ANSTO/E688

ansto

ANSTO/E688

ENVIRONMENTAL SURVEY AT LUCAS HEIGHTS RESEARCH LABORATORIES, 1987

by

M.S.GILES
I.J.FOY
E.L.HOFFMANN

REPORT E

December 1989
ISSN 1030-7745
ISBN 0 642 59900 9

AUSTRALIAN NUCLEAR SCIENCE
AND TECHNOLOGY ORGANISATION
LUCAS HEIGHTS RESEARCH LABORATORIES

ENVIRONMENTAL SURVEY AT LUCAS HEIGHTS RESEARCH LABORATORIES, 1987

BY

M.S. GILES
J.J. FOY
E.L. HOFFMANN

ABSTRACT

Results are presented of an environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1987. 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.

ISSN 1030-7745
ISBN 0 642 59900 9

The following descriptors have been assigned 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.

ANSTO; 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 (ANSTO) replaced the Australian Atomic Energy Commission (AAEC) 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

1 INTRODUCTION

Since 1959, surveys have been made by the Australian Atomic Energy Commission (and the newly formed Australian Nuclear Science and Technology Organisation (ANSTO)) 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 1987 are presented in **tables 2** to **15.** Authorised airborne releases are given in **tables 16** and **17.** Authorised liquid effluent discharges to the Metropolitan Water Sewerage and Drainage Board (MWS&DB) sewers are given in **table 18.**

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 Release

Measurable concentrations of iodine-131 were occasionally recorded in air samplers during the year. The highest reading was registered for the week ending 6 January 1987 and was 2.1×10^{-3} Bq m^{-3} (or 0.21 percent) 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 0.4 μSv y^{-1} or 4×10^{-4} of the limit.

The milk monitoring data for caesium-137 and iodine-131 are given in **table 3.** No iodine-131 was detected in milk during the year, and the levels of caesium-137 found were just above the minimum detectable level of 3×10^{-4} Bq g^{-1} (fresh weight).

Noble gas releases were always below the authorised limit during the year. See **tables 16** and **17.** 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. 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 1987.

5.3 Stormwater Outlets

Results for samples of soil and vegetation collected near stormwater outlets as a check on good housekeeping are shown in **table 5.** Results for water samples collected at the same site are given in **table 6.** The levels of ^{137}Cs found in the water samples were just above the limit of detection.

No tritium was detected in any of the stormwater samples.

If it is assumed that a person took all his or her drinking water supplies from the stormwater, the highest concentrations of ^{137}Cs measured represents 7×10^{-3} of the derived working limit (DWL). The ephemeral creek into which this stormwater flows is not used as a source of drinking water.

During 1987, 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 7.** 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.

Samples of water were collected from the SPCC sampling weir on Barden Creek at weekly intervals during 1987 to measure tritium and the results are shown in **table 8.** The highest concentration recorded represents 10^{-2} of the DWL which assumes that all drinking water is taken from that source. Average concentrations over the reported period represent 4×10^{-3} of the DWL.

5.4 Effluent Discharge Pipeline

Table 9 shows the dose rates at various points on the discharge pipeline during the 1987 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 near scour valve no. 1 on 25.5.87. This soil contained 0.023 Bq g^{-1} ^{137}Cs. 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. Results of soil analyses are given in **table 10.**

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 11.** All readings represent normal levels.

Samples taken in this area over the past 8 years have revealed levels of ^{90}Sr which are equivalent to background readings. Because the SPCC sampling points have been established since 1984 and serve as a check on freshwater inputs, it is proposed to discontinue sampling at the above two stations.

5.6 Little Forest Burial Ground

Results of measurements at the Little Forest Burial Ground (LFBG) are given in **tables 12, 13, 14** and **15.** The positions of sampling points are shown on **figure 2.** Tritium was found in BH10, OS2, OS3 and BHF. Of these, BHF is the only one which lies outside the fenced area. The concentration of tritium in all boreholes was similar to that found previously. 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. The minimum detectable level for Be is 0.2 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 Research Laboratories contained radioactivity which could be attributed to the operation of the site.

Discharges of airborne radioactive gases were always within authorised limits (**tables 16** and **17**). The dose to the most sensitive members of the public from ^{131}I releases, calculated from results in **table 2,** was 0.4 μSv 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

The authors would like to thank Mr J.A. Fogden for his assistance in field and laboratory work. Potassium levels were determined by the CSIRO's Division of Energy Chemistry (now the Division of Fuel Technology). The strontium-90 levels were determined by the Environmental Chemistry Section. Beryllium levels and initial estimates of plutonium-239 on the Little Forest Burial Ground air filters were determined by the AAEC's Health and Safety Division.

8 REFERENCES

AIRAC [1975] - Fallout over Australia from Nuclear Tests - Australian Radiation Laboratory and Bureau of Meteorology. Australian Ionising Radiation Advisory Council, Report No. 2. Australian Government Publishing Service, Canberra.

Fry R.M. [1966] - A reformulation of the Lucas Heights liquid effluent discharge authorisation AAEC/E156.

Giles, M.S., Stockdale, J.A. [1966] - The Lucas Heights environmental sampling program. AAEC/TM336.

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

ICRP [1977] - Recommendation of the International Commission on Radiological Protection. ICRP Publication No. 26. Pergamon Press, Oxford.

ICRP [1979] - Limits for Intakes of Radionuclides by Workers. ICRP Publication No. 30. Pergamon Press, Oxford.

NH&MRC [1981] - Recommended Radiation Protection Standards for Individuals Exposed to Ionising Radiation. National Health and Medical Research Council. Australian Government Publishing Service, Canberra.

Petersen, M.C.E. [1982] - Finite cloud dosimetry. *Proceedings of the 7th Annual Conference of the Australian Radiation Protection Society,* Canberra.

UNSCEAR [1977] - Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation. United Nations, New York.

