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**1998 Annual Report of Radiological Monitoring  
Results for the Chalk River and Whiteshell  
Laboratories Sites  
Volume 1 - Personnel Radiation Dosimetry**

B.E. Heinmiller



## 1998 ANNUAL REPORT OF RADIOLOGICAL MONITORING RESULTS FOR THE CHALK RIVER AND WHITESHELL LABORATORIES SITES

### VOLUME 1 - PERSONNEL RADIATION DOSIMETRY

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AECL

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ABSTRACT

This volume of the annual report summarizes  
OCCUPATIONAL RADIATION DOSES  
at the Chalk River and Whiteshell Laboratories  
for the calendar year 1998.

Separate volumes of this report summarize the  
LIQUID EFFLUENT MONITORING (Volume 2) and  
ENVIRONMENTAL MONITORING (Volume 3)  
at the same sites for the same period.

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1999 March

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1. INTRODUCTION

AECL operates the Chalk River Laboratories (CRL) located on the Ottawa River near Chalk River, Ontario, and the Whiteshell Laboratories (WL) located on the Winnipeg River near Pinawa, Manitoba, under the terms of licences granted by the Atomic Energy Control Board (AECB) [1,2].

Condition #22 c) and d) of the CRL site licence and Condition #22 c) and d) of the WL site licence require the preparation and submission to the AECB of an annual report for each calendar year, summarizing the results of monitoring of radiation exposures to personnel at AECL's research sites, and of radioactive substances in airborne and liquid effluents from the sites.

Volume 1 of this report, covering personnel radiation dosimetry, is intended to fulfil part of this requirement for both the CRL and WL sites for the calendar year 1998. Volumes 2 and 3 of this report, covering liquid effluent and environmental monitoring, respectively, fulfil the other requirements.

The Annual Safety Reports (required under Condition #22 a) of the CRL site licence and Condition #22 a) of the WL site licence) for the individual listed facilities contain dose information for operating staff of each of those facilities.

Both the CRL and WL sites are broad-based installations for nuclear operations, research, development, and demonstration, and operate a variety of facilities. Appendix A of the respective site licences lists the main nuclear facilities operated at each site. At CRL, these include the NRU Reactor, the ZED-2 Reactor, the Molybdenum-99 Production Facility, accelerator facilities, fuel fabrication facilities, hot-cell facilities, and waste management facilities. At WL, these include the Shielded Facilities (which include the Hot Cell Facility and the Immobilized Fuel Test Facility), accelerator facilities, and waste management facilities. In addition to these listed facilities, a variety of research, development and analytical laboratories exist at both sites.

Section 2 of this report discusses the radiation protection program within AECL, and Section 3 provides summary data on occupational radiation doses at the two licensed sites during 1998. Système International (SI) units are used throughout this report.

## 2. RADIATION PROTECTION PROGRAM AT AECL

The health and safety of AECL employees and the public, as a result of AECL operations, are governed by federal legislation under the Atomic Energy Control Act and the Atomic Energy Control Regulations made pursuant to the Act. Part V of those regulations specifies the requirements relating to health and safety, and Part VI describes precautions that must be adhered to by those engaged in the operation of nuclear facilities, or in the use of prescribed substances. Administration of the Act and the granting of licences for the operation of nuclear facilities, or related work, are performed by the AECB.

The Atomic Energy Control Regulations [4] specify maximum permissible doses for Atomic Radiation Workers for exposures to the whole body (50 mSv/a), to skin, bone or thyroid (300 mSv/a), to extremities (750 mSv/a), and to other single organs (150 mSv/a). Other dose limits also apply, and are detailed in Schedule II of the Atomic Energy Control Regulations.

The dose limits for exposures to members of the general public specified by the Atomic Energy Control Regulations are, in general, a factor of ten less than those for Atomic Radiation Workers.

AECL's Radiation Protection Policy #40301 (approved 1991 September) outlines the policies regarding all matters of radiation protection within the AECL Corporation. AECL's Radiation Protection Policy #40301 specifies that occupational radiation doses received by employees as a direct result of being employed by AECL, or by members of the general public as a result of AECL's operations, be as low as reasonably achievable, social and economic considerations being taken into account. Furthermore, AECL's Radiation Protection Policy also specifies that all radiation doses received by AECL employees shall be justified and, to the extent possible, radiation protection shall be optimized to ensure maximum net benefit.

AECL has developed a comprehensive set of fundamental operating rules and requirements, in the form of report RC-2000-633-0, AECL Research's Radiation Protection Requirements, 1994 February [3]. Implementation of these requirements is progressing. The radiological exposure management requirements detailed in RC-2000-633-0 establish Administrative Control Levels, and prescribe the establishment of Dose Control Points for all monitored workers, and describe the actions to be followed with respect to doses exceeding these values.

Increased radiological protection awareness and training continues to be a priority for AECL. Plans are in place to have this training completed for all individuals whose work involves direct exposure to ionizing radiation or radioactive materials.

### 3. OCCUPATIONAL RADIATION DOSES

AECL exercises close control over employee exposures to radiation. Personal dose histories are updated for Atomic Radiation Workers every monitoring period. This information is available at any time to the employee, and is reported to line management and radiation protection staff every monitoring period, so that all are aware of and can use the information in planning and work assignments. Any employee receiving 0.20 mSv or more in a monitoring period is issued a notice of the exposure. Annual summaries of employee dose equivalents are also reported to the National Dose Registry, operated by Health Canada.

Table 1 summarizes the radiation dose equivalents for workers at CRL and WL during 1998. Table 2 shows the maximum individual dose equivalents for workers at each of the two sites in the year. Tables 3 and 4 present data on distribution of whole-body and surface doses from external sources and tritium, and distribution of extremity doses, respectively, for workers at both sites. Distributions of whole-body, surface and extremity dose equivalents are depicted graphically in Figures 1, 2 and 3, respectively.

