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AN AERIAL RADIOLOGICAL SURVEY OF THE FEED MATERIALS PRODUCTION CENTER AND SURROUNDING AREA

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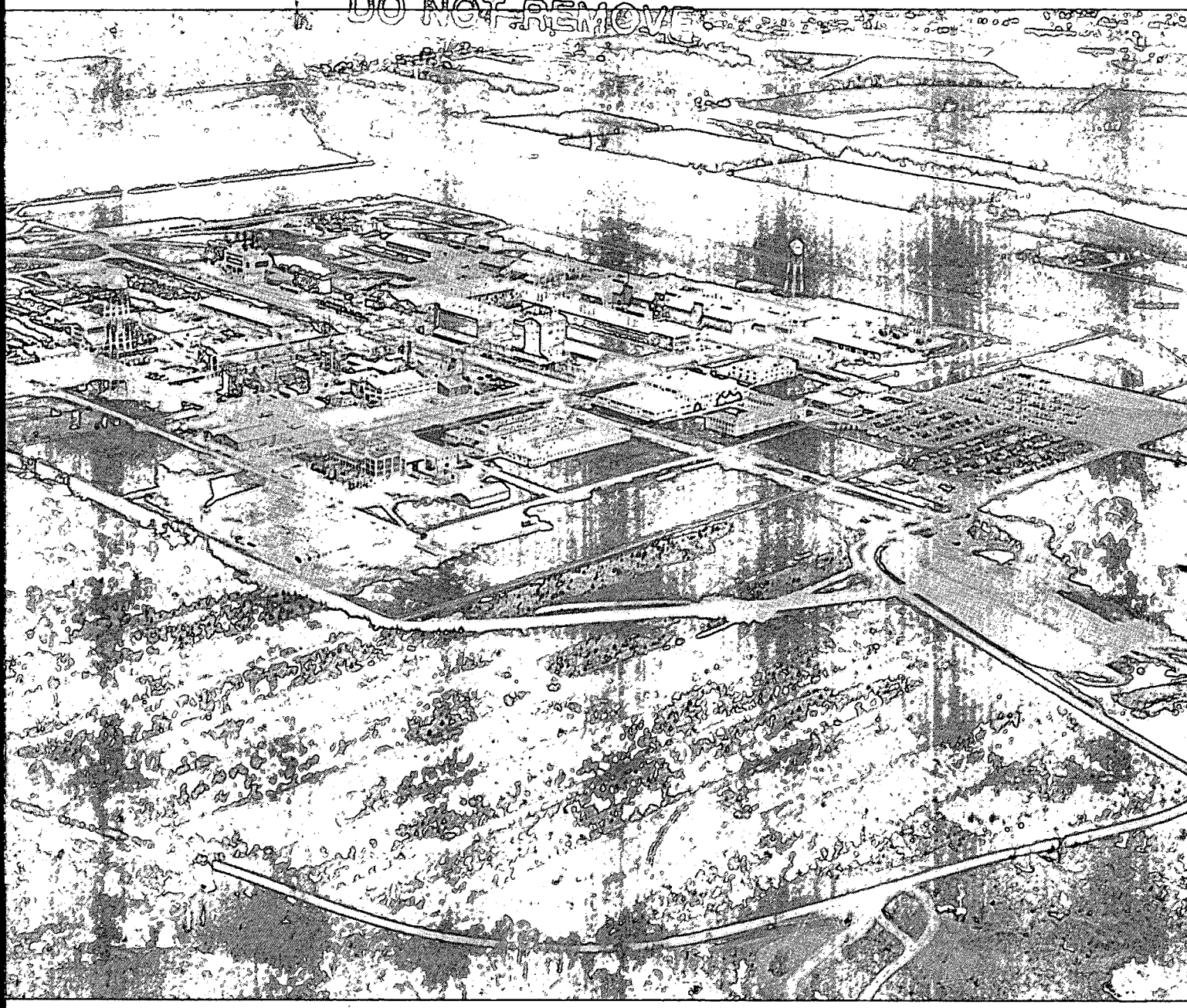

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DATE OF SURVEY: APRIL 1985

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ABSTRACT

An aerial radiological survey was performed over the area surrounding the Feed Materials Production Center, located near Fernald, Ohio, during the period April 24 to 27, 1985. The survey covered a 70-square-kilometer (27-square-mile) area centered on the plant.

The highest exposure rates, in excess of 0.35 milliroentgens per hour (mR/h), were inferred from the data measured directly over the plant. This radiation was due to the presence of nuclides which were consistent with normal plant operations. For the remainder of the survey area, the inferred radiation exposure rates, varying from 6 to 12 microroentgens per hour (μR/h), were due to naturally-occurring potassium, uranium, thorium, and daughter products. The reported exposure rate values include an estimated cosmic ray contribution of 3.7 μR/h.

Ground-based measurements, conducted during the time of the aerial survey, were compared to the aerial results. Pressurized ionization chamber readings and a group of soil samples were acquired at several locations within the survey area. The exposure rate values obtained from these measurements were in agreement with the inferred aerial results. Soil sample results showed several areas just outside the site boundary with slightly elevated amounts of U-238. The levels, however, were well below the detection limit of the aerial system.

The only off-site area that showed apparent above background activity in the aerial data was directly west of the storage silos. The symmetric shape of the contours, however, suggests that these elevated levels are due to "shine" from material stored on-site in the silos and not to actual off-site contamination.

Detailed comparison of the 1985 aerial survey data with a previous survey conducted in 1976 showed no significant change in any area outside the plant boundary.

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1.0 INTRODUCTION

An aerial radiological survey of the area surrounding the Feed Materials Production Center, located near Fernald, Ohio, was conducted from April 24 to 27, 1985 at the request of the U.S. Department of Energy's Oak Ridge Operations Office, Oak Ridge, Tennessee. The survey was performed using the Aerial Measuring System (AMS),[1] operated by EG&G Energy Measurements, Inc. for the U.S. Department of Energy (DOE). The plant is operated for the DOE by NLO, Inc. A similar aerial survey was conducted during August 1976 with a follow-up survey during May-June 1977.[2] The purposes of the 1985 survey were to map the distribution of all gamma-emitting radionuclides detectable from the surface and to determine if there had been any significant changes in the radiological characteristics of the area during the period between surveys.

