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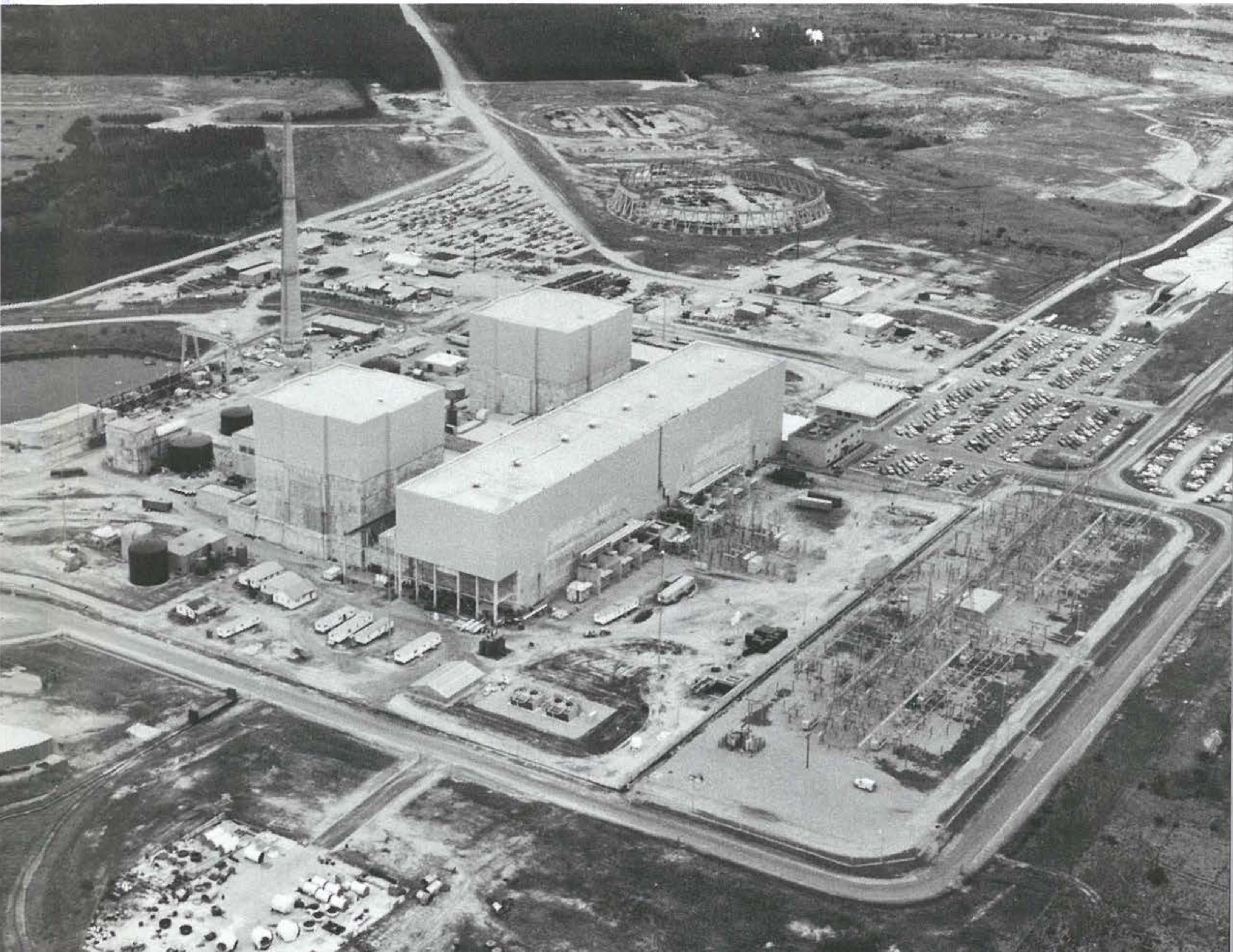

