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ENVIRONMENTAL RADIOACTIVITY IN CANADA 1981

Environmental Health Directorate
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ABSTRACT

The radiological surveillance program of the Department of National Health and Welfare is conducted for the purpose of determining levels of environmental radioactivity in Canada and assessing the resulting population exposures. Special investigations were carried out during 1981 on bottled mineral waters and in conjunction with unusual occurrences at nuclear reactor sites and a uranium refinery. Dose commitments have been estimated for the ongoing natural radioactivity, fallout and reactor studies. All measurements made during the year are below the limits recommended by the International Commission on Radiological Protection.

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INTRODUCTION

The Environmental Radiation Hazards Section of the Radiation Protection Bureau investigates the potential health effects to the Canadian population from natural and man-made sources of environmental radioactivity. This includes the evaluation of population doses from terrestrial and cosmic radiation and potential health risks from inhaling radioactivity in air or ingesting it in drinking water and food. The data are collected by operating a nation-wide network of sampling stations for air, precipitation, water vapour, drinking water, and milk and through special surveys.

In this report the results for 1981 are presented in tabular form. The graphical format used in previous reports has been retained to illustrate long-term trends. Results are given in SI units. Radioactivity measurements are in Becquerels (Bq). Once Becquerel is equivalent to 27 picocuries. Absorbed doses are in Grays (Gy) where one Gray is equal to 100 rads. Dose equivalents are in Sieverts (Sv) where one Sievert is equal to 100 rems.

In summary, the following studies were conducted.

- The nationwide program to study radium-226 and uranium in drinking water supplies continued.
- A program was initiated to determine natural radioactivity levels in bottled mineral water.
- The nationwide study of nuclear weapons fallout and the potential health impact of radioactive emissions from nuclear reactors in Canada was maintained.
- The pre-operational radioactivity study in the environs of the Point Lepreau Nuclear Generating Station, New Brunswick, continued.
- The study of external radiation exposure across Canada was maintained.
- Studies comparing the health impact of radionuclide emissions from coal and nuclear powered electrical generating facilities progressed.
- An investigation was undertaken in the town of Port Hope to determine uranium concentrations in air and deposition of uranium dust.
- The project to determine the toxicity of uranium in drinking water continued.

NATURAL RADIOACTIVITY

Studies of population exposures due to natural radioactivity continued with radiochemical analyses of drinking water and bottled mineral waters. Radium-226 was selected for study because of its high radiotoxicity; total uranium because of its chemical toxicity and because it is the precursor of a chain of radioactive daughters. The concentrations measured during 1981 were all less than the maximum acceptable concentrations of 1 Bq/L for radium-226 and 20 µg/L for uranium recommended in the Guidelines for Canadian Drinking Water Quality, 1978 (1).

Drinking Water

The program to determine natural radioactivity levels in treated drinking water and their potential impact on human health continued with the analysis of monthly composite water samples from the 13 municipalities shown in Figure 1. The program was discontinued at the 4 British Columbia locations after April because of consistently low or non-detectable values during 1980 and 1981 (4).

The results are presented in Tables 1 and 2. For the most part, the concentrations of radium-226 were at or near the detection limit of 5 mBq/L. The highest concentrations continued to be observed in both treated and untreated water from Elliot Lake and reached 50 mBq/L in June. The town is located at the centre of uranium mining activities in Ontario.

The uranium concentrations in Table 2 show considerable variations with time and location. As observed in previous reports (2,3,4) the highest concentrations occurred at Regina (12.7 µg/L in August). Regina draws part of its drinking water requirements from ground water sources whereas all other locations rely entirely on surface waters.

Bottled Mineral Water

A program to determine natural radioactivity levels in bottled mineral water and their potential impact on health was initiated. During the year, 13 domestic and 14 foreign brands were analyzed for radium-226 and uranium.

Concentrations of radium-226 in 17 of the 27 samples were at or near the detection limit of 10 mBq/L. The highest concentration observed for a foreign brand was 440 mBq/L and for a domestic brand, 18 mBq/L. In 10 of the 27 brands analyzed the uranium concentration was less than the limit of detection of 0.1 µg/L. The highest concentrations were 12.6 µg/L in a foreign brand and 6.8 µg/L in a domestic brand.

RADIOACTIVITY FROM FALLOUT

There were no unusual events during 1981, although residual activity from the October 1980 nuclear weapons test continued to be observed. The regular fallout monitoring program was maintained at stations across Canada. This program determines the levels of gross beta radioactivity in surface air particulates and in precipitation, and the levels of cesium-137 and strontium-90 in milk.

Surface Air and Precipitation

Sampling locations are shown in Figure 2. Results of the gross beta radioactivity analysis are given in Tables 3 and 4. Monthly samples of precipitation are now composited quarterly for analysis. Occasionally samples are lost at the site or enroute to the Radiation Protection Bureau. The number of samples received is shown in column 2 of Table 4. Quarterly values for deposition are those measured for the samples received. The annual deposition is for a 12-month period with estimated corrections for missing samples. Air filters continue to be collected and analyzed weekly.

Gross beta radioactivity concentrations in air were still strongly influenced by residual activity from the atmospheric nuclear weapons test of October 16, 1980 by the People's Republic of China. This is readily apparent from Figure 3 which summarizes the national average concentrations from 1978 to 1981. The influence on air seems to be greater than on precipitation. This phenomenon was observed at all stations across Canada but was most pronounced in southern Ontario were concentrations in air reached 10 millibecquerels per cubic metre in April. This is a factor of 10 higher than concentrations measured during the same period in 1980 [4].

Milk

Samples of whole milk collected weekly at the locations shown in Figure 4 were analyzed monthly for cesium-137 and quarterly for strontium-90. The results are given in Tables 5 and 6. The national levels are comparable to those observed in other countries. The cesium-137 to strontium-90 ratio is 1.4, a slight reduction over previous years but still in line with the 1982 UNSCEAR value of 1.6 [5]. The October 16, 1980 weapons test had no noticeable impact on the levels of these two radionuclides in milk. Average concentrations across Canada are in fact slightly lower than those observed in 1980, as seen by the four-year trends in Figure 5.

RADIOACTIVITY FROM NUCLEAR REACTORS

Environmental radioactivity studies are carried out in the vicinity of 6 nuclear reactor sites in Canada:

- the Whiteshell Nuclear Research Establishment (AECL-WNRE), Pinawa, Manitoba;
- the Bruce Nuclear Power Development (BNPD), Tiverton, Ontario, with a 220 MW(e) prototype generating station, four 750 MW(e) units in service (Bruce A) and four 750 MW(e) units under construction;
- the Pickering Nuclear Generating Station (PNGS), Pickering, Ontario, with four 500 MW(e) units in service (Pickering A) and four 500 MW(e) units under construction;
- the Chalk River Nuclear Laboratories (AECL-CRNL), Chalk River, Ontario;
- the Nuclear Power Demonstration Reactor (NPD), 25 MW(e) at Rolphton, Ontario;
- the Gentilly Nuclear Site (GNS), Gentilly, Quebec, with a 250 MW(e) prototype reactor and a 600 MW(e) unit under construction.

Samples of air water vapour, drinking water, milk, and biota are collected at the locations shown in Figures 6 to 11. Dose rate measurements of external gamma radiation are also made around BNPD, PNGS and GNS. These results are discussed in a separate section.

During 1981, special monitoring was carried out in connection with equipment malfunctions at the Nuclear Power Demonstration Reactor, the Bruce Nuclear Power Development, and the Gentilly Nuclear Site. The preoperational study of fission product radioactivity in the environs of the new 600 MW(e) Point Lepreau Nuclear Generating Station, New Brunswick, continued with the analysis of air water vapour. In addition monitoring was carried out on radioactivity in air particulates near the McMaster University Research Reactor, Hamilton, Ontario and in air particulates and sea water during the visits of nuclear vessels to Nova Scotia.

Air Water Vapour

Atmospheric water vapour is collected in metallic cells containing molecular sieve. They are placed around the Bruce (BNPD), Pickering (PNGS) and Gentilly (GNS) reactor sites. Air, drawn through the cells over a period of a month, deposits atmospheric moisture on the sieve. Subsequently, the cells are heated to desorb the water which is then anlayzed for tritium. The results for 1981 are given in Table 7. The highest monthly concentrations were observed at Stations 4 and 5 at Pickering at Station 5 at Bruce. The highest levels around the 3 sites were generally similar to those measured during the past three years [2,3,4].

Water

Untreated water is collected daily at drinking water intakes on the Winnipeg River, Lakes Huron and Ontario, the Ottawa River and the St. Lawrence River (Figures 7 and 11). Results of the quarterly analysis for cesium-137 and strontium-90 are given in Tables 8 and 9. Concentrations of both radionuclides remained within normal seasonal fluctuations and were due to residual fallout. The highest concentrations measured, 0.04 Bq/L for strontium-90, and 0.016 Bq/L for cesium-137, were factors of 250 and 3000 respectively, below the maximum acceptable concentrations of 10 Bq/L and 50 Bq/L recommended for Canadian drinking water [1].

Milk

Weekly samples of raw milk from the vicinity of WNRE and BNPD are analyzed for iodine-131, cesium-137 and potassium. Iodine-131 was not detected at either location. Results for cesium-137 during 1981 are shown in Table 5. The cesium-137 levels in raw milk from these sites were similar to those in pasteurized milk from the national network. This suggests, as has been observed in the past, that fallout was the major contributor to the radionuclide levels around the reactor locations. This is also confirmed by comparing the long-term trends in Figure 5.

Release from the Nuclear Power Demonstration Reactor

On July 19, 1981 an accidental spill of 680 000 litres of water containing 130 terabecquerels* of tritium occurred within the containment building of the Nuclear Power Demonstration Reactor (NPD) at Rolphton, Ontario. Ontario Hydro, which operates the reactor, obtained permission from the Atomic Energy Control Board (AECB) to release this water into the Ottawa River over a period of three days beginning August 17. The amount of tritium released was 1.6 per cent of the monthly limit of this station. Routine releases are generally less than one per cent of the limit.

The Radiation Protection Bureau initiated an intensive monitoring program at its drinking water stations at Rolphton, Deep River, Petawawa, Pembroke and Ottawa on August 17. The resulting analyses for tritium are shown in Figure 13, which clearly demonstrates the progression of the tritium pulse down the river. Normally, the tritium concentrations in the Ottawa River are less than the detection limit of 20 Bq/L. The highest observed concentration was 330 Bq/L at Deep River and tritium was still detectable at Ottawa, some 200 km downstream. The range of doses calculated for ingestion of the contaminated water is 0.1 µSv and 0.02 µSv for Deep River and Ottawa, respectively.

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* 1 terabecquerel = 10^{12} becquerels = 27 curies

Although this release gave no basis for health concern, it provided an excellent opportunity to study radionuclide transport in the Ottawa River. Table 10 summarizes the transport times and dilution factors for the municipalities downstream from Rolphton. It can be seen that the tritium pulse travelled with an average speed of about 3 km/day and required 40 days to reach Ottawa-Hull. The steady increase in dilution factors between Deep River and Ottawa is due to further mixing in the river and to evaporation. This information is being incorporated into predictive models for the Ottawa River to aid emergency response planning for the reactors at Rolphton and Chalk River.

Releases from the Bruce Nuclear Power Development

During the summer of 1981, there were two non-routine releases of radioactivity at BNPD. The first occurred between July 17 and July 19 when 100 to 200 litres of heavy water containing up to 15 TBq of tritium escaped from the heat exchanger at the Douglas Point Reactor and entered Lake Huron. This represents about 0.5% of the monthly derived release limit for tritium in water. Drinking water samples were collected daily at Kincardine and Port Elgin (see Figure 10) and analyzed for tritium. All results were at or below the detection limit of 20 Bq/L.

The second release occurred at Bruce "A" between August 29 and September 9 when 850 litres of sump water containing approximately 300 TBq of tritium evaporated and subsequently escaped to the outside atmosphere. This represents about 4% of the weekly derived release limit for airborne tritium. The target for normal operations is 1% of the derived release limit and actual releases average about 0.5% of the limit. No special monitoring was carried out in connection with this event. However, it can be seen from Table 7 that the monthly tritium measurements around Bruce were not unusually high during August or September.

Release from the Gentilly Nuclear Site

With advance approval from the AECB, the reactor at Gentilly, Quebec, released about 22 million litres of water containing 5 TBq of tritium into the St. Lawrence River. This was carried out over a two-week period beginning September 21, 1981. Weekly samples of drinking water were taken at the three sites shown in Figure 8 between September 21 and October 30. Analysis of these samples for tritium and gamma emitting radionuclides showed no activity that could be attributed to releases from the reactor.

Point Lepreau Study

This is the first Canadian reactor to have potential impact on the population through a marine environment. Online reactor operations are scheduled for 1982. Preoperational monitoring continued with measurements of tritium in atmospheric water vapour at the five collection units installed during 1980 in cooperation with Province of New Brunswick (Figure 12). Collaborative tritium measurements with the Health Physics Department of the New Brunswick Electric Power Commission also continued. During 1981 tritium concentrations were close to or below the current detection limit of 0.01 Bq/m^3.

