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AUSTRALIAN ATOMIC ENERGY COMMISSION
RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

ENVIRONMENTAL SURVEY AT THE AAEC RESEARCH ESTABLISHMENT
LUCAS HEIGHTS – RESULTS FOR 1973

by

D. R. DAVY
A. DUDAITIS

December 1974

Reprinted May 1979

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ABSTRACT

This report tabulates the results of the environmental survey at Lucas Heights during 1973 and compares them with derived maximum permissible concentrations appropriate to the local environment.

Possible doses to individual members of the local population as a result of Research Establishment operations are less than those due to weapons test fallout and much less than those due to natural radiation background.

CONTENTS

INTRODUCTION

This report gives results obtained from samples collected for the environmental survey program at Lucas Heights during 1973. The rationale for the program and a synopsis of results for the period 1965-1970 have been reported by Watson (1972).

2. SAMPLING PROGRAM

The Woronora estuary receives treated low level aqueous waste from the Research Establishment. Table 1 gives details of the collection and preparation of samples taken from the estuary for the environmental survey program. Figure 1 gives the location of estuary sampling stations.

Table 2 gives details of terrestrial samples and their preparation, and Figure 2 gives the location of terrestrial sampling stations.

3. TABULATION OF RESULTS

Tables 3 to 7 refer to samples collected from the Woronora estuary and Table 8 refers to milk samples from the terrestrial environment. These samples show no trace of radioactivity from airborne waste arising from the Research Establishment. Table 9 refers to samples taken from the closed solid waste burial ground (Station T 1, one mile from the Research Establishment).

4. DISCUSSION OF RESULTS

4.1 Woronora Estuary

The results for estuarine water, oysters, fish and beach sand are summarised in Table 12 where the average results for the period are expressed as fractions of the derived maximum permissible concentrations (m.p.c.). The results for the period 1967 to 1972 are included for comparison.

The isotopes detected were the same as were found in previous years. The levels for tritium in water, zinc-65 in oysters and cobalt-60 in fish were all less than one thousandth of the derived maximum permissible concentrations. Gross alpha and gross beta activities in beach sand samples, attributed to natural activity, were generally the same as in previous years at two thousandths and one thousandth of the derived maximum permissible concentrations.

Dosimeters placed on the bottom sand at the discharge point showed measurable results (Table 11 and Figure 3), and these levels are attributed to waste discharge operations. Cook & Dudaitis (1970) established that levels of gross alpha and gross beta activity bottom sands at 1.5 miles are not significantly different from those in beach sand samples in areas removed from possible influence by site operation, and are attributed to natural activity.

Water samples taken from 3.6 miles above the discharge point showed no significant changes from previous years.

Zostera (Table 7) showed the same activity concentrations as in previous years with cobalt-60 and manganese-54 gamma emitters detected. This activity is attributed to site operations. Also traces of uranium series were detected. This activity is attributed to the recent dredging of Woronora River. There are no identifiable human exposure routes for Zostera and hence no derived maximum permissible concentrations.

4.2 Terrestrial Samples Related to Possible Airborne Waste

Caesium-137 found in milk samples (Table 8) is attributable to the expected activity from weapons test fallout. (The lower limit of detection of iodine-131 in milk (Table 8) is 0.3 pCi g^{-1} fresh weight, at the 95 per cent confidence level.) There is no indication in these samples of any deposition of airborne waste from the Research Establishment. The figures are comparable to previous years.

4.3 Other Terrestrial Samples

Samples from the closed solid waste burial ground are listed in Table 9. Vegetation taken from the point nearest to the actual buried waste showed the presence of cobalt-60, caesium-137 and traces of mixed fission products. Water from boreholes in the burial ground showed only trace levels of 0.5 MeV gamma emitters.

Subsurface water from the burial ground is expected to drain into Mill Creek north of the burial ground (see Figure 2). For this reason, a line of five borehole sampling sites (designated A to E) is maintained just outside the northern perimeter of the burial ground. Water samples from these holes contain alpha activity from a near equilibrium (*i.e.* naturally occurring) uranium series.

During the year, a review was made of the safety assessment under which past operation of the burial ground had been approved. It was concluded that too much credit had been given to soil adsorption of trace elements, and too little attention to the eluting nature of the macro constituents in the ground water. A more realistic model was postulated and each of the many assumptions made in its development is being subjected to experimental evaluation.

The reported results (Table 9) are not inconsistent with the predictions from the model. It is however unable to explain the isolated region within the burial site that has a strontium-90 level in the surface soil of 15.7 pCi g^{-1}. Because of the small amount of radioactivity buried at the site, the predictive ability of any model is only important in so far as contamination of the neighbouring clay pits is a possibility to be evaluated.

Analysis of clay samples revealed strontium-90 (0.01 pCi g^{-1}) but no

cobalt-60 or caesium-137. For samples of this type, the detection limit on caesium-137 and cobalt-60 is about 0.1 pCi g^{-1}. Since strontium and cobalt have about the same mobility in soil (Saas & Grauby 1973), the detected strontium-90 can be attributed to fallout.

