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ENERGY MEASUREMENTS

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AN AERIAL RADIOLOGICAL SURVEY OF

POCATELLO AND SODA SPRINGS, IDAHO

AND SURROUNDING AREA

DATE OF SURVEY: JUNE - JULY 1986

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EG&G ENERGY MEASUREMENTS

AN AERIAL RADIOLOGICAL SURVEY OF POCATELLO AND SODA SPRINGS, IDAHO AND SURROUNDING AREA

DATE OF SURVEY: June-July 1986

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This Document is UNCLASSIFIED

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1. INTRODUCTION

Three aerial radiological surveys were conducted during the period 16 June through 15 July 1986 over the towns of Pocatello, Soda Springs, and Fort Hall, Idaho and the surrounding areas. The surveys were performed for the United States Environmental Protection Agency (EPA), Office of Radiation Programs, by the United States Department of Energy's (DOE) Remote Sensing Laboratory (RSL), utilizing the Aerial Measuring System (AMS) operated by EG&G Energy Measurements, Inc. (EG&G/EM), Las Vegas, Nevada. This work was completed in cooperation with a study by the EPA to conduct a dose assessment of human radiation exposure for industrial sources in Pocatello and Soda Springs, Idaho.

The aerial surveys were performed to document the natural terrestrial radiological environment of the three localities and to map the spatial extent and degree of contamination due to phosphate milling operations. The results of these surveys will be used for planning ground-based measurements in addition to being incorporated into the dose assessment document.

An important characteristic of airborne radiation detection systems is that the results are averages over large areas (several hectares) as compared to the small area covered by ground-based measurements. This has three significant consequences. First, an airborne radiation detection system can rapidly obtain measurements which are much more representative of an area-averaged value than hundreds, or perhaps thousands, of time-consuming ground-based measurements. Second, the intensity of localized sources or anomalies may be significantly underestimated because of this large-area averaging. This effect becomes increasingly pronounced as the spatial extent of the source becomes small with respect to the large area averaged by the airborne detection system. Finally, airborne detection systems "blur" the apparent edges of small anomalies. That is, the airborne system can "see," to some degree, anomalies that are off to the side of the aircraft in addition to those directly below. Therefore, ground-based measurements may be required to accurately measure the intensity of localized sources and to define the exact boundary of a small radiation anomaly.

2. SURVEY AREAS

The primary aerial survey sites of Pocatello and Soda Springs, located in the southeastern corner of the state of Idaho, were selected for this study by the EPA. The selection criteria were based on the presence of elemental phosphorus plants and the long-term, widespread use of slag material from the plants throughout the area.

The aerial survey of the Pocatello site, which included portions of both Bannock and Power Counties, covered an area of approximately 231 square kilometers (89 square miles). Included in the survey area were the towns of Pocatello and Chubbuck and surrounding areas, the FMC and Simplot plants, and the municipal airport. FMC is an elemental phosphorus plant, while Simplot is a phosphate fertilizer plant.

The Soda Springs site, located in Caribou County, covered an area of approximately 43 square kilometers (16.6 square miles) and included the town of Soda Springs and the Monsanto elemental phosphorus plant located just north of town. In addition, a small phosphate fertilizer plant and the Kerr-McGee vanadium plant, which processes phosphate materials and/or by-products, were also included.

A small survey over the town of Fort Hall, Idaho was also included in addition to the two primary sites of Pocatello and Soda Springs. Fort Hall is located in Bannock County on the Shoshone-Bannock Indian Reservation, approximately 19 kilometers (12 miles) north of Pocatello. This secondary site was selected as a background and system check area because of the limited use of slag material in the vicinity. The survey covered approximately 12.2 square kilometers (4.9 square miles) and was centered over the major portion of the settlement.

3. NATURAL BACKGROUND RADIATION

Natural background radiation originates from naturally-occurring radioactive elements present in the earth (terrestrial radiation) and radiation entering the earth's atmosphere from space (cosmic radiation).

Natural terrestrial gamma radiation originates primarily from the uranium and thorium decay chains and radioactive potassium. The natural terrestrial radiation levels depend upon the type of soil and bedrock immediately below and surrounding the point of measurement. Within cities, the levels are also dependent on the nature of the street and building materials. Local concentrations of these naturally-occurring nuclides produce exposure rate levels at the surface of the earth generally ranging from 1 to 20 microroentgens per hour (μR/h). The highest levels within the United States are normally found in the western states, primarily on the Colorado Plateau, as a result of higher uranium and thorium concentrations in surface minerals.

The uranium and thorium decay chains include radon--a radioactive, chemically inert gas--which diffuses through the soil and into the atmosphere. The rate of diffusion is highly variable and the atmospheric distribution of radon can be complex due to a variety of factors. Thus, the magnitude of the background radiation contributed by airborne radon and its daughters depends on the meteorological conditions, the mineral composition and permeability of the soil, as well as other physical conditions existing at each location at a particular time. Typically, radon contributes from 1 to 10 percent of the natural external background radiation exposure.

Cosmic rays, the space component, interact in a complex manner with elements of the earth's atmosphere and the soil. These interactions produce an additional natural source of ionizing radiation. Radiation levels due to cosmic rays vary with elevation (altitude) and slightly with geomagnetic latitude. Typical values range from 3 μR/h at sea level in Florida to 12 μR/h at an altitude of 3 kilometers (10,000 feet) in Colorado (Reference 1).

4. SURVEY EQUIPMENT AND PROCEDURES

The aerial measurement system, comprised of a radiation detector package and a specialized data acquisition and recorder system (REDAR IV*), was mounted on board a high-performance helicopter (Messerschmitt-Bolkow-Blohm BO-105). The detector package consisted of an array of 20 12.7-cm diameter by 5-cm thick (5-in. by 2-in.) sodium iodide (thallium-activated), NaI(Tl), scintillation detectors. This type of detector is particularly sensitive to gamma radiation.

*Radiation and Environmental Data Acquisition and Recorder system, Model IV.

The detector array was distributed equally between two cargo pods that were mounted on the landing skids of the helicopter. Signals from 19 of the detectors were summed to produce a single gamma spectrum with high sensitivity (i.e., able to detect low background levels of radiation). The remaining single detector was used to provide a gamma spectrum with less sensitivity for use in areas exhibiting greatly enhanced levels of radiation. Both spectra were simultaneously acquired and recorded which greatly extended the count rate operating range of the data acquisition system. This dual spectral capability also made it possible to conduct post-flight analyses which ensured that the system was functioning properly and no system failures had occurred during data collection flights, thus providing data integrity safeguards.

The REDAR IV system acquired, monitored, displayed, and recorded all survey data for each second of real time. The data stored on magnetic tape consisted of the dual gamma spectral data, as mentioned previously, and environmental data such as outside air temperature and absolute barometric pressure. Also included were positional data derived from a UHF radio ranging system and a radar altimeter. The REDAR IV system processed this positional data in real time to provide a navigational display for the helicopter pilot.

Each area was surveyed with a series of predetermined parallel lines spaced 76 meters (250 feet) apart and flown at a mean altitude of 46 meters (150 feet) above ground level (AGL). This procedure was chosen to achieve the most sensitive detector platform possible while still maintaining a safe flight configuration.

Detector background due to natural non-terrestrial radiation sources on board the aircraft, airborne radon, and cosmic rays was estimated from multi-altitude flights over a land test line located within the survey area and a water test line adjacent to the survey area. Variations in the radon contributions and soil moisture attentuation were monitored by repeating measurements at survey altitude over the land and water test lines before and after each flight.

More detailed discussions of the systems and procedures employed during aerial survey operations can be found in separate publications (References 2, 3 and 4).

5. DATA PROCESSING PROCEDURES

The data recorded on magnetic tape during the survey were processed with the Radiation and Environmental Data Analyzer and Computer (REDAC) system. This system consisted of a computer analysis laboratory mounted in a mobile van. An extensive inventory of software routines and supporting hardware was available for detailed data analysis. The data were processed during the actual survey period to assure complete coverage and data acquisition integrity, and to provide preliminary results as soon as possible. After completion of the surveys, the final data analysis was accomplished in Las Vegas using the RSL computer system.

For this series of surveys, the data analyses were directed toward producing two specific results: (1) a total terrestrial gamma radiation exposure rate contour map of each of the survey sites, and (2) the identification of anomalous areas above typical background, specifically those associated with the phosphate industry.

The principal representation of the survey results are isoradiation contour maps of exposure rate due to terrestrial gamma ray sources. Exposure rate contours were derived from gross count rate numbers which refer to integral count rates in that portion of the gamma ray energy spectrum between 0.05 and 3.00 MeV. Exposure rate isoradiation contours were constructed by plotting the processed radiation data as a function of position. The values reported represent averages over a large area (several hectares) and are expressed in microroentgens per hour (μR/h) at 1 meter above ground level. When comparing aerial survey results with ground-based measurements, it is important to note that 1 second of aerial survey data covers an area several thousand times larger than that measured by a single hand-held survey instrument 1 meter above ground level and several million times larger than a single soil sample. For large areas with slowly varying activity, such as typical natural background radiation, the agreement between ground-based measurements and those inferred from aerial data is generally quite good. Because of the large-area averaging property of the airborne system, the radiation from small, localized anomalies will be averaged over a larger area indicating a lower activity than actually exists at the ground surface. For these situations, ground measurements will not agree very well with the aerial results. The aerial data, therefore, serve to identify the existence of anomalies, but ground surveys are required for an accurate definition of the spatial extent and intensity of identified anomalies.

