MD. 91-5

EG&G ENERGY MEASUREMENTS GROUP

The REMOTE SENSING LABORATORY OF THE UNITED STATES DEPARTMENT OF ENERGY

ECT FOLLOW-UP REPORT

NOVEMBER 1979

EGG-R-002

AN AERIAL RADIOLOGICAL SURVEY OF THE

CURTIS BAY FACILITY

OF THE W. R. GRACE COMPANY

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APPROVED FOR PUBLICATION

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ATTACHMENT 4

ECT
Follow-Up Report

AN AERIAL RADIOLOGICAL SURVEY OF THE CURTIS BAY FACILITY

This is the second of two reports discussing the gamma ray radiation levels measured at the Curtis Bay facility of the W. R. Grace Company. The first report presented gross count contours and gamma ray spectra over the most active areas. Refined gross count isopleth maps will be presented here along with results from processing the data with a man-made gross count algorithm and an algorithm for extracting concentrations of a specific nuclide.

The data reported here result from measurements with an airborne system during the period 21 to 23 July 1979. Gamma rays were detected with 12.7 cm diameter by 5.1 cm thick NaI crystals, arranged in one array. The system was flown in a Boeing 105 helicopter at 60 m altitude along a grid of lines spaced 76 m apart. Position information from a microwave ranging system was recorded on magnetic tape along with the radiation data. Correlations between the two and extractions of specific types of nuclides were effected with a REDAC data processing system. A description of the equipment and operating procedures can be found in References 1 and 2.

The gross count rate isopleths are based on the sum of all counts in that portion of the gamma ray energy spectrum between 0.05 MeV and 3 MeV (Figure 1). The terrestrial component of gross count rate and the sum of exposure rates due to soil and cosmic ray activity are produced as follows:

1. Overfly a body of water at the survey altitude to measure the sum of count rates due to aircraft background, cosmic rays, and airborne radon daughter radionuclides. Such flights may not be performed on a daily basis due to distance between the survey area and an appropriate body of water
2. Measure count rate over the survey area.
3. Subtract item 1 from item 2 to obtain the sum of terrestrial count rate plus any difference that may exist between airborne radon daughter activity over the survey area and over the body of water.
4. Apply a predetermined factor to convert item 3 above to exposure rate. This factor is obtained by performing steps 1 and 2 over areas in close proximity to one another and correlating the subtracted data with exposure rate measurements on the ground.
5. Add a calculated cosmic ray contribution to the exposure rate.

Dependent on (1) proximity of the survey area to the body of water overflown in step 1, (2) differences in topography and meteorological conditions between the areas, and (3) differences in time between execution of the two flights, the counts resulting from step 3 and the isopleths shown in Figure 1 may be either rich or poor in radon daughter content. Daily variations in airborne radon daughter concentrations can lead to discontinuities in isopleths across boundaries between areas flown on different days. When necessary, corrections were made for this effect. The correction, based on data from a single cross track flight, adjusts counting rates to a constant component due to the radon daughter radiations. Although not precisely known, the radon daughter component is estimated to contribute an uncertainty no more than ±5% to the exposure rate.

The calibration described in step 4 is done over an area containing a typical mix of naturally occurring radionuclides. The conversion factor will be in error where the mix is atypical, where man-made nuclides exist, or when airborne radon daughter contributions are not completely subtracted. The conversion factor used was 1024 counts per second per μR/h one meter above the ground.

It should be stressed that inherent spatial resolution in any remote sensing survey that uses uncollimated detectors (such as the airborne system) is one to two times the distance between the surveyed surface and the detector. Therefore, ground surveys using detectors at the one meter level will not compare well with an aerial survey over areas that contain sources whose lateral dimensions are small relative to the aircraft altitude. Isopleths constructed from a ground survey over a point source will indicate a source width of one to two meters, whereas aerial survey isopleths over the same source will indicate a source width of at least several tens of meters.

Figure 1 shows several areas of activity that bear further scrutiny due to the magnitudes of the levels and shapes of the isopleths. Numbered bars in this figure define sections of flight lines which covered six of these areas. The nuclides responsible for this activity were sought by comparing background spectral data with spectral data accumulated while the aircraft was over each of the numbered lines or bars. The background for each area was taken from data gathered at positions just before and/or just after the bars. A typical background spectrum is shown in Figure 2 . Figures 3 through 8 present channel by channel differences between the bar data and its corresponding background. Arrows in these figures define positions of photopeaks which appear to be responsible for the excess activity. The nuclides associated with these photopeaks are identified as ^{208}Tl, ^{228}Ac, ^{214}Bi, and ^{40}K.

The man-made gross counting rate algorithm is designed to sense the presence of changes in spectral shape. Small changes in spectral shape accompany large changes in gross counting rate because radionuclides that produce the natural background spectrum change in more or less constant ratio. The algorithm senses counts in the lower portion of the spectrum in excess of those predicted on the premise that these counts bear a constant ratio to counts in the upper portion. Since the algorithm is designed to be most sensitive to man-made nuclides, the spectrum dividing line is chosen at an energy (1.4 MeV) above which most long-lived man-made nuclides do not emit gamma rays.

Application of this algorithm did not produce meaningful and contourable activity patterns. Examination of spectral data from areas associated with the largest man-made gross count excursions revealed no specific nuclides to which these excursions could be attributed. Minimum activities detectable with this algorithm are not quoted here, since they are nuclide dependent and have not been measured (even for common nuclides), and are not easily calculated.

Based on an examination of spectra from areas flagged by the gross count contours in Figure 1 the decision was made to process the data to isolate and quantify specific concentrations of ^{208}Tl.

Algorithms that are designed to quantify concentrations are normally set to sense the dominant photopeak of the nuclide of interest. Photopeak counts bear simple relationships to concentrations, whereas wide windows that accept counts from down-scattered photons do not. In order to suppress all but anomalous contributions of the nuclide of interest, photopeak counts are usually compared with counts in a background window of comparable width at another energy. The following algorithm was employed for this purpose:

$$CR_u = CR_P - \bar{R}_B CR_B$$

where

CR_u = anomalous ^{208}Tl counting rate in photopeak window.

CR_P = counting rate in photopeak window.

