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Environmental Monitoring Report for the Point Lepreau, N.B. Nuclear Generating Station – 1987, 1988

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Les établissements des Sciences et levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports en décembre 1981. Une liste complète de ces publications figure dans le volume 39, Index des publications 1982 du *Journal canadien des sciences halieutiques et aquatiques*. La série actuelle a commencé avec la publication du rapport numéro 1 en janvier 1982.

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ENVIRONMENTAL MONITORING REPORT FOR THE POINT LEPREAU, N.B. NUCLEAR GENERATING STATION - 1987, 1988

by

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ABSTRACT

Ellis, K.M., R.W.P. Nelson and J.N. Smith. 1990. Environmental monitoring report for the Point Lepreau, N.B., Nuclear Generating Station - 1987, 1988. Can. Tech. Rep. Hydrogr. Ocean. Sci. No. : 128: v + 91 pp.

The Point Lepreau Environmental Monitoring Program (PLEMP) established within the Department of Fisheries and Oceans in 1978 to assess the environmental impact of radioactive, thermal and chemical releases from the Point Lepreau N.B. Nuclear Generating Station (NGS) located on the Bay of Fundy has completed its 11th year of the monitoring program. This report contains results from the fifth and six years of the operational phase of the program. Samples for radionuclide analysis were collected from the marine, atmospheric, terrestrial and aquatic environments in the vicinity of the Point Lepreau NGS. These activities were compared to pre-operational activities to assess the environmental implications of the operation of nuclear reactors in coastal regions and to determine various parameters associated with the long term transport of radionuclides.

RÉSUMÉ

Ellis, K.M., R.W.P. Nelson and J.N. Smith. 1990. Environmental monitoring report for the Point Lepreau, N.B., Nuclear Generating Station - 1987, 1988. Can. Tech. Rep. Hydrogr. Ocean. Sci. No. : 128: v + 91 pp.

Le Programme de surveillance de l'environnement de la pointe Lepreau arrive au terme de sa onzième année d'existence. Il a été mis en oeuvre par le ministère des Pêches et des Océans en 1978 afin d'évaluer l'impact des décharges radioactives, thermiques et chimiques de la centrale nucléaire de la pointe Lepreau, située en bordure de la baie de Fundy. Le présent rapport expose les résultats de la cinquième et de la sixième année d'application du programme. On a comparé les résultats d'analyse d'échantillons de radionuclides prélevés dans des milieux marin, atmosphérique et terrestre ainsi qu'en eau douce aux environs de la centrale aux données recueillies dans la phase préopérationnelle du programme, dans le but

d'établir les impacts environnementaux des réacteurs nucléaires sur les régions côtières et de définir divers paramètres relatifs au transport des radionuclides à long terme.

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INTRODUCTION

The Point Lepreau Environmental Monitoring Program (PLEMP) was established in 1978 to assess the impact of the operation of the CANDU 600 nuclear reactor built at Point Lepreau on the shores of the Bay of Fundy (Figure 1). PLEMP, under the advisement of a working group made up of scientists from various departments (Appendix 1), was designed to provide a broad understanding of the processes which affect the radioactivity released from the NGS into the surrounding environment. The sampling program includes the collection of samples from the major environmental reservoirs - atmospheric, marine, terrestrial and aquatic - on a regular basis as a well as the measurement of key oceanographic parameters in order to identify transport pathways and determine fluxes of radionuclides along specific pathways.

The responsiblity for running PLEMP has been assigned to the Atlantic Environmental Radiation Unit within the Marine Chemistry Division, Scotia-Fundy Region, Department of Fisheries and Oceans located at Bedford Institute of Oceanography, Dartmouth, N.S.

PLEMP has been carried out in two phases. The pre-operational program ran from 1978 to 1982 when the reactor became operational. Results are summarized in Bishop et al (1980), Smith et al (1981, 1982) and Ellis et al (1984). Results for the first four years of the operational program are reported in Nelson et al (1985, 1986, and 1988). This report covers data accumulated in 1987 and 1988. All published reports related to the monitoring program by PLEMP are listed in Appendix 2.

In addition to monitoring the reactor effluents, the monitoring program has been useful in studying nuclear fallout in particular from the Chinese nuclear test in 1980 and from the Chernobyl nuclear power station accident in 1986 (Nelson el al, 1988, Smith and Ellis, 1990).

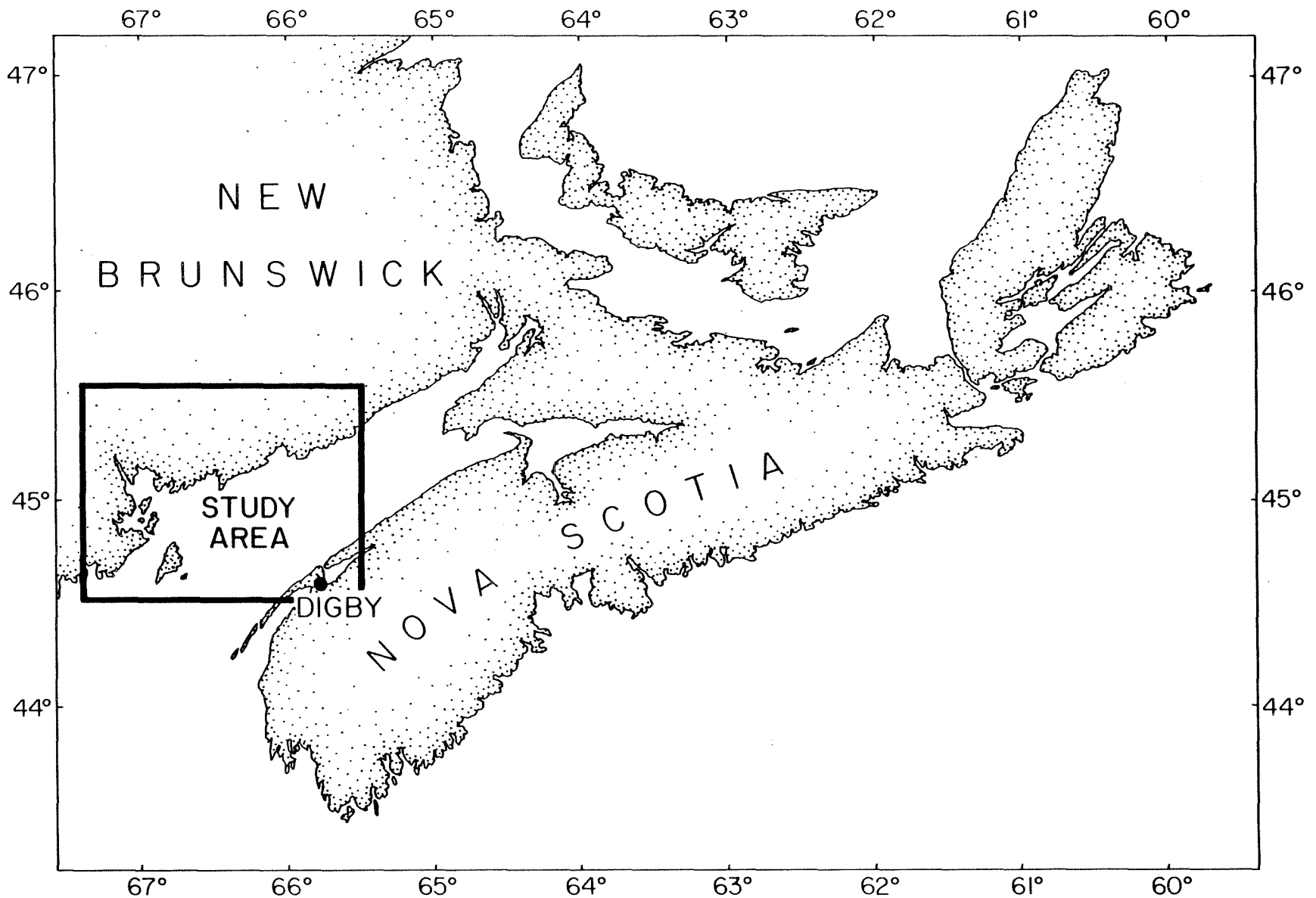

Figure 1: Location of the Point Lepreau study area on the Bay of Fundy.

2.0 POINT LEPREAU GENERATING STATION EFFLUENT RELEASES

Radioactive materials are produced as a result of various processes involved in the production of nuclear power (i.e. neutron activation of reactor support and encasement materials, creating activation products) and are released to the atmospheric, aquatic, terrestrial or marine environment from the Point Lepreau NGS. Emissions from the Point Lepreau NGS to the marine environment are closely monitored at the source under the mandate of the Liquid Effluent Monitoring Program (LEM) and to the atmosphere by the Gaseous Effluent Monitoring Program (GEM) conducted by the New Brunswick Electric Power Commission (NBEPC).

During 1987 and 1988, the reactor operated at full power with the exception of a few brief outages and annual maintenance shutdowns for a few weeks during April-May. A small boiler tube leak detected on December 27, 1987 which led to an increase in radionuclide concentrations in the boiler feedwater was repaired during the scheduled maintenance shutdown in April 1988 (NBEPC, 1988).

The liquid effluent monthly summaries for 1987 and 1988 are presented in Tables 1 and 2 (NBEPC 1987, 1988). The tritium activity and the activities of all other isotopes released in 1987 decreased from 1986 amounts but increased in 1988 to levels higher than the 1986 amounts. The gaseous effluent levels are presented in Figure 2. No increases in radionuclide effluent releases were measured as a result of the leak in the boiler tube. All releases are well below the DEL (Derived Emission Limits) set by Atomic Energy Control Board (AECB).

Table 1. Radionuclides in Liquid Effluent for 1987

Isotope	Mon DEL (Bq)	Monthly Release (Bq)												Total (Bq)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
H-3	4E18	4E13	2E12	8E11	1E13	8E12	4E12	4E12	4E12	3E12	4E12	1E12	2E13	9.6E13
Cr-51	4E15	4E6	4E5	–	2E6	–	–	–	–	1E6	–	–	6E5	8.2E6
Mn-54	4E13	–	4E5	–	1E5	–	–	–	–	–	–	–	4E5	1.2E6
Fe-59	1E13	–	1E6	–	–	–	–	–	–	–	4E5	–	–	1.5E6
Co-60	3E13	–	3E6	–	3E6	6E5	2E5	–	–	–	9E5	–	3E6	1.1E7
Sr-90	2E14	4E2	4E2	4E2	4E3	2E3	6E2	1E3	4E2	6E2	–	–	–	5.4E5
Nb-95	6E13	2E6	1E7	2E7	2E7	6E7	5E7	1E7	3E6	6E6	5E6	2E6	3E7	2.3E8
Zr-95	6E13	6E7	6E6	1E7	2E7	5E7	4E7	5E6	1E6	1E5	1E6	1E6	–	1.4E8
Ru-103	1E14	–	–	–	–	2E6	–	8E5	–	–	–	–	–	3.2E6
Ag-110m	1E13	–	–	–	3E5	–	2E5	3E5	–	–	–	–	1E6	2.2E6
I-131	1E13	5E4	–	–	–	–	–	–	–	–	–	7E4	–	1.4E5
Cs-134	4E13	–	–	–	2E6	–		–	–	5E5	–	–	4E5	2.3E6
Cs-137	7E13	–	–	–	6E6	–	–	5E5	4E5	7E5	–	–	7E6	1.4E7
Ce-144	2E13	–	–	–	–	1E6	–	–	–	–	–	–	–	1.1E6
Other													–	
Mo-99	No DEL calc.	–	–	–	1E5	–	–	–	–	1E5	–	–	–	1.4E6
Sn-113	No DEL calc.	–	5E5	–	–	–	3E6	–	–	–	–	–	–	5.8E5
Sb-122	No DEL calc.	–	–	2E5	–	–	–	3E6	–	–	–	–	–	3.3E6
Sb-124	No DEL calc.	–	2E6	4E5	–	1E7	3E6	2E7	3E6	1E6	3E5	1E6	1E7	5.1E7
Te-132	No DEL calc.	–	2E4		–	–	–	3E6	3E5	4E5	–	7E4	–	3.9E6
La-140	No DEL calc.	–		–	–	–	–	3E5	–	–	–	–	–	3.0E5
Gd-159	No DEL calc.	–	–	–	5E6	–	–	–		–	–	–	–	5.0E6
W-187	No DEL calc.	–	–	–	3E6	–	–	–	–	–	–	–	–	2.5E6

No Co-58, Zn-65, Ru-106, Ba-140, or Ce-141 were measured.
Data from NBEPC (1987)

Table 2. Radionuclides in Liquid Effluent for 1988

Isotope	Mon DEL (Bq)	Monthly Release (Bq)												Total (Bq)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
H-3	4E18	2E13	2E13	4E12	4E12	3E13	4E12	4E12	8E12	3E12	4E12	4E13	4E12	1.2E14
Mn-54	4E13	–	–	–	6E5	–	–	4E5	1E5	–	–	–	–	1.3E6
Fe-59	1E13	–	–	–	4E5	3E5	–	7E5	–	–	–	–	–	1.4E6
Co-60	3E13	9E5	–	–	6E6	2E6	–	3E6	2E5	9E5	3E6	2E6	2E5	1.6E7
Sr-90	2E14	4E4	–	–	1E6	2E5	6E4	–	–	2E5	6E4	8E5	6E4	1.6E6
Nb-95	6E13	1E6	5E5	1E6	6E7	2E7	1E7	6E6	3E7	2E6	1E6	4E5	4E5	5.6E7
Zr-95	6E13	4E5	4E5	4E5	1E8	1E7	6E6	2E6	6E5	1E6	–	–	2E5	4.3E6
Ru-103	1E14	–	–	–	3E6	8E5	–	–	–	–	–	–	–	1.1E8
Ag-110m	1E13	–	–	–	–	7E4	–	2E6	3E6	–	4E5	2E5	1E5	7.3E6
I-131	1E13	6E7	4E7	6E5	5E6	4E6	1E5	5E5	4E8	3E8	–	–	–	9.8E8
Cs-134	4E13	–	–	–	8E5	2E5	–	2E5	1E5	2E6	–	3E5	–	4.4E6
Cs-137	7E13	–	–	–	3E6	1E6	–	1E6	7E6	7E6	3E5	4E6	–	2.7E7
Ce-141	2E14	–	–	–	–	–	–	–	2E5	–	–	–	–	2.2E5
Ce-144	2E13	–	–	–	–	–	8E5	–	–	–	–	–	–	7.2E5
Other														
Tc-99m	(No DEL calc.)	–	3E6	–	–	–	–	–	–	–	–	–	–	2.7E6
Mo-99	(No DEL calc.)	–	–	–	–	–		–	1E8	1E8			–	2.4E8
Sb-122	(No DEL calc.)	–	–	–	–	–	–	–	3E5	1E6	–	–	–	1.4E6
Sb-124	(No DEL calc.)	4E6	–	3E5	3E6	3E6	–	–	5E6	3E6	–	6E5	2E6	2.0E7
I-132	(No DEL calc.)	3E6	–	–	–	–	–		–	–	–	–	–	2.6E6
I-133	(No DEL calc.)	7E7	3E7	2E5	–	–	–	–	2E8	7E7	–	–	–	3.5E8
I-134	(No DEL calc.)	4E6	–	–		–	–		–	–	–	–		3.6E6
I-135	(No DEL calc.)	4E7	2E7	–	–	–		–	2E7	–	–	–	–	8.0E7
Gd-159	(No DEL calc.)	–	8E5	–	–	2E6	–	–	–	–	–	2E6	–	5.2E6
W-187	(No DEL calc.)	–	–	–	–	–	–	4E5	8E5	–	–	–	–	1.2E6

No Cr-51, Co-58, Zn-65, Ru-106, or Ba-140 were measured.
Data from NBEPC (1988)

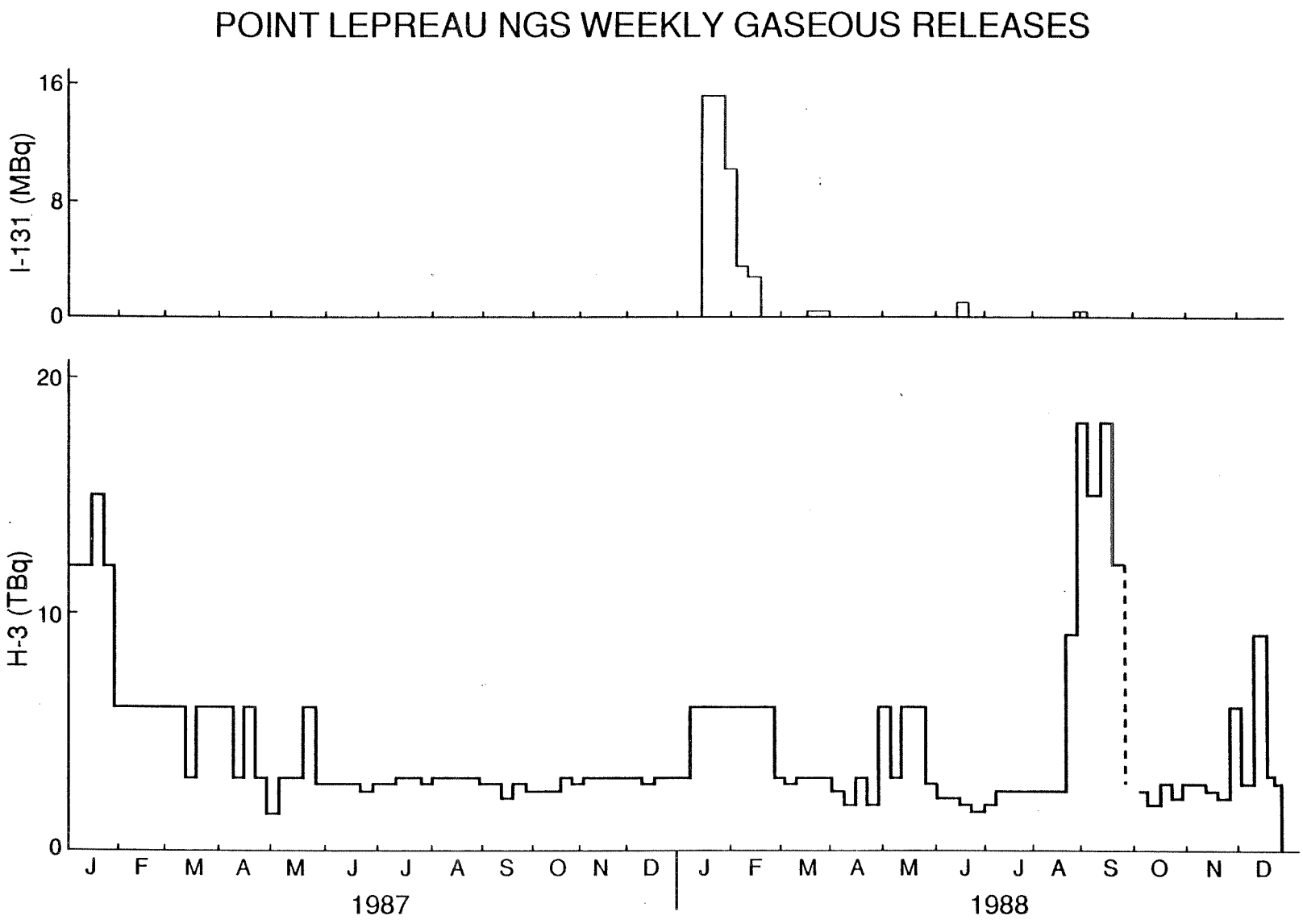

Figure 2: Gaseous effluent releases of I-131 and H-3 from Point Lepreau for 1987 and 1988 (NBEPC, 1987 and 1988).

3.0 MARINE ENVIRONMENT

3.1 Water Circulation

Water circulation patterns in the Bay of Fundy are dominated by a cyclonic, anticlockwise gyre with inflow along the coast of Nova Scotia and outflow along the New Brunswick coast passing to the east of Grand Manan Island (Bumpus and Lauzier, 1965). Low salinity water dominated by inputs from the Saint John River (which accounts for up to 60 % of the freshwater inputs) flows out at the surface, while denser shelf and slope waters mix across the shelf break and enter the Bay of Fundy at depths predominately below 100 meters. Water circulation patterns are seasonal and are largely controlled by the amount of freshwater input. Spring is the time of maximum river runoff resulting in maximum stratification and reduced vertical mixing. During the other seasons when freshwater runoff is diminished, there is less stratification allowing more vertical mixing.

A cruise (87-015) on the C.S.S. Dawson was carried out from May 19 to 25, 1987 with sample locations indicated in Figure 3. Salinity-depth profiles (Figure 4) from the three transects marked in Figure 3 illustrate the dominant circulation features for this time of year. The cruise appears to have occurred after the strong spring freshwater input and conditions are typical of summer. There is little stratification in the water except locally where freshwater inputs from the Saint John River (Transect B and C) and from Passamaquoddy Bay (Transect A) are apparent.

3.2 Chemical Oceanography

Samples of water were collected at surface and bottom depths using 12 l Niskins and a Rossette-CTD sampler at stations indicated in Figure 3. Temperature and salinity profiles were measured using the CTD unit during each cast of the rosette. A tidal study was undertaken by sampling through various stages of the tide while the ship was anchored at two different locations off the reactor effluent outfall. Sediment samples were collected at 14 locations using a box corer and a Lehigh gravity corer.

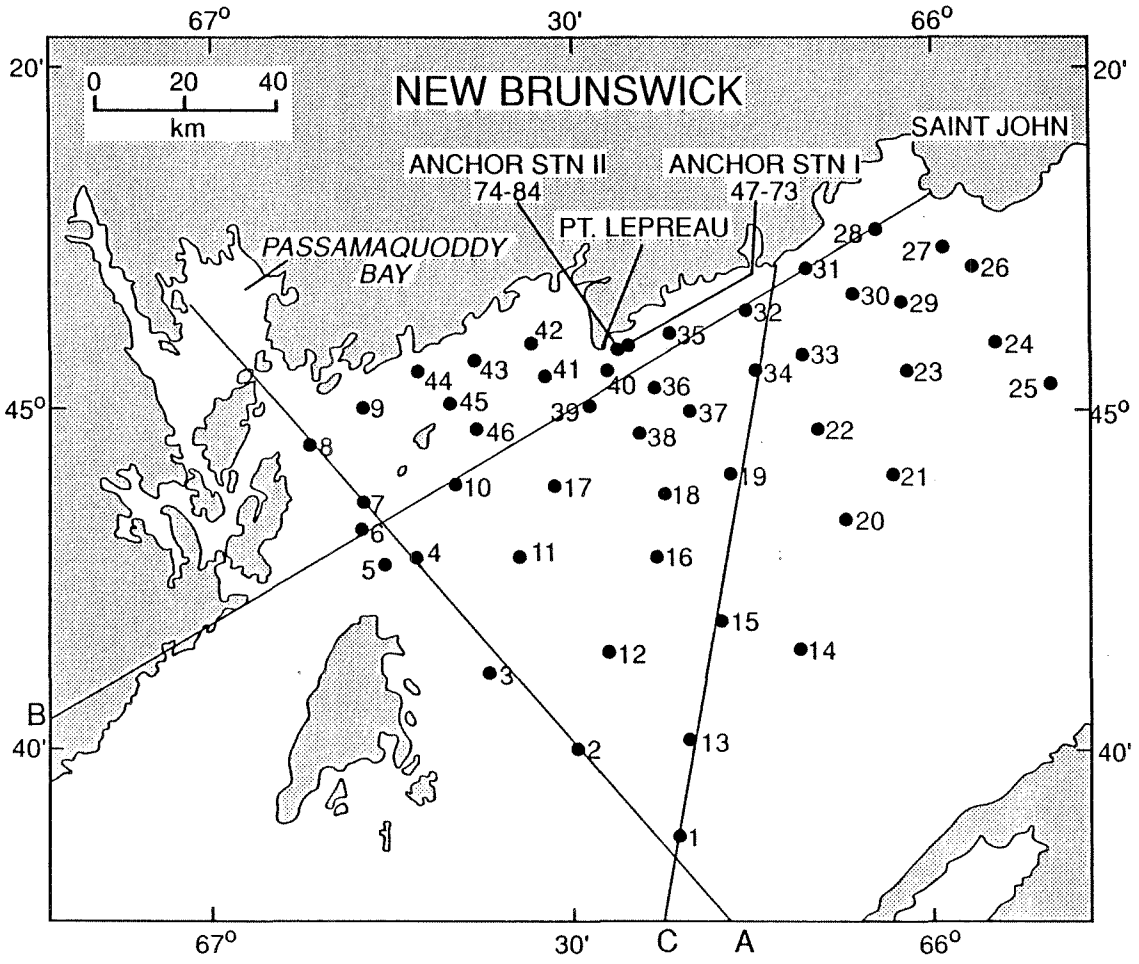

Figure 3. Station locations for Cruise 87-015 with transects A, B and C marked.