The terrestrial count rate is determined by subtracting estimates of the aircraft, radon, and cosmic background contributions to the system from the gross count rate measured each second at the survey altitude. The net count rates are then converted to exposure rates by using a predetermined conversion factor. This conversion factor, determined from years of study at a calibration range, assumes a uniformly distributed source covering an area which is large compared to the detector field-of-view (approximately 200 to 300 meters in diameter at the survey altitude of 46 meters). For a limited source distribution which is small compared to the detector system field-of-view, it is necessary to modify or correct the exposure rate values presented in the Results section by using the information in Table 1, provided that the area of distribution or boundaries of the source are known. Therefore, actual exposure rate values could be one to two orders of magnitude higher than those reported for an area which contains a small localized source (less than 25 meters in diameter).

Table 1. Correction Factors Versus Area of Source for Exposure Rate Data

Source Diameter (meters)	Correction Factor
10	100
25	10
50	6.5
100	2.5
200	1.2
300	1.0
>300	1.0

Anomalous or non-natural gamma sources can be found from increases in the total terrestrial gamma exposure rate data over typical background exposure rates. However, subtle anomalies are difficult to find using the exposure rate data in areas where the magnitude of the exposure rate is variable due to geologic or ground cover changes (i.e., changes in natural background radiation). Data reduction procedures, which exploit variations in spectral shape, were used to increase the aerial system's sensitivity to anomalous gamma emitters. To identify anomalous areas above typical background radiation, specifically those associated with the phosphate industry, an alternate analysis procedure was applied to the data.

This alternate procedure took into account the fact that phosphate ore, which occurs in nature, contains varying concentrations of elements from the uranium and thorium decay chains. In processing ore for elemental phosphorus and/or fertilizer, there are by-products in the form of slag that further concentrate these elements. As stated previously, elements of the uranium and thorium decay chains also occur in nature in areas that have no association with phosphate ore and/or slag. One of the more abundant daughter products in the uranium decay chain in phosphate slag is bismuth-214 (Bi-214). EG&G/EM has found from experience that the energetic gamma ray at 1.76 MeV from Bi-214 is found most readily in a search of the data for the presence of phosphate slag.

Therefore, the method chosen extracted and mapped only the net counts due to excess Bi-214. This procedure results in an enhanced representation of the spatial distribution of the isotope of concern which is relatively free from distortions due to variations in natural background radiation. Variations in background occur because soil is not homogeneous; it contains potassium, uranium, and thorium and their daughter products in varying amounts. It should be noted that only the excess bismuth is mapped in the survey area utilizing this procedure. There is no way to determine if that excess is solely associated with phosphate slag or some other material with higher than normal bismuth concentrations. This can only be determined by ground-based measurements and, to some extent, by photo interpretation based on historical information.

The Bi-214 extraction procedure requires that an estimate of the natural background radiation contribution be subtracted from a portion of the energy spectra that is dominated by the 1.76 MeV Bi-214 photopeak. The background contribution is estimated by comparing the ratio (k) of total counts in a window typified by background radiation to the total counts in the window dominated by Bi-214 observed in an area exhibiting only natural background radiation. A typical gamma spectrum indicating these windows is shown in Figure 1. The photopeak window A (1.58 to 1.93 MeV) accepts the 1.76 MeV gammas from Bi-214. The background window B (2.36 to 2.864 MeV) accepts the 2.61 MeV gammas from Tl-208. The combination of the background window B and the ratio k is used to remove counts due to higher energy gammas from naturally-occurring radionuclides from the Bi-214 window A. The equation for expressing the removal of background count rates from the Bi-214 window is as follows:

$$\text{Net Bi-214} = A - k(B)$$

The data presented in the Results section are reported in net counts per second. Table 2 provides conversion factors relating net Bi-214 photopeak count rates to source concentration values for a variety of source distributions.

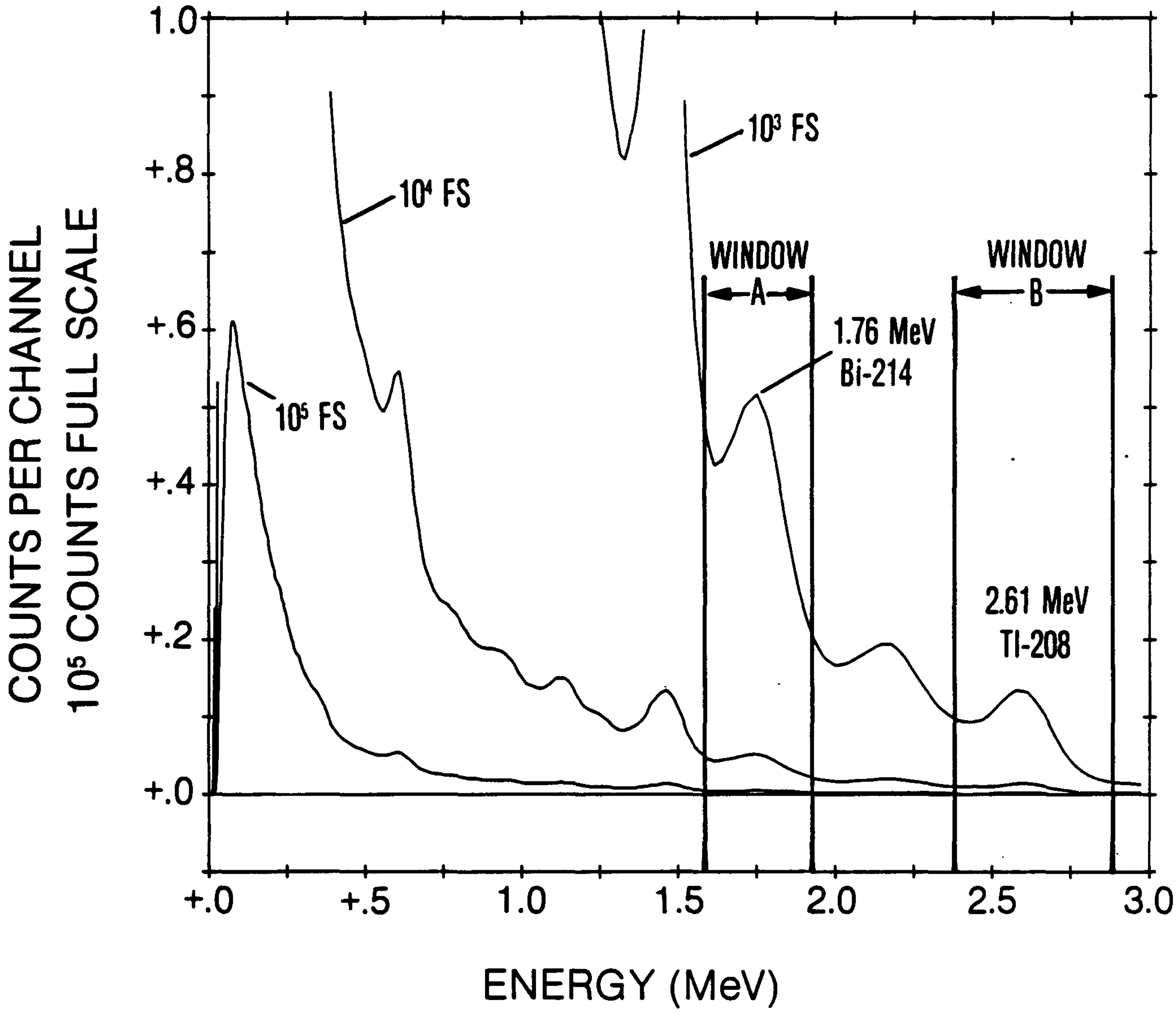


Figure 1 Typical Gamma Spectrum Indicating the Bismuth-214 Extraction Windows.

Table 2. Conversion Factors Relating Aerial Photopeak Count Rate Data to Bismuth-214[a] Concentration on the Ground for a Variety of Source Distribution Geometries

Conversion Factor[b]					
Point Source on Surface μCi/cps		Uniform Surface Distribution	Exponential Distribution		Uniform Volume Distribution
Directly Under Aircraft	At Lateral Distance of 45 m	μCi/m2 / cps	Relaxation Depth (cm)	μCi/m2 / cps	pCi/g[c] / cps
104	208	4.9(10-3)	0.1 1.0 10.0	5.0(10-3) 5.9(10-3) 1.3(10-2)	5.8(10-2)

[a]1.76 MeV photopeak.