In addition to the aerial measurements, a series of ground-based measurements were performed. The exposure rate measurements were made in two locations (Sites 1 and 2 in Figure 1) that were identified by the aerial survey as exhibiting only natural background radiation. Soil samples were also acquired in areas known to have elevated concentrations of uranium-238 (U-238), in areas showing anomalous radiation characteristics, at designated boundary sampling stations, and along the sensitive environmental pathway of Paddy's Run.

The results of the survey are reported as radiation exposure rates in microroentgens per hour (μR/h) extrapolated to 1 meter above ground level.

The approximate annual absorbed dose equivalent levels, attributed only to external sources of radiation and expressed in units of millirem per year (mrem/y), can be obtained by multiplying the reported exposure rate in μR/h by 8.76.

2.0 NATURAL BACKGROUND RADIATION

Natural background radiation originates from radioactive elements present in the earth as well as cosmic rays entering the earth's atmosphere from space. The terrestrial gamma rays originate primarily from the uranium and thorium decay chains as well as radioactive potassium. Local concentrations of these nuclides produce radiation levels at the surface of the earth typically in the range of 1 to 16 μR/h (9 to 140 mrem/y).

One member of both the uranium and thorium decay chains is an isotope of the noble gas radon which can diffuse through soil and be borne by air to other locations. Thus, the level of this airborne radiation depends on the meteorological conditions, the mineral content of the soil, and the soil permeability existing at each location at a particular time. This airborne radiation typically contributes from 1 to 10 percent of the natural background radiation levels.

Cosmic rays interact in a complex manner with the elements of the earth's atmosphere and soil. These interactions produce an additional natural source of gamma radiation. Radiation levels due to cosmic rays vary directly with the altitude and slightly with geomagnetic latitude. Typical values range from 3.3 μR/h at sea level in Florida to 12 μR/h at an elevation of 3,000 meters (10,000 feet) in Colorado.[3] The cosmic ray contribution in the Fernald survey area was estimated to be 3.7 μR/h.

Of special interest in this survey is the isotope U-238, which is handled by the Feed Materials Production Center and has been found at above background concentrations in three off-site wells. Naturally-occurring U-238 is found worldwide at concentrations of about 1 to 4 parts per million (ppm) or 0.3 to 1.3 picocuries per gram (pCi/g). This is one of the primordial isotopes which, because it is only weakly radioactive, remains from the time of planetary formation. In nature, U-238 is usually found in equilibrium with its daughter isotopes (Figure 2). Chemical and physical processes taking place in nature can, under certain circumstances, cause disequilibrium to occur. The U-238 processed at the Fernald plant has been completely separated from its daughter products as part of normal plant operations. These daughters begin to grow back immediately following separation, but because of the very long half-life of the daughter U-234 (2.48×10^5 years) reestablishment of equilibrium will require geological time spans.

U-238 is a very weak gamma emitter and cannot be detected directly by the Aerial Measuring System. Naturally-occurring U-238 that is in equilibrium with its daughters is measured using the intense gamma rays from bismuth-214 (see Figure 2). Because of the relative abundance of these gamma rays, the detectability for unseparated U-238 is about 3 pCi/g. Analysis of the separated U-238 distribution is done using a daughter of U-238, protactinium-234 (Pa-234m). Pa-234m

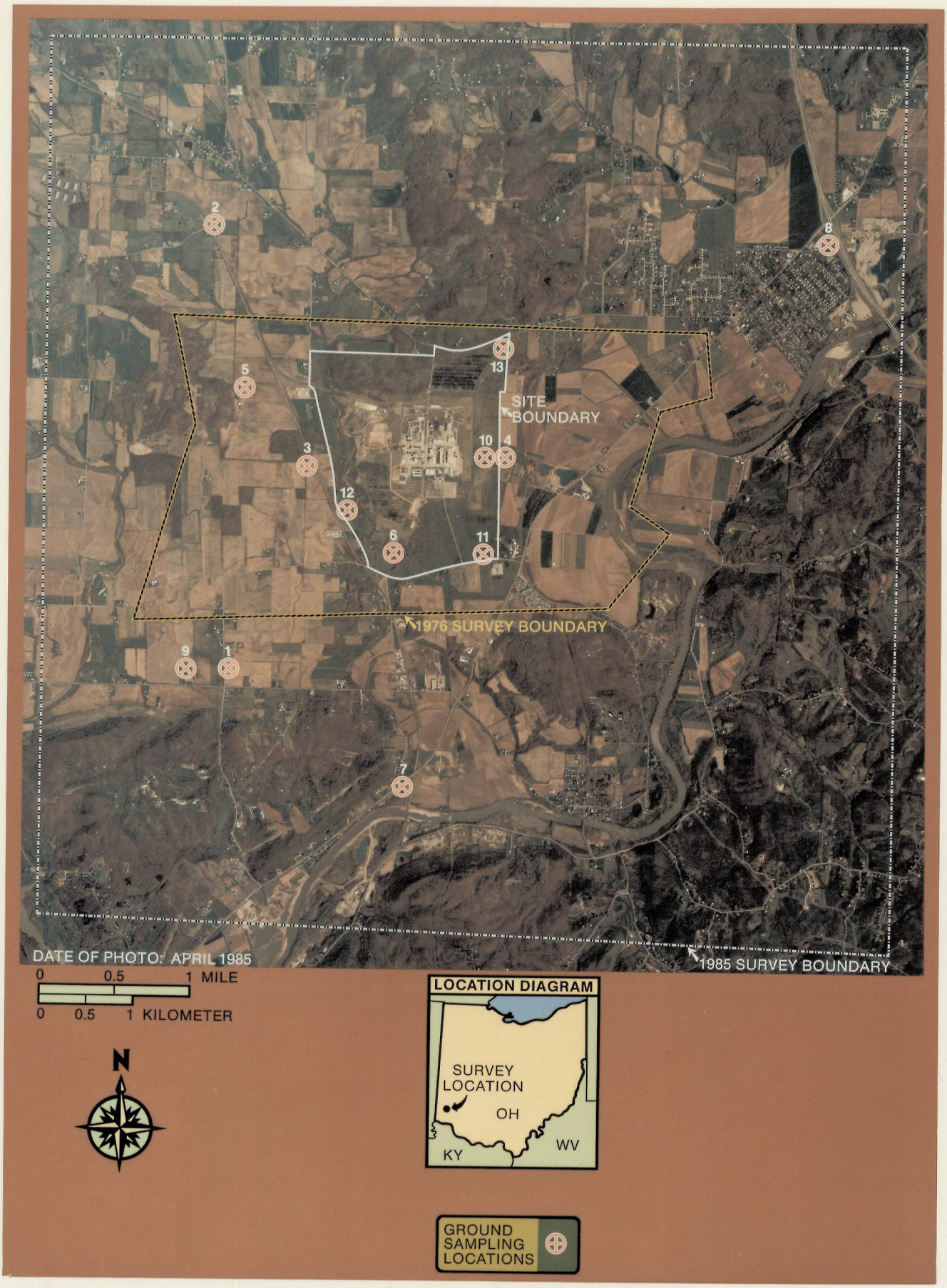


Figure 1. *AERIAL SURVEY BOUNDARIES FOR THE 1976 AND 1985 FEED MATERIALS PRODUCTION CENTER SURVEYS AND THE 1985 GROUND-BASED MEASUREMENT LOCATIONS*

