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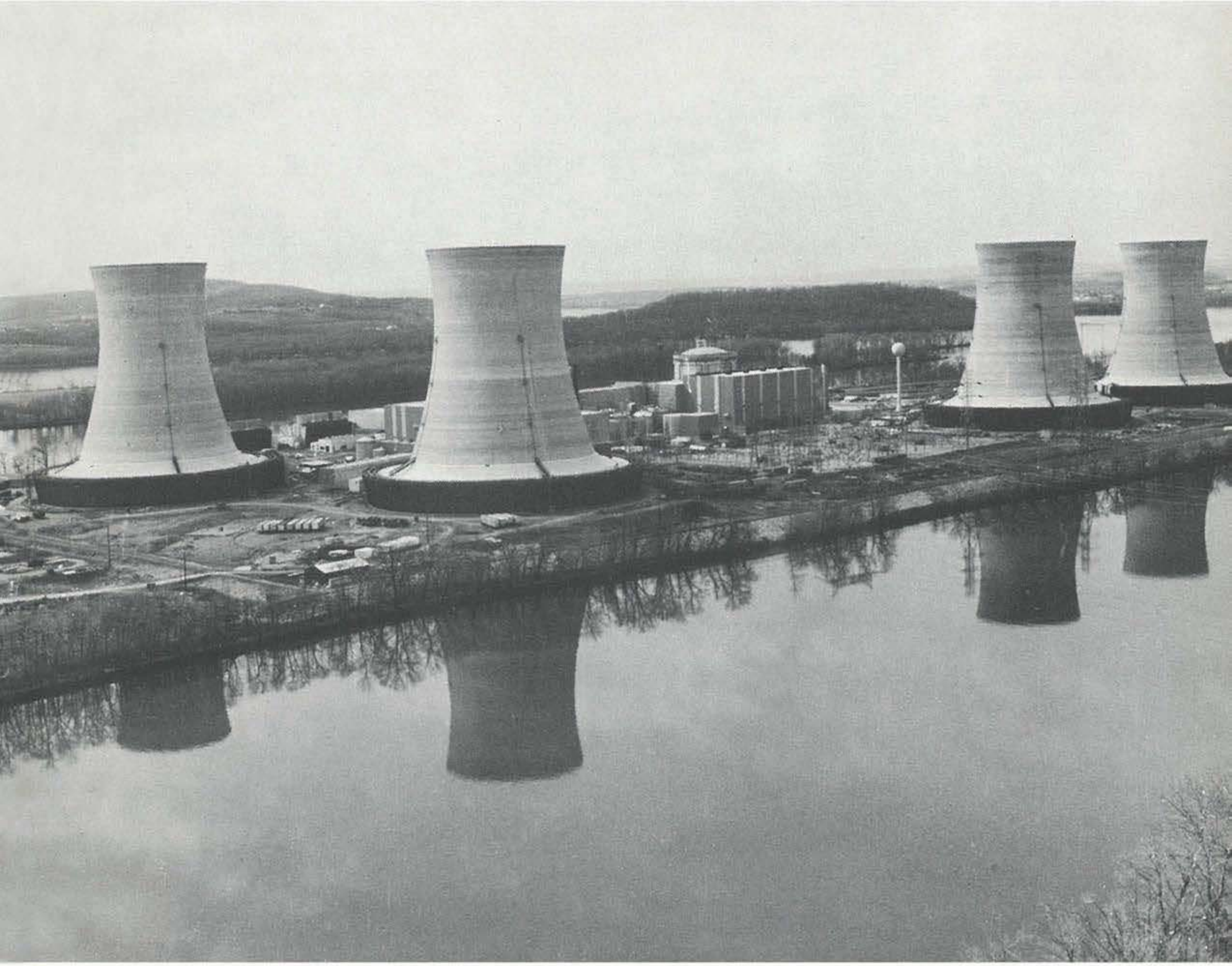
EGG-10282-1021
UC-41
AUGUST 1983



AN AERIAL RADIOLOGICAL SURVEY OF THE

THREE MILE ISLAND NUCLEAR STATION

AND SURROUNDING AREA

MIDDLETOWN, PENNSYLVANIA

DATE OF SURVEY: OCTOBER 1982

Printed in the United States of America.

Available from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS price codes

Printed copy: A02
Microfiche copy: A01

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This work was performed by EG&G/EM for the United States Nuclear Regulatory Commission through an EAO transfer of funds to Contract Number DE-AC08-83NV10282 with the United States Department of Energy.

ABSTRACT

An aerial radiological survey was performed over the area surrounding the Three Mile Island Nuclear Station during October 26 to 30, 1982. The survey covered an 82-square-kilometer area centered on the nuclear plant and encompassed the communities of Middletown, York Haven, Goldsboro and Royalton, Pennsylvania.

The highest radiation exposure rates, up to a maximum of 200 microroentgens per hour (μR/h), were inferred from data measured directly over the TMI facilities. This detected radiation was due to the presence of cobalt-58, cobalt-60 and cesium-137, which was consistent with normal plant operations. Similar activity is routinely observed in aerial surveys over nuclear power plants which have been or are presently in an operational mode. For the remainder of the survey area, the inferred radiation exposure rates varied from 6 to 14 μR/h. 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, along the river banks upstream and downstream of the survey area, and at the ground-based locations used for a previous aerial survey which was conducted in 1976. The exposure rate values obtained from these measurements were in agreement with the corresponding aerial data.

With the exception of the activity observed within the TMI facilities, no evidence of any contamination which might have occurred as a result of past reactor operations or the 1979 TMI Unit 2 accident was detected from the aerial survey data. This was further supported by the results of the soil sample analyses and the comparision with the 1976 aerial survey data.

