410529

PROTECTIVE AND REMEDIAL MEASURES

TAKEN FOLLOWING

THREE INCIDENTS OF FALLOUT

Gordon M. Dunning

Technical Advisor

United States Atomic Energy Commission

Washington, D. C.

To be given before a symposium "Radiation Protection of the Public in Large Scale Nuclear Disasters." Annual Meeting of the FACHVERBAND FUER STRAHLENSCHUTZ, Interlaken, Switzerland, May 1968.

The stated topic of this symposium is, "We want to discuss the radiation protection measures after a nuclear mass disaster by which large areas have become so severely contaminated with radioactive material that it constitutes a major hazard for the public." Fortunately it is not possible to document directly this topic because such an event has never occurred. We are forced then to look for other situations that may provide relevant information and guidance to our discussions.

There were three incidents that occurred following atmospheric nuclear weapons test detonations, and although they have been reported previously, bear recounting for they do show (a) what decisions were made and on what bases (b) the manner in which the decisions were carried out and (c) the results of the protective actions taken. (Figure 1)

There was a relatively heavy fallout on the Marshall Islands in the Pacific following an atomic test detonation on March 1, 1954 that required the evacuation of 239 inhabitants. There was also a situation in 1953 when, as a precautionary measure, about 4500 persons in St. George, Utah were asked to remain indoors for a period of two hours and in 1962 countermeasures were instituted by local and state health authorities in Salt Lake City in the State of Utah to reduce the levels of iodine-131 in the milk consumed by the public.

The Pacific incident in 1954 illustrates the necessity of, and benefits to be derived from, good safety plans that are fully implemented. The St. George, Utah incident in 1953 shows the favorable results from a program of education of local officials and the public and the close cooperation with the local authorities. The Salt Lake City, Utah incident in 1962

2

demonstrates the need for radiation protection guides that are clearly understood by all concerned and the necessity to monitor directly for the type of data required (such as iodine-131 in milk) rather than attempt to predict by extrapolating and reinterpreting other kinds of data.

A part of this presentation is given in first person in the hope of making the recounting of the incidents more interesting and to bring out certain points more vividly.

The Pacific Incident

On March 1, 1954 a 15 megaton[1.] thermonuclear shot designated as BRAVO, was fired on a reef extending from the Island of Namu located on the northwest part of Bikini Atoll.

Figure 2 shows the estimate that I made of the pattern of fallout from BRAVO - expressed as the doses that persons who were out-of-doors, without shielding, could have received over a two day period following the initial appearance of the fallout.

The doses shown over land areas were estimated from dose-rate readings by survey meters held at three feet above the ground. Doses over sea areas were extrapolations of land survey data and thus are much less certain. However, after constructing the "best fit" isodose lines, I calculated from these data that the total quantity of radioactivity that was deposited within 400 miles downwind represented about 2/3 of the total amount produced by the detonation. This estimate is not in conflict with those made in subsequent years by others who were able to incorporate more data from later surface detonations. In addition to the "absolute" values shown in Figure 2, the relatively sharp gradients of the isodose lines, especially those across the main line of the fallout, are of interest to those concerned with the subject of this symposium. Of course, patterns of fallout will be strongly a function of the wind structure.

Figure 3 shows the estimated exposure rate readings on D + 1 day based on monitoring data made by personnel on the ground two to four days after the detonation.[2] The usual factor of $time^{-1.2}$ was used to convert these data to exposure rate readings at D + 1 day and to the two day out-of-door doses shown in Figure 2. The validity of using this conversion factor may be estimated by noting the exposure rate readings taken on the Island of Rongelap (Figure 4).[2] There was essentially no rain on this island for about two weeks after the detonation and the winds were light. At the end of the second week after the detonation a heavy tropical storm occurred. This could account for the observed exposure rate readings after the 10th day being lower than those anticipated by the $time^{-1.2}$ relationship. Of course, there is no assurance that the exposure rate readings followed the straight solid line drawn between the 2nd and 10th days. It can only be inferred that any deviation would not be of major significance in terms of using the data in arriving at decisions for protective actions. As would be anticipated, the observed exposure rates deviate most from the $time^{-1.2}$ relationship at longer periods after the initial deposition - but these would be less crucial times. That is, the radiation exposure rates would be considerably less than at early times and more time would be available to evaluate the situation, make decisions and take action.

In brief, this was the pattern of fallout after the BRAVO event. What decisions were made and on what bases, how were the decisions carried out and what were the results of these actions?

Command personnel were aboard ships standing off Bikini Atoll at shot time. Some fallout did occur on these ships but by maneuvering the ships and by having the personnel remain below deck for a few hours the total dose was minimized. For example, my film badge later showed 150 milliroentgens.

By the time of our return to home base on Perry Island, Eniwetok, the radiation data on the northern island of Bikini had been obtained from automatic recorders and showed values up to the thousands of roentgens per hour at time of fallout. These were not unexpected values for the distances and times involved. It is to be recalled that until 1954 one school of thought held that high yield surface detonations would create intense fallout only in the immediate area of the shot and that most of the activity would be carried into the stratosphere where it would be scattered widely around the world. March 1, 1954 saw the dismissal of that school - permanently.

As had been planned previous to the detonation, an aerial survey was made at H + 31 hours over Rongelap Island, 115 statute miles to the east of ground zero. The reported radiation levels were about 4.0 roentgens per hour (extrapolated to ground level). The aerial reading subsequently was shown to be somewhat high, yet it triggered a chain of actions that was desirable. Obviously, something had happened to the predicted fallout pattern - later it was learned that shifting winds had veered the pattern southward over Rongelap, Ailinginae Atoll, Rongerik Atoll and Utirik Atoll.

Although it had not been anticipated that evacuation would be required, plans for such an eventuality had been made - as they should have been in a good safety plan. Both aircraft and surface ships were dispatched to Rongelap and at about H + 51 hours, 16 Rongelapese were evacuated by air and 48 by surface ship. Their total whole body exposure was about 175 rads.[3.] Although the radiation exposure levels on the Island of Sifo on Ailinginae Atoll were less than one-half those on Rongelap Island, 18 inhabitants of this island were also evacuated by ship at about H + 58 hours. They were all taken to the Island of Kwajalein and given the best medical care, and their needs amply supplied. They were moved to the Island of Ejit on Majuro Atoll in June 1954 and returned to their home islands on June 29, 1957. A full account of the initial medical findings are contained in reference 3. Subsequently, annual medical examinations have been made by Dr. Robert A. Conard and his associates at the Brookhaven National Laboratory and the results of this outstanding work are reported in reference 4.

By late in the evening of the second day after the BRAVO detonation, radiation reports had been received about the Island of Utirik - about 315 statute miles to the east. It was not as apparent that evacuation was essential as it was at Rongelap Island since the radiation levels were considerably less. There were cogent arguments against evacuation of the inhabitants: (a) the estimated radiation doses probably would not exceed 60 rads - even if they remained on the island for a lifetime (b) evacuation would involve a sizeable number of inhabitants (154) and would entail some degree of hazard and hardship and (c) since such action would not go unnoticed in worldwide discussions of nuclear weapons testing there should be an impelling safety reason to require evacuation.

Recognizing the validity of these arguments, the counterarguments were: (a) there were ships capable of removing the inhabitants from Utirik by the third day after shot day (b) it might be possible to save them 45 roentgens of exposure by doing so and (c) the major decision, in terms of public relations, had already been made when the first Rongelapese and Ailinginaese were evacuated.