McMaster University

Gross beta radioactivity levels on daily air filters were normal.

Nuclear Vessels

Nine nuclear submarines visited Shearwater, Nova Scotia, during 1981. Gross beta radioactivity was measured on air filters and gross gamma radioactivity on seawater samples collected before, during and after the visit. No activity was found that could be attributed to a release from the vessels.

EXTERNAL RADIATION EXPOSURE

Measurements of external gamma radiation dose rates are done quarterly at 13 environmental stations and at 14 locations around 3 nuclear reactor sites using thermoluminescent dosimeters (TLDs). Enhanced dose rates in the vicinity of nuclear reactors would be indicative of radioactive releases from nuclear operations. Figure 2 shows the 13 cities in which environmental dose rate measurements are made. The TLDs are attached to the weather housing of the air sampling equipment. Figures 6 to 8 show the 14 locations used for reactor environs monitoring at BNPD, PNGS and GNS. At these sites, the TLDs are attached to the housing of the air water vapour collection units.

Average dose rates for the first two quarters and the last half of 1981, together with the yearly cumulative doses, are presented in Tables 11 and 12. Occasionally TLDs are lost in transit or through vandalism while deployed on site. No value is reported in such cases; however, in determining the cumulative value, the average value for the remaining quarters is assumed. The values in Table 11 form the environmental stations give an indication of the range of normal background dose rates across Candaa. The values from the reactor environs in Table 12 fall within the same range which shows that these doses are attributable to normal background radiation.

In order to expand and upgrade the existing reactor and environmental monitoring network, the suitahbility of various TLD systems was investigated. A Victoreen 2810 TLD reader with glass-encapsulated CaF_2:Mn chips was chosen as the system most suited for measuring environmental levels of radioactivity. The reader has a range of 0.1 μGy to 2000 μGy, while the dosimeters have a sensitivity to 1 μGy with a measurement range up to 1000 Gy. The lower levels are ideal for measuring environmental levels of gamma radiation.

RESEARCH PROJECTS

Energy Impact Study

In 1979 a project was undertaken to compare the health impacts of radionuclide emissions from the coal-fired generating station at Nanticoke, on Lake Erie, and the nuclear generating station at Pickering on Lake Ontario. Previous reports have described the general outline of the study [2,3] and have given preliminary results based on gamma spectrometric analyses [3,4]. During 1981 the field sampling programs at Nanticoke and Pickering were completed. Radiochemical analyses for radium-226 and total uranium were carried out on air filter and precipitation samples. The sampling locations are shown in Figures 7 and 14.

There were no apparent trends in the results from Nanticoke that could be attributed to emissions from the thermal generating station. The annual average radium-226 concentrations in air at the five sites in Figure 14 varied from 0.7 to 2 $\mu Bq/m^3$ with a mean of 1.1 ± 0.2 $\mu Bq/m^3$. This is not significantly higher than the value of 0.6 ± 0.3 $\mu Bq/m^3$ for the Pickering area. Average monthly radium-226 depositions were $0.22 \pm 0.05 Bq/m^2$.month at site no. 2 and $0.52 \pm 0.25 Bq/m^2$.month at site no. 4. These are comparable to a mean value of $0.24 Bq/m^2$.month at New York City [6].

Preliminary results of this study were presented at an international symposium in June 1981 [7]. It was estimated that the highest dose commitment to the most exposed individual near the Nanticoke plant was about 0.1 μSv/year. Most of this resulted from inhalation during passage of the airborne plume.

Uranium Emissions in Port Hope

In May the Radiation Protection Bureau was requested by the Atomic Energy Control Board (AECB) to evaluate the health significance of enhanced uranium emissions from the Eldorado Nuclear Limited refinery in Port Hope, Ontario. From December 1980 to April 1981 the reported uranium levels in dustfall were up to 100 times their normal values, and the estimated air concentrations exceeded 1 $\mu g/m^3$. In the Bureau report to the AECB (8) it was estimated that the critical receptor would have received a committed lung dose of 20 mSv, or an effective whole-body dose of 3 mSv, as a result of emissions during this period. Furthermore, if the enhanced levels had persisted for a whole year, the effective dose commitment would have exceeded the ICRP annual limit of 5 mSv for members of the public [9].

The problem at the refinery was traced to a faulty baghouse filter which was subsequently corrected. In order to confirm that uranium concentrations had returned to lower values, and to determine the chronic levels of uranium exposure in the town, a one-year study of uranium concentrations in air and precipitation was initiated. In July a set of five air monitoring stations were installed at the sites shown in Figure 15. The stations at sites 6, 7, and 8 were moved to more permanent locations at sites 2, 3, and 4 in September. Airborne particulate matter was collected on glass fibre filters exposed for periods of one week at a flow rate of about 1200 m^3 per day. Particle-size measurements were carried out with the aid of a 4-stage Anderson Cascade Impactor attached at various times to the air inlets at each of the five monitoring stations. The particle-size determination was crucial to dose estimation, since lung deposition increases from 10% to 30% as particle-size decreases from 10 to 1 μm. The uranium content of each filter was determined by Atomic Energy of Canada Limited, Commercial Products using neutron activation techniques.

For the period July to December 1981, the average concentrations of airborne uranium in Port Hope varied from 5 to 20 ng/m^3, compared to normal background values of 0.1 ng/m^3 for rural locations in southern Ontario. The highest observed value during a one-week period was 160 ng/m^3 at site 2, just west of the refinery. Particle-size measurements showed that the mass median diameter of uranium-bearing particles was not significantly larger than that of normal airborne particulates (1 to 2 μm). The standard ICRP lung model (10) was used for dose calculations. Based on measurements from July to December, the highest annual dose commitment to lung was 3 mSv at site 2. Dose commitments at the other sites were an order of magnitude lower. The monitoring program will continue until the fall of 1982.

Uranium Toxicity Study

The project on the toxicity of uranium in laboratory animals continued. This project is being conducted jointly with the Bureau of Chemical Hazards for the purpose of re-assessing the current value (20 μg/L) for the maximum acceptable concentration of uranium in Canadian drinking water [(1)]. There is also concern that the radiological effects from uranium may be comparable to its chemically toxic effects.

During 1981 a 90-day study in Sprague Dawley rats was completed. Uranyl nitrate hexahydrate was administered in the drinking water at concentrations of 0.96, 4.8, 25, 120, and 600 mg/L. At the end of this period, the rats were sacrificed and subject to pathological examinations, chemical tests, and uranium residue analyses. Lesions were found in kidney, liver, and thyroid tissues. Uranium residues at the parts per million level were observable only in bone and kidney, and only at the two highest dose levels. Based on these results, the no-effect level for uranium in drinking water was estimated to lie in the range of 5 to 25 mg/L.

A similar study is being planned for rabbits in 1982. This species appears to be more sensitive than the rat in its response to the uranyl ion. The combined results from the two species will allow a more reliable extrapolation to effects in humans.

REVIEWS OF NUCLEAR FACILITIES EXPANSIONS

At the request of the Atomic Energy Control board, documentation was reviewed in connection with the expansion of the uranium hexafluoride facility at Port Hope and the proposed uranium trioxide refinery at Blind River. These reviews were undertaken to ensure that the public would not be exposed to unnecessary radiological health risks and that the calculations of radiation exposure estimates were correct. Our calculations indicate that the estimates were of the right order of magnitude, based on material presented in the documents, and were within ICRP limits for members of the public.

The following areas of health concern were raised in the Application to the Atomic Energy Control Board for Site Approval, Port Hope Uranium Hexafluoride Facilities Expansion:

- Clarification was requested on the methods of measuring external radiation exposure and uranium concentrations in the site vicinity.
- Exposure due to transportation of radioactive materials and to past operations should have been included.

- Annual limits of intake for inhalation and ingestion should have been based on the more recent ICRP-30 models and data.
- Population doses should have been estimated.

In the Application to the Atomic Energy Control Board for Construction Approval for a Uranium Trioxide Refinery at Blind River, the following areas of health concern were raised:

- Exposures from routine shipment of radioactive materials and from accident conditions should have been included.
- Concern was raised about the integrity of the dust collector systems, in particular, the likelihood of simultaneous failure of primary and back-up collectors.
- The complete dose from combined external, internal, and ingestion exposures should have been calculated.
- Several assumptions used in exposure calculations were optimistic rather than conservative.

Satisfactory responses to these points were provided by Eldorado Nuclear Limited in documentation they submitted to the Atomic Energy Control Board [11, 12].

INTERCOMPARISON PROGRAM

Laboratory quality control programs continued through participation in interlaboratory comparisons sponsored by the United States Environmental Protection Agency, the World Health Organization and the International Atomic Energy Agency. During 1981 milk and diet samples were analyzed for potassium-40, strontium-89, strontium-90 and iodine-131; air filters for gross beta and gross alpha radioactivity; water samples for gross beta and gross alpha radioactivity, tritium, radium-226 and uranium; and a soil sample for gamma emitting radionuclides.

SUMMARY

The studies carried out during 1981 allow estimates to be made of the individual effective dose equivalent commitments (doses) for some critical radionuclides in ingestion and inhalation pathways affecting many Canadians. These are summarized in Table 13 along with annual exposures to external gamma radiation and estimates of associated risks.

The table gives the range of doses estimated in each program based on the highest and lowest annual average radionuclide concentrations measured. The corresponding locations are also given. Doses from tritium in atmospheric water vapour were calculated assuming continuous annual exposure at the highest monthly concentration measured in the vicinity of the nuclear power reactor sites. Inhalation and skin absorption were considered. Canadian food consumption data [(13)] were used to calculate the intake of milk. Recently published ICRP dosimetric models and risk estimates were used for the calculations of doses and risks [(9, 10)].

As noted previously [(4)], natural background radiation is far more significant than contributions from residual fallout from nuclear weapons tests or from nuclear reactor emissions. The dose from external gamma radiation represents approximately 50 per cent of the total background to which Canadians are exposed. The remainder is due to cosmogenic and primordial radionuclides -- mainly carbon-14, potassium-40, lead-210 and radon-222.

The doses from fission products in water and milk due to fallout radioactivity are an order of magnitude less than those due to natural radionuclides in drinking water. As in previous years, discharges of tritium to the atmosphere were the only measurable routine releases from the nuclear power reactors in Canada. Exposures due to this were well within the ICRP recommended limits.

The risks given in Table 13 were estimated to the nearest power of 10 because of the uncertainties in associating detriment with dose. They represent the probability of contracting fatal cancer over a lifetime. In Canada the total risk over a lifetime is approximately 0.2 [(14)]. The risks in Table 13 are negligible in comparison.

REFERENCES

1. Federal-Provincial Working Group on Drinking Water, "Guidelines for Canadian Drinking Water Quality, 1978", Department of National Health and Welfare, Ottawa, 1979.

2. Environmental Health Directorate, "Environmental Radioactivity in Canada, January-June, 1979", 80-EHD-51, Department of National Health and Welfare, Ottawa, 1980.

3. Environmental Health Directorate, "Environmental Radioactivity in Canada, July-December, 1979". 82-EHD-76, Department of National Health and Welfare, Ottawa, 1982.

4. Environmental Health Directorate, "Environmental Radioactivity in Canada, 1980", 82-EHD-90, Department of National Health and Welfare, Ottawa, 1982.

5. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), "Ionizing Radiation: Sources and Biological Effects", United Nations, New York, 1982, p. 220.

6. Fisenne, I.M., Perry, P.M. and Keller, H.W., "Wet and Dry Deposition of Ra-226, Pb-210 and Stable Lead in an Urban Environment", Environmental Quarterly, EML-371, Environmental Measurements Laboratory, U.S. Department of Energy, April, 1980.

7. Tracy, B.L. and Prantl, F.A., "Radiolocial Implications of Thermal Power Production", IAEA-SM-254/4, Symposium on Health Effects of Different Energy Sources, Nashville, Tennessee, June 22-26, 1981.

8. Tracy, B.L. and Meyerhof, D.P., "Health Evaluation of Uranium Emissions in Port Hope, Ontario", report submitted to the Atomic Energy Control Board, August, 1981.

9. International Commission on Radiological Protection, "Recommendations of the International Commission on Radiological Protection", ICRP Publication 26, Pergamon Press, Oxford, 1977.

10. International Comission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers", ICRP Publication 30, Supplement to Part I, Pergamon Press, Oxford, 1979.

11. Eldorado Nuclear Limited, "Eldorado Nuclear Limited's Response to Radiation Protection Bureau Review dated June 23, 1981", submitted to the Atomic Energy Control Board, July, 1981.

12. Eldorado Nuclear Limited, "Responses to the Review by Radiation Protection Bureau, Department of National Health and Welfare, of the Application to the Atomic Energy Control Board for Site Approval, Port Hope UF_6 Facilities Expansion", submitted to the Atomic Energy Control Board, December, 1981.