AECL's radiation dose experience for 1998 compared to the previous five calendar years is summarized in Table 5 for CRL, and in Table 6 for WL.

During 1998, no AECL employee working at CRL or WL received a whole-body, or single-tissue dose equivalent in excess of any of the respective quarterly or annual Maximum Permissible Doses for Atomic Radiation Workers. Only 6% of all monitored workers at AECL's research sites received a whole-body dose equivalent in excess of 5 mSv, the Maximum Permissible Dose for a member of the general public.

Workers are monitored for intakes of radionuclides if they have the potential for intakes of such nuclides that would result in a committed effective dose exceeding 1 mSv. Internal doses are calculated, recorded, and included in the tables of this report for all workers monitored for tritium.

For intakes of radionuclides other than tritium, committed effective doses are calculated and recorded for all such intakes resulting in a committed effective dose exceeding 1 mSv. These doses are not included in the whole-body doses reported in the tables of this report. During 1998 no AECL employee exceeded this recording level.

In 1998 there were three unplanned events, all at CRL, resulting from unplanned exposure or potential exposure to ionizing radiation. Details of unplanned events are documented in their respective unplanned-event reports.

### 3.1 System and Reporting Biases

Although the dose data appearing in this report are considered to be sufficiently accurate and complete, the following paragraphs document a number of system biases and reporting biases in the data.

Calculated doses that are less than the lower limit of detection (LLD, nominally 0.05 mSv) are added to the accumulated dose equivalent if the calculated dose is positive. Calculated doses that are less than zero are entered as zero. This is the case where the dose indicated by the control dosimeters, which is a measure background radiation fields, is greater than the dose indicated by a respective employee dosimeter. This recording practice introduces an overreporting bias in the data, as there are non-zero dose entries accumulated that are not statistically meaningful.

The practice of shielding CRL site-background control dosimeters during normal working hours, so that Ar-41 is registered on employee dosimeters as occupational dose, may introduce a small (compared to the LLD) overestimate of employee doses, due to the shielding of control dosimeters from some natural background radiation in addition to Ar-41. Also, during what are normally non-working hours, the control dosimeters are exposed to nominally the same radiation fields as the plaques of workers not on site, but the exposure geometry is, for practical reasons, not identical. Any bias resulting from this would be small (compared to the LLD).

It is believed that an immediate second reading of site-background control dosimeters done (at CRL only) to establish machine zero results in reduced residual signal readout on the control dosimeters relative to that of the employee dosimeters. This results in a small (compared to the LLD) overestimate of employee doses. The practice at WL is to use two sets of controls, one to measure background and the other to measure machine noise.

Only partial (easily identified) correction of the TLD-100 overresponse to thermal-neutron fields is made. Lack of a total correction results in a small overreporting bias.

The data are incomplete at the time of this report. A few missing dose entries to be entered later are from confirmatory CR-39 neutron monitoring. The confirmatory neutron monitoring period coincides with the calendar year, and the constraint on processing throughput necessitates the late entries. Because of the nature of the monitored neutron fields and the TLD-100 overresponse to the thermal part of the spectra, the missed dose from the absence of these entries is considered negligible and is probably zero. The reporting of these entries will result in a small overreporting bias after their entry.

Other incomplete entries are TLD results that the database code has rejected, due to lack of complete employee identification information. Few of these rejects remain outstanding; most

such doses are less than the lower limit of detection, and the largest such dose equivalent is 0.14 mSv. These missing data result in an underreporting bias of less than 0.50 mSv collective dose equivalent.

Doses reported include doses received by CRL and WL employees at sites other than CRL and WL.

### 3.2 Dose Trends

Both collective photon dose and average photon dose at CRL continued on a small downward trend in 1998. Collective and average photon doses continue to be significantly lower than their respective values in 1991 when NRU reactor was down for repairs and NRX reactor was used as a replacement.

Average tritium dose per exposed worker shows an increase from 1992 to 1997, largely reflecting the production build-up from neutron activation in the NRU reactor heavy-water. Tritium doses remain lower than pre-1992 values because of the use of substitute heavy-water of lower specific activity that was introduced after repairs to NRU in 1991. In the years since NRX has been shut down (the last six years), the ratio of the average annual tritium dose to the tritium activity concentration in NRU heavy-water is very nearly a constant. However, 1998 shows a slight decrease in tritium doses compared to 1997, in spite of the increase in the specific activity of tritium in NRU heavy-water. This decrease may be attributable to liquid and ventilation confinement improvements and to fewer required work tasks involving exposure to tritiated heavy-water.

The average external photon whole-body doses at CRL and the average tritium doses of those exposed at CRL for the years 1989-1998 are depicted graphically in Figure 4. The average external photon whole-body doses at WL for the years 1989-1998 are depicted graphically in Figure 5.

The maximum individual whole-body dose equivalent for the year decreased from 1991 through 1994, because of a progressive AECL effort towards reducing maximum individual dose and achieving a target maximum of 20 mSv in 1994. The maximum individual whole-body dose equivalent has remained at less than 20 mSv for each of 1994, 1995, 1996, 1997, and 1998.

There were 67 employees, all at CRL, with whole-body doses greater than 10 mSv for 1998. In 1994, there were 119 employees, all at CRL, with whole-body doses greater than 10 mSv. In 1995 there were 98 employees at CRL and one employee at WL with whole-body doses greater than 10 mSv. In 1996 there were 102 employees at CRL and four employees at WL with whole-

body doses greater than 10 mSv. In 1997 there were 88 employees at CRL and one employee at WL with whole-body doses greater than 10 mSv.

Of the 67 employees with whole-body doses greater than 10 mSv in 1998, 42 worked in reactor operations, eight worked in reactor maintenance, 14 were involved in radiation protection for the sites, and three worked in other areas.

#### 4. CONCLUSIONS

Chalk River Laboratories and Whiteshell Laboratories operated in 1998 in compliance with the dose limits set out in the Atomic Energy Control Regulations. This report gives dose distributions by type of dose for both CRL and WL.