AN AERIAL RADIOLOGICAL SURVEY OF THE

BRUNSWICK STEAM ELECTRIC PLANT

AND SURROUNDING AREA

SOUTHPORT, NORTH CAROLINA

DATE OF SURVEY: MARCH 1980

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ABSTRACT

An aerial radiological survey was conducted from 15 to 20 March 1980 over the two-unit Brunswick Steam Electric Plant near Southport, North Carolina. The survey covered a 170-square-kilometer area centered on the plant. Radiological data were collected by flying along north-south lines spaced 152 meters (500 feet) apart at an altitude of 91 meters (300 feet) above ground level. Count rates obtained from the aerial platform were converted to exposure rates at 1 meter above the ground. Exposure rates over most of the area ranged between 5 and 9 microroentgens per hour (μR/h). Elevated exposure rates, up to 2400 μR/h, were detected over the plant site due to the presence of cobalt-58 and cobalt-60. The reported exposure rate values include an estimated cosmic ray contribution of 4 μR/h but do not include any contribution from airborne radionuclides. Airborne krypton-85 was detected in a plume when flying flight lines in the immediate vicinity downwind of the plant. The maximum concentration of airborne krypton-85 detected was approximately 200 picocuries per liter.

Ground-based measurements made during the same time period were compared to the aerial data. Ion chamber readings and soil samples were taken at five separate locations within the survey area. Exposure rate values obtained from these measurements were consistent with those obtained from the aerial data.

CONTENTS

1.0 INTRODUCTION

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

Since its inception in 1958, the AMS has continued a nationwide effort to document baseline radiological conditions surrounding energy-related sites of interest, including nuclear power plants, manufacturing and processing plants, and research laboratories employing nuclear materials.[1] The AMS is deployed for various aerial survey operations at the request of federal or state agencies, and by direction of the DOE.

The aerial radiological survey of the Brunswick Steam Electric Plant and surrounding area near Southport, North Carolina, was requested by the U.S. Nuclear Regulatory Commission. Two 800-megawatt electric (MWe) boiling water reactors have been in operation at the site since 1976. The purpose of the survey was to characterize the natural background radiation in the surveyed area.

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 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) (less than 5 microroentgens per hour, 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.

One member of both the uranium and thorium radioactive decay chains is an isotope of radon, a noble gas, which can both diffuse through the soil and travel through the air to other locations. Therefore, the level of airborne radiation due to these radon isotopes and their daughter products at any specific location depends on a variety of factors, including meteorological conditions, the mineral content of the soil, and soil permeability. Typically, airborne radiation contributes between 1 and 10 percent of the natural background 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 natural background radiation is largest at high altitudes and high latitudes. Annual doses in the United States due to cosmic rays range from about 28 mrems (3.2 μR/h) in Florida to about twice that in Wyoming.

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 in 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 depend upon a number of factors.

3.0 SURVEY SITE DESCRIPTION

To characterize the natural background radiation in the area surrounding the Brunswick Steam Electric Plant, the AMS was utilized from 15 to 20 March 1980 to survey a 170-square-kilometer area near Southport, North Carolina. The two-unit Brunswick Steam Electric Plant (operated by the Carolina Power and Light Company) was at the center of the survey area. During the survey period, Unit No. 1 was operational and Unit No. 2 was shut down for refueling. The plant is located approximately 3 km from the west bank of the Cape Fear River, 4 km north of Southport. The survey area is shown in Figure 1.

4.0 SURVEY EQUIPMENT AND PROCEDURES

4.1 Aerial Measurements

Measurements of both the total count rate and energy spectrum of gamma radiation were made during the aerial survey. These measurements

