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AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION

LUCAS HEIGHTS RESEARCH LABORATORIES

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ABSTRACT

Results are presented of an environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1985. 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 during this period is estimated to be less than 0.01 millisieverts, which is one 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; AUSTRALIA; BERYLLIUM 7; CESIUM 137; COBALT 60; CONTAMINATION; ENVIRONMENT; EXPERIMENTAL; DATA; FRESH WATER; GASEOUS WASTES; GROUND WATER; HUMAN POPULATIONS; IODINE 131; LIQUID WASTES; MAN; MILK; PLUTONIUM 239; PLANTS; RADIATION DOSES; RADIATION MONITORING; RADIOACTIVITY; RIVERS; SAND; SOILS; STRONTIUM 90; TRITIUM

EDITORIAL NOTE

The Australian Nuclear Science and Technology Organisation replaced the Australian Atomic Energy Commission on 27 April 1987. Reports issued after April 1987 have the prefix ANSTO with no change of the symbol (E, M, S or C) or numbering sequence.

CONTENTS

(Continued)

1. INTRODUCTION

Since 1959, surveys have been made by the Australian Atomic Energy Commission (AAEC)* of the radioactive content of 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 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) and by the National Health and Medical Research Council of Australia [NH&MRC 1981]. Doses recommended by these bodies are set for periods 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**. (The isotope symbols used in this report are listed in **appendix C**.)

3. ANALYTICAL METHODS

Analytical methods which have been modified and those which have been introduced since the previous survey are described in **appendix B**.

4. RESULTS

Environmental survey measurements taken during 1985 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.

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* In April, 1987, the AAEC was re-named the Australian Nuclear Science and Technology Organisation (ANSTO).

5.1 Airborne Release

Measurable concentrations of iodine-131 were recorded in air samplers, particularly during the first quarter of the year. The highest reading was registered for the week ending 26 November 1985, and was 3.6×10^{-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 iodine-131 in air concentration for the year would have resulted in an effective dose of 0.22 μSv y^{-1} or 2.2×10^{-4} of the limit.

The milk monitoring data for caesium-137 and iodine-131 are given in **table 3**. On 28 March 1985, 0.8 mBq g^{-1} of ^{137}Cs was found in a milk sample from Menai. This represents 1.6×10^{-3} of the derived limit, based on the assumption that an infant consumes 700 mL of milk per day. This figure is slightly above the limit of detection for ^{137}Cs in milk which is 0.3 mBq g^{-1} fresh weight. The limit of detection for iodine-131 in milk represents 4.5×10^{-2} of the derived limit.

Noble gas releases were always below the authorised limit during the year. See **table 14**. The method 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 one per cent of the NH&MRC recommendation.

5.2 Woronora Estuary Samples

Discharges of liquid effluent to the Woronora River ceased on 1 July 1980. Residual levels of radioactivity in samples from the estuary were monitored until December 1983 when no further radioactivity could be measured. In response to an incident involving vandalism to the effluent discharge pipeline, non-routine samples were collected from the estuary in September 1985. The routine water samples which are measured for tritium as a precaution against unknown accidental discharges continued to be collected throughout the year. No tritium was detected in these samples during 1985.

5.2.1 Estuary aquatic food chain

Analyses of oyster and fish samples collected in September from the Woronora River are reported in **tables 17** and **18** and for seagrass (*Zostera* sp.) in **table 19**. No radioactivity above background levels was found in the fish and oyster samples. The small amount of cobalt-60 found in *Zostera* is of the same order as that sampled in 1981. No food items were contaminated as a result of the breakage of the low-level effluent pipeline system.

5.2.2 Beach sand

Data for Woronora beach sand, sampled in September 1985, are given in **table 20**. There was no increase in the radioactivity on beach sand from the breakage of the low-level effluent pipeline. The activity is well below the limit for swimmers using the beaches [Fry 1966].

5.3 Stormwater Outlets

During 1985, water samples were collected from Strassman, Barden and MDP Creeks at points designated by the State Pollution Control Commission (SPCC). These points are shown on **figure 1**. Results for these samples are given in **table 6**. All results were well below the Clean Waters Regulations limits of 1.1 Bq L^{-1} for gross alpha activity and 11.1 Bq L^{-1} for gross beta activity.

Results for samples collected near stormwater outlets as a check on good housekeeping are shown in **table 5**. Some alpha radioactivity was found in water samples at a point 60 metres from the No.1 outlet which drains the south east corner of the site into MDP Creek. Detectable amounts of ^{60}Co, ^{137}Cs, ^{239}Pu and ^{3}H were also found. The limit of determination for ^{239}Pu was 0.00002 Bq L^{-1}, whereas the amount found in the January 15 sample, analysed because of its higher than normal alpha activity, was 0.01523 Bq L^{-1}.

If it is assumed that a person took all his or her drinking water supplies from the stormwater, the highest concentrations of ^{60}Co, ^{137}Cs and ^{239}Pu measured represent 2×10^{-4}, 4×10^{-4} and 4×10^{-2} of the derived working limit (DWL). When, as recommended by the ICRP, the concentrations are averaged over the year, the corresponding ratios to the DWL become 9×10^{-6}, 2.3×10^{-5} and

5×10^{-6}, respectively. The ephemeral creek into which this stormwater flows is not used as a source of drinking water.

Small amounts of tritium were present in stormwater collected in Barden Creek between 12 August and 8 October 1985. The source of this ^{3}H was traced to condensation from an airconditioning unit attached to the HIFAR reactor and this was subsequently redirected to the active drain system. The highest concentration recorded represents 2×10^{-2} of the DWL, which assumes that all drinking water is taken from that source. Average concentrations over the reported period represent 2.6×10^{-3} of the DWL.

5.4 Effluent Discharge Pipeline

Table 7 shows the dose rates at various points on the discharge pipeline during the 1985 survey. The maximum annual radiation dose for members of the public recommended by the ICRP [1979] is 1000 μSv per year. 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, so the limits would not be exceeded. Checks on water and soil at points along the pipeline revealed no radioactivity above background levels with the exception of a soil sample collected under Joint No. 6. This soil contained 0.41 Bq g^{-1} ^{137}Cs and 0.65 Bq g^{-1} ^{60}Co. As it was unlikely that the radioactivity of this soil could enter the human food chain there was no impact on members of the public. The soil analysis served as an early warning which enabled preventive maintenance to be carried out on Joint No. 6. Results of soil analyses are given in **table 8**.

5.5 Freshwater Section of 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 9**. All readings represent normal background levels.

5.6 Little Forest Burial Ground

Results of measurements at the Little Forest Burial Ground (LFBG) are given in **tables 10, 11** and **13**. The positions of sampling points are shown on **figure 2**. Tritium levels in BH10, OS2 and OS3 dropped in June but returned to 1984 levels in December. No tritium could be detected in BHD but a small amount of tritium was detected in BHF. BHD and BHF lie outside the fenced area. BHF is a sampling bore located approximately 30 m from the system of trenches. The tritium found in BHF, which is acting as a tracer, has no health significance since groundwater is not used from this area. No tritium was found in creeks draining the LFBG. No ^{239}Pu or beryllium (Be) was detected on remotely operating air sampler filters by initial estimates made on the quarterly samples but trace amounts of ^{239}Pu were found in composite samples for the year. The trace amount of ^{239}Pu is 3.0×10^{-3} of the derived working concentration (DWC) and presents no hazard to health. The minimum detectable level for Be is 0.001 μg m^{-3} and for ^{239}Pu 2.0×10^{-5} Bq m^{-3} after sampling 20 m^{3} of air. If more air is sampled, these limits are lowered proportionally. The threshold level value (TLV) for Be is 2 μg m^{-3} and the DWC for ^{239}Pu is 5×10^{-4} Bq m^{-3}. These limits were calculated assuming permanent exposure for 24 hours each day.

