equal to the distance from the compass point to the shelter location, inscribe a circle which passes through the downwind portion of the fallout pattern; forth, estimate the maximum value of the unit-time reference dose rate where the circle intersects the fallout pattern resulting from the weapon detonation location at the center of the circle. This procedure is repeated with all the neighboring fallout patterns which appear to have a significant effect.

For some winter wind conditions, the effective wind velocity may be twice that used to generate Fig. 4.1 (25 mph) and if these conditions are to be used, the length of the downwind patterns would be increased and the width reduced. For more detailed evaluations, several maps should be used, corresponding to several wind speeds, and more detailed contours should appear on the maps. The time of arrival is estimated by calculating the distance from the shelter location to the upwind edge of the pattern, as provided for the unit-time reference dose rate, and then dividing that distance by the effective wind velocity. Figure 4.3 can then be used to calculate the peak ERD or 4-day dose, from which the desired PF can be estimated.

An example of application of the procedure described above may be helpful. Suppose we are going to build a fallout shelter in the vicinity of Edgemont, South Dakota. In Fig. 4.5, two circles are drawn which pass through Edgemont and have their origins in the western edges of two of the darkest (heaviest fallout) regions in the vicinity of Edgemont. If the effective wind velocity were 25 mph and blew from the south-southwest at the time of the attack, the fallout pattern to the south of Edgemont in Fig. 4.5 would be rotated so that Edgemont would lie within the region of heaviest fallout of this pattern, and the fallout from detonations to the north would not affect Edgemont at all. Similarly, if the wind blew from the north-northeast at the time of the attack, the fallout pattern to the north of Edgemont would be rotated so that Edgemont would lie on the tip of the darkest portion of that pattern, and the fallout from detonations from the south would have no effect on Edgemont. The radii of the two circles are approximately 100 and 130 miles, and the unit-time reference dose rates are estimated to be 10,000 R/hr and 13,000 R/hr respectively, and the fallout arrival times are approximately 4 and 5.2 hours respectively.

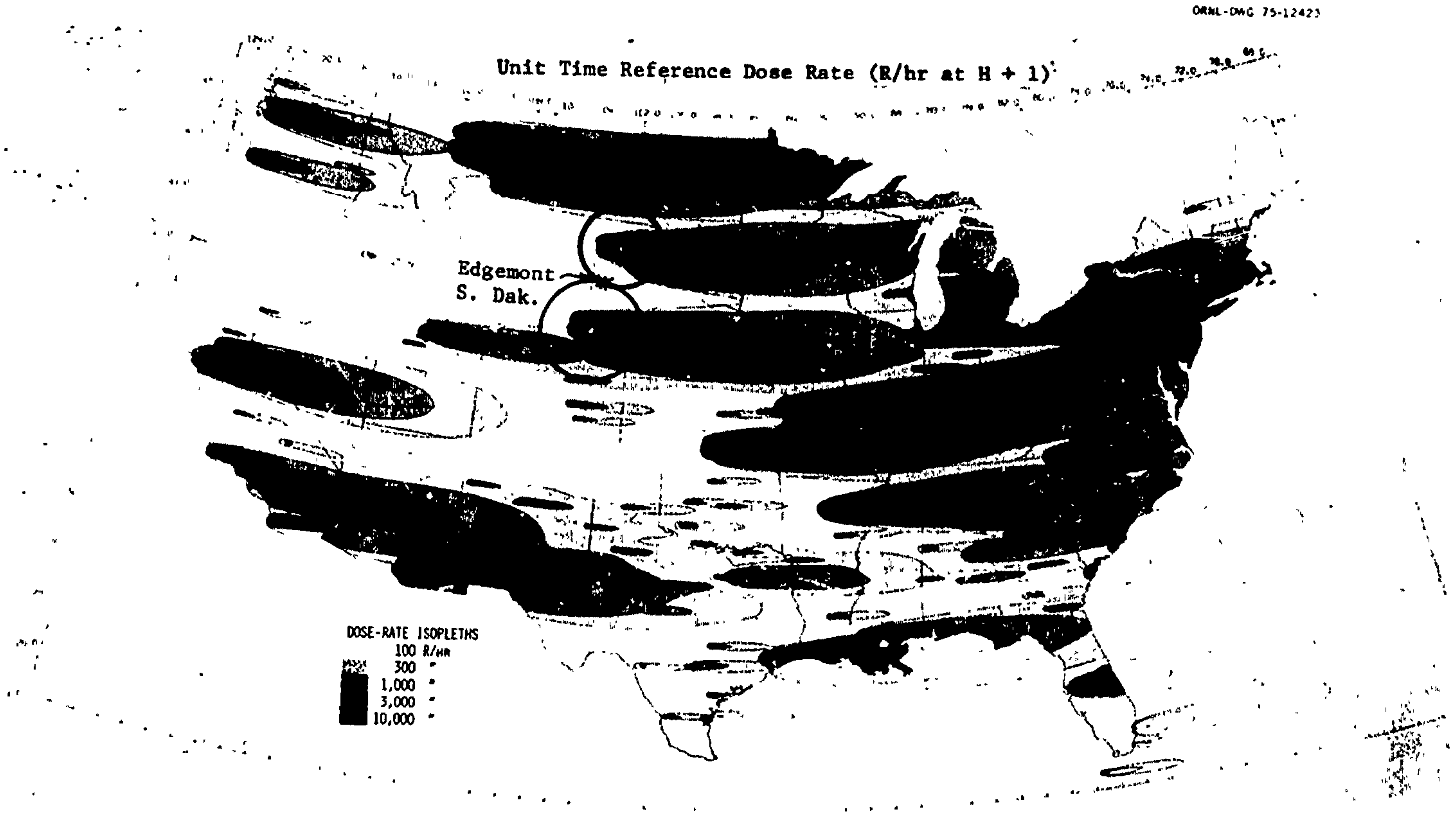

Fig. 4.5 Estimation of PF for Shelters at Edgemont, S.D.

From Fig. 4.3, the peak ERD factors are respectively 1.7 and 1.53, resulting in estimated peak ERDs to unprotected humans of 17,000 R and 19,900 R respectively. The latter number would be the preferred number to use for specifying the shelter PF, which would be about 400 if a peak ERD of 50 R were to be allowed in the shelter. If several maps were used, corresponding to different wind velocities, several values of the peak ERD would result, and the highest value obtained would be the value chosen for specifying the PF of the shelter.

Radiation levels are shown in Fig. 4.6 which would exist at one year after the attack if there were no decontamination measures taken and if no leaching by rain occurred. These results were estimated with the use of detailed analysis of the decay of the various isotopes (R. Chester, 1974) because the standard decay law does not apply after about five or six months after the detonation. At one year after the attack the radiation intensities are decaying slowly, and the one year dose starting at one year after the attack can be estimated approximately by multiplying the hourly dose-rate shown in Fig. 4.6 by by 8760, the number of hours in a year. The lowest contour in Fig. 4.6 is 0.0001 R/hr, and encompasses an area of 2.4 million square miles, 80% of the U.S. area, as listed in Table 4.5. The long-range effect of this radiation on humans will be discussed later in this chapter, and the effect on crops will be discussed in Chapter 6.

4.3 The U.S. RADEF Program

Radiological Defense (RADEF) is a first-priority emergency preparedness program at federal, state, and local levels of government, designed to enhance the survival of citizens from fallout threats in the event of a nuclear attack. Protection of the people from radiation hazards and early implementation of survival measures can be accomplished only through an organized capability of detecting, monitoring, reporting, and analyzing the fallout situation at each affected locality. Radiation measuring and detection instruments in the hands of trained personnel are the only means of gaining reasonably accurate information on the fallout radiation level at a given time and place, because the levels of

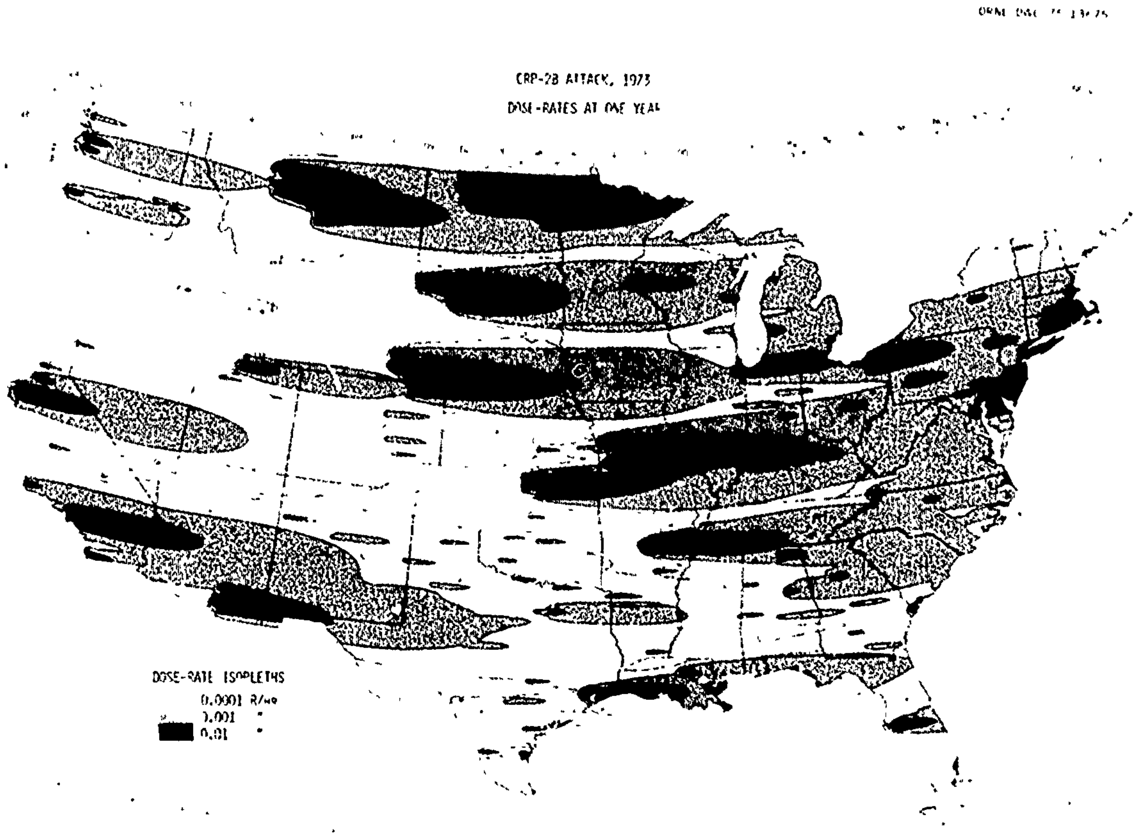

Fig. 4.6 Fallout Radiation Levels One Year After.

Table 4.5

Area Dose-Rates One Year After a Hypothetical Attack

Dose-rate, (R/hr)	Area (sq mi)	Cumulative Area (sq mi)	Percent of Area of Coterminous U.S.
0.1	108	108	0.004
0.01	347,000	347,000	11.7
0.001	1,089.000	1,436,000	48.5
0.0001	944,000	2,380,000	80.3
0.00001	274,000	2,654,000	89.5

radiation will vary in time due to local climatic conditions, during and after the fallout deposition, and the variations may be considerable over short distances.

Federal guidance relating to RADEF is given in Part E, Chapter 5, of the Federal Civil Defense Guide (FCDG), which is currently being updated by DCPA to include the changing strategic threat, crisis relocation, and various peacetime nuclear threats.

Five basic components of the RADEF program are:

(1) the provision of radiological monitoring capability for each shelter;

(2) the establishment of a network of appropriately dispersed centers of monitoring and reporting capability called "monitoring stations;"

(3) the development of capabilities at EOCs (Emergency Operating Centers) to process the raw radiological data into readily usable form, and to provide staff support through interpretation of data, provision of technical guidance, and recommendations of possible courses of action;

(4) the provision of instrumentation and training for the radiological self-help protection of emergency service and vital facility personnel; and

(5) the provision of dosimeters for postattack exposure control for civil defense workers engaged in recovery operations.

The provision of radiological monitoring in each shelter and in its immediate vicinity is essential in order to maintain a record of exposure for each individual, especially those who must make excursions out of the shelter for survival purposes. Radio broadcasts will be able to provide only general rough approximations of radiation levels in the environs of shelters.

The network of "monitoring stations" will serve as a base from which: (a) monitors will perform on-station monitoring during the period when the radiation hazard is great, and (b) detailed mobile monitoring will take place during the period when radiation rates will permit limited field operations on a controlled risk basis. Aerial monitoring can effectively supplement, but not replace, the detailed monitoring station functions, especially for monitoring transportation routes, agricultural lands, etc. Data obtained by the monitoring stations will be communicated to EOCs for processing, preferably by radio, in view of the threats to telephone lines from EMP, blast and fire.

The system of EOCs and monitoring stations requires trained RADEF officers (RDOs) plotters, analysts, recorders, and radiological monitors. As of June 30, 1975, there were 3500 qualified RDOs in the U.S., with a goal of 10,000, and 177,000 trained radiological monitors, with a goal of 380,000.

The basic radiological instruments necessary for measuring dose rates (survey meters) and accumulated dosages (dosimeters) are provided by the federal government to the states and through them to local government for use in community shelters and state and local monitoring stations. Additional and more specialized equipment has also become part of the total instrumentation relating to civil defense, such as aerial monitoring instruments, remote sensor radiation meters for EOCs, etc. To insure operational readiness and reliability, a system to control, maintain, repair, and calibrate equipment is also provided through federally-funded state shops.

This RADEF capability is deteriorating in some states due to shortage of state and federal funds, and from lack of interest in others.

A brief description of the DCPA radiological instruments for operational use is given in Chapter 7, Annex 1, of the Radiological Defense Planning and Operations Guide, SM-11.23.2, revised March 1967, Department of Defense. Office of Civil Defense. The number and general distribution of instruments in the U.S., as of July 1974, is listed in Table 4.6. The number of monitoring kits and other survey instruments are listed by state in Table 4.7. The monitoring kit contains one V-700 radiation survey meter (low range, high sensitivity), two V-715 high range gamma survey meters, two V-742 high range dosimeters, and one V-750 dosimeter charger. Many of the 138,000 shelter kits listed in Table 4.6 are located in areas which are considered to be high-risk areas under CRP. These kits should be moved to the relocation areas during the crisis period, and the plans for this movement should be made in detail at the local level before a crisis occurs.

Table 4.6

Radiation Detection Instruments Currently Distributed to States (figures rounded off)

Source: DCPA-Operations & Planning

	Number	Approximate Cost
A. Instruments		
Survey Meters		
Low Range (V-700) 0-.5 mr/hr 0-5 mr/hr 0-50 mr/hr	425,000	$ 60.00
Remote Sensor (V-711)	400	100.00
High Range (V-715) 0-.5 r/hr 0-5 r/hr 0-50 r/hr 0-500 r/hr	530,000	60.00
Remote Reading (V-717) Chamber remotable to 25'	80,000	100.00
High Range (V-720) 0-5 r/hr 0-50 r/hr 0-500 r/hr	95,000	80.00
Dosimeters (Self-reading)		
Training (V-138)	190,000	25.00
0-20 Roentgen (V-730)	130,000	20.00
0-100 Roentgen (V-740)	155,000	20.00
0-200 Roentgen (V-742)	2,700,000	20.00
Chargers		
For all dosimeters (V-750)	500,000	15.00

. . . . .

Table 4.6 (cont'd)

	Number
B. <u>Distribution</u>	
The total of instruments in states is about 5,100,000	
In monitoring stations* - 61,000 kits (1 ea. V-700, 2 ea. V-715, 2 ea. V-742, 1 ea. V-750)	366,000
In shelters - 138,000 kits (same except only one V-715	690,000
Emergency worker dosimeters and chargers in state buildings (e.g. national guard armories)	2,100,000
In state maintenance (one location per state)	900,000
In federal warehouse (Richmond, Virginia)	600,000
In training (high schools, etc. throughout states)	400,000

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*recommended siting: at 1-3 miles centers for urban areas.
at 7-10 miles centers for rural.

Table 4.7

Distribution of Monitoring Kits (July 1974)

State	Total Number of Sets (Monitoring Kits)	Other Survey Instruments
Alabama	1927	1
Alaska	371	0
Arizona	555	0
Arkansas	1187	1
California	6063	18
Colorado	524	0
Connecticut	1155	1
Delaware	185	121
Dist. of Col.	62	25
Florida	912	0
Georgia	1708	0
Hawaii	238	0
Idaho	699	82
Illinois	1426	127
Indiana	1142	10
Iowa	967	0
Kansas	1123	0
Kentucky	1447	0
Lousiana	1102	0
Maine	881	107
Maryland	1112	595
Massachusetts	1519	0
Michigan	1448	67
Minnesota	1504	1
Mississippi	867	0
Missouri	1201	0
Montana	992	0
Nebraska	1138	0
Nevada	424	0
New Hampshire	1	1
New Jersey	2126	0
New Mexico	704	0
New York	3952	2
North Carolina	990	0
North Dakota	811	22
Ohio	2154	0
Oklahoma	1581	0
Oregon	707	0
Pennsylvania	2346	1

Table 4.7 (con'd)

State	Total Number of Sets (Monitoring Kits)	Other Survey Instruments
Rhode Island	488	0
South Carolina	1083	0
South Dakota	796	0
Tennessee	1405	164
Texas	3321	0
Utah	592	5
Vermont	211	0
Virginia	893	15
Washington	1018	0
West Virginia	807	8
Wisconsin	2111	0
Wyoming	436	49

In addition to these instruments, 1100 V-781 aerial survey meters have been distributed to the states for use in the Civil Air Patrol aerial radiological monitoring program. The availability of aircraft, fuel, and runways for carrying out this program will be discussed in Chapter 7.

4.4 Radiological Exposure Control Guidelines

The basic approach of DCPA to control of radiological exposure is described in considerable detail in the Radiological Defense Planning and Operations Guide, SM-11.23.2, revised March 1967, (RDPOG) which is a reprint of published and draft materials from the Federal Civil Defense Guide. A more recent guide is given in NCRP Report No. 42, Radiological Factors Affecting Decision-Making in a Nuclear Attack, November 15, 1974. The underlying philosophy in both documents is to provide a description of the hazards of radiological exposure, how to detect and protect against it, and how to keep track of cumulative doses without attempting, for practical reasons, to specify precise exposure limits for all people in all kinds of situations which may occur in a post-attack situation.

One anticipated situation, for example, is that some shelters may be poorly stocked with food or water, and it may be necessary for someone in the shelter to volunteer to take a calculated risk and deliberately expose himself to radiation in order to procure supplies for survival. Another situation may occur after the radiation hazard has diminished to some extent, when it may become necessary for some shelterees to participate in radiological monitoring surveys, or in rescue work, or in the shipping of vital supplies to less fortunate areas. In all these cases it is extremely important to have detailed information on the radiological condition in the immediate vicinity of the shelter. This information could be obtained either by radiation survey meters in possession of the shelterees, or by radio communication (two-way) with someone external to the shelter who has conducted a survey of the shelter environment. If neither survey meters nor two-way communications with an external surveyor are available or possible, the shelterees may have to rely only on AM broadcasts for the radiological situation, which may be grossly in error for their particular location. The possibility of "hot spots" due to climatic conditions can result in radiation intensities which may be a hundred times stronger in one location than in another which is only a mile away. A more detailed discussion of shelter survival in hazardous radiation fields is given in Section 4.6, in this chapter.

During the early periods following a nuclear attack (the first week or two) before a complete evaluation of the hazards can be determined, the recommendations shown in Table 4.8, taken from RDPOG, p. 3-27, may be used as a guide for directing shelter and operational activities. In order to benefit from this guidance, there must be some kind of radiation survey meter in the shelter. As soon as information becomes available as to the age of the fallout, the guidelines in Table 4.8 should be modified. If the fallout is relatively young (2 or 3 hours old) at the time of measurement of the dose rate, the radioactivity is decaying rapidly, and relaxation of control of exposure to radiation in the shelter can be tolerated to some degree. However, if fallout is several days or weeks old at the time of measurement, then the radiation intensity is decaying slowly, and more rigid control of exposure is necessary.

The guideline for exposure of emergency personnel to radiation as given in RDPOG is that "to the extent practicable the ERD of emergency personnel should always be kept well below 200 R." For workers in critical areas (non-emergency) the comparable maximum ERD is 100 R. An extreme total exposure for emergency personnel during a 12 month period which would keep the ERD below 200 R during the first year, would permit no more than 200 R in the first month, no more than 25 R per week in the next 5 months, and no more than 10 R per week in the next 6 months. The maximum exposure for the entire year under this schedule is about 1000 R, which is extreme. There is one example in history so far where a person has received about 1000 R in a period of 106 days and survived (Lushbaugh, in Tobias and Todd, 1974, pp. 502-503). According to Lushbaugh, "If the experience of the one Mexican survivor can be used as a criterion, normal man may only be able to achieve similar tolerance to

Table 4.8

Guidelines for Shelter and Operational Activities
(Taken from RDPOG)

If Outside Dose Rate Has Fallen to: (in R/hr)	Activities That May Be Tolerated
Less than 0.5	No special precautions necessary for performance of essential tasks, except to keep fallout particles from contaminating people ar sleep in the shelter.
0.5 to 2	Outdoor activity (up to a few hours per day) tolerable for essential purposes, which include fire fighting, police action, rescue, repair, securing necessary food, water, medicine and blankets, important communications, disposition of waste, exercise and obtaining fresh air. Eating, sleeping, and all other activities should be conducted in the best available shelter.
2 to 10	Very short periods (less than an hour per day) of outdoor activity are tolerable for the most essential purposes. Shelter occupants should rotate outdoor tasks to minimize total doses. Outdoor activities of children should be limited to 10 to 15 minutes per day. Rescue, repair, communications and exercise may safely take place in less than optimum shelter.
10 to 100	Time outside of shelter should be held to a few minutes and limited to those few activities that cannot be postponed for at least one more day. Insofar as possible, all people should remain in the best available shelter no matter how uncomfortable.
Greater than 100	Outdoor activity of more than a few minutes may result in sickness or lethality. The only occasions which might call for moving are (1) risk of death or serious injury in present shelter from fire, collapse, thirst, etc., and (2) present shelter is greatly inadequate—might result in fatality—and better shelter is only a few minutes away.

an average marrow dose of about 6 rads/day if the irradiation is by high-energy, low LET photons." If this rate of exposure were tolerated for a year, the total dose would be about 3300 R from fallout-type radiation. In consideration of possible long-range effects of exposure to radiation, to be discussed in the next section, it is decidedly to the advantage of the individual to be exposed to the minimum quantity of radiation which is compatible with the accomplishment of an emergency task.

A comprehensive study of the effects of exposure to radiation was sponsored by NASA to establish guidelines for astronauts on space-flights of long duration (Space Radiation Study Panel, 1967). In the last chapter on Evaluations and Recommendations, it is assumed that an acceptable reference-equivalent space exposure (RES_m), established on the basis of the risk-versus-gain philosophy, was 250 reference-equivalent units (reu) for a one-year space mission. For fallout-type radiation, 250 reu is approximately equivalent to 250 rads, midline absorbed dose, or about 375 R, whole-body exposure. If this dose were absorbed according to the schedule given in Table 33 of Radiological Factors in Manned Space Flight (RFMSF hereafter) (Space Radiation Study Panel, 1967) the ERD, calculated according to the formula in RDPOG, at the end of the year would be about 30 rad, or an exposure ERD to fallout-type radiation of about 45 R. If this recommendation were applied to the extent that the guideline for exposure of emergency personnel to fallout radiation were lowered from 200 R to a maximum ERD of 50 R, then an exposure rate which would keep the ERD below 50 R during the first year would be as follows: less than 100 R in the first month; less than 15 R per week in the next five months; and less than 3 R per week in the remaining six months, for a total maximum yearly dose of about 475 R.

The ERD concept of human response to radiation has been discredited by a number of people (Sacher, 1958; Sacher and Grahn, 1964; Storer, 1959; Langham, 1967; Steward, 1974) yet it has provided the basis for extensive guidelines for control of exposure to radiation throughout the world, partly because none of the detractors cited proposed an alternative scheme for planning purposes in the event of large-scale radiation hazards presented by nuclear war. A recent effort to provide an alternate guideline is the "Penalty" table, reproduced in Table 4.9 from Appendix B of NCRP Report No. 42. It relates three categories of exposure rate conditions (columns a,b,c) with three categories of expected consequences (rows A,B,C), depending upon total accumulated exposure. Examples of the use of this table are given as follows, as quoted from the NCRP Report No. 42:

> Example 1:
>
> Purpose: To limit exposure to low medical risk. (Refer to row A.) To achieve this purpose, it would be necessary to limit the total radiation exposure of individuals to less than 150 R in any one week (column a); 200 R in any one month (column b); and 300 R in any four-month period (column c).
>
> For example, if individuals receive the one-week limit of 150 R (column a) within the first week, then the limit for additional exposure during the ensuing three weeks of the first month, to keep within the one-month limit (column b), would be 200 R - 150 R = 50 R. This additional exposure of 50 R could be received in any period of time, ranging from one day to three weeks of the ensuing three weeks of the first month, without exceeding the one-week or one-month limits in the "Penalty" Table. However, if this additional exposure of 50 R were received, for example, within the second week, then the individuals would have to be kept free of further exposure during the remainder of the first month to keep within the one-month limit for row A (200R). Similarly, if the individuals have received the limit of 200 R in the first month, without exceeding 150 R in any one week of that month, the limit of additional exposure for the ensuing three months of the first four months (column c) would be 100 R for a total of 300 R (200 R + 100 R) in four months.
>
> Example 2.
>
> Purpose: Operations at the intermediate level of significant medical risk (row B), justified by highly critical emergency situations.
>
> In this case, the decision-maker may find it necessary to allow greater exposure than one or another of the limits indicated in row A, but would be constrained whenever possible by other limits in row A, and always by limits in row B of the Penalty Table.

Table 4.9

The "Penalty" Table

		Accumulated Radiation Exposures (R) in Any Period of		
	Medical Care Will Be Needed By	a	b	c
		One Week	One Month	Four Months
A	NONE	150	200	300
B	SOME (5 percent may die)	250	350	500
C	MOST (50 percent may die)	450	600	—

> For example, if individuals who have received 150 R within the first week are required in some emergency to receive an additional 200 R during the remainder of the first month (for a total of 350 R in the first month), it is desirable, if possible, that the one-week constraint for row A (column a) be observed by allowing no more than 150 R of this additional exposure during any one week within that month, even though the one-month limit (200 R) and four-month limit (300 R) for row A will have been exceeded and the one-month limit (350 R) for row B will have been reached. If it is not possible to keep within any of the constraints for row A, then the row B constraints have to be applied, in an attempt to keep exposure in any one week as far as possible below 250 R, to limit the exposure during the first month to 350 R. Any additional exposure after this first month must be kept as far as possible below the additional 150 R which would attain the four-month limit of 500 R (row B).
>
> As in Example 1, the decision-maker could schedule exposures in a variety of ways within the constraining limits to meet the work required by the problem at hand.
>
> Example 3.
>
> Purpose: Operations at the high levels of medical risk (row C), justified only by extremely critical emergency situations.
>
> In extreme emergencies, situations could arise that might justify operating at the high risk level (row C). Those activities that could result in saving a significant number of lives may call for the deliberate exposure of some persons at the highest constraint levels where radiation sickness and a 50 percent probability of death are expected (row C). If such situations arise, the decision-makers would use for guidance row C of the Penalty Table in a manner similar to that discussed for the low or intermediate risk rows (A and B) in Examples 1 and 2 above.

According to Example 1, it would be necessary to limit the total radiation exposure to less than "300 R in any four-month period," if medical care were to be avoided. This criterion indicates that a total exposure of 900 R could be tolerated over a one-year period, without requiring medical care, as long as the total radiation exposure does not exceed 300 R in any four-month period.

One of the conclusions given in RFMBS may have some bearing on establishing a guideline for maximum exposure rates during emergency missions of short duration (less than two days): (p. 256) "For bone-marrow responses, doses delivered at dose rates of 50 rads/day and above are assumed to produce maximum injury per rad, while exposures at rates of 1 rad/day and below are assumed to produce minimum injury per rad accumulated." It is implied here that 50 rads or more is delivered in the maximum case. For fallout-type radiation, 50 rads/day corresponds to about 75 R/day whole-body exposure. This RFMSF conclusion could therefore lead to the criterion that emergency personnel should not be exposed to more than 75 R in any one day.

The Soviet Civil Defense Manual (Egorov et. al., 1970) defines fairly specific categories of radiation exposure rates, and relates them to the mode of transportation of the reconnaissance teams which undertake radiological surveys, as follows: (p. 163) "The terrain is considered contaminated if it has a dose rate of 0.5 R/hr or higher. As a rule reconnaissance on foot is continued to a dose rate not higher than 30 R/hr; in automobiles to a dose rate of not more than 100 R/hr. Reconnaissance of regions with higher radiation levels is carried out by reconnaissance groups (teams) only on special order by the chief who ordered the reconnaissance. Localities with higher dose rates, up to 200 R/hr, can be reconnoitered only in tanks or in armored transports, and higher than 200 R/hr in helicopters or in airplanes; such reconnaissance is conducted by higher CD staff officials."

The Soviet guidelines on exposure to fallout radiation are oriented strongly toward rescue work and getting factories into production as quickly as possible. Equations and tables in their CD manuals are based on the same standard radiation decay formula used in this country, i.e. $R=R_o t^{-1.2}$, where R is the dose rate at time t in hours after the detonation, and R_o is the unit-time reference dose rate. An interesting and useful table from the 1970 Soviet Civil Defense manual (Egorov et al., 1970), which shows permissible exposure times in an area contaminated by fallout, is reproduced in Table 4.10. An example is given of the use of this table in the Soviet manual, which will be related here in the following paragraph.

Table 4.10

Permissible Exposure Time in an Area Contaminated by Fallout Resulting from a Nuclear Blast (Soviet)

	Time of Entry Into the Contaminated Area (From the Time of the Blast) (hr)											
D/R Value[a]	0.5	1	2	3	4	5	6	7	8	9	10	12	24
		Exposure Time (in Hours and Minutes for Which the Determined Value D/R is Obtained for Different Times of Entry Into the Contaminated Area, Referred to the Blast Time.											
0.2	0-15	0-14	0-13	0-12	0-12	0-12	0-12	0-12	0-12	0-12	0-12	0-12	0-12
0.3	0-22	0-22	0-20	0-19	0-19	0-19	0-19	0-18	0-18	0-19	0-18	0-18	0-18
0.4	0-42	0-31	0-27	0-26	0-26	0-25	0-25	0-25	0-25	0-25	0-25	0-21	0-24
0.5	1-02	0-42	0-35	0-34	0-32	0-32	0-32	0-31	0-31	0-31	0-31	0-31	0-30
0.6	1-26	0-54	0-44	0-41	0-39	0-39	0-38	0-38	0-28	0-37	0-37	0-37	0-37
0.7	2-05	1-08	0-52	0-49	0-47	0-46	0-45	0-45	0-44	0-44	0-44	0-44	0-43
0.8	2-56	1-23	1-02	0-57	0-54	0-53	0-52	0-51	0-51	0-51	0-50	0-50	0-49
0.9	4-09	1-42	1-12	1-05	1-02	1-00	0-59	0-58	0-58	0-57	0-57	0-57	0-55
1.0	5-56	2-03	1-23	1-14	1-10	1-08	1-06	1-05	1-05	1-04	1-04	1-03	1-02
2.0	1562-00	11-52	4-06	3-13	2-46	2-35	2-29	2-24	2-20	2-18	2-16	2-13	2-06
2.5		31-00	6-26	4-28	3-48	3-28	3-16	3-08	3-03	2-59	2-55	2-51	2-40
3.0		96-39	9-54	6-09	5-01	4-28	4-10	3-58	3-49	3-43	3-38	3-30	3-14
4.0		3124-00	23-43	11-05	8-12	6-57	6-16	5-50	5-33	5-19	5-10	4-58	4-26
6.0			193-19	35-35	19-48	14-43	12-19	10-55	10-02	9-24	8-57	8-19	7-01
10.0				728-49	124-00	59-18	39-34	30-39	25-42	22-35	21-32	17-52	13-08

[a] D/R equals permissible dose in roentgens divided by the dose rate R/hr at the moment of entry into the contaminated region.

Suppose the nuclear explosion occurred at 6 o'clock, and the working crew is to enter the area at 8 o'clock, at which time the radiation intensity is measured at 20 R/hr. If the established allowable cumulative exposure is 40 R, how much time can the crew spend in the area? It is assumed that the radiation exposure is negligible until they enter the area. According to the measurement of the radiation intensity and the value of "established allowable dose," the ratio D/R = 40/20 = 2, and the time of entry is 2 hours after the blast, hence we find from Table 4.10 that the permissible exposure time in the area is 4 hours and six minutes.

The Soviet Civil Defense manuals do not discuss the basis for establishing permissible levels of radiation exposure, and the concept of ERD or the accumulative effect of radiation exposure are not introduced, although an instrument for measuring cumulative dose, a dosimeter, is described. However, if the duration of a work shift (or of exposure time) is restricted to no more and no less than four hours per day in a contaminated area, as implied in the Soviet manuals, then the entry times as given in Table 4.10 will never permit the maximum ERD to exceed 100 R. In the worst case, within the limits of Table 4.10, entry time will be at 24 hours after the blast, and the radiation fields will be decaying much more slowly than at earlier times. From Table 4.10 the four-hour exposure time corresponds to D/R = 3.6 (by interpolation), from which R = 11 R/hr, and R_o = 498 R/hr. If the same crew enters the same area at the same time every day for a four-hour exposure, their maximum ERD will be about 97 R at the thirteenth day, and it will decrease thereafter. The cumulative exposure at the time of peak ERD will be 109 R, and the cumulative exposures at 7 days, 1 month, and 4 months are, respectively 93 R, 129 R, and 155 R, all less than the maximum levels indicated in the "Penalty" Table (Table 4.9) for no medical care requirements.

