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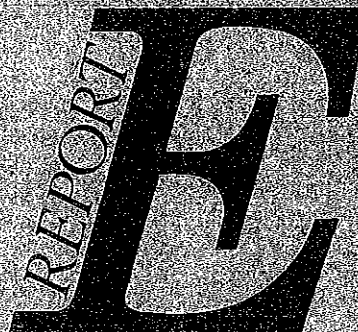


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ENVIRONMENTAL SURVEY  
AT  
LUCAS HEIGHTS  
RESEARCH LABORATORIES,  
1990

by

E.L. HOFFMANN



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AUSTRALIAN NUCLEAR SCIENCE  
AND TECHNOLOGY ORGANISATION

LUCAS HEIGHTS RESEARCH LABORATORIES

ENVIRONMENTAL SURVEY AT  
LUCAS HEIGHTS RESEARCH LABORATORIES, 1990

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E. L. HOFFMANN

ABSTRACT

Results are presented of an environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1990. 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.

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.

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## 1 INTRODUCTION

Since 1959, surveys have been made by the Australian Atomic Energy Commission (and the 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 operations. The results obtained in these surveys have been published regularly and are listed in **appendix A**.

During the early surveys (*i.e.* throughout the 1960's), 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 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 1990 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 (MSW&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.

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

### 5.1 Airborne release

Measureable 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 10th July 1990, and was  $3.6 \times 10^{-4}$  (or 0.036 per cent) of the derived working limit of  $10 \text{ Bq m}^{-3}$ . The derived air concentration for child members of the public [ICRP 1977, 1979], *i.e.* the most sensitive individuals, is  $10 \text{ Bq m}^{-3}$ . The average iodine-131 in air concentration for the year would have resulted in an effective dose of  $<0.3 \times 10^{-3} \text{ mSv y}^{-1}$  or  $<3 \times 10^{-4}$  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 throughout the year, and the single occurrence of caesium-137 was just above the minimum detectable level of  $3 \times 10^{-4} \text{ Bq g}^{-1}$  (fresh weight).

Noble gas releases were always below the authorised limit during the year. See tables 14 and 15. 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  $0.01 \text{ mSv y}^{-1}$ , *i.e.* less than one per cent of the NH&MRC recommendation.

### 5.2 Woronora Estuary Samples

Discharges of radioactivity 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 extraneous 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 1990 (see table 4).

### 5.3 Stormwater Outlets

Results for samples of soil and vegetation collected in stormwater outlets as a check on good housekeeping are shown in table 5. Results for water samples collected at the same sites are given in table 6.

Caesium was occasionally found in water samples from stormwater outlet No.1 (which drains the SE corner of the site into MDP Creek), and measurable amounts of radioactivity were detected in samples of soil and vegetation also collected at this point. These findings are likely to be due to a slight leak of sludge which was acknowledged by Waste Management during a pumping operation at the settling pond. Sampling within the stormwater system on site is continuing in an attempt to locate the source should any further leaks occur. Residual activity in soil and vegetation should decrease gradually over time.

The ICRP has recommended criteria for limiting uptake of radionuclides and given limits for selected nuclides and occupational exposure [ICRP 1979]. In the case of  $^{137}\text{Cs}$  the annual limit of intake (ALI) for occupational exposure has been set by the ICRP at  $4 \times 10^6 \text{ Bq}$ .

As annual limits for members of the public in the ICRP and NH&MRC recommendations are one tenth of those for occupational exposure, the ALI for a member of the public is therefore  $4 \times 10^5$  Bq. If a daily intake of water (from all sources) of 3 litres is assumed, as is stipulated for Reference Man [ICRP 1975], and the ALI is averaged over the year, the derived working limit (DWL) for drinking water concentration is  $365 \text{ Bq L}^{-1}$  for  $^{137}\text{Cs}$  and  $274 \text{ Bq L}^{-1}$  for  $^{134}\text{Cs}$ .

If it was assumed that a person took all of his or her drinking water supplies from the stormwater, the average  $^{137}\text{Cs}$  concentration in water measured during 1990 (Table 6) represents  $1.1 \times 10^{-5}$  or 0.001 per cent of the derived working limit. Making the same assumption, the average  $^{134}\text{Cs}$  concentration during 1990 represents  $1.4 \times 10^{-6}$  or 0.0001 per cent of the DWL.

Small amounts of tritium were occasionally found in stormwater outlet No.1 during 1990, however the results were just above the minimum limit of detection, which is  $0.25 \text{ Bq mL}^{-1}$ . No tritium was detected in any other stormwater drains.

None of these findings would be likely to cause radiation doses to man because no human food chains are involved, and because the ephemeral creek into which the stormwater flows is not used as a source of drinking water.

During 1990, 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 [SPCC 1970] limits of  $1.1 \text{ Bq L}^{-1}$  for gross alpha activity and  $11.1 \text{ Bq L}^{-1}$  for gross beta activity, as were those for water samples collected from stormwater outlet No.1 .

Samples of water were collected from the SPCC sampling weir on Barden Creek at weekly intervals during 1990 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 1990 survey. The maximum annual radiation dose for members of the public recommended by the ICRP[1979] is  $1000 \times 10^{-3} \text{ mSv}$  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 for soil taken below the pipeline joints were close to background levels, no samples of soil were collected along the pipeline in 1990.

#### 5.5 Little Forest Burial Ground

Results of measurements at the Little Forest Burial Ground (LFBG) are given in tables 10, 11, 12 and 13. The positions of sampling points are shown on figure 2.

Levels of  $^{60}\text{Co}$  found in samples of soil, vegetation and groundwater (MB16) are consistent with, or lower than, those found in the past. The levels of radionuclides measured are consistent with naturally occurring background concentrations for  $^{40}\text{K}$ ,  $^7\text{Be}$ , the  $^{238}\text{U}$  and  $^{232}\text{Th}$  series, and with global fallout for  $^{137}\text{Cs}$ . The burial trenches were not top-dressed with soil as was proposed in the 1989 Environmental Survey report, because a study of the LFBG and surrounds was to be commenced in 1990 by Coffey Partners International Pty.Ltd. for the N.S.W. Department of Planning.

Tritium was found in groundwater from the newest series of sampling bores: MB12, MB13, MB16, MB17 and MB20. The older bores BHF, BH10, OS2, and OS3 which have contained tritium in the past were also sampled, and the levels of tritium in these bores were similar to those found previously. Of these bores, only MB20 lies outside the fenced area, and the tritium found in MB20 has no health significance since tritium has a very low radiotoxicity and groundwater is not used from this area.

No tritium or other activity above background levels was detected in samples from creeks draining the LFBG.

