Ecological Effects Review of Chalk River Laboratories

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1.0 INTRODUCTION

1.1 Background

The *Nuclear Safety and Control Act* (NSCA) mandates the Canadian Nuclear Safety Commission (CNSC) to regulate the nuclear industry in a manner that prevents unreasonable risk to the environment and makes adequate provision for environmental protection, in conformity with international obligations. This mandate is reflected in the General Nuclear Safety and Control Regulations under the NSCA, and in the CNSC Regulatory Policy on Protection of the Environment. This policy indicates that licence applicants will be required to "demonstrate through performance assessments, monitoring, or other evidence, that their provisions to protect the environment are adequate".

The CNSC has indicated that an appropriate means of demonstrating this adequate protection of the environment is to conduct an ecological risk assessment (ERA) of the site, and to develop an ecological effects monitoring (EEM) program for the site. The CNSC has advised Atomic Energy of Canada Limited (AECL) that it would like to see progress towards completion of these tasks at the Chalk River Laboratories (CRL) prior to renewal of the existing site licence. The current licence expired on October 31, 2002. AECL requested an extension, and an extension was granted.

An Ecological Effects Review (EER) is an initial ERA, based on currently available information. Based on this initial assessment, recommendations are developed either for more detailed ERA involving gathering of additional site information, or for an ongoing EEM program. AECL selected Beak International Incorporated (now Stantec Consulting Ltd.) and ESG International Incorporated (ESG) to complete an EER for the CRL site, and to develop recommendations for an EEM program based on this work.

This EER follows available ERA guidance from the CCME (1996) and the U.S. EPA (1998). The approaches outlined in these documents are quite similar, notwithstanding some minor differences in terminology, however, neither document specifically addresses radionuclide issues. With respect to radionuclide risk assessment, common international practices are followed.

A Workplan for the EER was developed at the outset of the project (BEAK and ESG, 2002). The workplan outlined the goals, objectives and scope of the EER, and the general methodology to be followed. It was reviewed by the CNSC, and CNSC comments on the Workplan were provided to AECL and the project team.

1.2 Goals, Objectives and Scope

The overall management goals for the EER and any subsequent follow-up ERA work are:

- to assess, and to the extent practical, quantify the actual or potential effects on the (non-human) environment within and around the CRL site resulting from the current operations of nuclear facilities and associated support systems at the CRL site;

- to provide a suitable methodology for assessing compliance with regulatory requirements for protection of the environment, for verifying the adequacy of controls to prevent unreasonable risk to the environment, and to provide suitable input to management decisions regarding areas where remedial or corrective actions may be warranted; and

- to provide a basis for establishing an ecological effects monitoring program, if required, to verify the accuracy of EER/ERA predictions, and to measure any effects on the environment (or lack of effects) including any that cannot be adequately modelled in an EER/ERA.

More specific objectives for the EER were developed during the early stages of the project, as valued ecosystem components (VECs) were identified, and as measures of ecological effect are defined, to be estimated as part of the EER. These specific objectives or endpoints were incorporated into a conceptual model of the site and its ecology and potential ecological effects. The conceptual model provided a blueprint for subsequent estimation of ecological exposures and effects at the site.

The scope of the EER encompasses current operations, and ecological effects potentially arising from these operations. All current releases of contaminants to the natural environment, or other current stressors are considered. Past practices or events are considered where they may be producing a contaminant release or ecological exposure today. Possible or proposed future operations or events are not considered.

The natural environment includes all natural areas, both on-site and off-site, that may be subject to adverse impacts arising from site operations. Thus, any areas where natural biota may be exposed to contaminants or other stressors from site operations are considered to be part of the natural environment and within the scope of the EER study.

1.3 Organization of Report

The main sections of the EER report are as follows:

- 2.0 Problem Formulation
- 3.0 Exposure Assessment
- 4.0 Effects and Risk Characterization
- 5.0 Conclusions and Recommendations

Section 6.0 lists the references that are cited throughout the report.

2.0 PROBLEM FORMULATION

2.1 Engineered Site/Facility Descriptions

The engineered site and facilities within the site at CRL are described in this section to summarize information pertinent to development of the contaminant/stressor list and the conceptual exposure model. This section has been compiled through the following processes:

- acquisition and review of available information describing the engineered site and facilities;
- examination of locations, functions (under normal operations) and characteristics of the main nuclear and support facilities, and the known plumes (air, surface water, groundwater);
- examination of pertinent effluent and environmental monitoring data (radiological and non-radiological);
- examination of information on plume characteristics, including contaminant concentrations near points of discharge to surface water, plume and contaminant travel times, and associated local hydrology; and
- description of any abnormal events that may have persistent ecological impacts (i.e., those that were not fully remediated in the past, and where contaminants are persistent), including non-radiological contaminants.

Releases from each facility are described in an overview sense only in this section. The quantitative releases from the facilities are presented in Appendix 1 (Screening Data Used to Identify Contaminants of Potential Environmental Concern) and Section 3.0 (Exposure Characterization).

2.1.1 Overview

The Chalk River Laboratories (CRL) site is located in Renfrew County, Ontario on the shore of the Ottawa River, 160 km northwest of Ottawa. The site, which has a total area of about 4000 Ha, is situated within the boundaries of the Corporation of the Town of Deep River, with the town located northwest of the CRL property. The Ottawa River, which flows northwest to southeast, forms the northeasterly boundary of the site, the Petawawa Military Reserve abuts the CRL property to the southeast, and the Village of Chalk River in the Municipality of Laurentian Hills lies immediately to the southwest of the site.

The CRL site consists of gently rolling forested hills, interspaced with several small lakes. For security purposes access to the site is restricted to AECL employees and authorized visitors and contractors.

The CRL site was established in the mid 1940s, and has a history of various nuclear operations and facilities, primarily related to research. Most of the nuclear and associated support facilities and buildings on the site are located within a relatively small industrial plant site area adjacent to the Ottawa River near the southeast end of the property. The industrial area is contained within designated and fenced "Controlled Areas" for security and radiation protection purposes. Most non-nuclear facilities and offices are within an area designated as Controlled Area 1, with most of the nuclear facilities contained within a higher security Controlled Area 2 (RC-2000-633-0).

Various waste management areas for radioactive and non-radioactive wastes are located within the CRL property, along the southwest to northeast corridor formed by the main road leading from the Village of Chalk River to the main plant site. Active waste areas have controlled access, and are actually part of Controlled Area 2. Because they are physically separated from the other controlled facilities, they are discussed separately in this report.

The existing facilities, waste management areas and environmental features of CRL are depicted in Figure 2.1. These facilities include the main operations occurring within the Controlled Areas, and the various waste management areas (WMAs) around the site.

The main nuclear facilities at the CRL site as listed in the CNSC licences applicable to the site and currently operational or in construction are:

- NRU Reactor
- Molybdenum-99 Production Facility
- MAPLE 1 and MAPLE 2 Reactors
- New Processing Facility (NPF)
- Waste Treatment Centre (WTC)
- Universal Cells
- Fuels and Materials Cells
- Recycle Fuel Fabrication Laboratories (RFFL)
- Waste Management Areas – CRL
- Nuclear Fuel Fabrication Facilities
- Tritium Laboratory
- CECEUD Test Facility
- Heavy Water Upgrading Plant
- ZED-2 Reactor
- Health Physics Neutron Generator

Permanently shutdown nuclear facilities on the site, intended for or partly decommissioned, as listed in the CNSC licences are:

- The NRX Reactor
- Plutonium Recovery Laboratory
- Plutonium Tower

- Pool Test Reactor
- Waste Water Evaporator

Other small facilities on site that are not specifically listed within CNSC licences include:

- Hot Cells
- Biological Research Facility
- Decontamination Centre
- Active Laundry
- Filter Testing Laboratory
- Miscellaneous classified radioactive and non-radioactive laboratories located in various buildings.

Numerous non-nuclear facilities and buildings on site provide support systems or services to the site and the operation of the nuclear facilities. These include:

- Power House
- Sewage Treatment Plant
- Non-Radioactive Sanitary Landfill (Located south of the industrial plant site)
- Thermalhydraulics Test Loop Facilities
- Other non-nuclear chemical/engineering laboratories
- Fire Hall
- Vehicle & heavy equipment service shops
- Heavy Equipment Maintenance Shop
- Lead casting shop
- Machine / metal fabrication shop
- Various trades shops
- Various offices and cafeteria.

2.1.2 Main Nuclear Facilities

Many of the general facility descriptions presented below are taken from AECL (1990), with additional information taken from various AECL Annual Safety Reviews and from Annual Effluent Monitoring Reports (Niemi *et al.,* 2001) which describe facility emissions.

2.1.2.1 NRU Reactor

The NRU reactor was constructed in 1957, and is a large core, heavy-water (D_2O) moderated and cooled research reactor, operating at a power of up to 135 MW (thermal). NRU is operated in engineering experiments in support of power reactor development, for the production of medical radioisotopes, and for other basic and applied research.

The reactor is fuelled using low (<20%) enriched uranium silicide in aluminum dispersion fuel rods clad in aluminum within a D_2O filled calandria. Heat from the reactor is removed via heat exchangers to a secondary single pass cooling water system, pumped from and returned to the Ottawa River. Spent fuel rods are stored in a water-filled "rod-bay" system in the NRU building.

Characteristics of NRU waste stream are provided in AECL (2002a). These wastes are briefly described below.

The cooling water from NRU is monitored continuously for beta-gamma activity, and is discharged with other effluent from NRU and other facilities by the process sewer, which is also sampled continuously. Reactor low level active liquid wastes are collected and are discharged to the Waste Treatment Centre (WTC) for treatment.

Ventilation air exhaust from NRU is filtered and then released along with releases from the Dedicated Isotopes Facility (DIF) via the main reactor stack located about 1 km west of the main plant site, with secondary releases occurring from NRU building vents. These releases are monitored for Ar-41, I-125, I-131, C-14, particulate alpha and beta, and tritium oxide.

Solid waste from NRU is sent to the WTC and subsequently to waste storage areas at CRL, depending on radioactivity levels. These wastes include protective disposable clothing, wipes, dry mop heads, and contaminated or suspected contaminated paper products that are compacted, where feasible, loaded and sent to bunker storage in Waste Management Area "B" (WMA-B) (see Section 2.1.14 for overview of Waste Management Areas). Large contaminated or suspected contaminated items are placed in the Waste Management Areas. Highly radioactive items including irradiated fuel and reactor components are transferred to tile hole storage in WMA-B.

2.1.2.2 Molybdenum-99 Production Facility

The Molybdenum-99 facility is used for the dissolution and chemical extraction of Mo-99 (used to generate Technetium-99, a daughter product) and Xe-133. The production process, housed within heavily shielded cells, uses an irradiated uranium-based target (currently irradiated in the NRU Reactor). The Mo-99 and Xe-133 are used for medical diagnostic and treatment purposes after purification by MDS-Nordion.

Atmospheric releases from the Molybdenum-99 Production facility are filtered and exhausted at building 206, along with emissions from Cell 1 of the Universal Cells Facility. The combined release from both sources is monitored and reported, with most of the release attributed to Mo-99 production (AECL 2002b). Exhaust monitoring includes I-131, mixed fission product noble gases, and gross beta and gross alpha particulate.

High level liquid waste from the target dissolution process is generally transferred to the Fissile Solution Storage Tank (FISST) or, if and when necessary due to FISST availability, is solidified by cementing within the facility and sent to WMA "B" as solid waste. Low level liquid wastes from the Mo-99 production facility, including FISST Life Extension (FL/E) condensate is sent via the Active Drain system to the CRL WTC for treatment.

Solid wastes from the facility are managed according to their radiation levels. These include low-level contaminated wastes consisting largely of paper, disposable protective clothing and cleaning materials that are compacted and baled for bunker storage (WMA-B). Contaminated or slightly contaminated materials with short-lived isotopes are placed in sand trenches (WMA-C). Cell wastes (from inside the hot cell) are packaged and sent for tile hole storage (WMA-B). Cemented fissile liquid waste is packaged in pails and stored in Tile Holes in WMA-B.

2.1.2.3 MAPLE 1 and MAPLE 2 Reactors

The MAPLE 1 and MAPLE 2 reactors were recently constructed at the CRL site on behalf of MDS-Nordion for production of medical radioisotopes, taking over this function from the NRU Reactor. The MAPLE 1 reactor first achieved low power in 2000 and the two MAPLE reactors have subsequently been undergoing testing and commissioning prior to starting full operation. The MAPLE reactors are light-water cooled pool type reactors, and together with the New Processing Facility form the Dedicated Isotopes Facilities (DIF) complex. DIF is owned by MDS-Nordion and operated by AECL.

Ventilation exhaust from the MAPLE reactors discharges to the atmosphere after filtration via the NRU/DIF stack, which is monitored for Ar-41, C-14, tritium oxide, I-131, I-125 and gross beta and gross alpha particulate radioactivity. DIF (MAPLE 1) roof vents are monitored separately for I-131, I-125, gross beta particulates and gross alpha particulates. Liquid effluent from DIF includes cooling water and sump discharges that are discharged via the process sewer to the Ottawa River, after decontamination as required at the WTC. Contaminated solid wastes from the Maples are also managed at the WTC for WMA disposal.

2.1.2.4 New Processing Facility (NPF)

The NPF, which has recently been constructed at the CRL site on behalf of MDS-Nordion and is currently in testing and commissioning phase, is intended to process radioisotope targets irradiated in the MAPLE reactors to extract Mo-99 (for generation of Tc-99m) and Xe-133 for medical purposes. This facility is intended to replace the current Molybdenum-99 Production Facility in Building 225. The target processing and extraction processes in these two facilities are different, since the design of MAPLE targets is considerably different from the NRU Mo-99 targets.

High level liquid waste from the processing of irradiated targets in the NPF will be solidified within the facility using a calcining process, and will be transferred to WMA-G for storage in above ground concrete canisters.

Low level liquid wastes will be collected and transferred via the Active Drain system to the WTC for treatment.

Air effluents from the NPF are filtered and discharged, along with air from NRU and the MAPLE reactors, to the NRU/DIF reactor stack.

2.1.2.5 Waste Treatment Centre (WTC)

The Waste Treatment Centre (WTC) functions in the treatment of solid and liquid wastes from CRL facilities that are contaminated or suspected of being contaminated by radioactivity. The WTC also treats radioactive waste received by CRL from off-site waste generators.

Solid wastes are baled, after compacting if possible, and are transferred for storage in concrete bunkers in Waste Management Area "B". The number of 0.4 m^3 bales produced per year ranged between 217 and 258 from 1997 to 2001. The solid waste generated internally by the WTC are additional to those quantities, and include disposable clothing, paper and cleaning materials which are compacted where possible, baled and stored in WMA "B" bunkers. Slightly contaminated and suspected wastes (2.2 to 98.1 m^3/yr between 1997 and 2001) of WTC waste were also sent for sand trench storage in WMA "C".

Liquid waste is treated in variable amounts per year, ranging between 1,923 and 5,821 m^3 between 1997 and 2001. These wastes consist of Decontamination Centre Waste, Chemical Active Drain System Waste, Reactor Active Drains Waste and DIF waste. Treatment facilities include a Liquid Waste Evaporator (LWE) (to concentrate the waste) and a Liquid Waste Immobilization System (LWIS) which immobilizes the concentrate in bitumen, which is drummed and stored in WMA "B".

Atmospheric releases of radionuclides from the WTC occur via roof vents (exhaust fans); monitoring of the exhaust streams includes particulate gross alpha activity, particulate gross beta activity, tritium oxide and I-131. Treated liquid effluent from the WTC is discharged to the process sewer after sampling for gross alpha, gross beta and tritium oxide (Neimi *et al*., 2001). The liquid effluent is also regularly monitored for suspended solids, total phosphorus, nitrates, pH, conductivity, organic carbon, chemical oxygen demand, solvent extractables, metals, volatile organics and semi-volatiles (Turner, 2002).

2.1.2.6 Universal Cells

The Universal Cells are heavily shielded facilities designed and used for experimental manipulation, examination and testing of highly radioactive materials. Atmospheric emissions are filtered and released via roof vents and are monitored for particulate gross beta, particulate gross alpha and I-131 (Niemi *et al*., 2001). Liquid and solid wastes from the Universal Cells are treated at the WTC.

2.1.2.7 Fuels and Materials Cells (FMC)

The FMC facility is similar to the Universal Cells, and is used for examination and metallurgical testing and experimentation with highly radioactive fuels and reactor components. Atmospheric releases from this facility occur, after filtration, via roof vents, and are monitored for particulate gross beta, particulate gross alpha and I-131 (Niemi *et al.,* 2001).

2.1.2.8 Recycle Fuel Fabrication Laboratories (RFFL)

The RFFL was constructed as an annex to the south end of Building 375 during the 1970s. The purpose of the facility was the fabrication of experimental quantities of alpha-active ceramic fuels, typically: uranium-plutonium, thorium-plutonium, and thorium-233 U. The facility consists of several laboratories. The main fuel fabrication laboratory houses three interconnected lines of negative-pressure ventilated glove boxes and fume hoods, to allow the fabrication of sintered pellets of mixed-oxide fuel, which are then clad and sealed into CANDU-type fuel elements.

Atmospheric releases from this facility occur, after filtration, via roof vents, and are monitored for particulate gross beta and particulate gross alpha (Niemi *et al.,* 2001).

2.1.2.9 Waste Management Areas – CRL

These facilities are discussed in detail in Section 2.1.7.

2.1.2.10 Nuclear Fuel Fabrication Facilities (NFFF)

These facilities are used to produce all fuel assemblies and Mo-99 target assemblies for the NRU reactor and the MAPLE 1 reactor. Building roof vents are filtered and monitored for releases of particulate gross alpha and particulate gross beta to the atmosphere from the fuel fabrication process (Niemi *et al.*, 2001).

2.1.2.11 Tritium Laboratory

The Tritium Laboratory located in Building 250 is used almost exclusively for work with tritium in various chemical forms; the most common are tritium gas, usually stored as a metal tritide, and tritiated water. The laboratory serves as the primary facility for conducting R&D activities associated with heavy-water management and tritium control in CANDU reactors. In addition, tritium is dispensed under contract to Ontario Power Generation for their customers.

Atmospheric releases from these laboratories occur via roof vents, and are monitored for tritium in elemental (HT) and oxide (HTO) form (Niemi *et al.*, 2001).

2.1.2.12 CECEUD Facility

The Combined Electrolysis Catalytic & Exchange Upgrading/Detritiation (CECEUD) Test Facility is located in Building 215 in the Northwest extension to the Chalk River Laboratories Controlled Area 2. The CECEUD Test Facility demonstrated the combined electrolysis and catalytic exchange process for both heavy-water upgrading and detritiation.

This was done in two operational phases: upgrading, which was completed in 1999 December; and detritiation, completed in 2001 April. Facility operations have ceased and the facility is now unattended. However, it is regularly monitored in a ‘safe shutdown state’.

Air effluents from building roof vents are monitored for tritium in elemental and oxide form (Niemi *et al.*, 2001).

2.1.2.13 Heavy Water Upgrading Plant (HWUP)

This facility used distillation and electrolysis to clean and upgrade heavy water (D_2O) to meet quality and concentration specifications for reactor use. Atmospheric emissions from this facility are released via roof vents and are monitored for tritium oxide. Liquid effluent is discharged to the process sewer.

Upgrading operations in the HWUP ceased permanently in 1998 August. As of 1999 September 01 the facility ceased to be occupied on a regular basis; it was placed in a Safe Shutdown State (SSS) in preparation for eventual decommissioning, and is now secured against unauthorized entry. It is currently being monitored by security and radiation protection personnel, or by facility supervision on a daily basis. Periodic drum shipments of downgraded heavy water are made from the shipping dock area.

2.1.2.14 ZED-2 Reactor

The ZED-2 Reactor, located in Building 145 is a versatile, heavy-water moderated, zero energy (less than 200 watts) critical facility that can be used for a variety of experiments. It is used mainly for reactor physics measurements on various fuel types with several coolants over a range of lattice pitches. The reactor can also be used for measurements on mockups of reactivity control devices and fuel channels of both power and research reactors. A heavy-water region in which neutrons are well-thermalized can be assembled and used for neutron detector calibration and thermal neutron cross-section measurement. The reactor is operated for short periods (generally less than an hour) at a power of less than 200 watts on an average of about 70 days per year.

The facility does not generate any significant airborne or liquid radioactive wastes.

2.1.2.15 Health Physics Neutron Generator

The Health Physics Neutron Generator is a high-voltage accelerator, designed to accelerate 1 mA of deuterium ions through 150 keV. It produces 14 or 2.7 MeV neutrons, by the D(t,n) □or D(d,n)3 He reactions, when the deuteron beam strikes a titanium hydride target containing either tritium or deuterium. The accelerator is used mainly for studying the response of various neutron dosimeters and instruments to fast neutrons. It was put into service in 1961. The designed maximum outputs are 5×10^{10} 14 MeV neutrons, or about 5×10^{8} 2.7 MeV neutrons. The accelerator is normally operated close to its maximum output and is installed in a heavily-shielded, underground room in the radiation facility wing of Building 513 at CRL.

The facility does not generate any significant airborne or liquid radioactive wastes.

2.1.3 Permanently Shut-Down Nuclear Facilities

2.1.3.1 NRX Reactor

The NRX reactor is a D_2O moderated and cooled research reactor built in 1947. NRX has been used as a back-up for NRU in the production of short-lived radioisotopes (Mo-99, I-125) and miscellaneous irradiation. NRX has a rod bay that was used for spent fuel storage until 1995. However, the rod bay has leaked into groundwater since 1959, producing a plume of tritium and Sr-90 which discharges to the Ottawa River via groundwater and a storm sewer (04). Other radionuclides released, including Co-60, Cs-134, and Cs-137, appear to be contained in the ground adjacent to the NRX facility.

Airborne emissions from the facility's main stack and from roof vents with potential for radioactive releases continue to be monitored for gross alpha activity, gross beta activity and tritium oxide.

2.1.3.2 Plutonium Recovery Laboratory

Building 220 at CRL formed part of the Plutonium and Thorium Fuel Processing Facilities. The building was erected in 1947, and the facilities commissioned in 1949 to extract plutonium isotopes from enriched fuels used in research reactors during the late 1940s and early 1950s. Research and operations in Building 220 were discontinued in 1957.

The Plutonium Recovery Laboratory has remained in a static state since 1957, until it was accepted as a decommissioning project in 1990 by the Treasury Board. During this period, some dismantling and cleanup work was performed. This facility is presently in storage with surveillance state.

2.1.3.3 Plutonium Tower

This facility was built in 1948 as part of a joint AECL-UKAEA research program to develop methods of concurrent liquid aqueous extraction of plutonium from solutions of dissolved irradiated uranium. Research and operations in Building 223 were discontinued in 1954.

The Plutonium Tower remained in a static state since 1954 until the early 1980s, when process and ventilation equipment and services, including electrical power, were removed. Some decontamination work was done in the interior. The facility is presently in a storage with surveillance state.

2.1.3.4 Pool Test Reactor

The Pool Test Reactor (PTR) was a “zero energy” (100 W) reactor used for physics research. The PTR facility at CRL has not been operated since 1990 October. All irradiated fuel elements have been removed from the core and are currently stored in the dry storage block in the reactor room. The four main control elements have been disconnected from their hydraulic actuators, and are also stored in the reactor room. In 1994, the single fine control absorber and its actuator, as well as the actuators of the four main control elements, were removed from the PTR pool. The water remains in the pool, and the water purification and makeup system, and the radiation monitors are still maintained in an operating state.

2.1.3.5 Waste Water Evaporator

The Waste Water Evaporator facility in Building 228 was used as part of the process for irradiated fuel processing during the 1950s. Fuel processing activities ceased at CRL in 1958 and the uranium recovery equipment was removed from the Waste Water Evaporator. The facility was used for liquid waste evaporation with replacement evaporators fitted in 1959 and 1962. No processing activity has occurred since 1971. The facility is presently in storage with surveillance state.

2.1.4 Other Small Nuclear Facilities

2.1.4.1 Hot Cells

Two hot cells located in a laboratory within Building 250 are equipped for the dissolution of samples of irradiated fuel and cladding and subsequent fuel research including isotopic composition and separation procedures. Air effluents are filtered and discharged via roof vents and are monitored for gross beta and gross alpha particulates and I-131. Low level liquid waste is discharged via the Active Drain System for treatment at the WTC.

2.1.4.2 Biological Research Facility

The Biological Research Facility consists of various laboratories for conducting biology research using cell cultures and animals (e.g. mice), and includes a ^{60}Co gamma irradiation facility. The purpose of the facility is to enable AECL to improve and expand its underlying knowledge of biological processes and health effects of ionizing radiation.

There are no significant radioactive air or liquid emissions from the facility. Wastes containing biological materials are treated chemically or by autoclaving to eliminate any potential biological hazards prior to transfer to the WMAs.

2.1.4.3 The Decontamination Centre

This facility is used for cleaning radioactive contamination from the surfaces of vehicles, equipment and materials for re-use. Filtered atmospheric releases via roof vents (Bldg 468) with potential for radioactive releases are monitored for gross beta, gross alpha, I-131 and I-125 and tritium oxide. Liquid and solid wastes from the Decontamination Centre are treated at the CRL WTC.

2.1.4.4 Active Laundry

The Active Laundry is used to clean clothing, worn by employees working in potentially contaminated areas, and which may contain small quantities of radioactive contamination. The facility uses industrial washing machines. Wastewater, which contains detergents and may contain trivial levels of radioactivity, is discharged into the sanitary sewer system for treatment in the Sewage Treatment Plant.

2.1.4.5 Filter-Testing Laboratory

This facility is used for preparation and testing of HEPA filters and charcoal adsorber assemblies prior to installation in ventilation systems of nuclear facilities. Testing includes the use of small quantities of I-131 for measuring the removal efficiency of the charcoal adsorbers. Atmospheric releases from this laboratory occur via filtered roof vents and are monitored for I-131, particulate beta, and particulate alpha activities. The building also houses the CRL air effluent monitoring laboratory.

2.1.5 Main Non-Nuclear Support Facilities

2.1.5.1 Power House

The Power House provides water, steam for building heating, and compressed air to buildings on site, and serves as the distribution centre for electricity to the site.

Water is pumped from the Ottawa River through two intake wells and distributed through four systems:

- NRU cooling water, which is shock chlorinated for about ½ hour daily as necessary to prevent biofouling of heat exchangers.
- MAPLE reactor cooling water, which (when the reactors begin full operation) will also be shock chlorinated daily as necessary to prevent biofouling of heat exchangers.
- Service water system, which provides general-purpose water to buildings on site for domestic and some laboratory and process uses. This water is continuously chlorinated to kill bacteria.
- Fire water system, which serves building fire sprinkler systems and fire hydrants and other connections for fire fighting, as well as some cooling water applications. The water is continuously chlorinated to kill bacteria.

Steam for heating of most buildings on site and some minor process applications is produced in the Power House in large industrial boilers using No. 6 heavy oil as a fuel. The boilers consume approximately 10,000,000 L of fuel oil annually. Fuel consumption is minimized by use, to the extent practical, of steam generated by experimental loops in the NRU reactor to supplement the steam heating system: this typically accounts for about 10 to 15% of the total steam production. Burning the fuel oil results in emissions of NO_x, SO_x and CO_2 via the Power House stacks to the atmosphere. These emissions are regularly monitored. Liquid waste from boiler blowdown is directed into the sanitary sewer system for treatment in the Sewage Treatment Plant.

Compressed air for breathing air systems and for process applications is generated by operation of large air compressors in the Power House. These require cooling water, which is discharged to the Ottawa River via the Power House Drain. This flow is regularly monitored for both chemical and radioactive contaminants.

The Power House controls the distribution of electrical power to the plant site through switchgear located in a transformer yard adjacent to the building. It also provides back-up emergency electrical power through diesel generators.

2.1.5.2 Sewage Treatment Plant

Sanitary sewage from building throughout the plant site is collected in a sanitary sewer drainage system and directed to the Sewage Treatment Plant (STP) for treatment prior to discharge. The current STP, which was built in 1977, consists of single stage treatment in a reactor-clarifier flowed by chlorination of the effluent. Sludges from the clarifier are collected, digested and thickened prior to transfer to WMA – C for placement in the landfill, due to the potential for low levels of radioactive contaminants

2.1.5.3 Non-Radioactive Sanitary Landfill

A sanitary landfill facility for non-radioactive wastes is located just south of the main industrial plant site. The landfill receives domestic and non-hazardous solid industrial wastes, including construction scrap, demolition rubble, and low grade fill.

2.1.5.4 Thermalhydraulics Test Loop Facilities

The thermalhydraulics test loop facility is used to conduct research on heat transfer and removal in support of CANDU power reactor design and operation. The test loops simulate conditions inside a nuclear reactor fuel channel using halocarbons as a heat transfer fluid in order to avoid use of the very high temperatures and pressures required when using water. The loops originally used CFC's as the working fluid, but during the early 1990s the systems were converted first to HCFCs having an ozone depleting potential (ODP) of about 0.05 (relative to ODP for CFC-11 of 1.0), and subsequently to HFCs which have an ozone depleting potential of zero. Some emissions of HFCs to the atmosphere do occur, primarily due to losses when installing or removing experimental assemblies from the loops and occasional minor leakage from valves and fittings.

2.1.6 Liquid Drainage Systems

Four main drainage systems serve to collect and transfer wastewater and other liquid effluents within the CRL industrial plant site.

2.1.6.1 Sanitary Sewer System

The Sanitary Sewer system, which serves most buildings in both Controlled Areas 1 and 2, collects domestic wastewater from sinks, showers and washrooms in buildings, industrial and process wastewater from sinks, floor drains and sumps in various labs, workshops, and facilities, and some small volumes of cooling water. Small quantities of low toxicity water soluble chemicals may be discharged into this system from some labs and facilities, as well as very small incidental quantities of radioactive contaminants from showers and sinks in washrooms of nuclear facilities, effluent from the Active Laundry and some Class C radioactive laboratories located in Controlled Area 1. Wastewater collected in the sanitary sewer system is treated in the CRL Sewage Treatment Plant, chlorinated to kill any bacteria, and discharged to the Ottawa River, after separation of sludge that is sent to WMA-C. The STP effluent is continuously sampled and regularly analysed for both chemical and radioactive contaminants. Effluent from the STP, with a flow rate averaging about 5E+05 L/d, discharges through a 0.3 m (12”) pipe extending a distance of about 110 m (350 ft) into the river at a water depth of about 2 m. The effluent is not acutely toxic based on recent toxicity testing by Environment Canada.

2.1.6.2 Active Drain System

The Active Drain system collects low level radioactive wastewater from nuclear facilities and radioactive laboratories within the Controlled Area 2 in the CRL industrial plant site. Water collected in the Active Drain system may also contain small quantities of low toxicity water soluble chemicals but wastewaters containing large amounts of complexing compounds and detergents are not permitted due to process incompatibility and potential adverse effects on the final solidified retained waste. The Active Drain system consists of a network of underground pipes connecting to wastewater holding tanks on site for interim storage of the wastewater and/or transfer to the Waste Treatment Centre for treatment prior to monitored discharge to the Ottawa River via the Process Sewer. (Previously the low level wastewater collected by the Active Drain System was discharged via pipelines into in-ground dispersal pits in the Waste Management Areas.) The original Active Drain System consisted primarily of a single-walled underground piping system, and several leaks are known to have occurred from the system into the surrounding soil within the Controlled Area 2 (and/or along the pipeline route to the Dispersal Pits) during its lifetime. A new Active Drain System consisting of double contained underground piping system with an integral continuous leak detection system in the interstitial space and a new set of holding tanks with secondary spill containment has recently been constructed and is being commissioned.

2.1.6.3 Process Sewer System

The Process Sewer collects cooling water and authorized process type discharges from several major nuclear facilities within the Controlled Area 2, including the main cooling water discharges from the NRU Reactor and the MAPLE reactors, treated and monitored effluent from the Waste Treatment Centre, and monitored discharges from various sumps and holding tanks in these and other facilities. Effluent flow rates through the Process Sewer average about 8.3E+07 L/d, primarily due to the large volume of NRU coolant. The Process Sewer discharges to the Ottawa River through a 1.2 m (48") diameter pipe extending about 75m (250 ft) from shore (the shoreline was artificially built out at this point), at a water depth of about 17 m (55 ft), through a diffuser system consisting of three upward facing nozzles (about 0.8 m diameter) spaced along the last 8 m of the pipe. The Process Sewer carries waste heat from the reactors, occasionally contains some residual chlorine from periodic shock chlorination of the reactor cooling water, and may contain very small concentrations of radioactive materials. The effluent is continuously monitored for temperature, and continuously sampled with the samples analysed regularly for radioactive contaminants and periodically for chemical contaminants. The effluent is not acutely toxic based on recent toxicity testing by Environment Canada.

2.1.6.4 Storm Sewer System

The storm sewer system collects and discharges surface runoff, drainage from building roofs, footing and foundation drains, and clean cooling water from various building air conditioning chillers and other processes within the CRL industrial plant site and the associated parking lots. In some cases the storm drains, built in the 1940s and 1950s, made use of pre-existing natural streams running through the CRL plant site for this purpose in accordance with the general practices of the day, routing them through underground pipes. There is not a single discharge for the storm sewer system, but there are several different discharges from sub-systems serving different areas of the industrial plant site. The key discharge points are:

- The "O-4" Storm Sewer serves the majority of the Controlled Area 2, and discharges via a 1 m diameter closed pipe at the Ottawa River shoreline. Average flow rate through this storm sewer is about 6E+06 L/d. The discharge normally contains small quantities of radioactive material due to the foundation drains of one building partially intercepting a subsurface plume of radioactivity (predominantly tritium and Sr-90) originating from historic leakage from the NRX Rod Bays. This effluent is continuously sampled, and analysed regularly for radioactive contaminants and periodically for chemical contaminants.

- The "O-3" Storm Sewer serves the majority of the Controlled Area 1 within the plant site, including the majority of the parking lot areas inside and outside the Controlled Area 1 main gate. It discharges from a 1.2 m diameter underground pipe just outside the Controlled Area 1 fence and follows an open channel streambed with a moderate gradient for a distance of about 50 m before discharging into the Ottawa River. Average flow through this storm sewer is in the order of 5E+06 L/d. The effluent is regularly sampled and analysed for radioactive contaminants, and periodically for chemical contaminants.

- The "O-5" Storm Sewer serves the north boundary of the Controlled Area 2, adjacent to Building 570. Average flow through this storm sewer is in the order of 4E+05 L/d. The effluent is regularly sampled and analysed for radioactive contaminants, and periodically for chemical contaminants.

- The "O-1" Storm Sewer serves the southern end of the Controlled Area 1. Average flow through this storm sewer is in the order of 5E+05 L/d. The effluent is regularly sampled and analysed for radioactive contaminants, and periodically for chemical contaminants.

In addition to these main drainages, the following streams carry significant storm water flows (all these are monitored regularly for tritium, gross beta and gross alpha):

- Storm Sewer manholes 4F-6 and 4F-7, which collect surface and groundwater drainage from a portion of Controlled Areas 1 and 2 in the vicinity of and uphill from the Powerhouse. These sewers are routinely sampled and analyzed for radioactive contaminants.

- The main Powerhouse drain, which, in addition to drainage from within the Powerhouse, also collects some groundwater by way of a weeping tile system. This drain is routinely sampled and analyzed for both chemical and radioactive contaminants.

- The 06 Stream, which collects surface and groundwater drainage from Controlled Area 1. The stream is routinely sampled and analyzed for radioactive contaminants.

The Powerhouse drainage and the 03, 04 and 05 Storm Sewer flows were recently tested for toxicity by Environment Canada and were not acutely toxic.

2.1.7 Waste Management Areas (WMAs)

Detailed information on the construction and operational histories of the CRL waste management facilities are documented in a Safety and Hazards Analysis Report (McAuley *et al.*, 1995) and a Facilities Description Document (AECL, 1993). Dolinar *et al.* (2000) provided a concise summary of each WMA, including details on waste types and volumes, as well as operational history; the information presented herein is extracted from this source. Table 2.1 and Figure 2.2 summarize information on the WMAs and their operational timelines. The locations of these facilities are provided in Figure 2.1

2.1.7.1 WMA-A

WMA was used for the direct disposal of solids and liquids in trenches excavated in the overburden, beginning in 1946. A large quantity of radioactive waste was emplaced in WMA-A from the cleanup of the NRX reactor accident in 1952. Waste emplacement operations were terminated in 1955.

2.1.7.2 Liquid Dispersal Area

The Liquid Dispersal Area (LDA) is adjacent to WMA-A, and received liquid waste from holding tanks at Building 240 via a pair of pipelines over the period from 1953 to 2000. It includes:

- Reactor Pit #1 – received low level radioactive liquids from the NRU and NRX reactors including tritium, Sr-90, various fission products, and Pu between 1953 and 1956. In 1998 it was backfilled with contaminated equipment and with "suspect" soil and rock rubble (geologic materials excavated from the CRL Active Area), which may be locally contaminated.

- Reactor Pit #2 – established in 1956, was used to disperse low level radioactive wastewater from the NRU and NRX reactors. The wastewater contained tritium, Sr-90, and various fission and activation products. Since February 2000, this reactor waste has been treated at the WTC, although the reactor pit remains available as a back-up in the event of long term unavailability of the WTC pending the next phase of proposed upgrades of the WTC.

- Chemical Pit – established in 1956 to receive low level radioactive liquid wastewater containing some chemicals, originating from radioactive laboratories and various chemical processes on site. Beginning in 1992 this waste stream was rerouted to the WTC for treatment. As a result the Chemical Pit has not routinely received wastewater since 1992 and there have been no discharges to the pit since 1995, although the pit remains available for backup use. A groundwater treatment (pump and treat) facility is operated in the chemical pit area. Treated water is discharged to surface and returns to the aquifer.

- Laundry Pit – established in 1956 and used for only one year to disperse wastewater from the active area laundry and Decontamination Centre.

2.1.7.3 WMA-B

WMA-B was established for solid waste management in 1953. It includes:

- Unlined soil trenches, used for solid wastes between 1953 and 1963.
- Asphalt-lined and capped trenches – used for solid intermediate-level waste in the 1950s.

- Concrete Structures – used to store materials requiring modest shielding only, consisting of rectangular concrete bunkers until 1979 and, more recently, of cylindrical concrete bunkers. Infiltration of water into the bunkers is prevented using hinged covers while they are in active use and concrete covers when full.
- Tile Holes – used to store more highly radioactive material, and consisting of water-proofed concrete pipes on a concrete base, set within a trench above the water table.

A groundwater treatment (pump and treat) facility is operated at the northwest perimeter of Area B. Treated water is discharged to surface and returns to the aquifer.

2.1.7.4 WMA-C

WMA-C was established in 1963 for storage of low-level wastes that will be hazardous for less than 150 years and wastes that cannot be confirmed to be uncontaminated. These wastes are stored and covered in trenches. Excavated soils with little or no contamination from the CRL site are used to backfill the trenches. Wastes currently stored on surface include waste in drums and sections of the NRX stack.

2.1.7.5 WMA-D and Bulk Storage Area

WMA-D was established in 1976 to store old equipment known or suspected to be contaminated, plus containers of drums containing contaminated oils, and liquid scintillation cocktail waste. These materials are all stored above ground.

The Bulk Storage Area here was used prior to 1973, and contains large equipment parts from Control Area 2 that was believed to be free of contamination, but which have been more recently found to include some materials with low-level contamination.

2.1.7.6 WMA-E

This area is near the Waste Tank Farm, and was used between 1977 and 1984 to receive suspect and slightly contaminated soil and building material. Some suspect material was also placed here in 1999, but was later removed. The volume of suspect waste at WMA-E is small.

2.1.7.7 WMA-F

This area was established in 1976 for storage of contaminated soils and residues from Port Hope, Albion Hills and Ottawa, containing Ra-226, uranium and arsenic. This site ceased operation in 1979.

2.1.7.8 WMA-G

This facility was established in 1989 for above-ground dry storage in concrete canisters of irradiated fuel from the NPD power reactor at Rolphton. Recently additional canisters were constructed for storage of solidified high level molybdenum-99 production waste from the New Processing Facility when it begins operation.

2.1.7.9 WMA-H

This area was constructed in 2000/2001 as an area for modular above-ground storage of contained low-level radioactive waste.

2.1.7.10 Waste Tank Farm

The Waste Tank Farm was established in 1961 to store high- and intermediate-level waste from CRL. It consists of several tanks, some contained within stainless steel-lined concrete bunkers. These wastes can be recovered for treatment.

2.1.7.11 Acid, Chemical and Solvent Pits

Three pits were constructed north of WMA-C and are known collectively as the ACS Pits. These were used between 1982 and 1987 for inactive acids, chemicals and organic solvents.

2.1.7.12 Glass Block Sites

Two experimental sites were established for emplacement of vitrified waste containing decayed fission products for study of this method of waste immobilization.

2.1.7.13 Thorium Pit

The Thorium Pit was used to receive wastes from a U-233 extraction facility between 1955 and 1960. These wastes contained natural thorium, U-233 and small quantities of mixed fission products.

2.1.7.14 Nitrate Plant

The Nitrate Plant, a pilot plant used for the decomposition of ammonium nitrate in active waste solutions generated during fuel reprocessing operations of the time, was constructed in 1953 to the northwest of Waste Management Area C. The plant was operated until late in 1954, when a process upset resulted in untreated waste discharging to an infiltration pit that normally received condensate from the facility’s evaporator. The buildings, and at least some of the process equipment, were subsequently buried *in situ*.

A passive wall and curtain interception system has been installed southwest of the nitrate plant in order to treat the groundwater plume that flows in that direction. The interception wall is upgradient of Duke Swamp.

2.2 Releases to Surface Water and Groundwater

2.2.1 Releases to Surface Water

Various discharges of surface water occur to the environment from CRL facilities. Some of these surface water discharges are influenced by plumes of contaminated groundwater, which are described briefly in Section 2.2.2. These surface water discharges are categorized as process effluent, storm sewer and waste management area discharges, as summarized in Table 2.2. These discharge points are depicted in Figure 2.1. Information on loadings to the environment and resulting environmental concentrations is provided in Appendix 1 (Screening Data Used to Identify Contaminants of Potential Environmental Concern) and Section 3.0 (Exposure Characterization).

In addition to these point discharge locations, this EER also considers surface water exposures arising from diffuse discharge of contaminated groundwater plumes to surface water around the WMAs and from the plant site along the Ottawa River shoreline.

2.2.2 Releases to Groundwater

Contaminated groundwater plumes occur at several locations on the CRL property. These include plumes arising from the WMAs and from the plant site along the Ottawa River shoreline. These plumes have been studied intensively by CRL scientists and are well characterized in terms of their spatial distributions, concentrations of contaminants present and resulting concentrations in the affected watersheds. The principal groundwater plumes are listed in Table 2.3 and depicted schematically in Figures 2.1 and 2.3 to 2.5.

This EER considers the potential for direct exposure of soil dwelling organisms via groundwater plumes that may influence surface soils.

2.2.3 Areas of Potential Land Contamination

A review of historical records was recently completed by AECL (Amrouni, 1999) in order to identify areas within the CRL property that have a potential to be contaminated by virtue of their past use. While, contaminant releases to surface water or groundwater are not known to occur in these areas, they have not been fully investigated, and the possibility of such release exists. Table 2.4 provides a list of the areas that were identified, along with a description of the activity that was the basis for identifying a contamination potential. The type of contamination that may be present is included in the description, wherever a specific contaminant type can be associated with the historical site use(s).

2.3 Contaminants and Stressors of Potential Environmental Concern

2.3.1 Contaminants of Potential Environmental Concern (COPEC)

A preliminary screening evaluation was performed to identify contaminants of potential environmental concern (COPEC) for subsequent consideration in the ecological effects review. This screening was necessary to provide a rational basis for scoping of the contaminant component of the effects review (e.g., chemicals and radionuclides of potential concern, and the locations and media where these are of interest). The method used for selection of target contaminants involved (Gaudet *et al.*, 1994):

- identification of contaminants present in or released to the environment;
- tabulation (or estimation) of screening level environmental concentrations;
- comparison of concentrations to screening level toxicity benchmarks; and
- selection of contaminants based on this comparison.

The screening of chemicals and radionuclides is meant to focus the subsequent assessment. It does not preclude consideration of contaminants additional to the COPEC list, in any assessment location where the additional contaminants would contribute appreciably to the total exposure or risk.

Concentrations of contaminants were gathered from available site monitoring data (effluents, site surface water, groundwater, sediments and soils) and were estimated from recent loading data for releases to both air and water. The data are contained in annual performance and monitoring reports, as well as special investigation reports. The data sources are listed with the data in Appendix 1.

The radionuclides in effluents are often reported as loadings and thus the concentration values were often estimates. Other chemicals are generally reported as concentrations and were usually screened from the reported concentrations. For chemicals measured inside the WTC tanks, a dilution factor was applied to estimate the concentration that would result in the process sewer during release (Appendix 1).

For loadings to water, an "end of pipe" screening concentration was estimated as follows:

Screening Concentration (mg or Bq/L) = Loading (mg or Bq/s) / Effluent Flow (L/s)

For loadings to air, a "point of impingement" (POI) screening concentration was estimated as follows:

Screening Concentration (mg or Bq/m^3) = Loading (mg or Bq/s) x 1.8×10^{-4} s/m^3

The dilution factor (1.8×10^{-4} s/m^3) is a conservative generic value for a 100 m distance, zero release height and worst-case (class F – calm) atmospheric conditions (AECB, 1985). The 100-m distance is a conservative POI, since the maximum ground level concentration is at about this distance for the lowest reasonable release heights (5 to 10 m). The additional dilution caused by aboveground release (stack or vent) is ignored.

An inventory of chemical usage on site was reviewed, and chemicals potentially released in significant quantities were identified. Environmental concentrations were estimated for these chemicals assuming that the use rate approximates the loading rate, and following the methods outlined above for measured loadings. These chemicals were assumed to report to the sanitary sewer, without credit for removal during sewage treatment.

Atmospheric emissions factors were utilized to estimate releases to air of lead from the Lead Shop, and mercury from the Power House (from fuel oil combustion). The estimates of lead and mercury releases, to both air and water, are reported annually in Environment Canada's National Pollutant Release Inventory.

Both measured and estimated concentrations were compared to screening benchmark values which included federal and provincial guidelines for environmental quality (CCME, 1999; MOE, 1993, 1997, 1999, 2001). Radionuclide screening concentrations in water, sediment and soil were compared to screening benchmark values developed by the Oak Ridge National Laboratories (Blaylock *et al.*, 1993; Bechtel Jacobs, 1998) and the U.S. Department of Energy (DOE, 2000). The benchmarks and comparisons are discussed in more detail below.

The radionuclide screening benchmarks listed by Bechtel Jacobs (1998) for aquatic environments were developed following methodology by Blaylock *et al.* (1993) but their equations have incorporated unit conversions (from SI to Imperial units and from wet to dry weight sediments). Bechtel Jacobs made errors in parameterizing the equations (sediment K_d and BCF inputs on the wrong weight basis; see Appendix 1). These errors and the resulting benchmarks were corrected to accurately reflect the stated methodology.

The DOE (2000) screening benchmarks for radionuclides are very conservative, and meant for screening purposes only. They are focused on riparian or terrestrial wildlife receptors, utilize upper end pathways parameters, and assume complete absorption of both internal and external radiations of all types. Radionuclides identified as COPEC were generally identified on the basis of the DOE benchmarks.

The screening process included all contaminants measured above detection limit in each data report. Site effluents are continuously monitored at various regular frequencies and statistical summaries are prepared annually. The most recent data (years 2000, 2001) were utilized, supplemented by additional data from earlier years found in the recent reports. Annual averages for effluent concentrations were considered representative as averages when at least 25% of measurements were above detection limit. Maximum values were also listed and screened.

Chemical contaminants in effluents were compared to both federal and provincial surface water guidelines (Appendix 1). Proposed guidelines for federal wastewater discharge (Environment Canada, 2000) suggest an effluent screening value of ten times the surface water guideline. However, for the EER screening, an effluent average above a surface water guideline was used as a basis for COPEC identification. In addition, any chemical with an effluent maximum exceeding the surface water guideline by ten-fold was identified as a COPEC even if the average was below the surface water guideline. Lowest Chronic Values from Suter and Tsao (1996) are shown as ancillary information in the data screening tables (Appendix 1). These are lowest effect levels (water concentrations) for fishes and daphnid invertebrates, based primarily on data tabulated by the U.S. EPA for purposes of water quality criteria development. These provide a useful point of reference for chemical contaminants that do not have surface water guidelines.

Chemical contaminants in groundwater samples (WMA perimeter and Ottawa River shoreline wells) were compared to both surface water guidelines (federal/provincial) and MOE Table B criteria for groundwater (Appendix 1). The MOE Table B criteria were used as a basis for COPEC identification, since these criteria are specifically designed for groundwater screening.

Chemical contaminants in soils were compared to both federal and provincial soil quality guidelines for residential/parkland sites (Appendix 1). Similarly, chemical contaminants in sediments were compared to both federal and provincial sediment quality guidelines. Chemical contaminants in air were compared to provincial point-of-impingement air quality criteria.

Radionuclides in site effluents and sediments were compared in Appendix 1 to the ORNL and DOE water and sediment screening values for protection of aquatic life, and riparian wildlife. Radionuclides in soil were compared to the ORNL sediment values (no values available specifically for soil) and the DOE soil values for protection of terrestrial biota.

Radionuclides in air were compared to benchmarks derived from IAEA (1992) for H-3, C-14, Sr-90, I-131, Cs-137, and Pu-239, from Holford (1988) for Ar-41, and from Gorman (1986) for mixed fission product noble gases (Appendix 1) Concentrations in air were mainly estimated values, since there is limited monitoring of these concentrations within the site.

The IAEA (1992) values are deposition rates associated with an upper estimate of dose to plants and animals. From these values, the deposition rates associated with a 1 mGy/day dose were calculated, and the corresponding air concentrations were computed using typical deposition velocities as outlined in Appendix 1. The Holford (1988) and Gorman (1986) values are external dose coefficients, which were used to estimate the air concentrations corresponding to a 1 mGy/day dose.

The screening data and comparisons to benchmarks are tabulated in Appendix 1. Based on this evaluation of available data, contaminants of potential concern were identified, in association with particular site locations. The resulting list of COPECs and locations is shown in Table 2.5.

The Significant Environmental Aspects (SEA) database for CRL was reviewed to ensure that contaminants and locations listed there as priority issues were included in the final list of COPECs. Contaminants and locations retained on this basis are included in Table 2.5.