A decision was reached and evacuation of the 154 inhabitants of Utirik was started at about H + 55 hours and completed on H + 78 hours. They were also transported to Kwajalein where they were given the same care as those from Rongelap and Ailinginae and were returned to their home island of Utirik on June 5, 1954.*

In a retelling of this story more than a decade later the situation may appear so clear that the decisions should not have been difficult. However, like any emergency situation there are always uncertainties in the immediately available information. This was especially so since the initial radiation

*Twenty-eight members of the Task Group conducting the nuclear tests were evacuated from Rongerik Island at H + 28.5 and H + 34 hours. Their total external gamma dose was estimated to be 78 rads.[3] It was later reported by the Japanese that some fishermen aboard a vessel near the Pacific Proving Ground may have received higher exposures than the Marshallese.[5]

levels were estimated by conducting an aerial survey which was a technique not yet developed to its present reliable state. Also, as has been mentioned, at the time of BRAVO shot there was not indisputable proof that land surface bursts of high yield would produce such a heavy fallout at distances of a hundred miles and more, thus adding to suspicion of the initial aerial survey reports. Also, the energy yield of the detonation was twice that anticipated.[6]

Despite the best laid plans there always can be some element of risk and hardship in taking action under emergency conditions. However, the decision to conduct the first evacuation from Rongelap and Sifo Islands was easier than the second from Utirik, for here there were many more inhabitants who would be subjected to potential risk and hardship. Also, their maximum estimated lifetime radiation dose was 60 rads - an amount then equivalent to the maximum permissible over only a five-year period for atomic energy workers. Later, when these matters were discussed in the United Nations Trusteeship Council it was a favorable point to show that evacuation had been ordered. But suppose there had been unfortunate accidents during the evacuation - perhaps deaths. Would the decision to evacuate have been judged as wise?

There was not, however, a single casualty or injury during any of the evacuations. The well-laid safety plans and their efficient implementation paid rich dividends. But it should be pointed out quickly that these factors were abetted by two conditions (a) there were abundant capabilities at hand - aircraft, ships, equipment, trained personnel, etc. - and (b) the inhabitants were unaware of the potential hazard and were very cooperative. If there were a large and less amiable population, imbued with fear, rightly or wrongly, and there were only limited capabilities at hand for protective action - as might prevail under the conditions suggested for this symposium of a nuclear mass disaster - then there could be a different result.

This is all the more reason to proceed as far as possible now in the developing of practical radiation protection guides that can be synthesized into overall disaster plans and to conduct active programs of public education.

The St. George, Utah Incident

On May 19, 1953 a 32 kiloton nuclear shot, designated as HARRY, was fired on top of a 300 foot tower at the Nevada Test Site.[1.]

Figure 5 shows the estimated doses that could have accrued if perso were present and remained for a lifetime at a given location. Most of t area shown is uninhabited - that was one of the principal reasons for selecting the testing site in southern Nevada. The original site was 64 square miles. Later this was expanded to about 1350 square miles. In addition, there is an adjacent area of about 4700 square miles that is controlled.

The highest estimated dose from this fallout was about five rads (again based on the assumption of continued occupancy of the area) to tw persons at a nearby ranch.[7.] In terms of number of persons involved, St. George, Utah was affected most from the fallout from HARRY shot and is that story that will be retold.

For every nuclear detonation an Advisory Panel was convened with ex perts in many fields, such as meteorology, nuclear medicine, health phys and public health, as well as those especially qualified in the study of fallout predictions. Prior to May 19, 1953, the Panel had waited patien for 72 hours until the prediction of fallout was in an acceptable sector toward the northeast.

At the weather briefing on the evening of May 18, 1953, the predictions were encouraging enough to keep the shot on schedule for the next morning. As the long hours droned on during the night there were frequent formal and informal briefings, as the Air-Weather Service Unit constantly collected and evaluated new data. With continued favorable reports and with the zero hour approaching, decisions had to be made.

Mobile monitoring teams had been dispatched during the day and were in the general vicinity of their assigned locations. It was now necessary to spot them more definitely. Also, at about this time it was customary for the Liaison Officer of the Federal Aviation Agency, attached to the Test Organization at the Nevada Test Site, to direct the closure of certain air spaces for commercial aircraft from the Site out to specified distances, altitudes and times, principally to avoid the possibility of the flash of the detonation temporarily dazzling the eyes of pilots. Cloud tracker aircraft of the Test Organization were ordered to take off so as to be in position at H-Hour. Helicopter crews were alerted for close-in terrain surveys and L-20 and C-47 crews for more distant terrain surveys. The usual ground and aerial sweeps had been made in the afternoon to assure there was no unauthorized person in the close-in areas in the direction of the fallout. The technical crews reported their readiness for all experimental work on-site and off-site.

At 0505 Pacific Daylight time, on the morning of May 19, 1953, HARRY was detonated. Within a short time the initial technical data from HARRY shot was collected and most of the scientists went back to camp for a well earned rest. But not the radiological safety personnel - their day was just beginning.

The first on-site and off-site reports were encouraging. The fallout was progressing to the east-northeast and crossed Highway 93 south of Alamo and north of Glendale, Nevada as predicted. In anticipation of this event, roadblocks had been established on Highway 93 at Alamo at 0715, and at Glendale at 0725. This prevented persons being directly in the fallout as it occurred, thus reducing the whole body exposure and the possibility of direct contamination of personnel and equipment. The roadblocks were removed at 0851 and the cars monitored after they had traveled through the area. Precautionary closing of Highway 91-93 between Las Vegas and Glendale had been ordered at 0735 and lifted at 0805. A precautionary roadblock had been established at St. Goerge at 0745 but it was not until 1130 hours that this roadblock was lifted. All in all, hundreds of cars were monitored and about 40-50 vehicles were washed (at Government expense) according to the established radiological safety criteria.

Groom Mine was not directly in the path of the predicted fallout but since it was the nearest inhabited place - about 30 miles from ground zero - monitors were stationed there. At 0632 the radiation level rose rapidly to 140 milliroentgens per hour and the few inhabitants living there were asked to remain indoors. They were released at 0748 after the cloud had passed and the levels had subsided. At 0920 the radiation levels outside were 11 mr per hour and were dropping rapidly. Incidentally, there were other occasions when individuals or families located near the test site were temporarily relocated. Usually this involved from one to a dozen or so persons who were taken to one of the surrounding communities of their choosing, like Las Vegas, on the day before a detonation. They were pa a stipend by the day and were returned to their homesites as soon as cleared by radiological safety officers.

The trajectory of the air mass containing the radioactive debris south of Groom Mine, moved in an east-northeasterly direction, and cro Highway 93, south of Alamo - all about as predicted. The monitoring d suggested that the pattern was somewhat farther south than predicted, not disturbingly so. Beyond Highway 93 and in the line of the traject lay uninhabited country for many miles. Everything looked in good sha

The monitors at the St. George roadblock (actually at the junctio Highways 91 and 18 to the west of St. George) noted that at 0845 the b ground levels were increasing. By 0910 the levels had risen to 320 mr hour and a quick check of an automatic background recorder at nearby D College showed about the same reading. It was determined later, howev that the instruments had been contaminated by the fallout. When anoth nearby mobile team brought in clean instruments and a correction facto applied, the value was 220 mr per house.