No beryllium (Be) was detected on aerosol filters from the remotely operating air sampling station near the burial trenches. The minimum detectable level for Be is  $0.2 \times 10^{-3} \text{ mg m}^{-3}$  and for  $^{239}\text{Pu}$  is  $2.0 \times 10^{-5} \text{ Bq m}^{-3}$  after sampling  $20 \text{ m}^3$  of air. If more air is sampled, these limits are lowered proportionally. The threshold level value (TLV) for Be is  $2 \times 10^{-3} \text{ mg m}^{-3}$  and the derived working concentration (DWC), for  $^{239}\text{Pu}$  is  $5 \times 10^{-4} \text{ Bq m}^{-3}$ . These limits were calculated assuming permanent exposure for 24 hours each day. Initial estimates of  $^{239}\text{Pu}$  were all less than the DWC, and alpha spectrometry subsequently performed on a composite sample of filters for 1990 showed that the  $^{239}\text{Pu}$  level was 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 within authorised limits (tables 14 and 15). The dose to the most sensitive members of the public from  $^{131}\text{I}$  releases, calculated from results in table 2, was  $< 0.3 \times 10^{-3} \text{ mSv y}^{-1}$  and the calculated dose from released noble gases to the most exposed individuals was less than  $0.01 \text{ mSv y}^{-1}$ . These figures represent less than one per cent of the most restrictive limits recommended by the NH&MRC.

## 7 ACKNOWLEDGEMENTS

The author thanks Mr J. Arthur for his technical assistance in the field and laboratory. Beryllium levels and initial estimates of plutonium-239 on the LFBG air filters, as well as the iodine-131 levels in Maypack air samplers were determined by ANSTO's Occupational Health and Safety Program.

Alpha spectrometry (for  $^{239}\text{Pu}$ ) on the composite air filter sample from the LFBG was performed by the Environmental Radiochemistry Laboratory.

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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 $\alpha, \beta, \gamma$ 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 <sub>4</sub>	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, <sup>239</sup> Pu on air filters	Little Forest Burial Ground	Quarterly	Collected on 0.8 $\mu$ m aerosol filter	Disc, 1 cm diameter cut out for Be analysis. Composite made of the quarterly samples for <sup>239</sup> Pu analysis by $\alpha$ 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)	Yearly	Sampled by bottle	5L sample passed through cation-exchange resin and ashed <u>OR</u> evaporated to dryness residue then counted by gamma spectrometry.
	and Mill Creek (above junction with Barden Creek)			50 mL distilled for tritium. Gross alpha and beta counting done on residue.

**TABLE 2**  
**RADIOACTIVE IODINE IN AIR, 1990**

Week ending	$^{131}\text{I}$ (Bq m <sup>-3</sup> )	Week ending	$^{131}\text{I}$ (Bq m <sup>-3</sup> )
9.1.90	LLD	3.7.90	LLD
16.1.90	LLD	10.7.90	3.6x10 <sup>-3</sup>
23.1.90	LLD	17.7.90	LLD
30.1.90	LLD	24.7.90	3.2x10 <sup>-3</sup>
6.2.90	LLD	31.7.90	LLD
13.2.90	LLD	7.8.90	LLD
20.2.90	LLD	14.8.90	LLD
27.2.90	LLD	21.8.90	LLD
6.3.90	LLD	28.8.90	LLD
13.3.90	LLD	4.9.90	LLD
20.3.90	LLD	11.9.90	LLD
27.3.90	LLD	18.9.90	LLD
3.4.90	LLD	25.9.90	LLD
10.4.90	LLD	2.10.90	LLD
17.4.90	3.2x10 <sup>-3</sup>	9.10.90	LLD
24.4.90	LLD	16.10.90	LLD
1.5.90	LLD	23.10.90	LLD
8.5.90	LLD	30.10.90	LLD
15.5.90	LLD	6.11.90	LLD
22.5.90	LLD	13.11.90	LLD
29.5.90	2.7x10 <sup>-3</sup>	20.11.90	LLD
5.6.90	LLD	27.11.90	LLD
12.6.90	LLD	4.12.90	LLD
19.6.90	LLD	11.12.90	LLD
26.6.90	LLD	18.12.90	LLD
		2.1.91	2.6x10 <sup>-3</sup>

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 the 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<sup>-3</sup> Bq m<sup>-3</sup>.

**TABLE 3**  
**RADIOACTIVITY IN MILK SAMPLES, 1990**

Station	Date	Radioactivity (Bq g <sup>-1</sup> fresh volume)	
		Caesium-137	Iodine-131
T4	31.1.90	LLD	LLD
T4	1.3.90	4x10 <sup>-4</sup>	LLD
T4	29.3.90	LLD	LLD
T4	April-August*	-	-
T4	28.9.90	LLD	LLD
T4	30.10.90	LLD	LLD
T4	30.11.90	LLD	LLD
T4	3.1.91	LLD	LLD

LLD = Less than the limit of detection. For <sup>131</sup>I in milk this is 1x10<sup>-3</sup> Bq g<sup>-1</sup> fresh volume. For <sup>137</sup>Cs the minimum detectable level was 3x10<sup>-4</sup> Bq g<sup>-1</sup> fresh volume.

\* No sample available as the cow was not producing milk.

TABLE 4

TRITIUM IN WORONORA RIVER WATER SAMPLES  
AT STATION E5.9, 1990

Date	Tritium (Bq mL <sup>-1</sup> )	Date	Tritium (Bq mL <sup>-1</sup> )
2.1.90	LLD	3.7.90	LLD
9.1.90	LLD	10.7.90	LLD
16.1.90	LLD	17.7.90	LLD
23.1.90	LLD	24.7.90	LLD
30.1.90	LLD	31.7.90	LLD
6.2.90	LLD	7.8.90	LLD
13.2.90	LLD	14.8.90	LLD
20.2.90	LLD	21.8.90	LLD
27.2.90	LLD	28.8.90	LLD
6.3.90	LLD	4.9.90	LLD
13.3.90	LLD	11.9.90	LLD
20.3.90	LLD	18.9.90	LLD
27.3.90	LLD	25.9.90	LLD
3.4.90	LLD	2.10.90	LLD
10.4.90	LLD	9.10.90	LLD
17.4.90	LLD	16.10.90	LLD
24.4.90	LLD	23.10.90	LLD
1.5.90	LLD	30.10.90	LLD
8.5.90	LLD	6.11.90	LLD
15.5.90	LLD	13.11.90	LLD
22.5.90	LLD	20.11.90	LLD
29.5.90	LLD	27.11.90	LLD
5.6.90	LLD	4.12.90	LLD
12.6.90	LLD	11.12.90	LLD
19.6.90	LLD	18.12.90	LLD
26.6.90	LLD	27.12.90	LLD

The Derived limiting concentration(DLC) [ICRP 1979] for tritium is 80 Bq mL<sup>-1</sup> (if taken as drinking water).