Measurement and reporting biases have been documented. Considering all of the biases, it is believed that small doses (quantitatively comparable to those delivered by the natural radiation background) are somewhat overestimated and overreported.

#### 5. REFERENCES

1. Atomic Energy Control Board, "Chalk River Laboratories Nuclear Research and Test Establishment, Licence No. NRTE 1.1/98", 1999 February.
2. Atomic Energy Control Board, "Whiteshell Laboratories Nuclear Research and Test Establishment, Licence No. NRTE 2.1/98", 1998 November.
3. "AECL Research's Radiation Protection Requirements", Prepared by members of the Health Sciences and Services Division and Edited by T.A. Niemi, RC-2000-633-0, 1994 February.
4. Atomic Energy Control Regulations, CRC, 1978, c. 365, p.2325, with amendments to 1992 September 09, SOR/92-512.

Table 1: Summary of Radiation Doses at CRL and WL during 1998.

Radiation Exposure	CRL	WL
<u>External Whole-body Photon</u>		
Number of Workers with Detectable Dose	2321	492
Collective Dose Equivalent (person·Sv)	2.84	0.16
Average Dose Equivalent (mSv)	1.23	0.32
Maximum Dose Equivalent (mSv)	16.12	8.13
<u>External Surface Photon + Beta</u>		
Number of Workers with Detectable Dose	2321	492
Collective Dose Equivalent (person·Sv)	3.08	0.17
Average Dose Equivalent (mSv)	1.33	0.34
Maximum Dose Equivalent (mSv)	19.13	11.15
<u>Tritium</u>		
Number of Workers with Detectable Dose	321	0
Collective Dose Equivalent (person·Sv)	0.26	0
Average Dose Equivalent (mSv)	0.80	0
Maximum Dose Equivalent (mSv)	3.87	0
<u>Extremity</u>		
Number of Workers with Detectable Dose	246	50
Collective Dose Equivalent (Sv)	2.76	0.27
Average Dose Equivalent (mSv)	11.21	5.37
Maximum Dose Equivalent (mSv)	89.46	43.39
<u>Neutron</u>		
Number of Workers with Detectable Dose	11	0
Collective Dose Equivalent (person·Sv)	0.003	0
Average Dose Equivalent (mSv)	0.23	0
Maximum Dose Equivalent (mSv)	1.61	0

Table 2: Maximum Radiation Doses at CRL and WL during 1998.

Radiation Exposure	Individual Maximum Exposure (mSv)*	
	CRL	WL
Photon ( $\gamma$ )	16.12	8.13
Photon + Beta ( $\gamma + \beta$ )	19.13	11.15
Tritium (H3)	3.87	0.0
Extremity**	89.46	43.39
Neutron (N)	1.61	0.0
Whole-body ** ( $\gamma + H3 + N$ )	18.60	8.13
Surface ** ( $\gamma + \beta + H3 + N$ )	21.61	11.15

\* Maximum exposure in each category is not necessarily to the same individual, and therefore cannot be added directly to obtain maximum whole-body and skin dose.

\*\* The AEC regulatory limits are:  
50 mSv per year for whole-body exposure,  
300 mSv per year for skin exposure, and  
750 mSv per year for extremity exposure.

Note  $\gamma$  = photon,  $\beta$  = beta, H3 = tritium, N = neutron.

Table 3: Distribution of Whole-body and Surface Radiation Doses from External Sources and Tritium at CRL and WL during 1998.

Dose Range (mSv)	Whole-body Dose ( $\gamma + H3 + N$ )*				Surface Dose ( $\gamma + \beta + H3 + N$ )*			
	CRL		WL		CRL		WL	
	No. of Workers	person·Sv	No. of Workers	person·Sv	No. of Workers	person·Sv	No. of Workers	person·Sv
not exposed	7	0.000	169	0.000	7	0.000	169	0.000
below 1	1844	0.765	454	0.064	1810	0.768	453	0.063
1 to 2	145	0.207	21	0.032	150	0.216	19	0.028
2 to 3	75	0.187	8	0.019	77	0.190	9	0.022
3 to 4	51	0.177	3	0.011	57	0.196	4	0.014
4 to 5	34	0.156	4	0.018	37	0.166	3	0.013
5 to 10	105	0.754	2	0.013	115	0.818	3	0.018
10 to 15	57	0.695	0	0	58	0.704	1	0.011
15 to 20	10	0.164	0	0	16	0.264	0	0
20 to 25	0	0	0	0	1	0.022	0	0
25 to 30	0	0	0	0	0	0	0	0
30 to 35	0	0	0	0	0	0	0	0
35 to 40	0	0	0	0	0	0	0	0
40 to 45	0	0	0	0	0	0	0	0
over 45	0	0	0	0	0	0	0	0
Totals	2328	3.105	661	0.158	2328	3.345	661	0.170

\* Note  $\gamma$  = photon,  $\beta$  = beta, H3 = tritium, N = neutron.

Table 4: Distribution of Monitored Extremity Radiation Doses at CRL and WL during 1998.

Dose Range (mSv)	CRL		WL	
	No. of Workers	Sv Collective	No. of Workers	Sv Collective
not exposed	15	0.000	0	0.000
below 5	116	0.244	34	0.055
5 to 10	43	0.308	7	0.043
10 to 20	48	0.661	7	0.105
20 to 30	16	0.385	1	0.022
30 to 40	8	0.276	0	0
40 to 50	4	0.177	1	0.043
over 50	11	0.707	0	0
Totals	261	2.758	50	0.269

Table 5: Summary of Radiation Dose Experience at CRL since 1993.