The detected radioactivity in the stormwater drains reported in Table 10 is attributed to site operations. The radiological significance of this contamination is minimal. Attempts to find the source of this material have so far been unsuccessful, but they are continuing.

5. RADIOLOGICAL SIGNIFICANCE OF THE RESULTS

The results have been used to calculate the maximum potential doses to individual members of the local population from ingestion of oysters, fish or milk, or by the other exposure pathways which were taken into account in setting discharge limits. These are given in Table 13.

Maximum whole-body doses from the ingestion of tritium and zinc-65, attributable to operations at the Research Establishment, are 0.01 and 0.03 millirem per year respectively. The total annual dose for a hypothetical individual who consumes 70 g each of local oysters and fish, and swims daily at the discharge point, is 0.08 millirem. This is less than one five-thousandth of the maximum permissible dose limits for members of the public (ICRP 1966).

The traces of activity reported in other samples give no exposure to man. The activity in milk is attributable to fallout and the beach sand activity is natural. For comparison, internal and external whole-body dose from natural background radiation is of the order 100 millirem per year.

6. SUMMARY

During 1973, no radioactivity attributable to aerial dispersion from the Research Establishment was detected in the environment.

In the Woronora estuary, a number of radioisotopes were detected other than those that occur naturally, in weapons test fallout, or in quantities in excess of natural or fallout concentrations. These are attributed to low level liquid effluent discharges in the estuary. Those found were tritium (as water), cobalt-60 (in fish, Zostera and beach sand 1280 metres away from the discharge point), and zinc-65 (in oysters).

At the solid waste burial ground, cobalt-60 attributed to buried waste has been detected in vegetation taken near the buried material.

Levels of activity attributable to Research Establishment operations were similar to those of previous years and generally of the order of, or

less than, one thousandth of the appropriate derived maximum permissible concentrations.

Estimates of possible doses to individual members of the public from Research Establishment operations give results less than those attributable to weapons test fallout and much less than natural radiation background.

7. ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance received from members of Environment & Public Health Division and Chemical Technology Division in the collection, processing and chemical and radiochemical analysis of samples.

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ENVIRONMENTAL SURVEY RESULTS

(1973)

TABLES 1-13

NOTE: Upper limits shown in Tables 3-12 are at the 95 per cent confidence level of the counting statistics. Where an upper limit is given for an average this is the upper limit of the average of all results. Dashes indicate that no activity was detected and blank spaces that no measurement was made.

TABLE 1

DETAILS OF COLLECTION AND PREPARATION OF ESTUARINE SAMPLES

Sample	Stations	Collection Frequency	Collection Details	Special Steps in Preparation
Oysters	E4.4, E5.8 Control	Quarterly	Obtained from commercial leases	Opened by commercial openers. Drained on sieve for 5 minutes. Ashed
Fish	E0.8, E4.0	Quarterly	Caught by seine net	Whole fish ashed
Beach Sand	E0.8, E3.7	Six Monthly	Taken by scoop from top 2 in. in the intertidal region	Fraction between 60 and 120 mesh B.S.S. removed after ashing
Estuary Water	E3.6	Weekly	From surface by bucket	Distilled for tritium
Zostera	E1.0, E1.5 E2.9, E4.4 E5.8	Quarterly	Pulled from bottom by rake or hand	Ashed

TABLE 2

DETAILS OF COLLECTION AND PREPARATION OF TERRESTRIAL SAMPLES

Sample	Stations	Collection Frequency	Collection Details	Special Steps in Preparation
Milk	T3.1	Monthly	Obtained from bulk milk supplies	Gamma spectrometry of whole milk for iodine-131
Vegetation	T1	Six Monthly	Cut by hand clippers	Whole unwashed vegetation is ashed
Ground Water	T1	Six Monthly	Boreholes pumped out, allowed to refill, sample taken from bottom	The water is passed through 200 ml of Amberlite IRC 120 resin, which is then ashed
Creek Water	TO	Six Monthly	Taken in bucket	As for ground water (Distilled for tritium)
	T2	Six Monthly		

TABLE 3

WORONORA SAMPLES - OYSTER FLESH, 1973

Station	Date 1973	Radioactivity, pCi g^{-1} Fresh Weight			K (ppm)
		Gross Alpha	Gross Beta (less ^{40}K)	^{65}Zn	
E4.4	5.2	0.36	0.26	0.14	2500
	20.6	0.97	<0.52	0.21	3400
	15.10	0.21	0.46	0.22	2900
Average		0.51	<0.41	0.19	
E5.8	5.2	0.22	0.26	trace	2300
	9.5	0.20	<0.48	0.04	3200
	21.9	0.16	<0.54	trace	3500
Average		0.19	<0.43		
Hawkesbury River (H.R.)	5.2	0.40	0.08	-	3300
	7.5	0.27	0.45	-	2700
	21.9	0.08	<0.52	-	3200
Average		0.25	<0.35	-	
Oyster Shell Composite	5.2-15.10	1.74	0.91	-	300
		Derived m.p.c.		1000	
E4.4		Fraction of m.p.c.		2×10^{-4}	
E5.8		Fraction of m.p.c.		-	
H.R.		Fraction of m.p.c.		-	
Oyster Shell Composite		Fraction of m.p.c.		-	

