



AECL-MISC-362-97 (Vol. 3)

AUD6212-07-00

**1997 Annual Report of Radiological Monitoring Results
for the Chalk River and Whiteshell Laboratories Sites**

Volume 3 - Environmental Monitoring

R.D. Graham, N. Soonawala, T.A. Niemi



1997 ANNUAL REPORT OF RADIOLOGICAL MONITORING RESULTS FOR THE CHALK RIVER AND WHITESHELL LABORATORIES SITES

VOLUME 3 - ENVIRONMENTAL MONITORING

Prepared by  FOR 98 Apr. 28
N. Soonawala, Site Environmental Officer, WL Date

Prepared by  98 Apr 29
T.A. Niemi, Site Environmental Officer, CRL Date

Prepared & reviewed by  98/04/29
R.D. Graham, Environmental Protection Program Manager Date

Approved by  98 May 4
R.P.J. Lambert, Environmental Protection Program Authority Date

**1997 ANNUAL REPORT OF RADIOLOGICAL MONITORING RESULTS
FOR THE CHALK RIVER AND WHITESHELL LABORATORIES SITES**

VOLUME 3 -- ENVIRONMENTAL MONITORING

Complied and Edited

by

R.D. Graham, T.A. Niemi, Site Environmental Officer, CRL

and

N. Soonawala, Site Environmental Officer, WL

1998 April

**1997 ANNUAL REPORT OF RADIOLOGICAL MONITORING RESULTS
FOR THE CHALK RIVER AND WHITESHELL LABORATORIES SITES**

VOLUME 3 – ENVIRONMENTAL MONITORING

Compiled and Edited

by

R.D. Graham, T.A. Niemi, Site Environmental Officer, CRL

and

N. Soonawala, Site environmental Officer, WL

ABSTRACT

This volume of the annual report summarizes
ENVIRONMENTAL MONITORING
at the Chalk River and Whiteshell Laboratories
for the calendar year 1997.

NOTE: Separate volumes of this report summarize the
PERSONNEL RADIATION DOSIMETRY (Volume 1) and
EFFLUENT MONITORING (Volume 2)
for the same period.

TABLE OF CONTENTS

	<u>Page</u>
SUMMARY	i
1. INTRODUCTION	1
1.1 Purpose and Scope	1
1.2 Site Environmental Monitoring Programs	1
1.3 CRL and WL Facilities, Operations and Radioactive Emissions	2
2. CRL ENVIRONMENTAL MONITORING PROGRAM AND RESULTS FOR 1997	3
2.1 CRL Site Location	3
2.2 CRL Environmental Monitoring Program	4
2.3 Ambient Gamma Radiation in Air	4
2.3.1 Monitoring with Thermoluminescent Dosimeters	4
2.3.2 Ambient Radiation Measurements with Gamma Tracer System	6
2.4 Ambient Tritium in Air	7
2.5 Atmospheric Deposition of Radioactive Material	8
2.6 Land Gamma Radiation	9
2.7 Radioactivity in Milk	11
2.8 Radioactivity in Vegetation	11
2.9 Radioactivity in Surface Waters Within the CRL Site	13
2.10 Radioactivity in Surface Waters Off the CRL Site	14
2.11 Radioactivity in Ottawa River	16
2.11.1 Water	16
2.11.2 Fish	18
2.11.3 Beach Sediment	18
2.12 Meteorological Conditions	21
2.12.1 Atmospheric Dispersion Coefficients	22
3. WL ENVIRONMENTAL MONITORING PROGRAM AND RESULTS FOR 1997	24
3.1 WL Site Location	24
3.2 WL Environmental Monitoring Program	24
3.3 Ambient Gamma Radiation in Air	24
3.4 Land Gamma Radiation	26
3.5 Atmospheric Deposition of Radioactive Material	26
3.6 Radioactivity in Surface Waters Within the WL Site	27
3.7 Radioactivity in Winnipeg River	28
3.7.1 Water	28
3.7.2 Fish	31
3.7.3 River Sediment	32
3.8 Radioactivity in Vegetation	34
4. ASSESSMENT OF DOSES TO THE PUBLIC	35
4.1 General	35
4.2 CRL Air Effluent Pathways	35
4.3 CRL Liquid Effluent Pathways	38
4.4 WL Air Effluent Pathways	39
4.5 WL Liquid Effluent Exposure Pathways	40

5. QUALITY ASSURANCE.....42

5.1 CRL QA Intercomparisons.....42

5.2 WL QA Intercomparisons43

6. ACKNOWLEDGMENTS.....45

7. REFERENCES46

TABLES

Table 1: CRL Air Emissions - Average Releases in 1997 and Dominant DRL Pathways.....2

Table 2: CRL Liquid Effluents - Average Releases in 1997 and Dominant DRL Pathways3

Table 3: WL Air Effluents - Average Releases in 1997 and Dominant DRL Pathways3

Table 4: WL Liquid Effluents - Average Releases in 1997 and Dominant DRL Pathways.....3

Table 5: CRL Ambient Gamma Radiation Dose In Air -- TLD Monitoring -19975

Table 6: CRL Ambient Radiation Dose in Air -- Gamma Tracer Measurements - 19977

Table 7: CRL Ambient Tritium in Air -- Average Quarterly and Annual Concentrations in 19978

Table 8: Atmospheric Deposition of Gross Beta and Gross Alpha Activities
at CRL Boundary -- 1997.....9

Table 9: Mean Land Gamma Radiation on Roads - 1997
CRL Site Areas and Highway 17 10

Table 10: CRL - Monitoring of Radioactivity in Milk - 1997

Table 11: CRL Radionuclides in Vegetation - 1997..... 12

Table 12: Mean Concentration of Radionuclides in Surface Waters Associated with CRL Waste
Management Areas - 1997 13

Table 13: Gross Beta and Tritium in Various On-Site Surface Waters at CRL -
Mean Annual Concentrations - 1997 14

Table 14: Annual Tritium and Gross Beta Concentrations in Off-Site Surface Waters - 1997..... 14

Table 15: Radioactivity in Ottawa River Water -- Annual Mean Concentration -1997 16

Table 16: Radioactivity in Ottawa River Fish - 1997 19

Table 17: Radionuclide Concentrations in Ottawa River Beach Sediments - 1997.....20

Table 18: CRL Wind Direction -- Frequency Distribution in 1997.....21

Table 19: CRL Wind Speed Class - Frequency of Occurrence in 1997.....21

Table 20: CRL Stability Class -- Frequency And Mean Wind Speed in 1997.....22

Table 21: CRL Atmospheric Dispersion Coefficients Based on Ambient Gamma Dose-In-Air Data ...23

Table 22: CRL Atmospheric Dispersion Coefficients Based on Ambient Tritium-In-Air Data23

Table 23: Gamma Radiation in Air at WL Perimeter Total Gamma Dose25

Table 24: Gamma Radiation in Air at WL Controlled Area 2 Fence25

Table 25: Land Gamma Radiation Near WL -- Mean Gamma Dose Rate in Air26

Table 26: Atmospheric Deposition of Radioactivity in Precipitation at Pinawa --
Total Annual Deposition26

Table 27: Annual Mean Gross Beta and Gross Alpha Radioactivity -- in WL Drainage
Ditch Water, 199727

Table 28: Radioactivity in Winnipeg River Water -- Mean Concentration29

Table 29: Winnipeg River Mean Daily Flow Rate -- At Seven Sisters Generating Station29

Table 30: Radioactivity in Flesh of Winnipeg River Fish - 1997 31

Table 31: Average Radioactivity in Winnipeg River Fish -- Summary 1992-199733

Table 32: Radioactivity In Sediment Samples From The Winnipeg River.....34

Table 33: Radioactivity in WL Vegetation - 1997.....34

Table 34 : Typical Annual Average Background Radiation Dose In Canada35

Table 35: CRL -1997 Critical Group Dose at Balmer Bay From Noble Gas Emissions36

Table 36: CRL -1997 Dose to Critical Group at Balmer Bay From Inhalation of Tritium.....36

Table 37: CRL - 1997 Dose To Critical Group At Balmer Bay From Vegetable Ingestion37

Table 38:	CRL - 1997 Dose To Critical Group At Balmer Bay From Milk Ingestion.....	37
Table 39:	CRL - 1997 Total Estimated Dose to Critical Group At Balmer Bay From Air Effluent Exposure Pathways	37
Table 40:	CRL - 1997 Dose To Critical Group At Petawawa/Pembroke From Drinking Water	38
Table 41:	CRL - 1997 Dose To Critical Group At Petawawa/Pembroke From Fish Ingestion.....	38
Table 42:	CRL - 1997 Dose To Critical Group At Petawawa/Pembroke From Beach Exposure	39
Table 43:	CRL - 1997 Total Estimated Dose to Critical Group At Petawawa From Liquid Effluent Exposure Pathways.....	39
Table 44:	WL - 1997 Dose To Critical Group At Downstream Boundary From Drinking Water	40
Table 45:	WL - 1997 Dose To Critical Group At Downstream Boundary From Fish Ingestion	41
Table 46:	WL - 1997 Dose To Critical Group At Downstream Boundary From Beach Sediment Exposure	41
Table 47:	WL - 1997 Total Estimated Dose to Critical Group At Downstream Boundary From Liquid Effluent Pathways.....	41
Table 48:	1997 CRL QA-COG Inter-Laboratory Comparison of Gamma Emitters in Potatoes	42
Table 49:	1997 CRL QA-COG inter-Laboratory Comparison of C-14 and I-131 in Milk.....	42
Table 50:	WL Quality Assurance Program - EPA Intercomparison Results.....	44
Table 51:	WL Quality Assurance Program - IRC Intercomparison Results	45

FIGURES

Chalk River Laboratories

Figure 1	Ambient Gamma Dose in Air –1997.....	6
Figure 2	Ambient Gamma Dose in Air – Gamma Tracer Measurement – Balmer Bay 1997.....	7
Figure 3	Ambient Tritium in Air – Annual Average Concentration – 19979	8
Figure 4	Gross Beta Atmospheric Deposition – Monthly Average of 4 Monitoring Stations at CRL Boundary	9
Figure 5	Land Gamma Radiation on Roads	10
Figure 6	Gross Beta in Off-Site Surface Waters – Average of Annual Samples at 20 Locations	15
Figure 7	Tritium in Off-Site Surface Waters – Average of Annual Samples at 20 Locations	15
Figure 8	Tritium in Ottawa River Water	17
Figure 9	Strontium-90 in Ottawa River Water.....	17
Figure 10	Caesium-137 in Ottawa River Water.....	17

Whiteshell Laboratories

Figure 11	Ambient Gamma Radiation Dose in Air.....	25
Figure 12	Total Annual Deposition of Radioactivity in Precipitation at Pinawa.....	27
Figure 13	Gross Beta Activity in Surface Waters from Streams near the Waste Management Area ..	28
Figure 14	Gross Alpha Activity in Surface Streams from Streams near the Waste Management Area	28
Figure 15	Caesium-137 in Winnipeg River Water.....	30
Figure 16	Strontium-90 in Winnipeg River Water.....	30
Figure 17	Gross Beta Activity in Winnipeg River Water	30

APPENDICES

APPENDIX 1 CHALK RIVER LABORATORIES MAPS

MAP 1	CRL Environmental Monitoring Locations (Outside CRL Boundary).....	47
MAP 2	CRL Environmental Monitoring Locations (CRL Site and Immediate Surroundings)	48

APPENDIX 2 WHITESHELL LABORATORIES MAPS

MAP 3	Whiteshell Laboratories and Surrounding Area	49
MAP 4	Whiteshell Laboratories Site	50

APPENDIX 3 CHALK RIVER LABORATORIES WINDROSE DIAGRAMS

Diagram 1	CRL Windrose – Perch Lake 60 m, 1997	51
Diagram 2	CRL Windrose – Perch Lake 30 m, 1997.....	51
Diagram 3	CRL Windrose – Building 456, 1997	52

APPENDIX 4 WHITESHELL LABORATORIES WINDROSE DIAGRAMS

Diagram 1	WL Windrose – 61 m, 1997	53
Diagram 3	WL Windrose – 6 m, 1997	53

1997 ANNUAL REPORT OF RADIOLOGICAL MONITORING RESULTS FOR THE CHALK RIVER AND WHITESHELL LABORATORIES SITES

VOLUME 3 – ENVIRONMENTAL MONITORING

SUMMARY

This report, issued annually, summarizes and assesses the results of the comprehensive Site Radiological Environmental Monitoring Programs maintained by AECL in and around the Chalk River Laboratories (CRL) and Whiteshell Laboratories (WL) sites.

The programs monitor numerous environmental media at various locations at both sites representing potential pathways for radiation exposure to members of the public, as well as media and sample locations serving as indicators of possible trends. Monitored environmental media include ambient air, precipitation, surface waters including both the Ottawa River and Winnipeg River, milk, vegetables, fish, and river or beach sediments. The programs at the two sites differ somewhat due to differences in the types of facilities, actual emissions, and site histories.

Monitoring results for the calendar year 1997 verified that levels of radiation and radioactive contaminants in the environment outside the CRL and WL site boundaries due to operations at the sites, as well as the resulting radiation doses to members of the public were well below regulatory limits¹ and other applicable guidelines. The 1997 results were generally comparable with the results for 1996.

At CRL, monitoring of potential atmospheric effluent exposure pathways indicated measurable or potential contributions from CRL at off-site locations to ambient gamma radiation dose in air, ambient tritium in air, vegetables and milk. A new monitoring system for measuring ambient dose in air, intended to provide more accurate measurement of, and differentiation between, background radiation and the dose contribution from CRL was installed in late 1996 and operated successfully throughout 1997. Monitoring verified that the CRL contribution to ambient radiation dose in air, due to emissions of noble gases (primarily Argon-41), remained by far the dominant contributor to off-site dose (both airborne and liquid), and the results were generally consistent with effluent monitoring results.

Also at CRL, environmental monitoring of potential liquid effluent exposure pathways during 1997 indicated small but measurable concentrations of radionuclides in excess of background attributable to CRL operations in Ottawa River water, fish and beach sediments. Results were generally consistent with effluent monitoring results, with phosphorus-32, caesium-137 and tritium representing the most significant emissions.

At WL, monitoring of potential atmospheric effluent exposure pathways did not indicate any measurable contribution in excess of normal background levels resulting from WL operations. This is consistent with effluent monitoring results which indicated airborne emissions were very small. Monitoring of potential liquid effluent exposure pathways at WL during 1997 confirmed small but measurable contributions of some radionuclides (caesium-137 and strontium-90) from WL operations to downstream concentrations of radionuclides in Winnipeg River water, fish and sediments, consistent with effluent monitoring results.

Estimated doses to the most highly exposed members of the public due to CRL and WL emissions, based on the environmental monitoring results for 1997 are summarized in the following table. The estimated doses are very small compared with both the public dose limit and with typical average background radiation dose to the Canadian public.

¹ The current regulatory limit in Canada for radiation whole-body (effective) dose to members of the public from the operation of nuclear facilities or other activities involving ionizing radiation (excluding medical procedures) is 5 mSv per year. The Atomic Energy Control Board has proposed to reduce this limit to 1 mSv/a to bring Canada in line with recent recommendations by the International Commission on Radiological Protection (ICRP publication 60 [11]).

Table S.1: 1997 Total Estimated Doses to Critical Groups At CRL and WL Based on Environmental Monitoring

Site	CRL	CRL	WL	WL
Effluent Pathways	Airborne	Liquid	Airborne	Liquid
Critical Group	Infant living at Upriver Boundary	Adult living Downstream	Infant living at Boundary	Adult living Downstream
Total Effective Dose (mSv/a)	9.4E-02	7.9E-03	negligible	3.6E-04
-as % of public dose limit (5mSv/a)	1.9	0.16	(< 0.001)	0.007
-as % of typical average background radiation dose in Canada	3.0	0.25	(< 0.001)	0.011

1997 ANNUAL REPORT OF RADIOLOGICAL MONITORING RESULTS FOR THE CHALK RIVER AND WHITESHELL LABORATORIES SITES

VOLUME 3 – ENVIRONMENTAL MONITORING

1. INTRODUCTION

1.1 Purpose and Scope

This report summarizes results of environmental monitoring for AECL's Chalk River Laboratories (CRL) site located on the Ottawa River near Chalk River, Ontario and for AECL's Whiteshell Laboratories (WL) site located on the Winnipeg River near Pinawa, Manitoba. These laboratories operate under the terms of the Nuclear Research and Test Establishment Licences granted by the Atomic Energy Control Board (AECB) [1, 2].

The CRL and WL licences require that AECL submits to the AECB annual reports for each calendar year summarizing the results of monitoring of radiation exposures to personnel at the sites, the results of monitoring of radioactive materials in airborne and liquid effluents from the sites, and the results of environmental monitoring at the sites and surrounding areas. AECL reports the monitoring results in a three volume report entitled "Annual Report of Radiological Monitoring Results for the Chalk River Laboratories and Whiteshell Laboratories Sites", as report series AECL-MISC-362-yy. This report, Volume 3 of AECL-MISC-362, satisfies the licence requirement regarding environmental monitoring for the CRL and WL sites for the calendar year 1997. Results of personnel dose monitoring and effluent monitoring for 1997 are reported in Volumes 1 and 2 of AECL-MISC-362-97 respectively.

1.2 Site Environmental Monitoring Programs

AECL maintains comprehensive Site Environmental Monitoring Programs at both CRL and WL to ensure that radiation exposures as a result of releases of radioactive material in site effluents remain well below the annual dose limits specified in the Atomic Energy Control (AEC) Regulations², and as low as reasonably achievable, economic and social factors being taken into account (ALARA). The primary objectives of the CRL and WL site Environmental Monitoring Programs are:

- to provide a quantitative record of radioactive contaminants in the environment resulting from operation of the site(s), which will permit assessment of actual or potential radiation doses to critical groups and populations;
- to provide data to confirm compliance with regulatory limits and other guidelines, and to provide public assurance of compliance;
- to provide verification of the effectiveness of facility operation and control of emissions, and the adequacy of effluent monitoring; and
- to provide data to verify or refine the assumptions and models used in DRL calculations for the site(s), where applicable.

In addition, the following secondary objectives are considered in the design of site Environmental Monitoring Programs:

- to provide data for trend analysis;
- to provide baseline data and capability for monitoring and assessment in the event of emergency conditions; and
- to provide information and assurance to the public about site operations.

The current designs of the monitoring programs at the CRL and WL sites are generally consistent with guidelines in Canadian Standard CSA-N.288.4 [7], and take into account the facilities operating at the sites, actual emissions from the sites, the environmental pathways leading to radiation exposure to the most highly exposed members of the public (i.e. critical group³) as identified in the Derived Release Limits (DRLs)⁴ for the sites and to other local

² The current regulatory limit in Canada for effective radiation dose to members of the public from the operation of nuclear facilities or other activities involving ionizing radiation (excluding medical procedures) is 5 mSv per year. The Atomic Energy Control Board has proposed to reduce this limit to 1 mSv/a to bring Canada in line with recent recommendations by the International Commission on Radiological Protection (ICRP publication 60 [11]).

³ A critical group is an identifiable, relatively homogeneous group of people expected to receive the highest radiation dose as a result of emissions from a given facility [6].

⁴ Derived release limits (DRLs) are the approved (by the AECB) upper limits for releases of radioactive materials in emissions from a nuclear facility or site, derived on the basis of the dose limits for members of the public by means of environmental

populations, past monitoring results, as well as various historic, public and scientific considerations. Because the monitoring programs at CRL and WL have evolved somewhat separately, and because of differences in the types of operating facilities, types and quantities of radioactive emissions, and site histories, the programs at the two sites differ in various aspects. Specific designs of the programs at both sites may change from time to time in response to changes in these various factors.

The Site Environmental Monitoring Programs at both CRL and WL are conducted by groups independent of the direct line management of the CRL and WL facilities, under the general direction of AECL's Environmental Protection Program, as defined in the AECL Environmental Protection Program Manual, RC-2000-021.

1.3 CRL and WL Facilities, Operations and Radioactive Emissions

AECL's CRL and WL sites are broad-based installations for nuclear research, development and demonstration, and operate a variety of nuclear facilities. The respective Nuclear Research and Establishment Licences lists the main nuclear facilities at each site. In addition, there is a variety of smaller research, development and analytical laboratories at both CRL and WL. The main nuclear facilities at the CRL site which contribute to radioactive emissions are the NRU Research Reactor, the Molybdenum-99 Radioisotope Production Facility, the Heavy Water Upgrading Plant, the Universal Cells, and the Fuels and Materials Cells (FMC), the Waste Treatment Centre and the Waste Management Areas. The main nuclear facilities at the WL site which contribute to radioactive emissions are the Shielded Facilities that include the Hot Cell Facility and the Immobilized Fuel Test Facility, and the Active Liquid Waste Treatment Centre. There are no longer any operating nuclear reactors at the WL site.

Detailed results of the monitoring of radioactive material in airborne and liquid effluents from the CRL and WL sites are in Volume 2 of this report [3]. The following Tables 1 to 4 contain a brief summary of airborne and liquid releases from CRL and WL during 1997. The releases are expressed as average quantities of per monitoring periods (in becquerels (Bq)) and as percentages of the applicable Derived Release Limits (DRLs) based on off-site members of the public. Tables 1 to 4 also indicate the most highly exposed members of the off-site public (critical group) and the dominant exposure pathways to the critical groups, as identified by the DRL model calculations, using the methodology of the Canadian Standard, CSA N288.1 [6]. For practical purposes, the sum of site releases during the year as percent of the DRLs, represents a generally conservative upper bound radiation dose (as a percent of the regulatory dose limit for members of the public of 5 mSv in a year) to the most highly exposed members of the public due to emissions from the site.

Table 1: CRL Air Emissions - Average Releases in 1997 and Dominant DRL Pathways

Radionuclide	Average Release		Dominant Dose Pathway [4]	DRL Critical Group [4]
	(Bq/week)	(% DRL)*		
Argon-41	3.7E+14	1.0E+00	Air Immersion	Adult & Infant-Balmer Bay
Mixed Noble Gas	1.5E+13	3.6E-02	Air Immersion	Adult & Infant-Balmer Bay
Tritium (HTO&HT)	4.6E+12	4.2E-02	**Inhalation/Milk/Vegetables	Adult & Infant-Balmer Bay
Carbon-14 (CO ₂)	1.2E+10	7.2E-03	**Inhalation/Milk/Vegetables	Adult & Infant-Balmer Bay
Iodine -131	1.4E+08	6.7E-02	Milk Ingestion	Infant-Balmer Bay
Iodine -125	3.6E+07	2.7E-02	Milk Ingestion	Infant-Balmer Bay
Gross Beta Particulates	2.1E+06			
assuming all Sr-90		1.2E-04	Vegetable Ingestion	Infant-Balmer Bay
assuming all Cs-137		8.3E-05	Contaminated Ground	Infant-Balmer Bay
Gross Alpha Particulate	8.2E+03			
assuming all Pu-239		2.3E-05	Inhalation	Infant-Balmer Bay
assuming all U-234		4.8E-06	Inhalation	Infant-Balmer Bay
Site Total		1.2E+00		

* DRL_c = DRL based on critical group at site boundary

** The DRLs [4] for airborne tritium, and carbon-14 were based on a specific activity in atmosphere approach which calculated the total dose from these three pathways in combination rather than individually.

pathway analysis. The currently approved DRLs for the CRL and WL sites are given in references [4] and [5] respectively. Proposed new DRL values for CRL have been calculated and submitted to the AECB, and are under review.

Table 2: CRL Liquid Effluents - Average Releases in 1997 and Dominant DRL Pathways

Radionuclide	1997 Avg Releases		Dominant Dose Pathway [4]	Critical Group [4]
	(Bq/month)	% DRL _b		
Phosphorus-32	2.6E+09	1.2E-01	Fish Ingestion	Adults-Petawawa
Cesium-137	2.2E+09	2.5E-02	Fish Ingestion	Adults-Petawawa
Tritium	1.1E+13	4.0E-02	*Water Ingestion	Adults-Petawawa
Strontium-90	3.2E+09	2.3E-03	Vegetable Irrigation/ Ingestion	Adults-Petawawa
Cobalt-60	1.5E+09	3.3E-03	Fish Ingestion	Adults-Petawawa
Cesium-134	2.3E+08	3.4E-03	Fish Ingestion	Adults-Petawawa
Other Gamma emitters	1.1E+11	9.5E-03	Fish Ingestion	Adults-Petawawa
Gross Alpha(as Am-241)	1.6E+08	2.7E-03	Fish Ingestion	Adults-Petawawa
Site Total - Liquid		2.1E-01		

* The dominant exposure pathway for tritium stated in the current CRL DRL report [4] is vegetable irrigation. However, this is a modeling error which incorrectly assumes concentration of tritium oxide (i.e. water) by a factor of 2400 in soil due to spray irrigation.