Not relying solely on radio communications, Mr. Frank A. Butrico Public Health Service and head of the monitoring team had wisely calle Control Point at the Nevada Test Site by long distance telephone and w keeping Dr. Jack Clark of the Los Alamos Scientific Laboratory and me formed of the situation as it developed. As the radiation levels rose

St. George, we knew that they were exceeding predicted values at that point, yet they were well below hazardous amounts. It was more of a ques- tion of precisely how much higher might the radiation levels rise and how long would it require to take protective actions.

We decided to ask the residents of St. George to stay indoors, which they did from about 0930 to 1130 at which time they were released. Later the lifetime exposure at St. George was estimated to be about 2.5 rads from this fallout.[7] In retrospect, and please be assured that evaluatin in retrospect is much easier than prospect, it would appear that a large fraction of the potential whole body dose was not eliminated by this evas action. Remaining indoors did minimize direct body contamination and in- halation of radioactive debris during the period of time that it was fall to the ground and it did provide a somewhat more controlled situation in the event further action was deemed essential.

Again, the decision and action sound simple. However, there were ab 4500 persons involved, spread through the city. Hundreds of children wer at school. Cars and trucks were moving about the city on their normal business. This would be the first time that action would be taken with such a large community and on short notice. Instructions to evacuate imm diately might induce a panic with its attendant hazards and would, in fac bring many persons out of their homes, schools, and offices into the open during the time when the fallout was occurring most abundantly. We might actually do more harm than good, yet if action were needed it should come quickly to be fully effective. But was any emergency action really imper tive or what action was best when evaluated against potential risks?

These are the conflicts of arguments that decision-makers must cope wit often under trying emotional conditions, and under the pressure of time

As Mr. Butrico reported later, "At 0925 instructions were received have the people in St. George take cover. The Sheriff was notified and in turn contacted the radio station in Cedar City to get the announceme over the air. In addition, the school principals were notified of the ation so that the children would not be sent out into the open during r periods. At 0940 the bulk of the population in the city of St. George under cover. The effectiveness of the operation was amazing."

More lies behind this statement than is apparent. The radiologica safety group had conducted orientation sessions with the local official and to a lesser extent with the general public at St. George and other nities. Although the officials might not have thoroughly understood al the science involved they were aware of the potential problems. Most tant, a line of communication had been established so that no time was when a decision was made to act.

Another key factor was that orders to remain indoors came from a ognized officer of the law and a local man whom everyone knew and trus the orders did not come from a stranger dressed in white coveralls, wi Martian face mask, and a queer "ray instrument" in each hand. (This d scription is for purposes of illustration - the monitors did not actua dress in this manner.) Thus the populace accepted the order readily, quickly, and did so without panic or accidents.

At the time of the orientation sessions and formulation of safety plans, no one could clearly foresee exactly what emergencies might arise nor precisely what action might be called for. Yet the basic requirements of understanding and communications were established. These were all that were needed in this situation. Much more extensive plans and capabilities could be required in other situations. In any event, education of officials, especially those who are in positions of authority to order actions be taken, and of the public is one of the basic requirements of any good safety plan.

The Salt Lake City Incident

A nuclear device was detonated on or near the ground on July 7, 11, 14 and on 17, 1962, at the Nevada Test Site. A cratering shot also was fired on July 6, 1962 at the Site.

With increased alertness to possible environmental contamination and with monitoring methods that had been perfected in recent years which permitted rapid measurements of a large number of samples, the rise of iodine-131 levels in milk in the Salt Lake City environs was followed closely. As the levels rose from nondetectable amounts in early July to peak amounts on July 25, apprehension increased among the officials and residents of Salt Lake City, located about 350 miles northeast of the Nevada Test Site. It was understood by them that the (U.S.) Federal Radiation Council's Radiation Protection Guide was 36,500 picocuries of iodine-131 that might be ingested in any one year.[8] By the end of July the total ingested (based on usual assumptions and calculations) had risen to 27,000 picocuries. Although the amounts of iodine-131 per liter of milk were decreasing by then, the accumulated intake continued to increase, of course, toward the assumed "end point" of 36,500 picocuries. (The final tally was 37,040 picocuries).[9]

The press and others brought strong pressures to bear on the public officials to take action for they had come to understand the "limit" to be the 36,500 picocuries. The state and city health authorities met with representatives of the milk industry; as a consequence several actions were taken by the latter in early August. Of the 759 milk producers in the Salt Lake City area, 285 placed their cows on dry feed, 211 others diverted their milk into milk products. This represented 53,000 gallons of the 77,000 gallon total daily milk production.[9]

Obviously, these were not minimal actions. Two-thirds of the produce were affected, representing two-thirds of the milk supply for Salt Lake Ci The public was upset and worried. Some families switched to powdered milk and others eliminated milk from the diet of children.

On August 17, 1962, the U. S. Public Health Service released a statement, "The Utah action was based upon the radiation exposure guidelines recommended by the Federal Radiation Council and accepted by the President last September."[10]

Yet, on August 29, 1962, the Federal Radiation Council stated in a letter to the Joint Committee on Atomic Energy (Congress of the United St "The Council recognizes that premature action has been taken in some areas to reduce the intake of iodine-131 which action the Council would not have recommended under its interpretation of the guides . . ."[11] The exchange of letters between the Federal Radiation Council and the Joint Committee Atomic Energy led to such newspaper headlines as "States Chided for Acting Too Soon Against Radiation Threat in Milk."[12]

Much further discussion could be reported (references 13 and 14) abo this incident - who said what to whom and when and why - but this is suffi cient to illustrate how an unfortunate situation can arise if there are no clear understandings of the radiation protection guides and their appropriate application.

In a letter of August 17, 1962, from the (U.S.) Federal Radiation Council to the Joint Congressional Committee on Atomic Energy, it stated that the radiation protection guides, " . . . are not intended to set a line at which protective action should be taken or to indicate what kind of action should be taken." Yet without this advice, the guides were misinterpreted to mean a "limit", a "maximum", a "danger level." (In July 1964, the Federal Radiation Council did recommend Protection Action Guides that were appropriate for taking countermeasures.)[15].

On August 7, 1962, at the height of the scare in Salt Lake City, members of the U. S. Public Health Service and I met with officials in Salt Lake City. Later there was a discussion with the press and an interview on the local television station. It is to the credit of the citizens and the press of the Salt Lake City area that when proper interpretations were given of the Federal Radiation Council's guides, the local press reported that, "The scare over the content of radioactive iodine (I-131) in Utah milk subsided . . .".[16].

Such an occurrence, however, can leave a regrettable imprint. It is difficult enough to educate the public correctly without compounding the problem ourselves.

There is an addendum to this story.

Because of the increased interest in iodine-131 that this incident created, many attempts have been made to estimate the amount of iodine-131 in milk during past atmospheric tests based on such measurements as external gamma readings, concentrations of total beta activity in air and gross beta activity on gummed paper. All of these paper studies suffer such severe uncertainties as to seriously question their usefulness.

For example, local fallout patterns can have sharp gradients as illustrated in Figure 5. I have measured external gamma radiation levels in local fallout patterns that have varied one from the other by factors of 5 to 10, all within a few hundred meters. More than one paper study has been done using past monitoring data and attempting to establish correlations between external gamma readings and the amount of iodine-131 in milk. I recall one meticulously prepared study.[17] The mathematics was elegant. The only trouble was that the author had not determined, for example, that the external gamma readings he used were taken by monitors outside of a bar within the town while the pasture land was miles down the road. The monitors were not derelict in their duty since their first obligation was to assure safety of persons at the time of the fallout and they went to the places where people were located.