All the contaminants and concentrations identified in the screening process are considered to be potentially representative of current ecological exposures. Actual estimates of exposure are developed, and background contributions are considered, in Section 3.0, Exposure Characterization.

2.3.2 Stressors of Potential Environmental Concern (SOPEC)

Physical stressors of potential environmental concern (SOPEC) were identified based on experience at other nuclear facilities, and by a review of the Significant Environmental Aspect (SEA) database for CRL. These stressors include thermal releases to the aquatic environment (cooling water discharge), entrainment/impingement of aquatic biota (cooling water intake), and ongoing habitat alterations such as firebreaks and fence construction. The complete list of SOPECs and locations is shown in Table 2.6.

All the physical stressors identified are considered to be current rather than historical. Therefore, for example, habitat alterations associated with the original site construction are not identified and are not subsequently addressed in the EER.

2.4 Description of the Natural Environment

AECL has monitored various aspects of the CRL natural environment and ecosystems for many years. This section provides a summary of existing studies and synthesizes this information to provide a natural environment characterization of the CRL property. Key elements of this summary are the species lists for vascular plants, wildlife and fish, provided in Appendix 2. Information in Appendix 2 provides the base from which a candidate list of Valued Ecosystem Components was selected.

Recent key studies that specifically examined terrestrial and aquatic vegetation and wildlife on different parts of the CRL site include:

- Deep River Initial Assessment Report: Low-level Radioactive Waste Management (Siting Task Force [STF], 1995);
- Environmental Baseline Study for Waste Management Areas “B” and “C” at AECL Chalk River Laboratories (CH2M Gore & Storrie Limited, 1997);
- Environmental Baseline Study for Waste Management Area “A” at AECL Chalk River Laboratories (CH2M Gore & Storrie Limited, 1998); and,
- Canadian Neutron Facility Study: Terrestrial Environmental Features Report (North-South Environmental Inc., 2002).

Field inventories carried out for these studies covered all seasons and are adequate to characterize the flora, fauna and aquatic communities on site. However, not all survey types were carried out in all areas of the site.

2.4.1 Status of Species

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties and nationally significant populations for wildlife, fish, butterflies, molluscs, vascular plants, mosses and lichens. Endangered species are those that face imminent extirpation or extinction; Threatened species are those likely to become endangered if limiting factors are not reversed; and species of Special Concern (formerly Vulnerable/Rare) are those that have characteristics that make it particularly sensitive to human activities or natural events. Species may also be designated as Not at Risk or Data Deficient.

The status of provincially endangered and threatened species are identified by the Ontario Ministry of Natural Resources (OMNR) using procedures established by the Committee on the Status of Species at Risk in Ontario (COSSARO). Furthermore, provincial S-ranks have been assigned by the OMNR's Natural Heritage Information Centre (NHIC) using the best available scientific information, and have been reviewed by a group of experts on the flora and fauna of Ontario, to set protection priorities for rare species and natural communities. These S-ranks range from S1 to S5, where S5 is assigned to the most common species and secure populations. They are based on the total number of extant Ontario populations and the degree to which they are potentially or actively threatened with destruction. They are not legal designations. S4 and S5 species are generally uncommon to common in the province. Species ranked S1-S3 are considered to be rare in Ontario. The ranks are:

S1: Extremely rare in Ontario; usually fewer than 5 occurrences or very few remaining individuals; often especially vulnerable to extirpation.

S2: Very rare in Ontario; usually between 5-20 occurrences or with many individuals in fewer occurrences; often susceptible to extirpation.

S3: Rare to uncommon in Ontario; usually between 20-100 occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances.

S4: Uncommon to locally common in Ontario and apparently secure; usually more than 100 occurrences.

S5: Very common in Ontario and demonstrably secure.

SE: Exotic; not believed to be a native component of Ontario's flora. Numerical rankings after SE follow designations described above for native species.

Rank ranges, e.g. S2S3, indicate that the rank is either S2 or S3, but that current information is insufficient to differentiate. "**?**" following a rank indicates uncertainty about the assigned rank.

Regional status of wildlife in OMNR's Ontario Central Region was determined from the OMNR. Regional and local significance of plants follows Riley (1989).

Vegetation species sensitivity was assessed through the application of coefficient of conservatism values (CC), assigned to each native species in southern Ontario (Oldham *et al*., 1995). The CC is a relative value, ranging from 0 (low) to 10 (high), based on a species' tolerance of stress and disturbance, ecological amplitude (range of habitats) and fidelity to specific habitat. The occurrence of species with a CC of 9 or 10 can be good indicators of undisturbed conditions such as mature forests, fens or bogs. Species with a CC of 1 or 2 tolerate a wide range of habitat conditions and are characteristic of disturbed areas. The floristic quality of an area is reflected in the mean value of CC. For example, an old field or grazed woodlot would tend have a low mean CC; these habitats are dominated by opportunistic species that occur in a wide range of site conditions and are tolerant of disturbance. A bog, prairie or intact forest would have a higher value, reflecting the specific habitat requirements of many of the species and a generally undisturbed condition.

The site's vegetative character was further evaluated through examination of wetness and weediness indices. The value of the Wetland Index, ranging from -5 (obligate wetland) to 5 (upland) indicates the probability of a species occurring in wetland or upland habitats. All plants in southern Ontario have been assigned a wetland category, based on the designations developed for use by the United States Fish & Wildlife Service. Plants are designated into the following categories:

OBL (Obligate Wetland): occurs almost always in wetlands under natural conditions (estimated >99% probability)

FACW (Facultative Wetland): usually occurs in wetlands, but occasionally found in non-wetlands (estimated 67-99% probability)

FAC (Facultative): equally likely to occur in wetlands or non-wetlands (estimated 34-66% probability)

FACU (Facultative Upland): occasionally occurs in wetlands, but usually occurs in non-wetlands (estimated 1-33% probability)

UPL (Upland): occurs almost never in wetlands under natural conditions (estimated <1% probability).

The value of the Weediness Index, ranging from -1 (low) to -3 (high), quantifies the potential invasiveness of non-native plants. In combination with the percentage of non-native plants, it can be used as an indicator of disturbance.

Nomenclature of plant species mentioned in this report follow Newmaster *et al.* (1998).

2.4.2 Geology

The CRL property is located in Ontario Site Region 5E, Site District 5E-10 in the Petawawa Sand Plain physiographic region, within the Ottawa River Valley (Chapman and Putnam, 1984). The site occupies a former island in the channel of the Ottawa River, which existed at the end of the last glaciation and is now a ridge between the Ottawa River and the Maskinonge-Chalk Lake Valley (North-South Environmental Inc., 2002). The surrounding terrain, except for the Laurentian Mountains, located north and east across the Ottawa River, is characterized by gently rolling hills, interspaced with many small lakes.

The CRL site lies within the Grenville Province of the Canadian Shield and is characterized by sedimentary, volcanic and plutonic rock formations. Throughout Grenville, faults range from a few metres in length to tens of kilometres. The bedrock in the area is part of the Ontario Gneiss Segment, a geological formation that is part of the Central Gneiss Belt of the Canadian Shield (STF, 1995).

The CRL site is bounded to the east by the Mattawa River Fault along the Ottawa River, and to the west by a fault that runs through Big Rat Lake, Little Rat Lake, Maskinonge Lake, and Chalk Lake. The area falls within the west-northwest trending Ottawa-Bonnechere Graben. A graben forms when a series of central rock blocks drop between parallel faults (STF, 1995). No major movement along the fault system is believed to have occurred in the last 500 million years; however, moderate seismic activity, with typical Richter magnitudes of less than 5.5) does occur within eastern Ontario, and western Quebec.

The bedrock surface throughout the site is covered by a mixture of glacial and post-glacial sediments that are typically less than 30 metres thick (North-South Environmental Inc., 2002). Glacial till is located on the bedrock and is very thin or absent in some areas. The till is composed of a wide range of size fractions from very large blocks of rock to clay, with the smaller fractions being composed of approximately 70% sand, 25% silt and 5% clay. Approximately 50% of the CRL property is overlain by a combination of medium to fine fluvial and eolian sands (North-South Environmental Inc., 2002). There are a few isolated pockets of coarse fluvial deposits, while the remaining surface cover of the CRL property is bedrock outcrops and organic material (CH2M Gore & Storrie, 1997; STF, 1995).

2.4.3 Hydrology

This region receives moderate precipitation (827 mm/yr) that quickly infiltrates the highly permeable sands that cover most of the study area (CH2M Gore & Storrie, 1997). Surface runoff; however, is produced in approximately 10 per cent of the study area, where there are bedrock outcrops. In some of the sand deposits, the water table is found at tens of metres below the surface. In shallow aquifers, groundwater velocities can reach tens of cm/day because of the sand overburden, while flow in the bedrock depends on the fractures, and tends to be several orders of magnitude lower than in the sands (CH2M Gore & Storrie, 1997).

The dominant drainage feature in the study area is the Ottawa River, which runs northwest/southwest (Figure 2.6). Perch Lake, located midway along the southern boundary of the CRL site, drains to the Ottawa River by way of Perch Creek. Outside of the Perch Lake basin, surface drainage discharges either directly to the Ottawa River, or to Little Rat Lake, Big Rat Lake, Maskinonge Lake or Chalk Lake, and eventually to the Ottawa River (Kilpatrick and Arthur, 2000). The CRL property is dominated by a large bedrock ridge that runs parallel to the Ottawa River, with an altitude of 100 metres above the river level. This ridge, which generally runs parallel to the former Pembroke to Mattawa Road, separates surface drainage between the Ottawa River and the inland lakes (STF, 1995) (Figure 2.6).

Twin Lake, Dewdrop Lake, and 233 Lake, located in the middle portion of the study area, on the western side of the central rock ridge, appear to drain beneath the ground surface through sand deposits into Duke Swamp. Drainage from the swamp, located southwest of 233 Lake, discharges into Maskinonge Lake from two directions: from northwest via Lower Bass Lake, and from southeast via Duke Stream (Kilpatrick and Arthur, 2000). Drainage in wetland areas is also influenced by beaver activity and snowmelt (STF, 1995).

The Maskinonge Lake drainage basin, which has been heavily studied, drains approximately one-third of the CRL property. The five other drainage basins drain the remaining two-thirds of the CRL property. Approximate mean annual flows are as follows:

- Balmer Bay basin (to Ottawa River): 0.8×10^6 m^3/a
- Ottawa River basin (to Ottawa River): 1.9×10^6 m^3/a
- Perch Lake basin (to Ottawa River): 1.8×10^6 m^3/a
- Pumphouse Creek basin (to Chalk Lake): 4.9×10^6 m^3/a
- Maskinonge Lake basin (to Chalk Lake): 4.4×10^6 m^3/a
- Toussaint Lake basin (to Chalk Lake): 0.6×10^6 m^3/a
- Chalk Lake basin (to Ottawa River): 9.9×10^6 m^3/a

Watersheds and mean annual surface water discharges at CRL are depicted in Figure 2.6. The Perch Lake and Maskinonge Lake watersheds are of particular interest, since they drain the active waste management areas. Approximate mean annual flows are shown below for key monitoring points within these watersheds, based on Niemi *et al.* (2001) and estimates at several locations.

Watershed Location	Mean Discharge (m^3/a)
Perch Lake Watershed	
East Swamp Weir	8.8×10^4
Main Stream Creek	6.8×10^5
South Swamp Weir	4.7×10^3

Perch Lake Inlet 2	$6.8x10^5$
Spring B Discharge (est)	$2.5x10^5$
Perch Lake Inlet 1	$2.5x10^5$
Maskinonge Lake Watershed	
Duke Swamp Weir	$1.0x10^5$
Lower Bass Lake (est)	$2.5x10^5$
Bulk Storage Stream (est)	$1.6x10^5$

The Ottawa River is regulated by two dams in the vicinity of the study area: the downstream Chenaux dam (east of Cobden) and the Rapides-des-Joachims dam upstream. Depth and width of the Ottawa River varies between Deep River and Pembroke. Average depths at Deep River, Petawawa, and Pembroke are 24 m, 8 m, and 12 m, respectively (STF, 1995). Depths over 30 m occur in the mid-channel opposite the CRL site, and depths over 50 m occur in basins upriver from CRL and downriver from Pt. aux Baptime. The Ottawa River narrows to 750 m at Deep River and widens to approximately 2.5 km at Petawawa and Pembroke. Mean annual discharge is $2.65x10^{10}$ m^3/a.

2.4.4 Natural Heritage

The CRL property lies within the Site District 5-10, which is approximately 700,000 ha and extends from the eastern side of the Algonquin Dome to the Ontario-Quebec border at the Ottawa River. Site District 5-10 is characterized by a locally warm microclimate, coniferous and mixed shade-intolerant (e.g., pine, oak, poplar) forests, with the potential for rare species (North-South Environmental Inc., 2002).

The study area is in the Middle Ottawa Section of the Great Lakes – St. Lawrence Forest Region (Rowe, 1972), characterized by mixed forest, well represented by both deciduous and coniferous species. This region of the province is generally heavily forested with limited agricultural capability due to climate, hilly topography, and poor soils (STF, 1995). The variable topography of the rolling Precambrian Shield, as well as past disturbances, has a strong influence on the vegetation in the study area. Much of the area is well drained sandy soils; however, wetlands have developed in many areas where there is imperfect drainage or beaver activity.

Human disturbance, including the likely logging of white pine in the 1800s and early 1900s, and forest fires, has also influenced the current vegetation cover (STF, 1995).

2.4.4.1 Vegetation Communities

Vegetation community information was compiled from the following studies:

- Deep River Initial Assessment Report (STF, 1995) – approximately northern third of CRL property;

- Environmental Baseline Study for WMAs “B” and “C” at AECL Chalk River Laboratories (CH2M Gore and Storrie, 1997) – area surrounding WMAs “B” and “C”, including Cedar, Twin Lake, Dew Drop, 233, Duke, Cattail, Bulk Storage and Spring B Wetlands;
- Environmental Baseline Study for WMA “A” at AECL Chalk River Laboratories (CH2M Gore and Storrie, 1998) – area surrounding WMA “A”, including Perch Lake and East Swamp Wetlands; and
- Canadian Neutron Facility Study: Terrestrial Environmental Features Report (North-South Environmental, 2002) – area approximately bounded by Mattawa Road and Ottawa River to McQuestin Point.

No standard method of classifying vegetation was used in these studies.

In each study, vegetation communities were described qualitatively based on dominant plant species for tree, shrub, and ground cover; canopy conditions; relative age; soil wetness; and disturbance. Based on these data, vegetation communities were compared, standardized and compiled in Figure 2.7 for much of the CRL site. The CRL property is largely wooded, with the exception of the open wetland areas. Since most of the area was cleared for farming in the early 1900s, wooded uplands generally range from 40-80 years old, and wooded wetlands appear to be relatively young (CH2M Gore & Storrie, 1997). Forest cover species associations were mapped by Dendron (1987) for the entire site (Figure 2.8).

A brief summary of each vegetation community class (Figure 2.7) is provided below.

Wetland Communities – Swamp

Both open and wooded wetlands comprise a significant portion of the CRL property (CH2M Gore & Storrie, 1997). Deciduous swamp communities comprised of speckled alder shrubs and trees or black ash and silver maple are more abundant than coniferous swamp communities, typically dominated by black spruce or less commonly by white cedar.

Wetland Communities - Marsh

The study area includes a range of wetland types, many of which are dominated by shrubs or herbaceous and graminoid (grass-like) species because of the relatively permanent moisture regime (North-South Environmental Inc., 2002). Permanently flooded areas, generally associated with lake shores and the shore of the Ottawa River, support a range of robust emergents and aquatic floating-leaved plants.

Forest Communities

Forests within the CRL site are largely deciduous or mixed forest dominated by red maple, trembling and large-toothed aspens, and white pine. Natural coniferous forest characterized by cedar and pine species is much less common than mixed or deciduous within the study area as shown in Figure 2.7. Deciduous forest throughout the CRL site has abundant woody debris and snags, which are important habitat for wildlife and vegetation. Rock outcrops are common along the slopes to the Ottawa River.

Unforested Upland Communities

Rock barren is rare within the study area, and is generally found at the crest of rock ridges near the Ottawa River shoreline. These communities are comprised of lichens, mosses, grasses and sparse low shrubs. Non-granitic rock barrens are generally considered significant in Ontario.

Shoreline open sand dunes can be found along the shores of the Ottawa River at Point au Baptême. Although this community has been disturbed and supports a significant number of non-native species, sand dune vegetation communities are considered significant in Ontario and this area of the CRL property supports the majority of the provincially rare plant species observed on site. High aeolian dunes also occur adjacent to the WMA C.

Sand barrens were recorded on dune features north of Duke Wetland, northwest of the Twin Lake Wetland, around WMA A, and along the Perch Lake access road. Generally, sand barrens north of the road are of higher quality than those to the south (CH2M Gore & Storrie, 1998). These features are also considered to be provincially significant vegetation communities and support some provincially significant plant species.

Cultural Communities

Cultural meadows are unforested areas that are heavily influenced by human activities. These areas include roadsides, utility corridors, and abandoned agricultural lands.

Cultural plantations of white spruce and white pine are planted along McQuestin Point Road, and along Mattawa Road. These plantations are generally mature and densely grown, with a closed canopy.

2.4.4.2 Vascular Plants

A total of 525 species of vascular plants have been recorded on the CRL property. A complete list of species identified on the site is provided in Appendix 2. Approximately 87% are native and 13% are non-native. The proportion of native species on the site is higher than the proportion generally found in southern Ontario, but is in line with sites in central Ontario which have limited areas of disturbance. Generally, native species are indicative of an undisturbed ecosystem and are valued, while non-native species are not valued. The non-native species tend to be associated with cultural communities such as disturbed meadows and plantations, or utility areas such as roads and hydro corridors. Non-native species were also encountered at disturbed shoreline areas. Examination of the weediness indices indicates that the large majority of non-native species are not highly invasive, however, eight species of grasses and roadside weeds have the potential to invade natural communities on site.

No nationally or provincially Endangered or Threatened species of vascular plants have been recorded from the site. Ten species of vascular plants are provincially significant (S-Ranks of S2 or S3, very rare to uncommon in Ontario) (see bold species in Table 2.7). The majority of these are wetland obligate plants (i.e., wetland indices of –5 to –3) and are found in the central part of the property. Three are upland species (i.e., wetland indices of 3 to 5); two of these were only encountered on the sandy Pointe au Baptême. Twenty-five species are rare in the OMNR's Ontario Central Region, according to Riley (1989) (Table 2.7).

Many of the significant wetland species have a high coefficient of conservatism (i.e. 9 or 10), which is characteristic of species with a high degree of fidelity to a narrow range of synecological parameters. These species are usually indicative of mature, undisturbed communities and are intolerant of disturbance. More than 10% of the species recorded on site have a high coefficient of conservatism, resulting in a relatively high Floral Quality Index (121) for the CRL site. The vascular plant list suggests that the upland and wetland vegetation diversity are approximately equal.

2.4.4.3 Terrestrial Wildlife

A list of wildlife was compiled from all available studies. A total of 106 birds (103 likely breed on the CRL property), 12 amphibian, 10 reptile, and 23 mammal species were found in the study area. A complete list is provided in Appendix 2.

The CRL property is generally typical for a boreal region in Ontario in the representation of breeding birds, mammals, reptiles and amphibians (CH2M Gore & Storrie, 1997). One species, common musk turtle (stinkpot), has been designated Threatened by COSEWIC; four other species, wood turtle, Red-shouldered Hawk, Red-headed Woodpecker and eastern wolf, have been identified as species of Special Concern. The Red-headed Woodpecker (designated Vulnerable by COSSARO) and wood turtle are also considered to be provincially significant. The regionally rare Yellow-billed Cuckoo has been observed in two locations within the study area (CH2M Gore & Storrie, 1997).

Twenty-nine of the forest bird species are considered to be area-sensitive, that is, they require a minimum of 20 ha of suitable forest habitat for breeding. Some require up to 100 ha (Appendix 2). These birds are sensitive to forest fragmentation. Linear gaps greater than 30 m wide are generally considered to fragment the forest. Each forest fragment must be greater than the minimum habitat area to support area-sensitive forest bird species.

2.4.4.4 Fisheries and Aquatic Habitat

Forty-four species of fish have been encountered on the CRL site and the adjacent Ottawa River (Appendix 2). Some Ottawa River species are impinged or entrained at the NRU intake, as described by Yankovich *et al.* (2002). One species from the Ottawa River, lake sturgeon, is rare to uncommon in Ontario (rank S3). A second species from the Ottawa River, rosyface shiner, has been identified as nationally Threatened by COSEWIC.

Black bullhead was caught in the wetlands adjacent to Perch Lake by CH2M Gore & Storrie (1998). This species is ranked S3, rare to uncommon in Ontario.

The Siting Task Force (STF, 1995) described the diverse range of aquatic vegetation and fish species in the Ottawa River, Maskinonge Lake, Upper Bass Lake, Big Rat, and Little Rat Lakes. Perch Lake displays similar diversity (Yankovich, 2003). Unnamed Pond and Creek Complex, Upper Bass Creek, and Balmer Bay Pond and Creek Complex have no significant aquatic habitat value.

The fish community in Perch Lake has significantly changed over the past decade because of the introduction of northern pike into the lake in the mid- to late-1980s (Yankovich, 2003). In the early 1990s, the pike population proliferated, causing major disruptions to a previously substantial population of yellow perch. The perch population is virtually extirpated now, and population numbers have greatly diminished for chub, minnows, and pearl dace.

A variety of benthic and other invertebrates also inhabit Perch Lake in the upper sediment layers, on aquatic plants, and in the open water. Macro-invertebrates include: diving beetles, giant water bugs, waterboatmen, dragonflies, and other flies and nymphs. The various crustaceans include: snails, freshwater mussels, fingernail clams, leaches, and worms.

2.5 Valued Ecosystem Components

In EERs, potential environmental effects are examined for a cross-section of species selected from biological inventory information for the site. These typically include species of special significance or value, known as Valued Ecosystem Components (VECs), which are potentially subject to impact arising from site operations. VECs are normally selected to represent a cross-section of taxonomic groups and trophic levels, so that effects predictions can be extrapolated to similar species and trophic associations.

Candidate VECs were selected based on the following significance criteria:

- recognized by the scientific or professional communities as important due to their abundance, scarcity, endangered status or role in the ecosystem;
- recognized by the public as being important due to their environmental, commercial or economic value, or their role in maintaining quality of life; and
- legally recognized and afforded specific protection by a law, policy or regulation.

The candidate list (Table 2.8) includes both species that are common and widespread, because they perform important ecological functions in the ecosystem, and species that are rare and/or declining, because they have a higher perceived social value and may be particularly sensitive to human activity. The list was developed to ensure all major species groups were represented. It includes fish, mammals, birds, amphibians and reptiles, vascular plants, vegetation communities and invertebrates or groups of invertebrates. Furthermore, the list includes species which are potentially exposed to contaminants on the site (based on habitat or dietary preferences) and species that have existing data on radionuclides in tissues. Table 2.8 outlines the rationale for including each species on the preliminary list. This list will be discussed with stakeholders to ensure that local knowledge is adequately represented, and that species of special importance to the community and to local naturalist, conservation and government groups are considered.

Based on the long list of candidate VECs presented in Table 2.8, a shorter list was selected for risk characterization within the EER. These VECs were selected based on the specific media where COPECs were identified, on ecosystem characteristics in the vicinity of these areas (e.g., upland, wetland), and on the availability of data to facilitate risk characterization (e.g., tissue data, exposure factors). They were selected also to represent different trophic levels (e.g., producers, consumers) and different feeding strategies (e.g., herbivore, insectivore). Short-listed species are highlighted in Table 2.8.

2.6 Conceptual Model

The conceptual model (Suter, 1999) identifies the locations where receptor species (VECs) will be assessed with respect to radionuclide and/or chemical exposure (or physical stressors), and the exposure pathways to be considered in the assessment for each VEC. Exposure pathways represent the various routes by which radionuclides and/or chemicals may enter the body of the receptor, or (for radionuclides) how they may exert effects from outside the body.

Table 2.9 shows the environment(s) to be assessed, the relevant VECs and the measures of exposure to be used in assessing each VEC, for each COPEC from each screening location (Section 2.3). The VECs were selected from the highlighted species in Table 2.8.

The approach to exposure assessment (i.e., measures of exposure) is identified in Table 2.9 for the different categories of COPECs and VECs. For radionuclides, the radiation dose will be calculated to include both internal dose and external dose, as per Blaylock *et al.* (1993), for the radionuclides identified during COPEC screening at a particular location, and for any other radionuclide known to be present and expected to contribute appreciably to radiation dose. Doses from different radionuclides will be added to obtain a total radiation dose. For non-radionuclides, the organism exposures will be calculated either as media concentrations (for aquatic biota and for soil/sediment-dwelling organisms) or as intake doses for mammalian and avian wildlife (Sample and Suter, 1994). All pertinent exposure pathways will be considered.

2.6.1 Exposure Pathways

Exposure pathways include the routes of contaminant dispersion in the abiotic environment (from source areas to receptor species locations) and the routes of contaminant transport through the food chain to the receptor organism. Both will be considered, as appropriate to the species and location, using measured concentrations of COPECs wherever such data exist, and estimating concentrations where measured values are not available.

Inhalation exposure pathways will be considered when there is an atmospheric source of the COPEC, and if the measure of exposure for the COPEC is a dose. The benchmark levels for atmospheric gases, such as SO_2 and NO_x, are usually expressed as air concentrations. Therefore, an inhalation dose calculation is not required in these cases. Wildlife doses arising from inhalation of resuspended particulate contaminants are usually a minor component of dose as compared to incidental soil ingestion and soil to food pathways.

Figure 2.9 illustrates the exposure pathways that will be considered in calculating the dose to a muskrat at an aquatic site such as Perch Lake. For completeness, air concentrations of COPECs released to the atmosphere will be estimated from the release rates and known atmospheric dilution factors at each location. However, the main component of dose is expected to be associated with the aquatic environment (ingestion of aquatic plants, incidental ingestion of sediment and water ingestion). Similar pathways are considered for the water shrew (Figure 2.10) except that the food source is aquatic invertebrates.

For shoreline and/or mid-river discharge locations, known dilution factors will be applied, or dispersion models will be utilized, to estimate the spatial pattern of COPEC concentration down river from the discharge. It is expected that dilution factors can be derived from Klucas (2001) for any mid-river discharge. The NCRP (1996) model for a shoreline plume will be used for shoreline discharges if available monitoring data do not adequately describe the down river pattern.

Figure 2.11 illustrates the exposure pathways that will be considered in calculating the dose to a robin at an upland site, such as a WMA. Again, air concentrations of COPECs released to the atmosphere will be estimated from the release rates and known atmospheric dilution factors at each location. In addition, the dose from site soil will be calculated, including components from incidental soil ingestion and the soil to invertebrate pathway. Similar pathways are considered for the woodchuck (Figure 2.12) except that the food source is terrestrial plants.

Habitat has been considered in assigning VECs to upland areas. For example, resident mammals and birds will only occur when there is sufficient cover at the site. Most WMAs are sandy sites with sparse vegetation and very little cover. However, there are exceptions. A woodchuck burrow was observed on WMA F (September 2002) where a well-developed grassland community has become established. At many WMAs, only transient wildlife use of the site is plausible. Soil invertebrates (crickets, grasshoppers) may exist at most upland sites.

Site data on COPEC concentrations will be utilized wherever possible to represent soil, sediment, plant, animal and water concentrations. Estimated concentrations will be utilized as required to represent media that have not been sampled and analyzed. At most locations in Table 2.9, measured concentrations are available for at least some media. Concentration ratios, from similar CRL sites if possible, will be used to estimate media concentrations that are missing.

Soil concentrations will be chosen to represent depth zones that are appropriate to the receptor species present. Generally, shallow soils are most appropriate for representing exposures of plants with shallow roots and invertebrates that utilize shallow soils. Deeper soils may be appropriate if plants with deeper roots or burrowing mammals are present.

An upland exposure scenario is considered appropriate for any location where soil concentrations exceeded screening criteria. An aquatic or riparian scenario is considered appropriate for any location where water, sediment, groundwater or effluent concentrations exceeded screening criteria. In some cases, the aquatic environment assessed will be downgradient of the screening location. For example, if only deep groundwater is contaminated at the screening location, the environment where exposures may occur is necessarily downgradient.

Some wide-ranging receptor species, such as whitetail deer and eastern wolf, will utilize most of the CRL site. For these species, whole-site average concentrations of COPECs will be considered for each medium, rather than concentrations for a particular location of interest. Figure 2.13 illustrates the conceptual exposure pathways and relevant media for a dose calculation for the eastern wolf.

Pathways diagrams will be constructed in similar fashion for all VECs, based on the principles and examples cited above. Relevant exposure pathways will be highlighted on the generic pathways diagram, and specific plant and animal names will be assigned to represent the food chain.

2.6.2 Physical Stressors

Exposure to thermal effects in the vicinity of the process sewer will be estimated for aquatic biota (fishes, aquatic invertebrates) based on the thermal model developed by Klucas (2001). The thermal increments will vary seasonally as well as spatially. The range of thermal increments that are expected to be experienced by aquatic biota will be described.

Exposure to other physical stressors (Table 2.6) can be assumed to occur in the indicated locations, for organisms present in those locations. For example, aquatic organisms are entrained or impinged at the cooling water intakes. The nearest equivalent to exposure in these situations is the proportion of the population likely to experience the stress. These proportions will be estimated from the proportion of population area subjected to the stress. Since population boundaries are somewhat arbitrary, these proportions will be estimated for local (site) and broader regional scales.

2.6.3 Assessment and Measurement Endpoints

The assessment endpoints are attributes of the VECs that we wish to protect in our environmental programs (Suter *et al.*, 1993). The purpose of an environmental assessment is to evaluate whether these environmental protection goals are being achieved, or are likely to be achieved. The assessment endpoint for all VECs in this EER is population abundance.

The environmental protection goal is to maintain population abundance, and the purpose of the EER is to evaluate whether this is likely to be achieved.

Population abundance will not be directly measured or predicted in this EER. Forecasting stressor effects on population abundance requires development and parameterization of a population model which incorporates stressor effects on model parameters. This effort is beyond the scope of the EER.

Measurement endpoints are typically utilized to evaluate whether environmental protection goals are likely to be achieved. These are attributes of the VECs that are amenable to measurement in a field study or amenable to prediction in a desktop study. They should be logically related to the assessment endpoints, such that the measured or predicted attributes permit reasonable inferences as to achievement of environmental protection goals.

Organism survival and reproduction are measurement endpoints that are logically related to maintenance of population abundance, and are therefore suitable as measurement endpoints for this EER. However, they will not be directly measured. Possible effects of COPECs on survival or reproduction will be inferred or predicted by comparison of estimated doses to benchmark doses that have been associated with such effects in the literature.

For radiation doses to biota levels of 1 to 10 mGy/day have been widely used as benchmark values for possible reproduction or survival effects on individuals, but no measurable effects at the population level (NCRP, 1991; IAEA, 1992; UNSCEAR, 1996). For other COPECs, benchmark levels of exposure concentration or dose associated with possible reproduction or survival effects have been tabulated as LOEC or LOAEL values by various authors (Suter and Tsao, 1996; Sample *et al.*, 1996; Effroymson *et al.*, 1997a,b). Effect levels have also been described in environmental criteria documents (U.S. EPA, 1986; CCME, 1999). Preference will be given to values associated with approximately a 25% response level (e.g. EC_{25}) where such information is available. Otherwise, the LOEC or LOAEL values are considered to be appropriate. These values often approximate the desired response level since toxicology experiments are often designed to be able to detect such a response level.

For thermal exposures, the possible effects of thermal increments will be inferred by comparison of estimated values to critical values of thermal increments that have been associated with adverse effects such as embryonic mortality or hatch advance (Greig and Heltcher, 1989). For other physical stressors, such as entrainment/impingement, the estimated proportion of populations affected will be compared to benchmark values of exploitation levels that have been associated with measurable population consequences (e.g., McFadden, 1994). For such comparisons it is preferable to express the losses and population sizes in similar terms, e.g., adult equivalents lost as a proportion of adult population size.

2.6.4 Weight of Evidence

As discussed by Suter *et al.* (1993) and U.S. EPA (1998) multiple lines of evidence should be considered to the extent possible during risk characterization. The lines of evidence may include direct measurements of ecological effect, in addition to predictions of effect as outlined above. Direct measurements of ecological effect may include field survey data (e.g., organism densities, growth rates, community diversity) as well as toxicity test data for media collected on site. Such data will be utilized in a weight of evidence evaluation wherever they are available for the CRL site.

3.0 EXPOSURE ASSESSMENT

3.1 General Methods

For each of the "environments to be assessed" in Table 2.9, data were gathered representing measured values of COPECs in all relevant media. All measured radionuclides at a site were included, whether or not they were COPECs, in order to ensure that a total radiation dose could be estimated. The relevant media included water, sediment, and plant and animal tissues for aquatic sites, where contaminants were considered to arrive at the site primarily via groundwater, effluent or upgradient surface water. The relevant media included air, soil, and plant and animal tissues for upland sites, which were generally WMAs. The contaminants were considered to arrive at these sites primarily in association with waste disposal activities (e.g., spills to surface soil), although estimates were also made of soil activities that could arise from atmospheric deposition of airborne radionuclides.

Measured concentrations of COPECs were generally not available for all media of interest, although some sites (e.g., Perch Lake) have been well characterized with respect to radionuclides. Environmental partitioning calculations were performed to estimate concentrations in media that were not measured in order to better understand the implications of the measured values. Estimated and measured concentrations were compared to the extent possible based on availability of measured values at each site. The partitioning calculations are outlined in Section 3.1.1.

Modelled concentrations were used for COPECs in air, since measured concentrations in air were generally not available for receptor locations. Similarly, modelled concentrations in Ottawa River water were often used to represent the exposure levels expected in the vicinity of the various discharges to the river. The atmospheric and river modelling methods and results are described in Appendices 3 and 4.

Radiation doses were calculated for a variety of receptor organisms (Table 2.9) using the multimedia concentrations for the site, and giving preference to measured concentrations. Non-radionuclide doses were calculated for wildlife receptors (birds and mammals) for each COPEC. The dosimetric calculations are outlined in Section 3.1.2.

3.1.1 Environmental Partitioning

Water:sediment partitioning was estimated as described below in activity units:

$$C_{s(fw)} = \frac{\theta\, C_w \rho_w + (1-\theta)\, C_w\, K_d\, \rho_s}{\theta\, \rho_w + (1-\theta)\, \rho_s}$$

$$C_{s(dw)} = C_{s(fw)}/f_{dw}$$

$$f_{dw} = \frac{(1-\theta)\,\rho_s}{\theta\,\rho_w + (1-\theta)\,\rho_s}$$

where:

where:	$C_{s(fw)}$	=	concentration in sediment (Bq/kg FW)
	C_w	=	concentration in water (Bq/L)
	ρ_w	=	density of water (1 kg/L)
	θ	=	sediment porosity (unitless)
	K_d	=	distribution coefficient (L/kg solid)
	ρ_s	=	density of solids (kg/L)
	$C_{s(dw)}$	=	concentration in sediment (Bq/kg DW)
	f_{dw}	=	dry weight fraction of sediment (unitless)

Distribution coefficients for radionuclides were estimated from Perch Lake data (Yankovich and Killey, 2002), while distribution coefficients for heavy metals were estimated from Environment Canada data (unpublished site investigation, 2001). Metal values from the Perch Lake inlets were utilized where possible, and values from other streams were used as necessary to obtain quantitative data. The site data for persistent organics were generally insufficient for K_d estimation, being seldom detected in both water and sediment. For these compounds, K_{oc} values from the literature (Jones *et al.*, 1997) were used as required to estimate water: sediment partitioning.

The sediment K_d values used in environmental partitioning calculations are listed in Table 3.1. A sediment porosity of 0.6, based on Duke Swamp peat (Killey *et al.*, 1998), was generally used as a default value across the site. A porosity of 0.7 was used for Perch Lake, although values for different sediments here range from 0.5 to 0.9 (Yankovich and Killey, 2002). A solids density of 1.0 kg/L (organic sediment) was used for the inland aquatic sites, and 2.5 kg/L (sandy sediment) was used for the Ottawa River.

For ^{14}C, where water or sediment data were lacking, the concentration ratio observed in Duke Swamp (Killey *et al.*, 1998) was assumed to apply. In Duke Swamp, the peat soil averaged 400 Bq/kg C (200 Bq/kg DW whole sediment) and the surface water at the outflow averaged 6 Bq/L; thus, a water:dry soil ratio of 0.03 was considered to be reasonable.

Air:soil partitioning was estimated for particulate radionuclides (e.g., I-131) using OPG (2002) default values for long-term accumulation in soil due to atmospheric deposition. These values are calculated from dry+wet deposition velocities, and losses from soil due to erosion, leaching, radioactive decay and volatilization over a 40-year period. A 20-cm mixing depth in soil is assumed. The air:soil partitioning factors are listed in Table 3.2.

Air:soil partitioning was estimated for tritium (HTO) and $^{14}CO_2$ using OPG (2002) specific activity models as follows:

$$C_{s(pw)\_HTO} = (RF_{pw}/H_a)\, C_{a\_HTO}$$

$$C_{s(pw)\_14C} = (C_{s(pw)\_C}/C_{a\text{-}C})\, C_{a\_14C}$$

$$C_{s(fw)} = C_{s(pw)}/f_{pw}$$

$$f_{pw} = \frac{\theta\, \rho_w}{\theta\, \rho_w + (1-\theta)\, \rho_s}$$

where:
$C_{s(pw)}$ = concentration in soil porewater (Bq/L) (HTO or ^{14}C)
C_a = concentration in air (Bq/m^3) (HTO or ^{14}C)
RF_{pw} = ratio of HTO in porewater:air moisture (0.3)
H_a = atmospheric absolute humidity (0.0066 L/m^3)
$C_{s(pw)\_C}$ = concentration of carbon in soil porewater (1.2 g/m^3)
C_{a_C} = concentration of carbon in air (0.2 g/m^3)

Aquatic bioaccumulation factors (BAFs) for key radionuclides (^{90}Sr, ^{60}Co, ^{137}Cs) were estimated from Perch Lake data (Yankovich, 2003), using whole organism tissue measurements for fish, frogs, snails, other aquatic invertebrates and aquatic plants. For HTO, a BAF of 1 was assumed. For ^{14}C, a specific activity model for fish was used, as follows:

$$BAF_{\_14C} = C_{f\_C}/C_{w\_C}$$

where:
C_{f_C} = concentration of carbon in fish (121.8 g/kg FW)
C_{w_C} = concentration of carbon in water (g/L)

The fish carbon content (above) was cited by OPG (2002) and was assumed to be reasonable for most other aquatic biota. This value was doubled for snails to account for the carbon in the shell. The water carbon content ranged from 11 to 16 mg/L, based on Duke Swamp and Perch Lake data. The lower Duke Swamp value was used as a default for most sites.

Aquatic BAFs for metals were taken from IAEA (1994), if available, or from other sources (NRCC, 1985; NCRP, 1996). Aquatic plant BAFs were taken exclusively from NRCC (1985). Aquatic invertebrate BAFs for PAHs were computed from the biota-sediment accumulation factors (BSAFs) reported by Parkerton *et al.* (1992). Volatile organics were assumed not to bioaccumulate. The aquatic BAFs used are listed in Table 3.3.

Terrestrial plant bioaccumulation factors (BAFs) for particulate radionuclides and metals (plant:soil values) were taken from IAEA (1994), if available, or from other sources (Sheppard *et al.*, 1992; BJC, 1998). For C-14, a concentration ratio from Duke Swamp (Killey *et al.*, 1998) was assumed to apply. Terrestrial plant BAFs for PAHs were estimated from k_{ow} using the following equation from Travis and Arms (1988):

$$\log BAF = 1.588 - 0.578 \log k_{ow}$$

Terrestrial plant uptake of HTO at the upland sites was assumed to be primarily from the air. It was calculated using a specific activity model (OPG, 2002):

$$C_{p\_HTO} = (1.1(1-DW_p)/H_a)\ C_{a\_HTO}$$

where:
- 1.1 = isotopic discrimination factor
- DW_p = dry weight fraction for plant (0.25)
- H_a = atmospheric absolute humidity (0.0066 L/m^3)

The terrestrial plant uptake of ^{14}C at the upland sites was also assumed to be primarily from the air where plant tissue measurements were not available. It was calculated using a specific activity model (OPG, 2002):

$$C_{p\_14C} = (C_{p\_C}/C_{a\_C})\ C_{a\_14C}$$

where:
- C_{p_C} = concentration of carbon in plant (125 g/kg FW)
- C_{a_C} = concentration of carbon in air (0.2 g/m^3)

Terrestrial invertebrate bioaccumulation factors (BAFs) for particulate radionuclides and metals (invertebrate:soil values) were taken from Sample *et al.* (1998a). The terrestrial invertebrate BAFs for HTO and ^{14}C were estimated as described above for plants. Volatile organics were assumed not to bioaccumulate. The terrestrial BAFs used are listed in Table 3.4.

Transfer factors (TF) for terrestrial wildlife (birds and mammals) were estimated from beef and poultry values (IAEA, 1994) using the allometric equation given by MacDonald (1996), as follows:

$$TF = a\ W^{-0.7}$$

where:
- W = body weight (kg)

The "a" parameter was defined for mammals and birds based on the beef and poultry TF values, and then allometric TF values for other species were calculated. Small mammal data from Perch Lake and from Sample *et al.* (1998b) were used as comparative values where possible to validate the allometric values. The TF values for HTO and ^{14}C were defined for each species so as to produce similar activities in the tissues of food and consumer organisms. The TF values used are listed in Table 3.5.

Transfer factors were used to estimate the radionuclide concentrations in wildlife tissues arising from ingestion of food and water, and incidental ingestion of soil or sediment, as follows:

$$C_t = \Sigma\ C_x\ I_x\ TF$$

where:
- C_x = concentration in the ingested item (x) (Bq/kg)

I_x = ingestion rate of item x (kg/day)
TF = ingestion transfer factor (days/kg)

Food and water ingestion rates (fresh weight values) were taken from the U.S. EPA (1993) and soil/sediment ingestion rates (dry weight values) were estimated as 7% of the dry weight food intake (CCME, 1996). Wildlife exposure factors and feeding assumptions are summarized in Table 3.6.

Food chain calculations performed for small mammals and birds at the upland sites (WMAs) did not include ingestion of contaminated surface water, since these sites are dry, but did include inhalation of airborne radionuclides. Inhalation transfer factors were assumed to be equal to ingestion transfer factors, and units of m^3 rather than kg were used for C_x and I_x on the inhalation pathway. Inhalation rates were taken from the U.S. EPA (1993).

3.1.2 Dose Estimation

Radiation doses were estimated for aquatic biota following the methods outlined by Blaylock *et al.* (1993). The total dose from each radionuclide includes an internal component and external water and sediment components, as follows:

$$D_{int} = (5.76\text{x}10^{-4})\ (\Sigma\ E_x\ n_x\ AF_x)\ C_t$$
$$D_{ext,w} = (5.76\text{x}10^{-4})\ (\Sigma\ E_x\ n_x\ (1\text{-}AF_x))\ C_w$$
$$D_{ext,s} = (2.88\text{x}10^{-4})\ (\Sigma\ E_x\ n_x\ (1\text{-}AF_x))\ C_s$$

where: $5.76\text{x}10^{-4}$ = MeV/dis to μGy/h conversion factor
E_x = average energy per disintegration for emission x (MeV/dis)
n_x = proportion of transitions producing energy E_x
AF_x = fraction of internally emitted radiation absorbed
C_t = whole body tissue concentration (Bq/kg FW)
C_w = water concentration (Bq/L)
C_s = sediment concentration (Bq/kg FW)

The summation includes all emissions (β, γ) from the disintegration of the radionuclide and its short-lived daughter(s). The external sediment dose is doubled for infaunal organisms that are considered to be completely surrounded by sediment.

Radiation doses were estimated for terrestrial biota using the same equations, except that the external dose components arise from air and soil rather than water and sediment. The concentration in air (Bq/m^3) should actually be divided by 1.2 kg/m^3 (air density); however, this slight downward adjustment of air dose to terrestrial biota has been ignored.

The absorption factor (AF_x) in the radiation dose equations varies with emission type (β, γ) and energy and organism geometry (size). The emission energies and absorption factors used in the dose calculations are listed in Table 3.7.

Non-radionuclide doses to terrestrial wildlife were estimated following the methods of Sample and Suter (1994). The dose is calculated as a contaminant intake via ingestion pathways, as follows:

$$D_{ing} = \Sigma\, C_x\, I_x / W$$

where: C_x = concentration in the ingested item (x) (mg/kg)
I_x = ingestion rate of item x (kg/day)
W = body weight of consumer (kg FW)

Food, water and soil/sediment ingestion rates were taken from the U.S. EPA (1993) and CCME (1996), as noted above, and body weights were from U.S. EPA (1993) and Banfield (1974). The ingestion rates and body weights used for terrestrial wildlife were listed in Table 3.6.

3.2 Background Conditions

For the purposes of the EER, it is appropriate to recognize background levels of COPECs in waters and sediments of the region. For example, certain metals may exist at concentrations in surface water or sediment that exceed screening benchmark concentrations at locations unaffected by CRL operations, due to naturally high background conditions or, in the case of the Ottawa River, owing to the effects of upstream sources. In such cases, it is appropriate to complete a second screen of exposure concentrations in environmental media against these background concentrations and, where exposure concentrations remain comparable to or below background, any associated risks must be considered as natural background conditions. This section describes "background" concentrations of metals in local (inland) surface waters and sediments within the CRL site, as well as background concentrations in the Ottawa River.

For inland surface waters (i.e., excluding the Ottawa River), Yankovich *et al.* (2002) documented concentrations of trace metals in various surface waters around the CRL property, based on spring and fall sampling. The observed metal concentrations in Lower Bass Lake, Upper Bass Lake, Maskinonge Lake, Perch Lake Inlet 3 and Perch Lake Inlet 4 are considered to be representative of "background", as they are unaffected by CRL drainage or are sufficiently removed from CRL sources that measurable effects on water quality are considered unlikely. Based on two sampling events at each location, ten data points were considered for each parameter reported. The maximum concentration measured from these ten sampling events is considered the upper limit of background for the relevant parameter. For the trace element COPECs, upper limit of background concentrations, as mg/L total metal, are:

- Al: 1.5E-1
- As: 7.0E-4
- Cd: 8.0E-5
- Cu: 4.7E-3
- Fe: 1.2E0
- Pb: 5.6E-4

- Cr: 3.1E-3
- Zn: 7.0E-3

Similarly, background data for Ottawa River water quality are presented in Yankovich *et al.* (2002). For the trace element COPECs, upper limit of background concentrations in the river, as mg/L total metals, are:

- Al: 9.0E-2
- As: 9.0E-4
- Cd: 7.0E-5
- Cr: 2.2E-3
- Cu: 7.8E-3
- Fe: 1.52E-1
- Pb: 6.7E-4
- Zn: 9.4E-3

Background sediment quality data are available for inland lakes from Environment Canada (2002) and CH2M Hill (2002). "Background" lakes considered for trace metals are Maskinonge Lake, Lower Bass Lake and Sturgeon Lake. Maximum concentrations reported for trace element COPECs present in sediments, in mg/kg, are:

- Al: 7.3
- Cd: 1
- Cr: 65.7
- Cu: 39
- Fe: 59,600
- Pb: 111
- Zn: 200

Data on background conditions in Ottawa River sediments were based on an Environment Canada study (Environment Canada, 2001) which included parallel sampling by AECL (CH2M Hill, 2002). Data are also available from Merriman (1987) for a transect upstream of CRL (Transect E in Merriman, 1987). Surficial sediments were collected by Environment Canada (2001) upstream of CRL near Balmer Bay and McQuestion Point. Samples were analyzed for total metals, including As, Cd, Cr, Cu, Fe, Pb and Zn. Maximum metal concentrations (mg/kg dry weight) measured at these "background" locations are:

- As: 30
- Cd: 2.2
- Cr: 96.3
- Cu: 42
- Fe: 33,500
- Pb: 51
- Zn: 200

3.3 Aquatic Sites

3.3.1 Perch Lake and Inlets

3.3.1.1 Perch Lake

Among the inland aquatic receptor locations, Perch Lake has received the greatest attention in terms of research study on exposure pathways for radionuclides in the environment, as it represents the receiver for Areas A and B. Perch Lake provides habitat for a warmwater fish community, as well as for riparian and aquatic plant and wildlife species. It also provides only limited dilution for contaminants arising from WMA inputs, with mean monthly discharge ranging between about 0.02 m^3/s in late summer and 0.2 m^3/s in April.

Yankovich and Killey (2002) documented physical attributes and radionuclide concentrations of Perch Lake sediments. Sediments consist of organic-rich gyttja, covering 75% of the lake bottom, and sandy sediments covering the remaining 25%. The sandy sediments average 50.3% water, with a porosity of 35 to 45%, while the gyttja sediments average 92.7% water, with a porosity of 30 to 90%.

Concentrations of radionuclides in Perch Lake generally peaked in the early 1960s and between the mid-1970s and early 1980s, owing to the variable effects of inputs from the WMAs and atmospheric fallout associated with weapons testing (Yankovich and Killey, 2002). Recent sampling has shown that radionuclide concentrations (Co-60, Cs-137, H-3, Sr-90) in lake sediments vary relatively little on a spatial basis, but tend to be greater on average in gyttja sediments than in sandy sediments (Table 3.8). Sediment core data show that Cs-137 and Co-60 concentrations have declined in Perch Lake sediments over time due to reduced loadings as well as radioactive decay, while Sr-90 concentrations have increased, although reasons for this increase are unclear given that Sr-90 loadings to Perch Lake have increased only slightly since 1985 (Yankovich and Killey, 2002). Also, H-3 and Sr-90 concentrations in sediment porewaters are less than those present in overlying water (Yankovich and Killey, 2002). Overall, Perch Lake sediments represent a sink for most of the radionuclides present, and may potentially lead to relatively higher doses in benthic than in pelagic lake species.

Radionuclide concentrations in Perch Lake surface water have been monitored over many years. Temporal trends in concentrations of key radionuclides in Perch Lake water are presented in Figure 3.1, and show that concentrations of Sr-90, Co-60 and Cs-137 have declined since their peaks in the 1960s and 1970s. Tritium concentrations, however, have fluctuated within the same range over the last two decades. CRL 2000-2001 monitoring data for Perch Lake are used to assess current exposure conditions in Perch Lake receptors.

Concentrations of radionuclides in Perch Lake biota, including fish, primary producers, aquatic invertebrates, reptiles, amphibians and riparian mammals, have been reported by Yankovich (2003) and are summarized in Table 3.9. These data are used in the estimation of radiation doses to various Perch Lake receptor types (Appendix 5).