	1993	1994	1995	1996	1997	1998
Number of workers monitored (including terminated employees)	2898	2853	2724	2703	2546	2328
Number of workers receiving detectable exposure						
A. External Whole-body Photon	2890	2837	2712	2637	2533	2321
B. External Surface Photon + Beta	2890	2837	2712	2637	2533	2321
C. Tritium	340	297	274	306	341	321
D. Extremity	282	285	230	302	331	246
E. Neutron	281	218	123	79	36	11
Total radiation dose equivalent (person-Sv)						
A. External Whole-body Photon	4.83	4.52	3.96	3.81	3.40	2.84
B. External Surface Photon + Beta	5.35	5.03	4.35	4.20	3.78	3.08
C. Tritium	0.19	0.18	0.21	0.25	0.31	0.26
D. Extremity	1.89	1.58	1.48	3.67	2.59	2.76
E. Neutron	0.04	0.04	0.02	0.01	0.00	0.00
Largest individual annual dose equivalent (mSv)						
A. External Whole-body Photon	22.1	17.9	18.4	17.0	17.2	16.1
B. External Surface Photon + Beta	28.0	24.4	25.0	19.9	34.7	19.1
C. Tritium	16.6	3.0	3.9	4.9	4.9	3.9
D. Extremity	275.3	104.2	71.0	287.8	89.3	89.5
E. Neutron	0.7	0.7	0.9	0.6	0.5	1.6
Average dose equivalent of those exposed (mSv)						
A. External Whole-body Photon	1.67	1.59	1.46	1.44	1.34	1.23
B. External Surface Photon + Beta	1.85	1.77	1.60	1.59	1.49	1.33
C. Tritium	0.55	0.62	0.75	0.82	0.92	0.80
D. Extremity	6.69	5.53	6.43	12.16	7.82	11.21
E. Neutron	0.14	0.17	0.14	0.17	0.10	0.23

Table 6: Summary of Radiation Dose Experience at WL since 1993.

	1993	1994	1995	1996	1997	1998
Number of workers monitored (including terminated employees)	1066	1065	971	896	689	661
Number of workers receiving detectable exposure						
A. External Whole-body Photon	922	1015	873	778	586	492
B. External Surface Photon + Beta	922	1015	873	778	586	492
C. Tritium	0	0	0	0	0	0
D. Extremity	64	79	67	69	59	50
E. Neutron	0	0	12	0	17	0
Total radiation dose equivalent (person·Sv)						
A. External Whole-body Photon	0.42	0.36	0.33	0.35	0.21	0.16
B. External Surface Photon + Beta	0.47	0.40	0.34	0.41	0.22	0.17
C. Tritium	0.00	0.00	0.00	0.00	0.00	0.00
D. Extremity	0.23	0.27	0.36	0.42	0.50	0.27
E. Neutron	0.00	0.00	0.00	0.00	0.00	0.00
Largest individual annual dose equivalent (mSv)						
A. External Whole-body Photon	6.5	9.7	13.8	17.2	10.0	8.1
B. External Surface Photon + Beta	9.5	12.4	16.7	39.7	12.3	11.2
C. Tritium	0.0	0.0	0.0	0.0	0.0	0.0
D. Extremity	23.1	17.7	138.7	133.0	207.1	43.4
E. Neutron	0.0	0.0	0.2	0.0	0.1	0.0
Average dose equivalent of those exposed (mSv)						
A. External Whole-body Photon	0.46	0.35	0.38	0.45	0.35	0.32
B. External Surface Photon + Beta	0.51	0.39	0.39	0.53	0.38	0.34
C. Tritium	0.00	0.00	0.00	0.00	0.00	0.00
D. Extremity	3.58	3.43	5.40	6.06	8.41	5.37
E. Neutron	0.00	0.00	0.05	0.00	0.04	0.00