LLD = Less than the limit of detection. The limit of detection for tritium is 0.25 Bq mL<sup>-1</sup>

TABLE 5

RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION FROM  
STORMWATER OUTLETS, 1990

Sample Location	Date	Sample Type	Radioactivity (Bq g <sup>-1</sup> DW or FW) (1)			
			Gross $\alpha$	Gross $\beta$	Gamma-emitters	<sup>40</sup> K
Drain on road at West Fence	21.2.90	Soil	0.18	0.08	<sup>238</sup> U+ <sup>232</sup> Th series	N.D.
	27.4.90	Soil	0.09	0.13	<sup>238</sup> U+ <sup>232</sup> Th series	N.D.
	26.7.90	Soil	0.13	0.09	<sup>238</sup> U+ <sup>232</sup> Th series	0.02
	29.10.90	Soil	0.04	0.08	<sup>238</sup> U+ <sup>232</sup> Th series	0.03
Drain at Fermi St	21.2.90	Soil	0.36	0.28	<sup>238</sup> U+ <sup>232</sup> Th series	N.D.
	29.10.90	Soil	0.56	0.20	<sup>238</sup> U+ <sup>232</sup> Th series <sup>7</sup> Be=0.023	0.04
Drain opposite Bld.23	21.2.90	Soil	0.41	0.16	<sup>238</sup> U+ <sup>232</sup> Th series <sup>7</sup> Be=0.045	N.D.
	27.4.90	Soil	0.34	0.07	<sup>238</sup> U+ <sup>232</sup> Th series <sup>60</sup> Co=0.007 <sup>7</sup> Be=0.056	0.06
	26.7.90	Soil	0.76	0.24	<sup>238</sup> U+ <sup>232</sup> Th series Trace Co-60	N.D.
	29.10.90	Soil	0.59	0.21	<sup>238</sup> U+ <sup>232</sup> Th series <sup>137</sup> Cs=0.005	N.D.
Drain No.1 opp. Strassman Crescent	21.2.90	Soil	0.46	0.05	<sup>238</sup> U+ <sup>232</sup> Th series <sup>7</sup> Be=0.064 Trace Cs-137	0.30
	27.4.90	Veg.	<0.01	<0.01	Trace Cs-137 <sup>7</sup> Be=0.028	0.13
	27.4.90	Soil	0.45	0.35	<sup>238</sup> U+ <sup>232</sup> Th series <sup>60</sup> Co=0.038	0.04
	26.7.90	Veg.	0.01	0.14	<sup>238</sup> U+ <sup>232</sup> Th series <sup>7</sup> Be=0.023	0.14
26.7.90 29.10.90 29.10.90	Soil	0.25	0.14	<sup>238</sup> U+ <sup>232</sup> Th series	0.03	
	Soil	0.35	0.22	<sup>238</sup> U+ <sup>232</sup> Th series Trace Cs-137	N.D.	
	Veg.	<0.01	<0.01	<sup>238</sup> U+ <sup>232</sup> Th series <sup>137</sup> Cs=0.001 <sup>7</sup> Be=0.014	0.14	

Continued next page....

TABLE 5 continued...

RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION FROM  
STORMWATER OUTLETS, 1990

Sample Location	Date	Sample Type	Radioactivity (Bq g <sup>-1</sup> DW or FW) (1)			
			Gross $\alpha$	Gross $\beta$	Gamma-emitters	<sup>40</sup> K
Drain No.2 opp. Strassman Cres.	29.10.90	Soil	0.39	0.20	<sup>238</sup> U+ <sup>232</sup> Th series	0.08
Drain opposite Meteorological Tower	21.2.90	Soil	0.44	0.13	<sup>238</sup> U+ <sup>232</sup> Th series	0.08
	27.4.90	Soil	0.57	0.07	<sup>238</sup> U+ <sup>232</sup> Th series	0.13
Tower	26.7.90	Soil	0.50	0.16	<sup>238</sup> U+ <sup>232</sup> Th series	0.07
	29.10.90	Soil	0.43	0.26	<sup>238</sup> U+ <sup>232</sup> Th series	N.D.
20m from LHRL Stormwater Outlet No.1	21.2.90	Soil	0.71	0.44	<sup>238</sup> U+ <sup>232</sup> Th series <sup>137</sup> Cs=0.025 <sup>241</sup> Am=0.005	0.07
	21.2.90	Veg.	0.01	0.06	Trace Am-241 <sup>137</sup> Cs=0.017 <sup>134</sup> Cs=0.004 <sup>7</sup> Be=0.063	0.11
	27.4.90	Soil	0.57	0.32	<sup>238</sup> U+ <sup>232</sup> Th series <sup>137</sup> Cs=0.360 <sup>134</sup> Cs=0.008 <sup>241</sup> Am=0.009 <sup>144</sup> Ce=0.464	0.12
	27.4.90	Veg.	0.08	0.09	<sup>137</sup> Cs=0.012 <sup>134</sup> Cs=0.002 <sup>144</sup> Ce=0.009 <sup>95</sup> Nb=0.002 <sup>95</sup> Zr=0.001 <sup>241</sup> Am=0.001	0.11
	26.7.90	Soil	1.86	3.08	<sup>238</sup> U+ <sup>232</sup> Th series <sup>137</sup> Cs=0.387 <sup>134</sup> Cs=0.023 <sup>144</sup> Ce=0.648 <sup>241</sup> Am=0.198 Trace Co-60	0.13

Continued next page....

TABLE 5 continued...

RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION FROM  
STORMWATER OUTLETS, 1990

Sample Location	Date	Sample Type	Radioactivity (Bq g <sup>-1</sup> DW or FW) <sup>(1)</sup>			
			Gross $\alpha$	Gross $\beta$	Gamma-emitters	<sup>40</sup> K
20m from LHRL Stormwater Outlet No.1 continued...	26.7.90	Veg.	0.01	0.22	<sup>137</sup> Cs=0.046 <sup>134</sup> Cs=0.006 <sup>144</sup> Ce=0.008 <sup>7</sup> Be=0.037 Trace Am-241	0.11
	29.10.90	Soil	1.54	3.50	<sup>238</sup> U+ <sup>232</sup> Th series <sup>137</sup> Cs=0.658 <sup>134</sup> Cs=0.069 <sup>144</sup> Ce=0.552 <sup>241</sup> Am=0.275 <sup>60</sup> Co=0.016	0.06
	29.10.90	Veg.	0.01	0.11	<sup>137</sup> Cs=0.073 <sup>134</sup> Cs=0.007 <sup>144</sup> Ce=0.004 <sup>241</sup> Am=0.001 <sup>7</sup> Be=0.018	0.11

(1) Radioactivity is in units of Bq g<sup>-1</sup> Fresh Weight (FW) for vegetation and Bq g<sup>-1</sup> Dry Weight (DW) for soil samples.

\* Gross Beta results have had the activity due to natural Potassium-40 deducted.