The radiation doses are summarized in Table 3.10 which shows average and reasonable maximum dose estimates. For Sr-90, Cs-137 and Co-60, the average dose is based on a mean tissue concentration for the receptor type, which may include several species. The reasonable maximum dose is based on species maximum tissue concentrations, which may be averaged across species of the same general receptor type (e.g., across several species of aquatic plants). For HTO, the average dose is based on a mean surface water concentration, partitioned to the tissues of each receptor. The reasonable maximum dose is based on an upper bound surface water concentration, computed as mean + 2 standard deviations for years 2000-2001.

Concentrations of metals in Perch Lake surface water were reported by Yankovich *et al.* (2002) based on spring and fall sampling at the lake outlet. The highest of these two values for COPEC metals was used to represent Perch Lake water. Metals in surface water and sediment at Perch Creek Weir were reported by Environment Canada (2001) based on fall grab samples. These values were also considered in defining exposure levels for COPEC metals in Perch Lake. The metal exposure data and corresponding metal doses to reptiles, birds and mammals are summarized in Table 3.11.

3.3.1.2 Perch Lake Inlets

There are four inlets to Perch Lake and one outlet (Perch Creek). Of the four inlets, two are influenced by drainage from the waste management areas. Inlet 1 is influenced by drainage from WMA-B. Inlet 2 is influenced via Main Stream by drainage from WMA-A. Both these inlets are routinely monitored for radionuclides (Niemi *et al.*, 2001). In addition, metals concentrations in the inlet waters were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides, metals and organics were measured by Environment Canada (2001) in water and sediment grab samples from Inlets 1 and 2. All these data were used in the estimation of radiation doses, and of COPEC metal doses, to natural biota in Inlets 1 and 2 (Appendix 5).

The radionuclide concentrations are summarized in Table 3.12, as average and reasonable maximum values, based on measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values (Table 3.1). The estimates are consistent with, or somewhat higher than, the few measured sediment concentrations.

The radiation doses are summarized in Table 3.13, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for fish, frogs, snails, infaunal benthos, plants, water shrews and great blue herons. In general, the greatest dose contributions are from Sr-90, and for shrews and herons the food pathway dominates.

The concentrations of COPEC metals in the surface water and sediment of Perch Lake Inlets 1 and 2, along with corresponding doses to water shrews and great blue heron, are summarized in Table 3.14, based on grab sample data. Detection limit values were used as water concentrations for Hg, Cr, Pb and Cu, as a conservative assumption, when these substances were not detected in the inlet water but were detected in sediment.

3.3.2 Perch Creek

Concentrations of radionuclides and selected metals are routinely measured in Perch Creek at the weir (Niemi *et al.*, 2001; Turner, 2001). In addition, metals concentrations in Perch

Creek water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides, metals and a suite of organics in creek water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses, and of COPEC metal and PAH doses, to natural biota in Perch Creek (Appendix 5).

The radionuclide concentrations are summarized in Table 3.15, as average and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values (Table 3.1). The estimates seem to be consistent with the few measured sediment concentrations for Sr-90 and HTO, but seem high as compared to the measurements for Co-60 and Cs-137 in Perch Creek.

The radiation doses are summarized in Table 3.16, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for fish, frogs, snails, infaunal benthos, plants, water shrews and great blue herons. In general, the greatest dose contributions are from Sr-90, and for shrews and herons the food pathway dominates.

The concentrations of COPEC metals and PAHs in Perch Creek surface water and sediment, along with corresponding doses to water shrews and great blue heron, are summarized in Table 3.17. Average and reasonable maximum concentrations (mean and mean+2S, years 2000-2001) were available for Fe and Al in water. Otherwise, grab sample data were utilized. Detection limit values were used as water exposure concentrations for Cr and PAHs, as a conservative assumption, when these substances were not detected in Perch Creek water but were detected in sediment.

3.3.3 South Swamp

Concentrations of radionuclides are routinely measured in South Swamp at the weir that separates the swamp from T16 stream (Niemi *et al.*, 2001). In addition, metals concentrations in South Swamp water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides and metals in water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses and of COPEC metal doses, to natural biota in South Swamp (Appendix 5).

The radionuclide concentrations are summarized in Table 3.18, as mean and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values.

The radiation doses are summarized in Table 3.19, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for frogs, snails, infaunal benthos, plants, water shrews and great blue herons. The greatest dose contributions are from Sr-90, and for shrews and herons the food pathway dominates.

The concentrations of COPEC metals in South Swamp surface water and sediment, along with corresponding doses to water shrews and great blue herons, are summarized in Table 3.20. These are based on a small number of grab samples collected and analyzed by Yankovich *et al.* (2002) (water only) and Environment Canada (2001) (water and sediment). A detection limit value was used as a water exposure concentration for Hg, as a conservative assumption, since Hg was not detected in South Swamp water.

3.3.4 East Swamp

Concentrations of radionuclides are routinely measured in East Swamp at the weir (Niemi *et al.*, 2001). In addition, metals concentrations in East Swamp water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides and metals in water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses and of COPEC metal doses to natural biota in East Swamp (Appendix 5).

The radionuclide concentrations are summarized in Table 3.21, as mean and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values (Table 3.1).

The radiation doses are summarized in Table 3.22, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for frogs, snails, infaunal benthos, plants, water shrews and great blue herons. The greatest dose contributions are from Sr-90, and for shrews and herons the food pathway dominates.

The concentrations of COPEC metals in East Swamp surface water and sediment, along with corresponding doses to water shrews and great blue herons, are summarized in Table 3.23. These are based on a small number of water grab samples collected and analyzed by Yankovich *et al.* (2002) and Environment Canada (2001). Metal concentrations in sediments were estimated using K_d values (Table 3.1), since measurements in sediments were not available. Detection limit values were used as water exposure concentrations for Hg and Pb, as a conservative assumption, when Hg was not detected in East Swamp water.

3.3.5 West Swamp

Concentrations of radionuclides (tritium, gross β) have been occasionally measured in West Swamp water (Niemi and Soonawala, 1999) and sediment (Killey *et al.*, 1988; Doyle, 2001). Metals concentrations have not been measured at this location in either medium. Nor were Co-60 or Cs-137 measurements available. The data that were available were used in the estimation of radiation doses to natural biota in West Swamp (Appendix 5).

The radionuclide concentrations are summarized in Table 3.24, including estimated concentrations for HTO and measured Sr-90 in sediments. The measured values of Sr-90 in sediment substantially exceed the estimate from surface water, based on a Perch Lake K_d value.

The radiation doses are summarized in Table 3.25, using both measured and estimated sediment concentrations. The calculated doses are shown for fish, frogs, snails, infaunal benthos, plants, water shrews, great blue herons, muskrat, mallards and painted turtles. The greatest dose contributions are from Sr-90, and for wildlife species the food pathway dominates.

Doses of metals to wildlife species could not be estimated due to lack of available water and sediment data. No metals were identified as COPECs in West Swamp, although several were identified based on screening of groundwater in Area B upgradient of West Swamp.

3.3.6 Main Stream

Concentrations of radionuclides are routinely measured in Main Stream at the weir (Niemi *et al.*, 2001). In addition, metals concentrations in South Swamp water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides and metals in water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses and of COPEC metal doses, to natural biota in Main Stream (Appendix 5).

The radionuclide concentrations are summarized in Table 3.26, as mean and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values (Table 3.1). The estimates seem to be consistent with the few measured sediment concentrations for Sr-90 and Cs-137, but seem to be high as compared to the measurement for Co-60 in Main Stream.

The radiation doses are summarized in Table 3.27, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for fish, frogs, snails, infaunal benthos, plants, water shrews and great blue herons. The greatest dose contributions are from Sr-90, and for shrews and herons the food pathway dominates.

The concentrations of COPEC metals in Main Stream surface water and sediment, along with corresponding doses to water shrews and great blue herons, are summarized in Table 3.28. These are based on a small number of grab samples collected and analyzed by Yankovich *et al.* (2002) (water only) and Environment Canada (2001) (water and sediment). Detection limit values were used as water exposure concentrations for Hg and Cr, as a conservative assumption, when these metals were not detected in Main Stream water; Cr was detected in sediment.

3.3.7 Duke Swamp and Stream

Concentrations of radionuclides and selected metals are routinely measured in Duke Swamp at the Duke Stream Weir (Niemi *et al.*, 2001; Turner, 2001). Carbon-14 has been occasionally measured (Killey *et al.*, 1998). In addition, metals concentrations in Duke Swamp water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides and metals in water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses and of COPEC metal doses, to natural biota in Duke Swamp (Appendix 5).

The radionuclide concentrations are summarized in Table 3.29, as mean and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values. Carbon-14 in sediment was measured by Killey *et al.* (1998) in Bq/kg C and 50% carbon was assumed for this peaty sediment. These authors also measured C-14 in terrestrial plant material.

The radiation doses are summarized in Table 3.30, for average and reasonable maximum concentrations, using the estimated sediment values for radionuclides other than C-14. The calculated doses are shown for frogs, snails, infaunal benthos, plants, water shrews and great blue herons. The greatest dose contributions are estimated to arise from C-14, except for riparian plants which had lower C-14 doses and similar contributions from Co-60 and tritium. For shrews and herons, the food pathway dominates.

The concentrations of COPEC metals in Duke Swamp surface water and sediment, along with corresponding doses to water shrews and great blue herons, are summarized in Table 3.31. Average and reasonable maximum concentrations were available for Fe in water. Otherwise, grab sample data were utilized from Yankovich *et al.* (2002) (water only) and Environment Canada (2001) (water and sediment). Detection limit values were used as water exposure concentrations for Hg, Cr and Pb, as a conservative assumption, when these metals were not detected in Duke Swamp water; Cr and Pb were detected in sediments.

3.3.8 Bulk Storage Swamp and Stream

Concentrations of radionuclides are routinely measured in Bulk Storage Swamp at the Bulk Storage Swamp Weir (Niemi *et al.*, 2001). Carbon-14 has been occasionally measured (Killey *et al.*, 1998; CH2M Hill, 2002). In addition, metals concentrations in Bulk Storage Swamp water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides and metals in water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses and of COPEC metal doses, to natural biota in Bulk Storage Swamp (Appendix 5).

The radionuclide concentrations are summarized in Table 3.32, as mean and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values. The estimates seem to be consistent with the few measured sediment concentrations for Sr-90 and C-14, but seem to be high as compared to the measurements for Co-60 and Cs-137. A measured value was used for C-14 in sediment.

The radiation doses are summarized in Table 3.33, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for frogs, snails, infaunal benthos, plants, water shrews and great blue herons. The greatest dose contributions are estimated to arise from C-14, except for riparian plants which had lower C-14 doses (assumed to be air-driven) and contributions of similar magnitude from Sr-90 and Co-60. For shrews and herons, the food pathway dominates.

The concentrations of COPEC metals in Bulk Storage Swamp surface water and sediment, along with corresponding doses to water shrews and great blue herons, are summarized in Table 3.34. These are based on a small number of grab samples collected and analyzed by Yankovich *et al.* (2002) (water only) and Environment Canada (2001) (water and sediment). Detection limit values were used as water exposure concentrations for Hg and Cr, as a conservative assumption, when these metals were not detected in Bulk Storage Swamp water; Cr was detected in sediments.

3.3.9 Lower Bass Lake

Concentrations of radionuclides are routinely measured in Lower Bass Lake (Niemi *et al.*, 2001). Carbon-14 has been occasionally measured (CH2M Hill, 2002). In addition, metals concentrations in Lower Bass Lake water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides and metals in water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses and of COPEC metal doses, to natural biota in Lower Bass Lake (Appendix 5).

Lower Bass Lake is minimally influenced by CRL activities. It receives a portion of flow from the north end of Duke Swamp. In terms of heavy metals, this lake may be considered as a reference location.

The radionuclide concentrations are summarized in Table 3.35, as mean and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values. The estimates of HTO in sediment, for a given water concentration, are somewhat higher than the single measured value, which may reflect a conservative porosity assumption. There are no measurements of other radionuclides in sediment for comparison. A detection limit value was used for C-14 in sediments, as a conservative assumption, since C-14 was not detected in Lower Bass Lake sediments.

The radiation doses are summarized in Table 3.36, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for fish, frogs, snails, infaunal benthos, plants, water shrews and great blue herons. The greatest dose contributions are generally from Sr-90, although C-14 and/or HTO are equally important for some organisms. Only HTO and Sr-90 appear to be elevated in Lower Bass Lake as compared to Maskinonge Lake. For shrews and herons, the food pathway dominates.

The concentrations of COPEC metals in Lower Bass Lake surface water and sediment, along with corresponding doses to water shrews and great blue herons, are summarized in Table 3.37. These are based on a small number of grab samples collected and analyzed by Yankovich (2002) (water only) and Environment Canada (2001) (water and sediment).

3.3.10 Maskinonge Lake

Concentrations of radionuclides are routinely measured in Maskinonge Lake at the outlet to Chalk Lake (Niemi *et al.*, 2001). Carbon-14 has been occasionally measured (CH2M Hill, 2002). In addition, metals concentrations in Maskinonge Lake water were reported by Yankovich *et al.* (2002) based on spring and fall sampling events. Radionuclides and metals in water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses and of COPEC metal doses, to natural biota in Maskinonge Lake (Appendix 5).

The radionuclide concentrations are summarized in Table 3.38, as mean and reasonable maximum values, based on the measured concentrations in water (mean and mean+2S, years 2000-2001) and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values. The estimates of HTO in sediment, for a given water value, are somewhat higher than the single measured value, which may reflect a conservative porosity assumption. A measured value was used for C-14 in sediments.

The radiation doses are summarized in Table 3.39, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. The calculated doses are shown for fish, frogs, snails, infaunal benthos, plants, water shrews, great blue herons, muskrats, mallards and painted turtles. The greatest dose contributions are generally from C-14, which seems to reflect background conditions in Maskinonge Lake. For wildlife species, the food pathway dominates.

The concentrations of COPEC metals in Maskinonge Lake surface water and sediment, along with corresponding doses to wildlife species, are summarized in Table 3.40. These are based on a small number of grab samples collected and analyzed by Yankovich *et al.* (2002) (water only) and Environment Canada (2001) (water and sediment). Detection limit values were used as water exposure concentrations for Cr, Pb and Cd, as a conservative assumption, when these metals were not detected in Maskinonge Lake water; they were detected in sediments.

3.4 Ottawa River

Plume delineation work was completed by Stantec Consulting Ltd. (2003) (Appendix 4). This evaluation describes the mixing zones for the key effluent discharges to the Ottawa River, including the process sewer, the sanitary sewer, the powerhouse discharge, the 04 Storm Sewer, and Streams 01, 03, 05 and 06. The plume for each discharge was categorized as either "offshore" or "nearshore" for the exposure assessment. The "offshore" discharges discharge via offshore submerged outfalls, and consist of the process sewer and the sanitary sewer. The reader is referred to Appendix 4 for detail on the plume delineation.

For the process sewer, the dilution factor within the turbulent mixing zone is approximately 7:1 (i.e., 12.5% effluent), with dilution provided by a multiport diffuser installed at an 18-m depth in the river. A dilution factor of 10:1 was calculated as an average concentration within a near-field zone of 125 m^2. The effluent is diluted to 1% in river water within 1,000 m downstream of the discharge along the plume centreline.

The plume from the sanitary sewer is very small, with effluent concentrations falling below 0.1% within less than 100 m of the point of discharge. A dilution factor of 1,500:1 was calculated as an average concentration within a zone of 5 m wide by 25 m long in the downcurrent direction.

For the nearshore discharges, plume dilution factors were calculated as average concentrations within a zone of 5 m wide by 25 m long along the river shoreline at the point of effluent discharge (Appendix 4). This was considered representative of the home ranges of some relatively similar aquatic species such as benthic invertebrates and some small fish species. In these cases, effluents were determined to be diluted to approximately 7% (Streams 04 and 03) or less (other discharges) within these 125 m^2 areas.

For groundwater discharges to the Ottawa River shoreline, the plume is diffuse; however, the total discharge estimate (Niemi *et al.*, 2001) in relation to the other shoreline discharges and their dilution factors, indicates an approximate dilution factor of 5,000:1 for the nearshore zone that is subject to groundwater discharge.

Available exposure data for the vicinity of nearshore discharges to the Ottawa River are described in Section 3.4.1 below. Exposure data for the vicinity of the offshore discharges are described in Section 3.4.2.

3.4.1 Nearshore

The exposure assessment for the nearshore zone addresses exposures upgradient from the shoreline, i.e., streams prior to discharge in the river, as well as exposures downgradient of the shoreline, i.e., the river near the point of discharge. These aspects are addressed in Sections 3.4.1.1 and 3.4.1.2, respectively. While the streams prior to discharge are actually inland aquatic sites, they are discussed here with the nearshore zone because they are particularly relevant to the COPEC concentrations in the nearshore river where each stream discharges.

3.4.1.1 Streams Prior to Discharge

Concentrations of radionuclides (gross β, HTO) and selected metals and organics are routinely measured in the streams that carry site runoff to the Ottawa River shoreline (Niemi *et al.*, 2001; Turner, 2001). In addition, radionuclides, metals and organics in stream water and sediment grab samples were reported by Environment Canada (2001). All these data were used in the estimation of radiation doses, and COPEC metal and organic doses, to natural biota in the streams (Appendix 5).

The radionuclide concentrations are summarized in Table 3.41, as average and reasonable maximum values, based on the measured concentrations in water (mean+2S, years 2000-2001) and estimated or measured concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values (Table 3.1). The estimates are generally consistent with the few measured sediment concentrations, except for a high gross β measurement in Stream 5. Estimates for Cs-137 and Co-60 in sediment are generally lacking due to non-detection in stream water.

The radiation doses are summarized for Streams 5 and 6 in Table 3.42, for average and reasonable maximum concentrations, using the estimated sediment values for these two exposure conditions. Doses from Co-60 and Cs-137 are not shown, since these radionuclides are generally not detectable in the riverfront streams. Streams 5 and 6 represent the range of exposure concentrations and doses likely to be experienced by aquatic biota in the riverfront zone. Stream 6 is the worst case from this perspective. The calculated doses are shown for fish, frogs, snails, plants, water shrews and great blue herons.

The concentrations of COPEC metals and other contaminants in Stream 3 and 5 waters and sediments, along with corresponding doses to water shrews and great blue herons, are summarized in Table 3.43. Streams 3 and 5 represent all the COPEC contaminants that exceed benchmark concentrations in riverfront streams. The chlorine concentration shown in Stream 3 is a conservative estimate of reactive species based on total chlorine use. Reactive chlorine species will be present episodically in association with disinfection activities on the CRL site.

3.4.1.2 River Receiving Waters

Concentrations of radionuclides (gross β, HTO) and selected metals and organics in the nearshore zone of the Ottawa River were estimated by application of dilution factors to the measured water concentrations in nearshore discharge streams. The concentrations in these streams are routinely monitored (Niemi *et al.*, 2001; Turner, 2001) and were evaluated as stream environments in Section 3.4.1.1 above. The dilution factors were based on plume modelling (Appendix 4) and represent a near-field zone in the plume (0-25 m). For each contaminant, the streams that provide the main loadings to the river are examined. In addition, some measurements of Co-60 and Cs-137 in nearshore sediments (Niemi *et al.*, 2001), metals in nearshore waters (Yankovich *et al.*, 2002) and Sr-90 in riverfront trees (Lee and Hartwig, 2002) were available. All these data were used in estimation of radiation doses, and COPEC metal and organic doses, to natural biota of the nearshore zone (Appendix 5).

The radionuclide concentrations in near-field plumes are summarized in Table 3.44, as average and reasonable maximum values, based on the measured concentrations in the discharge streams (mean and mean+2S, years 2000-2001), dilution factors and estimated concentrations in sediments. The estimated sediment concentrations are based on Perch Lake K_d values (Table 3.1). Estimates for Cs-137 and Co-60 in sediment are generally lacking due to non-detection in the discharge streams.

The radiation doses are summarized for the powerhouse drain and Storm Sewer 4 discharge areas and for Pointe aux Baptime in Table 3.45, for average and reasonable maximum concentrations using the estimated sediment values for these two exposure conditions. Doses from Co-60 and Cs-137 are included only for Point aux Baptime where measurements in sediment were available. These locations represent the range of exposure concentrations and doses likely to be experienced by aquatic biota in the nearshore zone. Storm Sewer 4 is the worst case from this perspective. The calculated doses are shown for fish, frogs, snails, plants, water shrews, great blue herons and muskrats.

The concentrations of COPEC metals and other contaminants in the Stream 3 and 4 discharge areas and at Point aux Baptime, along with corresponding doses to water shrews, great blue herons and muskrats, are summarized in Table 3.46. These locations represent all the COPEC contaminants with significant loadings to the Ottawa River nearshore, and all the contaminants potentially exceeding benchmark concentrations here. The chlorine concentration for the Stream 3 discharge area is a conservative estimate based on total chlorine use. Reactive chlorine species will be present episodically in association with disinfection activities on the CRL site.

3.4.2 Offshore

Concentrations of radionuclides and selected metals and organics in the offshore zone of the Ottawa River were estimated by application of dilution factors to the measured water concentrations in the process sewer and the sanitary sewer. The concentrations in these effluents are routinely monitored (Niemi *et al.*, 2001; Turner, 2001). The dilution factors were based on plume modelling (Appendix 4) and represent a near-field zone in the plume (0-25 m). In addition, some water and sediment data from the vicinity of the process sewer were available from Environment Canada (2001) and some preliminary data were available from an AECL sediment survey (Lee and Hartwig, 2003). All these data were used in estimation of radiation doses, and COPEC metal and organic exposures, to aquatic biota in the offshore zone (Appendix 5).

The radionuclide concentrations in the near-field plumes are summarized in Table 3.47, as average and reasonable maximum values. Both estimated and measured concentrations in sediments are shown. The measured concentrations in sediments are well above partitioning estimates in the offshore river, suggesting a sediment influence from historical releases, and/or some radionuclides in the sediment particle matrix rather than adsorbed. Sediment measurements were unavailable for P-32 which was examined as a release from the process sewer. Measured sediment values were used if available for estimation of doses to aquatic biota.

The Lee and Hartwig (2003) sediment work in the vicinity of the process sewer discharge included sampling of sediments by coring, mapping of gamma radiation fields at the sediment surface, and dating of sediments to determine deposition rates. Much of these data are yet unavailable (2003 March). Radiation measurements showed that the area of elevated radioactivity covers a small area of river bottom, 400 m long and 200 m wide, at river depths of 8 to 30 m. This is the same area as identified by Ophel (1959) and Lee *et al.* (1991), indicating that the activity has been there for decades.

Assessment of the spatial and vertical pattern of total activity, and of its radionuclide composition, is ongoing. The most contaminated zone, in the immediate vicinity of the process sewer outfall, has gross β activity on the order of 61,400 Bq/kg DW (1,483 m^2 area, upper 10 cm). A more typical gross β activity, representing most of the contaminated area, is on the order of 13,300 Bq/kg DW (37,000 m^2 out of 45,000 m^2). A preliminary estimate of radionuclide composition, based on complete analysis of a single core to date, is 52% Cs-137, 31% Co-60 and 15% Sr-90.

Radiation doses are summarized in Table 3.48 for the sanitary sewer and process sewer discharge areas, for average and reasonable maximum concentrations, using the measured sediment concentrations where available. The doses arising from the sanitary sewer are negligible as compared to those in the vicinity of the process sewer.

The concentrations of COPEC metals and other contaminants in the sanitary sewer and process sewer discharge areas are summarized in Table 3.49. All the COPEC contaminants with potential to exceed benchmark concentrations in water or sediment at either location are shown. The chlorine concentration for the sanitary sewer discharge area is a conservative estimate based on total chlorine use. Reactive chlorine species will be present here episodically in association with disinfection activities on the CRL site. Estimates of Hg, Cd, pyrene and benzo(a)pyrene in water near the process sewer are based on measurements in the WTC, since these substances are not generally detectable in the process sewer effluent.

3.5 Upland Sites

3.5.1 WMA-A

Concentrations of radionuclides in air and in surface soils, as well as gamma radiation fields at various locations in WMA-A, are summarized in Table 3.50, as detailed in Appendix 5. Atmospheric concentrations are estimated based on modelling of five-year average release rates, while soil data are from Killey and Welch (1998) and Lounsbury and Adams (1999). Gamma field contour maps were used to estimate concentration averages and maxima at the various component locations within Area A.

Radiation doses are summarized in Table 3.50 for large and small terrestrial invertebrates, terrestrial plants, least shrews and robins assumed to reside at the various component locations of Area A. In reality, Area A affords very little suitable habitat to support resident terrestrial species, perhaps other than sparse vegetation growth and some invertebrates (e.g., insects). Thus, these doses may be realistic for a few individual plants and invertebrates, but are not realistic for robin or shrew, as they would only spend a small fraction of the time in Area A, and an even smaller fraction of the time in the various disposal pits (which are generally denuded of vegetation).

As at some of the other WMAs, mercury is also identified as a COPEC at Area A, based on its presence in groundwater at up to 0.00115 mg/L (AECL, 2002). Based on an assumed K_d of 16 for sandy soils (Sheppard and Thibault, 1990), this results in a predicted soil concentration of 0.0184 mg/kg dry weight assuming groundwater discharge through surface soil at this concentration. This predicted dry weight soil concentration was used in Appendix 5 to estimate tissue concentrations in biota by application of a soil-to-invertebrate transfer factor of 0.2965 L/kg FW (using a TF of 1.186 L/kg from Effroymson *et al.* (1997a), adjusted by 0.25 to convert to fresh weight) and a soil-to-plant transfer factor of 0.0859 (using a TF of 0.3437 from Effroymson *et al.* (1997b), adjusted by 0.25 to convert to fresh weight). Resulting tissue concentrations are 0.00546 mg/kg FW in invertebrates and 0.00158 mg/kg FW in terrestrial plants.

3.5.2 WMA-B

Concentrations of radionuclide in air and surface soils, as well as gamma fields across Area B and at Spring B, are summarized in Table 3.51, as detailed in Appendix 5. Atmospheric concentrations are based on modelling of five-year average release rates, while gamma field data are derived from gamma contours in Lounsbury and Adams (1999). Soil and plant tissue data are from Cooper and Rahman (1994), while additional soil data were taken from Doyle (2001).

Radiation doses are summarized in Table 3.51 for large and small terrestrial invertebrates, terrestrial plants, least shrews and robins assumed to reside either across Area B or downstream of Spring B. Area B does not provide adequate habitat to support a robin, while Spring B would be unlikely to support a resident shrew. The Area B average doses may provide adequate habitat to support a few resident shrews. However, the results appear realistic for the area downstream of Spring B, as the affected area may encompass a few hectares.

Mercury was identified as a COPEC at Area B, based on its occurrence in site groundwater at up to 0.0019 mg/L (AECL, 2002). Using a K_d of 16 for sandy soils (Sheppard and Thibault, 1990), this results in a predicted soil concentration of 0.03 mg/kg dry weight assuming groundwater discharge to surface soil at this concentration. This predicted soil concentration was used in Appendix 5 to estimate tissue concentrations in biota by application of a soil-to-invertebrate transfer factor of 0.2965 L/kg FW (using a TF of 1.186 L/kg from Effroymson *et al.* (1997a), adjusted by 0.25 to convert to fresh weight), and a soil-to-plant transfer factor of 0.0859 (using a TF of 0.3437 from Effroymson *et al.* (1997b), adjusted by 0.25 to convert to fresh weight). Resulting fresh weight tissue concentrations are 0.00901 mg/kg in invertebrates and 0.00261 mg/kg in terrestrial plants.

3.5.3 WMA-C

Concentrations of radionuclide in surface soils and terrestrial plants, as well as gamma radiation levels near the Thorium Pit and the Nitrate Plant, are summarized in Table 3.52, as detailed in Appendix 5 (from Killey *et al.*, 1998). Atmospheric concentrations of radionuclides are assumed to be zero, as they are well outside of the air plume reported in modelling of radionuclides from the main sources of atmospheric release. Data on plant tissues and on soils were taken from the Duke Swamp watershed (Killey *et al.*, 1998). Gamma radiation measurements were extracted from radiation contour maps in Killey *et al.* (1998).

Radiation doses are summarized in Table 3.52 for large and small invertebrates, terrestrial plants, least shrews and robins assumed to be resident at various locations within Area C. As in most other WMAs, this assumption is not realistic for the Thorium Pit or Nitrate Plant, with the possible exception of a few invertebrates and small plants. It may be realistic for shrews to inhabit an area just outside the compound, although there is unlikely enough habitat here to support a resident robin. The doses to plants, based on measured plant tissue concentrations, are also realistic.

Mercury was identified as a COPEC at Area C, based on its occurrence in site groundwater at up to 0.00013 mg/L (AECL, 2002). Using a K_d of 16 for sandy soils (Sheppard and Thibault, 1990), this results in a predicted soil concentration of 0.0021 mg/kg dry weight in Appendix 5, assuming groundwater discharge through surface soil at this concentration. This predicted soil concentration was used in Appendix 5 to estimate tissue concentrations in biota by application of a soil-to-invertebrate transfer factor of 0.2965 L/kg FW (using a TF of 1.186 L/kg from Effroymson *et al.* (1997a), adjusted by 0.25 to convert to fresh weight), and a soil-to-plant transfer factor of 0.0859 (using a TF of 0.3437 from Effroymson *et al.* (1997b), adjusted by 0.25 to convert to fresh weight). Resulting fresh weight tissue concentrations are 0.000617 mg/kg in invertebrates and 0.000179 mg/kg in terrestrial plants.

3.5.4 WMA-F

As described in Section 2.0, woodchucks are known to inhabit Area F, and are identified as a VEC. Woodchuck may burrow to depths of over 1.5 m (Burt and Grossenheider, 1964), and may therefore burrow into the waste underlying the 1.3 m deep cover over Area F waste. This waste area contains 119,000 tonnes of waste, containing 515 GBq of Ra-226, 4.2 to 13 tonnes of arsenic and 79 tonnes of uranium (Killey *et al.*, 1993).

Because Area F has a clean soil cover (Killey *et al.*, 1993), the vegetation consumed by the Area F woodchuck is uncontaminated. Soil ingested by the woodchuck is also likely to be clean, although a small amount may be consumed during grooming in the burrow when in contact with waste material.

MacDonald and Laverock (1998) evaluated radiation exposures in small burrowing mammals due to inhalation of radon in burrows, based on monitoring of radon in artificial burrows. They specifically accounted for hibernation time, inhalation rate and residency in the burrow and at surface. In this study, dose to lung was calculated for woodchuck as a function of radon concentration in the burrow and radon equilibrium equivalent factor, F, which was assumed to range between 0.4 and 0.7. The average Ra-226 concentration measured in soils at the artificial burrow sites was 35 Bq/kg (assuming values below detection limits at half the detection limit). Because Ra-226 is the source of Rn-222, this average is used here to develop a Ra:Rn ratio for estimation of an overall average Rn-222 concentration in an Area F burrow. The average Rn-222 concentration in the artificial burrows, averaged over burrows and seasons, was 9,990 Bq/m^3. It is acknowledged that MacDonald and Laverock (1993) found that Ra-226 was an inaccurate predictor of burrow radon concentration; however, this Ra:Rn ratio approach appears reasonable as an overall screen.

Area F soil has an average Ra-226 concentration of 4,328 Bq/kg, which should give rise to an estimated average radon concentration in woodchuck burrow air of 1.24x10^6 Bq/m^3. Assuming a mean F of 0.55, and applying the predictive model in MacDonald and Laverock (1993), the estimated annual dose to the exposed woodchuck due to radon inhalation is 18 Gy/y. As noted by the authors, the normal background radon dose to burrowing mammals and birds may commonly exceed 0.5 Gy/y.

Mercury was identified as a COPEC at Area F, based on its presence in site groundwater at up to 0.0002 mg/L (AECL, 2002). Using a K_d of 16 for sandy soils (Sheppard and Thibault, 1990), this results in a predicted soil concentration of 0.0032 mg/kg dry weight in Appendix 5, assuming groundwater discharge to surface soil at this concentration. This predicted soil concentration was used in Appendix 5 to estimate tissue concentrations in biota by application of a soil-to-invertebrate transfer factor of 0.2965 L/kg FW (using a TF of 1.186 L/kg from Effroymson *et al.* (1997a), adjusted by 0.25 to convert to fresh weight), and a soil-to-plant transfer factor of 0.0859 (using a TF of 0.3437 from Effroymson *et al.* (1997b), adjusted by 0.25 to convert to fresh weight). Resulting fresh weight tissue concentrations are 0.000949 mg/kg in invertebrates and 0.000275 mg/kg in terrestrial plants.

3.5.5 WMA-H

Concentrations of radionuclides in air, surface soils and plants at locations near WMA-H, combined with gamma radiation fields in this area, are summarized in Table 3.53, and detailed in Appendix 5. These values were all derived from Killey *et al.* (2000).

Radiation doses are summarized in Table 3.53 for terrestrial biota inhabiting Area H. The values given for terrestrial plants and invertebrates are realistic for small numbers of individuals inhabiting the WMA. The doses to shrews and robins are probably not realistic, owing to home range and/or habitat limitations.

3.5.6 Soil Invertebrates and Plants Over Groundwater Plumes

Contaminated groundwater plumes are found beneath the WMAs, beneath the reactor buildings, and in downgradient areas. As these plumes near their points of discharge to the surface, they may be close enough to the surface to interact with soil biota, such as earthworms and plants. These interactions are unlikely in the upgradient source areas where plumes are 5 to 10 m below grade. The interactions for discharge areas are addressed below.

Earthworms, like many soil invertebrates, feed on decaying organic matter, and are mainly found in the humus layer of the soil (Barnes, 1968). Under certain conditions, e.g., winter or dry periods, earthworms will burrow as deep as 2 or 3 m. They are generally not feeding at such times, and they do not burrow below the watertable. However, given watertable fluctuations, it is possible they may briefly encounter groundwater, or soil that has been influenced by groundwater. We believe it is conservative to assume that such encounters may occur 10% of the time.

The small swamps receiving groundwater discharge from the WMAs probably have water quality that resembles the groundwater quality in the discharge area. For example, the South Swamp mean + 2 S concentration of Sr-90 (estimated as gross $\beta/2$) is 20,650 Bq/L (Appendix 5). The 1999 maximum groundwater concentrations of Sr-90 in the perimeter wells of Area A and Reactor Pit 2, directly upgradient, are 6,350 and 14,700 Bq/L, respectively, estimated as gross $\beta/2$ (Appendix 1). The Sr-90 exposure is the main determinant of radiation dose in the swamp areas that receive groundwater plumes.

A soil invertebrate in the discharge area, when in contact with the groundwater plume, would receive exposures and doses less than those experienced by the invertebrates in South Swamp, exposed via surface water and sediment. This is because there would be less Sr-90 adsorption to soil as compared to sediment, and because soil invertebrate uptake factors would be lower, particularly as compared to mollusk values in the aquatic environment. Moreover, considering the soil invertebrate's lower frequency of contact with contaminated water, we would expect its long-term average doses to be further reduced by approximately ten-fold. Thus, while soil invertebrates may contact groundwater in the discharge areas, their radiation doses will not exceed the doses seen in the swamps and are expected to be substantially lower. Dose estimate for invertebrates in soil above the plume at South Swamp, as calculated in Appendix 5, are summarized in Table 3.54. The doses from Sr-90 are 0.9 μGy/h (average) to 8 μGy/h (upper limit) for full occupancy in the plume, and 0.09 to 0.8 μGy/h for 10% occupancy.

In the riverfront area where plumes from NRX and NRU discharge to the river, it is unlikely that surface water concentrations can represent the groundwater contact of soil invertebrates in the discharge area, because these surface waters are not hydraulically dominated by groundwater. Therefore, exposure and dose estimates have been developed for an earthworm, assuming that it burrows down at least 3 to 5 m into the NRX plume near the riverfront wells (Appendix 5). The results are summarized in Table 3.55.

Maximum groundwater values for each well (Killey and Eyvindson, 1999) were assumed to be at equilibrium with soil (using Sr-90 K_d = 20; Sheppard *et al.*, 1992) and uptake from soil to worm was estimated (using B_w = 0.016, dry soil to fresh tissue; based on Sample *et al.*, 1998). With dosimetry following Blaylock *et al.* (1993), doses from HTO are 5.71 to 10.3 μGy/h for full occupancy in the plume, and 0.57 to 1 μGy/h for 10% occupancy (Table 3.55). Doses from Sr-90 are 0.14 to 0.35 μGy/h for full occupancy and 0.014 to 0.035 for 10% occupancy. These doses indicate that burrowing soil invertebrates are not likely to be harmed by contact with the NRX plume.

Woody plants may have extensive subsurface root systems. Their horizontal and vertical extent is generally adapted to local conditions, depending on soil texture, organic content and bulk density (Craul, 1992). They avoid compacted soil layers and soils that are fully saturated for prolonged periods. Very few roots extend below a 1-m depth, although they may be somewhat deeper in well-drained soil (Himelick, 1986). Perhaps the best way of assessing contaminant uptake via roots from groundwater plumes is to measure contaminant levels in aboveground plant tissues.

The uptake of COPECs from sediments to riparian plants was estimated in Sections 3.3 and 3.4 for all aquatic sites (assuming sediments exposed on the banks). In addition, we have considered the measurements of radionuclides in plant tissues at some locations near where plumes discharge, e.g., alder along the riverfront area over the NRX plume.

As noted above for invertebrates, the small swamps receiving groundwater discharge from the WMAs probably have water quality that resembles the groundwater quality in the discharge area; however, soils above the plume will be less contaminated than swamp sediments. Riparian plants at South Swamp were estimated to contain 347,822 Bq/kg FW Sr-90 (average) or 3.21E6 Bq/kg (upper limit) based on uptake from sediment (Appendix 5). A bulrush sample collected at South Swamp (Environment Canada, 2001) contained 1,760 Bq/g gross β or 880,000 Bq/kg Sr-90. The dose for sediment-associated plants was estimated at 210.9 μGy/h (average) to 1,948 μGy/h (upper limit) (Appendix 5). Somewhat lower doses, from 6.9 to 64.4 μGy/h, were estimated for plants in soil above the plume (Table 3.54).

In the riverfront area, where plumes from NRX and NRU discharge to the river, gross β measurements in two alders growing over the NRX plume showed a clear plume influence (Lee and Hartwig, 2002). Their Sr-90 in tissue (estimated as gross β/2) was 2,112 and 8,934 Bq/kg FW (Appendix 5). Tissue estimates for plants assumed to be rooted in the NRX plume (at least 3 to 5 m deep) are 1.75E6 to 3.14E6 Bq/kg FW HTO, and 1,765 to 4,539 Bq/kg FW Sr-90 (groundwater concentrations from Killey and Eyvindson, 1999; Sr-90 K_d = 20, Sheppard *et al.*, 1992; B_v = 0.25, dry soil to fresh tissue, IAEA, 1994). With dosimetry following Blaylock *et al.* (1993), doses from HTO are 5.71 to 10.3 μGy/h and doses from Sr-90 are 1.09 to 2.81 μGy/h (Table 3.55). These doses indicate that rooted plants are not likely to be harmed by contact with the plume.

3.6 Large Mammals

Data on radionuclides in tissues of large mammals sampled at the CRL site are presented in Niemi *et al.* (2001, 2002). These samples were collected opportunistically from animals accidentally killed on the CRL property (usually by traffic). Average radionuclide concentrations in soft tissues (muscle) and corresponding doses for 2000 and 2001 deer samples are presented in Table 3.56. Evaluation of muscle (soft tissue) was considered more relevant than bone for this assessment, because the endpoint of interest is reproduction and reproductive tissues are more similar to muscle than to bone. The only detectible man-made radionuclides in deer were HTO and Sr-90. Doses to eastern wolf, assumed conservatively to feed exclusively on white-tailed deer (at 4.5 kg/d), are also presented in Table 3.56 based on the calculations presented in Appendix 5 (wolf were not directly sampled by AECL).

3.7 Road Salt

The CRL site has a substantial network of roads at the plant site, a paved access road and parking areas. The site has approximately 54 km of roadways, maintained in winter with the use of road salt (AECL, 2001). Assuming a typical road width of 8 m, this represents 432,000 m^2 of surface where salt is applied.

The exposure of organisms to salt will depend on the dilution and flow path followed by snowmelt along roadways. The least possible dilution will produce a worst case exposure condition for evaluation. To estimate exposure, the entire winter's road salt application can be assumed to be diluted in the annual snowmelt occurring on road surfaces. Based on meteorological records for the area, the annual amount of precipitation as snowfall is 202.6 mm (from STF, 1995). Based on AECL (2001), the total road salt use at CRL (year 2000) is 729 tonnes. The concentration of sodium chloride in the annual snowmelt falling on 432,000 m^2 of road surface is 7.29E8 grams ÷ (432,000 m^2 x 0.2026 m), or 8,329 mg/L (3,273 mg/L of sodium and 5,056 mg/L of chloride). The effects of these values on aquatic species will be assessed in Section 4.0.

Concentrations of salt in snowmelt cannot be readily used to determine concentrations in soil (Environment Canada, 2000). In general, soil concentrations peak in summer under dry weather conditions, based on available monitoring data (Environment Canada, 2000). It is reasonable to assume that elevated concentrations of sodium chloride will occur in soils along CRL roadways, as can be expected along Ontario roadways in general (Racette and Griffin, 1989).

3.8 Points of Impingement

Air plumes were modelled using five-year emission monitoring data, combined with the corresponding five-year meteorological record, to describe annual average atmospheric concentrations of radionuclides, NO_x and SO_2 around the CRL property (Appendix 3). These include concentrations of all important releases from the NRU reactor stack and vents, the Mo-99 stack, the power plant and building 250.

It was felt that the general effects of these emissions on CRL biota would be relatively small, as the emissions produce the greatest concentrations in and around the main Control Area, where workers are exposed to the same emissions on a daily basis. However, to evaluate this further, an assessment was done to examine the effects of exposure to the maximum annual average concentrations at the points of impingement for these releases. These points of impingement for the air emissions generally occur within or close to the main CRL plant site area, where the landscape is altered by human disturbance and where the diversity of natural biota will be diminished. These maximum concentrations are presented in Table 3.57.

Radiation doses to terrestrial VECs assumed to reside at each of the three principal points of impingement are presented in Table 3.58, based on the calculations presented in Appendix 5. These doses, along with the concentrations of NO_x and SO_2, are evaluated with respect to potential effects on VECs in Section 4.0.

3.9 Regional Emissions – Greenhouse Gases

Some atmospheric contaminants are of greater concern at a regional or global scale than at the local scale. These include CO_2, primarily from combustion of fuel at the powerhouse, as well as halocarbons which may contribute to global warming. The emission of CO_2 from CRL is 32,800 tonnes/y, while the annual emission of HCFC is 236 kg/y and of HFC is 475 kg/y, based on 2000 data (AECL, 2001). These two halocarbons have a global warming potential of 1,350 and 1,300 times that of CO_2 on a mass basis (AECL, 2001).

The “effect” of these regional emissions is described in Section 4.0, based on comparison against regional emission data for greenhouse gases.

4.0 EFFECTS AND RISK CHARACTERIZATION

4.1 General Methods

The potential for ecological effects arising from the documented COPEC exposure levels at each site (Section 3.0) was assessed by comparing these exposure levels to various benchmark levels representing the lowest levels at which adverse effects have been observed for different receptor organisms. The benchmark values were taken from the toxicological literature, as documented in Section 4.1.1. When the exposure values (EV) for an organism at a site exceed the benchmark values (BV), and if both are above typical background levels, a potential for adverse ecological effects is inferred.

The results of ecological effects monitoring (EEM) studies on the CRL site have also been considered. These studies have looked for effects that might be expected as a result of radiological or chemical exposures. These include studies of fish health in various lakes on the site, as well as studies of benthic invertebrate toxicity in Ottawa River sediments. The EEM study methods are outlined in Section 4.1.2 below.

Ecological effects from physical stressors on the CRL site have been assessed to the extent possible. These are effects that might be expected as a result of exposure to physical stressors of potential environmental concern (SOPECs). The stressors of interest here include entrainment/impingement of aquatic biota (cooling water intake), thermal increments related to cooling water discharge, and habitat alterations such as firebreaks and fences. The assessment methods are outlined in Section 4.1.3 below.

4.1.1 Benchmark Values

The benchmark values that have generally been used in assessing the potential significance of radiation dose to natural biota have been in the range of 1 to 10 mGy/day (40 to 400 µGy/h) (NCRP, 1991; IAEA, 1992; UNSCEAR, 1996; ACRP, 2002). Reproductive effects in mammals are the most sensitive endpoints, and are the basis for the IAEA (1992) and UNSCEAR (1996) recommendation of 1 mGy/day for terrestrial animals. The NCRP (1991) and UNSCEAR (1996) have recommended 10 mGy/day for aquatic organisms, while the IAEA (1992) and UNSCEAR (1996) have recommended the same value for terrestrial plants. A radiation benchmark value of 1 mGy/day (40 µGy/h) has been used in this assessment for all organisms, recognizing that this is likely a conservative value for some receptors.

The benchmark values used for non-radionuclide doses to birds and mammals are Lowest Observable Adverse Effect Level (LOAEL) values from Sample *et al.* (1996), if available, or from other sources if necessary. The benchmark doses of non-radionuclides to mammals have been scaled to body weight, as recommended by Sample *et al.* (1996). The benchmark doses used in this assessment are listed in Table 4.1.

The benchmark values used in assessing the potential significance of non-radionuclide exposures of other biota are media concentration values rather than doses. The values for aquatic biota (fish, invertebrates, aquatic plants) are usually lowest chronic values (LCV) or EC20 values from Suter and Tsao (1996), whichever is lowest. Fish values have been used to represent frogs due to the general scarcity of amphibian data. The aquatic toxicity benchmark concentrations used in this assessment are listed in Table 4.2.

In some cases, where adequate aquatic toxicity data are lacking for a particular taxon, CCME (1999) water quality objectives (or interim objectives) have been used as benchmark values. The interim objectives are considered to be quite conservative. In other cases, benchmark water concentrations (for aquatic invertebrates) have been estimated from benchmark sediment concentrations (Jones *et al.*, 1997; CCME, 1999) divided by K_d values.

Terrestrial plant and invertebrate benchmark values are Canadian soil quality guidelines (CCME, 1999) or Lowest Observable Effect Concentration (LOEC) soil concentrations from Effroymson *et al.* (1997a,b). The latter were used if a soil guideline was not available, or if higher than the guideline for either plants or invertebrates. The terrestrial plant values were considered appropriate for riparian plants at aquatic sites (assumed to be rooted in sediment), as well as for the strictly terrestrial species found at upland sites. The terrestrial toxicity benchmark concentrations used in this assessment are listed in Table 4.3.

4.2 Effects Monitoring

4.2.1 Perch Lake

In addition to the predicted effects on Perch lake biota, various measurements have been made on the health of Perch Lake fish populations to identify any actual adverse effects due to exposure to COPECs. Yankovich and Cornett (2001) measured growth (fish condition) and the occurrence of parasites, tumours and deformities in Perch Lake brown bullhead and northern pike, as a function of tissue Sr-90, Cs-137 and Co-60 concentration. None of the observed biological responses was related to exposure to radionuclides, even though other research has shown that fish condition can be adversely affected in fish receiving relatively high radiation doses (LeFrançois *et al.*, 1999).

Yankovich (2003) also examined the condition of Perch Lake pumpkinseed in comparison with condition of pumpkinseed from Perch Creek and local reference lakes (Figure 4.1). Again, the data show no impact on fish condition relative to nearby reference lakes.

These studies suggest that ecological effects, as measured in terms of fish growth or anomalies, do not occur in Perch Lake fish.

4.2.2 Ottawa River

Pollutech (2002) completed bioassays of sediments from the Ottawa River near the process sewer outfall on behalf of CRL (Appendix 6). The tests completed were the *Chironomus* *tentans* survival and growth test (Environment Canada, 1997) and the *Ceriodaphnia dubia* survival and reproduction test (ASTM, 1994). In all cases, survival and sublethal effects were generally comparable between CRL river sediments and laboratory controls, with the exception that *Chironomus* tended to show greater growth in Ottawa River sediments than in laboratory control sediments. Total radioactivity levels in the sediments tested were up to 19 Bq/g, and consisted mainly of Cs-137, Co-60, Eu-155, Eu-154, Eu-152 and Sr-90. Concentrations of Ni, Cu, As and Pb were similar in sediments near the outfall and in upstream reference sediments, while Hg concentrations were somewhat greater in sediments near the outfall. The results indicate no adverse effect on benthic species in the area affected by the process sewer discharge.

4.3 Aquatic Sites

The radiation doses to aquatic biota at the inland aquatic sites were estimated in Section 3.3. These doses are summarized in Table 4.4 and doses above 40 μGy/h are highlighted for further discussion.

Table 4.4 shows that radiation doses exceed this benchmark value for aquatic organisms in South Swamp and East Swamp (downgradient from WMA-A), in West Swamp (downgradient from WMA-B) and at Perch Lake Inlet 1 draining West Swamp. The aquatic organisms that may experience such doses include frogs (at East Swamp and South Swamp), small fish (at East Swamp), snails (at all four sites), aquatic plants (at East Swamp and South Swamp), and riparian plants (growing in swamp sediments). Water shrews (at East Swamp and South Swamp) and great blue herons (at South Swamp) may also exceed the 40 μGy/h benchmark, if they are resident at the specified location. It is likely that herons feed over larger territories and do not actually experience a 40 μGy/h dose level.

Using the higher benchmark value of 400 μGy/h that has been recommended by the NCRP (1991) and UNSCEAR (1996) for protection of aquatic organisms, the potential for adverse radiation effects would be confined to South Swamp (in general) and East Swamp (for snails only). It is unlikely that radiation effects on the local aquatic populations could be seen outside these two areas.

The exposures of aquatic biota to COPEC metals and organics at the inland aquatic sites were described in Section 3.3. The significant exposures are summarized as risk quotients (exposure value/benchmark value) in Table 4.5. There are no significant exposures of riparian wildlife, since exposure doses do not approach benchmark doses for these species.

Table 4.5 shows that copper is present in water at most locations across the site at concentrations above the benchmark values for sensitive aquatic organisms. This is probably a natural condition for the region. The upper limit of background for copper (0.0047 mg/L, Section 3.2) produces a risk quotient of 1.2 for fishes and frogs, and 2.4 for aquatic plants. The RQ values around the site are often slightly higher than this, or substantially higher based on Environment Canada (2001) data, as discussed below.