CR_B = counting rate in background window.

$\bar{R}_B$ = constant determined from the ratio of CR_P to CR_B over a background area.

Figure 9 is an isopleth map of concentration of ^{208}Tl generated by this algorithm using the following windows:

CR_P = counting rate in the interval between 2.36 MeV and 2.86 MeV

CR_B = counting rate in the interval between 1.32 MeV and 1.58 MeV

A sliding interval average was applied to the algorithm result before data were classified for contouring purposes. The original data had accumulation times of 1 second. The sliding interval had a major time interval of 3 seconds and a minor time interval of 1 second.

Dependent on (1) relative location of windows, (2) the specific nuclide of interest, and (3) energy resolution of the detector system, application of the stripping algorithm may result in a subtraction of photopeak counts from the photopeak window. Since factors that convert these counts to concentration are based on photopeak counts only, a correction factor must be applied to CR_u. It can be shown that the correction factor is equal to $1/(1-\overline{R}_{BG}g)$ where g is determined from the shape of the net ^{208}Tl spectrum over a contaminated area. The value of g is equal to the counts in the background window divided by the counts in the photopeak window as measured over this area. The relationship between isopleth letter lables and count rates is given in Table 1.

References 3, 4, and 5 give procedures for converting values in the last column of this table to ground concentrations. The activity is assumed to decrease exponentially with depth with a relaxation length $1/\alpha$. Table 2 gives conversion factors as a function of α, soil density ρ, sample depth X, and assumed angular response of the detector system. The values marked by an asterisk in Table 2 were selected as "best" value and used to construct the key shown on the isopleth map (Figure 9).

The 3 second major width of the sliding interval applied to the algorithm result, coupled with the 30 meter/second speed of the helicopter, degrades spatial resolution along the direction of flight to ~ 90 m. This sacrifice in inherent spatial resolution was traded for a decreased lower level of detectability. Spatial resolution perpendicular to the direction of flight remains at the intrinsic value of one to two times the altitude.

