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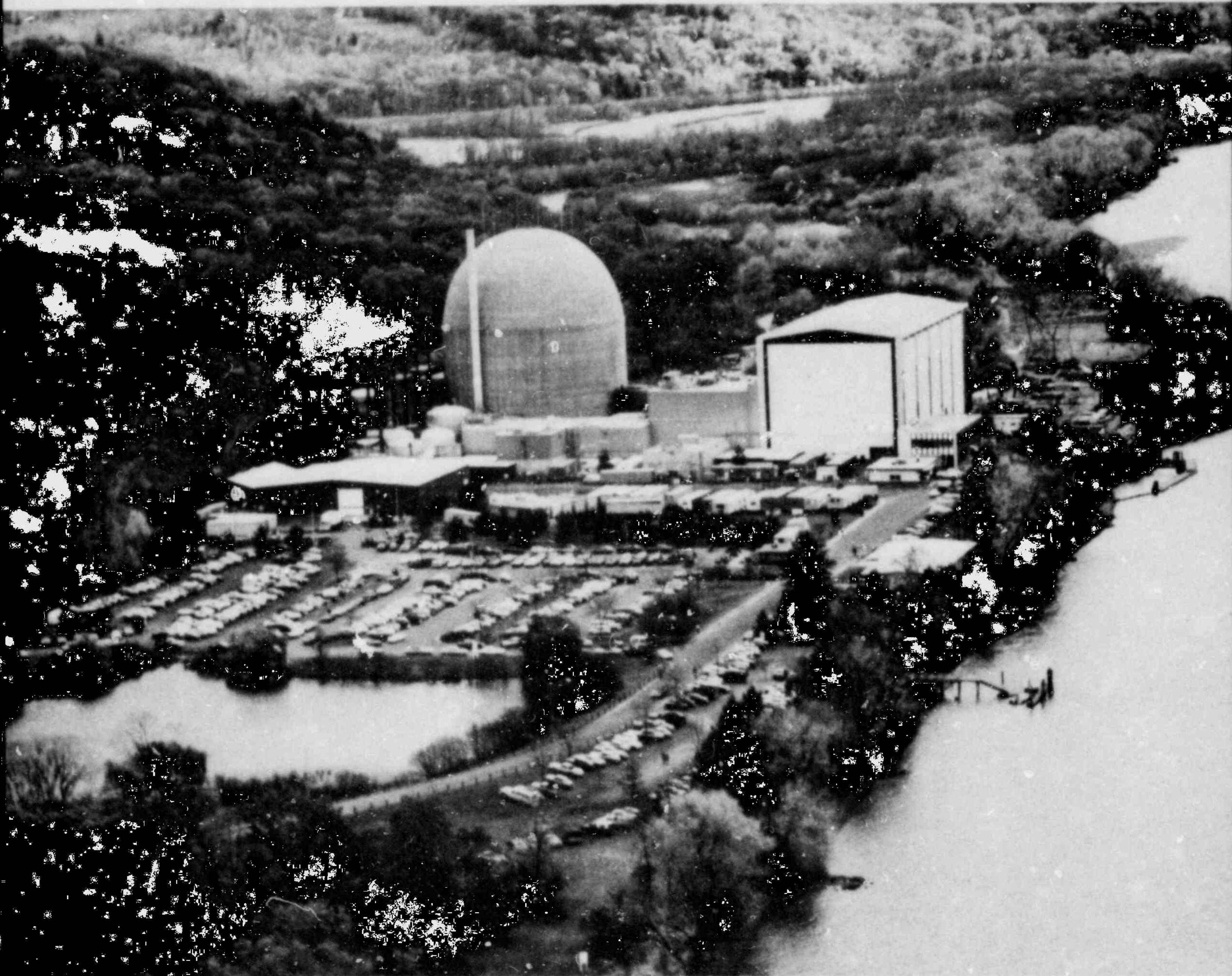

