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ENVIRONMENTAL SURVEY AT THE AAEC RESEARCH ESTABLISHMENT, LUCAS HEIGHTS - RESULTS FOR 1980

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ABSTRACT

Results are presented of the environmental survey at the AAEC Research Establishment, Lucas Heights, during 1980. They show that the only radioactivity detected which could be of Research Establishment origin and which could also be ingested by was due to tritium and ^{60}Co. The maximum credible dose which a member of the public could receive from this radioactivity is calculated to be 0.0006 of the derived working limit, i.e. 3 microsieverts, which is equivalent to about 0.03 per cent of the natural background; this is consistent with the most recent recommendations by the International Commission on Radiological Protection that exposures be kept as low as is reasonably achievable, and is a most satisfactory result.

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The following descriptors have been selected from the INIS Thesaurus to describe the subject content of this report for information retrieval purposes. For further details please refer to IAEA-INIS-12 (INIS: Manual for Indexing) and IAEA-INIS-13 (INIS: Thesaurus) published in Vienna by the International Atomic Energy Agency.

AAEC; AIR; AUSTRALIA; CESIUM 137; COBALT 60; CONTAMINATION; ENVIRONMENT; EXPERIMENTAL DATA; FISHES; FRESH WATER; GASEOUS WASTES; GROUND WATER; HUMAN POPULATIONS; IODINE 131; LIQUID WASTES; MAN; MILK; OYSTERS; PLANTS; RADIATION DOSES; RADIATION MONITORING; RADIOACTIVITY; RIVERS; SAND; SOILS; TRITIUM

ERRATA

AAEC/E542

p.22 (a) Station description should read:

Water pool across road from stormwater outlet.

(b) Footnote applies to all Table 12.

1. INTRODUCTION

Since 1959, a survey of the content of radioactivity in samples collected from the environs of Lucas Heights has been conducted to ensure that no unacceptable health effects have occurred as a result of operations at the AAEC Research Establishment*. The results obtained during the survey have been published regularly and details of previous publications are listed in Appendix A.

During the early part of the survey (i.e. throughout the 1960s), readily detectable amounts of weapons test fallout were present in samples collected around Lucas Heights [Giles and Stockdale 1966]. A large program of sampling was required to establish the general level of 'background' radioactivity arising from weapons test fallout in order to measure any additional radioactivity that may have been caused by Lucas Heights operations.

To establish this general background, samples were collected within a 60 km radius of the site; this expanded program was scaled down in 1970 because the Australian Radiation Laboratory had set up a monitoring system throughout Australia and routinely measured samples from the Sydney region. Results of these surveys were published by various authors in the Australian Journal of Science between 1957 and 1970, (see Appendix B). Further reports have been made by the Australian Ionising Radiation Advisory Council [AIRAC 1975] and the United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR 1977]. All of these studies provide a basis for comparison with the results for milk samples reported in the AAEC/E series of monographs (see Appendix A).

The present monitoring system is designed to detect radioactive contaminants which may have been released from the Lucas Heights Research Establishment, either routinely (under authorisations from the New South Wales health authorities) or accidentally, and to ensure that such concentrations do not result in intake of radioactivity by, or radiation doses to, members of the public in excess of derived working limits, in accordance with the recommendations of the International Commission on Radiological Protection (ICRP). These are accepted by the Australian advisory body, the National Health and Medical Research Council (NHMRC).

* Since 1981, the site formerly called AAEC Research Establishment has been renamed Lucas Heights Research Laboratories.

In this report, we tabulate the results of measurements taken during 1980 and calculate the maximum credible dose (see Section 6) which a member of the public could have received.

2. SAMPLE COLLECTION AND PREPARATION

Samples were collected at the sites shown on Figure 1 and the details of collection and sample preparation methods are given in Tables 1 and 2.

3. ANALYTICAL METHODS

Analytical methods which have been modified and methods which have been introduced since the previous survey are described in Appendix C.

4. RESULTS

Environmental survey measurements taken during 1980 are presented in Tables 3 to 15. Authorised airborne releases are discussed in Section 5.8. An account of authorised liquid effluent discharges first to the Woronora River and later to the Metropolitan Water Sewerage and Drainage Board sewers is given in Appendix D.

5. DISCUSSION OF RESULTS

5.1 Annual Limits of Intake for Tritium (^{3}H)

The ICRP has recommended criteria for limiting uptake of radionuclides and given limits for selected nuclides and occupational exposure [ICRP 1979]. In the case of ^{3}H, the annual limit of intake (ALI) for occupational exposure has been set by the ICRP at 3×10^{9} Bq. As annual limits for members of the public in the ICRP and NHMRC recommendations are one tenth of those for occupational exposure, the ALI for a member of the public is assumed to be 3×10^{8} Bq. If a daily intake of water of 3 L is assumed, as is stipulated for Reference Man [ICRP 1975] and the ALI is averaged over the year, the derived working limit for drinking water concentration is 274 Bq mL^{-1}.

5.2 Woronora Samples (Tables 2-7)

Cobalt-60 was again found in zostera samples. As zostera is not consumed by people, these levels do not constitute a direct source of exposure. However, zostera beds provide shelter and food for fish. Fish samples collected at the discharge point contained quantities of ^{60}Co which were small in absolute terms, but higher than in previous years. Natural radioactivity was present in beach sands at the same levels as in previous years.

5.3 Milk Samples (Table 8)

Concentrations of ^{137}Cs and ^{131}I in milk taken from cows at Menai were below detectable limits in all samples collected during the year. Some samples were reported to have trace amounts of ^{137}Cs. In those cases, small unresolvable peaks were seen in the spectrum, which could indicate its presence. The detectable levels for ^{131}I and ^{137}Cs represent 4.5 per cent and 0.6 per cent of the derived working limit respectively. The derived working limit has been based on the model of an infant consuming 0.7 L of milk per day.

The trend towards lower concentrations of ^{137}Cs seen in milk samples over the past four years is consistent with the diminishing amounts of weapons test fallout in the atmosphere. Iodine-131 from weapons test fallout is no longer seen because of its relatively short half-life (8 days).

5.4 Samples Related to the Little Forest Burial Ground (Tables 9-11)

5.4.1 Vegetation

Small amounts of ^{60}Co were found in the leaves of an acacia tree growing on top of one of the burial trenches. Some surface soil samples contained traces of ^{60}Co.

5.4.2 Groundwater

Because of the highly variable amounts of suspended solids in groundwater, the results have been reported as Bq g^{-1} of sediment. The values quoted in Table 10 refer to a 10 L sample of groundwater.

Apart from ^{3}H, only naturally occurring radioisotopes were found and these were at levels within the normal range of occurrence.

The results for gross α and gross β activity for 1979 [Giles and Dudaitis 1980, Table 10] were found to have a computational error and should be replaced by the values given in Table 10(a) of the present report. The new figures represent natural radioactivity only.

5.5 Stormwater Outlets (Table 12)

Small amounts of ^{137}Cs and ^{60}Co continue to be found in soil and vegetation near stormwater outlets. Measurable amounts of ^{137}Cs and ^{60}Co have also been seen in some stormwater samples, the highest reading for ^{137}Cs being 0.19 Bq L^{-1} and that for ^{60}Co being 0.14 Bq L^{-1}. Strontium-90 was found in water and sand in a pool across the road from stormwater outlet No.1. The highest reading in this water was 0.24 Bq L^{-1}.

The derived working limits for ^{137}Cs, ^{60}Co and ^{90}Sr in water, based on a similar model to that in Section 5.1, are 365, 1800 and 91 Bq L^{-1}, respectively. No pathway for human consumption can be defined for these types of radioactivity.

In many of the water samples, ^{3}H was present but generally in low concentrations. The highest concentration was 14.4 Bq mL^{-1}. The derived working limit for ^{3}H (see Section 5.1) is 274 Bq mL^{-1}.