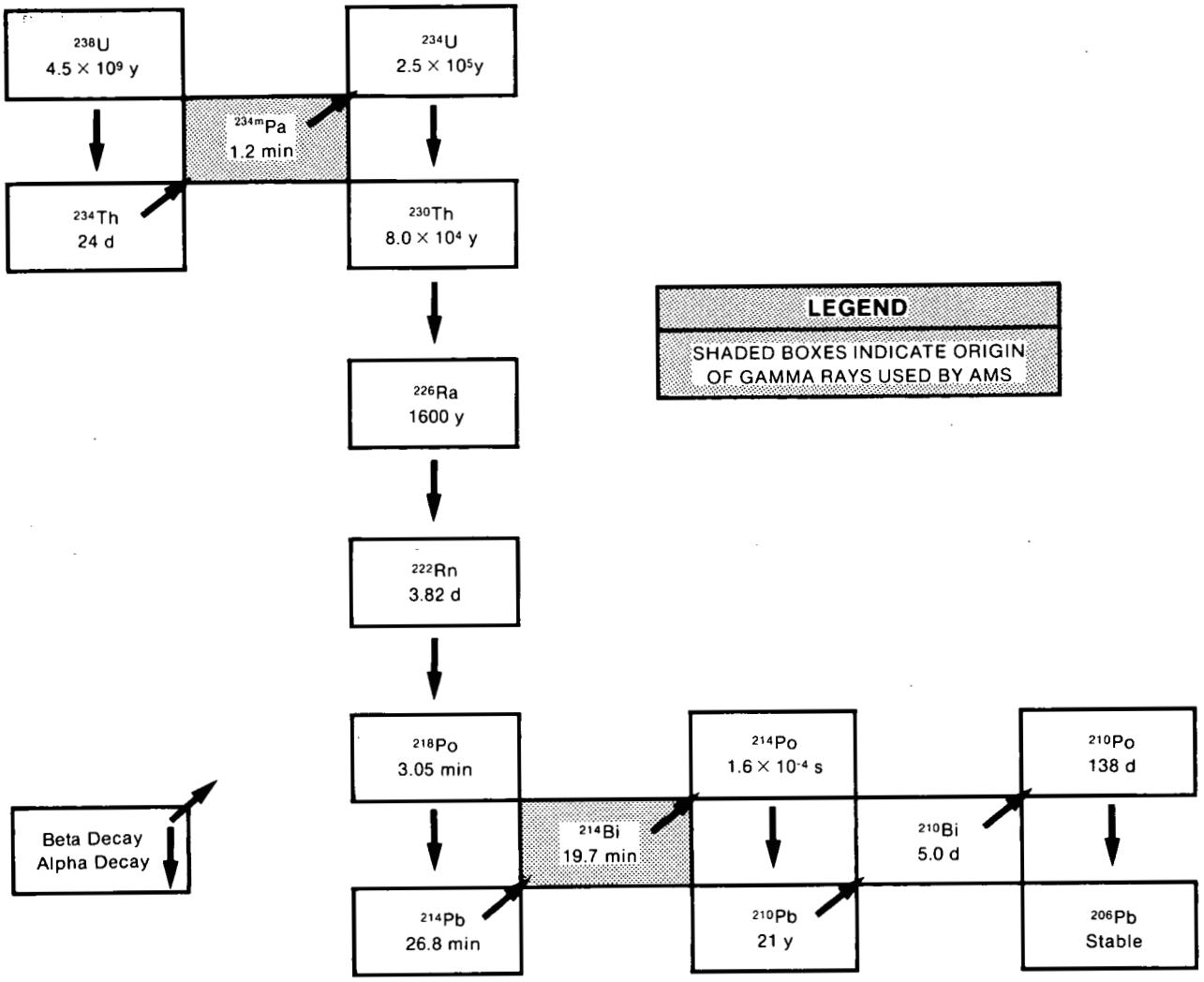


Figure 2. *DECAY SCHEME OF THE URANIUM SERIES SHOWING DAUGHTER ISOTOPES AND PRINCIPAL GAMMA RAYS USED BY THE AMS*

requires about 120 days to equilibrate with U-238 following separation from its daughters, after which time the Pa-234m can be accurately correlated with U-238.

3.0 SURVEY SITE DESCRIPTION

The Feed Materials Production Center is located on a 1,050-acre site approximately 33 kilometers (20 miles) northwest of Cincinnati, Ohio. Several rural communities are within 2 to 5 kilometers (1 to 2 miles) of the plant. The primary work at the Feed Materials Production Center is the production of purified uranium metal and compounds for use at other DOE sites. The U-235 content of the uranium may be depleted, normal, or slightly enriched. The average content is close to normal.

The aerial survey encompassed an area of 70 square kilometers (27 square miles) as outlined in Figure 1. This area was surveyed at an altitude of 46 meters (150 feet) above ground level (AGL) with a regular grid of 120 parallel flight lines, 8 kilometers (5 miles) in length and spaced 76 meters (250 feet) apart. The entire survey area was flown at an average ground speed of 36 m/sec (70 knots). Additional flights were made along both banks of the Greater Miami River from a point 4 kilometers (2 miles) upstream from the plant site to the Miami River's confluence with the Ohio River. Special attention was given to the first

oxbow in the Miami River downstream from the plant, since this location was most likely to show any deposition. Eleven flight lines, each about 2 kilometers (1 mile) long, were flown over the oxbow at an altitude of 46 meters (150 feet) and a line spacing of 76 meters (250 feet). No areas of elevated count rate were detected. In addition, both banks of Paddy's Run were surveyed from the plant to the confluence with the Miami River. No evidence of elevated count rates was found here either. Figure 3 shows the actual flight lines flown during both the 1976 and 1985 aerial surveys.