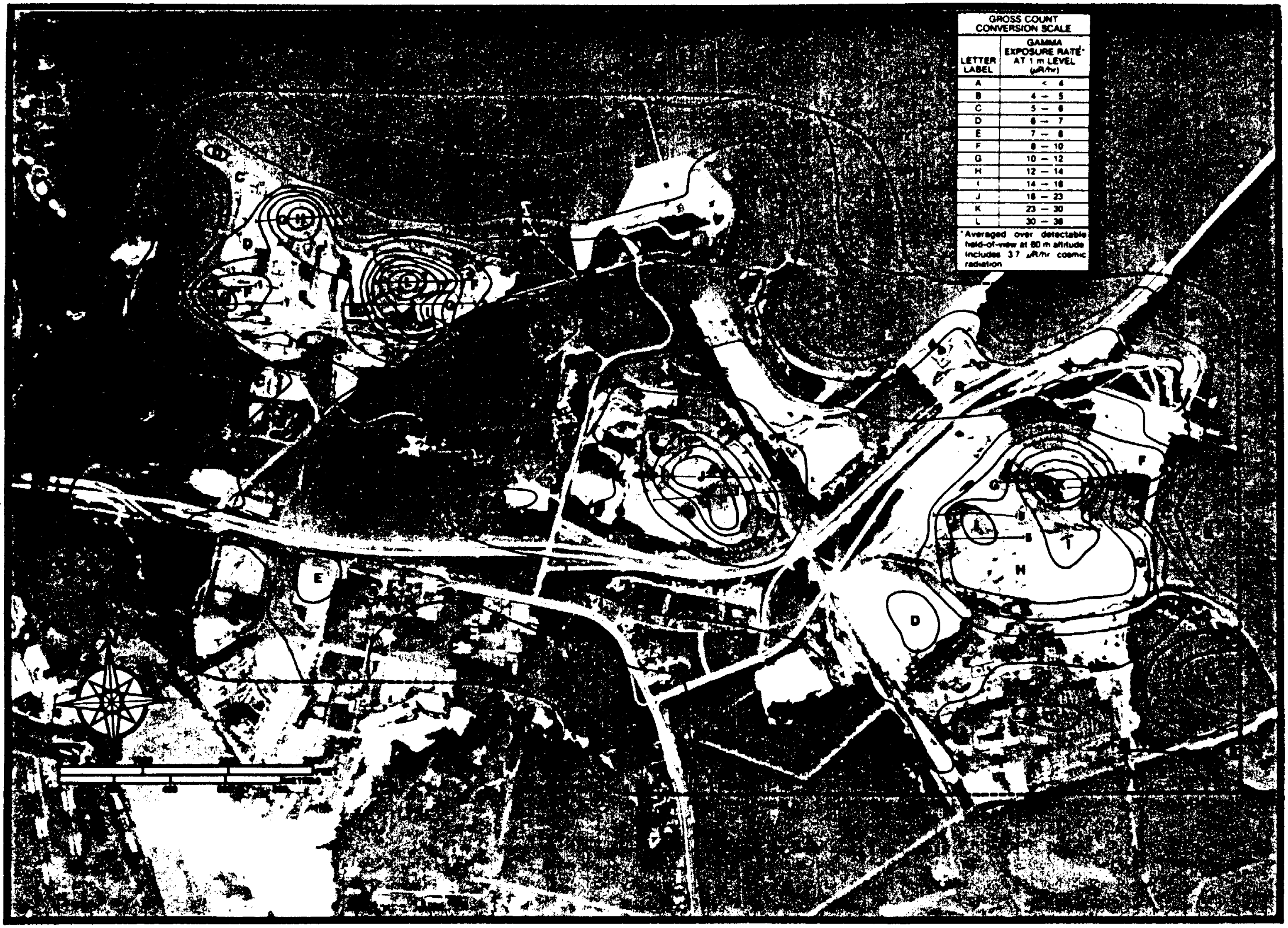

Figure 1. *EXPOSURE RATE ISOPLETHS FROM GROSS COUNT DATA, SUPERIMPOSED ON AN AERIAL PHOTOGRAPH OF THE CURTIS BAY AREA.*

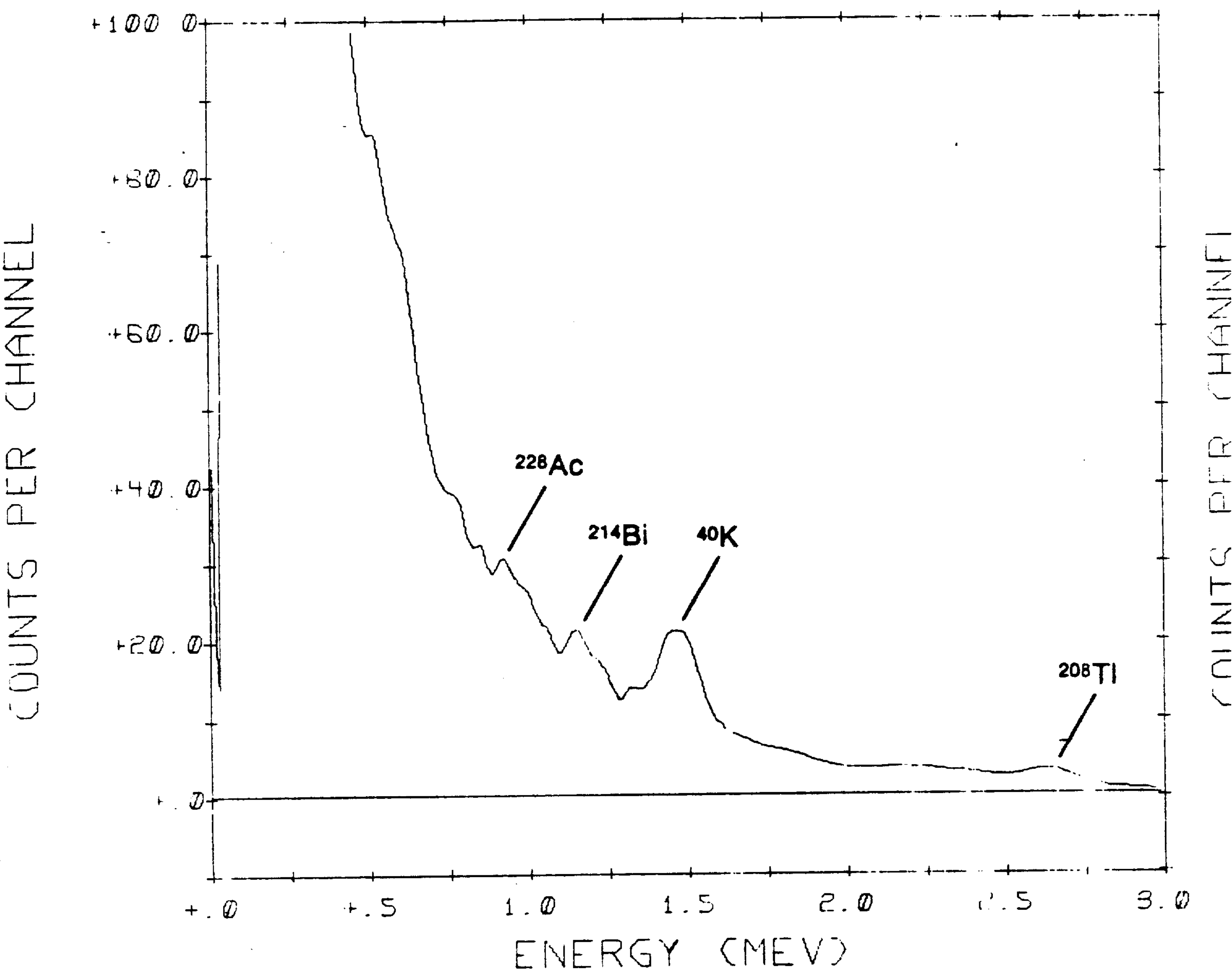

Figure 2. *Background gamma pulse height spectrum typical of the Curtis Bay area*