Checks on radioactivity in the freshwater section of the Woronora River at the point of entry for drainage from the Research Establishment were made throughout the year. Samples were also collected at the Heathcote Road crossing, above any possible input from Lucas Heights, in order to provide a direct measure of background levels. These are presented in Table 13. On two occasions, ^{3}H levels at the drainage point were slightly above natural background concentrations. All other readings represent normal background levels.

5.6 Effluent Discharge Pipeline (Tables 14 and 14(a))

The survey of radiation being emitted from the discharge pipeline revealed doserates shown in Table 14. The maximum level of direct radiation dose to members of the public set by the ICRP is 5000 μSv per year. This represents 0.57 μSv h^{-1} for a continuous 24 hour per day exposure. Because of the isolated position of the above-ground sections of the discharge pipe, an occupancy factor for members of the public must be very low and the allowable doserate correspondingly very high.

5.7 Radioactive Iodine in Air (Table 15)

During 1980, three continuously operating air samplers were installed along the eastern boundary of the Research Establishment. Some unresolvable peaks were present on the gamma spectrometer graphs which may indicate trace amounts of ^{131}I, but no clearly measurable quantities were found. The minimum detectable level for the method is 0.003 Bq m^{-3}. The derived air concentration for ^{131}I set by the ICRP [1979] for workers is 700 Bq m^{-3}. For members of the general public this is reduced to 70 Bq m^{-3}.

5.8 Airborne Releases (Tables 16 and 17)

Table 16 details measurements of radioactivity released to the atmosphere from various buildings at Lucas Heights for the four quarters of 1980. In Table 17 these levels are shown as fractions of the limits permitted under the NSW Radiological Advisory Council authorisation, outlined by Cook [1969]. A rationale of the authorisation and compliance requirements was given in a previous report [Hespe 1979].

6. RADIOLOGICAL SIGNIFICANCE OF RESULTS

As in previous surveys, a hypothetical individual has been considered in order to provide a conservative assessment of the radiological significance of the results of the survey. It is assumed that this individual:

- eats one dozen oysters (70 g) per day from the Woronora River,
- eats 70 g of fish from the Woronora River per day,
- drinks 250 litres of water per year from the freshwater section of the Woronora River at the point of highest concentration while picnicking/camping, and

. swallows 100 mL per day of water while swimming in the estuary.

An individual in this group would receive a dose of 2.9 μSv per year, i.e. 0.0006 of the dose limit for members of the public of 5 mSv per year which is recommended by the National Health and Medical Research Council and which is the legal limit in all States.

Doses from ^{3}H due to ingestion of water while swimming, or ingestion of water from the freshwater section of the Woronora River, have been included as there is always the possibility of small exposures from this pathway.

7. SUMMARY

During 1980, tritium and ^{60}Co were the only isotopes found in the environment which could have had their origin at the AAEC Research Establishment and which could also be assumed to be in foodstuffs. Conservative concepts were used to derive a maximum credible doserate of about 3 μSv for a hypothetical individual as a result of exposure to these isotopes.

8. ACKNOWLEDGEMENTS

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TABLE 1

COLLECTION AND PREPARATION OF WORONORA SAMPLES

Sample	Station(s)	Frequency	Method of Collection	Special Preparations
Oysters	E7.0, 9.3 Hawkesbury River (control)	Quarterly	Obtained from commercial leases	Opened by commercial openers. Drained on sieve for 5 min. Ashed
Fish	E1.3, 6.4 (or wherever available)	Quarterly	Taken by gill net	Whole fish ashed
Beach sand	E1.3, 5.9	Quarterly	Taken by scoop from top 50 mm in intertidal region	Sample ashed and sieved. Sample passing 10 mesh BSS counted for beta-gamma emitters. Sample between 60 and 110 mesh BSS counted for alpha emitters
Estuary water	E5.9	Weekly	From surface by bucket	Distilled for tritium
Zostera	E1.6, 2.4, E4.6, 7.0, E9.3	Quarterly (when available)	Harvested by hand or rake	Ashed

TABLE 2

COLLECTION AND PREPARATION OF SAMPLES OF MILK, AND GROUND AND CREEK WATER, VEGETATION, SOIL AND SAND

Sample	Station	Frequency	Collection Details	Special Preparations
Milk	T3	Monthly	Sampled from milk produced by locally grazed cows	Gamma spectrometry of whole milk
Radioactive iodine in air	TO	Weekly	Collected on Maypacks	Gamma spectrometry of Maypacks
Vegetation	T1; RE stormwater outlets	Six-monthly	Cut by hand clippers	Whole unwashed vegetation ashed
Sand/Soil	TO,T1, RE stormwater outlets	Six-monthly	Scooped from surface	As for beach sand Table 1
Groundwater	T1	Six-monthly	Boreholes pumped dry, allowed to refill and sampled from bottom	10 L sample evaporated to dryness and the residue counted
Creek water	T2	Six-monthly	Sampled by bucket or bottle	As for groundwater

TABLE 3

RADIOACTIVITY IN WORONORA AND HAWKESBURY OYSTERS, 1980

Station	Date	Radioactivity (Bq g^{-1} fresh weight)			K
		Gross alpha	Gross beta (less ^{40}K)	^{65}Zn	(μg g^{-1})
E 7.0	22 Jan.	0.009	0.003	n.d.	3900
	21 April	0.020	0.002	n.d.	3200
	23 Sept.	0.013	0.023	n.d.	2900
	15 Dec.	0.003	0.009	n.d.	3000
Average		0.011	0.009		
E 9.3	27 March	0.007	< 0.009	n.d.	3200
	12 June	0.010	0.007	n.d.	3100
	16 Sept.	0.007	0.013	n.d.	3100
	2 Dec.	0.002	0.005	n.d.	1300
Average		0.007	0.009		
Hawkesbury River	24 March	0.009	0.017	n.d.	3900
	24 June	0.008	0.015	n.d.	2400
	6 Oct.	0.006	0.017	n.d.	2800
	8 Dec.	0.005	0.005	n.d.	3000
Average		0.007	0.014		
Oyster Shell Composite 1980	1980	0.027	0.012	n.d.	100

n.d. - not detected

TABLE 4

RADIOACTIVITY IN WORONORA FISH, 1980

Station & variety	Date	Radioactivity ($Bq\ g^{-1}$ fresh weight)			K ($\mu g\ g^{-1}$)
		Gross alpha	Gross beta (less ^{40}K)	Gamma emitters	
EO					
Mullet	20 March	0.01	0.020	0.002 ^{60}Co Trace $^{238}U+^{232}Th$	2800
Mullet	16 July	0.01	0.02	0.003 ^{60}Co Trace $^{238}U+^{232}Th$	2100
Mullet	10 Dec.	0.02	0.01	Trace ^{60}Co Trace $^{238}U+^{232}Th$	2800
Average		0.013	0.02	0.002 ^{60}Co	
E6.6					
Mullet	18 Jan.	0.01	0.03	Trace $^{238}U+^{232}Th$	2300
Mullet	2 April	0.01	0.022	Trace $^{238}U+^{232}Th$	2500
Blackfish	2 April	0.02	0.010	Trace $^{238}U+^{232}Th$	3100
Mullet	18 July	0.02	0.02	Trace $^{238}U+^{232}Th$	2300
Mullet	26 Sept.	0.01	0.010	Trace $^{238}U+^{232}Th$	3300
Mullet	24 Dec.	0.01	0.01	Trace $^{238}U+^{232}Th$	2600
Average		0.013	0.017		

n.d. = not detected

TABLE 5
RADIOACTIVITY IN WORONORA BEACH SAND, 1980

Station	Date	Radioactivity (Bq g^{-1} dry weight)			K ($\mu g\ g^{-1}$)
		Gross alpha	Gross beta (less ^{40}K)	Gamma emitters	
E1.3	26 March	0.42	0.05	Trace $^{238}U+^{232}Th$	200
	8 July	0.03	0.05	Trace $^{238}U+^{232}Th$	300
	5 Sept.	0.21	0.050	Trace $^{238}U+^{232}Th$	200
	17 Dec.	0.95	0.05	n.d.	100
E5.9	26 March	0.41	0.25	Trace $^{238}U+^{232}Th$	300
	8 July	0.33	0.13	Trace $^{238}U+^{232}Th$	200
	5 Sept.	0.27	0.07	n.d.	300
	17 Dec.	0.11	0.22	n.d.	200
Average (all samples)		0.34	0.11		
d.l.c.		111	92.5		
Average fraction of d.l.c.		3.1×10^{-3}	1.2×10^{-3}		