There was a carefully documented test[18] performed after some leakage occurred following an underground nuclear detonation on March 13, 1964, at the Nevada Test Site. It showed that the amount of iodine-131 deposited on one farm about 70 miles from the test site differed from another by factors of two to five even though the farms were within five miles of each other in a broad valley with no significant topographical features separating them. In fact, the amounts of deposited iodine-131 at two places only

200 yards apart on a farm differed by a factor of seven.

To attempt to estimate quantitatively the amount of iodine-131 in milk by measurement of external gamma readings incorporates not only the uncertainties just mentioned but also adds those due to possible (a) fractionation of the fission product debris (b) incorporation of varying amounts of induced activities in the fallout (c) wide variances of retention of the debris on the foliage (as a function of particle size distribution and other factors) and (d) other variables such as accurate instrument response, especially at relatively low exposure rates (where most studies have been performed) and extrapolation of external gamma readings by the time$^{-1.2}$ relationship. All of these leave one with an uneasy feeling of confidence in the conclusions. The most gross relationship might be inferred in comparing different types of data such as external gamma levels and iodine-131 in milk but then only as an alert for possible additional monitoring. In fact, as stated in the report[18.] on the study made following the March 13, 1964 event, " . . . the external beta plus gamma measurements were background throughout the study . . . utilizing such relationships in this instance would have led to the conclusion that there would have been no measurable I-131 milk levels found whereas our data indicate that levels could actually have reached values near 700 pc/l had the study been started at an optimum time." (The highest measured value was 420 picocuries per liter.)

Even less can be said for using concentrations of radioactivity in the air as the basis for a model to predict quantitatively the amount of iodine-131 in milk. One analysis[19] of extensive monitoring data concluded, "The air network, which should act as an 'early warning' system, to warn us of approaching radioactive contamination, is of very limited value, if not misleading. The air network failed to give warning of high iodine-131 levels in milk in most places in the U. S. last fall." (fall of 1961).

Paper studies have been made[20] purporting to predict within a factor of two the dose to the thyroid based on estimated iodine-131 in milk, which in turn are based on gross total beta activity collected on gummed paper. Most of the uncertainties already mentioned and probably additional ones apply to this method of prediction.

In brief, monitoring procedures, equipment and data, if properly employed, are useful for the purpose for which they are intended. To extrapolate or reinterpret them into other forms of information is done so at a considerable risk oi authenticity.

It is recognized that some think more highly of these paper studies made to predict the iodine-131 content in milk from other data, but I believe there would be agreement on one point. If it is deemed essential to determine the iodine-131 content in milk then a good safety plan should provide for its direct and early measurement. The same assertion applies to all other key radiological data.

One final story. Even with the best laid plans and with a superior organization to carry them out, things can still go awry.

Following a cratering experiment using an underground nuclear explosive at the Nevada Test Site in the spring of 1965 some radioactivity contaminated pasture lands to the north of the site. As planned, radiological monitors went into immediate action. Among the many surveillance activities conducted was the daily collection of milk from the affected farms. In the midst of these daily collections, I received word by telephone that one of the cows had died. This was most difficult to explain since the measured levels of activities, both external gamma and iodine-131 in milk, were very low. An investigation revealed that samples of milk were sent from the farms to the laboratory on a daily basis. On this particular day no sample of milk was received from one farm but instead the monitor had written a note stating that the cow had "kicked the bucket" - which also is a slang phrase meaning someone has died. Further investigation verified that indeed she had literally kicked over the bucket and that was why there was no milk sample from that cow for that one day.

ACKNOWLEDGMENT

Acknowledgment is gratefully made to Mr. Robert E. Allen, Dr. Roy D. Maxwell and Mr. Tommy F. McCraw of the Division of Operational Safety, U. S. Atomic Energy Commission, for their assistance in the preparation of this paper.

REFERENCES

1. The Effects of Nuclear Weapons. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20401. Revised edition April 1962.

2. Radioactive Contamination of Certain Areas in the Pacific Ocean from Nuclear Tests. Dunning, G. M. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20401. August 1957.

3. Some Effects of Ionizing Radiation on Human Beings. Cronkite, E. P., Bond, V. P. and Dunham, C. L., editors. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20401. July 1956

4. Medical Survey of the People of Rongelap and Utirik Islands Eleven and Twelve Years After Exposure to Fallout Radiation (March 1965 and March 1966.) BNL 50029 (T-446). Conard, Robert A. et al. Brookhaven Natic Laboratory, Upton, New York 11973. April 1967 and previous annual reports.

5. Research in the Effects and Influences on the Nuclear Bomb Test Explosions II. Japan Society for the Promotion of Science. 1956.

6. Press statement by Lewis L. Strauss, Chairman, Atomic Energy Commissior March 31, 1954.

7. "Fallout From Nuclear Tests at the Nevada Test Site," TID 5551. Dunning, G. M. Presented at the Hearings on Fallout Before the Joint Committee on Atomic Energy, May 1959.

8. Background Material for the Development of Radiation Protection Standai Federal Radiation Council, Report No. 5, September 1961.

9. Utah's Experience with Radioactive Milk, A Joint Report of the Salt Lake City Department of Health and the Utah State Department of Healtl prepared by Utah State Department of Health with the assistance of the Salt Lake City Health Department and the U. S. Public Health Service, October 1, 1962.

10. Press release by the U. S. Department of Health, Education, and Welfar Public Health Service, August 17, 1962.

11. Letter from the Federal Radiation Council to Joint Committee on Atomic Energy, dated August 29, 1962 and released on September 1, 1962 by the JCAE.

12. The Washington Post, September 1, 1962.

13. Radiation Standards, Including Fallout. Hearings Before the Special Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy, Congress of the United States. June 1962.

14. Fallout, Radiation Standards, and Countermeasures. Hearings Before the Special Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy, Congress of the United States, June 1963.

15. Background Material for the Development of Radiation Protection Standards. Report No. 5, Federal Radiation Council. July 1964.

16. The Salt Lake City Tribune, August 8, 1962.

17. Iodine 131 in Fresh Milk and Human Thyroids Following a Single Deposition of Nuclear Test Fallout, TID-19266, Knapp, H. A. Office of Technical Services, Department of Commerce, Washington, D. C. 20235. June 1963.