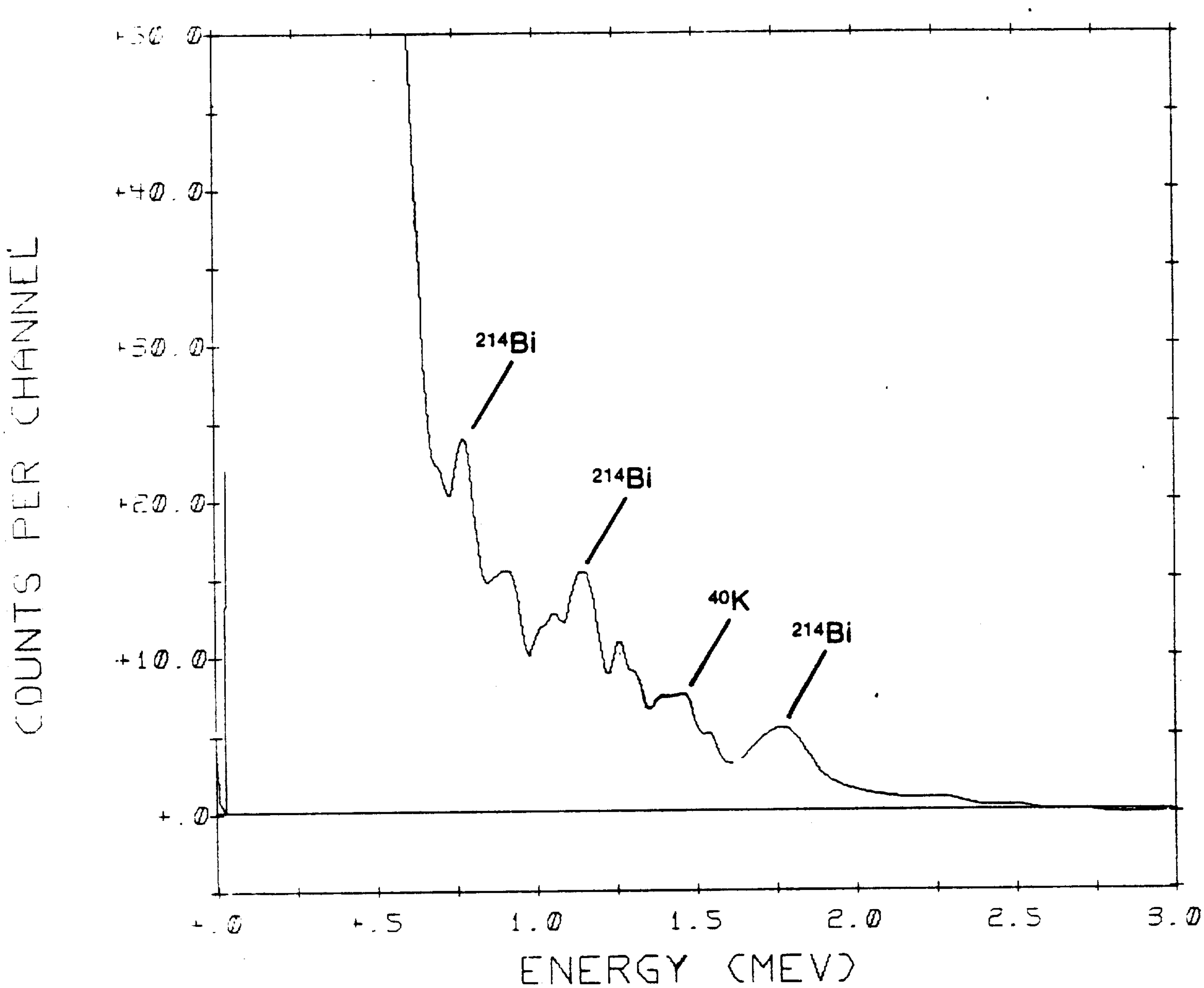

Figure 3. *Spectrum with background subtracted from area marked 1 in Figure 1*

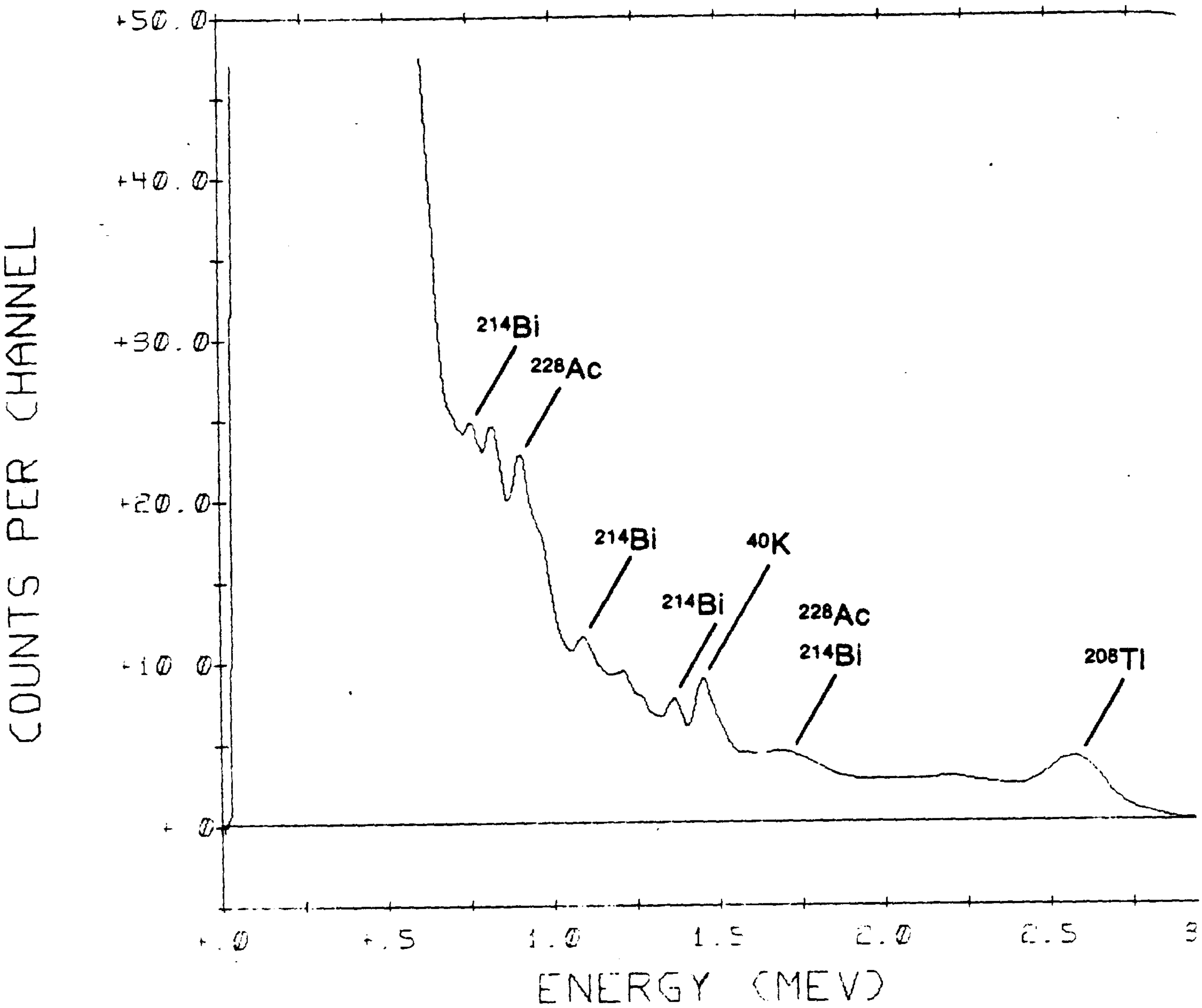

Figure 4. *Spectrum with background subtracted from area marked ? in Figure 1*

