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# INITIAL STUDY OF EFFECTS OF FALLOUT RADIATION ON SIMPLE SELECTED ECOSYSTEMS

by

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## ADMINISTRATIVE INFORMATION

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## ABSTRACT

The ecological balance maintained in many of our agricultural communities may be seriously affected by the effect of ionizing radiation from nuclear fallout on insect populations. In this study, the San Joaquin Valley in Central California was selected as the region for specific investigation to determine the extent of possible insect-population imbalance and the effect such an imbalance might have upon its agricultural production. The report discusses topographical and climatological conditions and presents data on the insect pest population and the agricultural commodities of the region. The beta bath dose at .003 cm tissue depth at various gamma-exposure-rate contour levels were computed and are presented in this report. The extent of the critical areas in which insect population imbalance may occur was determined for 1-, 10-, and 100-MT weapon bursts.

## SUMMARY

### THE PROBLEM

Insect population imbalance may occur in many of our agricultural communities as a result of ionizing radiation from nuclear fallout. In the absence of biological or chemical controls, this imbalance might cause widespread destruction and devastation of cropland and seriously impair the food resources of the country. For the purpose of defense planning, the biological and environmental consequences of nuclear fallout should be examined to determine the extent of insect population imbalance and its effect on their ecosystems. In this study, we shall investigate the extent of possible imbalance in the San Joaquin Valley.

### THE FINDINGS

The San Joaquin Valley was selected as the region for specific study. This region was selected for the following reasons: (1) it is well-defined as an ecological community; (2) its commodities are vital as a food source; and (3) data on production, climatological conditions, and insect-population distribution are well-documented. The study revealed that a 10-MT weapon burst over the Richmond area on San Francisco Bay would result in beta dose of sufficient level to sterilize many species of insects in the region while leaving other species relatively unharmed. The extent of this critical area (assuming 50% fission yield and a 15-mph wind) is approximately 13,000 square miles, or an area about equal to the size of the San Joaquin Valley.

The beta bath dose for six air gaps and the beta contact dose at .003 cm tissue depth were computed for various gamma-exposure-rate contour levels. Critical areas were determined on the basis of beta contact doses greater than 5000 rads in 5 days and 8000 rads in 45 days. For a 1-MT weapon burst with 50% fission yield and 15 mph wind, the critical

area is approximately bounded by the 35 r/hr standard-intensity contour line. The area within this contour is about 2,800 square miles. For a 10-MT burst, the critical area is bounded by the 60 r/hr line enclosing an area of about 13,000 square miles. For a 100-MT weapon yield, the critical area is extended to about 58,300 square miles and is approximately bounded by the 80 r/hr at 1 hour contour line.

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## SECTION 1

## INTRODUCTION

### 1.1 PURPOSE

This report documents the status of a study to determine the extent of ecological imbalance which may occur as a result of nuclear detonations and the effects such imbalance may ultimately have upon man. Specific data related to the geographical area (San Joaquin Valley in Central California) selected as the region for specific study are presented. General data pertaining to gamma and beta radiation from nuclear fallout, effects of ionizing radiation upon insects, animals and plants, and information on inter- and intra-relationships of insect species are also presented.

### 1.2 BACKGROUND

Ecology is the study of the interrelationship of plants and animals with their environments under natural conditions. These conditions may include periods of extreme weather conditions, fires caused by lightning, and other abrupt changes in the environment which may cause wide fluctuations in population composition and distribution. Although a static balance does not exist in a natural ecosystem, the community maintains itself with all the necessary exchanges among its members and preserves a more or less dynamic balance. In many ecosystems, however, where man is a dominant member of the community, the environment is altered to such an extent that the only natural conditions that remain are the climatological conditions. This is particularly true in the urban areas and in the vast agricultural communities. In this study, we are concerned primarily with an agricultural community whose production is relied heavily upon by man as a food source and in which insect population imbalance may occur as a result of radiation from nuclear fallout.

## 1.3 PROCEDURE

The study was divided into four major tasks: (1) a comprehensive survey of literature pertaining to the nature of ecological systems and the effects of ionizing radiation upon such systems; (2) selection of an ecosystem where insect population imbalance may occur as a result of radiation from fallout; (3) collection or preparation of data pertinent to the problem; and (4) development of a simplified modeling scheme which would reflect the various changes in the ecosystem as a result of radiation from nuclear fallout, or development of scenarios to describe the more conspicuous degradations in utility and ecological imbalances. This report documents the results and findings of the first three tasks. The work was terminated before significant progress in the fourth task covering either qualitative or quantitative modeling of ecosystem perturbations caused by fallout could be made.

## SECTION 2

## STATE OF THE ART

### 2.1 LITERATURE SURVEY

A comprehensive survey of literature pertaining to the nature of ecological systems and the effects of ionizing radiation upon such systems was undertaken. Bibliographies compiled by the following authors provided excellent reference sources for information and data: R.U. Ayres,[1,2] G.L. Clarke,[3] P. DeBach,[4] and J.D. Teresi and C.L. Newcombe.[5] The literature survey was intended to be a continuing project during the entire period of this study. Thus far, the survey has indicated a dearth of information regarding the relative abundance of specific insect species in relation to environmental changes and fluctuations in population of predators, prey, or parasites.

Several studies are currently underway to determine ecological effects of ionizing radiation. Among these are the studies conducted at Brookhaven National Laboratory,[6,7,8] the studies at Emory University[9] which make use of the 10 MW nuclear reactor operated by the Lockheed Aircraft Corporation in Georgia,[10] and the studies at Oak Ridge National Laboratory.[11,12,13] A comparative ecological study of the native fauna at the Nevada Test Site in order to investigate the effects of nuclear detonations on animals is being conducted at Brigham Young University.[14]

### 2.2 FIELD SURVEY

To obtain data and information on insect population and crop production, several contacts were established with Federal and California State agencies. The U. S. Department of Agriculture issues a weekly insect report* which would be helpful in determining the type and species of insect pests in any sector of the United States. Similarly, the California Department of Agriculture issues a monthly report** which could aid in pin-pointing insect infestation in the state. However, quantitative data for the various seasons and over a period of years are necessary before such data could be useful in correlating fluctuations in insect population and delineating the various channels of relationship among insects. The information disseminated by the State and Federal agencies on insects does not generally specify numeric quantities, but normally only identifies infestation as light, moderate, or heavy. Furthermore, beneficial insects, insect predators such as birds and small mammals, and insect parasites are not given the same amount of attention as are given pests. Insect pests of the San Joaquin Valley are discussed in Section 3.4.

Information on crop production, livestock commodities, and crop loss due to insect pests are reported on an annual basis in California.[15,16,17] The State accounts for about 10 percent of the total production of the United States. These data could be used to determine possible effect upon the national food supply if huge crop losses are sustained in the localized areas of normally high agricultural productivity such as the San Joaquin Valley. Crop and livestock commodities and losses are discussed in Section 3.3.

## 2.3 MATHEMATICAL ECOLOGY AND ECOSYSTEM MODELING

Mathematical ecology deals with the quantitative theory and analysis of ecosystems. This sector of ecology does not yet have any central theoretical formulation and for this reason the mathematical aspects of

*The "Cooperative Economic Insect Report" may be obtained from: Plant Pest Control Division; Agricultural Research Service; U. S. Department of Agriculture; Washington, D. C., 20425.

**The "Cooperative Insect Pest Report for California" may be obtained from: Bureau of Entomology; California Department of Agriculture; Sacramento, California, 95814.

ecology are incomplete.[18] The lack of theoretical formulation is due principally to the intrinsically complex elements that compose an ecosystem, and the continually changing relationships among its members. As soon as a theorem is advanced to describe a class of phenomena, the biological or physiological response of some members in the system is altered and the theorem is voided. If a particular insecticide were effective against an insect species, then subsequent generations of that species might build up an immunity to it and the effectiveness of the insecticide is thus diminished. Similarly, prey-predator and host-parasite relationships often change when the prey or host species adapts to the situation and develops some new means for survival. Or the predaceous or parasitic species may find some other food more palatable or more accessible and again upset the assignment of the mathematical formula that describes the relationship.

If one is willing to compromise the complexity of ecosystems, then some of the methods developed in econometry[19,20] and biometry[21] could be applied to the prediction of population composition and distribution. For this purpose, two basic simplifications of the ecosystem must be accepted. The first simplification is to assume that population behavior is orderly and therefore can be predicted; and the second is to group members of the ecosystem into major classifications depending upon their role within the community. For example, all food vegetation might be classified as crops while undesirable vegetation is classified as weeds. Other groups might be trees, granivorous insects, herbivorous insects, predaceous insects, birds, mammals, etc. The categories are chosen in such a way that members in which one is interested are isolated in separate classes. The grouping of members reduces the number of elements required to describe the many relationships, and permits the application of input-output analysis of economics to a homeostatic ecosystem.[22] Electronic analog computers have been used to simulate simplified ecosystem models and to solve population problems.[23]

## SECTION 3

## THE SAN JOAQUIN VALLEY AS AN AREA WHERE ECOLOGICAL IMBALANCE MAY OCCUR

### 3.1 GENERAL

In the agricultural communities of the United States, an unnatural ecological balance has been established and maintained by the efforts of man. These efforts take the form of biological and chemical control of insects, plants, and animals, the irrigation and cultivation of farmlands, and the addition of corrective chemicals and fertilizers to the soil. These efforts of course are directed towards the reduction of pests and the increase of livestock and commodities from farmlands. However, following a nuclear attack, man may be unable or unwilling to re-assert these efforts in the same intensity and thereby permit many agricultural areas to seek a natural ecological balance. The succession of such an ecosystem will be predicated upon a composition of plants and animals established by man and drastically affected by nuclear fallout. In this study, the effects of fallout upon an ecosystem of the San Joaquin Valley of California are investigated.

The selection of the San Joaquin Valley for subjective study was based upon these factors: (1) the area is well defined as an ecological community in that it has natural boundaries on practically its entire perimeter and the climate and topography of the region are relatively homogeneous; (2) the crop and livestock commodities produced in the area are vital as a food source for the entire western region of the United States; and (3) data on agricultural production, climatological conditions and insect population and distribution are well documented.

## 3.2 TOPOGRAPHY AND CLIMATE

The San Joaquin Valley is the region extending from Stockton, California in a southeasterly direction to Bakersfield. The length of the valley is about 250 miles and the width at its widest point is about 65 miles. The eight counties in the valley (see Fig. 3.1): San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern - compose the most productive agricultural region in the United States. Over 70 percent of the crop land in this area depends highly upon summer irrigation (see Fig. 3.2) so that the condition of watersheds in the surrounding mountainous regions would be a major factor in recovery after a nuclear attack.

The valley is bounded on three sides by mountain ranges (see Fig. 3.3) - the Diablo Range on the west, the Sierra Nevada on the east, and the Tehachapi on the south. Its northern portion is criss-crossed by a maze of sloughs in a delta region formed by the confluence of the Sacramento and San Joaquin rivers. The elevation of the heart of the valley is about 60 feet in the north, rising gradually to about 400 feet in the south.