CONTENTS

Tables

Appendix

1.0 INTRODUCTION

An aerial radiological survey of the area surrounding the Three Mile Island (TMI) Nuclear Station was conducted during October 26 to 30, 1982, at the request of the U.S. Nuclear Regulatory Commission. The survey was performed utilizing the Aerial Measuring System (AMS)[1], operated by EG&G Energy Measurements, Inc. for the U.S. Department of Energy. The TMI site, which is operated by the General Public Utility Company, is located near Middletown, Pennsylvania, on the Three Mile Island in the Susquehanna River approximately 24 kilometers downstream from the city of Harrisburg. The survey encompassed an area of 82 square kilometers as outlined in Figure 1. A similar aerial survey, over a larger area, was conducted during August 1976.[2] The purposes of the present survey were to map the distribution of all gamma-emitting radionuclides visible from the surface, and to determine if there had been any significant changes in the radiological characteristics of the area during the intervening period between surveys.

Generally, aerial radiological surveys are capable of: (1) detecting regions of enhanced radiation, (2) determining the averaged surface area exposure rate, and (3) identifying the specific radionuclide(s) responsible for any observable anomaly. However, since aerial detection systems tend to average exposure rates due to gamma ray emitting radionuclides over a large area, the results of the aerial measurements may underestimate the magnitude of localized sources. The results of this survey are reported as radiation exposure rates in microroentgens per hour (μR/h) extrapolated to 1 meter above ground level. The approximate annual absorbed radiation dose equivalent levels, attributed only to external sources of radiation and expressed in units of millirems per year (mrem/y), can be obtained by multiplying the reported exposure rate in μR/h by 8.76.

In addition to the aerial measurements, a series of ground-based measurements were performed. The ground-based measurements were acquired from several locations (see Figure 1), which were identified as exhibiting only natural background radiation.

2.0 NATURAL BACKGROUND RADIATION

Natural background radiation originates from radioactive elements present in the earth and cosmic rays entering the earth's atmosphere from space. The terrestrial gamma rays originate primarily from the uranium decay chain, the thorium decay chain, and 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). Some areas with high uranium and thorium concentrations in surface minerals exhibit even higher radiation levels, especially in the western states.[3]

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% of the natural background radiation levels.

Cosmic rays, the space component, interact in a complicated manner with the elements of the earth's atmosphere and the soil. These interactions produce an additional natural source of gamma radiation. Radiation levels due to cosmic rays vary directly with 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 3000 meters (10,000 feet) in Colorado.[3] The cosmic ray contribution in the TMI survey area was estimated to be 3.7 μR/h.

3.0 SURVEY SITE DESCRIPTION

The Three Mile Island Nuclear Station, operated by the General Public Utility Company, was at the center of an 82-square-kilometer survey area. The plant is located on the Three Mile Island in the Susquehanna River approximately 24 kilometers downstream from the city of Harrisburg, Pennsylvania. The nuclear power plant's two pressurized water reactors were shut down during the period of the aerial survey. The boundaries of the survey were chosen to encompass the communities of Middletown, York Haven, Goldsboro and Royalton. The majority of the survey area consisted primarily of agricultural areas and woodlands.

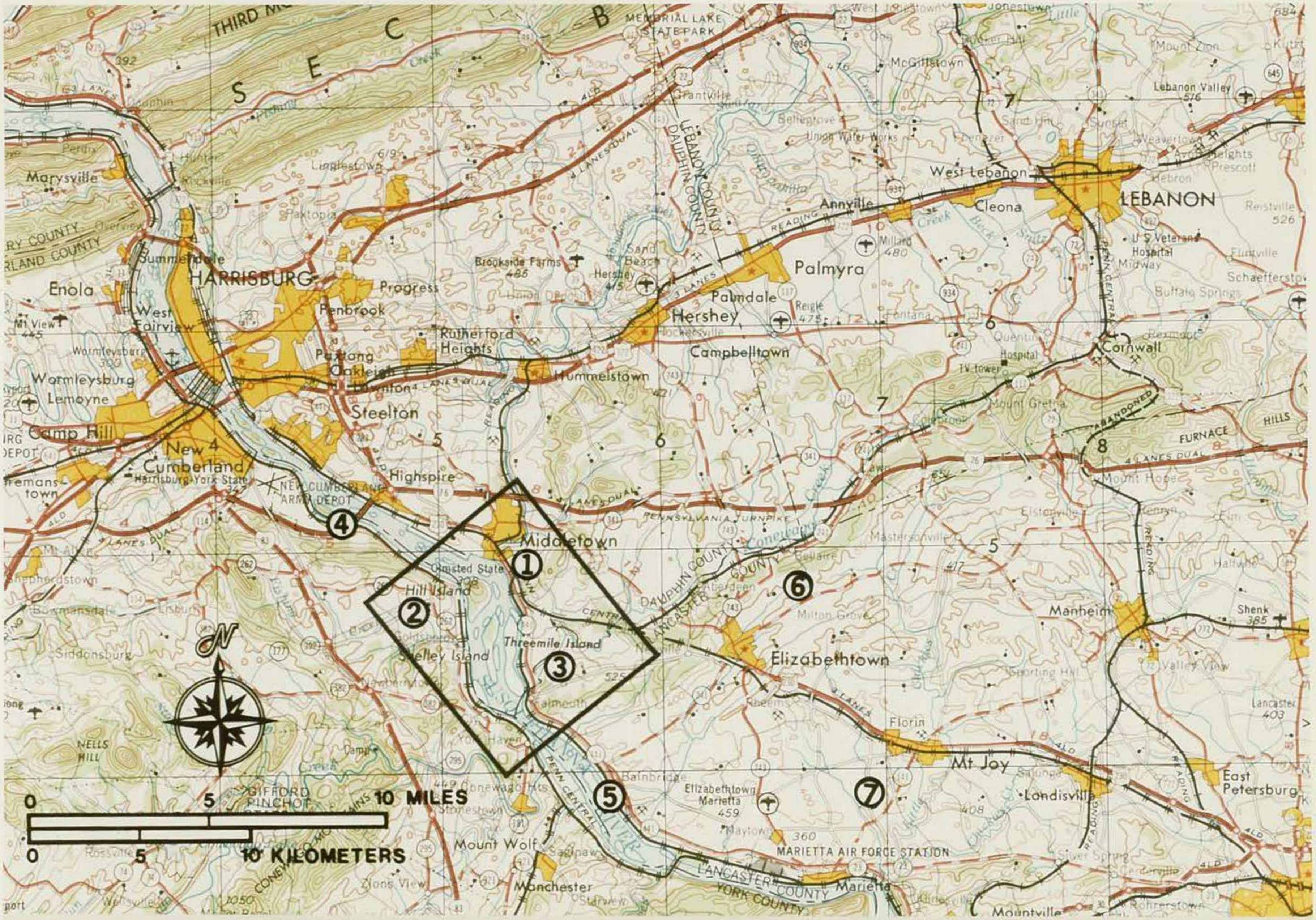


Figure 1. AERIAL SURVEY BOUNDARIES AND GROUND-BASED MEASUREMENT LOCATIONS FOR THE THREE MILE ISLAND NUCLEAR STATION (1982 SURVEY)

4.0 SURVEY EQUIPMENT AND PROCEDURES

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

4.1 Aerial Measurements

The Aerial Measuring System was comprised of a radiation detector package and a specialized data acquisition and recorder system (REDAR IV)* which were mounted on board a high performance helicopter.