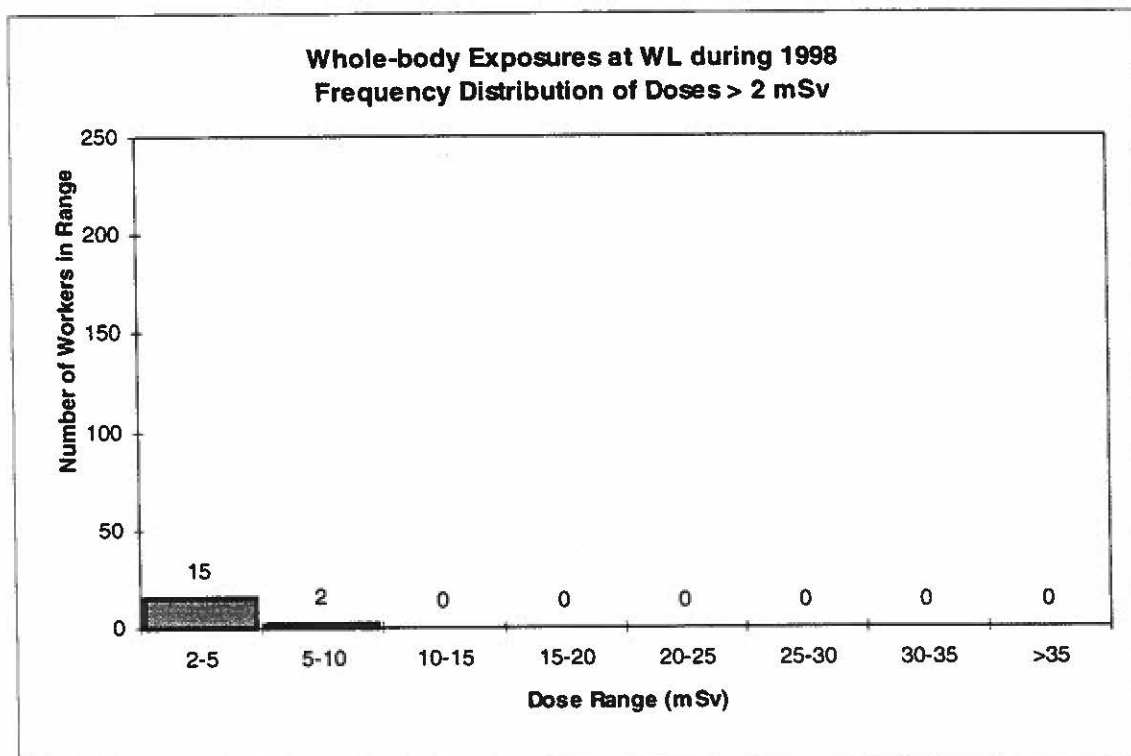
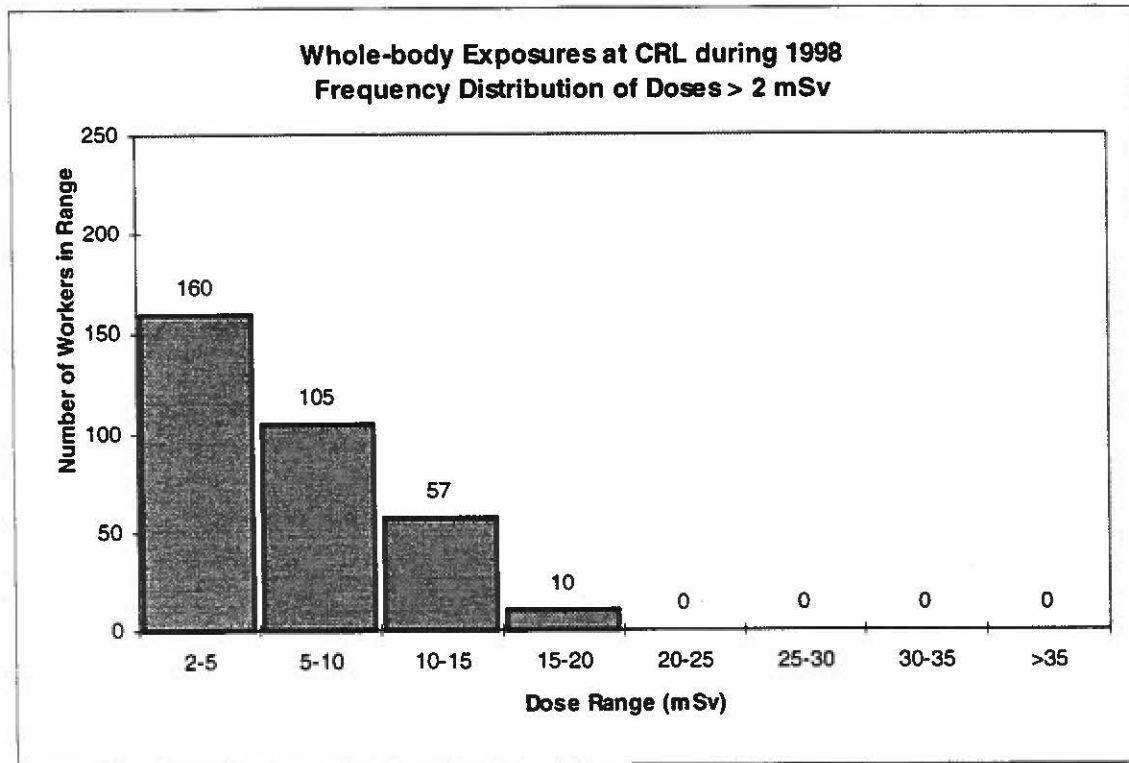


Figure 1: Whole-body Dose Distributions at CRL and WL during 1998.