13. Nutrition Canada, Bureau of Nutritional Sciences, "Food Consumption Patterns Report", Health Protection Branch, Health and Welfare Canada, Ottawa, 1976.

14. Health and Welfare Canada and Statistics Canada, "Mortality Atlas of Canada, Volume 1: Cancer", Department of National Health and Welfare and the Treasury Board, Ottawa, 1980.

REPORTS AND PRESENTATIONS

1. Meyerhof, D.P. and Quinn, J.M., "Environmental Radioactivity in Canada, 1972", Environmental Health Directorate Series, 81-EHD-71, April 1981.

2. Meyerhof, D.P., "Role of the Environmental Radiation Hazards Section in Evaluating Proposed Uranium Refinery Operations" presented at a Public Monitoring Committee Meeting, Blind River, May 11, 1981.

3. Meyerhof, D.P., Tracy, B.L., Quinn, J.M. and McGregor, R.G., "Review of the Application to the Atomic Energy Control Board for Site Approval, Port Hope UF Facilities Expansion", submitted to the Atomic Energy Control Board, May, 1981.

4. Meyerhof, D.P., "Review of Documentation Submitted to the Atomic Energy Control Board in Support of the Application for Construction Approval for a Uranium Trioxide Refinery in Blind River", submitted to the Atomic Energy Control Board, June 23, 1981.

5. Tracy, B.L. and Prantl, F.A., "Radiological Implications of Thermal Power Production", IAEA-SM-254/4, International Symposium on Health Effects of Different Energy Sources, Nashville, Tennessee, June 22-26, 1981.

6. Tracy, B.L. and Meyerhof, D.P., "Health Evaluation of Uranium Emission in Port Hope, Ontario", submitted to the Atomic Energy Control Board, August, 1981.

7. McGregor, R.G., "Current Activities in Radon Studies", presented at a meeting of the Working Group on Indoor Air Quality, September 22, 1981.

8. Quinn, J.M., "Methods Development in the Environmental Radiation Hazards Section", presented at the Workshop on Analytical Chemistry Related to Canada's Nuclear Industry, St. Jovite, Quebec, October 18-21, 1981.

9. McGregor, R.G. and Tracy, B.L., "Effects of Radioactive Emissions Resulting from Uranium Mining and Milling Operations on Man", Presented at Comparative Ecotoxicity of Uranium Mining and Milling Emissions Seminar, Saskatoon, Sask., October 21, 1981.

10. McGregor, R.G., "National Radon Survey Results", presented at a meeting of the Federal-Provincial Subcommittee on Radiation Surveillance, November 26, 1981.

Table 1. Radium-226 Levels in Drinking Water, 1981 (mBq/L)
(Detection Limit - 5 mBq/L)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
BRITISH COLUMBIA												
Kamloops	<5	<5	<5	<5	NS	NS	NS	NS	NS	NS	NS	NS
Kelowna City	<5	<5	6	<5	NS	NS	NS	NS	NS	NS	NS	NS
Kelowna S.E. Dist.	<5	<5	<5	<5	NS	NS	NS	NS	NS	NS	NS	NS
Penticton	<5	<5	<5	<5	NS	NS	NS	NS	NS	NS	NS	NS
NOVA SCOTIA												
Halifax	<5	<5	<5	<5	<5	<5	5	<5	<5	<5	<5	<5
ONTARIO												
Bancroft	<5	<5	NS	10	<5	<5	10	<5	<5	<5	<5	<5
Elliot Lake Treated	<5	7	10	30	20	50	40	20	20	20	20	20
Elliot Lake Untreat.	10	NS	40	20	20	7	20	10	6	30	30	20
Ottawa	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Port Hope	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
SASKATCHEWAN												
Regina	<5	<5	20	<5	<5	5	<5	5	<5	<5	<5	<5
Saskatoon	<5	<5	7	5	<5	<5	<5	<5	<5	<5	<5	<5
YUKON												
Whitehorse	<5	<5	9	<5	<5	<5	6	<5	<5	<5	<5	<5

NS - No Sample

Table 2. Uranium Levels in Drinking Water, 1981, (μg/L)
(Detection Limit - 0.1 μg/L)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
<u>BRITISH COLUMBIA</u>												
Kamloops	0.5	0.3	0.5	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kelowna City	2.1	1.7	1.9	2.2	NS	NS	NS	NS	NS	NS	NS	NS
Kelowna S.E. Dist.	0.2	0.7	0.8	0.7	NS	NS	NS	NS	NS	NS	NS	NS
Penticton	0.3	0.3	0.4	0.6	NS	NS	NS	NS	NS	NS	NS	NS
<u>NOVA SCOTIA</u>												
Halifax	0.3	0.3	0.1	0.3	0.3	0.5	0.5	0.4	0.9	0.3	<0.1	0.5
<u>ONTARIO</u>												
Bancroft	0.4	0.4	NS	0.1	1.9	0.6	0.7	<0.1	0.5	0.5	<0.1	0.9
Elliot Lake Treated	NS	0.8	1.3	2.1	0.9	2.1	<0.1	0.9	1.1	1.4	1.6	1.9
Elliot Lake Untreat.	2.4	0.7	0.9	2.7	1.5	1.4	0.8	1.4	0.8	3.2	3.1	1.8
Ottawa	<0.1	0.4	0.3	0.5	0.8	0.7	<0.1	0.5	1.2	0.3	0.5	0.3
Port Hope	1.0	1.3	2.5	2.6	0.4	1.1	1.9	1.4	2.3	1.9	1.1	2.0
<u>SASKATCHEWAN</u>												
Regina	9.5	7.8	5.6	6.8	8.3	12.1	12.3	12.7	7.5	7.1	9.3	8.9
Saskatoon	0.7	1.1	1.2	1.4	2.1	3.1	2.4	1.9	1.8	2.0	1.9	2.4
<u>YUKON</u>												
Whitehorse	1.8	1.8	1.9	2.1	1.2	1.0	0.5	0.3	0.5	1.2	0.5	0.8

NS - No Sample

Table 3. Gross Beta Activity in the Canadian Air Monitoring Network 1981

(Millibecquerels per cubic metre)

Sampling Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
Calgary	2.9	2.4	3.5	2.9	3.9	3.0	2.0	0.9	0.4	0.3	0.2	0.8	1.9
Churchill	3.1	3.3	4.9	5.4	5.1	0.8	1.0	1.0	0.5	0.4	0.6	1.0	2.3
Coral Harbour	2.3	2.4	3.0	4.4	2.7	1.4	1.2	0.4	0.3	0.2	0.4	0.3	1.6
Digby	0.0	1.7	3.0	5.1	5.5	2.0	1.2	0.0	0.0	0.3	0.2	0.4	2.2
Edmonton	3.8	3.7	5.8	5.0	5.4	3.3	2.7	1.2	0.7	0.6	0.5	0.8	2.8
Fredericton	2.1	2.8	5.2	5.9	6.5	3.2	2.3	1.0	0.7	0.6	0.3	0.5	2.6
Goose Bay	1.1	1.9	3.3	2.7	2.7	1.8	1.7	0.9	0.4	0.3	0.2	0.4	1.5
Greenwood	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.8	0.2	0.2	0.2	0.3	0.6
Halifax	2.4	2.6	3.8	6.0	4.8	2.7	1.7	1.1	0.6	0.5	0.2	0.3	2.2
Hay River	3.7	3.3	4.5	5.3	5.0	4.1	1.9	1.1	0.5	0.6	0.8	0.0	2.8
Inuvik	2.1	3.1	2.2	2.4	2.2	2.5	0.9	0.4	0.2	0.5	0.7	0.8	1.5
McMaster	3.7	3.1	5.7	9.8	8.0	5.4	4.4	2.1	0.9	0.7	0.7	0.8	3.8
Montreal	0.0	2.2	2.3	6.6	6.0	3.9	2.8	1.1	0.6	0.4	0.3	0.5	2.4
Moosonee	2.6	2.0	4.4	4.4	5.1	1.2	0.9	0.8	0.4	0.5	0.6	0.5	1.9
Ottawa	1.3	0.9	3.7	5.7	5.9	2.9	2.0	1.0	0.5	0.3	0.3	0.3	2.1
Quebec	1.2	1.6	4.3	4.4	5.4	4.0	2.3	0.9	0.5	0.4	0.3	0.5	2.1
Regina	2.6	2.4	3.2	1.7	3.3	2.4	1.7	1.1	0.5	0.6	0.5	1.1	1.7
Resolute	2.0	2.5	3.8	3.5	2.0	1.0	0.6	0.2	0.1	0.3	0.5	0.7	1.4
Saskatoon	2.8	2.0	3.8	2.5	3.1	2.3	2.6	1.0	0.5	0.6	0.6	1.0	1.9
Sault Ste. Marie	2.8	3.2	3.6	5.8	6.7	3.1	2.5	1.2	0.5	0.5	0.4	0.7	2.6
St. John's	1.5	1.0	1.9	3.3	3.1	0.7	1.4	0.7	0.3	0.2	0.3	0.1	1.2
Thunder Bay	1.9	2.2	4.2	5.4	5.1	2.9	3.0	1.5	0.6	0.8	0.9	1.0	2.5
Toronto	2.7	3.0	5.0	9.7	6.7	3.2	2.4	1.4	0.7	0.6	0.5	0.8	3.1
Vancouver	1.8	2.0	2.8	2.6	4.1	0.9	1.0	0.7	0.4	0.2	0.2	0.1	1.4
Whitehorse	1.4	3.1	2.4	3.3	3.3	2.2	1.0	0.7	0.3	0.3	0.5	0.7	1.6
Windsor	2.7	2.8	5.1	7.4	8.1	4.3	3.5	1.6	0.8	0.6	0.7	1.0	3.2
Winnipeg	3.4	2.6	4.4	3.6	6.5	5.2	3.1	1.4	0.7	0.9	1.3	0.9	2.8
Yellowknife	3.9	0.0	3.2	2.4	2.5	1.4	0.7	0.0	0.3	0.2	0.0	0.0	1.8
National Average	2.2	2.3	3.7	4.5	4.6	2.6	2.0	0.9	0.5	0.5	0.5	0.6	2.1

Table 4. Gross Beta Activity in the Canadian Precipitation Monitoring Network 1981 in Gigabecquerels per square kilometre

Station	Total No. of Samples	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Total Annual Deposition
Calgary	12	0.834E-01	0.912E-01	0.101E+00	0.332E-01	0.309E+00
Churchill	12	0.253E-01	0.639E-01	0.410E-01	0.351E-01	0.165E+00
Coral Harbour	12	0.222E-01	0.567E-01	0.496E-01	0.258E-01	0.154E+00
Digby	12	0.182E+00	0.196E+00	0.104E+00	0.766E-01	0.559E+00
Edmonton	12	0.404E-01	0.113E+00	0.107E+00	0.616E-01	0.322E+00
Fredericton	12	0.877E-01	0.244E+00	0.142E+00	0.567E-01	0.530E+00
Goose Bay	11	0.442E-01	0.188E+00	0.106E+00	0.474E-01	0.421E+00
Greenwood	10	0.912E-01	0.168E+00	0.471E-01	0.535E-01	0.432E+00
Halifax	12	0.174E+00	0.188E+00	0.949E-01	0.344E-01	0.491E+00
Hay River	11	0.286E-01	0.954E-01	0.994E-01	0.561E-01	0.305E+00
Inuvik	12	0.250E-01	0.700E-01	0.116E+00	0.414E-01	0.252E+00
Montreal	12	0.233E+00	0.307E+00	0.848E-01	0.274E-01	0.652E+00
Moosonee	12	0.649E-01	0.190E+00	0.155E+00	0.546E-01	0.464E+00
Ottawa**	12	0.133E+00	0.231E+00	0.102E+00	0.652E-01	0.531E+00
Quebec	12	0.200E+00	0.326E+00	0.113E+00	0.482E-01	0.687E+00
R.P.B.**	9	0.207E-01	0.139E+00	0.676E-01	0.544E-01	0.376E+00
Regina	10	0.393E-01	0.473E-01	0.148E+00	0.496E-01	0.341E+00
Resolute	11	0.276E-01	0.296E-01	0.628E-01	0.760E-01	0.214E+00
Saskatoon	12	0.388E-01	0.988E-01	0.611E-01	0.255E-01	0.224E+00
Sault Ste. Marie	12	0.282E+00	0.327E+00	0.957E-01	0.105E+00	0.810E+00
St. John's	9	0.168E+00	0.126E+00	0.897E-01	0.538E-01	0.583E+00
Thunder Bay	12	0.127E+00	0.309E+00	0.986E-01	0.521E-01	0.587E+00
Toronto	12	0.165E+00	0.158E+00	0.635E-01	0.950E-01	0.482E+00
Vancouver	12	0.216E+00	0.113E+00	0.818E-01	0.591E-01	0.470E+00
Whitehorse	11	0.272E-01	0.903E-01	0.115E+00	0.696E-01	0.330E+00
Windsor	12	0.111E+00	0.215E+00	0.179E-01	0.715E-01	0.415E+00
Winnipeg	12	0.396E-01	0.168E+00	0.456E-01	0.411E-01	0.294E+00
Yellowknife	9	0.242E-01	0.512E-01	0.[illegible]56E-01	0.579E-01	0.196E+00
National Average						0.400E+00

