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ABSTRACT

Results are presented of an environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1989. 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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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 1989 are presented in **tables 2** to **14.** Authorised airborne releases are given in **tables 15** and **16.** Authorised liquid effluent discharges to the Metropolitan Water Sewerage and Drainage Board (MWS&DB) sewers are given in **table 17.**

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. Occasionally, daughters of the ^{238}U and ^{232}Th decay series have been detected by gamma spectrometry, especially in soil samples. It should be noted that the ^{238}U and ^{232}Th chains are two of the three primordial radioactive decay series found in nature. The various daughter products of the ^{238}U and ^{232}Th series, if present, contribute to the gross alpha and gross beta levels of environmental samples.

5.1 Airborne Release

Measurable concentrations of iodine-131 were occasionally recorded in air samplers during the year (see **table 2**). The highest reading was registered for the week ending 18 April 1989 and was 2.8 x 10^{-3} (or 0.28 per cent) 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 <4x10^{-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 x 10^{-4} Bq g^{-1} (fresh weight).

Noble gas releases were always below the authorised limit during the year. See **tables 15** and **16**. 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 1989 (see **table 4**).

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**.

No soil or vegetation samples could be collected from LHRL Stormwater Outlet No. 1 during 1989 due to the banks of the channel having collapsed after flooding. A retaining wall was constructed and the whole channel lined with rocks to prevent further erosion.

Sampling at this station (which drains the south-east corner of the site into MDP Creek) will re-commence once the soil and vegetation have been re-established. Water sampling continued throughout the reconstruction period, and traces of ^{137}Cs were found which could not be quantified. The water sample collected on 7th November revealed a detectable quantity of ^{241}Am, and slightly elevated gross alpha and beta activity. However, these results were 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.

If it was assumed that a person took all of his or her drinking water supplies from the stormwater, the average ^{241}Am concentration measured during 1989 represents 0.006 (or 0.6%) of the derived working limit (DWL).

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

No tritium was detected in any of the stormwater samples.

During 1989, 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 1989 to measure tritium and the results are shown in **table 8.** No tritium was detected in any of these water samples.

5.4 Effluent Discharge Pipeline

Table 9 shows the dose rates at various points on the discharge pipeline during the 1989 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. Since the dose rate readings were close to background levels, no samples of soil were collected along the pipeline.

In response to leaks in joints Nos 3 and 4 of the liquid effluent discharge pipeline on 14/6/89, a sample from MDP Creek Weir (an official SPCC sampling point) was taken and analysed for radioactivity. The results appear in **table 10,** and were well below the limits required by the Clean Waters Act. No soil samples were available due to the rocky ground.

On 25/6/89 a leak from a direct air valve (DAV) pit on the Engadine side of the same pipeline was reported by the Water Board. A sample of the effluent which filled the pit was taken on 26/6/89 and analysed for gross alpha and beta activity. These results are reported in **table 10** and are also within the limits set by the Clean Waters Act. The leak was located in an area too isolated for any human exposure to have been likely. As a result of these two incidents of leakage in the pipeline, maintenance of all the joints and DAV pits along the pipeline was carried out in July 1989.

5.5 Little Forest Burial Ground

Results of measurements at the Little Forest Burial Ground (LFBG) are given in **tables 11, 12, 13, and 14.** The positions of sampling points are shown on **figures 2 and 3** (which show the position of the new MB series of monitoring bores). There appears to have been a gradual increase in levels of ^{60}Co found in soil at LFBG point No. 6 over the past five years, with an associated elevation in gross beta activity. It is proposed that the burial trenches be top-dressed with soil as part of the regular maintenance program.

Tritium was found in boreholes MB12, MB13, MB16, MB17 and MB20. Of these, only MB20 lies outside the fenced area. This newest series of boreholes was first sampled in 1988, when no tritium was found in MB20. In the past, BHF has been the only borehole outside the old fenced area to contain tritium. (Results ranged from 1.00 to 1.50 Bq L^{-1}.) In view of this fact (and considering that tritium acts as a tracer for groundwater movement), it is proposed that water sampling should be resumed at BHF and also at several of the old bores in which tritium has been detected. It should be noted that BHF now lies within the fence which was extended in 1988.

The levels of tritium found in the remaining bores in 1989 were similar to those found previously. The tritium found in MB20 has no health significance since groundwater is not used from this area. No tritium or other activity above background levels was found in creeks draining the LFBG.

No 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 x 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 x 10^{-4} Bq m^{-3}. These limits were calculated assuming permanent exposure for 24 hours each day. Initial estimates of ^{239}Pu were all <DWC, and α-spectrometry subsequently performed on a composite sample of filters for 1989 revealed levels of ^{239}Pu which were less than the limit of detection.

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 15** and **16**). The dose to the most sensitive members of the public from ^{131}I releases, calculated from results in **table 2**, was <0.4 $\mu Sv\ y^{-1}$ and the calculated dose from released noble gases to the most exposed individuals was less than 0.01 $mSv\ y^{-1}$. These figures represent less than one per cent of the most restrictive limit recommended by the NH&MRC.

7 ACKNOWLEDGEMENTS

Potassium levels were determined by the CSIRO's Division of Energy Chemistry (now the Division of Fuel Technology). Beryllium levels and initial estimates of plutonium-239 on the Little Forest Burial Ground air filters were determined by ANSTO's Occupational Health and Safety Program.