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 with polyethylene bottle at outlet of the drain	3 L weekly samples evaporated to dryness and the residue combined to form a monthly composite sample for α,β,γ counting and 50 mL collected and distilled for tritium.
	Barden Creek	Weekly	Sampled at the weir	50 mL distilled for tritium
	Others	Quarterly	Sampled by bottle at the outlet of the drain	Distilled for tritium
Estuary water (Woronora River)	E5.9	Weekly	From surface by bottle	Distilled for tritium
Radioactive iodine in air	Along eastern boundary of the site (TO)	Weekly	Collected on Maypacks (charcoal filters)	Gamma spectrometry of Maypacks
Milk	T_3	Monthly	Sampled from milk produced by locally grazed cow	Gamma spectrometry of whole milk
Vegetation	LHRL stormwater outlets	Six monthly where available	Cut by hand clippers	Gamma spectrometry of whole unwashed vegetation (ashed)
Groundwater	Little Forest Burial Ground (LFBG)	Six monthly	MB series bore holes pumped dry, allowed to refill and sampled from the bottom	10 L sample evaporated to dryness and the residue counted. 50 mL collected and distilled for tritium
Sand/soil	LFBG; LHRL stormwater outlets	Six monthly; quarterly	Scooped from surface	Sample ashed and sieved
Be, ^{239}Pu on air filters	Little Forest Burial Ground	Quarterly	Collected on 0.8 µm aerosol filter	Disc, 1 cm diameter cut out for Be analysis. Composite made of the quarterly samples for ^{239}Pu analysis by α spectrometry
Creekwater	T2	Yearly	Sampled by bottle	5 L collected and passed through cation-exchange resin then ashed and counted. 50 mL collected and distilled for tritium.

Table 1 contd.

Sample	Station	Frequency	Collection Details	Special Preparations
	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, 1987

Week ending	^{131}I (Bq m^{-3})	Week ending	^{131}I (Bq m^{-3})
6.1.87	$2.1x10^{-2}$	11.8.87	LLD
13.1.87	$8.0x10^{-3}$	18.8.87	LLD
20.1.87	$3.4x10^{-3}$	25.8.87	LLD
28.1.87	$3.6x10^{-3}$	1.9.87	LLD
3.2.87	$1.3x10^{-2}$	8.9.87	LLD
10.2.87	$1.4x10^{-2}$	15.9.87	LLD
18.2.87	$6.8x10^{-3}$	22.9.87	LLD
26.2.87	$2.9x10^{-3}$	29.9.87	LLD
3.3.87	LLD	6.10.87	LLD
10.3.87	LLD	13.10.87	$2.6x10^{-3}$
17.3.87	LLD	20.10.87	LLD
19.3.87	LLD	27.10.87	LLD
24.3.87	LLD	3.11.87	LLD
31.3.87	LLD	10.11.87	LLD
7.4.87	LLD	17.11.87	LLD
14.4.87	$6.1x10^{-3}$	24.11.87	LLD
21.4.87	$3.2x10^{-3}$	1.12.87	LLD
28.4.87	$3.4x10^{-3}$	9.12.87	LLD
5.5.87	LLD	15.12.87	LLD
12.5.87	$3.3x10^{-3}$	22.12.87	$3.6x10^{-3}$
19.5.87	LLD	29.12.87	LLD
26.5.87	LLD		
2.6.87	$2.6x10^{-3}$		
9.6.87	LLD		
16.6.87	LLD		
23.6.87	$2.6x10^{-3}$		
30.6.87	LLD		
7.7.87	LLD		
14.7.87	LLD		
21.7.87	LLD		
28.7.87	LLD		
5.8.87	LLD		

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 (1) all activity was released during the first day of sampling period; and (2) all the activity was concentrated at one sampling point.

LLD = Less than the limit of detection. The limit of detection for iodine-131 in air is $2.5x10^{-3}$ Bq m^{-3}.

TABLE 3

RADIOACTIVITY IN MILK SAMPLES, 1987

Station	Date	Radioactivity (Bq g^{-1} fresh volume)	
		^{137}Cs	^{131}I
T3	23.1.87	$6x10^{-4}$	LLD
T3	27.2.87	LLD	LLD
T3	19.3.87	LLD	LLD
T3	14.4.87	$5x10^{-4}$	LLD
T3	29.5.87	LLD	LLD
T3	24.6.87	LLD	LLD
T3	30.7.87	LLD	LLD
T3	27.8.87	LLD	LLD
T3	30.9.87	LLD	LLD
T3	28.10.87	$5x10^{-4}$	LLD
T3	26.11.87	LLD	LLD
T3	17.12.87	LLD	LLD

The analytical method used for ^{131}I in milk has a minimum detectable level of $1x10^{-3}$ Bq g^{-1} fresh volume. For ^{137}Cs the minimum detectable level was $3x10^{-4}$ Bq g^{-1} fresh volume.

LLD = Less than the limit of detection.

TABLE 4

TRITIUM IN WORONORA RIVER WATER SAMPLES
AT STATION E5.9, 1987

Date	Tritium ($Bq\ mL^{-1}$)	Date	Tritium ($Bq\ mL^{-1}$)	Date	Tritium ($Bq\ mL^{-1}$)
5.1.87	LLD	4.5.87	LLD	31.8.87	LLD
12.1.87	LLD	11.5.87	LLD	7.9.87	LLD
19.1.87	LLD	18.5.87	LLD	14.9.87	LLD
27.1.87	LLD	26.5.87	LLD	21.9.87	LLD
2.2.87	LLD	1.6.87	LLD	27.9.87	LLD
9.2.87	LLD	9.6.87	LLD	6.10.87	LLD
16.2.87	LLD	15.6.87	LLD	12.10.87	LLD
27.2.87	LLD	22.6.87	LLD	19.10.87	LLD
2.3.87	LLD	29.6.87	LLD	26.10.87	LLD
9.3.87	LLD	6.7.87	LLD	2.11.87	LLD
16.3.87	LLD	13.7.87	LLD	9.11.87	LLD
23.3.87	LLD	20.7.87	LLD	16.11.87	LLD
30.3.87	LLD	27.7.87	LLD	23.11.87	LLD
6.4.87	LLD	3.8.87	LLD	30.11.87	LLD
14.4.87	LLD	11.8.87	LLD	7.12.87	LLD
21.4.87	LLD	17.8.87	LLD	14.12.87	LLD
28.4.87	LLD	24.8.87	LLD	21.12.87	LLD
				29.12.87	LLD

Derived limiting concentration (DLC) [ICRP 1979].

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

LLD = Less than the limit of detection for tritium, which is 0.25 $Bq\ mL^{-1}$.