** Ottawa - Ottawa International Airport
R.P.B. - Radiation Protection Bureau

Table 5. Cesium-137 in the Canadian Milk Monitoring Network 1981

(Becquerels per litre)

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
Calgary, Alta.	0.06	0.05	0.15	0.23	0.05	0.05	0.05	0.07	0.14	<0.04	0.09	<0.04	0.08
Edmonton, Alta.	0.03	0.13	0.05	0.06	0.13	0.25	0.22	0.24	0.08	0.50	0.29	0.13	0.18
Moncton, N.B.	0.12	0.20	0.05	0.05	0.05	0.20	0.15	0.24	0.11	0.24	0.10	0.44	0.16
Halifax, N.S.	0.07	0.05	0.11	0.17	0.05	0.05	0.30	0.21	0.25	<0.04	0.15	0.10	0.13
Montreal, P.Q.	0.03	0.23	0.05	0.09	0.05	0.11	0.35	0.23	0.12	0.15	<0.04	0.08	0.12
Ottawa, Ont.	0.09	0.08	0.05	0.20	0.05	0.05	0.26	0.05	0.05	0.03	0.13	0.09	0.09
Quebec, P.Q.	0.23	0.22	0.05	0.16	0.20	0.10	0.09	0.18	0.29	<0.04	0.02	0.14	0.14
Regina, Sask.	0.09	0.13	0.17	0.08	0.05	0.14	0.05	0.05	0.08	0.17	0.04	<0.04	0.09
St. John's, Nfld.	0.22	0.17	0.16	0.16	0.08	0.25	0.37	0.42	0.33	0.20	0.02	0.06	0.20
Saskatoon, Sask.	0.09	0.05	0.14	0.05	0.05	0.11	0.09	0.05	0.05	0.27	<0.04	0.21	0.10
Sault Ste. Marie, Ont.	0.14	0.20	0.24	0.05	0.07	0.33	0.29	0.20	0.29	0.33	0.30	0.26	0.23
Thunder Bay, Ont.	0.11	0.25	0.12	0.27	0.05	0.24	0.32	0.17	0.07	0.05	NS	0.11	0.16
Toronto, Ont.	NS	NS	NS	NS	NS	NS	0.19	0.12	0.22	<0.04	<0.04	0.08	0.10
Truro, N.S.	0.14	0.23	0.17	0.15	0.05	0.14	0.13	0.05	0.16	0.08	0.22	0.08	0.13
Vancouver, B.C.	0.03	0.07	0.19	0.05	0.10	0.07	0.28	0.19	0.07	0.16	<0.04	<0.04	0.10
Windsor, Ont.	0.06	0.08	0.07	0.09	0.05	0.13	0.25	0.19	0.05	<0.04	0.17	0.25	0.12
Winnipeg, Man.	0.03	0.08	0.07	0.07	0.26	0.12	0.23	0.18	0.25	<0.04	<0.04	0.22	0.13
Whiteshell-A	0.04	0.25	0.12	0.07	0.14	0.11	0.10	0.11	0.17	0.12	0.06	0.14	0.12
Whiteshell-B	0.06	0.21	0.08	0.09	0.10	0.10	0.10	0.13	0.27	0.02	0.05	0.22	0.12
Bruce-A	0.09	0.17	0.08	0.08	0.16	0.18	0.15	0.08	0.11	0.06	0.24	0.14	0.13
Bruce-B	0.22	0.28	0.06	0.05	0.13	0.12	0.05	0.16	0.12	0.14	0.37	0.10	0.15
National Average	0.10	0.16	0.11	0.11	0.09	0.14	0.19	0.16	0.16	0.12	0.11	0.14	0.13

NS - No Sample

Table 6. Strontium-90 in the Canadian Milk Monitoring Network 1981

(Becquerels per litre)

Station	Jan. - March	April - June	July - Sept.	Oct. - Dec.	Annual Average
Calgary, Alta.	0.04	0.08	0.07	0.07	0.07
Edmonton, Alta.	0.07	0.08	0.21	0.09	0.11
Moncton, N.B.	0.06	0.10	0.10	0.07	0.08
Halifax, N.S.	0.05	0.12	0.09	0.05	0.08
Montreal, P.Q.	0.08	0.11	0.11	0.09	0.10
Ottawa, Ont.	0.08	0.06	0.12	0.15	0.10
Quebec, P.Q.	0.01	0.14	0.12	0.07	0.08
Regina, Sask.	0.08	0.07	0.11	0.03	0.07
St. John's, Nfld.	0.14	0.23	0.30	0.13	0.20
Saskatoon, Sask.	0.13	0.01	0.12	0.09	0.09
Sault Ste. Marie, Ont.	0.07	0.12	0.17	0.06	0.11
Thunder Bay, Ont.	0.12	0.15	0.22	0.04	0.13
Toronto, Ont.	NS	NS	0.04	0.01	0.03
Vancouver, B.C.	0.08	0.09	0.03	0.10	0.08
Windsor, Ont.	0.05	0.08	0.04	0.03	0.05
Winnipeg, Man.	0.07	0.11	0.05	0.09	0.08
National Average	0.08	0.10	0.12	0.07	0.09

NS - No Sample

Table 7. Tritium in Air Water Vapour Near Nuclear Generating Stations 1981

(Becquerels per cubic metre air)

Station		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
GENTILLY														
Location:	1 - 11.5 km NNE	0.49	0.12	<0.01	<0.01	<0.01	0.26	<0.01	<0.01	0.28	0.02	<0.01	0.02	0.10
	2 - 6.5 km NNE	0.07	NA	0.08	0.16	3.85	<0.01	0.06	<0.01	0.12	0.02	<0.01	0.02	0.40
	3 - 5 km NNW	0.12	0.03	0.22	0.05	2.77	<0.01	0.39	0.23	<0.01	<0.01	<0.01	<0.01	0.32
	4 - 7 km SW	<0.01	<0.01	<0.01	<0.01	<0.01	0.31	0.14	<0.01	<0.01	<0.01	0.04	<0.01	0.04
	5 - 6.5 km ENE	<0.01	0.12	0.17	0.06	0.56	<0.01	0.32	0.66	0.30	0.05	<0.01	<0.01	0.19
	6 - 12.5 km NE	0.16	0.87	0.37	0.41	0.55	<0.01	0.25	<0.01	<0.01	0.04	<0.01	<0.01	0.22
BRUCE														
Location:	1 - 3.5 km NE	5.47	4.90	5.71	2.76	4.52	2.52	0.86	6.65	NS	NS	NS	NS	4.17
	2 - 3.5 km ESE	0.69	1.88	NS	3.59	5.93	4.05	3.17	<0.01	5.97	1.89	0.09	2.05	2.66
	3 - 4 km S	0.53	0.34	2.40	3.29	2.22	2.32	0.05	2.93	3.31	1.86	1.02	0.60	1.74
	4 - 8 km SE	0.52	0.58	0.16	1.63	2.56	1.57	2.53	0.48	0.39	0.80	0.05	0.67	0.99
	5 - 8 km ESE	0.10	0.81	1.22	0.92	2.38	11.26	0.46	0.30	4.70	0.06	0.98	0.95	2.01
	6 - 40 km SE	0.04	NA	0.11	0.02	0.05	0.34	0.09	<0.01	0.26	0.26	0.11	<0.01	0.12
PICKERING														
Location:	1 - 1 km NNW	0.70	0.78	0.16	1.36	1.46	3.34	1.05	NS	NS	NS	NS	NS	1.26
	2 - 1.5 km NW	0.18	0.27	0.51	0.97	1.57	<0.01	0.70	1.64	1.48	0.14	0.54	0.18	0.68
	3 - 2 km NNW	0.04	0.38	1.22	0.66	0.52	0.10	1.21	1.46	0.64	0.35	0.34	1.39	0.69
	4 - 1.5 km NE	0.91	0.11	3.08	10.83	1.31	NS	3.04	1.86	0.47	1.38	1.46	1.62	2.37
	5 - 1 km E	9.20	1.08	6.53	0.25	1.64	8.04	<0.01	0.81	10.48	7.63	11.80	5.87	5.28
	6 - 13 km NW	0.06	0.09	NS	0.02	0.41	0.10	<0.01	0.22	0.22	0.07	0.04	0.02	0.11
	7 - 33 km SW	0.08	NA	0.09	0.03	NS	0.07	<0.01	0.48	0.10	0.03	0.02	<0.01	0.09

NA - Not Analysed

NS - No Sample

Table 8. Cesium-137 in Water Supplies from Nuclear Reactor Environs (Bq/L)

(Detection Limit is 0.001 Bq/L)

Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Average
Winnipeg River					
1) Pinawa	ND	ND	0.154E-02	ND	ND
2) Lac Du Bonnet	ND	ND	ND	0.107E-02	ND
3) Great Falls	0.160E-01	0.164E-01	0.761E-02	0.118E-01	0.130E-01
Lake Huron					
1) Port Elgin	ND	ND	ND	0.313E-02	0.125E-02
2) Kincardine	ND	0.157E-02	0.110E-02	0.266E-02	0.157E-02
Lake Ontario					
1) Toronto	ND	ND	0.199E-02	0.184E-02	0.121E-02
2) Ajax	0.104E-02	ND	ND	0.221E-02	0.137E-02
Ottawa River					
1) Rolphton	0.256E-02	0.464E-02	0.336E-02	0.528E-02	0.396E-02
2) Deep River	0.320E-02	0.557E-02	0.161E-02	0.308E-02	0.337E-02
3) Petawawa	0.192E-02	0.631E-02	0.127E-02	0.521E-02	0.368E-02
4) Pembroke	0.715E-02	0.291E-02	0.350E-02	0.123E-02	0.370E-02
5) Ottawa	0.633E-02	0.593E-02	ND	0.138E-02	0.345E-02
St. Lawrence River					
1) Becancour	ND	ND	ND	0.516E-02	0.211E-02
2) Grondines	ND	ND	0.123E-02	0.203E-02	ND
3) St. Romuald	0.133E-02	ND	0.150E-02	0.161E-02	0.112E-02

Table 9. Strontium-90 in Water Supplies from Nuclear Reactor Environs (Bq/L)

(Detection Limit is 0.001 Bq/L)

Station	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Average
Winnipeg River					
1) Pinawa	0.251E-01	0.211E-01	NA	0.124E-01	0.195E-01
2) Lac Du Bonnet	0.269E-01	0.267E-01	NA	0.180E-01	0.239E-01
3) Great Falls	0.451E-01	0.356E-01	NA	0.441E-01	0.416E-01
Lake Huron					
1) Port Elgin	0.181E-01	0.144E-01	NA	0.182E-01	0.169E-01
2) Kincardine	0.127E-01	0.134E-01	NA	0.967E-02	0.119E-01
Lake Ontario					
1) Toronto	0.276E-01	0.193E-01	NA	0.141E-01	0.203E-01
2) Ajax	0.178E-01	0.141E-01	NA	0.119E-01	0.146E-01
Ottawa River					
1) Rolphton	0.186E-01	0.198E-01	NA	0.188E-01	0.191E-01
2) Deep River	0.145E-01	0.131E-01	NA	0.155E-01	0.144E-01
3) Petawawa	0.682E-02	0.152E-01	NA	0.162E-01	0.127E-01
4) Pembroke	0.165E-01	0.156E-01	NA	0.138E-01	0.153E-01
5) Ottawa	0.163E-01	0.125E-01	NA	0.152E-01	0.147E-01
St. Lawrence River					
1) Becancour	0.235E-01	0.110E-01	NA	0.294E-01	0.213E-01
2) Grondines	0.365E-02	0.116E-01	NA	0.260E-02	0.595E-02
3) St. Romuald	0.179E-01	NA	NA	0.519E-02	0.785E-02

NA - Lost in analysis

Table 10. Transport of Tritium in the Ottawa River

	Down Stream Distance (Km)	Transit Time (Days)	Maximum Concentration (Bq/L)	Dilution Factor
Deep River	16	5	330	5.8×10^5
Petawawa	40	15	190	9.9×10^5
Pembroke	60	19	160	1.2×10^6
Ottawa	200	40	57	3.3×10^6