The radiation detector package was comprised of 20 thallium-activated sodium iodide, NaI(T*l*), scintillation crystals which were distributed equally within two cargo pods. Each of the NaI(T*l*) crystals was 12.7 cm in diameter and 5.1 cm thick (5 in. by 2 in.). The two cargo pods were mounted on the exterior of a Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter (Figure 2). A photomultiplier tube assembly was connected to each of the NaI(T*l*) crystals to convert the crystal's scintillation pulses to voltage pulses. The voltage pulses from nine tubes in one detector pod plus all ten tubes in the other pod were summed in order to produce a single spectrum with high sensitivity. The remaining single tube was used to provide a spectrum with lower sensitivity for use in areas exhibiting greatly enhanced radiation levels. The 19-detector and the single detector signals were each input to their respective analog-to-digital converters (ADC) in the REDAR-IV dual multichannel analyzer system (Figure 3). The gains and offsets for each of the 20 detectors were adjusted so that the photopeaks from sodium-22 and americium-241 calibration sources appeared in preselected channels of the REDAR-IV multichannel analyzers (MCA). The REDAR-IV system—a multi-microprocessor based real time data acquisition, analysis and recording system—was designed to be compact and engineered to operate in demanding environments such as encountered on board aircraft. A block diagram of the REDAR-IV system is presented in Figure 4.

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

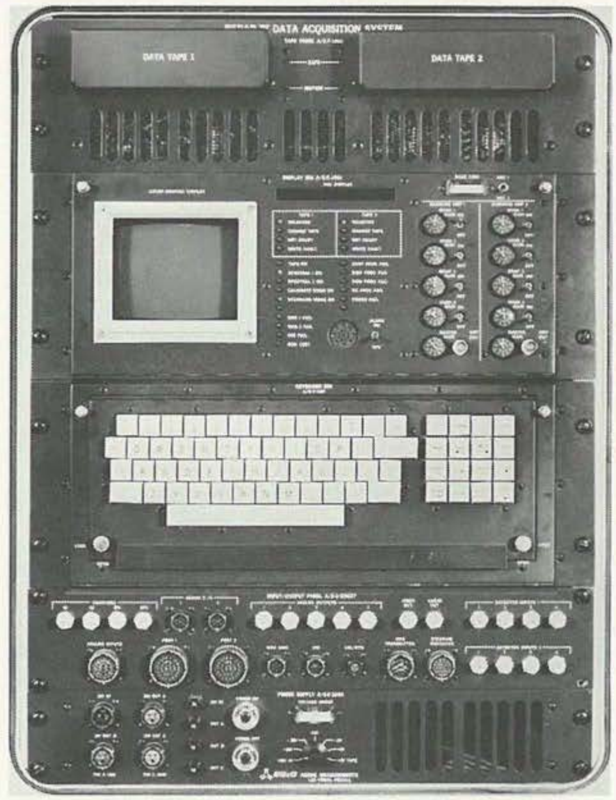


Figure 3. *REDAR-IV DATA ACQUISITION SYSTEM*

Each MCA (the 19-detector and single detector arrays) collected a 1024-channel gamma energy spectrum, scaled at 4 keV per channel, once every second. The 1024-channel spectrum was compressed into 256 channels before storage on magnetic tape, in accordance with the partitioning scheme summarized in Table 1. Since the resolution of the NaI(T*l*) crystals varies with the energy, this spectral compression scheme did not significantly compromise the photopeak identifications or analysis of the gathered spectral data.