If these examples are indicative of the Soviet policy towards exposure to fallout radiation, then we may conclude that, except for extreme emergency, the maximum permissible ERD for the Soviet emergency personnel is 100 R for a year, compared with 200 R indicated in the U.S.

RDPGG, and about 50 R ERD indicated (for astronauts) by the Space Radiation Study Panel (R[illegible]F). In general, the Soviet policy towards exposure to radiation appears to be more cautious than the U.S. policy, exemplified by higher PFs for shelters and lower limits for exposure doses.

The penalty table may be used to construct a table similar to that of the Soviet's shown in Table 4.10 which will indicate the time after detonation when an area can be entered for a regular period of time each day, for "shift" work, for example, such that the exposure to radiation will not result in requirement for medical aid. In Table 4.11, the time at which regular exposures of specific duration may begin, counting from detonation time, are shown for three different unit-time reference dose rates, 1000, 3000, and 10,000 R/hr. It is assumed that during the periods between exposures the workers are either physically removed from the area of contamination or else they are housed in shelters which have such a high PF that the radiation dose received while inside them is negligible.

Suppose, for example, the unit-time reference dose rate is 1000 R/hr, and we wish to begin regular shift work of eight hours per day in the contaminated region. According to Table 4.11, if we started working at 3.36 days after the detonation with 8 hours' exposure every day, the total exposure in one week would meet the penalty table maximum of 150 R in one week, but if work were continued in the same area for 8 hours' every day for a month, the exposure would be 270 R, which exceeds the dose of 200 R specified by the penalty table for requiring no medical care. In order to meet the penalty table specifications for no medical care, regular shift work of 8 hours' duration per day in an area with 1000 R/hr unit-time reference dose rate should not begin until about 5½ days after the detonation. We assume here that in the postattack environment people will work 7 days a week, without taking Saturdays and Sundays off.

Entry times for "shift" work in contaminated areas, based on the penalty table for no medical care requirements, are shown in graphical form for $100 \leq R_o \leq 1000$ in Fig. 4.7 and for $1000 \leq R_o \leq 10,000$ R/hr in

Table 4.11

Permissible Entry Times and Doses for Daily Exposure to Fallout Radiation with No Medical Care Required According to the Penalty Table

R_o, Unit-Time Reference Dose Rate (R/hr)	Entry Time After Detonation		t Duration of Exposure Per Day (Hours)	Exposure in Roentgens*			Peak ERD	Day of Occurrence of Peak ERD (After Detonation)
	Days	Hours		Week N=7	Month N=30	Four Months N=120		
1,000	1.37	32.88	4	150 ((145))	(220)((145))	(270) ((55))	160	15
1,000	1.60	38.40	4	(135)((130))	200 ((135))	(255) ((55))	150	16
1,000	1.10	26.40	4	(175)((170))	(245)((160))	300 ((60))	185	14
1,000	2.34	56.16	6	150 ((145))	(245)((170))	(325) ((70))	175	19
1,000	3.43	82.32	6	(110)((110))	200 ((140))	(275) ((65))	145	22
1,000	2.81	67.44	6	(130)((130))	(225)((155))	300 ((65))	160	20
1,000	3.36	80.64	8	150 ((150))	(270)((185))	(370) ((85))	190	21
1,000	5.58	133.92	8	(100) ((95))	200 ((145))	(295) ((70))	145	26
1,000	5.46	131.04	8	(100)((100))	(205)((145))	300 ((70))	145	26
3,000	5.50	132.00	4	150 ((150))	(305)((220))	(450)((110))	220	26
3,000	10.58	253.92	4	(85) ((80))	200 ((145))	(335) ((85))	145	33
3,000	13.00	312.00	4	(70) ((65))	175 ((130))	300 ((80))	130	36

Table 4.11 (cont'd)

R_o, Unit-Time Reference Dose-Rate (R/hr)	Entry Time After Detonation Days	Hours	t Duration of Exposure Per Day (Hours)	Exposure in Roentgens* Week N=7	Month N=30	Four Months N=120	Peak ERD	Day of Occurrence of Peak ERD (After Detonation)
3,000	8.63	207.12	6	150 ((150))	(345)((250))	(550)((140))	250	31
3,000	18.13	435.12	6	(70) ((70))	200 ((150))	(375)((105))	155	41
3,000	26.67	640.08	6	(50) ((45))	(145)((110))	300 ((90))	120	47
3,000	11.63	279.12	8	150 ((150))	(370)((275))	(630)((170))	275	34
3,000	25.75	618.00	8	(65) ((65))	200 ((150))	(410)((120))	160	47
3,000	41.67	1000.08	8	(40) ((40))	(130)((100))	300 ((95))	115	57
10,000	10.00	240.00	2	150 ((145))	(350)((255))	(570)((150))	255	32
10,000	21.00	504.00	2	(70) ((70))	200 ((150))	(385)((110))	155	43
10,000	32.00	768.00	2	(45) ((45))	(140)((105))	300 ((90))	115	51
10,000	19.00	456.00	4	150 ((150))	(430)((325))	(815)((230))	335	41
10,000	46.00	1104.00	4	(60) ((55))	200 ((155))	(470)((150))	175	59
10,000	83.00	1992.00	4	(30) ((30))	(110) ((85))	300 ((105))	110	76

*Exposures are underlined which duplicate the penalty table for "no medical care required." Numbers in single parentheses are the exposures for the periods indicated. Numbers in double parentheses give the ERD for the same exposure. Numbers are rounded off to the nearest multiple of five.

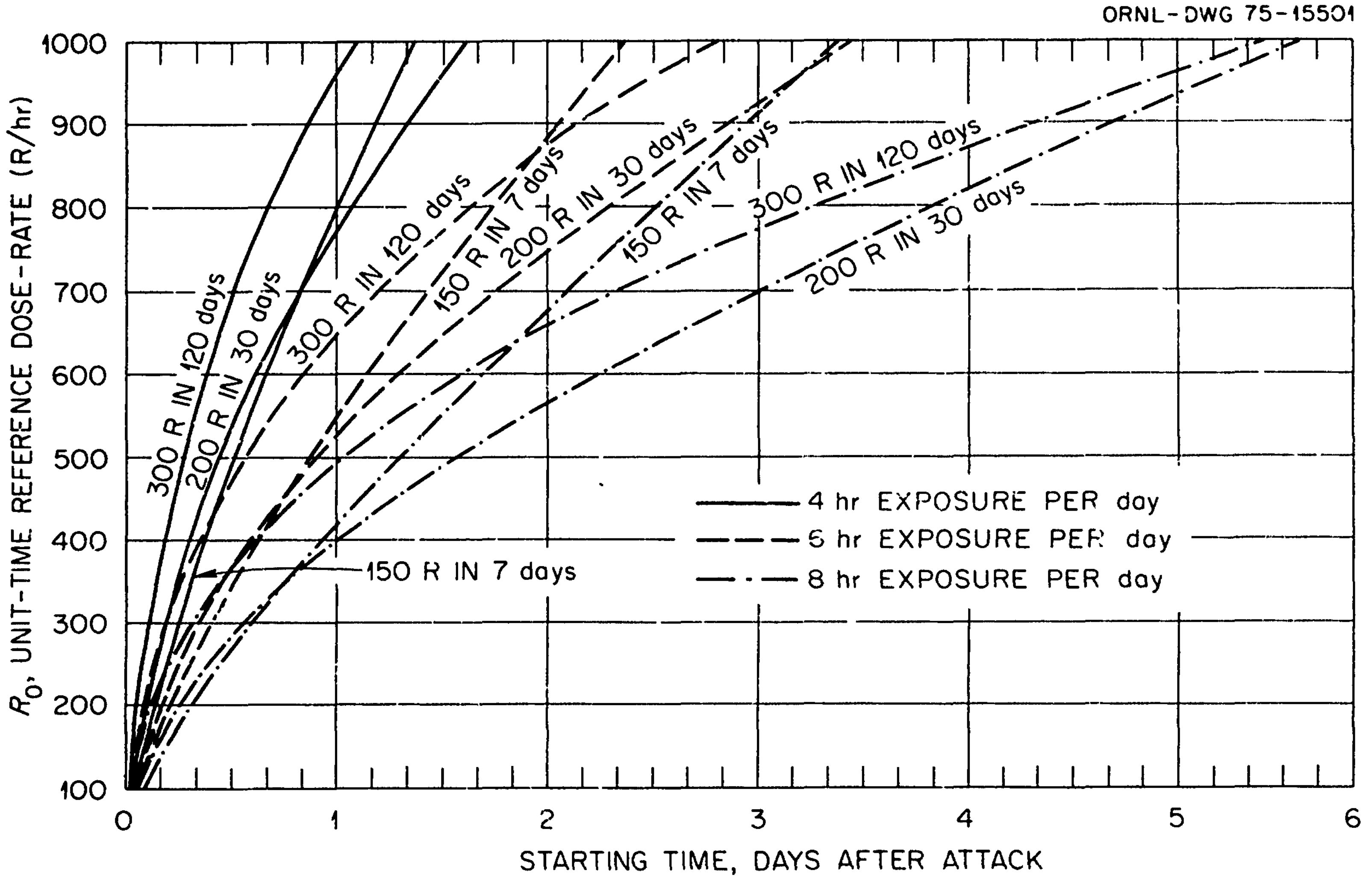

Fig. 4.7 Entry Times into Contaminated Areas for $100 \leq R_o \leq 1000$.

Fig. 4.8. For each specified daily exposure period there are three curves in each of these figures, corresponding to the week, month, and four-month dose accumulation periods specified by the penalty table. When the curves for a specific selected daily exposure period cross each other, the curve which gives the largest entry time should be used, if the penalty table requirements are to be met for all three dose accumulation periods.

The estimated entry times for shift work, as shown in Table 4.11, Figs. 4.7 and 4.8, are based on the assumption that the workers are exposed to negligible radiation during the daily periods between the workshift time in the contaminated area. This assumption implies either that the workers have access to fallout shelters which have a very high protection factor (over 1000), or that they can be transported to a radiation-free area for the time between shifts. These conditions may be unattainable in many locations, because the PF of most shelters will be under 200, and the distance to an uncontaminated area may be too far for practical commutation.

When the PF of shelters is taken into account, the number of possible conditions to consider becomes very large, hence we have investigated only one case as a representative example, viz, the fallout situation in Marshall, Minnesota, as discussed previously on page 44. In this case the unit-time reference dose rate at Marshall (the exposure rate which would have existed at Marshall at one hour after detonation if the fallout cloud had been transported instantly to Marshall) was assumed to be 2500 R/hr. Because of the assumed wind conditions, the fallout cloud does not arrive until around 13.5 hours (average) after the detonation.

We assume that the people of Marshall are in fallout shelters by the time the fallout arrives. Estimated exposures to radiation for people inside shelters of various protection factors are shown in Table 4.12 for various durations ranging from 4 days to 4 weeks. The numbers in Table 4.12 indicate that radiation exposure will be lethal to all occupants in shelters with PF of 5; 30-40% of those in shelters with PF of 10 will die from radiation exposure; all occupants in shelters with PF of 15 will require medical attention for radiation sickness according

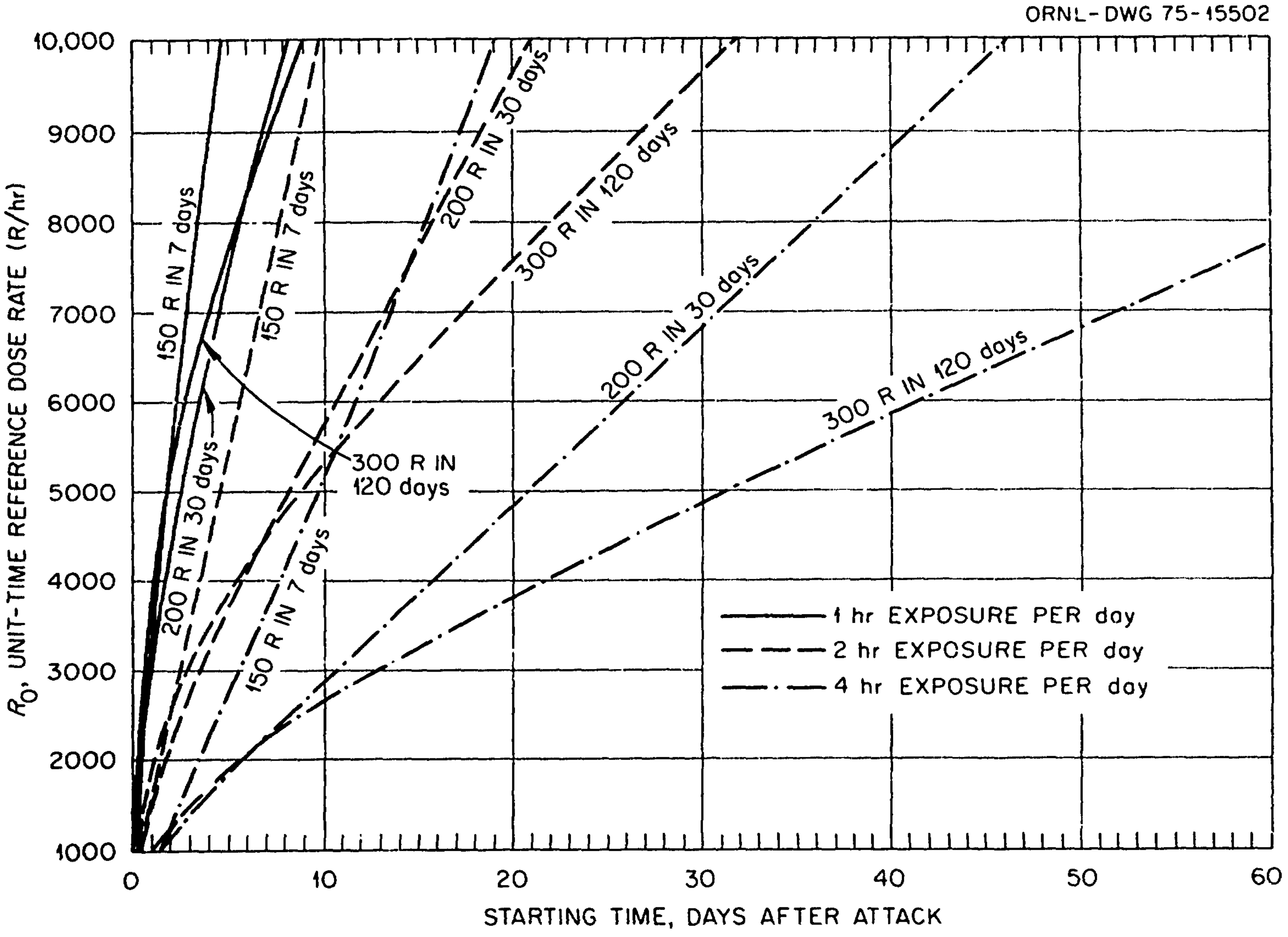

Fig. 4.8 Entry Times into Contaminated Areas for $1000 \leq R_o \leq 10,000$.

Table 4.12

Exposures in Shelters of Low PF. R_o = 2500 R/hr, Fallout Arrival Time 13.5 Hours After Detonation

PF	Exposure (R) Time in Shelter, Beginning When Fallout Arrives					Comments
	4 days	1 week	2 weeks	3 weeks	4 weeks	
5	508	602	710	770	808	100% lethal
10	254	301	355	385	404	30-40% lethal
15	169	201	237	263	269	100% radiation sickness
20	127	151	178	193	202	No medical attention required

to the Penalty Table; and no one will require medical attention for radiation sickness in shelters with PF of 20 or higher.

A PF of 10 is obtained by shielding with earth of about 12-in. thickness, or about 8 in. of concrete; and a PF of 100 is obtained with earth of about 24-in. thickness, or concrete of about 16-in. thickness.

In the shelter with PF of 20, no one can leave the shelter during the first four weeks without the possibility of requiring medical attention according to the Penalty Table.

Occupants in shelters of higher PF may leave the shelter at earlier times for daily work outside in the contaminated regions as indicated in Fig. 4.9. For example, occupants of shelters with PF of 25 may begin a 4-hour daily workshift outside as soon as 6 days after the detonations. If these people worked outside for 4 hours every day for a week, they would "use up" their "safe" (no medical care required) exposure of 150 R, and their subsequent exposures would have to be carefully monitored to keep their exposure below 200 R for the 4-week period, according to the Penalty Table. The functions of these early outside laborers would be first to map the existing radiation levels and then begin decontamination. Areas such as paved streets and buildings can be effectively decontaminated from fallout radiation by scrubbing and hosing, thus enabling others to come out and work with lower exposure to radiation.

It must be emphasized that these tables are presented for planning purposes only. In an actual situation the radiation decay rate may vary from the standard $t^{-1.2}$ rate used for the calculations, and the radiation intensity will vary considerably from one location to another, whereas the calculation of the tables is based on the assumption of a uniform radiation intensity throughout the entire area in which people are working. A representative fraction of the people working in contaminated areas must be wearing dosimeters, and checks should be made and the accumulated dose on each instrument recorded several times each day during the first week of work, and at the end of each day for the next few weeks thereafter.

For planning trips by truck drivers, buses, locomotives, etc., the protection factors listed in Table 4.13, taken from Burson (1974) may be

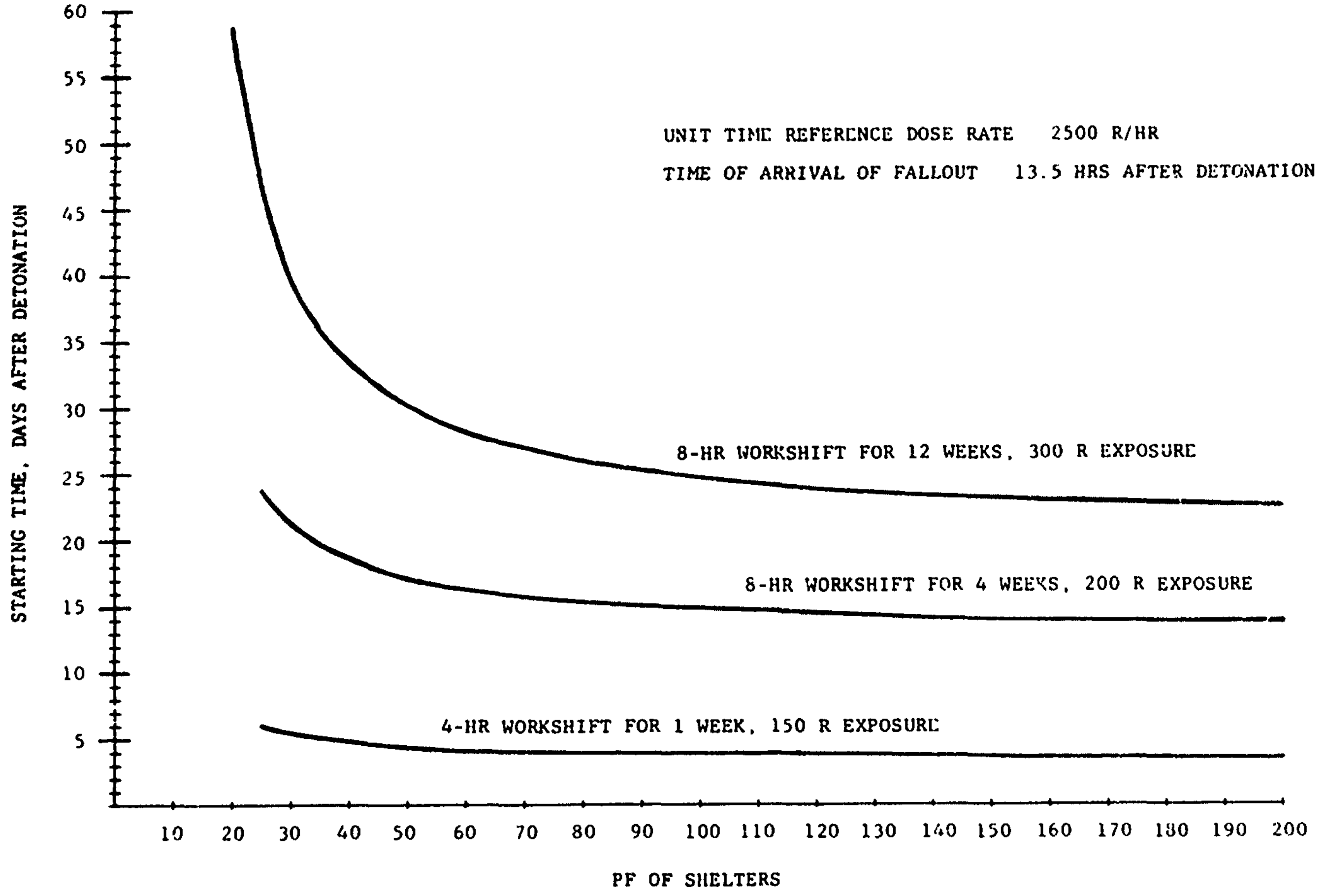

Fig. 4.9 Entry Times as a Function of Protection Factor of Shelters.

Table 4.13

Environmental Radiation Protection Factors Provided by Civilian Vehicles

Vehicle	Position	Protection Factor Range
Commercial bus (common type)	Throughout bus	1.5-2.0
Commercial bus (scenic cruiser type)	Throughout bus	1.5-2.0
School bus	Throughout bus	1.5-1.8
Passenger car	Passenger side (chest)	1.5-1.7
	Driver side	1.5-1.7
Pickup	Driver side	1.9-2.1
Crew cab	Driver side	1.8-2.0
	Back seat	1.8-2.0
Carryall	Driver side	1.7-1.9
	Rear side	1.7-1.9
2-1/2-ton truck	Driver side	1.8-2.0
	Center of bed	1.4-1.6
5-ton truck	Driver side	2.0-2.2
	Sleeper	1.9-2.1
Heavy Truck	Driver side	1.4-1.6
	Center of trailer	2.7-3.1
Fire truck	Driver side	2.7-3.1
	Standing area in back	1.6-1.8
Switch engine	Engineer's seat	3.0-3.5
Railway guard car	Sleeping quarters	2.2-2.6
	Kitchen area	2.4-2.8
	Center area	2.0-2.4
Heavy locomotive	Engineer's seat	3.0-3.5

SOURCE: Z. G. Burson, "Environmental and Fallout Gamma Radiation Protection Factors Provided by Civilian Vehicles," Health Physics, 26, 41-44, 1974.

used to estimate the starting time after detonation for trips through a radiation field of known average intensity, as determined by aerial monitoring first, and then by ground reconnaissance crews. For example, if the average radiation field over the trip area corresponds to a unit-time reference dose rate of 3000 R/hr, and the protection factor is 1.5 for the driver of a heavy truck, then the starting time after the detonation can be estimated from Fig. 4.8 by using the ordinate value of 2000 R/hr, obtained by dividing the average unit-time reference dose rate of 3000 by the protection factor, 1.5. As an example, if a portion of a regular trip involves 4 hours' exposure to this radiation field, the truck driver could start these particular trips five days after the detonation, according to Fig. 4.8.

4.5 The Basis for Radiological Exposure Control Guidelines

Highly effective control guidelines against a specific hazard can be generated if the effects of hazard on man are definitive, so that the consequences of any specific action involving the hazard can be accurately predicted. Unfortunately, the effects of fallout-type radiation on man are not sufficiently definable to permit precise prediction of the consequences of exposure. The effects on mammals other than man have been exhaustively researched by experiment, but the extrapolation of the results to man remains in question. The most thorough studies of the effects of fallout-type radiation on man must fall back on the experience of the Hiroshima and Nagasaki victims, the Rongalap natives, and extrapolations of relatively few radiation accidents and exposures of patients under clinical conditions.

With these observations in mind, it should be apparent that radiological exposure control guidelines established at the present time provide only an initial structure, which radiological officers in a postattack situation may completely change or extensively supplement on the basis of their actual experience.

For emergency personnel, the radiation exposure levels are based on the expectations of early responses which would interfere with the performance of their mission. NCRP Report No. 42 divides the symptoms of exposure to radiation into five groups as follows:

Group I Symptoms. Less than half of this group will vomit within 24 hours after the onset of exposure. There are either no subsequent symptoms or, at most, weakness and easy fatigue. There is a decrease in the blood cell counts. Less than 5 percent will require medical care. All others can perform their customary tasks. Any deaths that occur are caused by complications. Correlated Exposure. Sickness of this type has been seen after brief, whole-body doses of gamma and X-radiation in the range of 50-200 R. An ERD of external gamma radiation of 50-200 R may have a similar effect.

Group II Symptoms. More than half of this group will vomit soon after the onset of exposure and are sick for a few days. This is followed by a period of 1-3 weeks when there are few or no symptoms. During the latent period, typical changes occur in the blood count and can be used for diagnosis. At the end of the latent period, epilation (loss of hair) is seen in more than half, and this is followed by a moderately severe illness due primarily to the damage to the blood-forming organs. Most of the people in this group require medical care and more than half survive. Correlated Exposure. Sickness of this type has been seen after brief, whole-body doses of gamma or X-radiation on the order of 200-450 R. An ERD of external gamma radiation of the same size will probably cause a similar illness.

Group III Symptoms. This is a more serious version of the sickness described as Group II. The initial period of illness is longer, the latent period is shorter, and the main episode of illness is characterized by extensive hemorrhages and complicating infections. People in this group need medical care and hospitalization. Less than half survive. Correlated Exposure. Sickness of this type has been seen after brief whole-body gamma radiation with doses in excess of 450 R.

Group IV Symptoms. This is an accelerated version of the sickness described as Group III. All in this group begin to vomit soon after the onset of exposure, and this continues for several days or until death. Damage to the gastrointestinal tract predominates, manifested by uncontrollable diarrhea, which becomes bloody. Changes in the blood count occur early. Death occurs before the appearance of hemorrhages or epilation. All in this group need care, and it is unlikely that many will survive. Correlated Exposure. Sickness of this type has been seen after brief, whole-body exposure to gamma radiation in excess of 600 R. During protracted

> exposure to external gamma radiation, it is not probable that an illness of this type would be the first evidence of injury.
>
> Group V Symptoms. This is an extremely severe injury in which damage to the brain and nervous system predominates. Symptoms, signs, and rapid prostration come on almost as soon as the dose has been received. Death occurs within a few hours or a few days. Correlated Exposure. Sickness of this type has been seen after brief, whole-body exposure to gamma rays in excess of several thousand R, and to equivalent doses from neutrons.

Essentially the same five clinical levels of severity of acute radiation effects are described in the Radiological Defense Planning and Operations Guide.

The correlation of Group I and II symptoms with radiation exposure doses can be broken down into finer detail as a result of retrospective studies described by Lushbaugh (Tobias and Todd, 1974), in which a large volume of clinical data extracted from hospital charts of 2000 patients given therapeutic total-body irradiation were analyzed to give dose-response relations for the sypmtoms and signs of the prodromal syndrome. These data have been "corrected" for normal man in RFMSF. The correlation of dose with symptoms in these two groups will be of great practical significance to emergency workers in radiologically contaminated areas. The statistically determined single exposures that can be expected to produce these symptoms in 50% of the patients so exposed are shown in Table 4.14. The corrected values for normal man, as adopted by NCRP Report No. 42, are also shown. The table also shows estimates by Lushbaugh of the increased levels of exposures required for the same incidence of response, i.e., 50% of the patients, when the exposure period is lengthened by either fractionating the exposures, or by protracting the dose accumulation by lowering the dose rates.

According to Table 4.14, when total-body exposure of patients occurs promptly in less than one day, the effective doses for 50% incidence of these responses (ED_{50}) are anorexia (loss of appetite) 150 R; nausea, 210 R; vomiting, 275 R; and diarrhea, 350 R. According to Lushbaugh, et. al., (1966), the exposures for their 10% incidence would

Table 4.14

Accumulated Estimated Exposures[a] for 50% Incidence of Physiological Symptoms

Symptom	Exposure, Duration, and Number of Patients (Lushbaugh 1974)			Exposure for Normal Man (1 Day) (NCRP Report 42)	
	1 Day (504) (R)	8 Days (103) (R)	8 Days (1083) (R)	Single Radiation Exposure	95% Confidence Range
Anorexia	150	300	600	180	150-210
Nausea	210	400	750[b]	260	220-290
Vomiting	275	750	900[b]	320	290-310
Fatigue	225	400[b]	c	280	230-310
Diarrhea	348	800	c	360	310-410

[a] Midline upper abdominal dose, rad = 0.66 exposure R.

[b] "Guesstimate"; 20-30 R/day is the apparent threshold of dose rate. Longer exposures at lower rates are ineffective.

[c] Information lacking.

be about one-fourth of that for 50% incidence. In other words, the approximate effective doses for 10% incidence of these responses (ED_{10}) in patients are anorexia, 40 R; nausea, 55 R; vomiting, 70 R; and diarrhea, 90 R. Plans for the accomplishment of a mission by emergency personnel for which the outcome is critical for the survival of many people, such as the delivery of food supplies by truck, should probably take into consideration the ED_{10} rather than the ED_{50} as a basis for estimating maximum exposure during the mission. A truck driver who may require several days to complete his journey would be greatly impaired in performing his driving duty if nausea, vomiting, and diarrhea occurred during the second, third, or fourth day of the trip. Another factor which should be taken into consideration is the prediction, according to analysis by Lushbaugh (Tobias and Todd, 1974, p. 486), that a radiosensitive person who showed, for example, nausea at a low dose would be more likely to show other symptoms and signs of a greater damage per unit of radiation than a radioresistant person in whom nausea did not occur without a much greater exposure.

It is necessary to know at what levels of exposure fatalities will occur, and how quickly, for the purposes of triage and damage assessment. On the human lethal dose problem, Lushbaugh writes, (Tobias and Todd, p. 492): "There is a worldwide willingness to accept the estimate that the exposure that will kill the unattended normal man with 50% certainty within 60 days of exposure ($LD_{50/60}$) is 450 R and that the mechanism of death is damage to his hemapoietic system and defense mechanisms against infection. The degree of acceptance of this 450 R value is surprisingly high in view of its history and its lack of valid support from reported human data." The origin of the 450 R estimate lies buried in the personal notes of some of the ten members of a distinguished committee of U.S. radiotherapists, radiation physicists, and pathologists who polled the U.S. community of practicing radiotherapists to determine what size of single total-body (photon) exposures was considered "safe" and "unsafe". Subsequently, there have been several attempts to check the 450 R estimate from human case histories after both accidental and intentional radiation exposures. These are summarized in Table 4.15 to show how all studies have produced values lower

Table 4.15

Some Clinical and Statistical Estimates of Human Total-Body Radiation Tolerance

	Exposure for $LD_{50/60}$ (Roentgens)
Normal men	
Warren and Bowers (1950)	450
Cronkite and Bond (1960)	528
Langham (1967)	430
Jablon et al., (1969)	614[a]
Patients	
Mathe et al., (1964)	400
Langham (1967)	380
Lushbaugh et al., (1966)	370
Normal men + blast and burn trauma	
Lushbaugh and Auxier (1969)	394[b]

[a] Using RBE of fission neutron component = 4.

[b] Using RBE of fission neutron component = 2.

From: Space Radiation Biology and Related Topics, p. 496. Doses given in rads and rem have been converted to exposure in roentgens by dividing by 2/3.

than the original estimate and seem to indicate "that 450 R is too high to be considered an estimate of midline depth dose (absorbed radiation energy)" (Lushbaugh, op. cit.).

In a postattack situation, where there may be widespread shortage of doctors and medicine, particularly antibiotics, where the sanitary conditions may be unhealthy and morale may be poor, it may be more realistic to assume that 50% of the people exposed to a much lower radiation dose, say 350 R, will become fatalities. Under these conditions, the response to exposure to radiation may be closer to that of patients whose records were studied by Lushbaugh et al., (1966), for whom upper and lower dose-response relations for acute hemotologic syndrome is shown in Fig. 4.10. If we assume the reference dose to be 2/3 the exposure to photons in an average-sized man, then, according to Fig. 4.10, the mid-lethal dose is 250 rads or 375 R of whole-body exposure, the dose for lethality in 10% of those exposed is 75 rads, or about 115 R of whole-body expcsure, and the dose for lethality in 90% of those exposed is 400 rads, or 600 R of whole-body exposure.