Table 11. External Radiation Dose Measurements at Environmental Stations

Station	Dose Rate (μGy/h)			Cumulative Dose (mGy)
	Jan. - March	April - June	July - Dec.	Jan. - Dec.
Calgary, Alta.	0.12 ± 0.03	0.11 ± 0.03	0.13 ± 0.04	1.07 ± 0.15
Churchill, Man.	0.10 ± 0.03	0.12 ± 0.04	0.10 ± 0.03	0.92 ± 0.14
Fredericton, N.B.	0.10 ± 0.03	0.11 ± 0.03	0.10 ± 0.02	0.90 ± 0.10
Halifax, N.S.	0.15 ± 0.04	0.16 ± 0.04	0.13 ± 0.04	1.25 ± 0.18
Inuvik, N.W.T.	0.11 ± 0.04	NS	0.09 ± 0.03	0.85 ± 0.14
Ottawa, Ont.	0.10 ± 0.03	0.09 ± 0.02	0.11 ± 0.03	0.90 ± 0.12
Saskatoon, Sask.	0.20 ± 0.04	0.15 ± 0.04	NS	1.55 ± 0.18
St. John's Nfld.	0.17 ± 0.04	0.17 ± 0.03	0.15 ± 0.03	1.40 ± 0.14
Thunder Bay, Ont.	0.11 ± 0.02	0.12 ± 0.04	NS	1.01 ± 0.13
Toronto, Ont.	0.13 ± 0.03	0.10 ± 0.02	0.10 ± 0.03	0.96 ± 0.12
Vancouver, B.C.	0.10 ± 0.03	0.10 ± 0.03	0.09 ± 0.03	0.83 ± 0.13
Windsor, Ont.	0.10 ± 0.03	0.09 ± 0.03	0.05 ± 0.02	0.64 ± 0.11
Yellowknife, N.W.T.	0.16 ± 0.03	0.16 ± 0.03	0.13 ± 0.04	1.27 ± 0.15

NS - No Sample

Table 12. External Radiation Dose Measurements in the Vicinity of Nuclear Reactors

	Dose Rate (µGy/h)									Cumulative Dose (mGy)		
Station	BNPD			PNGS			GNS			Jan. - Dec.		
	Jan. March	April June	July Dec.	Jan. March	April June	July Dec.	Jan. March	April June	July Dec.	BNPD	PNGS	GNS
1	0.16 ± 0.04	0.10 ± 0.03	----	----	----	----	0.11 ± 0.03	0.11 ± 0.03	0.11 ± 0.03	1.14 ± 0.15	----	0.96 ± 0.13
2	0.17 ± 0.05	0.12 ± 0.03	0.10 ± 0.02	NS	0.11 ± 0.03	0.11 ± 0.03	----	----	----	1.07 ± 0.14	0.96 ± 0.13	----
3	0.13 ± 0.04	0.14 ± 0.04	0.10 ± 0.03	0.12 ± 0.04	0.11 ± 0.03	0.11 ± 0.03	----	----	----	1.03 ± 0.14	0.99 ± 0.14	----
4	0.10 ± 0.03	0.09 ± 0.02	0.08 ± 0.02	0.11 ± 0.03	0.12 ± 0.03	----	0.10 ± 0.02	0.11 ± 0.02	0.11 ± 0.03	0.77 ± 0.10	1.01 ± 0.13	0.94 ± 0.11
5	0.14 ± 0.04	0.12 ± 0.03	0.11 ± 0.03	0.13 ± 0.04	0.11 ± 0.03	0.11 ± 0.03	----	----	----	1.05 ± 0.14	1.02 ± 0.14	----
6	0.17 ± 0.05	0.15 ± 0.04	0.14 ± 0.03	0.11 ± 0.02	0.10 ± 0.02	0.09 ± 0.02	----	----	----	1.34 ± 0.18	0.88 ± 0.09	----
7	----	----	----	0.13 ± 0.03	0.10 ± 0.02	0.10 ± 0.03	----	----	----	----	0.96 ± 0.12	----

---- Sites Not Applicable

NS No Sample

Table 13. Summary of Doses and Implied Risks Determined through the Environmental Radioactivity Monitoring Program during 1981

Exposure Mode	Dose Range (μSv)	Location of Maximum	Implied Risk
External Gamma Radiation	600 - 1000		10^{-5}
Natural Radioactivity in Drinking Water (^{226}Ra, U)	1 - 10	Elliot Lake, Regina	10^{-7}
Fission Products in Drinking Water (^{90}Sr, ^{137}Cs)	0.2 - 1	Winnipeg River	10^{-8}
Fission Products in Milk (^{90}Sr, ^{137}Cs)	0.2 - 2	St. John's	10^{-8}
Tritium in Atmospheric Water Vapour	0.01 - 0.7	Bruce; Pickering	10^{-8}

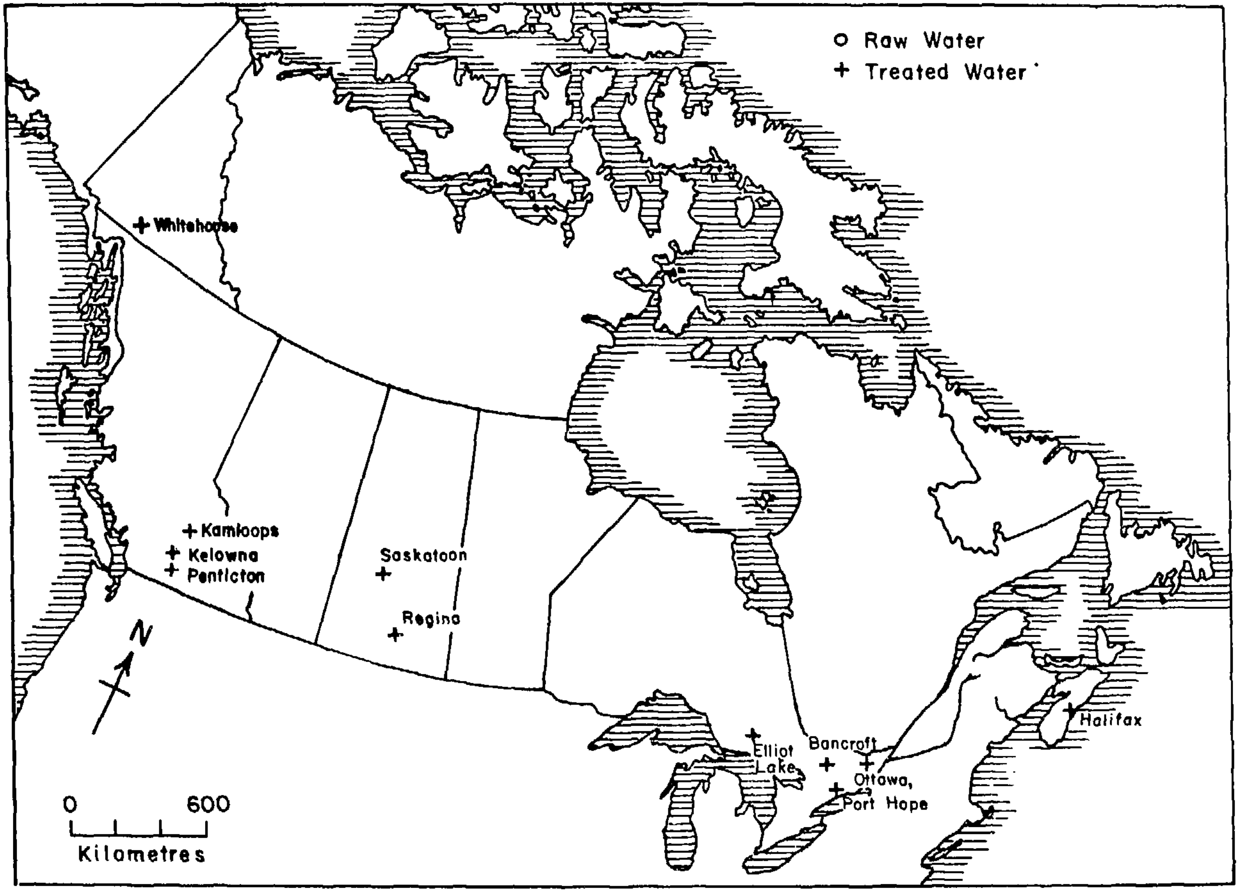


Figure 1. Canadian Sampling Station Network - Drinking Water

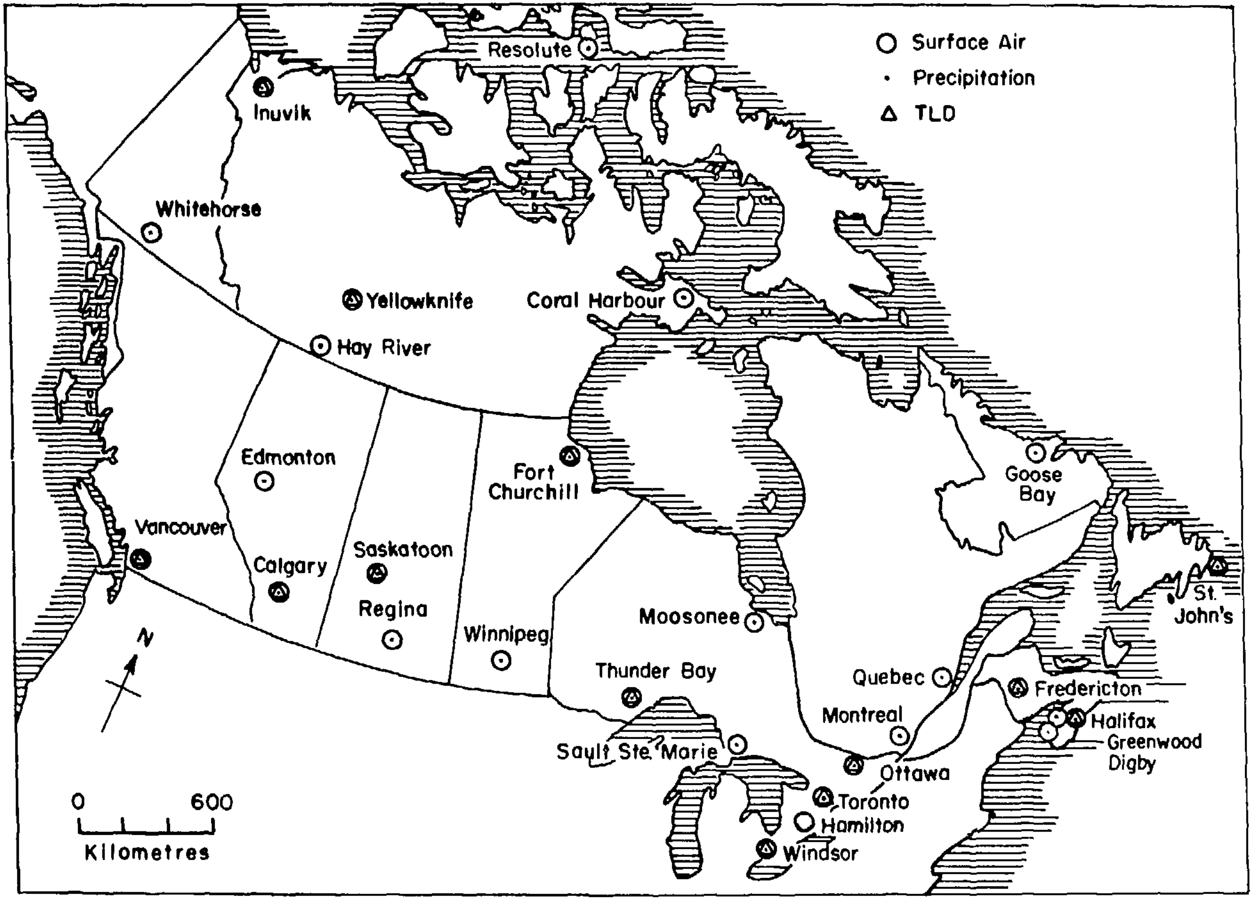


Figure 2. Canadian Sampling Station Network - Air, Precipitation and TLD

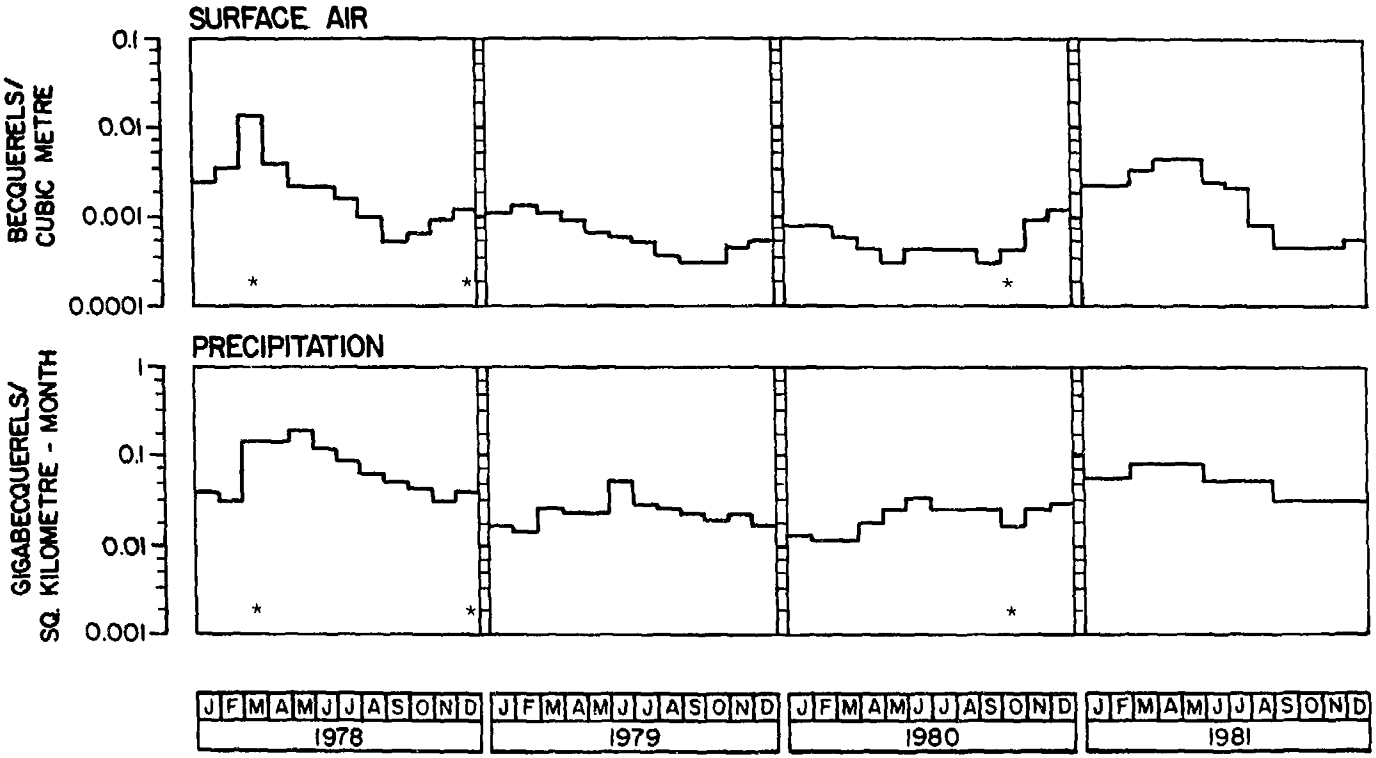


Figure 3. Gross Beta Radioactivity, National Averages, 1978-1981

* Atmospheric nuclear weapons tests conducted by the Peoples Republic of China at Lop Nor