The average rainfall (Fig. 3.4) in the region is as high as 20 inches per year in the north and less than 10 inches in the south. The climate is warm during the summer months with an average July temperature of about 80 degrees Fahrenheit giving the region a growing season of between 250 to 300 days (Fig. 3.5). Table 3.1 shows some sample weather data for this region.

Daily upper-air wind data for central California (Oakland station) were obtained from the Weather Bureau[25] for the period March 1951 through


Fig. 3.1 State of California County Boundaries. The San Joaquin Valley is the area enclosed by heavy line (Ref. 15). (Distributed by College of Agriculture, University of California and U. S. Department of Agriculture co-operating.)

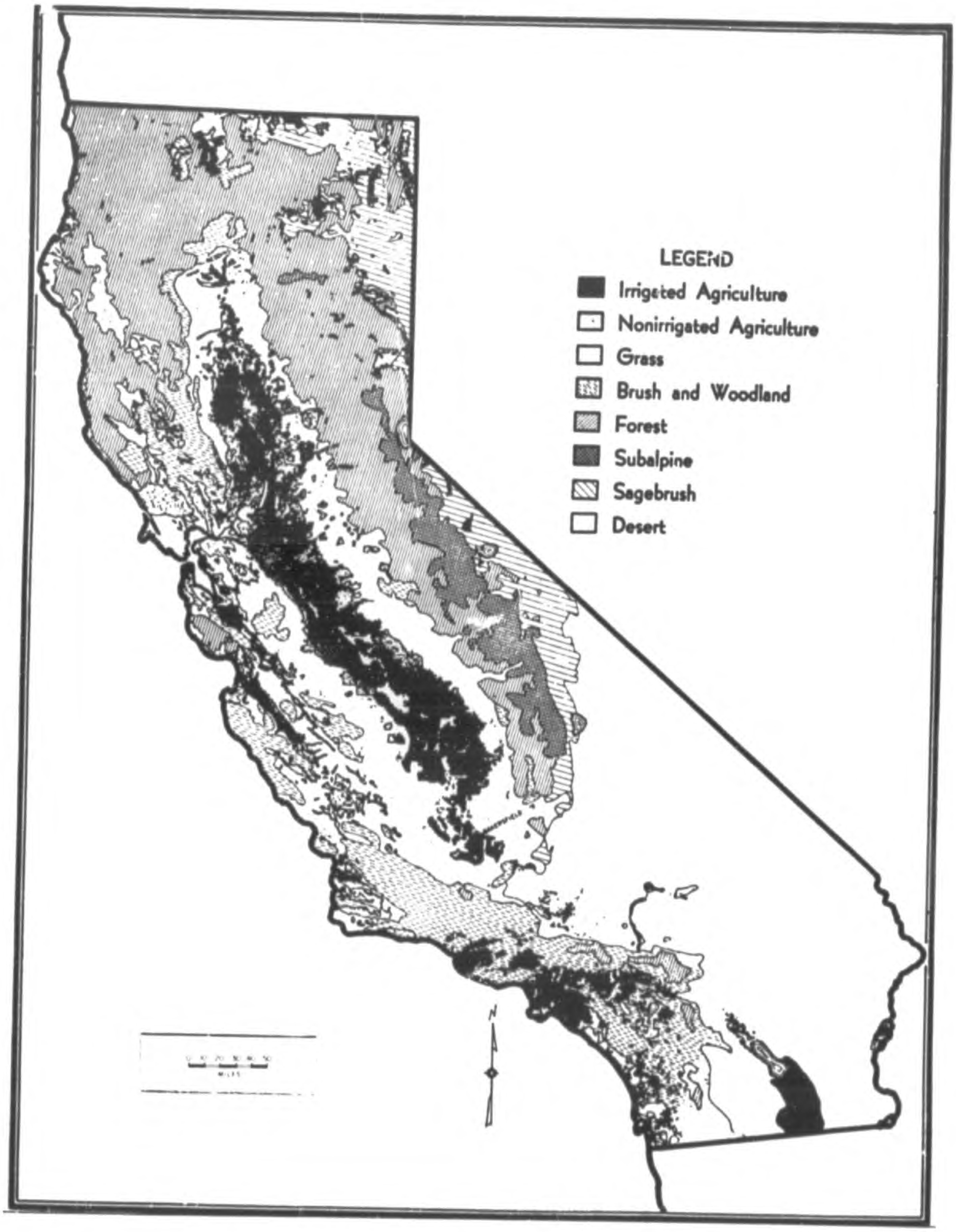
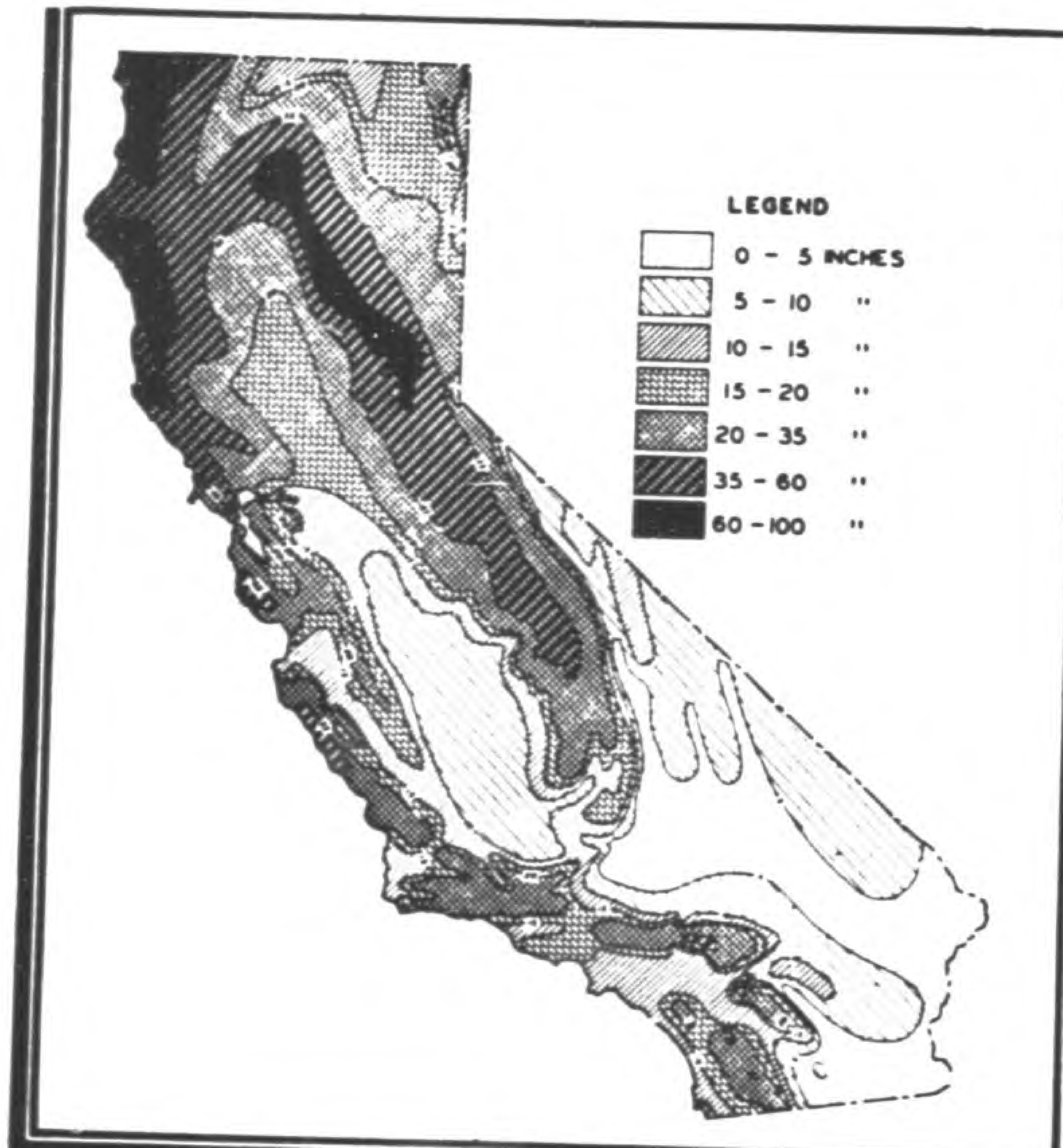



Fig. 3.2 Natural Cover and Land Use in California. (Distributed by College of Agriculture, University of California and U. S. Department of Agriculture co-operating.)

Co-operative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture co-operating. Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914. George B. Alcorn, Director, California Agricultural Extension Service.

**Fig. 3.3** Relief Map of California. (Distributed by College of Agriculture, University of California, and U. S. Department of Agriculture co-operating.)



