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ENVIRONMENTAL SURVEY AT THE LUCAS HEIGHTS RESEARCH LABORATORIES 1983

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ABSTRACT

Results are presented of the environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1983. These results are satisfactory. No radioactivity which could have originated from these laboratories was found in samples collected from possible human food chains. All low-level liquid and gaseous waste discharges were within authorised limits. The maximum possible annual dose to the general public from airborne waste discharges during this period is estimated to be less than 0.01 millisieverts, which is 1 per cent of the limit for long-term exposure that is recommended by the National Health and Medical Research Council.

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AAEC; AIR; CESIUM; CONTAMINATION; ENVIRONMENT; EXPERIMENTAL DATA; FRESH WATER; GASEOUS WASTES; GROUND WATER; HUMAN POPULATIONS; IODINE 131; LIQUID WASTES; MILK; NEW SOUTH WALES; PLANTS; RADIATION DOSES; RADIATION MONITORING; RADIOACTIVE EFFLUENTS; RADIOACTIVITY; RIVERS; SAND; SOILS; STRONTIUM 90; TRITIUM; WASTE WATER

CONTENTS

Continued

1. INTRODUCTION

Since 1959, surveys have been made by the Australian Atomic Energy Commission (AAEC) of the radioactive content in samples collected in the vicinity of the Lucas Heights Research Laboratories (LHRL) to ensure that no unacceptable health effects either have occurred or will occur as a result of nuclear research and operation. The results obtained in these surveys have been published regularly and are listed in Appendix A.

During the early surveys (*i.e.* throughout the 1960s), weapons test fallout was readily detectable in samples collected around Lucas Heights [Giles and Stockdale 1966]. Because of this, a large program of sampling was undertaken to establish the general levels of radioactivity arising from weapons test fallout, and so enable additional radioactivity caused by nuclear operations at Lucas Heights to be assessed. 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 (ARL) had set up a monitoring system throughout Australia and routinely measured samples from the Sydney region. Results of these early surveys were published between 1957 and 1970 as described by Giles and Dudaitis [1982]. 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]. These studies are used as a basis for comparison with the results for milk samples reported in the later AAEC surveys.

The present monitoring system is designed to detect radioactive contaminants which may have been released from the LHRL, either routinely (under authorisations from the New South Wales Department of Health) or accidentally, and to ensure that such concentrations do not result in radiation doses to members of the public in excess of limits recommended by the International Commission on Radiological Protection [ICRP 1977] and by the National Health and Medical Research Council of Australia [NH&MRC 1981]. Doses recommended by these bodies are set for periods of time which extend over a normal life-time span.

2. SAMPLE COLLECTION AND PREPARATION

Samples were collected at the sites shown in Figure 1, and details of collection and sample preparation methods are given in Table 1. (Note: The isotope symbols used are listed in Appendix B.)

3. ANALYTICAL METHODS

Analytical methods are the same as those used before.

4. RESULTS

Environmental survey measurements taken during 1983 are presented in Tables 2 to 13. Authorised airborne releases are given in Tables 14 and 15. Authorised liquid effluent discharges to the Metropolitan Water Sewerage and Drainage Board (MWS&DB) sewers are given in Table 16.

5. DISCUSSION OF RESULTS

Throughout the tables where gamma spectrometry has revealed small unresolvable peaks at particular energies these have been reported as trace amounts. This indicates the possible presence of the isotope in question but the amount is not quantifiable.

5.1 Airborne Releases

Measurable concentrations of ^{131}I were recorded in air samples taken betwen 20 March and 30 August. The highest reading obtained was on 28 June and was 3.2×10^{-3} of the derived working limit of 10 Bq m^{-3}. The derived air concentration for child members of the public [ICRP 1977, 1979], i.e. the most sensitive individuals, is 10 Bq m^{-3}. The average ^{131}I-in-air concentration for the year would have resulted in an effective dose of 0.8 μSv y^{-1}, or 8×10^{-4} of the limit.

The milk monitoring data for caesium-137 and iodine-131 are given in Table 3. At most, a trace of caesium-137 was found, with a limit of determination of 0.3 mBq g^{-1} (fresh weight). This was less than 6×10^{-3} of the derived limit, based on the assumption that an infant consumes 700 mL of milk per day. The limit of determination for ^{131}I in milk represents 4.5×10^{-2} of the derived limit.

Noble gas releases were always below the authorised limit during the year. The methodology of Petersen [1982] was used to calculate that, for an average year and given maximum authorised discharge levels, the most exposed individual would receive less than 0.01 mSv y^{-1} *i.e.* less than 1 per cent of the NH&MRC recommendation.

5.2 Woronora Estuary Samples

Zostera and sand from the Woronora estuary were collected again during 1983 to monitor residual radioactivity remaining from discharges made before 1 July 1980. (The discharge of low level liquid effluent was diverted from the Woronora River to the MWS&DB sewers at that time.)

Traces of ^{60}Co too small to be quantified were still present in zostera. Since further analyses of these samples will prove unproductive it was decided to discontinue collecting these samples from 1984 onwards.

5.3 Stormwater Outlets

Increased levels of α activity in stormwater were measured near the No.1 outlet at the south-east corner of the fenced area in February, March and September. During March, this activity was accompanied by β activity, ^{3}H, ^{137}Cs and ^{60}Co. Increased ^{3}H was measured in March, July and September. The highest level found for ^{137}Cs, ^{60}Co and ^{3}H respectively was 5.9×10^{-2}, 1.6×10^{-3} and 9.5×10^{-2} of the most conservative derived limit which assumes all drinking water is drawn from this source. When, as recommended by the ICRP, the concentrations are averaged over the year, the corresponding ratios to the derived working limit become 1.3×10^{-3}, 3.2×10^{-5} and 9.9×10^{-3} respectively.

The individual results for α activity recorded on 22 February, 2 March and 21 September are higher than the limits set out in the regulations to the NSW Clean Waters Act [1979]. However, these limits apply at the 1.6 km boundary of the site which is one kilometre downstream from where these samples were collected and dilution would reduce this level substantially at the boundary. More importantly the average of the results during the year (0.2 Bq L^{-1}) falls well below the required limit.

The ephemeral creek into which this stormwater drains is not used as a source of drinking water.

5.4 Effluent Discharge Pipeline

The survey of radiation being emitted from the discharge pipeline revealed the dose rates shown in Table 8. The maximum annual radiation dose for members of the public recommended by the ICRP is 1000 μSv per year [ICRP 1979]. Because of the isolated position of the exposed sections of the discharge pipe, the likelihood of occupancy by members of the public is very low and thus the limits would not be exceeded. Checks on water and soil at points along the pipeline revealed no extraneous radioactivity.