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

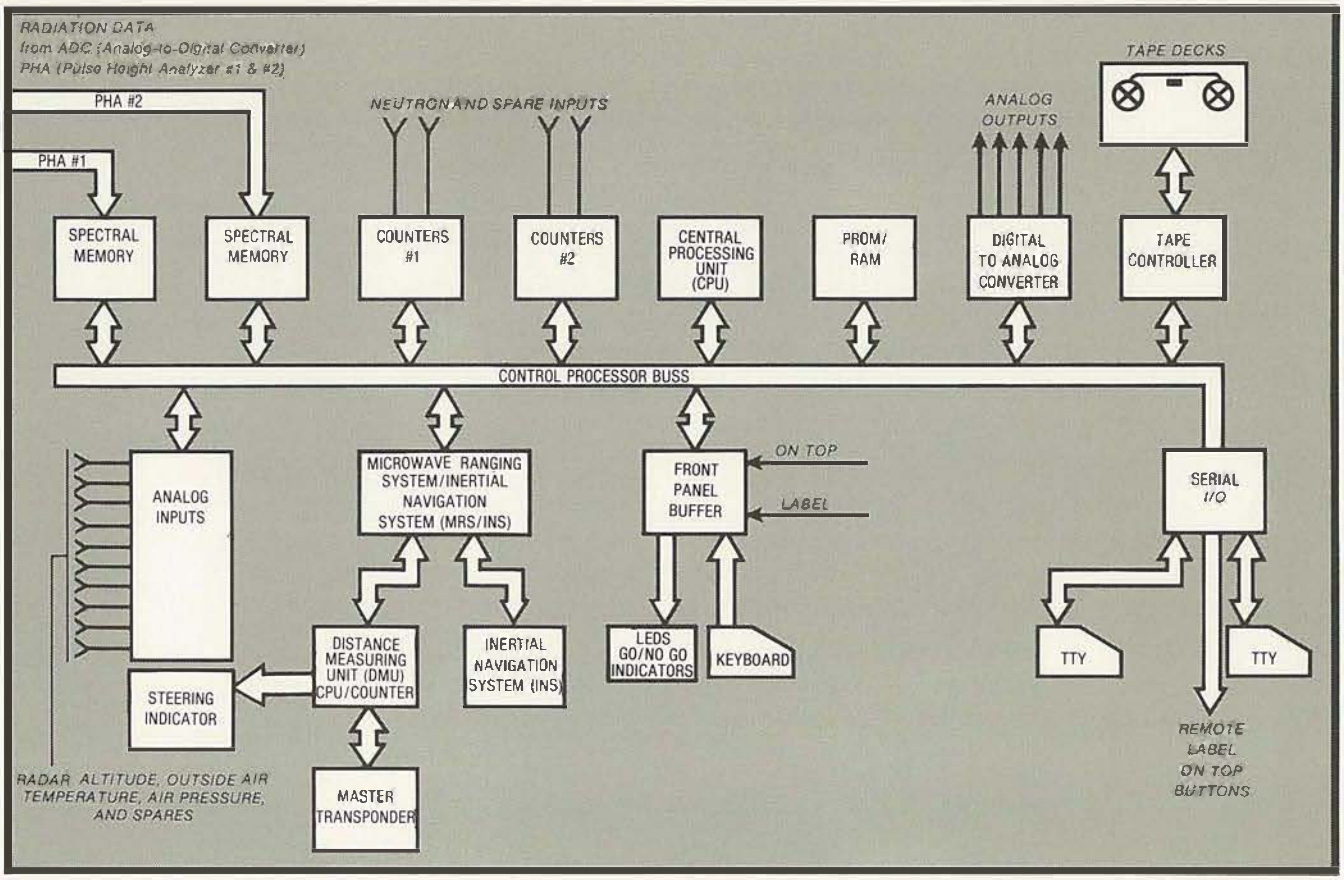


Figure 4. *REDAR-IV COMPUTER PROCESSOR SYSTEM BLOCK DIAGRAM*

Yet, this compression technique reduced the data storage requirements on magnetic tape by a factor of four.

In addition to the gamma energy spectral data, the REDAR-IV system also received and formatted the gross count data (gamma ray activity integrated over the energy range 0.04 to 3.0 MeV), the aircraft positional data, the ambient temperature and barometric pressure, and the system's live time information. Records containing four 1-second data points for the above cited parameters were recorded on magnetic tape once every 4 seconds. Radiological data, along with selected operational parameters, were displayed in real time on two cathode-ray tube monitors installed on board the helicopter.

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 delay to aircraft altitude above ground level. Positional and altitude information were also processed in real time by the steering micro-processor. These data provided steering indications to the pilot for flying the predetermined flight lines at the desired altitude.

Due to obstructions and terrain limitations, the survey area was divided into two sections (see Appendix A). Section A, which encompassed the community of Middletown, was surveyed with a regular grid of 28 parallel flight lines 8.5 kilometers (5.3 miles) in length, spaced 76 meters (250 feet) apart and flown at an altitude of 76 meters above ground level (AGL). Section B, which included the entire TMI facility, was surveyed with 64 lines spaced 122 meters (400 feet) apart and flown at an altitude of 107 meters (350 feet) AGL. The entire survey area was covered by 92 flight lines and flown at an average ground speed of 36 m/sec (70

Table 1. REDAR IV Spectral Data Compression Scheme

Eγ (keV)	Channel Input	Energy Coefficient ΔE (keV/channel)	Compressed Channel Output
0 - 300	0 - 75	4	0 - 75
304 - 1620	76 - 405	12	76 - 185
1624 - 4068	406 - 1017	36	186 - 253
4072 - Cutoff	1018 - 1023	N/A	254
> Cutoff	Forced to Zero	N/A	256

knots). To facilitate the data analysis, all of the aerial data was normalized to an average altitude of 91 meters (300 feet) AGL.

While enroute to the survey area from the local base of operations at Capital City Airport in New Cumberland, Pennsylvania, the non-terrestrial detector background radiation due to aircraft, radon and cosmic ray contributions were estimated from aerial measurements over the Susquehanna River. Estimates of background radon were also monitored by repeated measurements, before and after each flight, over a fixed test line located to the east of the survey area near Elizabethtown, Pennsylvania.

4.2 Ground-Based Measurements

Seven sets of ground-based measurements were performed for this survey at the locations shown in Figure 1. Three of the locations were within the boundaries of the current survey. Locations 4 and 5 were along the banks of the Susquehanna River north and south of the survey area. Locations 6 and 7 were within ±100 feet of the ground-based measurement locations used during the previous 1976 aerial survey.[2]

With the exception of the river bank locations, a measurement of the total gamma exposure rate and a group of soil samples were acquired at each location. The total gamma exposure rate measurement was made utilizing a pressurized ionization chamber. Soil samples were collected from five sites in each area where the ion chamber readings were acquired. At each of the river bank locations, only one set of soil samples was collected. All soil samples were returned to EG&G/EM's Santa Barbara Laboratory for analysis. The soil samples were analyzed to determine the concentrations of the major radionuclides. Results of the radionuclide assays and comparisons of the ground-based measurements with the inferred aerial results are presented in Section 5. Systems and procedures used to collect and analyze the soil samples are outlined in a separate publication.[5]

4.3 Data Reduction Procedures

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 5. 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.