TABLE 5

RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION FROM STORMWATER OUTLETS, 1987

Station	Date	Sample type	Radioactivity (Bq g^{-1} FW or DW*)			K ($\mu g\ g^{-1}$ DW)
			Gross α	Gross ß (less ^{40}K)	γ-emitters	
Drain on road at West Fence	22.1.87	Soil	0.42	0.13	Trace $^{238}U+^{232}Th$ series	549
	30.4.87	Soil	0.47	0.16	Trace $^{238}U+^{232}Th$ series	747
	10.7.87	Soil	0.39	0.21	Trace $^{238}U+^{232}Th$ series	376
	29.10.87	Soil	0.26	0.16	Trace $^{238}U+^{232}Th$ series	705
Drain at Fermi St.	22.1.87	Soil	0.37	0.27	Trace $^{238}U+^{232}Th$ series	1504
	30.4.87	Soil	0.37	0.31	Trace $^{238}U+^{232}Th$ series ^{137}Cs=0.017	1924
	10.7.87	Soil	0.45	0.54	Trace $^{238}U+^{232}Th$ series	1906
	29.10.87	Soil	0.44	0.33	Trace $^{238}U+^{232}Th$ series	1668
Drain opposite Bld.23	22.1.87	Soil	0.40	0.24	Trace $^{238}U+^{232}Th$ series ^{60}Co=0.024	470
	30.4.87	Soil	0.26	0.24	Trace $^{238}U+^{232}Th$ series ^{137}Cs=0.010 ^{60}Co=0.030	752
	10.7.87	Soil	0.32	0.24	Trace $^{238}U+^{232}Th$ series ^{137}Cs=0.011 ^{60}Co=0.029	460
	29.10.87	Soil	0.23	0.20	Trace $^{238}U+^{232}Th$ series ^{60}Co=0.043	634
Drain No.1 opposite Strassman Cres.	22.1.87	Vegetation	0.01	0.02	N.D.	3616
	22.1.87	Soil	0.37	0.24	Trace $^{238}U+^{232}Th$ series	608
	30.4.87	Soil	0.25	0.25	Trace $^{238}U+^{232}Th$ series	499
	30.4.87	Vegetation	0.01	0.02	N.D.	2988
	10.7.87	Soil	0.23	0.19	Trace $^{238}U+^{232}Th$ series	354
	10.7.87	Vegetation	0.01	0.01	N.D.	3880
	29.10.87	Soil	0.17	0.17	Trace $^{238}U+^{232}Th$ series	806
	29.10.87	Vegetation	0.01	0.01	N.D.	3456

Table 5 contd.

Station	Date	Sample type	Radioactivity (Bq g^{-1} FW or DW[1])			K ($\mu g\ g^{-1}$ DW)
			Gross α	Gross ß (less ^{40}K)	γ-emitters	
Drain No.2. opposite Strassman Cres.	22.1.87	Soil	0.34	0.12	Trace $^{238}U+^{232}Th$ series	337
	30.4.87	Soil	0.29	0.23	Trace $^{238}U+^{232}Th$ series	482
	10.7.87	Soil	0.25	0.24	Trace $^{238}U+^{232}Th$ series	329
	29.10.87	Soil	0.20	0.13	Trace $^{238}U+^{232}Th$ series	1053
Drain opposite meteorological tower	22.1.87	Soil	0.46	0.18	Trace $^{238}U+^{232}Th$ series	1271
	30.4.87	Soil	0.75	0.32	Trace $^{238}U+^{232}Th$ series	680
	10.7.87	Soil	0.45	0.24	Trace $^{238}U+^{232}Th$ series	451
	29.10.87	Soil	0.29	0.18	Trace $^{238}U+^{232}Th$ series	1098
20 m from LHRL stormwater outlet No.1	22.1.87	Soil	0.78	0.78	Trace $^{238}U+^{232}Th$ series ^{60}Co=0.023 ^{137}Cs=0.224	1550
	22.1.87	Vegetation	0.01	0.12	^{137}Cs=0.006	4066
	30.4.87	Soil	0.66	0.54	Trace $^{238}U+^{232}Th$ series ^{137}Cs=0.114 ^{60}Co=0.024	1378
	30.4.87	Vegetation	0.01	0.14	^{137}Cs=0.005	3402
	10.7.87	Soil	1.01	0.59	Trace $^{238}U+^{232}Th$ series ^{137}Cs=0.148 ^{60}Co=0.039 ^{54}Mn=0.015	546
	10.7.87	Vegetation	0.01	0.12	Trace $^{238}U+^{232}Th$ series ^{137}Cs=0.005	3280
	29.10.87	Soil	0.33	0.16	Trace $^{238}U+^{232}Th$ series	765

N.D. = not detected

1 Radioactivity in Bq g^{-1} fresh weight (FW) for vegetation samples and Bq g^{-1} dry weight (DW) for soil samples.

TABLE 6

RADIOACTIVITY IN WATER SAMPLES FROM STORMWATER OUTLETS, 1987

Station	Date	Radioactivity (Bq L^{-1})			Tritium (Bq mL^{-1})
		Gross α	Gross ß (incl. ^{40}K)	γ-emitters	
Drain behind Bld. 1	22.1.87	-	-	-	LLD
	30.4.87	-	-	-	LLD
	10.7.87	-	-	-	LLD
	29.10.87	-	-	-	LLD
Drain on West Fence Rd	10.7.87	-	-	-	LLD
	29.10.87	-	-	-	LLD
Drain opposite Fermi St	22.1.87	-	-	-	LLD
	30.4.87	-	-	-	LLD
	10.7.87	-	-	-	LLD
	29.10.87	-	-	-	LLD
Drain opposite Bld.23	29.10.87	-	-	-	LLD
Drain opposite Meteorological Station	10.7.87	-	-	-	LLD
	29.10.897	-	-	-	LLD
Drain No.1 opposite Strassman Cres.	22.1.87	-	-	-	LLD
	10.7.87	-	-	-	LLD
	29.10.87	-	-	-	LLD
LHRL Stormwater Outlet No.1 near South Gate	22.1.87	-	-	-	LLD
	30.4.87	-	-	-	LLD
	10.7.87	-	-	-	LLD
20 m from LHRL Stormwater outlet No.1.	22.1.87	-	-	-	LLD
	30.4.87	-	-	-	LLD
	10.7.87	-	-	-	LLD
	29.10.87	-	-	-	LLD
60 m from LHRL Stormwater outlet No.1.	5.1.87	0.29	0.61	N.D.	LLD
	12.1.87	0.21	0.28	N.D.	LLD
	19.1.87	0.27	0.29	N.D.	LLD
	27.1.87	0.24	0.27	N.D.	LLD
	2.2.87	0.28	0.22	N.D.	LLD
	9.2.87	0.28	0.23	N.D.	LLD
	16.2.87	0.13	0.26	N.D.	LLD
	27.2.87	0.08	0.20	N.D.	LLD
	2.3.87	0.18	0.17	N.D.	LLD
	9.3.87	0.11	0.44	N.D.	LLD
	16.3.87	0.14	0.36	N.D.	LLD
	23.3.87	0.34	0.39	Trace $^{238}U+^{232}Th$ series	LLD

Table 6 contd.