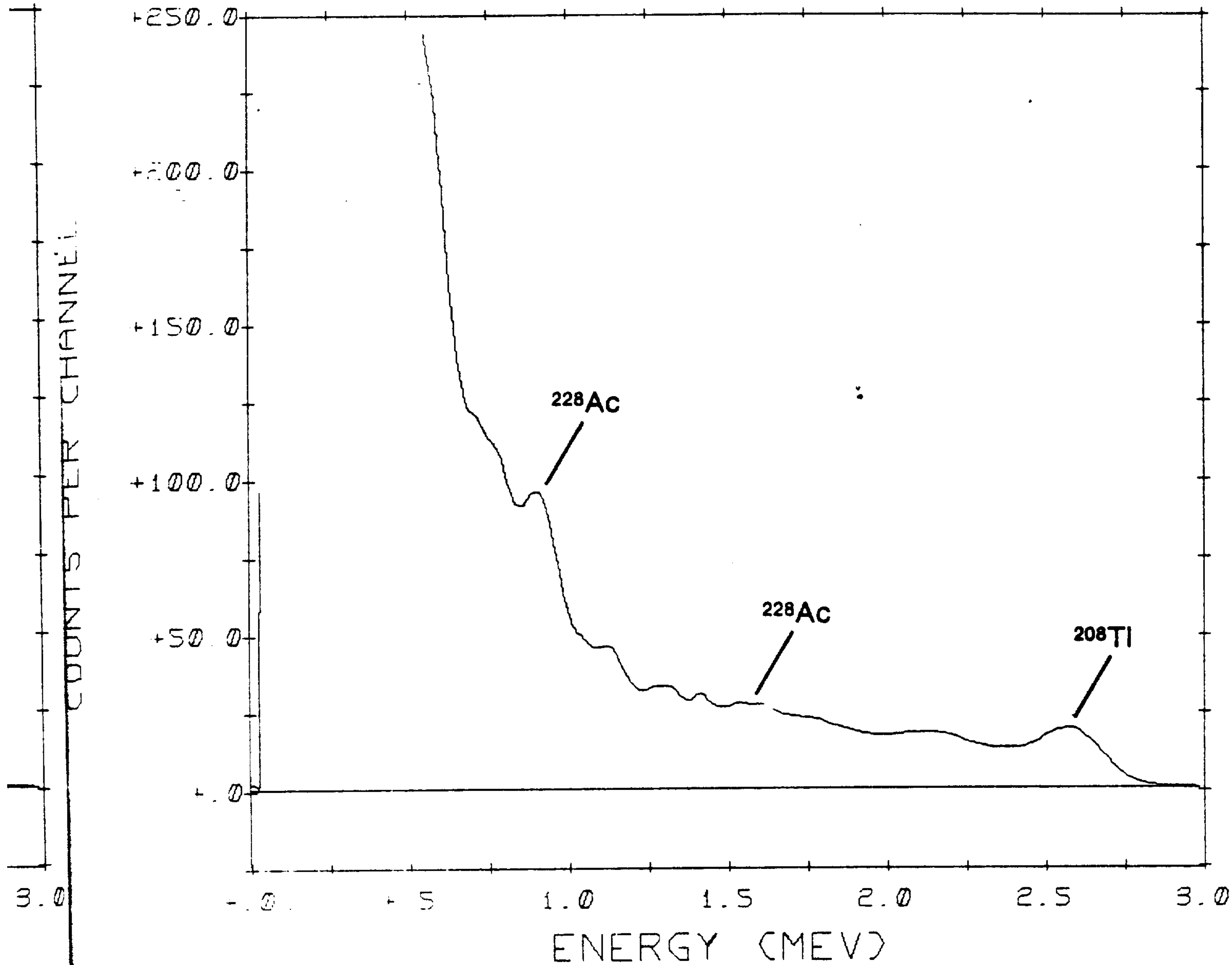

Figure 5. *Spectrum with background subtracted from area marked 3 in Figure 1*

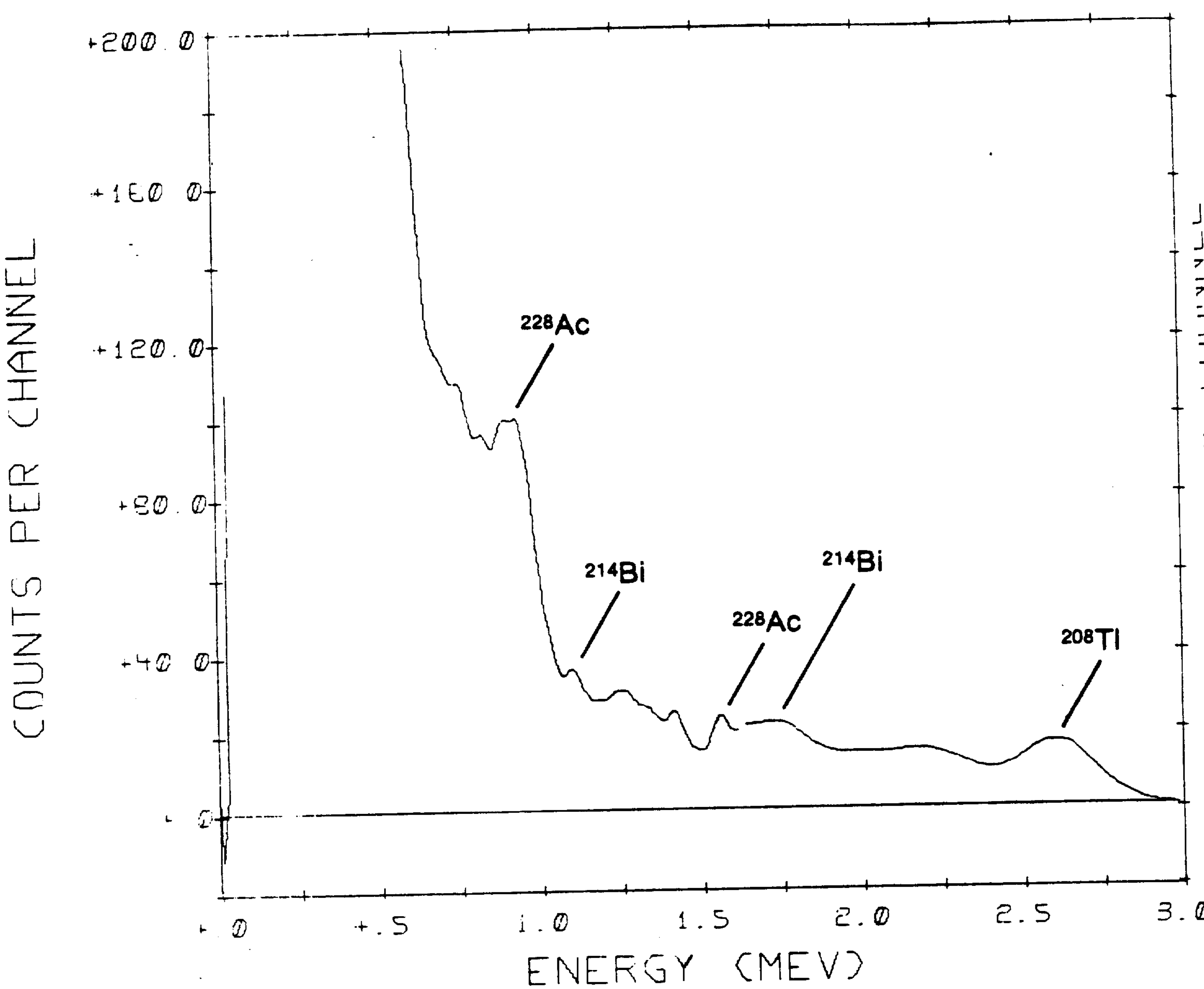

Figure 6. *Spectrum with background subtracted from area marked 4 in Figure 1*