5.5 Freshwater Sections of the Woronora River

Checks were made throughout the year on radioactivity in the freshwater section of the Woronora River at the point of entry for drainage from LHRL. Samples were also collected at the Heathcote Road crossing, upstream and above any possible input from LHRL, to provide a direct measure of background levels. These are presented in Table 10. All readings represent normal background levels.

Appendix C contains results of repeat analyses by the New Zealand Radiation Laboratories of samples of sand from the freshwater section of the Woronora River collected in 1982. They are lower than the results reported in AAEC/E591, reflecting the lower detection limit of the New Zealand method.

5.6 Little Forest Burial Ground

Sampling points for Little Forest Burial Ground are shown on Figure 2. Tritium was found in three of the groundwater bores from within the fenced area of the burial ground. No extraneous radioactivity was found in boreholes outside the fenced area (boreholes BHA to BHE). Since 1978, when measurements of ^{3}H commenced, there has been a trend towards increasing levels of ^{3}H in BH10, *i.e.* in the NE corner of the site. This suggests that groundwater movement is taking place in that direction, as predicted by earlier studies [Isaacs and Mears 1977].

Surface soil near trenches 56/57 and 68/69 within the fenced area showed higher than natural levels of α activity in very localised areas. All of the burial ground has since been top dressed with 30 cm of fine particle soil as part of the regular maintenance program.

6. SUMMARY

None of the samples taken from possible human food chains in the environs of the Lucas Heights Research Laboratories contained radioactivity which could be attributed to the operation of the site.

Discharges of airborne radioactive gases were always within authorised limits (Table 15). The dose to the most sensitive members of the public from ^{131}I releases was 8×10^{-4} mSv y^{-1} and the calculated dose from released noble gases to the most exposed individuals was less than 0.01 mSv. These figures represent less than 1 per cent of the most restrictive limit recommended by the NH&MRC.

7. ACKNOWLEDGEMENTS

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TABLE 1
SAMPLE COLLECTION SCHEDULE AND PREPARATION DETAILS

Sample	Station	Frequency	Collection Details	Special Preparations
Stormwater	TO	Weekly and Quarterly	Sampled by bucket at the outlet of the drain	10 L sample evaporated to dryness and the residue counted
Estuary water	E5.9	Weekly	From surface by bucket	Distilled for tritium
Radioactive iodine in air	TO	Weekly	Collected on Maypacks (charcoal filters)	Gamma spectrometry of Maypacks
Milk	T3	Monthly	Sampled from milk produced by locally grazed cows	Gamma spectrometry of whole milk
Beach sand	E1.3, 5.9	Six-monthly	Taken by scoop from top 50 mm in inter-tidal region	Sample ashed and sieved. Sample passing 10 mesh BSS counted for β-γ emitters. Sample between 60 and 110 mesh BSS counted for α emitters
Zostera	E1.6, 2.4, E4.6, 7.0, E9.3	Six-monthly	Harvested by hand or rake	Ashed
Vegetation	T1, LHRL stormwater outlets	Six-monthly	Cut by hand clippers	Whole unwashed vegetation ashed
Sand/Soil	TO, T1, T2; LHRL stormwater outlets	Six-monthly	Scooped from surface	As for beach sand
Groundwater	T1	Six-monthly	Boreholes pumped dry, allowed to refill and sampled from bottom	10 L sample evaporated to dryness and the residue counted
Creekwater	T2	Yearly	Sampled by bucket or bottle	As for groundwater

TABLE 2
RADIOACTIVE IODINE IN AIR, 1983

Week ending (1983)	^{131}I (Bq m^{-3})	Week ending (1983)	^{131}I (Bq m^{-3})
5/1	n.d.[1]	5/7	6.5×10^{-3}
11/1	n.d.	12/7	2.2×10^{-2}
18/1	n.d.	19/7	4.9×10^{-3}
25/1	n.d.	26/7	2.8×10^{-3}
1/2	trace[2]	2/8	4.6×10^{-3}
8/2	trace	9/8	3.6×10^{-3}
15/2	n.d.	16/8	6.3×10^{-3}
22/2	trace	23/8	5.6×10^{-3}
2/3	trace	30/8	4.4×10^{-3}
9/3	trace	6/9	trace
15/3	n.d.	13/9	n.d.
22/3	trace	20/9	trace
28/3	3.9×10^{-3}	28/9	trace
5/4	4.3×10^{-3}	5/10	n.d.
12/4	5.0×10^{-3}	11/10	n.d.
19/4	n.d.	18/10	n.d.
26/4	2.1×10^{-2}	25/10	n.d.
3/5	4.1×10^{-3}	1/11	n.d.
10/5	1.6×10^{-2}	8/11	trace
17/5	1.9×10^{-2}	15/11	trace
24/5	8.3×10^{-3}	22/11	n.d.
31/5	2.0×10^{-2}	30/11	n.d.
7/6	trace	6/12	trace
14/6	4.9×10^{-3}	13/12	n.d.
21/6	8.6×10^{-3}	20/12	n.d.
28/6	3.2×10^{-2}	29/12	n.d.

Three air samplers are located along the eastern boundary of the site, where suburban residences are closest. Results are calculated making the conservative assumptions that: all activity was released during the first day of sampling period; and all the activity was concentrated at one sampling point.

[1] not detected.
[2] trace < 3×10^{-3} Bq m^{-3}.

TABLE 3
RADIOACTIVITY IN MILK SAMPLES, 1983

Station	Date 1983	Radioactivity (Bq g^{-1} fresh weight)	
		^{137}Cs[2]	^{131}I[1]
T3	31/1	n.d.[3]	n.d.
(Menai)	28/2	trace	n.d.
	28/3	n.d.	n.d.
	29/4	trace	n.d.
	27/5	trace	n.d.
	29/6	n.d.	n.d.
	28/7	trace	n.d.
	30/8	trace	n.d.
	10/10	trace	n.d.
	31/10	n.d.	n.d.
	30/11	trace	n.d.
	30/12	trace	n.d.

[1] The analytical method used for ^{131}I in milk has a minimum detectable level of 1×10^{-3} Bq g^{-1}.

[2] For ^{137}Cs the minimum detectable level was 3×10^{-4} Bq g^{-1}.

[3] Not detected.