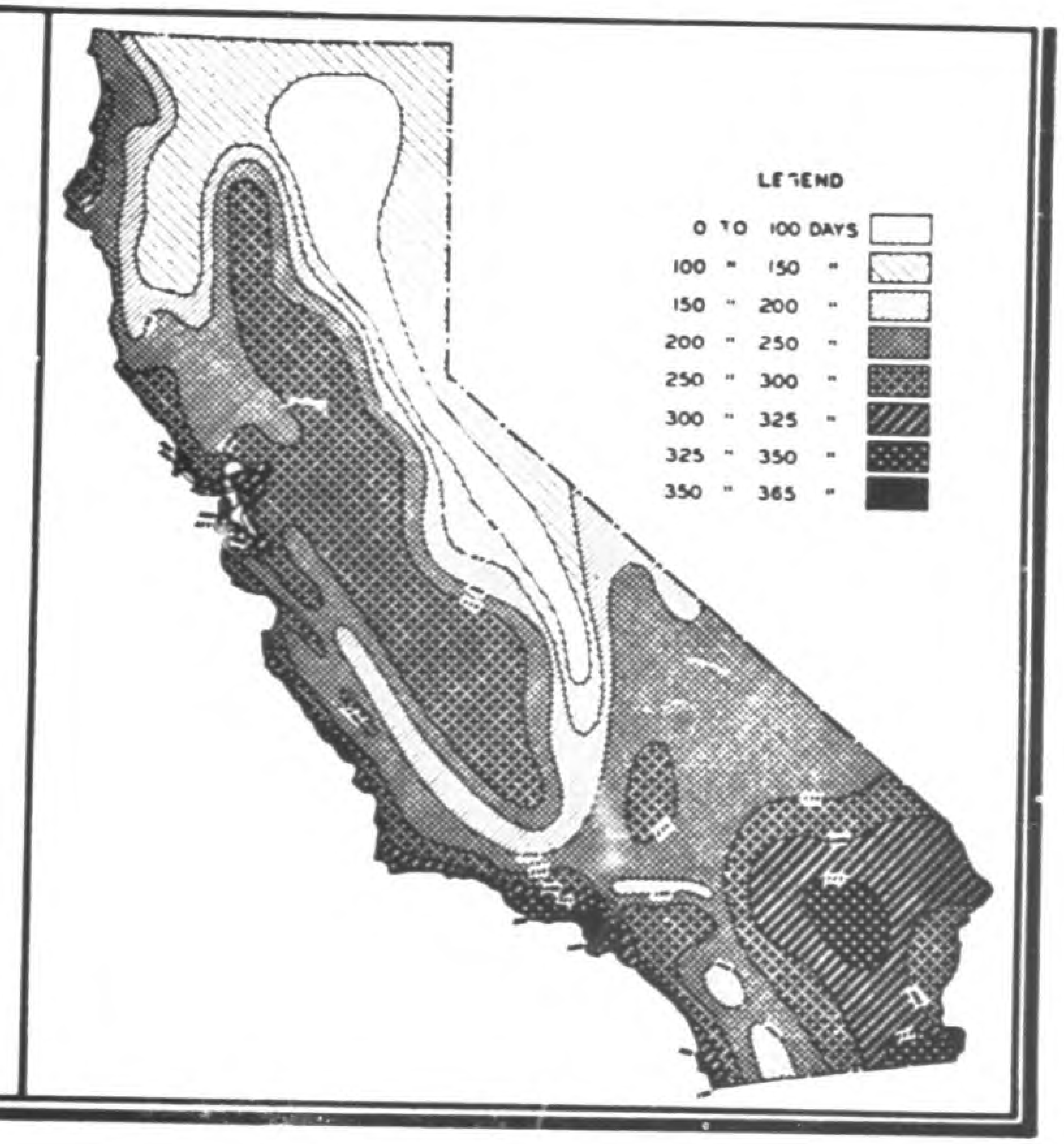




Fig. 3.4 Mean Annual Precipitation in California Fig. 3.5 Average Length of Growing Season
(Distributed by College of Agriculture, University of California, and U. S. Department of Agriculture co-operating.)

Table 3.1

Sample Weather Data in the San Joaquin Valley[24]

| | Modesto | Fresno | Bakersfield |
|---|---|---|---|
| Elevation (feet) | 91 | 331 | 404 |
| Average Precipitation (inches) | 11 | 10 | 6 |
| Growing Season (days) | 254 | 295 | 277 |
| Average January Temp. (°F) | 44 | 46 | 47 |
| Average July Temp. (°F) | 76 | 82 | 83 |
| All-time High Temp. (°F) | 111 | 115 | 118 |
| All-time Low Temp. (°F) | 15 | 17 | 13 |

Table 3.2

Average Monthly Effective Wind Speed
Over Central California (MPH)

| | | Eastward Component | Northward* Component | Effective Wind Speed |
|---|---|---|---|---|
| January | 1952-1958 | 47.17 | 4.96 | 47.43 |
| February | 1952-1958 | 36.85 | -12.12 | 38.79 |
| March | 1951-1958 | 27.95 | -8.34 | 29.17 |
| April | 1951-1958 | 33.83 | -11.39 | 35.69 |
| May | 1951-1958 | 27.01 | -17.35 | 32.10 |
| June | 1951-1958 | 30.35 | 4.84 | 30.73 |
| July | 1951-1958 | 14.37 | 16.12 | 21.60 |
| August | 1951-1958 | 23.09 | 10.80 | 25.49 |
| September | 1951-1957 | 22.68 | 15.32 | 27.37 |
| October | 1951-1957 | 30.51 | -5.00 | 30.92 |
| November | 1951-1957 | 31.39 | -16.68 | 35.54 |
| December | 1951-1957 | 43.85 | -2.15 | 43.90 |

*Negative values indicate wind component is to the south.

August 1958. These data provide wind speeds and directions at 13 altitude levels between 500 and 24,000 meters elevation. A FORTRAN computer program was developed to assimilate these data and derive an average monthly effective wind. Results of this program (Table 3.2) indicate that upper winds in this area generally come from the west, and in the Spring and Fall months there is a northerly component such that, if a nuclear device is detonated over the San Francisco Bay during these periods, the effective wind would carry radiation fallout down the valley. It should be noted that the upper wind speeds are much higher than the normal surface wind speeds. The average monthly effective wind was computed in the following manner. All data for a particular month over the years considered were analysed, and for each of thirteen altitude levels, the dominant wind direction of the daily winds was selected as the direction of the average monthly wind. The corresponding monthly wind speed was determined by averaging the daily winds at each level. The effect of this average monthly wind on a 100 micron-size particle as it passes through each altitude level was then determined, and the total lateral displacement of the particle over the time of fall was used to compute the average monthly effective wind. The particle falling speeds are the same as those used in the USNRDL Dynamic Fallout (D) Model.[26]

## 3.3 AGRICULTURAL PRODUCTION

The importance of the San Joaquin Valley could only be realized when its agricultural production is taken into consideration. The eight counties in the valley account for approximately 50 per cent of the total California agricultural cash recipts of 3.70 billion dollars; which in turn is about 10 per cent of the annual crop and livestock production of the United States. The principal commodities of this region are listed in Table 3.3 along with the active harvest season, California's share of U.S. production, and the approximate acreage

Table 3.3

Principal Crop and Livestock Commodities of the San Joaquin Valley[15,16,27] (1963-1965)

| Commodity | Active Harvest Season | California's Share of U.S. Production | Approx. Acreage in San Joaquin Valley (1000 acres) |
|---|---|---|---|
| Almonds | Aug. 15-Oct. 15 | 99.9 | 52 |
| Apricots | June 1-Aug. 10 | 99.5 | 10 |
| Asparagus | Mar. 1-June 30 | 48.4 | 30 |
| Barley | June 1-Aug. 20 | 16.8 | 1,400 |
| Beans, dry | Aug. 20-Nov. 15 | 13.3 | 120 |
| Beans, green lima | Aug. 15-Oct. 30 | 44.1 | 15 |
| Boysenberries | June 1-June 30 | 65.1 | 10 |
| Cattle and calves | -- | 6.6 | - |
| Cherries, sweet | May 25-June 10 | 34.6 | 8 |
| Chickens | -- | 2.8 | - |
| Cotton | Oct. 1-Nov. 30 | 11.5 | 800 |
| Cucumbers | May 1-Oct. 31 | 13.9 | 6 |
| Figs | June 10-Aug. 25 | 98.4 | 21 |
| Grapes | July 21-Nov. 5 | 91.8 | 340 |
| Hay | Apr. 15-Oct. 31 | 6.4 | 1,200 |
| Honey | -- | 13.5 | - |
| Melons | June 1-Oct. 15 | 50.4 | 65 |
| Milk and cream | -- | 7.0 | - |
| Nectarines | June 10-Sept.5 | 99.6 | 10 |
| Olives | Oct. 5-Feb. 10 | 99.9 | 15 |
| Onions | May 1-Oct. 31 | 18.4 | 7 |
| Oranges | Nov. 15-June 10 | 22.8 | 80 |
| Peaches | June 20-Sept. 5 | 67.1 | 75 |
| Peppers, bell | May 1-Nov. 30 | 18.6 | 3 |
| Plums | June 15-Aug. 1 | 93.1 | 20 |
| Potatoes | Nov. 15-Oct. 15 | 11.1 | 70 |
| Seed, Alfalfa | Aug. 15-Oct. 15 | 41.2 | 100 |
| Sheep and lambs | -- | 7.5 | - |
| Sorghum grain | Sept. 15-Nov.20 | 3.3 | 60 |
| Sugar beets | Apr. 15-Dec. 10 | 31.0 | 100 |
| Sweet Potatoes | July 15-Oct. 31 | 4.4 | 9 |
| Tomatoes | May 1-Nov. 30 | 50.5 | 50 |
| Turkeys | -- | 15.8 | - |
| Walnuts | Sept. 5-Nov. 5 | 98.2 | 70 |
| Wheat | June 15-Aug. 15 | 0.6 | 150 |
| Wool | -- | 7.4 | - |

harvested in the San Joaquin Valley.

3.4 INSECT PEST POPULATION

Intensive biological and chemical control of agricultural insect pests in California have prevented any disastrous outbreak in recent years. However, despite the expenditure of over $93 million in control funds in 1964, the assessable yield loss due to agricultural pests amounted to over $147 million.[17] Table 3.4 lists the insect groups which in 1964 had more than $1 million of estimated assessable* yield loss attributed to them by the California Department of Agriculture. It should be noted that much of this loss is due to devaluation in quality rather than to reduction in quantity of production. It can be safely assumed that, in the absence of control measures against the heaviest outbreaks, the damage would have been higher. Furthermore, in the aftermath of a nuclear attack, conditions in the valley may be altered to such an extent that insects which have been held in check by tight controls as well as by unfavorable breeding conditions, may become a major threat. Of particular interest is the fact that grasshoppers, which had been the cause of devastating destruction of cropland in other areas during periodic outbreaks, had only an estimated $147,000 of damage attributed to all species, and was therefore not listed separately in Table 3.4. The main reason for such light damage by grasshoppers is that infestation in California during this period had been limited principally to rangeland. The U.S. Department of Agriculture in its Cooperative Economic Insect Report[28] and its Grasshopper Adult Survey Map[29] indicates that the San Joaquin Valley is lightly infested with at least 8 species of grasshoppers. After a nuclear attack, this region may lack water or

*The assessable yield loss is determined by multiplying the estimated value of the entire crop, if undamaged, by the percent of crop loss caused by insects.

Table 3.4

Insects Which Cost Estimated Crop Loss of $1 Million or More in California - 1964[17]

| Insect | Assessable Yield Loss (Millions of $) | Control Cost (Millions of $) | % Loss of Crop Value* |
|---|---|---|---|
| Aphids | 14.5 | 10.6 | 1 - 4 |
| Armyworms | 2.3 | 1.3 | .02 - .2.7 |
| Corn Earworms | 22.2 | 13.7 | .1 - 14 |
| Crickets | 2.9 | .8 | 0 - 3 |
| Cutworms | 2.7 | 1.6 | .1 - 5.5 |
| Flea Beetles | 2.0 | 1.0 | .1 - 4 |
| Leafhoppers | 8.0 | 7.0 | .053- 7 |
| Loopers | 5.4 | 3.6 | .01 - 7 |
| Lygus Bugs | 14.9 | 8.1 | .2 - 15 |
| Mites | 33.0 | 19.6 | .02- 7 |
| Orange Tortrix | 1.1 | .3 | .2 - 7 |
| Oriental Fruit Moths | 1.0 | 1.3 | .1 - 6 |
| Peach Twig Borers | 1.8 | 3.1 | .75 - 5 |
| Potato Tuberworms | 1.7 | .9 | 1.85 - 13 |
| Scales | 6.0 | 6.9 | .5 - 10 |
| Stink Bugs | 6.2 | 2.2 | .01 - 7 |
| Thrips | 13.2 | 4.6 | .2 - 9 |
| Weevils | 1.7 | 1.1 | 3 - 6 |
| Others | 7.2 | 5.4 | - |
| Agricultural Pests Total | 147.8 | 93.1 | |

* The percentage range is the lowest-highest value of crop loss in areas of infestation.

facilities to irrigate the land for a period of time. In this case, the dry, hot condition would be favorable for the breeding of grasshoppers which prefer to lay their eggs in bare patches of dry soil near vegetation for food supply.