Table 3: WL Air Effluents - Average Releases in 1997 and Dominant DRL Pathways

Source	Average Release		Dominant Dose Pathway [5]	Critical Group [5]
	(Bq/week)	(% DRL _b)*		
Tritium:	2.0E+09	2.1E-05	Inhalation	Adult at boundary
Gross Beta Particulates -assuming all Sr-90 -assuming all Cs-137	2.5E+04	1.7E-04 4.8E-05	Vegetable Ingestion Contaminated Ground	Infant at boundary Adult at boundary
Iodine-131	1.4E+04	1.9E-04	Vegetable Ingestion	Infant at boundary
Site Total - Airborne		3.8E-04		

*DRL_b = DRL based on critical group at site boundary

Table 4: WL Liquid Effluents - Average Releases in 1997 and Dominant DRL Pathways

Source	Average Release		Dominant Dose Pathway [5]	Critical Group [5]
	(Bq/month)	(% DRL)		
Caesium-137	1.1E+08	7.0E-03	Fish Ingestion	Adult at downstream boundary
Strontium-90	8.5E+07	2.1E-03	Vegetable Irrigation/Ingestion	Infant at downstream boundary
Caesium-134	8.5E+05	7.6E-05	Fish Ingestion	Adult at downstream boundary
Cobalt-60	8.0E+05	2.5E-05	Fish Ingestion	Adult at downstream boundary
Ruthenium-106	4.7E+05	9.3E-07	Fish Ingestion	Adult at downstream boundary
Gross Alpha (assuming Pu-239)	8.3E+06	3.4E-04	Vegetable Irrigation/Ingestion	Infant at downstream boundary
Site Total - Liquid		9.6E-03		

2. CRL ENVIRONMENTAL MONITORING PROGRAM AND RESULTS FOR 1997

2.1 CRL Site Location

AECL's CRL site is located in Ontario on the south shore of the Ottawa River, about 200 km Northwest of Ottawa. Nearby communities include Chalk River, Deep River, Petawawa and Pembroke. A map of the CRL site and surrounding areas is in Appendix 1.

2.2 CRL Environmental Monitoring Program

At CRL, the Environmental Monitoring Program includes the following:

- a) Monitoring of airborne effluent exposure pathways:
- meteorological conditions,
 - ambient gamma radiation,
 - ambient tritium in air,
 - atmospheric deposition of radioactive material,
 - land gamma radiation,
 - radioactivity in milk, and
 - radioactivity in vegetables.
- b) Monitoring of liquid effluent exposure pathways:
- radioactivity in Ottawa River water,
 - radioactivity in fish from the Ottawa River,
 - radioactivity in beach sediments on the Ottawa River, and
 - radioactivity in various on-site surface waters,
 - radioactivity in various off-site surface waters.

Sampling locations for this monitoring are shown on maps in Appendix 1. Results of the monitoring during 1997 are presented in the following sections, 2.3 through 2.12. Dose estimates to members of the critical group off-site, based on the environmental monitoring results are in Section 4.

2.3 Ambient Gamma Radiation in Air

2.3.1 Monitoring with Thermoluminescent Dosimeters

In 1997, AECL maintained a network of 34 thermoluminescent dosimeter (TLD) monitoring stations within and around the CRL site and surrounding communities to monitor ambient radiation dose in air (air kerma). Eight of the monitoring stations were within the CRL site, 10 at the site boundary, and 16 in neighbouring communities. Maps 1 and 2 in Appendix 1 show the locations of the monitoring stations.

At the monitoring stations, the lithium fluoride (LiF) TLDs continuously measured the integrated exposure from natural background radiation plus contribution from airborne radioactive material released from CRL facilities, primarily the noble gas argon-41. Each monitoring station contained two TLD badges, each holding duplicate LiF chips in plaques. One of the TLD badges was collected and analyzed quarterly⁵ and the other annually. Each TLD reading was corrected for exposure during storage, handling and transport by subtracting the exposure received by "control" TLDs. During the actual measurement period, the control TLDs remained inside lead shielding in a specifically constructed building at the CRL west boundary where background radiation, for example from building materials is very low. As a result, the final TLD results do not include exposure due to high energy cosmic radiation that penetrates the lead shielding.

The monitoring results for 1997 are summarized in Table 4. Figure 1 depicts the total annual dose measured by the TLDs at four key monitoring locations on and off-site in the dominant wind directions for 1988 to 1997.

For comparison, external dose from background terrestrial gamma radiation (due to naturally occurring radionuclides within the earth, soil, rocks and building materials) within Canada averages about $330 \pm 185 \mu\text{Gy}$ per year [16]. Considerable variation in natural terrestrial background can occur with location and time due to factors such as types of rock and soil, type and source of material used building construction, snow cover and soil moisture.

Several of the TLD results for the CRL site indicate dose contributions in excess of natural background from CRL operations, due primarily to emissions of the noble gas argon-41 (half-life 1.8 hours) from the NRU reactor stack [3]. Actual radiation doses to all on-site personnel were monitored under AECL's Radiation Protection Program, and results are discussed in [10].

⁵ Quarterly collection of TLDs is not possible at 4 locations which are normally inaccessible in winter.

TLD results for the CRL site boundary and off-site locations were comparable with results for the previous four years (Figure 1) and, in general, within the normal range of variation in natural background in Canada.

In addition to TLD measurements, a new set of instruments was used in 1997 to monitor ambient gamma radiation and to obtain a more direct measure of dose contribution from CRL emissions at the site boundary (see section 2.3.2 below).

Table 5: CRL Ambient Gamma Radiation Dose in Air – TLD Monitoring –1997

TLD Stn # AND LOCATION		Ambient Radiation Dose in Air (Air Kerma) (μGy) (a)						
		Quarterly TLDs					Annual TLD	Mean Qtr&Ann
		Qtr 1	Qtr 2	Qtr 3	Qtr 4	Sum Qtrs		
CRL ON-SITE								
9	Main Gate	191	238	256	182	868	924	896
10	Bldg. 513, Indoors	134	135	156	160	585	633	609
16	Cafeteria (indoors)	161	188	N/A (d)	203	737 (g)	823	780
26	PIC (indoors)	207	236	238	245	925	931	928
27	PIC (outdoors)	241	309	305	237	1092	1110	1101
11	Mattawa Road, Acid Rain Stn.	78	116	102	116	412	446	429
33	Perch Lake Main	49	82	79	67	277	292	284
34	C-2 Fire Trail at Hydro Line	19	82	50	63	215	258	237
CRL SITE BOUNDARY								
1	Pointe au Bapteme	84	98	123	101	407	413	410
2	Perch Lake Satellite	57	51	67	52	227	225	226
3	C-2 Fire Trail	39	56	75	52	222	255	238
4	Ball Diamond	68	99	78	99	344	385	365
5	Chalk River, Ottawa St. (c)	39	73	98	97	306	305	305
6	Mountainview Subdivision	30	86	73	80	269	281	275
7	West Gate at Hydro Line	50	63	69	59	242	265	253
8	Balmer Bay (Sawchuk)	53	85	97	69	304	356	330
32	East Mattawa Road	42	84	80	71	278	321	299
43	Bldg 560 (Low Background Bldg.)	25	67	63	65	220	245	232
OFF-SITE								
12	Deep River, MacDonald Ave.	55	95	92	92	333	364	348
13	Quebec, Opposite CRL (b)	(b)	333	123	(b)	456	N/A (e)	N/A
15	Quebec, Harrington Bay	24	104	N/A (d)	120	331(g)	435	383
19	Quebec, Oiseau Point (Hilborn) (b)	(b)	219	N/A (e)	(b)	292 (g)	N/A (e)	N/A
20	Petawawa, Gutzman Rd	33	71	N/A (e)	39	190 (g)	N/A (e)	N/A
21	Petawawa, Portage Rd	55	102	94	95	346	366	356
22	Pembroke, Lloyd Rd.	22	80	66	75	243	280	262
23	Quebec, Ft. William	22	60	66	70	219	247	233
24	Deep River Hydro Yard	N/A(f)	105	63	91	345 (g)	382	363
25	Quebec, Schyan River (b)	(b)	201	70	(b)	272	N/A (e)	N/A
28	Quebec, Des Joachims	80	112	84	113	389	314	351
29	Highway 17, NPD Gate	36	53	28	55	172	253	213
31	Point Stewart (b)	(b)	298	96	(b)	394	N/A (e)	N/A
35	Petawawa Fire Hall	46	124	119	128	417	433	425
40	Demers Centre	68	96	95	99	359	370	365
41	Chichester	26	79	78	75	258	308	283

(a) Reported results exclude dose from cosmic radiation due to subtraction of exposure to control TLDs.

(b) Inaccessible in winter: 2nd Qtr result covers 9 months, Oct 96 to June 97; Annual TLD covers July 96 to June 97.

(c) TLD #5 relocated to Ottawa St, Chalk River (previously Bagg's Farm) - 2nd Qtr 1997.

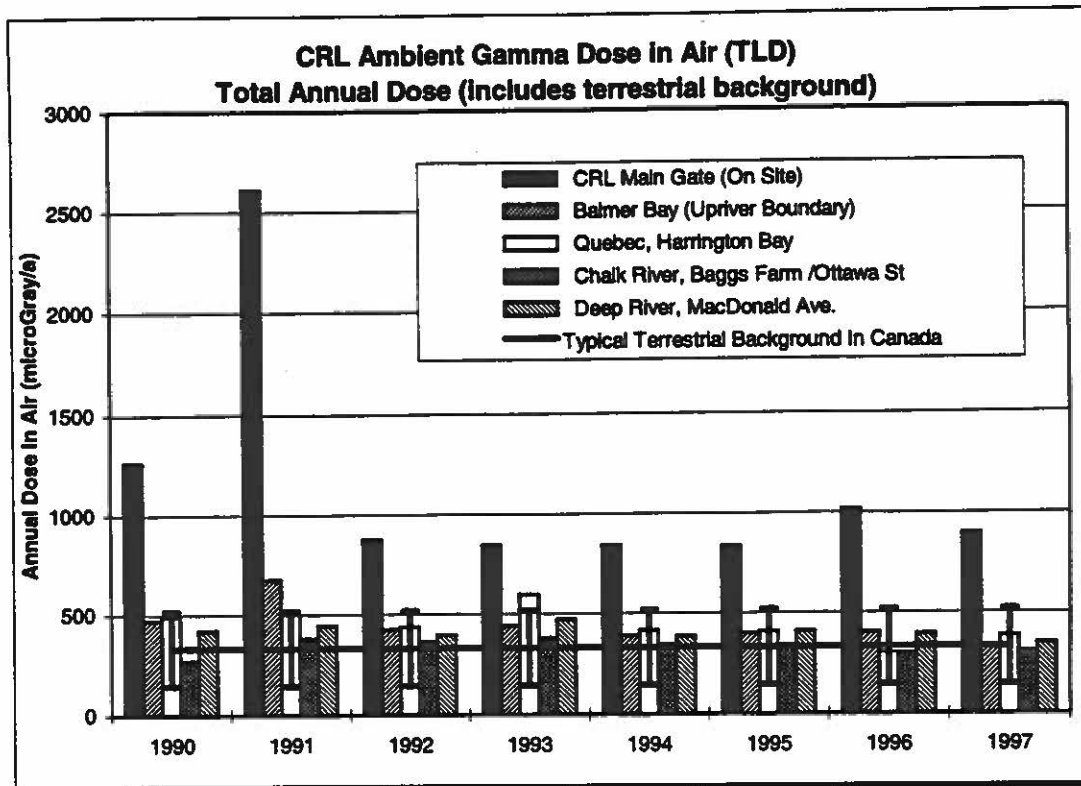
(d) No result available due to handling error.

(e) No result available due to failure to retrieve TLD.

(f) No result due to a faulty TLD.

(g) Reported sum of quarterly TLD results is extrapolation from results for 3 quarters where 1 quarterly result missing.

Figure 1



2.3.2 Ambient Radiation Measurements with GammaTracer System

In addition to the TLD ambient gamma radiation measurements, three automated continuously logging low level ambient radiation detectors containing dual Geiger tubes ("GammaTracer" units) were used at three key locations, to provide a more accurate measurement of natural background radiation dose and the dose contribution from noble gases (primarily argon-41) from CRL operations. The units were located at Balmer Bay, Harrington Bay, and CRL Building 560 (CRL Boundary at Plant Road in Chalk River), near TLD stations 8, 15 and 43 respectively. Balmer Bay and Harrington Bay are the locations of the nearest permanent and seasonal residents in the directions of the two predominant wind directions relative to the CRL plant site, and thus provide representative values of doses to the most highly exposed members of the public or critical groups. The GammaTracer station at Bldg. 560 provides a measure of doses to residents of Chalk River, which is located in a relatively low frequency wind direction. The dose contribution from CRL operations was determined from the GammaTracer results for these three locations, by subtracting the baseline background dose from the total dose received during the monitoring period.

Table 6 summarizes the GammaTracer monitoring results for 1997. The results are expressed as ambient dose equivalent (H^*10) Sieverts (see [11]). The dose contribution from CRL is also expressed in terms of absorbed dose in air (air kerma, Gy) using conversion factor from the US Department of Energy international intercomparison of environmental dosimeters [14]. Average annual background dose rates at the three locations (about 74 nSv(H^*10)/h or about 540 μ Gy/a) are consistent with the typical background dose rates in Canada due to terrestrial (330 ± 185 μ Gy/a) plus cosmic radiation (240 μ Gy/a) provided in [16].

Figure 2

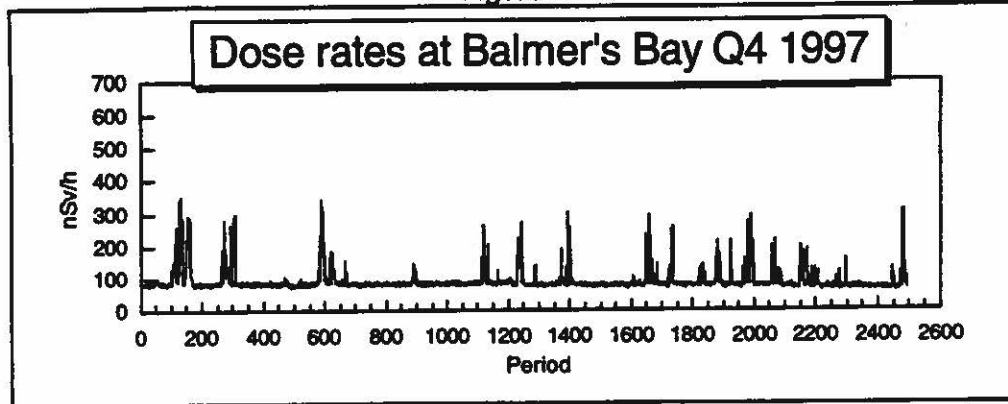


Table 6: CRL Ambient Radiation Dose in Air – Gamma Tracer Measurements – 1997

Location / Period	Total Dose rate (nSv/h)	Background Dose rate (nSv/h)	Contribution From CRL Noble Gas		
			Dose Rate (nSv/h)	Total Dose for Period	
				(μ Sv)	(μ Gy) (2)
Bldg. 560 (CRL Boundary at Plant Road)					
1st Quarter	57.4	55.4	2.0	4.1	3.4
2 nd Quarter	72.5	70.5	2.0	4.2	3.5
3 rd Quarter	80.8	79.8	1.0	2.3	1.9
4th Quarter (1)	73.5	72.0	1.6	4.7	3.9
1997 Average	71.0	69.5	1.5		
Total 1997				15.3	12.7
Balmer Bay					
1st Quarter	71.1	56.3	14.8	29.1	24.2
2nd Quarter	87.3	73.8	13.5	28.7	23.9
3rd Quarter	99.3	84.8	14.5	34.5	28.8
4th Quarter (1)	89.0	77.7	11.4	28.3	23.6
1997 Average	86.7	73.1	13.5		
Total 1997				120.6	100.5
Harrington Bay					
1st Quarter	69.8	64.5	5.3	11.0	9.1
2nd Quarter	88.4	81.9	6.4	13.9	11.6
3rd Quarter	96.4	89.2	7.2	16.3	13.6
4th Quarter (1)	84.1	81.6	2.5	5.7	4.7
1997 Average	84.7	79.3	5.4		
Total 1997				46.9	39.1

Background radiation dose includes both terrestrial and cosmic radiation.

1. 4th Quarter period ended 98-01-19/20.
2. GammaTracer units were calibrated in "Ambient Dose Equivalent" sieverts (H^*10) [11].
3. Converted to absorbed dose in air (air kerma) using conversion factor 1.2 Sv (H^*10)/Gy [14].

2.4 Ambient Tritium in Air

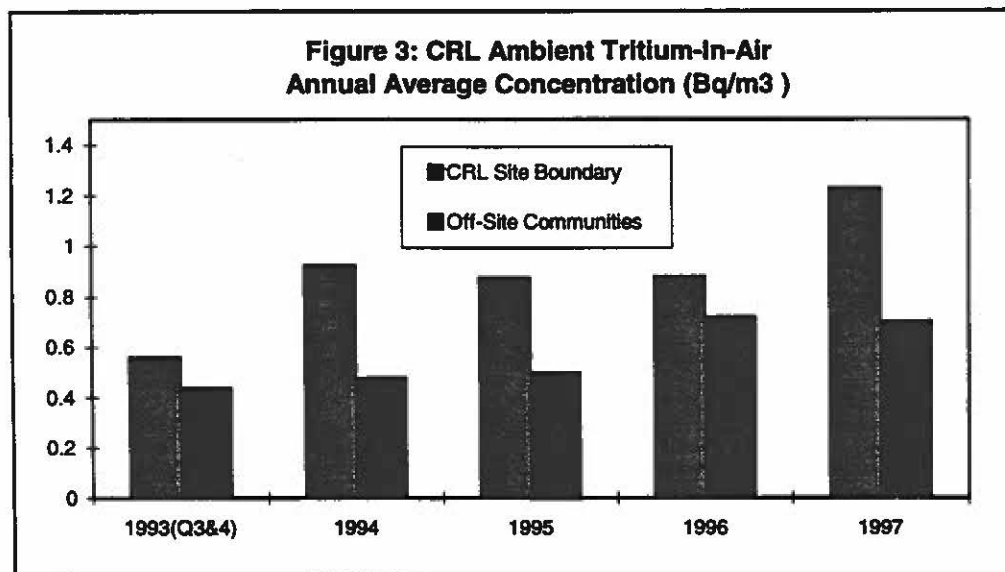
The ambient tritium in air concentrations were monitored during 1997 at a total of 11 locations within the CRL site, at the site boundary and off-site. Monitoring was by passive diffusion samplers, using sampler fluid consisting of 50% glycol and 50% water, that are designed to sample the ambient air at a rate of 1 litre per day. Analysis of the sampler fluid was by liquid scintillation counting. The samplers were collected and analyzed quarterly to coincide with the TLD analysis frequency.

The 1997 results are in Table 7. Figure 3 shows the annual average concentration of tritium in air at site boundary stations and in off-site locations for the past five years. Background levels of tritium in air in Ontario and Quebec, based on measurements by Health Canada range from about 0.09 to 0.26 Bq/m³ [12].

Tritium air concentrations at the CRL site boundary and at off-site locations in 1997 were measurable at levels greater than tritium background. The results indicated an increase in average boundary air concentrations in 1997 compared with the four previous years, which is consistent with reported increased airborne tritium emissions in 1997 due to increased operation of the CRL Heavy Water Upgrading facility. The results for off-site communities were similar to 1996, and are believed to be influenced, particularly at the Petawawa monitoring location, by emissions from another industrial source of tritium in the region.

Table 7: CRL Ambient Tritium in Air – Average Quarterly and Annual Concentrations in 1997

Stn. #	LOCATION	Q1 (Bq/m ³)	Q2 (Bq/m ³)	Q3 (Bq/m ³)	Q4 (Bq/m ³)	Average	Std. Dev.
ON-SITE							
H9	Main Gate, Bldg. 449J	5.4 ± 0.2	9.8 ± 0.5	7.7 ± 0.2	4.3 ± 0.1	6.79	2.49
H568	Sewage Treatment Plant	26.1 ± 0.4	41.3 ± 0.5	28.8 ± 0.3	13.3 ± 0.2	27.4	11.5
H145I	Bldg 145, Indoors	25.1 ± 0.4	60.8 ± 0.1	44.8 ± 0.4	18.2 ± 0.2	37.2	19.3
H145O	Bldg 145, Outdoors	51.2 ± 0.3	231 ± 2.2	53.9 ± 0.4	24.5 ± 0.1	90.1	94.6
CRL SITE BOUNDARY							
H1	CRL Sandspit	2.4 ± 0.3	4.6 ± 0.2	3.5 ± 0.1	1.6 ± 0.0	3.02	1.34
H4	Ball Diamond	0.3 ± 0.1	1.0 ± 0.2	0.3 ± 0.1	0.3 ± 0.1	0.46	0.37
H6	Mountain View Subdivision	0.2 ± 0.1	0.8 ± 0.2	0.4 ± 0.1	0.2 ± 0.04	0.40	0.29
H8	Balmer Bay, Sawchuck's	0.6 ± 0.1	1.5 ± 0.2	1.4 ± 0.1	0.7 ± 0.1	1.04	0.49
OFF-SITE							
H12	Deep River, MacDonald	0.2 ± 0.1	0.8 ± 0.1	0.5 ± 0.1	0.3 ± 0.1	0.46	0.26
H15	Harrington Bay	0.5 ± 0.1	1.2 ± 0.4	0.9 ± 0.1	0.3 ± 0.1	0.73	0.42
H35	Petawawa Fire Hall	0.7 ± 0.1	1.7 ± 0.4	0.7 ± 0.1	0.6 ± 0.04	0.93	0.55



2.5 Atmospheric Deposition of Radioactive Material

Samples of total wet and dry atmospheric deposition from four locations were collected in open buckets positioned about one metre above the ground. The samples were analyzed monthly for gross beta and gross alpha activities. Table 8 provides average and range of monthly gross beta and gross alpha activity in total atmospheric deposition at the four CRL site boundary deposition stations during 1997. The deposition monitoring serves primarily as a gross trend indicator, since it represents an intermediate step in environmental exposure pathways, and as a baseline for emergency preparedness purposes.

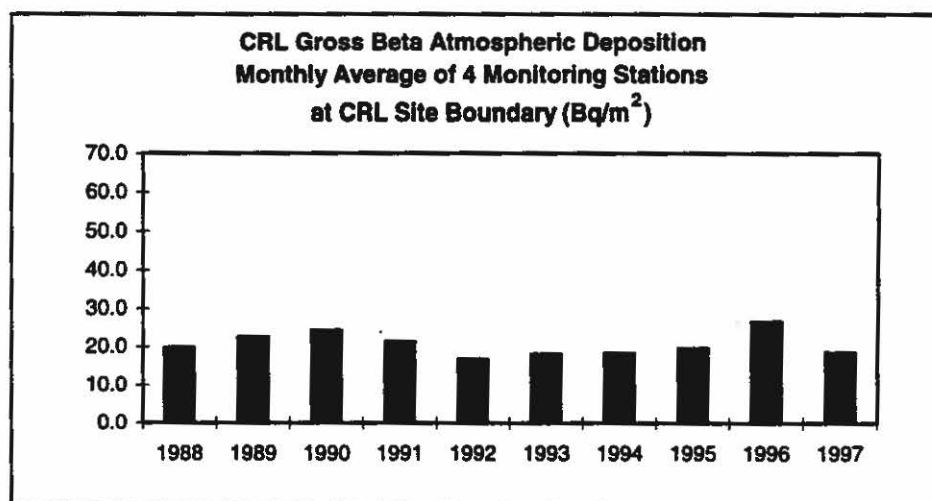
Annual average gross beta activity at the site boundary stations for the past ten years is in Figure 4. Locations of these stations correspond approximately with the TLD stations of the same number (see Appendix 1, Map 2).

Atmospheric deposition of gross beta activity due to fallout of naturally occurring radionuclides (primarily beryllium-7) within Ontario and Quebec typically ranges from about 17 to 30 Bq/m² per month [12]. The deposition at CRL and surrounding areas was not distinguishable from the values reported in [12].

Table 8: Atmospheric Deposition of Gross Beta and Gross Alpha Activities at CRL Boundary – 1997

Station #	Location	Monthly Deposition			
		Gross Beta		Gross Alpha	
		Average (Bq/m ²)	+/- (1 Std. Dev.)	Average (Bq/m ²)	+/- (1 Std. Dev.)
1	Pointe au Baptême	18.3	8.1	8.5	5.2
4	Building 560	18.8	5.6	8.9	3.7
7	West Gate @ Hydroline	16.2	8.2	6.3	5.1
8	Balmer Bay	20.9	13.0	6.2	4.9
	Average	18.5	8.7	7.5	4.7

Figure 4



2.6 Land Gamma Radiation

Radiation levels on road surfaces within the CRL site and Highway 17 East to Pembroke were surveyed using a sensitive dose rate meter (Geiger tube) mounted on a vehicle. The survey is performed annually. The survey routes are predefined and, to the extent possible, remain unchanged every year. The surveys are scheduled for periods when interference by airborne radioactive emissions from CRL is negligible. Measurement of land gamma radiation serves primarily as a gross trend indicator, since it is not one of the dominant exposure pathways, as a baseline for emergency preparedness, and as a check for any accidental contamination.

