The Problem

The most comprehensive data on fallout levels within a few hundred miles of the Nevada Test Site have resulted from direct measurements of open field external gamma dose rates and cumulative doses. Reliable measurements of the I-131 content of milk from cows grazing on pastures in the fallout pattern from a specific shot were not begun until the summer of 1962, and were still fragmentary at the time of the Des Moines venting (June 13, 1962), the low yield atmospheric test on July 14, 1962 (Small Boy), and the Plowshare experimental excavation experiment of July 6, 1962.

The development of a quantitative relation between the deposition level of fresh fission products in terms of the resulting external gamma dose rates and the resulting level of I-131 in milk for the days and weeks following deposition would thus be useful in three ways:

1. for estimating the doses to the thyroids of children from I-131 in milk from cows grazing on pastures which have experienced relatively high levels of fallout from Nevada tests;

2. to help achieve a better quantitative understanding of how radioiodine gets from the point of detonation into milk, in order that the planning and execution of nuclear tests can be done with due regard for the public health and safety;

3. to help guide and motivate the Commission's research program on fallout and radioiodine.

One would not expect that a single constant of proportionality relating the fallout level and the resulting level of I-131 in milk would adequately describe the many situations which can, and have, occurred within 300 miles of the Nevada Test Site. First, there are different modes of deposition. The fallout particles may be deposited dry, in a heavy shower, in a light mist, or by various gradations and combinations of these conditions. Second, wind as well as rain influence not only where fallout takes place, but how much is retained by the herbage eaten by cows. Third, even for a given shot, the fallout at different distances from the test site will consist of different sized particles with different physical and radiochemical characteristics, so that the same deposition of I-131 per unit area will lead to different levels of I-131 in milk. Fourth, there may be differences in the distribution of particle sizes, and of radioactivity with particle size, for shots of different yields, and almost certainly for shots fired at different altitudes and over (or under) different soils. Fifth, for a given deposition of I-131 per unit area, the levels of this nuclide in fresh milk might be expected to vary depending on the type of pasture, the number of cows per acre, the amount of supplemental feed they receive, and the time of year during which fallout occurs. Since so many factors can affect the actual levels of iodine in milk and [illegible] is known as to their precise effect, the [illegible] first [illegible] is [illegible] that of describing what ranges of iodine levels in milk have actually resulted from a given deposition of fresh fission products.

Even this relatively restricted objective is difficult to achieve at this time. Up thru the time of the Sedan and Small Boy tests in July, 1962, no systematic effort had been made to obtain the necessary data, so that the most direct information available is limited to coincidental measurements of milk levels and fallout deposition levels.

Designation of the Level of Fission Product Fallout from Nevada Tests

There are difficulties, both conceptual and practical, in designating the contamination level of nuclear test fallout. For unfractionated fission products — that is fission products for which the various nuclides are in the same proportions as for the debris taken as a whole, one can define a time-independent measure of the contamination level in terms of the kilotons-equivalent of deposited fission products per square mile, or the number of fissions represented per square foot of contaminated ground area. For fractionated debris however, no such simple measure exists.1/ One could [illegible] the total amount of I-131 deposited per unit area as the quantity of more direct interest, but this is not as readily measurable as is the external gamma dose rate, and very few measurements of this quantity have been made. For the areas around the Nevada Test Site, the most practical measure of the level of deposited fallout is the external gamma dose rate at 3 feet above an "open field" 2/ at some standard time following detonation. Note that this measure is only valid after all the fallout which is going to occur in a given area has already occurred, and after any relatively high transient dose rate due to airborne radioactivity in a passing fallout cloud has become small compared to the dose rate from material deposited on the ground.

1/ A definition of the contamination level of fractionated fission products has been under development for about a year by the U. S. Naval Radiological Defense Laboratory under a contract to the U. S. Atomic Energy Commission.

2/ A discussion of the concepts of infinite plane dose rate, open field dose rate, average population dose rate, and the observed quantitative relations between them in the areas around the Nevada Test Site is given in [illegible]. It is there concluded that the open field dose rate in the Nevada Test Site off-site area averages 7[illegible]% of the infinite plane dose rate.