Biological control of insect pests often includes the importation of natural enemies to deplete the pest population and retard its growth. Table 3.5 lists the entomophagous insects imported to control specific pests in California. These predaceous or parasitic insects are often reared in laboratories and released in areas of pest outbreaks. The entomophagous insects are themselves controlled by the depletion of the host or prey species.

Using Cesium-137 as a radioactive tracer, Crossley[30] has been able to estimate the vegetation consumption by insects at the White Oak Lake Bed in Tennessee. His calculations indicate that about six percent of the plant biomass was consumed by insects. The 1964 crop loss in California due to pest insects was estimated at four percent.

Table 3.5

Imported Entomophagous Insects Used for Biological Control of Pest Insects of California[4]

| Common and Scientific Name | Crop Attacked | Natural Enemies Used in Biological Control | Type |
|---|---|---|---|
| Calif. red scale<br>Aonidiella aurantii | citrus | Aphytis lingnanensis | parasite |
| Yellow scale<br>Aonidiella citrina | citrus | Comperiella bifasciata | parasite |
| Walnut aphid<br>Chromaphis juglandicola | walnut | Trioxys pallidus | parasite |
| Cottony-cushion scale<br>Icerya purchasi | citrus | Rodolia cardinalis | predator |
| Purple scale<br>Lepidosaphes beckii | citrus | Aphytis lepidosaphes | parasite |
| Fig scale<br>Lepidosaphes ficus | fig | Aphytis mytilaspidis | parasite |
| Pea aphid<br>Macrosiphum pisi | alfalfa,<br>peas | Aphidius smithi | parasite |
| Olive scale<br>Parlatoria oleae | olive,<br>deciduous | Aphytis maculicornis | parasite |
| Citrus mealybug<br>Planococcus citri | citrus | Crytolaemus montrouzieri<br>Leptomastidea abnormis | predator<br>parasite |
| Long-tailed mealybug<br>Pseudococcus adonidum | citrus<br>avocado | Anarhopus sydneyensis,<br>Tetracnemus peregrinus | parasite |
| Citrophilus mealybug<br>Pseudococcus gahani | citrus | Coccophagus gurneyi,<br>Tetracnemus pretiosus | parasites |
| San Jose scale<br>Quadraspidiotus perniciosus | deciduous | Prospaltella perniciosi | parasite |

Table 3.5 (Cont)

| Common and Scientific Name | Crop Attacked | Natural Enemies Used in Biological Control | Type |
|---|---|---|---|
| Black scale<br>Saissetia oleae | citrus,<br>olive | Metaphycus helvolus | parasite |
| Spotted alfalfa aphid<br>Therioaphis maculata | alfalfa | A complex of native predators and disease,<br>Praon palitans,<br>Trioxys utilis<br>Aphelinus semiflavus | predator<br>disease<br>parasites |
| Western grape leaf skeletonizer<br>Harrisina brillians | grapevine | Apanteles harrisinae,<br>Sturmia harrisinae | parasites |
| Elm leaf beetle<br>Galerucella xanthomelaena | elm | Erynnia nitida,<br>Tetrastichus brevistigma | parasites |
| Alfalfa weevil<br>Hypera postica | alfalfa | Bathyplectes curculionis | parasite |

## SECTION 4

## EFFECTS OF IONIZING RADIATION ON INSECTS AND TERRESTRIAL ECOSYSTEMS

### 4.1 BIOLOGICAL RESPONSE OF INSECTS

Ecological imbalance may occur as a result of nuclear fallout in areas where the exposure level is sufficient to produce drastic effects on selected populations. The imbalance would be most conspicuous when a prey or host species survives a level of radiation exposure while the population of the corresponding predators or parasites is decimated.

The effects of ionizing radiation on insects and associated invertebrates have been the subject of many independent studies. However, most of these studies were devoted to insects that could be easily raised in the laboratory, and for that reason, data for many field insects are still needed. Teresi and Newcombe have compiled available results of these studies in USNRDL-TR-982[5] and have found that approximately 5000 rads were sufficient to sterilize a large majority of the organisms considered in that report. Since sterility will eventually result in death of a population unless it is re-populated by fertile organisms from the outside, the extent of the critical area is a factor in insect population recovery.

The greater sensitivity of vertebrates to radiation would favor the surviving insect population of an ecosystem if each member of the system received equal doses. Mammals are estimated to have an $LD_{50-30}$* of 300 to 800 roentgens, while birds have an $LD_{50}$ of approximately 1000 roentgens.[22] Because of the size of the organisms involved, it is considered that the main hazard to insects will result from beta radiation, and the main hazards to their mammal and bird predators will result from gamma radiation.

*$LD_{50-30}$ is an exposure level that results in an expected 30%-50% fatality rate.

4.3 RADIATION EXPOSURE LEVELS

The effects of external beta radiation from nuclear fallout on large animals or plants are generally small compared to the effects of gamma radiation.[31] This is due to the fact that beta rays are less penetrating and can be substantially attenuated by clothing, hair, bark, etc. and thus contribute little to the total body dose of large organisms. However, the energy from beta particles deposited on unprotected skin or plants is absorbed at relatively shallow depths and the layer of tissue close to the source can thus receive high beta doses. The surface dose from beta radiation has been estimated to be perhaps forty times the gamma dose,[32] so that for thin-layer plants or small organisms, such as insects, the beta dose would present a more hazardous problem than the gamma.

The beta doses due to fallout radiation for weapon yields of 1, 10, and 100 MT have been computed for a tissue depth of .003 cm at various gamma-exposure-rate* contour lines and for various air gaps separating the tissue surface from the contaminated surface. The results indicate that the beta dose for the same gamma-exposure-rate contour lines are not significantly different for the 3 weapon yields considered. For this reason, only the results for a 1-MT weapon yield are listed in Tables 4.1 through 4.7 of this report. Table 4.1 shows the beta contact dose at a tissue depth of .003 cm. Tables 4.2 through 4.7 are beta-bath doses at the same tissue depth but with air gaps of 0.3, 1.0, 3.0, 10.0, 30.0 and 100.0 cm respectively, between the tissue and the radioactive particles.

The values in Tables 4.1 - 4.7 were determined by first computing the beta dose rate for 66 fission-product nuclides using the beta disintegration-rate multipliers of Brown[33] and the values of atoms

* All gamma-exposure-rate values used in this report are referred to 1 hr.

Table 4.1

Beta Contact Dose (Rads) at .003-cm Tissue Depth
At Various Gamma-Exposure-Rate Contour Levels

| Time* | | 1 R/Hr | 10 R/Hr | 50 R/Hr | 100 R/Hr | 200 R/Hr | 500 R/Hr | 1000 R/Hr | 2000 R/Hr |
|---|---|---|---|---|---|---|---|---|---|
| 14.5 | M | 5.07+1 | 5.07+2 | 2.54+3 | 5.09+3 | 1.02+4 | 2.57+4 | 5.20+4 | 1.05+5** |
| 21.3 | M | 1.07+2 | 1.07+3 | 5.37+3 | 1.07+4 | 2.16+4 | 5.43+4 | 1.10+5 | 2.21+5 |
| 31.2 | M | 1.65+2 | 1.65+3 | 8.28+3 | 1.66+4 | 3.33+4 | 8.38+4 | 1.69+5 | 3.41+5 |
| 45.8 | M | 2.20+2 | 2.20+3 | 1.10+4 | 2.21+4 | 4.44+4 | 1.11+5 | 2.25+5 | 4.53+5 |
| 1.00 | H | 2.52+2 | 2.52+3 | 1.27+4 | 2.53+4 | 5.10+4 | 1.28+5 | 2.58+5 | 5.20+5 |
| 1.12 | H | 2.68+2 | 2.68+3 | 1.34+4 | 2.69+4 | 5.41+4 | 1.36+5 | 2.74+5 | 5.51+5 |
| 1.64 | H | 3.13+2 | 3.13+3 | 1.57+4 | 3.14+4 | 6.32+4 | 1.59+5 | 3.20+5 | 6.43+5 |
| 2.40 | H | 3.57+2 | 3.57+3 | 1.79+4 | 3.59+4 | 7.21+4 | 1.81+5 | 3.65+5 | 7.33+5 |
| 3.52 | H | 4.01+2 | 4.01+3 | 2.01+4 | 4.03+4 | 8.10+4 | 2.03+5 | 4.10+5 | 8.23+5 |
| 5.16 | H | 4.40+2 | 4.40+3 | 2.21+4 | 4.42+4 | 8.90+4 | 2.23+5 | 4.51+5 | 9.05+5 |
| 7.56 | H | 4.71+2 | 4.71+3 | 2.37+4 | 4.74+4 | 9.53+4 | 2.39+5 | 4.82+5 | 9.69+5 |
| 11.1 | H | 4.93+2 | 4.93+3 | 2.48+4 | 4.96+4 | 9.97+4 | 2.50+5 | 5.05+5 | 1.01+6 |
| 16.2 | H | 5.09+2 | 5.09+3 | 2.56+4 | 5.12+4 | 1.10+5 | 2.59+5 | 5.21+5 | 1.05+6 |
| 23.8 | H | 5.23+2 | 5.22+3 | 2.62+4 | 5.25+4 | 1.06+5 | 2.65+5 | 5.35+5 | 1.07+6 |
| 1.45 | D | 5.35+2 | 5.34+3 | 2.68+4 | 5.37+4 | 1.08+5 | 2.71+5 | 5.47+5 | 1.10+6 |
| 2.13 | D | 5.45+2 | 5.45+3 | 2.74+4 | 5.48+4 | 1.10+5 | 2.77+5 | 5.57+5 | 1.12+6 |
| 3.12 | D | 5.55+2 | 5.54+3 | 2.78+4 | 5.57+4 | 1.12+5 | 2.81+5 | 5.67+5 | 1.14+6 |
| 4.57 | D | 5.63+2 | 5.63+3 | 2.83+4 | 5.66+4 | 1.14+5 | 2.86+5 | 5.75+5 | 1.15+6 |
| 6.70 | D | 5.72+2 | 5.72+3 | 2.87+4 | 5.75+4 | 1.16+5 | 2.90+5 | 5.84+5 | 1.17+6 |
| 9.52 | D | 5.81+2 | 5.80+3 | 2.91+4 | 5.83+4 | 1.17+5 | 2.94+5 | 5.93+5 | 1.19+6 |
| 14.4 | D | 5.90+2 | 5.89+3 | 2.96+4 | 5.92+4 | 1.19+5 | 2.99+5 | 6.01+5 | 1.20+6 |
| 21.1 | D | 5.98+2 | 5.98+3 | 3.00+4 | 6.01+4 | 1.21+5 | 3.03+5 | 6.10+5 | 1.22+6 |
| 30.9 | D | 6.07+2 | 6.07+3 | 3.05+4 | 6.10+4 | 1.23+5 | 3.08+5 | 6.19+5 | 1.24+6 |
| 45.3 | D | 6.15+2 | 6.14+3 | 3.09+4 | 6.18+4 | 1.24+5 | 3.12+5 | 6.27+5 | 1.25+6 |