6. SUMMARY

None of the samples taken from possible human food chains in the vicinity of the Lucas Heights Reseach 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, calculated from results in **table 2**, was 0.0022 mSv y^{-1} and the calculated dose from released noble gases to the most exposed individuals was less than 0.01 mSv y^{-1}. These figures represent one 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	MDP Creek 60 m from LHRL outlet No. 1	Weekly	Sampled by bucket at outlet of the drain	10 L sample evaporated to dryness and the residue counted and 50 mL collected and distilled for tritium
	Barden Creek	Weekly	Sampled at the weir	50 mL collected and distilled for tritium
	Others	Quarterly	Sampled by beaker at the outlet of the drain	Distilled for tritium
Estuary water	E5.9	Weekly	From surface by bottle	Distilled for tritium
Radioactive iodine in air	T0	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
Vegetation	T1, LHRL stormwater outlets	Six-monthly	Cut by hand clippers	Whole unwashed vegetation ashed
Sand/soil	T0,T1; LHRL stormwater	Six-monthly	Scooped from surface	Sample ashed and sieved. Sample passing 10 mesh BSS counted for beta and gamma emitters. Sample between 60 and 110 mesh BSS counted alpha emitters.
Groundwater	Little Forest Burial Ground	Six-monthly	Boreholes pumped dry, allowed to refill and sampled from the bottom	15 L sample evaporated to dryness and the residue counted. 50 mL collected and distilled for tritium

(Continued)

TABLE 1 (cont'd)

Sample	Station	Frequency	Collection Details	Special Preparations
Be, ^{239}Pu	Little Forest Burial Ground	Monthly	Collected on 0.8 μm filter	Disc, 1 cm diameter cut out for Be analysis. Composite made of the monthly samples for ^{239}Pu analysis by alpha spectrometry.
Creekwater	T2	Yearly	Sampled by bucket.	5 L collected and passed through cation-exchange resin then ashed and counted. 50mL collected and distilled for tritium.
	Barden Creek MDP Creek Strassman Creek	Monthly	Sampled by bottle, after rain	Prepared according to Clean Waters Act Regulations.

TABLE 2

RADIOACTIVE IODINE IN AIR, 1985

Week Ending	^{131}I (Bq m^{-3})	Week Ending	^{131}I (Bq m^{-3})
2.1.85	0.0027	2.7.85	LLD
8.1.85	0.0067	10.7.85	LLD
15.1.85	LLD	16.7.85	LLD
22.1.85	LLD	23.7.85	LLD
29.1.85	LLD	30.7.85	LLD
5.2.86	LLD	6.8.85	LLD
12.2.85	LLD	13.8.85	LLD
19.2.85	LLD	2.8.85	LLD
26.2.85	0.0065	27.8.85	LLD
5.3.85	0.0060	3.9.85	LLD
12.3.85	0.0046	10.9.85	LLD
19.3.85	0.0028	18.9.85	LLD
26.3.85	0.0204	27.9.85	LLD
2.4.85	LLD	1.10.85	LLD
9.4.85	LLD	9.10.85	LLD
16.4.85	LLD	15.10.85	0.0175
24.4.85	LLD	22.10.85	LLD
1.5.85	LLD	29.10.85	LLD
7.5.85	LLD	5.11.85	LLD
14.5.85	LLD	12.11.85	LLD
21.5.85	LLD	19.11.85	LLD
29.5.85	LLD	26.11.85	0.0360
4.6.85	LLD	3.12.85	LLD
11.6.85	LLD	10.12.85	LLD
18.6.85	LLD	17.12.85	LLD
26.6.85	LLD	24.12.85	LLD
		31.12.85	LLD

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

LLD = less than the limit of detection.

The limit of detection for ^{131}I in air is 0.0025 Bq m^{-3}.

TABLE 3

RADIOACTIVITY IN MILK SAMPLES, 1985

Station	Date	Radioactivity ($Bq\ g^{-1}$ fresh weight)	
		^{137}Cs	^{131}I
T3	31.1.85	LLD	LLD
(Menai)	27.2.85	0.0004	LLD
	28.3.85	0.0008	LLD
	29.4.85	LLD	LLD
	31.5.85	LLD	LLD
	27.6.85	LLD	LLD
	29.7.85	LLD	LLD
	29.8.85	LLD	LLD
	30.9.85	LLD	LLD
	24.10.85	LLD	LLD
	28.11.85	LLD	LLD
	30.12.85	LLD	LLD

The analytical method used for ^{131}I in milk has a minimum detectable level of 0.001 $Bq\ g^{-1}$ (fresh weight).

For ^{137}Cs the minimum detectable level was 0.0003 $Bq\ g^{-1}$ (fresh weight).

LLD = less than the limit of detection.

TABLE 4

TRITIUM IN WORONORA WATER SAMPLES AT STATION E5.9, 1985

Date	Tritium ($Bq\ mL^{-1}$)	Date (1985)	Tritium ($Bq\ mL^{-1}$)
2.1.85	LLD	2.7.85	LLD
8.1.85	LLD	8.7.85	LLD
15.1.85	LLD	15.7.85	LLD
21.1.85	LLD	22.7.85	LLD
30.1.85	LLD	29.7.85	LLD
4.2.85	LLD	5.8.85	LLD
13.2.85	LLD	12.8.85	LLD
18.2.85	LLD	20.8.85	LLD
25.2.85	LLD	26.8.85	LLD
4.3.85	LLD	2.9.85	LLD
13.3.85	LLD	9.9.85	LLD
18.3.85	LLD	16.9.85	LLD
25.3.85	LLD	23.9.85	LLD
1.4.85	LLD	1.10.85	LLD
9.4.85	LLD	8.10.85	LLD
15.4.85	LLD	14.10.85	LLD
22.4.85	LLD	21.10.85	LLD
29.4.85	LLD	28.10.85	LLD
6.5.85	LLD	4.11.85	LLD
13.5.85	LLD	11.11.85	LLD
21.5.85	LLD	18.11.85	LLD
27.5.85	LLD	26.11.85	LLD
3.6.85	LLD	2.12.85	LLD
11.6.85	LLD	9.12.85	LLD
18.6.85	LLD	17.12.85	LLD
25.6.85	LLD	23.12.85	LLD
		30.12.85	LLD

Derived limiting concentration [ICRP 1979].

DLC = 80 $Bq\ mL^{-1}$ (if taken as drinking water).

LLD = less than the limit of detection.

The limit of detection for tritium is 0.25 $Bq\ mL^{-1}$.

TABLE 5

RADIOACTIVITY IN SAMPLES FROM STORMWATER OUTLETS 1985

Sampling Location	Date	Sample Type	Radioactivity ($Bq\ g^{-1}$ dry weight) Gross α	Gross β (less ^{40}K) [1]	γ-emitters	Tritium ($Bq\ mL^{-1}$)	Potassium ($\mu g\ g^{-1}$)
Drain behind Bld.1	24.4.85	Soil	0.43	0.21	Trace ^{232}Th & ^{238}U series	-	1474
	24.4.85	Water	-	-		LLD	-
	12.7.85	Soil	0.41	0.24	Trace ^{232}Th & ^{238}U series	-	1472
	12.7.85	Water	-	-		LLD	-
	29.1.85	Water	-	-		LLD	-
Drain on west Fence road	10.1.85	Soil	0.25	0.16	Trace ^{232}Th & ^{238}U series	-	1164
	24.4.85	Soil	0.22	0.09	Trace ^{232}Th & ^{238}U series	-	495
	24.4.85	Water	-	-		LLD	-
	12.7.85	Soil	0.32	0.12	Trace ^{232}Th & ^{238}U series	-	441
	12.7.85	Water	-	-		LLD	-
	29.10.85	Soil	0.32	0.22	Trace ^{232}Th & ^{238}U series	-	475
	29.10.85	Water	-	-		LLD	-
Drain opposite Fermi Street	10.1.85	Soil	0.56	0.55	Trace ^{232}Th & ^{238}U series, Trace ^{137}Cs & ^{60}Co	-	4611
	10.1.85	Veg.*	0.003	LLD	0.50 MeV = 0.002, Trace ^{232}Th & ^{238}U series	-	5664
	14.1.85	Water	-	-		LLD	-
	24.4.85	Soil	0.48	0.24	Trace ^{232}Th& ^{238}U series	-	1962
	24.4.85	Water	-	-		LLD	-
	12.7.85	Soil	0.45	0.30	Trace ^{232}Th & ^{238}U series	-	1891
	12.7.85	Water	-	-		0.33	-
	29.1.85	Soil	0.30	0.25	Trace ^{232}Th & ^{238}U series	-	1824
	29.1.85	Water	-	-		0.49	-
Drain opposite Bld. 23	10.1.85	Soil	0.36	0.39	Trace ^{232}Th & ^{238}U series, ^{60}Co = 0.05	-	912
	10.1.85	Veg.	0.34	0.04	Trace ^{232}Th & ^{238}U series, ^{60}Co = 0.044	-	6670
	24.4.85	Soil	0.33	0.20	Trace ^{232}Th & ^{238}U series	-	559
	24.4.85	Water	-	-		LLD	-
	12.7.85	Soil	0.36	0.20	Trace ^{232}Th & ^{238}U series	-	480
	12.7.85	Water	-	-		LLD	-
	29.1.85	Soil	0.36	0.17	Trace ^{232}Th & ^{238}U series	-	431
	29.10.85	Water	-	-		LLD	-
Drain opposite Meteorological Station	10.1.85	Soil	0.49	0.34	Trace ^{232}Th & ^{238}U series	-	730
	24.4.85	Soil	0.86	0.33	Trace ^{232}Th & ^{238}U series	-	1176
	24.4.85	Water	-	-		LLD	-
	12.7.85	Soil	0.55	0.17	Trace ^{232}Th & ^{238}U series	-	774
	12.7.85	Water	-	-		LLD	-
	29.10.85	Soil	0.49	0.18	Trace ^{232}Th & ^{238}U series	-	634
	29.10.85	Water	-	-		LLD	-
Drain No.1 opposite Strassman Cr.	17.1.85	Soil	0.45	0.30	Trace ^{232}Th & ^{238}U series	-	698
	17.1.85	Water	-	-		LLD	-
	17.1.85	Veg.*	0.01	LLD	Trace 0.50 MeV, Trace ^{232}Th & ^{238}U series	-	4459
	24.4.85	Soil	0.36	0.25	Trace ^{232}Th & ^{238}U series	-	1313
	24.4.85	Water	-	-		LLD	-
	26.4.85	Veg.*	0.002	0.01	0.50 MeV = 0.005, Trace ^{232}Th & ^{238}U series	-	3968
	12.7.85	Soil	0.46	0.20	Trace ^{232}Th & ^{238}U series	-	774
	12.7.85	Water	-	-		LLD	-
	12.7.85	Veg.*	0.002	0.02	0.50 MeV = 0.004,- Trace ^{232}Th & ^{238}U series		4080.
	29.1.85	Soil	0.27	0.17	Trace ^{232}Th & ^{238}U series	-	617
	29.10.85	Water	-	-		LLD	-
	29.10.85	Veg.*	0.002	LLD	Trace ^{232}Th & ^{238}U series	-	4422