Derived limiting concentration (d.l.c.) taken from Fry [1966].

n.d. = not detected

TABLE 6

TRITIUM IN WORONORA WATER SAMPLES AT STATION E5.9, 1980

Date	Tritium (Bq mL^{-1})	Date	Tritium (Bq mL^{-1})	Date	Tritium (Bq mL^{-1})
4th Jan.	0.04	30th May	0.06	30th Oct.	< 0.04
11th Jan.	0.04	6th June	< 0.04	7th Nov.	< 0.04
18th Jan.	< 0.04	13th June	< 0.04	14th Nov.	< 0.04
25th Jan.	0.04	20th June	< 0.04	21st Nov.	0.13
1st Feb.	< 0.04	27th June	< 0.04	28th Nov.	0.06
8th Feb.	< 0.04	4th July	0.06	5th Dec.	0.20
15th Feb.	0.04	11th July	< 0.04	16th Dec.	0.20
22nd Feb.	< 0.04	18th July	< 0.04	22nd Dec.	< 0.04
29th Feb.	< 0.04	29th July	< 0.04	24th Dec.	< 0.04
7th March	< 0.04	5th Aug.	< 0.04		
14th March	< 0.04	15th Aug.	< 0.04		
21st March	< 0.04	22nd Aug.	< 0.04	Average	< 0.06
28th March	< 0.04	29th Aug.	< 0.04		
3rd April	0.10	5th Sept.	0.10		
11th April	0.12	12th Sept.	< 0.04		
18th April	< 0.04	19th Sept.	< 0.04		
28th April	0.21	26th Sept.	< 0.04		
2nd May	< 0.04	3rd Oct.	< 0.04		
9th May	< 0.04	10th Oct.	< 0.04		
16th May	< 0.04	17th Oct.	< 0.04		
26th May	< 0.04	23rd Oct.	< 0.04		

Derived limiting concentration taken from ICRP [1979]

d.l.c. = 274 Bq mL^{-1} (if taken as drinking water)

Average fraction of d.l.c. = 2×10^{-4}

TABLE 7
RADIOACTIVITY IN WORONORA ZOSTERA SAMPLES, 1980

Station	Date	Radioactivity ($Bq\ g^{-1}$ fresh weight)				K ($\mu g\ g^{-1}$)
		Gross alpha	Gross beta (less ^{40}K)	Gamma emitters		
				^{60}Co	$^{238}U+^{232}Th$ series	
E1.3	26th March	0.06	0.06	0.08	Trace	5700
	8th July	0.02	0.02	0.02	Trace	5400
	5th Sept.	0.06	0.04	0.03	Trace	5100
	17th Dec.	0.03	0.03	0.01	Trace	4000
E1.6	8th July	0.07	0.07	0.03	Trace	4800
E2.4	26th March	0.05	0.07	0.06	Trace	5900
	8th July	0.03	0.03	0.02	Trace	5600
	5th Sept.	0.05	0.03	0.02	Trace	4500
	17th Dec.	0.14	0.07	0.03	Trace	6700
E4.6	8th July	0.07	0.06	0.01	Trace	6000
	17th Dec.	0.08	0.21	Trace	Trace	3200

TABLE 8

RADIOACTIVITY IN MILK SAMPLES, 1980

Station	Date	Radioactivity (Bq g^{-1} Fresh Weight)	
		^{137}Cs	^{131}I
T3 (Menai)	31st Jan.	n.d.	n.d.
	29th Feb.	n.d.	n.d.
	28th March	Trace	n.d.
	9th May	n.d.	n.d.
	2nd June	Trace	n.d.
	30th June	n.d.	n.d.
	10th July	n.d.	n.d.
	22nd July	Trace	n.d.
	28th Aug.	Trace	n.d.
	2nd Oct.	n.d.	n.d.
	30th Oct.	n.d.	n.d.
	28th Nov.	n.d.	n.d.
	22nd Dec.	Trace	n.d.

The analytical method used for ^{131}I in milk has a minimum detectable level of 1×10^{-3} Bq g^{-1}. For ^{137}Cs the minimum detectable level was 0.0003 Bq g^{-1}.

n.d. = not detected

TABLE 9

RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION FROM LITTLE FOREST BURIAL GROUND, 1980

Location	Sample	Date	Radioactivity ($Bq\ g^{-1}$ fresh weight)					K ($\mu g\ g^{-1}$)
			Gross alpha	Gross beta (less ^{40}K)	Gamma emitters			
					0.5MeV	^{60}Co	$^{238}U+^{232}Th$	
Near Trench 1-5	Soil	20th June	0.8	0.6	n.d.	n.d.	Trace	4700
	Soil	12th Dec.	0.8	0.7	n.d.	Trace	Trace	3300
Near Trench	Soil	20th June	3.30	0.8	n.d.	Trace	Trace	4100
56-57	Soil	12th Dec.	1.4	0.8	n.d.	Trace	Trace	3200
Near Trench	Acacia	20th June	0.03	0.05	0.01	n.d.	Trace	2400
58-59	Acacia	12th Dec.	0.04	0.02	n.d.	n.d.	Trace	2500
Near Trench	Soil	20th June	1.1	1.2	n.d.	0.02	Trace	2500
68-69	Soil	12th Dec.	1.0	0.9	n.d.	Trace	Trace	4200
Near Trench 71	Acacia	20th June	0.02	9.1	n.d.	0.10	Trace	2000
	Acacia	12th Dec.	0.02	6.5	n.d.	Trace	Trace	1800
Near Trench	Soil	20th June	1.0	0.7	n.d.	Trace	Trace	5600
72-73	Soil	12th Dec.	0.9	0.80	n.d.	Trace	Trace	3700

n.d. = not detected

The gamma-ray peaks detected at approximately 0.5 MeV could be ^{7}Be (0.48 MeV), ^{103}Ru (0.5 MeV) or ^{106}Ru (0.51 MeV). ^{7}Be is a cosmic-ray produced activation product; ^{103}Ru and ^{106}Ru are fission products.

TABLE 10
RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM
LITTLE FOREST BURIAL GROUND, 1980

Bore hole no.	Bq g^{-1} sediment						Bq mL^{-1}	
	Gross alpha		Gross* beta		Gamma emitters		^{3}H	
	Jun.	Dec.	Jun.	Dec.	Jun.	Dec.	Jun.	Dec.
BH1	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
2	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
3	0.2	3.6	1.1	1.0	Trace ^{238}U, ^{232}Th series	Trace ^{238}U, ^{232}Th series	<0.04	-
4	2.3	2.4	0.8	0.9	n.d.	Trace ^{238}U, ^{232}Th series	<0.04	-
5	Dry	Dry	Dry	Dry	n.d.	Dry	-	Dry
6	2.6	3.1	1.0	0.90	Trace ^{238}U, ^{232}Th series	n.d.	<0.04	-
10	0.01	0.4	0.2	0.2	n.d.	n.d.	<0.04	-
OS1	0.03	0.8	0.6	0.4	n.d.	n.d.	<0.04	-
2	0.1	3.7	1.5	1.50	Trace ^{238}U, ^{232}Th series	n.d.	3.5	-
3	1.6	1.4	2.9	3.2	Trace ^{238}U, ^{232}Th series	Trace ^{238}U, ^{232}Th series	30.2	-
BHA	0.01	0.04	0.2	0.2	n.d.	n.d.	<0.04	-
B	0.01	1.14	0.2	0.1	n.d.	n.d.	<0.04	-
C	0.01	0.03	0.2	0.2	n.d.	n.d.	<0.04	-
D	0.2	0.09	0.2	0.20	n.d.	n.d.	<0.04	-
E	0.01	0.04	0.2	0.2	n.d.	Trace ^{238}U, ^{232}Th series	<0.04	-