Man and other animals appear to have a recovery capability from the harmful effects of exposure to radiation, because it is evident from much research and experience that those exposed to periodic doses, or to a low dose rate over a long period of time can withstand a much greater cumulative dose than when the same dose is administered in a short time of a few days or less. The increases and decreases in the number of cellular elements in the blood appear to be governed by bone-marrow and lymphocytic tissue recovery after total-body irradiation. Various mathematical models have been proposed to predict the reparability of humans, as described by Steward (Tobias and Todd, 1974, pp. 523-564). One of the best known models, devised by Blair (1952, 1953, 1956), gives an equation for ERD, as previously discussed, which is the damage remaining unrepaired at some specific time after exposure. The theory and application of this model is thoroughly described, exemplified, and applied to the postattack fallout situation by Davidson (1957); however, the results are not useful for current planning even if the ERD concept were still in vogue, because the model is based on fallout radiation

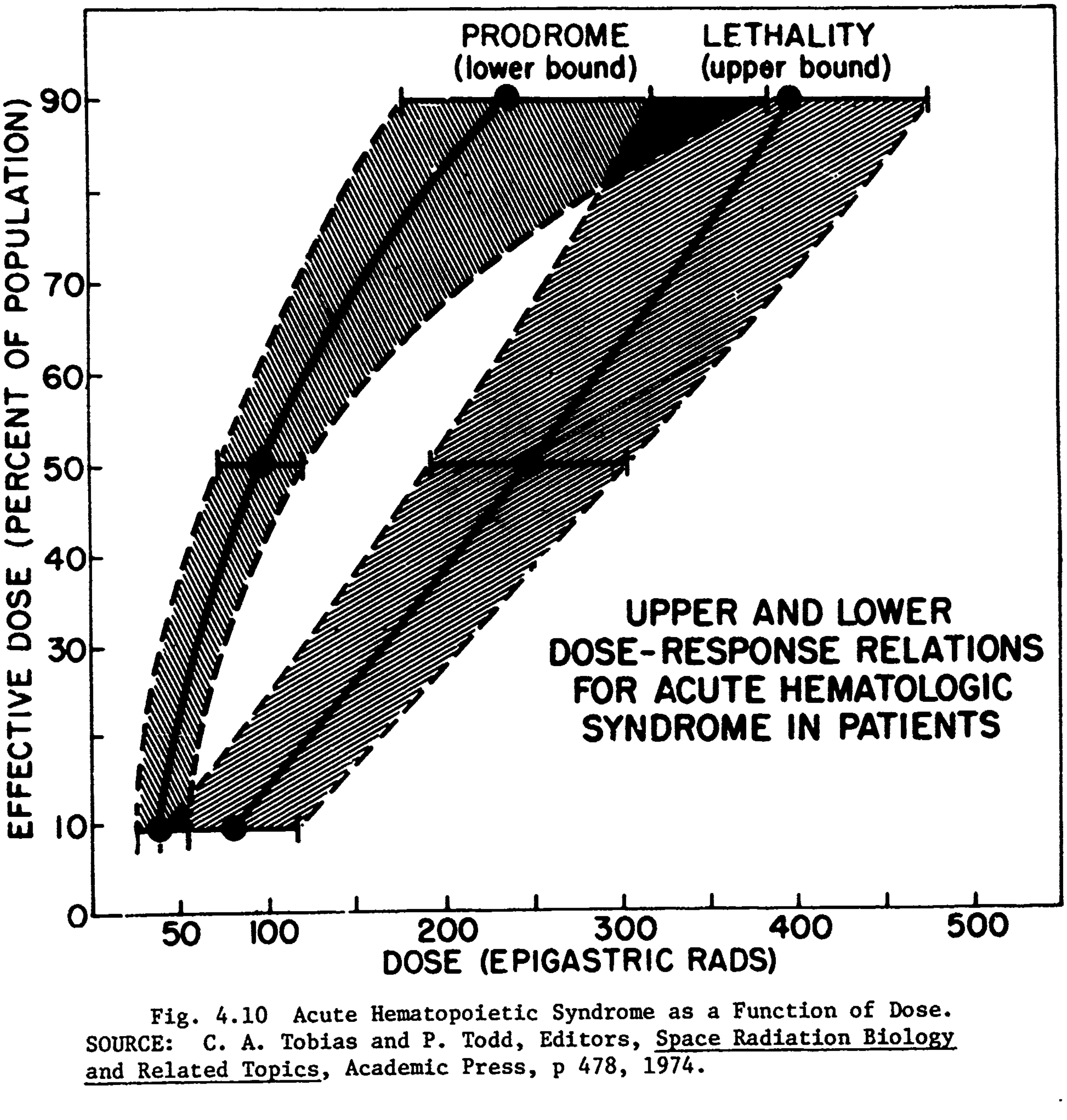

Fig. 4.10 Acute Hematopoietic Syndrome as a Function of Dose.
SOURCE: C. A. Tobias and P. Todd, Editors, <u>Space Radiation Biology and Related Topics</u>, Academic Press, p 478, 1974.

decay according to $t^{-1.33}$ rather than the current standard decay of $t^{-1.2}$. For want of models based on human data, this ERD concept has attained worldwide acceptance by planners for emergencies in which large segments of the population may be exposed to fallout radiations. Reviews of the inadequacies and limitations of this concept (Sacher, 1958; Sacher and Grahn, 1964; Storer, 1959; Langham, 1967; Steward, 1974) suggest its abandonment for human use. In this report, graphs and tables have been presented to indicate exposure guidelines based on both the ERD concept and the "Penalty" table, which is intended to replace the ERD concept.

The ultimate goal of radiation exposure guidelines is to present a general scheme by which RADEF officers and other emergency personnel can minimize the number of fatalities primarily in the first few weeks of a postattack situation, due to radiation hazards. If possible, exposures should be limited with regard to possible late responses such as life shortening, cataracts of the ocular lens, and leukemia. In many locations, these considerations would lead to requirements of shelters with much higher PF than presently considered. The estimated relationships of life-shortening probability and increased probability of leukemia to accumulated dose and intensity of whole-body radiation are shown in Figs. 4.11 and 4.12, respectively, as taken from RFMSF, pages 264 and 265.

4.6 Shelter Survival Conditions in a Hazardous Radiation Field

It is likely that many shelters in the immediate postattack environment will be found to have deficiencies of one kind or another. Some of these deficiencies may involve discomforts, but others may become lethal if not corrected. The latter category of deficiency will be considered here, and methods for coping with the various situations will be discussed.

The basic requirement of a shelter is, of course, that it provide protection from the harmful effects of radiation. The shelter should also be designed and stocked to provide adequate ventilation, water, and

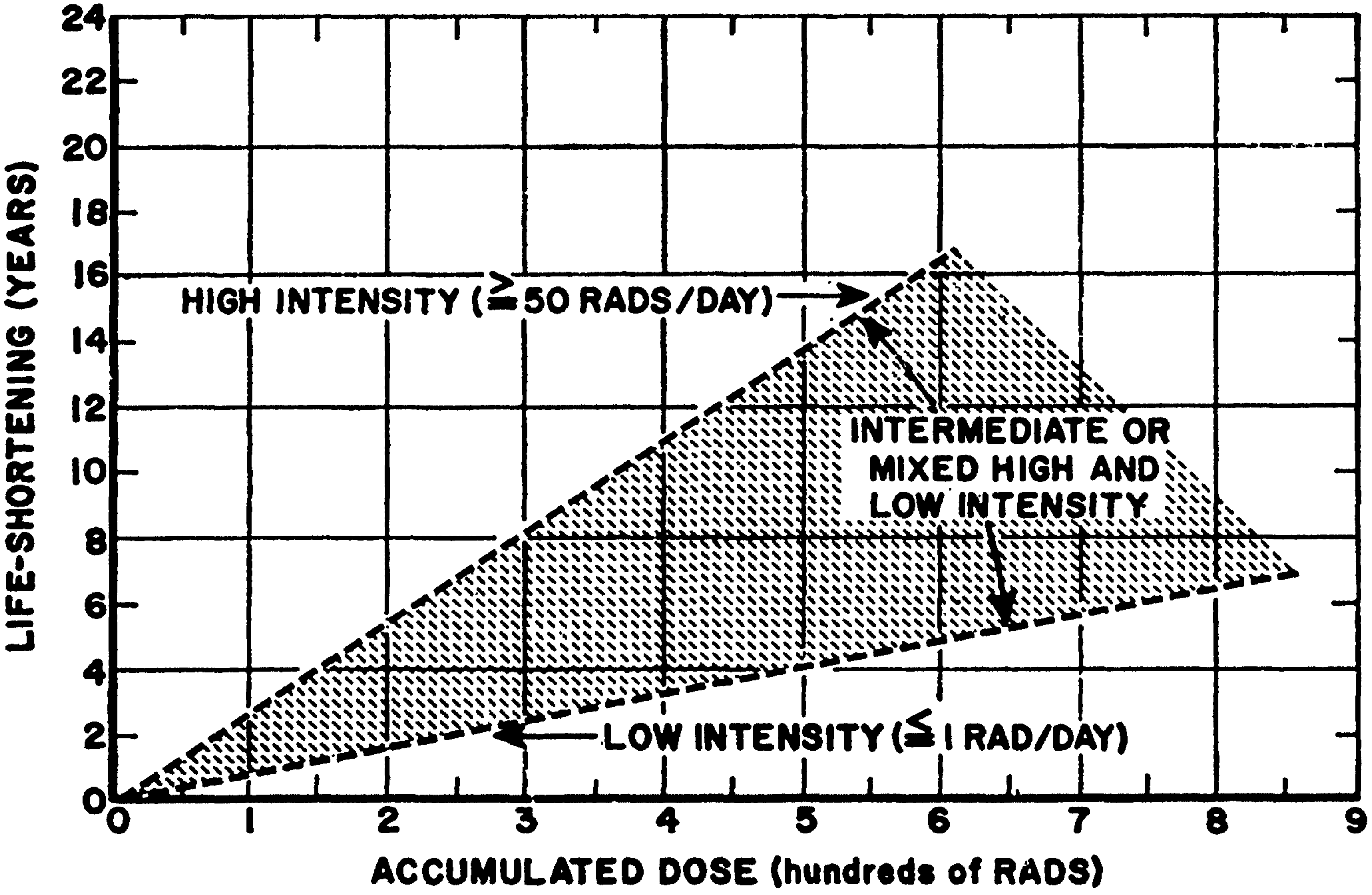

Fig. 4.11 Life Shortening vs Radiation Exposure. SOURCE: Space Radiation Study Panel, Radiobiological Factors in Manned Space Flight, Publication 1487, National Academy of Sciences, National Research Council, p 264, 1967.

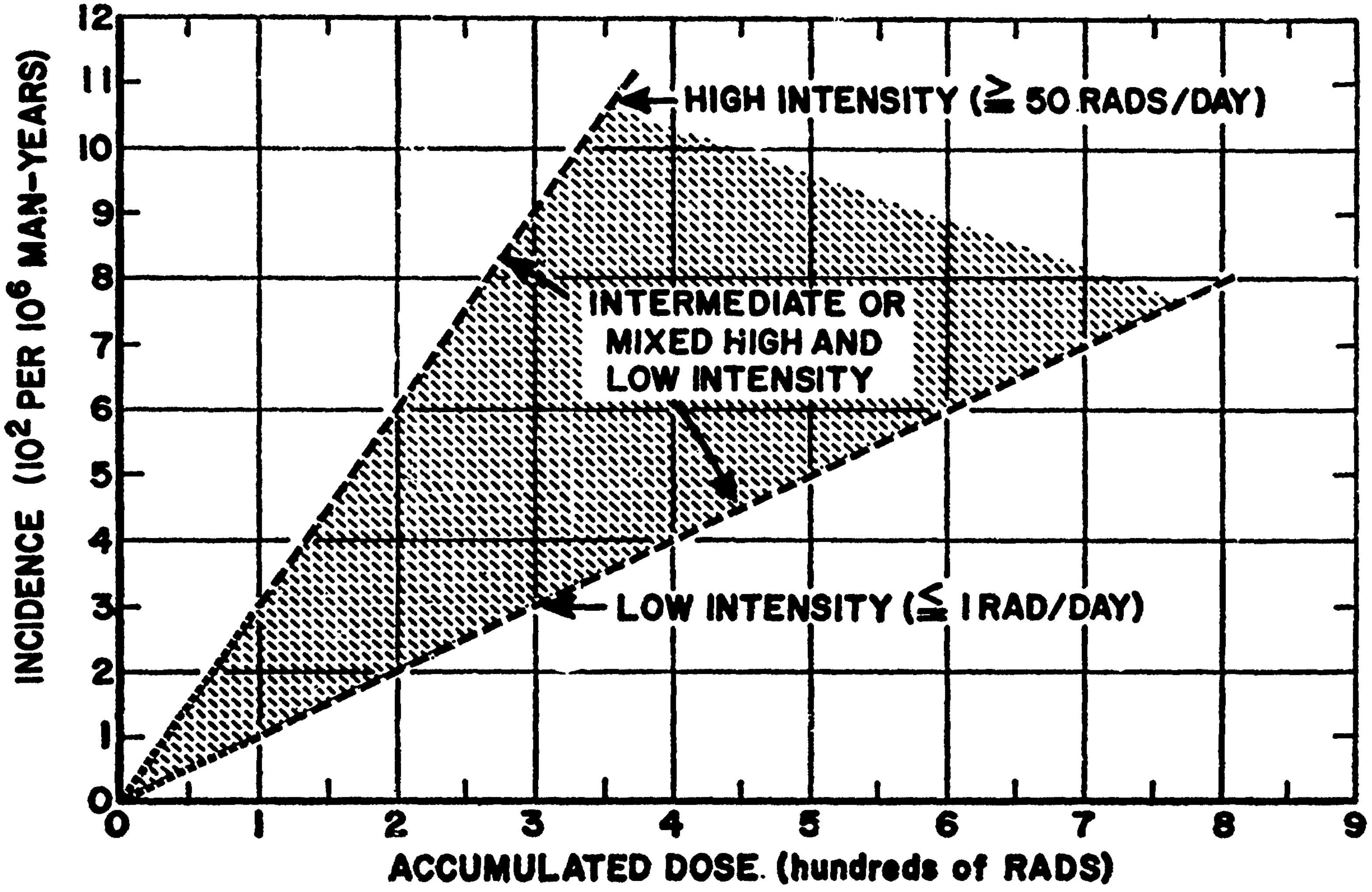

Fig. 4.12 Incidence of Leukemia vs Radiation Exposure. SOURCE: Space Radiation Study Panel, Radiobiological Factors in Manned Space Flight, Publication 1487, National Academy of Sciences, National Research Council, p 265, 1967.

food. A deficiency in any one of these four requirements may result in the necessity for one or more occupants to leave the shelter in search for help or supplies. Such forays may not be necessarily hazardous if the people leaving the shelter knew where to go or what to do.

The survival probability of occupants in a shelter can be greatly enhanced by having the following items on hand and in good working condition: a radiation survey meter and/or dosimeter, a telephone or two-way radio, and an AM radio receiver. The existence of these three survival items in the shelter in addition to its fulfillment of the four basic requirements listed above provide maximum survival probability for the occupants of the shelter through the shelter-phase of the postattack period.

If one of the basic requirements of the shelter, either the PF, ventilation, water or food supply is inadequate, it will become extremely urgent that some action be taken to prevent fatalities, if the shelter is situated in a potentially lethal field of fallout radiation. Suppose that while enroute the fallout radiation intensity threatens to become about ten times or more stronger than anticipated, due to a shift in wind direction. If the shelter has an AM radio and/or radio or telephone communication with the outside world, the occupants may possibly become informed of the possibility that the anticipated fallout will exceed their shelter's PF before the fallout arrives, thus enabling them to evacuate to a better shelter, or take steps to improve the PF of their shelter. The latter option would usually be open to those who had constructed an expedient shelter, but would not always be a possibility for those in large community shelters.

As an example of the opposite extreme situation, suppose the shelter doesn't possess any of the three survival items--it has no radio or telephone connection to the outside world and no radiation survey or dosimeter instruments. In this situation, an extra heavy fallout situation, as hypothesized above, will arrive without detection or warning, and the first prodromal reaction to the radiation exposure in the shelter, i.e., nausea and vomiting, could easily be interpreted by the occupants as the symptoms of an infectious GI virus. The total dose to each occupant could exceed the lethal exposure before anyone might realize that they were being over-exposed. This gruesome possibility points out the necessity for each shelter to have some kind of radiation detector. If an official CD survey meter or dosimeter is not on hand, then the occupants should construct an electroscope type of radiation detector, such as the Kearny Fallout Meter (Kearny, 1975). Instructions for constructing these meters should be widely disseminated, because there are not enough CD dosimeters and survey meters to supply all shelters, especially under the circumstances of a crisis relocation where many people will be improvising shelters or constructing expedient shelters. For the remainder of this discussion, we will assume that the shelters are equipped with some type of radiation detector.

Suppose that the PF of the shelter is adequate, but, through overcrowding and/or poor design, the ventilation is inadequate. Long before the level of carbon dioxide becomes lethal there will be a feeling of stuffiness and/or claustrophobia and, in the summer, overheating, among the occupants, to the extent that some will want to rush outside. In this situation the radiation meters may serve to convince the occupants that they should not leave the shelter. If two-way communication is available to the outside world, instructions may be obtained as to the availability of nearby shelter space to which some of the occupants may transfer; or, instructions may be received on how to improve the ventilation system of the shelter. In many large community shelters which are located inside large buildings, the radiation survey meters may be used to locate areas in the building where occupants may reside temporarily in order to relieve the burden on the ventilation system of the main shelter. Instructions for making improvised ventilating devices, such as the Kearny Air Pump, should be widely disseminated, and available to every shelter.

If there is inadequate water or food in the shelter, radio or telephone contact may be used to arrange for an emergency delivery, or to determine the closest point of supply to which volunteers from the shelter will run or drive to get the necessary supplies. The level of radiation intensity in the vicinity of the shelter should be monitored so that a fairly accurate prediction can be made of the dose to which the emergency crew will be exposed.

5. COMMUNICATIONS

5.1 AM Radio Broadcast

After a large nuclear attack on the United States, it will be essential that AM radio broadcasting facilities continue to function to the extent that network transmissions can be made which cover the entire area of the country. This capability is necessary to assure continuity of government, maintain morale, provide news and instructions, and alleviate the sense of isolation which may be prevalent, especially in areas where people are forced to stay in shelters for several weeks due to heavy fallout conditions. Every shelter should have at least one portable transistor radio. It may be necessary to run a wire to the outside to which the radio antenna is attached in order to obtain reception inside the shelter.

There are over four thousand commercial AM broadcasting stations in the U.S., and most of them are located outside target areas. The two greatest threats of nuclear war to the AM broadcast capability are (1) EMP (electromagnetic pulse) from the nuclear detonations and (2) lack of provision for operation under radioactive fallout conditions. Widespread electrical power failure is not a major threat to the AM broadcast capability because many key stations have been supplied by DCPA with emergency generators, with diesel oil storage for at least two weeks' operation under full load. The effects of nuclear EMP on those AM radio broadcast stations which are a part of the EBS (Emergency Broadcast System) have been analyzed by Nelson (1971) and Barnes (1974). Considerable uncertainty exists as to how many stations will remain functional after the EMPs of a nuclear war, but the prospect appears good that there will be adequate AM broadcasting capability within a few hours after the attack, partly due to protective devices and measures taken by some of the stations, and partly due to the usual practice of retaining spare parts on hand which would enable station engineering personnel to make repairs. Many stations maintain two transmitters with provision for rapid switching between them, which reduces the possibility of EMP damage to the transmitter which is not in operation (Nelson, 1971).

In addition to emergency generators, DCPA has provided most EBS stations with fallout protection for the studio, and with radiation survey meters. During the crisis period preceding a potential nuclear attack the studio fallout shelters can be stocked with any provisions which may be lacking, and additional preparations may also be made to prevent or repair damage from EMP.

The EBS will provide much necessary and useful information during the crisis period and also after the attack. One important bit of information which should be given before an attack is the precaution necessary to protect two-way radios from damage by EMP. For example, when tactical warning is given that a nuclear attack is imminent, owners of radio receivers should disconnect or fold down or telescope the antennas on their equipment to make them as small as possible (Barnes, 1974). Typical portable AM receivers do not have a long antenna, and are therefore not vulnerable to EMP. However, if an external wire is hooked to the radio antenna to improve reception inside a shelter, that wire should be disconnected for several hours after tactical warning is given, until the threat of EMP from nuclear detonations has diminished.

5.2 Two-Way Communications

Although much of the U.S. land-line communications network has been hardened against blast and EMP, it is not the policy of the Federal Civil Defense Guide to rely completely on telephones for postattack communication. Telephones may continue to operate in non-target areas for local calls, and telephones installed in large community shelters will be extremely useful. Telephones in homes where basements are used for shelters may also be used for early postattack emergency messages by shelter occupants who feel that the risk of brief exposure to radiation is offset by the possible gain achieved by exchanging a message. Some telephone exchanges are built with shielding against radiation so that operators may continue to work in them after a nuclear attack. Instructions given on local AM broadcasts should give information on whether telephones are working, and what numbers to dial for information and assistance.

In recent years, partly because the breakthrough in transistor technology resulting in low costs and compact size, there has been a tremendous growth in the use of CB (Citizens Band) radios, and other types of transmitters, as shown in Figs. 5.1-5.3. Suitably distributed, there would be enough (about 4 million, 1973) to have one in every shelter (about 1.8 million).

The number of transmitters of all types show a sharp increase in 1970-1971, except those mobile units used by industry (see Fig. 5.2), which decreased because of the sharp decline in petroleum exploration by industry due to Congressional changes in the tax structure on the petroleum industry.

A breakdown of transmitters authorized by the FCC in 1973 is listed in Table 5.1 taken from the FCC 1973 Annual Report, p. 298.

It is estimated that about 80% of all semi-trailer trucks are equipped with CB radios, and about 56% of those with radios are licensed, according to a poll by FCC. Portable CB units can probably transmit to the outside from most shelters, and would be especially useful in expedient shelters. If the unit cannot transmit through the shelter walls, then an external wire may be mounted and hooked to the antenna. The same precautions should be taken concerning damage from EMP as described above for AM radios. During the crisis period preceding a potential nuclear attack, one or two sets of fresh batteries should be purchased for each portable radio device. An assessment should be made to determine whether enough batteries exist in retail outlets to fulfill this requirement.

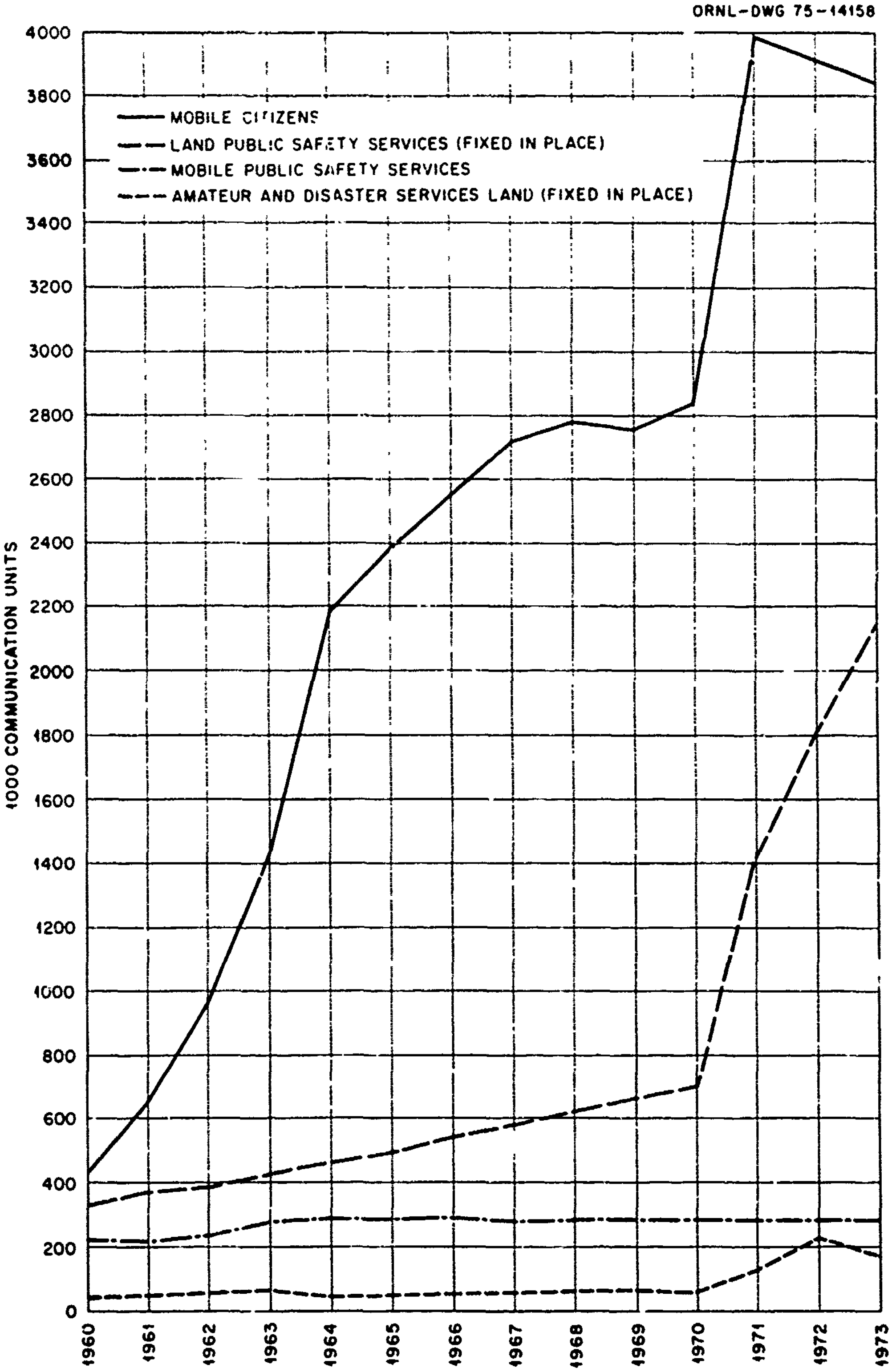

Fig. 5.1 Citizens Band and Amateur Radio Transmitters, 1960-1973.

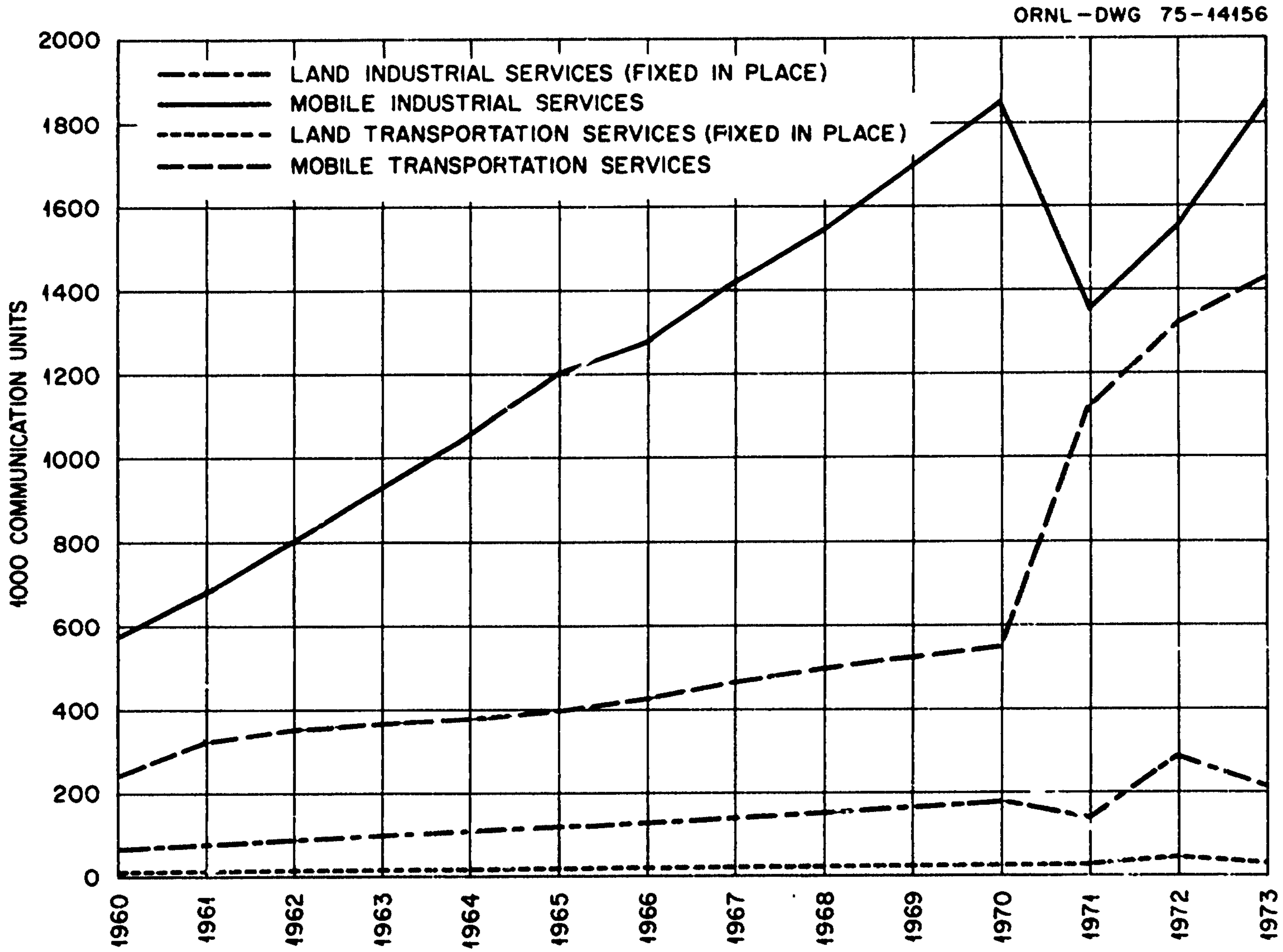

Fig. 5.2 Industrial and Transportation Radio Transmitters, 1960-1973.

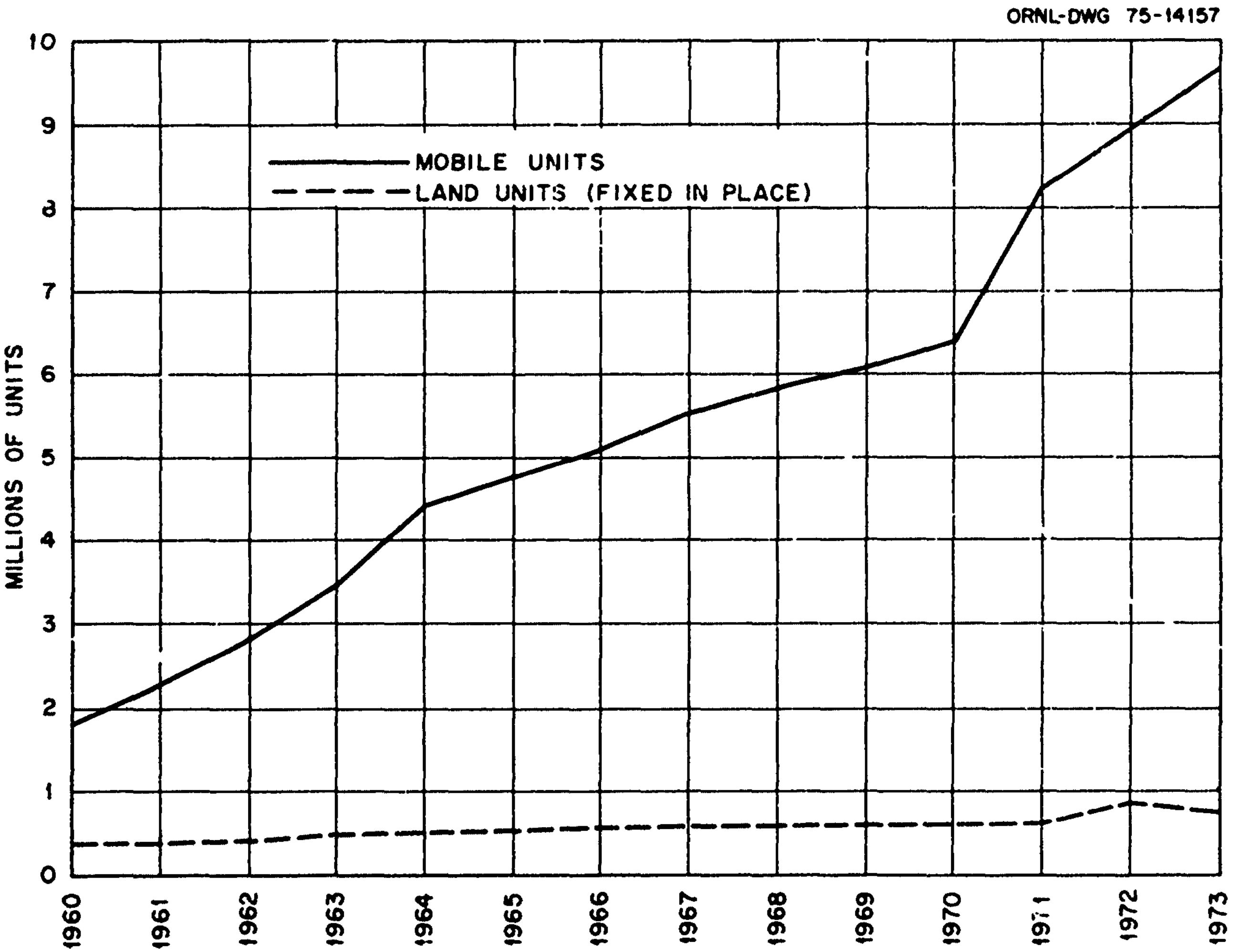

Fig. 5.3 Total Authorized Radio Transmitters, 1960-1973.

Table 5.1

Transmitters Authorized by FCC, 1973

Class of Station	Base or Fixed	Mobile	Total
Aircraft group	---	139,486	139,486
Aeronautical and fixed group	9,987	---	9,987
Aviation auxiliary group	977	5,373	6,350
Aviation radionavigation land	2,562	---	2,562
Civil air patrol	9,334	18,668	28,002
Operational fixed aviation service	61	---	61
Total aviation services	22,921	163,527	186,448
Police	47,401	1,114,904	1,162,305
Fire	25,487	340,521	366,008
Local government	29,489	307,939	337,428
Highway maintenance	24,531	208,688	233,199
Forestry conservation	40,093	104,849	144,942
Special emergency	8,458	61,852	70,310
State guard	388	1,114	1,502
Operational fixed public safety service	2,659	---	2,659
Total public safety services	178,506	2,139,867	2,318,373
Special industrial	37,290	371,444	408,734
Business	100,176	877,539	977,715
Power	16,718	285,844	302,562
Petroleum	11,986	98,667	110,653
Manufacturers	3,731	68,422	72,153

Table 5.1 (cont'd)

Class of Station	Base or Fixed	Mobile	Total
Manufacturers	3,731	68,422	72,153
Forest products	3,079	40,249	43,328
Industrial radiolocation	18,209	107	18,316
Motion picture	246	1,598	1,844
Relay press	349	8,360	8,709
Telephone maintenance	2,393	89,898	92,291
Operational fixed industrial services	14,729	---	14,729
Total industrial services	208,906	1,842,128	2,051,034
Railroad	14,887	1,145,721	1,160,608
Taxicab	3,722	126,166	129,888
Automobile emergency	2,437	23,102	25,539
Interurban-passenger (motor carrier)	108	10,121	10,229
Interurban property (motor carrier)	2,138	45,362	47,500
Urban passenger (motor carrier)	683	18,873	19,556
Urban property (motor carrier)	2,376	53,244	55,620
Operational fixed land transportation services	2,509	---	2,509
Total land transportation services	28,860	1,422,589	1,451,449
Citizens:			
Class A	1,980	12,680	14,660
Classes C and D	0	3,828,115	3,828,115
Total citizens services	1,980	3,840,795	3,842,775

Table 5.1 (cont'd)

Class of Station	Base or Fixed	Mobile	Total
Amateur	270,694	---	270,694
R.A.C.E.S.	8,625	---	8,625
Disaster	186	---	186
Total amateur and disaster services	279,505	---	279,505
Total safety and special services stations	720,678	9,408,906	10,129,584

6. THE FOOD AND WATER SITUATION

6.1 Water Supply

For most areas designated as reception areas in the U.S., there are abundant water sources. In many localities, local water purification equipment will be overloaded if evacuees and hosts attempt to use water at the pre-crisis rate of about 100 gal/day per person. Reduction in the use of purified water for bathing and washing will result in an adequate supply of drinking water for nearly all areas. In those few areas where the local water purification equipment will not be adequate to handle the overload, there will be other sources of water from streams and dams which can be purified by mobile emergency water purification units. Chlorine bleaches can be used to make many water sources safe for drinking. At worst, some people may use water from various sources for drinking without purification, and there is a danger that some of these people may consequently suffer from various dysenteries, typhoid, hepatitis, and other water-borne diseases. In general, there will be enough water such that people will not die of thirst in the postattack situation.