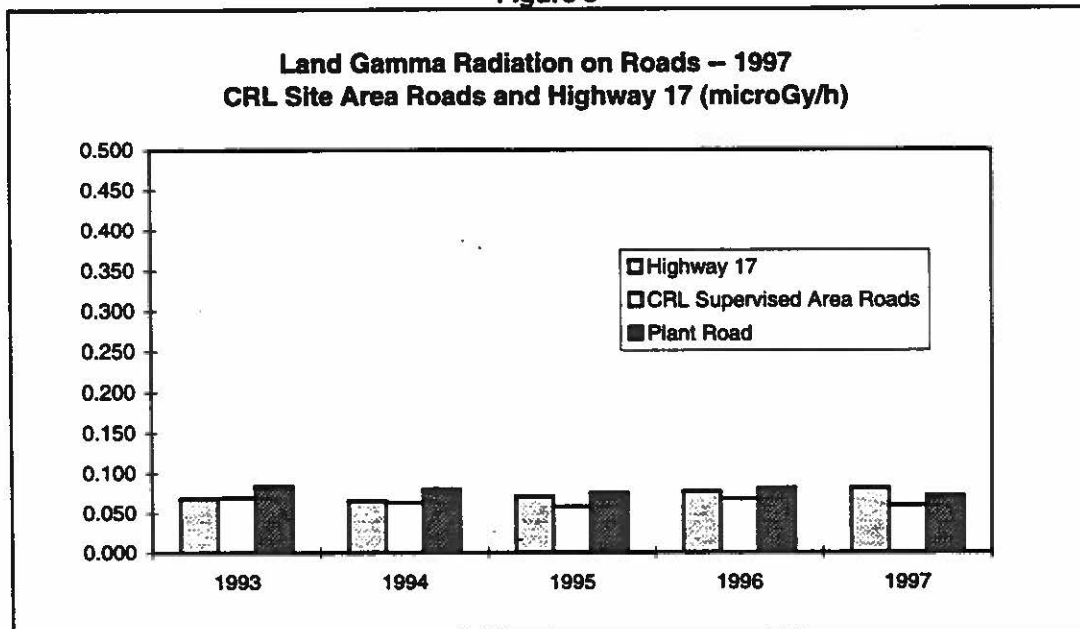
Land gamma survey results for 1997 are in Table 9. Figure 5 depicts levels of gamma dose rates on roads on CRL site and Highway 17 East for 1993 to 1997. In 1997, the dose rates remained at previous years' level on all monitored roads, confirming no accumulation of radioactive material from CRL operations.

**Table 9: Mean Land Gamma Radiation on Roads – 1997
CRL Site Areas and Highway 17**

ROAD LOCATION	DOSE RATE ($\mu\text{Gy/h}$)
PUBLIC AREA	
Chalk River to Pembroke (Highway 17)	0.081
Chalk River to Deep River (Highway 17)	0.081
Petawawa to Pembroke (Highway 17)	0.083
Average	0.082
CRL SITE AREA	
Supervised Area (formerly Outer Area)	
Main Stack Road	0.073
Mattawa Road East	0.053
Mattawa Road West	0.067
C-2 Fire Trail	0.043
Sandspit Road	0.063
Average	0.060
Uncontrolled Area	
Plant Road, Main Gate to C-2	0.072
Plant Road, C-2 to Highway 17	0.072
Average	0.072

- Gamma dose rate in air, excluding cosmic radiation.

Figure 5



2.7 Radioactivity in Milk

Monthly samples of processed whole milk from the local dairy in Deep River were analysed for iodine-131, by direct gamma spectrometry of the liquid milk. Quarterly composite samples of milk from the same source were ashed⁶ and analyzed for other gamma emitters using gamma spectrometry. Analysis of caesium-137 and potassium-40 were done on ashed samples. Monitoring of carbon-14 and tritium in milk started in the fourth quarter. These analyses were done from quarterly composite of monthly samples; tritium analysis on water distilled from the milk, and carbon-14 on combusted milk solids

Table 10 provides the monitoring results for 1997 as annual average concentrations. Iodine-131 was not detected in any samples. In the ashed samples, only potassium-40 that is a naturally occurring radionuclide, and caesium-137 were detected. Amounts of other gamma emitters were less than detection limits and are not included in Table 10. The observed caesium-137 concentrations are consistent with the concentrations present in Canadian milk as a result of global fallout from atmospheric testing of nuclear weapons, and the 1986 Chernobyl nuclear accident [12]. Tritium concentrations, which appear to be slightly elevated above typical background, may be influenced by emissions from another industrial source of tritium in the region. The observed concentrations of carbon-14 were indistinguishable from natural levels (230 Bq per kg of carbon) reported by UNSCEAR [15].

Table 10: CRL – Monitoring of Radioactivity in Milk – 1997

Radionuclide	Number of Samples	Average Concentration (Bq/L)	Avg. LLD b (Bq/L)
Iodine-131 ^a	12	< LLD	0.11+/-0.03
Potassium-40	4	84.6+/-2.7	0.3+/-0.1
Caesium-137	4	0.061+/-0.020	0.023+/-0.008
Tritium (free water)	1	26.3 +/- 0.98	
Carbon-14	1	231 +/- 24 (Bq/kg of carbon)	

- a) Iodine-131 activity is measured by gamma spectroscopy of 1 litre liquid milk monthly sample.
 b) LLD = lower limit of detection. Only nuclides above detection limits are shown in Table 10.
 c) Results of gamma spectroscopy of dried and ashed quarterly composite of monthly milk sample. Ashing cannot be used for I-131 analysis because of volatility of iodine.

2.8 Radioactivity in Vegetation

Samples of vegetables from private gardens in Balmer Bay and Deep River were analyzed for tritium, gross beta, and for gamma emitters using gamma spectrometry. Samples from local market gardens in the east end of Pembroke, located over 30 km from the CRL site, were analysed as a background comparison. Analysis results for 1997 are shown in Table 11.

Tritium results in all samples appear elevated above expected natural concentrations. Pembroke market gardens' crops were the highest and are believed to be affected by emissions from another industrial source (non-AECL) of tritium emissions in the region. Tritium concentrations in vegetables from Balmer Bay appear to be reasonably consistent with expected values based on CRL emissions and measured air concentrations (ratio of concentration in Balmer Bay vegetables to 3rd Quarter tritium air concentration at Balmer Bay (Table 7) is 57 versus a default transfer parameter value in CSA N288.1 [6] of 50).

The leafy vegetable sample from Balmer Bay are greater than in other samples, but appears to reflect increased concentrations of the naturally occurring radionuclides potassium-40 and berrilium-7 likely due to different chemical composition. Caesium-137 concentrations in the Balmer Bay sample also appear slightly greater than other samples, and are conservatively assumed to result from CRL operations in the dose assessment in Section 4.

⁶ The ashing method provides better detection limits for most radionuclides, but is not used to monitor for radioiodines due the potential for to their relative volatility.

Table 11: CRL Radionuclides in Vegetation – 1997

SAMPLE TYPE	LOCATION	Tritium* (Bq/kg, fresh wt.)	Gross Beta (Bq/kg, fresh wt.)	Be-7 ** (Bq/kg, fresh wt.)	K-40** (Bq/kg, fresh wt.)	Cs-137 ** (Bq/kg, fresh wt.)
Carrots	Deep River, Alder Cres.	33±2	86 ±2	<1.61	149 ±6.44	<0.23
Green beans	Deep River, Highland Cres.	30±1	91 ±2	<1.98	102 ±5.34	<0.24
Tomatoes	Deep River, Alder Cres.	18±1	66 ±1	<1.33	76 ±3.75	0.18 ±0.13
Swiss Chart (leafy)	Balmer Bay	80±2	173 ±4	51.64 ±5.5	248 ±11.21	3.05 ±0.56
Carrots	Market gardens, Pembroke east	252±3	57 ±1	<1.79	69 ±4.22	<0.22
Green Beans	Market gardens, Pembroke east	437±2	70 ±2	<1.11	70 ±4.18	0.08 ±0.14
Tomatoes	Market gardens, Pembroke east	255±2	79 ±1	<0.73	71 ±3.45	<0.13
Average	Deep River	40±2.8	104 ±5		144 ±14.48	
Average	Pembroke	315±3.7	69 ±2		70 ±6.87	

*Free water tritium

** Gamma Spectrometry results. Except for some naturally occurring radionuclides, all other radionuclides were below detection limits. (Be-7 and K-40 are naturally occurring radionuclides.)

2.9 Radioactivity in Surface Waters Within the CRL Site

Surface waters within the CRL site property that may normally contain some radioactive contaminants as a result of past or present activities at the CRL Waste Management Areas (WMAs), were regularly sampled and analysed. Sampling and analysis frequency for Chalk Lake was semi-annual. Liquid emissions from the CRL site by way of Perch Creek and Maskinonge Lake related to the concentrations in these streams are reported and discussed in the annual effluent monitoring report [3]. The results are reported here for completeness and for record purposes.

Table 12 summarizes mean concentrations of the most significant radionuclides in the CRL site surface waters related to WMAs during 1997. Radionuclide concentrations in 1997 remained elevated above natural levels and generally comparable with 1996 results. Since these surface waters are in the supervised areas within the CRL site boundary they are not normally accessible by members of the public and therefore do not represent a direct exposure pathway to the public.

**Table 12: Mean Concentration of Radionuclides in Surface Waters
Associated with CRL Waste Management Areas – 1997**

Waste Management Facility/Sample Location	Gross Beta (Bq/L)	⁹⁰ Sr & ⁹⁰ Y (Bq/L)	Ce-144 (Bq/L)	Ru-106 (Bq/L)	Cs-137 (Bq/L)	Co-60 (Bq/L)	Tritium (Bq/L)
Liquid Waste Management							
East Swamp Stream	3.76E+02	1.71E+02	<4.88E-02	8.66E-01	1.32E+00	8.58E+00	7.26E+04
Waste Management Area A							
South Swamp Stream	3.85E+03	*	<4.19E-01	<5.83E-01	<6.90E-02	<1.17E-01	1.54E+05
Main Stream	3.85E-01	*	6.97E-03	<1.41E-02	8.51E-03	2.13E-03	8.40E+02
Perch Lake Inlet # 2	8.30E+00	*	<4.74E-02	<3.19E-01	3.78E-02	2.70E-01	1.77E+04
Waste Management Area B							
Spring "B" Disposal	3.93E+03	*	<9.43E-01	<9.71E-01	<1.09E-01	<9.57E-02	1.11E+04
Perch Lake Inlet # 1	6.00E+01	*	<1.39E-02	<1.68E-02	<1.88E-03	<1.79E-03	1.72E+03
Perch Lake System							
Perch Creek Weir	8.56E+00	7.43E+00	<4.53E-02	<1.08E-01	<1.35E-02	<1.23E-02	1.10E+04
Waste Management Area C							
Duke Stream	4.62E-01	*	<1.46E-02	<3.83E-02	1.10E-02	1.01E-02	9.72E+04
Maskinonge Lake Outlet	2.79E-01	*	<1.49E-02	<3.98E-02	<3.94E-03	<4.93E-03	1.61E+03
Chalk Lake	1.03E-02	*	<1.88E-02	<3.5E-02	8.70E-03	3.28E-03	1.87E+02

- * Specific analyses for Sr-90 and Y-90 not routinely conducted on these streams.

Various other surface streams within the CRL site that are not normally expected to contain significant quantities of radioactive contamination were monitored periodically to verify no abnormal radionuclide levels or unplanned emission routes. Results for 1997 are summarized in Table 13. Radionuclide concentrations in these streams appear slightly elevated above natural background levels for tritium due to atmospheric deposition of airborne tritium emissions but, for comparison purposes, remain below Canadian drinking water standards [8].

**Table 13: Gross Beta and Tritium in Various On-Site Surface Waters at CRL
Mean Annual Concentrations - 1997**

Location	Gross Beta (Bq/L)	Tritium (Bq/L)
Streams in Plant Site Area, Discharging to Ottawa River:		
01 Stream (East end Controlled Area 1*)	0.044+/-0.009	216+/- 2.40
02 Stream (East of Controlled Area 1*)	0.098+/-0.010	107+/-0.96
Streams Discharging to Maskinonge or Chalk Lake:		
Toussaint Lake (NE Chalk Lake)	0.325+/-0.013	51.7+/-1.68
Black Duck Creek @ Plant Road	0.035+/-0.007	27.0+/-2.28
For comparison: Maximum acceptable concentration in Canadian drinking water [8]	5 (assuming Sr-90)	7000

* Formerly called "Inner Area"

2.10 Radioactivity in Surface Waters Off the CRL Site

Numerous surface water streams outside the CRL boundary (in addition to monitoring of the Ottawa River - see Section 2.11) were sampled at least annually and analyzed for gross beta and tritium activities to confirm there was negligible impact from CRL operations. Analysis results for 1997 are in Table 14. Figures 6 and 7 depict average annual gross beta and tritium concentrations at the various monitored locations for 1993 to 1997. All concentrations were well below the Canadian MACs for drinking water [8]. Tritium appears slightly elevated above natural background levels, likely due to atmospheric deposition resulting from CRL airborne emissions. Gross beta values in off-site surface waters continued to show a slightly decreasing trend.

**Table 14: Annual Tritium and Gross Beta Concentrations in Off-Site
Surface Waters - 1997**

Location	Tritium (Bq/L)	Gross Beta (Bq/L)
Streams South & East of CRL discharging to Ottawa River:		
Spring 1, CRL Petawawa near CRL	Dry	Dry
Spring 2, CRL Petawawa near CRL	59.0 ± 2.6	< 0.028
Spring 4, CRL Petawawa near CRL	Dry	Dry
Spring 5, CRL Petawawa near CRL	Dry	Dry
Spring 6, CRL Petawawa near CRL	27.7 ± 1.4	0.036 ± 0.009
Spring 7, CRL Petawawa near CRL	32.6 ± 1.6	< 0.028
Spring, King's Beach	19.1 ± 0.7	< 0.028
Spring, Oiseau Bay	45.1 ± 0.8	< 0.028
Downey Bay Creek	25.1 ± 0.8	< 0.028
Oiseau Creek	8.2 ± 0.8	< 0.028
Streams South of CRL (Hwy 17) discharging to Maskinonge & Chalk Lakes:		
Chalk River at Highway 17	15.0 ± 1.1	< 0.023
Little Tucker Creek	19.6 ± 1.0	0.029 ± 0.007
Big Tucker Creek	21.8 ± 2.8	0.032 ± 0.007
Black Duck Creek, Highway 17	25.3 ± 1.4	0.047 ± 0.008
Streams West of CRL discharging to Ottawa River upstream:		
King's Road Creek at Highway 17	23.2 ± 2.6	0.039 ± 0.008
Kennedy Creek at Wylie Road	19.9 ± 0.6	< 0.023
Kennedy Creek at Highway 17	15.7 ± 1.6	0.038 ± 0.008
Kennedy Creek, Welsh's Bay	17.8 ± 1.1	0.032 ± 0.007
Balmer Bay Creek	29.9 ± 2.2	< 0.023
Spring Creek at Highway 17	19.1 ± 2.3	0.033 ± 0.007
Average of Off-Site Streams	24.9	0.031

Figure 6

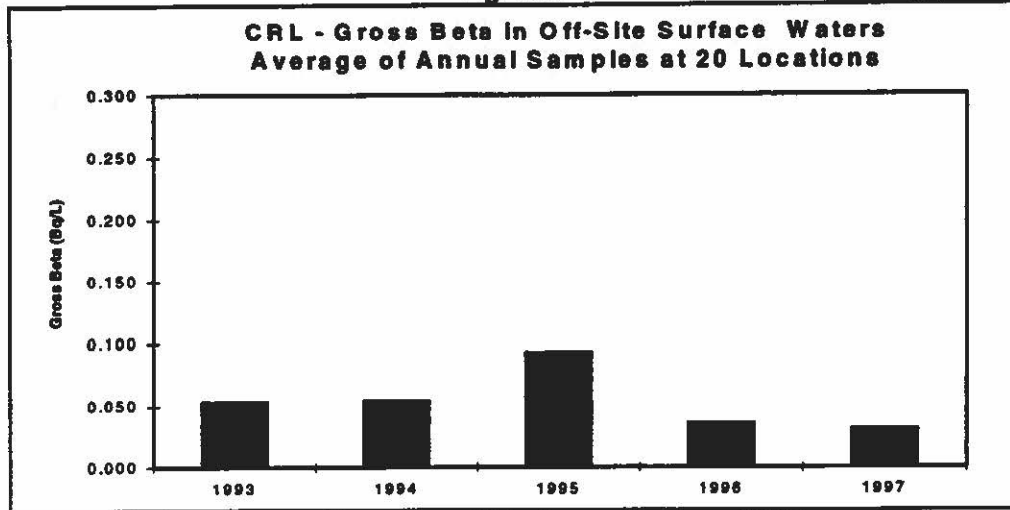
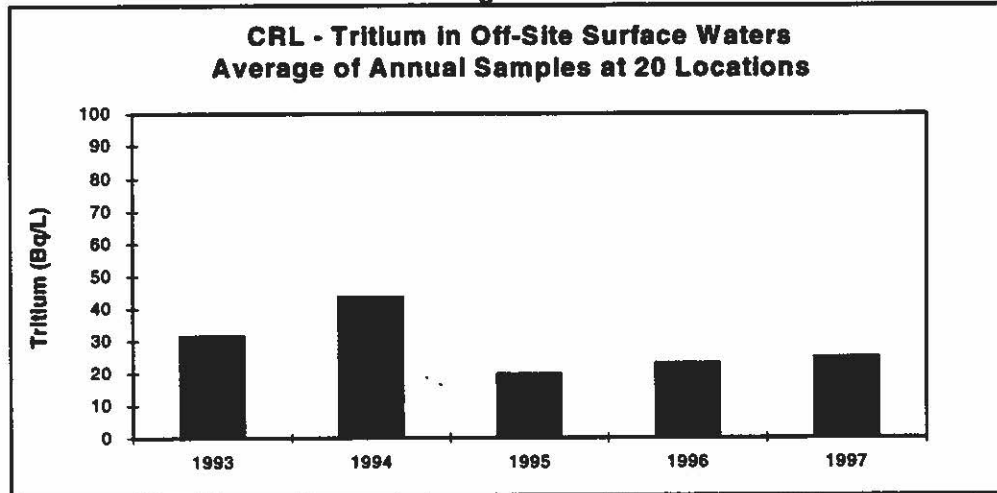


Figure 7



2.11 Radioactivity in Ottawa River

2.11.1 Water

Ottawa River water was sampled daily at pumping stations upstream of CRL at Rolphton (upstream of the decommissioned NPD nuclear generating station), Deep River, and downstream of the CRL site at Pembroke. Monthly composite samples were analyzed for tritium, gross beta, strontium-90 and gamma emitters. Weekly samples were collected at Point au Bapteme near the downstream boundary of the CRL site, and monthly composites were analysed for tritium and gross beta activities.

Table 15 provides annual mean and maximum monthly concentrations of radionuclides in the Ottawa River water at these locations in 1997, along with current values of the Canadian MACs [8] for these radionuclides in drinking water for general comparison purposes. Results of an annual verification sample 8 km downstream from CRL are also included. Figures 8, 9, and 10 depict the annual average concentrations of tritium, strontium-90 and caesium-137 upstream and downstream of CRL for the past 10 years. Downstream concentrations were slightly higher than upstream values due to emissions from CRL, but all were well below 1% of the MACs [8]. Results in 1997 were generally comparable with results for the past five years.

**Table 15: Radioactivity in Ottawa River Water
Annual Mean Concentration --1997**

Sample Location	Radionuclide	Average (Bq/L)	Maximum (Bq/L)	Month
Rolphton--Monthly composites of daily samples (28 km upstream)				
	Tritium	3.2	4.1	Jan
	Caesium-137	0.002	0.005	Jun
	Strontium-90	0.009	0.015	Nov
	Gross Beta	0.040	0.056	Nov
Deep River--Monthly composites of daily samples (9 km upstream)				
	Tritium	3.9	6.0	Sep
	Caesium-137	0.001	0.003	Mar
	Strontium-90	0.007	0.013	Jul
	Gross Beta	0.034	0.046	Oct
Pte. au Bapteme--Monthly composites of weekly samples (CRL downstream boundary)				
	Tritium	504	4400	Apr
	Gross Beta	0.459	0.968	Feb
Highview--Annual Sample (8 km downstream)				
	Tritium	10.4		Aug
	Gross Beta	0.011		Aug
Pembroke--Monthly composites of daily samples (28 km downstream)				
	Tritium	9.8	16.0	Apr & Jun
	Caesium-137	0.004	0.006	Jun
	Strontium-90	0.012	0.019	Nov
	Gross Beta	0.039	0.054	Feb

NOTE: For comparison, the current Canadian Maximum Acceptable Concentrations (MACs) for radionuclides in drinking water [8], based on 10% of the ICRP recommended annual dose limit for members of the public, 1 mSv [11] are:

Tritium: 7000 Bq/L
 Caesium-137: 10 Bq/L
 Strontium-90: 5 Bq/L
 Gross Beta (assuming Sr-90): 5 Bq/L

Figure 8

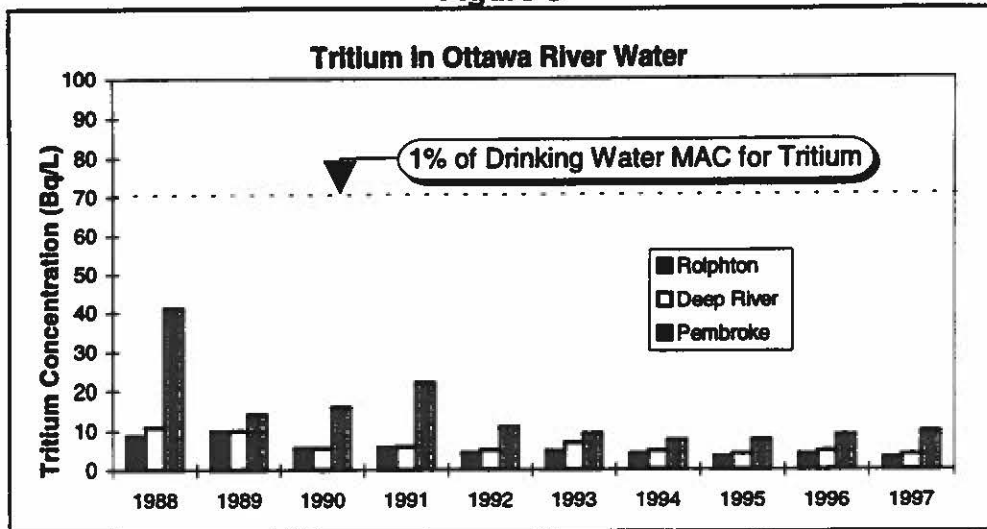


Figure 9

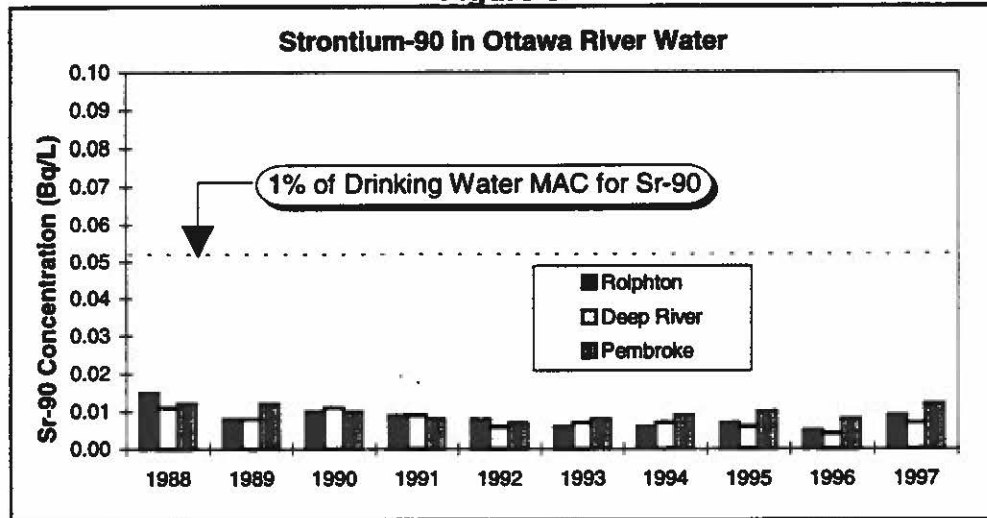
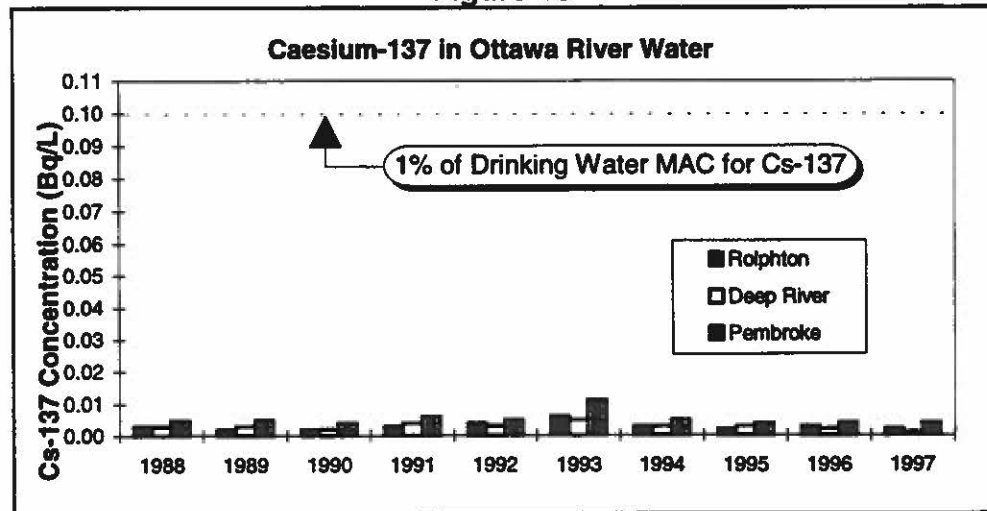


Figure 10



2.11.2 Fish

Fish samples (Walleye, Northern Pike, Small Mouth Bass) were collected from the Ottawa River at locations upstream (that is, above the Rolphton dam) and downstream from CRL. The fish muscle tissue was dried and ground for gamma spectrometry and phosphorus-32 analysis. An aliquot was ashed for gross beta activity and alpha activity analyses. After chemical separation of phosphorus, the samples were counted for radiophosphorus using liquid scintillation method. All results were corrected for the decay time between sample collection and radioactivity measurements.