4.0 SURVEY EQUIPMENT AND PROCEDURES

The equipment and procedures employed to perform the aerial and ground-based measurements and the data analysis techniques are discussed briefly in this section. A more detailed description of the systems and procedures can be found in previously published reports.[1,4]

4.1 Aerial Measurements

The Aerial Measuring System consists of a radiation detection package and a specialized data acquisition and recorder system which are mounted on board a Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter (Figure 4).

The radiation detector package consists of 8 thallium-activated sodium iodide, NaI(T*l*), scintillation crystals which are distributed equally in two pods. Each crystal is 10 cm × 10 cm × 41 cm (4 in. × 4 in. × 16 in.). The signals from the detector crystals are electronically summed to produce a single spectrum of high sensitivity. The spectral data are collected once each second and stored on magnetic tape along with the aircraft's positional data, the ambient temperature and barometric pressure, and the system's live time information.

The helicopter's position is established with two systems: a radar altimeter to measure the altitude and an ultrahigh frequency ranging system (URS) for determining the location at which a measurement is made.

4.2 Ground Truth Measurements and Soil Sampling

Soil samples were taken at 13 locations within the survey area, as shown in Figure 1 and described in Table 1. In addition, at Sites 1 and 2, located in typical background areas (as indicated by the aerial data), the total gamma exposure rate was measured using a pressurized ionization chamber. These measurements were made using the techniques described in a previously published report.[5] Soil samples 3 through 6 were taken in areas that showed anomalous radiation profiles. Sample 7 was taken along the bank of Paddy's Run downstream from the plant. Samples 8 and 9 were taken at two of the area schools (Elda Elementary and Crosby Elementary). Sample 10 was taken at the old incinerator site, which is known to have elevated levels of uranium. This location was sampled at successive depths to determine the vertical profile of deposited uranium (Figure 5). Samples 11 through 13 were taken at NLO boundary stations. Except for samples taken at the incinerator, all samples showing elevated amounts of U-238 were below the detection limit of the Aerial Measuring System.

4.3 Data Reduction Procedures

Data are recorded during each survey flight on magnetic tapes which are processed immediately after landing using a minicomputer system mounted in a mobile data processing laboratory (Figure 6). An extensive inventory of software routines and supporting equipment is available for detailed data analysis.

For this survey, the data analyses were directed to produce the following:

1. A total gamma exposure rate isopleth map.
2. A Pa-234m isopleth map indicating the presence (or absence) of U-238.
3. Spectral identification of anomalies that were detected.

Exposure rate contours were constructed from the gross count data derived from the integral counts between 0.05 and 3.05 MeV. The measured value of airborne radon, cosmic ray, and aircraft background radiation was subtracted from the gross count rates. The resulting net count rates, due to terrestrial sources of radiation, were converted to gamma exposure rates extrapolated to 1

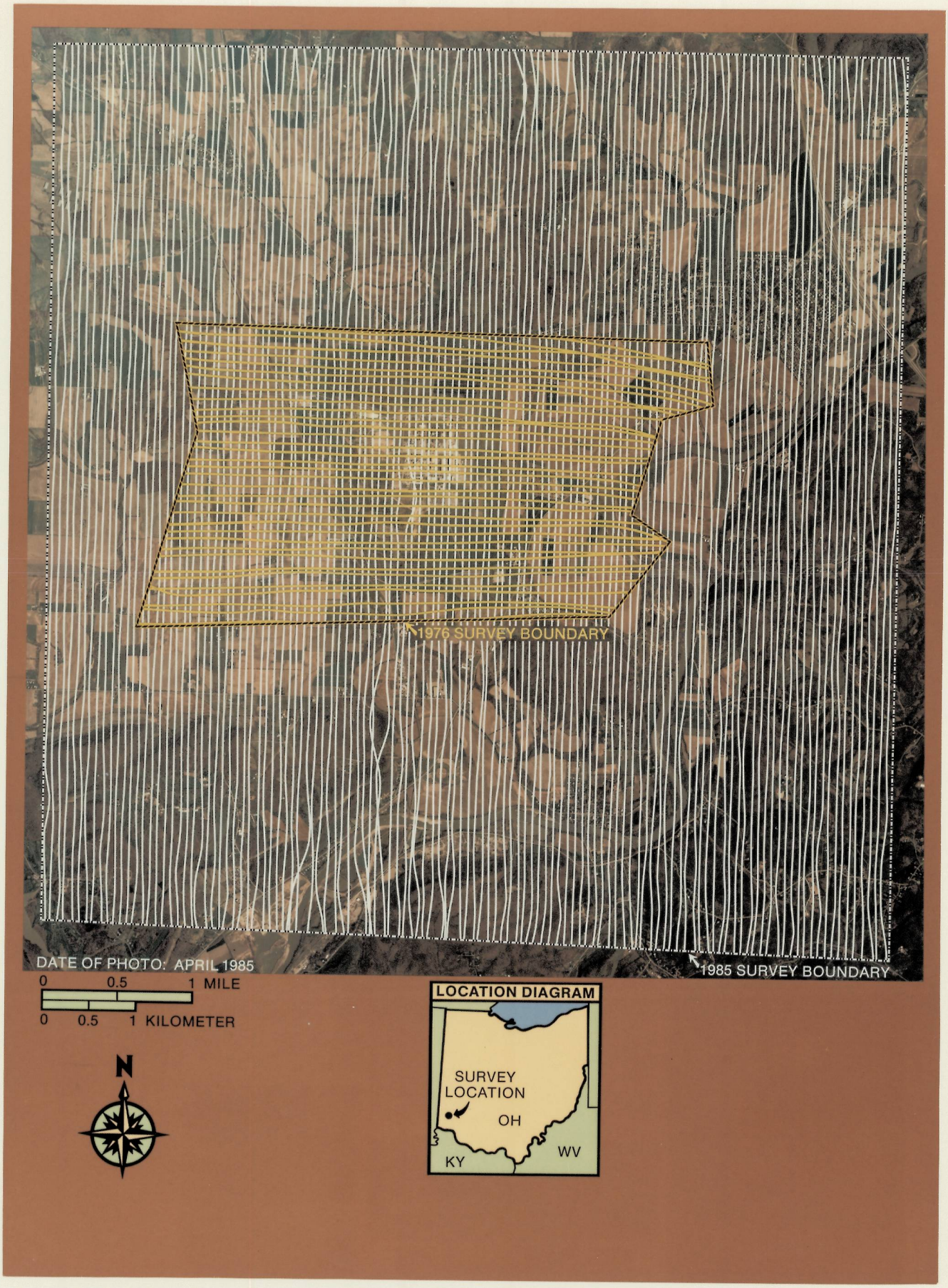


Figure. 3. *FLIGHT LINES FLOWN DURING THE 1976 AND 1985 AERIAL SURVEYS OVERLAID ON THE 1985 SURVEY MAP*

Figure 4. *MBB BO-105 HELICOPTER WITH DETECTOR PODS*

meter above the ground level by applying a conversion factor of 1,115 counts per second per μR/h. The calculated cosmic ray contribution of 3.7 μR/h was added to the converted exposure rate values to obtain the final isopleths.