TABLE 4

WORONORA SAMPLES - WHOLE FISH, 1973

Station		Date 1973	Radioactivity, pCi g^{-1} Fresh Weight			K (ppm)
			Gross Alpha	Gross Beta (less ^{40}K)	^{60}Co	
E0.8	Mullet	15.3	0.45	1.00	0.10	2400
	Mullet	28.6	0.69	0.19	0.04	3200
	Mullet	24.8	0.10	0.42	trace	2700
	Mullet	5.12	0.24	0.18	0.22	2900
	Bream	28.6	0.62	<0.68	trace	4900
	Bream	24.8	0.37	0.27	-	3500
	Bream	5.12	0.20	<0.66	0.10	4100
Average			0.38	<0.49	0.07	
E4.0	Mullet	8.3	0.48	0.14	-	3300
	Mullet	4.7	0.73	<0.58	-	3500
	Mullet	30.8	0.42	1.18	-	2100
	Mullet	12.12	0.35	0.02	-	3400
	Blackfish	4.7	0.75	<0.61	0.07	4000
	Blackfish	12.12	0.17	<0.60	0.10	4000
Average			0.48	<0.52	0.03	
	Derived m.p.c.				500	
E0.8	Fraction of m.p.c.				1×10^{-4}	
E4.0	Fraction of m.p.c.				6×10^{-5}	

TABLE 5

WORONORA SAMPLES - BEACH SAND, 1973

Station	Date 1973	Radioactivity, pCi g^{-1} Fresh Weight				K (ppm)
		Gross Alpha	Gross Beta (less ^{40}K)	^{60}Co	^{232}Th + daughters	
E0.8	30.1	4.95	1.45	trace	-	300
	26.7	4.87	1.71	-	-	300
	6.12	5.72	1.19	-	-	300
Average		5.18	1.45	-	-	
E3.7	30.1	8.65	1.56	-	-	300
	26.7	4.48	2.12	-	-	800
	7.12	9.98	2.35	-	trace	400
Average		7.70	2.01	-	-	
Derived m.p.c.		3000	2500	500	-	
Average fraction of m.p.c.		$2x10^{-3}$	$7x10^{-4}$	-	-	

TABLE 6

WORONORA SAMPLES - TRITIUM IN SURFACE WATER

AT STATION E3.6, 1973

Date 1973	Tritium pCi $m\ell^{-1}$	Date 1973	Tritium pCi $m\ell^{-1}$	Date 1973	Tritium pCi $m\ell^{-1}$
5.1	1.4	25.5	8.2	15.10	<1.0
12.1	<1.0	1.6	9.0	19.10	<1.0
19.1	2.9	8.6	3.5	26.10	4.0
26.1	2.0	15.6	3.2	2.11	5.3
2.2	<1.0	22.6	12.2	9.11	2.1
9.2	<1.0	29.6	8.5	16.11	5.0
16.2	<1.0	6.7	6.7	23.11	5.0
23.2	<1.0	13.7	6.0	30.11	4.8
2.3	<1.0	20.7	5.3	7.12	4.8
9.3	1.9	27.7	2.6	14.12	<1.0
16.3	<1.0	3.8	2.8	21.12	<1.0
23.3	<1.0	10.8	<1.0	28.12	1.4
30.3	4.2	17.8	3.0		
6.4	3.8	24.8	4.0	Average	3.3
13.4	3.2	30.8	1.6		
19.4	<1.0	7.9	1.3		
27.4	6.5	14.9	2.1	Derived m.p.c. = 3×10^{4} pCi $m\ell^{-1}$	
4.5	3.7	21.9	5.0		
11.5	3.3	28.9	3.0	Average fraction of m.p.c. = 1×10^{-4}	
18.5	1.2	5.10	4.0		

