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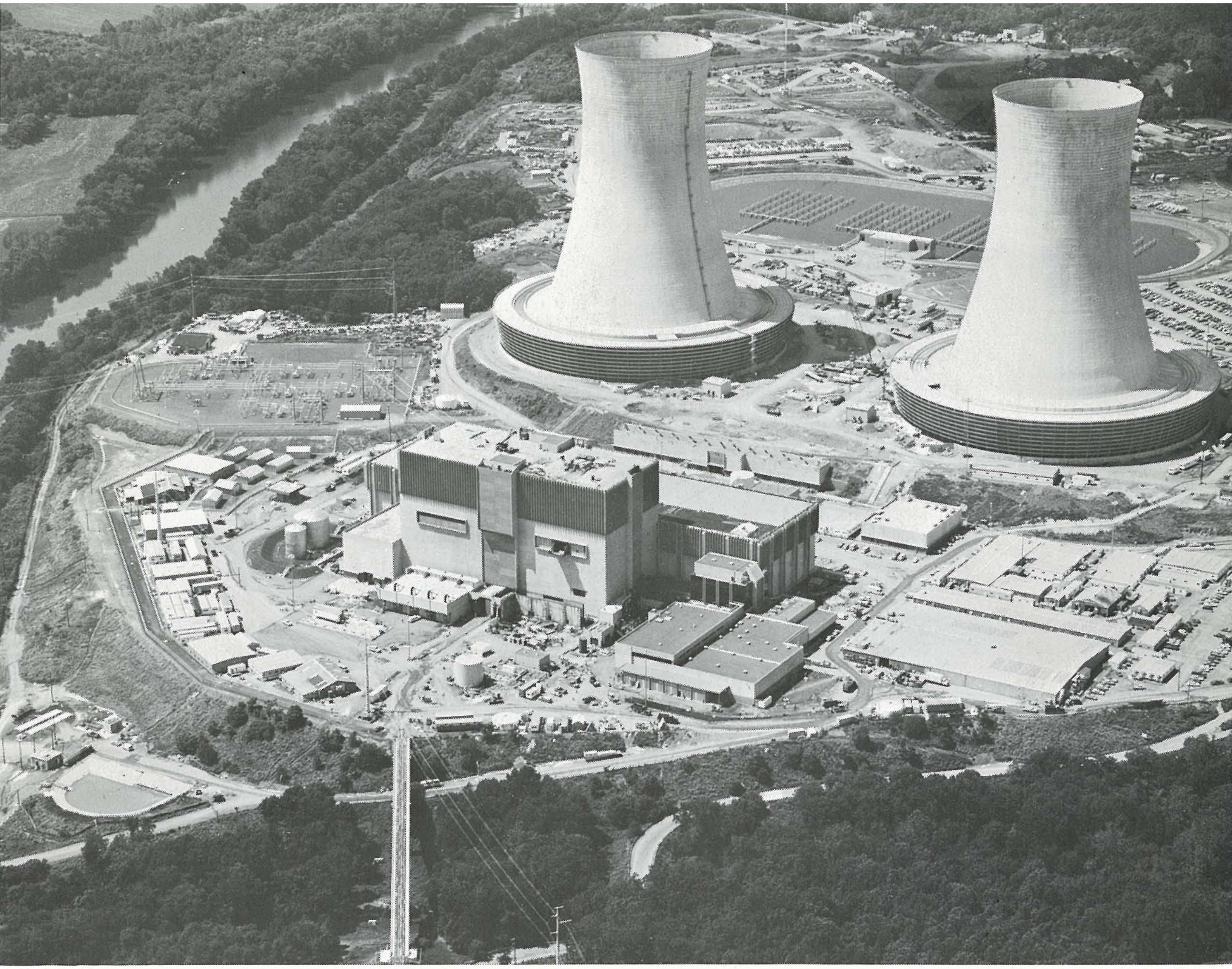

AN AERIAL RADIOLOGICAL SURVEY OF THE

LIMERICK GENERATING STATION

AND SURROUNDING AREA

POTTSTOWN, PENNSYLVANIA

DATE OF SURVEY: OCTOBER - NOVEMBER 1984

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ABSTRACT

An aerial radiological survey was conducted during the period October 15 to November 3, 1984 over a 260-square-kilometer (100-square-mile) area centered on the Limerick Generating Station in Pottstown, Pennsylvania. The survey was conducted at an altitude of 91 meters (300 feet) with line spacings of 152 meters (500 feet). Count rates were converted to exposure rates at 1 meter above ground level.