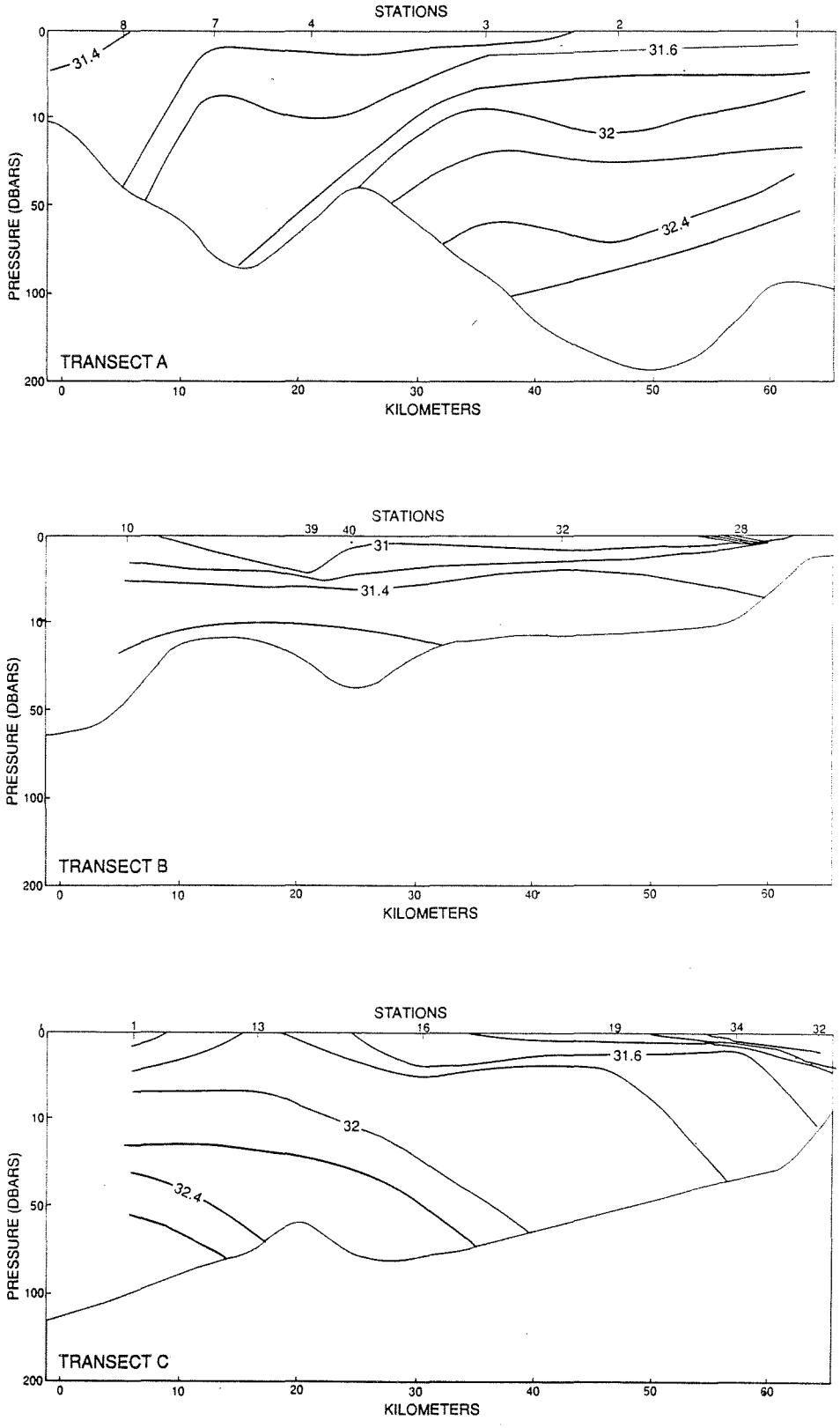

Figure 4: Salinity contours for Transect A, B and C on Figure 3 for cruise 87-015.

3.2.1 Sampling

Seawater samples were collected for salinity, nutrients and tritium analysis. Large volume water samples (48 l) were collected at selected locations and processed as illustrated in Figure 5. Details of sample separation have been described previously (Ellis et al, 1984). Briefly, water samples were passed through (1) a Whatman in-line cartridge filter to remove particles of size 0.3 micrometers or larger; (2) Chelex-100 cation exchange resin to remove activation products; and (3) a KCFC column (potassium cobalt ferrocynide) to remove cesium (Cs-134 and Cs-137). At the anchor station, 1 litre of water was passed through a 47 mm diameter, 0.4 micron pore size Nuclepore filter to measure SPM concentrations. In a few cases, samples of 20 l were collected after the columns for Sr-90 analysis. At selected stations, 100 l water samples were collected for plutonium analysis. A preconcentration step using a ferric hydroxide precipitation was carried out on board ship. Samples for a profile for Pb-210/Po-210 in water were collected at station 5. Twenty liter samples were filtered through 142 mm diameter, 0.4 micron pore size Nuclepore filters which were later analysed for particulate Pb-210/Po-210. The soluble Pb-210 and Po-210 was concentrated by coprecipitation with CoAPDC (Fleer and Bacon, 1984). The remaining separations for Pb-210/Po-210, plutonium (Wong, 1971) and strontium (IAEA, 1970) were completed in the laboratory at BIO. The nuclear instrumentation used in all analyses are outlined in Table 3.

3.2.2 Radionuclide Results

Results for salinity, nutrients, Cs-137 and tritium are given in Table 4. Results for Pb-210/Po-210, plutonium and Sr-90 are given in Table 5.

Cesium and Strontium

Cesium-137 and Sr-90 are long-lived ($t_{1/2}$ = 30 and 28 years respectively) fission products which are produced at a ratio of 1.5 (Cs-137/ Sr-90) during nuclear weapons tests and nuclear power production. Releases from the Sellafield nuclear reprocessing plant located in

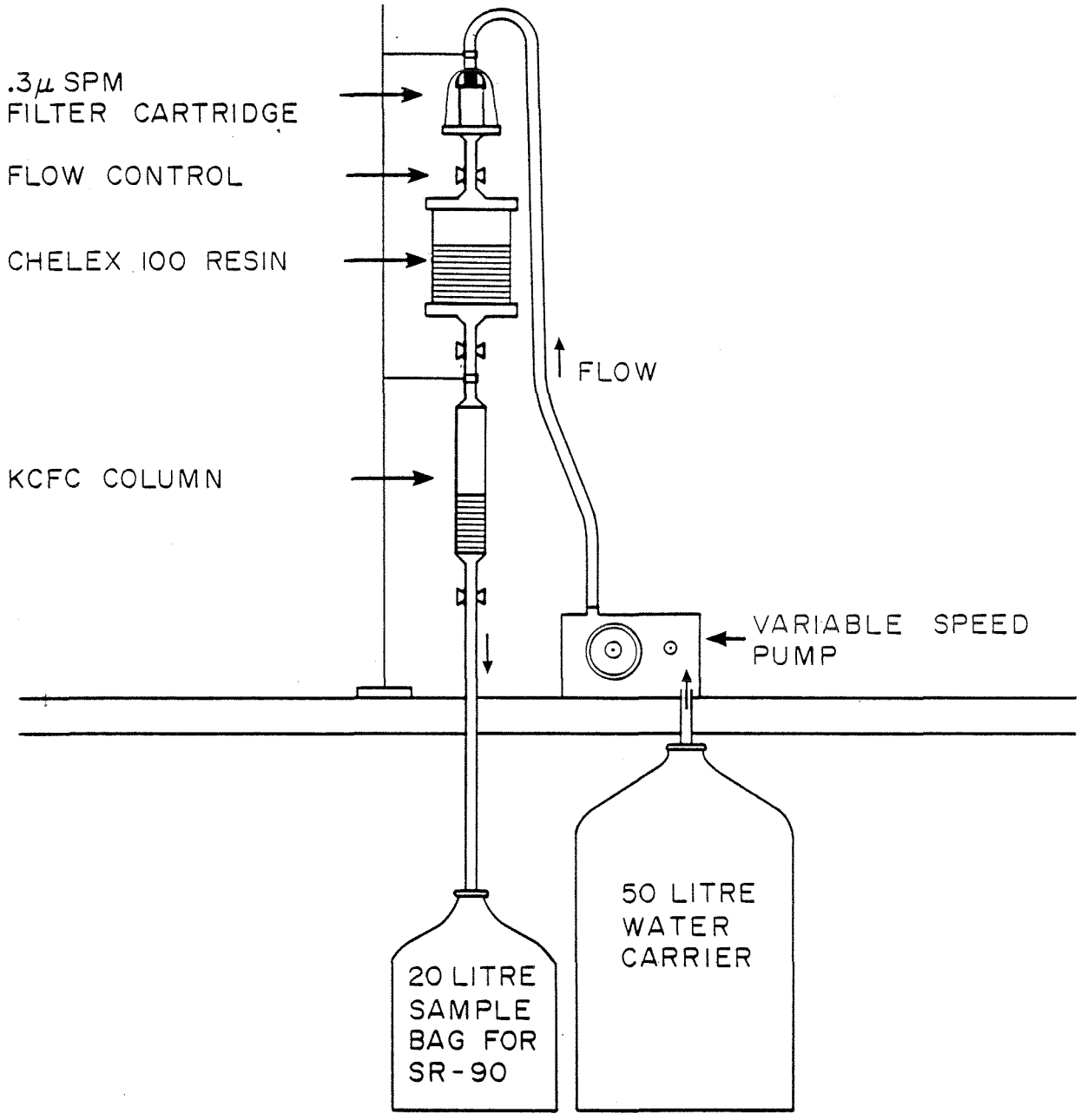

Figure 5. Schematic diagram of columns used to concentrate radionuclides from seawater.

Table 3. Summary of Nuclear Instrumentation Used in the AERU Laboratory.

Nuclide	Environmental Phase	Counting Matrix	Detection System
Cs-137	Seawater	KCFC	Ge and NaI Detectors
Cs-137	SPM	Filter Cartridge (0.3 μm)	Ge Detector
Cs-137	Sediment	Dried Bulk Sediment	Ge and NaI Detectors
Sr-90	Seawater, SPM and Sediment	Y-90 on Filter Paper	Alpha/Beta Counter
Gamma emitters	Seawater	Chelex-100 Eluate	Ge Detector
Gamma emitters	SPM	Filter Cartridge (0.3μm)	Ge Detector
H-3	Seawater	Gel (Water/Cocktail)	Liquid Scintillation Counter
Pb-210 (Po-210)	SPM, Sediments and Water	Nickel Discs	Alpha Spectrometer (Surface Barrier Detectors)
Pu-239,240	Sediment	Steel Disc	Alpha Spectrometer
Ra-226	Sediment	Ra-222 Gas	Gas Phase Scintillation Counter
Ra-226	Sediment	Bi-214 in Dried Bulk Sediment	Ge Detector

Table 4. Cruise Data from Cruise 87-015.

Sample No	Stn No	Depth (m)	Salinity (‰)	Silicate (μmoles/ℓ)	Phosphate (μmoles/ℓ)	Nitrate (μmoles/ℓ)	SPM (mg/ℓ)	Cs-137 (mBq/ℓ)	H-3 (Bq/ℓ)
26007	3	112	32.583	6.12	0.91	7.63	0.89	4.18 ± 0.37	
26008		56	32.104	4.31	0.79	5.72	0.67	3.08 ± 0.43	
26009		11	31.384	3.62	0.62	4.73	9.84	3.65 ± 0.40	
26010		11	31.387	5.61	0.68	4.74	1.05	3.47 ± 0.38	
26030	8	113	31.640	3.84	0.72	4.82	1.94	3.45 ± 0.43	
26031		8	31.196	4.52	0.64	3.91	1.38	3.21 ± 0.42	
26060	17	65	31.754	3.42	0.70	4.49	2.86	3.42 ± 0.32	
26061		3	30.671	4.86	0.59	5.23	1.29	3.38 ± 0.48	
26098	30	60	31.667	3.47	0.69	4.86	3.60	4.01 ± 0.42	
26099		3	29.466	6.03	0.58	5.14	2.33	2.80 ± 0.42	
26011	34	86	31.663	3.20	0.72	4.64	3.84	3.30 ± 0.38	
26112		5	30.678	4.15	0.61	4.44	1.27	3.48 ± 0.43	
26129	40	4	30.976	4.93	0.68	5.18	1.64	3.33 ± 0.40	
26133	42	26	31.182	4.93	0.71	5.32	1.93	3.18 ± 0.40	
26134		4	30.980	4.70	0.66	5.17	1.30	3.23 ± 0.43	
26151	47	30	31.408	3.94	0.66	5.03	2.14	3.63 ± 0.40	
26152		3	31.225	4.23	0.64	5.12	0.80		<2.6
26155	48	1	31.032	4.78	0.61	5.04	0.79		<2.6
26156	49	34	31.459	4.09	0.69	4.91	3.02	2.88 ± 0.45	
26157		1	31.352	4.61	0.68	5.09	1.62		<2.6
26160	50	4	31.263	4.57	0.69	5.17	0.97	3.22 ± 0.45	<3.9
26162	51	3	31.441	4.07	0.69	5.33	2.33		<2.7
26163	52	40	31.441	3.97	0.66	5.29	1.71	3.22 ± 0.7	
26164		3	31.208	4.26	0.63	5.36	0.70		<2.7
26166	53	3	31.187	4.29	0.65	5.40	0.91	3.60 ± 0.40	<2.7
26167	54	40	31.510	3.80	0.69	5.24	1.73	2.48 ± 0.42	
26168		5	31.183	4.42	0.65	5.44	0.49		<2.7
26170	55	4	31.261	4.03	0.68	5.21	4.12	3.87 ± 0.45	
26171	56	33	31.471	3.91	0.78	5.27	3.51	3.82 ± 0.42	
26172		3	31.333	3.81	0.72	5.20	1.77		<2.7
26174	57	4	31.301	3.77	0.73	5.24	1.06	3.70 ± 0.32	
26175	58	33	31.425	3.74	0.73	5.13	1.93	3.53 ± 0.48	
26176		3	31.281	3.82	0.70	5.08	-		<2.7

Table 4. Cruise Data from Cruise 87-015.

Sample No	Stn No	Depth (m)	Salinity (‰)	Silicate (μmoles/ℓ)	Phosphate (μmoles/ℓ)	Nitrate (μmoles/ℓ)	SPM (mg/ℓ)	Cs-137 (mBq/ℓ)	H-3 (Bq/ℓ)
26178	59	4	31.265	3.89	0.69	5.16	1.19	3.54 ± 0.45	<2.7
26179	60	33	31.419	3.69	0.71	5.13	1.47	3.85 ± 0.48	
26180		4	31.230	3.84	0.68	5.17	1.13		<2.6
26182	61	6	31.205	4.27	0.71	5.28	0.99		<3.2
26184	62	3	31.212	4.36	0.78	5.24	1.38		<3.2
26187	63	4	31.170	4.42	0.70	5.02	1.59	3.67 ± 0.51	<2.7
26188	64	35	31.371	4.02	0.72	5.19	2.94	3.75 ± 0.47	
26189		4	31.371	4.33	0.70	5.17	2.04		<2.6
26191	65	3	31.242	4.28	0.67	5.13	0.60		<2.6
26192	66	38	31.536	3.79	0.73	4.99	2.21	4.08 ± 0.40	
26193		3	31.223	4.33	0.67	5.26	0.90		<3.4
26195	67	3	31.284	4.26	0.70	5.11	0.66	3.87 ± 0.47	<2.6
26196	68	33	31.517	3.79	0.70	4.89	3.38	3.35 ± 0.52	
26197		3	31.280	4.06	0.65	5.06	0.76		<3.9
26302	69	2	31.334	3.74	0.61	4.98	1.93	3.15 ± 0.47	<2.6
26303	70	33	31.419	3.53	0.63	4.88	1.65	3.32 ± 0.38	
26304		2	31.308	3.63	0.62	4.89	0.52		<2.6
26305	71	31	31.387	3.50	0.64	4.80	1.25	3.62 ± 0.48	
26306		2	31.301	3.67	0.65	4.89	1.52		<2.6
26308	72	2	31.317	3.52	0.64	4.84	1.97		<2.6
26309	73	38	31.418	3.46	0.62	4.83	1.36	3.42 ± 0.32	
26310		2	31.266	3.55	0.64	4.93	0.71		<2.6
26312	74	3	31.383	3.85	0.68	4.91	1.90	3.05 ± 0.48	
26313	75	35	31.545	3.60	0.71	4.91	2.16	2.98 ± 0.52	
26314		2	31.362	3.88	0.68	5.02	1.28		<2.6
26316	76	2	31.342	3.85	0.67	4.97	0.82	3.34 ± 0.47	
26317	77	36	31.421	3.78	0.69	4.91	1.71	3.65 ± 0.43	
26318		4	31.321	4.46	0.68	4.93	0.90		<3.3
26320	78	3	31.273	3.82	0.62	5.02	1.03	3.82 ± 0.50	
26321	79	35	31.310	3.83	0.70	4.97	2.08	3.47 ± 0.51	
26324	80	3	31.256	3.67	0.58	4.84	0.70	3.72 ± 0.32	
26325	81	33	31.318	4.10	0.66	4.86	1.18	3.20 ± 0.53	
26328	82	5	31.199	3.75	0.55	4.93	0.78	3.62 ± 0.45	
26329	83	31	31.264	3.79	0.62	4.91	0.57	3.60 ± 0.55	

Table 5. Remaining Radionuclide Results from Cruise 87-015.

Plutonium

Sample No.	Stn No.	Depth (m)	Salinity (‰)	Pu-239 (mBq/ℓ)	Pu-238 (mBq/ℓ)
26011	3	112	32.371	0.018 ± 0.003	<0.001
26012	3	5	32.323	0.027 ± 0.005*	<0.003
26153	47	30	31.408	0.020 ± 0.003*	<0.011
26153	49	1	31.352	0.038 ± 0.012	<0.003

*low chemical yield

Po-210, Pb-210 (dpm/100ℓ)

Station 5

Sample No.	Depth (m)	Salinity (‰)	Soluble		Particulate		% on Particles	
			Pb-210	Po-210	Pb-210	Po-210	Pb-210	Po-210
26016	140	32.059	1.01	2.84	1.62	4.75	61.6	62.5
26017	103	31.570	1.17	1.18	0.81	2.18	40.9	64.9
26018	53	31.615	1.49	2.31	0.88	1.46	37.1	38.7
26019	20	31.366	2.14	9.82	1.71	3.18	44.4	24.5
26020	4	31.153	6.16	1.96	3.38	0.53	35.4	21.3

Sr-90

Sample No.	Stn No	Depth (m)	Salinity (‰)	Sr-90 (mBq/ℓ)	Cs-137/Sr-90
26009	3	11	31.384	3.50 ± 0.53	1.04
26160	50	4	31.263	3.83 ± 0.57	0.84
26166	53	3	31.187	3.33 ± 0.50	1.08

Great Britain and from the Chernobyl accident in the USSR in 1986 are enriched in Cs-137 leading to an increase in the ratio of Cs-137/Sr-90 (INSAG, 1986). These releases also contain measureable levels of the shorter-lived isotopes including Cs-134 ($t_{1/2}$ = 2.1 year). In marine systems, Sr-90 is totally dissolved, while 95-97 % of cesium remains in solution (Kupferman et al 1979).

The average Cs-137 activity measured in seawater for May 1987 was 3.5 mBq/l, in the range of levels found during previous pre-operational and operational cruises (Table 6). The average Sr-90 activity of 3.6 mBq/l (Table 6) gives an average Cs-137/Sr-90 ratio of 1.03, in good agreement with ratios measured in coastal regions (Bowen et al, 1974). No Cs-134 was detected in any water sample. The Cs-137 levels measured during the anchor stations are illustrated in Figure 6 with salinity, SPM concentrations and tidal conditions for surface and bottom water. SPM concentrations tended to increase during high tides. With the exception of a few high Whatman SPM samples, a reasonable correlation (r = 0.62) was found between results obtained using the two methods of SPM collection, the Whatman cartridge and the Nucleopore filter, where the Whatman filter collecting approximately 66 % more material. The Whatman paper filter values are higher because of (1) the smaller pore size Whatman filter collects more material, (2) the nature of the paper filter allows the effective pore size to decrease as the filter becomes loaded and (3) washing all the salt out of the paper filter is more difficult. The paper filters are useful for bulk sample collection and qualitative measurements of SPM levels but less accurate in determining exact SPM concentrations. Salinity values are generally 0.15 ‰ lower at the surface than the bottom. The average activities of Cs-137 at surface (3.55 Bq/l, sigma = 0.40) and bottom (3.44 Bq/l, sigma = 0.39) are similar and show little variablity with tidal condition, indicating a well mixed water mass.

SPM samples were analysed only for gamma emmitting isotopes and no Cs-137 was measured. Detection limits for typical counting conditions (water volume of 48 l, counting time of 1500 minutes, one month after sample collection) are given in Table 7. Distribution coefficients, k_d, are estimated by the following equation :

Table 6. Average Radionuclide Values Measured in the Bay of Fundy for All Cruises.

Cruise No.	Collection Date	Radionuclide Activities (mBq/ℓ)			
		Cs-137		Sr-90	H-3
		Particulate	Soluble*	Soluble**	
Pre-operational					
79-007	May 1979	–	3.8 ± 0.7, n=28	3±1, n=13	2700 ± 3000
79-027	Oct 1979	<0.8	2.6 ± 0.8, n=24	–	1700 ± 2700
80-018	Jun 1980	<0.8	4.2 ± 0.3, n=43	–	<2300
81-500	Feb 1981	<1.5	4.4 ± 0.5, n=20	–	2840 ± 1200
81-010	Apr 1981	<1.2	3.5 ± 0.3, n=33	–	2210 ± 580
Post operational					
83-003	Apr 1983	-	3.3 ± 0.6, n=30	–	2525 ± 910
84-025	Jul 1984	<0.4	3.0 ± 0.5, n=28	–	2933 ± 611
85-041	Dec 1985	<0.5	3.2 ± 0.4, n=18	–	3885 ± 1343
87-015	May 1987	<0.5	3.5 ± 0.3, n=46	3.6±0.3, n=3	<3900

*Mean radionuclide activities are calculated using a single value for the anchor station.
**Error reported here is the standard deviation for the mean value.

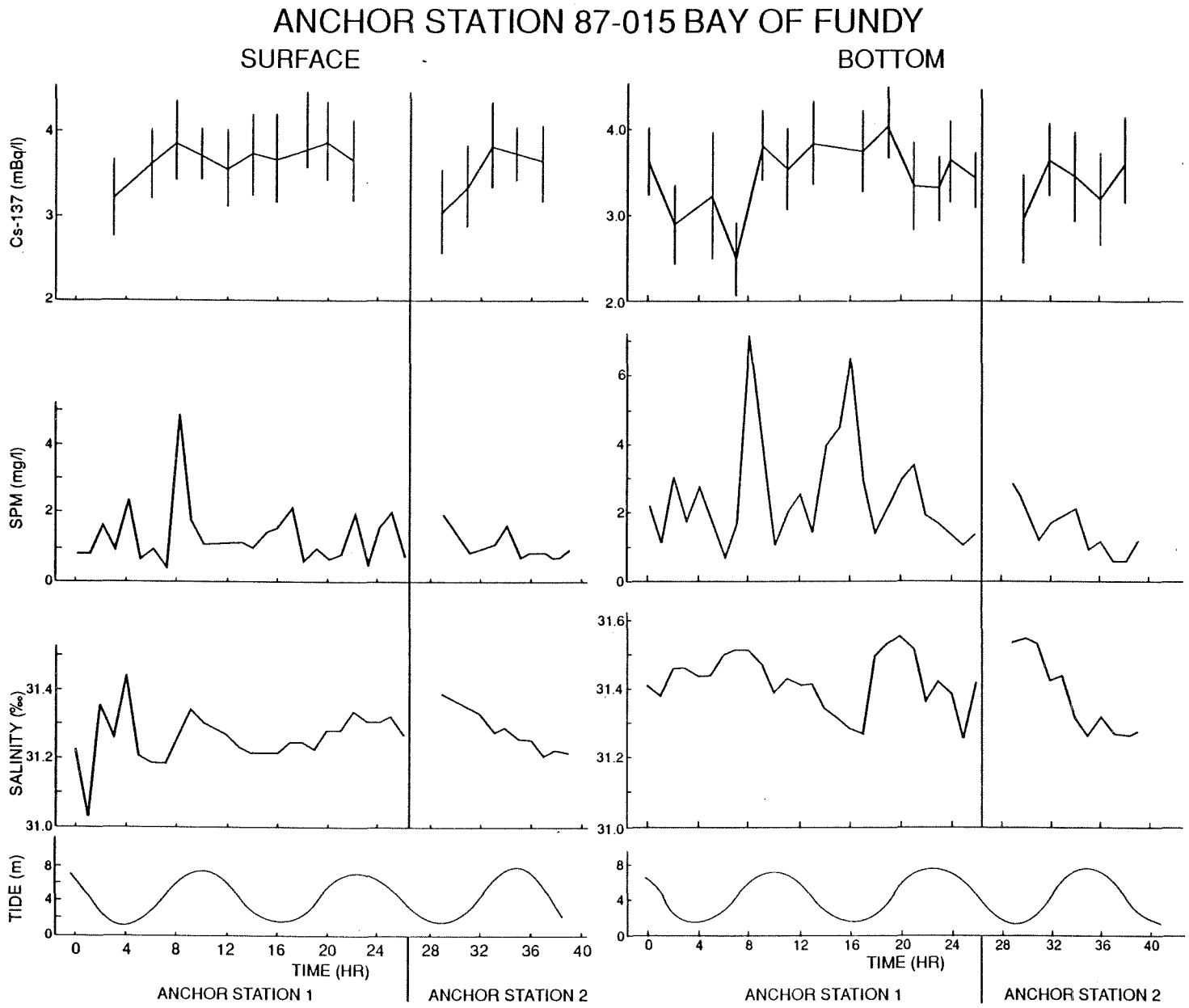

Figure 6: Cs-137, SPM and salinity as a function of tidal condition at the anchor station, cruise 87-015 for surface and bottom samples.

Table 7. Detection limits for Chelex elutant and SPM in seawater for typical counting conditions (50 l sample, 1500 min count and delay of 1 month between sample collection and counting).

Nuclide	Chelex (mBq/ℓ)	SPM	
		(Bq/g)	(mBq/ℓ)
Co-56	<4.0	<1.0	<1.5
Co-57	<0.02	<0.3	<0.4
Co-58	<7.0	<1.1	<1.6
Co-60	<0.02	<0.6	<0.9
Cr-51	<1.2E7	<16	<24
Fe-59	<1000	<3.1	<4.6
Mn-54	<0.02	<0.7	<1.1
Zn-65	<0.06	<1.7	<2.6
Cs-134	–	<0.6	<0.9
Cs-137	–	<0.4	<0.6

$$k_d = \frac{\text{Activity on particles (Bq/g)}}{\text{Activity in solution (Bq/ml)}}$$

The k_d for Cs-137 has been estimated to be in the range of 10^2 to 2×10^4 (IAEA, 1985). From a detection limit of approximately 0.18 Bq/g for SPM, the k_d for Cs-137 is measured to be $< 5 \times 10^4$.