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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 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_4	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	Gamma spectrometry of sieved and ashed sample. Gross alpha and beta counting also.
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

Table 1 contd.

Sample	Station	Frequency	Collection Details	Special Preparations
Creekwater	Barden Creek MDP Creek Strassman Ck	Monthly	Sampled by bottle, after rain	Prepared according to Clean Waters Act Regulations
	T2: Barden Creek (above junction with Mill Creek) and Mill Creek (above junction with Barden Creek)	Yearly	Sampled by bottle	5L sample passed through cation-exchange resin and ashed OR evaporated to dryness residue then counted by gamma spectrometry. 50 mL distilled for tritium. Gross alpha and beta counting done on residue.

TABLE 2

RADIOACTIVE IODINE IN AIR, 1989

Week ending	^{131}I ($Bq\ m^{-3}$)	Week ending	^{131}I ($Bq\ m^{-3}$)
3.1.89	LLD	11.7.89	LLD
10.1.89	LLD	18.7.89	LLD
17.1.89	LLD	25.7.89	LLD
24.1.89	LLD	1.8.89	LLD
31.1.89	LLD	8.8.89	LLD
7.2.89	LLD	15.8.89	LLD
14.2.89	LLD	22.8.89	LLD
21.2.89	LLD	29.8.89	LLD
28.2.89	LLD	5.9.89	LLD
7.3.89	LLD	12.9.89	LLD
14.3.89	$3.5x10^{-3}$	19.9.89	LLD
21.3.89	LLD	26.9.89	LLD
28.3.89	$2.9x10^{-3}$	3.10.89	LLD
4.4.89	LLD	10.10.89	$3.3x10^{-3}$
11.4.89	$1.7x10^{-2}$	17.10.89	LLD
18.4.89	$2.8x10^{-2}$	24.10.89	LLD
24.4.89	LLD	31.10.89	LLD
2.5.89	$8.4x10^{-3}$	7.11.89	LLD
9.5.89	$7.8x10^{-3}$	14.11.89	$3.0x10^{-3}$
16.5.89	LLD	21.11.89	$4.0x10^{-3}$
23.5.89	LLD	28.11.89	LLD
30.5.89	$8.6x10^{-3}$	5.12.89	LLD
6.6.89	$2.1x10^{-2}$	12.12.89	LLD
13.6.89	$2.7x10^{-3}$	19.12.89	$8.2x10^{-3}$
20.6.89	LLD	26.12.89	LLD
27.6.89	LLD	2.1.90	LLD
4.7.89	$4.6x10^{-3}$		

Four 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, 1989

Station	Date	Radioactivity (Bq g^{-1} fresh volume)	
		^{137}Cs	^{131}I
T4	24.1.89	LLD	LLD
"	28.2.89	$3x10^{-4}$	LLD
"	31.3.89	LLD	LLD
"	3.5.89	$4x10^{-4}$	LLD
"	30.5.89	LLD	LLD
"	27.6.89	LLD	LLD
"	1.8.89	LLD	LLD
"	31.8.89	LLD	LLD
"	28.9.89	$4x10^{-4}$	LLD
"	31.10.89	$7x10^{-4}$	LLD
"	30.11.89	LLD	LLD
"	20.12.89	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}.

LLD = not detected.

TABLE 4

TRITIUM IN WORONORA RIVER WATER SAMPLES
AT STATION E5.9, 1989

Date	Tritium ($Bq\ mL^{-1}$)	Date	Tritium ($Bq\ mL^{-1}$)	Date	Tritium ($Bq\ mL^{-1}$)
3.1.89	LLD	2.5.89	LLD	29.8.89	LLD
10.1.89	LLD	9.5.89	LLD	5.9.89	LLD
17.1.89	LLD	16.5.89	LLD	12.9.89	LLD
24.1.89	LLD	23.5.89	LLD	19.9.89	LLD
31.1.89	LLD	30.5.89	LLD	26.9.89	LLD
7.2.89	LLD	6.6.89	LLD	3.10.89	LLD
14.2.89	LLD	13.6.89	LLD	10.10.89	LLD
21.2.89	LLD	20.6.89	LLD	17.10.89	LLD
28.2.89	LLD	27.6.89	LLD	24.10.89	LLD
7.3.89	LLD	4.7.89	LLD	31.10.89	LLD
14.3.89	LLD	11.7.89	LLD	7.11.89	LLD
21.3.89	LLD	18.7.89	LLD	14.11.89	LLD
28.3.89	LLD	25.7.89	LLD	21.11.89	LLD
4.4.89	LLD	1.8.89	LLD	28.11.89	LLD
11.4.89	LLD	8.8.89	LLD	5.12.89	LLD
18.4.89	LLD	15.8.89	LLD	12.12.89	LLD
24.4.89	LLD	22.8.89	LLD	19.12.89	LLD
				26.12.89	LLD

Derived limiting concentration (DLC) [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 OF SOIL AND VEGETATION FROM STORMWATER OUTLETS, 1989