Dissolved organic carbon may complex with copper in the water column and may therefore ameliorate its biological uptake and aquatic toxicity.

It should be noted that copper values reported by Environment Canada (2001) are generally about ten times higher than those reported by Yankovich *et al.* (2002) for the same waterbodies. This order of magnitude difference is also seen at Lower Bass Lake, which may be considered a background location with respect to metals. Therefore, an analytical bias is suspected, and explains the higher RQ values for copper at most locations, including Lower Bass Lake.

Iron is frequently found above benchmark values for sensitive aquatic organisms in CRL waters, including Lower Bass Lake. The upper limit of background for iron (1.2 mg/L) produces a risk quotient of almost 1 for fishes and frogs, and 4 for snails and infaunal benthos. These RQ values are slightly exceeded at Perch Lake Inlet 2, Perch Lake and Perch Creek in the Perch Lake Basin, and at Duke Swamp and Bulk Storage Swamp in the Maskinonge Lake Basin.

Lead was found in water above the benchmark value for fishes and frogs at two locations (Main Stream and Stream 5). In both instances, the observation arises from the Environment Canada (2001) survey. The lead values reported by Yankovich *et al.* (2002) for Main Stream are about one-tenth of the Environment Canada value for the same location. Similar order of magnitude differences are seen at other locations where the two data sets have been compared. Lead was also present in sediment above the benchmark in Duke Swamp and Maskinonge Lake (maximum RQ of 3.2).

Aluminum was found in Stream 3 water above the benchmark value for sensitive aquatic plants. The RQ based on average water quality was 0.7 and the upper bound RQ was 2.2. The upper limit of background (Section 3.2) produces an RQ of about 0.3. Thus, aluminum is somewhat elevated in this stream.

Aluminum in sediment exceeds the benchmark value for riparian plants at all locations where it has been measured, including Lower Bass Lake. This is probably a natural condition since the RQ for Lower Bass Lake is one of the highest values. The average of five RQ values across the site is 81 and the range is 50 to 125. The upper limit of background (Section 3.2) produces an RQ of 146. It is likely that much of the aluminum is in the mineral matrix and is therefore unavailable.

Chromium in sediment exceeded the benchmark by small degrees in Maskinonge Lake, Bulk Storage Swamp, Perch Lake and Stream 5, with the maximum RQ at 1.8 (Maskinonge Lake). This appears to be a background condition, as outlined in Section 3.2.

Perch Creek sediments were characterized by modestly elevated RQs for various PAHs in sediments, with a maximum RQ of 4.4 for benthic invertebrates. This may imply some degree of risk to infaunal benthos from these compounds.

The data sets available for characterization of local background levels of metals in water and sediment are small (Section 3.2). Therefore, the true upper limit of background may be somewhat higher. Given these uncertainties, any RQ that is within a factor of 2 of the background value is unlikely to be ecologically meaningful.

Chlorine concentrations estimated for Stream 3 waters (assumed to be present as reactive species) substantially exceed the benchmark values for aquatic organisms, producing risk quotients of 18 and 33 for fishes and snails, respectively. The concentration estimates for chlorine species are uncertain since they are based on site usage rather than measurements in water, and they assume all chlorine used remains in the water. However, it is reasonable to expect some effects from chlorine release in this stream.

4.4 Ottawa River

The radiation doses to aquatic biota in the Ottawa River nearshore and offshore zones were estimated in Section 3.4. These doses are summarized in Table 4.6, and none exceed a 40 µGy/h benchmark.

The highest radiation doses are likely to be seen in the vicinity of the Process Sewer outfall. The doses shown for fishes and snails (2 to 4 µGy/h) assume full-time residency in the near-field plume. This is probably quite a conservative assumption for fishes. Infaunal benthic invertebrates (if present) would receive somewhat higher doses based on their more intimate association with sediments (assumed bioaccumulation from porewater). The sediment contamination near the outfall will be mainly of historical origin.

The radiation doses to aquatic biota in the nearshore zone of the river are generally much lower than those that would be experienced adjacent to the Process Sewer. For fishes and snails, they are in the range of 0.1 to 2 µGy/h, again assuming full-time residency. The highest doses in the nearshore zone are those estimated for Point aux Baptime, which is influenced by all upriver discharges, including the Process Sewer. Doses in the near-field zone of the Storm Sewer 4 discharge are somewhat lower, and those in other nearshore discharge areas are much lower.

The exposures of aquatic biota to COPEC metals and organics in the Ottawa River were described in Section 3.4. The significant exposures are summarized as risk quotients in Table 4.7. There are no significant exposures of riparian wildlife, since exposure doses do not approach benchmark doses for these species.

Table 4.7 shows that copper is present in nearshore waters (Point aux Baptime and Boat Launch) at concentrations above the benchmark values for sensitive aquatic organisms (RQ = 1.4 to 2.1 for fish, 0.9 to 1.3 for snails and infaunal benthos, 2.6 to 3.9 for aquatic plants). It is also present at such concentrations in the near-field zone of the Process Sewer (RQ = 0.9 to 2.4 for fish and 0.6 to 1.5 for snails). The upper limit of background for copper in the Ottawa River (Section 3.2) produces RQ values of 2.1 for fish and 1.3 for snails. Thus, the copper in the near-field zone of the Process Sewer may be slightly elevated on occasion, but generally the concentrations seen in the river are within the normal range.

Copper in water and copper, lead, chromium, cadmium, arsenic and zinc in river sediments in the offshore area (downstream of process sewer) have maximum concentrations above their respective benchmarks (RQ up to 6.3, arsenic in sediment) (Table 4.7). The upper limits of Ottawa River background for these metals (Section 3.2) produce RQ values similar to those arising from measured concentrations in offshore areas of CRL (RQ up to 5.1, arsenic in sediment). This indicates that non-radionuclide COPECs generally produce risks due to sediment and water exposure that are comparable to background.

The data sets available for characterization of local background levels of metals in water and sediment are small (Section 3.2). Therefore, the true upper limit of background may be somewhat higher. Given these uncertainties, any RQ that is within a factor of 2 of the background value is unlikely to be ecologically meaningful.

Chlorine concentrations estimated for the Stream 3 discharge zone (assumed to be present as reactive species) slightly exceed the benchmark values for aquatic organisms, producing risk quotients of 1.2 and 2.2 for fishes and snails/infaunal benthos, respectively. Chlorine was also considered as a possible issue for the discharge zone of the Sanitary Sewer outfall; however, RQ values of 0.1 and 0.2 were produced for this zone, indicating that toxic effects here are unlikely. The concentration estimates for chlorine species are uncertain since they are based on site usage rather than measures in water, and they assume all chlorine used remains in the water.

4.5 Upland Sites

The exposure to COPECs (concentrations and doses) at upland sites is described in Section 3.5 for WMA-A, WMA-B, WMA-C, WMA-F and WMA-H. In all cases, radiation doses in terrestrial receptors were calculated. The only non-radioactive COPEC recognized in soils at upland sites is mercury at all WMAs assessed except WMA-H.

Average and maximum radiation doses experienced by all VECs at these upland sites are summarized in Table 4.8, with all doses above the benchmark value highlighted. As indicated previously, the assumed benchmark in all cases is 40 µGy/h, or 1 mGy/day, generally to protect against reproductive effects. Based on this analysis, terrestrial biota were determined to be potentially at risk due to radiation exposure in Area A and Area F.

In Area A, doses above benchmark (RQ>1) were calculated for average and maximum exposure conditions in the Laundry Pit and for maximum exposure conditions in Reactor Pit 2 for all VECs. As discussed in Section 3.5, these areas contain very little habitat owing to a general absence of vegetation. The only VECs that may be expected to be exposed to doses above benchmark values are a few soil invertebrates and plants that may occur here. Shrews and robin are unlikely to have sufficient occupancy to receive doses above the benchmark owing to habitat limitations as well as home range limitations (in the case of robin).

In Area F, the woodchuck burrowing into the waste is estimated to receive a dose due to radon exposure that produces an RQ of 51, indicating a potential for reproductive effects. Woodchucks are known to occupy the WMA; thus, this conclusion is realistic from an occupancy perspective. The dose may be somewhat exaggerated, given that woodchuck would need to burrow quite deeply (more than 1.3 m) to reach the waste. As noted by MacDonald and Laverock (1998), burrowing mammals may be routinely exposed to radon doses of more than 1 mGy/d in unimpacted areas; however, the dose calculated here is greater than normally expected (by more than an order of magnitude). The fact that woodchuck are present at this location suggests that any radiation effects have not prevented their occurrence and survival. Overall, populations of burrowing mammals on the CRL property would not be threatened by any reproductive impairment of a few individuals in Area F.

Risk quotient values associated with exposure of upland VECs to mercury in soils are presented in Table 4.9, based on the detailed calculations presented in Appendix 5. In all cases, RQ values are very low (RQ <<1). It should be noted, however, that data on concentrations of mercury and other non-radionuclides in soils are very limited.

4.6 Large Mammals

Radiation doses to white-tailed deer and eastern wolf are very low, based on concentrations of HTO and Sr-90 measured in muscle from road-killed deer (Table 3.56). Risk quotient values are ≤0.00025 for both species, based on comparison against the 40 µGy/h (1 mGy/d) benchmark. As noted in Niemi *et al.* (2002), no anthropogenic radionuclides other than tritium and Sr-90 were detected in deer tissue.

4.7 Points of Impingement

Radiation doses arising from exposure to air plumes at the points-of-impingement locations for the principal atmospheric sources are presented in Table 3.57. In all cases, doses are much less than the benchmark of 1 mGy/day (40 µGy/h). The maximum dose calculated results in an RQ of 0.025 (small soil invertebrates exposed to releases from the NRU reactor building). No significant effects are predicted.

The effects of NO_x and SO_2 predicted at the point of impingement for the powerhouse were assessed based on comparison with the following benchmarks:

		Benchmark Value (mg/m^3)	Basis
NO_x	- plants	5	Heck (1964)
	- mammals	47	Doull *et al.* (1980) (dog LOAEL)

SO_2	- plants	0.055	Ontario ambient criterion, annual average (MOE, 1994)
	- mammals	0.267	Newman and Schreiber (1988) (rat study)

With point-of-impingement air concentrations of 3.5E-3 mg/m^3 for NO_x and 2.6E-2 mg/m^3 for SO_2, RQ values are <0.5 in all cases.

4.8 Physical Stressor Effects

Physical stressors of potential environmental concern (SOPEC) were identified based on experience at other nuclear facilities, and by a review of the Significant Environmental Aspect (SEA) database for CRL. All the physical stressors identified are current rather than historical which excludes alterations caused by the original construction of the site. The stressors identified include:

- thermal releases to the aquatic environment (cooling water discharge);
- entrainment/impingement of aquatic biota (cooling water intake), and
- other habitat alterations such as firebreaks, roads and fence construction.

The complete list of SOPECs and locations is shown in Table 2.9. These three factors are described in the following section.

The physical setting of the river at the CRL site is described briefly here in order to examine the physical SOPEC at the CRL facility. The Ottawa River in the area of CRL is a wide (up to 1.6 km), deep (up to 72 m), slow moving body of water (Merritt, 1964). River flow rates over between 1987 to 1991 ranged from a low of 191 m^3s^{-1} (September 1989) to a high of 2,311 m^3s^{-1} (June, 1989) with an average of approximately 840 m^3s^{-1} (Kilpatrick, 1999). The mean current speed between CRL and Petawawa, located 18 km downstream, derived from tracer tests, is approximately 5 cms (Merritt, 1964, Klukas, 1994).

The NRU intake is the most important water intake that draws water from offshore areas of the Ottawa River. The intake pipe is approximately 156 m long with a 1.35 m diameter and has a very coarse screen at the river end of the intake pipe.

The effluent discharge from the NRU reactor occurs via the process sewer.

4.8.1 Thermal Effects

Thermal effluent discharges occur through the process sewer, which carries once-through cooling water from the NRU reactor. The process sewer also conveys any cooling water discharged by the MAPLE reactors. Factors considered in assessing thermal discharges include:

- protection of important aquatic communities and important fish spawning areas;
- protection of acceptable aesthetic conditions; and

- protection of existing municipal water intakes.

An assessment of the thermal plume at the existing facility was undertaken by Klukas (2001). The likely receptors of interest are fish and aquatic invertebrates. Thermal plume effects on fish are complex and can result in both negative and positive effects. Positive effects generally occur in the form of enhanced growth rate (and thus survival) of different life stages. Negative effects include lethality especially due to hatch advance of eggs which may expose larvae to food shortages, and increased predation from predatory fish attracted to heated water.

When considering the effects of thermal discharge, it is appropriate to evaluate the facility in comparison with regulatory guidelines. The federal guidelines are provided in the *Guidelines for Effluent Quality and Wastewater Treatment at Federal Establishments, 1976* but are currently under review in the *Proposed Approach for Wastewater for Wastewater Effluent Quality Framework and Guidelines for Federal Facilities* (2000). The provincial guidelines applying to cooling water discharges are provided in the Policies Guidelines Provincial Water Quality Objectives (MOE, 1994). The current federal guideline for cooling water discharges is a temperature at the edge of the agreed-upon zone of influence in the receiving body of water of no more than 1C° above ambient. The corresponding provincial criterion is 10C° above ambient.

The federal guideline for cooling water discharges is a temperature at the edge of the zone of influence in the receiving water of no more than 1C° above ambient. This zone of influence must be small enough that there is a reasonable zone of passage for aquatic organisms in the receiving body of water.

The provincial guidelines are in part based on the protection of whitefish species, the most temperature-sensitive species found in the vicinity of most Ontario thermal stations. Whitefish are present in the Ottawa River. Eggs in spawning habitats exposed to warming of 3°C may be vulnerable to adverse effects. Cooling water discharge limits are set so as to minimize the area within the mixing zone having a temperature greater than 3°C above ambient.

Exposure to thermal effects in the vicinity of the process sewer was estimated for aquatic biota (fishes, aquatic invertebrates) based on the thermal dispersion model described by Klukas (2001). A conceptual model based on heat dissipation by mixing was used by Klukas *et al*. (2001), after a review of theoretical and field studies undertaken at nuclear facilities in Ontario. Several other dispersion models were also used to delineate the aquatic plume, but the Klukas model used historic data to quantify the extent of the thermal plume.

To evaluate dissipation of the thermal plume by mixing the following were considered:

- buoyancy of the discharge which is a function of the cooling water temperature and receiving water temperature;

- mixing at the discharge location from the buoyancy and momentum of the cooling water discharge;
- dispersion of the thermal plume by the currents and turbulence;
- location of the discharge, discharge structure and orientation;
- excess momentum of the cooling water discharge; and
- ambient currents and temperature stratification of the receiving water body.

Cooling water for the NRU is taken from 24 metres below the river surface. The cooling water flow rate through the reactor is approximately 75 m^3/min^{-1} in the winter and 90 m^3/min^{-1} in the summer. The water temperature at the intake ranges from a low of 1°C in January to a high of 20°C in September. The temperature rise of the cooling water is a function of the reactor heat output, the cooling water flow rate, the density and specific heat capacity of water and is given by the relationship:

$$\Delta T = \frac{H}{Qc_p\rho}$$

where:

	ΔT	=	temperature rise ($T_{discharge} - T_{intake}$ °C)
	H	=	the heat output of the reactor(s)
	c_p	=	specific heat of water (4.186 x 10^3 $J/kg^{-1}/°C$)
	ρ	=	density of water (~ 1000 kg/m^{-3})
	Q	=	cooling water flow rate (m^3/s^{-1})

The Process Sewer has a diameter of 1.2 m and discharges to the river at a distance 114 m offshore at a depth of 17 m below the water surface. The temperature data from the process sewer discharge and the NRU intake water for 1996 to 2000 indicate that the difference in temperature between discharge and intake ranged from a low of approximately 12C° in summer to a high of 20C° in winter.

For the most part the discharge from this outfall rises to the surface because of buoyancy effects. However, when the ambient river is less than 4°C the thermal plume may sink to the bottom. The temperature within the mixing zone is estimated from dilution estimates, ambient river and process sewer temperatures. The mixing zone is defined by the swirl where the buoyancy rises to the surface and is estimated to be between 10 and 20 m diameter based on summer observation by boat and the ice free zone in the winter. The temperature above ambient in the swirl is estimated to be 2.9C° in the winter and 1.7C° in the summer. On average the cooling water migrates downstream with the river currents, though currents in the top few metres of water are influenced by wind conditions. Tracer experiments have shown that the cooling water discharge forms a well-defined plume and then gradually becomes mixed over the complete width of the river (Merritt, 1964).

This zone that may have temperatures of 3C° above ambient is small, and is unlikely to reach the river bottom where whitefish and whitefish spawning habitat may be present.

Based on this information, the effects of the process water thermal plume on aquatic life are expected to be minor.

A simple 2-D advection model was applied to assess the dispersion of the plume and the decay of temperature of the outfall in uniform currents. The assessment considered mixing in the lateral direction only. These modeling predictions indicate the zone with temperatures elevated by more than 1C° above ambient, the federal guideline for temperature at the edge of the zone of influence, will be no more than 700 m downstream of the outfall and has a maximum width of 50 metres. The predicted zone affected by temperatures greater than 3°C above ambient, the threshold for which effects are expected in the most sensitive species, extends less than 200 m downstream of the outfall (Klukas, 2001).

4.8.2 Entrainment and Impingement

Water from the Ottawa River is used to cool the reactor. This process can cause entrainment and impingement of aquatic species resident in the river. Impingement occurs when aquatic biota are trapped against cooling water intake screens, whereas entrainment occurs when fish, aquatic invertebrates, eggs and larvae drawn into the cooling water system, pass through the heat exchanger and then are pumped back out. In an attempt to ensure that wildlife populations in the Ottawa River are protected against significant loss from the cooling water intake a study was undertaken by the Environmental Technologies Branch of CRL (Yankovich *et al*., 2002). The study presented findings from monitoring in the NRU intake over the period of a year during 2001-2002 and the results are presented in the following sections.

Factors which effect the number and mortality of impinged fish are flow rates, chlorination and reactor shut downs. The rate of flow in the NRU can be as high intake as 101.94 m^3/minute. On average, however, the flow through the intake is about 35 m^3/min, including both cooling water and fire water. Flow is also maintained through the NRX intake for service water and for the MAPLE reactors, which are not yet fully operational. The service water flow averages about 1 m^3/min. However, at normal operation, the MAPLE reactors will operate at a nominal maximum of about 14 m^3/min each, with typically only one reactor kept in operation with the second on standby. This will bring the total flow through the NRX intake to about 15 m^3/min on average. Chlorination occurs sporadically to prevent biofouling of the pumps. During chlorination, incidental mortality of entrained fish may occur.

The NRU intake is approximately 156 m long with a 1.35 m diameter. The pipe extends 126 m out into the river from a shoreline anchor and another 30 m from the shoreline to the powerhouse building and draws water from 24 meters. There is a very coarse screen at the river end of the intake pipe and later, in the powerhouse further screens remove larger fish and other biota then the water passes through finer filters before entering the CRL plant. The NRX intake draws water from two depths (9 and 12 m) through a Y-shaped intake. The NRX intake is not screened in the river, so that larger fish could potentially be entrained.

Regulatory evaluation of entrainment and impingement of aquatic biota is the responsibility of the Department of Fisheries and Oceans (DFO). In relation to industrial cooling water intakes, Section 30 of the federal Fisheries Act states:

- every water intake, ditch, channel or canal in Canada be provided at its entrance or intake with a fish guard or a screen, covering or netting so fixed as to prevent the passage of fish from any Canadian fisheries waters into the water intake;
- have meshes or holes of such dimensions as the Minister may prescribe;
- the owner or occupier of the water intake, ditch, channel or canal shall maintain the fish guard, screen, covering or netting in a good and efficient state of repair and shall not permit its removal except for renewal or repair; and
- during the time in which a renewal or repair is being effected, the sluice or gate at the intake or entrance of the water intake, ditch, channel or canal shall be closed in order to prevent the passage of fish into the water intake, ditch, channel or canal.

The DFO review of cooling water intake structures for effects on aquatic biota proceeds based on the intake velocity, screen opening size, swim type and capability of fish exposed to the intake structure and size of fish. Two guidelines are available to determine the appropriate intake velocity and mesh size for intake structures. For intake velocities less than 125L/s, the "*Freshwater Intake End-of-Pipe Fish Screen Guideline* (DFO, March 1995)" is applied. In the case of the intakes at the CRL facility, the "*Fish Screening Guide For Water Intakes* (DFO, February 1992)" should be applied.

Yankovich *et al*. (2002) examined entrainment and impingement in the NRU intake, but did not evaluate entrainment at NRX. The study found that of the approximately 85 fish species documented in this stretch of the Ottawa River, 20 species were observed in the NRU intake sump. In a one-year period, 9,088 fish were impinged in the NRU cooling water system. The key species found were trout-perch and rainbow smelt which represented 49% and 46% of the total, respectively. River redhorse, which represents a provincially-rare fish species, were not observed and only two small mouth bass and walleye, which are important sport fishing species were impinged.

The degree of fish entrainment by NRX is unknown. However, as the typical intake rates approach 14 m^3/min (as the MAPLE system becomes fully operational), the rates of entrainment mortality may be expected to be at least 40% of those for the NRU (in proportion to flow) or about 3,600 fish/year. The rate of impingement is potentially greater owing to the absence of screening at the end of the intake pipes and to the shallower location of the intake.

Eggs and larvae were not found in biweekly samples collected in the NRU although live zooplankton was identified. Fish eggs have been observed in the NRX in the past (Yankovich *et al*., 2002). Egg entrainment would only likely be an issue for a small percentage of the year during spawning. An evaluation of the habitat surrounding the intakes as well as literature on the impinged species, supports the idea that it is unlikely that fish are utilizing these areas for spawning. Both trout-perch and rainbow smelt, which represent the dominant species impinged in the NRU intake sump, typically spawn in streams, as opposed to in the open water of the Ottawa River. Therefore, their eggs are not expected to be impinged.

The study by Yankovich *et al*. (2002) concludes that based on the information collected during the year long study, relatively few fish are being drawn into the NRU sump relative to impingement values reported in the literature for other facilities. Generally, fish screens are required at end-of-pipe in order to prevent unimpeded entrainment into the facility.

These rates of fish entrainment/impingement mortality may be assessed as a function of fish production. The average weight of trout-perch and smelt, the two most commonly impinged species at NRU, is about 5 grams per fish. Assuming about 14,000 fish total entrained at NRU and NRX intake systems, the total mass of entrained fish is probably in the order of ~100 kg/year. This loss of fish may be compared very roughly to the fish productivity of this section of river, estimated using the morphoedaphic (MEI) index (Ryder, 1965). While the MEI model is applicable to lakes, the river in this region is lake-like. With a typical total dissolved solids concentration of ~30 mg/L (Yankovich *et al*, 2002) and a typical depth of 20 m near CRL, the total fish production (i.e., sustainable yield) is about 1.6 kg/ha. Thus, the loss of 100 kg/y of fish through entrainment is equivalent to the yield expected from 63 ha of river. Because this yield is applicable to all species, the effect on trout-perch and smelt would be equivalent to the yield from a somewhat larger area. Nevertheless, the magnitude of the fish loss due to impingement appears modest, but may be of local significance to the population abundance of the most affected species.

4.8.3 Other Habitat Alterations

4.8.3.1 Fences

Two types of fences have been erected around the CRL property: a four-foot fence and an eight-foot chain link fence. Some of these fences existed prior to 2001 and some were added between 2001 and 2002. The aim of the fencing is to reduce trespassing and clearly delineate the property boundaries. Fencing in wilderness areas is problematic because it can act as a barrier to movements of large mammals and has the potential to cause physical injury.

During the construction of fences, some locations which act as natural pathways for game animals and other small mammals were obstructed. In an attempt to quantify obstructions to wildlife and determine whether foraging or predator avoidance has been altered by the fencing operations, a study was undertaken by the Environmental Technologies Branch (Chaput *et al*., 2002). The study objective was to identify the current areas of game habitat and to assess the ability of bears, moose and wolves to traverse the property in search of forage and to evade predators. In addition the study made recommendations about the addition of game breaks. Game breaks are typically created by removing a small section of fence, sometimes replacing the chain link section with vertical steel posts such that animals can pass.

The study concluded that sixteen areas had significant wildlife activity. No evidence was found that the fences prevented the animals from reaching adequate food sources or evading predators during the winter months. There were, however, significant signs of animal activity near the fences suggesting that in specific areas the natural movements of animals has been altered. In addition the four-foot fences were identified as a hazard as they were not visible to deer or moose. There were two recorded incidents of entanglement in 2001 and 2002 which resulted in the animals (both deer) being euthanized.

The following recommendations were made to mitigate the effects of fences on local wildlife (Chaput *et al*., 2002). The height of the four-foot fences should be reduced and a wooden top rail added to increase visibility. The eight-foot fences have been shown to be a cause of habitat fragmentation and as the AECL property is widely thought to be an important wildlife corridor. It was recommended that a section of chain link be removed in the identified areas and replaced with a game break.

The quantification of the impact of fencing on wildlife is difficult to accomplish. However, it is reasonable to assume that some degree of adverse environmental effect occurs in some wildlife species as a result of fencing.

4.8.3.2 Firebreaks

Five firebreaks have been established on the south, west and north property boundaries. A firebreak is an existing barrier or a wide strip of land on which the native vegetation has been modified or cleared, to act as a buffer to the spread of fire so that forest fires burning into them can be more readily controlled. In the event of a fire a firebreak also acts vehicular access point to obtain water for fire control measures. Usually the break in the vegetation is 6 to 9 metres wide. This allows enough space for a tanker to enter the area and for two vehicles to pass if necessary.

The species most likely affected by the presence of a firebreak are area-sensitive birds, mammals, and forest vegetation. The vegetation could be affected by changes in woodland characteristics, such as species composition and diversity, direct loss of area, and edge effects such as sunscald and windthrow. Although the firebreaks are long, they are not wide and as a result, total forest area removal would be negligible and community and species diversity would not be adversely affected.

Gaps between forest habitat that are less than 20 m do not fragment the habitat from the perspective of area-sensitive wildlife species (Ontario Ministry of Natural Resources, 2000). Additionally, such gaps are generally less than the height of retained trees, which will still afford some shade and wind protection to the edge trees and minimize the effects of sunscald and windthrow of trees at the newly created edges. Some minor effects may be initially present, but the natural establishment of edge or sidewall vegetation through succession would provide an effective buffer to these effects.

No studies have been undertaken on the effects of the decreased vegetation cover on the siltation of the adjacent watercourses, but these are expected to be minimal due to the small area of the firebreaks. Additionally, low-growing herbaceous vegetation will continue to stabilize the soil.

In summary, the installation of firebreaks is not anticipated to create any adverse effects except for the direct loss of a negligible amount of forest habitat. Remaining habitat will not be fragmented and new edges will quickly adapt to the slightly altered conditions.

4.8.3.3 Roads/Traffic

Plant Road enters the facility from the western side. The road acts has the potential to cause physical effects in the following ways:

- collision events in mammals and birds;
- impede the migratory pathway of some species;
- salt runoff;
- traffic emissions and noise; and
- edge effects on vegetation.

The plant road is paved with a single lane traveling in each direction. It is approximately 7.785 km from the main T junction with Highway 10. It is traveled daily by 800 to 1,000 vehicles (Graham, 2003, pers. comm.). The speed varies but is probably about 80 km/hr with reduced speed zones of 250-500m at the guard house located at the entrance to the property and where the road approaches the main plant site area.

The area along the road between the gate and the main plant site area remains undeveloped with the exception of the Waste Management Areas which are set back to varying degrees with some tree cover between them and the road. There is wetland bordering the road in the Maskinonge Lake area, where amphibians and reptiles have been seen seasonally crossing the road. A record of fatalities of larger mammals such as moose and deer is kept by the Environmental Technologies Branch. Between 1997 and 2002 nine deer and five moose were killed in collision incidents. In 2000 a bear cub mortality was recorded and there were two collisions in 2002 (deer and moose). There have not been any studies on seasonal roadkill numbers of amphibians, reptiles or smaller mammals.

Large Mammal Mortality

Moose are solitary animals and prefer a mixture of habitats, with second growth forest and wetlands being preferred habitats. Their preferred food are a range of shrubs including willow, dogwood, juneberry, birch (MNR, 1988) which grow in wetlands and along the edges of forests. Moose are also attracted to salt in roadside ditches, which often makes them vulnerable to being hit by vehicles.

Densities of moose vary considerably in Ontario depending on the mix of habitats on the landscape and the impacts of forestry operations, hunting, the presence of predators and the density of roads and frequency of road traffic. On the Chapleau Crown Game Reserve densities are about 0.30 to 0.35 moose per square kilometre (MNR, 1988). In Manitoba densities of 0.02 to 0.2 moose/km^2 are recorded (Cross in litt). In the Algonquin area of Ontario there was an estimated population of 5000 moose with a regulated harvest of 500 animals annually in the 1980s.

It is expected that within the CRL (approximate area of 40 km^2), with the absence of hunting, logging and only one major road, there might be a population of 8 to 12 moose of various ages. Assuming approximately one third of the population are females of reproductive age, and assuming only one calf per year, approximately three calves per year might be born. Assuming a natural mortality of at least half of the calves to predators (bear, wolf, coyote) each year, there would be a recruitment of two moose per year. The recorded mortality from vehicle accidents of approximately one moose per year should not be sufficient to reduce the population overall. There is at present, no information on immigration or emigration of moose from the CRL and such movement would depend on factors such as the height of fencing, depth of snow in winter and whether there are waterways/wetlands for animals to move in or out of the area. One can assume that the present rate of traffic moose kills per annum is not sufficient to reduce the local population of moose.

White-tailed deer are common through much of southern Ontario and in some agricultural areas may reach high densities. They prefer a mixture of habitat types and the presence of winter deeryards of hemlock or eastern white cedar are often critical to their surviving the deep snow conditions of the Algonquin Region. Densities of deer are very variable and with little in the way of agricultural or residential activity within the CRL the conditions are assumed to be medium to poor. Home range for deer is dependent upon the availability of winter habitat as well as summer habitat and population levels in Ontario are 16 to 120 ha per animal. Assuming that the habitat within the CRL site supports the average density for Ontario (about 68 ha per deer), we assume a population of approximately 60 animals over the 40-km^2 site.

White-tailed deer normally have two young each year and, assuming that a third of the population are females in reproductive condition, there would be 20 females in breeding condition producing approximately 40 calves per year. As deer fawns are much easier to predate than moose calves, we can assume that only 25% (10) enter the breeding population the following year. We can therefore expect that the CRL population would be an expanding one. The nine deer killed by vehicles during the six-year period (average of 1.5 deer per year) would be insignificant at the population level.

Black bear are common in Ontario and the population is believed to be between 65,000 and 75,000 with densities of 0.2 to 0.6 bears per km^2 though some estimates are higher. Bears utilize a variety of forested habitats and often reach higher populations in areas where they have access to land fill sites or other areas of human edible waste. Population models developed by Yodzis and Kolenosky (1986) estimate that approximately 10% of a population could be harvested annually in east-central Ontario or about one bear/50 km^2. This suggests that the mortality of black bear due to bear/vehicle accidents within the CRL site is sustainable.

Mortality of Other Species

Reptiles are particularly susceptible to traffic mortality at certain times of year because females looking for places to lay their eggs are attracted to the soft, warm road edges. Some reptiles can live for decades, so the loss of pregnant females not only removes reproductive adults from the population but it also removes all their potential future offspring. In addition, surviving turtles can't lay extra eggs to compensate for increased mortality, so once a population starts to decline it is difficult to reverse the trend.

Amphibians are also at risk from road traffic mortality. Each spring millions of amphibians are drawn to marshes, ponds, lakes, creeks, pools and even puddles to breed. If this migration involves crossing a road a large number of amphibians can be killed over a relatively small area. Habitat fragmentation by roads, and the barrier effects to species movement, can lead to the severance of wildlife communities and their gradual isolation from one another. The degree of isolation depends on the relative success of different species in crossing roads. A number of studies have shown how roads inhibit wildlife movement and in many cases affect population numbers. For example, small mammals, amphibians, insects, and even some species of birds demonstrate a reluctance to cross roads where the distance between forest margins exceeds 20 metres (Mader, 1984; Andrews, 1990). In most cases, the barrier effect of the road is dependent on traffic flow levels and the type of road surface. At CRL, the width of the roadway and clearance is generally in the order of 20 m; thus, this fragmentation effect is probably small.

Other Habitat Effects

The area that the plant road traverses is a relatively undeveloped tract of woodland area. Vegetation and wildlife have adjusted to existing traffic noise and air pollution. The application of road salt and salt spray will have localized effects, particularly on salt-sensitive species such as white pine, and may attract wildlife to the roadway where they are susceptible to traffic mortality.

The introduction of roads into continuous forest habitat has the potential to introduce edge effects such as sunscald, windthrow and increased disturbance (e.g. littering). The edge effects from existing roads are a historical effect; since construction, the natural establishment of edge or sidewall vegetation through succession provides an effective buffer to these effects.

The effect of traffic on wildlife is probably one of the more significant effects of CRL on the local ecosystem in that it results in direct mortality of various wildlife species. However, the degree of impact on CRL wildlife populations is unlikely to be more significant than wildlife impacts along other regional roadways in the area.

4.9 Road Salt

The effects of road salt on aquatic species are evaluated here using aquatic benchmarks presented in Environment Canada (2000). These benchmarks, based on chloride, include a 48-hr LC25 for benthic invertebrates of 1,214 mg/L, a seven-day LC50 of zooplankton of 1,470 mg/L, a seven-day EC50 of 1,524 mg/L for amphibians and a seven-day EC25 of 989 mg/L for rainbow trout embryo. These benchmarks, when compared with the average exposure concentration in undiluted snowmelt (5,056 mg/L), suggest that adverse effects could occur in aquatic species if any reside along CRL roadways . The RQ values would be 3.3 for amphibians and 5.1 for trout.

The effects of road salt use on terrestrial species, such as invertebrates, vegetation and wildlife, cannot be readily assessed for CRL because salt concentrations in soils adjacent to the roadways cannot be readily inferred. It is reasonable to assume that some terrestrial effects are nonetheless present at CRL, as such effects are believed to be widespread along Canadian roadways (Environment Canada, 2000). These may include adverse effects on soil invertebrates, certain plant species, as well as wildlife. Wildlife effects can include toxicity to birds due to salt grain ingestion, and traffic roadkill due to attraction of wildlife to the salt-rich environment along CRL roadways.

There is no reason to expect that the effects of road salt at the CRL property are different from road salt effects on other regional roads or in built-up settings such as the main plant site area.

4.10 Regional Emissions – Greenhouse Gases

CRL releases 32,800 t/y of CO_2, 236 kg/y of HCFC and 475 kg/y of HFC. This represents a total of 33,740 t/y of CO_2 equivalents. This represents 0.0067% of the 500 megatonnes released per year in Canada from all human sources (from Environment Canada – State of the Environment INFOBASE, www.ec.gc.ca/soer-rec/English/Indicators/Issues/Climate/Tech_ Sup/ccsup03_e.cfm). These total emissions from CRL fell by about 21% between 1996 and 2000 (AECL, 2001). This emission source represents a relatively small contribution to the national inventory of greenhouse gas releases.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Radiation Doses

At most locations around the CRL site, radiation doses are below the benchmark values of 40 µGy/h (1 mGy/d) and 400 µGy/h (10 mGy/d) defined by the NCRP, IAEA and UNSCEAR for terrestrial animals and aquatic biota, respectively. A few locations exceed these benchmarks as described below.

Inland Aquatic Sites

Radiation doses exceeding 1 mGy/d and 10 mGy/d are predicted to occur under average exposure conditions at the following locations in the Perch Lake watershed:

Location	VECs Receiving >1-10 mGy/d	>10 mGy/d
Perch Lake Inlet 1	Snail	None
South Swamp	Frog, aquatic plants, riparian plants	Snail, water shrew
East Swamp	Fish, aquatic plants, water shrew	Snail
West Swamp	Snail, riparian plant	None

The highest average levels of exposure are calculated to occur in South Swamp. The highest average doses are estimated at 131 mGy/d for South Swamp snails (about 13X the NCRP/IAEA/UNSCEAR dose benchmark for aquatic species) and 11.7 mGy/d for water shrew (12X the IAEA/UNSCEAR benchmark for terrestrial animals). In East Swamp, the estimated average doses of 11.8 mGy/d for snails and 1.3 mGy/d for water shrews are marginally above their respective benchmarks.

Doses above the generic benchmark values do not necessarily produce adverse effects. For example, Cooley and Miller (1971) found no significant effects on snails receiving 240 mGy/d. However, doses well above benchmarks indicate a potential for adverse effects and suggest candidate locations for effects monitoring.

At maximum exposure levels, calculated radiation doses at each location are greater, with the greatest degree of increase over average occurring at South Swamp. All of these average and maximum doses are strongly dominated by Sr-90. None of the doses received above benchmarks affect more than a small portion of the Perch Lake watershed, and are therefore unlikely to be important to populations.

Doses were calculated to fall below 1 mGy/d for all aquatic site VECs under both average and maximum exposure conditions in all other inland aquatic locations, including Perch Lake, Perch Lake Inlet 2, Perch Creek, Main Stream, Duke Swamp, Lower Bass Lake, Maskinonge Lake, and the riverfront streams.

Ottawa River

Aquatic biota are predicted to all receive average and maximum doses below 1 mGy/d at nearshore mixing zone areas for Storm Sewer 4 and for all riverfront streams, at Pointe aux Baptime, and in the Process Sewer mixing zone area. The predicted doses are well below the NCRP/IAEA/UNSCEAR dose benchmark 10 mGy/d for aquatic species.

Terrestrial Sites

Radiation doses to VECs within or near the Waste Management Areas are predicted to exceed 1 mGy/d under average conditions in portions of Area A and Area F only:

Location	VECs Receiving >1-10 mGy/d	>10 mGy/d
Laundry Pit	Invertebrates, plants, shrew, robin	None
Area F	Woodchuck	Woodchuck

In Area A, doses to invertebrates and terrestrial plants are predicted to receive doses of more than 1 mGy/d (but less than 10 mGy/d) in the Laundry Pit only, with dose dominated by Sr-90 in surface soil. Least shrew and American robin were also calculated to receive doses in this range, but these doses are not considered realistic owing to home range and habitat factors – neither would reside within the Laundry Pit for sufficient time to receive doses above 1 mGy/d on average. This is because vegetation growth is controlled within the WMA, thereby eliminating most of the food source for herbivorous species and their predators (e.g., shrew, robin).

Also, doses may exceed 1 mGy/d at maximum exposure levels in terrestrial species if resident in Reactor Pit 2 in the vicinity of Area A. These doses are dominated by a local gamma field source. However, average doses here are calculated to fall below this benchmark. As in the Laundry Pit, few plants or insects may be expected to inhabit Reactor Pit 2.

In Area F, a historical site containing Port Hope waste soil, the woodchuck is predicted to receive a dose of 51 mGy/d due to radon inhalation in the burrow. This dose is above 1 mGy/d; however, the literature suggests that doses in burrowing mammals may routinely exceed 1 mGy/d. Non-burrowing species would not be exposed, as the waste is buried beneath a clean soil layer.

In all other cases, doses in terrestrial biota within or adjacent to waste management areas were predicted to be below 1 mGy/d.

The terrestrial VECs receiving doses above 1 mGy/d represent a few individuals within the confines of small waste management facilities. These doses are unlikely to lead to significant effects at the population level.

Large Mammals

Radiation doses in white-tail deer (based on tissue measurements) and in eastern wolf (based on calculation) remain well below 1 mGy/d.

Atmospheric Points of Impingement

Calculated doses to terrestrial biota resident at the maximum concentration locations for atmospheric emissions are well below 1 mGy/d.

5.1.2 Chemical Effects

Inland Aquatic Sites

At inland aquatic receptor locations, some aquatic VECs are predicted to receive chemical exposures above benchmarks, principally for copper, iron and lead. However, in all cases, risk quotients are similar to or only marginally greater than risk quotients calculated from limited data on background concentrations for these same metals in water and sediment. With a larger database on natural background, it is probable that all of these inland aquatic sites could be shown to have metal levels in water and sediment that do not differ from background. Locations with risk quotients apparently above background values (to be confirmed) include Perch Lake (Cu, Fe), Perch Creek (Fe), Duke Swamp (Fe), Bulk Storage Swamp (Fe), Main Stream (Pb). and riverfront streams (mainly Cu and Fe).

Reactive chlorine species and Al are estimated to potentially exceed pertinent benchmarks in Stream 3. In addition, Pb is estimated to potentially exceed its benchmark in Stream 5. The chlorine concern is based on a very conservative estimate, while the Pb concern is based on suspect data from an Environment Canada survey. Ecological effects of other chemical species were judged to be insignificant in inland surface waters.

Ottawa River

Aquatic VECs are also calculated to be exposed to metal concentrations above benchmarks in water and/or sediment in the Ottawa River. As indicated for inland aquatic sites, these are mainly due to metal concentrations above benchmarks (Cu in water; Cu, Pb, Cr, As and Zn in sediment), but risk quotients were only modestly greater than those calculated using limited Ottawa River background data indicating that these “effects” are mainly due to background conditions. Acute and chronic toxicity testing of sediments from the process sewer area showed no deleterious effects.

Ecological effects of other chemical species were judged to be insignificant to aquatic receptors in the Ottawa River. A modestly elevated risk quotient (RQ = 1.2 to 2.2) is predicted for aquatic species exposed to reactive chlorine species in the riverfront nearshore area (Stream 3 discharge area). However, acute toxicity testing of the effluents discharging to the river (Environment Canada, 2001) found that these effluents were not acutely lethal to rainbow trout or daphnids. The elevated risk quotients are likely due to conservatism in the estimation of chlorine concentrations. The observed non-toxicity of effluents is probably accurate, and it is probable that some chlorine was lost between sample collection and toxicity testing.

Terrestrial Sites

Based on very limited data on chemical concentrations in surface soils within the waste management areas, no adverse chemical effects are predicted for terrestrial VECs within the WMAs.

Atmospheric Points of Impingement

Annual average concentrations of SO_2 and NO_x resulting from powerhouse emissions, calculated for the worst-case point of impingement location, remain below their applicable benchmarks.

5.1.3 Thermal, Entrainment and Impingement Effects

Thermal effects of the discharge of reactor cooling water are predicted to be very minor, as the temperature rise measurable in the river is very small and the size of the thermal plume is small. The zone in which temperature rise may exceed 3°C extends less than 200 m downstream of the process sewer outfall.

The effects of impingement of fish in the NRU intake may be locally important to populations of trout-perch and rainbow smelt in the Ottawa River. Rates of impingement from the former NRX intake are small at present but may become more important as the MAPLE system becomes fully operational. A conservative estimate of impingement for both intakes, with MAPLE fully operational, is 100 kg/y. This is roughly equivalent to fish production from 63 ha of river.

5.1.4 Road Kill of Wildlife

Low numbers of large mammals (deer, moose, bear) are killed in traffic accidents along the CRL access road. The rate of mortality is of no consequence at the level of populations within the CRL property.

Mortality rates of amphibians and reptiles may be of local importance, especially where the CRL access road crosses wetland areas (e.g., near Maskinonge Lake). However, no data are available to assess this impact.

5.1.5 Road Salt

Substantial quantities of road salt are used in winter on CRL roads, and may lead to effects in wildlife (attraction to roads where traffic hazards exist, ingestion poisoning in birds).

These effects are unlikely to be any more significant than road salt effects along other regional roadways or in small urban areas.

5.1.6 Greenhouse Gases

Greenhouse gas emissions from CRL, assessed relative to national emissions, represent 0.0067% of the national total. Thus, the CRL contribution is small, and has been declining in recent years.

5.1.7 Other Habitat Factors

Other habitat manipulations at CRL, such as installation of fencing and creation of fire breaks, may produce local effects on wildlife movements and distributions. These effects are likely to be minor and comparable to the effects of similar activities throughout the region.

5.2 Recommendations

1. In the few instances where radiation or chemical doses were predicted to exceed benchmarks and, in the case of chemicals, to exceed background, it is recommended that AECL confirm exposure conditions (concentrations in biota for radioactivity, concentrations in the environment for chemicals) and confirm the presence of VECs or ecological receptors similar to VECs assessed herein. Measurements should also be made to confirm site-specific transfer parameters in these areas (sediment/soil K_ds, bioconcentration factors, etc.). Where exposures are confirmed to exceed benchmarks (and background), it is recommended that an assessment of population and/or community health be undertaken, or that mitigation measures to reduce the exposure be implemented.

2. It is recommended that a rigorous evaluation of background concentrations of metals be completed in the Ottawa River and in inland waters (water, sediment). This should be carried out prior to completion of follow-up monitoring of chemical effects at potentially impacted locations, as outlined in (1) above. In most cases, it is expected that an improved picture of background concentrations will demonstrate that most potential metal effects identified here are indistinguishable from background, and would not warrant further assessment.

3. Since groundwater monitoring wells near the Chemical Pit have detected polychlorinated biphenyls (PCBs) and tetrachlorodibenzofurans (TCDFs), it is recommended that the potential for migration of these substances should be addressed, either by modelling or by monitoring in East Swamp.

4. The lack of monitoring data for metals in the water and sediments of West Swamp should be rectified in future monitoring programs so that potential metal doses to

riparian wildlife can be addressed. Mercury and lead are of particular interest, since these metals have been detected in upgradient groundwater.

5. Vegetation control programs should be maintained in most waste management areas, as this will discourage colonization by biota and minimize the potential for doses such as estimated for organisms assumed to inhabit the Laundry Pit and Reactor Pit 2.

6. Fencing should be designed to exclude large mammals from waste management areas and perhaps other contaminated areas (e.g., South Swamp), and "game breaks" should be considered to permit large mammal passage through high fences elsewhere on the site, as recommended by Chaput *et al.* (2002).

7. Although no significant ecological effects are expected in the river due to radiation exposure, and chemical exposures are expected to be comparable to background, environmental effects studies should be conducted to confirm these conclusions. Such studies were commenced in 2002.

8. Further to Item #7, it is suggested that field investigations be undertaken in the Ottawa River to delineate the aquatic plumes originating from representative offshore and shoreline discharges.

9. Due to the potential localized adverse effects of traffic mortality on herptofauna, it is recommended that a study be completed to document the importance of road kill to such species during critical periods of the year.

10. It is recommended that fish impingement rates be determined in the MAPLE intake water (former NRX intake) after the full-power start-up of MAPLE.