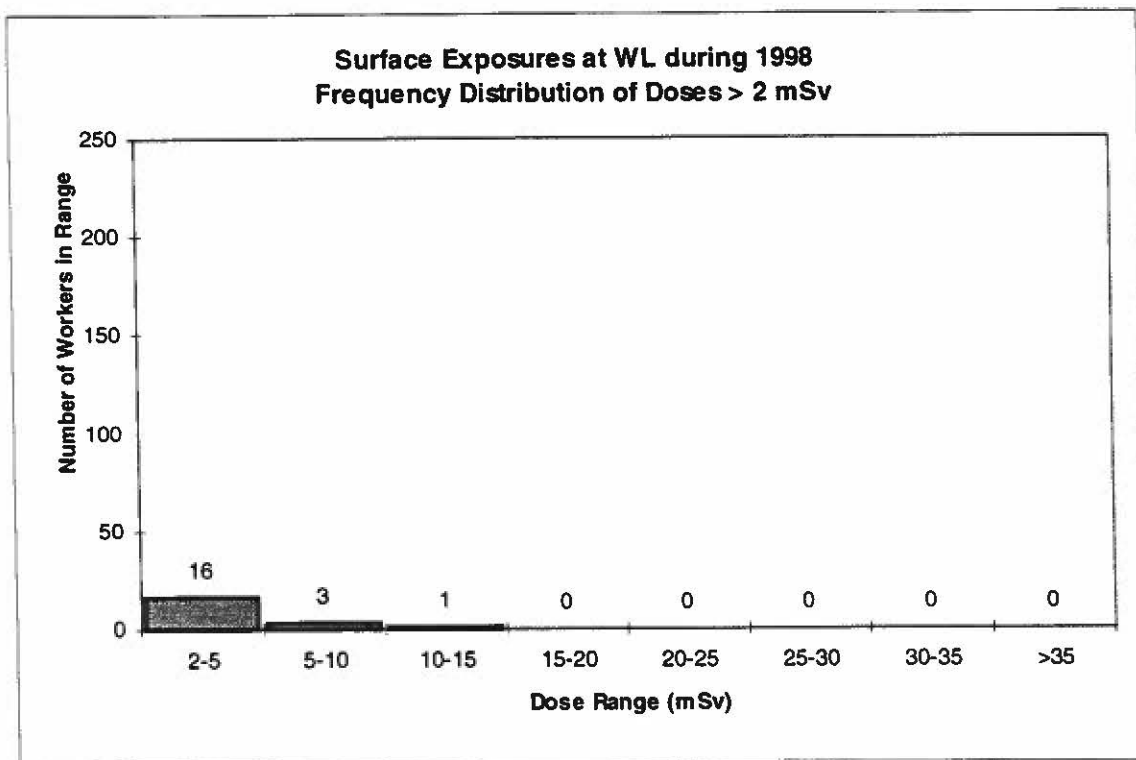
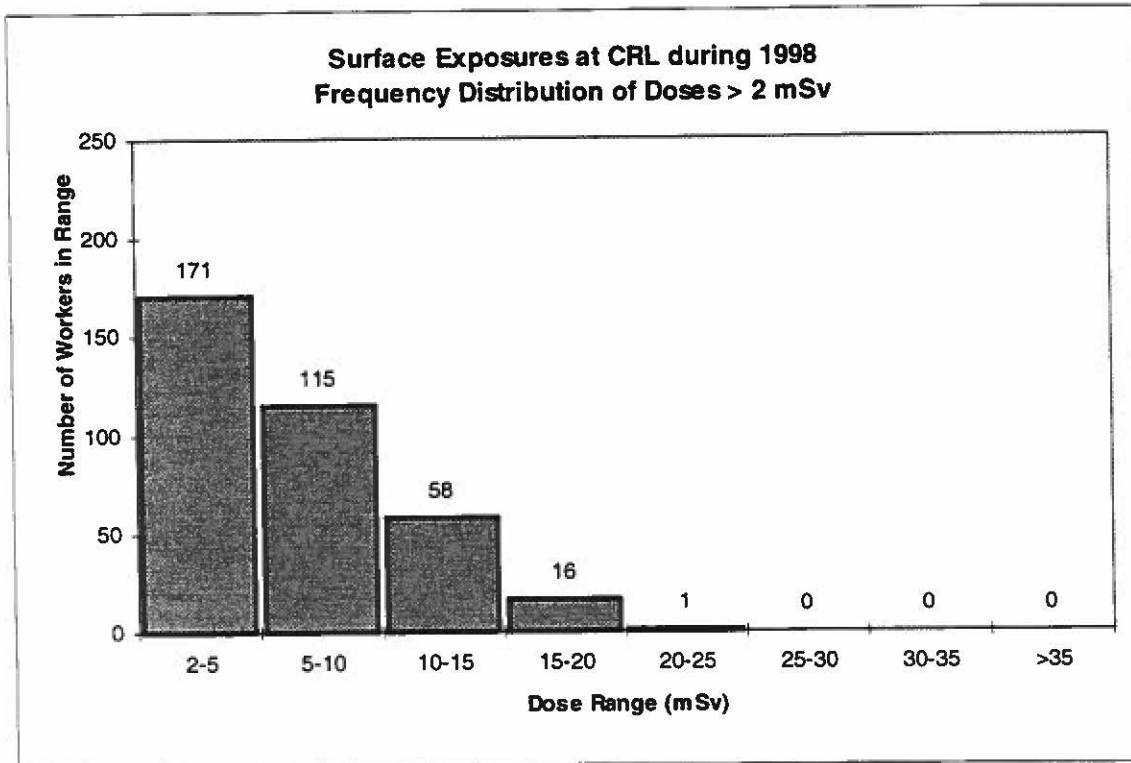


Figure 2: Surface Dose Distributions at CRL and WL during 1998.