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	23.1.89	Soil	0.66	0.05	Trace ^{238}U + ^{232}Th series	166
	27.4.89	Soil	0.93	0.02	Trace ^{238}U + ^{232}Th series	962
	31.7.89	Soil	0.65	0.29	Trace ^{238}U + ^{232}Th series	349
	25.10.89	Soil	0.47	0.20	Trace ^{238}U + ^{232}Th series	886
Drain opposite Fermi Street	31.7.89	Soil	0.61	0.31	Trace ^{238}U + ^{232}Th series	466
Drain opposite Bld.23	23.1.89	Soil	0.35	0.22	Trace ^{238}U + ^{232}Th series	557
	27.4.89	Soil	0.41	0.18	Trace ^{238}U + ^{232}Th series	455
	31.7.89	Soil	0.49	0.11	Trace ^{238}U + ^{232}Th series	158
	25.10.89	Soil	0.40	0.15	Trace ^{238}U + ^{232}Th series	651
Drain No.1 opposite Strassman Cres.	23.1.89	Vegetation	<0.01	0.03	Trace ^{238}U + ^{232}Th series	3560
	27.4.89	Soil	0.43	0.18	Trace ^{238}U + ^{232}Th series	297
	31.7.89	Soil	0.32	0.20	Trace ^{238}U + ^{232}Th series	236
Drain opposite meteorological tower	23.1.89	Soil	0.44	0.35	Trace ^{238}U + ^{232}Th series	603
	27.4.89	Soil	0.55	0.22	Trace ^{238}U + ^{232}Th series	413
	31.7.89	Soil	0.44	0.18	Trace ^{238}U + ^{232}Th series	166
	25.10.89	Soil	0.45	0.24	Trace ^{238}U + ^{232}Th series	652

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

NOTE: No soil or vegetation was collected from LHRL Stormwater outlet No.1 during 1989, due to reconstruction after flood - see text for more details.

TABLE 6

RADIOACTIVITY IN WATER SAMPLES FROM STORMWATER OUTLETS, 1989

Station	Date	Radioactivity (Bq L^{-1})			Tritium (Bq mL^{-1})
		Gross α	Gross ß (incl. ^{40}K)	γ-emitters	
Drain behind Bld. 1	23.1.89	-	-	-	LLD
	27.4.89	-	-	-	LLD
	31.7.89	-	-	-	LLD
	25.10.89	-	-	-	LLD
Drain on road at west fence	23.1.89	-	-	-	LLD
	27.4.89	-	-	-	LLD
	31.7.89	-	-	-	LLD
	25.10.89	-	-	-	LLD
Drain at Fermi St.	23.1.89	-	-	-	LLD
	27.4.89	-	-	-	LLD
	31.7.89	-	-	-	LLD
	25.10.89	-	-	-	LLD
Drain opposite Bld. 23	23.1.89	-	-	-	LLD
	27.4.89	-	-	-	LLD
	25.10.89	-	-	-	LLD
Drain No.1 opposite Strassman Cr.	23.1.89	-	-	-	LLD
	27.4.89	-	-	-	LLD
	31.7.89	-	-	-	LLD
	25.10.89	-	-	-	LLD
Drain No.2 opposite Strassman Cr.	27.4.89	-	-	-	LLD
Drain opposite meteorological tower	23.1.89	-	-	-	LLD
	27.4.89	-	-	-	LLD
	25.10.89	-	-	-	LLD

TABLE 6 cont.

RADIOACTIVITY IN SAMPLES OF WATER FROM STORMWATER OUTLETS, 1989

Station	Date	Radioactivity (Bq L^{-1})			Tritium (Bq mL^{-1})
		Gross α	Gross β (Incl. ^{40}K)	γ-emitters	
60 m from	January*	0.21	0.19	N.D.	LLD
LHRL	February*	0.10	0.22	N.D.	LLD
stormwater	March*	0.22	0.39	N.D.	LLD
outlet No.1	April*	0.21	0.26	N.D.	LLD
	May*	0.20	0.30	N.D.	LLD
	June*	0.24	0.20	N.D.	LLD
	July*	0.29	0.40	$^{238}U+^{232}Th$ series Trace ^{137}Cs	LLD
	August*	0.18	0.28	N.D.	LLD
	September*	0.22	0.34	Trace ^{137}Cs	LLD
	October*	0.22	0.62	Trace ^{137}Cs	LLD
	7.11.89	0.95	1.26	^{241}Am=0.10 Trace ^{137}Cs	-
	14.11.89	0.18	0.62	N.D.	-
	21.11.89	0.17	0.49	N.D.	-
	28.11.89	0.15	0.55	N.D.	-
	December*	0.18	0.48	N.D.	LLD

* Monthly composite samples made up of weekly additions.

LLD = Less than the limit of detection

N.D. = not detected

- = not measured

Radioactivity (Bq L^{-1}) refers to the radioactivity present per litre of water sample (suspended and dissolved).