[b]Conversion factors are given for the 20 12.7-cm x 5-cm NaI(Tl) detector array at an altitude of 46 meters (150 feet), assuming an air density of 1.0 g/l and a soil density of 1.5 g/cm^3 (10% soil moisture content). All results are computed for an isotropic detector angular response.

[c]1.82 μR/h/pCi/g for the entire radium-226 daughter series, assuming all members of the series are in equilibrium.

The conversion factors for Bi-214 activity also assume a uniformly distributed source covering an area which is large compared to the detector system field-of-view (approximately 350 meters in diameter for the 1.76 MeV gammas of Bi-214 at the survey altitude of 46 meters). For a finite source distribution which is small compared to the field-of-view of the detector system, it is necessary to modify or correct the data by utilizing the information in Table 3. As with the total terrestrial exposure rate values, the actual exposure rate or activity values contributed solely from Bi-214 could be significantly higher than those reported for a source localized in a small area.

Table 3. Finite Bismuth-214 Correction Factors Versus Area of Source	
Source Diameter (meter)	Correction Factor
12	90
24	21
50	6
80	3
140	1.7
180	1.4
300	1.1
350	1.1
>350	1.0

As stated previously, the airborne system can "see," to some degree, anomalies that are off to the side of the aircraft in addition to those directly below. Table 4 gives the point source conversion factors for a Bi-214 source on the surface of the ground for various lateral displacements up to 45 meters (148 feet).

Table 4. Bismuth-214 Point Source Conversion Factors	
Lateral Displacement (meters)	mCi Per Count Per Second[a]
0	0.104
9	0.108
18	0.120
27	0.140
36	0.170
45	0.208

[a]Assuming an aircraft velocity of 36 meters/second (70 knots) and an altitude of 46 meters (150 feet).

6. GROUND-BASED MEASUREMENTS

Exposure rates were measured at seven locations by the EPA during the survey period to verify the integrity of the aerial results. The locations for the ground-based measurements were chosen to be in areas which were assumed to exhibit only a natural background radiation level and away from any obvious anomalies. A Reuter-Stokes pressurized ion chamber (PIC) Model RSS-111 was used for each series of exposure measurements at a 1-meter height.

7. AERIAL SURVEY RESULTS

The results of the aerial radiological surveys conducted over each of the three areas (Pocatello, Fort Hall, and Soda Springs) are presented as contours of terrestrial gamma exposure rates and Bi-214 net count rates superimposed on aerial photographs of the respective sites.

The gamma exposure rate contours report the total external exposure rate due to uniformly distributed terrestrial sources in μR/h extrapolated to 1 meter above ground level and include a cosmic ray exposure rate of 5.4 μR/h for Pocatello and Fort Hall and 6.4 μR/h for Soda Springs. The cosmic ray exposure rate contributions vary due to the difference in the average elevation at the respective sites. In addition, the exposure rates reported over highly localized sources of radiation may be underestimated due to the large-area averaging by the aerial detection system.

7.1 Pocatello Survey Results and Discussion

For better resolution in presenting the data, the Pocatello survey area has been divided into four areas of interest. The Pocatello survey boundary and the areas of interest are illustrated in Figure 2. Table 5 provides a brief location description of each area.

Table 5. Areas of Interest Descriptions	
AREA	DESCRIPTION
Area 1	Northwest portion of the survey area that includes the FMC and Simplot sites and the municipal airport.
Area 2	Northeast portion of the survey area that includes the town of Chubbuck, the I-15 and I-86 interchange, some industrial complexes and Pineridge Mall.
Area 3	Center portion of the survey area that includes primarily the downtown area.
Area 4	Southern portion of the survey area that includes the southern portion of downtown and the Portneuf area.

The total terrestrial gamma exposure rate contour maps of the four areas are presented in Figures 3 (Area 1), 4 (Area 2), 5 (Area 3) and 6 (Area 4). As observed in Figures 3 through 6, the background exposure rates generally range from 11 to 17 μR/h (C-D levels) for all four areas of interest. As indicated in the figures, there are several areas where the total terrestrial exposure rate is considerably higher than the normal background range. The areas of higher than background exposure rate can be attributed to excess Bi-214.

The excess Bi-214 net count rate contour maps of the four areas of interest are shown in Figures 7, 8, 9 and 10. As stated in Section 5, the 1.76 MeV photopeak was utilized in mapping the areas of excess bismuth. The A-level contours represent the normal range of background levels of Bi-214; levels B and above represent areas of excess bismuth. In Area 1 (Figure 7), the FMC and Simplot plant sites clearly exhibit areas of higher than normal concentrations of Bi-214. In addition, the airport, several roads and highways, and the railroad tracks exhibit excess levels of bismuth. As indicated in Figures 8, 9 and 10, there are extensive areas with higher than normal concentrations of Bi-214 throughout the Pocatello valley.

7.2 Fort Hall Survey Results and Discussion

The total terrestrial gamma exposure rate contour map for the Fort Hall survey area is shown in Figure 11. As in the Pocatello survey area, the observed background exposure rate values range from 11 to 17 μR/h (C-D levels) for the majority of the area. There are a few areas where the exposure rates range to just over twice background.

The excess Bi-214 net count rate contour map is presented in Figure 12. The areas exhibiting excess bismuth (B level and higher) are fairly localized and associated primarily with paved areas.

7.3 Soda Springs Survey Results and Discussion

The total terrestrial gamma exposure rate contour map for the Soda Springs survey area is shown in Figure 13. The observed background exposure rates for the area range from 12 to 17 μR/h (C-D levels). As in the Pocatello survey, there are several areas where the total terrestrial exposure rate is considerably higher than background. These areas of higher exposure rates can also be attributed to excess bismuth concentrations.

Figure 14 represents the excess Bi-214 net count rates. The primary areas exhibiting excess concentrations of bismuth are the Monsanto elemental phosphorus plant, the Kerr-McGee vanadium plant, the primary highways that run through town and some secondary roads, and a few localized areas throughout the town.

7.4 Comparison of Aerial Survey Results and Ground-Based Measurements

Pressurized ion chamber measurements were collected at seven locations within the three survey areas. A total of three measurements each were collected within the Pocatello and Soda Springs survey areas and one in the Fort Hall survey area. The site locations (Numbers 1 through 7) are labeled on the appropriate figures (Figures 3, 4, 6, 11, and 13).

As indicated in Table 6, which presents a comparison of the ground-based and aerial platform measurements, the PIC measurements generally agree with the aerial measurement interval at each site.

Table 6. Comparison of Aerial and Ground-Based Measurements			
Sample Location	Corresponding Figure	Exposure Rate (μR/h at 1 Meter Above Ground Level)	
		Ion Chamber[a]	Inferred Aerial Data[b]
1	Figure 3	14.1	14.5- 17
2	Figure 4	13.6	11 - 14.5
3	Figure 6	12.3	11 - 14.5
4	Figure 11	13.1	11 - 14.5
5	Figure 13	16.2	17 - 22
6	Figure 13	13.8	15 - 17
7	Figure 13	15.2	17 - 22

[a]Reuter-Stokes Model RSS-111, Serial No. 140574.

[b]Includes a cosmic contribution.

There are several contributors to differences among the measurement methods:

1. The aerial data were not taken at exactly the same places or times as the ground data.

2. Each 1-second data point obtained with the airborne system covers an area several thousand times as large as the PIC measurement made at 1 meter.

3. The airborne detection systems "blur" the apparent edges of small anomalies; i.e., the airborne system can "see," to some degree, anomalies that are off to the side of the aircraft in addition to those directly below. Therefore, adjacent roads and/or paved areas where phosphate slag has been used as a base material will produce a slightly higher than normal result in an apparently undisturbed background area.