There may be a problem in some locations with soluble radioactive components of fallout, such as iodine, which may require special treatment of water by filtration, or distillation, or which may be counteracted by prophylactic measures. Radioactive iodine will not be present in well-water, but may be prevalent in lakes in fallout-contaminated areas (Brown, et al., 1968). If this water must be used it should be filtered. Filtration through about 5 in. of soil will remove the iodine, as determined by Kearny (Private Communication). Extensive research on expedient methods to remove radioactive contaminants from water has been performed by the Corps of Engineers.

If iodine is not removed from the water, doses of stable iodides should be taken orally to block thyroid uptake of the radioactive iodine (Ramsden, et al., 1967). The required doses range from 35 mg every 12 hours to 250 mg every 48 hours, depending on the size and activity of the subject.

Calculations by Brown, et al., (1968) indicate that the radiation dose due to consumption of water which contains other soluble nuclides, such as strontium and cesium, would be negligible for a 1600 MT attack but could be harmful for larger attacks. Filtration of water through soil removes these nuclides as well as iodine.

6.2 The Food Situation

The problem of supplying the relocated population of the U.S. with food during the crisis period has been investigated by Billheimer et al., (1975). Of the stocks that might be available at regional and local levels for distribution under crisis relocation conditions, Billheimer et al., found that wholesalers have an average of three weeks of inventory, retail outlets have an average of two weeks inventory, and consumers have an average inventory of two weeks, measured against current consumption levels. Food stockpiles under federal control are insignificant. Wholesale stocks tend to be held in regional distribution centers located in the largest cities, in target areas. Nearly two-thirds of the urbanized risk areas scheduled for evacuation under a crisis relocation strategy rely on metropolitan areas other than their own for at least 50% of their processed wholesale food supplies. Billheimer et al., concluded that the most effective strategy for food distribution under crisis relocation conditions is to allow agricultural output and major processing plants to follow normal distribution channels and to continue using risk area wholesale facilities to serve the evacuated population. Although this strategy may be the most effective, it will place a stress on transportation to distribute over the extra long lines, and retail outlets in the hosting areas will be strained to find adequate storage space and sales facilities. The transportation system will be further strained by the demand for extra supplies to prepare fallout shelters with reserve subsistence for at least two weeks' duration.

The kinds and relative quantities of food purchased by the typical American family is shown in Table 6.1, based on a survey taken by the U.S. Department of Agriculture.

Table 6.1

Distribution of the Food Dollar in Northeastern USA, 1965-66

Food Group by Urbanization	Spring	Summer	Fall	Winter
Meat, poultry, fish, eggs:				
All urbanizations	36	36	38	39
Urban	37	38	39	40
Rural nonfarm	34	33	36	37
Farm	34	30	33	38
Milk, cream, cheese:				
All urbanizations	13	12	14	13
Urban	12	12	13	13
Rural nonfarm	14	12	15	14
Farm	15	13	20	14
Grain products:				
All urbanizations	12	11	12	12
Urban	12	11	11	11
Rural nonfarm	13	12	13	13
Farm	12	13	11	12
Fresh vegetables (excluding potatoes):				
All urbanizations	5	6	4	4
Urban	5	6	4	4
Rural nonfarm	4	8	4	4
Farm	5	12	6	4
Fresh fruit:				
All urbanizations	4	5	4	4
Urban	4	5	4	4
Rural nonfarm	4	5	4	4
Farm	6	7	5	5
Commercially processed vegetables and fruit:				
All urbanizations	4	3	4	4
Urban	4	3	4	4
Rural nonfarm	4	5	4	4
Farm	3	2	3	4
Potatoes, sweetpotatoes (fresh and processed):				
All urbanizations	2	2	2	2
Urban	2	2	2	2
Rural nonfarm	3	3	2	2
Farm	3	4	2	2
Fats and oils:				
All urbanizations	3	3	3	3
Urban	3	3	3	3

Table 6.1 (cont'd)

Food Group by Urbanization	Spring	Summer	Fall	Winter
Rural nonfarm	4	4	4	3
Farm	4	4	4	5
Other (beverages, sugar, sweets, juices, etc):				
All urbanizations	21	22	19	19
Urban	21	20	20	19
Rural nonfarm	20	20	18	19
Farm	18	15	16	16
Total	100	100	100	100

If the CRP-2B attack takes place, wholesale food stocks in risk areas will most likely be destroyed, or become inaccessible for many weeks. Furthermore, according to studies by FPA (Federal Preparedness Agency) with the UNCLEX attack, which is similar to the CRP-2B attack, approximately 60% of the U.S. food processing plants will be destroyed by direct weapons effects, such as blast and fire. Most of the food in the form of livestock and poultry will become unavailable after the attack, either because much of the stock will be killed by fallout, for which little protection is being provided, or it will be impossible to process the livestock because of the lack of transport facilities and/or processing plants at convenient locations. Many of the surviving food processing plants will be unable to operate because of power outages or because of intense radiation from fallout.

The outcome of the cumulation of these effects on the food situation in the U.S. is uncertain. In most relocation areas, the total reserve of processed food will not exceed three or four weeks supply. Some of the surviving processing plants may be capable of tripling their output of products depending on grains, such as flour, corn meal, corn oil, margarine, and secondary products such as bread, cereals, noodles, spaghetti, etc., to the extent that lack of meat and dairy products can be tolerated in the areas which can be supplied by these processing plants. In many areas, the absence of adequate food processing plants may require that people turn to primitive methods of preparation of raw grains in order to survive. Many old recipes have been rediscovered as a result of the movement to communes in the U.S., and some of these and others have been tested and are described by Kearny (1975).

The innate capability of grain to be stored almost indefinitely with little care and without spoilage, and its suitability as a nearly complete food for human consumption, has drawn the attention of strategic planners throughout the entire known history of man. Currently, one of the principal slogans of Mao which is echoed throughout Red China is "Dig tunnels deep, store grain everywhere, prepare for war and disaster. . ." The Soviet Union is also preparing to store massive quantities of grain (USSR National Affairs, 1975), and is currently in the last five-years stage of a "shock construction" project to build storage facilities for 2.5 billion bushels of grain, enough to supply the Soviet population with 300 days of food.

The U. S. has consistently produced more grain annually than required by its population for human consumption. Since 1956, the total production of corn, wheat and soybeans annually in the U.S. has always been more than twice and occasionally three times the quantity needed annually by the U.S. population for adequate survival requirements, as shown in Fig. 6.1. The amount required per day for survival is estimated to be an average of two pounds of grain per person, based on a requirement of an average of 3000 calories per person per day (Garland, 1972). The extra quantity of grain produced is used primarily for feeding livestock and for exportation. The amount of grain on hand does not always exceed the annual minimum survival quantity, as shown in Fig. 6.2. From 1954 through 1965, the total quantity on hand always exceeded the minimum annual survival quantity, but it became less at times in 1966, 1971, 1973, and 1974, during certain quarters of the year. From Fig. 6.2, it is apparent that 30 to 40% of the annual U.S. grain production for the years 1965 through the present would be adequate for the minimum annual survival quantity.

Nearly all the grain stored on farms and 50-70% of the grain stored off farms, depending on the season, would not be affected by a nuclear attack. Grains stored off farms is distributed among local town and county elevators, warehouses, processing plants, and large central terminals. Many processing plants and most of the large terminals would be destroyed by the nuclear attack, but the bulk of off-farm storage is in the local elevators in small towns which would not be affected by the blast and fire of nuclear weapons detonated on major targets.

The corn, wheat, and soybeans stocks since 1945 are shown for the January 1 and April 1 reporting dates to USDA in Fig. 6.3, and for the July 1 and October 1 reporting dates in Fig. 6.4. The quantities reported on these dates reflect the actual situation of two to three months preceding the date. Thus, Fig. 6.3 indicates that through the winter months, the stocks on farms alone are usually sufficient for the

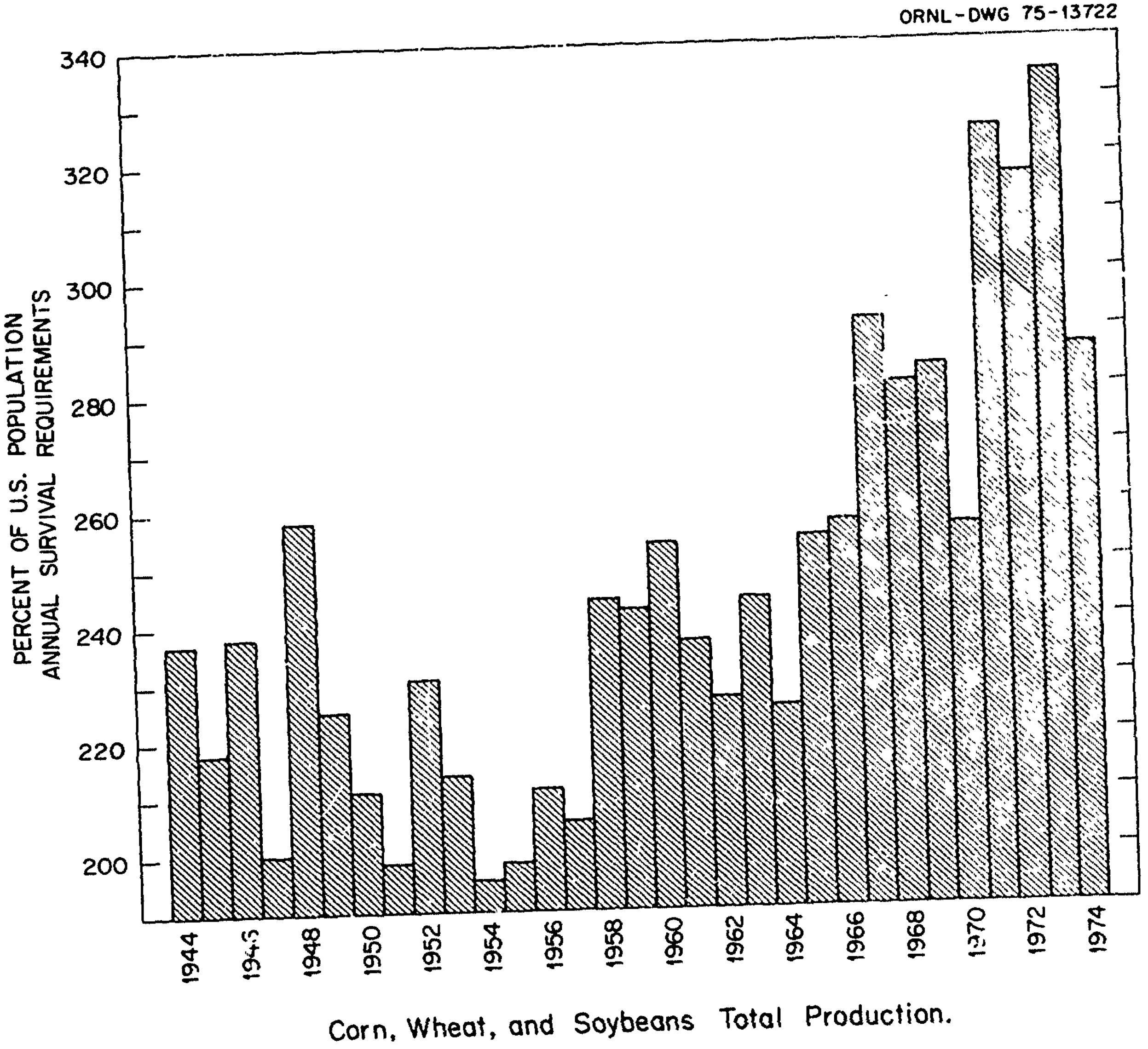

Fig. 6.1 Total Production of Corn, Wheat, and Soybeans as Percent of U.S. Population Minimum Survival Requirement.

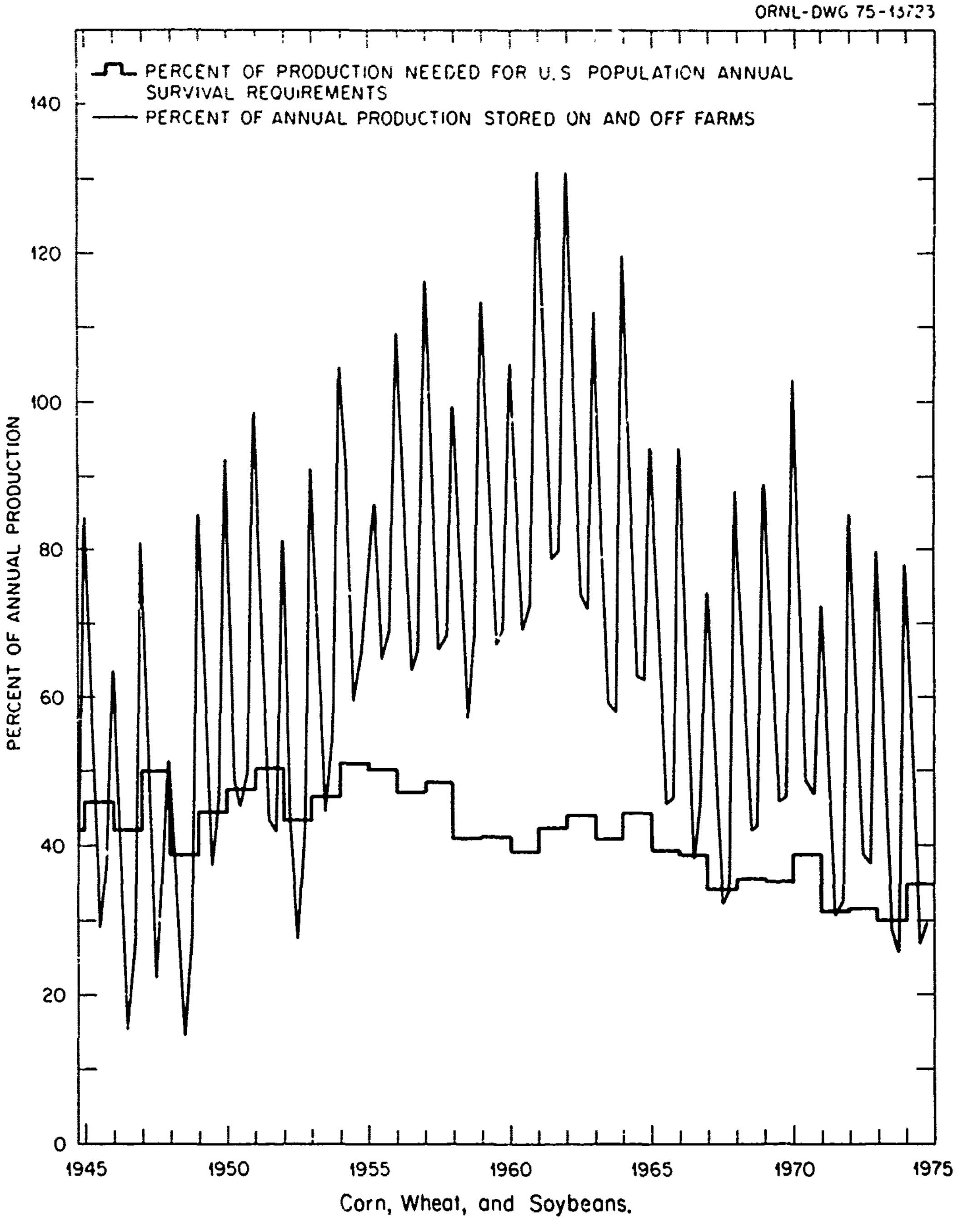

Fig. 6.2 Corn, Wheat, and Soybeans Stored On and Off Farms as Percent of Total Production.

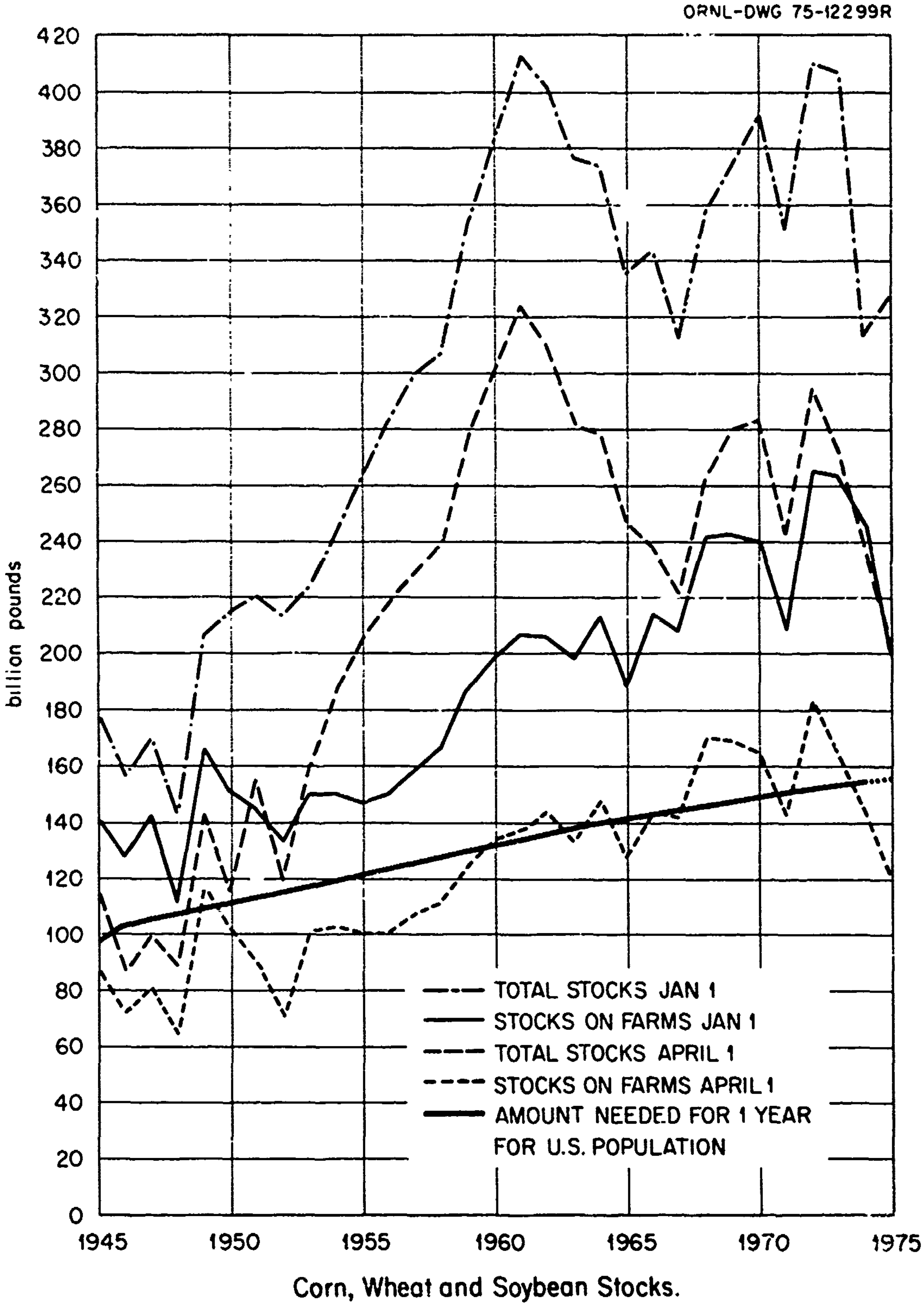

Fig. 6.3 Corn, Wheat, and S·vbean Stocks, January and April.

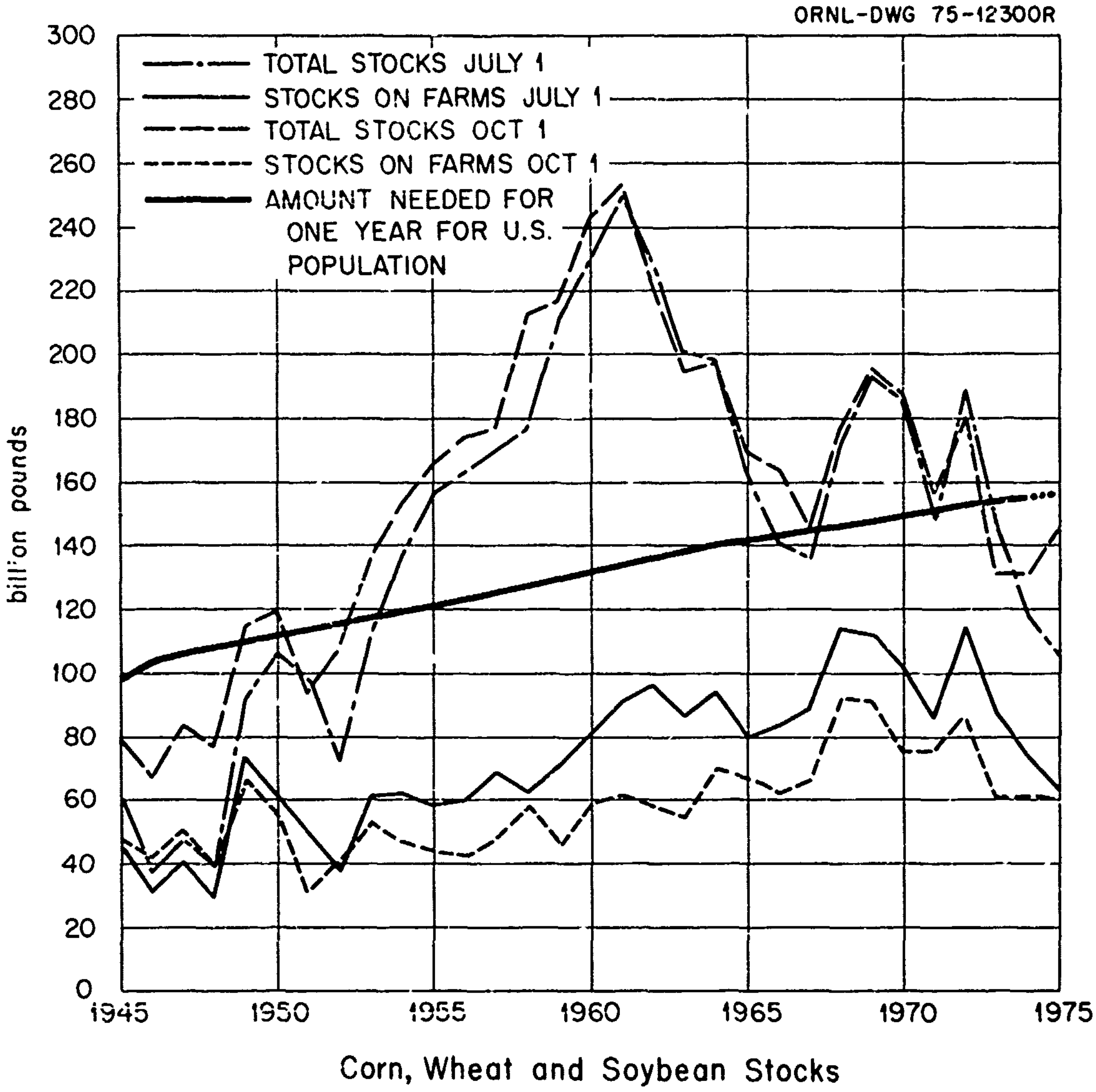

Fig. 6.4 Corn, Wheat, and Soybean Stocks, July and October.

minimum annual survival quantity. The peak total on- and off-farm quantity of grains stored was 410 billion pounds, or about 6.8 billion bushels, in 1961 and again in 1972, and the peak on-farm quantity of grain stored was about 265 billion pounds, or about 4.4 billion bushels, in 1972. These peak numbers are an indication of the total grain storage capacity in the United States. The current trend for on-farm storage capacity (Feedstuffs, 47 (48), p 1, November 24, 1975) is to increase it significantly, because farmers are becoming increasingly aware of the global market for grains with its associated large variation in price, and increased storage capacity enables them to hold their grain for the most favorable price. The price of wheat per bushel more than doubled in 1973, as shown in Fig. 6.5, primarily as a result of large sales to the Soviet Union.

Total grain stocks during summer and fall months, as shown in Fig. 6.4 have been adequate for a year's minimum survival for the years 1954-1966, but not during the years of 1974 and 1975. On-farm stocks by themselves have been adequate for at least six months' survival supply for the nation during the spring and summer months for all years since 1954. If a nuclear attack occurred during the spring or summer, the stocks on farms would be adequate for survival through September or later, and the harvest, although partially destroyed by fallout, would provide adequate food reserve through the next harvest.

Plant responses to irradiation, such as survival, growth inhibition or stimulation, and seed or grain yield, depend on dose, dose rate, plant species, type of radiation, and the developmental stage of the plant when irradiated. Killion and Constantin (1975) calculate that the dose required to reduce the yield to 50% is 2-4 kilorads in wheat and corn, and 8-12 kilorads in soybeans. Crops are planted at different times at different latitudes, hence if the attack occurs on a certain day, simultaneously as far as crops are concerned, crops which have just emerged from the ground will be more severely affected than those which have attained a good stand, or those which have not yet emerged from the ground.

A complex computer program has been developed by Ryan, Garza, and Brown (1974) for the purpose of estimating damage to crops by beta and

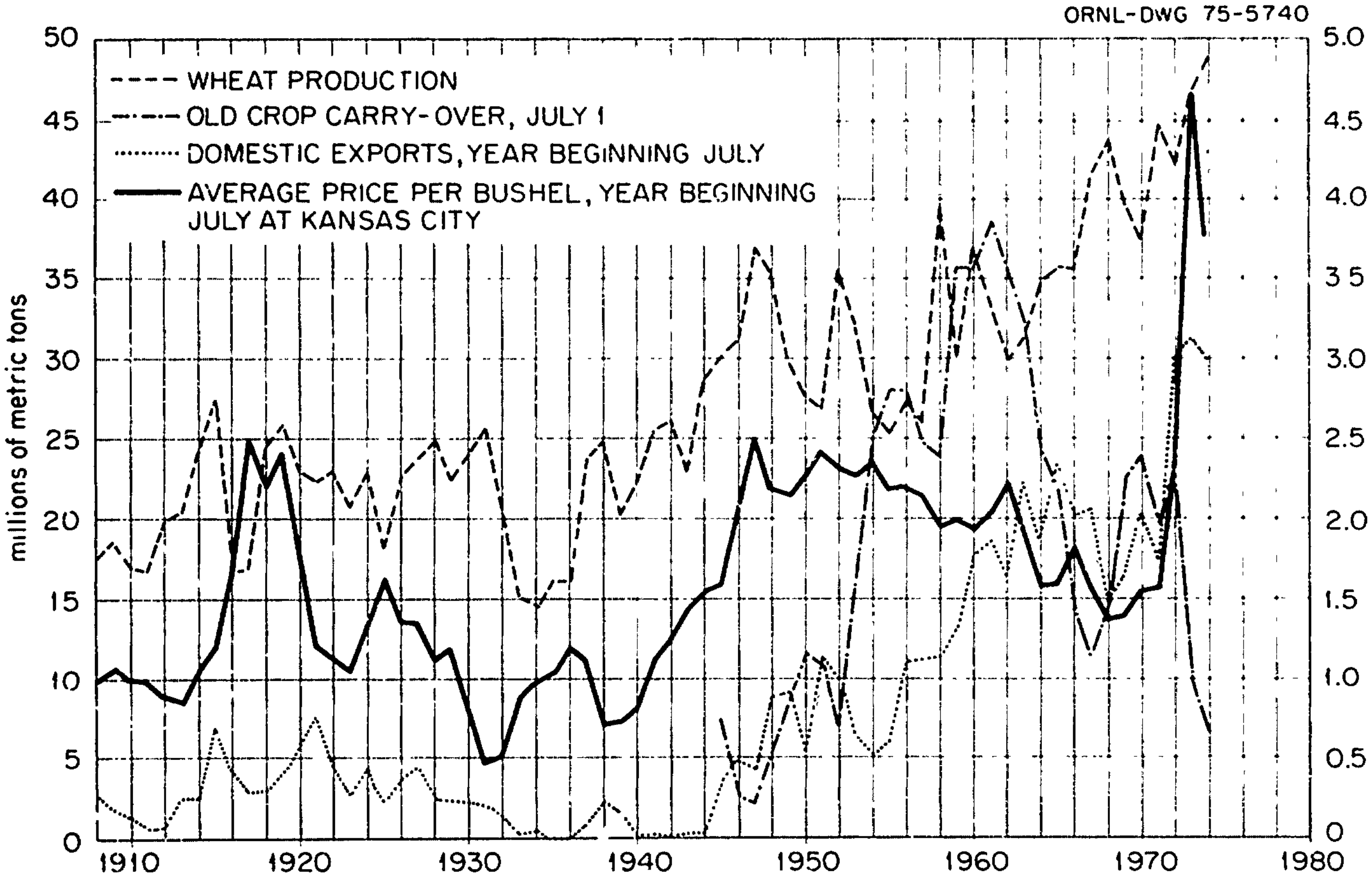

Fig. 6.5 Wheat Production Exports and Price, 1910-1975.

gamma irradiation from fallout from nuclear weapons. Two runs of this program were made by the Federal Preparedness Agency of the General Services Administration, one for each of two different hypothetical attacks, each occurring on June 1, and with crop data corresponding to the year 1974. According to Brown and Pilz (1969) the effect of fallout on the total U.S. crop production should be the most severe for an attack in the month of June. The attacks are very similar to the CRP-2B attack in terms of total number and yields of weapons but differ in distribution of the weapons on the United States. The "UNCLEX-MIKE" attack concentrates on military targets, and "UNCLEX-CHARLIE" concentrates on civilian targets. The wind conditions assumed for distributing the fallout corresponded to a typical meteorological situation for the month of March.

A summary of the results of the computer calculations for estimating surviving yield of crops is shown in Table 6.2. Note that the total estimated surviving yield is in the vicinity of 50% of the total production for 1974. Soybeans and sorghums are shown to have a high estimated yield because of a combination of factors, including their high resistance to damage by irradiation (Ryan, Garza, and Brown, 1974, p 34), the time of their growing season, and the distribution of their planting in relation to location of fallout from these attacks.

In order to investigate the sensitivity of the calculated surviving crop yield with changes in the agricultural model, we assumed a crop yield factor, Y, for each county, with values ranging between zero and unity, as a simplistic function of R_o, the unit time reference dose rate, varying according to

$$Y = \alpha - \beta R_o^t \quad .$$

The factors α and β are calculated by assuming boundary values of R_o for $Y = 0$ and $Y = 1$. Under these conditions, the equation provides essentially the identical curve as $Y = \alpha - \beta \ln R_o$ for $t \leq 0.01$.