A summary of the monitoring results is in Table 16 along with average values from the three previous years. 1997 results were comparable with previous years. Naturally occurring potassium-40 (not attributable to CRL operations) was present at similar concentrations in the upstream and downstream samples, and represented the majority of radioactivity in the fish. Phosphorus-32 was detected in downstream samples and was attributable to CRL operations. Cs-137 was detectable in upstream and downstream samples and was somewhat elevated compared with 1996 results. Cs-137 concentrations in downstream samples were slightly elevated over the upstream samples. Cs-134 was detectable in some downstream samples. Activities of other gamma emitting isotopes were less than the detection limit. Results from gross alpha analysis were less than or only marginally above detection limits.

2.11.3 Beach Sediment

Sediment samples from various public beaches on the Ottawa River were sampled and analyzed for gamma emitting radionuclides using gamma spectrometry. At each location, a composite sample of surface sand (0 to 3 cm deep) was collected in the region between low and high water level representative of typical occupancy. The results of the analyses are in Table 17.

Naturally occurring potassium-40 was by far the dominant radionuclide, with downstream concentrations comparable to those upstream as expected. Concentrations of caesium-137, caesium-134 and cobalt-60 were slightly elevated close to CRL, and decreased further downstream.

Table 16: Radioactivity in Ottawa River Fish – 1997

Location Species (#samples)		Length (cm)	Cs-134 (Bq/kg wet wt)	Cs-137 (Bq/kg wet wt)	K-40 (Bq/kg wet wt)	Gross Beta (Bq/kg wet wt)	P-32 (Bq/kg wet wt)	Gross Alpha (Bq/kg wet wt)
Above Rolphton (Deux Rivieres)								
Walleye (4)	1997 Avg.	27	< 1.46	11.3 ± 0.43	140 ± 5.95	139 ± 4.63		0.10 ± 0.13
	Range	22 - 29		9.13 - 13.1	133 - 145	133 - 145		< 0.7 - 0.21
	1996 Avg.		< 0.35	14.6 ± 0.4	131 ± 4.6	145 ± 10		< 2.5
	1994 Avg.		< 0.53	14.0 ± 2.8	124 ± 15	126 ± 35		
Petawawa Area (Highview), 9 km downstream								
Walleye (7)	1997 Avg.	38	4.61 ± 0.23	34.7 ± 0.71	153 ± 5.63	141 ± 4.07	1.25 ± 0.10	0.09 ± 0.18
	Range	29 - 48	1.40 - 6.40	5.60 - 46.9	144 - 158	121 - 168	0.88 - 1.65	< 0.03 - 0.30
	1996 Avg.		1.00 ± 0.40	34.5 ± 0.8	168 ± 7	168 ± 11	8.2 ± 0.2	< 3.6
	1995 Avg.		< 0.23	23.7 ± 3.7	141 ± 4	127 ± 15	0.8	< 0.64
	1994 Avg.		1.10 ± 0.37	26.3 ± 2.0	135 ± 16	136 ± 16		< 0.2
Westmeath Area (Waltham), 42 km downstream								
Walleye (1)	1997	33	< 2.99	26.9 ± 0.81	151 ± 6.6	131 ± 4.48	1.71 ± 0.11	0.10 ± 0.12
	Smallmouth Bass (4)	32	< 1.52	16.1 ± 0.48	109 ± 4.79	134 ± 3.95		< 0.4
	Range	28 - 35		3.74 - 24.3	19 - 150	118 - 155		< 0.03 - < 0.05
Northern Pike (2)	1997 Avg.	46	2.54 ± 0.20	26.8 ± 0.61	120 ± 4.90	126 ± 4.16		0.11 ± 0.13
	Range	40 - 52	< 1.87 - 3.22	24.5 - 29.0	109 - 132	124 - 128		0.05 - 0.17
	1996 Avg.		< 0.84	22.9 ± 0.6	115 ± 5.1	116 ± 7.0	3.1 ± 0.30	< 2.8
	1995 Avg.		< 0.40	29.4 ± 3.0	148 ± 14.7	148 ± 32.4		< 0.45
	1994 Avg.		< 1.00	30.4 ± 5.4	138 ± 5.7	144 ± 11.3		< 0.2

For P-32 analyses, 6 walleye from the Petawawa area and 3 walleye from the Westmeath area were analysed separately.

Table 17: Radionuclide Concentrations in Ottawa River Beach Sediments -- 1997

	Beach Location	Total Gamma Activity (Bq/kg)	Cs-134 (Bq/kg)	Cs-137 (Bq/kg)	Co-60 (Bq/kg)	K-40 (Bq/kg)
Upstream of CRL:						
1	Pine Point, Deep River	447	< 0.2	1.3 ± 0.1	< 0.2	422 ± 6.2
2	Lamure Beach, Deep River	417	0.6 ± 0.1	2.3 ± 0.2	< 0.3	355 ± 5.4
3	Indian Point, PQ	435	< 0.2	4.0 ± 0.2	< 0.2	407 ± 6.0
4	Cook's Cove, PQ	580	< 0.3	6.5 ± 0.2	< 0.3	554 ± 8.1
	Upstream Average - 1997	470	0.6	3.5	< 0.3	435
	1996	636	0.4	5.2	< 0.3	604
	1995	563	< 0.2	4.2	< 0.3	515
	1994	582	< 0.3	4.7	< 0.4	538
CRL Downstream Boundary:						
5A	Pte au Bapteme, Upstream	880	1.5 ± 0.2	57.2 ± 0.7	4.4 ± 0.2	791 ± 11.2
5B	Pte au Bapteme, Downstream	647	0.7 ± 0.1	38.3 ± 0.5	1.9 ± 0.2	562 ± 8.1
	Pte au Bapteme Average - 1997	764	1.1	47.8	3.2	677
	1996	697	0.4	44.9	2.5	614
Downstream of CRL:						
6	Oiseau Point, PQ, 5 km Downstream	598	0.2 ± 0.1	15.2 ± 0.2	0.6 ± 0.1	562 ± 8.1
7	King's Beach, 10 km Downstream	575	< 0.3	11.9 ± 0.2	0.2 ± 0.1	540 ± 8.0
8	Fort William, PQ	545	< 0.2	12.2 ± 0.2	0.2 ± 0.1	519 ± 7.6
9	Petawawa Point, Petawawa	904	< 0.3	4.6 ± 0.2	< 0.4	855 ± 12.1
10	Riverside Park, Pembroke	659	< 0.4	4.0 ± 0.2	< 0.3	614 ± 8.9
	Downstream Average - 1997	656	0.2	9.6	0.3	618
	1996	725	0.4	10.6	0.4	680
	1995	762	0.3	11.8	< 0.4	699
	1994	724	< 0.4	11.0	< 0.3	679

2.12 Meteorological Conditions

Meteorological conditions at the CRL site and surrounding areas were continuously monitored using instrumentation mounted on a meteorological tower at Perch Lake and on top of building 456 within the CRL Controlled Area 1 (formerly Inner Area). Monitoring at Perch Lake is at 30 m and 60 m levels.

Tables 18, 19, and 20 summarize the results for 1997. Appendix 3 shows the 1997 annual windrose diagrams (wind direction and speed) for the monitored locations. The data at the Perch Lake Tower is representative of conditions at the reactor stack that is on a ridge about one km from the Ottawa River. The data at the top of building 456 is representative of conditions at the stack and roof vents within the CRL Controlled Area 1 and Controlled Area 2 (formerly Active Area) closer to the river. The diagrams follow the meteorological convention indicating the direction from where the wind is blowing. The Ottawa River valley strongly channels the winds at both monitoring locations.

Much of the meteorological data for 1997 were affected by an instrumentation problem which affected the windspeed and wind direction calibrations, and was not discovered until the entire year data set were reviewed early in 1998. The data have been adjusted to attempt to account for the error, but there remains some uncertainty about accuracy of the windrose data.

Table 18: CRL Wind Direction -- Frequency Distribution in 1997

#	Windrose Sector (wind from)	Degrees	Perch Lake	Perch Lake	Building 456
			60m	30m	Roof
1	N	0	0.035	0.026	0.015
2	NNE	22.5	0.028	0.031	0.026
3	NE	45	0.029	0.028	0.025
4	ENE	67.5	0.034	0.031	0.042
5	E	90	0.059	0.051	0.030
6	ESE	112.5	0.086	0.099	0.042
7	SE	135	0.089	0.087	0.114
8	SSE	157.5	0.039	0.030	0.034
9	S	180	0.017	0.014	0.013
10	SSW	202.5	0.018	0.015	0.009
11	SW	225	0.023	0.021	0.011
12	WSW	247.5	0.051	0.052	0.037
13	W	270	0.097	0.111	0.077
14	WNW	292.5	0.240	0.242	0.104
15	NW	315	0.097	0.042	0.171
16	NNW	337.5	0.019	0.011	0.032
Calm	-	-	0.039	0.111	0.218

Table 19: CRL Wind Speed Class - Frequency of Occurrence in 1997

Class # Wind Speed (km/h)	WIND SPEED CLASS							Total
	1 0-1.5	2 1.5-6.0	3 6.1-12.0	4 12.1-20.0	5 20.1-30.0	6 30.1-39.0	7 >39	
Perch Lake 60m	0.039	0.156	0.318	0.352	0.126	0.008	0.000	1.000
Perch Lake 30m	0.111	0.275	0.378	0.204	0.033	0.000	0.000	1.000
Building 456	0.218	0.185	0.281	0.222	0.089	0.006	0.000	1.000

Table 20: CRL Stability Class – Frequency And Mean Wind Speed in 1997

	STABILITY CLASS						Total
	A	B	C	D	E	F	
Perch Lake 60m							
Frequency	0.203	0.049	0.088	0.241	0.278	0.141	1.000
Mean Wind Speed	13.4	11.2	12	13.6	12.4	9	
Perch Lake 30m							
Frequency	0.312	0.077	0.126	0.225	0.171	0.089	1.000
Mean Wind Speed	9.6	8.8	9.2	9.2	7.8	1.5	
Building 456							
Frequency	0.154	0.058	0.149	0.290	0.176	0.174	1.000
Mean Wind Speed	9.2	9.8	11.1	12.7	7.6	2.3	

2.12.1 CRL Atmospheric Dispersion Coefficients

The atmospheric dispersion coefficient (or dilution factor), which relates the concentration of a radionuclide in air at a location downwind of a source to the rate of release of that radionuclide to the atmosphere from that source, is a key parameter in the calculation of Derived Release Limits (DRLs) for all airborne effluent exposure pathways. In order to verify values for atmospheric dispersion coefficients assumed in DRL calculations for CRL, two separate and diverse sets of 1997 environmental monitoring data were compared with CRL site emissions during 1997 to assess the actual atmospheric dispersion at three key locations:

- a) Balmer Bay - the location of the nearest permanent resident outside the CRL boundary in the direction of the dominant upriver windrose direction, and location of the of-site "critical group" in the current DRL report for the CRL site [4]. The value of the annual average dispersion coefficient for this location assumed in the current DRL report is 5.0E-08 s/m³. The value assumed in the proposed new DRL for the CRL site [13], following re-evaluation of this parameter is 1.9E-07 s/m³.
- b) Harrington Bay - south-east of the CRL plant site on the opposite shore of the Ottawa River at location of the nearest seasonal residents in the dominant downriver windrose direction. The current DRL report does not provide a value for atmospheric dispersion at this location. The proposed new DRLs for CRL assume a dispersion coefficient of 5.5E-08 s/m³ applicable at this location and assumed for permanent residents at somewhat greater downwind distance.
- c) Building 560 (CRL "Low Background building") - located at the CRL westerly property boundary at the Plant Road, near the Village of Chalk River. The current DRL report does not provide a value for atmospheric dispersion at this location. The proposed new DRLs for CRL assume a dispersion coefficient of 4.6 E-08 s/m³ applicable at this location.

GammaTracer data on ambient radiation dose in air contribution from noble gas emissions from the CRL site were used in conjunction with data on Argon-41 emissions from CRL during 1997 as one means of determining the atmospheric dispersion coefficients. The atmospheric dispersion coefficient was calculated using the CSA N288.1 [6] model expression for external exposure to a semi-infinite cloud of radioactive material (Appendix E3 of [6]), modified by adding a finite cloud correction factor (from Figure E3 of [6]) to provide a conservative result.

$$D_s \text{ (Gy/s)} = 6.195\text{E-}14 * E_\gamma * \chi * \text{FCCF}$$

Where: E_γ = gamma energy per disintegration (MeV) (= 1.28 for Argon-41)

χ = air concentration of radionuclide at receptor (Bq/m³)
 = $R * \exp(-\lambda T) * P_{01} / 6.05\text{E+}05$

FCCF = finite cloud correction factor (= ~ 0.8 for Argon-41 at >= - 6 km)

R = Release rate of radioactive material (Argon-41) from source (Bq/week)

λ = Radioactive decay constant for Argon-41 = 0.38 (h⁻¹)

T = Transport time from source to receptor (h) = distance / mean wind speed
 (mean wind speed ~ 12 km/h)

P_{01} = Atmospheric dispersion coefficient (s/m³)

6.05E+05 = time units conversion factor (seconds/week)

To convert Gamma Tracer data from units of ambient dose equivalent (H*10) to absorbed dose in air (air kerma (Gy), a conversion factor of 1.2 Sv (H*10)/Gy has been used [14]. Thus:

$$D_a \text{ (Gy/s)} = D_{GT} \text{ (Sv(H*10)/h)} / \{1.2 \text{ (Sv(H*10) / Gy)} * 3600 \text{ (s/h)}\}$$

Table 21: CRL Atmospheric Dispersion Coefficients Based on Ambient Gamma Dose-In-Air Data

Period 1997	Avg. Ar-41 Emissions in period (Bq/week)	1997 GammaTracer Dose-In-Air Contribution From CRL (nSv*/h)			Calculated Atmospheric Dispersion Coefficient P ₀₁ (s/m ³)		
		Balmer Bay	Harrington Bay	Bldg 560 (Chalk River)	Balmer Bay	Harrington Bay	Bldg 560 (Chalk River)
		<i>Distance From Stack (km)</i>			<i>6</i>	<i>11</i>	<i>6</i>
		<i>Bearing (deg.)</i>			<i>308</i>	<i>128</i>	<i>234</i>
1st Quarter	4.4E+14	14.8	5.3	2.0	8.9E-08	3.8E-08	1.2E-08
2nd Quarter	3.8E+14	13.5	6.4	2.0	9.5E-08	5.3E-08	1.4E-08
3rd Quarter	3.6E+14	14.5	7.2	1.0	1.1E-07	6.2E-08	7.0E-09
4th Quarter	3.1E+14	11.4	2.5	1.6	9.8E-08	2.5E-08	1.3E-08
'97 Average	3.7E+14	13.5	5.4	1.5	9.7E-08	4.6E-08	1.1E-08

* GammaTracer Results are expressed as Ambient Dose Equivalent (H*10) [11]

The second method used for assessing atmospheric dispersion was to compare the ambient tritium in air concentrations measured at these locations in 1997 using passive tritium samplers, with the total monitored airborne tritium emissions from the site in 1997. The average dispersion coefficient over a monitoring period is taken to be:

$$P_{01} \text{ (s/m}^3\text{)} = (C - C_0) * 6.05E+05 / R$$

Where: C = Average ambient tritium in air concentration at location (Bq/m³)

C₀ = Normal background tritium concentration (~ 0.2 Bq/m³ assumed).

R = Average tritium release rate during period (Bq/week)

6.05E+05 = time units conversion (seconds/week).

Table 22: CRL Atmospheric Dispersion Coefficients Based on Ambient Tritium-In-Air Data

Period		Q1-1997	Q2-1997	Q3-1997	Q4-1997	1997 Avg
CRL Airborne Tritium Releases	Bq/week	3.9E+12	5.5E+12	5.4E+12	3.5E+12	4.6E+12
Ambient Average Tritium In Air Concentration (Bq/m³)						
MONITORING LOCATION	CODE					
Ball Diamond (Chalk River)	H4	0.25	1.01	0.31	0.26	0.46
Balmer Bay	H8	0.57	1.54	1.36	0.67	1.04
Harrington Bay, PQ	H15	0.47	1.23	0.89	0.31	0.73
Calculated Atmospheric Dispersion Coefficient (s/m³)						
Ball Diamond (Chalk River)	H4	7.8E-09	1.3E-07	1.7E-08	9.3E-09	4.0E-08
Balmer Bay (Sawchuk)	H8	5.7E-08	2.1E-07	1.8E-07	7.3E-08	1.3E-07
Harrington Bay, PQ	H15	4.2E-08	1.6E-07	1.1E-07	1.7E-08	8.1E-08

Both methods of estimating the atmospheric dispersion coefficient at these locations gave similar results. As previously indicated [9] the estimated value for Balmer Bay is greater than the value used in the existing DRL report, but values for all sites are generally consistent with the revised dispersion values assumed for the proposed new DRLs [13]. The results confirmed, consistent with CRL windrose frequencies, that the largest value is at Balmer Bay, with progressively lesser values at Harrington Bay and Chalk River.

3. WL ENVIRONMENTAL MONITORING PROGRAM AND RESULTS FOR 1997

3.1 WL Site Location

The Whiteshell Laboratories (WL) site is located in southeastern Manitoba on the east shore of the Winnipeg River, about 100 km northeast of Winnipeg. Nearby communities include Lac du Bonnet, Pinawa and Seven Sisters.

3.2 WL Environmental Monitoring Program

At WL, the Environmental Monitoring Program includes the following:

- a) Monitoring of airborne effluent exposure pathways
 - meteorological conditions,
 - ambient gamma radiation,
 - land gamma radiation,
 - atmospheric deposition of radioactive material, and
 - radioactivity in vegetation near site boundary.

- b) Monitoring of liquid effluent exposure pathways
 - radioactivity in Winnipeg River water,
 - radioactivity in fish from the Winnipeg River
 - radioactivity in river bottom sediment in the Winnipeg River,
 - radioactivity in vegetation within the site, and
 - radioactivity in surface waters within the site.

Sampling locations for this monitoring are shown on maps in Appendix 2. Results of the monitoring during 1997 are presented in the following sections, 3.3 through 3.8. Dose estimates to members of the critical group off-site, based on the environmental monitoring results are in Section 4.

3.3 Ambient Gamma Radiation in Air

AECL's monitoring stations were as follows: 4 ambient gamma radiation monitoring stations within WL Controlled Area 2 -- on the North, East, South and West sections of the security fence; 5 stations near the perimeter of WL site, their locations depending on the predominant wind directions; and 3 stations outside the WL site, in the town of Pinawa, at the Pinawa town yard, Kelsey House and the Pinawa Hospital. Since WL no longer has any operating nuclear reactors, there are no emissions of noble gases (as in the case of CRL) which could contribute measurably to ambient dose in air. This monitoring now serves basically as a gross trend indicator for historical purposes and for emergency preparedness reasons.

At the monitoring stations, thermoluminescent lithium fluoride (LiF) dosimeters (TLDs) continuously measured the integrated exposure from natural background radiation and airborne radioactive material releases. All TLDs were placed 1 m above the ground and the monitoring period for each TLD was the entire calendar year. The results for 1997 are in Tables 23 and 24. Results include natural background radiation due to terrestrial and cosmic sources. (Unlike the CRL TLD monitoring program in which subtraction of control TLD results in removing the cosmic ray component from the reported results.) Natural background radiation levels, measured in 1964 as part of the pre-operational environmental survey of the area, ranged from 0.08 to 0.14 $\mu\text{Gy/h}$ (0.7 to 1.2 mGy/a). Figure 11 shows the mean values for ambient gamma radiation in air at several locations at the WL site and at Pinawa for the years 1993 to 1997. TLD readings for 1997 were marginally higher than for 1996. However, even the highest readings are about the same as the pre-operational background referred to above. Consequently, it can be concluded that there is no other significant radiation source contributing gamma radiation in air, other than naturally occurring sources.

**Table 23: Gamma Radiation in Air at WL Perimeter
Total Gamma Dose**

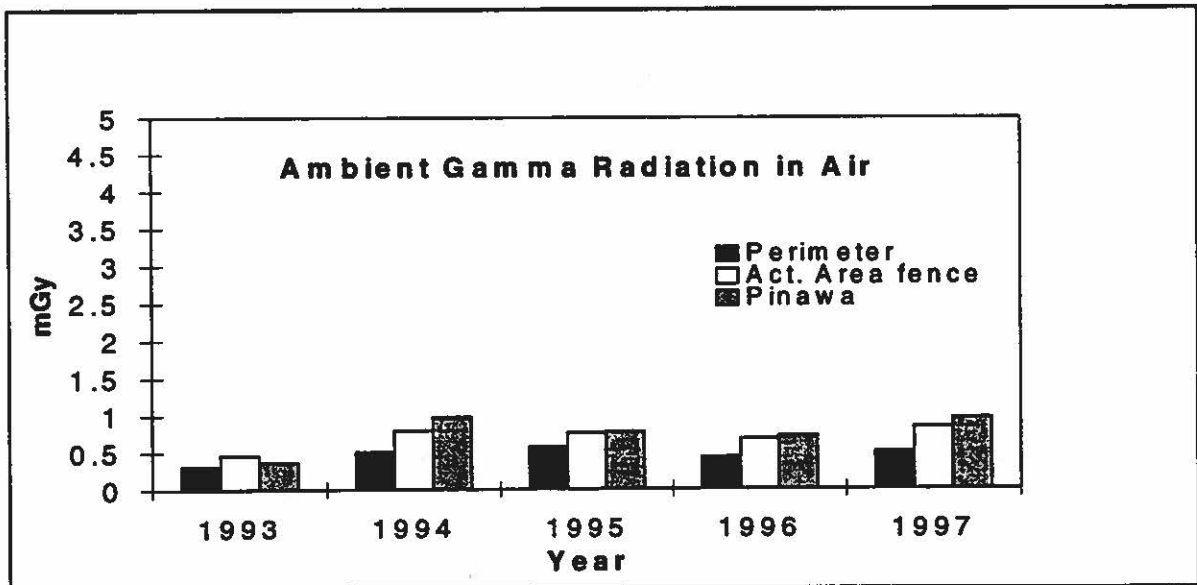
<i>Location</i>	1997 (mGy/a)
Perimeter	
ARMS*1, North	0.719
ARMS 2, ESE	
ARMS 3, SSE	0.636
ARMS 4, West	0.628
ARMS 5, North West	0.540
Mean	0.631
Pinawa	
Town Yard	0.831
Kelsey House	1.173
Hospital	0.877
Mean	0.960

*Ambient Radiation Monitoring Station (ARMS)
ARMS 2 data not available because of vandalism

Table 24: Gamma Radiation in Air at WL Controlled Area 2 Fence

<i>Location</i>	1997 (mGy/a)
South Fence	0.634
East Fence	0.771
North Fence	0.874
West Fence	1.079
Mean	0.840

Figure 11



3.4 Land Gamma Radiation

The dose rate due to ambient gamma radiation was measured once during the year at control points located on road routes along a 16 km radius surrounding the WL site. A hand-held AEP 5302 low-range gamma monitor was used and the measurements were made from a slow moving vehicle. Results for the years 1992 to 1997 are in Table 25. The results for 1997 are similar to those for previous years.