TABLE 4
TRITIUM IN WORONORA WATER SAMPLES AT STATION E5.9, 1983

Date 1983	Tritium[1] (Bq mL^{-1})	Date 1983	Tritium (Bq mL^{-1})	Date 1983	Tritium (Bq mL^{-1})
5/1	< 0.25	26/4	< 0.25	23/8	< 0.25
11/1	< 0.25	3/5	< 0.25	30/8	< 0.25
18/1	< 0.25	10/5	< 0.25	6/9	< 0.25
25/1	< 0.25	17/5	< 0.25	11/10	< 0.25
1/2	< 0.25	24/5	< 0.25	18/10	< 0.25
8/2	< 0.25	31/5	< 0.25	25/10	< 0.25
15/2	< 0.25	7/6	< 0.25	1/11	< 0.25
22/2	< 0.25	14/6	< 0.25	8/11	< 0.25
2/3	< 0.25	21/6	< 0.25	15/11	< 0.25
8/3	< 0.25	28/6	< 0.25	22/11	< 0.25
15/3	< 0.25	5/7	< 0.25	30/11	< 0.25
23/3	< 0.25	14/7	< 0.25	6/12	< 0.25
28/3	< 0.25	19/7	< 0.25	13/12	< 0.25
5/4	< 0.25	26/7	< 0.25	20/12	< 0.25
12/4	< 0.25	2/8	< 0.25	29/12	< 0.25
19/4	< 0.25	16/8	< 0.25		

[1] Derived limiting concentration (DLC) [ICRP 1979] = 80 Bq mL^{-1} (if taken as drinking water).

TABLE 5
RADIOACTIVITY IN WORONORA ZOSTERA SAMPLES, 1983

Station	Date 1983	Radioactivity ($Bq\ g^{-1}$ fresh weight) Gross α	Gross β (less ^{40}K)	Gamma emitters ^{60}Co	$^{238}U+^{232}Th$ series	K ($\mu g\ g^{-1}$)
E1.3	20/5	0.03	0.01	trace	trace	4500
	14/11	0.05	0.04	trace	trace	4100
E2.4	20/5	0.06	0.04	trace	trace	3800
	14/11	0.06	0.02	trace	trace	5000
E4.6	14/11	0.09	0.07	trace	trace	4100

TABLE 6
RADIOACTIVITY IN WORONORA BEACH SAND, 1983

Station	Date 1983	Radioactivity ($Bq\ g^{-1}$ dry weight) Gross α	Gross β (less ^{40}K)	γ emitters	K ($\mu g\ g^{-1}$)
E1.3	20/5	0.29	0.05	n.d[1]	200
	14/5	0.26	0.05	n.d.	200
E5.9	20/5	0.03	0.13	n.d.	250
	14/11	0.02	0.13	n.d.	250
Average (all samples)		0.15	0.09		
DLC[2]		111	92.5		
Average fraction of DLC		1.4×10^{-3}	9.7×10^{-4}		

[1] Not detected.

[2] Derived limiting concentration, from Fry [1966].

TABLE 7A
RADIOACTIVITY IN SAMPLES FROM STORMWATER OUTLETS, 1983

Station	Date	Sample	Radioactivity ($Bq\ g^{-1}$ fresh weight) Gross α	Gross β (less ^{40}K)	γ-emitters[1]	^3H ($Bq\ mL^{-1}$)	K ($\mu g\ g^{-1}$)
Drain behind	11/4	water	-[2]	-	-	<0.25	-
Bld.1	27/7	water	-	-	-	<0.25	-
Drain rear of	11/4	water	-	-	-	<0.25	-
Bld.9	11/4	soil	0.48	0.37	trace $^{238}U + ^{232}Th$ series	-	1500
	27/7	water	-	-	-	<0.25	-
	27/7	soil	0.34	0.31	trace $^{238}U + ^{232}Th$ series	-	1300
Drain on west	11/4	soil	0.25	0.10	trace $^{238}U + ^{232}Th$ series	-	450
fence road	27/7	soil	0.41	0.12	trace $^{238}U + ^{232}Th$ series	-	400
Drain opposite	11/4	water	-	-	-	<0.25	-
sub-station	11/4	soil	0.49	0.10	trace $^{238}U + ^{232}Th$ series	-	700
	27/7	water	-	-	-	<0.25	-
	27/7	soil	0.46	0.16	trace $^{238}U + ^{232}Th$ series	-	550
Drain at	11/4	soil	0.18	0.86	trace $^{238}U + ^{232}Th$ series	-	250
boom gate	27/7	soil	0.16	0.71	trace $^{238}U + ^{232}Th$ series	-	200
Drain west of	11/4	soil	0.96	1.15	trace $^{238}U + ^{232}Th$ series	-	900
test compound	27/7	soil	0.82	0.91	trace $^{238}U + ^{232}Th$ series	-	750
Drain near	11/4	soil	0.36	0.25	trace $^{238}U + ^{232}Th$ series	-	750
yellowcake	27/7	soil	0.62	0.34	trace $^{238}U + ^{232}Th$ series	-	700
store	27/7	water	-	-	-	<0.25	-
Drain at	11/4	soil	0.23	0.16	trace $^{238}U + ^{232}Th$ series	-	700
Fermi St.	11/4	water	-	-	-	0.3	-
	27/7	soil	0.19	0.19	trace $^{238}U + ^{232}Th$ series	-	500
	27/7	water	-	-	-	<0.25	-
Drain opposite	11/4	soil	0.60	0.39	trace $^{238}U + ^{232}Th$ series	-	1000
Bld.23	27/7	soil	0.53	0.45	trace $^{238}U + ^{232}Th$ series	-	1000
Drain No.1	11/4	soil	0.34	0.17	trace $^{238}U + ^{232}Th$ series	-	650
opposite	11/4	water	-	-	-	<0.25	-
Strassman Cr.	27/7	soil	0.31	0.15	trace $^{238}U + ^{232}Th$ series	-	400
	27/7	water	-	-	-	<0.25	-
	27/7	vegetation	0.003	0.01	trace $^{238}U + ^{232}Th$ series	-	5000
Drain No.2	11/4	soil	0.53	0.36	trace $^{238}U + ^{232}Th$ series	-	1200
opposite Strassman Cr.	27/7	soil	0.54	0.33	trace $^{238}U + ^{232}Th$ series	-	900
Drain rear	11/4	soil	0.28	0.15	trace $^{238}U + ^{232}Th$ series	-	1100
of Bld.20	27/7	soil	0.34	0.12	trace $^{238}U + ^{232}Th$ series	-	700

[1] The γ-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 spailation product, and ^{103}Ru and ^{106}Ru are fission products. $Bq\ g^{-1}$ refers to the number of disintegrations per second per gram at the energies indicated.

[2] Not measured.