* includes ^{40}K contribution

n.d. = not detected

\- = not measured

TABLE 10a

RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM LITTLE FOREST BURIAL GROUND, 1980

Bore hole no.	Bq g^{-1} sediment						Bq mL^{-1}	
	Gross alpha		Gross* beta		Gamma emitters		^{3}H	
	Jun.	Dec.	Jun.	Dec.	Jun.	Dec.	Jun.	Dec.
BH1	1.8	dry	0.9	dry	n.d.	dry	<0.04	dry
2	1.7	dry	1.1	dry	n.d.	dry	<0.04	dry
3	1.8	3.7	1.1	1.5	n.d.	Trace ^{238}U, ^{232}Th series	<0.04	0.12
4	1.8	2.3	0.8	1.0	n.d.	Trace ^{238}U, ^{232}Th series	<0.04	<0.04
5	2.6	dry	1.2	dry	Trace ^{238}U, ^{232}Th series	dry	<0.04	dry
6	1.8	3.3	0.8	1.4	n.d.	Trace ^{238}U, ^{232}Th series	<0.04	<0.04
10	0.20	3.1	0.6	1.1	n.d.	Trace ^{238}U, ^{232}Th series	0.48	-
OS1	0.1	0.8	0.6	0.5	Trace ^{238}U, ^{232}Th series	Trace ^{238}U, ^{232}Th series	-	<0.04
2	4.2	3.9	4.50	1.3	n.d.	Trace ^{238}U, ^{232}Th series	-	7.2
3	1.5	2.5	4.2	2.10	n.d.	Trace ^{238}U, ^{232}Th series	-	33.2
BHA	0.1	0.2	0.3	0.2	n.d.	n.d.	-	<0.04
B	0.1	0.2	0.20	0.2	n.d.	n.d.	<0.04	<0.04
C	0.09	0.06	0.3	0.20	n.d.	Trace ^{238}U, ^{232}Th series	<0.04	<0.08
D	0.1	0.5	0.30	0.3	n.d.	n.d.	-	<0.04
E	0.05	1.10	0.09	0.5	n.d.	Trace ^{238}U, ^{232}Th series	<0.04	<0.04

* includes ^{40}K contribution

n.d. = not detected

\- = not measured

TABLE 11
RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST BURIAL GROUND, 1980

SAND:

Station	Date	Radioactivity Bq g^{-1} dry weight			K ($\mu g\ g^{-1}$)
		Gross alpha	Gross beta (less ^{40}K)	Gamma emitters	
Bardens Creek above junction with Mill Creek	18.12	1.7	0.09	Trace ^{238}U&^{232}Th series	400
Mill Creek above junction with Bardens Creek	18.12	1.3	0.05	Trace ^{238}U&^{232}Th series	300

WATER:

Station	Date	Radioactivity Bq L^{-1}			^{3}H (Bq mL^{-1})
		Gross alpha	Gross beta (less ^{40}K)	Gamma emitters	
Bardens Creek above junction with Mill Creek	18.12	0.2	0.1	n.d.	-

n.d. = not detected

\- = not measured

TABLE 12

RADIOACTIVITY IN SAMPLES FROM STORMWATER OUTLETS, 1980

Station	Date	Sample	Radioactivity ($Bq\ g^{-1}$ fresh weight)			^{3}H ($Bq\ mL^{-1}$)	K ($\mu g\ g^{-1}$)
			Gross alpha	Gross beta (less ^{40}K)	Gamma emitters		
Drain behind Building 1	8.12	Water	-	-	-	0.44	-
Drain rear of Building 9	19.3	Soil	0.4	0.3	^{238}U&^{232}Th series=trace	-	1300
	19.3	Water	-	-	-	<0.04	-
	26.6	Soil	0.3	0.3	^{238}U&^{232}Th series=trace	-	
	26.6	Water	-	-	-	<0.04	-
	24.9	Soil	0.3	0.4	^{238}U&^{232}Th series=trace	-	
	8.12	Soil	0.4	0.4		-	900
	8.12	Water	-	-	-	0.07	-
Drain on road at west fence	19.3	Soil	1.0	0.3	^{238}U&^{232}Th series=trace	-	2200
	26.6	Soil	0.5	0.4	^{238}U&^{232}Th series=trace	-	650
	26.6	Water	-	-	-	0.06	-
	24.9	Soil	0.2	0.07	^{238}U&^{232}Th series=trace	-	200
	8.12	Soil	0.2	0.08	^{238}U&^{232}Th series=trace	-	350
	8.12	Water	-	-	-	<0.04	-
Drain opposite sub-station	19.3	Soil	0.6	0.2	^{238}U&^{232}Th series=trace	-	400
	24.9	Soil	0.6	0.3	^{238}U&^{232}Th series=trace	-	400
Drain at Boom Gate	19.3	Soil	0.4	0.3	^{238}U&^{232}Th series=trace	-	300
	26.6	Soil	0.2	0.06	^{238}U&^{232}Th series=trace	-	100
	24.9	Soil	0.2	0.1	^{238}U&^{232}Th series=trace	-	100
	8.12	Soil	0.2	0.08	^{238}U&^{232}Th series=trace	-	200
Drain west of test compound	19.3	Soil	0.8	0.8	^{238}U&^{232}Th series=trace	-	750
	26.6	Soil	0.6	0.6	^{238}U&^{232}Th series-trace	-	600
	24.9	Soil	0.7	1.0	^{238}U&^{232}Th series=trace	-	700
	8.12	Soil	0.07	0.8	^{238}U&^{232}Th series=trace	-	800
Drain near Yellowcake Store	19.3	Soil	0.4	0.3	^{238}U&^{232}Th series=trace	-	600
	24.9	Soil	0.4	0.3	^{238}U&^{232}Th series=trace	-	950
	8.12	Water	-	-	-	0.07	-
Drain at Fermi Street	19.3	Soil	0.3	0.2	^{238}U&^{232}Th series=trace	-	350
	19.3	Water	-	-	-	<0.04	-
	27.6	Soil	0.2	0.1	^{238}U&^{232}Th series=trace	-	600
	27.6	Water	-	-	-	<0.04	-
	24.9	Soil	0.2	0.1	^{238}U&^{232}Th series=trace	-	600
	8.12	Soil	0.30	0.2	^{238}U&^{232}Th series=trace	-	350
	8.12	Water	-	-	-	<0.04	-

Station	Date	Sample	Radioactivity (Bq g^{-1} Fresh Weight)			^{3}H Bq mL^{-1}	K μg g^{-1}	^{90}Sr (*)
			Gross alpha	Gross beta less ^{40}K)	Gamma emitters			
Drain at Fermi Street	21.4	Sand	-	-	-	-	-	0.0005
	21.4	Water	-	-	-	-	-	0.027
	14.5	Sand	-	-	-	-	-	0.0008
	14.5	Water	-	-	-	-	-	0.044
	18.6	Sand	-	-	-	-	-	0.0014
	18.6	Water	-	-	-	-	-	0.023
	27.6	Vegetation	0.01	0.02	0.5 MeV = 0.004 ^{238}U&^{232}Th series=trace	-	3200	-
	27.6	Sand	0.9	0.40	^{238}U&^{232}Th series=trace		400	-
	27.6	Water	-	-	-	1.4	-	-
	29.7	Sand	-	-	-	-	-	0.0013
	29.7	Water	-	-	-	1.3	-	0.047
	20.8	Water	-	-	-	1.6	-	0.033
	25.9	Sand	0.6	0.5	^{238}U&^{232}Th series=trace	-	600	-
	25.9	Water	-	-	-	3.2	-	-
	25.9	Vegetation	0.02	0.05	^{238}U&^{232}Th series=trace	-	4200	-
	30.9	Sand	-	-	-	-	-	0.0008
	30.9	Water	-	-	-	-	-	0.240
	21.10	Sand	-	-	-	-	-	0.0015
	21.10	Water	-	-	-	1.1	-	0.029
	17.11	Water	-	-	-	2.1	-	-
	26.11	Water	-	-	-	2.7	-	0.055
	26.11	Sand	-	-	-	-	-	0.0015
	11.12	Vegetation	0.03	0.08	^{238}U&^{232}Th series=trace	-	2000	-
	18.12	Water	-	-	-	1.3	-	0.024
	18.12	Sand	-	-	-	-	-	0.001

The gamma-ray peaks detected at approximately 0.5 MeV could be ^{7}Be (0.48 MeV), ^{103}Ru (0.5 MeV) or ^{106}Ru (0.51 MeV).
^{7}Be is a cosmic-ray produced spallation product; ^{103}Ru and ^{106}Ru are fission products.
In column 6 of this table Bq g^{-1} refers to the number of disintegrations per second per gram at the energies indicated.

n.d. = not detected
\- = not measured
(*) = Bq g^{-1} for sand and Bq L^{-1} for water.