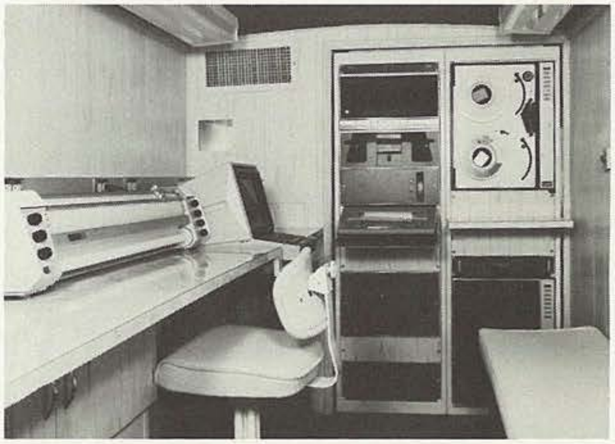


Figure 5. *MOBILE COMPUTER PROCESSING LABORATORY*

A total gamma exposure rate contour map was derived from the gross count data obtained while flying over the survey area. The gross count data, integrated between the energies of 0.04 to 3.0 MeV, represented all significant gamma ray activity. Estimates of the airborne radon, cosmic ray, and aircraft background radiations were subtracted from the measured gross count rates before conversion to terrestrial exposure rates. The estimated radiation backgrounds were measured from flights over the Susquehanna River and from repeated flights over a fixed test line residing near the survey area. The resulting net gross count rate can be expressed in the form:

$$GC = [(A_e \bullet W_{GC}) \bullet LT - BKG] \bullet ALT$$

where

- GC = Net gross count rate normalized for system live time and altitude variations (counts per second).
- W_{GC} = Measured gross count rate (cps).
- A_e = Detector effective area normalization factor.
- LT = System live time counting loss normalization factor.
- BKG = Non-terrestrial radiation background count rate (cps).
- ALT = Altitude variations normalization factor.

The resulting net count rates, due to terrestrial sources of radiation, were converted to gamma exposure rates extrapolated to 1 meter above ground level by applying a suitable conversion factor, which was predetermined at a calibration range near Lake Mead in Arizona. The conversion factor used for this survey was 795 counts per second per μR/h which was derived by using a normalized survey altitude of 91 meters AGL. The total gamma exposure rate, minus any contributions from airborne radon, was derived by adding an estimated cosmic ray contribution of 3.7 μR/h to the converted terrestrial gamma exposure rate values.

Utilizing the total gamma exposure rate data and the recorded positional information data, an isoradiation contour map was generated. The generated contours were overlaid on a composite of an aerial photograph and a set of U.S. Geological Survey maps of the surrounding area. The resulting overlay map shows both the spatial distribution and intensity of the terrestrial gamma ray emitters emanating from the survey area as inferred from the aerial data.

Identification of specific radionuclides responsible for any detected anomaly was determined from the measured 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. A typical gamma energy spectrum of the natural background radiation observed in the survey area is presented in Figure 6.

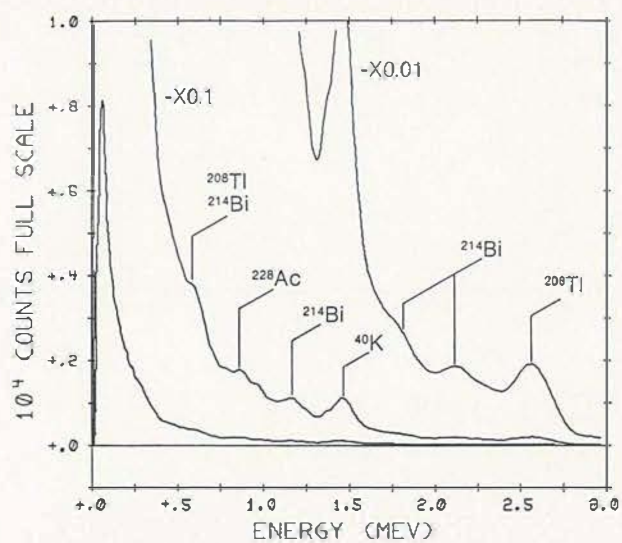


Figure 6. *TYPICAL GAMMA ENERGY SPECTRUM OF THE NATURAL RADIATION BACKGROUND FOR THE AREA SURROUNDING THE THREE MILE ISLAND NUCLEAR STATION*

A special data processing procedure was also applied to the aerial data to help determine if any man-made radioactive contamination existed within the survey area. This procedure takes advantage of the empirically determined fact that although natural background radiation levels can vary by factors of two or three or even 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. It is, therefore, possible to subtract away natural background contributions within a given "source" energy window by using the counts in a second "background" energy window and the average ratio between these windows from natural background for the area being surveyed. This subtraction procedure results in statistical oscillations around zero except over areas containing man-made contamination which contributes excess counts in the source window. Although this procedure can be applied to any portion of the gamma ray energy spectrum, the most general procedure is to place all counts below 1400 keV into the source window and all counts above 1400 keV into the background window. This is normally referred to as the man-made gross count (MMGC) stripping technique and is sensitive to most man-made contamination normally encountered. The advantage of this stripping procedure is illustrated in Figure 7. The upper plot shows the total count rate between 0.05 and 3.0 MeV as a function of time obtained along a flight line flown over the Department of Energy's Savannah River Plant. The lower plot shows the result of applying the MMGC stripping procedure. Locations 3 and 4 show obvious elevated activity in both plots. Locations 1 and 2, however, cannot be distinguished from normal background radiation fluctuations in the upper plot. The MMGC processing, on the other hand, readily identifies the areas as containing man-made contamination. This procedure allows very low level man-made activity to be identified even in the presence of much higher natural background activity.

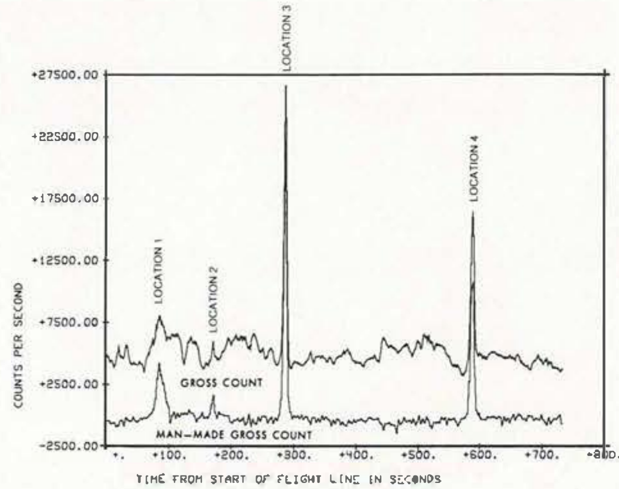


Figure 7. *EXAMPLE OF THE ENHANCEMENT OF THE DETECTABILITY OF MAN-MADE CONTAMINANTS OVER THE FLUCTUATING NATURAL BACKGROUND RADIATION EMPLOYING THE MMGC STRIPPING TECHNIQUE*

5.0 SURVEY RESULTS AND DISCUSSION

5.1 Aerial Survey Results

The results of the aerial radiological survey are shown in Figure 8 as exposure rate isoradiation contours. It should be noted that the water elevation levels of the Susquehanna River were significantly lower during the period of the aerial survey than the levels which are shown in Figure 8. In particular, the E-level activity which appears to be in the water below the apparent southern tip of the Three Mile Island was actually measured over rocks exposed due to the low water level. A detailed examination of the gamma ray spectral data obtained over this area showed only naturally occurring radionuclides. There was no indication of any man-made radioactivity which might have occurred as a result of operations at the TMI facility.