TABLE 6

## RADIOACTIVITY IN WATER SAMPLES FROM STORMWATER OUTLETS, 1990

Sampling Station	Date	Radioactivity (Bq L <sup>-1</sup> )			Tritium (Bq mL <sup>-1</sup> )
		Gross $\alpha$	Gross $\beta^*$	Gamma-emitters	
Drain behind Bld.1	21.2.90	-	-	-	LLD
	27.4.90	-	-	-	LLD
	26.7.90	-	-	-	LLD
	29.10.90	-	-	-	LLD
Drain on road at west fence	21.2.90	-	-	-	LLD
	27.4.90	-	-	-	LLD
	26.7.90	-	-	-	LLD
	29.10.90	-	-	-	LLD
Drain opp. Fermi St.	21.2.90	-	-	-	LLD
	27.4.90	-	-	-	LLD
	26.7.90	-	-	-	LLD
	29.10.90	-	-	-	LLD
Drain opp. Bld.23	27.4.90	-	-	-	LLD
	26.7.90	-	-	-	LLD
Drain No.1 opposite Strassman Crescent	21.2.90	-	-	-	LLD
	27.4.90	-	-	-	LLD
	29.10.90	-	-	-	LLD
Drain No.2 opposite Strassman Crescent	21.2.90	-	-	-	LLD
Drain opp. meteorological tower	21.2.90	-	-	-	LLD
Drain opp. Bld.53	26.7.90	-	-	-	LLD

continued next page...

TABLE 6 continued

## RADIOACTIVITY IN WATER SAMPLES FROM STORMWATER OUTLETS, 1990

Sampling Station	Date	Radioactivity (Bq L <sup>-1</sup> )			Tritium (Bq mL <sup>-1</sup> )
		Gross $\alpha$	Gross $\beta^*$	Gamma-emitters	
20m from stormwater outlet No.1	27.4.90	-	-	-	0.38
	26.7.90	-	-	-	LLD
	29.10.90	-	-	-	LLD
60m from stormwater outlet No.1 (see note)	January	0.15	0.44	N.D.	LLD
	February	0.36	8.12	<sup>137</sup> Cs=0.017 <sup>134</sup> Cs=0.005	LLD
	March	0.23	0.55	<sup>137</sup> Cs=0.017	LLD
	April	0.28	0.38	N.D.	LLD
	11.5.90	0.01	0.70	N.D.	LLD
	May	0.12	0.38	<sup>137</sup> Cs=0.017	LLD
	June	0.24	0.41	trace <sup>137</sup> Cs	LLD
	July	0.14	0.33	N.D.	0.39
	August	0.09	0.31	N.D.	0.40
	September	0.23	0.32	N.D.	LLD
	October	0.12	0.49	N.D.	LLD
	November	0.22	0.36	N.D.	LLD
December	0.36	0.29	N.D.	LLD	

N.D. = Not detected

- = Not measured

Radioactivity (Bq L<sup>-1</sup>) 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 is 0.25 Bq mL<sup>-1</sup>

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

Note: This collection point is still sampled weekly, however all the weekly samples for each month are combined to make a single composite sample. This is then analysed following normal procedure.

TABLE 7

RADIOACTIVITY IN WATER SAMPLES FROM SPCC SAMPLING  
POINTS, 1990

Date	Radioactivity (Bq L <sup>-1</sup> )					
	Strassman Creek		Barden Creek		MDP Creek	
	Gross $\alpha$	Gross $\beta$	Gross $\alpha$	Gross $\beta$	Gross $\alpha$	Gross $\beta$
1.2.90	LLD	LLD	LLD	LLD	LLD	0.18
28.2.90	LLD	LLD	LLD	LLD	LLD	0.32
26.3.90	LLD	LLD	LLD	LLD	LLD	0.25
27.4.90	LLD	LLD	LLD	LLD	LLD	0.14
21.5.90	LLD	0.25	LLD	0.36	LLD	0.43
3.7.90	LLD	0.12	LLD	0.10	LLD	0.14
30.7.90	LLD	LLD	LLD	0.10	LLD	LLD
28.8.90	LLD	0.10	LLD	LLD	LLD	0.13
25.9.90	LLD	LLD	LLD	LLD	LLD	0.12
23.10.90	LLD	LLD	LLD	LLD	LLD	LLD
28.11.90	LLD	0.19	LLD	0.17	LLD	0.22
17.12.90	LLD	LLD	LLD	LLD	LLD	0.19

LLD = Less than the limit of detection. The limits of detection  
for gross alpha = 0.07 Bq L<sup>-1</sup>,  
for gross beta = 0.10 Bq L<sup>-1</sup>.

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

TABLE 8

TRITIUM IN WATER FROM SPCC SAMPLING POINT  
AT BARDEN CREEK WEIR, 1990

Date	Tritium (Bq mL <sup>-1</sup> )	Date	Tritium (Bq mL <sup>-1</sup> )
2.1.90	LLD	3.7.90	LLD
9.1.90	LLD	10.7.90	LLD
16.1.90	LLD	17.7.90	LLD
23.1.90	LLD	24.7.90	LLD
30.1.90	LLD	31.7.90	LLD
6.2.90	LLD	7.8.90	LLD
13.2.90	LLD	14.8.90	LLD
20.2.90	LLD	21.8.90	LLD
27.2.90	LLD	28.8.90	LLD
6.3.90	LLD	4.9.90	LLD
13.3.90	LLD	11.9.90	LLD
20.3.90	LLD	18.9.90	LLD
27.3.90	LLD	25.9.90	LLD
3.4.90	LLD	2.10.90	LLD
10.4.90	LLD	9.10.90	LLD
17.4.90	LLD	16.10.90	LLD
24.4.90	LLD	23.10.90	LLD
1.5.90	LLD	30.10.90	LLD
8.5.90	LLD	6.11.90	LLD
15.5.90	LLD	13.11.90	LLD
22.5.90	LLD	20.11.90	LLD
29.5.90	LLD	27.11.90	LLD
5.6.90	LLD	4.12.90	LLD
12.6.90	LLD	11.12.90	LLD
19.6.90	LLD	18.12.90	LLD
26.6.90	LLD	27.12.90	LLD

Derived limiting concentration(DLC) [ICRP 1979].  
 DLC for tritium = 80mL<sup>-1</sup> (if taken as drinking water).  
 LLD = Less than the limit of detection. The limit of  
 detection for tritium is 0.25 Bq mL<sup>-1</sup>

TABLE 9

GAMMA SURVEY - EFFLUENT DISCHARGE PIPELINE, 1990  
 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 ( $\mu\text{Sv h}^{-1}$ )		Background range ( $\mu\text{Sv h}^{-1}$ )
		Ground	Pipeline	
4.5.90	Joints #1-17	<0.16	<0.11	0.05-0.13
	Joints #20-22	<0.10	<0.10	0.07-0.08
28.11.90	Joints #1-17	<0.30	<0.30	0.06-0.30
	Joints #20-22	<0.10	<0.10	0.08

Note: Joints No. 18 and 19 are inaccessible.