External Gamma Measurements Southeast of Salt Lake City

Although it had not been anticipated, a hot spot occurred southeast of Salt Lake City 300 - 400 miles from the point of detonation following passage of the Small Boy cloud.[1] The location of this hot spot was first determined by an airborne radiological survey, and on July 16, 17, and 18, a complete survey was made by airborne radiological survey teams from the U. S. Geological Survey and from Edgerton, Germeshausen, and Grier. The results of this survey are reported by Lawson et al (8, p. 39) and reproduced in Figure 21. The contours there shown were based on the conversion relations that 50,000 counts/sec. at 500 feet = 1 mr/hr at 3 feet above the ground, and the assumption that the dose rate went down as $t^{-1.2}$.

In addition to the airborne radiological surveys of the Small Boy hot spot, an on-the-ground survey along many of the highways throughout the area was made by a team of army personnel under the direction of E. Bouton and L. R. Wade of the Army's Nuclear Defense Laboratory (9). The highway network surveyed by the army monitors is also shown in Figure 21.

The data received from the Nuclear Defense Laboratory (9) is reproduced in Appendix [illegible] the [illegible] open field external gamma dose rates measured by [illegible] group on July 18, 1962, between the times of H + 91 hours and H + [illegible] hours, have been plotted as a function of distance along the roads monitored; these plots are shown in Figures 22, 23, and 24.

[1] The Small Boy pre-shot announcement (AEC release R-[illegible] of July 5, 1962) stated: "most of the radioactive particles produced by the detonation are expected to fall back to earth within a few miles, inside the Las Vegas Bombing and Gunnery Range. Radiological monitoring will be conducted at distances up to 300 miles from the shot point to obtain information on the limits of detectability of the radioactivity."

The [illegible] selected here is 24 hours following detonation, although in some cases [illegible] interest [illegible] those areas near Salt Lake City -- the fallout [illegible] always have arrived by this time. In such cases one can project [illegible] rate [illegible] hours either by graphical extrapolation [illegible] rate [illegible] if only a single measurement has been made, by assuming a [illegible] decay rate. It is known that different samples of debris from the same shot as well as samples of debris from different shots have decay characteristics which vary from a $T^{-1.2}$ decay law. However, unless the external gamma dose rate is due largely to one or more induced activities (as was the case for the Sedan shot, following which the 24 hour dose rate from the isotope W^{187} is believed to have been responsible for a significant fraction of the observed total dose rate), the open field, external gamma dose rate due to <u>deposited</u> fission products decreases in time approximately in accordance with a $T^{-1.2}$ law between, say, 6 hours and 6 months following detonation (1).

The symbol r_0 is used here to designate the open field dose rate, in mr/hr, from deposited fission products at 24 hours following detonation.

<u>Designation of Initial and Maximum Levels of I-131 in Fresh Milk</u>

Leng[illegible] and Com[illegible] report that when a cow is fed each day an amount of I-131 which has been reduced from the initial ration in accordance with the 8 day half life of this nuclide, a maximum level of I-131 in the cow's milk is reached at about 4 days. The I-131 milk concentration they report for the time period of 2 to 8 days following initiation of iodine intake varies very little from the maximum level. At 1 day it is about 70% of maximum. After 7 days they report that milk levels decrease with the 8 day half life of I-131.