As shown in Figure 8, the natural background radiation levels varied from 6 to 14 μR/h, which was found to be due to varying concentrations of the naturally occurring radioisotopes, i.e., members of the uranium and thorium decay chains and potassium-40 (see Figure 6). A listing of typical concentrations of the major soil radionuclide constituents within the survey area is presented in Section 5.2.

Radiation levels higher than background were found over the TMI facilities. The highest radiation levels, up to 200 μR/h, are evident over the section designated as the Southeast Acres storage area. A net gamma energy spectrum of the depicted J radiation level is shown in Figure 9. This net, background subtracted, spectrum is characteristic of cobalt-60 and cesium-137. The net gamma energy spectrum of the H radiation level depicted over the Unit 1 radwaste storage facility on the northwest section of the TMI plant is shown in Figure 10. This net spectrum is characteristic of cobalt-58, cobalt-60, and cesium-137. The isotopes cobalt-58 and cobalt-60 are found commonly in structural materials exposed to neutron radiation.[6] The isotope cesium-137 is one of the long-lived fission products. The level of activity observed over the TMI facilities is typical of that routinely observed in aerial survey data over nuclear power plants which have been or are currently in an operational mode and results from routine reactor operations. However, the distribution does show ^{137}Cs above what would normally be expected. This is a result of cleanup activities conducted following the TMI Unit 2 accident in March 1979.

⊗ GROUND-BASED MEASUREMENT LOCATIONS

CONVERSION SCALE	
LETTER LABEL	EXPOSURE RATE* (μR/h at 1 meter)
A	3.7 - 5.7
B	5.7 - 7.7
C	7.7 - 9.7
D	9.7 - 11.7
E	11.7 - 13.7
F	13.7 - 20
G	20 - 30
H	30 - 50
I	50 - 100
J	100 - 200

* Inferred from aerial survey data. Only applicable as large area averages. A cosmic ray contribution of 3.7 μR/h has been included in the exposure rate values.

Figure 8. *EXPOSURE RATE CONTOUR MAP OF THE AREA SURROUNDING THE THREE MILE ISLAND NUCLEAR STATION (1982 SURVEY)*

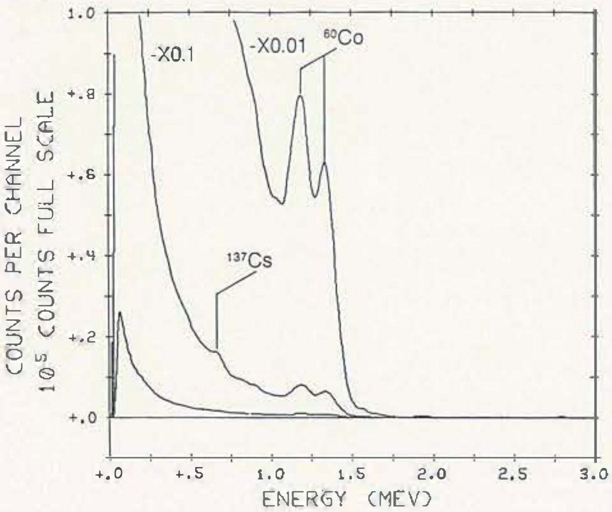


Figure 9. *NET GAMMA ENERGY SPECTRUM OF THE ELEVATED ACTIVITY DETECTED OVER THE SOUTHEAST ACRES STORAGE AREA AT THE THREE MILE ISLAND NUCLEAR STATION. The area of interest was the J exposure rate level shown in Figure 8.*

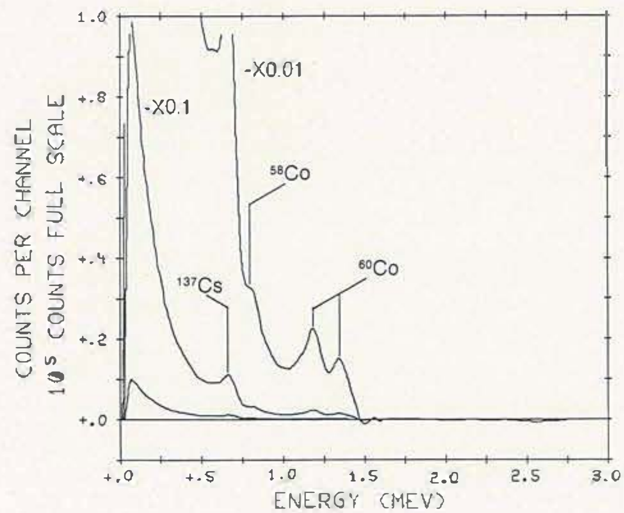


Figure 10. *NET GAMMA ENERGY SPECTRUM OF THE ELEVATED ACTIVITY DETECTED OVER THE UNIT 1 RADWASTE STORAGE FACILITY AT THE THREE MILE ISLAND NUCLEAR STATION. The area of interest was the H exposure rate level shown in Figure 8.*

Because the airborne detection system is not collimated, radiation from a localized source appears as a series of concentric contours surrounding the actual physical location of the source. This artifact arises because the uncollimated detectors "see" the radiation from a localized source before actually arriving over the source. This type of pattern appears in Figure 8 around both storage areas located within the TMI facilities. The actual physical location of the elevated radioactivity is confined to the center part of the concentric contours. In addition to covering a much smaller area than that inferred from the aerial data, the actual 1 meter exposure rate levels measured within the storage areas will be higher than those inferred from the aerial data. This arises as a result of the large-area averaging property of the airborne system. For localized sources such as the two storage locations within the TMI facility, the aerial data simply provide an indicator of elevated activity. Ground measurements are required to determine the actual physical extent and level of the activity.