TABLE 10

RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION  
 FROM LITTLE FOREST BURIAL GROUND, 1990

Sample Location	Sample Type	Date	Radioactivity ( $\text{Bq g}^{-1}$ DW or FW)			
			Gross $\alpha$	Gross $\beta^*$	Gamma-emitters	$^{40}\text{K}$
Point #6	Veg.	3.5.90	0.09	3.71	$^7\text{Be}=0.11$ $^{137}\text{Cs}=0.006$ $^{60}\text{Co}=0.097$	0.11
Point #6	Soil	18.12.90	0.61	2.97	$^{238}\text{U}+^{232}\text{Th}$ series $^{60}\text{Co}=0.10$ $^{137}\text{Cs}=0.006$	0.11
Point #5	Soil	18.12.90	0.61	0.43	$^{238}\text{U}+^{232}\text{Th}$ series	0.22

Note: Radioactivity is in units of  $\text{Bq g}^{-1}$  Fresh Weight (FW) for vegetation and  $\text{Bq g}^{-1}$  Dry Weight (DW) for soil samples.

\* Potassium-40 contribution to Gross Beta activity has been deducted.

TABLE 11

 RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM  
 LITTLE FOREST BURIAL GROUND, 1990

Bore Hole No.	Date	Radioactivity (Bq.g <sup>-1</sup> sediment)			Tritium (Bq mL <sup>-1</sup> )
		Gross $\alpha$	Gross $\beta^*$	gamma -emitters	
MB11	25.6.90	0.22	0.06	N.D.	LLD
MB12	"	0.32	0.18	N.D.	LLD
MB13	"	0.93	1.02	N.D.	8.5
MB14	"	1.97	0.43	Trace <sup>238</sup> U+ <sup>232</sup> Th series	LLD
MB15	"	1.86	0.38	N.D.	LLD
MB16	"	2.89	6.83	<sup>60</sup> Co=0.50	16.0
MB17	"	0.54	0.46	N.D.	3.0
MB18	"	2.86	0.65	N.D.	LLD
MB19	"	0.25	0.26	N.D.	LLD
MB20	"	0.84	0.80	N.D.	0.3
MB21	"	0.94	0.39	N.D.	LLD
BHF	2.7.90	1.41	5.16	N.D.	1.2
BH10	25.6.90	0.21	0.76	N.D.	5.5
OS2	"	2.95	1.18	N.D.	6.7
OS3	"	1.00	4.08	N.D.	3.0
MB11	18.12.90	0.11	0.04	N.D.	LLD
MB12	"	0.56	0.39	N.D.	1.0
MB13	"	0.09	0.19	N.D.	6.8
MB14	"	0.26	0.15	N.D.	LLD
MB15	"	2.04	0.43	N.D.	LLD
MB16	"	6.09	5.96	<sup>60</sup> Co=1.17	17.6
MB17	"	2.46	0.73	N.D.	3.3
MB18	"	0.89	0.26	N.D.	LLD
MB19	"	0.27	0.23	N.D.	LLD
MB20	"	0.39	0.58	N.D.	0.6
MB21	"	0.24	0.18	N.D.	LLD
BH10	"	0.22	0.84	N.D.	6.0
OS2	"	2.52	1.17	N.D.	2.6
OS3	"	2.13	2.86	N.D.	10.1
BHF	"	1.34	2.96	N.D.	3.1

LLD = Less than the limit of detection. LLD for tritium is 0.25Bq mL<sup>-1</sup>

N.D.= Not detected

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

TABLE 12

RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE  
FOREST BURIAL GROUND, 1990

SAND					
Sample Station	Date	Radioactivity(Bq g <sup>-1</sup> DW)			
		Gross $\alpha$	Gross $\beta^*$	Gamma-emitters	<sup>40</sup> K
Mill Creek (above junction with Barden Ck.)	14.11.90	0.42	0.28	<sup>238</sup> U + <sup>232</sup> Th series Trace <sup>137</sup> Cs	0.14
Barden Creek (above junction with Mill Ck.)	14.11.90	0.25	0.08	<sup>238</sup> U + <sup>232</sup> Th series	N.D.
WATER					
Sample Station	Date	Radioactivity(Bq L <sup>-1</sup> )			Tritium (Bq mL <sup>-1</sup> )
		Gross $\alpha$	Gross $\beta$	Gamma-emitters	
Mill Creek (above junction with Barden Ck.)	14.11.90	0.22	0.10	<sup>232</sup> Th series	LLD
Barden Creek (above junction with Mill Ck.)	14.11.90	0.44	0.07	N.D.	LLD

LLD = Less than the limit of detection.

LLD For Tritium is 0.25 Bq mL<sup>-1</sup>

N.D.= Not Detected

\* = Gross Beta results for soils have had the potassium-40 contribution deducted.

TABLE 13

## RESULTS OF AIR SAMPLING AT LITTLE FOREST BURIAL GROUND, 1990

Sampling period	Air volume sampled (m <sup>3</sup> )	Be (ug m <sup>-3</sup> ) (1)	<sup>239</sup> Pu (Bq m <sup>-3</sup> ) (2)
20.12.89 to 6.4.90	122.41	LLD	<DWC
6.4.90 to 4.7.90	16.79	LLD	<DWC
4.7.90 to 27.9.90	75.60	LLD	<DWC
27.9.90 to 18.12.90	136.43	LLD	<DWC
1990 Composite (3)	335.05	-	LLD

LLD = Less than the limit of detection. The limit of detection for Be is 0.2ug m<sup>-3</sup> and for <sup>239</sup>Pu is 2x10<sup>-5</sup> Bq m<sup>-3</sup>

- (1) The total limiting volume (TLV) for Be = 2 ug m<sup>-3</sup>.
- (2) The derived working concentration (DWC) for <sup>239</sup>Pu = 5x10<sup>-4</sup> Bq m<sup>-3</sup>.
- (3) Composite sample of duplicate sets of air filters for 1990. Result determined by alpha spectrometry.

TABLE 14

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL  
DISCHARGE POINTS, 1990

Period and Bld. Number	Gross $\alpha$ (kBq)	$^{131}\text{I}$ (MBq)	$^{90}\text{Sr}$ (MBq)	$^3\text{H}$ (GBq)	Fission Product noble gases (TBq)	Other activity (MBq)
<b>Quarter No.1</b>						
Bld. 2	<7	5150	<0.1	-	118.3	27900
3	<1	1.5	-	-	-	-
15(Hifar)	<2	2.3	<0.2	700	21.6	76
19	<11	33	<0.2	-	-	-
20	<5	3	<0.1	38	-	-
21A	2	0.6	0.04	-	-	-
21B	0.5	0.2	0.01	-	-	-
23A	<11	17900	<0.2	-	-	204
23B	<1	2.6	<0.02	-	-	-
41	<4	6.6	<0.08	-	-	-
56	<15	1.7	<0.3	-	-	-
57	<1	0.7	<0.02	4.4	-	-
<b>Quarter No.2</b>						
Bld. 2	<7	5580	<0.1	-	92.9	37900
3	<4	0.6	<0.1	-	-	-
15(Hifar)	<2	1.0	<0.1	750	18.3	39
19	<11	190	<0.2	-	-	-
20	<6	4	<0.1	24	-	-
21A	2	0.6	0.03	-	-	-
21B	0.4	0.1	0.01	-	-	-
23A	<10	1280	<0.2	-	-	309
23B	<1	0.5	<0.02	-	-	-
41	<4	0.6	<0.06	-	-	-
56	<14	1.9	<0.2	-	-	-
57	<1	0.5	<0.02	86.9	-	-
<b>Quarter No.3</b>						
Bld. 2	<7	5420	<0.1	-	103.8	24900
3	<5	0.5	<0.1	-	-	-
15(Hifar)	<3	2.2	<0.2	700	20.4	71
19	<11	70	<0.2	-	-	-
20	<6	<4	<0.1	7.2	-	-
21A	2	0.6	0.04	-	-	-
21B	0.4	0.1	0.01	-	-	-
23A	<10	1320	<0.3	-	-	112
23B	<1	0.5	<0.02	-	-	-
41	<4	0.9	<0.09	-	-	-
56	<15	0.9	<0.3	-	-	-
57	<1	0.2	<0.02	3.5	-	-