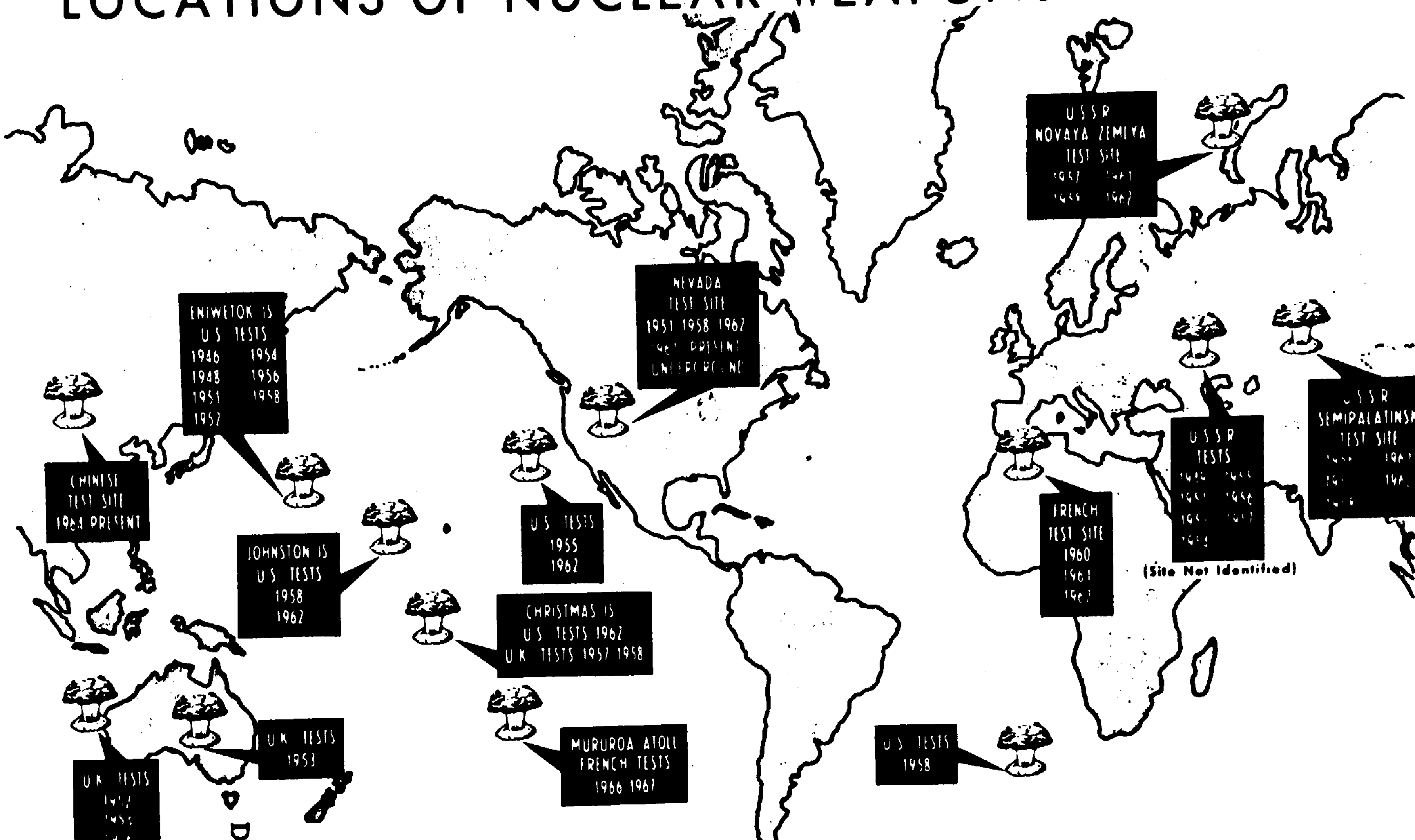
18. Dairy Farm Radioiodine Study Following the Pike Event, SWRHL-145. Barth, D. S. and Veater, J. G. Southwestern Radiological Health Laboratory, U. S. Public Health Service, Las Vegas, Nevada 89109.

19. "Monitoring Fallout From Nuclear Weapons Tests," Michelson, Irving. Presented at the Hearings on Fallout, Radiation Standards, and Countermeasures Before the Joint Committee on Atomic Energy. June 1962.

20. "Estimation of Dosage to Thyroids of Children in the U. S. From Nuclear Tests Conducted in Nevada During 1952 through 1955", Tamplin, A. R. Presented at the American Association for the Advancement of Science, December 27, 1967.

Figure 1.

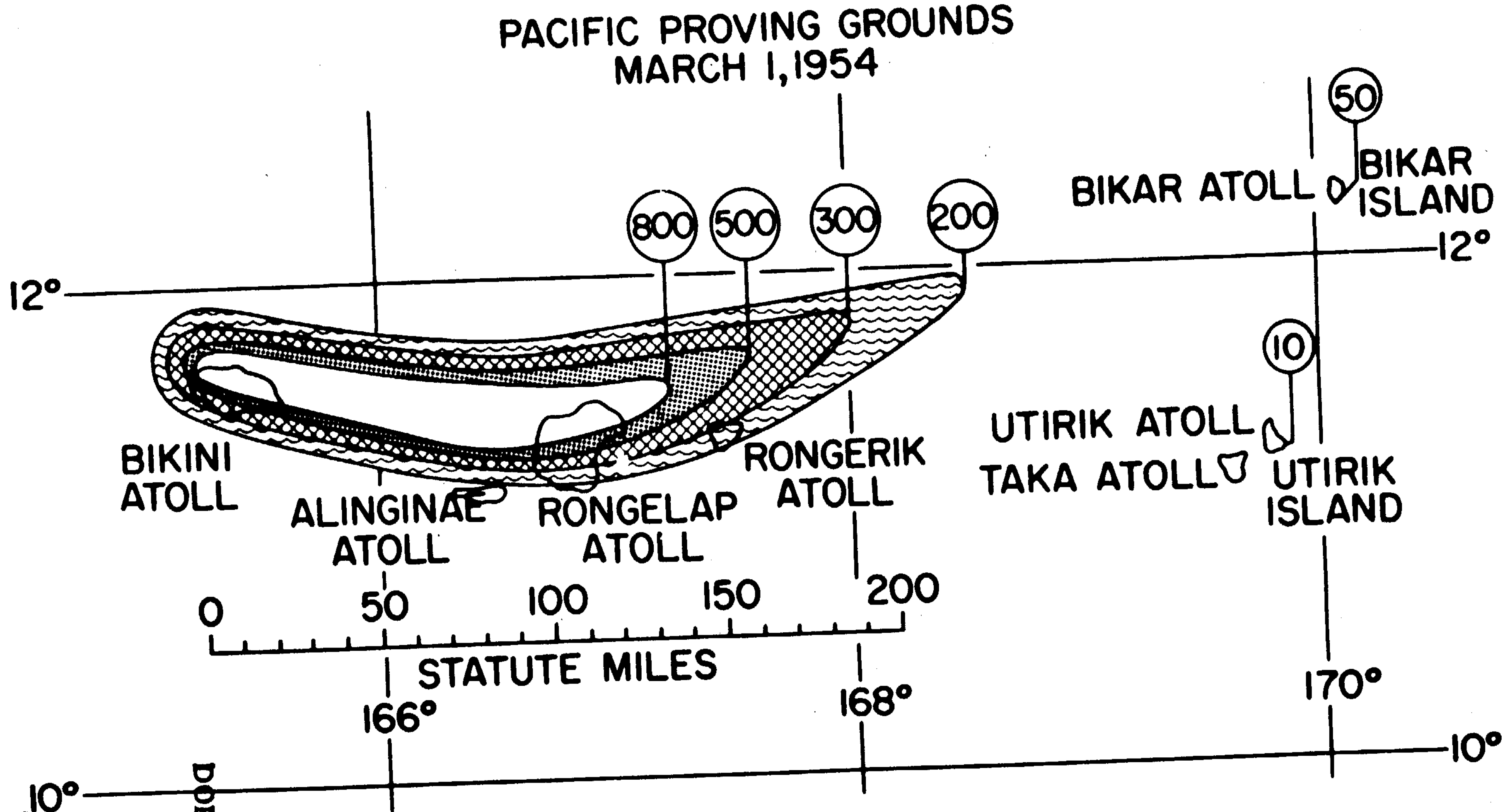
LOCATIONS OF NUCLEAR WEAPONS TEST SITES



Footnote:
UNDERGROUND NUCLEAR DETONATIONS WERE CONDUCTED NEAR CARLSBAD, NEW MEXICO, 1961; NEAR FALLON, NEVADA, 1963; NEAR HATTIESBURG, MISSISSIPPI, 1964 AND 1966; AMCHITKA ISLAND, ALASKA, 1965; NEAR FARMINGTON, NEW MEXICO 1967, AND HOT CREEK VALLEY, NEVADA, 1968. U.S.S.R. UNDERGROUND TESTS SINCE 1963 NOT INCLUDED.