AN AERIAL RADIOLOGICAL SURVEY OF THE

# HADDAM NECK PLANT

AND SURROUNDING AREA

HADDAM NECK, CONNECTICUT

DATE OF SURVEY: OCTOBER 1981

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## ABSTRACT

An aerial radiological survey was conducted over the Haddam Neck Plant near Haddam Neck, Connecticut. The survey, conducted from 15 to 22 October 1981, covered a 108-square-kilometer area centered on the plant. Radiological data were collected by flying at an altitude of 91 meters (300 feet) along lines oriented northeast-southwest and spaced 150 meters apart. Count rates obtained from the aerial platform were converted to exposure rates at 1 meter above the ground. The resulting exposure rates over most of the survey area were between 6 and 12 microroentgens per hour (μR/h). Elevated exposure rates, up to 900 μR/h, were detected directly over the plant 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.

Ground-based measurements made during the same time period were compared to the aerial survey results. Ion chamber readings and soil samples were taken from a location within the aerial survey boundaries. Exposure rate values obtained from these measurement techniques were in agreement with those obtained from the aerial data.

The data were also in agreement with those obtained from an aerial radiological survey conducted during August 1969. Comparison of the results indicated that no changes in the radiological characteristics of the 1981 survey area were detectable outside the plant boundaries.

# 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 the Energy Measurements Group of EG&G, an independent contractor. One of the major functions of the RSL is to manage an aerial surveillance program called the Aerial Measuring Systems (AMS).

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.[1] At the request of federal or state agencies, and by direction of the DOE, the AMS is deployed for various aerial survey operations.

The aerial radiological survey of the Haddam Neck Plant and surrounding area near Haddam Neck, Connecticut, was requested by the U.S. Nuclear Regulatory Commission. A 575-megawatt (electric) pressurized water reactor has been in operation at the site since 1968. A similar aerial survey was conducted during August 1969.[2] The purpose of the present survey was to characterize the natural background radiation in the survey area. In addition, it was desired to determine if there had been detectable changes in the radiological characteristics of the area during the intervening period between surveys.

## 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 from 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 $\mu$R/h) for the Atlantic and Gulf Coastal Plains and as high as 75 to 140 mrems (9 to 16 $\mu$R/h) on the Colorado Plateau.[3,4]

One member of each of the uranium and thorium decay chains is radon, a noble gas. This radioisotope can both diffuse through the soil and be transported in the air to other locations. Therefore, the level of airborne radiation, due to radon and its daughter products, at any specific location depends on a variety of factors including meteorological conditions, 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 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 $\mu$R/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 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 are dependent upon a number of factors.

## 3.0 SURVEY SITE DESCRIPTION

In order to characterize the natural background radiation in the area surrounding the Haddam Neck Plant, the AMS was utilized during the period 15 to 22 October 1981 to survey a 108-square-kilometer area near Haddam Neck, Connecticut. The Haddam Neck Plant, operated by the Connecticut Yankee Atomic Power Company, was at the center of the survey area. The plant is located on the east bank of the Connecticut River, approximately 32 kilometers southeast of Hartford. The reactor was shut down during the period of the aerial survey.

# 4.0 SURVEY PROCEDURES AND EQUIPMENT

## 4.1 Aerial Measurements

Measurements of the total count rate and energy spectrum of gamma radiation were made along 64 flight lines spaced 150 meters apart (Figure 1). Twenty thallium activated sodium iodide, NaI (T*l*), crystals mounted on a Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter (Figure 2) detected gamma rays while flying at an altitude of 91 meters (300 feet) above ground level and a ground speed of 36 meters per second (70 knots). Each NaI (T*l*) crystal was 12.5 cm in diameter and 5 cm thick. 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 each detector were summed and input to the Radiation and Environmental Data Acquisition and Recorder (REDAR) system on-board the aircraft. The REDAR system was composed of several microprocessor-based subsystems. The control subsystem collected and formatted gamma ray spectral data, gross count data (gamma ray activity integrated over the energy range 0.04 to 3.0 MeV), 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.