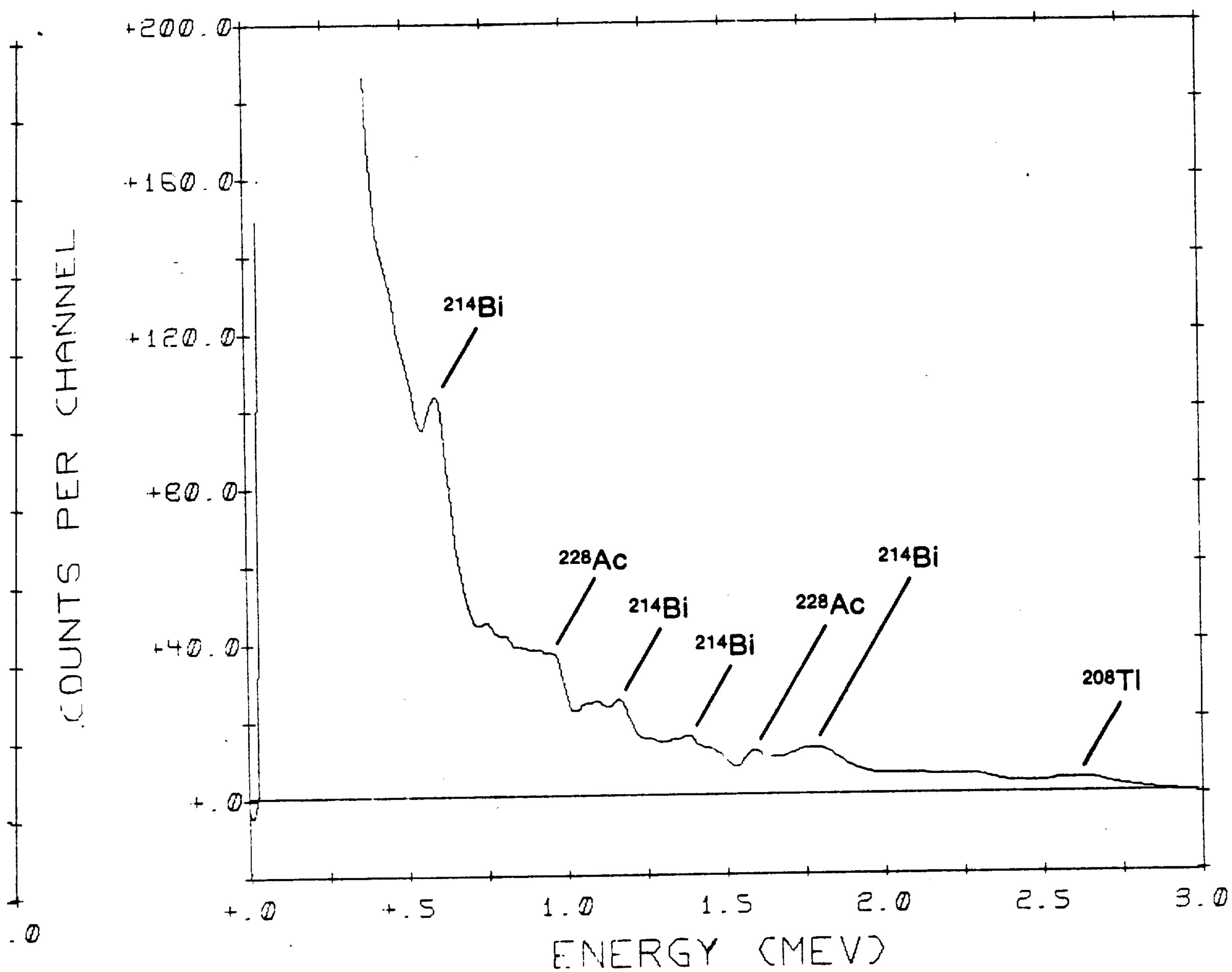

Figure 7. *Spectrum with background subtracted from area marked 5 in Figure 1*

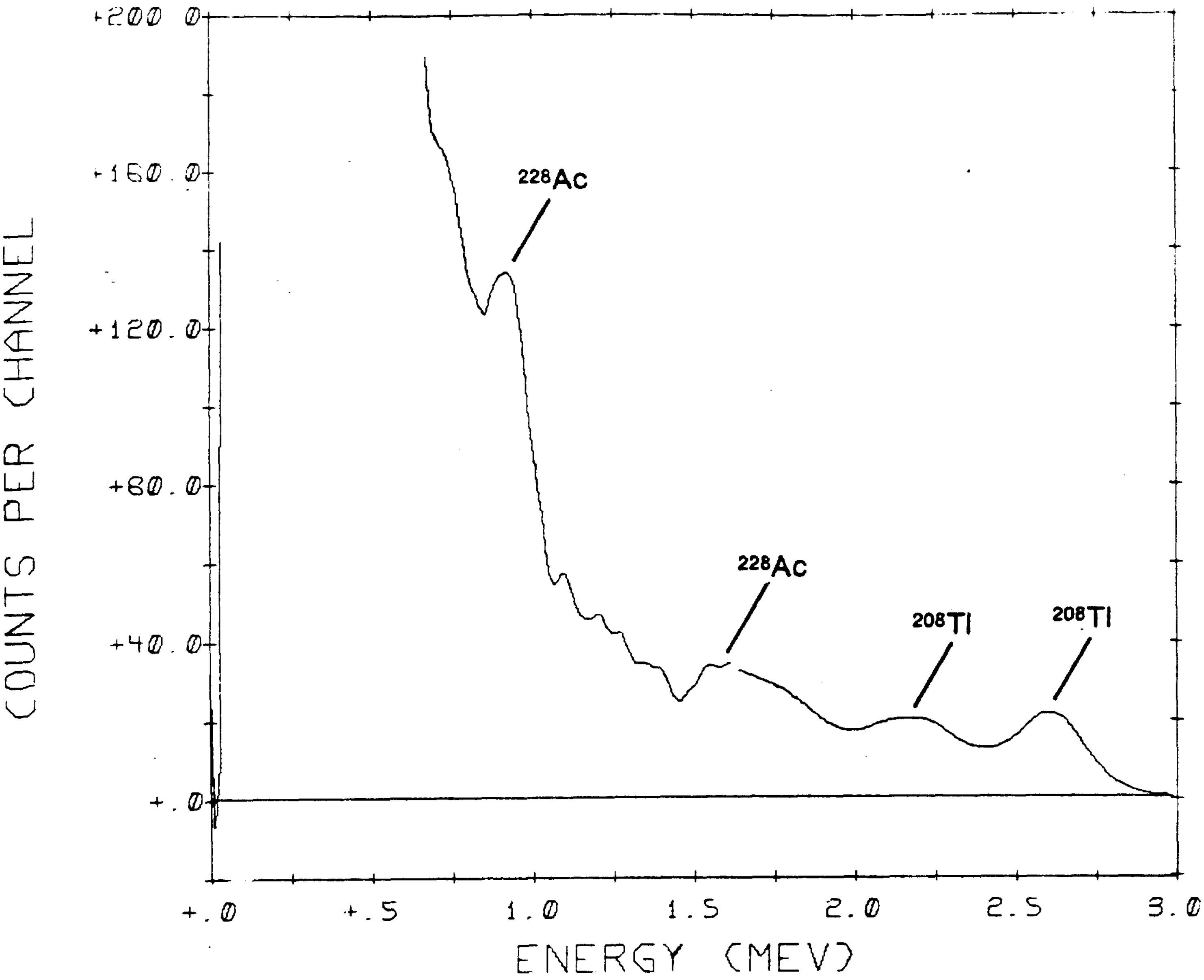