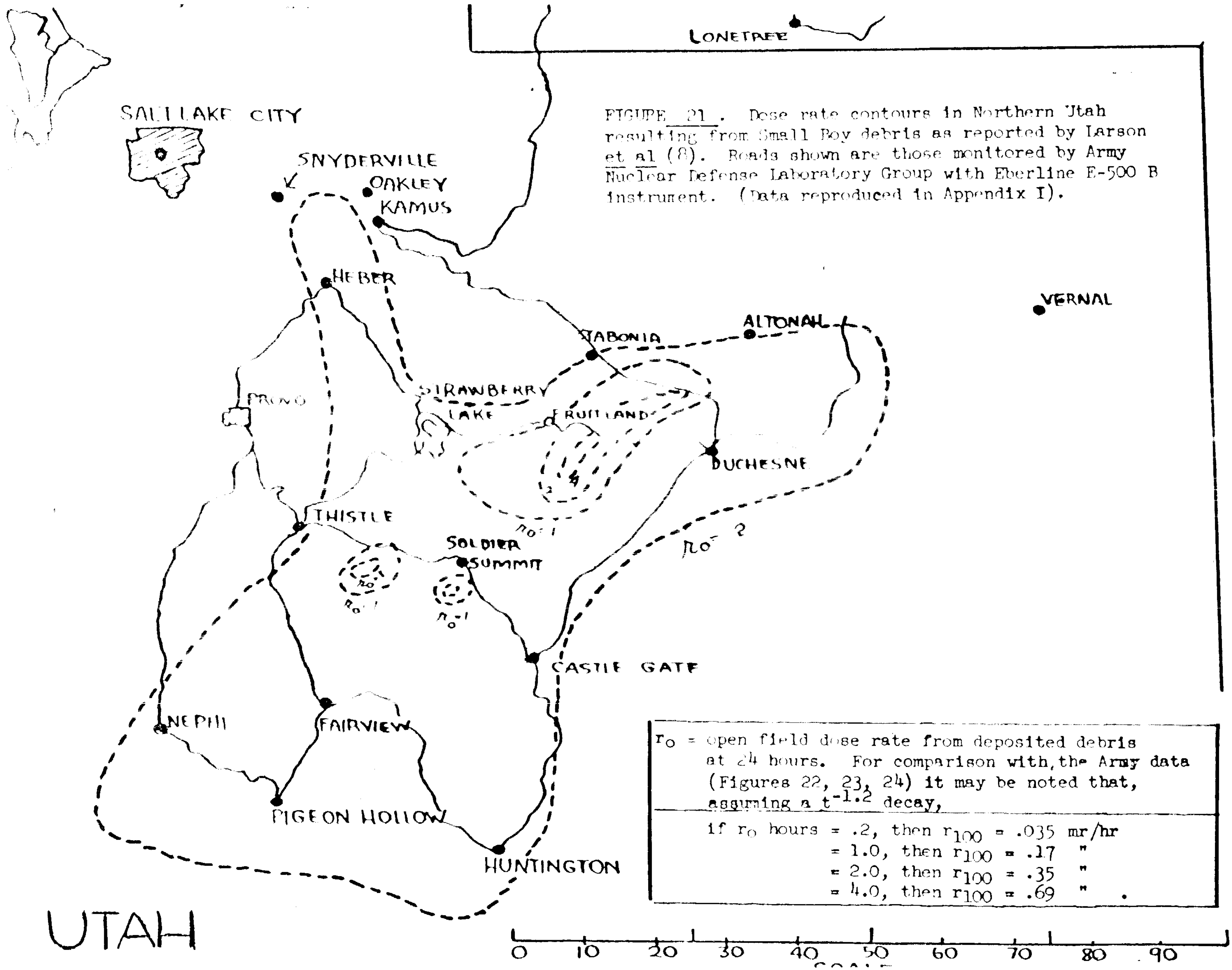