Aerial detection systems detect and average together gamma rays arriving from nuclides distributed over a large area on the ground. This average is a result of the limited angular resolution of the detectors and the motion of the helicopter. The angular resolution of the detectors depends primarily on their angular response, air attenuation of photons in the air and soil and, of course, detector-source separation. The former two factors are quite dependent upon photon energy. For instance, due to lack of collimation, the angular

Table 1. Ground-Based Measurement Locations

Site Number	Location Description
1	Benchmark site 1
2	Benchmark site 2
3A	Anomalous site - woods
3B	Anomalous site - cultivated field
4	Anomalous site - field
5	Anomalous site - field
6A	Paddy's Run Creek
6B	Paddy's Run Creek, below inlet of stream from fly ash pile
7	Paddy's Run Creek at Highway 128
8	Elda Elementary School yard
9	Crosby Elementary School yard
10	Incinerator area of plant
11	NLO Boundary Station 4
12	NLO Boundary Station 5
13	NLO Boundary Station 2

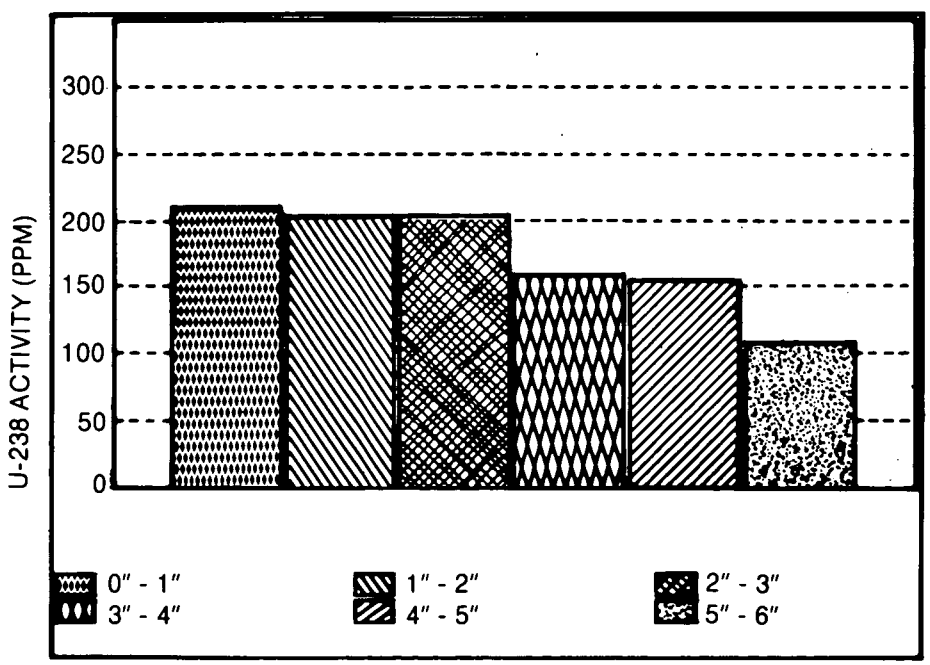


Figure 5. *DEPTH DISTRIBUTION OF SEPARATED U-238 AT SOIL SAMPLE SITE 10*

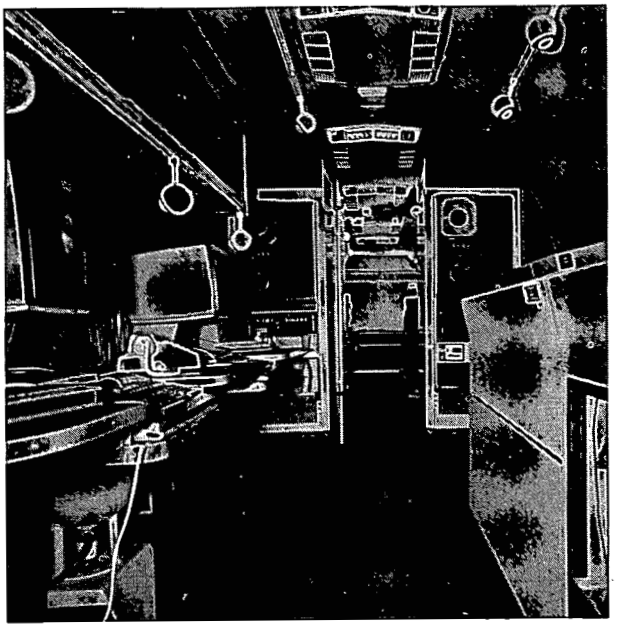


Figure 6. *MOBILE COMPUTER DATA PROCESSING LABORATORY*

response of the detectors is nearly isotropic for photons of energies greater than approximately 1.5 MeV. Near 60 keV, however, the angular response is almost a cosine function due to the physical shape and arrangement of the detectors.

Similarly, air attenuation of photons is negligible over distances comparable to the aircraft altitude for 1 to 2 MeV photons, but quite significant for gammas in the 100 keV range. These effects result in a detector field-of-view that varies considerably with energy. As an example, for a detector at an altitude of 30 meters (100 feet), approximately 63 percent of the observed K-40 (1,464 keV) count rate originates from a 140-meter-diameter area directly beneath the detector (1.5 hectares), yet an area only 60 meters in diameter (0.3 hectare) gives rise to the same fraction of counts due to the 60 keV Am-241 photons. The motion of the helicopter during the accumulation time (1 second) also contributes to the averaging, as the helicopter has moved nearly 30 meters. This averaging can be aggravated by smoothing the data to enhance sensitivity if the distance traveled by the helicopter during the smoothing interval exceeds the detector's field-of-view.

Special data processing procedures were also applied to the aerial data to help determine if any radioactivity above background existed within the survey area. These procedures take advantage of the empirically determined fact that although natural background radiation levels can vary by factors of two or three or more within a given survey area, the spectral shape generally remains constant. This implies that the ratio between different parts of the gamma ray energy spectrum will be essentially a constant for areas of background radiation.