Figure 8. *Spectrum with background subtracted from area marked 6 in Figure 1*

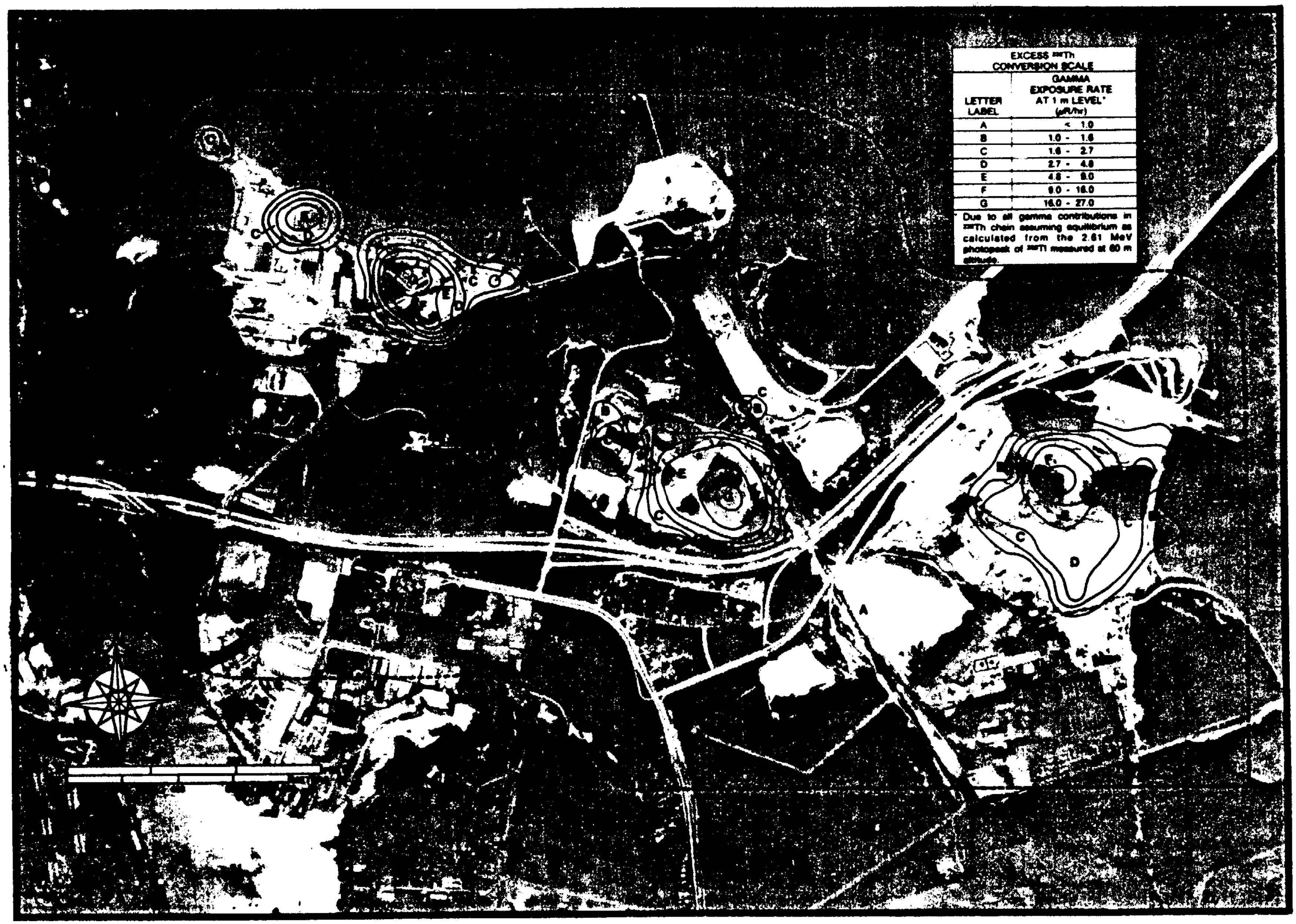

Figure 9. *EXCESS THORIUM ISOPLETHS FROM $_{208}$Tl PHOTOPEAK DATA (BACKGROUND HAS BEEN SUBTRACTED). SEE TABLE 2 FOR CONVERSION FACTORS.*