Gamma-Emitting Radionuclides

Many products of neutron activation of reactor support and encasement materials such as Zn-65, Co-60 and Mn-54 have high concentration factors in many species (IAEA, 1985). These isotopes have been concentrated from seawater on Chelex-100 resin and then eluted with 2N HCl and 2N HNO_3. An average retention efficiency of 90 % was determined using a NBS mixed gamma standard. Particulate levels are determined by gamma analysis of the filter cartridges. No gamma-emmiting isotopes were measured on the Chelex eluant or the SPM, thus no k_d can be estimated. The detection limits for Chelex-100 elutant and SPM for typical sampling and counting conditions (water volume of 48 l, counting time of 1500 minutes, one month after sample collection) are given in Table 7.

Plutonium

The majority of plutonium entering the marine environment originates from nuclear tests. Additional accidental releases of Pu-238 occurred as a result of the re-entry burn-up of the nuclear powered SNAP-9A satellite in 1968 and of Pu-239 when a B-52 bomber carrying 4 nuclear warheads crashed on the ice in Thule Harbour, Greenland in 1968. Levels of Pu-239 found in the Bay of Fundy water average 0.026 mBq/l while those of Pu-238 were below the detection limit of approximately 0.003 mBq/l (Table 5). These values are in the range of levels measured previously (Nelson et al, 1988).

Pb-210/Po-210

Measurements of the disequilibria between the U-238 series radionuclides, Ra-226, Pb-210 and Po-210 provide one of the best methods for determining removal rates of particle reactive substances from the water column and for studying the processes of scavenging (Fleer and Bacon 1984).

Levels of Pb-210 and Po-210 are listed in Table 5. The one sigma counting error for soluble data is approximately 15 % and for particulate values is 30 %.

Most measurements of total Pb-210 and Po-210 (soluble + particulate) were less than levels of 8.2 to 8.6 dpm/100 l measured for parent Ra-226 in the Bay of Fundy in 1984 (unpublished results). Both soluble and particulate Pb-210 decreased with depth. Polonium-210 activities in both phases were low at the surface, peaked at 20 m and then decreased with depth. Particulate levels of both Pb-210 and Po-210 showed elevated levels in the deepest sample. The percent activity on particles for Po-210 increased with depth from 21 to 64 %, while for Pb-210 a constant proportion (~ 40 %) remained on particles except in the bottom sample where 62 % of the Pb-210 is associated with particles. These observations are consistent with removal of Po-210 and to a lesser extent of Pb-210 from the water column by particles. The high percentage of particle-associated Pb-210 and Po-210 in the bottom sample may be evidence for particle resuspension.

Tritium

Environmental releases of tritium from Candu nuclear reactors are substantially greater than any other radionuclide due to the use of heavy water, D_2O, as the moderator and coolant. Tritium is measured in water samples after distillation under vacuum and counting for 500 to 1000 min in a liquid scintillation counter using methods outlined in previous reports (Ellis et al, 1984).

Tritium levels in seawater samples are below the detection limit (generally < 3.9 Bq/l) as was found during previous cruises (Table 6). Some elevated levels were measured

close to the outfall at times of effluent release during our release experiment (see Thermal Plume Studies, Section 3.4).

3.3 Sediment Studies

Sediment cores were collected from 14 locations during cruise 87-015 and were analysed at one cm intervals for Pb-210 and in some cases for Cs-137 and plutonium. Lead-210, produced in the natural decay series of U-238, is introduced into the coastal environment at a relatively constant rate from the atmosphere via the intermediate nuclide Rn-222. It is rapidly scavenged and accumulated in sediments as an unsupported excess above levels produced from the U-238 series nuclides present in the sediment. Measurements of excess Pb-210 activity as a function of depth can be used to determine sedimentation rates in undisturbed sediments. Nuclear fallout products such as Cs-137 and plutonium present in the sediments have been introduced from the atmosphere since the early 1950s as a result of weapons tests and are used to verify sedimentation rates and indicate the presence of sediment mixing.

Inventories of Pb-210 were determined and combined with previous data (Table 8) to update the distribution of Pb-210 inventories in the western Bay of Fundy (Figure 7). Cesium-137 inventories (Table 8) are shown in Figure 8 and distribution patterns are similar to those found for Pb-210. Largest inventories are found in the Quoddy region, at the northernly approaches of Passamaquoddy Bay where the sediment consists of fine-grained muds (Loring, 1979, Figure 9). This area consists of a net depositional sink for particle reactive elements. In contast, the sediments in the immmediate vicinity of Point Lepreau which grade into sandy sediments are characterized by lower inventories of Pb-210.

Profiles of Pb-210 and Cs-137 for three of the cores collected (26029, 26037 and 26101) are shown in Figure 10. Core 26029, collected at Station 9, is typical of cores from the Quoddy region, having high sedimentation rates and high inventories of Pb-210 and Cs-137. A sedimentation rate of approximately 1 cm/y is calculated. Using this sedimentation rate, the deepest penetration of Cs-137 in the sediment occurs in 1950, exactly the time of the

Table 8. Summary of Pb-210, Cs-137 and Plutonium Inventories in Sediments.

Site No	Location	Collection Date	Station No	Sample No	Inventory (dpm/cm²)			
					Pb-210	Cs-137	Pu-239	Pu-238
1	45°00.0' 66°29.5'	1979	3	2770	11.5	.47	.197	.078
		1983	4	6407	6.5			
2	45°05.8' 66°31.5'	1979	7	2792	17.1			
3	45°05.0' 66°36.0'	1979	8	2799	54.0			
		1980	28	3503	120.2			
4	45°03.0' 66°25.5'	1979	10	2814	10.8			
5	44°55.7' 66°32.5'	1979	7	7047	92.7	3.63		
		1980	24	3478	109.0*			
		1984	19	2142	18.1			
6	44°58.9' 66°50.8'	1979	11	7056	70.3	2.26 (cor)		
7	45°03.0' 66°19.0'	1979	20	7096	18.7	1.11		
8	45°03.2' 66°27.0'	1979	30	7145	16.0			
			30	7146	8.9			
9	45°01.0' 66°49.5'	1980	9	3436	307	2.79*	2.50	.083
		1981	37	7997	502	10.27		
		1983	41	6494	139.0		2.28	.075
10	45°00.0' 66°47.0'	1980	10	3442	167			
		1987	9	26037	196.1	5.96		
		1987	9	26038		5.69		
11	44°55.5' 66°40.0'	1980	13	3448	42.1			
		1984	20	2145	26.7			
		1987	7	26029	38.8	1.77		
12	44°51.0' 66°35.0'	1980	14	3453	95.4	4.95		
13	44°59.5' 66°38.5'	1980	25	3485	132.7			
		1981	35	7995	161	3.45 (cor)		
		1984	21	2148	190			
		1987	46	26150	122.6			
14	45°02.0' 66°43.0'	1980	26	3491	195.0			
		1981	36	7996	178	3.27 (cor)		
15	45°02.5' 66°38.5'	1980	27	3497	145.2*			
		1987	43	26138	168.8			
16	45°06.0' 66°31.0'	1980	29	3508	16.1			
17	45°02.0' 66°33.0'	1980	30	3514	38.5	0.73		

* Radionuclide levels are above background levels at bottom of core.

Table 8. Summary of Pb-210, Cs-137 and plutonium inventories in sediments.

Site No	Location	Collection Date	Station No	Sample No	Inventory (dpm/cm²)			
					Pb-210	Cs-137	Pu-239	Pu-238
18	45°03.4' 66°26.0'	1980	49	3560	29.8	0.62		
		1980	49	3567	26.2			
		1987	62	29185	44.1			
19	44°58.0' 66°45.0'	1981	39	8005	20.7	0.54*		
20	44°55.0' 66°47.5'	1981	40	8006	22.3			
21	45°00.0' 66°21.0'	1981	80	8097	8.4			
22	45°01.5' 66°24.0'	1981	79	8098	18.9			
23	44°40.1' 66°36.9'	1983	3	6407	6.5			
24	44°45.5' 66°34.0'	1983	5	6413	54.4		.40	.011
25	44°48.9' 66°52.1'	1983	7	6417	4.2			
26	45°07.8' 66°08.6'	1983	26	6459	14.7			
27	45°03.6' 66°11.0'	1983	27	6462	18.2			
28	44°11.0' 66°07.0'	1984	5	2112	6.5			
29	45°04.0' 66°34.4'	1984	23	2154	32.9			
30	45°52.5' 66°47.5'	1987	6	26025	21.7	1.60		
31	45°07.0' 66°07.1'	1987	30	26101	21.4	.73		
32	45°01.0' 66°43.2'	1987	44	26142	157.4			
33	45°00.2' 66°41.7'	1987	45	26146	15.8			

* Radionuclide levels are above background levels at bottom of core.

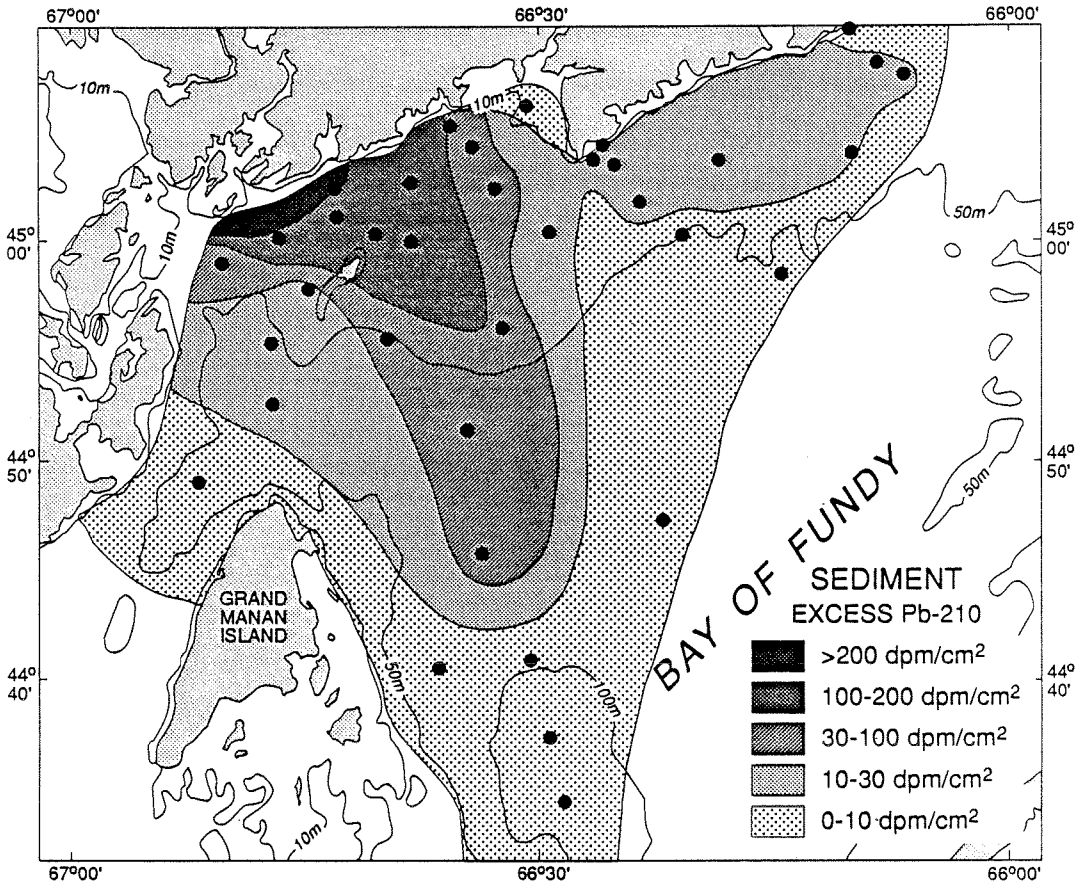

Figure 7. Excess Pb-210 inventories in sediment cores collected in the western Bay of Fundy.

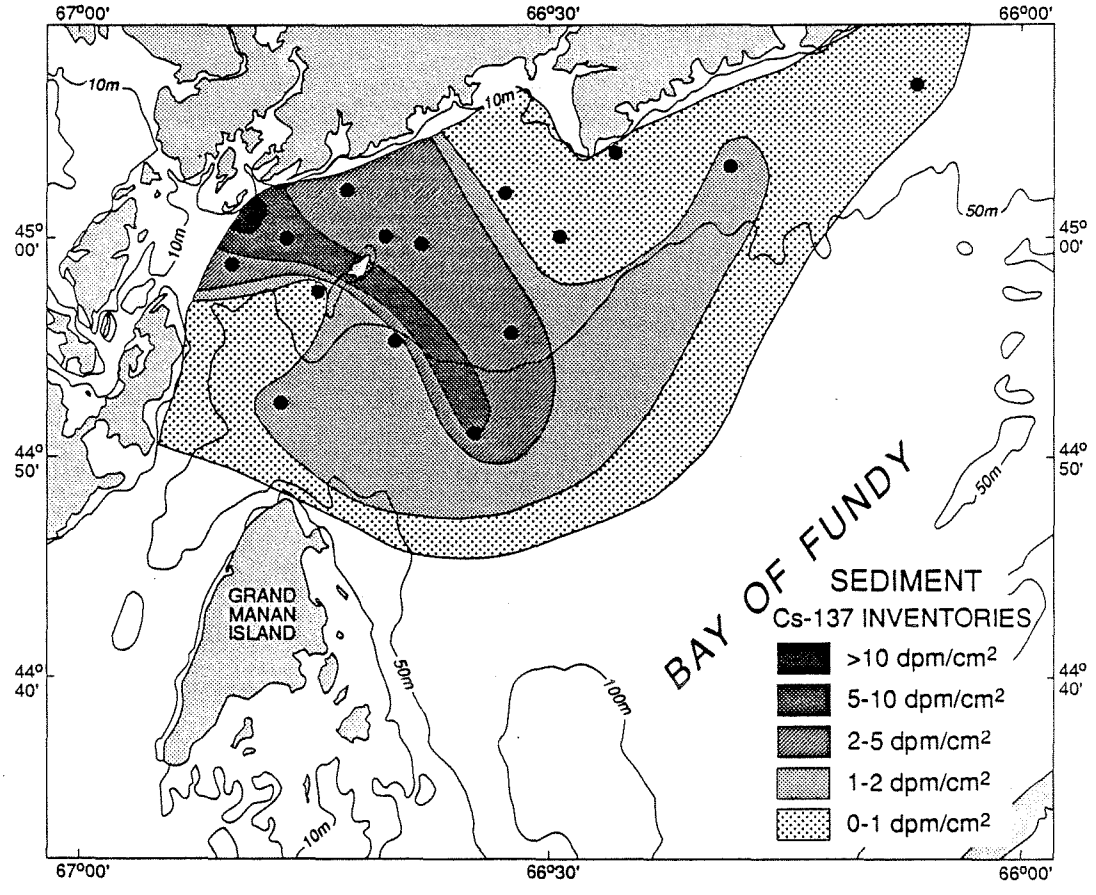

Figure 8. Cs-137 inventories in sediment cores collected in the western Bay of Fundy.

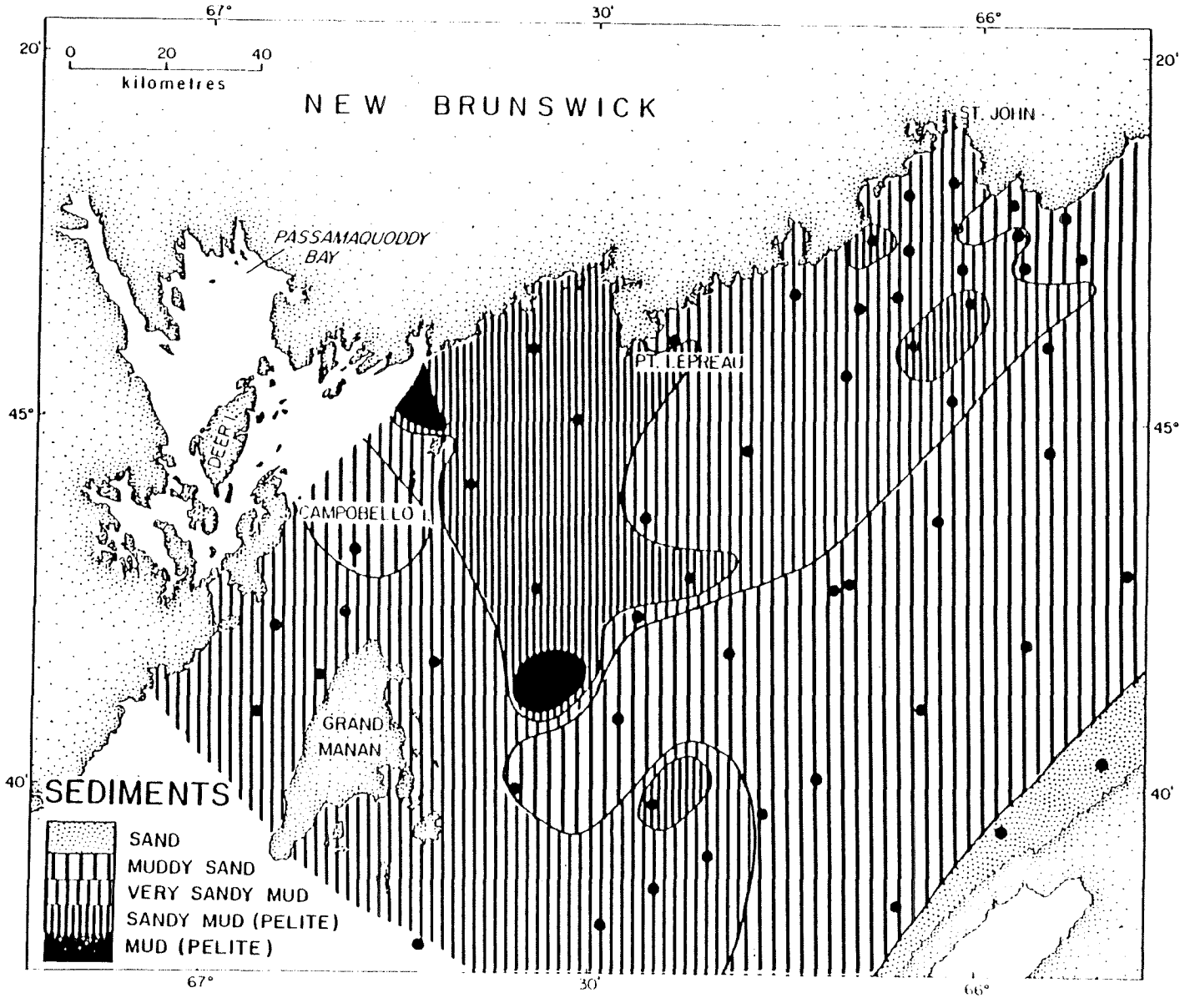

Figure 9. Particle size distributions of sediments in the western Bay of Fundy reproduced from Loring (1979).

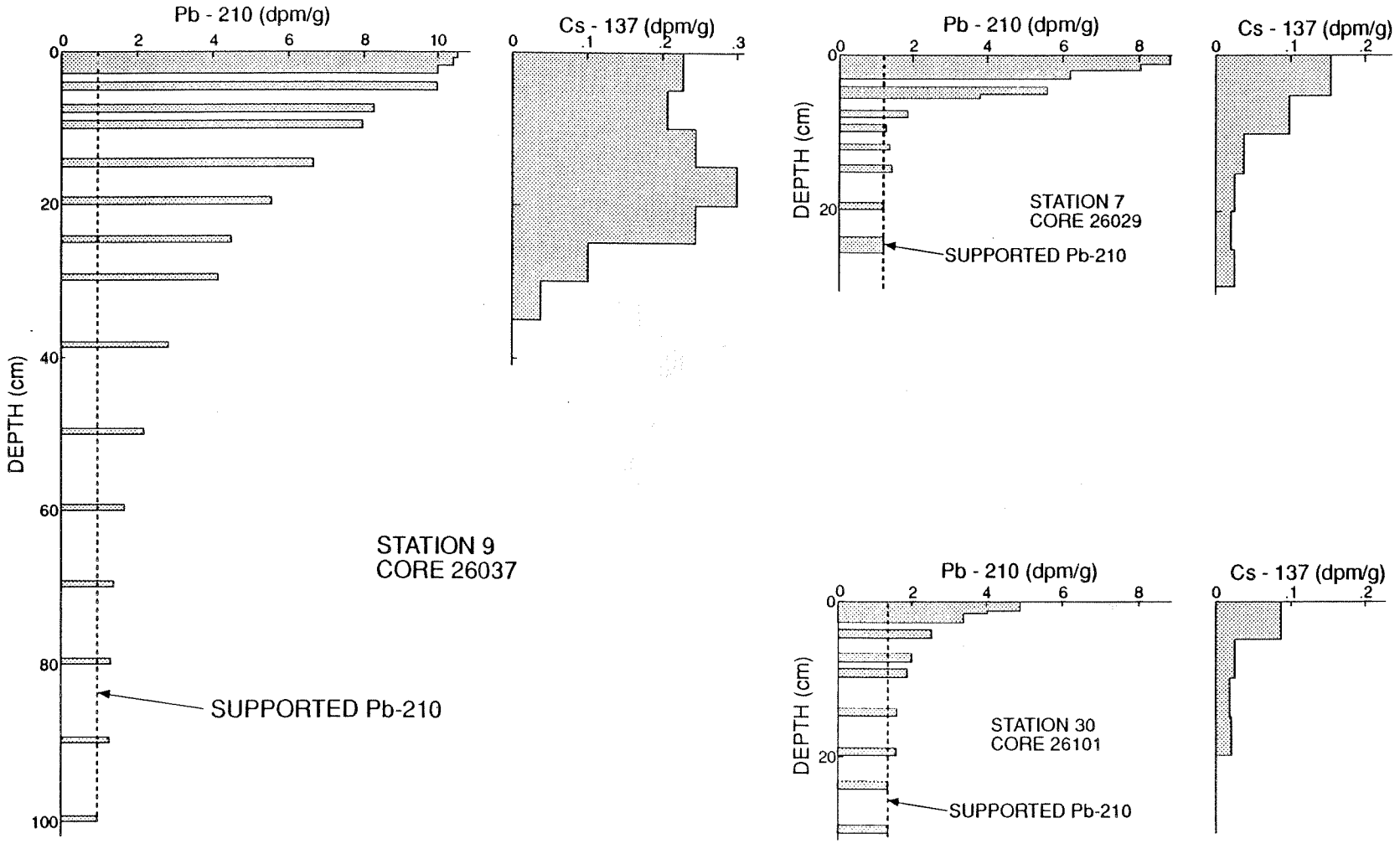

Figure 10. Radionuclide distributions in cores 26029, 26037 and 26101 collected in the Bay of Fundy during cruise 87-015.

commencement of nuclear test. The good agreement between the 1950 horizon predicted by both Pb-210 and Cs-137 indicates that there is little mixing of the sediments at this location. Station 7 (core 26037) is located on the edge of the high sediment accumulation area of the Quoddy region. The excess Pb-210 profile is characterized by high activities and low depth penetration and suggests a lower sedimentation rate. The deep penetration of Cs-137 below that of the excess Pb-210 indicates very active reworking of the sediment. Core 26101 was collected at Station 30 in the outer Saint John harbour entrance. This core has slightly reduced inventories of Pb-210 and Cs-137, a low sedimentation rate and relatively intense sediment reworking either by biological mixing or sediment resuspension.

3.4 Thermal Plume Studies

A series of surveys have been carried out in the vicinity of the cooling water outfall during the operational phase of the NGS usually during routine releases of liquid effluent. The results have been used to characterize the dispersion of effluents under various tidal conditions and at various times of year (Nelson *et al.*, 1985, 1986 and 1988).

During the cruise 87-015, three sets of observations were made from a small launch while the CSS Dawson was occupying a 39 hour anchor station nearby. These measurements were undertaken at High Water, 1/2 Falling Tide and Low Water. As with previous surveys, temperature and salinity profiles were obtained from the ship's launch using a portable Guildline digital CTD unit. Samples were collected at the surface and near bottom using a 1.7 l Niskin bottle and Loran-C positions were taken at beginning and end of CTD casts to determine launch drift in order to calculate surface currents when wind was not a dominant factor. In addition, CTD and current observations were made from the CSS Dawson while it occupied two different positions near the outfall site. During the 1/2 Tide Falling and Low Water sequences, the NGS undertook controlled liquid waste pumpouts to coincide with sampling in order to provide a measureable tritium signal in the outfall waters as an additional plume tracer. The details of these releases are given in Table 9.

Table 9. Details of liquid waste pumpout for Survey 87-015 during May 1987.

Pumpout No.	755	756
Start Date	May 22	May 23
Start Time	11:38	15:40
Duration (min)	69	60
Volume discharged	3.87E4	3.87E4
Average discharge rate (l/s)	8.6	8.6
H-3 activity discharged (Bq)	1.31E10	2.64E10
Average Inlet Temperature (°C)	4.6	4.6
Average outlet temperature (°C)	26.0	26.0

The station locations for the three surveys are shown in Figure 11. The locations for each survey were selected as being downstream from the outfall for that tidal condition. Results for salinity, temperature and tritium activity are presented in Table 10. Elevated temperatures were measured in the surface water and the temperature distribution for the three surveys are shown in Figure 12. Elevated temperatures were found close to the outfall in most cases. The surface tritium levels measured above background are shown in Figure 13. Measurements above background were made only during the controlled releases at 1/2 Tide Falling and the Low Water. In both cases, elevated levels of tritium were found north of the outfall, in Duck Cove, close to shore as expected for these conditions.

The results from this and all the other surveys are being consolidated into one comprehensive thermal plume study which will be published separately at a later date.