(Continued)

Station	Date	Sample	Radioactivity (Bq L^{-1})			^{3}H (Bq mL^{-1})	K (µg g^{-1})
			Gross alpha	Gross beta (less ^{40}K)	Gamma emitters		
RE storm-water outlet No. 1 near south gate contd....	12.5	Water	0.03	0.6	n.d.	1.6	-
	20.5	"	0.03	0.7	^{60}Co = trace	1.4	-
	26.5	"	-	-	-	1.5	-
	2.6	"	0.06	0.07	n.d.	0.1	-
	9.6	"	0.06	0.08	n.d.	0.06	-
	18.6	"	0.08	0.1	n.d.	0.3	-
	24.6	"	0.15	1.2	n.d.	1.0	-
	30.6	"	<0.01	0.3	n.d.	1.1	-
	9.7	"	<0.01	0.3	n.d.	1.3	-
	14.7	"	<0.01	0.7	n.d.	2.1	-
	22.7	"	<0.01	0.2	n.d.	0.8	-
	28.7	"	0.12	0.2	n.d.	0.6	-
	5.8	"	0.12	0.2	n.d.	1.4	-
	12.8	"	0.07	0.09	n.d.	0.2	-
	19.8	"	-	-	-	1.3	-
	25.8	"	-	-	-	0.7	-
	2.9	"	0.04	0.4	n.d.	1.3	-
	10.9	"	-	-	-	2.2	-
	16.9	"	0.07	0.7	n.d.	14.4	-
	23.9	"	0.04	0.07	n.d.	0.2	-
	30.9	"	0.08	0.7	n.d.	3.8	-
	7.10	"	0.3	1.0	^{137}Cs = 0.19 ^{60}Co = 0.14	-	-
	15.10	"	-	-	-	0.7	-
	20.10	"	0.03	0.2	n.d.	1.7	-
	27.10	"	0.03	0.3	n.d.	1.9	-
	4.11	"	-	-	-	3.3	-
	10.11	"	0.05	0.2	n.d.	0.6	-
	17.11	"	0.06	0.2	n.d.		-
	24.11	"	-	-	-	3.2	-
	2.12	"	0.07	0.2	n.d.	1.8	-
	8.12	"	-	-	-	0.6	-
	16.12	"	0.06	0.2	n.d.	1.7	-
	22.12	"	0.05	0.1	n.d.	0.1	-
	31.12	"	-	-	-	0.8	-
			Radioactivity (Bq g^{-1} Fresh Weight)				
RE storm-water outlet No. 2 near south gate	19.3	Soil	1.2	0.4	^{137}Cs = 0.02 ^{60}Co = 0.07 ^{238}U&^{232}Th series=trace	-	300
	19.3	Water	-	-	-	0.2	-
	27.6	Soil	0.3	0.2	^{137}Cs = trace ^{60}Co = trace ^{238}U&^{232}Th series=trace	-	300

(Continued)

Station	Date	Sample	Radioactivity (Bq g^{-1} fresh weight)			^{3}H (Bq mL^{-1})	K ($\mu g\ g^{-1}$)
			Gross alpha	Gross beta (less ^{40}K)	Gamma emitters		
Drain opposite Building 23	27.6	Soil	0.6	0.3	^{60}Co = 0.04 ^{137}Co = trace ^{238}U&^{232}Th series=trace	-	600
	24.9	Soil	0.5	0.4	^{60}Co = trace ^{238}U&^{232}Th series=trace	-	500
	8.12	Soil	0.8	0.4	^{60}Co = trace ^{137}Cs = trace ^{238}U&^{232}Th series=trace	-	700
Drain No.1 opposite Strassman Crescent	19.3	Water	-	-	-	0.15	-
	24.9	Soil	0.2	0.2	^{238}U&^{232}Th series=trace	-	650
	8.12	Soil	0.4	0.2	^{238}U&^{232}Th series=trace	-	650
	8.12	Water	-	-	-	<0.04	-
Drain No.2 opposite Strassman Crescent	19.3	Soil	0.8	0.3	^{238}U&^{232}Th series=trace	-	650
	27.6	Soil	0.5	0.4	^{238}U&^{232}Th series=trace	-	1100
	27.6	Water	-	-	-	<0.04	-
	24.9	Soil	0.4	0.4	^{238}U&^{232}Th series=trace	-	800
	8.12	Soil	0.2	0.2	^{238}U&^{232}Th series=trace	-	500
Drain rear of Building 20	19.3	Soil	0.3	0.08	^{238}U&^{232}Th series=trace	-	750
	27.6	Soil	0.3	0.1	^{238}U&^{232}Th series=trace	-	400
	24.9	Soil	0.3	0.1	^{238}U&^{232}Th series=trace	-	200
	8.12	Soil	0.4	0.09	^{238}U&^{232}Th series=trace	-	350
			Radioactivity (Bq L^{-1})				
RE storm-water outlet No. 1 near south gate	7.1	Water	0.07	0.80	n.d.	6.0	-
	14.1	"	0.06	0.6	n.d.	4.0	-
	21.1	"	0.06	0.3	n.d.	1.1	-
	30.1	"	0.04	0.1	n.d.	0.2	-
	4.2	"	0.2	0.1	n.d.	0.08	-
	12.2	"	0.09	0.08	n.d.	0.05	-
	18.2	"	0.09	0.03	n.d.	3.6	-
	25.2	"	-	-	-	2.3	-
	3.3	"	0.6	0.02	0.5 MeV = 0.11	1.3	-
	10.3	"	0.04	0.1	n.d.	0.3	-
	18.3	"	0.09	0.1	n.d.	0.06	-
	24.3	"	0.05	0.5	n.d.	3.1	-
	31.3	"	0.1	0.02	n.d.	0.04	-
	8.4	"	-	-	-	0.8	-
	14.4	"	-	-	-	1.6	-
	21.4	"	-	-	-	1.4	-
	28.4	"	-	-	-	0.6	-
	6.5	"	0.07	3.2	0.5 MeV = 0.19 ^{137}Cs = 0.13 ^{60}Co = trace	1.7	-

(Continued)

Station	Date	Sample	Radioactivity ($Bq\ g^{-1}$ Fresh Weight)			^{3}H ($Bq\ mL^{-1}$)	K ($\mu g\ g^{-1}$)
			Gross alpha	Gross beta (less ^{40}K)	Gamma emitters		
RE storm-water outlet No. 2 near south gate	27.6	Water	-	-	-	0.04	-
	25.9	Soil	0.2	0.3	^{137}Cs = 0.05 ^{60}60 = 0.07 ^{238}U&^{232}Th series=trace	-	450
	25.9	Water	-	-	-	0.04	-
	11.12	Soil	3.2	2.7	^{137}Cs = 0.91 ^{60}Co = 0.19 ^{238}U&^{232}Th series=trace	-	400
	11.12	Water	-	-	-	0.30	-
20 m from RE stormwater outlet No.1	27.6	Veget-ation	0.04	0.05	^{238}U&^{232}Th series=trace	-	4000
	27.6	Soil	0.8	0.6	^{60}Co = 0.06 ^{137}Cs = trace ^{238}U&^{232}Th series=trace	-	600
	27.6	Water	-	-	-	0.2	-
	11.12	Soil	1.3	3.5	^{60}Co = 0.13 ^{137}Cs = trace ^{238}U&^{232}Th series=trace	-	1000
Water pool across road from storm-water outlet No.1	19.3	Veget-ation	0.3	0.03	0.5 MeV = 0.003 ^{137}Cs = 0.001 ^{238}U&^{232}Th series=trace	-	4400
	19.3	Soil	0.9	0.3	^{60}Co = trace ^{238}U&^{232}Th series=trace	-	500