Thus, consider two energy windows: one containing a photopeak from the nuclide of interest, in this case Pa-234m, and the second encompassing a background region. The background region is chosen to be free of contributions from the nuclide of interest and at a higher energy than the photopeak of interest in order to eliminate contributions from gamma rays scattered out of the photopeak. The ratio, K, of these two windows is measured over a large background area free of excess Pa-234m.

$$K = \frac{\text{(counts in source window)}}{\text{(counts in background window)}}$$

The net count rate due to excess Pa-234m in an area is then equal to:

$$\text{Net Pa-234m} = \text{(counts in source window)} - K\,\text{(counts in background window)}$$

This subtraction procedure results in a net value which averages zero except over areas containing more than average Pa-234m causing excess counts in the source window. A similar procedure can be applied to detect the presence of any gamma-emitting radionuclide. An isopleth plot was produced to show the distribution of U-238 within the survey area by monitoring the 1.001 MeV Pa-234m gamma ray. The resulting net counts, due to terrestrial sources of Pa-234m, were converted to approximate soil concentrations by applying a suitable conversion factor whose value is greatly dependent upon a variety of factors. Some of these factors are: the aerial measurement system's sensitivity to the radionuclide in question, the vertical and spatial distribution of the radionuclides in the soil, the amount of soil moisture present, the presence of large bodies of standing water, and equilibrium between the measured daughter nuclide (Pa-234m) and the parent U-238. The Pa-234m conversion factor used for this survey was derived using the U-238 depth distribution

shown in Figure 5 as well as the measured variation in background count rates in the Fernald area. The appropriate conversion was determined to be 3 pCi/g per count/second. This gives a minimum detectability of 150 pCi/g for a volume source with a 20-cm e-folding depth, 9 μCi/m^2 for a uniformly distributed surface source, and 330 mCi for an unshielded point source.

Identification of specific radionuclides responsible for any elevated exposure rate was accomplished using the acquired gamma energy spectral data. By utilizing special calibration and spectral background stripping techniques, a net gamma energy spectrum for each area of interest was produced. No sources of man-made, or man-enhanced, radiation were found outside the plant boundary. A typical gamma energy spectrum of the natural background radiation observed in the survey area is presented in Figure 7. The survey was conducted in April while the fields were being fertilized for spring planting. Fertilizer contains potassium-40 and/or the uranium isotopes which sometimes enhance the natural background in an area.

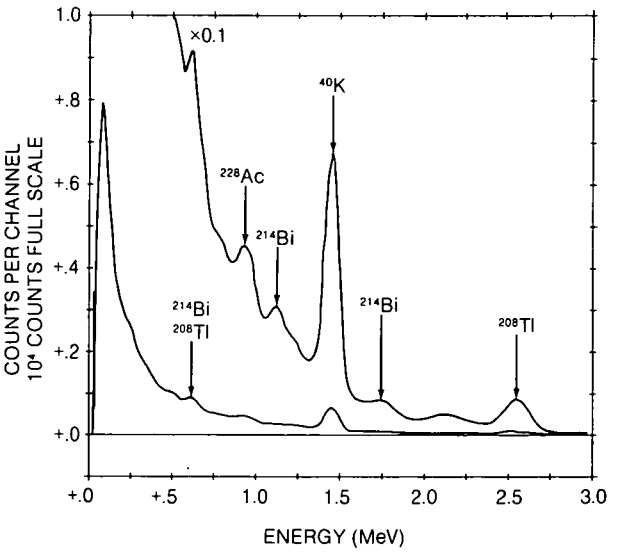


Figure 7. *TYPICAL BACKGROUND RADIATION GAMMA ENERGY SPECTRUM FOR THE AREA SURROUNDING THE FEED MATERIALS PRODUCTION CENTER*

5.0 SURVEY RESULTS AND DISCUSSIONS

5.1 Aerial Survey Results

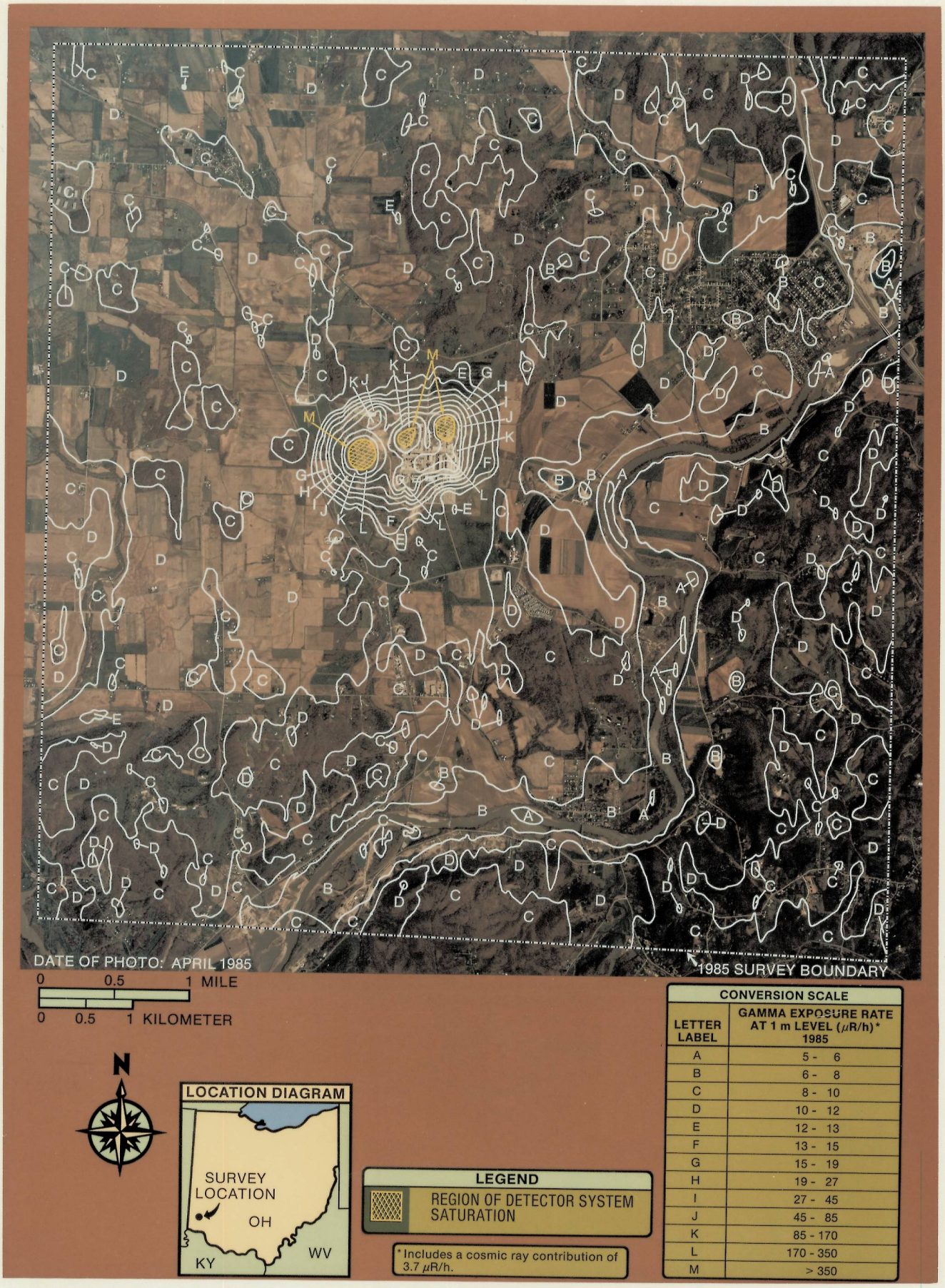
The results of the aerial radiological survey are shown in Figure 8 as exposure rate isoradiation contours. The natural background radiation levels outside the plant boundaries varied from 6 to 12 μR/h and were found to be due to varying concentrations of the naturally-occurring radioisotopes.