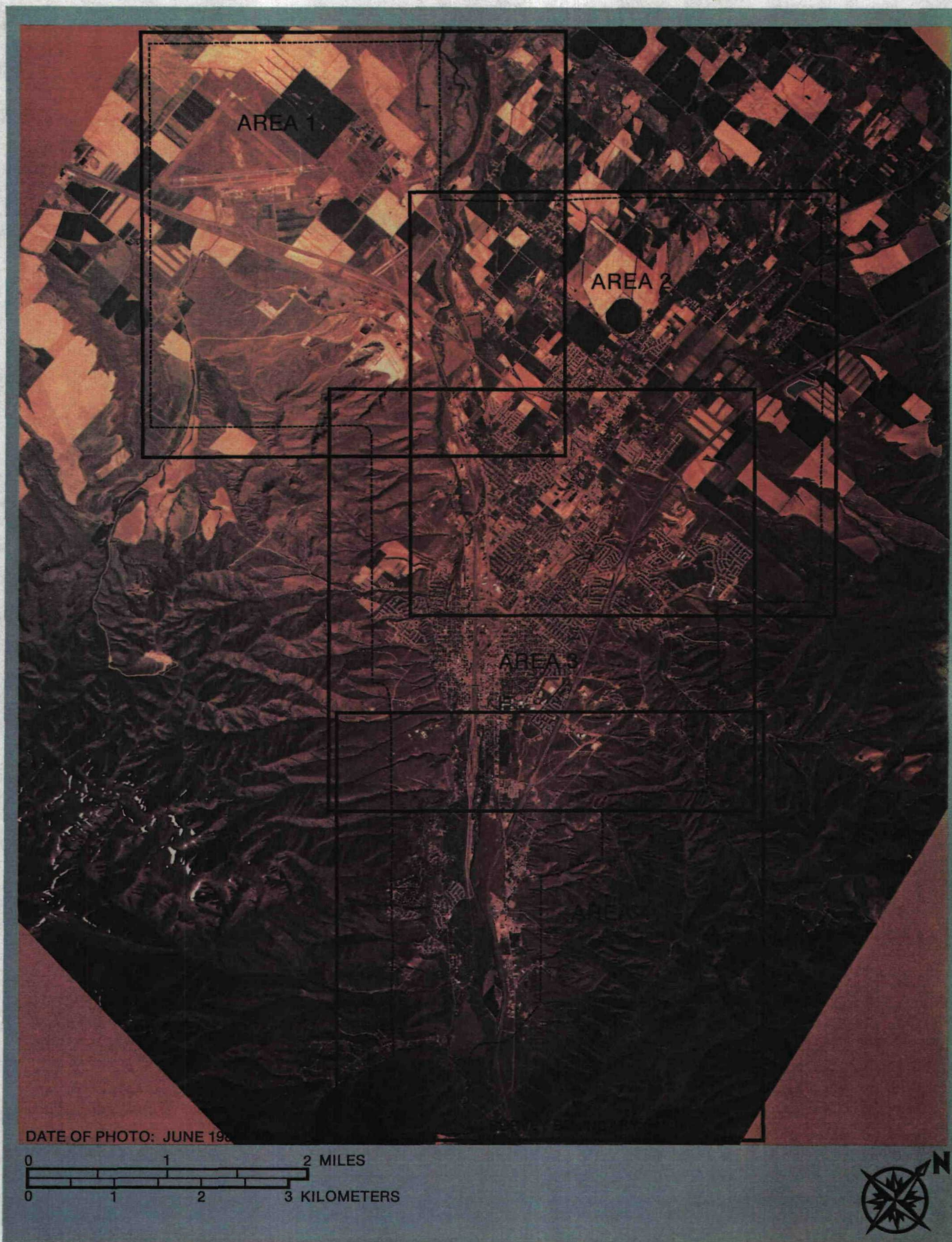
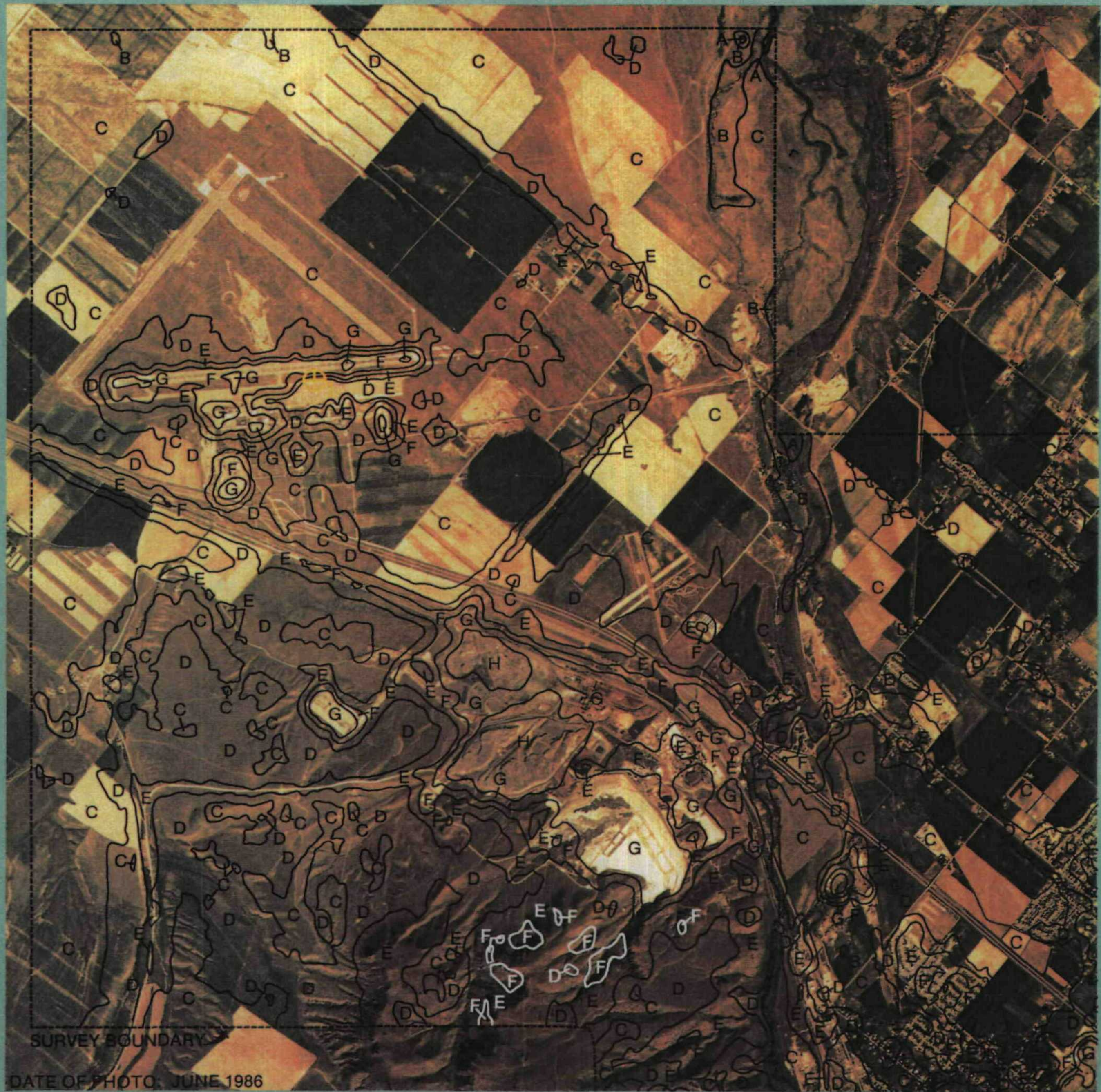
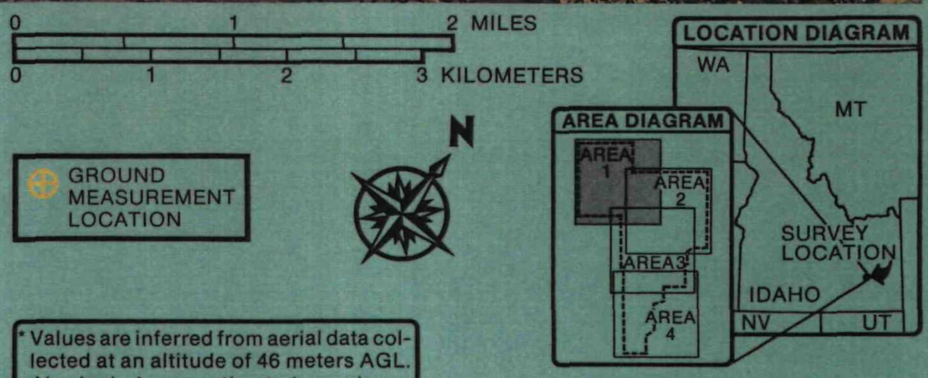


FIGURE 2. ***POCATELLO, IDAHO SURVEY BOUNDARY WITH AREAS OF INTEREST ILLUSTRATED FOR THE JUNE-JULY 1986 AERIAL RADIOLOGICAL SURVEY***