LLD for tritium = 0.25 Bq mL^{-1}

TABLE 7

RADIOACTIVITY AT SPCC SAMPLING POINTS, 1989
(Bq L^{-1})[a]

Date	Strassman Creek		Barden Creek		MDP Creek	
	Gross α	Gross ß*	Gross α	Gross ß*	Gross α	Gross ß*
23.1.89	LLD	LLD	LLD	0.12	LLD	0.16
22.2.89	LLD	0.10	LLD	LLD	LLD	0.17
24.3.89	LLD	LLD	LLD	LLD	LLD	0.17
26.4.89	LLD	LLD	LLD	LLD	LLD	0.15
24.5.89	LLD	0.13	LLD	0.14	LLD	0.10
16.6.89	LLD	LLD	LLD	0.13	LLD	0.12
26.7.89	LLD	LLD	LLD	0.10	LLD	0.13
28.8.89	LLD	0.38	LLD	LLD	LLD	0.15
22.9.89	LLD	0.12	LLD	LLD	LLD	0.12
18.10.89	LLD	LLD	LLD	LLD	LLD	0.10
14.11.89	LLD	LLD	LLD	LLD	LLD	LLD
13.12.89	LLD	0.11	LLD	0.12	LLD	0.18

(a) Minimum detection limit α = 0.07 Bq L^{-1}
Minimum detection limit β = 0.10 Bq L^{-1}
* includes ^{40}K contribution
- = not measured.
LLD = Less than the minimum detection limit.

TABLE 8

TRITIUM IN WATER FROM SPCC SAMPLING POINT AT BARDEN CREEK WEIR, 1989

Date	Tritium (Bq mL^{-1})	Date	Tritium (Bq mL^{-1})
3.1.89	LLD	4.7.89	LLD
10.1.89	LLD	11.7.89	LLD
17.1.89	LLD	18.7.89	LLD
24.1.89	LLD	25.7.89	LLD
31.1.89	LLD	1.8.89	LLD
7.2.89	LLD	8.8.89	LLD
14.2.89	LLD	15.8.89	LLD
21.2.89	LLD	22.8.89	LLD
28.2.89	LLD	29.8.89	LLD
7.3.89	LLD	5.9.89	LLD
14.3.89	LLD	12.9.89	LLD
21.3.89	LLD	19.9.89	LLD
28.3.89	LLD	26.9.89	LLD
4.4.89	LLD	3.10.89	LLD
11.4.89	LLD	10.10.89	LLD
18.4.89	LLD	17.10.89	LLD
24.4.89	LLD	24.10.89	LLD
2.5.89	LLD	31.10.89	LLD
9.5.89	LLD	7.11.89	LLD
16.5.89	LLD	14.11.89	LLD
23.5.89	LLD	21.11.89	LLD
30.5.89	LLD	28.11.89	LLD
6.6.89	LLD	5.12.89	LLD
13.6.89	LLD	12.12.89	LLD
20.6.89	LLD	19.12.89	LLD
27.6.89	LLD	26.12.89	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, 1989

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	
14.6.89	Joints #1 to 17	<0.12	<0.20	0.05 to 0.15
13.12.89	Joints #1 to 17	<0.10	<0.11	0.06 to 0.15
	Joints #20 to 22	<0.10	<0.10	0.08

Note Joints No 18 and 19 are inaccessible.

TABLE 10

RADIOACTIVITY IN SAMPLES TAKEN NEAR EFFLUENT DISCHARGE PIPELINE, 1989

Station	Date	Sample Type	Radioactivity ($Bq.g^{-1}D.W.$)			^3H ($Bq.mL^{-1}$)
			Gross α	Gross ß	γ-Emitters	
MDP Creek weir*	14.6.89	Water	0.03	0.12	-	LLD
Direct air valve pit, Engadine†	26.6.89	Water	0.33	8.03	-	-

* This sample was taken in response to leaks in the pipeline whilst discharging low-level liquid effluent.

† This sample was taken in response to an overflow leak from the direct air valve pit.

- = not measured.

LLD = Less than the limit of detection.

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

TABLE 11

RADIOACTIVITY IN SAMPLES OF SOIL
FROM LITTLE FOREST BURIAL GROUND, 1989

Sampling Location	Date	Radioactivity (Bq g^{-1} Dry Weight)			Potassium ($\mu g\ g^{-1}$)
		Gross α	Gross ß (Less ^{40}K)	γ-Emitters	
Point #5	28.6.89	1.02	0.82	$^{238}U + ^{232}Th$ series prominent	3273
Point #6	28.6.89	0.89	3.86	Trace $^{238}U + ^{232}Th$ series $^{60}Co = 0.37$ $^{137}Cs = 0.03$	1800
Point #5	7.12.89	0.83	0.67	$^{238}U + ^{232}Th$ series prominent Trace ^{60}Co	1284
Point #6	7.12.89	0.86	2.84	$^{238}U + ^{232}Th$ series prominent $^{137}Cs = 0.01$ $^{60}Co = 0.19$	2715

TABLE 12

RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM LITTLE FOREST BURIAL GROUND, 1989