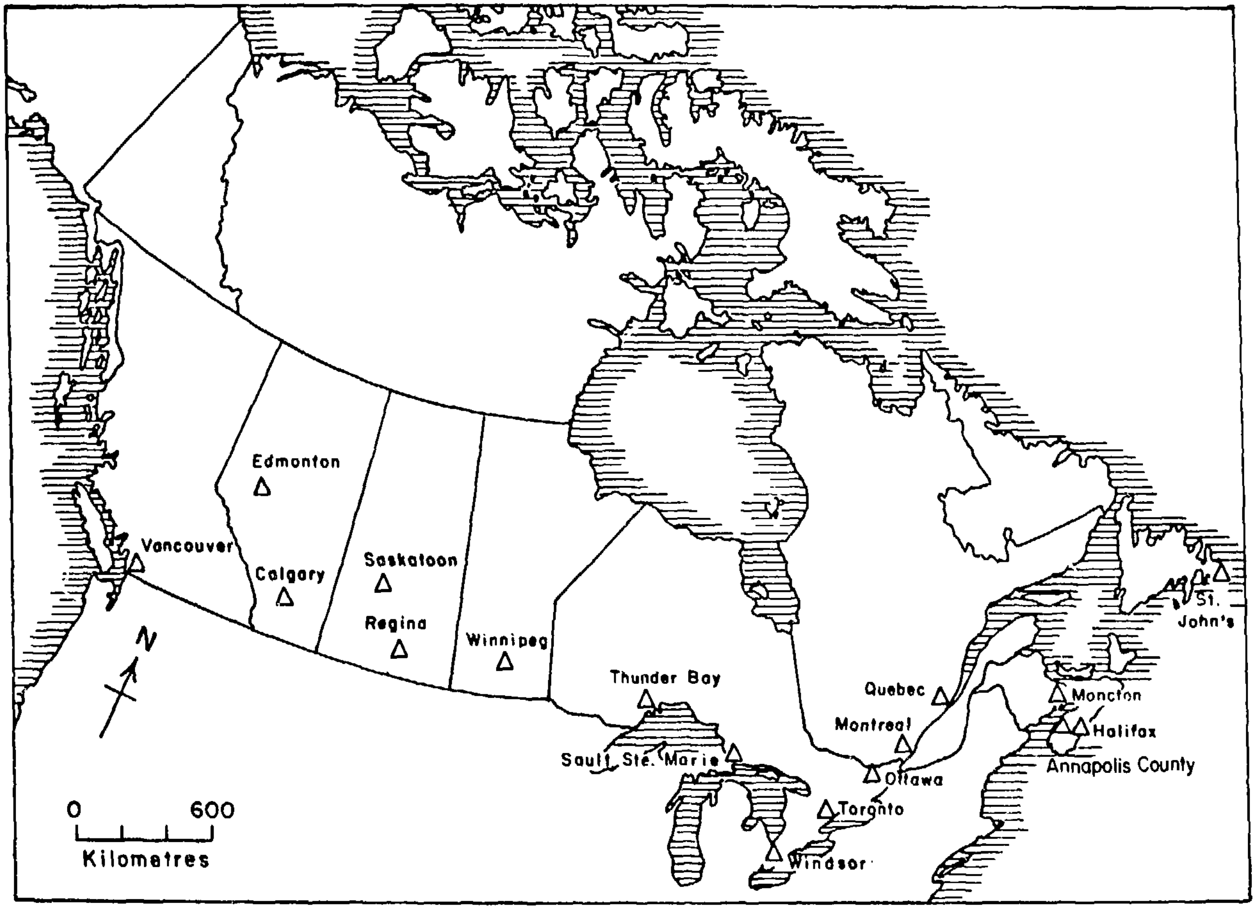


Figure 4. Canadian Sampling Station Network - Milk

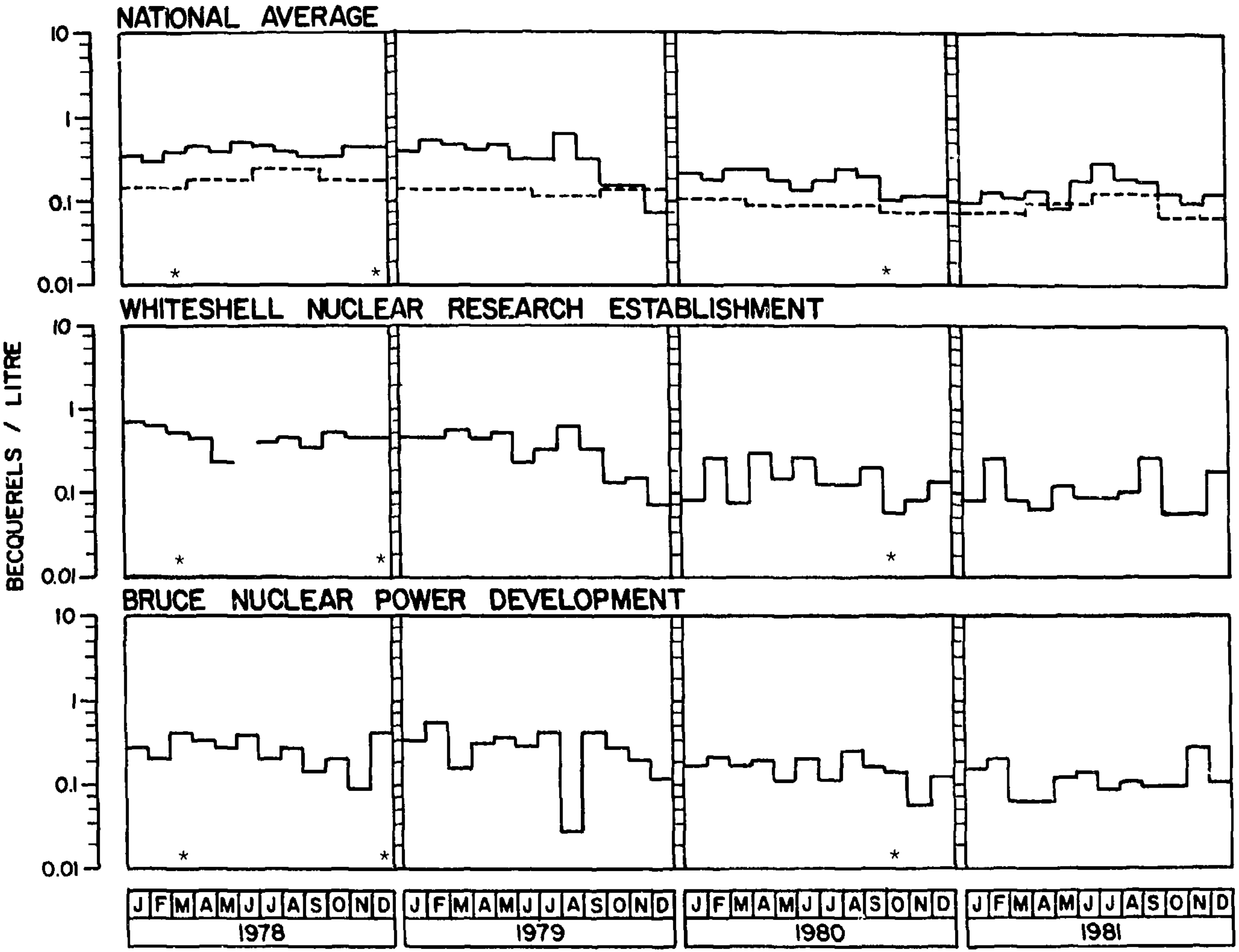


Figure 5. Radionuclide Levels in Milk, 1978-1981
Cesium-137 ----- Strontium-90

* Atmospheric Nuclear Weapons Test Conducted by the Peoples Republic of China at Lop Nor

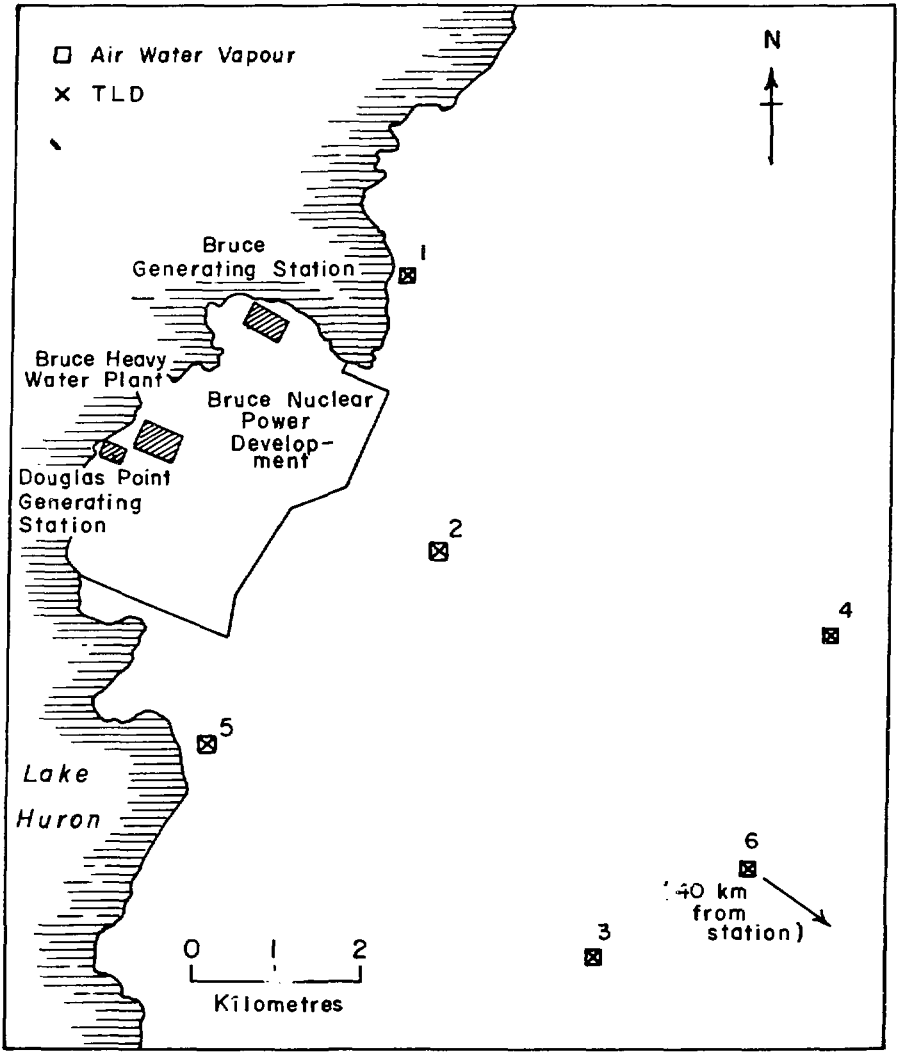


Figure 6. Sampling Stations in the Vicinity of the Bruce Nuclear Power Development