Table 1. ISOPLETH KEY FOR ^{208}Tl ISOPLETHS

LETTER LABEL	PHOTOPEAK COUNT RATES	
	CR_u (UNCORRECTED)	$CR_u/(1-\bar{R}_{Bg})$
A	< 6	< 11
B	6 - 9	11 - 16
C	9 - 15	16 - 27
D	15 - 27	27 - 49
E	27 - 50	49 - 91
F	50 - 90	91 -163
G	90 -150	163 -272

Table 2. CONVERSION FACTORS[1]

$\frac{\alpha}{\rho}$ $\frac{cm^2}{gm}$	Depth of Soil Sample ρx $\frac{gm}{cm^2}$	ISOTROPIC DETECTOR RESPONSE			COSINE DETECTOR RESPONSE			AVERAGED DETECTOR RESPONSE		
		Depth Integral of Specific Activity[2] μCi/m^2 per cps	Exposure Rate[3] at 1 Meter Level μR/hr per cps	Average Activity[2] in Soil Sample at Depth ρx pCi/gm per cps	Depth Integral of Specific Activity[2] μCi/m^2 per cps	Exposure Rate[3] at 1 Meter Level μR/hr per cps	Average Activity[2] in Soil Sample at Depth ρx pCi/gm per cps	Depth Integral of Specific Activity[2] μCi/m^2 per cps	Exposure Rate[3] at 1 Meter Level μR/hr per cps	Average Activity[2] in Soil Sample at Depth ρx pCi/gm per cps
Surface	1.6	.0081	.107	.509	.0144	.189	.900	.0113	.148	.705
6.25	1.6	.0083	.094	.516	.0146	.166	.910	.0114	.130	.713
.625	1.6	.0092	.072	.365	.0160	.125	.632	.0126	.099*	.498
.312	1.6	.0103	.066	.253	.0176	.113	.431	.0139	.089	.342
.206	1.6	.0113	.064	.199	.0191	.108	.336	.0152	.086	.267
.0625	1.6	.0181	.056	.108	.0293	.091	.174	.0237	.074	.141
Surface	4.8	.0081	.107	.170	.0144	.189	.300	.0113	.148	.235
6.25	4.8	.0083	.094	.172	.0146	.166	.303	.0114	.130	.475
.625	4.8	.0092	.072	.183	.0160	.125	.317	.0126	.099*	.250
.312	4.8	.0103	.066	.166	.0176	.113	.284	.0139	.089	.225
.206	4.8	.0113	.064	.148	.0191	.108	.250	.0152	.086	.199
.0625	4.8	.0181	.056	.098	.0293	.091	.158	.0237	.074	.128
Surface	8.0	.0081	.107	.102	.0144	.189	.180	.0113	.148	.141
6.25	8.0	.0083	.094	.103	.0146	.166	.182	.0114	.130	.143
.625	8.0	.0092	.072	.115	.0160	.125	.199	.0126	.099*	.157
.312	8.0	.0103	.066	.118	.0176	.113	.201	.0139	.089	.160
.206	8.0	.0113	.064	.114	.0191	.108	.193	.0152	.086	.154
.0625	8.0	.0181	.056	.089	.0293	.091	.144	.0237	.074	.117

(1) Calculated from 2.61 MeV photopeak of ^{208}Tl
(2) For ^{232}Th assuming chain equilibrium
(3) Due to all gamma contributions in ^{232}Th chain assuming chain equilibrium
* Used as Conversion Factor for Figure 9 Isopleths

Site	Authority	Health Priorities
Decontamination R&D Projects		
Stepan Co., Maywood, NJ	P.L. 98-50 Conference Report	High (V.P.)
W. R. Grace, Wayne, NJ	"	Low
NL Industries, Colonie, NY	"	Low (V.P.)
Latty Avenue, Hazelwood, MO	"	Medium
St. Louis Airport, St. Louis, MO	P.L. 98-360 House and Senate Reports on Bill	Low
Remedial Action Projects		
Ashland Oil, Tonawanda, NY (sites I and II)	Atomic Energy Act of of 1954, as amended (NE-20 authorization on 6/22/84)	Medium
Seaway Industrial Park, NY	"	Medium/Low
Mallinckrodt, MO	"	Medium/Low
W. R. Grace, Curtis Bay, MD	Atomic Energy Act of 1954, as amended (NE-20 authorization in this memorandum)	Low

ATTACHMENT 5

REFERENCES

1. Boyns, P. K. 1976. *The Aerial Radiological Measuring System (ARMS): Systems, Procedures, and Sensitivity (1976).* Report No. EGG-1183-1691. Las Vegas, NV: EG&G.

2. Jobst, J. E. 1979. "The Aerial Measuring Systems Program." *Nuclear Safety 20:136-47.*

3. Beck, H. L.; De Campo, J.; and Gogolak, C. 1972. *In Situ Ge (Li) and NaI (Tl) Gamma Ray Spectrometry.* HASL-258. (United States Atomic Energy Commission, Health and Safety Laboratory.) Springfield, VA: Technical Information Center, U.S. Department of Commerce.

4. Stuart, T. P. August 1977. *Limiting Values for Radionuclide Concentration in the Soil from Remote Spectrometer Measurements.* Report No. EGG-1183-1716. Las Vegas, NV: EG&G, Inc.

5. Stuart, T. P. 30 May 1978. *Factors That Convert Aerial Measurements to Concentration of Gamma Ray Emitters in the Soil - an Updated Calculational Procedure.* Company Memorandum. Las Vegas, NV: EG&G.