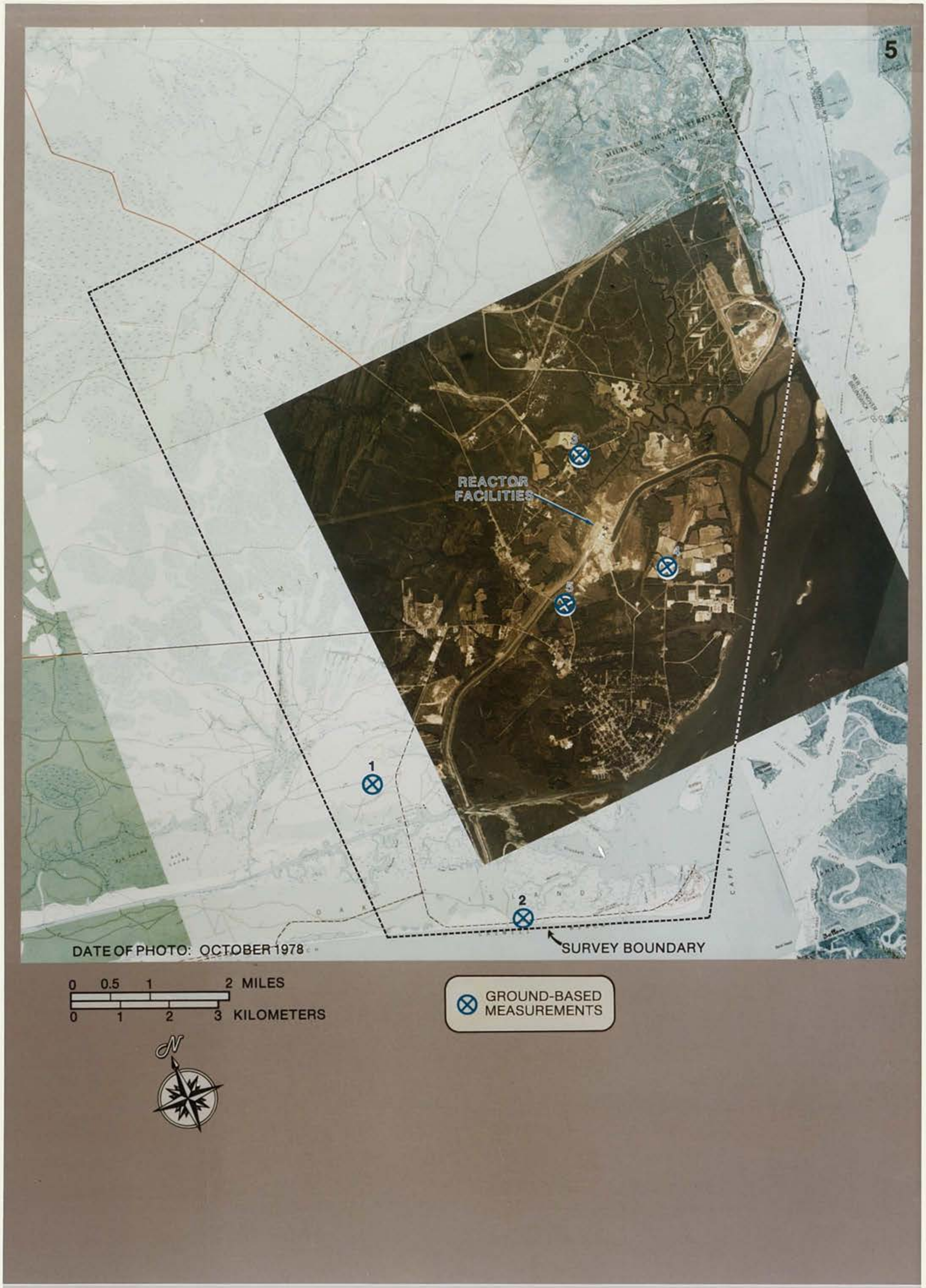


Figure 1. *AERIAL SURVEY BOUNDARIES SUPERIMPOSED ON AN AERIAL PHOTO AND USGS MAP OF THE AREA SURROUNDING THE BRUNSWICK STEAM ELECTRIC PLANT. Also shown are the locations of the ground sampling points.*

were made along 85 flight lines spaced 152 meters (500 feet) apart. Twenty thallium-activated sodium iodide [NaI(Tl)] crystals, mounted on a Hughes H-500 helicopter (Figure 2), detected the gamma rays. The helicopter was flown at an altitude of 91 meters (300 feet) above ground level at a ground speed of 30 meters per second (60 knots). Each NaI(Tl) crystal was 12.5 cm in diameter and 5 cm thick. The instrumentation and equipment used on this survey are described briefly here. A detailed description of AMS systems and procedures can be found in a previous report.[2]

Figure 2. *HUGHES H-500 HELICOPTER WITH DETECTOR PODS*

Scintillation pulses from each detector were summed and input to the Radiation and Environmental Data Acquisition and Recorder (REDAR) system on board the aircraft. These pulses were first fed to an analog-to-digital converter, then fanned out to: (1) a 300-channel analyzer for energy spectral information (0.05 to 3.05 MeV); (2) a gross count register for determining the rate of gamma ray detection integrated over energy; and (3) five single-channel analyzers set up to monitor gamma rays with energies of particular interest.