TABLE 7

WORONORA SAMPLES - ZOSTERA, 1973

Station	Date 1973	Radioactivity, pCi g^{-1} Fresh Weight				
		Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters		
				^{54}Mn	^{60}Co	^{238}U series
E0.8	30.1	1.4	1.8	1.4	3.4	-
	10.5	0.5	1.0	0.1	1.1	-
	26.7	0.8	1.3	0.6	3.1	-
	6.12	0.7	0.8	1.0	4.6	trace
Average		0.9	1.2	0.8	3.1	
E1.0	31.1	1.2	1.8	0.6	2.7	-
	10.5	1.0	0.9	0.1	1.4	-
	26.7	1.1	1.1	0.3	2.4	-
	6.12	1.1	1.1	0.8	3.9	trace
Average		1.1	1.2	0.5	2.6	
E1.5	31.1	1.0	1.1	0.3	1.4	-
	10.5	0.7	<1.1	0.1	1.1	-
	26.7	0.6	0.6	0.4	1.5	-
	6.12	0.8	0.9	0.8	2.7	trace
Average		0.8	<0.9	0.4	1.7	
E2.9	31.1	1.4	1.0	<0.1	0.4	-
	10.5	1.1	0.7	0.1	0.5	-
	26.7	2.7	1.4	-	0.5	trace
	6.12	3.8	0.8	trace	0.8	trace
Average		2.3	1.0	<0.1	0.6	
E4.4	31.1	1.6	1.4	-	0.1	-
	10.5	0.7	0.5	-	0.1	-
	26.7	1.0	0.1	-	0.1	trace
	6.12	2.5	1.1	-	trace	trace
Average		1.5	0.8	-	<0.1	
E5.8	31.1	1.5	<0.7	-	<0.1	

TABLE 8

TERRESTRIAL SAMPLES - MILK, 1973

Station	Date 1973	Radioactivity, pCi g^{-1} Fresh Weight	
		^{137}Cs	^{131}I
T3 (Menai)	16.1	0.02	-
	20.2	-	-
	15.3	-	-
	30.4	0.03	-
	17.5	-	-
	14.6	-	-
	23.7	<0.01	-
	16.8	-	-
	18.9	0.02	-
	4.10	<0.01	-
	14.11	0.01	-
	13.12	-	-
Average		<0.01	

Note: Minimum detectable level for iodine-131 in milk is 0.3 pCi g^{-1} fresh weight (0.3 nCi ℓ^{-1})

TABLE 9

TERRESTRIAL SAMPLES - SOLID WASTE BURIAL GROUND, 1973

Location	Sample	Date 1973	Radioactivity, pCi g^{-1} Fresh Weight			K (ppm)
			Gross Alpha	Gross Beta *(a)*	Gamma Emitters	
Near Trench No. 59	Acacia	21.2	0.9	13	0.3 0.5 MeV *(c)* 0.4 ^{137}Cs	3000
	Acacia	13.8	0.2	1.0	0.1 0.5 MeV trace ^{137}Cs	3500
Near Trench No. 70-71	Acacia	21.2	0.2	31	0.2 0.5 MeV 0.8 ^{60}Co	3600
	Acacia	13.8	0.2	31	0.3 0.5 MeV 3.7 ^{60}Co trace ^{238}U series	3100
	Grass	21.2	0.3	12	0.6 0.5 MeV 8.0 ^{60}Co	5100
	Grass	13.8	2.1	22	0.2 0.5 MeV trace ^{137}Cs trace ^{60}Co trace ^{238}U series	3100
Near Trench No. 69	Grass	22.8	1.8	38	0.6 0.5 MeV 1.5 ^{60}Co trace ^{238}U series	2200
	Top Soil *(b)*	22.8	24.7	63	36 ^{60}Co trace ^{238}U series	5800

(a) including ^{40}K for water results; excluding it for vegetation

(b) ^{90}Sr = 15.7 pCi g^{-1}

(c) The gamma-ray peak detected at approximately 0.50 MeV could be either ^{7}Be (0.48 MeV, 53 day half-life), ^{103}Ru (0.50 MeV, 40 day half-life) or ^{106}Ru (0.51 MeV, 1.0 year half-life). The unit pCi g^{-1} refers to the disintegrations per gram emitting a gamma photon of the energy quoted. Beryllium-7 is a cosmic ray-produced atmospheric activation product: the remainder are fission products.

TABLE 9 (cont.)

TERRESTRIAL SAMPLES - SOLID WASTE BURIAL GROUND, 1973

Location	Sample	Date 1973	Radioactivity, pCi ℓ^{-1}		
			Gross Alpha	Gross Beta (a)	Gamma Emitters
Bore Hole 1	Ground Water	21.2	1.4	3.8	-
Bore Hole 2	Ground Water	21.2	0.7	3.3	-
Bore Hole 3	Ground Water	21.2	2.7	6.5	-
Bore Hole 4	Ground Water	21.2	0.3	2.6	-
Bore Hole 5	Ground Water	21.2	0.4	3.9	-
Bore Hole 6	Ground Water	21.2	0.4	3.6	-
Bore Hole 10	Ground Water	21.2	15	11	trace ^{238}U series
Bore Hole OS1	Ground Water	21.2	0.1	3.1	-
Bore Hole OS2	Ground Water	21.2	0.5	4.6	-
Bore Hole OS3	Ground Water	21.2	3.8	24	-
Bore Hole A	Ground Water	21.2	<1.2	4.5	-
Bore Hole B	Ground Water	21.2	4.0	4.4	-
Bore Hole C	Ground Water	21.2	8.4	6.5	trace ^{238}U series
Bore Hole D	Ground Water	21.2	51	27	trace ^{238}U series
Bore Hole E	Ground Water	21.2	1.1	6.7	-
Bore Hole 1	Ground Water	13.8	1.3	3.4	-
Bore Hole 2	Ground Water	13.8	0.8	2.2	-
Bore Hole 3	Ground Water	13.8	<1.7	4.5	-
Bore Hole 4	Ground Water	13.8	1.4	3.7	-
Bore Hole 5	Ground Water	13.8	<1.8	1.7	-
Bore Hole 6	Ground Water	13.8	2.0	4.2	-
Bore Hole 10	Ground Water	13.8	20	12	trace ^{238}U series
Bore Hole OS1	Ground Water	13.8	<3.2	3.3	-
Bore Hole OS2	Ground Water	13.8	1.2	4.9	-
Bore Hole OS3	Ground Water	13.8	8.8	66	1.0 0.5 MeV
Bore Hole A	Ground Water	13.8	1.4	4.9	-
Bore Hole B	Ground Water	13.8	10	6.4	trace ^{238}U series
Bore Hole C	Ground Water	13.8	7.4	6.0	trace ^{238}U series
Bore Hole D	Ground Water	13.8	21	16	trace ^{238}U series
Bore Hole E	Ground Water	13.8	<2.4	5.2	-