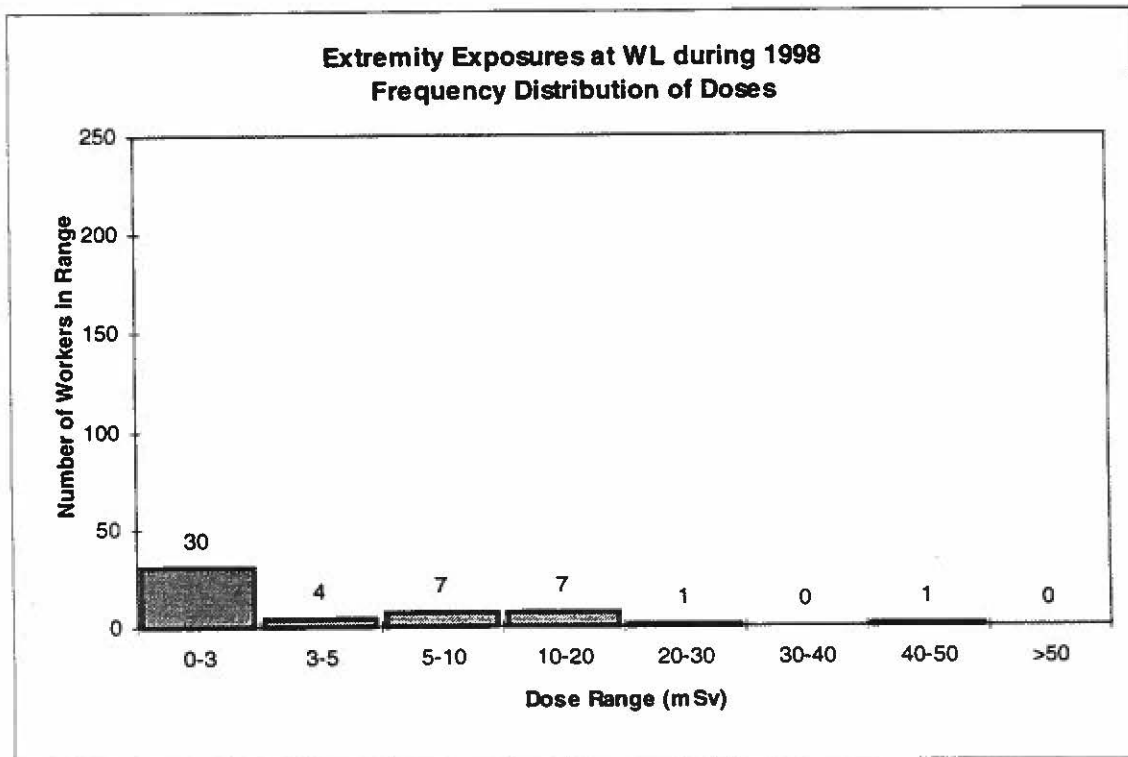
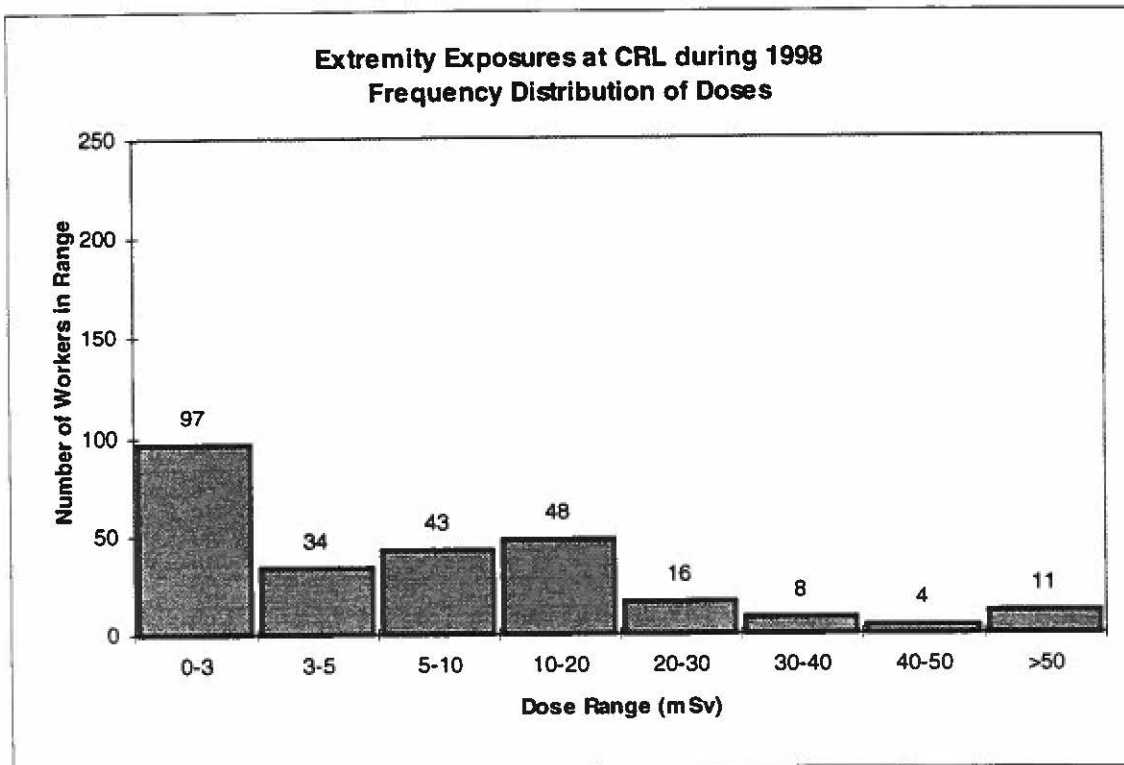


Figure 3: Extremity Dose Distributions at CRL and WL during 1998.