continued next page....

TABLE 14 continued...

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL  
DISCHARGE POINTS, 1990

Period and Bld. Number	Gross $\alpha$ (kBq)	$^{131}\text{I}$ (MBq)	$^{90}\text{Sr}$ (MBq)	$^3\text{H}$ (GBq)	Fission Product noble gases (TBq)	Other activity (MBq)
<b>Quarter No.4</b>						
Bld. 2	<12	7420	<0.15	-	100.8	45850
3	<6	1.0	<0.1	-	-	-
15(Hifar)	<2	1.4	<0.2	666	21.5	83
19	<11	31.5	<0.25	-	-	-
20	<5	0.4	<0.1	12	-	-
21A	2	0.1	<0.04	-	-	-
21B	0.8	0.4	<0.02	-	-	-
23A	<11	1430	<0.3	-	-	-
23B	<1.2	0.6	<0.03	-	-	-
41	<4	1.0	<0.09	-	-	-
56	<15	3.9	<0.3	-	-	-
57	<1	0.2	<0.04	10.2	-	-

- = 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 15

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL  
DISCHARGE POINTS, EXPRESSED AS FRACTIONS OF AUTHORISED  
QUARTERLY POINT DISCHARGE FOR 1990

Period and Bld. Number	Gross $\alpha$	$^{131}\text{I}$	$^{90}\text{Sr}$	$^3\text{H}$	Fission Product noble gases	Other Activity
<b>Quarter No.1</b>						
2	$<1.1 \times 10^{-5}$	$7.8 \times 10^{-2}$	$<1.6 \times 10^{-7}$	-	0.70	$1.7 \times 10^{-2}$
3	$<6.3 \times 10^{-4}$	$9.4 \times 10^{-5}$	-	-	-	-
15	$<6.1 \times 10^{-5}$	$1.4 \times 10^{-4}$	$<7.7 \times 10^{-6}$	$5.3 \times 10^{-3}$	0.80	$1.2 \times 10^{-3}$
19	$<3.3 \times 10^{-5}$	$1.0 \times 10^{-3}$	$<7.7 \times 10^{-7}$	-	-	-
20	$<1.8 \times 10^{-3}$	$1.8 \times 10^{-4}$	$<2.4 \times 10^{-4}$	$4.7 \times 10^{-3}$	-	-
21A	$2.0 \times 10^{-3}$	$1.0 \times 10^{-4}$	$2.9 \times 10^{-4}$	-	-	-
21B	$2.2 \times 10^{-3}$	$1.5 \times 10^{-4}$	$3.0 \times 10^{-4}$	-	-	-
23A	$<6.9 \times 10^{-4}$	1.1	$<1.5 \times 10^{-5}$	-	-	$6.2 \times 10^{-3}$
23B	$<1.5 \times 10^{-4}$	$1.6 \times 10^{-4}$	$<3.1 \times 10^{-6}$	-	-	-
41	$<1.2 \times 10^{-5}$	$4.1 \times 10^{-4}$	$<3.1 \times 10^{-7}$	-	-	-
56	$<1.9 \times 10^{-3}$	$3.9 \times 10^{-5}$	$<2.7 \times 10^{-4}$	-	-	-
57	$<1.6 \times 10^{-3}$	$1.9 \times 10^{-4}$	$<2.2 \times 10^{-4}$	$2.4 \times 10^{-3}$	-	-
<b>Quarter No.2</b>						
2	$<1.1 \times 10^{-5}$	$8.4 \times 10^{-2}$	$<1.6 \times 10^{-7}$	-	0.55	$2.4 \times 10^{-2}$
3	$<2.5 \times 10^{-3}$	$3.8 \times 10^{-5}$	$<7.7 \times 10^{-5}$	-	-	-
15	$<6.1 \times 10^{-5}$	$6.3 \times 10^{-5}$	$<3.8 \times 10^{-6}$	$5.8 \times 10^{-3}$	0.67	$5.9 \times 10^{-4}$
19	$<3.3 \times 10^{-5}$	$5.8 \times 10^{-3}$	$<7.7 \times 10^{-7}$	-	-	-
20	$<2.1 \times 10^{-3}$	$2.5 \times 10^{-4}$	$<2.4 \times 10^{-4}$	$3.0 \times 10^{-3}$	-	-
21A	$2.0 \times 10^{-3}$	$1.0 \times 10^{-4}$	$2.1 \times 10^{-4}$	-	-	-
21B	$1.7 \times 10^{-3}$	$7.7 \times 10^{-5}$	$3.0 \times 10^{-4}$	-	-	-
23A	$<6.3 \times 10^{-4}$	$8.0 \times 10^{-2}$	$<1.5 \times 10^{-5}$	-	-	$9.4 \times 10^{-3}$
23B	$<1.5 \times 10^{-4}$	$3.1 \times 10^{-5}$	$<3.1 \times 10^{-6}$	-	-	-
41	$<1.2 \times 10^{-5}$	$3.8 \times 10^{-5}$	$<2.3 \times 10^{-7}$	-	-	-
56	$<1.8 \times 10^{-3}$	$4.3 \times 10^{-5}$	$<1.8 \times 10^{-4}$	-	-	-
57	$<1.6 \times 10^{-3}$	$1.4 \times 10^{-4}$	$<2.2 \times 10^{-4}$	$4.8 \times 10^{-2}$	-	-
<b>Quarter No.3</b>						
2	$<1.1 \times 10^{-5}$	$8.2 \times 10^{-2}$	$<1.6 \times 10^{-7}$	-	0.61	$1.6 \times 10^{-2}$
3	$<3.1 \times 10^{-5}$	$3.1 \times 10^{-5}$	$<7.7 \times 10^{-5}$	-	-	-
15	$<9.1 \times 10^{-5}$	$1.4 \times 10^{-4}$	$<7.7 \times 10^{-6}$	$5.4 \times 10^{-3}$	0.76	$1.1 \times 10^{-3}$
19	$<3.3 \times 10^{-5}$	$2.1 \times 10^{-3}$	$<7.7 \times 10^{-7}$	-	-	-
20	$<2.1 \times 10^{-3}$	$<2.5 \times 10^{-4}$	$<2.4 \times 10^{-4}$	$8.9 \times 10^{-4}$	-	-
21A	$2.0 \times 10^{-3}$	$1.0 \times 10^{-4}$	$2.9 \times 10^{-4}$	-	-	-
21B	$1.7 \times 10^{-3}$	$7.7 \times 10^{-5}$	$3.0 \times 10^{-4}$	-	-	-
23A	$<6.3 \times 10^{-4}$	$8.3 \times 10^{-2}$	$<2.3 \times 10^{-5}$	-	-	$3.4 \times 10^{-3}$
23B	$<1.5 \times 10^{-4}$	$3.1 \times 10^{-5}$	$<3.1 \times 10^{-6}$	-	-	-
41	$<1.2 \times 10^{-5}$	$5.6 \times 10^{-5}$	$<3.5 \times 10^{-7}$	-	-	-
56	$<1.9 \times 10^{-3}$	$2.0 \times 10^{-5}$	$<2.7 \times 10^{-4}$	-	-	-
57	$<1.6 \times 10^{-3}$	$5.5 \times 10^{-5}$	$<2.2 \times 10^{-4}$	$1.9 \times 10^{-3}$	-	-