* Time after the nuclear burst.
** i.e. $1.05 \times 10^5$

Table 4.2

Beta Bath Dose (Rads) at .003 cm Tissue Depth - 0.3 cm Air Gap
At Various Gamma-Exposure-Rate Contour Levels

| Time* | | 1 R/Hr | 10 R/Hr | 50 R/Hr | 100 R/Hr | 200 R/Hr | 500 R/Hr | 1000 R/Hr | 2000 R/Hr |
|---|---|---|---|---|---|---|---|---|---|
| 14.5 | M | 1.41+1 | 1.40+2 | 7.03+2 | 1.40+3 | 2.83+3 | 7.09+3 | 1.43+4 | 2.86+4 |
| 21.3 | M | 3.01+1 | 3.00+2 | 1.50+3 | 3.00+3 | 6.05+3 | 1.52+4 | 3.05+4 | 6.10+4 |
| 31.2 | M | 4.80+1 | 4.78+2 | 2.40+3 | 4.79+3 | 9.63+3 | 2.41+4 | 4.85+4 | 9.69+4 |
| 45.8 | M | 6.65+1 | 6.63+2 | 3.32+3 | 6.64+3 | 1.34+4 | 3.34+4 | 6.72+4 | 1.34+5 |
| 1.00 | H | 7.85+1 | 7.82+2 | 3.92+3 | 7.84+3 | 1.58+4 | 3.95+4 | 7.92+4 | 1.58+5 |
| 1.12 | H | 8.42+1 | 8.39+2 | 4.21+3 | 8.42+3 | 1.69+4 | 4.24+4 | 8.50+4 | 1.69+5 |
| 1.64 | H | 1.01+2 | 1.00+3 | 5.03+3 | 1.01+4 | 2.02+4 | 5.07+4 | 1.02+5 | 2.01+5 |
| 2.40 | H | 1.16+2 | 1.16+3 | 5.80+3 | 1.16+4 | 2.33+4 | 5.84+4 | 1.17+5 | 2.32+5 |
| 3.52 | H | 1.31+2 | 1.30+3 | 6.54+3 | 1.30+4 | 2.63+4 | 6.59+4 | 1.32+5 | 2.61+5 |
| 5.16 | H | 1.45+2 | 1.45+3 | 7.26+3 | 1.45+4 | 2.92+4 | 7.32+4 | 1.47+5 | 2.90+5 |
| 7.56 | H | 1.59+2 | 1.59+3 | 7.97+3 | 1.59+4 | 3.21+4 | 8.03+4 | 1.61+5 | 3.19+5 |
| 11.1 | H | 1.73+2 | 1.73+3 | 8.66+3 | 1.73+4 | 3.48+4 | 8.73+4 | 1.75+5 | 3.47+5 |
| 16.2 | H | 1.86+2 | 1.86+3 | 9.34+3 | 1.87+4 | 3.76+4 | 9.41+4 | 1.89+5 | 3.75+5 |
| 23.8 | H | 1.99+2 | 1.99+3 | 9.98+3 | 2.00+4 | 4.02+4 | 1.01+5 | 2.02+5 | 4.00+5 |
| 1.45 | D | 2.11+2 | 2.10+3 | 1.06+4 | 2.11+4 | 4.25+4 | 1.06+5 | 2.13+5 | 4.23+5 |
| 2.13 | D | 2.21+2 | 2.21+3 | 1.11+4 | 2.22+4 | 4.46+4 | 1.12+5 | 2.24+5 | 4.43+5 |
| 3.12 | D | 2.30+2 | 2.30+3 | 1.15+4 | 2.31+4 | 4.64+4 | 1.16+5 | 2.33+5 | 4.60+5 |
| 4.57 | D | 2.38+2 | 2.38+3 | 1.19+4 | 2.39+4 | 4.81+4 | 1.20+5 | 2.41+5 | 4.76+5 |
| 6.70 | D | 2.46+2 | 2.46+3 | 1.24+4 | 2.47+4 | 4.97+4 | 1.24+5 | 2.49+5 | 4.92+5 |
| 9.52 | D | 2.55+2 | 2.54+3 | 1.28+4 | 2.56+4 | 5.14+4 | 1.29+5 | 2.57+5 | 5.08+5 |
| 14.4 | D | 2.63+2 | 2.63+3 | 1.32+4 | 2.64+4 | 5.31+4 | 1.33+5 | 2.66+5 | 5.24+5 |
| 21.1 | D | 2.72+2 | 2.71+3 | 1.36+4 | 2.73+4 | 5.48+4 | 1.37+5 | 2.74+5 | 5.40+5 |
| 30.9 | D | 2.80+2 | 2.79+3 | 1.40+4 | 2.81+4 | 5.65+4 | 1.41+5 | 2.82+5 | 5.57+5 |
| 45.3 | D | 2.88+2 | 2.87+3 | 1.44+4 | 2.88+4 | 5.80+4 | 1.45+5 | 2.90+5 | 5.72+5 |

* Time after the nuclear burst.

Table 4.3

Beta Bath Dose (rads) at .003 cm Tissue Depth - 1.0 cm Air Gap At Various Gamma-Exposure-Rate Contour Levels

| Time* | | 1 R/Hr | 10 R/Hr | 50 R/Hr | 100 R/Hr | 200 R/Hr | 500 R/Hr | 1000 R/Hr | 2000 R/Hr |
|---|---|---|---|---|---|---|---|---|---|
| 14.5 | M | 1.32+1 | 1.31+2 | 6.57+2 | 1.32+3 | 2.64+3 | 6.62+3 | 1.33+4 | 2.67+4 |
| 21.3 | M | 2.81+1 | 2.80+2 | 1.41+3 | 2.81+3 | 5.65+3 | 1.42+4 | 2.85+4 | 5.70+4 |
| 31.2 | M | 4.48+1 | 4.46+2 | 2.24+3 | 4.47+3 | 8.99+3 | 2.25+4 | 4.53+4 | 9.04+4 |
| 45.8 | M | 6.19+1 | 6.17+2 | 3.10+3 | 6.19+3 | 1.24+4 | 3.12+4 | 6.26+4 | 1.25+5 |
| 1.00 | H | 7.30+1 | 7.28+2 | 3.65+3 | 7.30+3 | 1.47+4 | 3.67+4 | 7.37+4 | 1.47+5 |
| 1.12 | H | 7.83+1 | 7.81+2 | 3.91+3 | 7.83+3 | 1.57+4 | 3.94+4 | 7.90+4 | 1.57+5 |
| 1.64 | H | 9.35+1 | 9.32+2 | 4.67+3 | 9.35+3 | 1.88+4 | 4.71+4 | 9.43+4 | 1.87+5 |
| 2.40 | H | 1.08+2 | 1.07+3 | 5.38+3 | 1.08+4 | 2.17+4 | 5.42+4 | 1.09+5 | 2.15+5 |
| 3.52 | H | 1.21+2 | 1.21+3 | 6.06+3 | 1.21+4 | 2.44+4 | 6.10+4 | 1.22+5 | 2.42+5 |
| 5.16 | H | 1.34+2 | 1.34+3 | 6.72+3 | 1.34+4 | 2.70+4 | 6.77+4 | 1.36+5 | 2.69+5 |
| 7.56 | H | 1.47+2 | 1.46+3 | 7.35+3 | 1.47+4 | 2.96+4 | 7.41+4 | 1.49+5 | 2.95+5 |
| 11.1 | H | 1.59+2 | 1.60+3 | 7.98+3 | 1.60+4 | 3.21+4 | 8.04+4 | 1.61+5 | 3.20+5 |
| 16.2 | H | 1.71+2 | 1.71+3 | 8.59+3 | 1.72+4 | 3.46+4 | 8.66+4 | 1.73+5 | 3.45+5 |
| 23.8 | H | 1.83+2 | 1.83+3 | 9.16+3 | 1.83+4 | 3.69+4 | 9.24+4 | 1.85+5 | 3.68+5 |
| 1.45 | D | 1.93+2 | 1.93+3 | 9.68+3 | 1.94+4 | 3.90+4 | 9.76+4 | 1.96+5 | 3.88+5 |
| 2.13 | D | 2.02+2 | 2.02+3 | 1.01+4 | 2.03+4 | 4.08+4 | 1.02+5 | 2.05+5 | 4.06+5 |
| 3.12 | D | 2.10+2 | 2.10+3 | 1.05+4 | 2.11+4 | 4.24+4 | 1.06+5 | 2.12+5 | 4.21+5 |
| 4.57 | D | 2.17+2 | 2.17+3 | 1.09+4 | 2.18+4 | 4.38+4 | 1.10+5 | 2.20+5 | 4.34+5 |
| 6.70 | D | 2.24+2 | 2.24+3 | 1.12+4 | 2.25+4 | 4.52+4 | 1.13+5 | 2.27+5 | 4.48+5 |
| 9.52 | D | 2.31+2 | 2.31+3 | 1.16+4 | 2.32+4 | 4.67+4 | 1.17+5 | 2.34+5 | 4.61+5 |
| 14.4 | D | 2.39+2 | 2.38+3 | 1.20+4 | 2.39+4 | 4.81+4 | 1.20+5 | 2.41+5 | 4.75+5 |
| 21.1 | D | 2.46+2 | 2.45+3 | 1.23+4 | 2.47+4 | 4.96+4 | 1.24+5 | 2.48+5 | 4.89+5 |
| 30.9 | D | 2.53+2 | 2.52+3 | 1.27+4 | 2.54+4 | 5.10+4 | 1.28+5 | 2.55+5 | 5.03+5 |
| 45.3 | D | 2.59+2 | 2.59+3 | 1.30+4 | 2.60+4 | 5.23+4 | 1.31+5 | 2.62+5 | 5.16+5 |

* Time after the nuclear burst.