**Table 25: Land Gamma Radiation Near WL
Mean Gamma Dose Rate in Air**

LOCATION	1992 ($\mu\text{Gy/h}$)	1993 ($\mu\text{Gy/h}$)	1994 ($\mu\text{Gy/h}$)	1995 ($\mu\text{Gy/h}$)	1996 ($\mu\text{Gy/h}$)	1997 ($\mu\text{Gy/h}$)
PUBLIC AREA (16 KM ROUTE)						
Plant Road & Hwy. 211	0.090	0.120	0.060	0.100	0.120	0.110
Hwy. 211 and Rifle Range	0.100	0.090	0.070	0.110	0.110	0.120
Pinawa Stage 1	0.100	0.120	0.070	0.140	0.130	0.110
Pinawa Stage 2	0.110	0.110	0.070	0.130	0.140	0.120
Junction Hwy. 11 and Hwy. 307	0.080	0.080	0.050	0.090	0.150	0.110
Bridge to Seven Sisters	0.090	0.120	0.060	0.110	0.120	0.130
Town Circuit at Dam	0.110	0.090	0.050	0.110	0.130	0.120
Junction Hwy. 214 and Hwy. 11	0.090	0.110	0.080	0.060	0.080	0.100
Lac du Bonnet Circuit	0.100	0.070	0.090	0.080	0.090	0.090
West Side of LDB Bridge	0.080	0.080	0.110	0.090	0.080	0.110
Hwy. 520 at Old Pinawa	0.090	0.080	0.140	0.110	0.130	0.140
Riverland School	0.110	0.070	0.120	0.110	0.120	0.120
Road at ARMS #1	0.100	0.090	0.140	0.130	0.150	0.120
WL SITE						
Bldg. 401 into Controlled Area 2	0.120	0.110	0.080	0.090	0.110	0.120
Road South side of 300	0.130	0.120	0.120	0.090	0.130	0.190
Road West side of 300	0.100	0.110	0.120	0.070	0.150	0.130
South side of 200 & 411	0.200	0.180	0.230	0.130	0.400	0.190
East of 100	0.130	0.100	0.190	0.070	0.140	0.140
East gate	0.130	0.100	0.130	0.090	0.100	0.110
North Rd. at Lagoon Rd.	0.120	0.100	0.120	0.060	0.120	0.090
Rd. East of Canister Area	0.100	0.200	0.190	0.100	0.160	0.170
East Rd. at WMA Gate	0.110	0.220	0.110	0.120	0.200	0.180
East Rd. at Landfill site	0.110	0.080	0.120	0.060	0.100	0.090

3.5 Atmospheric Deposition of Radioactive Material

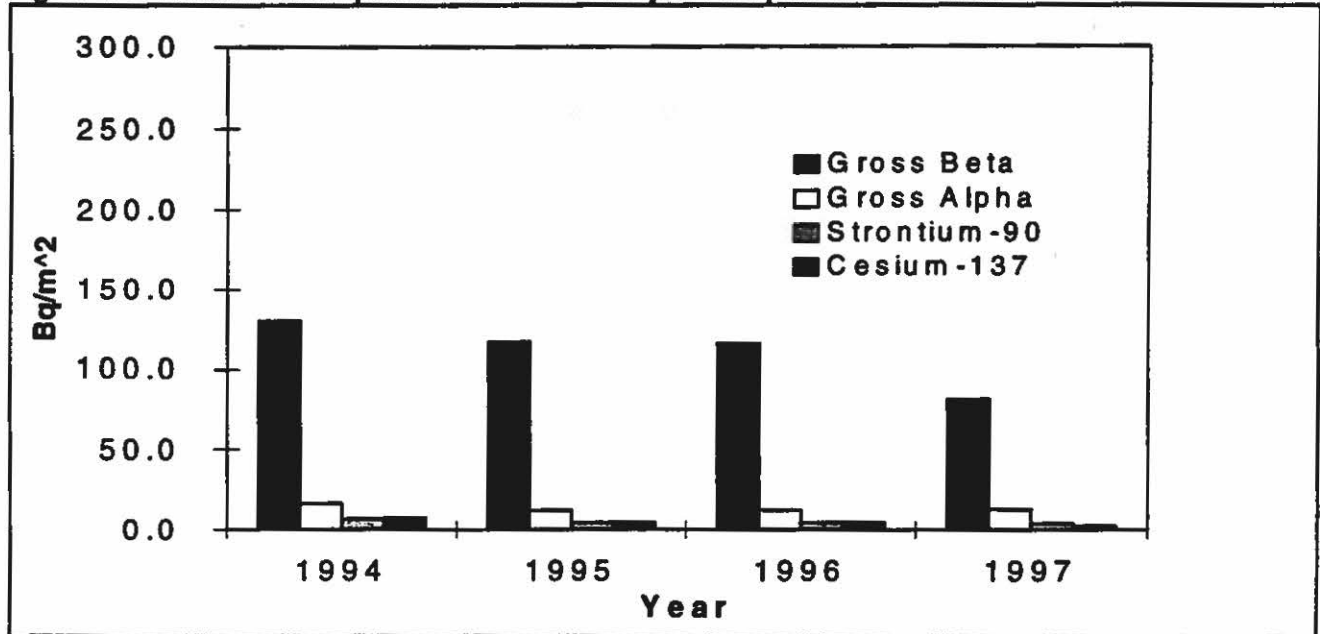
Atmospheric deposition of radioactive material in precipitation was measured at one location about 9 km east of WL and 2 km west of Pinawa. Rainfall was collected in a lined container mounted 1 m above the ground. Snowfall was collected on aluminium sheets at ground level or in lined rainfall containers. The samples were analyzed monthly for gross beta, gross alpha, strontium-90, and caesium-137. Results for the years 1994 to 1997 are shown in Table 26 and Figure 12. The 1997 results are slightly decreased from previous years.

Table 26: Atmospheric Deposition of Radioactivity in Precipitation at Pinawa

Year	Total Annual Deposition (Bq/m^2)			
	1994	1995	1996	1997
Gross Beta	130	117	115.9	81.4
Gross Alpha	16.4	12.2	12.4	13.0
Strontium-90	6.7	4.5	4.4	4.0
Cesium-137	7.4	4.7	4.5	2.7

NOTES: (1) Strontium-90 at equilibrium with daughter yttrium-90. (2) Two monthly values for Sr-90 in 1997 are statistical outliers and not included in calculation of annual activity.

Figure 12: Total Annual Deposition of Radioactivity in Precipitation at Pinawa.



For each year, the bars, from the left, show activity for gross beta, gross alpha, strontium-90 and caesium-137.

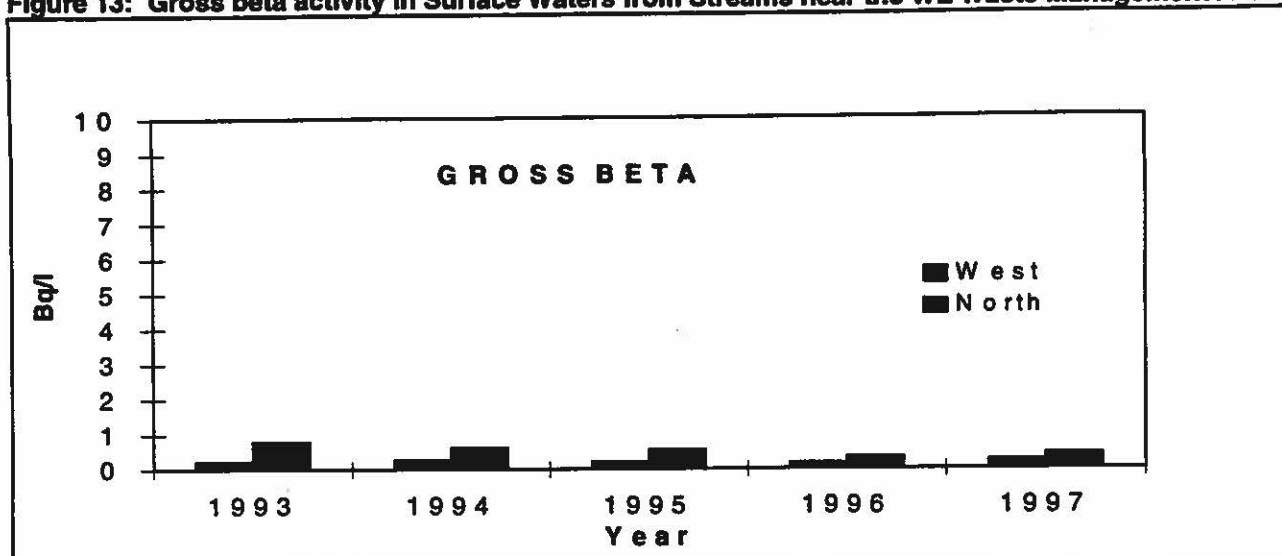
3.6 Radioactivity in Surface Waters Within the WL Site

Surface waters from the Waste Management Area (WMA) drain to a ditch that runs approximately 2 km west to the Winnipeg River (Map 4, Appendix 2). Water from the recharge area to the east of the WMA is diverted around the WMA to this westerly ditch. Another ditch that runs north to the site boundary drains the land beyond the WMA up to the site boundary. Samples were collected and analyzed monthly from both these ditches at locations indicated as #8 and #9 on Map 4 whenever sufficient runoff existed. A summary of the results is in Table 27. Figures 13 and 14 depict gross beta and gross alpha activities in drainage ditch water discharges from WMA at these two sampling locations. Results for 1997 were similar to those for previous years and decreasing.

Table 27: Annual Mean Gross Beta and Gross Alpha Radioactivity in WL Drainage Ditch Water, 1997

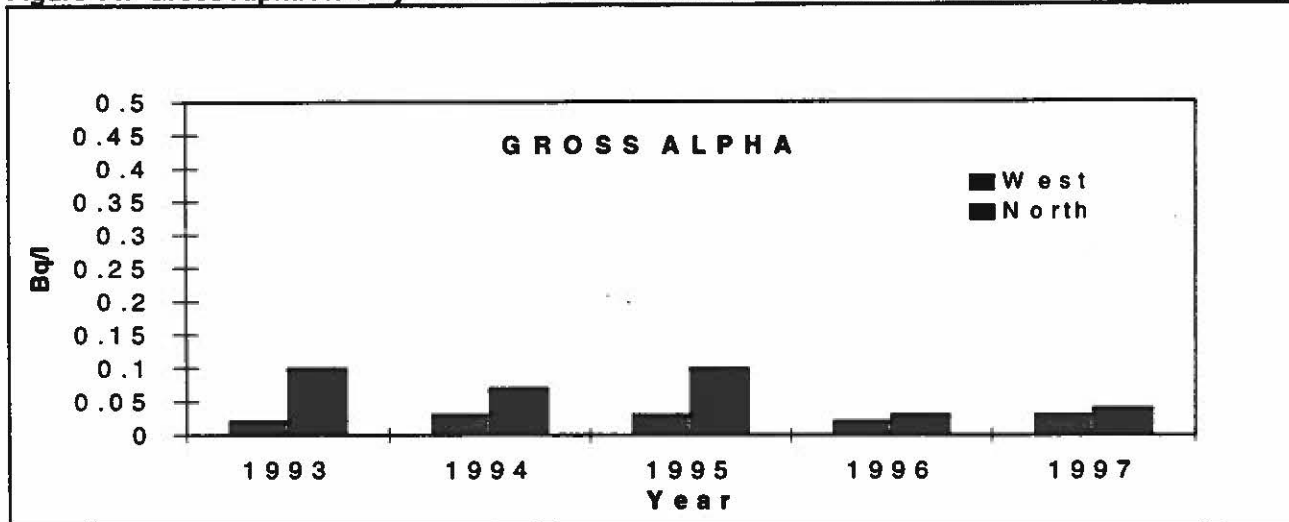
LOCATION	1997 (Bq/ L)
9 - Ditch from WMA West to Winnipeg River	
Gross Beta	0.25
Gross Alpha	0.03
8 - Ditch from WMA at North WL boundary	
Gross Beta	0.43
Gross Alpha	0.04

Figure 13: Gross beta activity in Surface Waters from Streams near the WL Waste Management Area



The left bar shows values west of the WMA, and the right bar shows values at the north WL boundary

Figure 14: Gross Alpha Activity in Surface Waters from Streams near the WL Waste Management Area



The left bar shows values west of the WMA, and the right bar shows values at the north WL boundary.

3.7 Radioactivity in Winnipeg River

3.7.1 Water

Monthly composite samples of Winnipeg River water were collected at four locations: at the Pinawa water treatment plant upstream of the WL site; 2 km downstream of the WL outfall at the site boundary; 10 km downstream at the Lac du Bonnet intake; and 28 km downstream at the Great Falls Generating Station. Before 1996, the samples were analyzed for gross beta, caesium-137, and strontium-90, and since 1996, gross alpha activity is also being monitored. Results for 1997 are in Table 28. Figures 15, 16 and 17 show the results for 1993 to 1997 for caesium-137, strontium-90 and gross beta, respectively. All concentrations were very small fractions of the maximum acceptable concentrations for radionuclides in Canadian drinking water [8], and the 1997 results were comparable with previous years' results. Concentrations downstream of WL in 1997 were not significantly different from upstream concentrations.

Measurements of the Winnipeg River flow rate, upstream of Whiteshell Laboratories at the Seven Sisters Generating Station, were provided by Manitoba Hydro. The maximum, minimum, and mean values of the flow rate in 1997 are shown in Table 29.

**Table 28: Radioactivity in Winnipeg River Water
Mean Concentration**

<i>Location</i>	1997 (Bq/ L)
<i>Pinawa (upstream from WL)</i>	
Caesium-137	0.002±0.001
Strontium-90	0.011±0.004
Gross Beta	0.057±0.009
Gross Alpha**	0.017±0.020
<i>Site (2 km downstream of outfall)*</i>	
Caesium-137	0.003±0.002
Strontium-90	0.011±0.005
Gross Beta	0.074±0.030
Gross Alpha**	0.014±0.007
<i>Lac du Bonnet (10 km downstream)</i>	
Caesium-137	0.001±0.001
Strontium-90	0.011±0.004
Gross Beta	0.059±0.010
Gross Alpha**	0.010±0.003
<i>Great Falls (28 km downstream)</i>	
Caesium-137	0.001±0.001
Strontium-90	0.014±0.002
Gross Beta	0.067±0.020
Gross Alpha**	0.012±0.005

* Routine monitoring 2 km downstream started in 1994.

** Monitoring started in 1996.

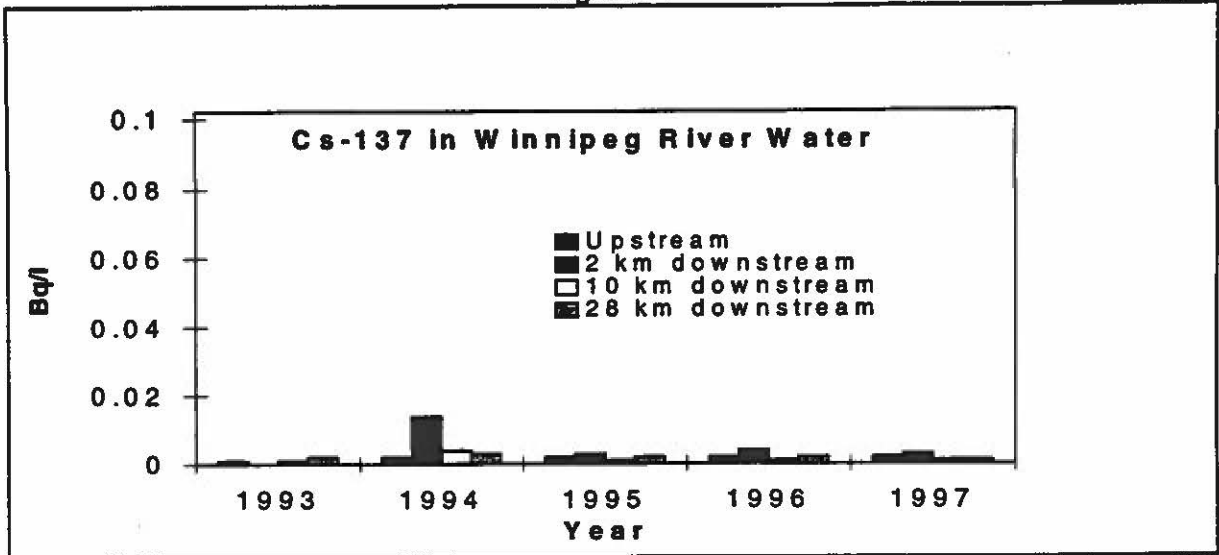
NOTE: The above results can be compared with the following current Canadian MACs for radionuclides in drinking water [8] :

Caesium-137: 10 Bq/ L
 Strontium-90: 5 Bq/ L
 Gross Beta (assuming Sr-90): 5 Bq/ L
 Gross Alpha (assuming Pu-239): 0.2 Bq/ L

**Table 29: Winnipeg River Mean Daily Flow Rate
At Seven Sisters Generating Station**

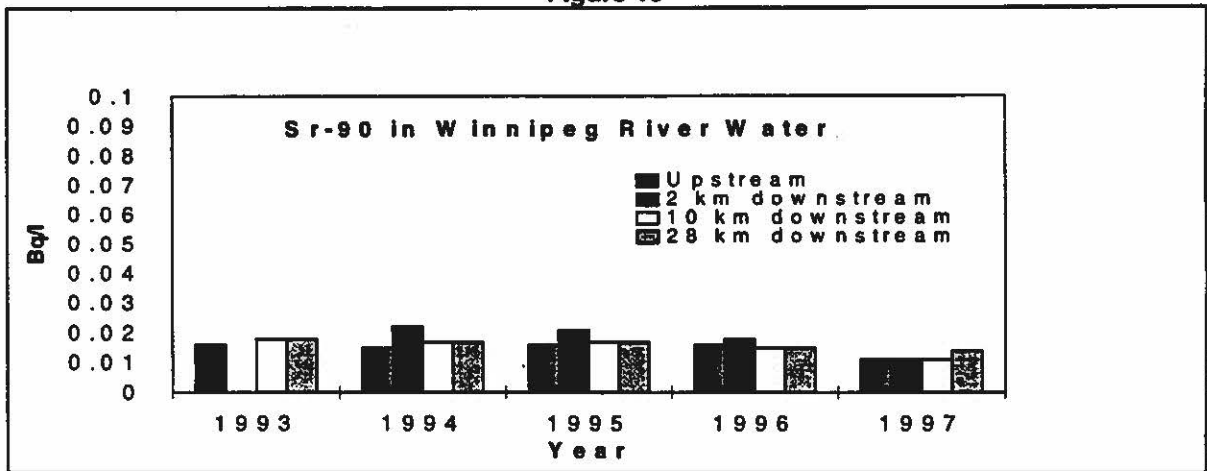
	1993 (m³/s)	1994 (m³/s)	1995 (m³/s)	1996 (m³/s)	1997 (m³/s)
High	1396	1228	1334	2011	2395
Date	Sep 28	Dec 27	Jan 14	Jun 07	May 10
Low	543	503	426	723	413
Date	Jun 15	Jun 25	Oct 9	Sep 28	Sep 30
Mean	993	884	903	1196	1109

Figure 15



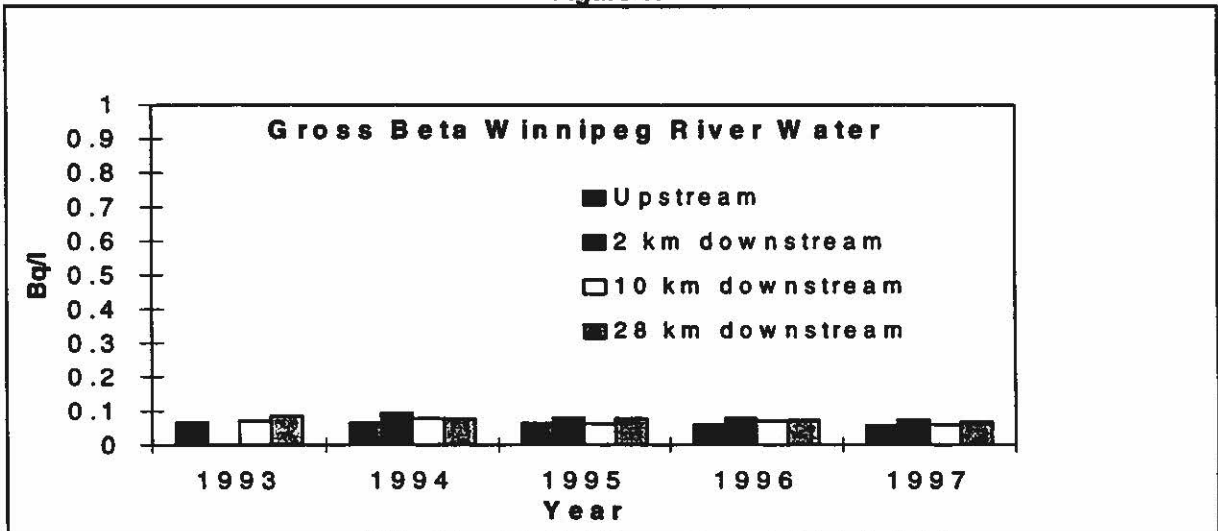
Canadian drinking water standard (MAC) for Cs-137 is 10 Bq/L.

Figure 16



Canadian drinking water standard (MAC) for Sr-90 is 5Bq/L.

Figure 17



3.7.2 Fish

Fish samples were collected annually from the Winnipeg River at locations upstream as well as downstream from WL, and the flesh was analyzed for radioactive materials. A summary of the 1997 results is in Tables 30 and 31. (Note that in 1997 no samples were collected at the location 5 km downstream of WL because of logistical difficulties caused by early freeze-up.) The 1997 results were similar to those of previous years. Caesium-137 concentrations were slightly increased in downstream samples, but were small in comparison with naturally occurring potassium-40, the dominant radionuclide in the samples. The gamma-spectrum analysis also produced data for radioisotopes other than those reported in the table, but only naturally occurring radioisotopes were detected in concentrations above trace amounts. The reported values, in Bq/kg, are for wet weight of fish flesh only. Gross alpha analysis commenced only in 1997.