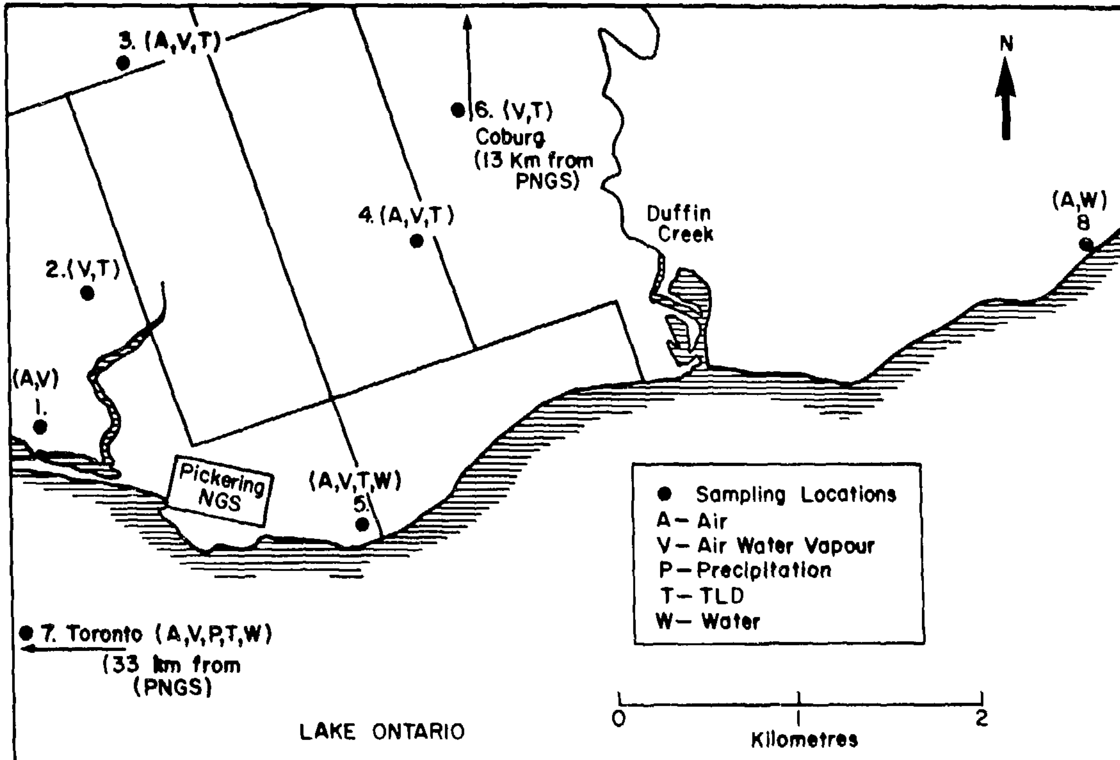
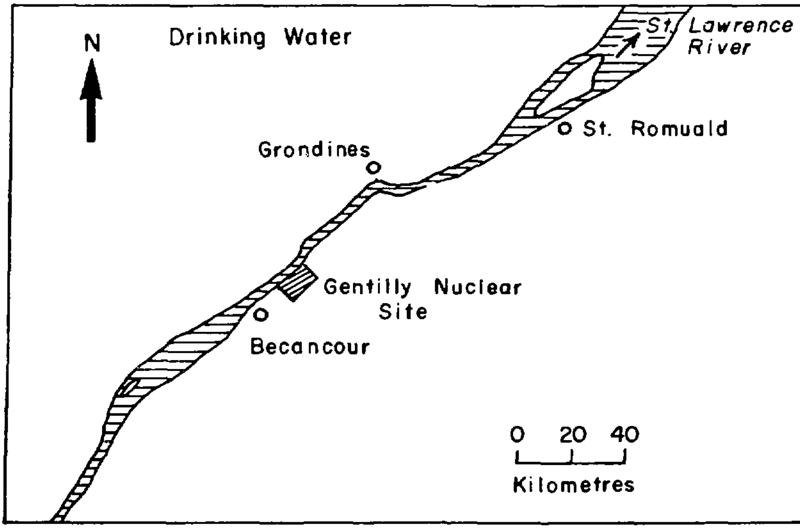


Figure 7. Sampling Stations in the Vicinity of the Pickering Nuclear Generating Station