continued next page...

TABLE 15 continued...

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL  
DISCHARGE POINTS, EXPRESSED AS FRACTIONS OF AUTHORISED  
QUARTERLY POINT DISCHARGE FOR 1990

Period and Bld. Number	Gross $\alpha$	$^{131}\text{I}$	$^{90}\text{Sr}$	$^3\text{H}$	Fission Product noble gases	Other Activity
<b>Quarter No.4</b>						
2	$<1.8 \times 10^{-5}$	$11.0 \times 10^{-2}$	$<2.3 \times 10^{-7}$	-	0.59	$2.9 \times 10^{-2}$
3	$<3.8 \times 10^{-3}$	$6.3 \times 10^{-5}$	$<7.7 \times 10^{-5}$	-	-	-
15	$<6.1 \times 10^{-5}$	$8.8 \times 10^{-5}$	$<7.7 \times 10^{-6}$	$5.1 \times 10^{-3}$	0.80	$1.3 \times 10^{-3}$
19	$<3.3 \times 10^{-5}$	$9.5 \times 10^{-4}$	$<9.6 \times 10^{-7}$	-	-	-
20	$<1.8 \times 10^{-3}$	$2.5 \times 10^{-5}$	$<2.4 \times 10^{-4}$	$1.5 \times 10^{-3}$	-	-
21A	$2.0 \times 10^{-3}$	$1.7 \times 10^{-5}$	$<2.8 \times 10^{-4}$	-	-	-
21B	$3.5 \times 10^{-3}$	$3.1 \times 10^{-4}$	$<6.1 \times 10^{-4}$	-	-	-
23A	$<6.9 \times 10^{-4}$	$8.9 \times 10^{-2}$	$<2.3 \times 10^{-5}$	-	-	-
23B	$<1.8 \times 10^{-4}$	$3.8 \times 10^{-5}$	$<4.7 \times 10^{-6}$	-	-	-
41	$<1.2 \times 10^{-5}$	$6.3 \times 10^{-5}$	$<3.5 \times 10^{-7}$	-	-	-
56	$<1.9 \times 10^{-3}$	$8.9 \times 10^{-5}$	$<2.7 \times 10^{-4}$	-	-	-
57	$<1.6 \times 10^{-3}$	$5.6 \times 10^{-5}$	$<4.4 \times 10^{-4}$	$5.7 \times 10^{-3}$	-	-

- = Not measured

TABLE 16

RADIOACTIVITY DISCHARGED TO THE MWS&DB SEWER  
DURING 1990

Quarter ending	Radioisotopes measured (MBq)			Percentage of* authorised limit
	$\alpha$ u	Tritium	$\beta$ u	
31 March 1990	27.34	$8.0 \times 10^5$	452.16	25.9
30 June 1990	91.69	$2.4 \times 10^6$	327.49	39.7
30 Sept. 1990	27.42	$2.5 \times 10^5$	497.50	28.0
31 Dec. 1990	15.53	$2.5 \times 10^5$	233.88	17.9

Au = A mixture of unidentified alpha-emitting nuclides taken as being all radium-226 (i.e.the worst possible case) when calculating the percentage of authorised limit.

Bu = A mixture of unidentified beta-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.