TABLE 7B
RADIOACTIVITY IN SAMPLES FROM STORMWATER OUTLETS, 1983

Station	Date	Sample	Radioactivity (Bq L^{-1}) Gross α	Gross β (incl. ^{40}K)	γ-emitters[1]	^{3}H (Bq mL^{-1})	K (μg g^{-1})
LHRL stormwater	5/1	water	-[2]	-	-	<0.25	-
outlet No.1	11/1	water	0.05	0.42	n.d.[3]	1.10	-
near south gate	18/1	water	-	-	n.d.	0.70	-
	25/1	water	0.03	0.13	n.d.	<0.25	-
	1/2	water	-	-	-	<0.25	-
	8/2	water	-	-	-	0.93	-
	15/2	water	-	-	-	<0.25	-
	22/2	water	-	-	-	0.52	-
	2/3	water	1.68	9.57	0.5 MeV = 0.16 ^{137}Cs = 2.95 ^{60}Co = 0.14 trace ^{238}U + ^{232}Th series	1.80	-
	8/3	water	-	-	-	1.09	-
	15/3	water	0.65	0.30	0.5 MeV = 0.04 ^{137}Cs = 0.26	<0.25	-
	23/3	water	0.16	0.22	trace ^{238}U + ^{232}Th series	<0.25	-
	28/3	water	0.36	0.25	^{137}Cs = trace	<0.25	-
	5/4	water	0.03	0.08	n.d.	<0.25	-
	12/4	water	0.08	0.07	n.d.	<0.25	-
	19/4	water	0.03	0.07	n.d.	<0.25	-
	26/4	water	0.10	0.08	n.d.	<0.25	-
	3/5	water	0.07	0.15	n.d.	<0.25	-
	10/5	water	0.16	0.26	n.d.	0.43	-
	17/5	water	0.05	0.07	n.d.	<0.25	-
	24/5	water	0.25	0.06	n.d.	<0.25	-
	31/5	water	0.15	0.17	n.d.	<0.25	-
	7/6	water	0.09	0.23	n.d.	0.28	-
	14/6	water	0.21	0.31	n.d.	<0.25	-
	21/6	water	0.07	0.12	n.d.	<0.25	-
	28/6	water	0.07	0.14	n.d.	0.26	-
	5/7	water	0.09	0.08	n.d.	<0.25	-
	14/7	water	0.12	0.12	n.d.	<0.25	-
	19/7	water	0.05	0.10	n.d.	<0.25	-
	26/7	water	0.09	0.14	n.d.	<0.25	-
	2/8	water	0.03	0.10	n.d.	<0.25	-
	16/8	water	0.11	0.18	n.d.	0.48	-
	23/8	water	0.06	0.18	n.d.	0.68	-
	30/8	water	0.13	0.35	n.d.	0.62	-
	6/9	water	0.20	0.19	n.d.	0.41	-
	21/9	water	1.13	0.95	trace ^{238}U + ^{232}Th series	0.99	-
	28/9	water	0.17	0.43	n.d.	0.35	-
	11/10	water	0.06	0.08	n.d.	<0.25	-
	18/10	water	0.02	0.06	n.d.	<0.25	-
	25/10	water	0.12	0.13	n.d.	<0.25	-
	1/11	water	0.13	0.14	n.d.	<0.25	-
	8/11	water	0.25	0.22	n.d.	0.35	-
	15/11	water	0.06	0.18	n.d.	0.37	-
	22/11	water	0.08	0.12	n.d.	0.31	-
	30/11	water	0.10	0.12	n.d.	0.33	-
	6/12	water	0.07	0.14	n.d.	0.35	-
	13/12	water	0.06	0.12	n.d.	0.28	-
	20/12	water	0.09	0.11	n.d.	<0.25	-
	29/12	water	0.14	0.10	n.d.	<0.25	-

[1] The γ-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, and ^{103}Ru and ^{106}Ru are fission products. Bq g^{-1} refers to the number of disintegrations per second per gram at the energies indicated.

[2] Not measured.

TABLE 7C
RADIOACTIVITY IN SAMPLES FROM STORMWATER OUTLETS, 1983

Station	Date	Sample	Radioactivity (Bq g^{-1} fresh weight) Gross α	Gross β (less ^{40}K)	γ-emitters[1]	^3H (Bq mL^{-1})	K ($\mu g\ g^{-1}$)
20 m from	11/1	water	-[2]	-	-	1.10	-
LHRL stormwater	11/1	soil	0.55	0.39	trace ^{60}Co, ^{137}Cs	-	1800
outlet No.1					trace ^{238}U + ^{232}Th series		
	11/1	vegetation	0.02	0.01	trace ^{238}U + ^{232}Th series	-	4400
	16/2	water	-	-	-	0.76	-
	13/4	water	-	-	-	<0.25	-
	13/4	soil	0.65	0.41	trace ^{60}Co, ^{137}Cs	-	1500
					trace ^{238}U + ^{232}Th series		
	13/4	vegetation	0.01	0.03	0.5 MeV = 0.008	-	3800
					trace ^{238}U + ^{232}Th series		
	29/6	water	-	-	-	<0.25	-
	29/6	soil	0.82	0.46	trace ^{60}Co	-	2100
					^{137}Cs = 0.07 Bq g^{-1} DW		
					trace ^{238}U + ^{232}Th series		
	29/6	vegetation	0.01	0.13	0.5 MeV = 0.008	-	2700
					^{137}Cs = 0.003		
					trace ^{238}U + ^{232}Th series		
	17/11	vegetation	0.01	0.04	trace ^{238}U + ^{232}Th series	-	5100

Continued next page

TABLE 7C (continued)