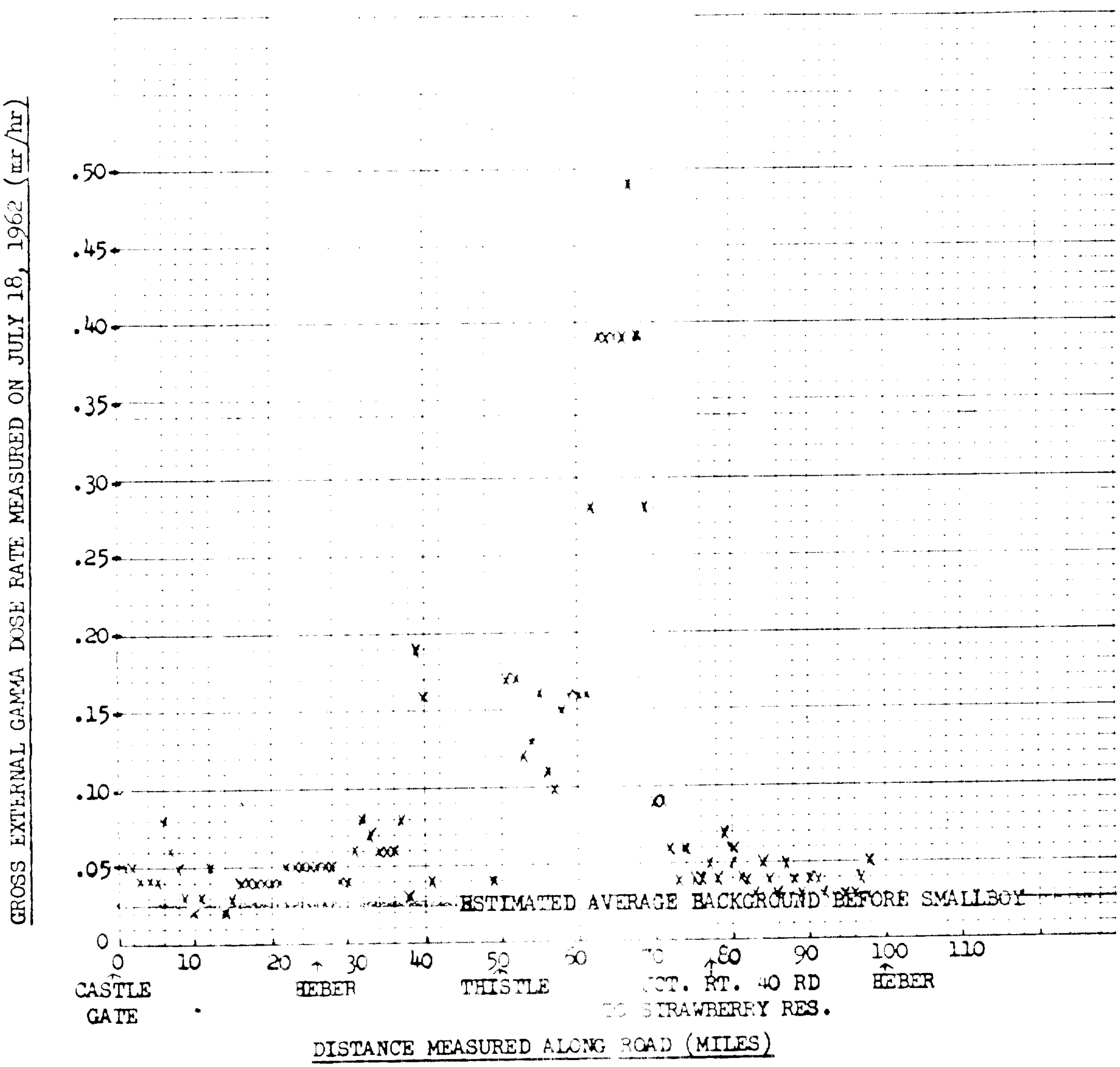