The special MMGC stripping technique, discussed in Section 4.3, was also applied to the aerial radiation data. With the exception of the two areas within the TMI facilities, there was no indication of any man-made contamination within the survey area.

Due to terrain limitations, most of the survey area was flown at an altitude of 107 meters (350 feet). A special flight, however, was flown along the banks of the Susquehanna River from 6.5 kilometers upstream to 10 kilometers downstream of the TMI facility at an altitude of 46 meters (150 feet). The lower altitude resulted in an increased sensitivity to possible man-made contamination which might have existed along the river banks. At this survey altitude, the aerial system is capable of detecting cesium-137 activity, in excess of local world-wide fallout, down to levels of approximately 0.7 pCi/g (0.4 μR/h). Again, the special processing technique did not reveal the presence of any man-made contamination.

5.2 Results of Ground-Based Measurements

Except for the river bank locations, each ground sampling point was chosen in an area which exhibited a relatively uniform spatial distribution of radiation due only to naturally occurring radionuclides. The ground-based measurement locations are identified in Figures 1 and 8 by the encircled numerals. The results of these measurements are given in Tables 2 and 3.

Table 2. Comparison of 1982 Ground-Based and Aerial Total Exposure Rate Measurement Results				
Site	Soil Moisture (%)	Ground Survey (μR/h) Ion Chamber	Ground Survey (μR/h) Soil Analysis Estimate[1]	Aerial Survey (μR/h)[1]
1	18.4	9.4	10.0	7.7 - 9.7
2	16.5	9.7	10.9	9.7 - 11.7
3	20.5	11.3	11.5	9.7 - 11.7

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

Table 3. 1982 Soil Sample Analysis Results				
Site	U-238 (ppm)	Th-232 (ppm)	Cs-137 (pCi/g)	K-40 (pCi/g)
1	3.4	10.6	0.30	11.4
2	3.7	11.8	0.29	14.0
3	4.6	12.7	0.28	14.7
4	3.3	12.5	0.15	16.7
5	3.9	12.1	N/D[1]	31.6

[1] N/D - not detectable (less than 0.1 pCi/g).

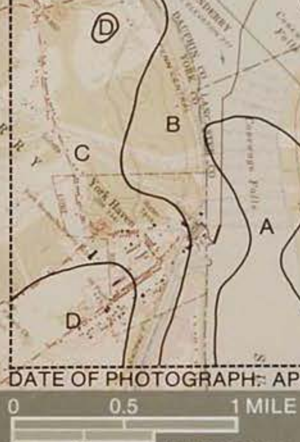
The total gamma exposure rate measured by both ground-based and aerial techniques are compared in Table 2 for each site (1, 2, and 3) within the survey area. The soil analysis estimates and the aerial measurements reported include an additional 3.7 μR/h cosmic ray contribution to the exposure rates in order to allow for direct comparison with the ion chamber data. The results summarized in Table 2 are within expected agreement. Any discrepancies noted are probably due to the area averaging effect of the aerial system and the uncertainties involved in the estimate of the airborne radon contribution.

Results of the radionuclide assay for each site within the survey area and the river bank sites are presented in Table 3. The values reported, except for the river bank sites, are averages of five samples obtained within each area. The results indicate that the higher radiation levels inferred from the aerial data taken over sites 2 and 3 were due to higher concentrations of naturally occurring radionuclidesand not cesium-137. Also, the results shown in Table 3 infer that no significant accummulation of cesium-137 existed downstream from the TMI facility at the site the soil sample (Site 5) was acquired. This supports the results of the special flight along the river banks which was discussed in Section 5.1.

5.3 Comparison of 1976 and 1982 Survey Results

The 1976 survey covered a larger area (2100 square kilometers) than the 1982 survey (82 square kilometers), but it was flown at a higher altitude (150 meters) with a much wider line spacing (930 meters). The survey parameters flown in the 1976 survey were typical of those flown prior to 1980 with fixed-wing aircraft. Starting in 1980, all reactor surveys have been flown with a helicopter platform at lower altitudes, slower speeds, and with much closer line spacings. Although the area surveyed is generally smaller than the older type survey, the more detailed

Figure 11. *FLIGHT LINES FLOWN DURING THE 1976 AND 1982 AERIAL SURVEYS OVER THE 1982 SURVEY AREA*



CONVERSION SCALE	
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* Inferred from aerial survey data. Only applicable as large area averages. A cosmic ray contribution of 3.7 μR/h has been included in the exposure rate values.

Figure 12. *EXPOSURE RATE CONTOUR MAP OF THE AREA SURROUNDING THE THREE MILE ISLAND NUCLEAR STATION (1976 SURVEY). Only that area covered during the 1982 survey is shown.*

helicopter surveys provide a marked improvement in sensitivity for detecting possible man-made contamination resulting from reactor operations.

Figure 11 shows the flight lines flown during the 1976 and 1982 surveys over the 1982 survey area. In addition to flying approximately 10 times as many flight lines in 1982 as in 1976, the 1982 survey was flown at half the speed of the 1976 survey leading to approximately 20 times the number of data points acquired per unit area.

That portion of the 1976 survey covered during 1982 was reprocessed to overlay the 1982 base map. The results are shown in Figure 12. These results vary slightly from those given in Reference 2 in order to correct for a small systematic difference between the aerial data taken from 1975 to 1979 with the fixed-wing aircraft and that taken from 1980 to the present with the helicopter system. This difference is discussed in detail in Reference 7. Comparing Figure 12 with Figure 8 shows good overall agreement between the two surveys. Because of the tremendous difference in spatial coverage between the two surveys, as illustrated in Figure 11, only very general features can be compared. A more direct comparison could have been made if the same survey parameters were flown in both surveys. However, this would have led to a very significant reduction in sensitivity to possible man-made contamination over that which was actually obtained in the 1982 survey.