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TABLES

TABLE 2.1: SUMMARY OF WASTE MANAGEMENT AREAS AT CRL AND ESTIMATES OF WASTE VOLUMES AND RADIOACTIVITY CONTENT (from Dolinar *et al*., 2000)

Area Designation	Period of Operation	Description	Waste Volume, m^3 (1)		Major Activity (2)		Notes
			Solid	Liquid	Type	TBq	
Waste Management Area A							Drawing: E-4500-2S5W-12
Liquid Wastes		Liquid wastes discharged into trenches in 1953 (4500 m^3), Sept 1954 (7.2 m^3) and Feb. 1955 (50 m^3).	n.a.	4,500 7.2 50	Mixed FP Mixed FP Mixed FP	330 6.3 34	Dilute aqueous Nitric acid / ammonium nitrate solution. Nitric acid solution. Source of a contaminated groundwater plume.
Solid Wastes	1946-1955	Solid wastes emplaced in unlined trenches and a variety of buried structures. Various drummed and bottled liquids emptied into below-grade concrete structures	N/A	Misc. liquids	N/A	N/A	Limited records for solid wastes and drummed/bottled liquids buried prior to 1952. Source of a contaminated groundwater plume.
Liquid Dispersal Area							Drawing: E-4500-2S5W
Reactor Pit #1	1953-1998	Liquid waste discharged to natural depression between 1953 and 1956. Lightly contaminated equipment and suspect soils later used to fill depression.	n.a.	230,000	β/γ α	100 0.1	Estimated disposal of 74 TBq ^{90}Sr plus 100 g (Pu equivalent) of alpha-emitters. Source of a contaminated groundwater plume.
Laundry Pit	1956-1957	Aqueous waste from Decontamination Centre and laundry discharged to engineered pit.	n.a.	680	β/γ α	0.06 0.0003	Small inventory compared with other LDA pits.
Chemical Pit	1956 – present	Liquid aqueous waste from site labs and chemical operations discharged to a gravel-filled pit.	n.a.	330,000	β/γ α Tritium	230 0.4 70	Source of a contaminated groundwater plume. Groundwater from Chem Pit plume is subject of pump and treat program.
Reactor Pit #2	1956 – present	Lightly contaminated water from rod storage bays, and NRX & NRU operations.	n.a.	1,500,000	β/γ α Tritium	500 0.5 1000	Source of a contaminated groundwater plume.
Waste Management Area B							Drawing: E-4500-2S7W-26
Sand Trenches	1953 - 1963	Solid wastes in unlined trenches covered with sand: intermediate level waste (ILW) emplaced prior to Aug 1956, only low level waste (LLW) emplaced after Sept 1956.	9000	Misc. bottled liquids	Mixed LLW and ILW	~75	Use discontinued in favour of engineered structures. Limited inventory data. Source of two separate contaminated groundwater plumes.
Asphalt lined trenches	1955 - 1959	Intermediate-level solid wastes, i.e. wastes having external fields >100 mR/hr at 30 cm, that were emplaced in asphalt-lined and –capped trenches.	1300	Misc. bottled liquids	ILW	N/A	Estimated to contain 0.6 TBq of ^{239}Pu.
Rectangular concrete bunkers	1959 - 1979	Low level solid wastes in rectangular concrete bunkers. (Below grade but above the water table.)	8500	Residual	LLW	A	
Special burials	1955 - 1973	Various materials including the NRU and the second NRX calandrias.	*	*	*	*	* See reference ______________ for details.
Circular concrete bunkers	1979 - present	Low level solid wastes. (Below grade but above the water table.)	6,850	Residual	LLW	A	

TABLE 2.2: LIQUID EFFLUENT DISCHARGES AND ASSOCIATED SAMPLING POINTS (from Turner, 2002, and Neimi *et al*., 2001)

Stream Type	Point Name	Description
Process Effluents	Waste Treatment Centre, Large Evaporator Condensate	Treated low-level radioactive waste waters Tanks 1-3 and 1-4 – Condensate from the Large Evaporator & Permeate from the RO units. (Discharges into Process Sewer)
	Waste Treatment Centre, Condensate from Wiped-Film Evaporators	Tank 13 – Distillate from the wiped film evaporators (used for concentrating and solidifying retained low-level waste in bitumen) (Discharges into Process Sewer)
	Process Sewer	Cooling water from reactors, sumps, flow and roof drains from NRU & NRX, D_2O Upgrader, WTC discharges
	Power House Drain	Cooling water, floor drainage from Bldg. 420
	Sanitary Sewer, Sewage Treatment Plant	Domestic water from over 80 buildings, including labs in the Controlled Area 1, and boiler blowdown from the Power House
Storm Sewers and Streams	Storm Sewer “03”	Natural spring, runoff from the Controlled Area 1 and parking lots, equipment cooling water
	Storm Sewer “04”	Groundwater, runoff from a large portion of the Controlled Area 2, equipment cooling water
	Storm Sewer “05”	Groundwater, runoff from the north-west portion of the Controlled Area 2
	MH-4F6 Sewer	Groundwater, runoff from the vicinity of the Power House and Transformer Yard
	MH-4F7 Sewer	Groundwater, runoff from the vicinity of the Power House and Transformer Yard
	Stream “01”	Groundwater and runoff from the south-west portion of the Controlled Area 1
	Stream “02”	Groundwater, runoff from the Supervised Area below the landfill
	Stream “06”	Groundwater, runoff from the northeast portion of Controlled Area 1.
Waste Management Areas	Duke Stream Bulk Storage Stream Lower Bass Lake Inlet	Groundwater and runoff from the WMAs in Maskinonge Lake basin
	Perch Creek Points upstream of Perch Lake	Perch Lake and basin, runoff from WMAs “A” & “B”, & LDA
Miscellaneous	Intake Water	Intake well in the Power House

Area Designation	Period of Operation	Description	Waste Volume, m^3 (1)		Major Activity (2)		Notes
			Solid	Liquid	Type	TBq	
Tile holes - Nuclear Reactor Fuels	1956 - present	Reactor Fuel high-level wastes in vertical, below-grade facilities.	1,187	n.a.	HLW	A	Estimates available for fissile material quantities. Fuel-bearing structures are the subject of a remediation program. See ____________ for further details.
Tile holes - ^{99}Mo wastes	1970 - present	High-level wastes arising from ^{99}Mo production.	A	n.a.	HLW	N/A	Estimates available for fissile material quantities
Tile holes - other wastes	1956 - present	A variety of high level wastes including reactor components	A	n.a.	HLW	N/A	Cell wastes, reactor components, Rod bay wastes
Waste Management Area C							Drawing: E-4500-0S11W
Surface Storage	1963 - present	Surface storage of limited amounts of drummed wastes, NRX Stack sections, drummed aqueous liquids, solidified oils, bulk suspect soils and other bulk items.	N/A	81	LLW	N/A	Stock piled soils may be re-used elsewhere in WMAs.
C Extension	1993 - present	Low-level Solid Waste (external fields <100 mR/hr at 30 cm) in unlined trenches. Higher proportion of drummed waste than Area C.	2600	Residual	LLW	A	Characterization data available for some radionuclide inventories. Source of groundwater contamination. Drawing: D-4500-36
Sand Trenches	1963 - present	Low-level Solid Waste (external fields <100 mR/hr at 30 cm) in unlined trenches. Total area is approx. 4.5 ha; impermeable cover installed on 0.7 ha in 1983 Nov. Waste is half from CRL and half from across Canada including Rolphton NPD.	88,000	Drummed & bottled liquids	LLW	N/A	Limited characterization data for radionuclide inventories. Source of a groundwater plume. Some waste retrievals have taken place. Drawing: OS11W-9 (slit trenches) Drawing: OS11W-12 (bulk trench)
Waste Management Area D	1976 to present	Fenced gravel compound used for above-ground storage of potentially contaminated equipment, materials and drummed liquids. Not a burial site.	585	200	LLW	A	The drummed liquids (lightly contaminated aqueous wastes and waste oils) are stored in marine containers. Drawing: E-4500-OS7W-15
Bulk Storage Area	prior to 1973	Fenced compound used for the storage of uncontaminated equipment intended for re-use. Some contaminated materials were also stored there.	N/A	n.a.	LLW	N/A	Field surveys of the compound have located and identified contaminated items
Waste Management Area E	1977 to 1984	Used for disposition of lightly contaminated & suspect bulk materials (building debris and soils) from the CRL Active Area	N/A	n.a.	Suspect slightly contaminated	N/A	The volume of suspect contaminated materials is believed to be a small fraction of the total volume of materials stored here
Waste Management Area F	1976 - 1979	Contaminated soils and slags from Port Hope, Albion Hills and Ottawa stored above the water table in sand valley. Unsuccessful clay cover	120,000 (Mg)	zero	Radium	0.5	Approx. 515 GBq Total ^{226}Ra, 4 - 13 Mg Arsenic, 80 Mg U. Drawing: E-4500-2S11W-9
Waste Management Area G	1989 - present	NPD spent fuel dry storage facility - above-ground concrete canisters.	4,921 (bundles)	zero	Irrad. U	See reference [i]	Complete inventory data available. Monitoring & surveillance confirms containment within structures (i). Drawing: OS9W-3

Area Designation	Period of Operation	Description	Waste Volume, m^3 (1)		Major Activity (2)		Notes
			Solid	Liquid	Type	TBq	
Waste Tank Farm	1961 - 1968	Tank farm with intermediate to high-level wastes in tanks in concrete vaults with leak-detection systems. Intermediate - T-40F (secondary concrete containment), T-40E (empty), T-40D (concrete pad) High level - T-283A,B,C,D (all with secondary concrete containment)	n.a.	68	β/γ α	150	Monitoring & surveillance confirms containment of these wastes and the facility includes emergency transfer lines. Drawing: E-4500-2N5W-16
Acid Chemical and Solvents Pits	1982 - 1987	Small Fenced Compound containing three small pits which as the names imply were used for different non-active liquid wastes and very small quantities of solid wastes.	Acid: minor	Acid: 11.2 Chem.: 2.7 Sol.: 5.3			Acid: Hydrochloric, Sulfuric, Nitric, Chromic acids, potassium carbonate powder, citric powder and acid batteries. Chemical: Scintillation fluids, Alconox and other cleaning agents, ammonia, alkylating agents, others. Solvent: Mixed solvents, oils, scintillation solutions, ammonia, varsol, acetone, others. Drawing: E-4500-2N11W-11
Glass Blocks	1958 - present	Experimental burial of mixed fission products in a vitrified wasteform	< 1	n.a.	β/γ α & FP	50	Two separate installations of 25 blocks each.
Thorium Pit	1955 - 1960	Reprocessing wastes from operation of the ^{233}U extraction facility.	n.a.	20	Nat. Th, ^{233}U and mixed FP	A	Approximate total of 45 m^3 reprocessing solution discharged in separate dispersals to crib containing ammonium carbonate (approx. 4000 kg nat. Th, 27 g ^{233}U). Drawing: E-4500-2N11W-11
Nitrate Plant	1953 - 1954	Discharges of mixed fission products in salt solutions to limed pit following a process accident. Decontaminating solutions also released. Contaminated rubble from Bldg 233 demolition.	N/A	200	β/γ	60	Estimated 60 TBq of β/γ activity (35% ^{90}Sr) in liquid releases - small α inventories. Plant demolished and buried on-site, no data for solid waste inventories. Drawing: E-4500-2N11W-11
Above Ground Buildings and Structures in Waste Management Areas							
Buildings and Structures in WMAs	1953 - present	Various buildings/ gatehouses	N/A	n.a.	N/A	N/A	See individual drawings listed above

(2) Inventories as of 1997
(3) Activity at time of emplacement - not corrected for decay
(4) N/A - no quantitative data available
(5) A - quantitative data available
(6) n.a. - not applicable

TABLE 2.3: SUMMARY OF RADIOACTIVE GROUNDWATER PLUMES IN THE CRL SUPERVISED AREA AND CONTROLLED AREA (from Dolinar *et al.*, 2000; Killey and Eyvindson, 1999)

Drainage Basin	**Area**	**Structure/Source of Contamination**	**Main Contaminants in Plumes**
Perch Lake	WMA-A	Sand Trench, reprocessing solutions	^{90}Sr, ^{137}Cs, areal extent 38,000 m^2
	LDA	Chemical Pit, active drain discharges	^{90}Sr, ^{60}Co, Alpha, areal extent 8,000 m^2
		Reactor Pit #1	^{90}Sr, areal extent 9,000 m^2
		Reactor Pit #2, rod bay water discharges	Tritium, areal extent 200,000 m^2; ^{90}Sr, areal extent 18,000 m^2
	WMA-B	Sand Trench	Tritium
		Sand and/or asphalt trenches	^{90}Sr, areal extent 8,500 m^2
	Glass Block Experiment	Blocks of vitrified waste placed to test leaching	^{90}Sr, areal extent 3,000 m^2
Maskinonge Lake	WMA-C	Mixed low-level wastes	Tritium, ^{14}C, areal extent 38,000 m^2
	Nitrate Plant	Reprocessing wastes, process upsets	^{90}Sr, ^{137}Cs, areal extent 16,000 m^2
	Thorium Plant	Reprocessing waste direct-to-ground discharge	^{90}Sr, areal extent 6,000 m^2
Ottawa River	Plant Site, Controlled Area 2	NRX rod bay leak, Bldg. 204, most (90%) reports to river via 04 Storm Sewer	Tritium, ^{90}Sr, areal extent 28,000 m^2
		NRU Building, from rod bay or pipeline from NRU to Liquid Dispersal Area	Tritium, areal extent 24,000 m^2
		Leaks from old active drain system, including Tank 240	Tritium &/or ^{90}Sr: plumes merge with NRX/NRU plumes.

TABLE 2.4: AREAS OF POTENTIAL LAND CONTAMINATION (from Amrouni, 1999)

	Area	Discussion
1	General Area Used for Landfill/ Backfill Activities	The area surrounding (and including) the CRL active and inner areas has been extensively re-worked as a result of the original site construction and various subsequent activities. The area immediately adjacent to the inner and active areas has been significantly disturbed and altered as a result of both backfilling and landfill type initiatives (including equipment burial). There are localized areas where debris is clearly visible at the surface, and at this time it is not known how much of the disturbed area was subject to these types of activities. Past records and observations indicate that suspect and/or contaminated material and equipment made their way into these areas, and the records also indicate that in several cases, contaminated material was subsequently retrieved. Decontamination of equipment may also have taken place in these areas. There is evidence that ash resulting from operation of the coal-fired boilers was buried in this area.
2	Snow Dumps (2)	Snow removed from various areas of the CRL site is placed in dumps located in the Supervised Area. There is a potential that these areas could be contaminated by, as a minimum, road salt.
3	Blimkie's Meadow	This area was used for the storage of surplus equipment utilized by the Environmental Research Branch in tracer studies, meteorological studies, etc. There is a potential that this area could be contaminated, or contain contaminated equipment.
4	Dawson City	This site was originally used as a construction camp during the time that the CRL site was being built. Subsequent to that it has been used for a number of other purposes such as (i) work on the hydrogen recombiner project, and (ii) a location for the concrete batch plant used on the MMIR Project. Currently it is being used as a storage site for material awaiting monitoring through the Waste Segregation Program.
5	Shooting Range	The area used for weapons training by AECL Security staff is known to contain spent ammunition (lead bullets).
6	1953 Pipeline Route	There is a potential for residual contamination along the route used for the piping that was used to transfer radioactive liquid to WMA A following the 1952 accident in NRX.
7	Stack Duct	The aboveground portion (replaced in 1992 by an underground duct) of the ventilation duct connecting NRU/NRX to the main exhaust stack. The interior of the stack duct is contaminated with radionuclides and there may be contamination in the region under the duct.
8	Landfill Attenuation Zones	The attenuation zone from the Millers Road landfill impinges on AECL property. Similarly the attenuation zone associated with the new landfill being constructed on Baggs Road will impinge on AECL property. No radioactive contamination is suspected.
9	Oiled CRL Roads	In the past, waste oil was used for dust suppression on CRL roads, and residual organic contamination may exist.
10	Hydro-Meteorological Study Area	Area used from early 1980 to early 1990 by the University of Toronto and AECL for hydro-meteorological studies. There is no reason to suspect radiological contamination, but there are significant amounts of items such as old lead batteries, etc.

TABLE 2.5: CONTAMINANTS OF POTENTIAL CONCERN WITH ASSOCIATED LOCATIONS AND MEDIA ON THE CRL SITE (see Appendix 1)

Contaminant	Locations	Media	Comment
CHEMICALS			
PCBs (total)	LDA	Groundwater	
Mercury	LDA	Groundwater	
	Area A	Groundwater	
	Area B	Groundwater	
	Area C	Groundwater	Based on fish consumption in SW
	Area F	Groundwater	Based on fish consumption in SW
	Nitrate Plant	Groundwater	Based on fish consumption in SW
Lead	LDA	Groundwater	
Copper	Area B	Groundwater	
	Inactive Landfill	Groundwater	
Trichloroethylene	Area B	Groundwater	
	Area C	Groundwater	
1,1-Dichloroethylene	Area B	Groundwater	
	Area C	Groundwater	
Carbon tetrachloride	Area B	Groundwater	
Aluminum	Sanitary Sewer	Effluent	
	Process Sewer	Effluent	
	Power House Drain	Effluent	
	Storm Sewer 1	Effluent	
	Storm Sewer 3	Effluent	
	Storm Sewer 4	Effluent	
	Storm Sewer 5	Effluent	
	Stream 02	Site Runoff	
	Duke Stream	Site Runoff	
	Perch Creek	Site Runoff	
Copper	Sanitary Sewer	Effluent	
	Process Sewer	Effluent	
	Power House Drain	Effluent	
	Storm Sewer 4	Effluent	
	Storm Sewer 3	Effluent	
	Storm Sewer 5	Effluent	
	Stream 02	Site Runoff	
	Bulk St. Stream	Site Runoff	
	Lower Bass Lake	Site Runoff	
Ammonia	Sanitary Sewer	Effluent	Deleted. Exceedance is very marginal
Phenolics	Power House Drain	Effluent	Based on maximum value
	Sanitary Sewer	Effluent	Based on maximum value
	Storm Sewer 1	Effluent	
	Stream 02	Site Runoff	
Iron	Power House Drain	Effluent	
	Sanitary Sewer	Effluent	
	Storm Sewer 3	Effluent	
	Stream 01	Site Runoff	
	Stream 02	Site Runoff	
	Perch Creek	Site Runoff	
	Duke Stream	Site Runoff	
Chloroform	Sanitary Sewer	Effluent	
	Power House Drain	Effluent	
	Storm Sewer 3	Effluent	
	Storm Sewer 4	Effluent	
	Stream 01	Site Runoff	

TABLE 2.5: CONTAMINANTS OF POTENTIAL CONCERN WITH ASSOCIATED LOCATIONS AND MEDIA ON THE CRL SITE (see Appendix 1)

Contaminant	Locations	Media	Comment
Mercury	Process Sewer	Effluent	Based on WTC maximum value
Lead	Sanitary Sewer	Effluent	
	Power House Drain	Effluent	Based on maximum value
	Process Sewer	Effluent	
	Stream 02	Site Runoff	
	Stream 05	Site Runoff	
	Duke Stream	Site Runoff	
	Bulk St. Stream	Site Runoff	
	Lower Bass Lake	Site Runoff	
Cadmium	Sanitary Sewer	Effluent	
	Power House Drain	Effluent	
	Duke Stream	Site Runoff	
Zinc	Sanitary Sewer	Effluent	
	Storm Sewer 1	Effluent	
Chlorine	Sanitary Sewer	Effluent	Estimate from Cl usage
	Process Sewer	Effluent	Estimate from Cl usage
	Storm Sewer 1	Effluent	Estimate from Cl usage
	Storm Sewer 3	Effluent	Estimate from Cl usage
Phosphorus	Process Sewer	Effluent	Based on WTC maximum value
Propanol	Sanitary Sewer	Effluent	Estimate from site usage
Fluoranthene	Sanitary Sewer	Effluent	
Pyrene	Sanitary Sewer	Effluent	
Benzo(a)pyrene	Sanitary Sewer	Effluent	Based on maximum value
Bis-2EH-phthalate	Process Sewer	Effluent	
Chromium	Perch Creek	Sediment	
	Perch Lake	Sediment	
	Main Stream	Sediment	
	Stream 01	Sediment	
	Stream 05	Sediment	
	Duke Stream	Sediment	
	Bulk St. Stream	Sediment	
	Lower Bass Lake	Sediment	
	Maskinonge Lake	Sediment	
	Upwelling Area*	Sediment	
Copper	Perch L. Inlet 2	Sediment	
	South Swamp	Sediment	
	Stream 05	Sediment	
	Duke Creek	Sediment	
	Maskinonge Lake	Sediment	
	Upwelling Area*	Sediment	
Iron	Perch Creek	Sediment	
	Perch L. Inlet 2	Sediment	
	Main Stream	Sediment	
	Stream 01	Sediment	
	Duke Stream	Sediment	
	Bulk St. Stream	Sediment	
	Lower Bass Lake	Sediment	
	Maskinonge Lake	Sediment	
	Upwelling Area*	Sediment	
Lead	Duke Stream	Sediment	
	Upwelling Area*	Sediment	

TABLE 2.5: CONTAMINANTS OF POTENTIAL CONCERN WITH ASSOCIATED LOCATIONS AND MEDIA ON THE CRL SITE (see Appendix 1)

Contaminant	Locations	Media	Comment
Zinc	Upwelling Area*	Sediment	
Cadmium	Upwelling Area*	Sediment	
Arsenic	Upwelling Area*	Sediment	
Naphthalene	Perch Creek	Sediment	
Phenanthrene	Perch Creek	Sediment	
Fluoranthene	Perch Creek	Sediment	
Pyrene	Perch Creek	Sediment	
Chrysene	Perch Creek	Sediment	
Benzo(a)pyrene	Perch Creek	Sediment	
Chlorine	Process Sewer	Effluent	Shock trt. of cooling water (SEA)
Sodium hydroxide	Sanitary Sewer	Effluent	Boiler blowdown - Power House
Road Salt	Roads, Ditches, Snow Dumps	Water, Soil	Saline soils, runoff to surface water (SEA)
NO_x	Heating Boilers	Air	Conservative est. for POI
SO_x	Heating Boilers	Air	Conservative est. for POI
CO_2	Power House	Air	Release to air (SEA)
CH_4	Power House	Air	Release to air (SEA)
Halocarbons (HFC)	General Site	Air	Release to air (SEA)
RADIONUCLIDES			
Strontium-90 or gross β	LDA	Groundwater	Based on aquatic life screen
	Reactor Pit 2	Groundwater	Based on aquatic life screen
	Area A	Groundwater	Based on aquatic life screen
	Area B	Groundwater	Leaching to west swamp (SEA)
	Area C	Groundwater	Leaching to surface water (SEA)
Cobalt-60	LDA	Groundwater	Based on aquatic life screen
Carbon-14	LDA	Groundwater	Based on aquatic life screen
	Area C	Groundwater	Leaching to surface water (SEA)
Tritium (HTO)	Area C	Groundwater	Leaching to surface water (SEA)
	Process Sewer	Effluent	Release to Ottawa R. (SEA)
	River Front Wells	Groundwater	Rod bay leaching to river (SEA)
Strontium-90 or gross β	Process Sewer	Effluent	Release to Ottawa R. (SEA)
	River Front Wells	Groundwater	Based on DOE riparian screen.
	South Swamp	Site Runoff	Based on DOE riparian screen
	East Swamp	Site Runoff	Based on DOE riparian screen
	West Swamp	Site Runoff	Based on DOE riparian screen
	Perch L. Inlet 1	Site Runoff	Based on DOE riparian screen
	Perch L. Max.	Site Runoff	Based on DOE riparian screen
	Spring B	Untrt. Effluent	Based on DOE riparian screen
Strontium-90 or gross β	South Swamp	Sediment	Based on DOE riparian screen
	East Swamp	Sediment	Based on DOE riparian screen
Strontium-90 or gross β	South Swamp	Soil	Based on DOE terrestrial screen
	Perch L. Inlet 1	Soil	Based on DOE terrestrial screen
	Main Stream Weir	Soil	Based on DOE terrestrial screen
Gross gamma	South Swamp	Soil	Based on DOE terrestrial screen
	Perch L. Inlet 1	Soil	Based on DOE terrestrial screen
	Main Stream Weir	Soil	Based on DOE terrestrial screen

TABLE 2.5: CONTAMINANTS OF POTENTIAL CONCERN WITH ASSOCIATED LOCATIONS AND MEDIA ON THE CRL SITE (see Appendix 1)

Contaminant	Locations	Media	Comment
Strontium-90 or gross β	West Swamp	Site Runoff	Based on DOE riparian screen
	Perch Lake	Site Runoff	Based on DOE riparian screen
	Spring B	Soil	
	Area A	Soil	Based on DOE terrestrial screen
	Area H	Soil	Based on DOE terrestrial screen
Gross gamma	South Swamp	Site Runoff	Based on DOE riparian screen
	East Swamp	Site Runoff	Based on DOE riparian screen
Gamma field	Laundry Pit	Above Soil	Based on 40 μSv/h screen
	Area B	Above Soil	Based on 40 μSv/h screen
Argon-41	NRU/DIF	Air	Based on conservative screen.
Mixed Noble Gases	Mo-99 Facility	Air	Release to air (SEA)
Tritium (HTO)	NRU/DIF	Air	Release to air (SEA).
Iodine-131	Mo-99 Facility	Air	Release to air (SEA)

* Upwelling Area refers to Process Sewer outfall area.

TABLE 2.6: PHYSICAL STRESSORS OF POTENTIAL CONCERN WITH ASSOCIATED LOCATIONS AND RECEPTORS ON THE CRL SITE

Stressor	Locations	Receptors	Concerns
Thermal Releases	Process Sewer to Ottawa River	Fishes and Aquatic Invertebrates	Lethality and/or Growth Effects
Entrainment/Impingement	Cooling Water Intakes from Ottawa River	Fishes and Aquatic Invertebrates	Lethality
Firebreaks	South, west and north property boundaries	Birds and Mammals Aquatic Life	Habitat Changes Increased Runoff/Siltation
Other Physical Works (Planned, in progress or recently completed)	E.g. Construction of MAGS facility (WMA-H)	Birds and Mammals Aquatic Life	Habitat Changes Increased Runoff/Siltation
Fences	South, west, (north?) property boundaries	Large Mammals	Barrier to Movements Physical Injury
Fences	Perimeter of Perch Lake Basin	Large Mammals	Barrier to Movements Physical Injury
Traffic	Plant Road	Mammals	Road kill

TABLE 2.7: RARE VASCULAR PLANTS ON THE CRL PROPERTY

Common Name	**Coefficient of Conservatism**	**Wetness Index**	**Provincial Status**	**Local Status Central Region**	**Source**
WETLAND SPECIES					
Marsh Water-starwort		-5	S5	Rare	
Elliptic-leaved St. John's-wort	9	-5	S5	Rare	
Farwell's Water-milfoil	8	-5	S4	Rare	
Purple Bladderwort	10	-5	S4	Rare	
Marsh Willow-herb	10	-5	S5	Rare	
Halberd-leaved Tearthumb	**8**	**-5**	**S3**	**Rare**	
Small Yellow Sedge	7	-5	S5	Rare	
Slender Cotton-grass	10	-5	S5	Rare	
Brown Beaked-rush	10	-5	S4?	Rare	
Smith's Club-rush	**10**	**-5**	**S2**	**Rare**	
Bayonet Rush	**10**	**-5**	**S3S4**		**CH2M 1998, Appendix 2**
Prickly Coontail	**8**	**-5**	**S3**		**CH2M 1997, Appendix C**
Grass-leaved Arrowhead	**10**	**-5**	**S3**		**N-S 2000**
Carey's Knotweed	**10**	**-4**	**S3S4**		
Low Umbrella Sedge	6	-4	S4	Rare	
Canadian St. John's-wort	8	-3	S4?	Rare	
Tall White Bog Orchis	10	-3	S5	Rare	
WETLAND/UPLAND SPECIES					
American Mountain-ash	8	-1	S5	Rare	
Sheep Laurel	9	0	S5	Rare	
Small Round-leaved Orchid	9	0	S4S5	Rare	
Hair-like Bulbostylis	5	2	S3?		
UPLAND SPECIES					
Fragile Fern	7	3	S5	Rare	
Jack Pine	9	3	S5	Rare	CH2M 1998, p.6-6
Purple Clematis	8	5	S4S5	Rare	
Millspaugh's Blackberry	7	5	S4?	Rare	
Closely-covered Sedge	**9**	**5**	**S2**	**Rare**	
Merritt Fernald's Sedge	6	5	S5	Rare	
Umbel-like Sedge	7	5	S5	Rare	
Coast Jointweed	**8**	**5**	**S3**		**CH2M 1997, 1998; N-S 2000**
Houghton's Cyperus	**8**	**5**	**S3?**		**CH2M 1997, Appendix D**
Slender Water-milfoil			S4	Rare	
Hooked-spur Violet			S4S5	Rare	

Please see Appendix 2 for a description of indices and status codes.

TABLE 2.8: PRELIMINARY LIST OF VALUED ECOSYSTEM COMPONENTS
(Note: Species in bold are evaluated further in the EER)

Species	Rationale
FISH	
Northern pike*	predatory, game fish present in larger lakes on site
Brown bullhead*	bottom-feeder, present in Perch and Maskinonge L.
Pumpkinseed*	herbivore/insectivore, present in lakes and some streams
Redbelly dace*	forage fish, common in most of the streams on site
Walleye	predatory, game fish in Ottawa River and larger lakes on site
Trout perch	forage fish, present in Ottawa River
MAMMALS	
White-tailed deer*	terrestrial herbivore, game species, large mammal
Mink	semi-aquatic piscivore/carnivore, socio-economic significance (furbearer)
Muskrat*	aquatic piscivore/herbivore, socio-economic significance (furbearer)
Star-nosed mole*	semi-aquatic insectivore, soil-dwelling small mammal
Woodchuck	soil-dwelling small herbivore, observed in WMA-F
Black bear*	terrestrial omnivore, large mammal
Snowshoe hare*	terrestrial herbivore, small mammal
Water shrew*	semi-aquatic, feeds on soil invertebrates
Least shrew	terrestrial herbivore, small mammal
Eastern wolf	terrestrial carnivore, large mammal, COSEWIC species of Special Concern
BIRDS	
Sharp-shinned Hawk	terrestrial predator – migratory
Great Blue Heron	aquatic predator – migratory
Ruffed Grouse*	terrestrial herbivore – resident
Pileated Woodpecker	terrestrial insectivore – resident
Red-headed Woodpecker	terrestrial insectivore, COSEWIC species of Special Concern – migratory
Mallard	aquatic herbivore – migratory/resident
American Robin	terrestrial insectivore/frugivore; feeds on soil invertebrates – migratory
AMPHIBIANS/REPTILES	
Bullfrog*	aquatic omnivore (amphibian)
Green frog*	aquatic omnivore (amphibian)
Snapping turtle*	aquatic omnivore (reptile)
Midland painted turtle*	aquatic omnivore (reptile) – highest radiation concentrations among turtles analyzed
Common musk turtle (stinkpot)	aquatic omnivore (reptile) – designated Threatened by COSEWIC
Wood turtle	terrestrial omnivore (reptile) – provincially significant (S2/Vulnerable in Ontario); COSEWIC species of Special Concern
Garter snake	terrestrial carnivore (reptile)
PLANTS	
Eastern white cedar*	wetland/upland coniferous tree, widespread on site
White water-lily*	aquatic plant, widespread in wetlands
Speckled alder*	wetland shrub/tree, widespread and common in thicket swamps
White pine	upland coniferous tree, highly sensitive to salt and $S0_2$
Yellow birch	wetland deciduous tree, highly sensitive to $S0_2$
Sweet fern	upland herb/shrub common in sandy soils
Smith's club rush	regionally and provincially rare wetland plant
Red maple*	widespread, common tree

TABLE 2.8: PRELIMINARY LIST OF VALUED ECOSYSTEM COMPONENTS
(Note: Species in bold are evaluated further in the EER)

OTHER	
Benthic invertebrates	aquatic, substrate-dwelling, occur throughout site
Freshwater mussels*	aquatic, water filtering, Ottawa River, Perch and Maskinonge L.
Fingernail clams	aquatic, water filtering, widespread on site
Snails*	
Soil invertebrates	soil dwelling invertebrates, widespread on site
COMMUNITIES	
Sand barren	provincially significant vegetation community; supports provincially and regionally significant plant species
Perch Lake wetland	qualifies for provincial significance; supports provincially and regionally significant plant species
Grassy meadow	occurs on or adjacent to some WMAs
Riparian vegetation	occurs along margins of small streams potentially affected by COPECs

* Radionuclide data available (Yankovich and Cornett, 2001; Yankovich et al., 2001; **Yankovich, 2003**; **Yankovich et al., 2003**).

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Screening Location	COPEC	Media Containing COPEC	Environment(s) to be Assessed	Relevant VECs	Measures of Exposure
Area A	Mercury Strontium-90 or gross β Strontium-90 or gross β Other radionuclides*	Groundwater Groundwater Soil	South Swamp T16 Stream Main Stream Perch Lake Inlet 2 Area A	GF, S, A, CR, WS, GBH, BI GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI G, SF, SI, LS, AR	Radionuclides dose to biota (int., ext.) gross β as Sr-90 Hg water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
Area B	Mercury Copper Trichloroethylene 1,1-Dichloroethylene Carbon tetrachloride Strontium-90 or gross β Gamma field Other radionuclides*	Groundwater Groundwater Groundwater Groundwater Groundwater Groundwater Above soil	West Swamp Perch Lake Inlet 1 Area B	RD, GF, S, A, CR, WL, WS, GBH, BI RD, GF, S, A, CR, WS, WL, GBH, BI G, SI, LS, AR	Radionuclides dose to biota (int., ext.) gross β as Sr-90 Hg, Cu, TCE, DCE, CT water conc. (aquatic biota) Sediment conc.. (riparian plant) Sediment conc.. (benthic invert.) dose to shrew, heron
Area C	Mercury Trichloroethylene 1,1-Dichloroethylene Strontium-90 or gross β Carbon-14 Tritium (HTO)	Soil Groundwater Groundwater Groundwater Groundwater Groundwater	Duke Swamp Duke Stream Bulk Storage Swamp Bulk Storage Stream	SI, RM, LS, AR GF, S, A, EWC, RM, WS, GBH, BI GF, S, A, EWC, RM, WS, GBH, BI GF, S, A, EWC, RM, WS, GBH, BI	Radionuclides dose to biota (int., ext.) gross β as Sr-90 Hg, TCE, DCE water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
Area F	Mercury Rn-222	Groundwater Woodchuck burrow air	No adjacent surface water Area F	 G, SI, AR, LS, SH, WC	Radionuclides dose to biota (int., ext.) radon in burrows Hg soil conc. (terrestrial biota) dose to robin, mammals
Area H	Strontium-90 or gross β Other radionuclides*	Soil	Area H	G, SF, SI, LS, AR	Radionuclides dose to biota (int., ext.) gross β as Sr-90
Boat Launch	Chromium Cadmium Lead Aluminum Iron Copper	River Water	Ottawa River nearshore	NP, S, A, CR, WL, WS, GBH, MR, BI	Al, Fe, Pb, Cd, Cr, Cu water conc. (aquatic biota) sediment conc. (riparian plant)
Bulk Storage Stream	Copper Lead Chromium	Site Runoff Site Runoff Sediment	Bulk Storage Stream Maskinonge Lake	GF, S, A, EWC, RM, WS, BI PS, BB, GF, S, A, CR, WL, WS, SP, GBH, MR, M, PT, BI	Cu, Pb, Cr, Fe water conc. (aquatic biota) Sediment conc. (riparian plant)

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Screening Location	COPEC	Media Containing COPEC	Environment(s) to be Assessed	Relevant VECs	Measures of Exposure
	Iron Radionuclides*	Sediment			Sediment conc. (benthic invert.) dose to shrew, heron Radionuclides* dose (int., ext.) gross β as Sr-90
Duke Stream Same as DSW?	Aluminum Iron Lead Cadmium Chromium Iron Lead Copper Radionuclides*	Site Runoff Site Runoff Site Runoff Site Runoff Sediment Sediment Sediment Sediment	Duke Stream Maskinonge Lake	GF, S, A, EWC, RM, WS, BI NP, GF, S, A, CR, WL, WS, SP, GBH, MR, M, PT, W, BI	Al, Fe, Pb, Cd, Cr, Cu water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Radionuclides* dose (int., ext.) gross β as Sr-90
East Swamp	Strontium-90 or gross β Strontium-90 or gross β Gross gamma Other Radionuclides*	Site Runoff Sediment Site Runoff	East Swamp East Swamp Stream Main Stream Perch Lake Inlet 2	RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI	Radionuclides dose to biota (int., ext.) gross gamma as Cs-137
General Site	Halocarbons (HFC)	Air	Global Air		HFC fraction of provincial emissions
Inactive Landfill	Copper	Groundwater	Perch Creek Ottawa River	CC, GF, S, A, CR, WS, GBH, BI TP, W, S, BI	Cu water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
Laundry Pit	Gamma field	Above Soil	Laundry Pit	G, SF, SI	Radionuclides dose to biota (int., ext.)
LDA	PCBs (total) Mercury Lead Strontium-90 or gross β Cobalt-60 Carbon-14	Groundwater Groundwater Groundwater Groundwater Groundwater Groundwater	East Swamp East Swamp Stream Main Stream Perch Lake Inlet 2	RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI	Radionuclides dose to biota (int., ext.) gross β as Sr-90 Hg, Pb, PCB water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
Lower Bass Lake	Copper Lead Chromium Iron Radionuclides*	Water Water Sediment Sediment Water, Sediment	Lower Bass Lake Maskinonge Lake	PS, BB, GF, S, A, CR, WS, GBH, MR, M, PT, BI PS, BB, GF, S, A, CR, WL, WS, SP, GBH, MR, M, PT, BI	Cu, Pb, Cr, Fe, Cu, Pb water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Screening Location	COPEC	Media Containing COPEC	Environment(s) to be Assessed	Relevant VECs	Measures of Exposure
					Radionuclides* dose to biota (int., ext.) gross β as Sr-90
Main Stream	Copper Lead Chromium Iron Radionuclides*	Water Water Sediment Sediment Water	Main Stream Perch Lake Inlet 2	RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI	Cr, Fe, Cu, Pb water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Radionuclides air concentrations dose to biota (int., ext.)
Main Stream Weir	Strontium-90 or gross β Gross gamma	Soil Soil	Main Stream Riparian Zone	A, CR, SI, AR	Radionuclides dose to biota (int., ext.) gross β as Sr-90
Points of Impingement	Radionuclides* SO_2, NO_x	Air	Upland sites near/at main control area	SI, G, LS, AR	Radionuclides air concentrations dose to biota (int., ext.)
Maskinonge Lake	Chromium Copper Iron Radionuclides*	Sediment Sediment Sediment	Maskinonge Lake	PS, BB, GF, S, A, CR, WL, WS, SP, GBH, MR, M, BI	Cr, Cu, Fe water conc. (aquatic biota) Sediment conc. (benthic invert.) Radionuclides dose to biota (int., ext.) gross β as Sr-90
Nitrate Plant	Mercury	Groundwater	Duke Swamp Duke Stream Bulk Storage Swamp Bulk Storage Stream	GF, S, A, EWC, RM, WS, BI GF, S, A, EWC, RM, WS, BI GF, S, A, EWC, RM, WS, BI GF, S, A, EWC, RM, WS, GBH, BI	Hg water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
NRU/DIF	Argon-41 Tritium (HTO)	Air Air	Site Air	SH, WTD, EW, WP, BBR	Radionuclides dose to biota (int., ext.)
Perch Creek	Copper Aluminum Iron Chromium Iron Naphthalene Phenanthrene Fluoranthene Pyrene Chrysene Benzo(a)pyrene	Site Runoff Site Runoff Site Runoff Sediment Sediment Sediment Sediment Sediment Sediment Sediment Sediment	Perch Creek Perch Creek Ottawa River	CC, GF, S, A, CR, WS, GBH, BI TP, W, S, BI	Al, Fe, Cr, Cu, PAHs water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Screening Location	COPEC	Media Containing COPEC	Environment(s) to be Assessed	Relevant VECs	Measures of Exposure
Perch Lake Inlet 1	Strontium-90 or gross β Strontium-90 or gross β Gross gamma	Site Runoff Soil Soil	Perch Lake Inlet 1	RD, GF, S, A, CR, WS, GBH, BI	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90 gross γ as Cs-137
Perch Lake Inlet 2	Copper Iron	Sediment Sediment	Perch Lake Inlet 2	RD, GF, S, A, CR, WS, GBH, BI	<u>Cu, Fe</u> water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
Perch Lake Maximum	Strontium-90 or gross β	Site Runoff	Perch Lake Perch Creek	PS, BB, GF, S, A, CR, WL, WS, PT, GBH, MR, M, BI CC, GF, S, A, CR, WS, GBH, BI	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90
Perch Lake	Chromium Strontium-90 or gross β Other Radionuclides*	Sediment Site Runoff	Perch Lake Perch Creek	PS, BB, GF, S, A, CR, WL, WS, PT, GBH, MR, M, BI CC, GF, S, A, CR, WS, GBH	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90
Pointe au Baptime	Aluminum Copper Cadmium Chromium Iron Lead Radionuclides*	Water	Ottawa River nearshore	NP, GF, S, WL, A, CR, WS, GBH, MR	<u>Al, Cu, Cd, Cr, Fe, Pb</u> water conc. (aquatic biota) sediment conc. (riparian plant) <u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90
Power House	CO_2 CH_4 NO_x SO_x	Air Air Air Air	Global Air (CO_2, CH_4) Site Air (NO_x, SO_x)	 SH, WTD, EW, WP, BBR	<u>CO_2, CH_4</u> fraction of provincial emissions <u>NO_x, SO_x</u> air conc. (terrestrial biota)
Power House Drain	Aluminum Copper Phenolics Iron Chloroform Lead Cadmium Radionuclides*	Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent	Ottawa River nearshore	NP, GF, S, A, CR, WL, WS, GBH, MR, BI	<u>Al, Cu, Fe, Pb, Cd, Organics</u> water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron <u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90
Process Sewer	Aluminum Copper Mercury Lead Chlorine Phosphorus Bis-2EH-phthalate	Effluent Effluent Effluent Effluent Effluent Effluent Effluent	Ottawa River offshore	TP, W, S, BI	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90 <u>Al, Cu, Hg, Pb, b2EHP</u> water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.)

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Screening Location	COPEC	Media Containing COPEC	Environment(s) to be Assessed	Relevant VECs	Measures of Exposure
	Chlorine Tritium (HTO) Strontium-90 or gross β	Effluent Effluent Effluent			dose to shrew, heron <u>P, Cl_2</u> water conc. (aquatic biota)
Reactor Pit 2	Strontium-90 or gross β	Groundwater	East Swamp East Swamp Stream Main Stream Perch Lake Inlet 2	RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90
River Front Wells	Tritium (HTO) Strontium-90 or gross β	Groundwater Groundwater	Ottawa River nearshore	NP, GF, S, WL, A, CR, WS, GBH, MR, BI	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90
Roads, Ditches, Snow Dumps	Road Salt	Water, Soil	Soils at snow dump Road-side ditches	Terrestrial biota Aquatic biota	<u>Na, Cl</u> soil conc. (terrestrial plants) water conc. (aquatic biota)
Sanitary Sewer	Aluminum Copper Phenolics Iron Chloroform Lead Cadmium Zinc Chlorine Propanol Fluoranthene Pyrene Benzo(a)pyrene Sodium hydroxide	Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent Effluent	Ottawa River nearshore	TP, W, S, BI	<u>Al, Cu, Fe, Pb, Cd, Zn, Organics</u> water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron <u>NaOH, Cl_2</u> water conc. (aquatic biota)
River Front Riparian Zone	Sr-90 as gross β	Riparian soil/sediment	Shoreline sediment	NP, GF, S, WL, A, CR WS, GBH, MR, BI	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90
South Swamp	Copper Strontium-90 or gross β Strontium-90 or gross β Strontium-90 or gross β Gross gamma Gross gamma Other Radionuclides*	Sediment Site Runoff Sediment Soil Soil Site Runoff Site Runoff	South Swamp T16 Stream Main Stream Perch Lake Inlet 2	GF, S, A, CR, WS, GBH, BI GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI	<u>Radionuclides</u> dose to biota (int., ext.) gross β as Sr-90 gross γ as Cs-137 <u>Cu</u> water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
Spring B	Strontium-90 or gross β Strontium-90 or gross β	Untreated Effluent Soil	West Swamp Perch Lake Inlet 1	RD, GF, S, A, CR, WS, GBH, BI CC or RD, GF, S, A, CR, WS, GBH, BI	<u>Radionuclides</u> dose to biota (int., ext.)

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Screening Location	COPEC	Media Containing COPEC	Environment(s) to be Assessed	Relevant VECs	Measures of Exposure
			Spring B forest	A, SI, DM	gross β as Sr-90
Storm Sewer 1	Aluminum Phenolics Zinc	Effluent Effluent Effluent	Stream 01 Ottawa River nearshore	RD, GF, S, A, CR, WL, WS, GBH, BI NP, GF, S, A, CR, WL, WS, GBH, MR, BI	Al, Zn, Phenolics water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Radionuclides dose to biota (int., ext.) gross β as Sr-90
Storm Sewer 3	Aluminum Copper Iron Chloroform Chlorine Radionuclides*	Effluent Effluent Effluent Effluent Effluent Effluent	Stream 03 Ottawa River nearshore	RD, GF, S, A, CR, WS, GBH, BI NP, GF, S, A, CR, WS, GBH, MR, BI	Al, Cu, Fe, Chloroform water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Cl_2 water conc. (aquatic biota) Radionuclides dose to biota (int., ext.) gross β as Sr-90
Storm Sewer 4	Aluminum Copper Chloroform Chlorine Radionuclides*	Effluent Effluent Effluent Effluent Effluent	Ottawa River nearshore	NP, GF, S, A, CR, WL, WS, GBH, MR, BI	Al, Cu, Fe, Chloroform water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Cl_2 water conc. (aquatic biota) Radionuclides dose to biota (int., ext.) gross β as Sr-90
Storm Sewer 5	Aluminum Copper	Effluent Effluent	Stream 05 Ottawa River nearshore	RD, GF, S, A, CR, WS, GBH, BI NP, GF, S, A, CR, WS, GBH, BI, MR	Al, Cu water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron
Stream 01	Iron Chloroform Chromium Iron Pyrene Radionuclides*	Site Runoff Site Runoff Sediment Sediment Sediment	Stream 01 Ottawa River nearshore	RD, GF, S, A, CR, WL, WS, GBH, BI NP, GF, S, A, CR, WL, WS, GBH, MR, BI	Cr, Fe, Organics water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Radionuclides dose to biota (int., ext.) gross β as Sr-90

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Screening Location	COPEC	Media Containing COPEC	Environment(s) to be Assessed	Relevant VECs	Measures of Exposure
Stream 02	Aluminum Copper Phenolics Iron Lead Radionuclides*	Site Runoff Site Runoff Site Runoff Site Runoff Site Runoff	Stream 02 Ottawa River nearshore	RD, GF, S, A, CR, WL, WS, GBH, BI NP, GF, S, A, CR, WL, WS, GBH, BI, MR	Al, Cu, Fe, Pb, Phenolics water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Radionuclides dose to biota (int., ext.) gross β as Sr-90
Stream 05	Lead Chromium Copper Radionuclides*	Site Runoff Sediment Sediment Site Runoff	Stream 05 Ottawa River nearshore	RD, GF, S, A, CR, WS, GBH, BI NP, GF, S; A, CR, WS, GBH, MR, BI	Pb, Cr, Cu water conc. (aquatic biota) sediment conc. (riparian plant) sediment conc. (benthic invert.) dose to shrew, heron Radionuclides dose to biota (int., ext.) gross β as Sr-90
Upwelling Area Process Sewer	Chromium Copper Iron Lead Zinc Cadmium Arsenic	Sediment Sediment Sediment Sediment Sediment Sediment Sediment	Ottawa River offshore	TP, W, S, BI	Cr, Cu, Fe, Pb, Zn, Cd, As sediment conc. (benthic invert.)
West Swamp	Strontium-90 or gross β Strontium-90 or gross β Other Radionuclides*	Site Runoff Site Runoff	West Swamp Perch Lake Inlet 1	RD, GF, S, A, CR, WS, GBH, BI RD, GF, S, A, CR, WS, GBH, BI	Radionuclides dose to biota (int., ext.) gross β as Sr-90
Overall Site	Tritium, Sr-90, Co-60, Cs-137	-	Local Terrain	WTD, EW	Radionuclides dose to biota (internal)

TABLE 2.9: ENVIRONMENTS TO BE ASSESSED, RELEVANT VECs AND MEASURES OF EXPOSURE FOR COPEC FROM EACH SCREENING LOCATION

Legend:

A	Alder
AR	American Robin
BB	Brown Bullhead
BBR	Black Bear
BI	Benthic Invertebrates
CC	Creek Chub
CR	Club Rush
DM	Deer Mouse
EW	Eastern Wolf
EWC	Eastern White Cedar
G	Grass (meadow)
GBH	Great Blue Heron
GF	Green Frog
LS	Least Shrew
M	Mallard
MR	Muskrat
NP	Northern Pike
PS	Pumpkinseed
PT	Painted Turtle
RD	Red-belly Dace
RM	Red Maple
S	Snail
SF	Sweet Fern
SI	Soil Invertebrate
SP	Stinkpot Turtle
WS	Water Shrew
WC	Woodchuck
SH	Snowshoe Hare
TP	Trout Perch
W	Walleye
WL	Water Lily
WP	White Pine
WS	Water Shrew
WTD	White-tail Deer

* Considered in Sections 3.0 and 4.0, although not screened in as COPECs.
Note: Other COPECs not listed are also assessed where screened in upgradient of screening location.

TABLE 3.1: DISTRIBUTION COEFFICIENTS (K_d) USED IN WATER:SEDIMENT PARTITIONING CALCULATIONS

Radionuclide or Chemical	K_d (L/kg)	Source of Data
Tritium (HTO)	0	IAEA (1994)
Strontium-90	621	Perch Lake Data (Yankovich, 2002)
Cobalt-60	9,790	Perch Lake Data (Yankovich, 2002)
Cesium-137	7,600	Perch Lake Data (Yankovich, 2002)
Mercury	100	Loam soil value (Sheppard *et al.*, 1992) x 10
Copper	627	Perch Lake Inlets (Environment Canada, 2001)
Lead	1,785	Riverfront Streams (Environment Canada, 2001)
Chromium	670	Sandy soil value X10 (OPG, 2002)
Iron	55,000	Perch Lake Inlets (Environment Canada, 2001)
Zinc	3,519	Perch lake Inlets (Environment Canada, 2001)
Chloroform	0.78	K_{oc} x f_{oc} of 1% (Jones *et al.*, 1997)
Phenolics	0.29	K_{oc} x f_{oc} of 1% (Jones *et al.*, 1997)
Bis-2EH-phthalate	295,121	K_{oc} x f_{oc} of 1% (Jones *et al.*, 1997)
2-propanol	0.011	K_{oc} x f_{oc} of 1% (Jones *et al.*, 1997)
Fluoranthene	1,072	K_{oc} x f_{oc} of 1% (Jones *et al.*, 1997)
Benzo(a)pyrene	10,233	K_{oc} x f_{oc} of 1% (Jones *et al.*, 1997)

TABLE 3.2: AIR:SOIL FACTORS USED IN PARTITIONING CALCULATIONS FOR AIRBORNE PARTICULATE RADIONUCLIDES

Radionuclide	Air:Soil Factor (m^3/kg)	Source of Data
Iodine-131	21.1	Deposition Model (OPG, 2002)
Tritium (HTO)	7.79	Specific Activity (OPG, 2002)
Carbon-14	0.00103	Specific Activity (OPG, 2002)

TABLE 3.3: BIOACCUMULATION FACTORS USED FOR AQUATIC ORGANISMS IN WATER:BIOTA PARTITIONING CALCULATIONS

Radionuclide or Chemical	Bioaccumulation Factor[1] (L/kg FW)					
	Large Fish	Small Fish	Green Frog	Snail[2]	Benthos	Aquatic Plant
Tritium (HTO)	1	1	1	1	1	1
Strontium-90	945	430	130	4,092	21.2	287
Cobalt-60	86	128	4.84	5,855	292	1,523
Cesium-137	627	225	414	323	243	185
Carbon-14	10,779	10,779	10,779	21,558	10,779	10,779
Phosphorus-32	26,000	26,000	-	10,000	10,000	-
Mercury	1,000	1,000	1,000	1,000	-	1,000
Copper	200	200	200	1,000	-	1,000
Lead	300	300	300	100	-	200
Chromium	200	200	200	100	-	200
Iron	200	200	200	3,200	-	1,000
Zinc	1,000	1,000	1,000	10,000	-	1,000
Arsenic	17	17	17	17	-	17

[1] Radionuclide values from Perch Lake data (Yankovich, 2003); metal values from IAEA (1994), NRCC (1985) or NCRP (1996).

[2] A bioaccumulation factor for PAHs was computed from BSAF values (Parkerton *et al.*, 1992) times K_d. A site-specific K_d was used if available.

TABLE 3.4: BIOACCUMULATION FACTORS USED FOR TERRESTRIAL PLANTS AND INVERTEBRATES IN SOIL:BIOTA PARTITIONING CALCULATIONS

Radionuclide or Chemical	Bioaccumulation Factor[1] (kg DW/kg FW)	
	Invertebrate	Terrestrial Plant[2]
Tritium (HTO)	16.04	16.04
Strontium-90	0.016	0.25
Cobalt-60	0.028	0.0235
Cesium-137	0.0013	0.0043
Carbon-14	12.5	12.5
Iodine-131	0.0085[3]	0.0085
Mercury	0.2965	0.0859
Copper	0.117	0.2
Lead	0.078	0.00033
Chromium	0.080	0.00025
Iron	-	0.001
Zinc	0.10	0.14
Arsenic	0.0369	0.00925

[1] Plant values from IAEA (1994), Sheppard *et al.* (1992) or BJC (1998); C-14 value from Duke Swamp data (Killey *et al.*, 1998). Invertebrate values from Sample *et al.* (1998).
[2] A BAF for PAHs was computed from K_{ow} (Travis and Arms, 1988).
[3] Plant value for I-131 used for terrestrial invertebrate.