These data, along with position and altitude at which the measurement was made, were stored on 9-track magnetic tape for later analysis. The altitude information was obtained from an on-board radar altimeter which gives the actual height above the ground accurate to approximately ±2 meters. Positional information was derived from a microwave ranging system (MRS) consisting of two remotely located transponders and an on-board interrogator. The on-board interrogator used the transit time of a microwave pulse to obtain the distance from the aircraft to each remote unit. The position information was also processed in real time on board the aircraft to provide steering information to the pilot for flying predetermined flight lines.

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 a 5-ton step van. The interior of this van is shown in Figure 3. The REDAC system consisted primarily of a Data General NOVA 840 computer and peripherals. An extensive inventory of software routines was available for data processing.

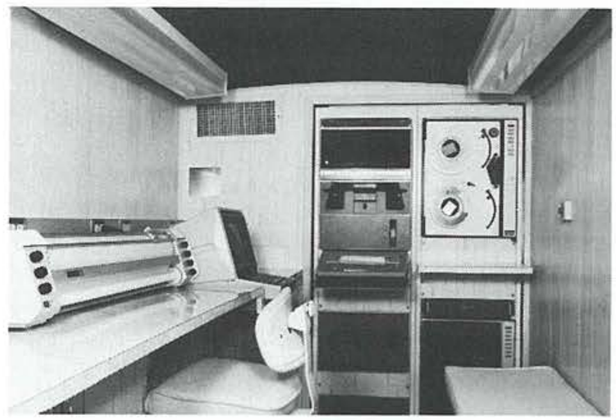


Figure 3. *MOBILE DATA PROCESSING LABORATORY*

4.2 Ground-Based Measurements

Soil samples were collected and exposure rate values measured at five locations within the survey area. Ground sampling was done during the same time period the aerial survey was conducted. The soil samples were analyzed and 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.[3] The ground sampling sites for the survey are shown in Figure 1.

5.0 RESULTS

5.1 Airborne Radiation (Plume)

In addition to the terrestrial radioisotopes, a plume of radioactive gas was detected in all aerial data taken downwind of the plant. Krypton-85 was identified as the source of this airborne radiation. To develop a radiation contour map describing the terrestrial radioisotope distribution, this airborne component had to be "stripped" from the data.

A gamma ray energy spectrum representative of the plume data is shown in Figure 4. The gamma rays from the terrestrial radioisotopes, cosmic rays, and airborne radon have been subtracted from this spectrum. The net result is characteristic of krypton-85, a noble gas fission product, which emits a gamma ray with an energy of 0.514 MeV. The maximum concentration of krypton-85 detected was approximately 200 picocuries per liter.

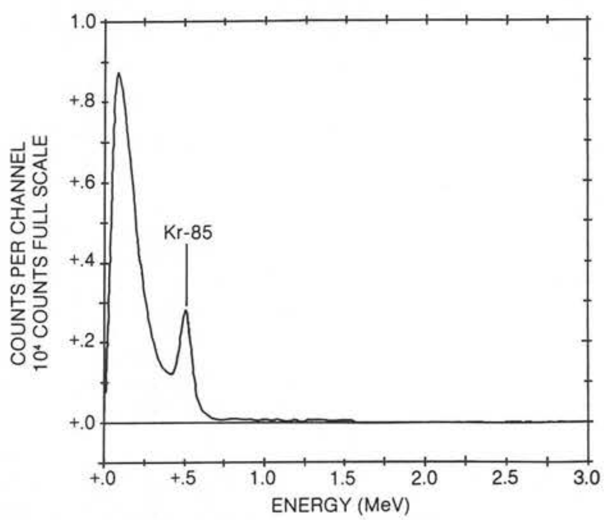


Figure 4. *GAMMA RAY ENERGY SPECTRUM TYPICAL OF THE PLUME DATA*

5.2 Terrestrial Radiation Distribution

Due to the plume of krypton-85, the gross gamma count rate downwind of the plant was not representative of the terrestrial radiation distribution. A gamma ray energy spectrum typical of the natural background radiation in the survey area is shown in Figure 5. Noted on the figure are the radioisotopes which emit gamma rays with energies corresponding to peaks in the spectrum. As illustrated in the figure, gamma rays characteristic of the uranium decay chain, the thorium decay chain, and potassium-40 are included in the energy "window" from 0.75 to 3.00 MeV. This energy window is unaffected by the gamma rays emitted by krypton-85 (see Figure 4). Thus, the multichannel spectral data corresponding to this energy window were utilized to produce an exposure rate contour map.