Bore Hole No.	Date	Sediment (Bq g^{-1})			^{3}H (Bq mL^{-1})
		Gross α	Gross β^{*}	γ-Emitters	
MB11	28.6.89	0.98	0.74	N.D.	LLD
MB12	"	1.07	0.40	N.D.	LLD
MB13	"	1.91	0.93	Trace $^{238}U+^{232}Th$ series	4.4
MB14	"	2.76	0.59	Trace $^{238}U+^{232}Th$ series	LLD
MB15	"	3.73	0.77	N.D.	LLD
MB16	"	5.49	7.04	Trace $^{238}U+^{232}Th$ series ^{60}Co =1.30	15.0
MB17	"	0.35	0.38	Trace $^{238}U+^{232}Th$ series	2.2
MB18	"	1.16	0.31	Trace $^{238}U+^{232}Th$ series	LLD
MB19	"	2.28	0.60	Trace $^{238}U+^{232}Th$ series	LLD
MB20	"	2.46	1.11	Trace $^{238}U+^{232}Th$ series	LLD
MB21	"	0.67	0.38	Trace $^{238}U+^{232}Th$ series	LLD
MB11	7.12.89	0.05	0.04	Trace $^{238}U+^{232}Th$ series	LLD
MB12	"	0.81	0.27	N.D.	1.2
MB13	"	0.31	0.46	Trace ^{60}Co	12.0
MB14	"	0.66	0.19	N.D.	LLD
MB15	"	0.77	0.20	N.D.	LLD
MB16	"	6.06	8.39	^{60}Co = 1.00	17.0
MB17	"	1.16	0.47	N.D.	3.0
MB18	"	0.93	0.29	N.D.	LLD
MB19	"	0.21	0.17	N.D.	LLD
MB20	"	0.37	0.78	N.D.	1.0
MB21	"	1.97	0.57	N.D.	LLD

LLD = Less than the limit of detection - LLD for ^{3}H is 0.25 Bq mL^{-1}

* All gross beta results include the contribution from natural potassium-40.

N.D. = not detected

TABLE 13
RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST BURIAL GROUND, 1989

SAND					
Sample Station	Date	Radioactivity (Bq g^{-1} DW)			K ($\mu g\ g^{-1}$)
		Gross α	Gross ß†	γ-emitters	
Mill Creek	18.12.89	0.80	0.05	$^{238}U+^{232}Th$ series	368

WATER					
Sample Station	Date	Radioactivity (Bq g^{-1} DW)			^{3}H (Bq mL^{-1})
		Gross α	Gross ß*	γ-emitters	
Mill Creek (above Junction with Barden Ck)	18.12.89	0.16	0.05	N.D.	LLD
Barden Creek (above Junction with Mill Ck)	18.12.89	0.25	0.11	N.D.	LLD

LLD = Less than the limit of detection
LLD for ^{3}H is 0.25 Bq mL^{-1}
N.D. = not detected
† Gross beta results have had the potassium-40 contribution deducted.
* Gross beta results include the contribution from natural potassium-40.

TABLE 14

RESULTS OF AIR SAMPLING AT LITTLE FOREST BURIAL GROUND, 1989

Sampling Period	Air volume Sampled (m^3)	(2) Be ($\mu g\ m^{-3}$)	(3) ^{239}Pu ($Bq\ m^{-3}$)
19.12.88 to 29.3.89	123.2	LLD	LLD†
29.3.89 to 28.6.89	34.1	LLD	LLD†
28.6.89 to 27.9.89	45.9	LLD	LLD†
27.9.89 to 20.12.89	125.4	LLD	LLD†
1989 composite(1)	-	-	LLD

† Preliminary estimates on α-drawer assembly

(1) Composite sample of duplicate sets of air filters for 1989. 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 $2 \times 10^{-5}\ Bq\ m^{-3}$.

TABLE 15
AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS, 1989

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	8	2360	0.1	-	77.2	10800
3	<7	0.8	<0.1	-	-	-
15(Hifar)	3	1.7	<0.4	850	15.1	44
19	<14	17	<0.2	-	-	-
20	<7	<1	<0.1	23	-	-
23A	<14	5490	<0.9	-	-	138
23B	<1	0.5	<0.02	-	-	-
41	<4	0.7	0.05	-	-	-
56	<18	<8.2	<0.2	-	-	-
57	<1	<0.2	<0.02	11.6	-	-
Quarter No. 2						
Bld.2	8	1540	0.1	-	92.3	6480
3	<6	0.8	<0.1	-	-	-
(Hifar) 15	33	1.3	<0.4	910	14.0	44
19	<13	11	<0.2	-	-	-
20	<5	<4	<0.1	10	-	
21A	2	1	-	-	-	-
21B	0.4	0.2	-	-	-	-
23A	<12	10700	<0.4	-	-	914
23B	<1	2.8	<0.02	-	-	-
41	<3	0.7	<0.05	-	-	-
56	<17	<7.6	<0.3	-	-	-
57	<1	<0.4	<0.02	13.6	-	-
Quarter No. 3						
Bld.2	<7	2060	<0.1	-	94.3	7700
3	<6	1.3	<0.1	-	-	-
(Hifar)15	<2	2.1	<0.4	960	15.1	56
19	<11	3	<0.2	-	-	-
20	<5	2	<0.1	48	-	-
21A	2	-	0.04	-	-	-
21B	0.4	0.1	0.01	-	-	-
23A	<10	4380	<0.2	-	-	205
23B	<1	1.4	<0.03	-	-	-
41	<4	1.7	<0.08	-	-	-
56	<14	3.0	<0.3	-	-	-
57	<1	0.2	<0.02	7.4	-	-
Quarter No. 4						
Bld.2	<8	3240	<0.1	-	88.0	12100
3	<5	0.3	<0.1	-	-	-
(Hifar)15	<3	2.0	<0.2	830	19.6	77
19	<12	1	<0.2	-	-	75
20	<5	1	<0.1	94	-	-
21A	2	0.5	0.04	-	-	-
21B	0.5	0.1	0.01	-	-	-
23A	<11	18200	<0.2	-	-	-
23B	<1	4.6	<0.02	-	-	-
41	<4	2.4	<0.08	-	-	-
56	<15	6.1	<0.3	-	-	-
57	<1	0.1	<0.02	4.6	-	-