Over most of the survey area, exposure rates varied from approximately 8 to 13 microroentgens per hour (μR/h). Two areas of increased count rates were seen. One of these areas was due to increased levels of naturally occurring radium, while the second was due to the presence of cobalt-60 and cesium-137. The cobalt-60 and cesium-137 were detected over a facility that launders contaminated clothing. The presence of detectable amounts of cobalt-60 and cesium-137 at this facility was consistent with the facility's normal operations.

CONTENTS

1.0 INTRODUCTION

The United States Department of Energy (DOE) maintains a Remote Sensing Laboratory (RSL) in Las Vegas, Nevada and an extension facility in Washington, D.C. The RSL is operated for the DOE by EG&G Energy Measurements, Inc. (EG&G/EM), a contractor of the DOE. One of the major functions of the RSL is to manage an aerial surveillance program called the Aerial Measuring System (AMS).[1]

Since its inception in 1958, the AMS has continued a nationwide effort to document baseline radiological conditions surrounding energy-related sites of interest. These sites include power plants, manufacturing and processing plants, and research laboratories employing nuclear materials. At the request of federal or state agencies, and by direction of the DOE, the AMS is deployed for various aerial survey operations.

An aerial radiological survey of the Limerick Generating Station, located in Pottstown, Pennsylvania, was requested by the United States Nuclear Regulatory Commission (NRC). Located on the site are Limerick Reactors 1 and 2. Limerick 1 is a 1055-megawatt (electric) boiling water reactor. At the time of the survey, Limerick 1 had recently received a low power license and preparations were underway to load fuel and go to 5 percent power production. Limerick 2, also a 1055-megawatt (electric) boiling water reactor, was approximately 30 percent constructed at the time of the survey.[2] The purpose of this survey was to characterize the natural background radiation in the area of the station for future reference.

2.0 NATURAL BACKGROUND RADIATION

Natural background radiation originates from radioactive elements present in the earth (i.e., the terrestrial component), airborne radon, and cosmic rays entering the earth's atmosphere from space. The terrestrial gamma radiation originates primarily from the uranium decay chain, the thorium decay chain, and radioactive potassium. The doses received from the gamma rays emitted by these naturally occurring radionuclides depend on the nature of the minerals in the ground. Annual doses from the terrestrial component of background radiation are as low as 15 to 35 millirems (mrems) (2 to 4 μR/h) for the Atlantic and Gulf Coastal Plains and as high as 75 to 140 mrems (9 to 16 μR/h) on the Colorado Plateau.[3,4]

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 any particular time. This airborne radiation typically contributes from 1 to 10 percent of the natural background radiation levels.

Cosmic rays interact with the elements of the earth's atmosphere and soil to produce an additional natural source of gamma radiation. The intensity of this radiation source depends on the altitude and, to a lesser extent, on the geomagnetic latitude. In general, the cosmic ray contribution to the natural background radiation is largest at high altitudes and high latitudes. Annual doses in the United States due to cosmic rays range from about 29 mrems (3.3 μR/h) in Florida to about twice that amount in Wyoming.[4]

External radiation may also be received from radioactive elements in building materials. In structures made of stone, concrete or brick, the radiation dose is generally higher than nearby wooden buildings. Additionally, doses are dependent upon the nature of the materials utilized for road and highway construction. Thus, radiation doses due to "natural" background sources are highly variable from location to location and are dependent upon a number of factors.