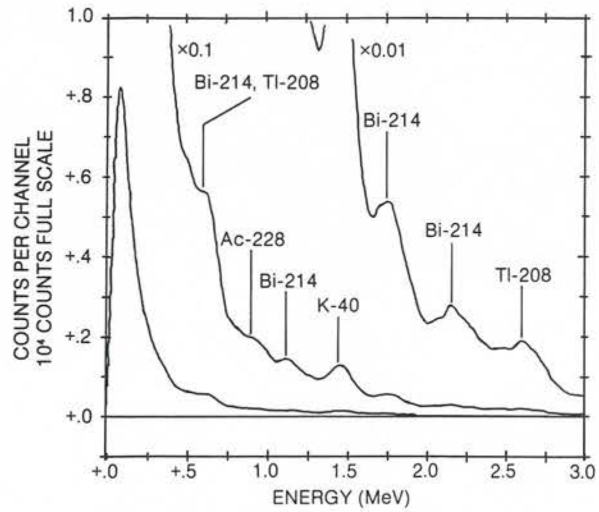
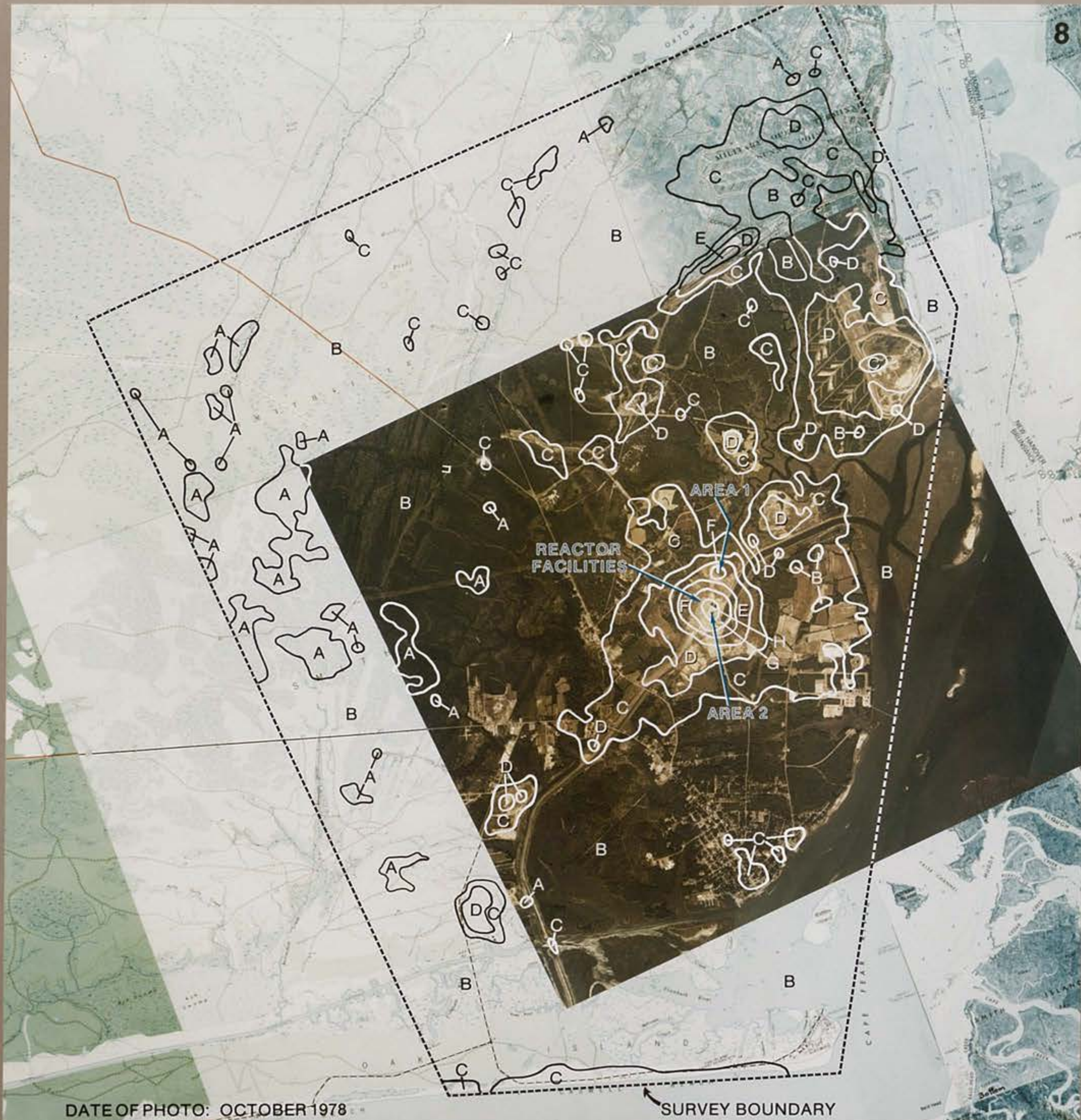