(Continued)

TABLE 5 (cont'd)

Sampling Location	Date	Sample Type	Radioactivity ($Bq\ g^{-1}$ dry weight) Gross α	Gross β (less ^{40}K)[1]	γ-emitters	Tritium ($Bq\ mL^{-1}$)	Potassium ($\mu g\ g^{-1}$)
Drain No.2	17.1.85	Soil	0.32	0.17	Trace ^{232}Th & ^{238}U series	-	690
opposite	17.1.85	Water	-	-		LLD	-
Strassman Cr.	24.4.85	Soil	0.57	0.20	Trace ^{232}Th & ^{238}U series	-	515
	24.4.85	Water	-	-		LLD	-
	12.7.85	Soil	0.22	0.15	Trace ^{232}Th & ^{238}U series	-	515
	12.7.85	Water	-	-		LLD	-
	29.10.85	Soil	0.23	0.14	Trace ^{232}Th & ^{238}U series	-	366
	29.10.85	Water	-	-		LLD	-
Bld.20 Drain	15.1.85	Soil	1.03	0.17	Trace ^{232}Th & ^{238}U series	-	880
extension	15.1.85	Water	-	-		LLD	-
	24.4.85	Soil	4.09	0.31	Trace ^{232}Th & ^{238}U series	-	742
	24.4.85	Water	-	-		LLD	-
	12.7.85	Soil	0.20	0.03	Trace ^{232}Th & ^{238}U series	-	544
	12.7.85	Water	-	-		LLD	-
	29.10.85	Soil	1.35	0.23	Trace ^{232}Th & ^{238}U series	-	330
	29.10.85	Water	-	-		LLD	-
20 m from LHRL	15.1.85	Soil	0.69	0.20	Trace ^{232}Th & ^{238}U series	-	640
Stormwater	15.1.85	Veg.*	0.01	LLD	0.50 MeV = 0.002, Trace ^{137}Cs, Trace ^{232}Th & ^{238}U series	-	4832
Outlet No.1							
	26.4.85	Soil	0.46	0.22	Trace ^{232}Th & ^{238}U series	-	683
	26.4.85	Veg.*	0.001	0.07	0.50 MeV = 0.010, Trace ^{232}Th & ^{238}U series	-	2254
	12.7.85	Soil	0.65	0.52	Trace ^{137}Cs, Trace ^{60}Co, Trace ^{232}Th & ^{238}U series	-	1212
	12.7.85	Veg.*	0.003	0.04	0.50 MeV = 0.1, Trace ^{232}Th & ^{238}U series	-	3774
	29.10.85	Soil	0.63	0.67	Trace ^{232}Th & ^{238}U series	-	598
	29.10.85	Veg.*	0.003	0.02	0.50 MeV = ND, ^{137}Cs = 0.005 Trace ^{232}Th & ^{238}U series	-	3181
	29.10.85	Water	-	-	-	LLD	
Aqueduct from	15.1.85	Water	-	-	-	0.34	-
Stormwater	24.4.85	Water	-	-	-	LLD	-
Outlet No.1	12.7.85	Water	-	-	-	LLD	-
	29.10.85	Water	-	-	-	LLD	-
60 m from LHRL	15.1.85	Soil	0.86	0.16	Trace ^{232}Th & ^{238}U series	-	396
Stormwater	26.4.85	Soil	0.78	0.14	Trace ^{232}Th & ^{238}U series	-	386
Outlet No.1	26.4.85	Water	-	-	-	LLD	-
	12.7.85	Soil	0.27	0.10	Trace ^{232}Th & ^{238}U series	-	406
	12.7.85	Water	-	-		LLD	-

(Continued)

TABLE 5 (Cont'd)

Sampling Location	Date	Sample Type	Radioactivity ($Bq L^{-1}$)			Tritium ($Bq mL^{-1}$)	Potassium ($\mu g g^{-1}$)
			Gross α	Gross β (incl. ^{40}K)	γ-emitters		
60 m from LHRL Stormwater Outlet No. 1 (Cont'd)	2.1.85	Water	0.23	0.26	ND	0.26	-
	8.1.85	Water	0.58	0.29	ND	0.28	-
	15.1.85	Water	1.04 (0.01523 ^{239}Pu)	0.40	ND	LLD	-
	21.1.85	Water	0.65	0.33	ND	LLD	-
	29.1.85	Water	0.66	0.27	ND	LLD	-
	4.2.85	Water	0.45	0.19	ND	LLD	-
	13.2.85	Water	0.81	0.34	ND	LLD	-
	18.2.85	Water	0.24	0.18	ND	LLD	-
	25.2.85	Water	0.26	0.21	ND	LLD	-
	4.3.85	Water	0.35	0.24	ND	LLD	-
	13.3.85	Water	0.38	0.29	ND	LLD	-
	18.3.85	Water	0.42	0.19	ND	LLD	-
	25.3.85	Water	0.12	0.33	ND	LLD	-
	1.4.85	Water	0.22	0.21	ND	LLD	-
	9.4.85	Water	0.29	0.79	ND	LLD	-
	15.4.85	Water	0.28	0.25	ND	LLD	-
	22.4.85	Water	0.20	0.18	ND	LLD	-
	29.4.85	Water	0.14	0.23	ND	LLD	-
	6.5.85	Water	0.19	0.24	ND	LLD	-
	13.5.85	Water	0.23	0.16	ND	LLD	-
	21.5.85	Water	0.21	0.17	ND	LLD	-
	27.5.85	Water	0.28	0.20	ND	LLD	-
	3.6.85	Water	0.26	0.20	ND	LLD	-
	11.6.85	Water	0.18	1.28	ND	0.69	-
	18.6.85	Water	0.20	0.19	ND	LLD	-
	25.6.85	Water	0.29	0.30	ND	LLD	-
	2.7.85	Water	0.29	0.29	ND	LLD	-
	8.7.85	Water	1.09 (0.00130 ^{239}Pu)	0.42	0.50 MeV = 0.148, ^{137}Cs = 0.042, ^{60}Co = 0.038	LLD	-
	15.7.85	Water	0.50	0.32	ND	LLD	-
	22.7.85	Water	0.15	0.15	ND	LLD	-
	29.7.85	Water	0.14	0.20	ND	LLD	-
	5.8.85	Water	0.19	0.12	ND	LLD	-
	12.8.85	Water	0.15	0.13	ND	LLD	-
	20.8.85	Water	0.83	0.61	0.50 MeV = 0.034, ^{137}Cs = 0.041, ^{60}Co = 0.036	LLD	-
	26.8.85	Water	0.41	0.40	ND	LLD	-
	2.9.85	Water	0.22	0.20	ND	LLD	-
	9.9.85	Water	0.57	0.51	^{137}Cs = 0.037, Trace ^{232}Th & ^{238}U series	LLD	-
	16.9.85	Water	0.17	0.20	ND	LLD	-
	23.9.85	Water	0.29	0.19	ND	LLD	-
	1.10.85	Water	0.74	0.31	Trace ^{232}Th & ^{238}U series	LLD	-
	8.10.85	Water	0.27	0.15	ND	LLD	-
	14.10.85	Water	0.34	0.20	ND	LLD	-
	21.10.85	Water	0.19	0.17	ND	LLD	-
	28.10.85	Water	0.08	0.14	ND	LLD	-
	4.11.85	Water	0.20	0.20	ND	LLD	-
	11.11.85	Water	0.43	0.19	ND	LLD	-
	18.11.85	Water	0.14	0.17	ND	LLD	-
	26.11.85	Water	0.26	0.23	ND	LLD	-
	2.12.85	Water	0.11	0.14	ND	LLD	-
	9.12.85	Water	0.07	0.16	ND	LLD	-
	17.12.85	Water	0.11	0.20	ND	LLD	-
	23.12.85	Water	0.18	0.20	ND	LLD	-
	30.12.85	Water	0.26	0.19	ND	LLD	-