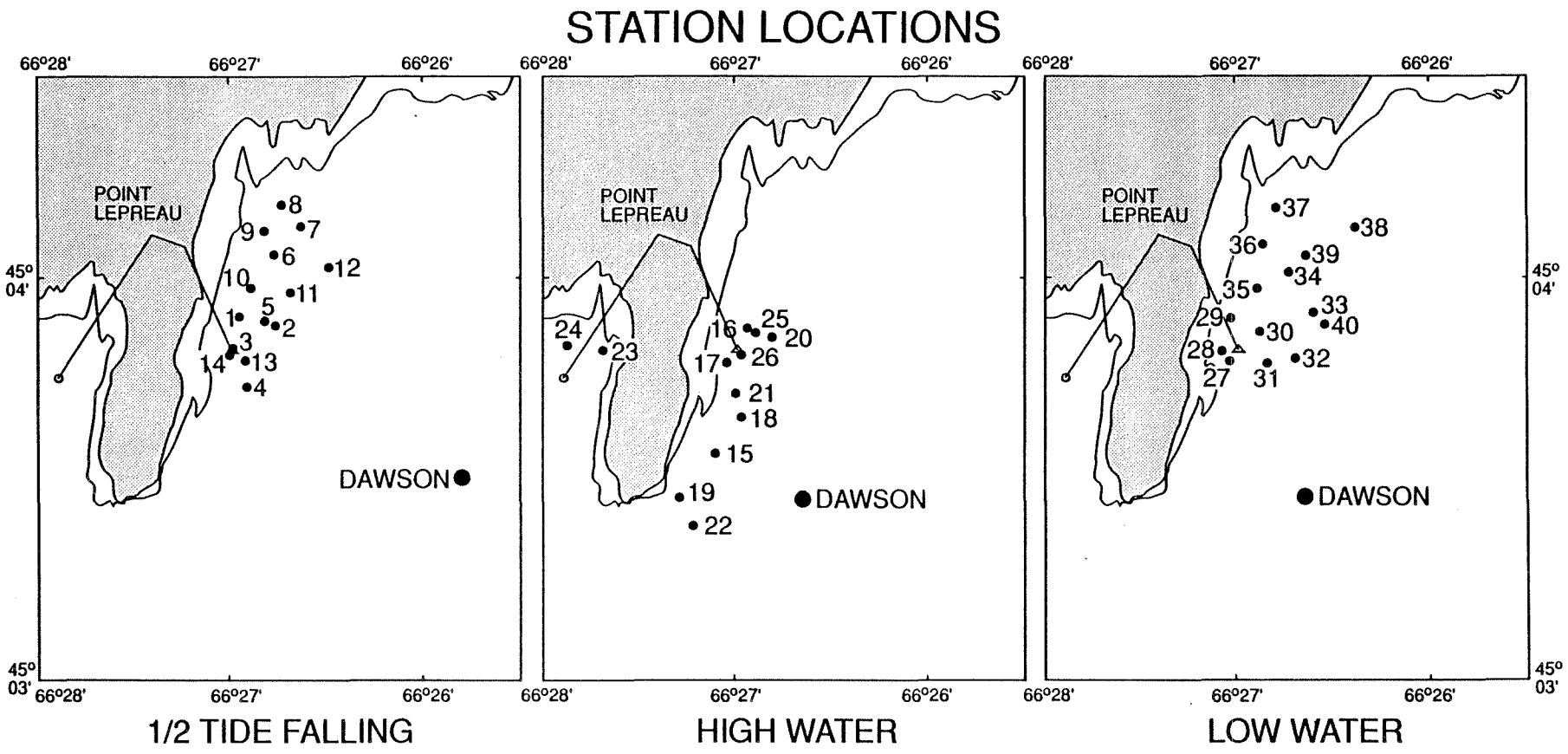

Figure 11. Station locations for launch surveys during cruise 87-015.

Table 10. Tritium results for launch survey during Cruise 87-015.

Station No	Collection Date and Time	Sample No	Sample Depth (m)	Salinity (‰)	H-3 (Bq/ℓ)	Temp. (°C)
1	May 22, 14:53	26201	1	31.41	'4.3 ± 2.7	4.09
		26202	13	31.440*	2.3 ± 2.7	3.96
2	May 22, 15:02	26203	1	31.41	<4.0	4.17
		26204	24	31.45	2.4 ± 2.7	3.91
3	May 22, 15:12	26205	1	31.38	12.0 ± 2.8	5.02
		26206	18	31.44	<4.1	4.08
4	May 22, 15:20	26207	1	31.28	3.2 ± 2.7	4.44
		26208	24	31.40	2.3 2.7	4.04
5	May 22, 15:30	26209	1	31.38	<2.4	4.17
		26210	22	31.42	<4.1	4.00
6	May 22, 15:40	26211	1	31.37	11.2 ± 2.8	5.45
		26212	18	31.43	<4.4	4.10
7	May 22, 15:46	26213	1	31.37	6.7 ± 2.8	5.30
		26214	11	31.43	<3.1	4.39
8	May 22, 15:54	26215	1	31.37	4.0 ± 2.7	4.86
		26216	7	31.405*	3.7 ± 2.7	4.29
9	May 22, 16:00	26217	1	31.35	6.8 ± 2.8	5.29
		26218	9	31.39	<2.3	4.72
10	May 22, 16:09	26219	1	31.33	7.5 ± 2.9	5.23
		26220	15	31.379*	<2.3	4.28
11	May 22, 16:18	26221	1	31.37	<2.3	4.16
		26222	22	31.41	<2.3	4.12
12	May 22, 16:25	26223	1	31.39	<2.3	4.14
		26224	21	31.40	<2.3	4.11
13	May 22, 16:40	26225	1	31.36	<2.3	4.22
		26226	23	31.387*	<2.3	4.17
14	May 22, 16:52	26227	1	31.30	<2.3	6.84
		26228	16	31.35	<2.3	4.25
15	May 23, 12:31	26231	1	31.36	<2.4	4.27
		26232	25	31.451*	<2.3	4.02
16	May 23. 12:49	26233		31.38	<2.3	4.19
		26234	23	31.47	<2.3	3.99
17	May 23, 12:56	26235	1	31.39	<2.3	5.18
		26236	15	31.45	<2.3	4.05

* Salinity measured using a 8400 Autosal Salinometer.

Table 10. Tritium results for launch survey during Cruise 87-015.

Station No	Collection Date and Time	Sample No	Sample Depth (m)	Salinity (‰)	H-3 (Bq/ℓ)	Temp. (°C)
18	May 23, 13:02	26237	1	31.39	<2.3	4.31
		26238	29	31.466*	<2.3	3.99
19	May 23, 13:09	26239	1	31.37	<2.5	4.37
20	May 23, 13:31	26241	1	31.43	<2.5	4.36
21	May 23, 13:38	26243	1	31.37	<2.5	4.47
22	May 23, 13:49	26245	1	31.32	<3.1	4.54
23	May 23, 14:02	26247	1	31.28	<2.6	4.71
24	May 23, 14:15	26249	1	31.23	<2.6	4.84
25	May 23, 14:35	26251	1	31.37	<2.9	4.30
26	May 23, 14:41	26253	1	31.40	2.9 ± 3.1	5.42
27	May 23, 18:49	26255	1	31.22	<2.5	4.98
28	May 23, 18:57	26257	1	31.23	<3.6	5.15
29	May 23, 19:01	26259	1	31.21	<5.0	6.92
30	May 23, 19:09	26261	1	31.17	14.2 ± 3.4	6.32
31	May23, 19:16	26263	1	31.23	<4.4	5.24
32	May 23, 19:23	26265	1	31.21	<3.5	5.63
33	May 23, 19:32	26267	1	31.17	<3.7	5.34
34	May 23, 19:50	26269	1	31.17	<4.7	5.54
35	May 23, 19:57	26271	1	31.25	29.0 ± 3.6	6 10
36	May 23, 20:03	26273	1	31.25	20.7 ± 3.5	6 52
37	May 23, 20:09	26275	1	31.233*	14.6 ± 3.4	6.39
38	May 23, 20:15	26277	1	31.21	<5.2	5.46
39	May 23, 20:23	26279	1	31.15	3.7 ± 3.3	5.46
40	May 23, 20:34	26281	38	31.19	<2.7	6.02

* Salinity measured using a 8400 Autosal Salinometer.

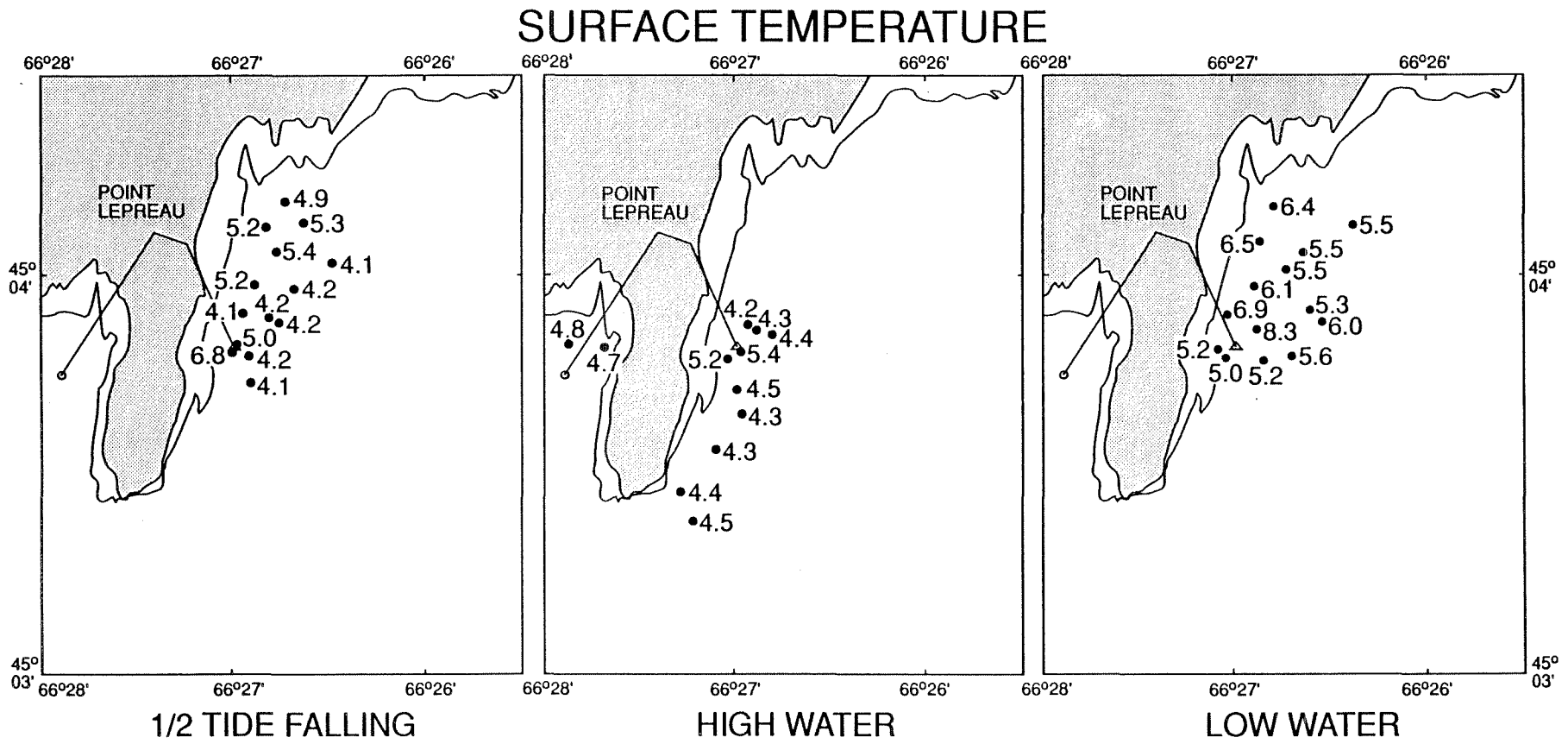

Figure 12. Surface temperatures for the launch surveys carried out during cruise 87-015.

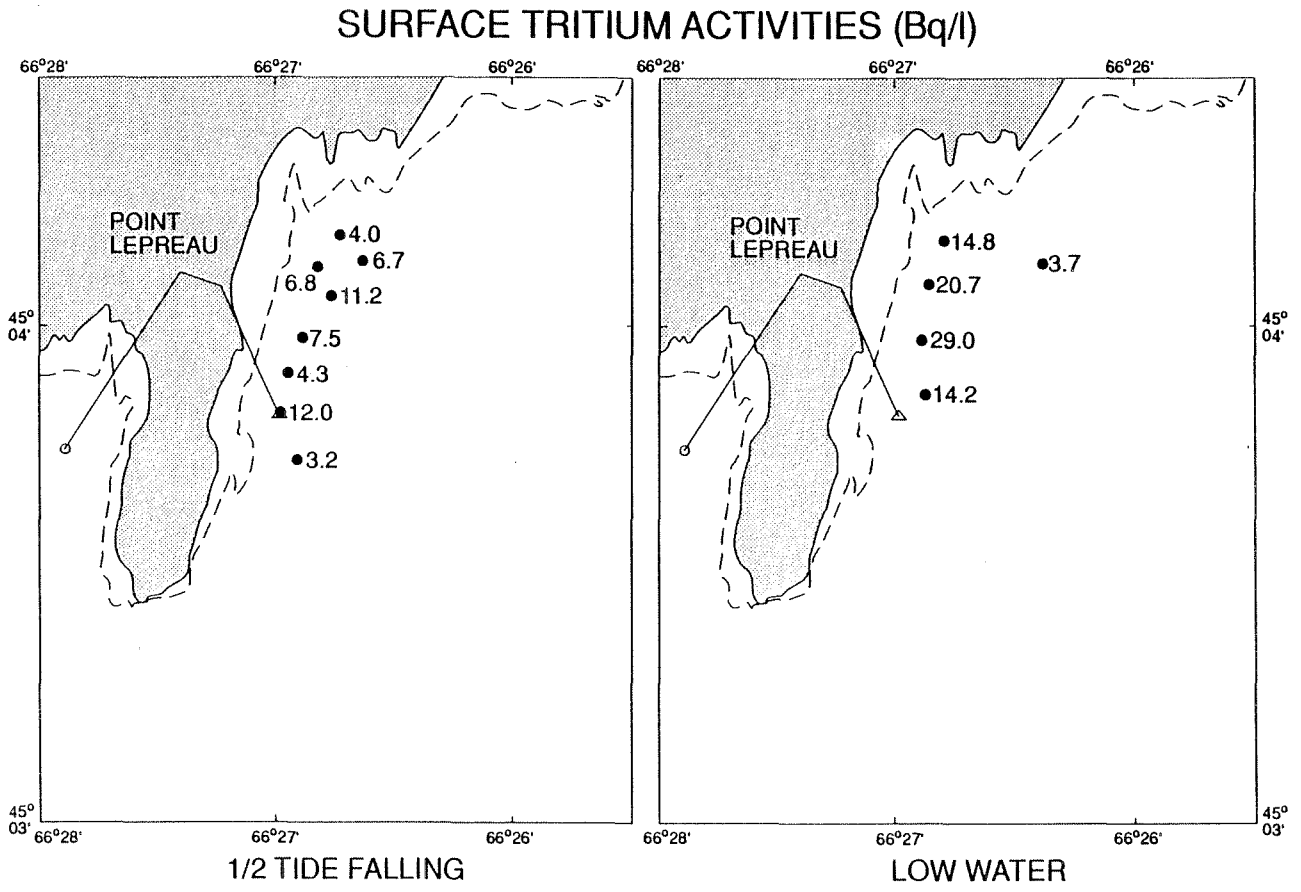

Figure 13. Tritium distribution during launch surveys carried out during cruise 87-015.

4.0 ATMOSPHERIC MONITORING

Radionuclides released from the NGS in the form of gaseous and atmospheric particulate emissions enter the marine, aquatic and terrestrial environment by direct deposition, by precipitation which has incorporated atmospheric radionuclides and by exchange with surface water.

The two principal components of the atmospheric monitoring program are (1) the ongoing compilation of a meterological data base for the Point Lepreau region which can be applied to the transport of airborne pollutants under diverse weather conditions and in atmospheric transport models, and (2) the collection of atmospheric samples (air vapour, gaseous I-131 and particulates) for radionuclide analysis.

4.1 Meteorological Data Collection

The meteorological data collection station is located in Musquash (Figure 14) at the New Brunswick Department of Transport depot. The station consists of a Fischer and Porter precipitation gauge and a thermohygrograph to record temperature and relative humidity. Wind speed and direction data (at 10 m) collected from an on site tower at the Point Lepreau NGS were provided by NBEPC. The Atmospheric Environment Service extracts the wind, temperature rainfall and relative humidity data for use in the monitoring program.

The monthly rainfall amounts for Musquash and Saint John airport and average monthly temperatures at Musquash are given in Table 11. Yearly rainfall amounts at Saint John airport range from 5 to 10 % higher than at Musquash and necessitate the continued maintenance of the precipitation collector at Musquash. Average monthly wind speeds are given in Table 11 and monthly distributions are illustrated in Figure 15. Average monthly wind speeds are high, approximately 14.5 km/hr. Wind speeds are greatest in the winter when winds are characterized by strong northerly winds while the summer is dominated by southwest winds.

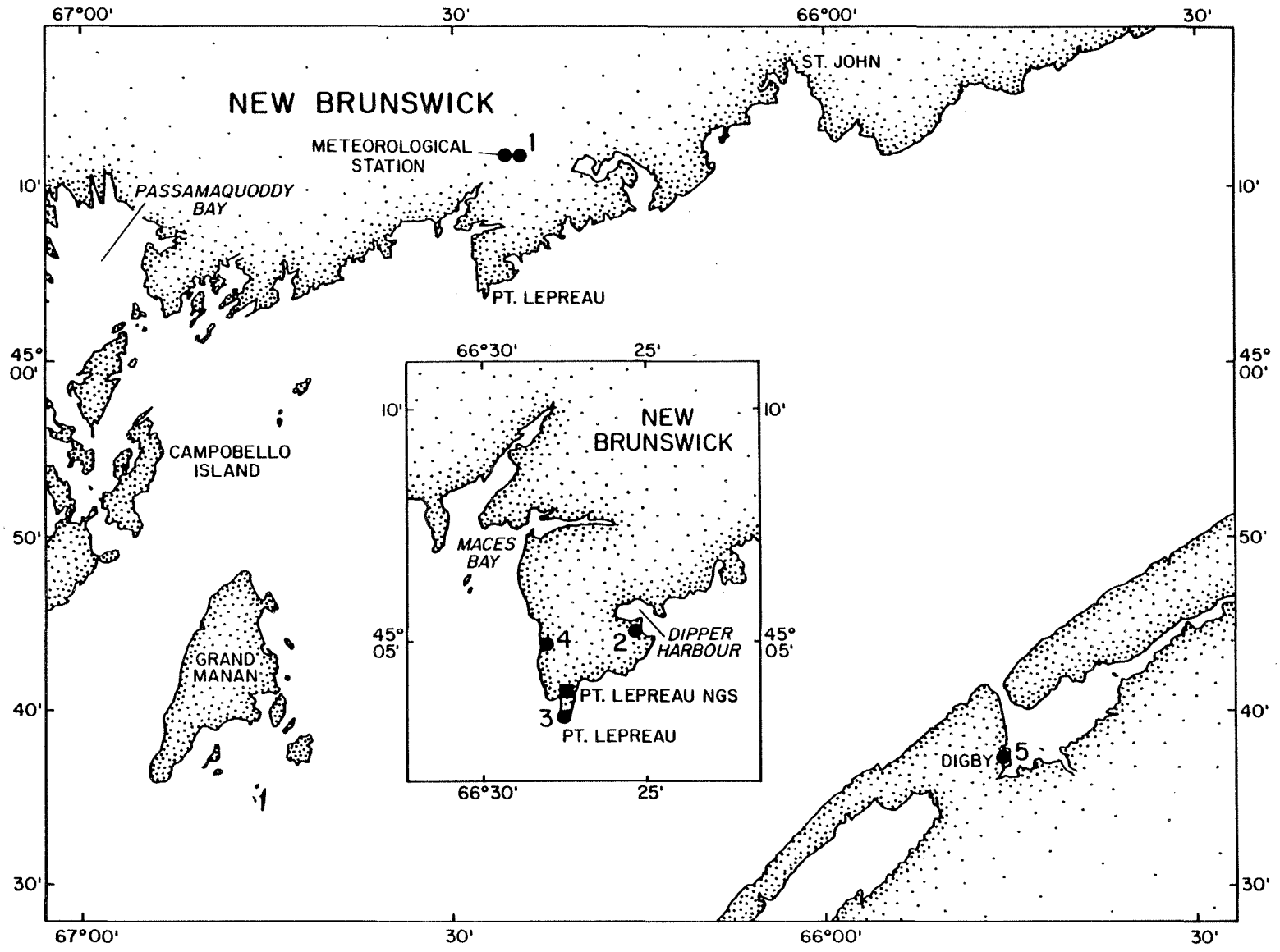

Figure 14: Air monitoring station locations.

Table 11. Meteorological Data for Point Lepreau During 1987 and 1988.

Year	Month	Musquash Ppt (mm)	Saint John Ppt (mm)	Average Temp(°C)	Wind Speed (km/h)
1987	Jan.	129.5	135.0	-7.9	18.8
	Feb.	27.9	42.2	-6.1	16.7
	Mar.	86.4	110.0	-0.9	15.1
	Apr.	63.5	58.4	5.8	15.6
	May	78.7	74.2	9.3	12.1
	Jun.	81.0	125.0	14.1	10.9
	Jul.	20.7	32.5	16.6	8.3
	Aug.	44.6	50.5	16.2	10.1
	Sep.	195.3	178.3	13.4	14.1
	Oct.	112.4	143.5	8.0	14.2
	Nov.	97.2	103.4	1.6	16.8
	Dec.	126.6	139.7	-1.4	17.7
Total Ppt(mm)		1063.8	1176.8		
1988	Jan.	86.4	95.7	-6.8	18.5
	Feb.	97.2	154.5	-5.7	18.5
	Mar.	41.4	38.9	-1.0	15.8
	Apr.	123.4	123.4	3.4	19.2
	May	108.4	108.4	9.6	12.5
	Jun.	74.8	74.8	12.7	9.8
	Jul.	107.8	107.8	16.8	7.4
	Aug.	150.4	150.4	16.9	8.9
	Sep.	85.7	85.7	12.3	13.0
	Oct.	131.7	131.7	6.6	17.8
	Nov.	215.3	215.3	3.7	19.2
	Dec.	64.5	64.5	-5.3	18.0
Total Ppt (mm)		1287.0	1351.1		

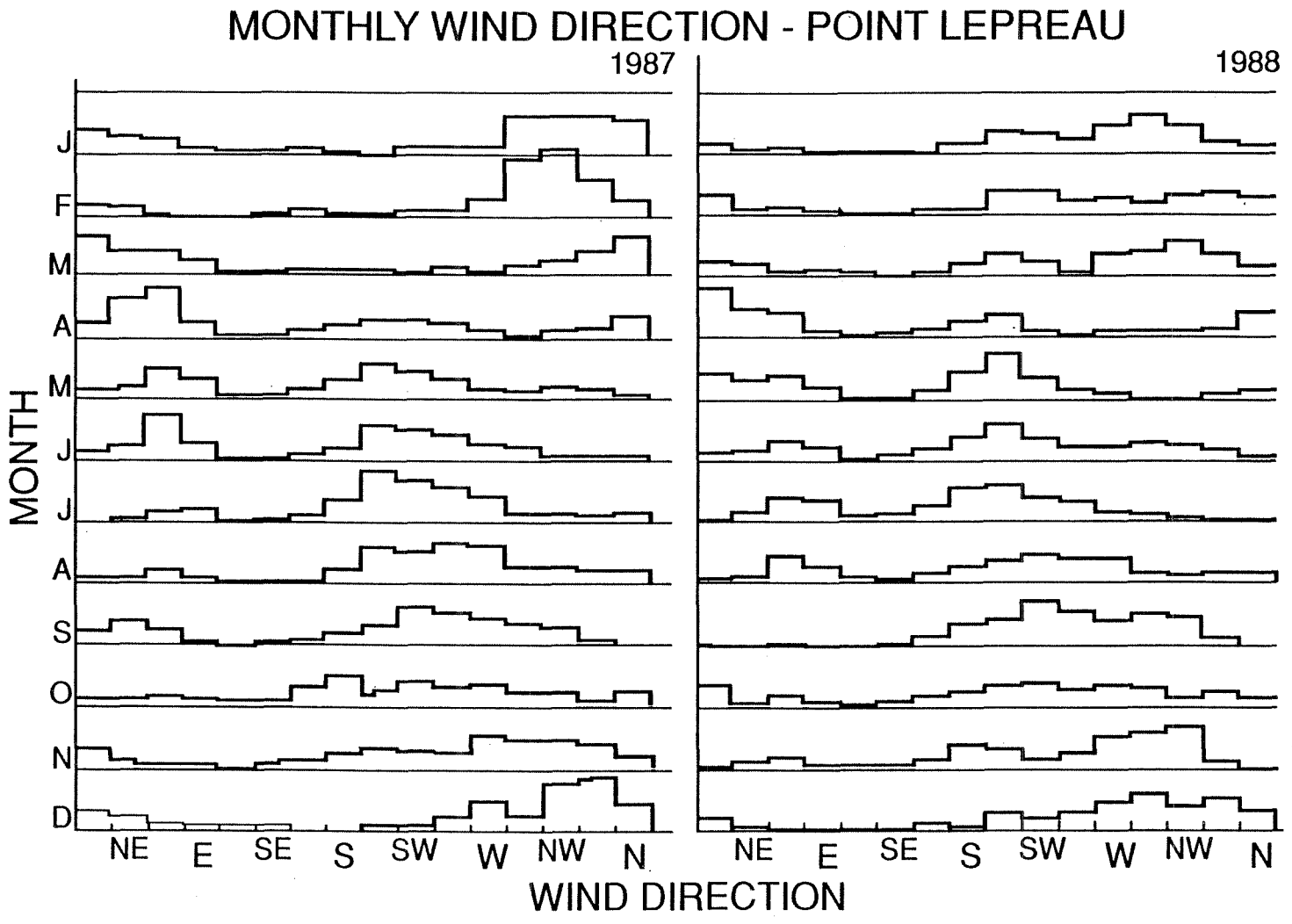

Figure 15. Monthly wind direction distributions at Point Lepreau 1987 and 1988.

4.2 Air Monitoring Results

AERU operates a network of five air monitoring stations at locations shown in Figure 14. The air monitoring stations were modified in 1988 by adding a second flow meter in order to measure more accurately the flow through the molecular sieve and the new design is illustrated in Figure 16. The components have been described previously (Bishop et al, 1980).

The approximate detection limits are 4×10^{-5} mBq/m^3 for particulate Cs-137, 3×10^{-2} mBq/m^3 for I-131 on the charcoal cartridge and 1×10^{-2} Bq/m^3 for H-3 in water vapour. These detection limits assume a 10 day delay between sampling and analysis.