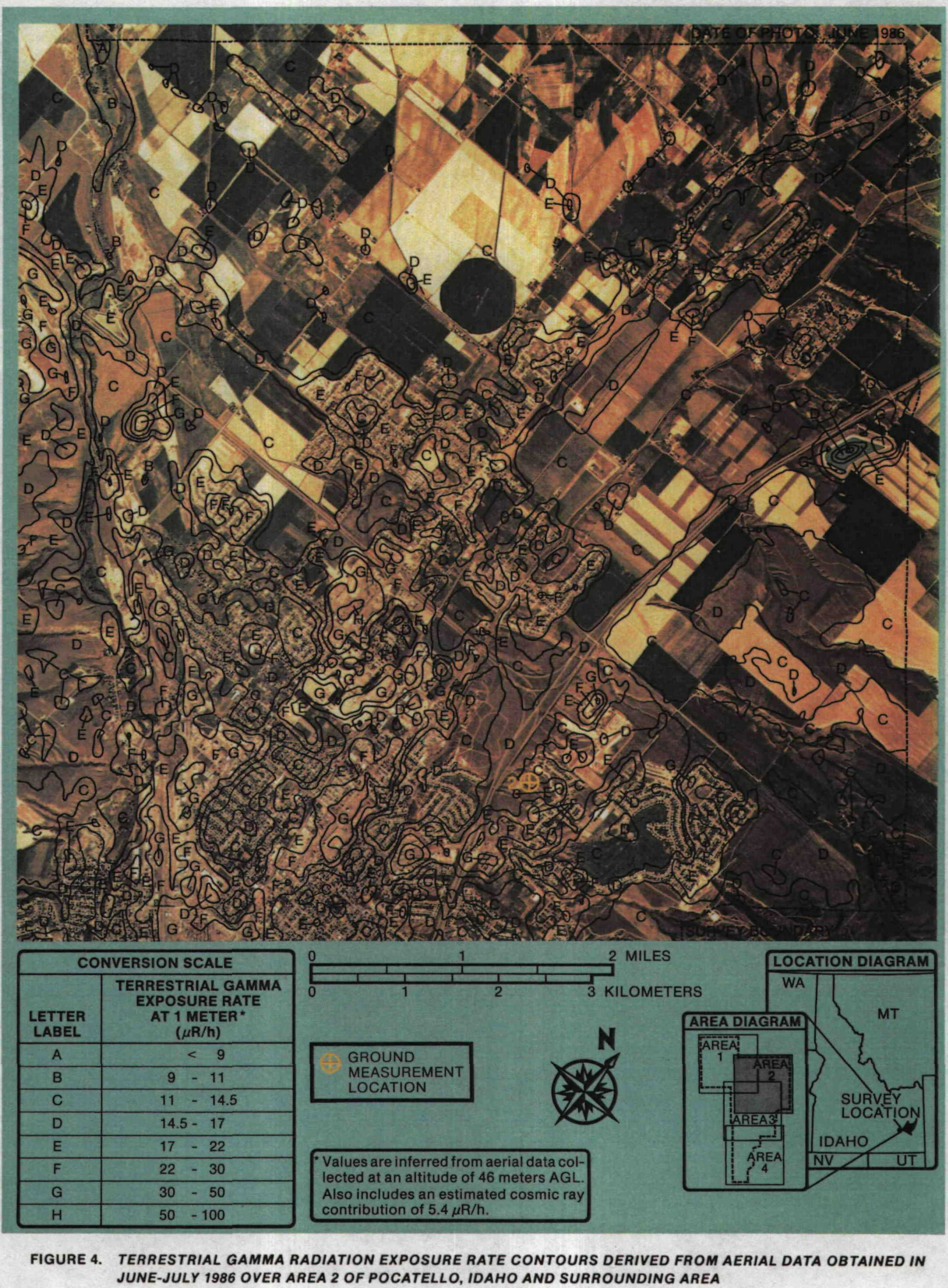
CONVERSION SCALE

LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100



* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 5.4 μR/h.

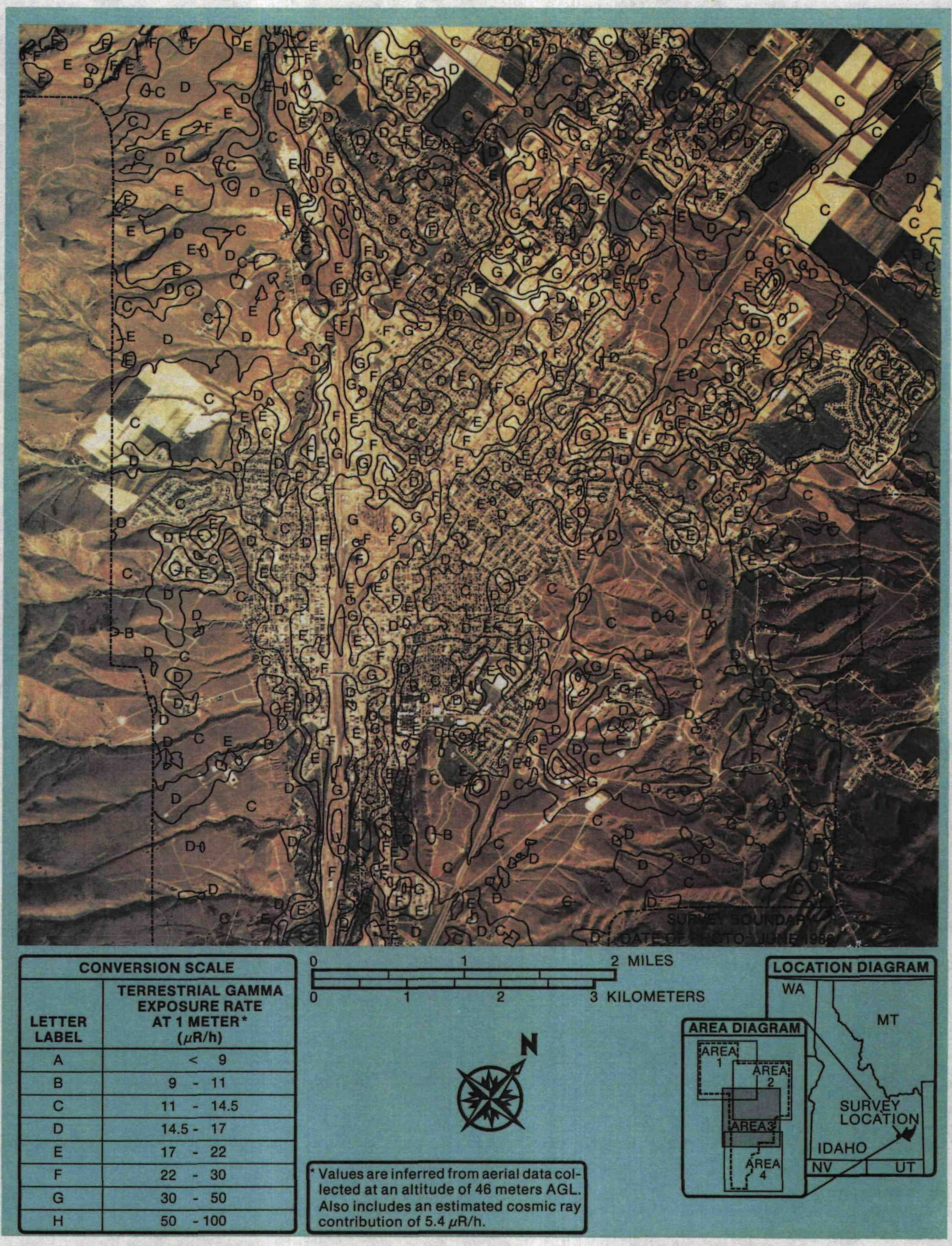
FIGURE 3. ***TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 1 OF POCATELLO, IDAHO AND SURROUNDING AREA***



CONVERSION SCALE

LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100

FIGURE 4. ***TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 2 OF POCATELLO, IDAHO AND SURROUNDING AREA***



CONVERSION SCALE	
LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100

FIGURE 5. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 3 OF POCATELLO, IDAHO AND SURROUNDING AREA*

CONVERSION SCALE	
LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50

0 1 2 MILES

0 1 2 3 KILOMETERS

⊕ GROUND MEASUREMENT LOCATION

N

* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 5.4 μR/h.