Figure 2

ISODOSE CONTOURS



The numbers on the above map represent the doses that would have been received over approximately 48 hours without shielding. The dose, above which survival is unlikely, is 800 r and below which survival is probable is 200 r.

Figure 3

APPROXIMATE GAMMA EXPOSURE RATES AT THREE FEET ABOVE THE GROUND ON D + 1 (One Day after Detonation) (Roentgens Per Hour)

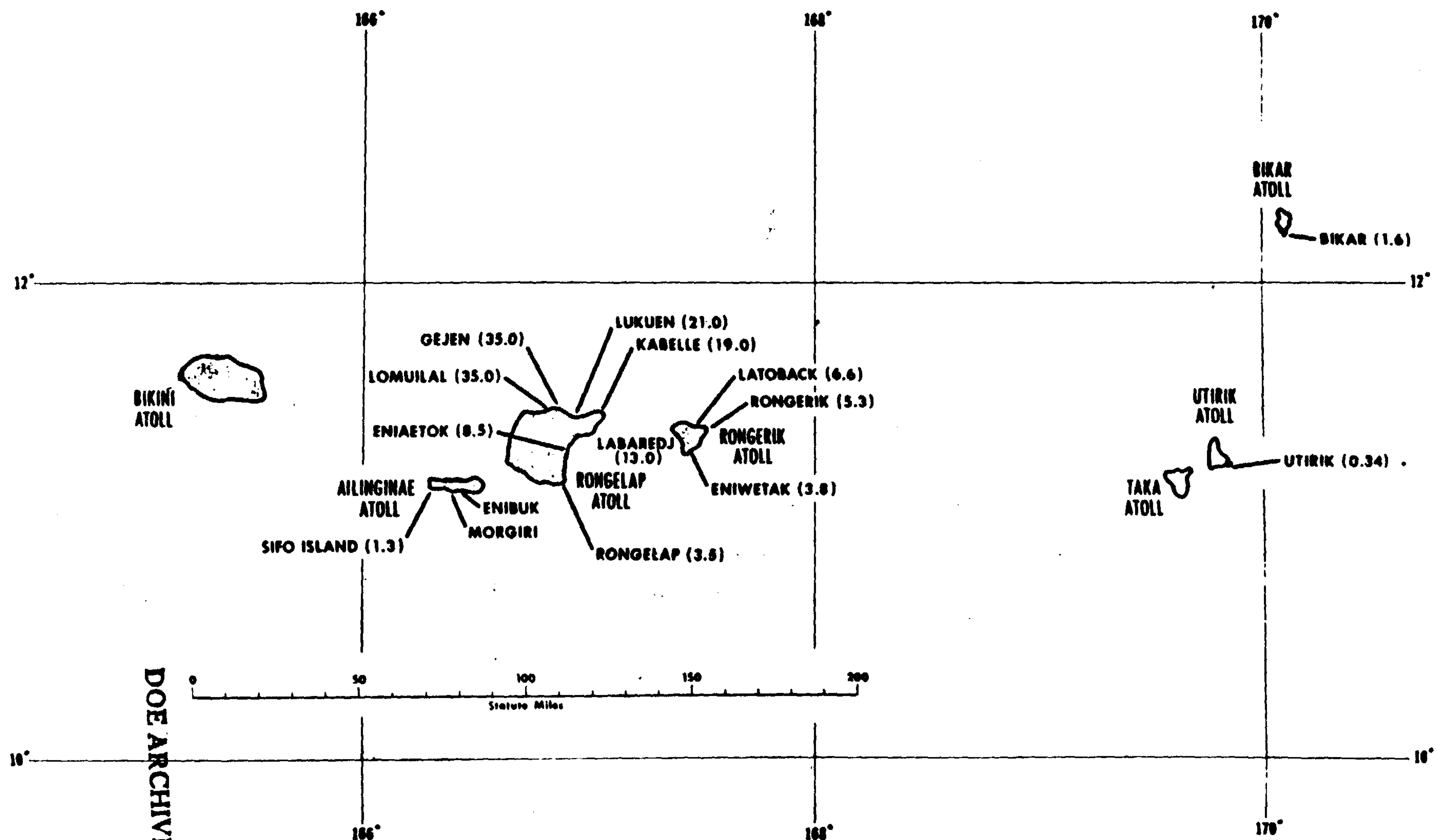


Figure 4

GAMMA EXPOSURE RATES ON THE ISLAND OF RONGELAP

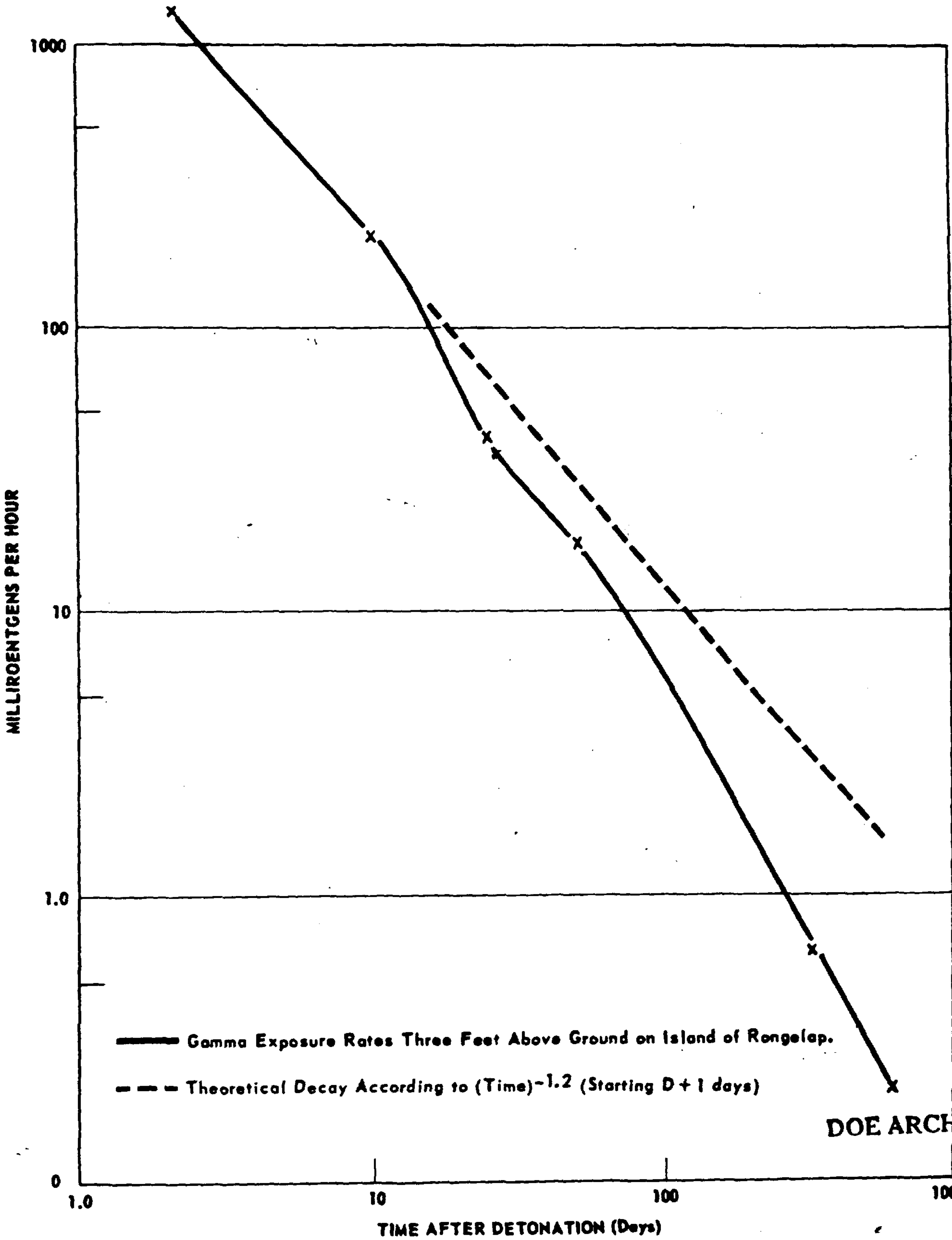
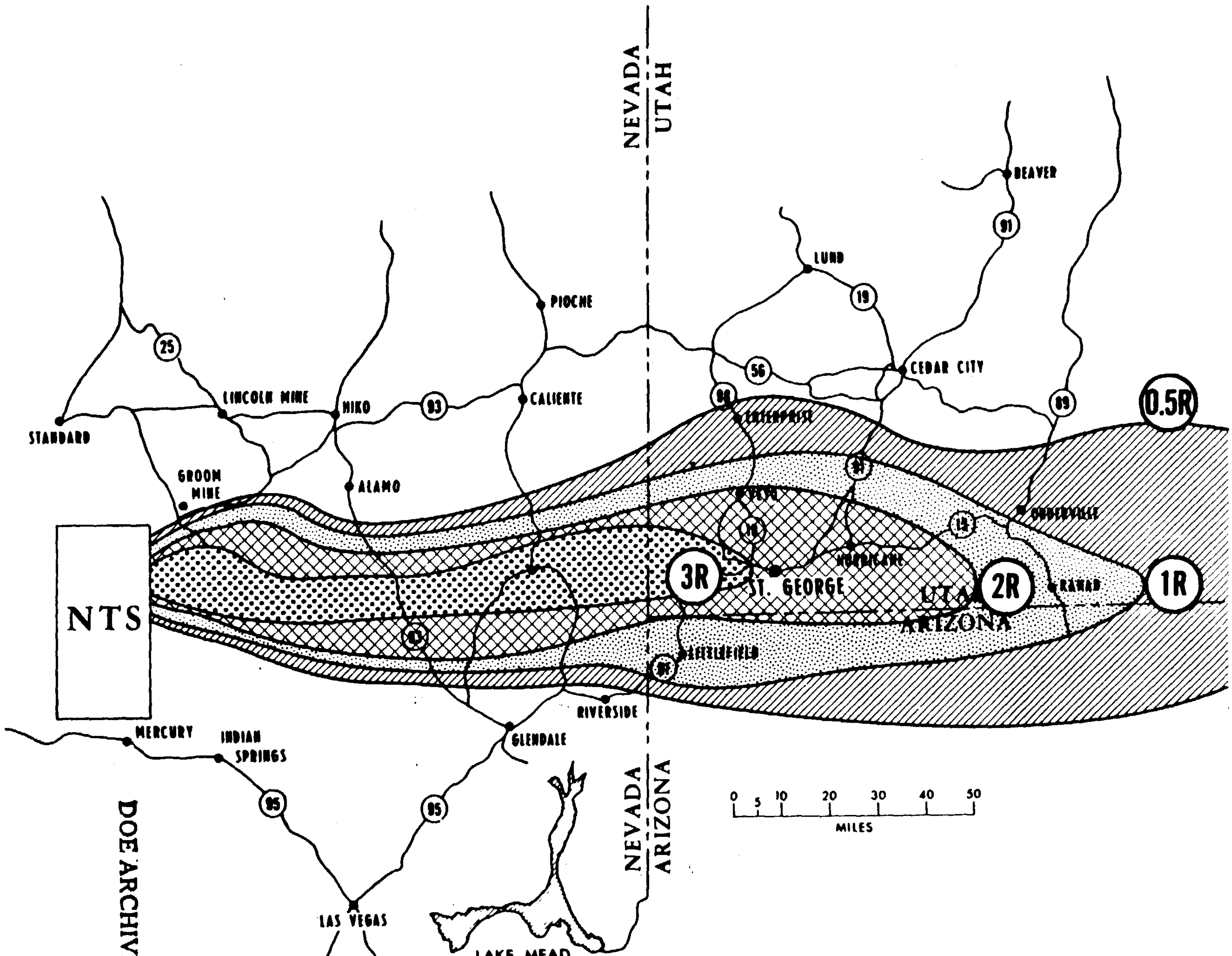


Figure 5

ESTIMATED EXPOSURES FOLLOWING HARRY SHOT MAY 19, 1953



The Spanish Incident

I have been asked to speak about the incident in Spain where plut ium was released from two nuclear bombs and contaminated the immediat area. In this instance I can only act as a reporter but here in brie are the data.

On January 17, 1966, a B-52 U. S. Air Force aircraft with nuclea bombs aboard crashed in Spain following an accident during a refuelin mission. One bomb was soon found in the soft soil of a river bed and one was found in the Mediterranean after an extensive search. Two ot bombs were shattered by their conventional high explosives upon impac land and in doing so scattered their contents over the local area. I in fact, an exact performance expected in case of an accident with nu bombs, i.e., they are designed so that in the event of an accident on their conventional high explosive will detonate. Of course, the radi active contents of plutonium and uranium were physically scattered, l any other debris, but there was no nuclear reaction.

The obvious question remains, what was the health hazard from th plutonium and uranium that was scattered in the environment?

Plutonium constitutes the greater potential hazard of the two sc that only this isotope will be considered. When plutonium reaches th air it quickly oxidizes forming insoluble plutonium oxide, or if it d solves in water, it forms an insoluble hydroxide. Thus, any plutoni taken into the body by inhalation or ingestion