- = 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 16

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS EXPRESSED AS FRACTIONS OF AUTHORISED QUARTERLY POINT DISCHARGE FOR 1989

Period and Bld. No.	Gross α	^{131}I	^{90}Sr	^{3}H	Fission product noble gases	Other activity
Quarter No. 1						
Bld.2	1.2×10^{-5}	3.6×10^{-2}	1.6×10^{-7}	-	0.45	6.7×10^{-3}
3	$<4.4\times10^{-3}$	5.0×10^{-5}	$<7.7\times10^{-5}$	-	-	-
Hifar(15)	9.1×10^{-5}	1.1×10^{-4}	$<1.5\times10^{-5}$	6.5×10^{-3}	0.56	6.7×10^{-4}
19	$<4.2\times10^{-5}$	5.1×10^{-4}	$<7.7\times10^{-7}$	-	-	-
20	$<2.5\times10^{-3}$	$<6.2\times10^{-5}$	$<2.4\times10^{-4}$	2.8×10^{-3}	-	-
23A	$<8.8\times10^{-4}$	0.34	$<6.9\times10^{-5}$	-	-	4.2×10^{-3}
23B	$<1.5\times10^{-4}$	3.1×10^{-5}	$<3.1\times10^{-6}$	-	-	-
41	$<1.2\times10^{-5}$	4.4×10^{-5}	1.9×10^{-7}	-	-	-
56	$<2.3\times10^{-3}$	1.8×10^{-4}	$<1.8\times10^{-4}$	-	-	-
57	$<1.6\times10^{-3}$	5.5×10^{-5}	$<2.2\times10^{-4}$	6.4×10^{-3}	-	-
Quarter No. 2						
Bld.2	1.2×10^{-5}	2.3×10^{-2}	1.6×10^{-7}	-	0.54	4.05×10^{-3}
3	$<3.7\times10^{-3}$	5.0×10^{-5}	$<7.7\times10^{-5}$	-	-	-
(Hifar)15	1.0×10^{-3}	8.1×10^{-5}	$<1.5\times10^{-5}$	7.0×10^{-3}	0.52	6.7×10^{-4}
19	$<3.9\times10^{-5}$	3.3×10^{-4}	$<7.7\times10^{-7}$	-	-	-
20	$<1.8\times10^{-3}$	$<2.5\times10^{-4}$	$<2.4\times10^{-4}$	1.2×10^{-3}	-	-
21A	2.0×10^{-3}	1.7×10^{-4}	-	-	-	-
21B	1.7×10^{-3}	1.5×10^{-4}	-	-	-	-
23A	$<7.5\times10^{-4}$	0.67	$<3.1\times10^{-5}$	-	-	2.8×10^{-2}
23B	$<1.5\times10^{-4}$	1.8×10^{-4}	$<3.1\times10^{-6}$	-	-	-
41	$<9.1\times10^{-6}$	4.4×10^{-5}	$<1.9\times10^{-7}$	-	-	-
56	$<2.2\times10^{-3}$	$<1.7\times10^{-4}$	$<2.7\times10^{-4}$	-	-	-
57	$<1.6\times10^{-3}$	$<1.1\times10^{-4}$	$<2.2\times10^{-4}$	7.6×10^{-3}	-	-
Quarter No.3						
Bld.2	$<1.1\times10^{-5}$	0.03	$<1.6\times10^{-7}$	-	0.55	4.8×10^{-3}
3	$<3.8\times10^{-3}$	8.1×10^{-5}	$<7.7\times10^{-5}$	-	-	-
Hifar(15)	$<6.1\times10^{-5}$	1.3×10^{-4}	$<1.5\times10^{-5}$	7.4×10^{-3}	0.56	8.5×10^{-4}
19	$<3.3\times10^{-5}$	9.1×10^{-5}	$<7.7\times10^{-7}$	-	-	-
20	$<1.8\times10^{-3}$	1.2×10^{-4}	$<2.4\times10^{-4}$	5.9×10^{-3}	-	-
21A	2.0×10^{-3}	-	2.8×10^{-4}	-	-	-
21B	1.7×10^{-3}	7.7×10^{-5}	3.0×10^{-4}	-	-	-
23A	$<6.2\times10^{-4}$	0.27	$<1.5\times10^{-5}$	-	-	6.2×10^{-3}
23B	$<1.5\times10^{-4}$	8.8×10^{-5}	$<4.7\times10^{-6}$	-	-	-
41	$<1.2\times10^{-5}$	1.1×10^{-4}	$<3.1\times10^{-7}$	-	-	-
56	$<1.8\times10^{-3}$	6.8×10^{-5}	$<2.7\times10^{-4}$	-	-	-
57	$<1.6\times10^{-3}$	5.5×10^{-5}	$<2.2\times10^{-4}$	4.1×10^{-3}	-	-
Quarter No.4						
Bld.2	$<1.2\times10^{-5}$	0.05	$<1.6\times10^{-7}$	-	0.52	7.6×10^{-3}
3	$<3.1\times10^{-3}$	1.9×10^{-5}	$<7.7\times10^{-5}$	-	-	-
Hifar(15)	$<9.1\times10^{-5}$	1.3×10^{-4}	$<7.7\times10^{-6}$	6.4×10^{-3}	0.72	1.2×10^{-3}
19	$<3.6\times10^{-5}$	3.0×10^{-5}	$<7.7\times10^{-7}$	-	-	1.1×10^{-4}
20	$<1.8\times10^{-3}$	6.2×10^{-5}	$<2.4\times10^{-4}$	1.2×10^{-2}	-	-
21A	2.0×10^{-3}	8.6×10^{-5}	2.8×10^{-4}	-	-	-
21B	2.2×10^{-3}	7.7×10^{-5}	3.0×10^{-4}	-	-	-
23A	$<6.9\times10^{-4}$	1.14	$<1.5\times10^{-5}$	-	-	-
23B	$<1.5\times10^{-4}$	2.9×10^{-4}	$<3.1\times10^{-6}$	-	-	-
41	$<1.2\times10^{-5}$	1.5×10^{-4}	$<3.1\times10^{-7}$	-	-	-
56	$<1.9\times10^{-3}$	1.4×10^{-4}	$<2.7\times10^{-4}$	-	-	-
57	$<1.6\times10^{-3}$	2.8×10^{-5}	$<2.2\times10^{-4}$	2.6×10^{-3}	-	-