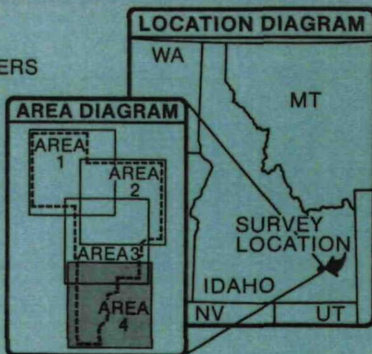


FIGURE 6. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 4 OF POCATELLO, IDAHO AND SURROUNDING AREA*

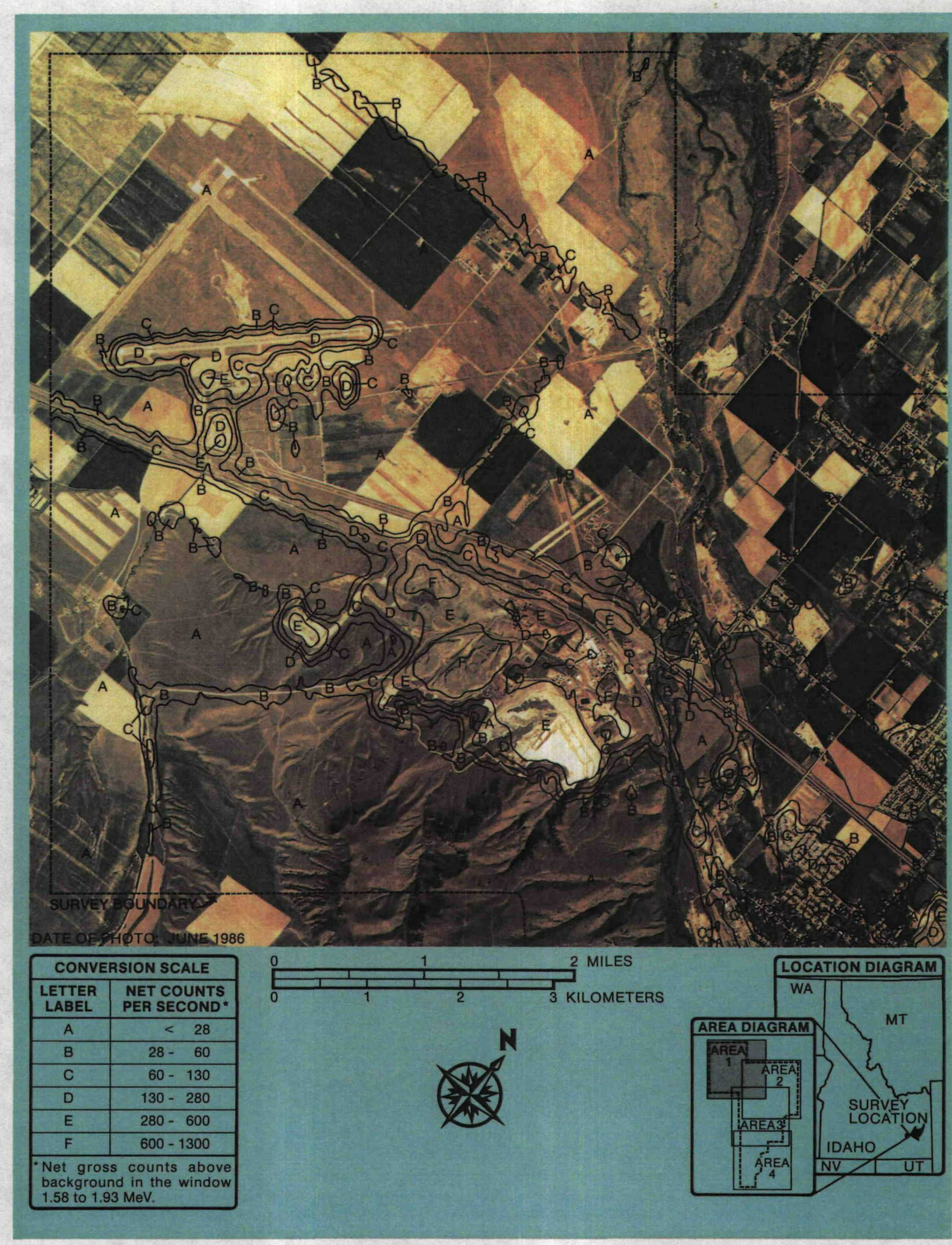
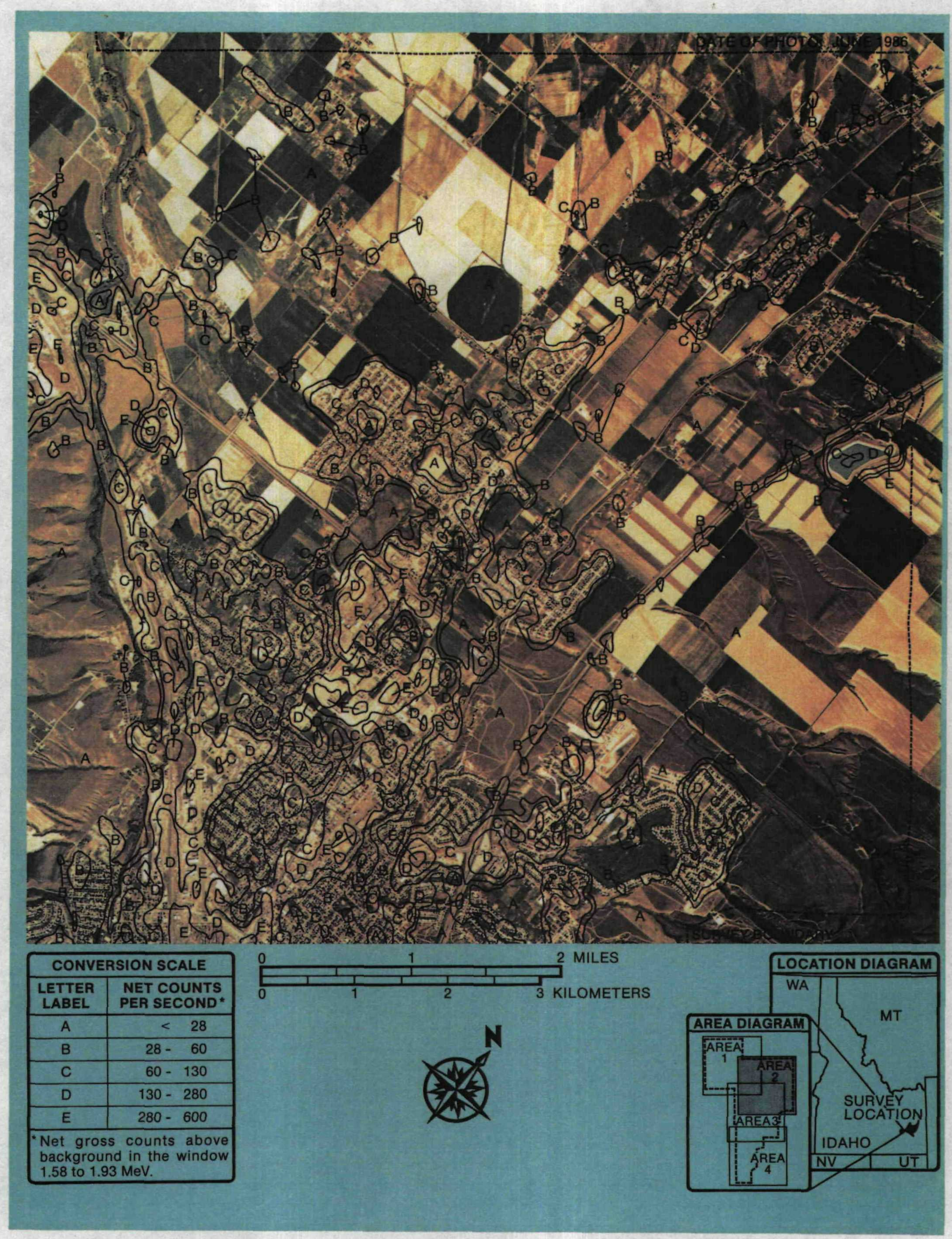