(a) including ^{40}K for water results; excluding it for vegetation.

TABLE 10

TERRESTRIAL SAMPLES - MISCELLANEOUS, 1973

Station	Sample	Date 1973	Radioactivity, pCi g^{-1} Fresh Weight				K (ppm)
			Gross Alpha	Gross Beta (less ^{40}K)	^{3}H pCi $m\ell^{-1}$	Gamma Emitters	
R.E. Stormwater Outlet near South Gate	Sand	27.2	130	76		28 ^{137}Cs 30 ^{60}Co	1000
	Sand	23.7	42	16		trace ^{137}Cs 0.9 ^{60}Co	1300
	Water	23.7			10		
R.E. Stormwater Outlet near South Gate,	Sand	27.2	113	73		20 ^{137}Cs 24 ^{60}Co	1200
20 metres away from it	Sand	23.7	97	30		6.6 ^{137}Cs 9.7 ^{60}Co	800
	Grass	27.2	0.3	3.2		0.8 0.5 MeV 0.7 ^{54}Mn 1.7 ^{137}Cs 0.7 ^{60}Co	4700
	Grass	23.7	0.4	0.5		0.1 0.5 MeV 0.6 ^{54}Mn 0.4 ^{137}Cs 0.4 ^{60}Co	5800
R.E. Stormwater Outlet near South Gate, 380 metres away from it	Sand	15.10	23	2.3		0.6 ^{137}Cs trace ^{232}Th+ daughters	300

TABLE 10 (cont.)

TERRESTRIAL SAMPLES - MISCELLANEOUS, 1973

Station	Sample	Date 1973	Radioactivity, pCi g^{-1} Fresh Weight				K (ppm)
			Gross Alpha	Gross Beta (less ^{40}K)	^{3}H pCi $m\ell^{-1}$	Gamma Emitters	
Stormwater Outlet outside R.E. safety fence:							
Opp. Strassman Cres.	Sand	20.2	19	29		3.9 ^{137}Cs 20 ^{60}Co trace ^{232}Th+daughters	1000
	Sand	23.7	7	11		trace ^{137}Cs 1.2 ^{60}Co trace ^{232}Th+daughters	600
Opp. Building 23	Sand	20.2	35	16		trace ^{137}Cs 12 ^{60}Co trace ^{232}Th+daughters	500
	Sand	23.7	23	20		194 ^{60}Co trace ^{232}Th+daughters	900
	Water	23.7			20		
Opp. Fermi Street	Sand	20.2	13	28		1.9 0.5 MeV 0.9 ^{137}Cs 0.5 ^{60}Co trace ^{232}Th+daughters	1900
	Sand	23.7	13	19		1.9 ^{137}Cs trace ^{60}Co trace ^{232}Th+daughters	1800
	Water	23.7			9		

TABLE 11

RESULTS OF LiF-TEFLON DOSIMETERS RADIATION DOSE READINGS ON BED OF WORONORA ESTUARY AT THE DISCHARGE POINT

Location of Dosimeters (Fig. 3)	*(a)* Dose in rems from 19.9.72 to 6.12.73
No. 1	Nil
2	0.05
3	0.04
4	0.14
5	0.11
6	0.07
7	0.22
8	
9	0.05

Note: Blank spaces indicate dosimeters have been vandalised during the period.

(a) Integrated dose from single dosimeter at specified position.