Curves of Y vs R_o are shown in Fig. 6.6 for the three boundary conditions shown in Table 6.3. Curve "B" shows $Y = 0.5$ at $R_o = 500$ R/hr,

Table 6.2

Estimated Surviving Yield of U.S. Crops

Crop	Total Production (1974)	Estimated Surviving Yield UNCLEX-CHARLIE		Estimated Surviving Yield UNCLEX-MIKE	
	(Bushels)	(Bushels)	(Percent)	(Bushels)	(Percent)
Barley	343,600	134,100	39.0	142,700	41.5
Corn	4,833,300	1,890,000	39.1	1,376,100	28.5
Irish Potatoes	413,100	187,100	45.3	175,700	42.5
Rye	28,500	8,100	28.5	7,800	27.3
Sorghums	909,800	851,400	93.6	749,500	82.4
Soybeans	1,269,800	1,269,800	100.0	1,269,800	100.0
Wheat	1,805,100	883,000	48.9	956,000	53.0
Totals	9,603,200	5,223,600	54.5	4,677,600	48.7

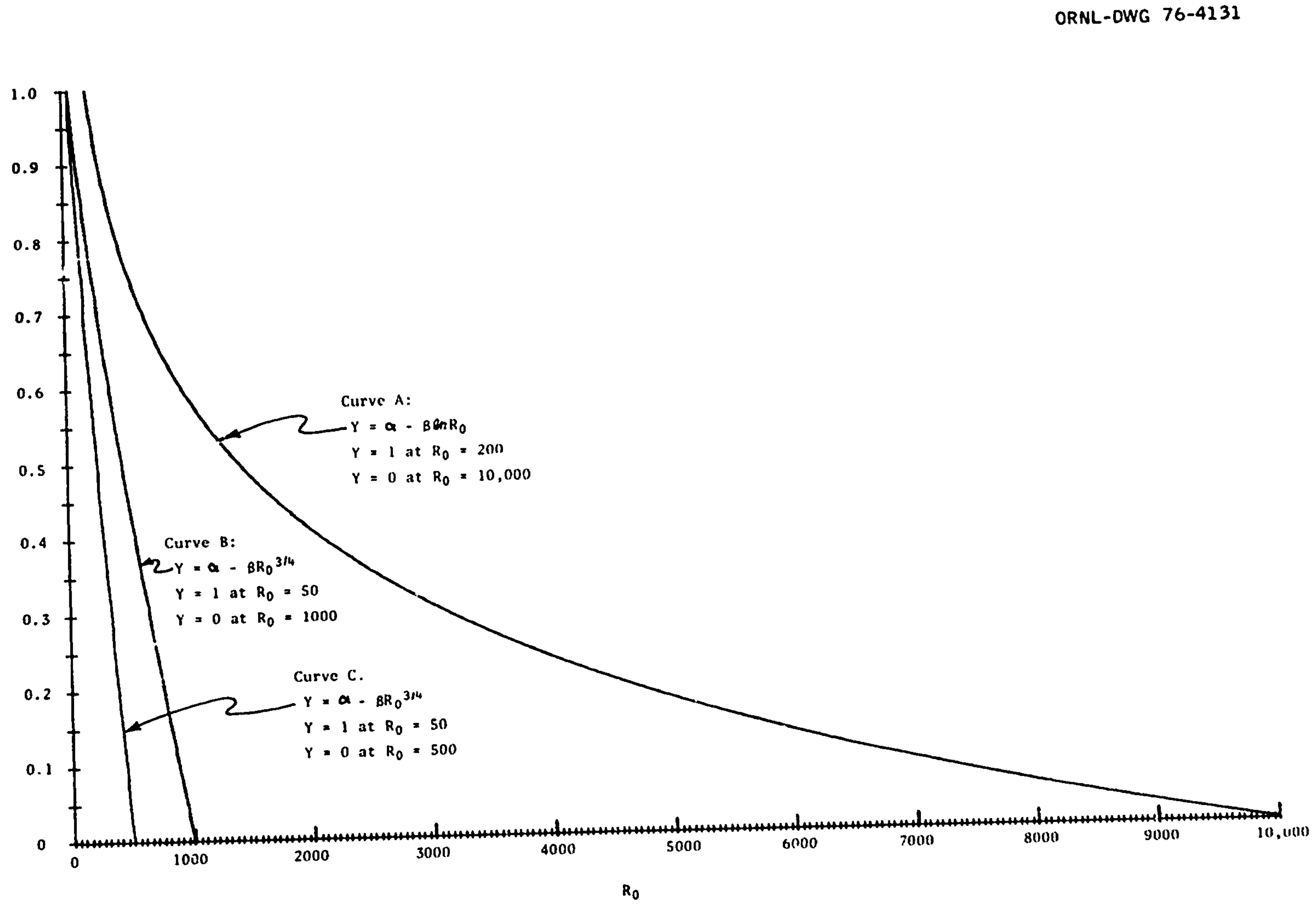

Fig. 6.6 Grain Yield as a Function of Unit-Time Reference Dose Rate.

corresponding to about 2000 roentgens exposure during a sixty-day growing time, at areas where the fallout arrives within one hour after the detonation. This exposure is approximately that amount required to reduce the yield of corn and wheat at maturity to 50% according to Killion and Constantin (1975). The yield would be greater than 50% at most places because the exposure to radiation would be less than 2000 R for these reasons:

1. The fallout will arrive later than one hour after detonation at most locations,

2. At northern latitudes, some seeds in the ground may still be ungerminated at the attack time, and thus less affected during the period of the most intense radiation,

3. In southern latitudes crops may be well developed at attack time and may be harvested before the period of 60 days is up, and

4. Rainfall may wash away significant amounts of fallout during the growing period.

The yield of grains for 1973 was estimated by determining R_o at the centroid of each county and then multiplying the production of grains for 1973 for that county by the value of Y corresponding to R_o. The results are shown in Table 6.3, giving 68% survival for the relatively insensitive case, 42.5% survival for the sensitive case, and 30.2% survival for the highly sensitive case.

For planning purposes, we will assume that grain stocks on farms and in rural elevators will be the major source of food required for survival in the postattack period. As we have seen from the data presented, this source is adequate to supply the relocated population until the following harvest, under most circumstances readily foreseen. We also assume that these grain stocks are located primarily in the counties in which they were produced. The location of grain-rich and grain-poor counties in the U.S. can be rapidly assessed by the maps shown in Figs. 6.7-6.13, which show the total quantities of all major grains produced in each county of the coterminous U.S. in 1973, according to USDA figures. A comparison with Figs. 3.5-3.11, which show the

Table 6.3

Total U.S. Grain Production for Three Different Sensitivities to Fallout Irradiation

Sensitivity	Y=1 (100% Yield) at R_o Listed Below (R/hr)	Y=0 (No Yield) at R_o Listed Below (R/hr)	t	Calculated Percent Survival (U.S.)
Relatively Insensitive	200	10,000	0.01	68.0
Sensitive	50	1,000	3/4	42.5
Highly Sensitive	50	500	3/4	30.2

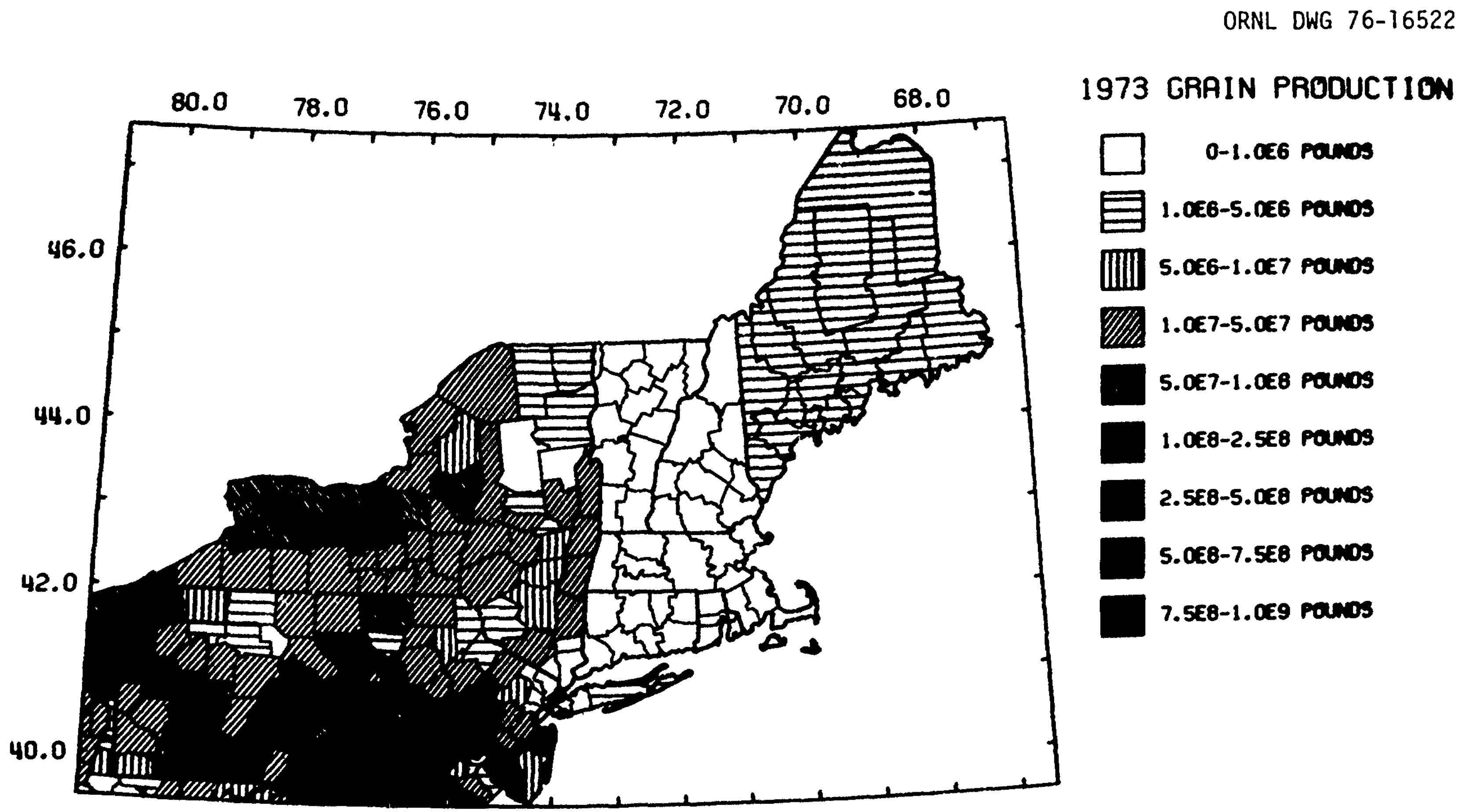

Fig. 6.7 Grain Production, 1973, Northeast, Based on Data Supplied by the Crop Reporting Board, USDA. In the legend, as an example, 1.0E6 indicates 1.0 x 10^6 pounds, or one million pounds.

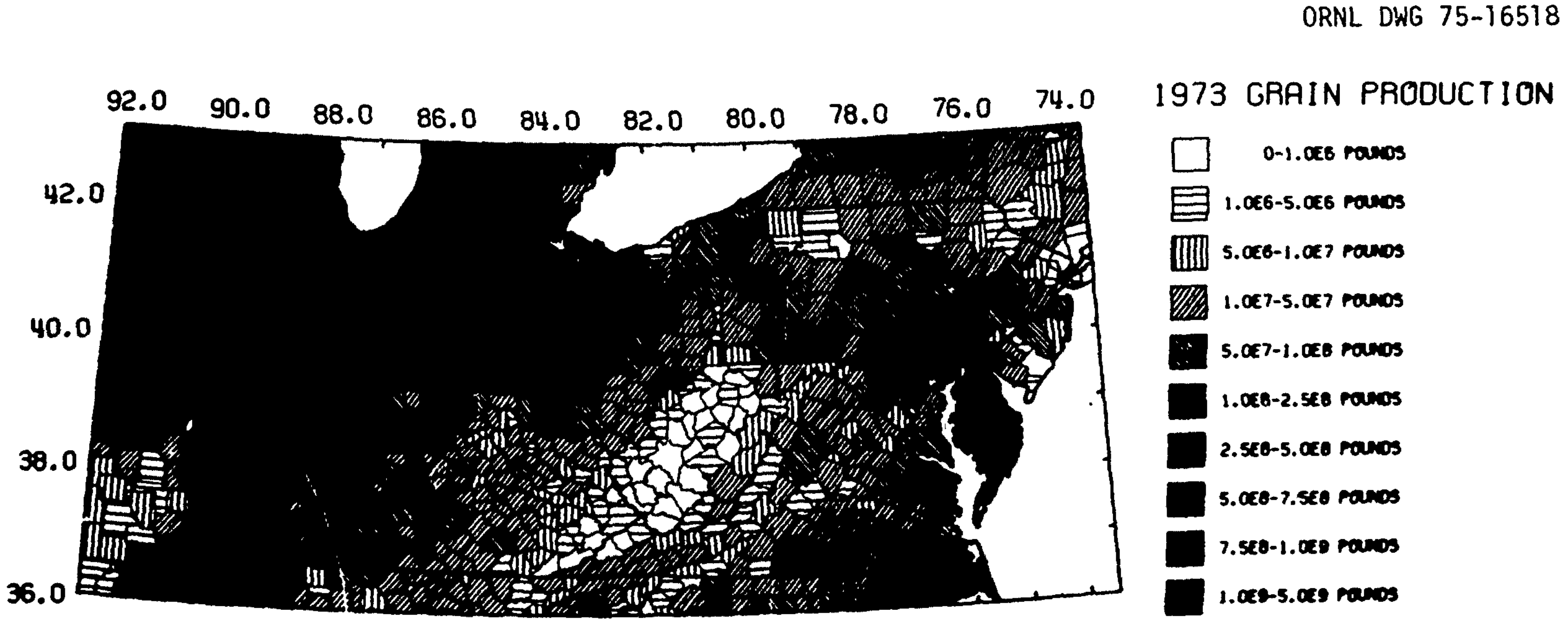

Fig 6.8 Grain Production, 1973, Central and East, Based on Data Supplied by the Crop Reporting Board, USDA. In the legend, as an example, 1.0E6 indicates 1.0 x 10^6 pounds, or one million pounds.

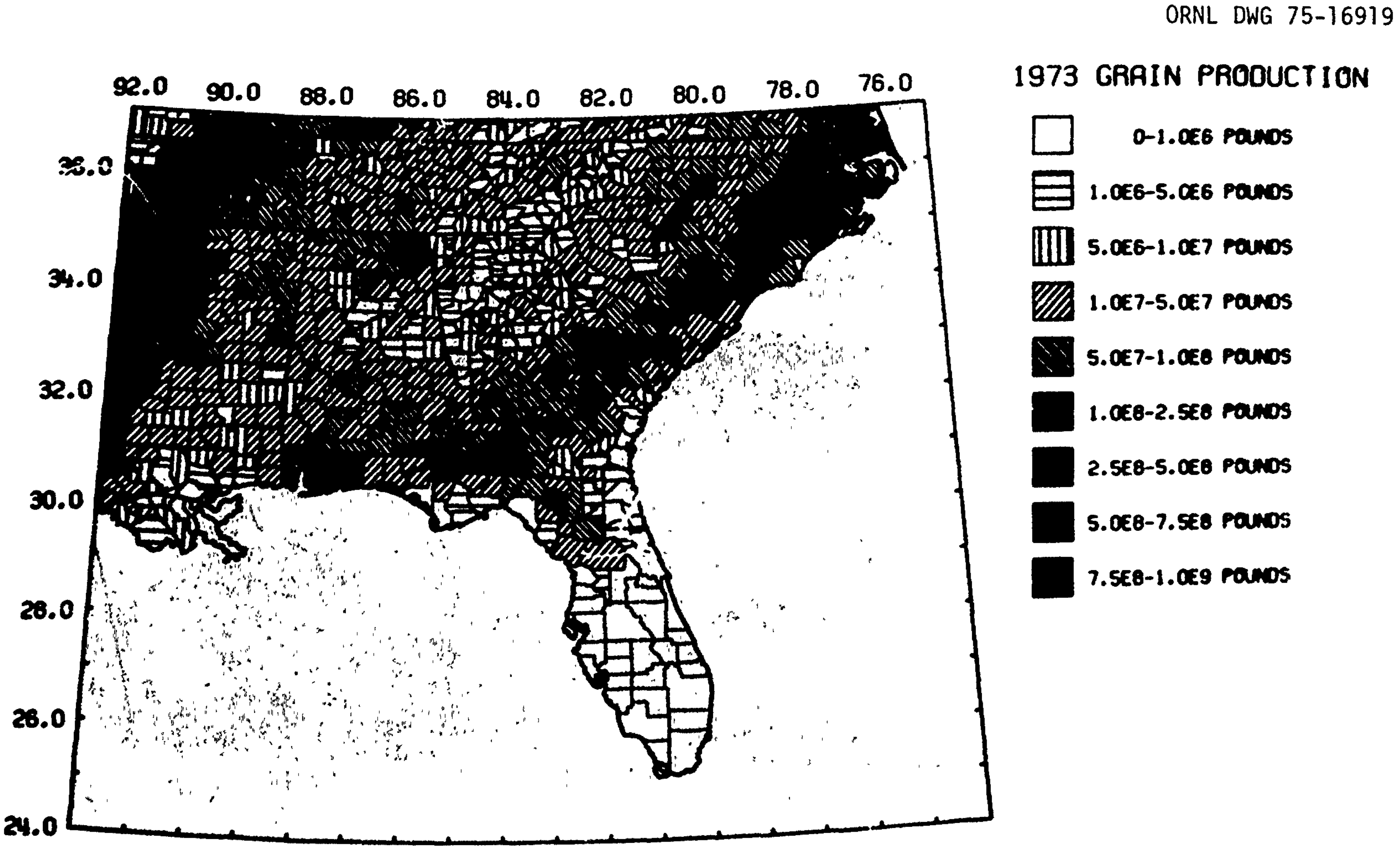

Fig. 6.9 Grain Production, 1973, Southeast, Based on Data Supplied by the Crop Reporting Board, USDA. In the legend, as an example, 1.0E6 indicates 1.0 x 10^6 pounds, or one million pounds.

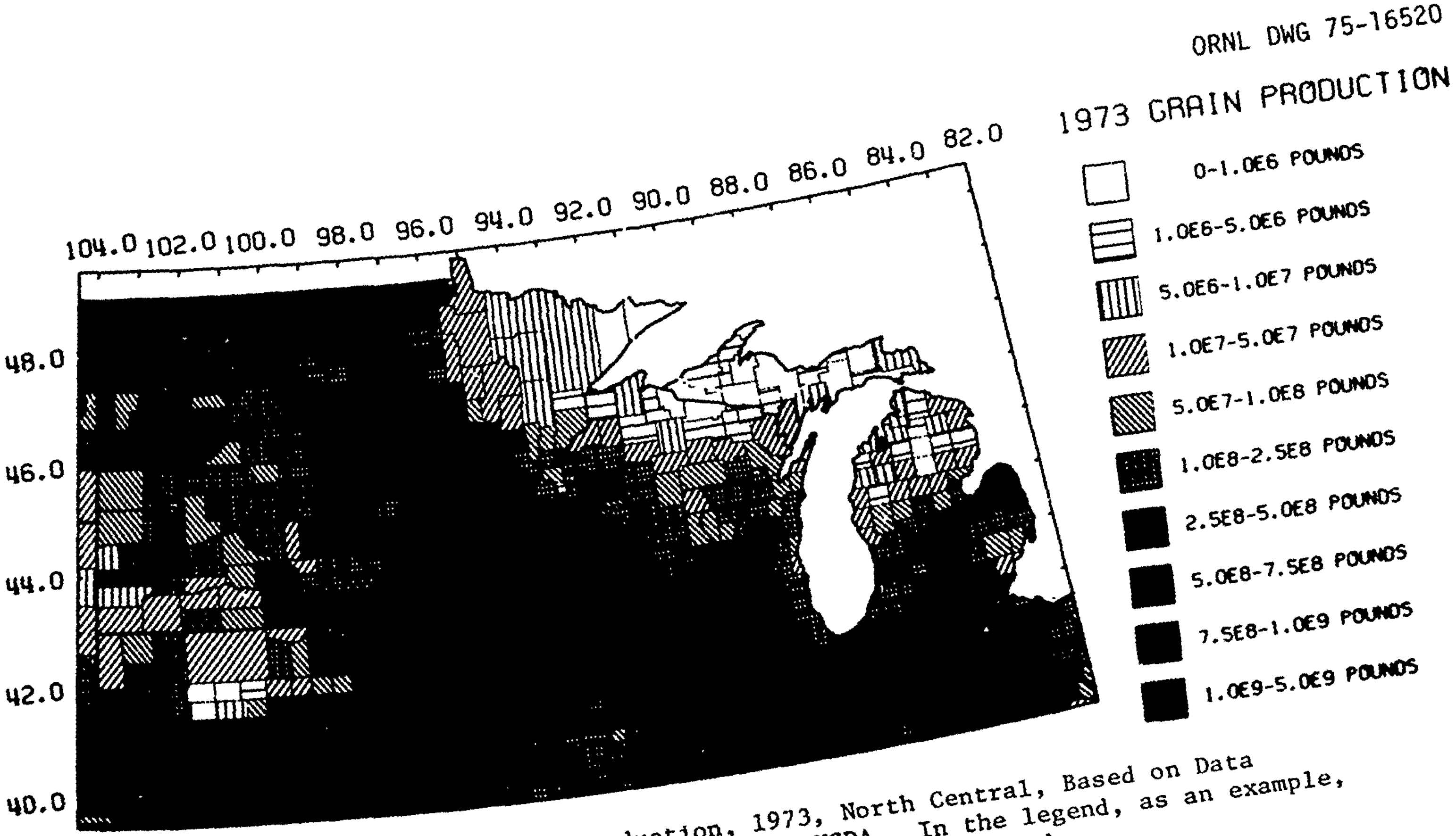

Fig. 6.10 Grain Production, 1973, North Central, Based on Data Supplied by the Crop Reporting Board, USDA. In the legend, as an example, 1.0E6 indicates 1.0 x 10^6 pounds, or one million pounds.

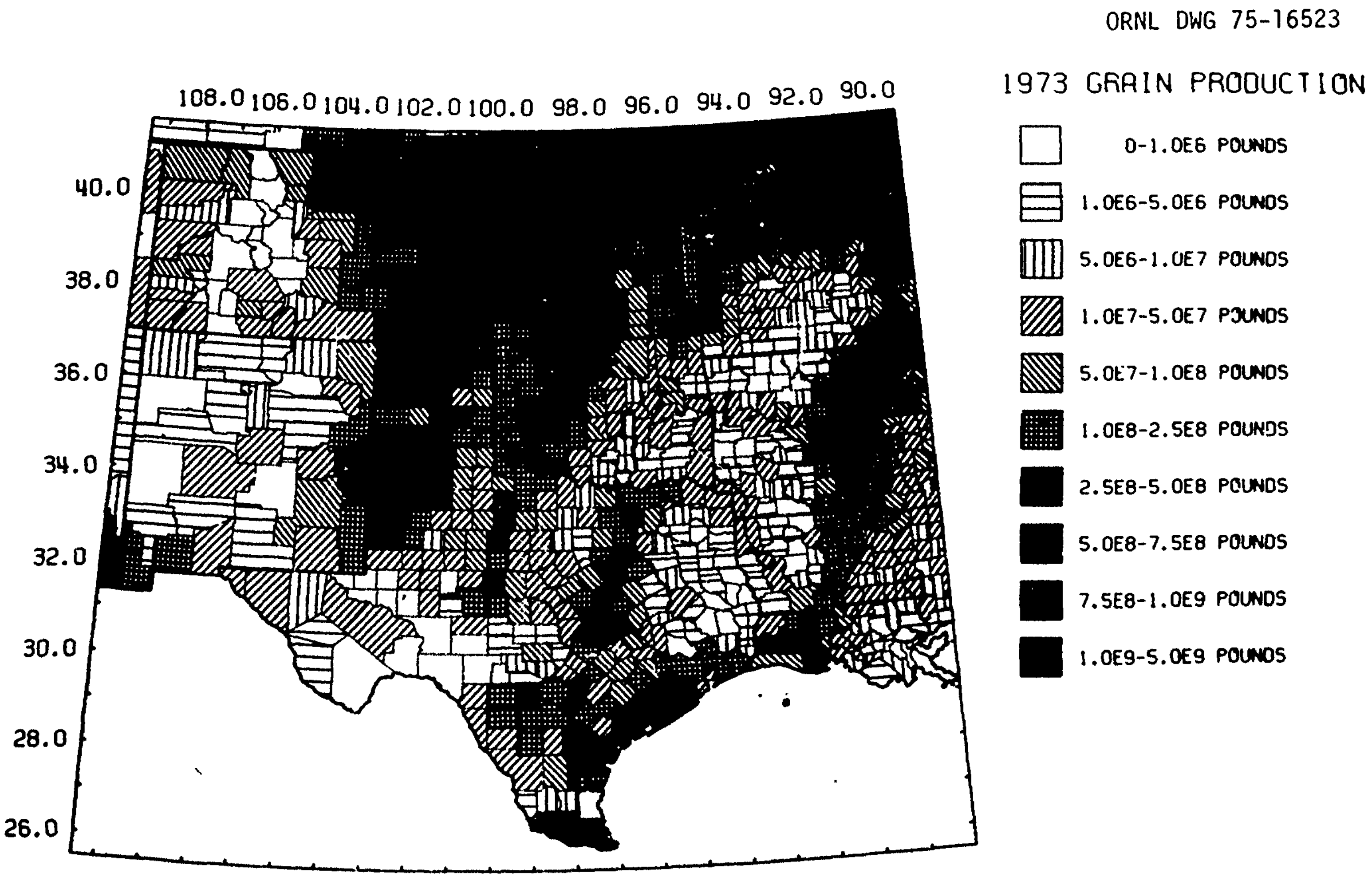

Fig. 6.11 Grain Production, 1973, South Central, Based on Data Supplied by the Crop Reporting Board, USDA. In the legend, as an example, 1.0E6 indicates 1.0 x 10^6 pounds, or one million pounds.

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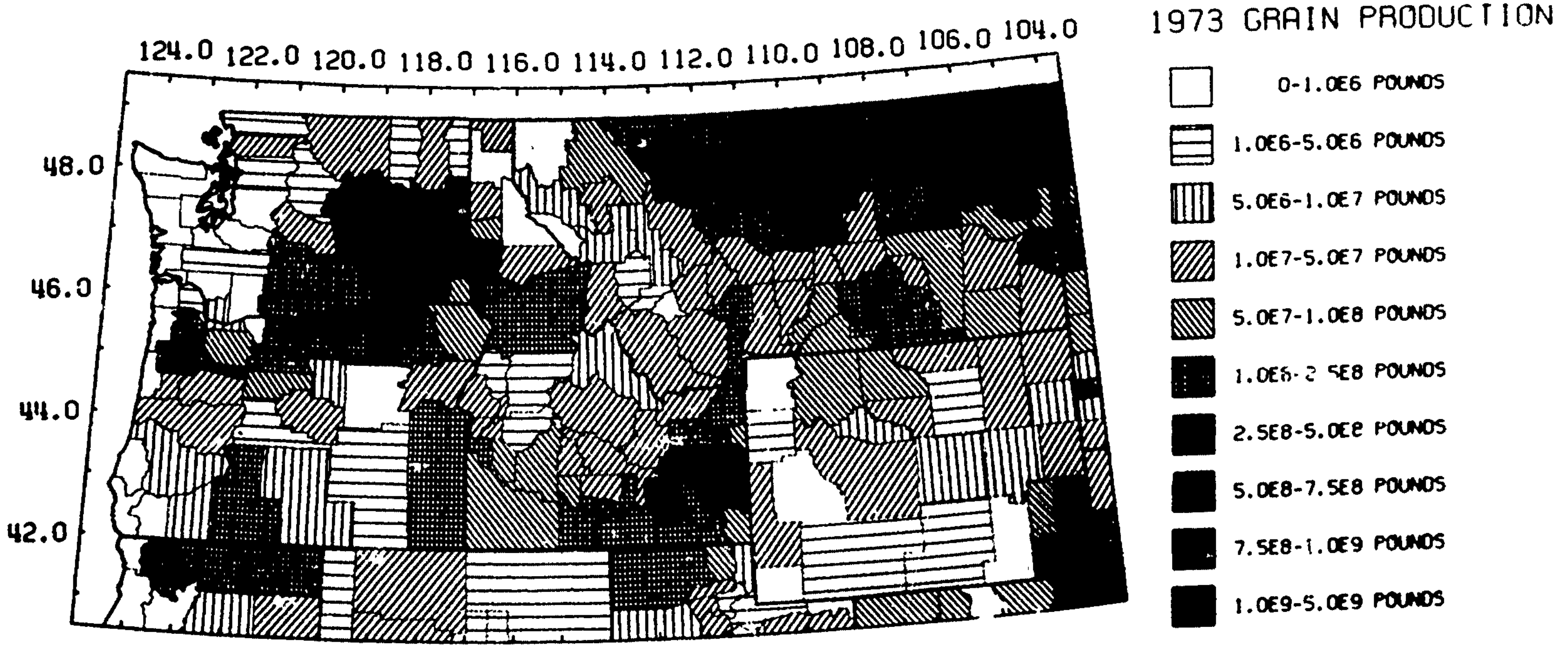


Fig. 6.12 Grain Production, 1973, Northwest, Based on Data Supplied by the Crop Reporting Board, USDA. In the legend, as an example, 1.0E6 indicates 1.0 x 10^6 pounds, or one million pounds.

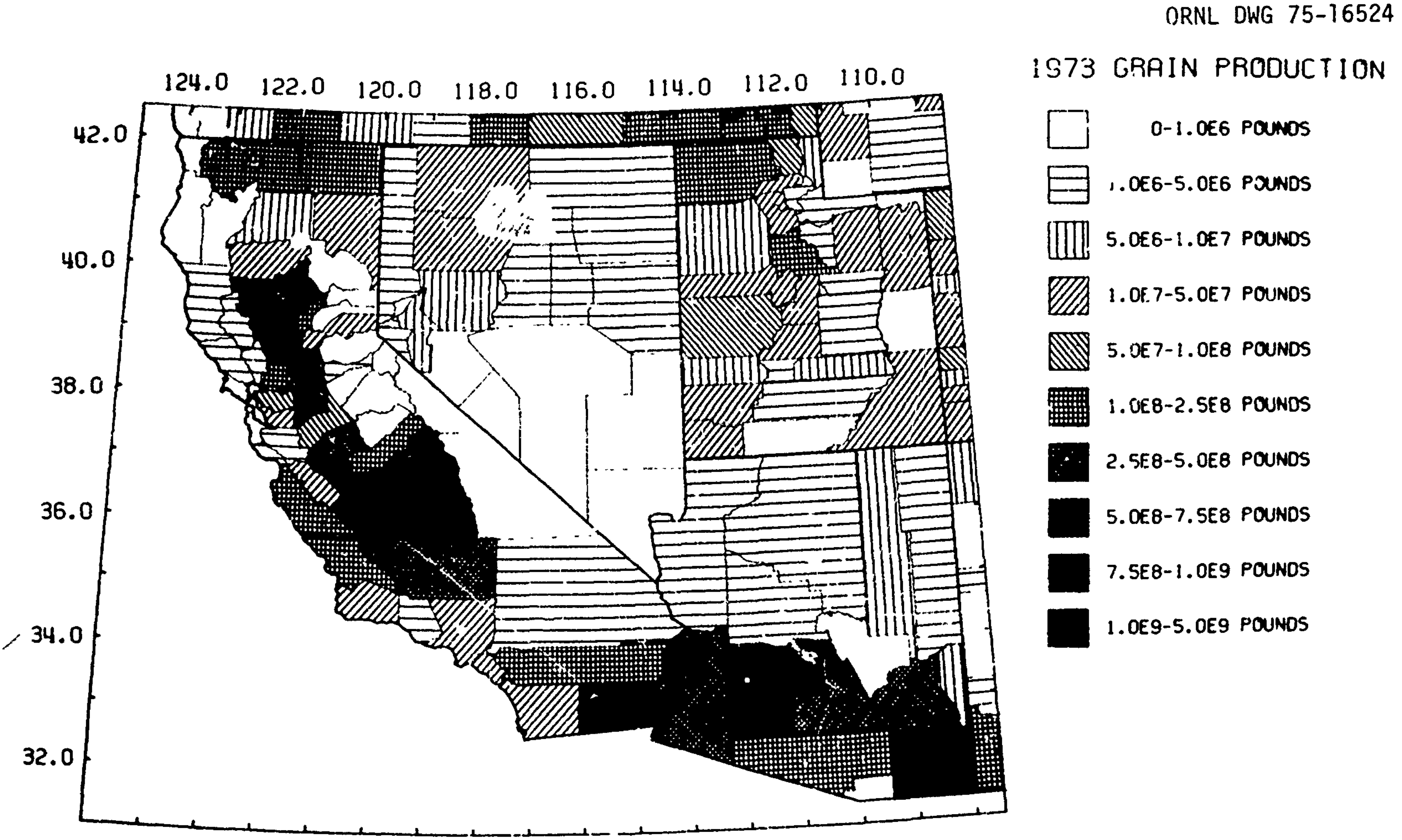


Fig. 6.13 Grain Production, 1973, Southwest, Based on Data Supplied by the Crop Reporting Board, USDA. In the legend, as an example, 1.0E6 indicates 1.0 x 10^6 pounds, or one million pounds.

distribution of relocated people by county according to the ADAGIO program, reveals that some regions, such as peninsular Florida, Northeastern U.S., and parts of California, are deficient in grain stocks but have a large number of people. This picture indicates that large quantities of grain may have to be shipped in order to avoid massive starvation. We assume that grain will be moved rather than the people, in order to avoid exposure of a large number of people to radiation from fallout. This situation could have been largely avoided if the evacuation plans had taken into account the location of grain stocks in addition to fallout avoidance and hosting capability, or if the grain had been moved and stored before the crisis, as recommended by Garland (1971).

In order to conserve fuel and to reduce exposure of operators to radiation, it would be desirable to minimize the total ton-miles in the shipments of grain. The solution of this problem involves linear programming of a typical transport problem, and will be presented in the next chapter on transportation.

We have assumed that the privately owned stocks of grains by farmers can be obtained by the government for relief of potential starvation of large fractions of the U.S. population in a postattack situation. Some form of guarantee should be given by the government to assure the farmer of just compensation for his labor and to allay his feelings of anxiety for his own future. Such a guarantee may be difficult to produce in a postattack situation unless it is evident to the farmer that the federal structure of government remains firmly in power. AM radio broadcasts of news and information, with frequent reassuring messages from the President would be necessary to convey this information (see Chapter 10).

6.3 The Effects of Dust and Depletion of the Ozone Layer Due to Nuclear Attack

It has been calculated that a 10^4 MT nuclear exchange would inject 10^7-10^8 tons of dust into the stratosphere (NAS 1975), which is of the same order as the amount estimated to be injected into the stratosphere by the volcanic eruption of Krakatoa in 1883. The total volume of earth and rock thrown into the sky by Krakotoa is estimated to be around 13 cubic miles. Thermonuclear explosions also produce NO, injecting approximately 10^4 tons of NO per megaton into the stratosphere, (NAS 1975) which may have a climatic effect as a result of ozone depletion and also as a result of formation of NO_2 in the atmosphere.

It appears that volcanic injections of the magnitude of Krakatoa may lead to minor cooling on a hemispheric or global average scale, but this statement must be qualified because the global mean temperature shows a variety of fluctuations on different time scales, not all of which can be explained in terms of volcanic injections. According to the Committee to Study the Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations (CSLWEMND) (NAS 1975), a deviation of 0.5° C from the average lasting for a few years might be expected from the stratospheric dust injection from a 10^4 MT nuclear exchange.