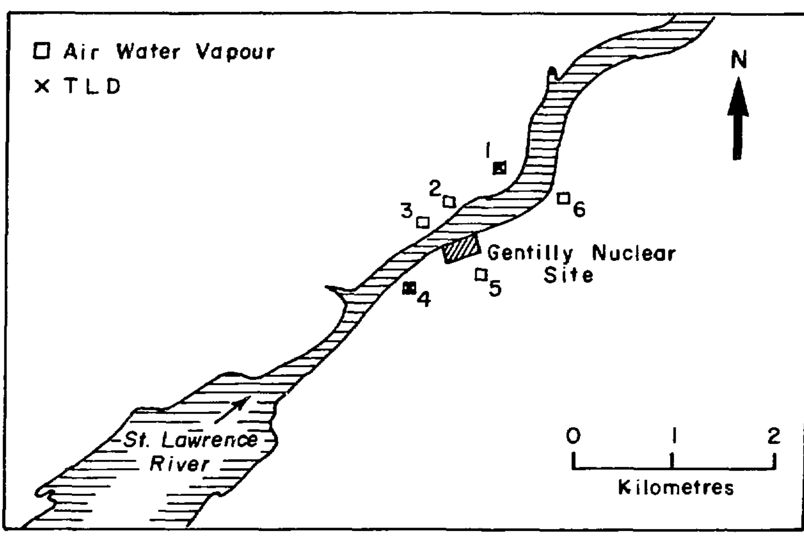


Figure 8. Sampling Stations in the Vicinity of the Gentilly Nuclear Site

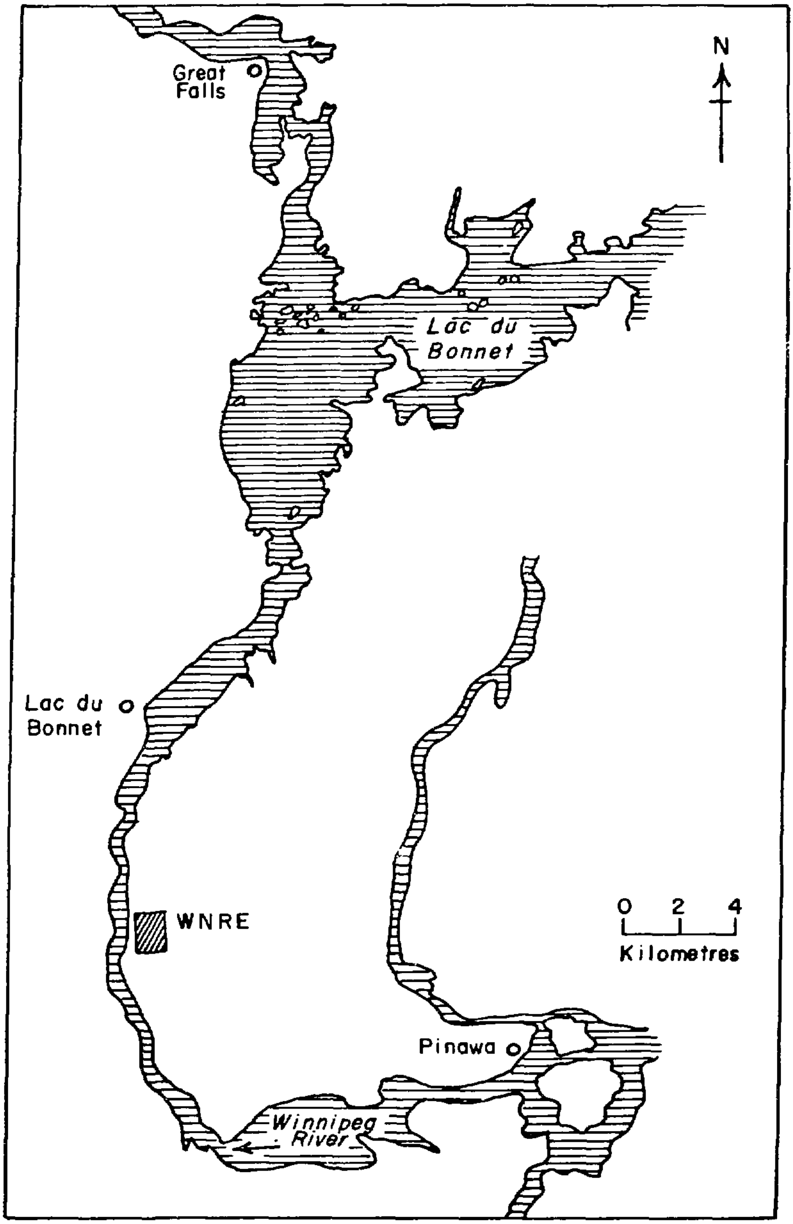


Figure 9. Sampling Locations on the Winnipeg River - Drinking Water

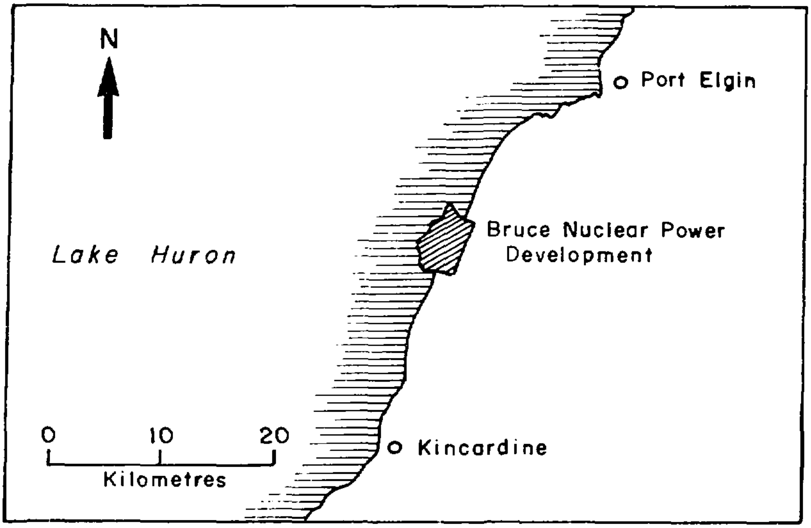


Figure 10. Sampling Locations on Lake Huron - Drinking Water

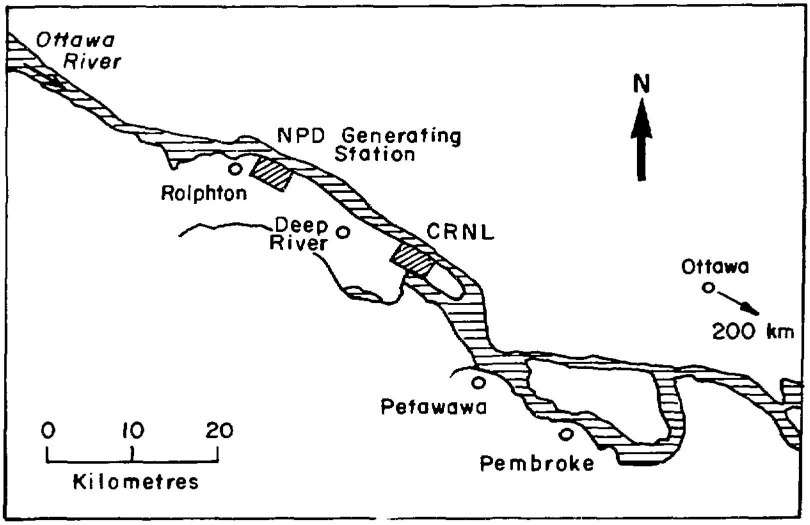


Figure 11. Sampling Locations on the Ottawa River - Drinking Water

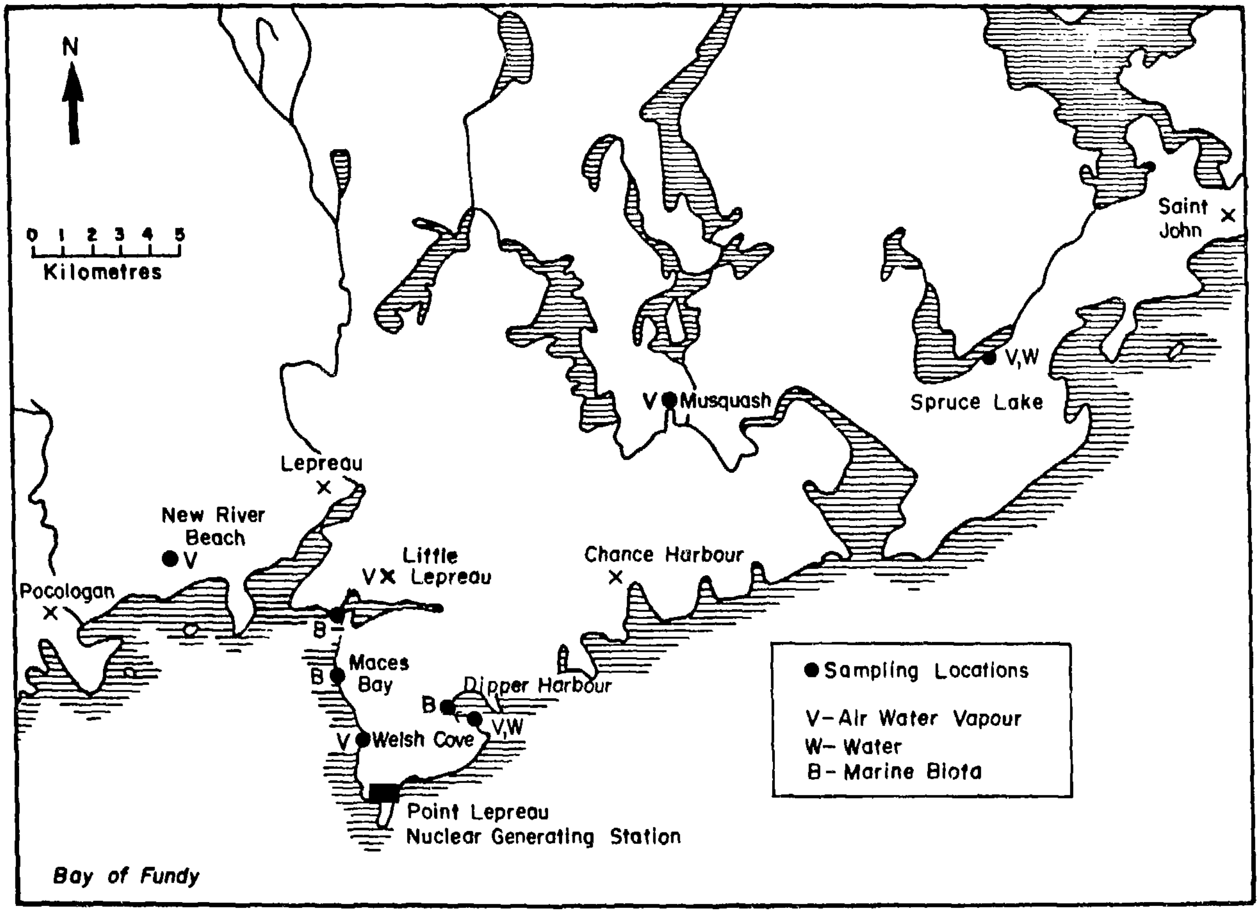


Figure 12. Sampling Locations in the Vicinity of the Point Lepreau Nuclear Generating Station

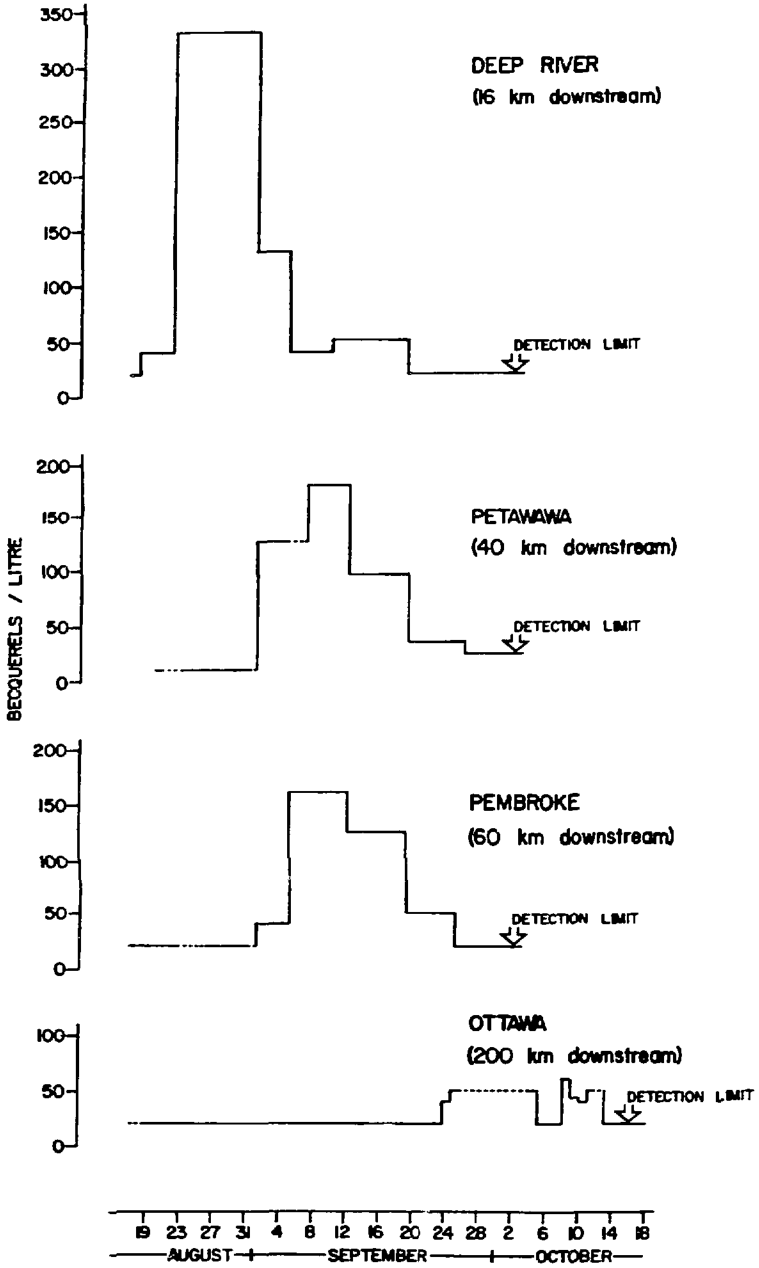


Figure 13. Tritium Concentrations at Sampling Stations on the Ottawa River, August-October, 1981

(Detection Limit is 20 Bq/L)

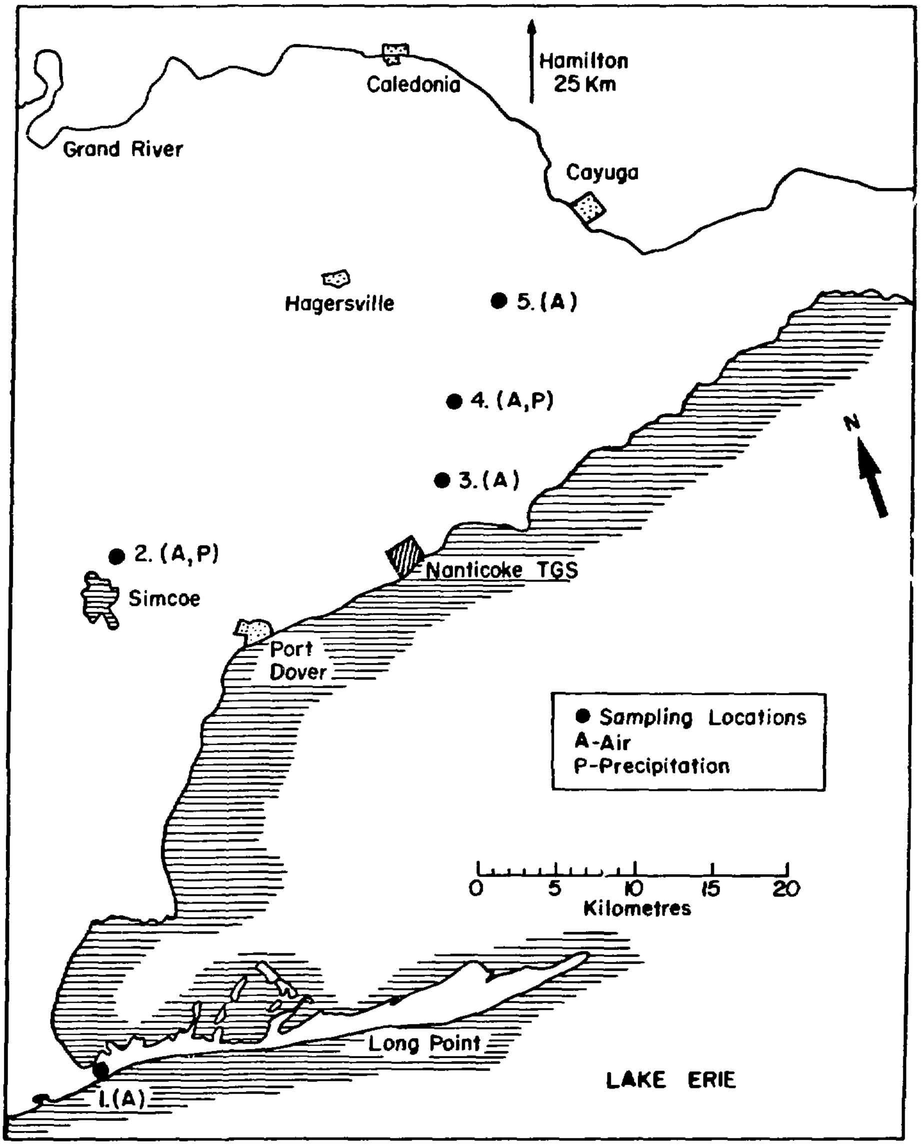


Figure 14. Sampling Stations in the Vicinity of the Nanticoke Thermal Generating Station

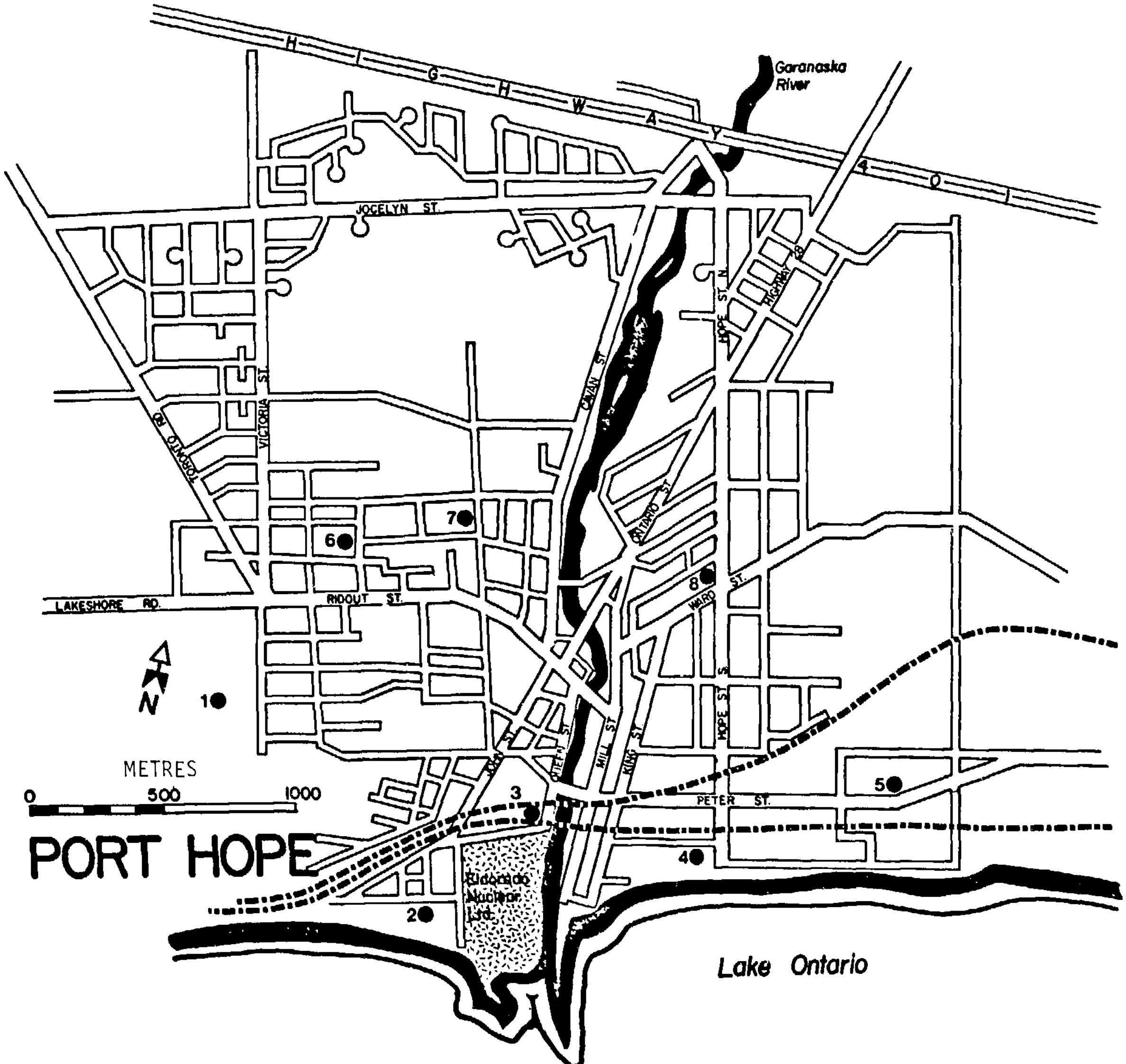


Figure 15. Sampling Stations in the Vicinity of the Eldorado Nuclear Limited Refinery in Port Hope, Ontario