TABLE 3.5: TRANSFER FACTORS USED FOR WILDLIFE SPECIES IN FOOD: TISSUE PARTITIONING CALCULATIONS

Wildlife Species	Transfer Factor[1] (d/kg FW)			
	Sr-90	Co-60	Cs-137	C-14 or HTO[2]
Water shrew	22	27	136	250
Great blue heron	0.08	2	10	2.494
Muskrat	0.49	0.61	3	2.353
Mallard	0.08	2	10	3.968
Painted turtle	0.35	0.43	9	27.78
White-tailed deer	0.04	0.05	0.23	0.5747
Eastern wolf	0.04	0.05	0.23	0.2222

[1] Values estimated from beef or poultry (IAEA, 1994) and an allometric adjustment for body weight (MacDonald, 1996).

[2] Specific activity model used for H-3 and C-14. TF is the reciprocal of the food ingestion rate, as given in Table 3.6. For example, for muskrat, TF = 1/0.425 kg/d = 2.353 d/kg.

TABLE 3.6: EXPOSURE FACTORS AND FEEDING ASSUMPTIONS FOR THE WILDLIFE SPECIES CONSIDERED

Wildlife Species	Weight (kg)	Food[1] (kg/d)	Water (L/d)	Air (m^3/d)	Dietary Assumption
Water shrew	0.006	0.004	0.0016	-	Snails (100%)
Least shrew	0.006	0.004	-	0.026	Invertebrates
Great blue heron	2.229	0.401	0.1	-	Frogs (100%)
American robin	0.082	0.098	-	0.06	Invertebrates
Muskrat	1.4	0.425	1.39	-	Aquatic plants (100%)
Mallard	1.1	0.252	0.065	-	Aquatic plants (100%)
Painted turtle	2.28	0.036	0.046	-	Snails (50%), Aquatic plants (50%)
White-tail deer	56.5	1.74	3.7	-	Aquatic plants (50%), Terrestrial plants (50%)
Eastern wolf	45	4.5	3.8	-	Deer (100%)

Exposure factors from U.S. EPA (1993).

[1] Incidental ingestion of soil or sediment while feeding is assumed to be 7% of the dry weight food intake (CCME, 1996).

TABLE 3.7: RADIATION EMISSIONS, ENERGIES AND ABSORPTION FACTORS USED IN CALCULATION OF RADIATION DOSES (Blaylock *et al.*, 1993)

Radionuclide	Yield	Beta (MeV)	Gamma (MeV)	Small Fish[1] (AF)		Large Fish[2] (AF)		Small Invertebrate[3] (AF)		Large Mammal[4] (AF)	
				Beta	Gamma	Beta	Gamma	Beta	Gamma	Beta	Gamma
Cesium-137	1	0.187	0	0.99	1	1	1	0.98	1	1	1
Barium-137m	0.946	0.0651	0.596	1	0.012	1	0.12	1	0.002	1	0.5
Cobalt-60	1	0.0965	2.5	1	0.0095	1	0.07	1	0.0015	1	0.5
Tritium (HTO)	1	0.00568	0	1	1	1	1	1	1	1	1
Strontium-90	1	0.196	0	1	1	1	1	0.98	1	1	1
Yttrium-90	1	0.935	1.69E-6	0.98	1	1	1	0.76	1	1	1
Carbon-14	1	0.0495	0	1	1	1	1	1	1	1	1
Iodine-131	1	0.19	0.38	1	0.012	1	0.09	0.98	0.0019	1	0.5
Phosphorus-32	1	0.695	0	1	1	1	1	0.875	1	1	1

[1] Mass 2 g, dimensions 3.1 x 1.6 x 0.78 cm, also used for frog, large invertebrate (e.g., snail), plant and shrew.
[2] Mass 1 kg, dimensions 45 x 8.7 x 4.9 cm, also used for turtle, heron, muskrat, mallard and robin.
[3] Mass 0.016 g, dimensions 0.62 x 0.31 x 0.16 cm.
[4] Mass 50 kg, dimensions 150 x 35 x 25 cm.

TABLE 3.8: RADIONUCLIDE CONCENTRATIONS IN PERCH LAKE WATER AND SEDIMENTS

Radionuclide and Sediment Type	n	Sediment Concentrations[1] Mean ± Standard Deviation (Bq/kg dry weight)	(Bq/kg wet weight)
Strontium-90:			
• Sediments (all)	20	2,245 ± 1,204	179 ± 75.8
• Sand	2	409 ± 118	203 ± 58.7
• Gyttja	18	2,449 ± 1,085	177 ± 78.4
Cesium-137:			
• Sediments (all)	20	132 ± 99.6	10.1 ± 6.70
• Sand	2	13.3 ± 5.30	6.59 ± 2.64
• Gyttja	18	145 ± 96.1	10.5 ± 6.94
Cobalt-60:			
• Sediments (all)	20	185 ± 80.6	15.0 ± 4.87
• Sand	2	37.9 ± 9.76	18.8 ± 4.85
• Gyttja	18	201 ± 66.5	14.5 ± 4.81

Radionuclide	n	Water Concentrations (Bq/L)[2] Mean	Upper
Strontium-90	12	3.6	5.0
Cesium-137	4	0.0172	0.0223
Cobalt-60	4	0.0189	0.0279
Tritium (HTO)	24	6,580	9,990
Gross β/2*	24	3.5	5.0

[1] Yankovich and Killey (2002). Sampled in 1997.
[2] Yankovich (2003). Sampled in 1997. Sr-90, Cs-137, Co-60.
AECL monitoring data (2000-2001). Tritium and Gross β.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.9: RADIONUCLIDE CONCENTRATIONS IN AQUATIC BIOTA COLLECTED IN PERCH LAKE IN 1997 (from Yankovich, 2003)

	Radionuclide Concentration (Bq/kg FW)								
	Sr-90			Cs-137			Co-60		
Aquatic Species	n	mean	max	n	mean	max	n	mean	max
Fishes[1]									
• Northern pike (whole/flesh)	21	1,870	2,510	32	31.7	47.6	32	1.11	1.88
• Pumpkinseed (whole/flesh)	53	3,400	6,600	24	10.8	22.8	24	4.69	31.4
• Brn bullhead (whole/flesh)	36	3,800	5,520	21	18.9	62.1	21	16.0	71.4
• Blacknose shiner (whole)	37	1,550	4,430	2	3.88	6.31	2	4.92	9.54
Frogs									
• Green frog (whole)	4	469	1,070	3	7.12	10.9	3	0.092	0.204
• Bullfrog (whole/flesh)*	2	371	572	2	4.10	4.31	2	0.059	0.109
Invertebrates									
• Freshwater mussels (flesh)	7	1,330	4,280	5	2.72	4.41	5	11.3	25.0
• Snails (whole)	5	14,700	25,600	5	5.56	20.0	5	68.7	142
• Macroinvertebrates	9	76.4	147	11	4.19	9.21	11	8.17	22.3
Turtles									
• Snapping turtle (flesh)	1	38.9	-	1	10.1	-	1	0.154	-
• Painted turtle (flesh)	2	70.3	108	3	7.03	12.6	3	0.396	1.33
Small Mammals									
• Water shrew (whole)	2	732	1,410	1	5.66	-	1	1.21	-
• Star-nosed mole (whole)	2	7.59	9.00	1	1.06	-	1	0.018	-
Aquatic Plants									
• Filamentous algae	6	1,430	1,900	4	0.73	2.53	4	28.6	78.4
• Stoneworts	7	622	1,100	4	1.06	2.14	4	47.1	91.1
• Common bladderwort	3	764	868	3	2.25	4.23	3	107	171
• Hornwort	9	990	1,500	4	0.64	1.13	4	19.9	47.8
• Fennel-leafed pondweed	5	232	331	3	4.12	6.80	3	42.8	75.4
• Big-leaf pondweed	5	909	1,260	3	1.78	3.36	3	27.6	61.8
• Watershield	4	730	929	3	1.69	2.08	3	4.95	6.15
• Yellow water-lily	9	4,260	6,470	4	16.2	23.7	4	13.9	34.9
• Fragrant water-lily	16	181	224	5	3.27	4.57	5	6.60	9.29
• Pickerelweed	11	405	1,000	4	0.89	2.87	4	2.32	7.17
• Reeds	8	224	360	4	0.19	0.30	4	1.83	4.28
• Common cattail	5	794	1,690	3	0.53	1.26	3	0.93	2.58
• Sedges	2	502	556	-	-	-	-	-	-
• Generic Plant	13	926	1,400	12	2.8	4.6	12	25	49

[1] Large fish analyzed whole for Sr-90, flesh for Cs-137 and Co-60. Small fish analyzed whole for all radionuclides.
* Sr-90 value for whole bullfrog is an estimate from flesh and bone values.

TABLE 3.10: RADIATION DOSES TO PERCH LAKE BIOTA

Receptor Type	Radiation Dose (μGy/h)									
	Sr-90		Cs-137		Co-60		HTO		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max
Large fish[1]	1.97	3.18	0.0037	0.0053	0.010	0.010	0.022	0.033	2.0057	3.2283
Frog[2]	0.252	0.498	0.0023	0.0025	0.011	0.011	0.022	0.033	0.2873	0.5445
Snail	8.79	15.3	0.0023	0.0039	0.011	0.011	0.022	0.033	8.8253	15.3479
Infaunal invertebrate	0.063	0.18	0.0039	0.014	0.022	0.08	0.022	0.033	0.11	0.307
Aquatic plant[3]	0.554	0.838	0.0020	0.0022	0.011	0.011	0.022	0.033	0.589	0.8842
Riparian plant[4]	0.304	0.519	0.0018	0.0018	0.011	0.011	0.022	0.033	0.3388	0.5648
Water shrew	0.438	0.844	0.0023	0.0023	0.011	0.011	0.022	0.033	0.4733	0.8903
Great blue heron*	0.0096	0.0182	0.0049	0.0058	0.010	0.010	0.022	0.033	0.0465	0.067
Painted turtle	0.0356	0.0704	0.0025	0.0029	0.010	0.010	0.022	0.033	0.0701	0.1163
Muskrat*	0.133	0.197	0.0022	0.0025	0.010	0.010	0.022	0.033	0.1672	0.2425
Mallard*	0.0127	0.0189	0.0029	0.0034	0.010	0.010	0.022	0.033	0.0476	0.0653

[1] Average for three species (pike, pumpkinseed, bullhead).
[2] Average for two species (green frog, bullfrog).
[3] Average for 12-13 species (Table 3.9).
[4] Average for three species (reeds, cattail, sedges).
* No tissue data; dose estimates based on food chain calculations.

TABLE 3.11: METAL CONCENTRATIONS AND DOSES TO PERCH LAKE BIOTA

Metal	Exposure Concentration Water (mg/L)	Sediment (mg/kg DW)	Dose to Biota (mg/kg•day) Water Shrew	Great Blue Heron	Muskrat	Mallard	Painted Turtle
Hg	<6.35E-5	0.161[1]	0.044	0.012	0.020	0.015	0.001
Cu	0.021	(13.22)[2]	14.16	0.798	6.47	4.81	0.336
Cu	<0.00652	10.8	4.47	0.269	2.04	1.49	0.106
Cr	0.002	(1.34)	0.15	0.076	0.131	0.092	0.005
Cr	<0.00596	41.2	0.88	0.344	0.587	0.439	0.026
Fe	1.09[3]	(59,953)	3,025	228	650	490	52.7
Fe	1.54	26,300	3,593	138	609	458	58.4

[1] Measured sediment value (Environment Canada, 2001).
[2] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[3] Below upper limit of background (Section 3.2).

TABLE 3.12: RADIONUCLIDE CONCENTRATIONS IN WATER AND SEDIMENTS OF PERCH LAKE INLETS 1 AND 2

Radionuclide	n	Water Concentration[1] (Bq/L)			
		Inlet 1		Inlet 2	
		Mean	Mean+2S	Mean	Mean+2S
Gross β/2*	24	21.95	40.3	2.77	5.25
Cesium-137	8	0.004	-	0.0096	0.016
Cobalt-60	8	0.016	-	0.026	0.045
Tritium (HTO)	24	1,970	2,930	12,900	28,000
Radionuclide	**n**	**Sediment Concentration[2] (Bq/kg FW)**			
		Inlet 1		Inlet 2	
		Mean	Mean+2S	Mean	Mean+2S
Gross β/2		5,465	10,035	688	1,307
Cesium-137		12.1	-	29.2	48.6
Cobalt-60		62.7	-	103	177
Tritium (HTO)		1,182	1,758	7,740	16,800

[1] AECL monitoring data for Perch Creek Weir (2000-2001).
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.13: RADIATION DOSES TO BIOTA IN PERCH LAKE INLETS 1 AND 2

Location and Receptor Type	Radiation Dose (μGy/h)									
	Sr-90*		Cs-137		Co-60		HTO		Total	
	mean	max	mean	max	mean	Max	mean	max	mean	max
Inlet 1										
Small fish	5.67	10.4	0.0023	-	0.0447	-	0.0064	0.0096	5.7234	10.46
Green frog	1.73	3.18	0.0022	-	0.0047	-	0.0064	0.0096	1.7433	3.197
Snail	53.7	98.6	0.0022	-	0.0047	-	0.0064	0.0096	53.7133	98.62
Infaunal invertebrate	0.96	1.76	0.0043	-	0.09	-	0.0064	0.0096	1.06	1.77
Aquatic plant	1.64	3.02	0.0021	-	0.0047	-	0.0064	0.0096	1.6532	3.04
Riparian plant	2.07	3.80	0.0021	-	0.0047	-	0.0064	0.0096	2.0832	3.82
Water shrew	4.77	8.75	0.0021	-	0.0047	-	0.0064	0.0096	4.7832	8.77
Great blue heron	0.065	0.119	0.0028	-	0.0420	-	0.0064	0.0096	0.1162	0.173
Inlet 2										
Small fish	0.714	1.36	0.0052	0.0087	0.074	0.127	0.0422	0.0916	0.8354	1.5873
Green frog	0.219	0.415	0.0054	0.0090	0.074	0.127	0.0422	0.0916	0.3406	0.6426
Snail	6.76	12.8	0.0053	0.0088	0.074	0.127	0.0422	0.0916	6.8815	13.0274
Infaunal invertebrate	0.12	0.23	0.010	0.017	0.15	0.26	0.042	0.092	0.32	0.60
Aquatic plant	0.478	0.908	0.0051	0.0086	0.074	0.127	0.0422	0.0916	0.5993	1.1352
Riparian plant	0.261	0.495	0.0056	0.0093	0.074	0.127	0.0422	0.0916	0.3828	0.7229
Water shrew	0.600	1.14	0.0052	0.0087	0.074	0.127	0.0422	0.0916	0.7214	1.3673
Great blue heron	0.008	0.015	0.0067	0.0111	0.069	0.119	0.0422	0.0916	0.1259	0.2367

* Estimated from gross β measurements in environmental media.

TABLE 3.14: METAL CONCENTRATIONS AND DOSES TO BIOTA IN PERCH LAKE INLETS 1 AND 2

Location and Metal	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron
Inlet 1				
Hg	<6.35E-5	0.099[2]	0.044	0.012
Cu	0.0325	20.4[1]	21.9	1.24
Cu	0.0108	6.77[2]	7.28	0.41
Cr	0.0035	2.35[1]	0.261	0.133
Cr	<0.00596	34.5[2]	0.801	0.323
Fe	0.80	44,001[1]	2,220	167
Fe	0.185	18,100[2]	606	63.6
Pb	0.00072	1.29[1]	0.063	0.043
Pb	<0.0071	1.79[2]	0.496	0.389
Inlet 2				
Cu	0.006	3.77[1]	4.05	0.228
Cu	<0.00652	25.5[2]	4.65	0.315
Cr	0.0025[3]	1.68[1]	0.187	0.095
Cr	<0.00596	49.4[2]	0.975	0.370
Fe	1.24	68,202[1]	3,441	259
Fe	1.84	23,300[2]	4,197	140
Pb	0.0011	2.04[1]	0.100	0.068
Pb	<0.0071	8.15[2]	0.570	0.409

[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Measured sediment value (Environment Canada, 2001).
[3] Below upper limit of background (Section 3.2).

TABLE 3.15: RADIONUCLIDE CONCENTRATIONS IN PERCH CREEK WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L) Mean	Water Concentration[1] (Bq/L) Mean+2S
Gross β/2*	102	2.83	5.8
Cesium-137	8	<0.01	0.0165
Cobalt-60	8	<0.0101	0.0179
Tritium (HTO)	24	11,100	18,100
Radionuclide		**Sediment Concentration[2] (Bq/kg FW) Mean**	**Sediment Concentration[2] (Bq/kg FW) Mean+2S**
Gross β/2*		705	1,444
Cesium-137		30.4	50.2
Cobalt-60		39.6	70.1
Tritium (HTO)		6,660	10,860

[1] AECL monitoring data for Perch Creek Weir (2000-2001).
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.16: RADIATION DOSES TO PERCH CREEK BIOTA

Receptor Type	Radiation Dose (µGy/h)									
	Sr-90*		Cs-137		Co-60		HTO		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max
Small fish	0.731	1.498	0.0054	0.0089	0.028	0.050	0.036	0.059	0.8004	1.6159
Green frog	0.224	0.458	0.0056	0.0093	0.028	0.050	0.036	0.059	0.2936	0.5763
Snail	6.92	14.19	0.0055	0.0091	0.028	0.050	0.036	0.059	6.9895	14.3081
Infaunal invertebrate	0.12	0.25	0.036	0.043	0.057	0.10	0.036	0.059	0.25	0.45
Aquatic plant	0.489	1.00	0.0054	0.0089	0.028	0.050	0.036	0.059	0.5584	1.1179
Riparian plant	0.267	0.547	0.0052	0.0086	0.028	0.050	0.036	0.059	0.3362	0.6646
Water shrew	0.615	1.259	0.0054	0.0090	0.028	0.050	0.036	0.059	0.6844	1.377
Great blue heron	0.0083	0.017	0.0070	0.0115	0.027	0.047	0.036	0.059	0.0783	0.1345

* Estimated from gross β measurements in environmental media.

TABLE 3.17: METAL AND PAH CONCENTRATIONS AND DOSES TO PERCH CREEK BIOTA

Metal or PAH	Exposure Concentration: Water (mg/L)	Exposure Concentration: Sediment (mg/kg DW)	Dose to Biota (mg/kg•day): Water Shrew	Dose to Biota (mg/kg•day): Great Blue Heron
Cu	0.0016	(1.01)[1]	1.08	0.061
Cu	0.0153	10.8[2]	10.33	0.585
Cr	0.0019[3]	(1.28)[1]	0.142	0.072
Cr	<0.0060	46.0[2]	0.936	0.359
Fe	1.72[4]	(94,602)[1]	3,669	359.8
Fe	2.55[5]	(140,254)	5,440	533.4
Fe	1.54	31,400[2]	3,285	154.3
Al	0.085[3,4]	-	-	-
Al	0.124[3,5]	3,570[6]	-	-
Naphthalene	<0.001	0.07	0.015	-
Phenanthrene	<0.00052	0.16	0.034	-
Fluoranthene	<0.00044	0.14	0.027	-
Pyrene	<0.00039	0.09	0.017	-
Chrysene	<0.00064	0.07	-	-
Benzo(a)pyrene	<0.00065	0.14	0.016	-

[1] Estimated sediment value (water value from AECL).
[2] Measured sediment value (Environment Canada, 2001).
[3] Below upper limit of background (Section 3.2).
[4] Mean of AECL monitoring data (2000-2001).
[5] Mean plus two standard deviations (2S).
[6] Measured sediment value (CH2M Hill, 2001).

TABLE 3.18: RADIONUCLIDE CONCENTRATIONS IN SOUTH SWAMP WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Mean+2S
Gross β/2*	102	2,235	20,650
Cesium-137	8	<0.0575	0.143
Cobalt-60	8	0.325	1.55
Tritium (HTO)	24	64,800	252,000
Radionuclide		**Sediment Concentration[2] (Bq/kg FW)**	
		Mean	Mean+2S
Gross β/2*		556,515	5.14E+6
Cesium-137		174.8	434.8
Cobalt-60		1,272.9	6,070.7
Tritium (HTO)		38,880	151,200

[1] AECL monitoring data for South Swamp Weir (2000-2001).
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.19: RADIATION DOSES TO SOUTH SWAMP BIOTA

Receptor Type	Radiation Dose (μGy/h)									
	Sr-90*		Cs-137		Co-60		HTO		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max
Green frog	176.7	1,632	0.032	0.080	0.908	4.33	0.212	0.824	177.852	1637.23
Snail	5,468	50,525	0.032	0.079	0.908	4.33	0.212	0.824	5469.15	50530.2
Infaunal invertebrate	9.8	90	0.062	0.15	0.18	0.87	0.21	0.82	10.4	91.8
Aquatic plant	386.3	3,570	0.031	0.077	0.908	4.33	0.212	0.824	387.451	3575.23
Riparian plant	210.9	1,948	0.030	0.075	0.908	4.33	0.212	0.824	212.05	1953.23
Water shrew	485.3	4,484	0.031	0.078	0.908	4.33	0.212	0.824	486.451	4489.23
Great blue heron	6.59	60.91	0.040	0.099	0.853	4.07	0.212	0.824	7.695	65.903

* Estimated from gross β measurements in environmental media.

TABLE 3.20: METAL CONCENTRATIONS AND DOSES TO SOUTH SWAMP BIOTA

Metal	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron
Hg	<6.35E-5	(0.00645)*	0.042	0.011
Cu	0.0117	(7.35)[1]	7.89	0.445
Cu	0.00926	22.5[2]	6.44	0.404
Pb	0.00101	(1.8)[1]	0.089	0.060
Pb	0.00825	22.5[2]	0.815	0.516

* Estimated sediment value (water value a detection limit, Environment Canada, 2001).
[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Measured sediment value (Environment Canada, 2001).

TABLE 3.21: RADIONUCLIDE CONCENTRATIONS IN EAST SWAMP WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L) Mean	Water Concentration[1] (Bq/L) Mean+2S
Gross β/2*	102	197.5	470
Cesium-137	24	0.471	0.951
Cobalt-60	24	2.62	5.28
Tritium (HTO)	102	27,300	93,000
Radionuclide		**Sediment Concentration[2] (Bq/kg FW) Mean**	**Sediment Concentration[2] (Bq/kg FW) Mean+2S**
Gross β/2*		49,178	117,030
Cesium-137		1,432.1	2,891.6
Cobalt-60		10,261	20,679
Tritium (HTO)		16,380	55,800

[1] AECL monitoring data for East Swamp Weir (2000-2001).
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.22: RADIATION DOSES TO EAST SWAMP BIOTA

	Radiation Dose (μGy/h)									
	Sr-90*		Cs-137		Co-60		HTO		Total	
Receptor Type	mean	max	mean	max	mean	max	mean	max	mean	max
Small fish	51.0	121.4	0.255	0.515	7.32	14.76	0.089	0.304	58.664	136.979
Green frog	15.6	37.1	0.264	0.534	7.32	14.76	0.089	0.304	23.273	52.698
Snail	483.2	1,150	0.260	0.525	7.32	14.76	0.089	0.304	490.869	1165.59
Infaunal invertebrate	0.82	19.5	0.51	1.02	15	30	0.089	0.30	16.4	50.8
Aquatic plant	34.1	81.2	0.253	0.511	7.32	14.76	0.089	0.304	41.762	96.775
Riparian plant	18.6	44.3	0.245	0.496	7.32	14.76	0.089	0.304	26.254	59.86
Water shrew	42.9	102.1	0.256	0.517	7.32	14.76	0.089	0.304	50.565	117.681
Great blue heron	0.582	1.39	0.328	0.662	6.87	13.85	0.089	0.304	7.869	16.206

* Estimated from gross β measurements in environmental media.

TABLE 3.23: METAL CONCENTRATIONS AND DOSES TO EAST SWAMP BIOTA

Metal	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron
Hg	<6.35E-5	(0.00645)*	0.042	0.011
Cu	0.0049	(3.08)[1]	3.30	0.186
Cu	0.00933	5.86[2]	6.29	0.354
Pb	0.00084	(1.50)[1]	0.074	0.050
Pb	<0.0071	12.68[2]	0.623	0.423

* Estimated sediment value (water value a detection limit, Environment Canada, 2001).
[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Estimated sediment value (water value from Environment Canada, 2001).

TABLE 3.24: RADIONUCLIDE CONCENTRATIONS IN WEST SWAMP WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Upper
Gross β/2*	-	30	-
Cesium-137	-	-	-
Cobalt-60	-	-	-
Tritium (HTO)	-	2,000	-
Radionuclide		**Sediment Concentration[2] (Bq/kg FW)**	
		Mean	**Upper**
Sr-90		306,538	640,000
Cesium-137		-	-
Cobalt-60		-	-
Tritium (HTO)		1,600	-

[1] AECL monitoring data for West Swamp (Niemi *et al.*, 1999).
[2] HTO from K_d (Table 3.1), porosity = 0.8, solids density = 1; Sr-90 from Killey *et al.* (1988) and Doyle (2001).
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.25: RADIATION DOSES TO WEST SWAMP BIOTA

Receptor Type	Radiation Dose (μGy/h)					
	Sr-90*		HTO		Total	
	Mean	Max	Mean	Max	Mean	Max
Large fish	18.5	18.5	0.0065	-	18.51	18.51
Green frog	2.66	3.02	0.0065	-	2.67	3.03
Snail	73.7	74.1	0.0065	-	73.71	74.11
Infaunal invertebrate	13	28	0.0065	-	13	28
Aquatic plant	5.48	5.84	0.0065	-	5.49	5.85
Riparian plant	46.1	96.3	0.0065	-	46.11	96.31
Water shrew	7.07	7.74	0.0065	-	7.08	7.75
Great blue heron	0.19	0.32	0.0065	-	0.20	0.33
Muskrat	1.91	2.70	0.0065	-	1.92	2.71
Mallard	0.18	0.26	0.0065	-	0.19	0.27
Painted turtle	0.58	0.63	0.0065	-	0.59	0.65

* Estimated from gross β measurements in environmental media.

TABLE 3.26: RADIONUCLIDE CONCENTRATIONS IN MAIN STREAM WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L) Mean	Mean+2S
Gross β/2*	24	0.165	0.41
Cesium-137	24	0.0045	0.0054
Cobalt-60	24	0.0105	0.0125
Tritium (HTO)	24	1,080	2,780
Radionuclide		**Sediment Concentration[2] (Bq/kg FW) Mean**	**Mean+2S**
Gross β/2*		40.96	102.46
Cesium-137		13.65	16.48
Cobalt-60		41.12	48.96
Tritium (HTO)		648	1,668

[1] AECL monitoring data for Main Stream Weir (2000-2001).
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.27: RADIATION DOSES TO MAIN STREAM BIOTA

Receptor Type	Radiation Dose (μGy/h)									
	Sr-90*		Cs-137		Co-60		HTO		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max
Small fish	0.042	0.106	0.0024	0.0029	0.0293	0.0349	0.0035	0.0091	0.0772	0.1529
Green frog	0.013	0.033	0.0025	0.0030	0.0293	0.0349	0.0035	0.0091	0.0483	0.08
Snail	0.402	1.01	0.0025	0.0030	0.0293	0.0349	0.0035	0.0091	0.4373	1.057
Infaunal invertebrate	0.0072	0.018	0.0048	0.0058	0.059	0.070	0.0035	0.0091	0.075	0.103
Aquatic plant	0.028	0.071	0.0024	0.0029	0.0293	0.0349	0.0035	0.0091	0.0632	0.1179
Riparian plant	0.016	0.039	0.0023	0.0028	0.0293	0.0349	0.0035	0.0091	0.0511	0.0858
Water shrew	0.036	0.089	0.0024	0.0029	0.0293	0.0349	0.0035	0.0091	0.0712	0.1359
Great blue heron	0.0005	0.0012	0.0031	0.0038	0.0276	0.0328	0.0035	0.0091	0.0347	0.0469

* Estimated from gross β measurements in environmental media.

TABLE 3.28: METAL CONCENTRATIONS AND DOSES TO MAIN STREAM BIOTA

Metal	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron
Hg	<6.35E-5	(0.00645)*	0.086	0.019
Cu	0.007	(4.40)[1]	4.98	0.311
Cu	0.00698	1.74[2]	4.68	0.257
Cr	0.0019[3]	(1.28)[1]	0.146	0.073
Cr	<0.00596	35.3	1.076	0.370
Fe	0.56[3]	(30,800)[1]	1,554	117.2
Fe	1.01[3]	20,300	2,391	100.3
Pb	0.00228	(4.07)[1]	0.466	0.181
Pb	0.0247	20.8	2.156	1.443

* Estimated sediment value (water value a detection limit, Environment Canada, 2001).
[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Measured sediment value (Environment Canada, 2001).
[3] Below upper limit of background (Section 3.2).

TABLE 3.29: RADIONUCLIDE CONCENTRATIONS IN DUKE SWAMP WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Mean+2S
Gross β/2*	23	0.128	0.275
Cesium-137	16	<0.0091	0.0242
Cobalt-60	16	0.0252	0.163
Tritium (HTO)	23	53,100	71,200
Carbon-14	-	6	-
Radionuclide		**Sediment Concentration[2] (Bq/kg FW)**	
		Mean	Mean+2S
Gross β/2*		31.87	68.35
Cesium-137		27.67	73.58
Cobalt-60		98.7	638.4
Tritium (HTO)		31,860	42,720
Carbon-14		80	-

[1] AECL monitoring data for Duke Swamp Weir (2000-2001). C-14 from Killey *et al.* (1998).
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1. C-14 from DW value.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.30: RADIATION DOSES TO DUKE SWAMP BIOTA

	Radiation Dose (µGy/h)											
	Sr-90*		Cs-137		Co-60		HTO		C-14		Total	
Receptor Type	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max
Green frog	0.010	0.022	0.0051	0.0136	0.070	0.456	0.174	0.233	1.84	-	2.10	2.56
Snail	0.313	0.672	0.0050	0.0134	0.070	0.456	0.174	0.233	3.69	-	4.25	5.06
Infaunal invertebrate	0.0056	0.012	0.013	0.036	0.14	0.92	0.17	0.23	1.8	-	2.13	3.00
Aquatic plant	0.022	0.047	0.0049	0.0130	0.070	0.456	0.174	0.233	1.84	-	2.11	2.59
Riparian plant	0.012	0.026	0.0047	0.0126	0.070	0.456	0.174	0.233	0.071	-	0.33	0.798
Water shrew	0.028	0.060	0.0050	0.0132	0.070	0.456	0.174	0.233	3.69	-	3.97	4.45
Great blue heron	0.00038	0.00081	0.0063	0.0169	0.0661	0.428	0.174	0.233	1.84	-	2.09	2.52

* Estimated from gross β measurements in environmental media.

TABLE 3.31: METAL CONCENTRATIONS AND DOSES TO DUKE SWAMP BIOTA

Metal	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron
Hg	<6.35E-5	(0.00645)*	0.042	0.011
Cu	0.0038[3]	(2.39)[1]	2.56	0.144
Cu	0.0159	34.8[2]	11.0	0.682
Cr	0.0002[3]	(0.13)[1]	0.015	0.0076
Cr	<0.00596	27.7[2]	0.722	0.302
Fe	1.26[4]	69,302	3,497	263.6
Fe	1.76[5]	96,803	4,885	368.2
Fe	0.755[3]	181,000[2]	3,722	597.0
Pb	0.00023[3]	(0.41)[1]	0.020	0.014
Pb	<0.0071	49.2[2]	1.05	0.538
Al	0.0635[3]	2,490[6]	-	-
Cd	0.00004[3]	(0.02)[1]	-	0.0015

* Estimated sediment value (water value a detection limit, Environment Canada, 2001).
[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Measured sediment value (Environment Canada, 2001).
[3] Below upper limit of background (Section 3.2).
[4] Mean of AECL monitoring data (2000-2001).
[5] Mean plus two standard deviations (2S).
[6] Measured sediment value (CH2M Hill, 2001).

TABLE 3.32: RADIONUCLIDE CONCENTRATIONS IN BULK STORAGE SWAMP WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Mean+2S
Gross β/2*	24	0.146	0.855
Cesium-137	16	<0.0078	0.0238
Cobalt-60	16	<0.0076	0.0153
Tritium (HTO)	24	1,220	1,500
Carbon-14	-	14	-
Radionuclide		Sediment Concentration[2] (Bq/kg FW)	
		Mean	Mean+2S
Gross β/2*		36.2	213
Cesium-137		23.7	72.4
Cobalt-60		29.8	59.9
Tritium (HTO)		732	900
Carbon-14		187	-

1 AECL monitoring data for Bulk Storage Swamp Weir (2000-2001). C-14 from Killey *et al.* (1998).
2 Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1.
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.33: RADIATION DOSES TO BULK STORAGE SWAMP BIOTA

Receptor Type	Radiation Dose (μGy/h)											
	Sr-90*		Cs-137		Co-60		HTO		C-14		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max
Green frog	0.012	0.068	0.0044	0.0134	0.021	0.043	0.004	0.005	4.30	-	4.34	4.43
Snail	0.356	2.09	0.0043	0.0131	0.021	0.043	0.004	0.005	8.61	-	8.99	10.76
Infaunal invertebrate	0.0064	0.037	0.0084	0.026	0.043	0.086	0.0040	0.0049	4.3	-	4.36	4.45
Aquatic plant	0.025	0.148	0.0042	0.0128	0.021	0.043	0.004	0.005	4.30	-	4.35	4.51
Riparian plant	0.014	0.081	0.0041	0.0124	0.021	0.043	0.004	0.005	0.166	-	0.209	0.307
Water shrew	0.032	0.186	0.0042	0.0130	0.021	0.043	0.004	0.005	8.61	-	8.67	8.86
Great blue heron	0.00043	0.0025	0.0054	0.0166	0.020	0.040	0.009	0.011	4.30	-	4.33	4.37

* Estimated from gross β measurements in environmental media.

TABLE 3.34: METAL CONCENTRATIONS AND DOSES TO BULK STORAGE SWAMP BIOTA

Metal	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron
Hg	<6.35E-5	(0.00645)*	0.042	0.011
Cu	0.003[3]	(1.89)[1]	2.02	0.114
Cu	0.0285	3.32[2]	19.0	1.04
Cr	0.0038	(2.55)[1]	0.284	0.145
Cr	<0.00596	44.6[2]	0.919	0.355
Fe	1.47	(80,852)[1]	4,079	307.5
Fe	1.14	25,200[2]	2,726	120.4
Pb	0.00032	(0.57)[1]	0.028	0.019
Pb	0.0135	6.93[2]	0.984	0.751
As	0.0006	(1.14)[1]	0.020	0.005
As	0.00012	0.177[2]	0.003	0.001

* Estimated sediment value (water value a detection limit, Environment Canada, 2001).
[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Measured sediment value (Environment Canada, 2001).
[3] Below upper limit of background (Section 3.2).

TABLE 3.35: RADIONUCLIDE CONCENTRATIONS IN LOWER BASS LAKE WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Mean+2S
Gross β/2*	24	0.271	0.451
Cesium-137	16	<0.0052	0.0081
Cobalt-60	16	<0.0061	0.0102
Tritium (HTO)	24	7,270	10,100
Carbon-14	1	0.1	-
Radionuclide		**Sediment Concentration[2] (Bq/kg FW)**	
		Mean	Mean+2S
Gross β/2*		67.5	112.3
Cesium-137		15.8	24.6
Cobalt-60		23.9	39.9
Tritium (HTO)		4,422	6,060
Carbon-14		<104	-

[1] AECL monitoring data for Lower Bass Lake (2000-2001). C-14 from CH2M Hill (2001).

[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1. C-14 from CH2M Hill (2001).

* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.36: RADIATION DOSES TO LOWER BASS LAKE BIOTA

Receptor Type	Radiation Dose (µGy/h)											
	Sr-90*		Cs-137		Co-60		HTO		C-14		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max
Large fish	0.167	0.278	0.0027	0.0042	0.016	0.027	0.024	0.033	0.031	-	0.2407	0.373
Green frog	0.021	0.036	0.0029	0.0046	0.017	0.029	0.024	0.033	0.031	-	0.0959	0.134
Snail	0.663	1.103	0.0029	0.0045	0.017	0.029	0.024	0.033	0.061	-	0.7679	1.23
Infaunal invertebrate	0.0059	0.0099	0.0056	0.0087	0.034	0.057	0.024	0.033	0.031	-	0.10	0.14
Aquatic plant	0.047	0.078	0.0028	0.0044	0.017	0.029	0.024	0.033	0.031	-	0.1218	0.175
Riparian plant	0.026	0.043	0.0027	0.0042	0.017	0.029	0.024	0.033	0.093	-	0.0697	0.202
Water shrew	0.059	0.098	0.0028	0.0044	0.017	0.029	0.024	0.033	0.061	-	0.1638	0.225
Great blue heron	0.0008	0.0013	0.0036	0.0056	0.016	0.029	0.024	0.033	0.031	-	0.0754	0.100

* Estimated from gross β measurements in environmental media.

TABLE 3.37: METAL CONCENTRATIONS AND DOSES TO LOWER BASS LAKE BIOTA

Metal	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron
Cu	0.0038	(2.39)[1]	2.56	0.144
Cu	0.0323	5.23[2]	21.6	1.18
Cr	0.0002	(0.134)[1]	0.015	0.008
Cr	0.0061	41.9[2]	0.897	0.351
Fe	0.56	(30,801)[1]	1,554	117.1
Fe	0.4295	32,100[2]	1,291	116.5
Pb	0.00023	(0.411)[1]	0.020	0.014
Pb	0.0123	4.17[2]	0.872	0.677
Al	0.0455	6,280[4]	-	-

[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Measured sediment value (Environment Canada, 2001).
[3] Below upper limit of background (Section 3.2).
[4] Measured sediment value (CH2M Hill, 2001).

TABLE 3.38: RADIONUCLIDE CONCENTRATIONS IN MASKINONGE LAKE WATER AND SEDIMENTS

Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Mean+2S
Gross β/2*	24	0.074	0.162
Cesium-137	16	<0.00584	-
Cobalt-60	16	<0.00593	-
Tritium (HTO)	24	1,030	1,380
Carbon-14	1	0.1	-

Radionuclide		Sediment Concentration[2] (Bq/kg FW)	
		Mean	Mean+2S
Gross β/2*		18.4	40.3
Cesium-137		<17.8	-
Cobalt-60		<23.2	-
Tritium (HTO)		618	828
Carbon-14		132	-

[1] AECL monitoring data for Maskinonge Lake outlet (2000-2001). C-14 from CH2M Hill (2001).

[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 1. C-14 from CH2M Hill (2001).

* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.39: RADIATION DOSES TO MASKINONGE LAKE BIOTA

Receptor Type	Radiation Dose (μGy/h)											
	Sr-90*		Cs-137		Co-60		HTO		C-14		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max
Large fish	0.046	0.100	0.0031	-	0.0156	-	0.0034	0.0045	0.031	-	0.099	0.154
Green frog	0.0058	0.0128	0.0033	-	0.0166	-	0.0034	0.0045	0.031	-	0.060	0.068
Snail	0.181	0.396	0.0032	-	0.0166	-	0.0034	0.0045	0.061	-	0.265	0.481
Infaunal invertebrate	0.032	0.0071	0.0063	-	0.033	-	0.0034	0.0045	0.031	-	0.077	0.082
Aquatic plant	0.0128	0.028	0.0031	-	0.0166	-	0.0034	0.0045	0.031	-	0.067	0.083
Riparian plant	0.0070	0.015	0.0030	-	0.0166	-	0.0034	0.0045	0.118	-	0.148	0.157
Water shrew	0.016	0.035	0.0032	-	0.0166	-	0.0034	0.0045	0.061	-	0.100	0.120
Great blue heron	0.0002	0.0005	0.0041	-	0.0156	-	0.0034	0.0045	0.031	-	0.054	0.056
Muskrat	0.025	0.054	0.0029	-	0.0156	-	0.0034	0.0045	0.031	-	0.078	0.108
Mallard	0.012	0.027	0.0032	-	0.0156	-	0.0034	0.0045	0.031	-	0.065	0.081
Painted turtle	0.012	0.027	0.0028	-	0.0156	-	0.0034	0.0045	0.046	-	0.080	0.096

* Estimated from gross β measurements in environmental media.

TABLE 3.40: METAL CONCENTRATIONS AND DOSES TO MASKINONGE LAKE BIOTA

Metal	Exposure Concentration		Dose to Biota (mg/kg•day)				
	Water (mg/L)	Sediment (mg/kg DW)	Water Shrew	Great Blue Heron	Muskrat	Mallard	Painted Turtle
Cu	0.0023[3]	(1.45)[1]	1.55	0.087	0.708	0.533	0.037
Cu	0.0148	28.9[2]	10.2	0.624	4.66	3.51	0.242
Cr	0.0031	(2.08)[1]	0.232	0.118	0.202	0.151	0.008
Cr	<0.00596	65.7[2]	1.17	0.422	0.717	0.537	0.032
Fe	0.086[3]	(4,730)[1]	238.7	17.98	51.32	38.67	4.16
Fe	0.432[3]	59,600[2]	1,617	203.2	448.2	337.9	30.8
Pb	0.000175[3]	(0.31)[1]	0.015	0.010	0.012	0.009	0.0005
Pb	<0.0378	111[2]	3.83	2.39	2.92	2.18	0.121
Cd	0.00007[3]	(0.03)[1]	-	0.003	-	-	-
Cd	<0.00398	0.97[2]	-	0.146	-	-	-
Al	0.04[3]	3,480[4]	-	-	-	-	-

[1] Estimated sediment value (water value from Yankovich *et al.*, 2002).
[2] Measured sediment value (Environment Canada, 2001).
[3] Below upper limit of background (Section 3.2).
[4] Measured sediment value (CH2M Hill, 2001).

TABLE 3.41: RADIONUCLIDE CONCENTRATIONS IN WATER AND SEDIMENTS OF RIVERFRONT STREAMS

Location and Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Mean+2S
Stream 1			
Gross β/2*	24	0.11	0.18
Tritium (HTO)	24	173	308
Stream 3			
Gross β/2	24	0.11	0.19
Tritium (HTO)	24	207	410
Stream 5			
Gross β/2	24	0.053	0.14
Tritium (HTO)	24	541	1,115
Stream 6			
Gross β/2	24	0.16	0.24
Tritium (HTO)	24	22,604	36,160
Location and Radionuclide		**Sediment Concentration[2] (Bq/kg FW)**	
		Mean	Mean+2S
Stream 1			
Gross β/2		40.6	69.5
Tritium (HTO)		65	115
Stream 3			
Gross β/2		40.8	74.4
Tritium (HTO)		78	154
Stream 5			
Gross β/2		20.4	2,000[3]
Tritium (HTO)		203	418
Stream 6			
Gross β/2		62.1	91.7
Tritium (HTO)		8,476	13,560

[1] AECL monitoring data for riverfront streams (2000-2001).
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 2.5.
[3] Grab sample collected by Environment Canada (2001).
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.42: RADIATION DOSES TO RIVERFRONT STREAM BIOTA

Location and Receptor Type	Radiation Dose (μGy/h)					
	Sr-90*		HTO		Total	
	Mean	Max	Mean	Max	Mean	Max
Stream 5						
Small fish	0.014	0.046	0.002	0.004	0.016	0.05
Green frog	0.004	0.021	0.002	0.004	0.006	0.025
Snail	0.128	0.342	0.002	0.004	0.13	0.346
Infaunal invertebrate	0.0033	0.0084	0.002	0.004	0.005	0.012
Aquatic plant	0.009	0.034	0.002	0.004	0.011	0.038
Riparian plant	0.005	0.489	0.002	0.004	0.007	0.493
Water shrew	0.011	0.043	0.002	0.004	0.013	0.047
Great blue heron	0.0002	0.002	0.002	0.004	0.0022	0.006
Stream 6						
Small fish	0.041	0.061	0.074	0.118	0.115	0.179
Green frog	0.013	0.019	0.074	0.118	0.087	0.137
Snail	0.391	0.578	0.074	0.118	0.465	0.696
Infaunal invertebrate	0.0099	0.015	0.074	0.118	0.084	0.133
Aquatic plant	0.028	0.041	0.074	0.118	0.102	0.159
Riparian plant	0.015	0.022	0.074	0.118	0.089	0.14
Water shrew	0.035	0.051	0.074	0.118	0.109	0.169
Great blue heron	0.0005	0.0007	0.074	0.118	0.0745	0.1187

* Estimated from gross β measurements in environmental media.

TABLE 3.43: NON-RADIONUCLIDE CONCENTRATIONS AND DOSES TO BIOTA IN RIVERFRONT STREAMS

Chemical	Exposure Concentration		Dose to Biota (mg/kg•day)	
	Water (mg/L)	Sediment[1] (mg/kg DW)	Water Shrew	Great Blue Heron
Stream 3				
Cu	0.0161[6]	10.1	10.86	0.612
Cu	0.0295[7]	18.5	19.89	1.12
Fe	0.634[5,6]	34,870	1,759	132.6
Fe	1.93[7]	106,151	5,356	403.7
Al	0.34[6]	-	-	-
Al	1.01[7]	-	-	-
Chloroform	0.0118	-	0.0032	0.0006
Chloroform	0.0344	-	0.0094	0.0016
Chlorine species	1.06[4]	-	0.0013	0.0496
Stream 5				
Cu	0.0038[5,6]	2.38	2.56	0.144
Cu	0.0087[7]	5.46	5.87	0.331
Cu	0.026	10.8[2]	17.4	0.971
Pb	0.0563	<7.1[2]	3.85	3.06
Cr	<0.00596	46[2]	0.936	0.359
Al	0.17[6]	-	-	-
Al	0.357[7]	-	-	-
Al	0.086[5]	4,440[3]	-	-

[1] Sediment values are estimates unless otherwise indicated.
[2] Measured sediment value (Environment Canada, 2001).
[3] Measured sediment value (CH2M Hill, 2001).
[4] Estimated from chlorine use, assuming all in water as reactive species.
[5] Below upper limit of background (Section 3.2).
[6] Mean of AECL monitoring data (2000-2001).
[7] Mean plus two standard deviations (2S).

TABLE 3.44: RADIONUCLIDE CONCENTRATIONS IN WATER AND SEDIMENTS OF THE NEARSHORE OTTAWA RIVER

Location and Radionuclide	n	Water Concentration[1] (Bq/L)	
		Mean	Mean+2S
Powerhouse Drain/500[4]			
Gross β/2*	24	0.00021	0.00067
Tritium (HTO)	24	7.75	24.0
Storm 4/15			
Gross β/2	24	0.086	0.172
Tritium (HTO)	24	368	744
Stream 6/5,000			
Gross β/2	24	0.000032	0.000047
Tritium (HTO)	24	4.52	7.23
Point aux Baptime			
Gross β/2	24	0.232	0.905
Tritium (HTO)	24	281	901
Riverfront Wells/5,000			
Gross β/2	54	0.046	-
Tritium (HTO)	54	172	-

Location and Radionuclide		Sediment Concentration[2] (Bq/kg FW)	
		Mean	Mean+2S
Powerhouse Drain/500			
Gross β/2		0.083	0.26
Tritium (HTO)		2.91	9.01
Storm 4/15			
Gross β/2		33.5	66.8
Tritium (HTO)		138	279
Stream 6/5,000			
Gross β/2		0.012	0.018
Tritium (HTO)		1.70	2.71

TABLE 3.44: RADIONUCLIDE CONCENTRATIONS IN WATER AND SEDIMENTS OF THE NEARSHORE OTTAWA RIVER

Location and Radionuclide		Sediment Concentration[2] (Bq/kg FW)	
		Mean	Mean+2S
Pointe aux Baptime			
Gross β/2		90	351
Cesium-137		34.4[3]	-
Cobalt-60		2.25[3]	-
Tritium (HTO)		105	337
Riverfront Wells/5,000			
Gross β/2		17.8	-
Tritium (HTO)		64.5	-

[1] AECL monitoring data for discharges (2000-2001) over dilution factor.
[2] Estimated from K_d (Table 3.1), porosity = 0.6, solids density = 2.5.
[3] Estimate from measured values of Cs-137 and Co-60 in beach sediment (dry weight) between low and high water. The corresponding estimate for K-40 is 504 Bq/kg FW.
[4] Dilution factor based on plume modelling (Appendix 4).
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.45: RADIATION DOSES TO NEARSHORE RIVER BIOTA

Location and Receptor Type	Radiation Dose (µGy/h)					
	Sr-90*		HTO		Total[1]	
	Mean	Max	Mean	Max	Mean	Max
Powerhouse Drain						
Large fish	1.3E-4	4.1E-4	2.5E-5	7.9E-5	1.55E-04	4.89E-04
Green frog	1.7E-5	5.4E-5	2.5E-5	7.9E-5	4.20E-05	1.33E-04
Snail	5.2E-4	1.6E-3	2.5E-5	7.9E-5	5.45E-04	1.68E-03
Infaunal invertebrate	1.3E-5	4.2E-5	2.5E-5	7.9E-5	3.8E-5	1.2E-4
Aquatic plant	3.7E-5	1.1E-4	2.5E-5	7.9E-5	6.20E-05	1.89E-04
Riparian plant	2.0E-5	6.4E-5	2.5E-5	7.9E-5	4.50E-05	1.43E-04
Water shrew	4.7E-5	1.5E-4	2.5E-5	7.9E-5	7.20E-05	2.29E-04
Great blue heron	6.0E-7	2.0E-6	2.5E-5	7.9E-5	2.56E-05	8.10E-05
Muskrat	8.7E-6	2.8E-5	2.5E-5	7.9E-5	3.37E-05	1.07E-04
Storm 4 Area						
Large fish	0.053	0.106	0.0012	0.0024	0.0542	0.1080
Green frog	0.007	0.014	0.0012	0.0024	0.0082	0.0164
Snail	0.211	0.421	0.0012	0.0024	0.212	0.423
Infaunal invertebrate	0.0054	0.011	0.0012	0.0024	0.0066	0.013
Aquatic plant	0.015	0.030	0.0012	0.0024	0.0162	0.0324
Riparian plant	0.008	0.016	0.0012	0.0024	0.0092	0.0184
Water shrew	0.019	0.037	0.0012	0.0024	0.0202	0.0394
Great blue heron	0.0003	0.0005	0.0012	0.0024	0.0015	0.0029
Muskrat	0.004	0.007	0.0012	0.0024	0.0052	0.0094
Pointe aux Baptime						
Large fish	0.143	0.557	0.0009	0.0029	0.159	0.567
Green frog	0.019	0.072	0.0009	0.0029	0.027	0.084
Snail	0.568	2.21	0.0009	0.0029	0.577	2.23
Infaunal invertebrate	0.014	0.056	0.0009	0.0029	0.024	0.059
Aquatic plant	0.040	0.157	0.0009	0.0029	0.050	0.168
Riparian plant	0.022	0.086	0.0009	0.0029	0.030	0.096
Water shrew	0.051	0.197	0.0009	0.0029	0.059	0.208
Great blue heron	0.0007	0.0027	0.0009	0.0029	0.010	0.014
Muskrat	0.009	0.037	0.0009	0.0029	0.018	0.047

[1] Total dose includes Cs-137 and Co-60 components at Pointe aux Baptime.
* Estimated from gross β measurements in environmental media.