During the 1976 survey, ground measurements were made at two locations identified as areas 6 and 7 in Figure 1. Although both locations were outside the 1982 aerial survey boundary, repeat measurements were made as part of the 1982 ground survey. Table 4 shows the comparison results. Site 7 showed virtually no change in either exposure rate level or soil composition between the two measurements. Site 6 actually showed a decrease in exposure rate primarily due to a decrease in potassium-40 activity. This site was an open field in 1976 but had been farmed in the years between the measurements, which could account for the observed decrease in potassium levels. At both locations, the cesium-137 activity was lower in 1982 than in 1976, consistent with the decrease expected from normal radioactive decay. With the exception of cesium-137, present at typical world-wide fallout levels, no evidence of any non-natural activity was observed at either site from the soil sample analyses. This was also the case for the other five ground sampling locations.

In conclusion, with the exception of two storage locations within the TMI facilities, the October 1982 aerial survey did not detect the presence of any radioactive contamination which might have occurred as a result of routine reactor operations or the 1979 TMI Unit 2 accident. This was further supported by the results of the ground measurements and the comparison with the 1976 aerial survey data.

Table 4. Comparison of 1976 and 1982 Ground-Based Radiological Measurement Results

	Site 6		Site 7	
Results	**1976**	**1982**	**1976**	**1982**
Soil Sample Analyses				
Soil Moisture (%)	13.4	16.2	11.6	16.2
U-238 (ppm)	5.1	3.8	5.1	4.8
Th-232 (ppm)	13.2	12.6	11.5	13.4
Cs-137 (pCi/g)	0.39	0.28	0.39	0.32
K-40 (pCi/g)	20.2	12.5	26.0	26.6
Exposure Rate Results (μR/h)				
Soil Analysis Estimate[1]	13.3	11.0	13.9	14.0
Ion Chamber	14.9	10.0	11.6	11.6

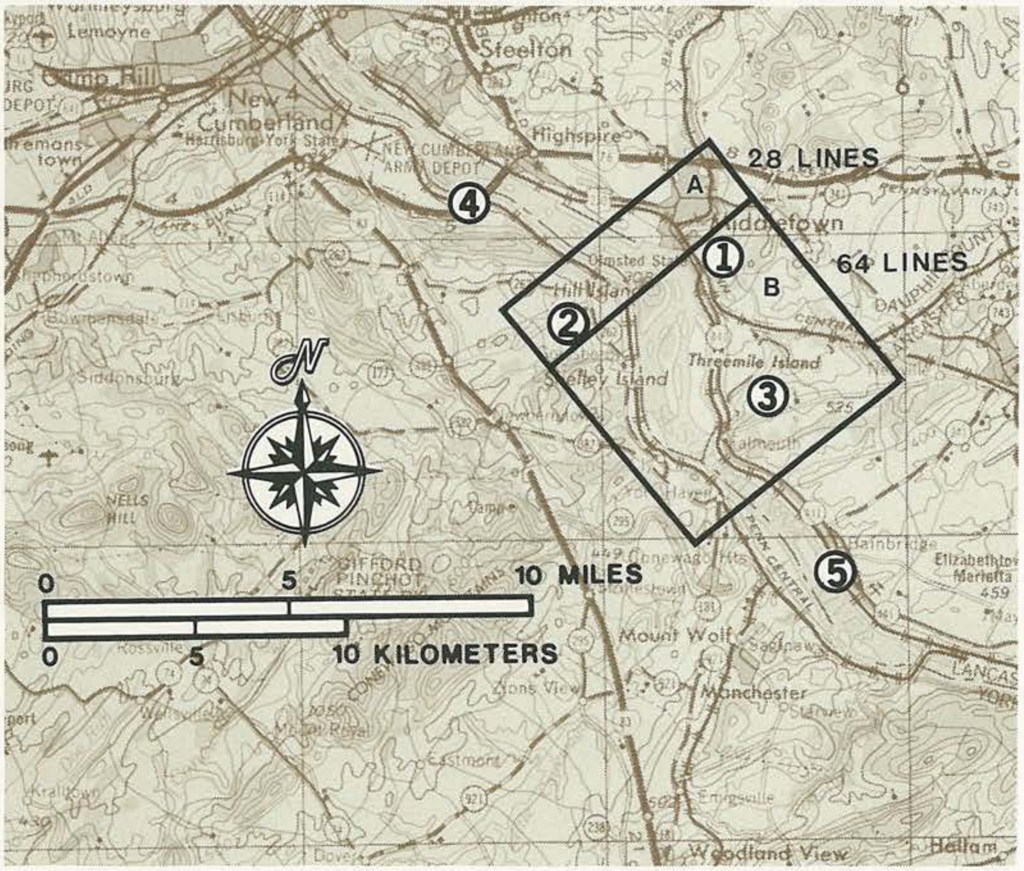
[1] Includes a cosmic ray contribution of 3.7 μR/h.

APPENDIX A

SURVEY PARAMETERS

Site:	Three Mile Island Nuclear Station
Location:	Near Middletown, Pennsylvania, on the Three Mile Island in the Susquehanna River, approximately 24 km downstream of the city of Harrisburg.
Survey Date:	26 to 30 October 1982
Survey Coverage:	82 km^2 (8.5 km × 9.6 km)
Project Scientist:	D.P. Colton
Survey Aircraft:	MBB BO-105 Helicopter - N9358B
Acquisition System:	REDAR-IV
Detector Array:	Twenty 12.7-cm diameter by 5.1-cm thick NaI(Tl) detectors (Cd-band shielded).
Lines Surveyed:	92

Due to terrain limitations, the survey area was divided into two sections:



	SECTION A	SECTION B
No. of Lines Surveyed	28	64
Survey Altitude	76 m (250 ft)	107 m (350 ft)
Line Spacing	76 m (250 ft)	122 m (400 ft)

Data Processing: Total Gamma Exposure Rate (Gross Counts)

Energy Window: 0.04 - 3.0 MeV
Conversion Factor: 795 cps per μR/h
Cosmic Ray Contribution: 3.7 μR/h

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