4.2.1 Tritium

Results for tritium analysis for 1987 and 1988 are given in Tables 12 and 13. Activities for samples collected before July 1988 were converted to Bq/m^3 using relative humidity and temperature data from the meteorological station at Point Lepreau. A flow meter for the molecular sieve portion of the air sampler was added in July 1988.

Tritium activities measured directly on the atmospheric moisture collected on the molecular sieve are shown in Figure 17 for stations 1, 2, 4 and 5, and Figure 18 for station 3 in units of Bq/ℓ of atmospheric moisture. Tritium activities are lowest at station 1 at Musquash and 5 at Digby, sites located farthest from the reactor. Higher levels are found at stations 2 (Dipper Harbour) and 4 (Welch's Cove) located approximately 5 km north of the reactor and highest levels are found at station 3, located closest to the reactor at the tip of the Point Lepreau peninsula. The conversion of this data to tritium activities in terms of air volume (Figures 19, 20 and 21) removes the biases as a result of increases in relative humidity during the summer. Tritium activities expressed in units of Bq/m^3 provide a more realistic distribution of tritium in air. Levels are similar to those measured in 1986 (Nelson et al., 1988). A comparison of air data collected during the same time by NBEPC (1987, 1988) and Health and Welfare Canada (Environmental Health Directorate, 1988, H. Marshall, 1989) is

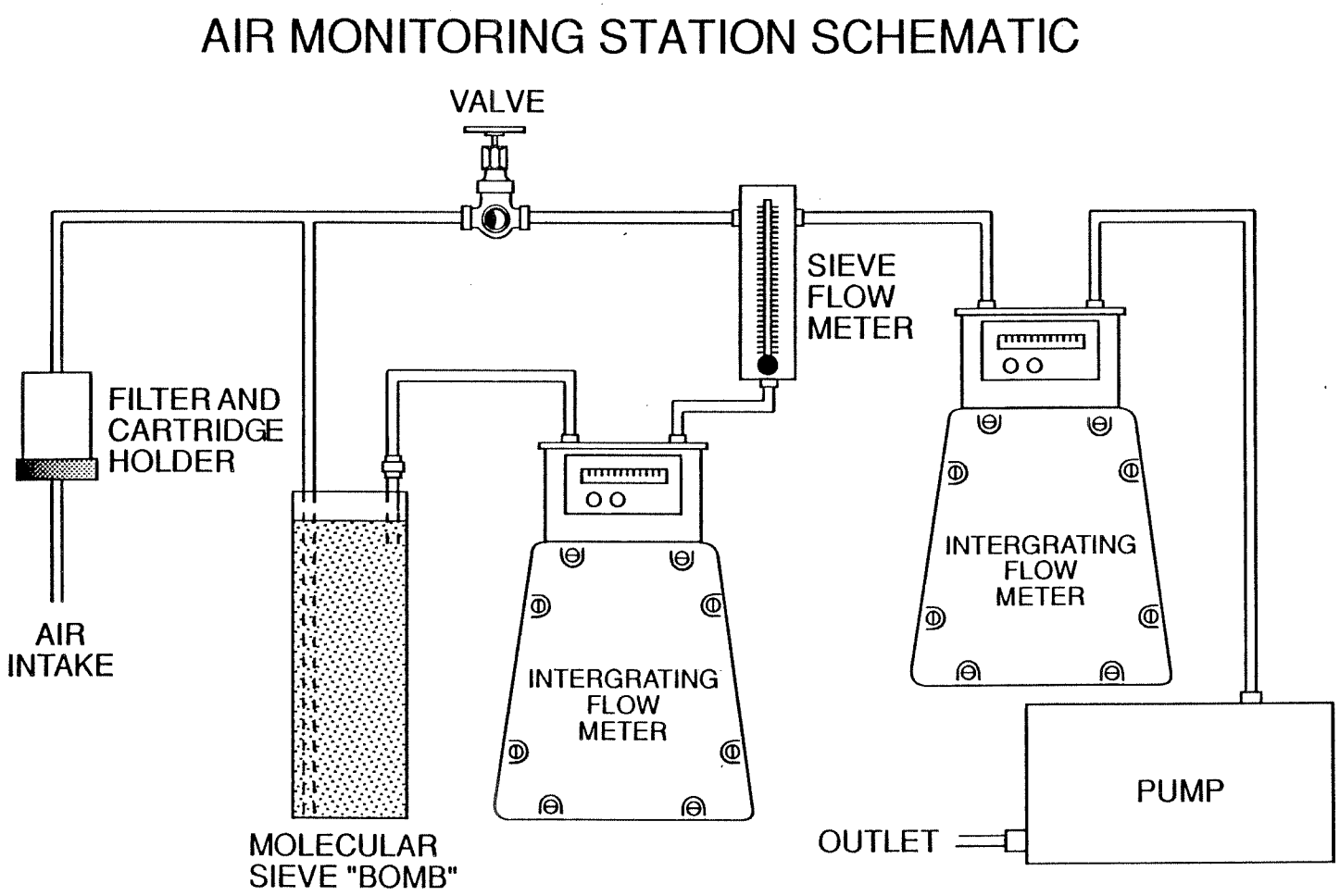

Figure 16: Schematic diagram of revised air monitoring station used in the field.

Table 12. Radionuclide Levels Measured in Air During 1987.

Station No	Sample No	Collection Date	Vol. (m^3)	H-3 (Bq/m^3)	Be-7 (mBq/m^3)
1	2776	13/01	792.9	<0.008	2.24 ± 0.16
	2781	11/02	1345	0.007 ± 0.007	
	2791	06/04	761.7	0.025 ± 0.016	2.53 ± 0.18
	2301	04/05	849.5	0.044 ± 0.015	5.49 ± 0.20
	2306	20/06	716.4	0.067 ± 0.025	3.07 ± 0.18
	26401	17/07	724.9	0.110 ± 0.028	<0.35
	26406	02/09	1195	0.003 ± 0.003	<0.23
	26411	03/10	1014	0.296 ± 0.030	3.37 ± 0.24
	26416	06/11	869.3	0.026 ± 0.014	3.46 ± 0.11
	26421	30/11	911.8		2.57 ± 0.04
2	2766	04/01	515.4	–	2.88 ± 0.23
	2777	31/01	792.9	–	2.02 ± 0.16
	2782	24/02	812.7	0.100 ± 0.011	2.45 ± 0.17
	2792	10/04	843.8	0.090 ± 0.015	2.70 ± 0.16
	2302	02/05	710.8	0.074 ± 0.017	5.48 ± 0.22
	2307	20/06	722.1	1.359 ± 0.034	4.97 ± 0.22
	26402	18/07	597.5	–	<0.54
	26407	28/08	623.0	0.439 ± 0.024	<0.41
	26412	28/09	801.4	0.045 ± 0.023	5.02 ± 0.24
	26417	06/11	812.7	0.243 ± 0.017	3.68 ± 0.15
	26422	29/11	909.0	0.077 ± 0.010	1.70 ± 0.12
3	2998	27/01	1260		1.80 ± 0.11
	2778	15/03	1322	0.763 ± 0.008	4.06 ± 0.13
	2793	08/04	1153	0.231 ± 0.033	2.33 ± 0.14
	2303	20/05	1198	0.548 ± 0.023	<0.028
	2308	03/07	1240	0.319 ± 0.032	1.77 ± 0.11
	26408	10/09	659.8	0.586 ± 0.036	<0.33
	26413	04/11	1226	0.110 ± 0.015	<0.55
	26418	15/12	1405	0.764 ± 0.015	2.47 ± 0.13
4	2773	22/01	821.2	0.069 ± 0.006	1.01 ± 0.13
	2779	13/02	812.7	0.029 ± 0.006	-

Table 12. Radionuclide Levels Measured in Air During 1987.

Station No	Sample No	Collection Date	Vol. (m^3)	H-3 (Bq/m^3)	Be-7 (mBq/m^3)
	2794	19/04	991.1	0.280 ± 0.021	2.12 ± 0.12
	2304	13/05	741.9	0.101 ± 0.017	4.89 ± 0.20
	2309	20/06	716.4	0.155 ± 0.026	4.36 ± 0.21
	26404	23/07	625.8	0.738 ± 0.034	<0.46
	26409	04/09	659.8	0.062 ± 0.025	<0.79
	26414	27/09	504.0	0.076 ± 0.022	<0.55
	26424	29/11	761.7	0.126 ± 0.014	1.45 ± 0.25
	26429	25/12	506.9	0.048 ± 0.009	1.91 ± 0.15
5	2780	17/01	839.3	0.007 ± 0.007	2.24 ± 0.24
	2785	08/02	734.0	0.018 ± 0.007	2.61 ± 0.14
	2790	27/02	739.9	0.014 ± 0.008	3.03 ± 0.19
	2795	06/04	–	0.023 ± 0.023	–
	2305	05/05	741.9	0.026 ± 0.014	4.34 ± 0.19
	2310	23/06	496.7	0.044 ± 0.027	4.15 ± 0.40
	26405	21/07	776.2	0.045 ± 0.028	<0.35
	26410	28/08	728.3	0.025 ± 0.025	<0.33
	26415	31/10	659.8	–	2.79 ± 0.17
	26420	24/10	690.9	0.022 ± 0.022	2.77 ± 0.19
	26425	29/12	919.5	0.009 ± 0.009	2.39 ± 0.16

Table 13. Radionuclide Levels Measured in Air During 1988.

Station No	Sample No	Collection Date	Vol. (m^3)	H-3 (Bq/m^3)	Be-7 (mBq/m^3)
1	26426	23/01	1068	0.037 ± 0.010	2.08 ± 0.09
	26435	14/02	903.3	0.036 ± 0.006	1.73 ± 0.16
	26440	26/03	886.3	–	3.27 ± 0.17
	26445	14/05	962.8	0.104 ± 0.022	1.06 ± 0.13
	26450	03/06	1005	0.103 ± 0.020	2.75 ± 0.13
	26455	24/06	713.6	0.118 ± 0.037	3.57 ± 0.23
	26460	20/06	–	0.204 ± 0.037	–
	33245	17/09	3344	0.136 ± 0.029	0.078 ± 0.037
	35589	19/09	18630	0.052 ± 0.015	–
	35594	10/12	3384	0.046 ± 0.008	0.11 ± 0.07
2	26427	23/01	863.7	0.071 ± 0.011	2.55 ± 0.19
	26436	12/02	829.7	0.159 ± 0.007	5.06 ± 0.24
	26441	26/03	1022	0.207 ± 0.012	1.46 ± 0.15
	26446	15/05	761.8	0.265 ± 0.024	2.01 ± 0.19
	26451	03/06	877.8	–	1.23 ± 0.15
	26456	22/06	775.9	0.327 ± 0.032	3.43 ± 0.20
	26461	19/07	5663	0.203 ± 0.037	1.14 ± 0.04
	33246	23/08	3894	0.576 ± 0.039	0.79 ± 0.04
	33251	03/10	5103	1.303 ± 0.039	1.12 ± 0.04
	35590	28/10	5312	0.345 ± 0.021	1.03 ± 0.04
	35595	03/12	5445	0.063 ± 0.009	1.07 ± 0.07
3	26423	27/01	1337	0.908 ± 0.016	3.67 ± 0.12
	26428	24/02	1303	1.437 ± 0.015	4.63 ± 0.13
	26437	13/04	1257	–	2.92 ± 0.14
	26442	25/05	1116	0.534 ± 0.031	2.09 ± 0.23
	26447	21/06	1017	0.172 ± 0.030	3.76 ± 0.16
	26452	10/07	2852	0.082 ± 0.034	2.04 ± 0.14
	33247	23/08	3695	0.620 ± 0.047	1.27 ± 0.05
	35591	12/11	13255	0.023 ± 0.013	0.71 ± 0.02
	35596	24/12	5114	0.541 ± 0.011	1.76 ± 0.05
4	26438	04/02	668.3	0.148 ± 0.009	2.17 ± 0.14
	26443	15/02	540.9	0.067 ± 0.006	2.17 ± 0.14??
	26448	28/03	640.0	0.173 ± 0.013	3.75 ± 0.29
	26453	15/05	640.0	0.135 ± 0.023	2.32 ± 0.22
	26458	10/06	630.0	0.348 ± 0.024	<0.57
	26463	14/07	1945	0.597 ± 0.041	1.93 ± 0.25

Table 13. Radionuclide Levels Measured in Air During 1988.

Station No	Sample No	Collection Date	Vol. (m^3)	H-3 (Bq/m^3)	Be-7 (mBq/m^3)
	33248	24/08	–	0.669 ± 0.039	–
5	26430	07/02	768.2	0.007 ± 0.003	3.92 ± 0.41
	26439	27/03	690.1	0.005 ± 0.002	2.65 ± 0.22
	26444	22/05	741.6	0.004 ± 0.003	1.01 ± 0.18
	26449	03/07	680.4	0.004 ± 0.002	2.05 ± 0.31
	26459	29/08	–	0.146 ± 0.036	–
	35593	02/11	2192	–	1.11 ± 0.07
	35598	03/12	11380	0.033 ± 0.009	0.31 ± 0.02

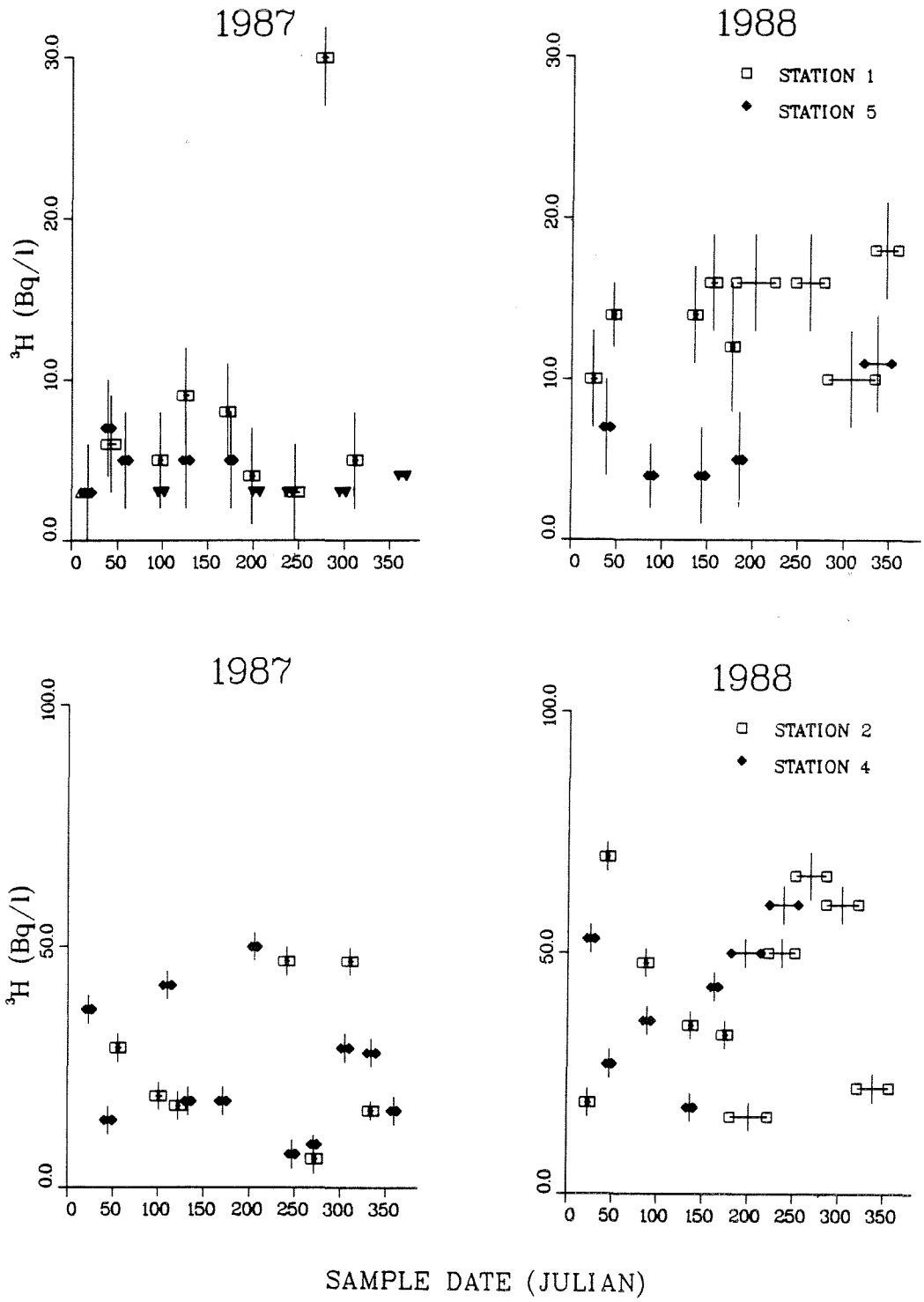

Figure 17: Tritium activity (Bq/l of air moisture) during 1987 and 1988 for air monitoring stations 1 and 5(upper) and 2 and 4(lower).

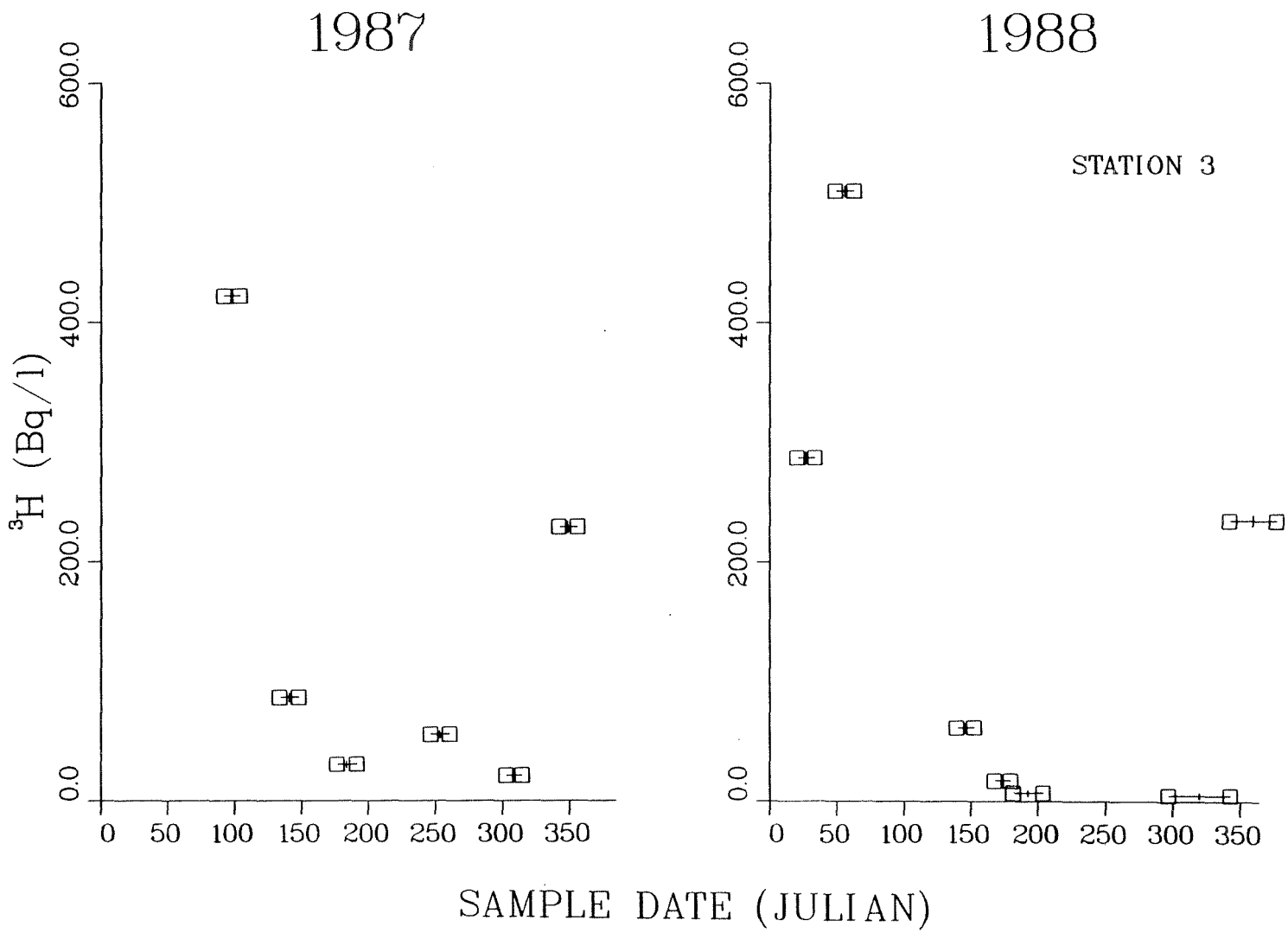

Figure 18: Tritium activity (Bq/l of air moisture) during 1987 and 1988 for air monitoring stations 3.

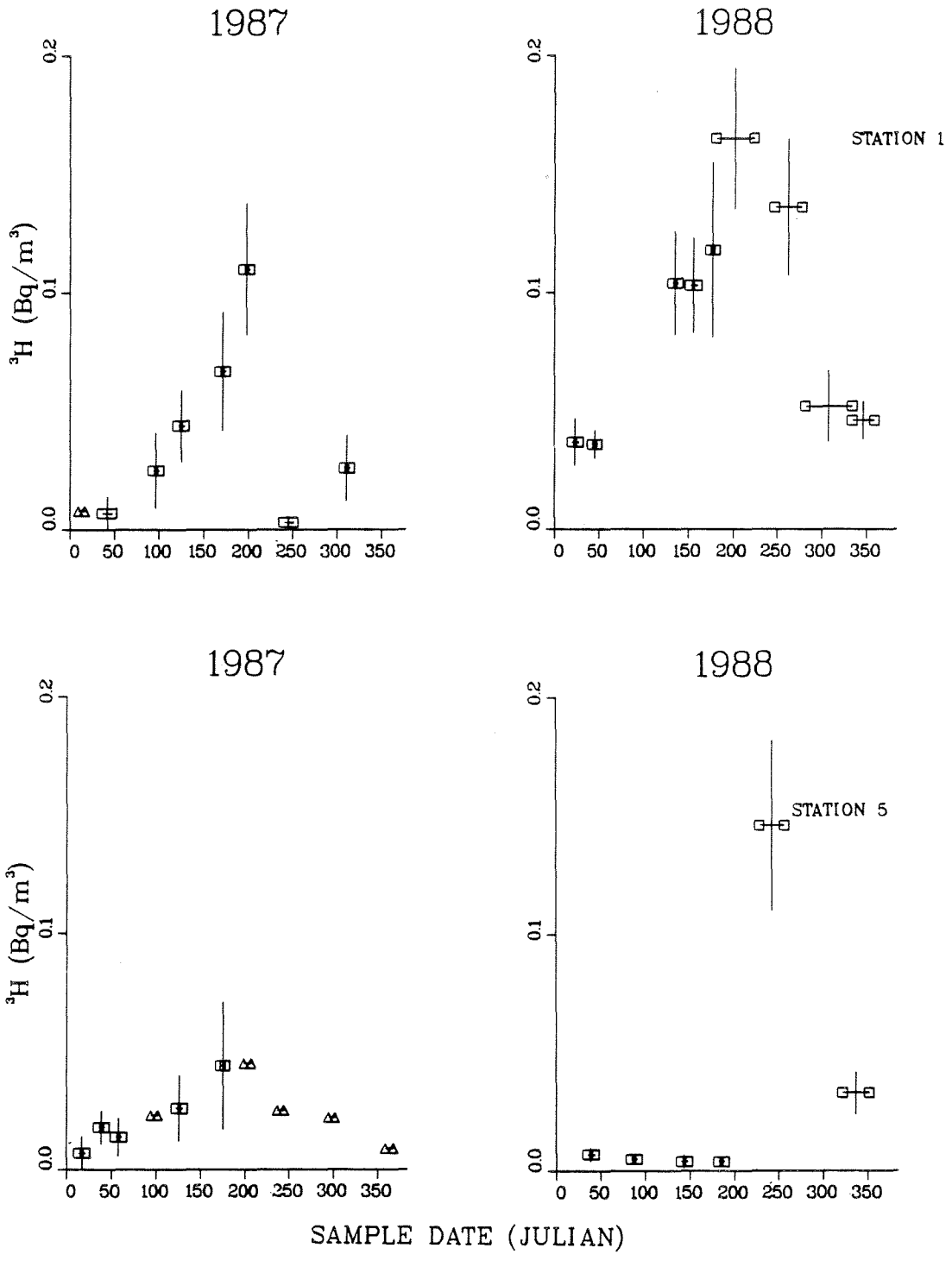

Figure 19: Tritium activity (Bq/m^3) during 1987 and 1988 for stations 1(upper) and 5(lower).