Station	Date	Sample	Radioactivity (Bq g^{-1} fresh weight) Gross α	Gross β (incl. ^{40}K)	γ-emitters[1]	^{3}H (Bq mL^{-1})	K ($\mu g\ g^{-1}$)
60 m from LHRL stormwater outlet No.1	22/2	water	1.62[4]	0.47[4]	trace $^{238}U + ^{232}Th$ series	<0.25	-
	2/3	water	-	-	-	0.65	-
	8/3	water	-	-	-	<0.25	-
	15/3	water	-	-	-	<0.25	-
	23/3	water	-	-	-	<0.25	-
	29/3	water	-	-	-	<0.25	-
	5/4	water	-	-	-	<0.25	-
	12/4	water	-	-	-	<0.25	-
	19/4	water	-	-	-	<0.25	-
	3/5	water	-	-	-	<0.25	-
	10/5	water	-	-	-	<0.25	-
	17/5	water	-	-	-	<0.25	-
	31/5	water	-	-	-	<0.25	-
	7/6	water	-	-	-	<0.25	-
	14/6	water	-	-	-	<0.25	-
	21/6	water	-	-	-	<0.25	-
	28/6	water	-	-	-	<0.25	-
	5/7	water	0.05[4]	0.11[4]	n.d.[3]	1.95	-
	14/7	water	0.14[4]	5.65[4]	0.13 MeV = trace 0.5 MeV = trace trace ^{137}Cs	3.56	-
	19/7	water	0.13[4]	1.84[4]	0.13 MeV = trace 0.5 MeV = trace trace ^{137}Cs	3.16	
	26/7	water	0.16[4]	1.08[4]	0.13 MeV = trace	2.17	-
	2/8	water	-	-	-	0.98	-
	16/8	water	-	-	-	0.76	-
	23/8	water	-	-	-	0.56	-
	30/8	water	-	-	-	0.62	-
	6/9	water	-	-	-	0.37	-
	21/9	water	-	-	-	0.42	-
	28/9	water	-	-	-	0.63	-
	11/10	water	-	-	-	<0.25	-
	18/10	water	-	-	-	<0.25	-
	25/10	water	-	-	-	<0.25	-
	1/11	water	-	-	-	<0.25	-
	8/11	water	-	-	-	<0.25	-
	15/11	water	-	-	-	<0.25	-
	22/11	water	-	-	-	<0.25	-
	30/11	water	-	-	-	<0.25	-
	16/11	soil	0.14	0.08	n.d.	-	200
	6/12	water	-	-	-	<0.25	-
	13/12	water	-	-	-	<0.25	-
	20/12	water	-	-	-	<0.25	-

[1] The γ-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, and ^{103}Ru and ^{106}Ru are fission products. Bq g^{-1} refers to the number of disintegrations per second per gram at the energies indicated.

[2] Not measured.

[3] Not detected.

[4] Bq L^{-1}.

TABLE 8
GAMMA SURVEY — EFFLUENT DISCHARGE PIPE LINE, 1983

Survey of exposed portions of pipeline between LHRL and the MWS&DB sewer connection using an Ericsson type 1368A field meter

Date	Location	Dose rate (μSv h^{-1})
30/5	Joint No.9	1.0
	All other pipe sections	<0.4
	Soil below joints	<0.3
16/11	All pipe sections	<0.4
	Soil below joints	<0.3

TABLE 9
RADIOACTIVITY IN SAMPLES TAKEN NEAR EFFLUENT DISCHARGE PIPELINE, 1983

Station	Date	Sample	Radioactivity (Bq g^{-1} dry weight) Gross α	Gross β (less ^{40}K)	γ-emitters	^{3}H (Bq mL^{-1})	K (μg g^{-1})
Near scour	29/6	soil	0.32	0.03	n.d.[1]	-[2]	300
valve No.1	29/6	water	-	-	-	<0.25	-
	16/11	soil	0.23	<0.01	n.d.	-	600
	16/11	water	-	-	-	<0.25	-
Woronora R. at	29/6	soil	0.28	0.08	n.d.	-	400
point where	29/6	water	-	-	-	<0.25	-
crossed by	16/11	soil	0.32	0.07	n.d.	-	200
effluent discharge pipe	16/11	water	0.13[4]	0.12[3][4]	n.d.	<0.25	-

[1] Not detected

[2] Not measured

[3] Incl. ^{40}K contribution

[4] Bq L^{-1}

TABLE 10
RADIOACTIVITY IN FRESHWATER SECTION OF WORONORA RIVER, 1983

Station	Date 1983	Radioactivity: Sand ^{90}Sr (Bq g^{-1})	Water ^{90}Sr (Bq L^{-1})	Water ^{3}H (Bq mL^{-1})
Woronora R. at	16/2	0.0001	0.007	<0.25
Heathcote Rd crossing	29/6	0.0002	0.005	-
(upstream of LHRL)	12/10	0.0009	0.023	<0.25
Woronora R. at	16/2	0.0002	0.013	<0.25
the point of	29/6	0.0004	0.021	-
entry of drainage from LHRL	12/10	0.0006	0.041	<0.25

TABLE 11
RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION FROM LITTLE FOREST BURIAL GROUND, 1983

Location	Sample	Date 1983	Radioactivity (Bq g^{-1} fresh weight) Gross α	Gross β (less ^{40}K)	Gamma emitters 0.5 MeV[1]	^{60}Co	$^{238}U + ^{232}Th$	K ($\mu g\ g^{-1}$)
TR 1-5	Soil	30/6	0.67	0.52	n.d.[2]	n.d.	n.d.	4900
	Soil	16/12	0.71	0.59	n.d.	trace	trace	3100
TR 56-57	Soil	30/6	3.70	0.79	n.d.	n.d.	n.d.	4800
	Soil	16/12	3.07	0.82	n.d.	n.d.	n.d.	3500
TR 68-69	Soil	30/6	1.12	1.04	n.d.	trace	trace	5100
	Soil	16/12	1.15	1.23	n.d.	trace	trace	3500
TR 72-73	Soil	30/6	0.86	0.62	n.d.	trace	n.d.	6100
	Soil	16/12	0.92	0.87	n.d.	trace	trace	4100
TR 58	Acacia	30/6	0.01	0.15	0.005	n.d.	n.d.	1500
(front)	Acacia	16/12	0.02	0.18	0.004	n.d.	n.d.	2700
TR 59 (back)	Acacia	30/6	0.02	0.05	0.04	n.d.	n.d	1500
TR 60	Acacia	16/12	0.01	0.02	0.008	n.d.	n.d.	2400
TR 53	Grass	16/12	0.002	0.11	0.011	n.d.	n.d.	3500
TR 56	Grass	16/12	0.07	0.06	0.013	n.d.	n.d.	3500
TR 71	Grass	16/12	0.01	1.19	0.005	0.017	n.d.	4800

[1] The γ-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, and ^{103}Ru and ^{106}Ru are fission products.

[2] Not detected.