(Continued)

TABLE 5 (cont'd)

Sampling Location	Date	Sample Type	Radioactivity ($Bq\ g^{-1}$ dry weight) Gross α	Gross β (less ^{40}K)	γ-emitters	Tritium ($Bq\ mL^{-1}$)	Potassium ($\mu g\ g^{-1}$)
MDP Creek	29.4.85	Soil	0.48	0.15	Trace ^{232}Th & ^{238}U series	-	475
SPCC sampling Point	29.4.85	Water	-	-		LLD	-
Drain behind Bld.9	14.1.85	Soil	0.54	0.19	Trace ^{232}Th & ^{238}U series	-	3220
	24.4.85	Soil	0.47	0.25	Trace ^{232}Th & ^{238}U series	-	1094
	24.4.85	Water	-	-			LLD
Drain opposite sub-station	14.1.85	Soil	0.30	0.20	Trace ^{232}Th & ^{238}U series	-	2400
	24.4.85	Soil	0.45	0.24	Trace ^{232}Th & ^{238}U series	-	1056
	24.4.85	Water	-	-		LLD	-
Drain at boom gate	14.1.85	Soil	0.33	0.11	Trace ^{232}Th & ^{238}U series	-	431
	24.4.85	Soil	0.33	0.18	Trace ^{232}Th & ^{238}U series	-	495
	24.4.85	Water	-	-		LLD	-
Drain west of test compound	10.1.85	Soil	0.87	0.90	Trace ^{232}Th & ^{238}U series	-	621
	10.1.85	Veg.*	0.02	LLD	0.50 MeV = 0.003	-	4191
	24.4.85	Water	-	-		LLD	-
	6.5.85	Soil	0.90	0.83	Trace ^{232}Th & ^{238}U series	-	906
Drain near Yellowcake Store	10.1.85	Soil	0.52	0.40	Trace ^{232}Th & ^{238}U series	-	1767
	24.4.85	Water	-	-		LLD	-
	6.5.85	Soil	0.44	0.31	Trace ^{232}Th & ^{238}U series	-	1166
Drain near Crossroad	14.1.85	Soil	0.42	0.18	Trace ^{232}Th & ^{238}U series	-	398
	24.4.85	Soil	0.38	0.22	Trace ^{232}Th & ^{238}U series	-	563
	24.4.85	Water	-	-		LLD	-

* Units are $Bq\ g^{-1}$ fresh weight.

(1) Gross β measurements for water samples include ^{40}K.

The γ-ray peaks detected at approximately 0.5 MeV could be ^{7}Be (0.48MeV), ^{103}Ru (0.50 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. In column 6 $Bq\ g^{-1}$ or $Bq\ L^{-1}$ refers to the number of disintegrations per second per gram or litre at the energies indicated.

ND = not detected. - = not measured. LLD = less than the limit of detection. The limit of detection from tritium is 0.25 $Bq\ mL^{-1}$.

TABLE 6

RADIOACTIVITY AT SPCC SAMPLING POINTS, 1985
(Bq per litre)

Date	Strassman Creek		Barden Creek		MDP Creek	
	Gross α	Gross β*	Gross α	Gross β*	Gross α	Gross β*
16.1.85	LLD	LLD	LLD	LLD	LLD	LLD
6.2.85	LLD	LLD	LLD	LLD	LLD	LLD
6.3.85	LLD	LLD	LLD	LLD	LLD	LLD
29.4.85	LLD	LLD	LLD	LLD	LLD	LLD
28.5.85	LLD	LLD	LLD	LLD	LLD	LLD
27.6.85	LLD	LLD	LLD	0.12	LLD	LLD
19.7.85	LLD	LLD	LLD	LLD	LLD	LLD
16.8.85	LLD	LLD	LLD	LLD	LLD	LLD
13.9.85	LLD	LLD	LLD	LLD	LLD	LLD
28.10.85	LLD	LLD	LLD	LLD	LLD	0.29
8.11.85	LLD	LLD	LLD	LLD	LLD	0.11
21.12.85	LLD	0.14	LLD	LLD	-	-
30.12.85	-	-	-	-	LLD	LLD

* Includes ^{40}K contribution.

\- = not measured.

LLD = less than the limit of detection.

Limits of detection were 0.07 Bq L^{-1} for α and 0.10 Bq L^{-1} for β.

TABLE 6A

TRITIUM IN WATER AT SPCC SAMPLING POINT AT BARDEN CREEK WEIR, 1985

Date	Tritium (Bq mL^{-1})	Date 1985	Tritium (Bq mL^{-1})
2.1.85	LLD	2.7.85	LLD
8.1.85	LLD	8.7.85	LLD
15.1.85	LLD	12.7.85	LLD
21.1.85	LLD	15.7.85	LLD
30.1.85	LLD	22.7.85	LLD
4.2.85	LLD	29.7.85	LLD
13.2.85	LLD	5.8.85	LLD
18.2.85	0.27	12.8.85	1.45
25.2.85	LLD	20.8.85	1.04
4.3.85	LLD	26.8.85	0.85
13.3.85	LLD	2.9.85	0.96
18.3.85	LLD	9.9.85	0.97
25.3.85	LLD	16.9.85	0.68
1.4.85	LLD	23.9.85	0.69
9.4.85	0.43	1.10.85	0.57
15.4.85	0.45	8.10.85	0.81
22.4.85	0.33	14.10.85	LLD
29.4.85	LLD	21.10.85	0.29
6.5.85	LLD	28.10.85	LLD
13.5.85	LLD	4.11.85	0.26
21.5.85	LLD	11.11.85	LLD
27.5.85	LLD	18.11.85	0.28
3.6.85	LLD	26.11.85	LLD
11.6.85	LLD	2.12.85	0.28
18.6.85	LLD	9.12.85	LLD
25.6.85	LLD	16.12.85	LLD
		23.12.85	LLD
		30.12.85	0.30

Derived limiting concentration (DLC) [ICRP 1979].

DLC = 80 Bq mL^{-1} (if taken as drinking water).

LLD = Less than the limit of detection.

Limit of detection for tritium 0.25 Bq mL^{-1}.

TABLE 7

GAMMA SURVEY - EFFLUENT DISCHARGE PIPELINE, 1985

Survey of exposed portions of pipeline, between LHRL and the MWS&D'B sewer connection using an EBERLINE type PRM-7 field rate meter.

Date	Location	Dose Rate(1) (μSv h^{-1}) Ground	Pipeline
28.5.85	Joint No. 6(2)	0.07	0.12
	Joint No. 16	0.06	0.14
	Joint No. 20	0.06	0.54
	Scour valve No.4	0.03	0.51
	All other joints	< 0.06	< 0.13

(1) Dose rate corrected for background which had a range of 0.05 to 0.11 μSv h^{-1}.

(2) Soil sample collected (see **table 8**).

TABLE 8

RADIOACTIVITY IN SAMPLES TAKEN NEAR EFFLUENT DISCHARGE PIPELINE, 1985

Sampling Location	Date	Sample Type	Radioactivity ($Bq\ g^{-1}$ dry weight) Gross α	Gross β Less ^{40}K	γ-Emitters	Tritium ($Bq\ mL^{-1}$)	Potassium ($\mu g\ g^{-1}$)
Under joint No.6	28.5.85	Soil	0.44	1.83	^{137}Cs = 0.41 ^{60}Co = 0.65 Trace ^{238}U & ^{232}Th	-	510
Near scour Valve No.1	28.5.85	Soil	0.52	0.10	Trace ^{238}U + ^{232}Th	-	366
	28.5.85	Water	-	-	-	LLD	-
River at point where crossed by effluent discharge pipe	28.5.85	Soil	0.33	0.07	ND	-	470
	28.5.85	Water	-	-	-	LLD	-

ND = not detected. - = not measured. LLD = less than the limit of detection.