Table 4.4

Beta Bath Dose (rads) at .003 cm Tissue Depth
3.0 cm Air Gap
At Various Gamma-Exposure-Rate Contour Levels

| Time * | 1 R/Hr | 10 R/Hr | 50 R/Hr | 100 R/Hr | 200 R/Hr | 500 R/Hr | 1000 R/Hr | 2000 R/Hr |
|---|---|---|---|---|---|---|---|---|
| 14.5 M | 1.19+1 | 1.18+2 | 5.92+2 | 1.18+3 | 2.38+3 | 5.97+3 | 1.20+4 | 2.41+4 |
| 21.3 M | 2.53+1 | 2.52+2 | 1.26+3 | 2.53+3 | 5.08+3 | 1.27+4 | 2.57+4 | 5.14+4 |
| 31.2 M | 4.02+1 | 4.00+2 | 2.01+3 | 4.01+3 | 8.07+3 | 2.02+4 | 4.07+4 | 8.13+4 |
| 45.8 M | 5.54+1 | 5.53+2 | 2.77+3 | 5.54+3 | 1.11+4 | 2.79+4 | 5.61+4 | 1.12+5 |
| 1.00 H | 6.52+1 | 6.50+2 | 3.26+3 | 6.52+3 | 1.31+4 | 3.28+4 | 6.59+4 | 1.31+5 |
| 1.12 H | 6.99+1 | 6.97+2 | 3.50+3 | 6.99+3 | 1.41+4 | 3.52+4 | 7.06+4 | 1.41+5 |
| 1.64 H | 8.33+1 | 8.31+2 | 4.17+3 | 8.34+3 | 1.68+4 | 4.20+4 | 8.41+4 | 1.67+5 |
| 2.40 H | 9.56+1 | 9.54+2 | 4.79+3 | 9.58+4 | 1.93+4 | 4.82+4 | 9.66+4 | 1.91+5 |
| 3.52 H | 1.07+2 | 1.07+3 | 5.39+3 | 1.08+4 | 2.16+4 | 5.42+4 | 1.09+5 | 2.15+5 |
| 5.16 H | 1.19+2 | 1.19+3 | 5.95+3 | 1.19+4 | 2.40+4 | 6.00+4 | 1.20+5 | 2.38+5 |
| 7.56 H | 1.30+2 | 1.30+3 | 6.51+3 | 1.30+4 | 2.62+4 | 6.56+4 | 1.31+5 | 2.61+5 |
| 11.1 H | 1.41+2 | 1.40+3 | 7.05+3 | 1.41+4 | 2.84+4 | 7.11+4 | 1.43+5 | 2.83+5 |
| 16.2 H | 1.51+2 | 1.51+3 | 7.58+3 | 1.52+4 | 3.05+4 | 7.64+4 | 1.53+5 | 3.04+5 |
| 23.8 H | 1.61+2 | 1.61+3 | 8.07+3 | 1.61+4 | 3.25+4 | 8.13+4 | 1.63+5 | 3.24+5 |
| 1.45 D | 1.70+2 | 1.69+3 | 8.50+4 | 1.70+4 | 3.42+4 | 8.58+4 | 1.72+5 | 3.41+5 |
| 2.13 D | 1.77+2 | 1.77+3 | 8.88+3 | 1.78+4 | 3.58+4 | 8.96+4 | 1.80+5 | 3.56+5 |
| 3.12 D | 1.84+2 | 1.83+3 | 9.21+3 | 1.84+4 | 3.71+4 | 9.28+4 | 1.86+5 | 3.69+5 |
| 4.57 D | 1.90+2 | 1.89+3 | 9.50+3 | 1.90+4 | 3.83+4 | 9.58+4 | 1.92+5 | 3.80+5 |
| 6.70 D | 1.95+2 | 1.95+3 | 9.79+3 | 1.96+4 | 3.94+4 | 9.87+4 | 1.98+5 | 3.91+5 |
| 9.52 D | 2.01+2 | 2.01+3 | 1.01+4 | 2.02+4 | 4.06+4 | 1.02+5 | 2.03+5 | 4.02+5 |
| 14.4 D | 2.07+2 | 2.07+3 | 1.04+4 | 2.08+4 | 4.18+4 | 1.05+5 | 2.09+5 | 4.13+5 |
| 21.1 D | 2.13+2 | 2.13+3 | 1.07+4 | 2.14+4 | 4.30+4 | 1.08+5 | 2.15+5 | 4.25+5 |
| 30.9 D | 2.19+2 | 2.18+3 | 1.10+4 | 2.19+4 | 4.41+4 | 1.10+5 | 2.21+5 | 4.36+5 |
| 45.3 D | 2.24+2 | 2.23+3 | 1.12+4 | 2.24+4 | 4.51+4 | 1.13+5 | 2.26+5 | 4.46+5 |

* Time after the nuclear burst.

Table 4.5

Beta Bath Dose (rads) at .003 cm Tissue Depth
10.0 cm Air Gap

At Various Gamma-Exposure-Rate Contour Levels

| Time * | | 1 R/Hr | 10 R/Hr | 50 R/Hr | 100 R/Hr | 200 R/Hr | 500 R/Hr | 1000 R/Hr | 2000 R/Hr |
|---|---|---|---|---|---|---|---|---|---|
| 14.5 | M | 8.80+0 | 8.77+1 | 4.40+2 | 8.80+2 | 1.77+3 | 4.43+3 | 8.93+3 | 1.79+4 |
| 21.3 | M | 1.88+1 | 1.87+2 | 9.39+2 | 1.88+3 | 3.77+3 | 9.46+3 | 1.91+4 | 3.81+4 |
| 31.2 | M | 2.98+1 | 2.97+2 | 1.49+3 | 2.98+3 | 5.99+3 | 1.50+4 | 3.02+4 | 6.03+4 |
| 45.8 | M | 4.11+1 | 4.10+2 | 2.05+3 | 4.11+3 | 8.26+3 | 2.07+4 | 4.16+4 | 8.29+4 |
| 1.00 | H | 4.83+1 | 4.82+2 | 2.42+3 | 4.83+3 | 9.71+3 | 2.43+4 | 4.88+4 | 9.72+4 |
| 1.12 | H | 5.17+1 | 5.16+2 | 2.59+3 | 5.18+3 | 1.04+4 | 2.60+4 | 5.23+4 | 1.04+5 |
| 1.64 | H | 6.16+1 | 6.14+2 | 3.08+3 | 6.16+3 | 1.24+4 | 3.10+4 | 6.22+4 | 1.23+5 |
| 2.40 | H | 7.06+1 | 7.04+2 | 3.53+3 | 7.07+3 | 1.42+4 | 3.56+4 | 7.13+4 | 1.41+5 |
| 3.52 | H | 7.91+1 | 7.90+2 | 3.86+3 | 7.93+3 | 1.59+4 | 3.99+4 | 7.99+4 | 1.58+5 |
| 5.16 | H | 8.73+1 | 8.72+2 | 4.37+3 | 8.75+3 | 1.76+4 | 4.41+4 | 8.83+4 | 1.75+5 |
| 7.56 | H | 9.52+1 | 9.51+2 | 4.77+3 | 9.55+3 | 1.92+4 | 4.81+4 | 9.64+4 | 1.91+5 |
| 11.1 | H | 1.03+2 | 1.03+3 | 5.16+3 | 1.03+4 | 2.08+4 | 5.20+4 | 1.04+5 | 2.07+5 |
| 16.2 | H | 1.10+2 | 1.10+3 | 5.53+3 | 1.11+4 | 2.23+4 | 5.58+4 | 1.12+5 | 2.22+5 |
| 23.8 | H | 1.17+2 | 1.17+3 | 5.88+3 | 1.18+4 | 2.37+4 | 5.93+4 | 1.19+5 | 2.36+5 |
| 1.45 | D | 1.23+2 | 1.23+3 | 6.18+3 | 1.24+4 | 2.49+4 | 6.23+4 | 1.25+5 | 2.48+5 |
| 2.13 | D | 1.29+2 | 1.28+3 | 6.44+3 | 1.29+4 | 2.59+4 | 6.50+4 | 1.30+5 | 2.58+5 |
| 3.12 | D | 1.33+2 | 1.33+3 | 6.66+3 | 1.33+4 | 2.68+4 | 6.72+4 | 1.35+5 | 2.67+5 |
| 4.57 | D | 1.37+2 | 1.37+3 | 6.85+3 | 1.37+4 | 2.76+4 | 6.91+4 | 1.38+5 | 2.74+5 |
| 6.70 | D | 1.40+2 | 1.40+3 | 7.04+3 | 1.41+4 | 2.83+4 | 7.09+4 | 1.42+5 | 2.81+5 |
| 9.52 | D | 1.44+2 | 1.44+3 | 7.22+3 | 1.45+4 | 2.91+4 | 7.28+4 | 1.46+5 | 2.88+5 |
| 14.4 | D | 1.48+2 | 1.47+3 | 7.40+3 | 1.48+4 | 2.98+4 | 7.46+4 | 1.49+5 | 2.95+5 |
| 21.1 | D | 1.51+2 | 1.51+3 | 7.58+3 | 1.52+4 | 3.05+4 | 7.64+4 | 1.53+5 | 3.03+5 |
| 30.9 | D | 1.55+2 | 1.54+3 | 7.75+3 | 1.55+4 | 3.12+4 | 7.81+4 | 1.56+5 | 3.09+5 |
| 45.3 | D | 1.58+2 | 1.58+3 | 7.91+3 | 1.58+4 | 3.18+4 | 7.97+4 | 1.60+5 | 3.16+5 |

* Time after the nuclear burst.

Table 4.6

Beta Bath Dose (rads) at .003 cm Tissue Depth
30.0 cm Air Gap
At Various Gamma-Exposure-Rate Contour Levels

| Time * | | 1 R/Hr | 10 R/Hr | 50 R/Hr | 100 R/Hr | 200 R/Hr | 500 R/Hr | 1000 R/Hr | 2000 R/Hr |
|---|---|---|---|---|---|---|---|---|---|
| 14.5 | M | 5.94+0 | 5.92+1 | 2.97+2 | 5.94+2 | 1.19+3 | 2.99+3 | 6.03+3 | 1.21+4 |
| 21.3 | M | 1.27+1 | 1.26+2 | 6.33+2 | 1.27+3 | 2.54+3 | 6.38+3 | 1.28+4 | 2.57+4 |
| 31.2 | M | 2.00+1 | 2.00+2 | 1.00+3 | 2.00+3 | 4.02+3 | 1.01+4 | 2.03+4 | 4.06+4 |
| 45.8 | M | 2.75+1 | 2.75+2 | 1.38+3 | 2.75+3 | 5.54+3 | 1.39+4 | 2.79+4 | 5.56+4 |
| 1.00 | H | 3.23+1 | 3.22+2 | 1.62+3 | 3.23+3 | 6.50+3 | 1.63+4 | 3.27+4 | 6.51+4 |
| 1.12 | H | 3.46+1 | 3.45+2 | 1.73+3 | 3.46+3 | 6.96+3 | 1.74+4 | 3.50+4 | 6.97+4 |
| 1.64 | H | 4.11+1 | 4.10+2 | 2.06+3 | 4.11+3 | 8.27+3 | 2.07+4 | 4.15+4 | 8.24+4 |
| 2.40 | H | 4.70+1 | 4.69+2 | 2.35+3 | 4.71+3 | 9.46+3 | 2.37+4 | 4.75+4 | 9.41+4 |
| 3.52 | H | 5.25+1 | 5.24+2 | 2.63+3 | 5.26+3 | 1.06+4 | 2.65+4 | 5.31+4 | 1.05+5 |
| 5.16 | H | 5.78+1 | 5.77+2 | 2.89+3 | 5.79+3 | 1.16+4 | 2.92+4 | 5.84+4 | 1.16+5 |
| 7.56 | H | 6.27+1 | 6.26+2 | 3.14+3 | 6.29+3 | 1.27+4 | 3.17+4 | 6.35+4 | 1.26+5 |
| 11.1 | H | 6.75+1 | 6.74+2 | 3.39+3 | 6.78+3 | 1.36+4 | 3.41+4 | 6.85+4 | 1.36+5 |
| 16.2 | H | 7.21+1 | 7.20+2 | 3.61+3 | 7.23+3 | 1.46+4 | 3.65+4 | 7.31+4 | 1.45+5 |
| 23.8 | H | 7.62+1 | 7.61+2 | 3.82+3 | 7.65+3 | 1.54+4 | 3.85+4 | 7.73+4 | 1.54+5 |
| 1.45 | D | 7.97+1 | 7.96+2 | 4.00+3 | 8.00+3 | 1.61+4 | 4.03+4 | 8.09+4 | 1.61+5 |
| 2.13 | D | 8.27+1 | 8.26+2 | 4.14+3 | 8.30+3 | 1.67+4 | 4.18+4 | 8.38+4 | 1.66+5 |
| 3.12 | D | 8.51+1 | 8.50+2 | 4.26+3 | 8.54+3 | 1.72+4 | 4.30+4 | 8.62+4 | 1.71+5 |
| 4.57 | D | 8.71+1 | 8.70+2 | 4.36+3 | 8.74+3 | 1.76+4 | 4.40+4 | 8.82+4 | 1.75+5 |
| 6.70 | D | 8.89+1 | 8.88+2 | 4.46+3 | 8.92+3 | 1.79+4 | 4.49+4 | 9.00+4 | 1.79+5 |
| 9.52 | D | 9.07+1 | 9.05+2 | 4.55+3 | 9.10+3 | 1.83+4 | 4.58+4 | 9.18+4 | 1.82+5 |
| 14.4 | D | 9.24+1 | 9.23+2 | 4.63+3 | 9.27+3 | 1.87+4 | 4.67+4 | 9.36+4 | 1.85+5 |
| 21.1 | D | 9.42+1 | 9.40+2 | 4.72+3 | 9.45+3 | 1.90+4 | 4.76+4 | 9.53+4 | 1.89+5 |
| 30.9 | D | 9.59+1 | 9.57+2 | 4.80+3 | 9.62+3 | 1.93+4 | 4.84+4 | 9.70+4 | 1.92+5 |
| 45.3 | D | 9.74+1 | 9.72+2 | 4.88+3 | 9.77+3 | 1.96+4 | 4.92+4 | 9.86+4 | 1.95+5 |