TABLE 12
RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM LITTLE FOREST BURIAL GROUND, 1983

Bore hole No.	Bq g^{-1} solids Gross α June	Gross α Dec.	Gross β[1] June	Gross β[1] Dec.	Gamma emitters June	Gamma emitters Dec.	Bq mL^{-1} ^{3}H June	^{3}H Dec.
BH1	2.1	-[2]	0.7	-[2]	n.d.[3]	-[2]	<0.25	[2]
BH2	2.7	-[2]	1.1	-[2]	n.d.	-[2]	<0.25	-[2]
BH3	4.7	-[2]	1.2	-[2]	trace ^{238}U ^{232}Th series	-[2]	<0.25	-[2]
BH4	2.6	3.1	0.7	1.0	trace ^{238}U, ^{232}Th series	trace ^{238}U, ^{232}Th series	<0.25	<0.25
BH6	1.9	1.5	0.7	0.5	n.d.	n.d.	<0.25	<0.25
BH10	0.3	0.02	0.3	0.4	n.d.	n.d.	1.2	1.0
OS1	0.7	0.2	0.5	0.2	n.d.	n.d.	<0.25	<0.25
OS2	2.7	2.2	1.4	1.8	trace ^{238}U, ^{232}Th series	n.d.	7.4	5.6
OS3	1.8	1.6	3.4	7.8	trace ^{238}U, ^{232}Th series	n.d.	14.7	11.5
BHA	1.2	0.6	0.7	0.4	n.d.	n.d.	<0.25	<0.25
BHB	0.06	0.08	0.1	0.2	n.d.	n.d.	<0.25	<0.25
BHC	0.09	0.03	0.1	0.3	n.d.	n.d.	<0.25	<0.25
BHD	0.2	0.3	0.4	0.4	n.d.	n.d.	<0.25	<0.25
BHE	0.2	0.05	0.3	0.3	n.d.	n.d.	<0.25	<0.25

[1] Includes ^{40}K contribution.

[2] Bore hole dry.

[3] Not detected.

TABLE 13
RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST BURIAL GROUND, 1983

SAND

Station	Date 1983	Radioactivity (Bq g^{-1} dry weight) Gross α	Gross β (less ^{40}K)	γ-emitters	K ($\mu g\ g^{-1}$)
Barden Creek above junction with Mill Creek	22/11	0.23	0.05	n.d.	160
Mill Creek above junction with Barden Creek	22/11	0.18	0.10	trace ^{238}U + ^{232}Th series	300

WATER

Station	Date 1983	Radioactivity (Bq L^{-1}) Gross α	Gross β (incl. ^{40}K)	γ-emitters	^3H (Bq mL^{-1})
Barden Creek above junction with Mill Creek	22/11	<0.01	0.03	n.d.	<0.25
Mill Creek above junction with Barden Creek	22/11	<0.01	0.07	n.d.	<0.25

TABLE 14
AIRBORNE RADIOACTIVITY RELEASES, 1983

Period Bld No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^{3}H (GBq)	^{41}A (TBq)	Fission product Noble gases (TBq)	Other activity (MBq)
1/1 - 30/3							
2	<62	1.6×10^4	<4	-	-	34	3.2×10^4
15	<6	<2	<2	6.4×10^2	22	-	$<1.2 \times 10^2$
19	<38	<2	<1	-	-	-	<1
23A	<8	4.2×10^3	<19	-	-	-	3.1×10^2
23B	<2	<1	<1	-	-	-	<1
41	<2	<2	<1	-	-	-	<1
57	-	-	-	18	-	-	-
1/4 - 30/6							
2	<50	7.5×10^4	<5	-	-	30	1.7×10^5
15	<4	<3	<1	1.4×10^3	20.6	-	<79
19	<15	<17	<1	-	-	-	<1
23A	<10	3.3×10^3	<9	-	-	-	9.0
23B	<2	<1	<1	-	-	-	<1
41	<8	<3	<1	-	-	-	<1
57	-	-	-	-	-	-	-
1/7 - 30/9							
2	<41	1.1×10^4	<0.3	-	-	48	2.1×10^4
15	<2	1.9	<0.2	1.1×10^3	21	-	1.1×10^2
19	<10	1.2×10^3	<0.1	-	-	-	22
23A	<9	3.8×10^3	<0.07	-	-	-	4.0×10^2
23B	<1.2	1.5	<0.01	-	-	-	0.3
41	<7	<1.4	<0.07	-	-	-	<0.2
57	-	-	-	108	-	-	-
1/10 - 31/12							
2	170	5.3×10^3	<0.5	-	-	68	6.9×10^3
15	<2	2.2	<0.2	7.2×10^2	17	-	105
19	<14	11	<0.5	-	-	-	-
23A	<9	2.8×10^3	<1.1	-	-	-	-
23B	<14	1.9	<0.05	-	-	-	-
41	<7	0.6	<0.08	-	-	-	-
57	-	-	-	41	-	-	-

TABLE 15
AIRBORNE RADIOACTIVITY RELEASES, 1983
AS FRACTIONS OF THE AUTHORISED LIMITS

Period Bld No.	Gross α	^{131}I	^{90}Sr	^{3}H	^{41}A	Fission product Noble gases	Other activity
1/1 - 30/3							
2	$<9.4 \times 10^{-5}$	0.24	$<6.3 \times 10^{-6}$	-	-	0.20	0.02
15	$<1.8 \times 10^{-4}$	1.3×10^{-4}	$<7.7 \times 10^{-5}$	4.9×10^{-3}	0.81	-	$<1.8 \times 10^{-3}$
19	$<1.2 \times 10^{-4}$	6.1×10^{-5}	$<3.8 \times 10^{-6}$	-	-	-	$<1.5 \times 10^{-6}$
23A	$<5.0 \times 10^{-4}$	0.26	$<1.5 \times 10^{-3}$	-	-	-	9.4×10^{-3}
23B	$<3.0 \times 10^{-4}$	6.3×10^{-5}	$<1.6 \times 10^{-4}$	-	-	-	$<6.3 \times 10^{-5}$
41	$<6.1 \times 10^{-6}$	1.3×10^{-4}	$<3.8 \times 10^{-6}$	-	-	-	$<1.5 \times 10^{-6}$
57	-	-	-	0.09	-	-	-
1/4 - 30/6							
2	$<7.7 \times 10^{-5}$	1.15[1]	$<7.7 \times 10^{-6}$	-	-	0.19	0.11
15	$<1.3 \times 10^{-4}$	1.9×10^{-4}	$<4.0 \times 10^{-5}$	0.01[2]	0.79	-	$<1.2 \times 10^{-3}$
19	$<4.7 \times 10^{-5}$	5.3×10^{-4}	$<4.0 \times 10^{-6}$	-	-	-	$<1.5 \times 10^{-6}$
23A	$<6.3 \times 10^{-4}$	0.21	$<6.9 \times 10^{-4}$	-	-	-	2.8×10^{-4}
23B	$<3.1 \times 10^{-4}$	6.3×10^{-5}	$<1.6 \times 10^{-4}$	-	-	-	$<6.3 \times 10^{-5}$
41	$<2.5 \times 10^{-5}$	1.9×10^{-4}	$<4.0 \times 10^{-6}$	-	-	-	$<1.5 \times 10^{-6}$
57	-	-	-	-	-	-	-
1/7 - 30/9							
2	$<6.2 \times 10^{-5}$	0.17	$<4.7 \times 10^{-7}$	-	-	0.29	0.01
15	$<6.1 \times 10^{-5}$	1.2×10^{-4}	$<7.7 \times 10^{-6}$	3.5×10^{-3}	0.78	-	1.67×10^{-3}
19	$<3.0 \times 10^{-5}$	0.04	$<3.8 \times 10^{-7}$	-	-	-	3.3×10^{-5}
23A	$<5.6 \times 10^{-4}$	2.4×10^{-4}	$<5.4 \times 10^{-6}$	-	-	-	0.01
23B	$<1.8 \times 10^{-4}$	9.4×10^{-5}	$<1.6 \times 10^{-6}$	-	-	-	1.9×10^{-5}
41	$<2.1 \times 10^{-5}$	$<8.8 \times 10^{-5}$	$<2.7 \times 10^{-7}$	-	-	-	$<3.0 \times 10^{-7}$
57	-	3.7×10^{-4}	-	0.72	-	-	-
1/10 - 31/12							
2	2.6×10^{-4}	0.08	$<7.8 \times 10^{-7}$	-	-	0.40	4.3×10^{-3}
15	$<6.1 \times 10^{-5}$	1.4×10^{-4}	$<7.7 \times 10^{-6}$	5.5×10^{-3}	0.63	-	1.6×10^{-3}
19	$<4.2 \times 10^{-5}$	3.3×10^{-4}	$<1.9 \times 10^{-6}$	-	-	-	-
23A	$<5.6 \times 10^{-4}$	0.18	$<8.5 \times 10^{-5}$	-	-	-	-
23B	$<2.1 \times 10^{-3}$	1.2×10^{-4}	$<7.8 \times 10^{-6}$	-	-	-	-
41	$<2.1 \times 10^{-5}$	3.8×10^{-5}	$<3.1 \times 10^{-7}$	-	-	-	-
57	-	-	-	0.27	-	-	-