- = not measured

TABLE 17

RADIOACTIVITY DISCHARGED TO THE MWS&DB SEWER DURING 1989

Quarter ending	Radioisotopes measured (MBq)			Percentage of authorised limit**
	*αu	^3H	†βu	
31 March 1989	43.06	$3.1x10^5$	219.90	32.10
30 June 1989	38.20	$7.9x10^5$	524.95	28.90
30 September 1989	30.39	$9.6x10^5$	367.59	35.20
31 December 1989	20.22	$1.0x10^6$	828.9	53.30

*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.

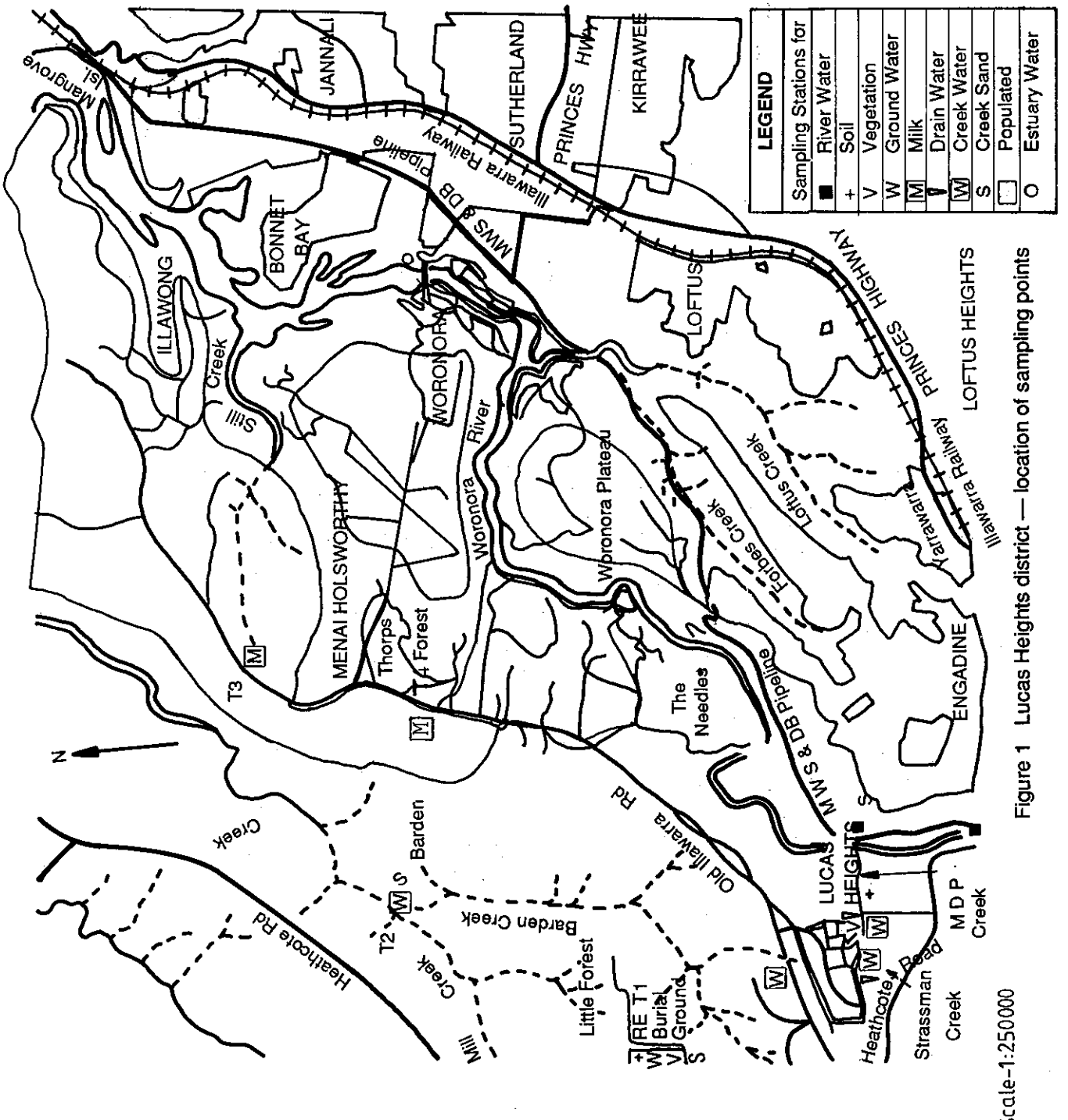
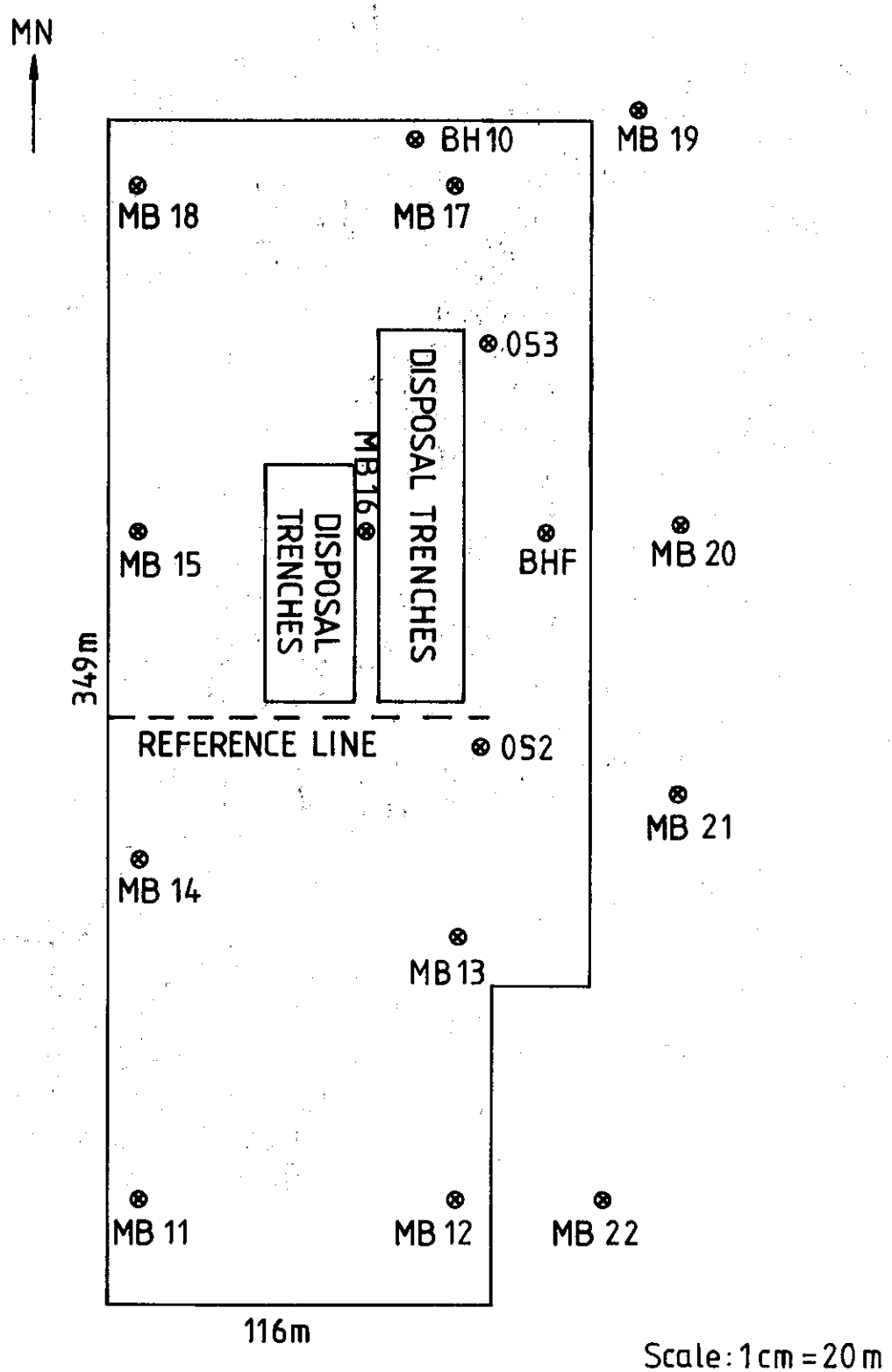


Figure 1 Lucas Heights district — location of sampling points

Figure 2. Little Forest Burial Ground - location of monitoring bores currently in use.



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.

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

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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.

Giles, M.S., Foy, J.J., Hoffmann, E.L. [1989] - Environmental Survey at Lucas Heights Research Laboratories, 1987. ANSTO/E688.

Giles, M.S., Foy, J.J., Hoffmann, E.L. [1990] - Environmental Survey at Lucas Heights Research Laboratories, 1988. ANSTO/E689.

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