3.0 SURVEY SITE DESCRIPTION

The AMS was utilized during the period of October 15 to November 3, 1984 to characterize the natural background radiation in the area of the Limerick Generating Station. The Limerick Station is located about 4 miles southeast of Pottstown, Pennsylvania in the southeastern portion of Pennsylvania, which is approximately 25 miles northwest of Philadelphia, Pennsylvania. The Station is situated on the banks of the Schuykill River. A series of ridges approximately 600 to 800 feet in elevation (altitude above sea level) lie to the north and south of the survey area. The ridges run roughly east to west.

An area of approximately 260 square kilometers (100 square miles), centered on the Limerick

Generating Station, was surveyed. A small area in the southeastern corner of the survey area was added in order to include an additional bend in the Schuykill River. It was felt that this would be a likely place for deposition of waterborne materials to occur.

4.0 SURVEY PROCEDURES AND EQUIPMENT

4.1 Aerial Measurements

Measurements of the total count rates and the energy spectrum of gamma radiation were made along 106 flight lines, which were spaced 152 meters (500 feet) apart. The gamma rays were detected by 20 thallium-activated sodium iodide, NaI(T*l*), crystals mounted on a Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter (Figure 1). Each NaI(T*l*) crystal was 12.7 cm in diameter and 5.1 cm thick (5 in. by 2 in.).

Figure 1. *MBB B0-105 HELICOPTER WITH DETECTOR PODS*

All survey flights were made at 91 meters (300 feet) above ground level and at a ground speed of 36 meters per second (70 knots). The instrumentation and equipment used for this survey are only briefly described here. A detailed description of AMS systems and procedures can be found in previously published reports.[1,5]

Scintillation pulses from 19 detectors were summed and input to the Radiation and Environmental Data Acquisition and Recorder (REDAR) system on board the aircraft. Information from a 20th tube was sent directly to the REDAR. This single detector information could be used if an area of extremely high radiation was overflown. Regions of very high activity would overload the summing amplifier's ability to respond to the individual events. The single detector also provided a convenient way of checking the quality of the data from the other 19 detectors.

The REDAR system was composed of several microprocessor-based subsystems. The control subsystem collected and formatted gamma ray spectral data and gross count data (gamma ray activity integrated over the energy range 0.04 to 3.0 MeV) from the single detector and the 19-detector array. It also collected aircraft positional data and system live time information. Records containing four 1-second data points for these parameters were stored on magnetic tape every 4 seconds. The tape subsystem consisted of a microprocessor and a dual cartridge digital recorder. Radiological data, along with selected operational parameters, were displayed on board the helicopter by the display subsystem. Two cathode-ray tubes were available for viewing these data in real time on board the helicopter.

The helicopter position over the survey site was determined by two systems: an ultrahigh frequency ranging system (URS) and a radar altimeter. The URS consisted of two remotely located transponders and an on-board interrogator. The on-board interrogator used the transit time of ultrahigh frequency pulses from the transponders to obtain the distance from the aircraft to each remote unit. This information was then used to precisely determine the helicopter's position in the survey area. The radar altimeter similarly measured the time lag for the return of a pulsed signal and converted this delay to aircraft altitude above ground level. Position and altitude information were also processed in real time by the steering microprocessor. These data provided steering indications to the pilot for flying the predetermined flight lines at the desired altitude.

Magnetic tapes with recorded data from the aerial radiological survey were processed after each flight with the Radiation and Environmental Data Analyzer and Computer (REDAC) system. This computerized data analysis system was built into an Airstream motor home which had been modified to carry the REDAC.

The REDAC system consisted primarily of a Data General Eclipse S-280 computer and peripherals. An extensive inventory of software routines was available for data processing. A preliminary analysis of the data was done in the field prior to completion of the survey to determine data quality.

A final, extensive analysis was later performed in the Washington, D.C. office of the Remote Sensing Laboratory.

4.2 Ground-Based Measurements

Exposure rate values were measured with a pressurized ionization chamber located 1 meter above the ground and by laboratory measurements of soil samples collected within the survey area. Ground samples were collected during the aerial survey. The soil samples were analyzed and the results tabulated for this report by scientists at EG&G/EM's Santa Barbara Laboratory. Systems and procedures for soil sample data collection and analysis are outlined in a separate publication.[6] The ground sampling sites for this survey are shown in Figure 2.