[1] This discharge was not in breach of the authorised limit for stack discharges from the Research Establishment, although it exceeded the normal working limit for discharges from this stack for the period. In calculating the *derived* authorist discharge limits, allowance is made for discharges from other stacks. Since only two out of the six stacks were dischargi any iodine-131, the authorised discharge limits are effectively doubled.

[2] This figure includes a contribution from Bld.57.

TABLE 16
RADIOACTIVITY DISCHARGED TO THE MWS&DB SEWER DURING 1983

Period	Radioisotopes measured (MBq) α_μ [1]	^3H	β_μ [2]	Percentage of authorised limit[3]
1/1 - 31/3	12.7	2.3×10^5	201	15
1/4 - 30/6	13.5	6.1×10^5	266	16
1/7 - 30/9	9.3	10.8×10^5	184	14
1/10 - 31/12	11.3	1.5×10^5	154	15

[1] A mixture of unidentified α-emitting nuclides taken as being all ^{226}Ra (*i.e.* the worst possible case) in calculating percentage of authorised limit.

[2] A mixture of unidentified β-emitting nuclides taken as being all ^{90}Sr (*i.e.* the worst possible case) when calculating the percentage of authorised limit.

[3] In the case of discharge to the MWS&DB sewer, the authorised limit is outlined in the regulations to the NSW Radioactive Substances Act published in Government Gazette No.136, 19 September 1980.