The effect of NO injection into the stratosphere was also investigated by CSLWEMND, with the conclusion that the detonation of 10^4 MT of nuclear weapons in the northern hemisphere would result in a maximum reduction of ozone in the stratosphere in the range of 30 to 70%, beginning a few weeks after the nuclear exchange, and gradually restoring to within 10% of the normal ozone content within 5 to 7 years after. The model used for this calculation is highly limited, and data for verification do not yet exist in sufficient quantity or with sufficient quality, hence the estimated range of uncertainty for the depletion of ozone varies within a factor of 2 or 3.

If the ozone layer is substantially depleted, much of the solar radiation in the wavelengths from about 2500 A through 3300 A, which would normally be absorbed by the ozone, will now pass through to the earth's surface. A 5% decrease in the average ozone concentration would cause a 26% increase in uv-B radiation (2800-3150 A); a 50% reduction in ozone would produce a fivefold to tenfold increase in uv-B radiation.

Although reliable data are meager with regard to effects of uv-B radiation on biological organisms, and the responses are variable and often subtle, the biological implications of increased uv radiation at the earth's surface are considered to be far-reaching by CSLWEMND. They conclude that some crops--corn, soybeans, barley, and alfalfa--would be affected only slightly by a fivefold to tenfold increase in uv-B radiation. Others, such as tomatoes, peas, beans, and onions would be severely "scalded" and even killed. The committee did not consider the synergistic effects of the combination of fallout radiation, increased uv radiation, and reduction in mean temperature, which could possibly result in much more severe reduction in crop yield than caused by any one of the effects alone.

The U.S. surplus capacity plus the ability to switch to the more resistant crops should enable this country to feed itself despite these kinds of ecological upsets. The critical factors for the U.S. agriculture will be the supply of fuel, fertilizer, and pesticides. Principal casualties from the possible ecological disturbance will be in countries with marginal to inadequate agriculture, especially if they are dependent on U.S. exports.

7. TRANSPORTATION FOR POSTATTACK SURVIVAL

7.1 Introduction

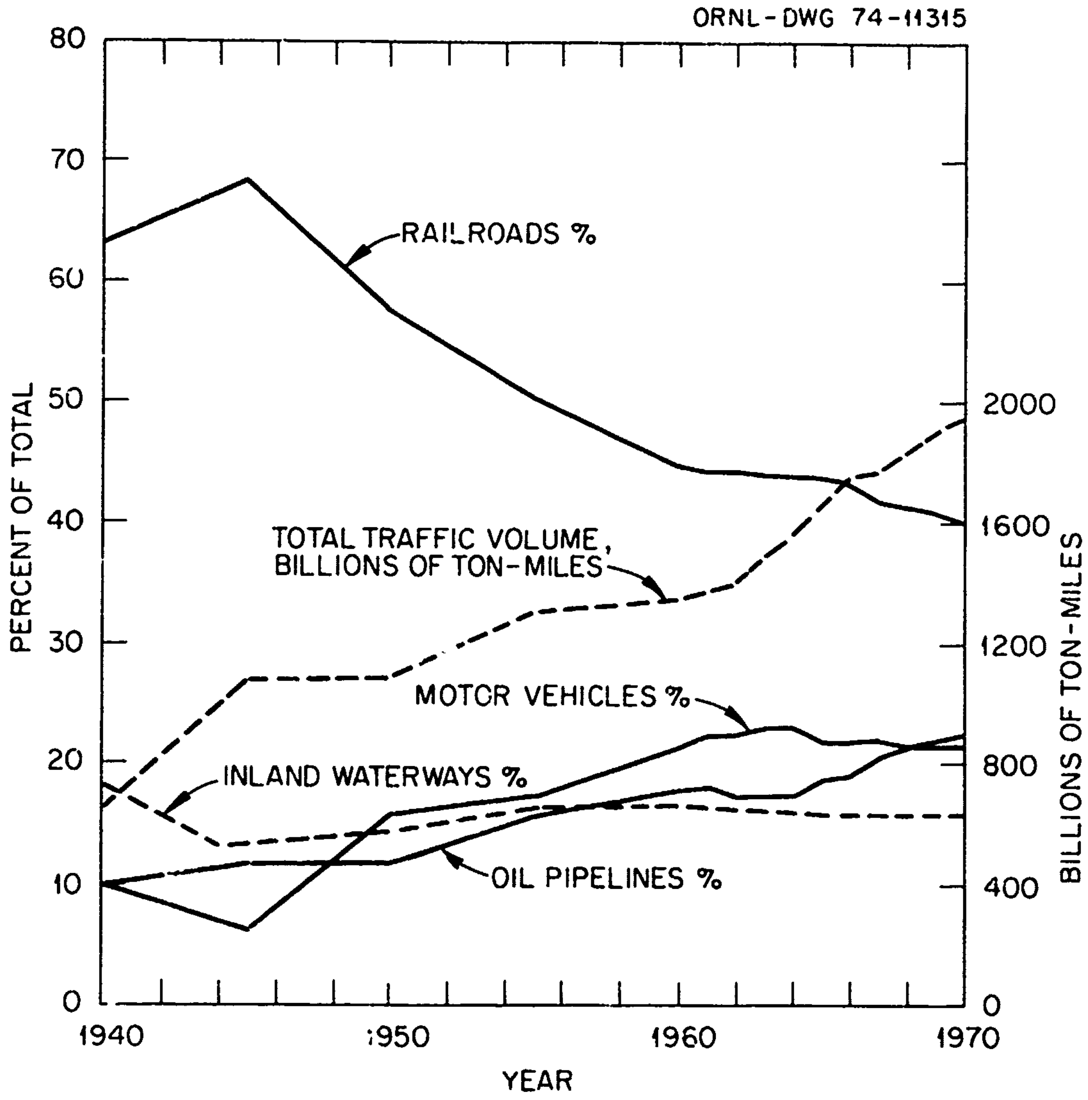
The U.S. has the greatest transport capability of any nation on earth. In 1970, the total volume of intercity traffic amounted to almost two trillion ton-miles, as shown in Fig. 7.1, of which the railroads transported about 40%, oil pipelines about 22.5%, motor vehicles 21.3%, inland waterways 15.7%, and aircraft (not shown in Fig. 7.1) about 0.5%.

The estimated number of privately and publicly owned transport units in the U.S. in 1972 is listed in Table 7.1. After a nuclear war, most of the motor vehicles and aircraft transport capability will remain intact, some rail and inland waterway transport capability will continue to exist, but oil pipelines will probably not be able to function at all for some weeks or months after the attack. In the following sections, each mode of transport will be briefly considered as to its survivability and functional contribution to general survivability. Finally, we will discuss the transport model for redistributing grain stocks to prevent starvation.

7.2 Oil Pipelines

Pipelines in themselves, being mostly buried and passing through sparsely populated areas, are fairly invulnerable to nuclear attack. However, the terminals are usually located in target areas, most pumping and flow control stations are operated by remote electronic controls which are vulnerable to EMP (Stephens, 1973), and the pump motors are completely dependent upon commercially supplied electrical power for their operation. When pipeline terminals are destroyed by nuclear blast, there will be further damage caused by the fires from spilled petroleum.

In 1972 there was about 172,000 miles of pipeline in the U.S., and the total deliveries for the year amounted to almost nine billion barrels, with a total trunkline traffic of about 2.7 trillion barrel-miles (The Oil and Gas Journal, June 11, 1973). Much of the oil transported by



Volume of Domestic Intercity Traffic (from *Statistical Abstract of the United States 1972*).

Fig. 7.1 Volume of Domestic Intercity Traffic.

Table 7.1

Estimated Number of Privately and Publicly Owned Transport Units[a]

	1950	1955	1960	1965	1970	1972
<u>Motor</u>						
Automobiles	40,339,007	52,144,739	61,682,304	75,251,386	89,279,864	96,859,746
Commercial Buses[b]	89,000	80,000	75,369	83,883	88,823	88,722
School & Other Buses	134,652	175,249	196,760	230,401	290,198	318,232
Motor Trucks[c]	8,598,962	10,288,804	11,914,249	14,795,051	18,748,421	21,239,163
<u>Rail</u>						
Freight Train Cars	2,032,966	2,018,398	1,984,639	1,816,426	1,799,342	1,716,937
Passenger Train Cars	43,585	36,894	28,396	21,516	11,378	7,763
Locomotives	42,951	33,533	31,178	30,061	29,122	29,338
<u>Air</u>						
Single Engine	57,353	55,221	68,036	81,192	109,673	116,898
Twin Engine	2,827	4,101	8,241	12,547	18,921	20,352
Three Engine	30	15	8	180	673	775
Four Engine	530	738	1,437	1,488	1,144	1,273

Table 7.1 (cont'd)

	1950	1955	1960	1965	1970	1972
Water						
Barges	13,805	14,875	16,777	17,033	19,809	22,245
Towboats	4,042	4,163	4,203	4,054	4,230	4,064
Ships	1,099	1,072	957	998	764	622

[a] Number of units fails to recognize greater capacity and utilization of newer equipment.

[b] Includes municipally owned transit units.

[c] The 1963, 1967, and 1972 Census of Transportation disclose, of the trucks surveyed, only a relatively small number were of the larger sizes, i.e.:

	Under 20,000 lbs.	%	20,000 to 26,000 lbs.	%	Over 26,000 lbs.	%	Miscellaneous Sizes	%
1963	9,466,800	78.4	1,255,800	10.4	736,750	6.1	615,825	5.1@
1967	12,399,840	87.2	739,440	5.2	1,089,720	7.6		
1972	17,420,000	88.3	828,000	4.2	1,500,000	7.6		

SOURCE: Transportation, Eleventh Edition, Transportation Association of America, December 1974.

pipelines is used for heating, and may become an item necessary for survival in some locations if the nuclear attack occurs in the winter. Two pipelines, the Plantation and the Colonial, begin in Louisiana and serve the eastern seaboard, supplying about two-thirds of the oil for the New York-New Jersey area. If these two lines were severed by a nuclear strike, it would require from 200 to 250 T-2 tanker equivalents to move this liquid from Galveston, Texas, to New York, a thirteen-day round trip including loading and unloading, according to Stephens (1973). This operation "would use all of the U.S. tankers, and the ports at each end, if they are not destroyed by the attack, would be so crowded that a complete traffic jam would result." It is evident from these comments that it would be desirable to construct bypass pipelines around major target areas, and to harden the control system to EMP.

Although oil may become necessary for survival of people in some situations, such as, for example, those in northern hospitals in the winter, this oil could be delivered by means other than pipelines, possibly by tanker trucks which delivered 28% of all petroleum in 1972 (Transportation Association of America, 1974). Healthy people in shelters may have provided an improvised wood-burning stove in their shelter during the crisis period, if it occurred in the winter. A design for an efficient improvised wood stove for cooking is described by Kearny (1975), as well as means for using newspaper wrapping around the body which will keep a person warm in subzero weather.

Other requirements for petroleum supplies, such as diesel fuel for trains and trucks to move grain to avert starvation, will exist in sufficient quantity in reserve stocks, and will not require the oil pipelines to be in operation immediately. For economic recovery it will be essential to restore the pipelines to operation as quickly as possible, but we do not believe their operation will be necessary for survival in the first few weeks following a nuclear attack.

7.3 Inland Waterways

Tugs, barges, and freighters which ply the U.S. inland waterway systems can be moved out of high-risk areas during the crisis period.

However, if the CRP-2B attack occurs, these vessels will have limited use for several weeks, perhaps months after the attack, because of the destruction of critical locks and ports, and obstruction of waterways by fallen bridges. Except for Lake Michigan and Lake Superior, the Great Lakes will be isolated from each other, from canals leading to inland waterways, and from the St. Lawrence Seaway, as far as waterborne commerce is concerned. About 28 of the 67 major ports of the Great Lakes will be destroyed, and these 28 handled about 70% of the total commerce through the Great Lakes ports in 1971 (World Almanac, 1974). The Mississippi and the Ohio rivers will each be fragmented into seven pieces for water traffic by destruction of locks. Along the Atlantic and Gulf coasts, 65 of 71 major ports will be bombed according to the CRP-2B attack, and these 65 ports handled about 945 million tons out of 965 in 1971, or about 98% of the commerce to Atlantic and Gulf coast ports. We conclude that the inland waterway system will play a very minor role if any, in the early postattack survival period.

7.4 Railroads

Rolling stock can be moved out of high-risk areas during the crisis period. Most of the major switchyards, warehouses and repair facilities are located in major cities and will be either severely damaged or destroyed in the CRP-2B attack. Previous studies (Hamberg, 1969) indicate that "in no case would rail traffic be completely blocked" by destruction of "rail activity centers," although circuitous routing would be required to get around the damaged facilities in several cases. The major restriction to rail shipments in the early postattack situation will be destroyed bridges across major rivers such as the Mississippi, Missouri, Ohio, and Tennessee. A few temporary railroad bridge construction sets may exist for military use, and railroad ferries exist at a few river locations, but these will probably not be adequate to rely upon. Shipments of crucial supplies across rivers during the first few weeks or months after the attack may have to be accomplished by unloading boxcars at transfer points along the rivers, where the materials are then transported by trucks across the rivers on portable pontoon bridges.

The railroads are equipped to carry grain in large quantities, and loading and unloading equipment for grain in and out of boxcars exists throughout the grain-producing rural areas. The lower cost and greater efficiency of rail movement at about 1.62¢ per ton-mile, 200 ton-miles per gallon of fuel (Hirst, 1972) as compared with 8.24¢ per ton-mile and 58 ton-miles per gallon for trucks (1973 prices), also makes the railroads appear attractive for the major bulk of emergency shipments in the postattack situation. The railroads and the trucking industry will be required to play a major role in grain shipments in the postattack situation to avoid starvation in many areas.

7.5 Commercial Aircraft and Airports

In 1974, the United States operated more than 12,000 airports, of which 3480 had asphalt or concrete runways of 500 feet or longer, as shown in Fig. 7.2. The data base for this information was obtained from FAA. Runways of 8000 feet or longer are usually associated with SAC facilities, and would probably become prime targets. Of 126 runways in this category, shown by circles in Fig. 7.2, all but 33 are bombed by the CRP-2B attack, indicating a possible oversight in the attack planning. The number of runways in different multiples of 1000 feet is shown in Fig. 7.3, where it is shown, for example, that there were 1198 airports with runway lengths between 3000 and 4000 feet in 1974, in the coterminous U.S.

In 1971, there were about 134,000 active aircraft in the U.S. (Statistical Abstracts of the U.S., 1974), of which 2700 were air carriers, and about 109,000 were single-engine fixed-wing aircraft.

CAP (Civil Air Patrol) aircraft will play a crucial role for survival in the first few weeks after a nuclear attack, accomplishing aerial assessment of damage, checking highways for obstructions and destroyed bridges, and conducting aerial monitoring of radiation from fallout. As mentioned before, 1100 aerial monitoring kits have been distributed to the states for mapping radiation fields from fallout by CAP aircraft.

Aircraft belonging to CRAF (Civil Reserve Air Fleet) and WASP (War Air Services Program) can be used for evacuation of people from disaster

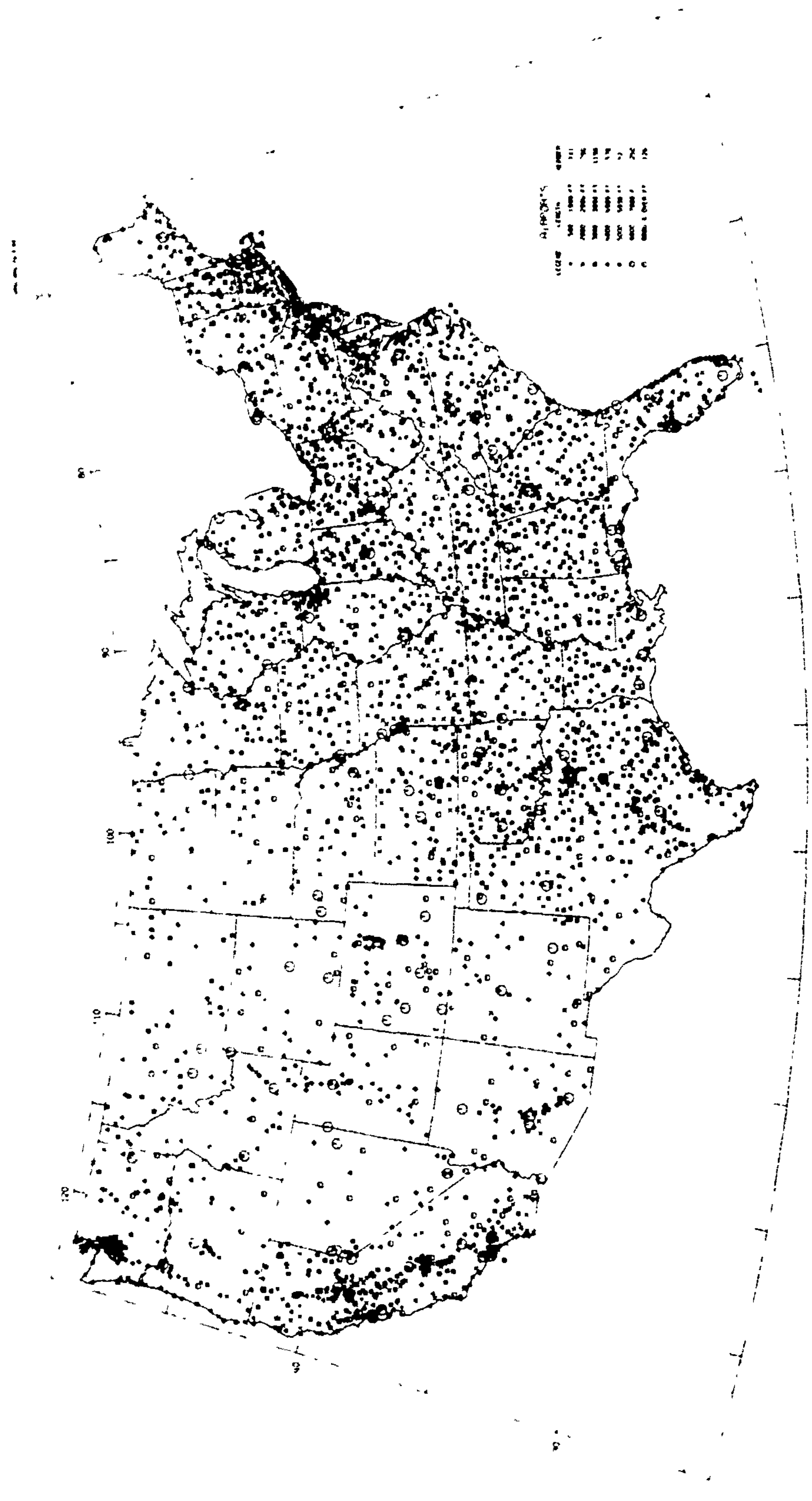


Fig. 7.2 Commercial Airports in the U.S. with Runways 500 ft or Longer.

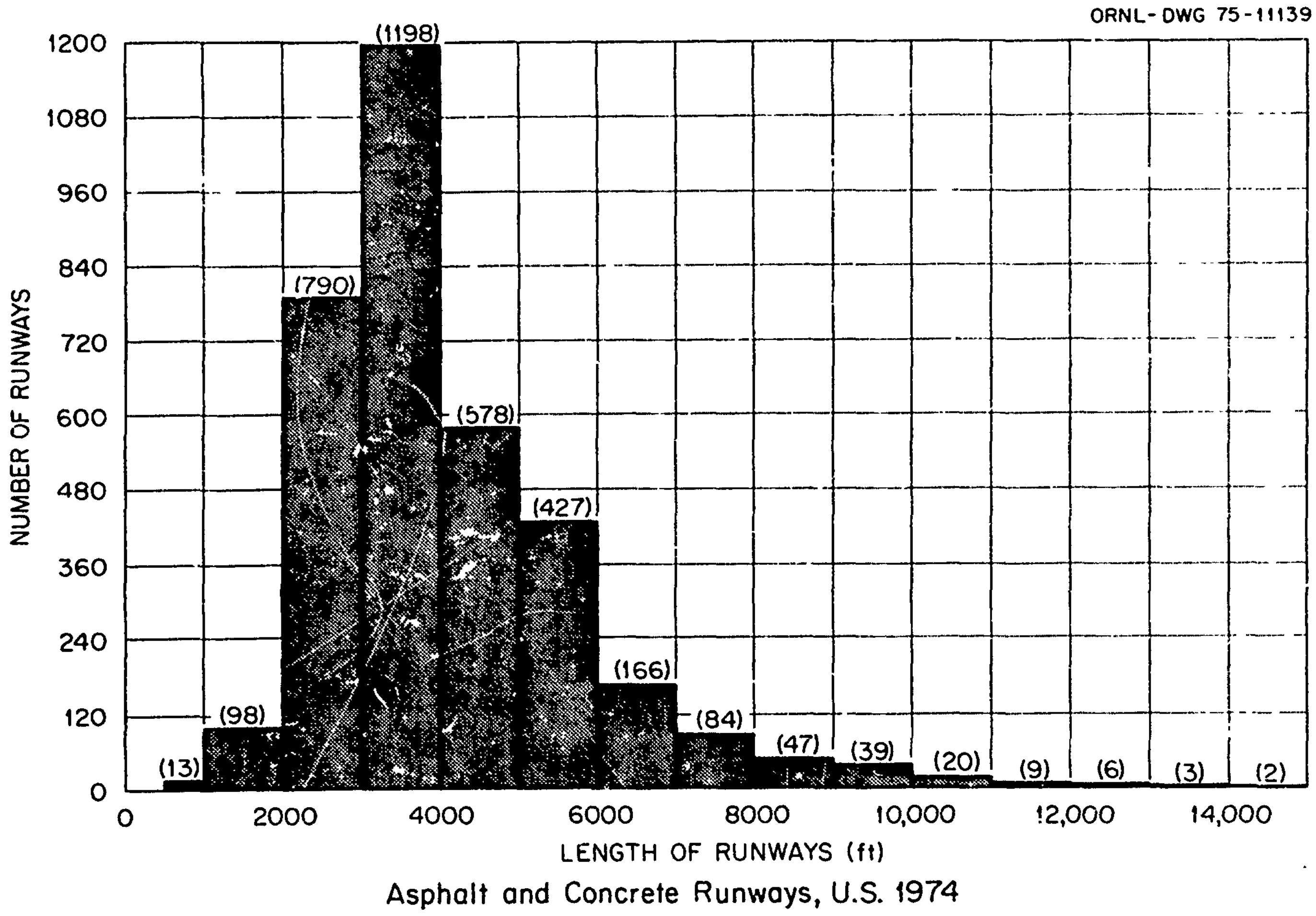


Fig. 7.3 Distribution of Airports by Runway Lengths.

areas, or from areas heavily affected by fallout, or they can be used for emergency airlift of supplies, or for aerial monitoring. Their capability for accomplishing these functions are briefly assessed in Appendix A.

Most of the airports have some fuel storage capacity, as shown in Figs. 7.4 and 7.5. About 95 million gallons capacity of the total of 139 million gallons exists on the 126 airports which have runways of 8000 feet or longer, and 91 of these airports are targeted by the CRP-2B attack. Because these runways are associated with SAC, we will assume that they are destroyed. The remaining airports have a storage capacity of about 44 million gallons. According to an inventory by the National Petroleum Council, 1974, the average quantity in the tanks is about 45% of full capacity, hence we might expect about 20 million gallons of aircraft fuel at airports to survive the nuclear attack. In 1971 the total fuel, gasoline and jet fuel, consumed for general aviation was 734 million gallons. At this rate of consumption, 20 million gallons would last for about 10 days; however, in the postattack situation, air travel and air shipments would be reduced to absolutely essential trips, and this fuel might be stretched to several weeks supply. After several weeks, fuel from other sources may be brought in by tanker trucks.

A priority listing of essential aircraft missions should be established for the postattack situation. The highest priorities should be given to light aircraft engaged in reconnaissance: (1) to assess damage; (2) to determine which surface transportation routes are open for traffic; and, (3) to monitor radiation intensities from fallout along transportation routes.

7.6 Trucks

There is a trend for truck terminals to be located along interstate highways outside of urban areas. Because of this trend, and because of the mobility of the trucks, we estimate that 60 to 80% of the current trucking capability would survive the CRP-2B attack, providing that adequate measures are taken during the crisis period to provide protection during the attack and after.

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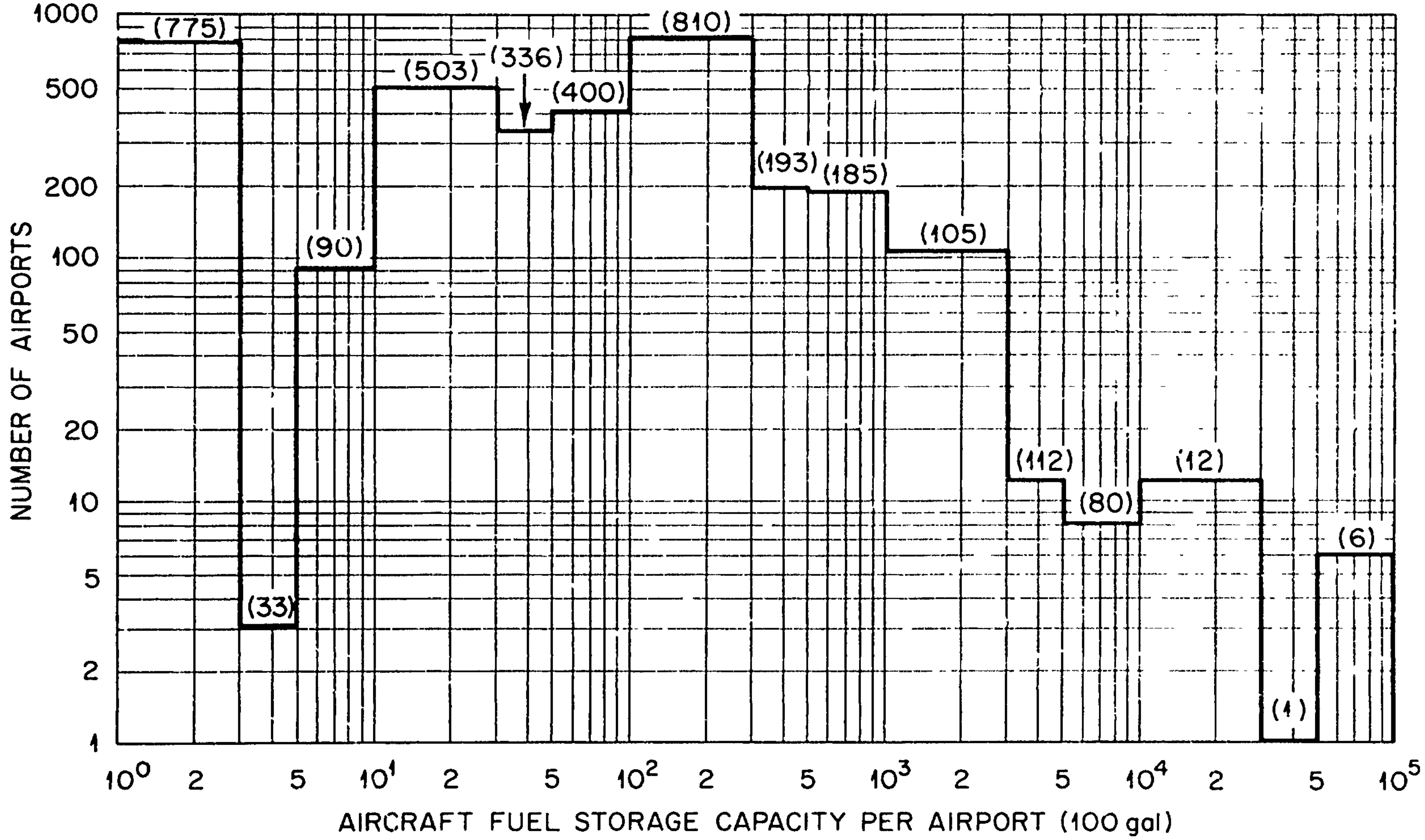
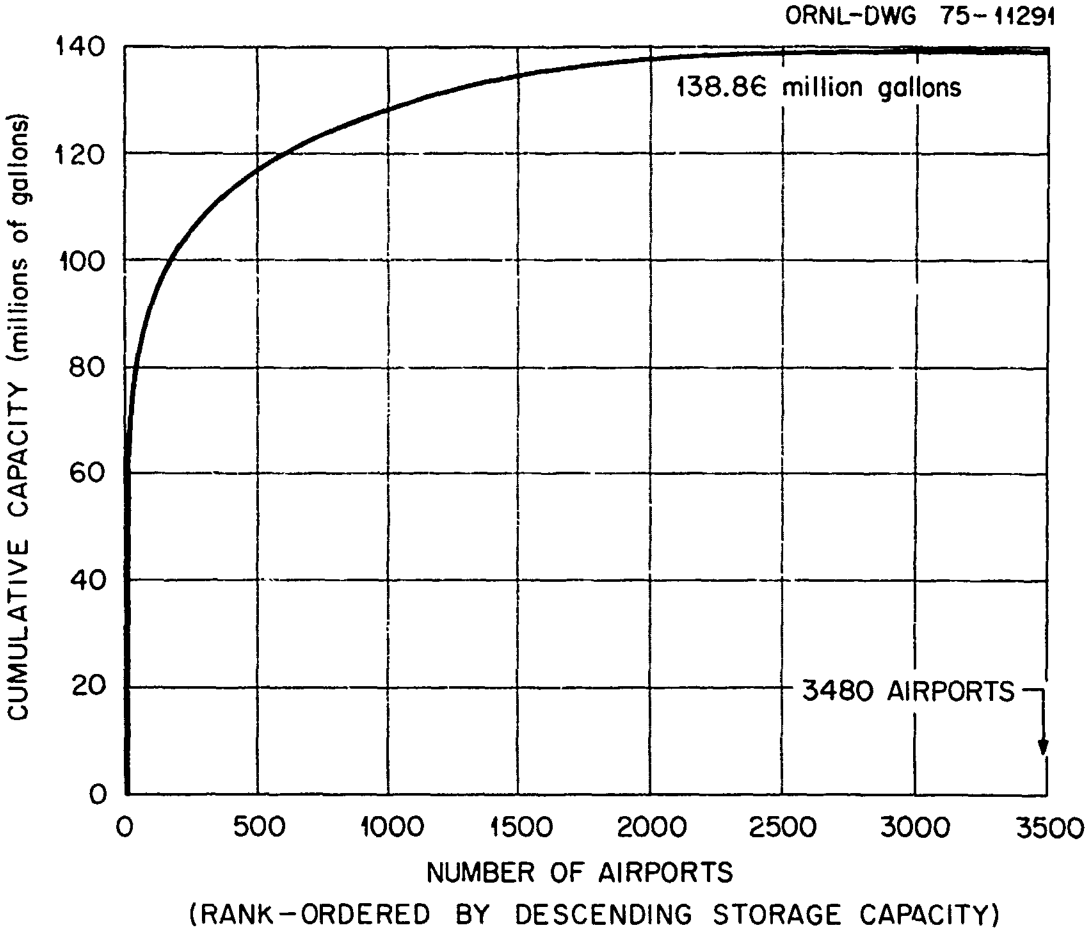


Fig. 7.4 Distribution of Fuel Storage Capacity.



Aircraft Fuel (all types) Storage Capacity at Commercial Airports, 1974 With Asphalt or Concrete Runways of 500ft or Longer.

Fig. 7.5 Cumulative Fuel Storage Capacity.

Most truck terminals contain sleeping quarters for truck drivers which would provide very little fallout protection. During the crisis period it would be highly advisable to construct expedient shelters at truck terminals in which drivers can rest and be protected from fallout radiation.

In 1972, trucks consumed about 8.1 billion gallons of fuel in transporting 470 billion ton-miles of intercity freight, about 8% of the total motor fuel (105 billion gallons) consumed for all highway traffic (Transportation Association of America, 1974), at an average rate of 22.2 million gallons and 1290 million ton-miles per day for trucks. The average quantity of distillate fuel oil, including diesel fuel, stored in tanks in 1973 was about 5.67 billion gallons, and the average quantity of gasoline was about 7.39 billion gallons (National Petroleum Council, 1974). We estimate that about 60% of these fuels will be destroyed in the CRP-2B attack, which would leave about 2.27 billion gallons of distillate fuel oil and diesel and 2.96 billion gallons of gasoline surviving, if these numbers were representative of the fuels in storage at the time of the attack. If this total of 5.23 billion gallons were to be used only by trucks in the postattack situation at the same average rate as before the attack, i.e., at 22.2 million gallons per day, this supply would last for 236 days, which is probably adequate to carry the nation through the survival state into the recovery stage. Part of this fuel would be used by railroads and automobiles.

7.7 Postattack Shipment of Grain Stocks

We assume that within two or three weeks after the attack most of the food on hand for the relocated population will be consumed; that 60% of food processing plants and warehouses are destroyed; that grain stocks will have to be shipped to the relocated people where processing for human consumption will take place, either by surviving and operating processing plants or by emergency primitive techniques; that 60% of the year's production of grain remains available and undamaged on farms and in grain elevators located within or nearby the counties in which the grain was produced; and that 89.6 million people are relocated according to the ADAGIO program and cannot readily relocate in the first few weeks after the attack because of fallout conditions, lack of a place to go, and lack of fuel for travelling.

The location of people by county is shown in Figs. 3.5-3.7, which may be compared with the distribution of grain produced per county, as shown in Figs. 6.7-6.13, for the year 1973. If, in addition to the assumptions above, we assume that two pounds of grain per person per day is adequate on the average for survival (Garland, 1972), an analysis of the data shows that 143 counties, containing a total of about 19.8 million people, mostly relocated population, have no grain stocks whatsoever; in other words, the number of food-days available from local grain stocks is zero, as shown in Fig. 7.6. In other locations, about 26 million people are located in counties in which the local grain stocks can supply zero to 5 days of food supply; about 8.7 million are in counties with 5 to 10 days food from grain stocks, and so forth, as shown in Fig. 7.6.