TABLE 13
RADIOACTIVITY IN FRESH WATER SECTION OF WORONORA RIVER, 1980

Station	Date	Radioactivity		
		Sand	Water	
		^{90}Sr (Bq g^{-1})	^{90}Sr (Bq L^{-1})	^{3}H (Bq mL^{-1})
Woronora River at Heathcote Road crossing	17.7	0.0003	0.028	<0.04
	29.7	0.0001	0.010	<0.04
	20.8	0.0001	0.011	<0.04
	30.9	0.0002	0.009	<0.04
	21.10	0.0001	0.011	<0.04
	26.11	0.0002	0.014	-
	18.12	<0.0001	0.012	<0.04
Woronora River at the point of drainage entrance	21.4	0.0005	0.011	-
	14.5	0.0001	0.017	-
	18.6	0.0002	0.012	0.18
	29.7	0.0005	0.008	0.15
	20.8	0.0002	0.005	<0.04
	30.9	0.0003	0.012	<0.04
	21.10	0.0002	0.006	<0.04
	26.11	0.0002	0.006	<0.04
	18.12	0.0002	0.007	<0.04

TABLE 14

GAMMA SURVEY - EFFLUENT DISCHARGE PIPE, 1980

Surveys of pipeline between the RE and Woronora River discharge point using a 1368A field ratemeter

Date	Location	Dose Rate ($\mu Sv\ h^{-1}$)
11.6	Join No. 9	0.8
11.6	Joins No. 7 and 20	0.6
11.6	All other pipe sections	<0.5
11.6	Soil below joins	<0.5
18.12	All pipe sections	<0.4
18.12	Soil below joins	<0.4

TABLE 14a

RADIOACTIVITY IN SAMPLES TAKEN NEAR EFFLUENT DISCHARGE PIPELINE, 1980

Station	Date	Sample	Radioactivity ($Bq\ g^{-1}$ dry weight)			^{3}H ($Bq\ mL^{-1}$)	K ($\mu g\ g^{-1}$)
			Gross alpha	Gross beta (less ^{40}K)	Gamma emitters		
Near scour valve No. 1	11.6	Sand	0.3	0.05	^{238}U & ^{232}Th series = trace	-	400
	11.6	Water	-	-	-	0.2	-
	18.12	Sand	0.4	0.1	^{238}U & ^{232}Th series = trace	-	500
	18.12	Water	-	-	-	0.20	-
River where effluent discharge pipe crosses	11.6	Sand	0.3	0.07	^{238}U & ^{232}Th series = trace	-	200
	11.6	Water	-	-	-	0.2	-
	18.12	Sand	0.40	0.08	^{238}U & ^{232}Th series = trace	-	250
	18.12	Water	-	-	-	< 0.04	-

TABLE 15
RADIOACTIVE IODINE IN AIR

Week ending	$^{131}I^{+}$ (Bq m^{-3})
5th October 1980	N.D.
12th	N.D.
19th	N.D.
26th	N.D.
2nd November	N.D.
9th	N.D.
16th	Trace
23rd	Trace
30th	Trace
7th December	Trace
14th	Trace
21st	Trace
28th	Trace

\+ Up to week ending 16th November 1980 a 15 mm x 75 mm NaI(Tℓ) crystal was used. Since then a 200 mm x 100 mm NaI(Tℓ) crystal has been used. Minimum detectable level is 0.003 Bq m^{-3}.

N.D. = not detected.

TABLE 16
AIRBORNE RADIOACTIVITY RELEASES, 1980

	Gross α (kBq)	^{131}I (MBq)	^{3}H (GBq)	^{41}Ar (GBq)	Other β/γ (MBq)	Fission product* noble gases (TBq)
Quarter No.1.						
Building 2	49	<10	-	-	<10	-
" 15	<10	<10	27×10^2	Nil+	<10	-
" 19	<10	<10	-	-	<10	-
" 23A	<10	2.6×10^2	-	-	<10	-
" 23B	<10	<10	-	-	<10	-
" 41	<10	<10	-	-	<10	-
Quarter No.2.						
Building 2	20	34	-	-	<10	-
" 15	<10	<10	1×10^3	3.2×10^3	<10	-
" 19	<10	-	-	-	<10	-
" 23A	<10	1.2×10^3	-	-	<10	-
" 23B	<10	<10	-	-	<10	-
" 41	<10	<10	-	-	<10	-
Quarter No.3.						
Building 2	65	8.7×10^2	-	-	<10	-
" 15	<10	<10	4.7×10^2	1.6×10^4	22	-
" 19	21	<10	-	-	<10	-
" 23A	<10	1.7×10^3	-	-	<10	-
" 23B	<10	9.8×10^3	-	-	<10	-
" 41	16	<10	-	-	<10	-
Quarter No.4.						
Building 2	50	5.8×10^2	-	-	<10	30.9
" 15	<10	<10	7.9×10^2	1.9×10^4	<25	-
" 19	<10	<10	-	-	<10	-
" 23A	<10	2.4×10^3	-	-	<10	-
" 23B	<10	<10	-	-	<10	-
" 41	<10	<10	-	-	<10	-

* No ^{99m}Tc radiopharmaceuticals were produced in the first three quarters of 1980.

\+ None produced, reactor shutdown.

TABLE 17

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS EXPRESSED AS FRACTIONS OF THE PERMITTED QUARTERLY DISCHARGE FOR 1980

	Gross α	^{131}I	^{3}H	^{41}Ar	Other β/γ	Fission product noble gases
Quarter No.1. Building 2	7.4×10^{-5}	$<2\times10^{-4}$			$<6\times10^{-6}$	
" 15	$<3\times10^{-4}$	$<6\times10^{-4}$	2.1×10^{-3}		$<2\times10^{-4}$	
" 19	$<3\times10^{-5}$	$<3\times10^{-4}$			$<2\times10^{-5}$	
" 23A	$<6\times10^{-4}$	1.6×10^{-2}			$<3\times10^{-4}$	
" 23B	$<2\times10^{-4}$	$<6\times10^{-4}$			$<6\times10^{-4}$	
" 41	$<3\times10^{-5}$	$<6\times10^{-4}$			$<2\times10^{-5}$	
Quarter No.2. Building 2	3×10^{-5}	5.2×10^{-4}			$<6\times10^{-6}$	
" 15	$<3\times10^{-4}$	$<6\times10^{-4}$	7.7×10^{-3}	1.2×10^{-1}	$<1.5\times10^{-4}$	
" 19	$<3\times10^{-5}$				$<1.5\times10^{-5}$	
" 23A	$<6\times10^{-4}$	7.5×10^{-2}			$<3\times10^{-4}$	
" 23B	$<2\times10^{-4}$	$<6\times10^{-4}$			$<6\times10^{-4}$	
" 41	$<3\times10^{-5}$	$<3\times10^{-5}$			$<1.5\times10^{-5}$	
Quarter No.3. Building 2	10^{-4}	1.3×10^{-2}			$<6\times10^{-6}$	
" 15	$<3\times10^{-4}$	$<6\times10^{-4}$	3.6×10^{-3}	0.6	3×10^{-4}	
" 19	6×10^{-4}	$<3\times10^{-4}$			$<1.5\times10^{-5}$	
" 23A	$<6\times10^{-4}$	10^{-1}			$<3\times10^{-4}$	
" 23B	$<1.5\times10^{-3}$	0.6			8×10^{-4}	
" 41	4.8×10^{-5}	$<6\times10^{-4}$			$<1.5\times10^{-5}$	
Quarter No.4. Building 2	7.6×10^{-5}	0.9×10^{-2}			$<6\times10^{-6}$	0.2
" 15	$<3\times10^{-4}$	$<6\times10^{-4}$	6.1×10^{-3}	0.7	$<4\times10^{-4}$	
" 19	$<3\times10^{-5}$	$<3\times10^{-4}$			$<1.5\times10^{-5}$	
" 23A	$<6\times10^{-4}$	0.15			$<3\times10^{-4}$	
" 23B	$<1.5\times10^{-3}$	$<6\times10^{-4}$			$<6\times10^{-4}$	
" 41	$<3\times10^{-5}$	$<6\times10^{-4}$			$<1.5\times10^{-5}$	