The limit of detection for tritium is 0.25 Bq mL^{-1}.

TABLE 9

RADIOACTIVITY IN FRESHWATER SECTION OF WORONORA RIVER, 1985

Sample Sitation Location	Date	Radioactivity		
		Sand	Water	
		^{90}Sr (Bq g^{-1})	^{90}Sr (Bq L^{-1})	Tritium (Bq mL^{-1})
60 m from LHRL storm-water outlet No. 1	16.1.85	LLD	0.014	-
	29.4.85	LLD	0.049	LLD
Woronora River at Heathcote Road (upstream of LHRL)	16.1.85	0.0007	0.017	LLD
	29.4.85	LLD	LLD	LLD
	31.10.85	LLD	0.012	LLD
	28.10.85	0.0007	0.060	
Woronora River at point of entry of drainage from LHRL(5)	16.1.85	0.0022	0.035	-
	31.7.85	0.0007	LLD	LLD
	28.10.85	LLD	LLD	LLD
Woronora River 80 m downstream of pipeline crossing	29.4.85	0.0010	LLD	LLD

LLD = less than the limit of detection. The limit of detection for ^{90}Sr in sand is 0.0007 Bq kg^{-1}; the limit of detection of ^{90}Sr in water is 0.0007 Bq L^{-1}; the limit of detection for tritium is 0.25 Bq mL^{-1}.

- = not determined.

The sample collected on 16 January 1985 was from the MDP creek at a point before it enters the Woronora River, while the samples collected in July and October were taken from the Woronora River at the mouth of MDP creek.

TABLE 10

RADIOACTIVITY IN SAMPLES OF SOIL FROM LITTLE FOREST BURIAL GROUND, 1985

Sampling Location	Sample Type	Date	Radioactivity (Bq g^{-1} dry weight)					Potassium ($\mu g\ g^{-1}$)
			Gross α	Gross β (less ^{40}K)	Gamma Emitters			
					0.5 MeV	^{60}Co	$^{238}U + ^{232}Th$	
Point No.1	Soil	3.1.85	0.59	0.60	ND	ND	Trace	4074
Point No.2	Soil	3.1.85	0.78	0.56	ND	ND	Trace	4012
Point No.3	Soil	3.1.85	0.64	0.57	ND	ND	Trace	3424
Point No.4	Soil	3.1.85	0.43	0.29	ND	ND	Trace	1106
Point No.5	Soil	3.1.85	0.43	0.29	ND	ND	Trace	2052
Point No.6	Soil	3.1.85	0.63	0.75	ND	ND	Trace	3316
Point No.1	Soil	26.6.85	0.43	0.42	ND	ND	Trace	3640
Point No.2	Soil	26.6.85	0.70	0.61	ND	ND	Trace	3698
Point No.3	Soil	26.6.85	0.62	0.60	ND	ND	Trace	3807
Point No.4	Soil	26.6.85	0.46	0.36	ND	ND	Trace	3135
Point No.5	Soil	26.6.85	0.44	0.33	ND	ND	Trace	3040
Point No.6	Soil	26.6.85	0.84	1.34	ND	0.07	Trace	5915

The γ-ray peaks detected at approximately 0.5MeV could be ^{7}Be (0.48 MeV), ^{103}Ru (0.50 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.

ND = not detected.

TABLE 11

RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM LITTLE FOREST BURIAL GROUND, 1985

Bore Hole No.	Date	Sediment ($Bq\ g^{-1}$) Gross α	Gross β (Incl. ^{40}K)	γ Activity	Tritium ($Bq\ mL^{-1}$)
BH 1	17.6.85	1.02	0.14	ND	LLD
BH 2	17.6.85	2.49	0.52	Trace ^{238}U + ^{232}Th series	LLD
BH 4	17.6.85	1.95	0.26	ND	LLD
BH 6	17.6.85	1.12	0.18	ND	LLD
BH 10	17.6.85	0.77	0.54	Trace ^{238}U + ^{232}Th series	2.36
OS 1	17.6.85	0.39	0.09	ND	LLD
OS 2	17.6.85	1.52	0.71	Trace ^{238}U + ^{232}Th series	4.60
OS 3	17.6.85	1.43	2.62	Trace ^{238}U + ^{232}Th series	11.11
BH A	17.6.85	1.01	0.29	ND	LLD
BH B	17.6.85	0.14	0.19	ND	LLD
BH C	17.6.85	0.05	0.18	ND	LLD
BH D	17.6.85	0.58	0.90	ND	LLD
BH E	17.6.85	0.23	0.25	ND	LLD
BH F	17.6.85	0.97	2.71	Trace ^{238}U + ^{232}Th series	1.38

ND = not detected. LLD = less than the limit of detection.

The limit of detection for tritium is 0.25 $Bq\ mL^{-1}$.

TABLE 12

RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST BURIAL GROUND, 1985

SAND

Sample Station Location	Date	Radioactivity (Bq g^{-1} dry weight)			Potassium ($\mu g\ g^{-1}$)	Uranium[(1)] ($\mu g\ g^{-1}$)
		Gross α	Gross β (less ^{40}K)	Gamma Emitters		
Barden Creek above junction with Mill Creek	23.12.85	0.42	0.05	Trace ^{238}U + ^{232}Th	446	0.35
Mill Creek above junction with Barden Creek	23.12.85	0.87	0.13	Trace ^{238}U + ^{232}Th	446	1.43

(1) uranium analysis by delayed neutron method.

WATER

Sample Station Location	Date	Radioactivity (Bq L^{-1})			Tritium (Bq mL^{-1})
		Gross α	Gross β (less ^{40}K)	Gamma Emitters	
Barden Creek above Junction with Mill Creek	23.12.85	0.18	0.12	ND	LLD
Mill Creek above junction with Barden Creek	23.12.85	0.13	0.08	ND	LLD

ND = not detected. LLD = less than the limit of detection.

The limit of detection for tritium is 0.25 Bq mL^{-1}.

TABLE 13

RESULTS OF AIR SAMPLING AT LITTLE FOREST BURIAL GROUND, 1985

Sampling Period	Air Volume Sampled (m^3)	(2) Be ($\mu g\ m^{-3}$)	(3) ^{239}Pu (Bq m^{-3})
24.01.85	306.67	LLD	LLD
21.02.85	60.17	LLD	LLD
22.03.85	40.44	LLD	LLD
24.04.85	31.47	LLD	LLD
30.05.85	8.73	LLD	LLD
27.06.85	18.25	LLD	LLD
25.07.85	28.61	LLD	LLD
27.08.85	31.35	LLD	LLD
30.09.85	43.42	LLD	LLD
24.10.85	77.07	LLD	LLD
21.11.85	110.36	LLD	LLD
Composite	599.25	-	1.5×10^{-6} (1)

(1) Composite sample of all air filters for 1985. Result determined by alpha spectrometry.

(2) TLV for Be = 2 $\mu g\ m^{-3}$. DWC for $^{239}Pu = 5 \times 10^{-4}$ Bq m^{-3}.

(3) LLD = less than the limit of detection. The limit of detection for Be is 10^{-3} $\mu g\ m^{-3}$ and for ^{239}Pu is 2×10^{-5} Bq m^{-3}.