Table 30: Radioactivity in Flesh of Winnipeg River Fish - 1997

LOCATION/ SPECIES	DATE	LENGTH (cm)	WEIGHT (kg)	Cs-137 Bq/Kg +/-		K-40 Bq/Kg +/-		Gross Beta Bq/Kg +/-		Gross Alpha Bq/Kg +/-	
Pinawa (Upstream of WL) White Sucker	30-Oct-97	42	1.25	0.37	0.12	131	3.53	109	7.35	<0.003	
		39	0.83	0.12	0.17	127	4.55	93	6.33	<0.003	
	30-Oct-97	45	1.25	0.18	0.14	133	3.76	111	7.59	<0.003	
		36	0.75	<0.29		113	4.37	94	6.49	<0.003	
		40	0.95	0.42	0.19	124	4.35	100	6.86	< 0.004	
	31-Oct-97	37	0.83	0.63	0.20	121	5.81	100	6.76	<0.003	
		44	1.30	0.50	0.13	122	3.42	95	6.44	<0.003	
		46	1.45	0.33	0.10	117	3.30	99	6.73	0.003	0.002
	6-Nov-97	40	1.00	0.54	0.18	135	4.66	100	6.78	<0.003	
		42	1.00	0.35	0.15	135	4.30	105	7.11	<0.003	
		38	0.70	0.27	0.22	135	5.38	100	6.80	<0.003	
			38	0.85	<u>0.39</u>	<u>0.16</u>	<u>123</u>	<u>5.32</u>	<u>98</u>	<u>6.61</u>	<u>0.003</u>
	Mean			<u>0.37</u>	<u>0.16</u>	<u>126</u>	<u>4.4</u>	<u>100</u>	<u>6.8</u>	<u>0.003</u>	<u>0.002</u>
Pickereel	30-Oct-97	27	0.20	0.47	0.37	159	7.7	117	7.8	<0.003	
		31	0.35	1.40	0.40	146	11.5	105	7.1	<0.003	
	31-Oct-97	34	0.35	1.22	0.42	139	8.3	100	6.8	<0.003	
		33	0.33	0.85	0.42	142	8.8	101	6.8	<0.003	0.002
		32	0.33	1.00	0.43	137	9.3	92	6.2	0.003	0.002
	6-Nov-97	31	0.40	<u>1.22</u>	<u>0.43</u>	<u>125</u>	<u>6.2</u>	<u>96</u>	<u>6.4</u>	<u><0.0022</u>	
	Mean			<u>1.03</u>	<u>0.41</u>	<u>141</u>	<u>8.6</u>	<u>102</u>	<u>6.9</u>	<u>0.003</u>	<u>0.002</u>
Pike	30-Oct-97	39	0.30	0.51	0.25	130	9.39	96	6.49	<0.003	
		41	0.38	0.46	0.28	143	6.91	110	7.42	<0.003	
		41	0.38	0.26	0.30	156	7.45	110	7.48	<0.003	
		42	0.50	0.69	0.24	142	5.91	103	7.03	0.003	0.002
		47	0.55	2.33	0.26	135	5.38	103	6.97	<0.003	
		38	0.30	0.64	0.27	142	10.08	93	6.31	<0.003	
		40	0.38	0.60	0.22	146	8.50	97	6.65	<0.003	
	31-Oct-97	72	1.80	1.08	0.11	119	2.95	108	7.30	<0.003	
		48	0.60	0.63	0.22	118	7.03	78	5.41	<0.003	
		46	0.55	<u>0.38</u>	<u>0.21</u>	<u>117</u>	<u>5.40</u>	<u>87</u>	<u>5.97</u>	<u><0.003</u>	
		Mean			<u>0.76</u>	<u>0.24</u>	<u>135</u>	<u>6.9</u>	<u>98</u>	<u>6.7</u>	<u>0.003</u>
Whitefish	30-Oct-97	43	1.15	0.13	0.12	134	3.85	112	7.55	<0.003	
	31-Oct-97	30	0.35	0.38	0.30	139	6.92	95	6.55	<0.003	
	6-Nov-97	35	0.55	< 0.27		<u>131</u>	<u>5.21</u>	<u>107</u>	<u>7.24</u>	<u><0.003</u>	
		Mean			<u>0.26</u>	<u>0.21</u>	<u>135</u>	<u>5.3</u>	<u>105</u>	<u>7.1</u>	<u><0.003</u>

Table 30 (continued): Radioactivity in Flesh of Winnipeg River Fish – 1997

LOCATION/ SPECIES	DATE	LENGTH (cm)	WEIGHT (kg)	Cs-137		K-40		Gross Beta		Gross Alpha		
				Bq/Kg	+/-	Bq/Kg	+/-	Bq/Kg	+/-	Bq/Kg	+/-	
0.5 Km (downstream of WL) White Sucker	16-Oct-97	41	0.90	0.82	0.24	121	6.54	88	6.03	<0.003		
		41	0.95	1.68	0.27	128	7.16	98	6.65	<0.003		
		34	0.60	0.94	0.26	115	5.65	94	6.32	<0.003		
	17-Oct-97	38	0.80	1.10	0.22	143	5.47	107	7.28	<0.003		
		29	0.35	1.20	0.34	136	8.50	89	6.11	<0.003		
		32	0.35	1.63	0.30	137	8.52	98	6.69	<0.003		
		30	0.30	<u>1.79</u>	<u>0.32</u>	<u>129</u>	<u>6.71</u>	<u>97</u>	<u>6.56</u>	<u><0.003</u>		
	Mean			<u>1.31</u>	<u>0.28</u>	<u>130</u>	<u>6.9</u>	<u>96</u>	<u>6.5</u>	<u><0.003</u>		
	Pickerel	16-Oct-97	47	1.15	2.01	0.17	142	3.93	115	7.73	<0.003	
			42	0.70	2.53	0.24	131	5.05	97	6.56	<0.003	
46			1.20	1.77	0.13	126	3.77	102	6.93	<0.003		
29			0.30	2.10	0.38	153	8.67	103	7.03	<0.003		
58			2.25	1.48	0.14	121	3.57	96	6.51	<0.003		
17-Oct-97		30	0.25	2.19	0.50	134	7.48	89	6.04	0.004	0.002	
		34	0.43	1.36	0.32	140	5.89	93	6.28	<0.003		
		33	0.35	1.51	0.41	138	6.35	88	6.00	<0.003		
		31	0.28	1.66	0.51	122	6.57	91	6.10	0.003	0.002	
		62	2.83	<u>2.15</u>	<u>0.14</u>	<u>124</u>	<u>3.17</u>	<u>104</u>	<u>7.03</u>	<u>0.005</u>	<u>0.003</u>	
Mean			<u>1.88</u>	<u>0.29</u>	<u>133</u>	<u>5.4</u>	<u>98</u>	<u>6.6</u>	<u>0.004</u>	<u>0.002</u>		
Pike	17-Oct-97	74	3.20	1.61	0.11	123	2.70	92	6.30	<0.003		
		40	0.43	1.69	0.32	126	6.64	107	7.26	0.003	0.002	
		47	1.38	1.27	0.12	128	3.29	104	7.04	<0.003		
		46	1.20	1.13	0.13	124	3.37	106	7.16	<0.003		
		65	1.80	<u>1.39</u>	<u>0.10</u>	<u>126</u>	<u>2.73</u>	<u>106</u>	<u>7.19</u>	<u><0.003</u>		
	Mean			<u>1.42</u>	<u>0.16</u>	<u>125</u>	<u>3.7</u>	<u>103</u>	<u>7.0</u>	<u>0.003</u>	<u>0.002</u>	
Whitefish	16-Oct-97	34	0.60	0.35	0.23	122	5.25	98	6.64	<0.003		
		34	0.60	0.29	0.21	130	5.12	106	7.18	<0.004		
		46	1.33	0.36	0.11	119	3.30	108	7.26	0.003	0.002	
	17-Oct-97	46	1.08	0.36	0.15	99	3.45	78	5.32	<0.003		
		47	1.20	0.31	0.11	116	3.27	90	6.14	<0.003		
		32	0.35	<u>0.59</u>	<u>0.31</u>	<u>144</u>	<u>6.41</u>	<u>94</u>	<u>6.41</u>	<u><0.003</u>		
Mean			<u>0.38</u>	<u>0.19</u>	<u>122</u>	<u>4.5</u>	<u>96</u>	<u>6.5</u>	<u>0.003</u>	<u>0.002</u>		

3.7.3 River Sediment

Annual core samples of the first centimetre of river bed sediment were taken at a number of locations between 0.7 km upstream and 13 km downstream of the WL outfall, and analyzed for radioactivity. Results for 1997 along with four previous years are in Table 32. As in the case of fish flesh analysis, gamma spectroscopy was used to scan for radioisotopes other than those reported below, however, no concentrations were detected other than for naturally occurring radioisotopes.

**Table 31: Average Radioactivity in Winnipeg River Fish
Summary 1992-1997**

Location/Year	White Sucker			Pickerel		
	Cs-137 (Bq/kg, wet weight)	K-40 (Bq/kg, wet weight)	Gross Beta (Bq/kg, wet weight)	Cs-137 (Bq/kg, wet weight)	K-40 (Bq/kg, wet weight)	Gross Beta (Bq/kg, wet weight)
Upstream of WL (Pinawa)						
1992	0.56	125	92	1.11	105	87
1993	0.42	116	91	1.32	121	96
1994	0.45	110	97	1.22	113	94
1995	0.36	100	91	0.76	112	93
1996	0.40	124	98	0.99	132	97
1997	0.37	126	100	1.03	141	102
Mean	0.43	117	95	1.07	121	95
0.5 km Downstream of WL						
1992	1.65	115	87	3.66	110	90
1993	1.84	122	96	2.04	117	90
1994	1.81	112	104	2.35	116	101
1995	2.18	99	93	2.21	112	99
1996	2.87	120	92	3.26	136	103
1997	1.31	130	96	1.88	133	98
Mean	1.94	116	95	2.57	121	97
5 km Downstream of WL						
1992	1.22	117	88	2.69	118	92
1993	1.56	120	96	2.46	122	100
1994	0.93	108	90	1.80	114	96
1995	1.41	102	93	1.90	109	97
1996	1.56	121	90	1.30	130	104
1997						
Mean	1.34	114	91	2.03	119	98
Location/Year	Pike			Whitefish		
Upstream of WL (Pinawa)						
1992	2.26	122	98	1.29	118	99
1993	0.16	115	90			
1994	0.69	114	98	0.17	118	95
1995	0.63	98	91	0.28	108	105
1996	0.66	116	90	0.58	134	105
1997	0.76	135	98	0.26	135	105
Mean	0.86	117	94	0.52	123	102
0.5 km Downstream of WL						
1992	2.54	115	90	4.28	127	87
1993	2.53	118	94	0.53	112	96
1994	2.62	103	100	0.55	111	102
1995	1.72	99	99	1.96	95	97
1996	4.63	114	99	1.56	121	90
1997	1.42	125	103	0.38	122	96
Mean	2.58	112	97	1.54	115	95
5 km Downstream of WL						
1992	2.07	112	86	0.79	120	90
1993	1.32	62	91	0.66	120	100
1994	2.08	99	86	0.60	111	105
1995	1.53	99	95	0.72	91	91
1996	1.62	118	101	0.72	120	92
1997						
Mean	1.72	98	92	0.70	112	96

NOTES: 1. No fish samples were collected in 1997 at the location 5 km downstream of WL.
2. Results reported are Bq/kg wet weight for fish flesh only.

Table 32: Radioactivity In Sediment Samples From The Winnipeg River

Loc#	Distance from Outfall (km) -Nuclide	1993 (kBq/m ²)	1994 (kBq/m ²)	1995 (kBq/m ²)	1996 (kBq/m ²)	1997 (Bq/kg)	1997 (kBq/m ²)
J04	-0.76 (upstream)						
	Gross Beta	9.40	4.82	4.27	4.39	659	4.84
	Gross Alpha	1.20	0.82	0.43	1.74	135	0.89
J02	-0.37 (upstream)						
	Gross Beta	6.62	1.72	8.14	6.33	609	7.12
	Gross Alpha	1.93	0.37	0.67	2.60	112	1.32
OFL	0.00 (outfall)						
	Gross Beta	69.0	39.6	11.7	17.17	20750	131
	Gross Alpha	2.90	1.97	1.05	2.11	717	4.76
K01	0.15 (downstream)						
	Gross Beta	22.93	516	8.91	24.59	20604	1.33
	Gross Alpha	9.00	7.00	8.54	5.22	684	9.65
K03	0.52 (downstream)						
	Gross Beta	1.50	1.90	1.83	1.16	163.6	2.33
	Gross Alpha	0.69	2.19	1.10	0.41	114	1.92
K05	0.79 (downstream)						
	Gross Beta	14.0	10.2	18.8	6.11	667	8.57
	Gross Alpha	1.20	0.84	1.89	2.08	204	2.44
K14	2.56 (downstream)						
	Gross Beta	3.55	3.80	6.69	1.08	139	1.89
	Gross Alpha	8.90	5.89	6.69	7.22	678	7.89
K19	3.48 (downstream)						
	Gross Beta	2.40	1.39	2.27	2.42	192	2.38
	Gross Alpha	0.36	0.55	0.23	0.99	84.8	1.54
K23	4.78 (downstream)						
	Gross Beta	12.0	9.82	9.68	6.57	498	7.40
	Gross Alpha	1.35	1.51	3.00	2.49	185	2.93
K30	13.06 (downstream)						
	Gross Beta	1.04	1.13	1.36	1.30	82.0	1.21
	Gross Alpha	11.0	7.89	4.46	5.26	386	6.55
K30	13.06 (downstream)						
	Gross Beta	1.50	1.13	3.06	1.60	242	4.07
	Gross Alpha	1.93	1.11	0.67	0.41	36.4	0.60
K30	13.06 (downstream)						
	Gross Beta	5.10	4.62	5.34	6.81	860	8.27
	Gross Alpha	1.70	1.09	1.26	1.78	198	1.89
K30	13.06 (downstream)						
	Gross Beta	1.06	0.65	0.75	1.38	230	2.20
	Gross Alpha	6.40	4.68	7.49	6.87	673	6.27
K30	13.06 (downstream)						
	Gross Beta	0.40	1.19	1.78	1.79	161	1.53
	Gross Alpha	0.79	0.66	0.79	0.20	54.3	0.50

3.8 Radioactivity in Vegetation

Samples of vegetation within the WL site were collected annually from the Ambient Radiation Monitoring Stations (ARMS) and adjacent to the WMA (Map 4, Appendix 2). The samples were analyzed for gross beta activity, gross alpha activity, strontium-90 and caesium-137. Results for 1997 are summarized in Table 33. It is evident that the results from the stations along the perimeter are quite low and comparable to background values.

Table 33: Radioactivity in WL Vegetation – 1997

Sampling Location	Annual Average (Bq/kg, wet weight)			
	Gross Beta	Gross Alpha	Sr-90	Cs-137
WL Perimeter ARMS #1	175	3.16	≤ 0.02	≤ 0.38
WL Perimeter ARMS #3	179	≤ 5.95	0.07	≤ 0.39
WL Perimeter ARMS #4	194	5.36	0.36	≤ 0.35
Outside WMA West Fence	187 to 1,991	3 to 25	23 to 735	1 to 31
North of Canister Storage	175	6	1.4	0.6

4. ASSESSMENT OF DOSES TO THE PUBLIC

4.1 General

The following sections examine and assess the radiation doses, due to emissions from the CRL and WL sites, during 1997 to the most highly exposed off-site members of the public in the critical groups as identified in the Derived Release Limit (DRL) reports for these sites. The dose assessments are based on the actual results of environmental monitoring of the dominant environmental pathways leading to critical group dose, where the monitoring indicates an actual or potential contribution above normal background from AECL. Dose conversion factors for calculating effective dose from inhalation, ingestion, or exposure to surfaces contaminated by radionuclides were taken from reference [6].

For comparison with the dose estimates below, the current regulatory dose limit in Canada specified by Atomic Energy Control Regulations, to members of the public as a result of human activities involving ionizing radiation (excluding medical diagnostic or treatment procedures) is 5 mSv in a year whole body effective dose. The draft revised Canadian regulations propose to reduce this public dose limit to 1 mSv in a year, consistent with the 1990 recommendations of the International Commission on Radiological Protection (ICRP) [11].

Also for comparison with the estimated doses in this report, typical annual average background radiation doses to adults from major natural sources of radiation and from medical diagnostic procedures, reported by the NCRP [16] and the UNSCEAR [15] are in Table 34. Actual background doses can vary considerably (one or more order of magnitude) depending on various factors such as elevation above sea level, local geology and housing construction.

Table 34 : Typical Annual Average Background Radiation Dose In Canada

Source of Exposure	Annual Average Effective Dose (mSv)
Natural Sources:	
-Cosmic radiation (Canada) [16]	0.27
-Terrestrial gamma radiation (Canada) [16]	0.23
-Radionuclides in the body (except radon) - (worldwide) [15]	0.23
-Radon and its decay products (worldwide) [15]	1.3
Medical diagnostic procedures (industrialized countries) [15]	1.1
Total Dose (Natural Sources + Medical Procedures)	3.1

4.2 CRL Air Effluent Exposure Pathways

As noted in Section 1.3, the critical group outside the CRL boundary for airborne emissions from CRL identified in the existing CRL DRL report [4] is either adults or infants at Balmer Bay.

Environmental monitoring of air effluent exposure pathways during 1997 indicated measureable or potential contributions from CRL at Balmer Bay in ambient gamma radiation dose in air due to emissions of noble gases (primarily Argon-41), ambient tritium in air, vegetables and milk.

Noble Gases- External Exposure in Plume

External gamma exposure due to noble gas emissions is estimated using the results of the GammaTracer ambient gamma radiation dose contribution from CRL noble gases measured at Balmer Bay after subtracting the natural background exposure. As noted in Section 1.3, emissions for noble gases, and Argon-41 in particular, represent the largest CRL emissions as a percentage of the DRLs for the site. Because the noble gases are chemically inert and decay with a fairly short radioactive half life, virtually all radiation dose from these emissions is due to external exposure to the atmospheric plume.

Table 35: CRL 1997 Critical Group Dose at Balmer Bay From Noble Gas Emissions

GammaTracer Ambient Dose Rate Contribution From CRL Noble Gas Emissions [Table 1]		Dose Conversion Factors Air kerma to effective dose (Sv/Gy)		Annual Effective Dose (mSv/a)	
Ambient Dose Equivalent -H*10 (nSv/h)	Air kerma (nGy/h) [see note 1]	Adult [23]	Infant [17]	Adult	Infant
13.5	11.3	0.75	0.91	0.074	0.090
Assumptions:					
Fraction of time exposed		1	1		

Note 1: The GammaTracer devices are calibrated to provide output in units of Ambient Dose Equivalent (H*10) [11]. A factor of 1.2 Sv (H*10)/Gy is used here to convert to units of absorbed dose in air (air kerma) [14].

Tritium - Inhalation / Immersion

Critical group dose due to inhalation of atmospheric tritium was estimated from the annual average measured ambient tritium in air at Balmer Bay for 1997. To be conservative, normal background concentrations of tritium in air in Ontario (typically about 0.2 Bq/m³) is ignored. The dose was estimated using the following expression, which includes a factor of two increase in calculated inhalation dose to account for possible tritium uptake through skin absorption (as recommended in [6]):

$$\text{Dose} = C \times I_a \times \text{DCF}_i \times \text{OF}_i \times A_s$$

Table 36: CRL--1997 Dose to Critical Group at Balmer Bay From Inhalation of Tritium

Radionuclide	Concentration in Air (Bq/m ³)	Dose Conversion Factor Inhalation DCF _i (Sv/Bq)		Effective Dose (mSv/a)	
		Adult	Infant	Adult	Infant
Tritium (HTO)	1.04	2.00E-11	5.80E-11	3.5E-04	1.7E-04
Assumptions:					
I _a = Breathing Rate (m ³ /a) [6]		8400	1400		
OF _i = Fraction of time exposed		1	1		
A _s = HTO skin absorption intake factor [6]		2	2		

Vegetable Ingestion

Critical group dose from consumption of vegetables grown at Balmer Bay was estimated using the measured concentrations, in vegetables from Balmer Bay, of radionuclides with concentrations potentially in excess of background (tritium and cesium-137). The dose to the critical group was estimated using the following expression. Natural background concentrations of these radionuclides were ignored in the calculation. It was assumed that 25% of vegetables consumed during the year were grown in Balmer Bay, an estimate considered reasonably consistent with local backyard gardening practice.

$$\text{Dose (nuclide n)} = C_n \times I_l \times G_l \times \text{DCF}_l$$

Table 37: CRL - 1997 Dose To Critical Group At Balmer Bay From Vegetable Ingestion

Radionuclide	Concentration in Vegetables (Bq/kg fresh weight)	Dose Conversion Factor for Ingestion - DCF _i (Sv/Bq)		Effective Dose (mSv/a)	
		Adult	Infant	Adult	Infant
Tritium	80	2.0E-11	5.8E-11	8.0E-05	9.7E-05
Cs-137	3	1.4E-08	1.4E-08	2.1E-03	8.8E-04
		Total Dose		2.2E-03	9.8E-04
Assumptions:					
Concentrations in vegetables from Balmer Bay [Table 11]					
I _v = Vegetable Consumption rate (kg/a) [6]		200	84		
G _v = Fraction from local sources		0.25	0.25		

Milk Ingestion

Although the current DRL report for CRL [4] assumes members of the critical group consume milk produced by cows assumed to graze at the CRL upriver boundary (i.e. Balmer Bay), dairy farming is not in fact practiced at this location. The critical group dose from milk ingestion was calculated using measured concentrations in milk supplied by a local dairy, and obtained from dairy herds within Renfrew County. Actual annual average measured values of tritium, caesium-137 and iodine-131 (assumed to be equal to detection limit even though all results were less than detection limit), ignoring natural background concentrations and possible contributions from other sources of tritium emissions within the area.

Table 38: CRL - 1997 Dose To Critical Group At Balmer Bay From Milk Ingestion

Radionuclide	Concentration In Milk (Bq/L)		Dose Conversion Factor For Ingestion (Sv/Bq)		Effective Dose (mSv/a)	
			Adult	Infant	Adult	Infant
Tritium	26.3		2.00E-11	5.80E-11	6.3E-05	3.4E-04
I-131	0.11	(detect. limit)	1.10E-08	8.70E-08	1.5E-04	2.1E-03
Cs-137	0.061		1.40E-08	1.40E-08	1.0E-04	1.9E-04
			Total Dose		3.1E-04	2.6E-03
Assumptions:						
Milk Ingestion Rate (L/a) [6]			120	220		
Fraction from local sources			1	1		

The total estimated doses in 1997 to members of the critical group at Balmer Bay from the above pathways, as summarized in Table 39, represent 1.5 % and 1.9 % of the annual public dose limit of 5mSv (whole body) effective dose to adults and infants respectively. In comparison, air emissions from the CRL site in 1997 (Table 1) represented, in total, 1.2 % of the DRLs based on this dose limit.

Table 39: CRL - 1997 Total Estimated Dose to Critical Group At Balmer Bay From Air Effluent Exposure Pathways

Pathway	Adult	Infant
External Exposure to Noble Gases	7.4E-02	9.0E-02
Tritium Inhalation/Immersion	3.5E-04	1.7E-04
Vegetable Ingestion	2.2E-03	9.8E-04
Milk Ingestion	3.1E-04	2.6E-03
Total Effective Dose (mSv/a)	7.7E-02	9.4E-02
Total Dose (as % of public dose limit)	1.5	1.9
Total Dose as % of typical background dose (Table 34)	2.5	3.0

4.3 CRL Liquid Effluent Exposure Pathways

As noted in Section 1.3, the critical group for liquid emissions from CRL identified in the existing DRL report is adults downstream of CRL on the Ottawa River (nominally at Petawawa). The dominant exposure pathway is identified as fish ingestion, although other pathways such as drinking water may also contribute lesser doses.

Environmental monitoring of liquid effluent exposure pathways during 1997 indicated measureable concentrations of radionuclides in excess of background attributable to CRL operations in Ottawa River water, fish and beach sediments.

Drinking Water

The dose to members of the downstream critical group due to drinking water from the Ottawa River was estimated from the annual average measured downstream concentrations (Pembroke) minus the average upstream concentrations at Rolphton. It was assumed there was no filtration or other pretreatment of the water prior to consumption that might remove any of the radionuclides. Dose was calculated using the following expression:

$$\text{Dose (nuclide } n) = C_n \times I_f \times G_f \times \text{DCF}_f$$

Table 40: CRL - 1997 Dose To Critical Group At Petawawa/Pembroke From Drinking Water

Radionuclide	Concentration In Drinking Water from CRL (Bq/L)	Dose Conversion Factor For Ingestion (Sv/Bq)		Effective Dose (mSv/a)	
		Adult	Infant	Adult	Infant
Tritium	6.6	2.0E-11	5.8E-11	9.2E-05	3.4E-05
Cesium-137	0.0020	1.4E-08	1.4E-08	2.0E-05	2.5E-06
Strontium-90	0.0027	3.4E-08	2.4E-07	6.4E-05	5.8E-05
Total Dose				1.8E-04	9.5E-05
Assumptions:					
Water consumption rate (L/a) [6]		700	90		
Fraction of water from Ottawa River		1	1		

Fish Ingestion

The dose to members of the critical group was estimated from the average measured concentrations in fish from the Ottawa River in the Highview area (between CRL and Petawawa) minus the average upstream concentrations in fish from Deux Riviere. The dose calculation used the following expression adapted from the Canadian Standard CSA N288.1 [6].

$$\text{Dose (nuclide } n) = C_n \times I_f \times G_f \times \text{DCF}_f$$

The fish consumption rate for adults was taken from the current CRL DRL report [4]. Although the DRL report assumes no fish consumption by infants, a consumption rate of 1 kg in a year was assumed [18].