Radiation levels higher than background were found over and immediately adjacent to the plant. The highest radiation levels were detected directly over the site and were in excess of the 350 μR/h saturation limit for the detector system. Exposure rates above background were confined to the plant site with the exception of an area directly west of the plant. The symmetric shape of the isoexposure contours suggests that these levels are due to "shine" from the nearby storage silos rather than ground deposition. Soil samples taken in the area (Site 3 in Figure 1), while showing slightly elevated levels of separated U-238, are not sufficiently elevated to account for the measured exposure rates.

Using the Pa-234m stripping technique described in Subsection 4.3, a contour map of the survey area was generated showing just the counts due to separated U-238. This map showed no areas of elevated activity outside the plant boundaries. More precisely, no areas outside the plant boundaries were found to exceed, at the 95 percent confidence level, the minimum detectability of the aerial measuring system. This minimum detectability for Pa-234m (or U-238), dependent on a variety of factors as described above, is about 150 pCi/g.

5.2 Ground-Based Measurement Results

The results of the radionuclide analysis of the soil samples taken from the "benchmark" locations, Sites 1 and 2 in Figure 1, are given in Table 2. There are no indications that any gamma-emitting isotopes other than those reported were present in the soil samples. The concentrations of U-238 are fairly typical of values found throughout the United States. These values have been found to range from 0.5 to 4 ppm.[6] The total gamma exposure rates measured by both the ground-based and aerial techniques are also compared in Table 2 for the background benchmark sites. The soil analysis estimates and the inferred aerial results include an additional 3.7 μR/h cosmic ray contribution to allow for direct comparison with the pressurized ion chamber data. The results summarized in Table 2 are within expected agreement.



LETTER LABEL	GAMMA EXPOSURE RATE AT 1 m LEVEL (μR/h)* 1985
A	5 - 6
B	6 - 8
C	8 - 10
D	10 - 12
E	12 - 13
F	13 - 15
G	15 - 19
H	19 - 27
I	27 - 45
J	45 - 85
K	85 - 170
L	170 - 350
M	> 350

Figure 8. *1985 EXPOSURE RATE CONTOUR MAP OF THE FEED MATERIALS PRODUCTION CENTER SURVEY AREA*

Table 2. Comparison of Exposure Rates Measured on the Ground with Those Inferred From the Aerial Data[1]

Site Number	Soil Sample Analysis (Average Values)					Gamma Exposure Rate at 1 Meter (μR/h)		
	Soil Moisture (%)	U-238 (ppm)	Th-232 (ppm)	Cs-137 (pCi/g)	K-40 (pCi/g)	Soil Analysis Estimate[2]	Ion Chamber[3]	Aerial Data
1	18.4 ± 0.9	2.9 ± 0.2	9.9 ± 0.5	0.29 ± 0.05	16.1 ± 0.6	10.7 ± 0.4	10.3 ± 0.5	10.1 ± 0.7
2	10.3 ± 1.8	2.8 ± 0.2	8.0 ± 0.8	0.24 ± 0.07	15.9 ± 0.3	10.1 ± 0.6	10.1 ± 0.5	10.2 ± 0.7
		(1 - 4)	(2 - 12)	(0.2 - 0.4)	(2 - 40)		(8 -25)	

[1] The numbers given in parentheses represent a typical range of values within the United States (see Reference 6).

[2] Includes a cosmic contribution of 3.7 μR/h and a moisture correction of the form 1/1+m.

[3] Reuter-Stokes Model RSS-111, Serial No. R574.

An extensive set of additional ground samples was collected. Besides the benchmark locations used to provide ground truth for the aerial measurements, samples were taken in all areas showing anomalous radiation patterns as well as particularly sensitive locations like the local schools and environmental pathways. These sample locations (3 through 13) are shown in Figure 1 and the results are given in Table 3.

Soil samples were taken at the old incinerator site (location 10), known to have excess U-238, in order to determine the depth profile of the deposited uranium. The depth profile analysis, shown in Figure 5, indicates that the maximum deposition rate probably occurred in the past. While these data cannot be accurately fitted with a simple exponential, for purposes of computing the minimum level of detectability an e-folding distance of 20 cm was chosen. The Th-232 results given in Table 3 as concentrations versus depth for soil sample site 10 suggests that excess thorium also exists at this location.

5.3 Comparison of the 1976 and 1985 Survey Results

The results of the 1976 survey are presented in Figure 9 for comparison with the 1985 survey results shown in Figure 8. There were several important differences in the systems used for these two surveys. These include:

1. A 3-second spectral accumulation time for the old system rather than the 1-second accumulation time characteristic of the present instrumentation. Because the measurements are made from a moving platform, temporal differences translate into spacial differences. The 1-second resolution of the current system gives better ground resolution.
2. Twenty 12.7 cm × 5.1 cm (5 in. × 2 in.) cylindrical sodium iodide crystals were used in the old system rather than the present more sensitive array of eight 10.2 cm × 10.2 cm × 40.1 cm (4 in. × 4 in. × 16 in.) sodium iodide logs.
3. A computer-based steering indicator in the present system allows much more accurate adherence to the preselected flight lines than was possible in the past when the lines were flown visually.