The helicopter position was established with two systems: a microwave ranging system (MRS) and a radar altimeter. The MRS consisted 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 radar altimeter similarly measured the time lag for the return of a pulsed signal and converted this 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 a five-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.

## 4.2 Ground-Based Measurements

Exposure rate values were measured with an ionization chamber located 1 meter above the ground and soil samples collected at one location within the survey area. Ground sampling was done during the same time period that the aerial survey was conducted. The soil samples were analyzed and results tabulated for this report by scientists at EG&G's Santa Barbara Laboratory. Systems and procedures for soil sample data collection and analysis are outlined in a separate publication.[6] The ground sampling site for this survey is shown in Figure 1.

# 5.0 RESULTS

## 5.1 1981 Survey Results

An exposure rate contour map of the area surrounding the Haddam Neck Plant is shown in Figure 4. The exposure rate values were derived from the gross count rates due to terrestrial gamma ray emitters. The airborne radon, cosmic ray, and aircraft background contributions were removed from these count rates by subtracting the count rate measured over the Connecticut River, approximately 10 km southeast of 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 the ground level by applying a conversion factor of 740 counts per second per $\mu$R/h. This factor was derived from many measurements made over areas with known concentrations of naturally occurring radioisotopes. An estimated cosmic ray

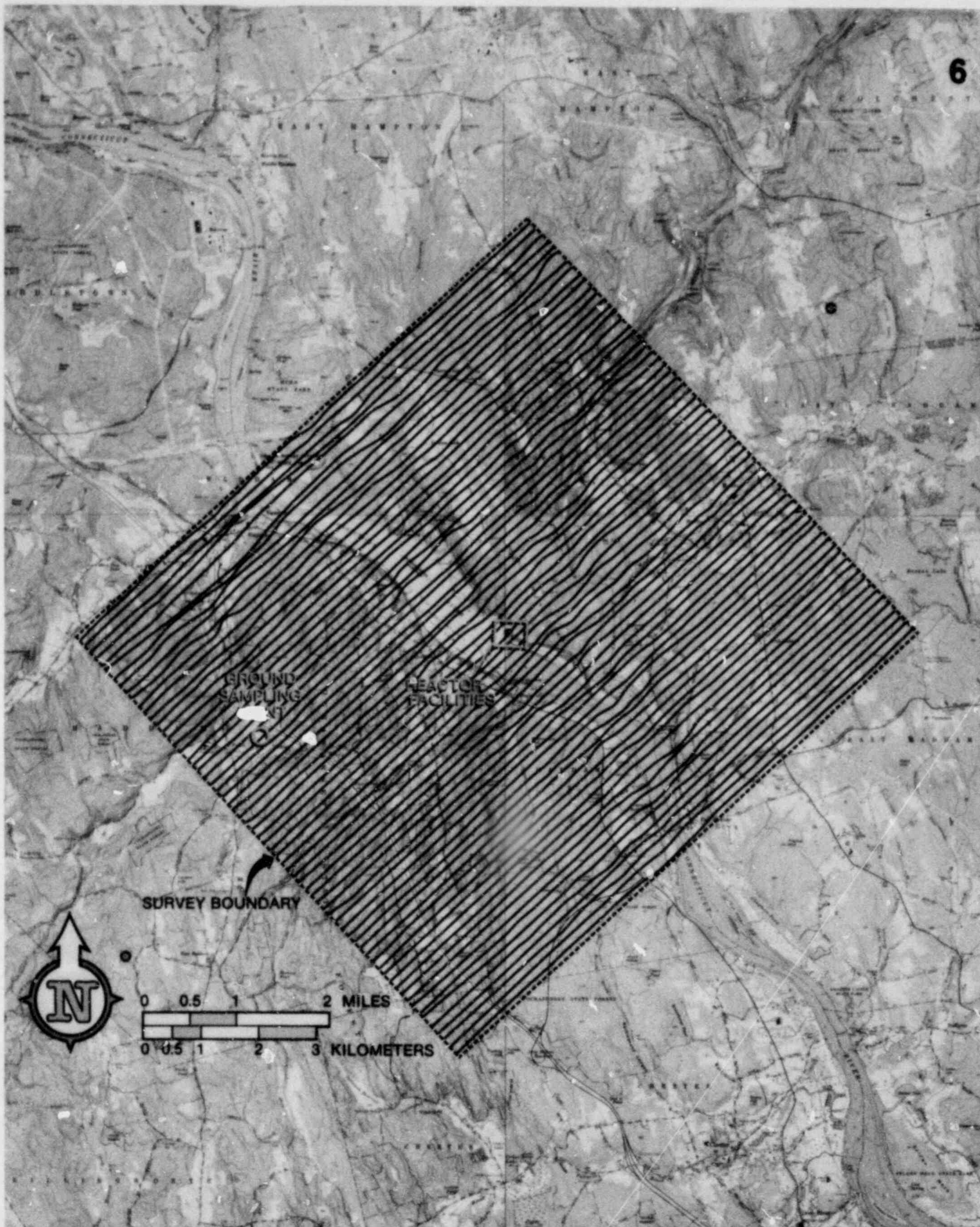


**Figure 1.** *FLIGHT LINES AND AERIAL SURVEY BOUNDARIES SUPERIMPOSED ON A USGS MAP OF THE AREA SURROUNDING THE HADDAM NECK PLANT*

**Figure 2.** *MBB BO-105 HELICOPTER WITH DETECTOR PODS*

contribution of 4 $\mu$R/h was then added to produce the total exposure rate at 1 meter minus any contribution from airborne radionuclides.