TABLE 14

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS, 1985

Period & Bld. No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^{3}H (GBq)	^{41}Ar (TBq)	Fission Product Noble Gases (TBq)	Other Activity (MBq)
Quarter No.1 24.12.84 to 26.3.85							
Bld.2	1.90 $\times 10^{1}$	3.5 $\times 10^{4}$	< 1.0 $\times 10^{-1}$	-	-	6.40 $\times 10^{1}$	4.8 $\times 10^{5}$
3	1.1 $\times 10^{2}$	7.0 $\times 10^{-1}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
15	2.5 $\times 10^{0}$	3.0 $\times 10^{-1}$	6.0 $\times 10^{-1}$	8.2 $\times 10^{2}$	1.66 $\times 10^{1}$	-	2.1 $\times 10^{2}$
19	2.7 $\times 10^{1}$	4.5 $\times 10^{0}$	< 2.0 $\times 10^{-1}$	-	-	-	Nil
23A	1.66 $\times 10^{1}$	1.7 $\times 10^{3}$	< 6.0 $\times 10^{-1}$	-	-	-	6.68 $\times 10^{1}$
23B	1.4 $\times 10^{0}$	8.0 $\times 10^{-1}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
41	7.5 $\times 10^{0}$	1.7 $\times 10^{0}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
56	2.34 $\times 10^{1}$	< 2.0 $\times 10^{0}$	< 2.0 $\times 10^{-1}$	-	-	-	Nil
57	4.3 $\times 10^{0}$	4.0 $\times 10^{-1}$	< 1.0 $\times 10^{-1}$	2.83 $\times 10^{1}$	-	-	Nil
64	4.70 $\times 10^{1}$	4.0 $\times 10^{-1}$	-	-	-	-	Nil
Quarter No.2 26.3.85 to 25.6.85							
Bld.2	< 1.3 $\times 10^{1}$	3.0 $\times 10^{3}$	< 3.0 $\times 10^{3}$	-	-	3.42 $\times 10^{1}$	5.9 $\times 10^{3}$
3	8.86 $\times 10^{1}$	< 1.3 $\times 10^{0}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
15	< 4.8 $\times 10^{0}$	< 7.0 $\times 10^{-1}$	< 2.0 $\times 10^{-1}$	5.1 $\times 10^{3}$	5.8 $\times 10^{0}$	-	5.74 $\times 10^{1}$
19	< 2.1 $\times 10^{1}$	2.74 $\times 10^{1}$	< 2.0 $\times 10^{-1}$	-	-	-	3.1 $\times 10^{1}$
23A	< 1.6 $\times 10^{1}$	5.1 $\times 10^{2}$	< 2.0 $\times 10^{-1}$	-	-	-	1.25 $\times 10^{2}$
23B	< 1.1 $\times 10^{0}$	< 4.0 $\times 10^{-1}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
41	< 6.4 $\times 10^{0}$	< 2.2 $\times 10^{0}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
56	< 2.0 $\times 10^{1}$	< 2.4 $\times 10^{0}$	< 2.5 $\times 10^{-1}$	-	-	-	Nil
57	< 3.0 $\times 10^{0}$	< 5.0 $\times 10^{-1}$	< 1.0 $\times 10^{-1}$	1.85 $\times 10^{1}$	-	-	Nil
64	3.40 $\times 10^{1}$	< 3.0 $\times 10^{-1}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
Quarter No.3 25.6.85 to 24.9.85							
Bld.2	1.71 $\times 10^{1}$	4.26 $\times 10^{2}$	< 1.0 $\times 10^{-1}$	-	-	1.25 $\times 10^{1}$	6.3 $\times 10^{2}$
3	8.31 $\times 10^{1}$	< 1.6 $\times 10^{0}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
15	5.1 $\times 10^{0}$	< 1.0 $\times 10^{0}$	< 1.0 $\times 10^{-1}$	1.56 +4	3.7 $\times 10^{0}$	-	5.29 $\times 10^{2}$
19	3.40 $\times 10^{1}$	< 1.0 $\times 10^{0}$	< 2.0 $\times 10^{-1}$	-	-	-	Nil
23A	2.08 $\times 10^{1}$	5.84 $\times 10^{2}$	< 3.0 $\times 10^{-1}$	-	-	-	1.5 $\times 10^{2}$
23B	1.5 $\times 10^{0}$	< 1.0 $\times 10^{0}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
41	7.1 $\times 10^{0}$	< 1.4 $\times 10^{0}$	< 1.0 $\times 10^{-1}$	-	-	-	Nil
56	1.78 $\times 10^{1}$	< 5.0 $\times 10^{0}$	2.2 $\times 10^{-1}$	-	-	-	Nil
57	2.9 $\times 10^{0}$	< 4.0 $\times 10^{-1}$	3.0 $\times 10^{-2}$	2.37 $\times 10^{1}$	-	-	Nil
64A	4.39 $\times 10^{1}$	< 8.0 $\times 10^{-1}$	4.0 $\times 10^{-2}$	-	-	-	Nil
64B	2.66 $\times 10^{1}$	< 3.0 $\times 10^{-1}$	-	-	-	-	Nil

(Continued)

TABLE 14 (cont'd)

Period & Bld. No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^{3}H (GBq)	^{41}Ar (TBq)	Fission Product Noble Gases (TBq)	Other Activity (MBq)
Quarter No.4 24.9.85 to 31.12.85							
Bld.2	$< 2.3 \times 10^{1}$	4.67×10^{3}	$< 5.0 \times 10^{0}$	-	-	6.94×10^{1}	$1.57\ 10^{4}$
3	1.29×10^{2}	$< 2.0 \times 10^{0}$	$< 5.0 \times 10^{0}$	-	-	-	Nil
15	$< 4.0 \times 10^{0}$	$< 3.0 \times 10^{0}$	$< 1.0 \times 10^{0}$	1.40×10^{3}	1.67×10^{1}	-	1.37×10^{2}
19	$< 4.8 \times 10^{1}$	$< 4.0 \times 10^{0}$	$< 1.1 \times 10^{1}$	-	-	-	4.9×10^{1}
23A	$< 1.2 \times 10^{1}$	1.39×10^{3}	$< 1.0 \times 10^{0}$	-	-	-	8.4×10^{1}
23B	$< 2.0 \times 10^{0}$	$< 2.0 \times 10^{-1}$	$< 1.0 \times 10^{0}$	-	-	-	Nil
41	$< 7.0 \times 10^{0}$	$< 2.0 \times 10^{0}$	$< 3.0 \times 10^{0}$	-	-	-	Nil
56	$< 2.6 \times 10^{1}$	$< 4.0 \times 10^{0}$	$< 9.0 \times 10^{0}$	-	-	-	Nil
57	$< 4.0 \times 10^{1}$	$< 1.0 \times 10^{0}$	$< 2.0 \times 10^{0}$	2.15×10^{1}	-	-	Nil
64A	$< 4.6 \times 10^{1}$	$< 1.0 \times 10^{0}$	$< 2.0 \times 10^{0}$	-	-	-	Nil
64B	$< 3.7 \times 10^{1}$	$< 2.0 \times 10^{0}$	$< 5.0 \times 10^{0}$	-	-	-	Nil

\- = not measured.

TABLE 15

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS EXPRESSED AS FRACTION OF AUTHORISED QUARTERLY POINT DISCHARGE FOR 1985

Period & Bld. No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^{3}H (GBq)	^{41}Ar (TBq)	Fission Product Noble Gases (TBq)	Other Activity (MBq)
Quarter No.1 24.12.84 to 26.03.85							
Bld.2	2.9×10^{-5}	5.3×10^{-1}	$< 1.6 \times 10^{-7}$	-	-	3.8×10^{-1}	3.0×10^{-1}
3	6.9×10^{-2}	4.4×10^{-5}	$< 7.7 \times 10^{-5}$	-	-	-	Nil
15	7.6×10^{-5}	1.9×10^{-5}	2.3×10^{-5}	6.3×10^{-3}	6.2×10^{-1}	-	3.2×10^{-3}
19	8.2×10^{-5}	1.4×10^{-4}	$< 7.7 \times 10^{-7}$	-	-	-	Nil
23A	1.0×10^{-3}	0.11	$< 4.6 \times 10^{-8}$	-	-	-	2.0×10^{-3}
23B	2.1×10^{-4}	5.0×10^{-5}	$< 1.6 \times 10^{-5}$	-	-	-	Nil
41	2.3×10^{-5}	1.1×10^{-4}	$< 3.8 \times 10^{-7}$	-	-	-	Nil
56	3.0×10^{-2}	$< 4.4 \times 10^{-5}$	$< 1.8 \times 10^{-3}$	-	-	-	Nil
57	3.6×10^{-3}	5.9×10^{-5}	$< 6.0 \times 10^{-3}$	8.6×10^{-3}	-	-	Nil
64	3.1×10^{-2}	4.7×10^{-5}	-	-	-	-	Nil
Quarter No.2 26.03.85 to 25.06.85							
Bld.2	$< 2.0 \times 10^{-5}$	4.6×10^{-2}	$< 1.6 \times 10^{-7}$	-	-	0.20	3.7×10^{-3}
3	5.5×10^{-2}	$< 8.1 \times 10^{-5}$	$< 7.7 \times 10^{-5}$	-	-	-	Nil
15	$< 1.5 \times 10^{-4}$	$< 4.4 \times 10^{-5}$	$< 7.7 \times 10^{-6}$	3.9×10^{-2}	2.2×10^{-1}	-	8.7×10^{-4}
19	$< 6.4 \times 10^{-5}$	8.3×10^{-4}	$< 7.7 \times 10^{-7}$	-	-	-	4.7×10^{-5}
23A	$< 1.0 \times 10^{-3}$	3.2×10^{-2}	$< 1.5 \times 10^{-5}$	-	-	-	3.8×10^{-3}
23B	$< 1.7 \times 10^{-4}$	$< 2.5 \times 10^{-5}$	$< 1.6 \times 10^{-5}$	-	-	-	Nil
41	$< 1.9 \times 10^{-5}$	$< 1.4 \times 10^{-4}$	$< 3.8 \times 10^{-7}$	-	-	-	Nil
56	2.5×10^{-3}	$< 5.3 \times 10^{-5}$	$< 2.3 \times 10^{-3}$	-	-	-	Nil
57	$< 2.5 \times 10^{-3}$	$< 7.4 \times 10^{-5}$	$< 6.0 \times 10^{-3}$	5.6×10^{-3}	-	-	Nil
64	2.3×10^{-2}	$< 3.5 \times 10^{-5}$	$< 4.6 \times 10^{-3}$	-	-	-	Nil
Quarter No. 3 25.06.85 to 24.09.85							
Bld.2	2.6×10^{-5}	6.5×10^{-3}	$< 1.6 \times 10^{-7}$	-	-	7.4×10^{-2}	3.9×10^{-4}
3	5.2×10^{-3}	$< 1.0 \times 10^{-4}$	$< 7.7 \times 10^{-5}$	-	-	-	Nil
15	1.5×10^{-4}	$< 6.2 \times 10^{-5}$	$< 3.8 \times 10^{-6}$	1.2×10^{-1}	1.4×10^{-1}	-	8.0×10^{-3}
19	1.0×10^{-4}	$< 3.0 \times 10^{-5}$	$< 7.7 \times 10^{-7}$	-	-	-	Nil
23A	1.3×10^{-3}	3.6×10^{-2}	$< 2.3 \times 10^{-5}$	-	-	-	4.5×10^{-3}
23B	2.3×10^{-4}	$< 6.2 \times 10^{-5}$	$< 1.6 \times 10^{-5}$	-	-	-	Nil
41	2.2×10^{-5}	$< 8.8 \times 10^{-5}$	$< 3.8 \times 10^{-7}$	-	-	-	Nil
56	2.3×10^{-3}	$< 1.1 \times 10^{-4}$	2.0×10^{-4}	-	-	-	Nil
57	1.8×10^{-3}	$< 4.5 \times 10^{-5}$	1.4×10^{-4}	7.2×10^{-3}	-	-	Nil
64A	2.9×10^{-2}	$< 9.5 \times 10^{-5}$	1.9×10^{-4}	-	-	-	Nil
64B	8.9×10^{-3}	$< 1.9 \times 10^{-4}$	-	-	-	-	Nil