Table 41: CRL - 1997 Dose To Critical Group At Petawawa/Pembroke From Fish Ingestion

Radionuclide	Concentration In Fish - Contrib. from CRL (Bq/kg)	Dose Conversion Factor For Ingestion (Sv/Bq)		Effective Dose (mSv/a)	
		Adult	Infant	Adult	Infant
Cesium-137	23.5	1.40E-08	1.40E-08	5.9E-03	3.3E-04
Cesium-134	4.6	2.0E-08	1.7E-08	1.7E-03	7.8E-05
Phosphorus-132	1.2	2.3E-09	1.3E-08	5.2E-05	1.6E-05
Total Dose				7.6E-03	4.2E-04
Assumptions:					
Average Concs. Highview - Deux Rivieres					
I_f = Fish Consumption Rate (kg/a)		18	1		
G_f = Fraction from local sources		1	1		

Beach Exposure

Dose to members of the downstream critical group due to assumed exposure to contaminated beach sediments was estimated from the average measured radionuclide concentrations at the beach at Pointe au Baptême, minus the average of measured concentrations at beaches upstream of CRL. Members of the critical group were assumed to spend about 100 hours per year on this beach, located near the downstream boundary of the CRL property. Dose was calculated using the following expression adapted, along with default parameters, from [6]:

$$\text{Dose (nuclide n)} = C_n \times OF_s \times W \times d_s \times DCF_g$$

Table 42: CRL - 1997 Dose To Critical Group At Petawawa/Pembroke From Beach Exposure

Radionuclide	Concentration in Beach Sand - Contrib. from CRL (Bq/kg)	Dose Conversion Factor - Ground Exposure - DCF _g (Sv.a ⁻¹ .Bq ⁻¹ .m ²)		Effective Dose (mSv/a)	
		Adult	Infant	Adult	Infant
Cesium-137	44.2	1.65E-08	2.50E-08	5.8E-05	8.8E-05
Cesium-134	0.8	4.3E-08	6.4E-08	2.7E-06	4.1E-06
Cobalt-60	2.9	6.2E-08	9.2E-08	1.4E-05	2.1E-05
		Total Dose		7.5E-05	1.1E-04
Assumptions:					
Average Conc. at Pt au Bapteme - Avg upstream					
OF _s =Occupancy Factor [6]		0.01	0.01		
W = shore width factor for river [6]		0.2	0.2		
d _s = effective sediment density(kg/m ₂) [6]		40	40		

The total estimated doses in 1997 to members of the critical group at Petawawa from the above pathways, as summarized in Table 43 below, represent 0.16 % and 0.01 % of the annual public dose limit of 5mSv (whole body) effective dose to adults and infants respectively. In comparison liquid emissions from CRL in 1997 represented, in total, 0.21% of the DRL based on this dose limit.

Table 43: CRL - 1997 Total Estimated Dose to Critical Group At Petawawa From Liquid Effluent Exposure Pathways

Pathway	Adult	Infant
Drinking Water	1.8E-04	9.5E-05
Fish Consumption	7.6E-03	4.2E-04
Cntaminated Beach Exposure	7.5E-05	1.1E-04
Total Effective Dose (mSv/a)	7.9E-03	6.3E-04
Total Dose (as % of public dose limit)	0.16	0.01
Total Dose as % of typical background dose (Table 34)	0.25	0.02

4.4 WL Air Effluent Exposure Pathways

As indicated in Section 1.3 above, the measured emissions to the atmosphere from WL facilities during 1997 were, in total, equivalent to less than 0.0004 % of the site derived release limits (DRLs) for an assumed critical group living at the WL boundary. Since the DRLs are determined on the basis of the continuous rate of release required to cause an annual dose equal to the regulatory limit for members of the public (5 mSv/a), this represents a potential radiation dose to members of this critical group of less than about 0.00002 mSv, or about 0.0006 % of the typical annual radiation dose to members of the public from natural sources and medical diagnostic procedures.

The dose level represented by the emissions is a factor of more than 2500 below the nominal trigger level of 0.050 mSv/a, recommended by the Canadian Standard CSA N288.4 [7], for establishment of an environmental monitoring

program. Nonetheless the WL environmental monitoring program does include monitoring of some potential atmospheric exposure pathways. As noted above, the results of this monitoring did not indicate, within the accuracy of the methodology, any measurable increases in radiation dose levels or concentrations of radioactive materials above the normal range of background levels. As a result, no specific calculations of dose to the critical group based on environmental monitoring results have been made here.

4.5 WL Liquid Effluent Exposure Pathways

As noted in Section 1.3, the critical group for liquid emissions from WL identified in the existing DRL report [5] is adults living at the downstream boundary of CRL on the Winnipeg River. The dominant exposure pathway is identified as fish ingestion, although other pathways such as drinking water may also contribute lesser doses.

Environmental monitoring of liquid effluent exposure pathways during 1997 indicated slightly increased concentrations of radionuclides, which may be attributable to WL operations, in Winnipeg River water, fish and river bottom sediments downstream of the WL site.

Drinking Water

The dose to members of the downstream critical group due to drinking water from the Winnipeg River was estimated from the annual average measured downstream concentrations at the WL downstream boundary minus the average upstream concentrations at Pinawa. It was assumed there was no filtration or other pretreatment of the water prior to consumption that might remove any of the radionuclides. Dose was calculated using the same expression as for CRL.

Table 44: WL - 1997 Dose To Critical Group At Downstream Boundary From Drinking Water

Radionuclide	Concentration In Drinking Water Contrib from WL (Bq/L)	Dose Conversion Factor For Ingestion-DCF _f (Sv/Bq)		Effective Dose (mSv/a)		
		Adult	Infant	Adult	Infant	
Cesium-137	0.0010	1.4E-08	1.4E-08	9.8E-06	1.3E-06	
Gross Beta (as Co-60)	0.017	1.7E-08	3.6E-08	2.0E-04	5.5E-05	
				Total Dose	2.1E-04	5.6E-05
Assumptions:						
Average Conc. Downstream boundary. - Pinawa						
Assumes gross beta increase is Co-60						
I _f = Water consumption rate (L/a) [6]		700	90			
G _f = Fraction of water from Winnipeg River		1	1			

Fish Ingestion

The dose to members of the critical group was estimated from the average measured concentrations in fish from the Winnipeg River 0.5 km downstream from the site process outfall minus the average upstream concentrations in fish from Pinawa, using data for the fish species exhibiting the largest difference in Cs-137 concentrations (in this case White Sucker). The dose calculation used the same expression as for CRL (see above). The fish consumption rate for adults was taken from the current WL DRL report [5]. Although the DRL report assumes no fish consumption by infants, a consumption rate of 1 kg/a was assumed [18].

Table 45 : WL - 1997 Dose To Critical Group At Downstream Boundary From Fish Ingestion

Radionuclide	Concentration In Fish Contrib. from WL (Bq/kg)	Dose Conversion Factor For Ingestion (Sv/Bq)		Effective Dose (mSv/a)	
		Adult	Infant	Adult	Infant
Cesium-137	0.94	1.40E-08	1.40E-08	1.0E-04	5.0E-06
				1.0E-04	5.0E-06
Assumptions: Avg Conc. (max. species) 0.5 km Downstr - Upstream Fish Consumption Rate (kg/a) [5] Fraction from local sources		20 1	1 1		

Beach Exposure

Dose to members of the downstream critical group due to assumed exposure to contaminated beach sediments was estimated from the average measured radionuclide concentrations in river bottom sediments downstream of the WL outfall minus the average of measured upstream concentrations. Dose was calculated using the following expression adapted, along with default parameters, from [6]:

$$\text{Dose (nuclide n)} = C_n \times OF_s \times W \times DF_s \times DCF_g$$

Concentrations on beaches were conservatively assumed to be equal concentrations on the river bottom (i.e. the dilution factor for shoreline deposits, DF_s , was assumed to be unity). Members of the critical group were assumed to spend about 100 hours per year on downstream beaches.

Table 46 : WL - 1997 Dose To Critical Group At Downstream Boundary From Beach Sediment Exposure

Radionuclide	Concentration in Sediment -Contribution from WL (Bq/m ²)	Dose Conversion Factor-Ground Exposure - DCF_g (Sv.a ⁻¹ .Bq ⁻¹ .m ²)		Effective Dose (mSv/a)	
		Adult	Infant	Adult	Infant
Caesium-137	1320	1.65E-08	2.50E-08	4.4E-05	6.6E-05
Gr. Alpha (as Am-241)	1400	8.1E-10	1.7E-09	2.3E-06	4.9E-06
			Total Dose	4.6E-05	7.1E-05
Assumptions: OF_s = Occupancy Factor [6] W = shore width factor for river [6] DF_s = dilution factor (shore deposit / river bottom)		0.01 0.2 1	0.01 0.2 1		

The total estimated doses in 1997 to members of the critical group at the WL downstream boundary from the above liquid effluent exposure pathways, as summarized in Table 47 below, represent 0.007 % and 0.003 % of the annual public dose limit of 5 mSv (whole body) effective dose to adults and infants respectively. In comparison, monitored liquid emissions from WL in 1997 (see Table 4) represented, in total, 0.0096 % of the DRL based on this same dose limit.

Table 47: WL - 1997 Total Estimated Dose to Critical Group At Downstream Boundary From Liquid Effluent Pathways

Pathway	Adult	Infant
Drinking Water	2.1E-04	5.6E-05
Fish Consumption	1.0E-04	5.0E-06
Contaminated Beach Exposure	4.6E-05	7.1E-05
Total Effective Dose (mSv/a)	3.6E-04	1.3E-04
Total Dose (as % of public dose limit)	0.007	0.003
Total Dose as % of typical background dose (Table 34)	0.011	0.004

5. QUALITY ASSURANCE

General quality assurance objectives for AECL's Environmental Monitoring Program are set out in RC-2000-21, AECL Environmental Protection Program Manual. In detail, the CRL and WL Environmental Monitoring Programs are conducted in accordance with laboratory specific environmental monitoring quality assurance manuals. The manuals include detailed working procedures for field operations, laboratory operations, laboratory administration, equipment performance and quality verification of analytical results.

Quality verification activities within the Environmental Monitoring Programs include periodic calibrations of counting instruments against traceable standards, process control measurements and data recording (for bias, precision, and background), historical reviews of measurements against previous results, and participation in intercomparison programs involving laboratories outside AECL.

Process control measurements include the routine calibration of instruments using traceable standards and the routine measurement of instrument backgrounds. Both of these types of data are incorporated into control charts to track instrument performance. Instruments and methods are tested using check sources and spike additions of known quantities of radionuclides, and regular analysis of duplicate or replicate samples.

5.1 CRL QA Intercomparisons

The CRL Environmental Research Branch laboratory participated in two inter-laboratory comparisons with members of the CANDU Owners Group (COG - AECL, Ontario Hydro, Hydro Quebec, and New Brunswick Power), one addressing gamma-emitters in foodstuffs (in this case potatoes) [19] and the other addressing the measurement of carbon -14 and iodine-131 in milk [20]. Results are summarized in Tables 48 and 49. In all cases, results provided by the Environmental Research Branch differed from the consensus values by less than 10%. Results with a relative difference of less than 20% are considered acceptable to the monitoring program. The Laboratory also participated in an intercomparison of gamma emitter measurements in water, but the results of that study are not yet available.

Table 48: 1997 CRL QA - COG Inter-Laboratory Comparison of Gamma Emitters in Potatoes

	Co-60 (Bq/kg)	Cs-134 (Bq/kg)	Cs-137 (Bq/kg)	Ba-133 (Bq/kg)
AECL	212.8	113.7	61.7	38.4
COG Average	224.1 ± 14	119.0 ± 7.5	63.6 ± 3.2	40.9 ± 3.1
AECL % Variance	5.0%	4.5%	3.0%	6.1%

Table 49: 1997 CRL QA - COG Inter-Laboratory Comparison of C-14 and I-131 in Milk

	C-14 (Bq/kgC)	I-131 (Bq/L)
AECL	961	77.4 ± 1.0
COG Average	1050 ± 84	75.0 ± 7.4
AECL % Variance	8.4%	3.2%

Quality control and assurance procedures and requirements for preparing, analysing, and reporting thermoluminescent dosimeter information are provided in [22]. The CRL Radiation Biology and Health Physics (RBHP) dosimetry lab, which prepares and analyses environmental TLDs at CRL, participates in environmental TLD intercomparisons sponsored by

the US Department of Energy (USDOE). These are generally held at 2-year intervals, and no intercomparison was held in 1997.

The dosimetry lab also participates in an annual analysis of a minimum of 50 personnel TLDs that are irradiated in groups of five by the National Research Council of Canada (NRCC) to 10 doses known only to NRCC. The results of the CRL analyses of those dosimeters are forwarded to the NRCC, who compile the findings and transfer the results to both AECL and the AECB. In the 1997 test, which exposed TLDs to exposures ranging from 130 to 4190 mR of radiation, the NRCC determined that CRL measurements provided a mean relative difference of +8%; the standard deviation of the relative differences was 2%. AECB criteria for these measurements require an overall bias of less than 10%, and a standard deviation of less than 7.5%. It is noted that the NRCC evaluation involves exposures substantially greater than those encountered in environmental TLD measurements, but these results are noted here as confirmation that TLD dosimetric procedures continue to be controlled.

5.2 WL QA Intercomparisons

The WL Environmental Monitoring Section participated in intercomparisons organized by the US Environmental Protection Agency (EPA) and by the International Reference Centre for Radioactivity (IRC). A summary of the results from these intercomparisons is given in Tables 50 and 51. The WL results met the EPA and IRC acceptance criteria in all but two cases. The WL Environmental monitoring laboratory's internal criteria for the intercomparisons consider results acceptable if the WL result is within ± 30 % of the known value, but flags any results more than ± 20 % of the known value. Most results for 1997 were considered acceptable, with a few exceptions most notably in the gross alpha and strontium-90 analyses. Practices for these two analyses were reviewed and actions taken to improve performance.

TABLE 50: WL Quality Assurance Program - EPA Intercomparison Results

Water Analysis	Sample Date	EPA Value		All Participants*		WL EM		EM/EPA
		Bq/L	+/-	Bq/L	+/-	Bq/L	+/-	
GROSS ALPHA	31-Jan-97	0.19	0.19	0.22	0.07	0.17	0.02	0.86
	15-Apr-97	1.78	0.44	1.74	0.34	2.31	0.04	1.30
	18-Jul-97	0.11	0.19	0.15	0.05	0.14	0.02	1.25
	21-Oct-97	1.85	0.46	1.75	0.28	1.28	0.18	0.69
	31-Oct-97	0.54	0.19	0.45	0.15	0.38	0.08	0.69
GROSS BETA	31-Jan-97	0.54	0.19	0.58	0.08	0.44	0.04	0.81
	15-Apr-97	3.78	0.57	3.60	0.33	3.48	0.09	0.92
	18-Jul-97	0.56	0.19	0.57	0.09	0.69	0.06	1.23
	21-Oct-97	5.31	0.80	4.97	0.55	5.07	0.25	0.96
	31-Oct-97	1.81	0.19	1.81	0.22	1.71	0.21	0.94
GAMMA								
Cobalt-60	15-Apr-97	0.78	0.19	0.81	0.08	0.93	0.13	1.19
	06-Jun-97	0.67	0.19	0.69	0.07	0.54	0.06	0.82
	21-Oct-97	0.37	0.19	0.39	0.07	0.51	0.06	1.37
	07-Nov-97	1.00	0.19	1.02	0.08	1.07	0.04	1.07
Zinc-65	06-Jun-97	3.70	0.37	3.82	0.22	3.87	0.24	1.05
	07-Nov-97	2.78	0.30	2.89	0.19	3.02	0.17	1.09
Cesium-134	15-Apr-97	1.15	0.19	1.06	0.07	1.05	0.04	0.91
	06-Jun-97	0.81	0.19	0.75	0.07	0.69	0.08	0.85
	21-Oct-97	1.52	0.19	1.40	0.11	1.48	0.24	0.98
	07-Nov-97	0.37	0.19	0.35	0.06	0.35	0.08	0.93
Cesium-137	15-Apr-97	0.81	0.19	0.84	0.07	0.97	0.04	1.20
	06-Jun-97	1.81	0.19	1.85	0.10	1.95	0.09	1.07
	21-Oct-97	1.26	0.19	1.31	0.09	1.44	0.10	1.15
	07-Nov-97	2.74	0.19	2.82	0.13	2.94	0.04	1.07
Barium-133	06-Jun-97	0.93	0.19	0.88	0.08	1.41	0.29	1.52
	07-Nov-97	3.66	0.37	3.50	0.23	3.69	0.19	1.01
RADIOCHEMICAL								
Strontium-89	17-Jan-97	0.44	0.19	0.44	0.15	0.42	0.02	0.94
	15-Apr-97	0.89	0.19	0.89	0.11	0.88	0.06	0.99
	11-Jul-97	1.63	0.19	1.61	0.18	2.41	0.04	1.48
	21-Oct-97	1.33	0.19	1.31	0.22	1.36	0.08	1.02
Strontium-90	17-Jan-97	0.93	0.19	0.87	0.14	0.89	0.04	0.96
	15-Apr-97	0.48	0.19	0.46	0.07	0.41	0.04	0.85
	11-Jul-97	0.59	0.19	0.57	0.07	0.51	0.06	0.85
	21-Oct-97	0.81	0.19	0.80	0.12	0.48	0.00	0.59

*results significantly different from the population mean are excluded
 +/- values are 2 sigma, based on counting criteria

TABLE 51: Quality Assurance Program - IRC Intercomparison Results

Total Diet Ash	Sample Date	IRC Value		All Participants*		WL EM		EM / IRC
		Bq/g	+/-	Bq/g	+/-	Bq/g	+/-	
Americium-241	January 1996	0.528	0.031	0.483	0.017	0.553	0.166	1.05
Cesium-137		1.060	0.100	1.044	0.014	0.963	0.049	0.91
Potassium-40		5.500	1.000	5.130	0.100	5.900	1.430	1.07

- Excluding those results significantly different from the population mean
- +/- values are 2 sigma based on counting criteria.
- IRC intercomparison results received 1997 October.

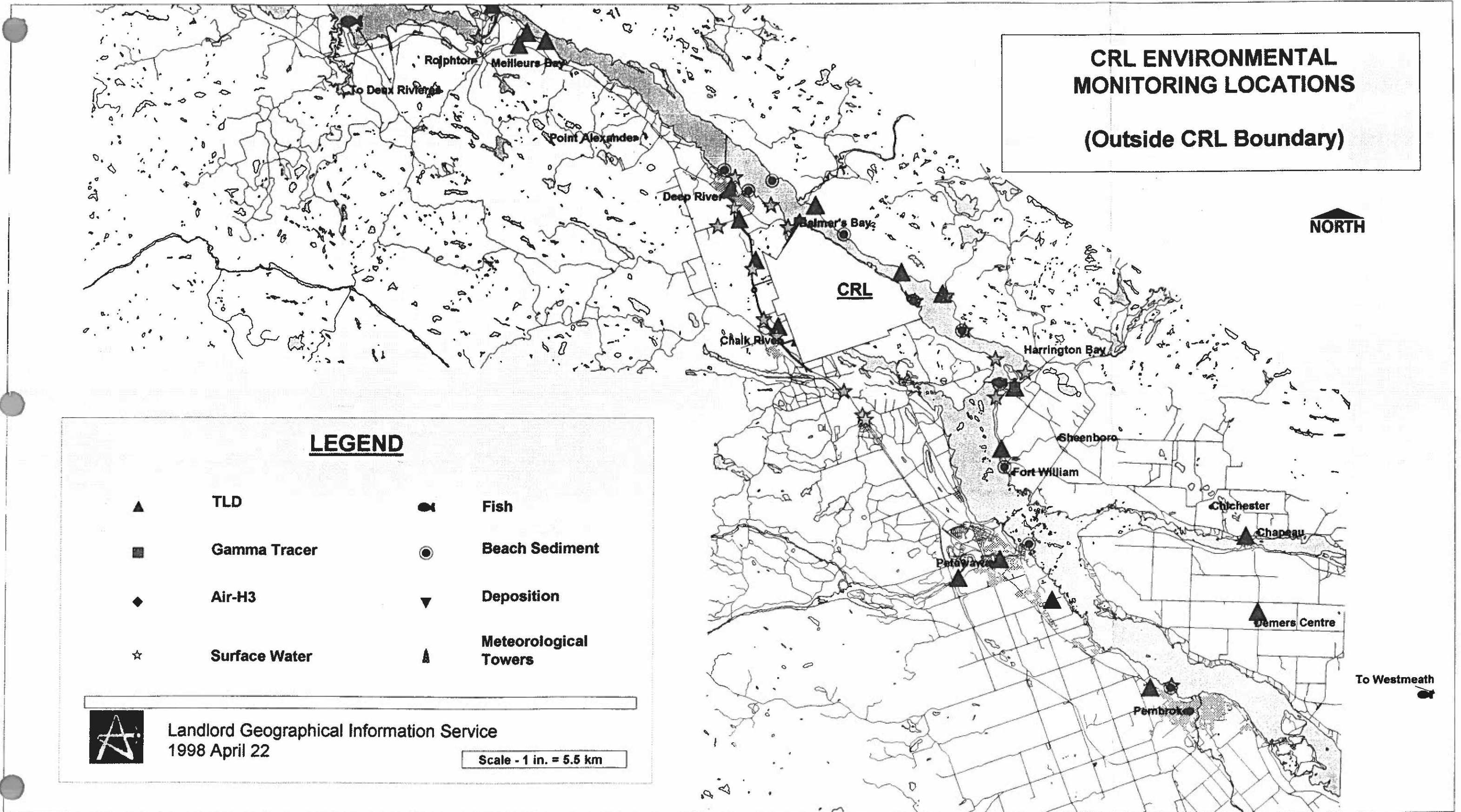
6. ACKNOWLEDGMENTS

The authors wish to thank the staff of the Environmental Research Branch at CRL and the Environmental Science Branch at WL for providing the data for this report, and for their assistance in compiling the report. In particular, we wish to thank D. Killey, T. Eve, B. O' Donnell, J. Cheung and W. Workman of the CRL Environmental Research Branch, and O.E. Acres and K. Ross of the WL Environmental Science Branch. The authors also wish to thank J. Westdal, formerly of Environmental, Safety and Regulatory Services Branch, WL for his preliminary work on this report prior to his retirement, and L. Nickel, Compliance Assurance Branch, for her help in producing the report.