5.0 RESULTS

5.1 Gross Count Data Analysis

An exposure rate contour map of the area surrounding the Limerick Generating Station is shown in Figure 2. The exposure rate values were derived from the gross count rates due to terrestrial gamma ray emitters. The results reported here have been converted to exposure rates at 1 meter above the ground by application of a predetermined conversion factor. This factor assumes a uniformly distributed source covering an area which is large compared with the field-of-view of the detector.

5.2 Man-Made Gross Count Analysis

A second data analysis was performed in which the low energy portion of the spectrum was compared with the high energy portion of the spectrum. This is referred to as the man-made gross count (MMGC) rate algorithm. The MMGC rate algorithm is designed to detect the presence of changes in spectral shape. Large changes in gross counting rates from natural radiation usually produce only small changes in spectral shape because the natural contributors to the background change in approximately constant ratios. The MMGC rate algorithm searches for counts in the lower energy portion of the spectrum in excess of those predicted on the premise that these counts should be a constant ratio to the counts in the upper energy portion of the spectrum. The spectrum is divided at 1.4 MeV. Above this energy, most long-lived, man-made nuclides do not emit gamma rays. Analytically, the algorithm can be expressed as:

$$\mathrm{MMGC} = \sum_{E=.04}^{1.39} (\mathrm{counts})_E - K \sum_{E=1.4}^{3.0} (\mathrm{counts})_E$$

where K is a constant chosen to normalize the upper energy window to about the same value as the lower energy window for areas containing normal background radiation.

5.3 Survey Results

5.3.1 Survey Data

Over most of the survey area, exposure rates between 8 and 13 μR/h were observed (Figure 2). The ridge to the north of the Station had exposure rates between 5 and 10 μR/h. A typical gamma ray energy spectrum for these regions is shown in Figure 3. Two locations with elevated exposures were seen in the survey area. Corresponding areas of high values were also seen in the MMGC data. The first area, which was located about one-half mile southeast of the Station, had exposure rate levels between 17 and 23 μR/h. A spectrum for this area (Figure 4) from which background was subtracted indicated the source to be radium, a naturally occurring radionuclide. This elevated count area overlies a transformer site for the Station. The radium is most likely contained in the crushed stone there.

The second area, located approximately 3 miles southeast of the Station, contained cobalt-60 and cesium-137. A background-subtracted spectrum for this area is shown in Figure 5. If it is assumed that the helicopter flew directly over a localized source of cobalt-60, the source strength corresponding to the measured count rate is calculated to be 7 mCi. By assuming the source to be midway between the flight lines (about 76 meters or 250 feet), the source strength would be about 14 mCi.[7] The NRC Region I office, located in King of Prussia, Pennsylvania, was notified of the location of the source of cobalt-60 and cesium-137. They found the area to correspond to a laundry facility that launders clothing which has been contaminated with radioactive materials.[8]