(Continued)

TABLE 15 (cont'd)

Period & Bld. No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^{3}H (GBq)	^{41}Ar (TBq)	Fission Product Noble Gases (TBq)	Other Activity (MBq)
Quarter No. 4 24.09.85 to 31.12.85							
Bld.2	$< 3.2 \times 10^{-5}$	6.6×10^{-2}	$< 7.2 \times 10^{-6}$	-	-	3.9×10^{-1}	9.2×10^{-3}
3	7.6×10^{-2}	$< 1.2 \times 10^{-4}$	$< 3.6 \times 10^{-3}$	-	-	-	Nil
15	$< 1.1 \times 10^{-4}$	$< 1.8 \times 10^{-4}$	$< 3.6 \times 10^{-5}$	1.0×10^{-2}	5.8×10^{-1}	-	1.9×10^{-3}
19	$< 1.3 \times 10^{-4}$	$< 1.1 \times 10^{-4}$	$< 3.9 \times 10^{-5}$	-	-	-	6.9×10^{-5}
23A	$< 7.1 \times 10^{-4}$	8.2×10^{-2}	$< 7.1 \times 10^{-5}$	-	-	-	2.3×10^{-3}
23B	$< 2.8 \times 10^{-4}$	$< 1.2 \times 10^{-5}$	$< 1.4 \times 10^{-4}$	-	-	-	Nil
41	$< 1.9 \times 10^{-5}$	$< 1.2 \times 10^{-4}$	$< 1.1 \times 10^{-5}$	-	-	-	Nil
56	$< 3.1 \times 10^{-3}$	$< 8.3 \times 10^{-5}$	$< 7.5 \times 10^{-2}$	-	-	-	Nil
57	$< 2.4 \times 10^{-3}$	$< 1.0 \times 10^{-4}$	$< 8.3 \times 10^{-3}$	6.0×10^{-3}	-	-	Nil
64A	$< 2.9 \times 10^{-2}$	$< 1.1 \times 10^{-4}$	$< 8.7 \times 10^{-3}$	-	-	-	Nil
64B	$< 1.2 \times 10^{-2}$	$< 1.1 \times 10^{-4}$	$< 1.1 \times 10^{-2}$	-	-	-	Nil

- = not measured.

TABLE 16

RADIOACTIVITY DISCHARGED TO THE MWS&DB SEWER DURING 1985

Quarter	Radioisotopes Measured (MBq)			Percentage of Authorised Limit**
	*au	^{3}H	^{+}Bu	
1	12.1	3.4×10^{5}	290.1	17.9
2	18.4	1.4×10^{5}	500.5	23.6
3	12.9	4.7×10^{5}	324.9	18.8
4	19.0	9.3×10^{5}	304.9	16.6

* au = a mixture of unidentified α-emitting nuclides taken as being all radium-226 (*i.e.* the worst possible case) when calculating percentage of authorised limit.

\+ Bu = a mixture of unidentified β-emitting nuclides taken as being all strontium-90 (*i.e.* the worst possible case) when calculating the percentage of authorised limit.

** 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.

TABLE 17

RADIOACTIVITY IN WORONORA OYSTERS, 1985

Station	Date	Radioactivity ($Bq\ g^{-1}$ fresh weight)			Potassium
		Gross α	Gross β (less ^{40}K)	^{65}Zn	($\mu g\ g^{-1}$)
E7.3	27.9.85	0.014	LLD	ND	2122

LLD = less than limit of detection.

TABLE 18

RADIOACTIVITY IN WORONORA FISH, 1985

Station & Variety	Date	Radioactivity (Bq g^{-1} fresh weight)			Potassium ($\mu g\ g^{-1}$)
		Gross α	Gross β (less ^{40}K)	Gamma Emitters	
E0.0 Blackfish	23.9.85	0.012	0.004	Trace $^{238}U + ^{232}Th$	3572

TABLE 19

RADIOACTIVITY IN WORONORA ZOSTERA SAMPLES, 1985

Station	Date	Radioactivity (Bq g^{-1} fresh weight)					Potassium ($\mu g\ g^{-1}$)
		Gross α	Gross β (less ^{40}K)	^{60}Co	Gamma Emitters $^{238}U + ^{232}Th$	0.50 MeV	
E1.3	23.9.85	0.060	0.032	0.008	Trace	0.006	4896
E1.6	23.9.85	0.045	0.029	0.001	ND	0.002	5170