TABLE 12

WORONORA SAMPLES: ANNUAL AVERAGES EXPRESSED AS FRACTIONS OF THE DERIVED MAXIMUM PERMISSIBLE CONCENTRATIONS (a)

Sample	Radioisotope and m.p.c.	Fractions of m.p.c.						
		1967	1968	1969	1970	1971	1972	1973
Water	^{3}H, 30 nCi $m\ell^{-1}$							
E 0		8×10^{-4}	7×10^{-4}	2×10^{-4}	5×10^{-4}			
E 1.5		3×10^{-4}	4×10^{-4}	1×10^{-4}	4×10^{-4}			
E 3.6			1×10^{-4}	7×10^{-5}	2×10^{-4}	7×10^{-5}	7×10^{-5}	1×10^{-4}
E 5.0			7×10^{-5}	3×10^{-5}	1×10^{-4}			
Oyster Flesh	^{65}Zn, 1000 pCi g^{-1}							
E 4.4		1×10^{-4}	1×10^{-4}	5×10^{-5}	2×10^{-4}	3×10^{-4}	3×10^{-4}	2×10^{-4}
E5.8		-	-	4×10^{-5}	8×10^{-5}	1×10^{-4}	-	-
Hawkesbury		-	-	-	-	-	-	-
Fish	^{60}Co, 500 pCi g^{-1}	1×10^{-4}	4×10^{-4}	2×10^{-4}	-	-	3×10^{-4}	9×10^{-5}
(Average of all samples)	^{90}Sr, 1 pCi g^{-1}	8×10^{-3}	8×10^{-3}	7×10^{-3}	6×10^{-3}			
	^{137}Cs, 200 pCi g^{-1}	5×10^{-5}	2×10^{-4}	3×10^{-5}	-	-	2×10^{-4}	-
Beach Sand	Gross Alpha							
(Average of all samples)	3000 pCi g^{-1}	1×10^{-3}	2×10^{-3}	3×10^{-3}	3×10^{-3}	3×10^{-3}	1×10^{-3}	2×10^{-3}
	Gross Beta							
	2500 pCi g^{-1}	5×10^{-4}	8×10^{-4}	$<1\times10^{-3}$	1×10^{-3}	4×10^{-4}	8×10^{-4}	7×10^{-4}

(a) Derived maximum permissible concentrations are taken from Fry (1966)

TABLE 13

POSSIBLE DOSES TO MEMBERS OF THE LOCAL POPULATION AS A RESULT OF EXPOSURE TO MEASURED CONCENTRATIONS

Sample	Isotope	Exposure Route	Possible Annual Dose (mrem)	Critical Organ
Oyster Flesh	Tritium	Ingestion	0.01	Whole Body
	Zinc-65	Ingestion	0.03	Whole Body
Fish	Tritium	Ingestion	0.01	Whole Body
	Cobalt-60	Ingestion	0.001	Whole Body
	Cobalt-60	Ingestion	0.015	Lower Large Intestines
Milk	Caesium-137	Ingestion	0.08	Whole Body
Estuary Water	Tritium	Daily Swimming at Discharge Point	0.01	Whole Body
Beach Sand	Gross Beta Activity	Regular Contact	2.04	Skin