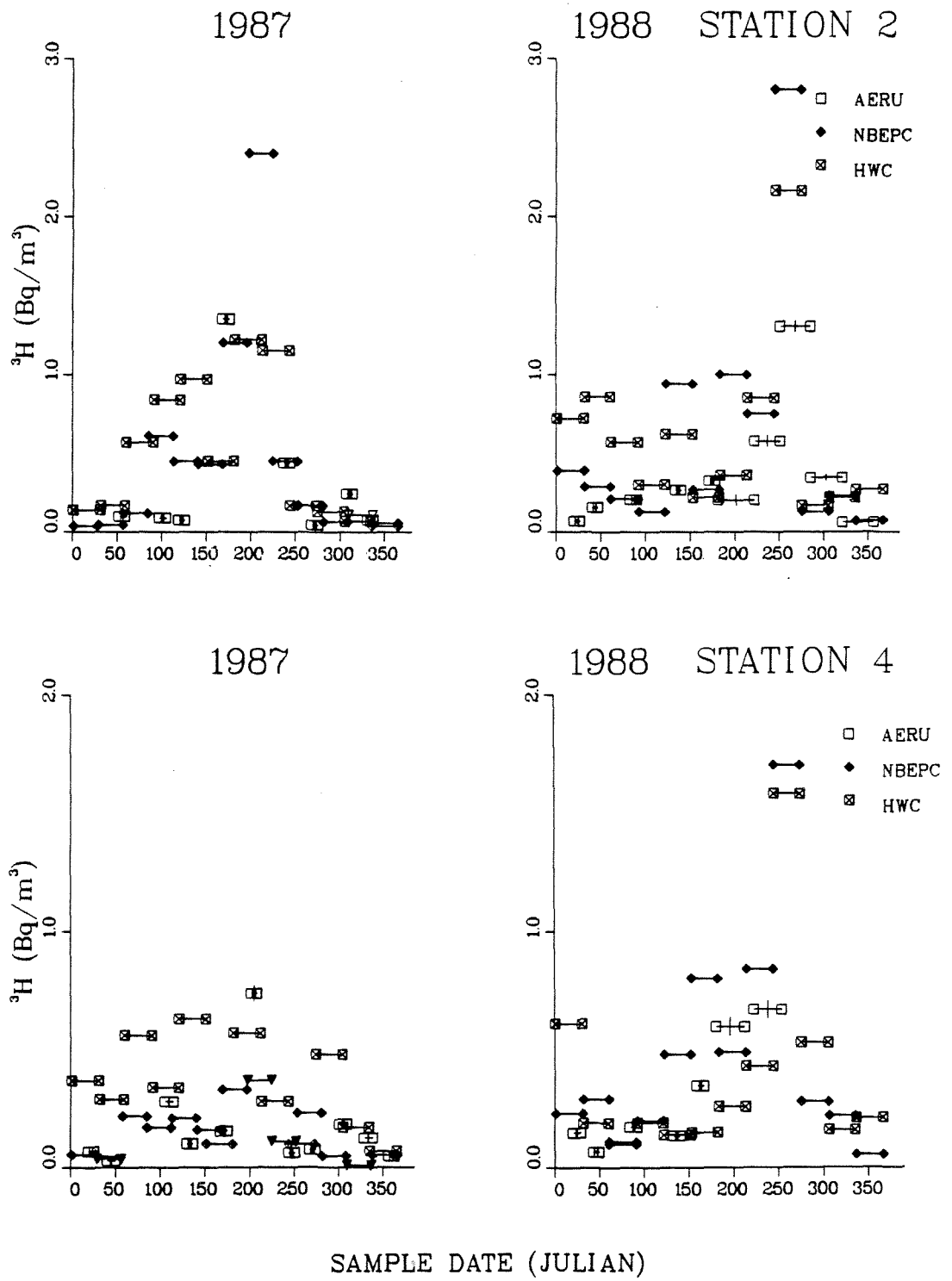

Figure 20: Tritium activity (Bq/m^3) during 1987 and 1988 for air monitoring stations 2(upper) and 4(lower). NBEPC and HWC activities are included for comparison at these two stations where samples are collected at the same locations.

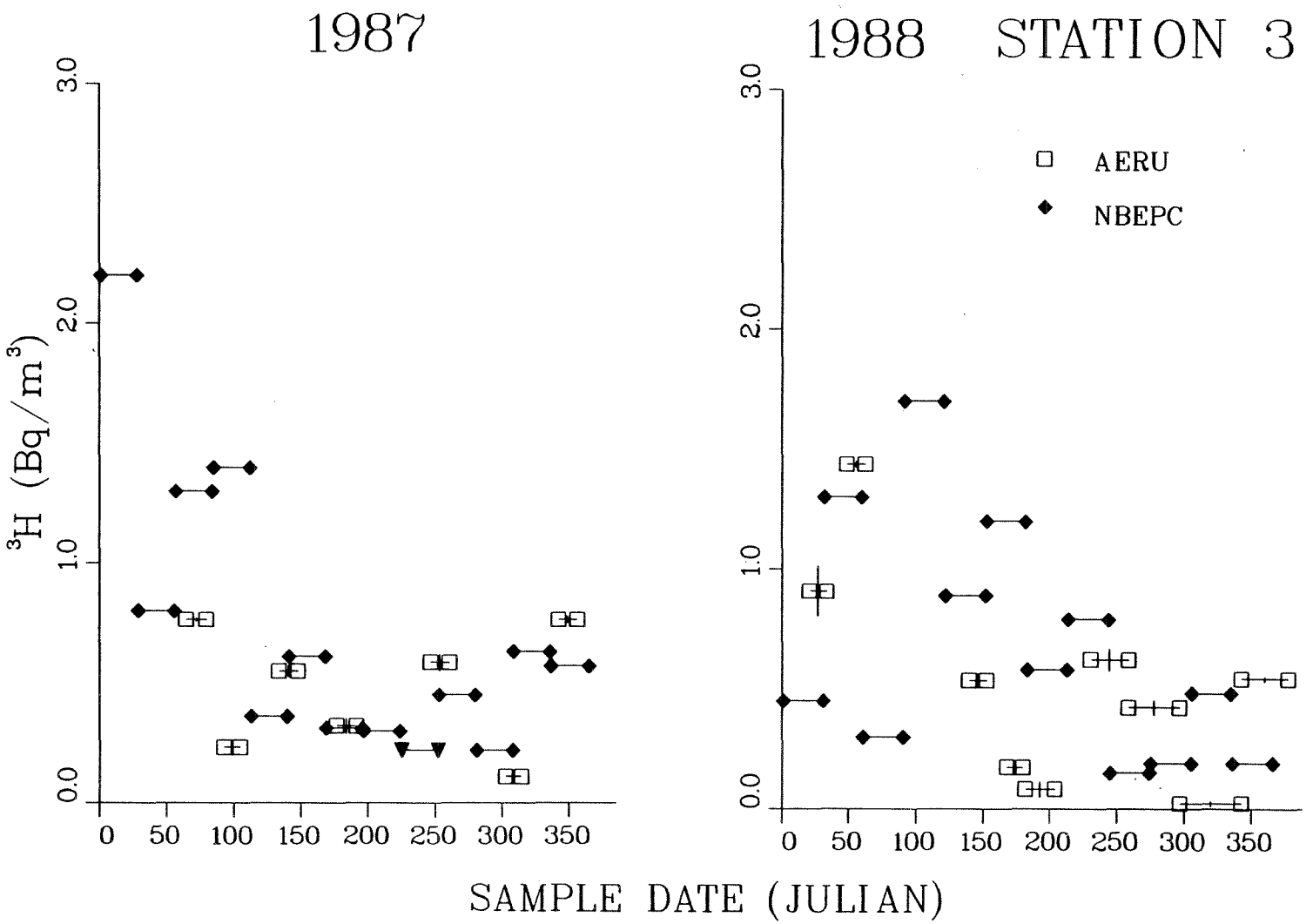

Figure 21: Tritium activity (Bq/m^3) during 1987 and 1988 for air monitoring station 3. A comparison with NBEPC is included for this station.

included in Figures 20 and 21. The AERU values show the same distributions and give the same levels as these two laboratories.

4.2.2 Air Filters and Cartridges

Air filters containing airborne particulate matter and air cartridges containing gaseous radionuclides were analysed for gamma-emitting radionuclides by direct counting on hyper-pure Ge detectors. The results are presented in Table 21 for 1987 and Table 22 for 1988. No isotopes, including I-131, were measured on the charcoal cartridge and only Be-7, a naturally occurring radioisotope was detected on the filters.

Because of the high specific activity of Be-7, its short half-life (53 days) and its particle affinity, it is useful in estimating aerosol residence times in the upper troposphere and particle deposition rates (Olsen et al 1985, Graustein and Turekian 1986).

The Be-7 activities show a range of 1.01 to 5.49 mBq/m^3 and an average value of 3.08 mBq/m^3 for all stations for 1987 and a range of 0.08 to 5.06 Bq/m^3 with an average value of 1.83 mBq/m^3 for 1988. These values are similar to average Be-7 values measured by NBEPC of 2.8 mBq/m^3 for 1987 (Sutherland, 1988) and 2.4 mBq/m^3 for 1988 Sutherland, 1989). The time distribution of Be-7 activities is illustrated in Figure 22. Activities increase in the spring at all stations when Be-7 levels in the troposphere are augmented by stratospheric Be-7 during the annual mixing of the stratosphere and the troposphere. Differences between stations in combination with individual precipitation rates give an indication of differences in overall deposition rates. The activities measured are in the range of those measured in previous years.

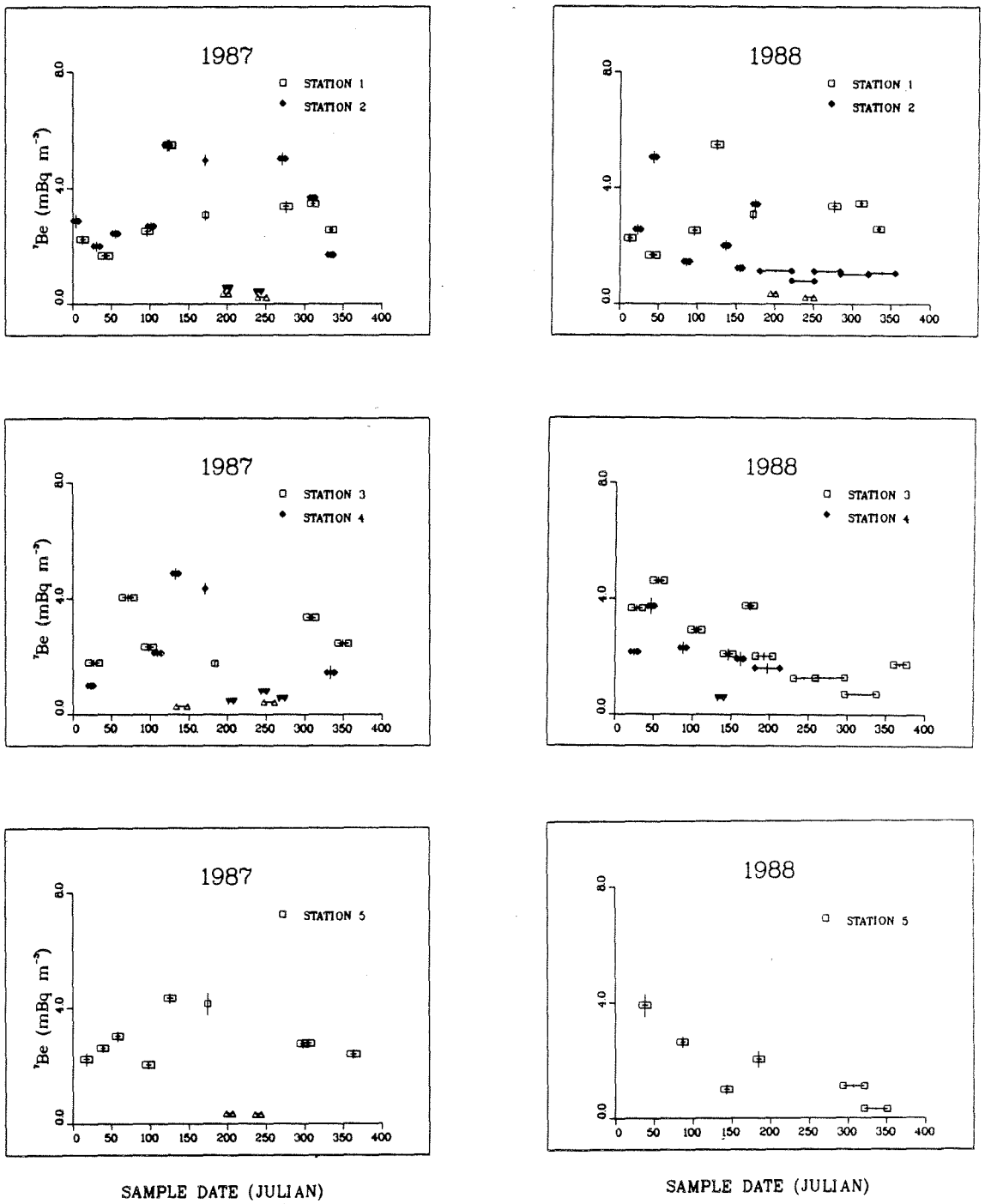

Figure 22: Be-7 activities (Bq/m^3) for 1987 and 1988 for all air monitoring stations. ∇ represents a less than value.

5.0 MARINE BIOLOGY

The marine biology of the area affected by the Point Lepreau NGS will depend on the physical and chemical characteristics of the marine environment (Chapter 3). The type of organisms which exist depend on the oceanographic parameters such as degree of wave action, salinity levels, water temperature, SPM concentrations and sediment type. The availability of released radionuclides to the marine biota also depends on many factors such as current direction and strength, seasonal-dependant stratification and SPM concentration.

Marine organisms can accumulate and redistribute radionuclides resulting in enhanced concentrations of radioactivity in these organisms. Accumulation rates and levels in marine organisms can vary with species and different trophic levels and are characterized by concentration factors and biological half-lives.

5.1 Sampling, Sample Processing and Analysis

Sampling sites for biological samples are shown in Figure 25. The marine sites are located in areas at the cooling water intake (Indian Cove, I-16), at the outfall (Duck Cove, I-17) and offshore (S-6) to assess releases from Point Lepreau NGS in the immediate area of the releases and (S-7) at Digby, N.S. to assess the movement of radionuclides across the Bay of Fundy.

Species collected are considered representative of the major marine habitats in the area and are known to accumulate radionuclides. Some commercial species have been added to the list. Samples were collected by the Atlantic Reference Centre (St. Andrews, N.B.), New Brunswick Department of the Environment and by AERU staff.

Samples are freeze-dried, homogenized and analysed directly in one of five different geometries for gamma-emitting radionuclides using a hyperpure-Ge detector with Canberra Spectan-F software. Typical concentration factors have been reported previously (Nelson et al., 1988). Typical detection limits for these geometries are given in Appendix 4. The tritium

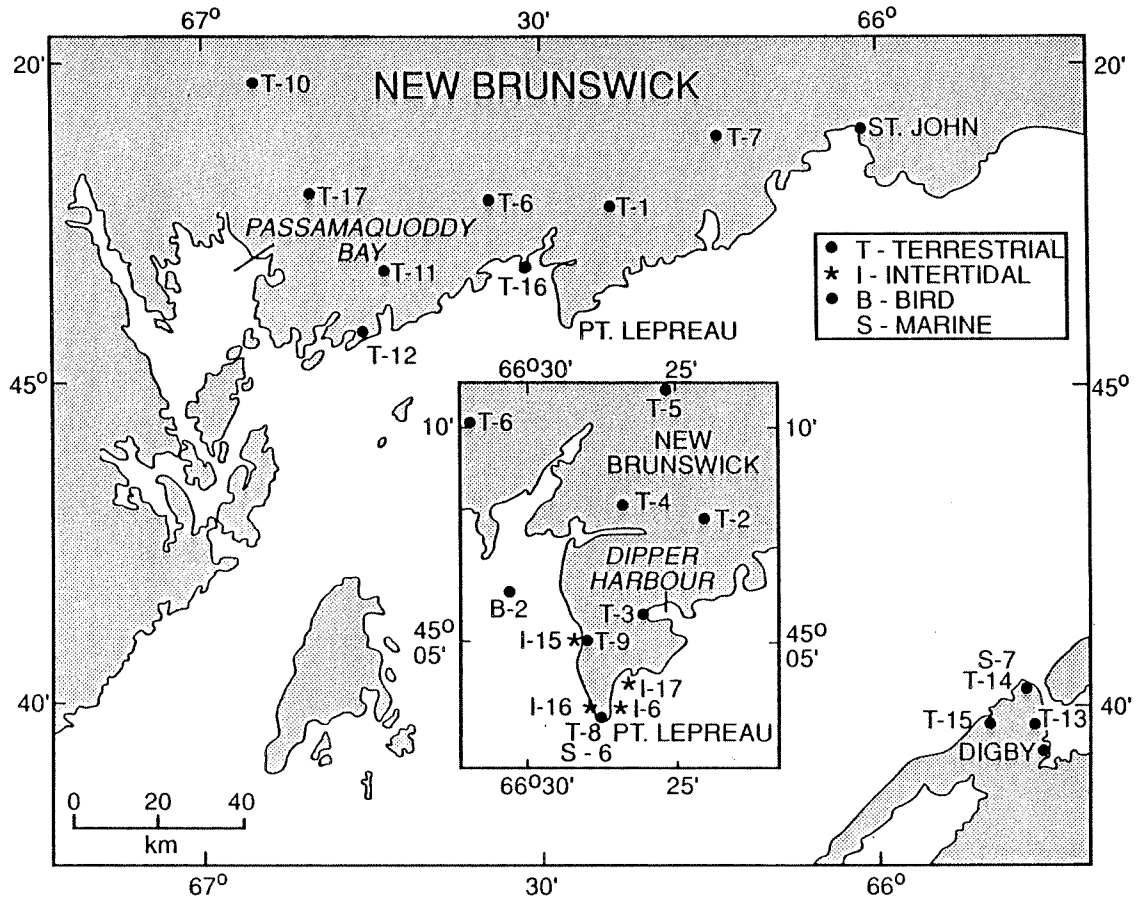

Figure 23: Sampling locations for all biological samples

content of biological samples was determined using an azeotrophic distillation method (Mogissi et al., 1973).

5.2 Marine Algae

Species selected for analysis include *Fucus vesiculosis*, *Ascophyllum nodosom*, *Laminaria sp.* and *Chondrus crispus*. The results are given in Table 14. Levels of Cs-137 were low, within the range of pre-operational levels. Cesium-134 released during the Chernobyl accident in 1986 was measured in one fucus sample in 1988.

5.3 Marine Animals

Species selected for analysis of marine molluscs are horse mussel (*Modiolus modiolus*) and periwinkle (*Littorina littorea*). Marine crustacea samples include lobster (*Homarus americanus*), gammarus (*Gammarus oceanicus*) and green crab (*Carcinus maenas*). One sea urchin (*Strongylocentrotus droebachiensis*) was collected and analysed. Cesium-137 levels were generally at or below detection limits and no Cs-134 was measured in any samples (Table 14). The large Cs-137 activity measured in gammarus sample #35474 has a large analytical error associated with it and reflects the low counting time rather than indicating a contaminated sample.

Table 14. Radionuclide Results for Marine Plants and Animals in 1987 and 1988.*

Species	No of Animals	Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)
Seaweed						
Fucus		14/07/87	35472	1-17	0.8 ± 0.4	<1
		14/07/87	35478	I-16	0.5 ± 0.2	<1
		29/06/88	33226	I-16	1.2 ± 0.5	<2
		29/06/88	33241	I-17	1.5 ± 0.3	0.6 ± 0.4
Ascophyllum		14/07/87	35471	I-17	<0.6	<1
		14/07/87	35476	I-16	<0.6	<1
		29/06/88	33225	I-16	0.8 ± 0.3	<1
		29/06/88	33242	I-17	0.5 ± 0.3	<1
Laminaria		14/07/87	2443	I-16	0.4 ± 0.2	<1
		14/07/87	35475	I-17	0.9 ± 0.4	<2
Chondrus		14/07/87	35470	I-17	<1	<2
		14/07/87	35477	I-16	<0.8	<1
Marine Animals						
Horse mussel	20	29/06/88	33228	I-17	<1	<1
	25	29/06/88	35379	I-17	<0.2	<0.2
	30	29/06/88	33240	I-17	0.2 ± 0.1	<0.2
Gammarus	40	04/11/87	35466	I-17	<10	<12
	10	04/11/87	35474	I-17	28 ± 12	<60
	20	14/07/87	35479	I-16	<20	<29
	17	29/06/88	35394	I-17	<2	<2
Lobster	3	05/06/87	35462	S-6	<0.6	
(hepat)	6	05/06/87	35460	S-7	<0.8	
(hepat)	12	05/06/87	35461	S-6	<0.5	
(hepat)	6	05/06/87	35395	S-7	<1	<2
(hepat)	6	30/06/88	35989	S-6	<1	<2
Sea urchin	12	04/11/87	35463	I-17	0.3 ± 0.1	
	11	04/11/87	35463	I-17	0.2 ± 0.1	
Periwinkle	40	14/07/87	2444	I-17	0.1 ± 0.5	<0.2
	35	29/06/88	33227	I-16	<0.3	<0.4
(shell)	40	29/06/88	33239	I-16	0.1 ± 0.1	<0.4
(flesh)	40	29/06/88	35239	I-16	<3	<3
Crab	6	14/07/87	35473	I-17	<2	<3
	3	14/07/87	35480	I-16	<3	<5
Clams	15	14/07/87	35481	I-16	<1	<2

* all results are for whole sample unless specified.

6.0 AQUATIC AND TERRESTRIAL ENVIRONMENTAL PHASES

Radionuclides can enter the aquatic or terrestrial systems through deposition of releases from the atmosphere or from the ground water. Ultimately, soils and sediments act as sinks of radionuclides but the distribution of radioactivity is determined by its initial distribution in the ecosystem.

The location of the sample sites is given in Figure 25 and include sites at Digby, N.S. in order to assess the transport of radionuclides across the Bay of Fundy. Samples are processed and analysed as described in the Marine Biological section (5.1).

6.1 Aquatic Systems

The distribution of radionuclides in the aquatic environment is governed by factors such as light, temperature, redox condition and sedimentation processes and differ from distributions in the marine environment mainly as a result of differences in ionic strengths of the two mediums.

The location of the seven sampling sites (T-1 to T-5, T-8 and T-9) is given in Figure 25. Two of the sites are small lakes (T-2 and T-4) and the remaining are stream locations.

6.1.1 Water Column Results

Freshwater samples were collected during two field trips in 1987 and 1988. The results are presented in Table 15. Tritium activities are highest at the outfall (I-17) and near the reactor. Samples collected for cesium analysis include one seawater sample from Duck Cove (I-17) and two stream samples. Cesium-137 is below detection limit in the freshwater samples while the seawater sample level is in the range of those previously measured in the Bay of Fundy (Table 4, Table 6). No. Cs-134 was detected in water samples.

Table 15. Tritium and Cs-137 Levels in Field Trip Water Samples.

Nuclide	Collection Date	Sample No	Site No	Soluble (Bq/ℓ)
H-3	29/06/88	33229	T-8	49.4 ± 3.9
	29/06/88	33232	I-17	109.1 ± 4.5
	29/06/88	33233	T-3	45.9 ± 3.8
	29/06/88	33234	T-9	25.7 ± 3.6
	29/06/88	33235	T-4	8.9 ± 3.4
	29/06/88	33244	T-1	7.1 ± 3.4
H-3	08/11/88	35701	T-9	104.9 ± 4.5
	08/11/88	35702	T-8	35.4 ± 3.7
	08/11/88	35703	I-17	105.6 ± 4.5
	08/11/88	35705	T-1	7.6 ± 3.4
	08/11/88	35706	T-4	4.4 ± 3.3

Nuclide	Collection Date	Sample No	Site No	Soluble (m, Bq/ℓ)	Part (Bq/g)
Cs-137	29/06/ 88	33231	T-18	<0.6	<2.0
	29/06 /88	33238	I-17	3.08±1.75	<0.5
	29/06 /88	33236	T-4	<0.6	<1.0

6.1.2 Sediment

Stream and lake sediment results are given in Table 16. A great deal of variation in Cs-137 activity is observed, probably as a result of variations in the vertical sampling depth of individual samples.

6.1.3 Aquatic Plants and Animals

Aquatic plant species collected in 1987 and 1988 include horsetail (*Equisetum sp.*), wild iris (*Iris veriscolor*) and bullrushes (*Typha sp.*). Cesium-137 is measured at or near the detection limit in these samples, in the range of pre-operational levels. Cesium-134, released to the environment during the Chernobyl accident, was measured in one iris sample (Table 17).

Aquatic animal species collected included frog (*Rana sp.*) and freshwater fish (*Cyprinidae sp.*) and results are presented in Table 18. Cesium-137 was measured in most samples at low levels, in the range of pre-operational levels. No Cs-134 was detected in any animal samples.

6.2 Terrestrial Systems

Biological uptake of fallout radioactivity is generally more efficient in the terrestrial environment compared to the aquatic and marine systems due to the absence of a diluting medium such as water, resulting in the accumulation of higher levels of fallout radionuclides as illustrated in previous PLEMP studies (Ellis et al, 1984, Nelson et al, 1985, 1986, 1988). Monitoring the terrestrial environment for 1987 and 1988 consisted of gamma analysis of soil and plant samples including a monthly sampling program for two lichen species and tritium analysis of several plant samples including a monthly sampling program for conifer needles.

6.2.1 Soil

A soil core was collected in July 1988 at the Point Lepreau lighthouse, in the same location as a core taken in 1981 (Smith et al, 1982). The A horizon penetrated to 18 cm, below which lay the B horizon from 18 to 25 cm and below that the C horizon. Cesium-134 and Cs-137 were detected at almost every depth and the data and distributions are shown in Table 19 and in Figure 24. The Cs-137

Table 16. Radionuclide Results for Lake Sediments and Soil for 1987 and 1988.

Sample type	Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Be-7 (Bq/kg)
Sediment	13/07/87	35389	T-4	2.8 ± 0.2	0.9 ± 0.2
	13/07/87	35414	T-1	5.5 ± 0.2	0.9 ± 0.2
	13/07/87	35414	T-1	9.0 ± 0.1	1.4 ± 0.1
	13/07/87	35443	T-2	18.9 ± 0.3	1.0 ± 0.2
	13/07/87	35444	T-5	18.4 ± 0.4	2.2 ± 0.2
	12/07/88	35987	T-3	13.0 ± 2.0	1.6 ± 0.2
	12/07/88	35988	T-8	3.0 ± 1.0	2.8 ± 0.2
	13/07/88	35986	T-5	13.8 ± 0.5	2.2 ± 0.3
Soil	13/07/87	35415	T-1	25.1 ± 0.2	1.4 ± 0.2
	13/07/87	35418	T-4	2.3 ± 0.1	2.8 ± 0.2
	13/07/87	35445	T-5	8.5 ± 0.4	2.4 ± 0.2
	13/07/87	35446	T-8	9.8 ± 0.2	2.1 ± 0.3
	14/07/87	35417	T-3	1.4 ± 0.1	2.1 ± 0.2
	14/07/87	35417	T-3	0.8 ± 0.1	1.7 ± 0.2
	15/07/87	35388	T-2	22.5 ± 0.2	7.4 ± 0.7

Table 17. Radionuclide Results for Aquatic Plants for 1987 and 1988.