Station	Date	Radioactivity (Bq L^{-1})			Tritium (Bq mL^{-1})
		Gross α	Gross ß (incl. ^{40}K)	γ-emitters	
60 m from LHRL Stormwater outlet No.1.	30.3.87	0.13	0.28	N.D.	LLD
	6.4.87	0.29	0.27	N.D.	LLD
	14.4.87	0.29	0.27	N.D.	LLD
	21.4.87	0.51	0.34	^{137}Cs=0.071	LLD
	28.4.87	0.42	0.36	N.D.	LLD
	4.5.87	0.22	0.29	N.D.	LLD
	11.5.87	0.29	0.67	N.D.	LLD
	18.5.87	0.22	0.28	N.D.	LLD
	26.5.87	0.36	0.30	N.D.	LLD
	1.6.87	0.24	0.22	N.D.	LLD
	9.6.87	0.28	0.37	N.D.	LLD
	15.6.87	0.32	0.27	N.D.	LLD
	22.6.87	0.18	0.38	N.D.	LLD
	29.6.87	0.12	0.19	N.D.	LLD
	6.7.87	0.20	0.26	N.D.	LLD
	13.7.87	0.26	0.28	N.D.	LLD
	20.7.87	0.23	0.16	N.D.	LLD
	27.7.87	0.19	0.40	N.D.	LLD
	3.8.87	0.17	0.20	N.D.	LLD
	12.8.87	0.16	0.32	N.D.	LLD
	17.8.87	0.23	0.39	N.D.	LLD
	24.8.87	0.07	0.29	N.D.	LLD
	14.9.87	0.11	0.22	N.D.	LLD
	21.9.87	0.13	0.21	N.D.	LLD
	28.9.87	0.08	0.19	N.D.	LLD
	6.10.87	0.19	0.22	N.D.	LLD
	12.10.87	0.06	0.08	N.D.	LLD
	19.10.87	0.08	0.11	N.D.	LLD
	26.10.87	0.13	0.22	N.D.	LLD
	2.11.87	0.14	0.20	N.D.	LLD
	9.11.87	0.13	0.24	N.D.	LLD
	16.11.87	0.11	0.20	N.D.	LLD
	23.11.87	0.07	0.24	N.D.	LLD
	30.11.87	0.05	0.19	N.D.	LLD
	7.12.87	0.20	0.09	N.D.	LLD
	14.12.87	0.34	0.10	N.D.	LLD
	21.12.87	0.30	0.10	N.D.	LLD
	30.12.87	0.20	0.11	N.D.	LLD

n.d. = not detected
- = not measured
Radioactivity (Bq L^{-1}) refers to the radioactivity present per litre of water sample (suspended and dissolved).
LLD = Less than the limit of detection.
The limit of detection for tritium in water is 0.25 Bq mL^{-1}.

TABLE 7

RADIOACTIVITY AT SPCC SAMPLING POINTS, 1987
($Bq\ L^{-1}$)[a]

Date 1987	Strassman Creek		Barden Creek		MDP Creek	
	Gross α	Gross ß*	Gross α	Gross ß*	Gross α	Gross ß*
13.1.87	LLD	LLD	LLD	LLD	LLD	0.24
11.2.87	0.05	0.17	0.03	0.18	LLD	0.27
3.3.87	0.03	0.14	LLD	LLD	LLD	0.30
10.4.87	0.01	LLD	0.01	LLD	LLD	0.22
28.5.87	LLD	LLD	LLD	LLD	LLD	LLD
16.6.87	LLD	0.11	LLD	LLD	LLD	0.11
3.7.87	LLD	LLD	LLD	LLD	LLD	0.42
12.8.87	LLD	0.11	LLD	0.11	0.03	0.21
30.9.87	LLD	0.12	LLD	0.10	LLD	0.11
14.10.87	LLD	LLD	LLD	LLD	LLD	0.12
17.11.87	LLD	LLD	LLD	LLD	LLD	0.17
11.12.87	LLD	LLD	LLD	LLD	LLD	0.18

LLD = Less than the minimum detection limit.

(a) Minimum detection limit α = 0.03 $Bq\ L^{-1}$,
Minimum detection limit ß = 0.10 $Bq\ L^{-1}$,
* includes ^{40}K contribution,
- = not measured.

TABLE 8

TRITIUM IN WATER FROM SPCC SAMPLING POINT AT BARDEN CREEK WEIR, 1987

Date	Tritium (Bq mL^{-1})	Date	Tritium (Bq mL^{-1})
5.1.87	0.35	6.7.87	LLD
12.1.87	0.52	13.7.87	LLD
19.1.87	0.60	20.7.87	LLD
27.1.87	0.63	27.7.87	LLD
2.2.87	0.68	3.8.87	LLD
9.2.87	0.78	10.8.87	LLD
16.2.87	0.67	17.8.87	LLD
27.2.87	0.53	24.8.87	LLD
2.3.87	0.57	31.8.87	LLD
4.3.87	0.26	7.9.87	LLD
9.3.87	0.32	14.9.87	LLD
16.3.87	0.41	21.9.87	LLD
23.3.87	0.33	28.9.87	LLD
30.3.87	0.33	6.10.87	LLD
6.4.87	0.36	12.10.87	0.31
14.4.87	0.39	19.10.87	LLD
21.4.87	0.28	26.10.87	LLD
28.4.87	0.31	2.11.87	LLD
4.5.87	LLD	9.11.87	LLD
11.5.87	LLD	11.11.87	LLD
18.5.87	LLD	16.11.87	LLD
26.5.87	LLD	23.11.87	LLD
1.6.87	LLD	30.11.87	LLD
9.6.87	LLD	7.12.87	LLD
15.6.87	LLD	14.12.87	LLD
22.6.87	LLD	21.12.87	LLD
29.6.87	LLD	30.12.87	LLD

Derived limiting concentration (DLC) [ICRP 1979]

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

LLD = Less than the limit of detection for tritium, which is 0.25 Bq mL^{-1}.