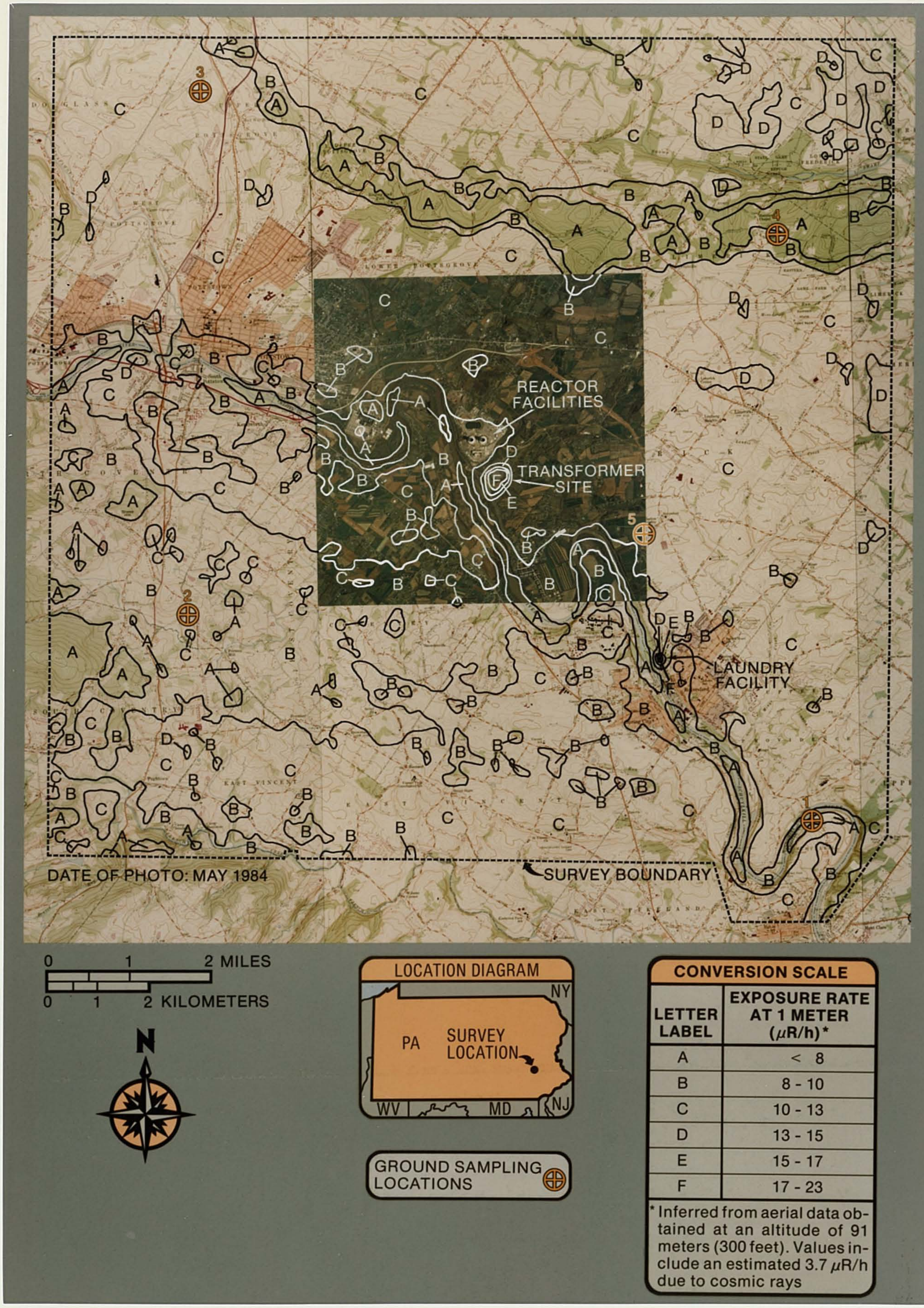

Figure 2. *GROUND SAMPLING LOCATIONS AND EXPOSURE RATE CONTOUR MAP OF THE LIMERICK GENERATING STATION FOR THE OCTOBER - NOVEMBER 1984 SURVEY*

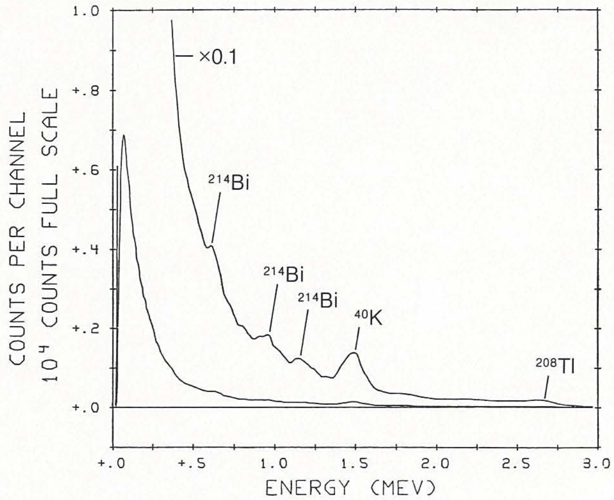

Figure 3. *TYPICAL BACKGROUND GAMMA RAY ENERGY SPECTRUM FOR THE SURVEY AREA*

5.3.2 Comparison of Survey Data With Ground Samples

In order to determine the accuracy of these results, the aerial exposure rate data were compared with measurements made on the ground (Table 1). Gamma ray exposure rates were not measured for ground sampling site 1. For the remaining four sites, an excellent agreement with the aerial data is seen.