Species	Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)
Iris	13/07/87	21475	T-1	10 ± 2	
(*Iris versicolor*)	13/07/87	21477	T-4	<8	
	13/07/87	21478	T-5	30 ± 2	2.5 ± 1.3
	13/07/87	21479	T-8	12 ± 3	
	13/07/87	21480	T-9	<5	
	14/07/87	21476	T-3	10 ± 2	
	13/07/88	35996	T-8	3 ± 2	<3
Horsetail	13/07/87	21490	T-8	<4	
(*Equisetum sp.*)	13/07/87	26295	T-4	<4	
	13/07/87	26296	T-5	32 ± 3	
	13/07/87	26297	T-9	16 ± 3	
	15/07/87	26291	T-1	<3	
	15/07/87	26292	T-2	26 ± 2	
	15/07/87	26293	T-3	<6	
	12/07/88	35391	T-8	<3	<3
	13/07/88	35963	T-3	6 ± 2	<3
Bullrushes	13/07/87	35435	T-1	5 ± 1	<3
(*Typha sp.*)	14/07/87	35436	T-5	<1	<1
	14/07/87	35437	T-9	<1	<1

Table 18. Radionuclide Results for Aquatic Animals for 1987 and 1988.

Species	No of Animals	Collection Date	Sample No	Site No	Cs-137 (Bq/kg)
Fish (*Cyprinidae sp.*)	2	14/07/87	21486	T-3	10 ± 1
	2	14/07/87	21488	T-5	15 ± 1
	3	15/07/87	21485	T-2	11 ± 1
	4	12/07/88	35393	T-3	14 ± 2
	4	12/07/88	36000	T-5	19 ± 1
Frog (*Rana sp.*)	2	14/07/87	21487	T-4	6 ± 2
	4	14/07/87	21489	T-5	24 ± 2
	1	15/07/87	21484	T-2	13 ± 3
Insects	40	14/07/88	35465/9	T-3	<18

Table 19. Results for Soil Core (33224) Collected June 29, 1988.

Depth (cm)	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)	Cs-134/ Cs-137	Cs-137		Cs-134 Total (Bq/cm^2)
				Total (Bq/cm^2)	Chernobyl (Bq/cm^2)	
0-2	67.1 ± 0.91	0.92 ± 0.21	0.014 ± 0.003	133	8	1.8
2-4	62.8 ± 0.79	0.79 ± 0.19	0.013 ± 0.003	112	6	1.4
4-6	51.9 ± 0.59	0.43 ± 0.30	0.008 ± 0.006	109	4	0.9
6-8	39.0 ± 0.67	1.33 ± 0.42	0.034 ± 0.010	79	11	2.7
8-10	28.8 ± 0.57	0.74 ± 0.37	0.026 ± 0.013	60	6	1.6
10-12	16.7 ± 0.51	0.33 ± 0.39	0.020 ± 0.026	34	3	0.7
12-14	7.4 ± 0.42	0.67 ± 0.36	0.091 ± 0.026	15	5	1.4
14-16	6.4 ± 0.43	0.68 ± 0.39	0.106 ± 0.061	13	5	1.4
16-18	4.0 ± 0.44	1.20 ± 0.22	0.300 ± 0.064	8	8	2.5
18-20	1.7 ± 0.23	0.52 ± 0.24	0.306 ± 0.166	4	4	1.3
20-22	0.71 ± 0.20	0.81 ± 0.17	1.141 ± 0.404	2	2	2.3
22-24	0.54 ± 0.09	<0.3	<0.56	2	2	0
24-26	<0.10	0.06 ± 0.3	>0.60	–	–	0.2
26-28	<0.26	0.5 ± 0.2	>1.9	–	–	0.8
28-30	<0.25	<0.2	–	–	–	–

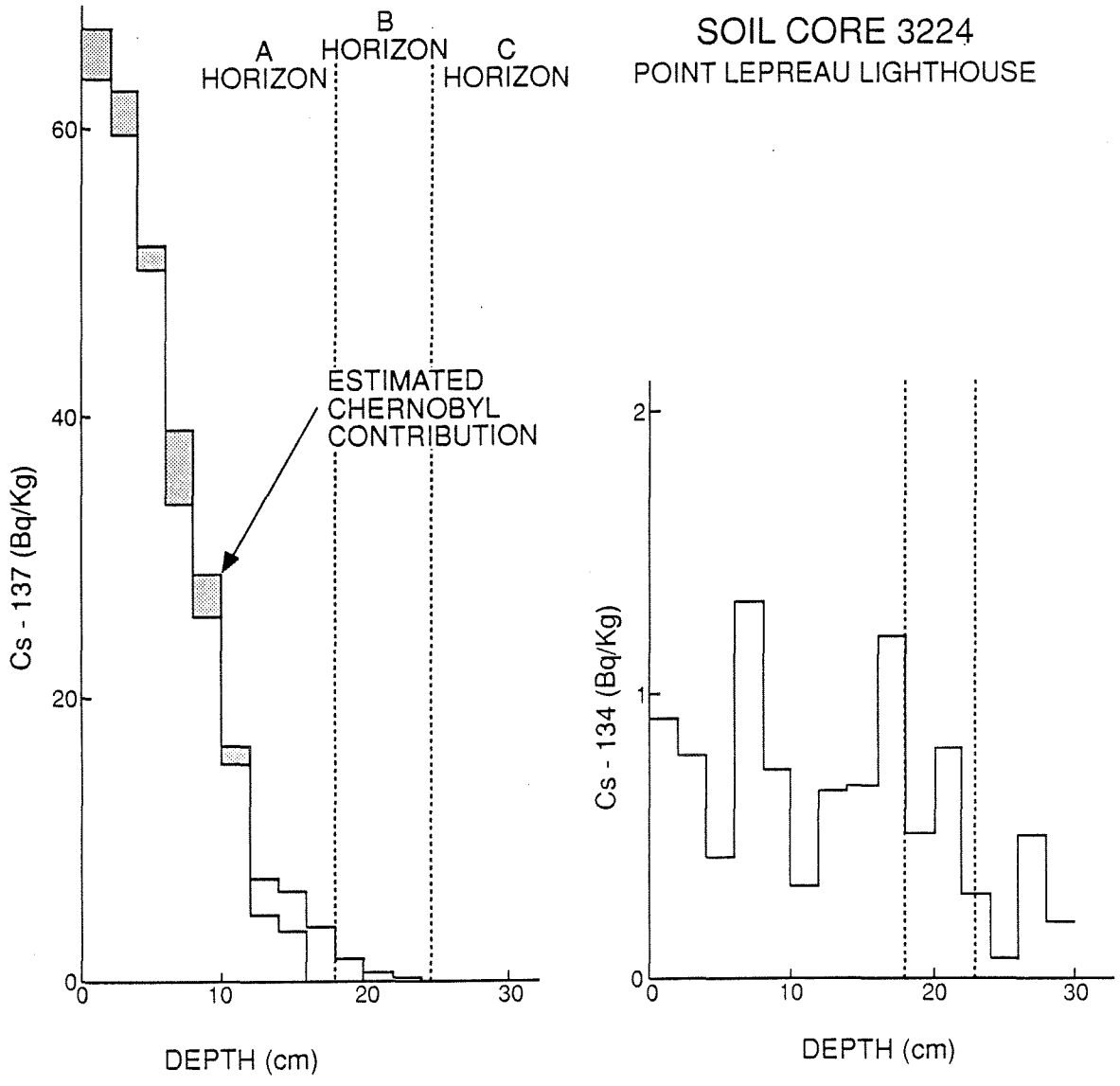

Figure 24: Cesium-137 and Cs-134 profiles in soil core #3224, collected on July 22, 1988.

signal represent a combination of fallout from nuclear tests and the Chernobyl accident in April, 1986 while the source of the Cs-134 is solely fallout from the Chernobyl accident. The initial Cs-134/Cs-137 ratio in Chernobyl fallout of 0.5 was used to estimate the amount of Cs-137 from Chernobyl as indicated in Figure 24.

Of interest is the deep penetration of Cs-134 in the soil. A possible explanation is that the fallout occurred in the late spring when precipitation was high and groundwater may have transported the Cs-134 (and the Cs-137) fallout deep into the soil. The integrated activity of total Cs-137 was 571 mBq/cm^3 (63 mBq/cm^3 from Chernobyl fallout) and the Cs-134 integrated activity was 18.9 mBq/cm^3. The Cs-137 integrated fallout activity of 508 mBq/cm^3 is substantially higher than found in 1981 (267 mBq/cm^3 decay corrected to 1988) and higher than expected from integrating atmospheric fallout (443 mBq/cm^3). The location selected for sampling may represent an area of soil accumulation.

Almost all (98 %) of the Cs-137 lies in the A horizon as was found in the cores taken in 1981. Most (76 %) of the Cs-134 was found in the A horizon.

Surface soil samples were collected in 1987 and results are given in Table 16. Cesium-137 activities range from 0.8 to 25.1 Bq/kg and reflect differences in (1) sample depth and (2) depositional locations. Levels are much lower than surface levels found in the soil core 3224 verifying the location of the soil core to be that of an area of net deposition. The activities found in the surface soil samples are comparable to the activities measured in the lake and stream sediment. No Cs-134 was detected in any sample.

6.2.2 Terrestrial Plants

The plant species selected for analysis include blueberry leaves (*Vaccinium sp.*), alder (*Alnus rugosa*), spruce needles and two types of lichen - *Cladonia rangiferina*, a ground lichen and *Usnea sp*, an arboreal lichen commonly known as 'old man's beard' or spanish moss.

Lichen communities have long been recognized as a reservoir of natural and artificial radionuclides. The accumulation of radionuclides is enhanced by the plant's persistant aerial parts,

slow growth rate, long life span, high surface to mass ratio and foliar absorption of nutrients. Modelling of lichen uptake at Point Lepreau (Ellis and Smith, 1987) show that ground lichen retain 10 to 30 % of fallout deposition.

Radionuclide results for gamma-emmitting radionuclides in blueberry and alder leaves are given in Table 20. The results for the ground and the aerial lichen are given in Tables 21 and 22 respectively.

An investigation of the relationship between Be-7, a naturally occurring radionuclide, and fallout radionuclides such as Cs-137 and Cs-134, in lichen over the past few years (Ellis and Smith, 1987) has allowed the calibration of each lichen plant for its collection efficiency for atmospheric fallout radionuclides.

The seasonal trends of Cs-137, Cs-134 and Be-7 were studied for cladonia and usnea at several sites through 1987 and 1988 (Figure 25 and 26). The similarity between Be-7 and both cesium isotopes in usnea is very striking with a correlation coefficient of 0.8 for both isotopes. Activities in both tend to increase in summer as a result of enhanced mixing of stratosphere and troposphere causing the movement of radionuclides from the upper to the lower atmosphere (Staley, 1982). Since the arboreal lichens obtain all of their nutrients directly from the atmosphere, the levels of radioactivity will reflect seasonal changes in atmospheric radionuclide levels. The relationship between radionuclides and seasonal variations in cladonia are less obvious. The higher activities of Cs-137 in cladonia are due to a longer biological half-life. Ground lichen accumulate radionuclides from several sources such as soil and rain, which although ultimately having atmospheric source of radionuclides, cause delays in uptake which make direct comparison with atmospheric levels more complicated.

6.3 Tritium in Aquatic and Terrestrial Systems

The majority of tritium from the reactor enters the environment in the form of tritiated water (HTO). Absorption of HTO by plants occurs through exchange between atmospheric moisture

Table 20. Radionuclide Levels in Terrestrial Plants for 1987 and 1988.

Species	Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)	Be-7 (Bq/kg)
Blueberry leaves	12/07/88	35392	T-8	4 ± 3	-	-
	12/07/88	35390	T-3	8 ± 3	-	-
Alder	14/07/87	35467	T-3	<4	<6	-
	13/07/87	35468	T-4	<2	<4	-
Sphagnum	13/07/87	21481	T-8	42 ± 5	3 ± 4	<242
	15/07/87	26361	T-2	100 ± 3	5 ± 2	286 ± 49
	13/07/87	26362	T-1	148 ± 4	10 ± 3	473 ± 62
	14/07/87	26363	T-3	86 ± 3	8 ± 3	608 ± 63
	13/07/87	26364	T-4	60 ± 3	8 ± 3	272 ± 65
	13/07/87	26365	T-5	90 ± 6	11 ± 5	690 ± 123
	13/07/87	26366	T-9	30 ± 4	9 ± 4	601 ± 107

Table 21. Radionuclide Results for Lichen (*Cladonia rangiferina*) for 1987 and 1988.

Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)	Be-7 (Bq/kg)
16/06/87	35439	T-14	14 ± 1	2 ± 1	64 ± 178
16/06/87	35440	T-13	48 ± 2	8 ± 2	289 ± 283
16/06/87	35441	T-15	19 ± 1	2 ± 1	110 ± 188
17/07/87	26334	T-12	121 ± 7	11 ± 6	277 ± 59
15/07/87	26335	T-2	125 ± 3	10 ± 1	352 ± 20
13/07/87	26336	T-3	61 ± 2	7 ± 2	497 ± 28
13/07/87	26337	T-1	36 ± 3	3 ± 2	612 ± 37
13/07/87	26338	T-6	119 ± 4	17 ± 2	484 ± 32
13/07/87	26339	T-16	132 ± 3	10 ± 2	410 ± 24
13/07/87	26340	T-17	83 ± 3	9 ± 2	390 ± 25
13/07/87	26341	T-10	106 ± 4	9 ± 3	376 ± 37
17/07/87	26342	T-11	74 ± 3	10 ± 2	402 ± 28
14/07/87	26350	T-4	79 ± 2	16 ± 4	525 ± 30
13/07/87	26351	T-6	335 ± 5	9 ± 2	405 ± 38
13/07/87	26356	T-7	55 ± 3	8 ± 3	566 ± 66
17/08/87	26377	T-2	76 ± 3	4 ± 1	216 ± 37
17/08/87	26378	T-3	65 ± 2	11 ± 2	367 ± 34
17/08/87	26379	T-6	70 ± 3	12 ± 2	704 ± 53
17/08/87	26380	T-7	85 ± 3	7 ± 2	553 ± 48
17/08/87	26381	T-1	53 ± 2	5 ± 1	247 ± 21
17/08/87	26387	T-4	84 ± 3	16 ± 2	723 ± 43
28/09/87	26371	T-6	52 ± 4	7 ± 3	641 ± 40
28/09/87	26372	T-3	65 ± 2	8 ± 2	558 ± 31
28/07/87	26373	T-7	158 ± 3	12 ± 2	648 ± 26
28/07/87	26374	T-4	57 ± 2	9 ± 2	376 ± 217
28/09/87	26375	T-1	39 ± 2	6 ± 2	255 ± 15
28/07/87	26376	T-2	54 ± 2	5 ± 1	125 ± 15
28/10/87	26394	T-1	52 ± 2	4 ± 1	472 ± 37
25/11/87	35401	T-4	62 ± 2	6 ± 1	383 ± 23
25/11/87	35407	T-1	61 ± 2	6 ± 2	428 ± 26
25/11/87	35411	T-7	51 ± 3	5 ± 2	500 ± 39
20/04/88	35906	T-1	152 ± 5	6 ± 2	153 ± 38
20/04/88	35909	T-3	76 ± 4	9 ± 3	175 ± 72
26/05/88	35910	T-1	73 ± 3	5 ± 1	306 ± 95
26/05/88	35912	T-3	50 ± 5	6 ± 2	150 ± 20
21/06/88	35902	T-1	66 ± 3	4 ± 2	330 ± 58
21/06/88	35904	T-8	37 ± 2	<2	248 ± 32
30/06/88	35935	T-15	68 ± 3	5 ± 2	608 ± 80

Table 21. Radionuclide Results for Lichen (*Cladonia rangiferina*) for 1987 and 1988.

Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)	Be-7 (Bq/kg)
30/06/88	35937	T-13	29 ± 7	5 ± 2	783 ± 116
30/06/88	35961	T-14	18 ± 2	3 ± 1	147 ± 89
12/07/88	35928	T-3	27 ± 3	3 ± 2	213 ± 77
12/07/88	35930	T-5	21 ± 2	4 ± 2	426 ± 46
12/07/88	35933	T-1	88 ± 2	1 ± 1	335 ± 31
13/07/88	35932	T-8	40 ± 4	4 ± 3	373 ± 70
15/09/88	35916	T-8	46 ± 11	<15	755 ± 110
15/09/88	35918	T-1	99 ± 4	3 ± 2	595 ± 36
03/10/88	35966	T-1	64 ± 4	2 ± 2	572 ± 54
03/10/88	35967	T-8	50 ± 13	10 ± 5	803 ± 167
25/11/88	35969	T-8	41 ± 6	5 ± 2	623 ± 75
25/11/88	35971	T-1	39 ± 4	4 ± 2	598 ± 53

Table 22. Radionuclide Results for Lichen (*Usnea sp.*) for 1987 and 1988.

Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)	Be-7 (Bq/kg)
05/06/87	35438	T-8	19 ± 1	3 ± 1	<175
05/06/87	36442	T-1	16 ± 1	1 ± 1	177 ± 251
13/07/87	21482	T-8	37 ± 2	8 ± 4	543 ± 83
13/07/87	26343	T-6	71 ± 3	7 ± 3	217 ± 46
13/07/87	26346	T-6	32 ± 2	3 ± 2	93 ± 29
13/07/87	26348	T-4	78 ± 4	10 ± 3	385 ± 54
13/07/87	26349	T-6	67 ± 3	8 ± 2	284 ± 44
13/07/87	26352	T-3	47 ± 3	5 ± 2	140 ± 38
13/07/87	26354	T-1	36 ± 2	7 ± 2	262 ± 37
13/07/87	26355	T-7	67 ± 4	7 ± 3	318 ± 47
13/07/87	26360	T-9	52 ± 3	12 ± 3	380 ± 52
14/07/87	26292	T-3	36 ± 2	5 ± 2	<108
14/07/87	26294	T-3	36 ± 2	5 ± 2	200 ± 48
14/07/87	26294	T-3	41 ± 5	<10	<472
14/07/87	26347	T-4	51 ± 3	7 ± 2	199 ± 21
14/07/87	26359	T-5	58 ± 4	9 ± 3	181 ± 74
15/07/87	21483	T-2	66 ± 3	8 ± 3	174 ± 99
15/07/87	26353	T-2	51 ± 3	9 ± 2	337 ± 39
17/07/87	26344	T-17	28 ± 2	2 ± 1	168 ± 30
17/07/87	26345	T-10	59 ± 3	14 ± 2	475 ± 36
17/07/87	26357	T-11	39 ± 3	4 ± 2	200 ± 41
17/07/87	26358	T-12	134 ± 6	31 ± 5	476 ± 77
17/08/87	26283	T-7	40 ± 2	5 ± 2	114 ± 28
17/08/87	26383	T-1	56 ± 4	<7	<344
17/08/87	26284	T-8	26 ± 2	6 ± 2	548 ± 88
17/08/87	26384	T-2	42 ± 4	5 ± 3	<137
17/08/87	26385	T-3	49 ± 2	6 ± 1	405 ± 52
17/08/87	26386	T-4	39 ± 3	4 ± 3	<161
28/09/87	26370	T-7	40 ± 3	6 ± 2	240 ± 48
28/09/87	26285	T-8	25 ± 3	4 ± 2	172 ± 4
28/08/87	26286	T-4	32 ± 3	6 ± 2	194 ± 34
28/09/87	26287	T-1	65 ± 3	9 ± 3	462 ± 42
28/09/87	26288	T-2	26 ± 2	6 ± 2	548 ± 88
28/09/87	26289	T-6	56 ± 2	6 ± 1	172 ± 17
28/09/87	26290	T-3	71 ± 5	<7	278 ± 49
28/10/87	26388	T-4	54 ± 4	11 ± 4	434 ± 83
28/10/87	26390	T-3	47 ± 4	10 ± 3	265 ± 114
28/10/87	26392	T-2	18 ± 4	<8	303 ± 112
28/10/87	26393	T-1	9 ± 3	6 ± 2	198 ± 79

Table 22. Radionuclide Results for Lichen (*Usnea sp.*) for 1987 and 1988.

Collection Date	Sample No	Site No	Cs-137 (Bq/kg)	Cs-134 (Bq/kg)	Be-7 (Bq/kg)
28/10/87	26395	T-6	44 ± 4	5 ± 3	269 ± 86
28/10/87	26397	T-7	36 ± 4	<8	<143
28/10/87	35442	T-1	16 ± 2	2 ± 2	192 ± 57
25/11/87	35404	T-3	23 ± 2	3 ± 1	127 ± 35
25/11/87	35410	T-6	30 ± 3	5 ± 2	160 ± 53
25/11/87	35412	T-7	33 ± 3	4 ± 2	251 ± 43
25/11/87	35413	T-8	18 ± 2	2 ± 1	166 ± 30
17/12/87	35450	T-1	33 ± 3	4 ± 2	201 ± 88
28/12/87	35447	T-4	24 ± 4	5 ± 3	233 ± 82
28/12/87	35448	T-4	78 ± 4	10 ± 3	385 ± 54
28/12/87	35449	T-2	15 ± 4	6 ± 3	165 ± 63
28/12/87	35451	T-6	66 ± 4	8 ± 3	246 ± 72
28/12/87	35452	T-7	28 ± 4	2 ± 3	109 ± 54
28/12/87	35453	T-8	23 ± 2	4 ± 2	372 ± 45
02/02/88	35454	T-8	18 ± 2	2 ± 2	159 ± 30
02/02/88	35455	T-3	21 ± 2	3 ± 2	95 ± 27
02/02/88	35456	T-1	14 ± 2	5 ± 2	153 ± 26
02/03/88	35457	T-8	17 ± 2	2 ± 1	185 ± 17
02/03/88	35458	T-8	14 ± 2	4 ± 1	108 ± 17
02/03/88	35459	T-1	16 ± 3	<5	93 ± 22
20/04/88	35907	T-8	20 ± 3	<5	266 ± 74
20/04/88	35908	T-3	25 ± 3	<5	228 ± 73
26/05/88	35911	T-1	40 ± 5	2 ± 2	108 ± 94
26/05/88	35913	T-3	56 ± 2	4 ± 1	298 ± 105
26/05/88	35914	T-8	35 ± 4	6 ± 1	557 ± 195
21/06/88	35901	T-1	26 ± 4	<5	122 ± 24
21/06/88	35903	T-8	21 ± 3	2 ± 1	262 ± 66
30/06/88	35934	T-15	27 ± 6	4 ± 3	726 ± 232
30/06/88	35936	T-13	32 ± 5	3 ± 2	237 ± 172
30/06/88	35960	T-14	30 ± 11	11 ± 6	377 ± 185
12/07/88	35927	T-3	24 ± 3	2 ± 1	217 ± 82
12/07/88	35929	T-5	27 ± 3	3 ± 2	94 ± 49
12/07/88	35962	T-1	36 ± 4	<6	156 ± 64
13/07/88	35931	T-8	23 ± 2	3 ± 1	417 ± 63
15/09/88	35915	T-8	11 ± 4	3 ± 2	197 ± 63
15/09/88	35917	T-1	22 ± 4	1 ± 2	115 ± 44
03/10/88	35964	T-1	34 ± 4	<6	99 ± 24
03/10/88	35965	T-8	27 ± 5	2 ± 2	78 ± 26
25/11/88	35968	T-8	22 ± 4	2 ± 2	180 ± 51
25/11/88	35970	T-1	38 ± 5	<2	122 ± 68

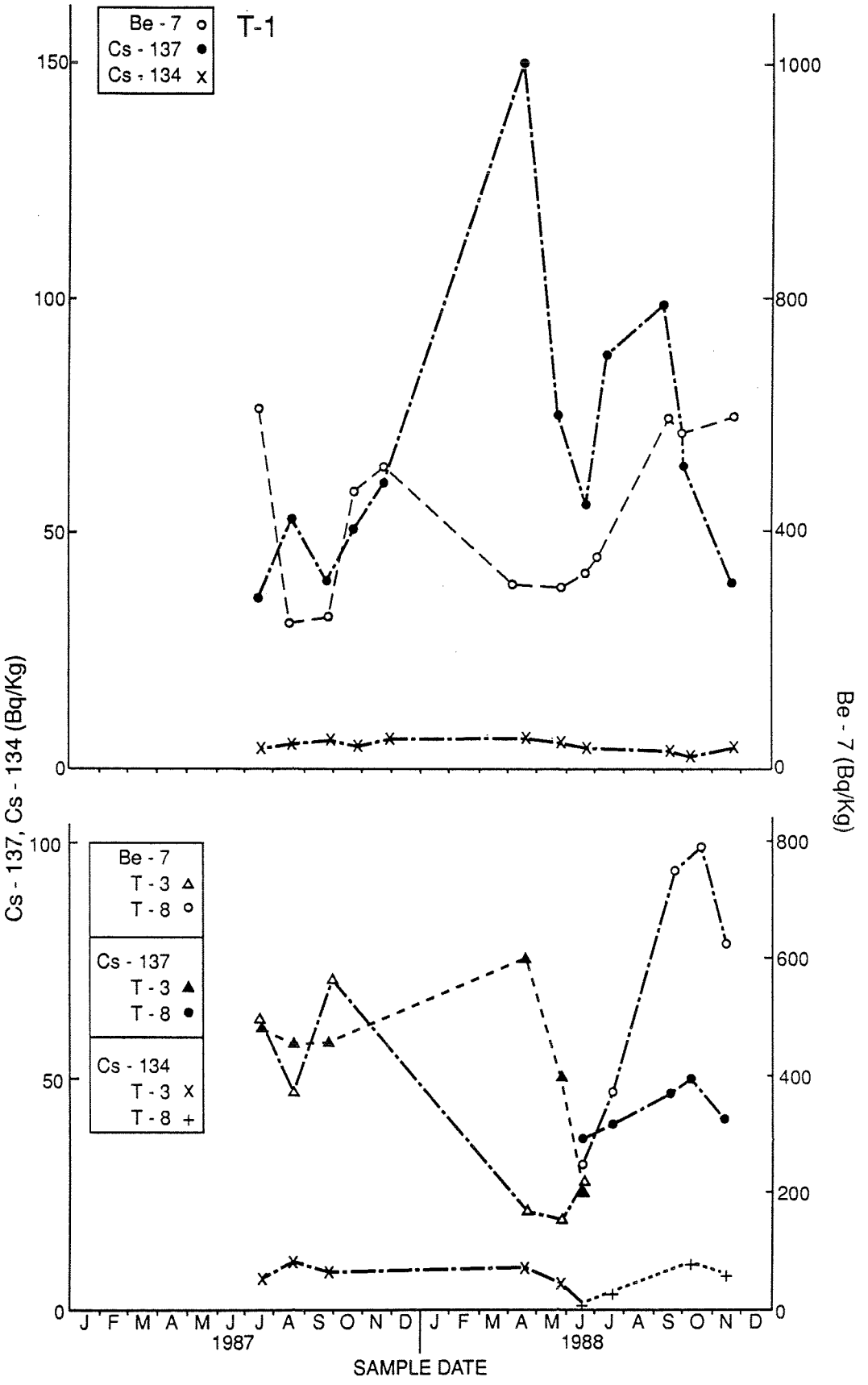

Figure 25: Time distributions of Cs-137, Cs-134 and Be-7 in Cladonia (lichen) at sites T-1, T-3 and T-8 for 1987 and 1988.