FIGURE 7. ***BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 1 OF POCATELLO, IDAHO AND SURROUNDING AREA***

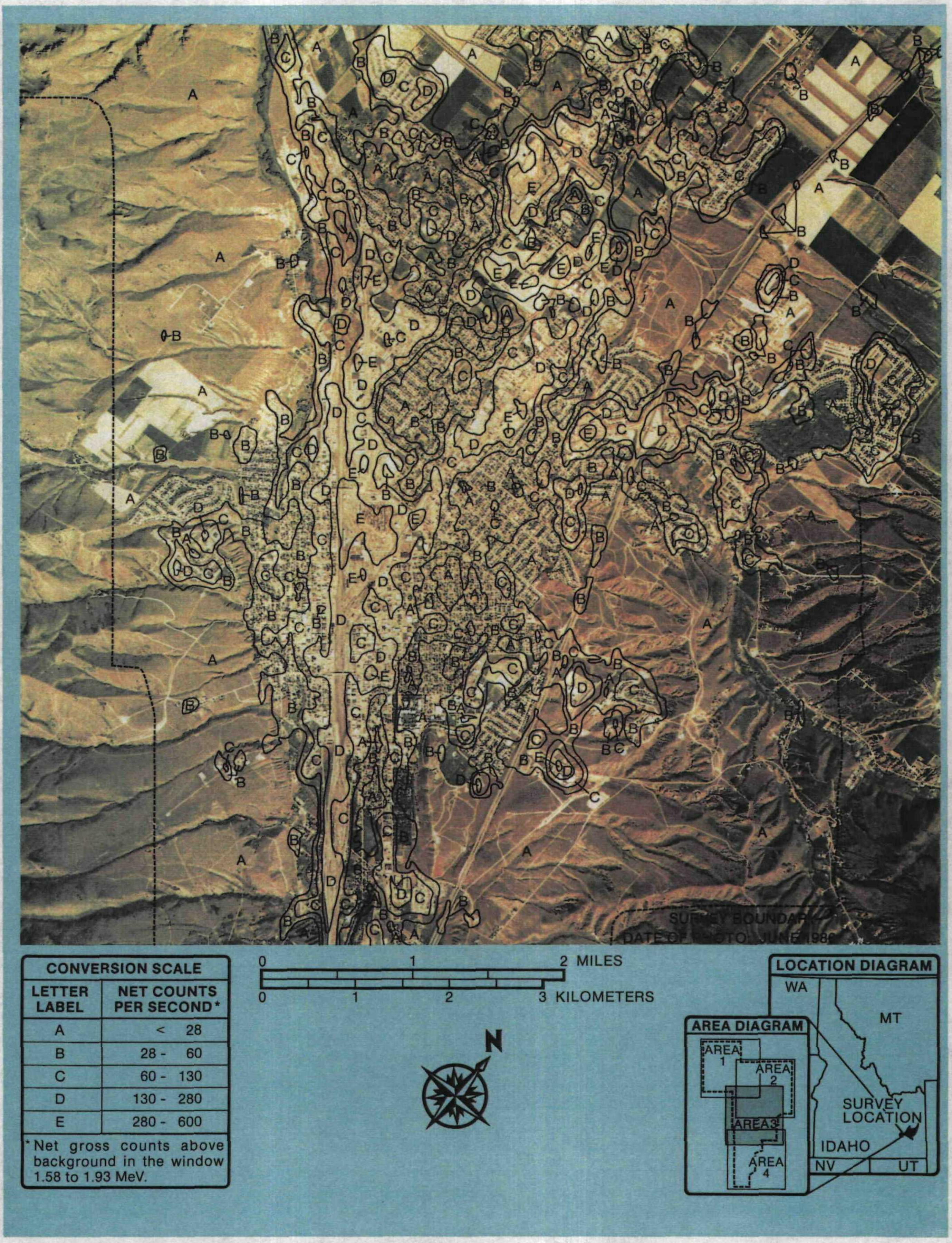


CONVERSION SCALE

LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
B	28 - 60
C	60 - 130
D	130 - 280
E	280 - 600

*Net gross counts above background in the window 1.58 to 1.93 MeV.

FIGURE 8. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 2 OF POCATELLO, IDAHO AND SURROUNDING AREA*



LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
B	28 - 60
C	60 - 130
D	130 - 280
E	280 - 600

*Net gross counts above background in the window 1.58 to 1.93 MeV.

FIGURE 9. ***BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 3 OF POCATELLO, IDAHO AND SURROUNDING AREA***

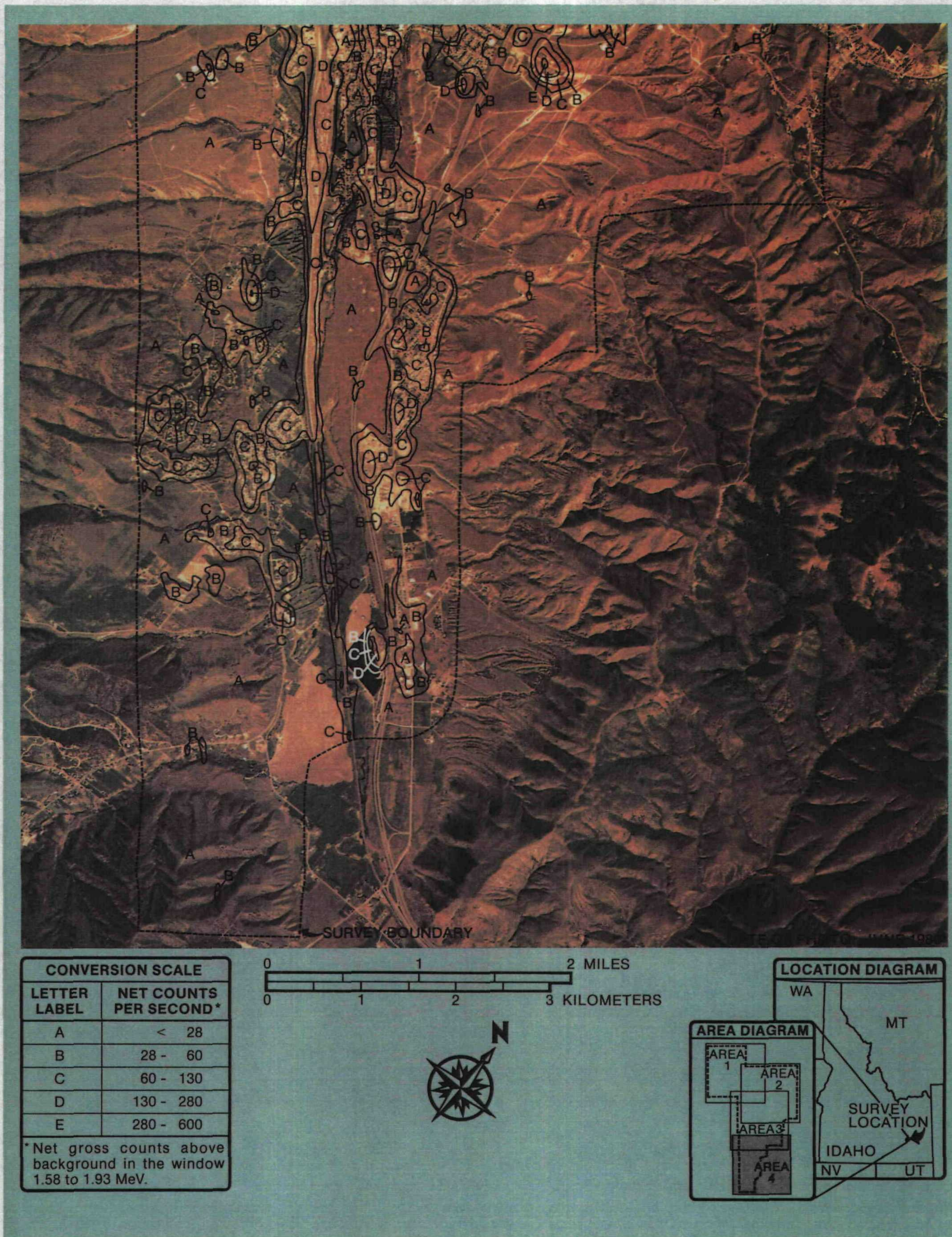
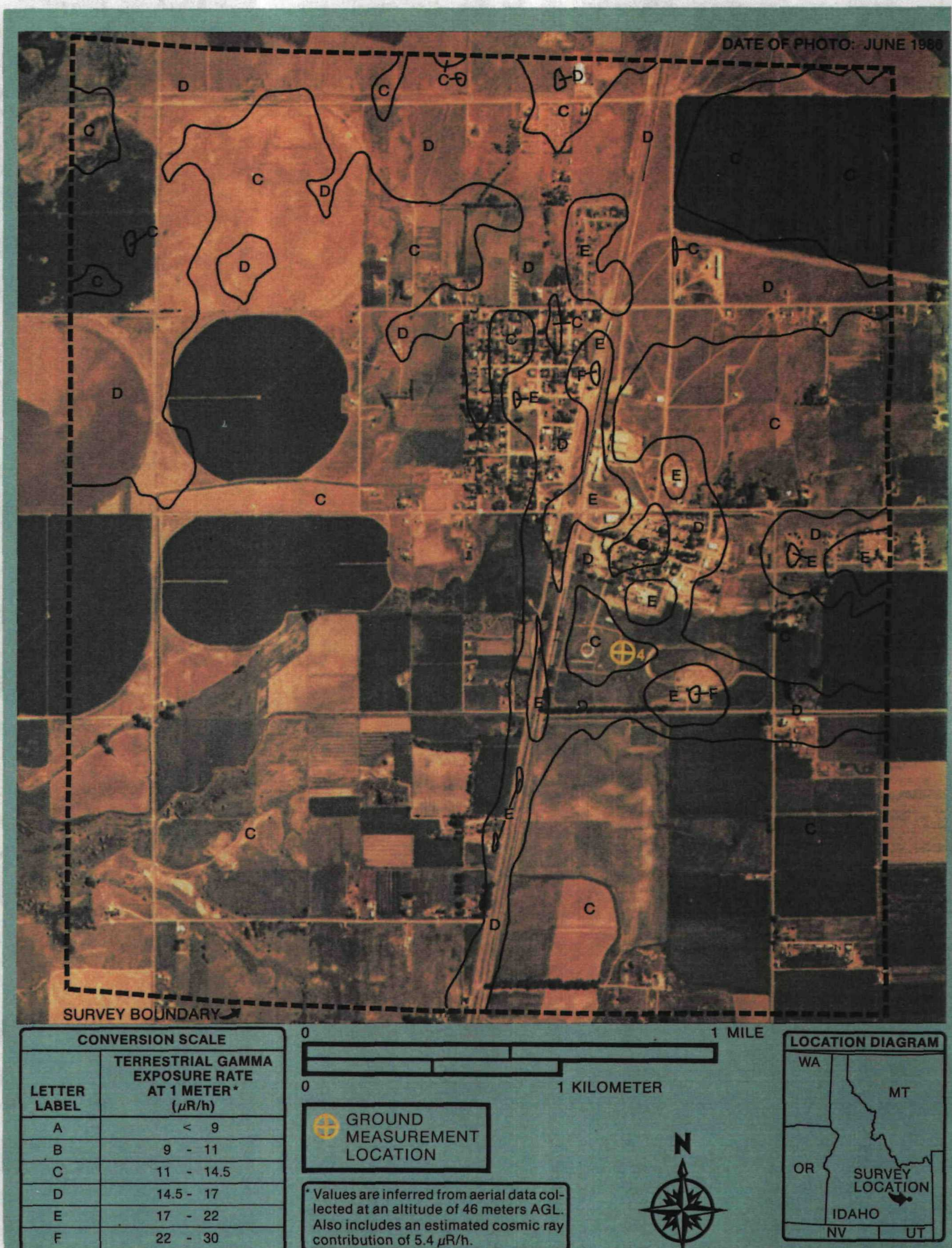