will not be absorbed t any appreciable extent. This is fortunate since plutonium has a lon half-life of about 24,000 years and if it reaches the bones will be eli inated only very slowly. On the other hand, any insoluble plutonium oxide inhaled into the lungs will be eliminated with a half time of about one year, i.e., one-half of any plutonium remaining in the lungs will be removed by natural body processes in the following year. The p tonium will be moved up from the lung, swallowed, and then it will pass quickly through the body - in a day or so - and be eliminated. This leaves one principal worry - what will be the radiation dose to the lu before the plutonium is eliminated from that organ?

But first, let us take a look at what happened in Spain.

One bomb landed near the village of Palomares - in fact so close t one man was knocked backwards through the doorway of his home by the bl wave from the high explosive. He was uninjured. The other bomb fell i an uninhabited place and at a sufficient distance from the first so the was very little overlapping of the patterns of contamination.

The potential sources of inhalation of plutonium under these cond tions are one, the cloud of radioactive material as it rolls by immediately after the event and, two, resuspension of the plutonium from tl ground into the air afterwards. Available data indicate that the first source will probably result in a higher amount of plutonium being deposited in the lungs.[1] Obviously there were no personnel monitors or equipment present at Palomares at the time of the accident, so what as ances can be given as to the degree of risk to the inhabitants?

As these types of nuclear weapons were being developed it was, of course, realized that just such an incident as happened near Palomares could occur. First, the nuclear weapons were designed so that only the high explosive would detonate. Second, extensive experiments were conducted, including two major field tests,[1., 2.] that showed the amount of plutonium that might be inhaled in the event of such an accident.