FIGURE 21. Dose rate contours in Northern Utah resulting from Small Boy debris as reported by Larson et al (8). Roads shown are those monitored by Army Nuclear Defense Laboratory Group with Eberline E-500 B instrument. (Data reproduced in Appendix I).

r_o = open field dose rate from deposited debris at 24 hours. For comparison with the Army data (Figures 22, 23, 24) it may be noted that, assuming a $t^{-1.2}$ decay,

if r_o hours = .2, then r_{100} = .035 mr/hr
= 1.0, then r_{100} = .17 "
= 2.0, then r_{100} = .35 "
= 4.0, then r_{100} = .69 " .

FIGURE 22. MEASUREMENTS OF GROSS, OPEN FIELD EXTERNAL GAMMA DOSE RATE ALONG U. S. HIGHWAY 50 AND 189 FROM CASTLE GATE, UTAH TO HEBER, UTAH. MEASUREMENTS MADE ON 18 JULY 1962 BY U. S. ARMY NUCLEAR DEFENSE LABORATORY (SEE DATA APPENDIX I).



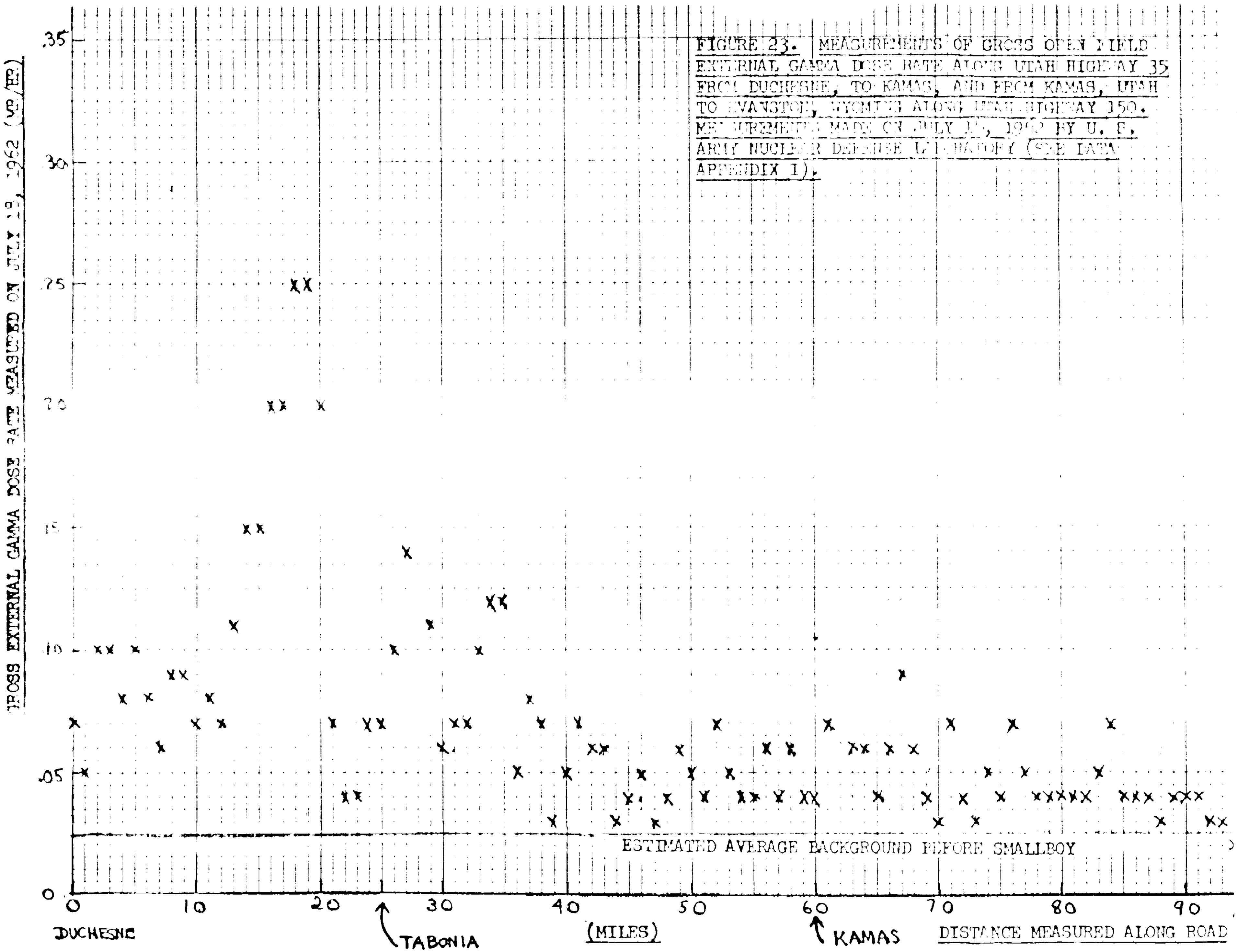
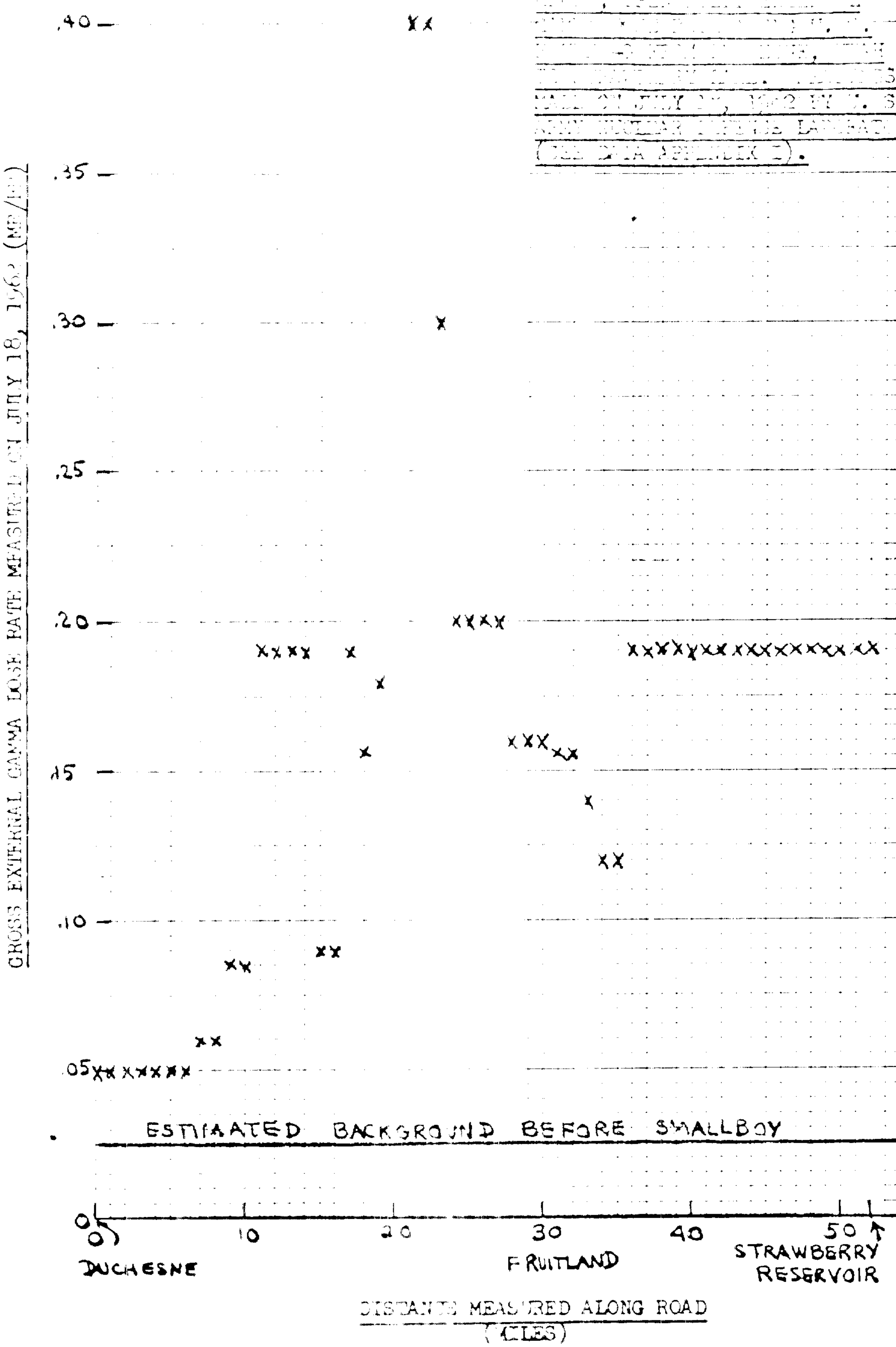