The exposure rates over most of the survey area were between 6 and 12 $\mu$R/h. Higher exposure rates east of the river (10 to 12 $\mu$R/h) are due to increased concentrations of thorium and potassium. Lower exposure rates west of the river (6 to 8 $\mu$R/h) occur over locations with below average concentrations of these same radioisotopes. Regions such as these are commonly encountered throughout the United States. A gamma ray energy spectrum typical of the background radiation present within the survey boundary is shown in Figure 5. The peaks in the spectrum occur at energies characteristic of the gamma rays emitted by naturally occurring radioisotopes, i.e., uranium and thorium decay chain members and potassium-40.

Increased radiation levels, up to 900 $\mu$R/h, were evident directly over the plant. A gamma ray energy spectrum from this area is shown in Figure 6. This background subtracted spectrum is characteristic of cobalt-58 and cobalt-60. Both are commonly found in structural materials exposed to neutron radiation.[3] A detailed analysis of the spectral data from all measurements made within the concentric contour lines surrounding the plant showed these isotopes to be the source of the increased radiation levels. The concentric pattern of contour lines evident over the plant is typical of localized sources of radiation. The D level extending to the east of the plant, however, was found to be due to an increased concentration of naturally occurring gamma ray emitters, specifically potassium-40 and thorium decay chain members.

The exposure rate conversion factor utilized for preparing Figure 4 is strictly valid only for radioisotope concentrations similar to those present at the calibration site and for activity distributed over a large area. Since the cobalt activity observed on site appears highly localized, the values reported in Figure 4 over these areas most likely underestimate the actual exposure rates there.

Results of the ground-based measurements are given in Table 1. The location of the ground sampling point was chosen in an area where only naturally occurring radioisotopes were detected by the aerial system. Comparisons are shown between the aerial data and results obtained by the ground sampling. A major contribution to any discrepancy between ground and aerial survey results lies in the fact that each aerial measurement represents an average exposure rate over a much broader area than does a ground measurement.