TABLE 9

GAMMA SURVEY - EFFLUENT DISCHARGE PIPELINE, 1987

Survey of exposed portions of pipeline between LHRL and the MWS&DB sewer connection using an EBERLINE type PRM-7 field rate meter

Date	Location	Dose rate ($\mu Sv\ h^{-1}$)		Background range ($\mu Sv\ h^{-1}$)
		Ground	Pipeline	
28.5.87	All joints*	<0.13	<0.16	0.06 to 0.14
27.11.87	Joint #17	0.07	0.09	0.06
	Joint #16†	0.12	0.80	0.07
1.12.87	Joints 1 to 15	<0.16	<0.22	0.06 to 0.14

* Except joints No.18-22 which were inaccessible due to track being washed out.

† A soil sample was collected (see Table 10) in which normal levels of α, β and γ activity were detected.

Note: there are twenty-two numbered joints in the effluent discharge pipeline.

TABLE 10
RADIOACTIVITY IN SAMPLES TAKEN NEAR EFFLUENT DISCHARGE PIPELINE, 1987

Station	Date	Sample Type	Radioactivity (Bq g^{-1} DW)			^{3}H (Bq mL^{-1})	K (µg g^{-1})
			Gross α	Gross β (Less ^{40}K)	γ-Emitters		
Near Scour valve No.1	28.5.87	Soil	0.65	0.23	^{137}Cs = 0.023 Trace ^{232}Th and ^{238}U series	-	579
	28.5.87	Water	-	-	-	LLD	-
	27.11.87	Soil	0.27	0.18	Trace ^{232}Th and ^{238}U series	-	498
	27.11.87	Water	-	-	-	LLD	-
River at point where crossed by effluent discharge pipe	28.5.87	Soil	0.22	0.06	Trace ^{232}Th and ^{238}U series	-	429
	28.5.87	Water	-	-	-	LLD	-
	27.11.87	Soil	0.24	0.07	Trace ^{232}Th and ^{238}U series	-	349
	27.11.87	Water	-	-	-	LLD	-
Under joint No.16	27.11.87	Soil	0.22	0.16	Trace ^{232}Th and ^{238}U series	-	829

DW = dry weight

- = not measured

LLD = Less than the limit of detection

The limit of detection for ^{3}H (tritium) is 0.25 Bq mL^{-1}

TABLE 11

RADIOACTIVITY IN FRESHWATER SECTION OF WORONORA RIVER, 1987

Station	Date	Radioactivity	
		Sand	Water
		^{90}Sr (Bq Kg^{-1} DW)	^{90}Sr (Bq L^{-1})
Woronora River at Heathcote Rd	30.1.87	0.10	LLD
crossing (ie upstream of LHRL)	29.4.87	2.10	0.0054
	3.7.87	0.30	0.0126
	29.10.87	0.15	0.0038
Woronora River at the point of	30.1.87	0.20	LLD
Lucas Heights stormwater	29.4.87	6.00	0.0021
drainage	3.7.87	0.70	0.0090
	29.10.87	0.20	0.0127

DW = Dry Weight

\- = not measured

Limit of detection : for ^{90}Sr in water is 0.0007 $Bq.L^{-1}$

: for ^{90}Sr in sand is 0.0007 Bq. $Kg^{-1}DW$

: for ^{3}H in water is 0.25 Bq mL^{-1}

LLD = Less than the limit of detection.

TABLE 12

RADIOACTIVITY IN SAMPLES OF SOIL
FROM LITTLE FOREST BURIAL GROUND, 1987

Sampling Location	Date	Radioactivity (Bq g^{-1} Dry Weight)			Potassium ($\mu g\ g^{-1}$)
		Gross α	Gross ß (Less ^{40}K)	γ-Emitters	
Point #1	5.6.87	0.76	0.74	Traces of $^{238}U+^{232}Th$ series	3160
Point #5	5.6.87	0.53	0.62	Traces of $^{238}U+^{232}Th$ series	1813
Point #6	5.6.87	0.71	2.16	Traces of $^{238}U+^{232}Th$ series ^{60}Co=0.130	5294
Point #1	15.12.87	0.82	0.69	Traces of $^{238}U+^{232}Th$ series	3409
Point #5	15.12.87	0.52	0.60	Traces of $^{238}U+^{232}Th$ series	1285
Point #6	15.12.87	1.01	3.13	Traces of $^{238}U+^{232}Th$ series ^{60}Co=0.242	1968

TABLE 13

RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM LITTLE FOREST BURIAL GROUND, 1987

Bore Hole No.	Date	Sediment (Bq g^{-1})			^{3}H (Bq mL^{-1})
		Gross α	Gross β (Incl. ^{40}K)	γ-Emitters	
BH4	5.6.87	3.94	0.90	Trace $^{238}U+^{232}Th$ series	LLD
BH10	5.6.87	0.33	0.43	N.D.	3.86
OS3	5.6.87	1.05	2.25	Trace $^{238}U+^{232}Th$ series	18.7
BHA	5.6.87	0.21	0.25	N.D.	LLD
BHB	5.6.87	0.20	0.13	Trace $^{238}U+^{232}Th$ series	LLD
BHC	5.6.87	0.12	0.15	N.D.	LLD
BHD	5.6.87	0.06	0.20	N.D.	LLD
BHE	5.6.87	0.16	0.19	N.D.	LLD
BHF	5.6.87	0.66	1.01	Trace $^{238}U+^{232}Th$ series	1.06
BH4	15.12.87	3.32	0.76	Trace $^{238}U+^{232}Th$ series	LLD
BH6	15.12.87	1.14	0.25	Trace $^{238}U+^{232}Th$ series	LLD
BH10	15.12.87	0.36	0.41	Trace $^{238}U+^{232}Th$ series	3.86
OS1	15.12.87	1.33	0.54	Trace $^{238}U+^{232}Th$ series	LLD
OS2	15.12.87	1.28	0.94	Trace $^{238}U+^{232}Th$ series	3.70
OS3	15.12.87	1.48	2.25	Trace $^{238}U+^{232}Th$ series	15.35
BHA	15.12.87	0.51	0.38	N.D.	LLD
BHB	15.12.87	0.25	0.13	N.D.	LLD
BHC	15.12.87	0.15	0.17	N.D.	LLD
BHD	15.12.87	0.95	0.52	Trace $^{238}U+^{232}Th$ series	LLD
BHE	15.12.87	0.19	0.21	N.D.	LLD
BHF	15.12.87	1.54	2.72	Trace $^{238}U+^{232}Th$ series	1.32

LLD = Less than the limit of detection - LLD for ^{3}H is 0.25 Bq mL^{-1}
N.D. = not detected