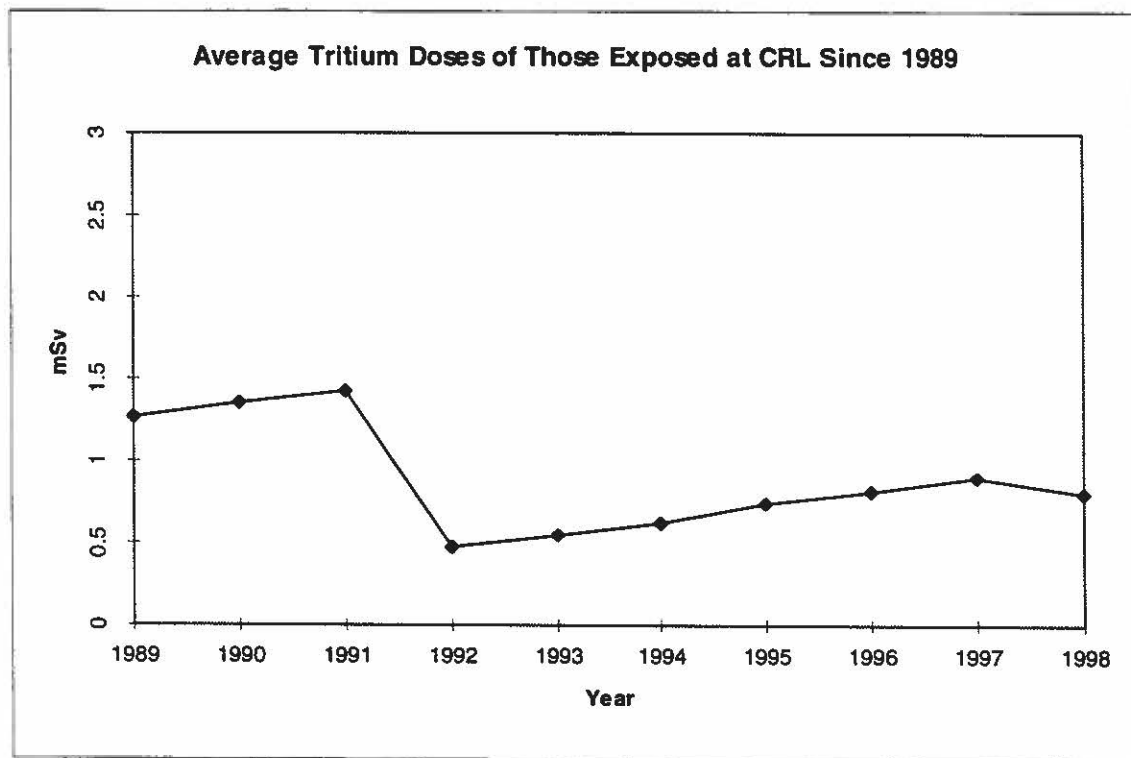
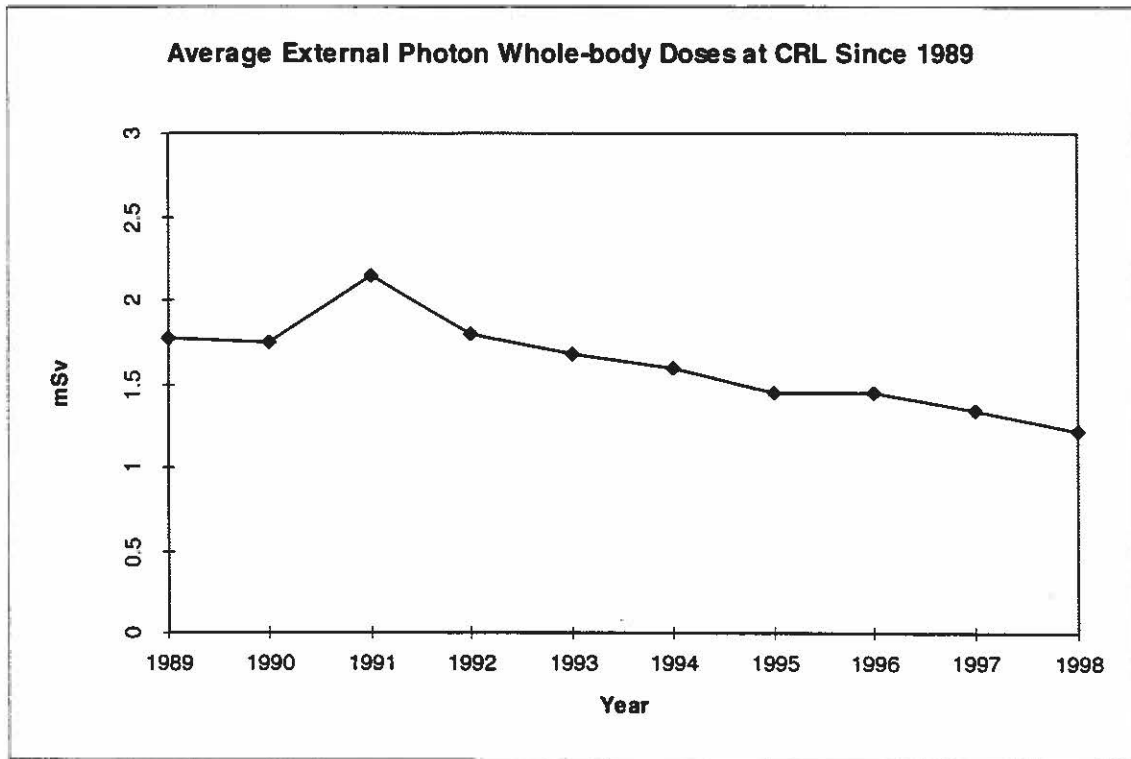


Figure 4: Average Annual Doses at CRL (1989-1998)

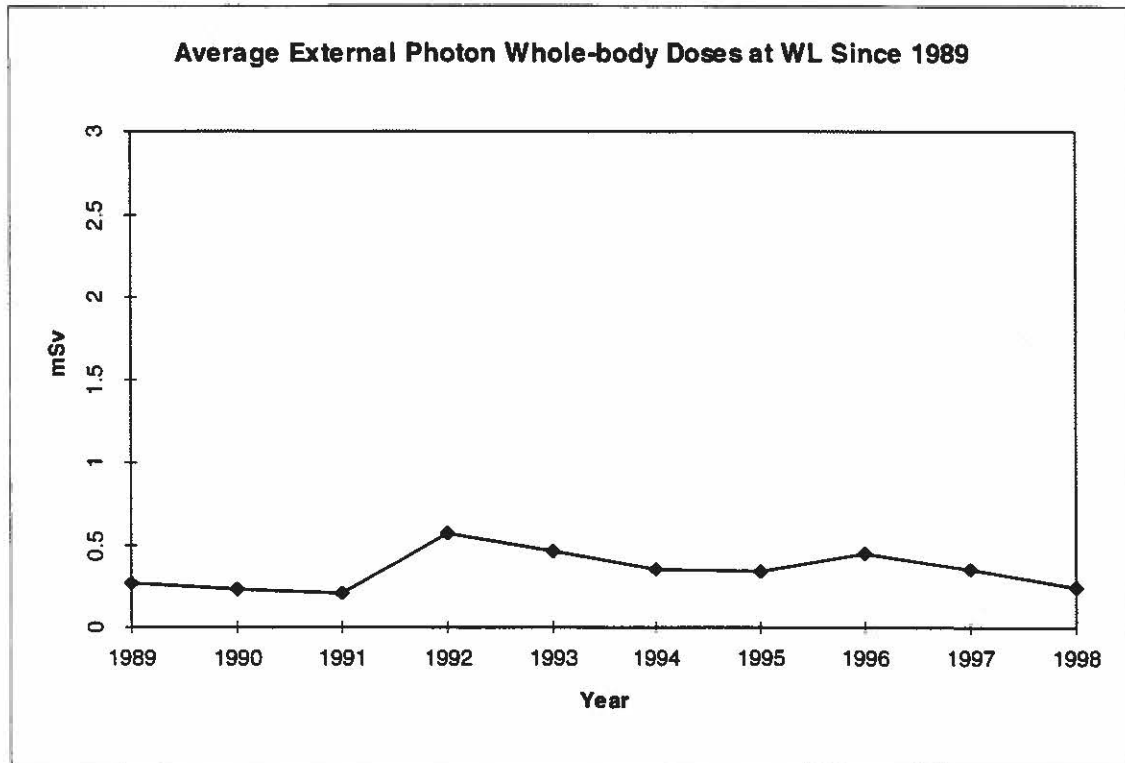


Figure 5: Average Annual Doses at WL (1989-1998)

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