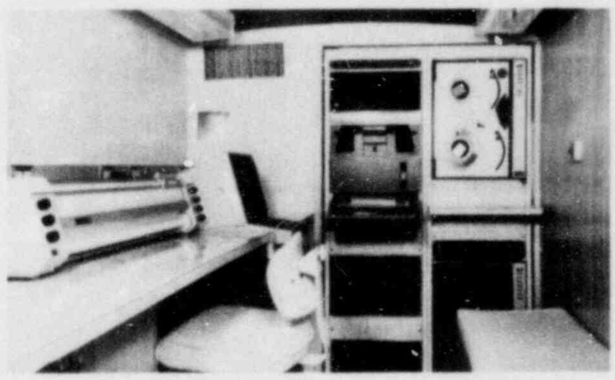

**Figure 3.** *MOBILE COMPUTER PROCESSING LABORATORY*

### 5.2 Comparison of the 1969 and 1981 Survey Results

The 1969 aerial radiological survey covered a much broader area than the 1981 survey. In addition, operational parameters such as flight line spacing and aircraft speed were different for the two surveys. This resulted in different sensitivities for small changes in the background radiation levels. A comparison of system and operational parameters for each survey is provided in Table 2.

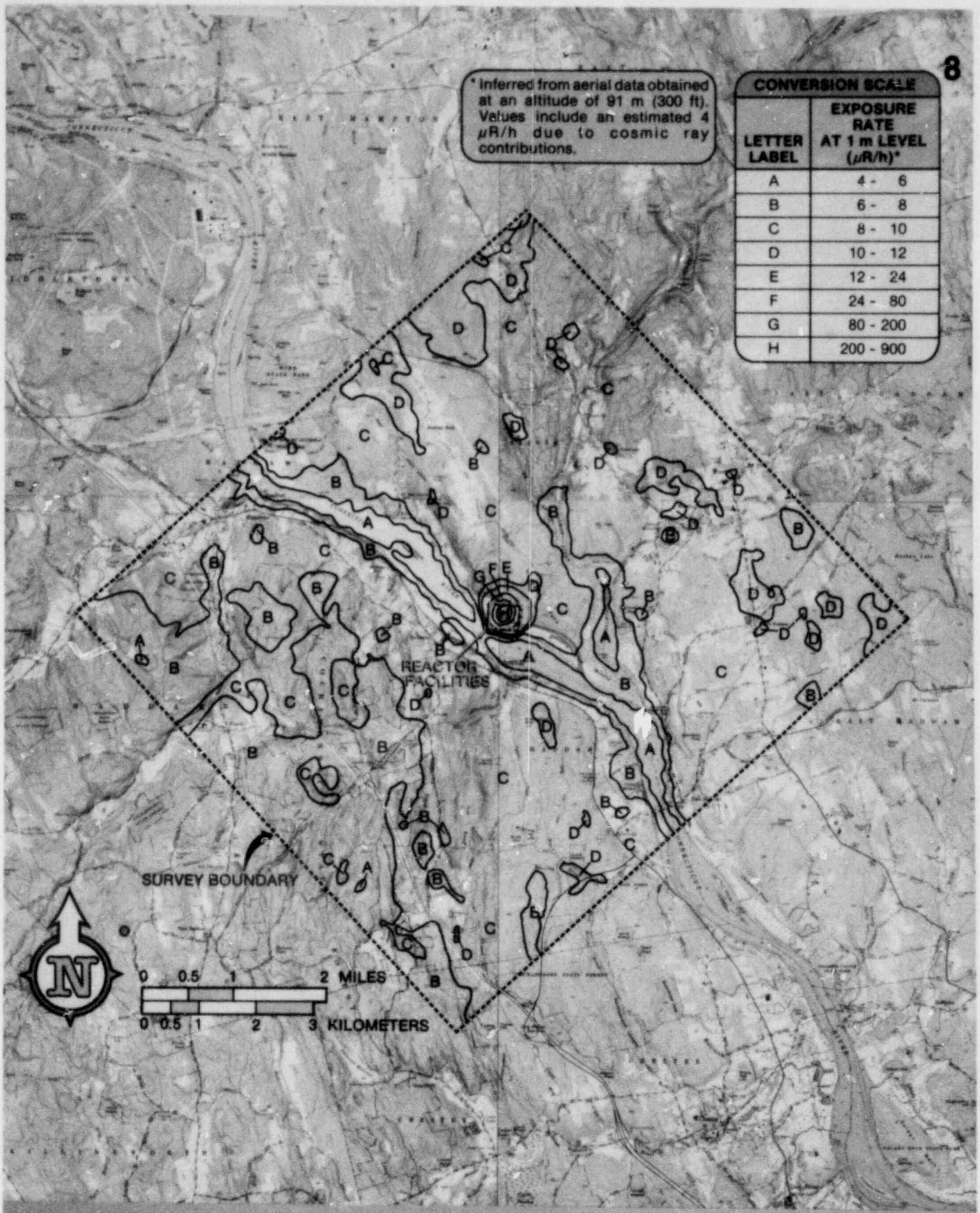


**Figure 4.** *EXPOSURE RATE CONTOUR MAP SUPERIMPOSED ON USGS MAP OF THE AREA SURROUNDING THE HADDAM NECK PLANT (1981 SURVEY)*

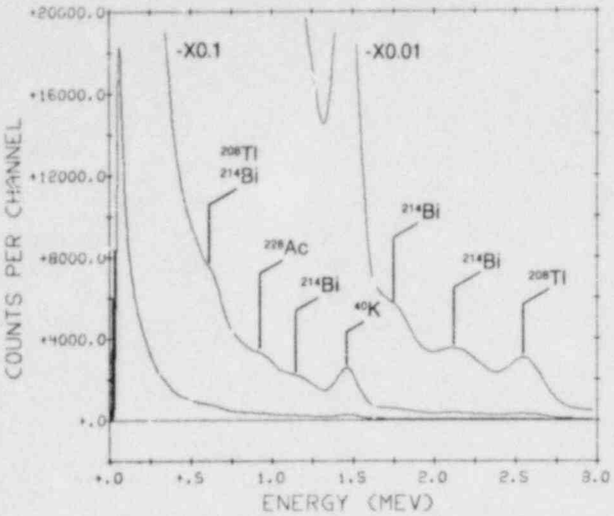


**Figure 5.** *GAMMA RAY ENERGY SPECTRUM TYPICAL OF THE NATURAL TERRESTRIAL BACKGROUND RADIATION IN THE AREA SURROUNDING THE HADDAM NECK PLANT*

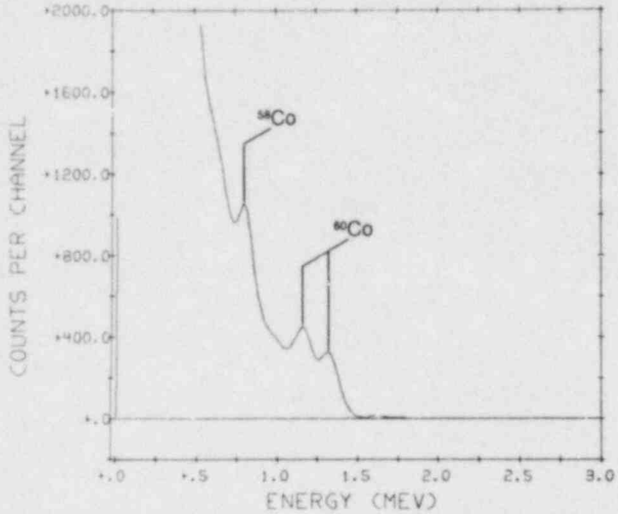


**Figure 6.** *GAMMA RAY ENERGY SPECTRUM OBSERVED OVER THE HADDAM NECK PLANT*

The changes in aerial survey equipment and techniques since 1969 make detailed comparisons between the results from both surveys of limited value. For example, during the 1981 survey increased detector area and the closely spaced flight lines resulted in enhanced sensitivity and better spatial resolution, respectively. Therefore, the ability to detect and define the extent of sources that are not widely distributed was greater and resulted in more detailed information about the survey area. However, comparisons between the two sets of results are still useful for determining if changes in the average radiological characteristics of the survey area have occurred during the intervening 12 years of plant operation.