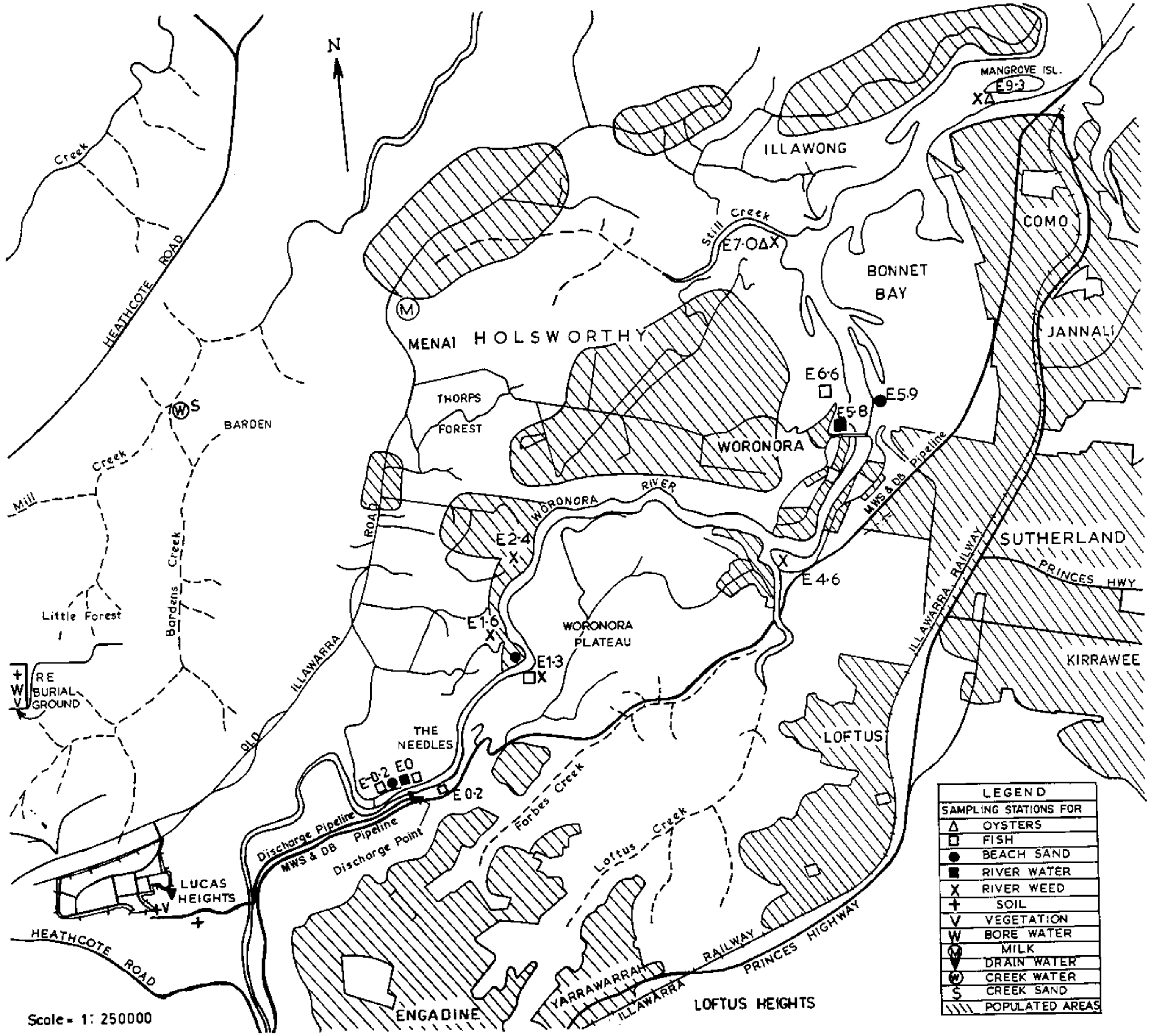

FIGURE 1. LUCAS HEIGHTS DISTRICT - LOCATION OF SAMPLING STATIONS

APPENDIX A

PREVIOUS ENVIRONMENTAL SURVEY REPORTS

Giles, M.S. and Stockdale, J.A. [1966] - Results of the Lucas Heights Biological Survey, December 1959 to December 1964. AAEC/E151.

Cook, J.E., Dudaitis, A. and Giles, M.S. [1969] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1965, 1966 and 1967. AAEC/E151 Supplement No.1.

Cook, J.E. and Dudaitis, A. [1970] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1968. AAEC/E151 Supplement No.2.

Cook, J.E. and Dudaitis, A. [1970] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1969. AAEC/E151 Supplement No.3.

Conway, N.F. and Dudaitis, A. [1972] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for Period January-July 1970. AAEC/E246.

Dudaitis, A. [1973] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for Period August 1970 to December 1971. AAEC/E271.

Dudaitis, A. [1974] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1972. AAEC/E301.

Davy, D.R. and Dudaitis, A. [1974] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1973. AAEC/E335.

Davy, D.R. and Dudaitis, A. [1976] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1974. AAEC/E375.

Hespe, E.D. [1979a] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1975, 1976 and 1977. AAEC/E467.

Hespe, E.D. [1979b] - Results of the 1978 Environmental Survey at the AAEC Research Establishment, Lucas Heights. AAEC/E494.

Giles, M.S. and Dudaitis, A. [1980] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1979. AAEC/E508.

APPENDIX B

LIST OF PUBLICATIONS ON WEAPONS TEST FALLOUT IN AUSTRALIA

(in chronological order)

Dwyer, L.J., Kearm, D.W., Stevens, D.J. and Titterton, E.W. [1957] - Search for fallout in Australia from the Christmas Island tests. Aust. J. Sci., 20(2)39-41.

Butement, W.A.S., Dwyer, L.J., Eddy, C.E., Martin, L.H. and Titterton, E.W. [1957] - Radioactive fallout in Australia from Operation 'Mozaic'. Aust. J. Sci., 20(5)125-135.

Keam, D.W., Dwyer, L.J., Martin, J.H., Stevens, D.J. and Titterton, E.W. [1958] - Global fallout in Australia during the period 26 November 1956 to 31 December 1957. Aust. J. Sci., 21(1)8-9.

Butement, W.A.S., Dwyer, L.J., Martin, L.H., Stevens, D.J. and Titterton, E.W. [1958] - Radioactive fallout in Australia from Operation Buffalo. Aust. J. Sci., 21(3)63-67.

Keam, D.W., Dwyer, L.J., Martin, J.H. and Titterton, E.W. [1959] - Global fallout in Australia during 1958. Aust. J. Sci., 22(1)51-54.

Dwyer, L.J., Martin, J.H., Stevens, D.J. and Titterton, E.W. [1959] - Radioactive fallout in Australia from Operation Antler. Aust. J. Sci., 22(3)97-106.

Blake, J.R., Dwyer, L.J., Martin, J.H. and Titterton, E.W. [1960] - Global fallout in Australia during 1959. Aust. J. Sci., 23(3)69-71.

Blake, J.R., Dwyer, L.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1962] - Global fallout in Australia during 1960-1961. Aust. J. Sci., 24(12)468-470.