6.0 CONCLUSIONS

A 260-square-kilometer (100-square-mile) area centered on the Limerick Generating Station was radiologically surveyed utilizing the AMS. Two regions of elevated count rates were seen. One region was determined to be due to naturally occurring radium and the second was determined to be due to cobalt-60 and cesium-137. Average exposure rates at 1 meter above ground level varied between 8 and 13 μR/h. A ridge to the north of the Limerick Station had exposure rates lower (5 to 10 μR/h) than the average for the survey area.

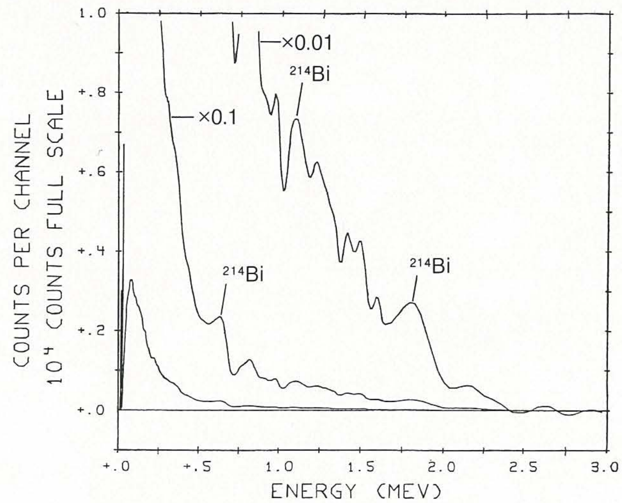

Figure 4. *BACKGROUND-SUBTRACTED GAMMA RAY ENERGY SPECTRUM COLLECTED OVER A TRANSFORMER SITE LOCATED NEAR THE LIMERICK GENERATING STATION*

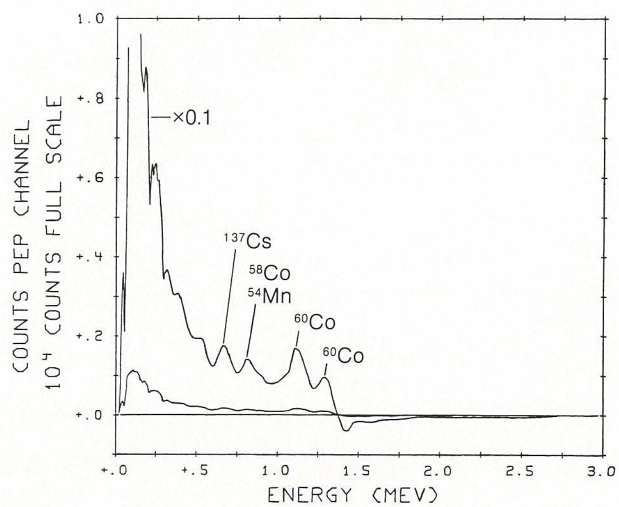

Figure 5. *BACKGROUND-SUBTRACTED GAMMA RAY ENERGY SPECTRUM COLLECTED OVER THE LAUNDRY FACILITY CONTAINING COBALT-60*

Table 1. Comparison of Ground-Based and Aerial Measurement Results				
Ground Sampling Location [1]	Soil Moisture (%)	Exposure Rate (μR/h at 1 Meter Above Ground Level)		
		Soil Analysis [2]	Ion Chamber [3]	Inferred Aerial Data [2]
1	18.9	([4])	([4])	5 - 8
2	19	9.7	9.5	8 - 10
3	21	12.1	11.1	10 - 13
4	22	9.3	9.5	8 - 10
5	19	10.7	10.3	10 - 13

[1] See Figure 2

[2] Includes a cosmic ray contribution of 3.7 μR/h.

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

[4] Spot analysis of river bank soil.

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