The results of the 1969 survey are shown in Figure 7. This figure was taken from Reference 2 and enlarged to show only the 1981 survey area. As shown in the figure, exposure rates between 8 and 10 $\mu$R/h covered most of the area east of the river, while exposure rates between 6 and 8 $\mu$R/h covered most of the area west of the river. Lower exposure rates (4 to 6 $\mu$R/h) were evident over the river banks and in the extreme western portion of the survey area over the Cockaponset State Forest.

These results compare well with those from the 1981 survey. Although the average exposure rates on both sides of the river inferred from the 1981 measurements were in the 8 to 10 $\mu$R/h range, exposure rates over a large portion of the area west of the river were lower than average (6 to 8 $\mu$R/h). The increased spatial resolution of the 1981 survey is evident in Figure 4. Here small regions of higher than average exposure rates (10 to 12 $\mu$R/h) were detected in the eastern portion of the survey area. The only significant changes in the radiological characteristics within the survey area were detectable directly over the plant. Here, the elevated exposure rates due to the presence of cobalt-58 and cobalt-60 can be related to activities at the plant and are localized over it.

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

| Measurement Technique | Exposure Rate ($\mu$R/h) at 1 m Above Ground |
|---|---|
| Ionization Chamber | 7.2 - 9.2 |
| Soil Sample Analysis | 7.9 - 9.5[a] |
| Aerial Measurement | 6 - 8[a] |

[a] Includes an estimated cosmic ray contribution of 4.0 $\mu$R/h.

## 6.0 CONCLUSIONS

An aerial radiological survey was conducted during October 1981 over a 108-square-kilometer area centered on the Haddam Neck Plant. The results showed that no detectable change in the radiological characteristics of the area have occurred off-site since 1969. A similar survey conducted during August 1969 showed the exposure rates over most of the area varied between 6 and 10 $\mu$R/h; those from the present survey varied between 6 and 12 $\mu$R/h. Locations with exposure rates between 10 and 12 $\mu$R/h were small in size and may not have been definable with the limited spatial resolution of the earlier survey. Increased radiation levels were detected over the plant during the 1981 survey. These were due to the presence of cobalt-58 and cobalt-60, both products of neutron activation. Only naturally occurring gamma ray emitters were detected over the rest of the survey area. The aerial results from the 1981 survey were also in agreement with those from ground-based measurements made at one location within the survey area.

**Table 2. Comparison of Parameters for the 1969 and 1981 Aerial Surveys**

| System and Operational Parameters | Year of Survey | |
|---|---|---|
| | 1969 | 1981 |
| Number of Detectors | 14 | 20 |
| Size of Each Detector (cm) | 10.2 × 10.2 | 12.5 × 5.0 |
| Time Interval for Spectral Accumulation (sec) | 240 | 1 |
| Time Interval for Gross Count Data (sec) | 1 | 1 |
| Aircraft Ground Speed (m/s) | 72 (140 knots) | 36 (70 knots) |
| Altitude (m) | 91 (300 feet) | 91 (300 feet) |
| Flight Line Spacing (km) | 1.85 | 0.15 |
| Total Area Covered ($km^2$) | 2330 | 108 |