TABLE 14

RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST BURIAL GROUND, 1987

SAND

Sample Station	Date	Radioactivity (Bq g^{-1} DW)			K ($\mu g\ g^{-1}$)
		Gross α	Gross ß (less ^{40}K)	γ-emitters	
Barden Creek (pre-confluence with Mill Ck.)	23.12.87	0.43	0.09	Trace ^{238}U + ^{232}Th series	398
Mill Creek (pre-confluence with Barden Ck.)	23.12.87	1.18	0.15	Trace ^{238}U+^{232}Th series	536

WATER

Sample Station	Date	Radioactivity (Bq L^{-1})			^{3}H (Bq mL^{-1})
		Gross α	Gross ß (incl. ^{40}K)	γ-emitters	
Barden Ck. (pre-confluence with Mill Ck.)	23.12.87	0.11	0.16	N.D.	LLD
Mill Ck. (pre-confluence with Barden Ck.)	23.12.87	0.03	0.06	N.D.	LLD

LLD = Less than the limit of detection

LLD for ^{3}H is 0.25 Bq mL^{-1}

N.D. = not detected

TABLE 15

RESULTS OF AIR SAMPLING AT LITTLE FOREST BURIAL GROUND, 1987

Sampling period	Air volume sampled (m^3)	(2) Be ($\mu g\ m^{-3}$)	(3) ^{239}Pu ($Bq\ m^{-3}$)
22.12.86 to 20.3.87	160.9	LLD	-
20.3.87 to 19.6.87	50.8	LLD	-
19.6.87 to 30.9.87	58.1	LLD	-
30.9.87 to 11.12.87	61.2	LLD	-
Composite (1)	331.0	-	LLD

(1) Composite sample of all air filters for 1987. Result determined by alpha spectrometry.

(2) TLV for Be = 2 $\mu g\ m^{-3}$.

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

LLD = less than the limit of detection. The limit of detection for Be is 0.2 $\mu g\ m^{-3}$ and for ^{239}Pu is 2×10^{-5} $Bq\ m^{-3}$.

TABLE 16
AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS, 1988

Period and Bld. No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^{3}H (GBq)	Fission product noble gases (TBq)	Other activity (MBq)
Quarter No. 1						
Bld.2	<5	1390	<0.1	-	99.7	5120
Bld.3	<5	1.3	<0.1	-	-	-
15(Hifar)	<2	2.1	<0.4	960	19.5	70
19	<11	-	<0.2	-	-	-
20	<5	<2	<0.1	-	-	-
23A	<9	6960	<0.2	-	-	-
23B	<1	2.1	<0.01	-	-	-
41	<3	0.4	<0.1	-	-	-
56	<14	<1.8	<0.2	-	-	-
57	<1	<1.0	<0.02	0.5	-	-
Quarter No.2						
Bld.2	<5	1420	<0.1	-	105.7	5030
3	<4	0.9	<0.1	-	-	3300
15	<2	1.7	<0.4	1040	17.1	50
19	<11	<1	<0.2	-	-	-
20	<5	<2	<0.1	41	-	-
23A	<9	2900	<0.2	-	-	206
23B	<1	0.1	<0.02	-	-	-
41	<3	0.7	<0.1	-	-	-
56	<14	<0.9	<0.2	-	-	-
57	<1	<0.3	<0.02	1.0	-	-
Quarter No.3						
1.2	<5	1380	<0.1	-	75.8	4510
3	<7	0.6	<0.1	-	-	-
15	<2	1.8	<0.6	960	17.4	61
19	<11	3	<0.2	-	-	-
20	<5	<2	<0.1	74	-	-
3A	<9	5720	<0.2	-	-	-
23B	<1	0.6	<0.02	-	-	-
41	<3	0.4	<0.1	-	-	-
56	<14	<2.0	<0.2	-	-	-
57	<1	<0.2	<0.02	0.8	-	-
Quarter No.4						
Bld.2	8	2140	0.1	-	91.9	7430
3	<6	0.9	<0.1	-	-	-
15	3	1.4	<0.6	1010	18.2	51
19	<14	2	<0.2	-	-	-
20	<7	<2	<0.1	136	-	-
23A	<14	3810	<0.2	-	-	1608
23B	<2	0.5	<0.02	-	-	-
41	<4	0.1	<0.1	-	-	-
56	<19	<4.1	<0.3	-	-	-
57	<2	<0.1	<0.02	3.2	-	-

- = not measured
Where discharge figures are quoted as less than certain amounts, the figure is the maximum possible discharge, based on the limits of detection. It does not necessarily imply that the radioactivity has been detected in the effluent.

TABLE 17

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS EXPRESSED AS FRACTIONS OF AUTHORISED QUARTERLY POINT DISCHARGE FOR 1988