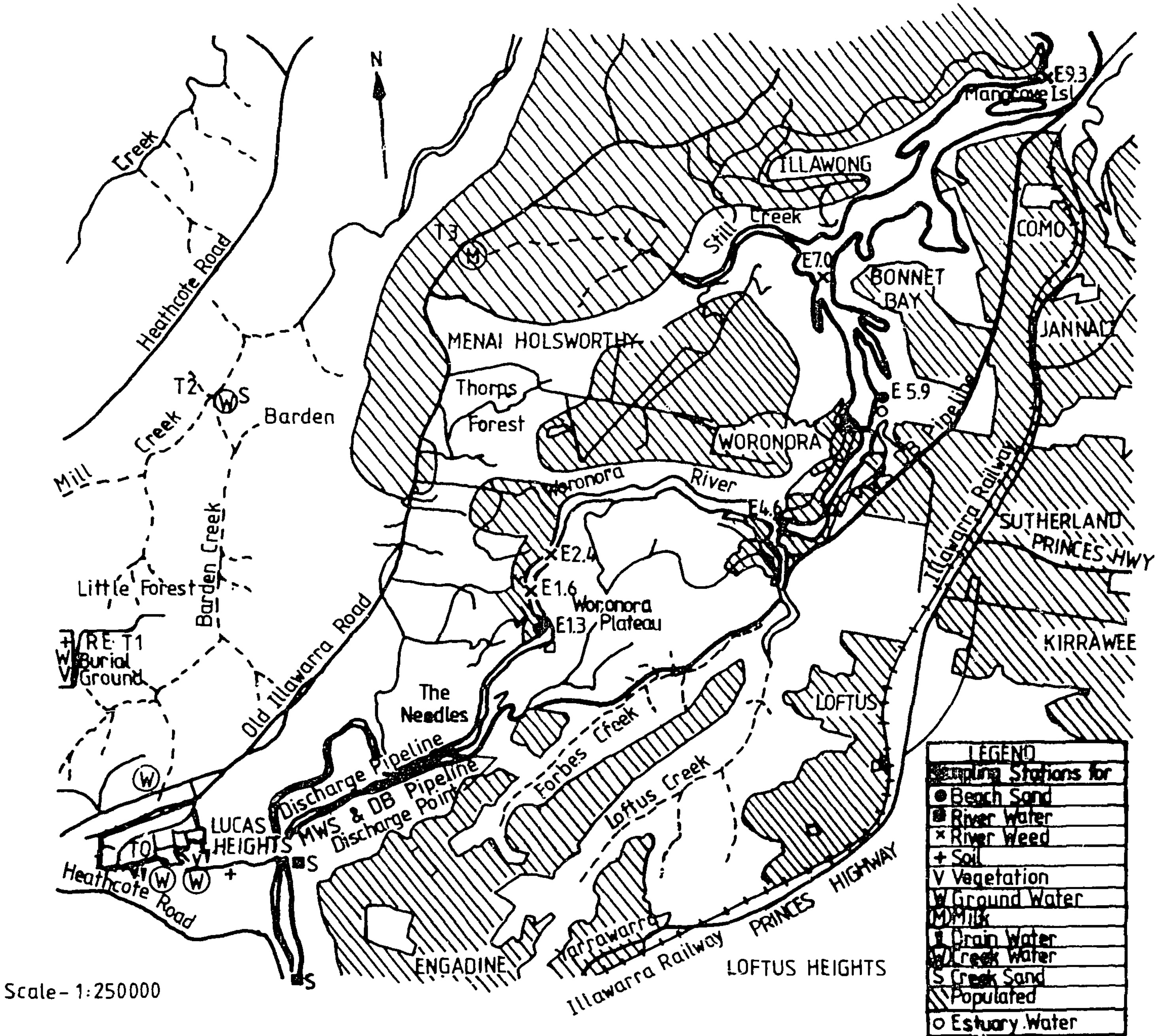

Figure 1 Lucas Heights district - location of sampling stations

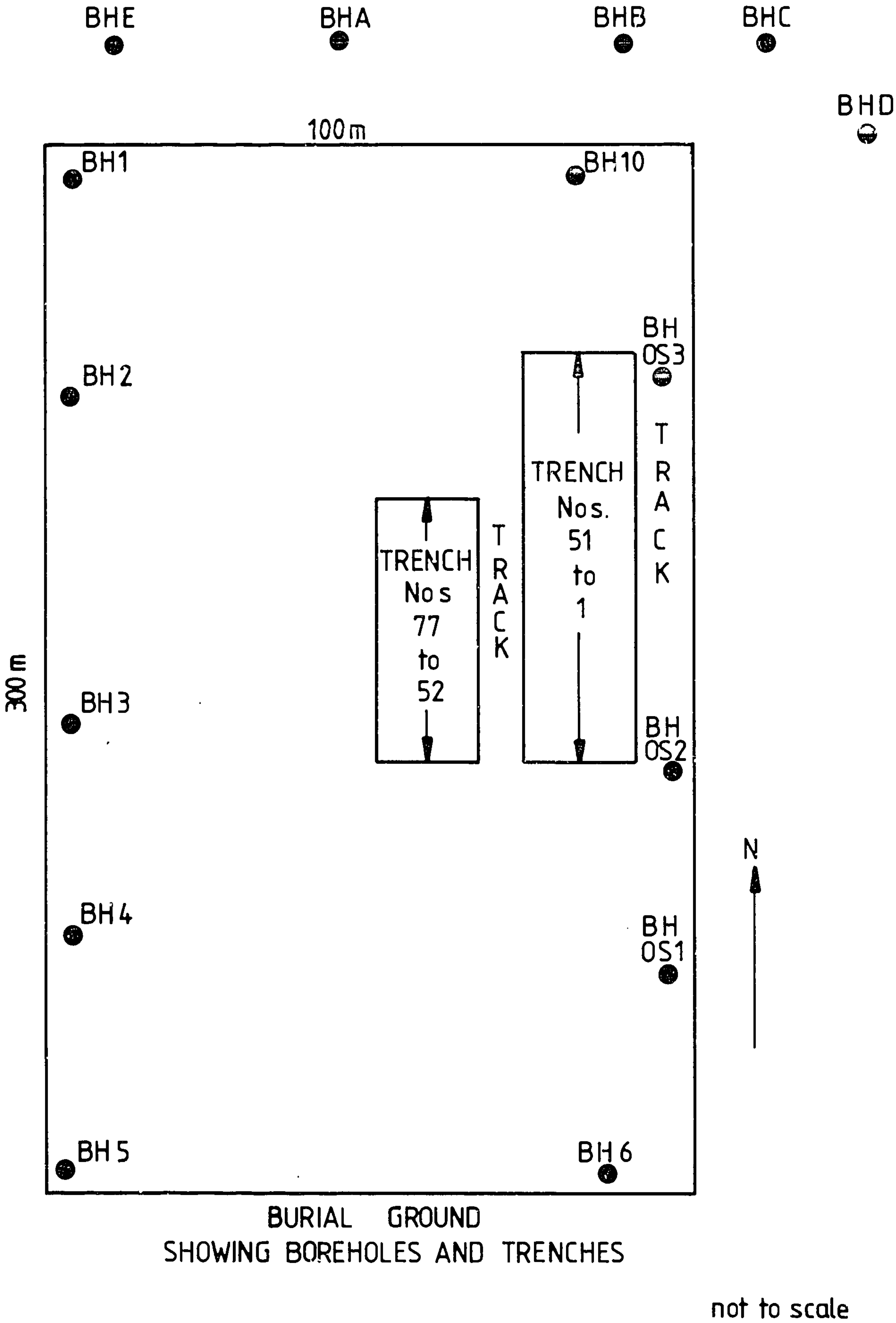

Figure 2 Little Forest Burial Ground — location of sampling stations

APPENDIX A
PREVIOUS ENVIRONMENTAL SURVEY REPORTS

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

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

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

Conway, N.F., 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., Dudaitis, A. [1974] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1973. AAEC/E335.

Davy, D.R., 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., Dudaitis, A. [1980] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1979. AAEC/E508.

Giles, M.S., Dudaitis, A. [1982] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1980. AAEC/E542.

Williams, A.R., Dudaitis, A. [1983] - Environmental Survey at the Lucas Heights Research Laboratories, 1981. AAEC/E563.

Giles, M.S., Dudaitis, A. [1984] - Environmental Survey at the Lucas Heights Research Laboratories, 1982. AAEC/E591.

APPENDIX B
LIST OF ISOTOPE SYMBOLS USED IN TABLES OF SURVEY RESULTS

Symbol	Name
^{41}Ar	argon-41
^{7}Be	beryllium-7
^{60}Co	cobalt-60
^{137}Cs	caesium-137
^{3}H	tritium
^{131}I	iodine-131
K	potassium (stable)
^{40}K	potassium-40
^{226}Ra	radium-226
^{103}Ru	ruthenium-103
^{106}Ru	ruthenium-106
^{90}Sr	strontium-90
^{232}Th	thorium-232
^{238}U	uranium-238
^{65}Zn	zinc-65

APPENDIX C
NEW ZEALAND NATIONAL RADIATION LABORATORY REPORT ON STRONTIUM IN SANDS FOR 1982

Results are expressed as becquerels ^{90}Sr/kg dry soil (dried at 110°C)

NRL No.	Soil Description	Date	Bq ^{90}Sr/kg ± 2 s.d.
1	Below weir, Heathcote Rd	1/4	0.08 ± 0.07
2	Below weir, Heathcode Rd	23/6	0.13 ± 0.07
3	Below weir, Heathcode Rd	13/10	0.01 ± 0.11
4	Woronora R. pipeline crossing	1/4	0.14 ± 0.07
5	Woronora R. pipeline crossing	23/6	0.05 ± 0.03
6	Woronora R. pipeline crossing	13/10	0.07 ± 0.02

General Comment

^{90}Sr content very low in all soils, approaching lower limit of detection.