TABLE 3.46: NON-RADIONUCLIDE CONCENTRATIONS AND DOSES TO BIOTA IN THE NEARSHORE ZONE OF THE RIVER

Chemical	Exposure Concentration		Doses to Biota (mg/kg•day)		
	Water (mg/L)	Sediment[1] (mg/kg DW)	Water Shrew	Great Blue Heron	Muskrat
Stream 3/15					
Cu	0.00105[4]	0.66[3]	0.706	0.040	0.322
Cu	0.00197[5]	1.23[3]	1.33	0.075	0.606
Fe	0.04227[4]	2,324	117	8.84	25.2
Fe	0.12847[5]	7,065	356	26.9	76.7
Al	0.02267[4]	-	-	-	-
Al	0.06733[5]	-	-	-	-
Chloroform	0.00079	0.0011	0.00022	0.00004	0.00079
Chloroform	0.00229	0.0032	0.00065	0.00011	0.00229
Chlorine species	0.071[2]	0.042	0.019	0.003	0.070
Storm 4/15					
Cu	0.00117[4]	0.73[3]	0.787	0.044	0.359
Cu	0.0035[5]	2.20[3]	2.360	0.133	1.077
Al	0.014[4]	-	-	-	-
Al	0.020[5]	-	-	-	-
Chloroform	0.00167[4]	0.0023	0.00047	0.00008	0.00167
Chloroform	0.00407[5]	0.0056	0.00115	0.00020	0.00407
Pointe aux Baptime					
Cu	0.0052	3.26[3]	3.506	0.198	1.601
Pb	0.00053	0.95[3]	0.047	0.032	0.038
Cr	0.0022	1.48[3]	0.164	0.084	0.144
Fe	0.271	14,905	752	56.7	162
Cd	0.00009	0.04[3]	-	0.0034	-
Al	0.12	-	-	-	-
Boat Launch					
Cu	0.0078	1.48	5.259	0.296	2.402
Pb	0.00067	1.20	0.059	0.040	0.048
Cr	0.0022	1.48	0.164	0.084	0.144
Fe	0.152	8,360	422	31.8	90.7
Cd	0.00007	0.03	-	0.003	-
Al	0.09	-	-	-	-

[1] Sediment values are estimates.
[2] Estimated from chlorine use, assuming all in water as reactive species.
[3] Below upper limit of background (Section 3.2).
[4] Mean of AECL monitoring data (2000-2001).
[5] Mean plus two standard deviations (2S).

TABLE 3.47: RADIONUCLIDE CONCENTRATIONS IN WATER AND SEDIMENTS OF THE OFFSHORE OTTAWA RIVER

Location and Radionuclide	n	Water Concentration[1] (Bq/L) Mean	Mean+2S
Sanitary Sewer/1,500[5]			
Gross β/2*	24	0.0003	0.0007
Tritium (HTO)	24	2.1	9.7
Process Sewer/10			
Strontium-90	24	0.0148	0.0961
Cesium-137	24	0.0156	0.0707
Cobalt-60	24	0.0124	0.0590
Tritium (HTO)	24	100	227
Phosphorus-32	24	0.0177	0.0877

Location and Radionuclide	Sediment Concentration[2] (Bq/kg FW)			
	Partition (mean)	Partition (mean+2S)	Measured (typical)	Measured (upper)
Sanitary Sewer/1,500				
Gross β/2*	0.11	0.29	-	-
Tritium (HTO)	0.78	3.6	-	-
Process Sewer/10				
Strontium-90	5.75	37.3	1,995[3]	9,210
Cesium-137	74.1	336	6,916[3]	31,928
Cobalt-60	75.9	361	4,123[3]	19,034
Tritium (HTO)	37.5	85.1	11,000[4]	-
Phosphorus-32	1.0	5.0	-	-

[1] AECL monitoring data for discharges (2000-2001) over dilution factor.
[2] Partition estimates from K_d (Table 3.1), porosity = 0.6, solids density = 2.5.
[3] Estimate based on dry weight measurements (Lee and Hartwig, 2003).
[4] Estimate based on grab sample, fresh weight (Environment Canada, 2001).
[5] Dilution factor based on plume modelling (Appendix 4).
* Gross β divided by 2 to estimate Sr-90 without Y-90. Dose calculation includes Y-90.

TABLE 3.48: RADIATION DOSES TO OFFSHORE RIVER BIOTA

Location and Receptor Type	Radiation Dose[1] (μGy/h)											
	Sr-90*		Cs-137		Co-60		HTO		P-32		Total	
	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max
Sanitary Sewer/ 1,500												
Large fish	0.00017	0.00046	-	-	-	-	6.77E-6	3.17E-5	-	-	1.77E-04	4.92E-04
Small fish	0.00007	0.00019	-	-	-	-	6.77E-6	3.17E-5	-	-	7.68E-05	2.22E-04
Snail	0.00069	0.00182	-	-	-	-	6.77E-6	3.17E-5	-	-	6.97E-04	1.85E-03
Benthos	0.00002	0.00005	-	-	-	-	6.77E-6	3.17E-5	-	-	2.68E-05	8.17E-05
Process Sewer/10												
Large fish	0.0091	0.0592	0.6540	0.6577	1.725	1.7256	0.00033	0.00074	0.184	0.913	2.57E+00	3.36E+00
Small fish	0.0105	0.0314	0.7357	0.7371	1.8377	1.8378	0.00033	0.00074	0.184	0.913	2.77E+00	3.52E+00
Snail	0.0429	0.2417	0.7359	0.7878	1.8377	1.8378	0.00033	0.00074	0.071	0.0351	2.69E+00	2.90E+00
Benthos	0.1993[2]	0.9203[2]	0.7684[2]	3.548[2]	3.7052[2]	17.105[2]	0.00033	0.00074	0.062	0.307	4.74E+00	2.19E+01

[1] Based on modelled near-field water, with measured sediment if available (Table 3.44).
[2] Benthic tissues estimated from porewater based on measured sediment values.
* Estimated from gross β value for the sanitary sewer discharge area. Estimated from Sr-90 measurements for the process sewer discharge area.

TABLE 3.49: NON-RADIONUCLIDE EXPOSURE CONCENTRATIONS FOR BIOTA IN THE OFFSHORE ZONE OF THE RIVER

Location and Chemical	Exposure Concentration	
	Water (mg/L)	Sediment[1] (mg/kg DW)
Sanitary Sewer/1,500		
Cu	6.9E-6[6]	0.0043[4]
Cu	1.8E-5[7]	0.0114[4]
Pb	6.0E-6[6]	0.0107[4]
Pb	1.8E-5[7]	0.0316[4]
Cd	3.3E-7[6]	0.00014[4]
Cd	8.3E-7[7]	0.00034[4]
Pyrene	<3.0E-8[6]	3.9E-5
Pyrene	1.7E-7[7]	1.9E-4
Benzo(a)pyrene	<1.0E-7[6]	0.0010
Benzo(a)pyrene	1.7E-7[7]	0.0017
Chlorine species	0.0057[3]	-
Process Sewer/10		
Hg	3.0E-6[5,6]	0.00028
Hg	1.2E-5[5,7]	0.00117
Cu	0.0034[6]	2.11[4]
Cu	0.0091[7]	5.74[4]
Cu	<0.0065	56.7[2]
Pb	1.3E-6[6]	0.0024[4]
Pb	5.7E-6[7]	0.0102[4]
Pb	<0.0071	59.0[2]
Cd	1.3E-7[5,6]	5.0E-5[4]
Cd	6.0E-7[5,7]	2.3E-4[4]
Cd	<0.0029	1.48[2,4]
Cr	<0.0021	106[2]
As	0.00065	37.4[2]
Zn	0.0034	308[2]
Pyrene	<3.0E-7[5,6]	0.0003
Pyrene	1.2E-6[5,7]	0.0014
Benzo(a)pyrene	<2.0E-7[5,6]	0.0020
Benzo(a)pyrene	9.0E-7[5,7]	0.0091

[1] Sediment values are estimates unless otherwise indicated.
[2] Measured sediment value (Environment Canada, 2001).
[3] Estimated from chlorine use, assuming all in water as reactive species.
[4] Below upper limit of background (Section 3.2).
[5] Estimates based on measurements in the WTC (not process sewer).
[6] Source is mean of AECL monitoring data (2000-2001).
[7] Source is mean plus two standard deviations (2S).

TABLE 3.50a: CONCENTRATIONS OF RADIONUCLIDES IN AIR AND SOILS AT TERRESTRIAL RECEPTOR LOCATION WMA-A AT CRL

COPC	Comment	Air Concentration (Bq/m^3)	Gamma Field (μGy/h)	Soil Concentration (Bq/kg D.W.)	Dose (μGy/h) Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Ar-41		8.00E+01			3.50E-02	3.50E-02	3.50E-02	3.50E-02	3.50E-02
Noble Gas	BqMeV	2.00E+00			3.56E-04	3.56E-04	3.56E-04	3.56E-04	3.56E-04
I-131		2.40E-05			5.19E-08	1.01E-07	5.19E-08	5.20E-08	1.54E-11
HTO		1.50E+00			6.13E-04	6.13E-04	6.13E-04	6.13E-04	6.13E-04
Sr-90	Laundry Pit			6.00E+04	8.44E-01	3.86E+00	9.24E+00	3.48E+00	2.92E+00
Sr-90	Laundry Pit			7.00E+04	9.84E-01	4.51E+00	1.08E+01	4.06E+00	3.77E+00
Sr-90	Avg Area A*			5.50E+03	7.74E-02	3.54E-01	8.47E-01	3.19E-01	2.96E-01
Sr-90	Max Area A*			2.00E+04	2.81E-01	1.29E+00	3.08E+00	1.16E+00	1.08E+00
C-14		3.60E-03			6.41E-05	6.41E-05	6.41E-05	6.41E-05	6.41E-05
Co-60	Laundry Pit			1.80E+04	1.10E+01	2.20E+01	1.10E+01	1.10E+01	1.10E+01
Co-60	Laundry Pit			1.90E+04	1.16E+01	2.33E+01	1.16E+01	1.16E+01	1.16E+01
Cs-137	Laundry Pit			2.80E+05	4.07E+01	4.12E+01	4.08E+01	5.69E+01	3.13E+02
Cs-137	Laundry Pit			9.60E+05	1.40E+02	1.41E+02	1.40E+02	1.95E+02	1.07E+03
Gamma Field	Laundry Pit (avg)		5.60E-01		5.60E-01	5.60E-01	5.60E-01	5.60E-01	5.60E-01
Gamma Field	Laundry Pit (max)		1.80E+00		1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00
Gamma Field	Area A (avg)		3.00E-01		3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Gamma Field	Area A (max)		1.00E+00		1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Gamma Field	Reactor Pit 1 (avg)		3.00E-01		3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Gamma Field	Reactor Pit 1 (max)		5.60E-01		5.60E-01	5.60E-01	5.60E-01	5.60E-01	5.60E-01
Gamma Field	Reactor Pit 2 (avg)		1.00E+01		1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01
Gamma Field	Reactor Pit 2 (max)		3.00E+02		3.00E+02	3.00E+02	3.00E+02	3.00E+02	3.00E+02
Gamma Field	Chemical Pit (avg)		1.80E+00		1.80E+00	1.80E+00	1.80E+00	1.80E+00	1.80E+00
Gamma Field	Chemical Pit (max)		5.60E+00		5.60E+00	5.60E+00	5.60E+00	5.60E+00	5.60E+00

TABLE 3.50b: TOTAL DOSES FROM ALL RADIOACTIVE COPECs AT WMA-A

COPC	Comment		Dose (µGy/h) Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Laundry Pit	Avg		5.31E+01	6.77E+01	6.16E+01	7.20E+01	3.27E+02
Laundry Pit	Max		1.54E+02	1.71E+02	1.64E+02	2.13E+02	1.09E+03
Area A	Avg		4.13E-01	6.90E-01	1.18E+00	6.55E-01	6.32E-01
Area A	Max		1.32E+00	2.33E+00	4.12E+00	2.20E+00	2.12E+00
Reactor Pit 1	Avg		3.36E-01	3.36E-01	3.36E-01	3.36E-01	3.36E-01
Reactor Pit 1	Max		5.96E-01	5.96E-01	5.96E-01	5.96E-01	5.96E-01
Reactor Pit 2	Avg		1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01
Reactor Pit 2	Max		3.00E+02	3.00E+02	3.00E+02	3.00E+02	3.00E+02
Chemical Pit	Avg		1.84E+00	1.84E+00	1.84E+00	1.84E+00	1.84E+00
Chemical Pit	Max		5.60E+00	5.60E+00	5.60E+00	5.60E+00	5.60E+00

Notes:
Air Concentrations based on annual average using 1997-2001 release rates and meteorological data.
Soil concentrations from **Lounsbury and Adams** (1999) and Killey and Welch* (1998).
Gamma field measurements based on **Lounsbury and Adams** (1999).

TABLE 3.51a: CONCENTRATIONS OF RADIONUCLIDES IN AIR AND SOILS AT TERRESTRIAL RECEPTOR LOCATION WMA-B AT CRL

COPC	Comment	Air Concentration (Bq/m^3)	Gamma Field (μGy/h)	Soil Concentration (Bq/kg D.W.)	Dose (μGy/h) Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Ar-41		8.00E+01			3.50E-02	3.50E-02	3.50E-02	3.50E-02	3.50E-02
Noble Gas	BqMeV	2.00E+00			3.56E-04	3.56E-04	3.56E-04	3.56E-04	3.56E-04
I-131		2.40E-05			5.19E-08	1.01E-07	5.19E-08	5.20E-08	6.95E-04
HTO		1.00E+00			5.80E-04	4.09E-04	4.09E-04	4.09E-04	6.13E-04
Sr-90	Downstream of Spring B			8.6E+01	1.21E-03	5.54E-03	3.02E-02	5.46E-04	7.21E-05
Sr-90	Downstream of Spring B			3.34E+02	3.56E-03	7.55E-03	5.03E-02	9.79E-04	2.80E-04
C-14		2.40E-03			4.28E-05	4.28E-05	4.28E-05	4.28E-05	4.28E-05
Gamma Field	Avg		1.00E+00		1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Gamma Field	Max		1.00E+01		1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01

TABLE 3.51b: TOTAL DOSES FROM ALL RADIOACTIVE COPECs AT WMA-B

	Comment		Dose (μGy/h) Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Area B	Avg		1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00
Area B	Max		1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01
Downstream of Spring B	Avg		1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00
Downstream of Spring B	Max		1.00E+01	1.00E+01	1.01E+01	1.00E+01	1.00E+01

Notes:

Air concentrations based on annual average using 1997-2001 release rates and meteorological data.

Soil concentrations from Cooper and Rahman (1994).

Gamma field measurements based on AECL surveillance monitoring data.

TABLE 3.52a: CONCENTRATIONS OF RADIONUCLIDES IN AIR AND SOILS AT TERRESTRIAL RECEPTOR LOCATION WMA-C AT CRL

COPC	Comment	Air Concentration (Bq/m^3)	Gamma Field (μGy/h)	Soil Concentration (Bq/kg D.W.)	Plant Concentration (Bq/kg F.W.)	Dose (μGy/h)				
						Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Ar-41		0.00E+00				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Noble Gas	BqMeV	0.00E+00				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131		0.00E+00				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HTO		0.00E+00				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14		0.00E+00				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	Outside fence*				2.50E+03	7.13E-02	7.13E-02	7.13E-02	7.13E-02	7.13E-02
Sr-90	Outside fence			2.00E+03	5.00E+02	2.81E-02	1.29E-01	3.08E-01	1.27E-02	1.27E-02
Cs-137	Outside fence			2.00E+02		2.91E-02	2.94E-02	2.92E-02	2.93E-02	2.95E-02
Gamma Field	Thorium Pit (avg)		1.20E-01			1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01
Gamma Field	Thorium Pit (max)		1.80E-01			1.80E-01	1.80E-01	1.80E-01	1.80E-01	1.80E-01
Gamma Field	Nitrate Plant (avg)		5.00E-01			5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01
Gamma Field	Nitrate Plant (max)		5.00E+00			5.00E+00	5.00E+00	5.00E+00	5.00E+00	5.00E+00

TABLE 3.52b: TOTAL DOSES FROM ALL RADIOACTIVE COPECs AT WMA-C

	Comment		Dose (μGy/h)				
			Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Area C	Thorium Pit (avg)		1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01
Area C	Thorium Pit (max)		1.80E-01	1.80E-01	1.80E-01	1.80E-01	1.80E-01
Area C	Nitrate Plant (avg)		5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01
Area C	Nitrate Plant (max)		5.00E+00	5.00E+00	5.00E+00	5.00E+00	5.00E+00
Outside WMA-C Compound			1.28E-01	2.29E-01	4.08E-01	1.13E-01	1.13E-01

Notes:

Air concentrations based on annual average using 1997-2001 release rates and meteorological data.

Soil concentrations from Killey *et al.*(1998).

Gamma field measurements based on AECL surveillance monitoring data.

Plant concentration from Killey *et al.* (1998). For C-14 adjusted from Bq/kg C to Bq/kg F.W. assuming 50% of plant D.W. is C and D.W. = 0.25 F.W. For Sr-90 converted to F.W. concentration assuming D.W. = 0.25 F.W. Invertebrate and vertebrate tissues assumed to equal plant tissue concentrations for C-14.

TABLE 3.53a: CONCENTRATIONS OF RADIONUCLIDES IN AIR AND SOILS AT TERRESTRIAL RECEPTOR LOCATION WMA-H AT CRL

COPC	Comment	Air Concentration (Bq/m^3)	Gamma Field (µGy/h)	Soil Concentration (Bq/kg D.W.)	Plant Concentration (Bq/kg F.W.)	Dose (µGy/h)				
						Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Ar-41		8.00E+01				3.50E-02	3.50E-02	3.50E-02	3.50E-02	3.50E-02
Noble Gas	BqMeV	2.00E+00				3.56E-04	3.56E-04	3.56E-04	3.56E-04	3.56E-04
I-131		2.40E-05				5.19E-08	1.01E-07	5.19E-08	5.20E-08	7.07E-13
HTO		1.00E+00			367	4.09E-04	4.09E-04	4.09E-04	4.09E-04	4.09E-04
C-14		2.40E-03				4.27E-05	4.27E-05	4.28E-05	4.28E-05	4.28E-05
Sr-90				4.58E+02	30.5	6.45E-03	2.95E-02	2.03E-02	2.91E-03	7.32E-04
Cs-137				7.85E+01	0.81	1.14E-02	1.16E-02	1.15E-02	1.15E-02	1.16E-02
Gamma Field	Avg		1.60E-01			1.60E-01	1.60E-01	1.60E-01	1.60E-01	1.60E-01
Gamma Field	Max		5.60E-01			5.60E-01	5.60E-01	5.60E-01	5.60E-01	5.60E-01

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TABLE 3.53b: TOTAL DOSES FROM ALL RADIOACTIVE COPECs AT WMA-H

	Comment		Dose (µGy/h)				
			Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Area H	Avg		2.14E-01	2.37E-01	2.28E-01	2.10E-01	2.08E-01
Area H	Max		6.14E-01	6.37E-01	6.28E-01	6.10E-01	6.08E-01

Notes:

Air concentrations based on annual average using 1997-2001 release rates and meteorological data.

Plant concentration data from Killey *et al.* (2000), assuming F.W. concentration = 0.25 times D.W. concentration.

Soil concentrations from Killey *et al.* (2000).

Gamma field measurements based on Killey *et al.* (2000).

TABLE 3.54: RADIATION DOSES TO SOIL MACROINVERTEBRATES AND TERRESTRIAL PLANTS IN AND ABOVE THE PLUME UPGRADIENT TO SOUTH SWAMP

Radionuclide	Groundwater (Bq/L)		Soil (Bq/kg DW)		Estimated Radiation Doses (μGy/h)[1]			
					Invertebrate (OF = 0.1)		Plant (OF = 1)	
	Area A	RP2	Area A	RP2	Area A	RP2	Area A	RP2
HTO	3.91E6	2,000	6.7E5	343	1.3	0.0007	12.8	0.0007
Sr-90 (B/2)	14,700	7,050	2.9E5	1.4E5	0.6	0.3	45.8	22.0

[1] Dose includes external (groundwater, soil) and internal components.

TABLE 3.55: RADIATION DOSES TO SOIL MACROINVERTEBRATES AND PLANTS IN AND ABOVE THE NRX PLUME IN THE RIVERFRONT AREA

Radionuclide	Groundwater (Bq/L)		Soil (Bq/kg DW)		Estimated Radiation Doses (μGy/h)[1]			
					Invertebrate (OF = 0.1)		Plant (OF = 1)	
	Upgradient[1]	Downgradient[2]	Upgradient[1]	Downgradient[2]	Upgradient[1]	Downgradient[2]	Upgradient[1]	Downgradient[2]
HTO	3.14E6	1.75E6	3.0E5	1.5E5	1.0	0.57	10.3	5.71
Sr-90	900	350	18,154	7,060	0.035	0.014	2.81	1.09

[1] Dose includes external (groundwater, soil) and internal components.
[2] Downgradient = well 610-9, upgradient = well 610-15 or 610-20.

TABLE 3.56: AVERAGE CONCENTRATIONS OF RADIONUCLIDES IN WHITE-TAILED DEER FLESH (Bq/kg FW), 2000 AND 2001, AND CORRESPONDING DOSES FOR DEER AND EASTERN WOLF

	Concentrations in Deer (Bq/kg FW)		Doses (μGy/h)	
	Sr-90	HTO	Deer	Wolf
2000	3.69	498	0.0040	0.0021
2001	7	1,650	0.010	0.0062

TABLE 3.57: LOCATION AND MAGNITUDE OF MAXIMUM CONCENTRATIONS OF RADIONUCLIDES, SULPHUR DIOXIDE AND NITROGEN OXIDES IN AIR AT CRL (from Appendix 3)

Contaminant	Source	Grid Easting (reduced UTM (m))	Grid Northing (reduced UTM (m))	General Location	Maximum Average Air Concentration (Bq/m^3 for Ar-41, C-14, HT, HTO and I-131; Bq.MeV/m^3 for mixed noble gases; g/m^3 for acid gases)
Ar-41	Reactor stack	6443	2435	Just south of reactor stack and just west of plant site area	8.19E+02
Mixed noble gases	Mo-99 stack (Building 225)	7270	2210	In main plant site area	3.30E+01
C-14	Reactor Stack	6443	2435	Just south of reactor stack and just west of plant site area	3.01E-02
HTO	Reactor Stack	6443	2435	Just south of reactor stack and just west of plant site area	3.86E+00
	NRU vents + other buildings	7037	2583	In main plant site area	2.29E+02
		7107	2513		
HT	Building 250	6921	2389	Western edge of plant site area	2.60E+01
I-131	Reactor stack	6443	2435	Just south of reactor stack and just west of plant site area	9.16E-05
	Mo-99 stack (Building 225)	7272	2211	In main plant site area	4.36E-05
	NRU vents + other buildings	7037	2583	In main plant site area	3.73E-03
		7107	2513		
SO_x	Power Plant	7273	2553	In main plant site area near river	2.55E-05
NO_x	Power Plant	7273	2553	In main plant site area near river	3.45E-06

TABLE 3.58: RADIATION DOSES (μGy/h) TO TERRESTRIAL VECs EXPOSED TO AIR EMISSIONS AT POINTS OF IMPINGEMENT FOR THE REACTOR STACK, THE NRU BUILDING RELEASES AND THE Mo-99 STACK

Source		Large Invertebrate	Small Invertebrate	Terrestrial Plant	Least Shrew	American Robin
Reactor						
	Ar-41	0.3583	0.3583	0.3583	0.3583	0.3583
	I-131	1.98E-07	3.84E-07	1.98E-07	1.98E-07	5.87E-11
	HTO	0.001578	0.001578	0.001578	0.001578	0.001578
	C-14	0.000536	0.000536	0.000536	0.000536	0.000536
	Total Dose	**0.360**	**0.360**	**0.360**	**0.360**	**0.360**
NRU						
	I-131	4.96E-01	0.961	0.4955	0.496	0.0001468
	HTO	0.09365	0.09365	0.09365	0.09365	0.09365
	Total Dose	**5.89E-01**	**1.05E+00**	**5.89E-01**	**5.90E-01**	**9.38E-02**
Mo-99						
	Noble Gas	0.1457	0.1457	0.1457	0.1457	0.1457
	I-131	9.43E-08	1.83E-07	9.43E-08	9.45E-08	2.79E-11
	Total Dose	**0.146**	**0.146**	**0.146**	**0.146**	**0.146**

Note: All VECs assumed to be resident at Point of Impingement.

TABLE 4.1: BENCHMARK DOSES FOR BIRD AND MAMMAL EXPOSURES TO METALS AND ORGANICS

Chemical Parameter	Benchmark Dose[1] (mg/kg•day)		
	Birds	Shrews	Muskrat
Mercury	0.9	19.7	5.25
Copper	61.7	55.3	14.7
Lead	11.3	221	58.8
Chromium	5.0	36.3	9.66
Cadmium	20	27.6	7.09
Arsenic	7.4	1.88	0.48
Zinc	131	884	226
Pyrene[2]	-	187	47.9
Benzo(a)pyrene	-	15	3.8
Chloroform	-	113	29
PCBs (Arochlor 1254)	1.8	1.0	0.26
1,1-DCE	-	82.9	21.2
TCE	-	10.5	2.69

[1] From Sample *et al.* (1996), unless otherwise indicated, with body weight adjustment for mammals.
[2] Pyrene benchmark from a mouse LOAEL of 125 mg/kg•d (U.S. EPA, 1989).

TABLE 4.2: BENCHMARK CONCENTRATIONS FOR AQUATIC ORGANISM EXPOSURES TO METALS AND ORGANICS

Chemical Parameter	Fish and Frog (mg/L)	Type of Benchmark	Snail and Benthos (mg/L)	Type of Benchmark	Benthos (mg/kg)	Type of Benchmark	Aquatic Plant[6] (mg/L)
Mercury	0.00023	LCV[1]	0.00096	LCV[3]	0.17	ISQG	-
Copper	0.0038	LCV[1]	0.0061	LCV	35.7	ISQG	0.002[7]
Lead	0.0188	LCV[1]	0.0255	LCV	35	ISQG	0.5
Chromium	0.051	EC20	0.0089	CWQG	37.3	ISQG	0.397
Iron	1.3	LCV	0.3	CWQG	-		-
Cadmium	0.0017	LCV[1]	0.00015	LCV[3]	0.6	ISQG	0.002
Arsenic	0.892	LCV[1]	0.45	LCV[3]	5.9	ISQG	0.048
Zinc	0.0364	LCV[1]	5.24	LCV	123	ISQG	0.03
Aluminum	3.28	LCV[1]	1.9	LCV[3]	-		0.46
bis-2EH-phthalate	>0.054	EC20	0.912	LCV	269,150	EQP[5]	-
Chloroform	1.24	LCV[1]	4.48	LCV	3.48	EQP	-
Phenolics	0.2	LCV[1]	2.0	LCV	0.58	EQP	20
Chlorine	0.059	LAV[2]	0.032	LAV	-		-
Naphthalene	0.45	EC20	>0.6	EC20[3]	0.0346	ISQG	33
Phenanthrene	0.0004	CWQG	0.11	EC20[3]	0.0419	ISQG	-
Pyrene	0.000025	CWQG	0.000025	CWQG	0.053	ISQG	-
Fluoranthene	0.03	LCV	0.015	LCV	0.111	ISQG	54.4
Chrysene	-		-		0.0571	ISQG	-
Benzo(a)pyrene	>0.003	EC20	0.0003	LCV	0.0319	ISQG	-
2-propanol	0.59	LCV	-		-		-
1,1-DCE	>2.8	LCV[1]	4.72	LCV[3]	-		>798
TCE	5.76	EC20	7.26	LCV[3]	-		-
Carbon tetrachloride	0.065[4]	EC20	5.58	LCV[3]	-		-
PCBs	0.4	EC20	1.2	EC20[3]	0.0341	ISQG	-

All LCV and EC20 values are from Suter and Tsao (1996).
[1] An EC20 was reported but the LCV was somewhat lower.
[2] Lowest acute value (LAV) appropriate to episodic releases.
[3] Value for daphnid invertebrates.
[4] Reported LCV was substantially higher than the EC20.
[5] EQP = Equilibrium partitioning value (Jones *et al.*, 1997).
[6] All aquatic plant benchmarks are LCVs.
[7] Canadian (CCME) water quality criterion used, as CCME criterion >LCV for aquatic plants.

TABLE 4.3: BENCHMARK SOIL CONCENTRATIONS FOR TERRESTRIAL PLANTS AND SOIL INVERTEBRATES

Chemical Parameter	Benchmark Concentration (mg/kg DW)		
	Plants[1]	Invertebrates[2]	CSQG[3]
Mercury	0.3	0.1	6.6 (12)
Copper	100	60	63 (63)
Lead	50	500	140 (300)
Chromium	1	0.4	64 (64)
Cadmium	4	20	10 (10)
Arsenic	10	60	12 (17)
Zinc	50	200	200 (200)
Aluminum	50	-	-
Phenolics[2]	70	30	3.8 (20)
PCBs	40	-	0.3 (33)
Naphthalene	0.14[4]	-	0.6[5]

[1] Effroymson *et al.* (1997a).
[2] Effroymson *et al.* (1997b).
[3] Canadian soil quality guideline – residential/parkland (ecological (soil contact) component in parentheses).
[4] Value for hydroponic solution divided by K_d.
[5] Provisional value.

TABLE 4.4: SUMMARY OF RADIATION DOSES FOR BIOTA AT AQUATIC SITES

Receptor Species	Radiation Dose (µGy/h)															
	Perch Lake		Perch Inlet 1		Perch Inlet 2		Perch Creek		South Swamp		East Swamp		West Swamp		Main Stream	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Large fish	2.0	3.2	-	-	-	-	-	-	-	-	-	-	18.5	18.5	-	-
Small fish	-	-	5.7	10.5	0.84	1.6	0.80	1.6	-	-	**58.7**	**137**	-	-	0.08	0.15
Green frog	0.29	0.54	1.7	3.2	0.34	0.64	0.29	0.58	**178**	**1,637**	23.3	**52.7**	2.7	3.0	0.05	0.08
Snail	8.8	15.3	**53.7**	**98.6**	6.9	13.0	7..0	14.3	**5,469**	**50,530**	**491**	**1,165**	**73.7**	**74.1**	0.44	1.1
Aquatic plant	0.59	0.88	1.7	3.0	0.6	1.1	0.56	1.1	**387**	**3,575**	**41.8**	**96.8**	5.5	5.9	0.06	0.12
Riparian plant	0.34	0.56	2.1	3.8	0.38	0.72	0.34	0.66	**212**	**1,953**	26.3	**59.9**	**46.1**	**96.8**	0.05	0.09
Water shrew	0.47	0.89	4.8	8.8	0.72	1.4	0.68	1.4	**486**	**4,489**	**50.6**	**118**	7.1	7.8	0.07	0.14
Great blue heron	0.05	0.07	0.12	0.17	0.13	0.24	0.08	0.13	7.7	**65.9**	7.9	16.2	0.20	0.33	0.03	0.05
Painted turtle	0.07	0.12	-	-	-	-	-	-	-	-	-	-	0.59	0.65	-	-
Muskrat	0.17	0.24	-	-	-	-	-	-	-	-	-	-	1.9	2.7	-	-
Mallard	0.05	0.07	-	-	-	-	-	-	-	-	-	-	0.19	0.27	-	-

Receptor Species	Radiation Dose (µGy/h)											
	Duke Swamp		Bulk Storage Swamp		Lower Bass Lake		Maskinonge Lake		Stream 5		Stream 6	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Large fish	-	-	-	-	0.24	0.37	0.10	0.15	-	-	-	-
Small fish	-	-	-	-	-	-	-	-	0.02	0.05	0.12	0.18
Green frog	2.1	2.6	4.3	4.4	0.10	0.13	0.06	0.07	0.01	0.03	0.09	0.14
Snail	4.3	5.1	9.0	10.8	0.77	1.2	0.27	0.48	0.13	0.35	0.47	0.70
Aquatic plant	2.1	2.6	4.3	4.5	0.12	0.18	0.07	0.08	0.01	0.04	0.10	0.16
Riparian plant	0.3	0.8	0.2	0.3	0.07	0.20	0.15	0.16	0.01	0.49	0.09	0.14
Water shrew	4.0	4.5	8.7	8.9	0.16	0.23	0.10	0.12	0.01	0.05	0.11	0.17
Great blue heron	2.1	2.5	4.3	4.4	0.07	0.10	0.05	0.06	0.002	0.006	0.07	0.12
Painted turtle	-	-	-	-	-	-	0.08	0.10	-	-	-	-
Muskrat	-	-	-	-	-	-	0.08	0.11	-	-	-	-
Mallard	-	-	-	-	-	-	0.07	0.08	-	-	-	-

Bold values exceed 40 µGy/h.
Underlined values exceed 400 µGy/h.

TABLE 4.5: RISK QUOTIENTS FOR SIGNIFICANT NON-RADIONUCLIDE EXPOSURES AT AQUATIC SITES

	Risk Quotient (Exposure Value/Benchmark Value)															
	Perch Lake		Perch Inlet 1		Perch Inlet 2		Perch Creek[1]		South Swamp		East Swamp		West Swamp		Main Stream	
Receptor Species	Low	High	Low	High	Low	High	Mean, Low	Max, High	Low	High	Low	High	Low	High	Low	High
Large fish	Cu **1.7** Fe 0.8	**5.5** **1.2**	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Small fish	- -	- -	Cu **2.8** Fe 0.1	**8.6** 0.6	Cu **1.6** Fe 0.9	**1.7** **1.4**	Cu 0.4 Fe **1.3**	**4.0** **2.0**	- -	- -	Cu **1.3** -	**2.5** -	- -	- -	Cu **1.8** Pb 0.1	**1.8** 1.3
Green frog	Cu **1.7** Fe 0.8	**5.5** **1.2**	Cu **2.8** Fe 0.1	**8.6** 0.6	Cu **1.6** Fe 0.9	**1.7** **1.4**	Cu 0.4 Fe **1.3**	**4.0** **2.0**	Cu **2.4** -	**3.1** -	Cu **1.3** -	**2.5** -	- -	- -	Cu **1.8** Pb 0.1	**1.8** 1.3
Snail/Benthos (water)	Cu **1.1** Fe 3.6	**3.4** **5.1**	Cu **1.8** Fe 0.6	**5.3** 2.7	Cu 0.9 Fe **4.1**	**1.1** **6.1**	Cu 0.3 Fe **5.7**	**2.5** **8.5**	Cu **1.5** -	**1.9** -	Cu 0.8 -	**1.5** -	- -	- -	Cu **1.1** Fe 1.9	**1.1** 3.4
Benthos (sediment)	Cr 1.1	1.1	-	-	Cr 1.3	**1.3**	PAH 1.2	**4.4**	-	-	-	-	-	-	-	-
Aquatic plant	Cu **3.3** -	**10.5** -	Cu **5.4** -	**16** -	Cu **3.0** -	**3.3** -	Cu 0.8 -	**7.6** -	Cu **4.6** -	**5.9** -	Cu **2.5** -	**4.7** -	- -	- -	Cu **3.5** -	**3.5** -
Riparian plant	-	-	-	-	-	-	Al 71	71	-	-	-	-	-	-	-	-

	Risk Quotient (Exposure Value/Benchmark Value)												
	Duke Swamp[1]		Bulk Storage Swamp		Lower Bass Lake		Maskinonge Lake		Stream 5[2]		Stream 3[3]		RQ based on Background (Section 2.3)
Receptor Species	Mean, Low	Max, High	Low	High	Low	High	Low	High	Mean, Low	Max, High	Mean	Max	
Large fish	- -	- -	- -	- -	Cu 1.0 -	**8.5** -	Cu 0.6 -	**3.9** -	- -	- -	- -	- -	Cu 1.2 Fe 0.9
Small fish	- -	- -	- -	- -	- -	- -	- -	- -	Cu 1.0 Pb **3.0**	**2.3** **3.0**	Cu **4.2** Cl_2 **18**	**7.8** **18**	
Green frog	Cu 1.0 Fe 1.0	**4.2** **1.4**	Cu 0.8 Fe 0.9	**7.5** **1.1**	Cu 1.0 -	**8.5** -	Cu 0.6 -	**3.9** -	Cu 1.0 Pb **3.0**	**2.3** **3.0**	Cu **4.2** Cl_2 **18**	**7.8** **18**	
Snail/Benthos (water)	Cu 0.6 Fe **4.2**	**2.6** **5.9**	Cu 0.5 Fe 3.8	**4.7** **4.9**	Cu 0.6 Fe 1.4	**5.3** 1.9	Cu 0.4 Fe 0.3	**2.4** 1.4	Cu 0.6 -	**1.4** -	Cu **2.6** Cl_2 **33**	**4.8** **33**	Cu 0.8 Fe 4.0
Benthos (sediment)	Pb 1.4	1.4	Cr 1.2	1.2	-	-	Pb 3.2 Cr 1.8	3.2 1.8	Cr 1.2	1.2	-	-	Pb 3.2 Cr 1.8
Aquatic plant	Cu 1.9 -	**8** -	Cu 1.5 -	**14.3** -	Cu 1.9 -	**16** -	Cu 1.2 -	**7.4** -	Cu 1.9 -	**4.4** -	Cu **8** Al **0.7**	**15** **2.2**	Cu 2.4 Al 0.3
Riparian plant	Al 50	50	-	-	Al 125	125	Al 70	70	Al 89	89	-	-	Al 146

Bold values indicate both benchmark and background exposure levels are exceeded.

[1] RQ based on mean and maximum water values for Fe, low and high water values for Cu, single sediment value for Al.

[2] RQ based on mean and maximum water values for Cu, single water value for Pb, single sediment value for Al.

[3] RQ based on mean and maximum water values for Cu and Al, single estimated value for chlorine.

TABLE 4.6: SUMMARY OF RADIATION DOSES FOR OTTAWA RIVER BIOTA

Receptor Species	Radiation Dose (μGy/h)					
	Storm Sewer 4 Near-Field Zone		Point aux Baptime		Process Sewer Near-field Zone	
	Mean	Max	Mean	Max	Mean	Max
Large fish	0.05	0.11	0.16	0.57	2.57	3.36
Small fish	-	-	-	-	2.77	3.52
Green frog	0.008	0.02	0.03	0.08	-	-
Snail	0.21	0.42	0.56	2.23	2.69	2.90
Aquatic plant	0.02	0.03	0.05	0.17	-	-
Riparian plant	0.009	0.02	0.03	0.10	-	-
Water shrew	0.02	0.04	0.06	0.21	-	-
Great blue heron	0.002	0.003	0.01	0.01	-	-
Muskrat	0.005	0.009	0.02	0.05	-	-
Benthos	-	-	-	-	4.74	21.9

TABLE 4.7: RISK QUOTIENTS FOR SIGNIFICANT NON-RADIONUCLIDE EXPOSURES IN THE OTTAWA RIVER

	Risk Quotient (Exposure Value/Benchmark Value)						
	Nearshore Zone			Offshore Zone			RQ based on Background (Section 2.3)
Receptor Species	Mean	Max	Location	Mean	Max	Location	
Large fish	Cu 1.4	2.1	PB, BL[1,2]	Cu 0.9	**2.4**	Pr. Sewer[2]	Cu 2.1
Small fish	Cl_2 **1.2**	**1.2**	Str. 3[2]	Cl_2 0.1	0.1	San. Sewer[2]	
Green frog	Cu 1.4	2.1	PB, BL[1,2]	Cu 0.9	**2.4**	Pr. Sewer[2]	
	Cl_2 **1.2**	**1.2**	Str. 3[2]	Cl_2 0.1	0.1	San. Sewer[2]	
Snail	Cu 0.9	1.3	PB, BL[1,2]	Cu 0.6	**1.5**	Pr. Sewer[2]	Cu 1.3
	Cl_2 **2.2**	**2.2**	Str. 3[2]	Cl_2 0.2	0.2	San. Sewer[2]	
Aquatic plant	Cu 2.6	3.9	PB, BL[1,2]	-	-		Cu 3.9
	Cu 0.5	1.0	Str. 3[2]	-	-		
Benthos	Cu 0.9	1.3	PB, BL[1,2]	Cu 0.6	**1.5**	Pr. Sewer[2]	Cu 1.3
	Cl_2 **2.2**	**2.2**	Str. 3[2]	Cu (Sed)	**1.6**	Pr. Sewer[3]	Cu 1.2
				Pb (Sed)	**1.7**	Pr. Sewer[3]	Pb 1.5
				Cr (Sed)	**2.8**	Pr. Sewer[3]	Cr 2.6
				Cd (Sed)	2.5	Pr. Sewer[3]	Cd 3.7
				As (Sed)	**6.3**	Pr. Sewer[3]	As 5.1
				Zn (Sed)	**2.5**	Pr. Sewer[3]	Zn 1.6

Bold values indicate both benchmark and background exposure levels are exceeded.
[1] PB = Point aux Baptime, BL = Boat Launch.
[2] RQ based on water concentrations and benchmarks, mean and maximum water values for Cu.
[3] RQ based on sediment concentrations and benchmarks.

TABLE 4.8: SUMMARY OF RADIATION DOSES AND RISK QUOTIENTS FOR BIOTA AT UPLAND SITES ((µGy/h)/RQ)

Total Doses	Large Invertebrates	Small Invertebrates	Terrestrial Plants	Least Shrew	American Robin	Woodchuck
WMA-A						
Laundry Pit (avg)	**5.31E+01/1.3**	**6.77E+01/1.7**	**6.16E+01/1.5**	**7.20E+01/1.8**	**3.27E+02/8.2**	-/-
Laundry Pit (max)	**1.54E+02/3.9**	**1.71E+02/4.3**	**1.64E+02/4.1**	**2.13E+02/5.3**	**1.09E+03/27**	-/-
Area A (avg)	4.13E-01/0.010	6.90E-01/0.017	1.18E+00/0.030	6.55E-01/0.016	6.32E-01/0.016	-/-
Area A (max)	1.32E+00/0.033	2.33E+00/0.058	4.12E+00/0.10	2.20E+00/0.055	2.12E+00/0.053	-/-
Reactor Pit 1 (avg)	3.36E-01/0.008	3.36E-01/0.008	3.36E-01/0.008	3.36E-01/0.008	3.36E-01/0.008	-/-
Reactor Pit 1 (max)	5.96E-01/0.015	5.96E-01/0.015	5.96E-01/0.015	5.96E-01/0.015	5.96E-01/0.015	-/-
Reactor Pit 2 (avg)	1.00E+01/0.25	1.00E+01/0.25	1.00E+01/0.25	1.00E+01/0.25	1.00E+01/0.25	-/-
Reactor Pit 2 (max)	**3.00E+02/7.5**	**3.00E+02/7.5**	**3.00E+02/7.5**	**3.00E+02/7.5**	**3.00E+02/7.5**	-/-
Chemical Pit (avg)	1.84E+00/0.046	1.84E+00/0.046	1.84E+00/0.046	1.84E+00/0.046	1.84E+00/0.046	-/-
Chemical Pit (max)	5.60E+00/0.14	5.60E+00/0.14	5.60E+00/0.14	5.60E+00/0.14	5.60E+00/0.14	-/-
WMA-B						
Area B (avg)	1.04E+00/0.026	1.04E+00/0.026	1.04E+00/0.026	1.04E+00/0.026	1.04E+00/0.026	-/-
Area B (max)	1.00E+01/0.26	1.00E+01/0.26	1.00E+01/0.26	1.00E+01/0.26	1.00E+01/0.26	-/-
Downstream Spring B (avg)	1.04E+00/0.026	1.04E+00/0.026	1.04E+00/0.026	1.04E+00/0.026	1.04E+00/0.026	-/-
Downstream Spring B (max)	1.00E+01/0.26	1.00E+01/0.26	1.00E+01/0.26	1.00E+01/0.26	1.00E+01/0.26	-/-
WMA-C						
Area C – Thorium Pit (avg)	1.20E-01/0.003	1.20E-01/0.003	1.20E-01/0.003	1.20E-01/0.003	1.20E-01/0.003	-/-
Area C – Thorium Pit (max)	1.80E-01/0.0045	1.80E-01/0.0045	1.80E-01/0.0045	1.80E-01/0.0045	1.80E-01/0.0045	-/-
Area C – Nitrate Plant (avg)	5.00E-01/0.013	5.00E-01/0.013	5.00E-01/0.013	5.00E-01/0.013	5.00E-01/0.013	-/-
Area C – Nitrate Plant (max)	5.00E+00/0.13	5.00E+00/0.13	5.00E+00/0.13	5.00E+00/0.13	5.00E+00/0.13	-/-
WMA-F	-/-	-/-	-/-	-/-	-/-	**2,050/51**
WMA-H						
Area H (avg)	2.14E-01/0.005	2.37E-01/0.0059	2.28E-01/0.0057	2.10E-01/0.0053	2.08E-01/0.0052	-/-
Area H (max)	6.14E-01/0.015	6.37E-01/0.0159	6.28E-01/0.016	6.10E-01/0.015	6.08E-01/0.015	-/-

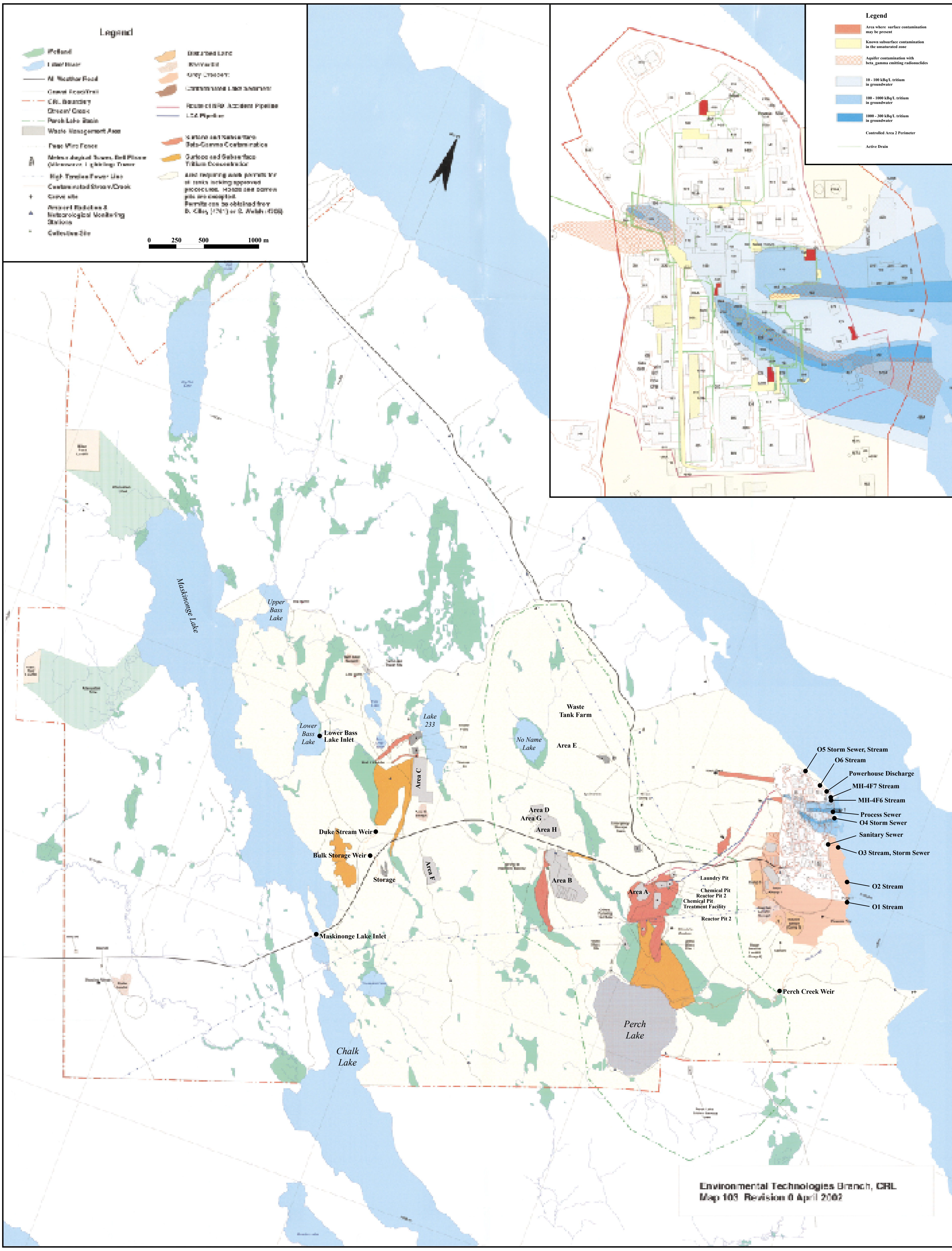
Note: Values in bold flag doses above benchmark (RQ >1).

TABLE 4.9: RISK QUOTIENT (RQ) VALUES FOR UPLAND VECs EXPOSED TO MERCURY IN SOIL

	Soil Invertebrate[1]	Terrestrial Plant[1]	Shrew[2]	Robin[3]
Area A	0.0028	0.0028	0.0002	0.0077
Area B	0.0045	0.0045	0.00032	0.013
Area C	0.00032	0.00032	0.000022	0.00087
Area F	0.00049	0.00049	0.000034	0.0013

[1] RQ for invertebrates and plants equal soil concentration divided by CCME soil quality criterion of 6.6 mg/kg.
[2] RQ for shrew based on estimated ingestion rate (invertebrates and soil) divided by benchmark of 19.7 mg/kg•day.
[3] RQ for robin based on estimated ingestion rate (invertebrates and soil) divided by benchmark of 0.9 mg/kg•day.