* Time after the nuclear burst.

Table 4.7

Beta Bath Dose (rads) at .003 cm Tissue Depth
100.0 cm Air Gap

At Various Gamma-Exposure-Rate Contour Levels

| Time* | | 1 R/Hr | 10 R/Hr | 50 R/Hr | 100 R/Hr | 200 R/Hr | 500 R/Hr | 1000 R/Hr | 2000 R/Hr |
|---|---|---|---|---|---|---|---|---|---|
| 14.5 | M | 3.06+0 | 3.06+1 | 1.53+2 | 3.07+2 | 6.17+2 | 1.55+3 | 3.12+3 | 6.27+3 |
| 21.3 | M | 6.50+0 | 6.49+1 | 3.25+2 | 6.51+2 | 1.31+3 | 3.29+3 | 6.62+3 | 1.33+4 |
| 31.2 | M | 1.02+1 | 1.02+2 | 5.11+2 | 1.02+3 | 2.06+3 | 5.16+3 | 1.04+4 | 2.08+4 |
| 45.8 | M | 1.39+1 | 1.39+2 | 6.97+2 | 1.39+3 | 2.80+3 | 7.03+3 | 1.41+4 | 2.83+4 |
| 1.00 | H | 1.63+1 | 1.62+2 | 8.14+2 | 1.63+3 | 3.27+3 | 8.21+3 | 1.65+4 | 3.29+4 |
| 1.12 | H | 1.74+1 | 1.73+2 | 8.69+2 | 1.74+3 | 3.50+3 | 8.76+3 | 1.76+4 | 3.51+4 |
| 1.64 | H | 2.04+1 | 2.04+2 | 1.02+3 | 2.05+3 | 4.12+3 | 1.03+4 | 2.07+4 | 4.12+4 |
| 2.40 | H | 2.32+1 | 2.32+2 | 1.16+3 | 2.33+3 | 4.68+3 | 1.17+4 | 2.35+4 | 4.67+4 |
| 3.52 | H | 2.57+1 | 2.57+2 | 1.29+3 | 2.58+3 | 5.20+3 | 1.30+4 | 2.61+4 | 5.18+4 |
| 5.16 | H | 2.81+1 | 2.81+2 | 1.41+3 | 2.82+3 | 5.67+3 | 1.42+4 | 2.85+4 | 5.66+4 |
| 7.56 | H | 3.03+1 | 3.02+2 | 1.52+3 | 3.04+3 | 6.11+3 | 1.53+4 | 3.07+4 | 6.11+4 |
| 11.1 | H | 3.23+1 | 3.23+2 | 1.62+3 | 3.24+3 | 6.52+3 | 1.63+4 | 3.28+4 | 6.53+4 |
| 16.2 | H | 3.41+1 | 3.41+2 | 1.71+3 | 3.43+3 | 6.89+3 | 1.73+4 | 3.47+4 | 6.90+4 |
| 23.8 | H | 3.57+1 | 3.56+2 | 1.79+3 | 3.58+3 | 7.20+3 | 1.81+4 | 3.63+4 | 7.22+4 |
| 1.45 | D | 3.69+1 | 3.69+2 | 1.85+3 | 3.71+3 | 7.45+3 | 1.87+4 | 3.75+4 | 7.47+4 |
| 2.13 | D | 3.79+1 | 3.78+2 | 1.90+3 | 3.80+3 | 7.65+3 | 1.92+4 | 3.85+4 | 7.66+4 |
| 3.12 | D | 3.86+1 | 3.86+2 | 1.94+3 | 3.88+3 | 7.80+3 | 1.95+4 | 3.92+4 | 7.80+4 |
| 4.57 | D | 3.92+1 | 3.91+2 | 1.97+3 | 3.93+3 | 7.91+3 | 1.98+4 | 3.98+4 | 7.91+4 |
| 6.70 | D | 3.97+1 | 3.96+2 | 1.99+3 | 3.98+3 | 8.01+3 | 2.01+4 | 4.03+4 | 8.01+4 |
| 9.52 | D | 4.01+1 | 4.01+2 | 2.01+3 | 4.03+3 | 8.11+3 | 2.03+4 | 4.08+4 | 8.10+4 |
| 14.4 | D | 4.06+1 | 4.06+2 | 2.04+3 | 4.08+3 | 8.20+3 | 2.05+4 | 4.12+4 | 8.19+4 |
| 21.1 | D | 4.11+1 | 4.10+2 | 2.06+3 | 4.12+3 | 8.29+3 | 2.08+4 | 4.17+4 | 8.28+4 |
| 30.9 | D | 4.15+1 | 4.14+2 | 2.08+3 | 4.16+3 | 8.38+3 | 2.10+4 | 4.21+4 | 8.37+4 |
| 45.3 | D | 4.20+1 | 4.19+2 | 2.10+3 | 4.21+3 | 8.46+3 | 2.12+4 | 4.26+4 | 8.46+4 |

* Time after the nuclear burst.

per square foot* at various times after burst and at various gamma-exposure-rate contour lines. The beta dose rate for each nuclide was then integrated over the time of exposure and the contributions from all nuclides were summed to obtain the total beta doses. The computations are for 100% fission yield and include a .75 terrain-roughness factor and a .75 instrument-response factor. To illustrate conversions of the data of the tables to another case; e.g., a 50% fission yield without the terrain-roughness and instrument-response factors, the tabulated values should be treated as follows:

$$\beta_{50} = \frac{\beta_{100} \times 0.5}{.75 \times .75} = 0.889\ \beta_{100}$$

The 66 nuclides chosen contribute 92% of the total fission-product beta activity at 2.8 hours, 95% at 28 hours, 98% at 12 days, and 98.3% at 117 days.[5]

The values in the tables are computed on the basis that all fallout particles for the area of the contours are down within 14.5 minutes after the burst. This of course is not true, especially for points that are some distance downwind from the burst point. This assumption, however, permits us to compute only one set of tables, and by adjusting the values for time of fallout arrival, the dose for any downwind point could be determined.**

*Input data and computer program for these computations, based on the method described by Miller,[34] were furnished by C. F. Miller and D. E. Clark of SRI.

**Suppose we wish to estimate the beta contact dose at a point 62 miles downwind from the burst point of a 1-MT weapon (50% fission) and on the 50 r/hr at 1 hour contour. Table 4.1 shows the dose buildup between 3.52 H and 5.16 H to be 2000 rads. Since the center line of the cloud does not reach the point until 4.13 hours after the burst, the dose received during this time interval may be estimated to be (.889)(2000) x (5.16-4.13)/(5.16-3.52) or approximately 1100 rads. The beta dose history for the point would then be zero through 3.52 H and 1100 rads at 5.16 H. The difference between this value and the table value of $2.21 \times 10^4$ at 5.16 H is $2.10 \times 10^4$. The dose at times subsequent to 5.16 H would then be equal to the table values minus this difference, i.e., the dose is approximately $7.3 \times 10^3$ rads at 4.57 D and $9.9 \times 10^3$ at 45.3 D.

4.3 EXTENT OF CRITICAL AREA

The idealized fallout-pattern features of Miller[34] were used to determine the extent of various exposure-rate contour lines for weapon yields of 1, 10, and 100 MT and a wind speed of 15 mph. The downwind distance from point of burst and the maximum width of various contours as well as the area bounded by them are shown in Tables 4.8 and 4.9 for 100% and 50% fission yields.

Using data from Tables 4.1, 4.5, 4.7, and 4.9, the 5-day and 45-day beta doses for a point on each of the standard-intensity contours of the three weapons considered were computed. The point selected for each contour is at half the distance from the burst point to the maximum downwind distance of the contour. Results of these computations are shown in Tables 4.10 and 4.11. Critical areas were determined on the basis of beta contact doses greater than 5000 rads in 5 days and 8000 rads in 45 days. For a 1-MT weapon burst with 50% fission yield and 15 mph wind, the critical area is approximately bounded by the 35 r/hr standard-intensity contour line. The area within this contour is about 2,800 square miles. For a 10-MT burst, the critical area is bounded by the 60 r/hr line enclosing an area of about 13,000 square miles. For a 100-MT weapon yield, the critical area is extended to about 58,300 square miles and is approximately bounded by the 80 r/hr at 1 hour contour line.