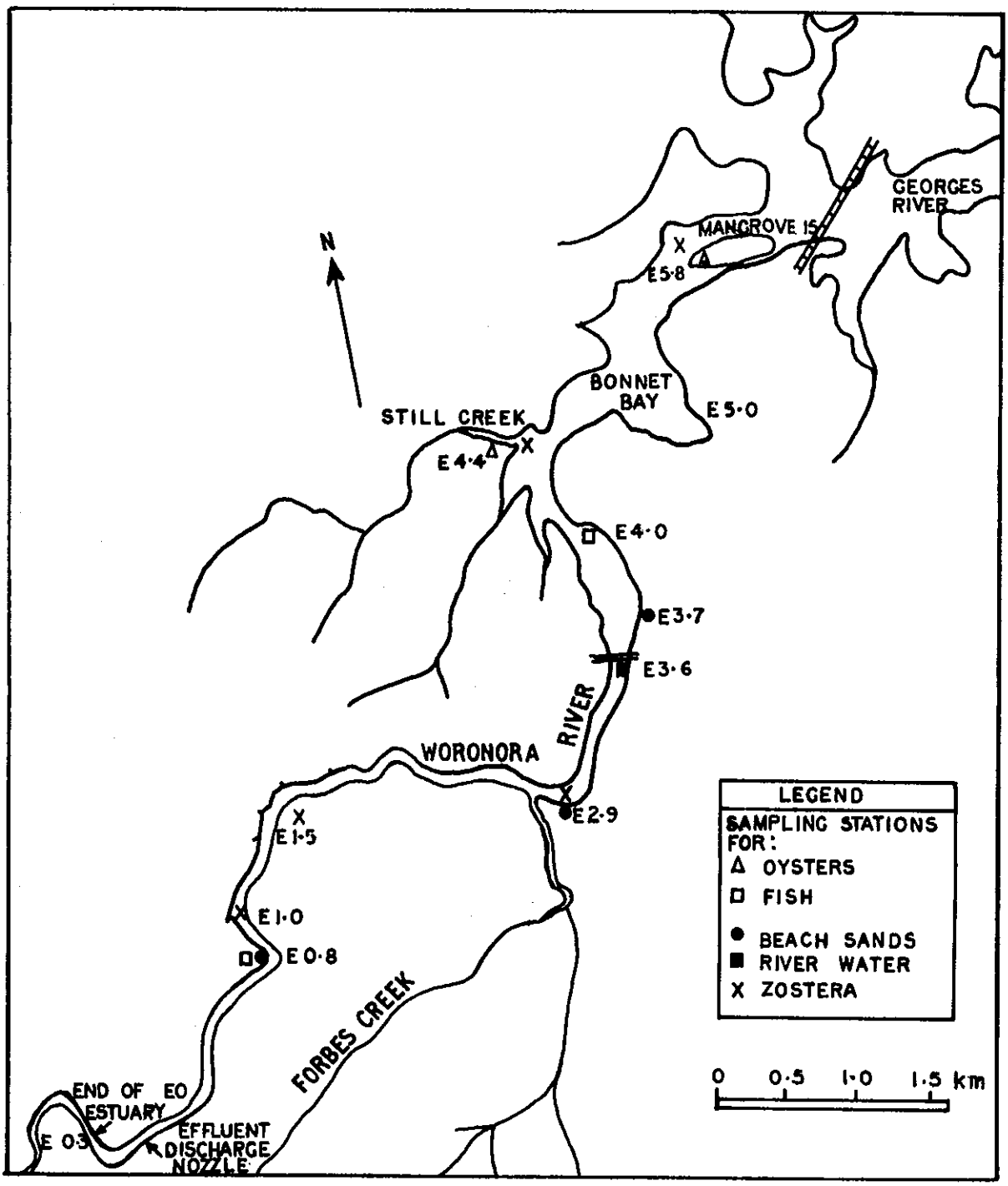

FIGURE 1. WORONORA ESTUARY SAMPLING STATIONS (1973)