Alsop, R.J.L., Moroney, J.R., Nunn, R.O., Stevens, D.J. and Titterton, E.W. [1963] - Global fallout in Australia during 1962. Aust. J. Sci., 25(10)426-429.

Bryant, F.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1963] - Strontium-90 in the Australian environment during 1961. Aust. J. Sci., 26(1)69-74.

Bonnyman, J. and Keam, D.W. [1963] - Iodine-131 levels in milk in Australia during the period May-November 1962. Aust. J. Sci., 26(3)74-76.

Alsop, R.J.L., Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1963] - Total beta activity in global fallout in Australia during 1963. Aust. J. Sci., 26(11)342-345.

Bryant, F.J., Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1964] - Strontium-90 in the Australian environment during 1962. Aust. J. Sci., 27(1)1-6.

Alsop, R.J.L., Bonnyman, J., Keam, D.W. and Molina-Ramos, J. [1965] - Concentration of ^{137}Cs in Australian milk during 1963. Aust. J. Sci., 27(8)219-222.

Bryant, F.J., Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1965] - Strontium-90 in the Australian environment during 1963. Aust. J. Sci., 27(8)222-226.

Gibbs, W.J., Moroney, J.R., Stevens, D.J., Titterton, E.W. and Wilson, G.V. [1965] - Strontium-90 in the Australian environment 1961-1963. Aust. J. Sci., 28(2)44-59.

Gibbs, W.J. and Wilson, G.V. [1965] - Meteorological implications of measurement of strontium-90 in Australia. Aust. J. Sci., 28(2)59-69.

Alsop, R.J.L., Bonnyman, J., Keam, D.W. and Molina-Ramos, J. [1965] - Concentration of caesium-137 in Australian milk during 1964. Aust. J. Sci., 28(2)69-71.

Bonnyman, J., Duggleby, J.C., Molina-Ramos, J. and Sewell, D.K.B. [1966] - Concentration of caesium-137 in Australian milk during 1965. Aust. J. Sci., 28(11)411-412.

Alsop, R.J.L., Bonnyman, J., Duggleby, J.C., Molina-Ramos, J. and Sewell, D.K.B. [1966] - Concentration of caesium-137 in Australian rainwater during 1964 and 1965. Aust. J. Sci., 28(11)413-417.

Fletcher, W., Gibbs, W.J., Moroney, J.R. and Stevens, D.J. [1966] - Strontium-90 in the Australian environment during 1964. Aust. J. Sci., 28(11)417-424.

Fletcher, W., Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1967] - Strontium-90 in the Australian environment during 1965. Aust. J. Sci., 29(9)319-325.

Bonnyman, J. and Duggleby, J.C. [1967] - Iodine-131 levels in milk in Australia during the period July-December 1966. Aust. J. Sci., 29(11)402-406.

Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1967] - Fallout over Australia from nuclear weapons tested by France in Polynesia from July to October 1966. Aust. J. Sci., 29(11)407-417.

Dyer, A.J. and Hicks, B.B. [1968] - Radioactive fallout from the French 1966 Pacific tests. Aust. J. Sci., 30(5)168-170.

Bonnyman, J. and Molina-Ramos, J. [1968] - Strontium-90 and caesium-137 in some Australian drinking water supplies - 1961-1965. Aust. J. Sci., 30(5)171-172.

Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1968] - Fallout over Australia from nuclear weapons tested by France in Polynesia during June and July 1967. Aust. J. Sci., 30(6)217-222.

Bonnyman, J. and Duggleby, J.C. [1968] - Iodine-131 concentrations in Australian milk resulting from the 1967 French nuclear weapons tests in Polynesia. Aust. J. Sci., 30(6)223-226.

Fletcher, W., Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1968] - Strontium-90 in the Australian environment during 1966. Aust. J. Sci., 30(8)307-313.

Bonnyman, J., Duggleby, J.C., Molina-Ramos, J. and Paterson, I.C. [1968] - Concentrations of caesium-137 in rainwater and milk in Australia during 1966. Aust. J. Sci., 30(8)313-317.

Fletcher, W., Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1968] - Strontium-90 in the Australian environment during 1967. Aust. J. Sci., 31(5)174-179.

Bonnyman, J., Duggleby, J.C., Molina-Ramos, J. and Paterson, I.C. [1968] - Concentrations of caesium-137 in rainwater and milk in Australia during 1967. Aust. J. Sci., 31(5)180-183.

Gibbs, W.J., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1969] - Fallout over Australia from nuclear weapons tested by France in Polynesia from July to September 1968. Aust. J. Sci., 31(11)383-392.

Gibbs, W.J., Matthews, W.K., Moroney, J.R., Stevens, D.J. and Titterton, E.W. [1970] - Strontium-90 in the Australian environment during 1968. Aust. J. Sci., 32(6)238-244.

Bonnyman, J., Duggleby, J.C., Molina-Ramos, J. and Paterson, I.C. [1970] - Concentrations of caesium-137 in rainwater and milk in Australia during 1968. Aust. J. Sci., 32(6)244-248.

APPENDIX C

ANALYTICAL PROCEDURES

Radioactive Iodine in Air

Radioactive iodine species are collected on activated charcoal in Maypack filters and measured on a 20 x 10 cm NaI (Tℓ) crystal. Pumping rates of the air samplers are between 45 and 50 L per minute.

APPENDIX D

LIQUID EFFLUENT DISCHARGES FROM AAEC RESEARCH ESTABLISHMENT DURING 1980 - COMPLIANCE WITH AUTHORISATION

A detailed account of the authorisation, approved by the NSW Health Commission and the NSW Maritime Services Board, under which discharges to the Woronora estuary were made, has been given in previous reports [Hespe 1979a,b]. Table D1 details radioactivity discharged to the Woronora estuary during 1980 and indicates the percentage of the authorised limit that was reached. Because the contributions due to unknown β and α activity were assumed to be ^{32}P and ^{226}Ra respectively (i.e. the worst possible cases for contamination), the percentage of authorised limit calculation is, if anything, overestimated.

Discharges of effluent to the Woronora River ceased at the end of the second quarter of 1980. Liquids after that period were released into the Metropolitan Water, Sewerage and Drainage Board (MWSDB) sewers and details for quarters 3 and 4 are given in Table D2.

TABLE D1

RADIOACTIVITY DISCHARGED TO THE WORONORA ESTUARY 1980

	Radioisotope measured (MBq)					
	^{210}Po	α_μ *	^{3}H	β_μ †	$^{114/114m}In$	% of authorised limit
Quarter No.1.	2.7×10^{-2}	13.7	3.3×10^{4}	4.4×10^{2}	8.9×10^{-2}	7.6
Quarter No.2.	4.1×10^{-2}	12.6	1.2×10^{5}	4.4×10^{2}	7.0×10^{-2}	

* α_μ = a mixture of unidentified α-emitting nuclides taken as being all ^{226}Ra (i.e. the worst possible case) in calculating per cent of the authorised limit.

† β_μ = a mixture of unidentified β-emitting nuclides taken as being all ^{32}P (i.e. worst possible case) in calculating per cent of the authorised limit.

TABLE D2
RADIOACTIVITY DISCHARGED TO THE MWSDB SEWERS DURING 1980

	Radioisotope measured (MBq)			
	α_μ*	^3H	β_μ†	% of** authorised limit
Quarter No.3.	22.5	1.2×10^5	7.6×10^2	35
Quarter No.4.	13.9	1.1×10^5	6.4×10^2	33

* α_μ = a mixture of unidentified α-emitting nuclides taken as being all ^{226}Ra (i.e. the worst possible case) in calculating per cent of the authorised limit.

† β_μ = a mixture of unidentified β-emitting nuclides taken as being all ^{90}Sr (i.e. the worst possible case) in calculating per cent of the authorised limit.

** In the case of the sewer discharge the authorised limit is outlined in the regulations to the NSW Radioactive Substances Act published in Government Gazette No. 136, 19 September 1980.