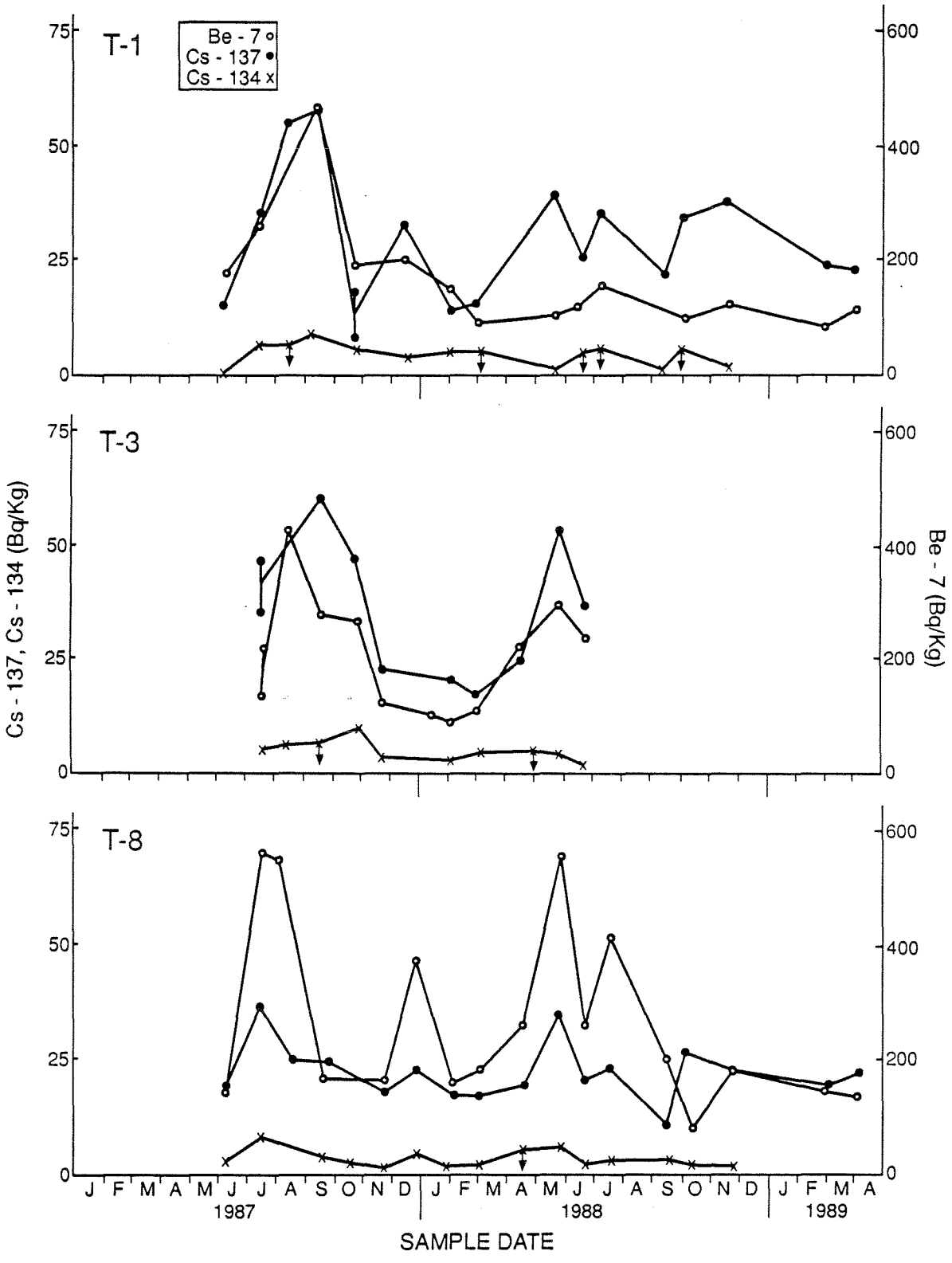

Figure 26: Time distributions of Cs-137, Cs-134 and Be-7 in Usnea (lichen) at sites T-1, T-3 and T-8 for 1987, 1988 and 1989.

and foliar water (Belot, 1986). Uptake also occurs through the root system by the same process and at rates similar to natural water (Murphy et al, 1982).

The tritium activities measured in the aquatic and terrestrial biological samples are given in Table 23 and 24 for 1987 and 1988 respectively. As noted in previous reports (Nelson et al, 1987,1988), the wide range of tritium activities measured (< 2 to 217 Bq/l for 1987 and < 4 to 350 Bq/l in 1988) reflect the variability in tritium atmospheric levels with time, from site to site and from species to species. Levels measured in terrestrial samples are similar to levels measured in atmospheric moisture during the same time period.

During 1987 and 1988, conifer needles were collected and analysed for tritum on a monthly basis for three sites, T-1, T-3 and T-8. The results (Table 23 and 24), shown in Figure 27 are compared to tritium gaseous releases from the NGS. Levels are generally higher at sites closest to the reactor with levels at site T-8 at the tip of Point Lepreau peninsula being the highest overall. Levels here are in the same range as air levels (Station 3, Figure 20) and both data sets show peaks in activity in winter 1987/88 coincident with a larger tritium release from the reactor. This enhanced release occurs during prevalent southwest winds (Figure 15) leading to peaks in conifer needle activities at T-3 and to a lesser extent at T-1 both located northeast of the plant. Again, levels are comparable to those found in air moisture collected at the same time (Station 3 similar to T-3 and Station 1 similar to T-1). The peak in gaseous releases reported for late summer of 1988 was only observed in conifer needles at T-8.

Tritium levels measured in terrestrial samples in the Digby area (sites T-13 to T-15) are in the range of those measured in air during this time period (Station 5, Figure 19). The levels are still at pre-operational levels and show no effect of inputs from the Point Lepreau NGS.

Table 23. Tritium Levels in Biological Samples for 1987.

Sample Type	Collection Date	Sample No	Site No	H-3 (Bq/ℓ)
Conifer Needles	24/10	2654	T-8	84 ± 3
	22/10	2656	T-17	19 ± 3
	22/10	2657	T-2	<4
	22/10	2659	T-5	<2
	22/10	2662	T-4	12.8 ± 2.6
	22/10	2663	T-9	3.9 ± 2.6
	22/10	2628	T-3	11 ± 3
	24/10	2654	T-3	84 ± 3
	28/10	35426	T-3	13.0 ± 2.9
	28/10	35429	T-6	3.3 ± 2.8
	28/10	35430	T-7	<2.6
	28/10	35431	T-8	7.8 ± 2.8
	28/10	35432	T-2	4.5 ± 2.9
	28/10	35433	T-6	5.2 ± 2.9
	25/11	35420	T-16	2.7 ± 2.6
	25/11	35421	T-1	2.3 ± 2.6
	25/11	35422	T-6	3.0 ± 3.0
	25/11	35423	T-7	2.0 ± 3.0
	25/11	35424	T-4	2.9 ± 2.8
	25/11	35425	T-4	9.4 ± 2.8
	25/11	35427	T-7	86.0 ± 2.9
	25/11	35428	T-2	5.4 ± 2.8
	28/12	33333	T-4	4.0 ± 3.1
	28/12	33334	T-3	9.9 ± 3.1
	28/12	33335	T-2	<4.0
	28/12	33336	T-1	4.8 ± 3.1
	28/12	33338	T-7	5.0 ± 3.0
	28/12	33339	T-6	2.9 ± 3.0
	28/12	33340	T-8	217.1 ± 4.9

Table 24. Tritium Levels in Biological Samples in 1988.

Sample Type	Collection Date	Sample No	Site No	H-3 (Bq/ℓ)
Conifer Needles	02/02	33307	T-8	68.1 ± 3.5
	02/02	33308	T-8	55.2 ± 3.4
	02/02	33309	T-3	94.1 ± 3.8
	02/02	33310	T-1	71.2 ± 2.9
	02/02	33311	T-3	114.3 ± 3.9
	02/02	33312	T-1	7.2 ± 2.9
	02/03	33301	T-1	17.5 ± 2.8
	02/03	33302	T-8	191.5 ± 4.5
	02/03	33303	T-3	154.6 ± 4.3
	02/03	33304	T-3	145.7 ± 4.2
	02/03	33305	T-1	17.2 ± 3.0
	02/03	33306	T-8	192.8 ± 4.5
	20/04	35956	T-1	6.1 ± 2.9
	20/04	35957	T-2	7.0 ± 2.9
	26/05	35938	T-3	67.7 ± 3.6
	26/05	35939	T-3	75.6 ± 3.7
	26/05	35940	T-8	15.0 ± 3.1
	26/05	35941	T-8	17.4 ± 3.1
	26/05	35942	T-1	16.2 ± 3.1
	26/05	35943	T-1	12.7 ± 3.0
	21/06	35919	T-1	18.9 ± 3.1
	21/06	35920	T-1	19.6 ± 3.1
	21/06	35921	T-8	15.0 ± 3.1
	21/06	35922	T-8	15.9 ± 3.1
	21/06	35923	T-3	10.9 ± 3.0
	21/06	35924	T-3	73.8 ± 3.7
	21/06	35925	T-3	74.8 ± 3.7
	21/06	35926	T-3	14.0 ± 3.0
	21/06	35950	T-8	350.0 ± 6.4
	21/06	35951	T-8	323.4 ± 6.2
	21/06	35952	T-4	33.6 ± 3.7
	21/06	35953	T-4	32.8 ± 3.7
	30/06	35954	T-15	<4.6
	30/06	35955	T-13	11.1 ± 2.9
	30/06	35959	T-14	2.7 ± 2.9
	12/07	35944	T-9	156.7 ± 4.4
	12/07	35945	T-3	52.9 ± 3.4
	12/07	35958	T-1	9.9 ± 2.9
	15/09	35946	T-8	29.0 ± 3.2
	15/09	35947	T-9	21.5 ± 3.1
	15/09	35948	T-1	11.7 ± 3.0
	15/09	35949	T-3	40.2 ± 3.8
	03/10	33421	T-3	33.5 ± 3.3
	03/10	35382	T-1	4.4 ± 2.8

Table 24. Tritium Levels in Biological Samples in 1988.

Sample Type	Collection Date	Sample No	Site No	H-3 (Bq/ℓ)
	03/10	35383	T-9	220.7 ± 4.7
	03/10	35384	T-8	21.9 ± 3.0
	25/11	33435	T-8	129.9 ± 4.0
	25/11	33436	T-3	42.3 ± 3.2
	25/11	33438	T-1	7.3 ± 2.8
	25/11	33439	T-9	92.3 ± 3.6
	25/11	35385	T-1	6.1 ± 2.8
	25/11	35386	T-8	34.4 ± 3.1
	25/11	35387	T-3	16.9 ± 2.9
	19/12	33429	T-8	275.8 ± 5.0
	19/12	33430	T-3	28.5 ± 3.1
	19/12	33431	T-1	12.6 ± 2.9
	19/12	33433	T-9	34.0 ± 3.1
Blueberry	17/07	33317	T-10	5.8 ± 2.9
	17/07	33318	T-17	<5.0
	17/07	33319	T-12	11.6 ± 2.9
	13/07	33320	T-16	4.2 ± 2.9
	15/07	33321	T-2	254.6 ± 3.1
	13/07	33322	T-1	57.7 ± 3.4
	13/07	33323	T-6	<4.1
	17/07	33325	T-11	7.9 ± 3.2
	13/07	33326	T-3	37.4 ± 3.5
	14/07	33327	T-4	<4.9
	13/07	33328	T-7	7.7 ± 3.2
	13/07	33329	T-9	11.8 ± 3.2
	13/07	33337	T-8	<5.1
Alder	13/07	35434	T-1	29.2 ± 3.3
	13/07	33314	T-8	29.5 ± 3.1
	15/07	33316	T-2	20.4 ± 3.0
	13/07	33330	T-5	2.9 ± 3.1
	13/07	33331	T-9	19.4 ± 3.3
Bullrush	13/07	33313	T-4	6.7 ± 2.9
	15/07	33315	T-2	13.4 ± 3.0
	14/07	33332	T-3	53.6 ± 3.7
	13/07	35435	T-1	9.3 ± 3.0
	14/07	35437	T-9	17 ±
	13/07	35436	T-5	3.4 ± 2.8

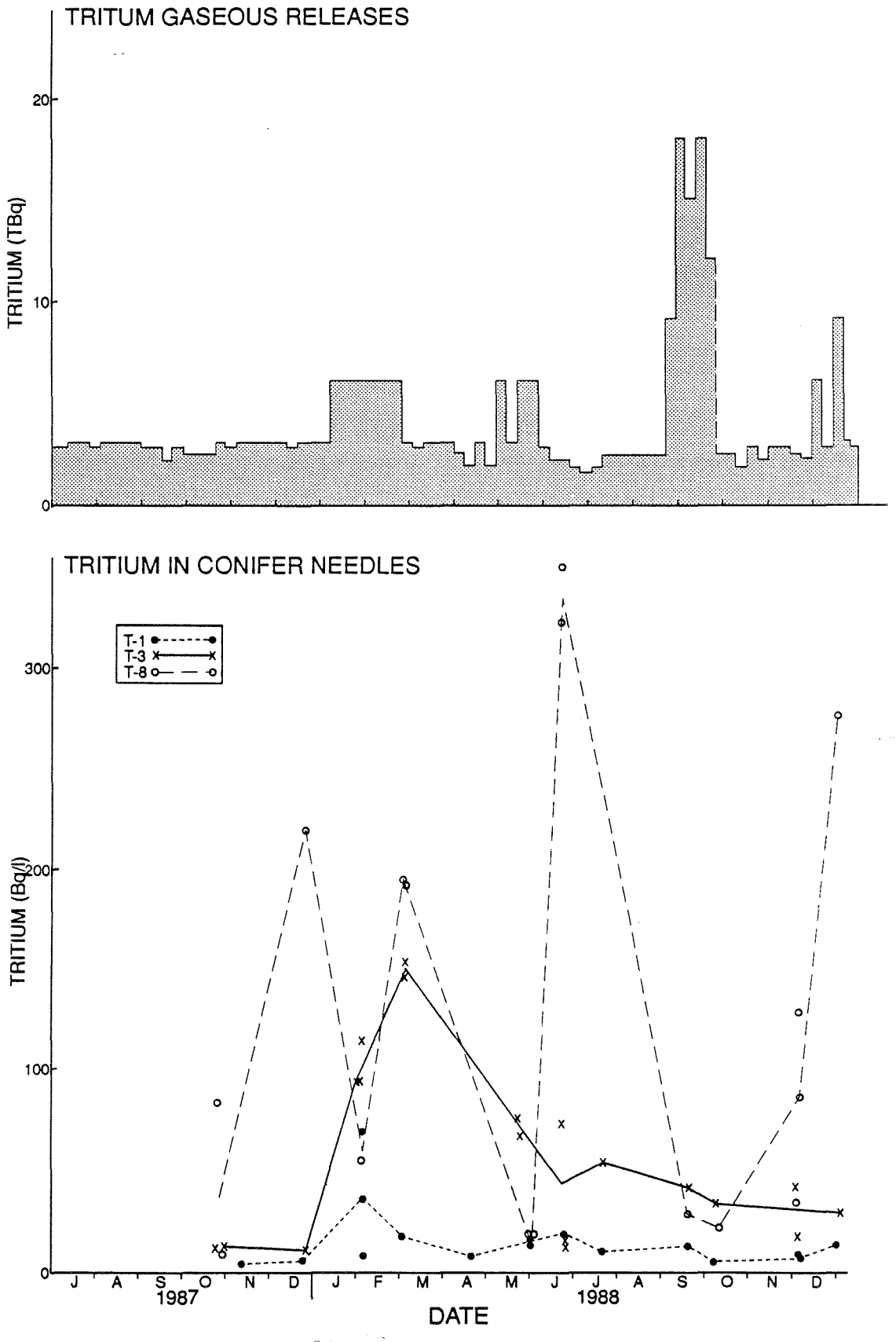

Figure 27: Time distribution of tritium in conifer needles compared to tritium gaseous releases (NBEPC 1988, 1989) for 1988 and 1989.

7.0 LABORATORY INTERCOMPARISON PROGRAM

The AERU laboratory participates in an ongoing laboratory intercomparison study run by the United States Environmental Protection Agency (EPA) in order to maintain a check on the laboratory's performance for accuracy and precision of radionuclide results. The results of the 'blind' experiments are published and distributed to all participants (the AERU laboratory number is 1-A). EPA provides a wide range of sample material to ensure a quality control check on all sample types.

The AERU results for 1987 and 1988 are presented in Table 25. Cesium-137 measurements on air filters continue to be in excellent agreement with EPA values as are the values for tritium, I-131 and Ra-226 in water. Comparison of the Sr-90 and Cs-137 values in water samples to EPA values shows some scatter but the average is in good ageement with the EPA average. Cesium-134 values tended to be low owing to a calibration error. Cobalt-60 values for water are generally in good agreement with EPA values.

Another intercomparison with the International Atomic Energy Agency (IAEA) for various marine samples was carried out in 1987 and 1988 and results are presented in Table 26. Agreement is very good for all three sample types of seaweed, sediment and seawater for Cs-137, Pb-210, Pu-239,240, Cs-134 and Ru-106.

Table 25. Results for intercalibration samples from EPA. Units for air filters are pCi and for water pCi/ℓ.

Sample Matrix	Collection Date	Nuclide	EPA Value	AERU Value	All Labs Value	AERU S.D.	All Labs S.D.	AERU EPA
Air Filter	12/07/86	Cs-137	22	23.7	24.1	0.6	3.6	1.08
	10/04/87	Cs-137	8	8.0	9.3	0.0	2.1	1.00
	28/08/87	Cs-137	10	10.3	10.6	0.6	1.9	1.03
	25/03/88	Cs-137	16	17.3	17.7	1.2	3.1	1.08
	26/08/88	Cs-137	12	12.7	12.6	0.6	2.7	1.06
Water	12/06/87	H-3	2895	2789	2785	105	292	0.96
	14/10/88	H-3	2316	2478	2318	76	238	1.07
Water	07/08/87	I-131	48.0	49.0	47.2	2.6	4.9	1.02
	05/08/88	I-131	76.0	69.7	77.3	2.9	7.6	0.92
	18/12/88	I-131	115.0	119.0	115.5	5.6	14.5	1.03
Water	19/06/87	Ra-226	7.3	7.3	7.0	–	1.2	0.99
	16/09/88	Ra-226	8.4	8.1	7.8	0.3	1.4	0.97
Water	08/01/88	Sr-90	15.0	13.7	14.3	2.3	1.6	0.91
Water	17/04/87	Co-60	8.0	8.0	9.0	0.0	1.9	1.00
		Cs-137	15.0	19.0	15.7	0.0	2.2	1.27
		Cs-134	20.0	16.0	18.2	0.0	2.6	0.80
	21/10/87	Ra-226	4.8	4.9	4.7	0.1	0.7	1.02
		Co-60	16.0	19.0	16.6	3.6	2.2	1.20
		Cs-137	24.0	25.3	24.3	2.5	2.2	1.06
		Cs-134	16.0	13.3	15.7	0.6	2.6	0.83
	24/04/88	Sr-90	5.0	7.3	5.1	0.6	1.0	1.47
		Co-60	50.0	54.7	50.8	2.1	4.0	1.09
		Cs-137	7.0	10.0	8.0	1.0	1.6	1.43
		Cs-134	7.0	5.3	7.2	0.6	1.6	0.76
	18/10/88	Sr-90	10.0	7.3	9.5	0.6	1.3	0.73
		Cs-137	15.0	17.7	15.7	2.3	1.7	1.18
		Cs-134	15.0	9.67	14.3	1.5	1.7	0.64

Table 26. Intercalibration results for samples provided by International Atomic Energy Agency (IAEA).

Sample Number	Sample Matrix	Nuclide	IAEA Value (Bq/kg)	AERU Value (Bq/kg)	AERU S.D. (Bq/kg)	AERU/ IAEA
SW-N-2	Sea water	Cs-137	159	148	–	0.93
SD-A-1	Sediment	Pb-210	72	71.9	1.3	0.99
IAEA-306	Baltic Sea Sediment	Cs-137	193	198	2	1.02
		Pu-239,40	5.4	6.0	0.3	1.11
		Cs-134	50.1	50.3	4.6	1.00
IAEA-307	Sea plant (Posidonia oceanica)	Ru-106	32.9	33.6	1.0	1.02
		Cs-137	5.0	6.2	0.3	1.20
		Cs-134	1.7	1.4	0.6	0.81
IAEA-308	Mediterranean seaweeds	Cs-137	6.9	6.4	0.1	1.08
		Cs-134	1.8	1.2	0.1	0.71
		Ru-106	21.4	22.6	0.8	1.06

8.0 CONCLUSIONS

1. The only radionuclide measured in the environment around the Point Lepreau reactor as a result of effluent releases from the plant is tritium (H-3).

2. Samples collected during a cruise in May 1987 showed negligible contamination in the Bay of Fundy from the Point Lepreau NGS. A thermal plume study undertaken during the cruise confirmed that released tritium was only measureable close to the effluent outfall.

3. Levels of radioactivity measured in marine organisms collected during 1987 and 1988 in the vicinity of the Point Lepreau NGS showed no evidence of increases above pre-operational levels.

4. Elevated levels of tritium were detected in atmospheric water vapour at some sampling stations owing to atmospheric releases of tritium from the Point Lepreau NGS. Tritium levels were greatest (up to one order of magnitude above background levels) at station 3, at the tip of Point Lepreau near the plant boundary and lowest at the Musquash and Digby locations.

5. Tritium levels in terrestrial plants reflect releases from the Point Lepreau NGS owing to their uptake of atmospheric moisture. Elevated levels of tritium measured on the Point Lepreau peninsula in plants and air in 1987 and 1988 are related to proximity to the reactor and the prevaling wind direction. Highest tritium levels were found at the tip of the Point Lepreau penisula.

6. Radionuclide levels of Cs-137 measured in terrestrial plants have not increased as a result of releases from the Point Lepreau NGS. Background activities from nuclear weapons fallout are lowest in annual plants and increase in longer lived plants such as moss and lichen which tend to retain nutrients.

7. Tritium levels in air, terrestrial plants and marine samples at Digby, N.S. are all at pre-operational levels and shown no contamination from the Point Lepreau NGS.

8. Trace amounts of Cs-134 found in soils, terrestrial and aquatic plant samples in 1987 and 1988 have been attributed to fallout from the Chernobyl accident which occurred in the USSR in May, 1986.

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APPENDIX 1

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APPENDIX 2

PLEMP REPORTS

Bishop F.J., Ellis K.M. and Smith, J.N. and Bewers, J.M. (1980) Pre-operational environmental monitoring report for the Point Lepreau, N.B. nuclear generating station. Bedford Institute of Oceanography Report Series - BI-R-80-1.

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APPENDIX 3

Conversion Factors for Radionuclide Units

1 Becquerel (Bq)	=	60 dpm
	=	27 pCi
	=	2.7×10^{-11} Curies (Ci)
1 Bq/ℓ	=	8.3 tritium units (TU)
1 Ci	=	3.7×10^{10}Bq
1 mCi	=	3.7×10^{7} Bq
1 pCi	=	3.7×10^{-2}Bq
1 dpm	=	0.0167 Bq
1 dpm	=	0.45 pCi
1 Tu	=	0.12 Bq/ℓ
1 Tu	=	7.2 dpm/ℓ
1 mCi/km^2	=	37 Bq/m^2

Appendix 4

Detection limits (Bq/kg) for each radionuclide and geometry assuming a counting time of 10^5 sec for analyses performed one month subsequent to sample collection. Detection limit for specific sample is determined by choosing detection limit for a radionuclide for the appropriate geometry and dividing by the sample weight. These estimates are approximate and will vary depending upon the specific counting times and delay between sample collection and analysis.

Nuclide	Half-life	Geometry 1	Geometry 2	Geometry 3	Geometry 4	Geometry 5
Ag-110m	253.0 d	150	94	95	95	47
Ba-140	12.8 d	1700	1700	1000	1000	490
Be-7	53.6 d	1100	1200	690	670	370
Ce-141	32.4 d	280	330	170	140	110
Ce-144	284.0 d	780	900	460	400	200
Co-56	77.0 d	130	140	90	90	40
Co-57	270.0 d	110	130	63	54	35
Co-58	71.0 d	130	140	77	78	39
Co-60	5.26 y	120	120	65	69	35
Cr-51	28.0 d	1700	1800	1100	1001	570
Cs-134	2.07 y	110	120	69	69	33
Cs-137	30.2 y	107	100	62	60	31
Eu-152	12.5 y	660	690	410	410	200
Eu-155	1.81 y	300	340	160	160	69
Fe-59	44.6 y	340	330	190	200	89
I-131	8.06 d	1200	1400	780	750	410
La-140	40.2 h	510	510	340	360	190
Mn-54	313.0 d	110	110	67	65	31
Nb-95	35.1 d	180	180	110	110	54
Ru-103	39.6 d	150	160	93	92	46
Ru-106	1.0 y	900	940	540	550	250
Sb-124	60.2 d	18	20	11	11	6
Sb-125	2.7 y	240	260	150	147	73
Zn-65	244.0 d	290	260	140	150	73
Zr-95	64.0 d	140	240	150	150	70