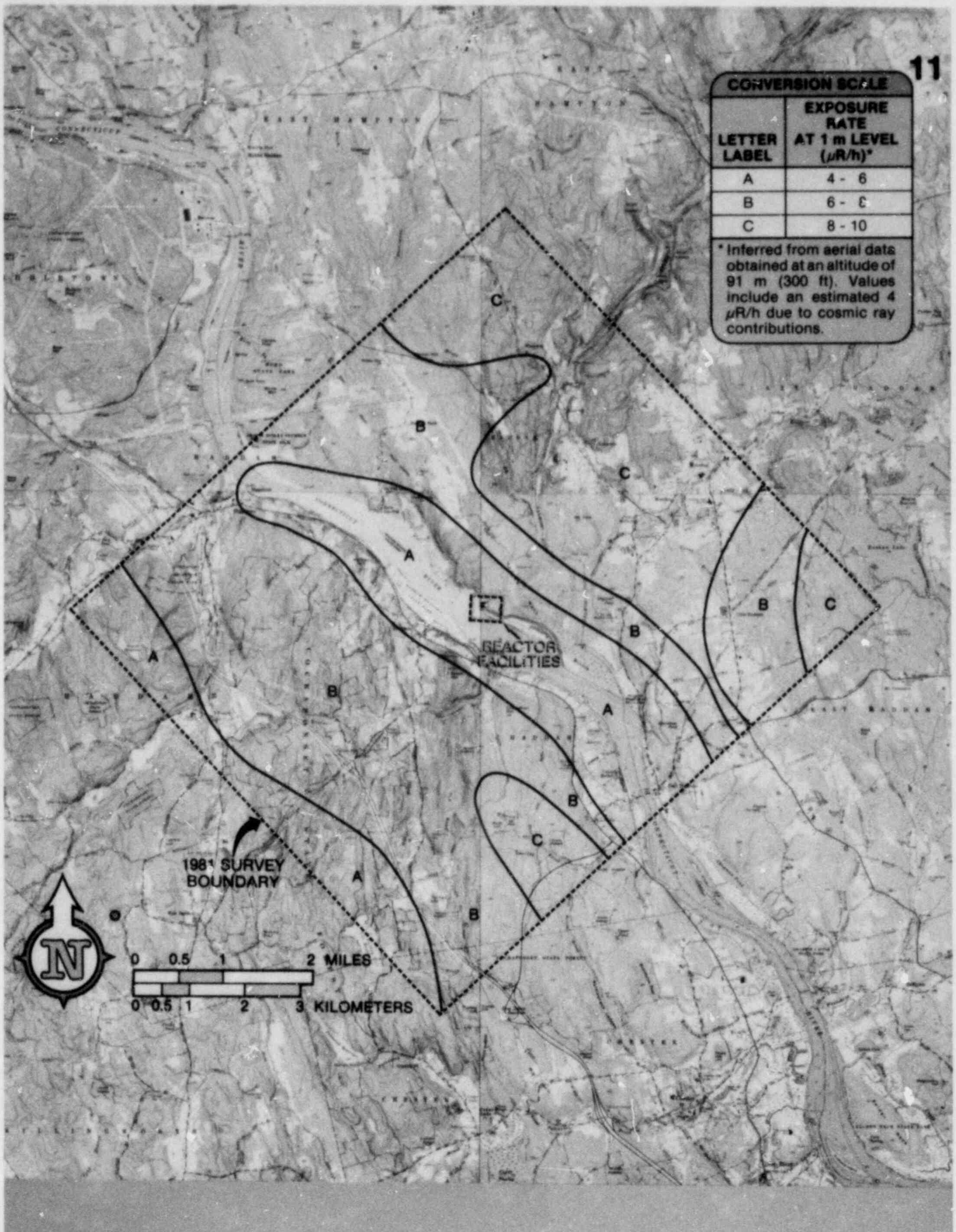


**Figure 7.** *EXPOSURE RATE CONTOUR MAP SUPERIMPOSED ON USGS MAP OF THE AREA SURROUNDING THE HADDAM NECK PLANT (1969 SURVEY)*

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