Table 4.8

Areas Bounded by Various Exposure Rate Contours* - 100% Fission

| Exposure Rate Contour (r/hr at 1 hr) | 1 | 10 | 50 | 100 | 200 | 500 | 1000 | 2000 |
|---|---|---|---|---|---|---|---|---|
| 1 MT weapon burst | | | | | | | | |
| Downwind distance to contour (miles) | 258 | 191 | 144 | 124 | 104 | 78 | 58 | 38 |
| Maximum width of contour (miles) | 63 | 45 | 32 | 26 | 21 | 13 | 7.8 | 2.4 |
| Area within contour (100 sq. miles) | 124 | 64 | 34 | 23 | 15 | 6.7 | 2.8 | .37 |
| 10 MT weapon burst | | | | | | | | |
| Downwind distance to contour (miles) | 529 | 410 | 327 | 290 | 255 | 208 | 172 | 137 |
| Maximum width of contour (miles) | 130 | 97 | 74 | 64 | 54 | 41 | 31 | 22 |
| Area within contour (100 sq. miles) | 534 | 305 | 182 | 139 | 103 | 62 | 38 | 20 |
| 100 MT weapon burst | | | | | | | | |
| Downwind distance to contour (miles) | 1081 | 866 | 716 | 651 | 586 | 500 | 435 | 372 |
| Maximum width of contour (miles) | 246 | 190 | 152 | 136 | 119 | 97 | 81 | 65 |
| Area within contour (100 sq. miles) | 2118 | 1298 | 849 | 684 | 537 | 369 | 263 | 177 |

*Computations based on Fallout Pattern Features of Miller[34] for 15 mph wind and 100% fission yield, (surface-roughness and instrument-response factors both equal 0.75).

Table 4.9

Areas Bounded by Various Exposure Rate Contours* - 50% Fission

| Exposure Rate Contour (r/hr at 1 hr) | 1 | 10 | 50 | 100 | 200 | 500 | 1000 | 2000 |
|---|---|---|---|---|---|---|---|---|
| 1 MT weapon burst | | | | | | | | |
| Downwind distance to contour (miles) | 238 | 171 | 124 | 104 | 84 | 58 | 38 | -- |
| Maximum width of contour (miles) | 58 | 39 | 26 | 21 | 15 | 7.9 | 2.4 | -- |
| Area within contour (100 sq. miles) | 104 | 50 | 23 | 15 | 8.6 | 2.8 | .37 | -- |
| 10 MT weapon burst | | | | | | | | |
| Downwind distance to contour (miles) | 493 | 374 | 290 | 255 | 209 | 172 | 137 | 101 |
| Maximum width of contour (miles) | 121 | 88 | 64 | 54 | 45 | 31 | 22 | 12 |
| Area within contour (100 sq. miles) | 458 | 248 | 139 | 103 | 67 | 38 | 20 | 7.3 |
| 100 MT weapon burst | | | | | | | | |
| Downwind distance to contour (miles) | 1017 | 802 | 651 | 586 | 521 | 435 | 372 | 286 |
| Maximum width of contour (miles) | 238 | 180 | 136 | 119 | 106 | 81 | 65 | 50 |
| Area within contour (100 sq. miles) | 1852 | 1095 | 684 | 537 | 406 | 263 | 177 | 98 |

*Computations based on Fallout Pattern Features of Miller[34] for 15 mph wind and 50% fission yield, (surface-roughness and instrument-response factors both equal 0.75).

Table 4.10

Approximate 5-day Beta Doses*

| Exposure Rate Contour (r/hr at 1 hr) | 1 | 10 | 50 | 100 | 200 | 500 | 1000 | 2000 |
|---|---|---|---|---|---|---|---|---|
| 1 MT weapon burst | | | | | | | | |
| Downwind mid-distance on contour (miles) | 119 | 86 | 62 | 52 | 42 | 39 | 19 | -- |
| Contact beta dose (rads) | 9.40+1 | 1.16+3 | 7.43+3 | 1.67+4 | 3.87+4 | 1.00+5 | 2.87+5 | -- |
| Beta bath dose - 10 cm air gap (rads) | 4.00+1 | 4.82+2 | 2.76+3 | 6.23+3 | 1.29+4 | 3.27+4 | 8.32+4 | -- |
| Beta bath dose - 100 cm air gap (rads) | 8.85+0 | 1.05+2 | 6.33+2 | 1.46+3 | 3.04+3 | 7.84+3 | 2.12+4 | -- |
| 10 MT weapon burst | | | | | | | | |
| Downwind mid-distance on contour (miles) | 247 | 187 | 145 | 128 | 105 | 86 | 69 | 51 |
| Contact beta dose (rads) | 5.50+1 | 7.70+2 | 4.01+3 | 8.68+3 | 2.06+4 | 5.90+4 | 1.39+5 | 3.41+5 |
| Beta bath dose-10 cm air gap (rads) | 2.70+1 | 3.25+2 | 1.89+3 | 4.00+3 | 8.93+3 | 2.41+4 | 5.34+4 | 1.20+5 |
| Beta bath dose - 100 cm air gap (rads) | 7.00+0 | 6.30+1 | 3.92+2 | 8.33+2 | 1.92+3 | 5.33+3 | 1.22+4 | 2.81+4 |
| 100 MT weapon burst | | | | | | | | |
| Downwind mid-distance on contour (miles) | 509 | 401 | 326 | 293 | 261 | 218 | 186 | 143 |
| Contact beta dose (rads) | 4.00+1 | 3.95+2 | 2.36+3 | 5.02+3 | 1.16+4 | 3.08+4 | 6.72+4 | 1.62+5 |
| Beta bath dose - 10 cm air gap (rads) | 1.50+1 | 1.88+2 | 1.11+3 | 2.37+3 | 5.15+3 | 1.48+4 | 3.25+4 | 7.53+4 |
| Beta bath dose - 100 cm air gap (rads) | 2.40+0 | 3.20+1 | 2.06+2 | 4.39+2 | 9.71+2 | 2.88+3 | 6.50+3 | 1.57+4 |

*15 mph wind and 50% fission yield with terrain-roughness and instrument-response factors both set equal to 1.

## Table 4.11

### Approximate 45-day Beta Doses*

| Exposure Rate Contour (r/hr at 1 hr) | 1 | 10 | 50 | 100 | 200 | 500 | 1000 | 2000 |
|---|---|---|---|---|---|---|---|---|
| **1 MT weapon burst** | | | | | | | | |
| Downwind mid-distance on contour (miles) | 119 | 86 | 62 | 52 | 42 | 39 | 19 | - |
| Contact beta dose (rads) | 2.40+2 | 1.64+3 | 9.92+3 | 2.17+4 | 4.81+4 | 1.25+5 | 3.36+5 | - |
| Beta bath dose - 10 cm air gap (rads) | 5.90+1 | 6.83+2 | 3.77+3 | 8.21+3 | 1.69+4 | 4.29+4 | 1.04+5 | - |
| Beta bath dose - 100 cm air gap (rads) | 1.13+1 | 1.31+2 | 7.57+2 | 1.73+3 | 3.56+3 | 9.15+3 | 2.38+4 | - |
| **10 MT weapon burst** | | | | | | | | |
| Downwind mid-distance on contour (miles) | 247 | 187 | 145 | 128 | 105 | 86 | 69 | 51 |
| Contact beta dose (rads) | 1.04+2 | 1.16+3 | 6.50+3 | 1.36+4 | 3.00+4 | 8.38+4 | 1.88+5 | 4.36+5 |
| Beta bath dose - 10 cm air gap (rads) | 4.70+1 | 5.26+2 | 2.89+3 | 5.98+3 | 1.29+4 | 3.43+4 | 7.43+4 | 1.60+5 |
| Beta bath dose - 100 cm air gap (rads) | 9.70+0 | 9.00+1 | 5.16+2 | 1.10+3 | 2.44+3 | 6.65+3 | 1.48+4 | 3.33+4 |
| **100 MT weapon burst** | | | | | | | | |
| Downwind mid-distance on contour (miles) | 509 | 401 | 326 | 293 | 261 | 218 | 186 | 143 |
| Contact beta dose (rads) | 8.90+1 | 8.79+2 | 4.85+3 | 9.95+3 | 2.10+4 | 5.57+4 | 1.17+5 | 2.56+5 |
| Beta bath dose - 10 cm air gap (rads) | 3.50+1 | 3.89+2 | 2.12+3 | 4.35+3 | 9.15+3 | 2.50+4 | 5.33+4 | 1.15+5 |
| Beta bath dose - 100 cm air gap (rads) | 5.00+0 | 5.90+1 | 3.30+2 | 7.05+2 | 1.49+3 | 4.20+3 | 9.16+3 | 2.10+4 |

*15 MPH wind and 50% fission yield with terrain-roughness and instrument-response factors both set equal to 1.

## SECTION 5

## CONCLUSIONS

The study thus far has revealed that, within the San Joaquin Valley, an ecological imbalance may occur as a result of fallout radiation from nuclear detonations. Wind conditions in the region are such that during the Spring or late Fall months a 5-MT to 10-MT weapon burst over the Richmond area in San Francisco Bay would probably cause fallout deposition over a large portion of the valley. The beta dose from the fallout deposit of such a weapon is of sufficient level to sterilize many species of insects in the region while leaving other species relatively unharmed. For a 10-MT weapon burst with fifty percent fission yield and a 15 mph wind, this critical area may encompass as much as 13,000 square miles, or an area approximately equal to the size of the San Joaquin Valley. The extent of the critical area and the natural boundaries of the region preclude the immediate repopulation of sterilized or annihilated species by migration from the outside.

The sudden and violent buildup of radiation levels adds a tremendous stress to the unstable balance of forces that exist in most agricultural communities. If countermeasures in the form of biological or chemical control of insect outbreaks are not employed, and the fields are abandoned, then an ecological succession towards a natural balance in the ecosystem would occur. However, the probability of such an occurrence is highly unlikely, since it is predicated upon the condition that man would abandon vitally important and fertile fields. Even with the gradual resumption of biological and chemical controls, however, insect population imbalance may exist for several years before the pre-attack conditions of the region are restored.

Although Federal and state agencies publish periodic reports on the relative abundance of specific pest insects, there is little information available to correlate fluctuations in insect population with environmental changes. Data on beneficial insects, other than those imported for biological control of pests, are generally not available. Field work to collect these data may be necessary since these insects form a vital element in the community.

Ecosystem modeling schemes which have been developed to study population behavior require a high degree of simplification in order to describe the system in mathematical terms. This simplification is necessary because of the large number of elements involved in a community and because data are not sufficient to permit reasonable assessment of the interrelationship of the various members in the community and to correlate population fluctuations with environmental changes. Because of the lack of mathematical formulation, the development of scenarios to describe perturbations in an ecosystem may be more feasible than the development of simplified mathematical models.

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13. ABSTRACT

The ecological balance maintained in many of our agricultural communities may be seriously affected by the effect of ionizing radiation from nuclear fallout on insect populations. In this sutdy, the San Joaquin Valley in Central California was selected as the region for specific investigation to determine the extent of possible insect-population imbalance and the effect such an imbalance might have upon its agricultural production. The report discusses topographical and climatological conditions and presents data on the insect pest population and the agricultural commodities of the region. The beta bath dose at .003 cm tissue depth at various gamma-exposure-rate contour levels were computed and are presented in this report. The extent of the critical areas in which insect population imbalance may occur was determined for 1-, 10-, and 100-MT weapon bursts.

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| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Fallout radiation<br>Radiation effects<br>Fallout on ecosystems<br>Ecosystems<br>Insect population imbalance | | | | | | |

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