Besides these differences in instrumentation between the two surveys, other differences include:

1. Different sized areas covered.
2. Flight lines flown in different directions.
3. No soil samples were taken in the old survey.
4. During the 1976 survey, an anomalous radon cloud was found northwest of the plant site. The area under the cloud, indicated in Figure 9 by the white hatching, was resurveyed in 1977 and found to be at background levels.
5. A systematic error of approximately 2 μR/h existed in all the aerial radiation data obtained between 1975 and 1980. The data presented in Figure 9 has been corrected for this error in order to allow a comparison to be made with the 1985 data.

Detailed comparison of the 1976 data with the 1985 data shows no significant change in any area not directly adjacent to the site. A slight decrease in exposure rate is indicated next to the site on both the east and west boundaries. This decrease appears to be real.

Table 3. Soil Sample Results

Site Number	Soil Moisture (%)	Natural U-238 (ppm)	Separated U-238 (ppm)	Th-232 (ppm)	Cs-137 (pCi/g)	K-40 (pCi/g)
3A	26.5	3.1 ± 0.1[1]	9 ± 2	8.3 ± 0.4	0.68 ± 0.04	16.9 ± 1.0
3B	19.0	3.2 ± 0.1	11 ± 2	10.0 ± 0.4	0.26 ± 0.02	17.8 ± 1.0
4	25.6 ± 1.5	3.4 ± 0.1	15 ± 3	11.1 ± 0.8	0.18 ± 0.03	14.1 ± 0.8
5	22.4 ± 0.2	3.4 ± 0.1	([2])	11.4 ± 0.9	0.26 ± 0.02	20.3 ± 1.2
6A	18.1	2.3 ± 0.1	([2])	5.1 ± 0.2	0.02 ± 0.004	11.9 ± 0.7
6B	22.9	3.1 ± 0.1	33 ± 3	8.9 ± 0.4	0.11 ± 0.09	13.4 ± 0.8
7	19.2 ± 5	2.3 ± 0.9	([2])	6 ± 3	0.01 ± 0.01	13 ± 6
8	23 ± 3	2.9 ± 0.1	([2])	6 ± 2	0.45 ± 0.02	13 ± 2
9	20 ± 6	2.4 ± 0.7	([2])	6 ± 3	0.4 ± 0.4	13 ± 2
10 (0 to 1")[3]	31.8	4.8 ± 0.2	212 ± 16	20.0 ± 0.8	0.64 ± 0.03	17.0 ± 1
10 (1" to 2")	24.5	4.9 ± 0.2	207 ± 15	21.0 ± 0.9	0.63 ± 0.03	19.0 ± 1
10 (2" to 3")	28.5	5.0 ± 0.2	208 ± 17	18.7 ± 0.8	0.98 ± 0.05	18.4 ± 1
10 (3" to 4")	23.4	4.6 ± 0.2	156 ± 12	15.8 ± 0.7	0.82 ± 0.05	17.6 ± 1
10 (4" to 5")	22.8	4.7 ± 0.2	152 ± 11	15.4 ± 0.7	0.68 ± 0.03	17.9 ± 1
10 (5" to 6")	22.4	4.3 ± 0.2	106 ± 8	14.1 ± 0.6	0.45 ± 0.03	18.2 ± 1
11	30.4	3.4 ± 0.1	14 ± 2	10.1 ± 0.5	0.79 ± 0.04	16.3 ± 0.9
12	27.7	3.1 ± 0.1	16 ± 3	9.8 ± 0.5	0.59 ± 0.04	17.4 ± 1
13	22.6	3.9 ± 0.2	10 ± 2	12.0 ± 0.5	0.31 ± 0.02	20.8 ± 1

[1] The ± indicates precision of an individual measurement or standard deviation of all values in the average, whichever is larger.

[2] Below the minimum detectable level (approximately 7 ppm).

[3] Depth profiles.

0 0.5 1 MILE

0 0.5 1 KILOMETER

N

LOCATION DIAGRAM

LEGEND

- REGION OF DETECTOR SYSTEM SATURATION
- RADON ANOMALY

* Includes a cosmic ray contribution of 3.7 μR/h.

CONVERSION SCALE

LETTER LABEL	GAMMA EXPOSURE RATE AT 1 m LEVEL (μR/h)* 1976
A	5 - 6
B	6 - 8
C	8 - 10
D	10 - 12
E	12 - 13
F	13 - 15
G	15 - 19
H	19 - 27
I	27 - 45
J	45 - 85
K	85 - 170
L	170 - 350
M	> 350

Figure 9. *1976 EXPOSURE RATE CONTOUR MAP OF THE FEED MATERIALS PRODUCTION CENTER SURVEY AREA*

APPENDIX A

SURVEY PARAMETERS

Site:	Feed Materials Production Center
Location:	Fernald, Ohio
Survey Dates:	April 24 to 27, 1985
Survey Coverage:	8 km × 8 km (5 mi × 5 mi) centered on the plant; Paddy's Run from the plant to the Miami River; the Miami River from Hamilton to the Ohio River.
Project Scientist:	G.R. Shipman
Survey Aircraft:	MBB BO-105 Helicopter-N60EG
Acquisition System:	REDAR IV
Detector Array:	Eight 10 cm × 10 cm × 41 cm NaI(Tl) logs
Lines Surveyed:	119
Survey Altitude:	45 m (150 ft)
Line Space Interval:	76 m (250 ft)
Navigation System:	URS

Data Processing:

1. Total gamma exposure rate (gross count)

   Energy Window: 0.05 to 3.05 MeV

   Conversion Factor, 1985 (cps at 45 m per μR/h): 1,115

   Conversion Factor, 1976 (cps at 91 m per μR/h): 735

   Cosmic Ray Contribution: 3.7 μR/h

2. Pa-234m count rate

   Source Window: 0.95 to 1.1 MeV

   Background Window: 1.1 to 3.05 MeV

   Conversion Factor: 3 pCi/g per cps

   Minimum Detectable Limit:

   Approximately 150 pCi/g for a volume source distributed using a 20-cm e-folding depth.

   9.2 μCi/m^2 for a uniformly distributed surface source.

   330 mCi for a point source.

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