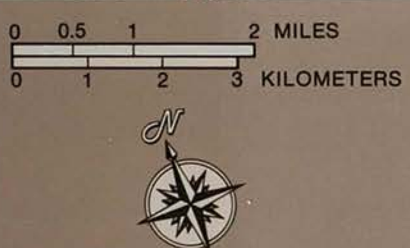
Figure 5. *GAMMA RAY ENERGY SPECTRUM TYPICAL OF THE NATURAL BACKGROUND RADIATION IN THE AREA SURROUNDING THE BRUNSWICK STEAM ELECTRIC PLANT*

The airborne radon and cosmic ray contributions to the count rate in this energy window were removed by subtracting the count rate measured over the Cape Fear River, approximately 5 km from the plant. Any contribution to these "water line" measurements from radioisotopes on the ground was negligible. The resulting net count rates of terrestrial origin were converted to approximate exposure rates at 1 meter above ground level by applying a conversion factor of 40 counts per second per μR/h. This factor was derived from many measurements made over areas with known concentrations of naturally occurring radioisotopes. An estimated cosmic ray contribution of 4 μR/h was then added to produce the total exposure rate at 1 meter.

An exposure rate contour map of the area surrounding the Brunswick Steam Electric Plant is shown in Figure 6. The exposure rates over most of the survey area were between 5 and 9 μR/h. The lower exposure rates observed over much of the western portion of the survey area are due to the swamps and creeks there. Standing water in those low-lying areas shielded the gamma radiation emitted by the terrestrial radioisotopes.

Elevated exposure rates were found in several locations within the survey boundaries. Exposure rates of 9 to 20 μR/h approximately 6 km northeast of the plant were determined to be due to higher than average concentrations of thorium and





CONVERSION SCALE	
LETTER LABEL	GAMMA RAY EXPOSURE RATE AT 1 m AGL (μR/h)*
A	< 5
B	5 - 7
C	7 - 9
D	9 - 12
E	12 - 20
F	20 - 60
G	60 - 100
H	> 100**

* Averaged over detector field-of-view at 91 meters altitude. Includes cosmic ray contribution of 4.0 μR/h.

** The maximum exposure rate, inferred from the largest measured count rate, was 2400 μR/h.

Figure 6. *EXPOSURE RATE CONTOUR MAP SUPERIMPOSED ON AN AERIAL PHOTO AND USGS MAP OF THE AREA SURROUNDING THE BRUNSWICK STEAM ELECTRIC PLANT*

potassium. Increased radiation levels were evident in two locations over the plant site (labeled Areas 1 and 2 in Figure 6). A gamma ray energy spectrum taken from the data corresponding to Area 1 in Figure 6 is shown in Figure 7. This background-subtracted spectrum is characteristic of cobalt-58 and cobalt-60 Both are commonly found in structural materials exposed to neutron radiation.[4] The spectra from Area 2 were also characteristic of the same cobalt isotopes. At this location, however, the energy peaks were not well resolved, indicating that the source of radiation there was more heavily shielded than in Area 1.