Period & Bldg. No.	Gross α	^{131}I	^{90}Sr	^{3}H	Fission Product Noble Gases	Other Activity
Quarter No. 1						
Bld.2	$<7.6\times10^{-6}$	0.02	$<1.6\times10^{-7}$	-	0.59	3.2×10^{-3}
3	$<3.1\times10^{-3}$	8.1×10^{-5}	$<7.7\times10^{-5}$	-	-	-
15(Hifar)	$<6.1\times10^{-5}$	1.3×10^{-4}	$<1.5\times10^{-5}$	7.4×10^{-3}	0.72	1.1×10^{-3}
19	$<3.3\times10^{-5}$	-	$<7.7\times10^{-7}$	-	-	-
20	$<1.6\times10^{-3}$	$<1.1\times10^{-4}$	$<2.0\times10^{-4}$	-	-	-
23A	$<5.6\times10^{-4}$	0.44	$<1.5\times10^{-5}$	-	-	-
23B	$<1.5\times10^{-4}$	1.3×10^{-4}	$<1.6\times10^{-6}$	-	-	-
41	$<9.1\times10^{-6}$	2.5×10^{-5}	$<3.8\times10^{-7}$	-	-	-
56	$<1.8\times10^{-3}$	$<4.1\times10^{-5}$	$<1.8\times10^{-4}$	-	-	-
57	$<1.4\times10^{-3}$	$<2.4\times10^{-4}$	$<2.0\times10^{-4}$	2.4×10^{-4}	-	-
Quarter No. 2						
Bld.2	$<7.6\times10^{-6}$	0.02	$<1.6\times10^{-7}$	-	0.62	3.14×10^{-3}
3	$<2.5\times10^{-3}$	5.6×10^{-5}	$<7.7\times10^{-5}$	-	-	-
15	$<6.1\times10^{-5}$	1.1×10^{-4}	$<1.5\times10^{-5}$	8.0×10^{-3}	0.63	7.6×10^{-4}
19	$<3.3\times10^{-5}$	$<3.0\times10^{-5}$	$<7.7\times10^{-7}$	-	-	-
20	$<1.8\times10^{-3}$	$<1.2\times10^{-4}$	$<2.5\times10^{-4}$	5.1×10^{-3}	-	-
23A	$<5.6\times10^{-4}$	0.18	$<1.5\times10^{-5}$	-	-	6.2×10^{-3}
23B	$<1.5\times10^{-4}$	6.3×10^{-6}	$<3.1\times10^{-6}$	-	-	-
41	$<9.1\times10^{-6}$	4.4×10^{-5}	$<3.8\times10^{-7}$	-	-	-
56	$<1.8\times10^{-3}$	$<2.0\times10^{-5}$	$<1.8\times10^{-4}$	-	-	-
57	$<1.7\times10^{-3}$	$<8.3\times10^{-5}$	$<2.2\times10^{-4}$	5.5×10^{-4}	-	-
Quarter No. 3						
Bld. 2	$<7.6\times10^{-6}$	0.02	$<1.6\times10^{-7}$	-	0.45	2.8×10^{-3}
3	$<4.4\times10^{-3}$	3.8×10^{-5}	$<7.7\times10^{-5}$	-	-	-
15	$<6.1\times10^{-5}$	1.1×10^{-4}	$<2.3\times10^{-5}$	7.4×10^{-3}	0.64	9.2×10^{-4}
19	$<3.3\times10^{-5}$	9.1×10^{-5}	$<7.7\times10^{-7}$	-	-	-
20	$<1.8\times10^{-3}$	$<1.2\times10^{-4}$	$<2.5\times10^{-4}$	9.1×10^{-3}	-	-
23A	$<5.6\times10^{-4}$	0.36	$<1.5\times10^{-5}$	-	-	-
23B	$<1.5\times10^{-4}$	3.8×10^{-5}	$<3.1\times10^{-6}$	-	-	-
41	$<9.1\times10^{-6}$	2.5×10^{-5}	$<3.8\times10^{-7}$	-	-	-
56	$<1.8\times10^{-3}$	$<4.5\times10^{-5}$	$<1.8\times10^{-4}$	-	-	-
57	$<1.7\times10^{-3}$	$<5.6\times10^{-5}$	$<2.2\times10^{-4}$	4.4×10^{-4}	-	-
Quarter No. 4						
Bld. 2	1.1×10^{-5}	3.4×10^{-2}	1.4×10^{-7}	-	0.51	4.4×10^{-3}
3	$<3.5\times10^{-3}$	5.3×10^{-5}	$<7.1\times10^{-5}$	-	-	-
15	8.3×10^{-5}	8.2×10^{-5}	$<2.1\times10^{-5}$	7.2×10^{-3}	0.63	7.2×10^{-4}
19	$<3.9\times10^{-5}$	5.5×10^{-5}	$<7.1\times10^{-7}$	-	-	-
20	$<2.3\times10^{-3}$	1.1×10^{-4}	$<2.5\times10^{-4}$	1.6×10^{-2}	-	-
23A	$<8.2\times10^{-4}$	0.22	$<1.4\times10^{-5}$	-	-	4.5×10^{-2}
23B	$<2.8\times10^{-4}$	2.9×10^{-5}	$<2.9\times10^{-6}$	-	-	-
41	$<1.1\times10^{-5}$	5.9×10^{-6}	$<3.6\times10^{-7}$	-	-	-
56	$<2.3\times10^{-3}$	$<8.7\times10^{-5}$	$<2.5\times10^{-4}$	-	-	-
57	$<2.9\times10^{-3}$	$<2.6\times10^{-5}$	$<2.0\times10^{-4}$	1.7×10^{-3}	-	-

- = not measured.

TABLE 18

RADIOACTIVITY DISCHARGED TO THE MWS&DB SEWER DURING 1987

Quarter ending	Radioisotopes measured (MBq)			Percentage of authorised limit**
	*αu	^3H	†βu	
31 March 1987	16.63	$2.8x10^5$	440.8	30.12
30 June 1987	18.77	$5.9x10^5$	537.4	35.28
30 September 1987	16.06	$6.0x10^5$	400.0	23.57
31 December 1987	20.67	$2.4x10^5$	343.9	25.54

*α_u = 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.

†β_u = 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 unit.