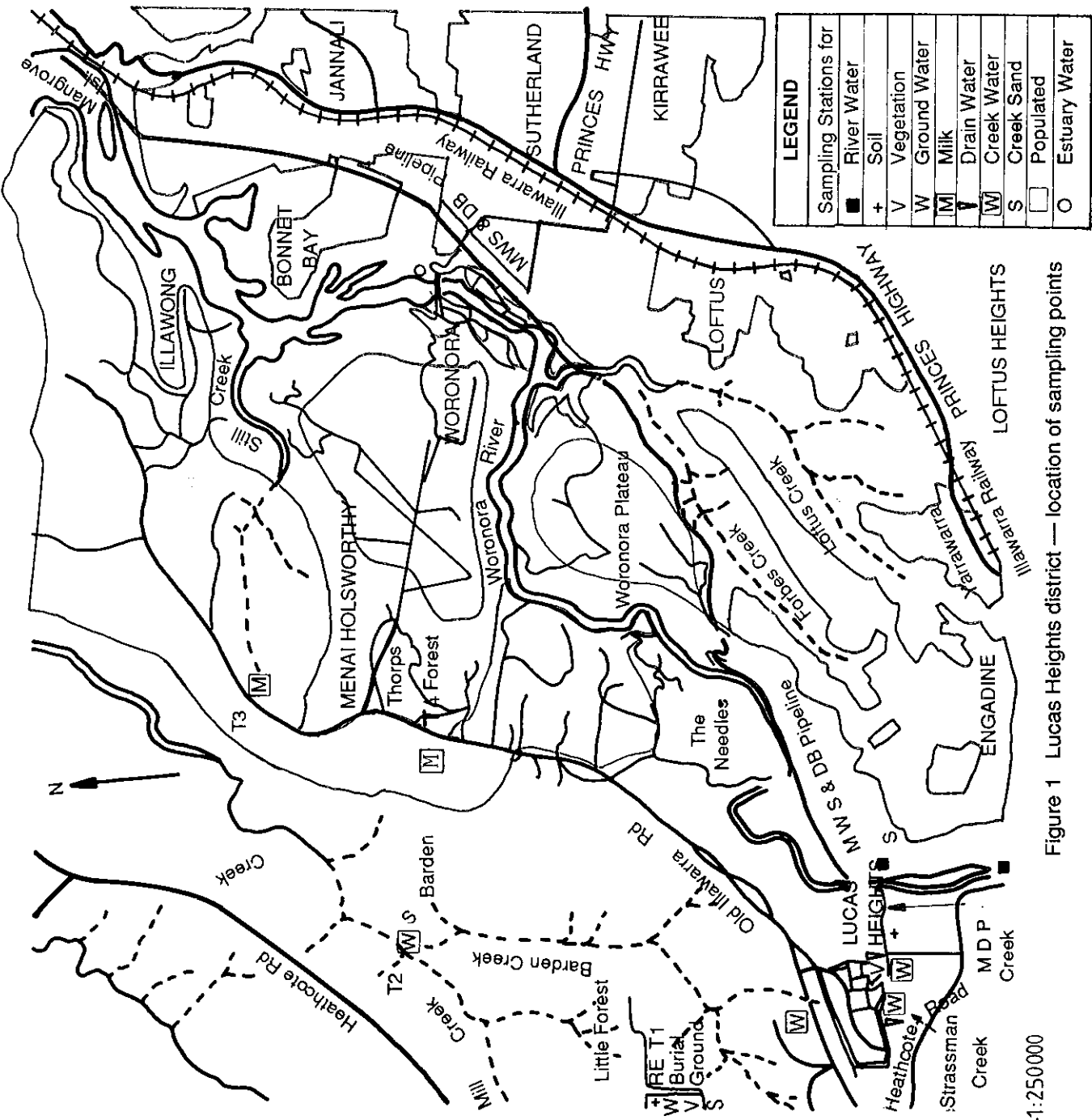
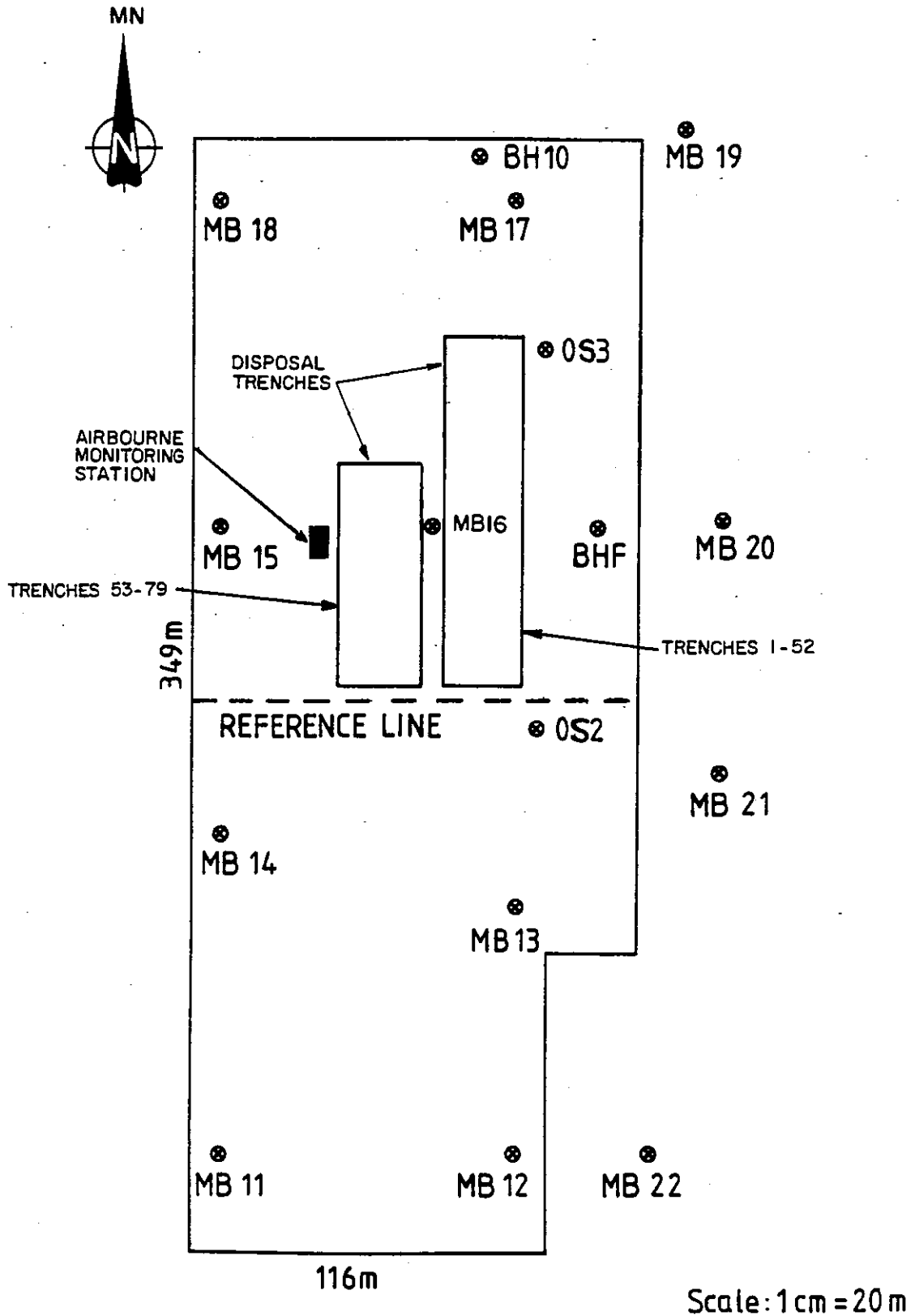


Figure 1 Lucas Heights district — location of sampling points

Scale-1:250000



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.
- 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.
- 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.
- Hoffmann, E.L., Arthur, A. [1990] - Environmental Survey at Lucas Heights Research Laboratories, 1989. ANSTO/E694

## APPENDIX B

## NEW ANALYTICAL PROCEDURES

Gamma spectrometry of environmental survey samples is now performed using a high-purity germanium crystal of 25% Relative Efficiency. This detector has greater peak resolution capability than the old sodium-iodide crystal used previously, therefore nuclide detection and identification has been greatly improved.

## APPENDIX C

LIST OF ISOTOPE SYMBOLS USED IN  
TABLES  
OF SURVEY RESULTS

Symbol	Name
<sup>241</sup> Am	americium-241
<sup>7</sup> Be	beryllium-7
<sup>60</sup> Co	cobalt-60
<sup>137</sup> Cs	caesium-137
<sup>134</sup> Cs	caesium-134
<sup>3</sup> H	tritium
<sup>131</sup> I	iodine-131
K	potassium(stable)
<sup>40</sup> K	potassium-40
<sup>95</sup> Nb	niobium-95
<sup>239</sup> Pu	plutonium-239
<sup>226</sup> Ra	radium-226
<sup>90</sup> Sr	strontium-90
<sup>232</sup> Th	thorium-232
<sup>238</sup> U	uranium-238
<sup>65</sup> Zn	zinc-65
<sup>95</sup> Zr	zirconium-95