FIGURE 23. MEASUREMENTS OF GROSS OPEN FIELD EXTERNAL GAMMA DOSE RATE ALONG UTAH HIGHWAY 35 FROM DUCHESNE, TO KAMAS, AND FROM KAMAS, UTAH TO EVANSTON, WYOMING ALONG UTAH HIGHWAY 150. MEASUREMENTS MADE ON JULY 18, 1962 BY U. S. ARMY NUCLEAR DEFENSE LABORATORY (SEE DATA APPENDIX 1).


GROSS EXTERNAL GAMMA DOSE RATE MEASURED ON JULY 18, 1962 (MR/HR)
.40
.35
.30
.25
.20
.15
.10
.05
0
ESTIMATED BACKGROUND BEFORE SMALLBOY
0
10
20
30
40
50
DUCHESNE
FRUITLAND
STRAWBERRY RESERVOIR
DISTANCE MEASURED ALONG ROAD (MILES)

[illegible]

To obtain the net dose rates from the Small Boy debris from the Army measurements, it is necessary to substract the component due to background prior to the shot. This measurement was not reported. It is assumed here to be 0.025 mr/hr, i.e. the same as measured at Alamo and Caliente in December, 1962.

The dose rate contours reported by Larson <u>et</u> <u>al</u> from aircraft measurements, and the surface measurements made by Lt. Wade and his monitors are generall consistent. Both indicate areas where the deposition level was approximate ly 20 times that noted in the Kamas - Oakley - Snyderville area. Both indicate some high levels of fallout on U. S. Route 40 between Duchesne and Strawberry Lake, and State Road 35 between Duchesne and Tabiona. The high levels between Fruitland and Strawberry Lake and Thistle and Strawberry Lak are not exactly indicated by the contours as shown. This might be due to a incorrect location of the 1 mr/hr-at-24-hour contour from the hot spot just east of Fruitland.

Although scattered light precipitation is reported in the hot spot area on July 14, 15, and 16, the readily available data (16) suggest that most of the fallout occurred largely without precipitation or with very little precipitation.

Larson's data (Figure 21, indicate that the locations at which milk samples were taken (Kamas, Oakley and Snyderville) lie on the edge of the hot spot area, and have 24 hour external gamma dose rates of less than 0.2 mr/hr. The only surface measurements which indicate an r_0 value at Kamas, Oakley, and Snyderville are those made by the army monitors on their route passing thru Kamas (Figure 23).

From Figure 23 it is seen that the <u>net</u> dose rate (i.e. substracting 0.025

mr/hr for natural background) within 5 miles of Kamas on the routes taken in and out of town lies between 0.015 mr/hr and 0.045 mr/hr, with an average value of 0.026 mr/hr. These measurements were made between H + [illegible] hours and H + 102 hours. Assuming a $t^{-1.2}$ decay rate, the average of the projected H + 24 hour dose rate in Kamas due to deposited debris would have been [illegible] mr/hr. This is about 50% greater than that estimated for Alamo and Caliente, but a factor of 10 lower than the 24 hour rate of 1.56 mr/hr noted in the Pahranagat Valley 9 miles south of Alamo (5, p. 26). Lacking better data, it is here assumed that r_0 for Kamas, Oakley, and Snyderville is in the range of 0.07 mr/hr at 24 hours to 0.30 mr/hr at 24 hours, with the best single estimate taken as 0.15 mr/hr at 24 hours.

It is of interest to compare the northeast Utah hot spot [illegible] Small Boy shot with one in the Troy-Albany New York area resulting [illegible] April 25, 1953 Simon shot of Upshot-Knothole test series. On that occasion a 43 kt. device was fired on a 300 foot tower at the Nevada Test Site. 36 hours later a severe thundershower in the upstate N. Y. area deposited beta activity totaling 1.6 X 10^6 d/m/ft.^{2} (17). From this datum one may compute (1, Appendix III) an open field dose rate (projected to 24 hours) of [illegible] mr/hr. The Small Boy hot spot shown in Figure [illegible] had 24 hour dose rates as high as [illegible] mr/hr over an area of about [illegible] square miles [illegible]. Most of the Small Boy hot spot had 24 hour dose rates in the range of [illegible] mr/hr to 1.0 mr/hr however.