The problem of calculating the shipments of grain from surplus areas to deficit areas such that the total ton-miles is minimized is a typical problem of linear programming (Hillier and Lieberman, 1974). The particular problem at hand was solved with an unpublished program called TRANSPORT, developed by Brady Holcomb of the Computer Sciences Division of Union Carbide Nuclear Division, and modified by Gary Westley and Philip Coleman. A formal statement of the problem is given in Appendix A.

When counties are used as the basic area cell, the requirements for solution of the problem with the TRANSPORT program exceeds the memory capability of our large computers, hence the county information was consolidated into BEAs (Business Economic Areas) as defined by the Department of Commerce. There are 171 BEAs in coterminous U.S.A., compared with about 3300 county-type divisions. The distributions of people, as relocated by ADAGIO, and the production of grain in 1973, are shown by BEAs in Figs. 7.7 and 7.8. A BEA was considered to be a source if 60% of the 1973 grain production in that BEA provided more than 365 days of food for the relocated ADAGIO population in that BEA, and shipments from a source were terminated when the reserve was depleted to the

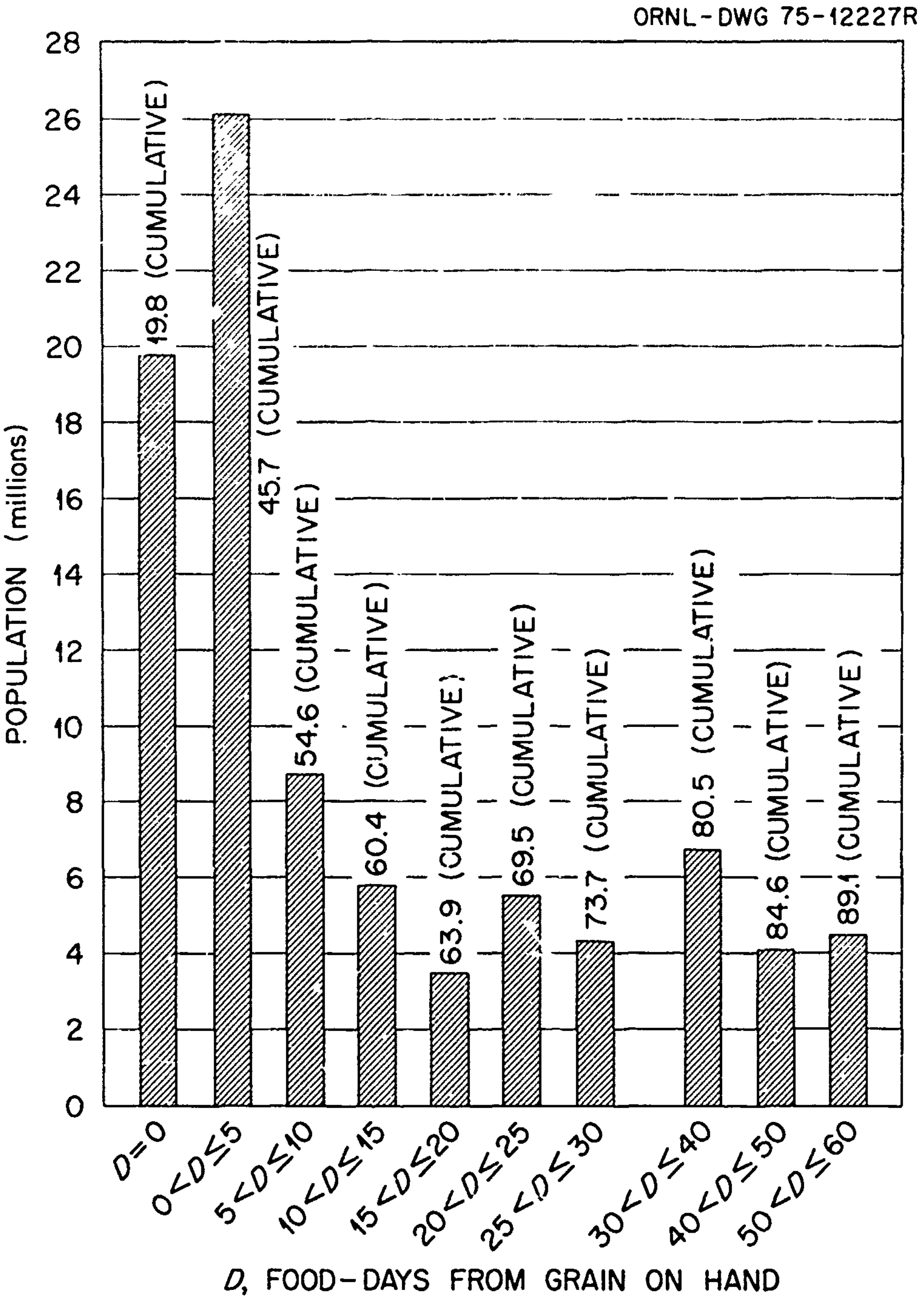


Fig. 7.6 Food-Days from Grain for Various Populations.

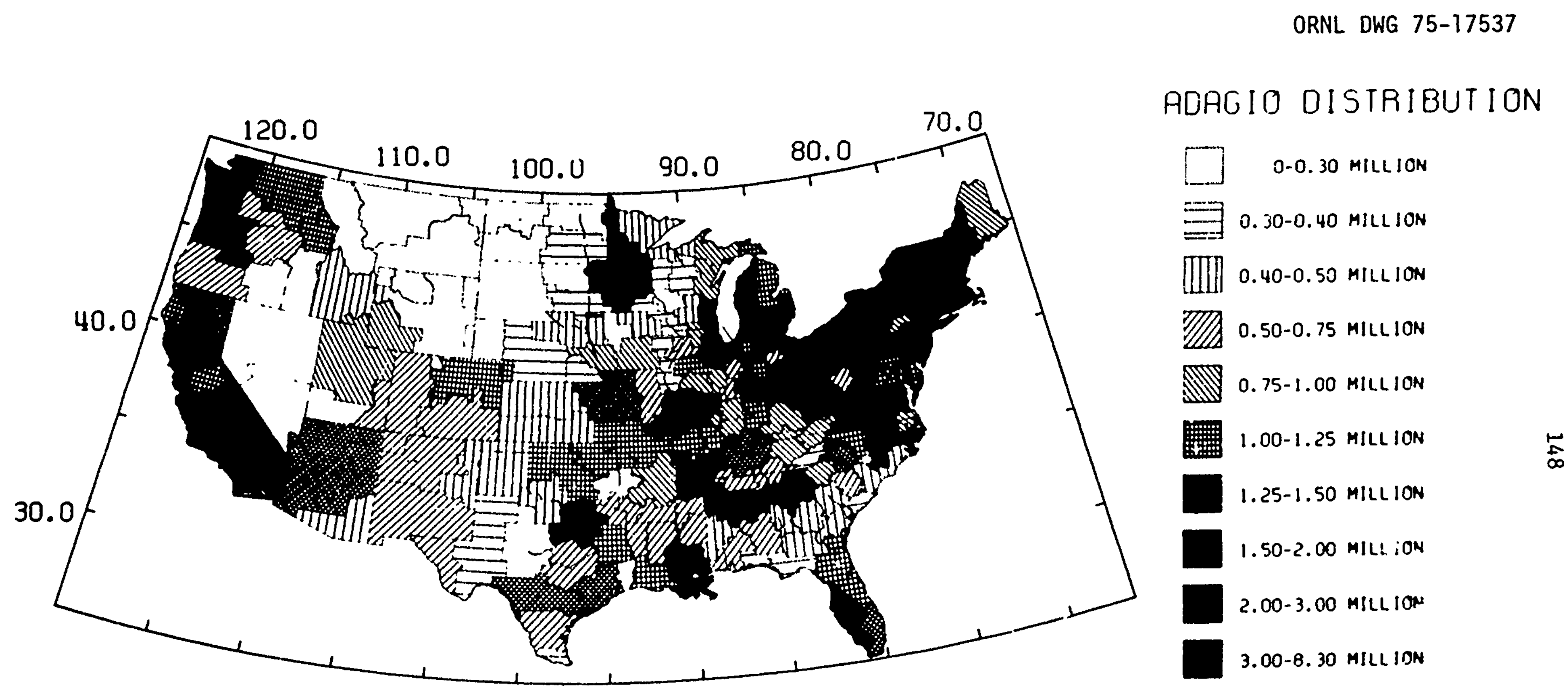


Fig. 7.7 Distribution of People, Relocated According to ADAGIO, Shown by BEAs.

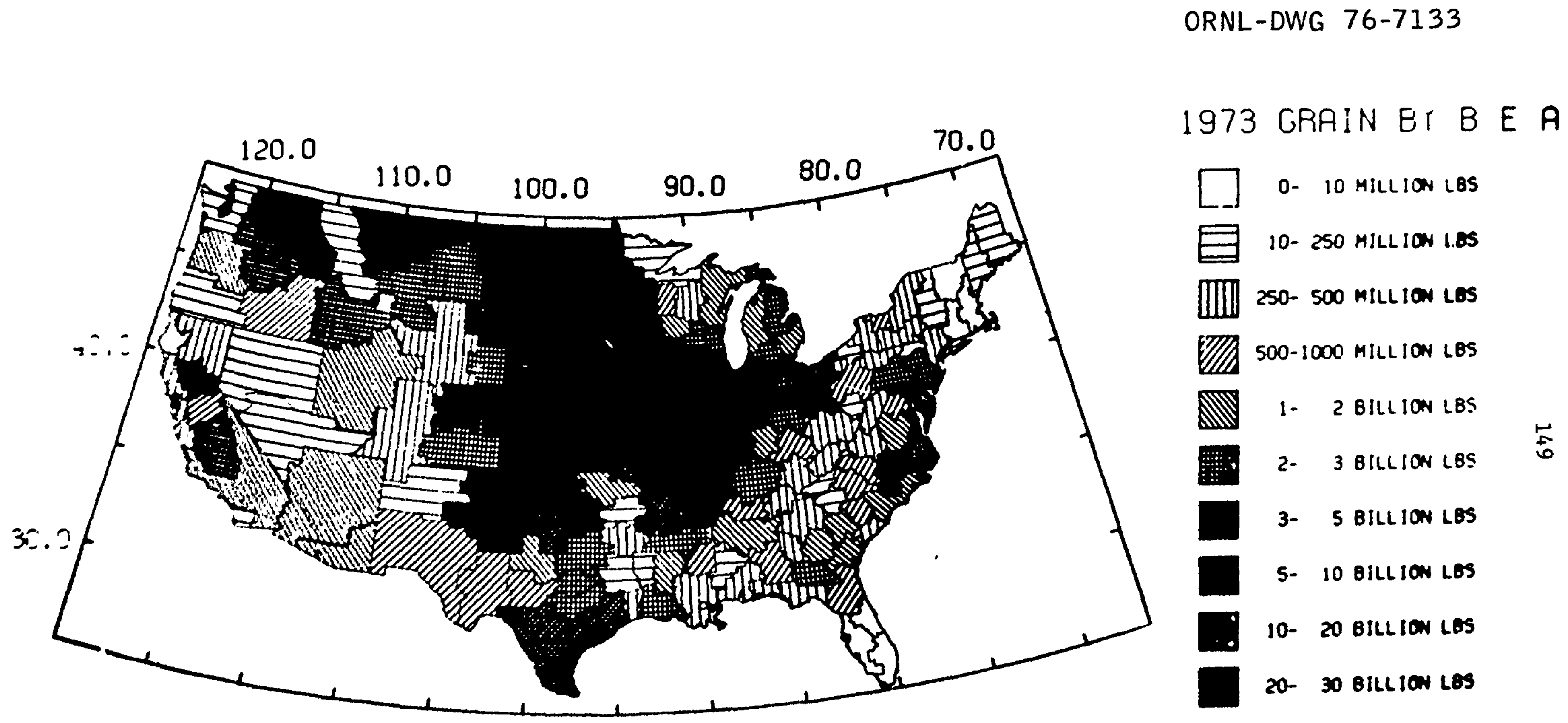


Fig. 7.8 Distribution of Production of Grain in 1973 by BEAs.

level of 365 food-days. Distances were computed along a great-circle on the earth's surface connecting the geographical centroids of the BEAs.

A solution of the grain shipment problem for the first six weeks is shown in Table 7.2. The total shipments amount to about 91,000 tons the first week, and increase to about 305,000 tons by the sixth week, as grain reserves in deficit BEAs are used up. The number of train carloads or truckloads or barges which would be required to ship the grain if only one mode of transportation were used is shown for each week in Table 7.2. The number of train carloads (or truckloads) for grain shipment increases from 1663 (or 5078) in the first week to 5785 (or 17,672) in the sixth-week, assuming that a closed or covered railroad car (adapted for emergency use) averages 55 tons per load, and a closed truck averages 18 tons per load. In comparison, the number of railroad carloads and truckloads per week in 1970, considering only those vehicles suitable for hauling grain, averaged about 266,000 and 308,000, respectively. The sixth week grain shipments in Table 7.2 would require about 2% of the 1970 railroad capability, or about 6% of the 1970 trucking capability, if only one mode of transportation were used. Due to inefficiencies in communication and control, a requirement for a much larger percentage of the U.S. transportation capability for shipping food supplies should be anticipated. Actually all three modes of transportation would be used to some extent, although the use of barges would probably be highly limited during the first few weeks because of the destruction to locks and port facilities, and obstructions by fallen bridges. Barges are extremely useful in hauling bulk cargo such as grain, averaging about 1100 tons per load, equivalent to about 20 average railroad carloads.

An analysis of alternative grain distribution systems has been made by Ladd and Lifferth (1975) for the purpose of optimizing the peacetime shipment problem. Their model could possibly be adapted to show changes which would improve the postattack shipment problem for the relocated population.

Note that in Table 7.2, the heaviest shipments are from the Baltimore BEA, #17, to the New England BEAs, in which 26.44 million people are

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TABLE F 2

Postattack Grain Shipments to Deficit Food Areas

BEA Source		BEA Destination			First Week				Second Week				Third Week				Fourth Week				Fifth Week				Sixth Week			
No.	Name	No.	Name	Distance (Miles)	Tons	RR CL	TRR	Barges	Tons	RR CL	TRR	Barges	Tons	RR CL	TRR	Barges	Tons	RR CL	TRR	Barges	Tons	RR CL	TRR	Barges	Tons	RR CL	TRR	Barges
38	Tallahassee, FL	37	Tampa-St. Petersburg, FL	261	3423	63	191	3	Source Exhausted				Source Exhausted				Source Exhausted				Source Exhausted				Source Exhausted			
168	Sacramento, CA	170	Eureka, CA	168	7366	134	410	*	79	49	42	*	7679	160	427	*	7670	160	4	*	479		*	*	479	360	427	*
163	Tucson, AZ	166	San Diego, CA	328	5922	108	329	*			518	*	4150	170	518	*	9330	170	518	*	9347	17	518	*	9330	170	518	*
17	Baltimore, MD	4	Boston, MA	416	13983								13983				13983				13983				13983			
		5	Hartford, CT	335	11146								11215				11214				11214				11214			
		3	Burlington, VT	459	13533				*				14355				14355				14355				14355			
		2	Portland, ME	552	3854	773	2362	36	15557				15758				15757				15757				15757			
		1	Bangor, ME	659	0				3117				6130				6130				6130				6130			
		14	New York, NY	249	0				29353	1633	4968	82					57903				57903				57903			
		6	Albany-Schenectady-Troy NY	377	0				0				3966	2262	685	117	22752	2695	7410	175	[illegible]				[illegible]			
		12	Binghampton, NY PA	241	0				0				0				0				[illegible]	1899	8858	[illegible]	5062			
		7	Syracuse, NY	356	0				0				0				0				0				190	5510	1013	[illegible]
41	Albany, GA	37	Tampa-St. Petersburg, FL	290	15180				18603				18603				18603				18603				18603			
		36	Miami, FL	376	9968				9968				9968				9968				9968				9968			
		35	Orlando, FL	231	6984	585	1786	30	7606	658	2010	55	7606	658	2010	55	7606	658	2010	55	7606	658	[illegible]	[illegible]	7606	658	2010	55
156	Yakima, WA	155	Seattle-Everett, WA	218	(91359)	(1663)	(5078)	(72)	6778	315	[illegible]	6	12500	228	695	12	12500	228	695	12	12500	8	695	3	12500	18	695	[illegible]
128	Waco, TX	130	Tyler, TX	134					(149266)	(2716)	(8292)	(121)	7734	161	410	*	8603	479	483	*	8693	158	693	*	8603	58	483	*
64	Columbus, OH	65	Clarksburg, WV	124									3263	60	182	*	3830	70	213	*	3830				3830			
		6	Buffalo, NY	257									(199991)	(3639)	(11113)	(157)	0				12466	97	896	37	27566			3
		52	Huntington-Ashland, WV, KY, OH	113													0				0				9211	56	7255	
167	Pueblo, CO	166	Albuquerque, NM	205													2223	42	356	*	5009	3	47	*	4109	3	[illegible]	*
68	Eau Claire, WI	87	Duluth-Superior MN-WI	142													(206925)	(3958)	(12066)	(1701)	4933	37	182	*	3003	55	[illegible]	[illegible]
42	Macon, GA	44	Atlanta, GA	95																	(244063)	(16921)	(14701)	(1202)	13709	49	782	*
																									(304858)	(5785)	(21672)	(719)

*No waterways connecting source and destination

() Numbers in parentheses are totals

located according to the ADAGIO distribution. In the seventh week (not shown in Table 7.2) the grain reserve in the Baltimore BEA is exhausted, and shipments to the New England BEAs must come from other more distant BEAs, such as Norfolk, VA. The solution for the shipment problem beyond six weeks may be meaningless for two reasons: (1) people may begin to move out of the relocation areas, and, (2) the Mississippi River may become open to barge traffic, and unloading facilities for ships and barges along the Atlantic coast may begin to operate, and grain shipments from the grain belt may become feasible. A complete solution of the grain shipment problem, involving costs of each mode of transportation and actual distances of travel, is infeasible because the precise location and degree of damage to facilities and the limitations imposed by fallout, debris and damaged bridges is unpredictable.

The solution of the grain shipment problem indicates that, within the assumptions described earlier, grain can be shipped to alleviate food shortages well within the capabilities of the surviving transportation facilities and petroleum.

8. PETROLEUM

Of 224 refineries in the U.S. in 1973, as shown in Fig 8.1, 136 are destroyed in the CRP-2B attack, and these 136 had 79.7% of the total U.S. crude refining capacity in 1973, the total being about 14.6 million barrels per stream-day (Oil and Gas Journal, April 1, 1974). In Canada there were 42 refineries in 1973 with a total capacity of 2.1 million b/sd, which is 71% of the capacity of those refineries in the U.S. which are not attacked in the CRP-2B attack. Refineries which produce asphalt only, are not considered here.

Of the remaining 88 refineries in the U.S. which are not struck by the CRP-2B attack, many would be inoperable because of the lack of electricity and/or the lack of feedstock such as crude oil, and those existing inside a region of fallout would also become inoperable, because none of them are constructed to operate under fallout conditions (Stephens, 1973). If the Soviets wished to destroy these remaining refineries, they would have to divert about 93 weapons to reduce the total surviving U.S. refining capacity to about 3% of the 1973 capacity, or 114 weapons for 2%, or 169 weapons for 1% remaining capacity, assuming that the system reliability of their weapons is 66.7%. Methods for analysis of surviving refining capability are given in Appendix C.

The petroleum industry requires a substantial inventory for operations and some inventory is unavailable, such as the product at the bottoms of tanks. Minimum operating inventories for 1973 for the U.S. are shown in Table 8.1, (National Petroleum Council, 1974). Illustrative operating conditions of the trans-Alaska pipeline are shown in Fig. 8.2. Under severe emergency conditions threatening survival, it may become necessary to tap into the unavailable supplies, that is, stocks in tank bottoms and in pipelines, although it may be inevitable that damage will be done to the part of the system which is tapped into.

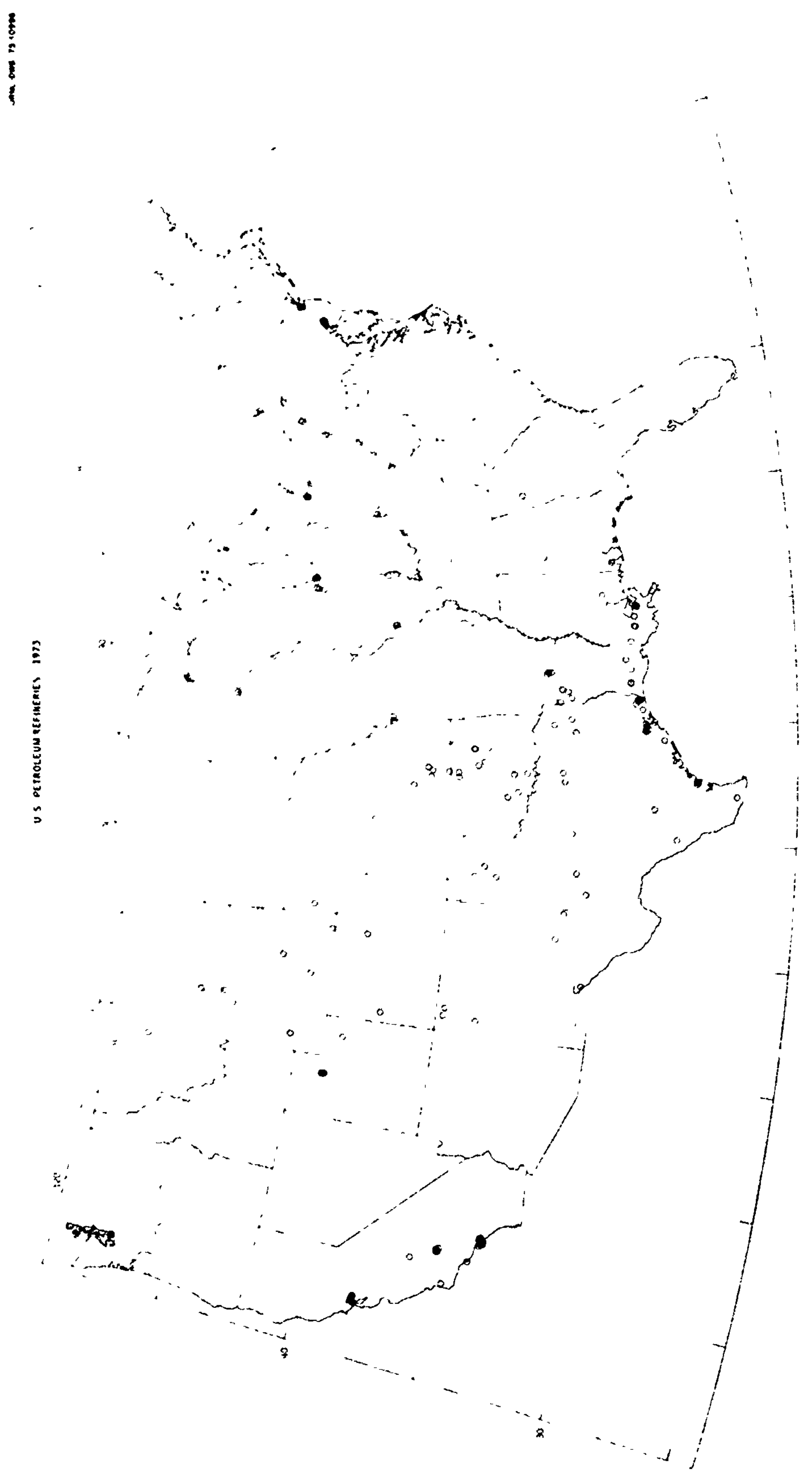

Fig. 8.1 Refineries in U.S.

Table 8.1

Minimum Operating Inventories, 1973
(Millions of Barrels)

	Total Inventory Reported to Bureau of Mines 9/30/73 (1)	Unavailable Inventory Reported to NPC 9/30/73 (2)	Minimum Operating Inventory (3)	Additional Inventory to Meet Seasonal Needs (4) (Percent of (3))
Crude Oil*	241	155	240	Nil
Products				
Gasolines (Including Avgas)	214	74	200	12%
Kerosine/Kero Jet	37	11	30	
District I-IV	6	2	5	
District V	42	13	35	26%
Naphtha Jet Fuel	5	1	5	-‡
Distillate Fuel Oil	199	37	100	108%
Residual Fuel Oil	62	11	50	Nil

*Includes producers' lease stocks.

‡Specific seasonal build-up levels are not shown for naphtha-type jet fuels. These are produced by blending certain components in the gasoline boiling range with components in the kerosine boiling range and seasonal fluctuations can be covered by inventories of these other products.

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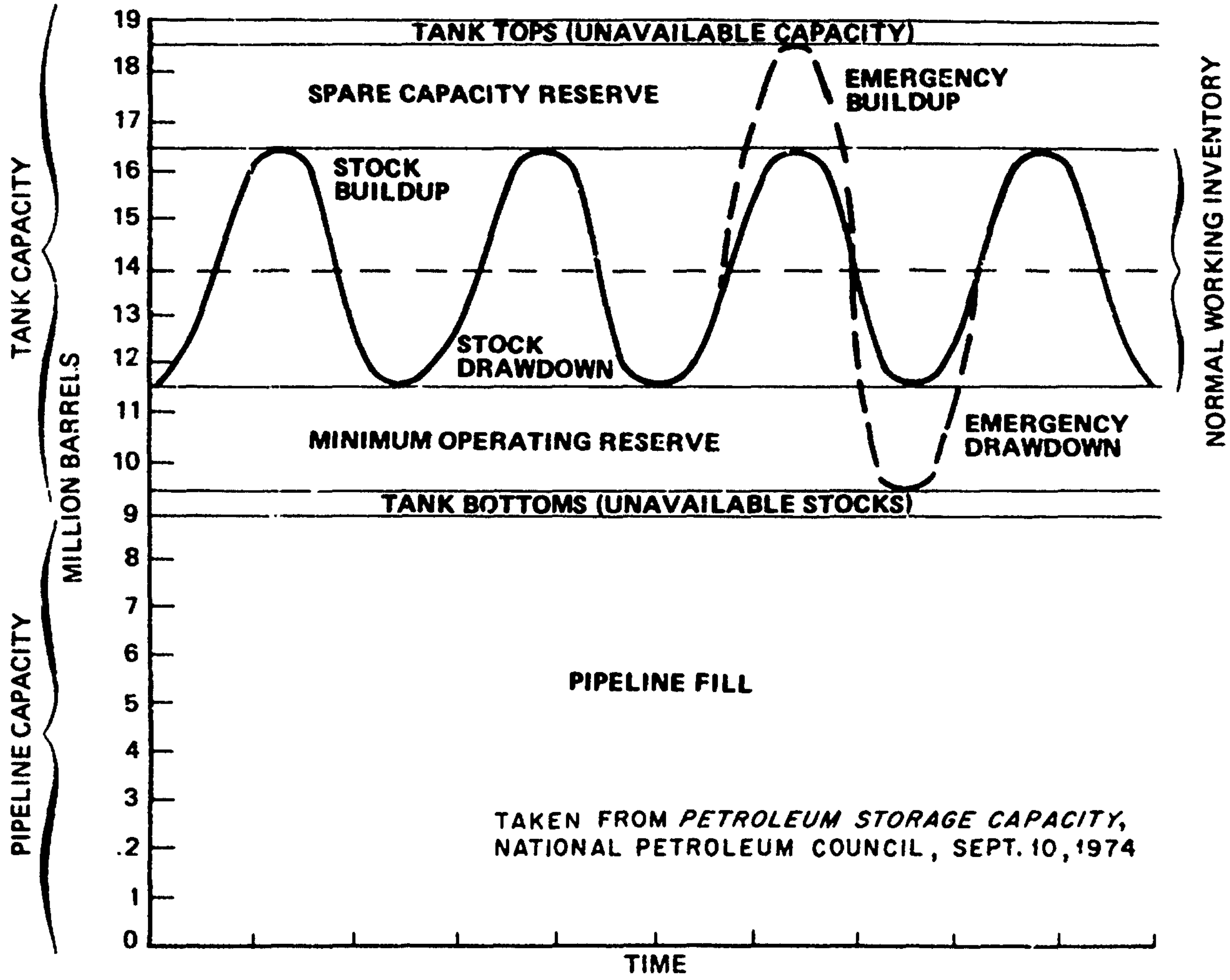

TAKEN FROM *PETROLEUM STORAGE CAPACITY*, NATIONAL PETROLEUM COUNCIL, SEPT. 10, 1974

Fig. 8.2 Illustrative Operating Conditions Trans-Alaska Pipeline.

9. THE MEDICAL LOAD

Our primary concern in this project is for the relocated population which has, in accordance with the assumptions given to us in our work statement, been adequately protected against fallout radiation, and has been removed from the area affected with blast and fire. If the shelters are also properly equipped, as discussed previously in section 4.6 and if the guidelines for exposure to radiation are properly observed, there should be little requirement for medical care for the relocated population beyond the normal situation. Under these particular conditions, the principal additional potential hazards will be the increased exposure to infectious disease brought about by the conditions of continued close proximity to other people in shelters, and, if the shelter is located in a cave, there is a high probability of histoplasmosis if bats have been using the cave.

A rough estimate of the maximum number of people who could become affected by a communicable disease in shelter can be made. The number of reported cases of infectious communicable diseases in the U.S. in 1974 is listed in Table 9.1. The total number of cases in 1972 was around 450,000. If we assume this number of cases occurs during the year in which relocation takes place, and also assume, very roughly, that the average duration of infectious stage is two weeks, and that 90% of the infected population is relocated into shelters, then it is probable that about 16,000 infected people enter shelters. In the worst case, each infected person will enter a different shelter. The average shelter occupancy is expected to be around 100 people, and if half of these contract the infectious diseases because of shelter conditions, then the total number of ill people in shelters may reach a maximum of about 800,000. These numbers do not include influenza, which may increase the number of ill people by as much as 25%, depending on the season.

As of December 31st, 1971, there were 316,545 medical doctors in the U.S., one doctor for an average of about 650 people. If doctors are distributed approximately according to the population, then 60-70% of

Table 9.1

Reported Cases of Specified Notifiable Diseases
United States, 1972-1974

Disease	1972	1973	1974
Amebiasis	2,199	2,235	2,743
Anthrax	2	2	2
Chickenpox	164,114	182,927	141,495
Diphtheria	152	228	272
Encephalitis	1,302	1,967	
Hepatitis	63,476	59,200	59,340
Leprosy	130	146	118
Measles (rubella)	32,275	26,690	22,094
Meningococcal infections	1,323	1,378	1,346
Mumps	74,215	69,612	59,128
Pertussis (whooping cough)	3,287	1,759	2,402
Poliomyelitis, total	31	8	7
Rheumatic fever, acute[a]	2,614	2,560	2,431
Rubella (German measles)	25,507	27,804	11,917
Salmonellosis, excluding typhoid fever	22,151	23,818	21,980
Shigellosis	20,207	22,642	22,600
Tuberculosis (newly reported cases)[b]	32,882	30,998	30,210
Typhoid fever	398	680	437
Typhus fever	541	700	780
Total	446,806	455,354	379,302

[a] Reports of cases of acute rheumatic fever were received from 36 states (see p. 8).

[b] Provisional figure for 1974.

SOURCE: MORBIDITY & MORTALITY, 23 (53) for year ending December 28, 1974, Center for Disease Control, U.S. Department of Health, Education, and Welfare.

these, or about 200,000 are located in the high risk-areas. If three-fourths of these doctors relocate with the population during the crisis period, and the others stay with their patients in the city hospitals, then there would be approximately 250,000 doctors surviving in the host areas after the attack. If the average shelter occupancy is 100 people, there will be about 1.8 million shelters, with one doctor for every seven shelters, for 700 people.

From these observations, we conclude that, if the shelters provide adequate protection against fallout, and if they are properly equipped, the initial medical load after an attack will not be severe in the host areas.

A number of caves have been stocked as fallout shelters, and a great many more caves could probably be adapted for use as shelters, as suggested in an article in PARADE magazine (June 15, 1975). One of the hazards of caves which could increase the medical load if caves were used extensively without taking precautions is the prevalence of the fungus, histoplasmosis, (Lewis, 1974) which develops in the droppings of bats or birds which have used the caves as shelters.

It would be useful for planning for a crisis relocation to have a survey of caves suitable for human occupancy, including the prevalence of histoplasmosis in the caves.

If the shelters in the host areas do not provide adequate protection from fallout radiation and are not properly equipped, there will obviously be a great increase in the medical load. Because of the lowering of the number of white blood cells due to exposure to harmful radiation, the resistance to infectious diseases is lowered, which, combined with possibly reduced morale and nonideal sanitary conditions in the shelters, could lead to rampant spreading of disease and more serious reactions to them in shelters which do not provide adequate fallout protection. Large quantities of antibiotics may be required to cope with this situation. Medical supplies should be moved to the host region during the crisis period. According to a study by Staackmann, et al., (1970), as much as 80% of the current drug manufacturing capability could be destroyed by an attack on the urbanized areas, but the surviving 20% could probably expand their operation in the postattack period and adequately meet the requirements.

10. GOVERNMENT AND THE ECONOMY

It is generally accepted among civil defense researchers (Allnut, 1971; W. M. Brown, 1971; Chenault, et al., 1967; Chenault and Nordlie, 1971; Dresch and Ellis, 1968; Goen and White, 1974) that a strong continuing government is essential for economic recovery after a nuclear attack. It is not as widely recognized that a strong federal government may be necessary for survival of a large number of people in the first few weeks after a nuclear attack, especially if these people have been removed from target areas by relocation during the crisis period. W. M. Brown (1971) has developed a scenario in which the federal government and most of the state governments are incapacitated due primarily to a failure to relocate during the crisis period preceding a nuclear attack, although a partial unplanned evacuation of the urban population occurs. Brown states that "the concept of rescue or assistance to neighboring communities fails because of the extreme threat to survival prospects felt nearly everywhere (due to fallout radiation, and shortages of food and fuel), and because of the lack of a national authority with the capability to effect the required actions" (insert added).