FIGURE 10. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 4 OF POCATELLO, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE

LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30

FIGURE 11. ***TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER FORT HALL, IDAHO AND SURROUNDING AREA***

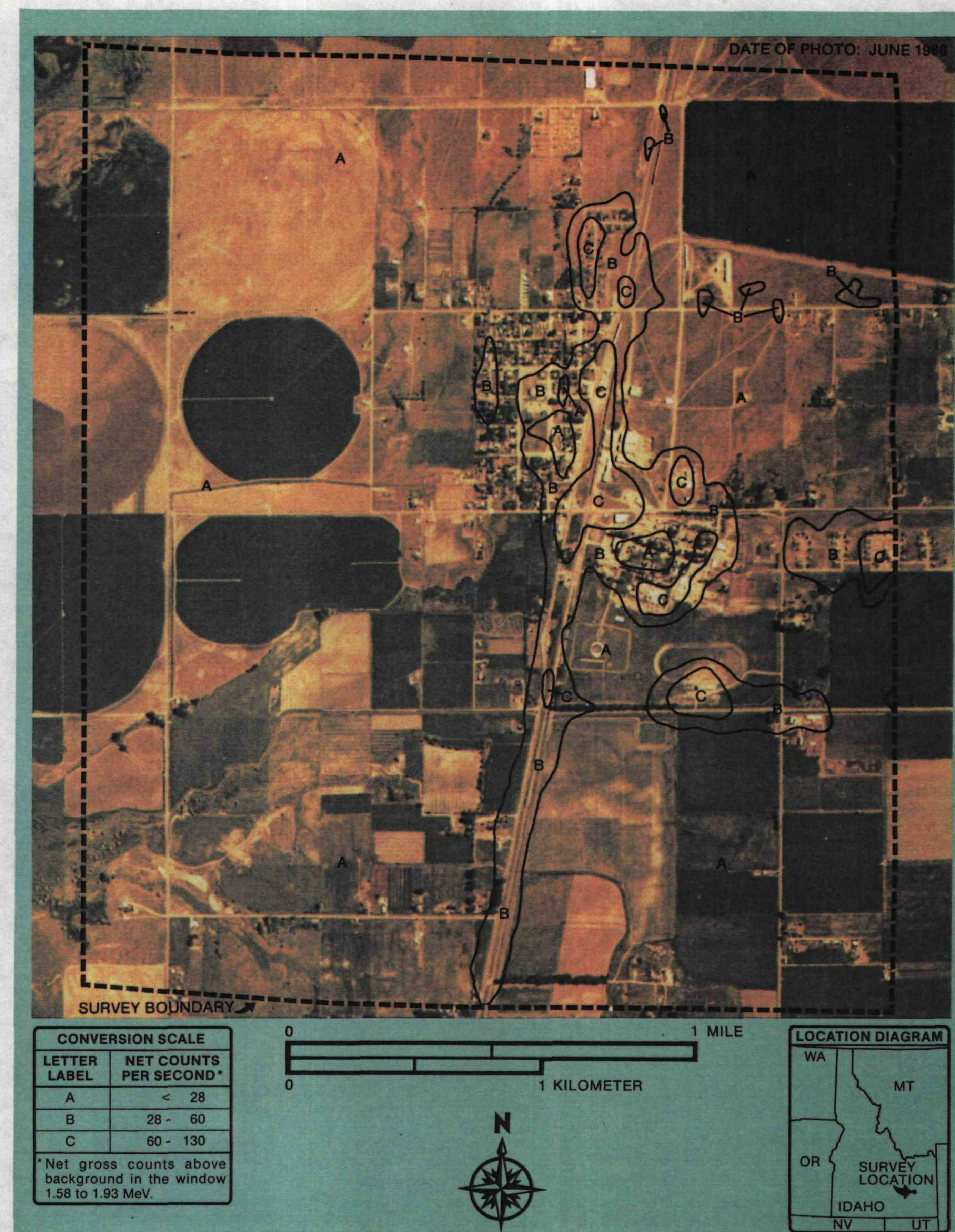


FIGURE 12. ***BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER FORT HALL, IDAHO AND SURROUNDING AREA***

CONVERSION SCALE	
LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 12
C	12 - 15
D	15 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100

* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 6.4 μR/h.

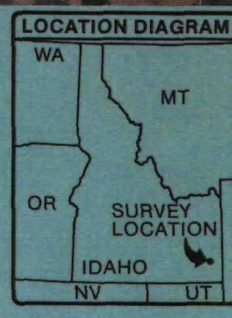


FIGURE 13. ***TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER SODA SPRINGS, IDAHO AND SURROUNDING AREA***

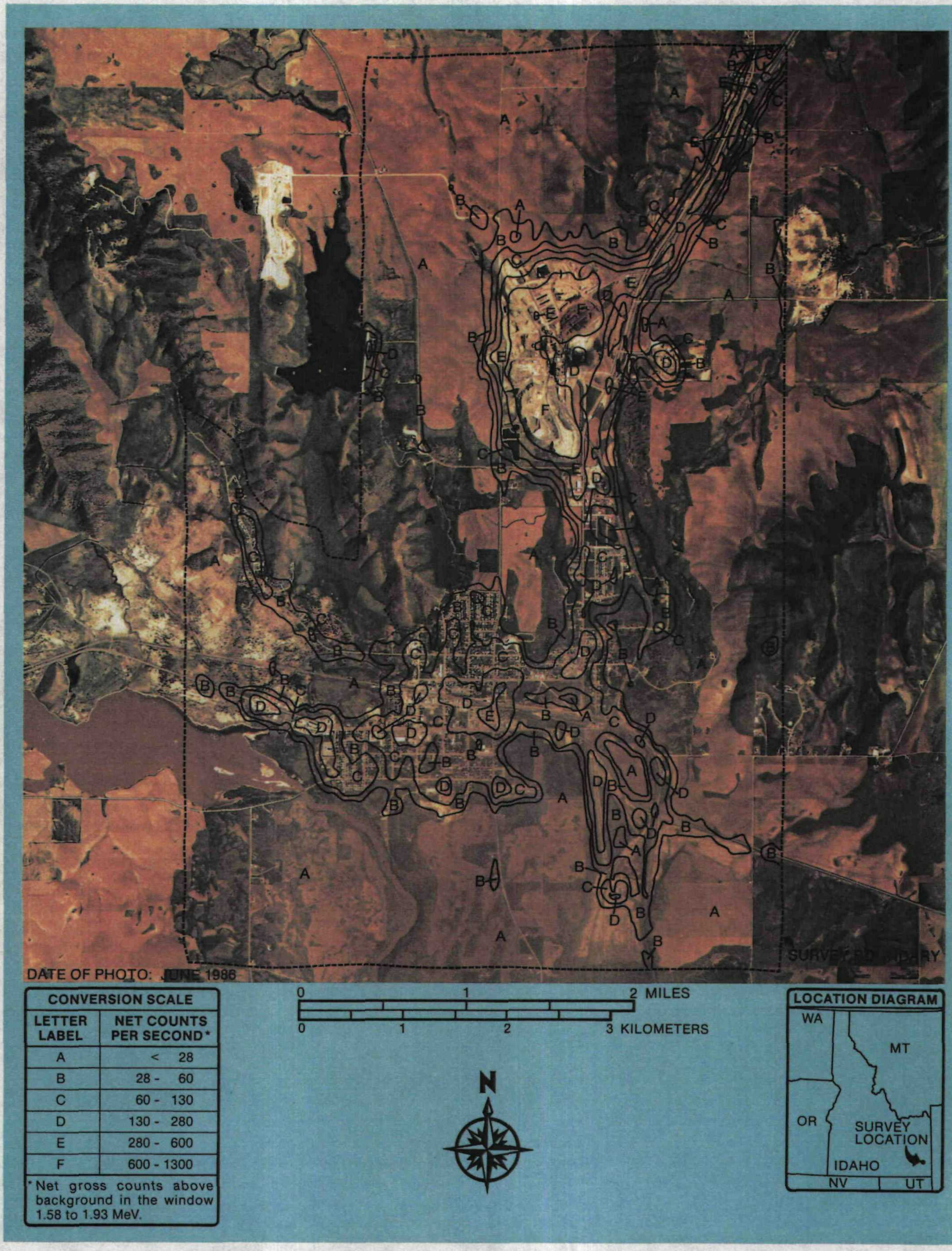


FIGURE 14. ***BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER SODA SPRINGS, IDAHO AND SURROUNDING AREA***

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