External Gamma - Milk Relations from the Small Boy Data

External gamma - milk relations at Alamo and Caliente, [illegible] Oakley, and Snyderville, Utah, following deposition of [illegible] Small Boy debris are summarized in Table II.

To obtain the net dose rates due to the Small Boy debris from the Army measurements, it is necessary to subtract the component due to background prior to the shot. This measurement was not reported. It is assumed here to be 0.025 mr/hr, i.e. the same as measured at Alamo and Caliente in December, 1962.

The dose rate contours reported by Larson et al from aircraft measurements, and the surface measurements made by Lt. Wade and his monitors are generally consistent. Both indicate areas where the deposition level was approximately 20 times that noted in the Kamas - Oakley - Snyderville area. Both indicate some high levels of fallout on U. S. Route 40 between Duchesne and Strawberry Lake, and State Road 35 between Duchesne and Tabiona. The high levels between Fruitland and Strawberry Lake and Tabiona and Strawberry Lake are not exactly indicated by the contours as shown. This might be due to an incorrect location of the 1 mr/hr-at-24-hour contour from the hot spot just east of Fruitland.

Although scattered light precipitation is reported in the hot spot area on July 14, 15, and 16, the readily available data (20) suggest that most of the fallout occurred largely without precipitation or with very little precipitation.

Larson's data (Figure 21) indicate that the locations at which milk samples were taken (Kamas, Oakley and Snyderville) lie on the edge of the hot spot area, and have 24 hour external gamma dose rates of less than 0.2 mr/hr. The only surface measurements which indicate an E_γ value at Kamas, Oakley, and Snyderville are those made by the army monitors on their route passing thru Kamas (Figure 23).

From Figure 23 it is seen that the net dose rate (i.e. subtracting 0.025

mr/hr [illegible] natural background) within 5 miles of [illegible] in the routes taken in [illegible] of town [illegible] between 0.015 mr/hr and 0.04[illegible] mr/hr, with an average value of 0.026 mr/hr. These measurements were made between T + [illegible] hours and T + [illegible] hours. Assuming a $t^{-1.2}$ decay rate, the average of the projected T + 24 hour dose rate in [illegible] due to deposited debris would have been 0.[illegible] mr/hr. This is about 50% greater than that estimated for Alamo and Caliente, but a factor of 10 lower than the 24 hour rate of 1.[illegible] mr/hr noted in the Pahranagat Valley 9 miles south of Alamo (5, p. 2[illegible]). Lacking better data, it is here assumed that r_0 for [illegible], Oakley, and Springville is in the range of 0.07 mr/hr at 24 hours to 0.30 mr/hr at 24 hours, with the best single estimate taken as 0.15 mr/hr at 24 hours.

It is of interest to compare the [illegible] Small Boy shot with one in the Troy-Albany New York area resulting from the April 25, 1953 Simon shot of Upshot-Knothole test series. In that occasion a 43 kt device was fired on a 300 foot tower at the Nevada Test Site. 36 hours later a severe thunderstorm in the upstate N.Y. area deposited radioactivity totaling [illegible] $d/m/ft.^2$ (17). From this datum one may compute (1, Appendix [illegible]) [illegible] dose rate (projected to 24 hours) of 1.[illegible] mr/hr. [illegible] in Figure [illegible] [illegible] of about [illegible] [illegible] the spot had 24 hour dose rates in the range of [illegible] mr/[illegible].

External Gamma - [illegible] Relations from the Small Boy Shot

External gamma-[illegible] relations at Alamo and Caliente, [illegible] and at [illegible], Oakley, and Springville, Utah, following deposition from the Small Boy shot, are summarized in Table II.