Our research indicates that a large-scale shipping program of grain may be necessary in the first few weeks after a nuclear attack, in order to avoid severe food shortages for 60-80 million people. This operation will require coordinated multi-state federal planning and supervision, as indicated by the grain shipments listed in Table 7.2.

The major supply of grain in the postattack situation will be in the hands of farmers and owners of rural elevators. Surrender of grain by these people for federal promissory notes will require their confidence and trust in the federal government. It is unlikely that sufficient federal law enforcement or military personnel will be available to confiscate food in face of widespread opposition by local authorities.

Federal authority will depend on: (1) the existence of a functional national leadership with the appearance of self confidence, and (2) the existence of a credible recovery program. The existence of each of these elements must be conveyed by convincing communications to the public. The President, or other emergent leaders, can make an enormous, almost indispensable, contribution to survival and recovery as well as national unity by frequent morale-building speeches broadcast on AM radio. The national resolve for recovery and unity could be increased by the existence of external threats, possibly from other than the Soviet Union. A strong feeling for revenge may arise, which may unite the nation toward a common goal even more intensely than the spirit which pervaded the nation during World War II ("Remember Pearl Harbor").

One of the plans for management of the economy in the postattack situation specifies that all resource allocations of major importance are to be directed by government agencies, and that inflationary pressures are to be controlled by price and resource-use regulations rather than by monetary authorities (Sobin, 1969). Sobin suggests that an inflationary gap may arise from the use of this system which could threaten the effectiveness of money as a means of exchange. He proposes that greater efficiency in resource management would result from a system that would divide the economy into two sectors: one would be controlled in the manner currently planned for the entire economy, and the other would be controlled by a system that would leave much larger scope for private initiative and allow prices to rise toward an equilibrium level appropriate to the supply and demand conditions existing in the postattack situation. The closely controlled sector would include all production for government and population survival use; the free sector would include all other production, including production of survival-type items in excess of survival needs.

The economic recovery measures instituted would have to be responsive to the conditions that actually prevailed after the attack. It is beyond the scope of this study to more than indicate that the economic problems would be national and require a strong, competent national government enjoying the confidence of the people for their solution.

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> hosting capacity is great (except in basement spaces) and where postattack workers could be housed relatively close to critical plants and families . . . Retail trade per capita appears to be a much sounder basis for deriving the relative hosting capacities of different communities than the oft-cited availability of basement spaces. The cost of providing improvised shelter in a community otherwise capable of expanding services will probably be far less than the costs of upgrading the organizational capacity of a community which happens to have many shelter spaces . . . The continuity of economic organizations is a salient factor in evacuation followed by attack, with the requirement for reorganizing the postattack economy to maximize production and distribution of essential goods and services."

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APPENDIX A

TRANSPORT BY COMMERCIAL AIRLINES

APPENDIX A. TRANSPORT BY COMMERCIAL AIRLINES[*]

A.1 Introduction

It is assumed here that most land routes are closed and seaports are destroyed. A massive airlift would then be the alternative for bringing in supplies and evacuating people from regions heavily contaminated with fallout. As shown in recent history, air evacuation and supply is possible.

The Berlin Airlift and the partial evacuation of Danang, Vietnam, have demonstrated the feasibility. A Boeing 747, with FAA-approved seating capacity of 498, was altered to have a capacity of over 1000, although it was not used in the evacuation. In similar conditions, other aircraft seating capacities could be extended.

Tables A.1 and A.2 list the aircraft available for evacuation purposes in the Reserve Air Fleet (CRAF) and War Air Services Program (WASP) fleet. These tables list the seat-mile and cargo ton-mile capacities of the fleet, using averaged data pertaining to normal operating procedures. These are listed to give an idea of the order of magnitude that is of interest. Table A.3 lists aircraft from each major grouping and contains information pertaining to them. With this information and the use of Figs. A.1 and A.2, an idea can be obtained of the length of runway required to launch a specified aircraft. This information has been listed in Table A.4 for the aircraft mentioned, also listed are flight times and fuel consumption for 500- and 1000-mile flights.

Of prime interest is that in an actual emergency situation, i.e., a crisis situation preceding a potential nuclear attack, no plan exists for the relocation of our commercial air fleet from target areas. A detailed plan should be developed to meet this situation.

A.2 Existing Programs

The CRAF and WASP were created in case of a national emergency by Executive Order 11490. They are comprised of all transport aircraft

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[*] Appendix A was written by Ronald R. Davis.

Table A.1

Annual Passenger Seat-Mile and Additional Cargo Ton-Mile Capacities of WASP Passenger Aircraft, Calendar Year 1975
International Fleet

Aircraft	Number in Certificated Carrier Fleet 12/31/74	International CRAF Fleet 12/31/74	International WASP Fleet 12/31/74	Annual Psgr. Seat-Mile Capacity Per Individual Aircraft (in thousands)	Annual Additional Cargo Ton-Mile Capacity Per Individual Aircraft (in thousands)
TURBOFAN-4 ENGINE					
707-300B	109	7	102	265,943	9,995
B-720B	7	-	7	216,741	5,464
B-747	104	69	35	657,679	39,758
DC-8-50	13	-	13	241,448	7,629
-61	34	-	34	340,530	11,119
-62	14	-	14	283,138	8,978
TURBOFAN-3 ENGINE					
B-727-100	68	-	68	163,162	3,802
-200	130	-	130	228,235	6,145
DC-10-10	22	-	22	409,771	19,868
-30/40	24	14	10	430,875	32,587
L-1011	47	-	47	457,987	18,357
TURBOJET-4 ENGINE					
B-707-300	10	-	10	258,457	8,497
B-720	3	-	3	220,752	8,059
DC-8-10/20	3	-	3	244,035	6,847
-30	4	-	4	231,425	7,243

Table A.1 (cont'd)

Aircraft	Number in Certificated Carrier Fleet 12/31/74	International CRAF Fleet 12/31/74	International WASP Fleet 12/31/74	Annual Psgr. Seat-Mile Capacity Per Individual Aircraft (in thousands)	Annual Additional Cargo Ton-Mile Capacity Per Individual Aircraft (in thousands)
TURBOPROP-4 ENGINE					
L-188 A/C/F	1	-	1	90,900	723
TOTALS	593	90	503		

SOURCE: J. F. Laufer, Civil Aeronautics Board War Air Service Program (WASP) Resource Report, Bureau of Economics, Civil Aeronautics Board, 1975.

Table A.2

Annual Passenger Seat-Mile and Additional Cargo Ton-Mile Capacities of WASP Passenger Aircraft, Calendar Year 1975 Domestic Fleet

Aircraft	Number in Certificated Carrier Fleet 12/31/74	Domestic CRAF Fleet 12/31/74	Domestic WASP Fleet 12/31/74	Annual Psgr. Seat Mile Capacity Per Individual Aircraft (in thousands)	Annual Add'l. Cargo Ton-Mile Capacity Per Individual Aircraft (in thousands)	Total Annual Psgr. Seat-Mile Capacity of WASP Fleet (in thousands)	Total Annual Additional Ton-Mile Capacity of WASP Fleet (in thousands)
TURBOFAN-4 ENGINE							
B-707-100B	90	—	90	204,484	9,633	18,403,560	866,970
B-720B	16	—	16	200,268	5,870	3,204,288	93,920
DC-8-61	14	—	14	295,891	12,203	4,142,474	170,842
TURBOFAN-3 ENGINE							
B-727-100	222	—	222	149,971	4,218	33,293,562	936,396
-200	205	—	205	192,994	6,330	39,563,770	1,297,650
DC-10-10	50	—	50	403,077	21,196	20,153,850	1,059,800
L-1011	23	—	23	394,616	20,086	9,076,168	461,978
TURBOFAN-2 ENGINE							
B-737-200	132	—	132	127,290	2,979	16,802,280	393,288
BAC-1-11-200	48	—	48	77,395	1,498	3,714,960	71,904
DC-9-10	69	—	69	98,725	2,575	6,812,025	177,675
-30	246	—	246	125,816	3,635	30,950,736	894,210

Table A.2 (cont'd)

Aircraft	Number in Certificated Carrier Fleet 12/31/74	Domestic CRAF Fleet 12/31/74	Domestic WASP Fleet 12/31/74	Annual Psgr. Seat Mile Capacity Per Individual Aircraft (in thousands)	Annual Add'l. Cargo Ton-Mile Capacity Per Individual Aircraft (in thousands)	Total Annual Psgr. Seat-Mile Capacity of WASP Fleet (in thousands)	Total Annual Additional Ton-Mile Capacity of WASP Fleet (in thousands)
TURBOJET-4 ENGINE							
B-720	6	—	6	201,779	924	1,210,674	5,544
DC-8-10/20	30	—	30	204,838	5,709	6,145,140	171,270
-30	11	—	11	214,474	7,754	2,359,214	85,294
DC-8-50	28	—	28	219,949	5,373	6,158,572	150,444
TURBOPROP-4 ENGINE							
L-188 A/C/F	19	—	19	81,585	742	1,550,115	14,098
TURBOPROP-2 ENGINE							
CV-580	104	—	104	42,566	1,129	4,426,864	117,416
-600	24	—	24	31,536	1,025	756,864	24,600
DHC-6	3	—	3	8,705	116	26,115	348
F-27	11	—	11	29,492	74	324,412	814
FH-227	40	—	40	33,014	293	1,320,560	11,720
YS-11	21	—	21	44,457	—	933,597	—
PISTON-2 ENGINE							
M-404	12	—	12	24,820	248	297,840	2,976
Totals	1,424	—	1,424			211,627,640	7,009,097

SOURCE: J. F. Laufer, Civil Aeronautics Board War Air Service Program (WASP) Resource Report, Bureau of Economics, Civil Aeronautics Board, 1975.

Table A.3

Characteristics of Representative Aircraft in the Commercial Fleet

Aircraft Manufacture	Boeing	Lockheed	McDonnell-Douglas	McDonnell-Douglas
Aircraft Model & Series	B-747-100	L-1011 TriStar	DC-9-30	DC-8-10/20
Number of Engines & Type	4 Engine Turbofan	3 Engine Turbofan	2 Engine Turbofan	4 Engine Turbojet
Quantity in U.S. Service	142	65	276	33
*Fuel Capacity (U.S. gal)	47,210	22,984	3,679	17,552
Passenger Limits	498	272	105	189
Cargo Wght. Limits (lbs)	174,689	85,500	26,700	34,500
Maximum Zero Fuel Weight	526,500	325,000	84,000	173,500
Maximum Landing Weight	564,000	358,000	98,100	199,500
Maximum Takeoff Weight	733,000	430,000	103,000	270,000
Wheel Track	36'1"	36'0"	16'6"	20'10"

*Jet fuel weight/gallon = 6.7 lb/gal.

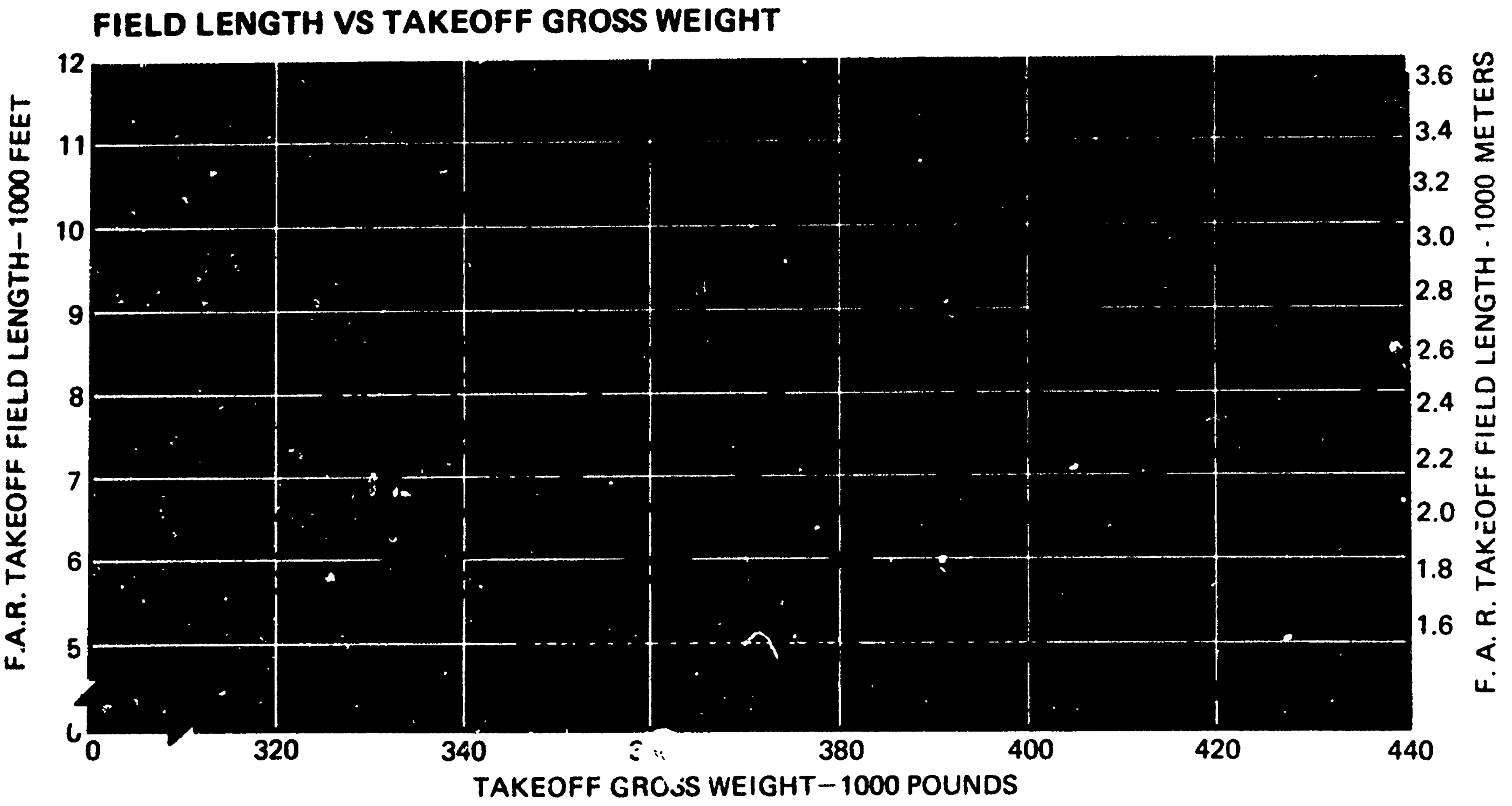

Fig. A.1 Field Length Requirements for the L-1011 Lockheed TriStar Aircraft. SOURCE: Lockheed-California Company, Lockheed 1011 Technical and Operations Summary, COA 1323, Burbank, California, June 1971.

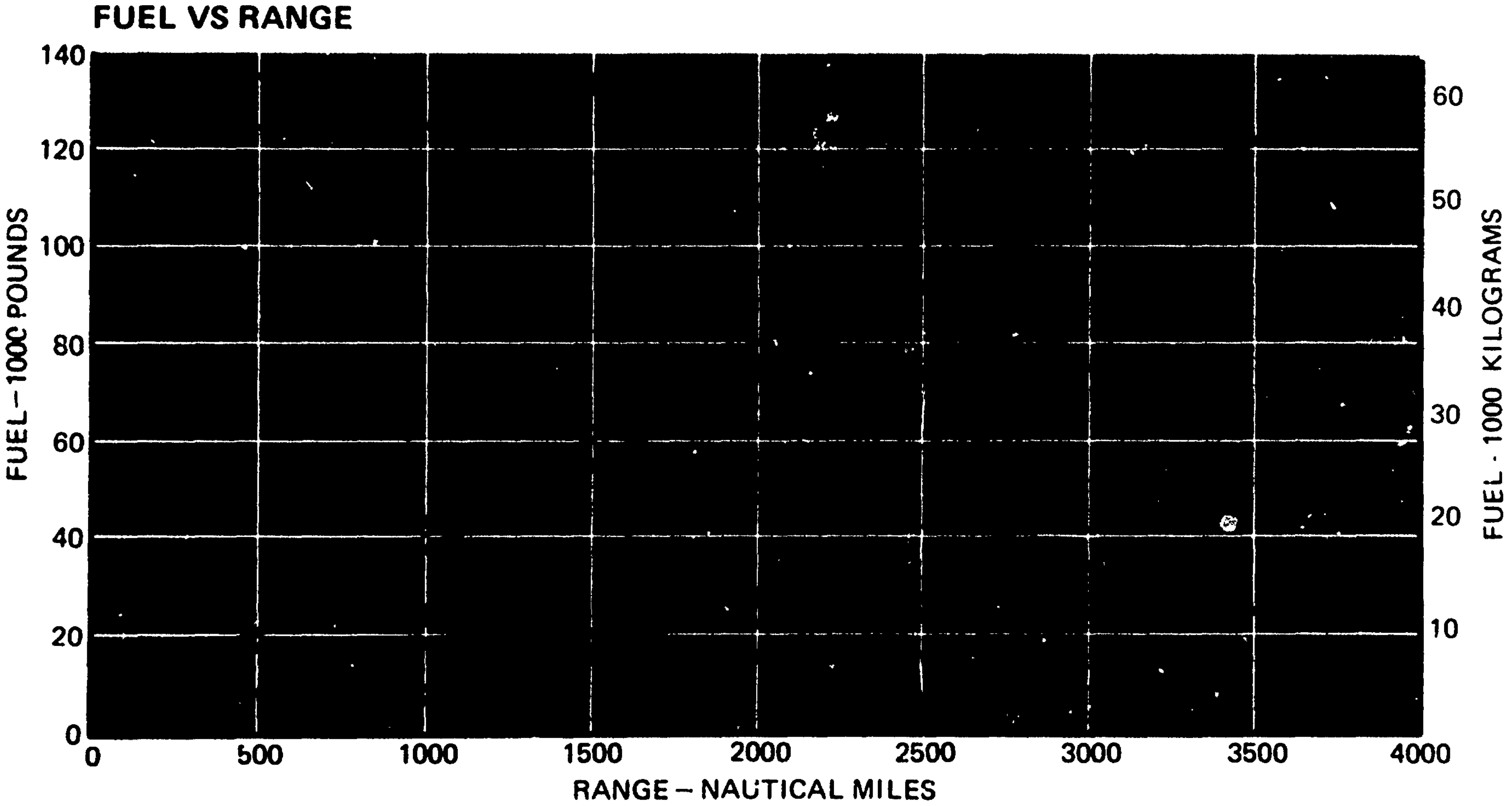

Fig. A.2 Fuel Requirements for the L-1011 Lockheed TriStar Aircraft.
SOURCE: Lockheed-California Company, Lockheed 1011 Technical and Operations Summary, COA 1323, Burbank, California, June 1971.

Table A.4

Performance Characteristics of Representative Aircraft

	B-747-100	L-1011	DC-9-30	DC-8-10/20
Maximum flight range from a 6,000 ft runway (Nautical Mile)	1,300	1,100	1,000	1,800
Maximum flight range from a 7,000 ft runway (Nautical Mile)	2,125	1,900	1,300	2,400
Runway length required for a 1,000 mile flight (ft)*	5,600	5,800	6,000	4,800
(1) Time of flight (hr)	2.4	2.4	2.4	2.4
(2) Fuel consumption (lb)	58,000	40,000	15,800	33,000
Runway length required for a 500 mile flight (ft)	5,300	5,500	4,750	4.200
(1) Time of flight (hr)	1.4	1.3	1.3	1.3
(2) Fuel consumption (lb)	33,000	22,000	8,800	19,000

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*These lengths are computed using the fuel (+ reserves) weight necessary to attain desired flight distance.

weighing over 12,500 lbs, and are controlled by the Department of Defense (CRAF) and Civil Aeronautics Board (WASP). The CAB publishes an annual resource report which lists the aircraft under its jurisdiction and data pertaining to the functions of the programs.

CRAF is composed of the most suitable U.S.-registered civil transport aircraft that are operationally capable of performing Department of Defense airlift. The Department of Defense is responsible for this program.

WASP is designed to provide for the maintenance of essential civil air routes and services. It also provides for the distribution and redistribution of air carrier aircraft among civil air transport carriers after the withdrawal of aircraft allocated to CRAF. The Civil Aeronautics Board is responsible for this program.

Two thousand seventeen aircraft comprise the CRAF and WASP fleet; each program has definite functions and duties, and they are regulated independently. For massive air evacuation to occur, priority must be shifted to schedule a maximum effort for each program. Procedures need to be documented and placed under the duties of the program.

A.3 Maintenance and Material Requirements

Information pertaining to the material requirements necessary to sustain operation of CRAF and WASP fleets were not available. Personal conversations with maintenance personnel associated with the aircraft were made to obtain an idea of the requirements necessary to maintain an aircraft in operation. They were asked to relate the operational stability of the aircraft and to estimate the parts and material requirements necessary to maintain operational status. Eastern Airlines Maintenance, Atlanta, conversation concerning DC-9, ". . . if given 6 to 8 hours notice, we can carry enough maintenance materials with our aircraft to maintain 90% of our fleet for a period of 6 months, allowing the remaining 10% for cannibalizing. . ." Eastern Airlines Heavy Maintenance, Miami, concerning B-727, ". . . most dependable aircraft we have . . . estimate a material requirement of 1000 lbs. per aircraft to maintain operation for 90 days."

To substantiate the opinions of these maintenance personnel, a check of Delta Airlines Maintenance Department was made which verified the estimates.

Estimates of support equipment necessary to maintain aircraft were given which ranged from 900-1200 lbs. In stating the conditions necessary to maintain the aircraft, the relocation of the aircraft from the target areas was proposed which implied the need to carry parts with them.

A.4 Description of Aircraft

For the purposes of this report only one aircraft is described in detail from each grouping of jet classification in Tables A.1 and A.2. This information is listed in Tables A.3 and A.4. The representative aircraft are Boeing's 747, Lockheed's L-1011, and McDonnell-Douglas's DC-8 and DC-9.

A.5 Alternate Airfields

Certain alternatives to formal runways could exist. To use dry lake and river beds, i.e., Utah Salt Flats, little would have to be done in preparing their surfaces for the accommodation of aircraft mentioned in this report. Also, portions of interstate highways could be used to accomodate certain selected aircraft that meet the desired criteria.

Wheel track, landing and takeoff distances, weights, and turning radii must be such as to meet the limitations of each specific aircraft. Careful planning is necessary in this respect.

The Department of Transportation, Concrete Division, supplied information concerning the concrete thickness of the interstate highway system. The interstates are relatively constant in thickness. Unreinforced highways are 10-11" in thickness. Reinforced highways are 9" thick. Figure A.3 shows the thickness of concrete necessary to support certain aircraft at various weight loads.

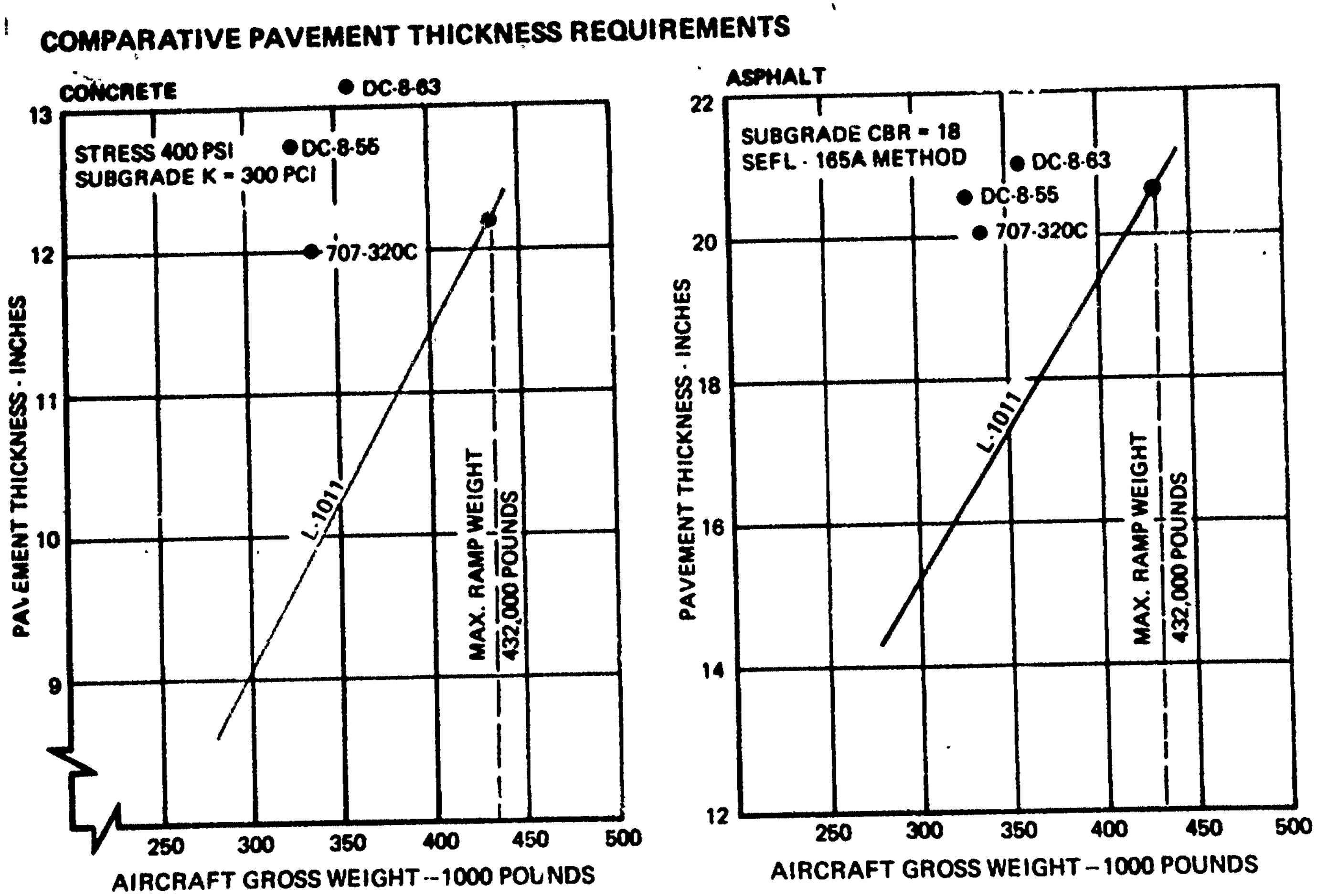

Fig. A.3 Runway Pavement Thickness for L-1011 Lockheed TriStar.
SOURCE: Lockheed-California Company, Lockheed 1011 Technical and Operations Summary, COA 1323, Burbank, California, June 1971.

APPENDIX B

MINIMIZATION OF TRANSPORT OF GRAIN

APPENDIX B. MINIMIZATION OF TRANSPORT OF GRAIN

The problem is to minimize the total ton-miles required to ship grain from BEAs (Business Economic Areas) which have a surplus to those which have a deficit.

Let Z = total ton-miles, the objective function,
x_{ij} = tons shipped from BEA *i* to BEA *j*,
d_{ij} = distance from BEA *i* to BEA *j* (straight-line, centroid to centroid),
x_i = initial quantity of grain in BEA *i*,
R_i = quantity of grain reserve in BEA *i* after shipments are completed (assume shipments are completed in zero time, at least for the first look at the problem),
P_i = number of people in BEA *i*,
S = number of days of grain reserve in grain-rich BEAs,
D = number of days of grain reserve to be built up in grain-poor BEAs.

Minimize $Z = \sum_i \sum_j d_{ij} x_{ij}$ subject to these constraints:

$\sum_j x_{ij} \leq X_i - R_i \geq 0$ (Total shipments from *i* do not deplete reserve in *i*) .

$\sum_i x_{ij} = R_j - X_j \geq 0$ (Sum of shipments to *j* are equal to reserve required in *j* minus initial quantity) .

For this particular problem we work with the distribution of the relocated U.S. population according to the ADAGIO program. We assume the grain reserve per BEA is 60% of the 1973 grain production.

We do not allow shipments of grain FROM counties in which $X_i < S \times 0.001 \times P_i$, ($X_i$ in tons); nor do we allow shipments TO counties in which $X_j > D \times 0.001 \times P_j$. We choose $S = 365$, and define

$R_i = S \times 0.001 \times P_i$ and $R_j = D \times 0.001 \times P_j$. Values are calculated for S and for D in mulitples of 7 days, up to 30 weeks.

Computer output lists source and deficit BEAs, distances, tons and ton-miles shipped.

APPENDIX C

SURVIVAL OF PETROLEUM REFINERIES

APPENDIX C. SURVIVAL OF PETROLEUM REFINERIES

We wish to determine the number of weapons of reliability, r, required to reduce the U.S. POL refining capacity to some fraction, k, of its present capacity.

Let c_j = crude capacity of the j-th refinery in barrels per stream day (b/sd), and

$$T = \sum_{i}^{N} c_j \text{, the total capacity of Nrefineries.}$$

Refineries which produce only asphalt will not be considered.

Let S = kT represent the expected surviving refining capacity, given by

$$S = \sum_{j=1}^{n} (1-r)^{n_j} c_j \quad , \qquad (1)$$

where n_j is the number of weapons delivered on the j-th refinery.

We assume the refineries are targeted so the expected surviving capacities are all equal, i.e.,

$$(1-r)^{n_j} c_j = (1-r)^{n_{j+1}} c_{j+1} \quad \text{, etc.} \qquad (2)$$

In this case,

$$S = N(1-r)^{n_j} c_j \quad , \qquad (3)$$

and the number of weapons to be delivered on the j-th refinery is given by

$$n_j = \ell n\left(\frac{S}{Nc_j}\right) / \ell n \; (1-r) \quad . \qquad (4)$$

The value of n_j is to be rounded off to the nearest positive integer, and is set equal to zero of n_j is negative (if $c_j < \frac{S}{H}$).

The total number of weapons is then obtained by summing over n_j.

The application of this formulation to U.S. and Canadian refineries results in the curves shown in Fig. C.1, in which $k = 0.03$, the reliability, r, has values of 0.5, 0.6, and 0.8, and the bombing list has been rank-ordered by decreasing capacity. If $r = 0.6$ (60% reliability), 800 weapons would be required to achieve an expectation of 3% survival of the capacity of U.S. and Canadian refineries.

We assume that a finite CEP has negligible effect on these calculations because we are dealing with megaton yield weapons and targets of high vulnerability.

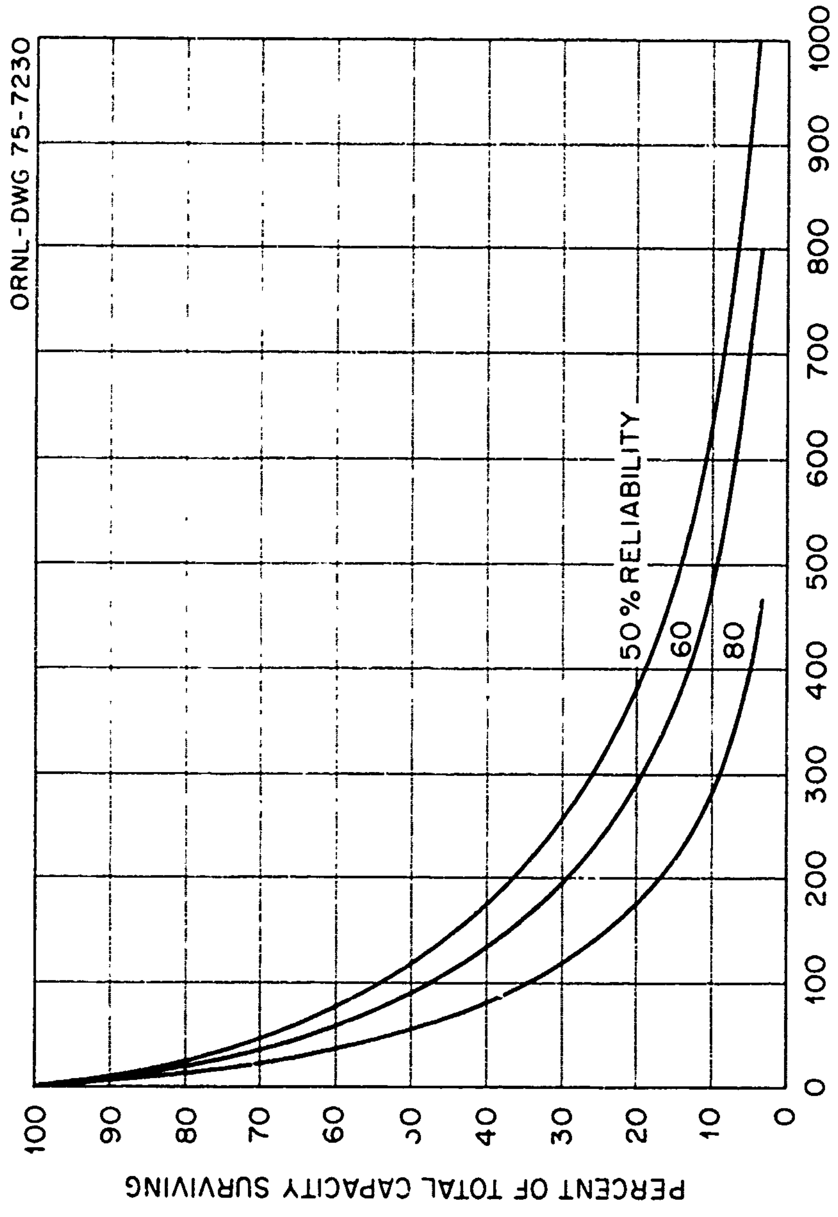

Fig. C.1 Survival of North American Refineries (266 in 1973) as a Function of Number of Warheads and Reliability.

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