In short, these experiments showed that if a person were exposed to the highest concentration of plutonium in the cloud from such an accident he might receive a total radiation dose to the lungs of about 5 to 10 rem. The second of the major field tests was conducted under inversion meteorological conditions in order to maximize the concentration in the air at ground level. To evaluate such a potential dose it may be recalled that the safety standard for the lungs of atomic energy workers is 12-15 rem each year.

As stated, any radiation exposure to the lungs as a result of resuspension of the plutonium from the ground (except possibly in the immediate impact area) probably would be less than that from passage of the cloud. In this case, however, it was possible and feasible to remove much of the plutonium from the environment by simply scraping off the soil to a depth of two to three inches. This action was taken over some 5-1/2 acres of land (0.022 square kilometers) resulting in 1100 cubic yards (283 cubic meters) of soil that was transported to the U. S. Atomic Energy Commission's Savannah River plant, near Aiken, South Carolina, and buried on April 14, 1966 in the same manner as other low-level radioactive waste material. Also removed from the site of the accident and buried at the U. S. Atomic Energy Commission site were about 400 cubic yards (100 cubic meters) of vegetation. Once again, the situation was one of only surface contamination of the vegetation, i.e., plutonium oxide is quite insoluble so that very little finds its way from the soil into the roots of plants. It was planned to deep plow some 300 acres having low but dis-ernible amounts of contamination but the operation was found to be so easily performed that the area was extended to a total of about 600 acres (2.4 square kilometers). This process reduced the surface contamination to undetectable amounts and essentially eliminated any resuspension of plutonium into the air. This information is summarized in the following table.

Approximate Levels and Areas of Plutonium Contamination
(total for both areas contaminated)

Counts per minute	Areas in square kilometers	Actions Taken
zero *	2.4	Deep plowed and water
700	2.0	(Deep plowed, watered
		(and
7,000	0.17	(vegetation removed
over 60,000	0.022	Surface scraped

* not detectable

All of this information on the Palomares incident is subject to correction by those who have firsthand knowledge.

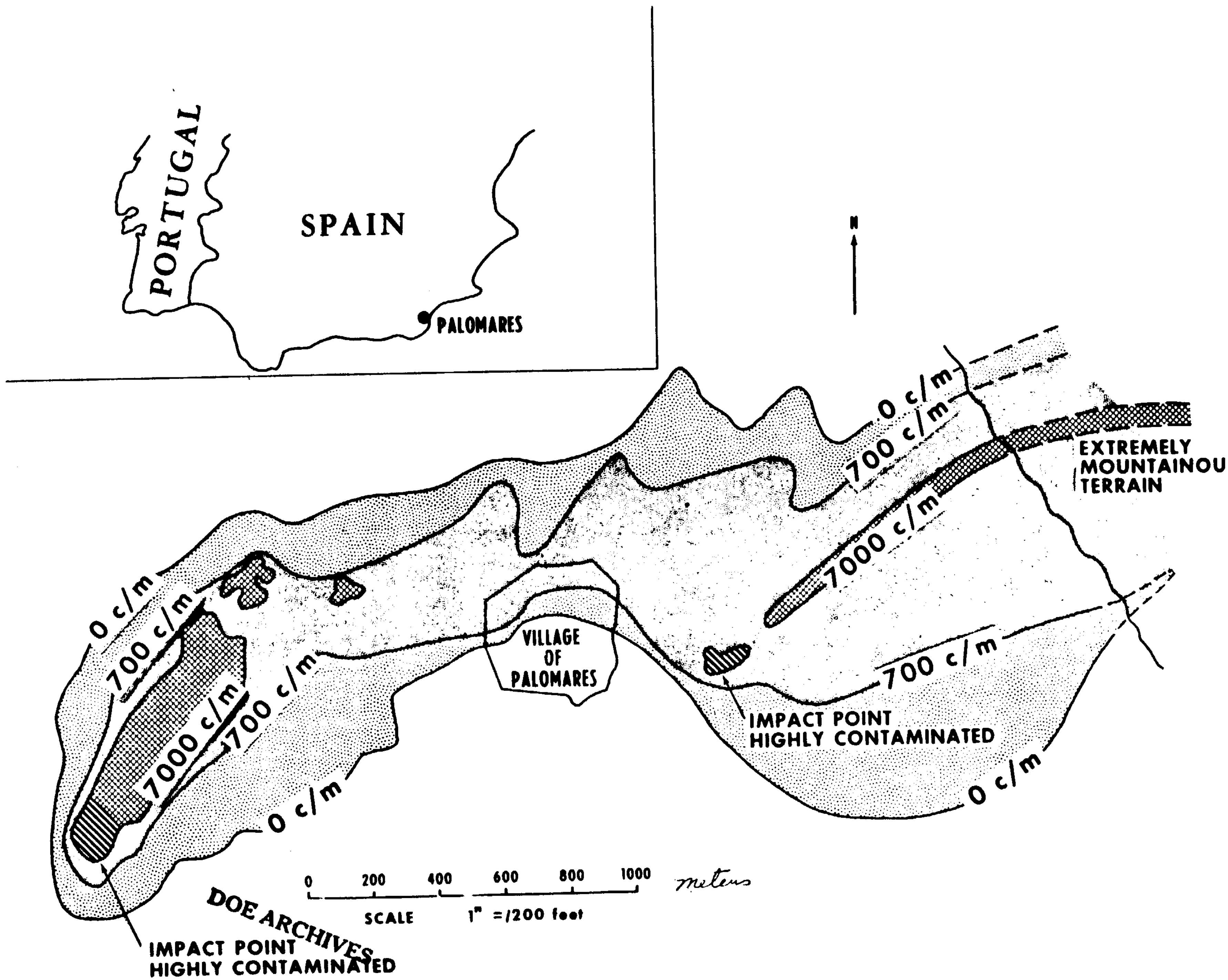
Since available data indicate that more plutonium probably would be inhaled during passage of the cloud than by the process of resuspension, and the former may result in only a 5 to 10 rem dose to the lungs, there may be some discussion on how extensive should be the clean-up or decontamination efforts. Probably the answer lies in the feasibility of those efforts. In time of a "nuclear mass disaster" decontamination measures solely for plutonium probably would not have first priority. At other times it is a question of valued judgment - what is operationally feasible and what is acceptable in terms of public reactions?

In any event it is comforting to know the data indicate that following the scattering of the plutonium from a bomb the potential dose to the lungs would not be large and that the dose due to resuspension probably would be less even if decontamination measures are not instituted.

REFERENCES

1. Summary Report, Test Group 57; Report No. ITR-515 (Del.), Shreve, J. D., Jr. Office of Technical Services, Department of Commerce, Washington, D. C. 20235. April 1958.

2. Operation Roller Coaster 1963. "Biological Studies Associated with a Release of Plutonium." Wilson, Robert and Terry, Jack. Available from the Symposium Division of Pergamon Press, Ltd.


PORTUGAL
SPAIN
PALOMARES
N
0 c/m
700 c/m
7000 c/m
EXTREMELY
MOUNTAINOUS
TERRAIN
VILLAGE
OF
PALOMARES
IMPACT POINT
HIGHLY CONTAMINATED
0 c/m
700 c/m
7000 c/m
IMPACT POINT
HIGHLY CONTAMINATED
0 200 400 600 800 1000 meters
SCALE 1" =1200 feet