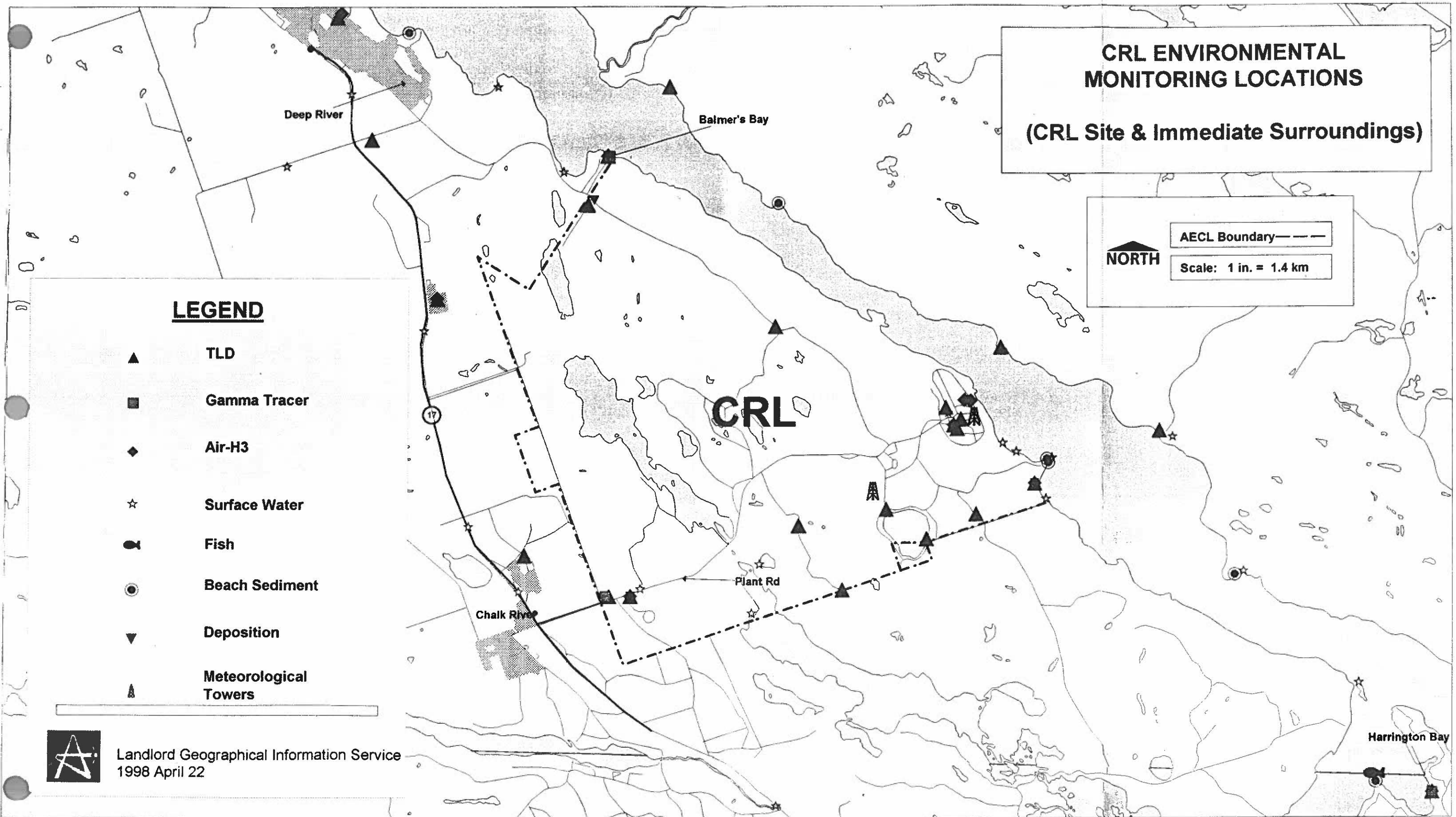
7. REFERENCES

1. Atomic Energy Control Board, "Chalk River Laboratories, Licence No. NRTE 1/96", 1996 October.
2. Atomic Energy Control Board, "Whiteshell Laboratories, Licence No. NRTE 2/96", 1996 October.
3. Niemi, J.A. Westdal, "1997 Annual Report of Radiological Monitoring Results For the Chalk River And Whiteshell Laboratories Sites Volume 2 - Effluent Monitoring", AECL-MISC-362-96, Vol.2, 1998 March*.
4. Palmer, "Derived Release Limits (DRLs) for Airborne and Liquid Effluents from the Chalk River Nuclear Laboratories During Normal Operations," Atomic Energy of Canada Limited, AECL-7243, 1981*.
5. Lemire, "Derived Release Limits for Radionuclides in Airborne and Liquid Effluents for the Whiteshell Nuclear Research Establishment," Atomic Energy of Canada Limited, AECL-10028, 1989*, and Addendum 1, 1992*.
6. Canadian Standards Association, "Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities", Canadian Standard, CAN/CSA-N288.1-M87, 1987 August.
7. Canadian Standards Association, "Guidelines for Radiological Monitoring of the Environment", Canadian Standard, CAN/CSA-N288.4-M90, 1990 November.
8. Health Canada, "Guidelines For Canadian Drinking Water Quality", Sixth Edition, Supply and Services Canada, Hull, 96-EHD-96, 1996.
9. Graham, T.A. Niemi, J.A. Westdal, "1996 Annual report of Radiological Monitoring Results for the Chalk River Laboratories and Whiteshell Laboratories Sites, Volume 3 – Environmental Monitoring", AECL-MISC-362-96 (Vol. 3)*.
10. Heinmiller, "1996 Annual report of Radiological Monitoring Results for the Chalk River Laboratories and Whiteshell Laboratories Sites, Volume 1, Personnel Dosimetry", AECL-MISC-362-96, (Vol. 1)*.
11. International Commission on Radiological Protection (ICRP), "The 1990 Recommendations of the International Commission on Radiological Protection" ICRP Publication 60, (Annals of the ICRP Vol. 21, No. 1-3), 1991.
12. Cooper, "Available Data For Establishing Background Levels in the Vicinity of Canadian CANDU Stations", RC-1185, COG-94-75, 1994 March.*
13. Audet, J.C. Baker, "Derived Release Limits for Airborne and Liquid Effluents from the Chalk River Laboratories During Normal Operations", Atomic Energy of Canada Limited, RC-1731 (Rev. 1), 1996 December.*
14. Department of Energy (DOE), "11th International Intercomparison of Environmental Dosimeters", 1997.
15. United Nations Committee on the Effects of Atomic Radiation, "Sources and Effects of Ionizing Radiation", UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes, United Nations, 1993.
16. National Council on Radiation Protection and Measurement, "Exposure of the Population in the United States and Canada from Natural Background Radiation", Recommendations of the National Council on Radiation Protection and Measurement, NCRP Report No. 94, 1987.
17. Petrousi et al, "Organ Doses for Foetuses, Babies, Children and Adults From Environmental Gamma Rays", Radiation Protection Dosimetry, Vol. 37, No.1, 1991.
18. Nutrition Canada, "Food Consumption Patterns Report", Department of National Health and Welfare Canada, 1977.
19. Cooper, E.L., W.J.G. Workman, and T.L. Eve, "Report on the COG intercomparison of measurements of gamma emitters in mashed potatoes in 1997", Atomic Energy of Canada Limited Report COG-97-312-I, 1997 June.
20. Cooper, E.L., W.J.G. Workman, A. Chaplin, and T.L. Eve, "Report on the COG intercomparison of measurements of ¹⁴C and simulated ¹³¹I in milk in 1997", Atomic Energy of Canada Limited Report COG-97-506-I, 1997 December.
21. Canadian Standards Association, "Requirements for the Competence of Environmental Laboratories", CAN/CSA-Z753-95, 1995 January.
22. Heinmiller, B.E., "Technical Basis Document For External Dosimetry At CRL", Atomic Energy of Canada Limited, Report RC-1525, 1995*.
23. International Commission on Radiological Protection (ICRP), "Data for Use in Protection against External Radiation", ICRP Publication 51, (Annals of the ICRP Vol. 17, No. 2/3).

* Unpublished report; sole source of copies is Scientific Document Distribution Office (SDDO), AECL, Chalk River, Ontario, K0J 1P0.

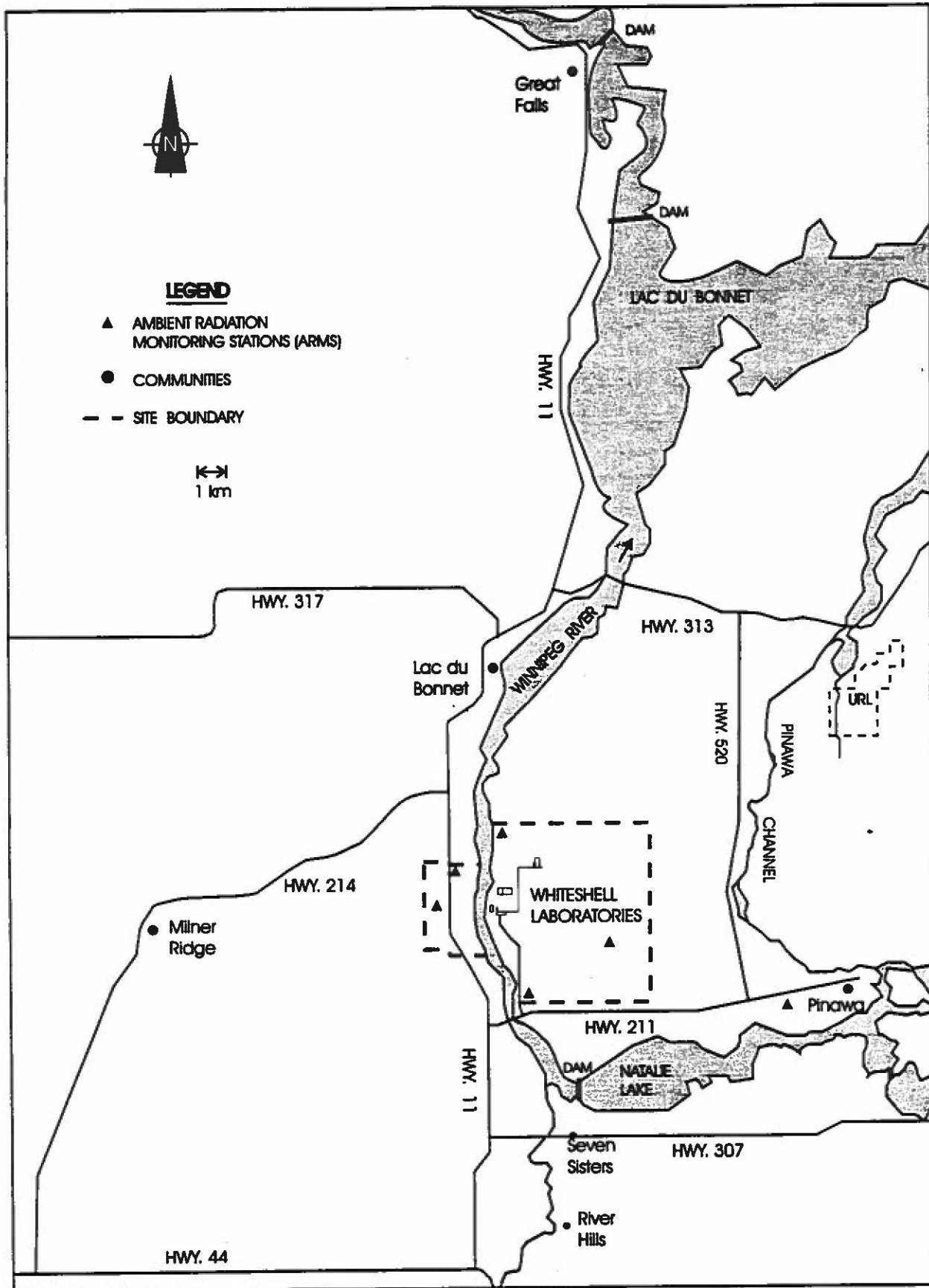


MAP 1: Location of Chalk River Laboratories – CRL Environmental Monitoring Stations
(Outside CRL Boundary)

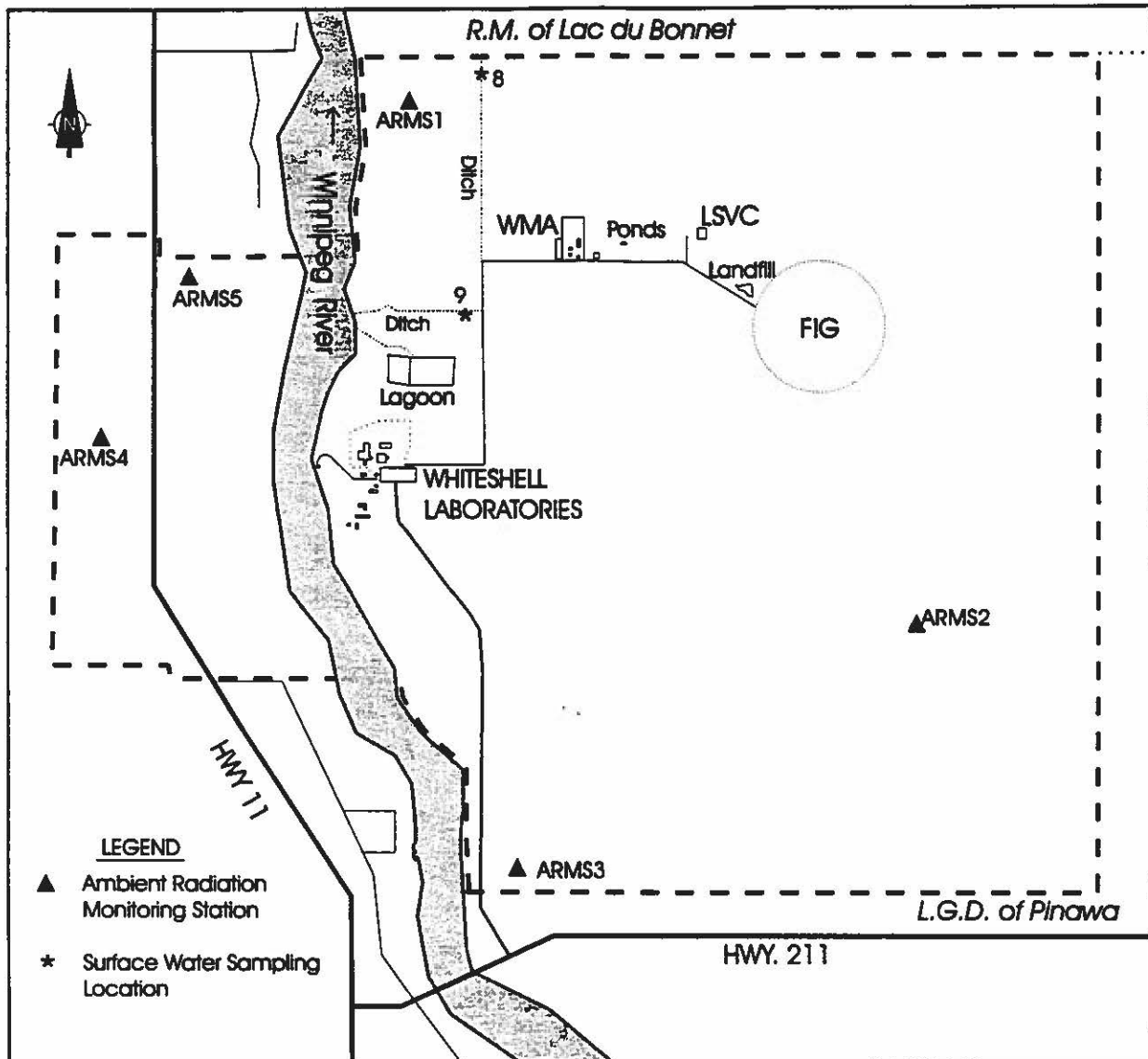


Landlord Geographical Information Service
1998 April 22

MAP 2: Chalk River Laboratories Site and Immediate Surroundings – CRL Environmental Monitoring Stations



MAP 3: Whiteshell Laboratories and Surrounding Area



MAP 4: Whiteshell Laboratories Site

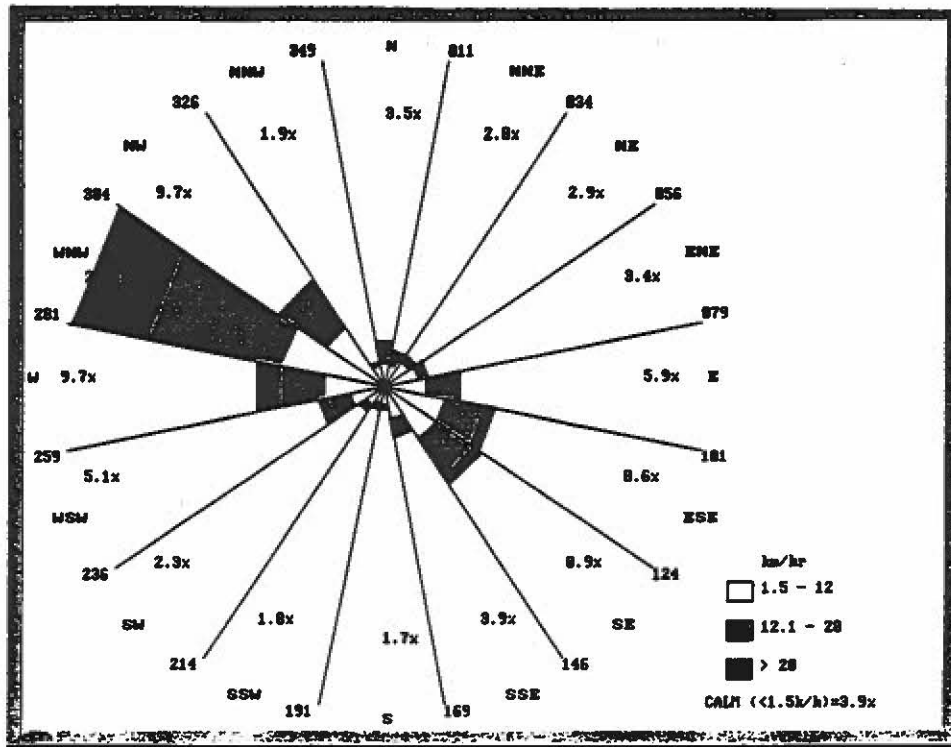


Diagram 1: CRL Windrose Perch Lake 60 m, 1997

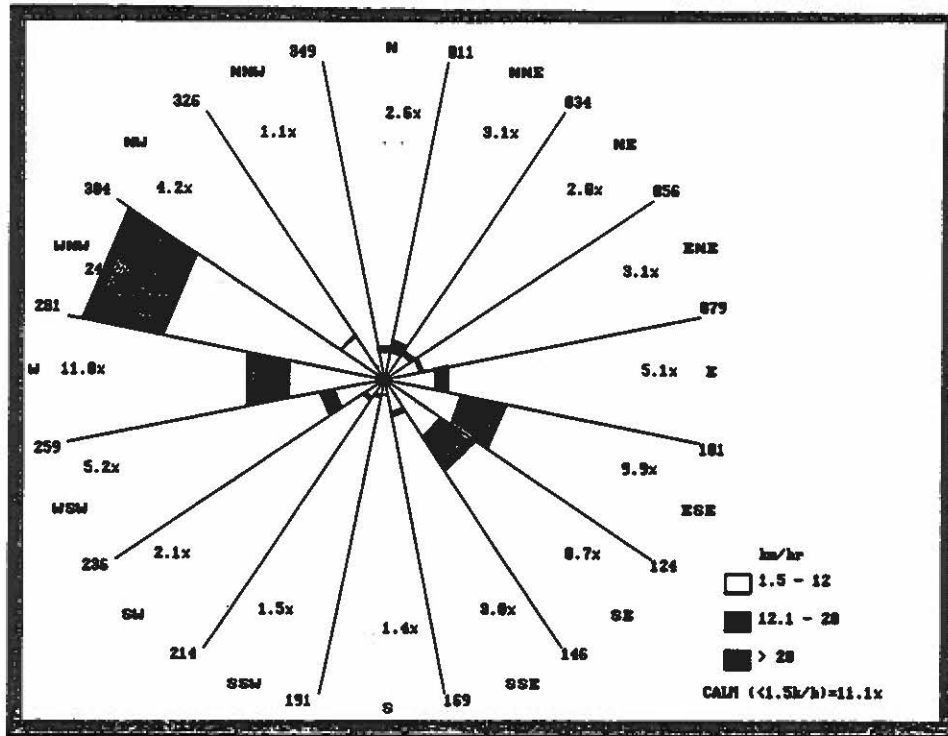


Diagram 2: CRL Windrose - Perch Lake 30 m, 1997

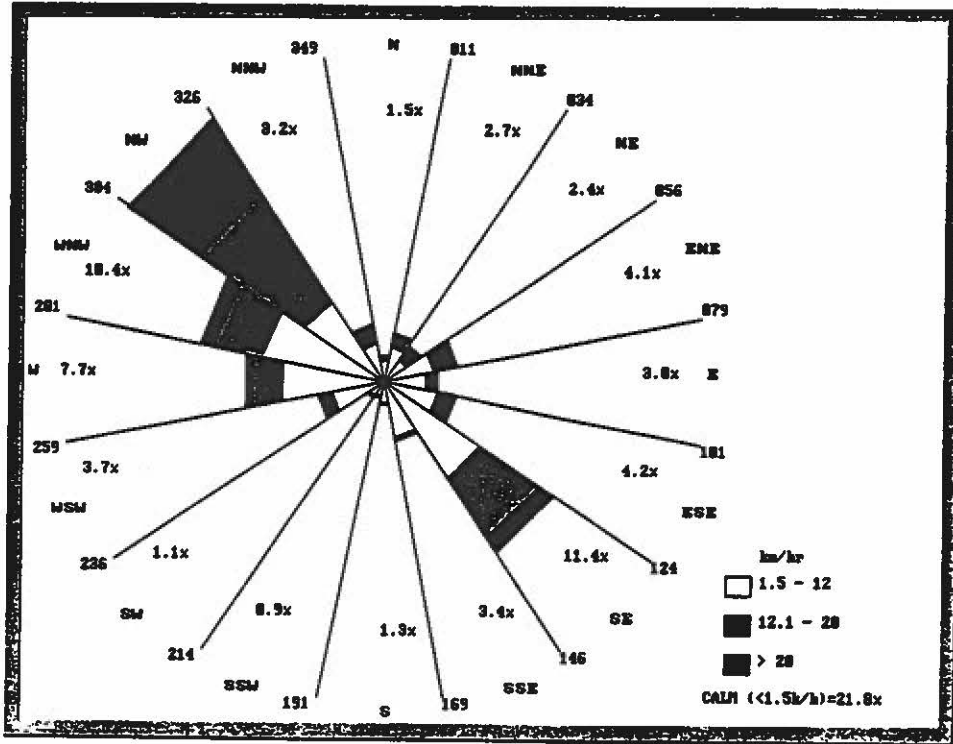


Diagram 3: CRL Windrose - Building 456, 1997

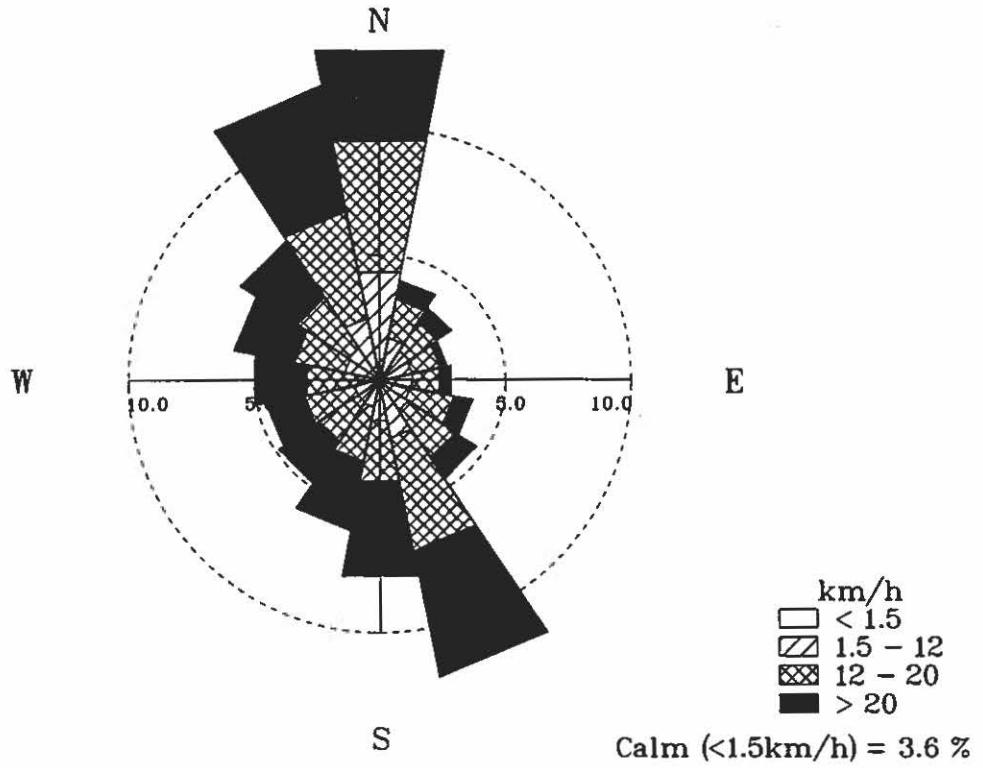


Diagram 1: WL Windrose - 61 m, 1996

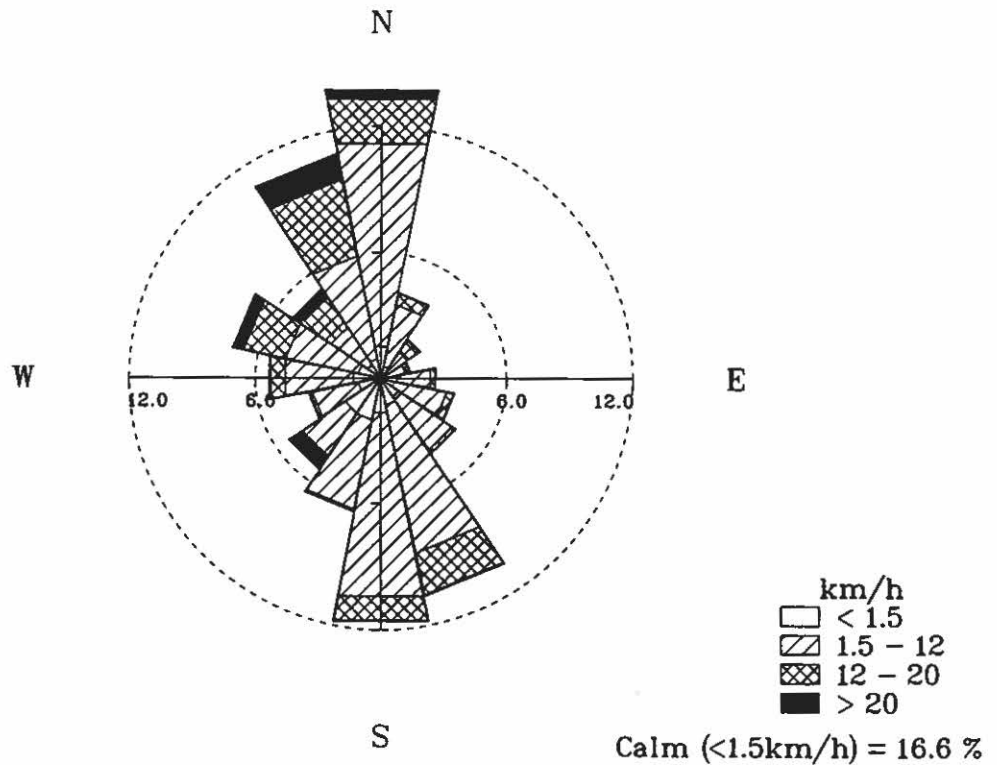


Diagram 2: WL Windrose - 6 m, 1997

Notice:

This report is not to be listed in abstract journals. If it is cited as a reference, the source from which copies may be obtained should be given as:

Scientific Document Distribution Office (SDDO)
AECL
Chalk River, Ontario
Canada KOJ 1J0

Fax: (613) 584-1745

Tel.: (613) 584-3311
ext.4623