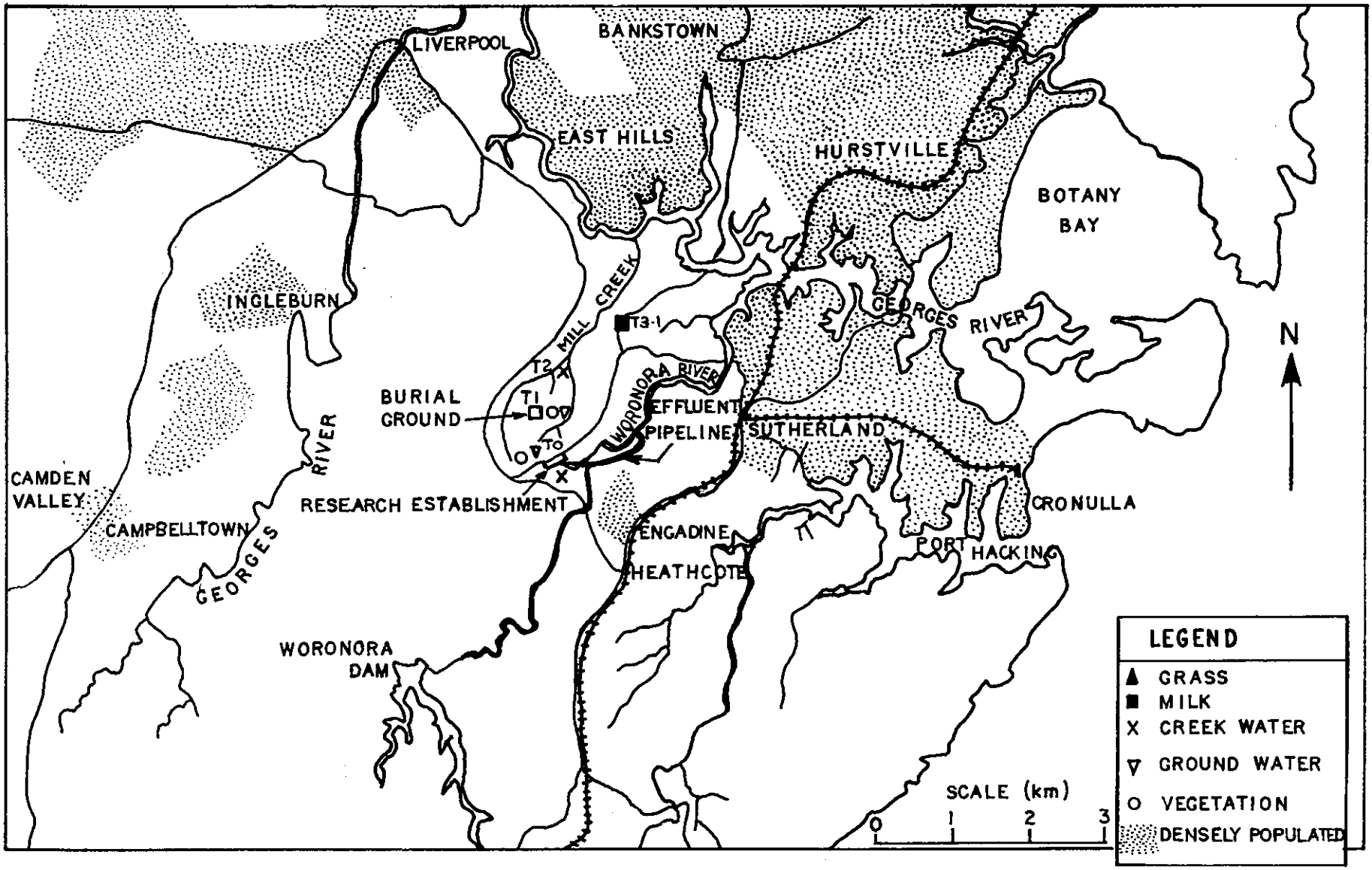

FIGURE 2. TERRESTRIAL SAMPLING STATIONS (1973)

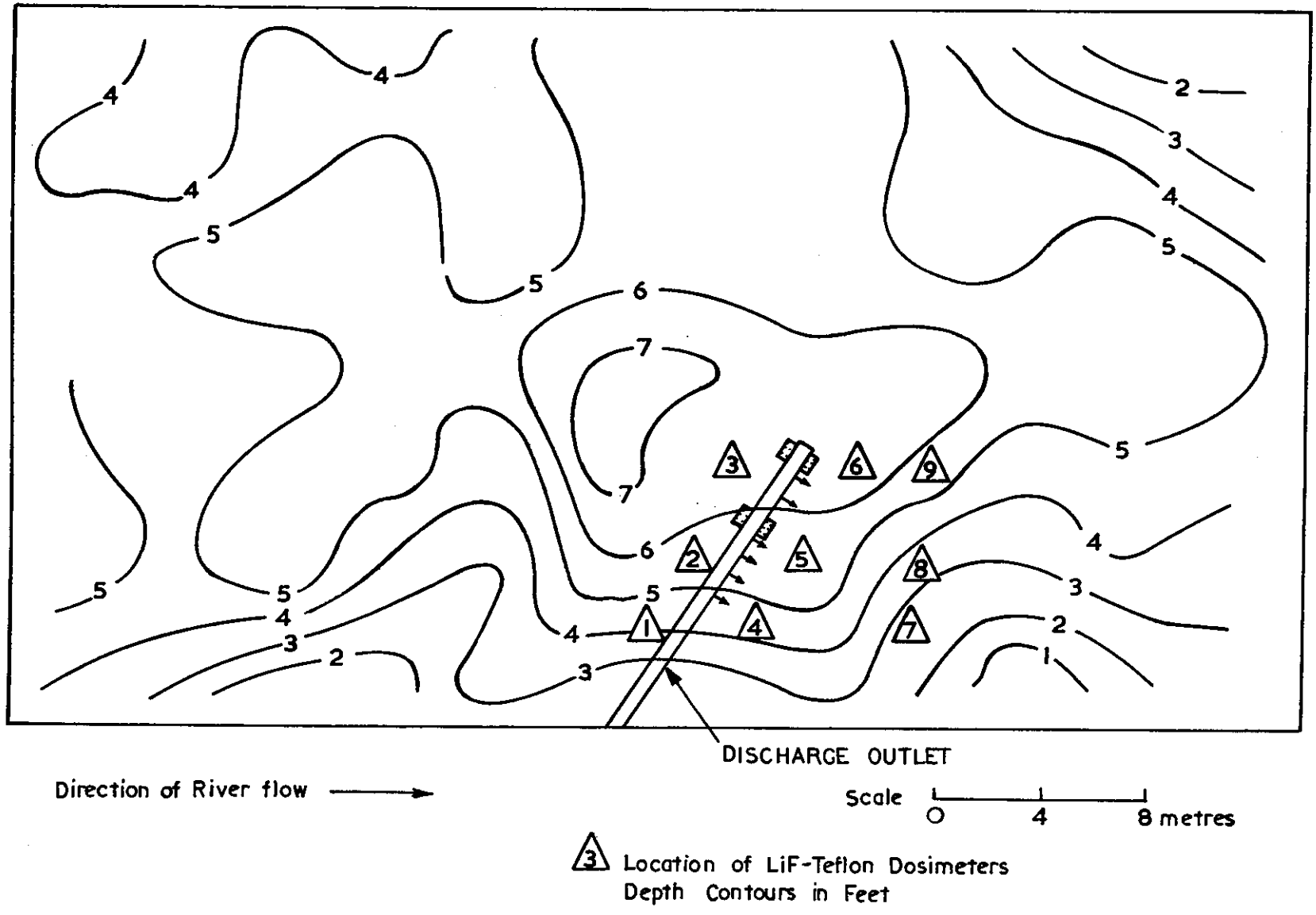

FIGURE 3. LOCATION OF LiF - TEFLON DOSIMETERS ON BED OF WORONORA ESTUARY AT THE DISCHARGE POINT