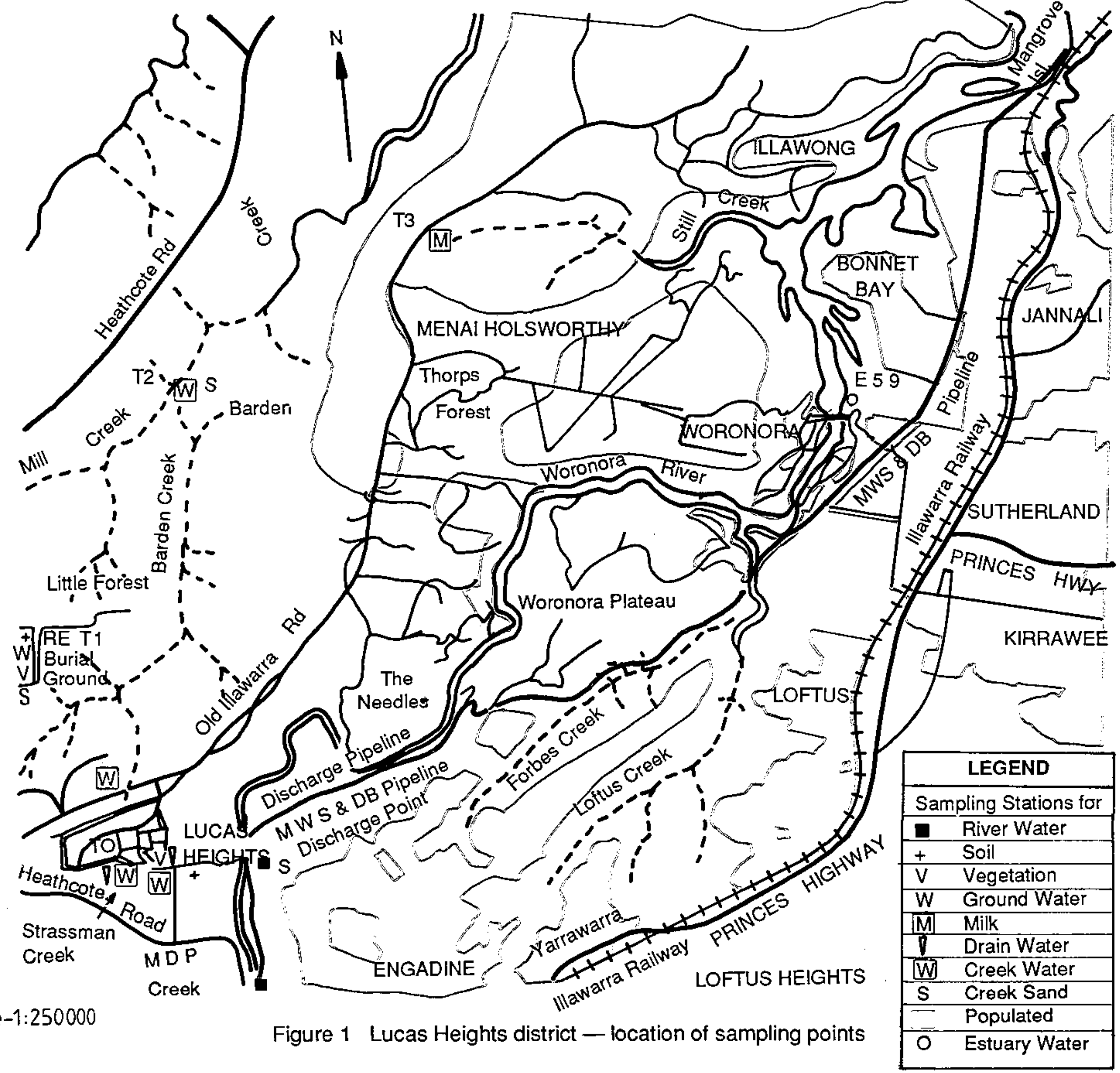
TABLE 20

RADIOACTIVITY IN WORONORA BEACH SAND, 1985

Station	Date	Radioactivity (Bq g^{-1} dry weight)			Potassium ($\mu g\ g^{-1}$)
		Gross α	Gross β (less ^{40}K)	Gamma Emitters	
E1.3	23.9.85	0.153	0.082	ND	288
DLC		111.0	92.5		
Average fraction of DLC		1.4×10^{-3}	8.9×10^{-4}		

ND = not detected except for ^{232}Th and ^{238}U series.

DLC = derived limiting concentration, from Fry [1966].



Scale-1:250000

Figure 1 Lucas Heights district — location of sampling points

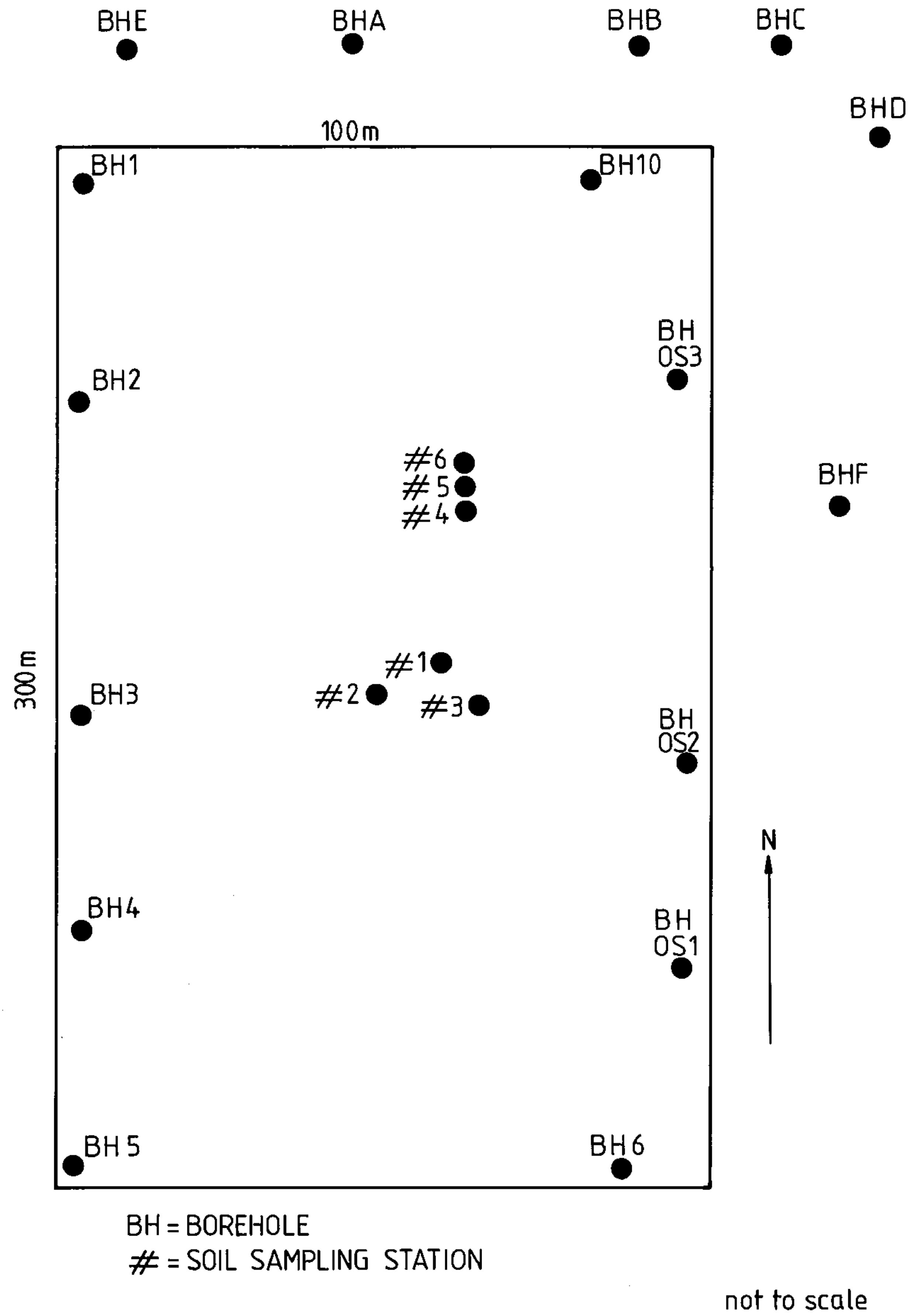


Figure 2 Little Forest Burial Ground — location of sampling stations

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 AAEC Research 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 Research Establishment, Lucas Heights. Results for 1973. AAEC/E335.

Davy,D.R., Dudaitis,A. [1976] - Environmental Survey at the 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 Research Establishment, Lucas Heights. Results for 1979. AAEC/E508.

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

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

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

Giles, M.S., Dudaitis, A. [1985] - Environmental Survey at the Research Establishment, Lucas Heights, 1983. AAEC/E622.

Giles, M.S., Dudaitis, A. [1986] - Environmental Survey at the Research Establishment, Lucas Heights, 1984. AAEC/E638.

APPENDIX B

NEW ANALYTICAL PROCEDURES

B1 Be AND ^{239}Pu IN AIR AT LITTLE FOREST BURIAL GROUND

B1.1 Be in Air at LFBG

From January 1985 (*i.e.* sample of February 21) the air at the Little Forest Burial Ground was sampled using Millipore (0.8 μm pore) aerosol monitors instead of Whatman No. 1 filter papers. The 0.8 μm pore filters are approved by the National Institute for Occupational Safety and Health (NIOSH) for monitoring airborne beryllium and compounds. [NIOSH 1977].

B1.2 ^{239}Pu in Air at LFBG

The initial ^{239}Pu in air was determined on a monthly basis and a series of duplicate samples was combined to provide a composite sample for the year which was analysed by alpha spectrometry [Puphal, 1982].

B2 STATE POLLUTION CONTROL COMMISSION (SPCC) SAMPLES

From October 1985 the gross alpha and gross beta activity was determined by using standard ^{241}Am and ^{137}Cs standard sources according to Method No. 703 of the American Public Health Association [APHA 1980].

B3 CREEKS DRAINING THE LITTLE FOREST BURIAL GROUND

The water from the creeks draining the Little Forest Burial Ground is prepared for the determination of gross alpha and gross beta activity by passing the water through a cation exchange resin. The method was modified in 1985 so that the IR-120 resin would be regenerated with acid before use [Vogel 1961].

APPENDIX C

LIST OF ISOTOPE SYMBOLS USED IN TABLES OF SURVEY RESULTS

SYMBOL	NAME
^{241}Am	americium-241
^{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
^{239}Pu	plutonium-239
^{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