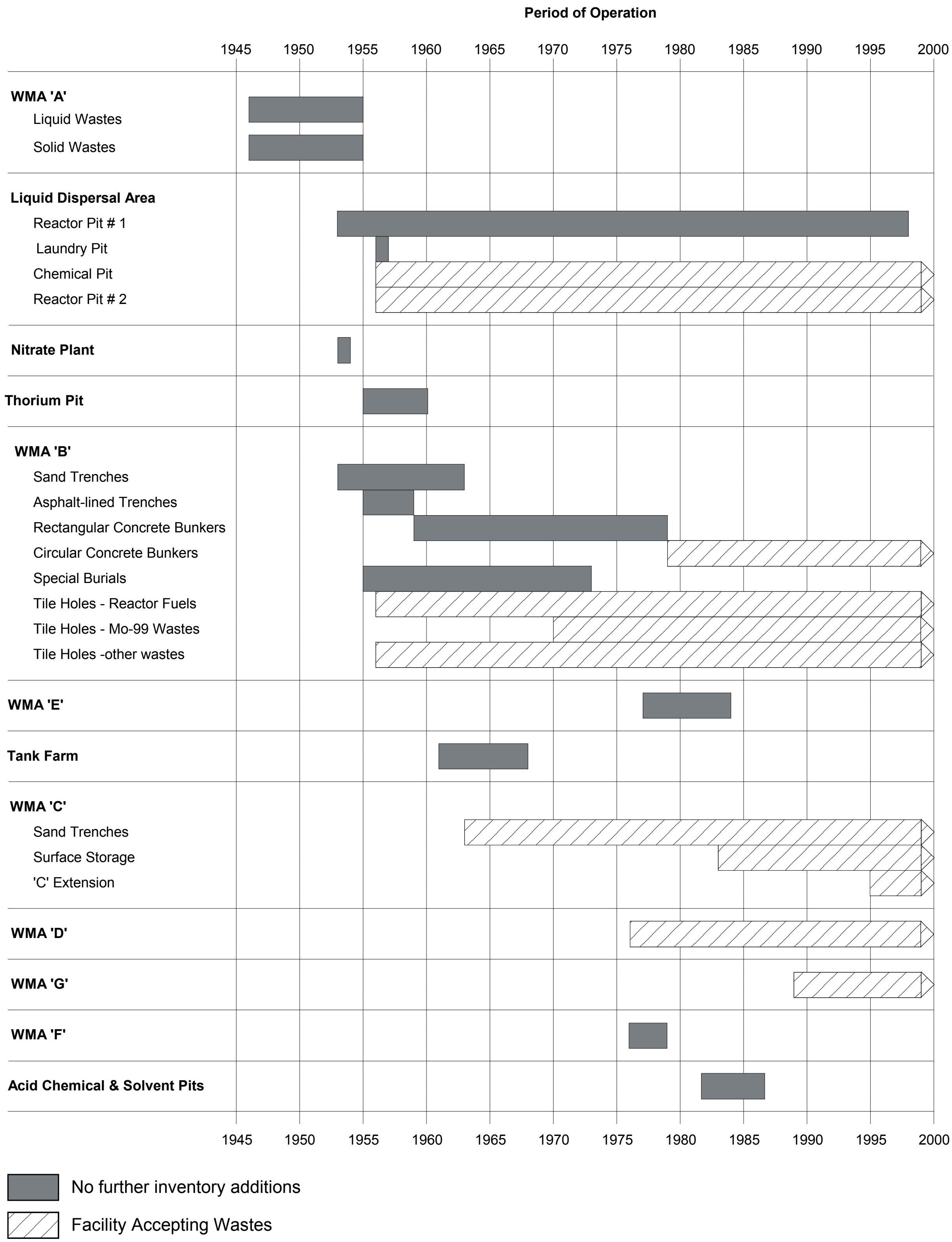
FIGURES



Privileged and Confidential

General Setting, Showing Key Environmental Features

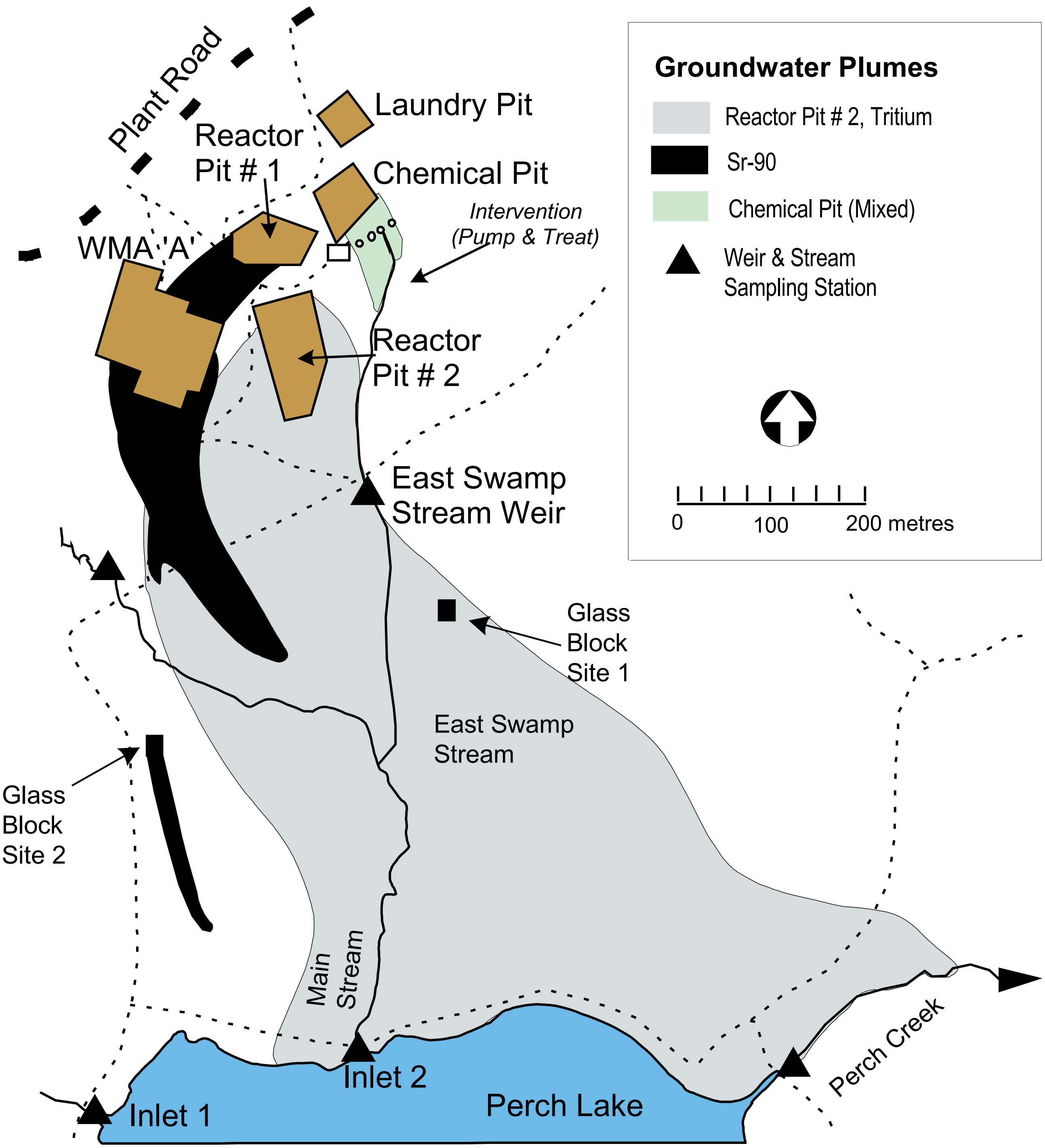
beak international incorporated	Figure 2.1	August 2002



Source: Dolinar *et al.* (2000)

Summarized Operational History of Waste Management Facilities at CRL

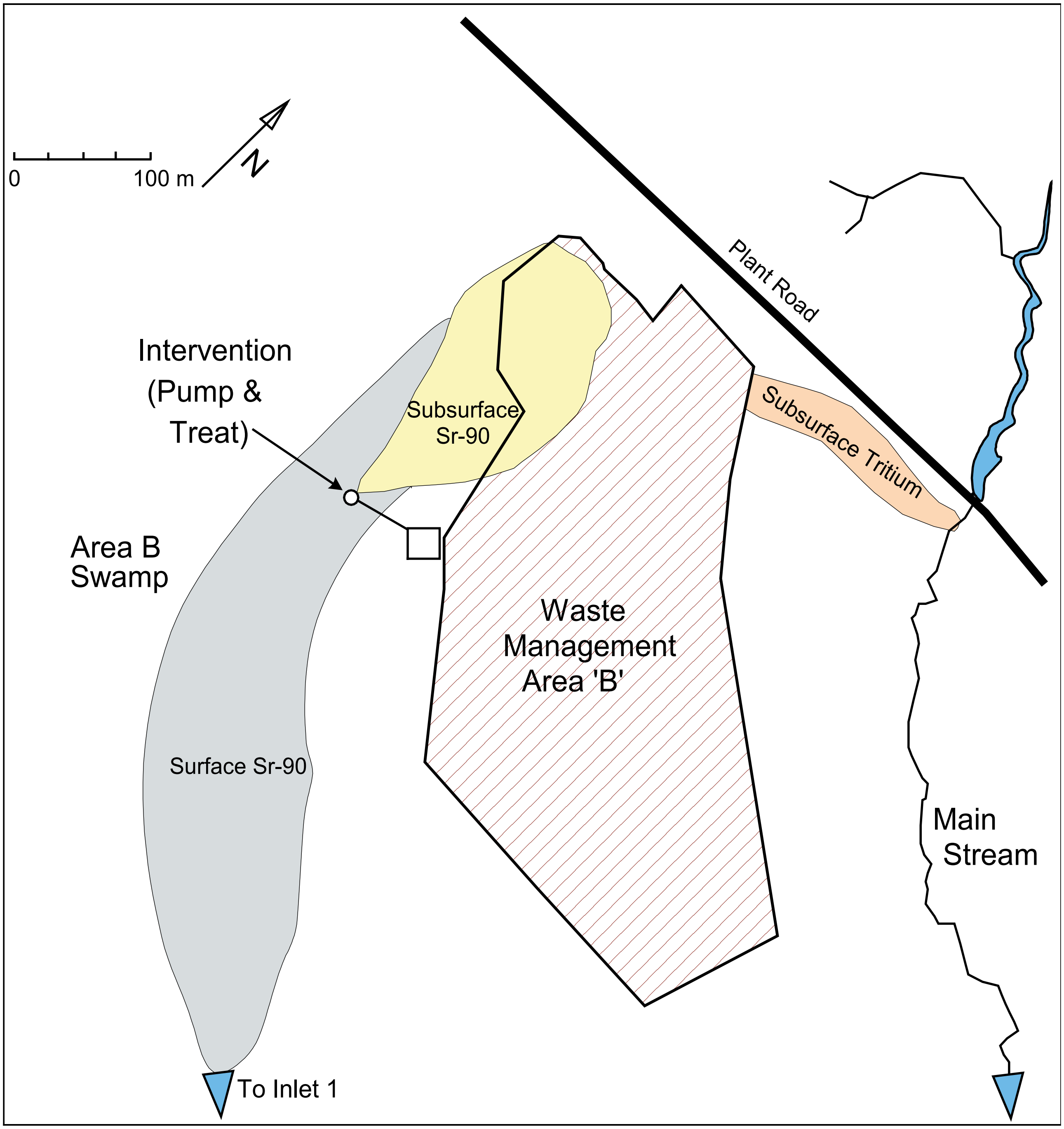
beak international incorporated | Figure **2.2** | August 2002



Source: Dolinar *et al.* (2000)

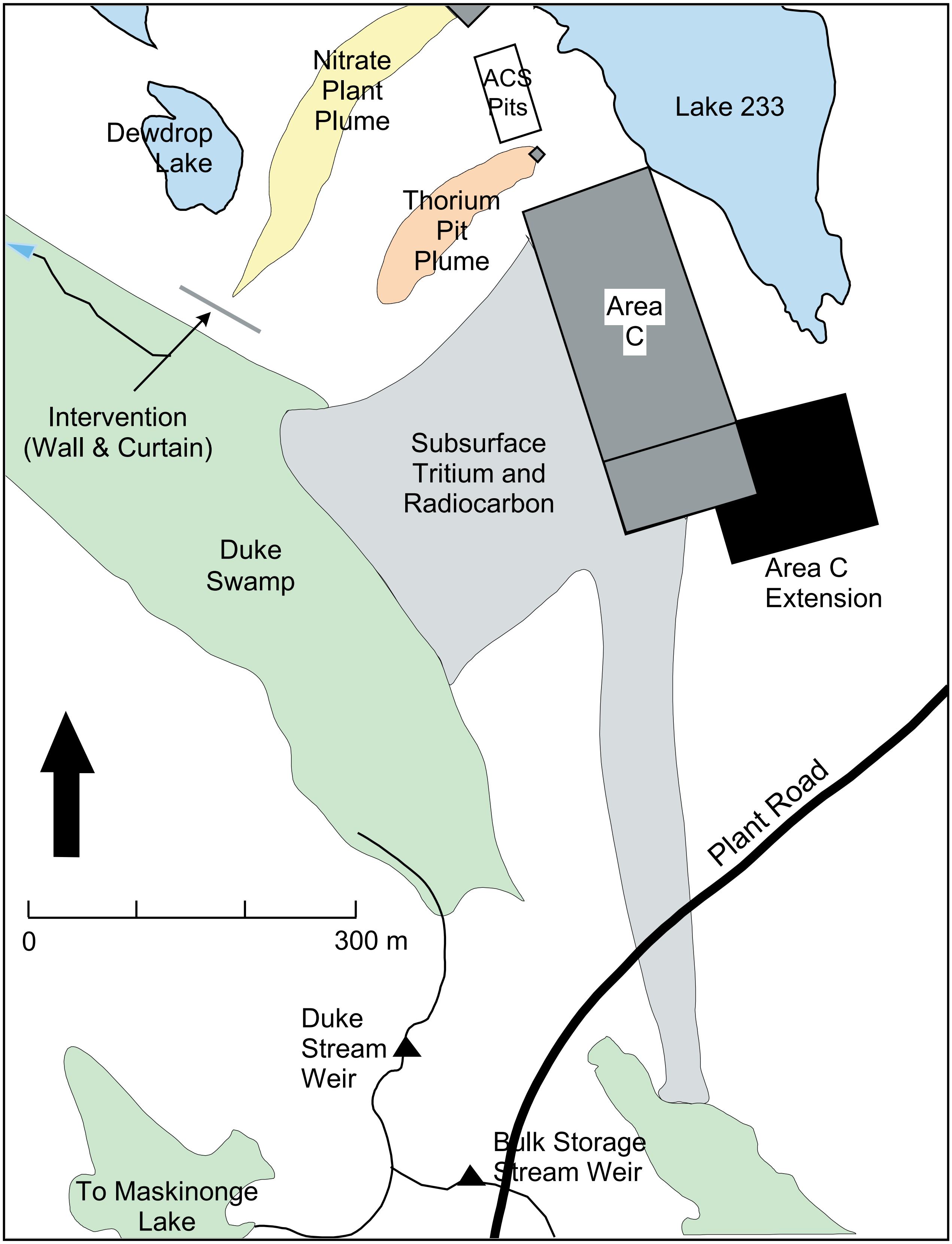
Subsurface Plumes Originating from WMA-A and the LDA

beak international incorporated	Figure 2.3	August 2002



Source: Dolinar *et al.* (2000)

Subsurface Plumes Originating from WMA -B		
beak international incorporated	Figure **2.4**	August 2002



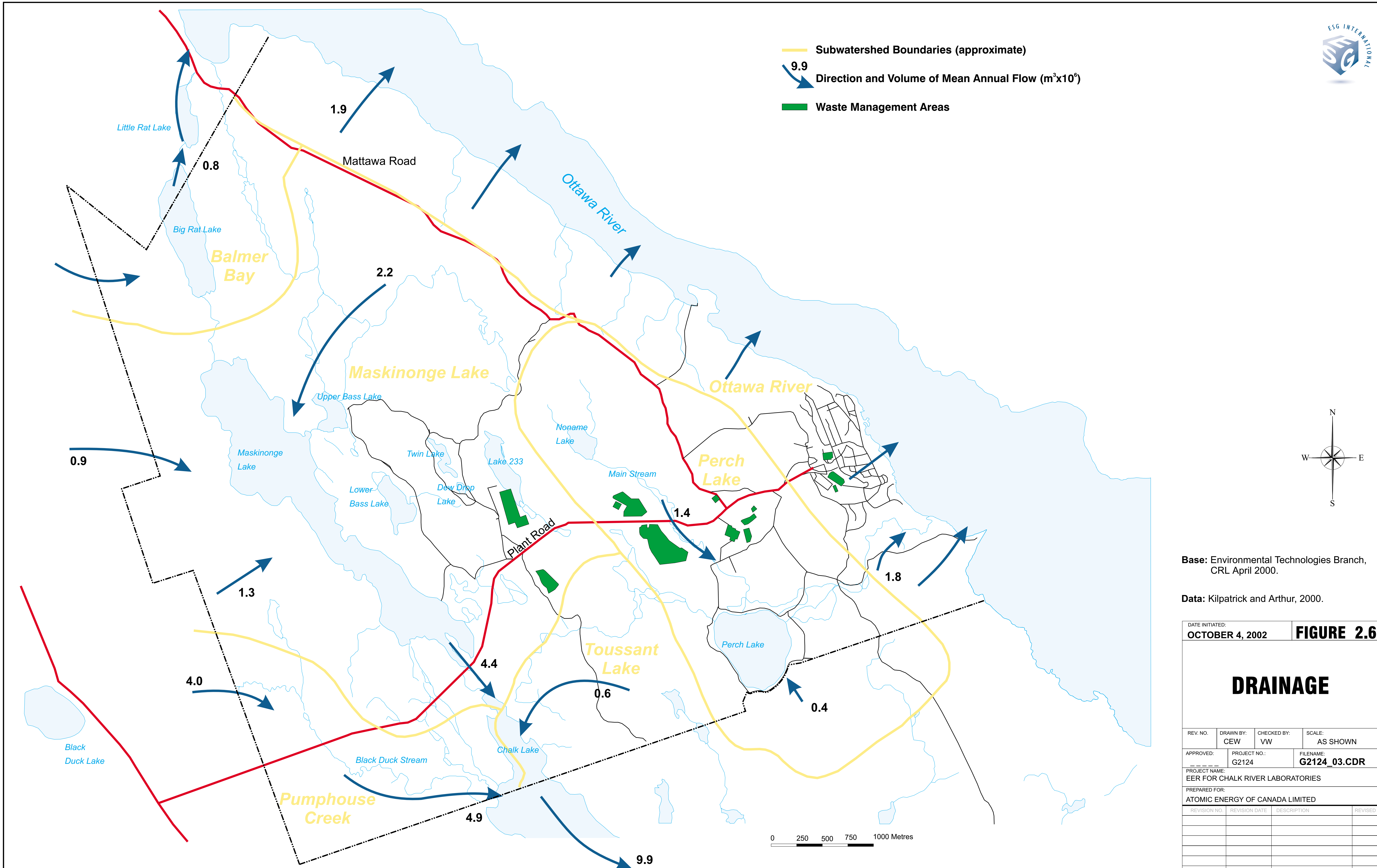
Source: Dolinar *et al.* (2000)

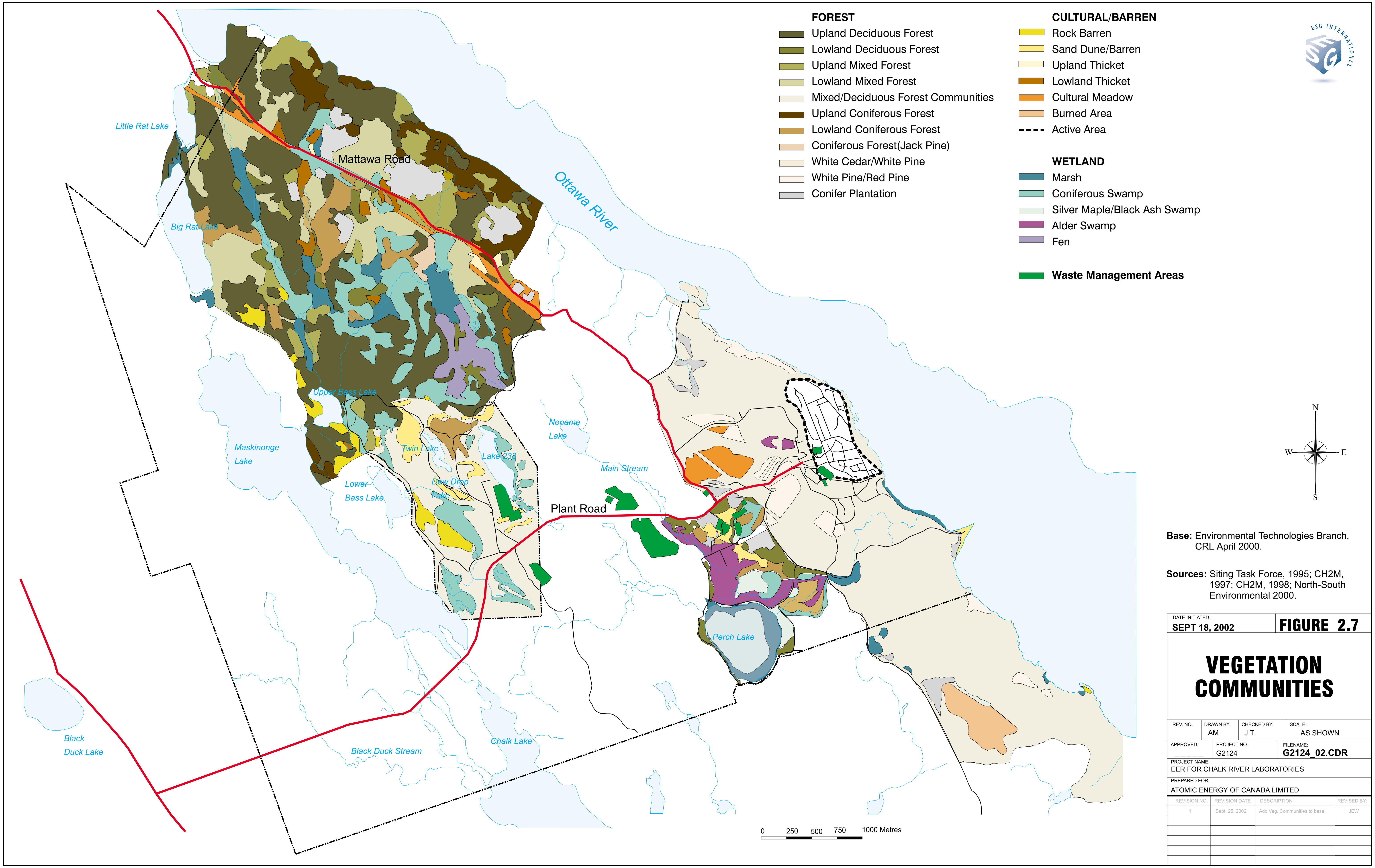
Plumes Originating from WMA-C, the Nitrate Plant and the Thorium Pit

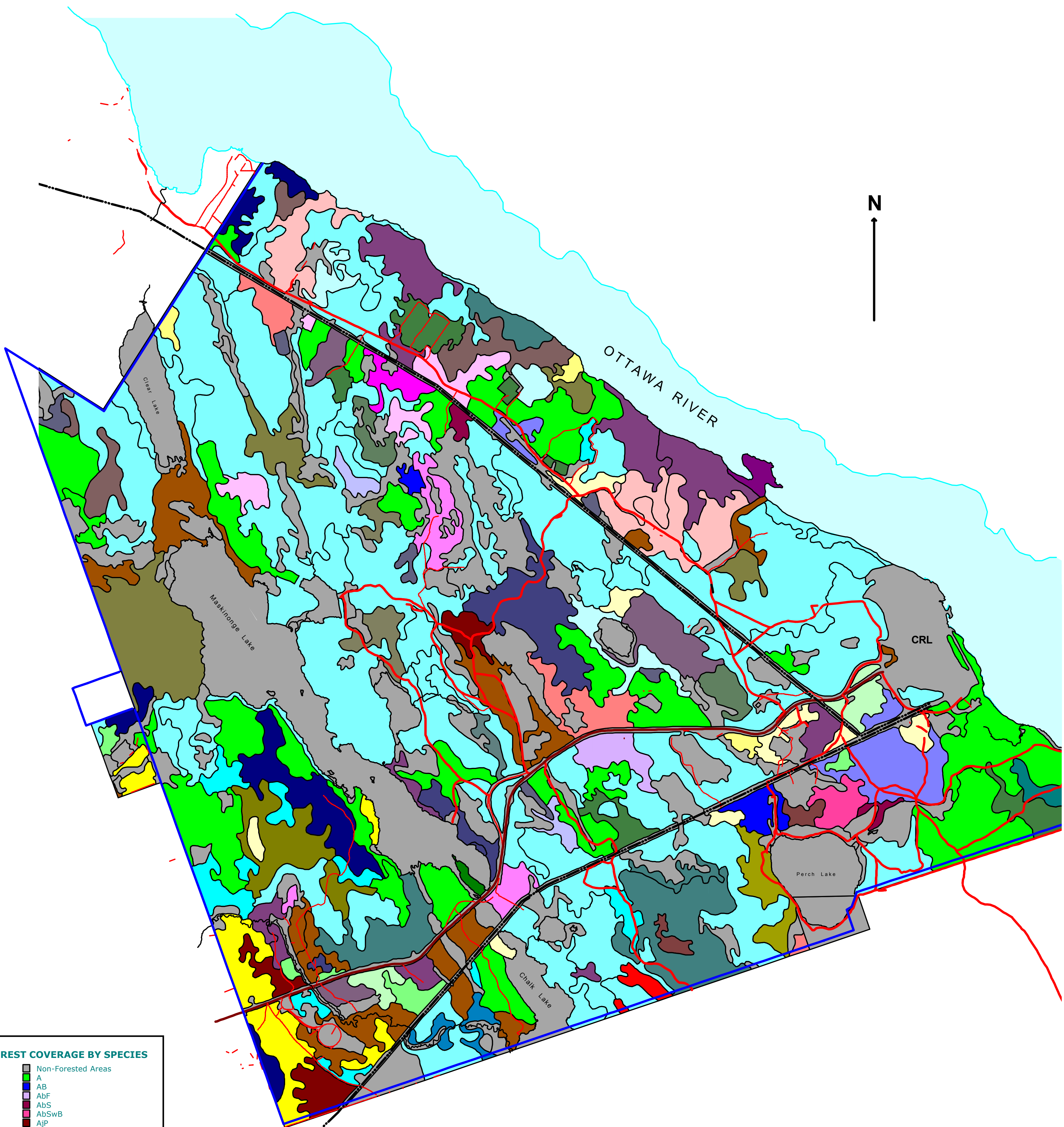
beak international incorporated

Figure **2.5**

August 2002


Subwatershed Boundaries (approximate)
9.9
Direction and Volume of Mean Annual Flow (m³x10⁶)
Waste Management Areas
Mattawa Road
Plant Road
Ottawa River
Little Rat Lake
Big Rat Lake
Balmer Bay
Maskinonge Lake
Upper Bass Lake
Lower Bass Lake
Twin Lake
Dew Drop Lake
Lake 233
Noname Lake
Main Stream
Perch Lake
Toussant Lake
Chalk Lake
Black Duck Stream
Black Duck Lake
Pumphouse Creek
1.9
0.8
2.2
0.9
1.3
4.0
4.4
0.6
1.4
1.8
0.4
4.9
9.9
0 250 500 750 1000 Metres
N
W
E
S
Base: Environmental Technologies Branch, CRL April 2000.
Data: Kilpatrick and Arthur, 2000.
DATE INITIATED: OCTOBER 4, 2002
FIGURE 2.6
DRAINAGE
REV. NO.
DRAWN BY: CEW
CHECKED BY: VW
SCALE: AS SHOWN
APPROVED:
PROJECT NO.: G2124
FILENAME: G2124_03.CDR
PROJECT NAME: EER FOR CHALK RIVER LABORATORIES
PREPARED FOR: ATOMIC ENERGY OF CANADA LIMITED
REVISION NO. REVISION DATE DESCRIPTION REVISED BY:


FOREST
Upland Deciduous Forest
Lowland Deciduous Forest
Upland Mixed Forest
Lowland Mixed Forest
Mixed/Deciduous Forest Communities
Upland Coniferous Forest
Lowland Coniferous Forest
Coniferous Forest(Jack Pine)
White Cedar/White Pine
White Pine/Red Pine
Conifer Plantation
CULTURAL/BARREN
Rock Barren
Sand Dune/Barren
Upland Thicket
Lowland Thicket
Cultural Meadow
Burned Area
Active Area
WETLAND
Marsh
Coniferous Swamp
Silver Maple/Black Ash Swamp
Alder Swamp
Fen
Waste Management Areas
Little Rat Lake
Big Rat Lake
Mattawa Road
Ottawa River
Upper Bass Lake
Maskinonge Lake
Lower Bass Lake
Twin Lake
Lake 233
Dew Drop Lake
Noname Lake
Main Stream
Plant Road
Perch Lake
Black Duck Lake
Black Duck Stream
Chalk Lake
0 250 500 750 1000 Metres
N
W
E
S
Base: Environmental Technologies Branch, CRL April 2000.
Sources: Siting Task Force, 1995; CH2M, 1997; CH2M, 1998; North-South Environmental 2000.
DATE INITIATED: SEPT 18, 2002
FIGURE 2.7
VEGETATION COMMUNITIES
REV. NO.
DRAWN BY: AM
CHECKED BY: J.T.
SCALE: AS SHOWN
APPROVED: _ _ _ _ _
PROJECT NO.: G2124
FILENAME: G2124_02.CDR
PROJECT NAME: EER FOR CHALK RIVER LABORATORIES
PREPARED FOR: ATOMIC ENERGY OF CANADA LIMITED
REVISION NO. | REVISION DATE | DESCRIPTION | REVISED BY:
1 | Sept. 25, 2002 | Add Veg. Communities to base | JEW



FOREST COVERAGE BY SPECIES

- Non-Forested Areas
- A
- AB
- AbF
- AbS
- AbSwB
- AjP
- AM
- AMwB
- AP
- APwB
- ArM
- ArMwB
- ArOP
- ArOwB
- AS
- ASwB
- Awb
- AwBbS
- AwBM
- AwBP
- AwBS
- AwBwP
- AwP
- AwPrM
- AwPwB
- AwS
- AwSwP
- bAbS
- bAbSeC
- bFAbS
- bS
- bSA
- bSbA
- bSbF
- bSeC
- bSeCbA
- bSwB
- bSwS
- hMP
- jP
- jPA
- jPrP
- jPS
- jPwB
- jPwP
- MA
- MAwB
- MwBA
- P
- PA
- PL
- PwB
- rMwB
- rPA
- rPwP
- wB
- wBA
- wBArM
- wBAwP
- wBrM
- wBrO
- wBS
- wP
- wPA
- wPrP
- wPwB
- wPwBA
- wS
- wSA
- wSbF

SPECIES	CODE
Pine (general)	P
White pine	wP
Red pine	rP
Jack pine	jP
Spruce (general)	S
White spruce	wS
Black spruce	bS
Balsam fir	bF
Larch	L
White cedar	eC
Aspen (general)	A
White birch	wB
Maple (general)	M
Hard maple	hM
Red maple	rM
Black ash	bA
Red oak	rO
Plantations	Pl

Map Scale

1 in = 265 m

meters 0 265 530 795 meters

Source

Gendron Resource Surveys Ltd.
Report dated 1987
Eng. Dwg. Reference # E-4500-33

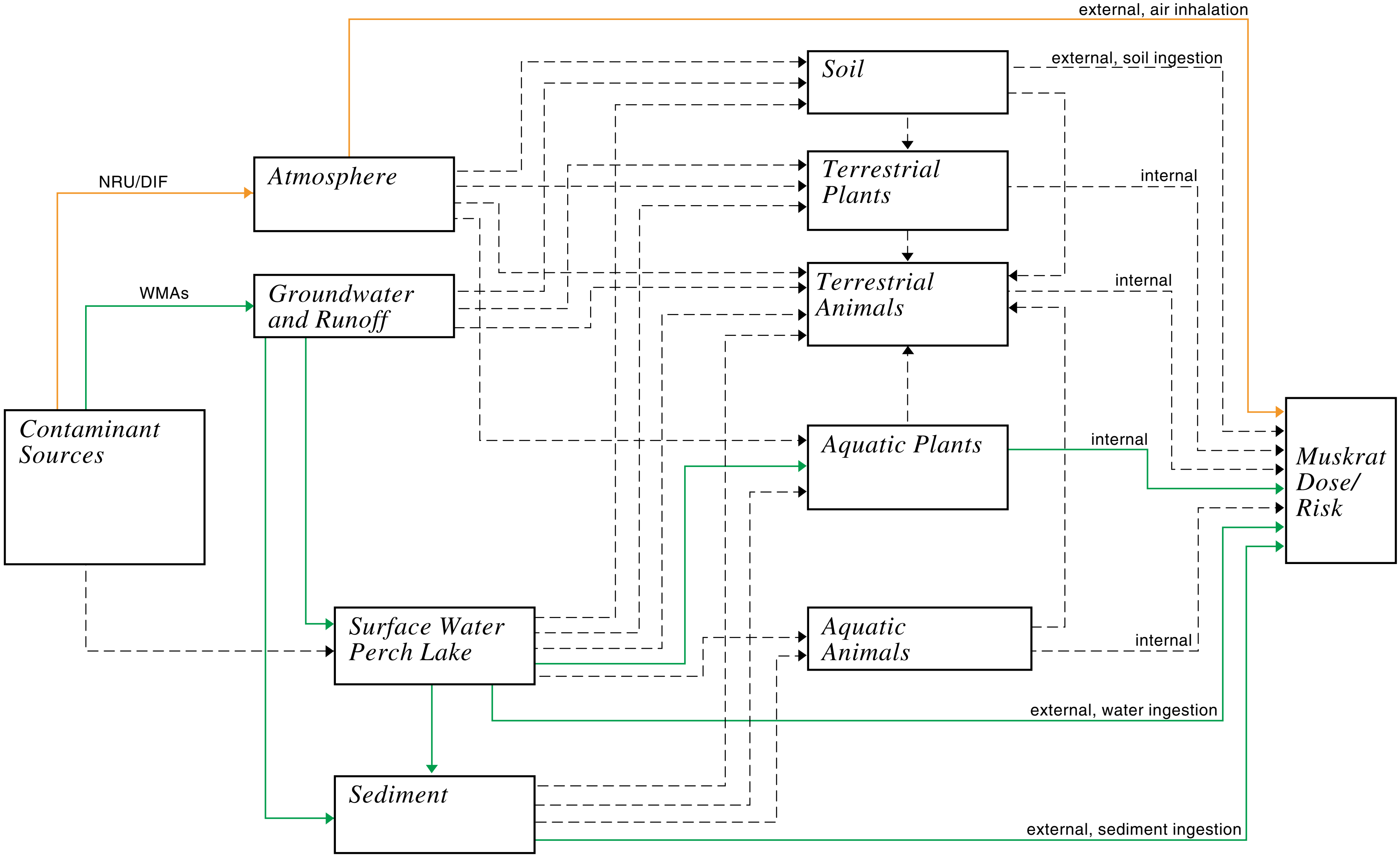
Chalk River Laboratories Exclusion Area
Forest Cover Species Type

beak international incorporated

Figure **2.8**

November 2002

Muskrat



Atmospheric pathways considered in this model

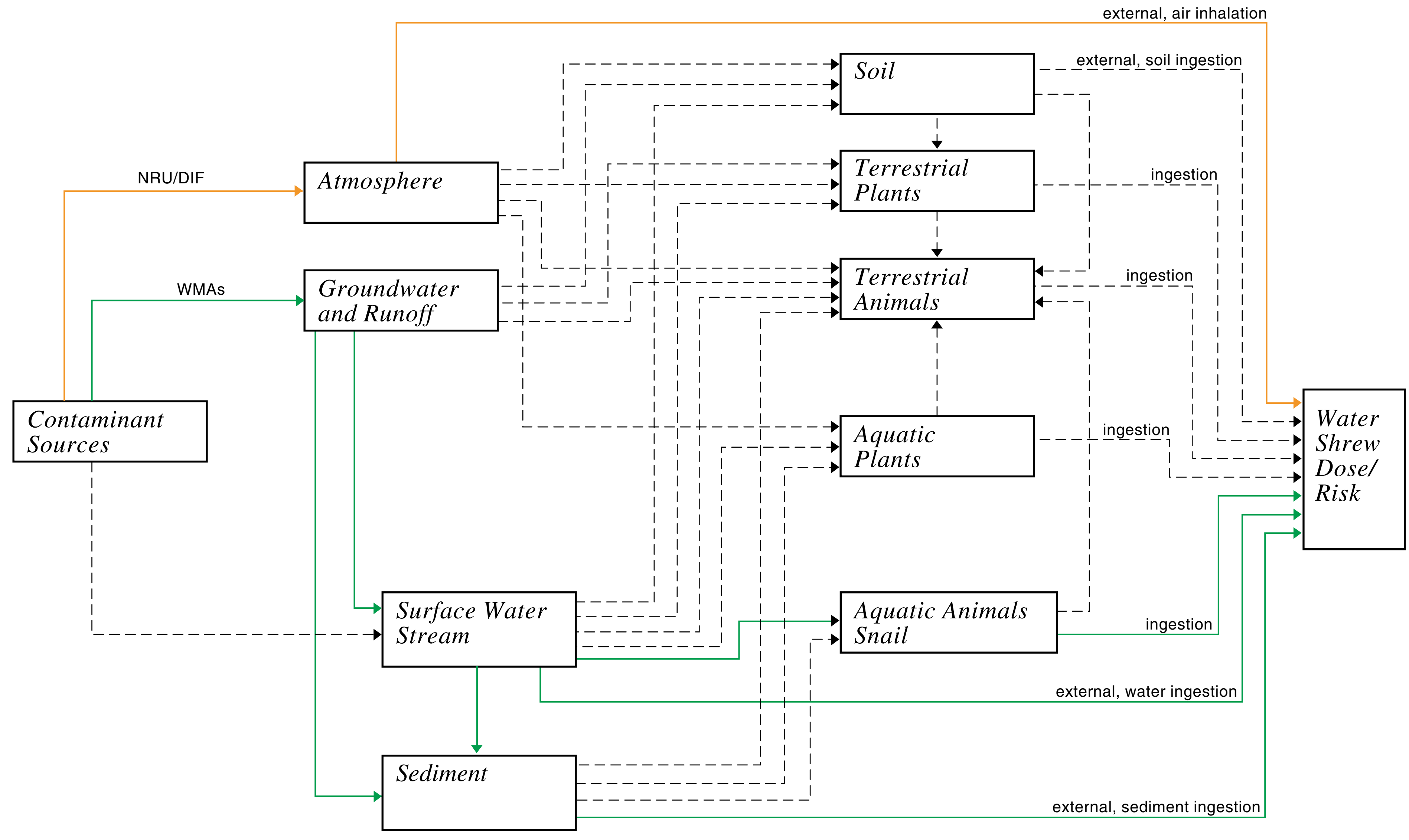
Aquatic pathways considered in this model

pathways not considered in this model

Muskrat Exposure Pathways

beak consultants limited	Figure 2.9	October 2002

Water Shrew



Atmospheric pathways considered in this model

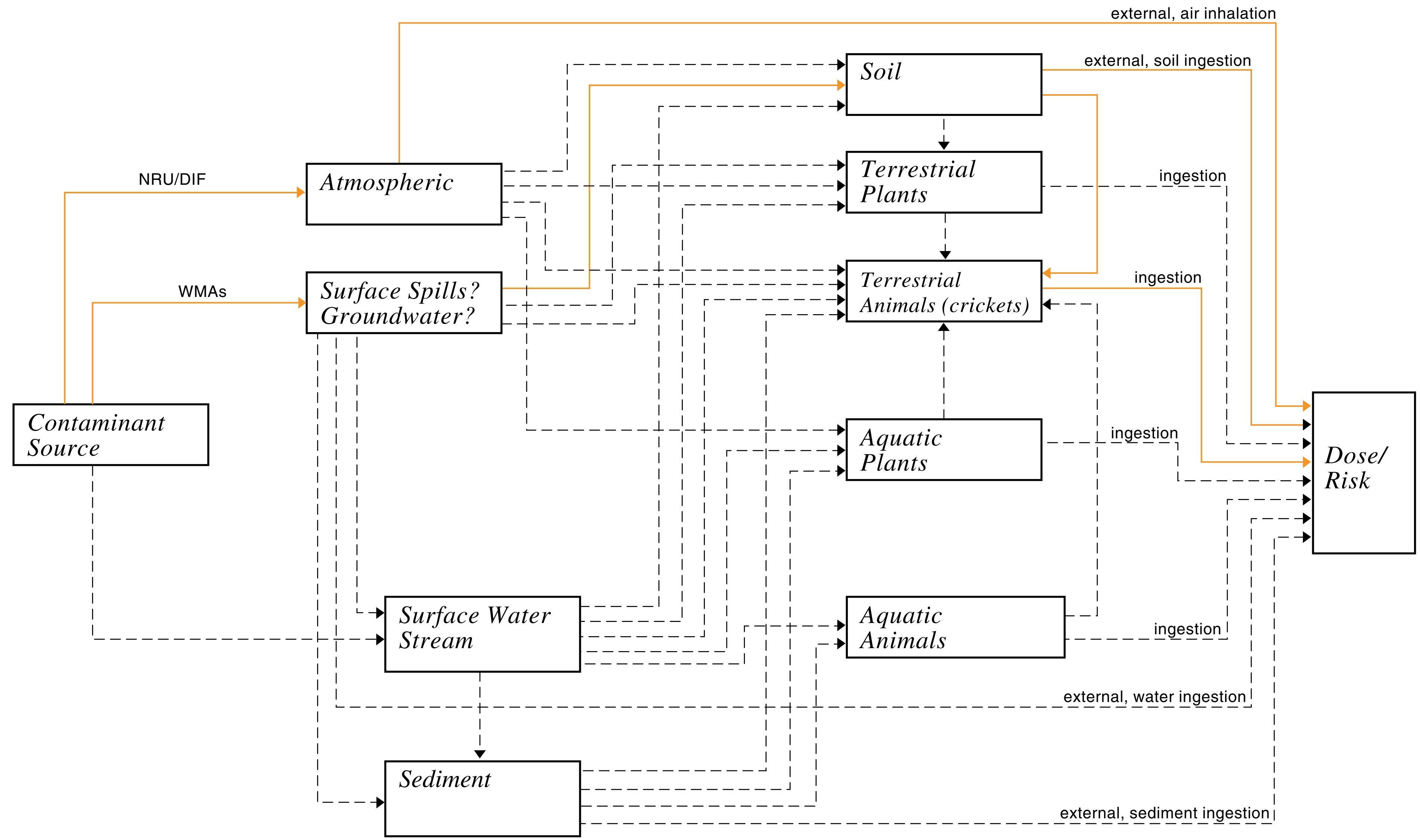
Aquatic pathways considered in this model

pathways not considered in this model

Water Shrew Exposure Pathways

beak consultants limited	Figure **2.10**	October 2002

Robin



Atmospheric pathways considered in this model

Aquatic pathways considered in this model

pathways not considered in this model

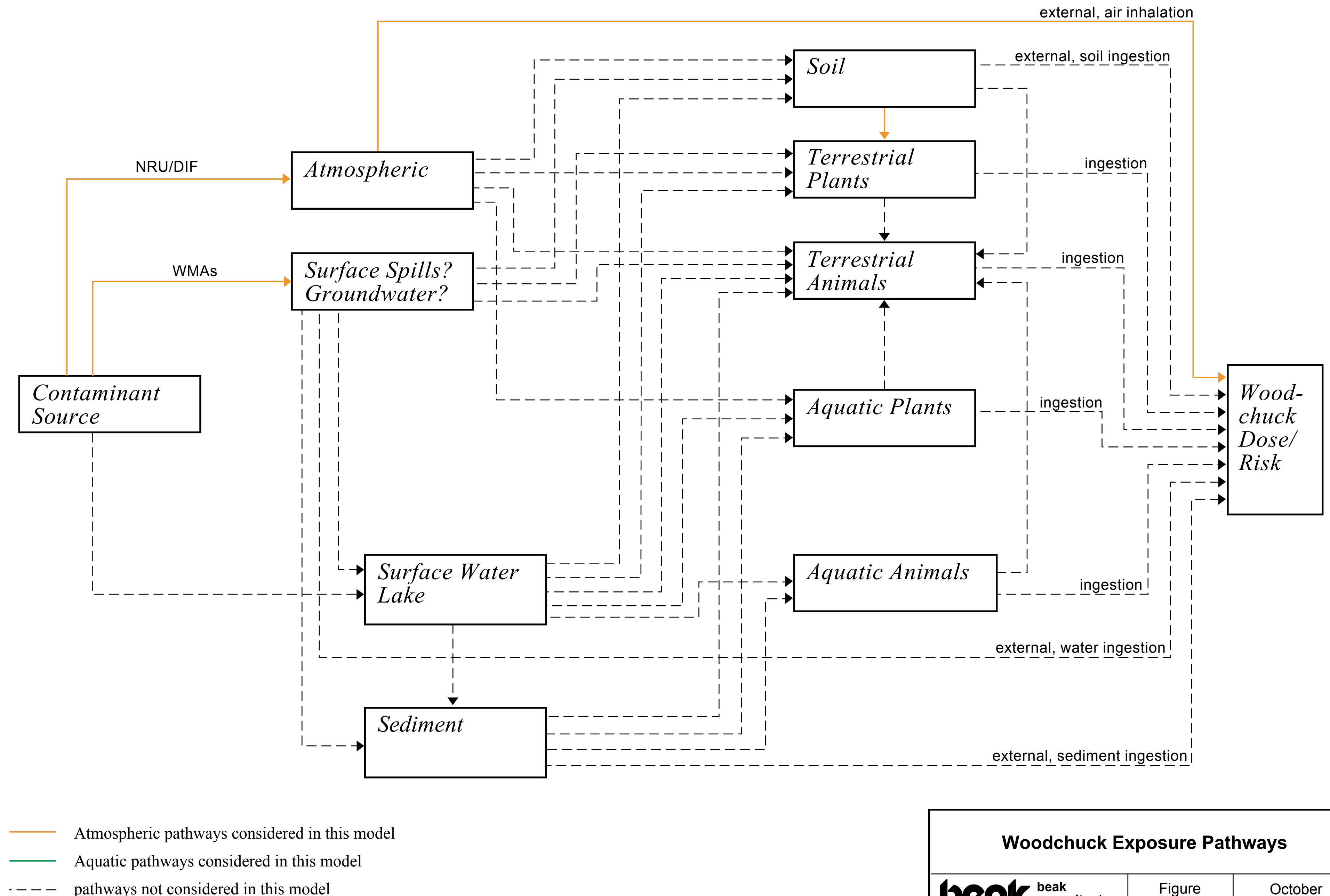
Robin Exposure Pathways

beak consultants limited

Figure **2.11**

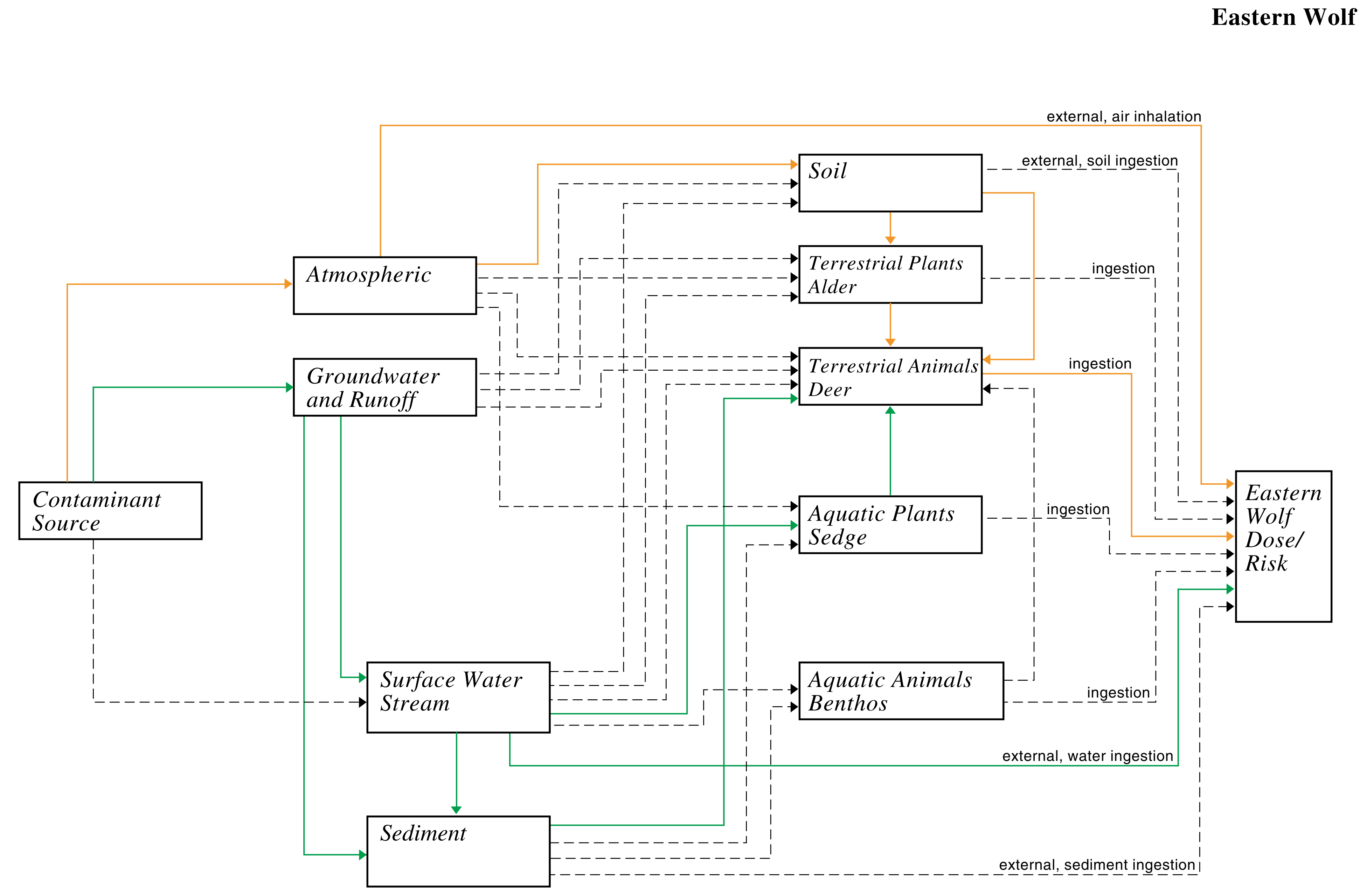
October 2002

Woodchuck



Woodchuck Exposure Pathways

beak consultants limited	Figure 2.12	October 2002



Atmospheric pathways considered in this model

Aquatic pathways considered in this model

pathways not considered in this model

Eastern Wolf Exposure Pathways

beak consultants limited	Figure 2.13	October 2002