**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.

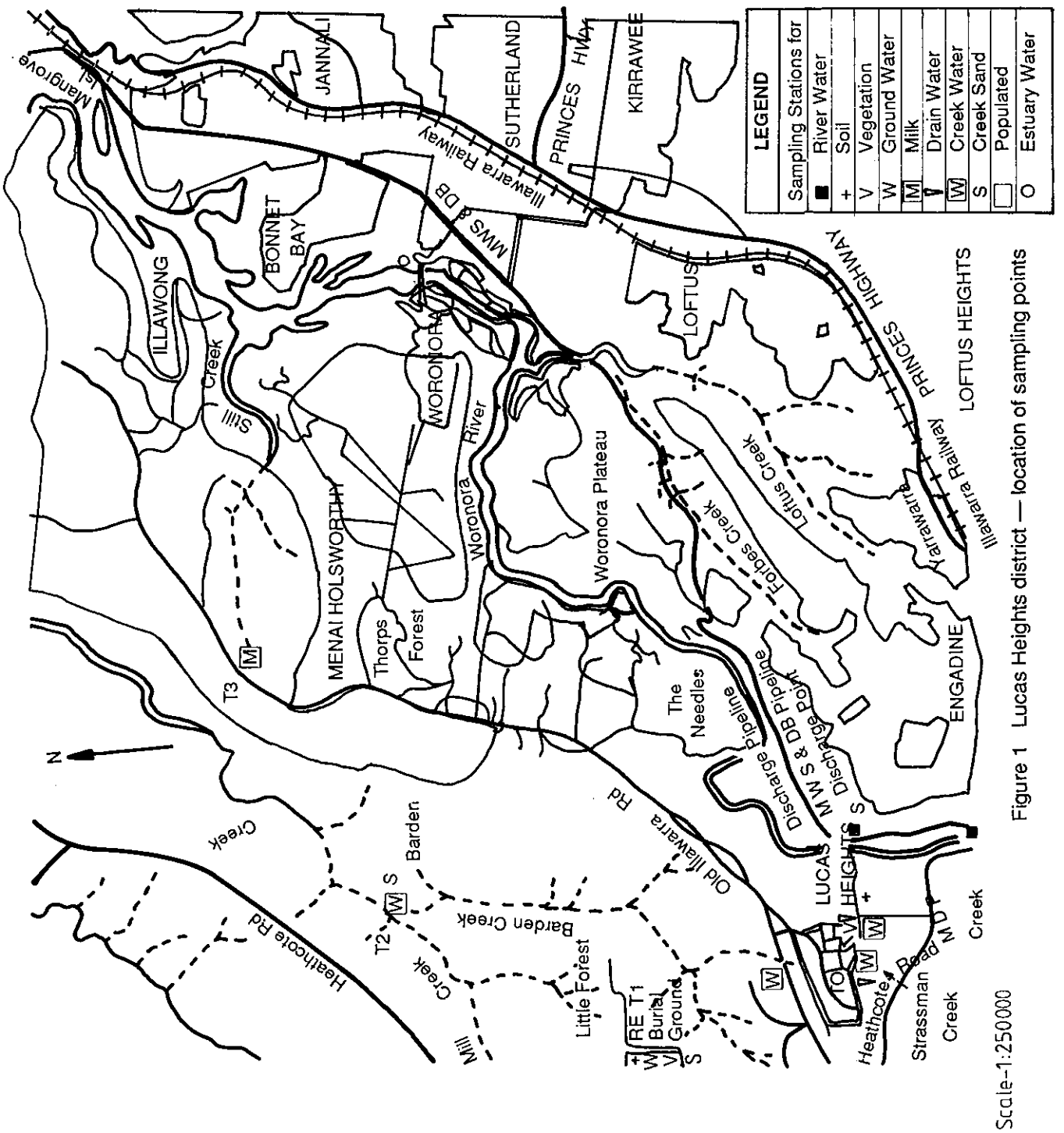

Figure 1 Lucas Heights district — location of sampling points

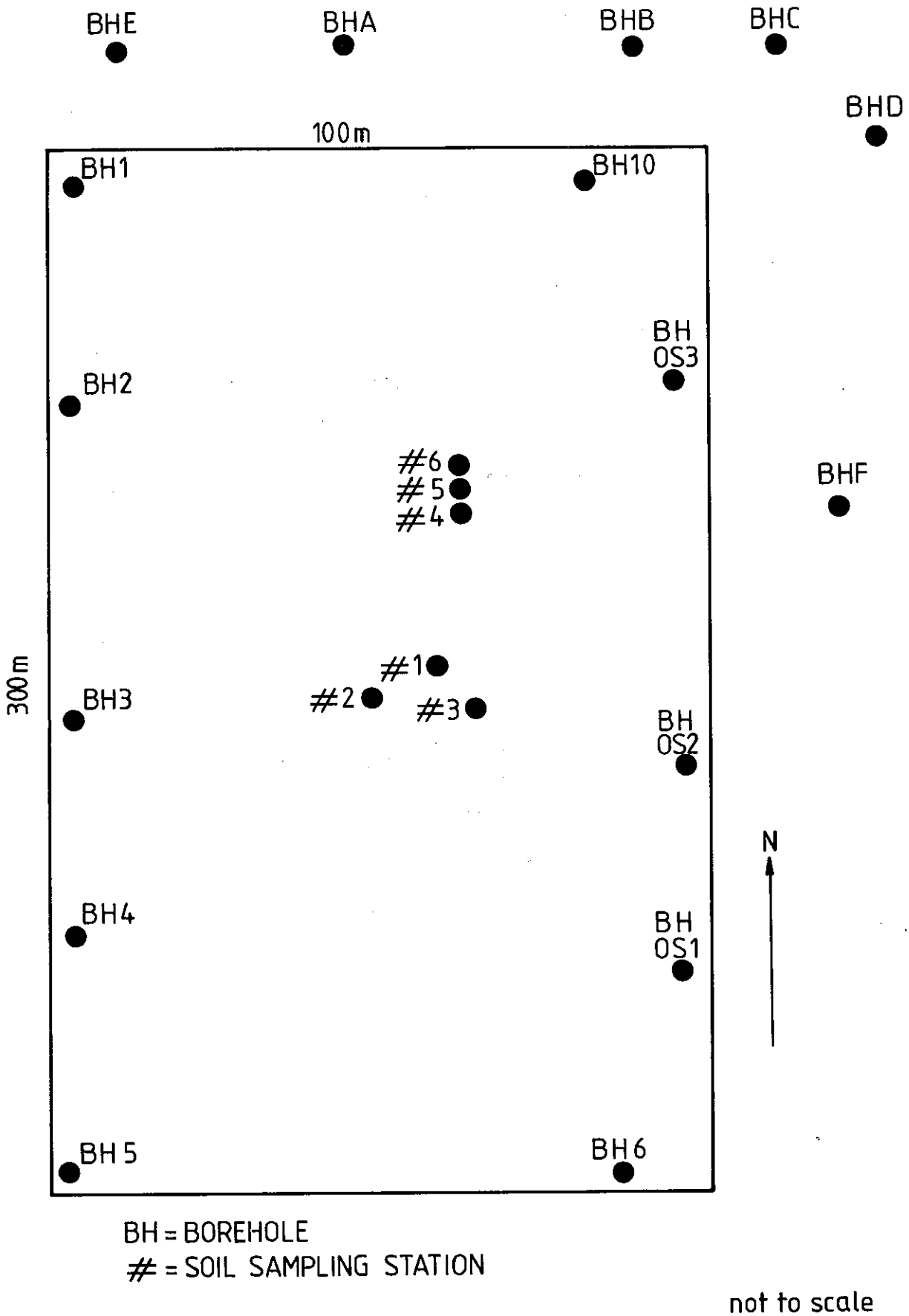

Figure 2 Little Forest Burial Ground — location of sampling stations

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.

Giles, M.S., Foy, J.J., Hoffmann, E.L. [1988] - Environmental Survey at the Research Establishment, Lucas Heights, 1985. AAEC/E677.

Giles, M.S., Foy, J.J., Hoffmann, E.L. [1989] - Environmental Survey at Lucas Heights Research Laboratories, 1986. ANSTO/E687.

APPENDIX B
NEW ANALYTICAL PROCEDURES

No new procedures were introduced since the previous report.

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
^{54}Mn	manganese-54
^{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