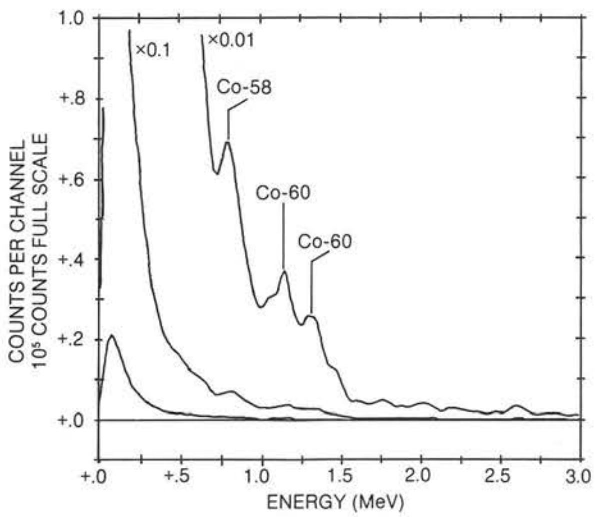


Figure 7. *GAMMA RAY ENERGY SPECTRUM OBSERVED OVER AREA 1 IN FIGURE 6*

Gross count data were analyzed to determine if man-made radioisotopes (other than krypton-85) that emit gamma rays with energies less than 0.75 MeV were present in the survey area. A contour map similar to that shown in Figure 6 was constructed using the data corresponding to the energy range 0.05 to 3.00 MeV. Due to the presence of the plume and wind shifts from flight to flight, there were discontinuities in these data between the end of one flight and the beginning of the next. All increased radiation levels found in this analysis but not evident in Figure 6 were due to airborne krypton-85.

5.3 Ground-Based Measurements

The results of the soil sample analysis are given in Table 1. Table 1 also lists the exposure rate values obtained from ion chamber measurements at each ground sampling location and the values obtained from the aerial measurements. A major contribution to any discrepancy between ground and aerial survey results is that each aerial measurement represents an average exposure rate over a much broader area than a ground measurement covers.

6.0 SUMMARY AND CONCLUSIONS

An aerial radiological survey was conducted in March 1980 over a 170-square-kilometer area centered on the two-unit Brunswick Steam Electric Plant. A plume of radioactive krypton-85 was detected in all data taken downwind of the plant. The maximum concentration of krypton-85 detected was approximately 200 picocuries per liter. The effects of the plume were eliminated from the aerial data to determine the terrestrial radiation distribution. Elevated exposure rates were detected over the plant site due to two localized sources, one directly over the plant buildings and the other approximately 600 meters to the northeast of the buildings. In both cases, the elevated exposure rates were due to cobalt-58 and cobalt-60. The spectral data taken directly over the plant building indicate that the source of radiation was shielded.

Exposure rates due to terrestrial isotopes in the rest of the survey area generally ranged between 5 and 9 μR/h The values for the western portion of the survey area were relatively low (4 to 7 μR/h) due to low-lying areas containing swamps and creeks. All radioisotopes detected off-site were typical natural background emitters. Ground-based measurement results from five locations within the survey area were consistent with the aerial data.

Table 1. Comparison of Aerial and Ground-Based Measurement Results

Location Number[1]	Exposure Rate (μR/h)		
	Ion Chamber[2]	Soil Sample Analysis[3]	Aerial Platform[3]
1	4.9	5.1	5 - 7
2	9.4	7.0	7 - 9
3	5.4	6.0	7 - 9
4	6.4	7.8	7 - 9
5	5.7	6.9	7 - 9

[1] Refer to Figure 1.

[2] Reuter-Stokes Model RS-111, Serial No. R3588.

[3] Includes a cosmic ray contribution of 4.0 μR/h.

REFERENCES

1. Jobst J.E. 1979. "The Aerial Measuring Systems Program." *Nuclear Safety,* March/April 1979, 20:136-147.

2. Boyns, P.K. 1976. *The Aerial Radiological Measuring Systems (ARMS): Systems, Procedures and Sensitivity.* Report No. EGG-1181-1619. Las Vegas, NV: EG&G/EM.

3. Mohr, R.; Fritzsche, A.; and Franks, L. 1976. *Ground Survey Procedures.* Report No. EGG-1183-2339. Santa Barbara, CA: EG&G/EM.

4. Glasstone, S.; and Jordan, W.H. 1980. *Nuclear Power and its Environmental Effects.* LaGrange Park, IL: American Nuclear Society.

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